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7. NEOGENE DIATOM BIOSTRATIGRAPHY FOR THE EASTERN EQUATORIAL PACIFIC OCEAN, LEG 138[1]

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ABSTRACT

Ocean Drilling Program (ODP) Leg 138 recovered more than 5500 m of Quaternary to middle Miocene (~17 Ma) sediments from 11 sites in the eastern equatorial Pacific Ocean. These sediments represent the most complete stratigraphic sequence recovered since the start of scientific ocean drilling by the Deep Sea Drilling Project (DSDP) and ODP. The diatoms observed generally are common to abundant and well-preserved throughout the samples examined. The assemblages are characterized by species typical of low-latitudes and regions of high surface-water productivity and are dominated by *Thalassiothrix longissima, Thalassionema nitzschioides, Azpeitia nodulifer*, and numerous species of *Thalassiosira* and *Nitzschia*.

Fifty-six biostratigraphic events were identified at Sites 844 through 852, allowing us, in part, to use the diatom zonation of Barron (1985a). This zonation was modified by replacing the *Rhizosolenia preabergonii* Zone and the upper portion of the *Nitzschia jouseae* Zone, as used by Barron (1985a), with the *Nitzschia marina* and *Nitzschia jouseae* zones, as used by Baldauf (1984, 1987). Twenty-nine biostratigraphic events have been correlated to the Leg 138 paleomagnetic stratigraphy of Schneider (this volume). Nineteen of these events are well constrained to permit recalibration. Diatoms were rare or absent in samples examined from Sites 853 and 854. As such, these sites are not included in the following discussion.

INTRODUCTION

During Leg 138, 42 holes at 11 sites in the eastern equatorial Pacific Ocean were cored to examine the paleoceanographic history of this region since the middle Miocene. Sites 844 through 847 form a north-south transect centering at 95°W longitude, and Sites 848 through 854 form a north-south transect at 110°W longitude (Table 1; Fig. 1). The sediments recovered during this cruise are unique in that they (1) compose near-continuous sequences representing about the last 17 m.y.; (2) have been examined at a sample spacing of 2 to 5 cm for color spectrum (Mix et al., this volume), GRAPE (Mayer et al., this volume), and magnetic susceptibility (Valet et al., this volume); (3) generally contain the major siliceous and calcareous microfossil groups, and (4) contain at Sites 844, 845, 848, 851, and 852, a magnetostratigraphy for portions of the Quaternary through upper middle Miocene sequences. As such, Leg 138 presents a unique opportunity to enhance current biostratigraphies and biochronologies to improve the temporal framework for refined paleoceanographic analysis.

This study presents the diatom biostratigraphic results of samples examined from Sites 844 through 852. In doing so, calibration of specific stratigraphic markers to magnetostratigraphic records have been reexamined on the basis of comparisons of Leg 138 diatom biostratigraphy and magnetostratigraphy (Schneider, this volume). The sparse occurrence or absence of diatoms from samples examined from Sites 853 and 854 exclude these sites from this study.

METHODS

Biostratigraphy/Biochronology

Diatom biostratigraphy for the equatorial Pacific has evolved from the original zonations proposed by Burckle (1972, 1977), Jousé (1973), and Bukry and Foster (1973) to the more recent zonal standard of Barron (1985a). In addition, numerous studies, including Burckle and Trainer (1979), Burckle et al. (1982), Sancetta (1984), Barron et al. (1985), and Baldauf (1985), have enhanced our understanding of the spatial and temporal distribution of diatoms in the equatorial Pacific region.

The Quaternary and Neogene diatom zonation of Barron (1985a, 1985b) consists of 18 zones and 21 subzones, with each zonal and subzonal boundary defined by the first or last stratigraphic occurrence of a specific species. The majority of these zonal and subzonal biomarkers have been calibrated directly with a magnetostratigraphy based on the studies of Burckle (1972, 1977), Burckle et al. (1982), Barron (1985a, 1985b), and Barron et al. (1985). The zonation used by Barron (1985a, 1985b) results from the studies of eastern equatorial Pacific sediments recovered primarily from DSDP Leg 85. In addition to the primary biostratigraphic markers, numerous secondary stratigraphic markers have also been defined for use in this region. The majority of these secondary events have been indirectly calibrated to the magnetostratigraphy and are considered useful only locally (i.e., the Leg 85/Leg 138 region).

In this study, we adhere to a slightly revised version of the diatom zonation proposed by Barron (1985a, 1985b) for the eastern equatorial Pacific. Barron (1985a) followed Burckle (1977) in using the *Rhizosolenia praebergonii* Zone as the interval from the first occurrence (FO) of *R. praebergonii* to the FO of *Pseudoeunotia doliolus*. Within the Leg 138 material, we have followed Baldauf (1984) in replacing, where needed, the *R. praebergonii* Zone with the *Nitzschia marina* Zone and an extended *Nitzschia jouseae* Zone (Fig. 2). The *N. marina* Zone is defined as the interval from the FO of *P. doliolus* to the last occurrence (LO) of *N. jouseae*. This zone is subdivided into two subzones on the basis of the LO of *Thalassiosira convexa*.

Actinocyclus moronensis has a scattered occurrence throughout its stratigraphic range. This limits the usefulness of the LO of *A. moronensis* to define the *T. yabei/A. moronensis* boundary, following Barron (1985a). We have used the LO of *Denticulopsis simonsenii*, where necessary, as a secondary marker for this zonal boundary. With the exception of several changes in taxonomic nomenclature discussed by Akiba and Yanagisawa (1985), the remaining zonation used here follows Barron (1985a).

During shipboard analysis, we adhered to the time scale of Berggren et al. (1985); (see Fig. 2). Berggren et al.'s (1985) chronology was slightly modified to incorporate the Blake, Cobb Mountain, and Reunion paleomagnetic events. Estimated ages for the Cobb

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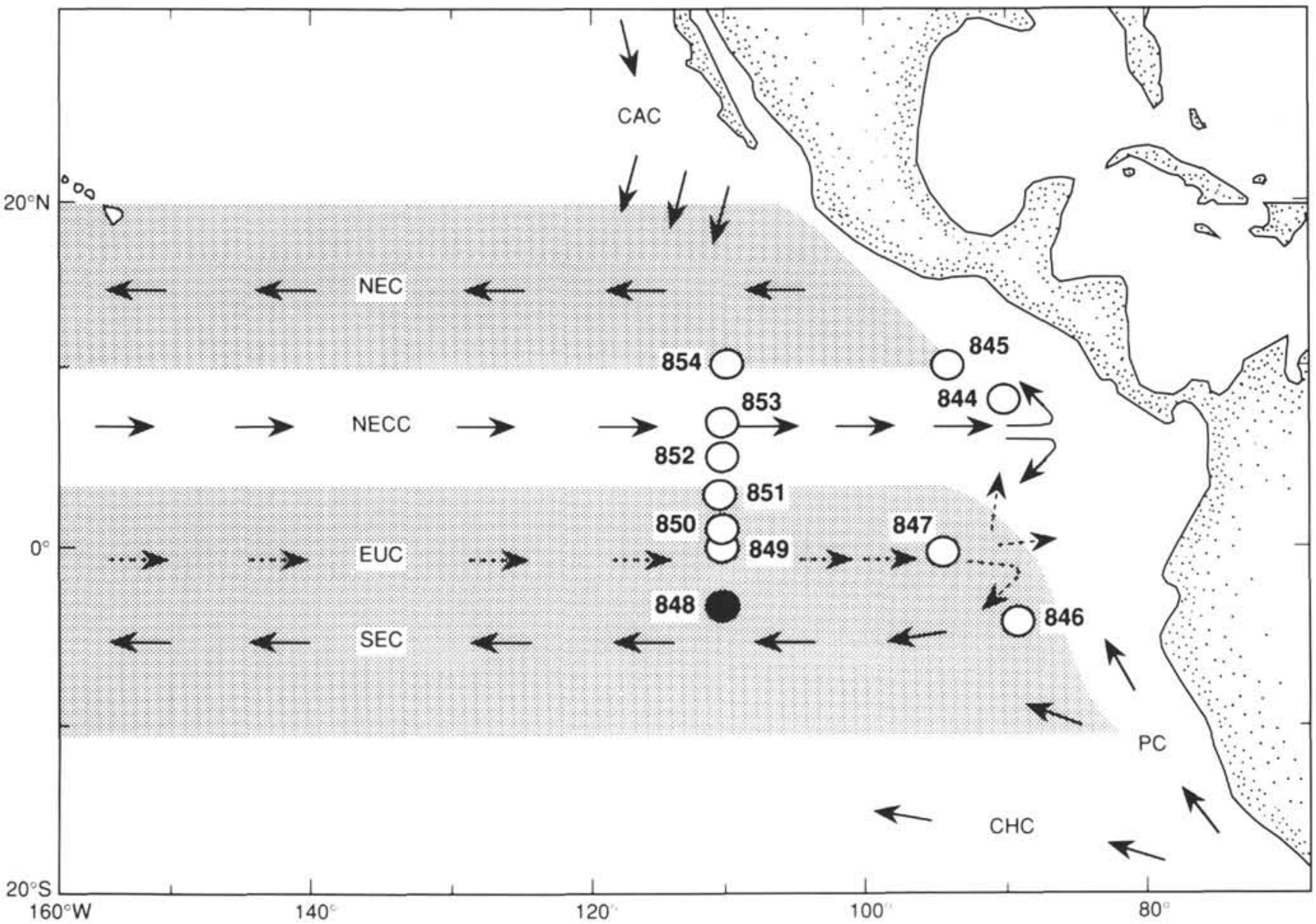

Figure 1. Location of Leg 138 sites (844–854) and generalized circulation system of the eastern equatorial Pacific Ocean. Surface currents = solid arrows, subsurface currents = dashed arrows: CAC = California Current; NEC = North Equatorial Current; NECC = North Equatorial Countercurrent; EUC = Equatorial Undercurrent; SEC = South Equatorial Current; PC = Peru Current; and CHC = Chile Current. Shaded areas represent general latitudinal extent of SEC and NEC.

Mountain and Reunion events follow Harland et al. (1982). Calibration of the diatom chronology to the Geopolarity Time Scale (GPTS) of Berggren et al. (1985) follows Barron (1985a, 1985b) and Barron et al. (1985), as Berggren et al. (1985) failed to include calibration of diatoms in their chronostratigraphy. Although for this manuscript we adhered to the more recent chronology of Cande and Kent (1992; see Table 2; Figs. 2 and 3), Berggren et al.'s (1985) chronology also has been presented here to be consistent with shipboard studies.

Biostratigraphic events, such as the first or last occurrences of a specific species, have been assigned to the sample containing the first or last observed specimens. Sample constraints, depth (meters below seafloor), and depth (composite) for each event are presented in the appropriate tables. The composite depth assignment follows that reported in Mayer, Pisias, Janecek, et al. (1992).

Techniques

Smear slides from selected samples were examined on a routine basis for stratigraphic markers. When required (because of low concentrations of specimens), selected samples from all sites were processed using hydrogen peroxide and hydrochloric acid, following a modified version of the procedures of Baldauf (1984). Strewn slides of the acid-clean material were prepared for samples from Site 845 and from Sites 847 to 852. These slides were examined using magnifications between 750 and 1250×. Slides examined from Sites 844B and 846B were generated using a random settling technique similar to that described by Bodén (1991).

RESULTS

Tables 3 through 5 provide the sample, meters below seafloor depth (mbsf) and meters composite depth (mcd) constraints for stratigraphic events identified for Sites 844 through 846, located along the eastern transect. Tables 6 through 8 provide similar data for stratigraphic events recognized for Sites 847 through 852, located along the western transect.

Site 844

Four holes (844A–844D) were cored at Site 844, situated on the Cocos Plate (Table 1; Fig. 1). Well-preserved diatoms are generally present throughout the Pleistocene (*Nitzschia reinholdii* Zone) to uppermost lower Miocene (Subzone B of the *Crucidenticula nicobarica* Zone) sequence. The biostratigraphy presented here for Hole 844B has been slightly revised from the shipboard work (see Mayer, Pisias, Janecek, et al., 1992). The continuous occurrence of diatoms combined with an excellent magnetostratigraphy (see Schneider, this volume) for the interval from C1n through 5n (0 to ~10 Ma) make this site an ideal type section for the low-latitude Pacific. In addition, diatom stratigraphic events examined from this site can be directly correlated to those recorded from DSDP Sites 573 through 574 by Barron (1985a).

Samples examined from Core 138-844B-1H were assigned to the *Pseusdoeunotia doliolus* Zone, based on the occurrence of *P. doliolus* stratigraphically above the LO of *Nitzschia reinholdii* in Sample

Table 1. Latitude, longitude, and water depth (drill-pipe measurement) of holes cored during Leg 138.

Hole	Latitude	Longitude	Water depth (m)
844A	7°55.28N	90°28.85W	3425.0
844B	7°55.28N	90°28.85W	3425.0
844C	7°55.28N	90°28.85W	3425.0
844D	7°55.28N	90°28.85W	3425.0
845A	9°34.95N	94°35.45W	3715.9
845B	9°34.95N	94°35.38W	3715.9
845C	9°34.95N	94°35.38W	3715.9
846A	3°5.70S	90°49.08W	3307.3
846B	3°5.70S	90°49.08W	3307.5
846C	3°5.70S	90°49.09W	3307.5
846D	3°5.80S	90°49.07W	3307.5
847A	0°11.59N	95°19.23W	3346.0
847B	0°11.59N	95°19.23W	3346.0
847C	0°11.58N	95°19.19W	3346.0
847D	0°11.58N	95°19.20W	3346.9
848A	2°59.63S	110°28.79W	3865.1
848B	2°59.63S	110°28.79W	3867.3
848C	2°59.65S	110°28.81W	3867.0
848D	2°59.66S	110°28.81W	3866.1
849A	0°10.98N	110°31.18W	3848.8
849B	0°10.98N	110°31.18W	3850.8
849C	0°10.99N	110°31.18W	3850.8
849D	0°10.99N	110°31.17W	3850.8
850A	1°17.84N	110°31.28W	3797.8
850B	1°17.83N	110°31.29W	3797.8
851A	2°46.22N	110°34.31W	3773.0
851B	2°46.22N	110°34.31W	3772.0
851C	2°46.21N	110°34.29W	3772.0
851D	2°46.21N	110°34.29W	3772.0
851E	2°46.21N	110°34.29W	3772.0
852A	5°17.57N	110°4.58W	3872.7
852B	5°17.57N	110°4.58W	3871.6
852C	5°17.55N	110°4.56W	3871.5
852D	5°17.55N	110°4.54W	3871.5
853A	7°12.66N	109°45.08W	3762.0
853B	7°12.66N	109°45.08W	3727.2
853C	7°12.65N	109°45.08W	3726.5
853D	7°12.65N	109°45.07W	3724.2
853E	7°12.65N	109°45.07W	3725.2
854A	11°13.43N	109°35.65W	3579.6
854B	11°13.43N	109°35.65W	3579.1
854C	11°13.43N	109°35.65W	3579.9

138-844B-2H-CC. The interval from the LO of *N. reinholdii* in Sample 138-844B-2H-CC and the FO of *P. doliolus* in Sample 138-844B-3H-2, 60 cm, was assigned to the *N. reinholdii* Zone (Table 3). The scattered occurrence of *R. praebergonii* at this site did not allow us to place the *N. reinholdii* A/B subzonal boundary.

The interval from Samples 138-844B-3H-4, 60 cm, through -4H-3, 60 cm, contain specimens of *Nitzschia marina* without specimens of *P. doliolus* or *Nitzschia jouseae*. This interval was assigned to the *N. marina* Zone, as used by Baldauf (1984). The LO of *Thalassiosira convexa*, which marks the Subzone A/B boundary, was not recognized in Hole 844B, but has been placed in Sample 138-844C-3H-6, 35 cm. Specimens of *R. praebergonii* occur sporadically throughout this interval in both holes. In Hole 844B, the lowest stratigraphic occurrence of this species is seen in Sample 138-844B-4H-3, 60 cm, which approximates the LO of *N. jouseae*. This stratigraphic placement suggests that this does not reflect the true LO of this species.

The stratigraphic sequence representing the lower portion of the lower Pliocene *N. jouseae* Zone through the upper Miocene *Actinocyclus moronensis* Zone (representing about a 5 m.y. interval) is condensed and occurs in the interval from the lower portion of Core 138-844B-4H through Section 138-844B-8H-2. Biostratigraphic events recognized in this interval include the FO of *T. convexa* in Sample 138-844B-5H-1, 120 cm; FO of *Thalassiosira praeconvexa* in Sample 138-844B-5H-2, 120 cm; FO of *Nitzschia miocenica* in Sample 138-844B-5H-3, 120 cm; LO of *Thalassiosira yabei* and the FO of *Nitzschia cylindrica* in Sample 138-844B-6H-1, 120 cm; FO of

Table 2. Age estimates for primary and secondary diatom biostratigraphic events for the equatorial Pacific Ocean.

Diatom event	Calibration/reference	Age (*1)	Age (*2)
T. *Nitzschia reinholdii*	C1n (Burckle, 1977)	0.65	0.65
T. *Nitzschia fossilis*		0.85	0.92
T. *Rhizosolenia matuyama*	C1n.1n (Burckle, 1978)	0.94	1.01
B. *Rhizosolenia matuyama*		1.10	1.17
T. *Rhizosolenia praebergonii* var. *robusta*	C1n (Burckle & Trainer, 1979)	1.55	1.64
B. *Pseudoeunotia doliolus*	C2n (Burckle, 1977)	1.80	1.90
T. *Rhizosolenia praebergonii*	C2n (Burckle, 1978)	1.85	1.95
T. *Thalassiosira convexa*	C2n (Burckle, 1978)	2.10	2.21
T. *Nitzschia jouseae*	C2An.1n (Burckle, 1978)	2.60	2.73
B. *Rhizosolenia praebergonii*	C2An.2n (Burckle, 1978)	3.00	3.14
B. *Thalassiosira convexa* var. *convexa*	C2An (Burckle & Trainer, 1979)	3.60	3.75
B. *Asteromphalus elegans*	C3n.1n (Burckle, 1978)	3.90	4.06
T. *Nitzschia cylindrica*	C3n.3n (Burckle, 1978)	4.30	4.50
B. *Nitzschia jouseae*	C3n.3n (Burckle, 1978)	4.50	4.73
B. *Thalassiosira oestrupii*		5.10	5.42
T. *Thalassiosira miocenica*	(Burckle, 1978)	5.10	5.42
T. *Nitzschia miocenica*	C3An.1n (Burckle, 1972)	5.55	5.96
T. *Nitzschia miocenica* var. *elongata*	C3An.1n (Burckle, 1978)	5.65	6.05
T. *Thalassiosira praeconvexa*	C3An.2n (Burckle, 1978)	5.80	6.25
B. *Thalassiosira miocenica*	C3An.2n (Burckle, 1978)	6.10	6.54
B. *Thalassiosira convexa*	C3An.2n (Burckle, 1978)	6.10	6.54
B. *Thalassiosira praeconvexa*	C3An.2n (Burckle, 1978)	6.30	6.69
T. *Nitzschia porteri*	C4n.1n (Burckle, 1978)	6.70	7.25
B. *Nitzschia miocenica*		6.75	7.33
T. *Rossiella paleacea*	C4n.1n (Burckle, 1978)	6.80	7.40
T. *Thalassiosira burckliana*	C4n.2n (Burckle, 1978)	7.00	7.61
B. *Nitzschia reinholdii*		7.30	7.94
B. *Nitzschia marina*		7.40	8.07
T. *Thalassiosira yabei*	C4n.1n (Burckle, 1978)	7.55	8.21
B. *Nitzschia cylindrica*		7.55	8.21
T. *Coscinodiscus loeblichii*		7.90	8.53
B. *Nitzschia fossilis*		8.10	8.74
B. *Thalassiosira burckliana*	C4An (Burckle, 1978)	8.20	8.85
B. *Coscinodiscus loeblichii*		8.40	9.06
T. *Azpeitia vetustissimus* var. *javanicus*		8.55	9.22
B. *Azpeitia vetustissimus* var. *javanicus*		8.75	9.46
T. *Denticulopsis simonsenii*		8.80	9.49
T. *Actinocyclus moronensis*	C4An.2n (Burckle, 1978)	8.90	9.58
B. *Actinocyclus ellipticus* var. *lanceolata*		9.90	10.40
T. *Synedra jouseana*		10.40	10.82
B. *Rossiella paleacea* var. *elongata*		10.60	11.00
T. *Crasepedodiscus cosinodiscus*		10.60	11.00
T. *Coscinodiscus gigas* var. *diorama*		10.70	11.09
T. *Actinocyclus ellipticus* var. *spiralis*		10.80	11.17
B. *Hemidiscus cuneiformis*	C5n.2n (Burckle, 1978)	11.10	11.44
B. *Rossiella praepaleacea*		11.45	11.81
T. *Actinocyclus ingens*		11.50	11.81
T. *Cestodiscus pulchellus*		11.60	11.89
B. *Nitzschia porteri*		11.70	11.98
B. *Coscinodiscus temperi* var. *delicata*		11.80	12.06
T. *Crucidenticula nicobarica*		12.20	12.40
T. *Annellus californicus*		12.40	12.57
B. *Coscinodiscus gigas*		12.60	12.74
T. *Coscinodiscus lewisianus*		12.80	12.92
B. *Denticulopsis punctata*		13.00	13.09
T. *Thalassiosira tappanae*		13.25	13.30
B. *Azpeitia nodulifer*		13.30	13.34
B. *Triceratium cinnamomeum*		13.40	13.43
B. *Denticulopsis simonsenii*		13.65	13.64
B. *Actinocyclus ellipticus* var. *spiralis*		14.20	14.16
T. *Cestodiscus peplum*		14.20	14.16
B. *Actinocyclus ellipticus*		14.40	14.36
B. *Coscinodiscus blysmos*		14.60	14.55
B. *Thalassiosira tappanae*		14.60	14.55
T. *Annellus californicus*		15.00	14.92
T. *Azpeitia praenodulifer*		15.40	15.28
B. *Actinocyclus ingens*		15.50	15.37
T. *Nitzschia maleinterpretaria*		15.60	15.47
T. *Coscinodiscus lewisianus* var. *simillis*		15.70	15.56
T. *Crucidenticula kanayae*		16.00	15.83
T. *Thalassiosira fraga*		16.20	16.02
B. *Cestodiscus peplum*		16.40	16.20
T. *Raphidodiscus marylandicus*		16.75	16.53
B. *Crucidenticula kanayae*		16.90	16.68

Note: T = top or last occurrence; B = bottom or first occurrence; *1 = ages using Berggren et al. (1985); *2 = ages using Cande and Kent (1992).

Table 3. Sample constraints of stratigraphically useful events from eastern transect Holes 844B through 847D.

Event	Hole 844B	Hole 844C	Hole 845A	Hole 845B	Hole 846B	Hole 846C	Hole 846D	Hole 847B	Hole 847C	Hole 847D
T. *N. reinholdii*	1-CC/2-CC	<1-CC	3-5, 120/3-6,120	1-CC/2-CC	3-3, 70/3-3, 121	2-CC/3-CC		1-CC/2-6, 70	1-CC/2-CC	1-CC/2-CC
T. *N. fossilis*		1-1, 70/1-2, 40	3-3, 30/3-5, 30		3-4, 70/3-CC	2-CC/3-CC	2-CC/3-CC	2-CC/3-3, 70	2-CC/3-CC	2-CC/3-CC
T. *R. matuyama*			3-5, 30/3-6, 30		4-6, 75/4-CC	3-CC/4-CC	3-CC/4-CC			
B. *R. matuyama*			3-6, 30/3-7, 30		5-4, 75/5-CC	4-CC/5-CC	4-CC/5-CC			
T. *R. praebergoni* v. *robustus*					7-3, 120/7-4, 20	6-CC/7-CC	5-CC/6-CC	6-1, 60/6-4, 60	5-6, 20/5-CC	5-CC/6-CC
B. *P. doliolus*	3-2, 60/3-4, 60	1-CC/2-4, 35	4-CC/5-1, 30	3-CC/4-CC	7-CC/8-1, 125	7-CC/8-CC	7-5, 10/7-5, 80	7-5, 60/7-6, 60	6-CC/7-CC	6-CC/7-CC
T. *T. convexa* s.l.		3-3, 35/3-6, 35	5-5, 120/5-6, 120		8-4, 120/8-5, 120	9-CC/10-CC	8-2, 130/8-3, 10	8-6, 60/8-CC	7-CC/8-CC	7-CC/8-CC
T. *N. jouseae*	4-3, 60/4-CC		6-1, 120/6-2, 120	4-CC/5-CC	11-1, 110/11-2, 121	10-CC/11-CC	11-1, 60/11-1, 120	9-CC/10-2, 60	9-CC/10-CC	9-CC/10-4, 120
B. *R. praebergonii* s.l.	4-3, 60/4-CC	2-CC/3-CC	6-2, 120/6-3, 120	5-CC/6-CC	12-6, 120/12-6, 140	10-CC/12-CC	11-CC/12-CC	10-CC/11-CC	10-2, 148/10-4, 148	10-CC/11-CC
F. *T. convexa* v. *convexa*			7-1, 120/7-2, 120		14-CC/15-1, 148		14-6, 10/14-6, 100	12-5, 70/12-CC	11-CC/12-CC	11-CC/12-CC
B. *A. elegans*								13-2, 60/13-CC		
T. *N. cylindrica*			8-2, 27/8-3, 27		18-CC/19-1, 148	17-CC/18-CC	18X-CC/20X-CC	14-CC/15-CC	15X-6, 75/15X-CC	
B. *N. jouseae*	4-CC/5-1, 120		8-1, 27/8-2, 27	7-CC/8-CC	19-CC/20-1, 148	18-CC/19-CC	19-5, 120/19-6, 30	18X-2, 90/18X-4, 90	17X-CC/18X-3, 120	
B. *T. oestrupii*			8-6, 120/8-CC		22-4, 148/22-5, 80		22-3, 20/22-3, 50			
T. *T. miocenica*			9-3, 120/9-4, 120		22-4, 148/22-5, 80		21X-CC/22X-CC	19X-CC/20X-5, 60	20X-1, 120/20X-2, 120	
T. *N. miocenica*	4-CC/5-1, 120	4-3, 75/4-4, 75	9-5, 120/9-6, 120		23X-7, 40/23X-CC		22X-CC/23X-CC			
T. *N. miocenica* v. *elongata*	4-CC/5-1, 120	4-1, 75/4-3, 75			23X-CC/24X-CC					
T. *T. praeconvexa*	4-CC/5-1, 120				23X-CC/24X-CC		22X-CC/23X-CC	22X-CC/23X-1, 60	21X-3, 100/21X-5, 50	
B. *T. miocenica*			9-CC/10-CC		25X-5, 1/25X-CC		24X-CC/25X-CC			
B. *T. convexa* v. *aspinosa*	5-1, 120/5-2, 120	4-3, 75/4-4, 75	9-CC/10-CC		25X-5, 1/25X-CC		24X-CC/25X-CC			
B. *T. praeconvexa*	5-2, 120/5-3, 120				25X-CC/26X-1, 120		25X-CC/26X-CC			
T. *N. porteri*					27X-2, 120/27X-3, 75					
B. *N. miocenica*	5-3, 120/5-5, 120	4-CC/5-CC	11-1, 29/11-3, 120		27X-6, 50/27X-CC					
T. *R. paleacea*	5-3, 120/5-5, 120	4-CC/5-CC			28X-3, 60/28X-3, 80					
B. *N. reinholdii*	5-5, 120/5-6, 120	4-CC/5-CC								
T. *T. yabei* Group	5-CC/6-1, 120	5-CC/6-CC	12-6, 30/12-CC	11-CC/13-4, 89	30X-1, 100/30X-1, 122					
B. *N. cylindrica*	6-1, 120/6-2, 120				30X-1, 60/30X-1, 122					
T. *C. loeblichii*	6-4, 60/6-CC									
B. *T. burckliana*	6-4, 60/6-CC									
B. *C. loeblichii*	6-CC/7-CC									
T. *D. simonsenii* s.l.	7-5, 60/7-CC	6-CC/7-CC	14-1, 120/14-CC	13-4, 89/16-CC	31X-CC/32X-1, 60					
T. *A. moronensis*	8-1, 60/8-2, 60	6-CC/7-CC								
T. *A. ellipticus* f. *lanceolata*					32X-CC/33X-CC					
T. *S. jouseana*	9-CC/10-CC									
T. *C. coscinodiscus*	9-CC/10-CC	8-CC/9-CC		15-CC/16-CC	34X-6, 90/34X-6, 120					
B. *R. paleacea* v. *elongata*	9-CC/10-CC				34X-6, 90/34X-6, 120					
T. *C. gigas* v. *diorama*			16-CC/17-CC		34X-6, 90/34X-6, 120					
T. *A. ingens*	12-CC/13-CC	12-CC/13-CC	18-CC/19-1, 120	18-CC/19-3, 20	36X-4, 30/36X-5, 103					
T. *C. pulchellus*	12-CC/13-CC		17-CC/18-CC							
B. *N. porteri*					36X-5, 103/36X-CC					
T. *C. temperi* v. *delicata*	12-CC/13-CC				36X-5, 103/36X-5, 120					
T. *A. californicus*	12-CC/13-CC	12-CC/13-CC								
B. *C. gigas* v. *diorama*					38X-2, 90/38X-3, 30					
T. *C. lewisianus*	14-CC/15-CC	14-CC/15-CC	20-3, 120/20-CC	19-CC/20-3, 67	38X-1, 90/38X-3, 120					
T. *T. tappanae*	15-CC/16-CC									
B. *T. cinnamomeum*	15-CC/16-CC	15-CC/16-CC								
B. *D. simonsenii* s.l.	16-CC/17-CC									
T. *C. peplum*	17-CC/18-CC		24X-CC/26X-CC							
B. *A. ellipticus*	18-CC/19-CC									
B. *C. blysmos*	19-CC/20-CC									
T. *A. californicus*	21X-CC/22X-CC									
B. *A. ingens*	23X-CC/24X-CC									
T. *C. lewisianus* v. *simillis*	24X-CC/25X-CC									
T. *T. fraga*	28X-CC/29X-7, 40									
B. *C. peplum*	28X-CC/29X-7, 40		29X-CC/30X-CC							
T. *R. marylandicus*	28X-CC/29X-7, 40									

Note: T = top or last occurrence of a species; B = bottom or first occurrence of a species; CC = core catcher; X = extended core barrel core. All samples were taken from APC-cored material unless noted otherwise.

Table 4. Depth constraints of stratigraphically useful events from eastern transect Holes 844B through 847D.

Event (mbsf)	844B top	844B bottom	844C top	844C bottom	845A top	845A bottom	845B top	845B bottom	846B top	846B bottom	846C top	846C bottom	846D top	846D bottom	847B top	847B bottom	847C top	847C bottom	847D top	847D bottom
T. *N. reinholdii*	4.53	14.48			24.3	25.8	9.73	21.49	18.7	21.7	21.84	31.45			6.59	14.7	11.97	21.34	6.61	16.54
T. *N. fossils*			0.7	1.9	20.4	23.4			21.7	26.17	21.84	31.45	21.61	32.93	16.08	19.7	21.34	31.07	16.54	25.84
T. *R. matuyama*					23.4	24.9			31.25	36.06	31.45	41.09	32.93	42.69						
B. *R. matuyama*					24.9	26.4			40.75	45.54	41.09	50.69	42.69	52.1						
T. *R. praebergonii* v. *robustus*									58.7	59.2	58.64	69.71	52.1	61.38	45.1	51.1	47.7	50.09	44.88	53.74
B. *P. doliolus*	14.75	19.3	9.1	13.95	36.49	36.4	27.95	41.19	64.26	65.25	69.71	78.36	64.9	65.6	60.6	62.1	59.19	69.09	53.74	63.64
T. *T. convexa* s.l.			21.95	26.45	43.3	44.8			69.7	71.2	87.63	97.95	71.1	71.4	71.6	72.83	69.09	77.35	63.64	73.2
T. *N. jouseae*	26.1	33.48			46.8	47.3	41.49	48.4	93.6	95.21	97.95	106.23	97.4	98	83.1	84.6	88.08	97.6	83.25	89.8
B. *R. praebergonii* s.l.	26.1	33.48	18.62	28.66	47.3	49.8	48.4	59.97	110.7	110.9	97.95	116.52	106.26	115.91	92.68	101.56	90.4	93.4	92.28	102.19
F. *T. conexa* v. *convexa*					56.3	57.8			130.78	131.98			131.9	132.8	108.2	111.58	107.1	116.44	102.19	111.51
B. *A. elegans*															113.1	121.05				
T. *N. cylindrica*					66.37	67.87			169.17	169.98	164.22	173.34	167.95	191.59	130.35	139.81	143.35	144.73		
B. *N. jouseae*	33.48	34.2			64.87	66.37	69.85	79.57	178.65	179.48	173.34	183.34	180	180.6	157.9	160.9	164.13	167.9		
B. *T. oestrupii*					73.3	74.55			202.98	203.8			204.3	204.7						
T. *T. miocenica*					78.3	79.8			202.98	203.8			201.21	210.74	174.52	180.5	183.7	185.2		
T. *N. miocenia*	33.48	34.2	31.85	33.35	81.3	82.8			215.9	216.26			210.74	220.16						
T. *N. miocenica* v. *elongata*	33.48	34.2	28.85	31.85					216.26	225.9										
T. *T. praeconvexa*	33.48	34.2							216.26	225.9			210.74	220.16	202.97	203.4	196.2	198.7		
B. *T. miocenica*					84.07	93.61			231.71	232.12			230.06	239.86						
B. *T. convexa* v. *aspinosa*	34.2	35.7	31.85	33.35	84.07	93.61			231.71	232.12			230.06	239.86						
B. *T. praeconvexa*	35.7	37.9							232.12	236.8			239.86	249.45						
T. *N. porteri*									247.9	248.95										
B. *N. miocenica*	37.9	40.2	38.18	47.56	83.89	97.3			253.2	253.56										
T. *R. paleacea*	37.9	40.2	38.18	47.56					258.5	258.7										
B. *N. reinholdii*	40.2	41.7	38.18	47.56																
T. *T. yabei* Group	42.9	43.7			110.4	112.36	108.02	122.49	274.9	275.12										
B. *N. cylindrica*	43.7	45.2							274.5	275.12										
T. *C. loeblichii*	49.7	52.52																		
B. *T. burckliana*	49.7	52.52																		
B. *C. loeblichii*	52.52	62.06																		
T. *D. simonsenii* s.l.	59	62.06	57.2	66.73	122.8	131.67	122.49	155.55	293.1	293.7										
T. *A. moronensis*	62.7	64.2	57.2	66.73																
B. *A. ellipticus* f. *lanceolata*									302.38	312.68										
T. *S. jouseana*	81.1	90.27																		
T. *C. coscinodiscus*	81.1	90.27	76.3	85.78			144.56	155.55	320.8	321.1										
B. *R. paleacea* v. *elongata*	81.1	90.27							320.8	321.1										
T. *C. gigas* v. *diorama*					150.62	159.95			320.8	321.1										
T. *A. ingens*	109.59	118.95	114.15	123.62	169.69	170.3	174.53	177.3	336.5	338.78										
T. *C. pulchellus*	109.59	118.95			159.95	169.69														
B. *N. porteri*									338.78	341.53										
T. *C. temperi* v. *delicata*	109.59	118.95							338.78	338.95										
T. *A. californicus*	109.59	118.95	114.15	123.62																
B. *C. gigas* v. *diorama*									353.4	354.3										
T. *C. lewisianus*	128.26	137.82	132.71	142.8	182.8	188.73	183.73	187.27	351.9	355.2										
T. *T. tappanae*	137.82	147.43																		
B. *T. cinnamomeum*	137.82	147.43	142.8	152.16																
B. *D. simonsenii* s.l.	147.43	157.07																		
T. *C. peplum*	157.07	166.43			218.25	245.52														
B. *A. ellipticus*	166.43	175.83																		
B. *C. blysmos*	175.83	185.58																		
T. *A. californicus*	194.69	204.27																		
B. *A. ingens*	213.9	223.65																		
T. *C. lewisanus* v. *simillis*	223.65	232.04																		
T. *T. fraga*	261.66	270.7																		
B. *C. peplum*	261.66	270.7			274.35	283.87														
T. *R. marylandicus*	261.66	270.7																		

Note: T = top or last occurrence of a species, B = bottom or first occurrence of a species.

Table 5. Depth constraints of stratigraphically useful events from eastern transect Holes 844B through 847D.

Event (mcd)	844B top	844B bottom	844C top	844C bottom	845A top	845A bottom	845B top	845B bottom	846B top	846B bottom	846C top	846C bottom	846D top	846D bottom	847B top	847B bottom	847C top	847C bottom	847D top	847D bottom
T. *N. reinholdii*	4.53	15.61			25.16	26.66	12.09	25.02	20.75	23.75	21.37	34.45			6.59	14.83	12.37	23.02	6.61	18.34
T. *N. fossilis*			1.2	2.4	21.26	24.26			23.75	28.22	21.37	34.45	23.51	34.63	16.21	20.05	23.02	33.47	18.34	28.84
T. *R. matuyama*					24.26	25.76			34.4	39.21	34.45	44.29	34.63	46.29						
B. *R. matuyama*					25.76	27.26			45.95	50.74	44.29	54.74	46.29	57.7						
T. *R. praebergonii* v. *robustus*									67	67.5	65.59	76.61	57.7	66.78	50.18	56.18	52.2	54.59	49.08	59.94
B. *P. doliolus*	17	21.55	9.6	15.25	38.62	39.91	32.25	45.07	72.56	74.95	76.61	85.96	73.3	74	67.35	68.85	64.89	76.89	59.94	70.84
T. *T. convexa* s.l.			24.3	28.8	46.81	48.31			79.4	80.9	98.88	111.6	80.5	80.8	79.78	81.01	76.89	85.55	70.84	81.5
T. *N. jouseae*	17.55	24.93			50.88	51.3	45.07	53.8	107.1	108.71	111.6	120.84	109.8	110.4	92.58	94.83	97.98	108.3	91.95	101.5
B. *R. praebergonii* s.l.	17.55	24.93	19.92	31.01	51.3	53.18	53.8	66.7	125.5	125.7	111.6	132.07	118.66	129.41	102.91	114.46	101.1	104.1	103.98	114.89
F. *T. convexa* v. *convexa*					61.16	62.66			147.93	151.68			148.7	149.6	121.23	124.61	119	128.74	114.89	125.11
B. *A. elegans*															127.1	124.61				
T. *N. cylindrica*					72.67	74.17			191.02	193.78	185.72	196.54	190.05	216.89	145.83	155.76	159.25	160.63		
B. *N. jouseae*	24.93	37.85			71.17	72.67	76.46	87.95	202.45	205.08	196.54	207.04	202.9	203.5	172.25	180.25	184.13	188.6		
B. *T. oestrupii*					79.6	80.85			233.43	234.25			234.65	235.05						
T. *T. miocenica*					86.31	87.81			233.43	234.25			231.76	241.09	193.87	199.85	203.4	204.9		
T. *N. miocenica*	24.93	37.85	36	37.5	89.31	90.81			249.9	250.26			241.09	254.01						
T. *N. miocenica* v. *elongata*	24.93	37.85	33	36					250.26	261.18										
T. *T. praeconvexa*,	24.93	37.85						250.26	261.18			241.09	254.01	222.32	222.75	215.6	218.1			
B. *T. miocenica*					92.08	102.09			266.81	267.22			263.41	273.66						
B. *T. convexa* v. *aspinosa*	37.85	39.35	36	37.5	92.08	102.09			266.81	267.22			263.41	273.66						
B. *T. praeconvexa*	39.35	41.55							267.22	271.9			273.66	283.25						
T. *N. porteri*									283	284.05										
B. *N. miocenica*	41.55	43.85	42.33	52.81	92.37	107.06			288.3	288.66										
T. *R. paleacea*	41.55	43.85	42.33	52.81					293.6	293.8										
B. *N. reinholdii*	43.85	45.35	42.33	52.81																
T. *T. yabei* Group	46.55	47.8	52.81	63.85	121.73	123.69	120.13	137.25	310	310.22										
B. *N. cylindrica*	47.8	49.3							309.6	310.22										
T. *C. loeblichii*	53.8	56.62																		
B. *T. burckliana*	53.8	56.62																		
B. *C. loeblichii*	56.62	68.76																		
T. *D. simonsenii* s.l.	65.7	68.76	63.85	74.38	136.7	145.65	137.25	175.25	328.2	328.8										
T. *A. moronensis*	69.85	71.35	63.85	74.38																
B. *A. ellipticus* f. *lanceolata*									302.38	347.78										
T. *S. jouseana*	89.75	100.9																		
T. *Cr. coscinodiscus*	89.75	100.9	85.61	95.96			162.86	175.25	355.9	356.2										
B. *R. paleacea* v. *elongata*	89.75	100.9							355.9	356.2										
T. *C. gigas* v. *diorama*					168.35	178.88			355.9	356.2										
T. *A. ingens*	123.12	132.75	126.15	136.62	188.97	190.96	194.83	197.8	371.6	373.88										
T. *C. pulchellus*	123.12	132.75			178.76	188.97														
B. *N. porteri*									373.88	376.63										
T. *C.temperi* v. *delicata*.	123.12	132.75						373.88	374.05											
T. *A. californicus*	123.12	132.75	126.15	136.62																
B. *C. gigas* v. *diorama*									388.5	389.4										
T. *C. lewisianus*	143.09	152.82	147.71	157.7	205.13	211.06	204.23	209.07	387	390.3										
T. *T. tappanae*	152.82	163.61																		
B. *T. cinnamomeum*	152.82	163.61	157.7	167.66																
B. *D. simonsenii* s.l.	163.61	172.67																		
T. *C. peplum*	172.67	183.48			243.48	270.75														
B. *A. ellipticus*	183.48	193.03																		
B. *C. blysmos*	193.03	204.21																		
T. *A. californicus*	213.32	222.9																		
B. *A. ingens*	232.53	242.28																		
T. *C. lewisanus* v. *simillis*	242.28	250.67																		
T. *T. fraga*	280.29	289.33																		
B. *C. peplum*	280.29	289.33			299.58	309.1														
T. *R. marylandicus*	280.29	289.33																		

Notes: T = top or last occurrence of a species, and B = bottom or first occurrence of a species. Depth constraints are in meters composite depth, as determined by the Shipboard Scientific Party (see Mayer, Pisias, Janecek, et al., 1992).

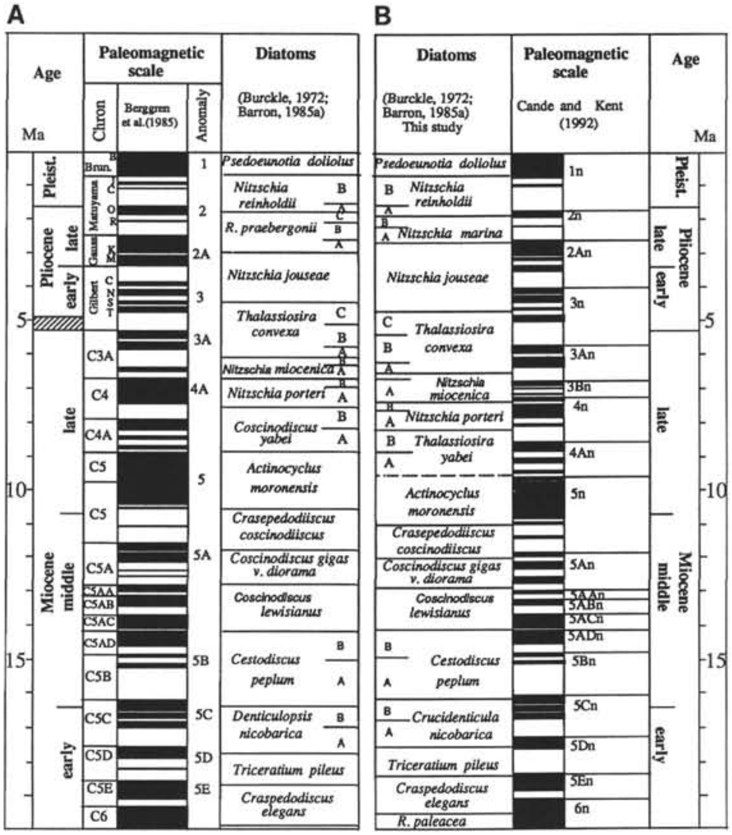

Figure 2. Comparison of the diatom zonation used here with the diatom zonation used aboard the ship (see Mayer, Pisias, Janecek, et al., 1992). **A.** Shipboard zonation has been calibrated to the chronology of Berggren et al. (1985). **B.** Zonation used here has been calibrated to the chronology of Cande and Kent (1992). See text for discussion of zones.

Thalassiosira burckliana in Sample 138-844B-6H-4, 120 cm; and the LO of *Denticulopsis simonsenii* in Sample 138-844B-7H-CC. Samples 138-844B-8H-2, 60 cm, through -9H-CC were assigned to the *A. moronensis* Zone, based on the occurrence of *A. moronensis* stratigraphically above the LO of *Craspedodiscus coscinodiscus* in Sample 138-844B-10H-CC. Sample 138-844B-13H-CC was assigned to the base of the *C. coscinodiscus* Zone on the basis of the occurrence of *Thalassiosira brunii* in this sample.

The diatom assemblage in the lowermost portion of Hole 844B is well preserved and abundant throughout the sequence, with most primary and secondary biostratigraphic indicators present. Samples from Core 138-844B-14H were assigned to the *Coscinodiscus gigas* var. *diorama* Zone. Samples 138-844B-15H-CC through -17H-CC represent the interval from the LO of *Coscinodiscus lewisianus* to the LO of *Cestodiscus peplum* and were assigned to the *C. lewisianus* Zone. Specimens of *C. peplum* occurred in samples examined from Cores 138-844B-19H through -28X, which allowed us to assign samples from these cores to the *C. peplum* Zone. The lowermost portion of Hole 844B has been placed in Subzone B of the *Crucidenticula nicobarica* Zone, based on the occurrence of *Raphidodiscus marylandicus*, *Coscinodiscus blysmos,* and *Crucidenticula kanayae* stratigraphically below the FO of *C. peplum* and stratigraphically above the LO of *Thalassiosira bukryi*.

Site 845

Diatoms are present throughout the Pleistocene (*P. doliolus* Zone) through the uppermost middle Miocene (Subzone B of the *C. nicobarica* Zone). Diatom preservation is generally good in the Pleistocene through upper Miocene portion of the sequence, but deteriorates as one proceeds lower in the sequence. Because of this, the stratigraphic indicator species were not always observed in samples examined from the lower sequence at Site 845.

The shipboard biostratigraphy (Mayer, Pisias, Janecek, et al., 1992) has been substantially revised for Hole 845A, as discussed below. No revisions were made to the biostratigraphy for Hole 845B. Samples 138-845A-1H-CC through -3H-5, 120 cm, and Sample 138-845B-1H-CC have been assigned to the *P. doliolus* Zone, based on the occurrence of *P. doliolus* stratigraphically above the LO of *N. reinholdii*.

Samples 138-845A-3H-6, 120 cm, through -4H-CC contain both *N. reinholdii* and *P. doliolus* and were assigned to the *N. reinholdii* Zone. This zone could not be subdivided as *R. praebergonii* did not occur consistently in the upper portion of its range at this site. Samples 138-845A-5H-1, 30 cm, through -6H-2, 120 cm, represent the interval between the FO of *P. doliolus* and the LO of *N. jouseae*. This interval was assigned to the *N. marina* Zone, as used by Baldauf (1984). The LO of *T. convexa* was assigned to Sample 138-845A-5H-6, 120 cm, and marks the A/B subzonal boundary.

The stratigraphic interval from Samples 138-845A-6H-2, 120 cm, to -8H-1, 27 cm, represents the total range of *N. jouseae*. This interval was assigned to the *N. jouseae* Zone, as used by Baldauf (1984). Secondary biostratigraphic markers in this interval include the FO of *Thalassiosira convexa* var. *convexa* in Sample 138-845A-7H-1, 120 cm, and the LO of *N. cylindrica* in Sample 138-845A-8H-3, 27 cm.

Sample 138-845A-9H-CC contains the first observed specimens of *Thalassiosira convexa* var. *aspinosa,* which defines the base of the *T. convexa* Zone. The interval between Sample 138-845A-8H-2, 27 cm, to -9H-4, 120 cm, were assigned to Subzone C of this zone, based on the LO of *Thalassiosira miocenica* in Sample 138-845A-9H-4, 120 cm. The Subzonal A/B boundary could not be placed, as *T.*

Table 6. Sample constraints of stratigraphically useful events from western transect Holes 848B through 852D.

Event	848B	848C	848D	849B	849C	849D
T. *N. reinholdii*	1-CC/2-CC	0/1-CC	1-CC/2-CC			1-CC/2-CC
T. *N. fossilis*	1-CC/2-CC	1-CC/2-CC	1-CC/2-CC	3-5, 75/4-1, 70		2-CC/3-CC
T. *R. matuyama*				3-5, 75/4-1, 70		
B. *R. matuyama*				4-1, 70/4-3, 80		
T. *R. praebergoni* v. *robustus*	3-6, 120/3-CC	2-CC/3-CC	2H-CC/3H-CC	5-4, 70/5-5, 70	4-CC/5-1, 70	4-CC/5-CC
B. *P. doliolus*	4-1, 120/4-2, 121	3-CC/4-1, 40	4H-2, 100/4H-CC	6-3, 15/6-5, 70	5-6, 70/6-CC	5-CC/6-CC
T. *T. convexa* s.l.	4-3, 120/4-4, 121	4-1, 40/4-2, 40	2H-CC/3H-CC	7-3, 60/7-CC	6-CC/7-1, 70	6-CC/7-CC
T. *N. jouseae*	4-4, 121/4-5, 121	4-2, 40/ 4-4, 40		8-2, 60/8-4, 60	7-6, 70/7-CC	6-CC/7-CC
B. *R. praebergonii* s.l.	4-6, 120/4-7, 10	4-4, 40/4-CC	4H-7, 40/4H-CC	9-2, 60/9-4, 60	8-5, 70/8-CC	7-CC/8-CC
F. *T. convexa* v. *convexa*	5-1, 120/5-2, 121			11-1, 70/11-2, 70	9-CC/10-CC	9-CC/10-CC
B. *A. elegans*	4-CC/5-4, 121					
T. *N. cylindrica*	5-4, 121/5-CC		4H-CC/5H-CC	15X-1, 70/15X-3, 70		
B. *N. jouseae*	6-2, 120/6-4, 121		4H-CC/5H-CC	16X-1, 70/16X-3, 70		16X-1, 70/16X-2, 70
B. *T. oestrupii*						
T. *T. miocenica*				20X-2, 70/20X-6, 70		
T. *N. miocenica*	7-2, 120/7-CC	6-CC/7-CC	6H-CC/7H-CC	21X-6, 24/21X-CC		20X-CC/21X-CC
T. *N. miocenica* v. *elongata*	7-5, 120/8-2, 121		6H-CC/7H-CC	21X-6, 24/21X-CC		20X-CC/21X-CC
T. *T. praeconvexa*	7-5, 120/8-2, 121			21X-6, 24/21X-CC		20X-CC/21X-CC
T. *R. praepaleacea*	8-2, 121/8-3, 121					
B. *T. miocenica*	8-3, 121/8-4, 70			24X-3, 60/24X-6, 60		23X-CC/24X-CC
B. *T. convexa* v. *aspinosa*	8-3, 121/8-4, 70			24X-3, 60/24X-6, 60		23X-CC/24X-CC
B. *B. praeconvexa*	8-4, 120/8-5, 121			26X-CC/27X-2, 70		
T. *N. porteri*						
B. *N. miocenica*	9-2, 36/9-2, 96		7H-CC/8H-CC	28X-4, 60/28X-5, 70		27X-CC/28X-CC
T. *R. paleacea*	9-2, 36/9-2, 96	7-CC/8-CC	7H-CC/8H-CC			
T. *T. burckliana*				31X-1, 70/31X-2, 70		
B. *N. reinholdii*				29X-2, 70/29X-5, 70		
T. *A. ellipticus* var *javanica*				29X-1, 70/29X-3, 70		28X-CC/29X-CC
T. *T. yabei* Group				31X-1, 70/31X-2, 70		29X-CC/30X-3, 60
B. *N. cylindrica*				30X-4, 55/30X-5, 70		29X-CC/30X-3, 60
T. *C. loeblichii*						
B. *T. burckliana*				31X-1, 70/31X-2, 70		
B. *C. loeblichii*						
T. *D. simonsenii*				32X-5, 70/33X-1, 70		31X-CC/32X-CC
T. *A. moronensis*						
T. *A. ellipticus*						
T. *S. jouseana*						
T. *C. coscinodiscus*						
B. *R. paleacea* v. *elongata*						
T. *C. gigas* v. *diorama*						

Notes: T = top or last occurrence of a species, B = bottom or first occurrence of a species, CC = core catcher, and X = extended core barrel. All samples were taken from APC-cored material unless noted otherwise.

praeconvexa, the subzonal indicator, did not occur consistently at this site. The interval from Samples 138-845A-10H-CC through -11H-1, 29 cm, was assigned to the *Nitzschia porteri* Zone. The inconsistent occurrence of *T. praeconvexa* similarly did not allow us to place the A/B subzonal boundary of this zone.

The LO of *T. yabei* occurs in Sample 138-845A-12H-CC and marks the base of the *N. porteri* Zone and the top of the *T. yabei* Zone. The base of the *T. yabei* Zone typically is defined by the LO of *A. moronensis* (Barron, 1985a). As previously discussed, this species has a scattered occurrence in the upper portion of its stratigraphic range and is not always a useful zonal indicator for the Leg 138 sediments. We used the LO of *D. simonsenii* as a secondary indicator for the base of the *T. yabei* Zone. This usage is supported by Barron (1985a), who on the basis of DSDP Leg 85 results, indicated that the LO of *D. simonsenii* approximates the LO of *A. moronensis*. Sample 138-845A-14H-1, 120 cm, was assigned to the base of the *T. yabei* Zone using this secondary marker.

Preservation and abundance of diatoms deteriorates in the lower portion of Hole 845A. Because of this, placement of stratigraphic indicators was less reliable. The LO of *C. coscinodiscus* could not be determined in Hole 845A, but has been placed in Sample 138-845B-16H-CC. Likewise, the FO of *Thalassiosira brunii* could not be placed in either hole. The LO of *C. lewisianus*, which marks the top of the *C. lewisianus* Zone, occurs in the interval between Samples 138-845A-20H-3, 120 cm, and -20H-CC and between Samples 138-845A-19H-CC and -20H-3, 120 cm.

Cestodiscus peplum occurs in Samples 138-845A-26X-CC through -29X-CC, which allowed us to assign these samples to the *C. peplum* Zone. The A/B subzonal boundary could not be placed. The occurrence of *C. nicobarica* and *Crucidenticula kanayae* without *C. peplum* in Samples 138-845A-30X-CC and -31X-2, 1 cm, suggests that these samples are equivalent to the *C. nicobarica* Zone. Diatoms were not observed below Sample 138-845A-31X-2, 11 cm.

Site 846

The recovered Pleistocene (*N. reinholdii* Zone) through middle Miocene (*C. lewisianus* Zone) sequence generally contains common and well-preserved diatoms. Revisions to the shipboard diatom biostratigraphy (Mayer, Pisias, Janecek, et al., 1992) were extensive for the upper 30 cores from Hole 846B and for the 26 cores from Hole 846D. Only minimal changes were made to the shipboard stratigraphy for the lower portion of Hole 846B and Holes 846A and 846C.

One core was recovered from Hole 846A. The occurrence of *P. doliolus* without *N. reinholdii* allowed us to assign samples from this core to be assigned to the *P. doliolus* Zone. Samples 138-846B-1H-CC through -3H-3, 70 cm, and Samples 138-846D-1H-CC through -2H-CC also were assigned to this zone. Samples 138-846B-3H-4, 70 cm, through -7H-CC and Samples 138-846D-3H-CC through -7H-5, 10 cm, were assigned to the *N. reinholdii* Zone. This zonal assignment is based on the co-occurrence of *P. doliolus* and *N. reinholdii* in these samples.

The interval from Samples 138-846B-7H-CC through -11H-2, 121 cm, represents the interval between the FO of *P. doliolus* and the LO of *N. jouseae* and was assigned to the *N. marina* Zone. The LO of *T. convexa* in Sample 138-846B-8H-5, 120 cm, marks the A/B subzonal boundary. The consistent occurrence of *R. praebergonii* at Site 846 also allowed for recognition of the *R. praebergonii* Zone,

Table 6 (continued).

850A	850B	851B	851C	851E	852B	852C	852D
1-CC/2-CC	1-2, 80/1-CC	1-CC/2-2, 25		1-CC/2-1, 80			
1-CC/2-CC	1-CC/2-CC	2-4, 25/2-6, 25	1-CC/2-CC	2-1, 80/2-3, 80	1-2, 25/2-2, 25	1-CC/2-CC	1-CC/2-CC
4-3, 60/4-4, 60	41, 60/4-2, 70	3-CC/4-1, 25	2-CC/3-CC	2-CC/3-CC	2-CC/3-2, 25	2-CC/3-CC	2-CC/3-CC
5-2, 60/5-5, 60	4-4, 70/4-6, 100	4-CC/5-1, 75	3-CC/4-CC	3-CC/4-CC	3-5, 25/3-6, 25	2-CC/3-CC	2-CC/3-CC
5-6, 65/5-7, 35	5-6, 65/5-7, 35	5-1, 75/5-3, 75	4-CC/5-CC	4-CC/5-2, 90		3-CC/4-CC	2-CC/3-CC
5-CC/6-CC	6-1, 80/6-3, 80	5-CC/6-3, 1	4-CC/5-CC	5-4, 90/5-6, 90	3-CC/4-2, 25	3-CC/4-2, 25	3-CC/4-CC
6-CC/7-CC	6-CC/7-CC	6-3, 1/6-5, 1	5-CC/6-CC	6-2, 90/6-6, 90	4-4, 25/4-6, 25	4-CC/5-4, 1	
7-4, 61/7-CC	7-4, 61/7-CC	7-5, 1/7-6, 1	6-CC/7-CC	7-4, 100/7-5, 78	5-2, 5/5-4, 25	5-4, 1/5-CC	
7-CC/8-CC	8-2, 80/8-CC	7-CC/8-CC			4-2, 25/4-4, 25		
	10-CC/11X-CC	9-CC/10-CC	8-CC/9-CC	9-2, 90/9-4, 63	6-4, 120/6-5, 120	5-CC/6-CC	5-CC/6-CC
	11X-CC/12X-CC	9-CC/10-CC	8-CC/9-CC	9-4, 63/9-5, 141	6-4, 120/6-5, 120	5-CC/6-CC	5-CC/6-CC
					7-4, 25/8-2, 25		
	18X-2, 52/18X-3, 51	13-CC/14-2, 70	12-CC/13-CC	13-CC/14-CC	8-2, 25/8-6, 25	7-CC/8-CC	
		14-5, 70/14-6, 70	13-CC/14-CC		8-2, 25/8-6, 25		
	19X-2, 80/19X-3, 80	15-2, 90/15-6, 20	8-2, 25/8-6, 25				
					8-6, 25/9-2, 25		
	21X-CC/22X-3, 80	15-CC/16X-4, 80		15X-4, 50/15X-CC	9-2, 25/9-3, 75		
	21X-CC/22X-3, 80	15-CC/16X-4, 80		15X-4, 50/15X-CC	8-6, 25/9-2, 25		
	22X-CC/23X-2, 60	16X-CC/17X-CC		15X-CC/16X-CC	8-6, 25/9-2, 25		
					9-CC/10-2, 25		
	26X-1, 80/26X-2, 58	18X-CC/19X-2, 80		17X-CC/18X-CC	9-2, 25/9-3, 75		
	26X-2, 60/26X-3, 58	19X-2, 80/19X-3, 80			9-6, 25, 10-2, 25		8-CC/9-CC
	26X-CC/27X-CC				10-6, 25/11-4, 25		8-CC/9-CC
					10-2, 25/10-6, 25		
	27X-6, 62/27X-7, 20	20X-CC/21X-CC			9-4, 25/10-2, 25	9-CC/10-CC	9-CC/10-CC
	28X-1, 5/28X-3, 23	21X-CC/22X-CC		21X-CC/22X-CC	10-6, 25/11-4, 25	9-CC/10-CC	9-CC/10-CC
	28X-3, 23/28X-CC	21X-CC/22X-CC		21X-CC/22X-CC	10-2, 25/10-6, 25		
	30X-CC/31X-CC				11-4, 25/11-6, 25		
	32X-4, 80/32X-5, 86	24X-CC/25X-1, 80		24X-CC/25X-CC			
	32X-CC/33X-1, 70	25X-2, 80/25X-7, 25					
	40X-2, 55/40X-4, 48						
		31-CC/32-CC					

as used by Barron (1985a, 1985b). Samples 138-846B-8H-1, 125 cm, through -12H-6, 120 cm, and Samples 138-846D-7H-5, 80 cm, through -11H-CC were assigned to the *R. praebergonii* Zone. Samples 138-846B-8H-1, 125 cm, and -8H-4, 20 cm, were assigned to Subzone C, based on the occurrence of *R. praebergonii* stratigraphically below the FO of *P. doliolus* (Sample 138-846B-7H-CC) and stratigraphically above the LO of *T. convexa* (Sample 138-846B-8H-5, 120 cm). Samples 138-846B-8H-5, 120 cm, through -11H-1, 120 cm, were assigned to Subzone B of this zone on the basis of the co-occurrence of *T. convexa* and *R. praebergonii* without *N. jouseae*. Samples 138-846B-11H-2, 120 cm, through -12H-6, 120 cm, wear assigned to Subzone A of this zone, based on the co-occurrence of *N. jouseae, T. convexa* and *R. praebergonii*.

The interval from Samples 138-846B-11H-2, 121 cm, through -19H-CC and Samples 138-846D-11H-1, 120 cm, through -19X-5, 120 cm, represent the total range of *N. jouseae* at this site and have been assigned to the *N. jouseae* Zone, as used by Baldauf (1984). Samples 138-846B-20H-1, 120 cm, through -25X-5, 70 cm, and Samples 138-846D-19H-6, 30 cm, through -24X-CC were placed in the *T. convexa* Zone. Samples 138-845B-20H-1, 120 cm, through -22X-4, 120 cm, were assigned to Subzone C, which consists of the interval between the FO of *N. jouseae* and the LO of *T. miocenica*, and Samples 138-846B-22H-5, 120 cm, through -23X-CC were assigned to Subzone B. The occurrence of *T. praeconvexa, N. miocenica, T. miocenica, T. convexa,* and *N. miocenica* var. *elongata* allowed us to assign Samples 138-846B-24X-CC through -25X-5, 70 cm, to Subzone A of the *T. convexa* Zone. Samples 138-846B-25X-CC through -27X-6, 50 cm, and Samples 138-846D-25X-CC and -26X-CC were assigned to the *N. miocenica* Zone, based on the occurrence of *N. miocenica* without *T. convexa*.

The interval from Samples 138-846B-27X-CC through -30X-1, 30 cm, has been assigned to the *N. porteri* Zone. The LO of *T. yabei* group in Sample 138-846B-30X-1, 22 cm, marks the top of the *T. yabei* Zone. Here, the *T. yabei* group consists of the plicate forms of *Thalassiosira* (i.e., *T. yabei, T. plicatus*). The base of the *T. yabei* Zone only tentatively has been placed, as the marker species, *A. moronensis*, is scattered in the upper part of its range at this site. Sample 138-846B-32X-2, 60 cm, approximates the base of this zone. Placement of the zonal boundary at a depth equivalent to this sample is supported by the abundant occurrence of the secondary indicator *D. simonsenii* in this sample.

Assignment of samples to the *C. coscinodiscus, C. gigas* var. *diorama*, and *C. lewisianus* zones was similar to that of the shipboard biostratigraphy. Samples 138-846B-34X-CC through -36X-5, 103 cm, were placed in the *C. coscinodiscus* Zone. Samples 138-846B-36-CC through -38X-1, 90 cm, were assigned to the *C. gigas* var. *diorama* Zone, and Samples 138-846B-38X-5, 41 cm, and the lower portion of Core 138-846B-38X are equivalent to the *C. lewisianus* Zone. Diatoms were not observed in samples examined below Core 138-846B-38X.

Site 847

The Pleistocene (*N. reinholdii* Zone) through uppermost Miocene (*T. convexa* Zone) sequence generally contains few-to-common, well-preserved diatoms. Minimal changes to the shipboard biostratigraphy

Table 7. Depth constraints of stratigraphically useful events from western transect Holes 848B through 852D.

Event (mbsf)	848B top	848B bottom	848C top	848C bottom	848D top	848D bottom	849B top	849B bottom	849C top	849C bottom	849D top	849D bottom	850A top	850A bottom
T. *N. reinholdii*	2.23	12.27	0	5.47	8.64	20.23					8.36	22.97	7.68	16.74
T. *N. fossilis*	2.23	12.3	5.47	17.7	8.64	20.23	22.95	26.4			22.97	32.79	7.68	16.74
T. *R. matuyama*							22.95	26.4						
B. *R. matuyama*							26.4	29.5						
T. *R. praebergonii*	20.5	21.73	17.7	28.06	20.23	30.51	40.4	41.9	37.83	39.7	41.48	51.9	30.3	31.8
B. *P. doliolus*	22.53	24.03	28.06	28.46	32.5	39.76	47.81	51.7	47.3	49.03	51.9	60.92	38.3	42.8
T. *T. convexa*	25.53	27.03	28.46	30.16			57.8	64.26	49.03	58.7	60.92	70.93	44.35	45.55
T. *N. jouseae*	27.03	28.83	30.16	33.65			65.8	68.8	65.7	68.03	60.92	70.93	46.21	55.81
B. *R. praebergonii*	30.03	30.42	33.65	38.82	39.4	39.76	75.3	78.3	74.3	77.44	70.93	79.2	55.81	65.22
F. *T. convexa* v. *convexa*	31.9	33.4					92.49	94.1	86.58	96.62	89.76	99.05	65.11	70.11
B. *A. elegans*	31.17	36.42											65.22	74.76
T. *N. cylindrica*	36.42	40.53			39.76	50.75	131	134						
B. *N. jouseae*	43.1	46.1			39.76	50.75	140.7	143.7			145.3	146.7		
B. *T. oestrupii*														
T. *T. miocenica*							179.9	185.9						
T. *N. miocenica*	52.4	59.77	59.88	70.81	61.4	71.87	195.04	196.61			191.7	201.14		
T. *N. miocenica* v. *elongata*	56.9	61.9			61.4	71.87	195.04	196.61			191.7	201.14		
T. *T. praeconvexa*	56.9	61.9	70.81				195.04	196.61			191.7	201.14		
T. *R. praepaleacea*	61.9	63.4												
B. *T. miocenica*	63.4	64.4					219.0	224.4			220.86	230.56		
B. *T. convexa*	63.4	64.4					219.9	224.4			220.86	230.56		
B. *T. praeconvexa*	65	66.5					242	247.5						
T. *N. porteri*														
B. *N. miocenica*	70.56	71.15			71.87	82.92	260.1	262.3			259.27	268.44		
T. *R. paleacea*	70.58	71.15	70.81	81.41	71.87	82.92								
T. *T. burckliana*							284.6	286.1						
B. *N. reinholdii*							270.8	275.3						
T. *A. ellipticus* v. *javanicus*							269.3	272.3			268.44	278.44		
T. *T. yabei*							284.6	286.1			278.44	288.07		
B. *N. cylindrica*							308.25	309.0			278.44	288.07		
T. *C. loeblichii*														
B. *T. burckliana*							284.6	286.1						
B. *C. loeblichii*														
T. *D. hustedtii*							295.8	308.25			297.7	307.49		
T. *A. moronensis*														
T. *A. ellipticus*														
T. *S. jouseana*														
T. *C. coscinodiscus*														
B. *R. paleacea* v. *elongata*														
T. *C. gigas* v. *diorama*														

Notes: T = top or last occurrence of a species, B = bottom or first occurrence of a species, and CC = core catcher sample. All samples are taken from APC-cored material unless noted otherwise.

(Mayer, Pisias, Janecek, et al., 1992) were completed. Samples examined from Core 1H of each hole contains *P. doliolus* without *N. reinholdii*. Because of this, these cores were placed in the *P. doliolus* Zone. Samples 138-847B-2H-6, 70 cm, through -7H-5, 60 cm, 138-847C-3H through -6H-CC and -847D-3H-CC through -6H-CC were assigned to the *N. reinholdii* Zone. This zonal assignment was based on the co-occurrence of *P. doliolus* and *N. reinholdii*. The consistent occurrence of *R. praebergonii* in samples from this site allowed us to recognize the LO of *R. praebergonii* and the A/B subzonal boundary in Samples 138-847B-6H-4, 60 cm; -847C-5H-CC; and -847D-6H-CC, as used by Barron (1985a, 1985b).

Samples 138-847B-7H-5, 60 cm, through -10H-2, 60 cm, represent the interval between the FO of *P. doliolus* and the LO of *N. jouseae* and were assigned to the *N. marina* Zone of Baldauf (1984). The consistent occurrence of *R. praebergonii* at this site also allowed for usage of the *R. praebergonii* Zone, as used by Barron (1985a, 1985B), and permitted assignment of Samples 138-847B-7H-6, 60 cm, through -10H-CC; 138-847C-7H-CC through -10H-2, 148 cm; and 138-847D-7H-CC through -10H-CC to the *R. praebergonii* Zone. Samples 138-847B-7H-6, 60 cm, through -8H-6, 60 cm, were assigned to Subzone C, based on the occurrence of *R. praebergonii* stratigraphically below the FO of *P. doliolus* (Sample 138-847B-7H-5, 60 cm) and stratigraphically above the LO of *T. convexa* (Sample 138-847B-8H-CC). Samples 138-847B-8H-CC through -9H-CC were assigned to Subzone B of this zone, based on the co-occurrence of *T. convexa* and *R. praebergonii* without *N. jouseae*. Samples 138-847B-10H-2, 60 cm, through -10H-CC were assigned to Subzone A, based on the co-occurrence of *N. jouseae, T. convexa*, and *R. praebergonii*.

Samples 138-847B-10H-2, 60 cm, through -18H-2, 90 cm; 138-847C-10H-CC through -17X-CC; and 138-847D-10-4, 120 cm, through -12H-CC were assigned to the *N. jouseae* Zone, as used by Baldauf (1984) on the basis of the consistent occurrence of *N. jouseae* stratigraphically throughout this sequence. Samples from the remaining portion of Holes 847B and 847C were assigned to the *Thalassiosira convexa* Zone. The LO of *T. praeconvexa* in Samples 138-847B-23X-1, 60 cm, and -847C-21X-5, 50 cm, marks the A/B subzonal boundary of this zone.

Site 848

The Pleistocene (*N. reinholdii* Zone) through upper Miocene (*Nitzschia porteri* Zone) sequence contains common and well-preserved diatoms. The shipboard biostratigraphy (Mayer, Pisias, Janecek, et al., 1992) was completed at a spacing of 1.5 m. Because of this, this stratigraphy was not refined onshore. Thus individual events are shown in Tables 6-8, but the reader is referred to Mayer, Pisias, Janecek, et al. (1992) for a detailed discussion of the biostratigraphy for this site. A brief summary of the biostratigraphy places samples from Cores 138-848B-1H and -1H in the *P. doliolus* Zone. The interval from Samples 138-848B-2H-CC through -4H-1, 120 cm; 138-848C-2H-CC through -3H-CC; and 138-848D-2H-CC through -4H-2, 100 cm, were assigned to the *N. reinholdii* Zone. Samples 138-848B-4H-2, 121 cm, through -4H-4, 121 cm; 138-844C4H-1, 40 cm, through -4H-2, 40 cm, represent the interval from the FO of *P. doliolus* to the LO of *N. jouseae* and were assigned to the *N. marina* Zone. The interval representing the total range of *N. jouseae* includes

Table 7 (continued).

850B top	850B bottom	851B top	851B bottom	851C top	851C bottom	851E top	851E bottom
5.3	12.78	7.58	9.25			9.86	10.3
12.74	22.15	12.25	15.25	11.82	121.66	10.3	13.3
32.2	33.7	27.1	26.75	21.86	31.44	19.19	29.06
35.7	38	36.41	36.75	31.44	41.18	29.06	38.55
48.65	49.85	36.75	39.75	41.18	49.22	38.55	40.4
51.3	54.3	45.89	48.51	41.18	49.22	43.4	46.4
60.6	70.11	48.51	51.51	49.22	59.99	49.9	51.4
65.1	70.11	61.01	62.51	59.99	69.39	62.5	63.78
71.8	79.59	65.04	74.54				
98.49	106.9	84.14	93.46	78.59	87.93	78.4	81.1
106.9	117	84.14	93.46	78.59	87.93	81.13	83.41
151.2	152.7	103.01	112.64	97.23	107.58		
167.02	168.51	122.19	123.7	117.15	126.62	124.06	133.68
		128.2	129.7	126.62	136.14		
176.5	177	133.4	138.7				
203.15	206.9	140.89	145.8			138	141.94
203.15	206.9	140.89	145.9			138	141.94
212.83	214.9	150	159.87			141.94	147.13
242.4	243.9	169.49	180.7			154.75	164.4
243.9	245.98	171.7	173.2				
251.49	260.79						
259.1	260.18	188.93	197.14				
260.75	263.93	197.14	207.29			190.11	199.68
263.93	270.62	197.14	207.29			190.11	199.68
289.57	299.34						
304.5	306.06	226.56	227.21			221.47	230.98
308.22	309.6	228.7	234.75				
378.45	381.38						
		293.96	302.94				

Samples 138-848B-4H-5, 121 cm, through -6H-2, 120 cm. This interval was assigned to the *N. jouseae* Zone of Baldauf (1984).

Samples 138-848B-6H-4, 120 cm, through -8H-3, 120 cm; 138-848C-6H-CC and -7H-CC; and 138-848D-4H-CC were placed in the *T. convexa* Zone. Samples 138-848B-8H-4, 70 cm, through -9H-2, 36 cm, and 138-848D-8H-CC were assigned to the *N. miocenica* Zone, based on the occurrence of *N. miocenica* without *T. convexa* var. *aspinosa.* Preservation of diatoms in the interval equivalent to and stratigraphically below the *N. porteri* Zone (Cores 138-848B-10H through -11H, 138-848C-8H through -9H, and 138-848D-10H) was generally poor to moderate. No zonal assignments for this interval was possible.

Site 849

A Pleistocene (*N. reinholdii* Zone) to upper Miocene (*Actinocyclus moronensis* Zone) sequence was recovered having well-preserved diatoms that were consistently present. The shipboard biostratigraphy (Mayer, Pisias, Janecek, et al., 1992) for Hole 849B was substantially revised and is presented below. The biostratigraphy for Holes 849C and 849D has not been adjusted.

The biostratigraphic constraints for diatom events from Hole 849B are shown in Tables 6 through 8. Although the LO of *N. reinholdii* could not be determined, the LO of *Nitzschia fossilis* in Sample 138-849B-4H-1, 70 cm, indicates that the LO of *N. reinholdii* should stratigraphically occur above this sample.

The co-occurrence of *P. doliolus* and *N. reinholdii* in samples from Cores 138-849D-4H through -6H-3, 15 cm, allowed us to assign these samples to the *N. reinholdii* Zone. The LO of *R. praebergonii,* which marks the A/B subzone, was placed in Sample 138-849D-5H-5, 70 cm. The interval from the FO of *P. doliolus* in Sample 138-849D-6H-3, 15 cm, to the LO of *N. jouseae* in Sample 138-849D-8H-4, 60 cm, was assigned to the *N. marina* Zone. The occurrence of *R. praebergonii* is scattered at this site, placing into question its stratigraphic reliability. The LO of *T. convexa* was placed in Sample 138-849D-7H-CC and marks the A/B subzonal boundary.

The *N. jouseae* Zone extends from Sample 138-849D-8H-4, 60 cm, through Sample 138-849D-16H-1, 70 cm. Within this interval, the FO of *T. convexa* var. *convexa* was placed in Sample 138-849D-11H-1, 70 cm, and the LO of *N. cylindrica* was placed in Sample 138-849D-15H-3, 70 cm.

The FO of *T. convexa* var. *aspinosa* in Sample 138-849D-24X-3, 60 cm, allowed us to assign the interval from Sample 139-849D-16H-1, 70 cm, through -24X-3, 60 cm, to the *T. convexa* Zone. The subzonal indicators permitted subdivision of this zone. The LO of *T. miocenica,* which marks the B/C boundary, and the LO of *T. praeconvexa,* which marks the A/B boundary, occur in the lowermost portion of Core 138-849D-21X. The LO of *T. miocenica* was placed in Sample 138-849D-21X-6, 24 cm, and the LO of *T. praeconvexa* was placed in Sample 138-849D-21X-CC.

The *N. miocenica* Zone extends from the base of the *T. convexa* Zone (Sample 138-849D-24X-3, 60 cm) to the FO of *N. miocenica* in Sample 138-849D-28X-4, 60 cm. The FO of *T. praeconvexa* is unreliable at this site; thus, we were unable to place the A/B subzonal boundary. The LO of *T. yabei* was placed in Sample 138-849D-31X-2, 70 cm, and marks the base of the *N. porteri* Zone. Within this zone,

Table 8. Depth constraints of stratigraphically useful events from western transect Holes 848B through 852D.

Event (mcd)	848B top	848B bottom	848C top	848C bottom	848D top	848D bottom	849B top	849B bottom	849C top	849C bottom	849D top	849D bottom	850A top	850A bottom
T. *N. reinholdii*	2.43	15.07	0	5.47	8.44	18.28					8.36	22.97	7.68	18.28
T. *N. fossilis*	2.42	15.07	5.47	15.45	8.44	18.28	15.63	19.9			22.97	32.79	7.68	18.28
T. *R. matuyama*														
B. *R. matuyama*														
T. *R. praebergoni*	24.45	25.68	15.45	25.06	18.28	27.81	40.4	43.4	37.83	49.03	41.48	51.9	33.3	34.8
B. *P. doliolus*	26.88	28.38	25.06	24.9	29.9	37.16	47.81	51.7	49.03	57.4	51.9	60.92	42.1	46.6
T. *T. convexa*	29.88	31.38	24.9	25.9	18.28	27.81	57.8	64.26	57.4	68.03	60.92	70.93	48.15	49.35
T. *N. jouseae*	31.38	32.88	25.9	27.9			65.8	68.8	57.4	68.03	60.92	70.93	50.01	61.56
B. *R. praebergonii*	34.38	34.77	27.9	34.57	37	37.16	75.3	78.3	60.03	77.44	70.93	79.2	61.56	72.57
F. *T. convexa* v. *convexa*	37.55	39.05					92.49	94.1	86.58	96.62	89.76	99.05	72.46	72.57
B. *A. elegans*	35.52	42.05											72.57	83.76
T. *N. cylindrica*	42.05	46.18			37.16	46.75								
B. *N. jouseae*	58.57	61.57			37.16	46.75	140.7	149.53			144.41	154.2		
B. *T. oestrupii*														
T. *T. miocenica*														
T. *N. miocenica*	59.1	66.47	53	63.06	56.4	65.07	187.16	196.61			191.7	201.14		
T. *N. miocenica* v. *elongata*	63.6	69.35			56.4	65.07	187.16	196.61			191.7	201.14		
T. *T. praeconvexa*	63.6	69.35					187.16	196.61			191.7	201.14		
T. *R. praepaleacea*	69.35	70.85									220.86	230.56		
B. *T. miocenica*	70.85	71.85					219.9	224.4			220.86	230.56		
B. *T. convexa*	70.85	71.85					219.9	224.4						
B. *B. praeconvexa*	72.35	73.85					242	247.5			259.27	268.44		
T. *N. porteri*											268.44	278.44		
B. *N. miocenica*	80.16	80.75			65.07	75.42	269.78	275.08			278.44	288.07		
T. *R. paleacea*	80.16	80.75	63.06	72.31	65.07	75.42					278.44	288.07		
B. *N. reinholdii*											297.7	307.49		
T. *A. ellipticus* v. *javanicus*							264.68	274.38						
B. *N. marina*														
B. *N. cylindrica*							308.25	309.9						
T. *T. yabei*							308.25	309.9						
T. *C. loeblichii*														
B. *T. burckliana*														
B. *T. burcklina*														
B. *C. loeblichii*														
T. *D. hustedtii*							295.8	308.25						
T. *A. moronensis*														
T. *A. ellipticus*														
T. *S. jouseana*														
T. *C. coscinodiscus*														
B. *R. paleacea* v. *elongata*														
T. *C. gigas* v. *diorama*														

Note: T = top or last occurrence of a species, B = bottom or first occurrence of a species. Determined by Mayer, Pisias, Janecek, et al. (1992).

N. reinholdii has an FO in Sample 138-849D-29X-5, 70 cm, and *T. burckliana* has an LO in Sample 138-849D-31X-1, 70 cm.

The remaining portion of the hole was assigned to the *T. yabei* Zone, based on the occurrence of *T. yabei* above the occurrence of *A. moronensis.* However, note that the scattered occurrence of *A. moronensis* at this site reduced its usefulness as a stratigraphic marker. Similar to other sites, we used the LO of *D. simonsenii* as an indicator for the base of this zone. Using this criterion, the lower portion of the hole approximates the base of the *T. yabei* as the LO of *D. simonsenii* was placed in Sample 138-849D-33X-1, 70 cm.

Site 850

Pleistocene (*N. reinholdii* Zone) to upper middle Miocene (*Craspedodiscus coscinodiscus* Zone) sediment was recognized. Few changes were made to the shipboard biostratigraphy for Hole 850B, discussed in Mayer, Pisias, Janecek, et al. (1992). No change was made to the stratigraphy of Hole 850A. The zonal boundaries were placed as follows.

The LO of *N. reinholdii* in Sample 138-850B-1H-CC allowed us to place Core 1H in the *P. doliolus* Zone. The FO of *P. doliolus,* which marks the base of the *N. reinholdii* Zone, was placed in Sample 138-850B-4H-4, 70 cm. Within this zone, the LO of *R. praebergonii* has been tentatively placed in Sample 138-850B-4H-2, 70 cm, allowing us to place the A/B subzonal boundary in this sample. The *N. marina* Zone extends from the FO of *P. doliolus* to the LO of *N. jouseae*. The LO of *N. jouseae* was placed in Sample 138-850B-6H-3, 80 cm. The A/B subzonal boundary is defined at the LO of *T. convexa,* which was placed in Sample 138-850B-5H-7, 35 cm.

The FO of *N. jouseae,* which marks the base of the *N. jouseae* Zone was placed in Sample 138-850B-11X-CC. Within this interval, the FO of *T. convexa* var. *convexa* was placed in Sample 138-850B-7H-4, 61 cm, and the LO of *N. cylindrica* was placed in Sample 138-850B-11X-CC. The FO of *T. convexa* in Sample 138-850B-21X-CC allowed us to place Samples 138-850B-12X-CC through -21X-CC into the *T. convexa* Zone. The FO of *T. miocenica,* a secondary indicator for the base of this zone, also occurs in Sample 138-850B-21X-CC. The C/B subzonal boundary, based on the LO of *T. miocenica* was not defined. The B/A subzonal boundary based on the LO of *T. praeconvexa* was placed in Sample 138-850B-19X-3, 80 cm.

The *N. miocenica* Zone is defined as the interval between the FO of *T. convexa* and the FO of *N. miocenica.* This later species has an FO in Sample 138-850B-26X-1, 80 cm, allowing for placement of the interval from Samples 138-850B-22X-3, 80 cm, through -26X-1, 80 cm, in this zone. The FO of *T. praeconvexa* in Sample 138-850B-22X-CC allowed us to place the A/B subzonal boundary in this sample.

The LO of *Thalassiosira yabei* in Sample 138-850B-28X-3, 23 cm, allowed for placement of the interval from Samples 138-850B-26X-2, 60 cm, through -28X-3, 23 cm, in the *N. porteri* Zone. The A/B subzonal boundary, defined as the LO of *T. burckliana,* was

Table 8 (continued).

850B top	850B bottom	851B top	851B bottom	851C top	851C bottom	851E top	851E bottom	852B top	852B bottom	852C top	852C bottom	852D top	852D bottom
5.3	12.78	7.58	19.52			9.86	13.8	2.9	7.4				
14.68	24.05	7.58	19.52	15.32	21.86	13.8	19.8	2.9	7.4	6.08	16.88	10.97	121.84
36.55	38.05	31.25	32.8	25.86	37.49	22.69	33.26	20.4	26.4	16.88	26.53	21.84	31.14
40.01	42.4	32.8	35.5	37.49	48.03	33.26	44.74	20.4	26.4	16.88	26.53	21.84	31.14
47.6	49.1	43.05	46.05	48.03	57.72	44.75	47.2	26.4	28.6	26.53	36.31	21.84	31.14
56.58	58.3	52.19	56.36	48.03	57.72	50.2	53.2	28.6	33	26.53	36.31		
67.25	69.25	56.36	59.36	57.72	68.69	57.6	62.4			36.31	42.51		
79.55	87.34	69.46	70.96	68.69	78.99	71.1	72.38	42.95	47.45	42.51	48.08		
		73.49	84.4										
106.24	114.65	94.54	105.41	89.09	100.23	89.45	92.18	57.55	58.6	48.08	59.13	53	64.1
114.65	124.75	94.54	105.41	89.09	100.23	92.18	94.46	57.55	58.6	48.08	59.13	53	64.1
158.95	160.45												
		116.16	127.64	110.33	122.24	118.43	122.47						
174.77	176.26	137.99	140.85	133.15	143.72	140.36	150.38	73.85	78.35	68.73	79.84		
		145.35	146.86	143.72	154.54					68.73	79.84		
184.25	184.75	151.75	157.05										
210.9	214.65	159.24	164.55			154.4	158.34						
210.9	214.65	159.24	164.55			154.4	158.34						
220.58	222.65	168.55	183.37			158.34	167.93						
250.15	253.73	197.94	201.45			178.25	192.1		82.15	87.65	79.84	90.78	
251.65	253.73	201.45	202.95										85.92
266.85	267.93	224.88	236.49						96.1	97.6	90.78	102.04	97.13
267.93	268.54												
269.29	271.77	236.49	246.64			231.48	243.58		103.6	104.4			
271.77	278.01	236.49	246.64			231.48	243.58		103.6	104.4	90.78	102.04	97.13
297.32	307.09												
312.25	313.81	272.66	276.3			268.17	280.08		117.3	119			
315.97	317.35	277.8	284.85										
386.2	389.13	352.36	352.36–363.19										

placed in Sample 138-850B-27X-CC. The FO of *N. cylindrica* occurs in Sample 138-850B-28X-3, 23 cm, and consistently occurs at an interval equivalent to the LO of *T. yabei.*

Sample 138-850B-33X-1, 70 cm, contains specimens of *A. moronensis.* Because of the scattered occurrence of this species in the top of its range, this occurrence permitted only tentative placement of the base of the *T. yabei* Zone. As at previous Leg 138 holes, the LO of *D. simonsenii* was used as a secondary indicator for this boundary. In Hole 850B, the LO of *D. simonsenii* was placed in Sample 138-850B-32X-5, 86 cm, slightly above the LO of *A. moronenisis.* The Subzone A/B boundary was placed in Sample 138-850B-30X-CC, based on the placement of the FO of *T. burckliana* in this sample. The base of the *A. moronensis* Zone was placed in Sample 138-850B-40X-4, 48 cm, at the LO of *C. coscinodiscus.*

Site 851

Pleistocene (*N. reinholdii* Zone) to uppermost middle Miocene (*C. coscinodiscus* Zone) sediment was recovered at this site. Few changes to placement of the Hole 851B zonal boundaries, previously completed aboard the ship (Mayer, Pisias, Janecek, et al., 1992) were made.

The FO of *N. reinholdii* in Sample 138-851B-2H-2, 25 cm, defines the base of the *P. doliolus* Zone and the FO of *P. doliolus* in Sample 138-851B-4H-CC, which marks the base of the *N. reinholdii* Zone. The LO of *R. praebergonii* has been tentatively placed in Sample 138-851B-4H-1, 25 cm, allowing us to place the A/B subzonal boundary in this sample. The *N. marina* Zone extends from the FO of *P. doliolus* in Sample 138-851B-4H-CC to the LO of *N. jouseae* in Sample 138-851B-6H-3, 1 cm. The A/B subzonal boundary defined at the LO of *T. convexa* was placed in Sample 138-851B-5H-3, 75 cm.

The FO of *N. jouseae* defines the base of the *N. jouseae* Zone in Sample 138-851B-9H-CC. Within this interval, the FO of *T. convexa* var. *convexa* was placed in Sample 138-851B-7H-5, 1 cm, and the LO of *N. cylindrica* was placed in Sample 138-851B-10H-CC. *Thalassiosira convexa* var. *aspinosa* has an FO in Sample 138-851B-15H-CC, allowing for the base of the *T. convexa* Zone equivalent to this sample. The *N. miocenica* zone is defined as the interval between the FO of *T. convexa* and the FO of *N. miocenica.* The FO of *N. miocenica* was placed in Sample 138-851B-18X-CC, allowing placement of the interval from Samples 138-851B-16X-4, 80 cm, to -18X-CC in this zone. The FO of *T. praeconvexa* in Sample 138-851B-16H-CC permitting us to place the A/B subzonal boundary in this sample.

The interval from Samples 138-851B-19X-2, 80 cm, through -22X-CC was assigned to the *N. porteri* Zone. The subzonal A/B boundary was not determined. Sample 138-851B-25X-7, 25 cm, contains the LO of *A. moronensis* and was assigned to the lowermost portion of the *A. moronensis* Zone. However, because of the unreliable occurrence of *A. moronensis,* we placed this boundary at the LO of *D. simonsenii* in Sample 138-851B-25X-1, 80 cm. The LO of *C. coscinodiscus* in Sample 138-851B-32HX-CC suggests that this sample is at least equivalent to or older than the *C. coscinodiscus* Zone.

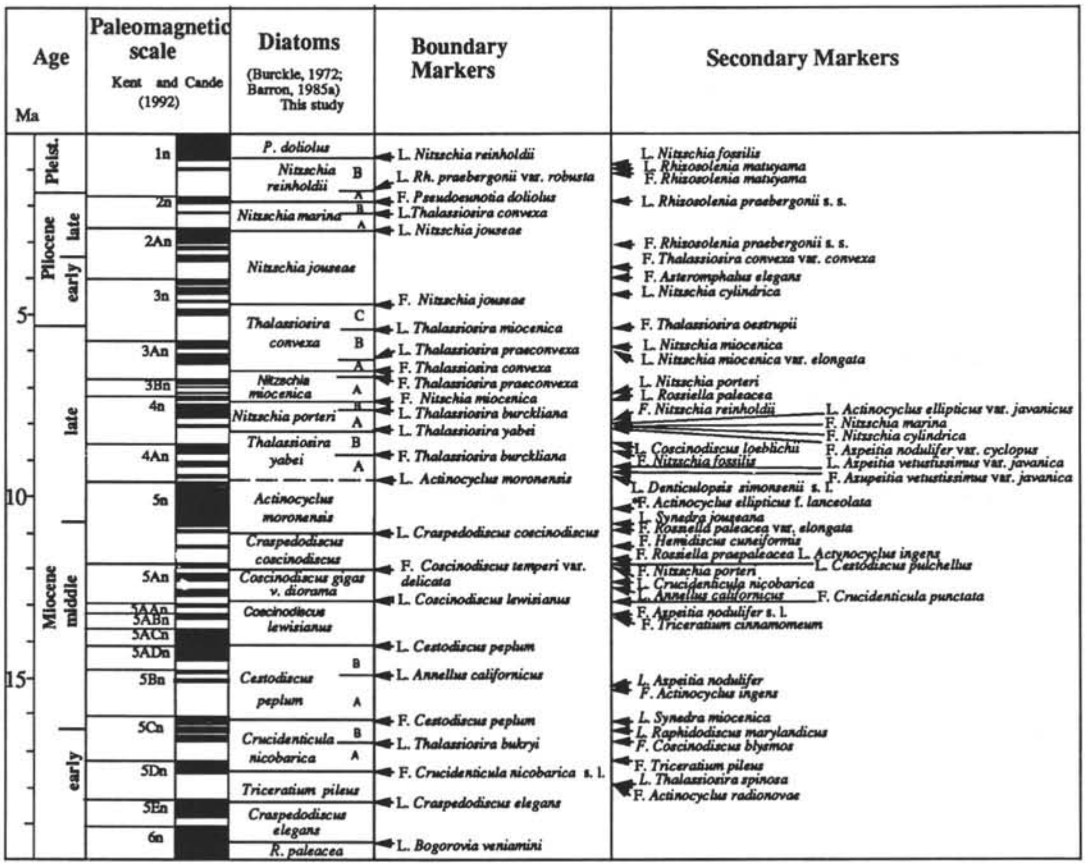

Figure 3. Correlation of primary and secondary stratigraphic markers used in this study. Events have been calibrated to the geochronology of Cande and Kent (1992). L = last occurrence, F = first occurrence.

Site 852

The stratigraphic sequence recovered consists of Pleistocene (*N. reinholdii* Zone) to uppermost middle Miocene (*T. yabei* Zone) sediments. The shipboard biostratigraphy discussed in Mayer, Pisias, Janecek, et al. (1992) has been extensively revised as follows.

The LO of *N. reinholdii* is not well constrained at this site because of the scattered occurrence of this species in the uppermost portion of the stratigraphic sequence. The LO of *Nitzschia fossilis* in Sample 138-852B-2H-2, 25 cm, and the occurrence of *R. praebergonii* in Sample 138-852B-3H-2, 25 cm, indicates that these samples are equivalent to the *N. reinholdii* Zone. The FO of *P. doliolus* in Sample 138-852B-3H-5, 25 cm, permits placement this sample in the *P. doliolus* Zone. The *N. marina* Zone extends from the FO of *P. doliolus* to the LO of *N. jouseae*. The interval from Samples 138-852B-3H-5, 25 cm, to -4H-2, 25 cm, was assigned to this zone. The FO of *N. jouseae*, which marks the base of the *N. jouseae* Zone, was placed in Sample 138-852B-6H-4, 120 cm. Within this interval, the FO of *T. convexa* var. *convexa* was placed in Sample 138-852B-5H-2, 5 cm, and the LO of *N. cylindrica* was placed in Sample 138-852B-6H-5, 120 cm. The FO of *T. convexa* in Sample 138-852B-8H-6, 25 cm, suggesting that this sample approximates the base of the *T. convexa* Zone. The LO of *N. miocenica* in Sample 138-852B-7H-4, 25 cm, marks the B/C subzonal boundary. The FO of *T. praeconvexa* in Sample 8H-2, 25 cm, marks the A/B subzonal boundary.

Samples 138-852B-8H-6, 25 cm, to -19H-2, 25 cm, represent the interval from the FO of *T. convexa* var. *aspinosa* to the FO of *N. miocenica* and were placed in the *N. miocenica* Zone. The FO of *T. praeconvexa* also in Sample 138-852B-8H-6, 25 cm (i.e., equivalent to the placement of the FO of *T. convexa*) results from both the sample interval and the low sedimentation rates at this site. The LO of *T. yabei* in Sample 138-852B-11H-4, 25 cm, allowed us to assign the interval from Samples 138-852B-9H-3, 75 cm, through -11H-4, 25 cm, to the *N. porteri* Zone. The subzonal A/B boundary was placed in Sample 138-852B-11H-4, 25 cm. The FO of *N. cylindrica* occurs in Sample 138-852B-10H-2, 25 cm. The occurrence of *T. burckliana* in Sample 138-852B-11H-4, 25 cm, suggests that this sample approximates the lower portion of Subzone B of the *T. yabei* Zone.

DISCUSSION

The recovery of both a well-preserved diatom assemblage and paleomagnetic stratigraphies from Sites 844, 845, 848, 851, and 852 allowed us to evaluate the correlation of specific diatom events to the paleomagnetic record. The good quality magnetostratigraphy and reasonable sample spacing (generally less than 1.5 m) allowed us to complete such correlations for about the last 6 m.y. Variability of the magnetostratigraphy and/or poor stratigraphic constraint limits such correlations for that part of the stratigraphic sequence older than 6 m.y. Correlations of specific diatom biostratigraphic events with the magnetostratigraphy of Schneider et al. (this volume) were completed for Sites 844 (Fig. 4), 845 (Figs. 5 and 6), Site 848 (Fig. 7), Site 851 (Fig. 8), and Site 852 (Fig. 9). Only those events that presently are considered reliable have been discussed below. The number of each event corresponds to that used in the tables.

1. LO *Nitzschia reinholdii*. This event has been widely used as a primary stratigraphic indicator for the low latitudes and to a lesser degree in the middle and high latitudes. The LO of *N. reinholdii* (i.e., *N. reinholdii* of Barron and Baldauf, 1986) in the low latitudes has

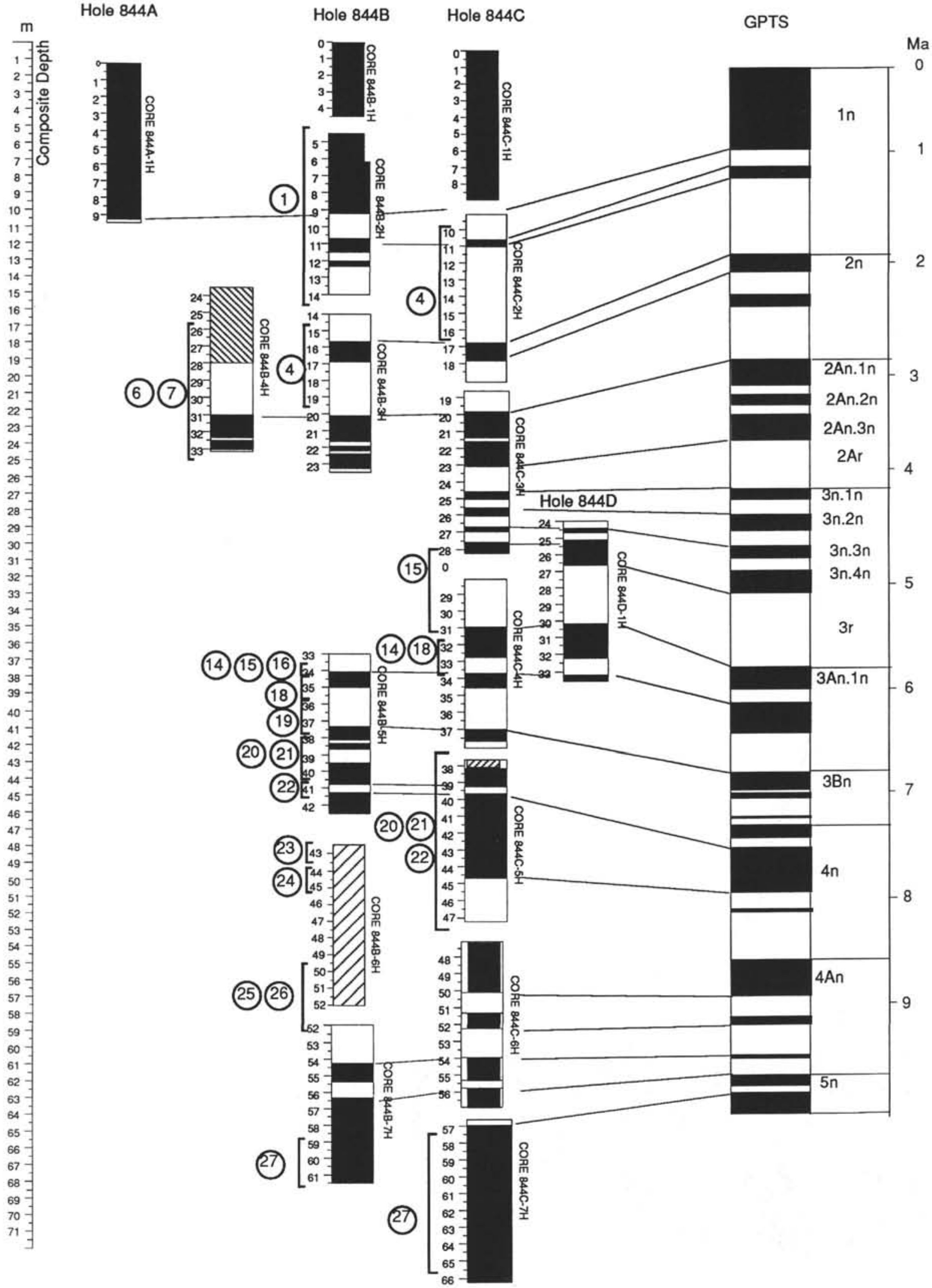

Figure 4. Diatom biostratigraphic events correlated with the paleomagnetic results (Schneider et al., this volume) for Site 844. Events are plotted both in mbsf and mcd. 1 = LO of *N. reinholdii*; 4 = FO of *P. doliolus*; 6 = LO of *N. jouseae*; 7 = FO of *R. praebergonii*; 14 = LO of *N. miocenica*; 15 = LO of *N. miocenica* var. *elongata*. 16 = LO of *T. praeconvexa*; 18 = FO of *T. convexa* var. *aspinosa*; 19 = FO of *T. praeconvexa*; 20 = FO of *N. miocenica*; 21 = LO of *R. paleacea*; 22 = FO of *N. reinholdii*; 23 = FO of *N. cylindrica*; 24 = LO of *T. yabei*; 25 = LO of *C. loeblichi*; 26 = FO of *T. burckliana*; 27 = LO of *D. simonsenii*.

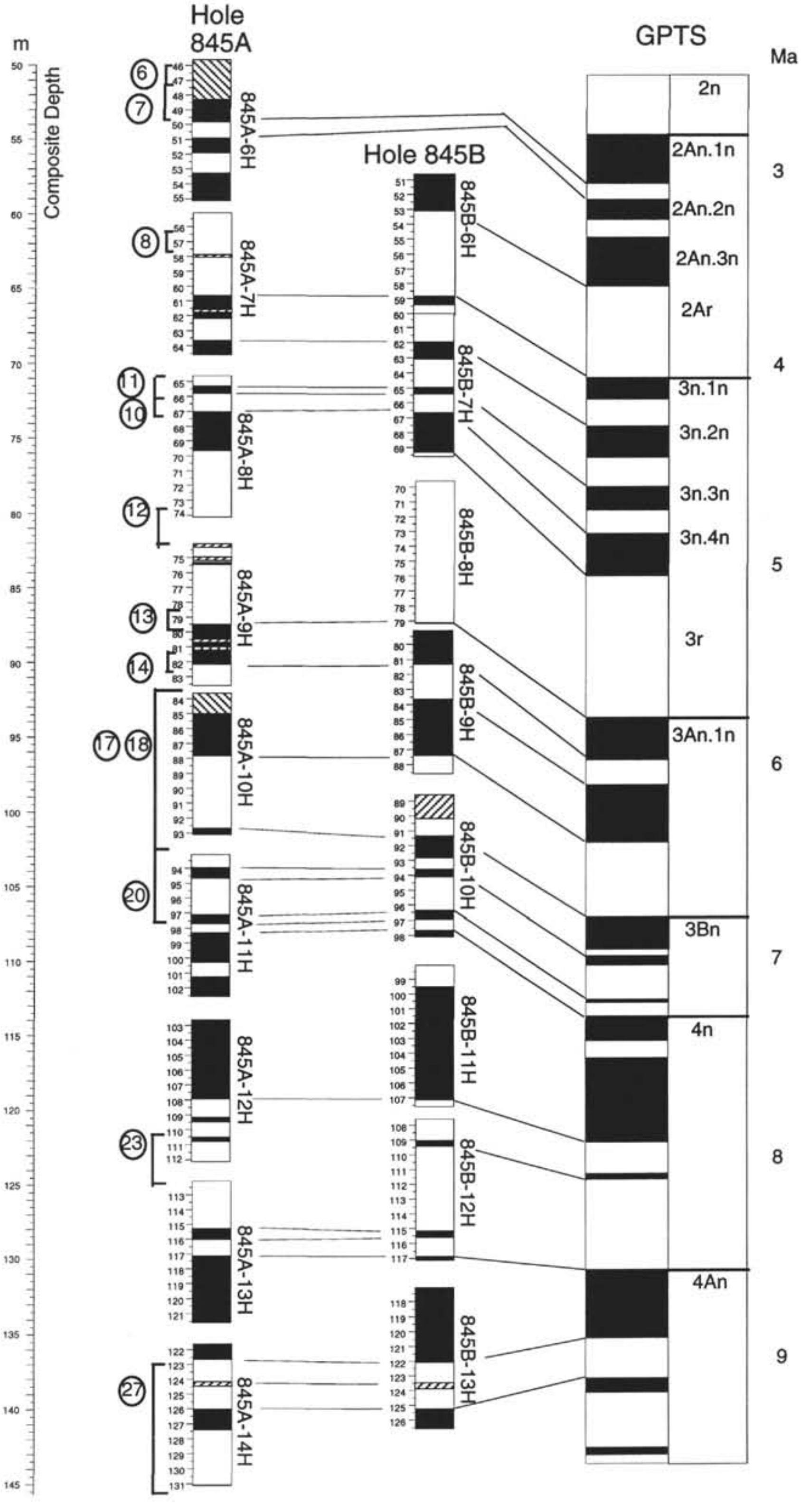

Figure 5. Diatom biostratigraphic events correlated with the paleomagnetic results (Schneider et al., this volume) for Site 845. Events are plotted both in mbsf and mcd. 6 = LO of *N. jouseae*; 7 = FO of *R. praebergonii*; 8 = LO of *T. convexa*; 10 = LO of *N. cylindrica*; 11 = FO of *N. jouseae*; 12 = FO of *T. oestrupii*; 13 = LO of *T. miocenica*; 14 = LO of *N. miocenica*; 17 = FO of *T. miocenica*; 18 = FO of *T. convexa* var. *aspinosa*; 20 = FO of *N. miocenica*; 23 = FO of *N. cylindrica*; 27 = LO of *D. simonsenii*; 28 = LO of *A. ingens*; 29 = LO of *C. lewisianus*.

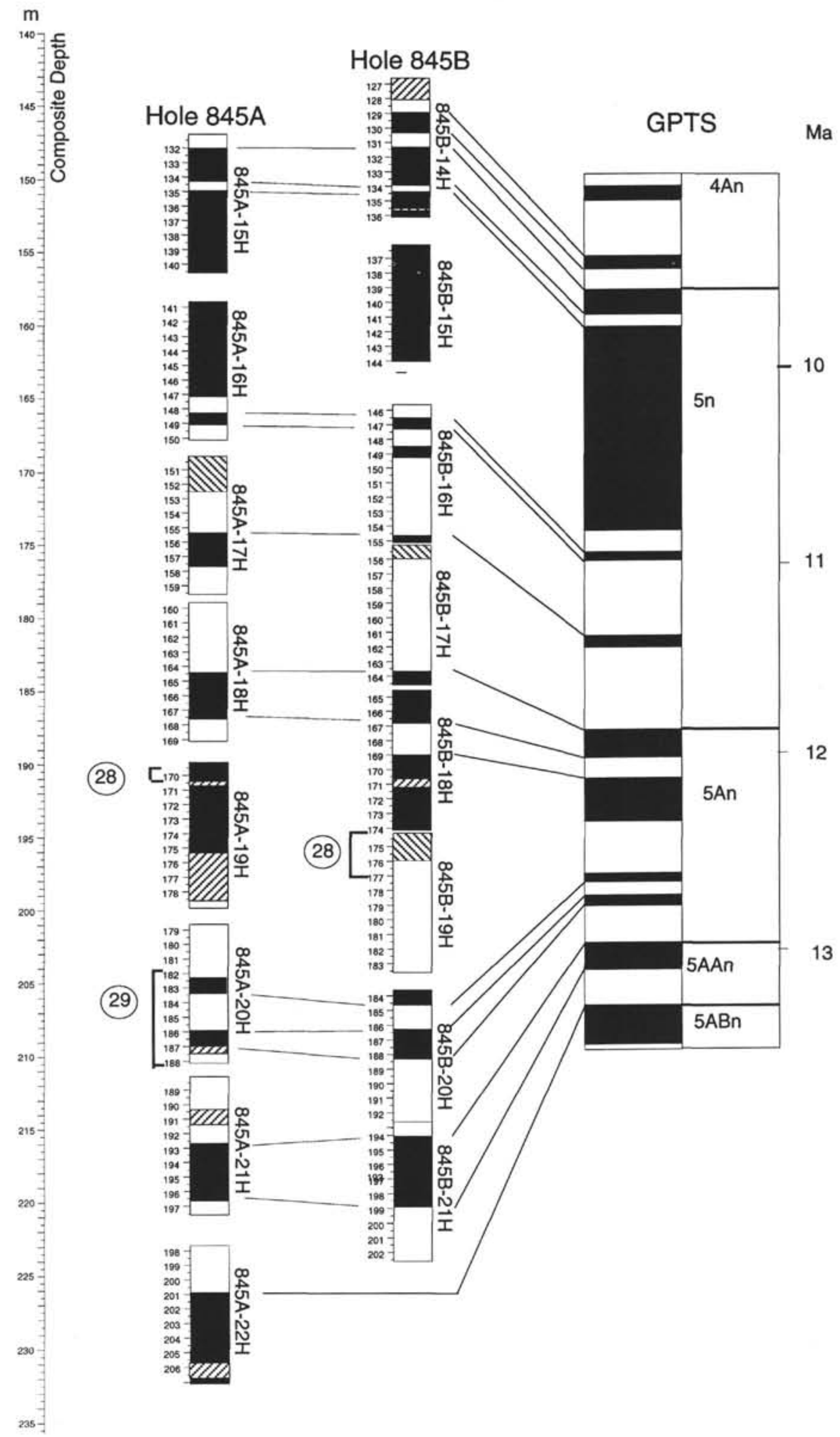

Figure 5 (continued).

been correlated by Burckle (1977, 1978), Barron (1985a, 1985b), and Baldauf (1985; among other researchers) with the lowermost portion of the Brunhes Chron (C1n of Cande and Kent, 1992) and has an estimated age of 0.65 Ma (also 0.65 Ma using Cande and Kent, 1992; see Table 2). In the middle latitude Pacific (Koizumi and Tanimura, 1985), North Atlantic (Baldauf, 1984 and 1987), and the Indian Ocean (Schrader, 1974), the LO of *N. reinholdii* has been calibrated to the middle to upper portion of the Brunhes Chron (C1n of Cande and Kent, 1992). However, Mikkelsen (1990) correlated the LO of *N. reinholdii* with the uppermost part of the Matuyama Chron (C1n.1n) approximately and assigned an estimated age of 0.9 Ma (1.0 Ma using Cande and Kent, 1992). This approximates the last continuous occur-

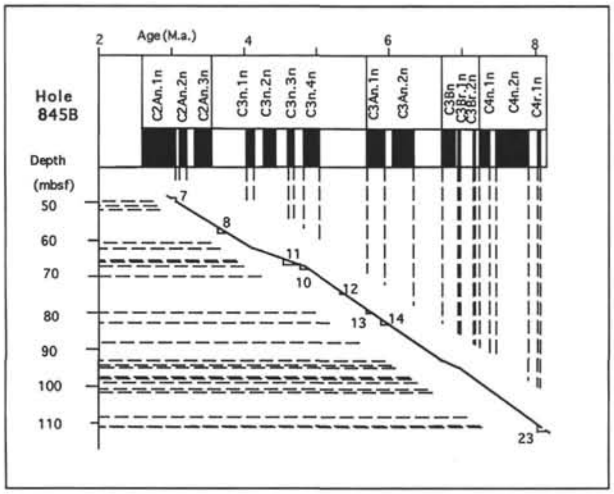

Figure 6. Calibration of selected events to the magnetostratigraphic results of Schneider (this volume) for Hole 845B. Event: 7 = FO of *R. praebergonii*; 8 = LO of *T. convexa*; 11 = FO of *N. jouseae*; 10 = LO of *N. cylindrica;* 12 = LO of *T. oestrupii* group; 13 = LO of *T. miocenica*; 14 = LO of *N. miocenica*; 23 = FO of *N. cylindrica.*

rence of *N. reinholdii* at several of the Leg 138 sites. Age estimates for this event by these authors range between 0.44 and 0.9 Ma (0.4–1.0 Ma using Cande and Kent, 1992).

The stratigraphic range of *N. reinholdii* is sometimes scattered in the upper half of its range in the Leg 138 sediments. This is especially true at Sites 844, 849, and 850. This event is well constrained in Holes 845A, 846B, 851B, and 851E. At these latter sites, a reliable magnetostratigraphy occurs only at Site 851. In both Holes 851B and 851E, the LO of *N. reinholdii* correlates with the lower portion of C1n (Fig. 8) and has an age estimate of between 0.46 and 0.57 Ma in Hole 851B and an age of between 0.66 and 0.69 Ma in Hole 851E.

2. LO *Nitzschia fossilis.* This event has been noted by numerous researchers to approximate the LO of the silicoflagellate *Mesocena quadrangula* (Barron, 1985a, 1985b; Baldauf, 1984, 1985). A similar correspondence can be seen at the Leg 138 sites. The LO of *N. fossilis* has been correlated by Barron (1980) to approximate the top of the Jaramillo Subchron (equivalent to C1n.1n) with an approximate age of 0.85 Ma (0.92 Ma using Cande and Kent, 1992). At ODP Site 710 in the Indian Ocean, Mikkelsen (1990) reported that the LO of *N. fossilis* lies in the upper part of the Matuyama Chron. In the northwest Pacific (Koizumi and Tanimura, 1985) and in the North Atlantic (Baldauf, 1984), this event correlates with the lowermost portion of the Brunhes Chron (equivalent to C1n), indicating that this event is diachronous between various oceanographic regions.

The LO of *N. fossilis* is constrained in Holes 845B, 846B, 851C, and 851E. The reliable magnetostratigraphy in holes from Site 851 (Fig. 8) allowed for direct comparisons between this event and the magnetostratigraphy. The LO of *N. fossilis* correlates with the lowermost portion of C1n to the upper portion of C1n1n (midway between C1n and C1n.1n). This event has an estimated age of between 0.78 and 0.85 Ma in Hole 851C and an age of between 0.68 and 0.88 Ma in Hole 851E. This event clearly is useful as a secondary indicator in the eastern equatorial Pacific.

3. LO *Rhizosolenia praebergonii.* The LO of *R. praebergonii* was correlated by Burckle and Trainer (1979) and Barron (1985a) with an interval just above the Olduvai Subchron (equivalent to C2n) having an estimated age of 1.55 Ma (1.64 Ma using Cande and Kent, 1992). Koizumi and Tanimura (1985) correlated this event with the lower portion of the Matuyama Chron and assigned an age of 2.4 to 2.5 Ma. Baldauf (1984) indicated that *R. praebergonii* had a scattered stratigraphic occurrence in the North Atlantic, suggesting that this event is stratigraphically useful only regionally.

The LO of *R. praebergonii* is well constrained in Holes 846B, 847B, 847C, 849B, 849C, 851B, and 852B. Paleomagnetic control for these holes is well constrained in Holes 852B (Fig. 9). In Hole 852B, the LO of *R. preabergonii* approximates the top of C2n and has an estimated age of between 1.64 and 1.75 Ma. This age estimate is similar to those previously determined for this event in the eastern equatorial Pacific.

4. FO *Pseudoeunotia doliolus.* This event in the low latitude Pacific has been calibrated with the middle of the Olduvai Subchron (C2n) by Burckle (1972, 1977) and Barron (1985a). An age of 1.80 Ma (1.90 Ma using Cande and Kent, 1992) was assigned to this event by these authors. Several previous authors also have indicated that this event may be diachronous between the low and middle latitudes, with age estimates that range between 1.8 and 2.0 Ma (1.9–2.1 Ma using Cande and Kent, 1992) in the northwest Pacific (Koizumi and Tanimura, 1985).

The FO of *P. doliolus* is well constrained at Sites 848, 851, and 852, where this event correlates to an interval directly above Chron C2An.1n (Figs. 7, 8, and 9). The FO of *P. doliolus* has an age of between 2.15 and 2.21 Ma at Site 851 and an age of between 2.12 and 2.24 Ma at Site 852. The age of 1.95 to 2.02 Ma for this event at Site 848 is less reliable because of uncertainty in the placement of the magnetic events.

5. LO *Thalassiosira convexa.* Burckle (1978) calibrated this event to the lower portion of the Matuyama Subchron (equivalent to lower portion of C2n) and assigned an age of 2.10 Ma (using Cande and Kent, this calibration has an age of 2.21 Ma) for this event in the equatorial Pacific. An equivalent age was determined by Baldauf (1985) and Barron (1985a) also for the equatorial Pacific region. This event has been best constrained at Site 851 (Fig. 9), where it correlates to an interval directly above Chron 2An.1n. At this site, this event has an estimated age of 2.35 Ma. Note that this event also correlates to the magnetostratigraphy at Site 844 (Fig. 4). However, the sampling constraint at this site is coarser. At Site 844, this event is older and occurs in C2An.1n through C3n.3n. This older correlation reflects an inconsistent occurrence of the species at Site 844. This event also was recognized at Site 848 (Fig. 7), but a poor magnetic record precluded age estimates.

6. LO *Nitzschia jouseae.* This event is well constrained at Sites 851 (Fig. 8) and 852 (Fig. 9). At Site 851, this event correlates to the middle portion of C2An.1n and has an age of 2.75 to 2.80 Ma. At Site 852, this event correlates with the uppermost portion of C2An.1n and has an estimated age of 2.60 to 2.75 Ma. This slightly younger age at Site 852 may reflect misplacement of the top of C2An.1n as a result of a coring gap (see Fig. 9). The ages of this event derived from this study approximate those from previous studies. Koizumi and Tanimura (1985) assigned an age of 2.48 to 2.58 Ma (equivalent to about 2.6–2.7 Ma using Cande and Kent, 1992) to this event. Likewise, Barron (1985a) assigned an age of 2.6 Ma (2.73 Ma using Cande and Kent, 1992).

7. FO *Rhizosolenia praebergonii.* The FO of this species is well constrained at Sites 851 and 852. At these sites, this event correlates with an interval representing the lowermost portion of C2An.1n to the uppermost portion of C2An.2n. The estimated age of this event is 3.0 to 3.15 Ma. This age in comparable to that of Burckle (1978) and Barron (1985a) for the equatorial Pacific region. Koizumi and Tanimura (1985) indicated that *R. praebergonii* has a shorter duration at the mid-latitude Pacific (DSDP Hole 580) of about 300 k.y. compared to its longer duration (about 1.5 Ma occurrence) in the lower latitudes. The brief occurrence of *R. praebergonii* was interpreted by Koizumi and Tanimura (1985) to represent incursion of this species into the middle latitudes during warm events. This was also implied by its scattered occurrence in the high latitudes of the North Atlantic during the latest Pliocene (see Baldauf, 1984, 1987). This event is well constrained at Site 848 (Fig. 7). Here, the FO of *R. praebergonii*

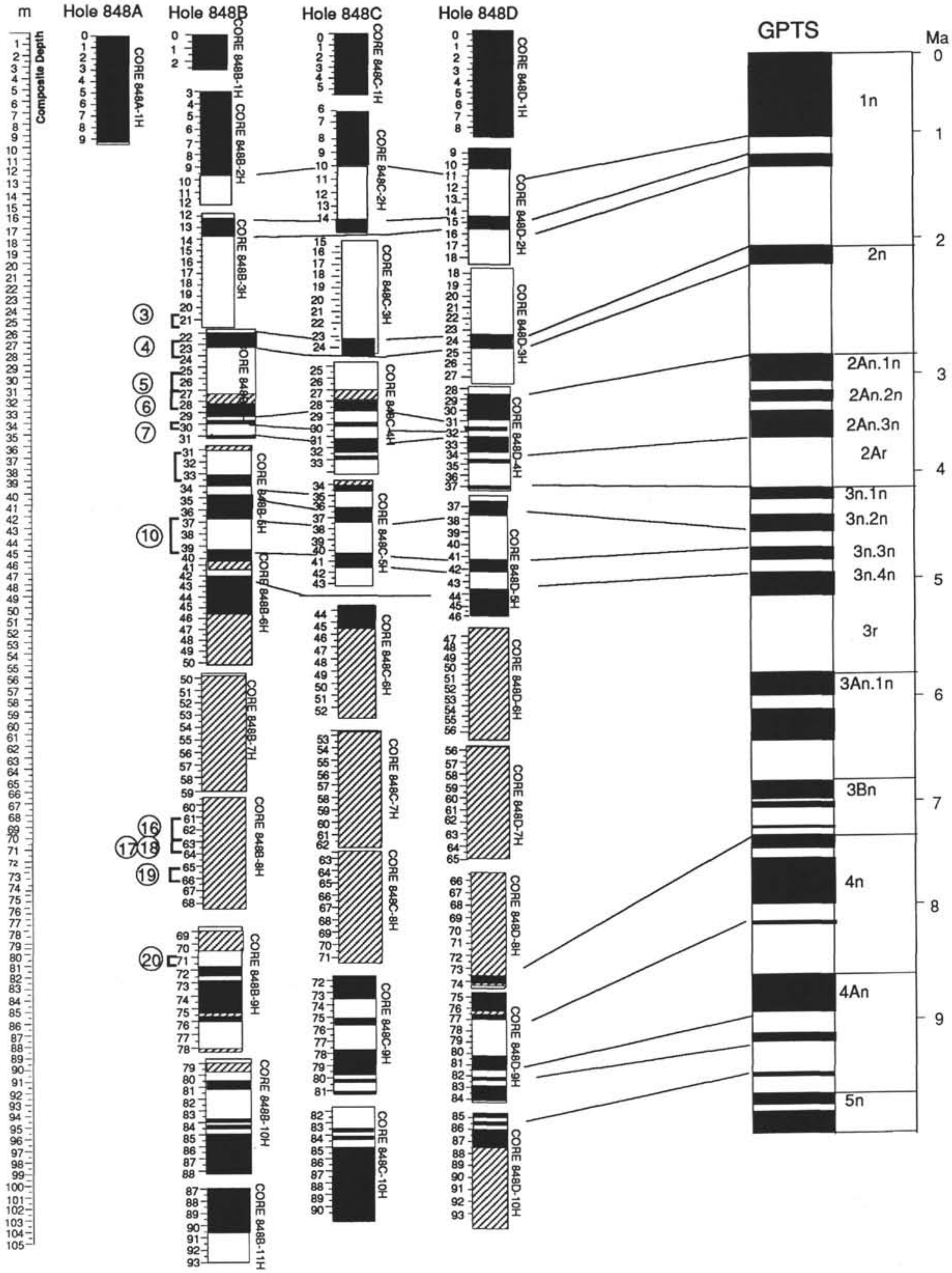

Figure 7. Diatom biostratigraphic events correlated with the paleomagnetic results (Schneider et al., this volume) for Site 848. Events have been plotted both in mbsf and mcd. 3 = LO of *R. praebergonii*; 4 = FO of *P. doliolus*; 5 = LO of *T. convexa* s.l.; 6 = LO of *N. jouseae*; 7 = FO of *R. praebergonii*; 10 = LO of *N. cylindrica*; 16 = LO of *T. praeconvexa*; 17 = FO of *T. miocenica*; 18 = FO of *T. convexa* var. *aspinosa*; 19 = FO of *T. praeconvexa*; 20 = FO of *N. miocenica.*

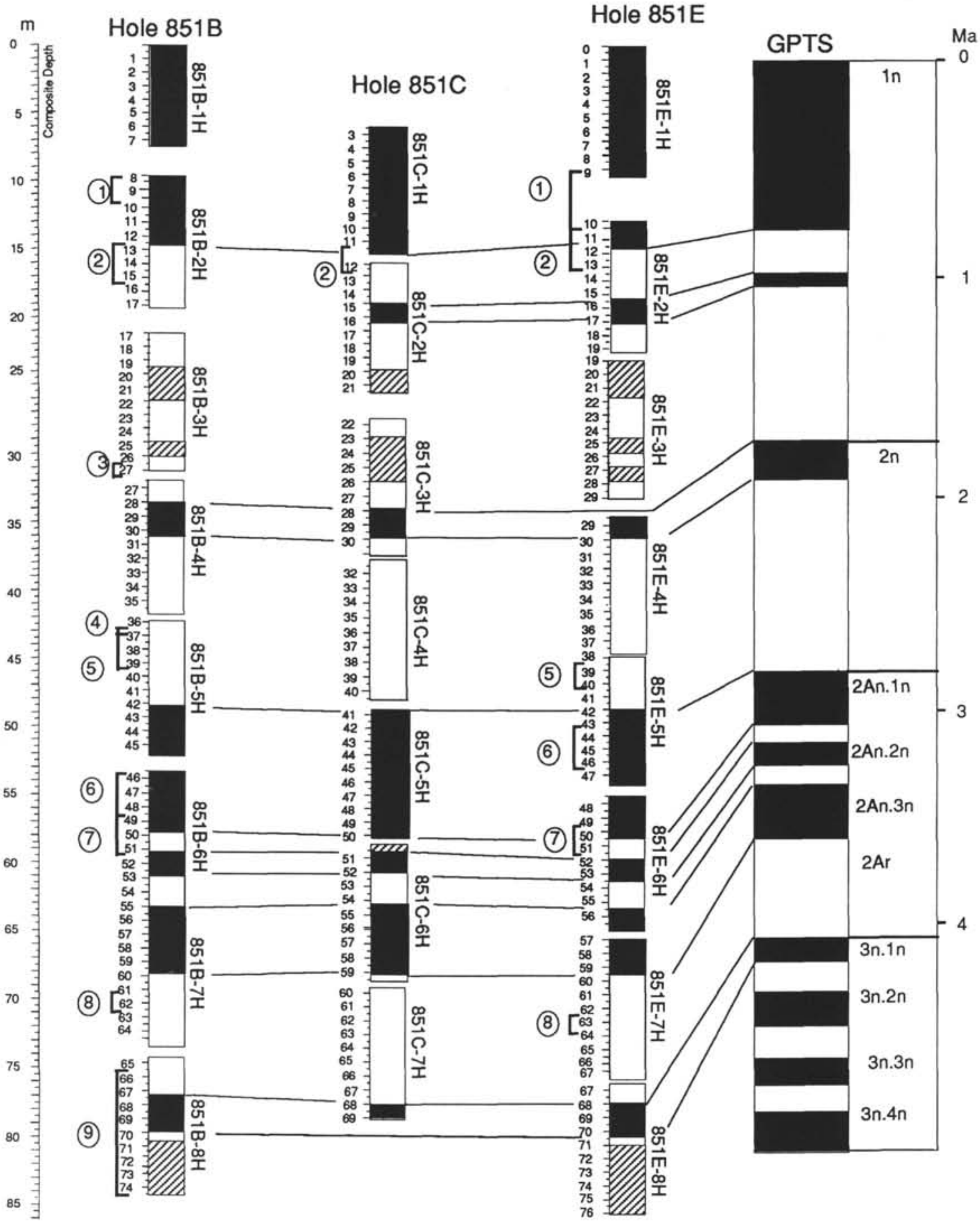

Figure 8. Diatom biostratigraphic events correlated with the paleomagnetic results (Schneider et al., this volume) for Site 851. Events were plotted both in mbsf and mcd. 1 = LO of *N. reinholdii*; 2 = LO of *N. fossilis*; 3 = LO of *R. praebergonii*; 4 = FO of *P. doliolus*; 5 = LO of *T. convexa* s.l.; 6 = LO of *N. jouseae*; 7 = FO of *R. praebergonii*; 8 = LO of *T. convexa*; 9 = LO of *A. elegans*.

approximates the upper portion of the interval between C3n.1n and C3n.2n. An age of 4.2 Ma was estimated for this event at this site.

8. FO *Thalassiosira convexa* var. *convexa*. The FO of this variety is well documented for use in the eastern equatorial Pacific (see Burckle, 1978; Burckle and Trainer, 1979; Barron, 1985a; and Baldauf, 1985) and equatorial Indian Ocean (Schrader, 1974). This event was calibrated to the upper Gilbert (lower C2An–upper C3n) by Burckle (1978). An age estimate of 3.6 Ma (3.75 Ma, using Cande and Kent, 1992) was determined by Burckle and Trainer (1979) and Barron (1985a).

The FO of *T. convexa* var. *convexa* is well constrained stratigraphically at numerous Leg 138 sites (Sites 846 through 851). Unfortunately, direct correlation with a reliable magnetostratigraphy occurs in Holes 845A (Figs. 5 and 6) and 852B (Fig. 9). In Hole 845A, this event correlates with the middle to upper portion of C2An and has an estimated age 3.64 to 3.79 Ma. The correlation of this event with the magnetostratigraphy in Hole 852B is less constrained. In Hole 852B, this event correlates with most of the interval representing C2An. The age of this event in Hole 852B is between 3.63 to 3.88 Ma. These age constraints are in agreement with the estimated age of 3.6

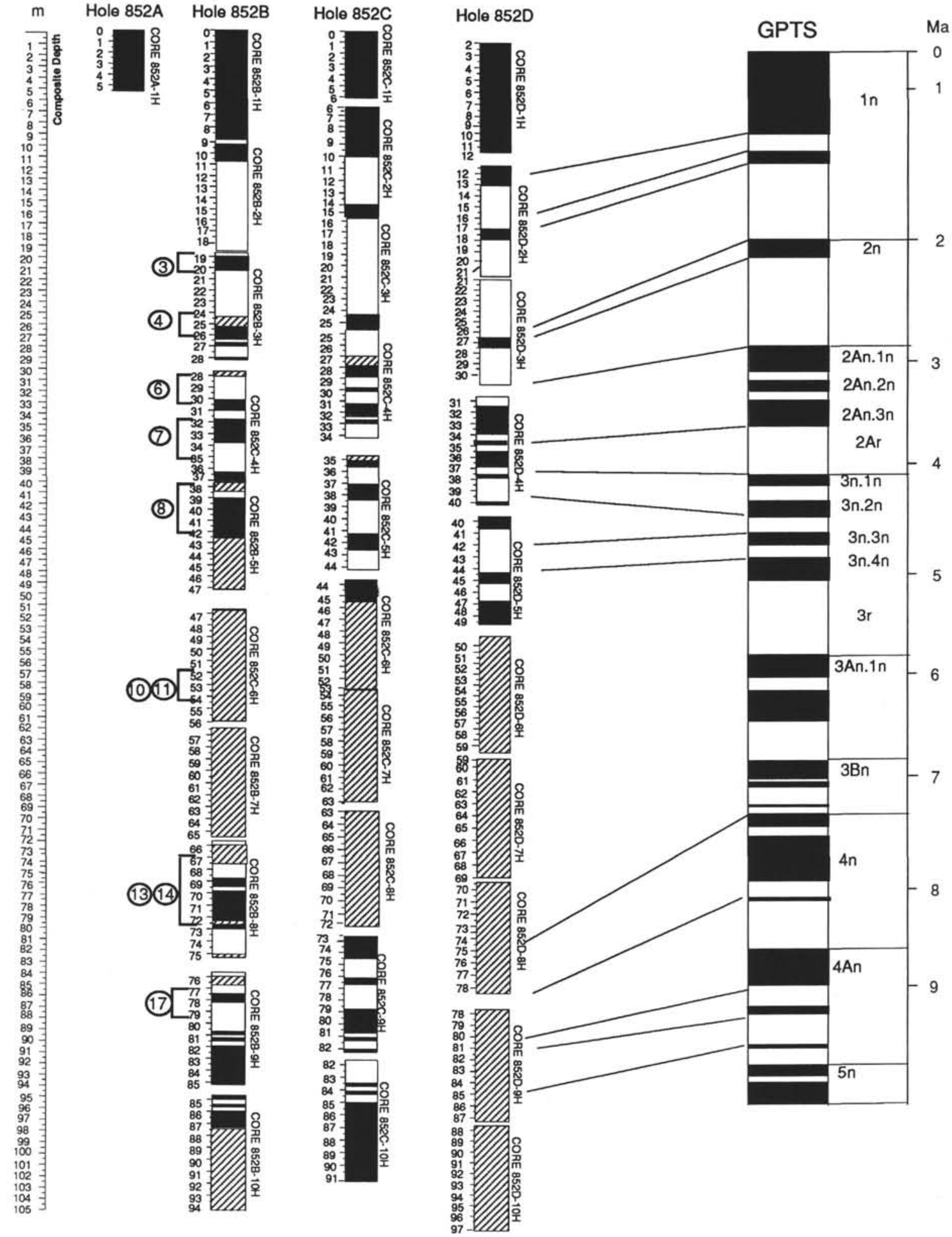

Figure 9. Diatom biostratigraphic events correlated with the paleomagnetic results (Schneider et al., this volume) for Site 852. Events were plotted in both mbsf and mcd. 3 = LO of *R. praebergoni*; 4 = FO of *P. doliolus*; 6 = LO of *N. jouseae*; 7 = FO of *R. praebergonii*; 8 = LO of *T. convexa*; 10 = LO of *N. cylindrica*; 11 = FO of *N. jouseae*; 13 = LO of *T. miocenica*; 14 = LO of *N. miocenica*; 17 = FO of *T. miocenica.*

Ma (3.75 Ma using Cande and Kent, 1992), assigned by Burckle and Trainer (1979) and Barron (1985a).

9. FO *Asteromphalus elegans.* Although this species occurs throughout the low latitudes of the world oceans, the stratigraphic occurrence of this species is poorly constrained. The stratigraphic continuity of this event is best known in the eastern equatorial Pacific (Burckle, 1978; Barron, 1985a, 1985b). In this region, Burckle (1978) calibrated this event to event a' of the Gilbert Chron (C3n.1n) and assigned an estimated age of 3.9 Ma (4.06 Ma, using Cande and Kent, 1992). Baldauf (1984, 1987) noted the occurrence of this species in the middle latitude North Atlantic, but noted that this species had a scattered and inconsistent stratigraphic occurrence.

The occurrence of this species in the Leg 138 sediments is scattered, resulting in this event being reasonably constrained only in Holes 848B and 851C. However, the paleomagnetic stratigraphy for these stratigraphic intervals is unreliable (see Fig. 7). In Hole 851C, the FO of *Asteromphalus elegans* approximates C3n.1n, suggesting an age somewhat similar to that determined by Burckle (1978), but additional samples are necessary to constrain this event further.

10. LO *Nitzschia cylindrica.* The LO of *N. cylindrica* is a useful secondary stratigraphic indicator for the equatorial Pacific (Burckle, 1978; Barron, 1985a, 1985b), the low to middle latitudes of the North Atlantic (Baldauf, 1984, 1987; Baldauf and Pokras, 1990), and the low latitudes of the Indian Ocean (Schrader, 1974). Burckle (1978) calibrated this event to event c' of the Gilbert Chron (C3n.3n) in the eastern equatorial Pacific. Both Burckle (1978) and Barron (1985a) assigned an age of 4.3 Ma (4.5 Ma, using Cande and Kent, 1992) to this event in the eastern equatorial Pacific.

The LO of *N. cylindrica* is constrained in the Leg 138 sediments at Sites 846 through 849, 851, and 852. Calibration of the Leg 138 magnetostratigraphy is completed in Holes 845B (Fig. 5), 848B (Fig. 7), and 852B (Fig. 9). However, the magnetostratigraphy is somewhat in question for Holes 848B and 852B. In Hole 845A, this event approximates the interval from the base of C3n.3n to the uppermost portion of C3n.4n. This event has an estimated age at this site of between 4.48 and 4.75 Ma. In Hole 852B, this event correlates with the uppermost portion of C3n.4n and has an tentative age of 4.82 to 4.9 Ma, slightly older than that derived by Burckle (1978). In Hole 848B, this event has a correlation similar to that in Hole 852B. However, the paleomagnetic stratigraphy above and below this event is poorly defined making these latter correlations questionable.

11. FO *Nitzschia jouseae.* This event is well documented for use through the warm water sphere, including the equatorial Pacific (Burckle, 1972 1977, 1978; Barron, 1985a, 1985b; Baldauf, 1985; Sancetta, 1984). In the middle latitudes of the North Atlantic, this event was recognized and determined to be stratigraphically useful by Baldauf (1984, 1987). Baldauf and Pokras (1990) also recognized the usefulness of this event in the low-latitude eastern Atlantic. The LO of *N. jouseae* has also been used as a zonal indicator in the Indian Ocean (Schrader, 1974). Burckle (1978) calibrated this event to the c' event of the Gilbert (C3n.3n) and assigned it an age of 4.5 Ma (4.73 Ma, using Cande and Kent, 1992).

This event has been stratigraphically constrained at Sites 844 through 850 and Sites 851 and 852. Paleomagnetic stratigraphy allows correlation of this event to the magnetostratigraphy (Schneider et al., this volume) for Holes 845B (Fig. 5) and 852B (Fig. 9). The FO of *N. jouseae* approximates the LO of *N. cylindrica* in both of these holes. In Hole 852B, the sample constraints are identical for both of these events. In Hole 845B, the FO of *N. jouseae* and the LO of *N. cylindrica* are observed in the same sample (138-845B-8H-2, 27 cm). The only difference is that the other constraining samples occur over a 2-m interval.

This event approximates the upper portion of C3n.4n at Site 852 and occurs in an interval associated with C3n.3n-C3n.4n at Site 845. Age estimates for this event range between 4.75 and 4.82 and between 4.56 and 4.7 Ma. These ages approximate the earlier calibration of Burckle (1978), who estimated an age of 4.5 Ma (4.75 Ma, using Cande and Kent) for this event.

12. FO *Thalassiosira oestrupii* group. Burckle (1978), Barron (1985a), and Baldauf (1985) discussed the stratigraphic usefulness of this event as a secondary stratigraphic marker for the eastern equatorial Pacific. Barron (1981) actually defined a *Thalassiosira oestrupii* Zone with the base of this zone defined by the FO of *T. oestrupii.* This zone was used for the middle latitude Pacific. A somewhat similar zone was developed for use in the southern ocean by Baldauf and Barron (1991). *T. oestrupii* also has been shown to be stratigraphically useful in the Indian Ocean (Schrader 1974) and the North Atlantic (Baldauf 1984, 1987; Baldauf and Pokras, 1990).

The FO of *T. oestrupii* has been calibrated to an interval just above Chron 5 (C3An) by Burckle (1978). Barron (1981) suggested that this event approximated the lowermost reversed interval of the Gilbert Chron (lower C3n) and had estimated an age of 5.1 Ma (5.42 Ma, using Cande and Kent, 1992). In the southern ocean, Baldauf and Barron (1991) also assigned an age of 5.1 Ma (5.42 Ma, using Cande and Kent, 1992) for this event. Note that Bodén (1992) recently completed a detailed taxonomic analysis of several forms of *Thalassiosira.* In doing so, he defined several new species, some of which were most likely grouped into *T. oestrupii* by previous researchers. In the Leg 138 sediments, we grouped various forms of *Thalassiosira* into the *T. oestrupii* group.

The FO of *T. oestrupii* group was observed in Holes 845A, 846B, and 846D. The paleomagnetics for Hole 845A suggest that the FO of this event approximates the middle portion of C3n and has an age of between 5.38 and 5.46 Ma. This age estimate is tentative, as this event occurs over an interval that represents a coring gap.

13. LO *Thalassiosira miocenica.* This event was used as a secondary stratigraphic indicator in the eastern equatorial Pacific by Burckle (1972, 1977, 1978), Barron (1985a, 1985b), and Baldauf (1985). This event also was recognized as being useful in the middle latitude North Atlantic (Baldauf 1984, 1987) and Indian Ocean (Schrader, 1974). The LO of *T. miocenica* approximates the FO of *T. oestrupii* and the *T. oestrupii* group and was calibrated to the lowermost Gilbert Chron (C3n) by Burckle (1978). This event has an estimated age of 5.1 Ma (5.42 Ma, using Cande and Kent, 1992).

The LO of *T. miocenica* is recorded and well constrained at Sites 845 through 847, 849, 850, and 852. Hole 845B (Fig. 5) has the most reliable magnetostratigraphy for correlation. At this site, this event was calibrated with the lowermost portion of C3n to the uppermost portion of C3An.1n in this hole and has an age of between 5.63 and 5.73 Ma. The slightly older age for this event compared to that of Burckle (1978) may result from the constraints of the paleomagnetic stratigraphy in the upper portion of Core 138-845B-9H (see Fig. 6).

14. LO *Nitzschia miocenica.* Similar to most of the other events discussed above, the LO of *N. miocenica* has been used as a stratigraphic marker in the low-latitude Pacific, the low- to middle-latitude North Atlantic, and the low-latitude Indian Ocean (Burckle, 1972, 1977, 1978; Barron, 1985a, 1985b; Baldauf, 1984, 1985, 1987; Schrader, 1974). In addition, this species was observed in the extreme southern latitudes of the Indian Ocean in the Kerguelen Plateau region and appeared to have a similar stratigraphic range as those determined elsewhere (Baldauf and Barron, 1991). In the eastern equatorial Pacific, Baldauf (1985) quantitatively determined that the last abundant occurrence of this species was at 5.6 Ma (6.00 Ma, using Cande and Kent, 1992), about 0.1 Ma prior to the LO of this species.

Although this event has been determined at Sites 844 through 846, 849, 850, and 852, the combined biostratigraphy and magnetostratigraphy can be correlated in Holes 845B and 852B. In Hole 845B, this event correlates with the lowermost portion of C3An.1n and the uppermost portion of the reversed interval between C3An.1n and C3An.2n. An age estimate cannot be calculated as the base of C3An.2n is uncertain in this hole. The LO of *N. miocenica* has a similar correlation in Hole 852B; however, the placement of the base of C3An.2n also is uncertain in this hole.

Stratigraphic events that occur in sediments older than those that contain the LO of *N. miocenica* are less tightly constrained either by the sampling interval, preservation, or by the uncertainty in the magnetostratigraphic record. As such, these are not discussed here.

16. LO *Thalassiosira praeconvexa.* This event marks the Subzone A/B boundary of the *Thalassiosira convexa* Zone, as used by Burckle (1977), Barron (1985a, 1985b), and Baldauf and Iwai (this study). This event has been recognized throughout the low-latitude Pacific (Barron, 1985a, 1985b) the low- and middle-latitude North Atlantic (Baldauf, 1984, 1987), and the southern portion of the Indian Ocean (Baldauf and Barron, 1991). Burckle (1978) calibrated this event to paleomagnetic Chron C3An.2n and assigned an age of 5.8 Ma (6.25 Ma, using Cande and Kent, 1992).

This event was identified at Leg 138 Sites 844 and 846 through 851 and has been calibrated at Site 844 to an interval equivalent to the uppermost portion of paleomagnetic Chron C3An.2n to the lowermost portion of C3An.1n (Fig. 3). Based on this correlation, this event has an estimated age of 6.15 Ma at Site 844 (Fig. 3).

18. FO *Thalassiosira convexa.* Burckle (1972), Barron (1985a, 1985b), and Baldauf (1984, 1987), among others, have used this event to mark the base of the *T. convexa* Zone. Although Schrader (1974) recorded *T. convexa* in samples from DSDP Site 238 in the Indian Ocean, Schrader preferred to use the FO of *T. miocenica* to mark the base of his Zone 15. Barron (1985a, 1985b) and Baldauf (1984, 1987) indicated that the FO of *T. miocenica* and *T. convexa* var. *aspinosa* are contemporaneous, and any difference in the stratigraphic placement of these events is a result of difference in species concepts.

Burckle (1978) calibrated the FO of *T. convexa* to paleomagnetic Chron C3An.2n and assigned an age of 6.1 Ma (6.54 Ma, using Cande and Kent, 1992). This event is recorded at Sites 844 through 846 and 848 through 851. At Site 844, this event correlates with the interval equivalent to the lower portion of paleomagnetic event C3An.2n to the upper portion of C3An.2n. An estimated age of 6.15 to 6.42 Ma was calculated for this event at Site 844, based on sampling constraints.

20. FO *Nitzschia miocenica.* Burckle (1972, 1977), Barron (1985a, 1985b), and Baldauf and Iwai (this study) used this event to mark the base of the *N. miocenica* Zone. This event also is stratigraphically useful in the low-latitude Indian Ocean and has been used to mark the base of Zone 17 (Schrader, 1974). This event was not recognized in the middle- to high-latitude North Atlantic as *N. miocenica* has a scattered occurrence in this region (Baldauf, 1984, 1987). Barron (1992) calibrated this event to paleomagnetic event C4n.1n and assigned an estimated age of 6.75 Ma (7.33 Ma, using Cande and Kent, 1992).

This event is recorded at Sites 844, 845, and 848 through 851. Although present sample constraints are broad, this event at Site 844 correlates with an interval that represents the lower portion of paleomagnetic event C3Bn.1n to the upper portion of C4n.1n and has an age of between 6.89 and 7.32 Ma.

21. LO *Rossiella paleacea* This event was used as a secondary marker species by Burckle (1978), by Barron (1985a, 1985b) for the eastern equatorial Pacific, and as a primary stratigraphic indicator by Schrader (1974) for the Indian Ocean. Burckle (1978) correlated this event to paleomagnetic event C4n.1n and assigned it an age of 6.8 Ma (7.40 Ma, using Cande and Kent, 1991). *R. paleacea* has occurred consistently throughout Sites 844, 848 and 850. Sample constraints for this event at Site 844 are similar to those for the FO of *N. miocenica.* Because of this, this event at Site 844 has an age constraint of 6.89 to 7.32 Ma.

22. FO *Nitzschia reinholdii. N. reinholdii* Kanaya ex Barron and Baldauf (1986) is a secondary stratigraphic marker that is useful in the low-latitude Pacific. Although this event can also be recognized in the North Atlantic and elsewhere, reliable calibration to a paleomagnetostratigraphy has been limited. Barron (1985a) assigned an age of 7.3 Ma (7.94 Ma, using Cande and Kent, 1992) for this event.

This event was observed at Sites 844 and 849. At Site 844, this event correlates with an interval that represents the lower portion of paleomagnetic event C4n.1n to the upper portion of C4n.2n and has an age older than 7.32 Ma. The lower age constraint cannot be directly correlated with the magnetostratigraphy at Site 844.

CONCLUSIONS

Leg 138 provided a unique opportunity to examine the diatom assemblages from numerous near-continuous stratigraphic sequences from the eastern equatorial Pacific Ocean. Results of this study show that the standard diatom zonation of Barron (1985a, 1985b), for the most part, has been useful throughout this region. The somewhat inconsistent occurrence of *Rhizosolenia praebergonii* in Leg 138 samples required that the *Rhizosolenia praebergonii* and *Nitzschia jouseae* zones (as used by Barron, 1985a) be replaced by the *Nitzschia marina* and *Nitzschia jouseae* zones, as discussed by Baldauf (1984).

The near-continuous stratigraphic sequences and the excellent paleomagnetostratigraphy from several of the Leg 138 sites also allowed us to reevaluate previous age determinations for most of the Quaternary through upper Miocene diatom biostratigraphic events. In doing so, the age estimates determined here approximate those previously determined, once the previous ages were adjusted to Cande and Kent's chronology (1992).

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