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3. EASTERN INDIAN OCEAN CRETACEOUS AND PALEOGENE QUANTITATIVE BIOSTRATIGRAPHY[1]

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ABSTRACT

During ODP Leg 121 holes were drilled at seven sites, on a transect across Broken Ridge and along Ninetyeast Ridge.

The four Broken Ridge sites recovered a Turonian to Holocene composite section, recording its environmental and tectonic history. The three Ninetyeast Ridge sites sampled a Late Cretaceous to Tertiary paleoenvironmental transect and a record of hot-spot volcanism.

$CaCO_3$ content, weight percent >40-µm residue content, and weight distribution of the size fractions were recorded for all samples from all sites. Species distribution was determined quantitatively for two fractions. The number of >125-µm planktonic foraminifers per gram dry sediment and the percentage of >250-µm planktonic foraminifers of the >125-µm fauna were calculated, which provides a powerful means to study the paleoenvironment, as it gives information on size distribution, productivity, bottom currents, and dissolution.

The description of *Morozovella variospira* (Belford, 1984) is emended, based on observations of material from middle Paleocene sediments from Site 758 on northern Ninetyeast Ridge.

INTRODUCTION

The scientific objectives of Ocean Drilling Program (ODP) Leg 121 were threefold: first, to obtain data on the breakup of the Broken Ridge–Kerguelen Plateau in order to test varying hypotheses of passive margin formation; second, to recover a record of the Tertiary paleoceanography of the southeastern Indian Ocean; and third, to sample the history of the Kerguelen hot spot.

Broken Ridge and the Kerguelen-Heard Plateau formed as an oceanic platform from basaltic intraplate volcanism in the Early Cretaceous (Morgan, 1981). Broken Ridge was separated from the Kerguelen Plateau at about anomaly 18 time (about 42 Ma) (Berggren et al., 1985; Mutter and Cande, 1983). After the breakup, Kerguelen Plateau remained more or less stationary, while Broken Ridge moved northward with the Australian plate to its present position at about 30°S (Fig. 1) and was uplifted isostatically, tilting the existing Cenomanian–middle Eocene deposits, which were partially eroded (Davies, Luyendyk, et al., 1974). The tilted beds are discordantly overlain by subhorizontal late Eocene and younger deposits. Sites 752 to 755 were drilled on a transect across Broken Ridge (Figs. 2 and 3 and Table 1), providing a composite section of Turonian to Pleistocene age. Postrift oozes and chalks are winnowed and some hiatuses are present in upper Eocene and lower Oligocene deposits (as also recorded by Kennett, 1982; Keller, 1983). This has been interpreted as the result of the separation of Australia from Antarctica, causing cooling of Antarctica (Kennett, 1982) and thereby increasing the activity of bottom currents. These currents would have been more intense over the shallow sill formed by Ninetyeast Ridge and Broken Ridge.

Very little material from directly above the unconformity could be recovered, as it consists of loose gravels and other shallow-water deposits. At Site 753 the youngest material from below the unconformity was recovered, but overlap with Site 752 was not established. Drilling had to be terminated in middle Eocene limestones. Site 755 drilled the oldest sedimentary rocks but failed to reach the prominent basement reflector. Prerift material consists of chalks to limestones with intercalated chert and the amount of volcanic ash increases downcore.

Ninetyeast Ridge formed when the Indian plate moved northward over the Kerguelen hot spot (Luyendyk, 1977; Luyendyk and Rennick, 1977). Sites 756 through 758 were drilled along Ninetyeast Ridge (Fig. 2 and Table 1). At Site 756, Quaternary, Neogene, and Oligocene oozes were recovered overlying upper Eocene foraminiferal limestones, which overlie basement basalts. At Site 757 a fairly complete Pleistocene to lower Eocene section was recovered, grading downward into upper Paleocene volcanic ashes. At Site 758 a thick, complete Quaternary, Neogene, and Oligocene section was recovered. The Eocene occurs in one core-catcher sample only, indicating a period of nondeposition and/or erosion. The Paleocene is well preserved and almost complete, only Zones P0, P1a, and part of P1b are missing, as is the top of the Maestrichtian. Downhole in the Cretaceous, the amount of volcanic ash increases and the preservation of foraminifers deteriorates rapidly.

The Cretaceous/Tertiary boundary was cored twice, at Sites 752 and 758. At Site 758 preservation is excellent, but the lowermost Paleocene and uppermost Cretaceous are missing. Preservation is poor at Site 752, but sedimentation was continuous across the Cretaceous/Tertiary boundary. The boundary is marked by a 6-m-thick layer of volcanic ashes, which is barren of foraminifers. Lowermost Paleocene faunas are very poorly preserved; the *Globigerina eugubina* Zone and *Guembelitria cretacea* Zone (Smit, 1977) were not recognized.

PREVIOUS STUDIES

Little is known about pre-Neogene planktonic foraminifers from the Indian Ocean. Deep Sea Drilling Project (DSDP) Leg 22 drilled sites in the Wharton Basin and on Ninetyeast Ridge (Berggren et al., 1974; Davies, Luyendyk, et al., 1974; McGowran, 1974; Pessagno and Fouad, 1974). The Paleocene and Eocene were deposited in shallow-water facies at Sites 214, 216, and 217 and in deep-water facies at Sites 213 and 215. Site 214 probably

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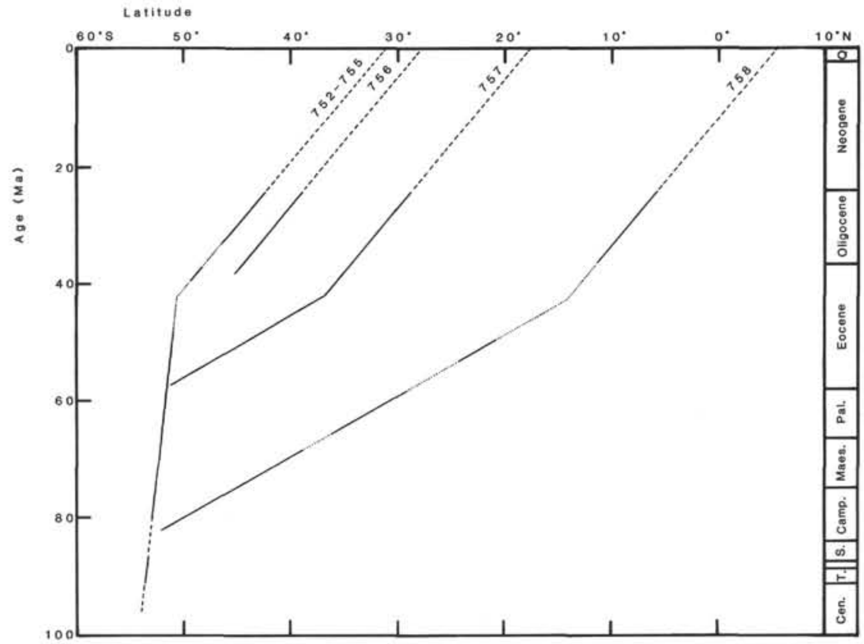


Figure 1. Latitude vs. time diagram of Leg 121 sites. Dotted line = hiatus, dashed line = not drilled or not studied.

contains a continuous section through the Paleogene, unlike the other sites, which show hiatuses. Preservation is generally poor below the Oligocene and zonal markers are rare.

During DSDP Leg 26, sites were drilled in the Wharton Basin and on Broken Ridge (Boltovskoy, 1974; Herb, 1974). In the faunas from Site 255 (Broken Ridge) markers are rare and the zonal schemes of Banner and Blow (1965) and Blow (1969) were found inapplicable. Below a lower Miocene section, Eocene and Santonian material with poorly preserved faunas was recovered.

On DSDP Leg 28 a number of sites were drilled south of Australia, close to Antarctica (Kaneps, 1975; Hayes, Frakes, et al., 1975). The recovered faunas indicate a temperate to subtropical climate from the Oligocene onward. Older faunas are generally very poorly preserved and typical for a cool, austral climate. Only a few species of *Catapsydrax*, *Globigerina*, and *Chiloguembelina* were recognized.

MATERIAL AND METHODS

A maximum of 50% of each sample (20 cm^3, except core-catcher [CC] samples, which are larger) was dried at 50°C for 24 hr, after which a subsample of about 0.5 g was taken for carbonate content analysis. The remainder was weighed and soaked in tap water. Many samples readily disintegrated, but some ultrasonic cleaning was necessary. The samples were wet-sieved, using 40-µm sieve cloth, and dried at 50°C. The residue was dry-sieved over a set of sieves of 250 and 125 µm; the fractions were weighed. Many samples, especially those of Cretaceous and Eocene age, contain small pebbles of undisintegrated material, which accumulated in the >250-µm fraction, causing a high weight proportion of >250-µm material and a high residue percentage. The weight percent <40-µm material of well-preserved, carbonate-rich samples indicates the amount of calcareous nannofossils in the sediment and provides a means of determining nannoplankton vs. foraminiferal carbonate production. Comparing the weight percentages of the different fractions (<40, 40–125, 125–250, and >250 µm), combined with the preservation, provides information on the possible winnowing of fine material, dissolution, and different rates of production per size class.

The >250- and 125–250-µm fractions were dry split until a workable aliquot remained. This was strewn on a picking tray, and random specimens were identified until 150–200 specimens of each fraction had been counted. As a result of handling and splitting problems, the 40–125-µm fraction was not counted, but only scanned for species not present or rarer in the coarser fractions, and relative frequencies were estimated. The distribution and relative frequency of radiolarians, ostracodes, *Inoceramus* prisms, glauconite, and volcanic ash particles were also recorded.

Planktonic foraminifers were identified using Berggren (1977), Bolli and Saunders (1985), Caron (1985), Jenkins (1966, 1985), Kennett and Srinivasan (1983), Masters (1977), Nederbragt (1989, in press), Pessagno (1967), Postuma (1971), Robaszynski and Caron (1979), Robaszynski et al. (1984), Stainforth et al. (1975), Subbotina (1953), and Toumarkine and Luterbacher (1985).

RESULTS

General Remarks

The fauna in the >250-µm fraction usually has few species in common with that in the 125–250-µm fraction and commonly contains only a few percent of the total number of specimens present. Many markers and conspicuous species occur only in the >250-µm fraction and thus constitute an insignificant percentage of the total fauna. The overall fauna composition will rarely differ much from that of the 125–250-µm fraction (in agreement with Berger, 1971). The counts for both fractions are presented separately.

Benthic/planktonic (B/P) ratios (expressed as $(B/(B + P)) \cdot 100$, because benthic foraminifers are usually rarer than planktonic foraminifers) are almost always higher for the >250-µm fraction than for the 125–250-µm fraction. This implies that whenever planktonic foraminiferal faunas are studied quantitatively or when B/P ratios are determined, it is crucial to state which fraction was studied. B/P ratios are partially controlled by sample quality; smooth-walled benthic foraminifers are more

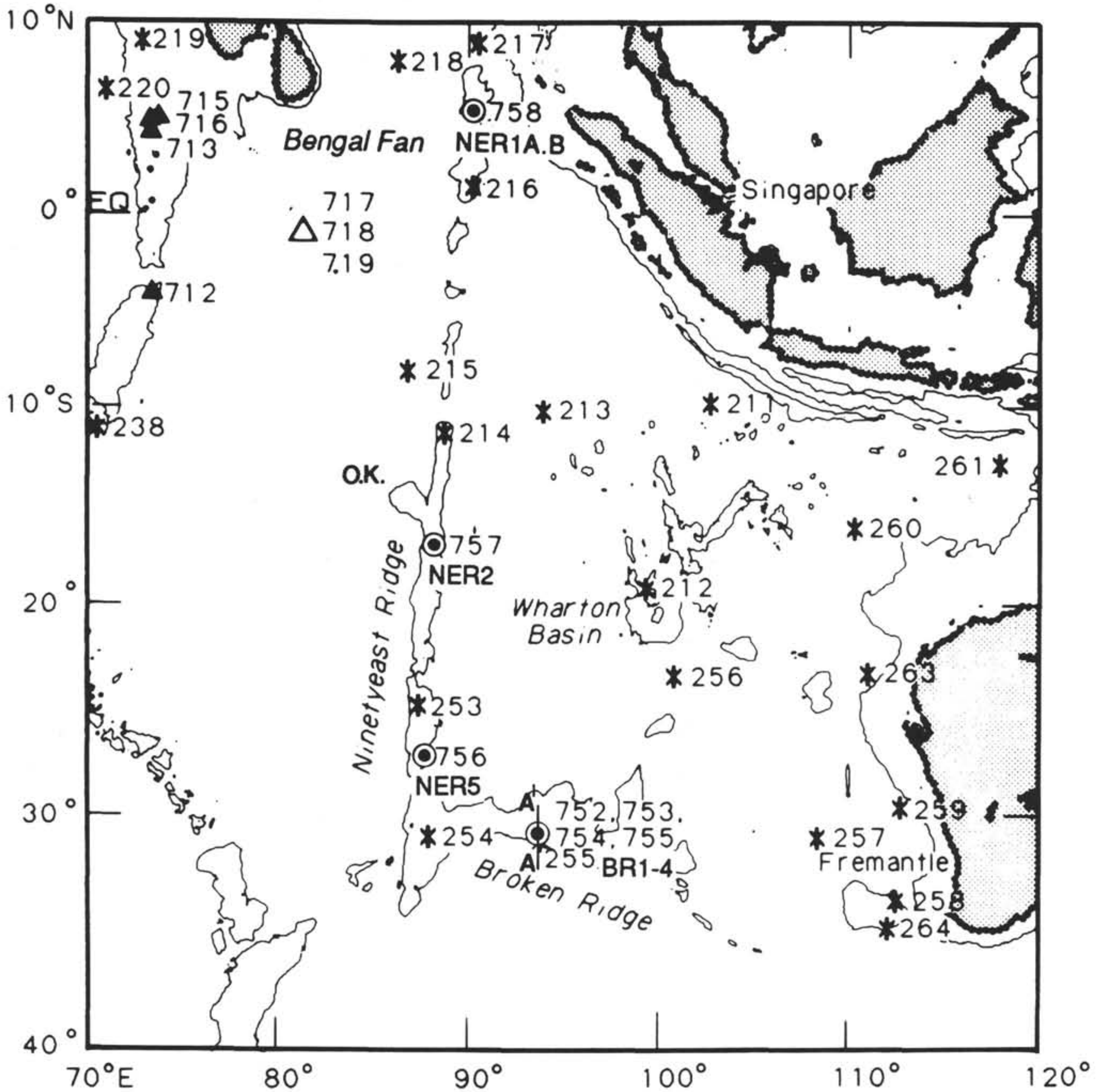


Figure 2. Location map of Leg 121 sites, eastern Indian Ocean.

easily freed from indurated chalks than are rougher walled planktonic foraminifers, causing higher B/P ratios in harder sediments.

From the proportion that was examined and the number of planktonic foraminifers present in the >125-µm residue, we calculated the number of >125-µm planktonic foraminifers per gram dry sediment. Knowing the number of specimens in the 125–250-µm and >250-µm fraction, the proportion of >250-µm foraminifers of the >125-µm fauna was also calculated. This provides information on productivity, the size distribution of planktonic foraminiferal faunas, and possible dissolution or selective removal of small, delicate foraminifers.

Quantitative Results

Site 752

Calcium carbonate content at this site fluctuates at about 80%, with two major exceptions (Fig. 4A). One occurs at 90–110 m below seafloor (mbsf) and includes condensed sedimentation with two hiatuses separating the upper Oligocene from the upper Eocene and the upper Eocene from the middle Eocene, respectively. The other, at 350–360 mbsf, corresponds to the Cretaceous/Tertiary boundary. Other, smaller fluctuations are due to varying proportions of volcanic ash.

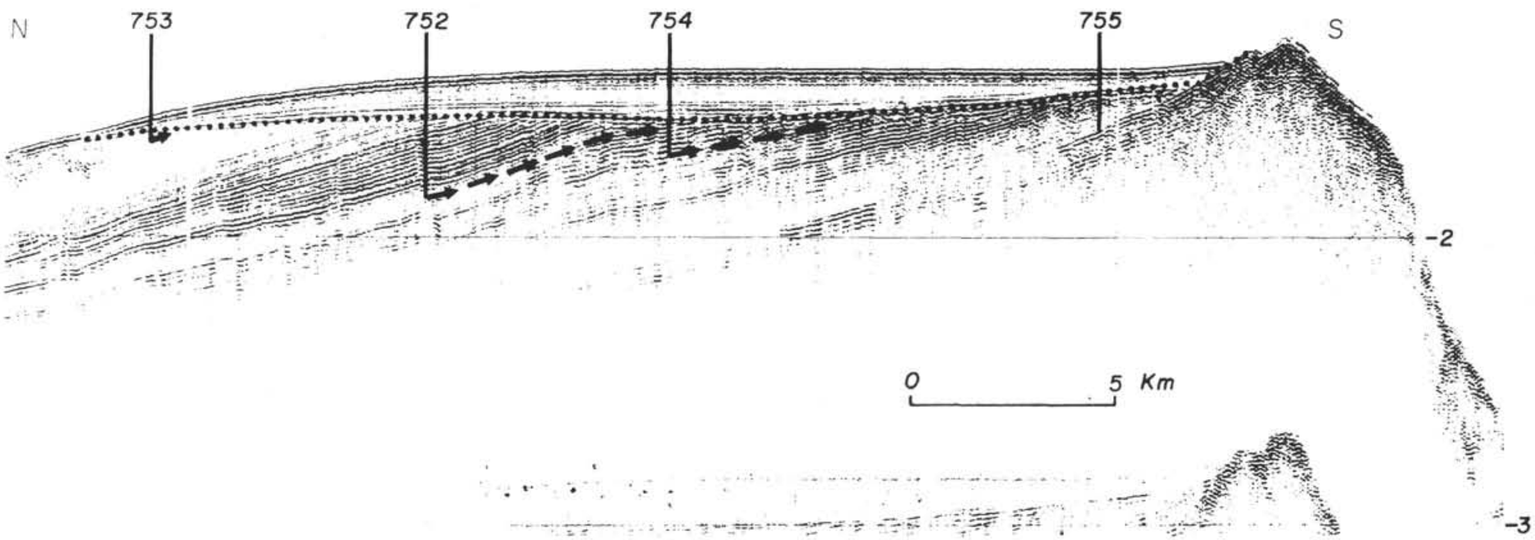


Figure 3. Seismic cross section of Broken Ridge with position (see also Fig. 2), penetration, and correlation of Sites 752–755.

Table 1. Leg 121 site summaries.

Hole	Latitude (degrees)	Longitude (degrees)	Water depth (m)	Penetration (m)	Cored (m)	Recovery (m)
752A	−30.89120	93.57800	1086.3	317.60	317.60	217.32
752B	−30.89140	93.57750	1086.3	435.60	158.00	112.34
753A	−30.83900	93.58990	1176.1	62.80	62.80	61.06
753B	−30.83850	93.58990	1176.1	100.20	48.20	0.04
754A	−30.94060	93.56650	1063.6	172.10	170.00	128.27
754B	−30.94060	93.56650	1065.5	354.70	232.00	91.85
755A	−31.02980	93.54670	1057.9	208.40	178.40	80.21
756A	−27.35550	87.59680	1518.1	9.70	9.70	9.70
756B	−27.35550	87.59680	1518.1	104.30	104.30	105.70
756C	−27.35420	87.59820	1515.8	159.0	76.60	61.81
756D	−27.35480	87.59740	1513.13	221.0	101.2	46.04
757A	−17.02430	88.18160	1650.2	9.40	9.40	9.40
757B	−17.02430	88.18160	1652.1	374.80	374.80	271.94
757C	−17.02320	88.18020	1643.6	420.70	106.10	67.78
758A	5.38420	90.36120	2923.6	676.80	676.80	453.83
758B	5.38400	90.36120	2925.6	96.00	96.00	98.68
758C	5.38400	90.36110	2922.2	9.40	9.40	9.40

The weight percentage >40-µm residue (Fig. 4B) is high down to 110 mbsf, suggesting winnowing of the sediments during the late Eocene and Oligocene. For the lower part of the section, values fluctuate but are generally low for the Eocene and Paleocene (110–350 mbsf), increasing somewhat below the Cretaceous/Tertiary boundary. High volcanic ash content causes high values just above the Cretaceous/Tertiary boundary.

Graphing the size distribution by weight (Fig. 4C) shows much 125–250-µm material in the Oligocene samples, which is probably due to winnowing. Very little fine material is present from 90 to 110 mbsf (middle Eocene). Because this material was deposited immediately before the period of uplift and erosion this is probably due to dissolution. In contrast, little coarse material generally is present in the lower middle Eocene and Paleocene section (110–350 mbsf). The poor sample quality farther downhole has prevented reliable estimates of the fraction distributions for many samples. Material from just above the Cretaceous/Tertiary boundary consists mostly of fine volcanic ash particles.

The benthic/planktonic ratio for the 125–250-µm fraction (Figs. 11A, 12A, and 13A) shows two conspicuous peaks. One, at 90–110 mbsf, corresponds to the hiatuses in the middle Eocene to lower Oligocene; the other, at 350–360 mbsf, corresponds to the Cretaceous/Tertiary boundary. Otherwise, ratios are low except for the Cretaceous.

The number of >125-µm planktonic foraminifers per gram sample (Fig. 4D) fluctuates strongly. It is highest in the Oligocene and Paleocene.

Foraminifers >250 µm constitute 1% to 5% of the >125-µm fauna for the Oligocene and Eocene and less than 1% for the Paleocene and Cretaceous, with a single, unexplained exception (Fig. 4E).

The late Oligocene faunas are well preserved. The early Oligocene fauna in Sample 121-752A-10H-CC is poorly preserved and corroded. This sample contains much glauconite. Coral, bryozoan, and echinoderm fragments occur in lower Oligocene Sample 121-752A-11H-3, 110–115 cm. Sample 121-752A-12X-CC is almost barren. Radiolarians occur in most Eocene samples. The count of Sample 121-752A-16X-CC is unreliable due to very poor preservation; Sample 121-752A-20X-CC is barren, and faunas from all older samples are poorly preserved. The fauna in Sample 121-752A-21R-1, 110–115 cm, is aberrant: all specimens are high spired, globular, and rough walled. The percentage of undeterminable planktonic foraminifers closely corresponds to the state of preservation. The specimens in all samples between Section 121-752B-8R-CC and the Cretaceous/Tertiary boundary are deformed, probably because of compaction of the low-carbonate sediment.

Site 753

Preservation is moderate to good at Site 753 and few specimens remained unnamed. The calcium carbonate content is very high (more than 90%), but fluctuates more below 40 mbsf (Fig. 5A). At this depth, the weight percent of residue >40-µm drops from 50%–60% to less than 10% (Fig. 5B). These changes coincide with a hiatus between the upper Oligocene and the middle Eocene. The weight percentages of >250- and 125–250-µm material drop slightly downcore (Fig. 5C). This all indicates winnowing, starting in the Oligocene.

The number of >125-µm planktonic foraminifers per gram sediment is very high (60,000) in Sample 121-753A-5H-CC (Oligocene) and low (about 3000) in the older samples from this site (Fig. 5D). The >250-µm planktonic foraminifers constitute 4% to 8% of the >125-µm fauna (Fig. 5E).

The late Eocene unconformity (Sample 121-753A-6H-CC) is marked by fish teeth, sponge spicules, and calcite rhombs. Preservation is poor and many specimens are broken.

Site 754

Calcium carbonate content at Site 754 is constant and high (95%) down to 120 mbsf (the Quaternary, Neogene, and upper Oligocene), then drops abruptly to 70%–80% in the Eocene and Cretaceous, with major fluctuations (Fig. 6A). An interval with very low calcium carbonate content (20%–25%) occurs at 300–320 mbsf, and no foraminifers could be recovered from this interval. The Quaternary, Neogene, and Oligocene show relatively high residue percentages, which are possibly due to winnowing (Fig. 6B). The size distribution does not reflect this, as the <125-µm fraction constitutes 50 to 60 weight percent of the residue (Fig. 6C). For the Eocene and Cretaceous, samples with much coarse material are of poor quality, whereas others may be of better quality.

Benthic/planktonic ratios show a clear increase downcore, with a peak in the middle Eocene (Figs. 16 and 17). The number of >125-µm planktonic foraminifers per gram sediment is high but fluctuating for the Paleogene and consistently low for the Cretaceous (Fig. 6D). The percentage >250-µm foraminifers of the >125-µm fauna is higher for the Paleogene (1% to 9.5%) than for the Cretaceous (<1%) (Fig. 6E).

Preservation decreases downcore from good in Samples 121-754A-11H-CC through 121-754A-12H-CC to very poor in Sample 121-754A-14X-CC. Samples 121-754A-13X-CC to 121-754A-14X-CC (122–132 mbsf), from the unconformity, are marked by very poor preservation and abundant glauconite. Cretaceous samples are of poor to very poor quality. Samples 121-754B-21R-CC to 121-754B-24R-CC (316–345 mbsf) are barren and were not plotted. The species distribution thus largely reflects preservation, especially for the >250-µm fractions, which commonly contain fewer then 50 specimens. Samples 121-754A-11H-CC and 121-754A-12H-CC contain many ostracodes, which indicate an (upper) bathyal depth (W. Meyboom, pers. comm., 1990). *Inoceramus* is abundant in the upper part of the Cretaceous, down to Sample 121-754B-10R-CC (210 mbsf).

Site 755

Calcium carbonate content is very low at Site 755, always less than 60% and about 30% on average, whereas volcanic ash content is high (Fig. 7A). The weight percent >40-µm residue reflects sample quality and fluctuates strongly (Fig. 7B). The same is true for the weight distribution of the fractions (Fig. 7C) and the benthic/planktonic ratio (Fig. 18). Benthic/planktonic ratios are 20% to 40% in samples of better quality, but may be 100% in poor

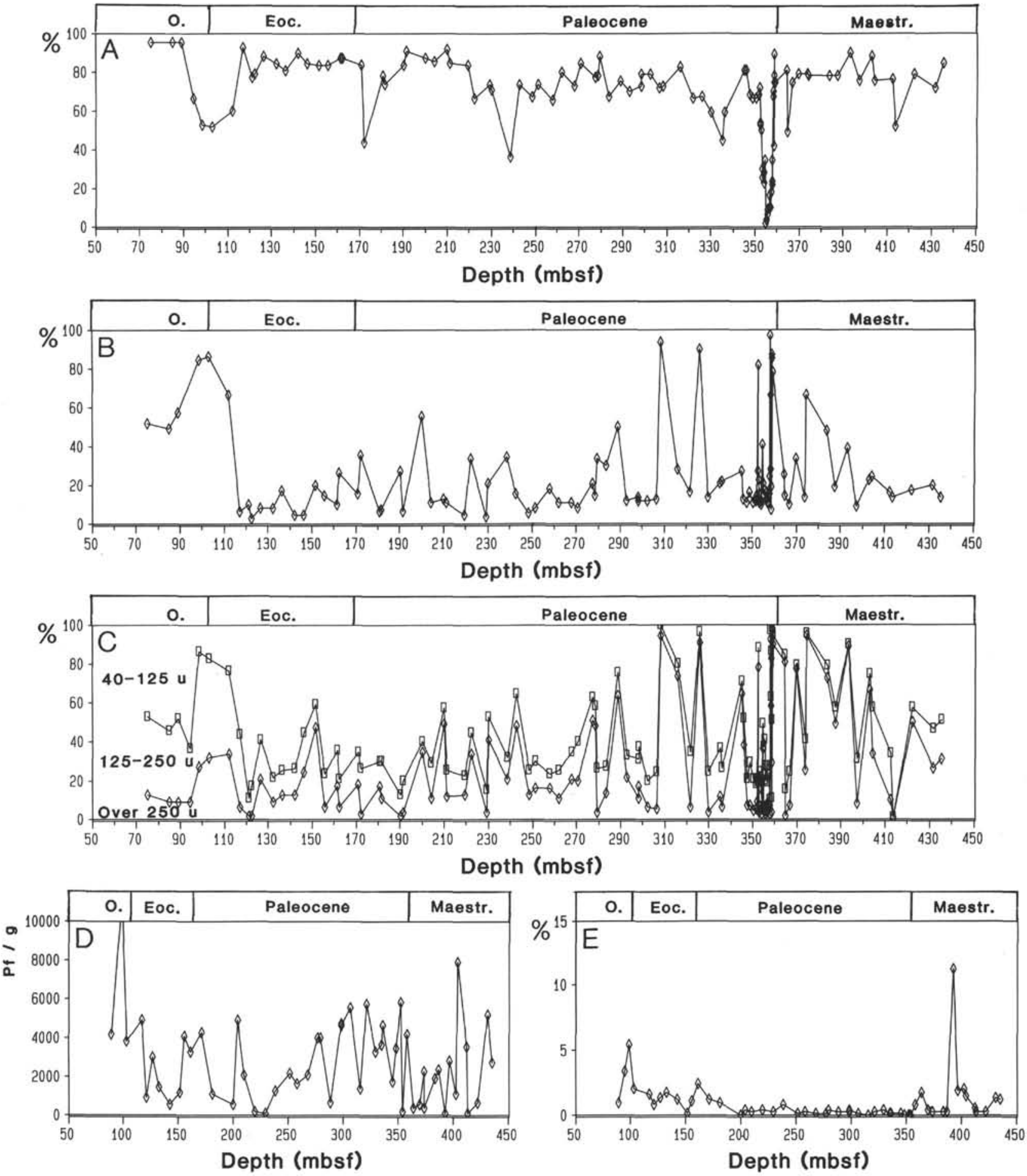


Figure 4. Site 752. Calcium carbonate content (**A**), weight percent >40-µm residue (**B**), weight distribution of 40–125-, 125–250-, and >250-µm fractions (**C**), number of >125 µm planktonic foraminifers per gram dry sample (**D**), and percentage >250-µm planktonic foraminifers of >125-µm fauna. **E.** Note scale difference between Figures 4A–4C and 4D and 4E.

samples. The number of planktonic foraminifers per gram sample is low to very low, typically only several hundred (Fig. 7D). The >250-µm foraminifers are more common in older samples (Fig. 7E). Preservation is generally very poor, many samples are barren, and many >250-µm fractions contain only a few specimens, which explains the erratic species distributions. *Inoceramus* prisms and radiolarians are present in most samples.

Site 756

Calcium carbonate content at Site 756 is uniformly high at about 95% (Fig. 8A), and the weight percent >40-µm residue fluctuates between 5% and 35%, with a slight tendency to decrease downcore (Fig. 8B). The weight percent <125-µm residue is about 50% in the Neogene, increasing to about 70% in the

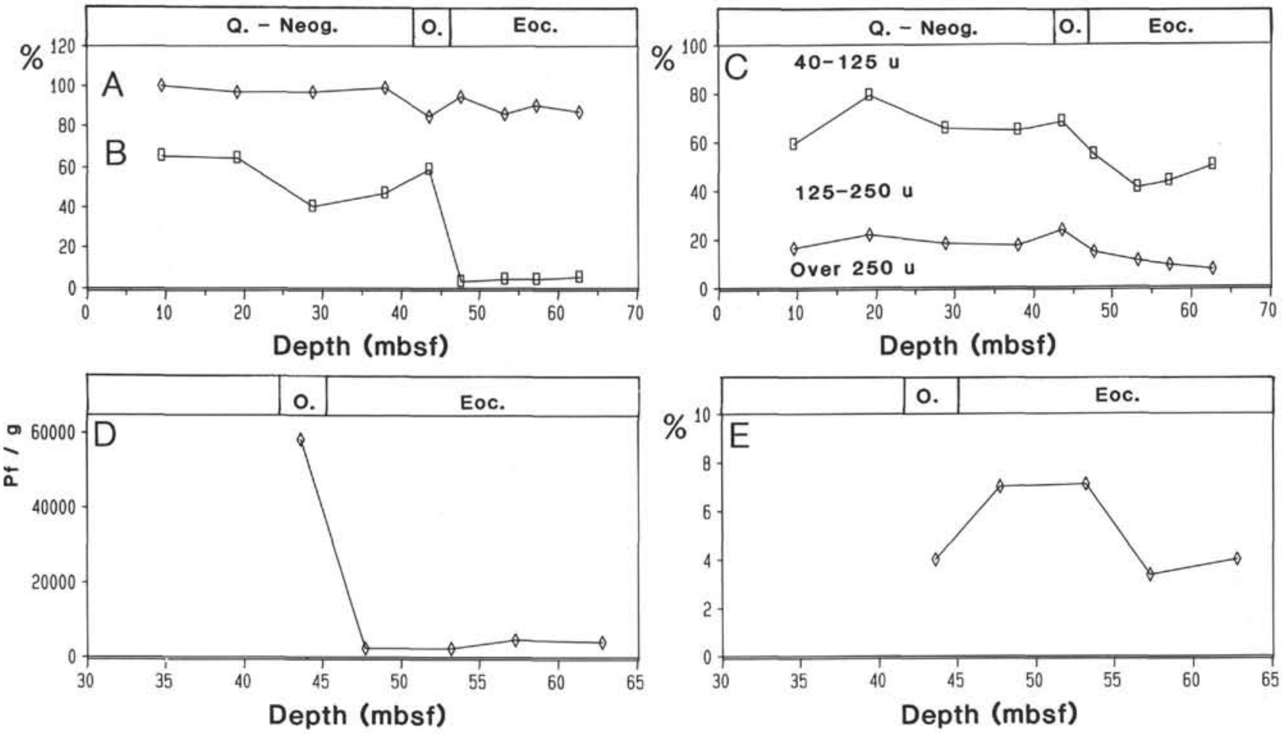


Figure 5. Site 753. Calcium carbonate content (**A**), weight percent >40-µm residue (**B**), weight distribution of 40–125-, 125–250-, and >250-µm fractions (**C**), number of >125-µm planktonic foraminifers per gram dry sample (**D**), and percentage >250-µm planktonic foraminifers of >125-µm fauna (**E**). Note scale difference between Figures 5A–5C and 5D and 5E.

Paleogene (Fig. 8C). The percentage >250-µm residue is low (5% to 10%).

Although many specimens are broken, preservation is good. Breakage, therefore, probably occurred during sample processing. Large *Globigerina* species proved most vulnerable.

Planktonic foraminifers are extremely abundant in upper Oligocene sediments (more than 48,000 per gram in Sample 121-756B-8H-2, 110–115 cm), indicating slight winnowing, which removed fine material, such as nannoplankton (Fig. 8D). Older sediments contain 2000 to 15,000 >125-µm foraminifers per gram. The >250-µm foraminifers are relatively abundant at this site (Fig. 8E). Benthic/planktonic ratios vary from 5% to 25%, depending on sample quality (Fig. 19).

Glauconite occurs in Sample 121-756C-7H-CC (139 mbsf), indicating a possible hiatus near the Oligocene/Eocene boundary. Reworking is fairly common, and *Globigerinatheka index* (Finlay, 1939a) was found in Samples 121-756B-8H-CC and 121-756B-9H-CC. Ostracodes are common in Samples 121-756B-8H-1, 110–115 cm, to 121-756B-9H-1, 110–115 cm, and they indicate a probable upper bathyal depth (W. Meyboom, pers. comm., 1990). Sample 121-756C-6X-CC contains fish teeth and reworked foraminifers, and fish teeth are also present in Sample 121-756C-7X-CC. Samples 121-756C-8X-CC and 121-756C-9X-CC were too indurated to yield any foraminifers.

Site 757

Calcium carbonate content at Site 757 is high (90%) down to 210 mbsf (the Quaternary, Neogene, Oligocene, and most of the Eocene), then drops abruptly to less than 10% in the Paleocene, which consists largely of volcanogenic material (Fig. 9A). The weight percent >40-µm residue drops from 50% to 10% within the Neogene and to 5% in the Oligocene and Eocene. Lower Eocene and older samples yield up to 75% residue, consisting of volcanic ash and tuff and pebbles of undisintegrated material (Fig. 9B). The >250-µm material constitutes 40 weight percent of the Neogene samples, dropping abruptly to 5% in the Oligocene (Fig. 9C). The <125-µm material accounts for more than 70% of the Oligocene residues. The Oligocene is thin (20 m) but complete, and there are thus no indications of strong winnowing. The high >250-µm material content in the Neogene may be caused by strong winnowing. The >250-µm material content is 40% in the upper Eocene, decreasing to 20% in the lower Eocene. This is probably caused by dissolution, as preservation is poor.

The number of >125-µm planktonic foraminifers is generally low, at 500 to 4000 per gram sample (Fig. 9D). Sample 121-757B-11H-2, 110–115 cm, (lower Miocene) contains more than 6000 foraminifers per gram, and Samples 121-757B-22X-CC and 121-757B-23X-CC contain more than 10,000 foraminifers per gram. The >250-mm foraminifers account for less than 5% of the >125-µm fauna for the Oligocene, again arguing against strong winnowing (Fig. 9E). In the upper Eocene the >250-µm foraminifers make up 20% to 60% of the fauna, indicating severe winnowing or dissolution of smaller, thin-walled foraminifers. In these faunas many specimens are corroded or broken. Dissolution, therefore, seems more likely. Smaller foraminifers are more abundant in the middle and lower Eocene, accounting for 80% to 90% of the >125-µm fauna.

The benthic/planktonic ratios are generally low, with peaks in the upper Eocene and lower Eocene (Figs. 20 and 21).

The faunas from Samples 121-757B-16H-CC to 121-757B-20H-CC consist largely of indistinct, rough-walled, globular species. Samples 121-757B-23X-CC and 121-757B-24X-3, 46–48 cm, contain glauconite and a poorly preserved fauna. Samples 121-757B-24X-CC to 121-757B-26X-CC yielded no microfauna at all.

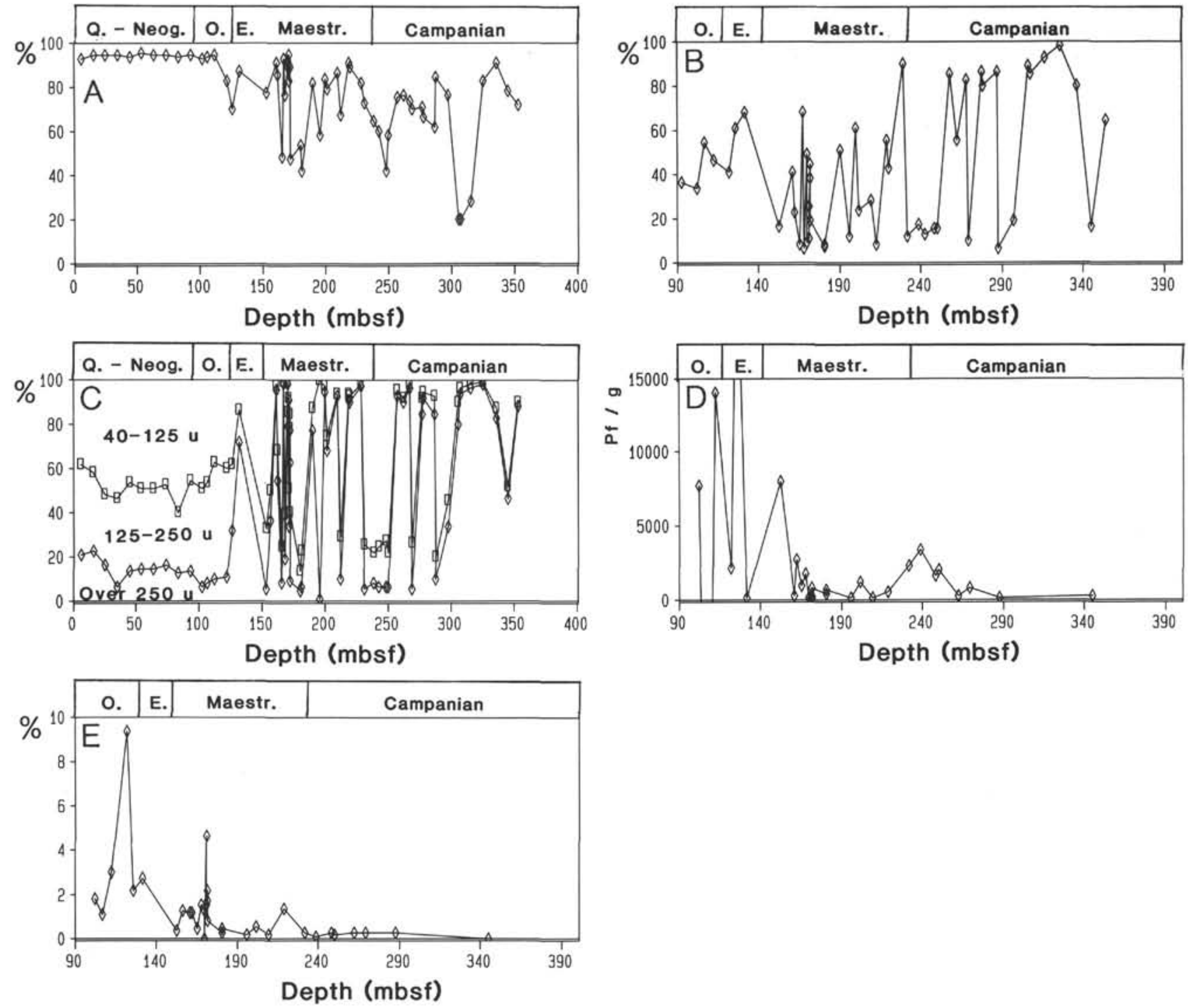


Figure 6. Site 754. Calcium carbonate content (**A**), weight percent >40-µm residue (**B**), weight distribution of 40–125-, 125–250-, and >250-µm fractions (**C**), number of >125-µm planktonic foraminifers per gram dry sample (**D**), and percentage >250-µm planktonic foraminifers of >125-µm fauna (**E**). Note different scales.

Site 758

Calcium carbonate content at Site 758 is about 60% in the most recent sediments, increasing to about 90% in the upper Paleogene sediments (Fig. 10A). This reflects increasing terrigenous input during the Neogene as the Himalayan mountain chain formed. Carbonate content is even higher from 180 to 300 mbsf (the Oligocene and Paleocene), up to 95%. Downcore, the carbonate content decreases rapidly as volcanic ash becomes a more important component, and below 420 mbsf carbonate content is rarely higher than 20%. The weight percent >40-µm residue is low (generally less than 20%) for the entire Tertiary and uppermost Cretaceous (Fig. 10B). The residue content is higher for the older samples, reflecting both volcanic ash content and poorer sample quality. Neogene residues contain more >250-µm weight percent material than those of the Paleogene (15% to 20% vs. 5% to 15%) and less <125-µm material (Fig. 10C). Coarse material constitutes a larger part of Cretaceous sample residues, again reflecting both volcanic ash content and sample quality.

The number of >125-µm planktonic foraminifers per gram sample decreases from about 10,000 for the upper Oligocene to less than 2000 for the lower Oligocene, indicating winnowing, especially during the early Oligocene (Fig. 10D). The upper Paleocene contains more than 25,000 foraminifers per gram sediment, decreasing to about 5000 in the Upper Cretaceous. With one exception (Sample 121-758A-42X-3, 111–114 cm, which is poorly sieved and contains more than 9000 foraminifers per gram, mostly very small Heterohelicidae) the number then decreases to 500 to 1000 for the Campanian sediments. The >250-µm foraminifers are most abundant in the upper Paleocene, constituting up to 20% of the >125-µm fauna, reflecting the favorable circumstances for large *Morozovella* species (Fig. 10E). The consistent and fairly high percentage of >250-µm foraminifers in the lower Oligocene (about 15%) suggests winnowing. This diminishes in the middle Oligocene, where >250-µm foraminifers become much rarer. Lower Maestrichtian and Campanian faunas contain very few >250-µm foraminifers, reflecting unfavorable circumstances for larger planktonic foraminifers at high latitudes. The shift from a cold to a warm climate occurred in the late Maestrichtian, resulting in both more specimens and more species.

Benthic/planktonic ratios are generally low in Paleogene faunas (Figs. 22–24), especially for the Paleocene. A benthic/plank-

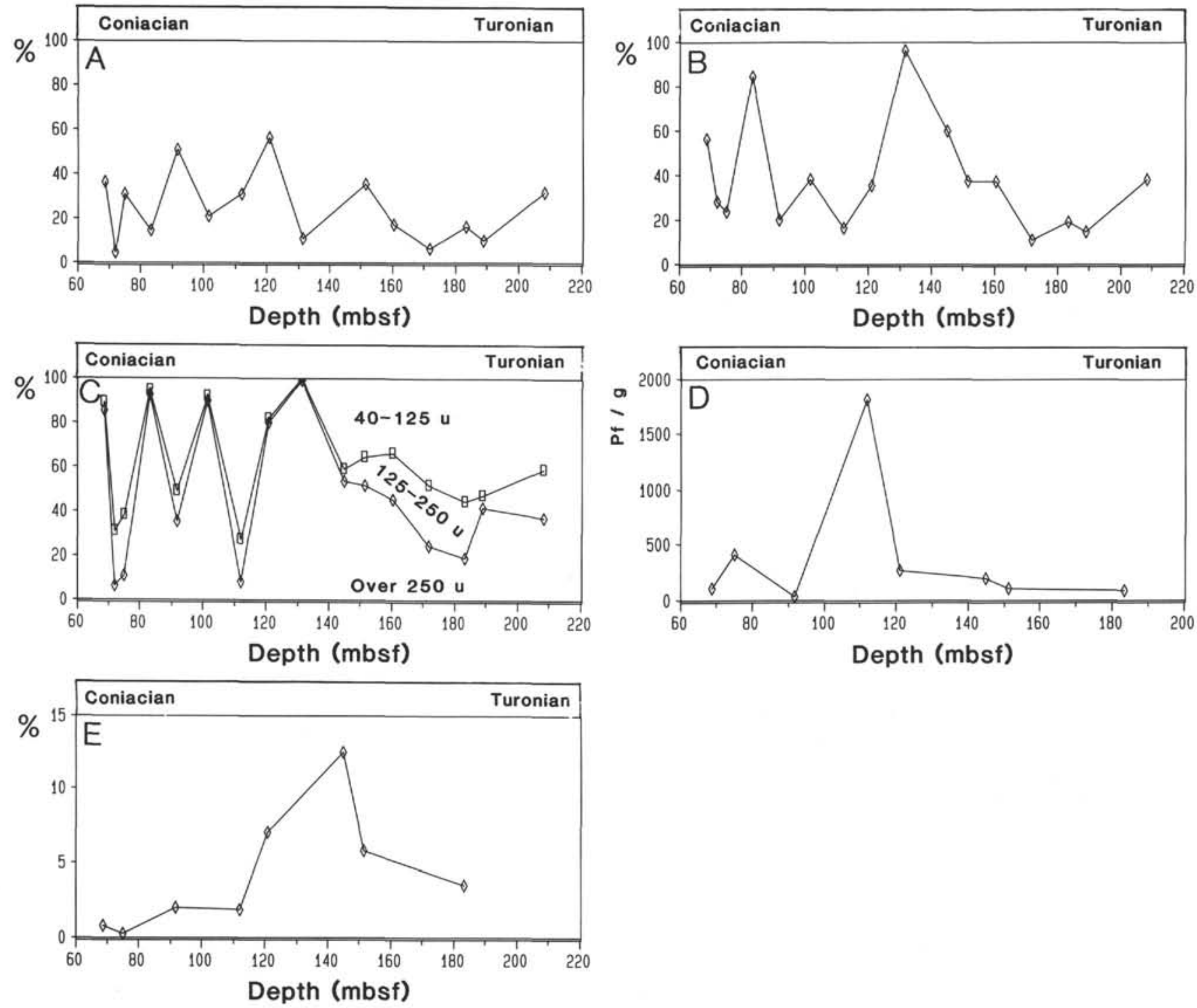


Figure 7. Site 755. Calcium carbonate content (**A**), weight percent >40-μm residue (**B**), weight distribution of 40–125-, 125–250-, and >250-μm fractions (**C**), number of >125-μm planktonic foraminifers per gram dry sample (**D**), and percentage >250-μm planktonic foraminifers of >125-μm fauna (**E**).

tonic ratio peak occurs at 256 mbsf (Sample 121-758A-27X-CC), where Eocene faunas are present within a hardground. Cretaceous faunas yield higher benthic/planktonic ratios, which increase from 5% in upper Maestrichtian to 30% (125–250-μm fraction) and 90% (>250-μm fraction) in the Campanian samples (Fig. 25).

Preservation of Oligocene and Paleocene material is excellent, but the Eocene material is poorly preserved and mixed with fish teeth, glauconite, quartz grains, and felspar grains. Radiolarians are common and well preserved in all Oligocene samples. Cretaceous material is poorly preserved except for the uppermost Maestrichtian. *Inoceramus* prisms are common, and volcanic ash content increases downcore. Preservation is very poor below 400 mbsf (Sample 121-758A-44X-CC).

Biostratigraphy

Site 752 (Figs. 11–14 and Table 2)

We assign Sample 121-752A-10H-2, 110–115 cm (89 mbsf), to the Oligocene-Miocene (Zones P22/N4). *Globoquadrina dehiscens* (Chapman, Parr, and Collins, 1934) and *Globigerina praebulloides* Blow, 1959 dominate the >250-μm fraction. The 125–250-μm fraction is dominated by *Globigerinita glutinata* (Egger, 1893), *Globorotaloides suteri* Bolli, 1957a, and *G. praebulloides* Blow, 1959. Important rarer species include *Globigerina ciperoensis* Bolli, 1954, *G. angulisuturalis* Bolli, 1957a, and *Fohsella kugleri* (Bolli, 1957a).

Sample 121-752A-10H-CC (95 mbsf) is of early Oligocene age, based on abundant *Globigerina linaperta* Finlay, 1939a in the >250-μm fraction and *Chiloguembelina cubensis* (Palmer, 1934) in the 125–250-mm fraction and the absence of *Acarinina*.

Samples 121-752A-11H-3, 110–115 cm, to 121-752A-12X-CC (102–111 mbsf) are of middle Eocene age (Zones P13-14). *Acarinina densa* (Cushman, 1925b) is common, and *Globigerinatheka* sp. cf. *G. index* (Finlay, 1939a) dominates the >250-μm fractions. In the 125–250-μm fractions, additional species include *Acarinina coalingensis* (Cushman and Hanna, 1927), *Catapsydrax howei* (Blow and Banner, 1962), *Globigerina linaperta* Finlay, 1939a (Sample 121-752A-11H-3, 110–115 cm), and *Truncorotaloides rohri* Brönnimann and Bermúdez, 1953 (Sample 121-752A-11H-CC).

The lower middle Eocene, Zones P10 to P12, is defined by the presence of *Globigerina frontosa* Subbotina, 1953, *Acarinina pentacamerata* (Subbotina, 1947), and *Morozovella aragonensis* (Nuttall, 1930) in Samples 121-752A-13X-3, 5–8 cm, to 121-

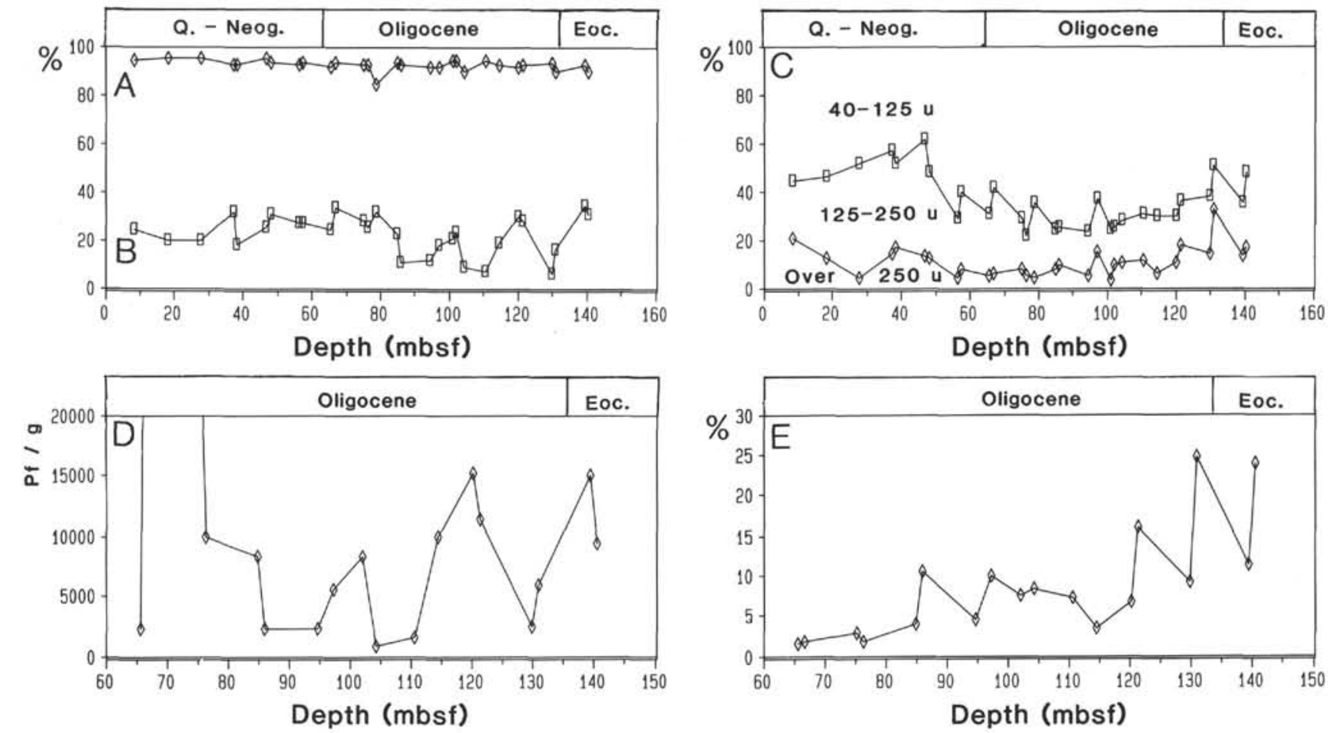


Figure 8. Site 756. Calcium carbonate content (A), weight percent >40-µm residue (B), weight distribution of 40–125-, 125–250-, and >250-µm fractions (C), number of >125-µm planktonic foraminifers per gram dry sample (D), and percentage >250-µm planktonic foraminifers of >125-µm fauna (E). Note scale difference between Figures 8A–8C and 8D and 8E.

752A-14X-CC and 121-752B-2R-1, 115–118 cm. *A. coalingensis* dominates the >250-µm fractions, together with *Globigerina eocaena* Guembel, 1868. The 125–250-µm fractions are almost completely dominated by small, compact *Acarinina* spp.

The middle/lower Eocene boundary is placed at about 137 mbsf, between Samples 121-752A-14X-CC and 121-752A-15X-CC, based on the first appearance of *Globigerina frontosa*, *G. eocaena*, *Acarinina pentacamerata*, and *Catapsydrax howei*. We could not zone the lower Eocene (Zones P6-9, Samples 121-752A-15X-CC to 121-752A-17X-CC, 137–162 mbsf) because of the lack of marker species. Compact *Acarinina* species dominate both fractions. *Morozovella marginodentata* (Subbotina, 1953) and *M. subbotinae* (Morozova, 1939) are rare, *Globigerina linaperta* is common in all samples, and large *Chiloguembelina wilcoxensis* is rare to common.

The occurrence of *Globigerina velascoensis* Cushman, 1925d and *Morozovella aequa* (Cushman and Renz, 1942) in Sample 121-752A-18X-CC indicates the uppermost Paleocene (Zone P5). Samples 121-752A-18X-CC to 121-752A-22X-3, 110–115 cm, (169–203 mbsf) represent Zone P5, with *G. linaperta*, *G. spiralis* Bolli, 1957b, *G. triangularis* White, 1928, and rare *Acarinina* sp. cf. *A. pentacamerata* and *A. gravelli* (Brönnimann, 1952a).

Because *Planorotalites pseudomenardii* (Bolli, 1957b) is rare (1.2% in Sample 121-752A-22R-CC) and keeled *Morozovella* species are absent, we cannot separate Zones P3b and P4. *A. coalingensis* is abundant to dominant, and *A. mckannai* (White, 1928) is rare. We consider their first appearances in Sample 121-752A-28X-CC (268 mbsf) as indicative for the base of Zone P3b.

Samples 121-752A-29X-CC and 121-752A-30X-CC (277–280 mbsf) contain *Morozovella angulata* (White, 1928) (together with abundant *M. uncinata* (Bolli, 1957b)), indicating Zone P3a. *M. uncinata* without *M. angulata* occurs in Sample 121-752A-31X-CC (288 mbsf), indicating Zone P2.

We assign Samples 121-752B-5R-1, 118–121 cm, to 121-752B-8R-CC (298–335 mbsf) to Zone P1b, with *Morozovella pseudobulloides* (Plummer, 1926), *Globigerina triloculinoides* Plummer, 1926, and *Planorotalites compressa* (Plummer, 1926), and without species from Zone P1a, like *Globigerina fringa* Subbotina, 1950 and *G. edita* Subbotina, 1953.

These two species indicate Zone P1a in Samples 121-752B-9R-1, 56–59 cm, to 121-752B-10R-6, 130–131 cm (336–353.5 mbsf). The fauna in these samples is small sized, poorly preserved, and commonly crushed or deformed.

All samples from Sections 121-752B-10R-7, 121-752B-11R-1, and 121-752B-11R-2 are entirely barren, as is Sample 121-752B-11R-3, 88–89 cm (353.7–358.7 mbsf). These samples are taken from the interval immediately above the Cretaceous/Tertiary boundary.

We assign Samples 121-752B-11R-3, 96–97 cm, to 121-752B-17R-1, 106–109 cm, to the *Abathomphalus mayaroensis* Zone, but the marker species is very rare. Several species of Heterohelicidae and Globotruncanidae are restricted to this zone, and *Archaeoglobigerina*, *Globigerinelloides*, and some species of *Heterohelix* are more common in older samples.

It is interesting that *Rugoglobigerina hexacamerata* Brönnimann, 1952a occurs in the oldest samples, grading into *Rugotruncana subcircumnodifer* (Gandolfi, 1955) in the lower part of the *A. mayaroensis* Zone. Therefore, we maintain *Rugotruncana* as a valid genus, in disagreement with Robaszynski et al. (1984), who denied the existence of this genus. It also indicates the close relationship between *Archaeoglobigerina*, *Rugoglobigerina*, and *Rugotruncana*. Also remarkable is the abundance of *Rugoglobigerina rugosa*. This species is much rarer in the Cretaceous at Site

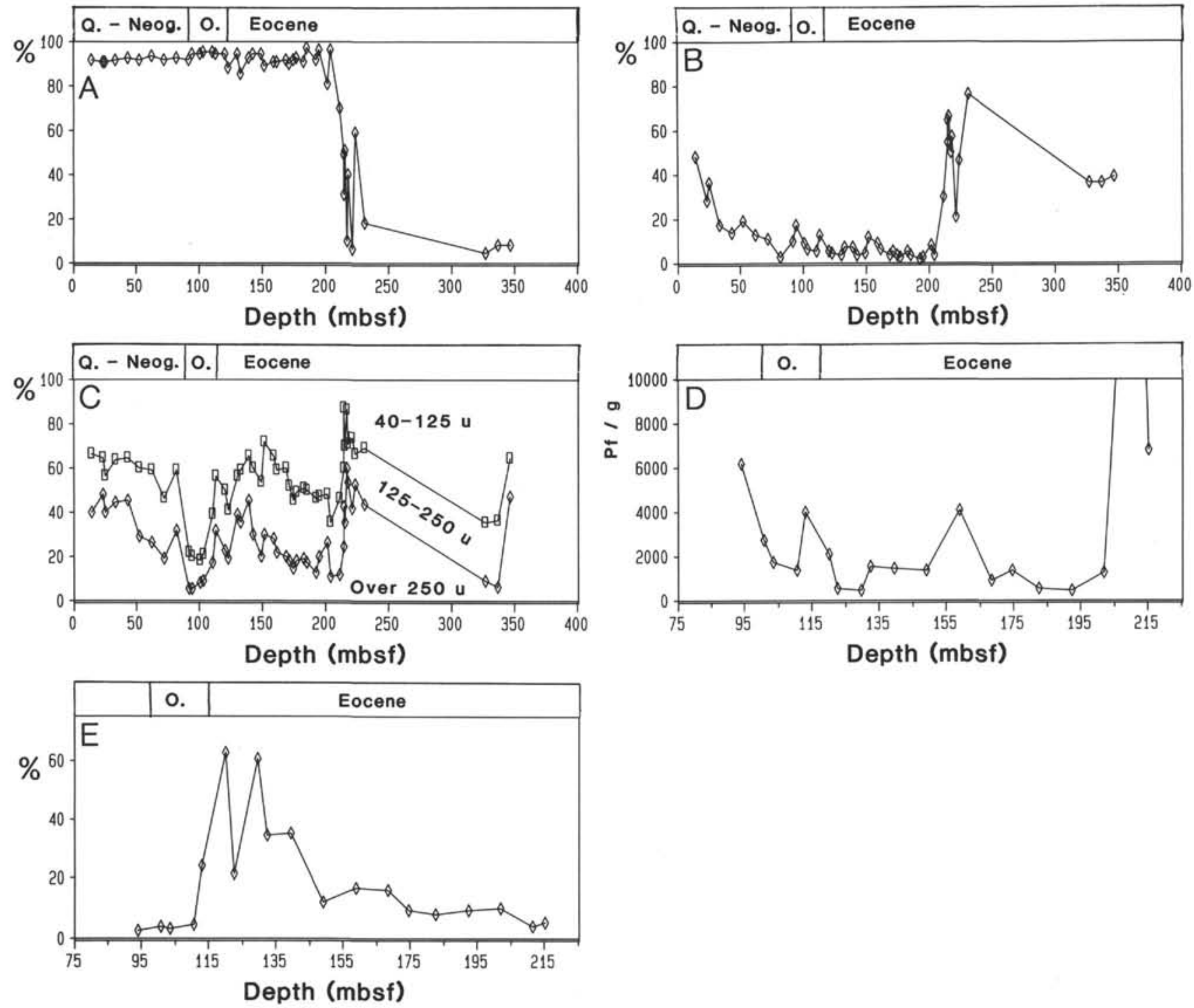


Figure 9. Site 757. Calcium carbonate content (**A**), weight percent >40-μm residue (**B**), weight distribution of 40–125-, 125–250-, and >250-μm fractions (**C**), number of >125-μm planktonic foraminifers per gram dry sample (**D**), and percentage >250-μm planktonic foraminifers of >125-μm fauna (**E**). Note scale difference between Figures 9A–9C and 9D and 9E.

758. Latitude difference may be the cause, as Site 752 was situated at about 50°S and Site 758 at about 35°S (Fig. 1).

Site 753 (Fig. 15 and Table 3)

The >250-μm fraction of Sample 121-753A-5H-CC (44 mbsf) contains *Globigerina euapertura* Jenkins, 1960, *G. angiporoides* Hornibrook, 1965, *G. tripartita* Koch, 1926, and *Globoquadrina praedehiscens* Blow and Banner, 1962. The 125–250-μm fraction contains abundant *Globigerinita glutinata* (Egger, 1893) and *Globorotaloides suteri* Bolli, 1957a, plus rarer *Fohsella kugleri* (Bolli, 1957a), *Globigerina praebulloides* Blow, 1959, and *G.* sp. cf. *G. quinqueloba* Natland, 1938. This indicates a late Oligocene age, Zone P22.

All other samples except 121-753A-7H-CC are of middle Eocene age, Zones P12-14 and possibly as old as Zone P11. *Acarinina coalingensis* (Cushman and Hanna, 1927) and *A. densa* (Cushman, 1925b) dominate the >250-μm fractions, with *A. coalingensis* and *Morozovella convexa* (Subbotina, 1953) dominating the 125–250-μm fractions. *Globigerina linaperta* Finlay, 1939a is present but rare in both fractions, and *Pseudohastigerina micra* (Cole, 1927) occurs in the 125–250-μm fractions.

The occurrence of *Globigerina frontosa* Subbotina, 1953 in Sample 121-753A-7H-CC (62 mbsf) assigns this sample to the early middle Eocene, Zones P10-12. Otherwise, this sample resembles the previous samples. *Guembelitria columbiana* Howe, 1939 is common to abundant in the <125-μm fraction of Samples 121-753A-6H-3, 110–115 cm, 121-753A-6H-CC, and 121-753A-7H-CC. *Pseudohastigerina naguewichiensis* (Myatliuk, 1950) occurs in the <125-μm fraction of Samples 121-753A-6H-3, 110–115 cm, and 121-753A-7H-CC.

Site 754 (Figs. 16 and 17 and Table 4)

The >250-μm fraction of Samples 121-754A-11H-CC and 121-754A-12H-3, 110–115 cm, (102.5–107 mbsf) are dominated by *Globigerina euapertura* Jenkins, 1960. *Globoquadrina praedehiscens* Blow and Banner, 1962, *Globigerina tripartita* Koch, 1926, and *Catapsydrax unicavus* Bolli, Loeblich, and Tappan, 1957 are common. The 125–250-μm fractions are dominated by *Globorotaloides suteri* Bolli, 1957a and *Globigerinita glutinata* (Egger, 1893). Also present are *Globigerina angustiumbilicata* Bolli, 1957a, *Fohsella kugleri* (Bolli, 1957a), *Jenkinsella continuosa*/*J. nana*, *Jenkinsella mayeri* (Cushman and Ellisor,

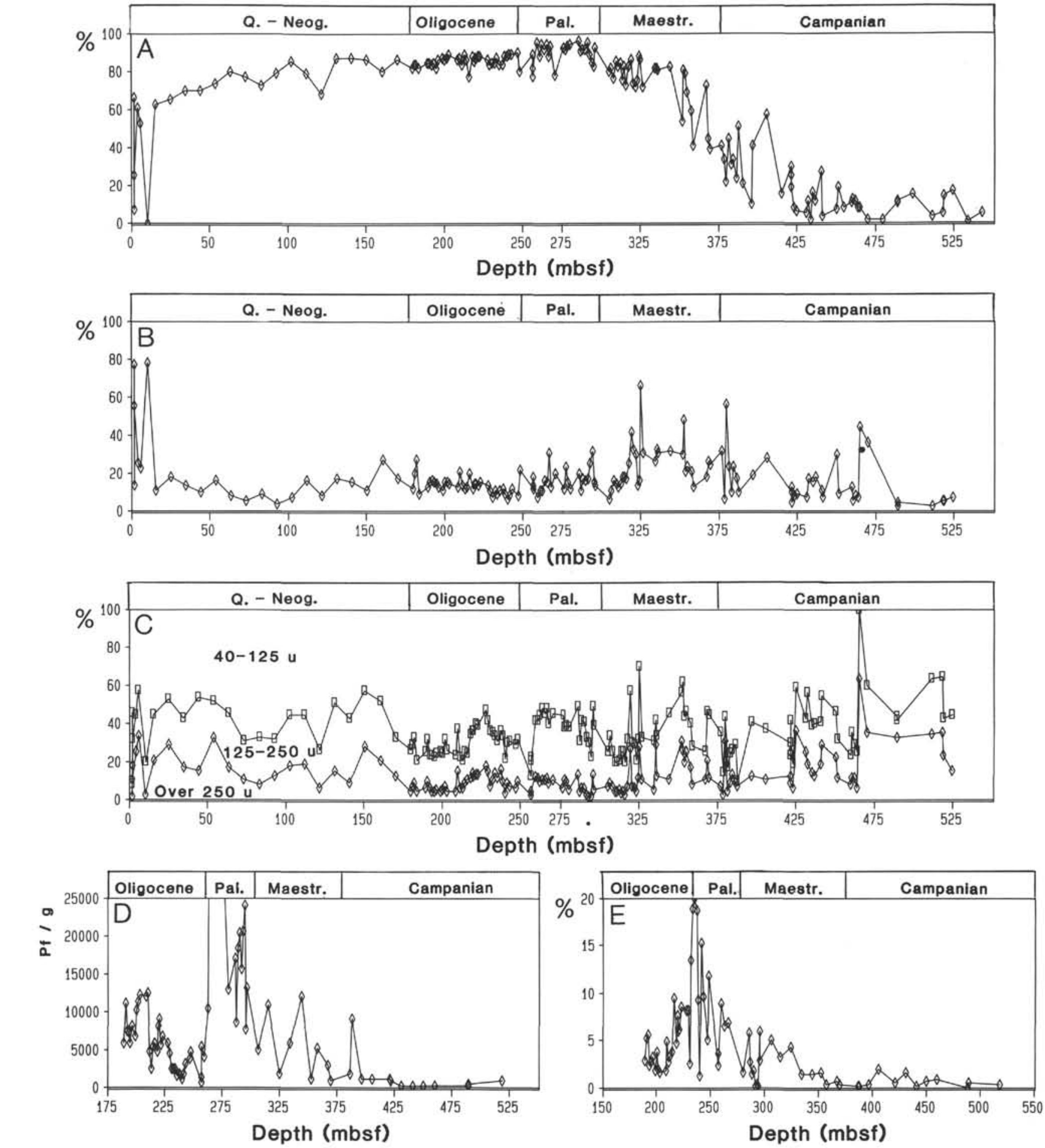


Figure 10. Site 758. Calcium carbonate content (**A**), weight percent >40-µm residue (**B**), weight distribution of 40–125-, 125–250-, and >250-µm fractions (**C**), number of >125-µm planktonic foraminifers per gram dry sample (**D**), and percentage >250-µm planktonic foraminifers of >125-µm fauna (**E**). Note scale difference between Figures 10A–10C and 10D and 10E.

1939), and *Zeaglobigerina woodi* (Jenkins, 1960). Sample 121-754A-11H-CC also contains *Globoquadrina dehiscens* (Chapman, Parr, and Collins, 1934) (>250-µm). This clearly indicates an Oligocene-Miocene age (P22/N4). Sample 121-754A-12H-3, 110–115 cm, we date as late Oligocene, Zone P22. Because *Chiloguembelina cubensis* (Palmer, 1934) is present in the <125-µm fraction it must be close to Zone P21. On this basis, we date Sample 121-754A-12H-CC as Zone P21, although we did not see its marker species, *Jenkinsella opima* (Bolli, 1957a). The 125–250-µm fraction contains both *Globigerinita glutinata* and *Globigerina officinalis* Subbotina, 1953, also indicating a middle Oligocene age.

The >250-µm fraction of Sample 121-754A-13X-CC contains both *J. opima* and *Turborotalia increbescens* (Bandy, 1949). It

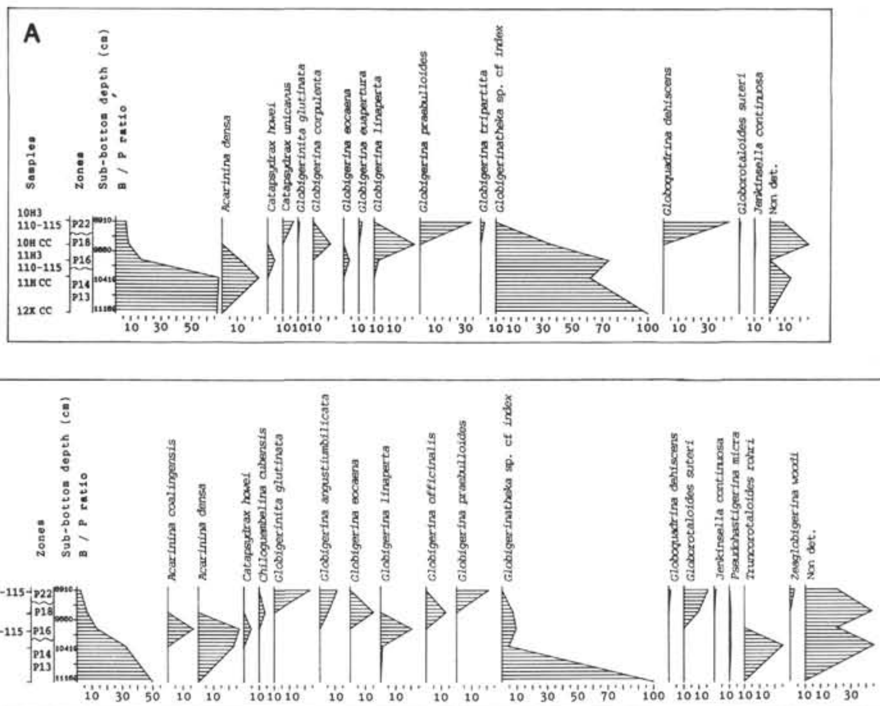


Figure 11. Frequency distribution of selected middle Eocene–Oligocene planktonic foraminifers from Hole 752A. Vertical scale 1:750. **A.** Specimens >250 µm. **B.** Specimens 125–250 µm.

also contains glauconite and (reworked) Eocene fauna. We date this sample as early Oligocene, Zone P20. We consider the record of *Globigerina ampliapertura* Bolli, 1957a in Sample 121-754A-12H-CC as erroneous.

Sample 121-754A-14X-3, 110–115 cm (126 mbsf), contains few foraminifers, mostly *Globigerinatheka* sp. cf. *G. index* (Finlay, 1939a) and *Globigerina eocaena* Guembel, 1868. In the 125–250-µm fraction *Acarinina coalingensis* (Cushman and Hanna, 1927) and *A. densa* (Cushman, 1925b) occur. The 125-250-µm fraction of Sample 121-754A-14X-CC contains few recognizable foraminifers. We recognized *Acarinina densa*, *Globigerina linaperta*, and *Globigerinatheka index*, together with a few specimens of *Truncorotaloides rohri* Brönnimann and Bermúdez, 1953. This indicates a (late?) middle Eocene age, Zones P13-14 and perhaps Zone P12.

Abathomphalus mayaroensis (Bolli, 1951) occurs in Sample 121-754B-5R-CC (161 mbsf), establishing overlap with Site 752. This is also the only good dating possible in the Cretaceous at this site.

The >250-µm fraction of all Cretaceous samples is dominated by *Archaeoglobigerina* spp., usually *A. australis* Huber, 1990. *Globotruncana arca* (Cushman, 1926) occurs commonly down to Sample 121-754B-13R-2, 110–113 cm (231 mbsf), and is very rare below that. The 125–250-µm fractions are dominated by *Globigerinelloides multispinatus*/*G. volutus*, *Heterohelix planata* (Cushman, 1938), and *H. globulosa* (Ehrenberg, 1840).

Heterohelix punctulata (Cushman, 1938) is common in Samples 121-754B-11R-CC, 121-754B-12R-CC, and 121-754B-13R-CC (219–238 mbsf). According to Pessagno (1967), in Texas this species is most abundant in the upper Campanian. Therefore, we place the Campanian/Maestrichtian boundary above this interval.

Site 755 (Fig. 18)

The genus *Marginotruncana* (mainly *M. marginata* (Reuss, 1854) and *M. pseudolinneiana* Pessagno, 1967) occurs in Samples 121-755A-5R-2, 61–64 cm, to 121-755A-11R-1, 65–68 cm, (67–121 mbsf), assigning them to the late Turonian–Coniacian. We cannot reconcile this with the Santonian date for Sample 121-755A-5R-2, 61–64 cm, which was arrived at on board.

Samples 121-755A-13R-4, 16–19 cm, to 121-755A-17R-3, 114–119 cm, (144–183 mbsf) contain *Dicarinella* species (*D. canaliculata* (Reuss, 1854), *D. hagni* (Scheibnerova, 1962), *D. imbricata* (Mornod, 1949–1950), and *D. primitiva* (Dalbiez, 1955)) and *Whiteinella baltica* Douglas and Rankin, 1969. This implies a middle to possibly early Turonian age for these samples.

Site 756 (Fig. 19 and Table 5)

Samples 121-756B-7H-CC and 121-756B-8H-1, 110–115 cm, (66–67 mbsf) are of early Miocene age (Zone N4). *Globoquadrina dehiscens* (Chapman, Parr, and Collins, 1934) and *G. praedehiscens* Blow and Banner, 1962 are common in the >250-µm fractions, and *Globigerinoides* species are rare. In the 125–250-µm fractions the most important species are *Fohsella kugleri* (Bolli, 1957a), *Globigerinita glutinata* (Egger, 1893), and *Globorotaloides suteri* Bolli, 1957a.

Zone P22 is represented by Samples 121-756B-8H-CC to 121-756B-9H-CC (75–85 mbsf), with dominant *Globigerina euapertura* Jenkins, 1960 and rare to common *Catapsydrax unicavus* Bolli, Loeblich, and Tappan, 1957, *Globigerina galavisi* Bermúdez, 1960, *G. praebulloides* Blow, 1959, *G. sellii* (Borsetti, 1959), and *G. praedehiscens* in the >250-µm fractions. In the 125–250-µm fractions *Globigerinita glutinata* (Egger, 1893) and *Globorotaloides suteri* are dominant. Other species are *Globigerina angustiumbilicata* Bolli, 1957a, *Jenkinsella continuosa* (Blow, 1959), and *J. nana* (Bolli, 1957a). *Chiloguembelina cubensis* (Palmer, 1934) is present in the <125-µm fraction of Sample 121-756A-8H-CC.

The absence of *J. opima* (Bolli, 1957a) makes recognition of Zone P21 difficult. We consider the transition from *Globigerina officinalis* Subbotina, 1953 to *Globigerinita glutinata* (Egger, 1893) between Samples 121-756B-9H-CC and 121-756B-10H-1,

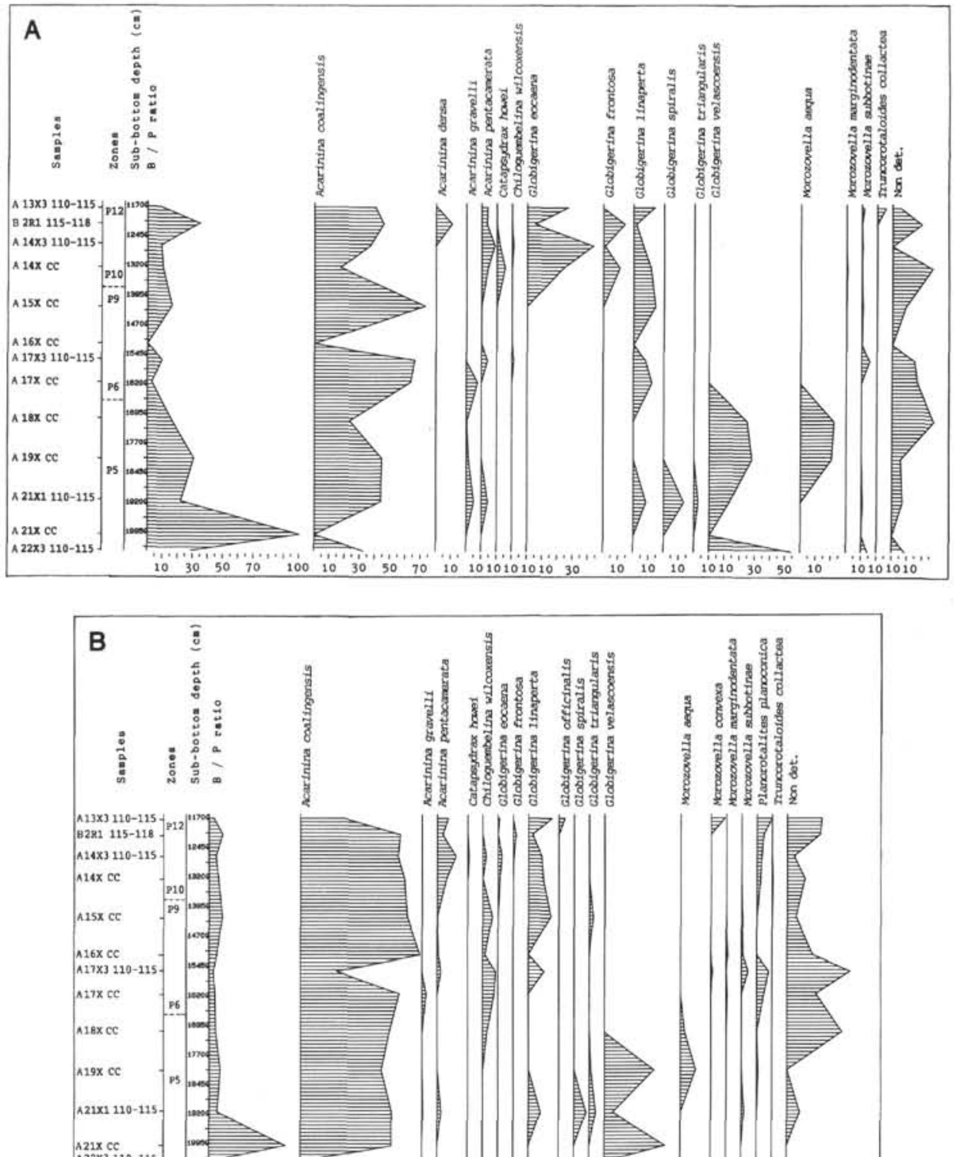


Figure 12. Frequency distribution of selected late Paleocene–middle Eocene planktonic foraminifers from Holes 752A and 752B. Vertical scale 1:750. **A.** Specimens >250 µm. **B.** Specimens 125–250 µm.

110–115 cm, as indicative for the top of this zone. Fauna composition otherwise changes very little.

The occurrence of *Globigerina ampliapertura* Bolli, 1957a in Samples 121-756C-5X-3, 140–145 cm, to 121-756C-6X-1, 110–115 cm, (115–131 mbsf) indicates Zone P20.

Sample 121-756C-6X-CC (130 mbsf) shows a much different fauna. *Jenkinsella* is absent, *Globigerina praebulloides* is replaced by *G. eocaena* Guembel, 1868, and *G. angustiumbilicata* and *Globorotaloides suteri* are much rarer. The few specimens of *Globigerinatheka index* (Finlay, 1939a), *Hantkenina* sp., and *Turborotalia cunialensis* (Toumarkine and Bolli, 1970) we consider reworked; thus, this sample is of earliest Oligocene age, Zone P19.

Samples 121-756C-7X-1, 110–115 cm, to 121-756C-8X-1, 110–115 cm, (131–140.5 mbsf) contain *Globigerinatheka index*, *G. subconglobata* (Shutskaya, 1958), *Hantkenina alabamensis* Cushman, 1925a, *H. brevispina* Cushman, 1925a, and *Turborotalia* spp., indicating a latest Eocene age, Zones P17-18.

Site 757 (Figs. 20 and 21 and Table 6)

In Sample 121-757B-11H-2, 110–115 cm (94 mbsf), several species of *Globigerinoides* occur (*G. altiaperturus* Bolli, 1957a, *G. sacculifer* (Brady, 1877), and *G. trilobus* (Reuss, 1850)), which clearly indicates an earliest Miocene age. Large *Globigerina* species are common, and *Globigerina euapertura* Jenkins, 1960 is remarkably rare.

We assign Sample 121-757B-11H-CC (101 mbsf) to the Oligocene-Miocene, Zones P22/N4, with abundant *Fohsella kugleri* (Bolli, 1957a) and *Globigerinita glutinata* (Egger, 1893).

The lack of marker species in Samples 121-757B-12H-2, 110–115 cm, to 121-757B-13H-2, 110–115 cm, (103–113 mbsf) makes separation of Zones P18 to P21 difficult. *Globigerina euapertura* dominates the >250-µm fractions (up to 70%), and *G. galavisi* Bermúdez, 1960 and *G. tripartita* Koch, 1926 are common. The 125–250-µm fractions are dominated by *Globorotaloides suteri*

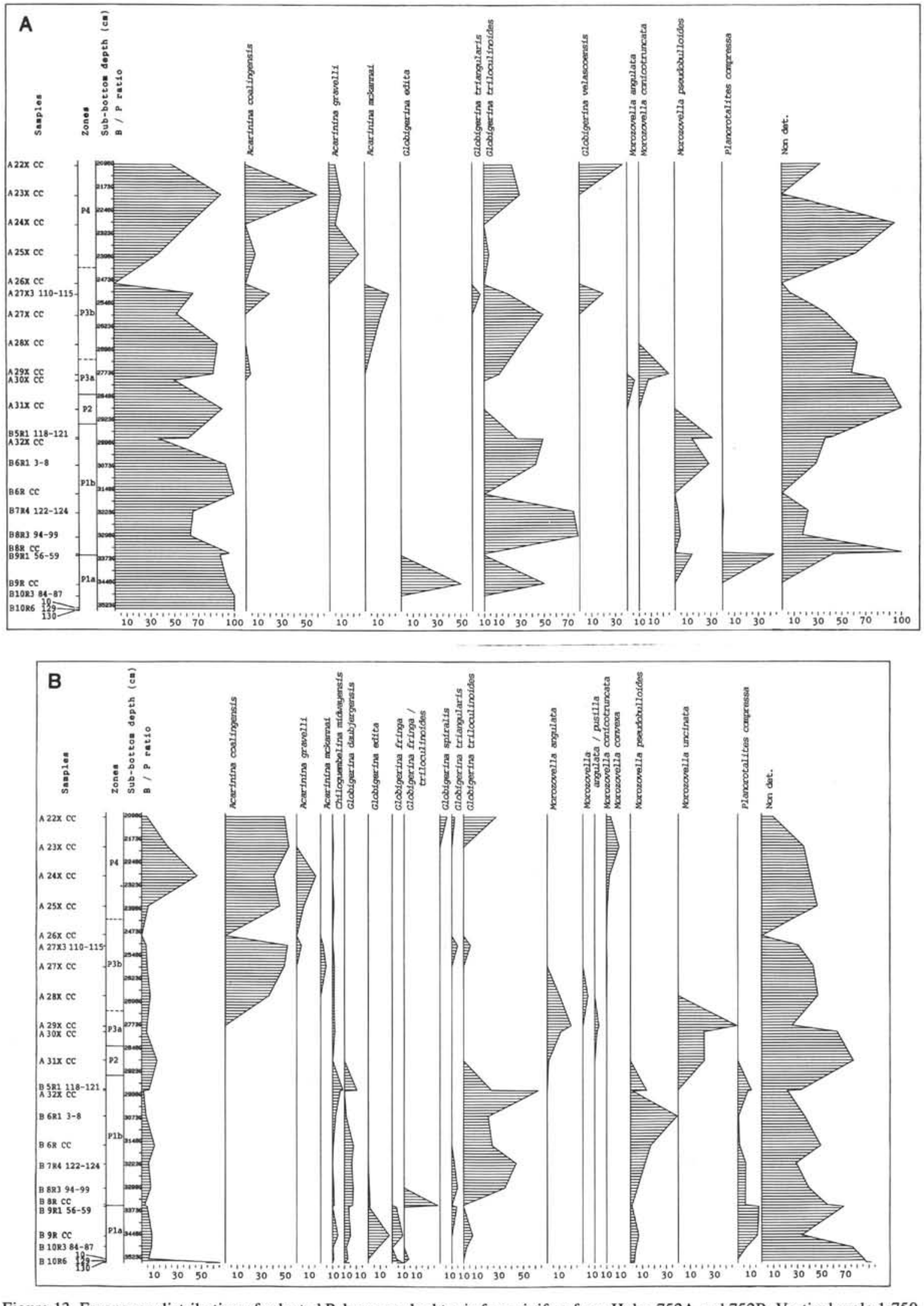


Figure 13. Frequency distribution of selected Paleocene planktonic foraminifers from Holes 752A and 752B. Vertical scale 1:750. **A.** Specimens >250 μm. **B.** Specimens 125–250 μm.

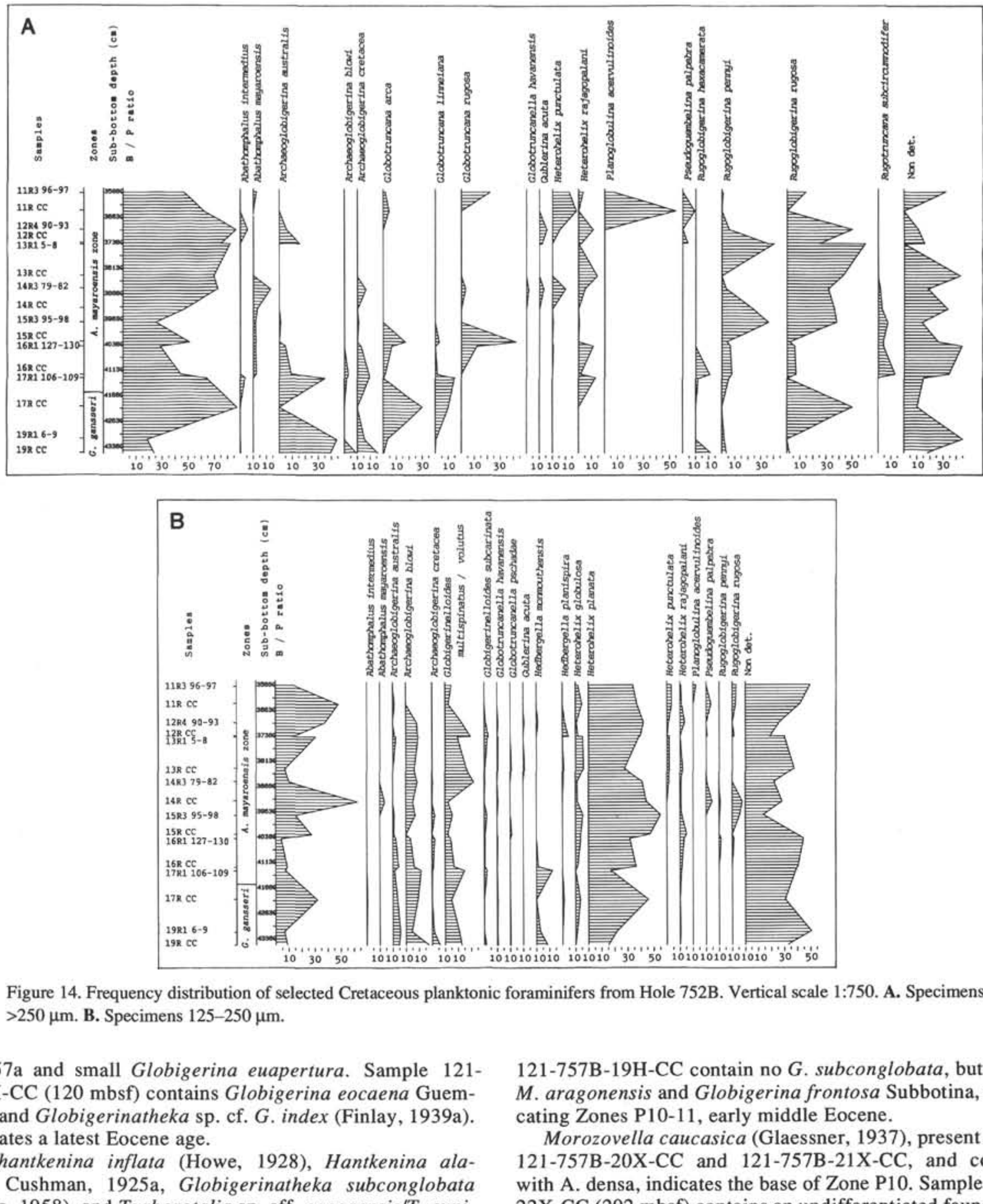


Figure 14. Frequency distribution of selected Cretaceous planktonic foraminifers from Hole 752B. Vertical scale 1:750. **A.** Specimens >250 μm. **B.** Specimens 125–250 μm.

Bolli, 1957a and small *Globigerina euapertura*. Sample 121-757B-13H-CC (120 mbsf) contains *Globigerina eocaena* Guembel, 1868 and *Globigerinatheka* sp. cf. *G. index* (Finlay, 1939a). This indicates a latest Eocene age.

Cribrohantkenina inflata (Howe, 1928), *Hantkenina alabamensis* Cushman, 1925a, *Globigerinatheka subconglobata* (Shutskaya, 1958), and *Turborotalia* sp. aff. *cocoaensis/T. cunialensis*, occurring in Sample 121-757B-14H-2, 110–115 cm (123 mbsf), indicate a late Eocene age. Poorly preserved late Eocene faunas (Zones P15 to P17), lacking marker species, were found in Samples 121-757B-14H-2, 110–115 cm, to 121-757B-15H-CC (130–140 mbsf). *G. euapertura* is common, as are species of *Globigerinatheka*.

Acarinina species (notably *A. densa* (Cushman, 1925b)), indicating a middle Eocene age, are abundant to dominant in the faunas from Samples 121-757B-16H-CC to 121-757B-21X-CC (149–192 mbsf). Samples 121-757B-16H-CC and 121-757B-17H-CC yielded *Globigerinatheka subconglobata* (Shutskaya, 1958) without *Morozovella aragonensis* (Nuttall, 1930), indicating Zones P12-14. Faunas from Samples 121-757B-18H-CC and 121-757B-19H-CC contain no *G. subconglobata*, but do contain *M. aragonensis* and *Globigerina frontosa* Subbotina, 1953, indicating Zones P10-11, early middle Eocene.

Morozovella caucasica (Glaessner, 1937), present in Samples 121-757B-20X-CC and 121-757B-21X-CC, and co-occurring with A. densa, indicates the base of Zone P10. Sample 121-757B-22X-CC (202 mbsf) contains an undifferentiated fauna we assign to the early Eocene, Zones P7-8, with abundant *A. coalingensis* (Cushman and Hanna, 1927) and *Morozovella convexa* (Subbotina, 1953).

We assign Samples 121-757B-23X-CC and 121-757B-24X-3, 46–48 cm, (212–215 mbsf) to Zone P6, earliest Eocene, based on the occurrence of *Chiloguembelina wilcoxensis* (Cushman and Ponton, 1932a), *Globigerina velascoensis* Cushman, 1925d, and *Morozovella aequa* (Cushman and Renz, 1942). Sample 121-757B-23X-CC also contains abundant (27%) *Acarinina wilcoxensis* (Cushman and Ponton, 1932a), a species not recorded from any other Leg 121 sample.

Remarkable is the occurrence of a species virtually indistinguishable from *Clavatorella nicobarensis* Srinivasan and Ken-

Table 2. Distribution of additional species from Holes 752A and 752B.

Species	Frequency (%)	Sample (interval in cm)
middle Eocene–Oligocene >250 μm		
Globigerina angiporoides Hornibrook, 1965	0.9	752A-11H-3, 110–115
Globigerina binaiensis Koch, 1935	0.4	752A-10H-3, 110–115
Globigerina sellii (Borsetti, 1959)	0.4	752A-10H-3, 110–115
Jenkinsella mayeri (Cushman and Ellisor, 1939)	0.4	752A-10H-3, 110–115
Turborotalia increbescens (Bandy, 1949)	0.9	752A-11H-3, 110–115
Turborotalia pomeroli (Toumarkine and Bolli, 1970)	0.9	752A-11H-3, 110–115
<250 μm		
Fohsella kugleri (Bolli, 1957a)	0.6	752A-10H-3, 110–115
Globigerina angulisuturalis Bolli, 1957a	0.6	752A-10H-3, 110–115
Globigerina ciperoensis Bolli, 1954	0.3	752A-10H-3, 110–115
Globigerinella obesa (Bolli, 1957a)	1.3	752A-10H-CC
Jenkinsella nana (Bolli, 1957a)	0.6	752A-10H-3, 110–115
upper Paleocene–middle Eocene >250 μm		
Globigerina cryptomphala Glaessner, 1937	1.6	752-13X-3, 110–115
Globigerina inaequispira Subbotina, 1953	2.1	752-21X-1, 110–115
Globigerina senni (Beckmann, 1953)	3.2	752-14X-CC
Morozovella occlusa (Loeblich and Tappan, 1957)	1.6	752-18X-CC
<250 μm		
Chiloguembelina martini (Pijpers, 1933) (<125 μm)		752-13X-3, 110–115, 752-2R-1, 115–118, 752-14X-3, 110–115, 752-17X-3, 110–115
Chiloguembelina sp. non det.	0.5	752-19X-CC
	0.4	752-21X-1, 110–115
(<125 μm)		752-14X-3, 110–115, to 752-21X-CC
Guembelitria columbiana Howe, 1939 (<125 μm)		752-13X, 752-14X
Planorotalites imitata (Subbotina, 1953)	1.1	752-19X-CC
	1.3	752-21X-1, 110–115
Pseudohastigerina wilcoxensis (Cushman and Ponton, 1932a)	2.1	752-13X-3, 110–115
Paleocene >250 μm		
Acarinina pentacamerata (Subbotina, 1947)	6.7	752A-27X-CC
Morozovella aequa (Cushman and Renz, 1942)	1.2	752A-22X-CC
Morozovella conicotruncata (Subbotina, 1947)	25.0	752A-30X-CC
Planorotalites pseudomenardii (Bolli, 1957b)	1.2	752A-22X-CC
<250 μm		
Chiloguembelina sp. non det. (observed)		752A-25X-CC, 752A-27X-CC, 752A-28X-CC
Planorotalites imitata (Subbotina, 1953)	1.0	752A-22X-CC
	0.7	752A-28X-CC
Planorotalites pseudomenardii (Bolli, 1957b)	1.0	752A-22X-CC
Guembelitria cretacea Cushman, 1933 (<125 μm)		752B-10R-6, 130–133
Cretaceous >250 μm		
Globotruncanita angulata (Tilev, 1951)	0.8	752B-11R-3, 96–97
Globotruncanita elevata (Brotzen, 1934)	1.7	752B-14R-3, 79–82
Pseudotextularia elegans (Rzehak, 1891)	2.5	752B-11R-3, 96–97
	13.6	752B-11R-CC
<250 μm		
Globigerinelloides yaucoensis (Pessagno, 1960)	0.4	752B-17R-1, 106–109
Heterohelix costulata (Cushman, 1938)	1.2	752B-11R-CC
Heterohelix dentata Stenestad, 1968 (observed)		752B-12R-4, 90–93, 752B-13R-1, 5–8, 752B-14R-3, 79–82
Pseudotextularia elegans (Rzehak, 1891)	0.4	752B-11R-3, 96–97

nett, 1976 in the 125–250-μm fraction of Samples 121-757B-11H-CC (0.5%) and 121-757B-12H-CC (0.8%) (Pl. 4, Figs. 8–12). The range of this species is late Miocene to early Pliocene (N16-19). No other late Neogene species were found, so contamination is unlikely. The only species with which it may be confused are *Protentella clavicamerata* Jenkins, 1977 and *Clavigerinella nazcaensis* Quilty, 1976. *P. clavicamerata* is entirely planispiral, with a thin, pustulose wall, whereas the specimens found are initially trochospiral with a coarsely perforate wall. Small specimens of *C. nazcaensis* have a similar gross morphology, but have

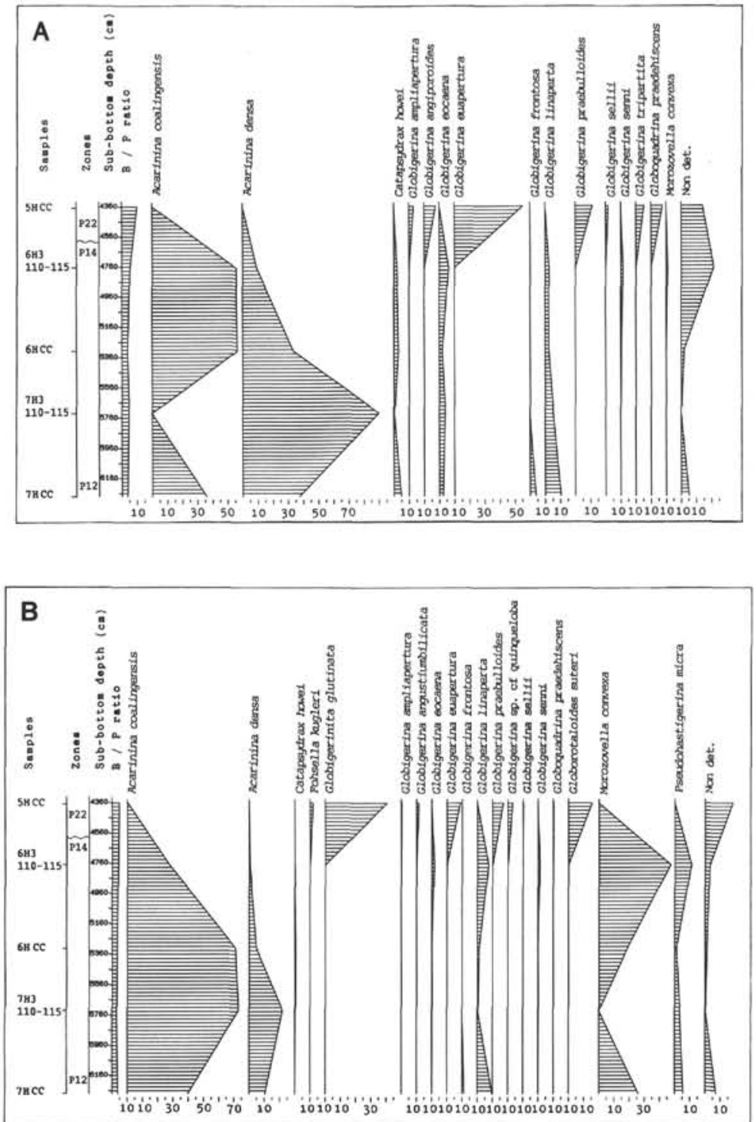


Figure 15. Frequency distribution of selected planktonic foraminifers from Hole 753A. Vertical scale 1:200. **A.** Specimens >250 µm. **B.** Specimens 125–250 µm.

Table 3. Distribution of additional species from Hole 753A.

Species	Frequency (%)	Core, section, interval (cm)
>250 μm		
Globigerina galavisi Bermudez, 1960	1.8	5H-CC
Jenkinsella continuosa (Blow, 1959)	1.8	5H-CC
<250 μm		
Chiloguembelina cubensis (Palmer, 1934) (<125 μm)		5H-CC
Chiloguembelina martini (Pijpers, 1933) (<125 μm)	0.3	7H-CC
		5H-CC, 6H-CC, 7H-CC
Globigerinella obesa (Bolli, 1957a)	1.6	5H-CC
Pseudohastigerina naguewichiensis (Myatliuk, 1950) (<125 μm)		6H-3, 110–115, 7H-CC

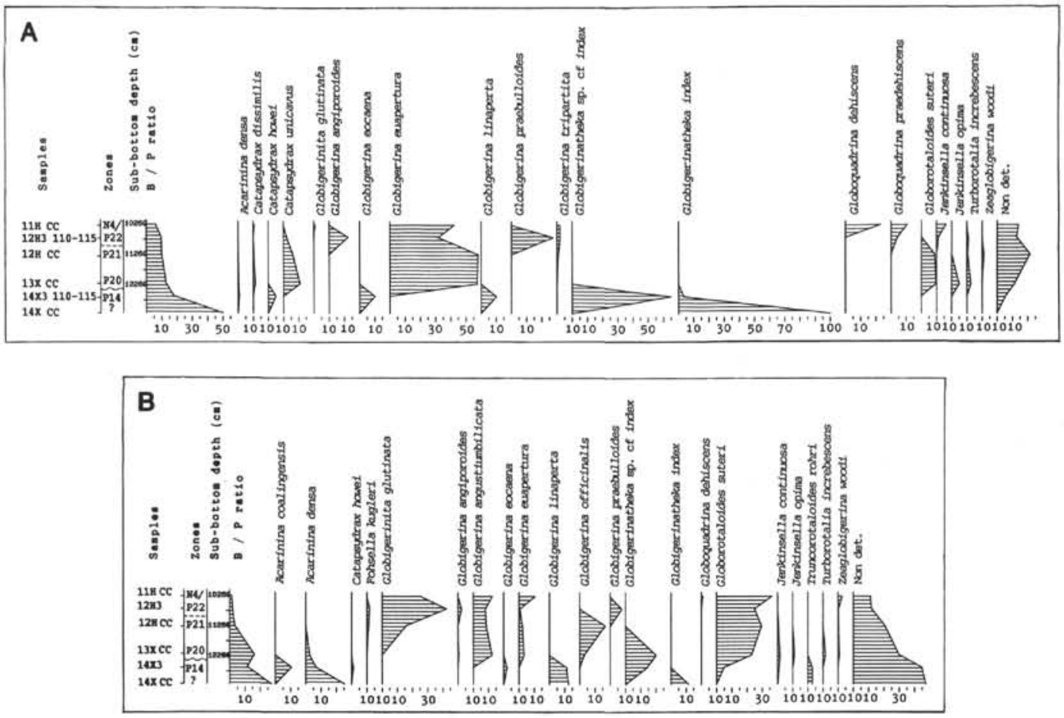


Figure 16. Frequency distribution of selected Paleogene planktonic foraminifers from Hole 754A. Vertical scale 1:1000. **A.** Specimens >250 µm. **B.** Specimens 125–250 µm.

a thin, finely perforate wall. The same species was also found in upper Oligocene samples from Site 758.

Site 758 (Figs. 22–25 and Table 7)

Globigerina euapertura Jenkins, 1960 is dominant (20% to 70%, average 50%) in all >250-µm Oligocene faunas. Other common Oligocene species are *Catapsydrax dissimilis* (Cushman and Bermúdez, 1937), *C. unicavus* Bolli, Loeblich, and Tappan, 1957, *Globigerina galavisi* Bermúdez, 1960, *G. praebulloides* Blow, 1959, *G. sellii* (Borsetti, 1959), and *G. tripartita* Koch, 1926.

Samples 121-758A-20X-CC to 121-758A-21X-2, 110–115 cm, (189–192 mbsf) contain several *Globoquadrina* species, indicating the Oligocene-Miocene (P22/N4).

Zone P22 (Samples 121-758A-21X-3, 110–115 cm, to 121-758A-23X-5, 110–115 cm; 193–216 mbsf) is characterized by *Jenkinsella mayeri* (Cushman and Ellisor, 1939) and fairly common *Globigerina binaiensis* Koch, 1935 in the >250-µm fractions. *Globigerina angustiumbilicata* Bolli, 1957a and *G.* sp. cf. *G. quinqueloba* Natland, 1938 dominate the 125–250-µm fractions. *Fohsella kugleri* (Bolli, 1957a) is common in the upper half of the zone and rare in the lower half.

Zone P21 (Samples 121-758A-23X-CC to 121-758A-25X-CC; 218–237 mbsf) is clearly identifiable from common *Jenkinsella opima* (Bolli, 1957a) in the >250-µm fractions. *G. binaiensis* is present but rare. In the 125–250-µm fractions, *G. angustiumbilicata* is less abundant than before, and *Globorotaloides suteri* Bolli, 1957a has replaced *G.* sp. cf. *G. quinqueloba*. *Jenkinsella nana* (Bolli, 1957a) is common. *Chiloguembelina cubensis* (Palmer, 1934) is rare in the 125–250-µm fractions, but common to dominant in the <125-µm fractions.

The lack of marker species (especially *Globigerina ampliapertura* Bolli, 1957a, *Pseudohastigerina micra* (Cole, 1927), and *Turborotalia increbescens* (Bandy, 1949)) makes separation of Zones P19 and P20 (Samples 121-758A-26X-1, 110–115 cm, to 121-758A-26X-CC; 239-246 mbsf) difficult.

Eocene faunas occur only in samples from Section 121-758A-27X-CC (257 mbsf) and are of poor quality. *Acarinina* spp. and *Morozovella* spp. indicate a (early) middle Eocene age, whereas the calcareous nannoplankton indicate a late Eocene age (J. J. Pospichal and P. Resiwati, pers. comm., 1990).

Samples 121-758A-28X-2, 115–120 cm, and 121-758A-28X-4, 115–120 cm, (259–262 mbsf) contain well-preserved late Paleocene faunas, Zone P5, with many large species of *Morozovella* and *Acarinina* plus *Globigerina velascoensis* Cushman, 1925d.

The marker for Zone P4, *Planorotalites pseudomenardii* (Bolli, 1957b), occurs in Samples 121-758A-28X-CC to 121-758A-30X-3, 115–120 cm (267–269 mbsf). *Acarinina mckannai* (White, 1928) occurs in the upper part of this zone; *Globigerina triloculinoides* Plummer, 1926 occurs in the lower part. Dominant in the >250-µm fraction of Sample 121-758A-30X-3, 115–120 cm, is the large species *Morozovella variospira* (Belford, 1984). Intermediate forms connect this species to typical *M. pseudobulloides* in Samples 121-758A-31X-1, 115–120 cm, and 121-758A-31X-2, 115–120 cm.

Samples 121-758A-30X-CC and 121-758A-31X-1, 115–120 cm, (286–287 mbsf) contain common *Morozovella pusilla* (Bolli, 1957b) and *Globigerina velascoensis*, but no *P. pseudomenardii* (Bolli, 1957b), indicating Zone P3b.

Faunas indicating Zone P3a, characterized by the presence of *M. angulata* (White, 1928) and less common *M. pusilla* and lacking *G. velascoensis*, were found in Samples 121-758A-31X-2, 115–120 cm, and 121-758A-31X-3, 115–120 cm (288–290 mbsf).

M. uncinata (Bolli, 1957b) and *M. praecursoria* (Morozova, 1957) occur commonly in Samples 121-758A-31X-4, 115–120 cm, and 121-758A-31X-5, 115–120 cm, (291–293 mbsf) assigning them to Zone P2.

Sample 121-758A-31X-6, 115–120 cm (294 mbsf), contains rare *M. trinidadensis* (Bolli, 1957b), indicating Zone P1b. No

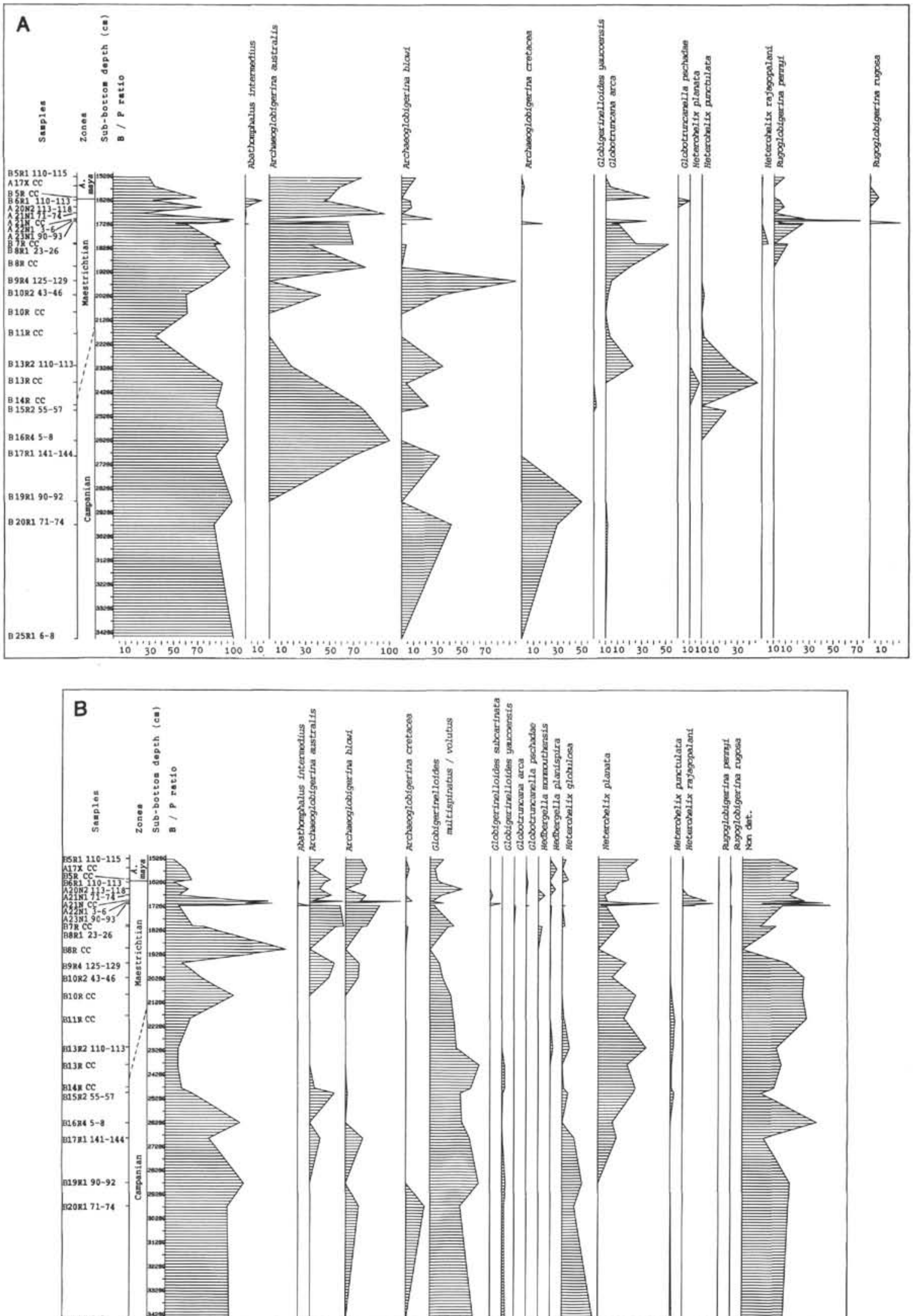


Figure 17. Frequency distribution of selected Cretaceous planktonic foraminifers from Holes 754A and 754B. Vertical scale 1:1000. **A.** Specimens >250 µm. **B.** Specimens 125–250 µm.

Table 4. Distribution of additional species from Holes 754A and 754B.

Species	Frequency (%)	Sample (interval in cm)
Paleogene >250 μm		
Globigerina ampliapertura Bolli, 1957a	2.6	754A-12H-CC
Globigerina galavisi Bermudez, 1960	0.8	754A-11H-CC
	1.3	754A-12H-3, 110–115
	0.51	754A-3H-CC
Globigerina sellii (Borsetti, 1959)	2.6	754A-12H-3, 110–115
Jenkinsella mayeri (Cushman and Ellisor, 1939)	0.9	754A-12H-3, 110–115
Zeaglobigerina labiacrassata (Jenkins, 1966)	0.5	754A-13H-CC
<250 μm		
Globigerina falconensis Blow, 1959	0.2	754A-11H-CC
Globigerinita uvula (Ehrenberg, 1861)	0.2	754A-11H-CC
	0.7	754A-12H-CC
Jenkinsella mayeri (Cushman and Ellisor, 1939)	0.3	754A-12H-3, 110–115
	0.7	754A-12H-CC
Pseudohastigerina micra (Cole, 1927)	0.4	754A-14X-3, 110–115
Tenuitella munda (Jenkins, 1966)	2.6	754A-12H-CC
Zeaglobigerina labiacrassata (Jenkins, 1966)	0.4	754A-13H-CC
Cretaceous >250 μm		
Abathomphalus mayaroensis (Bolli, 1959)		754B-5R-CC
Globotruncana linneiana (d'Orbigny, 1839)	0.5	754B-5R-1, 110–115
	0.3	754A-21N-1, 71–74
	25.0	754A-21N-CC
	3.7	754B-10R-2, 43–46
	1.9	754A-17R-CC
Rugoglobigerina hexacamerata Brönnimann, 1952a	5.6	754A-20N-2, 113–118
	1.0	754A-21N-1, 71–74
<250 μm		
Globotruncanella havanensis (Voorwijk, 1937)	0.9	754B-7R-1, 110–113

earliest Paleocene and latest Maestrichtian faunas were found, indicating an hiatus between 294 and 296 mbsf.

Samples 121-758A-31X-CC to 121-758A-33X-CC (296–312 mbsf) contain rare and primitive *Abathomphalus mayaroensis* (Bolli, 1951), indicating the base of the *A. mayaroensis* Zone. Sample 121-758A-31X-CC contains a diverse fauna with many species indicating warm to subtropical conditions, although most of these are extremely rare and only present outside of the count.

A. intermedius (Bolli, 1951) occurs in Samples 121-758A-34X-CC and 121-758A-35X-CC (325–333 mbsf) without *A. mayaroensis*, indicating a middle Maestrichtian age.

Below 333 mbsf, age-indicative species are almost entirely lacking. Samples 121-758A-36X-CC to 121-758A-40X-2, 97–100 cm, (343–370 mbsf) contain a fauna with *Globotruncana arca* (Cushman, 1926), *G. linneiana* (d'Orbigny, 1839), *Heterohelix punctulata* (Cushman, 1938), *Rugoglobigerina pennyi* Brönnimann, 1952a, and *Heterohelix rajagopalani* (Govindan, 1972). We assign a Maestrichtian to Maestrichtian-Campanian age to these samples. Older samples, assigned a Campanian age, contain poorly preserved faunas dominated by *Archaeoglobigerina blowi* Pessagno, 1967 and *A. cretacea* (d'Orbigny, 1840) (>250-μm fractions). The 125–250-μm fractions contain *A. blowi*, *Globigerinelloides multispinatus*/*G. volutus*, *Heterohelix globulosa* (Ehrenberg, 1840), and *H. planata* (Cushman, 1938).

In the 125–250-μm fraction of Samples 121-758A-21X-1, 110–115 cm, and 121-758A-21X-2, 110-115 cm, (1.3% and 0.4%, respectively) a species indistinguishable from *Clavatorella nicobarensis* Srinivasan and Kennett, 1976 was found (see biostratigraphy for Site 757). Also, a planispiral species is present at very low frequency. This species resembles *Protentella prolixa* Lipps, 1964, which ranges from Zones N12 to N14 (middle Miocene). One specimen (Pl. 5, Fig. 12) has a double aperture and resembles biapertural specimens of *Globigerinelloides multispinatus* (Lalicker, 1948). Reworking is unlikely, as we saw no other reworked foraminifers and the state of preservation is not different. Contamination is unlikely for the same reasons.

Throughout the Oligocene, we found a variety of *Globigerina tripartita* Koch, 1926. It has two to two and a half chambers in the final whorl, which together constitute 75% to 90% of the test size. As with *G. tripartita*, abortive, bullalike final chambers are common. This form, which we have named *Globigerina* sp. "*bipartita*," seems to indicate warm to subtropical conditions, as we found it at Site 758 only.

CONCLUSIONS

The recovered faunas clearly reflect the paleoclimate. Late Maestrichtian faunas contain many species that indicate a warm climate. However, most of these are extremely rare, so a temperate to subtropical climate must be assumed. Other samples from the Cretaceous are dominated by species of *Heterohelix*, *Globigerinelloides*, and *Archaeoglobigerina*, indicative of a cold, austral climate (Nederbragt, 1990; Huber, 1990). A subtropical climate during the Paleocene is indicated by the faunas from Site 758. The faunas from Site 752 indicate a more temperate climate, but selective preservation may have influenced the interpretation. All early and middle Eocene faunas indicate a more temperate climate, although the more tropical species may have been removed by dissolution. The late Eocene and Oligocene faunas show a clear differentiation, with faunas from the northernmost sites indicating a subtropical climate.

Quantitative sample and fauna processing provides much valuable data for relatively little extra work. Combined with informa-

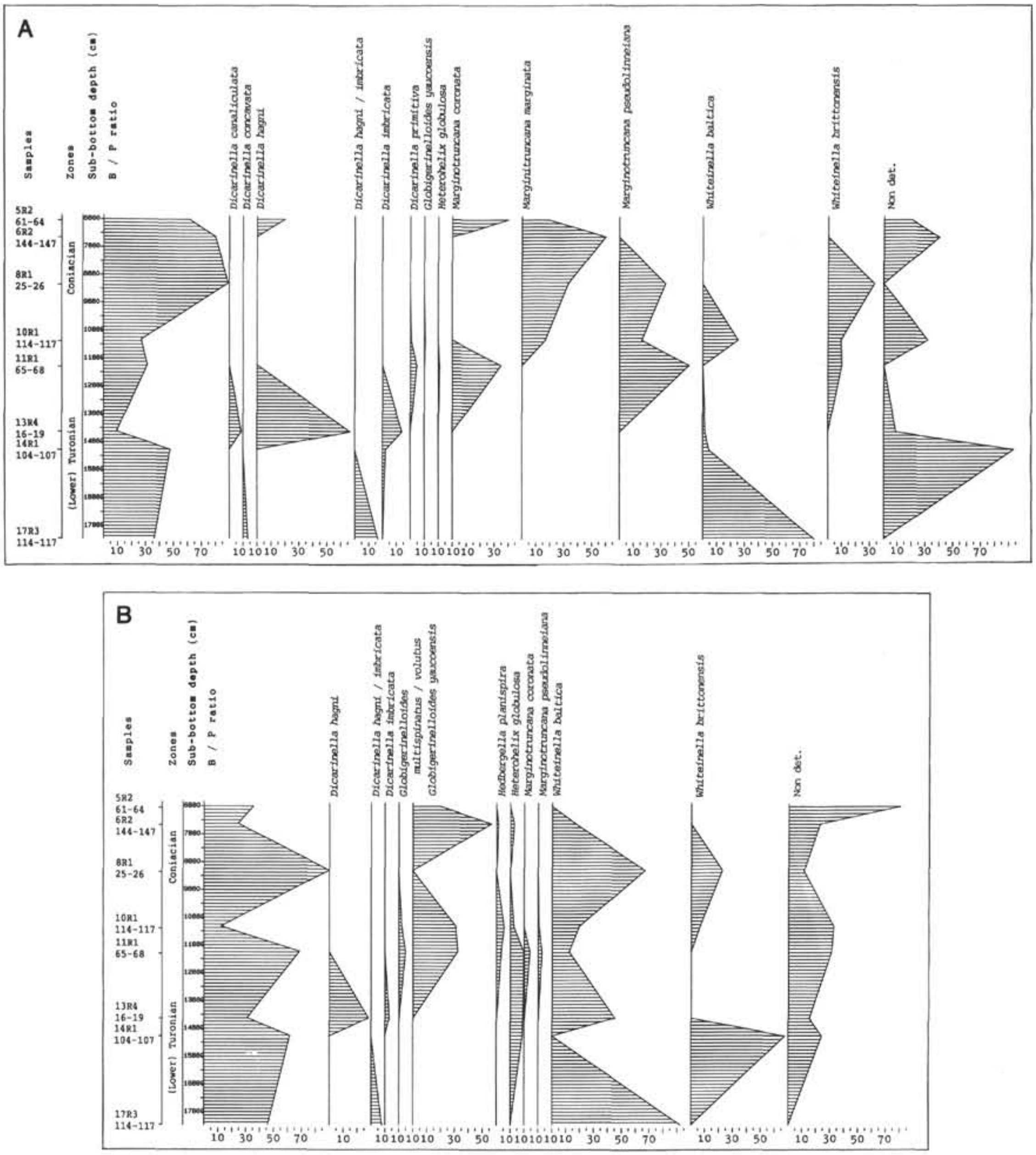


Figure 18. Frequency distribution of planktonic foraminifers from Hole 755A. Vertical scale 1:1000. **A.** Specimens >250 μm. **B.** Specimens 125–250 μm.

tion on size distribution and preservation, important observations on fauna composition, paleoceanography, climate, and productivity can be made.

Although dating is not always as accurate as with fully tropical faunas, the zonations of Banner and Blow (1965) and Blow (1969) could generally be used, which facilitates comparison with other tropical areas. The zonations based on high-latitude faunas (e.g., Jenkins, 1966, 1985), are harder to apply, show poorer resolution, and are hard to compare with tropical zonations.

SYSTEMATICS

In this report, the Globigerinina are classified following Nederbragt (in press) for Cretaceous Heterohelicidae, Robaszynski and Caron (1979) and Robaszynski et al. (1984) for the Globotruncanidae, and Toumarkine and Luterbacher (1985), Bolli and Saunders (1985), and Kennett and Srinivasan (1983) for the Globigerinidae. Some modifications have been made. We classify all precursors of the angular-conical Morozovellids under *Morozovella*, although they are commonly named *Subbotina* (Berggren, 1977). The Paleogene Globigerinids are classified as *Globigerina*, not as *Subbotina*, because we feel that the differences between these are insufficient to warrant separate genera. Indeed, some species show a coarse, honeycombed wall pattern, but these intergrade with species with a *Globigerina*-type wall structure. Some species of *Globigerina* (e.g., *G. euapertura*) intergrade with species ascribed to *Subbotina*.

Kennett and Srinivasan's (1983) subgenera of *Globorotalia* have been given generic rank.

Some indistinct and biostratigraphically unimportant species of *Globigerinelloides* and *Acarinina* have been grouped together.

Species are illustrated to show variability, interpretation of species concept, or aberrant forms.

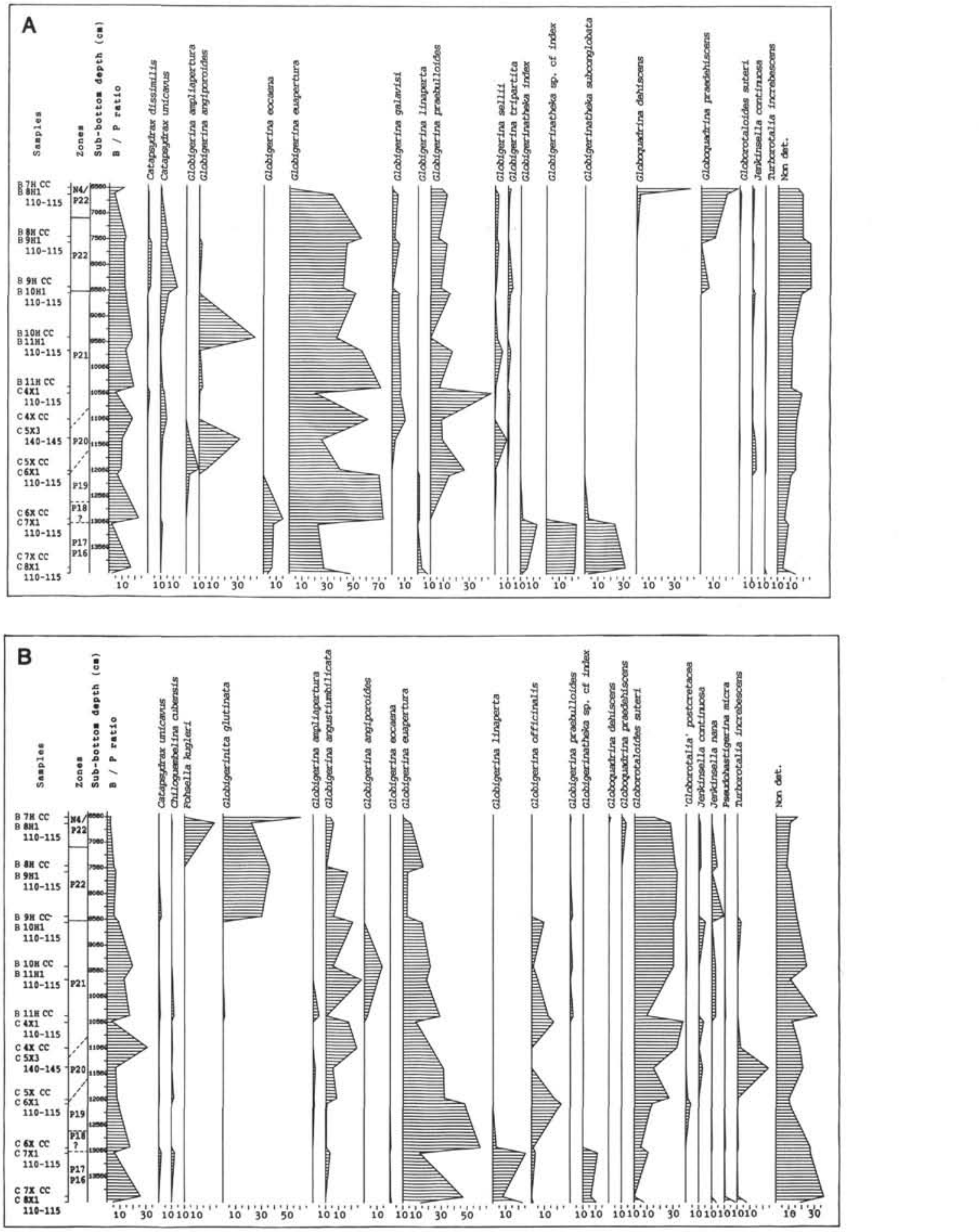


Figure 19. Frequency distribution of selected planktonic foraminifers from Holes 756B and 756C. Vertical scale 1:500. **A.** Specimens >250 µm. **B.** Specimens 125–250 µm.

Suborder GLOBIGERININA Delage and Herouard, 1896
Family HETEROHELICIDAE Cushman, 1927c

Genus *Chiloguembelina* Loeblich and Tappan, 1956

Chiloguembelina cubensis
(Pl. 2, Figs. 1 and 2)

Guembelina cubensis Palmer, 1934, p. 74, figs. 1–6.

Remarks. Although rare in many lower and middle Oligocene 125-250-µm fractions, this species can be extremely abundant in the <125-µm fractions. In these sections its last occurrence seems to be just above the top of the *J. opima* Zone (P21), as it was found by Beckmann (1957) in the Caribbean. According to Palmer (1940), Renz (1948), Bermúdez (1949), Blow (1979), and Jenkins (1985), it may range into the upper Oligocene.

Chiloguembelina martini

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

Remarks. *C. martini* is usually rare in the <125-µm fractions of the middle Eocene from Site 757.

Table 5. Distribution of additional species from Holes 756B and 756C.

Species	Frequency (%)	Sample (interval in cm)
>250 μm		
Globigerina gortanii (Borsetti, 1959)	0.6	756B-10H-1, 110–115
Globigerinoides spp.	1.1	756B-7H-CC
	1.1	756B-8H-1, 110–115
Hantkenina brevispina Cushman, 1925a	0.4	756C-6X-CC
Turborotalia cocoaensis/T. cunialensis	0.4	756C-7X-1, 110–115
Turborotalia pomeroli (Toumarkine and Bolli, 1970)	0.3	756C-8X-1, 110–115
<250 μm		
Catapsydrax dissimilis (Cushman and Bermudez, 1937)	0.4	756B-10H-1, 110–115
Globigerina angulisuturalis Bolli, 1957a	0.9	756B-11H-CC
Globigerina ciperoensis Bolli, 1954	0.3	756B-9H-CC
Globigerina inaequispira Subbotina, 1953	0.4	756C-5X-CC
	1.0	756C-6X-CC
Globigerina ouachitaensis Howe and Wallace, 1932	3.7 ·	756C-8X-1, 110–115
Globigerina sp. cf. *quinqueloba* Natland, 1938	2.3	756B-8H-CC
Globigerinita uvula (Ehrenberg, 1861)	0.2	756B-8H-CC
Guembelitria columbiana Howe, 1939 (<125 μm)		756C-4X-CC
Jenkinsella mayeri (Cushman and Ellisor, 1939)	0.2	756B-8H-CC
Pseudohastigerina naguewichiensis (Myatliuk, 1950)	0.4	756B-9H-1, 110–115
	0.4	756C-5X-CC
Zeaglobigerina labiacrassata (Jenkins, 1966)	0.9	756B-9H-CC

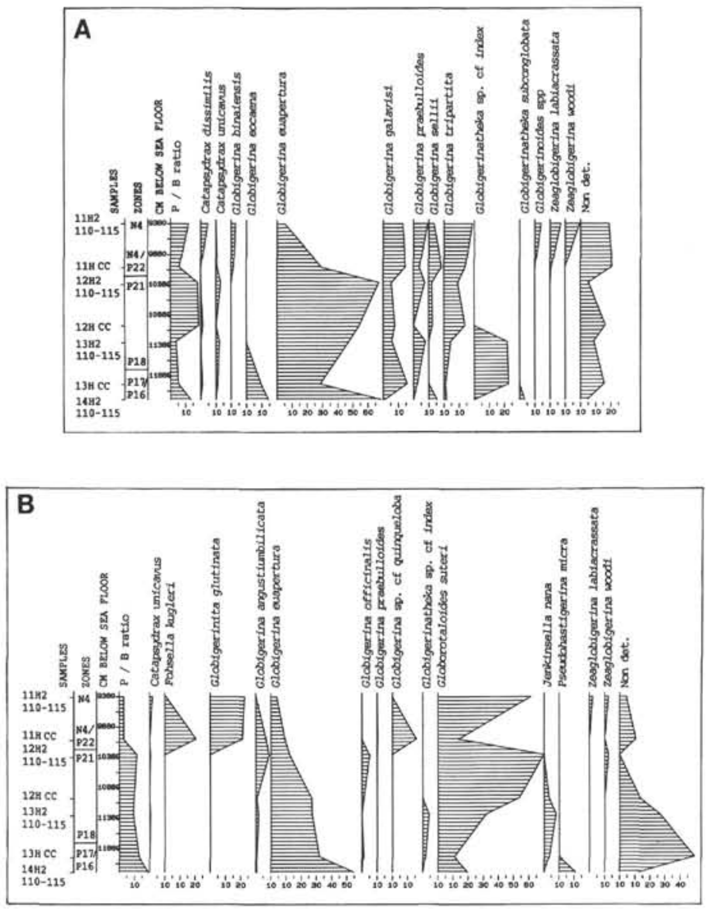


Figure 20. Frequency distribution of selected late Eocene–Oligocene planktonic foraminifers from Hole 757B. Vertical scale 1:500. **A.** Specimens >250 μm. **B.** Specimens 125–250 μm.

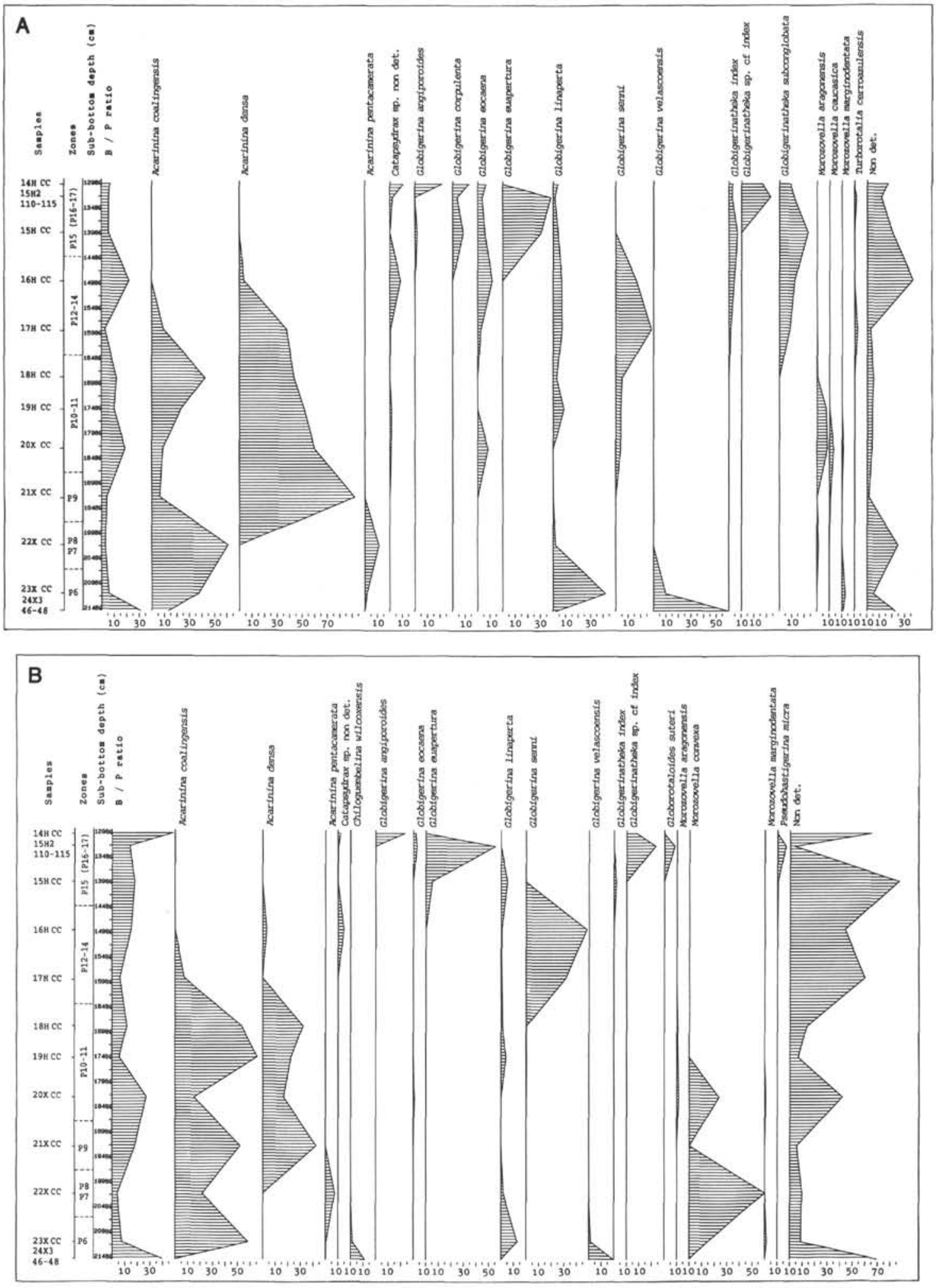


Figure 21. Frequency distribution of selected Eocene planktonic foraminifers from Hole 757B. Vertical scale 1:500. **A.** Specimens >250 μm. **B.** Specimens 125–250 μm.

Table 6. Distribution of additional species from Hole 757B.

Species	Frequency (%)	Core, section, interval (cm)
Oligocene >250 μm		
Cribrohantkenina inflata (Howe, 1928) (observed)		14H-2, 110–115
Globigerina ampliapertura Bolli, 1957a	0.5	14H-2, 110–115
Globigerina angiporoides Hornibrook, 1965	1.1	13H-2, 110–115
Globigerina corpulenta Subbotina, 1953	3.8	12H-CC
Globigerina gortanii (Borsetti, 1959)	0.6	13H-2, 110–115
	0.5	13H-CC
Globigerinatheka index (Finlay, 1939a)	0.5	14H-2, 110–115
Globoquadrina praedehiscens Blow and Banner, 1962	5.4	11H-CC
Hantkenina alabamensis Cushman, 1925a	0.5	14H-2, 110–115
Jenkinsella continuosa (Blow, 1959)	2.9	11H-2, 110–115
Turborotalia sp. non det. (observed)		14H-2, 110–115
<250 μm		
Cassigerinella chipolensis (Cushman and Ponton, 1932b)	0.4	12H-2, 110–115
Chiloguembelina cubensis (Palmer, 1934) (<125 μm)		13H-CC
Aff. *Clavatorella nicobarensis* Srinivasan and Kennett, 1976	0.5	11H-CC
	0.8	12H-CC
Globigerina angiporoides Hornibrook, 1965	0.7	13H-2, 110–115
	1.1	13H-CC
	0.8	14H-2, 110–115
Globigerina angulisuturalis Bolli, 1957a	0.4	12H-2, 110–115
Globigerinella obesa (Bolli, 1957a)	0.3	11H-2, 110–115
Jenkinsella continuosa (Blow, 1959)	0.8	11H-2, 110–115
Pseudohastigerina naguewichiensis (Myatliuk, 1950) (<125 μm)		13H-CC
Tenuitella munda (Jenkins, 1966)	0.9	11H-CC
Eocene >250 μm		
Globigerina frontosa Subbotina, 1953	0.6	18H-CC
Morozovella aequa (Cushman and Renz, 1942)	1.5	23X-CC
Morozovella crassata (Cushman, 1925b)	1.1	20X-CC
Morozovella subbotinae (Morozova, 1939)	0.5	23X-CC
Truncorotaloides topilensis (Cushman, 1925c)	0.8	17H-CC
<250 μm		
Chiloguembelina martini (Pijpers, 1933) (<125 μm)		19X through 23X
Globigerina ouachitaensis Howe and Wallace, 1932	0.7	17H-CC
Guembelitria columbiana Howe, 1939 (<125 μm)		22X-CC, 23X-CC
Morozovella aequa (Cushman and Renz, 1942)	0.5	23X-CC

Chiloguembelina midwayensis
(Pl. 2, Figs. 3, 4, and 7)

Guembelina midwayensis Cushman, 1940, p. 65, pl. 11, fig. 15.

Remarks. This species is rare in the Paleocene at Sites 752 and 758.

Chiloguembelina subtriangularis
(Pl. 2, Fig. 5)

Chiloguembelina subtriangularis Beckmann, 1957, p. 91, pl. 21, figs. 5a–5b, p. 85, text fig. 15, nos. 39–42.

Remarks. This species is rare to very rare in 125–250-μm fractions at Sites 752 and 758, but abundant in some of the <125-μm fractions at Site 758.

Chiloguembelina wilcoxensis

Guembelina wilcoxensis Cushman and Ponton, 1932a, p. 66, pl. 8, figs. 16–17.

Remarks. *C. wilcoxensis* is usually rare in upper Paleocene–lower Eocene samples from Sites 752 and 757.

Genus *Gublerina* Kikoine, 1948

Gublerina acuta

Gublerina acuta robusta de Klasz, 1953b, p. 247, figs. 4a–5b.

Remarks. This species is rare in the upper Maestrichtian at Sites 752 and 758. This local range is paleoenvironmentally controlled, as elsewhere the species is known to range throughout the Maestrichtian.

Genus *Guembelitria* Cushman, 1933

Guembelitria columbiana
(Pl. 2, Fig. 6)

Guembelitria columbiana Howe, 1939, p. 62, pl. 8, figs. 12–13.

Remarks. *G. columbiana* occurs in the <125-μm fraction of several Eocene samples. Usually it is rare and extremely small. It is most common at Site 753, where it occurs throughout the middle Eocene. Usually, it is found in the mid-middle Eocene (Kroon and Nederbragt, in press). This species can be so extremely small that it will pass through the commonly used 63-μm sieves.

Guembelitria cretacea

Guembelitria cretacea Cushman, 1933, p. 37, pl. 4, figs. 12a–12b.

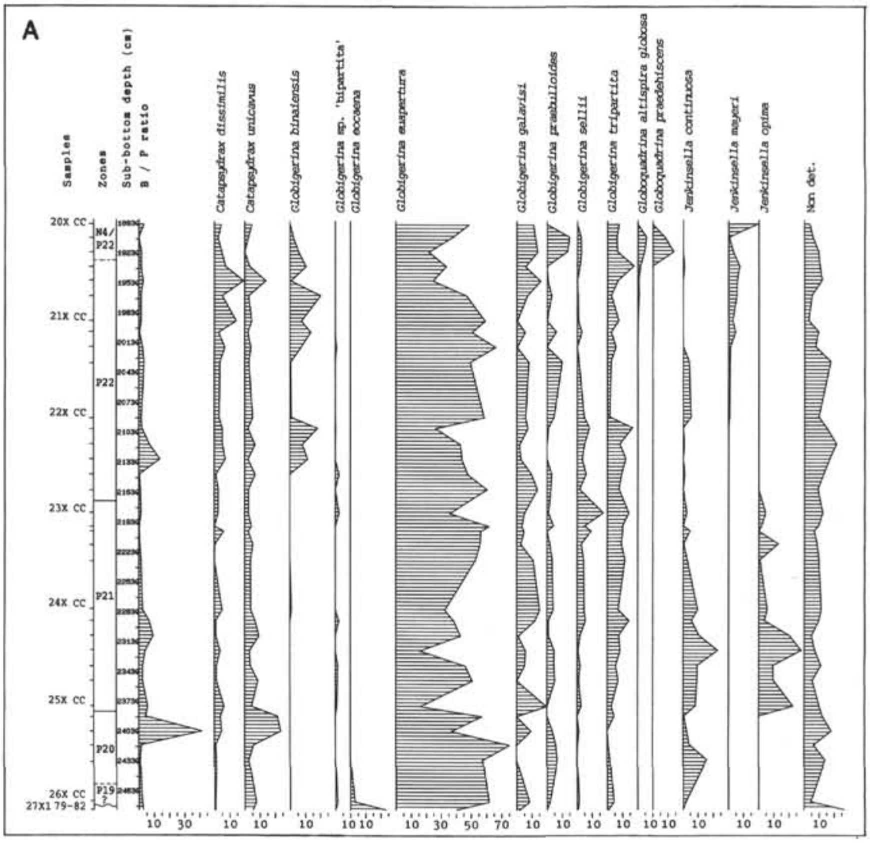
Remarks. We observed a single, poorly preserved specimen in the <125-μm fraction of Sample 121-752B-10R-6, 130–133 cm.

Genus *Heterohelix* Ehrenberg, 1843

Heterohelix costulata

Guembelina costulata Cushman, 1938, p. 16–17, pl. 3, figs. 7a–9.

Remarks. *H. costulata* is extremely rare in the upper Maestrichtian at Site 752. Its local range is paleoenvironmentally controlled, and elsewhere it is known to range from the middle Campanian to the top of the Maestrichtian.



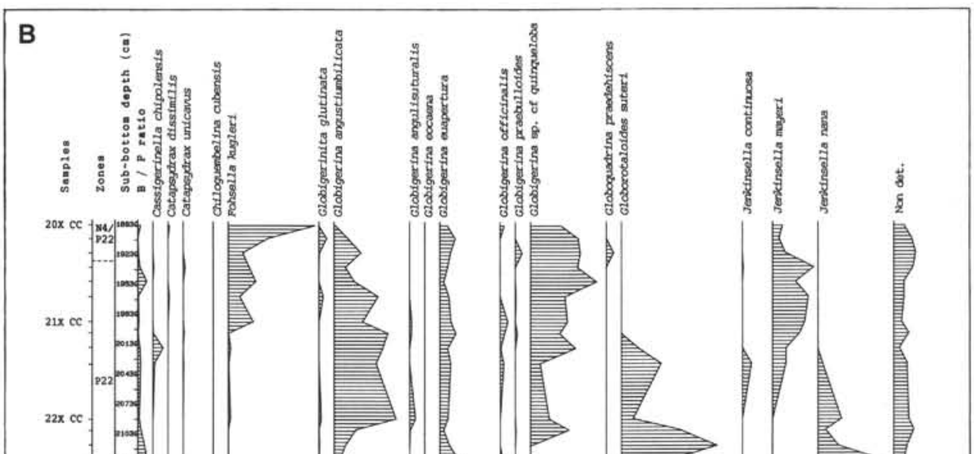


Figure 22. Frequency distribution of selected Oligocene planktonic foraminifers from Hole 758A. Vertical scale 1:300. **A.** Specimens >250 µm. **B.** Specimens 125–250 µm.

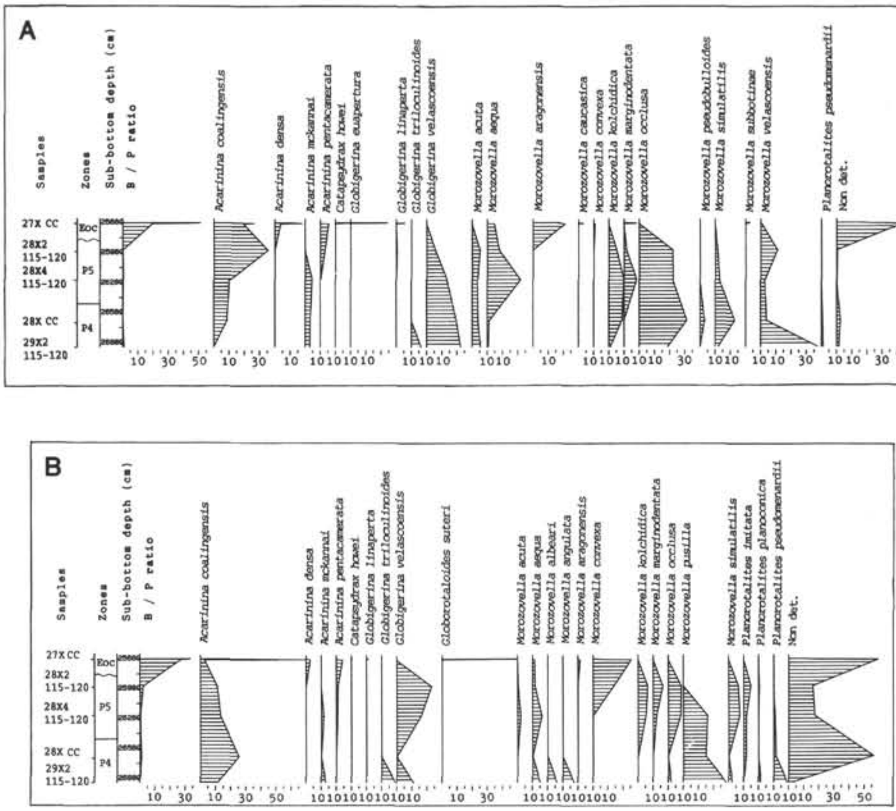


Figure 23. Frequency distribution of selected late Paleocene–Eocene planktonic foraminifers from Hole 758A. Vertical scale 1:300. **A.** Specimens >250 µm. **B.** Specimens 125–250 µm.

Heterohelix dentata

Heterohelix dentata Stenestad, 1968, p. 67–68, pl. 1, figs. 3–6, 8–9.

Remarks. This species is extremely rare in the upper Maestrichtian at Sites 752 and 758. As it is known to range from the upper Campanian to the upper Maestrichtian, its local range is paleoenvironmentally controlled.

Heterohelix globulosa

Textularia globulosa Ehrenberg, 1840, p. 135, pl. 4, figs. 2, 4–5, 7–8.

Remarks. Intermediate forms with the more compressed *H. planata* (Cushman, 1938) are common. This species is rare in all Maestrichtian samples, and more common in older samples.

Heterohelix planata

Guembelina planata Cushman, 1938, p. 12–13, pl. 2, figs. 13a–14.

Remarks. Intermediate forms with *H. globulosa* (Ehrenberg, 1840), which has more globular chambers, and *H. rajagopalani* (Govindan, 1972), which is ornamented, are common. It typically dominates the 125–250-µm fraction of the pre-Maestrichtian samples. Although the species has a conspicuous first appearance within the Campanian at Site 754, it is known to range from the lowermost Campanian to the Maestrichtian.

Heterohelix punctulata

Guembelina punctulata Cushman, 1938, p. 13, pl. 2, figs. 15–16b.

Remarks. *H. punctulata* is usually rare but widespread in the Maestrichtian and Campanian samples. Elsewhere, it is most abundant in the upper Campanian (Pessagno, 1967).

Heterohelix rajagopalani

Gublerina rajagopalani Govindan, 1972, p. 170, pl. 2, figs. 1–5.

Remarks. Intermediate forms with the unornamented *H. planata* (Cushman, 1938) are common. Occurring from the middle Maestrichtian upward, its local range is paleoenvironmentally controlled, as elsewhere it is known to occur in the lower Maestrichtian as well.

Heterohelix semicostata

Gublerina semicostata Cushman, 1938, p. 16, pl. 3, figs. 6a–6b.

Remarks. *H. semicostata* is extremely rare when present in the upper Maestrichtian of Site 758.

Genus *Planoglobulina* Cushman, 1927c

Planoglobulina acervulinoides

Guembelina acervulinoides Egger, 1899, p. 35, pl. 14, figs. 20–22 (non figs. 14–18).

Remarks. *P. acervulinoides* is rare to common in the *A. mayaroensis* Zone at Sites 752 and 758.

Planoglobulina multicamerata

Ventilabrella multicamerata de Klasz, 1953a, p. 230, pl. 5, figs. 1a–1b.

Remarks. This species was found outside of the count in Sample 121-758B-31X-CC.

Planoglobulina riograndensis

Ventilabrella riograndensis Martin, 1972, p. 88–89, pl. 2, figs. 1–4b.

Remarks. *P. riograndensis* was found outside of the count in Sample 121-758B-31X-CC.

Genus *Pseudoguembelina* Brönnimann and Brown, 1953

Pseudoguembelina costulata

Guembelina costulata Cushman, 1946, p. 108, pl. 46, figs. 10a–10b.

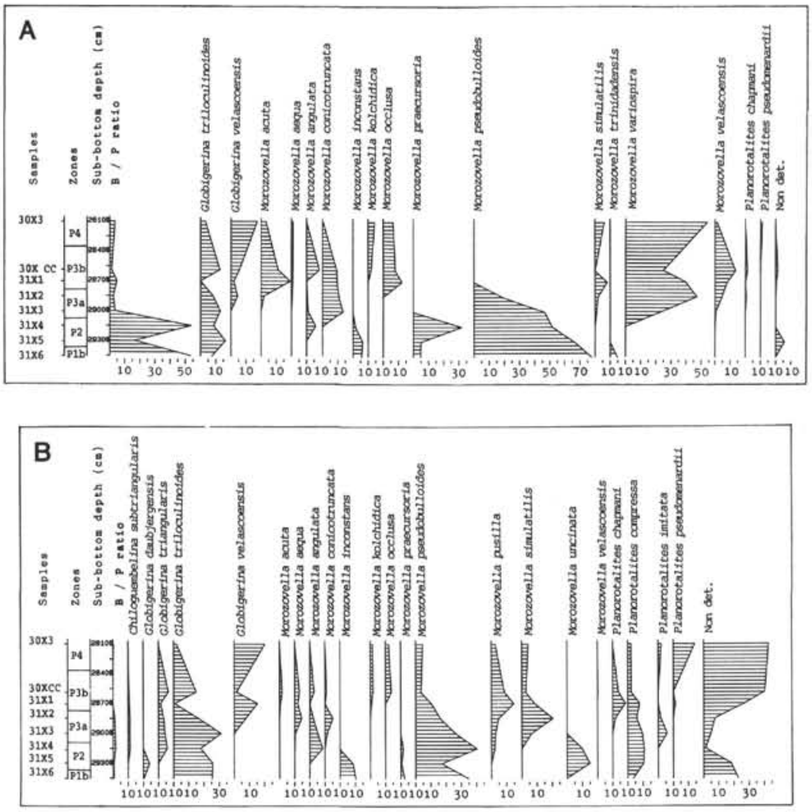


Figure 24. Frequency distribution of selected Paleocene planktonic foraminifers from Hole 758A. Vertical scale 1:300. **A.** Specimens >250 μm. **B.** Specimens 125–250 μm.

Remarks. This species is extremely rare in the upper Maestrichtian at Site 758.

Pseudoguembelina palpebra

Pseudoguembelina palpebra Brönnimann and Brown, 1953, p. 155, text figs. 9a–10b.

Remarks. This species is usually rare; we found it in the upper Maestrichtian at Site 758. Elsewhere it is also known from the middle Maestrichtian.

Genus *Pseudotextularia* Rzehak, 1891

Pseudotextularia elegans

Cuneolina elegans Rzehak, 1891, p. 4.

Remarks. *P. elegans* is rare in the upper Maestrichtian. As it is known elsewhere from the lower and middle Maestrichtian, its local range is paleoenvironmentally controlled.

Pseudotextularia intermedia

Pseudotextularia intermedia de Klasz, 1953a, p. 231, pl. 5, figs. 2a–2c.

Remarks. *P. intermedia* is extremely rare in the upper Maestrichtian at Site 758.

Pseudotextularia nuttalli

Guembelina nuttalli Voorwijk, 1937, p. 192, pl. 2, figs. 1–9.

Remarks. Rare specimens probably referable to this species (A. J. Nederbragt, pers. comm., 1990) occur in the upper Maestrichtian at Site 758.

Genus *Racemiguembelina* Montanaro Gallitelli, 1957

Racemiguembelina fructicosa

Guembelina fructicosa Egger, 1899, p. 36, pl. 14, figs. 8–9, not figs. 24–26.

Remarks. *R. fructicosa* occurs outside of the count in Sample 121-758B-31X-CC.

Family GLOBOTRUNCANIDAE Brotzen, 1942

Genus *Abathomphalus* Bolli, Loeblich, and Tappan, 1957

Abathomphalus mayaroensis

Globotruncana mayaroensis Bolli, 1951, p. 190, 198, pl. 35, figs. 10–12.

Remarks. Rare and usually rather small, with a weakly developed second keel, the encountered *A. mayaroensis* specimens are intermediate with *A. intermedius* (Bolli, 1951) at Sites 752, 754, and 758.

Abathomphalus intermedius

Globotruncana intermedia Bolli, 1951, p. 198, pl. 35, figs. 7–9.

Remarks. Usually rare, commonly small, and with the second keel typically weakly developed, the *A. intermedius* that were found are intermediate with *Globotruncanella pschadae* (Keller, 1946).

Genus *Archaeoglobigerina* Pessagno, 1967

Archaeoglobigerina australis
(Pl. 1, Figs. 1–3)

Archaeoglobigerina australis Huber, 1990, pl. 2, figs. 11–13, pl. 3, figs. 1–7.

Remarks. The presence of many forms intermediate with *Rugoglobigerina pennyi* Brönnimann, 1952a shows the close affinities of *Archaeoglobigerina* with *Rugoglobigerina*. We consider it to be the unornamented (high latitude?) equivalent of *R. pennyi*.

Archaeoglobigerina blowi

Archaeoglobigerina blowi Pessagno, 1967, p. 316, pl. 59, figs. 5–7.

Remarks. Intermediate forms with *R. rugosa* (Plummer, 1926) occur in the Maestrichtian, but the species also occurs in older samples. The

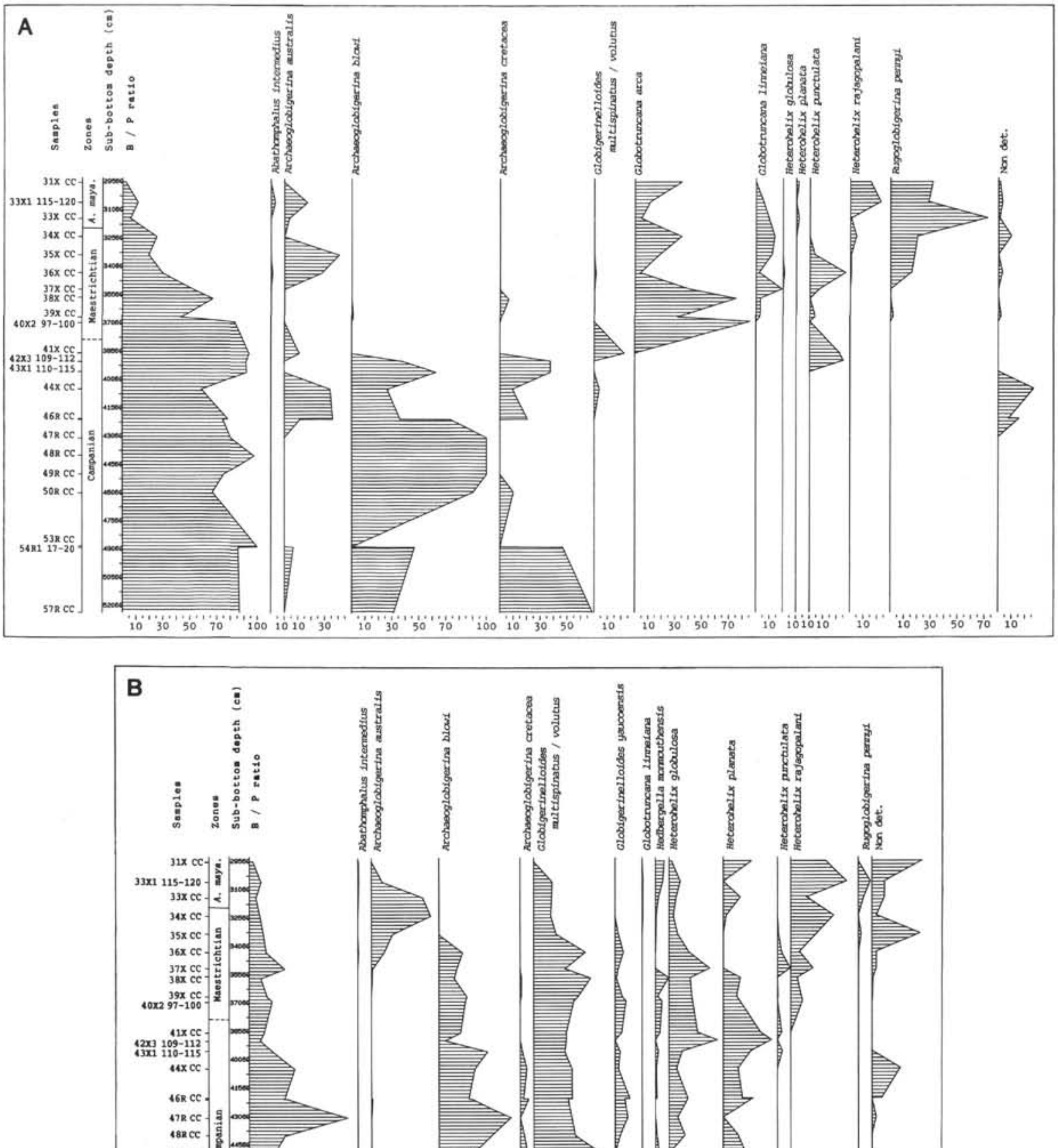


Figure 25. Frequency distribution of selected Cretaceous planktonic foraminifers from Hole 758A. Vertical scale 1:1500. Note scale difference with previous figures. **A.** Specimens >250 µm. **B.** Specimens 125–250 µm.

commonly dominating occurrence in the 125–250-µm fractions is due to the "dumping" of small *Archaeoglobigerina* forms into this species.

Archaeoglobigerina bosquensis

Archaeoglobigerina bosquensis Pessagno, 1967, p. 316–317, pl. 60, figs. 10–12.

Remarks. If present, *A. bosquensis* has been counted as *A. australis* Huber, 1990.

Archaeoglobigerina cretacea
(Pl. 1, Figs. 4 and 5)

Globigerina cretacea d'Orbigny, 1840, p. 34, pl. 3, figs. 12–14.

Remarks. Higher trochospiral forms, which are intermediate between this species and *A. australis*, are common. In the Maestrichtian, intermediate forms with *Rugoglobigerina hexacamerata* Brönnimann, 1952a also occur. The species is most common in Campanian samples.

Genus *Dicarinella* Porthauld, 1970

Dicarinella canaliculata

Rosalina canaliculata Reuss, 1854, p. 70, pl. 26, figs. 4a–4b.

Remarks. This species occurs only in Sample 121-755A-13R-4, 16–19 cm.

Dicarinella hagni

Praeglobotruncana hagni Scheibnerova, 1962, p. 219, figs. 6a–6c.

Remarks. Forms intermediate between this species and *D. imbricata* (Mornod, 1949–1950) occur in Sample 121-755A-17R-3, 114–117 cm.

Dicarinella imbricata

Globotruncana (Globotruncana) imbricata Mornod, 1949–1950, p. 589–590, fig. 5 (IIIa–IIId).

Remarks. See *D. hagni* (Scheibnerova, 1962).

Genus *Globotruncana* Cushman, 1927a

Globotruncana arca

Pulvinulina arca Cushman, 1926, p. 23, pl. 3, figs. 1a–1c.

Remarks. Forms intermediate between this species and *G. rugosa* (Marie, 1941) occur. Its local range is paleoenvironmentally controlled, and elsewhere it ranges from the Santonian to the middle Maestrichtian. We found it in the middle and also the upper Maestrichtian.

Globotruncana linneiana

Rosalina linneiana d'Orbigny, 1839, p. 101, pl. 5, figs. 10–12.

Globotruncana orientalis

Globotruncana orientalis El Naggar, 1966, p. 125, pl. 12, figs. 4a–4d.

Remarks. *G. orientalis* occurs in the Maestrichtian at Site 758 only, but is abundant in some >250-µm fractions.

Globotruncana rosetta

Globigerina rosetta Carsey, 1926, p. 44, pl. 5, figs. 3a–3b.

Remarks. *G. rosetta* was found in Sample 121-758B-31X-CC only.

Globotruncana rugosa

Rosalinella rugosa Marie, 1941, p. 240, pl. 36, fig 3. 340a–340c.

Remarks. See *G. arca* (Cushman, 1926), of which it is a high-latitude variant.

Globotruncana ventricosa

Globotruncana canaliculata var. *ventricosa* White, 1928, p. 284, pl. 38, figs. 3a–3c.

Remarks. This species was found only in the >250-µm fraction of Samples 121-758B-31X-CC and 121-758B-39X-CC.

Genus *Globotruncanella* Reiss, 1957

Globotruncanella havanensis

Globotruncana havanensis Voorwijk, 1937, p. 195, pl. 1, figs. 25–26, 29. Redescribed and refigured by van Hinte (1963), pl. 12, figs. 1a–1c.

Remarks. *G. havanensis* is widespread but usually rare.

Globotruncanella petaloidea

Globotruncana (Rugoglobigerina) petaloidea subsp. *petaloidea* Gandolfi, 1955, p. 52, pl. 3, figs. 13a–13c.

Remarks. *G. petaloidea* is rare in the Maestrichtian at Site 758.

Globotruncanella pschadae

Globorotalia pschadae Keller, 1946, p. 99, pl. 2, figs. 4–6.

Remarks. *G. pschadae* is widespread but usually rare.

Genus *Globotruncanita* Reiss, 1957

Globotruncanita angulata

Globotruncana lugeoni Tilev, var. *angulata* Tilev, 1951, p. 46, pl. 3, figs. 1a–1c, 13a–13c.

Remarks. We observed a single specimen in Sample 121-752B-11R-3, 96–97 cm.

Globotruncanita stuarti

Rosalina stuarti de Lapparent, 1918, p. 11, pl. 1, figs. 5–7, pl. 4 (p. 12), pl. 5 (p. 13).

Remarks. *G. stuarti* occurs outside of the count in Sample 121-758B-31X-CC.

Globotruncanita stuartiformis

Globotruncana (Globotruncana) elevata Brotzen, subsp. *stuartiformis* Dalbiez, 1955, p. 169, text figs. 10a–10c.

Remarks. This species occurs outside of the count in Sample 121-758B-31X-CC.

Genus *Hedbergella* Brönnimann and Brown, 1958

Hedbergella holmdelensis

Hedbergella holmdelensis Olsson, 1964, p. 160, pl. 1, figs. 2a–2c.

Remarks. This species is very rare and we included it in the count of *H. monmouthensis* (Olsson, 1960).

Hedbergella monmouthensis

Globorotalia monmouthensis Olsson, 1960, p. 47, pl. 9, figs. 22–24.

Remarks. See *H. holmdelensis* Olsson, 1964.

Hedbergella planispira
(Pl. 1, Figs. 6–8)

Globigerina planispira Tappan, 1940, p. 122, pl. 9, figs. 12a–12c.

Remarks. Although the range of this species is reported as Turonian-Cenomanian, small specimens indistinguishable from *H. planispira* occur in many samples of Maestrichtian and Campanian age.

Genus *Marginotruncana* Hofker, 1956

Marginotruncana coronata

Globotruncana lapparenti Brotzen, subsp. *coronata* Bolli, 1945, p. 233, text fig. 1, nos. 21–22, pl. 9, figs. 14–15.

Marginotruncana marginata

Rosalina marginata Reuss, 1854, p. 36, pl. 13, figs. 18a–18b.

Marginotruncana pseudolinneiana

Marginotruncana pseudolinneiana Pessagno, 1967, p. 310, pl. 65, figs. 24–27, pl. 76, figs. 1–3.

Genus *Rosita* Robaszynski, Caron, Gonzalez Donoso, and Wonders, 1984

Rosita walfischensis

Globotruncana walfischensis Todd, 1970, p. 153, pl. 5, figs. 8a–8b.

Remarks. *R. walfischensis* was found in Sample 121-758B-31X-CC only.

Genus *Rugoglobigerina* Brönnimann, 1952a

Rugoglobigerina hexacamerata

Rugoglobigerina (Rugoglobigerina) reicheli hexacamerata Brönnimann, 1952a, p. 23, pl. 2, figs. 10–12.

Remarks. *R. hexacamerata* occurs in the Maestrichtian and is usually rare. Intermediate forms with its ancestor, *Archaeoglobigerina cretacea* (d'Orbigny, 1840), and its descendant, *Rugotruncana subcircumnodifer* (Gandolfi, 1955), occur.

Table 7. Distribution of additional species from Hole 758A.

Species	Frequency (%)	Core, section, interval (cm)
Oligocene >250 μm		
Globigerina ampliapertura Bolli, 1957a	1.0	25X-CC
Globigerina angiporoides Hornibrook, 1965	2.0	26X-CC
Globigerina binaiensis Koch, 1935		23X-4, 110–115
		24X-4, 110–115
		25X-1, 110–115
Globigerina gortanii (Borsetti, 1959)	6.3	25X-CC
Turborotalia increbescens (Bandy, 1949)	0.5	26X-CC
<250 μm		
Aff. *Clavatorella nicobarensis* Srinivasan and Kennett, 1976	1.3	21X-1, 110–115
	0.4	21X-2, 110–115
Globigerina ampliapertura Bolli, 1957a	0.6	26X-3, 110–115
Globigerina ciperoensis Bolli, 1954	1.2	21X-3, 110–115
	0.4	22X-CC
Globigerina ouachitaensis Howe and Wallace, 1932	0.7	25X-3, 110–115
"*Globorotalia*" *postcretacea* (Myatliuk, 1950)	0.4	23X-2, 110–115
	0.8	24X-2, 110–115
Pseudohastigerina naguewichiensis (Myatliuk, 1950) (<125 μm)		27X-1, 110–115
Tenuitella munda (Jenkins, 1966)	1.1	22X-CC
Turborotalia increbescens (Bandy, 1949)	0.5	26X-4, 110–115
upper Paleocene–Eocene <250 μm		
Chiloguembelina midwayensis (Cushman, 1940)	2.8	27X-CC
Chiloguembelina subtriangularis Beckmann, 1957 (<125 μm)		29X-2, 110–115
Globigerina triangularis White, 1928	0.5	28X-2, 110–115
	0.9	28X-4, 110–115
Morozovella pseudobulloides (Plummer, 1926)	0.5	28X-CC
Pseudohastigerina naguewichiensis (Myatliuk, 1950)	0.5	27X-CC, 27–29
Truncorotaloides rohri Brönnimann and Bermudez, 1953	0.4	27X-CC, 32–34
Paleocene >250 μm		
Morozovella albeari (Cushman and Bermudez, 1949)	1.1	30X-3, 110–115
	0.5	30X-CC
	0.5	31X-3, 110–115
Morozovella kolchidica (Morozova, 1961) (observed)		31X-1, 110–115
<250 μm		
Chiloguembelina midwayensis (Cushman, 1940) (<125 μm)		31X-1, 110–115, 31X-2, 110–115
Chiloguembelina subtriangularis Beckmann, 1957 (<125 μm)		30X-3, 110–115, 31X-5, 110–115
Morozovella albeari (Cushman and Bermudez, 1949)	0.9	30X-CC
Planorotalites imitata (Subbotina, 1953) (<125 μm)		31X-4, 110–115
Planorotalites planoconica Subbotina, 1953)	1.0	30X-3, 110–115

Rugoglobigerina pennyi
(Pl. 1, Fig. 9)

Rugoglobigerina (Rugoglobigerina) rugosa pennyi Brönnimann, 1952a, p. 34, pl. 4, figs. 1–3.

Remarks. Dominant in some >250-μm fractions. Specimens possibly referable to *R. milamensis* Smith and Pessagno, 1973 and *R. rotundata* Brönnimann, 1952a have been included in the count of this species. It is connected with other *Rugoglobigerina* species and with *Archaeoglobigerina australis* Huber, 1990 by intermediate forms.

Rugoglobigerina rugosa
(Pl. 1, Figs. 10 and 11)

Globigerina rugosa Plummer, 1926, p. 38, pl. 2, figs. 10a–10d.

Remarks. This species is widespread but rarely common in the Maestrichtian. Intermediate forms with *Archaeoglobigerina blowi* Pessagno, 1967 and *R. pennyi* Brönnimann, 1952a occur commonly.

Genus *Rugotruncana* Brönnimann and Brown, 1956

Rugotruncana subcircumnodifer
(Pl. 1, Figs. 12–15)

Globotruncana (Rugoglobigerina) pennyi subcircumnodifer Gandolfi, 1955, p. 73, pl. 7, figs. 7a–7c.

Remarks. Rare to fairly common in the middle Maestrichtian at Site 752, it is connected with *Rugoglobigerina hexacamerata* Brönnimann, 1952a by intermediate forms.

Genus *Whiteinella* Pessagno, 1967

Whiteinella baltica

Whiteinella baltica Douglas and Rankin, 1969, p. 197, text figs. 9a–9i.

Whiteinella brittonensis

Hedbergella brittonensis Loeblich and Tappan, 1961, p. 274–275, pl. 4, figs. 1–8.

Family PLANOMALINIDAE Bolli, Loeblich, and Tappan, 1957
Genus *Globigerinelloides* Cushman and Ten Dam, 1948

This genus is common to dominant in most of the 125–250-μm fractions of Cretaceous age. A number of species have been described, but we could recognize only a few of them. As their stratigraphic use is limited, we grouped them in a few loosely interpreted species. *G. subcarinatus* (Brönnimann, 1952a) is flat, with a final whorl with few, abruptly enlarging chambers, and this definition is not modified. *G. multispinatus* (Lalicker, 1948) includes forms with two apertures as well as the more common forms with a single aperture. It is wider than *G. volutus* (White, 1928), which has a smoother wall and chambers that

Table 7 (continued).

Species	Frequency (%)	Core, section, interval (cm)
Cretaceous >250 μm		
Abathomphalus mayaroensis (Bolli, 1951)	1.1	33X-CC
Globotruncana rosetta (Carsey, 1926)	8.9	31X-CC
Globotruncana rugosa (Marie, 1941)	1.1	33X-CC
Globotruncana ventricosa White, 1928	0.5	31X-CC
	4.0	39X-CC
Gublerina acuta de Klasz, 1953b	3.7	31X-CC
Planoglobulina acervulinoides (Egger, 1899)	0.6	36X-CC
Pseudotextularia nuttalli (Voorwijk, 1937)	0.5	33X-1, 115–120
Rosita walfischensis (Todd, 1970)	0.9	31X-CC
Rugoglobigerina hexacamerata Brönnimann, 1952a	0.5	31X-CC
	5.7	33X-1, 115–120
Occurring outside of the count in Sample 121-758A-31X-CC only		
Globotruncanita stuarti (de Lapparent, 1918)		
Globotruncanita stuartiformis (Dalbiez, 1955)		
Planoglobulina multicamerata (de Klasz, 1953a)		
Planoglobulina riograndensis (Martin, 1972)		
Pseudotextularia intermedia de Klasz, 1953a		
Racemiguembelina fructicosa (Egger, 1899)		
<250 μm		
Globotruncana arca (Cushman, 1926)	1.9	31X-CC
	2.1	34X-CC
	0.4	39X-CC
Globotruncanella petaloidea (Gandolfi, 1955)	0.8	35X-CC
	0.5	38X-CC
Globotruncanella pschadae (Keller, 1946) (observed)	1.4	31X-CC
		33X-CC
Gublerina acuta de Klasz, 1953b	1.4	31X-CC
Hedbergella planispira (Tappan, 1940)	1.0	53R-CC
	0.8	54R-1, 17–20
	2.7	57R-CC
Heterohelix dentata Stenestad, 1968	0.6	33X-CC
Heterohelix semicostata (Cushman, 1938)	0.5	37X-CC
Pseudotextularia nuttalli (Voorwijk, 1937)	0.6	33X-CC
Rugoglobigerina hexacamerata Brönnimann, 1952a	0.6	33X-CC

increase less abruptly in size. These species, which intergrade in the lower Maestrichtian, were counted together. Finally, *G. yaucoensis* (Pessagno, 1960) is used for all forms with many (>5) chambers in the final whorl, such as *G. impensus* Sliter, 1977 and *G. prairihillensis* Pessagno, 1967.

Globigerinelloides asperus

Phanerostomum asperum Ehrenberg, 1854, p. 23, pl. 30, figs. 26a–26b, pl. 32, figs. 24, 42.

Remarks. Where present (in some samples from Site 755) *G. asperus* has been counted as *G. yaucoensis* (Pessagno, 1960).

Globigerinelloides multispinatus

Biglobigerinella multispinatus Lalicker, 1948, p. 624, pl. 92, figs. 1–3.

Remarks. This species is common to dominant in most of the 125-250-μm fractions of Cretaceous age.

Globigerinelloides subcarinatus

Globigerinella messinae subcarinata Brönnimann, 1952a, p. 44–45, pl. 1, figs. 10–11, text figs. 21a–21m.

Globigerinelloides volutus
(Pl. 1, Figs. 16 and 17)

Globigerina voluta White, 1928, p. 197–198, pl. 28, figs. 5a–5b.

Remarks. *G. volutus* is common to dominant in most of the 125–250-μm fractions of Cretaceous age.

Globigerinelloides yaucoensis
(Pl. 1, Figs. 18–20)

Planomalina yaucoensis Pessagno, 1960, p. 98, pl. 2, figs. 14–15, pl. 5, fig. 4.

Family GLOBIGERINIDAE Carpenter, Parker, and Jones, 1862
Genus *Catapsydrax* Bolli, Loeblich, and Tappan, 1957

Catapsydrax dissimilis

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

Remarks. *C. dissimilis* is widespread but rarely common.

Catapsydrax howei

Globigerinita howei Blow and Banner, 1962, p. 109, fig. 11, x–xiv, pl. 14, figs. p–r.

Remarks. We may have confused this species with *Globigerina cryptomphala* Glaessner, 1937 in poorly preserved faunas.

Catapsydrax unicavus

Catapsydrax unicavus Bolli, Loeblich, and Tappan, 1957, p. 37, pl. 7, fig. 9.

Remarks. *C. unicavus* can resemble compact *Globigerinas* with an aberrant final chamber. The abundances are, therefore, not reliable.

Genus *Globigerina* d'Orbigny, 1826

Globigerina ampliapertura

Globigerina ampliapertura Bolli, 1957a, p. 108, pl. 22, figs. 4–7.

Remarks. This distinct marker species is rare in early Oligocene faunas.

Globigerina angiporoides
(Pl. 2, Fig. 8)

Globigerina angiporoides Hornibrook, 1965, p. 834–838, figs. 1–2.

Remarks. Typical specimens are rare and many are intermediate with *G. linaperta* Finlay, 1939a. The species is most common at Sites 756 and 757.

Globigerina angulisuturalis

Globigerina ciperoensis angulisuturalis Bolli, 1957a, p. 109, pl. 22, fig. 11.

Remarks. This zonal marker is very rare at Sites 757 and 758. All specimens found are intermediate with *G. angustiumbilicata* Bolli, 1957a.

Globigerina angustiumbilicata
(Pl. 2, Fig. 9)

Globigerina ciperoensis angustiumbilicata Bolli, 1957a, p. 109, pl. 22, figs. 12–13.

Remarks. *G. angustiumbilicata* is common to abundant in most middle and upper Oligocene 125–250- and <125-µm fractions. Many specimens show four abruptly enlarging chambers in the final whorl and a somewhat extraumbilical aperture. These are lower trochospiral than *G. officinalis* Subbotina, 1953 and bullaless *Globigerinita glutinata* (Egger, 1893).

Globigerina binaiensis

Globigerina binaiensis Koch, 1935, p. 558.

Remarks. Rare at Site 757, this species is more common at Site 758, where it ranges up into the lower Miocene, where we saw it co-occurring with *Fohsella peripheroronda* (Blow and Banner, 1966).

Globigerina sp. "*bipartita*"
(Pl. 2, Figs. 10–12)

Remarks. See *Globigerina tripartita* Koch, 1926.

Globigerina bulloides

Globigerina bulloides d'Orbigny, 1826, p. 277, no. 1.

Remarks. As true *G. bulloides* is very rare in the upper Oligocene at Site 758, we counted the few specimens as *G. praebulloides* Blow, 1959.

Globigerina ciperoensis

Globigerina ciperoensis Bolli, 1954, p. 1–3, figs. 3–4.

Remarks. This zonal marker is very rare at Sites 757 and 758. Most specimens we observed are intermediate with *G. angustiumbilicata* Bolli, 1957a.

Globigerina corpulenta

Globigerina corpulenta Subbotina, 1953, p. 76, pl. 9, figs. 5–7, pl. 10, figs. 1–4.

Remarks. This species differs from *G. gortanii* (Borsetti, 1959) by being lower trochospiral.

Globigerina cryptomphala

Globigerina bulloides d'Orbigny, var. *cryptomphala* Glaessner, 1937, p. 29, pl. 1, fig. 1.

Remarks. *G. cryptomphala* can resemble *Catapsydrax howei* (Blow and Banner, 1962). We consider it an extreme form of *G. eocaena* Guembel, 1868 with an aberrant final chamber.

Globigerina daubjergensis

Globigerina daubjergensis Brönnimann, 1953, p. 340, fig. 1.

Globigerina edita

Globigerina edita Subbotina, 1953, p. 62–63, pl. 2, figs. 1a–1c.

Globigerina eocaena

Globigerina eocaena Guembel, 1868, p. 662, pl. 2, fig. 109. (Em. Hagn and Lindenberg, 1966.)

Remarks. Intermediate forms with other *Globigerina* species are common. Aberrant final chambers occur commonly.

Globigerina euapertura
(Pl. 2, Figs. 13–16)

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

Remarks. All specimens of *Globigerina* with three to four appressed chambers in the final whorl, when not referable to any other species, were lumped under *G. euapertura*. More commonly than not, the final chamber is aberrant, commonly rendering it hard to distinguish from *Catapsydrax*. Our use of this "species" as a "waste basket" only partly explains its extreme abundance (up to 90%).

Globigerina fringa

Globigerina fringa Subbotina, 1950, p. 104, pl. 5, figs. 19–21.

Remarks. Forms intermediate between this species and *G. triloculinoides* Plummer, 1926 occur in the lowermost Paleocene of Site 752.

Globigerina frontosa

Globigerina frontosa Subbotina, 1953, p. 84, pl. 12, figs. 3–7.

Remarks. *G. frontosa* is a useful indicator for the lower half of the middle Eocene.

Globigerina galavisi
(Pl. 2, Fig. 17)

Globigerina galavisi Bermúdez, 1960, p. 1183–1184, pl. 4, fig. 3.

Remarks. *G. galavisi* is intermediate between *G. venezoelana* Hedberg, 1937 (which is larger and has more appressed chambers) and *G. euapertura* Jenkins, 1960 (which is smaller and more compact). Aberrant final chambers occur commonly.

Globigerina gortanii

Catapsydrax gortanii Borsetti, 1959, p. 205–212, pl. 1, fig. 1.

Globigerina inaequispira

Globigerina inaequispira Subbotina, 1953, p. 69, pl. 6, figs. 1–4.

Globigerina linaperta

Globigerina linaperta Finlay, 1939a, p. 125, pl. 3, figs. 54–56.

Remarks. Intermediate forms with *G. eocaena* Guembel, 1868 occur in the lower Eocene, and intermediate forms with *G. angiporoides* Hornibrook, 1965 occur in the upper Eocene/lower Oligocene.

Globigerina officinalis

Globigerina officinalis Subbotina, 1953, p. 78, pl. 11, figs. 1–7.

Remarks. *G. officinalis* is the ancestor of *Globigerinita glutinata* (Egger, 1893), from which it differs by being less compact and lacking a bulla. Four-chambered *G. angustiumbilicata* Bolli, 1957a specimens are lower trochospiral.

Globigerina ouachitaensis

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

Globigerina praebulloides
(Pl. 2, Figs. 18–20)

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

Remarks. Intermediate forms with *G. euapertura* Jenkins, 1960 occur. It grades into *G. bulloides* d'Orbigny, 1826 and *Globoquadrina altispira globosa* Bolli, 1957a in the Oligocene-Miocene at Site 758. Aberrant final chambers occur commonly.

Globigerina quinqueloba
(Pl. 3, Figs. 1–3)

Globigerina quinqueloba Natland, 1938, p. 149, pl. 6, figs. 7a–7c.

Remarks. *Globorotaloides suteri* Bolli, 1957a is connected to a species resembling *G. quinqueloba* in the upper Oligocene at Sites 757 and 758 (Zones P22/N4) by intermediate forms. This form generally has five chambers in the final whorl (*Globorotaloides suteri* has three to four) and a more lobate outline. It is also connected with *Fohsella kugleri* (Bolli, 1957a), as indicated by intermediate forms.

Globigerina sellii

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

Remarks. *G. sellii* is usually rare and is connected with *G. binaiensis* Koch, 1935 and *G. tripartita* Koch, 1926 by intermediate forms.

Globigerina senni

Sphaeroidinella senni Beckmann, 1953, p. 394–395, fig. 20, pl. 26, figs. 2–4.

Remarks. Occurrences and abundances are not reliable, because as a result of poor preservation we often could not distinguish this species from *Acarinina coalingensis* (Cushman and Hanna, 1927), which has a more extraumbilical aperture. It seems to range somewhat higher.

Globigerina spiralis

Globigerina spiralis Bolli, 1957a, p. 70, pl. 16, figs. 16–18.

Globigerina tapuriensis

Globigerina tapuriensis Blow and Banner, 1962, p. 97–98, pl. 10, figs. h–k.

Remarks. We consider this form, with three chambers in the final whorl, as a variant of *G. euapertura* Jenkins, 1960.

Globigerina triangularis

Globigerina triangularis White, 1928, p. 195–196, pl 28, figs. 1a–1b.

Globigerina triloculinoides

Globigerina triloculinoides Plummer, 1926, p. 134, pl. 8, fig. 10.

Globigerina tripartita

Globigerina bulloides d'Orbigny, var. *tripartita* Koch, 1926, p. 746, figs. 21a–21b.

Remarks. This species is always underrepresented because it is commonly broken or damaged. Aberrant final chambers occur commonly. A variety of this species with two very large chambers in the final whorl (informally named *Globigerina* sp. "*bipartita*"; Pl. 2, Figs. 10–12) occurs in the Oligocene at Site 758.

Globigerina velascoensis

Globigerina velascoensis Cushman 1925d, p. 19, pl. 3, fig. 6.

Globigerina venezoelana

Globigerina venezoelana Hedberg, 1937, p. 681, pl. 92, fig. 7.

Remarks. If present, we counted this species as *G. galavisi* Bermúdez, 1960.

Genus *Globigerinatheka* Brönnimann, 1952b

Globigerinatheka barri

Globigerinatheka barri Brönnimann, 1952b, p. 27–28, fig. 1.

Remarks. As this species is rare and always co-occurs with *G. subconglobata* (Shutskaya, 1958), of which it may be a variety, we counted it as that species.

Globigerinatheka index
(Pl. 3, Figs. 4–9)

Globigerinoides index Finlay, 1939a, p. 125, pl. 14, figs. 85–88.

Remarks. Small specimens, usually with globular chambers and lacking accessory apertures, occur much more commonly than the species. Their distribution is listed under *Globigerinatheka* sp. cf. *G. index*.

Globigerinatheka subconglobata

Globigerinoides subconglobatus Chalilov, var. *subconglobatus* Shutskaya, 1958, p. 86–87, pl. 1, figs. 4–11.

Genus *Globigerinita* Brönnimann, 1951

Globigerinita glutinata

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

Remarks. This species is interpreted to include both forms with and without bulla. Many different forms occur in the Oligocene-Miocene. *Globigerinita naparimaensis* Brönnimann, 1951 and *Tinophodella ambitacrena* Loeblich and Tappan, 1957 are considered synonyms of *Globigerinita glutinata*.

Globigerinita uvula

Pylodexia uvula Ehrenberg, 1861, p. 206–207, 308.

Remarks. *G. uvula* is very rare. It was found in some late Oligocene age samples.

Genus *Globigerinoides* Cushman, 1927a

Globigerinoides, indicative for the Neogene, was observed in Samples 121-756B-7H-CC and 121-757B-11H-2, 110–115 cm. We recognized the following species:

Globigerinoides altiaperturus
(Pl. 3, Fig. 10)

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

Globigerinoides sacculifer

Globigerina sacculifera Brady, 1877, p. 535. Figs. in Brady, 1884, p. 604, pl. 80, figs. 11–17, pl. 81, fig. 2, pl. 82, fig. 4.

Globigerinoides trilobus
(Pl. 3, Fig. 11)

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

Genus *Globoquadrina* Finlay, 1947

Globoquadrina altispira globosa

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

Remarks. Occurring in the Oligocene-Miocene at Site 758, it is connected to *Globigerina praebulloides* Blow, 1959 by intermediate forms.

Globoquadrina dehiscens

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

Remarks. *G. dehiscens* is common to abundant in the Oligocene-Miocene at Sites 752, 754, and 756. Aberrant final chambers are very common.

Globoquadrina praedehiscens
(Pl. 3, Figs. 12 and 13)

Globoquadrina dehiscens praedehiscens Blow and Banner, 1962, p. 116, pl. 15, figs. q–s.

Remarks. *G. praedehiscens* is connected to *Globigerina euapertura* Jenkins, 1960), its probable ancestor, by intermediate forms. Aberrant final chambers occur commonly.

Genus *Zeaglobigerina* Kennett and Srinivasan, 1983

Zeaglobigerina labiacrassata

Globigerina labiacrassata Jenkins, 1966, p. 1102, fig. 8, nos. 64–71.

Zeaglobigerina woodi

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

Family GLOBOROTALIIDAE Cushman, 1927a
Genus *Acarinina* Subbotina, 1953

Acarinina angulosa

Globigerina soldadoensis angulosa Bolli, 1957b, p. 71, pl. 16, figs. 4–6.

Remarks. See *A. coalingensis* (Cushman and Hanna, 1927).

Acarinina broedermanni

Globorotalia broedermanni Cushman and Bermúdez, 1949, p. 40, pl. 7, figs. 22–24.

Acarinina coalingensis
(Pl. 3, Figs. 14–20, and Pl. 4, Fig. 6)

Globigerina coalingensis Cushman and Hanna, 1927, p. 219, pl. 14, figs. 4a–4b.

Remarks. This species is the central form in a plexus of four-chambered forms with more or less appressed chambers and a rounded or somewhat angular periphery (*A. soldadoensis angulosa* (Bolli, 1957b), *A. esnaensis* LeRoy, 1953, *A. nitida* (Martin, 1943), *A. pseudotopilensis* (Subbotina, 1953), and *A. soldadoensis* (Brönnimann, 1952c)). Because these are connected by intermediate forms and most have similar ranges, we counted them together. *A. primitiva* (Finlay, 1947) (= *Globoquadrina primitiva*) is a junior synonym.

Acarinina densa
(Pl. 4, Figs. 1 and 2 and cf Fig. 5)

Pulvinulina crassata Cushman, var. *densa* Cushman, 1925b, p. 301.

Remarks. This species (of which *A. bullbrooki* (Bolli, 1957a) is a junior synonym) is sporadically dominant in middle Eocene faunas. It is one of the few middle Eocene *Acarininas* clearly distinguishable from the *A. coalingensis* plexus.

Acarinina esnaensis

Globigerina esnaensis LeRoy, 1953, p. 31, pl. 6, figs. 8–10.

Remarks. See *A. coalingensis* (Cushman and Hanna, 1927).

Acarinina gravelli
(Pl. 4, Fig. 4)

Globigerina gravelli Brönnimann, 1952a, p. 12–13, pl. 1, figs. 16–18.

Remarks. Forms intermediate between *A. gravelli* and *A. pentacamerata* (Subbotina, 1947) occur. Also, there is some intergradation with the *A. coalingensis* plexus.

Acarinina mckannai

Globigerina mckannai White, 1928, p. 194, pl. 27, fig. 16.

Acarinina nitida

Globigerina nitida Martin, 1943, p. 115, pl. 7, figs. 1a–1c.

Remarks. See *A. coalingensis* (Cushman and Hanna, 1927).

Acarinina pentacamerata
(Pl. 4, Fig. 3, and cf Fig. 5)

Globorotalia pentacamerata Subbotina, 1947, p. 128, pl. 7, figs. 12–17 (non pl. 9, figs. 24–26).

Remarks. Intermediate forms between this species and *A. broedermanni* and *A. gravelli* occur, with some intergrading with the *A. coalingensis* plexus.

Acarinina primitiva

Globoquadrina primitiva Finlay, 1947, p. 291, pl. 8, figs. 129–134.

Remarks. See *A. coalingensis* (Cushman and Hanna, 1927).

Acarinina pseudotopilensis

Acarinina pseudotopilensis Subbotina, 1953, p. 227, pl. 21, figs. 8–9, pl. 22, figs. 1–3.

Remarks. See *A. coalingensis* (Cushman and Hanna, 1927).

Acarinina soldadoensis

Globigerina soldadoensis Brönnimann, 1952c, p. 7, 9, pl. 1, figs. 1–9.

Remarks. See *A. coalingensis* (Cushman and Hanna, 1927).

Acarinina wilcoxensis
(Pl. 4, Fig. 7)

Globorotalia wilcoxensis Cushman and Ponton, 1932a, p. 71, pl. 9, figs. 10a–10c.

Remarks. Specimens clearly referable to this species are common (27%) only in Sample 121-752A-13X-3, 110–115 cm.

Genus *Clavatorella* Blow, 1965

Clavatorella nicobarensis
(Pl. 4, Figs. 8–12)

Clavatorella nicobarensis Srinivasan and Kennett, 1976, p. 74–79, pl. 1, figs. 1–13.

Remarks. A species indistinguishable from *C. nicobarensis* occurs in the uppermost Oligocene at Sites 757 and 758, although its reported range is upper Miocene–Pliocene.

Genus *Fohsella* Kennett and Srinivasan, 1983

Fohsella kugleri
(Pl. 4, Figs. 13 and 14)

Globorotalia kugleri Bolli, 1957a, p. 118, pl. 28, figs. 5–6.

Remarks. *F. kugleri* is common to dominant in the 125–250-µm and <125-µm fractions of many upper Oligocene samples. The species is connected to a form related to *Globorotaloides suteri* Bolli, 1957a, (here named *Globigerina* sp. cf. *G. quinqueloba* Natland, 1938) by intermediate forms. As the phylogenetical position of *F. kugleri* is uncertain, this may be significant.

Genus *Globigerinella* Cushman, 1927a

Globigerinella obesa

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

Remarks. *G. obesa* is rare in many late Oligocene faunas.

Genus *Globorotalia* Cushman, 1927a

"Globorotalia" postcretacea
(Pl. 4, Figs. 15–17)

Globigerina postcretacea Myatliuk, 1950, p. 280, pl. 4, fig. 3.

Remarks. Small specimens occur in the <125-µm fraction of many Oligocene samples. Superficially, it can resemble *Globigerina angustiumbilicata*, but has a smoother wall and a more clearly extraumbilical aperture.

Genus *Globorotaloides* Bolli, 1957a

Globorotaloides suteri
(Pl. 4, Figs. 18–20)

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

Remarks. Usually dominant (commonly about 60%) in the 125–250-µm fractions, *G. suteri* is also common in the <125-µm fractions. In the upper Oligocene samples the species is connected a four- to five-chambered form with a more lobulate outline by intermediate forms. (See *Globigerina quinqueloba* Natland, 1938.)

Genus *Jenkinsella* Kennett and Srinivasan, 1983

Jenkinsella continuosa

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

Remarks. Intermediate forms with other *Jenkinsella* species occur commonly.

Jenkinsella mayeri

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

Remarks. Most specimens are intermediate between *J. continuosa* (Blow, 1959) and *J. mayeri*. We consider *J. siakensis* (LeRoy, 1939) a junior synonym, in agreement with Bolli and Saunders, 1982.

Jenkinsella nana

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

Remarks. Intermediate forms with other *Jenkinsella* species occur commonly.

Jenkinsella opima

Globorotalia opima opima Bolli, 1957a, p. 117, pl. 28, figs. 1–2.

Remarks. Intermediate forms with other *Jenkinsella* species are common. In order to preserve its value as a marker species we counted all intermediate forms as *J. continuosa* (Blow, 1959) or *J. nana* (Bolli, 1957a).

Genus *Morozovella* McGowran, 1968

Intermediate forms are very common, especially between the ornamented forms, and usually involve the number of chambers in the final whorl and the height of the umbilical side.

Morozovella acuta

Globorotalia wilcoxensis Cushman and Ponton, var. *acuta* Toulmin, 1941, p. 608, pl. 82, figs. 6–8.

Morozovella aequa

Globorotalia crassata (Cushman), var. *aequa* Cushman and Renz, 1942, p. 12, pl. 3, fig. 3.

Morozovella albeari

Globorotalia albeari Cushman and Bermúdez, 1949, p. 33, pl. 6, figs. 13–15.

Morozovella angulata

Globigerina angulata White, 1928, p. 191, pl. 27, fig. 13.

Morozovella aragonensis

Globorotalia aragonensis Nuttall, 1930, p. 288, pl. 24, figs. 6–11.

Remarks. This robust, easily identifiable species is a useful indicator of the lower half of the middle Eocene, even though it is usually rare.

Morozovella caucasica

Globorotalia aragonensis Nuttall, var. *caucasica* Glaessner, 1937, p. 31, pl. 1, fig. 6.

Remarks. The encountered specimens show only a weak ornamentation and are thus intermediate with *M. aragonensis* (Nuttall, 1930). This species is a good indicator of the upper part of the lower Eocene and the lowermost middle Eocene.

Morozovella conicotruncata

Globorotalia conicotruncata Subbotina, 1947, p. 115–116, pl. 4, figs. 11–13, pl. 9, figs. 9–10.

Remarks. It is connected to *M. velascoensis* (Cushman, 1925d) by intermediate forms with weak ornamentation.

Morozovella convexa

Globorotalia convexa Subbotina, 1953, p. 209, pl. 17, figs. 2–3.

Morozovella crassata

Pulvinulina crassata Cushman, 1925b, p. 300, pl. 7, fig. 4.

Remarks. We consider the well-known *M. spinulosa* (Cushman, 1927b) a junior synonym of this species.

Morozovella inconstans

Globigerina inconstans Subbotina, 1953, p. 58, pl. 3, figs. 1–2.

Morozovella kolchidica

Globorotalia kolchidica Morozova, 1961, p. 17, pl. 2, fig. 2.

Morozovella marginodentata

Globorotalia marginodentata Subbotina, 1953, p. 212–213, pl. 17, figs. 14–16, pl. 18, figs. 1–3.

Morozovella occlusa

Globorotalia occlusa Loeblich and Tappan, 1957, p. 191, pl. 55, fig. 3.

Morozovella praecursoria

Acarinina praecursoria Morozova, 1957, p. 1111, fig. 1.

Morozovella pseudobulloides

Globigerina pseudobulloides Plummer, 1926, p. 33, pl. 8, fig. 9.

Remarks. The recorded occurrence of this species in the 125–250-µm fraction of samples from Zones P3b and P4 at Site 758 probably concerns small, immature specimens of *M. variospira* (Belford, 1984).

Morozovella pusilla

Globorotalia pusilla pusilla Bolli, 1957b, p. 78, pl. 20, figs. 8–10.

Morozovella simulatilis

Discorbina simulatilis Schwager, 1883, p. 120, pl. 29, fig. 15.

Morozovella subbotinae

Globorotalia subbotinae Morozova, 1939, p. 80–81, pl. 2, fig. 16.

Morozovella trinidadensis

Globorotalia trinidadensis Bolli, 1957a, p. 73, pl. 16, figs. 19–23.

Morozovella uncinata

Globorotalia uncinata Bolli, 1957a, p. 74, pl. 17, figs. 13–15.

Morozovella variospira (Belford, 1984), em. van Eijden and Smit
(Fig. 26; Pl. 5, Figs. 1–8)

Globorotalia (Turborotalia) variospira Belford, 1984, p. 18, pl. 24, figs. 15–17, pl. 25, figs. 1–7.

Description. Umbilical side: Aperture extraumbilical-umbilical, a medium to high arc, on the last to the last three chambers bordered by an umbilical tooth or wide lip. Umbilicus wide and deep, usually partially covered by an umbilical tooth or teeth (Fig. 26 and Pl. 5, Figs. 1 and 3). Sutures straight and deeply depressed. Four to five chambers in the final whorl (usually four and a half). Chambers increasing abruptly in size as added, but the final two or three chambers can be of subequal size (cf

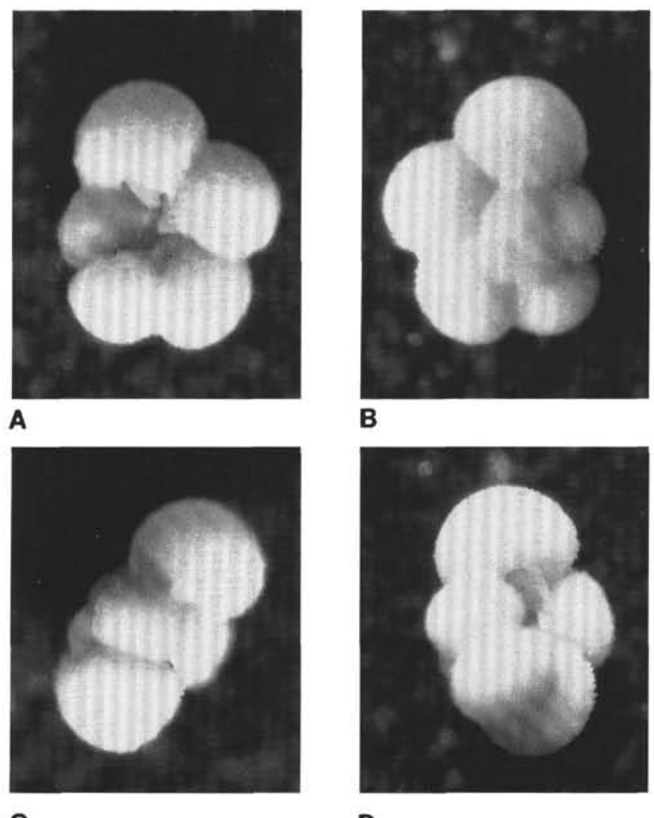


Figure 26. *Morozovella variospira* (Belford, 1984), em., Sample 121-758A-30X-CC. **A.** Umbilical view. **B.** Spiral view. **C.** Side view. **D.** Oblique side view. Magnification 50×.

Pl. 5, Figs. 1 with 2). Some of the final chamber(s) can be displaced toward the umbilicus.

Spiral side: Outline strongly lobate. Sutures straight, with some slightly curved backward, and deeply depressed. Chambers strongly inflated. Twelve to 15 chambers, arranged in three to three and a half whorls (Fig. 26 and Pl. 5, Figs. 6 and 7).

Lateral view: Trochospire is usually low, sometimes moderately high in specimens with chambers displaced toward the umbilicus. Profile broadly rounded (Fig. 26 and Pl. 5, Figs. 4 and 5).

Wall calcareous, densely perforate surface with small pustules that grade into a honeycomb pattern. Diameter of full-grown specimens up to 0.80 mm, and usually between 0.4 and 0.7 mm.

Intraspecies variability. Smaller, immature specimens with only four chambers in the final whorl may have a broad lip over the aperture of the final chamber only. The umbilicus of these specimens is narrower. Large, mature specimens may have five chambers in the final whorl, which increase gradually in size, with a number of chambers of subequal size. These specimens usually show prominent apertural teeth and a wide umbilicus. In spiral view, the stage with four rapidly enlarging chambers per whorl is easily discerned. The apertural tooth of displaced chambers is commonly weakly developed.

Diagnosis. *M. variospira* differs from all other Paleocene species of planktonic foraminifers by the presence of apertural teeth. This, together with its large size, makes it very conspicuous and easily recognized. Small, immature specimens resemble *M. pseudobulloides* (Plummer, 1926), which they differ from by their larger size, wider umbilicus, and the presence of an apertural lip or tooth on at least one chamber. The only species morphologically similar are *Globoquadrina altispira globosa* Bolli, 1957a and *Neogloboquadrina dutertrei* (d'Orbigny, 1839), which have radically different stratigraphical ranges and are phylogenetically unrelated.

Phylogeny. Intermediate forms between this species and *M. pseudobulloides* in the lower part of the range of *M. variospira* show that it descended from *M. pseudobulloides*. It may represent a gerontic form of that species.

Stratigraphic distribution. Lower part of Zone P3a (*M. angulata* Zone) to halfway Zone P4 (*P. pseudomenardii* Zone). At Site 758 it occurs in Samples 121-758A-30X-1, 115–120 cm, to 121-758A-31X-3, 115–120 cm.

The species is not as variable in coiling mode as Belford (1984) thought it was, and almost all specimens are very low trochospiral. The most important difference with the original description is that prominent apertural teeth are present, which were not observed by Belford. Its phylogenetic position and stratigraphic range are now known in some detail.

Remarks. The figured specimens will be deposited in the Dutch National Museum of Natural History in Leiden, under the first author's name.

Morozovella velascoensis

Pulvinulina velascoensis Cushman, 1925d, p. 19, pl. 3, fig. 5.

Genus *Planorotalites* Morozova, 1957

Planorotalites australiformis
(Pl. 5, Figs. 9 and 10)

Globorotalia australiformis Jenkins, 1966, p. 1112–1113, fig. 11, nos. 92–96.

Remarks. This species (probably a variant of *P. planoconica* (Subbotina, 1953)) is conspicuously present in the 125–250-µm fraction of Sample 121-752A-13X-3, 110–115 cm, of early middle Eocene age.

Planorotalites chapmani

Globorotalia chapmani Parr, 1938, p. 87, pl. 9, figs. 8–9.

Planorotalites compressa

Globigerina compressa Plummer, 1926, p. 135, pl. 8, fig. 11.

Planorotalites ehrenbergi

Globorotalia ehrenbergi Bolli, 1957b, p. 77, pl. 20, figs. 18–20.

Planorotalites imitata

Globorotalia imitata Subbotina, 1953, p. 206, pl. 16, figs. 14–16.

Planorotalites planoconica

Globorotalia planoconica Subbotina 1953, p. 210, pl. 17, figs. 4–6.

Planorotalites pseudomenardii

Globorotalia pseudomenardii Bolli, 1957b, p. 77, pl. 20, figs. 14–17.

Genus *Protentella* Lipps, 1964

Protentella clavicamerata

Protentella clavicamerata Jenkins, 1977, p. 308–312, pl. 4, figs. 12–14, pl. 5, figs. 1–8.

Protentella prolixa
(Pl. 5, Figs. 11 and 12)

Protentella prolixa Lipps, 1964, p. 124, pl. 2, figs. 8–9.

Remarks. Although *P. prolixa* is reportedly restricted to the upper Miocene and the Pliocene, we found specimens indistinguishable from this species in the upper Oligocene of Sites 757 and 758.

Genus *Tenuitella* Fleisher, 1974

Tenuitella munda

Globorotalia munda Jenkins, 1966, p. 1121, fig. 14, nos. 126–133, fig. 15, nos. 152–156.

Remarks. Usually rare if present and commonly hard to recognize, this species does not seem to be a good marker species, although it is used as such by Jenkins (1966).

Genus *Truncorotaloides* Brönnimann and Bermúdez, 1953

Truncorotaloides collactea

Globorotalia collactea Finlay, 1939b, p. 327, pl. 29, figs. 164–165.

Truncorotaloides rohri

Truncorotaloides rohri Brönnimann and Bermúdez, 1953, p. 818–819, pl. 87, figs. 7–9.

Truncorotaloides topilensis

Globigerina topilensis Cushman, 1925c, p. 7, pl. 1, fig. 9.

Remarks. *T. topilensis* is rare and not quite typically developed in Sample 121-757B-17H-CC.

Genus *Turborotalia* Cushman and Bermúdez, 1949

All *Turborotalia* species are rare. This is due to the fact that they are susceptible to dissolution, combined with the fact that most of them are restricted to low latitudes.

Turborotalia cerroazulensis

Globigerina cerro-azulensis Cole, 1928, p. 17, pl. 1, figs. 11–13.

Turborotalia cocoaensis

Globorotalia cocoaensis Cushman, 1928, p. 75, pl. 10, fig. 3.

Turborotalia cunialensis

Globorotalia cerroazulensis cunialensis Toumarkine and Bolli, 1970, p. 144, pl. 1, fig. 37.

Turborotalia increbescens

Globigerina increbescens Bandy, 1949, p. 120, pl. 23, fig. 3.

Turborotalia pomeroli

Globorotalia cerroazulensis pomeroli Toumarkine and Bolli, 1970, p. 140, pl. 1, figs. 10–18, pl. 2, figs. 1–2, 11–19.

Family HANTKENINIDAE Cushman, 1927a
Genus *Cassigerinella* Pokorný, 1955

Cassigerinella chipolensis

Cassidulina chipolensis Cushman and Ponton, 1932b, p. 98, pl. 15, fig. 2.

Remarks. *C. chipolensis* is rare but consistently present in the Oligocene of Site 758, and very rare at Site 757.

Genus *Cribrohantkenina* Thalmann, 1942

Cribrohantkenina inflata

Hantkenina inflata Howe, 1928, p. 14, pl. 14, fig. 2.

Remarks. *C. inflata* was observed in samples from Section 121-757B-14H by a shipboard scientist.

Genus *Hantkenina* Cushman, 1925a

Fragments (usually spines) of unidentifiable species of *Hantkenina* occur in Samples 121-756C-6X-CC, 121-756C-7X-4, 110–115 cm, 121-756C-7X-CC, and 121-757B-14H-1, 110–115 cm.

Hantkenina alabamensis

Hantkenina alabamensis Cushman, 1925a, p. 3, fig. 1, pl. 1, figs. 1–6.

Remarks. We found a single specimen in Sample 121-757B-14H-1, 110–115 cm.

Hantkenina brevispina

Hantkenina brevispina Cushman 1925a, p. 1, pl. 2, fig. 3.

Remarks. We found a single specimen in Sample 121-756C-6X-CC.

Genus *Pseudohastigerina* Banner and Blow, 1959

Pseudohastigerina micra

Nonion micrus Cole, 1927, p. 22, pl. 5, fig. 12.

Remarks. *P. micra* is usually rare in the middle and upper Eocene, and very rare in the lower Oligocene.

Pseudohastigerina naguewichiensis

Globigerinella naguewichiensis Myatliuk, 1950, p. 281, pl. 4, figs. 4a–4b.

Remarks. This species occurs only rarely outside of the <125-μm fraction, usually in the lower Oligocene.

Pseudohastigerina wilcoxensis

Nonion wilcoxensis Cushman and Ponton, 1932a, p. 64, pl. 8, fig. 11.

Remarks. *P. wilcoxensis* was found only in Sample 121-752A-13X-2, 110–115 cm.

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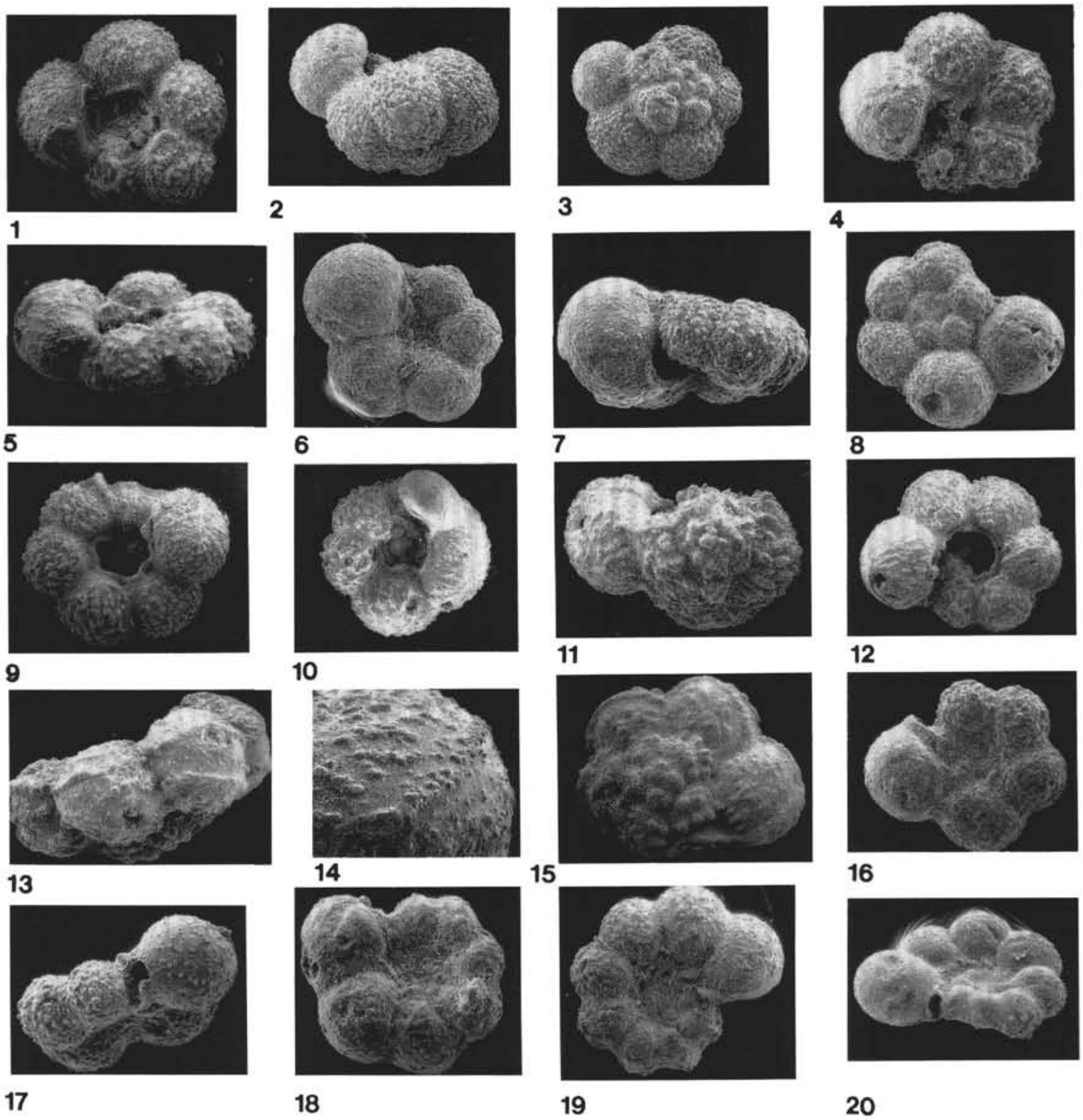

Plate 1. **1–3.** *Archaeoglobigerina australis* Huber, 1990. Fig. 1. Umbilical view, note absence of tegillum. Sample 121-758A-31X-CC, 60×. Fig. 2. Side view. Sample 121-758A-31X-CC, 80×. Fig. 3. Spiral view, Sample 121–758A-46R-CC, 30–34 cm, 60×. **4, 5.** *Archaeoglobigerina cretacea* (d'Orbigny, 1840) specimens with tendency toward *Rugoglobigerina hexacamerata* Brönnimann, 1952a. Fig. 4. Umbilical view, note poorly developed tegillum. Sample 121-754A-21N-1, 71–74 cm, 70×. Fig. 5. Side view, Sample 121-754A-20N-2, 113–118 cm, 60×. **6–8.** *Hedbergella* sp. cf. *H. planispira* (Tappan, 1940). Fig. 6. Umbilical view, Sample 121-752B-16R-CC, 90×. Fig. 7. Side view, Sample 121-754A-21N-1, 71–74 cm, 160×. Fig. 8. Spiral view, Sample 121-752B-12R-4, 90–93 cm, 100×. **9.** *Rugoglobigerina pennyi* Brönnimann, 1952a. Note absence of tegillum and slightly aligned costellae. Sample 121-752B-19R-CC, 60×. **10, 11.** *Rugoglobigerina rugosa* (Plummer, 1926), Sample 121-758A-31X-CC. Fig. 10. Umbilical view, note absence of tegillum and unornamented abortive final chamber, 60×. Fig. 11. Side view, 80×. **12–15.** *Rugotruncana subcircumnodifer* Gandolfi, 1955. Fig. 12. Weakly ornamented specimen, Sample 121-752B-16R-CC, 40×. Fig. 13. Side view, showing keels and unperforated peripheral band. Sample 121-752B-16R-CC, 60×. Fig. 14. Detail of final chamber, showing wall structure. Sample 121-754A-21N-1, 71–74 cm, 160×. Fig. 15. Spiral view, showing aligned costellae. Sample 121-752B-16R-CC, 60×. **16, 17.** *Globigerinelloides volutus* (White, 1928). Fig. 16. Umbilical view, Sample 121-754B-13R-CC, 140×. Fig. 17. Side view, Sample 121- 758A-41X-CC, 160×. **18–20.** *Globigerinelloides yaucoensis* Pessagno, 1960 group. Fig. 18. Specimen from the Coniacian, note similarity with Figure 19. Sample 121-755A-10R-1, 114–117 cm, 120×. Fig. 19. Maestrichtian specimen, Sample 121-758A-36X-CC, 120×. Fig. 20. Side view, Sample 121-758A-36X-CC, 120×.

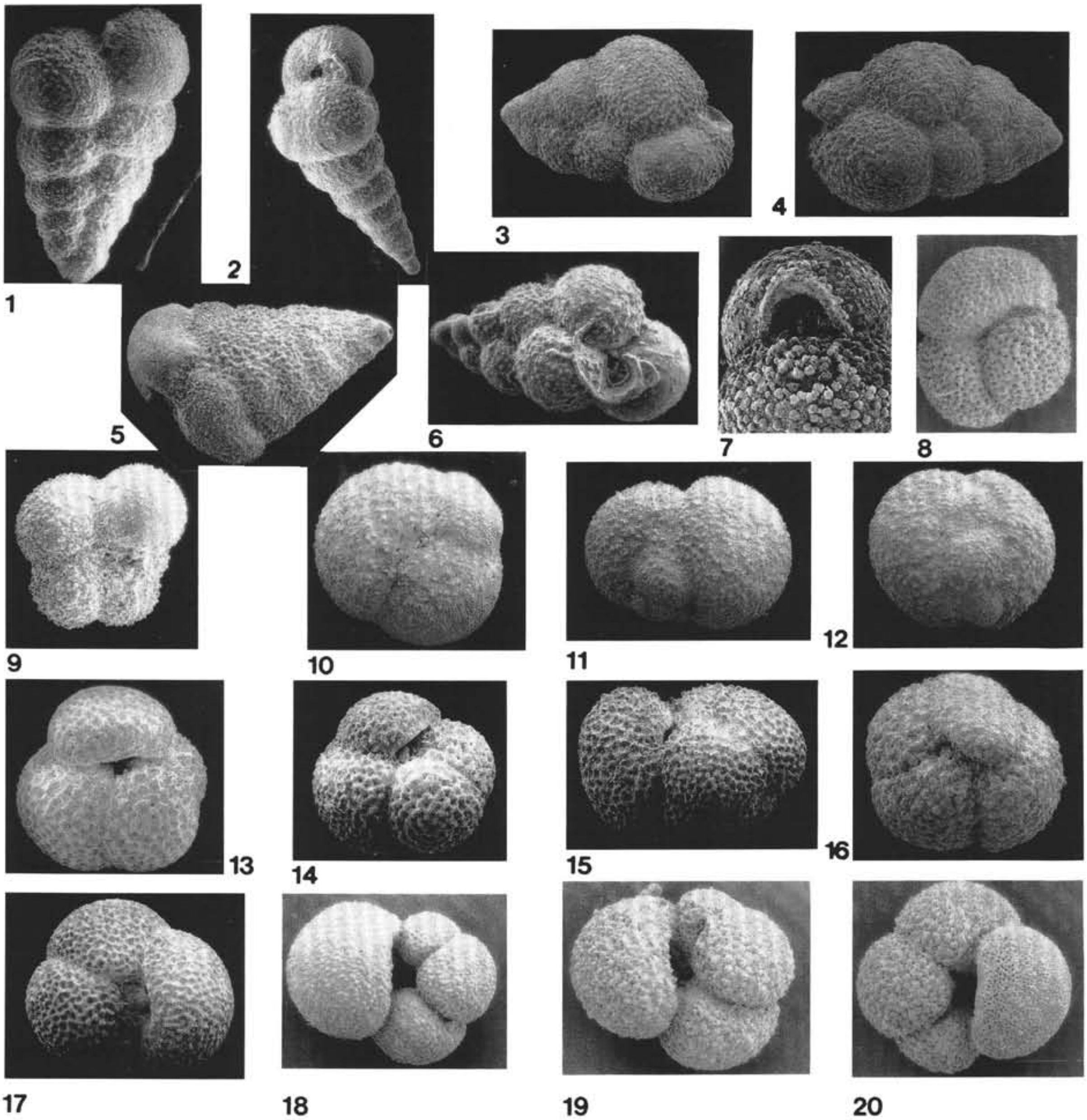

Plate 2. **1, 2.** *Chiloguembelina cubensis* (Palmer, 1934) Fig. 1. Sample 121-756C-5X-CC, 220×. Fig. 2. Slender, somewhat twisted specimen, Sample 121-756C-5X-CC, 140×. **3, 4, 7.** *Chiloguembelina wilcoxensis* (Cushman and Ponton, 1932a). Fig. 3. Well-developed, large specimen, Sample 121-752A-14X-3, 110–115 cm, 60×. Fig. 4. Small specimen with aberrant final chamber, Sample 121-752A-15X-CC, 110×. Fig. 7. Detail of aperture, Sample 121-752A-14X-3, 110–115 cm, 140×. **5.** *Chiloguembelina subtriangularis* Beckmann, 1957, Sample 121-753A-7H-CC, 200×. **6.** *Guembelitria columbiana* Howe, 1939, Sample 121-753A-7H-CC, 280×. **8.** *Globigerina angiporoides* Hornibrook, 1965, Sample 121-756C-5X-CC, 80×. **9.** *Globigerina angustiumbilicata* Bolli, 1957a. Specimen with four chambers in the final whorl and a somewhat extraumbilical aperture. Sample 121-758A-21X-1, 128–133 cm, 140×. **10–12.** *Globigerina* sp. "*bipartita*." Fig. 10. Umbilical view of a specimen with a relatively large antepenultimate chamber. Sample 121-758A-23X-4, 115–119 cm, 30×. Fig. 11. Side view of an elongate specimen, Sample 121-758A-22X-2, 115–120 cm, 30×. Fig. 12. Spiral view. Note very small, bullalike, abortive final chamber. Sample 121-758A-23X-4, 115–119 cm, 30×. **13–16.** *Globigerina euapertura* Jenkins, 1960. Fig. 13. Specimen closely referable to the original description, Sample 121-756B-8H-1, 110–115 cm, 60×. Fig. 14. Specimen with aberrant final chamber, Sample 121-756B-10H-1, 110–115 cm, 60×. Fig. 15. Side view, Sample 121-754A-12H-CC, 60×. Fig. 16. *Globigerina* sp. or *Catapsydrax* sp. Sample 121-757B-15H-CC, 60×. Fig. 17. *Globigerina galavisi* Bermúdez, 1960, Sample 121-756B-10H-1, 110–115 cm, 50×. **18–20.** *Globigerina praebulloides* Blow, 1959. Fig. 18. Normal specimen, Sample 121-756B-8H-2, 110–115 cm, 80×. Fig. 19. More compact specimen, Sample 121-756B-8H-2, 110–115 cm, 80×. Fig. 20. Specimen resembling *G. euapertura* Jenkins, 1960, Sample 121-756B-8H-2, 110–115 cm, 80×.

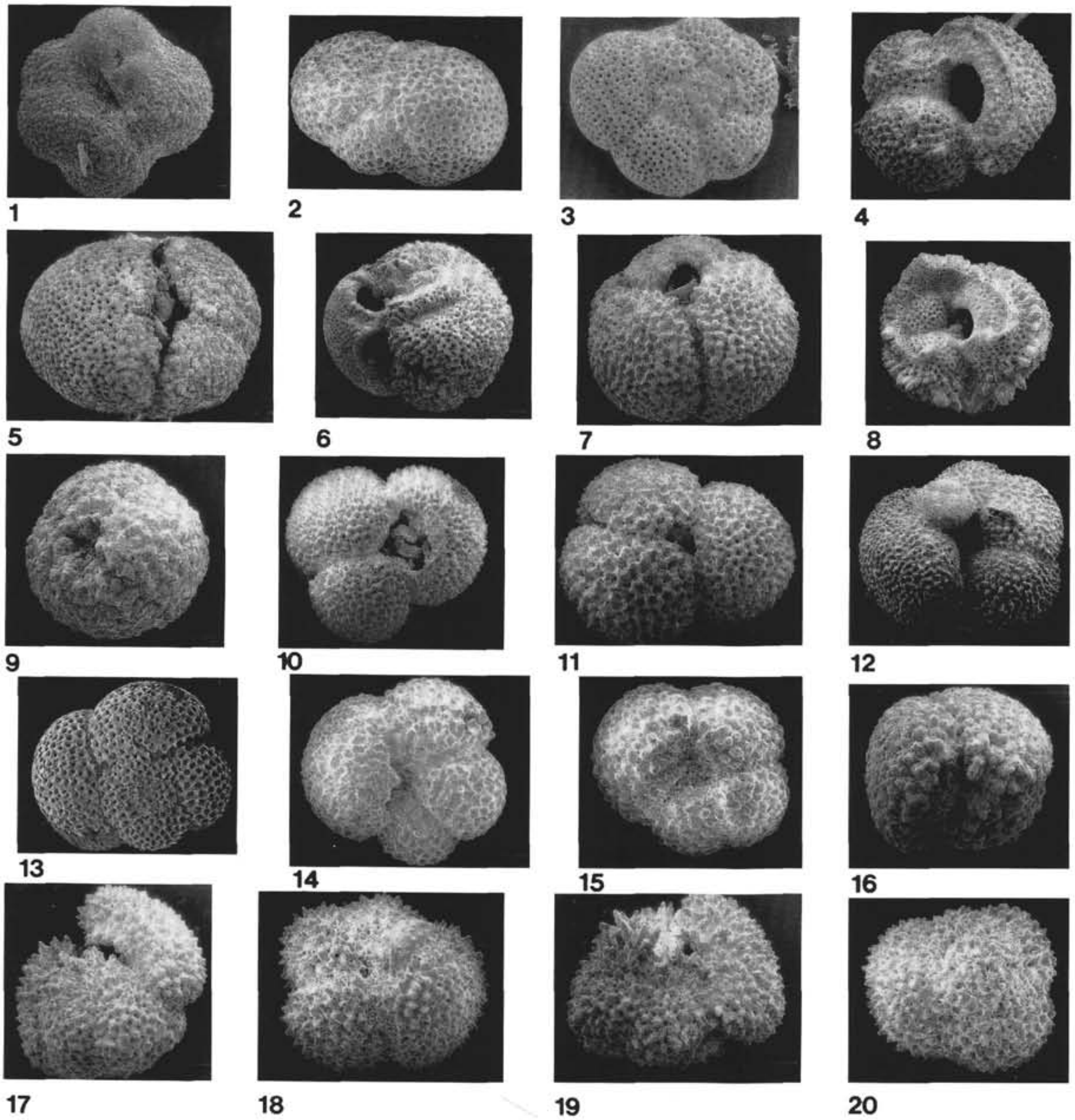

Plate 3. **1–3.** *Globigerina* sp. cf. *G. quinqueloba* Natland, 1938, Sample 121-758A-21X-2, 126–131 cm, 140×. Fig. 1. Umbilical view. Fig. 2. Side view. Fig. 3. Spiral view. **4, 5, 9.** *Globigerinatheka* sp. cf. *G. index* (Finlay, 1939a). Fig. 4. Typical specimen with inflated chambers and depressed sutures, Sample 121-754A-14X-3, 110–115 cm, 80×. Fig. 5. Compact specimen with cleftlike sutures, Sample 121-752A-11H-CC, 60×. Fig. 9. Very compact specimen, Sample 121-752A-11H-CC, 60×. **6–8.** *Globigerinatheka index* (Finlay, 1939a), Sample 121-752A-11H-CC, 60×. Fig. 6. Typical specimen. Fig. 7. Specimen with small final chamber. Fig. 8. Broken specimen, showing juvenile "cf. *G. index*" stage. Compare with Figure 4. **10.** Globigerinoides altiaperturus Bolli, 1957a, Sample 121-757B-11H-2, 110–115 cm, 80×. **11.** *Globigerinoides trilobus* (Reuss, 1850), spiral view. Sample 121-757B-11H-2, 110–115 cm, 50×. **12, 13.** *Globoquadrina praedehiscens* Blow and Banner, 1962, Sample 121-754A-12H-CC. Fig. 12. Umbilical view of specimen with abortive, bullalike final chamber, 60×. Fig. 13. Spiral view, 70×. **14–17.** *Acarinina coalingensis* (Cushman and Hanna, 1927) group. Fig. 14. Specimen with relatively small final chamber, Sample 121-752A-21X-1, 110–115 cm, 110×. Fig. 15. Specimen with relatively large final chamber, Sample 121-752A-14X-3, 110–115 cm, 110×. Fig. 16. Compact specimen with angular final chamber (*A. nitida* (Martin, 1943)), Sample 121-757B-17H-CC, 80×. Fig. 17. Side view of specimen with rugose wall, Sample 121-758A-28X-2, 115–120 cm, 80×. **18–20.** Very rugose specimens of the *A. coalingensis* group. Figs. 18, 20. Sample 121-753A-6H-3, 110–115 cm, 130×, Fig. 19. Sample 121-758A-28X-2, 115–120 cm, 90×.

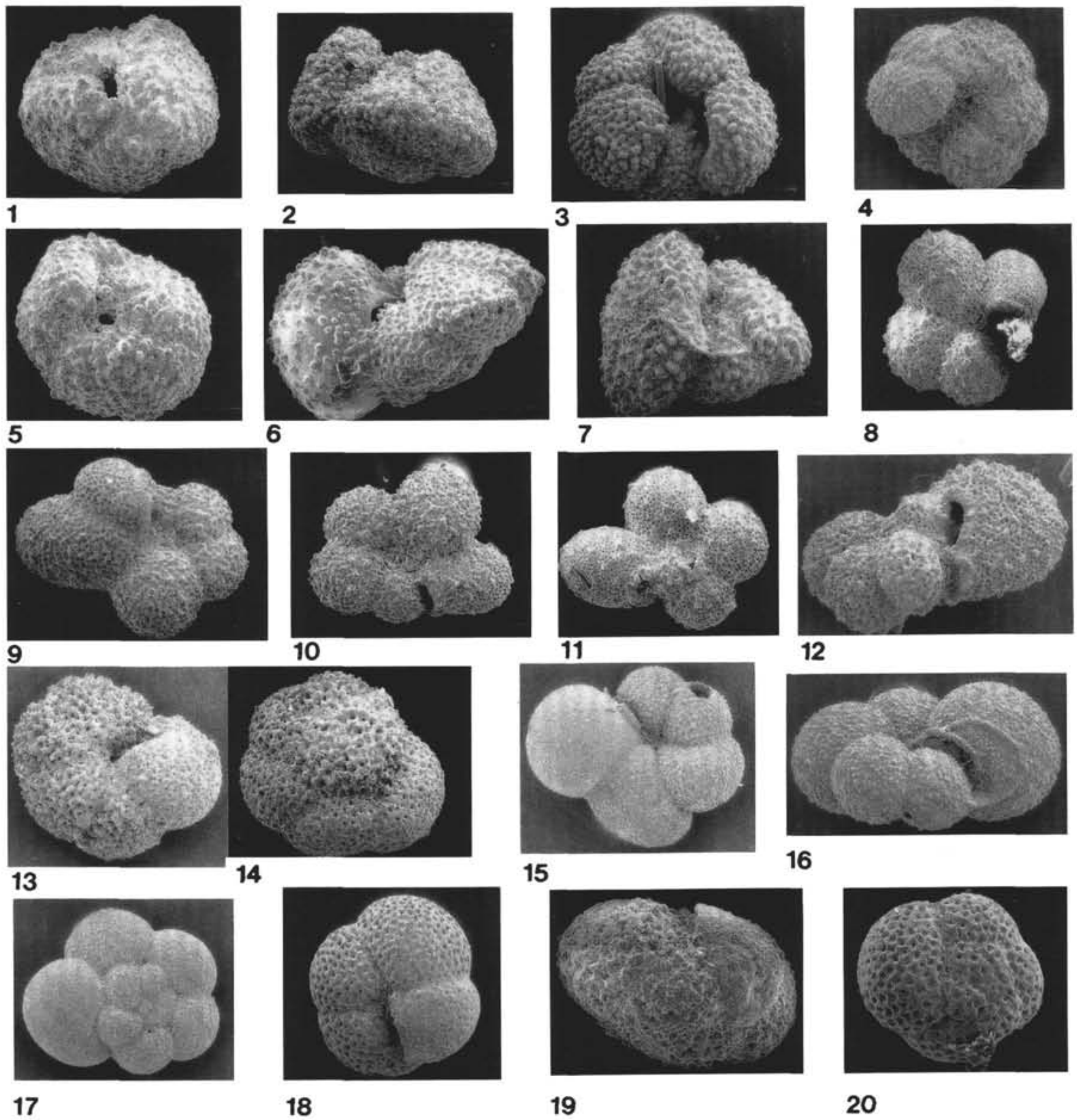

Plate 4. **1, 2.** *Acarinina densa* (Cushman 1925b). Fig. 1. Umbilical view, Sample 121-757B-20X-CC, 80×. Fig. 2. Side view, Sample 121-757B-17H-CC, 80×. **3.** *Acarinina pentacamerata* (Subbotina, 1947), specimen showing affinity with the *A. coalingensis* group, Sample 121-752A-21X-1, 110–115 cm, 70×. **4.** *Acarinina gravelli* (Brönnimann, 1952a), Sample 121-752A-27X-CC, 90×. **5.** *Acarinina* sp., intermediate between *A. densa* and *A. pentacamerata* Sample 121-752A-22X-CC, *100*×. **6.** *Acarinina* sp. Small, planoconvex specimen with inflated final chamber, considered as belonging to the *A. coalingensis* group, to which it is linked by intermediate forms. Sample 121-752A-21X-1, 110–115 cm, 140×. Fig. 7. *Acarinina wilcoxensis* (Cushman and Ponton, 1932a), Sample 121-752A-13X-3, 110–115 cm, 90×. **8–12.** Aff. *Clavatorella nicobarensis* Srinivasan and Kennett, 1976. Fig. 8. Small specimen with small final chamber, Sample 121-758A-21X-2, 110–115 cm, 120×. Fig. 9. Large specimen with small final chamber, Sample 121-758A-21X-1, 110–115 cm, 100×. Fig. 10. Large specimen with large final chamber. Note almost equatorial aperture. Sample 121-758A-21X-1, 110–115 cm, 100×. Fig. 11. Small specimen with large final chamber, Sample 121-758A-21X-1, 110–115 cm, 110×. Fig. 12. Side view, Sample 121-758A-21X-1, 110–115 cm, 120×. **13, 14.** *Fohsella kugleri* (Bolli, 1957a), Sample 121-757B-11H-CC. Fig. 13. Umbilical view, 140×. Fig. 14. Spiral view, 160×. **15–17.** "*Globorotalia*" *postcretacea* (Myatliuk, 1950).Sample 121-756C-5H-CC. Figs. 15 and 17. 120×. Fig. 16. 160×. **18–20.** *Globorotaloides suteri* Bolli, 1957a. Fig. 18. Sample 121-758A-22X-CC, 120×. Figs. 19, 20. Sample 121-758A-25X-1, 110–115 cm, 140×.

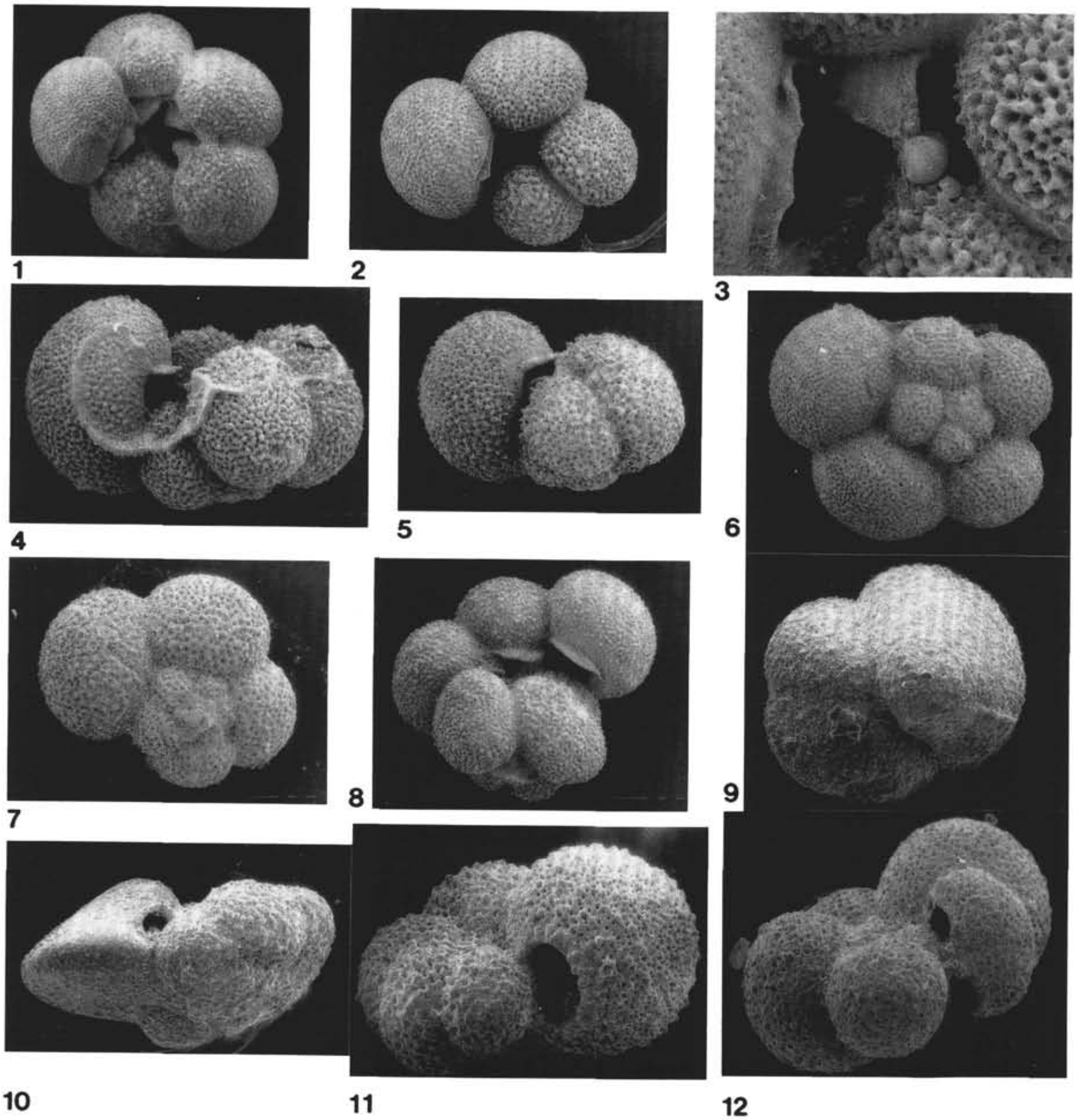

Plate 5. **1–8.** *Morozovella variospira* (Belford, 1984). Fig. 1. Large specimen with five chambers in the final whorl and well-developed apertural teeth. Sample 121-758A-30X-3, 115–120 cm, 50×. Fig. 2. Small specimen with four chambers in the final whorl and poorly developed apertural teeth. Sample 121-758A-30X-1, 115–120 cm, 60×. Fig. 3. Detail of the umbilicus of a medium-sized specimen. Apertural tooth of final chamber broken. Sample 121-758A-30X-1, 115–120 cm, 150×. Fig. 4. Side view of a large specimen with four and a half chambers in the final whorl. Sample 121-758A-30X-CC, 60×. Fig. 5. Side view of a small specimen with four chambers in the final whorl. Sample 121-758A-31X-1, 115–120 cm, 75×. Fig. 6. Spiral view of a large specimen with five chambers in the final whorl, the final chamber is broken. Sample 121-758A-30X-CC, 50×. Fig. 7. Spiral view of a small specimen, Sample 121-758A-30X-CC, 75×. Fig. 8. Aberrant, high-trochospiral specimen. Note poorly developed apertural teeth. Sample 121-758A-30X-CC, 50×. **9, 10.** *Planorotalites australiformis* (Jenkins, 1966), Sample 121-752A-13X-3, 110–115 cm. Fig. 9. 125×. Fig. 10. 150×. **11, 12.** Aff. *Protentella prolixa* Lipps, 1964, Sample 121-758A-21X-1, 128–133 cm, 150×. Fig. 11. Typical specimen. Fig. 12. Specimen with aberrant final chamber with two apertures.