15. DIATOM BIOSTRATIGRAPHY OF THE MIDDLE- AND HIGH-LATITUDE NORTH ATLANTIC OCEAN, DEEP SEA DRILLING PROJECT LEG 94[1]

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ABSTRACT

Moderately well-preserved diatoms are present in lower Miocene to Quaternary sediment recovered during DSDP Leg 94, except for the upper middle Miocene to upper Miocene, which is typically barren of diatoms.

The diatom species are characteristic of a warm-temperate assemblage similar to that described by Baldauf (1985a) from the Rockall Plateau region of the North Atlantic Ocean. The diatom zonation of Baldauf (1985a) is recognized for the upper Miocene to Quaternary. The diatom zonation of Barron (1983, 1985a) from the Pacific Ocean is utilized in the lower and middle Miocene. The recognition of these zonations over a wide geographic region indicates that diatoms are useful for biostratigraphic control of specific time-intervals in the North Atlantic Ocean.

Pliocene and Quaternary diatom datums are correlated directly to the paleomagnetic stratigraphy of Leg 94, and absolute ages are estimated for the first or last occurrence of species. Several biostratigraphic events are synchronous in the mid- to high-latitude North Atlantic Ocean but diachronous between the North Atlantic and North Pacific oceans; others are synchronous between both oceans.

Denticulopsis seminae and *D. seminae* var. *fossilis* are observed at several Leg 94 sites. The occurrence of this species within the middle Quaternary of the North Atlantic Ocean suggests that an open communication may have existed between the North Atlantic Ocean and the Bering Sea.

INTRODUCTION

Because few diatom biostratigraphic or paleoceanographic studies existed for the middle- to high-latitude North Atlantic Ocean (see Baldauf, 1985a, for discussion), a middle Miocene to Holocene diatom zonation was developed by Baldauf (1985a) from material from Deep Sea Drilling Project Leg 81, within the Rockall Plateau region of the North Atlantic Ocean. The late Miocene to Holocene part of this zonation is based on the occurrence in the North Atlantic of a warm-temperate diatom assemblage similar to that recorded from the eastern equatorial Pacific by Burckle (1972, 1977), Baldauf (1985b), and Barron (1985a).

The middle Miocene diatom zones proposed by Baldauf (1985a) for the Rockall Plateau region utilize both warm-temperate species and species more characteristic of the cool, high latitudes. Problems in using low-latitude marker species within the high-latitude North Atlantic Ocean are discussed by Backman et al. (1985). The major difficulty in using diatoms for biostratigraphic control in the North Atlantic Ocean is the sporadic preservation of silica in the sediment. In Leg 81 material, diatoms are generally concentrated within specific stratigraphic intervals. For example, they are normally absent in the upper middle Miocene to lower upper Miocene but are present in the lower middle Miocene. In the upper Pliocene–Pleistocene of Hole 552A (Fig. 1), diatom abundance and preservation also fluctuate, probably in response to changing oceanographic conditions affecting diatom productivity, and it is often difficult accurately to place the stratigraphic first or last occurrence of a species within this interval. Thus, it was not always possible accurately to correlate diatom events to the paleomagnetic record in Hole 552A. Nor was it possible to consider whether the diatom datums in the North Atlantic and equatorial Pacific oceans were isochronous. Stratigraphic ranges and absolute ages of diatom datums previously established in the equatorial Pacific Ocean were accepted unless proven different.

The results of Deep Sea Drilling Project Leg 94 in the middle to high-latitude North Atlantic Ocean (Norfolk,

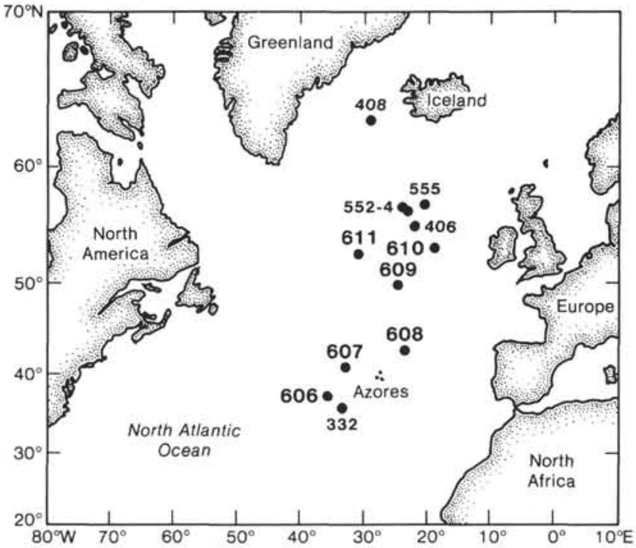

Figure 1. Location of DSDP Leg 94 sites and other DSDP sites discussed in this chapter.

[1] Ruddiman, W. F., Kidd, R. B., Thomas, E., et al., *Init. Repts. DSDP*, 94: Washington (U.S. Govt. Printing Office).

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Va., to St. John's, Newfoundland) allowed testing of the synchrony of Pliocene and Pleistocene datums. On Leg 94, *Glomar Challenger* cored 15 holes at 6 sites (606–611) in a transect running approximately south–north from the middle (37°N) to high (53°N) latitudes of the North Atlantic Ocean (Fig. 1). Complete stratigraphic sections were obtained by duplicate hydraulic piston coring from almost all sites for approximately the last 3.5 m.y. A good paleomagnetic record was recovered at all Leg 94 sites for the interval from the Brunhes to the Gauss/Gilbert boundary. Below the Gauss the quality of the paleomagnetic record varies from site to site (see Clement and Robinson, this volume).

The diatom abundance and preservation in Pliocene material recovered during Leg 94 are better than at Site 552 but vary somewhat with latitude.

EPOCH/STAGE AND ZONAL BOUNDARIES

The geochronology and chronostratigraphy of Berggren et al. (in press) have been used as the framework for Leg 94 studies. The epoch stage boundaries used for the Leg 94 studies are Oligocene/Miocene boundary, 23.7 Ma; Miocene/Pliocene boundary, 5.3 Ma; Pliocene/Pleistocene boundary; 1.6 Ma.

Berggren et al. (in press) directly correlated the calcareous nannofossil and foraminiferal zones to paleomagnetic stratigraphy, but made no attempt to correlate the diatom zonation. Barron et al. (1985) correlated the diatom datums and zones directly to paleomagnetic stratigraphy; they correlated the calcareous nannofossil and foraminiferal zones to the diatom zones and secondarily to paleomagnetic stratigraphy.

For Leg 94, Barron et al.'s (1985) correlation of the diatom datums and zones to the paleomagnetic stratigraphy was used, but the correlation of the calcareous nannofossil and foraminiferal datums and zones follows that of Berggren et al. (in press). Thus the correlations among the diatom, calcareous nannofossil, and foraminiferal zones used during Leg 94 differ in part from the correlations of Barron et al. (1985; see also Baldauf et al., this volume). The zonal boundaries which differ are the NN11/NN12, NN10/NN11, NN6/NN7, and the NN5/NN6 calcareous nannofossil boundaries of Martini (1971).

DIATOM ZONATION

Figure 2 displays the diatom zonation used in this study. The late middle Miocene to Holocene biozones used herein are as defined by Baldauf (1985a), except for the *Pseudoeunotia doliolus* and *Nitzschia reinholdii* Zones. The early middle Miocene zonation defined by Baldauf (1985a) for DSDP Sites 555 and 408 (Fig. 1) is only partially recognized in Leg 94 material, because several of these zones are defined by species such as *Denticulopsis praedimorpha* and *Rhizosolenia barboi*, which are characteristic of a cool assemblage not typical of Leg 94 material. Instead, the occurrence of warm-temperate species in the lower Miocene and lower middle Miocene sediments of Leg 94 sites allows recognition and use of the biozones defined by Barron (1983, 1985a) for the equatorial Pacific Ocean. Table 1 summarizes the zonal assignments of the Leg 94 samples examined.

Craspedodiscus elegans Zone

Definition. Defined by Barron (1983, 1985a) as the interval from the last occurrence of *Bogorovia veniamini* to the last occurrence of *Craspedodiscus elegans*. Age: early Miocene.

Remarks. Numerous secondary markers have been defined by Barron (1983) for use in recognizing this early Miocene zone. The first occurrences of *Coscinodiscus lewisianus* var. *robustus* and *Thalassiosira fraga* approximate the base of the *Craspedodiscus elegans* Zone. The last occurrence of *Coscinodiscus rhombicus* approximates the top of this zone (Barron, 1985b).

Correlation. Barron et al. (1985) correlate the *Craspedodiscus elegans* Zone with planktonic foraminiferal Zone N5, the upper portion of calcareous nannofossil Zone NN2, and the upper portion of the *Stichocorys delmontensis* radiolarian Zone. In Leg 94 material, the *C. elegans* Zone correlates to the planktonic foraminiferal *Globigerinoides trilobus* and the undifferentiated NN2–NN3 calcareous nannofossil zones (Baldauf et al., this volume).

Triceratium pileus Zone

Definition. Defined by Barron (1983) as the interval containing *Triceratium pileus* between the last occurrence of *Craspedodiscus elegans* and the first occurrence of *Denticulopsis nicobarica*. Age: early Miocene.

Remarks. The last occurrence of *Coscinodiscus rhombicus* approximates the base of this zone in the equatorial Pacific (Barron, 1983). *Thalassiosira spinosa* and *Actinocyclus radionovae* both have a last occurrence within this zone (Barron, 1983).

Barron (1985a) states that within the lower portion of this zone at Hole 575A (Cores 9–12) the diatom assemblage is dominated by fragments of a diatom similar to *Ethmodiscus rex*. In Hole 610 (Cores 23 and 24) and Hole 406 (Cores 24–28) a similar diatom assemblage occurs (Baldauf, this volume).

Correlation. Barron et al. (1985) correlate the *T. pileus* Zone to calcareous nannofossil Zone NN3, the upper portion of the foraminiferal N5 and lower portion of the N6 zones, and the *Stichocorys delmontensis* and *S. wolffi* radiolarian zones. In the Leg 94 material, the *Triceratium pileus* Zone correlates with the middle portion of the *Globigerinoides trilobus* foraminiferal Zone and the upper portion of the undifferentiated NN2–NN3 calcareous nannofossil zones (Baldauf et al., this volume).

Denticulopsis nicobarica Zone

Definition. Defined by Barron (1983) as the interval from the first occurrence of *Denticulopsis nicobarica* to the first occurrence of *Cestodiscus peplum*. Two subzones are separated by the last occurrence of *Thalassiosira bukryi*. Age: early Miocene.

Remarks. The subzones defined by Barron (1983) are not recognized in the Leg 94 material. Barron (1985a) reports that the last occurrence of *Thalassiosira fraga* approximates the top of this zone; it is used here to recognize the zone.

For the North Atlantic Ocean, Baldauf (1985a) defined a *D. nicobarica* Zone that is clearly different from that defined by Barron (1983) for the equatorial Pacific Ocean. Baldauf's (1985a) *D. nicobarica* Zone is a middle Miocene zone defined as the interval from the last occurrence of *Coscinodiscus lewisianus* to the first occurrence of *Rhizosolenia barboi*.

Correlation. The *Denticulopsis nicobarica* Zone of Barron (1983) is correlated by Barron et al. (1985) to the upper part of calcareous nannofossil Zone NN3 through the middle of Zone NN4, the upper portion of foraminiferal Zone N6 and Zone N7, and the *Stichocorys wolffi* through middle *Calocyletta costata* radiolarian zones. Baldauf et al., (this volume) correlate the *Denticulopsis nicobarica* Zone of Barron (1983) with the upper portion of the *Globigerinoides trilobus* foraminiferal Zone and the upper portion of the undifferentiated NN2–NN3 and NN4 calcareous nannofossil zones.

Cestodiscus peplum Zone

Definition. Defined by Barron (1983) as the interval of the total range of *Cestodiscus peplum*. Two subzones are defined by the last occurrence of *Annellus californicus* within the *C. peplum* Zone. Age: early middle Miocene.

Remarks. The last occurrence of *Thalassiosira fraga* approximates the base of this zone (Barron, 1985a), and the last occurrence of *Coscinodiscus blysmos* in the Pacific corresponds to its top (Barron, 1983).

Correlation. Barron et al. (1985) correlate the *C. peplum* Zone to the interval from the middle portion of calcareous nannofossil Zone NN4 to the upper portion of Zone NN5, to foraminiferal Zones N8

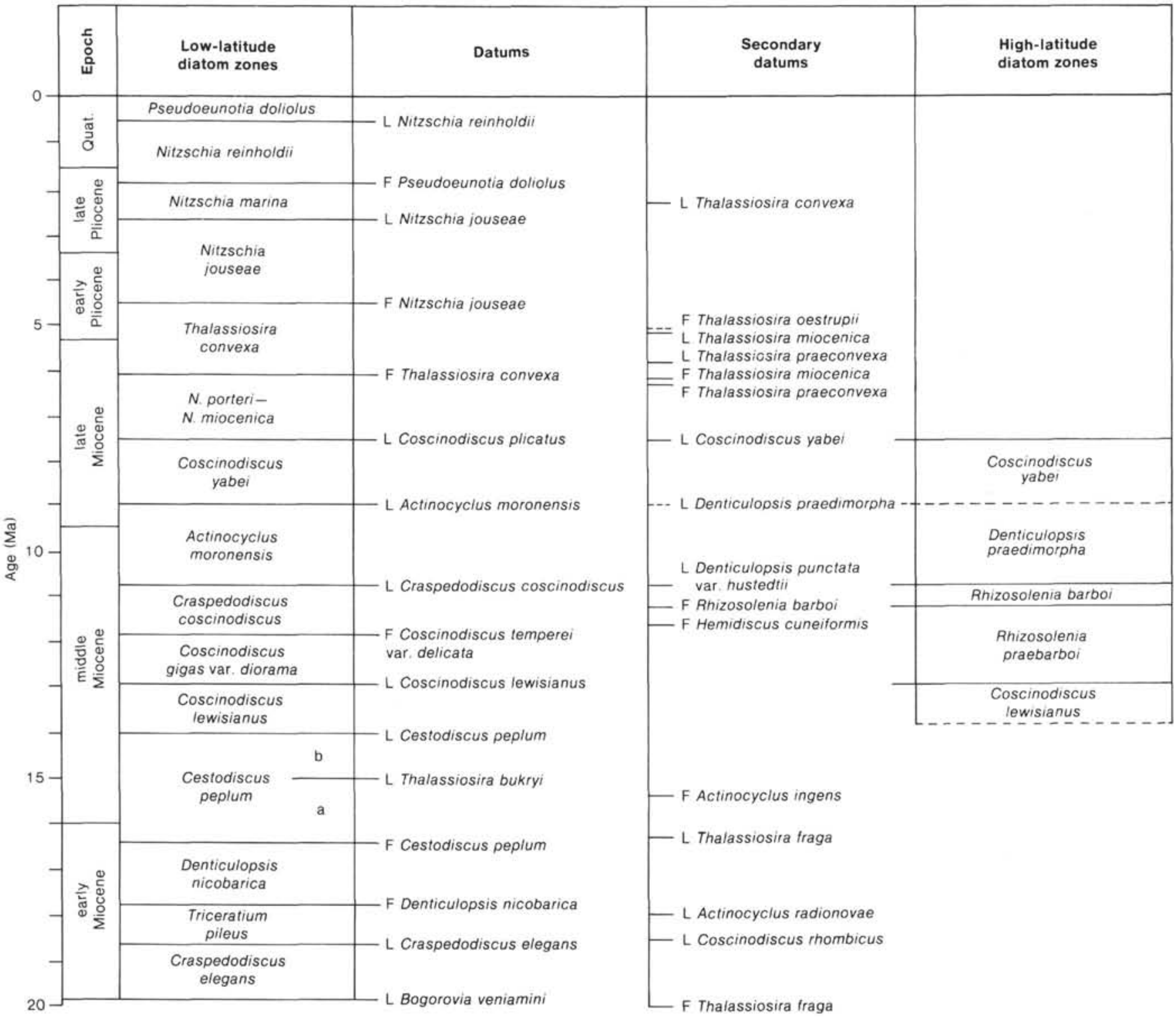

Figure 2. Diatom zonation used in this report. The late Miocene to Quaternary portion is as described by Baldauf (1985a) for the Rockall Plateau region of the North Atlantic Ocean. The early Miocene to late Miocene part is the zonation defined by Barron (1983, 1985b) for the equatorial Pacific Ocean. High-latitude diatom zones from Baldauf (1985a). L = last occurrence, F = first occurrence.

through the lower portion of N10, and from the middle portion of the radiolarian *Calocycletta costata* Zone through the lower portion of the *Dorcadospyris alata* Zone. The *C. peplum* Zone is correlated by Baldauf et al. (this volume) to the *Globigerinoides trilobus, Praeorbulina glomerosa curva*, and *Globorotalia mayeri* foraminiferal zones, as well as to the calcareous nannofossil NN4, NN5, and NN6 zones. Baldauf et al. (this volume) correlate the upper *C. peplum* Zone to the lower calcareous nannofossil Zone NN6 differently from Barron et al. (1985), probably because ranges of the zonal species are diachronous between the Pacific and Atlantic oceans (see also Baldauf, this volume).

Coscinodiscus lewisianus Zone

Definition. Schrader (1976), modified by Barron (1985b); this zone was defined as the interval from the last occurrence of *Cestodiscus peplum* to the last occurrence of *Coscinodiscus lewisianus*. Age: middle Miocene.

Remarks. In the *Coscinodiscus lewisianus* Zone defined by Baldauf (1985a) for the high-latitude North Atlantic, the top of the zone is based on the last occurrence of *C. lewisianus*; Barron (1985b) uses the same marker. Because of silica dissolution no base was defined by Baldauf (1985a) for this zone, and the base defined by Barron (1985b), which can be recognized within the mid-latitudes of the North Atlantic, is used in this chapter.

Correlation. Barron et al. (1985) correlate the *Coscinodiscus lewisianus* Zone with the uppermost NN5 through the lower NN6 calcareous nannofossil zones, to the upper N10 through the lower N12 foraminiferal zones, and to the middle radiolarian *Dorcadospyris alata* Zone.

The last occurrence of *C. lewisianus* is correlated by Barron et al. (1985) to paleomagnetic Chron 14. This correlation is used also in this chapter.

The correlations between foraminiferal, calcareous nannofossil, and diatom zones by Barron et al. (1985) differ from the correlations used for Leg 94 (Baldauf et al., this volume). The reader is referred to the remarks under the *C. peplum* Zone and to Baldauf et al. (this volume) for further discussion.

Baldauf et al. (this volume) correlate the *C. lewisianus* Zone with the uppermost NN6 through lowermost NN7 zone, as well as with the *Globorotalia mayeri* foraminiferal Zone. This zone also correlates with the uppermost *Denticulopsis lauta* and lower *D. hustedtii–D. lauta* zones of Koizumi (1973) in the North Pacific.

Table 1. The zonal placement of samples from DSDP Leg 94.

	Holes															
Diatom zone	606	606A	607	607A	608	608A	609	609A	609B	610	610A	610B	611	611A	611C	611D
Pseudoeunotia doliolus	1,CC 2,CC	1,CC	1-1 3-2	1,CC 2,CC	1-3 2-2	1,CC 2,CC	1,CC 3,CC	1,CC 2,CC	1,CC 2,CC		1,CC		1,CC 3-3	1,CC	1,CC 4,CC	1,CC
Nitzschia reinholdii	3-1 7-5	2,CC 5,CC	3-3 9-3	3,CC 9,CC	2-4 6,CC	3,CC 6,CC	4-1 14,CC		4,CC 14,CC		3,CC 10,CC	9,CC 12,CC	3,CC 7-6	4,CC 8,CC	6,CC 9,CC	
N. marina	7-6 9,CC	6,CC 9,CC	9-4 10,CC	10,CC	7-2 11,CC	8,CC 10,CC	15-1 24,CC		16,CC 20,CC		11-4 15-5	13,CC 15,CC	8,CC 14,CC	10,CC 13,CC	11,CC 15,CC	2,CC
N. jouseae	10,CC 11-3	10,CC					25,CC 28,CC		21,CC 29,CC	6,CC 8,CC	15,CC 21,CC	16,CC			16,CC 32,CC	3,CC 14,CC
Thalassiosira convexa				24,CC 25-1												
N. miocenica–N. porteri																
Coscinodiscus yabei																
Actinocyclus moronensis																
Craspedodiscus coscinodiscus										15-4 15,CC						
Coscinodiscus gigas v. *diorama*					29-5 31-1					16-2?						
C. lewisianus					31-2 34,CC					16-4 16,CC						
Cestodiscus peplum										17-1 23,CC?						
Denticulopsis nicobarica										24-1?						
Triceratium pileus										24-3 25-2						
Craspedodiscus elegans										25-3 27,CC						

Note: Core and section numbers only are given.

Coscinodiscus gigas var. *diorama* Zone

Definition. Defined by Barron (1985b) as the interval containing *Coscinodiscus gigas* var. *diorama*, between the last occurrence of *C. lewisianus* and the first occurrence of *C. temperei* var. *delicata*. Age: middle Miocene.

Remarks. *Denticulopsis nicobarica* last occurs within this zone (Barron, 1985a). The first occurrence of *Hemidiscus cuneiformis* is directly above the top of the *C. gigas* var. *diorama* Zone (Barron et al., 1985) and is used here to approximate the top of this zone.

Correlation. This zone correlates with calcareous nannofossil Zone NN7 and the middle *G. mayeri* foraminiferal Zone (Baldauf et al., this volume). Barron et al. (1985) correlate the *C. gigas* var. *diorama* Zone to uppermost Zone NN6. See remarks under the *Cestodiscus peplum* Zone and Baldauf et al. (this volume) for the differences in correlation between Barron et al. (1985) and Baldauf et al. (this volume).

The *Coscinodiscus gigas* var. *diorama* Zone also correlates to the *Denticulopsis nicobarica* Zone of Baldauf (1985a) and Subzone "b" of the *D. hustedtii–D. lauta* Zone of Barron (1980a). Because Barron (1983) defined an early Miocene *D. nicobarica* Zone before Baldauf (1985a) published his middle Miocene *D. nicobarica* Zone, the *D. nicobarica* Zone of Baldauf (1985a) needs to be redefined to avoid confusion. Therefore, the interval previously representing the *D. nicobarica* Zone of Baldauf (1985a) is now referred to as the *Rhizosolenia praebarboi* Zone, defined as the stratigraphic interval which contains *R. praebarboi*, between the last occurrence of *C. lewisianus* and the first occurrence of *R. barboi*.

Barren Interval

Burckle (1972) and Barron (1985b) defined the late middle Miocene through late Miocene *Craspedodiscus coscinodiscus, Actinocyclus moronensis, Coscinodiscus yabei, Nitzschia porteri*, and *N. miocenica* zones for the equatorial Pacific Ocean. These zones are not recognized in Leg 94 material, because the upper middle Miocene through upper Miocene samples examined are barren of diatoms.

Thalassiosira convexa Zone

Definition. Defined by Burckle (1972) as the interval from the first occurrence of *Thalassiosira convexa* to the first occurrence of *Nitzschia jouseae*. Three subzones are defined by Burckle (1972). Subzone A occurs from the base of the zone to the last occurrence of *T. praeconvexa*, Subzone B extends from the top of Subzone A to the last occurrence of *T. miocenica*, and Subzone C occurs from the top of Subzone B to the top of the zone. Age: late Miocene and earliest Pliocene.

Remarks. The first occurrence of *T. miocenica* is used by Baldauf (1985a, b) and Barron (1985a) as a secondary marker for the base of this zone, which is recognized at Holes 609A and 552A. Within Leg 81 material, the majority of samples that occur stratigraphically below the *T. convexa* Zone are barren or contain rare diatom fragments (Baldauf, 1985a).

Correlations. The *T. convexa* Zone correlates to calcareous nannofossil Zones NN11 and NN12 and to the *Globorotalia conomiozea/G. margaritae/Globigerina nepenthes* foraminiferal zones (Baldauf et al., this volume; Barron et al., 1985). This zone also correlates to Subzone "a" and part of Subzone "b" of the North Pacific *Denticulopsis kamtschatika* Zone of Barron (1980a).

Nitzschia jouseae Zone

Definition. Defined by Burckle (1972); top defined by Baldauf (1985a). Interval from the first to the last occurrences of *Nitzschia jouseae*. Age: Pliocene.

Remarks. Burckle (1972) originally defined the top of the *N. jouseae* Zone by the first occurrence of *Rhizosolenia praebergonii*. This species occurred only sporadically and was not stratigraphically useful in Leg 81 material, so Baldauf (1985a) redefined the top of the zone as the last occurrence of *N. jouseae*. The rare occurrence of *R. praebergonii* in Leg 94 material also indicates that *R. praebergonii* is not biostratigraphically useful within the mid- and high-latitude North Atlantic Ocean.

Correlation. Baldauf et al. (this volume) correlate this zone to calcareous nannofossil Zones NN13 through NN16 and to the *Globorotalia margaritae/Globigerina nepenthes* through *Globorotalia miocenica* foraminiferal zones. The *N. jouseae* Zone of Baldauf (1985a) also correlates to the *N. jouseae* Zone and to Subzone A of the *Rhizosolenia praebergonii* Zone of Burckle (1972).

Nitzschia marina Zone

Definition. Defined by Baldauf (1985a) as the interval from the last occurrence of *Nitzschia jouseae* to the first occurrence of *Pseudoeunotia doliolus*. Age: Pliocene.

Remarks. *Thalassiosira convexa* last occurs within this zone. Although Burckle (1972), Barron (1985a), and Baldauf (1985a, b) place the last occurrence of *T. convexa* midway between the Gauss/Matuyama paleomagnetic Chron boundary and the base of Olduvai Paleomagnetic Subchron, within the Leg 94 material the last occurrence of *T. convexa* is consistently older (see Discussion).

Correlation. The *N. marina* Zone correlates to upper calcareous nannofossil Zone NN16, the undifferentiated NN17–NN18 Zone, and lower Zone NN19. It also correlates to the upper *Globorotalia miocenica* and *Globigerinoides obliquus* var. *extremus* foraminiferal zones (Baldauf et al., this volume) and to Subzones B and C of the *Rhizosolenia praebergonii* Zone of Burckle (1972).

Nitzschia reinholdii Zone

Definition. Defined by Burckle (1977) as the interval from the first occurrence of *Pseudoeunotia doliolus* to the last occurrence of *Nitzschia reinholdii*. Two subzones are recognized and are subdivided by the last occurrence of *Rhizosolenia praebergonii* var. *robustus* (Burckle, 1977). Age: latest Pliocene and early Quaternary.

Remarks. The last occurrence of *Nitzschia fossilis* and the silicoflagellate *Mesocena quadrangula* fall within this zone.

Correlation. The *N. reinholdii* Zone of Burckle (1977) correlates with the lower calcareous nannofossil Zone NN19 and the foraminiferal *Globorotalia truncatulinoides* Zone (Baldauf et al., this volume). The *N. reinholdii* Zone of Burckle (1977) also correlates to the lower *Pseudoeunotia doliolus* Zone of Burckle (1972).

Pseudoeunotia doliolus Zone

Definition. Defined by Burckle (1977) as the interval containing *Pseudoeunotia doliolus* stratigraphically above the last occurrence of *Nitzschia reinholdii*, to the present. Age: late Quaternary.

Remarks. Burckle (1972) originally defined the *P. doliolus* Zone as the interval from the first occurrence of *P. doliolus* to the present; he later (1977) divided it into the *N. reinholdii* and *P. doliolus* zones.

Correlation. This zone correlates to upper calcareous nannofossil Zone NN19 and Zones NN20 and NN21 and to the upper *Globorotalia truncatulinoides* foraminiferal Zone (Baldauf et al., this volume).

METHODS

One sample was examined from each core section (1.5 m) of the first hole at each site. Usually only core-catcher samples were examined from subsequently cored holes.

Approximately 1.5 cm^3 of sample were placed into a 400 ml beaker and disaggregated by the addition of 10 ml of 30% hydrogen peroxide. Then 30 ml of 37% HCl was added and the sample was gently heated, if required, until carbonates and organic carbons were removed. The sample was neutralized by the addition of approximately 300 ml of distilled water and decanted after 2 hr. of settling. The decanting process was repeated until a pH of 7 was achieved. Strewn slides were prepared on 22 × 30 mm (No. 1 thickness) cover glasses and mounted in Hyrax on 22 × 75 mm glass slides.

Strewn slides of acid-cleaned material prepared aboard the *Glomar Challenger* were reexamined, together with additional samples processed at onshore facilities. One strewn slide was examined in its entirety at ×500 with an Olympus BH-2 light microscope. Species identifications were confirmed at ×1250. Species were recorded as abundant (A) if two or more specimens were present in one field of view at 500×, common (C) if one specimen occurred in two fields of view, few (F) if one specimen was observed in each horizonal transect, and rare (R) if specimens were encountered less frequently than that. The quality of fossil preservation of samples (poor—P, moderate—M, and good—G) is based on the number of finely silicified species such as *Nitzschia fossilis, Pseudoeunotia doliolus*, and *N. jouseae* compared to the number of heavily silicified species such as *Coscinodiscus marginatus* and *C. nodulifer*. The absolute ages assigned to the diatom datums in this manuscript are based on direct correlations with the Leg 94 paleomagnetic results (Clement and Robinson, this volume). The ages (in m.y.) are estimated from the age assigned to the paleomagnetic chron or subchron boundaries that constrain the diatom event; see also Baldauf et al., this volume.

BIOSTRATIGRAPHY

Site 606

Two holes were cored at Site 606 on the western flank to the Mid-Atlantic Ridge, using the Advanced Piston Corer. Lower Pliocene through Holocene sediment was recovered. Common, moderately well preserved diatoms are generally present in the middle Pliocene to Holocene, but diatoms are absent from the lower Pliocene.

The diatom assemblage is composed of warm-temperate species such as *Coscinodiscus nodulifer, C. nodulifer* var. *cyclopus, Nitzschia fossilis, N. jouseae, N. reinholdii, Pseudoeunotia doliolus, Rhizosolenia bergonii*, and *Roperia tesselata* (see Table 1).

Hole 606 (37°20.32′N, 35°29.99′W, 3007 m water depth)

Eighteen cores (167.75 m) were recovered from Hole 606. Diatoms are generally present in the middle Pliocene to Holocene and absent from the lower Pliocene. Table 2 shows the stratigraphic occurrence of selected diatom species for samples from Holes 606 and 606A. Cores 606-12 through 606-18 are generally barren of diatoms.

Cores 606-1 and 606-2 are assigned to the *Pseudoeunotia doliolus* Zone of Burckle (1977) based on the occurrence of *P. doliolus* stratigraphically above the last occurrence of *Nitzschia reinholdii* between Samples 606-2,CC and 606-3-1, 43–45 cm (11.16–12.84 m). This biostratigraphic event occurs approximately 7 m above the Matuyama/Brunhes paleomagnetic boundary, which is placed by Clement and Robinson (this volume) between Samples 606-3-5, 128 cm and 606-3-6, 6 cm. Correlation of the last occurrence of *N. reinholdii* with the Hole 606 paleomagnetics results in an estimated age of 0.44–0.47 Ma for this event.

In the equatorial Pacific, the last occurrence of *N. reinholdii* has an age of 0.65 Ma as estimated from paleomagnetic data (Burckle, 1977). Although this datum is diachronous between the high-latitude Atlantic and the equatorial Pacific, it is isochronous within the North Atlantic (see Discussion) and allows recognition of the *P. doliolus* and *N. reinholdii* biozones of Burckle (1972, 1977) in the North Atlantic Ocean.

Samples 606-3-1, 43–45 cm through 606-7-5, 43–45 cm are assigned to the *N. reinholdii* Zone of Burckle (1977). The first occurrence of *P. doliolus*, which defines the base

Table 2. The stratigraphic occurrence of selected diatom species and silicoflagellates (*) for samples from Holes 606 and 606A.

Core-Section (interval in cm)	Abundance	Preservation	*Actinocyclus curvatulus*	*A. divisus*	*A. ehrenbergii*	*A. ellipticus*	*Actinoptychus bipunctatus*	*A. undulatus*	*Asterolampra grevillei*	*A. marylandicus*	*Asteromphalus arachne*	*A. flabellatus*	*A. hookeri*	*A. imbricatus*	*Bacteriastrum hyalinum*	*Coscinodiscus asteromphalus*	*C. africanus*	*C. crenulatus*	*C. marginatus*	*C. nodulifer*	*C. nodulifer* var. *cyclopus*	*C. oculis-iridis*	*C. radiatus*	*C. tabularis*	*Cyclotella* group	*Diploneis* sp.	*Ethmodiscus rex*	*Hemidiscus cuneiformis*	*Melosira granulata*	*M. sulcata*	*Navicula* sp. 1	*Nitzschia fossilis*	*N. interrupta*	*N. jouseae*	*N. marina*	*N. panduriformis*	*N. reinholdii*	*Nitzschia* sp. 1	*Nitzschia* group	*Pseudoeunotia doliolus*	*Rhizosolenia barboi*	*R. bergonii*	*R. curvirostris*	*R. praebergonii*	*R. styliformis*	*Roperia tesselata*	*Stephanopyxis turris*	*Thalassionema nitzschioides*	*Thalassiosira convexa* var. *convexa*	*T. eccentrica*	*T. leptopus*	*T. oestrupii*	*T. plicata*	*T. symbolophora*	*Thalassiothrix longissima*	*Triceratium cinnamomeum*	*Mesocena quadrangula**	Diatom zones
Hole 606																																																											
1,CC	F	M					R			R								R		R								R					F		F					F		R				F		F		R	R	R			R			*Pseudoeunotia doliolus*
2-3, 43-45	F	M		R	R										R			R								R	R	R	R		R		R		F					R						R		R		R	R	F		R				
2,CC	C	G	R	R	R		R			R		R			R			R		R							R				R		R		C			R	R	C		R						F		R	R	F		F	R			
3-1, 43-45	C	G		R	R	R	R										R	R		F				R				F	R						F		R			C		R				R		R		R	R	C	R		R			*Nitzschia reinholdii*
3-3, 43-45	F	M		R						R		R						R		R							R	R	R				R		F		F			R	R							F		R	R							
3-4, 43-45	C	G	R	R	R		R			R					R		R			R				R		R		R				F	F		R		R	R		F		R	R			R	R	F		R	R	F	R	R	F			
3-5, 43-45	A	G	R	R	R	R					R	R			R			R		R				R			R	R			R	R	R		R		C			C							R	C		R	R	R	R	R	R		R	
3-6, 43-45	C	G			R	R				R	R	R	R		R		R	F	R	C								F				R	R		F		F			F					R	R		R		R	R	F	R	R	R	R	R	
3,CC	A	M	R			R	R	R		R		R			F			R	R	R				R		R	R		R	R	R	F	R		R		F	R	R	C	R	R	R		R		R	C		F	R	C		R	F		F	
4-1, 43-45	C	G									R	R			R		R	R	R	F				R				R	R	R		R	R		R		R			F		F			R	F		R		R	R	F	R	R	R		R	
4-3, 43-45	F	M	R					R							R			F		R								R	F	R		R	R				R	R		R								R		F		R		R	R		F	
5-3, 43-45	R	P																		R								R									R		R			R								R	R	F					R	
5,CC	R	P																																	R		R													R		R			R			
6-4, 43-45	C	G			R	R						R			R			R	R	C	F			R	R		R	F				R	R		R		C			R		R			R			R		R		F	R		R			
7-2, 43-45	A	G	R	R	R	R			R			F	R	R	R	R	R	R	R	C	F			R			R	R				C	R		R		R			R		R				F		R		F	F	F	R	R	R	R		
7-4, 43-45	A	G	R	R		R					R	R		R			R			F	F			F		R		R				R	R		F	R	F	R	R	R		F						R		F		C	R		R			
7-5, 43-45	C	M		R							R	R			R		R	R		C	C			R			R	F				F			F		F	R		R		F		R				R		R	R	F	R	R	R	R		
7-6, 43-45	A	G	R		R	R					R	R	R	R	R		R	R		C	F		R	F			R	F				F			F		C					R			R	R		R		F	R	F	R		F	R		*Nitzschia marina*
7,CC	C	M	R																	F			R					R	R			R			R		F									R		R		R	R	F			R		R	
8-3, 43-45	C	M	R	R	R			R							R		R			R				R				R				R	R		R		F					R						R		R	R	F	R	R	R			
8,CC	F	M	R									R								R							R					R			R		R											R		R		R						
9-3, 43-45	F	M	R	R								R							R	C								F				R			F		F					R						R		F		F			R			
9,CC	F	M	R	R	R	R														R								R							R		R											R	R		R				R			
10,CC	C	M		R		R					R				R		R	R		F	R	R		R			R	R				R		R	R		R							R		R		R	R	R	R				R	R		*Nitzschia jouseae*
11-3, 43-45	C	M				R												R		R	R		R				R	R				R		R	F		R	R			R			F		R		R	R	R	R	R			R			
Hole 606A																																																										
1,CC	F	M																		R								R	R				R		R					R						R		R			R	R						*P. doliolus*
2,CC	F	M			R							R					R			F							R	R	R						F		R			F							R	R			R	F			R			*Nitzschia reinholdii*
3,CC	C	G		R								R			R	R	R	R		R	R							F				F	R		F		C	R		F		R				F		R		R	R	F	R	R	R		R	
4,CC	F	G		R	R	R						R															R					R			R		F			R						R		R		R		R	R	R	R		R	
5,CC	C	G			R	R								R		R			R		R			R			R	R				R			R		F			R		R				R		R		R	R	F	R		F			
6,CC	R	P																R		R	R														R																							*Nitschia marina*
8,CC	C	G		R		R				R						R				F	R						R	R				R			R							R				R		R		R	R	F			R			
9,CC	R	P																									R	R				R			R		R											R	R	R	R							
10,CC	F	M			R															R					R			R	R			R		R	R											R		R	R	R	R				R			*Nitzschia jouseae*

Note: R = rare, F = few, C = common, A = abundant. Preservation is either poor (P), moderate (M), or good (G). See Appendix for species list.

The following samples are barren of diatoms: *Hole 606:* 4,CC; 6,CC; 11,CC; 12-3, 43-45 cm; 12,CC; 13-3, 43-45 cm; 13,CC; 14-3, 43-45 cm; 14,CC; 15-3, 43-45 cm; 16-3, 43-45 cm; 16,CC; 17-3, 43-45 cm; 17,CC; 18-3, 43-45 cm; 18,CC. *Hole 606A:* core-catcher samples from Cores 11 through 19.

The following samples contain rare diatom fragments: *Hole 606:* 6-3, 43-45 cm; 7-3, 43-45 cm; 10-3, 43-45 cm; 15,CC. *Hole 606A:* 7,CC of this zone, falls between Samples 606-7-5, 43–45 cm and 606-7-6, 43–45 cm (57.24–58.74 m). At Site 606, the first occurrence of *P. doliolus* is correlated with the lowermost Olduvai Subchron, the base of which is placed (Clement and Robinson, this volume) between Samples 606-7-2, 97 cm and 606-7-6, 35 cm. An estimated age of 1.78–1.84 Ma is derived for this datum at Hole 606, approximating the age of 1.8 Ma assigned by Barron (1985b) to this event in the equatorial Pacific.

The last occurrences of *N. fossilis* and the silicoflagellate *Mesocena quadrangula* are within the *N. reinholdii* Zone, in Samples 606-3-4, 43–45 cm and 606-3-5, 43–45 cm, respectively. In Hole 606, both of these datums correlate with the earliest Brunhes. The last occurrence of *N. fossilis* in the North Pacific Ocean is placed by Koizumi and Kanaya (1976) midway between the top of the Jaramillo and the base of the Brunhes. Burckle (1977) places the last occurrence of *M. quadrangula* at an interval equivalent to the last occurrence of *N. fossilis*. Koizumi and Kanaya (1977) assigned both datums an extrapolated age of 0.79 Ma in the Pacific Ocean, approximately 0.15 m.y. older than the age assigned to these datums at Site 606 in the North Atlantic (0.58–0.69 Ma).

Samples 606-7-6, 43–45 cm through 606-9,CC are assigned to the *N. marina* Zone of Baldauf (1985a). In Hole 606, *T. convexa* last occurs in Sample 606-9,CC. Correlation of this datum with Hole 606 paleomagnetic stratigraphy places the last occurrence of *T. convexa* at the Gauss/Matuyama boundary, with an estimated age of 2.3–2.5 Ma. This placement corresponds to the last common occurrence of *T. convexa* in Hole 552A, within the Rockall Plateau region of the North Atlantic Ocean (Sample 552A-10-2, 0–3 cm, equivalent to the Gauss/Matuyama boundary) (Baldauf. 1985a). The actual last occurrence of *T. convexa*, based on a 10-cm sample interval, is placed at Sample 552A-9-1, 63 cm, one-third of the way between the Gauss/Matuyama boundary and the Olduvai (2.2 Ma). This placement is in agreement with the results of Baldauf (1985b) and Burckle and Trainer (1979) in the equatorial Pacific. A sampling interval similar to that used in Hole 552A is required to determine if *T. convexa* occurs between Sample 606-9,CC and Section 606-9-3 at Site 606.

The last occurrence of *N. jouseae* in Sample 606-10,CC is correlated with the upper Gauss. The estimated age of 2.56–2.85 Ma derived for this event in Hole 606 spans the age of 2.6 Ma assigned to it in Hole 552A by Baldauf (1985a) as well as that assigned in the eastern equatorial Pacific by Baldauf (1985b), Burckle and Trainer (1979), and Barron (1985a). Samples 606-10,CC and 606-11-3, 43–45 cm are assigned to the *Nitzschia jouseae* Zone of Baldauf (1985a).

Hole 606A (37°20.29′N; 35°30.017′W, 3007 m water depth)

Nineteen cores (178.4 m, lower Pliocene through Holocene) were recovered from Hole 606A. The distribution of diatoms in this hole is similar to their occurrence in Hole 606. Diatoms were observed in the middle Pliocene to Holocene and absent in the lower Pliocene. The stratigraphic occurrence of selected species for samples examined from Holes 606 and 606A appears in Table 2. Cores 606A-11 through 606A-19 are generally barren of diatoms.

Core 606A-1 is placed in the *Pseudoeunotia doliolus* Zone of Burckle (1977), based on the occurrence of *P. doliolus* above the last occurrence of *Nitzschia reinholdii*. Samples 606A-2,CC through 606A-5,CC are assigned to the *N. reinholdii* Zone of Burckle (1977). The first occurrence of *P. doliolus*, which defines the base of this zone, falls between Samples 606A-5,CC and 606A-8,CC. The exact placement of this event is difficult, because Sample 606A-6,CC is barren of diatoms and Sample 606A-7,CC contains rare and poorly preserved specimens.

Samples 606A-8,CC and 606A-9,CC are tentatively assigned to the *N. marina* Zone of Baldauf (1985a), based on the occurrence of *Thalassiosira convexa* in Sample 606A-7,CC and the absence of both *N. jouseae* and *P. doliolus* throughout this sample interval. Sample 606A-10,CC is placed in the *N. jouseae* Zone of Baldauf (1985a) based on the presence of *N. jouseae*.

Site 607

The principal objective at Site 607 was paleoenvironmental interpretation of the upper Neogene. Site 607 is located on the western flank of the Mid-Atlantic Ridge, northwest of Site 606 (Fig. 1).

Diatoms are present in the uppermost Pliocene to Holocene from Holes 607 and 607A, but except for a 50-cm interval at Hole 607A they are generally absent from the upper Miocene and lower Pliocene.

Hole 607 (41°00.068′N; 32°57.438′W, 3426.8 m water depth)

Thirty cores (284.4 m) of upper Miocene to Holocene sediment were recovered at Hole 607. Few, moderately well preserved diatoms are generally present within the upper 10 cores (92 m). Except for Sample 607-15,CC which contains rare nondiagnostic fragments, diatoms are absent from samples below Core 607-10. Table 3 displays the stratigraphic occurrence of selected diatom species in samples from Hole 607.

Samples 607-1-1, 43–45 cm through 607-3-2, 43–45 cm are assigned to the *Pseudoeunotia doliolus* Zone of Burckle (1977), based on the occurrence of *P. doliolus* without *Nitzschia reinholdii*. The last occurrence of *N. reinholdii* is between Samples 607-3-2, 43–45 cm and 607-3-3, 43–45 cm. Correlation of this biostratigraphic event with the Hole 607 paleomagnetic stratigraphy of Clement and Robinson (this volume) gives an estimated age of 0.44–0.47 Ma (early Brunhes), similar to the estimated age of 0.41–0.47 Ma determined for the last occurrence of *N. reinholdii* at Site 606.

Samples 607-3-3, 43–45 cm through 607-9-3, 43–45 cm are placed in the *N. reinholdii* Zone of Burckle (1977) by the first occurrence of *P. doliolus* in Sample 607-9-3, 43–45 cm. The first *P. doliolus* is correlated to the lower Olduvai (Clement and Robinson, this volume), with an estimated age of 1.75–1.78 Ma, approximating the estimated age of 1.78–1.83 Ma assigned to this datum at Site 606.

Within the *N. reinholdii* Zone, *N. fossilis* last occurs in Sample 607-4-3, 43–45 cm and the silicoflagellate *Mesocena quadrangula* in Sample 607-5-1, 43–45 cm. The

Table 3. The stratigraphic occurrence of selected diatom species and silicoflagellates (*) from Hole 607.

Core-Section (interval in cm)	Abundance	Preservation	*Actinocyclus curvatulus*	*A. divisus*	*A. ehrenbergii*	*A. ellipticus*	*Actinoptychus bipunctatus*	*A. undulatus*	*Asterolampra grevillei*	*A. marylandicus*	*Asteromphalus flabellatus*	*Bacteriastrum hyalinum*	*Coscinodiscus africanus*	*C. asteromphalus*	*C. crenulatus*	*C. marginatus*	*C. nodulifer*	*C. nodulifer* var. *cyclopus*	*C. oculis-iridis*	*C. radiatus*	*C. tabularis*	*Denticulopsis seminae* group	*Diploneis* sp.	*Ethmodiscus rex*	*Hemidiscus cuneiformis*	*Melosira granulata*	*M. sulcata*	*Navicula* sp. 1	*Nitzschia fossilis*	*N. interrupta*	*N. marina*	*N. panduriformis*	*N. reinholdii*	*Nitzschia* sp. 1 "punctata"	*Nitzschia* sp. 2	*Podosira glacialis*	*Pseudoeunotia doliolus*	*Rhaphoneis amphiceros*	*Rhizosolenia barboi*	*R. bergonii*	*R. curvirostris*	*R. hebetata*	*R. styliformis*	*Rhizosolenia* sp.	*Roperia tesselata*	*Stephanopyxis turris*	*Synedra ulna*	*Thalassionema nitzschioides*	*Thalassiosira eccentrica*	*T. leptopus*	*T. oestrupii*	*T. plicata*	*T. symbolophora*	*Thalassiosira* sp. 1	*Thalassiothrix longissima*	*Triceratium cinnamomeum*	Freshwater species	*Mesocena quadrangula**	Diatom zones
1-1, 43-45	A	G	R		R		R	R	R			F	R	F			C		R					R	F						C				F	F	F			R					F			C	F	C	R				R				*Pseudoeunotia doliolus*
1-2, 43-45	F	M		R	R		R	R					R	F	R	R	F		R						R						F						F			R			R		F			R	F	R	R				R				
1-3, 43-45	A	G	F	F	R						R	R	R	R	F		F							R	F	R					C			R	R	R	C								R	F		F	F	F	F	R	R		C				
1-5, 43-45	A	M	F	F	F							F		F		R	R		R					R						F	F			R	R		C			R					F			R	R	R	R		R		C				
1-6, 43-45	F	M	R	R	R		R					R	R	R			R								R					R	R			R	R		F			R			R		R				R	F	R		R	R	R				
1,CC	R	M	R	R																											R																	R	R						R				
2-1, 43-45	C	M	F	F	F		R						R		R	R	R	R	R						R		R				F			R			C					R	R		R				R	F	R						R		
2-2, 43-45	C	G	R	R	R		R					R				R											R			R	F				R		F			R				R	R			R		R	R	R	R		R	R			
2-3, 43-45	R	M		R																					R						R																		R		R								
2-4, 43-45	A	G	R	R	R					R					R		R		R						R	R	R			R	F			R	F		C			R	R	R			F	R		F	R	R	R		R		F	R	R		
2-5, 43-45	F	G			R										R	R	R				R				R						F						R			R								R		R	R				R				
2-6, 43-45	A	G	R	R	F		R					R	R			R	R	R	R	R	R			R	F						R			R		R	A		R		F				R	R		C	F	R	C		R	C	A				
2,CC	C	G	R	R	R	R	R	R				R			F		R				R				R	R	R			R	F				R		C		R		R					R		F	R	F	F	R			R		R		
3-1, 43-45	F	M			R																R										R						F		R	R	F	R			R			R	R	R	R	R			R				
3-2, 43-45	A	M	R	F	F				R			R	R		R									R	R			R			R			R	R		F		F	R	R	R		R		F		R	R	R	F			F	F				
3-3, 43-45	F	M	F	R							R			R			R				R				R	R				R	R		R		R		R		R				R	R		R		R	F	R	F		R						*Nitzschia reinholdii*
3-4, 43-45	F	M	R	R	R								R		R	R	R	R							R	R					F		R	R			F			R			R					R	R	R	R			R					
3,CC	F	M	R	R	R		F								R		R						R	R	R	F					R		R				F			F	R					R		F	F	F	R				R				
4-1, 43-45	A	G			R		C						R		R	R	F				R				F		R	R			F		F		R		C	R	R	R	R				F	R		F	R	R	R				R				
4-3, 43-45	C	M	R	R			R	R				R	R			R	R			R				R	R				C	R	F		F	R			F			R			R		R	F			R	F	F				F				
4-4, 43-45	C	G	F	R	R	R	R			R		R											R		R	R			C	R	R		R	R		F				R		R			R	R		R	R	R	F	R			R				
4-5, 43-45	R	M															R				R				R								R				R												R										
4-6, 43-45	F	G	R	R	R	R							R		R	R	F				R				R		R	R	F	R	R		R		R		R		R	R		R	F	R	R	R		R	R	R	R	R		F	R				
4,CC	A	G	R	F	R		R				R	R			R	R								R	R		R		C	R	C		C	R	R		C			R	R					R		F	R	F	F	R	R		F				
5-1, 43-45	A	G	R	R		R	R		R			F	R		F	R	R								R		R		C	R	F		R	F	R		F	R			R		R		R	R		F	R	R	F		R	R	F			R	
5-2, 43-45	F	G	R		R		R		R			R	R		R	R	F	R	R		R		R		R		R		R	R	F		R		R		R			R	R	F			F	R		R	F		R	F			F	R		R	
5-3, 43-45	A	G	R	F	R							F	R		R	R	R					R			R				C		R		R	R	R		F		R		R		F			R	R	F	R	R	C	F	R		A			F	
5-4, 43-45	A	G	F	F								F	R			R	R		R			R			R		R		F	R	F		F				R		R	R	R	R	R		R			R	F	R	R	R	R		R			F	
5-5, 43-45	R	P			R											R	R																R																						R				
5-6, 43-45	R	M		R													R								R				R	R	R		R				R												R	R					R			R	
5,CC	R	M											R				R								R					R	R		R				R			R								R	R	R					R				
6-1, 43-45	A	G	R		R			R				F	R		R	R	R	R			R	R			R	R	R		C	F	F		F	R	R		F		F	R			R		R			R	R	R		R	R		F		R	R	
6-5, 43-45	F	G		R											R	R	R				R	R					R		F	R	R		F	R	R		R		R	R					R			R	R	R	R		R		F				
6-6, 43-45	F	M		R																	R				R				F	R	R		R	R	R		R		F			R						R				R		R	R				
7-1, 43-45	R	P										R			R		R				R				R				R		R		F				R												R					R	R				
7-2, 43-45	A	G		F	R			R				F				R	R		R		R				F	R	R		C		F		C	R	F		C		R			R	R	R	R				R	R	C	R	R	R	F				
7-5, 43-45	F	M		R																					R						R		F		R		R		R			R	R	R				F	R	R	F	R	R		R				
7,CC	R	M													R		R												R					R														R	R						R				
8-1, 43-45	A	G	R	R								R	R			R					R				R	R	R		F		R		F	R	R		C			R			R					R	F		R			R	F				
8-2, 43-45	F	P																	R		R				R				F				F		R							R							R	R				R	R				
8-3, 43-45	F	M		R									R		R		F				R				F	R			F		R		R	R	R		R											R	F	R	F	R							
8-4, 43-45	C	M		R	R	R						R	R				R	R		R	R				C	R			F		R		C				R		R	R			R	R				R	F	R	F	R			R	R			
9-2, 43-45	R	P															R								R								R																	R									
9-3, 43-45	C	M	F	R								R				R	F	F			R				R	R			F	R	R		F	R			R			R								R	F	R		R			F				
9-4, 43-45	C	M	R			R						R		R		R	C	C			R				C				R		R		F							R								R	R	F	F	R	R		R				*Nitzschia marina*
9-6, 43-45	C	G	R		R							R	R		R		R	F	R	R	R		R		F				F		R	R	C		R					R					R			R	R	R	F	F	R	R	F	R			
10-2, 43-45	R	P																																														R			R								
10-3, 43-45	F	M	R								R				R		R								F	R			F				F		R													R	F	R	R				R				
10,CC	F	M	R	R				R				R					R				R			R	R				F		F		R															R	F		R	R			R				

Note: R = rare, F = few, C = common, A = abundant. Preservation is either poor (P), moderate (M), or good (G). See Appendix for species list.

The following samples are barren of diatoms: *Hole 607:* 4-2, 43-45 cm; 6-2, 43-45 cm; 6-3, 43-45 cm; 6-4, 43-45 cm; 7-3, 43-45 cm; 7-6, 43-45 cm; 8-5, 43-45 cm; 8-6, 43-45 cm; 8,CC; 9-1, 43-45 cm; 10-1, 43-45 cm; 10-4, 43-45 cm; 10-5, 43-45 cm; 11-3, 43-45 cm; 11,CC; 12-3, 43-45 cm; 12,CC; 13-3, 43-45 cm; 13,CC; 14-3, 43-45 cm; 14,CC; 15-3, 43-45 cm; 16-3, 43-45 cm; 16,CC; 17-3, 43-45 cm; 17,CC; 18-3, 43-45 cm; 18,CC; 19-3, 43-45 cm; 19,CC; 20-3, 43-45 cm; 21-3, 43-45 cm; 21,CC; 22,CC; 23,CC; 24,CC; 25,CC; 26,CC; 27,CC; 28,CC; 29,CC; 30,CC. *Hole 607A:* 11,CC; 12,CC; 13,CC; 14,CC; 15,CC; 18,CC; 19,CC; 20,CC; 21,CC; 22-3, 43-45 cm; 25-3, 43-45 cm; 25,CC; 26-3, 43-45 cm; 26,CC.

The following samples contain rare diatom fragments: *Hole 607:* 6,CC; 7-4, 43-45 cm; 15,CC. These samples had no residue after acid treatment: *Hole 607A:* 1-4, 43-45 cm; 9-3, 43-45 cm; 16,CC; 17,CC.

last occurrence of *N. fossilis* is correlated to the lower Brunhes, with an estimated age of 0.54–0.60 Ma. The last occurrence of *M. quadrangula* approximates the Matuyama/Brunhes boundary; it has an age of 0.73 Ma in Holes 607, different from the age of 0.58–0.69 Ma determined in Hole 606.

Rare specimens of *Denticulopsis seminae* and *D. seminae* var. *fossilis* (hereafter referred to as the *D. seminae* group) occur at Site 607 within the upper *N. reinholdii* Zone. Specimens of this group are observed in Samples 607-5-3, 43–45 cm, 607-5-4, 43–45 cm, 607-6-1, 43–45 cm, and 607-6-5, 43–45 cm. No specimens were observed in Samples 607-5-5, 43–45 cm, 605-5-6, 43–45 cm and 607-5,CC. These samples contain rare, poor to moderately well preserved diatoms, and the *D. seminae* group is probably not preserved. The significance of the occurrence of the *D. seminae* group at Site 607 and other Leg 94 sites is addressed in the Discussion.

Samples 607-9-4, 43–45 cm through 607-10,CC represent the interval between the last *N. jouseae* and the first *P. doliolus*. This interval is assigned to the *N. marina* Zone of Baldauf (1985a).

Hole 607A (41°00.068′N, 32°57.438′W, 3426.8 m water depth)

Twenty-six cores (311.3 m) were recovered from Hole 607A. The oldest sediment recovered is placed in the upper Miocene NN11 calcareous nannofossil Zone (Takayama and Sato, this volume).

Few moderately well preserved diatoms are generally present within the uppermost 9 cores (78 m). Cores 607A-1 and 607A-2, are assigned to the *Pseudoeunotia doliolus* Zone of Burckle (1977) based on the occurrence of *P. doliolus* above the last occurrence of *Nitzschia reinholdii*. The last occurrence of *N. reinholdii* is in Sample 607A-3,CC and the first occurrence of *P. doliolus* is in Sample 607A-9,CC. Therefore, Samples 607A-3,CC through 607A-9,CC are assigned to the *N. reinholdii* Zone of Burckle (1977). Several stratigraphic events occur within this zone. *Nitzschia fossilis* last occurs in Sample 607A-4,CC, and *Mesocena quadrangula* and the *Denticulopsis seminae* group in Sample 607A-5,CC.

Sample 607A-10,CC is tentatively placed in the *N. marina* Zone of Baldauf (1985a) by the absence of *P. doliolus* and *N. jouseae*. Exact stratigraphic placement of this sample is, however, difficult, as only rare, poorly preserved specimens were observed.

Except for Samples 607A-24,CC and 607A-25-1, 43–45 cm, samples below Sample 607A-10,CC are barren of diatoms (Table 3). In several cases no processed residue remained after the sediment sample was treated with hydrochloric acid. Samples 607A-24,CC and 607A-25-1, 43–45 cm are placed in the *Thalassiosira convexa* Zone of Burckle (1972), based on the occurrence of *T. convexa* and *T. miocenica* without *N. jouseae*. The occurrence of *T. miocenica* and *T. nativa*, as well as the absence of *T. oestrupii* s. str., suggests that these samples are late Miocene to early Pliocene in age. This, of course, assumes that the ranges of these species are isochronous between the North Atlantic and the equatorial Pacific oceans.

Thalassiosira miocenica is correlated by Burckle (1978) with a paleomagnetic period ranging from late Chron 6 (6.1 Ma) to the earliest reversal of the Gilbert Chron (5.1 Ma). Barron et al. (1985) also place the first occurrence of *T. oestrupii* in the earliest reversed event of the Gilbert Chron, equivalent to the last occurrence of *T. miocenica*. Baldauf (1985b) recognized a slight stratigraphic overlap between the last *T. miocenica* and the first *T. oestrupii* s. str., and extrapolated an age of 5.1 Ma for the last *T. miocenica*, similar to that assigned it by Barron et al. (1985).

Site 608

Site 608 consists of two holes cored on the southern flank of the King's Trough tectonic complex (Fig. 1). Middle upper Eocene through Quaternary sediments were recovered. Rare to abundant diatoms occur within the middle Miocene and middle Pliocene to Holocene sediments. The diatom assemblage is a warm-temperate assemblage similar to that at Sites 606 and 607.

Hole 608 (42°50.205′N, 23°05.252′W, 3526 m water depth)

Fifty-nine cores (530.3 m) were recovered in Hole 608. Except for the uppermost Quaternary (Baldauf et al., this volume), a continuous stratigraphic sequence of Quaternary through middle upper Oligocene sediment was recovered. A hiatus lasting about 9.5 m.y. separates middle upper Oligocene from middle upper Eocene sediment.

Diatoms were observed in middle Miocene and middle Pliocene through upper Quaternary sediments. Table 4 illustrates the stratigraphic occurrence of selected species for samples examined from Hole 608 and lists barren samples.

The last occurrence of *Nitzschia reinholdii* in Sample 608-2-4, 43–45 cm allows Samples 608-1-3, 43–45 cm through 608-2-2, 43–45 cm to be assigned to the *Pseudoeunotia doliolus* Zone of Burckle (1977), based on the occurrence of *P. doliolus* above the last occurrence of *N. reinholdii*. Samples 608-2-4, 43–45 cm through 608-6,CC are assigned to the *N. reinholdii* Zone of Burckle (1977) by the first occurrence of *P. doliolus* in Sample 608-6,CC.

Within the *Nitzschia reinholdii* Zone, *N. fossilis* last occurs in Sample 608-2-5, 43–45 cm. The *Denticulopsis seminae* group, which occurs within the *N. reinholdii* Zone at Site 607, does not occur at Site 608.

Samples 608-7-2, 43–45 cm through 608-9,CC are assigned to the *Nitzschia marina* Zone of Baldauf (1985a). Rare specimens of *N. jouseae* in Sample 608-11,CC allow this sample to be placed in the *N. jouseae* Zone of Baldauf (1985a). The majority of samples examined from Cores 608-12 to 608-28 are barren of diatoms, but several contain rare diatom fragments (Table 4).

Few, moderately well preserved diatoms occur in samples from Section 608-29-5 through Core 608-32. Occasional samples within this interval contain abundant, well preserved diatoms. The species in this middle Miocene interval include *Actinocyclus ingens, Annellus californicus, Coscinodiscus gigas* var. *diorama, C. lewisianus, C.*

Table 4. The stratigraphic occurrence of selected diatom species from Hole 608.

Core-Section (interval in cm)	Abundance	Preservation	Actinocyclus curvatulus	A. divisus	A. ehrenbergii	A. ellipticus	A. ingens	A. moronensis	Actinoptychus bipunctatus	A. undulatus	Annellus californicus	Asterolampra grevillei	A. marylandicus	A. symmetricus	Asteromphalus flabellatus	A. hookeri	A. imbricatus	Bacterium hyalinum	Cestodiscus sp.	Cocconeis scutellum	Coscinodiscus africanus	C. asteromphalus	C. crenulatus	C. gigas var. diorama	C. lewisianus	C. marginatus	C. nodulifer	C. nodulifer var. cyclopsis	C. plicatus	C. praenodulifer	C. radiatus	C. salisburyanus	C. tabularis	C. vetustissimus	C. yabei	Craspedodiscus coscinodiscus	Cyclotella group	Denticulopsis hustedtii	D. hyalina	D. nicobarica	D. punctata	D. punctata var. hustedtii
1-3, 43–45	R	G		F	R																						R															
1-5, 43–45	A	G	F	R	R																	R	R				R						R									
1,CC	R	M	R	R					R												R						R															
2-1, 43–45	R	P																																								
2-2, 43–45	F	M																								R	C						F									
2-4, 43–45	F	G		R		R			R														R				R						R									
2-5, 43–45	F	G																								R																
2,CC	F	M		R						R					R						R		R			R	R										R					
3,CC	R	M	R																																							
4-3, 43–45	F	M	R									R				R		R			R	R	F			R	F				R		R									
4,CC	R	P																																								
5-3, 43–45	A	M		R									R		R						R		R				C	F					R									
5-4, 43–45	F	G	F	R						R							R				R						R						R									
5-6, 43–45	R	P	R																																							
5,CC	F	G	R	R											R												F						R									
6-1, 43–45	R	M																									R															
6-2, 43–45	F	M	R																		R					R	F						R				R					
6-3, 43–45	R	M																																								
6-4, 43–45	F	P		R																																	R					
6-5, 43–45	C	G	R			R											R				R						F						R									
6,CC	F	M	R	R	R	F									R											R	R															
7-2, 43–45	F	G																			R					R	R						R									
7-3, 43–45	F	P	R												R											R	F										R					
7,CC	F	M	R	R											R											R	F															
8,CC	F	M	R												R												R															
9,CC	R	P		R																																						
11,CC	R	P																									R	R														
29-5, 43–45	F	M				R	R			R		R			R											R							R		R			R				R
29,CC	A	M		R	C	F	A	R		F	R	R	R													C		R	R						R	R		F		R		F
30-3, 43–45	A	G			C	F	C	F		F		R	R	R										R		C		R	R				F	R	F	F		F		R		R
30-5, 43–45	A	M			R	R	C			R		R	R						R					R		F	R		R		R	R	R	R	R	R		R				F
30,CC	C	M			R	R	F			R			R											R		R			R				R					F				F
31-1, 43–45	F	G				R	F			R		R														R										R		R				F
31-2, 43–45	A	G				F	F			R		R							R	R					R	F				R			F		R	R		F				F
31-3, 43–45	A	G				F	F			F		R													F	F				R			R		R			R		R	R	R
31,CC	F	P		R	R		R																		R	R										R		R				R
32-1, 43–45	F	M		R		R	R			R												R				F			R		R		R			R		R		F		R
32-9, 43–45	A	M			R	R	F			F			F						R			R			R	F				R		R	R					R		R		
32,CC	C	M				R	C			R		R	R						R						F	F				R						R		F	R		R	F

Note: R = rare, F = few, C = common, A = abundant, r = rare reworked specimens. Preservation is either poor (P), moderate (M), or good (G). See Appendix for species list.

The following samples are barren of diatoms: *Hole 608:* 2-3, 43–45 cm; 3-3, 43–45 cm; 5-5, 43–45 cm; 10,CC; 12,CC; 13,CC; 15,CC; 16,CC; 17,CC; 19,CC; 20,CC; 21,CC; core-catcher samples for Cores 22–28, 37–46, and 48–52; 56,CC; 57-3, 43–45 cm. *Hole 608A:* 7,CC; core-catcher samples for Cores 11–16.

The following samples contain rare diatom fragments. *Hole 608:* 8-3, 43–45 cm; 10-3, 43–45 cm; 14,CC; 18,CC. Sample 608-53,CC had no residue after acid treatment.

plicatus, C. praenodulifer, Craspedodiscus coscinodiscus, Denticulopsis hustedtii, D. nicobarica, D. hustedtii var. *punctata*, and *Synedra jouseana*.

The last occurrence of *Coscinodiscus lewisianus* in Sample 608-31-2, 43–45 cm allows Samples 608-29-5, 43–45 cm through 608-31-1, 43–45 cm to be placed in the *C. gigas* var. *diorama* Zone of Barron (1985b). Samples 608-31-2, 43–45 cm through 608-32,CC can be placed in the *C. lewisianus* Zone of Barron (1985b). Samples below Core 608-32 are barren of diatoms (Table 4).

Hole 608A (42°50.205′N; 23°05.252′W, 3526 m water depth)

Sixteen cores (146.4 m) of Pliocene through Holocene sediment were recovered from Hole 608A. Diatom occurrence is similar to that in the Pliocene to Holocene sediment of Hole 608.

Cores 608A-1 and 608A-2 are assigned to the *Pseudoeunotia doliolus* Zone of Burckle (1977), based on the occurrence of *P. doliolus* above the last *Nitzschia reinholdii*. Cores 608A-3 through 608A-6 are assigned to the *N. reinholdii* Zone of Burckle (1977). The placement of the base of this zone at the first occurrence of *P. doliolus* is difficult because Sample 608A-7,CC is barren of diatoms and Samples 608A-8,CC and 608A-9,CC contain rare, poorly preserved diatom fragments. Sample 608A-10,CC is placed in the *N. marina* Zone of Baldauf (1985a), based on the absence of *P. doliolus* and *N. jouseae* in this sample. Samples 608A-11,CC through 608A-16,CC are barren of diatoms.

Site 609

Site 609 is located on the eastern flank of Mid-Atlantic Ridge, approximately 450 n. mi. (725 km) west–south-

Table 4 (continued).

Diogramma sp.	Diploneis group	Hemidiscus cuneiformis	Liradiscus bipolaris	Macrora stella	Mederia splendida	Melosira granulata	M. sulcata	Navicula sp. 1	Nitzschia cf. cylindrica	N. fossilis	N. heteropolica	N. interrupta	N. jouseae	N. reinholdii	N. marina	Nitzschia sp. 1	Nitzschia group	Pleurosigma sp.	Pseudoeunotia doliolus	Rhizosolenia barboi	R. bergonii	R. curvirostris	R. miocenica	R. praebergonii	R. styliformis	Rossiella praepaleacea	Roperia tesselata	Rouxia cf. diploneis	Stephanopyxis turris	Synedra jouseana	Thalassionema nitzschioides	Thalassiosira convexa	T. eccentrica	T. leptopus	T. oestrupii	T. plicata	T. symbolophora	Thalassiothrix longissima	Triceratium cinnamomeum	Triceratium sp.	Diatom zones
																											R							F							
		F										R			F	F			C								R				R		F	F	F		R				*Pseudoeunotia doliolus*
						R									F												R				R		R	R	R			R			
		R													R				R														R					R			
		C													R				F		R				R								R	F							
						R						R		R	R				F		R						R				R		R	R	F		R	R			*Nitzschia reinholdii*
						R		R		R		R		R	R	R	R		R	R	R	R									R		R	R	F		R				
		F								R		R		F	R				F	R	R				R								R	R	F		R	R			
		R								R				R	R				R		R										R		R	R	R			R			
		F							R	F		R		C	F	R			R	R	R						R		R		R		F	F	F		R	F			
										R																												R			
		F								F		R		C	F				R		R						R				R			R	F			F	R		
		C								F		R		F	F	R	R		R		R				R		R				R		R	R	F			R			
		R								R				R																			R	R							
		R								R			r	R	R				R		R			R					R		R	r	R	R	R	R	R	F			
															R						R												R					R			
		F								F				R	R		R		R		R										R		R	R	R			F			
																								R									R								
		R								R				R																			R	R	R			R			
	R	F							R	R		R		R	R		R		R		R			R					R		F	r	R	R	R	R		F	R		
		R								R				F	R				R		R												R	R	R			R			
		R								R		R		R		R	R							R			R						R	R	R			R			*Nitzschia marina*
		F												F	R																R	R	F	R			R				
		F								F				F	R																R		F	R	R			R	R		
		R								R				R	R																R		R	R	R			R			
		R																																							
		R								R				R																			R	R				R			
																																									?
																														R	R							R			*Coscinodiscus gigas* var. *diorama*
				R			R																							F	F			R				C			
					R																							R		F	R			R				C	R		
				R																						R					C			R				C			
					R																							R			R			R				F			
																															R			R				R			
					R						R															R				R	C		R	R				A		R	*Coscinodiscus lewisianus*
R		R		R							R																			R	R			R				C			
																													R		R							F			
R																														R	F			R				F		R	
				R																											A		R	R				F			
				R														R					R						R		C			R				C		R	

west of Ireland and approximately 150 n. mi. (240 km) south of the Charlie Gibbs Fracture Zone (Fig. 1). Four holes were cored at Site 609, using the hydraulic piston corer and extended core barrel. Upper Miocene to Holocene sediments were recovered. The principal objectives at Site 609 included paleoenvironmental reconstruction to obtain information on the history of deep water flow, Neogene carbonate dissolution, and ice rafting.

Hole 609 (49°52.667′N; 24°14.287′W, 3884 m water depth)

Forty-two cores (399.4 m) of upper Miocene to Holocene sediments were recovered. Diatoms are generally present within the upper 28 cores (265 m), which are late Pliocene to Holocene in age. The diatom species present are characteristic of a warm-temperate assemblage similar to that observed at Sites 606, 607, and 608. Diatoms are generally well preserved and are common to abundant. Table 5 lists the stratigraphic occurrence of selected diatom species for samples from Hole 609. Samples below Core 609-28 are barren or contain rare diatom fragments.

The last occurrence of *Nitzschia reinholdii* is between Samples 609-4-1, 43–45 cm and 609-3,CC. *Pseudoeunotia doliolus* occur above the last occurrence of *N. reinholdii*, allowing Samples 609-1,CC through 609-3,CC to be assigned to the *P. doliolus* Zone of Burckle (1977). The last occurrence of *N. reinholdii* correlates with the middle Brunhes Chron as recognized at Hole 609 by Clement and Robinson (this volume). The age of 0.41–0.44 Ma estimated for this event at Site 609 agrees with the ages estimated at Sites 606, 607, and 608.

Few reworked specimens of *Thalassiosira convexa* are observed in Sample 609-4-1, 43–45 cm. The last occurrence of *N. fossilis* (estimated age of 0.5–0.65 Ma) occurs in Sample 609-5-3, 43–45 cm, slightly below the last occurrence of *N. reinholdii*. The last occurrence of *Mesocena quadrangula* is in Sample 609-6-1, 43–45 cm.

Table 5. The stratigraphic occurrence of selected diatom species and silicoflagellates (*) from Hole 609.

Core-Section (interval in cm)	Abundance	Preservation	*Actinocyclus curvatulus*	*A. divisus*	*A. ehrenbergii*	*A. ellipticus*	*A.* cf. *oculatus*	*Actinoptychus bipunctatus*	*A. undulatus*	*Asteromphalus flabellatus*	*A. imbricatus*	*Bacteriastrum hyalinum*	*Bacteriosira fragilis*	*Coscinodiscus africanus*	*C. asteromphalus*	*C. crenulatus*	*C. marginatus*	*C. nodulifer*	*C. nodulifer* var. *cyclopus*	*C. oculus-iridis*	*C. radiatus*	*C. tabularis*	*Delphineis* sp.	*Denticulopsis seminae* group	*Diploneis* sp.	*Hemidiscus cuneiformis*	*Melosira granulata*	*M. sulcata*	*Navicula* sp. 1	*Nitzschia fossilis*	*N. interrupta*	*N. jouseae*	*N. marina*	*N. panduriformis*	*N. reinholdii*	*Nitzschia* sp. 1	*Nitzschia* group	*Podosira glacialis*	*Pseudoeunotia doliolus*	*Rhizosolenia barboi*	*R. bergonii*	*R. curvirostris*	*R. hebetata*	*R. praebergonii*	*R. styliformis*	*Rhizosolenia* sp.	*Roperia tesselata*	*Stephanogonia* sp.	*Stephanopyxis turris*	*Thalassionema nitzschioides*	*Thalassiosira convexa*	*T. eccentrica*	*T. gravida*	*T. leptopus*	*T. nidulus*	*T. oestrupii*	*T. plicata*	*T. symbolophora*	*Thalassiosira* sp.	*Thalassiothrix longissima*	*Triceratium cinnamomeum*	*Trinacria* sp.	*Mesocena quadrangula**	Diatom zones
1,CC	A	G	F	F								F		R	F		F			F		F				F							F						R				F		C		F			F		F		F		A		F		C				
2-3, 43–45	F	M		R				F				R			F	R	R			R						R		R			R		R			R		R	F		R		F		F		F			R		R	R	R		F		R		R				
2-4, 43–45	R	M																											R										R	R		R	R						R				R	R		R				R				
2-6, 43–45	A	G	F	F	R					R		R					R	F		R		R				R							R			R	R		C				F		R		F		R	F		F	R	R		C	R	F		F				*Pseudoeunotia doliolus*
2,CC	A	G	F	R				R									F					R																	F	R		F	F		R					F				F		F		R		A				
3-1, 43–45	A	G	F									R				F	R	R		R	R	F				R					R		R			R	R	R	R		F	R	R		R		R			R		R		R		C	F	R		C				
3-3, 43–45	C	M	R	R	R			R							R		F			R						R		R					F	R		R	R		F	F		F	R							R		R		F		F		F						
3,CC	R	M	R														R																R						R				R											R		R		R						
4-1, 43–45	A	G	R	F	R	F		F		R		R			R	R	R	R				R				F					R		F		R		R	F	C	R	R	R			R		R		F	C	f			F		C		C			R			
4-3, 43–45	A	G	R	F				R						R		R	F					R						R			R		R		R	R	R	R	C	F		R	R		R				R	F		R		R		F		A						
5-3, 43–45	C	G	R	R				R	R			R		R		R	R	R		R		R				R		R	R	F			R		R		R		F	R	R	R	R		R	R	R		R	R		R	R	F	R	F	R	R		F	R			
5,CC	F	M	R	F	R							R		R			F							R				R					R		R				R				R		R							F								R				
6-1, 43–45	A	G	F	R	R					R		R			R	R	F	R		R	R	R		F		R				R			F		F	R	R		C	F	F	F	R		R		C		R	F		R	R	F		C	R	F	R	F			R	
6-2, 43–45	A	G	F	F				R		R		F				R		F		R		R				R	R	R		R	R		R		R	R	R		F	F	R	F	F		R	R	F	R		C		R		F	R	F		R		C			F	
6-5, 43–45	R	M		R	R												R							C											R								R																					
6,CC	C	G	R	R	R												F							A				R		R			R		R				R	R			F							F		R		R		R				F				
7-3, 43–45	A	G	R	R	R		R	R	R			R	R				F	R			R			F		R		R	R	F	R		R		R	R	R	R	R	R	R		R			R	R		R			R	F	R		R		F		F			F	
7,CC	C	G		R			R					R					R					R		F		R				C	F				F	R	R		R	R			R							F		F		F	R	C				C			F	
8,CC	C	M	R									R				R								R		R		F		F	R		R		F		R		F				R		R							F		R		F		R		F			R	
9-3, 43–45	F	M	R	R													R					R			R					R	R				R	R	R		R		R		R							R		R		R					R	F				
9-5, 43–45	R	G																									R								R				R											R		R		R		R		R		R				*Nitzschia reinholdii*
9-6, 43–45	A	G		R	R				R		R	R					R	R			R	R				R		R		C	R		R	R	R	R	R	R	F	R	R		R				F			R		R		R		C		R		C				
9,CC	A	G	F	R						R		R				R	R					R				F				C			F		F	R	R	R	F	F					R		R			F		F		F		C	R	R	R	R				
10-3, 43–45	A	G	R	R	R							R			R		R	R		R						R		F		C	R		F		C	F	R		R	F	R				F					C		F	R	F		C			R	C			R	
10,CC	R	M		R	R												R													R			R		R				R				R							R						R				R				
11-3, 43–45	F	M	R																											R					R				R	R			R							R		R								R				
11-5, 43–45	F	G			R												R					R						R							R								R		R					R		R				R		R		R				
11,CC	A	G	R	F						R		R					F	F		R		R				R				C			F		C			R	C				R		R					F		C		R		C	R		R	A				
12-3, 43–45	A	G	R	R	R							R		R				R				R				F				F	R		F	R	F	R			R		R		R				R			C		F	R	F		C				C				
12,CC	R	P															R																										R																					
13,CC	R	M		R	R																							R																						R										R				
14-3, 43–45	C	M	R	R													R	F								F				F			R		F				R						R					F		R		R		F	R		R	F				
14,CC	C	M	F	F													F	R	R			R				F							R		R				R		R		R							F		F		R		F			F	F				
15-1, 43–45	A	M	F	C			F					R					A	C	F			R				R		R					R		R	R											R		R	F				R		F		R		R				
15-2, 43–45	F	M		R													R	F				R				F				R			F		F								R							R		R		R		R	R							
15-3, 43–45	C	M	R	R												R		R							R	F		R		F			R		F								F	R	R					F		R		F	R	F	R		R					
15,CC	C	M	R	R					R							R	F	R								R				R	R		R				R								R					F		F		R		F			R	F				
16,CC	R	P		R																						R				R					R															R										R				
17-3, 43–45	R	P																								R									R																									R				
17,CC	C	P	R	F						R		R					F									F				R			R																	F		F		R		F	R			C				
18-1, 43–45	C	M	F	R					R			R					C	R				F				C		R		R	R				R														F	R		R		R		R		R	R	F				*Nitzschia marina*
18,CC	R	P															R																																											R				
19,CC	A	G	F	F	R					R		F					R								R	R	R			F			R		F	R	R								R		F			C		R		R		F	R	R	R	A		R		
20-3, 43–45	A	G	C	C	F				R			F					F	F		R		R				F		R		F			F		R	R		R		R	R		R	R			R	R	C	A	R	F		R		R		R		C				
20,CC	C	M	R	R	R	R			R		R	R		R			R	R					R			F				F	R									R			R						F	F	R	R		F		F				F	R			
22-1, 43–45	A	G	F	C	R				R	R		R				R	F	F				R	F			C		R		F	R		R		F	R	R				R		R	R			R		C	C	F	R		R		F		R		C				
22,CC	A	G	F	R	R	R			R	R		R				R	F	F								F				F					F									R			R		C	F	F			R		F		R	R	F				
24-3, 43–45	A	G	R	R	F											R	R	F	R			R				C				C					C		R												C	C	R	R		R		R		R		R				
24,CC	F	M															R									R				R					R														R	R		R		R		R				R				
25,CC	R	M		R																						R						R	R																		R			R						R				*N. jouseae*
28,CC	F	P															R	R								R																								R		R		R			R			R				

Note: R = rare, F = few, C = common, A = abundant, f = few reworked specimens. Preservation is either poor (P), moderate (M), or good (G). See Appendix for species list.

The following samples are barren of diatoms: *Hole 609:* 2-1, 43–45 cm; 4,CC; 5-1, 103–105 cm; 5-2, 43–45 cm; 6-3, 43–45 cm; 8-3, 43–45 cm; 13-3, 43–45 cm; 13-5, 43–45 cm; 16-3, 43–45 cm; 25-3, 43–45 cm; 26,CC; 27,CC; 29,CC; 30,CC; 31,CC; 32,CC; 33,CC; 34,CC; 35-4, 43–45 cm; 35,CC; 36-3, 43–45 cm; 36-6, 43–45 cm; 36,CC; 37,CC; 38,CC; 39,CC; 40,CC; 41-5, 43–45 cm; 41,CC; 42,CC. *Hole 609B:* Core-catcher samples for Cores 8, 10, 15, and 31–38.

The following samples contain rare diatom fragments: Sample 609-20-2, 43–45 cm. *Hole 609B:* Core-catcher samples from Cores 3, 12, 27, 28, and 30.

There was no recovery in Cores 609-21, 609-23, 609B-18, and 609C-3.

Except for Sample 609-6-2, 43–45 cm, rare to abundant specimens of the *Denticulopsis seminae* group are observed in most samples from 609-5,CC through 609-8,CC.

The first occurrence of *P. doliolus* is placed between Samples 609-14,CC and 609-15-1, 43–45 cm. Samples 609-4-1, 43–45 cm through 609-14,CC are assigned to the *N. reinholdii* Zone of Burckle (1977). The first occurrence of *P. doliolus* in Hole 609 is correlated with the lowermost Olduvai and has an extrapolated age of 1.84–1.86 Ma.

Samples 609-15-1, 43–45 cm through 609-24,CC represent the interval between the last occurrence of *N. jouseae* and the first occurrence of *P. doliolus* and are assigned to the *N. marina* Zone of Baldauf (1985a). The last occurrence of *T. convexa* falls within this interval, between Samples 609-20-3, 43–45 cm and 609-19,CC. Correlation with the paleomagnetic results of Clement and Robinson (this volume) places this datum slightly below the Gauss/Matuyama boundary, one-fifth of the way between this boundary and the top of the Kaena Subchron, and assigns it an estimated age of 2.48–2.62 Ma in Hole 609.

Samples 609-25,CC and 609-28,CC are tentatively assigned to the *N. jouseae* Zone of Baldauf (1985a) by the occurrence of *N. jouseae* in Sample 609-25,CC.

Hole 609A (49°52.667′N; 24°14.287′W, 3883 m water depth)

Two cores (19.2 m) of upper Quaternary sediment were recovered from Hole 609A. Core 609A-1 is assigned to the *Pseudoeunotia doliolus* Zone of Burckle (1977). Core 609-2 is placed in the *Nitzschia reinholdii* Zone of Burckle (1977).

Because of an excess 28.2 m of drill pipe, the top of Core 609A-1 was recovered at a sub-bottom depth of 28 m rather than at the sediment/water interface. This explains why the *N. reinholdii/P. doliolus* zonal boundary occurs between Cores 609A-1 and 609A-2 whereas it occurs in Core 4 of Hole 609.

Hole 609B (49°52.667′N, 24°14.287′W, 3883 m water depth)

Thirty-eight cores (354.7 m) of upper Miocene to Holocene sediment were recovered from Hole 609B. Diatoms are generally present in the upper 29 core-catcher samples examined. Within these cores, diatoms are generally common and well preserved.

Cores 609B-1 and 609B-2 are placed in the *Pseudoeunotia doliolus* Zone of Burckle (1977), based on the occurrence of *P. doliolus* above the last occurrence of *Nitzschia reinholdii*. The base of this zone is tentatively placed between Samples 609B-2,CC and 609B-4,CC. Sample 609B-3,CC is barren of diatoms.

Sample 609B-14,CC contains *P. doliolus*, which allows the sample interval between Samples 609B-4,CC and 690B-14,CC to be assigned to the *N. reinholdii* Zone of Burckle (1977). The base of the *N. reinholdii* Zone, between Samples 609B-14,CC and 609B-16,CC, cannot be accurately placed because Sample 609B-15,CC is barren of diatoms.

Nitzschia fossilis last occurs in Sample 609B-5,CC. Samples 609B-6,CC and 609B-7,CC contain few to common specimens of the *Denticulopsis seminae* group. Sample 609B-7,CC also contains few specimens of *Mesocena quadrangula*.

Samples 609B-16,CC through -20,CC are assigned to the *N. marina* Zone of Baldauf (1985a). *Thalassosira convexa* last occurs within this zone at Sample 609B-20,CC. Sample 609B-21,CC contains *N. jouseae*, which places this sample in the *N. jouseae* Zone of Baldauf (1985a). Diatoms in Samples 609B-22,CC and 609B-23,CC are poorly preserved, and *N. jouseae* is not present. Samples 609B-24,CC through 609B-29,CC contain *N. jouseae* and are placed into the *N. jouseae* Zone of Baldauf (1985a).

Hole 609C (49°52.667′N, 24°14.287′W, 3883 m water depth)

Seven cores (190.4 m) of upper Miocene through Holocene sediment were recovered from Hole 609C, where coring began at a sub-bottom depth of 123.2 m. All core-catcher samples contain diatoms. Samples from Core 609C-1 and all succeeding samples are assigned to the late Pliocene *Nitzschia marina* Zone of Baldauf (1985a) rather than the latest Pliocene through Quaternary *N. reinholdii* or *P. doliolus* Zones of Burckle (1977). This zonal assignment is based on the occurrence of *Thalassiosira convexa* in Samples 609C-6,CC and 609C-7,CC as well as the absence of *P. doliolus, N. jouseae, T. miocenica*, and *T. nativa* from all samples. The occurrence of *T. convexa* in Samples 609C-6,CC and 7,CC suggests that these samples approximate the lowermost *N. marina* Zone. Such a stratigraphic placement agrees with the nannofossil and foraminiferal biostratigraphy (Baldauf et al., this volume).

Site 610

Six holes were drilled near the axis of the Feni sediment drift in the Rockall Trough (Fig. 1). Four holes (610 and 610A–C) were located on the crest of a sediment wave, and two (610D and E) were drilled in an adjacent trough approximately 0.7 km north and in water 28 m deeper. The objectives at Site 610 were to date the uppermost regional seismic reflector "R2" of Roberts (1975) and to document the characteristics of sedimentary waves and "drift" sediments.

Hole 610 (53°13.297′N, 18°53.213′W, 2417 m water depth)

Hole 610 was continuously hydraulic piston cored to a depth of 48 m (5 cores), washed from 48–147 m, and then continuously cored from 147 m to 185 m (Cores 6–9). Below this depth, the hole was spot cored every 50 m for the interval from 147–636 m and then continuously cored from 636 m to the bottom of the hole at 723 m.

Lower Miocene to Holocene material was recovered from Hole 610. Diatom abundance and preservation are variable throughout the hole. In general, diatoms are sparse within the upper five cores, present occasionally in Cores 610-6 through 610-9, and are absent in Cores 610-10 through 610-14. They are present in the remaining cores except for Core 610-22. Table 6 shows the occurrence of selected species in samples from Hole 610.

Table 6A. The stratigraphic occurrence of selected diatom species and silicoflagellates (*) from Hole 610.

Core-Section (interval in cm)	Abundance	Preservation	Actinocyclus curvatulus	A. divisus	A. ehrenbergii	A. ellipticus	A. ingens	A. ingens var. 1	Annellus californicus	Asterolampra grevillei	A. marylandicus	Asteromphalus affinis	A. flabellatus	A. robustus	Actinoptychus undulatus	Bacteriastrum hyalinum	Biddulphia aurita	Cestodiscus peplum	C. puchellus	C. radionovae	Coscinodiscus africanus	C. blysmos	C. gigas var. diorama	C. lewisianus	C. marginatus	C. nodulifer	C. nodulifer var. cyclopus	C. oculis-iridis	C. plicatus	C. praenodulifer	C. radiatus	C. rhombicus	C. salisburyanus	C. symbolophorus	C. tabularis	C. yabei	Craspedodiscus coscinodiscus	Cylotella group	Denticulopsis hustedtii	D. hyalina	D. lauta	D. nicobarica	D. praedimorpha	D. punctata var. hustedtii	Diogramma sp.	Diploneis group	Ethmodiscus rex	Eucampia balaustium	Goniothecium decoratum	Grammatophora sp.
6-5, 48-50	C	M		F	R								R																																					
6,CC	C	G	R	R	R	F																				F									R											R				
8-1, 48-50	A	G	F	F	R																R				R	R																							r	
8-6, 48-50	F	G	R	R	R	R							R													R	R											R												
8,CC	F	M	R	F	R																				R	R																				R				
9,CC	R	P	R	R																																														
15-4, 48-50	C	G		R	R		C				R				F		R								F	R		R	F				R	R	R	F			C	R	R		R	R		R				
15,CC	C	M					C	R		R	R				F	R	R								F	R			R				R		R	F			R	R	R			F						
16-2, 68-70	R	P					R								R										R						R																			
16-4, 48-50	A	M			R	R	C			R					F								R	R	R										R	F	F		F			R				R				
16-5, 98-110	C	M		R	F	R	R	R	R	R					F								R	R				R	F		R				R	R			F	R	R			R						
16,CC	R	P													R										R														R											R
17-1, 49-51	F	M					F					R			R			R	R			R			R						R			R					R	R										
17-2, 40-42	C	M					C	R		R					R							R		R	R					R	R															R	R			R
17-3, 45-47	F	P									R											R			R																						R			
17-5, 49-51	F	P					R								R										R																									
17-6, 49-51	F	P					R								R							R			R					R	R																R			
17,CC	R	P													R										R																						R			
18-5, 48-50	F	M													R			R	R					R	R																				R		R			
18,CC	R	P													R									R																							R			
19,CC	R	P					R																																											
20-2, 104-106	R	P																							R																						R			
23-1, 48-50	R	P						R																	R																					R	R			
23,CC	R	P														R									R					R																R	R			
24-1, 38-40	F	M									R					R			R						R																					R	R			
24-3, 44-46	C	G												R	R										F			R		R																R	A			
24,CC	F	P			R										R										F						R																F	R		
25-2, 38-40	C	M			R						R				R										R					R		F		R											R		F			
25-3, 38-40	A	G			R						R				R				R	R					R					R	R	F		R													A		R	
25-4, 38-40	F	M								R					R					R					R					R	R	R		R																
25,CC	R	P																							R																									
26,CC	F	P																																																
27-2, 42-44	F	G								R					R				R						R			R		R	R			R													R	R		
27-3, 42-44	C	M													R				R	R				R	R			R		R	R	R		R													R			
27,CC	C	M								R					R					R					F				R		R		R	R		R											R	R		

Note: R = rare, F = few, C = common, A = abundant, r = rare reworked specimens. Preservation is either poor (P), moderate (M), or good (G). See Appendix for species list.

The following samples are barren of diatoms: *Hole 610:* 1-3, 43–45 cm; 1,CC; 2,CC; 3,CC; 4,CC; 5-4, 43–45 cm; 7,CC; 9-4, 43–45 cm; 22-5, 43–45 cm; 22-6, 43–45 cm; 22,CC. *Hole 610A:* 1-3, 43–45 cm; 2-3, 43–45 cm; 2,CC; 3-2, 43–45 cm; 3-3, 43–45 cm; 4-3, 43–45 cm; 4,CC; 5-2, 43–45 cm; 5,CC; 9,CC; 10-3, 43–45 cm; 11,CC; 19-4, 43–45 cm; 20-4, 43–45 cm. *Hole 610B:* 2,CC; 5,CC; 6,CC; 7,CC. *Hole 610C:* core-catcher samples from Cores 1–5. *Hole 610D:* core-catcher samples from Cores 1–5; *Hole 610E:* 2,CC; 3-4, 43–45 cm; 4-2, 43–45 cm; 4,CC; 5,CC: 6,CC; 7-3, 43–45 cm; 7,CC.

The following samples contain rare diatom fragments. *Hole 610:* 2-3, 43–45 cm; 3-3, 43–45 cm; 4-4, 43–45 cm; 5,CC; 10-3, 43–45 cm; 10,CC; 11-2, 43–45 cm; 11,CC; 12,CC; 13-2, 43–45 cm; 13,CC; 14-3, 43–45 cm; 14,CC; 20-2, 43–45 cm; 20,CC; 21,CC; 22-5, 43–45 cm; 22-6, 43–45 cm; 22-6, 43–45 cm; 24-2, 43–45 cm. *Hole 610A:* 2-5, 43–45 cm; 7,CC; 12,CC; 13,CC. *Hole 610B:* 1,CC; 3,CC; 4,CC; 8,CC. Sample 610C-5,CC. Sample 610D-6,CC. *Hole 610E:* 1-2, 43–45 cm; 1-3, 43–45 cm; 3,CC; 6-2, 43–45 cm.

The diatom assemblage in Hole 610 is similar to the warm-temperate assemblages at the previous Leg 94 sites. Within the middle Miocene sediment, species such as *Actinocyclus radionovae, Cestodiscus peplum, Coscinodiscus rhombicus, C. blysmos*, and *C. praenodulifer* allow the recognition of the biozones defined by Barron (1983) for the equatorial Pacific region. The rare occurrence of *Denticulopsis nicobarica, D. praedimorpha*, and *D. punctata* var. *hustedtii* allow only partial recognition of the middle Miocene diatom zones defined by Baldauf (1985a).

Diatom preservation is very poor in the upper 5 cores of Hole 610. Samples 610-6-5, 48–50 cm and 610-6,CC contain common moderately well preserved to well-preserved diatoms. The occurrence of *Nitzschia jouseae* in Samples 610-6,CC through 610-8,CC allows this interval to be assigned to the *N. jouseae* Zone of Baldauf (1985a); reworked specimens of *Goniothecium decoratum, Stephanogonia hanzawae*, and *Trinacria excavata* var. *tetragona* occur occasionally.

Samples from 610-9,CC through 610-14,CC contain sparse, poorly preserved diatoms and cannot be zoned. Core 610-15 is equivalent to the middle Miocene *Craspedodiscus coscinodiscus* Zone of Barron (1983). Species present include *Actinocyclus ingens, Coscinodiscus nodulifer, C. plicatus, C. yabei, D. hustedtii, D. hyalina, D. lauta, D. praedimorpha, D. punctata* var. *hustedtii, D. nicobarica, Hemidiscus cuneiformis, Mediaria splendida*, and *Rhizosolenia barboi*.

The *Craspedodiscus coscinodiscus* Zone is correlated with the *D. nicobarica/R. barboi* zones of Baldauf (1985a). The occurrence of *H. cuneiformis* in samples from Core 610-15 support this zonal assignment. At Site 555, *H. cuneiformis* has a first occurrence within the *R. barboi* Zone (11.2 Ma), which corresponds to its stratigraphic range at Hole 610.

Sample 610-16-2, 48–50 cm contains rare, poorly preserved diatoms. The absence of both *H. cuneiformis* and *Coscinodiscus lewisianus* suggests that this sample is equivalent to the *C. gigas* var. *diorama* Zone of Barron (1983). However, this zonal assignment is tentative, because the diatoms in this sample are poorly preserved.

Sample 610-16,CC contains *A. ingens, Annellus californicus, C. gigas* var. *diorama, C. lewisianus*, and *D.*

Table 6A (continued).

Hemiaulus polymorphus	Hemidiscus cuneiformis	Macrora stella	Mediaria splendida	Melosira granulata	M. sulcata	Navicula lyra	Nitzschia cf. cylindrica	N. fossilis	N. interrupta	N. jouseae	N. marina	N. reinholdii	N. panduriformis	Nitzschia group	Opephora sp.	Podosira glacialis	Rhaphoneis amphiceros	Rhaphidodiscus marylandica	Rhizosolenia barboi	R. bergonii	R. curvirostris	R. hebetata	R. miocenica	R. praebarboi	R. styliformis	Rossiella praepaleacea	Rouxia cf. diploneis	Stephanogonia hanzawae	Stephanopyxis turris	Thalassionema nitzschioides	Thalassiosira convexa	T. eccentrica	T. fraga	T. leptoporus	T. oestrupii	T. plicata	T. spinosa	T. symbolophora	Thalassiosira sp. 2 jacksonii	Thalassiothrix longissima	Trinacria excavata var. tetragonia	Triceratium cinnamomeum	Mesocena apiculata curvatulus*	Naviculopsis quadrangula*	Diatom zones
	C			R		R		R			R	F			R	R			C		F							r	F			R		F		R		R		R	r				?
	C			R		R		R		R	R	F	R				F		C	R								r	F	F	R	R		F	F	R		R		F					
	C			R	R			C		F		F	R	R	R														F	C	R	F			C				F	A					*Nitzschia jouseae*
	F				R			R	R	R	R	R	R						R										R	R	R	R			R			R	R	R					
	F			R			R	R		R		R	R		R				R		R								R	C		R			R	R		R							
				R								R																															R		?
R	F	R	R	R											R				F			R	R	R	R	R	R			C				R						F		R			*Craspedodiscus coscinodiscus*
	R	R	R	R											R				F			R		R	R					F				R						F					
																			R															R						R					*C. gigas* var. *diorama*
				F											R								R	F					R	F										F					
R				R											R												R		R			R		R				R		F					*Coscinodiscus lewisianus*
				R																																				R					
				R											R									R					R	R				R						R					
				R											R									R						F										C			R		
				R																																								
																								R																				
				R																				R						R															
R		R		R		R									R														R											R					*Cestodiscus peplum*
						R									R														R											R					
																																								R					
						R									R													R												R					?
						R									R													R	R											R					?
				R											R													R	R				R									R			*D. nicobarica* ?
R		R		R													R							R				R	R				F				R					R			
				R																																							R	*Triceratium pileus*
R		R		R																								R					F				F					R			
		R		R										R			F	F						R					R				F				F								
																													R				R				F			R					
				R																																							R	
				R																																									*Craspedodiscus elegans*
R		R		R																									R				R							R		R			
				R																				R				R	R				R				R			R		R			
				R											R												R					R				R			R	R	R		R	

hustedtii. The occurrence of *C. lewisianus* places this sample in the *C. lewisianus* Zone of Barron (1983), and that of *D. punctata, D. hustedtii*, and *Actinocyclus ellipticus* suggests the middle portion of the zone. The base of the *C. lewisianus* Zone is defined by the last occurrence of *Cestodiscus peplum* (Barron, 1983), which is not observed in this sample.

Few to common, moderately well preserved diatoms occur in Core 610-17. Typical species observed include *Coscinodiscus blysmos, C. lewisianus, C. praenodulifer, Cestodiscus peplum, Actinocyclus ingens, R. praebarboi,*, and *Ethmodiscus* sp. The occurrence of *C. peplum*, although rare, suggests that this core is equivalent to the *C. peplum* Zone of Barron (1983). The occurrence of *Coscinodiscus blysmos* in Samples 610-17-1, 49–51 cm, 610-17-2, 40–42 cm, 610-17-3, 45–47 cm, and 610-17-6, 49–51 cm supports this tentative zonal placement. Barron (1983) placed the last occurrence of *C. blysmos* within the equatorial Pacific at approximately the top of the *Cestodiscus peplum* Zone.

Sample 610-18-5, 43–45 cm contains few moderately well preserved diatoms, including *C. peplum* and *C. pulchellus*, which allows placement in the *C. peplum* Zone of Barron (1983).

Samples from Cores 610-19 through 610-23 contain rare diatom fragments except samples from Core 610-22, which are barren of diatoms. Within this interval (636.6–684.0 m), diatoms and silicoflagellates decline in abundance downhole. Sponge spicules are concentrated in some samples, and dissolution and reprecipitation of silica can be observed on some diatom frustules. Additional features observed in this interval include inclined bedding, microfaults, and flattened foraminifers.

A regional seismic reflector picked from the survey profile at a two-way traveltime of 0.75 s corresponds to the depth of Core 610-19 (636–646 m, see Site 610 site chapter, this volume; Masson and Kidd, this volume). The association of the seismic reflector with the interval of Hole 610 which exhibits silica dissolution and other sedimentary features suggests that carbonate and silica dissolution and an increase in the silica content of the sediment may all be related (see Baldauf, this volume).

Cores 610-24 through 610-27 were continuously cored. Sample 610-24-1, 38–40 cm may correlate with the *D. nicobarica* Zone of Barron (1983). According to Barron (1983), *Thalassiosira fraga* last occurs in the upper *D. nicobarica* Zone, whereas *T. spinosa* occurs below this zone. Thus the presence of *T. fraga* and the absence of *T. spinosa* from Sample 610-24-1, 38–40 cm suggest that this sample may be correlated with the *D. nicobarica* Zone of Barron (1983). However, *T. spinosa* may be preservationally excluded from this sample.

Table 6B. The stratigraphic occurrence of selected diatom species and silicoflagellates (*) from Hole 610A.

Core-Section (interval in cm)	Abundance	Preservation	*Denticulopsis seminae* group	*Nitzschia fossilis*	*N. jouseae*	*N. reinholdii*	*Pseudoeunotia doliolus*	*Thalassiosira convexa*	*T. oestrupii*	*Mesocena quadrangula**	Diatom zones
1,CC	C	M					F				*P. doliolus*
3,CC	A	M				R	C		F		*Nitzschia reinholdii*
6,CC	C	M	R	F		R	C		C	F	
8,CC	F	M		F		F	R		R		
10,CC	C	M		F		F	F		F		
11-4, 43–45	A	G		F		F			F		*Nitzschia marina*
13-5, 43–45	A	G		F		F			F		
14-3, 43–45	R	P				R					
14,CC	C	M				R			F		
15-1, 43–45	C	G		R		R			R		
15-3, 43–45	C	M		R		R		R	R		
15-5, 43–45	A	G		R		R		R	R		
15,CC	A	G			R	R		F	F		*Nitzschia jouseae*
16-3, 43–45	A	G		R		F		R	R		
16,CC	C	M		R		F		R			
17-3, 43–45	C	M		R	R	R		R	R		
17,CC	C	M				F		F			
18-4, 43–45	A	G		R		F		F	F		
18,CC	C	M		R	R	R		R	R		
19,CC	F	P		R					R		
20,CC	F	P			R						
21-2, 43–45	C	M		R	R	R		R	R		
21,CC	F	P		R		R		R			

Note: See Table 6A for symbols and list of barren samples.

Samples 610-24-3, 43–45 cm through 610-25-2, 43–45 cm are tentatively assigned to the *Triceratium pileus* Zone of Barron (1983), based on secondary marker species. Barron (1983) indicates that *Actinocyclus radionovae* and *T. spinosa* last occur in the *Triceratium pileus* Zone and that the last occurrence of *Coscinodiscus rhombicus* corresponds to the base of this zone. *Coscinodiscus rhombicus* occurs in Sections 610-27-3, 610-25-4, 610-25-3, and 610-25-2, suggesting that if its stratigraphic range is similar to that mentioned by Barron (1983), then the sample interval from 610-25-3 through Core 610-27 is equivalent to the *Craspedodiscus elegans* Zone of Barron (1983).

Hole 610A (53°13.297′N, 18°53.213′W, 2417 m water depth)

Twenty-one cores (201 m) of lower Pliocene to Holocene material were recovered from Hole 610A. Diatoms are generally present in all core-catcher samples examined. Table 6 shows the stratigraphic occurrence of selected diatom species from this hole.

Sample 610A-1,CC is assigned to the *Pseudoeunotia doliolus* Zone of Burckle (1977), based on the occurrence of *P. doliolus* above the last occurrence of *Nitzschia reinholdii*. Samples 610A-3,CC through 610A-10,CC are assigned to the *N. reinholdii* Zone of Burckle (1977). Because Sample 610A-2,CC is barren of diatoms, the top of this zone can only tentatively be placed between Samples 610A-1,CC and 610A-3,CC.

Within this zone, Sample 610A-6,CC contains rare specimens of the *Denticulopsis seminae* group, few specimens of the silicoflagellate *Mesocena quadrangula*, and the last occurrence of *N. fossilis*. This however, is unlikely to be a true last occurrence of the species, which at Sites 606–609 is observed above the last *M. quadrangula*, in the lower Brunhes Chronozone. Clement and Robinson (this volume) place the Matuyama/Brunhes boundary between Samples 610A-5-3, 8 cm and 610A-5-4, 10 cm, above Sample 610A-6,CC. Thus it is assumed that the true last occurrence of *N. fossilis* is stratigraphically above Sample 610A-6,CC, but that the poor preservation in Samples 610A-4,CC and 610A-5,CC inhibits recognition of this event.

The first occurrence of *P. doliolus*, which defines the base of the *N. reinholdii* Zone of Burckle (1977), falls between Samples 610A-10,CC and 610A-11-4, 43–45 cm (94.2–100.39 m sub-bottom). Clement and Robinson (this volume) place the Olduvai between 93.47 and 98.63 m sub-bottom depth. Therefore, the first occurrence of *P. doliolus* in Hole 610A has an estimated age of 1.80–1.91 Ma, which is in agreement with the age of this event at the other Leg 94 sites.

The sample interval from 610A-11-4, 43–45 cm through 610A-15-5, 43–45 cm is placed in the *N. marina* Zone of Baldauf (1985a). The last occurrence of *Thalassiosira convexa* is within this interval, in Sample 610A-15-3, 43–45 cm (134.29–137.29 m), one third of the distance between the Gauss/Matuyama boundary and the top of the Kaena. It is assigned an age of 2.56–2.62 Ma in Hole 610A.

Nitzschia jouseae occurs sporadically in the sample interval from 610A-15,CC through 610A-21,CC, which is assigned to the *N. jouseae* Zone of Baldauf (1985a). The last occurrence of *N. jouseae* between Samples 610A-15,CC and 610A-15-5, 43–45 cm (140.29–143.40 m) is dated at 2.74–2.77 Ma in Hole 610A.

Hole 610B (53°13.297′N, 18°53.213′W, 2417 m water depth)

Sixteen cores (146.8 m) of lower Pliocene through Holocene sediment were recovered from Hole 610B. Cores 610B-1 through 610B-8 contain rare, poorly preserved diatoms or are barren of diatoms (Table 6). Generally, few, moderately well preserved diatoms were observed in Cores 610B-9 through 610B-16.

Samples 610B-9,CC through 610B-12,CC contain both *Nitzschia reinholdii* and *Pseudoeunotia doliolus* and are, therefore, placed in the *N. reinholdii* Zone of Burckle (1977). The base of the zone is tentatively placed between Samples 610B-12,CC and 610B-13,CC based on the occurrence of *N. reinholdii* without *P. doliolus* in Sample 610B-13,CC. *Nitzschia jouseae* occurs in Sample 610B-16,CC and allows this sample to be assigned to the *N. jouseae* Zone of Baldauf (1985a). Samples 610B-13,CC, 610B-14,CC, and 610B-15,CC are placed in the interval between the first occurrence of *P. doliolus* and the last occurrence of *N. jouseae* and are assigned to the

N. marina Zone of Baldauf (1985a). The last occurrence of *Thalassiosira convexa* in Sample 610B-15,CC is directly above the base of the *N. marina* Zone.

Hole 610C (53°13.297′N, 18°53.213′W, 2417 m water depth)

Six cores of upper Pliocene to Holocene sediment were recovered from Hole 610C. The majority of samples examined contain rare fragments or are barren of diatoms (Table 6).

Samples 610C-1,CC, 610C-2-4, 43–45 cm, and 610C-5-1, 43–45 cm contain rare, poorly preserved diatoms. The occurrence of *Nitzschia fossilis* suggests that these samples are equivalent to the *N. reinholdii* Zone of Burckle (1977) or older. *Nitzschia fossilis* has a last occurrence at the other Leg 94 sites within the lower Brunhes paleomagnetic Chronozone. All other samples from Hole 610C are barren of diatoms.

Hole 610D (53°13.467′N, 18°53.690′W, 2445 m water depth)

Seven cores (66 m) of upper Miocene to Holocene sediment were recovered from Hole 610D. The majority of samples contain rare fragments or are barren of diatoms (Table 6). Only Sample 610C-4,CC contains diagnostic diatoms. The occurrence of the *Denticulopsis seminae* group in this sample suggests that it is equivalent to the *Nitzschia reinholdii* Zone Burckle (1977).

Hole 610E (53°13.297′N; 18°53.213′W, 2433 m water depth)

All Samples from Hole 610E were Barren (Table 6).

Site 611

Six holes were drilled on the southeastern flank of Gardar Drift (Fig. 1). Four holes were cored on the crest of a sediment wave and the other two in a trough approximately 0.5 n. mi. to the southeast. Miocene through Quaternary sediment was recovered from this site.

Hole 611 (52°50.47′N, 30°18.58′W, 3203 m water depth)

Fourteen cores (125.8 m) of upper Pliocene to Holocene sediment were recovered from Hole 611. Diatoms were few to abundant and moderately well to well preserved. The diatom assemblage is somewhat comparable to the assemblages observed at previous sites, but robust specimens of *Coscinodiscus marginatus* and *C. nodulifer* are in greater abundance. Table 7 lists the stratigraphic occurrence of selected diatom species for samples from Hole 611.

Samples 611-1,CC through 611-3-3, 46–48 cm are placed in the *Pseudoeunotia doliolus* Zone of Burckle (1977), based on the occurrence of *P. doliolus* above the last *Nitzschia reinholdii*. The last occurrence of *N. reinholdii*, between Samples 611-3-3, 46–48 cm and 611-3,CC is correlated to the lower Brunhes paleomagnetic Chronozone as determined in Hole 611 by Clement and Robinson (this volume) and has an estimated age of 0.51–0.73 Ma, slightly older than the last occurrence of *N. reinholdii* at the other Leg 94 sites. *Nitzschia fossilis* and *Mesocena quadrangula* also last occur in Sample 611-3,CC. Normally the last occurrence of these two species is below the last occurrence of *N. reinholdii*, within the lowest Brunhes paleomagnetic Chronozone. The fact that all three last occur together in Sample 611-3,CC suggests that this is not the true last occurrence of *N. reinholdii* and that this species should occur above Sample 611-3,CC, where it may be preservationally excluded.

Samples 611-3,CC through 611-7-6, 46–48 cm are assigned to the *N. reinholdii* Zone of Burckle (1977). The base of this zone is defined by the first occurrence of *P. doliolus* in Sample 611-7-6, 46–48 cm, approximately at the base of the Olduvai as identified in Hole 611 by Clement and Robinson (this volume). This event has an estimated age of 1.61–1.9 Ma, in agreement with the age assigned to the first occurrence of *P. doliolus* at other Leg 94 sites.

The remaining samples from Hole 611 represent the interval from the last occurrence of *N. jouseae* to the first occurrence of *P. doliolus* and are assigned to the *N. marina* Zone of Baldauf (1985a). *Thalassiosira convexa* last occurs in this zone between Samples 611-14-1, 46–48 cm and 611-14-2, 46–48 cm. The Gauss/Matuyama boundary is placed by Clement and Robinson (this volume) between Samples 611-13-3, 97 cm and 611-13-4, 97 cm (110.58–112.08 m). The last occurrence of *T. convexa* is slightly older than the Gauss/Matuyama boundary and has a tentative age of 2.58–2.62 Ma.

Reworked specimens are occasionally observed in the lower stratigraphic samples examined from Hole 611. Specimens of *T. convexa* occur in Sample 611-10-2, 46–48 cm; *Hemiaulus polymorphus* occurs in Samples 611-9-3, 46–48 cm and 611-13-4, 46–48 cm, and *Actinocyclus ingens* in Sample 611-13-2, 46–48 cm.

Hole 611A (52°50.47′N, 30°18.58′W, 3201 m water depth)

Fourteen cores (132 m) of Pliocene to Holocene sediment were recovered from Hole 611A. Diatom occurrence is similar to that at Hole 611. The *Pseudoeunotia doliolus, Nitzschia reinholdii*, and *Nitzschia marina* zones can be recognized but the zonal boundaries cannot be placed so precisely as at Hole 611 because sample preservation is poor and only core-catcher samples were examined at Hole 611A. Table 7 lists the samples that contain only rare fragments or are barren of diatoms.

Sample 611A-1,CC is placed in the *P. doliolus* Zone of Burckle (1977) based on the occurrence of *P. doliolus* without *Nitzschia reinholdii*. The base of this zone is not accurately placed, because Samples 611A-2,CC and 611A-3,CC are barren of diatoms.

The occurrence of *P. doliolus* in Samples 611A-4,CC and 611A-6,CC and of *N. reinholdii* in Samples 611A-4,CC and 611-6,CC place these samples in the *N. reinholdii* Zone of Burckle (1977). This zonal assignment is supported by the occurrence in Sample 611A-4,CC of *N. fossilis*, which, previous Leg 94 sites, consistently has a last occurrence in the middle *Nitzschia reinholdii* Zone.

Table 7A. The stratigraphic occurrence of selected diatom species and silicoflagellates (*) from Hole 611.

Core-Section (interval in cm)	Abundance	Preservation	*Actinocyclus curvatulus*	*A. divisus*	*A. ehrenbergii*	*A. ingens*	*Actinocyclus* cf. *oculatus*	*Actinoptychus bipunctatus*	*A. undulatus*	*Asteromphalus arachne*	*A. flabellatus*	*Bacteriastrum hyalinum*	*Biddulphia aurita*	*Cocconeis scutellum*	*Coscinodiscus africanus*	*C. crenulatus*	*C. marginatus*	*C. nodulifer*	*C. oculis-iridis*	*C. radiatus*	*C. tabularis*	*Denticulopsis seminae* group	*Diploneis* group	*Hemiaulus cuneiformis*	*Hemidiscus polymorphus*	*Hyalodiscus* sp.	*Melosira sulcata*	*Navicula* sp. 1	*Nitzschia fossilis*	*N. grunowii*	*N. interrupta*	*N. marina*
1,CC	F	M										R					F														R	R
2-4, 46-48	A	M	F	F			R										F		R						R							R
2-5, 46-48	A	G		F				R	R								R	R	R												R	R
2,CC	R	P																														
3-2, 46-48	F	M		R													R		R													R
3-3, 46-48	F	G	R														R															R
3,CC	F	M	R	R								R			R		R				R	R			R				R			R
4-2, 46-48	A	G	F	F			R	R				R				R	F	R			R	C					R		R			R
4-5, 46-48	F	G			R											R	F					F			R							R
4,CC	A	G	R	F			R		R								F					C							R			
5-1, 46-48	F	M															R					R										
5-3, 46-48	C	G		R	R												F	R			R	C							R			R
5-4, 46-48	C	G															R	R				C					R		F			R
5-6, 46-48	F	G												R			R					F							F			
6-3, 46-48	F	M															R								R		R		F			R
6-4, 46-48	A	M		R													F				R						R		F			R
6,CC	R	P																											R			
7-2, 46-48	A	G															C		R		R				R		R		R			
7-5, 46-48	A	G	R	R								R					F	R			R				R				F			R
7-6, 46-48	F	M	R	R													F								R				F			
8,CC	F	M		R														R							R		R		R			R
9-1, 46-48	A	G	R'	R			F										F	R							R				R			
9-2, 46-48	R	M	R	R													R		R						R							
9-3, 46-48	C	M	R	F	R							R					R	R						r	R		R		C			R
10-1, 46-48	C	M	R	F					R								F						R		R		R		F			R
10-2, 46-48	F	G	F	R	R						R						R								R				R	R	R	R
10-3, 46-48	C	G	F	F	R				R			R					F		R						R		R		R		R	R
10-4, 46-48	C	G	R	R	R						R	R					F								R		R		R		R	R
10-6, 46-48	F	G		R					R		R						R	R							R		R		R		R	R
11-3, 46-48	A	M	R	F	R						F	R					F						R		R		R		R		R	
11,CC	C	M	R	F													F								R				F			F
13-2, 46-48	A	G	F	C	R	r			F	R	R	R					F	R	R	R					F		R		F			F
13-4, 46-48	F	M	R	R													R	R	R					r	R	R			R			R
14-1, 46-48	A	G	F	R								R					F	R	R		R				R		R	R	R		R	R
14-2, 46-48	A	G	R	R								F					C								R			R	R			R
14-3, 46-48	A	G		R	R			R	R			R	R				C	R	R		R				R		R	R	R		R	R
14,CC	F	M	R														R															

Core-Section (interval in cm)	*N. reinholdii*	*Nitzschia* sp. 1	*Nitzschia* group	*Podosira glacialis*	*Pseudoeunotia doliolus*	*Rhizosolenia barboi*	*R. bergonii*	*R. curvirostris*	*R. hebetata*	*R. praebergonii*	*R. styliformis*	*Rhizosolenia* sp.	*Roperia tesselata*	*Stephanopyxis turris*	*Thalassionema nitzschioides*	*T. eccentrica*	*T. gravida*	*T. leptopus*	*T. oestrupii*	*T. plicata*	*T. symbolophora*	*Thalassiosira* sp.	*Thalassiothrix longissima*	*Triceratium cinnamomeum*	Freshwater species	*Mesocena quadrangula**	Diatom zones
1,CC					R						F				R	R		R	F	R			F				*Pseudoeunotia doliolus*
2-4, 46-48					R	F		C	R					C	C	R		R	C		R		A				
2-5, 46-48			R		R	R			R					C	F		R	R	R		R	R	A		R		
2,CC						R										R		R					R				
3-2, 46-48					R				R							R		R					R				
3-3, 46-48					R				R		R			R		R		R	R				R				
3,CC	R		F	R		R	R		R		R		R		F	R	R	R	F	R			F			R	*Nitzschia reinholdii*
4-2, 46-48	F		R		F		R	R	R		R	R	R	F	F	R		R	F		R		A			F	
4-5, 46-48	F			R	R	R			F						R	R		R	R	R	R		R			R	
4,CC	R			R		F		R	F					R	F	R		F					C				
5-1, 46-48	R				R				R							R							R				
5-3, 46-48	R	R	R	R	F				R		R				R	R			R	R	R		F				
5-4, 46-48	F	R		R	F	R			R				F	R	F	R		R	R	R		R	F		R	R	
5-6, 46-48	R	R			R	R			R				R		R	R		R	R		R		R				
6-3, 46-48	R				R				R				R		F	R	R		F		R	R	F				
6-4, 46-48	R	R	R		R	R	R	F	R				R		A			R	F		R	R	A				
6,CC					R																		R				
7-2, 46-48	F	R		R		C			C		R			R	C		R	R	F		R		C				
7-5, 46-48	F	R		R	R		R		R					R	F	R	R	R	R	R		R	F				
7-6, 46-48	F				R				R		R				R	R	R		R				F				
8,CC	R								R					R	F				R				F				*Nitzschia marina*
9-1, 46-48	F		R				R						R		C	R			A	R	R	R	R				
9-2, 46-48	R					R	R								R				R								
9-3, 46-48	C			R										R	R	R			C	R		R					
10-1, 46-48	F		R	R			R		R						F	R			R		R		F				
10-2, 46-48	R		R						R		R				F	R	R		F				R				
10-3, 46-48	F						R				R			R	F		R		R		R						
10-4, 46-48	R		R	R					R	R					F	R		R	R		R	R	F				
10-6, 46-48			R						R						F	R		R	F		R	R	R				
11-3, 46-48	R		R												C	R		R	R	R	R		F				
11,CC	F														C			R	R				F				
13-2, 46-48	R		R			R	R		R				R	R	A	R		R	C		R		A	R			
13-4, 46-48	R															R		R			R	R					
14-1, 46-48	R	R												F	C			R	R			R	F				
14-2, 46-48						R								C	A	F		C	F				A		R		
14-3, 46-48	R		R			F	R		F					R	A		R	C	R				A				
14,CC														R	R				R								

Note: R = rare, F = few, C = common, A = abundant, r = rare reworked specimens. Preservation is either poor (P), moderate (M), or good (G). See Appendix for species list.

The following samples are barren of diatoms: *Hole 611:* 4-1, 43-45 cm; 6-2, 43-45 cm; 7-4, 43-45 cm; 7,CC; 8-1, 43-45 cm; 8-2, 43-45 cm; 8-3, 43-45 cm; 8-4, 43-45 cm; 8-5, 43-45 cm; 9,CC; 13-1, 43-45 cm. *Hole 611A:* 2,CC; 3,CC; 5,CC; 7,CC; 9,CC. *Hole 611C:* 5,CC; 10,CC; 29,CC; 31,CC: 32-3, 43-45 cm; 32-6, 43-45 cm; core-catcher samples from Cores 33, 37, 38, 41-44, 46. Sample 611D-12,CC. Sample 611E-2,CC.

The following samples contain rare diatom fragments: *Hole 611:* 3-4, 43-45 cm; 3-6, 43-45 cm; 5,CC; 8-6, 43-45 cm; 10,CC; 12,CC. *Hole 611C:* 12,CC; 21,CC; 30,CC; 37,CC; 45,CC.

Table 7B. The stratigraphic occurrence of selected diatom species and silicoflagellates (*) from Hole 611C.

Core-Section (interval in cm)	Abundance	Preservation	*Denticulopsis seminae* group	*Nitzschia* cf. *cylindrica*	*N. fossilis*	*N. jouseae*	*N. reinholdii*	*Pseudoeunotia doliolus*	*Rhizosolenia praebergonii*	*Thalassiosira convexa*	*Mesocena quadrangula**	Diatom zones
1,CC	F	M										*Pseudoeunotia doliolus*
2,CC	F	M						R				
3,CC	C	G						F				
4,CC	A	G						C				
6,CC	C	M	C		R		R				R	*Nitzschia reinholdii*
8,CC	F	M			F		R	F				
9,CC	A	G			C		F	C				
11,CC	A	G			C		C					*Nitzschia marina*
13,CC	C	M			F							
14,CC	A	M			F		R					
15-4, 43–45	C	M			R		R					
15,CC	C	G					F			R		
16-6, 43–45	A	G			R	R	R		R	F		*Nitzschia jouseae*
16,CC	C	M			F	R				F		
17,CC	F	M								R		
18-2, 43–45	A	G			R	R	R			F		
18,CC	F	M			F	R	F					
19-3, 43–45	C	M					R			R		
19,CC	F	M					R			F		
20,CC	C	M			R		R					
22,CC	F	M				R	F					
23-2, 43–45	C	M			R		R					
23,CC	F	M			R		R					
24-5, 43–45	A	M			R	R	R					
24,CC	F	P			R		R					
26,CC	F	P			R		R					
27-4, 43–45	A	M			R	R	R					
27,CC	C	M			F							
29-4, 43–45	C	M		R	R	R	R					
32-2, 43–45	R	P			R							
32.CC	F	M		R	R		R					

Note: See Table 7A for symbols and list of barren samples.

The occurrence of the *Denticulopsis seminae* group and of *Mesocena quadrangula* in Sample 611-4,CC also support this zonal placement.

The base of the *N. reinholdii* Zone is only tentatively placed between Samples 611A-8,CC and 611A-10,CC, because Sample 611A-9,CC is barren of diatoms. Samples 611A-10,CC through 611A-13,CC are placed in the *N. marina* Zone, based on the absence of *P. doliolus* and *N. jouseae* and the occurrence of *T. convexa* in Sample 611A-13,CC.

Hole 611B (52°50.15′N, 30°19.10′W, 3228 m water depth)

One core (8.9 m) of Quaternary sediment was recovered from Hole 611B. The core-catcher sample contains few, poorly-preserved diatoms. The rare occurrence of *Pseudoeunotia doliolus* without *Nitzschia reinholdii* suggests that this sample is equivalent to the *P. doliolus* Zone of Burckle (1977).

Hole 611C (52°50.15′N, 30°19.19′W, 3230 m water depth)

Forty-seven cores (511.6 m) of middle Miocene to Holocene sediment were recovered from Hole 611C. Diatoms are generally moderately well preserved and are rare to abundant in samples examined. Fragments of *Thalassionema nitzschioides* and *Thalassiothrix longissima* are the most common. Specimens of *Coscinodiscus marginatus* and *C. nodulifer* are more robust than at the other Leg 94 sites. Table 7 shows the ranges of stratigraphically useful markers and identifies samples which are barren or contain rare diatom fragments.

Samples 611C-1,CC through 611C-4,CC are assigned to the *Pseudoeunotia doliolus* Zone of Burckle (1977), based on the occurrence of *P. doliolus* without *Nitzschia reinholdii*. Sample 611C-5,CC is barren of diatoms and does not allow accurate placement of the last occurrence of *N. reinholdii*. *Nitzschia reinholdii* is last observed in Sample 611C-6,CC, which also contains *N. fossilis*, *Mesocena quadrangula*, and the *Denticulopsis seminae* group. The last occurrence of *N. reinholdii* is assumed to occur stratigraphically above Sample 611C-6,CC but is not recognized because of the poor sample preservation, as at Hole 611A.

Pseudoeunotia doliolus and *N. reinholdii* both occur in Samples 611C-8,CC and 611C-9,CC, allowing these samples to be assigned to the *N. reinholdii* Zone of Burckle (1977). Sample 611C-10,CC is barren of diatoms, inhibiting accurate placement of the base of the *N. reinholdii* Zone.

Nitzschia jouseae last occurs in Sample 611C-16-6, 43–45 cm. Therefore, Samples 611C-11,CC through 611C-15,CC represent the interval between the last *N. jouseae* and the first *P. doliolus* and are assigned to the *N. marina* Zone of Baldauf (1985a). The last occurrence of *Thalassiosira convexa* in Sample 611C-15,CC supports this zonal assignment.

Nitzschia jouseae occurs sporadically in the interval from Cores 611C-16 through 611C-29, suggesting that this sample interval corresponds to the *N. jouseae* Zone of Baldauf (1985a). The remaining samples examined from Hole 611C contain either diatoms that are not age-diagnostic or rare fragments, or are barren of diatoms (Table 7).

Hole 611D (52°50.47′N, 30°18.58′W, 3195 m water depth)

Fourteen cores (244.1 m) of Pliocene and Quaternary sediment were recovered. The diatom assemblage is similar to that at other 611 holes and preservation and abundance are comparable to that in Hole 611C.

Sample 611D-1,CC is assigned to the *Pseudoeunotia doliolus* Zone of Burckle (1977), based on the occurrence of *P. doliolus* without *Nitzschia reinholdii*. The interval from 15.2 to 128 m sub-bottom depth was washed; thus Core 611D-2,CC (128.9–138.5 m) corresponds to the lower *N. marina* Zone of Baldauf (1985a). This zonal placement is based on the occurrence of *Thalassiosira* *convexa* without *P. doliolus* or *N. jouseae* in Sample 611D-2,CC. *Nitzschia jouseae* is observed in core-catcher samples from Cores 3, 5, 6, 8, and 14. This interval is thus equivalent to the *N. jouseae* Zone of Baldauf (1985a).

Hole 611E (52°50.47′N, 30°18.58′W, 3195 m water depth)

Two cores (25.7 m) of Quaternary sediment were recovered from Hole 611E. Sample 611E-1,CC is placed in the *Pseudoeunotia doliolus* Zone, based on the occurrence of *P. doliolus* without *N. reinholdii*. Sample 611E-2,CC is barren of diatoms.

DISCUSSION

The correlation of biostratigraphic events to the magnetostratigraphy for seven Leg 94 holes is shown in Figure 3. The quality of the diatom preservation determined which holes were selected. Seven diatom datums and one silicoflagellate datum are recognized within the Pliocene and Quaternary sediments from these holes. Table 8 shows the constraining samples and depths for each datum at all holes (see also Baldauf et al., this volume).

Nitzchia reinholdii

The last occurrence of *Nitzschia reinholdii* is observed at all Leg 94 sites. In Hole 611 it coincides with the last occurrence of *N. fossilis, Mesocena quadrangula*, and the *Denticulopsis seminae* group and in Hole 611C with the last occurrence of *N. fossilis*. At the other Leg 94 sites, it occurs above the last occurrences of these species, suggesting that at Holes 611 and 611C the actual last occurrence of *N. reinholdii* is not recognized because diatom preservation is poor.

The last occurrence of *N. reinholdii* at the other Leg 94 sites corresponds to the middle Brunhes paleomagnetic Chron (Fig. 3). The estimated ages for this event are shown in Table 8. Holes 607 and 609 have the most refined sample constraints (Table 8) for this datum for which an estimated age of 0.44 Ma is tentatively assigned in the North Atlantic.

This datum level is synchronous throughout the middle- and high-latitude North Atlantic Ocean, but diachronous when the age is compared with the age of this event in the Pacific Ocean. Koizumi (1975a), Burckle (1977), Burckle and Opdyke (1977), Barron (1985a), and Barron et al. (1985) have placed the last occurrence of *N. reinholdii* in the early Brunhes paleomagnetic Chron, and assigned ages of 0.65 Ma (Burckle, 1972) and 0.65–0.70 (Barron et al., 1985). Sancetta (1985) recognized an age of 0.55 Ma at Site 580 in the northwest Pacific.

Nitzschia fossilis

Except for Hole 610A, where preservation was poor, the last occurrence of *N. fossilis* was observed at all sites (Fig. 3), and in all holes it is correlated with the early Brunhes paleomagnetic Chron. The range at Hole 611C, from the upper Matuyama to lower Brunhes, is due to the broad sample constraints, which result from an interval containing poorly preserved diatoms. In Hole 611 the last occurrence of *N. fossilis* is not reliable because of the concentration of events at one stratigraphic level in this hole.

Holes 606, 607, and 608 have the most refined stratigraphic constraints for the last occurrence of *N. fossilis* (Table 8). An estimated age of 0.58–0.60 Ma is suggested for this event in the North Atlantic Ocean. As with *N. reinholdii*, the last occurrence of *N. fossilis* seems to be isochronous between the middle and high latitudes of the North Atlantic Ocean but it is diachronous between the North Atlantic and Pacific oceans.

Koizumi and Kanaya (1976) correlated the last occurrence of *N. fossilis* with an interval between the Matuyama/Brunhes boundary and the top of the Jaramillo Subchron. A similar stratigraphic placement was derived by Barron (1980b), who placed this event at an interval approximating the last occurrence of *Mesocena quadrangula* in the equatorial Pacific Ocean and assigned it an extrapolated age of 0.79 Ma. Burckle (1977) and Burckle and Opdyke (1977) have suggested a similar stratigraphic placement for this event in the North Pacific Ocean.

Mesocena quadrangula

Within Leg 94 material, the last occurrence of *M. quadrangula* approximates the Matuyama/Brunhes boundary (Fig. 3). Holes 606, 607, and 609 have the best stratigraphic constraints for this datum (Table 8). In Hole 611 its placement is questionable because of the concentration of datums at the same stratigraphic level; in Hole 611C it is tentative because *M. quadrangula* is so rare. The slight age difference for this event between Hole 606 and Holes 607 and 609 (Table 8) suggests that it may be slightly diachronous between the mid- and high-latitude North Atlantic Ocean and also between the North Atlantic and equatorial Pacific oceans (see also Baldauf et al., this volume).

Pseudoeunotia doliolus

The first occurrence of *P. doliolus* is observed in all Leg 94 holes (Fig. 3). Holes 606, 607, and 609 have the most refined stratigraphic constraints for this datum (Table 8). The slight difference between the age obtained at Hole 607 and the ages obtained at Holes 606 and 609 might result from small-scale changes in sedimentation rate. An age of 1.84 Ma is assigned to this event in the North Atlantic Ocean, approximating its age in the equatorial Pacific Ocean, where Burckle (1977, 1978), Burckle and Trainer (1979), and Barron (1980b) correlate it to the lower middle Olduvai and have assigned an age of 1.8 Ma.

Thalassiosira convexa

The last occurrence of *T. convexa* is observed in Holes 606, 610A, 611, and 611C. In Hole 606 this event is correlated with the early Matuyama Chron and has an estimated age of 2.3–2.5 Ma. In the other Leg 94 holes where this event is observed, it is correlated to the later portion of the Kaena Subchron in the Gauss Chron (Fig. 3, Table 8).

In Hole 552A the last common occurrence of *T. convexa* is placed in Sample 552A-10-2, 0–3 cm, equivalent to the Gauss/Matuyama boundary (Baldauf, 1985a) and the true last occurrence in Sample 552A-9-1, 63 cm occurs approximately one-third of the way between the

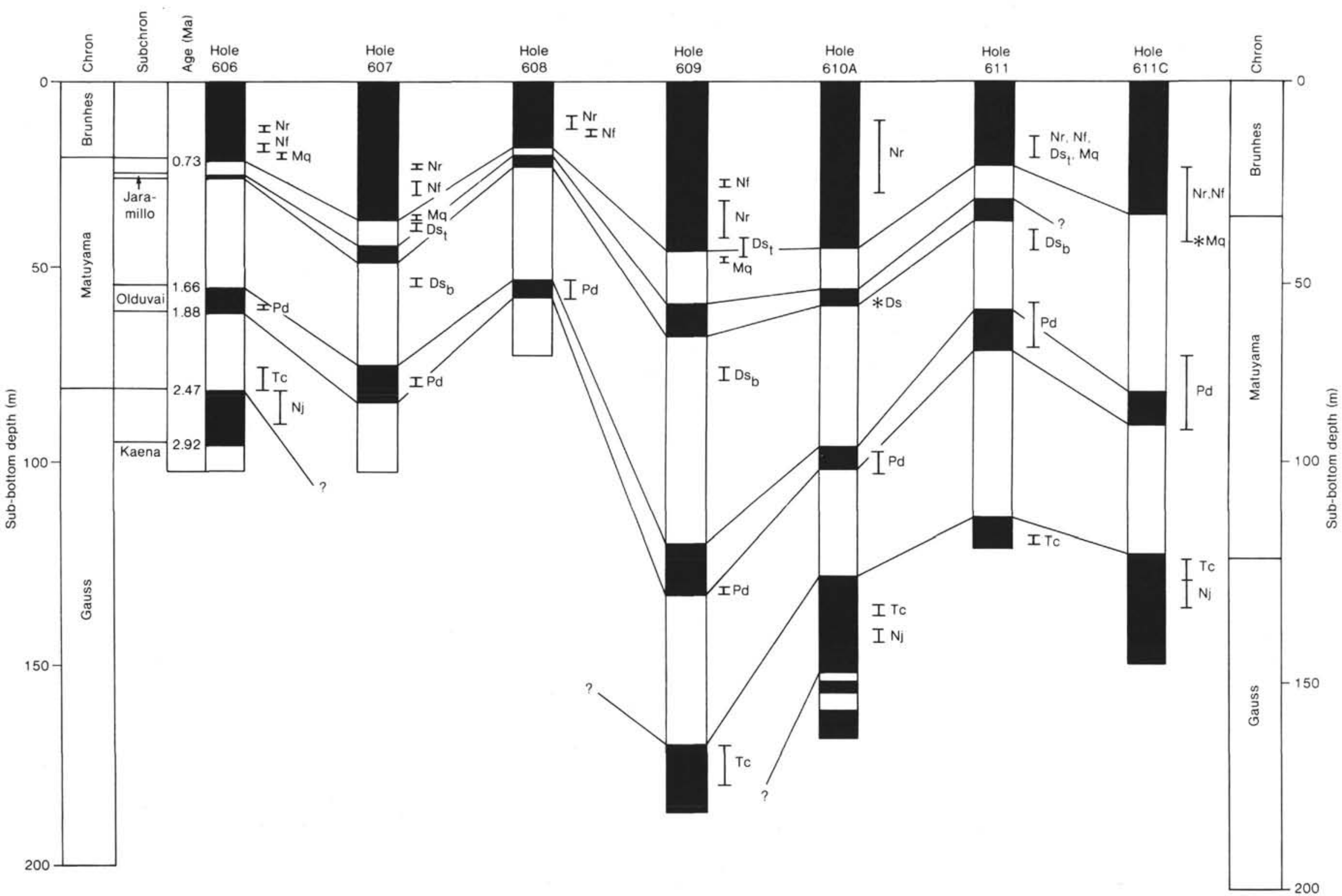

Figure 3. Correlation of selected diatom events to the paleomagnetic results (Clement and Robinson, this volume), plotted versus depth for Leg 94 Holes. Nr = the last occurrence of *Nitzschia reinholdii*, Nf = last occurrence of *N. fossilis*, Mq = last occurrence of the silicoflagellate *Mesocena quadrangula*. Ds_t = the last occurrence of the *Denticulopsis seminae* group, Ds_b = the first occurrence of the *Denticulopsis seminae* group, Pd = the first occurrence of *Pseudoeunotia doliolus*, Tc = the last occurrence of *Thalassiosira convexa, and Nj = the last occurrence of Nitzschia jouseae*. * means that the first and last occurrence of the taxon occur in the same sample.

Table 8. The sample, depth, and age constraints of Pliocene and Quaternary diatom datums for Leg 94 holes.

Sample (interval in cm)	Sub-bottom depth (m)	Age (Ma)
L *N. reinholdii*		
606-2,CC to 606-3-1, 43-45	11.11-12.84	0.41-0.48
607-3-2, 43-45 to 607-3-3, 43-45	21.24-22.64	0.44-0.48
608-2-2, 43-45 to 608-2-4, 43-45	8.94-11.94	0.42-0.56
609-3,CC to 609-4-1, 43-45	25.81-26.64	0.43-0.44
610A-1,CC to 610A-3,CC	9.00-28.20	0.15-0.48
611-3-3, 46-48 to 611-3,CC	14.07-19.60	0.51-0.71
611C-4,CC to 611C-6,CC	22.00-40.60	0.48-0.86
L *N. fossilis*		
606-3-3, 43-45 to 606-3-4, 43-45	15.84-17.34	0.58-0.64
607-4-1, 43-45 to 607-4-3, 43-45	25.64-28.64	0.54-0.64
608-2-4, 43-45 to 608-2-5, 43-45	11.94-13.44	0.56-0.63
609-4-3, 43-45 to 609-5-3, 43-45	29.65-39.24	0.49-0.65
—	—	—
611-3-3, 46-48 to 611-3,CC	14.07-19.60	0.51-0.71
611C-4,CC to 611C-6,CC	22.00-40.60	0.48-0.86
L. *M. quadrangula*		
603-3-4, 43-45 to 606-3-5, 43-45	17.34-18.84	0.64-0.69
607-4,CC to 607-5-1, 43-45	34.68-35.24	0.73-0.74
—	—	—
609-5,CC to 609-6-1, 43-45	44.69-45.84	0.73-0.75
—	—	—
611-3-3, 46-48 to 611-3,CC	14.07-19.60	0.51-0.71
611C-6,CC	40.60	0.86
L. *D. seminae* group		
—	—	—
607-5-2, 43-45 to 607-5-3, 43-45	36.74-38.24	0.78-0.81
—	—	—
609-5-3, 43-45 to 609-5,CC	39.24-44.69	0.65-0.73
610A-6,CC	56.5	0.98
611-3-3, 46-48 to 611-3,CC	14.07-19.60	0.51-0.71
611C-6,CC	40.60	0.86
F. *D. seminae* group		
—	—	—
607-6-5, 43-45 to 607-6-6, 43-45	50.84-52.34	1.08-1.11
—	—	—
609-8,CC to 609-9-3, 43-45	73.94-77.64	1.06-1.12
610A-6,CC	56.5	0.98
611-5-6, 46-48 to 611-6-3, 46-48	33.77-42.87	1.07-1.22
611C-6,CC	40.60	0.86
F *P. doliolus*		
606-7-5, 43-45 to 606-7-6, 43-45	57.24-58.74	1.81-1.86
607-9-3, 43-45 to 607-9-4, 43-45	76.64-78.14	1.74-1.78
608-6,CC to 608-7-2, 23-25	50.46-56.79	1.62-1.94
609-14,CC to 609-15-1, 43-45	130.53-131.04	1.84-1.85
610A-10,CC to 610A-11-4, 48-50	94.20-100.39	1.73-1.91
611-7-6, 46-48 to 611-8,CC	56.97-68.20	1.62-1.90
611C-9,CC to 611C-11,CC	70.00-89.20	1.48-1.92
L *T. convexa*		
606-9-3, 43-45 to 606-9-4, 43-45	73.44-79.79	2.30-2.50
—	—	—
—	—	—
609-19,CC to 609-20-3, 43-45	172.32-182.04	2.48-2.62
610A-15-1, 48-50 to 610A-15-3, 48-50	134.29-137.29	2.58-2.65
611-14-1, 46-48 to 611-14-2, 46-48	116.67-118.17	2.59-2.62
611C-15-4, 43-45 to 611C-15,CC	122.97-127.70	2.44-2.54
L *N. jouseae*		
606-9,CC to 606-10,CC	79.79-48.85	2.50-2.77
—	—	—
—	—	—
—	—	—

Table 8 (continued).

Sample (interval in cm)	Sub-bottom depth (m)	Age (Ma)
L *N. jouseae* (Cont.)		
610A-15-5, 48-50 to 610A-15,CC	140.29-143.00	2.70-2.75
—	—	—
611C-15,CC to 611C-16-6, 43-45	127.70-135.57	2.54-2.70

Note: F = first occurrence; L = last occurrence.

Gauss/Matuyama boundary and the base of the Olduvai. Burckle and Trainer (1979) and Barron et al. (1985) made similar correlations and have assigned an age of ~2.2 Ma for the true last occurrence of this species in the equatorial Pacific Ocean. In Holes 610A, 611, and 611C, the last occurrence of *T. convexa* corresponds to its last common occurrence in Hole 552A, suggesting that the datum recognized in the Leg 94 holes is not the true last occurrence. The last common occurrence and the actual last occurrence of *T. convexa* were determined at Hole 552A by using a 10 cm sampling interval, and a similar interval is required to make the determination for Leg 94.

Nitzschia jouseae

The last occurrence of *N. jouseae* is observed in Holes 606, 610A, and 611C, where it corresponds to the upper part of the Gauss. (Fig. 3). Hole 610A has the most refined stratigraphic control (Table 8), but *N. jouseae* does not have a continuous stratigraphic occurrence there (Table 6). The age is estimated at 2.70–2.75 Ma. Ages at Holes 606 and 611C are between 2.50 and 2.77; overall, an age of 2.54–2.70 Ma is assigned to this event for the mid- to high-latitude Atlantic Ocean; see Baldauf et al. (this volume).

In Hole 552A the last occurrence of *Nitzschia jouseae* is placed between Samples 552A-10-2, 30–32 cm and 552A-10-2, 20 cm, midway between the Kaena Subchron and the Gauss/Matuyama boundary. This is similar to the range observed in Leg 94 material as well as to that recognized by Burckle and Trainer (1979) in the equatorial Pacific Ocean, where an age of 2.6 Ma is assigned to the event (Burckle, 1978 and Burckle and Trainer, 1979).

Denticulopsis seminae Group

Denticulopsis seminae and *D. seminae* var. *fossilis*, which are referred to as the *D. seminae* group, occur in Holes 607, 609, 610A, and 611. The first occurrence is one-fifth of the way between the base of the Jaramillo Subchron and the top of the Gauss paleomagnetic Chron in Holes 607, 609, and 611 (Fig. 3). The similarity among the ages assigned the event at these holes suggests that this first occurrence is isochronous throughout Leg 94 material.

The last occurrence of the *D. seminae* group is placed approximately one-third of the way between the Matuyama/Brunhes Chron boundary and the top of the Jaramillo Subchron (Hole 607) or immediately above the base of the Brunhes (Hole 609) (Fig. 3). The last occurrence of the *D. seminae* group in Hole 611 coincides with the last occurrences of *Nitzschia reinholdii. N. fossilis, and Mesocena quadrangula* (Fig. 3). The concentration of events in Hole 611 suggests that the last occurrence of the *D. seminae* group can be only approximately placed, with a tentative age of 0.51–0.71 Ma. The extrapolated ages assigned to this event in Holes 607 and 609 suggest that the event may be slightly older in Hole 607 than in Holes 609 and 611.

Schrader and Fenner (1976) have reported the occurrence of *Denticulopsis seminae* at about 2.2 Ma in Pliocene sediments assigned to the *Thalassiosira kryophila* Zone at Site 336 in the Norwegian Sea, earlier than its occurrences in Leg 94 Quaternary sediment from the North Atlantic Ocean.

Denticulopsis seminae is presently common in the high-latitude North Pacific Ocean and the Bering Sea, where it is characteristic of the subarctic gyre (Sancetta, 1983). In Holocene slope and basin sediments of the Bering Sea, *D. seminae* dominates the diatom assemblage, composing up to 25% of the flora (Baldauf, 1982). Sancetta (1981, 1982) suggests that in the Bering Sea *D. seminae* is characteristic of relatively warm water with moderate salinity.

The occurrence of the *D. seminae* group in the North Atlantic Ocean is significant, as it suggests that these species either evolved independently in the North Pacific and North Atlantic oceans or were transported between oceans. The latter hypothesis suggests that an icefree polar connection may have existed between the North Atlantic Ocean and the Bering Sea during the middle Quaternary.

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APPENDIX

Flora List

Actinocyclus curvatulus Janisch, 1878 *in* Schmidt et al., 1874-1959, pl. 57, fig. 31; Hustedt, 1958, pp. 129-130, pl. 8, fig. 81. Plate 2, Figs. 2, 14.

Actinocyclus divisus (Grunow) Hustedt, 1958, p. 129, pl. 8, fig. 81. Synonym: *Coscinodiscus divisus* Grunow, 1884, p. 31, pl. 4, fig. 16.

Actinocyclus ehrenbergii Ralfs *in* Pritchard, 1861, p. 834; Hustedt, 1929, p. 525, fig. 298.
Actinocyclus ellipticus Grunow *in* Van Heurck, 1883, pl. 124, fig. 10; Schrader, 1973, pl. 8, figs. 7-9, 12-14, 16, 17.
Actinocyclus ingens Rattray, 1890a, p. 149, pl. 11, fig. 7; Baldauf and Barron, 1980, pl. 1, figs. 1-4; Baldauf and Barron, 1982, p. 68, pl. 1, figs. 6-10; Baldauf, 1985a, pl. 7, figs. 1, 2, 5, 7. Plate 2, Fig. 1.
Actinocyclus moronensis Deby *in* Rattray, 1890a, p. 195; Barron, 1981, pl. 1, fig. 10; Barron, 1986, fig. 9.16.
Actinocyclus radionovae Barron, 1983, p. 504, pl. III, figs. 1-3, pl. VI, figs. 4-6. Synonym: *Cestodiscus* sp. Bukry, 1973a, pl. 3, fig. 16. Barron (1983) observed *A. radionovae* to be restricted to the lower Miocene at Sites 71, 77, and 495 in the equatorial Pacific Ocean.
Actinocyclus oculatus Jousé, 1968, p. 18, pl. 2, figs. 2-5; Koizumi, 1973, p. 831, pl. 2, figs. 8, 9.
Actinocyclus sp. Plate 4, Fig. 5.
Actinoptychus bipunctatus Lohman, 1941, p. 79, pl. 16, figs. 7, 10-12. Plate 4, Fig. 9.
Actinoptychus undulatus (Bailey) Ralfs *in* Pritchard, 1861, p. 839, pl. 5, fig. 88. Plate 4, Fig. 6. Synonym: *Actinocyclus undulatus* Bailey, 1842, pl. 2, fig. 11.
Annellus californicus Tempère *in* Tempère and Peragallo, 1908, p. 60; Hanna, 1932. pl. 4, fig. 8; Barron, 1981, pls. 6 and 7, all figures; Barron, 1985, figs. 12.8, 12.11.
Asterolampra grevillei (Wallich) Greville, 1860, p. 113, pl. 4, fig. 21; Ralfs *in* Pritchard, 1861, p. 835; Hustedt, 1929, p. 489, fig. 274. Synonym: *Asteromphalus grevillei* Wallich, 1860, p. 47, pl. 2, fig. 15.
Asterolampra marylandica Ehrenberg, 1844b, p. 76, fig. 10; Hustedt, 1929, pp. 485-587, fig. 271.
Asteromphalus affinis Greville, 1862, p. 45, pl. 7, figs. 7, 9; Gombos, 1980, p. 234.
Asteromphalus arachne (Brebisson) Ralfs *in* Pritchard, 1861, p. 837, pl. 5, fig. 66; Hustedt, 1929, p. 496, fig. 278. Synonym: *Spatangidium arachne* Brebisson, 1857, p. 296, pl. 3, fig. 1.
Asteromphalus flabellatus (Brebisson) Greville, 1859, p. 160, pl. 7, figs. 4, 5. Plate 3, Fig. 2. Synonym: *Spatangidium flabellatum* Brebisson, 1857, p. 298, pl. 3, fig. 4.
Asteromphalus hookeri Ehrenberg, 1844b, fig. 3; Hustedt, 1958, pp. 127-128, pl. 8, figs. 88-90.
Asteromphalus imbricatus Wallich, 1860, p. 46, pl. 2, fig. 9; Ralfs *in* Pritchard, 1861, p. 837.
Asteromphalus robustus Castracane, 1875, p. 393, pl. 6, fig. 5; Hustedt, 1929, p. 496, fig. 278. Plate 3, Fig. 4.
Asteromphalus sp. Plate 3, Fig. 3.
Bacteriastrum hyalinum Lauder, 1864, p. 8, pl. 3, fig. 7; Barron, 1980b, pl. 2, fig. 10; Baldauf, 1985a, pl. 1, fig. 5. Plate 6, Fig. 10.
Bacteriosira fragilis Gran, 1900, p. 114; Jousé, 1962, fig. 2, no. 15; Sancetta, 1982, p. 227, pl. 2, figs. 1-4. Synonym: *Coscinodiscus bathyomphalus* Cleve, 1883, pl. 38, fig. 81.
Biddulphia aurita (Lyngbye) Brebisson and Godey 1838, p. 12; Hustedt 1930, p. 846, fig. 501. Synonym: *Diatoma auritum* Lyngbye, 1819, p. 182, fig. 62D.
Cestodiscus peplum Brun, 1891, p. 6, pl. 19, fig. 5; Reinhold, 1937, pl. 7, figs. 10 and 11; Barron, 1985b, figs. 9.17 and 9.18; Schrader and Fenner, 1976, p. 966, pl. 14, fig. 11.
Cestodiscus pulchellus Greville, 1866, p. 123, pl. 11, fig. 5; Gombos, 1975, pl. 5, figs. 3, 6; Barron, 1985b, fig. 10.15. Plate 4, Fig. 10.
Cocconeis scutellum Ehrenberg, 1838, p. 194, pl. 14, fig. 8; Hustedt, 1930, p. 191, fig. 267; Baldauf and Barron, 1982, p. 69, pl. 6, fig. 1.
Coscinodiscus africanus Janisch, 1878 *in* Schmidt et al., 1874-1959, pl. 59, figs. 24 and 25; Hustedt, 1928, p. 428, fig. 231.
Coscinodiscus blysmos Barron, 1983, p. 504, pl. II, figs. 6, 7, pl. VI, fig. 7. Barron (1983) recognized this species in upper lower Miocene and lower middle Miocene sediment at DSDP Sites 71, 77, and 495 in the equatorial Pacific Ocean. *Coscinodiscus blysmos* is thought by Barron (1983) to be related to *C. radiatus* because of its similar morphology and because samples which contain one also contain the other.
Coscinodiscus crenulatus Grunow, 1884, p. 31, pl. 4D, fig. 17; Hustedt, 1928, p. 411, fig. 219.
Coscinodiscus gigas var. *diorama* (Schmidt) Grunow, 1884, p. 76.
Coscinodiscus lewisianus Greville, 1866, p. 78, pl. 8, figs. 8-10; Schrader, 1973, p. 703, pl. 8, figs. 1-6, 10, 15; Barron, 1985b, fig. 9.10; Baldauf, 1985a, pl. 8, fig. 7; Schrader and Fenner, 1976, p. 970, pl. 21, figs. 4, 6. Plate 1, Fig. 9.
Coscinodiscus marginatus Ehrenberg, 1841a, p. 142; Ehrenberg, 1854, pl. 18, fig. 44; Hustedt, 1930, p. 416, fig. 223; Baldauf and Barron, 1982, p. 69, pl. 5, figs. 2, 3, 7. Plate 1, Figs. 1, 8.
Coscinodiscus nodulifer Schmidt, 1878, *in* Schmidt et al., 1874-1959, pl. 59, figs. 20-23; Kanaya, 1971, pl. 40.3, figs. 1-4; Barron, 1985b, figs. 10.10, 10.11; Barron, 1980b, p. 457, 460, pl. 4, figs. 2, 5, 6-8, pl. 11, figs. 2-6. Plate 1, Figs. 3, 7.
Coscinodiscus nodulifer var. *cyclopus* Jousé, 1977, pl. 45, figs. 11, 15; pl. 48, figs. 1-6, pl. 52, figs. 6-7, pl. 77, fig. 17, pl. 78, figs. 1-4 pl. 79, fig. 16; Barron, 1980b, pl. 4, fig. 3. Plate 1, Fig. 6.
Coscinodiscus oculus-iridis Ehrenberg, 1839, p. 147; Ehrenberg, 1854, pl. 18, fig. 42, pl. 19, fig. 2.
Coscinodiscus plicatus Grunow, 1878 *in* Schmidt et al., 1874-1959, pl. 59, fig. 1; Grunow, 1884, p. 73, pl. 3C, fig. 10; Schrader, 1973, p. 703, pl. 6, fig. 23; Barron, 1985b, figs. 10.1, 10.2.
Coscinodiscus praenodulifer Barron, 1983, p. 511, pl. III, figs. 9, 10, pl. VI, fig. 8.
Coscinodiscus radiatus Ehrenberg, 1839, p. 148, pl. 3, figs. 1a-c; Hustedt, 1930, p. 420, fig. 255.
Coscinodiscus rhombicus Castracane, 1886; Schrader and Fenner, 1976, pl. 21, figs. 1-3, 5. Plate 1, Fig. 5.
Coscinodiscus salisburyanus Lohman, 1948, p. 164, pl. 7, fig. 5; Baldauf and Barron 1982, p. 69, pl. 4, fig. 4.
Coscinodiscus symbolophrus Grunow, 1884, p. 82, pl. 4(D), figs. 3-6; Hanna, 1932, p. 184.
Coscinodiscus tabularis Grunow, 1884, p. 86; Rattray, 1890b, p. 583, fig. 135; Baldauf and Barron, 1982, p. 69, pl. 4, figs. 6, 7.
Coscinodiscus vetustissimus Pantocsek, 1886, p. 71, pl. 20, fig. 186; Baldauf and Barron, 1982, p. 69, pl. 3, figs. 5-7.
Coscinodiscus yabei Kanaya, 1959, p. 86, pl. 5, figs. 6-9; Schrader, 1973, p. 704, pl. 6, figs. 1-6; Barron, 1985b, fig. 10.3.
Craspedodiscus coscinodiscus Ehrenberg, 1844c, p. 266; Ehrenberg, 1854, pl. 18, fig. 10; Rattray, 1890b, p. 600; Kanaya, 1971, p. 555, pl. 40.4, figs. 1-3; Barron, 1985b, fig. 12.12; Gombos, 1975, pl. 4, figs. 5, 6. Plate 1, Fig. 4.
Cyclotella group. Specimens are not separated by species. Members of this genus have a brackish to freshwater origin and are displaced in the marine environment.
Denticulopsis hustedtii (Simonsen and Kanaya) Simonsen, 1979, p. 64; Baldauf and Barron, 1982, pl. 7, figs. 7, 8. Plate 6, Fig. 12. Synonym: *Denticula hustedtii* Simonsen and Kanaya, 1961, p. 501, pl. 1, figs. 19-25, pl. 2, figs. 36-47; Schrader, 1973, p. 704, pl. 2, figs. 28-34, 36-47.
Denticulopsis hyalina (Schrader) Simonsen, 1979, p. 64; Baldauf and Barron, 1982, pl. 7, figs. 2, 4. Synonym: *Denticula hyalina* Schrader, 1973, p. 704, pl. 1, figs. 12-22.
Denticulopsis lauta (Bailey) Simonsen, 1979, p. 64; Baldauf and Barron, 1982, p. 70, pl. 7, fig. 5. Synonym: *Denticula lauta* Bailey, 1854, p. 9, figs. 1, 2.
Denticulopsis nicobarica (Grunow) Simonsen, 1979, p. 65; Baldauf and Barron, 1982, pl. 7, fig. 6. Synonym: *Denticula nicobarica* Grunow, 1868, p. 97, pl. la, fig. 5.
Denticulopsis praedimorpha (Akiba) Barron, 1981, p. 529, pl. 4, figs. 8-10. Synonym: *Denticula praedimorpha* (Akiba) Barron, 1980a, pl. 1, figs. 18-20.
Denticulopsis punctata (Schrader) Simonsen, 1979, p. 65; Baldauf and Barron, 1982, pl. 7, fig. 7. Synonym: *Denticula punctata* Schrader, 1973, p. 705, pl. 1, figs. 25-30, pl. 3, figs. 16, 17.
Denticulopsis punctata var. *hustedtii* (Schrader) Simonsen, 1979; Barron, 1981, pl. 4, fig. 1. Synonym: *Denticula punctata* var. *hustedtii* Schrader, 1973, p. 705, pl. 1, figs. 23, 24.
Denticulopsis seminae (Simonsen and Kanaya) Simonsen, 1979; Barron, 1981, p. 529, Sancetta, 1982, p. 230, pl. 3, figs. 1-3; Baldauf, 1985a, pl. 3, figs. 12-14. Synonyms: *Denticula marina* Seminae, 1956, fig. 2; Jousé, 1962, fig. 3, no. 10; *Denticula seminae* Simonsen and Kanaya, 1961, p. 503, pl. 1, figs. 26-30; Barron, 1980a, pl. 1, fig. 1. Specimens of *D. seminae* and *D. seminae* var. *fossilis* are grouped together, and are recorded as the *Denticulopsis seminae* group. Plate 5, Figs. 11, 12, 13?, 14-16.

Denticulopsis seminae var. *fossils* (Koizumi) Simonsen, 1979. Synonym: *Denticula seminae* var. *fossilis* Schrader; Koizumi, 1975b, pl. 1, figs. 3, 4. See comments under *D. seminae*.

Diploneis group. Plate 3, Fig. 8. Specimens of this group were not separated by species.

Diogramma sp. Plate 5, Fig. 22.

Ethmodiscus rex (Wallich) Hendey *in* Hendey and Wiseman, 1953, p. 51, pl. 1, fig. 2. Synonym: *Coscinodiscus rex* Wallich *in* Rattray, 1890b, p. 568, fig. 120. Two varieties of this species occur in the lower and middle Miocene sediment at Hole 610. These forms are not distinguished because only fragments were observed.

Eucampia balastium Castracane, 1886, p. 97, pl. 98, fig. 5; Hustedt, 1958, pp. 136–137, pl. 5, figs. 40–43; Schrader and Fenner, 1976, p. 981, pl. 10, figs. 17, 18.

Goniothecium decoratum Brun, 1891, p. 28, pl. 12, fig. 6; Schrader and Fenner, 1976, p. 982, pl. 6, figs. 3, 5, pl. 37, figs. 1–5, 11–14. Specimens of this species in Leg 94 material are reworked. Schrader and Fenner (1976) record *G. decoratum* from the Eocene and Oligocene sediments of the Norwegian Sea.

Grammatophora sp. Plate 3, Fig. 9.

Hemiaulus polymorphus Grunow, 1884, p. 66, pl. II(B), figs. 42–50; Fenner, 1977, p. 522, pl. 21, fig. 11, pl. 22, fig. 13, pl. 23, figs. 10, 11.

Hemidiscus cuneiformis Wallich, 1860, p. 42, pl. 2, figs. 3, 4; Barron, 1980b, pl. 1, figs. 9, 10. Plate 4, Figs. 7, 8.

Liradiscus bipolaris Lohman, 1948, p. 165, pl. 8, fig. 5.

Macrora stella (Azpeitia) Hanna, 1932, p. 196, pl. 12, fig. 7. Plate 4, Fig. 4. Synonym: *Pyxidicula stella* Azpeitia, 1911, pp. 150–152, pl. 1, fig. 1.

Mediaria splendida Sheshukova-Poretzkaya, 1962, p. 210, pl. 2, fig. 5; Baldauf and Barron, 1982, pl. 7, fig. 15.

Melosira granulata (Ehrenberg) Ralfs *in* Pritchard, 1861, p. 820; Hustedt, 1930, p. 87, fig. 44. Synonym: *Gallionella granulata* Ehrenberg, 1841a, p. 415. This species inhabits brackish and fresh water and is displaced in the marine environment.

Melosira sulcata (Ehrenberg) Kutzing, 1844, p. 55, pl. 2, fig. 7. Synonym: *Gallionella sulcata* Ehrenberg, 1838, p. 170, pl. 21, fig. 5.

Navicula sp. 1 of Baldauf, 1985a, pl. 6, fig. 9.

Nitzschia sp. cf. N. *cylindrica* Burckle, 1972, pp. 239–240, pl. 2, figs. 1–6; Schrader, 1973, p. 707, pl. 5, figs. 27, 32, 33.

Nitzschia fossilis (Frenguelli) Kanaya *in* Kanaya and Koizumi, 1970; Schrader, 1974, p. 914, pl. 4, figs. 9–11, 24, 25; Barron, 1980a, pl. 2, figs. 3, 4; Baldauf, 1985a, pl. 4, figs. 8, 10, 11, 14, 15, 16?, 17?. Plate 5, Figs. 5, 7, 8, 10.

Nitzschia interrupta (Reichelt *in* Kuntze) Hustedt, 1927, p. 168. Plate 5, Fig. 17. Synonym: *Denticula interrupta* Reichelt *in* Kuntze, 1898, p. 392.

Nitzschia jouseae Burckle, 1972, p. 240, pl. 2, figs. 17–20; Schrader, 1973, pl. 4, figs. 20, 21, 22–23(?)

Nitzschia marina Grunow *in* Cleve and Grunow, 1880, p. 70; Grunow *in* Van Heurck, 1881, pl. 57, figs. 26–27; Schrader, 1973, pl. 4, figs. 17–19; Schrader, 1974a, pl. 5, figs. 1–2, 5, 14?. Plate 5, Figs. 1, 4. *N. marina* is characterized by parallel sides and slightly pointed apices. However, wide morphological variation does occur, with forms seeming to blend into a intermediate *N. fossilis–N. reinholdii* category (Baldauf, 1985a).

Nitzschia miocenica Burckle, 1972, pp. 240–241, pl. 2, figs. 10–15; Barron, 1980a, p. 672, pl. 2, fig. 8, pl. 3, figs. 3, 4; Balduaf, 1985a, pl. 6, figs. 15, 16. This species is extremely rare in Leg 94 material.

Nitzschia panduriformis Gregory, 1857, p. 529, fig. 57; Fenner, 1977, p. 525, pl. 32, figs. 27–29; Baldauf, 1985a, pl. 5, fig. 8.

Nitzschia reinholdii Kanaya and Koizumi, 1970; Schrader, 1973, p. 708, pl. 4, figs. 12–16, pl. 5, figs. 1–9; Barron, 1981, pl. 4, fig. 15; Baldauf, 1985a, pl. 4, figs. 5–7, pl. 5, fig. 4. Plate 5, Figs. 2, 3, 6.

Nitzschia sp. 1. of Baldauf 1985a, pl. 6, fig. 12. Plate 5, Fig. 20.

Nitzschia sp. 2. Plate 5, Figs. 18, 19.

Nitzschia group. A variety of small *Nitzschia* in Leg 94 material is combined into the *Nitzschia* group.

Opephora sp. 1. of Baldauf, 1985a, pl. 4, fig. 9.

Podosira glacialis (Grunow) Jörgensen, 1905, p. 97, pl. 6, fig. 7; Schrader and Fenner, 1976, p. 993, pl. 16, figs. 1–4, 13, pl. 17, fig. 1; Sancetta, 1982b, p. 235, pl. 3, figs. 16–18. Plate 3, Fig. 5. Synonym: *Podosira hormeides* var. *glacialis* Grunow, 1884, p. 108, pl. 5e, fig. 32.

Pseudoeunotia doliolus (Wallich) Grunow *in* Van Heurck, 1881, pl. 35, fig. 22; Schrader, 1973, p. 708, pl. 4, figs. 1–8. Plate 5, Fig. 9. Synonym: *Synedra doliolus* Wallich, 1860, p. 48, pl. 2, fig. 19.

Rhaphidodiscus marylandicus Christian, 1887, pp. 66–68; Hanna, 1932, p. 208, pl. 14, figs. 3, 4; Baldauf and Barron, 1982, p. 71, pl. 3, fig. 3.

Rhaphoneis amphiceros Ehrenberg, 1844b, p. 87; Hustedt, 1959, p. 174, figs. 680–681; Schrader, 1973, pp. 708–709, pl. 25, figs. 2, 3.

Rhizosolenia barboi (Brun) Tempère and Peragallo, 1908, p. 26, no. 47; Schrader, 1973, p. 709, pl. 24, figs. 4, 7. Synonym: *Pyxilla barboi* Brun, 1894, p. 87, pl. 5, figs. 16, 17, and 23.

Rhizosolenia bergonii Peragallo, 1892, p. 110, pl. 15, fig. 5; Schrader, 1973, p. 709, pl. 9, figs. 1–5, 7, 8, 10, 12, 22, 23; pl. 10, figs. 24, 29. Plate 6, Figs. 1, 2, 6, 9.

Rhizosolenia curvirostris Jousé, 1959, p. 48, pl. 2, fig. 17; Donahue, 1970, pp. 135–136, fig. 6; Schrader, 1973, p. 709, pl. 24, figs. 5, 6, 8, 9. Specimens of this species differ in the amount of curvature and the robustness of the lateral spine (see Baldauf, 1985a).

Rhizosolenia hebetata Bailey, 1856, p. 5, pl. 1, figs. 18, 19. Plate 6, Fig. 3.

Rhizosolenia miocenica Schrader, 1973, p. 707, pl. 10, figs. 2–6, 9–11; Barron, 1980a, pl. 4, fig. 8; Schrader and Fenner, 1976, p. 996, pl. 9, figs. 5, 11, 13, 14.

Rhizosolenia praebarboi Schrader, 1973, p. 709, pl. 24, figs. 1–3; Barron, 1980a, pl. 2, fig. 18.

Rhizosolenia praebergonii Muchina, 1965; Burckle, 1972, pl. 1, fig. 1; Koizumi, 1968, p. 217, pl. 34, figs. 20, 21; Schrader, 1973, pl. 10, fig. 7, pl. 9, fig. 6.

Rhizosolenia styliformis Brightwell, 1858, p. 95, pl. 5, figs. 5a, b, and d; Hustedt, 1930, pp. 584–588, figs. 333–335; Schrader, 1973, pl. 10, figs. 1, 18, 19, 20, 21; pl. 9, fig. 9?. Plate 6, Fig. 7.

Rhizosolenia sp. 1. Plate 6, Figs. 4, 8.

Rhizosolenia sp. 2. Plate 6, Fig. 5.

Roperia tesselata (Roper) Grunow, *in* Van Heurck, 1883, pl. 118, figs. 6, 7; Barron, 1980b, pl. 3, figs. 8, 10. Plate 2, Fig. 9.

Stephanogonia hanazawae Kanaya, 1959, p. 118, pl. 11, figs. 3–7; Schrader and Fenner, 1976, p. 1000, pl. 12, figs. 10, 12, pl. 13, figs. 5, 7, 8.

Stephanopyxis turris (Greville and Arnott) Ralfs *in* Pritchard, 1861, p. 826, pl. 5, fig. 74; Fenner, 1977, p. 532, pl. 12, figs. 8, 9. Synonym: *Cresswellia turris* Gerville and Arnott, 1857, p. 538.

Synedra jouseana Sheshukova-Poretzkaya, 1962, p. 208, fig. 4; Schrader, 1973, pl. 23, figs. 21–23, 25, 28. Plate 5, Fig. 21.

Synedra ulna (Nitzsch) Ehrenberg, 1838, p. 211, pl. 17, fig. 1. Synonym: *Bacillaria ulna* Nitzsch, 1817, p. 99, pl. 5.

Thalassionema nitzschioides (Grunow) Van Heurck, 1896, p. 319, fig. 75; Schrader, 1973, pl. 23, figs. 2, 6, 8, 9, 10, 26, 29, 34, 12–13.

Thalassiosira convexa Muhina, 1965; Schrader, 1974, pl. 2, figs. 1–5, 10–13; Barron, 1980b, pl. 8, fig. 1. Plate 2, Fig. 5. Schrader, 1974, named a variety, *T. convexa* var. *aspinosa*; this variety is grouped together with *T. convexa* s. str.

Thalassiosira eccentrica Cleve, 1904, p. 216,; Sheshukova-Poretzkaya, 1967, pp. 141–142, pl. 14, fig. 4; Schrader, 1973, pl. 25, fig. 17, pl. 16, figs. 5, 6. Plate 2, Fig. 7; Plate 4, Fig. 3.

Thalassiosira fraga Schrader *in* Schrader and Fenner, 1976, p. 1001, pl. 16, figs. 9–12; Barron, 1983, p. 512, pl. IV, figs. 3, 5. Plate 2, Figs. 8, 12, 13.

Thalassiosira gravida Cleve, 1896, p. 12, pl. 2. figs. 14–16; Hustedt, 1928, p. 325, fig. 161. Specimens of this species are most abundant at Site 611.

Thalassiosira jacksonii Koizumi and Barron *in* Koizumi, 1980, p. 396, pl. 1, figs. 11–14; Barron, 1980a, pl. 6, figs. 2, 6, ld?; Baldauf, 1985a, pl. 5, fig. 11. Synonym: *Thalassiosira* sp. b Schrader and Fenner, 1976, pl. 17, figs. 5, 10.

Thalassiosira leptopus (Grunow) Hasle and Fryxell, 1977, figs. 1–14, 94–96. Plate 1, Fig. 2. Synonym: *Coscinodiscus lineatus* Ehrenberg; Reinhold, 1937, pl. 11, fig. 7.

Thalassiosira nativa Sheshukova-Poretzkaya, 1959, p. 41, pl. 1, fig. 8, pl. 4, fig. 5; Barron, 1985b, fig. 11.4; Barron, 1980a, pl. 6, figs. 8, 9, 12.

Thalassiosira nidulus (Tempère and Brun *in* Brun and Tempère 1889) Jousé, 1961, p. 63, pl. 3, figs. 4, 5. Synonym: *Stephanopyxis nidulus* Tempère and Brun *in* Brun and Tempère, 1889, p. 57, pl. 8, fig. 10.

Thalassiosira nordenskioeldii Cleve, 1873, p. 7, pl. 1, fig. 11; Hustedt, 1928, p. 321, fig. 157; Sancetta, 1982, p. 243, pl. 5, figs. 8, 9.

Thalassiosira oestrupii (Ostenfeld) Proskina-Lavrenko, 1949; Hasle, 1960, p. 8, pl. 1, figs. 5, 7, and 1; Schrader, 1974, pl. 1, figs. 3–11, 13–16, 19, 20; pl. 14, fig. 5. Plate 2, Figs. 3, 4, 6.

Thalassiosira plicata Schrader, 1974, p. 917, pl. 3, figs. 1–2, 4–9. Plate 4, Fig. 1.

Thalassiosira spinosa Schrader *in* Schrader and Fenner, 1976, p. 636, pl. 6, figs. 5–7; Barron, 1983, p. 512, pl. 10, fig. 8.

Thalassiosira symbolophora Schrader, 1974, p. 912, pl. 4, figs. 1–2, 4–8. Plate 4, Fig. 2.

Thalassiosira sp. 1. Plate 2, Fig. 10.

Thalassiosira sp.2. Plate 2, Fig. 11.

Thalassiothrix longissima Cleve and Grunow *in* Cleve and Moller, 1878, No. 118, No. 207; Schrader, 1973, pl. 23, figs. 7, 17, 18.

Triceratium cinnamoneum Greville, 1863, p. 232, pl. 9, p. 2; Pantocsek, 1889, p. 110.

Trinacria excavata var. *tetragona* Rabinovich, 1947 (according to Hollerbakh and Krassavina, 1971, p. 591. Plate 3, Figs. 6?, 7.

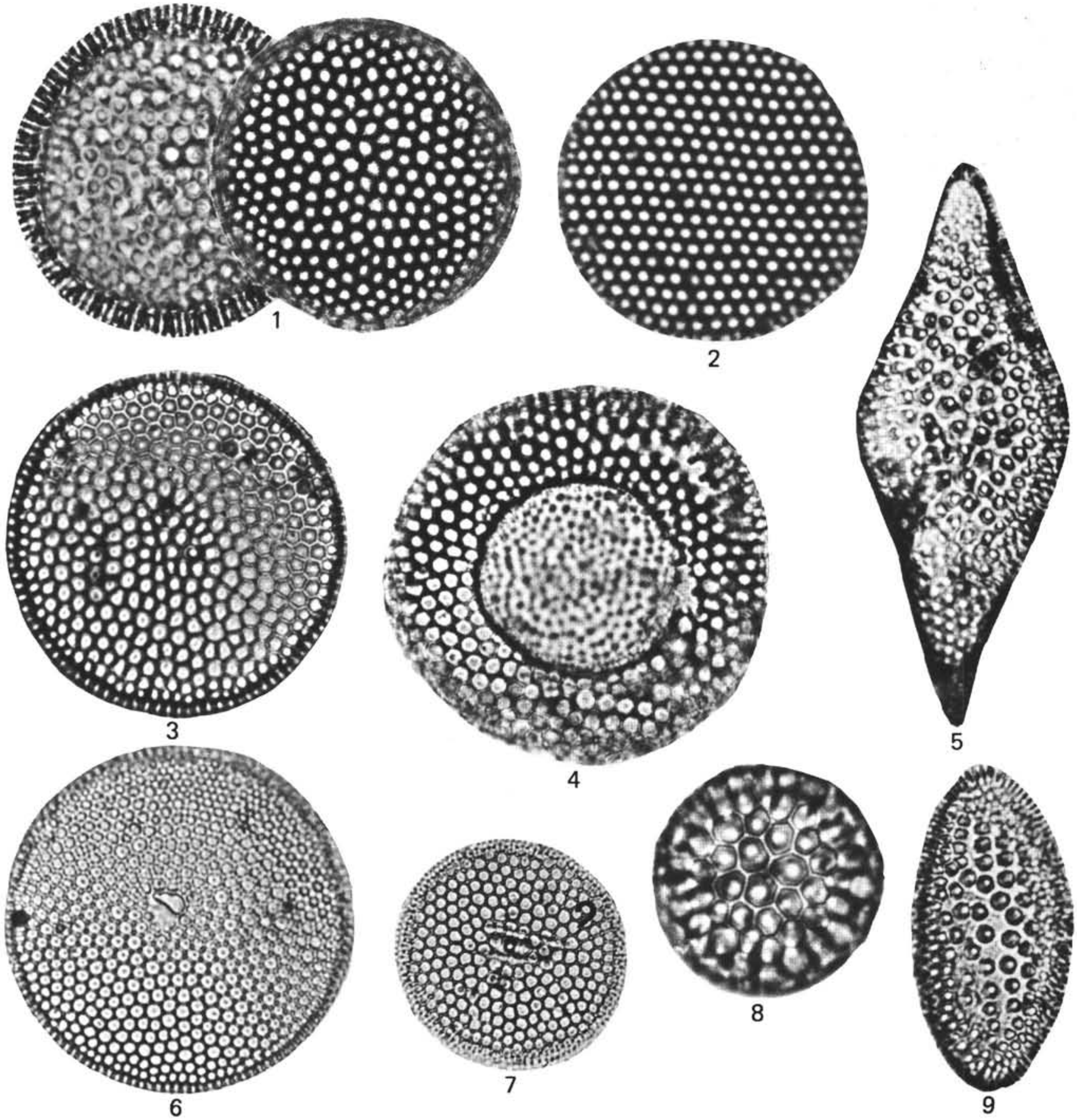

Plate 1. **1.** *Coscinodiscus marginatus* Ehrenberg, Sample 609-15-1, 43–45 cm, 113 μm. **2.** *Thalassiosira leptopus* (Grunow) Hasle and Fryxell, Sample 607A-25-1 43–45 cm, 28 μm. **3, 7.** *Coscinodiscus nodulifer* Schmidt, (3) Sample 609-18-1, 43–45 cm, 42 μm; (7) Sample 608-5-3, 33–35 cm, 28 μm. **4.** *Craspedodiscus coscinodiscus* Ehrenberg, Sample 610-16-4, 48–50 cm, 62 μm. **5.** *Coscinodiscus rhombicus* Castracane, Sample 610-25-3, 48–50 cm, length 56 μm. **6.** *Coscinodiscus nodulifer* var. *cyclopus* Jousé, Sample 607-9-4, 43–45 cm, 40 μm. **8.** *Coscinodiscus* cf. *marginatus* Ehrenberg, Sample 609-18-1, 43–45 cm, 25 μm. **9.** *Coscinodiscus lewisianus* Greville, Sample 610-27-6, 48–50 cm, length 28 μm.

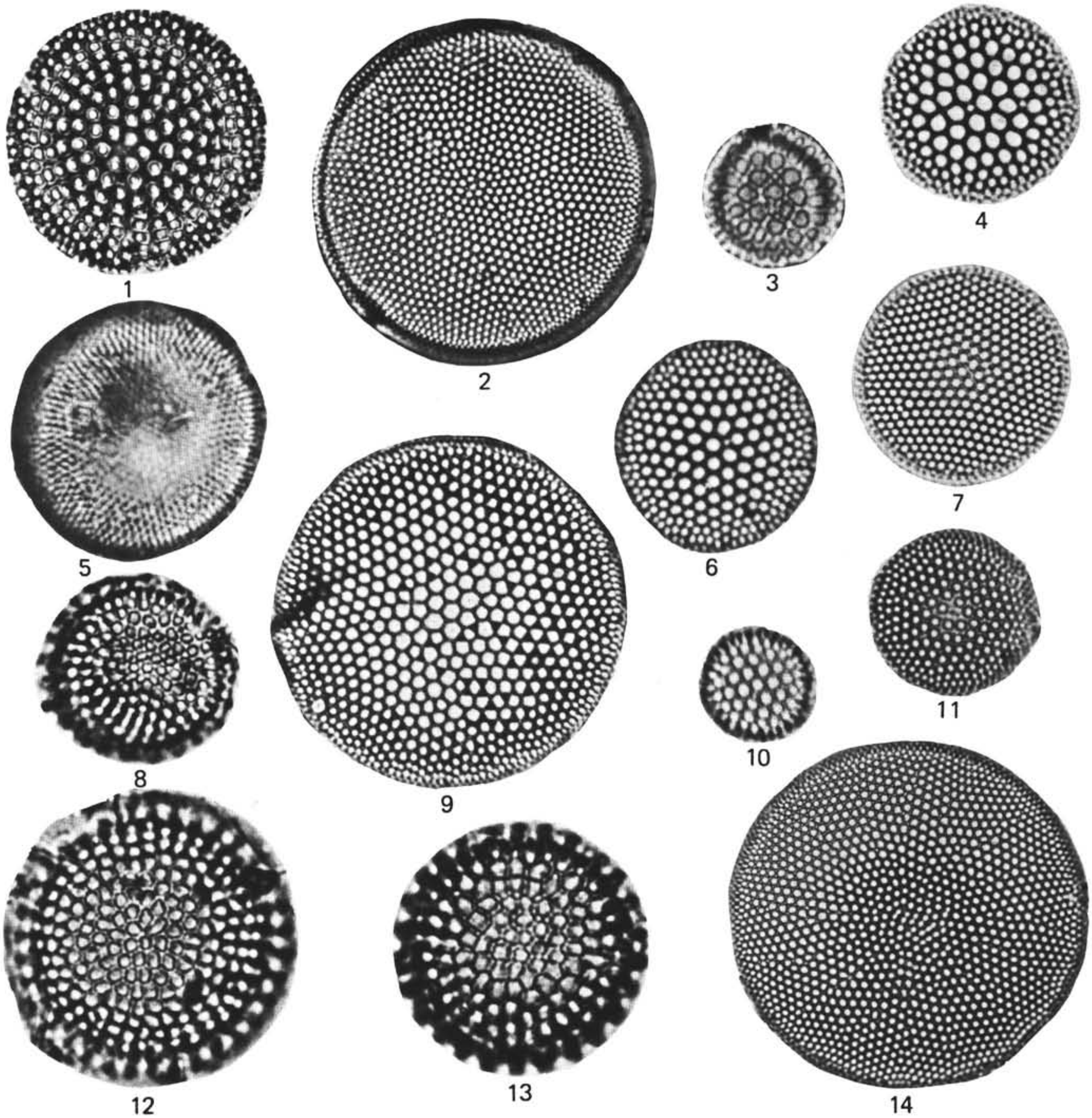

Plate 2. **1.** *Actinocyclus ingens* Rattray, Sample 406-23-2, 100–102 cm, 30 μm. **2, 14.** *Actinocyclus curvatulus* Janisch, (2) Sample 609-20-3, 43–45 cm, 40 μm; (14) Sample 607-7-2, 43–45 cm, 50 μm. **3.** *Thalassiosira* cf. *oestrupii* (Ostenfeld) Proschkina-Lavrenko, Sample 611-4-2, 46–48 cm, 8 μm. **4, 6.** *Thalassiosira oestrupii* (Ostenfeld) Proschkina-Lavrenko, (4) Sample 609-15-1, 43–45 cm, 14 μm; (6) Sample 607-5-4, 43–45 cm, 17 μm. **5.** *Thalassiosira convexa* Muchina, Sample 607A-25-1, 43–45 cm, 36 μm. **7.** *Thalassiosira eccentrica* (Ehrenberg) Cleve, Sample 609-7-3, 43–45 cm, 28 μm. **8, 12, 13.** *Thalassiosira fraga* Schrader, (8) Sample 610-27-6, 42–44 cm, 17 μm; (12, 13) Sample 610-27-2, 42–44 cm (12, 42 μm; 13, 23 μm). **9.** *Roperia tesselata* (Roper) Grunow, Sample 607-9-6, 43–45 cm, 42 μm. **10.** *Thalassiosira* sp. 1, Sample 609-12-3, 43–45 cm, 8 μm. **11.** *Thalassiosira* sp. 2, Sample 609-12-3, 43–45 cm, 7 μm.

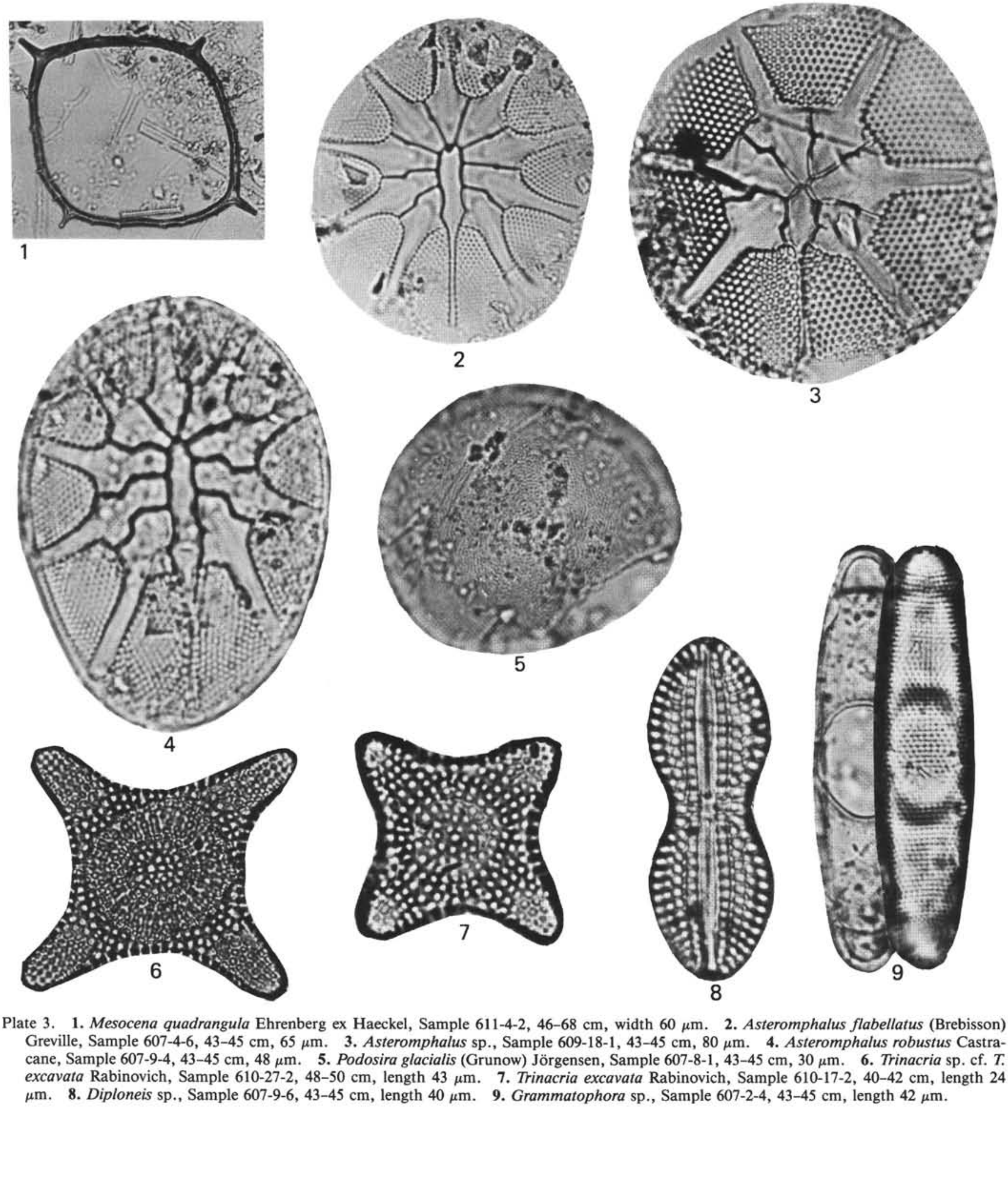

Plate 3. **1.** *Mesocena quadrangula* Ehrenberg ex Haeckel, Sample 611-4-2, 46–68 cm, width 60 μm. **2.** *Asteromphalus flabellatus* (Brebisson) Greville, Sample 607-4-6, 43–45 cm, 65 μm. **3.** *Asteromphalus* sp., Sample 609-18-1, 43–45 cm, 80 μm. **4.** *Asteromphalus robustus* Castracane, Sample 607-9-4, 43–45 cm, 48 μm. **5.** *Podosira glacialis* (Grunow) Jörgensen, Sample 607-8-1, 43–45 cm, 30 μm. **6.** *Trinacria* sp. cf. *T. excavata* Rabinovich, Sample 610-27-2, 48–50 cm, length 43 μm. **7.** *Trinacria excavata* Rabinovich, Sample 610-17-2, 40–42 cm, length 24 μm. **8.** *Diploneis* sp., Sample 607-9-6, 43–45 cm, length 40 μm. **9.** *Grammatophora* sp., Sample 607-2-4, 43–45 cm, length 42 μm.

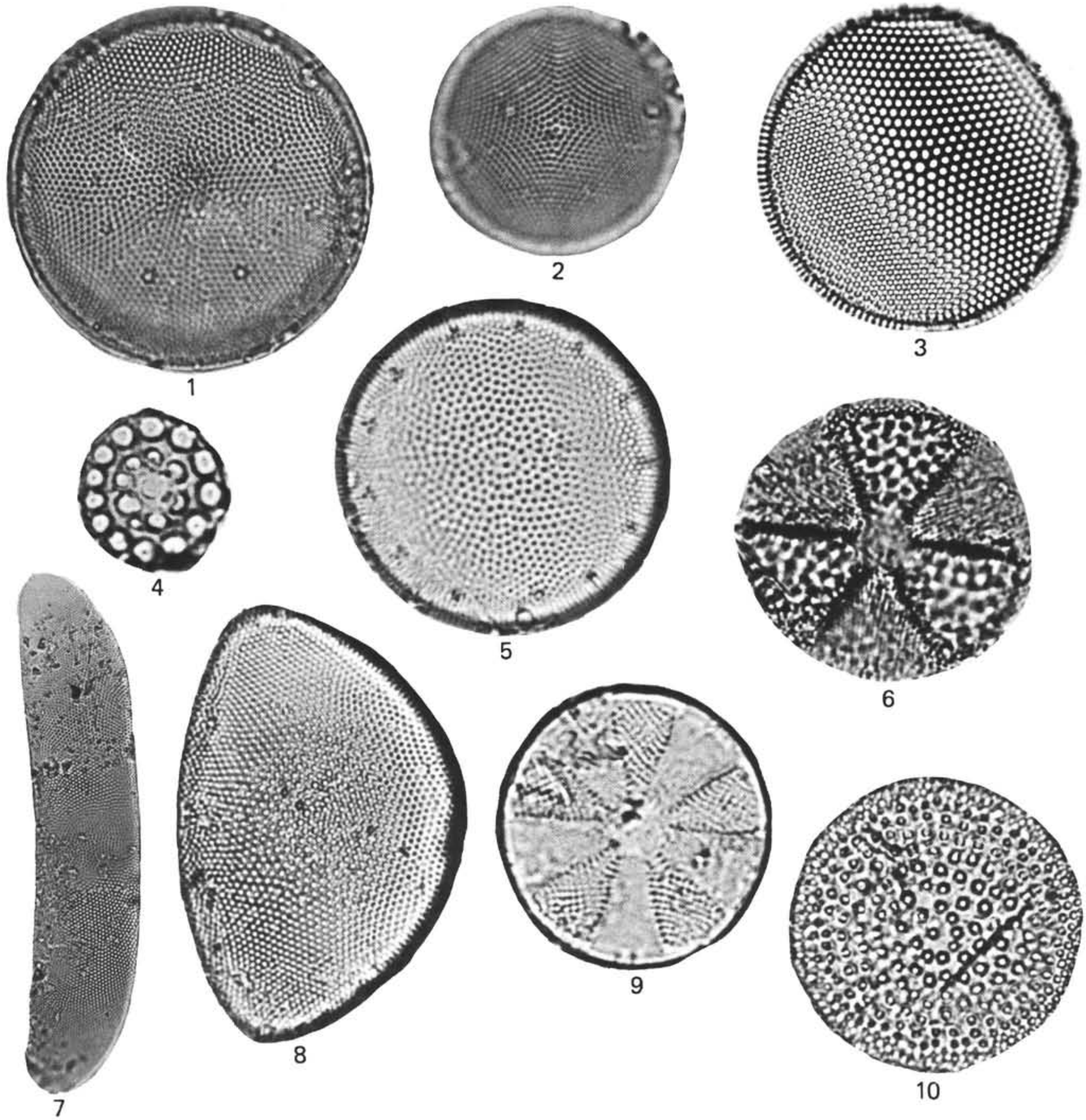

Plate 4. **1.** *Thalassiosira plicata* Schrader, Sample 607-9-4, 43–45 cm, 42 μm. **2.** *Thalassiosira symbolophora* Schrader, Sample 607-5-2, 43–45 cm, 23 μm. **3.** *Thalassiosira eccentrica* (Ehrenberg) Cleve, Sample 607-8-3, 43–45 cm, 42 μm. **4.** *Macrorastella* (Azpeitia) Hanna, Sample 610-27-2, 48–50 cm, 10 μm. **5.** *Actinocyclus* sp., Sample 607-2-4, 43–45 cm, 34 μm. **6.** *Actinoptychus undulatus* (Bailey) Ralfs, Sample 610-27-6, 42–44 cm, 28 μm. **7, 8.** *Hemidiscus cuneiformis* Wallich, (7, 8) Sample 607-9-4, 43–45 cm (7, length 127 μm; 8, length 56 μm). **9.** *Actinoptychus bipunctatus* Lohman, Sample 607-4-1, 43–45 cm, 59 μm. **10.** *Cestodiscus pulchellus* Greville, Sample 610-27-2, 48–50 cm, 45 μm.

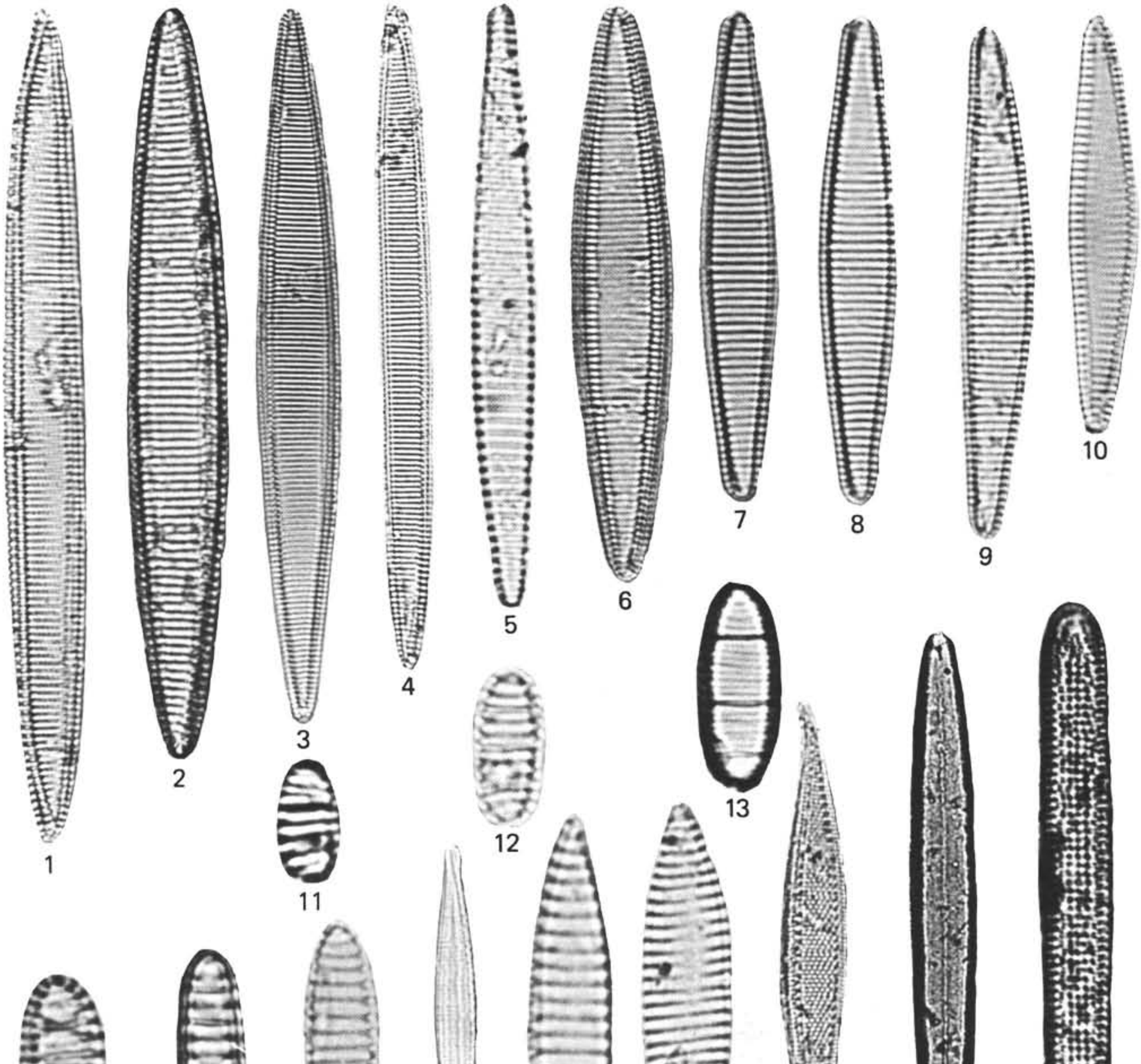

Plate 5. **1, 4.** *Nitzschia marina* Grunow, (1) Sample 607-2-4, 43–45 cm, length 84 μm; (4) Sample 607-9-4, 43–45 cm, length 57 μm. **2, 3, 6.** *Nitzschia reinholdii* Kanaya and Koizumi, (2) Sample 607-2-4, 43–45 cm, length 71 μm; (3) Sample 607-8-1, 43–45 cm, length 90 μm; (6) Sample 607-6-5, 43–45 cm, length 70 μm. **5, 7, 8, 10?.** *Nitzschia fossilis* (Frenguelli) Kanaya (5, 10) Sample 607-2-4, 43–45 cm (5, 56 μm; 10, 42 μm); (7, 8) Sample 607-9-4, 43–45 cm (7, 34 μm; 8, length 42 μm). **9.** *Pseudoeunotia doliolus* (Wallich) Grunow, Sample 607-2-4, 43–45 cm, length 51 μm. **11, 12, 13?, 14–16.** *Denticulopsis seminae* group, (11, 13) Sample 609-7-3, 43–45 cm (11, length 5 μm; 13, length 17 μm); (12) Sample 607-6-11, 43–45 cm, length 8 μm; (14–16) Sample 611-4-2, 46–48 cm, (14, length 14 μm; 15, 16 μm; 16, 17 μm). **17.** *Nitzschia interrupta* Hustedt, Sample 607-6-5, 43–45 cm, length 36 μm. **18, 19.** *Nitzschia* sp. 1, (18) Sample 609-7-3, 43–45 cm, length 20 μm; (19) Sample 609-3-3, 43–45 cm, length 30 μm. **20.** *Nitzschia* sp. 2 of Baldauf (1985a), Sample 606-2,CC, length 36 μm. **21.** *Synedra jouseana* Sheshukova-Poretzkaya, Sample 610-27-2, 48–50 cm, length 77 μm. **22.** *Diogramma* sp., Sample 609-7-3, 43–45 cm, length 56 μm.

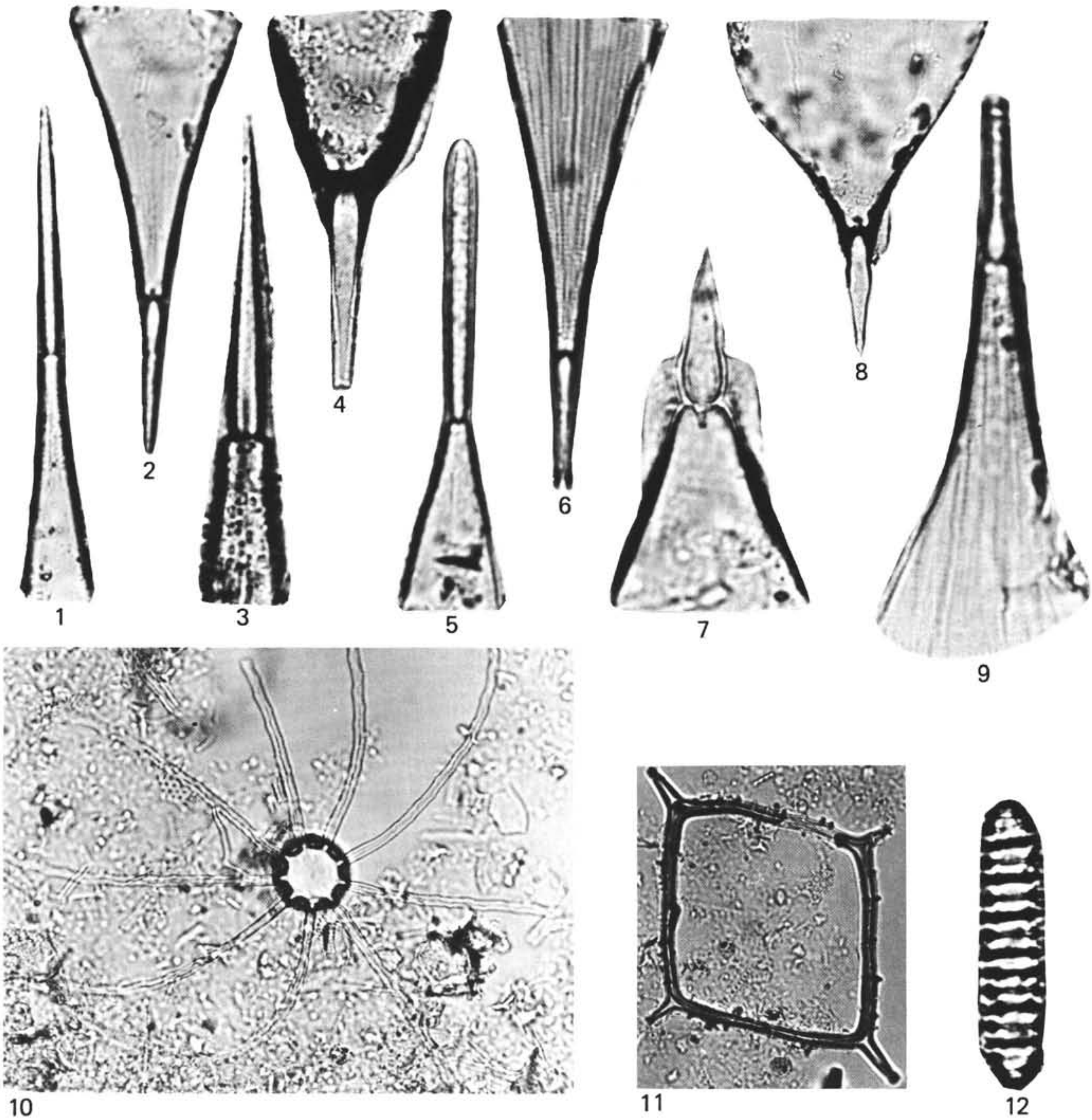

Plate 6. **1, 2, 6, 9.** *Rhizosolenia bergonii* Peragallo, (1) Sample 607-4-6, 43–45 cm, length 60 μm; (2) Sample 609-7-3, 43–45 cm, 56 μm; (6) Sample 609-5-3, 43–45 cm, length 58 μm; (9) Sample 609-2-3, 43–45 cm, length 66 μm. **3.** *Rhizosolenia hebetata* Bailey, Sample 609-11-3, 43–45 cm, length 56 μm. **4, 8.** *Rhizosolenia* sp. 1, (4) Sample 609-7-3, 43–45 cm, length 56 μm; (8) Sample 607-7-5, 43–45 cm, length 90 μm. **5.** *Rhizosolenia* sp. 2, Sample 607-7-5, 43–45 cm, length 80 μm. **7.** *Rizosolenia styliformis* Brightwell, Sample 607-4-6, 43–45 cm, length 65 μm. **10.** *Bacteriastrum hyalinum* Lauder, Sample 607-7-2, 43–45 cm, width 120 μm. **11.** *Mesocena quadrangula* Ehrenberg ex Haeckel, Sample 607-7-2, 43–45 cm, width 56 μm. **12.** *Denticulopsis hustedtii* Simonsen, Sample 610-16-4, 48–50 cm, length 25 μm.