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8. Miocene Planktonic Foraminiferal Biostratigraphy of Sites 1143 and 1146, ODP Leg 184, South China Sea[1]

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ABSTRACT

The biostratigraphy of Miocene-age sediment samples recovered from Ocean Drilling Program Sites 1143 and 1146, South China Sea, is presented. The preservation of the planktonic foraminifers recovered from both sites varies widely, from poor to very good. The volume of biogenic sediment in the >63-µm size fraction also varies considerably, with many samples being dominated by mud. In comparison to shipboard biostratigraphy, based on core catcher analyses with a depth resolution of ~10 m, we analyzed samples from the two stratigraphic columns every 2–3 m (~45- to 93-k.y. resolution). The placement of planktonic foraminifer zonal boundaries was made at a resolution of ~1.5 m at Site 1146 and ~3.0 m at Site 1143. The higher resolution has resulted in significant changes in biostratigraphic zonal boundary locations compared to shipboard results.

For the time interval of 5.54–10.49 Ma, the changes in zonation reveal similar age-depth models at both sites, with three segments of changing sedimentation rate through the upper Miocene, though the differences in sedimentation rates at Site 1146 are subtler than those at Site 1143. The boundary between lithologic Units II and III at Site 1146 corresponds to a sharp change in sedimentation rate (58 to 21 m/m.y.) at 15.1 Ma (the first occurrence of *Orbulina suturalis*). At this site, the interval from 16.4 to 15.1 Ma is characterized by very high mass accumulation rates in the noncarbonate fraction. Above this interval the carbonate fraction becomes increasingly important in the sediment flux to the South China Sea. At Site 1143, sedimentation rates increase from 8 to 99 m/m.y. at 8.6 Ma. This corresponds to a dramatic increase in

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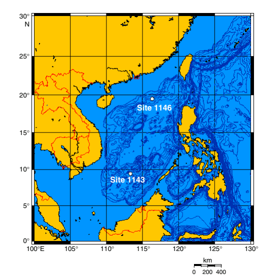
both carbonate and noncarbonate mass accumulation rates at the site, but no change in lithology.

INTRODUCTION

Investigating the historical development of the East Asian Monsoon was one of the primary goals of Ocean Drilling Program (ODP) Leg 184, South China Sea. An important component to achieving this objective is establishing an accurate biostratigraphic record of the basin. During Leg 184, one site was drilled in the southern South China Sea (Site 1143) and five sites were drilled in the northern part (Sites 1144–1148). This report presents the biostratigraphic analysis of 258 Miocene-age sediment samples recovered from Sites 1143 (112 samples) and 1146 (146 samples). The purpose of this biostratigraphy is to provide a planktonic foraminiferal age-depth model that improves upon what was created during the cruise (Wang, Prell, Blum, et al., 2000). Site 1143 is located at 9°21.72′N, 113°17.11′E (water depth = 2772 m), and Site 1146 is located at 19°27.40′N, 116°16.37′E (water depth = 2091 m) (Fig. F1). Both sites are within the influence of, and record the effects of, the East Asian monsoon. Site 1143 is also strongly affected by the seasonal fluctuations of the Western Pacific Warm Pool (e.g., McPhaden, 1993; Wang, 1999).

F1. Locations of Leg 184 sites, p. 31.



METHODS

Continuous hemipelagic sediments from Sites 1143 and 1146 were recovered using a combination of advanced hydraulic piston coring and extended core barrel drilling. This report focuses upon the Miocene-age sediments recovered from both sites (5.32 Ma and older). Specifically, sediment samples were examined from the lowermost Pliocene (beginning several cores above the base of planktonic foraminiferal Zone N19/calcareous nannofossil Zone CN10) to the bottom of the drilled holes. For Site 1143 the studied interval is from 182.91 to 512.91 meters composite depth (mcd) (Samples 184-1143A-20H-1, 115–117 cm, through 184-1143C-54X-CC, 43–48 cm). For Site 1146 the studied interval is from 295.17 to 643.11 mcd (Samples 184-1146A-30X-5, 10–14 cm, through 64X-CC, 35–41 cm). In general, three samples per core (~9.6 m) were studied from both sites. Zonal boundaries and primary datums are placed at the average depth of the two samples that constrained them (Tables T1, T2, T3, T4).

T1. Distribution of planktonic foraminifers, Site 1143, p. 38.

T2. Distribution of planktonic foraminifers, Site 1146, p. 41.

T3. Planktonic foraminifer datums, Site 1143, p. 42.

T4. Planktonic foraminiferal datums, Hole 1146A, p. 43.

Sediment volumes of ~10 cm^3 (Site 1143) and ~20 cm^3 (Site 1146) were collected; the larger volume was taken for Site 1146 when the processing of Site 1143 samples yielded few foraminifers (on average). All samples were soaked in a mixture of three parts water to one part hydrogen peroxide (initially 40% wt/vol H_2O_2) and Calgon (adjusting the pH to alkaline) for several days. The mixture was then washed over a 63-µm screen, and the residues were dried in an oven at 60°C. The residues from the >150-µm sieve fraction were examined for the species present (richness), relative abundance, and preservation.

Each sample was first repeatedly split with a microsplitter until a volume of sediment, equivalent to that used for a population analysis (~2000 tests), was obtained and evenly spread onto a picking tray. This smaller but representative sample volume allows for a more accurate visual assessment of species relative abundances and preservation. Abundances were categorized as follows:

P = present (<1% to only a single test observed).
R = rare (1%–5%).
F = few (5%–10%)
A = abundant (10%–30%).
D = dominant (>30%).

Sample preservation was qualitatively estimated by the degree of test breakage and/or dissolution:

V = very good (<20% fragmentation, no evidence of etching).
G = good (20%–50% fragmentation and/or minor etching of susceptible species).
P = poor (>50% fragmentation, assemblage consists of mainly dissolution-resistant species).

To determine species richness and to place zonal boundaries accurately, foraminiferal tests were spread upon a picking tray and examined using a binocular microscope (typically, a minimum of two trays were examined). In some cases a large fraction of the vial or its entire contents were examined (because of low to moderate yields after washing or the scarcity of a marker species). Tests of representative species were mounted on gummed slides. Both authors examined all samples.

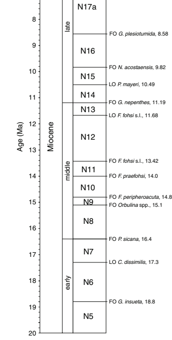
The observed species and their relative abundances, as well as sample preservation, are recorded in occurrence tables for each site (Site 1143, Table **T1;** Site 1146, Table **T2**). The primary intent of this report is to locate and substantiate the placement of planktonic foraminiferal biostratigraphic zonal boundaries within the two sites by using both primary and secondary marker species. The resulting biostratigraphy provides the basis for a revised age-depth model based on planktonic foraminifers. However, the species ranges presented on the occurrence tables herein (Tables **T1, T2**) should be considered provisional with the exception of the species used to define the biostratigraphic zones.

The species concepts used to identify the planktonic foraminifers for this report closely follow Kennett and Srinivasan (1983), Chaisson and Leckie (1993), Chaisson and Pearson (1997), and Norris (1998) except where stated in the **"Appendix,"** p. 13. The notes that follow briefly describe the species observed at both sites and/or provide commentary as to how we differentiated these taxa from other similar species.

BIOSTRATIGRAPHIC ZONATION

We followed the planktonic foraminiferal zonal scheme of Blow (1969) as amended by Kennett and Srinivasan (1983). In addition, we adopted the coiling change of all species of *Pulleniatina* to define the top of Zone N19 (Chaisson and Leckie, 1993). Figure **F2** depicts this zonal scheme and the primary biostratigraphic datums used for this report. Where possible, we used the astrochronologically tuned planktonic foraminiferal ages of Chaisson and Pearson (1997) for datums between 4.08 and 13.42 Ma. For species not listed by these authors or for samples older than 13.42 Ma, the untuned ages of Berggren et al. (1995) and Curry, Shackleton, Richter, et al. (1995) were used (see Tables **T3** [Site 1143], **T4** [Site 1146]).

F2. Zonal scheme, zonal marker species, and ages, p. 32.



Zone N19

Definition: Interval between the first occurrence (FO) of *Sphaeroidinella dehiscens* s.l. (interval base) and the coiling change of *Pulleniatina,* sinistral to dextral (interval top).
Age: 5.54–4.08 Ma; latest Miocene–early Pliocene.
Occurrence:
Site 1143: The base of this zone is at an average depth of 218.1 mcd (between Samples 184-1143A-24X-3, 115–117 cm [216.6 mcd], and 24X-5, 115–117 cm [219.6 mcd]).
Site 1146: The base of this zone is at an average depth of 319.88 mcd (between Samples 184-1146A-33X-1, 9–12 cm [318.36 mcd], and 33X-3, 14–17 cm [321.41 mcd]).

Zone N18

Definition: Interval between the FO of *Globorotalia tumida* (interval base) and the FO of *Sphaeroidinella dehiscens* s.l. (interval top).
Age: 5.82–5.54 Ma; latest Miocene.
Occurrence:
Site 1143: The zone is between the average depths of 218.1 mcd (between Samples 184-1143A-24X-3, 115–117 cm [216.6 mcd], and 24X-5, 115–117 cm [219.6 mcd]) and 228.30 mcd (between Samples 25X-CC, 26–33 cm [224.07 mcd], and 26X-1, 115–117 cm [232.52 mcd]).
Site 1146: The zone is between the average depths of 319.88 mcd (between Samples 184-1146A-33X-1, 9–12 cm [318.36 mcd], and 33X-3, 14–17 cm [321.41 mcd]) and 322.88 mcd (between Samples 33X-3, 14–17 cm [321.41 mcd], and 33X-5, 9–12 cm [324.36 mcd]).

Subzone N17b

Definition: Interval between the FO of *Pulleniatina primalis* (interval base) to the FO of *Globorotalia tumida* (interval top).
Age: 6.4–5.82 Ma; late Miocene.
Occurrence:
Site 1143: The zone is between the average depths of 228.30 mcd (between Samples 184-1143A-25X-CC, 26–33 cm [224.07 mcd], and 26X-1, 115–117 cm [232.52 mcd]) and 239.79 mcd (between Samples 26X-5, 115–117 cm [238.52 mcd], and 26X-CC, 41–48 cm [241.05 mcd]).
Site 1146: The zone is between the average depths of 322.88 mcd (between Samples 184-1146A-33X-3, 14–17 cm [321.41 mcd], and 33X-5, 9–12 cm [324.36 mcd]) and 338.04 mcd (between Samples 34X-CC, 5–9 cm [337.56 mcd], and 35X-1, 10–14 cm [338.52 mcd]).

Subzone N17a

Definition: Interval between the FO of *Globorotalia plesiotumida* (interval base) to the FO of *Pulleniatina primalis* (interval top).
Age: 8.58–6.4 Ma; late Miocene.
Occurrence:
Site 1143: The zone is between the average depths of 239.79 mcd (between Samples 184-1143A-26X-5, 115–117 cm [238.52 mcd], and 26X-CC, 41–48 cm [241.05 mcd]) and 454.56 mcd (between Samples 184-1143C-48X-1, 115–117 cm [453.06 mcd], and 48X-3, 115–117 cm [456.06 mcd]).
Site 1146: The zone is between the average depths of 338.04 mcd (between samples 184-1146A-34X-CC, 5–9 cm [337.56 mcd], and 35X-1, 10–14 cm [338.52 mcd]) and 408.13 mcd (between Samples 184-1146A-41X-4, 0–2 cm [406.63 mcd], and 41X-6, 0–2 cm [409.63 mcd]).

Zone N16

Definition: Interval between the FO of *Neogloboquadrina acostaensis* (interval base) and the FO of *Globorotalia plesiotumida* (interval top).

Age: 9.82–8.58 Ma; late Miocene.

Occurrence:

Site 1143: The zone is between the average depths of 454.56 mcd (between Samples 184-1143C-48X-1, 115–117 cm [453.06 mcd], and 48X-3, 115–117 cm [456.06 mcd]) and 467.26 mcd (between Samples 49X-3, 115–117 cm [465.76 mcd], and 49X-5, 115–117 cm [468.76 mcd]).

Site 1146: The zone is between the average depths of 408.13 mcd (between Samples 184-1146A-41-4, 0–2 cm [406.63 mcd], and 41X-6, 0–2 cm [409.63 mcd]) and 433.13 mcd (between Samples 44X-3, 0–2 cm [432.38 mcd], and 44X-4, 0–2 cm [433.88 mcd]).

Zone N15

Definition: Interval between the last occurrence (LO) of *Paragloborotalia mayeri* (interval base) and the FO of *Neogloboquadrina acostaensis* (interval top).

Age: 10.49–9.82 Ma; late Miocene.

Occurrence:

Site 1143: The zone is between the average depths of 467.26 mcd (between Samples 184-1143C-49X-3, 115–117 cm [465.76 mcd], and 49X-5, 115–117 cm [468.76 mcd]) and 470.6 mcd (between Samples 49X-5, 115–117 cm [468.76 mcd], and 50X-1, 113–115 cm [472.44 mcd]).

Site 1146: The zone is between the average depths of 433.13 mcd (between Samples 184-1146A-44X-3, 0–2 cm [432.38 mcd], and 44X-4, 0–2 cm [433.88 mcd]) and 444.58 mcd (between Samples 45X-4, 0–2 cm [443.83 mcd], and 45X-5, 0–2 cm [445.33 mcd]).

Zone N14

Definition: Interval between the FO of *Globoturborotalita nepenthes* (interval base) and the LO of *Paragloborotalia mayeri* (interval top).

Age: 11.19–10.49 Ma; middle–late Miocene.

Occurrence:

Site 1143: The top of this zone is at the average depth of 470.6 mcd (between Samples 184-1143C-49X-5, 115–117 cm [468.76 mcd], and 50X-1, 113–115 cm [472.44 mcd]), whereas its base is below the drilled interval for this site (Sample 54X-CC, 43–48 cm [512.91 mcd]).

Site 1146: Zones N14 and N13 could not be distinguished at Site 1146 because of the stratigraphic overlap of *Globoturborotalita nepenthes* (FO) and *Globorotalia fohsi* s.l. (LO). Therefore, a combined Zone N13–N14 ranges between 444.58 mcd (between Samples 184-1146A-45X-4, 0–2 cm [443.83 mcd], and 45X-5, 0–2 cm [445.33 mcd]) and 470.28 mcd (between Samples 47X-6, 0–2 cm [469.53 mcd], and 47X-7, 0–2 cm [471.03 mcd]).

Zone N13

Definition: Interval between the LO of *Globorotalia fohsi* s.l. (interval base) and the FO of *Globoturborotalita nepenthes* (interval top).

Age: 11.68–11.19 Ma; middle Miocene.

Occurrence:

Site 1143: The base of this site is in Zone N14.

Site 1146: See above comments for Zone N14.

Zone N12

Definition: Total range of *Globorotalia fohsi* s.l. (interval base and top).

Age: 13.42–11.68 Ma; middle Miocene.
Occurrence:
Site 1146: The zone is between the average depths of 470.28 mcd (between Samples 184-1146A-47X-6, 0–2 cm [469.53 mcd], and 47X-7, 0–2 cm [471.03 mcd]) and 504.85 mcd (between Samples 51X-4, 0–2 cm [504.1 mcd], and 51X-5, 0–2 cm [505.6 mcd]).

Zone N11

Definition: Interval from the FO of *Globorotalia praefohsi* (interval base) to the FO of *Globorotalia fohsi* s.l. (interval top).
Age: 14.0–13.42 Ma; middle Miocene.
Occurrence:
Site 1146: The zone is between the average depths of 504.85 mcd (between Samples 184-1146A-51X-4, 0–2 cm [504.1 mcd], and 51X-5, 0–2 cm [505.6 mcd]) and 521.43 mcd (between Samples 52X-CC, 0–2 cm [519.85 mcd], and 53X-2, 0–2 cm [523 mcd]).

Zone N10

Definition: Interval between the FO of *Globorotalia peripheroacuta* (interval base) and the FO of *Globorotalia praefohsi* (interval top).
Age: 14.8–14.0 Ma, middle Miocene.
Occurrence:
Site 1146: The zone is between the average depths of 521.43 mcd (between Samples 184-1146A-52X-CC, 0–2 cm [519.85 mcd], and 53X-2, 0–2 cm [523 mcd]) and 533.45 mcd (between Samples 54X-1, 0–2 cm [531.95 mcd], and 54X-3, 0–2 cm [534.95 mcd]).

Zone N9

Definition: Interval between the FO of *Orbulina* spp. (interval base) and the FO of *Globorotalia peripheroacuta* (interval top).
Age: 15.1–14.8 Ma; middle Miocene.
Occurrence:
Site 1146: The zone is between the average depths of 533.45 mcd (between Samples 184-1146A-54X-1, 0–2 cm [531.95 mcd], and 54X-3, 0–2 cm [534.95 mcd]) and 541.38 (between Samples 54X-CC, 0–2 cm [539.81 mcd], and 55X-2, 0–2 cm [542.95 mcd]).

Zone N8

Definition: Interval between the FO of *Praeorbulina sicana* (interval base) and the FO of *Orbulina* spp. (interval top).
Age: 16.4–15.1 Ma; middle Miocene.
Occurrence:
Site 1146: The zone is between the average depths of 541.38 mcd (between Samples 184-1146A-54X-CC, 0–2 cm [539.81 mcd], and 55X-2, 0–2 cm [542.95 mcd]) and 617.16 mcd (between Samples 62X-2, 10–14 cm [616.41 mcd], and 62X-3, 10–14 cm [617.91 mcd]).

Zone N7

Definition: Interval between the LO of *Catapsydrax dissimilis* (interval base) and the FO of *Praeorbulina sicana* (interval top).
Age: 17.3–16.4 Ma; early Miocene.

Occurrence:

Site 1146: The zone is between the average depths of 617.16 mcd (between Samples 184-1146A-62X-2, 10–14 cm [616.41 mcd], and 62X-3, 10–14 cm [617.91 mcd]) and 622.3 mcd (between Samples 62X-5, 7–11 cm [620.88 mcd], and 62X-7, 10–14 cm [623.71 mcd]).

Zone N6

Definition: Interval between the FO of *Globigerinatella insueta* (interval base) and the LO of *Catapsydrax dissimilis* (interval top).

Age: 18.8–17.3 Ma; early Miocene.

Occurrence:

Site 1146: The zone is between the average depths of 622.3 mcd (between Samples 184-1146A-62X-5, 7–11 cm [620.88 mcd], and 62X-7, 10–14 cm [623.71 mcd]) and 636.31 mcd (between Samples 64X-2, 10–14 cm [634.81 mcd], and 64X-4, 9–13 cm [637.8 mcd]).

Zone N5

Definition: Interval between the LO of *Paragloborotalia kugleri* (interval base) and the FO of *Globigerinatella insueta* (interval top).

Age: 21.5-18.8 Ma; early Miocene.

Occurrence:

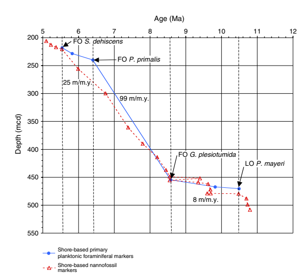
Site 1146: The top of the zone is at 636.31 mcd (between Samples 184-1146A-64X-2, 10–14 cm [634.81 mcd], and 64X-4, 9–13 cm [637.8 mcd]), whereas the base of this zone is below the drilled interval for this site (Sample 184-1146A-64X-CC, 10–14 cm [643.11 mcd]).

SEDIMENTATION HISTORY

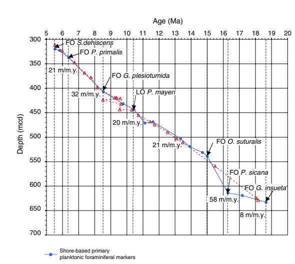
Figures F3 and F4 are age-depth models that depict the primary planktonic foraminiferal marker species listed in Table T3 (Site 1143; southern South China Sea) and Table T4 (Site 1146; northern South China Sea), respectively. The plot for Site 1143 (Fig. F3) shows three distinct intervals in the upper Miocene having sediment accumulation rates of 25 m/m.y. (5.5–6.4 Ma), 99 m/m.y. (6.4–8.6 Ma), and 8 m/m.y. (8.6–10.5 Ma). The lowermost leg of this plot (8.6–10.5 Ma; 8 m/m.y.) may contain a diastem in the sedimentary column (at ~455 mcd) based on the concentration of both foraminiferal and nannofossil datums. Although Site 1143 exhibits dramatic changes in sedimentation rates through the studied interval, the entire section corresponds to a single lithologic unit (Subunit IB; Wang, Prell, Blum, et al., 2000). In addition, shipboard studies of carbonate and total organic carbon show no appreciable change in trend through the Miocene.

The age-depth model for Site 1146 (Fig. F4) includes the same three upper Miocene intervals as Site 1143, though the differences in sedimentation rates between these intervals are more subtle. The observed rates are 21 m/m.y. (5.5–6.4 Ma), 32 m/m.y. (6.4–8.6 Ma), and 20 m/m.y. (8.6–10.5 Ma). At both sites, the interval from 6.4 to 8.6 Ma has the highest sedimentation rates of the upper Miocene. As at Site 1143, the interval of Zone 14 to Zone N19 (uppermost middle Miocene to basal Pliocene) at Site 1146 lies entirely within a single lithologic unit (Unit II). Total organic carbon shows no appreciable change in trend for this interval, though carbonate levels decrease from ~50–60 wt% to ~35–40 wt% below ~420 mcd (Zone N16; at about Section 184-1146A-42X-CC) (Wang, Prell, Blum, et al., 2000).

F3. Age-depth plot, Site 1143, p. 33.



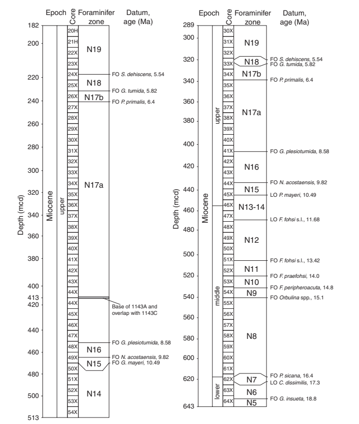
F4. Age-depth plot, Hole 1146A, p. 34.



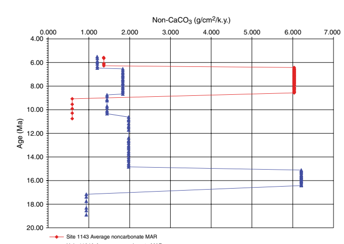
Because the drilled interval at Site 1146 extends deeper than at Site 1143, three additional sedimentary intervals have been identified in the middle and lower Miocene. These intervals and their sedimentation rates are 21 m/m.y. (10.5–15.1 Ma), 58 m/m.y. (15.1–16.4 Ma), and 8 m/m.y. (16.4–18.8 Ma). At Site 1146 the base of Zone N9 (FO of *Orbulina suturalis* at 15.1 Ma; between Sections 184-1146A-55X-2 and 54X-CC) corresponds to a dramatic change in sedimentation rate (58 to 21 m/m.y.) and the boundary between lithologic Units II and III (553.02 mcd), as described by the shipboard sedimentologists (Wang, Prell, Blum, et al., 2000). This lithologic boundary is based on a color change in the sediment from brownish gray with an increasing number of green intervals (base of Unit II) to a distinct greenish gray (Unit III). However, shipboard analyses of carbonate and total organic carbon show no significant changes across this boundary. A summary of the sedimentation history for both sites, with respect to age and core depth, is presented in Figure F5.

The large increase in mass accumulation rates (MARs) from 16.4 to 15.1 Ma at Site 1146 is mostly due to an increase in the noncarbonate fraction (Figs. F6, F7). This increase could be the result of lowered sea level or greater fluvial input. From 15.1 to 8.58 Ma, carbonate MARs increase steadily, whereas noncarbonate MARs decrease. A second large increase in MARs is observed in the interval from 8.58 to 6.4 Ma. At Site 1146 this increase is largely in the carbonate fraction, whereas at Site 1143 both the carbonate and noncarbonate fractions increase sharply. The observed increases in MARs during the late Miocene may be attributable to the onset of the East Asian monsoon. At 6.4 Ma, both sites show a marked decrease in MARs to approximately pre-8.58-Ma values.

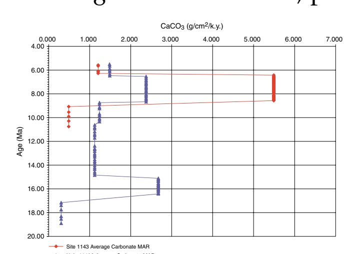
F5. Planktonic foraminiferal first and last occurrences, p. 35.



F6. Average noncarbonate MAR, p. 36.



F7. Average carbonate MAR, p. 37.



CONCLUSIONS

The biostratigraphic record at both Sites 1143 and 1146 is apparently continuous and clearly resolved in the sediments examined for this study. One exception to the complete delimitation of this record was the FO of *Globoturborotalita nepenthes* at Site 1146. Though strict definitions were applied for this species and its ancestor, *Globoturborotalita druryi*, its sporadic record and stratigraphic overlap with *Globorotalia fohsi* s.l. necessitated combining Zones N13 and N14. This overlap has been found elsewhere. A similar transposition of *G. nepenthes* and *G. fohsi* s.l. datums was observed at Deep Sea Drilling Project (DSDP) Sites 563 and 608 (see the discussion by Berggren et al., 1995). A second exception may lie at Site 1143, between 10.49 and 8.58 Ma. In this interval the planktonic foraminiferal and calcareous nannofossil datums appear to cluster and may represent a diastem.

At both sites the planktonic foraminiferal biostratigraphic record agrees well with the corresponding calcareous nannofossil record. Of particular note are the rapid changes in sedimentation rates observed between 10.49 and 5.54 Ma (Fig. F3) at Site 1143. These changes in sedimentation do not correspond to a change in lithologic units or shipboard geochemistry. Site 1146 does exhibit a lithologic change that corresponds well to a significant change in sedimentation rates at ~15.1 Ma as determined by this study. However, the shipboard geochemical record shows no corresponding change in trend. Mass accumulation rates at Site 1146 are sharply higher in the interval from 16.4 to 15.1 Ma and may be the result of lowered sea level or greater fluvial input. Both sites have a second interval of elevated mass accumulation rates from

8.58 to 6.4 Ma, which may be due to the onset of the East Asian monsoon.

The planktonic foraminiferal species observed in this study also provide several continuous, well-represented evolutionary lineages. For example, the following complete lineages were present in the sediments studied at both sites: the *Globorotalia merotumida–Globorotalia plesiotumida–Globoratlia tumida* plexus; the *Globorotalia archeomenardii–Globorotalia praemenardii–Globorotalia menardii* plexus; the *Globorotalia peripheroronda–Globorotalia peripheroacuta–Globorotalia praefohsi–Globorotalia fohsi* plexus; and the *Globigerinoides bisphericus–Praeorbulina* spp.–*Orbulina* spp. plexus. These lineages offer a rich opportunity to examine in detail the complex evolution of the species that compose them.

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APPENDIX

Taxonomic Notes

We closely followed the species concepts of Kennett and Srinivasan (1983) and Chaisson and Leckie (1993). Additional resources included Bolli and Saunders (1985), Pearson (1995), Chaisson and Pearson (1997), and Norris (1998). The notes briefly describe the 73 species observed at both sites (combined) and/or provide commentary regarding how we differentiated these taxa from other similar species. For each species the original reference is cited in the synonymies below and included in our reference list.

Beella praedigitata **(Parker)**

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.

Comments: At Site 1143, *B. praedigitata* is observed in only one sample. At Site 1146 it is absent.

Candeina nitida **d'Orbigny**

Candeina nitida d'Orbigny, 1839, p. 107, pl, 2, figs. 27–28; Kennett and Srinivasan, 1983, p. 229, pl. 57, figs. 6–8.

Comments: *C. nitida* is readily identifiable at both sites by its microperforate surface and sutural apertures. The trochospire can be moderate to high. The species is seen throughout its range, though in individual samples abundances are <1%.

Catapsydrax dissimilis **(Cushman and Bermúdez)**

Globigerina dissimilis Cushman and Bermúdez, 1937, p. 25, pl. 3, figs. 4–6.

Catapsydrax dissimilis (Cushman and Bermúdez) Kennett and Srinivasan, 1983, p. 22, pl. 2, figs. 1, 3–8.

Comments: *C. dissimilis* has a small, compact test with a distinctly cancellate microstructure. Most notable is the aperture, which is covered by a single umbilical bulla that has two or more accessory openings around its margin. Kennett and Srinivasan (1983) and other authors assign morphotypes of *C. dissimilis* that have one accessory opening to the species *Catapsydrax unicavus,* whereas Bolli and Saunders (1985) treat these two species as synonymous. In samples having poor preservation, *C. dissimilis* can be mistaken for juvenile *Globoquadrina venezuelana*, though the bulla on *C. dissimilis* has a finer surface texture and is small and deflated relative to the last chamber of *G. venezuelana*.

Catapsydrax parvulus **Bolli, Loeblich, and Tappan**

Catapsydrax parvulus Bolli, Loeblich, and Tappan, 1957, p. 36, pl. 7, fig. 10a–c; Kennett and Srinivasan, 1983, p. 26, pl. 2, figs. 7–9.

Comments: *C. parvulus* was observed in only two samples through its range at Site 1146. Bearing a single accessory opening, *C. parvulus* is differentiated from *Catapsydrax unicavus* by its much smaller size and more embracing chambers.

Catapsydrax unicavus **Bolli, Loeblich, and Tappan**

Catapsydrax unicavus Bolli, Loeblich, and Tappan, 1957, p. 37, pl. 7, fig. 9a–c; Kennett and Srinivasan, 1983, p. 26, pl. 3, figs. 1–3.

Comments: In following Kennett and Srinivasan (1983), *C. unicavus* possesses an umbilical bulla that has a single aperture (see ***"Catapsydrax dissimilis,"*** p. 13).

Dentoglobigerina altispira (Cushman and Jarvis)

Globigerina altispira Cushman and Jarvis, 1936, p. 5, pl. 1, fig. 13a–c.

Globigerina 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.

Dentoglobigerina altispira (Cushman and Jarvis) Chaisson and Leckie, 1993, p. 155, pl. 9, fig. 8.

Comments: At both Sites 1143 and 1146, *D. altispira* exhibits a wide range of variation in test size, stage of development (juvenile through adult), height of trochospire, and chamber embracement. We use the concept of a sensu latu form of *D. altispira* that has well-developed apertural teeth, a deep umbilicus, and a low to high trochospire. Juvenile forms exhibit a small test, coarse surface texture, four and one-half to five chambers in the final whorl, and an aperture open to the umbilicus.

Globigerina bulloides d'Orbigny

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.

Comments: Abundant *G. bulloides* is widely interpreted as indicating high seasonal productivity in the upper water column, which in turn is associated with areas of upwelling (e.g., Duplessy et al., 1981). *G. bulloides* is observed sporadically at both sites in the South China Sea, and within any one sample its abundances are typically <1%. It is characterized by a smooth microstructure with fine pustules, four lobate chambers in the final whorl that increase rapidly in size, a high-arched rimless umbilical aperture, and a generally small test size, though exceptions are observed. *Globigerina falconensis* is distinguished from *G. bulloides* by a thin lip over a lower arched umbilical aperture.

Globigerina falconensis Blow

Globigerina falconensis, Blow, 1959, p. 177, pl. 9, figs. 40a–c; Bolli and Saunders, 1985, p. 303, figs. 5.2, 4.

Globigerina (*Globigerina*) *falconensis* (Blow) Kennett and Srinivasan, 1983, p. 40, pl. 7, figs. 1–3.

Comments: *G. falconensis* is rarely seen at Sites 1143 and 1146, and in individual samples its abundances are <1% (see ***"Globigerina bulloides,"*** p. 14).

Globigerina praebulloides Blow

Globigerina praebulloides Blow, 1959, p. 180, pl. 8, fig. 47a–c; pl. 9, fig. 48.

Globigerina (*Globigerina*) *praebulloides* (Blow) Kennett and Srinivasan, 1983, p. 38, pl. 6, figs. 1–3.

Comments: *G. praebulloides* occurs in a single sample at Site 1146. *G. praebulloides* is similar to *G. bulloides* and is characterized by a thicker, heavier test with a lower aperture.

Globigerinatella insueta Cushman and Stainforth

Globigerinatella insueta Cushman and Stainforth, 1945, p. 69, pl. 13, figs. 7–9; Kennett and Srinivasan, 1983, p. 228, pl. 56, fig. 2; pl. 57, figs. 4, 5; Chaisson and Leckie, 1993, p. 157, pl. 10, figs. 4–6; Pearson, 1995, p. 56, pl. 2, figs. 13–22.

Comments: The abundance of *G. insueta* is rare at Site 1146. Primitive forms of *G. insueta* can possess as few as one raised areal aperture or exhibit extensive sutural bullae and/or areal bullae (that are underlain by raised areal apertures when dissected). In accordance with Pearson (1995) and Chaisson and Leckie (1993) we found *G. insueta* to be fully intergradational with *Globigerinita glutinata* at Site 1146. Although both species possess a fine ultrastructure, *G. glutinata* is generally smaller in size and quadralobate in outline, compared with the distinctly spherical shape of *G. insueta*. *G. insueta* is distinguished from *Praeorbulina sicana* by its microperforate surface texture and the aforementioned apertures and bullae. See Pearson (1995) for a detail discussion of this genus and scanning electron photomicrographs of the species.

Globigerinella aequilateralis (Brady)

Globigerina aequilateralis Brady, 1879, p. 285 (Brady, 1884, pl. 80, figs. 18–21).

Globigerinella aequilateralis (Brady) Kennett and Srinivasan, 1983, p. 238, pl. 59, fig. 1; pl. 60, figs. 4–6.

Comments: At Sites 1143 and 1146, *G. aequilateralis* is found intermittently throughout its range and exhibits abundances of <1% in individual samples. *G. aequilateralis* has five to six chambers in the final whorl that increase very rapidly in size (see ***"Globigerinella obesa,"*** p. 15).

Globigerinella obesa (Bolli)

Globorotalia obesa Bolli, 1957, p. 119, pl. 29, figs. 2a–3.

Globigerinella obesa (Bolli) Kennett and Srinivasan, 1983, p. 234, pl. 59, figs. 2–5.

Comments: *G. obesa* is observed sporadically at Sites 1143 and 1146 with abundances in any one sample being <1%. *G. obesa* has four inflated chambers in the final whorl (*Globigerinella aequilateralis* has five to six chambers) that rapidly increase in size (compared to *Globigerinella praesiphonifera*). However, its chambers are more embracing than those of *Globigerinella calida*, which makes it less lobate in outline. Our concept of *G. obesa* incorporates *Globigerinella pseudobesa*.

Globigerinita glutinata (Egger)

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.

Comments: *G. glutinata* is readily recognized by its smooth surface texture, small test size, and, in many individuals, the presence of an apertural bulla. At both Sites 1143 and 1146, *G. glutinata* is found in nearly all of the examined samples, though abundances ranged from <1% to ~30%.

Globigerinita uvula (Ehrenberg)

Pylodexia uvula Ehrenberg, 1861, pl. 2, figs. 24–25.

Globigerinita uvula (Ehrenberg) Kennett and Srinivasan, 1983, p. 224, pl. 56, figs. 6–8.

Comments: *G. uvula* is differentiated from *Globigerinita glutinata* by the high spire of its test. *G. uvula* was not observed at Site 1143, though at Site 1146 it was observed in a few samples and at abundances of <1%.

Globigerinoides altiapertura Bolli

Globigerinoides triloba altiapertura Bolli, 1957, p. 113, pl. 25, fig. 7a–c.

Globigerinoides altiapertura (Bolli) Kennett and Srinivasan, 1983, p. 54, pl. 10, fig. 1; pl. 11, figs. 4–6; Chaisson and Leckie, 1993, p. 157, pl. 2, figs. 9–11.

Comments: *G. altiapertura* bears a nearly circular primary aperture and a large secondary aperture. Tests that have a primary aperture that is wider than tall are considered to be *Globigerinoides obliquus*. *G. altiapertura* was not observed at Site 1143, whereas at Site 1146 it was observed in a few samples and at abundances of <1%.

Globigerinoides bisphericus Todd

Globigerinoides bisphericus Todd, 1954, p. 681, pl. 1, figs. 1a–c, 4; Jenkins et al., 1981, p. 265, pl. 1, fig. 1a–c.

Comments: The definition of *G. bisphericus* by Jenkins et al. (1981) is closely adhered to in differentiating this species from its descendent, *Praeorbulina sicana* (which marks the base of Zone N8). A specimen in which the final chamber envelopes 15%–20% of the test (more than *Globigerinoides triloba* but less than *P. sicana*), has two slitlike apertures, and a shallow umbilicus was identified as *G. bisphericus*. Specimens of *P. sicana* exhibited greater envelopment, at least three apertures, and no umbilicus (see ***"Praeorbulina sicana,"*** p. 29).

Globigerinoides conglobatus (Brady)

Globigerina conglobata Brady, 1879, p. 28b.

Globigerinoides conglobatus (Brady) Kennett and Srinivasan, 1983, p. 58, pl. 12, figs. 4–6.

Comments: *G. conglobatus* was observed throughout its range at Sites 1143 and 1146, though abundances were typically rare in any one sample. The species exhibits a large, compact test with embracing chambers and a broad, low primary aperture; some specimens are also heavily calcified.

Globigerinoides extremus Bolli and Bermúdez

Globigerinoides obliquus extremus Bolli and Bermúdez, 1965, p. 139, pl. 1, figs. 10–12; Bolli and Saunders, 1985, p. 194, fig. 20.11.

Globigerinoides extremus (Bolli and Bermúdez) Kennett and Srinivasan, 1983, p. 58, pl. 12, figs. 1–3.

Comments: *G. extremus* is observed throughout its anticipated range at both sites, though abundances vary widely from sample to sample. *G. extremus* is differentiated from *Globigerinoides obliquus* by its laterally compressed ultimate chamber, which in later forms can have a "flattened slope" or "beret" appearance. Both Berggren et al. (1995) and Chaisson and Pearson (1997) note the FO of *G. extremus* to be coincident with the FO of *Globigerinoides plesiotumida*. However, at Site 1143 the FO of *G. extremus* was ~31 m higher in the column, whereas at Site 1146 the two first occurrences were nearly coincident.

Globigerinoides mitra Todd

Globigerinoides mitra Todd, 1957, p. 302, figs. 3, 6.

Comments: *G. mitra* is observed in only a single sample from Site 1146. It has a large primary aperture that is located directly over the suture between two earlier chambers. Thus, *G. mitra* is similar to *Globigerinoides ruber* and *Globigerinoides subquadratus*. However, it is distinguished from these two species by its larger ultimate chamber and finer surface structure.

Globigerinoides obliquus **Bolli**

Globigerinoides obliquus obliquus Bolli, 1957, p. 113, pl. 25, fig. 10a–c.

Globigerinoides obliquus (Bolli) Kennett and Srinivasan, 1983, p. 56, pl. 11, figs. 7–9; Chaisson and Leckie, 1993, p. 158, pl. 2, figs. 1–2.

Comments: In following Chaisson and Leckie (1993) a broad concept is applied to *G. obliquus*. It is differentiated from *Globigerinoides extremus* by having a more inflated final chamber (less laterally compressed) and from *Globigerinoides altiapertura* by possessing a primary aperture that is wider than it is tall. At Sites 1143 and 1146, *G. obliquus* has a long-ranging occurrence and its abundance varies from present to dominant in individual samples.

Globigerinoides ruber **(d'Orbigny)**

Globigerina rubra d'Orbigny, 1839, p. 82, pl. 4, figs. 12–14.

Globigerinoides ruber (d'Orbigny) Kennett and Srinivasan, 1983, p. 78, pl. 10, fig. 6; pl. 17, figs. 1–3.

Comments: *G. ruber* is a distinct though very uncommon species at both sites and exhibits widely varying abundances in individual samples. The homeomorph *Globigerinoides subquadratus* is not observed at Site 1143, but it is found below the first occurrence of *G. ruber* at Site 1146.

Globigerinoides sacculifer **(Brady)**

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; Chaisson and Leckie, 1993, p. 158, pl. 2, fig. 16.

Comments: This long-ranging species is found throughout the sediment column and often in very high abundances at both sites. *G. sacculifer* is gradational with several closely related species, specifically, *Globigerinoides triloba, Globigerinoides quadrilobatus,* and *Globigerinoides immaturus*. As a consequence of this gradation, we group the latter two species with *G. sacculifer*, but we do differentiate *G. triloba*. The aforementioned grouping is based on the observation that when the final sacklike, gametogenic chamber of *G. sacculifer* is removed by dissection, the remaining test is indistinguishable from *G. quadrilobatus* and *G. immaturus*. We differentiate *G. triloba* from *G. sacculifer* by the former having a strongly cancellate microstructure, embracing chambers, and very low-arched apertures.

Globigerinoides subquadratus **Brönnimann**

Globigerinoides subquadratus Brönnimann, 1954, p. 680, pl. 1, fig. 8a–c; Kennett and Srinivasan, 1983, p. 74, pl. 16, figs. 1–3; Chaisson and Leckie, 1993, p. 159, pl. 2, fig. 12.

Comments: This homeomorph of *Globigerinoides ruber* is consistently observed only at Site 1146 and often in great abundances. Its last occurrence is below the first occurrence of *G. ruber*.

Globigerinoides triloba **(Reuss)**

Globigerina triloba Reuss, 1850, p. 374, pl. 447, fig. 11a–c.

Globigerinoides triloba (Reuss) Kennett and Srinivasan, 1983, p. 62, pl. 10, fig. 4; pl. 13, figs. 1–3.

Globigerinoides trilobus (Reuss) Bolli and Saunders, 1985, p. 196, fig. 20.15.

Comments: *G. trilobus* is rarely seen at Site 1143. At Site 1146 *G. triloba* is much more common throughout its range, though its abundance within individual samples is rare. We differentiate *G. triloba* from *Globigerinoides sacculifer* by the strongly cancellate and compact test of the former taxon and its very low-arched apertures (see ***"Praeorbulina sicana,"*** p. 29, ***"Globigerinoides bispherícus,"*** p. 16, and ***"Globigerinoides sacculifer,"*** p. 17).

Globoquadrina baroemoenensis **(LeRoy)**

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

Globoquadrina baroemoenensis (LeRoy) Kennett and Srinivasan, 1983, p. 186, pl. 46, figs. 1–3; Chaisson and Leckie, 1993, p. 159, pl. 9, figs. 5–7.

Comments: At Sites 1143 and 1146 *G. baroemoenensis* exhibits abundances of <1% in the few samples where it is observed. It is characterized by four slightly compressed chambers in the final whorl, an open umbilicus, and a small apertural tooth on the last chamber. *Globoquadrina venezuelana* and *Dentoglobiquadrina altispira* are similar species, though the former can be differentiated from *G. baroemoenensis* by more embracing chambers, a less open umbilicus, and the lack of an apertural tooth. *D. altispira* has four or more chambers with no compression, a wider umbilicus, and typically an apertural tooth on the last two or three chambers.

Globoquadrina binaiensis **(Koch)**

Globigerina binaiensis Koch, 1935, p. 558.

Globoquadrina binaiensis (Koch) Kennett and Srinivasan, 1983, p. 182, pl. 44, figs. 1, 3; pl. 45, figs. 1–3.

Comments: The presence of *G. binaiensis*, among other secondary planktonic foraminiferal markers, constrains the age of the bottom of Site 1146 to Zone N5. The species exhibits three chambers in the final whorl that rapidly increase in size. The final chamber is enlarged and bears a distinctly flattened, broad, partially imperforate apertural face, which is as wide as the test itself. Similar species include *Globoquadrina sellii* and *Globoquadrina dehiscens*, though the former is differentiated from *G. binaiensis* by the flattened face on the final chamber, whereas the latter is differentiated by having three and one-half to four chambers in the final whorl.

Globoquadrina dehiscens **(Chapman, Parr, and Collins)**

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

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

Comments: *G. dehiscens* was not observed at Site 1143, whereas at Site 1146 it occurs throughout its range and with widely varying abundances from one sample to the next. We observed both adult and juvenile tests that have a flat spiral side, three and one-half to four embracing chambers in the final whorl, and a final chamber that bears a flattened face (resembling an "anvil") (see ***"Globoquadrina binaiensis,"*** p. 18).

Globoquadrina sellii **Borsetti**

Globoquadrina sellii Borsetti, 1959, p. 209, pl. 1, fig. 3a–d.

Globigerina sellii (Borsetti) Bolli and Saunders, 1985, p. 181, fig. 14.11.

Comments: *G. sellii* was observed only in two samples near the base of the section at Site 1146 and with abundances of <1%. *G. sellii* is distinguished from *Globoquadrina binaiensis* by having a somewhat compressed but perforate apertural face on the final chamber and chambers in the final whorl that increase more slowly in size. *Globoquadrina dehiscens* is also similar to *G. sellii*, though it has three and one-half to four chambers in the final whorl.

Globoquadrina venezuelana (Hedberg)

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

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

Comments: *G. venezuelana* is observed sporadically at both sites in the South China Sea, and its abundance in any one sample is rare. In general, the species has a large test, though juvenile forms were observed. Our concept of *G. venezuelana* closely follows that of Kennett and Srinivasan (1983), where the final whorl has four embracing chambers that rapidly increase in size and a final chamber that lacks an apertural tooth. Occasionally a fifth, kummerform-like chamber may be seen over the umbilicus. Similar species are **"*Dentoglobigerina altispira,*"** p. 14, **"*Globoquadrina baroemoenensis,*"** p. 18, and **"*Catapsydrax dissimilis*"** p. 13; see the comments for each of these species.

Globorotalia archeomenardii Bolli

Globorotalia archeomenardii Bolli, 1957, p. 119, pl. 28, fig. 11a–c; Bolli and Saunders, 1985, p. 220, fig. 32.6a–c; Chaisson and Leckie, 1993, p. 160, pl. 5, figs. 16–20.

Globorotalia (*Menardella*) *archeomenardii* (Bolli) Kennett and Srinivasan, 1983, p. 122, pl. 28, figs. 3–5.

Comments: *G. archeomenardii* is observed over a limited range at Site 1146, and its abundance is rare in individual samples. Our concept of *G. archeomenardii* follows that illustrated by Kennett and Srinivasan (1983). Specifically, *G. archeomenardii* is similar to *Globorotalia praemenardii* except it is generally smaller in size with a less lobate periphery and it lacks a raised keel (but in some instances it has an imperforate band). *Globorotalia praescitula* has a less acute margin in edge view and only four to four and one-half elongated, crescentic chambers (particularly the final chamber).

Globorotalia birnageae Blow

Globorotalia birnageae Blow, 1959, p. 210, pl. 17, fig. 108a–c; Chaisson and Leckie, 1993, p. 160, pl. 4, figs. 19–22.

Globorotalia (Fohsella) birnageae (Blow) Kennett and Srinivasan, 1983, p. 94, pl. 21, figs. 6–8.

Comments: *G. birnageae* has a smaller size, more rounded periphery, and a more circular outline than *Globorotalia peripheroronda*. The ultimate chamber of the species is characterized by a pronounced flaplike lip that can resemble an apertural plate.

Globorotalia cibaoensis Bermúdez

Globorotalia cibaoensis Bermúdez, 1949, p. 285, pl. 22, figs. 21–23; Chaisson and Leckie, 1993, p. 160, pl. 6, figs. 12–14, 19.

Globorotalia (*Hirsutella*) *cibaoensis* (Bermúdez) Kennett and Srinivasan, 1983, p. 136, pl. 32, figs. 1–3.

Comments: *G. cibaoensis* is occasionally observed through its range at both sites, and its abundance is often <1% in any one sample. The species exhibits considerable variability, having four to four and one-half chambers in the final whorl, a biconvex to slightly planoconvex edge view (flattened more on the spiral side), and a low, sometimes slightly arching, aperture. Similar species include *Globorotalia scitula* (four to five less inflated chambers with a slitlike aperture and sweeping, crescentic chambers, particularly the final chamber), *Globorotalia juanai* (having an umbilically inflated final chamber), and *Globorotalia margaritae* (a thinner test, concave umbilical side, and thin keel).

Globorotalia conoidea Walters

Globorotalia miozea conoidea Walters, 1965, p. 124, figs. 8, I–M.

Globorotalia (*Globoconella*) *conoidea* (Walters) Kennett and Srinivasan, 1983, p. 112, pl. 26, figs. 4–6.

Globorotalia conoidea (Walters) Bolli and Saunders, 1985, p. 276, figs. 7.14a–15c.

Comments: *G. conoidea* is found intermittently at both Sites 1143 and 1146, and its abundance is <1% in individual samples. Similar species include *Globorotalia miozea* (less vaulted on the umbilical side and having a less distinct keel than *G. conoidea*); *Globorotalia conomiozea* (having a more highly vaulted umbilical side with a nearly flat spiral side); and *Globorotalia tumida* (possessing a larger test, thicker keel, and a more oblate outline) (also see ***"Globorotalia tumida,"*** p. 24).

Globorotalia fohsi s.l. Cushman and Ellisor

Globorotalia fohsi Cushman and Ellisor, 1939, p. 12, pl. 2, fig. 6a–c.

Globorotalia lobata Bermúdez, 1949, p. 286, pl. 22, figs. 15–17.

Globorotalia fohsi robusta Bolli, 1950, pp. 84, 89, pl. 15, figs. 3a–c.

Globorotalia (*Fohsella*) *fohsi fohsi* (Cushman and Ellisor) Kennett and Srinivasan, 1983, p. 100, pl. 23, figs. 1–3.

Globorotalia (Fohsella) fohsi lobata (Bermúdez) Kennett and Srinivasan, 1983, p. 100, pl. 21, fig. 2; pl. 23, figs. 4–6.

Globorotalia (Fohsella) fohsi robusta (Bolli) Kennett and Srinivasan, 1983, p. 102, pl. 23, figs. 7–9.

Globorotalia fohsi s.l. (Cushman and Ellisor) Chaisson and Leckie, 1993, p. 160, pl. 3, figs. 1–4.

Comments: Our concept of *G. fohsi* s.l. incorporates the subspecies *G. fohsi fohsi, G. fohsi lobata,* and *G. fohsi robusta* (also see Chaisson and Leckie, 1993). This follows in part the reasoning presented by Bolli and Saunders (1985) that the "cockscomb" chambers indicative of fully carinate *G. fohsi lobata* also occur on partially carinate *Globorotalia praefohsi*. *G. fohsi* s.l. is recognized by having an imperforate band and/or a thin raised keel around the entire final whorl of its test. In edge view the last few chambers of the final whorl are sharply tapered to form an acute peripheral margin with a thin keel. At Site 1146 the abundance of *G. fohsi* s.l. is rare throughout its range (see ***"Globorotalia praefohsi,"*** p. 23).

Globorotalia juanai Bermúdez and Bolli

Globorotalia juanai Bermúdez and Bolli, 1969, pp. 171, 172, pl. 14, figs. 1–6; Bolli and Saunders, 1985, p. 216, figs. 30.20–21a–c, 30.22–24; Chaisson and Leckie, 1993, p. 161, pl. 6, figs. 17, 18.

Globorotalia (*Hirsutella*) *juanai* (Bermúdez and Bolli) Kennett and Srinivasan, 1983, p. 134, pl. 31, figs. 6–8.

Comments: *G. juanai* is observed in few samples at both sites, and its abundance in any one sample is rare. The species is identified by four to four and one-half chambers in the final whorl, inflated chambers on the umbilical side, and the absence of a keel. Similar species include *Globorotalia scitula* and *Globorotalia margaritae*, where the former has a rounded biconvex edge view and the latter is thinner and convex on the ventral side (also see ***"Globorotalia cibaoensis,"*** p. 19).

Globorotalia lenguaensis s.l. Bolli

Globorotalia lenguaensis Bolli, 1957, p. 120, pl. 29, fig. 5a–c.

Globorotalia (*Globorotalia*) *paralenguaensis* (Bolli) Blow, 1969, p. 402, pl. 46, figs. 1–6.

Globorotalia (*Globorotalia*) *lenguaensis* (Bolli) Kennett and Srinivasan, 1983, p. 152, pl. 36, figs. 5–7.

Globorotalia (*Globorotalia*) *paralenguaensis* (Blow) Kennett and Srinivasan, 1983, p. 154, pl. 37, figs. 1–3.

Globorotalia lenguaensis s.l. (Bolli) Chaisson and Leckie, 1993, p. 161, pl. 7, figs. 16–20.

Comments: *G. lenguaensis* s.l. is found sporadically through its anticipated range at Site 1146, often in rare abundances. The species typically has an oblate form, appears biconvex in edge view, lacks a peripheral keel, and is differentiated from *Globorotalia scitula* by having six to seven chambers in the final whorl. For this study our concept of *G. lenguaensis* s.l. incorporates *G. paralenguaensis*.

Globorotalia limbata (Fornasini)

Rotalia limbata Fornasini, 1902, pp. 30, 31, pl. 5, fig. 3 (lectotype).

Globorotalia (*Menardella*) *limbata* (Fornasini) Kennett and Srinivasan, 1983, p. 124, pl. 29, figs. 4–6.

Globorotalia limbata (Fornasini) Chaisson and Leckie, 1993, p. 161, pl. 5, fig. 10.

Comments: In agreement with Chaisson and Leckie (1993), this species has seven to eight chambers in the final whorl, a circular to slightly oblate outline, and a symmetrical, narrow edge view. Similar tests having five to six and one-half chambers in the final whorl are designated as *Globorotalia menardii*, and those with nine or more chambers are designated as *Globorotalia multicamerata*. *G. limbata* has a single occurrence at Site 1143, but it is more prevalent in the sediments of Site 1146, though its abundance in each sample is typically rare.

Globorotalia margaritae Bolli and Bermúdez

Globorotalia margaritae Bolli and Bermúdez, 1965, p. 132, pl. 1, figs. 16–18; Bolli and Saunders, 1985, p. 217, 30.1–5, 30.9–14; Chaisson and Leckie, 1993, p. 161, pl. 6, figs. 5–9.

Globorotalia (*Hirsutella*) *margaritae* (Bolli and Bermúdez) Kennett and Srinivasan, 1983, p. 136, pl. 32, figs. 4–6.

Comments: *G. margaritae* has a limited record at both South China Sea sites, and in samples where it is observed its abundance is rare. This limited range is due to its FO being in Zone N19 (above the FO of *Sphaeroidinella dehiscens*). *G. margaritae* is differentiated from similar species (*Globorotalia cibaoensis* and *Globorotalia scitula*) by its thinner test, concave umbilical side, and thin keel.

Globorotalia menardii s.l. (Parker, Jones, and Brady)

Rotalia menardii Parker, Jones, and Brady, 1865, p. 20, pl. 3, fig. 81.

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

Globorotalia menardii s.l. (Parker, Jones, and Brady) Chaisson and Leckie, 1993, p. 161, pl. 5, figs. 7–9, 15.

Comments: *G. menardii* s.l. is seen consistently throughout its range at both sites, though abundances are rare in any one sample. Our concept of the species is broad (particularly with respect to size), though recognition is limited to tests that have a circular to subcircular peripheral outline; symmetrical and "thin" edge view compared to the *Globorotalia tumida* lineage; five to six and one-half chambers in the final whorl; and a raised keel that ranges from delicate to heavy. These characteristics are sufficient to differentiate *G. menardii* s.l. from similar species such as *G. tumida* (thicker, teardrop shape in edge view)*; Globorotalia plesiotumida* (a lobate ultimate chamber and asymmetrical in edge view); *Globorotalia merotumida* (vaulted umbilical side)*; Globorotalia limbata* (possessing seven to eight chambers); and *Globorotalia multicamerata* (nine or more chambers).

Globorotalia merotumida Blow and Banner

Globorotalia merotumida Blow and Banner, 1965, p. 1352, text fig. 1; Bolli and Saunders, 1985, p. 225, fig. 33.7; Chaisson and Leckie, p. 161, pl. 7, figs. 11–15.

Globorotalia (Globorotalia) merotumida (Blow and Banner) Kennett and Srinivasan, 1983, p. 154, pl. 37, figs. 4–6.

Comments: At Sites 1143 and 1146, *G. merotumida* is often abundant throughout its range (see ***"Globorotalia plesiotumida,"*** p. 23, and ***"Globorotalia menardii,"*** p. 21).

Globorotalia multicamerata Cushman and Jarvis

Globorotalia multicamerata (d'Orbigny) var. *multicamerata* Cushman and Jarvis, 1930, p. 367, pl. 34, fig. 8a–c.

Globorotalia (*Menardella*) *multicamerata* (Cushman and Jarvis) Kennett and Srinivasan, 1983, p. 126, pl. 29, figs. 7–9.

Globorotalia multicamerata (Cushman and Jarvis) Bolli and Saunders, 1985, p. 224, fig. 32.5a–c, p. 229, figs. 35.16–19.

Comments: *G. multicamerata* is differentiated from *Globorotalia limbata* by having a more circular periphery and nine or more chambers in the final whorl. The species is absent at Site 1143, and it is observed in three samples at Site 1146 (see ***"Globorotalia limbata,"*** p. 21).

Globorotalia peripheroacuta Blow and Banner

Globorotalia (Turborotalia) peripheroacuta Blow and Banner, 1966, p. 294, pl. 1, fig. 2a–c.

Globorotalia (Fohsella) peripheroacuta (Blow and Banner) Kennett and Srinivasan, 1983, p. 96, pl. 22, figs. 4–6.

Globorotalia fohsi peripheroacuta (Blow and Banner) Bolli and Saunders, 1985, p. 213, figs. 29.5a–c, 29.13a–c.

Globorotalia peripheroacuta (Blow and Banner) Chaisson and Leckie, 1993, p. 162, pl. 3, figs. 14–15.

Comments: Later forms of *G. peripheroacuta* are distinguished from *Globorotalia praefohsi* by its coarser wall texture and a pinched (axially compressed) but distinctly rounded peripheral margin in the last few chambers (see ***"Globorotalia praefohsi,"*** p. 23).

Globorotalia peripheroronda Blow and Banner

Globorotalia (*Turborotalia*) *peripheroronda* Blow and Banner, 1966, p. 294, pl. 1, fig. 1a–c.

Globorotalia (*Fohsella*) *peripheroronda* (Blow and Banner) Kennett and Srinivasan, 1983, p. 96, pl. 22, figs. 1–3.

Globorotalia fohsi peripheroronda (Blow and Banner) Bolli and Saunders, 1985, p. 213, figs. 29.6a–c, 29.14a–c.

Globorotalia peripheroronda (Blow and Banner) Chaisson and Leckie, 1993, p. 162, pl. 3, figs. 11, 19, 20.

Comments: *G. peripheroronda* is the first species in the evolutionary lineage of the *Globorotalia (Fohsella)* spp. Its later forms are gradational with *Globorotalia peripheroacuta*. *G. peripheroronda* is distinguished from the latter by its coarser wall texture and broadly rounded peripheral margin. It is distinguished from *Paragloborotalia mayeri* by its low aperture and less inflated chambers.

Globorotalia plesiotumida Blow and Banner

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

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

Globorotalia plesiotumida (Blow and Banner) Bolli and Saunders, 1985, p. 227, fig. 33.5; Chaisson and Leckie, 1993, p. 162, pl. 7, figs. 1, 2, 6–10.

Comments: *G. plesiotumida* is a species that is highly gradational with *Globorotalia merotumida.* To differentiate the two we follow the criteria of Kennett and Srinivasan (1983) and Chaisson and Leckie (1993) (i.e., specimens that have a final chamber with a length to width ratio equal to one or greater, as viewed on the spiral side were accepted as *G. plesiotumida*). Viewed from the umbilical side, *G. plesiotumida* has a distinctly more lobate final chamber than *G. merotumida. G. plesiotumida* is differentiated from *Globorotalia menardii* by its more oblate peripheral outline and its more asymmetrical edge view (flatter on the spiral side and more vaulted on the umbilical side).

Globorotalia praefohsi Blow and Banner

Globorotalia (*Globorotalia*) *praefohsi* Blow and Banner, 1966, p. 295, pl. 1, figs. 3, 4; pl. 2, figs. 6, 7, 10, 11.

Globorotalia (*Fohsella*) *praefohsi* (Blow and Banner) Kennett and Srinivasan, 1983, p. 98, pl. 22, figs. 7–9.

Globorotalia fohsi praefohsi (Blow and Banner) Bolli and Saunders, 1985, p. 213, figs. 29.3a–c, 29.11a, b.

Globorotalia praefohsi (Blow and Banner) Chaisson and Leckie, 1993, p. 162, pl. 3, figs. 5–7.

Comments: Our species concept of *G. praefohsi* is a gradational form between *Globorotalia peripheroacuta* and *Globorotalia fohsi* that can be partly keeled, or possess a partial imperforate band, or possess an acute margin that is perforate (also see Kennett and Srinivasan, 1983; Chaisson and Leckie, 1993). For example, late forms of *G. "praefoshi"* are distinguished from *G. fohsi* s.l. by the presence of an imperforate band and/or a thin raised keel that is limited to the last two or three chambers of the final whorl. *G. praefoshi* is distinguished from *G. peripheroacuta* by a tapered and distinctly acute peripheral margin on the last two or three chambers of the final whorl and a smoother microstructure.

Globorotalia praemenardii Cushman and Stainforth

Globorotalia praemenardii Cushman and Stainforth, 1945, p. 70, pl. 13, fig. 14a–c; Bolli and Saunders, 1985, p. 220, 32.7a–c; Chaisson and Leckie, 1993, p. 162, pl. 5, figs. 12–14.

Globorotalia (*Menardella*) *praemenardii* (Cushman and Stainforth) Kennett and Srinivasan, 1983, p. 122, pl. 28, figs. 6–8.

Comments: *G. praemenardii* occurs regularly through its anticipated range at Site 1146, though its abundance is rare. The species is differentiated from its ancestor, *Globorotalia archeomenardii,* by being larger and possessing a keel, and from its descendent, *Globorotalia menardii*, by being smaller, less calcified, and having only five to five and one-half chambers in the final whorl, and a thinner keel.

Globorotalia praescitula Blow

Globorotalia scitula (Brady) subsp. *praescitula* Blow, 1959, p. 221, pl. 19, fig. 128a–c.

Globorotalia (*Globoconella*) *praescitula* (Blow) Kennett and Srinivasan, 1983, p. 108, pl. 24, fig. 1; pl. 25, figs. 4–6.

Globorotalia praescitula (Blow) Chaisson and Leckie, 1993, p. 162, pl. 4, figs. 7–11.

Comments: At Site 1146 *G. praescitula* occurs throughout its range and with abundances in any one sample being <1%. *G. praescitula* is differentiated from its descendant *Globorotalia scitula* by its smaller test and more inflated umbilical side.

Globorotalia scitula (Brady)

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.

Comments: *G. scitula* is frequently observed through its long range at Sites 1143 and 1146, though in individual samples abundances are <1%. *G. scitula* is differentiated from *Globorotalia cibaoensis* by a narrower aperture, less inflated chambers, and by having more elongate, crescentic chambers. Unlike *G. scitula, Globorotalia praescitula* is characterized by its more inflated umbilical side.

Globorotalia tumida (Brady)

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.

Globorotalia tumida (Brady) Chaisson and Leckie, 1993, p. 163, pl. 7, figs. 3–5.

Comments: *G. tumida* s.s. is recognized by its large, oblate form in umbilical view and swollen, teardrop shape opposite the final chamber as seen in edge view. The test bears a heavy and wide keel and is strongly pustulose near the umbilicus. *G. tumida* can be mistaken for especially tumid (and evolutionarily late) forms of *Globorotalia merotumida* and forms of *Globorotalia conoidea* that are not highly vaulted. However, these latter species are generally smaller in size, more circular in equatorial view, have thinner keels, and are less calcified. *G. tumida* is consistently thicker and more tumid in edge view than large, heavily keeled forms of *G. menardii*.

Globorotalia cf. *G. zealandica* Hornibrook

Globorotalia cf. *G. zealandica* Hornibrook, 1958, p. 667, figs. 18, 19, 30.

Globorotalia (*Globoconella*) *zealandica* (Hornibrook) Kennett and Srinivasan, 1983, p. 108, pl. 25, figs. 1–3.

Comments: *G. zealandica* was observed low in the section at Site 1146 and always with abundances of <1% in any one sample. *G. zealandica* resembles *Globorotalia praescitula*, except that the former has four chambers (instead of four to four and one-half for *G. praescitula*), greater umbilical vaulting, and an aperture with a rimmed arch.

Globorotaloides hexagona (Natland)

Globigerina hexagona Natland, 1938, p. 149, pl. 7, fig. 1a–c.

Globorotaloides hexagona (Natland) Kennett and Srinivasan, 1983, p. 216, pl. 54, figs. 1, 3–5.

Comments: *Globorotaloides hexagona* makes a single appearance at Site 1146 (see ***"Globorotaloides variabilis,"*** p. 25).

Globorotaloides variabilis Bolli

Globorotaloides variabilis Bolli, 1957, p. 117, pl. 27, figs. 15a–20c; Kennett and Srinivasan, 1983, p. 214, pl. 53, figs. 2, 6–8; Chaisson and Leckie, 1993, p. 164, pl. 9, fig. 3.

Comments: *G. variabilis* is observed in only four samples from Site 1146, and its abundance is rare. *G. variabilis* possesses a distinctly cancellate surface and five to six chambers in the final whorl that increase rapidly in size. The rapidly enlarging chambers and lack of an apertural lip help distinguish it from juvenile forms of *Dentoglobigerina altispira*. Although trochospiral, the species is also recognized by its flattened spiral side. Blow (1969) considered *G. variabilis* to be a subspecies of *Globorotaloides hexagona*, but we differentiate the two by the former having more embracing chambers and a subacute peripheral margin.

Globoturborotalita apertura (Cushman)

Globigerina apertura Cushman, 1918, p. 57, pl. 12, fig. 8a–c.

Globoturborotalita apertura (Cushman) Hofker, 1976, pp. 47–53.

Globigerina (*Zeaglobigerina*) *apertura* (Cushman) Kennett and Srinivasan, 1983, p. 44, pl. 8, figs. 4–6.

Comments: In the South China Sea *G. apertura* is rarely observed in the sediment column at Site 1143, though it is frequently seen at Site 1146. At both sites its abundance is rare in individual samples. The species is differentiated from *Globoturborotalita woodi* by having a larger and wider aperture. High-spired forms are identified as *Globoturborotalita decoraperta*, though these two species are gradational.

Globoturborotalita decoraperta (Takayanagi and Saito)

Globigerina druryi Akers *decoraperta* Takayanagi and Saito, 1962, p. 85, pl. 28, fig. 10a–c.

Globoturborotalita decoraperta (Takayanagi and Saito) Hofker, 1976, pp. 47–53.

Globigerina decoraperta (Takayanagi and Saito) Kennett and Srinivasan, 1983, p. 48, pl. 9, figs. 4–6.

Comments: *G. decoraperta* occurs sporadically at both South China Sea sites and with abundances of <1% in any one sample. We consider this species to be a high-spired morphotype of *Globoturborotalita apertura* (see ***"Globoturborotalita apertura,"*** p. 25).

Globoturborotalita druryi (Akers)

Globigerina druryi Akers, 1955, p. 654, pl. 65, fig. 1.

Globoturborotalita druryi (Akers) Hofker, 1976, pp. 47–53.

Globigerina (*Zeaglobigerina*) *druryi* (Akers) Kennett and Srinivasan, 1983, p. 46, pl. 8, figs. 7–9.

Comments: For Site 1146, *G. druryi* is observed throughout its anticipated range and in rare abundances. Late forms of *G. druryi* overlap and are highly gradational with early forms of *Globoturborotalita nepenthes*. *G. druryi* is distinguished from *G. nepenthes* by having a smaller, more compact test, a small, low-arched aperture, and four to four and one-half chambers in the final whorl that increase uniformly in size (see **"*Globoturborotalita nepenthes*,"** p. 26).

Globoturborotalita nepenthes (Todd)

Globigerina nepenthes Todd, 1957, p. 301, fig. 7a, b.

Globoturborotalita nepenthes (Todd) Hofker, 1976, pp. 47–53.

Globigerina (Zeaglobigerina) nepenthes (Todd) Kennett and Srinivasan, 1983, p. 48, pl. 9, figs. 1–3.

Comments: The abundance of *G. nepenthes* varies from rare to abundant throughout its range at Sites 1143 and 1146. For Site 1146 early forms of *G. nepenthes* overlap and are gradational with *Globoturborotalita druryi*. It is distinguished from *G. druryi* by having a larger, more oblate, droopy form, a distinctly raised apertural lip, and a more elongate final chamber resembling a protruding thumb.

Globoturborotalita woodi (Jenkins)

Globigerina woodi Jenkins, 1960, p. 352, pl. 2, fig. 2a–c.

Globoturborotalita woodi (Jenkins) Hofker, 1976, pp. 47–53.

Globigerina (*Turborotalita*) *woodi woodi* (Jenkins) Chaproniere, 1981, p. 124, pls. 1, 2.

Globigerina (*Zeaglobigerina*) *woodi* (Jenkins) Kennett and Srinivasan, 1983, p. 43, pl. 7, figs. 4–6.

Comments: *G. woodi* is observed through its long range at Sites 1143 and 1146, while its abundance varies from rare to abundant. It has a compact test with a low to moderate trochospire, cancellate surface, chambers that increase slowly in size, and a round, symmetrical aperture with a thin rim. Forms having a large, wide aperture in the final chamber are considered to be *Globoturborotalita apertura* (or *Globoturborotalita decoraperta* if a high spire is present).

Neogloboquadrina acostaensis (Blow)

Globorotalia acostaensis Blow, 1959, p. 208, pl. 17, fig. 106a–c.

Neogloboquadrina acostaensis (Blow) Kennett and Srinivasan, 1983, p. 196, pl. 47, fig. 1; pl. 48, figs. 1–3; Chaisson and Leckie, 1993, p. 164, pl. 8, fig. 5.

Comments: *N. acostaensis* is seen throughout its range, though its abundance within individual samples is variable. Tests of *N. acostaensis* are distinguished from *Neogloboquadrina humerosa* by their smaller size, fewer chambers, and apertural plate. Some early forms of *N. acostaensis* possess a kummerform final chamber. *Neogloboquadrina continuosa* is distinguished from *N. acostaensis* by the absence of a kummerform chamber and/or an apertural plate, having a flat spiral side, and a high-arched aperture.

Neogloboquadrina continuosa (Blow)

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

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

Comments: *N. continuosa* is very uncommon through its range at Site 1143, though at Site 1146 it is slightly more prevalent. In all samples where the species is found, its abundance is rare. Our concept for *N. continuosa* is a test with four chambers rapidly increasing in size, a flat spiral side, and a high-arched aperture with a distinct rim.

Neogloboquadrina humerosa (Takayanagi and Saito)

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. 48, figs. 4–6; Chaisson and Leckie, 1993, p. 164, pl. 8, figs. 7, 8.

Neogloboquadrina humerosa humerosa (Takayanagi and Saito) Bolli and Sanders, 1985, p. 208, fig. 27.8a–c, p. 209, fig. 28.15a–c.

Comments: *N. humerosa* is observed throughout its anticipated range at both sites, though it is rare in individual samples. *N. humerosa* exhibits five to six chambers in the final whorl and an aperture open to the umbilicus. *N. humerosa* is typically larger than *Neogloboquadrina acostaensis* and lacks the apertural plate characteristic of the latter taxon. In general, *N. humerosa* is similar in size to *Neogloboquadrina dutertrei* but is flatter on the spiral side and lacks the apertural teeth of the latter taxon.

Neogloboquadrina pachyderma (Ehrenberg)

Aristospira pachyderma Ehrenberg, 1861, pp. 276, 277, 303.

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

Comments: *N. pachyderma* (D) is observed sporadically at Sites 1143 and 1146, and its abundance is always rare. *N. pachyderma* has four to four and one-half embracing chambers, a cancellate surface, and a low arch aperture. The species is believed to have evolved from *Neogloboquadrina continuosa*, which has four chambers that increase rapidly in size, is less cancellate, has a flat dorsal (spiral) side, and a highly arched aperture.

Orbulina bilobata (d'Orbigny)

Globigerina bilobata d'Orbigny, 1846, p. 164, pl. 9, figs. 11–14.

Orbulina bilobata (d'Orbigny) Kennett and Srinivasan, (1983), p. 88, pl. 18, fig. 1; pl. 20, figs. 7–9.

Comments: *O. bilobata* is a long-ranging species that occurs throughout the sediment column at both sites, though in individual samples abundances are rare. Some authors (e.g., Bolli and Saunders, 1985) regard *O. bilobata* to be a variant of *Orbulina universa* and of no stratigraphic value.

Orbulina suturalis Brönnimann

Orbulina suturalis Brönnimann, 1951, p. 135, text fig. IV, figs. 15, 16, 20; Kennett and Srinivasan, 1983, p. 86, pl. 20, figs. 1–3.

Comments: *O. suturalis* is seen throughout the sedimentary column at both sites and has individual sample abundances of <1%. The base of Zone N9 is marked by the FO of *Orbulina* spp. (following the tropical zonal scheme of Kennett and Srinivasan, 1983); thus, it is important to determine the FO of *O. suturalis* and the FO of *Orbulina universa*. The final chamber of *O. suturalis* has small apertures along its sutures as well as areal apertures. The presence of areal apertures and smaller sutural apertures differentiate this species from *Praeorbulina glomerosa circularis* (which lacks areal apertures), a species that is regarded as being the direct ancestor of *O. universa* and *O. suturalis*. *O. universa* is differentiated from *O. suturalis* by having a final chamber that completely envelops earlier chambers, thereby lacking the "Globigerina" chambers and small sutural apertures of the latter taxon.

Orbulina universa d'Orbigny

Orbulina universa d'Orbigny, 1839, p. 3, pl. 1, fig. 1; Kennett and Srinivasan, 1983, p. 86, pl. 18, fig. 2; pl. 20, figs. 4–6.

Comments: *O. universa* is recognized by its completely enveloping final chamber and absence of "Globigerina" chambers and sutural apertures. It is observed, with greatly varying abundances, in nearly every sample examined at Sites 1143 and 1146 (see **"*Orbulina suturalis,*"** p. 27).

Paragloborotalia mayeri (Cushman and Ellisor)

Globorotalia mayeri Cushman and Ellisor, 1939, p. 11, pl. 2, fig. 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.

Paragloborotalia mayeri (Cushman and Ellisor) Chaisson and Leckie, 1993, p. 164, pl. 8, figs. 16–20.

Comments: Our concept of *P. mayeri* includes *G. siakensis* because of the highly gradational nature of these forms. Similar species are *Globorotalia challengeri* (smaller and more cancellate in the early chambers of the final whorl); *Neogloboquadrina continuosa* (having only four chambers in the final whorl); and *Globorotalia peripheroronda* (less inflated chambers and lower aperture). In uppermost Zone N6 through lowermost Zone N8, some tests of *P. mayeri* are gradational with *Globorotalia bella.*

Paragloborotalia nana Bolli

Globorotalia opima nana Bolli, 1957, p. 118, pl. 28, fig. 3a–c.

"*Globorotalia*" *nana* (Bolli) Kennett and Srinivasan, 1983, p. 106, pl. 24, figs. 3–5.

Comments: *P. nana* occurs in only a single sample at Site 1146. This species is similar to *Neogloboquadrina continuosa*, but it has four to four and one-half chambers in the final whorl (instead of four for *N. continuosa*) and a lower arched aperture.

Praeorbulina glomerosa s.l. (Blow)

Globigerinoides glomerosa curva Blow, 1956, p. 58, text fig. 1, n. 9–14.

Globigerinoides glomerosa glomerosa Blow, 1956, p. 58, text fig. 1, n. 15–19; text fig. 2, n. 1, 2.

Globigerinoides glomerosa circularis Blow, 1956, p. 58, text fig. 2, n. 3, 4.

Praeorbulina glomerosa curva (Blow) Kennett and Srinivasan, 1983, p. 82, pl. 18, figs. 3, 4.

Praeorbulina glomerosa glomerosa (Blow) Kennett and Srinivasan, 1983, p. 82, pl. 18, figs. 5–7.

Praeorbulina glomerosa circularis (Blow) Kennett and Srinivasan, 1983, p. 84, pl. 19, figs. 1–5.

Comments: Our species concept of *P. glomerosa* s.l. includes the subspecies *P. glomerosa curva, P. glomerosa glomerosa,* and *P. glomerosa circularis*. At Site 1146 it is observed over a limited range of cores and in low abundances. *P. glomerosa* s.l. is characterized by slitlike or porelike sutural apertures and a final chamber that envelopes most of the test. It is differentiated from *Orbulina suturalis* by the final chamber lacking areal apertures and from *Orbulina universa* by the final chamber not fully enveloping all earlier chambers (see **"*Orbulina suturalis,*"** p. 27, and **"*Orbulina universa,*"** p. 27). *P. glomerosa* s.l. is also similar to *Praeorbulina sicana* (see **"*Praeorbulina sicana,*"** p. 29).

Praeorbulina sicana **(DeStefani)**

Globigerinoides sicanus DeStefani, 1950, p. 9, fig. 6; Kennett and Srinivasan, 1983, p. 62, pl. 13, figs. 4–6.

Praeorbulina sicana (DeStefani) Bolli and Saunders, 1985, p. 199, fig. 24.7; Chaisson and Leckie, 1993, p. 165, pl. 2, figs. 5, 6.

Comments: *P. sicana* was observed at Site 1146 in very low abundances throughout its anticipated range. The strict species concepts of Jenkins et al. (1981) and Chaisson and Leckie (1993) are used to differentiate *P. sicana* from *Globigerinoides bisphericus* and *Praeorbulina glomerosa* s.l. Specifically, *P. sicana* exhibits an envelopment of the test by the final chamber of 30%–40% (vs. 15%–20% [*G. bisphericus*] and 40%–70% [*Praeorbulina glomerosa curva*]); at least three slitlike to slightly arched apertures; a spherosity intermediate to *G. bisphericus* and *P. glomerosa* s.l.; and no umbilicus. Near the FO of this species, specimens of *Globigerinoides subquadratus* were observed with an inflated ultimate chamber bearing three high-arched apertures (similar to the *P. sicana* bearing four apertures pictured by Norris, 1998).

Pulleniatina primalis **Banner and Blow**

Pulleniatina primalis Banner and Blow, 1967, p. 142, pl. 1, figs. 3–8; pl. 3, fig. 2a–c; Kennett and Srinivasan, 1983, p. 200, pl. 49, figs. 1, 3–5; Chaisson and Leckie, 1993, p. 165, pl. 8, fig. 1.

Comments: For this study the FO of *P. primalis* is marked by the rapid appearance of typical forms, though Sample 184-1143-26X-CC exhibited transitional forms. At Site 1146, *P. primalis* is more gradational with *Neogloboquadrina acostaensis*, though it is differentiated from the latter by a smoother test and lack of an apertural plate.

Sphaeroidinella dehiscens **(Parker and Jones)**

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.

Comments: *S. dehiscens* is recognized by the presence of a secondary aperture on the spiral side of the test. As noted by Norris (1998), the initial appearance of the secondary aperture is very small, slightly larger than a pore in the cortex. This makes the FO of the species difficult to distinguish from its ancestor, *Sphaeroidinellopsis paenedehiscens*. At Site 1146, morphotypes resembling *Sphaeroidinellopsis kochi* and *Sphaeroidinellopsis seminulina* that possessed a secondary aperture were not identified as *S. dehiscens*.

Sphaeroidinellopsis kochi **(Caudri)**

Globigerina kochi Caudri, 1934, text fig. 8a, b.

Sphaeroidinellopsis kochi (Caudri) Kennett and Srinivasan, 1983, p. 210, pl. 52, figs. 1–3; Chaisson and Leckie, 1993, p. 166, pl. 10, figs. 10, 14, 18.

Comments: At both Sites 1143 and 1146, *S. kochi* is consistently observed throughout its anticipated range and it exhibits widely variable abundances, often rare but occasionally abundant. Our species concept always has more than three chambers, often bearing a glassy cortex, though cortexless specimens are seen, and a lobate outline, particularly in tests having more than four chambers. Tests resembling *Sphaeroidinellopsis seminulina* that have a kummerform or a full fourth chamber were identified as *S. kochi*.

Sphaeroidinellopsis paenedehiscens Blow

Sphaeroidinellopsis paenedehiscens Blow, 1969, p. 386, pl. 30, figs. 4, 5, 9; Kennett and Srinivasan, 1983, p. 210, pl. 52, figs. 4–6; Chaisson and Leckie, 1993, p. 166, pl. 10, fig. 9.

Comments: *S. paenedehiscens* is observed consistently throughout its anticipated range at both South China Sea sites, and its abundance in individual samples varies widely. The species has three highly embracing chambers in the final whorl, but its thick cortex of secondary calcite gives it an "egg-shaped" appearance. Similar species include *Sphaeroidinella dehiscens* and *Sphaeroidinellopsis seminulina*. *S. dehiscens* is differentiated from *S. paenedehiscens* by its secondary aperture, which in primitive forms may be very small and requires careful inspection for detection. *S. seminulina* is differentiated from *S. paenedehiscens* by being more lobate in form (i.e., having a "rounded triangle" shape).

Sphaeroidinellopsis seminulina (Schwager)

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; Chaisson and Leckie, 1993, p. 166, pl. 10, figs. 8, 11–13.

Comments: *S. seminulina* is observed consistently throughout the sedimentary column at both sites in the South China Sea, and in some samples it is very abundant. Because of the varying degree of cortex development observed in specimens of *S. seminulina* low in the section at Site 1146 (Zones N7 and N8), our species concept includes *Sphaeroidinellopsis disjuncta*. Other species similar to *S. seminulina*, but differentiated, are *Sphaeroidinellopsis kochi* and *Sphaeroidinellopsis paenedehiscens,* where the former is characterized by having more than three chambers in the final whorl and the latter by being less lobate (having an "egg" shape) (see **"*Sphaeroidinellopsis paenedehiscens*,"** p. 30).

Figure F1. Location map for the two Leg 184 sites examined in this study. Map provided by Online Map Creation, Martin Weinelt (**www.aquarius.geomar.de/omc/make_map.html**) 8/28/2002.

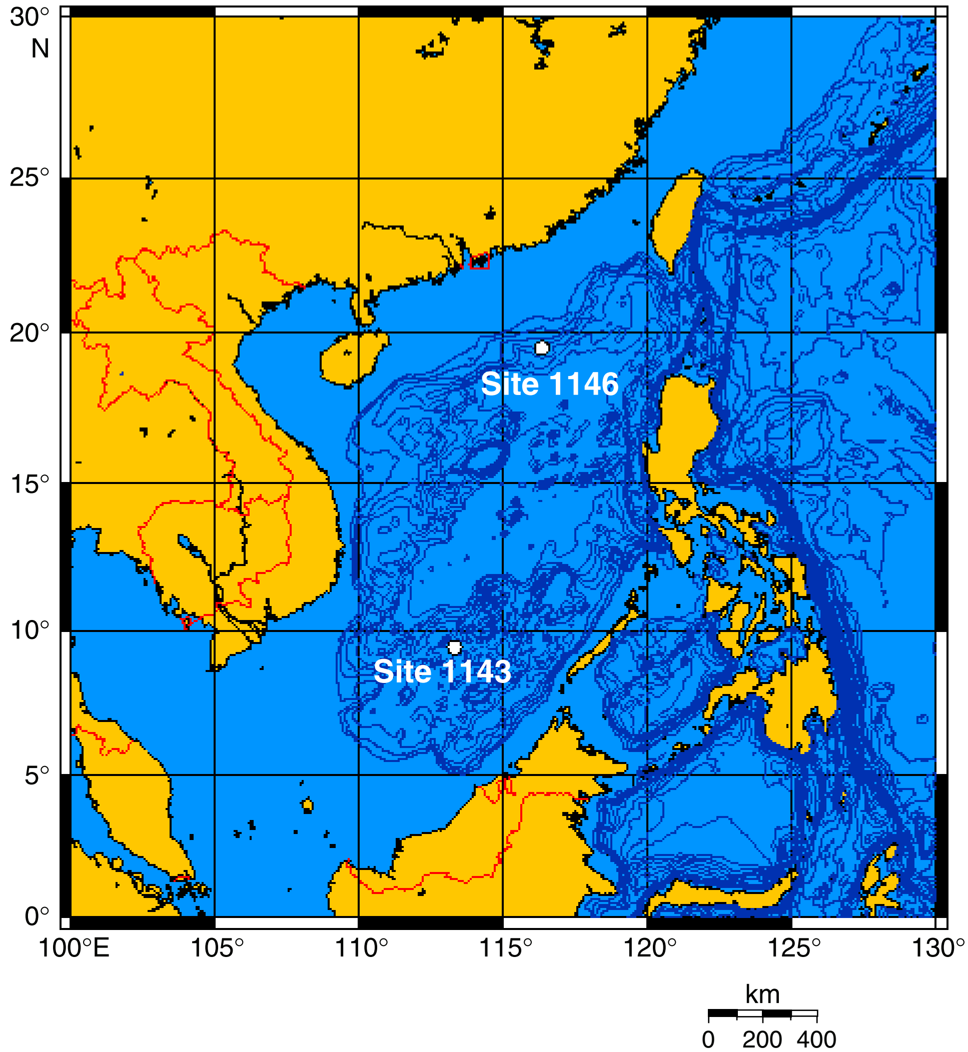

Figure F2. Zonal Scheme, zonal marker species, and ages used in this study. Zonal scheme from Kennett and Srinivasan (1983); datum ages from Berggren et al. (1995), Curry, Shackleton, Richter, (1995), and Chaisson and Pearson (1997). FO = first occurrence, LO = last occurrence.

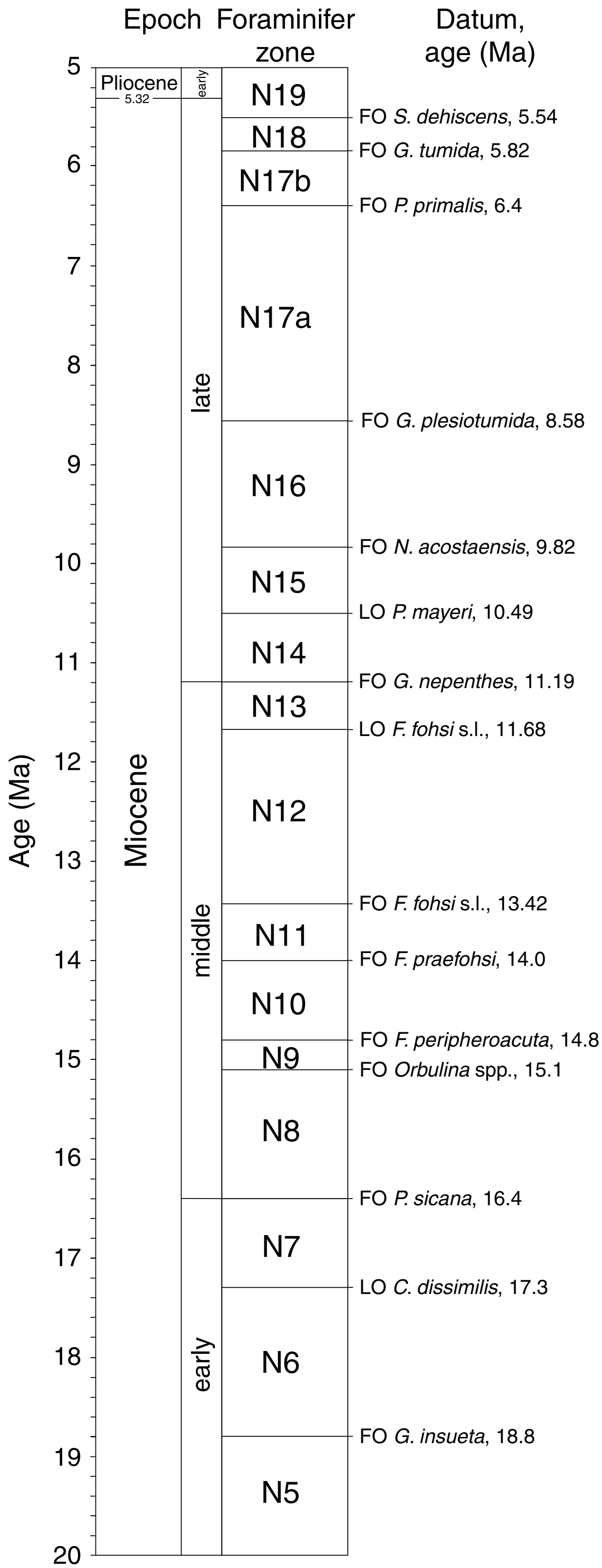

Figure F3. Age-depth plot for Site 1143 based on distribution of datums (primary marker species) and their ages as given in Table T3, p. 42. Sediment accumulation rates are based on foraminifer datums: 25 m/m.y. (5.5–6.4 Ma), 99 m/m.y. (6.4–8.6 Ma), and 8 m/m.y. (8.6–10.5 Ma). Vertical dashed lines bracket the time intervals used to calculate sediment accumulation rates. Error bars for datums are omitted due to the resolution of the depth scale and symbol size. FO = first occurrence, LO = last occurrence. Nannofossil data provided by J. Shyu (pers. comm., 2002).

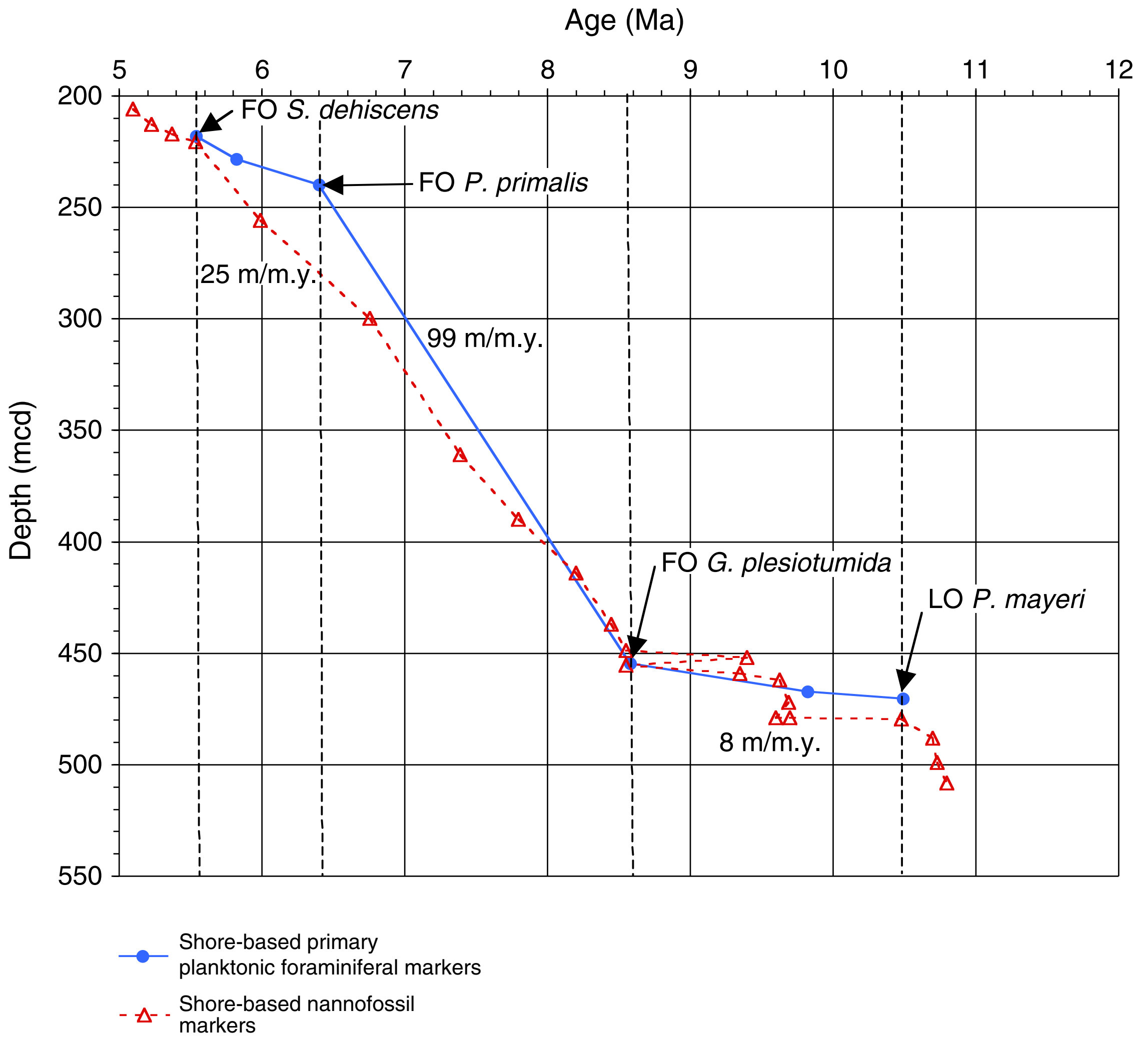

Figure F4. Age-depth plot for Hole 1146A based on distribution of datums (primary marker species) and their ages as given in Table T4, p. 43. Sediment accumulation rates are based on foraminifer datums: 21 m/m.y. (5.5–6.4 Ma), 32 m/m.y. (6.4–8.6 Ma), 20 m/m.y. (8.6–10.5 Ma), 21 m/m.y. (10.5–15.1 Ma), 58 m/m.y. (15.1–16.4 Ma), and 8 m/m.y. (16.4–18.8 Ma). Vertical dashed lines depict the time intervals used to calculate sediment accumulation rates. Error bars for datums are omitted due to the resolution of the depth scale and symbol size. FO = first occurrence, LO = last occurrence. Nannofossil data provided by J. Shyu (pers. comm., 2002).

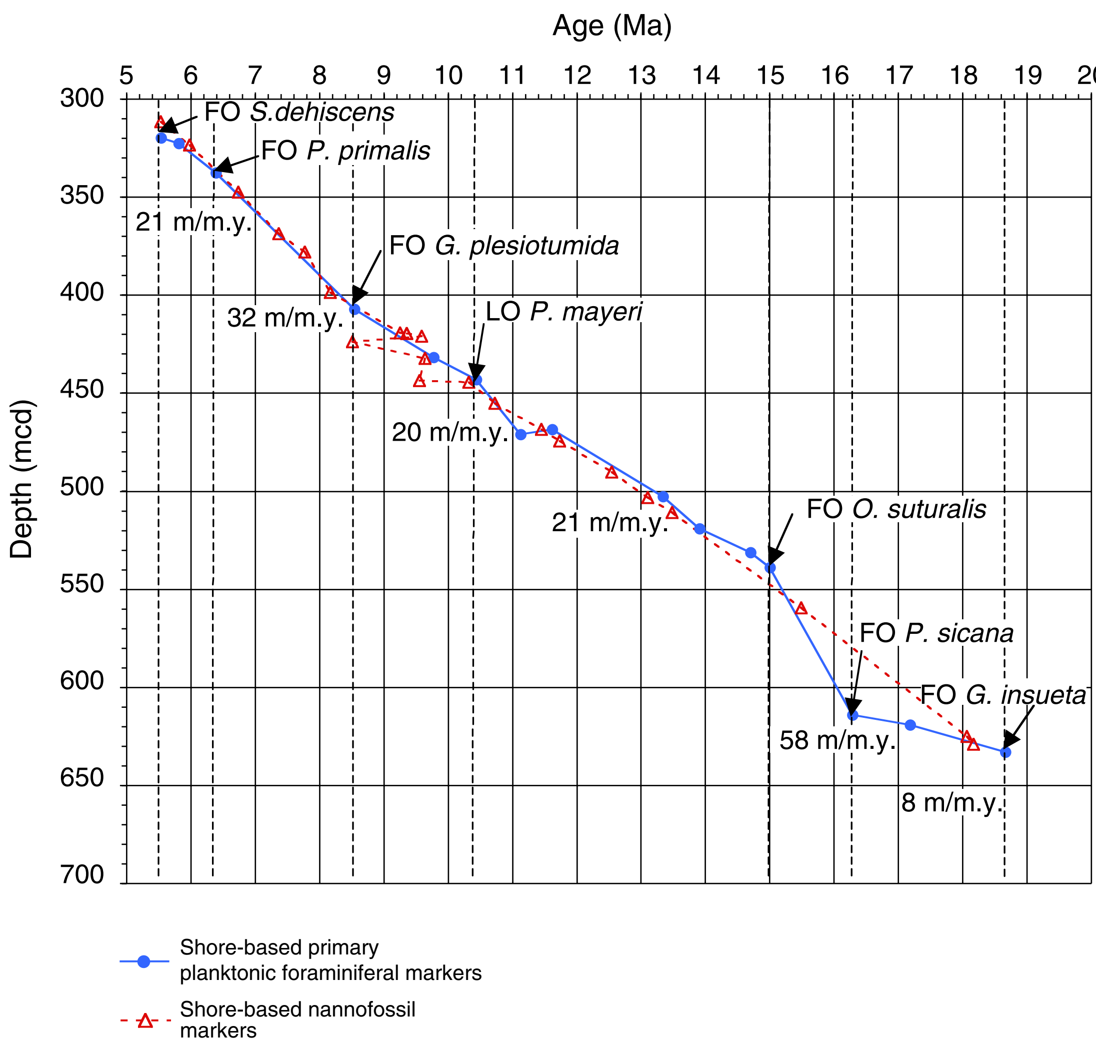

Figure F5. Planktonic foraminiferal first and last occurrences with respect to depth and core number at Site 1143 (left) and Hole 1146A (right). FO = first occurrence, LO = last occurrence.

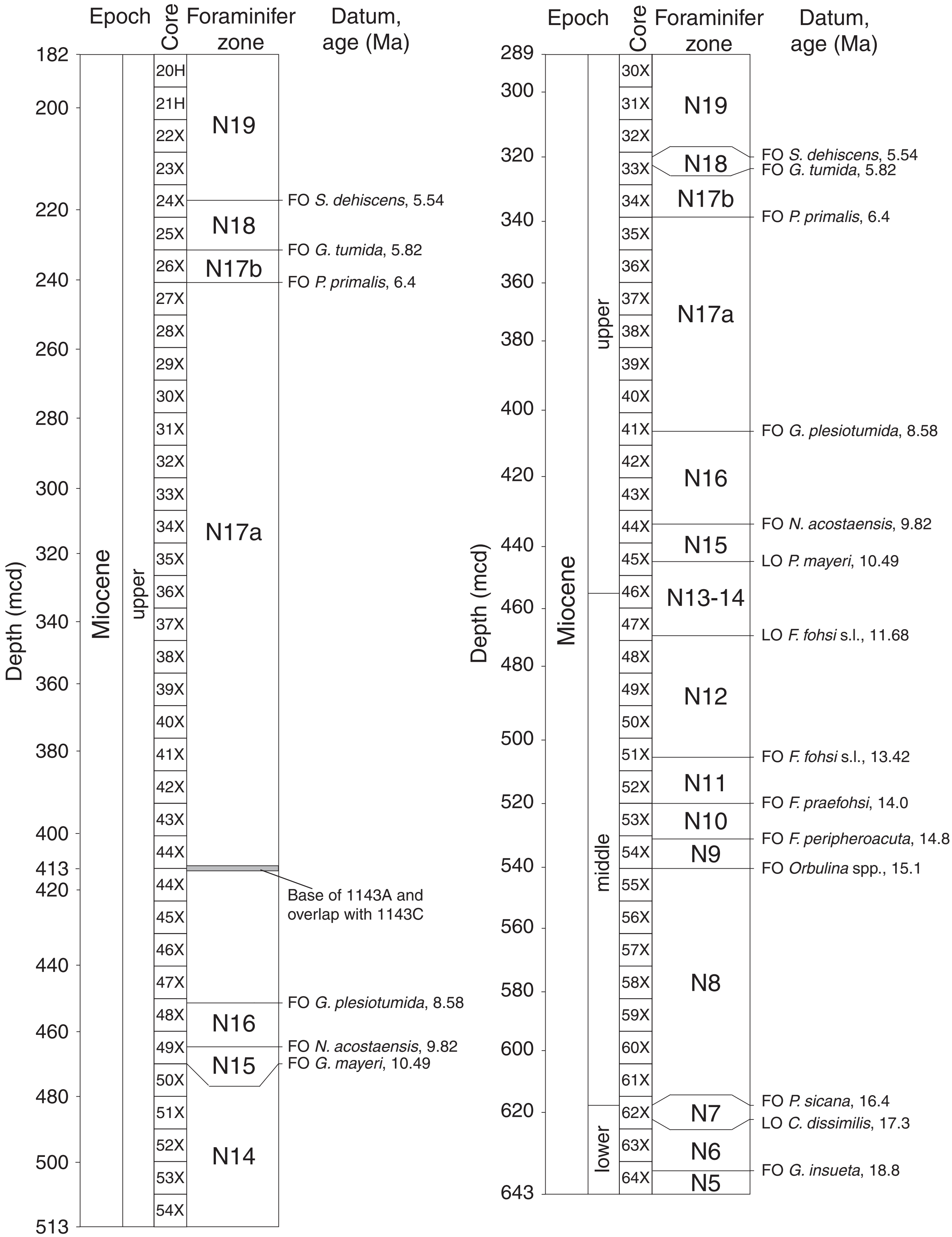

Figure F6. Average noncarbonate mass accumulation rates (MARs) for Site 1143 (Holes 1143A and 1143C) and Hole 1146A, based on average linear sedimentation rates and interpolated ages determined from the planktonic foraminiferal age-depth models (Figs. **F3,** p. 33, and **F4,** p. 34) and sediment carbonate content data from Wang, Prell, Blum, et al. (2000).

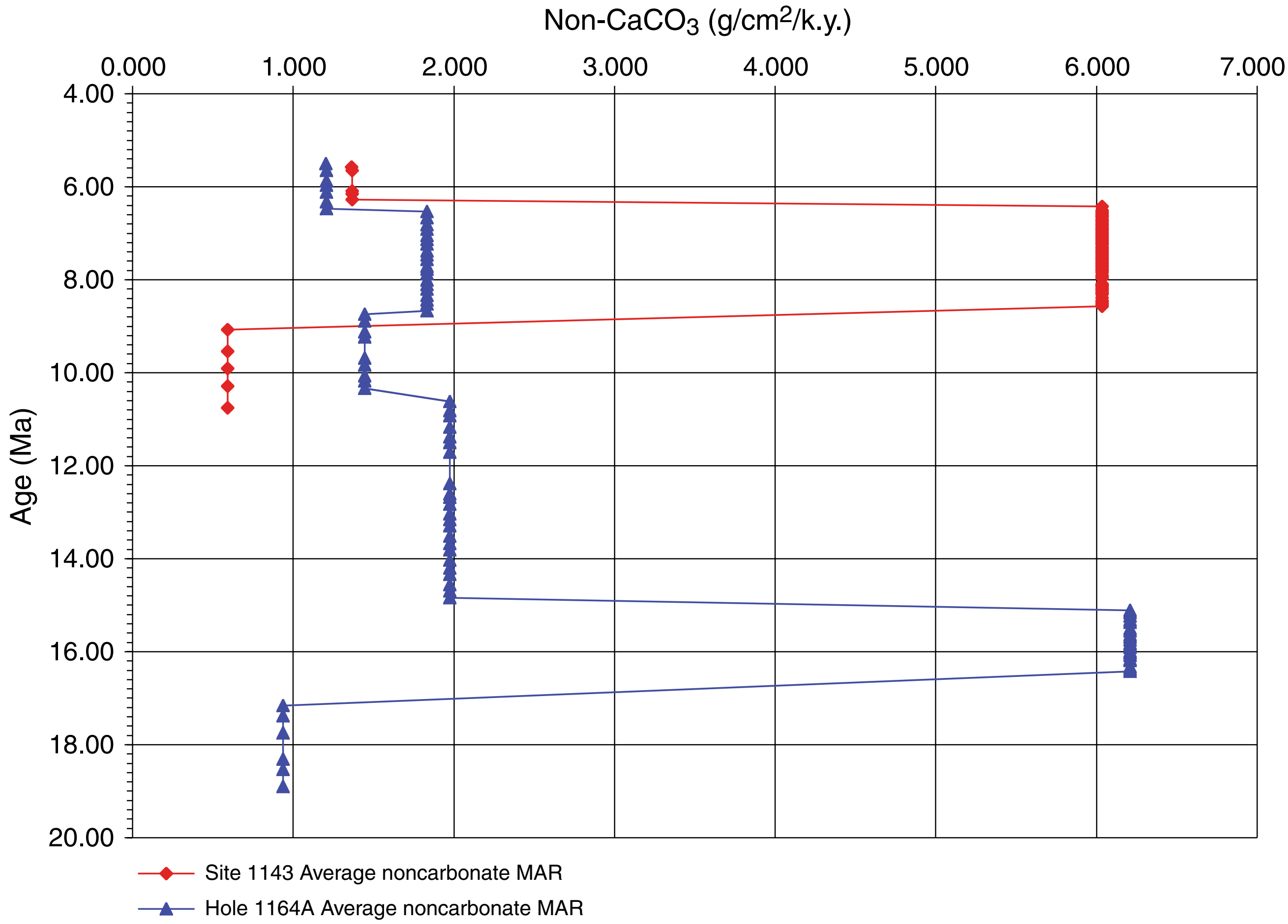

Figure F7. Average carbonate mass accumulation rates (MARs) for Site 1143 (Holes 1143A and 1143C) and Hole 1146A, based on average linear sedimentation rates and interpolated ages determined from the planktonic foraminiferal age-depth models (Figs. F3, p. 33, and F4, p. 34) and sediment carbonate content data from Wang, Prell, Blum, et al. (2000).

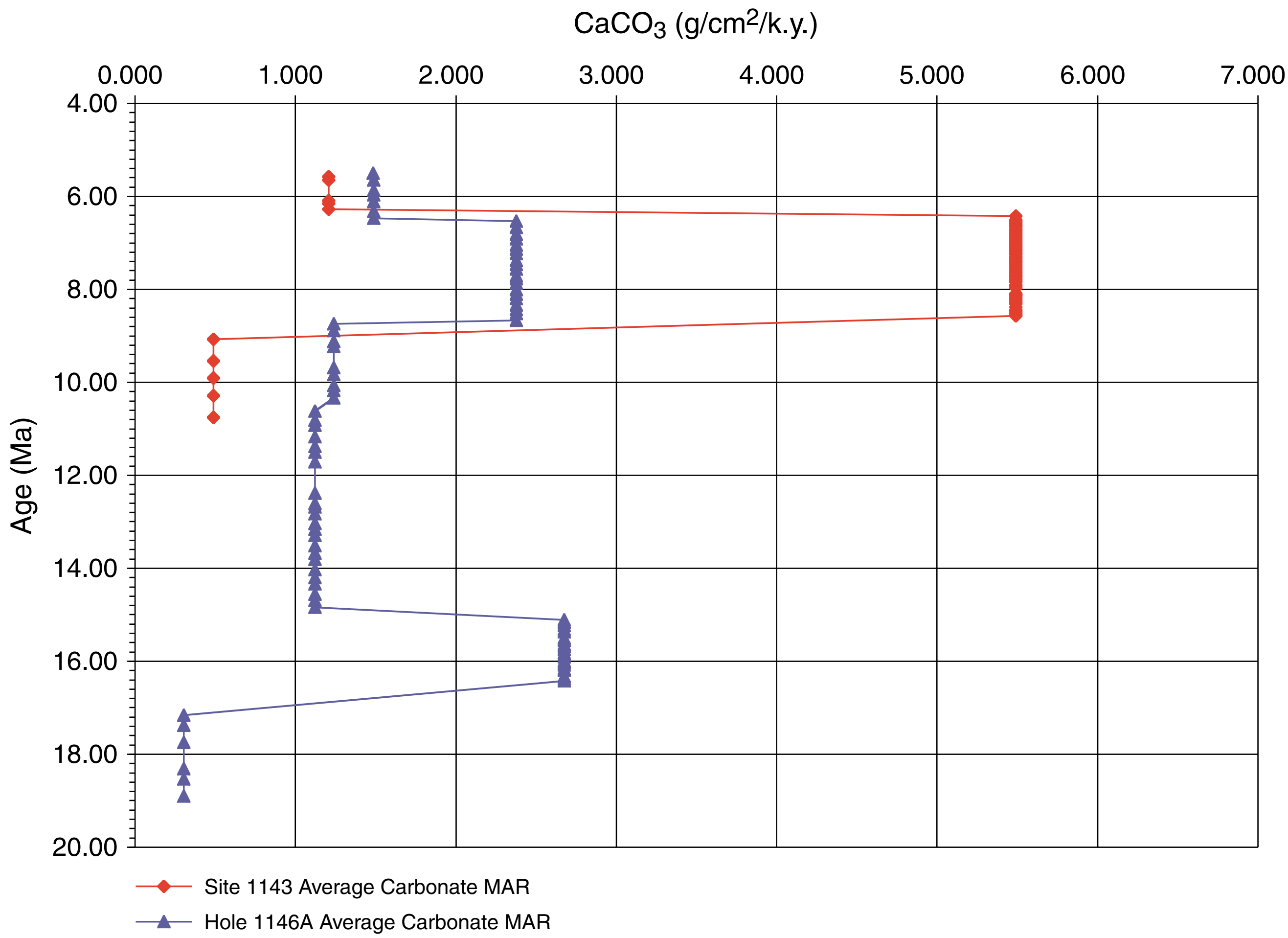

Table T1. Distribution of planktonic foraminifers, Site 1143 (Miocene). (See table notes. Continued on next two pages.)

Foraminifer zone	Core, section, interval (cm)	Average sample depth (mbsf)	Average sample depth (mcd)	Preservation	*Beella praedigitata*	*Candeina nitida*	*Dentoglobigerina altispira*	*Globigerina bulloides*	*Globigerina falconensis*	*Globigerinella aequilateralis*	*Globigerinella obesa*	*Globigerinita glutinata*	*Globigerinoides conglobatus*	*Globigerinoides extremus*	*Globigerinoides obliquus*	*Globigerinoides ruber*	*Globigerinoides sacculifer*	*Globigerinoides trilobus*	*Globoquadrina baroemoenensis*	*Globoquadrina dehiscens*	*Globoquadrina venezuelana*	*Globorotalia cibaoensis*	*Globorotalia conoidea*	*Globorotalia juanai*	*Globorotalia lenguaensis*	*Globorotalia limbata*	*Globorotalia margaritae*	*Globorotalia menardii*	*Globorotalia merotumida*	*Globorotalia plesiotumida*	*Globorotalia praemenardii*	*Globorotalia scitula*	*Globorotalia tumida*	*Globoturborotalita apertura*	*Globoturborotalita decoraperta*	*Globoturborotalita nepenthes*	*Globoturborotalita woodi*	*Neogloboquadrina acostaensis*	*Neogloboquadrina continuosa*	*Neogloboquadrina humerosa*	*Neogloboquadrina pachyderma*	*Orbulina bilobata*	*Orbulina suturalis*	*Orbulina universa*	*Paragloborotalia mayeri*	*Pulleniatina primalis*	*Sphaeroidinella dehiscens*	*Sphaeroidinellopsis kochi*	*Sphaeroidinellopsis paenedehiscens*	*Sphaeroidinellopsis seminulina*	Comments
	184-1143A-																																																		
	20H-1, 115–117	175.06	182.91	P						P		P		R	P		F											R		P		P	R				P	P		P				P		R	P	R		R	
	20H-3, 115–117	178.06	185.91	P			R	P		P				R	P		R						R				P	R		P			R			P				R				R		R	P	R	R	F	
	20H-5, 115–117	181.06	188.91	P			R	R		P				R	R		R		P				P					R	P	P			R			P	P	R		R				R		R	P	F	P	F	
	21H-1, 115–117	184.56	194.68	P			R	R	P	P		P		R	R		F						P			P		R		P			F	P		R	P			R				F		R	P	R	P	F	
	21H-3, 115–117	187.56	197.68	G			R			P		R		R	A		P									P		R	P	P		P				P	R	P		F		P		R		P	P	R	R	A	
	21H-5, 86–88	190.27	200.39	G			A	P		P	P	F		F	F		P											R	P	P		P	P			R	R	F		P		P		F				F	P	F	
N19	22X-1, 115–117	191.56	202.26	G			F	P		P		F		R	F		A									P		P		P			R			R	R	F		P		P		F				F	P	A	
	22X-3, 115–117	194.56	205.26	G		P	R			P	P	R		F	F		A									P		A	P	F		P	F			P	P	P		R		P		F		F		F	P	A	
	23X-1, 115–117	199.16	209.66	G			P	P		P				P	P		P				P			P					P							P	P	P		P				P		P		P		P	1
	23X-3, 115–117	202.16	212.66	G			A			P	P	R		R	F		F									R		F	R	R						P	P	P		R			P	F				F	R	A	
	23X-CC, 22–29	202.46	212.96	G			R	P		R		P	P	R	F		F					P					P	F		R						P	P	R		R		P		F		R	P	R	P	A	
	24X-1, 115–117	203.16	213.60	G		P	A	P		P		F		R	F		A									R		R	P	R		P				P	F	P			P	P		F		R	P	R	R	F	
	24X-3, 115–117	206.16	216.60	G		P	R	P		R		P		F	A		A					P	P				P	F	P	P			R			P	P			R		P		F			P	F	P	R	
N18	24X-5, 115–117	209.16	219.60	P		P	R							R	R		F					P	P										R					P		R				R		R		F	R	A	2
	24X-CC, 31–40	211.68	222.12	G		P	R				P	P	P	R	F		A											F	P	P			R			P	R	R		P		P		F		P		R	P	F	
	25X-1, 115–117	212.76	221.48	G	P	P	R					R	P	R	F		F					P	P	P				R	P				R			P	R	F		P	P	P		R				R	R	R	
	25X-CC, 26–33	215.35	224.07	G		P				P		R		A	A		A					P	P	R				F		P			F		P	P	R	R		R		P		R		P		R	R	R	
N17b	26X-1, 115–117	222.36	232.52	VG		P				P		P		F	F		F					P		P				R	P	P		P		P	P	R	R	R		R	P	P		F		R		F	R	F	
	26X-3, 115–117	225.36	235.52	G				P		P		F		R	F		A									P		P	R	P						R	F	R		P		P		F		P		A		A	
	26X-5, 115–117	228.36	238.52	VG			R					P		R	F		F											P	R	R						R	F	R				R		F		R		R	F	F	
	26X-CC, 41–48	230.89	241.05	G		P	R			P	P	R	R	R	F		F											P	P	P				R		R	F	R	R	R	P	R		F		P		F	R	F	
N17a	27X-1, 115–117	231.96	241.74	P			P					P		R	R														P	P						P		P		P	P			P					P	P	2
	27X-CC, 22–29	234.21	243.99	P		P	P										P											P	P								P	P						P					P	P	2
	28X-1, 115–117	241.56	251.88	P		P	F					P	P	P	R		F					P		P				R	R	R		P				R	R	F		P	P		P	F				F	P	F	2
	28X-3, 115–117	244.56	254.88	G		P	F						P	R	F		A							P				R	F	P		P						A		F		P		A				R	R	F	
	28X-5, 115–117	247.56	257.88	G			F						P	R	A		A											P	P	P		P				P	R	A		F		P		F				P		F	
	28X-CC, 28–35	248.98	259.30	G			R					P		R	A		A											R	P	P		P				P	R	A		R		R		F				P	R	F	
	29X-1, 115–117	251.16	260.58	G		P	A					P		R	A		A	P			P	P						R	P	R				P	P	R	R	F		F		P	R	F				R	P	F	
	29X-3, 117–119	254.18	263.60	P			P					P			P		P												P							P	P	P						P				P		P	2
	29X-5, 115–117	257.16	266.58	G			F							R	F		A											R	R	P		P		P		R	F	F		P		P	P	R				R		A	
	30X-1, 115–117	260.76	270.70	G		P	R	P		P		R		F	A		A				P	P		P				R	R	F						R	P	R		R		P		F				P	P	R	
	30X-3, 115–117	263.76	273.70	G			A					P		R	F		A	P				P		P				R	P	P		P				R	F	A		R		R		A				P		R	
	30X-5, 115–117	266.76	276.70	G		P	F	P			P	P		R	A		A	R										R	F			R				P	F	A		P		P		F				P	P	F	
	31X-1, 114–116	270.35	280.47	G		P	F				P	F		R	F		A						P	R				R	R	P		R				P	R	F				P		R				P		F	
	31X-3, 114–116	273.35	283.47	P			R	P				R		P	F		A							P	P	P		R	P	P		P		P		P	P	A				P		P				R	P	A	2
	31X-5, 115–117	276.36	286.48	G		P	F	P				R		R	F		A	P					R	R				P	F			R				R	F	F				P		F				P	P	F	
	32X-1, 114–116	280.05	290.39	P			P						P		P		P							P															P												2
	32X-3, 115–117	283.06	293.40	G			R					P		P	P		R											P	P			P				R	R	P						P				F	P	A	2
	32X-5, 115–117	286.06	296.40	P			F					P	P	R	F		A						P	P				P	P			P				R	P	R										P	P	F	2

Table T1 (continued).

Foraminifer zone	Core, section, interval (cm)	Average sample depth (mbsf)	Average sample depth (mcd)	Preservation	*Beella praedigitata*	*Candeina nitida*	*Dentoglobigerina altispira*	*Globigerina bulloides*	*Globigerina falconensis*	*Globigerinella aequilateralis*	*Globigerinella obesa*	*Globigerinita glutinata*	*Globigerinoides conglobatus*	*Globigerinoides extremus*	*Globigerinoides obliquus*	*Globigerinoides ruber*	*Globigerinoides sacculifer*	*Globigerinoides trilobus*	*Globoquadrina baroemoenensis*	*Globoquadrina dehiscens*	*Globoquadrina venezuelana*	*Globorotalia cibaoensis*	*Globorotalia conoidea*	*Globorotalia juanai*	*Globorotalia lenguaensis*	*Globorotalia limbata*	*Globorotalia margaritae*	*Globorotalia menardii*	*Globorotalia merotumida*	*Globorotalia plesiotumida*	*Globorotalia praemenardii*	*Globorotalia scitula*	*Globorotalia tumida*	*Globoturborotalita apertura*	*Globoturborotalita decoraperta*	*Globoturborotalita nepenthes*	*Globoturborotalita woodi*	*Neogloboquadrina acostaensis*	*Neogloboquadrina continuosa*	*Neogloboquadrina humerosa*	*Neogloboquadrina pachyderma*	*Orbulina bilobata*	*Orbulina suturalis*	*Orbulina universa*	*Paragloborotalia mayeri*	*Pulleniatina primalis*	*Sphaeroidinella dehiscens*	*Sphaeroidinellopsis kochi*	*Sphaeroidinellopsis paenedehiscens*	*Sphaeroidinellopsis seminulina*	Comments
	33X-1, 116–118	289.67	300.33	P			F					R			F		P	P					P	P				R	R							P	F	F				P		F						F	2
	33X-3, 115–118	292.67	303.33	P			R					R		P	P		A											R	P	P						P	P	F					P	R						A	2
	33X-5, 118–120	295.69	306.35	G		P	R	P			P	P		P	F		A	P			P	P		P				R	R							R	R	R		P				R					P	A	
	34X-1, 116–118	299.27	309.93	G			F					R		P	F		A	P										P	F	P		R				R	F	A		P				F				F		F	2
	34X-3, 120–122	302.31	312.97	G			A			P		R		R	F		A	P						P				R	R	P		P				R	F	A		P				R				F	P	A	2
	34X-5, 115–117	305.26	315.92	P			R					P			R		A											R	R							R	R	P						F				A	P	A	1
	35X-1, 115–117	308.86	318.90	G			R					P			A		A							P				P	R	P		P				P		R		P		P		R				R	P	A	2
	35X-3, 112–114	311.83	321.87	G			R	P				R		R	R		A							P				R	P	P		P				P	P	A						F				R	P	A	1
	35X-5, 114–116	314.85	324.89	G			F					P	P	P	A		A													P		P		P		P	P	R						R						A	2
	36X-1, 115–117	318.46	329.12	G			A					R		R	F		D	R										R	R	P		P				R	R	A		A		P		R				P		P	
	36X-3, 118–120	321.49	332.15	G			F	P				R		R	A		A											R	P	R		P				R	R	A				P		F				A	P	A	
	36X-5, 115–117	324.46	335.12	G			A					R		R	R		A											R	F	P		P				R	F	F						F					F	A	
	37X-1, 115–117	328.06	338.98	VG			F			P		P	P	F	A	P	A											R	P	P		P				P	R	R		P		P		R				R		F	
	37X-3, 117–122	331.10	342.02	P			P								P		P																			P		P													1
	37X-5, 117–120	334.10	345.02	P			F					F		P	R		D											F	F			P				P	F	A						P							1
	38X-1, 115–117	337.56	349.14	P			F	P				P		P	R		D											P	R								R	F			P	P		F				P		F	2
	38X-3, 115–117	340.56	352.14	G		P	F					F		R	F		A	P										P	R	P		P				R	F	A					P	F				R	P	A	2
	38X-5, 115–117	343.56	355.14	G			A	P			P	R		R	R		A											P	P	P						F	R	A				P		R						A	
	39X-1, 115–117	347.26	358.84	P		P	R		P		P		R	R	F		A											R	P	P						R	P	F		P		P		R				R		F	2
	39X-3, 115–117	350.26	361.84	G			R					R		R	F		A											P	P	P		P				R	R	A						R				R		A	3
N17a	39X-5, 115–117	353.26	364.84	G			F	P				F		F	A		A	P			P	P				P		R	P	P		P				R	R	F				P		R				P		R	
	40X-1, 115–117	356.86	368.18	G			R				P	R	P	P	F		F	R			P							R	R	P						R	R	A				R	P	R				F	P	F	2
	40X-3, 115–117	359.86	371.18	G			F	P				F			R		A											P	R			P				R	F	A						R				R		A	2
	40X-CC, 43–49	363.26	374.58	G			A					F			F		A											P	R							F	R	A						R				P		R	2
	41X-1, 115–117	366.06	377.64	G		P	F		P	P	P	R	P	R	F		A				P	P		P				R	R			P				R	P	F				P	P	R				F	P	F	2
	41X-3, 114–116	369.05	380.63	G		P	A			P		F	P	R	F		A	P	P		P		P					R	R	P						P	R	A				P		R				R	P	R	
	41X-5, 114–116	372.05	383.63	P		P	A		P	R	R	F	A	R	A		A	P			P	P		P		R		F	R	R						P	R	F				P		R				F	P	F	
	42X-1, 115–117	375.66	389.70	G			F			P	P	R	P	P	F		A	P			P							R	R	P						R	R	R				P	P	P				F	P	R	2
	42X-3, 115–117	378.66	392.70	G		P	A		P	P	P	R		P	A		A	R	P		P							P	R	R						R	F	R				P		R				F	R	F	2
	42X-5, 115–117	381.66	395.70	P			R			P	P	R			F		D	P			P							R	R	P						R	R	F						F				P		R	
	43X-CC, 17–19	384.38	398.42	G			R				P	P		P	A		A						P	P				R	R	P						R	R	F				P		R				P		A	2
	44X-1, 113–115	395.04	408.10	G			F					F		R	F		A											R	R							R	F	F						F				F		F	2
	44X-3, 117–119	398.08	411.14	G		P	R			P		P			A		A											R	R	R						R	R	F				P		R				P		A	2
	184-1143C-																																																		
	42X-1, 115–117	382.86	395.26	P		P	R	P		R	R	F		P	A		A				P					R		R	F	P				P		R	F	R				P	P	R				F	R	F	
	42X-3, 115–117	385.86	398.26	G			R	P			P	R		P	F		A	P			P							R	F							P	R	F			P			R				R		A	2
	42X-5, 115–117	388.86	401.26	G		P	R	P		P	P	F		P	A		A				P							F	R	P				P		P	R	R				R		R				R	P	R	
	43X-3, 115–117	395.46	407.86	P			R			P		R		P	F		A							P				R	P	P		P		P		R	F	R					P	R				P		A	
	44X-1, 114–116	402.15	414.55	G			F	P				R		P	F		A	P								P		F	F							P	R	F						F				F		F	
	44X-3, 115–117	405.16	417.56	G		P	F			P	P	F		P	A		A												P							F	F	F				P		P				A	P	A	

Table T1 (continued).

Foraminifer zone	Core, section, interval (cm)	Average sample depth (mbsf)	Average sample depth (mcd)	Preservation	*Beella praedigitata*	*Candeina nitida*	*Dentoglobigerina altispira*	*Globigerina bulloides*	*Globigerina falconensis*	*Globigerinella aequilateralis*	*Globigerinella obesa*	*Globigerinita glutinata*	*Globigerinoides conglobatus*	*Globigerinoides extremus*	*Globigerinoides obliquus*	*Globigerinoides ruber*	*Globigerinoides sacculifer*	*Globigerinoides trilobus*	*Globoquadrina baroemoenensis*	*Globoquadrina dehiscens*	*Globoquadrina venezuelana*	*Globorotalia cibaoensis*	*Globorotalia conoidea*	*Globorotalia juanai*	*Globorotalia lenguaensis*	*Globorotalia limbata*	*Globorotalia margaritae*	*Globorotalia menardii*	*Globorotalia merotumida*	*Globorotalia plesiotumida*	*Globorotalia praemenardii*	*Globorotalia scitula*	*Globorotalia tumida*	*Globoturborotalita apertura*	*Globoturborotalita decoraperta*	*Globoturborotalita nepenthes*	*Globoturborotalita woodi*	*Neogloboquadrina acostaensis*	*Neogloboquadrina continuosa*	*Neogloboquadrina humerosa*	*Neogloboquadrina pachyderma*	*Orbulina bilobata*	*Orbulina suturalis*	*Orbulina universa*	*Paragloborotalia mayeri*	*Pulleniatina primalis*	*Sphaeroidinella dehiscens*	*Sphaeroidinellopsis kochi*	*Sphaeroidinellopsis paenedehiscens*	*Sphaeroidinellopsis seminulina*	Comments
	44X-5, 115–117	408.16	420.56	VG		P	F	P		P	P	A		P	A		A							P				R	R	R				P	P		R	F				P		R				F	P	A	
	44X-CC, 46–52	410.24	422.64	G		P	F		P	P		F		P	A		A				P	P						R	R	P		P				P	R	R				P	P	R				P	P	A	
	45X-1, 113–115	411.84	424.24	VG			F	P	P	P	P	F			A		A				P							P	P							F	F	R					P	P				R	P	A	
	45X-3, 116–118	414.87	427.27	P			R				P	F			A	P	A												R							F	R	R						R				F	R	A	
	45X-5, 115–117	417.86	430.26	G			F			P	P	R			F	P	A												F			P				F	F	P						R				R		F	
N17a	46X-1, 118–120	421.49	433.89	G			A	P		P	R	F			A	P	D				P							P	P			P				F	F	R					P	P				R		A	
	46X-3, 115–117	424.46	436.86	G		P	F		P	P		A			A		A				P		R					P	R	P				P		A	F	F		P		P	P	P				P		A	
	47X-1, 115–117	431.06	443.46	G			R		P	P		A			A	P	D				R			P				R	R	P		P		P	P	P	F	R	P					R				F		A	
	47X-3, 115–117	434.06	446.46	G			R					R					A																			R	R	P						R				F		A	
	47X-5, 115–117	437.06	449.46	G			R	P		R	R	A			F	P	D							P					R	P		P				R	P	R					P	R				F		R	
	47X-CC, 36–42	439.73	452.13	G			F	P		P	P	R			F		A				P			P				P	P							P	R	R					P	R				F	R	A	
	48X-1, 115–117	440.66	453.06	P		P	A				P	R			F		D					P		P				P	R	P						P	F	R						R				P		P	
	48X-3, 115–117	443.66	456.06	G			R					R			R		A											P	P							F	R	R					R	R				A		A	
	48X-5, 125–130	446.78	459.18	P			F					R			P		A								P			P								R	R	P						R				A		A	
N16	48X-CC, 33–39	448.15	460.55	P			F	P		P		F			A	P	A											R	R							R	F	F					P	P				A		A	
	49X-1, 115–117	450.36	462.76	P			R				P	R			R		A		P		P							P	P			P				R	R	R						R				A		A	
	49X-3, 115–117	453.36	465.76	G			F	P			P	F					A								P			R	R			P				P	R	P						F				A		A	
N15	49X-5, 115–117	456.36	468.76	P			R				P	R				A	A								P			F								R	R							R				F	P	A	
	49X-CC, 42–47	458.22	470.62	NA																																															3
	50X-1, 113–115	460.04	472.44	P			F				P	R					A								P			R			P	P				P	R							P	P					A	
	50X-3, 116–118	463.07	475.47	G			R								F		F								P			P			P					R	R							P				P	P	D	
	50X-5, 117–120	466.09	478.49	P			F				P	R			A		A											P								R	F							P	P			R		F	
	50X-CC, 27–33	467.63	480.03	G			R					R			A		F								R			P			P					P	A							R	F			R		F	
	51X-1, 115–117	469.66	482.06	G			F	P				R			A		A											P				P				P	A							R	F			R		F	
	51X-3, 115–117	472.66	485.06	P			R								A		A																				A						P	R	F			R	R	A	2
	51X-5, 115–117	475.66	488.06	G			A	P				F			F		F			P	P															F	F							R	P			A		A	
N14	52X-1, 115–117	479.36	491.76	G			F			P	P	F			F					P																P	F								A			A		A	
	52X-3, 114–116	482.35	494.75	P			R	P				R			R		P																			R	R					P		R	A			R	P	A	2
	52X-5, 104–106	485.25	497.65	P			R					P			F		R			P																	F							P	F						1
	53X-1, 115–117	489.06	501.46	P			R					F					R			A								P								P	F						P	P	A			A		A	2
	53X-3, 115–116	492.06	504.46	P			P					P					P																			R								P	P			R		D	2
	53X-5, 115–116	495.06	507.46	P			P					P					P																			P	P							P	P					P	2
	54X-1, 148–150	499.09	511.49	G			A										A																			P	A								A				P	A	
	54X-CC, 43–48	500.49	512.89	G			F					P				P	A			P																P	P							R	A			R		A	

Notes: Preservation: VG = <20% fragments, G = 20%–50% fragments, P = >50% fragments; NA = not applicable, ash layer. Occurrence: P = <1% of the assemblage, R = 1%–5%, F = 5%–10%, A = 10%–30%, D = >30%. Comments: 1 = sample having very few foraminifers after standard washing. 2 = sample rich in aggregates of clay after standard washing; contains few planktonic foraminifers. 3 = ash layer; very few planktonic foraminifers.

Table T2. Distribution of planktonic foraminifers, Site 1146 (Miocene). (This table is available in an **oversized format.**)

Table T3. Planktonic foraminifer datums, Site 1143.

			Top			Bottom			
Datum	Stratigraphic position	Age (Ma)	Core, section, interval (cm)	Depth (mbsf)	Depth (mcd)	Core, section, interval (cm)	Depth (mbsf)	Depth (mcd)	Interpolated depth (mcd)
			184-1143A-			184-1143A-			
FO *Sphaeroidinella dehiscens*	Top Zone N18/Base Zone N19	**5.54**	24X-3, 115–117	206.16	216.6	24X-5, 115–117	209.16	219.6	218.1
FO *Globorotalia tumida*	Top Zone N17b/Base Zone N18	**5.82**	25X-CC, 26–33	215.35	224.07	26X-1, 115–117	222.36	232.52	228.3
FO *Globigerinoides conglobatus*		**6.2**	42X-1, 115–117	375.66	389.7	42X-3, 115–117	378.66	392.7	391.2
FO *Pulleniatina primalis*	Top Zone N17a/Base Zone N17b	6.4	26X-5, 115–117	228.36	238.52	26X-CC, 41–48	230.89	241.05	239.79
			184-1143C-			184-1143C-			
FO *Candeina nitida*		**8.44**	48X-1, 115–117	440.66	453.06	48X-3, 115–117	443.66	456.06	454.56
FO *Globigerinoides extremus*		**8.58**	44X-CC, 46–52	410.24	422.64	45X-1, 113–117	411.84	424.24	423.44
FO *Globorotalia plesiotumida*	Top Zone N16/Base Zone N17a	**8.58**	48X-1 115–117	440.66	453.06	48X-3, 115–117	443.66	456.06	454.56
FO *Globorotalia cibaoensis*		**9.44**	48X-1, 115–117	440.66	453.06	48X-3, 115–117	443.66	456.06	454.56
FO *Globorotalia juanai*		**9.76**	48X-1, 115–117	440.66	453.06	48X-3, 115–117	443.66	456.06	454.56
FO *Neogloboquadrina acostaensis*	Top Zone N15/Base Zone N16	**9.82**	49X-3, 115–117	453.36	465.76	49X-5, 115–117	456.36	468.76	467.26
LO *Paragloborotalia mayeri*	Top Zone N14/Base Zone N15	**10.49**	49X-5, 115–117	456.36	468.76	50X-1, 113–115	460.04	472.44	470.6
Bottom of hole (above FO *Globoturborotalita nepenthes*)		**<11.19**				54X-CC, 43–48	500.49	512.91	512.91

Notes: Boldface ages are astrochronologically tuned (from Chaisson and Pearson, 1997, and Berggren et al., 1995). FO = first occurrence, LO = last occurrence.

Table T4. Planktonic foraminifer datums, Hole 1146A.

Datum	Stratigraphic position	Age (Ma)	Top: Core, section, interval (cm)	Top: Depth (mbsf)	Top: Depth (mcd)	Bottom: Core, section, interval (cm)	Bottom: Depth (mbsf)	Bottom: Depth (mcd)	Average depth (mcd)
			184-1146A-			184-1146A-			
FO *Sphaeroidinella dehiscens*	Top Zone N18/Bottom Zone N19	**5.54**	33X-1, 9–12	299.61	318.36	33X-3, 14–17	302.66	321.41	319.88
FO *Globorotalia tumida*	Top Zone N17b/Bottom Zone N18	**5.82**	33X-3, 14–17	302.66	321.41	33X-5, 9–12	305.61	324.36	322.88
LO *Globorotalia lenguaensis*		6.0	36X-CC, 5–9	337.9	360	37X-2, 0–2	339.61	362.36	361.18
FO *Globigerinoides conglobatus*		**6.2**	38X-CC, 0–2	357.15	380.9	39X-2, 0–2	358.81	382.61	381.76
FO *Pulleniatina primalis*	Top Zone N17a/Bottom Zone N17b	6.4	34X-CC, 5–9	318.61	337.56	35X-1, 10–14	318.82	338.52	338.04
FO *Globorotalia plesiotumida*	Top Zone N16/Bottom Zone N17a	**8.58**	41X-4, 0–2	381.01	406.63	41X-6, 0–2	384.01	409.63	408.13
FO *Globorotalia extremus*		**8.58**	41X-6, 0–2	384.01	409.63	41X-CC, 0–2	385.99	411.61	410.62
FO *Neogloboquadrina acostaensis*	Top Zone N15/Bottom Zone N16	**9.82**	44X-3, 0–2	408.31	432.38	44X-4, 0–2	409.81	433.88	433.13
LO *Paragloborotalia mayeri*	Top Zone N14/Bottom Zone N15	**10.49**	45X-4, 0–2	419.41	443.83	45X-5, 0–2	420.91	445.33	444.58
FO *Globoturborotalita nepenthes*	Top Zone N13/Bottom Zone N14	**11.19**	48X-1, 0–2	443.71	471.92	48X-2, 0–2	445.21	473.42	472.67
LO *Globorotalia fohsi* s.l.	Top Zone N12/Bottom Zone N13	**11.68**	47X-6, 0–2	441.61	469.53	47X-7, 0–2	443.11	471.03	470.28
FO *Globorotalia fohsi* s.l.	Top Zone N11/Bottom Zone N12	**13.42**	51X-4, 0–2	476.91	504.1	51X-5, 0–2	478.41	505.6	504.85
FO *Globorotalia praefohsi*	Top Zone N10/Bottom Zone N11	14.0	52X-CC, 0–2	491.41	519.85	53X-2, 0–2	493.11	523	521.43
FO *Globorotalia peripheroacuta*	Top Zone N9/Bottom Zone N10	14.8	54X-1, 0–2	501.21	531.95	54X-3, 0–2	504.21	534.95	533.45
LO *Praeorbulina sicana*		14.8	54X-CC, 0–2	509.07	539.81	55X-2, 0–2	512.31	542.95	541.38
FO *Globorotalia praemenardii*		14.9	54X-CC, 0–2	509.07	539.81	55X-2, 0–2	512.31	542.95	541.38
LO *Globigerinatella insueta*		15.0	54X-CC, 0–2	509.07	539.81	55X-2, 0–2	512.31	542.95	541.38
FO *Orbulina suturalis*	Top Zone N8/Bottom Zone N9	15.1	54X-CC, 0–2	509.07	539.81	55X-2, 0–2	512.31	542.95	541.38
FO *Praeorbulina sicana*	Top Zone N7/Bottom Zone N8	16.4	62X-2, 10–14	579.62	616.41	62X-3, 10–14	581.12	617.91	617.16
LO *Catapsydrax dissimilis*	Top Zone N6/Bottom Zone N7	17.3	62X-5, 7–11	584.09	620.88	62X-7, 10–14	586.92	623.71	622.3
FO *Globigerinatella insueta*	Top Zone N5/Bottom Zone N6	18.8	64X-2, 10–14	598.82	634.81	64X-4, 9–13	601.81	637.8	636.31
LO *Globoquadrina binaiensis*		19.1	64X-6, 8–12	604.8	640.79	64X-7, 12–16	606.34	642.33	641.95
Bottom of hole						64X-CC, 10–14	606.83	643.11	643.11

Notes: Boldface ages are astrochronologically tuned (from Chaisson and Pearson, 1997, Berggren et al., 1995, and Curry et al., 1995). FO = first occurrence, LO = last occurrence.