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9. OLIGOCENE PLANKTONIC FORAMINIFER BIOSTRATIGRAPHY OF HOLE 803D (ONTONG JAVA PLATEAU) AND HOLE 628A (LITTLE BAHAMA BANK), AND COMPARISON WITH THE SOUTHERN HIGH LATITUDES[1]

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ABSTRACT

Ocean Drilling Program Hole 803D (Leg 130) from the western tropical Pacific (Ontong Java Plateau) and Hole 628A (Leg 101) from the western subtropical North Atlantic (Little Bahama Bank) contain rich assemblages of planktonic foraminifers. The uppermost Eocene–basal Miocene section of Hole 803D is apparently complete, whereas the Oligocene section of Hole 628A contains three unconformities based on planktonic foraminiferal evidence. Anomalous ranges are recorded for *Chiloguembelina cubensis* and *Globigerinoides primordius. C. cubensis* is found to range throughout the upper Oligocene of both sites, and *G. primordius* first occurs near the base of upper Oligocene Zone P22 in Hole 628A. Paleomagnetic stratigraphy provides constraints on the last occurrence (LO) of *Subbotina angiporoides,* the first occurrence (FO) of *Globigerina angulisuturalis,* the FO of *Globigerinoides primordius,* the FO of *Paragloborotalia pseudokugleri,* and the LO of *Chiloguembelina cubensis.*

In general, taxon ranges, total diversity, and the composition of the planktonic foraminiferal assemblages from Holes 628A and 803D are similar. Differences in the composition of planktonic foraminiferal assemblages between the two sites are interpreted to be primarily the result of enhanced dissolution at Site 803 (e.g., paucity of *Globigerina angulisuturalis* and absence of *G. ciperoensis).* However, the greater abundances of *Subbotina angiporoides* in subtropical Hole 628A and *Paragloborotalia opima* in tropical Hole 803D are probably related to oceanographic differences between the two low-latitude sites. Comparison between the low and southern high latitudes illustrates some similarities in the composition of Oligocene planktonic foraminiferal assemblages as well as some important differences. Species such as *Pseudohastigerina* spp., *Turborotalia increbescens, "Turborotalia" ampliapertura, Paragloborotalia opima, P. pseudokugleri, P. semivera/mayeri, Globigerinella obesa, Globigerina angulisuturalis, G. gortanii, G. ouachitaensis, G. sellii, G. tapuriensis, G. tripartita, G. pseudovenezuelana, Subbotina*? *eocaena* and *S.*? *yeguaensis* are absent or have rare occurrences in the subantarctic Oligocene assemblages. Biogeographic gradients, although not as pronounced as during the late Neogene, were nonetheless significant during the Oligocene.

INTRODUCTION

The stratigraphic record of the Oligocene contains valuable information about changing climatic and oceanographic conditions as the high latitudes cooled and ice caps formed on the continent of Antarctica. In latest Eocene/earliest Oligocene time, a major cooling step is recorded in the oxygen isotopes of benthic foraminifers as cold deep-water masses filled the ocean basins (e.g., Savin et al., 1975; Shackleton and Kennett, 1975; Kennett and Shackleton, 1976; Boersma and Shackleton, 1977; Keigwin, 1980; Matthews and Poore, 1980; Miller and Curry, 1982; Corliss et al., 1984; Miller and Fairbanks, 1985). The initiation of pyschrospheric circulation in the Oligocene represents the transition from an Eocene mode of deep-water formation to a Neogene mode similar to today's circulation (Kennett and Stott, 1990, 1991). Additional significant cooling steps are also recorded in the mid- and latest Oligocene (Keigwin and Keller, 1984; Miller et al., 1987, 1988). The mid-Oligocene step was associated with a major drop in eustatic sea level (Haq et al., 1987).

The plankton also record changing oceanographic and climatic conditions during the Oligocene as meridional temperature gradients decreased, biogeographic provinces broadened and became fewer in number, and planktonic foraminiferal faunas became more generalized (e.g., Cifelli, 1969; Haq et al., 1977; Kennett, 1977, 1978). Although planktonic foraminiferal diversity was relatively low during Oligocene time and the biogeographic ranges of many species expanded, important differences remained in assemblage diversity and composition between low and high latitudes, and between ocean basins. In addition, taxon first and last occurrences in the Oligocene may be highly diachronous between ocean basins, even within an ocean basin, as recently shown by Hess et al. (1989).

We have examined two low-latitude Oligocene sections, one from the tropical western Pacific (Ocean Drilling Program [ODP] Leg 130, Hole 803D) and one from the subtropical western North Atlantic (ODP Leg 101, Hole 628A) (Fig. 1). Both sites contain rich assemblages of planktonic foraminifers. Recent ODP drilling in the southern high latitudes has provided new Oligocene records of planktonic foraminiferal populations for comparison with our low-latitude results (e.g., Stott and Kennett, 1990; Huber, 1991; Nocchi et al., 1991). Our purpose here is to document planktonic foraminiferal distribution through the uppermost Eocene–basal Miocene interval of Holes 628A and 803D, to compare assemblage composition between these two low-latitude sites, and to examine the similarities and differences in assemblage composition between the low latitudes and southern high latitudes based on recent ODP results. In addition, we have tried to clarify the species concepts of many of the low-latitude Oligocene taxa by comparing each with related taxa, and by illustrating some of the range of morphologic variability within each taxon.

METHODS

A total of 129 samples were examined for planktonic foraminifers in Holes 628A and 803D. Samples were soaked in a neutral pH mixture of diluted hydrogen peroxide and Calgon for an hour or so. Chalky samples were ultrasonicated for 10–15 s. The sediment was washed over a 63 µm sieve. Small bits of chalk were carefully squeezed between the finger tips to enhance disaggregation. This physical manipulation of the sediments did not result in enhanced breakage of foraminiferal tests. The samples were then dried in an oven. Nearly all samples had to be washed twice to free the foraminifer tests from the chalky matrix.

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[1] Berger, W.H., Kroenke, L.W., Mayer, L.A., et al., 1993. *Proc. ODP, Sci. Results,* 130: College Station, TX (Ocean Drilling Program).

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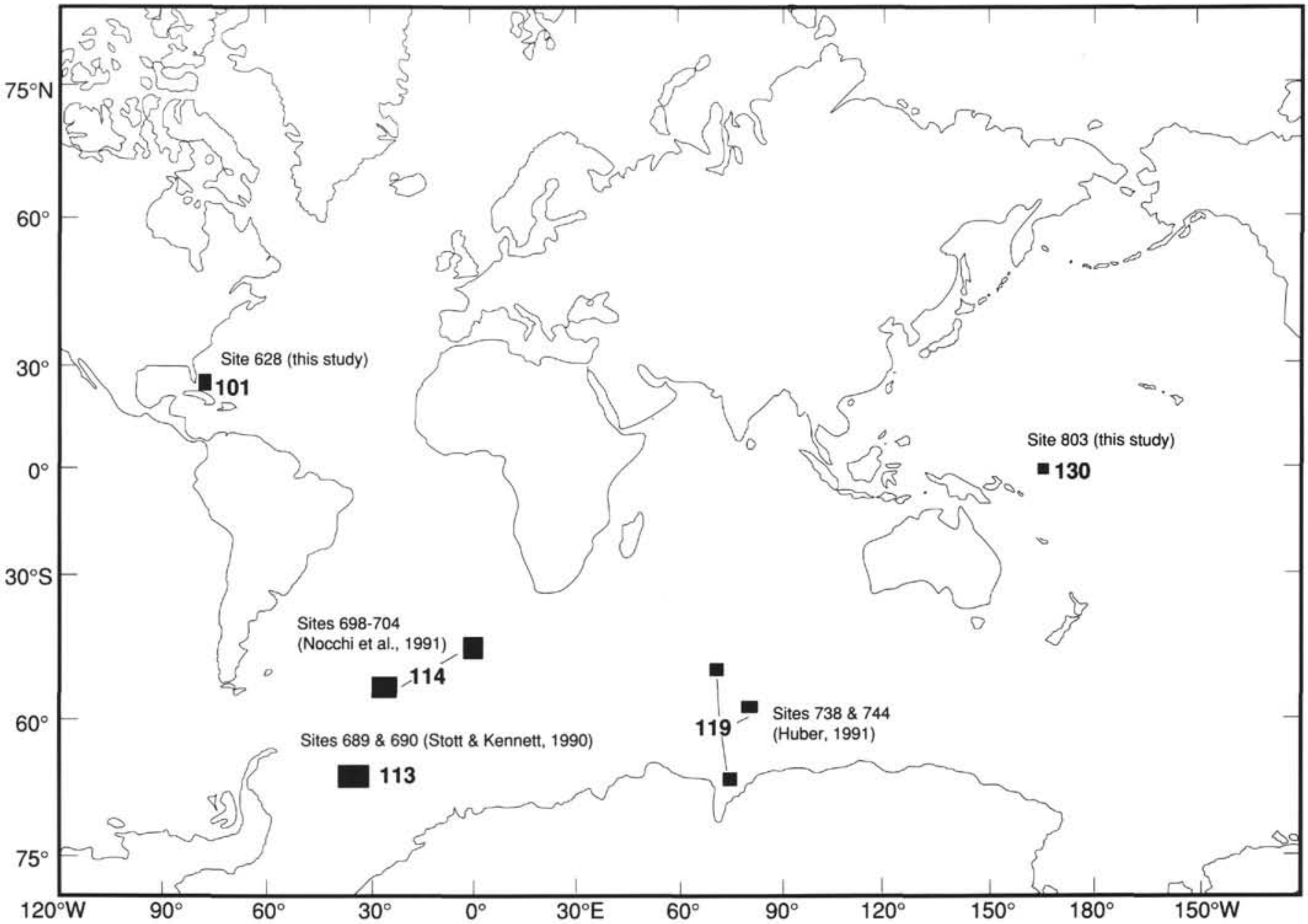

Figure 1. Map showing the location of ODP Sites 628 (Little Bahama Bank, Leg 101) and 803 (Ontong Java Plateau, Leg 130), and the location of the southern high-latitude ODP sites discussed in the text (Maud Rise, Leg 113; South Atlantic transect, Leg 114; and southern flank of the Kerguelen Plateau, Leg 119).

The disaggregated sediment was sprinkled on a picking tray, and individual specimens were picked and mounted on a gummed population slide. All samples were examined at least twice. Relative abundance data was based on the >63 µm fraction, although the >250 µm, 150–250 µm, and 63–150 µm fractions were also examined for rare species. Two categories of foraminiferal species abundance were recorded; rare = <5%, and few to common = >5%. Foraminiferal preservation was based on a qualitative assessment of the degree of test breakage and/or dissolution. The relative abundance of radiolarians was also noted.

HOLE 628A (LITTLE BAHAMA BANK)

Hole 628A (27°38.10′N, 78°18.95′W) was drilled on Little Bahama Bank in the western North Atlantic in a water depth of 966 m (Austin, Schlager, Palmer, et al., 1986). We examined 42 samples from Cores 101-628A-16H through -29X for planktonic foraminifers (Fig. 2). This interval represents the uppermost Eocene (Zone P17) through Oligocene (Zone P22). The uppermost Oligocene is truncated by an unconformity; sediments of middle Miocene Zone N12 overlie sediments of uppermost Zone P22 (the unconformity occurs in the coring break between Cores 101-628A-15H and -16H). Foraminiferal preservation is moderately good to good in most of the samples examined, and radiolarian abundance is low.

Three unconformities were recognized in the Oligocene section based on planktonic foraminiferal evidence: P22/P21a, P21a/P19, and P19/P18 (Fig. 2). These unconformities are associated with an interval of interbedded calcareous ooze and chalk, foraminifer-nannofossil ooze and chalk, and unlithified packstone and floatstone in Cores 101-628A-24X through -26X. The bulk of the Oligocene section is composed of nannofossil ooze and chalk and foraminifer-nannofossil ooze and chalk in Cores 101-628A-16H through -23X, and calcareous ooze and chalk in Cores 101-628A-27X and -28X. Core 101-628A-29X (uppermost Eocene) consists of nannofossil ooze. The change in lithology across the Eocene/Oligocene boundary raises the possibility that another unconformity may be present in the coring break between Cores 101-628A-28X and -29X, although there is no compelling planktonic foraminiferal evidence for an unconformity through this interval. The evidence for the unconformities is discussed in the "Biostratigraphy" section (this chapter).

Sager (1988) established the paleomagnetic stratigraphy for the Oligocene of Hole 628A, although we have reinterpreted this record based on the planktonic foraminiferal biostratigraphy presented below (Fig. 2). The paleolatitude of Site 628 during the Oligocene was 25.8°N (Sager, 1988).

HOLE 803D (ONTONG JAVA PLATEAU)

Hole 803D (2°25.98′N, 160°32.46′E) was drilled on the Ontong Java Plateau in the western equatorial Pacific in a water depth of 3412 m (Kroenke, Berger, Janecek, et al., 1991). We examined 87 samples from Cores 130-803D-35X through -60X for planktonic foraminifers

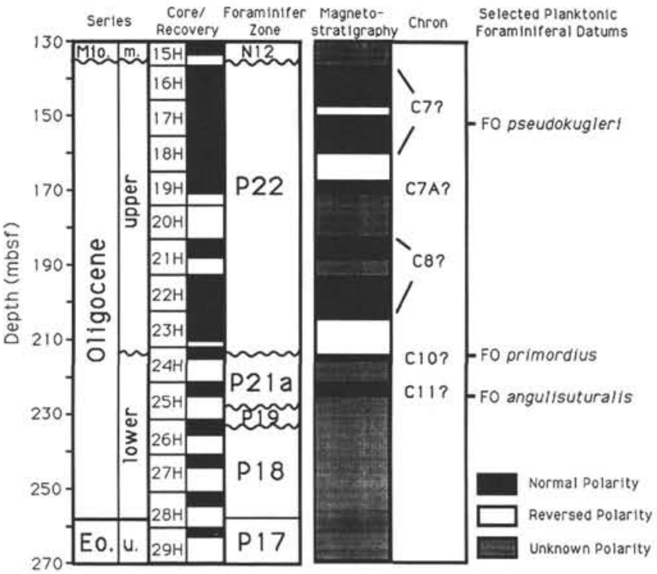

Figure 2. Planktonic foraminiferal biostratigraphy and magnetostratigraphy of the uppermost Eocene and Oligocene from Hole 628A. Magnetostratigraphy is from Sager (1988). Paleomagnetic chrons have been reinterpreted based on the planktonic foraminiferal evidence presented here. Selected planktonic foraminiferal first (FO) and last (LO) occurrences with correlation to the paleomagnetic record are shown. Scale to the left corresponds to meters below seafloor.

(Fig. 3). This interval represents the uppermost Eocene (Zone P17) through basal Miocene (basal Zone N4). The section appears to be complete based on the planktonic foraminiferal evidence. The bulk of the section is composed of nannofossil chalk. Foraminiferal preservation ranges from moderately good to poor. The sediments have probably experienced some dissolution, based on foraminiferal preservation and the abundance of radiolarians.

A preliminary shipboard paleomagnetic stratigraphy was established for the Oligocene of Hole 803D by Musgrave and Tarduno (in Kroenke, Berger, Janecek, et al., 1991, pp. 130–134) (Fig. 3). They concluded that Site 803 was at a paleolatitude of about 4.5°S during the Oligocene.

BIOSTRATIGRAPHY

Zonal Criteria, Taxon Ranges, and Unconformities

We have followed the tropical Paleogene planktonic foraminiferal biostratigraphic zonation of Berggren and Miller (1988) (Fig. 4). The uppermost Eocene to lowermost Miocene part of this zonal scheme represents a revision of earlier zonal criteria by Bolli (1957a, 1957b, 1966), Berggren (1969), Blow (1969), Stainforth et al. (1975), Poore (1984), Bolli and Saunders (1985), and Toumarkine and Luterbacher (1985) (Fig. 4). Berggren and Miller (1988) have separated zonal criteria into two categories: those with well-known magnetochronologic age estimates (after Berggren et al., 1985) and those with age estimates based on biochronology. Our work on the Oligocene of Holes 628A and 803D calls into question the magnetochronologic age estimates of several taxa including the first occurrence (FO) of *Globigerinoides primordius* and the last occurrence (LO) of *Chiloguembelina cubensis*. These results are based on biostratigraphic and magnetostratigraphic evidence (Figs. 2 and 3).

The uppermost Eocene–basal Miocene sequence of Hole 803D is apparently complete based on the planktonic foraminiferal biostratigraphy and the lack of major changes in lithology. On the other hand, Hole 628A contains three stratigraphic breaks within the Oligocene based on the planktonic foraminiferal biostratigraphy and lithology. In addition, the uppermost Oligocene is truncated by a major unconformity at this site. The evidence for these stratigraphic breaks is discussed below.

Turborotalia cerroazulensis Partial Range Zone (Zone P17)

Definition: Partial range of the nominate taxon between the LO of *Cribrohantkenina inflata* (base) and the LO of *T. cerroazulensis* s.l. (top).

Discussion: The LO of the *T. cerroazulensis* group is coincident with the LO of *Hantkenina alabamensis* at both sites. Preservation is moderately good in the uppermost Eocene of Hole 628A (Fig. 5). In this hole, the *T. cerroazulensis* group is represented by the subspecies *T. cerroazulensis cunialensis, T. cerroazulensis cocoaensis, T. cerroazulensis cerroazulensis*, and *T. cerroazulensis pomeroli*, as well as whole specimens of *Hantkenina alabamensis*. Preservation is poor in the uppermost Eocene of Hole 803D, and only rare specimens of *T. cerroazulensis pomeroli* and spines of *Hantkenina* are recorded in this interval (Fig. 6). Typical specimens of *Pseudohastigerina micra* are present through the uppermost Eocene of both sites.

The Eocene/Oligocene boundary interval in Hole 628A is assumed to be complete based on the planktonic foraminiferal biostratigraphy, but a change in lithology from nannofossil ooze in Core 101-628A-29X (uppermost Eocene) to calcareous ooze and chalk in Core 101-628A-28X (basal Oligocene) (Austin, Schlager, Palmer, et al., 1986) suggests the possibility of a stratigraphic break in this interval. The Eocene/Oligocene boundary in Hole 803D is also assumed to be complete, but a marked change in foraminiferal preservation is present across the boundary, from poor in the uppermost Eocene to moderately good in the basal Oligocene samples. Keller et al. (1987) show a widespread hiatus (PHc) in the basal Oligocene associated with the development of the psychrosphere.

Chiloguembelina cubensis–Pseudohastigerina spp. Partial Range Zone (Zone P18)

Definition: Concurrent partial ranges of the nominate taxa between the LO of *Turborotalia cerroazulensis* s.l. (base) and the LO of the *Pseudohastigerina* spp. group (top).

Discussion: Forms referable to *Pseudohastigerina naguewichiensis* and *P.* aff. *micra* characterize the basal Oligocene zone of both sites. *Pseudohastigerina* spp. occur persistently throughout Zone P18 and the extinction of the genus is a reliable datum at these sites (Figs. 5 and 6). *Chiloguembelina cubensis* is also a common constituent of the P18 assemblages. *Cassigerinella chipolensis* first occurs in the basal Oligocene sample of Hole 803D (130-803D-58X-CC), although its absence in the uppermost Eocene may be ascribed to dissolution at this site. The FO of *C. chipolensis* has been used by some workers to mark the base of the Oligocene (e.g., Bolli, 1957a, 1957b; Bolli and Saunders, 1985). However, *C. chipolensis* is present in the uppermost Eocene sediments of Hole 628A, suggesting that this taxon is not a reliable indicator of the Eocene/Oligocene boundary (see discussion in Berggren and Miller, 1988). *Globigerina tapuriensis*, although present at both sites, has a more persistent occurrence in Hole 803D. On the other hand, *Subbotina angiporoides* and *S. linaperta* s.l. are more common in Hole 628A. *Globigerina tripartita* first occurs in the basal Oligocene sample of both sites, and *Turborotalia increbescens* last occurs in the upper part of Zone P18.

An unconformity may separate Zones P18 and P19 in Hole 628A based on the LO of *Pseudohastigerina* spp. in Sample 101-628A-26X-2, 102–104 cm, and the FO of *Paragloborotalia opima* in Sample 101-628A-26X-1, 74–76 cm (Fig. 5). Core 101-628A-26X contains interbedded foraminifer-nannofossil ooze and chalk, and unlithified packstone and floatstone (Austin, Schlager, Palmer, et al., 1986). A thick interval of packstone and floatstone occurs between these two samples, suggesting erosion and/or downslope transport. No major widespread hiatus event is present in this interval, according to an analysis of the global distribution of late Paleogene hiatuses by Keller et al. (1987).

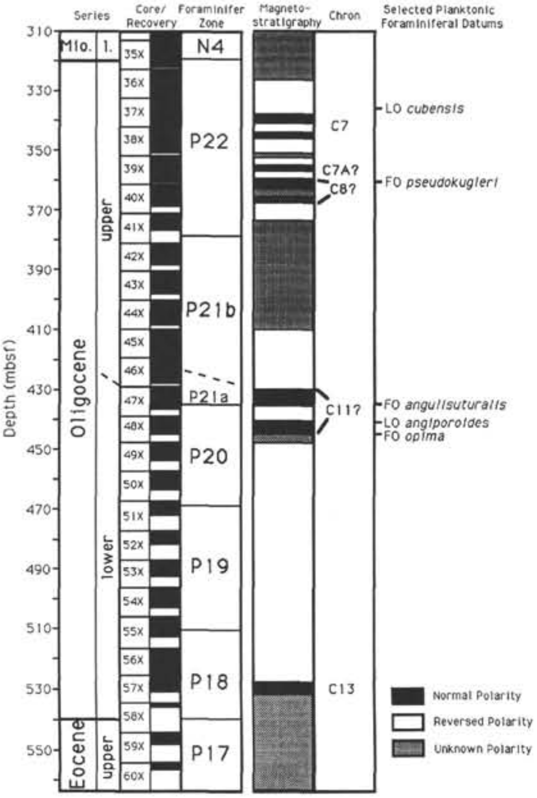

Figure 3. Planktonic foraminiferal biostratigraphy and magnetostratigraphy of the uppermost Eocene to basal Miocene from Hole 803D. Magnetostratigraphy is from Musgrave and Tarduno (in Kroenke, Berger, Janecek, et al., 1991). Selected planktonic foraminiferal first (FO) and last (LO) occurrences with correlation to the paleomagnetic record are shown. Scale to the left corresponds to meters below seafloor.

"Turborotalia" ampliapertura Partial Range Zone (Zone P19)

Definition: Partial range of the nominate taxon between the LO of *Pseudohastigerina* spp. group (base) and the LO of the nominate taxon (top).

Discussion: A fairly strict species concept is applied here to *"Turborotalia" ampliapertura.* This taxon is gradational with *Globigerina euapertura. "T." ampliapertura* is distinguished by its narrower and higher arched aperture. *Paragloborotalia opima* and *Globigerina sellii* both first occur in Zone P19 of Hole 628A, but they do not occur until Zone P20 of Hole 803D (Figs. 5 and 6).

An unconformity separates Zone P19 and Subzone P21a in Hole 628A based on the LO of in situ *"Turborotalia" ampliapertura* in Sample 101-628A-26X-1, 74–76 cm, and the FO of *Globigerina angulisuturalis* in Sample 101-628A-25X-CC (Fig. 5). In addition, reworked planktonic foraminifers from Zone P17 (and P18?) are present in Sample 101-628A-25X-CC. Core 101-628A-25X had only 37% recovery; interbedded foraminifer-nannofossil ooze and chalk, and unlithified packstone and floatstone were recovered in Core 101-628A-24X above and Core 101-628A-26X below (Austin, Schlager, Palmer, et al., 1986), suggesting an interval of erosion and/or downslope transport. This interval does not correspond with a peak in global hiatus distribution (Keller et al., 1987).

Globigerina sellii Partial Range Zone (Zone P20)

Definition: Partial range of the nominate taxon between the LO of *"Turborotalia" ampliapertura* (base) and the FO of *Globigerina angulisuturalis* (top).

Discussion: Zone P20 is not represented by the samples examined from Hole 628A because of the presence of an unconformity between Zone P19 and Subzone P21a. The FO of *Paragloborotalia opima* and the FO of *Globigerina sellii* are noted in the upper part of Zone P20 in Hole 803D, associated with the base of Chron C11 Normal (Figs. 3 and 6). The LO of *Subbotina angiporoides* is in the uppermost part of Zone P20 in Hole 803D, associated with the lower part of Chron C11 Normal, just below the FO of *Globigerina angulisuturalis* (see also Berggren et al., 1985; Berggren and Miller, 1988). *Globigerina praebulloides* first occurs near the base of Zone P20 in Hole 803D, but it is recorded in Zone P19 from Hole 628A.

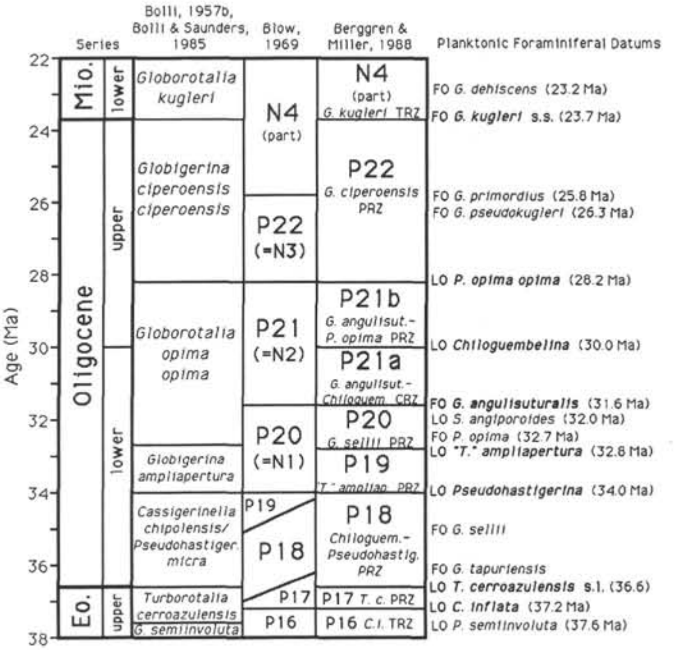

Figure 4. Planktonic foraminiferal zonation of the uppermost Eocene–basal Miocene interval used in this study. Ages of planktonic foraminiferal datums are from Berggren et al. (1985) and Berggren and Miller (1988).

Globigerina angulisuturalis/Paragloborotalia opima Concurrent Range Zone (Zone P21)

Definition: Concurrent range of nominate taxa between the FO of *Globigerina angulisuturalis* (base) and the LO of *Paragloborotalia opima* (top).

Globigerina angulisuturalis/Chiloguembelina cubensis Concurrent Range Subzone (Subzone P21a)

Amended definition: Concurrent range of the nominate taxa between the FO of *Globigerina angulisuturalis* (base) and the last "common" occurrence of *Chiloguembelina cubensis* (top).

Discussion: *Globigerina angulisuturalis* is a common taxon throughout Subzone P21a of Hole 628A, but it occurs only rarely in Subzone P21a of Hole 803D. At both sites, the FO of *G. angulisuturalis* is associated with the upper part of Chron C11 Normal in agreement with Berggren et al. (1985) and Berggren and Miller (1988). *Globigerina ciperoensis* is also common throughout this zone in Hole 628A, but it is not present at all in this or subsequent zones in Hole 803D. *Paragloborotalia opima* is common throughout Subzone P21a of Hole 803D, but it occurs only rarely in Subzone P21a of Hole 628A. *P. opima* is distinguished from *P. nana* based on the size criteria of Bolli and Saunders (1985).

The placement of the top of Subzone P21a is problematic at both sites because of the rare occurrence of *Chiloguembelina cubensis* throughout the upper Oligocene, particularly in Hole 628A. In Hole 628A, the top of Subzone P21a is based, in part (see below), on the last "common" (i.e., >5%) occurrence of *C. cubensis* (Fig. 5). Likewise in Hole 803D, the top of Subzone P21a is tentatively placed at the last "common" occurrence of *C. cubensis* between Samples 130-803D-

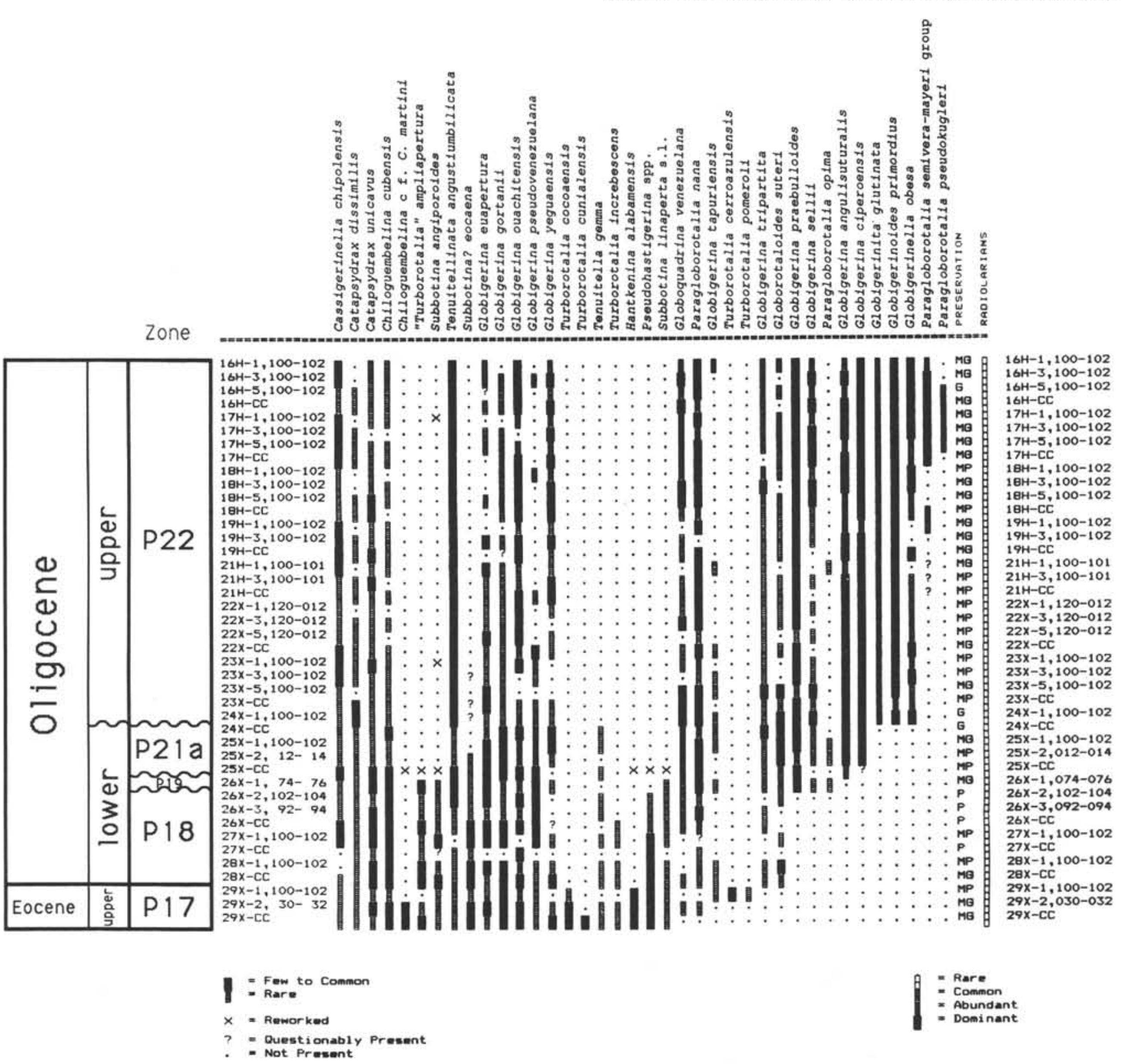

Figure 5. Graphic distribution of planktonic foraminifers throughout the uppermost Eocene and Oligocene of Hole 628A (Little Bahama Bank). Reworked species are denoted by an "X". Foraminiferal relative abundance: rare = <5% and few to common = >5%. Foraminiferal preservation: G = good, MG = moderately good, MP = moderately poor, and P = poor.

46X-3, 51–53 cm and -47X-1, 51–53 cm (Fig. 6). It should be noted, however, that Sample 130-803D-43X-1, 49–51 cm, near the top of Zone P21, contains "common" *C. cubensis*. Another sample, from the basal part of Zone 22, also contains common *C. cubensis* (Sample 130-803D-41X-1, 55–57 cm), but this latter sample also contains reworked uppermost Eocene or lower Oligocene specimens of *Pseudohastigerina* spp. and *"Turborotalia" ampliapertura*.

An unconformity separates Subzone P21a and Zone P22 in Hole 628A based on the last common occurrence of *C. cubensis* in Sample 101-628A-24X-CC, and the FO of *Globigerinoides primordius* in Sample 101-628A-24X-1, 100–102 cm (Fig. 5). Core 101-628A-24X contains interbedded calcareous ooze and chalk, and unlithified and partially lithified packstone in the interval between these two samples (Austin, Schlager, Palmer, et al., 1986), suggesting erosion and/or downslope transport. This interval corresponds with two peaks in global hiatus distribution (PHb and PHaa), according to an analysis by Keller et al. (1987).

The basal sample of Subzone P21a in Hole 628A (Sample 101-628A-25X-CC) contains numerous reworked taxa indicative of uppermost Eocene Zone P17, including *Hantkenina alabamensis* and *Chiloguembelina* sp., lending support to the interpretation of an unconformity between Zone P19 and Subzone P21a in Hole 628A.

Globigerina angulisuturalis–Paragloborotalia opima Partial Range Subzone (Subzone P21b)

Amended definition: Concurrent partial ranges of the nominate taxa between the last "common" occurrence of *Chiloguembelina cubensis* (base) and the LO of *Paragloborotalia opima* (top).

Discussion: Subzone P21b is not represented by the samples examined from Hole 628A because of the presence of an unconformity between Subzone P21a and Zone P22. *Paragloborotalia opima* is a persistent taxon throughout Subzone P21b of Hole 803D, whereas *Globigerina angulisuturalis* occurs only sporadically (Fig. 6). *Chi-*

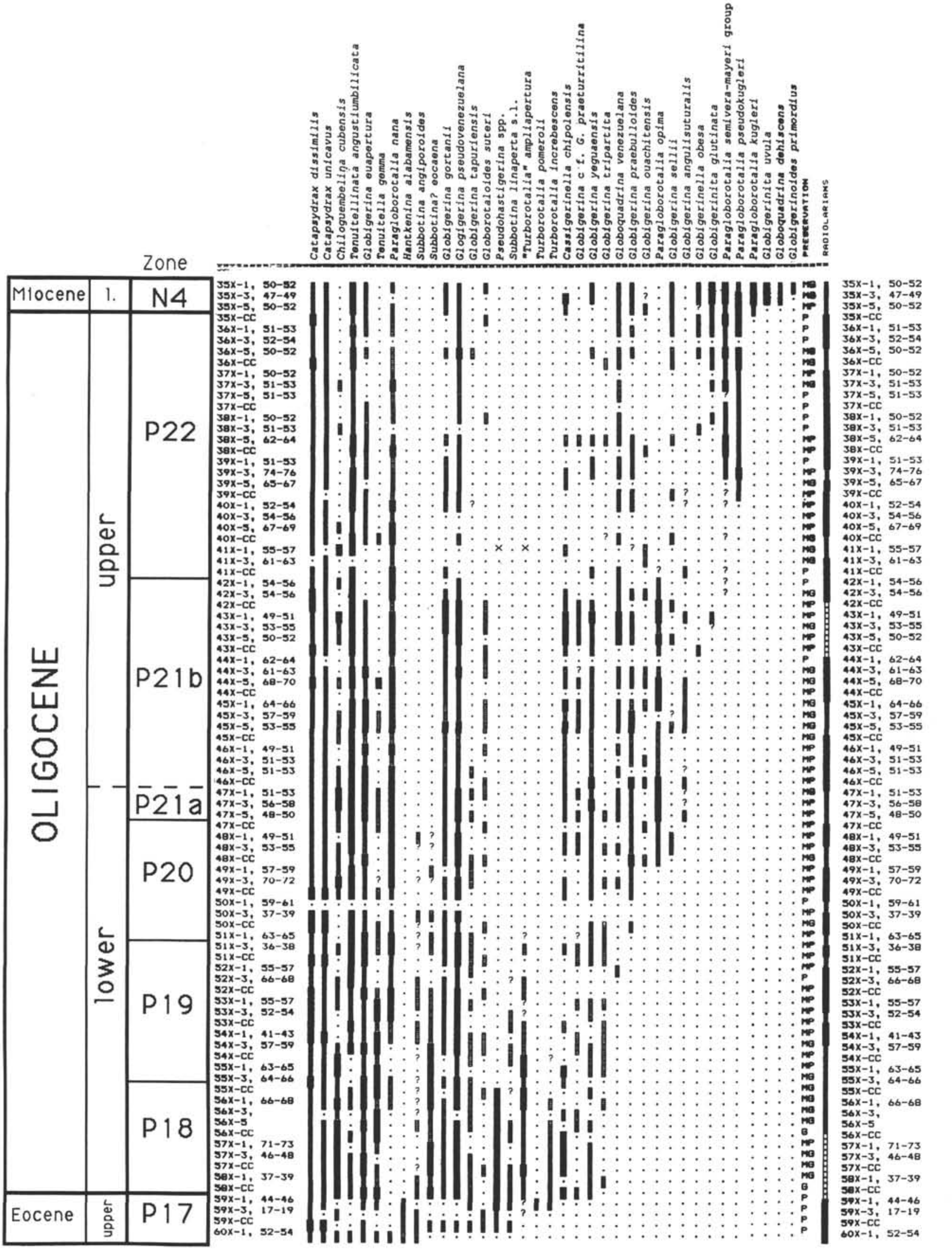

Figure 6. Graphic distribution of planktonic foraminifers throughout the uppermost Eocene to basal Miocene of Hole 803D (Ontong Java Plateau). Reworked species are denoted by an "X". Foraminiferal relative abundance: rare = <5% and few to common = >5%. Foraminiferal preservation: G = good, MG = moderately good, MP = moderately poor, P = poor.

loguembelina cubensis also occurs sporadically throughout this zone in Hole 803D.

Globigerina ciperoensis Partial Range Zone (Zone P22)

Definition: Partial range of the nominate taxon between the LO of *Paragloborotalia opima* (base) and the FO of *Paragloborotalia kugleri* (top).

Discussion: *Globigerinoides primordius* occurs commonly throughout Zone P22 in Hole 628A. This taxon first occurs in Sample 101-628A-24X-1, 100–102 cm (Fig. 5). Berggren et al. (1985) and Berggren and Miller (1988) reported the first occurrence of *G. primordius* at 25.8 Ma (within Chron C7 Normal) and the first common occurrence of *G. primordius* at 24.5 Ma (within Chron C6C Reversed). Although an unconformity is present at the base of Zone P22 in Hole 628A (between Samples 101-628A-24X-1, 100–102 cm, and -24X-CC), the calcareous nannofossil data of Moran and Watkins (1988) indicate that the basal part of Zone P22 overlies the unconformity. This interpretation is based on the FO of *Sphenolithus ciperoensis* in Sample 101-628A-24X-1, 80–81 cm (just above the unconformity), and the LO of *S. distentus* in Sample 101-628A-23X-CC. These two calcareous nannofossil datums have ages of 30.2 and 28.2 Ma, respectively (Berggren et al., 1985). The Subzone P21b/Zone P22 boundary is placed at the LO of *Paragloborotalia opima* with an age of 28.2 Ma (Berggren et al., 1985; Berggren and Miller, 1988). The FO of *G. primordius*, therefore, is closer to 28.0 Ma (within Chron C8 Reversed), provided that specimens of *S. distentus* have not been reworked upward (Fig. 2). The FO of *Paragloborotalia pseudokugleri* (26.3 Ma) in Sample 101-628A-17H-5, 100–102 cm, and the paleomagnetic record of the Zone P22 interval also support the conclusion of an "early" FO of *G. primordius* in Hole 628A (Fig. 2).

Globigerina ciperoensis does not occur in Hole 803D, but it is a common taxon throughout Zone P22 in Hole 628A. The FOs of *Paragloborotalia semivera/mayeri* and *P. pseudokugleri* are in the lower part of Zone P22 in Hole 803D. The FO of *P. pseudokugleri* is at the top of Chron C8 in Hole 803D (Fig. 3). In Hole 628A, the FO of *P. pseudokugleri* is associated with the middle part of Chron C7 Normal (Fig. 2).

Chiloguembelina cubensis occurs persistently throughout Zone P22 in Hole 628A, and sporadically through much of this zone in Hole 803D. Blow (1969, p. 222) had noted that *C. cubensis* can occur as high as Zone N3 (= P22). *Paragloborotalia opima* occurs from the upper part of Zone P20 through Subzones P21a and P21b in Hole 803D, and its LO is a reliable datum at this site (Fig. 6). In contrast, *P. opima* occurs only sporadically in Hole 628A, and an anomalous occurrence of this taxon, based on the size criteria of Bolli and Saunders (1985), occurs in Zone P22 (Sample 101-628A-21H-1, 100–101 cm) (Fig. 5). This particular sample correlates to the uppermost part of Chron C8 and contains no other evidence of reworking (Fig. 2). Several samples from Zone P22 in Hole 628A do contain reworked upper Eocene or lower Oligocene taxa, but the possibility exists that the *P. opima/P. nana* group represents ecophenotypes whose *P. opima* morphotype may display diachronous occurrences between the major ocean basins.

A major unconformity truncates the upper part of Zone P22 in Hole 628A. Keller et al. (1987) and Keller and Barron (1983) recognize numerous global hiatuses during the latest Oligocene to the middle Miocene (PHa, NH1a, NH1b, NH2).

Paragloborotalia kugleri Total Range Zone (Zone N4)

Definition: Total range of the nominate taxon.

Discussion: Zone N4 is not present in Hole 628A because of the presence of a major unconformity between Zones P22 and N12 (Austin, Schlager, Palmer, et al., 1986). In Hole 803D, the FO of *Paragloborotalia kugleri* s.s. is in Sample 130-803D-35X-5, 50–52 cm, the FO of *Globoquadrina dehiscens* is in Sample 130-803D-35X-3, 47–49 cm, and the FO of *Globigerinoides primordius* is in Sample 130-803D-35X-1, 50–52 cm (Fig. 6). Note the "late" FO of *G. primordius* in Hole 803D compared with its very early FO in Hole 628A. Berggren et al. (1985) noted that the FO of *G. dehiscens* is slightly higher than the FO of *P. kugleri* s.s. in the stratotype of the Aquitanian Stage. Our results from Hole 803D concur with that sequence of first occurrences.

SEDIMENTATION RATES

The planktonic foraminiferal datums, ages, and stratigraphic positions used to construct age vs. depth curves for Holes 803D and 628A are presented in Tables 1 and 2, respectively. The ages of planktonic foraminiferal first (FO) and last occurrences (LO) are from Berggren et al. (1985). Hole 803D contains a continuous record of sediment accumulation during the Oligocene (Fig. 7). The average sedimentation rate is 17.0 m/m.y. Upper Oligocene Zone P22 had a slightly lower rate of 13.8 m/m.y. compared with the lower and mid-Oligocene, which averaged 18.7 m/m.y.

The Oligocene of Hole 628A is punctuated by several hiatuses based on planktonic foraminiferal ranges. The evidence used to delineate these stratigraphic breaks was discussed in the previous section. Upper Oligocene Zone P22 had relatively high sedimentation rates; 31 m/m.y. represents a minimum rate because of the uncertainty of the magnitude of the unconformity between Zone P22 and Subzone P21a (Fig. 8). However, the calcareous nannofossil evidence of Moran and Watkins (1988) suggests that the basal part of Zone P22 is present above the unconformity (the nannofossil CP19a/CP19b zonal boundary, which correlates with the lowermost part of Zone P22

Table 1. Planktonic foraminifer datums, ages, and stratigraphic positions in Oligocene to basal Miocene, Hole 803D.

Planktonic foraminifer datums	Age (Ma)	Top of interval	Bottom of interval	Depth (mbsf)	Interpolated depth (mbsf)
FO *Paragloborotalia kugleri*	23.7	35X-5, 50–52	35X-CC	319.50–322.01	320.76
FO *Paragloborotalia pseudokugleri*	26.3	39X-CC	40X-1, 52–54	360.66–361.82	361.24
LO *Paragloborotalia opima*	28.2	42X-1, 54–56	42X-3, 54–56	381.24–384.78	383.01
LO *Chiloquembelina* (common)	30.0	46X-3, 51–53	46X-5, 51–53	422.81–425.81	424.31
FO *Globigerina angulisuturalis*	31.6	47X-5, 48–50	47X-CC	435.48–436.20	435.84
FO *Paragloborotalia opima*	32.7	52X-1, 55–57	52X-3, 66–68	477.45–480.56	479.01
LO "*Turborotalia*" *ampliapertura*	32.8	52X-3, 66–68	52X-CC	480.56–481.42	480.99
LO *Pseudohastigerina* spp.	34.0	54X-CC	55X-1, 63–65	502.93–506.63	504.78
LO *Hantkenina* spp.	36.6	58X-CC	59X-1, 44–46	535.86–544.74	540.30
LO *Turborotalia cerroazulensis* gr.	36.6	58X-CC	59X-1, 44–46	535.86–544.74	540.30

Notes: LO = last occurrence and FO = first occurrence. Ages are from Berggren et al. (1985).

Table 2. Planktonic foraminifer datums, ages, and stratigraphic positions in Oligocene, Hole 628A.

Planktonic foraminifer datums	Age (Ma)	Top of interval	Bottom of interval	Depth (mbsf)	Interpolated depth (mbsf)
FO *Paragloborotalia pseudokugleri*	26.3	17H-5, 100–102	17H-CC	153.10–155.66	154.38
LO *Chiloguembelina* (common)	30.0	24X-1, 100–102	24X-CC	212.90–215.67	214.28
FO *Globigerina angulisuturalis*	31.6	25X-CC	26X-1, 74–76	225.21–232.14	228.67
LO *Subbotina angiporoides*	32.0	25X-CC	26X-1, 74–76	225.21–232.14	228.67
LO "*Turborotalia*" *ampliapertura*	32.8	25X-CC	26X-1, 74–76	225.21–232.14	228.67
LO *Pseudohastigerina* spp.	34.0	26X-1, 74–76	26X-2, 102–104	232.14–233.92	233.03
LO *Turborotalia cerroazulensis* gr.	36.6	28X-CC	29X-1, 100–102	254.39–261.20	257.79
LO *Hantkenina* spp.	36.6	28X-CC	29X-1, 100–102	254.39–261.20	257.79

Notes: LO = last occurrence and FO = first occurrence. Ages are from Berggren et al. (1985).

according to Berggren et al. [1985], occurs in Core 101-628A-23X and the unconformity occurs within Core 101-628A-24X). Mid-Oligocene Subzone P21a is bounded by unconformities; it has a sedimentation rate of at least 9 m/m.y. Lower Oligocene Zone P19 is also bounded by unconformities and is represented by only one sample (101-628A-26X-1, 74–76 cm). Cores 101-628A-24X to -26X contain numerous beds of unlithified packstone and floatstone, and it is within this interval that the three Oligocene unconformities occur. Cores 101-628A-27X and -28X consist of calcareous ooze and chalk with no evidence of redeposition or unconformities. This interval had an average sedimentation rate of 9.5 m/m.y. and represents lower Oligocene Zone P18.

COMPARISON OF LOW-LATITUDE SITES 628 AND 803

Overall, the total diversity and composition of planktonic foraminiferal assemblages through the Oligocene of Holes 628A (Little Bahama Bank) and 803D (Ontong Java Plateau) are very similar. In addition, the observed stratigraphic ranges of many of the taxa are similar at both sites (Fig. 9). Important differences are present, however, some of which are paleoceanographically related whereas others may be caused by dissolution at the Pacific site.

In the lower Oligocene (Zone P18 to Subzone P21a), both holes contain common occurrences of *Catapsydrax dissimilis, C. unicavus, Chiloguembelina cubensis, Pseudohastigerina* spp., *Tenuitella gemma, "Turborotalia" ampliapertura, Subbotina? eocaena, G. euapertura, G. gortanii,* and *G. pseudovenezuelana* (Figs. 5 and 6). Other taxa characteristic of the lower Oligocene of both sites but with less persistent and rare occurrences include *Paragloborotalia nana, Tenuitellinata angustiumbilicata, Turborotalia increbescens, Globigerina tapuriensis, G. tripartita, Subbotina linaperta* s.l., *S.? yeguaensis,* and *Globorotaloides suteri. Subbotina angiporoides, Globigerina angulisuturalis, G. ouachitaensis,* and *G. praebulloides* occur at both sites but are significantly more common in Hole 628A, whereas *Paragloborotalia opima* is much more common in Hole 803D. The poor showing of the three species of *Globigerina* in Hole 803D may be a result of enhanced dissolution at this site, but the distribution and abundance differences of *S. angiporoides* and *P. opima* between Holes 628A and 803D are probably related to paleoceanographic differences between the subtropical western North Atlantic and tropical western Pacific during early Oligocene time.

In the upper Oligocene (Subzone P21b to Zone P22), both holes contain common occurrences of *Catapsydrax* spp., *Paragloborotalia nana, Globigerina angustiumbilicata, G. venezuelana, Paragloborotalia pseudokugleri,* and *P. semivera/mayeri*. Other taxa with persistent but rare occurrences at both sites include *Globigerinita glutinata, Globigerina euapertura,* and *Chiloguembelina cubensis. Globigerinella obesa, Globigerina angulisuturalis, G. ouachitaensis, G. praebulloides, G. sellii,* and *Subbotina? yeguaensis* are present in the upper Oligocene of both sites but are much more common in Hole 628A. *Globigerina tripartita* virtually vanishes from the upper Oligocene assemblages of Hole 803D, but it is a persistent taxon throughout Zone P22 in Hole 628A. In addition, *Globigerinoides primordius* and *Globigerina ciperoensis* are common taxa of the upper Oligocene (Zone P22) of Hole 628A but are not present in upper Oligocene sediments of Hole 803D. Enhanced dissolution, particularly in Zone P22 of Hole 803D, may be primarily responsible for the differences in upper Oligocene assemblages between the two sites. However, the marked differences in the distribution of *Globigerinoides primordius,* which first occurs in basal Miocene Zone N4 of Hole 803D but ranges throughout uppermost Oligocene Zone P22 of Hole 628A, may be related to paleoceanographic differences between the two sites.

COMPARISON WITH THE SUBANTARCTIC

Recent studies of planktonic foraminifers from subantarctic Oligocene deep-sea sequences have been published by Stott and Kennett (1990) from the Maud Rise in the Weddell Sea, Huber (1991) from the southern Kerguelen Plateau, and Nocchi et al. (1991) from the South Atlantic (Fig. 1). Important differences in species distribution and assemblage composition exist between the low and southern high latitudes that bear on the paleobiogeography and paleoceanography of the Oligocene.

Characteristic taxa of the subantarctic lower Oligocene assemblages include *Subbotina angiporoides, S. utilisindex, Globorotaloides suteri, Chiloguembelina cubensis, Tenuitella gemma, T. munda, Praetenuitella spp., Paragloborotalia nana, Catapsydrax unicavus,* and *Globigerina labiacrassata. Globigerina labiacrassata, Tenuitella munda,* and *Praetenuitella* spp. were not found in lower Oligocene sediments in either of the low latitude sites. *Subbotina angiporoides* and *S. utilisindex* (probably equivalent to our *S. linaperta* s.l.) occur in much greater abundances in the subantarctic than in the low latitudes. The other taxa occur in similar abundances in both the low and southern high latitudes. *Pseudohastigerina* spp., *Turborotalia increbescens, "Turborotalia" ampliapertura, Subbotina? eocaena, S.? yeguaensis, Globigerina gortanii, G. tapuriensis, G. tripartita,* and *G. pseudovenezuelana* are noticeably absent or have rare occurrences in the subantarctic lower Oligocene assemblages. Huber (1991) reports rare but persistent occurrences of *Pseudohastigerina micra, Subbotina? eocaena, Globigerina gortanii,* and *G. pseudovenezuelana* from one of two holes examined from the southern Kerguelen Plateau.

Subantarctic assemblages from the upper Oligocene are characterized by *Catapsydrax* spp., *Globigerina labiacrassata, G. euapertura, G. praebulloides, Globigerinita juvenilis, Globorotaloides suteri, Tenuitella munda,* and *Tenuitellinata angustiumbilicata. Paragloborotalia opima, Globigerina ciperoensis,* and *Globigerinella obesa* are also noted in the South Atlantic holes (Nocchi et al., 1991). *Globigerina labiacrassata* was not observed in upper Oligocene sediments from either of the low-latitude sites, and *Tenuitella munda* occurs only sporadically in Hole 803D. *Globigerina euapertura* and *Globigerinita juvenilis* (equivalent to our *G. glutinata*) are more common in the upper Oligocene assemblages from the subantarctic. The other taxa occur in similar abundances in both the low and southern high latitudes. Noticeably absent, or with rare occurrences

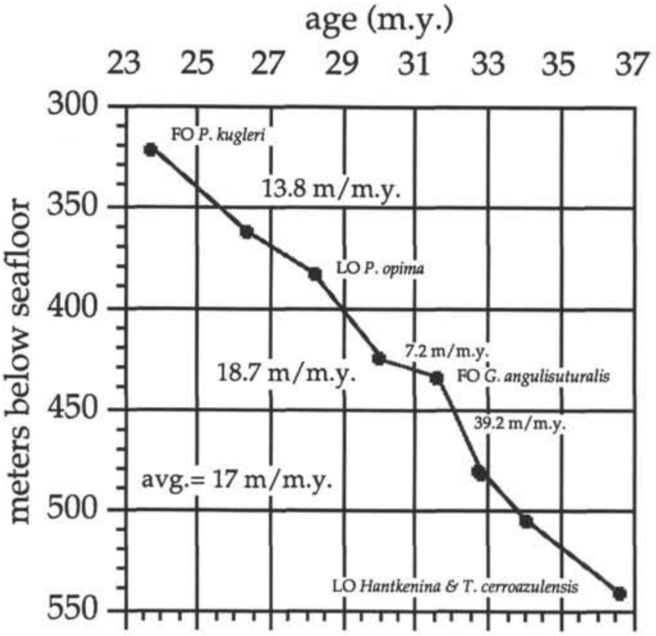

Figure 7. Age vs. depth plot of the Oligocene to basal Miocene of Hole 803D based on planktonic foraminiferal datums presented in Table 1. The low sedimentation rates in the mid-Oligocene may, in part, be an artifact of a "low" LO for "common" *Chiloguembelina* spp. at this site.

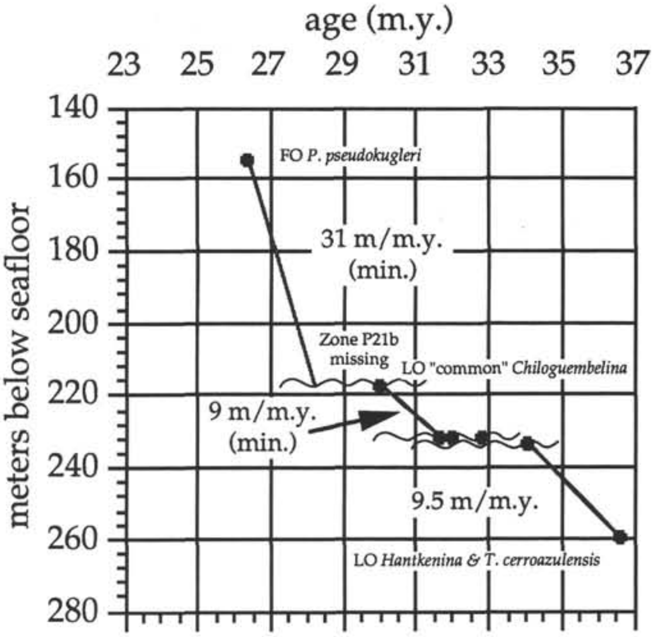

Figure 8. Age vs. depth plot of the Oligocene of Hole 628A based on planktonic foraminiferal datums presented in Table 2. Wavy lines correspond with hiatuses in the section.

in the subantarctic upper Oligocene assemblages are *Paragloborotalia pseudokugleri, P. semivera/mayeri, Globigerina angulisuturalis, G. gortanii, G. ouachitaensis, G. sellii, G. tripartita*, and *Subbotina? yeguaensis.*

SUMMARY AND CONCLUSIONS

Hole 803D from the tropical western Pacific (Ontong Java Plateau, 4.5°S paleolatitude) contains a complete uppermost Eocene to basal Miocene sequence based on planktonic foraminiferal evidence. Hole 628A from the subtropical western North Atlantic (Little Bahama Bank, 25.8°N paleolatitude) is possibly complete across the Eocene/Oligocene boundary, but it contains three unconformities within the Oligocene: between Zones P18/P19, P19/P21a, and P21a/P22. The uppermost part of Zone P22 is truncated by an unconformity and is overlain by sediments of Zone N12 (middle Miocene).

Chiloguembelina cubensis has been found to range persistently throughout upper Oligocene Subzone P21b and in much of Zone P22 in Holes 628A and 803D. In Hole 803D, the LO of *C. cubensis* is at the top of Chron C7 or basal C6C (25.3–25.5 Ma, according to Berggren et al., 1985). Berggren et al. (1985) and Berggren and Miller (1988) use the LO of *C. cubensis* to define the top of Subzone P21a at 30.0 Ma (within Chron C10 Normal). We propose the use of the last "common" (>5%) occurrence of *C. cubensis* to define the Subzone P21a/P21b boundary.

In Hole 628A, common (>5%) *Globigerinoides primordius* is found to range throughout uppermost Oligocene Zone P22. Although Zone P22 is bounded at its base by an unconformity (between Samples 101-628A-24X-1, 100–102 cm, and -24X-CC), the calcareous nannofossil data of Moran and Watkins (1988) indicate that little or none of the basal Zone P22 is missing (the nannofossil Zone NP24/NP25 boundary occurs within Core 101-628A-23X). This places the FO of *G. primordius* within Chron C8 Reversed (27.7–28.1 Ma, according to Berggren et al., 1985). This FO is significantly older than the first "rare" *G. primordius* at 25.8 Ma and the first "common" *G. primordius* at 24.5 Ma cited by Berggren et al. (1985) and Berggren and Miller (1988).

The FO of *Paragloborotalia pseudokugleri* appears to be diachronous between Holes 628A and 803D. In Hole 628A, the FO of *P. pseudokugleri* is within Chron C7 Normal (approximately 25.8 Ma, according to Berggren et al., 1985). In Hole 803D, the FO of *P. pseudokugleri* is at the top of Chron C8 (approximately 27.0 Ma, according to Berggren et al., 1985).

The FO of *Globigerina angulisuturalis*, used to define the Zone P20/Subzone P21a boundary, is found within Chron C11 Normal in Holes 628A and 803D (31.6 Ma, according to Berggren et al., 1985). These findings are consistent with Berggren et al. (1985) and Berggren and Miller (1988), suggesting that *G. angulisuturalis* has an isochronous FO in the Atlantic and Pacific. However, Hess et al. (1989) document a diachronous FO for this taxon between ocean basins based on the Sr-isotope stratigraphy. The fact that an unconformity is present at the base of Subzone P21a in Hole 628A (North Atlantic) complicates the interpretation somewhat, but the data of Hess et al. (1989) suggest that the FO of *G. angulisuturalis* is younger in the Atlantic (29.8–31.2 Ma) than in the Pacific (31.8–32.0 Ma) for the sites investigated, a finding that contrasts with the results from Hole 628A (i.e., the FO of *G. angulisuturalis* is at least 31.6 Ma in the Bahamas site).

In general, taxon ranges, total diversity, and the composition of the planktonic foraminiferal assemblages from Holes 628A and 803D are similar. Some differences exist between the sites in assemblage composition, particularly in the species abundances *Globigerina,* but these differences may be more closely related to enhanced dissolution at the Pacific site than to major differences in the physical or biological oceanography of the water masses between the sites during the Oligocene. Clear exceptions to this trend include the greater abundance of *Subbotina angiporoides* in subtropical Hole 628A and the greater abundance of *Paragloborotalia opima* in tropical Hole 803D.

A comparison between the low and southern high latitudes (Stott and Kennett, 1990; Huber, 1991; Nocchi et al., 1991) illustrates some similarities in the composition of Oligocene planktonic foraminiferal assemblages, as well as some important differences. The relative abundances of such taxa as *Catapsydrax* spp., *Tenuitella gemma, Paragloborotalia nana, Globigerina angustiumbilicata, G. praebulloides,* and *Globorotaloides suteri* are similar in the subantarctic and

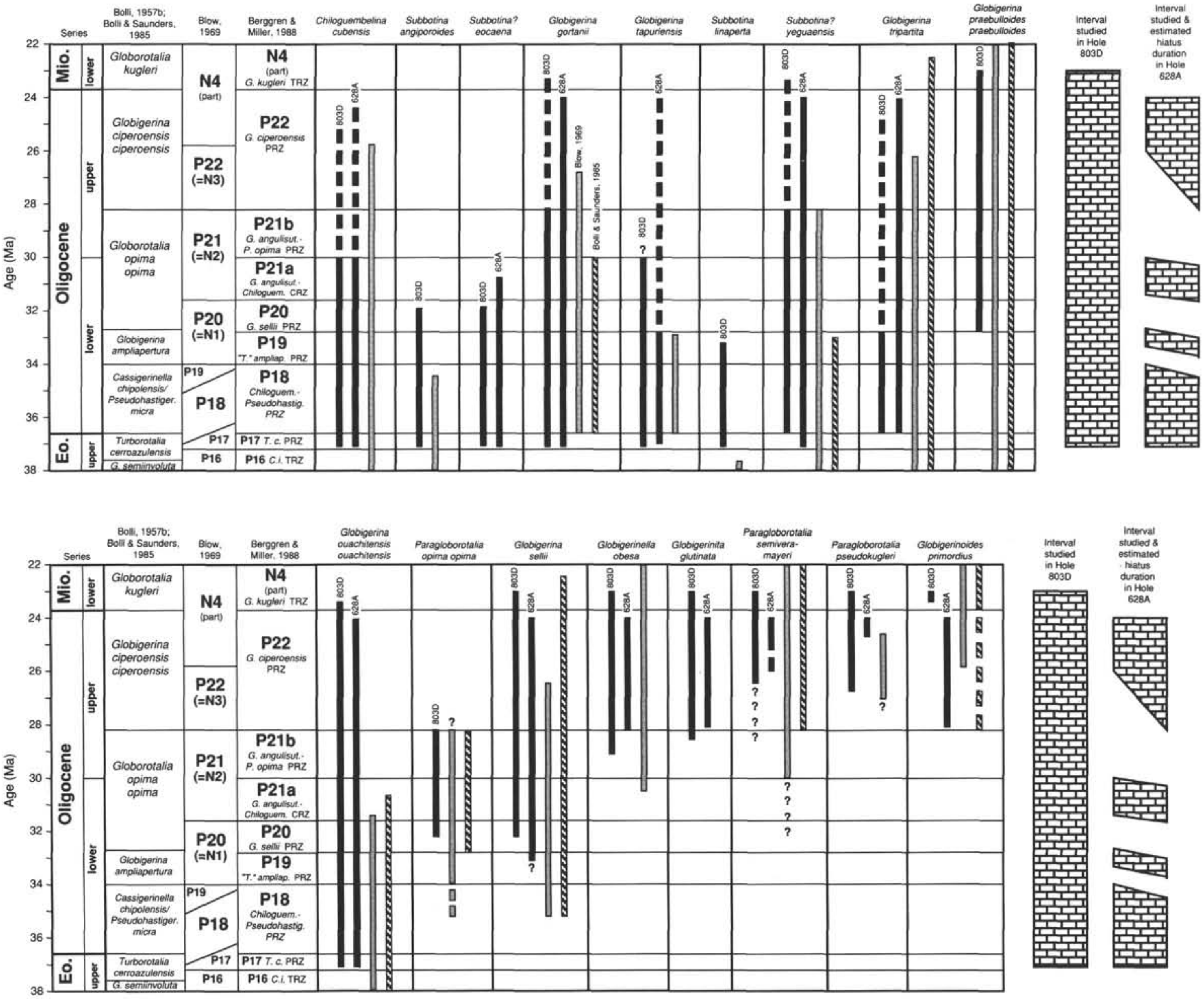

Figure 9. Comparison of selected planktonic foraminiferal stratigraphic ranges in Holes 628A and 803D. The ranges are compared with the published ranges of Blow (1969; stippled bars) and Bolli and Saunders (1985; diagonal striped bars). Also shown is the approximate extent of the stratigraphic records studied in both sites, and the approximate duration of hiatuses based on the planktonic foraminiferal evidence from the Oligocene of Hole 628A.

low latitudes. *Subbotina angiporoides, S. utilisindex, Globigerina euapertura, Tenuitella munda,* and *Globigerinita juvenilis* are more common in the subantarctic than in the tropics/subtropics. *Globigerina labiacrassata, G. brazeri, G. woodi, Catapsydrax echinatus,* and species of *Praetenuitella* were not recorded in either low-latitude site examined here. Noticeably absent, or with rare occurrences in the subantarctic Oligocene assemblages, are *Pseudohastigerina* spp., *Turborotalia increbescens, "Turborotalia" ampliapertura, Paragloborotalia opima, P. pseudokugleri, P. semivera/mayeri, Globigerinella obesa, Subbotina? eocaena, S.? yeguaensis, Globigerina angulisuturalis, G. gortanii, G. ouachitaensis, G. sellii, G. tapuriensis, G. tripartita,* and *G. pseudovenezuelana.* This comparison of planktonic foraminiferal assemblages between the low and southern high latitudes illustrates that biogeographic gradients, although not as pronounced as during the late Neogene, were nonetheless significant during the Oligocene.

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TAXONOMIC NOTES

We have attempted to document as many taxa as possible within the time constraints of this study, but we have not separated out all species, particularly those of the genus *Globigerina.* Unidentified globigerinids occur in all samples examined and therefore have not been included on the distribution tables. We did, however, focus much of our effort on the species concepts and stratigraphic ranges of the commonly known low-latitude taxa, with particular attention addressed to the range of morphologic variability and the criteria used to distinguish closely related taxa. Generic assignments based on phylogenetic relationships for some Oligocene taxa have yet to be firmly established. Because this is primarily a biostratigraphic study, we largely followed the recent literature in assigning individual species to genera. The following is a list of the principal references used to identify species: Blow and Banner (1962), Blow (1969), Bolli (1957a, 1957b), Bolli and Saunders (1985), Jenkins (1985), Kennett and Srinivasan (1983), Poore and Brabb (1977), Poore and Bybell (1988), Stainforth et al. (1975), and Toumarkine and Luterbacher (1985).

Cassigerinella chipolensis (Cushman and Ponton)
Plate 7, Figs. 18–19

Cassidulina chipolensis Cushman and Ponton, 1932, p. 98, pl. 15, figs. 2a–c.

Discussion: *Cassigerinella chipolensis* differs from *Cassigerinella* sp. by its slightly smaller size and more inflated chambers.

Cassigerinella sp.
Plate 7, Fig. 17

Discussion: *Cassigerinella* sp. is distinguished from *C. chipolensis* by its slightly larger size and distinctly flattened, lenticular test. This taxon was only recorded in the lower to mid-Oligocene of Hole 628A.

Catapsydrax dissimilis (Cushman and Bermudez)
Plate 3, Figs. 16–17

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

Catapsydrax unicavus Bolli, Loeblich and Tappan
Plate 3, Fig. 15

Catapsydrax unicavus Bolli, Loeblich and Tappan, 1957, p. 37, pl. 7, figs 9a–c.

Discussion: The bulla of *Catapsydrax unicavus* is low across the umbilicus in contrast with the inflated bulla-like final chamberlet often observed in *Globigerina gortanii. Catapsydrax unicavus* is distinguished from *Globorotaloides suteri* in having only four chambers in the final whorl, an umbilical aperture, and a bulla centered over the umbilicus.

Chiloguembelina cubensis (Palmer)
Plate 1, Figs. 14–17

Guembelina cubensis Palmer, 1934, p. 73, text-figs. 1–6.

Discussion: *Chiloguembelina cubensis* ranges throughout the uppermost Eocene and Oligocene of Holes 628A and 803D, although it becomes rare in the upper Oligocene (Subzone P21b to Zone P22).

Chiloguembelina cf. *C. martini* (Pijpers)
Plate 1, Fig. 13

Chiloguembelina martini Pijpers, 1933, p. 57, figs. 6–10.

Discussion: *Chiloguembelina* cf. *C. martini* is distinguished from *C. cubensis* by its larger size, flatter test, and droopy chambers. This taxon is restricted to the uppermost Eocene of Hole 628A.

Globigerina angulisuturalis Bolli
Plate 9, Figs. 1–6

Globigerina ciperoensis angulisuturalis Bolli, 1957b, p. 109, pl. 22, figs. 11a–c; Bolli and Saunders, 1985, pp. 182–183, figs. 13.4–7.

Discussion: This distinctive taxon is closely related to *Globigerina ciperoensis,* but it is distinguished by its deep U-shaped intercameral sutures and generally smaller size. *G. angulisuturalis* is a common taxon of the mid- and upper Oligocene of Hole 628A, but it is recorded only sporadically in Hole 803D.

Globigerina ciperoensis Bolli
Plate 9, Figs. 7–10

Globigerina ciperoensis ciperoensis Bolli, 1957b, p. 109, pl. 22, figs. 10a–b; Bolli and Saunders, 1985, pp. 182–183, figs. 13.1–3.

Discussion: *Globigerina ciperoensis* is a common taxon of the mid- and upper Oligocene of Hole 628A, but it was not observed in Hole 803D.

Globigerina euapertura Jenkins
Plate 4, Figs. 10–13

Globigerina euapertura Jenkins, 1960, p. 351, pl. 1, figs. 8a–c.

Discussion: *Globigerina euapertura* is characterized by its relatively large size, four chambers in the final whorl, and a broad, low aperture that lacks a lip. It is distinguished from *Subbotina? eocaena* s.l. by having a distinctly broader and lower arched aperture and a more compact test (i.e., more embracing chambers). *G. euapertura* differs from *Globigerina pseudovenezuelana* in having an arched aperture, as opposed to the lower, nearly straight aperture of the latter taxon. A gradational specimen is illustrated on Plate 4, Figure 14. It differs from *"Turborotalia" ampliapertura* in having a broader and lower arched aperture. *G. euapertura* ranges through the uppermost Eocene and Oligocene of Holes 628A and 803D.

Globigerina gortanii (Borsetti)
Plate 3, Figs. 7–14

Catapsydrax gortanii Borsetti, 1959, p. 205, pl. 1, figs. 1a–d.
Globigerina gortanii (Borsetti) Bolli and Saunders, 1985, p. 177, fig. 13.17.

Discussion: *Globigerina gortanii* is characterized by its bulla-like final chamberlet and variable dorsal convexity. The last chamberlet in *G. gortanii* is "parachute-like" in its inflation, thereby distinguishing it from the true bulla in

Catapsydrax unicavus. High-spired forms may be referred to as *Globigerina praeturritilina* Blow and Banner (e.g., Plate 3, Fig. 9). Without the bulla-like chamberlet, *G. gortanii* resembles *Subbotina*? *eocaena* in overall chamber shape and arrangement. *G. gortanii* was found throughout the uppermost Eocene–basal Miocene interval studied.

Globigerina ouachitaensis Howe and Wallace
Plate 9, Figs. 11–12

Globigerina ouachitaensis Howe and Wallace, 1932, p. 74, pl. 10, figs. 7a–c.

Discussion: *Globigerina ouachitaensis* is characterized by its relatively wide umbilicus, four globular chambers in the final whorl, and moderate dorsal convexity. It is distinguished from *Globigerina ciperoensis* in possessing one less chamber in its final whorl and a generally higher spire.

Globigerina praebulloides Blow
Plate 9, Figs. 13–14

Globigerina praebulloides Blow, 1959, p. 180, pl. 8, figs. 47a–c.

Discussion: *Globigerina praebulloides* is characterized by its relatively large final chamber, distinctive elongate shape, and lobate outline. *G. praebulloides* lacks the apertural lip or well-developed imperforate rim found in *G. ouachitaensis* and *Subbotina*? *eocaena.* In addition, *G. praebulloides* tends to be smaller than the latter taxon.

Globigerina pseudovenezuelana Blow and Banner
Plate 4, Figs. 15–17

Globigerina pseudovenezuelana Blow and Banner, 1962, p. 100, pl. 11, figs. J–L; Poore and Brabb, 1977, p. 256, pl. 4, figs. 8–9; Bolli and Saunders, 1985, pp. 180–181, fig. 13.21.

Discussion: *Globigerina pseudovenezuelana* is distinguished from *G. euapertura* by having a narrower umbilicus and lower, nearly straight aperture. A gradational specimen is illustrated on Plate 4, Figure 14. *G. pseudovenezuelana* tends to be slightly smaller and has more inflated chambers than *Globoquadrina venezuelana*.

Globigerina tapuriensis Blow and Banner
Plate 5, Figs. 11–16

Globigerina tripartita tapuriensis Blow and Banner, 1962, p. 97, pl. 10, figs. H–K.
Globigerina tapuriensis (Blow and Banner) Bolli and Saunders, 1985, p. 181, fig. 14.12.

Discussion: *Globigerina tapuriensis* differs from *Globigerina euapertura* in having only three chambers in the final whorl that increase rapidly in size. The aperture of *G. tapuriensis* is centered over a suture rather than over a chamber as in *G. euapertura.* It differs from *Globigerina tripartita* in having more globular, inflated chambers, particularly the ultimate chamber, and in having an arched aperture. The overall chamber arrangement and chamber shape of *G. tapuriensis* is similar to *Globigerina sellii,* but it differs from the latter taxon in lacking a flattened apertural face.

Globigerina tripartita Koch
Plate 5, Figs. 6–10

Globigerina bulloides var. *tripartita* Koch, 1926, p. 746, figs. 21a–b.
Globigerina tripartita (Koch) Bolli and Saunders, 1985, p. 181, fig. 14.13.

Discussion: *Globigerina tripartita* is characterized by its compact test, three chambers in the final whorl, and appressed, caplike final chamber. The final chamber is often smaller and/or less inflated than the penultimate chamber. Like *G. sellii* and *G. tapuriensis, G. tripartita* has its aperture centered over a suture. *G. tripartita* differs from *G. tapuriensis* in having a distinctive appressed final chamber and narrower umbilicus. This taxon displays considerable morphologic variability.

Globigerinella obesa (Bolli)
Plate 7, Figs. 15–16

Globorotalia obesa Bolli, 1957b, p. 119, pl. 29, figs. 2a–3.
Globigerinella obesa (Bolli) Kennett and Srinivasan, 1983, p. 234, pl. 59, figs. 2–5.

Discussion: *Globigerinella obesa* resembles *Tenuitella munda* in chamber number and arrangement, but the former taxon is larger and has larger pores.

Globigerinita glutinata s.l. Parker
Plate 6, Fig. 1

Globigerinita glutinata Parker, 1962, p. 246, pl. 9, figs. 1–16.

Discussion: We did not distinguish *Tenuitellinata juvenilis* (Egger) and *Globigerinita glutinata* as two separate taxa, following Kennett and Srinivasan (1983). Li Qianyu (1987, p. 311) states that *T. juvenilis* first appears in the early Oligocene and *G. glutinata* s.s. first appears in the early Miocene. Although we acknowledge that nonbullate forms (i.e., "*juvenilis*") are more common in the Oligocene than bullate forms (i.e., "*glutinata*"), we find occasional bullate forms in the upper Oligocene of Holes 628A and 803D.

Globigerinoides primordius Blow and Banner
Plate 9, Figs. 15–20

Globigerinoides quadrilobatus primordius Blow and Banner, 1962, p. 115, pl. 9, figs. Dd–Ff.

Discussion: Well-developed specimens of *Globigerinoides primordius* are present in the basal part of Zone P22 in Hole 628A (Plate 9, Figs. 17–18). *G. primordius* is a common taxon throughout upper Oligocene Zone P22 in Hole 628A. In Hole 803D, the FO of *G. primordius* is in the basal Miocene Zone N4.

Globoquadrina dehiscens (Chapman, Parr and Collins)
Plate 8, Figs. 17–18

Globorotalia dehiscens Chapman, Parr, and Collins, 1934, p. 569, pl. 11, fig. 6.

Globorotaloides suteri Bolli
Plate 3, Fig. 18

Globorotaloides suteri Bolli, 1957b, p. 117, pl. 27, figs. 13a–c.

Discussion: *Globorotaloides suteri* is distinguished from *Catapsydrax unicavus* in having four to five chambers in the final whorl and an umbilical-extraumbilical aperture. *G. suteri* often possesses a bulla-like final chamber that is variable in size, but when present it typically is not centered over the umbilicus as in *C. unicavus* (i.e., it resembles a kuemmerform final chamber).

Hantkenina alabamensis Cushman
Plate 1, Figs. 11–12

Hantkenina alabamensis Cushman, 1925, p. 3, pl. 1, fig. 1.

Paragloborotalia kugleri (Bolli)
Plate 8, Figs. 1–5

Globorotalia kugleri Bolli, 1957b, p. 118, pl. 28, figs. 5a–c.
Paragloborotalia kugleri (Bolli) Spezzaferri, 1991, p. 317, pl. 1, figs. 5a–c, pl. 2, figs. 1a–d and 2a–d.

Discussion: *Paragloborotalia kugleri* is assigned to the genus *Paragloborotalia* following the work of Spezzaferri (1991). Sensu stricto forms of *P. kugleri* are used to define the base of the Miocene in the low latitudes (Berggren et al., 1985; Berggren and Miller, 1988). *P. kugleri* is distinguished from *P. pseudokugleri* by its subacute margin and arched sutures on the spiral side.

Paragloborotalia nana (Bolli)
Plate 7, Figs. 1–2

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

Discussion: *Paragloborotalia nana* is distinguished from *P. semivera/mayeri* by its slightly smaller size, fewer chambers, and lower apertural arch. *P. nana* is distinguished from *P. opima* by its smaller size following the size criteria of Bolli and Saunders (1985).

Paragloborotalia opima (Bolli)

Plate 7, Figs. 3–4 and 9

Globorotalia opima opima Bolli, 1957b, p. 117, pl. 28, figs. 1a–c.

Discussion: Bolli and Saunders (1985) established size criteria to distinguish *Paragloborotalia opima* from *P. nana.* According to these criteria, *P. opima* must be >0.38 mm (most fall in a range from 0.39 to 0.50 mm). *P. opima* is common and well developed in the mid-Oligocene of Hole 803D, but it occurs only sporadically in Hole 628A.

Paragloborotalia pseudokugleri (Blow)

Plate 8, Figs. 8–16

Globorotalia (Turborotalia) pseudokugleri Blow, 1969, p. 391, pl. 10, figs. 4–6, pl. 39, figs. 5–6.
Paragloborotalia pseudokugleri (Blow) Spezzaferri, 1991, p. 315, pl. 1, figs. 1a–c, 2a–d, and 3a–d.

Discussion: *Paragloborotalia pseudokugleri* is assigned to the genus *Paragloborotalia* following the work of Spezzaferri (1991). *P. pseudokugleri* is distinguished from *P. kugleri* by its rounded margin and straight sutures on the spiral side. In the early part of its range, *P. pseudokugleri* is distinguished from juvenile specimens of the *P. semivera/mayeri* group by possessing 6 chambers in the final whorl compared with 5 to 5-1/2 in the latter. *P. pseudokugleri* is distinctly circular in outline and generally possesses a lower apertural arch compared with *P. semivera/mayeri.*

Paragloborotalia semivera/mayeri group

Plate 7, Figs. 5–8 and 10–14

Globorotalia mayeri Cushman and Ellisor, 1939, p. 11, pl. 2, figs. 4a–c.
Globigerina semivera Hornibrook, 1961, p. 149, pl. 23, figs. 455–457.

Discussion: We did not attempt to distinguish between *Paragloborotalia semivera* and *P. mayeri* because of their very close similarity in upper Oligocene sediments. The *P. semivera/mayeri* group differs from *P. nana* in their slightly larger size, more numerous chambers (5 to 5-1/2 compared with 4), distinctive oblong shape, and more open umbilicus. *P. semivera/mayeri* is distinguished from *P. opima* by its smaller size and less inflated chambers.

Pseudohastigerina micra (Cole)

Plate 6, Figs. 14–17 and 20–21

Nonion micrus Cole, 1927, p. 22, pl. 5, fig. 12.
Pseudohastigerina micra (Cole) Toumarkine and Luterbacher, 1985, pp. 118–119, figs. 21.1–8.

Discussion: *Pseudohastigerina micra* was difficult to distinguish from *P.* cf. *naguewichiensis* because of the small size of the species and the nature of preservation in many of the uppermost Eocene–lower Oligocene samples (e.g., note etching on specimens illustrated on Plate 6, Figs. 20–21, giving the impression of "larger" pores). In general, *P. micra* has more chambers, a smoother wall, and a subacute margin as compared with *P. naguewichiensis.* However, at the stereomicroscope the two taxa display many gradational features.

Pseudohastigerina cf. *naguewichiensis* (Myatliuk)

Plate 6, Figs. 18–19

Globigerinella naguewichiensis Myatliuk, 1950, p. 281, pl. 4, figs. 4a–b.
Pseudohastigerina naguewichiensis (Myuatliuk) Toumarkine and Luterbacher, 1985, p. 119, figs. 21.10–16.

Discussion: *Pseudohastigerina* cf. *P. naguewichiensis* is distinguished from *P. micra* by its rounded margin and more coarsely perforate test.

Subbotina angiporoides (Hornibrook)

Plate 1, Figs. 18–20

Globigerina angiporoides Hornibrook, 1965, p. 835, figs. 1a–i and 2.

Discussion: *Subbotina angiporoides* is a persistent taxon throughout much of the uppermost Eocene–lower Oligocene of Hole 628A. In Hole 803D, specimens of *S. angiporoides* are poorly developed and numerous questionable occurrences are noted. Its LO is in the upper part of Zone P20 in Hole 803D.

Subbotina? *eocaena* s.l. Gümbel

Plate 2, Figs. 7–11

Globigerina eocaena Gümbel, 1868, p. 662, pl. 2, figs. 109a–b; Hagn and Lindenberg, 1969, p. 236, pl. 1, figs. 1–6; Poore and Brabb, 1977, pp. 255–256, pl. 4, figs. 10–12.

Discussion: For the purposes of this study, large globigerinids with four chambers in the final whorl and an arched umbilical aperture bordered by an imperforate rim or thin lip are lumped under the concept of *Subbotina*? *eocaena* s.l. (also see discussions by Stainforth et al., 1975, and Poore and Brabb, 1977). The chambers in *S.*? *eocaena* are more inflated and the test is more lobate than the compact quadrilobate tests of *Globigerina euapertura, G. pseudovenezuelana,* and *"Turborotalia" ampliapertura. S.*? *eocaena* differs further from *Globigerina euapertura* in having a narrower and higher arched aperture and less embracing chambers. It differs from *S.*? *yeguaensis* in lacking a distinct toothlike apertural lip. *S.*? *eocaena* s.l. ranges throughout the lower Oligocene Zone P20 in Hole 803D and into Subzone P21a in Hole 628A.

Subbotina linaperta s.l. (Finlay)

Plate 2, Figs. 1–6

Globigerina linaperta Finlay, 1939, p. 125, pl. 13, figs. 54–57.

Discussion: This taxon, as applied in this study, may include forms referable to *Globigerina utilisindex* Jenkins and Orr, with which it is gradational (see discussion by Jenkins and Orr, 1973). *Subbotina linaperta* s.l. ranges up into Zone P19 (lower Oligocene) in Holes 803D and 628A.

Subbotina? *yeguaensis* s.l. Wienzierl and Applin

Plate 3, Figs. 1–6

Globigerina yeguaensis Wienzierl and Applin, 1929, p. 408, pl. 43, figs. 1a–b; Bolli and Saunders, 1985, pp. 180–181, fig. 13.23.

Discussion: We follow Bolli and Saunders (1985) in placing *Globigerina galavisi* Bermudez in synonymy with *Subbotina*? *yeguaensis. S.*? *yeguaensis* s.l. differs from *S.*? *eocaena* s.l. in possessing a definite toothlike apertural flap. This taxon ranges throughout the Oligocene of both Holes 628A and 803D. Specimens form the upper Oligocene Zone P22 have as many as five chambers in the final whorl and a wider umbilicus. Such specimens are transitional with early forms of the *Dentoglobigerina altispira* group (Cushman and Jarvis).

Tenuitella gemma (Jenkins)

Plate 6, Figs. 6 and 11–13

Globorotalia gemma Jenkins, 1966, p. 115, fig. 11, nos. 97–103.

Discussion: We agree with Jenkins (1966) and Li Qianyu (1987) that *Tenuitella gemma* is not a junior synonym of *Globigerina postcretacea* Myatliuk. *T. gemma* is gradational with *Tenuitellinata angustiumbilicata* in the lower Oligocene.

Tenuitellinata angustiumbilicata (Bolli)

Plate 6, Figs. 4–5

Globigerina ciperoensis angustiumbilicata Bolli, 1957b, p. 109, pl. 22, figs. 12–13; Bolli and Saunders, 1985, pp. 182–183.

Discussion: We follow Li Qianyu (1987) in placing *Globigerina angustiumbilicata* in the genus *Tenuitellinata.* This taxon is microperforate and is therefore phylogenetically unrelated to *Globigerina ciperoensis. T. angustiumbilicata* is gradational with *Tenuitella gemma* in the lower Oligocene. Gradational specimens are illustrated on Plate 6, Figures 7–10. Clear distinction between the two taxa is based on the position of the aperture.

"Turborotalia" ampliapertura (Bolli)

Plate 4, Figs. 3–8

Globigerina ampliapertura Bolli, 1957b, p. 108, pl. 22, figs. 6a–c; Poore and Brabb, 1977, p. 255, pl. 1, figs. 7–9.

Discussion: "*Turborotalia*" *ampliapertura* differs from *Globigerina euapertura* in having a higher arched aperture that is nearly circular in shape. A gradational form is illustrated on Plate 4, Figure 9. Only forms displaying such a distinct apertural shape are assigned to "*T.*" *ampliapertura*. "*T.*" *ampliapertura* is distinguished from *Subbotina*? *eocaena* s.l. in having a more compact test and an umbilical aperture without a lip.

Turborotalia cerroazulensis (Cole)

Plate 1, Figs. 7–8

Globigerina cerroazulensis Cole, 1928, p. 217, pl. 1, figs. 11–13.
Turborotalia cerroazulensis cerroazulensis (Cole) Toumarkine and Luterbacher, 1985, p. 137, figs. 34.3–4 and 36.16–18.

Discussion: A gradational specimen between *Turborotalia cerroazulensis* and *T. cocoaensis* is illustrated on Plate 1, Figures 1 and 6.

Turborotalia cocoaensis (Cushman)

Plate 1, Figs. 2–3

Globorotalia cocoaensis Cushman, 1928, p. 75, pl. 10, figs. 3a–c.
Turborotalia cerroazulensis cocoaensis (Cushman) Toumarkine and Luterbacher, 1985, p. 138, figs. 34.2 and 36.10–12.

Discussion: A gradational specimen between *Turborotalia cerroazulensis* and *T. cocoaensis* is illustrated on Plate 1, Figures 1 and 6.

Turborotalia cunialensis (Toumarkine and Bolli)

Globorotalia cerroazulensis cunialensis Toumarkine and Bolli, 1970, p. 144, pl. 1, fig. 37.
Turborotalia cerroazulensis cunialensis (Toumarkine and Bolli) Toumarkine and Luterbacher, 1985, p. 138, figs. 34.1 and 36.1–6.

Discussion: A gradational specimen between *Turborotalia cocoaensis* and *T. cunialensis* is illustrated on Plate 1, Figures 4 and 5.

Turborotalia increbescens (Bandy)

Plate 4, Figs. 1–2

Globigerina increbescens Bandy, 1949, p. 120, pl. 23, figs. 3a–c.

Discussion: *Turborotalia increbescens* is gradational with "*Turborotalia*" *ampliapertura*. *T. increbescens* ranges throughout much of basal Oligocene Zone P18 in Holes 628A and 803D.

Turborotalia pomeroli (Toumarkine and Bolli)

Plate 1, Fig. 10

Globorotalia cerroazulensis pomeroli Toumarkine and Bolli, 1970, p. 140, pl. 1, fig. 13.
Turborotalia cerroazulensis pomeroli (Toumarkine and Bolli) Toumarkine and Luterbacher, 1985, p. 137, figs. 34.9 and 35.4–9.

Discussion: A gradational specimen between *Turborotalia pomeroli* and *T. cerroazulensis* is illustrated on Plate 1, Figure 9.

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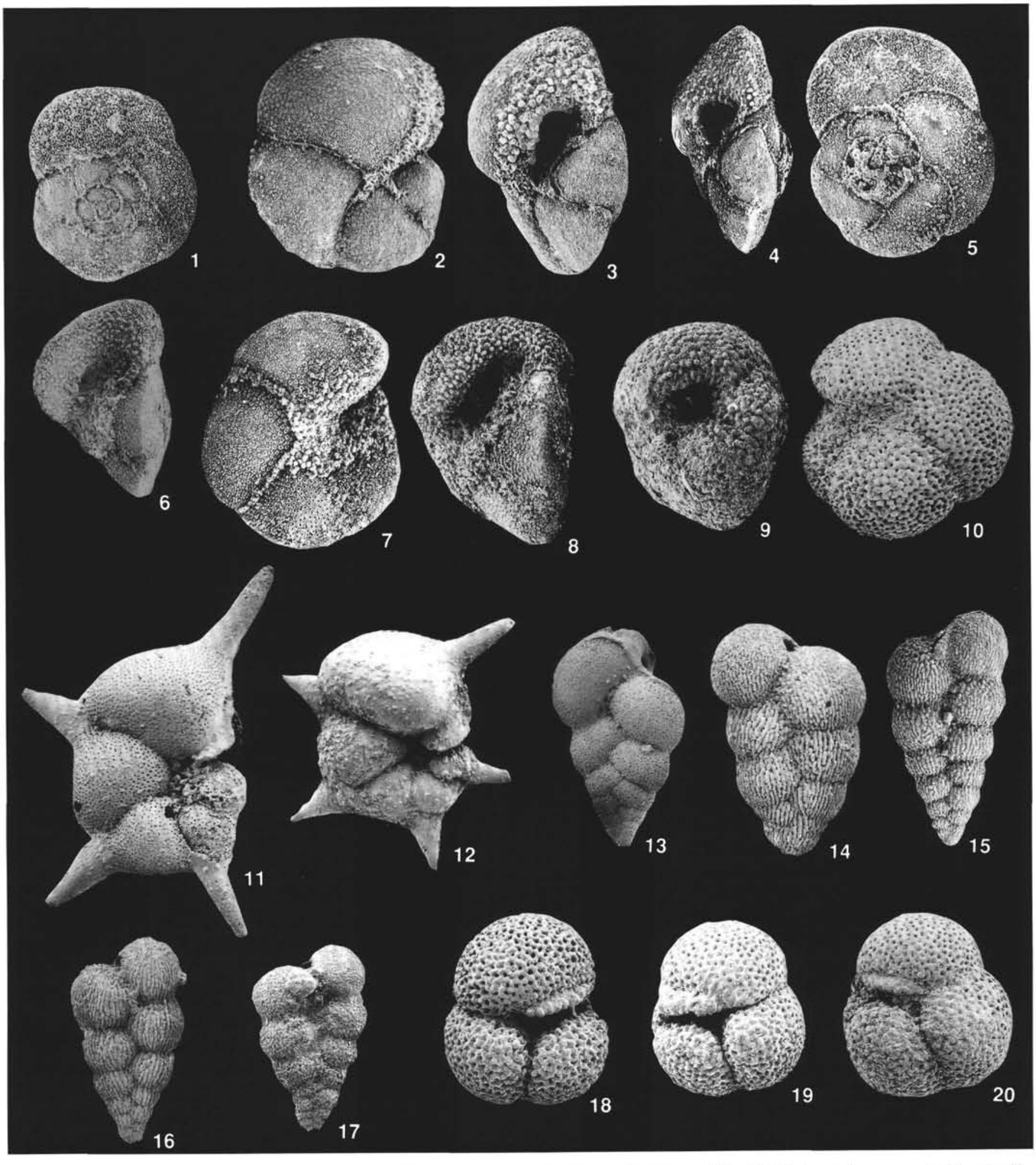

Plate 1. **1, 6.** *Turborotalia cerroazulensis–cocoaensis* transition; Sample 101-628A-29X-1, 100–102 cm, ×70. **2–3.** *Turborotalia cocoaensis;* Sample 101-628A-29X-CC, ×100. **4–5.** *Turborotalia cocoaensis-cunialensis* transition; Sample 101-628A-29X-2, 30–32 cm, ×100. **7–8.** *Turborotalia cerroazulensis;* Sample 101-628A-29X-1, 100–102 cm, ×70. **9.** *Turborotalia cerroazulensis-pomeroli* transition; Sample 130-803D-59X-1, 44–46 cm, ×100. **10.** *Turborotalia pomeroli;* Sample 101-628A-29X-1, 100–102 cm, ×100. **11.** *Hantkenina alabamensis;* Sample 101-628A-29X-CC, ×100. **12.** *Hantkenina* cf. *H. alabamensis;* Sample 101-628A-29X-CC, ×70. **13.** *Chiloguembelina* cf. *C. martini;* Sample 101-628A-29X-CC, ×100. **14–17.** *Chiloguembelina cubensis;* (14) Sample 130-803D-47X-1, 51–53 cm, ×150; (15) Sample 101-628A-26X-1, 74–76 cm, ×150; (16) Sample 101-628A-16H-3, 100–102 cm, ×200; (17) Sample 130-803D-57X-3, 46–48 cm, ×100. **18–20.** *Subbotina angiporoides;* (18) Sample 101-628A-27X-1, 100–102 cm, ×100; (19) Sample 130-803D-54X-1, 41–43 cm, ×100; (20) Sample 101-628A-26X-1, 74–76 cm, ×100.

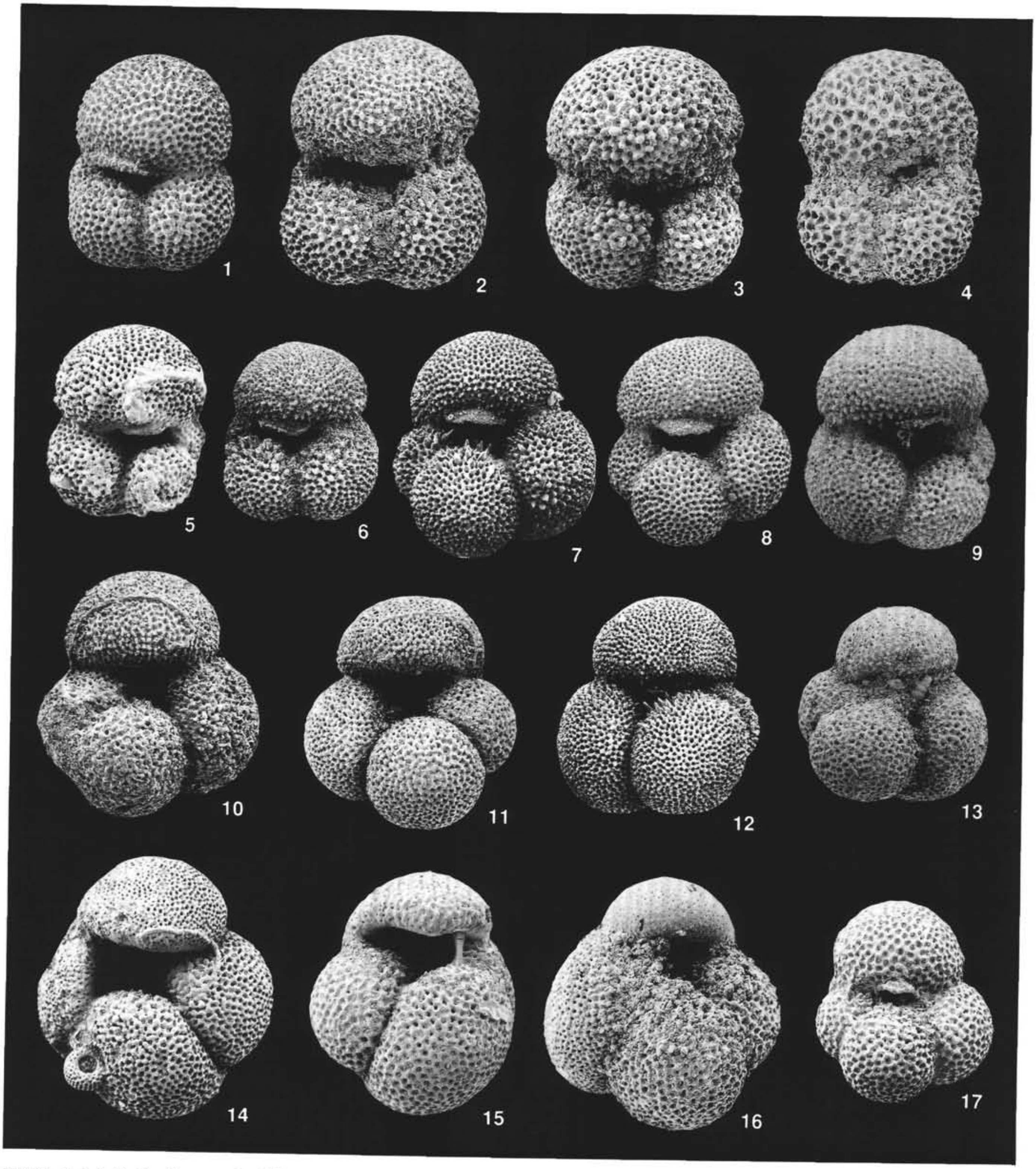

Plate 2. **1–6.** *Subbotina linaperta* s.l.; (1) Sample 101-628A-28X-1, 100–102 cm, ×100; (2) Sample 101-628A-29X-2, 30–32 cm, ×100; (3) Sample 101-628A-26X-CC, ×100; (4) Sample 101-628A-29X-1, 100–102, ×100; (5) Sample 130-803D-54X-3, 57–59 cm, ×70; (6) Sample 101-628A-28X-CC, ×70. **7–11.** *Subbotina*? *eocaena;* (7) Sample 101-628A-29X-CC, ×70; (8) Sample 101-628A-27X-1, 100–102 cm, ×70; (9) Sample 101-628A-26X-CC, ×70; (10) Sample 101-628A-29X-2, 30–32 cm, ×70; (11) Sample 101-628A-28X-CC, ×70. **12–17.** *Globigerina/Subbotina* spp.; (12) Sample 101-628A-29X-CC, ×70; (13) Sample 101-628A-26X-1, 74–76 cm, ×70; (14) Sample 130-803D-56X-5, interval uncertain, ×70; (15) Sample 130-803D-47X-5, 48–50 cm, ×100; (16) Sample 101-628A-25X-CC, ×100; (17) Sample 130-803D-58X-CC, ×70.

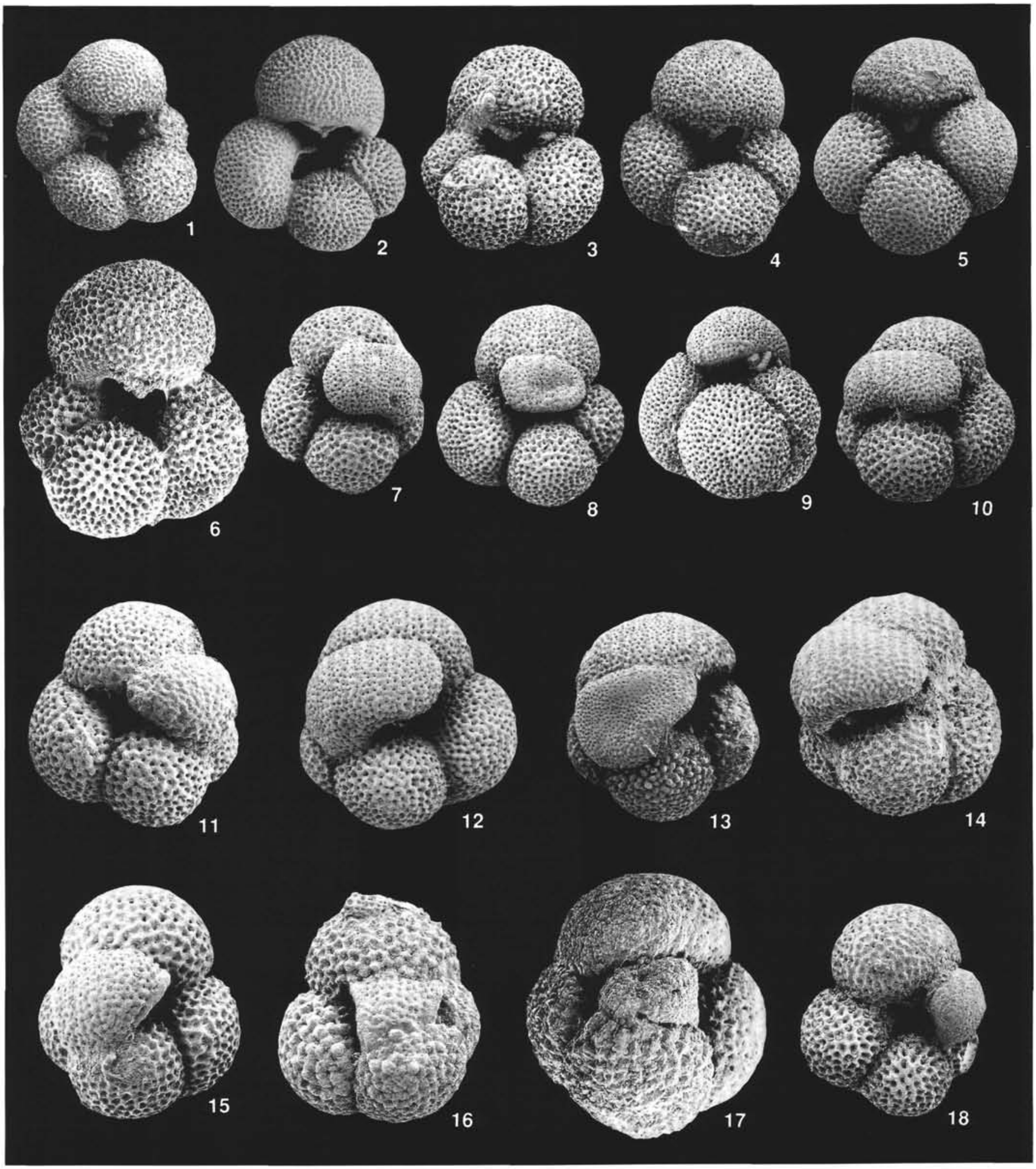

Plate 3. **1–6.** *Subbotina*? *yeguaensis;* (1) Sample 101-628A-16H-3, 100–102 cm, ×70; (2) Sample 101-628A-16H-3, 100–102 cm, ×70; (3) Sample 101-628A-29X-CC, ×70; (4) Sample 101-628A-27X-1, 100–102 cm, ×70; (5) Sample 130-803D-43X-1, 49–51 cm, ×70; (6) Sample 101-628A-28X-CC, ×100 **7–14.** Globigerina gortanii; (7) Sample 130-803D-44X-5, 68–70 cm, ×70; (8) Sample 101-628A-27X-1, 100–102 cm, ×70; (9) Sample 101-628A-27X-1, 100–102 cm, ×70; (10) Sample 101-628A-28X-CC, ×70; (11) Sample 130-803D-36X-5, 50–52 cm, ×100; (12) Sample 101-628A-22X-CC, ×70; (13) Sample 130-803D-51X-CC, ×70; (14) Sample 101-628A-18H-5, 100–102 cm, ×100. **15.** *Catapsydrax unicavus;* Sample 130-803D-51X-CC, ×100. **16–17.** *Catapsydrax dissimilis;* (16) Sample 130-803D-46X-3, 53–55 cm, ×100; (17) Sample 101-628A-17H-CC, ×100. **18.** *Globorotaloides suteri;* Sample 101-628A-18H-CC, ×100.

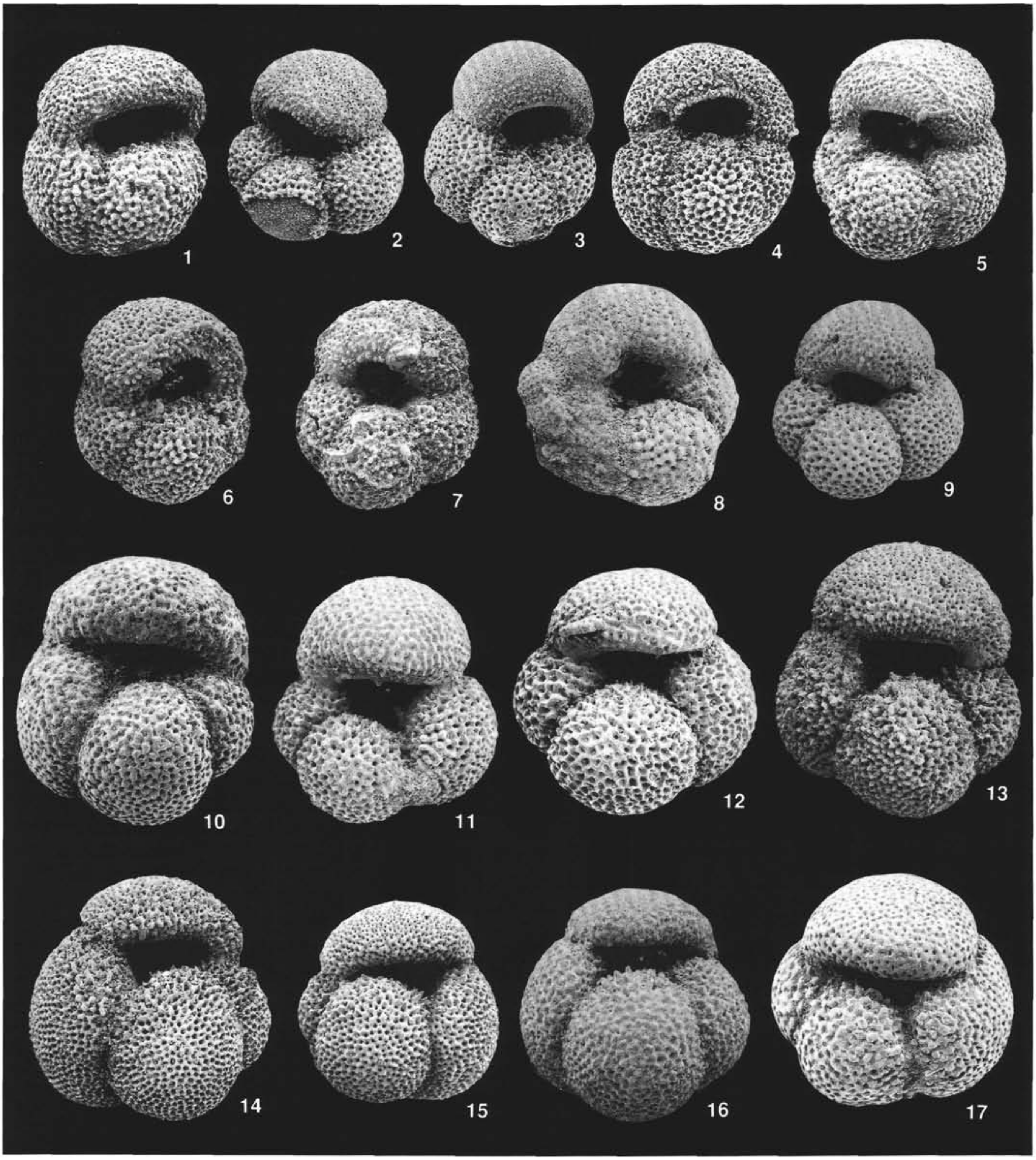

Plate 4. **1–2.** *Turborotalia increbescens;* (1) Sample 130-803D-58X-CC, ×100; (2) Sample 101-628A-58X-CC, ×100. **3–8.** "*Turborotalia*" *ampliapertura;* (3) Sample 101-628A-26X-1, 74–76 cm, ×100; (4) Sample 101-628A-26X-1, 74–76 cm, ×100; (5) Sample 130-803D-58X-CC, ×100; (6) Sample 101-628A-26X-CC, ×100; (7) Sample 101-628A-28X-1, 100–102 cm, ×100; (8) Sample 130-803D-51X-3, 36–38 cm (last occurrence), ×100. **9.** "*Turborotalia*" *ampliapertura/Globigerina euapertura* transition; Sample 101-628A-23X-CC, ×70. **10–13.** *Globigerina euapertura;* (10) Sample 130-803D-58X-CC, ×100; (11) Sample 130-803D-45X-CC, ×100; (12) Sample 101-628A-25X-2, 12–14 cm, ×100; (13) Sample 101-628A-25X-CC, ×70. **14.** *Globigerina euapertura/Globigerina pseudovenezuelana* transition; Sample 101-628A-26X-CC, ×70. **15–17.** *Globigerina pseudovenezuelana;* (15) Sample 101-628A-27X-1, 100–102 cm, ×70; (16) Sample 101-628A-17H-1, 100–102 cm, ×70; (17) Sample 130-803D-57X-CC, ×100.

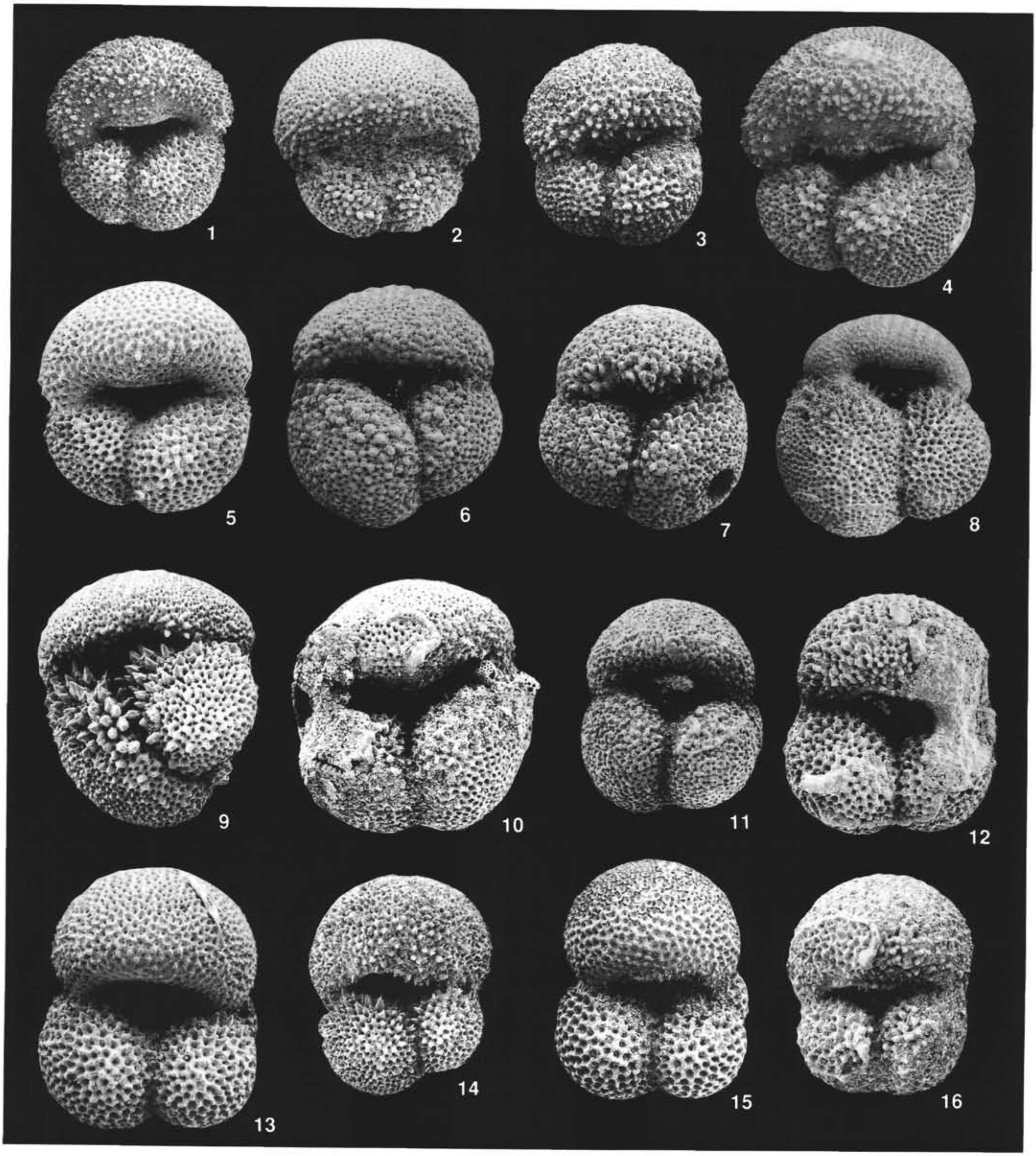

Plate 5. **1–5.** *Globigerina sellii;* (1) Sample 101-628A-16H-CC, ×70; (2) Sample 101-628A-26X-1, 74–76 cm, ×70; (3) Sample 130-803D-36X-5, 50–52 cm, ×70; (4) Sample 101-628A-17H-CC, ×70; (5) Sample 101-628A-16H-1, 100–102 cm, ×100. **6–10.** *Globigerina tripartita;* (6) Sample 101-628A-24X-1, 100–102 cm, ×70; (7) Sample 101-628A-22X-5, 120–122 cm, ×70; (8) Sample 101-628A-18H-5, 100–102 cm, ×70; (9) Sample 130-803D-43X-5, 50–52 cm, ×70; (10) Sample 130-803D-54X-3, 57–59 cm, ×100. **11–16.** *Globigerina tapuriensis;* (11) Sample 130-803D-58X-CC, ×70; (12) Sample 130-803D-48X-CC, ×100; (13) Sample 101-628A-26X-1, 74–76 cm, ×100; (14) Sample 101-628A-21H-1, 100–102 cm, ×70; (15) Sample 101-628A-26X-1, 74–76 cm, ×100; (16) Sample 101-628A-28X-1, 100–102 cm, ×100.

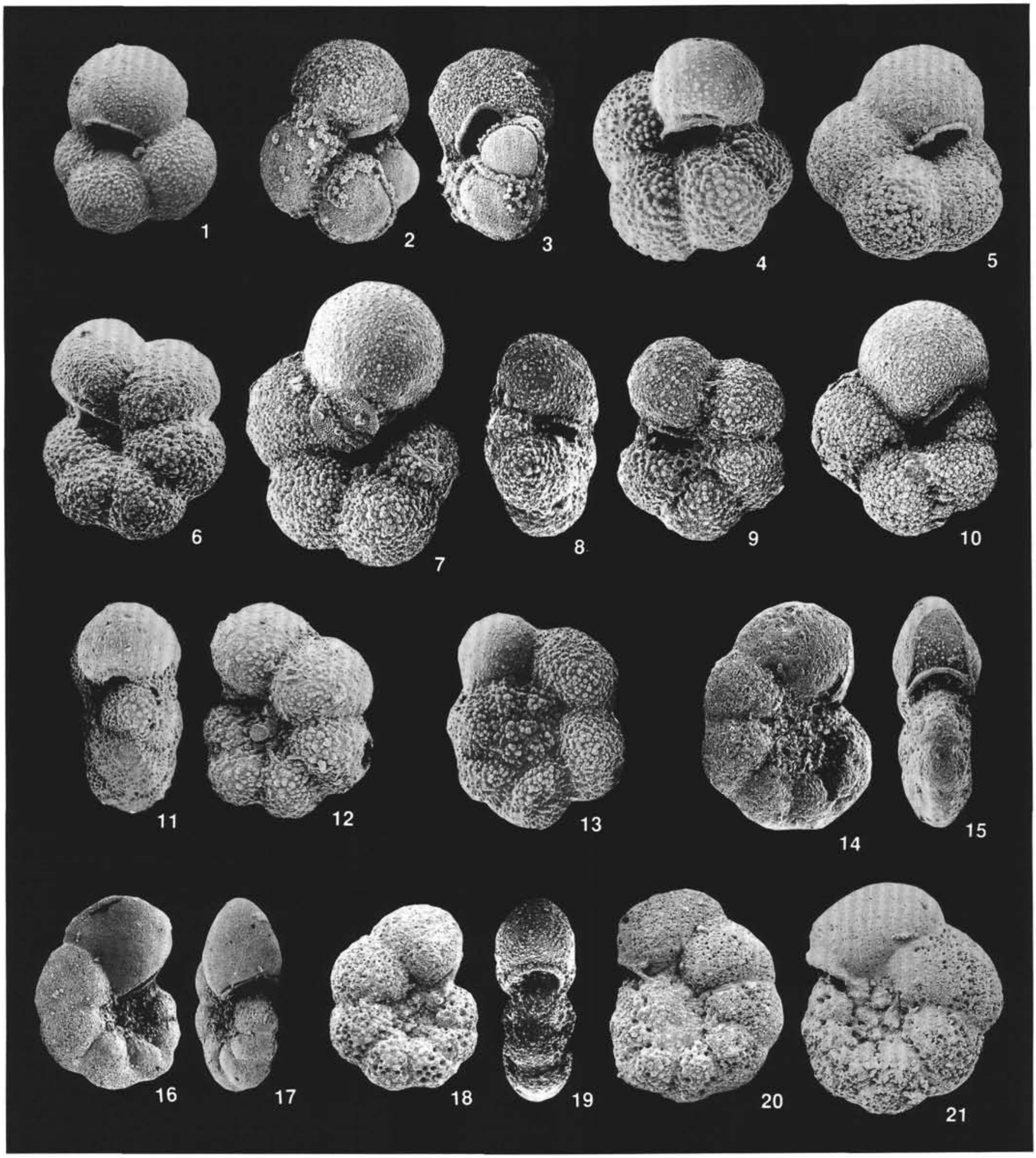

Plate 6. **1.** *Globigerinita glutinata* s.l.; Sample 101-628A-18H-1, 100–102 cm, ×200. **2–3.** *Tenuitella munda;* Sample 130-803D-35X-5, 50–52 cm, ×150. **4–5.** *Tenuitellinata angustiumbilicata;* (4) Sample 101-628A-16H-CC, ×200; (5) Sample 130-803D-51X-3, 36–38 cm, ×200. **6, 11–13.** *Tenuitella gemma;* (6) Sample 130-803D-40X-CC, ×300; (11–12) Sample 101-628A-26X-1, 74–76 cm, ×300; (13) Sample 101-628A-19H-1, 100–102 cm, ×300. **7–10.** *Tenuitellinata angustiumbilicata/Tenuitella gemma* transition; (7) Sample 130-803D-53X-1, 55–57 cm, ×200; (8–9) Sample 130-803D-54X-3, 57–59 cm, ×200; (10) Sample 130-803D-54X-3, 57–59 cm, ×200. **14–17.** *Pseudohastigerina micra;* (14–15) Sample 101-628A-29X-1, 100–102 cm, ×150; (16–17) Sample 101-628A-29X-2, 30–32 cm, ×100. **18–19.** *Pseudohastigerina* cf. *P. naguewichiensis;* (18) Sample 130-803D-57X-1, 71–73 cm, ×200; (19) Sample 101-628A-28X-CC, ×200. **20–21.** *Pseudohastigerina* aff. *P. micra;* (20) Sample 101-628A-27X-1, 100–102 cm, ×200; (21) Sample 101-628A-27X-1, 100–102 cm, ×200.

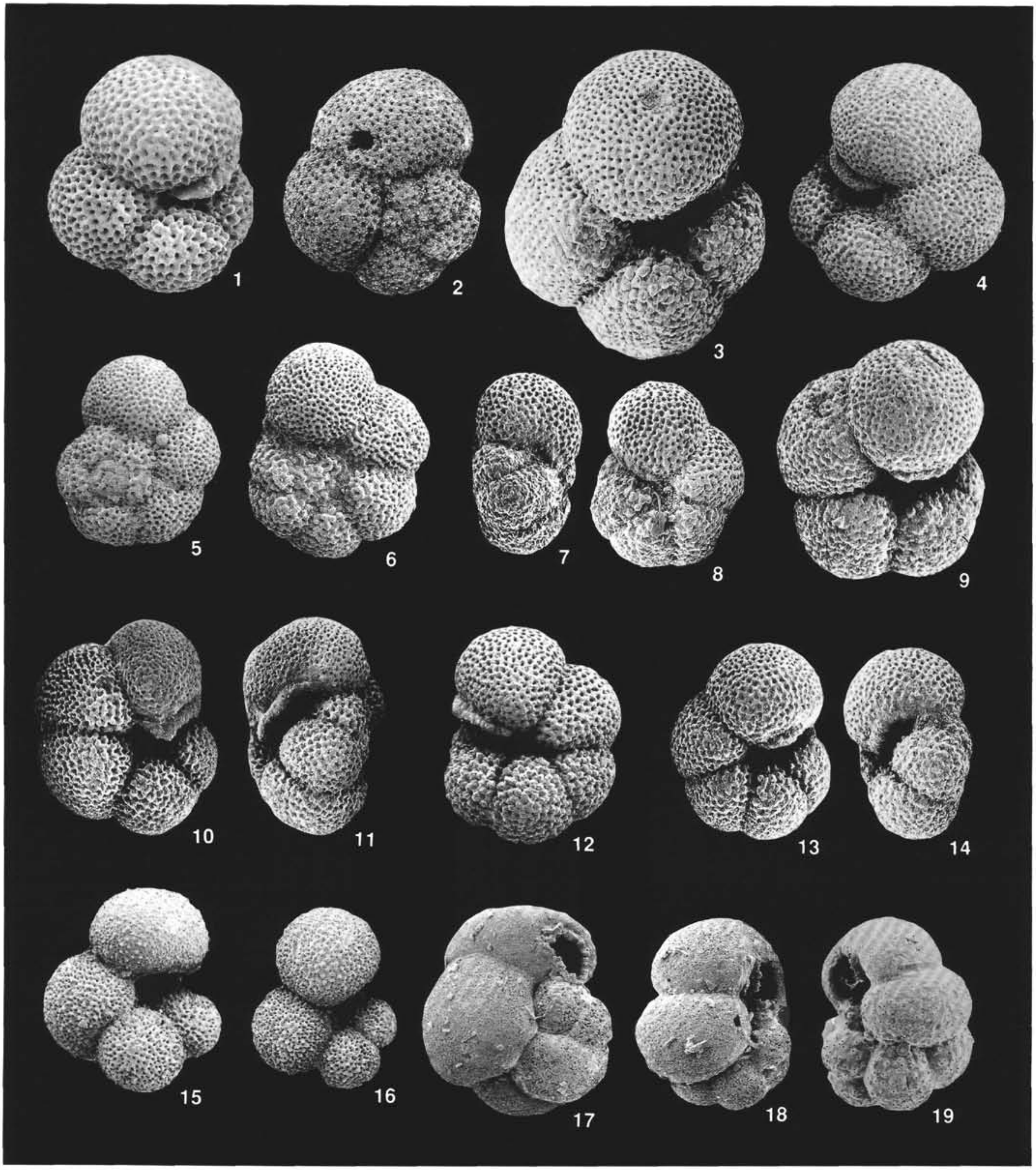

Plate 7. **1–2.** *Paragloborotalia nana;* (1) Sample 101-628A-16H-1, 100–102 cm, ×150; (2) Sample 101-628A-26X-1, 74–76 cm, ×150. **3–4, 9.** *Paragloborotalia opima;* (3) Sample 130-803D-42X-CC, ×100; (4) Sample 101-628A-21H-1, 100–102 cm, ×100; (9) Sample 130-803D-48X-CC (first occurrence), ×100. **5–8, 10–14.** *Paragloborotalia semivera/mayeri* group; (5) Sample 101-628A-16H-5, 100–102 cm, ×100; (6) Sample 130-803D-36X-CC, ×100; (7–8) Sample 130-803D-36X-CC, ×100; (10–11) Sample 101-628A-16H-3, 100–102 cm, ×100; (12) Sample 130-803D-36X-5, 50–52 cm, ×100; (13–14) Sample 130-803D-40X-CC, ×100. **15–16.** *Globigerinella obesa;* (15) Sample 101-628A-17H-1, 100-102 cm, ×100; (16) Sample 101-628A-18H-CC, ×100. **17.** *Cassigerinella* sp.; Sample 101-628A-26X-CC, ×150. **18-19.** *Cassigerinella chipolensis*; (18) Sample 101-628A-26X-CC, ×200; (19) Sample 101-628A-19H-1, 100-102 cm, ×200.

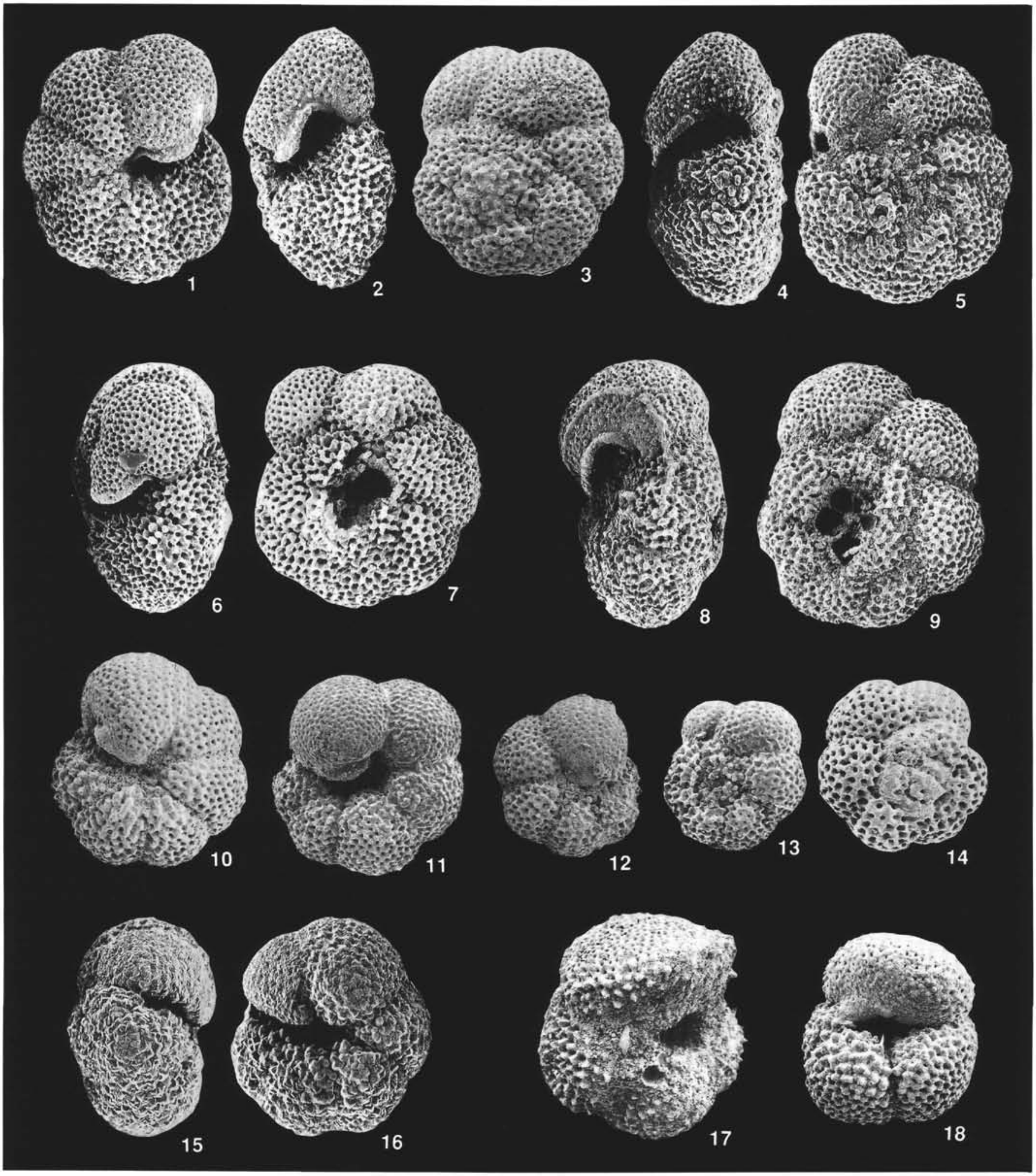

Plate 8. **1–5.** *Paragloborotalia kugleri;* (1–2) Sample 130-803D-35X-5, 50–52 cm (first occurrence), ×150; (3) Sample 130-803D-35X-5, 50–52 cm (first occurrence), ×150; (4–5) Sample 130-803D-35X-3, 47–49 cm, ×150. **6–16.** *Paragloborotalia pseudokugleri;* (6–7) Sample 130-803D-35X-CC, ×150; (8–9) Sample 130-803D-36X-CC, ×150; (10) Sample 130-803D-36X-CC, ×150; (11) Sample 101-628A-17H-3, 100–102 cm, ×150; (12) Sample 101-628A-16H-5, 100–102 cm, ×150; (13) Sample 101-628A-16H-CC, ×150; (14) Sample 130-803D-39X-CC (first occurrence), ×150; (15–16) Sample 130-803D-39X-CC (first occurrence), ×150. **17–18.** *Globoquadrina dehiscens;* (17) Sample 130-803D-35X-3, 47–49 cm (first occurrence), ×100; (18) Sample 130-803D-35X-1, 50–52 cm, ×100.

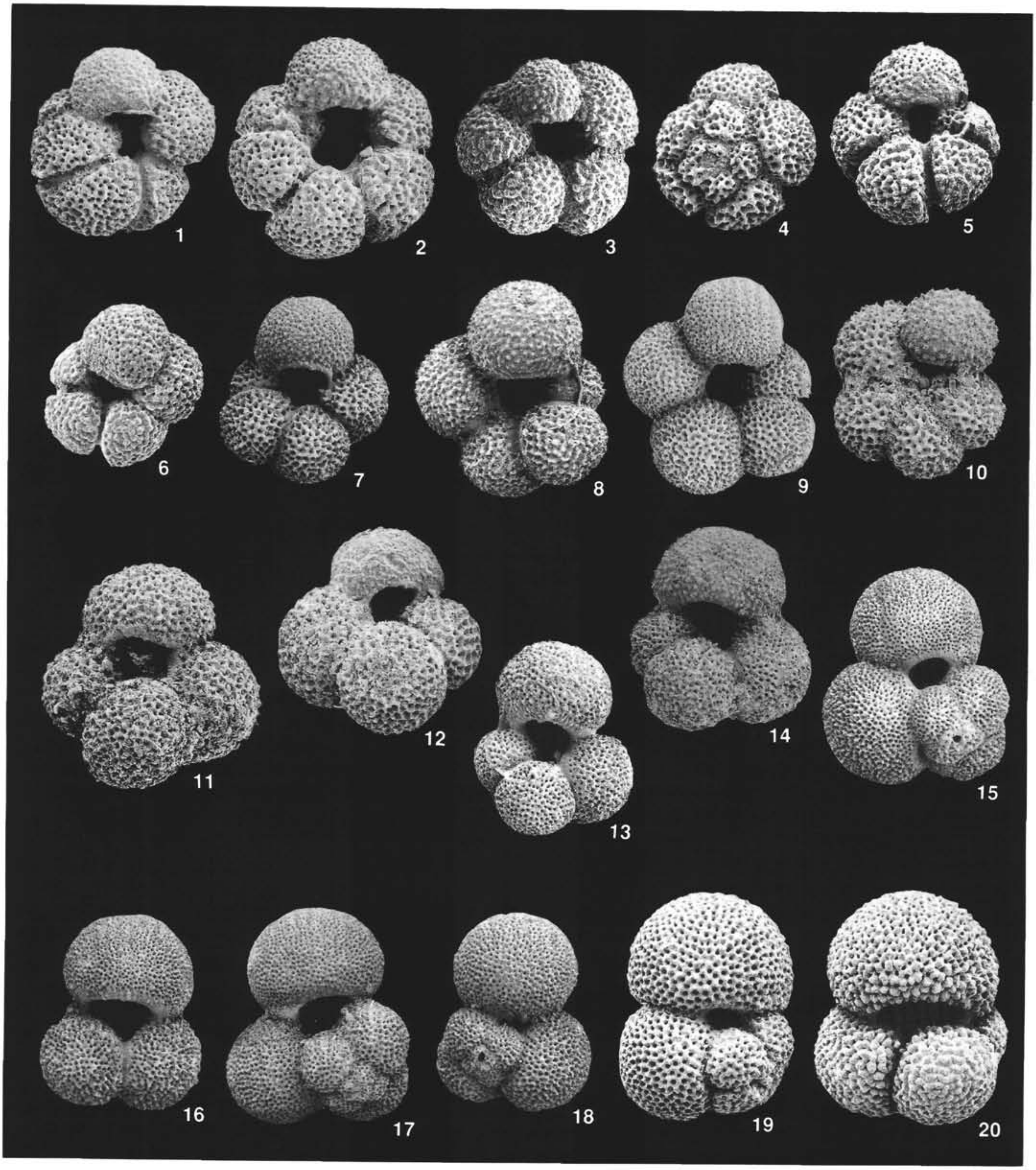

Plate 9. **1–6.** *Globigerina angulisuturalis;* (1) Sample 101-628A-16H-3, 100–102 cm, ×150; (2) Sample 101-628A-16H-3, 100–102 cm, ×150; (3) Sample 130-803D-43X-1, 49–51 cm, ×150; (4) Sample 101-628A-16H-3, 100–102 cm, ×150; (5) Sample 101-628A-25X-2, 12–14 cm (first occurrence), ×150; (6) Sample 130-803D-47X-5, 48–50 cm (first occurrence), ×150. **7–10.** *Globigerina ciperoensis;* (7) Sample 101-628A-19H-3, 100–102 cm, ×100; (8) Sample 101-628A-18H-5, 100–102 cm, ×150; (9) Sample 101-628A-16H-3, 100–102 cm, ×100; (10) Sample 101-628A-19H-1, 100–102 cm, ×150. **11–12.** *Globigerina ouachitensis;* (11) Sample 101-628A-29X-2, 30–32 cm, ×150; (12) Sample 101-628A-23X-CC, ×150. **13–14.** *Globigerina praebulloides;* (13) Sample 101-628A-18H-CC, ×100; (14) Sample 101-628A-16H-5, 100–102 cm, ×100. **15–20.** *Globigerinoides primordius;* (15) Sample 101-628A-16H-1, 100–102 cm, ×70; (16) Sample 101-628A-16H-1, 100–102 cm, ×70; (17) Sample 101-628A-24X-1, 100–102 cm (first occurrence), ×70; (18) Sample 101-628A-24X-1, 100–102 cm (first occurrence), ×70; (19) Sample 130-803D-35X-1, 50–52 cm (first occurrence), ×100; (20) Sample 130-803D-35X-1, 50–52 cm (first occurrence), ×100.