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34. PLANKTONIC FORAMINIFER BIOSTRATIGRAPHY: EASTERN EQUATORIAL ATLANTIC[1]

Richard D. Norris[2]

ABSTRACT

Four sites were drilled during Ocean Drilling Program Leg 159 on the continental slope off the Côte d'Ivoire and Ghana in the eastern equatorial Atlantic. Samples rich in planktonic foraminifers range in age from the Holocene to early Miocene, whereas Cenozoic samples older than this contained either poorly preserved foraminifer assemblages or were completely barren. Preservation of foraminifers is best at the two shallowest sites (Site 959, 2090 m water depth, and Site 960, 2048 m water depth) and degrades with increasing water depth. Foraminifers are almost completely absent at Site 962 at 4648 m. Even in the shallow water sites, preservation is moderate in the Pleistocene, the earliest Pliocene, and the early to middle Miocene where there is extensive fragmentation of the <150-µm fraction and often dissolution of the interiors of large, robust specimens. Preservation is good through much of the upper Pliocene and the upper Miocene.

Planktonic foraminifer assemblages are typical of the tropical oceans, although temperate species such as *Neogloboquadrina pachyderma* (sinistral), *Globorotalia panda,* and *Globorotalia miozea* are found sporadically. *Globorotaloides hexagona* is absent from Leg 159 sites throughout upper Pliocene Zones Pl4 and Pl5 and may prove to have a pattern of disappearance from upper Pliocene Atlantic sediments similar to *Globorotalia tumida* and species of *Pulleniatina.* The recovered section at Site 959 is almost biostratigraphically complete between lower Miocene Zone N7 and the Holocene, although there is probably a hiatus in the middle Miocene that has cut out, or greatly thinned, Zone N9. The other Leg 159 sites are less complete. The middle Miocene section is missing at both Sites 960 and 961, and Site 961 also has a hiatus across the Miocene/Pliocene boundary.

INTRODUCTION

During Ocean Drilling Program (ODP) Leg 159, the easternmost sites available in the equatorial part of the Atlantic Ocean (Fig. 1) were drilled. Cores from the Côte d'Ivoire margin are of particular interest because they are well placed to monitor the latitudinal position of the major east-west currents in the equatorial current system. A depth transect of sites was drilled during Leg 159, which permits comparison of intermediate water and deep water chemistries and sedimentation in the eastern equatorial Atlantic (Table 1).

The present study describes the Miocene–Holocene planktonic foraminifer record at Sites 959, 960, 961, and 962. The most detailed study was of material from Holes 959A, 959B, and 960C, where planktonic foraminifers were generally well preserved and recovery of the sedimentary record was nearly complete. Sites 959 and 960 are of additional interest because the sediments at Site 960 accumulated on a topographic high, whereas those drilled at Site 959 were deposited in the adjacent Côte d'Ivoire-Ghana Basin. The two sites are only 6 km apart and at similar water depths (~2000 m; Fig. 1). Hence, it is possible to compare the distribution of hiatuses between the basin and the topographic high in the absence of major differences in sediment sources or surface water oceanography.

METHODS

Pelagic sediments in Holes 959A, 959B, 959C, 960C, and 962B were recovered using a combination of advanced hydraulic piston coring (APC) and extended core barrel (XCB) drilling. Detailed hole-to-hole core integration is possible only at Site 959 where the magnetic susceptibility record is sufficiently variable to provide good tie points between the various holes. Correlation was made among the holes of Site 959 to provide well-defined datums in the upper Miocene and Pliocene portions of the record. Such hole-to-hole integration was not possible at the other sites because only single, long APC holes were drilled (Holes 960C and 962B) or only rotary coring was done with low recovery, as at Site 961. Accordingly, the most detailed biostratigraphic work concentrated on Sites 959, 960, and 962.

In general, one sample per section was analyzed, except at Site 961 where mainly core catchers were studied. The sample density allowed datums to be constrained to within 1.5 m of core. An exception was in the upper Miocene and Pliocene section at Site 959, where examination of samples taken for a study of Pliocene paleoceanography permitted a resolution of ~20 cm. Sediment volumes of ~10 cm^3 were taken, which typically yielded large numbers of foraminifers. All samples were soaked in tap water and 3% Calgon overnight and washed though a 38-µm screen. The residues were dried in a 50°C oven.

The residues in the >150-µm sieve fraction were examined nonquantitatively using a binocular microscope. The abundance of each species was estimated as follows: A = abundant (>30%); C = common (15%–30%); F = few (3%–15%), R = rare (1%–3%), and T = trace (only a single specimen observed). Typically, several thousand specimens were observed for each sample.

Preservation was estimated visually and, in some cases, by scanning electron microscopy (SEM). Estimates of preservation include the percentage of broken specimens as well as the degree of etching and dissolution of large foraminifers. In this report, G = good (<20% fragmentation, shells with delicate structures intact, no evidence of solution pitting), M = moderate (>20%–<50% fragmentation, with or without fragmentation or dissolution of large specimens); P = poor (>50% fragmentation, assemblage consisting mainly of dissolution-resistant species and extensive evidence of dissolution); B = barren (all foraminifers fragmentary or destroyed).

Foraminifer identification closely follows the species concepts of Kennett and Srinivasan (1983). Descriptions of all the taxa recognized in Leg 159 sediments are given under the "Systematic Paleontology" section in this paper. I did not attempt to subdivide the varieties of the *Globorotalia mayeri-siakensis* group. Recognition of species in the *Fohsella fohsi* group follows Chaisson and Leckie (1993), in which the first representatives of *F. fohsi* are defined as having a complete peripheral keel.

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[2]MS-23, Woods Hole Oceanographic Institution, Woods Hole, MA 02543-1541, U.S.A. RNorris@cod.whoi.edu

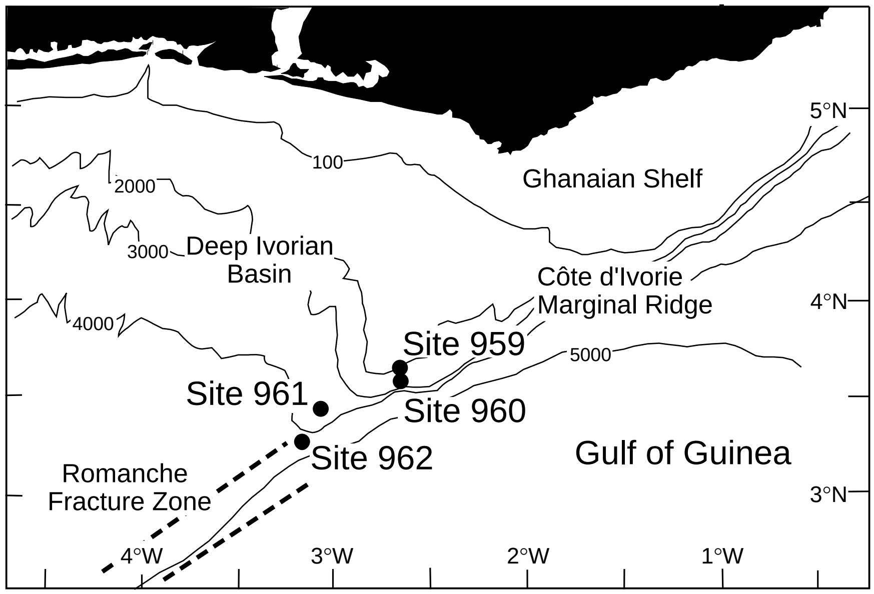

Figure 1. Location of Leg 159 sites in the Gulf of Guinea off the coast of the Côte d'Ivoire-Ghana in West Africa.

Table 1. Latitude, longitude, and water depths of Leg 159 sites.

Site number	Latitude	Longitude	Water depth (m)
959	3°37.659′N	2°344.112′W	2090
960	3°34.979′N	2°44.009′W	2048
961	3°26.542′N	3°3.513′W	3292
962	3°15.077′N	3°10.921′W	4637

BIOSTRATIGRAPHIC ZONATION

The tropical Pliocene–Pleistocene zonal scheme of Berggren et al. (1995a) and tropical Miocene zonation of Kennett and Srinivasan (1983) were used with some modifications that are discussed below. I have not used the Miocene zonation of Berggren et al. (1995a) because several of the datum markers used by these authors are absent in Leg 159 material and I have found it difficult to apply the late middle Miocene zonation consistently in this material, as discussed below. However, the Pliocene zonal scheme of Berggren et al. (1995b) provides much finer stratigraphic resolution than the zonation of Kennett and Srinivasan (1983). Figure 2 shows the relationship between the planktonic foraminifer biostratigraphic zonation used here and the biostratigraphic datums used in this study.

Zone N4

Definition: Total range of *Fohsella kugleri.*
Estimated age: 23.1–21.5 Ma, early Miocene.
Discussion: Zone N4 has been subdivided by the first appearance datum (FAD) of *Globoquadrina dehiscens* at the base of Subzone N4b (= M1b in the zonation of Berggren et al., 1995b). However, Premoli Silva and Spezzaferri (1990) have recorded the FAD of *G. dehiscens* in late Oligocene Zone P22 in the Indian Ocean, which suggests considerable uncertainty about the biostratigraphic significance of this species. Subzone N4a (= M1a of Berggren et al., 1995b) is characterized by the co-occurrence of *F. kugleri* and *Globigerinoides primordius.*

Zone N5

Definition: Interval between the last appearance datum (LAD) of *F. kugleri* and the FAD of *Globigerinatella insueta* within the partial range of *Catapsydrax dissimilis.*
Estimated age: 21.5–18.8 Ma; early Miocene.
Discussion: This zone is equivalent to Zone M2 of Berggren et al. (1995b).

Zone N6

Definition: Interval between the FAD of *G. insueta* and the LAD of *C. dissimilis/Catapsydrax unicavus.*
Estimated age: 18.8–17.3 Ma; early Miocene.
Discussion: This zone is equivalent with M3 of Berggren et al. (1995b).

Zone N7

Definition: Interval between the LAD of *C. dissimilis* and the FAD of *Praeorbulina sicana.*
Estimated age: 17.3–16.4 Ma, early Miocene.
Discussion: I follow Jenkins et al. (1981) in distinguishing between *P. sicana* and *Globigerinoides bisphericus. Globigerinoides bisphericus* intergrades extensively with *Globigerinoides sacculifer* (var. *trilobus*). As noted by these authors, *P. sicana* is characterized by four apertures around the final chamber, whereas *G. bisphericus* has only two or three apertures and an umbilicus not obscured by the last chamber. This zone is equivalent to Zone M4 of Berggren et al. (1995b)

Zone N8

Definition: Interval between the FAD of *P. sicana* and the FAD of *Orbulina suturalis.*
Estimated age: 16.4–15.1 Ma, middle Miocene.
Discussion: This zone corresponds to Zone M5 of Berggren et al. (1995b).

Subzone N8a

Definition: Interval between the FAD of *P. sicana* and the FAD of *Praeorbulina glomerosa.*
Estimated age: 16.4–16.1 Ma, early middle Miocene.
Discussion: This zone corresponds to the base of Zone N8 of Blow (1969; 1979) and M5a of Berggren et al. (1995b).

Subzone N8b

Definition: Interval from the FAD of *P. glomerosa* to the FAD of *Orbulina suturalis.*
Estimated age: 16.1–15.1 Ma, early middle Miocene.
Discussion: Zone N8b corresponds to the upper part of Zone N8 of Blow (1969; 1979) and Zone M5b of Berggren et al. (1995b).

Zone N9

Definition: Interval between the FAD of *O. suturalis* and the FAD of *Fohsella peripheroacuta.*
Estimated age: 15.1–14.8 Ma middle Miocene.
Discussion: This zone corresponds completely with Zone M6 of Berggren et al. (1995b).

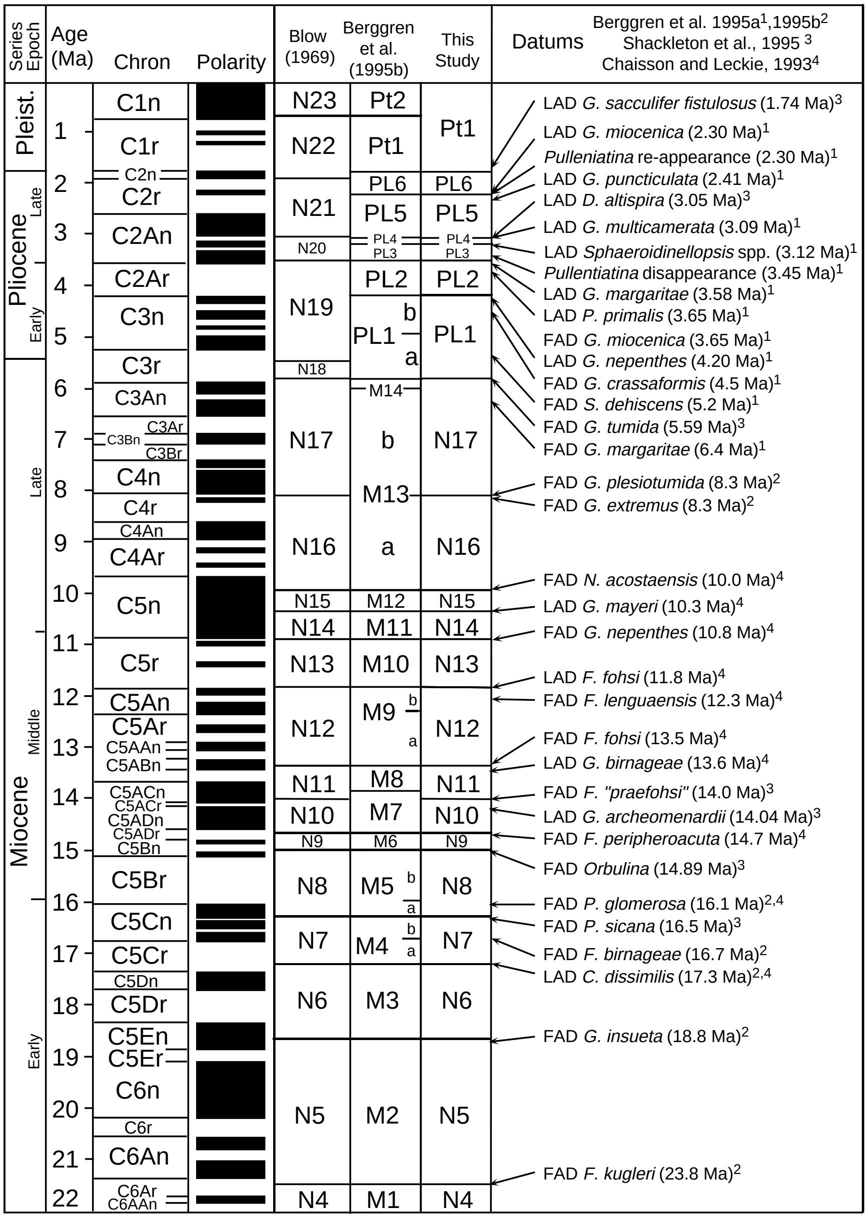

Figure 2. Biostratigraphic zonation used in this study compared to other zonal schemes and the magnetopolarity timescale. FAD = first appearance datum, LAD = last appearance datum. The ages of biostratigraphic datums used in this report are from the ODP Leg 138 *Initial Reports* volume (Mayer, Pisias, Janacek, et al., 1992) for the Miocene and Berggren et al. (1995a) for the Pliocene to Holocene.

Zone N10

Definition: Interval between the FAD of *F. peripheroacuta* and the FAD of *Fohsella "praefohsi."*

Estimated age: 14.8–13.0 Ma, middle Miocene.

Discussion: In this study, I elevate the subgenus *Fohsella* to generic rank, given the distinctiveness of the members of the taxon and their independent evolution of keeled morphology from that of other keeled Neogene lineages. The top of Zone N10 is defined by the first appearance of *Fohsella "praefohsi"*—a form that shows considerable variability in the degree of axial compression and development of the peripheral keel. In my usage, *F. "praefohsi"* includes forms that have a smooth wall texture and a strongly acute periphery, which may or may not have a partial keel on the early part of the last whorl, whereas *F. peripheroacuta* has a coarse wall texture throughout most of the final whorl,and the last chamber is never keeled. The variation present in *F. "praefohsi"* renders its first appearance (the definition of the top of Zone N10 of Blow, 1969; 1979) somewhat difficult to determine. Furthermore, the taxonomic status of *F. "praefohsi"* is in doubt since Bolli and Saunders (1985, p. 215) argue that the holotype represents an intermediate form between *Fohsella fohsi lobata* and *F. fohsi fohsi* (see discussion in systematic section). However, the concept of *F. "praefohsi"* as represented by the paratype does appear to represent an intermediate form between *F. peripheroacuta* and *F. fohsi* sensu stricto (Berggren et al., 1995b, p. 160) and as such has been widely applied in tropical biostratigraphy. I retain use of *F. "praefohsi"* sensu Kennett and Srinivasan (1983) pending resolution of this taxonomic problem.

Zone N11

Definition: Interval from the FAD of *F. "praefohsi"* to the FAD of *F. fohsi.*

Estimated age: 13.0–12.7 Ma.

Discussion: Berggren et al. (1995b) has suppressed Zone N11 in their Zone M7 by disregarding *F. "praefohsi"* as a useful datum and by reporting the FAD of *F. "praefohsi"* as the same age as that of *F. fohsi* (both 12.7 Ma). The FAD *Fohsella "praefohsi"* clearly predates the FAD of *F. fohsi* at many tropical sites (e.g., ODP Site 714 [Indian Ocean], ODP Site 806 [western tropical Pacific], DSDP Site 151 [Caribbean] and at ODP Site 959 [this study], among others). Accordingly, the ages of the FADs of both *F. "praefohsi"* and *F. fohsi* reported by Berggren et al. (1995b) are suspect and the utility of Zone N11 is supported.

Zone N12

Definition: Interval from the FAD of *F. fohsi* to the LAD of *Fohsella fohsi robusta*.

Estimated age: 12.7–12.3 Ma; middle Miocene.

Discussion: The extinction of *F. fohsi robusta* (and other variants of *F. fohsi*) is a well-marked event. Berggren et al. (1995b) erected the division of Zones M8 and M9a on the FAD of *F. fohsi lobata,* a variant of *F. fohsi* that has a "cockscomb" or lobate periphery. In as much as lobate forms of *F. "praefohsi"* occur below the FAD of *F. fohsi* ssp. (for instance at ODP Hole 806B, western tropical Pacific), the range of *F. fohsi lobata* may be difficult to establish reliably (see also Pearson, 1995, p. 45–46). Likewise, the transition between *F. fohsi fohsi* and *F. fohsi robusta* is gradual and leads to some uncertainty in the lower bound of Zone M9b of Berggren et al. (1995b), but once it is abundant, *F. fohsi robusta* is an easily recognized form with an umbilically convex test and nearly flat spiral surface that contrasts with a more teardrop-shaped or biconvex profile in the other varieties of *F. fohsi.*

Zone N13

Definition: Interval between the LAD of *F. fohsi robusta* and the FAD of *Globotruborotalia nepenthes.*

Estimated age: 11.9–11.8 Ma; middle Miocene.

Discussion: Zone N13 corresponds to Zone M10 of Berggren et al. (1995b). The determination of the FAD of *G. nepenthes* is often difficult in other than well-preserved assemblages. Berggren et al. (1995b) argued that the FAD of *Fohsella lenguaensis* occurs close to that of *G. nepenthes* in Caribbean sections and can be used to identify the top of Zone M10 (= N13). However, Chaisson and Leckie (1993) recorded the FAD of *F. lenguaensis* significantly below the FAD of *G. nepenthes* in the western tropical Pacific (at ODP Site 806), which is also the case at ODP Site 959 (this study).

Zone N14

Definition: Interval between the FAD of *G. nepenthes* and the LAD of *Globorotalia mayeri.*

Estimated age: 11.8–11.4 Ma; middle Miocene.

Discussion: Zone N14 corresponds to Zone M11 of Berggren et al. (1995b). Zone N14 is represented by only ~2 m of sediment at Site 959, the only Leg 159 site where N14 has been recognized.

Zone N15

Definition: Interval between the LAD of *G. mayeri* and the FAD of *Neogloboquadrina acostaensis.*

Estimated age: 11.4–10.9 Ma; middle–late Miocene.

Discussion: Zone N15 is equivalent with Zone M12 of Berggren et al. (1995b). The FAD of *N. acostaensis* is a well-marked datum at Site 959, the only Leg 159 site where this datum does not appear to occur at an unconformity.

Zone N16

Definition: Interval between the FAD of *N. acostaensis* and the FAD of *Globorotalia plesiotumida*.

Estimated age: 10.9–8.3 Ma; late Miocene.

Discussion: This zone is equivalent with Zone M13a of Berggren et al. (1995b). These authors suggest that the top of M13a (= N16) can be approximated by the FAD of *Globigerinoides extremus.* Indeed, *G. extremus* has a FAD simultaneous with that of *G. plesiotumida* at Site 959 and only slightly younger than this at Site 960.

Zone N17

Definition: Interval from the FAD of *G. plesiotumida* to the FAD of *G. tumida.*

Estimated age: 8.3–5.6 Ma, late Miocene.

Discussion: Zone N17 is typically subdivided on the FAD of *Pulleniatina primalis,* which marks the base of Zone N17b. However, *P. primalis* does not appear in Leg 159 sites until late in the early Pliocene, well after the FAD of *G. tumida.* Berggren et al. (1995b) suggested that Zone N17 can be divided by the LAD of *F. lenguaensis* (which marks the base of Zone M14). *Fohsella lenguaensis* is a small but easily recognized species common in the tropics and subtropics. Unfortunately, *F. lenguaensis* does not range as high as *G. plesiotumida* at Leg 159 sites.

Zone PL1

Definition: Interval from the FAD of *G. tumida* to the LAD of *G. nepenthes.*

Estimated age: 5.6–4.18 Ma; early Pliocene.

Discussion: The base of this zone approximately corresponds to the FAD of *Globorotalia margaritae* and the LAD of *Globoquadrina dehiscens.* At Site 959, *G. margaritae* ranges ~5 m below the FAD of *G. tumida. Globoquadrina dehiscens* has been observed ~8 m above the base of Zone PL1. *Globorotalia margaritae* has its FAD coincident with that of *G. tumida* and the LAD of *G. dehiscens* at Site 960. Berggren et al. (1995a) noted that *Sphaeroidinella dehiscens* has its FAD slightly above that of *G. tumida* and may provide a means of recognizing the base of Zone PL1 in favorable conditions. The FAD of *S. dehiscens* was found well above the FAD of *G. tumida* in Sites 959 and 960.

Berggren et al. (1995a, 1995b) suggested subdividing Zone PL1 using the LAD of *Globorotalia cibaoensis* to mark the top of Zone PL1a. The occurrence of *G. cibaoensis* is rather spotty in Leg 159 sites, making it unwise to rely on this datum. Berggren (1977) suggested using the FAD of *Globorotalia crassaformis* to recognize Zone PL1c, although Berggren et al. (1995b) have eliminated this species as a subzone marker owing to the difficulty in identifying this zone in many subtropical sites. The FAD of *G. crassaformis* is a well-marked datum at Sites 959 and 960 but appears to be younger than at other Atlantic sites by ~200 k.y. (Norris, Chap. 40, this volume).

Zone PL2

Definition: Interval between the LAD of *G. nepenthes* and the LAD of *G. margaritae.*

Estimated age: 4.18–3.58 Ma; early Pliocene.

Discussion: *Globorotalia margaritae* has a well-defined LAD in Leg 159 sites, whereas *G. nepenthes* becomes very rare near the top of its range. Both species are found primarily in the <212-µm fraction at the tops of their ranges. *Globorotalia margaritae* also becomes somewhat atypical near its LAD. Specimens of *G. margaritae* are more inflated than typical for this species and have a well-developed keel only on the last chamber just below the LAD of this taxon in Hole 959C.

Zone PL3

Definition: Interval between the LAD of *G. margaritae* and the LAD of *Sphaeroidinellopsis seminulina.*

Estimated age: 3.58–3.12 Ma; late Pliocene.

Discussion: The LAD of *Sphaeroidinellopsis* spp. (including *S. seminulina, S. kochi,* and *S. paendehiscens*) is a very well marked event at Leg 159 sites and provides one of the best planktonic foraminifer datums at these sites. *Sphaeroidinellopsis seminulina* has been found above the top of Zone PL3 in small numbers at Sites 959 and 960, which suggests some reworking has occurred. The LAD of *Sphaeroidinellopsis* spp. approximately coincides with the LAD of *Globoquadrina venezuelana*.

Zone PL4

Definition: Interval between the LAD of *Sphaeroidinellopsis seminulina* and the LAD of *Dentoglobigerina altispira.*

Estimated age: 3.12–3.09 Ma; late Pliocene.

Discussion: The LAD of *D. altispira* reportedly coincides approximately with that of *Globorotalia multicamerata* (Berggren et al., 1995a), and the LADs of these species are within 1.5 m of each other at Leg 159 sites. The distinctiveness of both *D. altispira* and *G. multicamerata* makes the top of this zone easily recognizable.

Zone PL5

Definition: Interval between the LAD of *D. altispira* and the LAD of *Globorotalia miocenica.*

Estimated age: 3.09–2.30 Ma; late Pliocene.

Discussion: In addition to the ranges of the zone markers, the top of Zone PL5 is easily recognized by the reappearance of *Pulleniatina* in the Atlantic Ocean. Zone PL5 also contains the LAD of *Globorotalia puncticulata.*

Zone PL6

Definition: Interval between the LAD of *G. miocenica* and the LAD of *Globigerinoides facculifer fistulosus.*

Estimated age: 2.30–1.77 Ma; latest Pliocene.

Discussion: *Globigerinoides sacculifer fistulosus* is very rare in Leg 159 sediments and does not provide an adequate datum for recognition of the top of Zone PL6. Berggren et al. (1995a) note that the FAD of *G. truncatulinoides* falls close to the LAD of *G. sacculifer fistulosus* outside the southwestern Pacific. Unfortunately, *G. truncatulinoides* is also rare in all the sites examined here.

Zone Pt1

Definition: Interval between the LAD of *G. sacculifer fistulosus* and the Holocene.

Estimated age: 1.77–0.0 Ma; Pleistocene and Holocene.

Discussion: Typical markers of the Pleistocene such as the LAD of *G. sacculifer fistulosus,* the FAD of *G. truncatulinoides,* and the LAD of *Globorotalia tosaensis* are very rare in Leg 159 sediments making it difficult to establish an accurate foraminifer zonation.

SITE DESCRIPTIONS

Deep Ivorian Basin (Site 959)

Site 959 (3°37.70′N, 2°44.10′W, 2100 m water depth) is located on the landward edge of the Côte d'Ivoire-Ghana marginal ridge where the Romanche Fracture Zone intersects the African continent. The sequence is biostratigraphically complete, or nearly so, from the upper Oligocene to the Holocene at this site. Planktonic foraminifers were studied most intensely from the Pleistocene to middle Miocene interval of Hole 959B and from the uppermost lower Miocene section of Hole 959A. On the ship, about one sample per section was studied from these holes, in addition to core catchers that were examined throughout all holes. The distribution of planktonic foraminifers is given in Table 2 and the depths and ages of the major datums are listed in Table 3.

Preservation of planktonic foraminifers is moderate to good though the uppermost lower Miocene to Holocene. Dissolution has led to extensive fragmentation in the Pleistocene, the lowermost Pliocene, and the middle Miocene. Particularly notable is the almost complete dissolution of the inner whorls of some heavily encrusted species, such as *Globorotalia tumida* and *Neogloboquadrina dutertrei* in the Pleistocene and lower Pliocene. Dissolution renders these species almost useless for stable isotope studies in the Pleistocene even though the shells often appear to be intact from the outside. Despite strong fragmentation, many delicate-walled foraminifers are preserved in all but the most strongly dissolved samples. Partial pyritization is common throughout the Holocene to upper Miocene sequence. Preservation markedly deteriorates in the middle Miocene to upper Oligocene with many samples entirely barren, but barren zones alternate with intervals of moderate to good preservation down to the uppermost lower Miocene. Below Core 159-959A-23X (Zone N7), samples contain only very rare, dissolution-resistant species that are practically useless for detailed biostratigraphy. Accordingly, I have not attempted a detailed description of foraminifer assemblages below Core 159-959A-23X.

The Pleistocene is recognized by the LAD of *Globigerinoides sacculifer fistulosus* at the base of Zone Pt1 and the scattered presence of *Globorotalia truncatulinoides*. *Globorotalia tosaensis* was found in only one sample (159-959C-3H-3, 20–22.5 cm; 15.0 m below seafloor [mbsf]) so it is not possible to subdivide Zone Pt1 with planktonic foraminifers. Foraminifers are very abundant but are only moderately preserved with extensive fragmentation and dissolution of chamber interiors. All samples contain abundant glauconite. Common taxa include *Neogloboquadrina dutertrei, Globorotalia menardii, G. tumida, Globorotalia scitula, Pulleniatina obliquiloculata,* and *Globigerinoides sacculifer* from Sample 159-959B-2H-CC through 3H-7, 55–57 cm (5.0–24.05 mbsf).

Globigerinoides sacculifer fistulosus, whose LAD marks the Pliocene/Pleistocene boundary, has been found only sporadically and always in very small numbers. At Site 959, *G. sacculifer fistulosus* typically has only a single tubular extension from the last chamber and these tend to be short. The LAD of *G. sacculifer fistulosus* has been placed in Sample 159-959C-3H-3, 30–32.5 cm (15.11 mbsf), whereas the FAD of *G. truncatulinoides* has been located in Sample 159-959C-3H-2, 140–142 cm (14.7 mbsf), which suggests that the Pliocene/Pleistocene boundary lies between these two samples. Specimens referable to cf. *G. sacculifer fistulosus* occur as high as Sample 159-959C-3H-3, 10–12 cm (14.9 mbsf). These foraminifers have small bumps on the final sac-like chamber and often display the flared final chamber morphology typical of *G. sacculifer fistulosus.* I provisionally place the Pliocene/Pleistocene boundary at 14.8 mbsf in Hole 959C, midway between the LAD of *G. cf. fistulosus* and the FAD of *G. truncatulinoides.*

An apparently continuous record of the Pliocene was recovered at this site. The top of Zone PL5 is well defined by the LAD of *Globorotalia miocenica* and the Atlantic reappearance datum of *P. obliquiloculata* (both occur between Sample 159-959B-3H-CC and 159-959B-3H-7, 59–61 cm; ~24.05 mbsf). Zone PL5 contains a well-marked LAD for *Globorotalia puncticulata* and the local reappearance of right-coiled *Neogloboquadrina pachyderma.* Common species include *N. dutertrei,* heavily encrusted specimens of *G. crassaformis, Globorotalia triangula,* the common occurrence of *G. miocenica* and, less abundant, *Globorotalia pertenuis, Orbulina universa,* and *Neogloboquadrina acostaensis.*

The top of Zone PL4 is well marked by the LAD of *Dentoglobigerina altispira* in Sample 159-959B-5H-3, 59–61 cm (37.09 mbsf). This datum is also approximated by the LAD of *Globorotalia multicamerata* in Sample 159-959B-5H-4, 59–61 cm (38.59 mbsf). The LAD of *Sphaeroidinellopsis seminulina* occurs in Sample 159-959B-5H-7, 51–53 cm (43.01 mbsf) along with that of *Sphaeroidinellopsis kochi* and *Sphaeroidinellopsis paendehiscens,* which all mark the base of Zone PL4. Species characteristic of Zone PL4 include well-preserved *G. crassaformis, G. miocenica, G. triangula, G. sacculifer,* and *G. multicamerata.*

Samples 159-959B-5H-7, 51–53 cm, through 6H-6, 59–61 cm (43.01–51.09 mbsf), contain characteristic species of Zone PL3, including *D. altispira, Sphaeroidinellopsis* spp., *G. miocenica, N. acostaensis, Globoquadrina venezuelana, G. tumida, G. plesiotumida, N. dutertrei,* and the occasional occurrence of *Sphaeroidinella dehiscens* and *P. obliquiloculata. Sphaeroidinella dehiscens* develops its large secondary aperture in the upper part of Zone PL3, and occasional specimens with a very small secondary aperture occur as low as Zone PL1.

The last occurrence of *Globorotalia margaritae* is a well-defined datum in Sample 159-959B-6H-7, 54–57 cm (52.34 mbsf), and 52.22 mbsf in Hole 959C. The LAD of *G. margaritae* marks the top of Zone PL2. Species ranging in Zone PL2 include common *G. tumida, D. altispira,* and *G. sacculifer* and the less common occurrence of both *Pulleniatina primalis* and *S. kochi.* Samples throughout the zone are generally well preserved.

The base of Zone PL2 occurs just below Sample 159-959B-7H-5, 59–61 cm (59.09 mbsf), with the trace occurrence of *Globoturborotalita nepenthes* in Sample 159-959B-7H-6, 59–61 cm (60.59 mbsf). *Globoturborotalita nepenthes* becomes common in Sample 159-959B-7H-CC (62.09 mbsf), but is generally rare through the lower Pliocene. The LAD of *Globorotalia cibaoensis* occurs in Sample 159-959B-8H-CC (71.59 mbsf), but this species has a sufficiently discontinuous range as to make the recognition of the Subzone PL1a/PL1b boundary unreliable. In contrast, the FAD of *G. crassaformis* is very well defined in Sample 159-959B-7H-CC (62.09 mbsf and 63.42 mbsf in Hole 959C), and suggests the presence of Subzone PL1c of Berggren (1977).

The base of the Pliocene is marked by the first appearance of *G. tumida* in Sample 159-959B-10H-4, 59–61 cm (86.09 mbsf). The first specimens of *G. tumida* are clearly transitional to *Globorotalia plesiotumida* in that they have not developed the tear-drop axial pro-

Table 2. Distribution of planktonic foraminifers at Site 959. Interval between 0 and 166.5 mbsf from Hole 959B and between 161.7 and 212.68 mbsf from Hole 959A.

Foraminifer zone	Core, section, interval (cm)	Depth (mbsf)	Abundance	Preservation	*G. plesiotumida*	*G. merotumida*	*G. tumida*	*G. truncatulinoides*	*G. crassaformis*	*G. crassula*	*G. theyeri*	*G. inflata*	*G. triangula*	*G. puncticulata*	*G. cibaoensis*	*G. juanai*	*G. scitula*	*G. praescitula*	*G. panda*	*G. hirsuta*	*G. margaritae*	*G. miozea*	*G. limbata*	*G. menardii*
	159-959B-																							
Pt1	1H-CC	5	A	M			A	R	R			R					R							?
	2H-CC	14.5	A	M			R	R	F	R	R	R					R							?
PL6	3H-5, 55-57	21.05	A	M													R							
	3H-6, 55-57	22.55	A	M						F		F	R				F							
	3H-7, 55-57	24.05	A	G					F		F						R							
PL5	3H-CC	24.05	C	M			R			R							F							R
	4H-1, 59-61	24.59	A	G						R	R									F				F
	4H-2, 59-61	26.09	A	M					F	R	R		R				R			F				
	4H-3, 59-61	27.59	A	G							R		R				F			R				
	4H-4, 59-61	29.09	A	G					R				F	R			R			F				
	4H-5, 59-61	30.59	C	G					F					R										F
	4H-6, 59-61	32.09	C	G					F					R			F			F				
	4H-7. 60-62	33.6	A	G					F				R	F										
	4H-CC	33.6	A	G					R					R			F							
	5H-1, 59-61	34.09	A	G					R								R							
	5H-2, 59-61	35.59	C	G					R								R							
PL4	5H-3, 59-61	37.09	C	G			F										R			F				C
	5H-4. 59-61	38.59	A	G								R		R			R			F				C
	5H-5, 59-61	40.09	C	M			R		F		R													F
	5H-6, 59-61	41.59	A	M	R?		F		R					R						F				
PL3	5H-7, 51-53	43.01	A	G								F?					R			F				F
	5H-CC	43.01	A	G	R												F			R				
	6H-1, 59-61	43.59	C	M					F				R	R			R							
	6H-2, 59-61	45.09	A	G	F				R					R			R							F
	6H-3, 59-61	46.59	A	G	R		F		R								R							
	6H-4, 59-61	48.09	A	G					F					R			F							
	6H-5, 59-61	49.59	A	G	R				F								R							F
	6H-6, 59-61	51.09	A	G			F										R							C
PL2	6H-7, 54-57	52.54	A	M			F		F								R				R			
	6H-CC	52.54	A	G	F		C		F								R							F
	7H-1, 59-61	53.09	A	G	R		C		F												F			
	7H-2, 59-61	54.59	A	G	R		C		F								R				R			F
	7H-3, 59-61	56.09	A	G			C		F												R			F
	7H-4, 59-61	57.59	A	G	R				F								R				F			C
	7H-5, 59-61	59.09	A	G	R				F								R				R			
PL1B	7H-6, 59-61	60.59	C	G	R				R								R				R			C
	7H-7, 59-61	62.09	C	G	R		R		R								R				R			C
	7H-CC	62.09	A	G	C		F		R								R							F
	8H-1, 59-61	62.59	C	G	R																F			C
	8H-2, 59-61	64.09	A	G	F		R														F			C
	8H-3, 59-61	65.59	A	G																	F			F
	8H-4, 59-61	67.09	A	G	C												R				R			F
	8H-5, 59-61	68.59	C	G	F																R			C
	8H-6, 59-61	70.09	C	M													R				T			C
	8H-7, 59-61	71.59	A	G	R												R				R			C
PL1A	8H-CC	71.59	A	G	C										F		F				R			C
	9H-2, 59-61	73.59	A	G	R												R				R			F
	9H-3, 59-61	75.09	A	G	F		R										R				F			C
	9H-4, 59-61	76.59	A	G	C		F								R		R				F			C
	9H-5, 59-61	78.09	C	G	R		C										R				F			C
	9H-6, 59-61	79.59	A	G			F								R		R				F			A
	9H-7, 59-61	81.09	C	M											R		R				R			C
	9H-CC	81.09	C	M			F ?								F		R				F			A

Core, section, interval (cm)	*G. multicamerata*	*G. exilis*	*G. pertenuis*	*G. miocenica*	*G. pseudomiocenica*	*G. praemenardii*	*G. archeomenardii*	*F. lenguaensis*	*F. fohsi*	*F. "praefohsi"*	*F. peripheroacuta*	*F. birnageae*	*F. peripheroronda*	*D. altispira*	*G. venezuelana*	*G. woodi*	*G. prawoodi*	*G. apertura*	*G. decoraperta*	*G. rubescens*
159-959B-																				
1H-CC															R(R)					
2H-CC																				R
3H-5, 55-57																				
3H-6, 55-57																				
3H-7, 55-57																				
3H-CC				R																R
4H-1, 59-61			R	C																R
4H-2, 59-61			F	C														R		
4H-3, 59-61			F	C																R
4H-4, 59-61			F	C														R		
4H-5, 59-61			F	C																
4H-6, 59-61			F	F														R		
4H-7. 60-62			R	C	F															
4H-CC			A	C														R		F
5H-1, 59-61			F	C	F													R		
5H-2, 59-61			F	F	C														R	
5H-3, 59-61			F	R	C									R				R		
5H-4. 59-61	R		F											R				R	F	
5H-5, 59-61	C													R						
5H-6, 59-61	C													R	F			R	F	
5H-7, 51-53	C		R	R	F										C			R	R	
5H-CC	C	R	R	R										R				R		
6H-1, 59-61	F				C									R				R		
6H-2, 59-61	F													F	R			R		
6H-3, 59-61				R	C									F	F			R		
6H-4, 59-61	R				F									F	F			F	R	
6H-5, 59-61					F									F	R			R	R	
6H-6, 59-61														F	F				R	
6H-7, 54-57															F			R		
6H-CC															R					
7H-1, 59-61														C	R			R	R	
7H-2, 59-61	R													F	R			F	R	
7H-3, 59-61															R				R	
7H-4, 59-61														F	F				R	
7H-5, 59-61		F												R	R				R	
7H-6, 59-61														C	R			R		
7H-7, 59-61	R													F	R			R		
7H-CC															R					
8H-1, 59-61														R	R			F		
8H-2, 59-61														F	F			R	F	
8H-3, 59-61														F				R	F	
8H-4, 59-61														C	R			R	F	
8H-5, 59-61														F	R			F	F	
8H-6, 59-61														F	R			R		
8H-7, 59-61														R	F			F		
8H-CC														R	C				R	
9H-2, 59-61														F	F	R		F	R	
9H-3, 59-61														F	F			F		
9H-4, 59-61														F	F	R		F	F	
9H-5, 59-61														F	F	R		F		
9H-6, 59-61														F	R			R		
9H-7, 59-61														F	F	R		R		
9H-CC															F				R	

Core, section, interval (cm)	*G. druryi*	*G. nepenthes*	*G. bulloides*	*G. subquadratus*	*G. sacculifer*	*G. sacc. fistulosus*	*G. obliquus*	*G. bulloideeus*	*G. altiapertura*	*G. boli*	*G. extremus*	*G. ruber*	*G. seigliei*	*G. mitra*	*G. conglobatus*
159-959B-															
1H-CC					C							F			R
2H-CC			R		C					F		C			R
3H-5, 55-57			R		A					R		C			R
3H-6, 55-57			R		F							A			R
3H-7, 55-57			R		C							C			R
3H-CC			R		C	R				F	R	C			R
4H-1, 59-61			R		A	R				F		F			
4H-2, 59-61			R		F					F		C			R
4H-3, 59-61					C					F		C			R
4H-4, 59-61					C	R					F	C			
4H-5, 59-61			F		A						F	C			
4H-6, 59-61					C					R	F	C			R
4H-7. 60-62					C						F	C			
4H-CC			R		C					F	R	F			
5H-1, 59-61			R		A						F	C			R
5H-2, 59-61					A	CF.				F	F	A			R
5H-3, 59-61			R		A	R				R	F	A			
5H-4. 59-61					C		F			R		C			
5H-5, 59-61					C			R			C				
5H-6, 59-61			R		C	CF.					F	F			R
5H-7, 51-53					C					R		C			
5H-CC					C						F	F			
6H-1, 59-61			R		A					R	R	F			
6H-2, 59-61			R		C					R	R	R			R
6H-3, 59-61			F		C					R	F	C			R
6H-4, 59-61			R		C					R	R	C			R
6H-5, 59-61			R		A					R		F			
6H-6, 59-61			R		A		F				F				
6H-7, 54-57			F		C		F			R	F				
6H-CC					C		C								
7H-1, 59-61			F		A			R			F				
7H-2, 59-61			F		C		F			R	F				
7H-3, 59-61			C		C		F			R					
7H-4, 59-61					C		F				C				
7H-5, 59-61			F		C		F				F				F
7H-6, 59-61		T			C		C				R				R
7H-7, 59-61			R		C		C				F				R
7H-CC		C			C		C				C				
8H-1, 59-61		R	R		C		C			F	C				R
8H-2, 59-61		T	F		C		C			F	C				R
8H-3, 59-61		R	F		C		C			F	F				R
8H-4, 59-61		R			C		C			F	F				
8H-5, 59-61		R			F		A			R	F				R
8H-6, 59-61		R			A		R			R	C				R
8H-7, 59-61		R	F		C		C			R	F				
8H-CC		F	F		C		A			F	R				
9H-2, 59-61		R			C		R			R	C				R
9H-3, 59-61		R			C					R	F				R
9H-4, 59-61		R			C		C			R	F		R		
9H-5, 59-61		F	F		C		C			F					R
9H-6, 59-61		F			A		F			R	F				R
9H-7, 59-61		R	R		F		F				F				
9H-CC		R			A		C								

Notes: Abundance: A = abundant, C = common, F = few, R = rare, T = trace; Preservation: G = good, M = moderate, P = poor, B = barren as described in the text. Shaded bars = dissolved samples; ? = uncertain identification of possibly reworked specimens.

Table 2 (continued).

Foraminifer zone	Core, section, interval (cm)	Depth (mbsf)	Abundance	Preservation	*G. mayeri*	*G. siakensis*	*G. continuosa*	*N. acostaensis*	*N. continuosa*	*N. humerosa*	*N. dutertrei*	*N. pachyderma* (r)	*N. pachyderma* (l)	*N. nympha*	*S. disjuncta*	*S. kochi*	*S. seminulina*	*S. paendeshicens*	*S. deshicens*	*P. obliquiloculata*	*P. primalis*	*P. praecursor*	*O. universa*	*O. bilobata*	*O. suturalis*	*P. glomerosa*	*P. sicana*	*G. bisphericus*	*G. glutinata*	*G. uvula*	*Tenuitella sp.*	*G. insueta*	*G. varabilis*	*G. praesiphonifera*	*G. aequilateralis*	*G. pseudoobeasa*	*G. obesa*	*G. hexagona*	*Cl. bermudezi*	*G. calida*	*H. digitata*	*B. praedigitata*	*G. dehiscens*	*C. nitida*
	159-959B-																																											
Pt1	1H-CC	5	A	M							A									R			F						F						R			R		R	R			
	2H-CC	14.5	A	M							A	F							F	R			R						F						R			R						
PL6	3H-5, 55-57	21.05	A	M							A	C							F				F						F					R	R						R			
	3H-6, 55-57	22.55	A	M							A	F							F	R			F						R						R									
	3H-7, 55-57	24.05	A	G				F			A	F							F	F			R						F						R									
PL5	3H-CC	24.05	C	M							A	F							F				F												R									
	4H-1, 59-61	24.59	A	G				F			A								F				R						F						R									
	4H-2, 59-61	26.09	A	M				F			A	F											F						C						R									
	4H-3, 59-61	27.59	A	G				F			A	R											F						F						R						R			
	4H-4, 59-61	29.09	A	G				F		F	C												F						F						R									
	4H-5, 59-61	30.59	C	G				F			C								R				F						F						R						R			
	4H-6, 59-61	32.09	C	G				C			C								R										F						F							R		
	4H-7. 60-62	33.6	A	G						R	C								R				F	R													F							
	4H-CC	33.6	A	G				C		R	A												F						F						F									
	5H-1, 59-61	34.09	A	G							A								F				F						R						F						R	R		
	5H-2, 59-61	35.59	C	G				R			A						T		F				R						F	R					R							R		
PL4	5H-3, 59-61	37.09	C	G							A								R										F						R			F						
	5H-4. 59-61	38.59	A	G				R			C								F				F												F									R
	5H-5, 59-61	40.09	C	M				F		R	A												R						C						F			F				R		
	5H-6, 59-61	41.59	A	M				C			A												R																					
PL3	5H-7, 51-53	43.01	A	G				R			A					R	R	F	F				R						F						R			R						
	5H-CC	43.01	A	G							A					R							F												R			F						
	6H-1, 59-61	43.59	C	M				F			A						R		R		R		R						F						R			R						
	6H-2, 59-61	45.09	A	G						F	A					R	R		R				R						F						R			R						R
	6H-3, 59-61	46.59	A	G						F	A					R	F												F						F			F						F
	6H-4, 59-61	48.09	A	G							A					R	F			R	F		F						F						R			R						
	6H-5, 59-61	49.59	A	G				R			A					R	R	R	R				R						F						F			R					R	R
	6H-6, 59-61	51.09	A	G							C						F	R					R						F						R			R						R
PL2	6H-7, 54-57	52.54	A	M							A					R		R		R	F		R												R			R						
	6H-CC	52.54	A	G							C							R	R				F												R	R								
	7H-1, 59-61	53.09	A	G							A							F		R	F								R					R	F			R						R
	7H-2, 59-61	54.59	A	G						R	C						F	R	R				R						F					R	R			R						
	7H-3, 59-61	56.09	A	G						F	C					R	F		R		F	R	R						T						F			R						
	7H-4, 59-61	57.59	A	G				F		F	F					R		R			F		F												R		R	F						
	7H-5, 59-61	59.09	A	G				R		C	C						F				F		F						R						R			R						
PL1B	7H-6, 59-61	60.59	C	G						C	C					F	F		R				R						R						R		R	R						
	7H-7, 59-61	62.09	C	G							C					F	R		R		F		R						R						R		R	R						R
	7H-CC	62.09	A	G							F					R	F	F			R		F												R			F						
	8H-1, 59-61	62.59	C	G				F			C					F	R	R	R		F								R						F			R				R		
	8H-2, 59-61	64.09	A	G				F			C		R			F	R	F					F						F	R					R		R	F						R
	8H-3, 59-61	65.59	A	G				F			A		R					F	R				F						R						R	R		R						
	8H-4, 59-61	67.09	A	G				F			C					F	R		R				F												F			F						R
	8H-5, 59-61	68.59	C	G				F			A					F	F		R										F						R			F						
	8H-6, 59-61	70.09	C	M				F			A					F		F	R				R	R											R			R						
	8H-7, 59-61	71.59	A	G				R			F					F		F	R				F						R						R		R							R
PL1A	8H-CC	71.59	A	G				F			R					F	C	C	R				F												F		R							
	9H-2, 59-61	73.59	A	G				F			F		R			F		F	R				F						F						F									R
	9H-3, 59-61	75.09	A	G				F			C		R				R	F					F	R					F						R		R	F						F
	9H-4, 59-61	76.59	A	G				F					R			F	R						R						F						F	R	R							R
	9H-5, 59-61	78.09	C	G				F			F					R	R	F					F												R								F	R
	9H-6, 59-61	79.59	A	G				R			C					F	R	F	R																F			F					F	R
	9H-7, 59-61	81.09	C	M				R			C					R	F	F					R												R			F						
	9H-CC	81.09	C	M						F						R	C		_					R											R									

Table 2 (continued).

Foraminifer zone	Core, section, interval (cm)	Depth (mbsf)	Abundance	Preservation	*G. plesiotumida*	*G. merotumida*	*G. tumida*	*G. truncatulinoides*	*G. crassaformis*	*G. crassula*	*G. theyeri*	*G. inflata*	*G. triangula*	*G. puncticulata*	*G. cibaoensis*	*G. juanai*	*G. scitula*	*G. praescitula*	*G. panda*	*G. hirsuta*	*G. margaritae*	*G. miozea*	*G. limbata*	*G. menardii*	*G. multicamerata*	*G. exilis*	*G. pertenuis*	*G. miocenica*	*G. pseudomiocenica*	*G. praemenardii*	*G. archeomenardii*	*F. lenguaensis*	*F. fohsi*	*F. "praefohsi"*	*F. peripheroacuta*	*F. birnageae*	*F. peripheroronda*	*D. altispira*	*G. venezuelana*	*G. woodi*	*G. prarwoodi*	*G. apertura*	*G. decoraperta*	*G. rubescens*	*G. druryi*	*G. nepenthes*	*G. bulloides*	*G. subquadratus*	*G. sacculifer*	*G. sacc. fistulosus*	*G. obliquus*	*G. bulloideeus*	*G. altiapertura*	*G. bolli*	*G. extremus*	*G. ruber*	*G. seigliei*	*G. mitra*	*G. conglobatus*
PL1A	10H-1, 59-61	81.59	C	M	R										R		R				R			C														F	R			F	R				F		F		C				F				
	10H-2, 59-61	83.09	C	M	R										R		R				F			C															F	R						F			C		F			R	C				
	10H-3, 59-61	84.59	C	M	F		R?								R		F				F			C																									F		C								
	10H-4, 59-61	86.09	C	M	F		R?								R						R			C														F	F							F			C						C				
N17	10H-5, 59-61	87.59	C	G											R		F				C			C																		F							C		C			F	C				
	10H-6, 59-61	89.09	A	G	F												R				F			C														C	F							R			C		C				C				
	10H-7, 59-61	90.59	A	G											R						C			F														F								R			A		C				C				
	10H-CC	90.59	C	G											F									F														R	R							C					C								
	11H-1, 59-61	91.09	C	M	R										R						R			F																		F									C				C				
	11H-2, 59-61	92.59	C	G	F										F						F																		F							R			C		C				A				
	11H-3, 59-61	94.09	C	G	F										F	R								C																											F				F				
	11H-4, 59-61	95.59	C	G	F										C									C														F	F			F							C		F				F		R		
	11H-5, 59-61	97.09	C	G											C									C														F											C		F				F		R		
	11H-6, 59-61	98.59	C	G	F										C	F					?			F														F	F								R		C		C				F				
	11H-7, 59-61	100.1	C	G	F										F	R								F														F	F				R				R		C		C								
	11H-CC	100.1	C	G	F										R		F							F														C	F										C		C				F				
	12H-1, 59-61	100.6	C	M	F										C	R								F														F	F										C		C				F				
	12H-2, 59-61	102.1	C	M	R	R									F	R								F														F	F							R			C		C				C				
	12H-3, 59-61	103.6	C	G	F	R									F	R								F														R								R	R		C						C				
	12H-4, 59-61	105.1	A	G	F										F	R								C														F	F							R	R		C		C				F				
	12H-5, 59-61	106.6	A	G											F								R	T														F	R							R	R		C						R				
	12H-6, 59-61	108.1	A	G	F										F	F	R						R	C															R							F	R				C				R				
	12H-CC	109.5	C	G	P																		R	P														P											P		P				P				
	13H-1, 59-61	110.1	C	M	F	F									F								F															F	R										C		C								
	13H-2, 59-61	111.6	F	M		F											R						F															R	R							R					F				F				
	13H-3, 59-61	113.1	F	M		R									R		R							R														F											C		C				F				
	13H-4, 59-61	114.6	C	M	R												R						R															F	R										F		C				F		R		
	13H-5, 59-61	116.1	C	M	F										F		R																					F									F		C		C						R		
	13H-6, 59-61	117.6	F	M																			F																								F				C				R		R		
	13h-7, 59-61	119.1																																																									
	13H-CC	119.1	C	G	F	R									R									C														F	F										C						F				
	14H-1, 59-61	119.6	C	G	R	F									R		R																					F											C		C	F			R		R		
	14H-2, 59-61	121.1	C	G	F										F																							C									R				C				F				
	14H-3, 59-61	122.6	F	P																																			C							R			R		F								
	14H-4, 59-61	124.1	A	G	R	R											R							R														F	C							F	R		C		C				F				
	14H-5, 59-61	125.6	C	M	F	F											R																					F	F										C		C				R				
	14H-6, 59-61	127.1	A	G		R											R																					F	F							C			C		C								
	14H-CC	128.5	A	G													R							R														R	A							A			R										
	15H-2, 59-61	130.6	A	G	R	F									R	R	F							R															F	R		R					R		C		C	R			R				
N16	15H-3, 59-61	132.1	A	M		F									R		F				?			R														F	F			R				R	R		A		F								
	15H-4, 59-61	133.6	A	G		R									F		R						R															R	F							F			C		C						R		
	15H-5, 59-61	135.1	A	G		F									R	R	R							F														F	F	C						R	R		C		C								
	15H-6, 59-61	136.6	A	M		R									R		R						R															C		C		R				R			C		F								
	15H-7, 57-59	138.1	A	M		T											R							F								R						C	C							R			A		F								
	15H-CC	138.1	A	G													F							F								R							A	R						F			C										
	16H-2, 60-62	140.1	A	G		R											R						R	F								R						F	C	R		R	R			R	R		C		C			R					
	16H-3, 59-61	141.6	C	G	T	R											R						F									R							F	R		R				F			C		C			R					
	16H-4, 59-61	143.1	C	M																			F									R						C	F							F	R		C		F								
N15	16H-5, 59-61	144.6	C	M		R																	F									F							F							F			C		R								
	16H-6, 59-61	146.1	C	M		R																										F							C							F			C										
	16H-7, 59-61	147.6	C	M		R																	F																C							R			C										
	16H-CC	147.6	A	G													R							R														F	F							A			C		F								

Table 2 (continued).

Foraminifer zone	Core, section, interval (cm)	Depth (mbsf)	Abundance	Preservation	*G. mayeri*	*G. siakensis*	*G. continuosa*	*N. acostaensis*	*N. continuosa*	*N. humerosa*	*N. dutertrei*	*N. pachyderma* (r)	*N. pachyderma* (l)	*N. nympha*	*S. disjuncta*	*S. kochi*	*S. seminulina*	*S. paendeshicens*	*S. deshicens*	*P. obliquiloculata*	*P. primalis*	*P. praecursor*	*O. universa*	*O. bilobata*	*O. suturalis*	*P. glomerosa*	*P. sicana*	*G. bisphericus*	*G. glutinata*	*G. uvula*	*Tenuitella* sp.	*G. insueta*	*G. varabilis*	*G. praesiphonifera*	*G. aequilateralis*	*G. pseudoobeasa*	*G. obesa*	*G. hexagona*	*Cl. bermudezi*	*G. calida*	*H. digitata*	*B. praedigitata*	*G. dehiscens*	*C nitida*
PL1A	10H-1, 59-61	81.59	C	M				F		R	C						R	F											F					R										
	10H-2, 59-61	83.09	C	M				F		R	C					R	F						F						R						R			R						R
	10H-3, 59-61	84.59	C	M				F		R	A																		R															
	10H-4, 59-61	86.09	C	M												F	F						C						R									R						
N17	10H-5, 59-61	87.59	C	G												F	F						C						R						R			F						
	10H-6, 59-61	89.09	A	G				C									C						C	R					R									F						R
	10H-7, 59-61	90.59	A	G				C								F	F						F						R						F			F						F
	10H-CC	90.59	C	G				C		C						F	F	F					F						R									C						R
	11H-1, 59-61	91.09	C	M				F																					R															
	11H-2, 59-61	92.59	C	G				C								R	F						F						F									R						
	11H-3, 59-61	94.09	C	G																									R															
	11H-4, 59-61	95.59	C	G													C	F					F	R					R														F	
	11H-5, 59-61	97.09	C	G												F	C	F											R						F		R	F					F	R
	11H-6, 59-61	98.59	C	G												R	F						F						R									F					F	
	11H-7, 59-61	100.1	C	G												R	R							R					R						R		F	R						R
	11H-CC	100.1	C	G													F						C	R					R						R	F		R						
	12H-1, 59-61	100.6	C	M												R	F						F	R					R						R			R					F	R
	12H-2, 59-61	102.1	C	M				C		C							R						F						R						R			R					F	R
	12H-3, 59-61	103.6	C	G						F						R	F						F	R					R								F	R						
	12H-4, 59-61	105.1	A	G				C								R	F						F	R					R									R					F	
	12H-5, 59-61	106.6	A	G				C									F						F	F					R									F						R
	12H-6, 59-61	108.1	A	G				C		F						R	F						F	R					R								F	F				R		
	12H-CC	109.5	C	G												P	P						P						R															
	13H-1, 59-61	110.1	C	M				R		T						R	R						F	R					R						R		R	F					F	
	13H-2, 59-61	111.6	F	M				R		R							R												R						R			R						
	13H-3, 59-61	113.1	F	M				R															R						R									R					C	
	13H-4, 59-61	114.6	C	M				F								R	R						F						R						R		R	R					F	R
	13H-5, 59-61	116.1	C	M																									R						R		R	F						
	13H-6, 59-61	117.6	F	M				F															F	R					R	R					R		R						C	R
	13h-7, 59-61	119.1																											R															
	13H-CC	119.1	C	G													F						F						R														R	
	14H-1, 59-61	119.6	C	G				F								R							R	R					R	R												R		
	14H-2, 59-61	121.1	C	G				C								R	R						F						R					F			F	R				R		R
	14H-3, 59-61	122.6	F	P				R								F	F						C						R								R							
	14H-4, 59-61	124.1	A	G				C							R	F	R						R						R						R		F							R
	14H-5, 59-61	125.6	C	M				F								F	F						F	R					R									R					F	R
	14H-6, 59-61	127.1	A	G												F	R						F						R						R			R					F	R
	14H-CC	128.5	A	G				F								F	F						F						R									C						
	15H-2, 59-61	130.6	A	G				C		R						R	R						C	R					R					R	R									R
N16	15H-3, 59-61	132.1	A	M				R		R						F	F						F	R					R	R					R		R						F	
	15H-4, 59-61	133.6	A	G				F		R						R	R						F						R								R	R					C	F
	15H-5, 59-61	135.1	A	G						R	?					F	F						C						R					F	F		R	F					C	
	15H-6, 59-61	136.6	A	M				F								R	R						F						R								R	F					R	
	15H-7, 57-59	138.1	A	G				R								F	F						F						R					R		F	R	F						
	15H-CC	138.1	A	G				C								F	F												R							R		F						
	16H-2, 60-62	140.1	A	G				F								R	F						C	R					R							R		F					C	
	16H-3, 59-61	141.6	C	G				F								R							F						R						R	R	F	F				R		
	16H-4, 59-61	143.1	C	M				R		F						R	F						F						R								F							R
N15	16H-5, 59-61	144.6	C	M												R	R						R															F						
	16H-6, 59-61	146.1	C	M												F							R															F						
	16H-7, 59-61	147.6	C	M												C	C						F															F						
	16H-CC	147.6	A	G												R	F						C															F						R

Table 2 (continued).

Foraminifer zone	Core, section, interval (cm)	Depth (mbsf)	Abundance	Preservation	G. plesiotumida	G. merotumida	tumida	G. truncatulinoides	G. crassaformis	G. crassula	G. theyeri	G. inflata	G. triangula	G. puncticulata	G. cibaoensis	G. juanai	G. scitula	G. praescitula	G. panda	G. hirsuta	G. margaritae	G. miozea	G. limbata	G. menardii	G. multicamerata	G. exilis	G. pertenuis	G. miocenica	G. pseudomiocenica	G. praemenardii	G. archeomenardii	F. lenguaensis	F. fohsi	F. "praefohsi"	F. peripheroacuta	F. birnageae	F. peripheroronda	D. altispira	G. venezuelana	G. woodi	G. prarwoodi	G. apertura	G. decoraperta	G. rubescens	G. druryi	G. nepenthes	G. bulloides	G. subquadratus	G. sacculifer	G. sacc. fistulosus	G. obliquus	G. bulloideeus	G. altiapertura	G. bolli	G. extremus	G. ruber	G. seigliei	G. mitra	G. conglobatus
N15	17H-1, 59-61	148.1	C	M																			R									F							C							C			C					F					
	17H-2, 8-10	149.5	A	G													R						R							R								F	C	F						F			C										
N14	17H-2, 59-61	149.6	A	M													R						R									R						C	C	F						F	R												
	17H-3, 59-61	151.1	F	M																			R							R		R							C							F								C					
	17H-4, 59-61	152.6	A	G																												R						C	C										F									R	
	17H-5, 59-61	154.1	C	M													R					R		R						R								F	C						R				C		F								
N13	17H-6, 59-61	155.6	F	G																			R															F	F										C		C								
	17H-7, 59-61	157.1	F	M																										R									C			R							R		C								
	17H-CC	157.1	A	G													R		R					C						F								C	C								R		C		C								
	18H-1, 59-61	157.6	R	P																										R									C			R																	
	18H-2, 59-61	159.1	A	G														R						R						F		F						F				F	F				F		C										
	18H-3, 59-61	160.6	C	M																				R						F			F					C	R								R	C	C										
	18H-4, 59-61	162.1	F	M																										F		C	F						F			F						F	C		F							F	
N12	18H-5, 59-61	163.6	C	M														R														R	R					F	F										C										
	18H-6, 59-61	165.1	R	P																														R				F	F										R		F								
	18H-7, 59-61	166.6	C	G																												R	F	R					F								R	F	C									F	
	18H-CC	166.5	F	M														R												R			C					F	C	C								F	A										
	159-959A-																																																									
	18H-1, 57-62	161.7	A	G																										R		R	R					R	R	F		R	R				R	C	F		F			F				R	
	18H-2, 55-60	163.2	A	G														R														R	R					F	R								F		F		F			F				R	
	18H-3, 55-60	164.7	F	M														R														F	R					F	R						R				F		R			R					
	18H-4, 45-50	166.1	C	M														R												R		R	R						R	R								R	C		F			R				R	
N12	18H-5, 57-62	167.7	A	G																		T											R	R				F	R	F			R						C		F			F				R	
	18H-6, 56-61	169.2	F	M														R				T								T			R	R					R										F					F					
	18H-7, 55-60	170.7	C	G														R												R			R	F					R	F							R	F	C		C			F				R	
	18H-CC	170.7	A	G																		R								R	R		R					R	R	F							R		C		C							R	
	19H-1, 56-60	171.2	R	M																										R				F				F	R								R	R	C		C			R					
	19H-2, 56-60	172.7	A	G																										R			T	F				R	R	R							F		C		F								
	19H-3, 56-61	174.2	R	P																		T												F	R				R				R						F										
N11	19H-4, 55-60	175.7	B	P																																																							
	19H-5, 55-60	177.2	B	P																																																							
	20X-1, 57-62	180.7	A	M														R												R				R	F				R	R							R		C										
	20X-2, 57-62	182.2	C	P																										R					R		F		R								R		C										
N10	20X-3, 57-62	183.7	C	P																										R					R		F		R								R		F										
	20X-4, 56-61	185.2	C	P																											R						R		R										C										
	20X-5, 57-62	186.7	A	M																											F						R		R								R		C										
	20X-6, 57-62	188.2	A	P																											R						R		R	R									F										
	21X-1, 55-58	189.7	F	M																											R						C	R		R							F	R	C									R	
	21X-2, 57-60	191.2	C	M														R													R					R	R	R	R									R	C										
N8	21X-3, 57-59	192.7	F	M																										R							F	R											C										
	21X-4, 56-58	194.2	F	M																											R						F		R								R		C									R	
	21X-5, 54-57	195.6	F	M														R													R					R	F	R		R								R	C										
	21X-6, 57-59	197.2	F	M														R													R					R	F		R		R								C				R						
	22X-1, 54-57	199.1	A	G														R													R					F	C			R	R							F	C				R						
	22X-2, 50-58	200.6	A	G														R																			F			F	R							F	C									R	
	22X-3, 56-59	202.2	C	G														R																		R	F				F								C										
	22X-4, 57-59	203.7	A	G														R																		R	F			R	F							F	C										
	22X-5, 57-59	205.2	A	G																																R	F		R	R	R							F	C				R						
	22X-6, 43-46	206.5	C	G																											T					R	C				R								C				R					F	
	22X-7, 55-57	207.7	R	P																			T														R												F										
	23X-1, 54-58	208.1	C	M														R																		R	F	R		F								F	F										
N7	23X-2, 58-62	209.7	C	P														R																			F				F								R										
	23X-3, 60-64	211.2	C	G														R																		R	F				R							F											
	23X-4, 58-61	212.7	R	P																																																							

Table 2 (continued).

Foraminifer zone	Core, section, interval (cm)	Depth (mbsf)	Abundance	Preservation	*G. mayeri*	*G. siakensis*	*G. continuosa*	*N. acostaensis*	*N. continuosa*	*N. humerosa*	*N. dutertrei*	*N. pachyderma* (r)	*N. pachyderma* (l)	*N. nympha*	*S. disjuncta*	*S. kochi*	*S. seminulina*	*S. paendeshicens*	*S. deshicens*	*P. obliquiloculata*	*P. primalis*	*P. praecursor*	*O. universa*	*O. bilobata*	*O. suturalis*	*P. glomerosa*	*P. sicana*	*G. bisphericus*	*G. glutinata*	*G. uvula*	*Tenuitella* sp.	*G. insueta*	*G. varabilis*	*G. praesiphonifera*	*G. aequilateralis*	*G. pseudoobeasa*	*G. obesa*	*G. hexagona*	*Cl. bermudezi*	*G. calida*	*H. digitata*	*B. praedigitata*	*G. dehiscens*	*C nitida*
N15	17H-1, 59-61	148.1	C	M						R						F	C						F												R			C						
	17H-2, 8-10	149.5	A	G	C	R										F							F											R			R	F					F	
N14	17H-2, 59-61	149.6	A	M												F	C						C		R									R				C					C	
	17H-3, 59-61	151.1	F	M												R	C						C											R	R			R					C	
	17H-4, 59-61	152.6	A	G	R											F	F						F											F				F	R				C	
	17H-5, 59-61	154.1	C	M	F									R		R	R						F											R			R	F	F					
N13	17H-6, 59-61	155.6	F	G	R					F				R	R	F							F											R				R	F					
	17H-7, 59-61	157.1	F	M	F									F	R	R									R													F	F				R	
	17H-CC	157.1	A	G	A											R	F						F		C				R					F		F		R					F	
	18H-1, 59-61	157.6	R	P	F																				F																		C	
	18H-2, 59-61	159.1	A	G	C										F	R							C		R				F	R				F				R	R				C	
	18H-3, 59-61	160.6	C	M	C										F								F		C				F				R					R	R				C	
	18H-4, 59-61	162.1	F	M	C																				A				F	F			R	R				R	R				F	
N12	18H-5, 59-61	163.6	C	M	C																				R								R					R						
	18H-6, 59-61	165.1	R	P	F																				R								R					F					F	
	18H-7, 59-61	166.6	C	G	F																				C								R				R							
	18H-CC	166.5	F	M	A											R	R								F				R				R	R			R							
	159-959A-																																										R	
	18H-1, 57-62	161. 7	A	G	F		R								R										R				F	R			F	R				R						
	18H-2, 55-60	163. 2	A	G	C		R								R								R		R				R	R		cf.	R	R			R	R						
	18H-3, 55-60	164. 7	F	M	F		R																	R	R				R	R		cf.	F	R									R	
	18H-4, 45-50	166. 1	C	M	C											R							R		R				R									R						
N12	18H-5, 57-62	167. 7	A	G	C		R								R	R																	R	R				F						
	18H-6, 56-61	169. 2	F	M	F		R								F								T										F					F						
	18H-7, 55-60	170. 7	C	G	F										R								R		R				R	R		cf.		R				F						
	18H-CC	170.7	A	G	F		F								R	R							R		R				F			cf.	R	F				F						
	19H-1, 56-60	171. 2	R	M	C																		R						R	R				R				R	R					
	19H-2, 56-60	172. 7	A	G	C										R	R													F	R		cf.	R	R										
	19H-3, 56-61	174.2	R	P																													R											
N11	19H-4, 55-60	175. 7	B	P																																								
	19H-5, 55-60	177. 2	B	P																																								
	20X-1, 57-62	180. 7	A	M	R																				R								R	R									F	
	20X-2, 57-62	182. 2	C	P	R																																						F	
N10	20X-3, 57-62	183. 7	C	P	R																													F									F	
	20X-4, 56-61	185. 2	C	P	R																									R		cf.		C				R					F	
	20X-5, 57-62	186. 7	A	M	R																						R			R			R					R						
	20X-6, 57-62	188. 2	A	P	R																						R						R	F					R				R	
	21X-1, 55-58	189. 7	F	M	F																					R	R		R	R			R						R				F	
	21X-2, 57-60	191. 2	C	M			R																			R	F		R			cf.		F					R				F	
N8	21X-3, 57-59	192. 7	F	M																							R		R				R	F									R	
	21X-4, 56-58	194. 2	F	M	F		R																				R						R	F									R	
	21X-5, 54-57	195.6	F	M			R																				R		R		R		R	F										
	21X-6, 57-59	197. 2	F	M	R																					R	F							F									R	
	22X-1, 54-57	199. 1	A	G																							F		R		R	cf.	R	F				R	R					
	22X-2, 50-58	200. 6	A	G																							R	F	R		R	T	R	F					R				R	
	22X-3, 56-59	202. 2	C	G																								R	R		R	R	R						R				R	
	22X-4, 57-59	203. 7	A	G			R																				R	F					R	C					R				R	
	22X-5, 57-59	205. 2	A	G																								F				T	F	F					R				R	
	22X-6, 43-46	206. 5	C	G																								F		T			R	F				T	R				R	
	22X-7, 55-57	207. 7	R	P	R																							R															R	
	23X-1, 54-58	208. 1	C	M	R		R																					F			R		R	F				R	R				R	
N7	23X-2, 58-62	209. 7	C	P	F																							F																
	23X-3, 60-64	211. 2	C	G	F				R																			F			R		R	F					R					
	23X-4, 58-61	212. 7	R	P																																								

Table 3. Distribution of planktonic foraminifers at Site 959.

Datum	Age (Ma)	Top (Hole, core, section, interval)	Base (Core, section, interval)	Top (mbsf)	Base (mbsf)	Average depth (mbsf)
FAD *Globorotlaia truncatulinoides*	2	959C-3H-2, 140-142 cm	3H-3, 10-12 cm	14.7	14.9	14.8
LAD ***Globigerinoides sacculifer fistulosus***	1.74	959C-3H-2, 140-142 cm	3H-3, 10-12 cm	14.7	14.9	14.8
Re-appearance of *Pulleniatina obliquiloculata*	2.3	959B-3H-7, 55-57 cm	3H-CC	24.05	24.05	24.05
LAD ***Globorotalia miocenica***	2.3	959B-3H-7, 55-57 cm	3H-CC	24.05	24.05	24.05
LAD ***Dentogloboquadrina altispira***	3.05	959B-5H-2, 59-61 cm	5H-3, 59-61 cm	35.59	37.09	36.34
LAD *Globorotalia multicamerata*	3.09	959B-5H-3, 59-61 cm	5H-4, 59-61 cm	37.09	38.59	37.84
LAD ***Sphaeroidinellopsis* spp.**	3.12	959B-5H-6, 59-61 cm	5H-7, 51-53 cm	41.59	43.01	42.3
LAD *Pulleniatina primalis*	3.65	959B-5H-CC	6H-1, 59-61 cm	43.01	43.59	43.3
LAD *Pulleniatina obliquiloculata*	3.95	959B-6H-3, 59-61 cm	6H-4, 59-61 cm	46.59	48.09	47.34
LAD ***Globorotalia margaritae***	3.58	959B-6H-6, 59-61 cm	6H-7, 54-57 cm	51.09	52.54	51.82
LAD ***Globotruborotalia nepenthes***	4.2	959B-7H-5, 59-61 cm	7H-6, 59-61 cm	59.09	60.59	59.84
FAD *Globorotalia crassaformis*	4.5	959B-7H-7, 59-61 cm	7H-CC	62.09	62.09	62.09
LAD *Globorotalia cibaoensis*	4.6	959B-8H-7, 59-61 cm	8H-CC	71.59	71.59	71.59
FAD ***Globorotalia tumida***	5.59	959B-10H-4, 59-61 cm	10H-5, 59-61 cm	86.09	87.59	86.84
FAD *Sphaeroidinella dehiscens*	5.2	959B- 9H-6, 59-61 cm	9H-7, 59-61 cm	79.59	81.09	80.34
FAD *Globorotalia margaritae*	6.4	959C-11H-5, 20-22 cm	11H-5, 40-42 cm	94.01	94.22	94.11
FAD ***Globorotalia plesiotumida***	8.3	959B-15H-2, 59-61 cm	15H-3, 59-61 cm	130.59	132.09	131.34
FAD *Globigerinoides extremus*	8.3	959B-15H-2, 59-61 cm	15H-3, 59-61 cm	130.59	132.09	131.34
FAD ***Neogloboquadrina acostaensis***	10	959B-16H-4, 59-61 cm	16H-5, 59-61 cm	143.09	144.59	143.84
FAD ***Globotruborotalia nepenthes***	10.8	959B-17H-3, 59-61 cm	17H-4, 59-61 cm	151.09	152.59	151.84
LAD ***Paragloborotalia mayeri***	10.3	959B-17H-1, 59-61 cm	17H-2, 8-10 cm	148.09	149.51	148.84
LAD ***Globorotalia fohsi***	11.8	959B-18H-2, 59-61 cm	18H-3, 59-61 cm	159.09	160.59	159.84
FAD *Globorotalia lenguaensis*	12.3	959A-18H-4, 45-50 cm	18H-5, 57-62 cm	166.05	167.67	166.86
FAD ***Globorotalia fohsi***	13.5	959A-19H-2, 56-60 cm	19H-3, 56-60 cm	172.66	174.16	173.41
FAD ***Globorotalia "praefohsi"***	14	959A-20X-1, 57-62 cm	20X-2, 57-62 cm	180.67	182.17	181.42
FAD ***Globorotalia peripheroacuta***	14.7	959A-20X-3, 57-62 cm	20X-2, 57-62 cm	180.67	182.17	181.42
FAD *Praeorbulina glomerosa*	16.1	959A-22X-1, 54-57 cm	22X-2, 50-58 cm	199.14	200.6	199.87
FAD ***Praeorbulina sicana***	16.5	959A-22X-4, 57-59 cm	22X-5, 57-59 cm	203.67	205.17	204.42

Note: Boldfaced species = those defining biozones.

file typical of *G. tumida*. However, they do have a distinctly tumid final chamber that is somewhat more pointed in spiral view than the quadrate profile of the last chamber of *G. plesiotumida.* The first appearance of *S. dehiscens* has also been used to approximate the Miocene/Pliocene boundary, but I have found the FAD of *S. dehiscens* occurs 5.4 m above the FAD of *G. tumida* in Hole 959C despite intensive searching for specimens of *S. dehiscens* with the minute secondary aperture typical of the first representatives of this species. Conversely, the FAD of *G. margaritae* that has often been described as falling close to the Miocene/Pliocene Boundary occurs ~8.2 m below the FAD of *G. tumida* in Hole 959C. It is notable that an interval of intense dissolution and fragmentation occurs between 83.61 and 87.81 mbsf in Hole 959C, which may reflect the Messinian event (Norris, Chap. 40, this volume). Use of the top of the dissolution interval as a marker for the base of the Pliocene would suggest that the Miocene/Pliocene boundary should be placed at 83.5 mbsf and above the FAD of *G. tumida* in agreement with the time scale of Berggren et al. (1995a, 1995b).

For much of the upper Miocene section, the age constraints provided by planktonic foraminifers are less well defined than the datums in the Pliocene. The LAD of *Fohsella lenguaensis* has been suggested as a means of recognizing the base of Zone M14 (= the upper part of N17; Berggren et al., 1995b). However, *F. lenguaensis* has a relatively short range at Site 959 and has a well-marked LAD within N16 before the FADs of *Globorotalia plesiotumida* and *Globigerinoides extremus.* Zone N17 also cannot be subdivided on the traditional criterion of the FAD of *P. primalis* because this datum occurs within the upper part of Zone PL1 (Sample 159-959B-8H-1, 59–61 cm; 62.59 mbsf) just below the FAD of *G. crassaformis.* The base of N17 is easily recognized by the simultaneous FADs of *G. plesiotumida* and *G. extremus* in Sample 159-959B-15H-2, 59–61 cm (130.59 mbsf). A single specimen of *G. plesiotumida* was found ~11 m below this datum, but this may reflect reworking or possibly an odd variant of *Globorotalia merotumida* or *Globorotalia limbata.* Dissolution and fragmentation are common in the >250-µm fraction through much of Zone N17.

The FAD of *Neogloboquadrina acostaensis* is a well-defined datum for the base of Zone N16 in Sample 159-959B-16H-4, 59–61 cm (143.09 mbsf). Preservation deteriorates near the base of Zone N16, and foraminifers become less abundant than is typical higher in the section. Nonetheless, we can recognize both N15 and N14, respectively, by the LAD of *Globorotalia mayeri* in Sample 159-959B-17H-1, 59–61 cm (148.09 mbsf), and the FAD of *G. nepenthes* in Sample 159-959B-17H-3, 59–61 cm (149.59 mbsf). *Globoturborotalita nepenthes* is continuously present for >18 m above its FAD, which suggests that this datum is reliable.

The LAD of *Fohsella fohsi* occurs in Sample 159-959B-18H-3, 59–61 cm (160.59 mbsf), and indicates the Zone N13/N12 boundary. Preservation is very erratic throughout Zone N12 and N13 with some samples almost completely destroyed by dissolution while others contain pretty, glassy-walled foraminifers. The complete complement of morphotypes of *F. fohsi* occurs at Site 959, including *F. fohsi fohsi*, *F. fohsi lobata,* and *F. fohsi robusta.* The morphotypes of *F. fohsi* have an overlapping range with *F. lenguaensis,* whose FAD occurs in Sample 159-959A-18H-4, 45–50 cm (166.05 mbsf), just below the LAD of *F. "praefohsi."* The base of Zone N12 is approximated by the FAD of *F. fohsi* in Sample 159-959A-19H-2, 56–60 cm (172.66 mbsf). Unfortunately, the three samples immediately below this are barren or very poorly preserved, rendering the exact position of the N12/N11 zonal boundary problematic. The bases of Zones N11 and N10 are also uncertain in Hole 959A because of poor foraminifer preservation near these horizons. The FAD of *F. peripheroacuta* occurs in Sample 159-959A-20X-3, 57–62 cm (183.67 mbsf), and that of *F. "praefohsi"* occurs in Sample 159-959A-20X-1, 57–62 cm (180.67 mbsf), which suggests a somewhat condensed, but biostratigraphically complete section.

Zone N9 is apparently absent at Site 959 or obscured by poor foraminifer preservation as the FAD of *Orbulina suturalis* (Sample 159-

959A-20X-3, 57–62 cm; 183.67 mbsf) occurs at the same level as the FAD of *F. peripheroacuta. Praeorbulina glomerosa glomerosa, Praeorbulina glomerosa curva,* and *Praeorbulina sicana* all occur consistently within Zone N8 with the FAD of *P. sicana,* falling in Sample 159-959A-22X-4, 57–59 cm (203.67 mbsf) and that of *P. glomerosa* spp. (undivided) in Sample 159-959A-22X-1, 54–57 cm (199.14 mbsf). The ancestor of *Praeorbulina, Globigerinoides bisphericus,* occurs consistently and frequently below the FAD of *P. sicana.* Forms of *G. bisphericus* with three apertures around the final chamber are common, and the species grades into a two-apertured form like a highly inflated *Globigerinoides trilobus* with moderately high arched apertures within Core 159-959A-23X.

Preservation of Neogene planktonic foraminifers permanently deteriorates below Sample 159-959A-23X-3, 60–64 cm (211.2 mbsf). Occasional dissolution resistant species are found below this level but their rarity makes it impossible to construct an accurate sequence of foraminifer zones below Zone N7.

Côte d'Ivoire-Ghana Marginal Ridge (Site 960)

Rotary drilling of Hole 960A severely disturbed the recovered sections, and recovery averaged only one to three sections per core. Hole 960B consisted only of a single mudline APC core that penetrated to 7.1 mbsf. A combination of APC and XCB coring in Hole 960C produced excellent recovery rates through nearly the entire cored sequence so that we were able to analyze one sample per section through the upper 129.7 m (first 14 cores). The distribution of planktonic foraminifers is given in Table 4, and the depths and ages of the major datums are listed in Table 5.

Preservation of planktonic foraminifers in Hole 960C is virtually the same as that in nearby Site 959: foraminifers are moderately preserved in the Pleistocene, well preserved in most of the Pliocene, dissolved and fragmented in the earliest part of Zone PL1, corresponding approximately with the Messinian desiccation event, and tending to show progressively poorer preservation below the latest Miocene. Intervals characterized by poor preservation at Site 959, such as the middle Miocene, are associated with hiatuses in Hole 960C. Nonetheless, we can recognize all the late Miocene to Holocene foraminifer zones within Hole 960C.

In Pleistocene Zone Pt1, foraminifers are abundant but only moderately preserved because the interiors of robust species like *N. dutertrei* and *G. tumida* are entirely dissolved. The occasional presence of *G. tosaensis* indicates that the lower part of Pleistocene Zone Pt1 occurs at less than 0.17 mbsf (Sample 159-960C-1H-1, 17–19 cm). The base of Zone Pt1 occurs between Samples 159-960C-2H-4, 34–36 cm, and 2H-6, 35–37 cm (11.04–14.05 mbsf), based on the LAD of *G. sacculifer fistulosus* and the FAD of *G. truncatulinoides*. Neither datum is well defined because both marker species are rare and without continuous records at this site.

The Pliocene is biostratigraphically complete, although some intervals are relatively condensed compared with the sequence at Site 959. The presence of *G. sacculifer fistulosus* in the absence of *G. miocenica* indicates that Pliocene Zone PL6 occurs between samples 159-960C-2H-6, 35–37 cm, and 2H-7, 34–36 cm (14.05–15.54 mbsf). *Globorotalia miocenica* occurs in Sample 159-960C-2H-CC (15.7 mbsf) suggesting that Zone PL6 is relatively thin (~2 m) compared to the record at nearby Site 959, where the zone is ~9 m thick. Zone PL5 extends from Sample 159-960C-2H-CC (15.7 mbsf), to 3H-5, 34–36 cm (22.04 mbsf), with the regular occurrence of well-preserved *G. miocenica* and *G. pertenuis.* The reappearance datum for *P. obliquiloculata* occurs at the top of Zone PL5. The top of Zone PL4 is marked by the LAD of *D. altispira* in Sample 159-960C-3H-6, 35–37 cm (23.55 mbsf) and extends through Sample 159-960C-4H-2, 34–36 cm (27.04 mbsf). Single specimens of *Sphaeroidinellopsis* occur in several samples above the apparent base of Zone PL4, making it hard to clearly identify the base of the zone. Normally all species of *Sphaeroidinellopsis* have simultaneous LADs, but in Hole 960C, *S. kochi* has its LAD one section above that of the other Pliocene species in this genus. The discrepancy in range of *Sphaeroidinellopsis* species might be resolved with more detailed sampling.The base of Zone PL3 is comparatively easy to recognize by the well-defined LAD of *G. margaritae* in Sample 159-960C-5H-4, 35–37 cm (39.55 mbsf). Likewise, the LAD of *G. nepenthes* is clear in Sample 159-960C-6H-4, 34–36 cm (49.04 mbsf), and marks the base of Zone PL2.

Zone PL1 is difficult to subdivide owing to the near absence of *G. cibaoensis.* The base of the zone occurs within an interval of moderate to poor preservation between 69.54 mbsf and 76.04 mbsf. I have drawn the base of Zone PL1 at the FAD of *G. tumida* in Sample 159-960C-9H-1, 34–36 cm (73.04 mbsf), but it is possible that poor preservation has affected the apparent range of *G. tumida.* At Site 959, the base of Zone PL1 occurs at the base of an interval of moderate preservation, and Zone N17 immediately below this is characterized by good preservation. Hence, if the intervals of dissolution are equivalent between Sites 959 and 960, the base of Zone PL1 may be found at 76.04 mbsf with further study.

Upper Miocene Zone N17 is identified between Samples 159-960C-9H-2, 34–36 cm, and 10H-5, 34–36 cm (74.54–88.54 mbsf), based on the FAD of *G. tumida* at 73.04 mbsf and the FAD of *G. plesiotumida* at 88.54 mbsf. Preservation is generally good throughout this zone except at the base where foraminifer assemblages are almost entirely destroyed by dissolution. As at Site 959, it is not possible to use *F. lenguaensis* to subdivide Zone N17 because of the scattered occurrence of this species in Leg 159 sites.

Preservation is moderate to poor between Samples 159-960C-10H-6, 34–36 cm, and 13H-7, 34–36 cm (90.04–120.04 mbsf). It is difficult to zone the upper part of this sequence because foraminifer assemblages are almost completely dissolved. *Globoturborotalita nepenthes* has its FAD in Sample 159-960C-10H-5, 34–36 cm (88.54 mbsf), together with the FAD of *G. plesiotumida,* which indicates that this sample is still within Zone N17. The next sample below this (Sample 159-960C-10H-6, 34–36 cm; 90.04 mbsf) has the LAD of *G. mayeri,* which suggests the sample belongs to Zone 13 or older. Foraminifers are almost completely absent in this sample, making it difficult to accept the absence of species as useful biostratigraphic information. Members of the *Fohsella* group appear in Sample 159-960C-10H-7, 34–36 cm (91.54 mbsf), with the occurrence of *F. peripheroacuta* and *F. peripheroronda.* The co-occurrence of these taxa suggests that at least some sediment belonging to Zone N10 occurs in Hole 960C. Zone N9 is apparently present to at least Sample 159-960C-11H-3, 34–36 cm (95.04 mbsf), where occasional specimens of *Orbulina suturalis* have been found. The FAD of *P. sicana* marks the base of Zone N8 in Sample 159-960C-11H-5, 34–36 cm (98.04 mbsf). In turn, Zone N7 can be recognized to about Sample 159-960C-13H-2, 33–35 cm (112.53 mbsf). The LAD of *C. dissimilis/unicavus* occurs in Sample 159-960C-13H-3, 34–36 cm (114.04 mbsf), and suggests the presence of Zone N6 or older sediments below this point. It is impossible to accurately zone sediments below 120.04 mbsf using foraminifers because nearly all samples are completely barren.

Côte d'Ivoire-Ghana Slope (Site 961)

Rotary drilling severely disturbed the cores throughout the recovered section at Site 961, so biostratigraphic work was confined to core catchers in all but a few cases. Core 159-961A-13R was not re-

Table 4. Distribution of planktonic foraminifers in Hole 960C.

Foraminifer zone	Core, section, interval (cm)	Depth (mbsf)	Abundance	Preservation	*G. plesiotumida*	*G. merotumida*	*G. tumida*	*G. truncatulinoides*	*G. tosaensis*	*G. crassaformis*	*G. triangula*	*G. puncticulata*	*G. inflata*	*G. cibaoensis*	*G. juanai*	*G. scitula*	*G. praescitula*	*G. hirsuta*	*G. margaritae*	*G. limbata*	*G. archeomenardii*	*G. menardii*	*G. multicamerata*	*G. exilis*	*G. pertenuis*	*G. miocenica*	*G. pseudomiocenica*	*F. lenguaensis*	*F. birnageae*	*F. peripheroacuta*	*F. peripheroronda*	*D. altispira*	*G. venezuelana*	*G. druryi*	*G. nepenthes*	*G. bulloides*	*G. apertura*	*G. decoraperta*	*G. woodi*	*G. seigliei*	*G. altiapertura*	*G. parawoodi*	*G. extremus*	*G. ruber*	*G. subquadratus*	*G. sacculifer*	*G. sacc. fistulosus*	*G. diminutus*	*G. obliquus*	*G. bulloideus*	*G. bollii*	*G. conglobatus*	*G. mayeri*	*G. continuosa*	*N. acostaensis*	*N. humerosa*	*N. dutertrei*	*N. pachyderma* (r)	*N. pachyderma* (l)
	159-960C-																																																										
Pt1	1H-01, 17-19	0.17	A	M			R	R	R	F			R									R														R								C		F											C	R	
Pt1	1H-02, 18-20	1.68	A	M			R	R		F			R									R														R		R	R					C		C					F						C	F	
Pt1	1H-03, 17-19	3.17	A	M			R			R			R									R														R	R		R					C		C					F						C	F	
Pt1	1H-04, 60-65	5.1	A	M						R												R														T								C		C					F	R					C	F	
Pt1	1H-05, 17-19	5.67	A	M			R			R			R									R														R			R					C		C					F	R					C	R	
Pt1	2H-01, 34-36	6.54	A	M			R			R			F									F														F								C		C					R						C	F	
Pt1	2H-02, 32-34	8.02	A	M			R			R			F									R														R		R						C		C					R						C	R	
Pt1	2H-03, 34-36	9.54	A	M			R			R			R																							F	R	R						C		C					F						C	R	R
Pt1	2H-04, 34-36	11.04	A	M			F	R		F			R									R																						C		C					F	R					C	R	
Pt1	2H-05, 34-36	12.54	A	M			R			R												R														R								C		C					F	R					A	F	
PL6	2H-06, 35-37	14.05	A	G									T																							R		R						C		C	T				F	R			R		A	F	
PL6	2H-07, 34-36	15.54	A	G			R			R												R														R			R					C		C					F				R		A	R	
PL5	3H-01, 34-36	16.04	A	G							R							R						R	R	R										R	R		R					C		C					F				R		C	R	
PL5	3H-02, 34-36	17.54	A	G						R	R	R	R					R						R	R	R											R	R	R				R	C		C	F				R				F		C		
PL5	3H-03, 34-36	19.04	A	G					R	R		R	R											R	R	F										R	R	R	R				R	C		C	T				R				F		C		
PL5	3H-04, 34-36	20.54	A	G						R		R												R	R	R	R									R	R	R	R					C		C	T				R				R		C		
PL5	3H-05, 34-36	22.04	A	G						R															R	F	F									R	R	R	R					F		C						R			R		C		
PL4	3H-06, 35-37	23.55	A	G								R						R				R	F	R								R				R	R						F	F		F	T				R	R			R		A		
PL4	3H-07, 34-36	25.04	A	G								R						R				R	R	R			R					R				R	R	R	F				F	F		C					R	R			F		C		
PL4	4H-01, 34-36	25.54	A	G								R										R	R	R	R	R	R									R	R	R	F					F		C	R				R	R			F		C		
PL4	4H-02, 34-36	27.04	A	G			R			R		R						R				R	R	R			R					T	R			R	R		R				F	F		F					R	R			R		A		
PL3	4H-03, 34-36	28.54	A	G								R						R					F				R						R			R	R	R	R				F	C		C					R	R			F		C		
PL3	4H-04, 34-36	30.04	A	G						R		R												R			R					R	F			R	R	R	R				R	R		C	?		F		R	R			R		C		
PL3	4H-05, 34-36	31.54	A	G			F			F												R	R									R	F			R	R		R					F		F			R		R						C		
PL3	4H-06, 34-36	33.04	A	G			R			R												R										R	R			R	R	R	R					R		F					R	R			R		C		
PL3	4H-07, 34-36	34.54	A	G			R			R												R										F	R			R	R	R	R				F	R		F			F		R				R		C		
PL3	5H-01, 35-37	35.05	A	G			R			R												R										R	R			R	R	R	R				F	R		F			C		R	R			R		C		
PL3	5H-02, 35-37	36.55	A	G						R												R		F								R	R			F	R		R				F	R		C			R		R	R					C		
PL3	5H-03, 35-37	38.05	A	M			C			R								R				R										R	R			R	R	R					F			C			F		R	R			R		F		
PL2	5H-04, 35-37	39.55	A	G			F			R									R			R										R	R			R	R	R	R				F			F			F		R				R		C		
PL2	5H-05, 35-37	41.05	A	G			F			R									R			R	R									R	R			R	R		R				F			C			R		R	R			R		C		
PL2	5H-06, 35-37	42.55	A	G			F			R									R			F										R	R			R	R		R				C			C			R			R			R		F		
PL2	5H-07, 35-37	44.05	A	G			F			R									R			F										R	R			F	R	R	R				F			F			R		R	R			R		F		
PL2	6H-01, 34-36	44.54	A	G			F			R									R			F										R	R			R	R	R	R				R			F			F		R	R			R		F		
PL2	6H-02, 34-36	46.04	A	M	R					R									R			R										R	F				R	R	R				R			F			F		R	R					F		
PL2	6H-03, 34-36	47.54	A	G	T					R								R	R			R										R	R				R	R	R				F			F			F			R			R		C		
PL1	6H-04, 34-36	49.04	A	G	R		R			R									R			F										R	R		R	R	R	R	R				F			F			F		R	R			R		C		
PL1	6H-05, 34-36	50.54	A	G	R		R											R	R			F										R			R	R	R		R				F			C			F			R			R		C		
PL1	6H-06, 34-36	52.04	A	G	R		R												R			F										R	R		T	R	R	R	R				R			F			R			R			R		C		
PL1	6H-07, 34-36	53.54	A	G	R		R							R					R			R										R			R	R	R	R	R				R			R			F		R	R			R		F		
PL1	7H-01, 35-37	54.05	A	G	R		R												R	R		R										R			T	R	R	R	R				F			F			F		R	R			R		F		
PL1	7H-02, 34-36	55.54	A	G			R												R	R		F										R	R		R		R	R	R				F			F			F						R		C		
PL1	7H-03, 34-36	57.04	A	G	R														R	R		F										R			R		R		R				F			C			F		R				R		C		R
PL1	7H-04, 34-36	58.54	A	G	R		R												R	R		F										R	R		R		R	R	R				F			C			C			R			R		F		R
PL1	7H-05, 34-36	60.04	A	G	R		F							R					R	R		F										R	R		R	R	R	R					F			F			C						R		F		
PL1	7H-06, 34-36	61.54	A	G	R		R												R	R		F										R	R		R	R		R	R				F			F			C		R						F		
PL1	7H-07, 34-36	63.04	A	M	R		F												R	R		F										R	R		R	R			R				F			F			F			R			R		R		R
PL1	8H-01, 34-36	63.54	A	G	R		C												R	R		F										R	R		R	R	R	R	R				F			F			F			R			R		C		R
PL1	8H-02, 34-36	65.04	A	G	R		F												R	R		C										R	R		R		R	R	R				F			F			F						R		R		
PL1	8H-03, 34-36	66.54	A	G	R		F												R	R		C										R	R		R		R	R	R				F			F			F			R			R		R		
PL1	8H-04, 34-36	68.04	A	G	R		R												R	R		F										R	R		R		R	R	R				F			C			C								R		
PL1	8H-05, 34-36	69.54	A	M	R		R												R	R		R										R	R		R		R						F			F			C						R		F		

Note: Symbols as in Table 2.

Table 4 (continued).

Foraminifer zone	Core, section, interval (cm)	Depth (mbsf)	Abundance	Preservation	*S. kochi*	*S. seminulina*	*S. paendeshicens*	*S. deshicens*	*P. obliquiloculata*	*P. primalis*	*P. praecursor*	*P. Bsphericus*	*P. sicana*	*P. glomerosa*	*O. universa*	*O. suturalis*	*O. bilobata*	*G. glutinata*	*G. uvula*	*Tenuitella sp.*	*G. varabilis*	*G. suteri*	*G. praesiphonifera*	*G. aequilateralis*	*G. obesa*	*G. calida*	*G. hexagona*	*C. bermudezi*	*P. prolixa*	*B. digitata*	*B. praedigitata*	*G. dehiscens*	*C. unicavus*	*C. dissimilis*	*C nitida*
Pt1	1H-01, 17-19	0.17	A	M				R	R						R			R						R		R									R
	1H-02, 18-20	1.68	A	M											R			F						R			R								
	1H-03, 17-19	3.17	A	M											R			R						R			R								
	1H-04, 60-65	5.1	A	M											R			F									R								
	1H-05, 17-19	5.67	A	M				T	R						R			F						R			R								
	2H-01, 34-36	6.54	A	M				T	R						R			F						R						T					R
	2H-02, 32-34	8.02	A	M				R	R						R			F						R			R								
	2H-03, 34-36	9.54	A	M				F							F			F						F		R	R								
	2H-04, 34-36	11.04	A	M				R	R						F			F						R			R								
	2H-05, 34-36	12.54	A	M				F	R						R			R						R						R					
PL6	2H-06, 35-37	14.05	A	G				F	R						R			R						R		R									
	2H-07, 34-36	15.54	A	G				F	R						F			R						R		R									
PL5	3H-01, 34-36	16.04	A	G				R							R			R	R																
	3H-02, 34-36	17.54	A	G				R							R			R								R									
	3H-03, 34-36	19.04	A	G		T		R							R			R							R										
	3H-04, 34-36	20.54	A	G				R							R			F						R	R										
	3H-05, 34-36	22.04	A	G				T							F			R						R	R										
PL4	3H-06, 35-37	23.55	A	G				T							R			R	R					R			R								
	3H-07, 34-36	25.04	A	G				R							R			R	R					R			R				R				
	4H-01, 34-36	25.54	A	G		T		R							R			R						R	R		R								
	4H-02, 34-36	27.04	A	G											R			R						R	R		R								
PL3	4H-03, 34-36	28.54	A	G	R				R						R			F						R			R								
	4H-04, 34-36	30.04	A	G		R	R	R							R			R						R	R		R								R
	4H-05, 34-36	31.54	A	G			R	R							R			R							R		R								
	4H-06, 34-36	33.04	A	G	R	R	R	R							R			R						R			R								
	4H-07, 34-36	34.54	A	G	R	R	R								R			R						R			R								
	5H-01, 35-37	35.05	A	G		R									R			R						R	R		R								R
	5H-02, 35-37	36.55	A	G		R	R								T			R						R			R								
	5H-03, 35-37	38.05	A	M	R	R			R	R					R	R		F						R			R								
PL2	5H-04, 35-37	39.55	A	G		R									R			R						R	R		R								
	5H-05, 35-37	41.05	A	G		R									R	R		R	R					R	R		R								
	5H-06, 35-37	42.55	A	G		R									R		R	F	R					R	R		R								R
	5H-07, 35-37	44.05	A	G		F		R	F	R					R			R						R	R		R								
	6H-01, 34-36	44.54	A	G	R	R	R		F						R	R	R	R						R	R		R								
	6H-02, 34-36	46.04	A	M	R	R			R		R				R			R	R					R	R		R			R					R
	6H-03, 34-36	47.54	A	G	R	R	R			R	R				R			R						R			R								
PL1	6H-04, 34-36	49.04	A	G	R	R	R								F	R		R						R			R								
	6H-05, 34-36	50.54	A	G	R	R				R					R		R	F						R	R		R								
	6H-06, 34-36	52.04	A	G	R	R				R					R	R		R						R	R		R								
	6H-07, 34-36	53.54	A	G	R	R									R		R	R						R	R		R								R
	7H-01, 35-37	54.05	A	G		R	R	R							R			R						R	R		R								R
	7H-02, 34-36	55.54	A	G	R	R		R							R		R	R						R	R		R								R
	7H-03, 34-36	57.04	A	G	R	R	R								R	R	R	R						R	R		R								R
	7H-04, 34-36	58.54	A	G	R	R									R			R						R	R										R
	7H-05, 34-36	60.04	A	G	R	R	R								R	R		R						R	R										
	7H-06, 34-36	61.54	A	G		R	R								R	R	R	R						R	R										R
	7H-07, 34-36	63.04	A	M	R	R	R								R			R									R								R
	8H-01, 34-36	63.54	A	G	R	R	R								R			R						R	R		R								R
	8H-02, 34-36	65.04	A	G	R	R									R	R		R						R	R		R								R
	8H-03, 34-36	66.54	A	G	R	R									R	R		R	R					R	R		R								R
	8H-04, 34-36	68.04	A	G	R	R									R		R	R						R	R										R
	8H-05, 34-36	69.54	A	M	R	R									R			R							R		R								R

Table 4 (continued).

Foraminifer zone	Core, section, interval (cm)	Depth (mbsf)	Abundance	Preservation	*G. plesiotumida*	*G. merotumida*	*G. tumida*	*G. truncatulinoides*	*G. tosaensis*	*G. crassaformis*	*G. triangula*	*G. puncticulata*	*G. inflata*	*G. cibaoensis*	*G. juanai*	*G. scitula*	*G. praescitula*	*G. hirsuta*	*G. margaritae*	*G. limbata*	*G. archeomenardii*	*G. menardii*	*G. multicamerata*	*G. exilis*
PL1	8H-06, 34-36	71.04	A	M	R		R												R	R		F		
	8H-07, 34-36	72.54	A	M	R		R												R	R		R		
	9H-01, 34-36	73.04	A	M	F		R												R	R				
N17	9H-02, 34-36	74.54	C	M	R									R		R			R	R				
	9H-03, 34-36	76.04	F	P	R									R		R			R					
	9H-04, 34-36	77.54	A	G	F									R	R	R				R				
	9H-05, 34-36	79.04	A	G	R									R		R								
	9H-06, 34-36	80.54	A	G	R	R								R	R	R								
	9H-07, 34-36	82.04	A	G	R	R								R		R								
	10H-02, 34-36	84.04	A	G	T	R										R								
	10H-03, 34-36	85.54	A	G	R	R								R		R								
	10H-04, 34-36	87.04	R	P	R	F																		
	10H-05, 34-36	88.54	F	M	R											R								
N10-N13	10H-06, 34-36	90.04	R	P																				
N10	10H-07, 34-36	91.54	R	P																	R			
N9	11H-02, 34-36	93.54	R	P																	R			
	11H-03, 34-36	95.04	C	M																	R			
N8	11H-04, 34-36	96.54	C	M																				
	11H-05, 34-36	98.04	R	P																	F			
N7	11H-06, 34-36	99.54	F	M																	F			
	11H-07, 34-36	101	C	M																	F			
	12H-01, 34-36	101.5	C	M																				
	12H-02, 34-36	103	C	M																				
	12H-03, 34-36	104.5	C	M													R							
	12H-04, 34-36	106	F	M																				
	12H-05, 34-36	107.5	F	M																				
	12H-06, 34-36	109	F	M													R							
	12H-07, 34-36	110.5	F	P																				
	13H-01, 34-36	111	R	P																				
	13H-02, 33-35	112.5	R	P																				
N6 or older (to N4b)	13H-03, 34-36	114	F	P																				
	13H-04, 34-36	115.5	R	P																				
	13H-05, 34-36	117	R	P																				
	13H-06, 34-36	118.5	R	P																				
	13H-07, 34-36	120	R	P																				
	14H-02, 34-36	122	B																					
	14H-03, 34-36	123.5	B																					
	14H-04, 34-36	125	B																					
	14H-05, 34-36	126.5	B																					
	14H-06, 34-36	128	R	P																				
	14H-07, 35-37	129.6	B																					

Core, section, interval (cm)	*G. pertenuis*	*G. miocenica*	*G. pseudomiocenica*	*F. lenguaensis*	*F. birnageae*	*F. peripheroacuta*	*F. peripheroronda*	*D. altispira*	*G. venezuelana*	*G. druryi*	*G. nepenthes*	*G. bulloides*	*G. apertura*	*G. decoraperta*	*G. woodi*	*G. seigliei*	*G. altiapertura*	*G. parawoodi*	*G. extremus*	*G. ruber*
8H-06, 34-36								R	R		R		R						F	
8H-07, 34-36								R	R		R		R	R	R				C	
9H-01, 34-36								F			R	R							C	
9H-02, 34-36								R	R		R	R	F	R	R				F	
9H-03, 34-36									R		R				R				F	
9H-04, 34-36								R	R		F	R	R		R				R	
9H-05, 34-36								R	R		R	R			R				F	
9H-06, 34-36								R	R			R	R	R	R				F	
9H-07, 34-36								R	R		R	R		R	F	R			F	
10H-02, 34-36								F	F		R		R	R	R	R				
10H-03, 34-36				R				F	F		R	R			R				R	
10H-04, 34-36								R	F		R				R					
10H-05, 34-36				R					R		R				R					
10H-06, 34-36				R				R												
10H-07, 34-36						F	C	R	F											
11H-02, 34-36							F	R	F									R		
11H-03, 34-36							F	R	F											
11H-04, 34-36							F		F											
11H-05, 34-36							F		F											
11H-06, 34-36							F		R									R		
11H-07, 34-36							F		F											
12H-01, 34-36							C		F											
12H-02, 34-36							C		F						R					
12H-03, 34-36							F								R					
12H-04, 34-36						R	F		R						R			R		
12H-05, 34-36							F		R									R		
12H-06, 34-36							F		R									R		
12H-07, 34-36							R		C											
13H-01, 34-36									C											
13H-02, 33-35									R											
13H-03, 34-36									C											
13H-04, 34-36									F											
13H-05, 34-36									C											
13H-06, 34-36																				
13H-07, 34-36									C											
14H-02, 34-36																				
14H-03, 34-36																				
14H-04, 34-36																				
14H-05, 34-36																				
14H-06, 34-36									R											
14H-07, 35-37																				

Core, section, interval (cm)	*G. subquadratus*	*G. sacculifer*	*G. sacc. fistulosus*	*G. diminutus*	*G. obliquus*	*G. bulloideus*	*G. bollii*	*G. conglobatus*	*G. mayeri*	*G. continuosa*	*N. acostaensis*	*N. humerosa*	*N. dutertrei*	*N. pachyderma* (l)	*N. pachyderma* (r)
8H-06, 34-36		C			F			R			R				
8H-07, 34-36		F			F			R							
9H-01, 34-36		C			R						R				
9H-02, 34-36		F			R			R			R				
9H-03, 34-36		R					R				R	R			
9H-04, 34-36		F			F			R			R				
9H-05, 34-36		C			F		R				F	R			
9H-06, 34-36		C			F	R					R	R			
9H-07, 34-36		C			R			R			R				
10H-02, 34-36		C					R				R	R			
10H-03, 34-36		C			F	R					R	R			
10H-04, 34-36		R			R							R			
10H-05, 34-36		R			R							F			
10H-06, 34-36									R						
10H-07, 34-36									F						
11H-02, 34-36		R							F						
11H-03, 34-36		C			F				F						
11H-04, 34-36		R		R	F										
11H-05, 34-36	R	R		R					R						
11H-06, 34-36		F			F				R	R					
11H-07, 34-36	C	C		R						R					
12H-01, 34-36	C	C							R						
12H-02, 34-36	C	C							R						
12H-03, 34-36	F	C								R					
12H-04, 34-36	F	C							R	R					
12H-05, 34-36	F	C							R	R					
12H-06, 34-36	F	C		R					R	R					
12H-07, 34-36		R							R						
13H-01, 34-36		R		R					R						
13H-02, 33-35	T	R							R						
13H-03, 34-36		R							F						
13H-04, 34-36	T	R							R						
13H-05, 34-36									R						
13H-06, 34-36															
13H-07, 34-36									R						
14H-02, 34-36															
14H-03, 34-36															
14H-04, 34-36															
14H-05, 34-36															
14H-06, 34-36									R						
14H-07, 35-37															

Table 4 (continued).

Foraminifer zone	Core, section, interval (cm)	Depth (mbsf)	Abundance	Preservation	*P. obliquiloculata*	*S. kochi*	*S. seminulina*	*S. paendeshicens*	*S. deshicens*	*P. primalis*	*P. praecursor*	*G. bisphericus*	*P. sicanus*	*P. glomerosa*	*O. universa*	*O. suturalis*	*O. bilobata*	*G. glutinata*	*G. uvula*	*Tenuitella sp.*	*G. varabilis*	*G. suteri*	*G. praesiphonifera*	*G. aequilateralis*	*G. obesa*	*G. calida*	*G. hexagona*	*C. bermudezi*	*P. prolixa*	*B. digitata*	*B. praedigitata*	*G. dehiscens*	*C. unicavus*	*C. dissimilis*	*C nitida*
PL1	8H-06, 34-36	71.04	A	M											R		R	R						R	R		R								R
	8H-07, 34-36	72.54	A	M		R	R								R			R							R		R								
	9H-01, 34-36	73.04	A	M			R								R		R	R						R	R		R								R
N17	9H-02, 34-36	74.54	C	M		R	R								R	R	R	R							R		R								R
	9H-03, 34-36	76.04	F	P		R	R								R	R		R									F								
	9H-04, 34-36	77.54	A	G			R								R			R						R			R					R			R
	9H-05, 34-36	79.04	A	G		R	R								F	R		R	R						R		R					R			R
	9H-06, 34-36	80.54	A	G		R	R								F			R							R							R			R
	9H-07, 34-36	82.04	A	G											F		R	R						R	R		R								R
	10H-02, 34-36	84.04	A	G		R	R								F			R	R				R	R	R		R				R	R			?
	10H-03, 34-36	85.54	A	G		R	R								R			R	R		R			R	R		R					R			
	10H-04, 34-36	87.04	R	P			R								R			R					R		R		R					R			
	10H-05, 34-36	88.54	F	M		R	R								R	R		R					R	R			R								
N10-N13	10H-06, 34-36	90.04	R	P		R	F											R			R						R					R			
N10	10H-07, 34-36	91.54	R	P		F	F											R			R		R				R					F			
N9	11H-02, 34-36	93.54	R	P														R		R	F		R				R	R				R			
	11H-03, 34-36	95.04	C	M								R		R		R		R					F									F			
N8	11H-04, 34-36	96.54	C	M								R									R		F									F			
	11H-05, 34-36	98.04	R	P								R	R							R	R		F				R		R			F	R		
N7	11H-06, 34-36	99.54	F	M								F									R		R				R					F			
	11H-07, 34-36	101	C	M								C						R		R	R		R					R				C			
	12H-01, 34-36	101.5	C	M								C									R		F				R					C			
	12H-02, 34-36	103	C	M								C									R		F				R		R			C			
	12H-03, 34-36	104.5	C	M								F									R		F				R	R	R			C			
	12H-04, 34-36	106	F	M								F							R	R	R		F				R	R	R			C			
	12H-05, 34-36	107.5	F	M								C									R		C				R	R				F			
	12H-06, 34-36	109	F	M								C									R		C				R	R				F			
	12H-07, 34-36	110.5	F	P															R		R	R										F			
	13H-01, 34-36	111	R	P																		R										R			
	13H-02, 33-35	112.5	R	P																	R											R			
N6 or older (to N4b)	13H-03, 34-36	114	F	P														R		R		R					R					F	F		
	13H-04, 34-36	115.5	R	P															R			R										F			
	13H-05, 34-36	117	R	P																		R										F	R	R	
	13H-06, 34-36	118.5	R	P																		R					R						R	R	
	13H-07, 34-36	120	R	P																													R	R	
	14H-02, 34-36	122	B																																
	14H-03, 34-36	123.5	B																																
	14H-04, 34-36	125	B																																
	14H-05, 34-36	126.5	B																																
	14H-06, 34-36	128	R	P																															
	14H-07, 35-37	129.6	B																																

Table 5. Planktonic foraminifer datums for Hole 960C.

Datum	Age (Ma)	Top (core, section, interval)	Base (core, section, interval)	Top (mbsf)	Base (mbsf)	Average depth (mbsf)
FAD *Globorotlaia truncatulinoides*	2	2H-4, 34-36 cm	2H-5, 34-36 cm	11.04	12.54	11.79
LAD ***Globigerinoides sacculifer fistulosus***	1.74	2H-5, 34-36 cm	2H-6, 35-37 cm	12.54	14.05	13.3
Re-appearance of *Pulleniatina obliquiloculata*	2.3	2H-7, 34-36 cm	2H-CC	15.54	15.7	15.62
LAD ***Globorotalia miocenica***	2.3	2H-CC	3H-1, 34-36 cm	15.7	16.04	15.87
LAD ***Dentogloboquadrina altispira***	3.05	3H-5, 34-36 cm	3H-6, 35-37 cm	22.04	23.55	22.8
LAD *Globorotalia multicamerata*	3.09	3H-5, 34-36 cm	3H-6, 35-37 cm	22.04	23.55	22.8
LAD ***Sphaeroidinellopsis* spp.**	3.12	4H-2, 34-36 cm	4H-3, 34-36 cm	27.04	28.54	27.8
LAD *Pulleniatina primalis*	3.65	5H-2, 35-37 cm	5H-3, 35-37 cm	38.05	39.55	38.8
LAD *Pulleniatina obliquiloculata*	3.95	5H-6, 35-37 cm	6H-1, 34-36 cm	44.05	44.54	44.8
LAD ***Globorotalia margaritae***	3.58	5H-3, 35-37 cm	5H-4, 35-37 cm	38.05	39.55	38.8
LAD ***Globotruborotalia nepenthes***	4.2	6H-3, 34-36 cm	6H-4, 34-36 cm	47.54	49.04	48.29
FAD *Globorotalia crassaformis*	4.5	6H-4, 34-36 cm	6H-5, 34-36 cm	49.04	50.54	49.8
LAD *Globorotalia cibaoensis*	4.6	6H-6, 34-36 cm	6H-7, 34-36 cm	52.04	53.54	52.8
FAD ***Globorotalia tumida***	5.59	9H-1, 34-36 cm	9H-2, 34-36 cm	73.04	74.54	73.8
FAD *Sphaeroidinella dehiscens*	5.2	7H-2, 34-36 cm	7H-3, 34-36 cm	55.54	57.04	56.29
FAD *Globorotalia margaritae*	6.4	9H-3, 34-36 cm	9H-4, 34-36 cm	76.04	77.54	76.8
FAD ***Globorotalia plesiotumida***	8.3	10H-5, 34-36 cm	10H-6, 34-36 cm	88.54	90.04	89.29
FAD ***Neogloboquadrina acostaensis***	10	10H-3, 34-36 cm	10H-4, 34-36 cm	85.54	87.04	86.29
FAD ***Globotruborotalia nepenthes***	10.8	10H-5, 34-36 cm	10H-6, 34-36 cm	88.54	90.04	89.29
LAD ***Globorotalia mayeri***	10.3	10H-5, 34-36 cm	10H-6, 34-36 cm	88.54	90.04	89.29
FAD *Globorotalia lenguaensis*	12.3	10H-6, 34-36 cm	10H-7, 34-36 cm	88.54	90.04	89.29
FAD ***Globorotalia peripheroacuta***	14.7	10H-7, 34-36 cm	11H-2, 34-36 cm	91.54	93.54	92.54
LAD *Globorotalia archeomenardii*	14.04	10H-6, 34-36 cm	10H-7, 34-36 cm	90.04	91.54	90.79
FAD *Praeorbulina glomerosa*	16.1	11H-3, 34-36 cm	11H-4, 34-36 cm	95.04	96.54	95.79
FAD ***Praeorbulina sicana***	16.50	11H-5, 34-36 cm	11H-6, 34-36 cm	98.04	99.54	98.79
LAD ***Catapsydrax dissimilis/unicavus***	17.3	13H-2, 34-36 cm	13H-3, 34-36 cm	112.53	114.04	113.29

Note: Boldfaced species = those defining biozones.

covered at all, and most of the cores contained no more than 2 or 3 sections of sediment. The distribution of planktonic foraminifers is given in Table 6 and the depths and ages of the major datums are listed in Table 7.

Preservation is highly variable throughout the recovered sequence. Intervals without preserved planktonic foraminifers occur in the lower Pliocene and the Miocene, whereas remaining samples alternate between moderate to good preservation. Samples are continuously barren of planktonic foraminifers below Sample 159-961A-15R-CC (138.5 mbsf).

Sample 159-961A-1R, 3–5 cm, contains a moderately preserved assemblage including *G. tumida* and *P. obliquiloculata* without *G. sacculifer fistulosus* or *G. truncatulinoides.* Nannoplankton from this sample indicate a latest Pleistocene or Holocene age, but the planktonic foraminifers could be diagnostic of either a Pleistocene or late Pliocene age.

The Pliocene is very condensed and can be recognized between Samples 159-961A-1R-CC and 4R-CC (3.4–32.3 mbsf). Samples 159-961A-1R-CC and 2R-CC (3.4–13.1 mbsf) contain a fauna suggestive of Zone PL5 because *G. miocenica* (or *G. pseudomiocenica*) occurs in the absence of *D. altispira, Sphaeroidinellopsis* spp., and *G. margaritae*, whose LADs all mark successively older Pliocene zones. The LADs of *Sphaeroidinellopsis* spp. and *D. altispira* coincide in Sample 159-961A-3R-1, 34–36 cm (13.44 mbsf), and suggest the presence of Zone PL3. The lower boundary of this zone cannot be defined precisely owing to severe dissolution in Sample 159-961A-3R-3, 34–36 cm (16.44 mbsf), but the presence of *G. margaritae* without *G. nepenthes* in Sample 159-961A-3R-CC (22.7 mbsf) suggests the occurrence of Zone PL2 at this level. A barren interval at 23.59 mbsf prevents precise determination of the base of Zone PL2. However, Sample 159-961A-4R-CC contains *G. nepenthes* and *G. tumida*, suggesting the presence of Zone PL1. Samples 159-961A-5R-1, 64–66 cm through 6R-CC (32.94–51.5 mbsf) contain a discontinuous record of *G. plesiotumida* and *G. extremus* and are assigned to Zone N17. Below this interval, *N. acostaensis* has a spotty record down to Sample 159-961A-9R-CC (80.6 mbsf), suggesting the presence of Zone N16. Samples 159-961A-10R-CC and 11R-CC cannot be zoned using planktonic foraminifers because of severe dissolution. However, the presence of *G. praescitula* in Sample 159-961A-11R-CC (99.9 mbsf) suggests that this sediment belongs to Zone N12 or an older zone.

An occurrence of *F. birnageae* in Sample 159-961A-12R-CC (109.6 mbsf) suggests Zone N7 or N8, but marker species such as *Orbulina suturalis* and members of the genus *Praeorbulina* are absent. I provisionally assign the interval between 99.9 mbsf and 138.5 mbsf to Zone N7/N8, although samples between 119.3 and 138.5 mbsf do not contain *F. birnageae* or other distinctive marker species and so might belong to an older Miocene zone. Preservation is moderate to poor in this interval and makes zonal identification tentative, at best. No planktonic foraminifers were observed in Neogene sediments below Sample 159-961A-15R-CC (138.5 mbsf).

Côte d'Ivoire-Ghana Trough (Site 962)

The pelagic cover at Hole 962B was drilled with APC and provided excellent recovery of the stratigraphic section. The Cenozoic section at Site 962 is greatly condensed compared to the other Leg 159 sites and preservation of calcareous microfossils is very poor at almost every level. Nonetheless, samples were studied at a frequency of one per section. The distribution of planktonic foraminifers is given in Table 8 and the depths and ages of the major datums are listed in Table 9.

Samples taken between the top of Section 159-962B-1H-1 and Sample 159-962B-2H-CC (0.0–17.0 mbsf) contain a Holocene to upper Pliocene assemblage dominated by dissolution-resistant taxa such as *Globorotalia tumida, N. pachyderma* (dextral) and *N. dutertrei. Pulleniatina obliquiloculata* occurs as low as Sample 159-962B-2H-6, 50–52 cm, and suggests that Zone Pt1 or Zone PL6 extends to a depth of ~14 mbsf. The interval between Samples 159-962B-2H-7, 50–52 cm, and 2H-CC (16.6–17 mbsf) does not contain any distinctive marker taxa and may range in age from Zone Pt1 to PL5. In contrast, Sample 159-962B-3H-1, 53–55 cm (17.53 mbsf), contains *G. miocenica* and *G. pertenuis* but lacks specimens of the dissolution-resistant species *D. altispira, G. venezuelana,* and *Sphaeroidinellopsis* spp., and can be assigned to Zone PL5. *Sphaeroidinellopsis* occurs in Sample 159-962B-3H-2, 50–52 cm (19 mbsf), and suggests an assignment to Zone PL3 or an older zone. The occurrences of *Sphaeroidinellopsis, G. tumida,* and *S. dehiscens* in samples between

Table 6. Distribution of planktonic foraminifers in Hole 961A.

Foraminifer zone	Core, section, interval (cm)	Depth (mbsf)	Abundance	Preservation	*G. plesiotumida*	*G. merotumida*	*G. tumida*	*G. truncatulinoides*	*G. crassaformis*	*G. triangula*	*G. puncticulata*	*G. cibaoensis*	*G. juanai*	*G. scitula*	*G. praescitula*	*G. margaritae*	*G. menardii*	*G. multicamerata*	*G. exilis*	*G. pertenuis*	*G. miocenica*	*G. pseudomiocenica*	*F. lenguaensis*	*F. birnageae*	*F. peripheroronda*	*D. altispira*	*G. venezuelana*	*G. druryi*	*G. nepenthes*	*G. bulloides*	*G. apertura*	*G. decoraperta*	*G. woodi*
PL5	1R-CC	3.4	A	M			F		R								R					R								F			
	2R-CC	13.1	A	G			R		R	R	R									F	F	F								F	F	R	
	3R-01, 34-35	13.44	C	G														R								F	R						
PL3	3R-02, 34-35	14.94	A	M	R				F								R	R															
PL2	3R-CC	22.7	C	G			C		F							R			R							F	R						
PL1	4R-CC	32.3	A	G	R		F									R	C									R	F		F				
	5R-01, 64-66	32.94	F	M								R																					
N17	5R-02, 64-66	33.88	F	M	F							R		R		F	F												R				
	5R-CC	41.9	C	M								F	R	R			F									F					R		
	6R-CC	51.5	C	G	F									R												F	R		C		R		R
	7R-CC	61.2	C	G		R																				F	F		F		R		
	8R-01, 90-92	62.1	C	G										R			F						R										
N16	8R-CC	71	C	G		R																					F		R		F		
	9R-CC	80.6	F	M		R																	R				C		R			R	R
	10R-CC	90.3	B																														
	11R-CC	99.9	R	M											R													T					
N7/N8	12R-CC	109.6	F	G																				F	C	R	F						
	13R-CC	119.3									NO RECOVERY																						
	14R-CC	128	R	P																						R	R						
	15R-CC	138.5	R	M																						R							
	16R-CC	148	B																														
	17R-CC	157.5	B																														
	18R-CC	167	B																														
Unzoned	19R-01, 33-35	167.7	B																														
	19R-CC	176.5	B																														
	20R-01, 111-113	178.1	B																														
	20R-CC	186.1	B																														
	21R-01, 109-111	187.8	B																														
	21R-CC	195.5	B																														

Core, section, interval (cm)	*G. seigliei*	*G. altiapertura*	*G. extremus*	*G. ruber*	*G. subquadratus*	*G. sacculifer*	*G. sacc. fistulosus*	*G. obliquus*	*G. conglobatus*	*G. mayeri*	*N. acostaensis*	*N. dutertrei*	*N. pachyderma* (r)	*S. kochi*	*S. seminulina*	*S. paendeshicens*	*S. deshicens*	*P. obliquiloculata*	*O. universa*	*O. bilobata*	*G. glutinata*	*G. varabilis*	*G. praesiphonifera*	*G. aequilateralis*	*G. obesa*	*G. hexagona*	*B. praedigitata*	*G. dehiscens*	*C nitida*
1R-CC				C		C						C	F				R	F	F		F			F					
2R-CC				C		C	R					C					R		F		F			F					
3R-01, 34-35									R						R														
3R-02, 34-35						C						C				R	R		C					F					R
3R-CC			C			C						C		F	R				F					R					
4R-CC									R			C		R	F		R							R					R
5R-01, 64-66																													
5R-02, 64-66											F	C			F											R			R
5R-CC			F			C		F												R	R					R			
6R-CC						C		F			F				F								R		R	R	R	R	
7R-CC	F					C		C			F			F	F				F	R	F		F						R
8R-01, 90-92																													
8R-CC	R	C				C									F				F		F			R					
9R-CC						C					R			F	F				F							R		R	
10R-CC																													
11R-CC						T																							
12R-CC					F	C				F													F			R		F	
13R-CC																													
14R-CC					R																	R							
15R-CC						R																R						R	
16R-CC																													
17R-CC																													
18R-CC																													
19R-01, 33-35																													
19R-CC																													
20R-01, 111-113																													
20R-CC																													
21R-01, 109-111																													
21R-CC																													

Note: Symbols as in Table 2.

Table 7. Planktonic foraminifer datums for Hole 961A.

Datum	Age (Ma)	Top (Core, section, interval)	Base (Core, section, interval)	Top (mbsf)	Base (mbsf)	Average depth (mbsf)
LAD ***Globorotalia margaritae***	3.58	3R-2, 34-35 cm	3R-CC	14.94	22.7	18.82
LAD ***Globotruborotalia nepenthes***	4.2	3R-CC	4R-CC	22.7	32.3	27.5
FAD *Globorotalia crassaformis*	4.5	3R-CC	4R-CC	22.7	32.3	27.5
LAD *Globorotalia cibaoensis*	4.6	4R-CC	5R-1, 64-66 cm	32.3	32.94	32.62
FAD ***Globorotalia tumida***	5.59	4R-CC	5R-1, 64-66 cm	32.3	32.94	32.62
FAD *Sphaeroidinella dehiscens*	5.2	4R-CC	5R-1, 64-66 cm	32.3	32.94	32.62
FAD *Globorotalia margaritae*	6.4	5R-2, 64-66 cm	5R-CC	33.88	41.9	37.89
FAD ***Globorotalia plesiotumida***	8.3	6R-CC	7R-CC	51.5	61.2	56.35
FAD ***Neogloboquadrina acostaensis***	10	9R-CC	10R-CC	80.6	90.3	85.45
FAD ***Globotruborotalia nepenthes***	10.8	9R-CC	10R-CC	80.6	90.3	85.45
FAD *Globorotalia lenguaensis*	12.3	9R-CC	10R-CC	80.6	90.3	85.45

Note: Species in boldface are biozone markers.

Table 8. Distribution of planktonic foraminifers in Hole 962B.

Foraminifer zone	Core, section, interval (cm)	Depth (mbsf)	Abundance	Preservation	*G. tumida*	*G. truncatulinoides*	*G. crassaformis*	*G. inflata*	*G. scitula*	*G. menardii*	*G. pertenuis*	*G. miocenica*	*D. altispira*	*G. venezuelana*	*G. apertura*	*G. decoraperta*	*G. woodi*	*G. extremus*	*G. ruber*	*G. sacculifer*	*G. obliquus*	*G. conglobatus*	*N. acostaensis*	*N. humerosa*	*N. dutertrei*	*N. pachyderma* (r)	*S. kochi*	*S. seminulina*	*S. paendeshicens*	*S. deshicens*	*P. obliquiloculata*	*O. universa*	*G. glutinata*	*T. humilis*	*G. obesa*	*G. hexagona*	*C nitida*
Pt1-PL6	1H-01, 50-52	0.5	R	P															R	F					C	F					R						
	1H-02, 50-52	2	R	P																																	
	1H-03, 50-52	3.5	R	P	F		C		R	R									C	F						F					F					R	R
	1H-04, 50-52	5	B																																		
	1H-05, 78-80	6.78	B																																		
	1H-CC	7.5	R	P	F															F		R		R	F	R											
	2H-01, 50-52	8	B																																		
	2H-02, 50-52	9.5	B																																		
	2H-03, 50-52	11	R	P	T																										T	T					
	2H-04, 50-52	12.5	R	P	F					F															C												
	2H-05, 50-52	14	R	P			R			R															R												
	2H-06, 50-52	15.5	R	P			F	R								R			C	F		R			C						C		R	R			
Pt1/PL5	2H-07, 50-52	16.6	R	P																					R											R	
	2H-CC	17	R	P	R															F					R												
PL5	3H-01, 53-55	17.53	R	P			R	R	R		R	F			F		R	F		C			F		C							F	R				
PL3-PL1	3H-02, 50-52	19	R	P										R				R	R	R		R			F				F	F							
	3H-03, 50-52	20.5	B																																		
	3H-04, 50-52	22	R	P	C		R			R			F	R			R	F		R	F		R		C		R	F				F	R		R		
	3H-05, 50-52	23.5	B																																		
	3H-06, 51-53	25.01	B																																		
	3H-07, 50-52	26.1	B																																		
	3H-CC	26.5	R	P						R								R		F			T	R	F			R	R	F			R				
Unzoned	4H-01, 50-52	27	B																																		
	4H-02, 51-53	28.51	B																																		
	4H-03, 51-53	30.01	B																																		
	4H-04, 50-52	31.5	B																																		
	4H-05, 51-53	33.01	B																																		
	4H-06, 51-53	34.51	B																																		
	4H-07, 51-53	36.01	B																																		
	4H-CC	36	R	P																T																	
	5H-01, 40-42	36.4	B																																		
	5H-02, 40-42	37.9	B																																		
	5H-03, 40-42	39.4	B																																		
	5H-04, 40-42	40.9	B																																		
	5H-05, 40-42	42.4	B																																		
	5H-06, 40-42	43.9	B																																		
	5H-07, 40-42	45.4	B																																		

Note: Symbols as in Table 2.

Table 9. Planktonic foraminifer datums for Hole 962B.

Datum (Site 962)	Age (Ma)	Top (Core, section, interval)	Base (Core, section, interval)	Top (mbsf)	Base (mbsf)	Average depth (mbsf)
Re-appearance of *Pulleniatina obliquiloculata*	2.3	2H-6, 50-52 cm	2H-7, 50-52 cm	15.5	16.6	16.05
LAD ***Globorotalia miocenica***	2.3	2H-CC	3H-1, 50-52 cm	17	17.53	17.27
LAD *Dentogloboquadrina altispira*	3.05	3H-3, 50-52 cm	3H-4, 50-52 cm	20.5	22	21.25
LAD ***Sphaeroidinellopsis* spp.**	3.12	3H-1, 50-52 cm	3H-2, 50-52 cm	17.53	19	8.26
FAD *Globorotalia crassaformis*	4.5	3H-4, 50-52 cm	3H-5, 50-52 cm	22	23.5	22.75
FAD *Sphaeroidinella dehiscens*	5.2	3H-CC	4H-1, 50-52 cm	26.5	27	26.75

Note: Species in boldface are biozone markers.

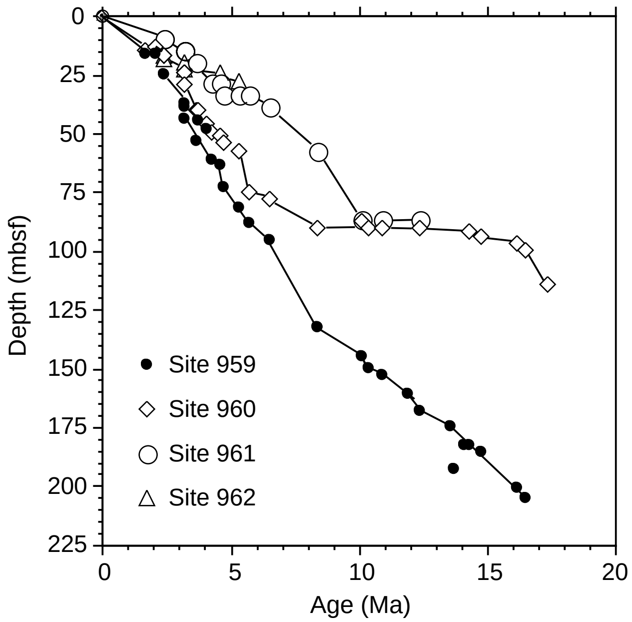

Figure 3. Age/depth plot for Leg 159 sites based on distribution of datums and their ages as given in Tables 3, 5, 7, and 9.

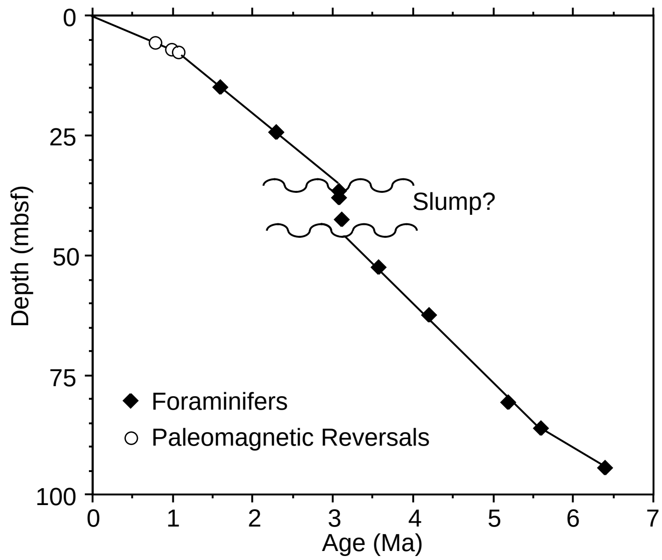

Figure 4. Age/depth plot for the upper Miocene to Holocene interval at Site 959. The abrupt increase in apparent sediment accumulation rate at ~3 Ma is interpreted as a slump.

Sample 159-962B-3H-2, 50–52 cm, and 3H-CC (19.0-26.5 mbsf) demonstrate that this interval is entirely Pliocene in age with a zonal assignment of Zone PL3 to PL1. The presence of *G. crassaformis* in Sample 159-962B-3H-4, 50–52 cm (22 mbsf), suggests that overlying sediments are no older than the very youngest part of Zone PL1 because this species has its FAD close to the top of PL1a in other Leg 159 sites. Sediments below Sample 159-962B-3H-CC (26.5 mbsf) cannot be zoned with planktonic foraminifers because of the almost complete dissolution of calcareous microfossils.

SEDIMENTATION HISTORY

Figure 3 is a plot of planktonic foraminifer datums for the four sites drilled during Leg 159. All the sites show modest sedimentation rates of less than 1 cm/k.y. in the Pleistocene. Site 961 has a distinctly lower accumulation rate (0.5 cm/k.y.) in the Pleistocene than the other sites. The top of the Pliocene appears to be truncated at Site 961 because Zone PL6 is apparently missing and both Pt1 and PL5 are condensed into the 3.5-m recovered interval.

Sedimentation rates increase to a long-term rate of 2 cm/k.y. in the Pliocene at Sites 959 and 960, which are both at the shallow end of the depth transect of Leg 159 sites (~2000 m water depth). The long-term sedimentation rate is nearly constant at Site 959 but shows a series of steps at Site 960 that suggests periods in which sedimentation dropped to ~1 cm/k.y. in the late Pliocene and earliest Pliocene. A sharp increase in sedimentation rate apparently occurs in the middle Pliocene (~3.09 to 3.12 Ma) at Site 959 that may represent a slump (Fig. 4). There are a number of unexplained voids in Hole 959C within the interval where sedimentation rates are anomalously high. The voids may reflect discontinuity surfaces that have been pulled apart during core retrieval. Both Sites 959 and 960 show an interval of dissolution near the Pliocene/Miocene boundary that corresponds approximately with the Messinian desiccation event. Dissolution during the Messinian may be responsible for a slight decrease in apparent sedimentation rate ~5 Ma at Site 960 and a hiatus over the same interval at Site 961. In contrast, Site 962, at the deep end of the depth transect (~4600 m water depth), shows very low rates of accumulation, ~0.3 cm/k.y. through the Pliocene.

Sedimentation rates of ~2 cm/k.y. continue into the upper Miocene at Site 959. Site 961 also shows little change in sedimentation rate between the Pliocene and late Miocene other than the hiatus across the Miocene/Pliocene boundary. However, the record at Site 960 suggests that erosion or nondeposition have affected much of the upper Miocene. Dissolution has removed planktonic foraminifers from the Miocene portion of the record at Site 962 rendering further comparison with foraminifer datums at other Leg 159 sites impossible.

The long-term sedimentation rate at Site 959 changes from ~2 cm/k.y. to 0.9 cm/k.y. near the base of Zone N17 and remains at this rate into the lower Miocene. The change in sedimentation rate corresponds to a general decline in the quality of planktonic foraminifer preservation and carbonate content of the sediments and may reflect the overall low rates of carbonate accumulation observed in many regions prior to or ~8–10 Ma (Peterson et al., 1992; Pisias et al., 1995). Site 960 shows an unconformity at this level that has removed sediments ranging in age from the lower part of Zone N17 (~8 Ma) to somewhere in Zone N10 (~14 Ma). Low sedimentation punctuated by hiatuses continued in this core back to ~16 Ma. Curiously, the Miocene record at Site 961 shows the onset of relatively high sedimentation rates of between 1 and 2 cm/k.y. at 10 Ma, which is nearly 2 m.y. before an increase in the sedimentation rate at both Sites 959 and 960. This early rise in sedimentation rate may reflect downslope transport from the shallower sites on the marginal ridge.

CONCLUSIONS

The holes drilled at the four sites on the Côte d'Ivoire-Ghana marginal ridge show substantial similarities in their histories. All sites are characterized by low rates of sedimentation in the Miocene. Sites near the seaward edge of the Côte d'Ivoire-Ghana marginal ridge (Sites 960 and 961) display major unconformities that have cut out much of the middle and upper Miocene, whereas Site 959 in the Deep Ivorian Basin had low but stable sedimentation rates into the late

Miocene. Sediment accumulation picked up in the latest Miocene and continued into the Pliocene in accord with typically high sedimentation rates for this time period in sites distributed around the globe. In general, Leg 159 sites in deep water (Sites 961 and 962) have lower rates of sedimentation than those higher on the marginal ridge. Although Sites 959 and 960 are at virtually the same water depth, Site 960 shows much more variation in sedimentation rates throughout the Pliocene, probably because of its position exposed to bottom currents on the top of the marginal ridge. For example, a major Miocene hiatus occurs at Site 960 and stands in contrast to low but stable sedimentation rates at Site 959; apparently erosion rather than an absence of sediment supply is responsible for this hiatus. All sites display a change in sedimentation rate near the Pliocene/Pleistocene boundary. Typically, there is a drop in sediment accumulation rate in the latest Pliocene. However, Site 962 shows a modest increase over its long-term sedimentation rate from ~0.3 cm/k.y. to ~1 cm/k.y., which may reflect downslope transport of sediments stripped from shallower portions of the Côte d'Ivoire-Ghana margin.

SYSTEMATIC PALEONTOLOGY

The present taxonomy is based upon the species concepts of Kennett and Srinivasan (1983), with some emendations by Blow (1979), Blow (1969), Bolli and Saunders (1985), Chaisson and Leckie (1993), and Pearson (1995). Partial references to the type of material are listed below for each species, and full references can be found in standard works such as Kennett and Srinivasan (1983).

Beella digitata (Brady)

Globigerina digitata Brady, 1879, p. 599, pl. 80, figs. 6–10.

Discussion: Kennett and Srinivasan (1983) report that this species appears in Zone Pt1. However, *Beella digitata* has a discontinuous range from the core top to near the base of Zone PL5 at Site 959 and scattered occurrences within Zone Pt1 at Site 960. This species differs from its presumed ancestor, *Beella praedigitata* by its more elongate final chambers.

Beella praedigitata (Parker)

Globigerina praedigitata Parker, 1967, p. 151, pl. 19, figs. 5–8.

Discussion: Scattered records of *Beella praedigitata* occur from Zone PL5 to Zone N17 at Site 959 and in Zone N17 at Site 960. This species is distinctive because of its high trochospire, faintly pustulose, perforated surface texture, and tendency toward slight radial elongation of the chambers.

Candeina nitida

Candeina nitida d'Orbigny, 1839, p. 107, pl. 2, figs. 27–28.

Discussion: *Candeina nitida* occurs episodically at Sites 959, 960, and 961. The fist occurrence of this species appears to be at the top of N16 at Sites 959 and 961, but scattered records have been found as low as Zone N8 at Site 959 and presumably represent downhole contaminants. Chaisson and Leckie (1993) have also reported the FAD of *C. nitida* in the upper part of Zone N16 in the western equatorial Pacific.

Catapsydrax dissimilis (Cushman and Bermudez)

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

Discussion: *Catapsydrax dissimilis* is characterized by the presence of several infralaminal apertures around the single bulla, whereas *Catapsydrax unicavus* has a single, large aperture on one side of the bulla. Both species are rare in the upper part of Zone N6 at Site 960 and have been observed in highly dissolved assemblages from the lower Miocene of Site 959.

Catapsydrax unicavus Bolli, Leoblich, and Tappan

Catapsydrax unicavus Bolli, Loeblich, and Tappan, p. 37, pl. 7, fig. 9a–c.

Discussion: *Catapsydrax unicavus* ranges slightly higher than *C. dissimilis* at Site 960 and has been used to define the top of Zone N16 there.

Clavatorella bermudezi (Bolli)

Hastigerinella bermudezi Bolli, 1957, p. 112, pl. 25, fig. 1a–c.

Discussion: *Clavatorella bermudezi* has a fairly regular occurrence from the top of Zone N13 to the top of Zone N12 and then again within Zones N7 and N8 at Site 959. This species is also present in Zones N7 and N8 at Site 960. In both sites, specimens are recognized largely by isolated clavate chambers, but well-preserved, complete specimens are also present throughout this species' range. *Clavatorella bermudezi* appears to intergrade with *Globorotaloides hexagona* from which it differs mainly in its more delicate construction and more radially elongate chambers.

Dentoglobigerina altispira (Cushman and Jarvis)

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

Discussion: *Dentoglobigerina altispira* has been recorded at all Leg 159 sites and is moderately common at Sites 959 and 960, with a nearly continuous pattern of occurrence from the top of Zone PL4 to the base of Zone N9. Scattered occurrences have also been noted within Zone N7 and N8 at Site 959, but the species is rare. Both high and low trochospiral forms are common and are distinguished from globoquadrinids by the somewhat compressed chambers, serrated umbilical teeth, and tendency to form a pustulose collar around the umbilicus.

Fohsella

Discussion: In this study, I elevate the subgenus *Fohsella* to generic rank given their independent evolution of keeled morphology from other keeled Neogene lineages such as *Globorotalia (Globoconella), Globorotalia (Hirsutella),* and *Globorotalia (Menardella).*

Fohsella birnageae (Blow)

Globorotalia birnageae Blow, 1959, p. 210, pl. 17, fig. 108a–c.

Discussion: *Fohsella birnageae* is a small species with a nearly circular profile in spiral view and coarse perforations similar to *Fohsella peripheroronda.* This species has been recorded in Zones N7 and N8 at Site 959 and in Zone 7 at Site 960.

Fohsella fohsi (Cushman and Ellisor)

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

Discussion: *Fohsella fohsi* is here considered to include forms of the genus *Fohsella* that possess a complete peripheral keel. Variants in the chronocline such as *Fohsella fohsi robusta* and *Fohsella fohsi lobata* have not been separated in this study, although they have been recognized in this material. *Fohsella fohsi* ranges over ~12 m of section at Site 959.

Fohsella lenguaensis (Bolli)

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

Discussion: *Fohsella lenguaensis* is a tiny species with an ovate outline and a rounded periphery. The chambers have distinctly recurved sutures on the spiral surface with a very low rate of chamber enlargement. The final chamber often juts out from the earlier whorl and the aperture is nearly covered by a flap similar to that of other fohsellids. The assignment of this species to *Fohsella* is not widely agreed upon; many authors have proposed a link to the *Globorotalia tumida* lineage (Cifelli and Scott, 1986; Kennett and Srinivasan, 1983). I follow the observation of similarities in preservation of *Fohsella fohsi* and *Fohsella lenguaensis* made by Chaisson and Leckie (1993) and the abundance of the latter species within the range of the fohsellids in proposing that *Fohsella lenguaensis* is the final species in the *Fohsella* morphocline. *Fohsella lenguaensis* is probably descended from *Fohsella fohsi,* with which it shares similarities in early ontogeny, preservation, and wall texture.

Fohsella peripheroacuta (Blow and Banner)

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

Discussion: *Fohsella peripheroacuta* is a transitional form between *Fohsella peripheroronda* and *Fohsella "praefohsi." Fohsella peripheroacuta* has the coarsely perforate wall of *F. peripheroronda* but the final chambers are axially compressed and become subacute in the geologically youngest members of this morphospecies. Varieties that develop a smooth wall and a sharply acute periphery are referred to *Fohsella "praefohsi."*

Fohsella peripheroronda (Blow and Banner)

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

Discussion: *Fohsella peripheroronda* is characterized by a coarsely perforate wall, strongly recurved spiral sutures (which distinguish it from *Globorotalia mayeri*) and a slit–like aperture. Specimens of *F. peripheroronda* are larger than *F. birnageae* and more oblate in outline. *Fohsella peripheroronda* ranges from Zone N10 to at least Zone N7 and has been found in poorly preserved and unzoned samples below this.

Fohsella "praefohsi" (Blow and Banner)

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

Discussion: The concept of Blow and Banner (1966), Chaisson and Leckie (1993), and Kennett and Srinivasan (1983) is followed here, who described *F. "praefohsi"* as a partly keeled, smooth-walled form transitional between *F. peripheroacuta* and *F. fohsi.* However, I also include forms that have a strongly acute periphery and smooth wall but do not actually have an imperforate keel. Indeed, my concept is supported by close examination of specimens identified as *F. "praefohsi"* by Kennett and Srinivasan (1983, pl. 22, fig. 7–9), Chaisson and Leckie (1993; pl. 3, figs. 5–7), and Vincent and Toumarkine (1990; pl. 4, figs. 1–3), all of which illustrate specimens with completely perforate margins including perforations in the "keel." My observations from many tropical sites suggest that *F. "praefohsi"* can have an extremely acute periphery and still not have an imperforate keel on any chambers (Norris et al., 1993; fig. 1).

Bolli and Saunders (1985) state that the holotype of *F. "praefohsi"* is intermediate between *F. fohsi fohsi* and *F. fohsi lobata* because it has a "cockscomb" outline in spiral view. In their view, the holotype cannot be the part of the ancestral stock of the *F. fohsi fohsi* group. While they may be correct that the holotype of *F. "praefohsi"* is geologically too young to be ancestral to *F. fohsi,* I have also observed "cockscomb" peripheries on fohsellids that do not have a keel and, therefore, cannot be representatives of *F. fohsi.*

Clearly, the definition of *F. "praefoshi"* is vague since this morphotype displays a variety of features of both *F. peripheroacuta* and *F. fohsi.* I prefer to distinguish *F. "praefohsi"* from *F. peripheroacuta* by both the generally more acute periphery and smoother wall texture of *F. "praefohsi"* compared to its ancestor. Later representatives of *F. "praefoshi"* differ from *F. fohsi* entirely in having an incomplete, imperforate keel.

Globigerina

Discussion: *Globigerina* is characterized by a more or less smooth wall ornamented with small pustules that form around spine bases. The wall is not cancellate and the pores are cylindrical rather than flaring open toward the exterior shell wall as in *Globigerinoides* and other cancellate-walled taxa.

Globigerina bulloides d'Orbigny

Globigerina bulloides d'Orbigny, 1826, p. 277.

Discussion: *Globigerina bulloides* is a rare constituent from the late Pleistocene to the early Miocene (Zones Pt1 to N8). Pleistocene *Globigerina bulloides* are much larger than those found in older sediments, but all specimens have the pustulose wall texture and large umbilical aperture typical of the species. Early Miocene forms tend to have a somewhat quadrate aperture reminiscent of *Globigerina ciperoensis* and may grade into *Globigerina praebulloides.*

Globigerinella

Discussion: *Globigerinella* is characterized by a nearly smooth wall ornamented with small pustules that form around spine bases—a wall texture similar to that of the genus, *Globigerina*. Early representatives of the genus (*G. obesa, G. praesiphonifera*) are trochospirally coiled with an umbilical–extraumbilical aperture, which accounts for their initial assignment to the genus *Globorotalia* (e.g., Bolli, 1957). The genus develops an equatorial aperture late in the ontogeny of *Globigerinella siphonifera*.

Globigerinella calida (Parker)

Globigerina calida Parker, 1962, p. 221, pl. 1 figs. 9–13 and 15.

Discussion: This species is very rare, having been observed occasionally in Zone Pt1 at Site 959 and from Zone Pt1 to the upper part of Zone PL5 at Site 960. *Globigerinella calida* is distinguished from *Globigerinella obesa* by having a more open umbilicus, an often radially elongate final chamber, and a thin lip.

Globigerinella praesiphonifera (Blow)

Hastigerina siphonifera praesiphonifera Blow, 1969, p. 408, pl. 54, figs. 7–9.

Discussion: This species has been recorded consistently from Zone N17 to Zone N7 at both Sites 959 and 960. Scattered occurrences of this species in the Pliocene are probably variants of *Globigerinella calida.* These Pliocene specimens lack the thin lip characteristic of *Globigerinella calida* and do not have the elongate final chambers common to this species. *Globigerinella praesiphonifera* is characterized by trochospiral coiling and an umbilical–extraumbilical aperture (by comparison with the partially or completely equatorial aperture of *Globigerinella siphonifera*) and loose coiling that results in an open umbilicus.

Globigerinella obesa (Bolli)

Globorotalia obesa Bolli, 1957, p. 119, pl. 29, fig. 2a–c.

Discussion: *Globigerinella obesa* is recorded regularly in the Pliocene and upper Miocene at Sites 959 and 960 and sporadically at Site 959 between Zone N16 and N12. Typical specimens have four to four and a half highly inflated chambers, a narrow umbilicus, and no lip.

Globigerinella siphonifera (d'Orbigny)

Globigerina siphonifera d'Orbigny, 1839, figs. 2.3g and h.

Discussion: This species is nearly continuously present, but always rare between the Pleistocene and the upper Miocene (Zone N17) at Site 960 and sporadically as low as Zone N14 at Site 959. *Globigerinella siphonifera* is distinguished from all related species by its equatorial aperture and relatively large size. Specimens tend to be fragmentary in the early part of the range of this species at Site 959.

Globigerinita

Discussion: *Globigerinita* is a widespread taxon characterized by a small, microperforate, nonspinose test with finely pustulose or hispid surface texture and an umbilical aperture.

Globigerinita glutinata (Egger)

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

Discussion: This species has been recorded in the >150-µm fraction from all Leg 159 sites. *Globigerinita glutinata* has a nearly continuous occurrence in samples from Site 959 and 960 from the Pleistocene to lower Miocene Zone N6. Both bullate and nonbullate forms have been observed in nearly all samples, and forms with a single, particularly large bulla appear to intergrade with *Globigerinatella insueta,* but they do not have areal apertures or the overlapping bullae typical of *G. insueta*.

Globigerinita uvula (Ehrenberg)

Pylodexia uvula Ehrenberg, 1861, p. 308; Ehrenberg, 1873, pl. 2, figs. 24–25.

Discussion: *Globigerinita uvula* is distinguished from *Globigerinita glutinata* by its high, "ice cream cone" spire. This species has a very intermittent pattern of occurrence from the Pliocene to the lower Miocene at Sites 959 and 960.

Globigerinoides

Discussion: *Globigerinoides* is recognized by its cancellate-spinose wall texture, globular chambers with an umbilical primary aperture and the presence of one or more secondary apertures. The genus may be polyphyletic with separate ancestry of the lineage leading to *Globigerinoides ruber* and *Globigerinoides conglobatus* and the lineage leading to *Globigerinoides sacculifer*, *Sphareoidinella*, and *Orbulina.*

Globigerinoides bisphericus Todd

Globigerinoides bisphericus Todd, 1954, p. 681, pl. 1, fig. 1a–c.

Discussion: This species is characterized by a greatly enlarged final chamber that overhangs the earlier chambers in the final whorl. I include in this species specimens that have either two and three apertures around the final chamber. Forms with only two apertures typically have one aperture much larger than the other and the final chamber is hemispherical. This species is distinguished from *Globigerinoides trilobus* by the extreme size of the final chamber and the reduced umbilicus of *G. bisphericus. Praeorbulina sicanus* is similar to *G. bisphericus,* but has four apertures around the final chamber.

Globigerinoides conglobatus (Brady)

Globigerina conglobatus Brady, 1879, p. 28b; Brady, 1884, p. 9, pl. 80, figs. 1–5.

Discussion: *Globigerinoides conglobatus* has a discontinuous occurrence from the Pleistocene to the upper Miocene (Zone N17) at Sites 960 and 959.

Globigerinoides extremus Bolli and Bermudez

Globigerinoides obliquus extremus Bolli and Bermudez, 1965, p. 139, pl. 1, figs. 10–12.

Discussion: *Globigerinoides extremus* is distinguished from its ancestor *Globigerinoides obliquus* by its more distinctly flattened final chamber and typical medium to high trochospiral shell. At Sites 959 and 960, this species ranges from near the top of Zone PL5 to the base of Zone N17.

Globigerinoides sacculifer fistulosus (Schubert)

Globigerina fistulosus Schubert, 1910, p. 323, text fig. 2, fig. 13a–c.

Discussion: *Globigerinoides sacculifer fistulosus* has trace occurrences in samples from the Pliocene/Pleistocene boundary to within Pliocene Zone PL4. The characteristic tubulospines on the final chamber are never well developed at Leg 159 sites and often consist only of a row of short knobs on an axially compressed final chamber or a single elongate sac-like chamber that extends into a short tubulospine. Specimens without at least one well-defined tubulospine are referred to as cf. *G. sacculifer fistulosus. Globigerinoides sacculifer fistulosus* has been found consistently in latest Pliocene-age samples that have been intensively studied from Hole 959C.

Globigerinoides mitra Todd

Globigerinoides mitra Todd, 1957, p. 302, pl. 78, figs. 3 and 6.

Discussion: *Globigerinoides mitra* is a large, medium to high-spired species with high-arched secondary apertures and a delicate wall. This species has been found intermittently from Zone N13 to Zone N7 at Site 959 and within Zone N7 at Site 960.

Globigerinoides obliquus Bolli

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

Discussion: This species has a somewhat compressed final chamber and large primary aperture. *Globigerinoides obliquus* is recorded frequently to commonly in nearly all samples from Pliocene Zone PL3 to middle Miocene Zone N12 at Sites 959 and 960 and has been found occasionally at Sites 961 and 962.

Globigerinoides ruber (d'Orbigny)

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

Discussion: *Globigerinoides ruber* is common from the Pleistocene to Pliocene Zone PL3 in all Leg 159 sites. Most specimens are moderately high spired and reach moderately large size in the Pleistocene. A wide species concept is used here to include both pink and white varieties and high- and low-spired morphotypes.

Globigerinoides sacculifer (Brady)

Globigerina sacculifer Brady 1877, p. 164, pl. 9, figs. 7–10; Brady, 1884, p. 604, pl. 80, figs. 11–17; pl. 81, fig. 2; and pl. 82, fig. 4.

Discussion: *Globigerinoides sacculifer* is one of the most common species in Leg 159 foraminifer assemblages. This species is abundant to common from the Pleistocene to the lower Miocene Zone N6 at Site 959. No attempt has been made to separate *Globigerinoides trilobus* and *Globigerinoides quadrilobatus* from *Globigerinoides sacculifer,* although the sac-like final chamber has been observed to become common only in the late Miocene to Pleistocene portion of this species' range.

Globigerinoides seigliei Bermudez and Bolli

Globigerinoides seigliei Bermudez and Bolli, 1969, p. 164, pl. 8, figs. 10–12.

Discussion: This species is a large, high-spired form similar to *Globigerinoides mitra*, but differs in the cancellate wall texture of *G. seigliei. Globigerinoides seigliei* has been recorded in a few samples from upper Miocene Zones N17 and N16 at Site 959 and in Zone N17 at Site 960.

Globigerinoides subquadratus Brönnimann

Globigerinoides subquadratus Brönnimann, 1954, p. 680, pl. 1, fig. 8a–c.

Discussion: This species closely resembles *Globigerinoides ruber* and may be conspecific with it. *Globigerinoides subquadratus* has distinctive, high-arched apertures, two or more secondary apertures and the same lightly pustulose wall texture characteristic of the *Globigerinoides ruber* lineage, but appears to show less morphological variation than Pleistocene populations of *G. ruber* and has a distinctly different stratigraphic range from this species in Leg 159 sites. *Globigerinoides subquadratus* has been recorded from lower to middle Miocene Zones N7 to N12 at Site 959 and Zones N8 to N6 at Site 960.

Globigerinoides bulloideus Crescenti

Globigerinoides bulloideus Crescenti, 1966, p. 43, text fig. 8, no. 3–3a and text fig. 9.

Discussion: *Globigerinoides bulloideus* closely resembles *Globigerina bulloides* in gross morphology, but differs from this species in possessing a lightly cancellate wall texture and a small secondary aperture. This species has been recorded occasionally from Pliocene Zone PL4 to Miocene Zone N17 at Sites 959 and 960.

Globigerinoides altiapertura Bolli

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

Discussion: This species closely resembles *Globigerinoides obliquus*, but differs in having a larger secondary aperture and a nearly circular primary and secondary aperture compared to the somewhat compressed apertures in *G.*

obliquus. A few specimens of *Globigerinoides altiapertura* have been found in Zones N7 and N8 at Sites 959 and 960.

Globigerinoides diminutus Bolli

Globigerinoides diminutus Bolli, 1957, p. 114, pl. 25, fig. 11a–c.

Discussion: This species is a heavily crusted, compact taxon with minute primary and secondary apertures and typically only three chambers in the final whorl compared to four, less-appressed chambers in the similar species *Globigerinoides bollii. Globigerinoides diminutus* has been recorded from lower Miocene Zones N7 and N8 at Site 960.

Globigerinoides bollii Blow

Globigerinoides bollii Blow, 1959, p. 189, pl. 10, fig. 65a–c.

Discussion: *Globigerinoides bollii* closely resembles *Globoturborotalita woodi* from which it differs in having a tiny secondary aperture and a smaller primary aperture as well as a more compact test in many cases. The size of the secondary aperture is larger in *Globigerinoides parawoodi* than in *Globigerinoides bollii.* This species has been recorded from the upper Miocene Zone N16 to the Pleistocene at Sites 959 and 960.

Globigerinoides parawoodi Keller

Globigerinoides parawoodi Keller, 1981, p. 304, pl. 4, figs. 1–11.

Discussion: This species has been used here to describe small forms similar to *Globigerinoides bollii* that have a single high-arched secondary aperture nearly the same size as the primary aperture. As such, my species concept does not completely match that of Keller, who envisioned a taxon with a rather small secondary aperture. *Globigerinoides parawoodi* has been found from middle and lower Miocene Zones N9 to N7 at Sites 959 and 960.

Globoquadrina

Discussion: *Globoquadrina* is probably a polyphyletic taxon that contains possibly unrelated or distantly related forms such as *Globoquadrina venezuelana* (characterized by a distinctive weakly cancellate but heavily calcified test and globular chambers) and the *Globoquadrina dehiscens* group that has a distinctly flattened apertural face and cancellate, nonspinose surface texture. All species in this genus possess an apertural tooth and an umbilical primary aperture.

Globoquadrina dehiscens (Chapmann, Parr, and Collins)

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

Discussion: *Globoquadrina dehiscens* is identified by its low spire, flat apertural face, single, triangular apertural tooth, and three and a half to four chambers in the final whorl.

Globoquadrina venezuelana (Hedberg)

Globigerina venezuelana Hedberg, 1937, p. 681, pl. 92, fig. 7a–b.

Discussion: *Globoquadrina venezuelana* is a rare but regular component of planktonic foraminifer assemblages at all Leg 159 sites and ranges from its LAD just above the Zone PL3/PL4 boundary through the lower Miocene at Sites 959, 960, and 961. This species is concentrated in poorly preserved samples where it may dominate the foraminifer assemblages. Typical specimens have three large, globular chambers with a fourth smaller and often irregularly shaped final chamber. The spire is typically low and the initial whorls may be difficult to make out because of secondary calcification.

Globorotalia

Discussion: In this paper, *Globorotalia* refers to unkeeled descendants of *Globorotalia (Jenkinsella) mayeri* and their keeled derivatives in the subgenera, *Menardella, Truncorotalia, Hirsutella, Globorotalia,* and *Globoconella.* Split off from this group are the keeled and unkeeled forms of the *Fohsella* lineage (leading to *Fohsella fohsi*) and the *Neogloboquadrina/Pulleniatina* group that may be derived from nonspinose forms like *Globorotalia mayeri. Globorotalia (Jenkinsella)* is retained for nonspinose, cancellate walled, nonkeeled forms, with slightly curved spiral sutures during the early stages of growth. It is possible that members of *Globorotalia (Jenkinsella)* may be redescribed as members of the spinose genus, *Paragloborotalia,* but, as yet, convincing evidence for a spinose wall texture has not been demonstrated for the jenkinsellids. *Fohsella* is split off as a discrete genus, given its clear derivation from unkeeled ancestors in the late Oligocene.

Globorotalia archeomenardii Bolli

Globorotalia archeomenardii Bolli, 1957, p. 119, pl. 28, fig. 11a–c.

Discussion: This species is distinguished from its descendant, *Globorotalia praemenardii,* by its small size and lack of a raised peripheral keel. However, *Globorotalia archeomenardii* does possess an imperforate band. *Globorotalia praescitula* has a distinctly more coarsely perforate test, more umbilically inflated axial profile, and fewer chambers (~4 to 4.5) compared to the five chambers typical of *Globorotalia archeomenardii. Globorotalia archeomenardii* has been recorded from Zone N8 at Site 959 and Zones N98 to N10 at Site 960.

Globorotalia crassaformis (Galloway and Wissler)

Globigerina crassaformis Galloway and Wissler, 1927, p. 41, pl. 7, fig. 12.

Discussion: *Globorotalia crassaformis* is characteristic of Pleistocene to lower Pliocene samples at all Leg 159 sites. This species has a distinctive and well-documented FAD just below the LAD of *Globoturborotalita nepenthes* (Zone PL1). This FAD appears to be younger than recorded elsewhere in the Atlantic (Norris, Chap. 40, this volume). Most specimens are unkeeled, but keeled morphotypes have been observed occasionally and intergrade with *Globorotalia crassula.*

Globorotalia cibaoensis Bermudez

Globorotalia cibaoensis Bermudez, 1949, p. 285, pl. 22, figs. 21–23.

Discussion: *Globorotalia cibaoensis* is a small species with a weakly pustulose wall texture that has a sharp but nonkeeled periphery. This species intergrades with *Globorotalia scitula* from which it differs in its sharper periphery and tendency to be somewhat umbilically inflated. *Globorotalia cibaoensis* ranges from the upper part of Zone N16 to the lower half of Zone PL1. The LAD of this taxon is not well defined at Leg 159 sites making it difficult to subdivide Zone PL1.

Globorotalia crassula Cushman and Stewart

Globorotalia crassula Cushman and Stewart, 1930, p. 77, pl. 7, fig. 1a–c.

Discussion: *Globorotalia crassula* is a nearly biconvex form that may be a weakly umbilically inflated variant of *Globorotalia crassaformis.* This species has been recorded only from the upper Pliocene (upper Zone PL5) to the Pleistocene at Site 959.

Globorotalia exilis Blow

Globorotalia exilis Blow, 1969, p. 396, pl. 7, figs. 1–3, pl. 42, figs. 1, 5.

Discussion: This species is a large, thin-walled species that resembles *Globorotalia pertenuis. Globorotalia exilis* differs from *G. pertenuis* in possessing a more open umbilicus, less lobate periphery, and typically more protruding final chamber. *Globorotalia exilis* is a rare species that ranges from the base of Zone PL2 to the top of Zone PL5 at Sites 959 and 960.

Globorotalia hirsuta (d'Orbigny)

Rotalina hirsuta d'Orbigny, 1839, p. 131, pl. 1, figs. 34–36.

Discussion: *Globorotalia hirsuta* is a large, four-chambered, pustulose species with a nearly biconvex profile in Leg 159 sediments. This species is most abundant from the top of Zone PL3 to the top of Zone PL5 at both Sites

959 and 960, but there are scattered records of a pustulose form close to *Globorotalia hirsuta* as low as the top of Zone PL1 at Site 960. The pustulose specimens in the lower Pliocene are apparently lightly crusted variants of *Globorotalia margaritae* although *G. margaritae* is normally a five-chambered species with a nearly smooth wall.

Globorotalia inflata (d'Orbigny)

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

Discussion: *Globorotalia inflata* is present from Pliocene Zone PL4 though the Pleistocene. Small specimens similar to smooth-walled *Globorotalia puncticulata* have been recorded from the top of Zone PL3 at Site 959. Both three- and four-chambered individuals of *G. inflata* have been recorded throughout the range of this species. Juveniles are pustulose like *G. puncticulata*, but have more compact coiling. Intermediates between *G. inflata* and *G. triangula* have also been observed in upper Pliocene samples from Site 959.

Globorotalia juanai Bermudez and Bolli

Globorotalia juanai Bermudez and Bolli, 1969, p. 171–172, pl. 14, figs. 1–6.

Discussion: This species ranges from the top of Zone N16 into the upper part of Zone N17 at Site 959. Near the top of its range, *Globorotalia juanai* becomes difficult to separate from fat forms of *Globorotalia cibaoensis. Globorotalia juanai* is distinguished from *Globorotalia cibaoensis* by its more umbilically inflated test and rounded periphery.

Globorotalia limbata (Fornasini)

Rotalia limbata Fornasini, 1902, p. 30–31, pl. 5, fig. 3; Lectotype.

Discussion: *Globorotalia limbata* has six or more chambers in the final whorl compared to the typical five chambers in the last whorl of *Globorotalia menardii.* The heavy crust of *Globorotalia limbata* serves to distinguish this species from thin-walled *Globorotalia exilis. Globorotalia limbata* ranges from the Zone N14 to the middle of Zone PL1. A single record has been found in Zone N13, which may reflect downhole contamination or an odd variant of *Globorotalia menardii.*

Globorotalia margaritae Bermudez and Bolli

Globorotalia margaritae Bermudez and Bolli, 1965, p. 138, pl. 1, figs. 1–9.

Discussion: *Globorotalia margaritae* has a well-defined range in Leg 159 sites from the upper part of Zone N17 to the top of Zone PL2. Specimens are nearly always five-chambered although a few six-chambered forms have been observed. The axial profile varies from slightly spirally convex to weakly umbilically convex. As noted for *Globorotalia hirsuta*, some small, four-chambered forms with a pustulose wall texture have been noted near the top of the range of *Globorotalia margaritae.*

Globorotalia mayeri Cushman and Ellisor

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

Discussion: My species concept for *Globorotalia mayeri* includes 6–7 chambered forms commonly referred to as *Globorotalia siakensis* following Bolli and Saunders (1982). *Globorotalia mayeri* ranges from middle Miocene Zone N14 to at least as low as Zone N6, below which dissolution has removed virtually all foraminifers.

Globorotalia menardii (Parker, Jones, and Brady)

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

Discussion: *Globorotalia menardii* ranges from the Pleistocene to the middle Miocene Zone N12, although the distribution of this species becomes noticeably more spotty below the base of the Pliocene. *Globorotalia menardii* is nearly absent in Zone PL5 during the peak in abundance of *Globorotalia miocenica.*

Globorotalia merotumida Blow and Banner

Globorotalia merotumida Blow and Banner, 1965, p. 1352, text fig. 1.

Discussion: *Globorotalia merotumida* is a small, heavily crusted taxon in Leg 159 sites, where it ranges from Zone N15 to the middle of Zone N17. This species has a raised peripheral keel and a low spiral surface similar to *Globorotalia plesiotumida.* The final chamber is about as broad as it is long in *G. merotumida* and is distinctly longer than it is broad in *G. plesiotumida.*

Globorotalia miocenica Palmer

Globorotalia menardii miocenica Palmer, 1945, p. 70, pl. 1, fig. 10a–c.

Discussion: *Globorotalia miocenica* is a thin-walled species with a nearly flat spiral surface and a circular periphery in spiral view. It is distinguished from *Globorotalia pseudomiocenica* by the flatness of the spire. *Globorotalia miocenica* ranges from the top of Pliocene Zone PL3 to the top of Zone PL5.

Globorotalia miozea Findlay

Globorotalia miozea Findlay, 1939, p. 326, pl. 29, figs. 159–161.

Discussion: Specimens were observed in only a single sample from middle Miocene Zone N13 at Site 959. They are heavily crusted, umbilically inflated and possess a sharp, but nonkeeled periphery. The aperture is nearly closed.

Globorotalia multicamerata Cushman and Jarvis

Globorotalia multicamerata Cushman and Jarvis, 1930, p. 367, pl. 34, fig. 8a–c.

Discussion: *Globorotalia multicamerata* intergrades with *Globorotalia limbata. Globorotalia multicamerata* is characterized by seven or more chambers in the final whorl, a nearly circular outline, and a deep umbilical pit. *Globorotalia multicamerata* ranges from the upper part of Pliocene Zone PL1 to the top of Zone PL4 and is most abundant near the top of its range.

Globorotalia panda Jenkins

Globorotalia panda Jenkins, 1960, p. 364, pl. 4, fig. 10a–c.

Discussion: This typically mid to high latitude homeomorph of *Globorotalia margaritae* has been found in a single sample within Zone N13 at Site 959. Specimens do not have a well developed keel and are biconvex to spirally convex with five chambers in the final whorl. These forms could represent downhole contamination of noncarinate *Globorotalia margaritae.*

Globorotalia pertenuis Beard

Globorotalia pertenuis Beard, 1969, p. 552, pl. 1, figs. 1–6; pl. 2, figs. 5–6.

Discussion: This species is notable for its large, thin-walled, nearly flat test and its tendency to develop extensions of the aperture lip over the umbilicus. Specimens are not always clearly separable from *Globorotalia exilis* with which it largely overlaps in stratigraphic range in Leg 159 sites.

Globorotalia plesiotumida Blow and Banner

Globorotalia (Globorotalia) tumida plesiotumida Blow and Banner, 1965, p. 1355, fig. 2a–c.

Discussion: *Globorotalia plesiotumida* is distinguished from all other species in the shape of its final chamber, which is longer than it is broad, and is elongate in the direction of coiling (as opposed to the somewhat radially elongate final chamber in *G. tumida*). The two species are of similar size in the lower Pliocene but Pleistocene representatives of *G. tumida* are distinctly larger than lower Pliocene members of this group. *Globorotalia plesiotumida* grades into *G. tumida*, making it difficult to clearly recognize the FAD of *G. tumida.* However, *G. plesiotumida* does not become extinct at the same level as the FAD of *G. tumida,* but persists into the lower part of Pliocene Zone PL2 at Sites 959 and 960.

Globorotalia praemenardii Cushman and Stainforth

Globorotalia praemenardii Cushman and Stainforth, p. 70, pl. 13, fig. 14a–c.

Discussion: *Globorotalia praemenardii* is present in low numbers from Zones N10 to Zone N14 at Site 959. This species is distinguished from *G. menardii* by its thin keel and smaller, less heavily calcified test.

Globorotalia praescitula Blow

Globorotalia praescitula Blow, 1959, p. 221, pl. 19, fig. 128a–c.

Discussion: This species is present sporadically from the base of Zone N13 to Zone N7 at Site 959. *Globorotalia praescitula* is a very small species that has a more coarsely perforate wall than geologically younger, keeled globorotaliids, and lacks a well-defined keel. The shell tends to be biconvex or umbilically convex, and the outline is often strongly lobate.

Globorotalia pseudomiocenica Bolli and Bermudez

Globorotalia pseudomiocenica Bolli and Bermudez, 1965, p. 140, pl. 1, figs. 13–15.

Discussion: This species is similar to *Globorotalia miocenica* in most respects other than its moderate elevation of the spiral surface. Small specimens are similar to *G. menardii,* but are more lightly calcified and more umbilically inflated. *Globorotalia pseudomiocenica* ranges from Pliocene Zone PL3 to Zone PL5 at Sites 959 and 960.

Globorotalia puncticulata (Deshayes)

Globigerina puncticulata Deshayes, 1832, p. 170; Banner and Blow, 1960, p. 15, pl. 5, figs 7a–c (Lectotype).

Discussion: *Globorotalia puncticulata* ranges from Zone PL3 to near the top of Zone PL5 at Sites 959 and 960. Specimens are nearly always small and thin walled and resemble axially compressed, four-chambered specimens of juvenile *Globorotalia inflata.*

Globorotalia scitula (Brady)

Pulvinulina scitula Brady, 1882, p. 27, pl. 5, fig. 5; Lectotype.

Discussion: This species ranges from the base of Zone N13 to the Pleistocene. *Globorotalia scitula* is characteristically four chambered, with a rounded periphery and an imperforate band. The chambers are much broader than they are long, as in related species such as *G. cibaoensis* and *G. theyeri,* but the smooth wall and rounded periphery are distinctive of *G. scitula*.

Globorotalia theyeri Fleisher

Globorotalia theyeri Fleisher, 1974, p. 1028, pl. 12, fig. 9; pl. 13, figs. 1–5.

Discussion: *Globorotalia theyeri* is present from Pliocene Zone PL5 into the Pleistocene. This species is characterized by a smooth, thin wall and a slightly umbilically inflated, weakly carinate test with a lobate outline in spiral view. *Globorotalia hirsuta* is more pustulose and is often spirally convex.

Globorotalia triangula Theyer

Globorotalia inflata triangula Theyer, 1973, p. 199–201, pl. 1, figs. 1–7.

Discussion: *Globorotalia triangula* is closely related to *G. inflata,* but has a triangular test in axial view and a lumpy, heavy, calcite crust compared to the smooth cortex of *G. inflata.* The aperture of *G. triangula* may be nearly closed by secondary calcification. This species ranges from Zone PL3 to the upper Pliocene Zone PL6.

Globorotalia truncatulinoides (d'Orbigny)

Rotalina truncatulinoides d'Orbigny, 1839, p. 132, pl. 2, figs. 25–27.

Discussion: This species is very rare in Leg 159 sites, requiring much searching to identify its first occurrence. However, *G. truncatulinoides* appears to be present in nearly all samples from the Pleistocene of Hole 959C, where a detailed study was made to identify the FAD of this species.

Globorotalia tumida (Brady)

Pulvinulina menardii (d'Orbigny) var. tumida Brady, 1877, p. 535; Brady, 1884, pl. 103, figs., 4–6.

Discussion: *Globorotalia tumida* is present from its FAD at the base of the Pliocene to the Pleistocene in Sites 959, 960, and 961 and is one of the few globorotaliids to remain in samples from the highly dissolved assemblages of Site 962. The FAD of this species is identified by the appearance of forms with a pointed and swollen ("tumid") final chamber compared to the oblong chamber of *G. plesiotumida* and by a shift from an umbilically inflated axial profile to a teardrop-shaped silhouette. The change in the shape of the final chamber appears to occur before that of the shell profile and has been used here as the primary criterion for recognition of the FAD of *G. tumida. Globorotalia tumida* is nearly completely absent during Pliocene Zones PL5 and PL6.

Globorotaloides

Discussion: *Globorotaloides* is a long-ranging, possibly heterogeneous, group that includes forms with radially elongate chambers such as *G. hexagona* and strongly inflated species that develop an umbilical bulla late in the life cycle (e.g., *G. varabilis* and *G. suteri*). All have a coarsely cancellate test with well-developed interpore ridges on an apparently nonspinose wall.

Globorotaloides hexagona (Natland)

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

Discussion: This species is present in most samples from Sites 959 and 960, except in Pliocene Zones PL5 and PL6 where it follows *G. tumida* in its absence. Two varieties of *G. hexagona* have been recognized in Leg 159 material: a four-chambered form with inflated chambers and a slightly elevated spire that is common throughout the Pliocene and Pleistocene, and a variant with five somewhat radially elongate chambers and a nearly flat spiral surface that occurs throughout the range of this species. The five-chambered variant of *G. hexagona* grades into *Clavatorella bermudezi* in the lower Miocene by further radial extension of the chambers.

Globorotaloides suteri Bolli

Globorotaloides suteri Bolli, 1957, p. 117, pl. 27, fig. 9a–13b.

Discussion: This species is larger and has more inflated chambers than *Globorotaloides varabilis* and the spiral surface is not as flat. The two species overlap in range in the lower part of Zone N7 just before the LAD of *G. suteri.*

Globorotaloides varabilis Bolli

Globorotaloides varabilis Bolli, 1957, p. 117, pl. 27, fig. 15a–20c.

Discussion: *Globorotaloides varabilis* is a four-chambered species with moderately inflated chambers that increase in size more rapidly than in either *G. hexagona* or *G. suteri*. Bullate individuals are common and the inflated bulla almost completely covers the aperture as in species of *Catapsydrax. Globorotaloides varabilis* is most common from Zone N7 to N13 at Sites 959 and 960.

Globoturborotalita Hofker

Discussion: *Globoturborotalita* is used here as the generic group of cancellate walled foraminifers that have been generally described as members *Globigerina* despite the finely perforate, pustulose wall texture characteristic of that group. Kennett and Srinivasan (1983) referred to cancellate-walled *"Globigerina"* as the subgenus *Zeaglobigerina* whose type species is *"Globigerina" woodi.* The type species for *Globoturborotalita* is *G. rubescens,* but the relationship of this species to the *woodi* group is still unclear. Hence, it possible that *Globoturborotalita* is not synonymous with *Zeaglobigerina.*

Globoturborotalita apertura Cushman

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

Discussion: The aperture of *Globoturborotalita apertura* is very large compared to related species such as *Globoturborotalita rubescens* and *Globoturborotalita woodi. Globoturborotalita apertura* has a lower trochospire than *Globoturborotalita decoraperta* and is frequently somewhat larger. The range of *G. apertura* extends nearly continuously from Zone PL5 to the top of Zone N17 at Sites 959, 960, and 961, with scattered occurrences in Pt1 at Site 960, and in N16 at Sites 959 and 961.

Globoturborotalita decoraperta (Takayanagi and Saito)

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

Discussion: This species is a regular constituent of the >150-µm sieve fraction in moderately preserved to well preserved material in Leg 159 sites. It is characterized by a high trochospire, cancellate surface, and a very large primary aperture—the latter similar to that of *G. apertura. Globoturborotalita decoraperta* ranges from Zone PL5 to Zone N12 at Site 959 and has been recorded from the Pleistocene to Zone N17 at Site 960.

Globoturborotalita druyri (Akers)

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

Discussion: *Globoturborotalita druyri* has only been recorded within N12 and N13 from Site 959 where it is recognized by its heavy aperture lip and similarity to juveniles of *Globoturborotalita nepenthes* that have not yet added the distinctive "thumb-shaped" final chamber of that species.

Globoturborotalita nepenthes (Todd)

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

Discussion: *Globoturborotalita nepenthes* is a distinctive but relatively rare component of foraminifer assemblages at Sites 959 and 960 where it has nearly continuous occurrence in samples throughout its range. The species is easily recognized by the protruding final chamber and coarsely cancellate wall. Specimens just below the LAD of this species are rare and atypically small.

Globoturborotalita woodi (Jenkins)

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

Discussion: *Globoturborotalita woodi* is a small species with a distinctive, high-arched aperture situated over a chamber in the four-chambered final whorl, and a thin lip, if any. This species ranges from N7 to Pt1 and is difficult to separate from *Globoturborotalita rubescens* near the top of its range. However, *G. rubescens* has a more evolute coiling geometry than *G. woodi,* which results in a more lobate periphery in umbilical view.

Globigerinatella insueta Cushman and Stainforth

Globigerinatella insueta Cushman and Stainforth, 1945, p. 69, pl. 13, figs. 6–9.

Discussion: *Globigerinatella insueta* is regarded as a monospecific genus by most authors (Bolli and Saunders, 1985; Kennett and Srinivasan, 1983). Pearson (1995) has shown that *Globigerinatella insueta* is preceded by a similar form that lacks the characteristic areal apertures of the genus and is gradational into *Globigerinita glutinata.* Typical examples of *Globigerinatella insueta* are very rare in Leg 159 sites and have been found only near the Zone N7/N8 boundary at Site 959. I have observed small forms similar to *Globigerinatella* sp. (sensu Pearson, 1995) to range above the LAD of *G. insueta* to near the top of Zone N12 at Site 959. Some of these forms are clearly trochospiral in the early whorls but develop one or more hemispherical chambers that partly envelop the initial whorls and lack areal apertures in the microperforate, pustulose wall. I have referred to these forms as "cf. *Globigerinatella insueta*" and their range is indicated by "cf." on the range charts. However, "cf. *Globigerinatella insueta*" is not indicative of the true range of *Globigerinatella insueta* sensu strictu.

Neogloboquadrina

Discussion: *Neogloboquadrina* is characterized by a nonspinose cancellate test with straight spiral sutures. Intermediates between species of this genus are uncommon in Leg 159 material other than the gradational transition from *N. humerosa* to *N. dutertrei.*

Neogloboquadrina acostaensis (Blow)

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

Discussion: This species is small, tightly coiled, and four to five chambered with a large flap that completely covers the aperture. Specimens in the upper Pliocene are commonly four chambered but are distinguished from *N. pachyderma* by their very large aperture flap.

Neogloboquadrina continuosa (Blow)

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

Discussion: Small, four chambered neogloboquadrinids with an arched aperture are placed in *N. continuosa* and are recorded from Zones N12 to N7 at Sites 959 and 960.

Neogloboquadrina dutertrei (d'Orbigny)

Globigerina dutertrei d'Orbigny, 1839, pl. 2, fig. 1; Lectotype.

Discussion: *Neogloboquadrina dutertrei* is generally a large, low trochospiral species with an umbilical-extraumbilical aperture and a prominent lip in Leg 159 material. Variants with an umbilical aperture and apertural teeth are rarely encountered. However, specimens in the middle and lower Pliocene frequently develop an extensive, irregular aperture lip or flap that covers much of the umbilicus and are similar to specimens described from the Ontong Java Plateau by Chaisson and Leckie (1993). *Neogloboquadrina dutertrei* has a distinct FAD just above the base of Pliocene Zone PL1 at Sites 959 and 960.

Neogloboquadrina humerosa (Takayanagi and Saito)

Globorotalia humerosa Takayanagi and Saito, 1962, p. 78, pl. 28, fig. 1a–2b.

Discussion: This species ranges from the upper Pliocene (Zone PL5) to the base of Zone N16 at Site 959. *Neogloboquadrina humerosa* is distinguished from *N. dutertrei* and *N. acostaensis* by lacking an aperture lip. Specimens assignable to either *N. dutertrei* or *N. humerosa* (by, for example, having a narrow lip or lacking a lip but having a moderately high trochospire) are rare but regular members of foraminifer assemblages in the Pliocene.

Neogloboquadrina pachyderma (Ehrenberg)

Aristospira pachyderma Ehrenberg, 1861, pp. 276, 277, and 303. Banner and Blow, 1960, p. 4, pl. 3, fig. 4a–c.

Discussion: Both dextral and sinistral specimens of *N. pachyderma* have been encountered. All are heavily crusted, four-chambered specimens with a nearly square outline and a narrow aperture. They do not appear to be merely specimens of *N. acostaensis* from which the aperture flap has been removed because all specimens are heavily encrusted. Dextral individuals are most abundant in the Pleistocene and uppermost Pliocene (to the top of Zone PL5) while sinistral forms have been found only in the middle of lower Pliocene Zone PL1 at Sites 960 and 959.

Orbulina bilobata (d'Orbigny)

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

Discussion: *Orbulina bilobata* is a distinctive morphospecies that probably does not represent more than a variant of *O. universa*. Bilobed specimens have been encountered primarily in the lower Pliocene and upper Miocene (Zones PL1 and N17).

Orbulina suturalis Brönnimann

Orbulina suturalis Brönnimann, 1951, p. 135, text fig. IV, figs. 15–16, 20.

Discussion: This species is encountered regularly in Zones N12 and 13, but has a discontinuous range into the lower Pliocene (Zone PL1). Most specimens have well-developed areal apertures, but in some cases the areal apertures are few in number or confined to the area close to the exposed part of the early whorl (see examples on Pl. 2, Figs. 17 and 22, from Zone N12). Like *O. bilobata, Orbulina suturalis* is likely to be a variant of *O. universa*

Orbulina universa d'Orbigny

Orbulina universa d'Orbigny, 1839, p. 3, pl. 1, fig. 1.

Discussion: *Orbulina universa* is present in nearly every sample from the Pleistocene to Zone N12 at Sites 959 and 960. This species is distinguished from all others by its completely enveloping chamber and absence of sutural pores.

Praeorbulina glomerosa Blow

Praeorbulina glomerosa Blow, 1956, pp. 64–65, text fig. 1, nos. 9–19; text fig. 2, nos. 1–4 and 12–15.

Discussion: The various subspecies of *P. glomerosa* (e.g., *P. glomerosa curva,* and *P. glomerosa glomerosa*) have not been separated here. Forms of *P. glomerosa* have been found in both Zones N8 and N9, but are always rare.

Praeorbulina sicana (DeStefani)

Globigerinoides sicanus DeStefani, 1950, p. 9, fig. 6.

Discussion: *Praeorbulina sicana* ranges through most of Zone N8 at Site 959. This species is distinguished from *Globigerinoides* and *Praeorbulina glomerosa* by possessing four high-arched apertures around the final chamber (rather than two or three in *G. bisphericus* and more than four slit-like apertures in *P. glomerosa*).

Protentella prolixa Lipps

Protentella prolixa Lipps, 1964, p. 124, pl. 2, fig. 8a–9c.

Discussion: Specimens of this species are very small and compressed along the coiling axis. When preserved whole, they possess one or two very radially elongate chambers and an equatorial aperture. The wall texture is finely perforate with a few bumps on the ends of the clavate chambers that may represent spine bases analogous with those of *Hastigerina pelagica*. *Protentella prolixa* has been found only in Zones N7 and N8 at Site 960 during a search for well-preserved specimens of *C. bermudezi*. Consequently, the full stratigraphic range of *P. prolixa* is probably not well documented here.

Pulleniatina obliquiloculata (Parker and Jones)

Pullenia sphaeroides (d'Orbigny) var *obliquiloculata* Parker and Jones, 1865, p. 368, pl. 19, fig. 4a–b.

Discussion: *Pulleniatina obliquiloculata* is distinguished from other members of this genus by its streptospiral coiling in which the last chambers in the final whorl grow toward the spiral surface. This species is distributed within Zone PL2 to PL3 and from the base of Zone PL6 to the top of the Pleistocene at Sites 959 and 960. The distinctive stratigraphic gap in the range of *P. obliquiloculata* is the source of several important datums in Atlantic Ocean biostratigraphy. Less lengthy but potentially biostratigraphically important gaps exist in the ranges of other species such as *G. hexagona, G. tumida,* and *G. menardii.*

Pulleniatina praecursor Banner and Blow

Pulleniatina obliquiloculata (Parker and Jones) praecursor Banner and Blow, 1967, p. 139, pl. 3, fig. 3a–c.

Discussion: *Pulleniatina praecursor* is an intermediate between *P. primalis* and *P. obliquiloculata.* The aperture does not extend to the spiral surface but otherwise the test is nearly as compact as that of *P. obliquiloculata.*

Pulleniatina primalis Banner and Blow

Pulleniatina primalis Banner and Blow, 1967, p. 142, pl. 1, figs. 3–8; pl. 3, fig. 2a–c.

Discussion: This species is the first representative of the genus *Pulleniatina* in Leg 159 material and has a short range from the top of Zone PL1 (just below the FAD of *G. crassaformis*) into Zone PL3.

Sphaeroidinella and *Sphaeroidinellopsis*

Discussion: This group is a well-known clade that contains at least two distinct branching events: one leading to *S. kochi* and one consisting of the survival of *S. seminulina* long after the appearance of its descendant, *S. paendehiscens.* The LADs of *S. seminulina, S. kochi* and *S. paendehiscens* are distinctive datums in Leg 159 sediments. The evolution of the group from *S. disjuncta* is not well developed in these sites.

Sphaeroidinella dehiscens (Parker and Jones)

Sphaeroidina bulloides d'Orbigny var. dehiscens Parker and Jones, 1865, p. 369, pl. 19, fig. 5.

Discussion: Variants of *S. paendehiscens* with a minute secondary aperture are included in this species. The secondary aperture is initially a small hole only slightly larger than a pore. Consequentially, identification of the FAD of *S. dehiscens* is time consuming and is difficult to define precisely, particularly in sediments where dissolution has caused pitting in specimens of *S. paendehiscens.*

Sphaeroidinellopsis disjuncta (Finlay)

Sphaeroidinella disjuncta Finlay, 1940, p. 467, pl. 67, figs. 224–228.

Discussion: This species is rare in Leg 159 sites but is recorded sporadically in Zones N12 and N13 at Site 959. *Sphaeroidinellopsis disjuncta* is distinguished from *S. seminulina* by its poorly developed cortex, four-chambered final whorl, and umbilical aperture bordered by a thick lip.

Sphaeroidinellopsis kochi (Caudri)

Globigerina kochi Caudri, 1934, p. 144, text fig. 8a–b.

Discussion: S*phaeroidinellopsis kochi* ranges almost continuously from Zone N12 to its distinctive LAD that helps define the top of Pliocene Zone PL3. This species is distinguished from all other species in this group by its radially elongate chambers. The cortex is often poorly developed over the coarsely cancellate wall.

S*phaeroidinellopsis paendehiscens* Blow

Sphaeroidinellopsis subdehiscens paendehiscens Blow, 1969, p. 386, pl. 30, figs. 4, 5, and 9.

Discussion: *Sphaeroidinellopsis paendehiscens* is identical with the earliest occurring specimens of *S. dehiscens,* except for the presence of a secondary aperture on the spiral surface in the latter taxon. The outline of *S. paendehiscens* is more quadrate and elliptical than in *S. seminulina,* and the sutures are completely buried by the cortex. *Sphaeroidinellopsis paendehiscens* occurs sporadically in Zone N17 and becomes extinct close to the same level as other members of its genus at the top of Zone PL3.

Sphaeroidinellopsis seminulina (Schwager)

Globigerina seminulina Schwager, 1866, p. 256, fig. 112.

Discussion: This species is characterized by three globular chambers, a heavy cortex, and a single irregular to slit-like aperture. The final chamber can be somewhat pointed or may be an irregular kummerform chamber on a specimen with three ordinary globular chambers. *Sphaeroidinellopsis seminulina* ranges from Zone N12 to the top of Zone PL3.

Tenuitella sp.
(sensu Pearson 1995, p. 53, pl. 1, figs. 23–24)

Discussion: Pearson (1995) has described a large trochospirally coiled microperforate species from Sites 871, 872, and 873 in the early Miocene of the northwest Pacific. These specimens have five chambers in the last whorl, a distinctive apertural tooth or flaring lip, and a pustulose surface texture around the umbilicus. I have observed the same species in Zone N8 at Pacific Site 865 and have found smaller but otherwise similar specimens in Zones N6 to N9 at Sites 959 and 960. These have four to five chambers in the final whorl, a pustulose surface texture around the umbilicus, a distinct triangular tooth that partly covers the umbilicus, and a low trochospire. The aperture is slit-like. The last chamber does not show the high degree of variation in shape observed in many specimens from Pacific sites.

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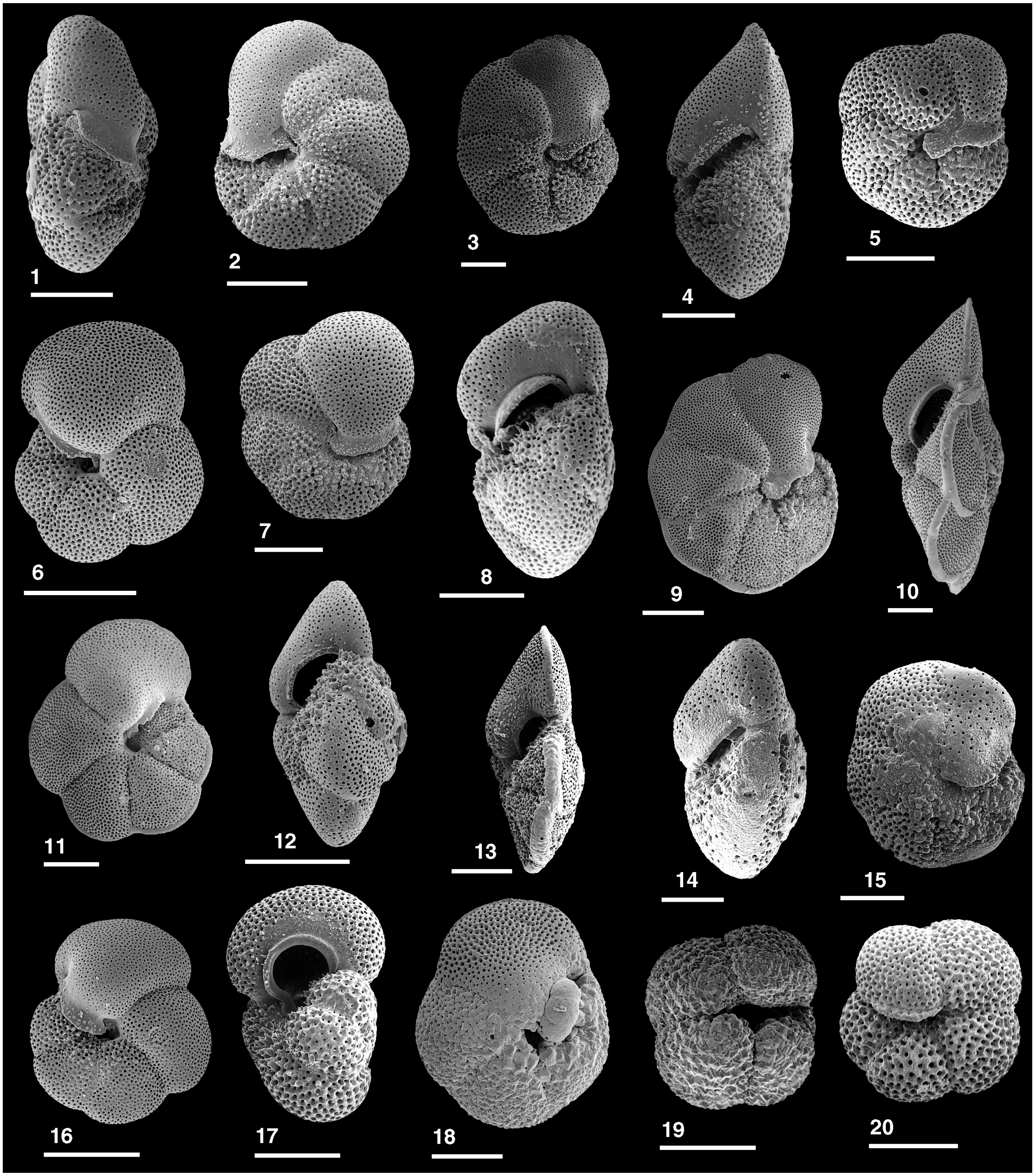

Plate 1. All scale bars are 100 µm, except for Specimen 5, which is 50 µm. **1–2.** *Fohsella peripheroacuta* (Sample 159-959A-20X-1, 57–62 cm). **3–4.** Form transitional from *F. peripheroacuta* to *F. "praefohsi"* (Sample 159-959A-21X-2, 57–59 cm). **5.** *Fohsella birnageae* (Sample 159-959A-21X-5, 54–56 cm). **6, 16.** *Globorotalia praescitula* (Sample 159-960C-12H-6, 34–36 cm). **7.** *Fohsella peripheroronda* (Sample 159-959A-21X-2, 57–59 cm). **8.** *Fohsella peripheroacuta* transitional to *Fohsella peripheroacuta* (Sample 159-959A-20X-1, 57–62 cm). **9–10.** *Fohsella fohsi* (Sample 159-959A-18H-1, 57–60 cm). **11, 13.** *Globorotalia praemenardii* (Sample 159-959A-18H-1, 57–59 cm). **12.** *Globorotalia archeomenardii* (Sample 159-959A-21X-2, 57–62 cm). **14–15.** *Fohsella lenguaensis* (LAD. Sample 159-959A-15H-7, 56–58 cm). **16.** *Globorotalia praescitula* (Sample 159-960C-12H-6, 34–36 cm). **17.** *Globorotalia mayeri* group (Sample 159-959A-18H-2, 55–57 cm). **18.** *Globorotalia miozea* (Sample 159-959A-18H-2, 55–57 cm). **19.** *Neogloboquadrina pachyderma,* typical sinistral specimen from the early Pliocene (Sample 159-959B-8H-3, 59–61 cm). **20.** *Neogloboquadrina acostaensis* (Sample 159-959B-11H-7, 59–61 cm).

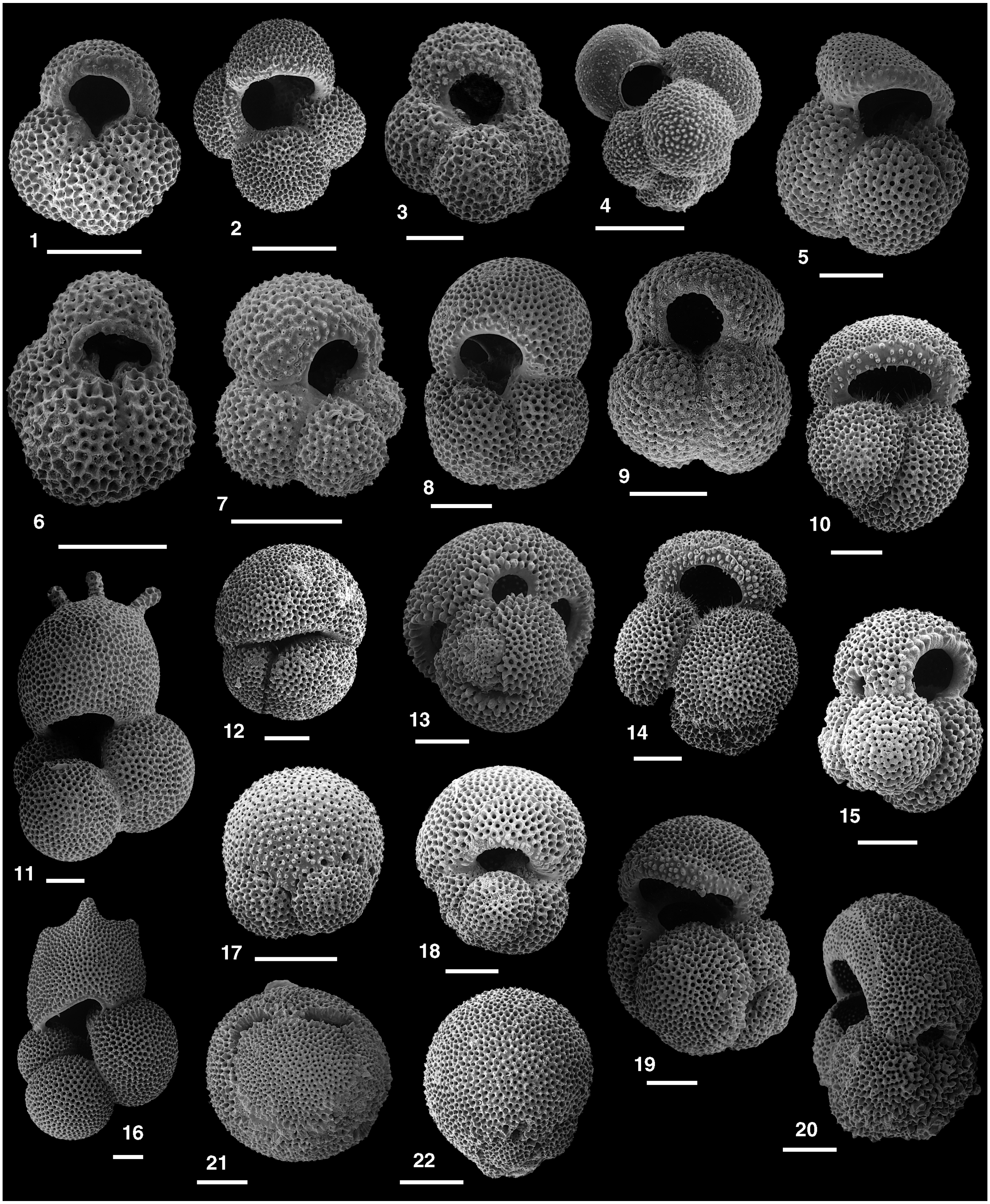

Plate 2. All scale bars are 100 µm. **1–2.** *Globoroturborotalia apertura* (1 = Sample 159-960C-3H-7, 34–36 cm. 2 = Sample 159-959B-5H-1, 59–61 cm). **3.** *Globoroturborotalia woodi* (Sample 159-959B-8H-1, 59–61 cm). **4.** *Globoroturborotalia decoraperta* (Sample 159-959B-8H-1, 59–61 cm). **5.** *Globigerinoides extremus* (Sample 159-959B-7H-1, 59–61 cm). **6.** *Globoroturborotalia nepenthes* (LAD; Sample 159-959C-8H-2, 140 cm). **7.** *Globoroturborotalia parawoodi*; specimen has a small supplementary aperture on the spiral side (Sample 159-959A-18H–5, 55–57 cm). **8.** *Globigerinoides altiapertura* transitional to *Globigerinoides obliquus* (Sample 159-960C-12H-6, 34–36 cm). **9, 15.** *Globigerinoides subquadratus* (9 = Sample 159-960C-12H-6, 34–36 cm; 15 = Sample 159-959A-18H-2, 55–57 cm). **10.** *Globigerinoides obliquus* (Sample 159-959B-10H-6, 59–61 cm). **11.** *Globigerinoides sacculifer fistulosus* (Sample 159-959B-5H-3, 59–61 cm). **12, 18.** *Globigerinoides bisphericus* (12 = Sample 159-959A-22X-2, 60–62 cm; 18 = Sample 159-960C-12H-2, 34–36 cm). **13.** *Praeorbulina sicana* showing three of the four apertures (Sample 159-960C-12H-6, 34–36 cm). **14.** *Globigerinoides ruber* (Sample 159-959B-5H-3, 59–61 cm). **16.** *Globigerinoides sacculifer* cf. *fistulosus* (Sample 159-959B-4H-2, 59–61 cm). **17, 22.** *Orbulina suturalis* (17 = Sample 159-959A-18H-2, 55–57 cm; 22 = Sample 159-959A-18H-1, 57–59 cm). **19.** *Globigerinoides mitra* (159-959A-18H-5, 55–57 cm). **20.** *Globigerinoides seigliei* (Sample 159-959B-7H-1, 59–61 cm). **21.** *Praeorbulina glomerosa* (Sample 159-959A-21X-2, 57–59 cm).

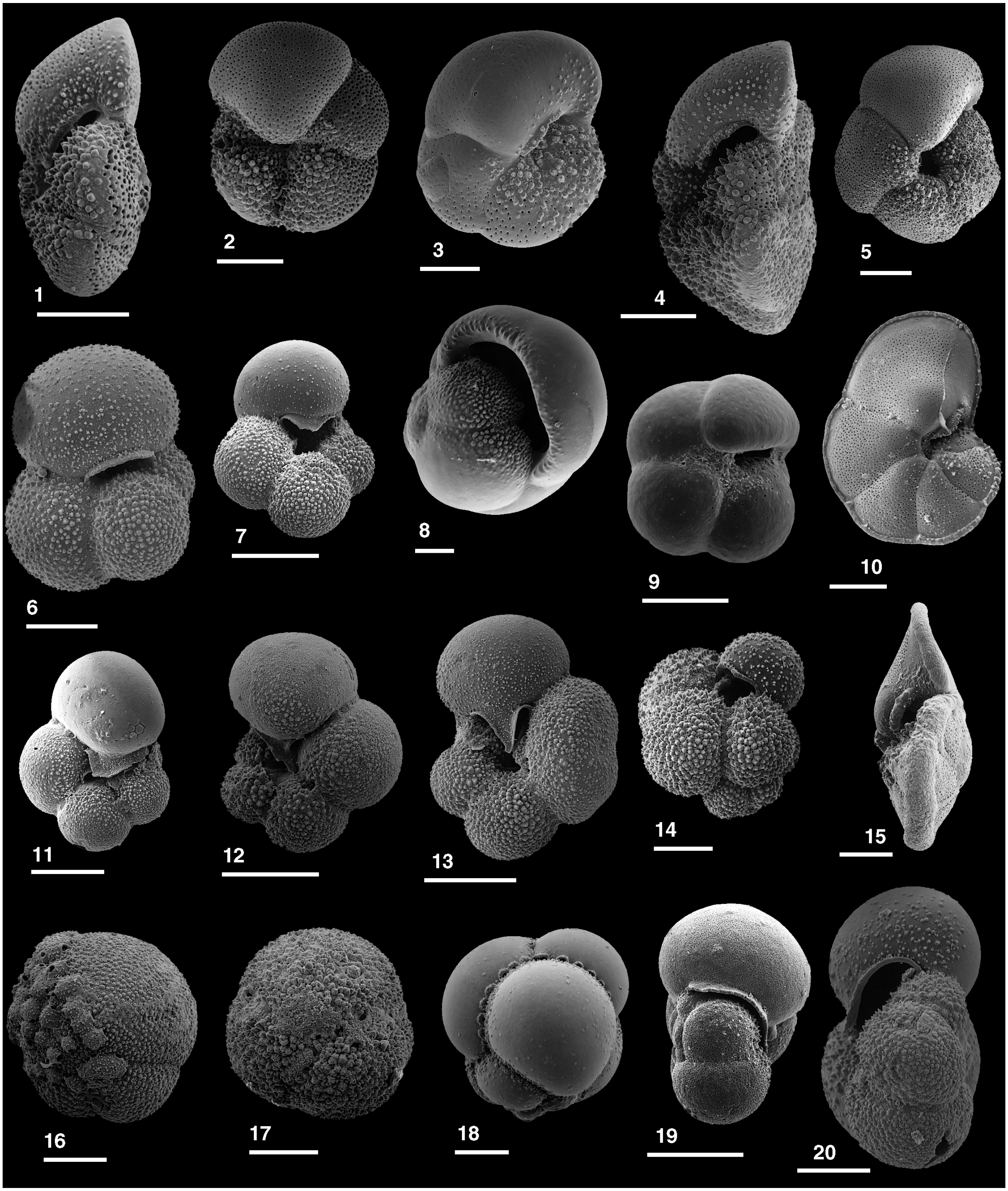

Plate 3. All scale bars are 100 µm except specimens 6 and 20, which are 50 µm. **1–2.** *Globorotalia cibaoensis* (Sample 159-959B-11H-7, 59–61 cm). **3.** *Globorotalia scitula* (Sample 159-959B-4H-2, 59–61 cm). **4–5.** *Globorotalia crassaformis* (Sample 159-959B-7H-1, 59–61 cm). **6.** *Globigerinita glutinata* (Sample 159-959A-18H-2, 55–57 cm). **7, 11–13, 19–20**. *Tenuitella* sp. Note aperture teeth, pustulose wall texture and highly variable aperture height (7, 13 = Sample 159-959A-21X-2, 57–59 cm; 11, 19 = Sample 159-960C-12H-6, 34–36 cm; 12, 20 = Sample 159-959A-22X-3, 56–58 cm). **8.** *Pulleniatina obliquiloculata* (Sample 159-959B-3H-5, 55–57 cm). **9.** *Pulleniatina primalis* (Sample 159-959B-8H-1, 59–61 cm). **10, 15.** *Globorotalia tumida* (FAD, Sample 159-960C-3H-7, 34–36 cm). **14.** *Globigerinita uvula* (Sample 159-959A-18H-2, 55–57 cm). **16.** *Globigerinatella insueta* (Sample 159-959A-22X-3, 56–58 cm). **17.** *Globigerinatella* sp. that lacks typical areal apertures (Sample 159-959A-22X-3, 56–58 cm). **18.** *Candeina nitida* (Sample 159-959B-11H-7, 59–61 cm).

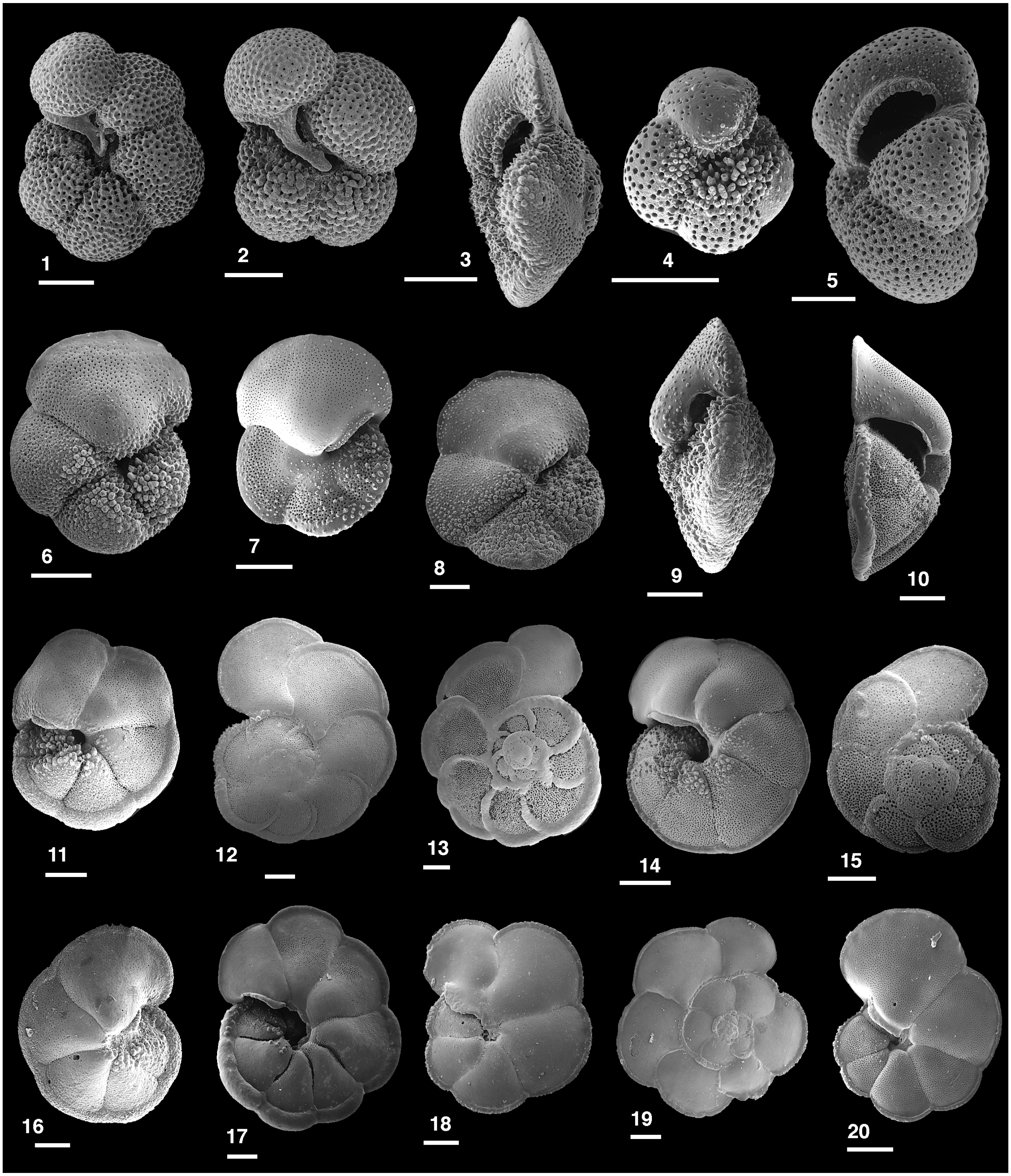

Plate 4. All scale bars are 100 µm, except specimen 5, which is 50 µm. **1–2.** *Neogloboquadrina dutertrei* with unusual umbilical projections of the aperture lips. Compare with specimens figured from the western Pacific by Chaisson and Leckie (1993; Sample 159-959C-8H-5, 60–62 cm). **3, 6–7.** *Globorotalia margaritae* (3, 6 = Sample 159-959B-10H-6, 59–61 cm. 7 = Sample 159-7H-2, 59–61 cm). **4–5.** *Globorotalia puncticulata* (Sample 159-959B-5H-1, 59–61 cm). **8–9.** *Globorotalia hirsuta* (Sample 159-959B-5H-3, 59–61 cm). **10, 14.** *Globorotalia miocenica* (Sample 159-959B-4H-2, 59–61 cm). **11.** *Globorotalia menardii* (Sample 159-959B-7H-1, 59–61 cm). **12.** *Globorotalia limbata* (Sample 159-959C-11H-1, 100–102 cm). **13, 17.** *Globorotalia multicamerata* (Sample 159-959B-5H-7, 59–61 cm). **15.** *Globorotalia plesiotumida* (Sample 159-959B-11H-7, 59–61 cm). **16.** *Globorotalia tumida*, early form (FAD; Sample 159-960C-3H-7, 35–37 cm). **18–19.** *Globorotalia pertenuis* (Sample 159-959B-4H-2, 59–61 cm). **20.** *Globorotalia exilis* (Sample 159-959B-5H-1, 59–61 cm).

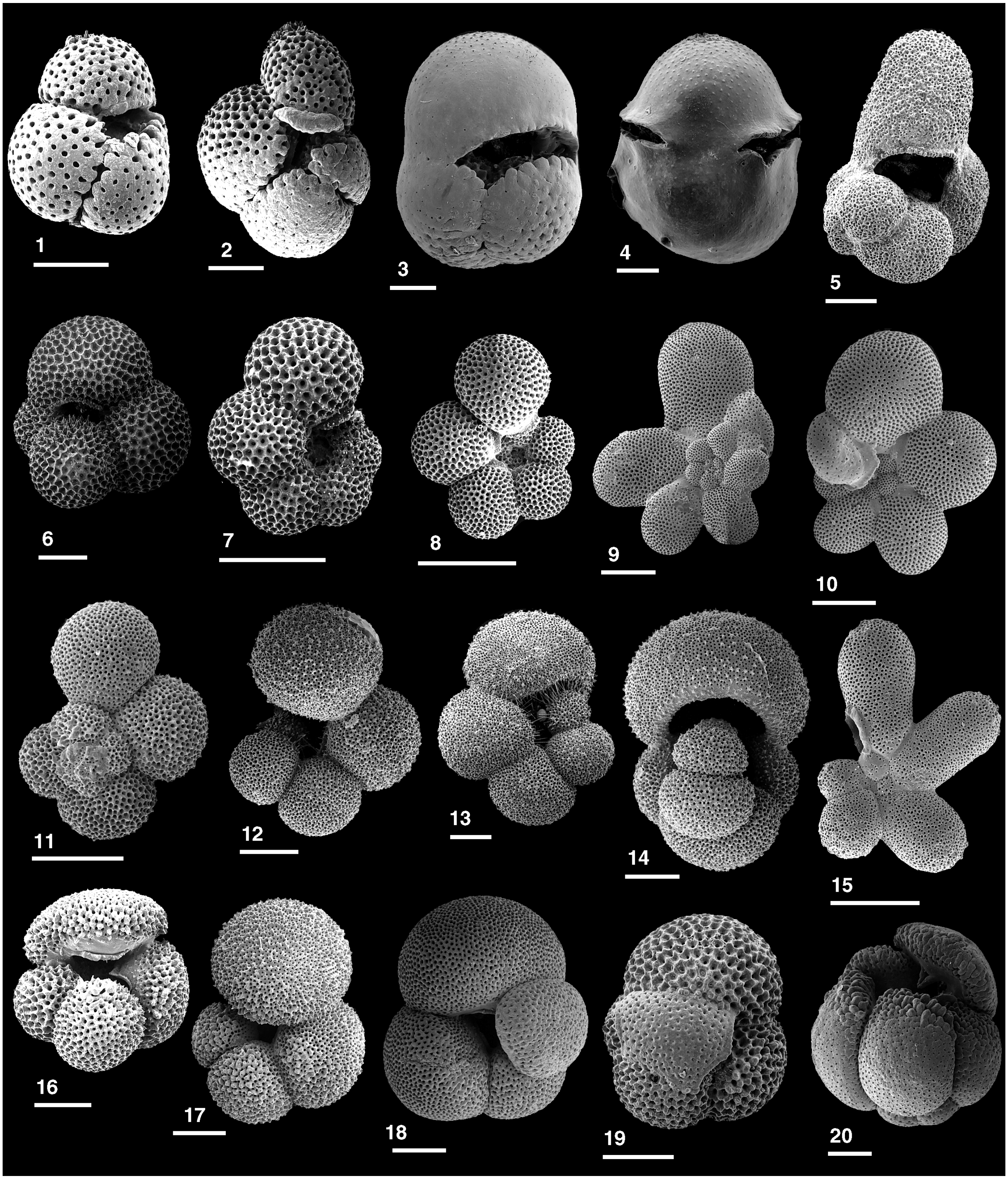

Plate 5. All scale bars are 100 µm. **1–2.** *Sphaeroidinellopsis disjuncta* showing partial development of the cortex (1 = Sample 159-959A-18H-2, 55–57 cm; 2 = Sample 159-959A-18H-5, 55–57 cm). **3.** *Sphaeroidinellopsis paendehiscens* (Sample 159-959B-9H-5, 59–61 cm). **4.** *Sphaeroidinella dehiscens* with three apertures (Sample 159-959B-3H-5, 55–57 cm). **5.** *Beella digitata* (Sample 159-959B-3H-5, 55–57 cm). **6–8.** *Globorotaloides hexagona* showing variation in development of evolute coiling and lobateness of the periphery (6 = Sample 159-959B-10H-6, 59–61 cm; 7–8 = Sample 159-959A-18H-2, 55–57 cm). **9–10.** *Clavatorella bermudezi* (9 = Sample 159-959A-21X-2, 57–59 cm; 10 = Sample 159-960C-12H-2, 34–36 cm). **11–12.** *Globigerinella praesiphonifera* (Sample 159-959A-18H-2, 55–57 cm). **13–14.** *Globigerinella siphonifera* (13 = Sample 159-959B-3H-5, 55–57 cm; 14 = Sample 159-959B-7H-1, 59–61 cm). **15.** *Protentella prolixa* (Sample 159-959A-22X-2, 50–52 cm). **16.** *Globoquadrina dehiscens* (Sample 159-959B-18H-2, 55–57 cm). **17.** *Globigerinella obesa* (Sample 159-959B-9H-5, 59–61 cm). **18.** (?)*Globorotaloides suteri* (Sample 159-960C-12H-2, 34–36 cm). **19.** *Catapsydrax dissimilis* (Sample 159-960C-13H-1, 34–36 cm). **20.** *Dentogloboquadrina altispira* (Sample 159-959B-10H-6, 59–61 cm).