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23. BIOSTRATIGRAPHIC SUMMARY FOR LEG 138[1]

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ABSTRACT

The sediments recovered during Leg 138 have provided us with a remarkable opportunity to improve the stratigraphic framework for east-central Pacific Ocean Neogene age sediments. In this chapter, we review some of the data that have been generated and derive best estimates for the ages of potentially useful biostratigraphic datums, within the paleomagnetic temporal framework of Shackleton et al. determined for this volume and also, for comparison, according to the 1985 and 1992 paleomagnetic time scales of Berggren et al. and Cande and Kent, respectively.

INTRODUCTION

Despite advances in magnetostratigraphy, stable isotope stratigraphy and various manifestations of cyclostratigraphy, it is still true that biostratigraphy is the essential tool by which the geological evidence for environmental changes is put into a temporal framework. Advances in biostratigraphy and in other tools for stratigraphic correlation go hand in hand, and, in this chapter, we link the multiple stratigraphic and geochronological efforts that have been devoted to Leg 138 sediments with a view to further improvements in the basis of Neogene biostratigraphy and biochronology.

Remarkably high resolution was achieved in the shipboard biostratigraphies for all the major microfossil groups examined (Mayer, Pisias, Janecek, et al., 1992). Moreover, considerable further advances have been made in the ensuing months. Detailed descriptions of the biostratigraphy of the eleven sites cored during Leg 138 are given elsewhere: Baldauf and Iwai (this volume) for diatoms; Raffi and Flores (this volume) for nannofossils; Moore (this volume) for radiolarians; Vincent and Toumarkine (this volume) for Miocene foraminifers; Shackleton, Hall, and Pate (this volume) for foraminifers in Site 846. Raffi et al. (this volume) have also reviewed and synthesized the nannofossil biostratigraphy. In this chapter, we discuss the data primarily in relation to the reliability of, and improved age calibrations of, a large number of biostratigraphic datum levels. The locations of the Leg 138 sites and of others discussed in the text are given in Table 1.

Shipboard work was conducted using calibrations based on the summaries by Berggren et al. (1985b). Much of the information for Pacific sediments was summarized by Barron et al. (1985a) in a review that was largely based on the successes of Deep Sea Drilling Project (DSDP) Leg 85 (Pisias et al., 1985; Barron et al., 1985b).

TIME SCALE

The calibrations attempted here are possible in part because age models that were developed for the sites (Shackleton et al., this volume) were independent of the biostratigraphy to a large extent. These age models originated from an astronomical calibration of GRAPE density cycles through the entire Pliocene. Because several sites have good magnetic polarity records, this enabled the Pliocene magnetic polarity sequence to be dated astronomically, confirming the pioneering work of Hilgen (1991a, 1991b). This calibration, together with a new radiometric date for the top of C5n obtained by Baksi (1992, 1993), was used to put a new age calibration on the revised polarity sequence compiled by Cande and Kent (1992). Table 2 gives the complete polarity time scale of Shackleton et al. (this volume), henceforth, SCHPS94. The age models developed for each site are very detailed because they entailed correlating individual GRAPE density maxima and minima to insolation maxima and minima; they are listed as Tables 1 to 11 in Shackleton et al. (this volume).

Reliable magnetostratigraphy was obtained for major segments of the polarity scale in several sites, as follows: in Site 844, from the Brunhes to C5n; in Site 845, from the Gauss to C5ABn; in Site 848, from the Brunhes to the Gilbert and from C4 to C5n; in Site 850, from the basal Matuyama to the uppermost Gilbert; in Site 851, from the Brunhes to the Cochiti; in Site 852, from the Brunhes to C3A and from C4A to C5n; in Site 853, from the Brunhes to C4; and in Site 854, from the Brunhes to C5n. Details are given in the site chapters in Mayer, Pisias, Janecek, et al. (1992), but it should be noted that part of the record of Site 844 has been reinterpreted by Schneider (this volume), who also provided additional data from Site 845. Despite this broad coverage, we think that, for the section younger than about 10 Ma, the reliability of the intersite correlations based on GRAPE density fluctuations is so good that datum age estimates should be based on all sites rather than being based primarily on those sites that preserve a magnetostratigraphic record. From that point to the base of the magnetostratigraphic record of Site 845, we consider estimates based on Site 845 to be the most reliable.

The upper and lower depth limit of each datum (mcd) in each site is given in Table 3 (complete table on CD-ROM, back pocket), which summarizes data in the individual chapters referred to above. We have obtained the ages of the upper and lower limits defining each datum in each site, using the age models given in Tables 1 to 11 in Shackleton et al. (this volume); these are given in Table 4. In Table 5 (complete table on CD-ROM, back pocket), all the estimates for each datum are sorted by age. This provides an immediate indication of the apparent diachrony for each datum; the total (observed) diachrony is the amount by which the oldest age for the upper limit of the datum exceeds the youngest age estimate for the lower limit of the datum.

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Table 1. Location of sites discussed.

Site	Longitude	Latitude	Depth (m)
ODP 844	7°55.279′N	90°28.846′W	3414.5
ODP 845	9°34.950′N	94°35.448′W	3704.2
ODP 846	3°05.696′S	90°49.078′W	3307.3
ODP 847	0°11.593′N	95°19.227′W	3334.3
ODP 848	2°59.634′S	110°28.791′W	3853.4
ODP 849	0°10.983′N	110°31.183′W	3837.1
ODP 850	1°17.837′N	110°31.283′W	3786.1
ODP 851	2°46.223′N	110°34.308′W	3761.3
ODP 852	5°17.566′N	110°04.579′W	3861.0
ODP 853	7°12.661′N	109°45.084′W	3726.0
ODP 854	11°13.433′N	109°35.652′W	3567.9
DSDP 608	42°50.205′N	23°05.252′W	3526
DSDP 573	0°29.91′N	133°18.57′W	4301
DSDP 574	4°12.52′N	139°19.81′W	4561
ODP 709	3°54.9′S	60°33.1′W	3038
ODP 710	4°18.7′S	60°58.8′E	3824
ODP 714	5°03.6′N	73°47.2′E	2038

The figures in Tables 4 and 5 have been used to make best estimates of the age of each datum.

BEST ESTIMATES FOR BIOSTRATIGRAPHIC DATUMS

It is not obvious what is the most reliable means for obtaining a "best estimate" for each datum. For the majority of datums, we have made the biostratigrapher's assumption, that the datum is "synchronous" and that the "scatter" is noise. In these cases, our aim was to estimate the age of least conflict, rounded to the nearest 0.01 Ma. We worked with two different approaches. For the first approach, we obtained the median of the upper limits, and the median of the lower limits, for each datum. The datum age is the mean of these two figures; obviously, the smaller the difference between the median upper and lower limits, the better the estimate. We chose to use the median, rather than the mean, because the mean is frequently heavily weighted toward the distant values obtained in sites that were sampled at wider depth intervals. For the second approach, we simply took the midpoint between the oldest of all the upper limits, and the youngest of all the lower limits. If the diachrony is large, this method places undue weight on discrepant estimates rather than on the best estimates. We have assumed that if the diachrony is less than the difference between the medians, the second method proves the more reliable estimate. A negative figure for diachrony means that there is no overlap between lower and upper bounds on the estimates for the datum, as one would expect if the datum is synchronous and there are no inconsistencies in the age models or the observations. Moore (this volume) used a graphic method that is related to our second approach, but which is even more conservative. Table 6 gives the estimates of the ages of every datum based on each of our two methods.

In the majority of cases, we assumed that the best estimate for the age of a datum was given by whichever of the two methods outlined above provided the better-constrained estimate. Only in the relatively few cases where diachrony is very clear, have we taken a different approach and looked for the youngest, well-constrained sample for an extinction, and the oldest, well-constrained sample for a first appearance. For ages younger than about 10 Ma, we have assumed that the age models are equally good for all sites, except that because it was not possible to develop high-resolution age models based on GRAPE density for Sites 844 and 845 (and parts of Sites 852, 853, and 854), we have used judgment to exclude discrepant estimates from those sites. On the other hand, for the late Miocene, we paid special attention to estimates that have been directly derived from the magnetostratigraphy in the same site. For ages between 13.25 and 10 Ma, we have assumed that estimates made in Site 845, which has a well-preserved magnetostratigraphy, are more reliable than those based on other sites. This is appropriate since it has not so far proved possible to develop detailed GRAPE density correlations between sites for the interval older than 10 Ma. We have no age control other than biostratigraphy for those segments of the age models older than 13.25 Ma for any site. However, it is still useful to examine the degree of consistency among the age estimates.

Moore et al. (1993) took a different approach; they examined the spatial distribution of radiolarian datum ages among the Leg 138 sites. We have not taken this approach for the other microfossil groups for two reasons. First, spatially variable preservation has a more adverse effect on the other groups. Second, although Moore (this volume) attempted to cover all sites at comparable resolution, not all sites were examined at the same resolution for the other fossil groups.

In Table 7, we show four ages for each datum. First, we give the best estimate as estimated above, based on the time scale of Shackleton et al. (this volume) and, hence, related to the magnetic polarity time scale in that chapter (SCHPS94). Second, we recalibrated these estimates to the polarity time scale (CK92) of Cande and Kent (1992). We have not discussed these estimates, but present them for the benefit of those who may choose to work with that scale. Third, we recalibrated the age estimates back to the polarity scale (BKF85) presented by Berggren et al. (1985a). This scale was used for the Neogene time scale of Berggren et al. (1985b), which formed the basis for shipboard work during this and many other ODP cruises. Thus, the figures in this column (labeled "BKF85") may be compared with other estimates that were also based on the BKF85 polarity time scale. Fourth, we give the ages (where available) for those datums, as listed by the Shipboard Scientific Party (1992, tables 4–7). Because most of these ages are derived from BKVC85, they are also based on the BKF85 polarity scale.

In Figure 1, we show the differences between our new estimates for the datum ages and those used by the Shipboard Scientific Party (1992, tables 4–7). Although Figure 1 correctly shows the differences between our new calibrations and those previously in use, it is misleading because it combines the effect of using a new magnetostratigraphic time scale with the effect of improving calibrations with respect to the magnetostratigraphy. For example, the trend of deviations away from the zero line arises from the difference between our magnetostratigraphic time scale and the one that was the basis for the ages used by the Shipboard Scientific Party (1992). Because the objective of this chapter is to examine the biostratigraphic calibrations, we have removed this trend in Figure 2.

In Figure 2, we show differences between our new estimates for the datum ages after recalculation with respect to the BKF85 magnetostratigraphic time scale and the ages used by the Shipboard Scientific Party (1992). Several comments may be made about this figure, which shows the extent to which our calibrations with respect to the magnetic polarity scale differ from those of the Shipboard Scientific Party (1992). First, most of the youngest datums have been studied widely and their ages are already well established with reference to the oxygen isotope record (e.g., Hays and Shackleton, 1976; Thierstein et al., 1976; Morley and Shackleton, 1979; Backman and Shackleton, 1983). As might be expected, in Figure 2, deviations for these datums fall close to the zero line. The diatom datums had not previously been examined in the same way, and we have almost certainly improved their age estimates. Second, in view of the fact that the magnetostratigraphy of Leg 138 extended only to 13.25 Ma, ages older than that are dependent on earlier biostratigraphic correlations. Third, the data in Figure 2 are not random; there is a clear tendency for nearby estimates to diverge in the same direction, especially if they are for the same microfossil group. This suggests that there were indeed systematic errors in earlier age estimates and that these were aggravated by the fact that it is only rarely possible to examine all microfossil groups satisfactorily in the same sections.

NANNOFOSSIL CALIBRATIONS

In the interval from 9 to 13 Ma, there are surprising discrepancies between our estimates and those used earlier that deserve comment.

Table 2. Magnetic polarity time scale used in this work (SCHPS94) and in previous studies (BKF85, CK92).

Name (BKF85 or conventional anomaly)	BKF85 Age (Ma)	CK92 Age (Ma)	SCHPS94 Age (Ma)	Name unified (CK92)
Brunhes/Matuyama	0.73	0.780	0.780	C1n (o)
Jaramillo (t)	0.91	0.984	0.990	C1r.1n (t)
Jaramillo (o)	0.98	1.049	1.070	C1r.1n (o)
Olduvai (t)	1.66	1.757	1.770	C2n (t)
Olduvai (o)	1.88	1.983	1.950	C2N (o)
Matuyama/Gauss	2.47	2.600	2.600	C2An.1n (t)
Kaena (t)	2.92	3.054	3.054	C2An.1n (o)
Kaena (o)	2.99	3.127	3.127	C2An.2n (t)
Mammoth (t)	3.08	3.221	3.221	C2An.2n (o)
mammoth (o)	3.18	3.325	3.325	C2An.3n (t)
Gauss/Gilbert	3.40	3.553	3.610	C2An.3n (o)
Cochiti (t)	3.88	4.033	4.188	C3n.1n (t)
Cochiti (o)	3.97	4.134	4.320	C3n.1n (o)
Nunivak (t)	4.10	4.265	4.478	C3n.2n (t)
Nunivak (o)	4.24	4.432	4.604	C3n.2n (o)
Sidufjall (t)	4.40	4.611	4.782	C3n.3n (t)
Sidujfall (o)	4.47	4.694	4.880	C3n.3n (o)
Thvera (t)	4.57	4.812	4.981	C3n.4n (t)
Thvera (o)	4.77	5.046	5.228	C3n.4n (o)
3A	5.35	5.705	5.875	C3An.1n (t)
3A	5.53	5.946	6.122	C3An.1n (o)
3A	5.68	6.078	6.256	C3An.2n (t)
3A	5.89	6.376	6.555	C3An.2n (o)
	6.37	6.744	6.919	C3Bn (t)
	6.50	6.901	7.072	C3Bn (o)
4	6.70	7.245	7.406	C4n.1n (t)
4	6.78	7.376	7.533	C4n.1n (o)
4	6.85	7.464	7.618	C4n.2n (t)
4	7.28	7.892	8.027	C4n.2n (o)
4	7.35	8.047	8.174	C4r.1n (t)
4	7.41	8.079	8.205	C4r.1n (o)
4A	7.90	8.529	8.631	C4An (t)
4A	8.21	8.861	8.945	C4An (o)
4A	8.41	9.069	9.142	C4Ar.1n (t)
4A	8.50	9.149	9.218	C4Ar.1n (o)
	8.71	9.428	9.482	C4Ar.2n (t)
	8.80	9.491	9.543	C4Ar.2n (o)
5	8.92	9.592	9.639	C5n.1n (t)
5	10.42	10.834	10.839	C5n.2n (o)
	10.54	10.940	10.943	C5r.1n (t)
	10.59	10.989	10.991	C5r.1n (o)
	11.03	11.378	11.373	C5r.2n (t)
	11.09	11.434	11.428	C5r.2n (o)
5A	11.55	11.852	11.841	C5An.1n (t)
5A	11.73	12.000	11.988	C5An.1n (o)
5A	11.86	12.108	12.096	C5An.2n (t)
5A	12.12	12.333	12.320	C5An.2n (o)
	12.46	12.618	12.605	C5Ar.1n (t)
	12.49	12.649	12.637	C5Ar.1n (o)
	12.58	12.718	12.705	C5Ar.2n (t)
	12.62	12.764	12.752	C5Ar.2n (o)
5AA	12.83	12.941	12.929	C5AAn (t)
5AA	13.01	13.094	13.083	C5AAn (o)
5AB	13.20	13.263	13.252	C5ABn (t)
5AB	13.46	13.476	13.466	C5ABn (o)
5AC	13.69	13.674	13.666	C5ACn (t)
5AC	14.08	14.059	14.053	C5ACn (o)
5AD	14.20	14.164	14.159	C5ADn (t)
5AD	14.66	14.608	14.607	C5ADn (o)
5B	14.87	14.800	14.800	C5Bn.1n (t)
5B	14.96	14.890	14.890	C5Bn.1n (o)
5B	15.13	15.038	15.038	C5Bn.2n (t)
5B	15.27	15.162	15.162	C5Bn.2n
5C	16.22	16.035	16.035	C5Cn.1n (t)
5C	16.52	16.318	16.318	C5Cn.1n (o)
5C	16.56	16.352	16.352	C5Cn.2n (t)
5C	16.73	16.515	16.515	C5Cn.2n (o)
5C	16.80	16.583	16.583	C5Cn.3n (t)
5C	16.98	16.755	16.755	C5Cn.3n (o)
5D	17.57	17.310	17.310	C5Dn (t)
5D	17.90	17.650	17.650	C5Dn (o)
5E	18.56	18.317	18.317	C5En (t)
5E	19.09	18.817	18.817	C5En (o)
6	19.35	19.083	19.083	C6n (t)
6	20.45	20.162	20.162	C6n (o)
6A	20.88	20.546	20.546	C6An.1n (t)
6A	21.16	20.752	20.752	C6An.1n (o)
6A	21.38	21.021	21.021	C6An.2n (t)
6A	21.71	21.343	21.343	C6An.2n (o)
6AA	21.90	NA		
6AA	22.06	NA		
6AA	22.25	21.787	21.787	C6AAn (t)
6AA	22.35	21.877	21.877	C6AAn (o)
6B	22.57	22.166	22.166	C6AAr.1n (t)
	NA	22.263	22.263	C6AAr.1n (o)
	NA	22.471	22.471	C6AAr.2n (t)
6B	22.97	22.505	22.505	C6AAr.2n (o)
6C	23.27	22.599	22.599	C6Bn.1n (t)
6C	23.44	22.760	22.760	C6Bn.1n (o)
6C	23.55	23.357	23.357	C6Cn.1n (t)
6C	23.79	23.537	23.537	C6Cn.1n (o)
6C	24.04	23.678	23.678	C6Cn.2n (t)
6C	24.21	23.800	23.800	C6Cn.2n (o)
	NA	23.997	23.997	C6Cn.3n (t)
	NA	24.115	24.115	C6Cn.3n (o)
7	25.5	24.722	24.722	C7n.1n (t)

Notes: BKF85 = Berggren et al. (1985a), CK92 = Cande and Kent (1992), and SCHPS94 = Shackleton et al. (this volume). (t) = termination and (o) = onset. In BKF85 column, NA = not present in Berggren et al. (1985a). In CK92 column, NA = exact equivalent not present in Cande and Kent (1992).

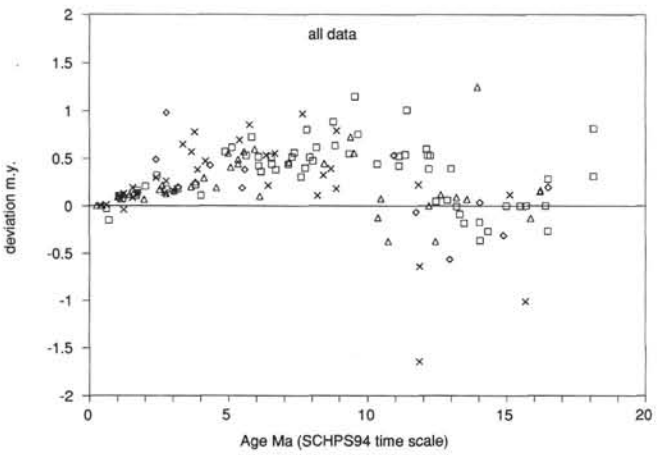

Figure 1. Differences between literature ages (Shipboard Scientific Party, 1992, largely based on, or intended to be consistent with, Berggren et al., 1985b) and ages estimated on the basis of Leg 138 results, based on the SCHPS94 time scale (Shackleton et al., this volume). Open squares = diatoms, open diamonds = foraminifers, open triangles = nannofossils, and crosses = radiolarians.

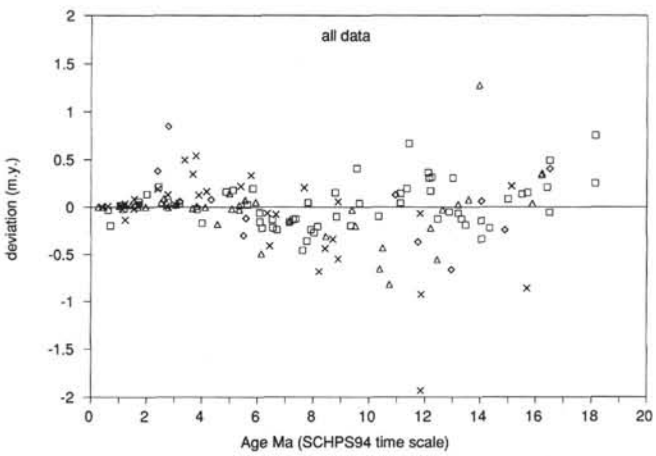

Figure 2. Differences between literature ages (Shipboard Scientific Party, 1992, largely based on, or intended to be consistent with, Berggren et al., 1985b) and ages estimated on the basis of Leg 138 results, but recalculated in terms of the magnetic polarity time scale used by Berggren et al. (1985a). Symbols as in Figure 1.

Table 3. Depths (mcd) of datums in Leg 138 sites.

		844 (t)	844 (o)	845 (t)	845 (o)	846 (t)	846 (o)	847 (t)	847 (o)	848 (t)	848 (o)
t	*N. reinholdii*	NA	NA	23.15	25.02	21.37	23.75	12.37	14.83	8.44	12.27
t	*N. fossilis*	1.20	2.40	21.25	24.25	23.75	26.22	16.21	20.05	8.44	12.27
t	*R. matuyama*	NA	NA	24.25	25.75	34.63	39.21	NA	NA	NA	NA
b	*R. matuyama*	NA	NA	25.75	27.25	49.95	50.74	NA	NA	NA	NA
t	*R. praebergonii* var. *robusta*	NA	NA	NA	NA	67.00	67.50	52.20	54.56	24.35	25.68
b	*P. dolius*	17.00	19.92	38.62	39.91	73.30	74.00	67.35	68.85	28.06	28.25
t	*T. convexa*	24.30	28.60	46.81	48.31	80.50	80.80	79.78	81.01	29.75	30.51
t	*N. jouseae*	17.55	24.93	50.66	51.30	107.10	108.70	92.58	94.83	31.35	32.75
b	*R. praebergonii*	19.92	24.93	51.30	53.16	125.50	125.70	102.91	104.10	34.35	34.64
b	*T. convexa* f. *convexa*	NA	NA	61.16	62.66	148.70	149.60	121.23	124.61	37.55	39.05
b	*A. elegans*	NA	NA	NA	NA	NA	NA	127.10	135.05	35.52	43.55
t	*N. cylindrica*	NA	NA	72.67	74.17	191.02	193.76	145.83	153.76	43.55	46.18
b	*N. jouseae*	24.93	37.85	71.17	72.67	202.45	203.50	177.25	180.25	48.60	50.75
t	*T. miocenica*	36.00	37.85	86.31	87.61	233.45	234.25	184.54	193.87	NA	NA
b	*T. oestrupii*	NA	NA	79.60	80.65	233.45	234.25	NA	NA	NA	NA
t	*N. miocenica*	NA	NA	89.31	90.61	249.90	250.26	193.87	204.90	59.10	63.06
t	*N. miocenica* var. *elongata*	33.00	36.00	NA	NA	250.26	261.18	NA	NA	63.60	65.07
t	*T. praeconvexa*	24.93	37.85	NA	NA	250.26	261.18	215.60	222.75	63.60	69.35
t	*R. praepaleacea*	NA	NA	NA	NA	NA	NA	NA	NA	69.35	70.85
b	*T. miocenica*	NA	NA	92.08	102.09	266.01	267.22	NA	NA	70.85	71.85
b	*T. convexa* var. *aspinosa*	37.85	39.35	92.08	102.09	266.01	267.22	NA	NA	70.85	71.85
b	*T. praeconvexa*	39.35	41.55	NA	NA	267.22	271.90	NA	NA	72.35	73.85
t	*N. porteri*	NA	NA	NA	NA	283.00	284.05	NA	NA	NA	NA
b	*N. miocenica*	42.33	43.85	92.37	107.06	288.30	288.70	NA	NA	80.16	80.75
t	*R. paleacea*	42.33	43.85	NA	NA	293.60	293.80	NA	NA	80.16	80.75
t	*T. burckliana*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*N. reinholdii*	43.85	45.35	NA	NA	NA	NA	NA	NA	NA	NA
t	*A. ellipticus* var. *javanicus*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*N. marina*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*N. cylindrica*	47.80	49.30	NA	NA	309.60	310.20	NA	NA	NA	NA
t	*T. yabei*	46.55	47.80	121.79	123.69	310.00	310.20	NA	NA	NA	NA
b	*A. nodulifer* var. *cyclops*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*C. loeblichii*	53.80	56.62	NA	NA	NA	NA	NA	NA	NA	NA
b	*N. fossilis*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*T. burckliana*	53.80	56.62	NA	NA	NA	NA	NA	NA	NA	NA
b	*C. loeblichii*	56.62	68.76	NA	NA	NA	NA	NA	NA	NA	NA
t	*D. hustedtii*	65.70	68.76	134.74	145.65	328.44	328.60	NA	NA	NA	NA
t	*A. moronensis*	69.86	71.35	NA	NA	NA	NA	NA	NA	NA	NA
b	*A. ellipticus* f. *lanceolata*	NA	NA	NA	NA	337.48	347.78	NA	NA	NA	NA
b	*R. paleacea* var. *elongata*	NA	NA	NA	NA	355.00	356.20	NA	NA	NA	NA
t	*C. gigas* v. *diorama*	NA	NA	166.35	170.64	355.00	356.20	NA	NA	NA	NA
t	*S. jouseana*	89.75	100.90	NA	NA	NA	NA	NA	NA	NA	NA
t	*C. coscinodiscus*	89.75	100.90	NA	NA	355.00	356.20	NA	NA	NA	NA
t	*A. ingens*	123.12	132.75	188.97	190.96	371.70	373.83	NA	NA	NA	NA
t	*C. pulchellus*	123.12	132.25	176.76	188.97	NA	NA	NA	NA	NA	NA
t	*N. porteri*	NA	NA	NA	NA	373.83	376.63	NA	NA	NA	NA
b	*T. brunii*	123.12	132.95	NA	NA	373.83	374.00	NA	NA	NA	NA
b	*C. gigas* v. *diorama*	NA	NA	NA	NA	388.50	389.40	NA	NA	NA	NA
t	*A. californicus*	126.15	132.75	NA	NA	NA	NA	NA	NA	NA	NA
t	*C. lewisianus*	147.71	152.82	205.15	211.06	387.00	390.30	NA	NA	NA	NA
t	*T. tappanae*	152.82	163.61	NA	NA	NA	NA	NA	NA	NA	NA
b	*T. cinnamoneum*	157.70	167.61	NA	NA	NA	NA	NA	NA	NA	NA
b	*D. simonsenii*	163.61	172.67	NA	NA	NA	NA	NA	NA	NA	NA
t	*C. peplum*	172.67	183.48	251.00	270.75	NA	NA	NA	NA	NA	NA
b	*A. ellipticus*	183.48	193.03	NA	NA	NA	NA	NA	NA	NA	NA

Notes: Full generic names appear in Table 6. In column headings, (t) = termination, and (o) = onset. In first column, t = top of range, b = bottom of range, tc = top of common occurrence, and bc = bottom of common occurrence. NA = not present.

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First, our age for the base of *Discoaster hamatus,* when converted back to BKF85, is 9.87 Ma, whereas Backman et al. (1990) derived an age of 10.50 Ma at tropical Indian Ocean DSDP Site 710 with primary magnetostratigraphic control. However, Olafsson (1991) obtained an age of 9.9 Ma in Site 608 in the North Atlantic, also with primary magnetostratigraphy. The base of C5N.2n is more securely determined both in that site and in Site 845 than in Site 710. We conclude that our estimate is probably better than that of Backman et al. (1990).

The upper limit of *Coccolithus miopelagicus* in Site 608 is some distance below the base of *Discoaster hamatus* (Olafsson, 1991), whereas the two datums are consistently close to each other in Leg 138 sites (but in both regions, the upper limit of *C. miopelagicus* lies between the first occurrences of *Catinaster coalitus* and *D. hamatus*). Our estimate for the age of the base of *D. hamatus* is consistent with that of Olafsson (1991). Thus, it seems likely that *C. miopelagicus* disappeared earlier in the region of Site 608 than in the equatorial Pacific and, hence, that ours is the more reliable estimate of the true last appearance datum (LAD) of the species.

The base of *Catinaster coalitus* was estimated at 11.1 Ma by Backman et al. (1990), whereas our estimate is equivalent to 10.31 Ma on the BKF85 scale. However, Backman et al. (1990) based their estimate on an interpolation between the base of *Discoaster hamatus* (for which they used an age of 10.5 Ma) and the upper limit of *Sphenolithus heteromorphus* at 13.5 Ma; their estimate would be closer to ours using our age (discussed above) for the base of *D. hamatus,* and we conclude that our estimate is reliable.

Our age for the upper limit of *Coronocyclus nitescens* is equivalent to 11.86 Ma on the BKF85 scale, whereas Rio et al. (1990) obtained 12.66 ± 0.19 Ma at tropical Indian Ocean DSDP Site 714. Their age is based on an interpolation between the ages for the base of *Catinaster coalitus* and the upper limit of *Sphenolithus hetero-*

morphus, using the ages obtained by Backman et al. (1990). Using our ages for these two events, the discrepancy is significantly reduced. The uncertainty quoted by Rio et al. (1990) is based on the large gap between the conventional depth (mbsf) for the core-catcher sample and the remainder of the recovered core; probably a younger age estimate would be more realistic, also, in view of the fact that the base of *Discoaster kugleri* was observed higher in the same core (recovery in Site 714, Core 9H was less than 5 m; we assume that the sample given in Rio et al., 1990, table 26, as 714A-9H-5-30 was, in fact, 714A-9H-4-30).

The age for the base of *Discoaster kugleri* in Site 714 (Backman et al., 1990) was again based on a linear interpolation between the base of *D. hamatus* (for which they used an age of 10.5 Ma) and the upper limit of *S. heteromorphus* at 13.5 Ma; our estimate is not in conflict with their data. The sedimentation rate in Site 714 was low and, in light of our findings, it is significant that Rio et al. (1990) found the upper limit for *Coronocyclus nitescens* at the same position as the lower limit of *D. kugleri* in Site 709, which has a much higher sedimentation rate, confirming that these datums are close in age.

For the base of *Triquetrorhabdalus rugosus,* our estimate is essentially identical, when converted to the BKF85 scale, with that obtained by Olafsson in Site 608 with direct paleomagnetic control. Our estimate for the upper limit of *Cyclicargolithus floridanus* agrees well with that given by Backman et al. (1990), based on an interpolation at central Pacific DSDP Site 574. Olafsson (1991) showed that this species survived much longer at mid-latitude Site 608 (see also Raffi et al., this volume). However, our estimate for the base of *Reticulofenestra pseudoumbilicus* is equivalent to 13.88 Ma on the BKF85 scale, much older than the 12.70 Ma estimate of Olafsson based on Site 608. In Site 608, the base of *R. pseudoumbilicus* is well separated from the upper limit of *Sphenolithus heteromorphus,* whereas at the three Leg 138 sites that contain both datums, they were observed to coincide. Because our estimate for the top of *S. heteromorphus* is only slightly older than Olafsson's estimate based on Site 608, we assume that this datum is essentially synchronous and that the first appearance of *R. pseudoumbilicus* in the region of Site 608 is nearly 1 m.y. after its first appearance in the Leg 138 region. Our estimate in Table 4 for the upper limit of *S. heteromorphus* depends on a somewhat poorly constrained age model in Site 845, and an extension of the sedimentation rate observed in the interval with magnetostratigraphic control yields a younger age estimate (about 13.47 Ma; Raffi and Flores, this volume) that is closer to that estimated by Olafsson (1991).

RADIOLARIAN AND DIATOM CALIBRATIONS

The ages for several of the radiolarian datums have been compared with estimates (Shipboard Scientific Party, 1992) that were made by Johnson and Nigrini (1985) for the central Pacific DSDP Site 573. Their estimates were based on an age model for the site that, in turn, depended on datum levels for the other microfossil groups, so that precise comparison is inappropriate; we comment only on those cases where a major disagreement is evident. Our age for the base of *Diartus pettersoni* is equivalent to 11.56 Ma on the BKF85 scale, about 1 m.y. younger than that given by Johnson and Nigrini (1985) for Site 573. However, these authors observed much younger first appearances in the western Pacific (11.0–11.3 Ma) and the Indian Ocean (10.6–10.8 Ma), so that the first appearance of this species may be significantly diachronous (conceivably explaining the seemingly earlier appearance in Site 846). The upper limit of *Dorcadospyris alata* displays an even greater discrepancy; again, however, Johnson and Nigrini (1985) reported widely discrepant estimates in different regions, with our estimate being closer to theirs for the western Pacific and for Site 573.

Regarding the diatom datums, it is significant that a number of the literature estimates that we use (Shipboard Scientific Party, 1992) are based on pioneering work by Burckle (1978) on piston cores from the equatorial Pacific Ocean that preserved magnetostratigraphic records, but at a major sacrifice in sedimentation rate. In general, our age estimates are close to the published figures, but with a pattern of consistent offsets for nearby datums that probably arise from artifacts of very low accumulation rate. We assume that our estimates, based on higher sedimentation rates, are more reliable.

Our age estimates for the last appearance of *Nitzschia cylindrica* and the first appearance of *Nitzschia jousseae* are older than those of Burckle (1978) and Barron et al. (1985a). It is possible that this reflects a difference in species concepts, because forms intermediate between the two species were observed in Leg 138 sediments. Similarly, the age of the first appearance of *Thalassiosira oestrupii* may be affected by differing species concepts.

FORAMINIFERAL DATUMS

For the upper limit of *Globigerinoides fistulosus,* we have included additional data from Sites 846 and 849 contributed by A.C. Mix (pers. comm., 1993). Samples typically contain only one or two specimens, but one may assume that these are not reworked, as there is no reservoir of material rich in this species to provide reworked specimens. The upper limit in Site 846 is at about the same age as observed in Site 677 (Shackleton et al., 1990), but in Site 849 it is somewhat earlier. Several of the Pliocene datums were only determined at close intervals in Site 846 (Shackleton et al., this volume); the estimates provided by that site are in excellent agreement with previous data. In the middle Miocene sections, useful calibrations come from Sites 844, 845, and 846.

INDIVIDUAL SITE AGE-DEPTH PLOTS

Figures 3 through 13 show the limits within which each datum is placed in each site, plotted at the ages estimated in Table 7 (column labeled "SCHPS94"). For each site, the line represents the age model from Shackleton et al. (this volume). These figures enable us to identify site-specific problems (sedimentation rates are given by Shackleton et al., this volume). For example, Figure 5 suggests that there is a problem in the lower part of Site 846, where the base of *Discoaster kugleri* and the base of *Diartus pettersoni* both fall well off the calibration line. These two datums fall in Core 138-846B-38X; the recovery in Core 138-846B-37X was low, and nothing was recovered in Core 138-846B-39X. The distribution of *D. kugleri* above its reported first appearance is erratic, and it is possible that this core contains mixed material, although Raffi et al. (this volume) remind us that the first appearance of *D. kugleri* is an unreliable marker.

In Figure 3 (Site 844), the apparent wide limits on the deepest two diatom datums indicate that they fall between the lowest sample examined and the bottom of the hole. In Figure 6 (Site 847), the departures of three diatom datums from the age-depth line may indicate an error in the age model, but this is not certain because in this site the diatom stratigraphy is based only on shipboard work. In Figures 12 and 13 (Sites 853 and 854), a combination of poor preservation and low sedimentation rate limited the time resolution of many determinations.

WHICH DATUMS ARE SYNCHRONOUS?

Moore et al. (1993) have already examined the radiolarian datum levels discussed here and separated out those that are broadly synchronous over the range covered by Leg 138 from those that are not. They were able to show, for those datums that are clearly nonsynchronous, that the spatial pattern of each extinction or first appearance is related to the presence of the species in some, but not all, of the water masses overlying the Leg 138 coring sites, either shortly after the species first appears, or as its geographic range is reduced before extinction. Clearly, the reverse is axiomatically true: a datum cannot appear synchronous unless the species spread rapidly into all the relevant water masses when it first appeared, and its demise was not preceded by a perceptible contraction in viable range.

Table 4. Ages (Ma) of datums in Leg 138 sites.

		844 (t)	844 (o)	845 (t)	845 (o)	846 (t)	846 (o)	847 (t)	847 (o)	848 (t)	848 (o)
t	*N. reinholdii*	NA	NA	0.957	1.051	0.556	0.639	0.365	0.454	0.553	0.775
t	*N. fossilis*	0.115	0.187	0.861	1.013	0.639	0.715	0.490	0.650	0.553	0.775
t	*R. matuyama*	NA	NA	1.013	1.088	0.918	1.079	NA	NA	NA	NA
b	*R. matuyama*	NA	NA	1.088	1.164	1.346	1.361	NA	NA	NA	NA
t	*R. praebergonii* var. *robusta*	NA	NA	NA	NA	1.858	1.870	1.660	1.712	1.584	1.746
b	*P. dolius*	1.629	2.114	1.738	1.803	1.981	1.997	2.030	2.060	2.049	2.069
t	*T. convexa*	3.203	4.659	2.341	2.492	2.132	2.142	2.424	2.450	2.367	2.499
t	*N. jouseae*	1.700	3.461	2.729	2.793	2.738	2.762	2.801	2.876	2.638	2.837
b	*R. praebergonii*	2.114	3.461	2.793	2.981	3.135	3.140	3.159	3.206	3.181	3.249
b	*T. convexa* f. *convexa*	NA	NA	3.742	3.895	3.774	3.806	3.793	3.918	3.837	4.192
b	*A. elegans*	NA	NA	NA	NA	NA	NA	4.026	4.332	3.411	4.698
t	*N. cylindrica*	NA	NA	4.930	5.063	4.887	4.951	4.598	4.677	4.698	4.879
b	*N. jouseae*	3.461	6.256	4.743	4.930	5.222	5.242	5.191	5.265	5.093	5.240
t	*T. miocenica*	6.002	6.256	5.809	5.886	5.802	5.807	5.368	5.605	NA	NA
b	*T. oestrupii*	NA	NA	5.435	5.493	5.802	5.807	NA	NA	NA	NA
t	*N. miocenica*	NA	NA	6.040	6.141	6.102	6.111	5.605	5.830	5.644	5.939
t	*N. miocena* var. *elongata*	5.520	6.002	NA	NA	6.111	6.365	NA	NA	5.982	6.101
t	*T. praeconvexa*	3.461	6.256	NA	NA	6.111	6.365	6.074	6.185	5.982	6.460
t	*R. praepaleacea*	NA	NA	NA	NA	NA	NA	NA	NA	6.460	6.575
b	*T. miocenica*	NA	NA	6.212	6.976	6.519	6.559	NA	NA	6.575	6.656
b	*T. convexa var. aspinosa*	6.256	6.657	6.212	6.976	6.519	6.559	NA	NA	6.575	6.656
b	*T. praeconvexa*	6.657	7.024	NA	NA	6.559	6.745	NA	NA	6.697	6.819
t	*N. porteri*	NA	NA	NA	NA	7.125	7.147	NA	NA	NA	NA
b	*N. miocenica*	7.203	7.477	6.226	7.339	7.247	7.262	NA	NA	7.333	7.382
t	*R. paleacea*	7.203	7.477	NA	NA	7.387	7.390	NA	NA	7.333	7.382
t	*T. burckliana*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*N. reinholdii*	7.477	7.651	NA	NA	NA	NA	NA	NA	NA	NA
t	*A. ellipticus* var. *javanicus*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*N. marina*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*N. cylindrica*	7.851	7.974	NA	NA	8.186	8.259	NA	NA	NA	NA
t	*T. yabei*	7.749	7.851	8.251	8.343	8.235	8.259	NA	NA	NA	NA
b	*A. nodulifer* var. *cyclops*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*C. loeblichii*	8.025	8.904	NA	NA	NA	NA	NA	NA	NA	NA
b	*N. fossilis*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*T. burckliana*	8.025	8.904	NA	NA	NA	NA	NA	NA	NA	NA
b	*C. loeblichii*	8.904	10.168	NA	NA	NA	NA	NA	NA	NA	NA
t	*D. hustedtii*	9.906	10.168	8.856	9.503	9.315	9.325	NA	NA	NA	NA
t	*A. moronensis*	10.266	10.400	NA	NA	NA	NA	NA	NA	NA	NA
b	*A. ellipticus f. lanceolata*	NA	NA	NA	NA	9.940	10.746	NA	NA	NA	NA
b	*R. paleacea* var. *elongata*	NA	NA	NA	NA	11.086	11.160	NA	NA	NA	NA
t	*C. gigas* v. *diorama*	NA	NA	10.964	11.191	11.086	11.160	NA	NA	NA	NA
t	*S. jouseana*	11.248	11.566	NA	NA	NA	NA	NA	NA	NA	NA
t	*C. coscinodiscus*	11.248	11.566	NA	NA	11.086	11.160	NA	NA	NA	NA
t	*A. ingens*	12.218	12.566	12.054	12.123	12.031	12.150	NA	NA	NA	NA
t	*C. pulchellus*	12.218	12.548	11.479	12.054	NA	NA	NA	NA	NA	NA
t	*N. porteri*	NA	NA	NA	NA	12.150	12.306	NA	NA	NA	NA
b	*T. brunii*	12.218	12.573	NA	NA	12.150	12.159	NA	NA	NA	NA
b	*C. gigas* v. *diorama*	NA	NA	NA	NA	12.966	13.016	NA	NA	NA	NA
t	*A. californicus*	12.327	12.566	NA	NA	NA	NA	NA	NA	NA	NA
t	*C. lewisianus*	12.922	13.053	12.611	12.796	12.883	13.066	NA	NA	NA	NA
t	*T. tappanae*	13.053	13.340	NA	NA	NA	NA	NA	NA	NA	NA
b	*T. cinnamoneum*	13.180	13.453	NA	NA	NA	NA	NA	NA	NA	NA
b	*D. simonsenii*	13.340	13.596	NA	NA	NA	NA	NA	NA	NA	NA
t	*C. peplum*	13.596	13.901	14.559	15.595	NA	NA	NA	NA	NA	NA
b	*A. ellipticus*	13.901	14.173	NA	NA	NA	NA	NA	NA	NA	NA
b	*C. blysmos*	14.173	14.495	NA	NA	NA	NA	NA	NA	NA	NA
t	*A. californicus*	14.758	15.018	NA	NA	NA	NA	NA	NA	NA	NA
b	*A. ingens*	15.240	15.466	NA	NA	NA	NA	NA	NA	NA	NA
t	*C. lewisianus* var. *similis*	15.466	15.659	NA	NA	NA	NA	NA	NA	NA	NA
t	*T. fraga*	16.374	16.596	NA	NA	NA	NA	NA	NA	NA	NA
b	*C. peplum*	16.374	16.596	16.276	16.450	NA	NA	NA	NA	NA	NA
t	*R. marylandicus*	16.374	16.596	NA	NA	NA	NA	NA	NA	NA	NA
b	*C. coscinodiscus* ss.	16.859	18.081	NA	NA	NA	NA	NA	NA	NA	NA
b	*C. nicobarica*	16.859	18.081	NA	NA	NA	NA	NA	NA	NA	NA
b	*E. huxleyi*	NA	NA	NA	NA	NA	NA	0.095	0.146	NA	NA
t	*P. lacunosa*	0.363	0.513	0.701	0.716	0.438	0.452	0.409	0.449	0.377	0.460
b	Reentry medium *Gephyrocapsa* spp.	0.907	1.070	0.943	1.019	1.017	1.047	1.000	1.027	1.021	1.024
t	Large *Gephyrocapsa* spp.	1.070	1.262	1.171	1.194	1.228	1.251	1.222	1.240	1.187	1.227
b	Large *Gephyrocapsa* spp.	1.360	1.451	1.260	1.336	1.523	1.542	1.482	1.498	1.429	1.498
t	*C. macintyrei*	1.451	1.687	1.412	1.487	1.616	1.654	1.580	1.602	1.562	1.601
b	*G. oceanica* sl.	1.813	1.916	1.639	1.715	1.668	1.680	1.724	1.761	1.601	1.615
t	*D. brouweri*	2.152	2.227	1.961	2.097	2.057	2.069	2.060	2.078	1.845	1.891
t	*D. pentaradiatus*	2.510	2.916	2.573	2.622	NA	NA	NA	NA	2.491	2.562
t	*D. surculus*	2.916	3.418	NA	NA	2.509	2.525	2.596	2.612	2.491	2.562
t	*D. tamalis*	NA	NA	NA	NA	2.958	3.013	2.758	2.781	2.700	2.810
t	*S. abies*	NA	NA	NA	NA	3.608	3.637	3.683	3.701	3.411	3.649
t	*R. pseudoumbilicus*	NA	NA	NA	NA	3.739	3.848	3.789	3.813	3.762	3.837
bc	*D. asymmetricus*	NA	NA	NA	NA	4.134	4.148	4.466	4.486	4.027	4.192
t	*A. primus*	NA	NA	NA	NA	4.489	4.506	4.507	4.540	4.381	4.468
t	*C. acutus*	5.444	5.477	NA	NA	4.925	4.941	4.976	5.018	4.919	5.014
b	*C. rugosus*	NA	NA	NA	NA	5.063	5.092	5.075	5.091	5.240	5.254
b	*C. acutus*	NA	NA	5.336	5.351	5.326	5.348	5.345	5.348	5.310	5.328
t	*T. rugosus*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*D. quinqueramus*	5.520	5.562	5.435	5.458	5.586	5.590	5.659	5.678	5.542	5.559
t	Circular reticulofenestrids	NA	NA	NA	NA	5.998	6.010	NA	NA	NA	NA
t	*A. amplificus*	5.858	5.889	NA	NA	6.010	6.020	NA	NA	5.897	5.917

Table 4 (continued).

	844 (t)	844 (o)	845 (t)	845 (o)	846 (t)	846 (o)	847 (t)	847 (o)	848 (t)	848 (o)
b *A. amplificus*	6.608	6.656	6.552	6.583	6.108	6.153	NA	NA	6.490	6.509
b Circular reticulofenestrids	NA	NA	NA	NA	6.399	6.459	NA	NA	NA	NA
t Absence *R. pseudoumbilicus*	6.894	6.946	6.744	6.783	7.039	7.070	NA	NA	6.913	6.929
b *A. primus*	7.208	7.354	7.175	7.381	7.111	7.122	NA	NA	7.316	7.364
t *M. convallis*	7.693	7.733	NA	NA	7.716	7.789	NA	NA	8.245	8.362
b *D. berggrenii*	8.014	8.008	8.461	8.485	7.927	7.953	NA	NA	8.362	8.473
b *D. pentaradiatus*	8.008	8.004	NA	NA	NA	NA	NA	NA	NA	NA
b *D. loeblichi*	8.004	8.306	NA	NA	8.394	8.500	NA	NA	8.535	8.599
b Absence *R. pseudoumbilicus*	8.695	8.758	NA	NA	8.631	8.713	NA	NA	8.535	8.599
t *D. hamatus*	9.373	9.404	NA	NA	9.760	9.798	NA	NA	9.379	9.408
b *M. convallis*	9.358	9.397	NA	NA	9.337	9.434	NA	NA	9.182	9.206
b *D. neohamatus*	NA	NA	NA	NA	NA	NA	NA	NA	9.538	9.660
b *C. coalitus*	10.692	10.761	10.710	10.743	10.696	10.723	NA	NA	NA	NA
b *D. hamatus*	10.213	10.347	10.272	10.290	10.403	10.492	NA	NA	10.261	10.288
t *C. miopelagicus*	10.347	10.481	10.417	10.431	10.551	10.640	NA	NA	10.288	10.317
t *C. floridanus*	13.558	13.583	13.183	13.201	13.330	14.054	NA	NA	NA	NA
t *C. nitescens*	12.412	12.445	12.107	12.130	13.330	14.054	NA	NA	NA	NA
tc *D. kugleri*	11.311	11.360	11.364	11.384	11.335	11.369	NA	NA	NA	NA
bc *D. kugleri*	11.771	11.787	11.702	11.719	11.779	11.875	NA	NA	NA	NA
b *D. kugleri*	12.391	12.412	12.130	12.145	13.278	13.317	NA	NA	NA	NA
b *C. macintyrei*	NA	NA	12.130	12.145	NA	NA	NA	NA	NA	NA
t *C. premacintyrei*	12.764	12.797	12.228	12.262	NA	NA	NA	NA	NA	NA
b *T. rugosus*	12.946	12.970	12.636	12.677	NA	NA	NA	NA	NA	NA
t *D. signus*	13.042	13.107	NA	NA	NA	NA	NA	NA	NA	NA
b *R. pseudoumbilicus*	14.039	14.055	13.840	13.861	13.330	14.054	NA	NA	NA	NA
t *S. heteromorphus*	14.039	14.055	13.840	13.861	13.330	14.054	NA	NA	NA	NA
t *H. ampliapertura*	15.786	15.840	15.898	15.912	15.644	15.939	NA	NA	NA	NA
b *D. signus*	16.204	16.219	16.187	16.202	15.971	16.484	NA	NA	NA	NA
t Acme *D. deflandrei*	NA	NA	16.202	16.229	NA	NA	NA	NA	NA	NA
t *S. universus*	0.363	0.737	0.402	0.423	0.381	0.417	0.404	0.490	0.474	0.561
b *C. tuberosa*	0.363	0.737	0.575	0.701	0.454	0.603	0.583	0.662	0.632	0.644
t *L. neoheteroporos*	0.942	1.083	1.024	1.053	0.988	1.053	1.067	1.094	1.089	1.120
t *A. angulare*	0.942	1.083	1.053	1.099	1.116	1.145	1.094	1.148	1.122	1.154
t *T. vetulum*	1.083	1.451	1.124	1.194	1.222	1.257	1.223	1.260	1.154	1.186
b *L. nigriniae*	1.083	1.451	1.194	1.279	1.222	1.257	1.148	1.223	1.220	1.251
b *T. trachelium*	1.451	1.933	1.597	1.740	1.559	1.652	1.504	1.543	1.467	1.520
b *P. minithorax*	1.451	1.933	1.487	1.597	1.449	1.479	1.543	1.703	1.746	1.791
b *A. angulare*	1.451	1.933	1.738	1.798	1.687	1.824	1.712	1.778	1.746	1.791
t *P. prismatium*	1.451	1.933	1.668	1.738	1.687	1.824	1.712	1.778	1.690	1.741
t *L. heteroporos*	1.451	1.933	1.487	1.597	2.069	2.090	2.038	2.129	1.467	1.520
t *A. jenghisi*	2.206	2.568	2.029	2.331	2.345	2.391	2.450	2.609	2.354	2.471
b *T. davisiana*	2.568	2.936	2.622	2.857	2.714	2.797	2.713	2.789	2.638	2.709
t *S. peregrina*	2.568	2.936	2.857	2.880	2.714	2.797	2.789	2.801	2.638	2.709
t *A. pliocenica*	2.936	3.461	3.289	3.593	3.268	3.303	3.201	3.338	3.591	4.156
b *L. heteroporos*	2.936	3.461	3.103	3.167	3.350	3.370	2.979	3.048	2.471	2.562
t *L. audax*	3.843	5.180	3.967	4.039	3.989	4.042	3.562	3.710	3.663	3.675
t *P. fistula*	5.180	5.300	3.289	3.593	4.305	4.343	4.094	4.106	3.663	3.675
b *L. neoheteroporos*	2.206	2.568	3.167	3.240	3.421	3.438	2.979	3.048	2.471	2.562
t *P. dolium*	3.843	5.180	3.967	4.039	4.042	4.134	4.094	4.106	3.663	3.675
b *A. ypsilon*	3.461	3.843	3.593	3.641	3.650	3.748	3.918	4.094	3.804	3.926
t *D. penultima*	3.843	5.180	4.737	4.849	4.134	4.183	4.106	4.227	4.052	4.149
b *S. tetras*	3.461	5.180	3.805	3.885	4.042	4.134	4.106	4.227	4.052	4.149
b *P. prismatium*	3.461	3.843	4.329	4.358	4.719	4.734	4.829	4.865	4.751	4.786
t *S. omnitubus*	5.554	5.807	5.298	5.345	5.502	5.533	5.368	5.475	4.949	4.992
t *S. corona*	5.807	6.879	7.056	7.142	5.502	5.533	5.662	5.756	5.424	5.497
t *S. johnsoni*	5.768	6.879	6.435	6.543	6.419	6.491	6.418	6.476	6.303	6.345
b *S. delmontensis* to *S. peregrina*	5.807	6.879	6.759	6.807	6.559	6.650	6.418	6.591	6.567	6.572
t *C. caepa*	5.807	6.879	6.977	7.056	6.559	6.650	6.476	6.520	6.170	6.225
b *S. omnitubus*	7.203	7.467	7.142	7.266	7.261	7.318	NA	NA	7.057	7.454
t *D. hughesi*	7.467	7.749	7.588	7.627	7.639	7.657	NA	NA	7.506	7.647
b *S. berminghami*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t *S. wolffi*	8.000	8.904	8.796	8.854	8.841	8.872	NA	NA	8.818	8.893
t *B. miralestensis*	7.749	8.022	8.214	8.247	8.366	8.590	NA	NA	8.017	8.198
t *D. pettersoni*	8.022	8.008	8.587	8.631	8.366	8.590	NA	NA	8.489	8.565
b *D. hughesi*	8.000	8.904	8.854	8.903	9.181	9.315	NA	NA	8.818	8.893
b *D. pettersoni* to *D. hughesi*	8.000	8.904	8.671	8.724	8.590	8.717	NA	NA	8.718	8.818
t *C. japonica*	9.914	10.168	10.055	10.106	10.032	10.148	NA	NA	NA	NA
t *C. cristata*	10.168	10.525	10.373	10.518	10.778	10.841	NA	NA	NA	NA
t *L. thornburgi*	8.904	9.671	11.412	11.440	10.778	10.841	NA	NA	NA	NA
t *L. renzae*	11.824	11.901	11.744	11.807	11.760	11.814	NA	NA	NA	NA
t *C. cornuta*	11.744	11.824	11.807	11.838	11.898	11.981	NA	NA	NA	NA
b *D. pettersoni*	11.824	11.901	11.807	11.838	12.974	13.225	NA	NA	NA	NA
t *D. alata*	11.824	11.901	11.838	11.869	NA	NA	NA	NA	NA	NA
b *C. japonica*	12.327	12.351	12.428	12.501	12.348	12.437	NA	NA	NA	NA
b *C. caepa*	13.510	13.593	13.121	13.194	NA	NA	NA	NA	NA	NA
b *L. thornburgi*	12.980	13.053	13.605	13.626	NA	NA	NA	NA	NA	NA
t *S. armata*	13.761	13.901	13.626	13.673	NA	NA	NA	NA	NA	NA
t *L. parkerae*	14.410	14.495	14.177	14.607	NA	NA	NA	NA	NA	NA
t *O. octopyle*	14.495	14.597	14.177	14.607	NA	NA	NA	NA	NA	NA
t *C. bramlettei*	14.882	15.018	14.177	14.607	NA	NA	NA	NA	NA	NA
t *C. costata*	15.173	15.249	15.010	15.052	NA	NA	NA	NA	NA	NA
b *D. dentata* to *D. alata*	15.466	15.566	15.846	15.861	NA	NA	NA	NA	NA	NA
t *L. stauropora*	15.659	15.774	15.903	15.919	NA	NA	NA	NA	NA	NA
b *L. parkerae*	15.659	15.774	15.919	15.932	NA	NA	NA	NA	NA	NA
t *S. diaphenes*	15.844	15.919	16.011	16.025	NA	NA	NA	NA	NA	NA
b *C. bramlettei*	17.019	17.099	16.052	16.097	NA	NA	NA	NA	NA	NA

Table 4 (continued).

		849 (t)	849 (o)	850 (t)	850 (o)	851 (t)	851 (o)	852 (t)	852 (o)	853 (t)	853 (o)	854 (t)	854 (o)
t	*N. reinholdii*	0.361	0.936	0.363	0.635	0.487	0.699	0.275	0.677	NA	NA	NA	NA
t	*N. fossilis*	0.942	1.110	0.714	0.898	0.784	1.050	0.275	0.677	NA	NA	NA	NA
t	*R. matuyama*	0.942	1.110	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*R. matuyama*	1.110	1.239	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*R. praebergonii* var. *robusta*	1.700	1.741	NA	NA	1.660	1.749	1.868	2.303	NA	NA	NA	NA
b	*P. dolius*	1.957	2.051	2.126	2.138	1.749	1.918	1.868	2.303	NA	NA	NA	NA
t	*T. convexa*	2.380	2.622	2.359	2.403	2.338	2.441	2.303	2.493	NA	NA	NA	NA
t	*N. jouseae*	2.733	2.850	2.765	2.844	2.765	2.826	2.493	2.852	NA	NA	NA	NA
b	*R. praebergonii*	3.141	3.217	3.253	3.352	3.042	3.147	3.134	3.778	NA	NA	NA	NA
b	*T. convexa* f. *convexa*	3.764	3.875	3.799	4.200	3.784	3.873	3.824	4.290	NA	NA	NA	NA
b	*A. elegans*	NA	NA	3.500	3.994	3.946	4.505	NA	NA	NA	NA	NA	NA
t	*N. cylindrica*	4.934	4.993	4.704	4.939	4.691	4.797	4.991	5.081	NA	NA	NA	NA
b	*N. jouseae*	5.159	5.226	4.939	5.268	4.797	4.876	4.991	5.081	NA	NA	NA	NA
t	*T. miocenica*	5.812	5.864	5.809	5.835	5.589	5.677	NA	NA	NA	NA	NA	NA
b	*T. oestrupii*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*N. miocenica*	6.053	6.065	6.049	6.074	6.069	6.135	5.993	6.222	NA	NA	NA	NA
t	*N. miocena* var. *elongata*	6.053	6.065	NA	NA	6.195	6.215	NA	NA	NA	NA	NA	NA
t	*T. praeconvexa*	6.053	6.065	6.210	6.227	6.323	6.454	NA	NA	NA	NA	NA	NA
t	*R. praepaleacea*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*T. miocenica*	6.492	6.522	6.578	6.604	6.404	6.484	NA	NA	NA	NA	NA	NA
b	*T. convexa* var. *aspinosa*	6.492	6.522	6.578	6.604	NA	NA	NA	NA	NA	NA	NA	NA
b	*T. praeconvexa*	6.713	6.835	6.645	6.665	6.597	6.802	NA	NA	NA	NA	NA	NA
t	*N. porteri*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*N. miocenica*	7.235	7.314	7.314	7.348	7.174	7.296	6.760	6.843	NA	NA	NA	NA
t	*R. paleacea*	NA	NA	7.348	7.383	7.296	7.341	NA	NA	NA	NA	NA	NA
t	*T. burckliana*	8.270	8.308	7.651	7.956	NA	NA	NA	NA	NA	NA	NA	NA
b	*N. reinholdii*	7.573	7.867	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*A. ellipticus* var. *javanicus*	7.507	7.783	7.853	7.875	7.890	8.306	7.477	7.588	NA	NA	NA	NA
b	*N. marina*	NA	NA	7.875	7.956	NA	NA	NA	NA	NA	NA	NA	NA
b	*N. cylindrica*	8.008	8.098	7.974	8.034	8.070	8.463	7.951	8.028	NA	NA	NA	NA
t	*T. yabei*	8.270	8.308	8.034	8.194	8.070	8.463	7.951	8.028	NA	NA	NA	NA
b	*A. nodulifer* var. *cyclops*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*C. loeblichii*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*N. fossilis*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*T. burckliana*	8.270	8.308	8.744	9.033	NA	NA	NA	NA	NA	NA	NA	NA
b	*C. loeblichii*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*D. hustedtii*	8.798	9.520	9.196	9.258	9.372	9.505	9.141	9.470	NA	NA	NA	NA
t	*A. moronensis*	NA	NA	9.332	9.401	9.558	9.753	NA	NA	NA	NA	NA	NA
b	*A. ellipticus* f. *lanceolata*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*R. paleacea* var. *convexa*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*C. gigas* v. *diorama*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*S. jouseana*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*C. coscinodiscus*	NA	NA	11.238	11.308	11.180	11.363	NA	NA	NA	NA	NA	NA
t	*A. ingens*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*C. pulchellus*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*N. porteri*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*T. brunii*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*C. gigas* v. *diorama*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*A. californicus*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*C. lewisianus*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*T. tappanae*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*T. cinnamoneum*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*D. simonsenii*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*C. peplum*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*A. ellipticus*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*C. blysmos*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*A. californicus*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*A. ingens*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*C. lewisianus* var. *similis*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*T. fraga*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*C. peplum*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*R. marylandicus*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*C. coscinodiscus* ss.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*C. nicobarica*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*E. huxleyi*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*P. lacunosa*	0.401	0.441	0.407	0.458	0.344	0.364	0.415	0.490	0.728	0.749	0.440	0.621
b	Reentry medium *Gephyrocapsa* spp.	1.003	1.042	0.957	1.008	1.001	1.024	0.979	1.040	0.978	1.082	0.957	1.067
t	Large *Gephyrocapsa* spp.	1.199	1.233	1.240	1.293	1.250	1.266	1.209	1.263	NA	NA	NA	NA
b	Large *Gephyrocapsa* spp.	1.368	1.412	1.394	1.435	1.430	1.450	1.513	1.561	1.314	1.499	NA	NA
t	*C. macintyrei*	1.564	1.588	1.545	1.599	1.555	1.620	1.669	1.747	1.499	1.605	1.586	1.695
b	*G. oceanica* sl.	1.698	1.709	1.700	1.832	1.660	1.723	1.669	1.747	1.644	1.712	1.586	1.695
t	*D. brouweri*	2.052	2.058	2.140	2.149	1.950	1.976	1.807	1.898	1.712	1.793	NA	NA
t	*D. pentaradiatus*	NA	NA	NA	NA	NA	NA	2.490	2.548	2.370	2.469	2.384	2.434
t	*D. surculus*	2.486	2.536	2.612	2.702	2.758	2.765	2.818	2.870	2.715	2.744	2.515	2.571
t	*D. tamalis*	2.752	2.760	2.750	2.768	2.758	2.765	2.928	2.991	2.804	3.071	NA	NA
t	*S. abies*	3.646	3.692	3.675	3.720	3.551	3.623	3.593	3.672	3.874	3.907	NA	NA
t	*R. pseudoumbilicus*	3.788	3.792	3.799	3.807	3.788	3.817	3.781	3.841	3.874	3.907	3.725	5.994
bc	*D. asymmetricus*	NA	NA	NA	NA	3.908	4.054	3.875	3.926	4.130	4.311	NA	NA
t	*A. primus*	NA	NA	4.554	4.687	4.598	4.648	4.471	4.680	4.545	4.615	NA	NA
t	*C. acutus*	NA	NA	4.939	5.031	4.972	4.982	4.939	4.965	4.966	5.063	NA	NA
b	*C. rugosus*	5.055	5.075	5.031	5.047	4.972	4.982	4.905	4.939	5.063	5.090	NA	NA
b	*C. acutus*	5.340	5.354	5.333	5.342	5.356	5.377	5.307	5.332	5.321	5.370	NA	NA
t	*T. rugosus*	5.340	5.354	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*D. quinqueramus*	5.595	5.600	5.605	5.620	5.550	5.558	5.494	5.536	5.321	5.370	3.725	5.994
t	Circular reticulofenestrids	NA	NA	6.224	6.246	NA	NA	NA	NA	NA	NA	NA	NA
t	*A. amplificus*	6.050	6.056	6.008	6.028	5.853	5.902	5.897	5.993	5.860	5.904	NA	NA

Table 4 (continued).

		849 (t)	849 (o)	850 (t)	850 (o)	851 (t)	851 (o)	852 (t)	852 (o)	853 (t)	853 (o)	854 (t)	854 (o)
b	*A. amplificus*	6.098	6.120	6.302	6.336	6.462	6.501	6.551	6.687	6.539	6.570	NA	NA
b	Circular reticulofenestrids	NA	NA	6.792	6.828	NA	NA	NA	NA	NA	NA	NA	NA
t	Absence *R. pseudoumbilicus*	6.256	6.265	6.518	6.522	7.001	7.034	6.687	6.779	6.671	6.773	NA	NA
b	*A. primus*	6.878	6.937	6.828	6.885	7.212	7.226	7.179	7.245	7.118	7.176	NA	NA
t	*M. convallis*	NA	NA	NA	NA	7.218	7.229	NA	NA	NA	NA	NA	NA
b	*D. berggrenii*	7.521	7.538	7.383	7.418	7.890	7.963	8.061	8.079	8.238	8.253	5.994	8.199
b	*D. pentaradiatus*	NA	NA	NA	NA	NA	NA	8.405	8.439	NA	NA	NA	NA
b	*D. loeblichi*	NA	NA	8.390	8.421	8.404	8.431	8.439	8.470	NA	NA	NA	NA
b	Absence *R. pseudoumbilicus*	9.058	9.119	8.847	8.876	8.554	8.777	8.630	8.755	NA	NA	NA	NA
t	*D. hamatus*	9.190	9.251	9.444	9.492	9.460	9.472	9.274	9.386	NA	NA	NA	NA
b	*M. convallis*	9.058	9.119	9.492	9.517	9.499	9.550	9.274	9.386	NA	NA	NA	NA
b	*D. neohamatus*	9.545	9.593	9.444	9.492	9.656	9.674	9.414	9.479	NA	NA	NA	NA
b	*C. coalitus*	NA	NA	NA	NA	10.806	10.823	NA	NA	NA	NA	NA	NA
b	*D. hamatus*	10.173	10.275	10.512	10.513	10.490	10.501	10.674	10.685	NA	NA	NA	NA
t	*C. miopelagicus*	10.376	10.473	10.531	10.563	10.501	10.510	10.685	10.727	NA	NA	NA	NA
t	*C. floridanus*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*C. nitescens*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tc	*D. kugleri*	11.315	11.329	11.409	11.563	11.289	11.300	NA	NA	NA	NA	NA	NA
bc	*D. kugleri*	NA	NA	NA	NA	11.692	11.709	NA	NA	NA	NA	NA	NA
b	*D. kugleri*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*C. macintyrei*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*C. premacintyrei*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*T. rugosus*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*D. signus*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*R. pseudoumbilicus*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*S. heteromorphus*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*H. ampliapertura*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*D. signus*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	Acme *D. deflandrei*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*S. universus*	0.397	0.505	0.402	0.582	0.320	0.373	0.384	0.444	0.000	0.269	0.497	0.650
b	*C. tuberosa*	0.583	0.813	0.582	0.635	0.487	0.651	0.532	0.768	0.000	0.269	0.497	0.650
t	*L. neoheteroporos*	0.957	1.042	1.003	1.128	1.112	1.182	1.114	1.150	1.082	1.295	0.783	1.033
t	*A. angulare*	1.042	1.249	1.003	1.128	1.182	1.250	1.114	1.150	1.082	1.295	1.155	1.257
t	*T. vetulum*	1.042	1.249	1.194	1.315	1.250	1.394	1.114	1.243	1.082	1.295	1.155	1.257
b	*L. nigriniae*	1.042	1.249	1.194	1.315	1.182	1.250	1.205	1.243	1.295	1.586	1.444	1.549
b	*T. trachelium*	1.428	1.543	1.461	1.628	1.660	1.780	1.756	1.803	1.295	1.586	1.444	1.549
b	*P. minithorax*	1.428	1.543	1.628	1.700	1.660	1.780	1.243	1.276	0.708	1.037	1.444	1.549
b	*A. angulare*	1.726	1.755	1.700	1.931	1.660	1.780	1.756	1.803	1.899	2.180	1.769	1.913
t	*P. prismatium*	1.726	1.755	1.700	1.931	1.660	1.780	1.608	1.711	1.586	1.899	1.769	1.913
t	*L. heteroporos*	1.543	1.609	1.461	1.628	1.562	1.660	1.608	1.711	1.586	1.899	1.549	1.652
t	*A. jenghisi*	2.482	2.506	2.449	2.515	2.269	2.371	2.381	2.432	NA	NA	2.115	2.303
b	*T. davisiana*	2.622	2.807	2.653	2.729	2.726	2.765	2.741	2.764	NA	NA	2.490	2.590
t	*S. peregrina*	2.622	2.807	2.729	2.855	2.726	2.765	2.764	2.813	NA	NA	2.490	2.590
t	*A. pliocenica*	3.217	3.309	3.133	3.185	3.367	3.447	3.518	3.633	NA	NA	NA	NA
b	*L. heteroporos*	3.207	3.217	2.979	3.133	2.913	2.956	3.134	3.140	NA	NA	NA	NA
t	*L. audax*	3.764	3.961	3.675	3.811	3.674	3.774	3.755	3.776	NA	NA	NA	NA
t	*P. fistula*	3.694	3.764	3.484	3.675	3.448	3.514	3.454	3.518	NA	NA	NA	NA
b	*L. neoheteroporos*	3.207	3.217	2.979	3.133	2.913	2.956	3.134	3.140	NA	NA	NA	NA
t	*P. dolium*	3.764	3.961	3.811	3.948	3.774	3.946	3.810	3.947	NA	NA	NA	NA
b	*A. ypsilon*	3.961	4.003	3.811	3.948	3.946	4.103	3.998	4.057	NA	NA	NA	NA
t	*D. penultima*	4.174	4.323	4.200	4.320	4.151	4.268	4.115	4.181	NA	NA	NA	NA
b	*S. tetras*	4.174	4.323	4.200	4.320	4.151	4.268	4.115	4.181	NA	NA	NA	NA
b	*P. prismatium*	4.737	4.746	4.762	4.842	4.505	4.877	4.492	4.983	NA	NA	NA	NA
t	*S. omnitubus*	5.385	5.419	5.360	5.393	5.373	5.454	4.983	5.076	NA	NA	NA	NA
t	*S. corona*	5.586	5.622	5.754	5.758	5.791	5.830	5.897	6.055	NA	NA	NA	NA
t	*S. johnsoni*	6.230	6.326	6.313	6.375	6.245	6.282	6.244	6.275	NA	NA	NA	NA
b	*S. delmontensis* to *S. peregrina*	6.652	6.682	6.645	6.670	6.633	6.678	6.816	6.837	NA	NA	NA	NA
t	*C. caepa*	6.230	6.326	6.313	6.375	6.282	6.329	6.771	6.795	NA	NA	NA	NA
b	*S. omnitubus*	6.970	7.072	7.116	7.168	6.802	7.012	7.204	7.275	NA	NA	NA	NA
t	*D. hughesi*	7.617	7.841	7.710	7.781	7.518	7.721	7.620	7.661	NA	NA	NA	NA
b	*S. berminghami*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*S. wolffi*	8.900	9.030	8.824	9.033	8.942	8.976	9.113	9.163	NA	NA	NA	NA
t	*B. miralestensis*	8.208	8.346	8.194	8.349	8.126	8.271	8.070	8.106	NA	NA	NA	NA
t	*D. pettersoni*	8.208	8.346	8.350	8.404	8.271	8.306	8.378	8.531	NA	NA	NA	NA
b	*D. hughesi*	8.208	8.346	8.824	9.033	8.867	8.942	8.981	9.113	NA	NA	NA	NA
b	*D. pettersoni* to *D. hughesi*	8.525	8.623	8.594	8.744	8.572	8.821	8.889	8.973	NA	NA	NA	NA
t	*C. japonica*	9.881	10.207	10.119	10.187	10.054	10.120	9.946	10.054	NA	NA	NA	NA
t	*C. cristata*	10.771	10.877	10.637	10.702	10.638	10.711	NA	NA	NA	NA	NA	NA
t	*L. thornburgi*	9.881	10.207	9.332	9.678	10.120	10.132	NA	NA	NA	NA	NA	NA
t	*L. renzae*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*C. cornuta*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*D. pettersoni*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*D. alata*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*C. japonica*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*C. caepa*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*L. thornburgi*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*S. armata*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*L. parkerae*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*O. octopyle*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*C. bramlettei*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*C. costata*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*D. dentata* to *D. alata*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*L. stauropora*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*L. parkerae*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*S. diaphenes*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*C. bramlettei*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 4 (continued).

		849 (t)	849 (o)	850 (t)	850 (o)	851 (t)	851 (o)	852 (t)	852 (o)	853 (t)	853 (o)	854 (t)	854 (o)
b	*A. octopyle*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*C. cingulata*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*D. prismatica*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*G. toxaria*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*G. tosaensis*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*Pulleniatina* L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*G. fistulosus*	1.837	1.840	NA	NA	1.660	2.269	NA	NA	NA	NA	NA	NA
b	*G. truncatulinoides*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*G. obliquus*	NA	NA	NA	NA	2.765	3.367	NA	NA	NA	NA	NA	NA
t	*G. limbata*	2.151	2.622	1.447	2.010	1.660	2.269	1.608	2.548	1.082	2.880	NA	NA
t	*G. altispira*	3.420	3.764	2.449	2.979	2.765	3.367	NA	NA	NA	NA	NA	NA
t	*S. seminulina*	3.420	3.764	2.449	2.979	2.765	3.367	3.518	4.492	1.082	2.880	NA	NA
t	*P. spectabilis*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*G. tumida*	NA	NA	NA	NA	5.261	5.549	7.275	8.028	5.090	6.108	NA	NA
t	*G. dehiscens*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*G. siakensis*	NA	NA	NA	NA	10.856	11.180	8.602	10.773	NA	NA	NA	NA
t	*G. fohsi* group	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*G. fohsi lobata*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*G. fohsi fohsi*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*G. archaeomenardii*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*G. praefohsi*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*O. suturalis*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b	*P. sicana*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

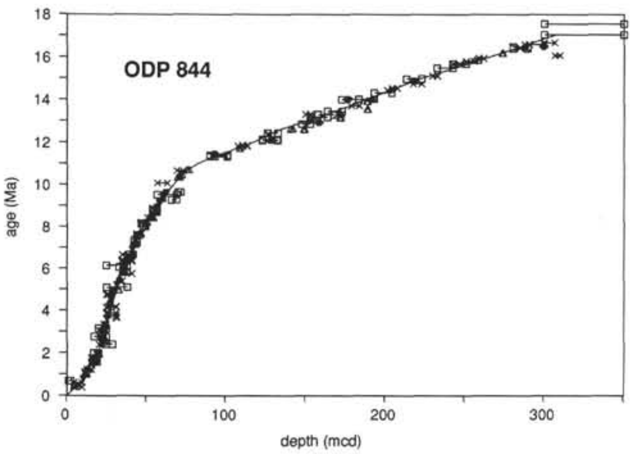

Figure 3. Age-depth plot for Site 844. The line shows the age-depth relationship given by Shackleton et al. (this volume). For each biostratigraphic datum, the upper and lower depth limits are shown at the ages estimated in the column labeled "Best" in Table 6. Symbols as in Figure 1, with the addition of solid triangles = magnetics.

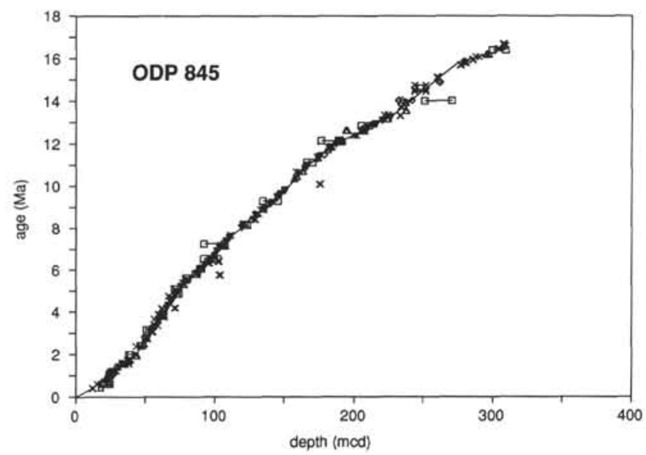

Figure 4. As in Figure 3, for Site 845. Symbols as in Figure 3.

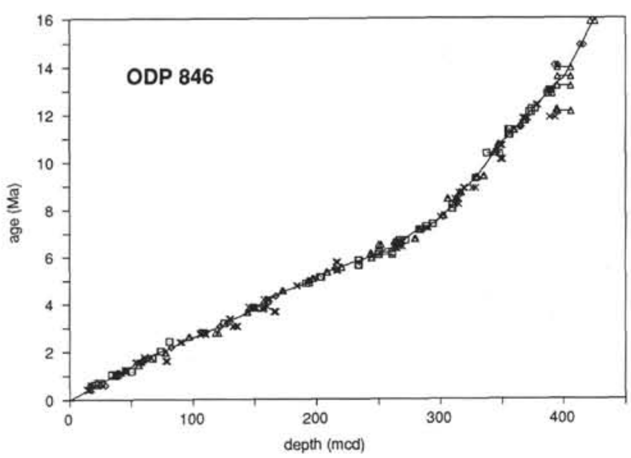

Figure 5. As in Figure 3, for Site 846. Symbols as in Figure 1.

Here, we have examined the data from a biostratigrapher's standpoint. Table 5 (complete table on CD-ROM, back pocket) gives the upper and lower estimates of each datum in each site, with each upper and lower estimate sorted by age. If every age model were perfect, and if every datum were synchronous over the region covered, then every upper bound would be younger than the true age of the event, and every lower bound would be older than the true age. If this were the case, the separation would be an indication only of how closely the biostratigrapher sampled for each datum in each site. In reality, there is some overlap between the oldest upper limit, and the youngest older limit, for virtually every one of the datums. This overlap, which we call raw diachrony, is estimated in Table 6 (column labeled "Best") for each datum considered. Several factors certainly contribute to this raw diachrony. First, it is probable that not all datums should be regarded as synchronous; Moore et al. (1993), taking an ecologic rather than a biostratigraphic standpoint, demonstrated this for several of the datums discussed here. Second, the placement of several datums is seriously distorted by preservation problems in some sites. Third, some

Table 4 (continued).

		844 (t)	844 (o)	845 (t)	845 (o)	846 (t)	846 (o)	847 (t)	847 (o)	848 (t)	848 (o)
b	*A. octopyle*	16.621	16.859	16.430	16.450	NA	NA	NA	NA	NA	NA
t	*C. cingulata*	16.481	16.554	16.348	16.362	NA	NA	NA	NA	NA	NA
t	*D. prismatica*	16.859	17.019	16.415	16.430	NA	NA	NA	NA	NA	NA
b	*G. toxaria*	16.554	16.621	NA	NA	NA	NA	NA	NA	NA	NA
t	*G. tosaensis*	NA	NA	NA	NA	0.454	0.794	NA	NA	NA	NA
t	*Pulleniatina* L	NA	NA	NA	NA	NA	NA	0.858	1.223	NA	NA
t	*G. fistulosus*	NA	NA	NA	NA	1.744	1.747	1.504	1.848	NA	NA
b	*G. truncatulinoides*	NA	NA	NA	NA	NA	NA	2.330	2.450	NA	NA
t	*G. obliquus*	NA	NA	NA	NA	NA	NA	2.450	2.801	NA	NA
t	*G. limbata*	NA	NA	NA	NA	2.175	2.178	2.330	2.450	1.746	3.411
t	*G. altispira*	NA	NA	NA	NA	3.043	3.048	NA	NA	NA	NA
t	*S. seminulina*	NA	NA	NA	NA	3.202	3.207	3.562	3.918	3.411	4.879
t	*P. spectabilis*	NA	NA	NA	NA	4.335	4.337	3.918	4.332	NA	NA
b	*G. tumida*	NA	NA	NA	NA	NA	NA	5.368	5.605	NA	NA
t	*G. dehiscens*	NA	NA	NA	NA	5.489	5.491	NA	NA	NA	NA
t	*G. siakensis*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
t	*G. fohsi* group	11.318	11.366	11.584	11.592	11.597	11.681	NA	NA	NA	NA
b	*G. fohsi lobata*	13.174	13.213	12.847	12.891	12.960	13.044	NA	NA	NA	NA
b	*G. fohsi fohsi*	13.686	13.728	13.550	13.577	13.211	13.336	NA	NA	NA	NA
t	*G. archaeomenardii*	14.129	14.173	13.702	14.079	NA	NA	NA	NA	NA	NA
b	*G. praefohsi*	14.271	14.314	14.165	14.640	14.242	14.390	NA	NA	NA	NA
b	*O. suturalis*	14.866	14.909	15.101	15.143	14.795	15.041	NA	NA	NA	NA
b	*P. sicana*	16.821	NA	NA	NA	NA	NA	NA	NA	NA	NA

Note: Full generic names appear in Table 6.

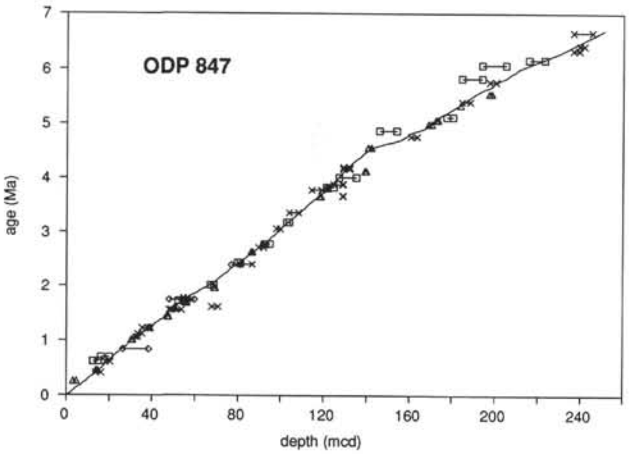

Figure 6. As in Figure 3, for Site 847. Symbols as in Figure 1.

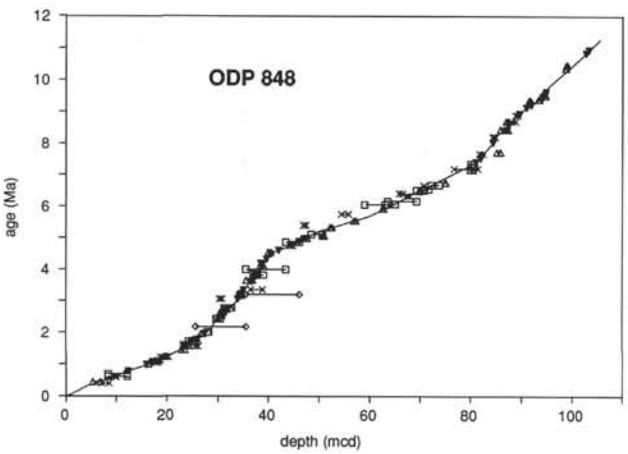

Figure 7. As in Figure 3, for Site 848. Symbols as in Figure 3.

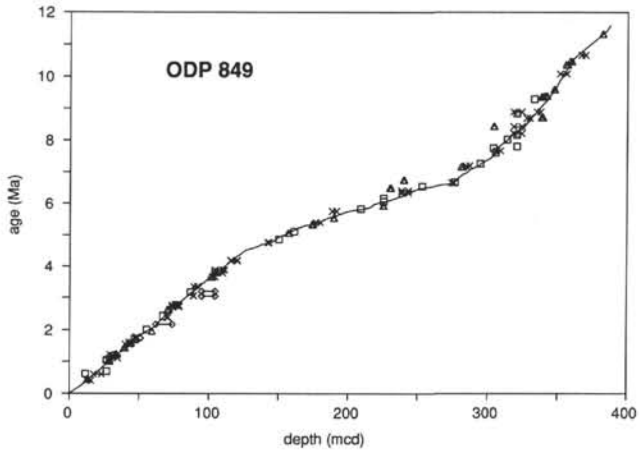

Figure 8. As in Figure 3, for Site 849. Symbols as in Figure 3.

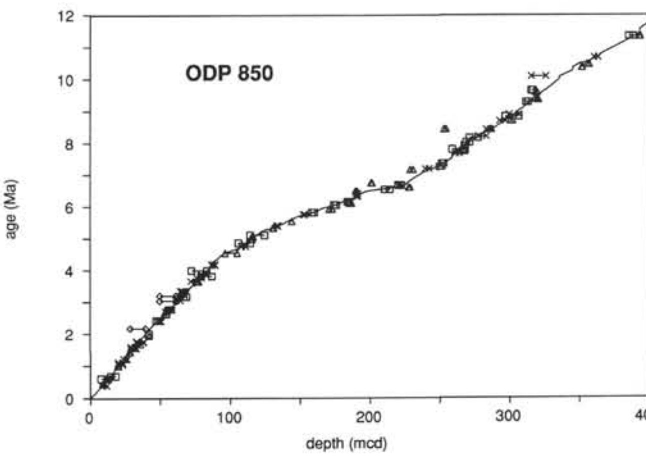

Figure 9. As in Figure 3, for Site 850. Symbols as in Figure 3.

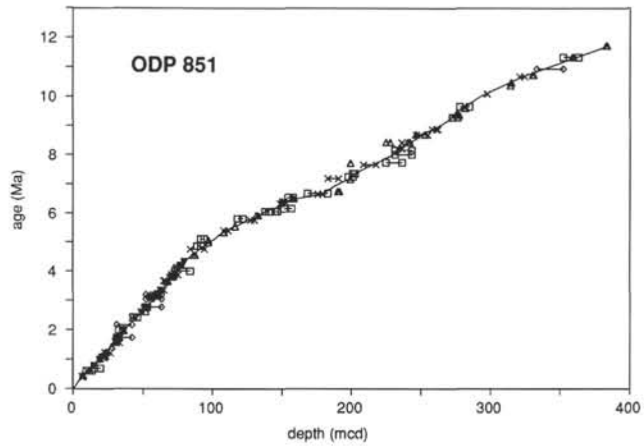

Figure 10. As in Figure 3, for Site 851. Symbols as in Figure 3.

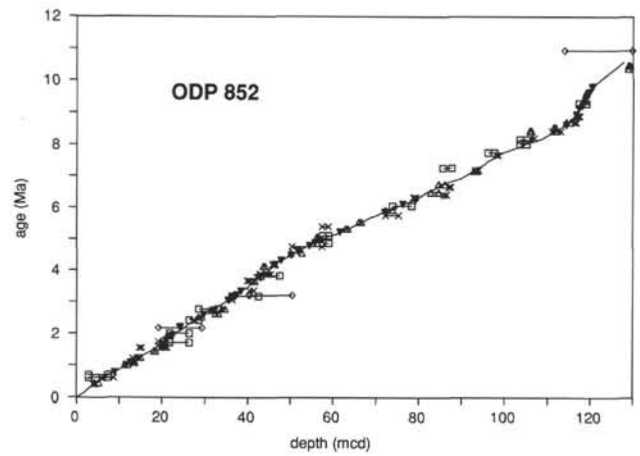

Figure 11. As in Figure 3, for Site 852. Symbols as in Figure 3.

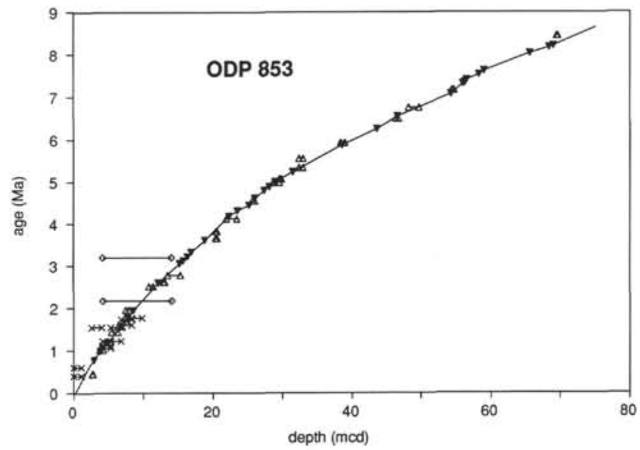

Figure 12. As in Figure 3, for Site 853. Symbols as in Figure 3, except for the deletion of diatoms (open squares).

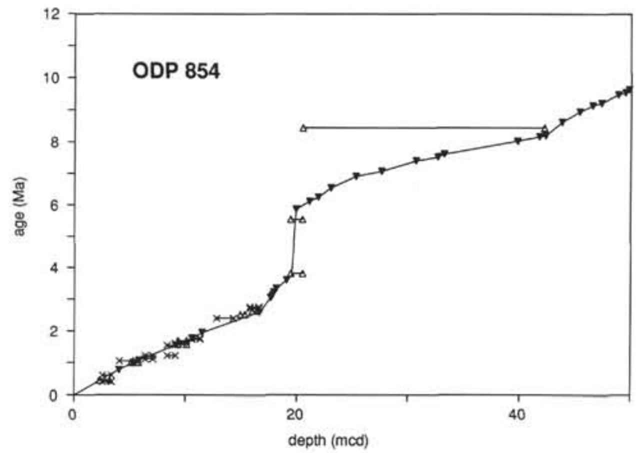

Figure 13. As in Figure 3, for Site 854. Symbols as in Figure 3, except for the deletion of diatoms (open squares) and foraminifers (open diamonds).

sites were examined at wide intervals for some microfossil groups; it seems clear that a datum is more readily mislocated if only scattered samples are examined. Fourth, because judgment is required to decide whether a species is "present" or "absent," it may be that the criteria used were not optimal, or that they were not applied uniformly. Finally, the age models that we have used may not be sufficiently accurate.

The column labeled "Uncertainty" in Table 7 indicates those datums that do appear to be diachronous, although it is difficult to devise an objective means for doing this. For the radiolarians, Moore et al. (1993) showed that in the majority of cases, the diachrony is mappable and probably represents true ecological diachrony. Where this is not yet clear, we have indicated a query. In some cases, a reexamination of the material may indicate that the datum is not, in fact, diachronous, either because the age model is insufficiently precise or because the datum was mislocated. Of course, a datum may be functionally diachronous as a result of the species concerned being susceptible to dissolution or overgrowth, or simply being difficult to identify, even if its spread or demise were not spatially diachronous. Thus, a large estimate of raw diachrony in the "Best" column should be taken as a caution for that datum, regardless of its cause.

We have compared the diachrony of the datums for the various microfossil groups, separating first appearance datums (FADs) from last appearance datums (LADs). The data suggest that no significant difference exists between the reliability of FADs and LADs. However, it is difficult to devise objective means for eliminating less reliable observations in a way that is valid for all fossil groups, so that it is not easy to assess the relative quality of biostratigraphic datums from different microfossil groups, except in a very general sense. In addition, one should devise a means of assessing diachrony that is applicable to all groups. Finally, each biostratigrapher had different objectives in recording the information summarized here, and there was not time to examine all datums in all sites with equal care. For these reasons, we have not tabulated these comparisons.

Another approach to the evaluation of datum levels is to examine the distribution of estimates in individual sites for the age of each datum. Here, one has to take into account the fact that not all datums were examined in equal depth resolution. In general, datums were examined at high resolution subject to the constraints of preservation on the one hand, and to the time available on the other; if poor preservation is the reason a datum was not constrained closely, it is obvious that the observation is of less value. However, experience shows that observations of the position of datums that are made hastily aboard ship in core-catcher samples frequently require revision. For this reason, we have divided the 988 observations tabulated into those that are constrained within 0.21 m.y. or closer (786 observations) and the rest (202 observations). In Table 8, the data for the "well-defined" datums and the remainder are summarized. We found that the well-defined nannofossil datums were examined on average to within 0.05 Ma and that the radiolarians and diatoms were examined to within 0.08 and 0.09 Ma, respectively. We have estimated the deviation of each of these individual datum age estimates from the best value for that datum. The mean deviation of all nannofossil determinations from the best value is about 0.09 Ma; the equivalent figure for diatoms is 0.09 Ma, and for radiolarians, 0.15 Ma. For the whole data set and for all microfossil groups, the mean deviation is 0.39; taking the poorly constrained determinations only, the value is 0.50. If the observation for less well-constrained datums were no less reliable, one might expect the mean deviation to approximate half the constraining range; the fact that the figure is far greater supports our initial assumption that the reliability of a biostratigraphic datum determination deteriorates more than proportionately if the observations have been too widely spaced. In the context of ODP work, this finding strongly supports the strategy of refining the placement of each datum in a single hole at a site, rather than covering each hole in less detail. The summary in Table 8 suggests that the resolution within which a datum is defined is absolutely critical; it may well be that many of the datums that are indicated as possibly diachronous in Table 7 may prove synchronous on closer examination.

It is not clear from Table 8 whether one can define the level of refinement beyond which the law of diminishing returns sets it. At first sight, it appears that this point was passed in the case of the nannofossils. On the other hand, one may note that the reentry of medium-sized *Gephyrocapsa* spp., examined at all 11 sites, shows an overall raw diachrony of only 0.01 Ma. This figure must be so low partly because of the chance that it is close to a magnetic reversal, so that at the sites in which the GRAPE age model would be expected to be less reliable, magnetostratigraphy fills the gap. However, the fact remains that this datum is clearly applicable with a remarkably high degree of precision. It may be that many other datums could be defined with equal precision. It may also be the case that in parts of our records, the age models could now be rendered more reliable by introducing biostratigraphic constraints. One remarkable feature of the Leg 138 work is that it was possible to develop a set of age models that did not contain biostratigraphical constraints, which provided an unusual opportunity to evaluate the reliability of the methods that are generally used. This does not mean that the age models are not amenable to further improvement.

To summarize the extent to which the Leg 138 calibrations may affect the biostratigraphic time scale, we show in Figure 14 the differences between our calibrations and those in use aboard ship, excluding those that we have characterized in Table 8 as being diachronous and excluding the interval older than 14 Ma that is far from our primary magnetostratigraphic control. Figure 14 shows that, for the Pliocene, the ages of all the reliable biostratigraphic datums were already known with respect to the polarity time scale to within 0.2 Ma; our new calibrations are probably really significant only for the diatoms. However, in the Miocene section, it seems clear that there were significant uncertainties in the ages of a number of important datums and that the Leg 138 calibrations have reduced those uncertainties.

CONCLUSIONS

The sediments recovered during Leg 138 have provided us an opportunity to obtain an internally consistent set of age estimates for biostratigraphic datums from the main microfossil groups used in marine biostratigraphy. For the time interval from 13.25 Ma to the present, these estimates are calibrated to the magnetic reversal scale and are tabulated in terms of the polarity time scale developed by Shackleton et al. (this volume) as well as for two other scales (BKF85; Cande and Kent, 1992). Although only a small number of datums are demonstrably synchronous over the area studied to better than 0.1 Ma, more intensive work on these sequences will probably increase that number. The estimates given in Table 6 probably constitute the most homogeneous set of biostratigraphic datum ages that is at present available for the Neogene.

Table 5. Placement of biostratigraphic datums in Leg 138 sites.

	Biostratigraphic datum	Limit of placement	Age (Ma)	Type of datum	Site of observation
t	*Nitzschia reinholdii*	t	0.28	D	852
t	*Nitzschia reinholdii*	t	0.36	D	849
t	*Nitzschia reinholdii*	t	0.38	D	847
t	*Nitzschia reinholdii*	t	0.55	D	848
t	*Nitzschia reinholdii*	t	0.57	D	846
t	*Nitzschia reinholdii*	t	0.57	D	851
t	*Nitzschia reinholdii*	t	0.96	D	845
t	*Nitzschia reinholdii*	o	0.45	D	847
t	*Nitzschia reinholdii*	o	0.63	D	850
t	*Nitzschia reinholdii*	o	0.63	D	846
t	*Nitzschia reinholdii*	o	0.67	D	852
t	*Nitzschia reinholdii*	o	0.70	D	851
t	*Nitzschia reinholdii*	o	0.77	D	848
t	*Nitzschia reinholdii*	o	0.94	D	849
t	*Nitzschia reinholdii*	o	1.05	D	845
t	*Nitzschia fossilis*	t	0.09	D	844
t	*Nitzschia fossilis*	t	0.28	D	852
t	*Nitzschia fossilis*	t	0.49	D	847
t	*Nitzschia fossilis*	t	0.55	D	848
t	*Nitzschia fossilis*	t	0.63	D	846
t	*Nitzschia fossilis*	t	0.71	D	850
t	*Nitzschia fossilis*	t	0.79	D	851
t	*Nitzschia fossilis*	t	0.86	D	845
t	*Nitzschia fossilis*	t	0.94	D	849
t	*Nitzschia fossilis*	o	0.18	D	844
t	*Nitzschia fossilis*	o	0.64	D	847
t	*Nitzschia fossilis*	o	0.67	D	852
t	*Nitzschia fossilis*	o	0.72	D	846
t	*Nitzschia fossilis*	o	0.77	D	848
t	*Nitzschia fossilis*	o	0.90	D	850
t	*Nitzschia fossilis*	o	1.01	D	845
t	*Nitzschia fossilis*	o	1.05	D	851
t	*Nitzschia fossilis*	o	1.11	D	849
t	*Rhizosolenia matuyama*	t	0.92	D	846
t	*Rhizosolenia matuyama*	t	0.94	D	849
t	*Rhizosolenia matuyama*	t	1.01	D	845
t	*Rhizosolenia matuyama*	o	1.08	D	846
t	*Rhizosolenia matuyama*	o	1.09	D	845
t	*Rhizosolenia matuyama*	o	1.11	D	849
b	*Rhizosolenia matuyama*	t	1.09	D	845
b	*Rhizosolenia matuyama*	t	1.11	D	849
b	*Rhizosolenia matuyama*	t	1.39	D	846
b	*Rhizosolenia matuyama*	o	1.16	D	845
b	*Rhizosolenia matuyama*	o	1.24	D	849
b	*Rhizosolenia matuyama*	o	1.40	D	846
t	*R. praebergonii* var. *robusta*	t	1.58	D	848
t	*R. praebergonii* var. *robusta*	t	1.66	D	847
t	*R. praebergonii* var. *robusta*	t	1.66	D	851
t	*R. praebergonii* var. *robusta*	t	1.70	D	849
t	*R. praebergonii* var. *robusta*	t	1.86	D	846
t	*R. praebergonii* var. *robusta*	t	1.87	D	852
t	*R. praebergonii* var. *robusta*	o	1.71	D	847
t	*R. praebergonii* var. *robusta*	o	1.74	D	849
t	*R. praebergonii* var. *robusta*	o	1.75	D	848
t	*R. praebergonii* var. *robusta*	o	1.75	D	851
t	*R. praebergonii* var. *robusta*	o	1.87	D	846
t	*R. praebergonii* var. *robusta*	o	2.30	D	852
b	*Pseudoeunotia doliolus*	t	1.63	D	844
b	*Pseudoeunotia doliolus*	t	1.74	D	845
b	*Pseudoeunotia doliolus*	t	1.75	D	851
b	*Pseudoeunotia doliolus*	t	1.87	D	852
b	*Pseudoeunotia doliolus*	t	1.96	D	849
b	*Pseudoeunotia doliolus*	t	1.98	D	846
b	*Pseudoeunotia doliolus*	t	2.03	D	847
b	*Pseudoeunotia doliolus*	t	2.05	D	848
b	*Pseudoeunotia doliolus*	t	2.13	D	850
b	*Pseudoeunotia doliolus*	o	1.80	D	845
b	*Pseudoeunotia doliolus*	o	1.92	D	851
b	*Pseudoeunotia doliolus*	o	2.00	D	846
b	*Pseudoeunotia doliolus*	o	2.05	D	849
b	*Pseudoeunotia doliolus*	o	2.06	D	847
b	*Pseudoeunotia doliolus*	o	2.07	D	848
b	*Pseudoeunotia doliolus*	o	2.11	D	844
b	*Pseudoeunotia doliolus*	o	2.14	D	850

Notes: In the column labeled "Biostratigraphic datum," t = top of range, b = base of range, tc = top of common occurrence, and bc = bottom of common occurrence. In the column labeled "Age," t = the upper limit of the placement of the datum, and o = the lower limit. In the column labeled "Type of datum," D = diatom (from Baldauf and Iwai, this volume), F = foraminifer (from Vincent and Toumarkine, this volume; from the site chapters in Mayer, Pisias, Janecek et al., 1992; or from Shackleton et al., this volume), N = nannofossil (Raffi and Flores, this volume), and R = radiolarian (Moore, this volume).

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Table 6. Estimates for ages of datums (see text for details).

		Med.	Dif.	Mid.	Diac.	Best	Unc.	Choice	Type
b	*Emiliania huxleyi*	0.12	0.04	0.12	–0.04	0.26		Lit	N
t	*Stylatractus universus*	0.44	0.10	0.39	0.23	0.41		Lit	R
t	*Pseudoemiliania lacunosa*	0.45	0.06	0.58	0.30	0.46		Lit	N
b	*Collosphaera tuberosa*	0.61	0.08	0.45	0.36	0.61	0.08	Median	R
t	*Nitzschia reinholdii*	0.62	0.14	0.71	0.51	0.62	0.14	Median	D
t	*Globorotalia tosaensis*	0.63	0.35	0.63	–0.35	0.59		Lit	F
t	*Nitzschia fossilis*	0.70	0.14	0.56	0.76	0.70	0.14	Median	D
b	Reentrance medium *Gephyrocapsa* spp.	1.01	0.06	1.02	0.01	1.02	0.01	Mid	N
t	*Pulleniatina* left-coiling	1.04	0.36	1.04	–0.36	0.84		Lit	F
t	*Rhizosolenia matuyama*	1.02	0.15	1.05	–0.07	1.05	–0.07	Mid	D
t	*Lamprocyrtis neoheteroporos*	1.06	0.07	1.07	0.08	1.06	0.07	Median	R
t	*Anthocyrtidium angulare*	1.12	0.06	1.13	0.10	1.12	0.06	Median	R
b	*Rhizosolenia matuyama*	1.18	0.13	1.28	0.23	1.18	0.13	Median	D
t	*Theocorythium vetulum*	1.21	0.11	1.22	0.06	1.22	0.06	Mid	R
b	*Lamprocyrtis nigriniae*	1.23	0.08	1.33	0.22	1.23	0.08	Median	R
t	Large *Gephyrocapsa* spp.	1.24	0.05	1.22	0.06	1.24	0.05	Median	N
b	Large *Gephyrocapsa* spp.	1.44	0.06	1.45	0.22	1.44	0.06	Median	N
b	*Pterocorys minithorax*	1.55	0.11	1.40	0.71	1.55	0.11	Median	R
b	*Theocorythium trachelium*	1.55	0.16	1.64	0.24	1.55	0.16	Median	R
t	*Calcidiscus macintyrei*	1.58	0.04	1.58	0.18	1.58	0.04	Median	N
t	*Lamprocyrtis heteroporos*	1.61	0.10	1.80	0.55	1.61	0.10	Median	R
b	Medium *Gephyrocapsa* spp.	1.69	0.04	1.71	0.20	1.69	0.04	Median	N
t	*R. praebergonii* var. *robusta*	1.72	0.07	1.79	0.16	1.72	0.07	Median	D
t	*Pterocanium prismatium*	1.74	0.09	1.74	0.06	1.74	0.06	Mid	R
t	*Globigerinoides fistulosus*	1.77	0.14	1.79	0.09	1.74	0.01	846	F
b	Anthocyrtidium angulare	1.77	0.07	1.83	0.15	1.77	0.07	Median	R
b	*Pseudoeunotia doliolus*	2.01	0.10	1.97	0.33	2.01	0.10	Median	D
t	*Discoaster brouweri*	2.04	0.06	1.97	0.36	1.96		Lit	N
t	*Globorotalia limbata*	2.10	0.80	2.17	0.32	2.18	0.00	846	F
b	*Globorotalia truncatulinoides*	2.39	0.12	2.39	–0.12	2.39	–0.12		F
t	*Anthocyrtidium jenghisi*	2.40	0.10	2.39	0.18	2.40	0.10	Median	R
t	*Thalassiosira convexa*	2.43	0.13	2.67	1.06	2.43	0.13	Median	D
t	*Discoaster pentaradiatus*	2.52	0.06	2.50	0.14	2.52	0.06	Median	N
t	*Discoaster surculus*	2.63	0.05	2.73	0.39	2.63	0.05	Median	N
b	*Theocalyptra davisiana*	2.71	0.13	2.67	0.15	2.71	0.13	Median	R
t	Stichocorys peregrina	2.76	0.09	2.73	0.27	2.76	0.09	Median	R
t	*Discoaster tamalis*	2.78	0.04	2.86	0.20	2.78	0.04	Median	N
t	*Globigerinoides obliquus*	2.85	0.48	2.78	–0.04	2.78	–0.04	Mid	F
t	*Nitzschia jouseae*	2.79	0.11	2.78	0.04	2.78	0.04	Mid	D
t	Globoquadrina altispira	3.06	0.31	3.20	0.44	3.05	0.01	846	F
b	*Lamprocyrtis neoheteroporos*	3.06	0.15	2.99	0.86	3.06	0.15	Median	R
b	*Lamprocyrtis heteroporos*	3.06	0.16	2.96	0.79	3.06	0.16	Median	R
b	*Rhizosolenia praebergonii*	3.18	0.08	3.12	0.27	3.18	0.08	Median	D
t	*Sphaeroidinellopsis seminulina*	3.44	0.26	3.22	0.68	3.20	0.01	846	F
t	*Anthocyrtidium pliocenica*	3.36	0.18	3.39	0.41	3.36	0.18	Median	R
t	*Sphenolithus* spp.	3.66	0.05	3.75	0.25	3.66	0.05	Median	N
t	*Phormostichoartus fistula*	3.67	0.02	4.35	1.67	3.67	0.02	Median	R
t	*Lychnodictyum audax*	3.78	0.06	3.84	0.31	3.78	0.06	Median	R
t	*Reticulofenestra pseudoumbilicus*	3.82	0.05	3.83	0.08	3.82	0.05	Median	N
b	*Thalassiosira convexa* f. *convexa*	3.85	0.13	3.83	0.03	3.83	0.03	Mid	D
b	*Amphirhopalum ypsilon*	3.88	0.14	3.82	0.36	3.88	0.14	Median	R
t	*Phormostichoartus dolium*	3.89	0.15	3.89	0.41	3.89	0.15	Median	R
b	*Asteromphalus elegans*	4.07	0.70	4.01	0.04	4.01	0.04	Mid	D
bc	*Discoaster asymmetricus*	4.13	0.09	4.20	0.54	4.13	0.09	Median	N
b	*Spongaster tetras*	4.17	0.12	4.05	0.31	4.17	0.12	Median	R
t	*Didymocyrtis penultima*	4.20	0.14	4.45	0.59	4.20	0.14	Median	R
t	*Pulleniatina spectabilis*	4.23	0.21	4.33	0.00	4.33	0.00	846	F
t	*Amaurolithus primus*	4.56	0.10	4.54	0.13	4.56	0.10	Median	N
b	*Pterocanium prismatium*	4.76	0.07	4.34	0.99	4.76	0.07	Median	R
t	*Nitzschia cylindrica*	4.87	0.15	4.84	0.31	4.87	0.15	Median	D
t	*Ceratolithus acutus*	4.99	0.06	5.19	0.50	4.99	0.06	Median	N
b	*Ceratolithus rugosus*	5.07	0.02	5.09	0.30	5.07	0.02	Median	N
b	*Nitzschia jouseae*	5.12	0.25	5.05	0.34	5.12	0.25	Median	D
b	*Ceratolithus acutus*	5.34	0.02	5.35	0.03	5.34	0.02	Median	N
t	*Triquetrorhabdulus rugosus*	5.35	0.01	5.35	–0.01	5.35	–0.01		N
t	*Solenosphaera omnitubus*	5.40	0.05	5.27	0.56	5.40	0.05	Median	R
t	*Globoquadrina dehiscens*	5.49	0.00	5.49	0.00	5.49	0.00		F
t	*Discoaster quinqueramus*	5.55	0.02	5.52	0.29	5.55	0.02	Median	N
b	*Globorotalia tumida*	5.59	0.54	6.42	1.73	5.59	0.54	Median	F
b	*Thalassiosira oestrupii*	5.63	0.04	5.65	0.31	5.63	0.04	Median	D
t	*Siphostichartus corona*	5.76	0.01	6.28	1.56	5.76	0.01	Median	R
t	*Thalassiosira miocenica*	5.83	0.03	5.80	0.40	5.83	0.03	Median	D
t	*Amaurolithus amplificus*	5.93	0.05	5.97	0.16	5.93	0.05	Median	N
t	*Nitzschia miocenica*	6.07	0.04	5.97	0.27	6.07	0.04	Median	D
t	*N. miocenica* var. *elongata*	6.08	0.05	6.10	0.19	6.08	0.05	Median	D
t	Circular reticulofenestrids	6.12	0.02	6.12	0.21	6.12	0.02	Median	N
t	*Thalassiosira praeconvexa*	6.17	0.19	6.20	0.25	6.17	0.19	Median	D
t	*Stichocorys johnsoni*	6.34	0.07	6.35	0.16	6.34	0.07	Median	R
t	*Calocycletta caepa*	6.42	0.21	6.61	0.75	6.42	0.21	Median	R
b	*Amaurolithus amplificus*	6.50	0.02	6.37	0.49	6.50	0.02	Median	N
t	*Rossiella praepaleacea*	6.52	0.12	6.52	–0.12	6.52	-0.12	Mid	D
b	*Thalassiosira miocenica*	6.54	0.08	6.53	0.10	6.54	0.08	Median	D
b	*T. convexa* var. *aspinosa*	6.57	0.13	6.55	0.06	6.55	0.06	Mid	D
b	Circular reticulofenestrids	6.62	0.05	6.63	0.33	6.62	0.05	Median	N
b	*Stichocorys delmontensis* to *S. peregrina*	6.66	0.05	6.70	0.25	6.66	0.05	Median	R
b	*Thalassiosira praeconvexa*	6.73	0.16	6.69	0.05	6.69	0.05	Mid	D
t	Absence *Reticulofenestra pseudoumbilicus*	6.76	0.04	6.65	0.78	6.76	0.04	Median	N

Table 6 (continued).

		Med.	Dif.	Mid.	Diac.	Best	Unc.	Choice	Type
t	*Nitzschia porteri*	7.14	0.02	7.14	–0.02	7.14	–0.02		D
b	*Amaurolithus primus*	7.17	0.12	7.10	0.44	7.17	0.12	Median	N
b	*Solenosphaera omnitubus*	7.20	0.15	7.14	0.25	7.20	0.15	Median	R
b	*Nitzschia miocenica*	7.27	0.11	7.09	0.49	7.27	0.11	Median	D
t	Rossiella paleacea	7.36	0.05	7.37	0.05	7.37	0.05	Median	
b	*Nitzschia reinholdii*	7.64	0.23	7.61	–0.08	7.61	–0.08	Mid	D
t	*Diartus hughesi*	7.65	0.09	7.67	0.08	7.67	0.08	Mid	R
t	*Minylitha convallis*	7.73	0.05	7.74	1.01	7.73	0.05	Median	N
t	*A. ellipticus* var. *javanicus*	7.75	0.15	7.74	0.30	7.75	0.15	Median	D
t	*Thalassiosira burckliana*	7.81	0.31	7.81	–0.31	7.81	–0.31	Mid	D
b	*Nitzschia marina*	7.92	0.09	7.92	–0.09	7.92	–0.09		D
b	*Nitzschia cylindrica*	8.03	0.07	8.08	0.22	8.03	0.07	Median	D
t	*Thalassiosira yabei*	8.17	0.19	8.06	0.42	8.17	0.19	Median	D
t	*Botryostrobus miralestensis*	8.21	0.10	8.24	0.26	8.21	0.10	Median	R
t	*Diartus pettersoni*	8.43	0.13	8.45	0.28	8.43	0.13	Median	R
b	*Discoaster berggrenii*	8.07	0.15	7.94	1.04	8.45		Mag	N
b	*Discoaster loeblichii*	8.45	0.06	8.49	0.13	8.45	0.06	Median	N
b	*Discoaster pentaradiatus*	8.46	0.07	8.45	0.01	8.55		Mag	N
b	*Diartus pettersoni* to D. *hughesi*	8.70	0.17	8.76	0.27	8.70	0.17	Median	R
b	Absence *R. pseudoumbilicus*	8.71	0.15	8.83	0.46	8.71	0.15	Median	N
t	*Coscinodiscus loeblichii*	8.79	0.29	8.79	–0.29	8.79	–0.29		D
b	*Thalassiosira burckliana*	8.84	0.29	8.84	–0.19	8.84	–0.19	Mid	D
b	*Diartus hughesi*	8.89	0.10	8.77	0.83	8.89	0.10	Median	R
t	*Stichocorys wolffi*	8.89	0.13	8.98	0.26	8.89	0.13	Median	R
t	*Denticulopsis simonsenii*	9.35	0.30	9.59	0.65	9.35	0.30	Median	D
b	*Minylitha convallis*	9.37	0.06	9.31	0.38	9.37	0.06	Median	N
t	*Discoaster hamatus*	9.40	0.03	9.51	0.51	9.40	0.03	Median	N
b	*Discoaster neohamatus*	9.52	0.04	9.57	0.18	9.52	0.04	Median	N
b	*Coscinodiscus loeblichii*	9.55	1.24	9.55	–1.24	9.55	–1.24		D
t	*Discoaster neohamatus*	9.60	0.12	9.60	–0.12	9.60	–0.12	Mid	N
t	*Actinocyclus moronensis*	9.66	0.19	9.84	0.87	9.66	0.19	Median	D
t	*Cyrtocapsella japonica*	10.09	0.12	10.09	0.07	10.09	0.07	Mid	R
t	*Lithoperta thornburgi*	10.09	0.17	10.54	1.74	10.09	0.17	Median	R
t	*A. ellipticus* f. *lanceolata*	10.35	0.81	10.35	–0.81	10.35	–0.81		D
b	*Discoaster hamatus*	10.38	0.08	10.57	0.60	10.38	0.08	Median*	N
t	*Coccolithus miopelagicus*	10.48	0.04	10.60	0.56	10.48	0.04	Median*	N
t	*Carpocanopsis cristata*	10.68	0.07	10.65	0.26	10.68	0.07	Median	R
b	*Catinaster coalitus*	10.73	0.04	10.79	0.13	10.73	0.04	Median	N
b	*Globorotalia siakensis*	10.47	1.41	10.94	–0.03	10.94	–0.03	Mid	F
t	*Coscinodiscus gigas* var. *diorama*	11.10	0.15	11.13	–0.07	11.13	–0.07	Mid	D
b	*R. paleacea* var. *elongata*	11.13	0.07	11.13	–0.07	11.13	–0.07	Mid	D
t	*Craspedodiscus coscinodiscus*	11.34	0.20	11.28	0.23	11.34	0.20	Median	D
tc	*Discoaster kugleri*	11.36	0.03	11.47	0.27	11.34	–0.02	845	N
t	*Synedra jouseana*	11.41	0.32	11.41	–0.32	11.41	–0.32		D
b	*Sphaeroidinella subdehiscens*	11.74	0.33	11.74	–0.33	11.74	–0.33	Mid	F
bc	*Discoaster kugleri*	11.81	0.06	12.06	0.67	11.74	–0.02	845	N
t	*Lithoperta renzae*	11.79	0.05	11.82	0.01	11.82	0.01	Mid	R
t	*Cyrtocapsella cornuta*	11.83	0.03	11.86	0.08	11.83	0.03	Median	R
t	*Dorcadospyris alata*	11.86	0.05	11.86	–0.03	11.86	–0.03	Mid	R
b	*Diartus pettersoni*	11.86	0.08	12.42	1.16	11.86	0.08	Median	R
t	*Actinocyclus ingens*	12.10	0.10	12.17	0.10	12.10	0.10	Median	D
t	*Coronocyclus nitescens*	12.43	0.03	12.73	1.20	12.12	–0.02	845	N
b	*Calcidiscus macintyrei*	12.14	0.01	12.14	–0.01	12.14	–0.01		N
t	*Cestodiscus pulchellus*	12.08	0.45	12.14	0.17	12.14	0.17	Mid	D
b	*Thalassiosira brunii*	12.28	0.18	12.19	0.06	12.19	0.06	Mid	D
b	*Discoaster kugleri*	12.40	0.02	12.71	1.14	12.20	–0.02	845	N
b	*Nitzschia porteri*	12.23	0.16	12.23	–0.16	12.23	–0.16		D
b	*Cyrtocapsella japonica*	12.40	0.09	12.39	0.08	12.39	0.08	Mid	R
t2	*Annellus californicus*	12.45	0.24	12.45	–0.24	12.45	–0.24		D
b	*Triquetrorhabdulus rugosus*	12.81	0.03	12.82	0.27	12.62	–0.03	845	N
t	*Calcidiscus premacintyrei*	12.51	0.04	12.51	0.50	12.65	–0.03	845	N
t	*Coscinodiscus lewisianus*	12.97	0.17	12.86	0.12	12.86	0.12	Mid	D
b	*Globorotalia fohsi lobata*	12.94	0.23	12.94	–0.23	12.94	–0.23	Mid	F
b	*Coscinodiscus gigas* var. *diorama*	13.00	0.05	13.00	–0.05	13.00	–0.05		D
t	*Discoaster signus*	13.08	0.07	13.08	–0.07	13.08	–0.07		N
t	*Cyclicargolithus floridanus*	13.46	0.25	13.38	0.36	13.19	–0.02	845	N
t	*Thalassiosira tappanae*	13.20	0.29	13.20	–0.29	13.20	–0.29		D
b	*Lithoperta thornburgi*	13.32	0.05	13.33	0.55	13.32	0.05	Median	R
b	*Triceratium cinnamoneum*	13.32	0.27	13.32	–0.27	13.32	–0.27		D
b	*Calocycletta caepa*	13.35	0.08	13.35	0.32	13.35	0.08	Median	R
b	*Denticulopsis simonsenii*	13.47	0.26	13.47	–0.26	13.47	–0.26	Mid	D
t	*Sphenolithus heteromorphus*	13.95	0.21	13.95	0.18	13.57	–0.02	845	N
t	*Stichocorys armata*	13.74	0.09	13.72	0.09	13.72	0.09	Median	R
b	*Reticulofenestra pseudoumbilicus*	13.95	0.21	13.95	0.18	13.95	0.18	Mid	N
t	*Cestodiscus peplum*	14.32	0.87	14.03	0.26	14.03	0.26	Mid	D
b	*Actinocyclus ellipticus*	14.04	0.27	14.04	–0.27	14.04	–0.27		D
t	*Globorotalia archaeomenardii*	14.04	0.27	14.04	–0.27	14.04	–0.27	Mid	F
b	*Globorotalia fohsi* group	14.04	0.27	14.04	–0.27	14.04	–0.27	Mid	F
b	*Coscinodiscus blysmos*	14.34	0.33	14.34	–0.33	14.34	–0.33		D
t	*Liriospyrys parkarae*	14.43	0.26	14.46	–0.09	14.46	–0.09	Mid	R
t	*Acrocubus octopyle*	14.47	0.27	14.55	–0.10	14.55	–0.10	Mid	R
t	*Carpocanopsis bramlettei*	14.67	0.28	14.75	0.27	14.75	0.27	Mid	R
t1	*Anellus californicus*	14.89	0.26	14.89	–0.26	15.0		Lit	D
b	*Orbulina suturalis*	14.89	0.26	14.89	–0.26	14.89	–0.26		F
t	*Calocycletta costata*	15.12	0.06	15.11	0.12	15.12	0.06	Median	R
b	*Actinocyclus ingens*	15.36	0.23	15.36	–0.23	15.5		Lit	D
t	*Coscinodiscus lewisianus* var. *similis*	15.57	0.19	15.57	–0.19	15.7		Lit	D

Table 6 (continued).

		Med.	Dif.	Mid.	Diac.	Best	Unc.	Choice	Type
b	*Dorcadospyris dentata* to *D. alata*	15.69	0.05	15.71	0.28	15.69	0.05	Median	R
t	*Liriospyris stauropora*	15.81	0.06	15.84	0.13	15.81	0.06	Median	R
b	*Liriospyris parkerae*	15.82	0.06	15.85	0.15	15.82	0.06	Median	R
t	*Helicosphaera ampliaperta*	15.85	0.12	15.87	0.06	15.87	0.06	Mid	N
t	Eucyrtidium diaphenes	15.95	0.05	15.97	0.09	15.95	0.05	Median	R
b	*Carpocanopsis bramlettei*	16.08	0.05	16.08	–0.05	16.08	–0.05	Mid	R
b	*Discoaster signus*	16.21	0.03	16.20	0.00	16.20	0.00	Midpoint	N
t	Acme *Discoaster deflandrei*	16.22	0.03	16.22	–0.03	16.22	–0.03		N
b	*Cestodiscus peplum*	16.43	0.20	16.41	–0.08	16.4		Lit	D
t	*Carpocanopsis cingulata*	16.44	0.04	16.42	0.12	16.44	0.04	Median	R
t	*Raphidodiscus marylandicus*	16.49	0.23	16.49	–0.23	16.49	–0.23		D
t	*Thalassiosira fraga*	16.49	0.23	16.49	–0.23	16.49	–0.23		D
b	*Praeorbulina sicana*	16.50	0.25	16.50	–0.25	16.50	–0.25		F
b	*Giraffospyris toxaria*	16.55	0.07	16.59	–0.07	16.59	–0.07	Mid	R
b	*Acrocubus octopyle*	16.59	0.13	16.54	0.17	16.59	0.13	Median	R
t	*Didymocyrtis prismatica*	16.68	0.09	16.65	0.43	16.68	0.09	Median	R

Notes: In Column 1, t = top; b = base; reent = reentry of the species; circ = circular. Med. = datum age based on the median of ages which define the upper and the low limits of the datum. Dif. = difference between these medians. Mid. = age at the midpoint between the youngest estimate of the estimates of the lower limit and the oldest of the estimates of the upper limit of the datum. Diac. = diachrony (i.e., the amount by which the oldest of the estimates of the upper limit exceeds the youngest of the estimates of the lower limit); if the figure in this column is negative, the data are fully consistent with a synchronous datum. Best = our best estimate of the datum age. Unc. = measure of the uncertainty in this estimate, generally from Diac. columns. Choice = whether the best estimate is based on the median (Median), on the midpoint (Mid), or if it is estimated on another basis (an asterisk indicates that a discrepant estimate was ignored; a blank implies that the two estimates are identical; a site number indicates that the estimate is based on that site only; Mag implies that the estimate is based on the sites with magnetostratigraphy; Lit implies that the best estimate is from the published literature). Type = the microfossil type, with D = diatom, F = foraminifer, N = nannofossil, and R = radiolarian.

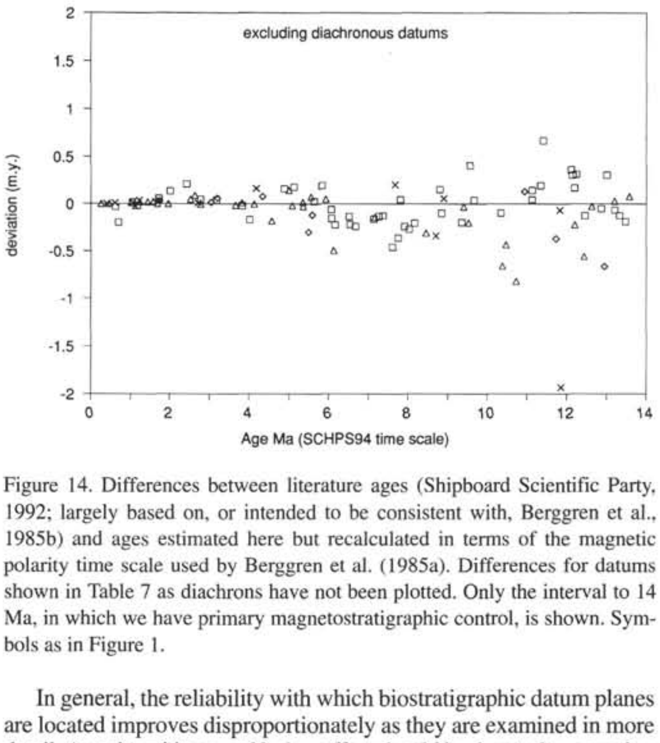

Figure 14. Differences between literature ages (Shipboard Scientific Party, 1992; largely based on, or intended to be consistent with, Berggren et al., 1985b) and ages estimated here but recalculated in terms of the magnetic polarity time scale used by Berggren et al. (1985a). Differences for datums shown in Table 7 as diachrons have not been plotted. Only the interval to 14 Ma, in which we have primary magnetostratigraphic control, is shown. Symbols as in Figure 1.

In general, the reliability with which biostratigraphic datum planes are located improves disproportionately as they are examined in more detail. At a site with several holes, effort should be devoted to covering one hole carefully, rather than several holes in a cursory fashion. When time is a constraint, it is probably more valuable to determine a few datums carefully, instead of determining many with less attention.

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Table 7. Best estimates for ages of biostratigraphic datums determined in Leg 138 sites.

		SCHPS94	CK92	BKF85	SSP92	Raw dif.	Adj dif.
t	*Nitzschia reinholdii*	0.62	0.62	0.62	0.65	−0.03	−0.03
t	*Nitzschia fossilis*	0.70	0.70	0.66	0.85	−0.15	−0.19
t	*Rhizosolenia matuyama*	1.05	1.03	0.96	0.94	0.11	0.02
b	*Rhizosolenia matuyama*	1.18	1.16	1.08	1.10	0.08	−0.02
t	*R. praebergonii* var. *robusta*	1.72	1.70	1.61	1.55	0.17	0.06
b	*Pseudoeunotia doliolus*	2.01	2.04	1.93	1.80	0.21	0.13
t	*Thalassiosira convexa*	2.43	2.43	2.31	2.10	0.33	0.21
t	*Nitzschia jouseae*	2.78	2.78	2.65	2.60	0.18	0.05
b	*Rhizosolenia praebergonii*	3.18	3.18	3.04	3.00	0.18	0.04
b	*Thalassiosira convexa* f. *convexa*	3.83	3.73	3.58	3.60	0.23	−0.02
b	*Asteromphalus elegans*	4.01	3.89	3.73	3.90	0.11	−0.17
t	*Nitzschia cylindrica*	4.87	4.69	4.46	4.30	0.57	0.16
b	*Nitzschia jouseae*	5.12	4.94	4.68	4.50	0.62	0.18
b	*Thalassiosira oestrupii*	5.63	5.45	5.13	5.10	0.53	0.03
t	*Thalassiosira miocenica*	5.83	5.64	5.30	5.10	0.73	0.20
t	*Nitzschia miocenica*	6.07	5.89	5.49	5.55	0.52	−0.06
t	*N. miocenica* var. *elongata*	6.08	5.90	5.49	5.65	0.43	−0.16
t	*Thalassiosira praeconvexa*	6.17	5.99	5.58	5.80	0.37	−0.22
t	*Rossiella praepaleacea*	6.52	6.34	5.87	6.00	0.52	−0.13
b	*Thalassiosira miocenica*	6.54	6.36	5.88	6.10	0.44	−0.22
b	*T. convexa* var. *aspinosa*	6.55	6.37	5.89	NA	NA	NA
b	*Thalassiosira praeconvexa*	6.69	6.51	6.06	6.30	0.39	−0.24
t	*Nitzschia porteri*	7.14	6.97	6.54	6.70	0.44	−0.16
b	*Nitzschia miocenica*	7.27	7.10	6.62	6.75	0.52	−0.13
t	*Rossiella paleacea*	7.37	7.20	6.68	6.80	0.57	−0.12
b	*Nitzschia reinholdii*	7.61	7.46	6.84	7.30	0.31	−0.46
t	*A. ellipticus* var. *javanicus*	7.75	7.60	6.99	7.35	0.40	−0.36
t	*Thalassiosira burckliana*	7.81	7.66	7.05	7.00	0.81	0.05
b	*Nitzschia marina*	7.92	7.77	7.16	7.40	0.52	−0.24
b	*Nitzschia cylindrica*	8.03	7.89	7.28	7.55	0.48	−0.27
t	*Thalassiosira yabei*	8.17	8.04	7.35	7.55	0.61	−0.20
t	*Coscinodiscus loeblichii*	8.79	8.69	8.05	7.90	0.89	0.15
b	*Thalassiosira burckliana*	8.84	8.74	8.10	8.20	0.64	−0.10
t	*Denticulopsis simonsenii*	9.35	9.29	8.61	8.80	0.55	−0.20
b	*Coscinodiscus loeblichii*	9.55	9.50	8.81	8.40	1.15	0.41
t	*Actinocyclus moronensis*	9.66	9.61	8.94	8.90	0.75	0.04
b	*A. ellipticus* f. *lanceolata*	10.35	10.32	9.80	9.90	0.44	−0.10
t	*Coscinodiscus gigas* v. *diorama*	11.13	11.13	10.74	10.70	0.43	0.04
b	*R. paleacea* var. *elongata*	11.13	11.13	10.74	10.60	0.53	0.14
t	*Craspedodiscus coscinodiscus*	11.34	11.35	10.99	10.80	0.54	0.19
t	*Synedra jouseana*	11.41	11.42	11.07	10.40	1.01	0.67
t	*Actinocyclus ingens*	12.10	12.11	11.86	11.50	0.60	0.36
t	*Cestodiscus pulchellus*	12.14	12.15	11.91	11.60	0.54	0.31
b	*Thalassiosira brunii*	12.19	12.20	11.97	11.80	0.39	0.17
t	*Nitzschia porteri*	12.23	12.24	12.02	11.70	0.53	0.32
t2	*Annellus californicus*	12.45	12.46	12.28	12.40	0.05	−0.12
t	*Coscinodiscus lewisianus*	12.86	12.87	12.75	12.80	0.06	−0.05
b	*Coscinodiscus gigas* v. *diorama*	13.00	13.01	12.91	12.60	0.40	0.31
t	*Thalassiosira tappanae*	13.20	13.21	13.14	13.20	−0.00	−0.06
b	*Triceratium cinnamoneum*	13.32	13.33	13.28	13.40	−0.09	−0.12
b	*Denticulopsis simonsenii*	13.47	13.48	13.46	13.65	−0.18	−0.19
t	*Cestodiscus peplum*	14.03	14.04	14.06	14.20	−0.17	−0.14
b	*Actinocyclus ellipticus*	14.04	14.04	14.06	14.40	−0.37	−0.34
b	*Coscinodiscus blysmos*	14.34	14.34	14.38	14.60	−0.26	−0.22
t1	*Anellus californicus*	15.00	15.00	15.08	15.00	0.00	0.08
b	*Actinocyclus ingens*	15.50	15.50	15.64	15.50	0.00	0.14
t	*Coscinodiscus lewisianus* var. *similis*	15.70	15.70	15.85	15.70	0.00	0.15
b	*Cestodiscus peplum*	16.40	16.40	16.61	16.40	0.00	0.21
t	*Thalassiosira fraga*	16.49	16.49	16.70	16.20	0.29	0.50
t	*Raphidodiscus marylandicus*	16.49	16.49	16.70	16.75	−0.27	−0.05
b	*Crucidenticula nicobarica*	18.12	18.12	18.05	17.80	0.32	0.25
b	*Crasepedodiscus coscinodiscus* ss.	18.12	18.12	18.05	17.30	0.82	0.75
t	*Globorotalia tosaensis*	0.59	0.59	0.59	NA	NA	NA
t	*Pulleniatina* left	0.84	0.84	0.78	NA	NA	NA
t	*Globigerinoides fistulosus*	1.74	1.73	1.63	1.60	0.14	0.03
t	*Globorotalia limbata*	2.18	2.20	2.09	NA	NA	NA
b	*Globorotalia truncatulinoides*	2.39	2.40	2.28	1.90	0.49	0.38[a]
t	*Globigerinoides obliquus*	2.78	2.78	2.65	1.80	0.98	0.85[a]
t	*Globoquadrina altispira*	3.05	3.05	2.92	2.90	0.15	0.02
t	*Sphaeroidinellopsis seminulina*	3.20	3.20	3.06	3.00	0.20	0.06
t	*Pulleniatina spectabilis*	4.33	4.14	3.98	3.90	0.43	0.08
t	*Globoquadrina dehiscens*	5.49	5.31	5.00	5.30	0.19	−0.30
b	*Globorotalia tumida*	5.59	5.40	5.08	5.20	0.39	−0.12
t	*Globorotalia siakensis*	10.94	10.93	10.53	10.40	0.53	0.13
b	*Sphaeroidinella subdehiscens*	11.74	11.74	11.43	11.80	−0.07	−0.37
b	*Globorotalia fohsi lobata*	12.94	12.95	12.84	13.50	−0.57	−0.66
t	*Globorotalia archaeomenardii*	14.04	14.04	14.06	NA	NA	NA
b	*Globorotalia fohsi* group	14.04	14.04	14.06	14.00	0.04	0.06
b	*Orbulina suturalis*	14.89	14.89	14.96	15.20	−0.31	−0.24
b	*Praeorbulina sicana*	16.50	16.50	16.71	16.30	0.20	0.41
b	*Emiliania huxleyi*	0.26	0.26	0.26	0.26	0.00	0.00
t	*Pseudoemiliania lacunosa*	0.46	0.46	0.46	0.46	0.00	0.00
b	Reentry medium *Gephyrocapsa* spp.	1.02	1.00	0.93	0.92	0.09	0.01
t	Large *Gephyrocapsa* spp.	1.24	1.22	1.14	1.12	0.12	0.02
b	Large *Gephyrocapsa* spp.	1.44	1.42	1.34	1.32	0.12	0.02
t	*Calcidiscus macintyrei*	1.58	1.56	1.48	1.45	0.13	0.03

Table 7 (continued).

	SCHPS94	CK92	BKF85	SSP92	Raw dif.	Adj dif.
b Medium *Gephyrocapsa* spp.	1.69	1.68	1.58	1.58	0.11	0.00
t *Discoaster brouweri*	1.96	1.99	1.89	1.89	0.07	–0.00
t *Discoaster pentaradiatus*	2.52	2.53	2.40	2.35	0.17	0.05
t *Discoaster surculus*	2.63	2.63	2.50	2.41	0.22	0.09
t *Discoaster tamalis*	2.78	2.78	2.65	2.65	0.13	–0.00
t *Sphenolithus* spp.	3.66	3.59	3.44	3.45	0.21	–0.01
t *Reticulofenestra pseudoumbilicus*	3.82	3.72	3.57	3.56	0.26	0.01
bc *Discoaster asymmetricus*	4.13	3.98	3.83	3.83	0.30	–0.00
t *Amaurolithus primus*	4.56	4.37	4.19	4.37	0.19	–0.18
t *Ceratolithus acutus*	4.99	4.82	4.57	4.43	0.56	0.14
b *Ceratolithus rugosus*	5.07	4.90	4.64	4.66	0.41	–0.02
b *Ceratolithus acutus*	5.34	5.16	4.87	4.85	0.49	0.02
t *Triquetrorhabdulus rugosus*	5.35	5.16	4.87	4.90	0.44	–0.03
t *Discoaster quinqueramus*	5.55	5.37	5.05	4.98	0.57	0.07
t *Amaurolithus amplificus*	5.93	5.75	5.38	5.33	0.60	0.05
t Circular reticulofenestrids	6.12	5.94	5.53	6.02	0.10	–0.49
b *Amaurolithus amplificus*	6.50	6.32	5.85	NA	NA	NA
b Circular reticulofenestrids	6.62	6.44	5.98	NA	NA	NA
t Absence *Reticulofenestra pseudoumbilicus*	6.76	6.58	6.16	NA	NA	NA
b *Amaurolithus primus*	7.17	7.00	6.56	6.70	0.47	–0.14
t *Minylitha convallis*	7.73	7.58	6.97	NA	NA	NA
b *Discoaster berggrenii*	8.45	8.34	7.69	8.00	0.45	–0.31
b *Discoaster loeblichii*	8.45	8.34	7.69	NA	NA	NA
b *Discoaster pentaradiatus*	8.55	8.44	7.81	NA	NA	NA
b Absence*Reticulofenestra pseudoumbilicus*	8.71	8.61	7.97	NA	NA	NA
b *Minylitha convallis*	9.37	9.31	8.62	NA	NA	NA
t *Discoaster hamatus*	9.40	9.34	8.64	8.67	0.73	–0.03
b *Discoaster neohamatus*	9.52	9.46	8.76	8.96	0.56	–0.20
t *Discoaster neohamatus*	9.60	9.55	8.87	NA	NA	NA
b *Discoaster hamatus*	10.38	10.36	9.84	10.50	–0.12	–0.66
t *Coccolithus miopelagicus*	10.48	10.46	9.97	10.40	0.08	–0.43
b *Catinaster coalitus*	10.73	10.72	10.28	11.10	–0.37	–0.82
tc *Discoaster kugleri*	11.36	11.36	11.02	NA	NA	NA
bc *Discoaster kugleri*	11.74	11.74	11.43	NA	NA	NA
b *Calcidiscus macintyrei*	12.14	12.15	11.91	NA	NA	NA
b *Discoaster kugleri*	12.20	12.21	11.98	12.20	0.00	–0.22
t *Coronocyclus nitescens*	12.43	12.44	12.25	12.80	–0.38	–0.55
b *Triquetrorhabdulus rugosus*	12.62	12.63	12.47	12.50	0.12	–0.03
t *Calcidiscus premacintyrei*	12.65	12.66	12.51	NA	NA	NA
t *Discoaster signus*	13.08	13.09	13.00	NA	NA	NA
t *Cyclicargolithus floridanus*	13.19	13.20	13.13	13.10	0.09	0.03
t *Sphenolithus heteromorphus*	13.57	13.58	13.58	13.50	0.07	0.08
b *Reticulofenestra pseudoumbilicus*	13.95	13.96	13.98	12.70	1.25	1.28 [a]
t *Helicosphaera ampliaperta*	15.87	15.87	16.04	16.00	–0.13	0.04
b *Discoaster signus*	16.20	16.20	16.39	16.05	0.15	0.34
t Acme *Discoaster deflandrei*	16.22	16.22	16.41	16.05	0.16	0.36
t *Stylatractus universus*	0.41	0.41	0.41	0.41	0.00	0.00
b *Collosphaera tuberosa*	0.61	0.61	0.61	0.60	0.01	0.01
t *Lamprocyrtis neoheteroporus*	1.06	1.04	0.97	0.95	0.11	0.02
t *Anthocyrtidium angulare*	1.12	1.10	1.03	1.05	0.07	–0.02
t *Theocorythium vetulum*	1.22	1.20	1.13	1.09	0.13	0.04
b *Lamprocyrtis nigriniae*	1.23	1.21	1.14	1.27	–0.04	–0.13 [a]
b *Pterocorys minithorax*	1.55	1.53	1.44	1.46	0.09	–0.02 [a]
b *Theocorythium trachelium*	1.55	1.53	1.45	1.36	0.19	0.09 [a]
t *Lamprocyrtis heteroporus*	1.61	1.60	1.50	NA	NA	NA [a]
t *Pterocanium prismatium*	1.74	1.73	1.63	1.60	0.14	0.03
b *Anthocyrtidium angulare*	1.77	1.75	1.66	NA	NA	NA
t *Anthocyrtidium jenghisi*	2.40	2.41	2.29	2.10	0.30	0.19 [a]
b *Theocalyptra davisiana*	2.71	2.71	2.58	2.57	0.14	0.01
t *Stichocorys peregrina*	2.76	2.76	2.63	2.50	0.26	0.13 [a]
b *Lamprocyrtis neoheteroporus*	3.06	3.06	2.92	2.90	0.16	0.02 [a]
b *Lamprocyrtis heteroporus*	3.06	3.06	2.93	NA	NA	NA [a]
t *Anthocyrtidium pliocenica*	3.36	3.35	3.21	2.71	0.65	0.50 [a]
t *Phormostichoartus fistula*	3.67	3.60	3.45	3.10	0.57	0.35 [a]
t *Lychnodictyum audax*	3.78	3.69	3.54	3.00	0.78	0.54 [a]
b *Amphirhopalum ypsilon*	3.88	3.78	3.62	NA	NA	NA [a]
t *Phormostichoartus dolium*	3.89	3.78	3.63	3.50	0.39	0.13 [a]
b *Spongaster tetras*	4.17	4.02	3.87	3.70	0.47	0.17
t *Didymocyrtis penultima*	4.20	4.04	3.89	NA	NA	NA
b *Pterocanium prismatium*	4.76	4.58	4.38	NA	NA	NA
t *Solenosphaera omnitubus*	5.40	5.21	4.92	4.70	0.69	0.22 [a]
t *Siphostichartus corona*	5.76	5.57	5.23	4.90	0.86	0.33 [a]
t *Stichocorys johnsoni*	6.34	6.16	5.74	5.80	0.54	–0.06 [a]
t *Calocycletta caepa*	6.42	6.24	5.79	6.20	0.22	–0.41 [a]
b *Stichocorys delmontensis* to *peregrina*	6.66	6.48	6.02	6.10	0.56	–0.08 [a]
b *Solenosphaera omnitubus*	7.20	7.04	6.58	NA	NA	NA [a]
t *Diartus hughesi*	7.67	7.52	6.90	6.70	0.97	0.20
t *Botryostrobus miralestensis*	8.21	8.08	7.42	8.10	0.11	–0.68 [a]
t *Diartus pettersoni*	8.43	8.31	7.66	8.10	0.33	–0.44 [a]
b *Diartus pettersoni* to *Diartus hughesi*	8.70	8.60	7.96	8.30	0.40	–0.34
b *Diartus hughesi*	8.89	8.80	8.15	8.70	0.19	–0.55 [a]
t *Stichocorys wolffi*	8.89	8.81	8.16	8.10	0.79	0.06
t *Cyrtocapsella japonica*	10.09	10.05	9.48	NA	NA	NA
t *Lithoperta thornburgi*	10.09	10.05	9.48	NA	NA	NA
t *Carpocanopsis cristata*	10.68	10.66	10.22	NA	NA	NA [a]
t *Lithoperta renzae*	11.82	11.83	11.52	NA	NA	NA

Table 7 (continued).

		SCHPS94	CK92	BKF85	SSP92	Raw dif.	Adj dif.
t	*Cyrtocapsella cornuta*	11.83	11.84	11.53	11.60	0.23	–0.07
t	*Dorcadospyris alata*	11.86	11.87	11.57	13.50	–1.65	–1.93
b	*Diartus pettersoni*	11.86	11.87	11.57	12.50	–0.64	–0.93 [a]
b	*Cyrtocapsella japonica*	12.39	12.40	12.20	NA	NA	NA
b	*Lithoperta thornburgi*	13.32	13.33	13.28	NA	NA	NA
b	*Calocycletta caepa*	13.35	13.36	13.32	NA	NA	NA
t	*Stichocorys armata*	13.72	13.72	13.74	NA	NA	NA
t	*Liriospyrys parkarae*	14.46	14.46	14.50	NA	NA	NA
t	*Acrocubus octopyle*	14.55	14.55	14.60	NA	NA	NA
t	*Carpocanopsis bramlettei*	14.75	14.75	14.81	NA	NA	NA
t	*Calocycletta costata*	15.12	15.12	15.22	15.00	0.12	0.22
b	*Dorcadospyris dentata* to *D. alata*	15.69	15.69	15.84	16.70	–1.01	–0.86
t	*Liriospyris stauropora*	15.81	15.81	15.97	NA	NA	NA
b	*Liriospyris parkerae*	15.82	15.82	15.98	NA	NA	NA
t	*Eucyrtidium diaphenes*	15.95	15.95	16.12	NA	NA	NA
b	*Carpocanopsis bramlettei*	16.08	16.08	16.26	NA	NA	NA
t	*Carpocanopsis cingulata*	16.44	16.44	16.65	NA	NA	NA
b	*Giraffospyris toxaria*	16.59	16.59	16.81	NA	NA	NA
b	*Acrocubus octopyle*	16.59	16.59	16.81	NA	NA	NA
t	*Didymocyrtis prismatica*	16.68	16.68	16.90	NA	NA	NA

Note: SCHPS94 = our estimate, based on the time scale of Shackleton et al. (this volume); CK92 = our estimate, calibrated back to the polarity time scale of Cande and Kent (1992); BKF85 = our estimate, calibrated back to the polarity time scale of Berggren et al. (1985a); SSP92 = age used by Shipboard Scientific Party (1992), based on Berggren et al. (1985b). Raw difference = the difference between our estimate and that used by the Shipboard Scientific Party (1992). Adjusted difference = the difference between our estimate recalibrated to BKF85, and that used by the Shipboard Scientific Party (1992). t = top of range, and b = bottom of range.

[a] This datum is probably significantly diachronous.

Table 8. Mean deviation of estimates from individual sites from calibration ages for those datums determined to 0.2 m.y. or better and for the remainder.

Datum	Mean deviation	Mean constraint
Radiolarians	0.15	0.08
Nannofossils	0.10	0.05
Diatoms	0.10	0.09
All groups[a]	0.39	0.25
All groups[b]	0.50	0.55

Notes: An insufficient number of foraminifer datums was determined for this comparison. The radiolarian, nannofossil, and diatom datums were constrained within 0.2 m.y. or better.

[a]All groups, all data.

[b]Constrained less well than 0.2 m.y.