1. PLANKTONIC FORAMINIFER BIOSTRATIGRAPHY AT SITE 925: MIDDLE MIOCENE–PLEISTOCENE[1]

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ABSTRACT

Ocean Drilling Program Site 925 is situated on Ceara Rise in the western tropical Atlantic at 4°12′N, 43°30′W and in 3041 m water depth. The section contains well-preserved planktonic microfossils through the late Miocene, with only moderate dissolution of carbonate in the middle Miocene. No unconformities are apparent.

Datums used to establish the biozonation, and to further refine the age model, were constrained shipboard to within 1.5 m. In general, one sample per core has been re-examined to identify all species present. *Globorotalia menardii, Globorotalia tumida, Globorotalia truncatulinoides, Pulleniatina obliquiloculata,* and *Neogloboquadrina dutertrei* vary considerably in abundance, and each is occasionally absent in the Pleistocene, which suggests significant oceanographic change through this interval. The published ages assigned to planktonic foraminifer datums are compared to those suggested by the astrochronologic time scale. Several significant discrepancies (>0.25 m.y.) are found. Some are due to taxonomic problems (e.g., first occurrence [FO] of *Pulleniatina finalis,* FO and last occurrence [LO] of *Hirsutella cibaoensis,* LO *Neogloboquadrina acostaensis*), but many may identify real diachrons (e.g., LO *Hirsutella margaritae* and FO *Truncorotalia crassaformis*). Discrepancies that involve zonal boundary markers (FO *Globoturborotalita nepenthes* and LO *Fohsella fohsi*) should be further studied, as revisions to the Neogene zonation may be in order.

Global rates of planktonic foraminiferal taxonomic evolution are compared to values measured at Site 925. Significant discrepancies are found, which suggests that the closing of the Central American Seaway decoupled patterns of evolution in the tropical Atlantic and Pacific.

An assessment of planktonic foraminiferal dissolution at all five sites in the Ceara Rise depth transect reveals three apparent "transgressions" of corrosive bottom water to shallower depths on the rise between 10 and 12 Ma, at 7 Ma, and at 1 Ma.

INTRODUCTION

The biostratigraphy for Site 925 (and other sites of Ocean Drilling Program [ODP] Leg 154) has been carried out in a manner inverse to the normal procedure. Datums were more tightly constrained shipboard rather than post-cruise, and those data are published in Curry, Shackleton, Richter, et al. (1995). In order to assist in the construction of the composite section (King et al., this volume), 122 samples were examined shipboard between the top of Hole 925B (~0.01 Ma) and base of Zone N13 (11.8 Ma). The primary goal of the shipboard examination was to identify datum events for species that have been assigned ages by Berggren et al. (1985) and Chaisson and Leckie (1993). Toward this end, some samples received only cursory inspection shipboard to find particular taxa and constrain a first or last occurrence (LO). However, in the majority of samples the stratigraphic occurrence of a large number of species was recorded. These were species of interest for biostratigraphic or evolutionary reasons.

Post-cruise analysis of samples in Hole 925B consisted of detailed examination of one sample per core (30 samples), usually in Section 5, in order to compile a more complete tally of species in the sediment assemblage, including those that are rare. These data have been used to calculate species richness, rate of speciation, rate of extinction, rate of turnover, and rate of diversification at 1 m.y. intervals for the last 12 m.y. This study follows the procedures outlined by Wei and Kennett (1986), and the data for Site 925 are compared to Wei and Kennett's (1986) global figures. The data in the present study may also be compared to with those of Chaisson and Leckie (1993), who made similar calculations using data from ODP Hole 806B.

In addition, the record of foraminifer test preservation at all sites for the last 12 m.y. is summarized. The vertical movement of the foraminifer lysocline and the carbonate compensation depth (CCD) over Ceara Rise from the end of the middle Miocene to the Pleistocene is interpreted using the semiquantitative evaluation of the preservation of the sediment assemblage.

SITE DESCRIPTION

Site 925 is located on Ceara Rise (Fig. 1) in the western tropical Atlantic (4°12´N, 43°29´W). Ceara Rise was formed on the Mid-Atlantic Ridge at ~80 Ma (Kumar and Embley, 1977) in conjugation with the Sierra Leone Rise, and it has subsequently drifted largely westward and slightly northward (Mountain and Curry, 1995).

Site 925 is the shallowest site (3041 m) in the depth transect drilled on Leg 154. Sediment accumulation rates have been steadily rising (from 13 to 33 m/m.y.) during the last 12 m.y. The unconformities and slumps that mark the records of deeper sites on Ceara Rise (Curry, Shackleton, Richter, et al., 1995) are absent at Site 925.

The sediment that has accumulated over the last 12 m.y. in Hole 925B is composed of two units. Unit I extends from Core 154-925B-1H through 15H (early Pliocene time), and is subdivided into Subunit IA (0–30 mbsf), a nannofossil clay with foraminifers, and Subunit IB (30–135 mbsf), a nannofossil ooze with varying numbers of foraminifers. Lithologic Unit II (135–290 meters below seafloor [mbsf]) is a nannofossil ooze with varying amounts of clay and 20% more carbonate than Unit I. It is also divided into two subunits: Subunit IIA

[1]Shackleton, N.J., Curry, W.B., Richter, C., and Bralower, T.J. (Eds.), 1997. *Proc. ODP, Sci. Results,* 154: College Station, TX (Ocean Drilling Program).

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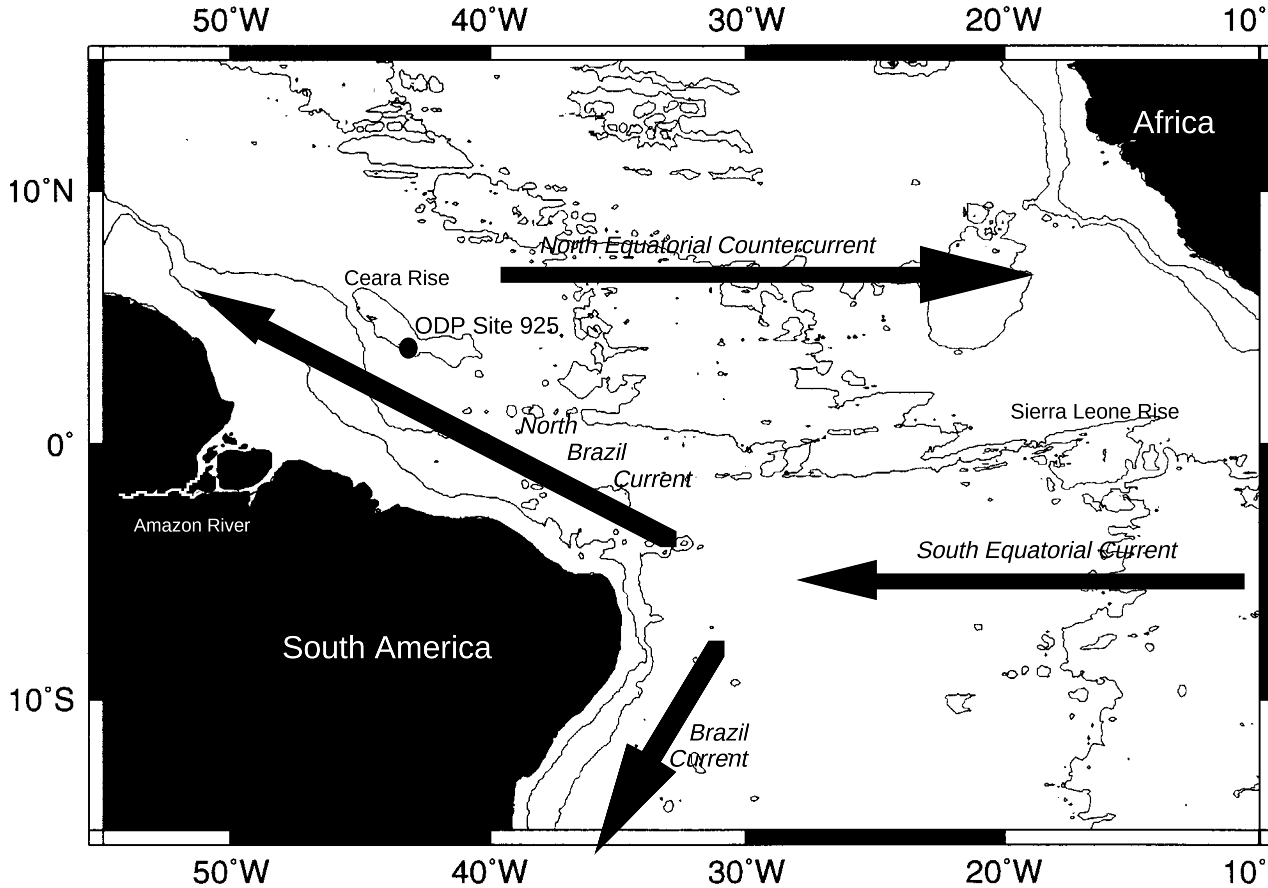

Figure 1. Location of Site 925 in the western tropical Atlantic Ocean.

(135–210 mbsf) is a nannofossil ooze with clay alternating with clayey nannofossil ooze, while Subunit IIB (210–290 mbsf) is a nannofossil ooze with the highest average carbonate content in the entire sequence (Curry, Shackleton, Richter, et al., 1995).

Site 925 is in a region that experiences convergence and downwelling through most of the year (Hastenrath and Lamb, 1977; Hastenrath, 1985; Philander, 1990). In its present position Site 925 lies beneath the boundary of the North Equatorial Countercurrent (NECC) and the North Brazil Current (NBC), a continuation of the South Equatorial Current (Fig. 1). The strength and position of the NECC/NBC boundary increases seasonally (Molinari and Johns, 1993) as the intertropical convergence zone (ITCZ) moves toward the equator during the northern hemisphere winter. Faunal and isotopic evidence presented by Chaisson and Ravelo (this volume) suggests that the intensity of convergence at Site 925 has increased through the last 5.5 m.y. due to southward movement of the ITCZ, which accompanied the late Neogene cooling of the Northern Hemisphere.

METHODS

Samples were soaked in a neutral mixture of dilute hydrogren peroxide and Calgon for 1–6 hours. Chalky samples were manually broken up after initial soaking to assist complete disaggregation. Most processing was done on board ship, where disaggregated material was wet-sieved through a 45-µm screen, and the >45-µm fraction was dried on a hot plate. The material was then dry-sieved through a 150-µm screen and the fractions were archived separately. (The procedure for samples that were processed post-cruise was similar, except the >63-µm fraction was saved.)

The >150-µm fraction was examined thoroughly in order to note rare species. At least two trays of sediment were inspected. The fine fraction was then checked for small taxa, such as *Streptochilus* spp. and *Turborotalita humilis.* Semiquantitative estimates of relative abundance were made by examination of the >150-µm fraction, unless a taxon was found only in the fine (>45 µm) fraction. Three categories of abundance were employed: rare (1%–3%), few (4%–15%), and common (16%–30%). The estimate of relative abundance was made by counting the number of specimens of a particular taxon in 4 adjacent quadrants in 3 different locations on the tray. The number of specimens counted in this way was treated as an approximation of the percentage on the tray. Preservation of foraminifers was classified as either good (>90% of specimens unbroken; few signs of dissolution) or moderate (30%–90% of specimens unbroken or dissolved). Fragment percentages were determined in the same manner as the relative abundance of taxa. No samples in the last 12 m.y. at Site 925 contain species with >30% abundance or can be described as having less than moderate preservation.

The composite section of King et al. (this volume) was constructed shipboard by splicing the magnetic susceptibility records of overlapping cores from adjacent holes. The drilling crew systematically offset core breaks in the multiple holes cored at each site on Ceara Rise. High-resolution multisensor track (MST) measurements were made on each section. These records are plotted and spliced together using a program that identified a match of maximum coherence. Nannofossil and planktonic foraminifer datums (in Curry, Shackleton, Richter, et al., 1995) were also used to insure that the continuous depth record was accurately joined to the time domain.

The continuous magnetic susceptibility record was subjected to spectral analysis and revealed a strong cyclic component. This regular variation in the quantity of magnetically susceptible minerals in these deep sea sediments was interpreted as a proxy record of climatic changes associated with periodic fluctuation of insolation related to precession (Hays et al., 1976; Shackleton et al., 1995; Shackleton et al., this volume). The length of a precession cycle (19 k.y.) served as a unit of measurement. Ages were assigned to the depth domain by counting precession cycles down the composite section to produce an astrochronologically "tuned" age model for Leg 154 sites.

Table 1 shows the age assignments given to specific depths at Site 925. The first column lists horizons on the composite section (meters composite depth [mcd]) and the second column lists the equivalent depth in Hole 925B (meters below sea floor [mbsf]). Only age assignments that bracket samples used in this study are given in Table 1, and sample ages are determined by linear interpolation.

ZONAL CRITERIA

We follow the zonal scheme of Blow (1969) as emended by Srinivasan and Kennett (1981a, 1981b) and Kennett and Srinivasan (1983), excluding the subdivision of Zone 17, which is not possible due to the truncation of the *Pulleniatina primalis* range in Hole 925B (Fig. 2).

Ages for zonal boundaries are those of Berggren et al. (1985), but they have been transformed to bring them into accord with the Leg 154 time scale. The last 14 m.y. of the Leg 154 time scale is a composite of astrochronological time scales by Shackleton et al. (1990), Hilgen (1991), and Shackleton et al. (1995).

The Pliocene Epoch is subdivided into late, middle and early ages in accordance with Rio et al. (1994) and Curry, Shackleton, Richter, et al. (1995).

In the following discussion, the bottom sample included in a zone is given (i.e., the lower boundary is between that sample and the next deepest sample).

Zone N22

Age: latest Pliocene to Holocene.
Definition: Total range of *Globorotalia truncatulinoides.*
Discussion: The first occurrence (FO) of *Globorotalia truncatulinoides* has been shown to be diachronous between the subtropics and the tropics, but within the tropics this species seems to have appeared isochronously (Spencer-Cervato et al., 1994).
Occurrence in Hole 925B: Sample 154-925B-7H-4, 68–70 cm, to the top of the section (57.93–0 mbsf).

Zone N21/N20

Age: middle to late Pliocene.
Definition: Interval between the FO of *Globorotalia miocenica* and the FO of *Globorotalia truncatulinoides.*
Discussion: The rarity of *Globorotalia tosaensis* in Hole 925B samples makes certain demarcation of the base of Zone N21 impossible.
Occurrence in Hole 925B: Sample 154-925B-12H-7, 65–67 cm, to 7H-5, 65–67 cm (109.41–57.93 mbsf).

Zone N19

Age: early Pliocene to latest Miocene.
Definition: Interval between the FO of *Sphaeroidinella dehiscens* s.l. and the FO of *Globorotalia miocenica.*
Discussion: The Miocene/Pliocene boundary at 5.38 Ma is not approximated by any planktonic foraminifer datum event that is constrained by magnetostratigraphy.
Occurrence in Hole 925B: Sample 154-925B-17H-4, 65–67 cm, to 13H-1, 66–67 cm (152.91–109.41 mbsf).

Zone N18

Age: latest Miocene.
Definition: Interval between the FO of *Globorotalia tumida* and the FO of *Sphaeroidinella dehiscens* s.l.
Discussion: The stratigraphic range of *Globorotalia tumida* is discontinuous, and the taxon is often rare in the assemblage at Site 925. It occurs in the upper Miocene, is absent in the lower Pliocene, and then is found again in the upper Pliocene, but its FO is accepted as reliable.
Occurrence in Hole 925B: Sample 154-925B-18H-1, 66–68 cm, to 17H-5, 65–67 cm (157.92–152.91 mbsf).

Zone N17

Age: late Miocene.
Definition: Interval between the FO of *Globorotalia plesiotumida* and the FO of *Globorotalia tumida.*
Occurrence in Hole 925B: Sample 154-925B-25H-3, 65–67 cm, to 18H-2, 66–68 cm (227.40–157.92 mbsf).

Zone N16

Age: late Miocene.
Definition: Interval between the FO of *Neogloboquadrina acostaensis* and the FO of *Globorotalia plesiotumida.*
Occurrence in Hole 925B: Sample 154-925B-27H-2, 65–67 cm, to 25H-4, 64–66 cm (244.91–227.40 mbsf).

Zone N15

Age: late to middle Miocene transition.
Definition: Interval between the LO of *Paragloborotalia mayeri* and the FO of *Neogloboquadrina acostaensis.*
Occurrence in Hole 925B: Sample 154-925B-28H-7, 65–67 cm, to 27H-3, 65–67 cm (261.41–244.91 mbsf).

Zone N14

Age: late to middle Miocene transition.
Definition: Interval between the FO of *Globoturborotalita nepenthes* and the LO of *Paragloborotalia mayeri.*
Occurrence in Hole 925B: Sample 154-925B-29H-7, 65–67 cm, to 29H-1, 65–67 cm (270.91–261.41 mbsf).

Zone N13

Age: middle Miocene.
Definition: Interval between the LO of *Fohsella fohsi* s.l. and the FO of *Globoturborotalita nepenthes.*
Occurrence in Hole 925B: Sample 154-925B-30H-6, 65–67 cm, to 30H-1, 65–67 cm (279.66–270.91 mbsf).

PLANKTONIC FORAMINIFERAL DATUMS

Datums are generally constrained to within 1.5 meters, except where an event is within a core break. The astrochronological time scales of Bickert et al. (Chapter 16, this volume), 0–2.5 Ma, Tiedemann and Franz (this volume), 2.5–5.0 Ma, and Shackleton and

Table 1. Comparison of biostratigraphic and astrochronologic age models at Site 925.

Astrochronologic age model			Samples in this study		
Composite depth (mcd)	Core depth (mbsf)	Age (Ma)	Sample depth (mbsf)	Age (Ma)	Core, section, interval (cm) 154-925B-
3.63	3.63	0.091			
4.43	3.73	0.112	3.65	0.10	1H-3, 65–67
12.55	11.85	0.321			
13.47	12.77	0.344	12.65	0.34	2H-6, 65–67
22.96	20.05	0.588			
24.26	21.35	0.631	20.65	0.61	3H-5, 65–67
34.52	31.02	0.985			
35.32	31.82	1.010	31.65	1.00	4H-6, 65–67
44.78	40.84	1.328			
46.36	42.70	1.386	41.15	1.34	5H-6, 65–67
52.28	48.62	1.593			
53.33	49.67	1.632	49.05	1.61	6H-5, 55–57
61.90	57.56	1.913			
63.21	58.87	1.955	58.65	1.95	7H-5, 65–67
71.63	67.52	2.219			
72.47	68.36	2.242	68.15	2.24	8H-5, 65–67
81.32	75.99	2.535			
83.49	78.16	2.601	77.65	2.59	9H-5, 65–67
92.30	86.51	2.887			
94.17	88.38	2.946	87.15	2.91	10H-5, 65–67
105.76	96.49	3.241			
106.46	97.19	3.26	96.65	3.25	11H-5, 65–67
115.42	105.27	3.564			
117.08	106.93	3.622	106.15	3.59	12H-5, 65–67
124.02	111.95	3.852			
126.15	114.08	3.924	112.6	3.87	13H-3, 65–67
136.15	123.81	4.231			
138.02	125.68	4.302	125.15	4.28	14H-5, 65–67
147.25	133.94	4.681			
148.30	134.99	4.727	134.65	4.71	15H-5, 65–67
158.50	143.68	5.081			
159.00	144.18	5.104	144.15	5.10	16H-5, 65–67
168.60	153.18	5.551			
169.10	153.68	5.571	153.65	5.57	17H-5, 65–67
179.75	162.88	6.043			
180.55	163.68	6.08	163.16	6.06	18H-5, 65–67
189.45	172.18	6.33			
190.35	173.08	6.353	172.65	6.34	19H-5, 65–67
197.75	179.67	6.647			
208.70	187.41	6.667	182.15	6.65	20H-5, 65–67
212.00	190.71	6.819			
212.95	191.66	6.859	191.65	6.86	21H-5, 65–67
222.70	200.99	7.514			
229.00	204.49	7.707	201.15	7.52	22H-5, 65–67
234.95	210.44	7.987			
235.35	210.84	8.007	210.65	8.00	23H-5, 65–67
245.20	220.03	8.365			
245.50	220.33	8.386	220.15	8.37	24H-5, 65–67
256.85	229.34	8.722			
257.25	229.74	8.745	229.65	8.74	25H-5, 65–67
265.95	238.17	9.338			
267.45	239.67	9.428	239.15	9.40	26H-5, 65–67
276.75	248.04	10.013			
280.50	252.15	10.106	248.65	10.03	27H-5, 65–67
285.60	257.25	10.276			
293.30	261.93	10.521	258.15	10.32	28H-5, 65–67
298.80	267.43	10.842			
299.90	268.53	10.919	267.65	10.86	29H-5, 65–67
308.40	275.56	11.412			
308.80	275.96	11.432	275.65	11.42	30H-4, 65–67

Notes: Composite depth section: King et al., this volume. Tuned age models: Bickert et al., Chapter 16, this volume (0–2.5 Ma); Tiedemann and Franz, this volume (2.5–5.0 Ma); Shackleton and Crowhurst, this volume (5.0–13.0 Ma).

Crowhurst (this volume), 5.0–14.0 Ma, are used to derive the "Ceara Rise ages" in Table 2. The "published ages" for planktonic foraminifer events in Table 2, like the zonal boundary markers described in the previous section, are taken from Berggren et al. (1985) and transformed to the Leg 154 time scale by linear interpolation. Because comparable time scales are used to derive both the Ceara Rise and published ages, differences between estimated ages for faunal events are not likely to be artifactual. Rather, they are likely due to either a taxonomic problem, diachrony or discontinuous occurrence of a taxon near its FO or LO in Hole 925B.

The Appendix is a range chart that compares the stratigraphic ranges of species at Site 925 to the global ranges given by Kennett and Srinivasan (1983) and provides a semi-quantitative estimate of relative abundance. Some additional datums have been newly assigned ages at Site 925 (Table 3).

Globoturborotalita

At Site 925 the last appearance of *Gt. apertura* is slightly later (1.64 vs. 1.9 Ma) than was determined by interpolating between datums at Site 806 in the western equatorial Pacific (Chaisson and Leckie, 1993). The 200–250 k.y. difference in age estimates falls within the margin of error for the Site 806 age estimates. Further work is required to constrain this datum. Other workers (e.g., Lourens et al., 1992) have noted the difficulty of distinguishing between *Gt. apertura* and *Gt. rubescens* in the late Pliocene. This taxonomic problem argues against the widespread usage of this datum. The LOs of the other Neogene globoturborotalitids at Site 925 conform well (within 150 k.y.) to the published estimates (Table 2).

Globigerinoides

The published age of the LO of *Gs. fistulosus* at 1.7 Ma (Berggren et al., 1985) is just above the Pliocene/Pleistocene boundary. In Hole 925B, this event is between Samples 154-925B-7H-3, 65–67 cm, and 7H-4, 65–67 cm, at 56.43 mbsf. According to the astrochronologic time scale of Bickert et al. (Chapter 16, this volume), this depth corresponds to an age of 1.88 Ma, slightly older than the published age. The sediment accumulation rate through this interval is ~29 m/m.y. (Curry, Shackleton, Richter, et al., 1995), which gives the age estimate an error of ~0.05 Ma. The age of the LO of *Gs. extremus* at Site 925 agrees well with the published estimate (Table 2). The FO of this species is more difficult to identify because the morphological transition from *Gs. obliquus* to *Gs. extremus* is a gradual one ("Taxonomic Notes"). The age of the FO of *Gs. extremus* in Hole 925B is calculated as 8.58 ± 0.03 Ma, significantly older than the published age of 8.0 Ma (Table 2). The LO of *Gs. obliquus* is between Sample 154-925B-5H-6, 65–67 cm, and 5H-4, 65–67 cm (39.65 mbsf), which corresponds to an age of 1.30 ± 0.06 Ma (Table 3). This agrees with the bracketed estimates for this datum in Hole 658A (Leg 108) in the Canary Current of the eastern tropical Atlantic (Weaver and Raymo, 1989). However, this early Pleistocene age is younger than the late Pliocene last appearance published by Kennett and Srinivasan (1983), and the early Pliocene last appearance of *Gs. obliquus* published by Bolli and Saunders (1985) and observed by Chaisson and Leckie (1993) at Site 806.

Menardella

The LO of *M. multicamerata* is consistently one sample above that of *Dentoglobigerina altispira* at Leg 154 sites (Curry, Shackleton, Richter, et al., 1995), although these datums both have a published age of 3.0 Ma (Berggren et al., 1985). The difference between the ages of these events in Hole 925B is 10 k.y., according to the tuned time scale of Tiedemann et al. (this volume). The FO and LO of *M. miocenica* (3.77 ± 0.02 and 2.38 ± 0.02 Ma) and *M. pertenuis* (3.52 ± 0.03 and 2.33 ± 0.02 Ma) in Hole 925B agree well with the published ages (3.6 and 2.3 Ma, and 3.5 and 2.6 Ma, respectively). The LO of *Menardella exilis* is higher than the range (upper Zone N18 to Zone N21/N22 boundary) indicated by Kennett and Srini-

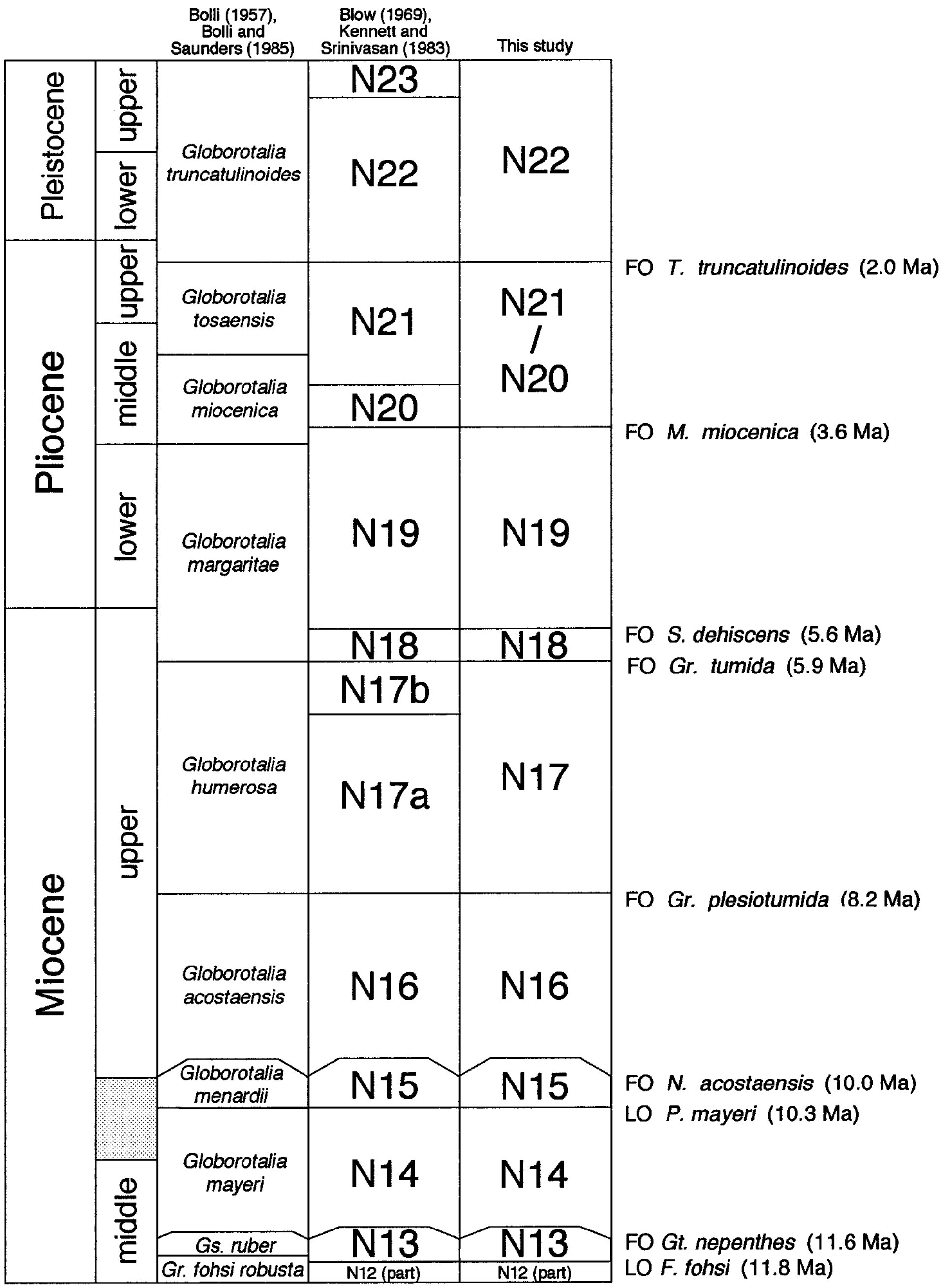

Figure 2. Zonal scheme at Site 925 compared to those of Bolli (1957)/Bolli and Saunders (1985) and Blow (1969)/Kennett and Srinivasan (1983).

vasan (1983), but the estimated age of this event in Hole 925B agrees well with that of Berggren et al. (1985). The FO of *M. exilis* (4.45 ± 0.04 Ma) is above the level (Zone N18) indicated by Kennett and Srinivasan (1983), while Berggren et al. (1985) do not supply an age for this datum (Table 3). The stratigraphic range of *M. limbata* in Hole 925B corresponds well to the range (Zone N14 to Zone N21) published in Kennett and Srinivasan (1983). *M. limbata* closely resembles *M. menardii,* but the morphotype does demonstrate stratigraphic integrity. It seems to appear at the end of the middle Miocene (10.57 ± 0.26 Ma) and disappear at the beginning of the late Pliocene (2.38 ± 0.02 Ma). These may be useful datums (Table 3), at least in the Atlantic basin where this complex is more morphologically differentiated, but further work is required to more tightly constrain the ages of these events.

Truncorotalia

The FO of *T. truncatulinoides* marks the base of Zone N22. This datum is time-transgressive in the higher-latitudes (southwest South Pacific) where the taxon first appears, but seems to be isochronous in

Table 2. Revised absolute ages for planktonic foraminiferal datums.

Planktonic foraminifer age events in Hole 925B	Core, section, interval (cm)		Depth (mbsf)			Ceara Rise age (Ma)	Published age (Ma)
	Top	Bottom	Top	Bottom	Mean		
FO *P. finalis*	7H-6, 68–70	8H-1, 65–67	60.19	62.16	61.18	2.04 ± 0.03	1.4
LO *Gs. fistulosus*	7H-3, 65–67	7H-4, 68–70	55.66	57.19	56.43	1.88 ± 0.03	1.7
LO *Gt. apertura*	6H-5, 55–57	6H-6, 55–57	49.06	50.56	49.81	1.64 ± 0.03	1.9
LO *Gs. extremus*	7H-5, 68–70	7H-6, 68–70	58.69	60.19	59.44	1.98 ± 0.03	1.9
FO *T. truncatulinoides*	7H-4, 68–70	7H-5, 65–67	57.19	58.66	57.93	1.92 ± 0.03	2.0
LO *M. exilis*	8H-1, 65–67	8H-2, 65–67	62.15	63.65	62.90	2.09 ± 0.02	2.2
LO *M. miocenica*	8H-7, 53–55	9H-1, 65–67	71.04	71.66	71.35	2.38 ± 0.02	2.3
Re-appearance, *Pulleniatina*	8H-5, 53–55	8H-6, 65–67	68.15	69.65	68.90	2.26 ± 0.03	2.3
LO *Gt. woodi*	8H-6, 65–67	8H-7, 53–55	69.66	71.04	70.35	2.33 ± 0.02	2.3
LO *Gt. decoraperta*	10H-1, 65–67	10H-2, 65–67	81.16	82.66	81.91	2.75 ± 0.03	2.6
LO *M. pertenuis*	8H-6, 65–67	8H-7, 53–55	69.65	71.05	70.35	2.33 ± 0.02	2.6
LO *D. altispira*	10H-7, 58–60	11H-1, 65–67	90.09	90.66	90.38	3.11 ± 0.02	3.0
LO *M. multicamerata*	10H-6, 65–67	10H-7, 58–60	88.66	90.09	89.38	3.10 ± 0.03	3.0
LO *Ss. seminulina*	10H-7, 58–60	11H-1, 65–67	90.09	90.66	90.38	3.11 ± 0.02	3.1
Disappearance, *Pulleniatina*	12H-1, 54–56	12H-2, 69–71	100.05	101.7	100.88	3.41 ± 0.03	3.5
FO *M. pertenuis*	12H-3, 65–67	12H-4, 54–56	103.16	104.55	103.86	3.52 ± 0.03	3.5
FO *M. miocenica*	12H-CC	13H-1, 66–68	109.11	109.66	109.39	3.77 ± 0.02	3.6
LO *H. margaritae*	13H-2, 66–68	13H-3, 60–62	111.17	112.61	111.89	3.85 ± 0.03	3.6
Pulleniatina, sin. to dex.	13H-7, 51–53	14H-1, 65–67	118.52	119.16	118.84	4.08 ± 0.03	4.0
LO *Gt. nepenthes*	14H-7, 10–12	15H-1, 10–12	127.61	128.11	127.86	4.39 ± 0.01	4.3
LO *Gr. plesiotumida*	12H-7, 51–53	13H-1, 66–68	109.02	109.67	109.35	3.77 ± 0.02	4.4
FO *T. crassaformis* s.l.	14H-5, 65–67	14H-6, 65–67	125.15	126.65	125.90	4.31 ± 0.04	4.7
LO *H. cibaoensis*	11H-4, 65–67	11H-5, 65–67	95.15	96.65	95.90	3.22 ± 0.03	5.0
LO *N. acostaensis*	6H-4, 55–57	6H-5, 55–57	47.55	49.05	48.30	1.58 ± 0.03	5.1
LO *Gq. baroemoenensis*	11H-4, 65–67	11H-5, 65–67	95.15	96.65	95.90	3.22 ± 0.03	5.4
FO *S. dehiscens*	17H-4, 65–67	17H-5, 65–67	152.16	153.66	152.91	5.54 ± 0.04	5.6
FO *Gr. tumida*	18H-1, 66–68	18H-2, 66–68	157.17	158.67	157.92	5.82 ± 0.04	5.9
FO *H. margaritae*	18H-5, 66–68	18H-6, 66–68	163.17	164.67	163.92	6.09 ± 0.03	6.2
FO *H. cibaoensis*	26H-5, 65–67	26H-6, 65–67	239.15	240.65	239.90	9.44 ± 0.05	7.7
FO *C. nitida*	24H-7, 65–67	25H-2, 65–67	223.16	225.16	224.16	8.44 ± 0.04	8.0
FO *Gs. extremus*	25H-3, 65–67	25H-4, 62–64	226.66	228.13	227.40	8.58 ± 0.03	8.0
FO *Gr. plesiotumida*	25H-3, 65–67	25H-4, 62–64	226.66	228.13	227.40	8.58 ± 0.03	8.2
FO *N. acostaensis*	27H-2, 65–67	27H-3, 65–67	244.16	245.66	244.91	9.82 ± 0.06	10.0
LO *P. mayeri*	28H-7, 65–67	29H-1, 65–67	261.16	261.66	261.41	10.49 ± 0.02	10.3
FO *Gt. apertura*	29H-6, 65–67	30H-2, 65–67	269.16	272.66	270.91	11.19 ± 0.13	10.8
FO *G. decoraperta*	30H-4, 65–67	30H-5, 65–67	275.65	277.15	276.40	11.46 ± 0.04	11.2
FO *Gt. nepenthes*	29H-7, 65–67	30H-1, 65–67	270.66	271.16	270.91	11.19 ± 0.02	11.4
LO *F. fohsi* s.l.	30H-6, 65–67	31H-1, 65–68	278.66	280.66	279.66	11.68 ± 0.15	11.8
FO *Gr. lenguaensis*	32H-4, 65–67	32H-5, 66–68	294.66	296.17	295.42	12.85 ± 0.05	12.3
FO *F. robusta*	32H-7, 65–67	33H-1, 65–67	299.16	299.66	299.41	13.18 ± 0.02	12.7
FO *F. fohsi*	33H-4, 65–67	33H-5, 65–67	304.16	305.66	304.91	13.42 ± 0.04	13.5

Note: Published absolute ages are those of Berggren et al. (1985), converted to the Leg 154 time scale, which uses the Cande and Kent (1992) revision of the global polarity time scale.

the tropics (Spencer-Cervato et al., 1994). The published age for the tropical FO is 2.0 Ma (Berggren et al., 1985), and it is first observed in Hole 925B at a level (57.93 mbsf) corresponding to 1.92±0.03 Ma. *T. tosaensis* is rare and occurs only sporadically in Hole 925B. It appears well above its globally accepted first appearance in the middle Pliocene at a level (68.90 mbsf) corresponding to 2.26 Ma. This age is well after the Berggren et al. (1985) age of 3.24 Ma (converted to Leg 154 time scale) for the base of Zone N21. *T. crassaformis* is never a numerically significant member of the assemblage at Site 925 (Chaisson and Ravelo, this volume), but it occurs consistently in Hole 925B down to 125.90 mbsf. This corresponds to an age of 4.31 ± 0.04 Ma, which is younger than the published estimate of 4.7 Ma (Berggren et al., 1985).

Hirsutella

The FO and LO of *H. cibaoensis* (9.44 ± 0.05 and 3.22 ± 0.03 Ma) are significantly different from the stratigraphic range (Zone N17A to Zone N19) presented by Kennett and Srinivasan (1983) and the published ages (7.7 and 5.0 Ma) of Berggren et al. (1985); the species appears earlier and disappears later. The distinction between *H. cibaoensis* and *H. scitula* is difficult to make (see "Taxonomic Notes"), which may account for the departure from the published range at Site 925. By contrast, the range of *H. juanai* in Hole 925B agrees well with the published range (Zone N16 to Zone N18) in Kennett and Srinivasan (1983). The FO, between 239.15 and 248.65 mbsf, corresponds to an age of 9.76 ± 0.26 Ma (Table 3). The taxon occurs more consistently in Hole 925B in the lower part of its range, and its LO cannot be assigned a reliable age. The range of *Hirsutella margaritae* in Hole 925B also agrees well with the published stratigraphic ranges (uppermost Zone N18 to uppermost Zone N19/20) of both Kennett and Srinivasan (1983) and Bolli and Saunders (1985). However, its range is slightly more restricted than the published ages; 6.09 ± 0.03–3.85 ± 0.03 Ma in Hole 925B vs. 6.2–3.6 Ma (Berggren et al., 1985). The FO of *H. margaritae* is represented by the *primitiva* morphotype (or subspecies), but the sample above the FO contains well developed *H. margaritae margaritae.* This suggests that the FO of this species may be later at this western tropical Atlantic site compared to its FO in other areas.

Globorotalia

Gr. merotumida is quite rare and does not occur in the top half of its published range at Site 925. The first appearance of *Gr. plesiotumida* marks the base of Zone N17 and has a published age of 8.2 Ma. The astrochronologically determined age of the level (227.40 mbsf) of its FO is 8.58 ± 0.03 Ma. The base of Zone N18 is marked by the first appearance of *Gr. tumida* and has a published age of 5.9 Ma (Berggren et al., 1985). *Gr. tumida* is very rare near its FO (157.92 mbsf) and disappears in Hole 925B a short distance above it (149.15 mbsf) at 5.38 ± 0.04 Ma. It reappears at 62.90 mbsf (2.09 ± 0.03 Ma) and is observed sporadically to the top of the section. Between 5.38 and 2.09 Ma *Gr. tumida* is observed in only one sample (Sample 154-925B-13H-1, 66–68 cm; 109.66 mbsf) at a level corresponding to an age of 3.78 Ma. The discontinuous range of *Gr. tumida* in the tropical

Table 3. Newly assigned absolute ages for datums at Site 925.

Planktonic foraminifer events in Hole 925B	Core, section, interval (cm)		Depth (mbsf)			Ceara Rise age (Ma)
	Top	Bottom	Top	Bottom	Mean	
LO *Globigerinoides obliquus*	5H-4, 65–67	5H-6, 65–67	38.15	41.15	39.65	1.30 ± 0.10
LO *Menardella limbata*	8H-7, 50–55	9H-1, 65–67	71.03	71.65	71.34	2.38 ± 0.02
FO *Menardella exilis*	14H-7, 10–12	15H-1, 65–67	127.60	128.65	128.13	4.45 ± 0.04
LO *Sphaeroidinellopsis kochi*	14H-5, 65–67	15H-5, 65–67	125.15	134.65	129.90	4.53 ± 0.17
FO *Turborotalita humilis*	17H-5, 65–67	18H-5, 65–67	153.65	163.16	158.41	5.84 ± 0.17
FO *Globigerinoides conglobatus*	18H-5, 65–67	19H-5, 65–67	163.16	172.65	167.91	6.20 ± 0.41
FO *Hirsutella juanai*	26H-5, 65–67	27H-5, 65–67	239.15	248.65	243.90	9.76 ± 0.26
FO *Menardella limbata*	28H-5, 65–67	29H-5, 65–67	258.15	267.65	262.90	10.57 ± 0.26

Atlantic has long been known. A recent paper by G.A. Jones (unpubl. data) documents the timing and the biogeography of the repopulation events of this species in the Holocene. The stratigraphically high FO of *Gr. tumida* and the low FO of *Gr. plesiotumida* has the effect of lengthening Zone N17 at Site 925 by 0.90 m.y.

Paragloborotalia

The last appearance of Paragloborotalia mayeri marks the base of Zone N15 and is assigned an age of 10.3 Ma (Berggren et al., 1985). The astrochronologically determined age of the level (261.41 mbsf) of this LO in Hole 925B is 10.49±0.02 Ma. P. mayeri is moderately common to common up to Sample 154-925B-29H-5, 65–67 cm (267.65 mbsf), but it is rare at its LO in Hole 925B.

Turborotalita

Ta. humilis is found in the >150-µm fraction only once (in Sample 154-925B-13H-3, 65–67 cm), and it is difficult to estimate its abundance in the >45-µm fraction. It occurs regularly in the middle Pliocene and middle Pleistocene portions of Hole 925B, and sporadically between these two intervals. Its FO in this hole agrees well with the published level (Zone N18) of Kennett and Srinivasan (1983), and corresponds to an age of 5.84 ± 0.17 Ma (Table 3).

Globoquadrina

Three globoquadrinids are present at the bottom of the section examined. The LO of *Gq. dehiscens* in Hole 925B is in the upper part of Zone N17, whereas the global range (Kennett and Srinivasan, 1983) extends up into Zone N18. By contrast, the ranges of *Gq. venezuelana* and *Gq. baroemoenensis* in Hole 925B extend up into the middle Pliocene, while the global ranges of these species (Kennett and Srinivasan, 1983; Bolli and Saunders, 1985) extend, respectively, only into the early Pliocene and to the Miocene/Pliocene boundary. *Gq. venezuelana* exhibits much morphological variation throughout its range (see "Taxonomic Notes" section), and in Samples 154-925B-16H-5, 65–67 cm, and 13H-3, 65–67 cm, in the lower Pliocene it resembles *Gq. pseudofoliata,* a similar but unrelated species (Kennett and Srinivasan, 1983), which is normally found only in the Pacific (Thompson and Sciarrillo, 1978). Its LO in Hole 925B is at a level (91.40 mbsf) corresponding to 3.11 ± 0.03 Ma. *Gq. baroemoenensis* is quite rare and occurs only sporadically in Hole 925B. It resembles *Gq. venezuelana,* but has a more open umbilicus and is smaller. Its LO in Hole 925B is at a level (91.9 mbsf) corresponding to 3.11 ± 0.33 Ma.

Dentoglobigerina

D. altispira occurs, and is occasionally quite common, from the bottom of the section examined to an abrupt extinction in the middle Pliocene. Because the species is widespread, abundant, easily identifiable and disappears abruptly, this is an important datum to constrain. The LO of *D. altispira* is at a level (90.38 mbsf) corresponding to 3.11 ± 0.03 Ma. At Site 847 in the eastern equatorial Pacific the LO is at 3.02 Ma, and at Site 806 in the western equatorial Pacific it is at 3.04 Ma (Chaisson, 1996).

Neogloboquadrina

The stratigraphic range of *N. acostaensis* is shown as extending only into the lower Pliocene in Kennett and Srinivasan (1983), while Bolli and Saunders (1985) show the species' range extending up to the Holocene. The first appearance of *N. acostaensis* marks the base of Zone N16 with a published age of 10.0 Ma (Berggren et al., 1985). Its FO in Hole 925B is at a level (244.91) corresponds to an age of 9.82±0.04 Ma. The LO of this species is given an age of 5.1 Ma by Berggren et al. (1985), which corresponds well to the early Pliocene last appearance (at the top of Zone N19/20) shown by Kennett and Srinivasan (1983). However, in Hole 925B specimens attributed to this species range up into the lower Pleistocene (48.30 mbsf) to a level corresponding to an age of 1.58 ± 0.03 Ma indicating a definite taxonomic problem (see "Taxonomic Notes"). The FO of *N. dutertrei* in Hole 925B is in earliest Pliocene–age sediments, which agrees with the range (Zone N18 to Zone N22) given by Bolli and Saunders (1985), but is considerably older (Zone N21 to Zone N22) than that of Kennett and Srinivasan (1983). The level of this event (143.40 mbsf) in Hole 925B corresponds to an age of 5.07 ± 0.03 Ma. At its first occurrence, this species is distinguished from the similar form *N. humerosa* by its more umbilical aperture and by the smaller number (five) of chambers in its final whorl.

Pulleniatina

The published age of the FO of "*P. finalis*" is 1.4 Ma (Berggren et al., 1985), but the FO in Hole 925B is between 154-925B-7H-6, 68–70 cm, and 8H-1, 65–67 cm (61.18 mbsf), which corresponds to an age of 2.04 ± 0.03 Ma. It is unlikely that *P. finalis* is a morphotype descended from *P. obliquiloculata,* and it is more likely an ecophenotype of *P. obliquiloculata. P. obliquiloculata* is not observed in Hole 925B in the lower Pliocene, although its published range (Kennett and Srinivasan, 1983; Bolli and Saunders, 1985) extends down that far. Instead, this species first occurs at this site above the "Atlantic interim," during which pulleniatinids are absent from the Atlantic basin. The stratigraphic range of *P. primalis* is also truncated at the lower end in Hole 925B. In the Pacific basin, the late Miocene first appearance of *P. primalis* at 6.4 Ma (Berggren et al., 1985) can be used to divide Zone N17 into subzones A and B. However, in Hole 925B, this species does not appear until the base of the Pliocene, and it is generally quite rare and sporadic. See Table 2 for the ages of the top and bottom of the pulleniatinid "Atlantic interim" and the switch from sinistral to dextral coiling. The transition is rapid and complete at this site as it is in the western equatorial Pacific at Site 806 (Chaisson and Leckie, 1993; Chaisson, 1996). The *primalis* morphotype occurs up into the lower Pleistocene in Hole 925B, which differs from the late Pliocene extinction shown by Kennett and Srinivasan (1983), and the range given by Bolli and Saunders (1985), which extends up to the Holocene. This morphotype is also found into the Pleistocene at Site 847 in the eastern equatorial Pacific (Chaisson, 1996). The stratigraphic integrity of pulleniatinid morphotypes seems to decline in regions that are ecologically suboptimal for this genus, with the western equatorial Pacific being the optimal region for this genus (Parker and Berger, 1971).

Sphaeroidinellopsis and *Sphaeroidinella*

Ss. kochi and *Ss. seminulina* are present from the bottom of the section examined. *Ss. kochi* occurs consistently from the middle Miocene to middle upper Miocene in Hole 925, then occurs sporadically up to the Miocene/Pliocene boundary. This is a distinctive species and is highly solution resistant. Its LO in Hole 925B is at a level (129.90 mbsf) corresponding to an age of 4.53 ± 0.17 Ma. With further study this age will be more tightly constrained. Neither *Ss. seminulina* nor *Ss. paenedehiscens* extend up to levels equivalent to the tops of the global ranges (Zones N21 and N19/20, respectively) indicated by Kennett and Srinivasan (1983). The first appearance of *Sa. dehiscens* marks the base of Zone N19, and is given an age of 5.6 Ma (Berggren et al., 1985). The transition from *Ss. paenedehiscens* to *Sa. dehiscens* is defined by the addition of a secondary aperture on the spiral side of the test. This aperture can be quite small in specimens near the FO and gradually increases in size upsection until it nearly joins the primary aperture (a morphotype called *excavata*). The FO of *Sa. dehiscens* in Hole 925B is at 152.91 mbsf, which corresponds to an age of 5.54 ± 0.04 Ma. It is necessary to search carefully for the rare specimens with a minute secondary aperture in order to find the correct level for this datum.

PLANKTONIC FORAMINIFER EVOLUTION AT SITE 925

In accordance with Wei and Kennett (1986) and Chaisson and Leckie (1993), rates of evolution are calculated per million years. The alternative is to use foraminifer biozones as a standard interval, but many FOs and LOs are at zone boundaries, which can lead to artifactual rates. The average length of a foraminifer biozone is 1.2 m.y., further justifying the selection of the million-year interval (Wei and Kennett, 1986).

Before rates of taxonomic evolution can be calculated, three parameters must be counted in each sample: species richness, number of FOs, and number of LOs. An average of all per-sample values is then derived for each million-year interval. The number of samples per million years varies between one and five. The species richness values for each sample (prior to averaging) are shown in Fig. 3.

Rates of taxonomic evolution are calculated as follows:

Rate of speciation:	$r_s = 1/D \cdot S/\Delta t$
Rate of extinction:	$r_e = 1/D \cdot E/\Delta t$
Rate of turnover:	$r_t = r_s + r_e$
Rate of diversification:	$r_d = r_s - r_e$

where D = species richness (diversity), S = number of FOs, E = number of LOs, and Δt = time interval.

A record of species richness—a simple count of the number of species per sample through the study interval—is shown in Fig. 3. In Figures 4 and 5 rates of planktonic foraminifer evolution at Site 925 are plotted vs. global tropical values averaged from a number of sites (Wei and Kennett, 1986).

Miocene

(Samples 154-925B-17H-5, 65–67 cm, to 30H-4, 65–67 cm)

Species richness is at its lowest level of the last 12 m.y. in Samples 154-925B-28H-5, 65–67 cm, 29H-5, 65–67 cm, and 30H-4, 65–67 cm. The number of species per sample through this interval varies between 16 and 18 (Fig. 3). The increase in species richness from a low of 16 to a Miocene maximum of 30 species in Sample 154-925B-25H-5, 65–67 cm, in Zone N16 between 8.2 and 10.0 Ma, coincides with improved preservation, but it is not fully attributable to post-depositional factors. Another cause of progressively greater species richness is the evolution of new species. In the samples examined for the shore-based study, 11 species first occur between Samples 154-925B-30H-5, 65–67 cm, and 25H-5, 65–67 cm: *Globoturborotalita apertura, Globorotalia limbata, Globigerinoides extremus, Gs. ruber, Globorotalia lenguaensis, Gr. paralenguaensis, Gr. cibaoensis, Gr. juanai, Gr. merotumida,* and *Neogloboquadrina acostaensis,* and *Candeina nitida* (Appendix A). Only *Paragloborotalia mayeri* disappears through the same interval (after Sample 154-925B-25H-5, 65–67 cm).

Between Samples 154-925B-25H-5, 65–67 cm, and 17H-5, 65–67 cm, species richness declines to a minimum of 21 species in Sample 154-925B-21H-5, 65–67 cm, before recovering to 29 species at the top of this interval (Fig. 3). This decline in the number of species of planktonic foraminifers in uppermost Miocene sediments is a pantropical phenomenon (Wei and Kennett, 1986) and is also observed in Hole 806B in the western equatorial Pacific (Chaisson and Leckie, 1993). This diversity decline (Kennett, 1977) occurs during a time of falling sea level and the growth of the West Antarctic ice sheet (Wei and Kennett, 1986). This temporary decline in diversity at Site 925 is caused in part by the extinction of some species, including *Globorotalia paralenguaensis* (above Sample 154-925B-25H-5, 65–67 cm), *Neogloboquadrina continuosa* (above Sample 154-925B-24H-5, 65–67 cm), and the early disappearance in Hole 925B of *Globorotalia lenguaensis* and *Globorotaloides variabilis.* Some species, such as *Globoturborotalita apertura, Gt. decoraperta, Globigerina falconensis, Globigerinoides ruber, Globorotalia menardii, Globorotalia limbata, Gr. cibaoensis, Gr. merotumida, Gq. dehiscens, Neogloboquadrina humerosa,* and *Sphaeroidinellopsis kochi* are either missing from or are rare in many samples through this late Miocene interval.

The rate of speciation at Site 925 is generally higher than the global rate except between 10 and 12 Ma and between 4 and 6 Ma. A large global speciation event near the Miocene/Pliocene boundary has only a muted expression at Site 925 (Fig. 4). Both global and Site 925 extinction rates are quite low through the late Miocene interval. For all tropical species and those present at Site 925 the smoothed records of species richness (averaged per million years) are sub-parallel through the middle to late Miocene (Fig. 5). Through the interval studied, Site 925 generally has 20 fewer species than are present in all the tropical oceans, but between 10 and 8 Ma this difference decreases to 10 fewer species at Site 925. This region thus appears to have supported its most diverse planktonic foraminifer fauna of the last 12 m.y. between 9 and 8 Ma in the late Miocene (Fig. 5).

Pliocene and Pleistocene

(Samples 154-925B-16H-5, 65–67 cm, to -1H-3, 65–67 cm)

A pronounced maximum in speciation (Fig. 4) at the Miocene/Pliocene boundary is largely responsible for the largest peak in global turnover rates in the last 12 m.y. (Fig. 5). By contrast, the largest peak in turnover rate at Site 925 is between 4 and 3 Ma, and this is driven by a maximum in the extinction rate in the middle Pliocene at this site. Both global and Site 925 diversification rates become negative between 5 and 4 Ma and remain so to the top of the section.

The global rate of extinction increases between 7 and 5 Ma (Fig. 5) and remains at approximately the same level through the Pliocene. By contrast, the rate of extinction at Site 925 increases dramatically after 4 Ma to a level that is more than twice the global rate between 4 and 3 Ma (Fig. 5). The discrepancies in timing and magnitude may have a regional cause. The peak in extinction rate at Site 925 follows the closing

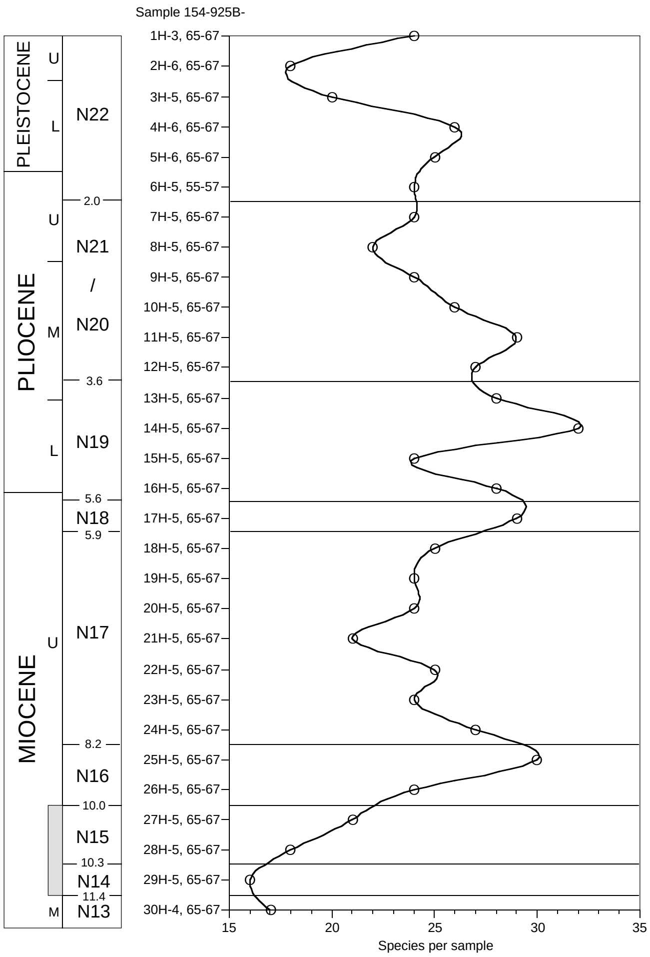

Figure 3. Species richness per sample in Hole 925B for the last 12 m.y.

of the Central American Seaway, and it is generally synchronous with a decline in the abundance of the dominant thermocline-dwelling species at this site (Chaisson and Ravelo, this volume).

The general trend of the turnover rate at Site 925 is increasing through the Pliocene (Fig. 5), driven by rates of extinction and speciation that are greater than the global rates (Fig. 4). Turnover decreases to a lower level in the Pleistocene at Site 925, but does not return to the early Pliocene level. Global turnover rates generally decline through the Pliocene–Pleistocene interval (Fig. 5).

FORAMINIFER PRESERVATION

The vertical movement of the foraminiferal lysocline (Berger, 1970) over Ceara Rise through the last 12 m.y. can be interpreted by correlating intervals of increased foraminifer shell breakage and dissolution between deeper and more shallow sites. Site 925 is the shallowest site on Ceara Rise (3042 m), and severe dissolution is not observed in any samples examined in the interval covering the last 12 m.y. (Fig. 6). At Site 929 (4358 m), the deepest site on the transect, "good" preservation is observed only in scattered samples, and some intervals are completely barren of planktonic foraminifers.

Between Samples 154-925B-29H-5, 65–67 cm, and 30H-6, 65–67 cm, preservation is often only "moderate" or "moderate-to-good," which may contribute to the low species counts through Zones N13 and N14 (Fig. 3). At deeper sites on Ceara Rise this part of the middle to upper Miocene is an interval of more intense dissolution, and it may correspond to the Neogene hiatus (NH)3 of Keller and Barron (1983) and Barron (1989). In Hole 927A (water depth: 3314 m), preservation also declines in some Zone N14 age samples (in Cores 154-927A-26H and 27H) to "moderate" or "good-to-moderate" levels. These samples are in a displaced portion of the section. Older upslope sediment slid to the location of Hole 927A during Zone N16/N15 time, leaving less well-preserved Zone N14 and N13 age sediments unconformably deposited over better preserved younger sediments. In situ Zone N14 and N13 sediments in Core 154-927A-28H are not as poorly preserved as those in the higher, displaced package. In Hole 926A (water depth: 3598 m) foraminifer preservation in Zones N14 and N13 is "poor" in some samples at the bottom of Core 154-926A-25H and the top of Core 26H. This pattern of dissolution indicates that during lower Zone N14 and upper Zone N13 time (~11.6 Ma) the foraminiferal lysocline rose to a position between 3314 and 3598 m depth on Ceara Rise.

Foraminifer preservation in Hole 925B (water depth: 3042 m) is uniformly good to excellent above the middle/upper Miocene boundary until Sample 154-925B-2H-3, 65-64 cm, in Zone N22, where many fragments are observed and preservation declines to "moderate" (Fig.6). This brief deterioration in preservation at Hole 925B likely corresponds to a more lengthy interval in the Hole 927A (3314 m depth), where moderate preservation is observed in all samples examined between Sample 154-927B-2H-4, 70–72 cm, and 3H-4, 70–72 cm.

TAXONOMIC NOTES

Site 925 is a shallow, low-latitude pelagic location with uninterrupted sediment accumulation. As such, it presents an excellent opportunity to clarify species concepts and to describe stratigraphic trends in morphological change.

STREPTOCHILUS

Streptochilus Brönnimann and Resig, 1971; Kennett and Srinivasan, 1983, p. 21, pl. 1, figs. 2, 6–8.

Stratigraphic range: Sample 154-925B-29H-5, 65–67 cm, to 3H-5, 65–67 cm.

Remarks: Individual *Streptochilus* species were not identified in this study. For a detailed examination of species in this genus, see Resig (1993).

GLOBOTURBOROTALITA

Assignment of this genus name to the below-listed species is dependent on the supposed phylogenetic connection between *Gt. rubescens* Hofker and a Neogene ancestor. Kennett and Srinivasan (1983) linked *Gt. rubescens* with *Globigerina (Zeaglobigerina) decoraperta,* and acknowledged the possible priority of *Globoturborotalita.* Lourens et al. (1992) proposed the derivation of *Gt. rubescens* from *Globoturborotalita apertura.*

Globoturborotalita nepenthes

Globigerina nepenthes Todd, 1957, p. 301, figs. 7a–b.
Globigerina (Zeaglobigerina) nepenthes Todd. Kennett and Srinivasan, 1983, p. 48, pl. 9, figs. 1–3.
Globoturborotalita nepenthes (Todd). Hofker, 1977.

Stratigraphic range: Sample 154-925B-30H-1, 65–67 cm, to 15H-5, 65–67 cm (with a questionable occurrence at 11H-5, 65–67 cm) (Zone N14 to middle Zone N19).

Remarks: This is the most common globigerine in the >150 µm fraction from its FO at the base of Zone N14 (above Sample 154-925B-30H-1, 65–67 cm; 270.91 mbsf; 11.6 Ma) through Sample 154-925B-21H-5, 65–67 cm, in the upper Miocene.

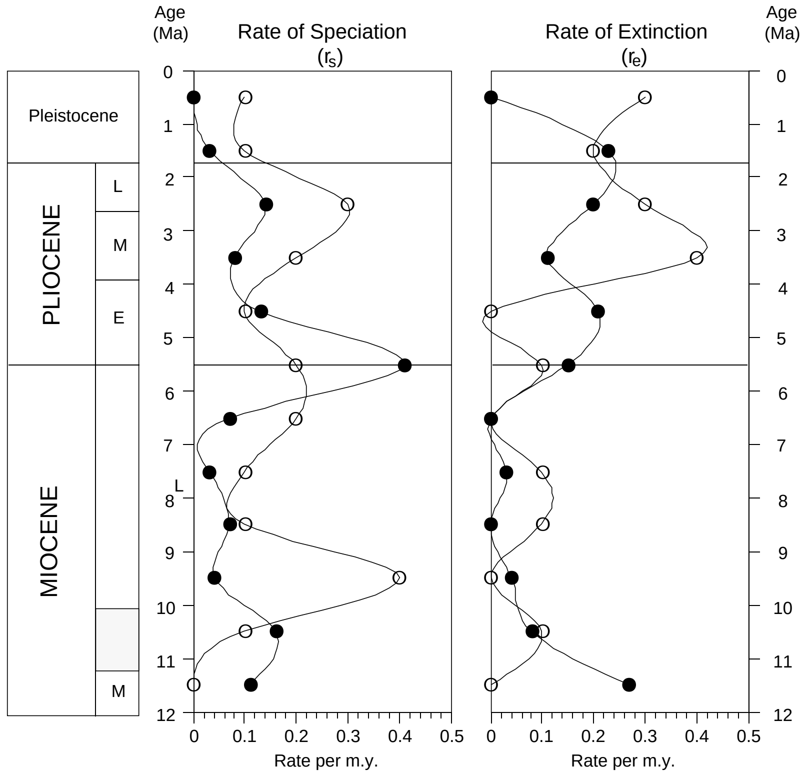

Figure 4. Rates of planktonic foraminifer speciation and extinction; global (dark circles) vs. Hole 925B (open circles). Averaged per million years (cf. Wei and Kennett, 1986).

Globoturborotalita woodi

Globigerina woodi Jenkins, 1960, p. 352, pl. 2, figs. 2a–c.
Globigerina (Zeaglobigerina) woodi Jenkins. Kennett and Srinivasan, 1983, p. 43, pl. 7, figs. 4–6.
Globigerina (Turborotalita) woodi woodi Jenkins. Chaproniere, 1981, p. 124, pls. 1, 2.
Globoturborotalita woodi (Jenkins). Hofker, 1977.

Stratigraphic range: Bottom of section examined to 154-925B-8H-7, 53–55 cm (to upper Zone N21/20).

Globoturborotalita apertura

Globigerina apertura Cushman, 1918, p. 57, pl. 12, figs. 8a–c.
Globigerina (Zeaglobigerina) apertura Cushman. Kennett and Srinivasan, 1983, p. 44, pl. 8, figs. 4–6.

Stratigraphic range: Sample 154-925B-29H-5, 65–67 cm, to 6H-6, 55–57 cm (Zone N14 to lower Zone N22).

Globoturborotalita decoraperta

Globigerina druryi Akers *decoraperta* Takayanagi and Saito, 1962, p. 85, pl. 28, figs. 10a–c.
Globigerina decoraperta Takayanagi and Saito. Kennett and Srinivasan, 1983, p. 48, pl. 9, figs 4–6.

Stratigraphic range: Bottom of section examined to 154-925B-10H-2, 65–67 cm (to top of Zone N21/20).

Globoturborotalita rubescens

Globigerina rubescens Hofker, 1956, p. 234, pl. 32, fig. 26; pl. 35, figs. 18–21.
Globigerina (Zeaglobigerina) rubescens Hofker. Kennett and Srinivasan, 1983, p. 50, pl. 9, figs. 7–9.
Globoturborotalita rubescens (Hofker). Hofker, 1977.

Stratigraphic range: Sample 154-925B-13H-2, 66–68 cm, to 1H-3, 65–67 cm (base of Zone N21/N20 to top of Zone N22).

Remarks: This species is difficult to distinguish from *Gt. woodi* from the middle Pliocene to lower Pleistocene, where their ranges overlap. A conservative definition is adopted for *Gt. rubescens* and a more inclusive one for *Gt. woodi.* This decision is made based on the large amount of morphologic variation observed in *Gt. woodi* throughout its range. Specimens are called *Gt. rubescens* if they have a relatively smooth final chamber and a relatively loose whorl, which gives the test a more tetrahedral appearance. By contrast, the chambers of *Gt. woodi* tend to be more tightly embracing. In addition, the apertural lip of *Gt. rubescens* tends to be more distinct to even flange-like (Sample 154-925B-9H-5, 65–67 cm), and the aperture itself tends to be round (Sample 154-925B-8H-5, 65–67 cm).

Globoturborotalita tenella

Globigerinoides tenella Parker, 1958, p. 280, pl. 6, figs. 7–11.
Globigerinoides tenellus Parker. Kennett and Srinivasan, 1983, p. 80, pl. 17, figs. 7–9.
Globoturborotalita tenella (Parker). This study.

Stratigraphic range: Sample 154-925B-6H-5, 55–57 cm, to 1H-3, 65–67 cm (base of Zone N22 to top of Zone N22).

Remarks: This species is identical to *Gt. rubescens* except for the addition of an accessory aperture. The presence of the accessory aperture led Parker (1958) to assign it to the polyphyletic genus *Globigerinoides.* Kennett and Srinivasan (1983) acknowledge the artificial nature of *Globigerinoides,* but retained it until more work was carried out on the lineages involved. In the interest of paring *Globigerinoides* down to a monophyletic genus we interpret the close resemblance of this species to *Gt. rubescens* as evidence for phylogenetic relatedness, and we reassign it to the genus *Globoturborotalita.*

GLOBIGERINA

Globigerina bulloides

Globigerina bulloides d'Orbigny, 1826, p. 3, pl. 1, figs. 1–4.
Globigerina (Globigerina) bulloides d'Orbigny. Kennett and Srinivasan, 1983, p. 36, pl. 6, figs. 4–6.

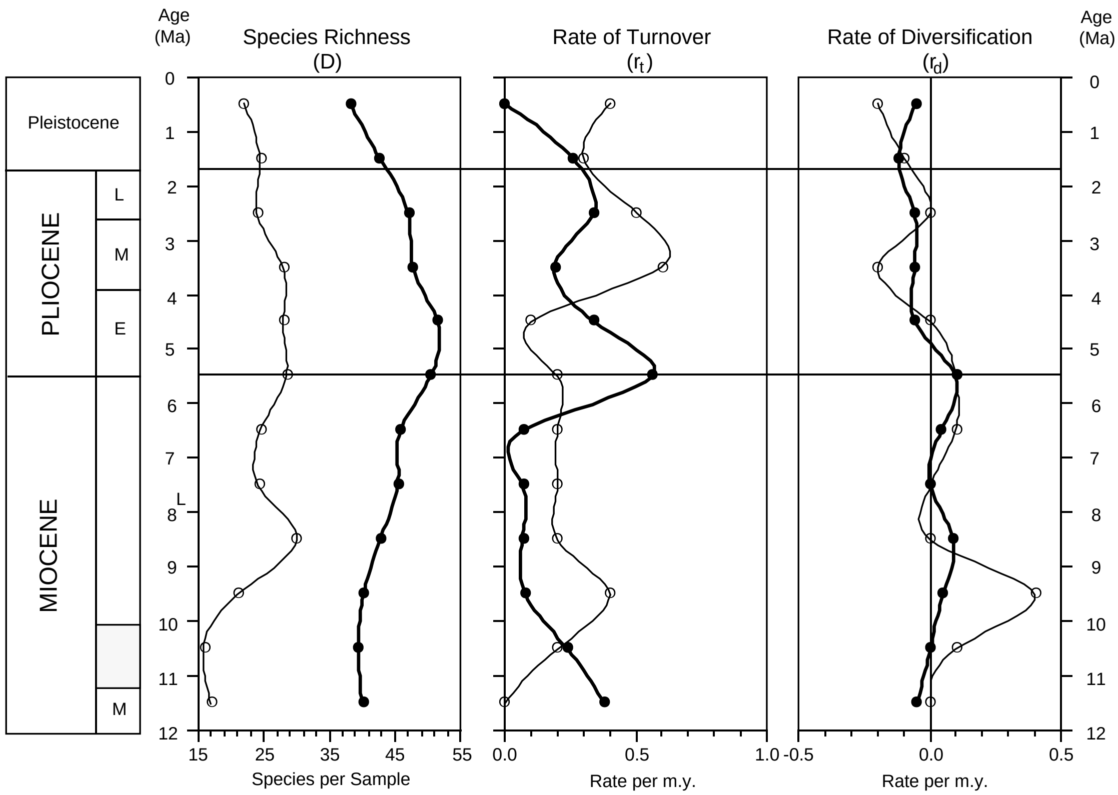

Figure 5. Rates of planktonic foraminifer species richness, turnover, and diversification; global (dark circles) vs. Hole 925B (open circles). Averaged per million years (cf. Wei and Kennett, 1986).

Stratigraphic range: Sample 154-925B-23H-5, 65–67 cm (lower Zone N17).

Globigerina falconensis

Globigerina falconensis Blow, 1959, p. 177, pl. 9, figs. 40a–c, 41.
Globigerina (Globigerina) falconensis Blow. Kennett and Srinivasan, 1983, p. 40, pl. 7, figs. 1–3.

Stratigraphic range: Sample 154-925B-25H-5, 65–67 cm, to 1H-3, 65–67 cm (Zone N16 to top of Zone N22).

GLOBIGERINOIDES

Globigerinoides extremus

Globigerinoides obliquus extremus Bolli and Bermudez, 1965, p. 139, pl. 1, figs. 10–12; Bolli and Saunders, 1985, p. 194, figs. 20.11
Globigerinoides extremus Bolli. Kennett and Srinivasan, 1983, p. 58, pl. 12, figs. 1–3.

Stratigraphic range: Sample 154-925B-25H-3, 65–67 cm, to 6H-5, 55–57 cm (lower Zone N17 to lower Zone N22).

Remarks: *Gs. extremus* is considered a variant of *Gs. obliquus* by Bolli and Saunders (1985) and their figured holotypes are quite similar in appearance. The distinction between *Gs. extremus* and *Gs. obliquus* cannot be easily drawn at the FO of the former species, which is assigned an age of 8.0 by Berggren et al. (1985; adjusted to the Leg 154 time scale). The transition from the ancestral species to the descendant is gradual and can be observed between Samples 154-925B-27H-5, 65–67 cm, and 25H-5, 65–67 cm (248.65 to 229.65 mbsf). The datum is placed at the level where the compression of chambers in the final whorl reaches a maximum and the size of the final chamber is reduced relative to the penultimate chamber.

Globigerinoides obliquus

Globigerinoides obliqua Bolli, 1957, p. 113, pl. 25, figs. 10a–c.
Globigerinoides obliquus Bolli. Kennett and Srinivasan, 1983, p. 56, pl. 11, figs. 7–9.

Stratigraphic range: Bottom of section examined to 154-925B-5H-6, 65–67 cm (to lower Zone N22).

Remarks: The morphology of this species is quite variable. It can be large with inflated chambers and a large aperture (Sample 154-925B-29H-5, 65–67 cm) or smaller with compressed chambers that give the test a quadrate appearance (Sample 154-925B-26H-5, 65–67 cm). The abundance of this species gradually declines through the Pliocene as the abundance of *Globigerinoides ruber* increases until the abundance of these two species become roughly equal at Sample 154-925B-12H-5, 65–67 cm. After this point *Gs. obliquus* becomes quite small and rare.

Globigerinoides conglobatus

Globigerina conglobata Brady, 1879, p. 28b.
Globigerinoides conglobatus (Brady). Kennett and Srinivasan, 1983, p. 58, pl. 12, figs. 4–6.

Stratigraphic range: Sample 154-925B-18H-5, 65–67 cm, to 1H-1, 65–67 cm (upper Zone N17 to top of N22).

Remarks: Specimens of this taxon that are not fully encrusted may be confused with specimens of *Globigerinoides extremus* having particularly compressed chambers. *Gs. conglobatus* may be distinguished by its more globose test.

Globigerinoides sacculifer

Globigerina sacculifera Brady, 1877, p. 164, pl. 9, figs. 7-10.
Globigerinoides sacculifer (Brady). Kennett and Srinivasan, 1983, p. 66, pl. 14, figs. 4–6.

Stratigraphic range: Throughout section examined.

Remarks: In Sample 154-925B-26H-5, 65–67 cm, *Gs. sacculifer* specimens with large, irregular sac-like final chambers make their first appearance

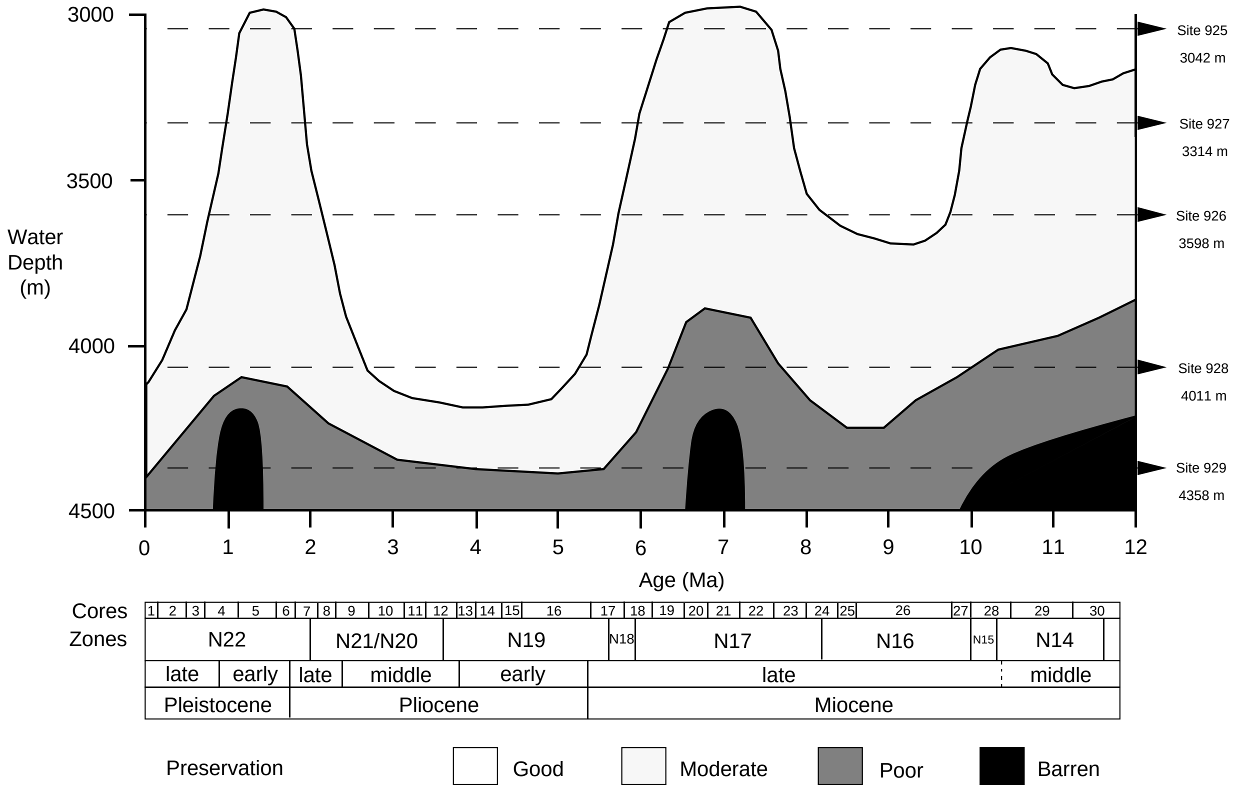

Figure 6. Dissolution of planktonic foraminifer tests at five sites in the depth transect down Ceara Rise. Degree of dissolution was estimated shipboard based on the amount of fragmentation and etching of specimens.

in Hole 925B. In Sample 154-925B-25H-5, 65–67 cm, transitional forms between *Sphaeroidinellopsis seminulina* and *Gs. sacculifer* are frequently observed. These specimens have only a partially realized cortex and the polygonal texture of the underlying test surface is clearly visible.

Globigerinoides fistulosus

Globigerina fistulosa Schubert, 1910, p. 323, text fig. 1.
Globigerinoides fistulosus (Schubert). Kennett and Srinivasan, 1983, p. 68, pl. 14, figs. 7–9.

Stratigraphic range: Sample 154-925B-11H-2, 65–67 cm, to 7H-5, 65–67 cm (upper Zone N21/20).

Remarks: *Gs. fistulosus* develops from *Gs. sacculifer* by adding multiple "final" sac-like chambers. Below the FO of *sensu stricto* forms of *Gs. fistulosus*, *Gs. sacculifer* with increasingly ornamented final chambers are observed. Above the LO the morphological transition in the reverse sense is observed. The downward extension of the stratigraphic range of *Gs. fistulosus* in Hole 925B may be due in part to our inclusion of less elaborate morphologies in the species definition.

ORBULINA

Orbulina universa

Orbulina universa d'Orbigny, 1839, p. 3, pl. 1, fig. 1; Kennett and Srinivasan, 1983, p. 86, pl. 20, figs. 4–6.

Stratigraphic range: Throughout section examined.

Remarks: Bilobate specimens are observed often in the uppermost Miocene and lower Pliocene and only rarely in other parts of the section. "Sutured" specimens ("*Orbulina suturalis*"), with earlier chambers visible as a perforated circle on the outer wall of the spherical terminal chamber, are observed in Sample 154-925B-30H-4, 65–67 cm. See Pearson and Chaisson (this volume) for a discussion of the praeorbuline lineage.

GLOBOCONELLA

Globoconella puncticulata
Plate 2, Figs. 12, 13

Globigerina puncticulata Deshayes, 1832, tome 2, no. 2, p. 170. Banner and Blow, 1960, p. 15, pl. 5, figs. 7a–c (lectotype).
Globorotalia (Globoconella) puncticulata (Deshayes). Kennett and Srinivasan, 1983, p. 116, pl. 27, figs. 4–6.

Stratigraphic range: Sample 154-925B-10H-5, 65–67 cm, to 6H-5, 55–57 cm (upper Zone N21/20 to lower Zone N22).

Remarks: *Gc. puncticulata* does not appear at this tropical site until late (Sample 154-925B-10H-5, 65–67 cm, in the middle Pliocene) in its global range (Kennett and Srinivasan, 1983). Because this site is outside the usual geographic range of *Gc. puncticulata* it is not surprising that irregular morphotypes are observed. In Sample 154-925B-10H-5, 65–67 cm, many specimens of *Gc. puncticulata* resemble *T. crassaformis. Gc. puncticulata* may be distinguished by its larger aperture, which gradually widens toward the spiral side. The apertural face of *Gc. puncticulata* is rounded, while that of *T. crassaformis* is generally flat. The final chamber of a *T. crassaformis* specimen is more inflated than earlier chambers, causing it to rise higher from the umbilicus. *Gc. puncticulata* gives rise to *Gc. inflata* in the late Pliocene (Kennett and Srinivasan, 1983). In the tropical region early *Gc. inflata* takes the form of "*Gc. triangula.*" If the late Pliocene to early Pleistocene range of *Gc. triangula* is added on to the range of *Globorotalia inflata* in the tropics, it is equivalent to the range of *Gr. inflata* in the higher latitudes (Weaver and Raymo, 1989). In Sample 154-925B-7H-5, 65–67 cm, forms transitional between *Gc. puncticulata* and *Gc. triangula* are observed.

Globoconella triangula/inflata
Plate 2, Figs. 14, 15, 16, 17

Globigerina inflata d'Orbigny, 1839, p. 134, pl. 12, figs. 7–9.

Globorotalia (Globoconella) inflata (d'Orbigny). Kennett and Srinivasan, 1983, p. 118, pl. 27, figs. 7–9.

Stratigraphic range: Sample 154-925B-8H-1, 65–67 cm, to 3H-5, 65–67 cm (upper Zone N21/20 to middle Zone N22).

Remarks: Weaver and Raymo (1989) note that joining the ranges of "*Globorotalia*" *inflata* and "*Globorotalia" triangula* in the eastern equatorial Pacific creates a stratigraphic range equivalent to that of *"Globorotalia" inflata* in the higher latitudes, and conclude that *"Gr." triangula* is a tropical ecophenotype of *"Gr." inflata.*

MENARDELLA

Members of this group are divided into normally perforate and finely perforate subgroups. Taxonomic remarks are made about each subgroup, rather than about individual taxa.

Menardella menardii
Plate 1, Figs. 1, 2

Rotalia menardii Parker, Jones, and Brady, 1865, p. 20, pl. 3, fig. 81; Bolli and Saunders, 1985, p. 220, 34.1–10.
Globorotalia (Menardella) menardii Parker, Jones, and Brady. Kennett and Srinivasan, 1983, p. 124, pl. 28, fig. 2.; pl. 29, figs. 1–3.

Stratigraphic range: Throughout section examined.

Menardella limbata
Plate 1, Fig. 3

Rotalia limbata Fornasini, 1902, p. 30–31, pl. 5, fig. 3 (lectotype).
Globorotalia (Menardella) limbata (Fornasini). Kennett and Srinivasan, 1983, p. 124, pl. 29, figs. 4–6.

Stratigraphic range: Sample 154-925B-28H–5, 65–67 cm, to 9H-1, 65–67 cm (Zone N15 to upper Zone N21/20).

"Globorotalia pseudomiocenica"
Plate 1, Figs. 7 and 8

Globorotalia pseudomiocenica Bolli and Bermudez, 1965, p. 140, pl. 1, figs. 13–15; Bolli and Saunders, 1985, p.230, figs. 31.1, 35.1–3.

Stratigraphic range: Sample 154-925B-24H-5, 65–67 cm, to 13H-3, 65–67 cm (lower Zone N17 to upper Zone N19).

Menardella multicamerata
Plate 1, Fig. 4

Globorotalia menardii (d'Orbigny) var. *multicamerata* Cushman and Jarvis, 1930, p. 367, pl. 34, figs. 8 a–c.
Globorotalia multicamerata Cushman and Jarvis. Bolli and Saunders, 1985, p. 220, 32.5 a–c.
Globorotalia (Menardella) multicamerata Cushman and Jarvis. Kennett and Srinivasan, 1983, p. 126, pl. 29, figs. 7–9.

Stratigraphic range: Sample 154-925B-18H-7, 65–67 cm, to 11H-1, 65–67 cm (upper Zone N17 to lower Zone N21/20).

Remarks: Stainforth et al. (1975) used the term 'menardiform' to refer a very broad category of globorotaliid. In this paper the term refers only to forms attributable to the subgenus *Menardella* (cf. Kennett and Srinivasan, 1983). The menardiform globorotaliids can be assigned to two separate groups based on surface texture: several normally perforate descended from *M. archeomenardii* and the three finely perforate taxa that evolved in the middle Pliocene from *M. limbata*.

The base of the stratigraphic range of *M. menardii* is in Zone N12 (Kennett and Srinivasan, 1983; Bolli and Saunders, 1985), and specimens in Sample 154-925B-30H-5, 65–67 cm, resemble *M. praemenardii.* That is, they are smaller, have a weaker keel and a generally ovate equatorial outline. In Sample 154-925B-23H-5, 65–67 cm, numerous small *M. menardii* were observed.

From Sample 154-925B-30H-5, 65–67 cm, to 20H-5, 65–67 cm, *M. menardii* (and *M. limbata*) are all sinistrally coiled (except in Sample 154-925B-22H-5, 65–67 cm). In the uppermost Miocene (Samples 154-925B-19H-5, 65–67 cm, through 16H-5, 65–67 cm) both dextrally and sinistrally coiled specimens are found. All specimens are dextrally coiled between Sample 154-925B-14H-5, 65–67 cm, and 9H-5, 65-67 cm. *M. menardii* is virtually absent between Sample 154-925B-10H-7, 58–60 cm, and 8H-2, 65–67 cm (as is *M. limbata*). The transition from dextral to sinistral coiling takes place between Sample 154-925B-9H-5, 65–67 cm, and 9H-1, 65–67 cm, and *M. menardii* are then generally sinistrally coiled to the top of the section.

M. limbata in Sample 154-925B-26H-5, 65–67 cm, have a flat spiral side and relatively straight spiral sutures. This sample marks the advent of specimens of *M. limbata* that are fully differentiated from *M. menardii. M. pseudomiocenica* is treated as a junior synonym for *M. limbata* (Kennett and Srinivasan, 1983). Specimens designated "*pseudomiocenica*" have a flattened spiral side, a feature shared by *M. miocenica* and *M. limbata,* but they are distinguished from normal *M. limbata* by their nearly circular equatorial periphery. Specimens closely resembling true *M. miocenica* are found in Sample 154-925B-22H-5, 65–67 cm. This is well below the FO of *M. miocenica,* but *M. pseudomiocenica* can also be distinguished by its thicker, more opaque, and more coarsely perforate test. In Sample 154-925B-15H-5, 65–67 cm, *M. pseudomiocenica* is the most common menardiform globorotaliid.

Menardella exilis
Plate 1, Figs. 6 and 9

Globorotalia (Globorotalia) cultrata exilis Blow, 1969
Globorotalia (Mendardella) exilis Blow. Kennett and Srinivasan, 1983, p. 128, pl. 28, fig. 1; pl. 30, figs. 1–3.

Stratigraphic range: Sample 154-925B-14H-7, 10–12 cm, to 8H-2, 65–67 cm (middle Zone N19 to upper Zone N21/20).

Menardella miocenica
Plate 2, Figs. 1, 2, 3, 4

Globorotalia menardii (d'Orbigny) var. *miocenica* Palmer, 1945.
Globorotalia (Menardella) miocenica, Palmer. Kennett and Srinivasan, 1983, p. 128, pl. 30, figs. 4–6.

Stratigraphic range: Sample 154-925B-12H-CC to 9H-1, 65–67 cm (Zone N21/20).

Menardella pertenuis
Plate 1, Figs. 10 and 11

Globorotalia pertenuis Beard, 1969, p. 552, pl. 1, figs. 1–6; pl. 2, figs. 5–6; Bolli and Saunders, 1985, p. 220, 33.3 a–c.
Globorotalia (Menardella) pertenuis Beard. Kennett and Srinivasan, 1983, p. 130, pl. 30, figs. 7–9.

Stratigraphic range: Sample 154-925B-12H-3, 65–67 cm, to 8H-7, 53–55 cm (Zone N21/20).

Remarks: Prior to the appearance of separate finely perforate species, isolated specimens of normally perforate taxa are observed. Some specimens of finely perforate *M. menardii* first appear in Sample 154-925B-17H-5, 65–67 cm. In Sample 154-925B-12H-5, 65–67 cm, many *M. limbata* have the high gloss of *M. exilis,* but they are not thin in equatorial view like the latter species. Finely perforate specimens of *M. menardii* are also observed in Sample 154-925B-2H-5, 65–67 cm, well above the last appearance of the finely perforate menardiform species. These isolated instances of finely perforated individuals indicate that the alternate texture is present in the genome of the longer ranged, normally perforate species. In the Pliocene tropical Atlantic and Caribbean this morphotype apparently became reproductively isolated and spawned a small radiation of three short-ranged species.

Large, flat "*exilis*" type menardiforms are observed in Sample 154-925B-20H-5, 65–67 cm, in the upper Miocene, but the thin, delicate true *M. exilis* are found only in the middle Pliocene, and are well developed through Core 154-925B-8H. In Sample 154-925B-10H-5, 65–67 cm, some *M. exilis* specimens show *fimbriata*-type spines on the keel. In the same sample very well developed *M. miocenica* are observed, having 5 to 9 chambers, a perfectly flat spiral side, and a circular periphery. Well-developed specimens of *M. pertenuis* can be found in Sample 154-925B-9H-5, 65–67 cm. They are very large, thin with successive apertural flaps covering the umbilicus. Many distorted specimens are also observed in this sample, which look as if the tests were so delicate that they collapsed partially during calcification.

TRUNCOROTALIA

Truncorotalia truncatulinoides

Rotalia truncatulinoides d'Orbigny, 1839, p. 132, pl. 2, figs. 25–27.
Globorotalia truncatulinoides (d'Orbigny). Lamb and Beard, 1972, p. 56, pl. 24, figs. 1–4, pl. 25, figs. 1–7, pl. 26, figs. 1–3; Jenkins and Orr, 1972; p. 1104, pl. 33, figs. 4–6; Stainforth et al., 1975, figs. 209–211.
Globorotalia truncatulinoides truncatulinoides (d'Orbigny). Bolli and Saunders, 1985, p. 234, fig. 37.4–5.
Globorotalia (Truncorotalia) truncatulinoides (d'Orbigny). Kennett and Srinivasan, 1983, p. 148, pl. 34, fig. 2; pl. 35, figs. 4–6.

Stratigraphic range: Sample 154-925B-7H-4, 68–70 cm, to 1H-1, 65–67 cm (Zone N22).

Truncorotalia tosaensis

Globorotalia tosaensis Takayanagi and Saito, 1962, p. 81, pl. 28, figs. 11a–12c; Lamb and Beard, 1972, p. 56, pl. 22, figs. 1–7, pl. 23, figs. 1–2; Jenkins and Orr, 1972, p. 1104, pl. 33, figs. 1–3; Stainforth et al., 1975, p. 413, figs. 206–207.
Globorotalia tosaensis tosaensis Takayanagi and Saito. Bolli and Saunders, 1985, p. 234, fig. 37.8.
Globorotalia (Truncorotalia) tosaensis Takayanagi and Saito. Kennett and Srinivasan, 1983, p. 148, pl. 34, fig. 1, pl. 35, figs. 1–3.

Stratigraphic range: Sample 154-925B-8H-5, 65–67 cm, to 3H-5, 65–67 cm (upper Zone N21/20 to middle Zone N22).

Remarks: The transition from *T. tosaensis* to *T. truncatulinoides* is defined by the development of an imperforate peripheral keel or band. Specimens of *T. tosaensis* very close to *T. truncatulinoides,* but with perforate peripheral bands, are observed both above the FO of the latter species in Sample 154-925B-5H-6, 65–67 cm, and below it in Sample 154-925B-8H-5, 65–67 cm.

Specimens of the delicate *tenuitheca* morphotype are observed in Sample 154-925B-4H-6, 65–67 cm. Rare specimens of the *cavernula* morphotype (Kennett and Srinivasan, 1983) are observed in Samples 154-925B-1H-1, 65–67 cm, and 1H-3, 65–67.

Truncorotalia crassaformis
Plate 2, Figs. 6, 7, 8, 9, 10, 11

Globigerina crassaformis Galloway and Wissler, 1927, p. 41, pl. 7, fig. 12.
Globorotalia (Truncorotalia) crassaformis (Galloway and Wissler). Kennett and Srinivasan, 1983, p. 146, pl. 34, figs. 6–8.
Globorotalia crassaformis crassaformis (Galloway and Wissler). Bolli and Saunders, 1985, p. 230, 36.6–7.

Stratigraphic range: Sample 154-925B-14H-5, 65–67 cm, to 1H-1, 65–67 cm (middle Zone N19 to top of Zone N22).

Remarks: This species exhibits a broad range of morphologic variability, but no useful stratigraphic integrity was observed for any of the various morphotypes. Several varieties may occur in one sample, as in the middle Pliocene. Sample 154-925B-10H-5, 65–67 cm. One form is sub-quadrate, high-spired, and has only an imperforate band. A second form is ovate in peripheral outline and lower spired. A third form is more delicate than the previous two and fully keeled.

Truncorotalia crassula
Plate 2, Fig. 5

Globorotalia crassula Cushman and Stewart, 1930, p. 77, pl. 7, figs. 1a–c.
Globorotalia (Truncorotalia) crassula Cushman and Stewart. Kennett and Srinivasan, 1983, p. 144, pl. 34, figs. 3–5.

Stratigraphic range: Sample 154-925B-15H-1, 65–67 cm, to 13H-5, 65–67 cm (lower Zone N19 to middle Zone N21/20).

HIRSUTELLA

Hirsutella cibaoensis
Plate 2, Figs. 18 and 19

Globorotalia cibaoensis Bermudez, 1949, p. 285, pl. 22, figs. 21–23.
Globorotalia (Hirsutella) cibaoensis Bermudez. Kennett and Srinivasan, 1983, p. 136, pl. 32, figs. 1–3.

Stratigraphic range: Sample 154-925B-26H-5, 65–67 cm, to 11H-5, 65–67 cm (Zone N16 to lower Zone N21/20).

Remarks: This species is distinguished from *H. scitula* by its coarser textured test and the delicate keel on the final chamber. Well-developed specimens are found in upper Miocene Sample 154-925B-22H-5, 65–67 cm, below its published FO (Kennett and Srinivasan, 1983). In Sample 154-925B-18H-5, 65–67 cm, specimens with an imperforate band entirely around the periphery of the test are observed, resembling *H. margaritae primitiva.* In Sample 154-925B-17H-5, 65–67 cm, *H. cibaoensis* specimens have fully keeled chambers.

Hirsutella juanai

Globorotalia juanai Bermudez and Bolli, 1969, p. 171–172, pl. 14, figs. 1–6; Bolli and Saunders, 1985, p. 216, 30.20–21a–c, 22–24.
Globorotalia (Hirsutella) juanai Bermudez and Bolli. Kennett and Srinivasan, 1983, p. 134, pl. 31, figs. 6–8.

Stratigraphic range: Sample 154-925B-26H-5, 65–67 cm, to 18H-5, 65–67 cm (Zone N16 to top of Zone N17).

Hirsutella scitula

Pulvinulina scitula Brady, 1882, p. 27, pl. 5, fig. 5 (lectotype).
Globorotalia (Hirsutella) scitula (Brady). Kennett and Srinivasan, 1983, p. 134, pl. 31, figs. 1, 3–5.

Stratigraphic range: Throughout section examined.

Hirsutella margaritae
Plate 2, Fig. 20

Globorotalia margaritae Bolli and Bermudez, 1965, p. 138, pl. 1, figs. 1–9; Bolli and Saunders, 1985, p. 216, 30.1–5, 30.9–14.
Globorotalia (Hirsutella) margaritae Bolli and Bermudez. Kennett and Srinivasan, 1983, p. 136, pl. 32, figs. 4–6; Bolli and Saunders, 1985.

Stratigraphic range: Sample 154-925B-18H-5, 66–68 cm, to 13H-2, 66–68 cm (uppermost Zone N17 to lowermost Zone N21/20).

GLOBOROTALIA

Globorotalia lenguaensis

Globorotalia lenguaensis Bolli, 1957, p. 120, pl. 29, figs. 5a–c.
Globorotalia (Globorotalia) paralenguaensis Blow, 1969, p. 402, pl. 46, figs. 1–6.
Globorotalia (Globorotalia) lenguaensis Bolli. Kennett and Srinivasan, 1983, p. 152, pl. 29, figs. 5a–c.
Globorotalia (Globorotalia) paralenguaensis Blow. Kennett and Srinivasan, 1983, p. 154, pl. 37, figs. 1–3.

Stratigraphic range: Sample 154-925B-32H-4, 65–67 cm, to 23H-5, 65–67 cm (upper Zone N15 to lower Zone N17).

Remarks: The FO of this species was located shipboard. It is not observed between Sample 154-925B-32H-2, 65–67 cm, and 27H-5, 65–67 cm.

Globorotalia paralenguaensis

Globorotalia (Globorotalia) paralenguaensis Blow, 1969, v. 1, p. 402, pl. 46, figs. 1–6; Kennett and Srinivasan, 1983, p. 154, pl. 37, figs. 1–3.

Stratigraphic range: Sample 154-925B-27H-5, 65–67 cm, to 25H-5, 65–67 cm (upper Zone N15 to the top of Zone N16).

Globorotalia merotumida

Globorotalia (Globorotalia) merotumida Blow and Banner (in Banner and Blow), 1965, p. 1352, text fig. 1; Kennett and Srinivasan, 1983, p. 154, pl. 37, figs. 4–6.

Globorotalia merotumida Blow and Banner. Bolli and Saunders, 1985, p. 227, fig. 33.7.

Stratigraphic range: Sample 154-925B-27H-5, 65–67 cm, to 20H-5, 65−67 cm (upper Zone N15 to middle Zone N17).

Remarks: Specimens possibly assignable to *Globorotalia merotumida* are found in Sample 154-925B-18H-3, 66–68 cm.

Globorotalia plesiotumida

Globorotalia (Globorotalia) tumida (Brady) *plesiotumida* Blow and Banner (in Banner and Blow), 1965, p. 1353, figs. 2a–c.

Globorotalia (Globorotalia) plesiotumida Blow and Banner. Kennett and Srinivasan, 1983, p. 156, p. 37, figs. 7–9.

Globorotalia plesiotumida Blow and Banner. Bolli and Saunders, 1985, p. 227, fig. 33.5.

Stratigraphic range: Sample 154-925B-25H-3, 65–67 cm, to 13H-1, 66−68 cm (base of Zone N17 to top of Zone N19).

Remarks: Specimens at the LO of this species are very close to *Globorotalia tumida.* They are relatively large with secondary encrusting calcite, but they retain a flat spiral side. Specimens in Sample 154-925B-13H-3, 60–62 cm, do not have the typical final chamber (radial length > tangential width), but the spiral side is flat and the test is ovate in umbilical view.

Globorotalia tumida

Pulvinulina menardii (d'Orbigny) var. *tumida* Brady, 1877, pl. 103, figs. 4–6.

Globorotalia (Globorotalia) tumida tumida (Brady). Kennett and Srinivasan, 1983, p. 158, pl. 36, fig. 1; pl. 38, figs. 1–3.

Stratigraphic range: Sample 154-925B-18H-1, 66–68 cm, to 1H-1, 65–67 cm (base of Zone N18 to top of Zone N22). With long intervals in which no specimens are found.

Globorotalia ungulata

Globorotalia ungulata Bermudez, 1960, p. 1304, pl. 15, figs. 6a–b.

Globorotalia (Globorotalia) ungulata Bermudez. Kennett and Srinivasan, 1983, p. 160, pl. 36, figs. 3–4; pl. 38, figs 7–9.

Stratigraphic range: Sample 154-925B-10H-5, 65–67 cm, to 1H-3, 65–67 cm (middle Zone N21/20 to the top of Zone N22).

PARAGLOBOROTALIA

Paragloborotalia mayeri

Globorotalia mayeri Cushman and Ellisor, 1939, p. 11, pl. 2, figs. 4a–c.

Globorotalia siakensis LeRoy, 1939, p. 262, pl. 4, figs. 20–22.

Globorotalia (Jenkinsella) mayeri Cushman and Ellisor. Kennett and Srinivasan, 1983, p. 174, pl. 43, figs. 4–6.

Globorotalia (Jenkinsella) siakensis LeRoy. Kennett and Srinivasan, 1983, p. 172, pl. 42, figs. 1, 6–8.

Stratigraphic range: Bottom of section examined to Sample 154-925B-29H-1, 65–67 cm (to base of Zone N15).

TURBOROTALITA

Turborotalita humilis

Truncatulina humilis Brady, 1884, p. 36, pl. 8, fig. 1 (lectotype).

Turborotalita humilis (Brady). Kennett and Srinivasan, 1983, p. 167, pl. 41, figs. 1, 3–5.

Stratigraphic range: Sample 154-925B-26H-5, 65–67 cm, to 2H-6, 65–67 cm (Zone N18 to top of Zone N22).

GLOBOQUADRINA

Globoquadrina venezuelana
Plate 2, Figs. 21 and 22

Globigerina venezuelana Hedberg, 1937, p. 681, pl. 92, figs. 72b.

Globoquadrina venezuelana (Hedberg). Kennett and Srinivasan, 1983, p. 180, pl. 44, figs. 5−7.

Stratigraphic range: Bottom of section examined to Sample 154-925B-11H-2, 65–67 cm (to lower Zone N21/20).

Remarks: In all samples between 154-925B-30H-5, 65−67 cm, and 25H-5, 65−67 cm (except 29H-5, 65−67 cm) *Gq. venezuelana* specimens have an uncharacteristically loose trochospire with a very open umbilicus and inflated chambers, causing them to closely resemble *Gq. pseudofoliata,* a Pliocene taxon that may have descended from *Gq. venezuelana* (Thompson and Sciarrillo, 1978). *Gq. venezuelana* specimens often have a flap-like, kummerform chamber covering the umbilicus. *Gq. venezuelana* specimens in Sample 154-925B-29H-5, 65−67 cm, have a more normal morphology. Chambers are compressed and the overall appearance is similar to that of *Gq. dehiscens.*

Globoquadrina dehiscens

Globorotalia dehiscens Chapman, Parr and Collins, 1934, p. 569, pl. 11, figs. 36a−c.

Globoquadrina dehiscens (Chapman, Parr and Collins). Kennett and Srinivasan, 1983, p. 184, pl. 44, fig. 2; pl. 45, figs. 7−9.

Stratigraphic range: Bottom of section examined to Sample 154-925B-19H-5, 65−67 cm (to upper Zone N17).

Globoquadrina baroemoenensis
Plate 2, Fig. 23

Globigerina baroemoenensis LeRoy, 1939, p. 263, pl. 6, figs. 1-2.

Globoquadrina baroemoenensis (LeRoy). Kennett and Srinivasan, 1983, p. 186, pl. 6, figs. 1−3.

Stratigraphic range: Bottom of section examined to Sample 154-925B-11H-5, 65−67 cm (to lower Zone N21/N20).

DENTOGLOBIGERINA

Dentoglobigerina altispira

Globigerina altispira Cushman and Jarvis, 1936, p. 5, pl. 1, figs. 13a−c.

Globoquadrina altispira globosa Bolli, 1957, p. 111, pl. 24, figs. 9a–10c.

Dentoglobigerina altispira altispira (Cushman and Jarvis). Kennett and Srinivasan, 1983, p. 188, pl. 46, figs. 4–6.

Dentoglobigerina altispira globosa (Bolli). Kennett and Srinivasan, 1983, p. 189, pl. 44, fig. 4; pl. 46, figs. 7−9.

Stratigraphic range: Bottom of section examined to Sample 154-925B-11H-1, 65−67 cm (to lower Zone N21/20).

Remarks: *D. altispira* also varies greatly morphologically. In Sample 154-925B-26H-5, 65–67 cm, specimens are very compressed and nearly quadrate in umbilical view, while in Sample 154-925B-25H-5, 65−67 cm, *D. altispira* specimens have a high trochospire and their chambers are more inflated.

NEOGLOBOQUADRINA

Neogloboquadrina continuosa

Globorotalia opima Bolli subsp. *continuosa* Blow, 1959, p. 218, pl. 19, figs. 125 a−c.

Neogloboquadrina continuosa (Blow). Kennett and Srinivasan, 1983, p. 192, pl. 47, figs. 3–5.

Stratigraphic range: Sample 154-925B-26H-5, 65–67 cm (Zone N16).

Remarks: Single specimens are found above the published (Kennett and Srinivasan, 1983) global last appearance.

Neogloboquadrina pachyderma

Aristopira pachyderma Ehrenberg, 1861, p. 276, 277, 303; Banner and Blow, 1960, p. 4, pl. 3, figs. 4a−c (lectotype).

Neogloboquadrina pachyderma (Ehrenberg). Kennett and Srinivasan, 1983, p. 192, pl. 47, figs. 2, 6–8.

Stratigraphic range: Sample 154-925B-11H-6, 65–67 cm, to 3H-5, 65–67 cm (lower Zone N21/20 to middle Zone N22). With lengthy intervals through which no specimens are found.

Neogloboquadrina acostaensis
Plate 2, Fig. 24

Globorotalia acostaensis Blow, 1959, p. 208, pl. 17, figs. 106a–c.
Neogloboquadrina acostaensis (Blow). Kennett and Srinivasan, 1983, p. 196, pl. 47, fig. 1; pl. 48, figs. 1–3.

Stratigraphic range: Sample 154-925B-27H-2, 65–67 cm, to 6H-5, 55–57 cm (base of Zone N16 to lowermost Zone N22).

Remarks: Kennett and Srinivasan (1983) show an early Pliocene extinction for this species. Berggren et al. (1985) give an age of 5.1 Ma (transformed to Leg 154 time scale) for its LO, an event that was verified by Chaisson and Leckie (1993) in the western equatorial Pacific. Bolli and Saunders (1985) show a stratigraphic range that extends to the Recent. The LO at Site 925 is at approximately the Pliocene/Pleistocene boundary. Either this species has a very diachronous LO or there are taxonomic difficulties, as suggested by Loubere and Moss (1986) with their designation of a *acostaensis-pachyderma* intergrade. In Samples 154-925B-7H-5, 65–67 cm, and 4H-6, 65–67 cm, both *N. acostaensis* and *N. acostaensis-pachyderma* intergrade are more abundant than the "*dutertrei*" morphotype.

Neogloboquadrina humerosa

Globorotalia humerosa Takayanagi and Saito, 1962, p. 78, pl. 28, figs. 1a–2b.
Neogloboquadrina humerosa (Takayanagi and Saito). Kennett and Srinivasan, 1983, p. 196, pl. 28, figs. 1a–2b.

Stratigraphic range: Sample 154-925B-25H-5, 65–67 cm, to 9H-2, 65–67 cm (Zone N16 to upper Zone N21/20).

Neogloboquadrina dutertrei

Globigerina dutertrei d'Orbigny, 1839, pl. 2, fig. 1 (lectotype).
Neogloboquadrina dutertrei (d'Orbigny). Kennett and Srinivasan, 1983, p. 198, pl. 48, figs. 7–9.

Stratigraphic range: Sample 154-925B-16H-4, 65–67 cm, to 1H-1, 65–67 cm (lower Zone N19 to top of Zone N22).

Remarks: In Sample 154-925B-20H-5, 65–67 cm, *"humerosa," "dutertrei,"* and *"pseudopima"* (cf. Bolli and Saunders, 1985) morphotypes can all be distinguished. In Sample 154-925B-18H-5, 65–67 cm, neogloboquadrinids are rare, and the *"humerosa"* vs. the *"dutertrei"* morphotypes are distinguished by the greater angle of the trochospire in the latter. In Samples 154-925B-13H-3, 65–67 cm, and 11H-5, 65–67 cm, *"dutertrei"* with apertural plates are observed. Specimens of *"dutertrei"* lacking apertural plates are observed in Sample 154-925B-10H-5, 65–67 cm. In Sample 154-925B-5H-6, 65–67 cm, six-chambered neogloboquadrinids have umbilical apertures and no apertural plates, thus combining the characteristics of "*dutertrei*" and "*humerosa*."

PULLENIATINA

Pulleniatina primalis

Pulleniatina primalis Banner and Blow, 1967, p. 142, pl. 1, figs. 3–8; pl. 3. figs. 2a–c; Kennett and Srinivasan, 1983, p. 200, pl. 49, figs. 1, 3–5.

Stratigraphic range: Sample 154-925B-16H-5, 65–67 cm, to 12H-2, 69–71 cm, and Sample 154-925B-8H-5, 65–67 cm, to 5H-6, 65–67 cm (lower Zone N19 to lower Zone N21/20 and upper Zone N21/20 to lower Zone N22).

Pulleniatina obliquiloculata

Pullenia sphaeroides (d'Orbigny) var. *obliquiloculata* Parker and Jones, 1865, p. 368, pl. 19, figs. 4a–b.
Pulleniatina obliquiloculata (Parker and Jones), Kennett and Srinivasan, 1983, p. 202, pl. 49, fig. 2; pl. 50, figs. 6–9.

Stratigraphic range: Sample 154-925B-8H-5, 65–67 cm, to 1H-1, 65–67 cm (upper Zone N21/20 to top of Zone N22).

Remarks: The stratigraphic ranges of pulleniatinids are discontinuous in the Atlantic (Bolli and Saunders, 1985) and, moreover, the morphotypes do not have stratigraphic integrity, as they do in the western equatorial Pacific (Chaisson and Leckie, 1993). *P. obliquiloculata* does not occur in the early Pliocene at Site 925 before the "Atlantic interim", although its published range (Kennett and Srinivasan, 1983) suggests that it should. Furthermore, the *primalis* morphotype persists upsection at Site 925 beyond its published LO (Kennett and Srinivasan, 1983; Berggren et al., 1985), as it does in the eastern equatorial Pacific (Chaisson, 1996).

SPHAEROIDINELLOPSIS

Sphaeroidinellopsis kochi

Globigerina kochi Caudri, 1934, text figs. 8 a–b.
Synonym: *Sphaeroidinella multiloba* LeRoy, 1944, p. 91, pl. 4, figs. 7–9.
Synonym: *Sphaeroidinella dehiscens subdehiscens* Blow, 1959, p. 195, pl. 12, figs. 71a–c.
Sphaeroidinellopsis kochi (Caudri). Kennett and Srinivasan, 1983, pl. 52, figs. 1–3.

Stratigraphic range: Bottom of section examined to Sample 154-925B-15H-5, 65–67 cm (to middle Zone N19).

Sphaeroidinellopsis seminulina

Globigerina seminulina Schwager, 1866, p. 256, pl. 7, fig. 112.
Sphaeroidinellopsis seminulina seminulina (Schwager). Kennett and Srinivasan, 1983, p. 206, pl. 51, figs. 1, 6–8.

Stratigraphic range: Bottom of section examined to Sample 154-925B-11H-1, 65–67 cm (to upper Zone N21/20).

Sphaeroidinellopsis paenedehiscens

Sphaeroidinellopsis paenedehiscens Blow, 1969, p. 386, pl. 30, figs. 4, 5, 9; Kennett and Srinivasan, 1983, p. 52, figs. 4–6.

Stratigraphic range: Sample 154-925B-22H-2, 65–67 cm, to 12H-5, 65–67 cm (middle Zone N17 to upper Zone N21/20).

SPHAEROIDINELLA

Sphaeroidinella dehiscens

Sphaeroidina bulloides d'Orbigny var. *dehiscens* Parker and Jones, 1865, p. 369, pl. 19, fig. 5.
Sphaeroidinella dehiscens (Parker and Jones). Kennett and Srinivasan, 1983, p. 212, pl. 51, fig. 2; pl. 52, figs. 7–9.

Stratigraphic range: Sample 154-925B-17H-4, 65–67 cm, to 2H-2, 65–67 cm (base of Zone N19 to upper Zone N22).

GLOBOROTALOIDES

Globorotaloides variabilis

Globorotaloides variabilis Bolli, 1957, p. 117, pl. 27, figs. 15a–20c; Kennett and Srinivasan, 1983, p. 214, pl. 53, figs. 2, 6–8.

Stratigraphic range: Bottom of section examined to Sample 154-925B-25H-5, 65–67 cm (to upper Zone N16).

Globorotaloides hexagonus

Globigerina hexagona Natland, 1938, p. 149, pl. 7, figs. 1a–c.
Globorotaloides hexagona (Natland). Kennett and Srinivasan, 1983, p. 216, pl. 54, figs. 1, 3–5.

Stratigraphic range: Throughout section examined.

GLOBIGERINITA

Globigerinita glutinata

Globigerina glutinata Egger, 1893, p. 371, pl. 13, figs. 19–21.

Globigerinita glutinata (Egger). Kennett and Srinivasan, 1983, p. 224, pl. 56, figs. 1, 3–5.

Stratigraphic range: Throughout section examined.

CANDEINA

Candeina nitida

Candeina nitida d'Orbigny, 1839, p. 107, pl, 2, figs. 27–28; Kennett and Srinivasan, 1983, p. 228, pl. 57, figs. 6–8.

Stratigraphic range: Sample 154-925B-24H-7, 65–67 cm, to 1H-2, 65–67 cm (lower Zone N17 to top of Zone N22).

BEELLA

Beella praedigitata

Globigerina praedigitata Parker, 1967, p. 151, pl. 19, figs. 5–8.
Beella praedigitata (Parker). Kennett and Srinivasan, 1983, p. 232, pl. 58, figs. 2–5.

Stratigraphic range: Sample 154-925B-19H-5, 65–67 cm, to 3H-5, 65–67 cm (upper Zone N17 to middle Zone N22).

Beella digitata

Globigerina digitata Brady, 1879, p. 599, pl. 80, figs. 6–10.
Beella digitata (Brady). Kennett and Srinivasan, 1983, p. 232, pl. 58, figs. 2, 6–8.

Stratigraphic range: Sample 154-925B-6H-5, 55–57 cm, to 1H-3, 65–67 (Zone N22).

GLOBIGERINELLA

Globigerinella aequilateralis

Globigerina aequilateralis Brady, 1879, p. 285 (figs. in Brady, 1884, pl. 80, figs. 18–21.
Globigerinella aequilateralis (Brady). Kennett and Srinivasan, 1983, p. 238, p. 59, fig. 1; pl. 60, figs. 4–6.

Stratigraphic range: Throughout section examined.

Remarks: Fully planispiral adult *Ge. aequilateralis* make their first appearance in Sample 154-925B-26H-5, 65–67 cm. This marks the completion of the morphological transition at Site 925 from *Ge. praesiphonifera* to *Ge. aequilateralis*, slightly later (Zone N16) than the global transition in Zone N12 (Kennett and Srinivasan, 1983; Bolli and Saunders, 1985). *Globigerinella (= Hastigerina) aequilateralis* and *Globigerinella (= Hastigerina) siphonifera* (*Globigerinella aequilateralis* 'A' and 'B') were not distinguished in this study (cf. Bolli and Saunders, 1985).

Globigerinella calida

Globigerina calida Parker, 1962, p. 221, pl. 1, figs. 9–13, 15.
Globigerinella calida (Parker). Kennett and Srinivasan, 1983, p. 240, pl. 60, figs. 7–9.

Stratigraphic range: Sample 154-925B-5H-6, 65–67 cm, to 1H-3, 65–67 cm (upper Zone N21/20 to top of Zone N22).

CONCLUSIONS

The astrochronologic time scale is a valuable tool for assigning precise and accurate age to planktonic foraminifer datums. Continued use of "tuned" time scales will likely reveal geographic patterns of datum diachrony that will suggest isolation of basins or water masses by the tectonic closing of gateways and the movement of oceanic fronts. The majority of the discrepancies between ages given in this paper and those of Berggren et al. (1985) are likely because of real diachrony. A minority of the departures are admittedly because of taxonomic difficulties, and the "Taxonomic Notes" included in this paper should clarify some of these problems.

Species richness rises to peaks in the early late Miocene (8.7 Ma) and the early Pliocene (4.3 Ma). These peaks (30 and 32 species, respectively) are separated by a low in the middle late Miocene (6.9 Ma), which is likely exacerbated, but not necessarily caused, by carbonate dissolution through this interval (Fig. 6). After the early Pliocene peak, species richness declines toward the top of the section. The middle Pleistocene minimum in species richness is also associated with an interval of strong carbonate dissolution at Site 925. In general, patterns of species richness and rates of foraminifer evolution at Site 925 do not adhere to global patterns as closely as does the biostratigraphy of Site 806 in the western equatorial Pacific. Site 925 biostratigraphy more strongly reflects regional dissolution effects and basin-wide biogeographic patterns. The latter are principally in the form of late first occurrences and early last occurrences apparently related to the progressive restriction of surface circulation through the Central American Seaway during the early Pliocene.

Three distinction intervals of increased dissolution of planktonic foraminifer tests are observed through the section that represents the last 12 m.y. at Ceara Rise. Two of these "events" (centered at 7 and 1 Ma) are observable in Site 925 sediments. The third (12–10 Ma) does not affect the shallowest site on the Ceara Rise transect, but is observed at all deeper sites.

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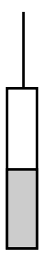
Ms 154SR-104

APPENDIX

KEY



Present in the world ocean (Kennett and Srinivasan, 1983), but absent in Hole 925B sediments.

Portion of Hole 925 stratigraphic range that overlaps the global range of Kennett and Srinivasan (1983).

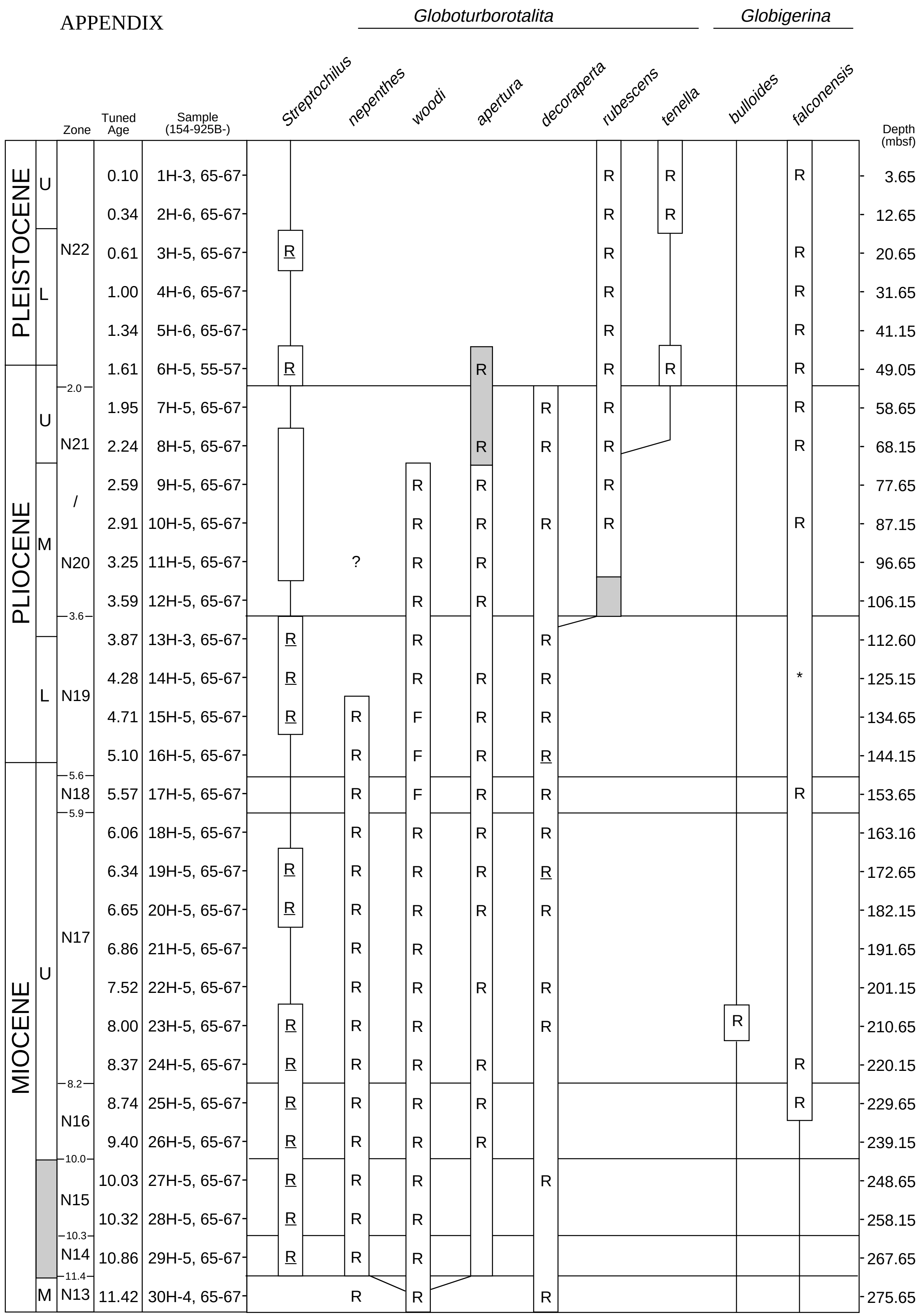
Portion of Hole 925B stratigraphic range that extends beyond the global range of Kennett and Srinvasan (1983)

R Rare (1–3%)
F Few (4–15%)
C Common (16-30%)

An underlined letter indicates that the taxon is present only in the fine fraction.

* Single specimen found
? Specimen of questionable identity
s Sinistrally coiled
d Dextrally coiled
b Bilobate
t Sutured

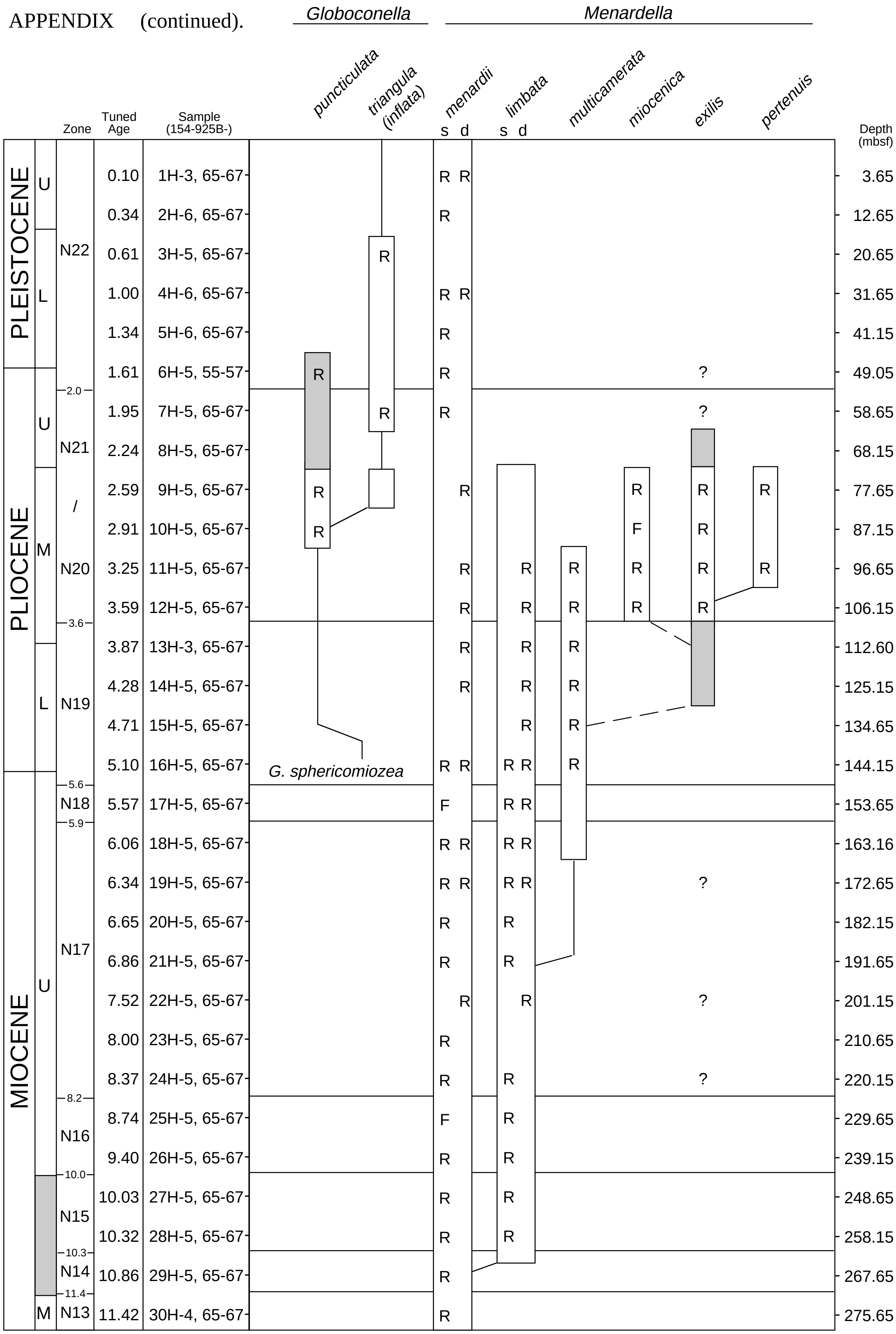
APPENDIX


Globoturborotalita
Globigerina
Streptochilus
nepenthes
woodi
apertura
decoraperta
rubescens
tenella
bulloides
falconensis
Zone
Tuned Age
Sample (154-925B-)
Depth (mbsf)
PLEISTOCENE
PLIOCENE
MIOCENE
N22
N21
N20
N19
N18
N17
N16
N15
N14
N13
0.10 1H-3, 65-67 3.65
0.34 2H-6, 65-67 12.65
0.61 3H-5, 65-67 20.65
1.00 4H-6, 65-67 31.65
1.34 5H-6, 65-67 41.15
1.61 6H-5, 55-57 49.05
1.95 7H-5, 65-67 58.65
2.24 8H-5, 65-67 68.15
2.59 9H-5, 65-67 77.65
2.91 10H-5, 65-67 87.15
3.25 11H-5, 65-67 96.65
3.59 12H-5, 65-67 106.15
3.87 13H-3, 65-67 112.60
4.28 14H-5, 65-67 125.15
4.71 15H-5, 65-67 134.65
5.10 16H-5, 65-67 144.15
5.57 17H-5, 65-67 153.65
6.06 18H-5, 65-67 163.16
6.34 19H-5, 65-67 172.65
6.65 20H-5, 65-67 182.15
6.86 21H-5, 65-67 191.65
7.52 22H-5, 65-67 201.15
8.00 23H-5, 65-67 210.65
8.37 24H-5, 65-67 220.15
8.74 25H-5, 65-67 229.65
9.40 26H-5, 65-67 239.15
10.03 27H-5, 65-67 248.65
10.32 28H-5, 65-67 258.15
10.86 29H-5, 65-67 267.65
11.42 30H-4, 65-67 275.65

APPENDIX (continued).

Epoch	Subepoch	Zone	Tuned Age	Sample (154-925B-)	*Globigerinoides extremus*	*Globigerinoides obliquus*	*Globigerinoides conglobatus*	*Globigerinoides ruber*	*Globigerinoides trilobus*	*Globigerinoides quadrilobatus*	*Globigerinoides sacculifer*	*Globigerinoides fistulosus*	*Orbulina universa*		Depth (mbsf)
PLEISTOCENE	U	N22	0.10	1H-3, 65-67			R	C	R	F	F		R		3.65
			0.34	2H-6, 65-67			R	C	R	F	F		R		12.65
	L		0.61	3H-5, 65-67			R	F	R	F	F		R	b	20.65
			1.00	4H-6, 65-67		*	R	C	R	F	F		R		31.65
			1.34	5H-6, 65-67		R	R	C	R	R	F		R		41.15
			1.61	6H-5, 55-57	R	R	R	C	R	R	R		R		49.05
PLIOCENE	U	2.0 / N21	1.95	7H-5, 65-67	R	R	R	F	R	F	F	R	R	b	58.65
			2.24	8H-5, 65-67	R		R	F	R	F	F		R		68.15
	M	N21/N20	2.59	9H-5, 65-67	R	F	R	F	R	F	F	R	R		77.65
			2.91	10H-5, 65-67	R	R	R	C	R	F	F	R	R		87.15
		N20	3.25	11H-5, 65-67	F	R	R	F	R	R	F		R		96.65
			3.59	12H-5, 65-67	R	R		R	R	F	R		R	b	106.15
	L	3.6 / N19	3.87	13H-3, 65-67	R	R	R	R	R	F	F		R		112.60
			4.28	14H-5, 65-67	R	F	R	R	R	F	F		R	b	125.15
			4.71	15H-5, 65-67	F	R	R	R	R	F	R		R	b	134.65
			5.10	16H-5, 65-67	R	R	R		R	F	F		R	b	144.15
MIOCENE	U	5.6 / N18 / 5.9	5.57	17H-5, 65-67	R	F	R	R	F	F	F		R		153.65
		N17	6.06	18H-5, 65-67	R	F	R		F	F	F		R		163.16
			6.34	19H-5, 65-67	R	F	*	*	R	F	F		R	b	172.65
			6.65	20H-5, 65-67	R	F			R	F	R		F	b	182.15
			6.86	21H-5, 65-67		F		R	R	F	R		R	b	191.65
			7.52	22H-5, 65-67	R	F		*	R	F	R		R		201.15
			8.00	23H-5, 65-67	R	F		*	R	F	F		R		210.65
			8.37	24H-5, 65-67	R	F		R	R	F	F		R		220.15
		8.2 / N16	8.74	25H-5, 65-67		F		*	R	F	F		R		229.65
			9.40	26H-5, 65-67		F			R	F	F		R		239.15
		10.0 / N15	10.03	27H-5, 65-67		F		R	R	C	R		R		248.65
			10.32	28H-5, 65-67		C			R	F	R		R		258.15
		10.3 / N14	10.86	29H-5, 65-67		F			R	F	R		R		267.65
	M	11.4 / N13	11.42	30H-4, 65-67		R	*Gs. subquadratus*		R	F			R	t	275.65

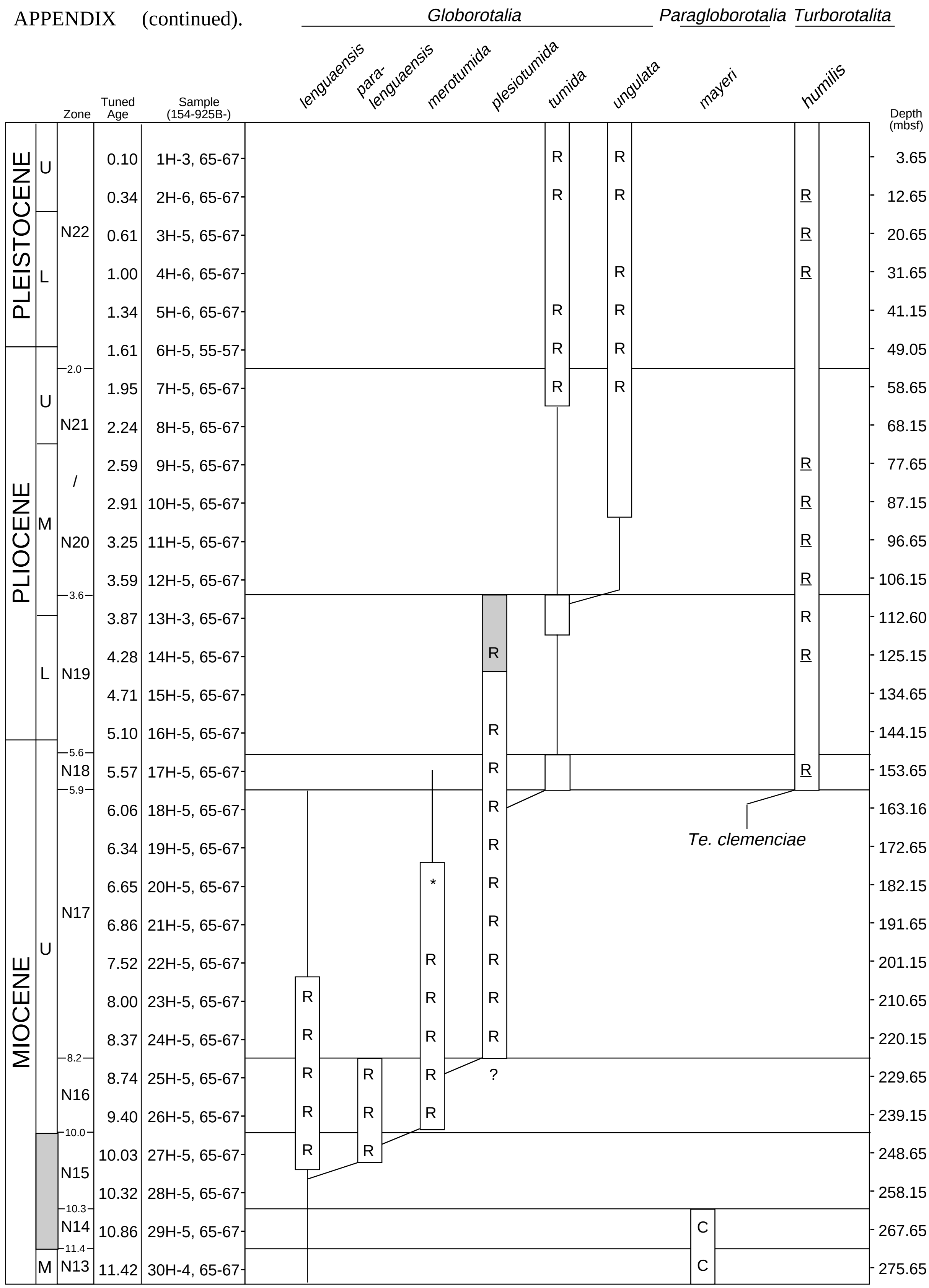
APPENDIX (continued).



APPENDIX (continued).

Epoch		Zone	Tuned Age	Sample (154-925B-)	*Truncorotalia* cavernula	*Truncorotalia* truncatulinoides s	*Truncorotalia* truncatulinoides d	*Truncorotalia* tosaensis	*Truncorotalia* crassaformis	*Truncorotalia* crassula	*Hirsutella* cibaoensis	*Hirsutella* scitula	*Hirsutella* juanai	*Hirsutella* margaritae	Depth (mbsf)
PLEISTOCENE	U	N22	0.10	1H-3, 65-67	R	R	R		R			R			3.65
			0.34	2H-6, 65-67			F		R			R			12.65
	L		0.61	3H-5, 65-67		F		R	R			R			20.65
			1.00	4H-6, 65-67			R		R			R			31.65
			1.34	5H-6, 65-67		R	R	R				R			41.15
			1.61	6H-5, 55-57					R			R			49.05
PLIOCENE	U	2.0 N21	1.95	7H-5, 65-67					R			R			58.65
			2.24	8H-5, 65-67				R	R			R			68.15
	M	/	2.59	9H-5, 65-67					R			R			77.65
			2.91	10H-5, 65-67					R			R			87.15
		N20	3.25	11H-5, 65-67					R		R	R			96.65
			3.59	12H-5, 65-67					R			R			106.15
	L	3.6 N19	3.87	13H-3, 65-67					R	R		R		R	112.60
			4.28	14H-5, 65-67					R	R	R	R		R	125.15
			4.71	15H-5, 65-67							R	R		R	134.65
			5.10	16H-5, 65-67							R	R		R	144.15
MIOCENE	U	5.6 N18	5.57	17H-5, 65-67							R	R		R	153.65
		5.9 N17	6.06	18H-5, 65-67							R	R	R	R	163.16
			6.34	19H-5, 65-67							R	R	R		172.65
			6.65	20H-5, 65-67							R	R			182.15
			6.86	21H-5, 65-67								R	R		191.65
			7.52	22H-5, 65-67							R	R	*		201.15
			8.00	23H-5, 65-67								R	R		210.65
			8.37	24H-5, 65-67							R	R	R		220.15
		8.2 N16	8.74	25H-5, 65-67							R	R			229.65
			9.40	26H-5, 65-67							R	R	R		239.15
		10.0 N15	10.03	27H-5, 65-67											248.65
			10.32	28H-5, 65-67								R			258.15
		10.3 N14	10.86	29H-5, 65-67								R			267.65
	M	11.4 N13	11.42	30H-4, 65-67								R			275.65

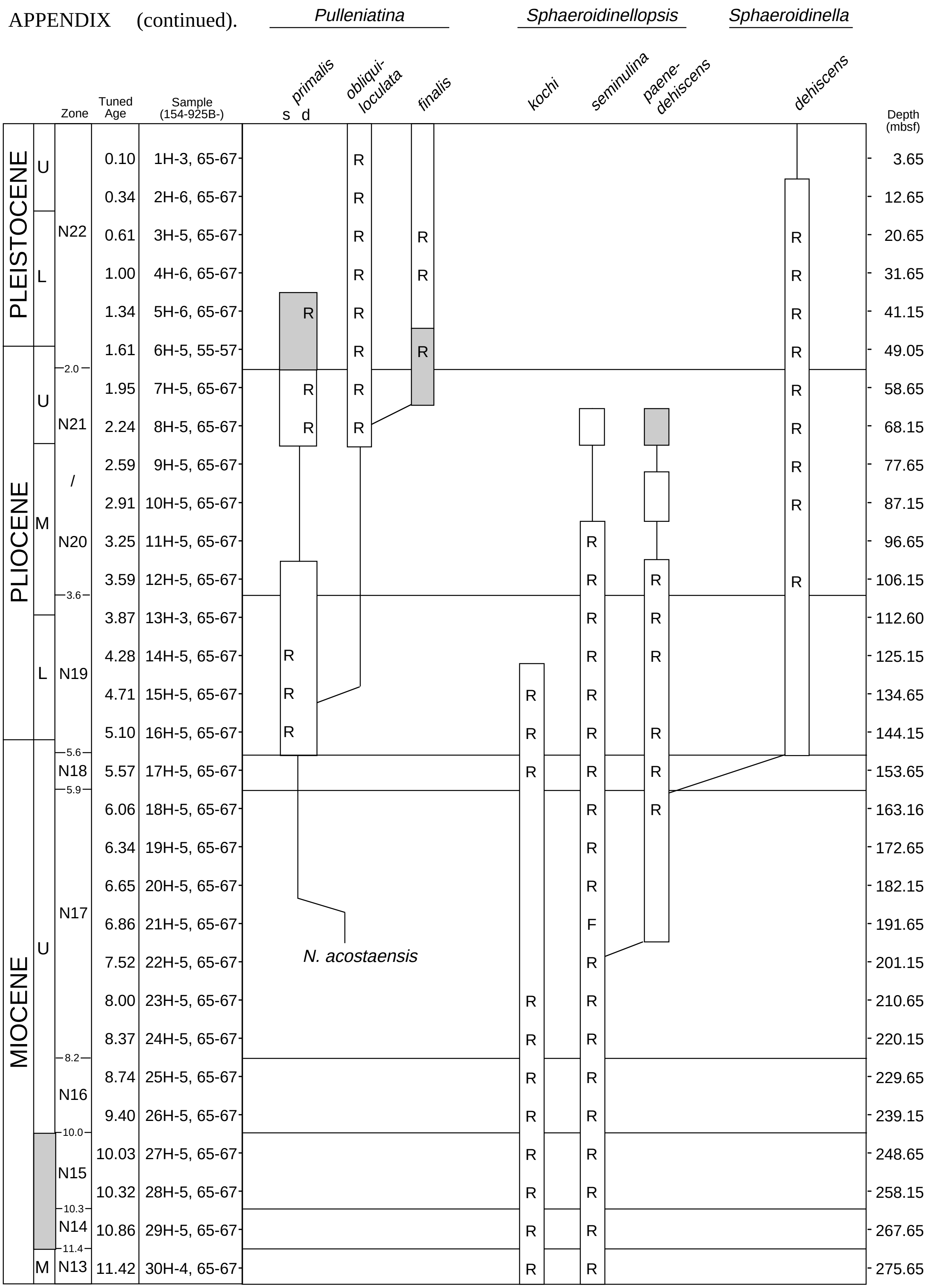
APPENDIX (continued).



APPENDIX (continued).

Epoch	Subepoch	Zone	Tuned Age	Sample (154-925B-)	*Globoquadrina venezuelana*	*Globoquadrina dehiscens*	*Globoquadrina baroemoenensis*	*Dentoglobigerina altispira*	*Neogloboquadrina pachyderma*	*Neogloboquadrina continuosa*	*Neogloboquadrina acostaensis*	*Neogloboquadrina humerosa*	*Neogloboquadrina dutertrei*	Depth (mbsf)
PLEISTOCENE	U	N22	0.10	1H-3, 65-67									R	3.65
PLEISTOCENE	U	N22	0.34	2H-6, 65-67									F	12.65
PLEISTOCENE	L	N22	0.61	3H-5, 65-67					R				R	20.65
PLEISTOCENE	L	N22	1.00	4H-6, 65-67					R				R	31.65
PLEISTOCENE	L	N22	1.34	5H-6, 65-67									R	41.15
PLEISTOCENE	L	N22	1.61	6H-5, 55-57							R		R	49.05
		2.0												
PLIOCENE	U	N21	1.95	7H-5, 65-67							R		R	58.65
PLIOCENE	U	N21	2.24	8H-5, 65-67							R		R	68.15
PLIOCENE	M	/	2.59	9H-5, 65-67							R	R	F	77.65
PLIOCENE	M	N20	2.91	10H-5, 65-67							R	R	F	87.15
PLIOCENE	M	N20	3.25	11H-5, 65-67	R		R	F			R		R	96.65
PLIOCENE	M	N20	3.59	12H-5, 65-67	R			F			R	R	R	106.15
		3.6												
PLIOCENE	L	N19	3.87	13H-3, 65-67	R		R	F			R	R	R	112.60
PLIOCENE	L	N19	4.28	14H-5, 65-67	R			R			R	R	R	125.15
PLIOCENE	L	N19	4.71	15H-5, 65-67				F			R		R	134.65
PLIOCENE	L	N19	5.10	16H-5, 65-67	R			R			R	R		144.15
		5.6												
MIOCENE	U	N18	5.57	17H-5, 65-67	R			F			R		*	153.65
		5.9												
MIOCENE	U	N17	6.06	18H-5, 65-67	R			R			R			163.16
MIOCENE	U	N17	6.34	19H-5, 65-67	R	R		R			<u>R</u>			172.65
MIOCENE	U	N17	6.65	20H-5, 65-67	R	R		R			F	R	?	182.15
MIOCENE	U	N17	6.86	21H-5, 65-67	R	R		R			F			191.65
MIOCENE	U	N17	7.52	22H-5, 65-67	R	R		R			F			201.15
MIOCENE	U	N17	8.00	23H-5, 65-67	R			R			F			210.65
MIOCENE	U	N17	8.37	24H-5, 65-67	R			C		*	R		?	220.15
		8.2												
MIOCENE	U	N16	8.74	25H-5, 65-67	R	R	R	F		*	R	*		229.65
MIOCENE	U	N16	9.40	26H-5, 65-67	R	R		R		R	R			239.15
		10.0												
MIOCENE		N15	10.03	27H-5, 65-67	R	R		R						248.65
MIOCENE		N15	10.32	28H-5, 65-67	R	R		R						258.15
		10.3												
MIOCENE		N14	10.86	29H-5, 65-67	R	R		R						267.65
		11.4												
MIOCENE	M	N13	11.42	30H-4, 65-67	R	R	R	R						275.65

APPENDIX (continued).



APPENDIX (continued).

Epoch		Zone	Tuned Age	Sample (154-925B-)	*Globorotaloides variabilis*	*Globorotaloides hexagonus*	*Globigerinita glutinata*	*Candeina nitida*	*Beella praedigitata*	*Beella digitata*	*Globigerinella aequilateralis*	*Globigerinella calida*	Depth (mbsf)
PLEISTOCENE	U	N22	0.10	1H-3, 65-67		R	R	R		R	R	R	3.65
			0.34	2H-6, 65-67			F			R	R		12.65
	L		0.61	3H-5, 65-67			R		R	R	R	R	20.65
			1.00	4H-6, 65-67		R	R	R	R	R	R		31.65
			1.34	5H-6, 65-67		R	R	R		R	R	R	41.15
			1.61	6H-5, 55-57			R			R	R		49.05
PLIOCENE	U	2.0 N21 / N20	1.95	7H-5, 65-67			R				R		58.65
			2.24	8H-5, 65-67		R	R	R	R		R	R	68.15
	M		2.59	9H-5, 65-67			R				R		77.65
			2.91	10H-5, 65-67			R	R	R		F		87.15
			3.25	11H-5, 65-67		R	R	R			R		96.65
			3.59	12H-5, 65-67		R	R	R			R		106.15
	L	3.6 N19	3.87	13H-3, 65-67		R	R	R			R		112.60
			4.28	14H-5, 65-67		R	R	R			R		125.15
			4.71	15H-5, 65-67		R		R			R		134.65
			5.10	16H-5, 65-67		R	R	R			R		144.15
MIOCENE	U	5.6 N18	5.57	17H-5, 65-67		R	R	R			R		153.65
		5.9 N17	6.06	18H-5, 65-67			R	R	*		R		163.16
			6.34	19H-5, 65-67			R	R	*		R		172.65
			6.65	20H-5, 65-67		R	R	R			R		182.15
			6.86	21H-5, 65-67		R	R				R		191.65
			7.52	22H-5, 65-67		R	R	R			R		201.15
			8.00	23H-5, 65-67		R	R	R			R		210.65
			8.37	24H-5, 65-67		R	R	R			R		220.15
		8.2 N16	8.74	25H-5, 65-67	R	R	R	*			R		229.65
			9.40	26H-5, 65-67		R	R				R		239.15
		10.0 N15	10.03	27H-5, 65-67	R	R	R				R		248.65
			10.32	28H-5, 65-67	R	R	R				R		258.15
		10.3 N14	10.86	29H-5, 65-67		R	R				R		267.65
	M	11.4 N13	11.42	30H-4, 65-67	R	R	R						275.65

G. bulloides

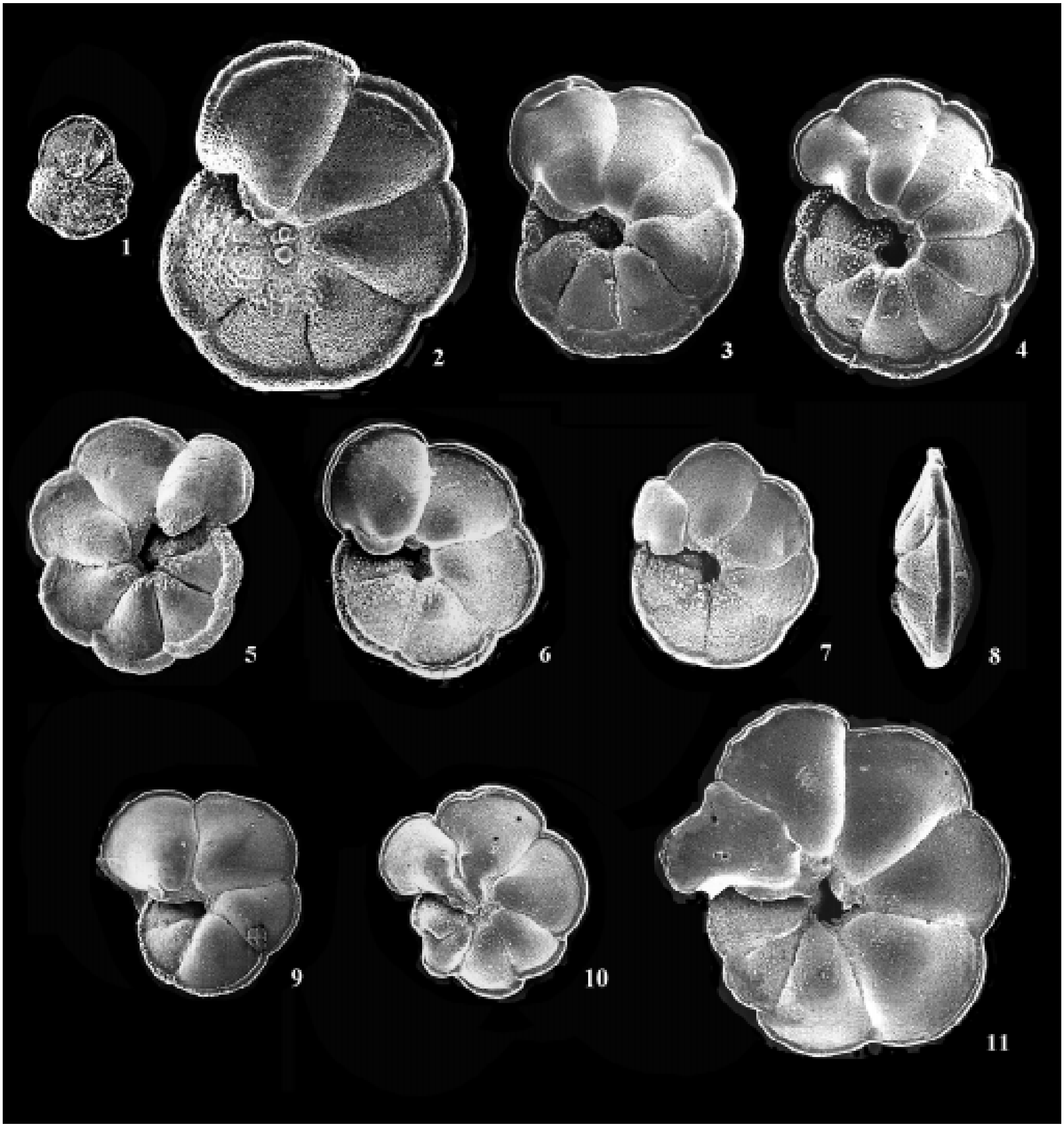


Plate 1. Menardiform globorotaliids. **1.** *Menardella praemenardii-menardii* transitional form (Sample 154-925B-30H-4, 65–67 cm), umbilical view. **2.** *Menardella menardii* (Sample 154-925B-12H-5, 65–67 cm), umbilical view. **3.** *Menardella limbata* (Sample 154-925B-10H-7, 58–60 cm), umbilical view. **4.** *Menardella multicamerata* (Sample 154-925B-10H-7, 58–60 cm), umbilical view. **5.** *Menardella "exilis"* (Sample 154-925B-24H-5, 65–67 cm), umbilical view. **6.** *Menardella exilis* (Sample 154-925B-11H-5, 65–67 cm), umbilical view. **7, 8.** *Menardella pseudomiocenica* (Sample 154-925B-15H-5, 65–67 cm), umbilical view (7), edge view (8). **9.** *Menardella exilis* (Sample 154-925B-8H-7, 53–55 cm), umbilical view. **10.** *Menardella pertenuis* (Sample 154-925B-8H-5, 65–67 cm), umbilical view. **11.** *Menardella pertenuis* (Sample 154-925B-10H-1, 65–67 cm), umbilical view. All specimens are magnified 75×.

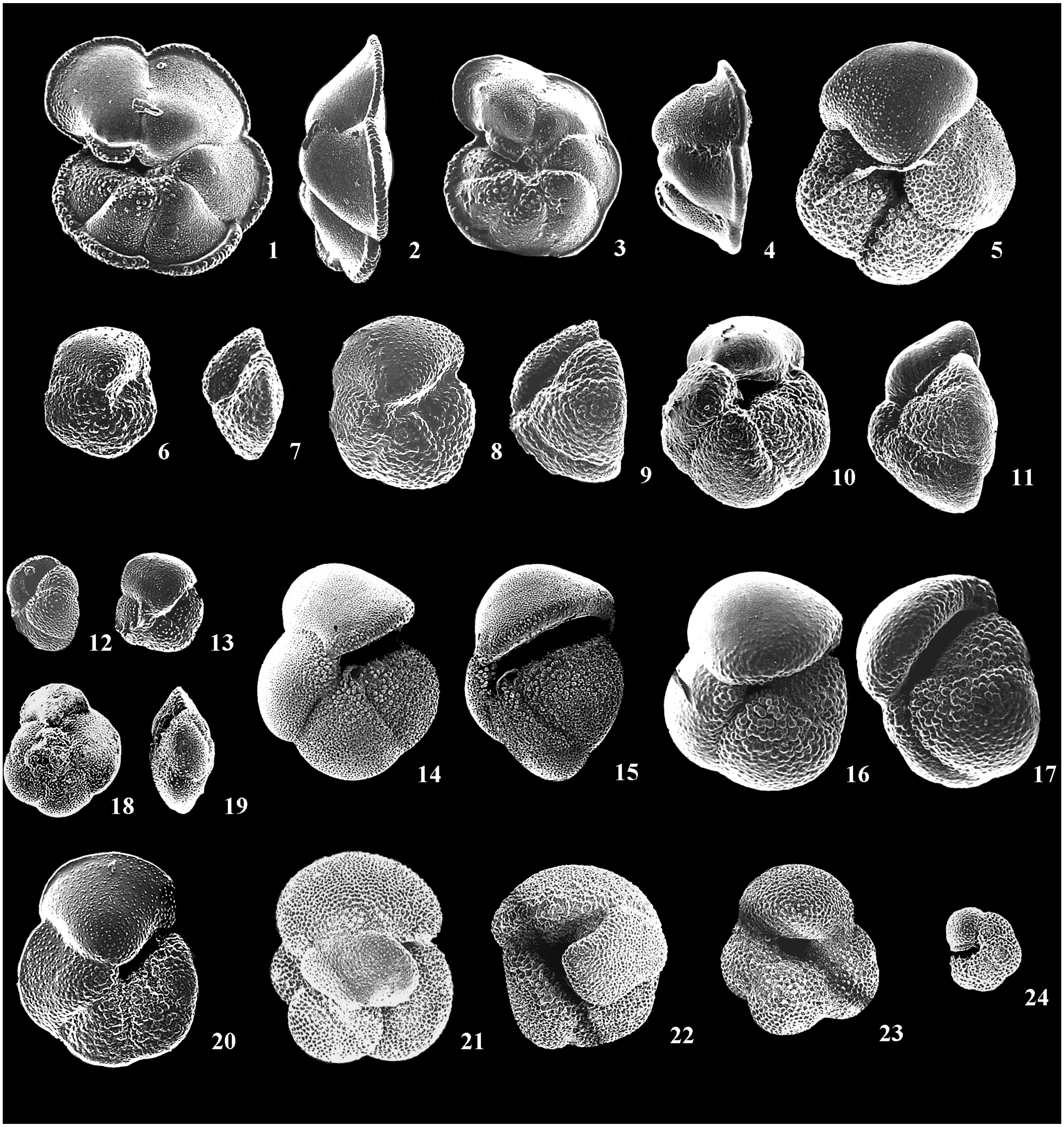


Plate 2. **1, 2.** *Menardella miocenica* (Sample 154-925B-10H-7, 58−60 cm), umbilical view (1), edge view (2). **3, 4.** *Menardella miocenica* (Sample 154-925B-9H-5, 65−67 cm), umbilical view (3), edge view (4). **5.** *Truncorotalia crassula-crassaformis* transitional form (Sample 154-925B-10H-1, 65−67 cm), umbilical view. **6, 7.** *Truncorotalia crassaformis* (Sample 154-925B-10H-5, 65−67 cm), umbilical view (6), edge view (7); keeled specimen. **8, 9.** *Truncorotalia crassaformis* (Sample 154-925B-10H-5, 65−67 cm), umbilical view (8), edge view (9); unkeeled specimen. **10, 11.** *Truncorotalia crassaformis* (Sample 154-925B-8H-1, 65−67 cm), umbilical view (10), edge view (11). **12, 13.** *Globoconella puncticulata* (Sample 154-925B-10H-5, 65−67 cm), edge view (12), umbilical view (13). **14, 15.** *Globoconella puncticulata-triangula* transitional form (Sample 154-925B-7H-5, 65−67 cm), umbilical view (14), edge view (15). **16, 17.** *Globoconella triangula* (Sample 154-925B-7H-5, 65−67 cm), umbilical view (16), edge view (17). **18, 19.** *Hirsutella cibaoensis* (Sample 154-925B-24H-5, 65−67 cm), spiral view (18), edge view (19). **20.** *Hirsutella margaritae margaritae* (Sample 154-925B-10H-7, 58−60 cm), umbilical view. **21.** *Globoquadrina venezuelana* (Sample 154-925B-11H-5, 65−67 cm), umbilical view. **22.** *Globoquadrina venezuelana* (Sample 154-925B-19H-5, 65−67 cm), umbilical view. **23.** *Globoquadrina baroemoenensis* (Sample 154-925B-25H-5, 65−67 cm), umbilical view. **24.** *Neogloboquadrina acostaensis* (Sample 154-925B-9H-2, 65−67 cm), umbilical view. All specimens are magnified 75×.