33. LATE OLIGOCENE TO RECENT BENTHIC FORAMINIFERS FROM DEEP SEA DRILLING PROJECT SITES 608 AND 610, NORTHEASTERN NORTH ATLANTIC[1]

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ABSTRACT

Deep-sea benthic foraminiferal faunas were studied from Sites 608 (depth 3534 m, 42°50'N, 23°05'W) and 610 (depth 2427 m, 53°13'N, 18°53'W). The sampling interval corresponded to 0.1 to 0.5 m.y. at Site 608 and in the sections of Site 610 from which core recovery was continuous.

First and last appearances of benthic foraminiferal taxa are generally not coeval at the two sites, although the faunal patterns are similar and many species occur at both sites. Major periods of changes in the benthic faunas, as indicated by the numbers of first and last appearances and changes in relative abundances, occurred in the early Miocene (19.2–17 Ma), the middle Miocene (15.5–13.5 Ma), the late Miocene (7–5.5 Ma), and the Pliocene–Pleistocene (3.5–0.7 Ma). A period of minor changes in the middle to late Miocene (10–9 Ma) was recognized at Site 608 only.

These periods of faunal changes can be correlated with periods of paleoceanographic changes: there was a period of sluggish circulation in the northeastern North Atlantic from 19.2 to 17 Ma, and the deep waters of the oceans probably cooled between 15.5 and 13.5 Ma, as indicated by an increase in $\delta^{18}O$ values in benthic foraminiferal tests. The period between 10 and 9 Ma was probably characterized by relatively vigorous bottom-water circulation in the northeastern Atlantic, as indicated by the presence of a widespread reflector. The faunal change at 7 to 5.5 Ma corresponds in time with a worldwide change in $\delta^{13}C$ values, and with the Messinian closing of the Mediterranean. The last and largest faunal changes correspond in time with the onset and intensification of Northern Hemisphere glaciation.

INTRODUCTION

Deep-sea benthic foraminifers from the North Atlantic Ocean have been studied more intensely than similar faunas from other oceans. Pioneering studies of Quaternary faunas were made by Brady (1884—material from the *HMS Challenger*), Cushman (1923), and Phleger, Parker, and Peirson (1953). Streeter (1973) used the data from the latter authors in a quantitative study and concluded that deep-sea faunal associations of benthic foraminifers are related to the water masses below which they are living, and that the faunal associations changed from glacial to interglacial intervals during the last 150,000 yr. Streeter and Shackleton (1979) compared the faunal composition during the last 150,000 yr. with the oxygen isotopic ratios from tests of *Uvigerina* species. Schnitker (1974; 1980) recognized a similar correlation between water masses and benthic faunal composition in the western North Atlantic, and concluded that *Epistominella exigua*-dominated faunas are presently typical of the deep-ocean basins north of 35°N. South of 35°N, faunas have abundant *Nuttallides umbonifera;* faunas typified by *Uvigerina* and *Hoeglundina* species occur at somewhat shallower depths along the continental margins and the Mid-Atlantic Ridge. During interglacial periods the faunas resembled the modern ones, but during glacial periods the *Uvigerina–Hoeglundina* faunas migrated basinward and became dominant in the deep basins north of about 35°N, while a mixed *Uvigerina peregrina–Epistominella exigua* fauna lived more to the south, and a mixed *Epistominella exigua–Nuttallides umbonifera* fauna dominated south of 23°N.

In high-resolution studies of benthic foraminiferal faunas of the Rockall Plateau area, Schnitker (1984) concluded that orbital parameters induced fluctuations in the faunal composition of benthic foraminifers in the late Miocene and during the glacial Pliocene and Pleistocene. The same author (Schnitker, 1982) also described even higher-frequency oscillations in the faunal composition of Quaternary benthic foraminifers (650–2500 yr.).

Older faunas (Paleogene–Recent) from material recovered on DSDP Leg 12 at sites in the North Atlantic and Bay of Biscay were discussed by Berggren (1972). He concluded that there was a major change in deep-sea benthic foraminiferal faunal composition during the middle Miocene, but he did not present data on the exact timing or the sequence of first and last appearances of taxa. Schnitker (1979) studied Paleogene to Recent faunas from the Bay of Biscay (DSDP Leg 48), and concluded that there were major faunal changes at Paleocene/Eocene boundary, at the Eocene/Oligocene boundary, at the Oligocene/Miocene boundary, at the end of the middle Miocene, and in the Pliocene. According to Miller (1983), however, Paleogene faunal changes in the Bay of Biscay occurred over the period from early middle Eocene to earliest Oligocene, and did not coincide with the Eocene/Oligocene boundary.

Murray (1984; and this volume) described and quantitatively analyzed benthic deep-sea faunas from the North Atlantic, including the Rockall Plateau area (DSDP Leg 81). He compared Recent faunas with their older counterparts, and deduced bottom-water movements from the changes in faunal composition with time. Berggren and Schnitker (1983) reviewed the Cretaceous to Recent environmental history of the northeastern North Atlantic,

[1] Ruddiman, W. F., Kidd, R. B., Thomas, E., et al., *Init. Repts. DSDP*, 94: Washington (U.S. Govt. Printing Office).

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and concluded that there was a major taxonomic turnover in the benthic microfauna in the middle Miocene, so that benthic microfaunas assumed their present-day aspect at that time. In Schnitker's paper (in press) on the benthic foraminiferal faunas from the Rockall area and the Bay of Biscay the author also concluded that there was a major faunal turnover in the middle Miocene (15–13 Ma), recognized at depths between 1650 and 4400 m.

A middle Miocene faunal turnover in benthic foraminiferal faunas was described from the Pacific Ocean (Woodruff and Douglas, 1981; Woodruff, 1985). These authors concluded that the major faunal change was coeval with a major increase in $\delta^{18}O$ values in benthic foraminiferal tests. This increase in benthic $\delta^{18}O$ values has been recognized worldwide (e.g., Woodruff et al., 1979; Savin et al., 1981; Miller et al., 1985; Pisias et al., 1985; Vincent et al., 1985). Thomas (1985; 1986), however, in a study of benthic foraminifers from the eastern equatorial Pacific, decided that the faunal changes at that location were initiated before the middle Miocene increase in oxygen isotopic values, and occurred between 18.5 and 13.5 Ma. The beginning of the faunal changes appeared to be correlated with an increase in $CaCO_3$ dissolution, and the onset of an increase in $\delta^{13}C$ values in benthic and planktonic foraminiferal tests (Vincent and Killingley, 1985; Vincent et al., 1985).

In this chapter I describe benthic foraminiferal faunas from DSDP Sites 608 and 610 (water depths about 3.5 and 2.5 km, respectively, Fig. 1), from an age range of late Oligocene to Recent. The sampling density was highest at Site 608 (generally corresponding to 0.1 to 0.5 m.y.). At this site the core recovery was good, as was the preservation of the calcareous microfauna. At Site 610, recovery and preservation were not as good, especially in the deeper part of the hole (lower Miocene), and the site was spot-cored in large intervals in the middle to upper Miocene. The faunas are described generally, and large-scale changes with time are discussed. A more detailed description of the early to middle Miocene events is presented by Thomas (in press). Correlations are made between the faunal record and the oxygen and carbon isotopic records from Site 608 (see Miller et al., this volume), and the ages of the first and last appearances of taxa are determined by extrapolation of the paleomagnetic data in Clement and Robinson (this volume).

MATERIAL AND METHODS

I used material from DSDP Sites 608 (water depth 3534 m, 42° 50′N, 23°05′W) and 610 (water depth 2427 m, 53°13′N, 18°53′W, see Fig. 1). Hole 608 was cored continuously with the hydraulic piston corer (HPC) to about 150 m sub-bottom, then cored continuously with the extended core barrel (XCB) to middle Eocene basaltic basement at about 530 m sub-bottom. In this chapter I describe faunas from the upper 455 m of the cored section, that is, upper Oligocene to Recent. Below 455 m (Core 608-49) there is an interval of about 10 m of sediment with mixed Eocene–Oligocene faunas (see Site 608 report, this volume), representing about 10 m.y. of time. Below this interval there are middle-upper to upper-middle Eocene sediments on top of the basaltic basement.

Site 610 is situated on Feni Drift, a major sediment drift in the Rockall Trough. I used samples from Holes 610, 610A, and 610E to obtain a section that is as complete as possible. Hole 610 was drilled and spot-cored to a final depth of 723 m in lower Miocene siliceous

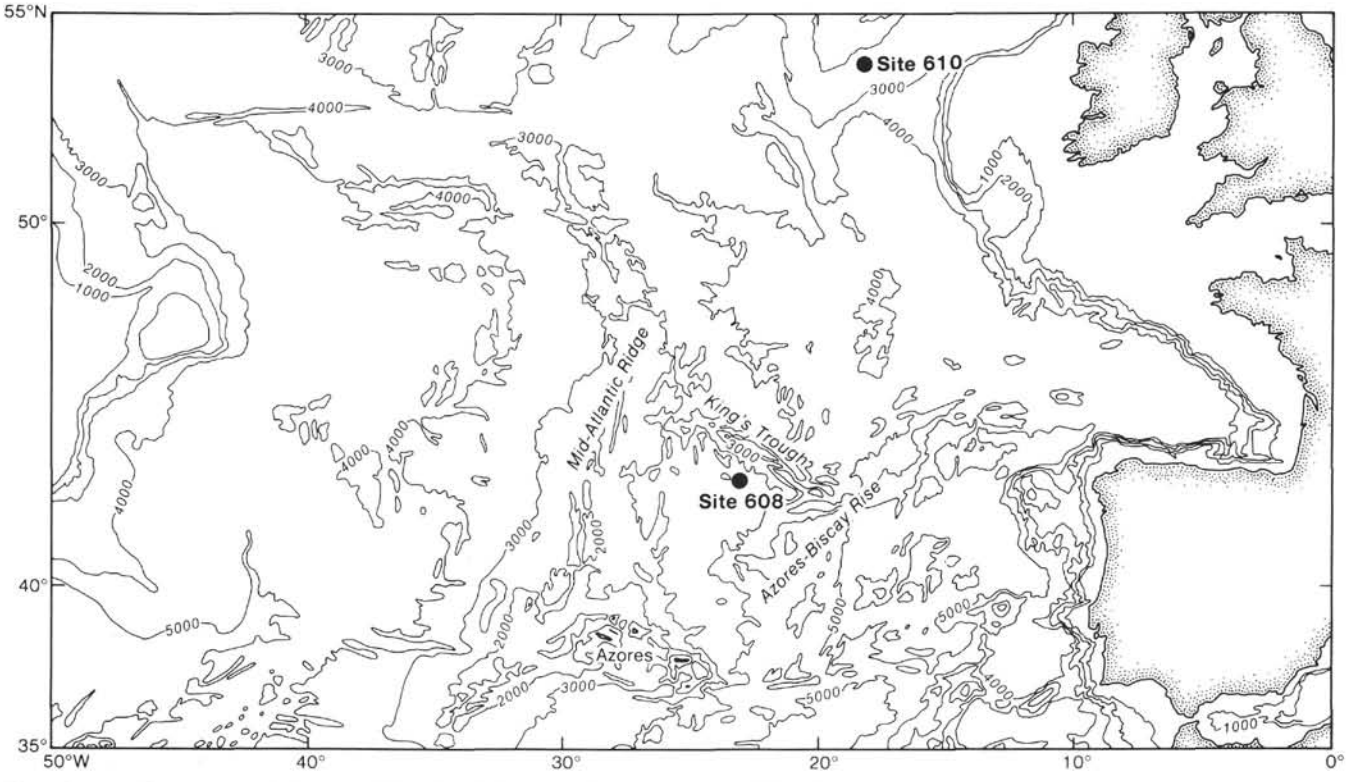


Figure 1. Location map of DSDP Sites 608 and 610, Leg 94. The contour interval is 1000 m.

chalks (NN3, see Takayama and Sato, this volume). Hole 610A is the second HPC hole in the upper part of the section; Holes 610 and 610A together give a complete section through the Pleistocene and Pliocene. In Hole 610E seven cores of upper Miocene sediment were recovered. Hole 610 was cored continuously below 635 m in the lower middle and lower Miocene (9 cores), but recovery was poor (about 50%). Overall, large parts of the upper and middle Miocene were not recovered because of spot-coring; in these intervals one core (9.5 m) was recovered every 50 m (see Site 610 report, this volume, for the spatial relations between the holes).

From both sites I studied core-catcher samples from sediments younger than about 12 Ma and sediments older than 21 Ma, and additional samples from the interval corresponding to 12 to 21 Ma (Appendix A). The sampling interval corresponded to a time interval of about 0.5 m.y. in the upper and lower parts of the section, 0.1 to 0.2 m.y. in the middle and lower Miocene. Overall, 85 samples from Site 608 and 68 samples from Site 610 were studied. Absolute ages were assigned from extrapolation of the paleomagnetic data presented by Clement and Robinson (this volume), using the time scale of Berggren, Kent, and Flynn (1985) and Berggren, Kent, and Van Couvering (1985). At Site 610, time control is poor in the spot-cored part of the section (200–600 m sub-bottom); ages were estimated from the sedimentation-rate curve (see Site 610 report, this volume) and are not reliable.

Samples were washed through a 63-μm sieve and air-dried. Indurated chalks in the lower part of Hole 610 (Cores 610-19 through 610-27) were dried at 110°C, then soaked in kerosene, and heated in water. Some samples in Cores 610-25 through 610-27 could not be used because even repeated kerosene treatment did not separate the foraminiferal tests from the chalks. In most samples the preservation of benthic foraminifers was good, with no evidence of dissolution or overgrowths, but in the lower part of Hole 610 many foraminifers were crushed and flattened, and filled with clear, sparry calcite. In general, benthic foraminifers in these samples were better preserved than planktonic foraminifers.

Species–specimen plots were drawn for several samples by plotting the number of species versus the number of specimens while counting. The species–specimen curves become parallel to the species axis at about 180 specimens; in other words, many extra specimens had to be counted to find few extra species. Therefore I decided to obtain about 200 specimens per sample and not to use samples in which fewer specimens were present (note that there is no significant positive correlation between the number of species and the number of specimens in the samples, Fig. 2). Most samples contained sufficient specimens for study, with the exception of samples from the lower part of Hole 610 (see Appendix A for counts).

I made a strewing on a 5 × 9-cm picking tray to determine how abundant benthic foraminifers were in the sample. If fewer than 5 specimens were present in this strewing, the sample was not used. If more than 5 specimens were present, the amount of sample needed to obtain 200 specimens was estimated, and a split of that size was made in a sample splitter. If not enough specimens were present in the split, extra splits were made. All specimens were picked and mounted in numbered slides. Some of the *Cibicidoides* spp. specimens were used for isotopic analyses (Miller et al., this volume).

I used the entire size fraction >63 μm, because counts were inconsistent when the fraction >125 μm was separated. Some samples have numerous specimens of *Stilostomella* spp., *Pleurostomella* spp., or small *Bolivina* spp., and these linear species can pass through the 125-μm sieve. The number of specimens that actually passes, however, depends upon the way in which the sieve is handled (how vigorously shaken, how long shaken). Because the majority of the benthic foraminifers in most samples is >125 μm, the results of this study can (with some caution) be compared with studies in which the >125-μm size fraction was used, but not with studies in which the >250-μm fraction was used.

RESULTS

The counts of all specimens of benthic foraminifers are shown in Appendix A, together with sample numbers, sub-bottom depths, assigned ages, numbers of specimens per sample, and number of species per sample. No assigned ages are shown for the samples from the lower (spot-cored) section of Hole 610 because exact age determinations cannot be made for those samples. The taxonomy is presented in Appendix B.

Diversity

The diversity, expressed as number of species per sample, is high in most samples, as expected for deep-sea faunas (e.g., Douglas and Woodruff, 1981). Generally there are between 50 and 65 species per 200 specimens. The average number of species is 53 (±11) at Site 608, 56 (±7) at Site 610; these numbers are not significantly different. The exception is an interval between about 340 and 355 m sub-bottom at Site 608, where only 12 to 47 species were found per sample, as a result of extremely high relative abundances of *Bolivina* spp., especially *Bolivina spathulata* (see below). A relatively low diversity (39–49 species) was also found in some samples from the glacial intervals of the Pliocene and Pleistocene (recognized as glacial by the presence of ice-rafted material and cold-water planktonic foraminifers; see Weaver, this volume); there is no correlation between the number of species found and sub-bottom depth, or degree of induration of the sediment (Thomas, 1985; in press).

The total number of taxa recognized at the sites is 201; 144 (71.6%) of the taxa occur at both sites, 38 (18.9%) occur at Site 608 only, 19 (9.5%) at Site 610 only. In total, 182 taxa were recognized at Site 608, 163 at Site 610. The "additional" taxa at Site 608 do not occur in the lower part of the section (upper Oligocene), the time equivalent of which was not recovered at Site 610. Many of the taxa occurring at one site only are rare, with exception of *Cassidulina teretis* at Site 610, which has a maximum relative abundance of 37% in some samples younger than 3 Ma, and several *Fursenkoina* species in the lower Miocene of the same site (see Appendix A).

Relative Abundance

Relative abundances of the most common species and species groups are shown plotted versus sub-bottom depth in Figures 3 (Site 608) and 4A and B (upper and lower part, Site 610); also indicated on these figures are the paleomagnetic chrons after Clement and Robinson (this volume). Figure 5 shows the same data as plotted in Figure 3, but plotted versus absolute age. In Figure 6 the relative abundances of some of the most common species and species groups are shown plotted versus absolute age for Sites 608 and 610 for the last 8 m.y.; a similar plot for the lower part of the holes could not be constructed because the time control for Hole 610 is poor.

The most striking feature of the plots of relative abundance at Site 608 (Figs. 3, 5) is the extremely high relative abundance of *Bolivina* spp. in Cores 608-37 and -38. Except for this interval, the most common taxa throughout the studied interval at both sites are *Oridorsalis* spp. (more abundant at Site 608—see Fig. 6). *Gyroidinoides* spp., unilocular forms, *Cibicidoides* spp. (the *Cibicidoides kullenbergi* group together with *Cibicidoides bradyi* throughout, *Cibicidoides wuellerstorfi* from the middle Miocene up), and *Pullenia* spp. The latter taxon was more common at Site 610 after 2.4 Ma, from

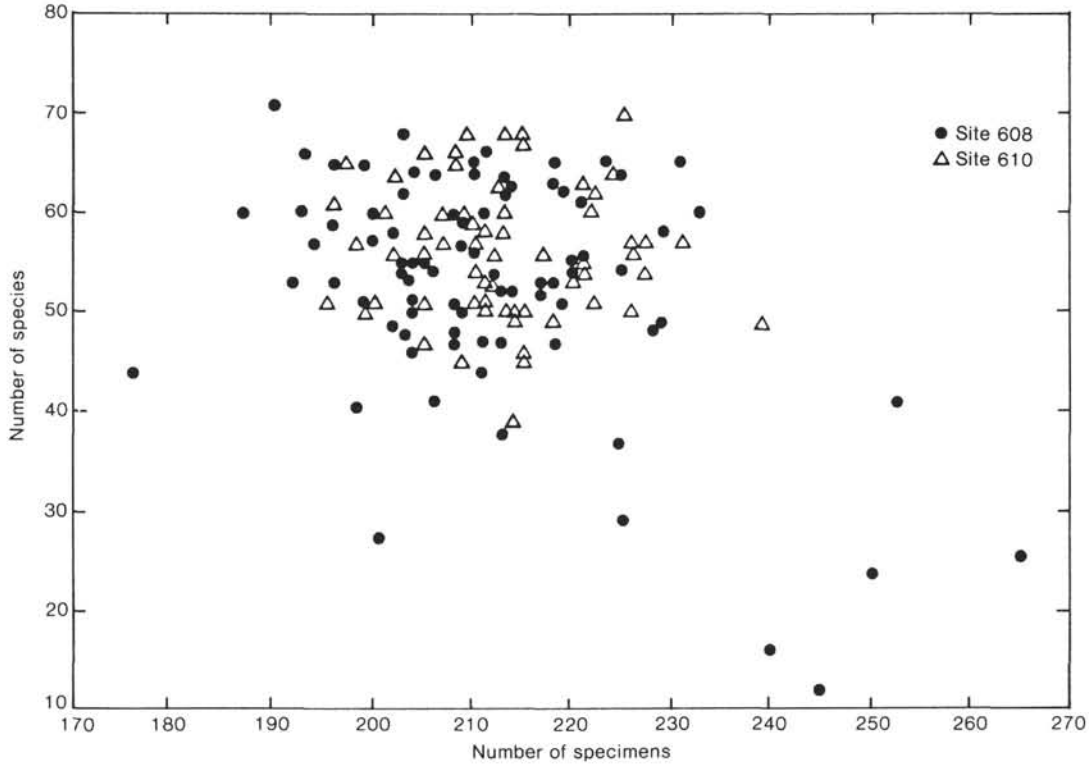


Figure 2. Plot of number of species versus number of specimens for Sites 608 and 610. Note the absence of a positive correlation.

6 to 8 Ma, and before 14 Ma than at other times. *Globocassidulina subglobosa* is common throughout the section at Site 608, and relatively rare at Site 610, especially above a level corresponding to about 2.4 Ma. All these taxa have long ranges and cosmopolitan distributions (e.g., Woodruff and Douglas, 1981; Thomas, 1985; in press).

Nuttallides umbonifera is rare at Site 610, and at Site 608 the taxon had in most samples a relative abundance of less than 5% before about 6.5 Ma; the relative abundance was usually between 5 and 10% from 6.5 Ma to 1.5 Ma, but fluctuated between 0.5 and 23%. After 1.5 Ma *N. umbonifera* was extremely rare at Site 608. *Epistominella exigua* had fluctuating relative abundances at both sites, usually between 2 and 12%, but was more abundant in the mudline sample from Site 608 (24%). *Eilohedra weddellensis* is absent or very rare in the lower part of the section at both sites; it increased in relative abundance to more than 5% after 0.8 Ma at Site 608 and 0.2 Ma at Site 610. *Cassidulina teretis* occurs at Site 610 only, and has strongly fluctuating relative abundances in the sediments from the last 3 m.y., with a maximum value of about 37%.

Melonis spp. are present throughout the section at Site 610, but had a first appearance at about 20.5 Ma at Site 608. At this site, *Melonis* spp. had their highest relative abundance between 6 and 15 Ma (relative abundance usually between 5 and 10%); the relative abundance decreased after 6 Ma. At Site 610 *Melonis* spp. were usually less abundant than at Site 608 before the Pliocene, but increased in relative abundance after about 2.8 Ma; from 2.8 Ma to Recent, *Melonis* spp. (mainly *Melonis pompilioides*) fluctuated strongly in relative abundance, from a few to more than 20% (Fig. 6).

Pleurostomella spp. constituted 2 to 10% of the fauna in most samples older than 6.5 Ma at Site 608; they decreased in relative abundance after that time, and species of *Pleurostomella* are absent from sediment younger than 1.5 Ma. At Site 610 they had relative abundances similar to those at Site 608 before about 15 Ma, and later constituted less than 5% of the fauna until about 0.8 Ma; they are not found in younger samples. *Stilostomella* spp. had their last appearance at the same time as *Pleurostomella* spp. at both sites (1.5 Ma at Site 608, 0.8 Ma at Site 610); before that time they formed usually between 5 and 20% of the total fauna at Site 610. At Site 608 they were less than 5% of the fauna from 6 to 1.5 Ma, usually similar in relative abundance to the values at Site 610 before 6 Ma. Uniserial lagenids at Site 608 decreased in relative abundance from 5 to more than 10% before about 10 Ma to less than 5% after that time.

Miliolids are rare or absent in the lower part of the section at both sites. They were consistently present at Site 608 after 12 Ma, and increased in relative abundance after 3 Ma (Fig. 6). At Site 610 miliolids increased in relative abundance after about 2.4 Ma (usually 2–10%, Fig. 6).

Bulimina spp. usually had relative abundances of less than 5% at both sites, but were somewhat more common at Site 610 than at Site 608. *Uvigerina* spp. fluctuated in relative abundance irregularly at both sites, with

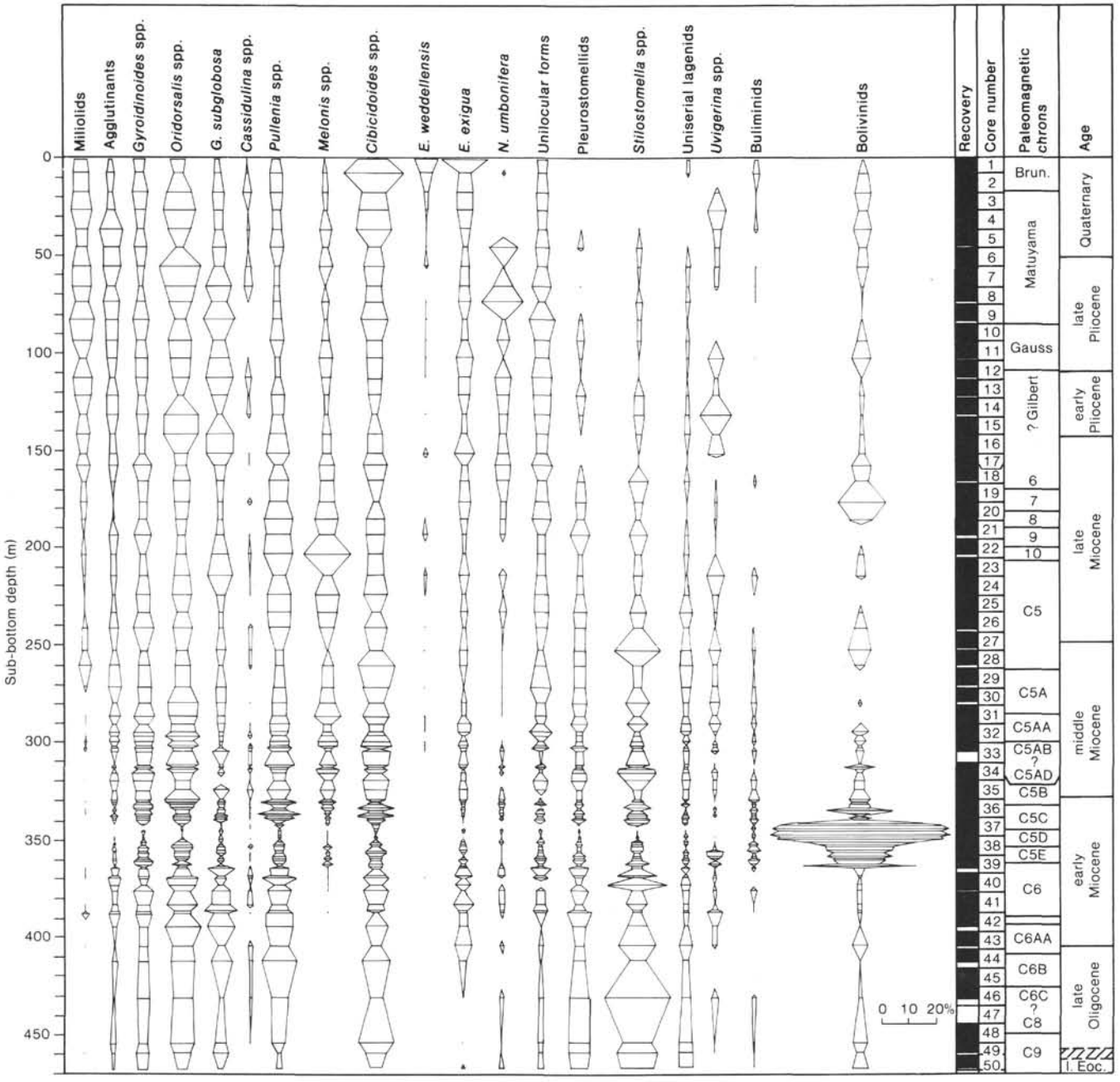
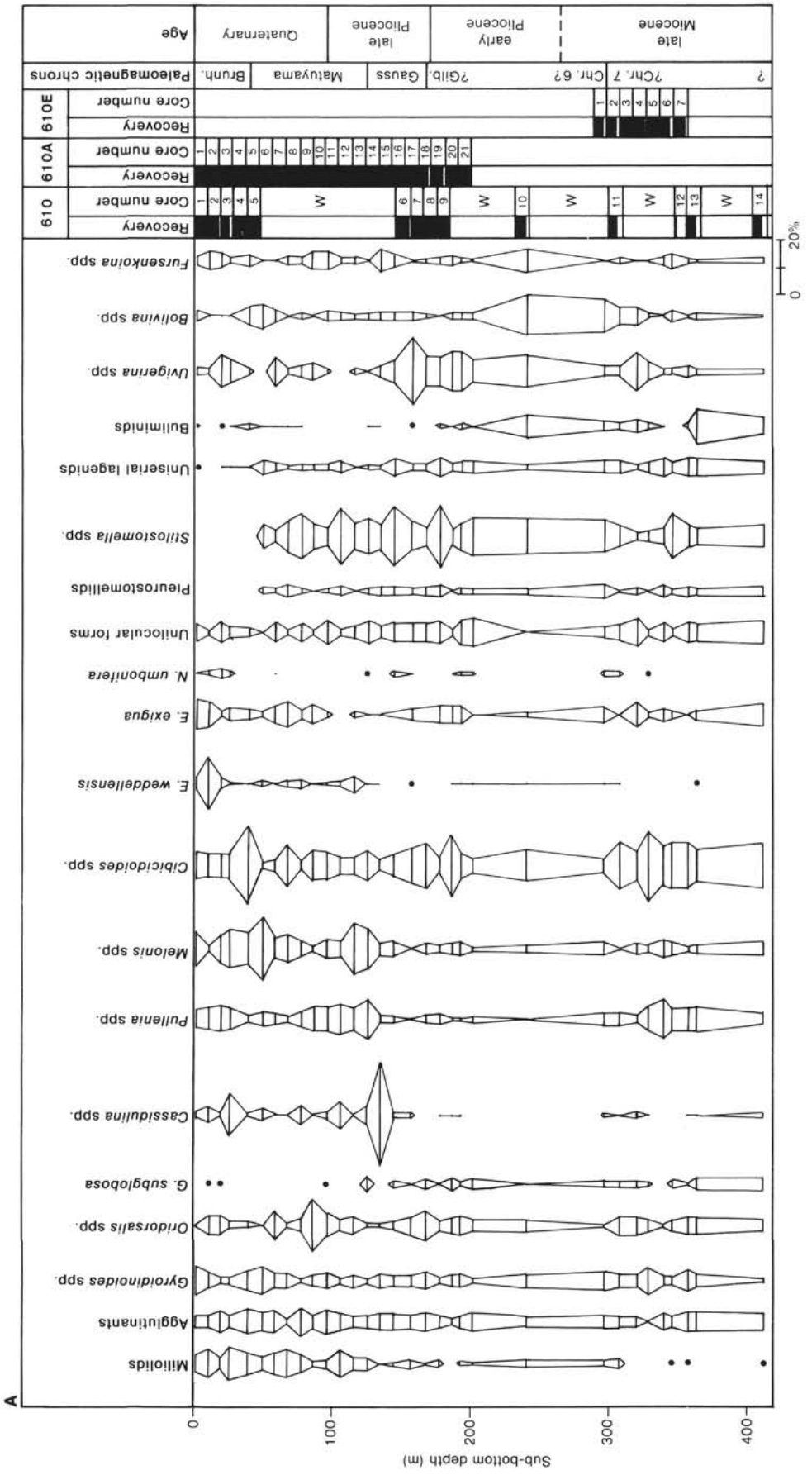


Figure 3. Relative abundances of the most common species and species groups at Site 608, plotted versus sub-bottom depth. Paleomagnetic chrons are after Clement and Robinson (this volume); also indicated are core number and recovery.

Uvigerina peregrina increasing in relative abundance after about 6.5 Ma at Site 610, somewhat later (5.5–6.0 Ma) at Site 608 (Appendix A, Tables 1, 2).

At Site 608 extremely high percentages of *Bolivina* spp. were noted in Cores 608-37 and -38 (Figs. 3, 5); the *Bolivina* are predominantly *Bolivina spathulata*, but at some levels also *Bolivina striatula* and *Bulivina pseudoplicata* (Thomas, in press). It is unlikely that these high relative abundances are the result of downslope transport: the *Bolivina* specimens have thin, delicate tests and do not show signs of abrasion. At different levels in the cores different species of *Bolivina* are predominant (Thomas, in press); in some sediments recognized as debris flows by shipboard scientists (see Site 608 report, this volume) the faunas do not have abundant *Bolivina*. The highest relative abundances of *Bolivina* (more than 90%) occur in Cores 608-37 and -38 (341–351 m sub-bottom); this level is in calcareous nannofossil Zone NN4 (Takayama and Sato, this volume), and paleomagnetic Chrons C5C–C5E (Clement and Robinson, this volume; see also Fig. 3); the estimated age is 17 to 18.2 Ma. The lowest peak in relative abundance of *Bolivina* occurs in Core 608-39, at about 363 m sub-bottom (about 19.2 Ma; Fig. 5). *Bolivina* spp. relative abundances fluctuated considerably during the Miocene, with peaks of *Bolivina spathulata* and *Bolivina striatula* (together more


Age
late Miocene
early Pliocene
late Pliocene
Quaternary
Paleomagnetic chrons
?
Chr. 7
Chr. 6?
?Gilb.
Gauss
Matuyama
Brunh.
610
610A
610E
Recovery
Core number
W
A
Sub-bottom depth (m)
0
100
200
300
400
0
20%
Miliolids
Agglutinants
Gyroidinoides spp.
Oridorsalis spp.
G. subglobosa
Cassidulina spp.
Pullenia spp.
Melonis spp.
Cibicidoides spp.
E. wedellensis
E. exigua
N. umbonifera
Uniocular forms
Pleurostomellids
Stilostomella spp.
Uniserial lagenids
Bulimids
Uvigerina spp.
Bolivina spp.
Fursenkoina spp.

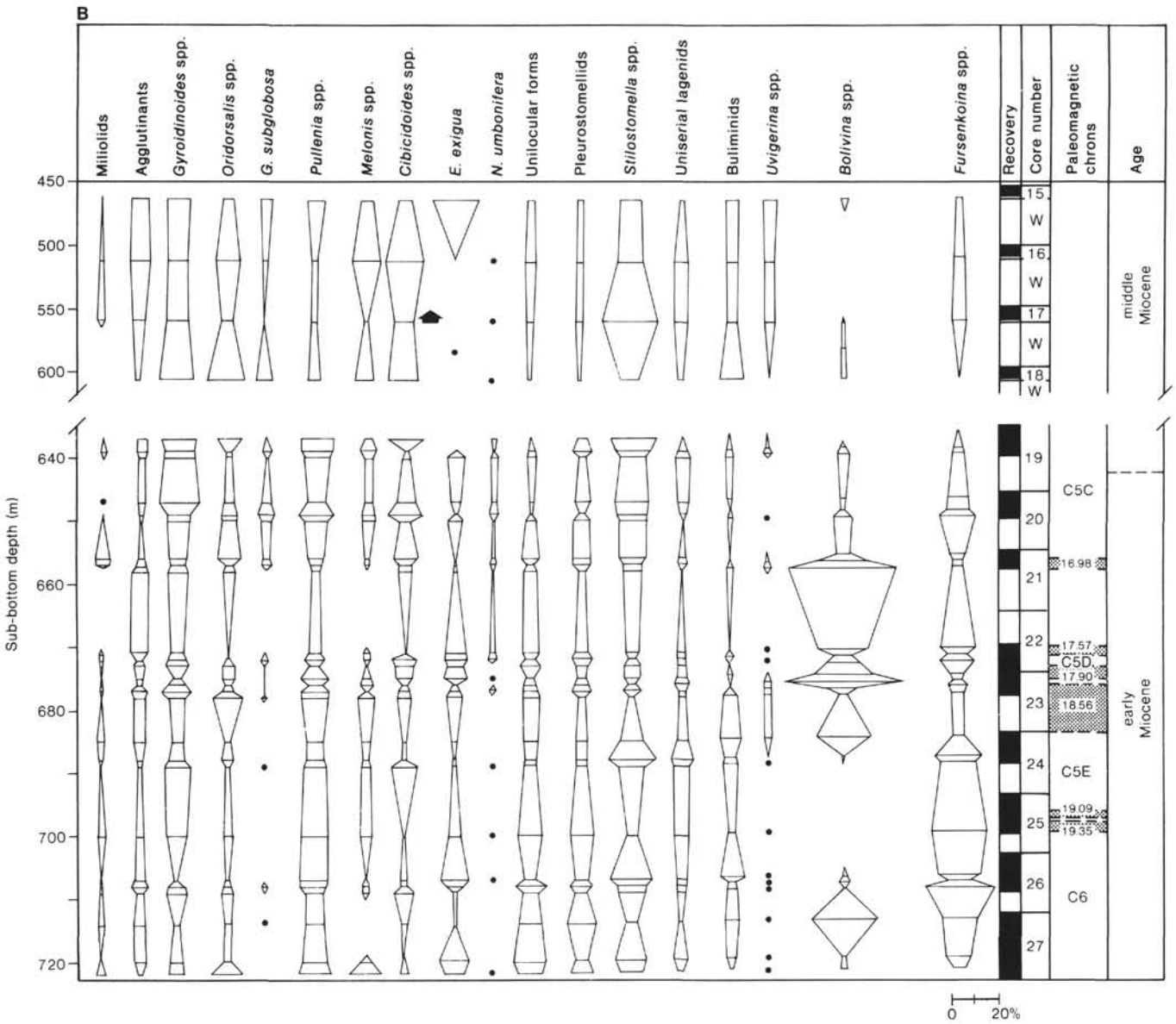


Figure 4. Relative abundances of the most common species and species groups at Site 610, plotted versus sub-bottom depth for the upper part (A) and the lower part (B) of the section. Indicated are core number and recovery for Holes 610, 610A, and 610E (W in Core number column indicates washed section). The sub-bottom depths for Hole 610E have been adjusted by 30 m, to make up for the difference in depth on the wave crest and in the wave trough (see Site 610 report, this volume). Paleomagnetic chrons are after Clement and Robinson (this volume). In 4B the arrow indicates the FA of *Cibicidoides wuellerstorfi*; the shaded intervals in the Paleomagnetic chron column indicate the depth interval in which the reversal boundary occurs; numbers give the age, following Berggren, Kent, and Flynn (1985).

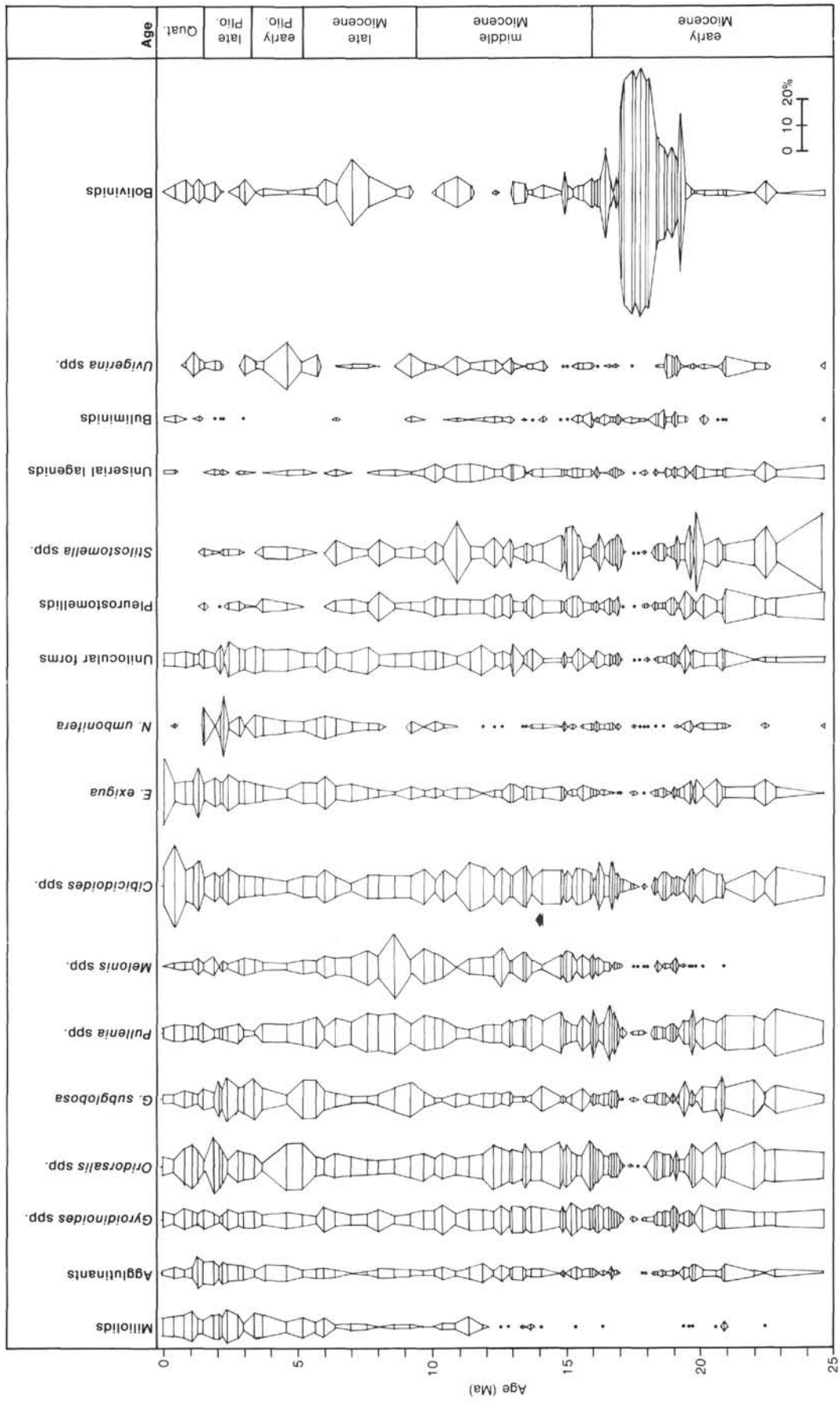


Figure 5. Relative abundances of the most common species and species groups at Site 608, plotted versus time. The age model was constructed using the paleomagnetic data of Clement and Robinson (this volume) and the time scale of Berggren, Kent, and Van Couvering (1985). The arrow indicates the FA of *Cibicidoides wuellerstorfi*.

than 30%) at 334 m sub-bottom (~16.4 Ma), of *Bolivina striatula* and *Bolivina pseudoplicata* (together 16%) at 312 m sub-bottom (~14.9 Ma), and of *Bolivina translucens* (25%) at 176 m (~7 Ma).

At Site 610 the relative abundances of *Bolivina* spp. are never as high as at Site 608, but *Bolivina spathulata* is relatively abundant (up to 45%) in Cores 610-21, -22, and the top of -23. This interval is (within the limits of resolution of this study) coeval with the level of highest relative abundances of *Bolivina* at Site 608, that is, within calcareous nannofossil Zone NN4 (Takayama and Sato, this volume), and paleomagnetic Chrons C5C–C5E (Clement and Robinson, this volume; see also Fig. 4B): the estimated age is 17 to 18.5 Ma. In this interval and just below, *Fursenkoina* spp. are also relatively abundant at Site 610 (up to 27%, but usually 10–15%); the genus decreased in relative abundance at the end of the early Miocene (it is rare at Site 608).

In conclusion, there were changes in relative abundances between 19.2 and 17 Ma (increase in *Bolivina* at both sites, more extreme at Site 608), between 14 and 15 Ma (decrease in *Pleurostomella* at Site 610, increase in *Melonis* at Site 608), from 10 to 9 Ma (decrease in uniserial lagenids at Site 608), between 5 and 7 Ma (increase in miliolids and *Nuttallides umbonifera*, decrease in *Pleurostomella, Stilostomella*, and *Melonis* at Site 608), and during the last 3 m.y. (more miliolids at Site 610, less *Nuttallides umbonifera* at Site 608, last appearances of *Stilostomella* and *Pleurostomella* at both sites, increase in *Cassidulina teretis* and *Melonis* at Site 610, increase in *Eilohedra weddellensis* at both sites).

First and Last Appearances (FAs and LAs)

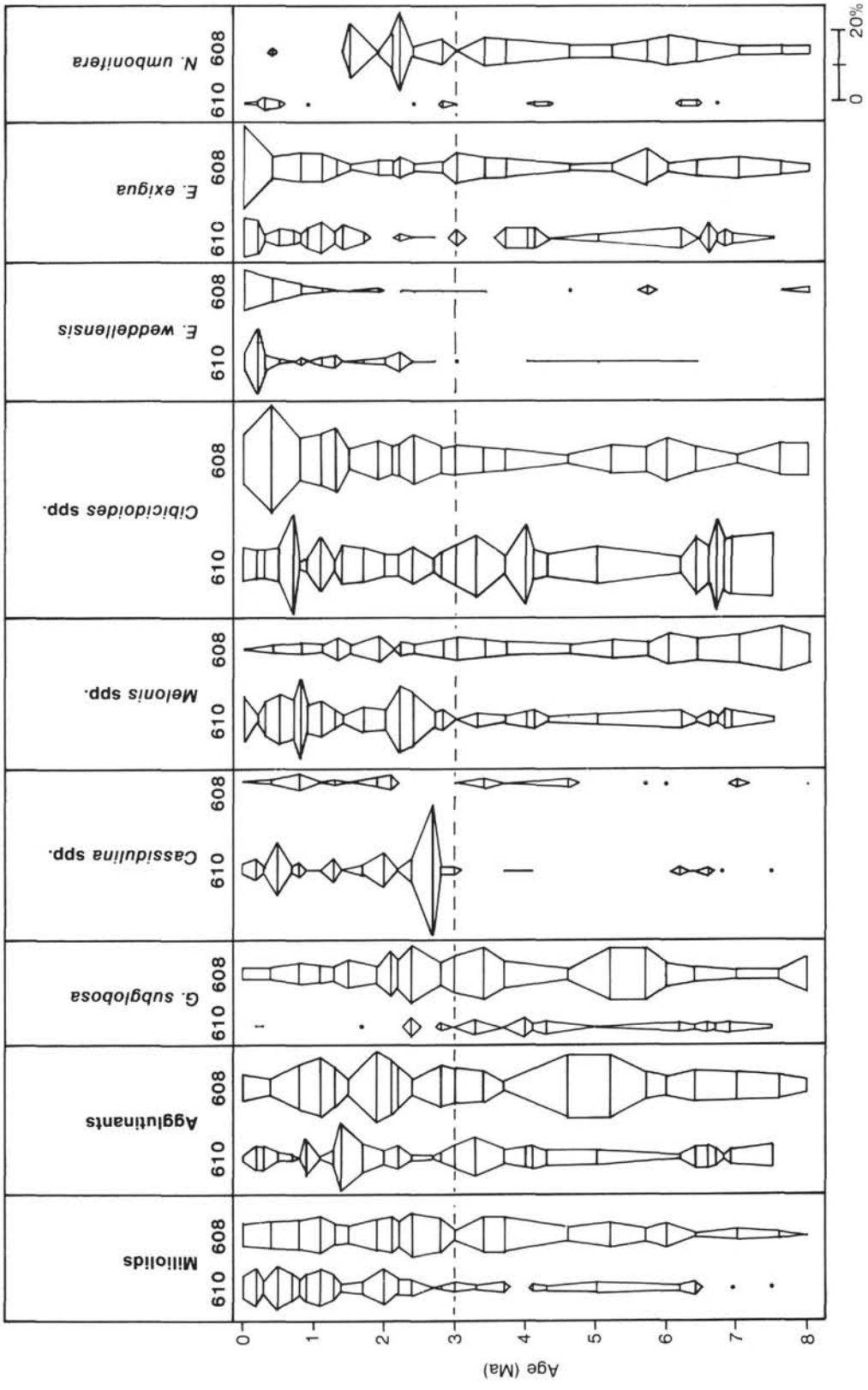
FAs and LAs are difficult to determine with accuracy and precision for deep-sea benthic foraminiferal species, because the most common species have long ranges and do not have FAs or LAs in the studied interval (i.e., late Oligocene to Recent). For rare species the exact position at which FAs and LAs are actually found may be considerably different from the real position, because the probability of actually finding a rare species is low. I used FAs and LAs of species that have a reasonably well-defined consecutive range, that is, the rarest species were not used. The position of all FAs and LAs used are given in Tables 1 (Site 608) and 2 (Site 610), and ranges of selected species are shown in Figure 7. Listed are all the FAs and LAs observed, whether they are a result of migration (immigration or emigration, lateral or vertical migration) or evolution (evolution or extinction). At present there are not enough data available on deep-sea benthic foraminiferal faunas from all oceans to determine whether a specific faunal event (FA or LA) is local, regional, or global, especially because of the confusion in taxonomy, which makes comparison with data of other authors difficult. I decided to list all faunal events that are recognizable at Sites 608 and 610 to find out if these events are evenly distributed through time or concentrated in specific periods. If faunal events cluster in some periods, then the clustering probably indicates changes in the deep-sea environment in these periods, whether the benthic foraminifers reacted by evolution or migration. Figure 8 is a cumulative plot of faunal events versus time for Site 608 and 610.

Of the 182 taxa recorded at Site 608, 39 are long-ranging, 101 are too rare to determine whether they have a FA or LA, 24 taxa have a FA, and 21 a LA (3 species have a FA and a LA; a total of 45 faunal events). At Site 610, 42 of the recognized taxa range throughout the section, 77 are too rare to determine a FA or LA, 23 have a FA, and 25 a LA (4 species have both a FA and a LA; a total of 48 faunal events). The long-ranging taxa comprise about 50 to 60% of the total fauna in most samples.

In my opinion, it is presently not possible to compare data on ranges of most species with data from other authors without comparing the actual material because of taxonomical problems. Therefore the following discussion is not meant to give an overview of all available data, but to compare the data from a deeper site (Site 608) with those of a shallower Atlantic site (Site 610), and the data from the two Atlantic sites with data from the Pacific (Thomas, 1985). Of all faunal events, 8 only occurred in the same calcareous nannofossil zone at Sites 608 and 610 (see Tables 1 and 2), that is, 3 in NN19 (LA *Pleurostomella obtusa*, LA *Stilostomella annulifera*, and LA *Stilostomella lepidula*), 3 in NN11 (FA *Pyrgo murrhina*, FA *Bolivina translucens*, LA *Nonion havanense*), 1 in NN5 (FA *Cibicidoides wuellerstorfi*), and 1 in NN3 (FA *Ehrenbergina caribbea*). The FA of *C. wuellerstorfi* (14.1–14.8 Ma at Site 608) occurred at a similar time, but probably slightly earlier, in the equatorial Pacific (15.0–15.6 Ma) (Thomas, 1985). This FA is coeval with the increase in oxygen isotopic ratios in the tests of benthic foraminifers at Site 608 (Miller et al., this volume). The FA of *Ehrenbergina caribbea* at 17 to 20 Ma in the equatorial Pacific may correlate with this event at Atlantic Sites 608 and 610 (18.7–19.0 Ma). Several other faunal events at the deepest Atlantic site (Site 608) might be correlated with the same faunal events in the deep equatorial Pacific, for example, the FA of the *Melonis barleeanus* group at about 20 Ma (Thomas, 1986).

Overall, few of the faunal events can be correlated in time between Site 608 (3.5 km) and Site 610 (2.5 km), or between the northeast Atlantic and DSDP Sites 573, 574, and 575 in the equatorial Pacific, although the faunal patterns are similar: for instance, *Stilostomella* spp., *Pleurostomella* spp., and the uniserial lagenids decrease in abundance at all these sites. The timing, however, is different at different depths and in different areas.

Faunal events are not evenly distributed through time (Fig. 8). The event rate, that is, the number of faunal events per time unit, was low at Sites 608 and 610 before about 19 Ma, with a small increase associated with the strong increase in relative abundance of *Bolivina* spp. An increase in the event rate occurred at both sites between about 13.5 and 15.5 Ma, but the precise time cannot be determined at Site 610 because this interval was spot-cored. This increase can be correlated at Site 608 with the increase in oxygen isotopic ratios in benthic foraminiferal tests in the lower middle Miocene (Miller et al., this volume; Fig. 8), which has been observed world-


Miliolids
Agglutinants
G. subglobosa
Cassidulina spp.
Melonis spp.
Cibicidoides spp.
E. wuddellensis
E. exigua
N. umbonifera
610
608
0
20%
0
1
2
3
4
5
6
7
8
Age (Ma)

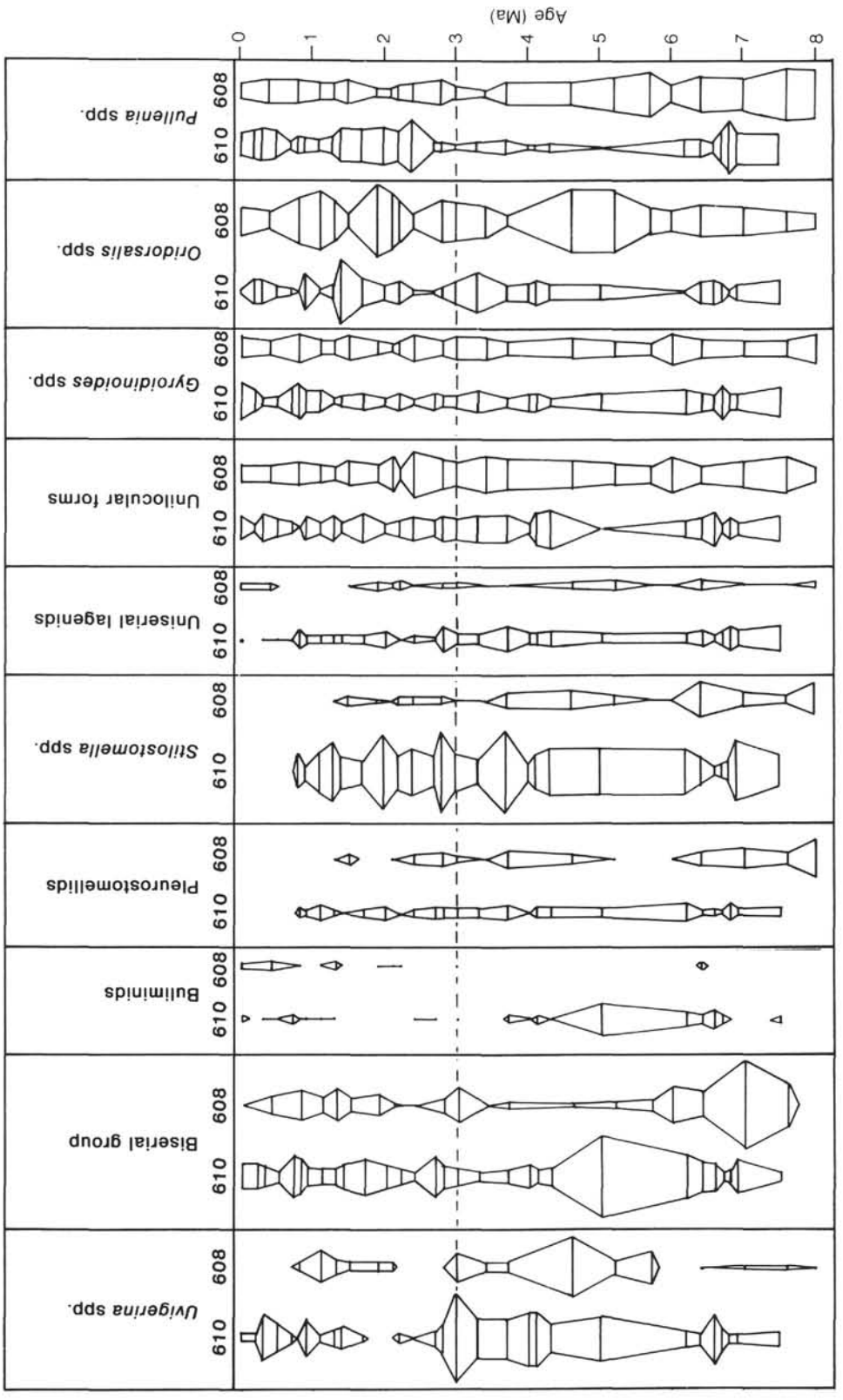


Figure 6. Relative abundances of the most common species and species groups at Sites 608 and 610, plotted versus time for the last 8 m.y. The age models were constructed using the paleomagnetic data of Clement and Robinson (this volume) and the time scale of Berggren, Kent, and Van Couvering (1985).

Table 1. First and last appearances (FAs and LAs) of taxa at Site 608.

Event	Sample	CNZ	Age (Ma)
LA *Eponides tumidulus*	2,CC	NN19	0.8–1.1
FA *Eponides repandus*	3,CC	NN19	1.1–1.3
LA *Pleurostomella obtusa*[a]	4,CC	NN19	1.1–1.3
LA *Stilostomella annulifera*[a]	4,CC	NN19	1.1–1.3
LA *Stilostomella lepidula*[a]	4,CC	NN19	1.1–1.3
FA *Cibicides variabilis*	4,CC	NN19	1.3–1.5
LA *Pleurostomella acuminata*	5,CC	NN16	1.3–1.5
LA *Bolivina pseudoplicata*	5,CC	NN16	1.3–1.5
LA *Pleurostomella alternans*	5,CC	NN16	1.3–1.5
LA *Pleurostomella bolivinoides*	5,CC	NN16	1.3–1.5
FA *Ehrenbergina trigona*	5,CC	NN16	1.5–1.9
FA *Stainforthia complanata*	6,CC	NN16	1.9–2.1
FA *Pyrgo elongata*	10,CC	NN16	2.8–3.0
FA *Pyrgo lucernula*	10,CC	NN16	2.8–3.0
LA *Ehrenbergina caribbea*	11,CC	NN16	2.8–3.0
LA *Uvigerina graciliformis*	11,CC	NN16	2.8–3.0
FA *Sigmoilopsis schlumbergeri*	11,CC	NN16	3.0–3.4
FA *Quinqueloculina pygmaea*	13,CC	NN15	3.7–4.6
LA *Stilostomella subspinosa*	14,CC	NN14	3.7–4.6
LA *Bigenerina nodosaria*	16,CC	NN12–13	5.2–5.6
FA *Uvigerina peregrina*[b]	16,CC	NN12–13	5.2–5.6
LA *Stilostomella abyssorum*	18,CC	NN11	6.0–6.4
LA *Pyrgo murrhina*[a]	18,CC	NN11	6.4–7.0
FA *Bolivina translucens*[a,b]	20,CC	NN11	7.6–8.0
LA *Nonion havanense*[a]	21,CC	NN11	7.6–8.0
LA *Bolivina striatula*	23,CC	NN9	8.6–9.2
LA *Bulimina alazanensis*	23,CC	NN9	8.6–9.2
LA *Anomalina alazanensis spissiformis*[b]	24,CC	NN9	9.2–9.7
LA *Bolivinopsis cubensis*	28,CC	NN8	10.9–11.4
FA *Sigmoilina tenuis*	28,CC	NN8	11.4–11.9
FA *Melonis pompilioides*	31-4	NN6	12.6–12.9
LA *Cibicidoides laurisae*	32-3	NN6	12.9–13.0
LA *Cibicidoides havanense*	33,CC	NN5	13.7–14.1
FA *Eilohedra weddellensis*	33-2	NN5	13.7–14.1
FA *Cibicidoides wuellerstorfi*[a]	33,CC	NN5	14.1–14.8
FA *Ophthalmidium pusillum*	33,CC	NN5	14.1–14.8
LA *Cibicidoides perlucidus*	34-1	NN5	14.1–14.8
LA *Gyroidinoides girardanus*	34-2	NN5	14.8–14.9
LA *Bolivina spathulata*	36-2	NN4	16.0–16.1
LA *Pleurostomella acuta*	36-2	NN4	16.0–16.1
FA *Cibicidoides cicatricosus*	36-5	NN4	16.6–16.7
FA *Ehrenbergina caribbea*[a]	38,CC	NN3	18.8–18.9
FA *Bolivina spathulata*	40-1	NN3	19.6–19.7
FA *Melonis affinis*	40,CC	NN3	20.1–20.6
FA *Bolivina striatula*	42,CC	NN3	22.0–22.4

Note: Ages are from extrapolation of the paleomagnetic data of Clement and Robinson (this volume); calcareous nannofossil zones (CNZ) are after Takayama and Sato (this volume).

[a] Events that occur in the same nannofossil zone at Site 610.

[b] An increase or decrease in abundance.

Table 2. First and last appearances (FAs and LAs) of taxa at Site 610.

Event	Sample	CNZ	Age (Ma)
LA *Chrysalogonium tenuicostatum*	5,CC	NN19	0.7–0.8
LA *Stilostomella consobrina*	5,CC	NN19	0.7–0.8
LA *Stilostomella lepidula*[a]	5,CC	NN19	0.7–0.8
LA *Pleurostomella bolivinoides*	5,CC	NN19	0.7–0.8
LA *Pleurostomella acuminata*	A6,CC	NN19	0.8–0.9
LA *Stilostomella annulifera*[a]	A7,CC	NN19	0.9–1.1
LA *Orthomorphina glandigena*	A7,CC	NN19	0.9–1.1
FA *Bolivina subspinescens*	A7,CC	NN19	1.1–1.3
LA *Textularia agglutinans*	A8,CC	NN19	1.1–1.3
LA *Pleurostomella obtusa*[a]	A10,CC	NN19	1.4–1.7
LA *Bolivina spathulata*	A11,CC	NN18	1.7–2.0
FA *Eponides tumidulus*	A12,CC	NN18	2.2–2.4
FA *Pyrgo elongata*	A12,CC	NN18	2.2–2.4
FA *Hopkinsina pacifica*	A13,CC	NN18	2.4–2.7
FA *Hoeglundina elegans*	A13,CC	NN18	2.4–2.7
LA *Bulimina microcostata*	A14,CC	NN17	2.4–2.7
FA *Cassidulina teretis*	6,CC	?NN16	3.0–3.3
FA *Melonis barleeanus*	6,CC	?NN16	3.0–3.3
LA *Ehrenbergina trigona*	7,CC	?NN16	3.0–3.3
LA *Melonis affinis*	7,CC	?NN16	3.0–3.3
FA *Uvigerina bononiensis*	7,CC	?NN16	3.0–3.3
LA *Ehrenbergina caribbea*	A20,CC	NN15	4.0–4.1
FA *Melonis pompilioides*	A21,CC	NN15	4.3–5.0
FA *Stainforthia complanata*	10,CC	?	5.0–6.2
LA *Cibicidoides trinitatensis*	E1,CC	NN12	5.0–6.2
LA *Fursenkoina cylindrica*	E1,CC	NN12	5.0–6.2
LA *Cibicidoides* cf. *kullenbergi*	E2,CC	NN11	6.2–6.4
FA *Pyrgo murrhina*[a]	E2,CC	NN11	6.4–6.6
FA *Eilohedra weddellensis*	E2,CC	NN11	6.4–6.6
LA *Nonion havanense*	E3,CC	NN11	6.4–6.6
FA *Ehrenbergina trigona*	E3,CC	NN11	6.6–6.7
FA *Uvigerina peregrina*[b]	E4,CC	NN11	6.7–6.8
FA *Cibicidoides cicatricosus*	E5,CC	NN11	6.8–6.9
FA *Pyrgo lucernula*	E5,CC	NN11	6.8–6.9
FA *Bolivina translucens*[a,b]	E6,CC	NN11	6.9–7.5
LA *Pleurostomella alternans*	14,CC	?NN9	8.6–10.5
FA *Uvigerina bononiensis*	15,CC	?	12.0–13.5
LA *Anomalina alazanensis spissiformis*[b]	16,CC	NN6	12.0–13.5
FA *Francesita advena*	16,CC	NN6	13.5–14.5
LA *Bolivinopsis cubensis*	17,CC	NN5	13.5–14.5
FA *Sigmoilopsis schlumbergeri*	17,CC	NN5	14.5–15.5
FA *Cibicidoides wuellerstorfi*[a]	17,CC	NN5	14.5–15.5
LA *Pleurostomella acuta*	19-1	NN5	15.3–15.4
LA *Fursenkoina mexicana*	19-2C	NN5	15.3–15.4
FA *Bulimina elongata subulata*	19,CC	NN5	15.5–15.9
FA *Stilostomella annulifera*	24-1	NN3	18.7–18.8
FA *Ehrenbergina caribbea*[a]	24-3	NN3	18.9–19.0
LA *Bigenerina nodosaria*	26-4	NN3	19.5–19.6

Note: Ages are from extrapolation of the paleomagnetic data of Clement and Robinson (this volume), (ages in the spot-cored interval are not accurate). Calcareous nannofossil zones (CNZ) are after Takayama and Sato (this volume).

[a] Events that occur in the same nannofossil zone at Site 608.

[b] An increase or decrease in abundance.

wide (Woodruff and Douglas, 1981; Savin et al., 1981). At Site 610 the event rate was low between 13.5 and 7 Ma, and it increased sharply between 7 and 6 Ma, between 3.3 and 2.0 Ma, and 1.3 and 0.7 Ma. At Site 608 the event rate was stable between 13.5 and 3 Ma (except for a possible small increase at 10–9 Ma), but somewhat higher than before 15 Ma, and there was no increase in the event rate between 7 and 6 Ma. Therefore the difference between the event rate curves at Sites 608 and 610 increased between 13.5 and 7 Ma, to decrease again at 7 Ma (Fig. 8B). The cumulative curves of faunal events at the two sites have a relatively constant difference of 5 events between 3.5 and 6.5 Ma; this difference exists because there were more events at Site 610 at about 3 Ma than there were at Site 608, although the event rate at Site 608 increased sharply between 3.0 and 2.8 Ma, and between 1.5 and 1.1 Ma.

The variation in the event rates is also demonstrated in Figure 9, where the midpoints of the ranges of FAs and LAs were plotted versus time in a histogram with a unit width of 0.5 m.y. Obviously the largest number of FAs and LAs occurred between 0.5 and 3.5 Ma at both sites: from the 45 faunal events at Site 608, 17 events (38%) occurred during this period, and for Site 610 the numbers are 21 (44%) out of 48. At Site 610 11 events out of 48 (23%) occurred between 7 and 5.5 Ma, at which time there was no concentration of FAs or LAs at Site 608. A third period with relatively many faunal events was between 13.5 and 15.5 Ma at Site 608 (6 events i.e., 13%), and between 14 and 15.5 Ma at Site 610 (6 events, 12.5%). The apparent difference in age is probably the result of the poor time control at Site 610.

In counting FAs and LAs as a measure of faunal change, the FAs and LAs of relatively rare species re-

ceive as much weight as those of more common species, but the latter have more impact on the total aspect of the fauna: the FA of *Cibicidoides wuellerstorfi*, for instance, is of more importance for the total fauna than the LA of *Nonion havanense*. Thomas (1986) discussed the concept of similarity of a fauna in a sample to a fauna in a mudline sample from the same site; the similarity was defined as the percentage of specimens in a sample that belongs to species that are found in a mudline sample from the same site. At Site 608 the similarity of the fauna increased from 60 to 70% in the late Oligocene (similar to a figure of 67.5% for Oligocene assemblages as given by Boltovskoy, in press) to 70 to 80% at 15 to 14 Ma, then changed gradually and with large fluctuations to about 90% similarity at about 6 Ma. These numbers emphasize that a large proportion of the total fauna belonged to long-ranging species, and that the occurrence of FAs and LAs does not have to mean an important change in the total aspect of the fauna (Boltovskoy, 1980a and 1980b).

DISCUSSION

About 60% of the total deep-sea benthic foraminiferal faunas at Site 608 and 610 belongs to long-ranging species, existing since at least the late Oligocene. Faunal events can generally not be correlated from one site to another site (especially to another site at different depth or in another basin): only eight out of the 45 events at Site 608, and of the 48 events at Site 610, occurred in the same calcareous nannofossil zone at Sites 608 and 610 (Tables 1 and 2). All other events are recognized at one site only, or the timing is different. The FA of *Sigmoilopsis schlumbergeri*, for instance, occurred at 14.5 to 15 Ma at Site 610 (depth about 2.5 km), and at 3.0 to 3.4 Ma at Site 608 (depth about 3.5 km). This species was recorded by Schnitker (in press) to have a FA at 14 Ma, in his discussion of benthic foraminiferal faunas from DSDP Sites 552 to 555 (Rockall Plateau area, 1600–3000 m water depth) and DSDP Site 400 (Bay of Biscay, 4400 m). Several other faunal events described in Schnitker (in press) occurred at different times at one or both of Sites 608 and 610. For instance, *Melonis pompilioides* has a FA at 16 Ma according to Schnitker (in press), but this event occurred at 12.6 to 12.7 Ma at Site 608, and at 4.3 to 5.0 Ma at Site 610. Many benthic species may migrate slowly (slower than the deep-water circulation rate of the oceans) from one area to another, or from one depth level to another, and thus show time-transgressive first or last appearances. In my opinion many faunal events in deep-sea benthic foraminifers cannot be used for biostratigraphy (especially between sites at different depths or within different basins) without careful evaluation that the events are indeed coeval.

Changes in overall aspect of the benthic foraminiferal fauna can be the result of changes in relative abundances of species, or of the addition of new species (FAs) or the loss of old species (LAs). During the last 25 m.y. there were four periods during which the deep-sea benthic foraminiferal faunas at Sites 608 and 610 changed more than at other times; in addition, there was one additional period of less important, but marked changes at Site 608.

1. 19.2–17 Ma. During this period the relative abundance of *Bolivina* spp. was high at Site 610 (up to 45%) and extremely high at Site 608 (more than 90%). In my opinion these high relative abundances cannot be fully explained as yet. Similar *Bolivina*-rich faunas have been found where sediments are rich in organic matter, either because of low oxygen content in the bottom waters as a result of sluggish circulation (e.g., southern California basins [Harman, 1964; Boltovskoy and Wright, 1976] and the Mediterranean sapropels [Cita and Podenzani, 1980; Van der Zwaan, 1980; Mullineaux and Lohmann, 1981]), or because of high productivity in the surface waters on continental slopes (Sen Gupta et al., 1981; Casey et al., 1981; also, see Thomas, in press, for a more detailed discussion).

The high relative abundances of *Bolivina* spp. in the deep, open northeastern Atlantic might be explained best by postulating that the circulation of the deep waters was sluggish in the early Miocene; the effects of this sluggish circulation might have been aggravated at Site 608 by the rugged topography (see Site 608 report, this volume). The ventilation in the basin probably improved toward the end of the early Miocene, which ended the high relative abundances of *Bolivina* spp., and brought the benthic $\delta^{13}C$ values closer to those of the western basin (Miller et al., this volume). The presence of a widespread reflector (R2—Miller and Tucholke, 1983) in the northeastern Atlantic dated as late early Miocene also suggests increased ventilation; at Site 610 this reflector can probably be located just above the level of high *Bolivina* abundances (Site 610 report, this volume).

2. 15.5–13.5 Ma. In this period there was an increase in FAs and LAs at both sites, combined with a decrease in relative abundance of *Pleurostomella* spp. at Site 610, and an increase in *Melonis* spp. at Site 608. These faunal changes occurred in calcareous nannofossil Zone NN5 (Takayama and Sato, this volume) in the early middle Miocene, at the same time as an increase in benthic foraminiferal $\delta^{18}O$ values (Miller et al., this volume; Fig. 8). Similar faunal changes have been reported to have occurred at this time by Berggren (1972), Berggren and Schnitker (1983), and Schnitker (in press), but I disagree with the conclusion of these authors that the benthic microfaunas assumed their present-day aspect during the middle Miocene. My data suggest that later faunal changes (see below) were more important than those in the early middle Miocene: of all first and last appearances during the last 25 m.y., only 6 (out of 45 at Site 608, 48 at Site 610) occurred at this time, and only about 10% of the total faunas were affected (Thomas, in press).

These faunal changes may have been the result of cooling of the deep waters of the oceans, as a result of increased ice volume on Antarctica, which in its turn may have been caused by the opening of the Drake passage and the thermal isolation of Antarctica (Shackleton and Kennett, 1975). Alternatively, the cool deep waters may have resulted from the sinking of the Iceland-Faeroe Ridge (Berggren and Schnitker, 1983; Miller et al., this volume) and the inflow of cold, northern water masses.

3. 10–9 Ma. Several FAs and LAs occurred at Site 608, and the uniserial lagenids showed a decrease in rel-

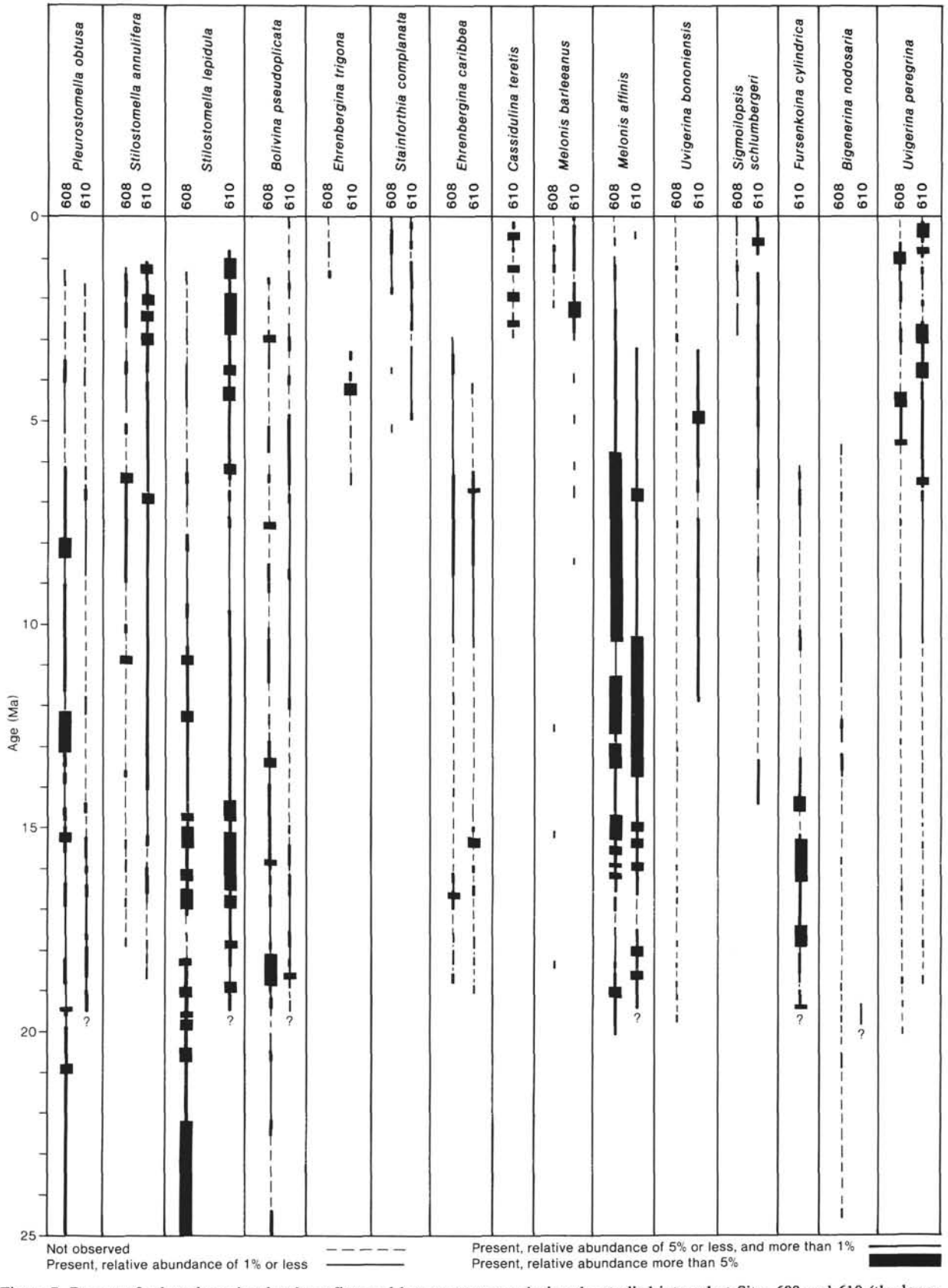


Figure 7. Ranges of selected species that have first and last appearances during the studied interval at Sites 608 and 610 (the lower boundary of recovery at Site 610 is indicated by ?). The age models were constructed using the paleomagnetic data of Clement and Robinson (this volume) with the time scale of Berggren, Kent, and Van Couvering (1985). Ages for the late to middle Miocene at Site 610 are not precise because of spot-coring.

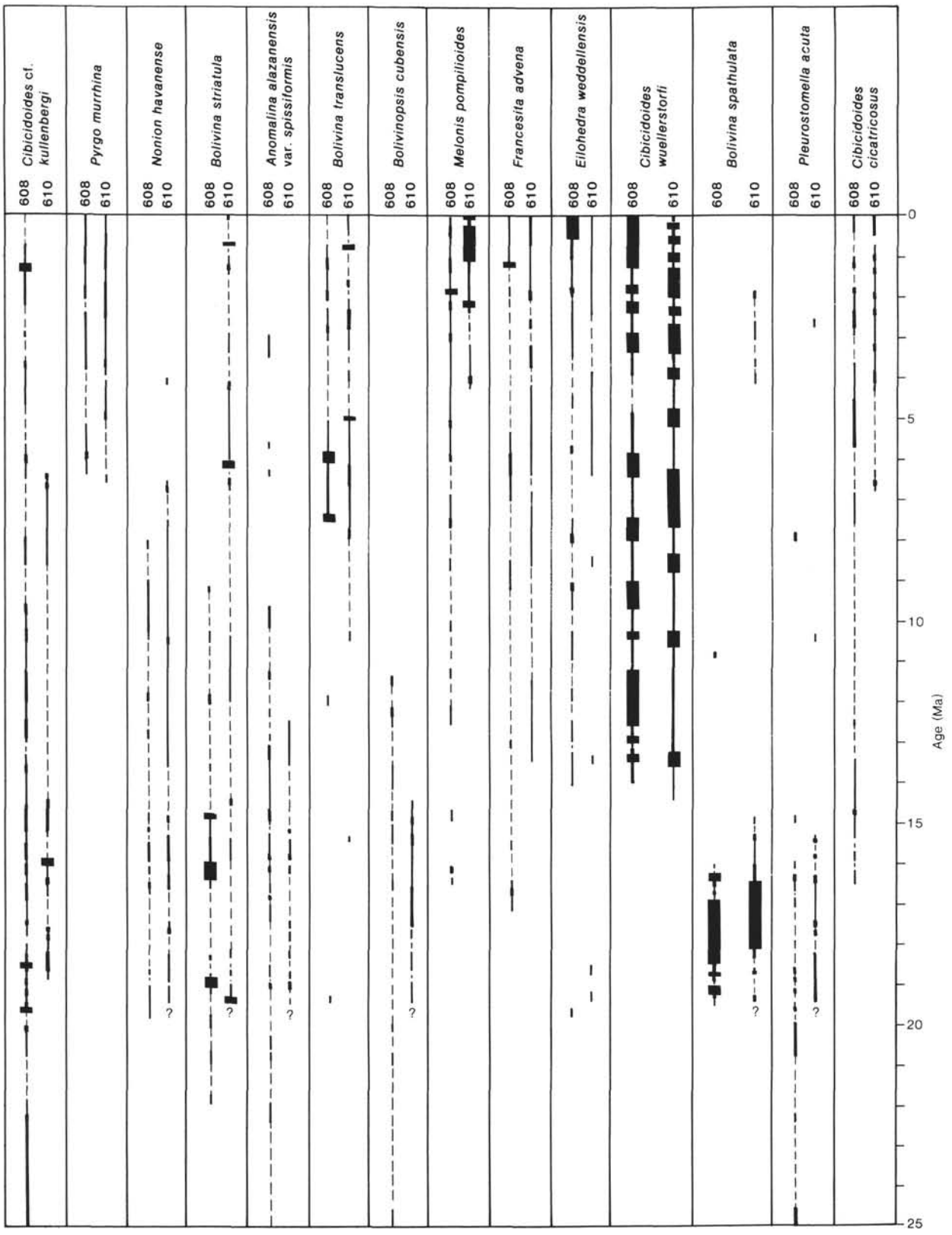


Figure 7 (continued).

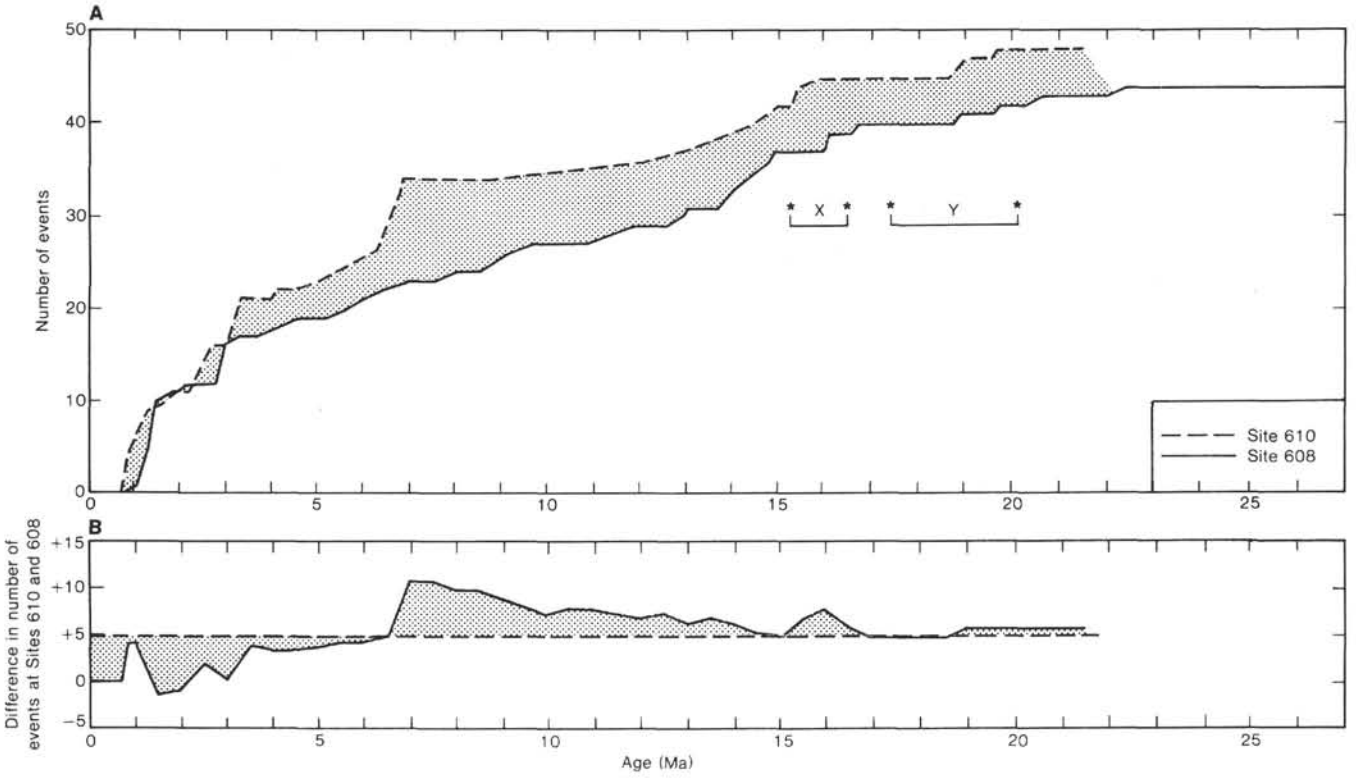


Figure 8. A. Cumulative plot of faunal events (first and last appearances) versus time for Sites 608 and 610. A steep slope of the curve indicates intervals during which many events occurred. Line marked *X* indicates the timing of the increase in $\delta^{18}O$ values, after Miller et al. (this volume). Line marked *Y* indicates the timing of the increase in $\delta^{13}C$ values, after Miller et al. (this volume). B. Difference between the cumulative faunal events curves shown in Figure 8A for Sites 608 and 610. Note the increase in the difference between 13.5 and 7 Ma.

ative abundance. No obvious changes were observed at Site 610. In many sedimentary sequences (especially in the Rockall Trough area) there is a prominent reflector dated at about 10 Ma (R1—Miller and Tucholke, 1983). The presence of this reflector may indicate a more vigorous bottom-water circulation during this period.

4. 7–5.5 Ma. In this period there were 11 FAs and LAs at Site 610 (23% of all faunal events recorded at the site during the last 20 m.y.). At Site 608 there were changes in relative abundance: an increase in miliolids and *Nuttallides umbonifera*, a decrease in *Pleurostomella* spp. *Stilostomella* spp., and *Melonis* spp. Schnitker (in press) also noted faunal changes at about this time at DSDP sites in the Rockall Plateau area (depths 1600–2700 m), but not in the Bay of Biscay (4000 m). Murray (this volume), in a quantitative study of benthic foraminiferal faunas from Sites 609 through 611, suggests that changes in watermass structure occurred in the late Miocene. He proposes that Antarctic Bottom Water (AABW) or a similar water mass, which is characterized by the presence of relatively abundant *Nuttallides umbonifera* (= *Osangularia umbonifera* in Murray's nomenclature) penetrated far north at this time. This hypothesis is supported by the relatively high relative abundances of *N. umbonifera* between 6.5 and 1.5 Ma at Site 608. Murray's (this volume) hypothesis is also in agreement with that of Blanc and Duplessy (1982), who suggested that the production of North Atlantic Deep Water (NADW) stopped in the latest Miocene, as a result of the Messinian closure of the Mediterranean and the lack of salty Mediterranean Sea Overflow Water (MSOW); therefore AABW could penetrate further north. This change in deep-water circulation, as suggested by the benthic foraminiferal faunal changes, is most clearly observed in the Rockall Plateau area (this chapter; Schnitker, in press); possibly the faunal changes are related to a change in Norwegian Sea Outflow water in the Rockall Trough (Masson and Kidd, this volume; Reid, 1979). Carbon isotopic evidence presented by Keigwin et al. (this volume), however, suggests no change in production of NADW in the late Miocene.

Keigwin et al., (this volume) also present oxygen isotopic data, which they interpret as suggestive of short glacial maxima between 5.5 and 5.0 Ma, but not of prolonged glaciation. This is in contrast with earlier theories that invoked the presence of major ice caps on Antarctica in the late Miocene (Shackleton and Kennett, 1975; Cita and Ryan, 1979). Whatever the exact configuration was of bottom waters in the late Miocene, there were major environmental changes, as indicated by a worldwide change in $\delta^{13}C$ values in the tests of benthic and planktonic foraminifers at about 6.2 Ma (Bender and Keigwin, 1979; Keigwin, 1979; Haq et al., 1980; Vincent et al., 1980; Loutit and Keigwin, 1982; Keigwin et al., this volume). Possibly the late Miocene changes in $\delta^{13}C$ values were the result of changes in total biomass; these changes might be orbitally forced through low-latitude precipitation, as suggested by Keigwin and Boyle (1985). Evidence from the comparison of benthic foraminiferal faunas as presented in this paper and by Mur-

ray (this volume) suggests that there was a change in deep-water circulation in the northeastern Atlantic at about the time of the closure of the Mediterranean and the change in carbon isotopic ratios.

5. 3.5–0.7 Ma. Many FAs and LAs occurred at Sites 608 and 610 during this period (Figs. 8, 9), as well as changes in relative abundances; the long-established taxa of *Pleurostomella* and *Stilostomella* disappeared, and cold-water species (e.g., *Cassidulina teretis*) appeared.

During this interval the glaciation of the Northern Hemisphere started, but the exact timing is still being discussed. McDougall and Wensink (1966) documented glaciation on Iceland at about 3.1 Ma. Shackleton et al. (1984) concluded that ice rafting started at about 2.5 Ma at Site 552 (Rockall Plateau area) and that oxygen isotopic evidence also suggested growth of ice sheets at that time. Data from Leg 94 (Raymo et al., this volume; Ruddiman et al., this volume) indicate that the isotopic evidence for the initiation of glaciation is not clear-cut, and that some environmental changes may have occurred between 3.1 and 2.4 Ma (see also Ruddiman et al., this volume).

Evidence from benthic foraminifers as presented in this chapter was not collected with a sampling density sufficient to resolve glacial–interglacial fluctuations at a time scale dictated by orbital parameters (Ruddiman and McIntyre, 1976, Ruddiman and McIntyre, 1984), but the data can give information on the overall faunal changes associated with the initiation of glaciation. The distribution of faunal events during the period from 3.5 to 0.7 Ma is bimodal at both sites (Fig. 9), with peaks from 1.5 to 1.1 Ma and 3.0 to 2.5 Ma at Site 608, and somewhat broader peaks (1.3–0.7 Ma and 3.3–2.4 Ma) at Site 610. This suggests that changes in bottom water, which may have been associated with the onset of glaciation, were first felt by benthic foraminifers at Sites 608 and 610 at about 3 Ma, possibly somewhat earlier at the shallower site. Then the faunas stabilized, but suffered many LAs of taxa between 1.5 and 0.7 Ma: the decrease in relative abundance of *Nuttallides umbonifera* at Site 608 at 1.5 Ma might indicate a retreat of an AABW-like bottom-water mass from the site. The benthic faunas do not show many changes at about 2.5 Ma, when ice rafting started at the Leg 94 sites, and when there were major changes in the planktonic foraminiferal faunas (Raymo et al., this volume).

CONCLUSIONS

1. Major changes in the composition of deep-sea benthic foraminiferal faunas at Sites 608 and 610 (northeastern North Atlantic) occurred in the early Miocene (19–17.2 Ma), middle Miocene (15.5–13.5 Ma), late Miocene (7–5.5 Ma), and Pliocene–Pleistocene (3.5–0.7 Ma). The changes during the first period may have resulted from sluggish circulation, during the second from cooling of the deep waters, during the third from changes in deep-water circulation resulting from the closure of the Mediterranean, and during the last period from changes in deep-water circulation as a result of the onset and intensification of Northern Hemisphere glaciation.

2. The last period of faunal changes was the most important, as is evident from the large number of last and a few first appearances, and many changes in relative abundances. The second most important period was the late Miocene, followed by the middle Miocene. Faunal changes in the early Miocene consisted of a temporary dramatic increase in *Bolivina* spp., and did not involve many irreversible changes (first or last appearances).

3. The patterns of faunal changes are similar at the two sites (e.g., decrease in relative abundance of *Pleurostomella* spp. and *Stilostomella* spp.), but the timing of specific first and last appearances is usually different at the two sites. Faunal events in deep-sea benthic foraminiferal faunas can be used for biostratigraphy after careful scrutiny only.

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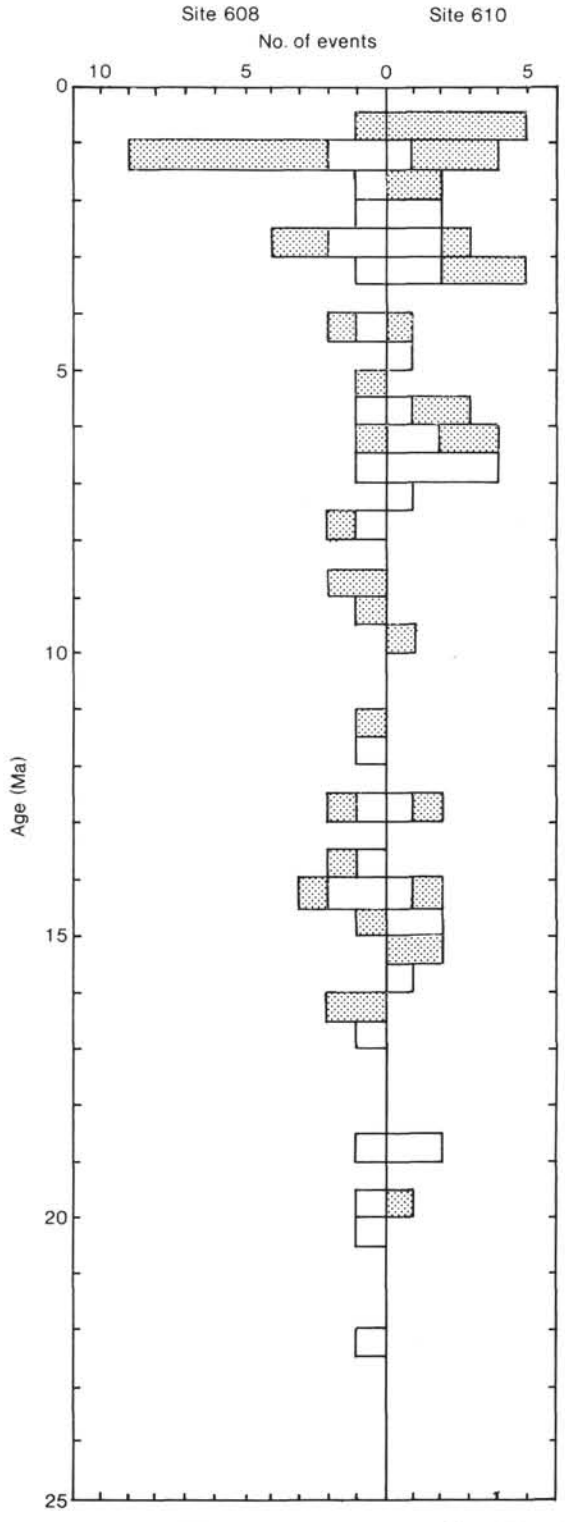

Figure 9. Histogram of first and last appearances at Sites 608 and 610. The first appearances are shown as blank bars, the last appearances as stippled bars.

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APPENDIX A
Counts of Benthic Foraminifers (Tables 1 and 2)

Table 1. Counts of benthic foraminifers in Site 608 samples.

Epoch boundaries	Sample	Sub-bottom depth (m)	Age (Ma)	No. of specimens	No. of species	*Allomorphina trigona*	*Ammonia*? sp.	*Amphicoryna hirsuta*	*Angulogerina angulosa*	*Angulogerina carinata*	*Anomalina alazanensis* var. *spissiformis*	*Anomalinoides globulostus*	*Anomalinoides semicribratus*	*Asterigerinoides guerichi*	*Astrononion novozealandicum*	*Astrononion stelligerum*	*Bigenerina nodosaria*	*Bolivina capitata*	*Bolivina globulosa*	*Bolivina goësii*	*Bolivina pettersoni*	*Bolivina pseudoplicata*	*Bolivina spathulata*	*Bolivina striatula*	*Bolivina subspinescens*	*Bolivina translucens*	*Bolivinita quadrilatera*	*Bolivinopsis cubensis*	*Bulimina alazanensis*
Quaternary	1-1	0.00	0.0	208	48																								
	1,CC	7.00	0.4	229	49							1																	
	2,CC	16.60	0.8	229	58							1			2										5				
	3,CC	26.20	1.1	196	53							3			2									1	4				
	4,CC	35.80	1.3	199	51		1								4										3				
	5,CC	45.40	1.5	193	66		1					1			6							5			1				
Pliocene	6,CC	55.00	1.9	203	48																				6				
	7,CC	64.60	2.1	208	51																				3				
	8,CC	72.96	2.2	206	41										1							2							
	9,CC	82.12	2.4	200	60																				1				
	10,CC	93.40	2.8	206	64										6						4	2			3				
	11,CC	102.42	3.0	194	57						1				3				5			11			2				
	12,CC	112.02	3.4	206	54		1				1				2							1							
	13,CC	121.41	3.7	187	60										2							2							
	14,CC	130.55	4.6	204	64																								
	15,CC	140.91	5.2	203	55																	2			1				
upper Miocene	16,CC	151.0	5.7	209	50						1						3					3			1				
	17,CC	156.52	6.0	220	54																				19				
	18,CC	164.91	6.4	233	60						1				3							6			5				
	19,CC	175.70	7.0	202	49										1		1								50				
	20,CC	185.30	7.6	205	55	1									1							13			12				
	21,CC	192.50	8.0	203	53										10														
	22,CC	203.04	8.6	204	51			1				2			10							3							
	23,CC	214.20	9.2	200	57										1							6		3					3
	24,CC	223.70	9.7	217	53						4	1			2														1
	25,CC	233.30	10.1	203	68			3			3	1			5			3				1							
	26,CC	241.34	10.4	218	65			2				2					1	6				7		1					1
	27,CC	251.50	10.9	213	62					2		1			2		2	1		9		9	6						1
	28,CC	260.32	11.4	218	63						3	2					1	8				3						2	1
middle Miocene	29,CC	271.20	11.9	196	65			1				2																	
	30,CC	279.32	12.3	218	53						1											4						4	
	31-4	286.20	12.6	211	60												4											2	
	31,CC	290.46	12.9	213	62		2	1			2				1		2					1							
	32-3	294.30	13.0	223	65												1					10		8	1				
	32-4	295.80	13.1	203	65		3				4											3							
	32,CC	299.09	13.4	210	56						3						5	1		1		12							3
	33-1	301.00	13.5	209	57		1				2	1					3					2							1
	33-2	302.26	13.7	210	65						1				2		1					2		1				1	1
	33,CC	304.16	14.1	221	61						1				1							8						2	3
	34-1	310.72	14.8	213	52			1			4	1			1							3							1
	34-2	311.85	14.9	209	59						6				1							10		23				1	
	34-3	313.40	15.0	204	50		1				2				1							9		2					
	34-4	315.50	15.2	217	52			1												1		3		2				1	
	34,CC	318.99	15.4	199	65			1			2	1								1		4		6				1	
	35-3	323.26	15.6	219	62		1				1				1							4		6					4
lower Miocene	35,CC	328.71	15.9	204	55						6						1					13		9					2
	36-1	329.70	16.0	208	47		2								2							9		7					
	36-2	331.20	16.1	210	64		1	2							1			1				1	1	18					4
	36-3	332.70	16.2	253	41						9											3		23					1
	36-4	334.20	16.4	213	52																	7	54	11					
	36-5	335.70	16.6	225	64			1	1						1					2		2	16	1				1	
	36-6	337.20	16.7	213	63			1	1		2											5	2						
	36,CC	337.62	16.8	193	60							1			1			1		1		10	3						2
	37-1	339.30	16.9	208	60						3				2							9	1						1
	37-2	340.80	17.0	225	37																	2	141						
	37-3	342.30	17.1	201	27						1							1				1	162						
	37-4	343.80	17.4	245	12						1											1	223						
	37-5	345.30	17.5	265	25													1				2	219						
	37-6	346.80	17.7	240	16																	2	220						
	37,CC	348.17	17.9	225	29			1														6	182						
	38-1	348.90	18.0	250	24																	1	214						
	38-2	350.50	18.2	209	41																	14	102						
	38-3	351.90	18.3	211	44										1							13	74						
	38-4	353.40	18.4	211	47																	11	59	5					1
	38-5	354.90	18.6	213	47						1											55	16						
	38-6	356.40	18.7	219	51				1		2				3				1			55	3						
	38,CC	358.10	18.8	192	53										4					1		18	44	1					1
	39-1	358.50	18.9	202	58			1							1					1		29	3	19					
	39-2	360.00	19.0	212	54			1							2		1					9	3	46					
	39-3	361.50	19.1	218	47						4											1	1	44					
	39-4	363.00	19.2	213	38								1									4	120	1					
	39,CC	364.34	19.4	190	71		1	1			1							2				4	3		2				1
	40-1	368.95	19.6	220	55						2											1	2						
	40-2	369.20	19.7	203	54		2	2				1			1							2							
	40-4*	372.68	19.8	176	44						2				1		1				1			1					
	40,CC*	376.22	20.1	196	59										1					1		1		1				2	
	41-4	382.55	20.6	220	55										3		2					3							
	41-6	386.10	20.8	203	62		2								1		2					2		2				1	
	41,CC	386.90	20.9	211	66							1			2		2					2		1				1	1
	42,CC	394.24	22.0	198	41		1				1				9							1		1					
Oligocene	43,CC	403.98	22.4	225	54	1	1				1				1							6							
	44,CC	411.62	22.8	204	46		1		1						8					2								1	
	46,CC	431.05	24.6	228	48										1		1	1				3							
	48,CC	454.10	27.0	231	65						1			2	2		1					17							

Note: Ages are extrapolated from the paleomagnetic data in Clement and Robinson (this volume). Samples with an asterisk (*) did not contain sufficient specimens and were not used in the analysis.

Table 1 (continued).

Bulimina elongata var. *subulata*	*Bulimina jarvisi*	*Bulimina marginata*	*Bulimina microcostata*	*Bulimina tarda*	*Buliminella grata*	*Cassidulina crassa*	*Cassidulina havanensis*	*Cassidulina teretis*	*Cassidulina transiucens*	*Cassidulinoides bradyi*	*Cassidulinoides tenuis*	*Chilostomella ovoidea*	*Chrysalogonium tenuicostatum*	*Cibicides lobatulus*	*Cibicides variabilis*	*Cibicidoides bradyi*	*Cibicidoides cicatricosus*	*Cibicidoides grimsdalei*	*Cibicidoides havanensis*	*Cibicidoides kullenbergi*	*Cibicidoides* cf. *kullenbergi*	*Cibicidoides laurisae*	*Cibicidoides mundulus*	*Cibicidoides perlucidus*	*Cibicidoides robertsonianus*	*Cibicidoides trinitatensis*	*Cibicidoides wuellerstorfi*	*Cibicidoides wuellerstorfi* var. C	*Cyclammina cancellata*	*Dentalina communis*	*Dentalina intorta*	*Dentalina nuesti*	*Dentalina subsoluta*	*Dorothia brevis*	*Dorothia* cf. *brevis*	*Eggerella bradyi*
4						1									5		1			9			2				12	2			2						1
6						3									12		2			3							55				2					2	1
1						11									3	2					6		3				14										2
2						2									1		2			4	6		4				13										3
2			2			3									1	2	3			5	11						15							1			13
						1			1											1	4		1				6							1			4
1						7										1	3				5						14				1					7
			1			9											2				6						9									7
1						2											2				5						12			4						5
																1	5			5						14	3						2		3
																4	3									9	1		1	1					5
1					1					1						2	1				2						11				2					5
						7										3										1	12				1					5
						2						1					1			1	3						7				1				1	
											4						3			3	1				2		1				2		1			2
															2					6					2		5				2					4
						1							1				3				2		2				6									1
						1					1									4	9						15				1					4
1				2																5	1						11				1		1		1	3
						4					1					1										1	3									2
															1					2						11	4			1						3
						2										2					4				1		11				2			1			3
						3							1			3				4						7					2			1			2
1						1										1				1						14				1					11	1
																2				2	3		3			21										
						4							1			4				2	1					1	4				1						5
1											5					1					3						22				2		1			4
2						3										1				3	1		2		2	1	4				2				1	1
			1								3	1				1				12			1				20				2		1			4
		3														2				3		1	2				17		1	1		1				6
1		5									2		1			2					1						14			1						1
		2														2	1			5	4		1				16				1					5
		5				1					1		1			1				3	4		2		1		7			1						1
	1										1					2				3	1	2	1				12		1	1						6
		3				2					2		1			4				11		3				1	2					2		1		2
				1		2						1								4	2					1	23						2			3
											1					2	1			2	2	1	1			1	24								1	22
				1		4					4						1	1		2	4		1				5				3					2
1						4								3		6	1		5	5	1				2	10				1				1		2
						4								1		1	3		1	6	6	1	5	4	1											
					1	3										1	1		1	7	3	1	2		1					1						4
		5														1				10	6	2	4	1		1				1						
1		1				1	1									1	2		3	6	3															3
1		6				1								1		7	2	1	2	8	2	2	3		2						1	1		1		4
						6	1									3			3	7	7	2	2	2		2				2						1
	3	7					1						3			3	1		2	7	5	1			1						1					1
		2					1									1					1	2	1	2	2	1										6
			1			2							3			3				2	7	3	1		1					1						1
		2							4											14	9	1	10	6		2										
		7		2							2					3	1			4	2	2	6							1						
		4						1	2							2	2		3	7	4				1					1						
		4				1							1			3			4	9	9	5	4	2	1	1			1	1					6
		1		1		1							1						1	8	5		1	1					1						
		4		4		1			1							2				5	5	4	2		1	1			2						1
	2	1											1			1				4	2		1	3											
		2				1										1				1	1	3	1												
		5				1										1				3	2		2												
													2								4		1												
		3																			2														
		3														2				3									2						1
		2									1					1					1														
			1										1							4	2			2					2	1					
		11				2			1				1						1	2	6	3	3						2				1		1
		8				2			1		3						2			4	3								1			1			
		16																		3	12	6	3												1
		3				1			1		1		1							8	7	2	6	1		1				1					
		3		1		2										1				6	1	1	2			3			2						
		5				2										1				2	8		3												
		14							1							2				2	6		1			1							2		
		4		1		1							1							12		3		1		1			1			2			1
						1			2										2	3	3	3	3		1										
	1			3									1							2	1	1	1	1		2			1						1
						3					2					1				4	7	4	6							1			1		5
						2			2				1			3				7	12	5							2						3
											1		2						1	7		1	4												
		5		2		2			1				1			5			2	5	3	7		3		1			2	1					2
		2		1		7										4				7	2			3	2	1									1
		2														5		1	1	4	2	3		2	1			3					2		
		1				1							1			1				1				1	1						2			1	1
												1							3	10	1			2	7								1		1
							1		3		1					3				3	3	2		1	2							1	1			
						3										1				14	9	1	2	3	1								1		2
		4					1		1		1					3				3	7	2		1	4										
		2	1				1									1		2	6	7	3	5	5	9	1	3			3						

Table 1 (continued).

Epoch boundaries	Sample	Sub-bottom depth (m)	Age (Ma)	No. of specimens	No. of species	*Eggerella propinqua*	*Ehrenbergina caribbea*	*Ehrenbergina trigona*	*Elphoedra weddellensis*	*Ellipsodimorphina subcompacta*	*Ellipsoglandulina* aff. *fragilis*	*Ellipsoglandulina laevigata*	*Ellipsoglandulina multicostata*	*Ellipsoglandulina* sp.	*Ellipsopolymorphina* sp.	*Epistominella exigua*	*Eponides pusillus*	*Eponides regularis*	*Eponides repandus*	*Eponides tumidulus*	*Favocassidulina favus*	*Francesita advena*	*Fursenkoina bradyi*	*Fursenkoina ciperana*	*Fursenkoina cylindrica*	*Fursenkoina mexicana*	*Fursenkoina pauciloculata*	*Fursenkoina pontoni*	*Fursenkoina schreibersiana*
Quaternary	1-1	0.00	0.0	208	48				25							50				6		5							
	1,CC	7.00	0.4	229	49				16							16			1	3		1	1						
	2,CC	16.60	0.8	229	58			2	6							20			3	2		3	1						1
	3,CC	26.20	1.1	196	53				3							16			1			1	1			1			
	4,CC	35.80	1.3	199	51	1			2							10					1	14							
	5,CC	45.40	1.5	193	66			4	1	1						4													
Pliocene	6,CC	55.00	1.9	203	48				3							11						1	1						
	7,CC	64.60	2.1	208	51											11				1									
	8,CC	72.96	2.2	206	41				2							13													
	9,CC	82.12	2.4	200	60				1	4						7											1		
	10,CC	93.40	2.8	206	64				1		1					8													
	11,CC	102.42	3.0	194	57		1		1							18							1						
	12,CC	112.02	3.4	206	54		6		1							13											1		
	13,CC	121.41	3.7	187	60		4									11											1		
	14,CC	130.55	4.6	204	64		1		1							5				1		1	2						
	15,CC	140.91	5.2	203	55		2									6													
upper Miocene	16,CC	151.0	5.7	209	50		1		7							23	3					1	1						
	17,CC	156.52	6.0	220	54		1									8						3							
	18,CC	164.91	6.4	233	60		10									12						5							
	19,CC	175.70	7.0	202	49		3									13						1							
	20,CC	185.30	7.6	205	55		3		1							9													
	21,CC	192.50	8.0	203	53		2		4							4		2											
	22,CC	203.04	8.6	204	51		3									3						1	2						
	23,CC	214.20	9.2	200	57		1		3	1						11						1					1		
	24,CC	223.70	9.7	217	53		1		1							5													
	25,CC	233.30	10.1	203	68		1									8							1						
	26,CC	241.34	10.4	218	65		1		1		1					4													
	27,CC	251.50	10.9	213	62				1							9													
	28,CC	260.32	11.4	218	63											9													
middle Miocene	29,CC	271.20	11.9	196	65		1		1							1													
	30,CC	279.32	12.3	218	53											6													
	31-4	286.20	12.6	211	60				1							4													
	31,CC	290.46	12.9	213	62				1							15													
	32-3	294.30	13.0	223	65				1							14	1												
	32-4	295.80	13.1	203	65					1						3							1		1				
	32,CC	299.09	13.4	210	56				2							8													
	33-1	301.00	13.5	209	57											12							1						
	33-2	302.26	13.7	210	65				1							9							1						
	33,CC	304.16	14.1	221	61		1		1							8								1					
	34-1	310.72	14.8	213	52											11													
	34-2	311.85	14.9	209	59											9		1											
	34-3	313.40	15.0	204	50											2													
	34-4	315.50	15.2	217	52											6													
	34,CC	318.99	15.4	199	65											5													
	35-3	323.26	15.6	219	62											13						2							
lower Miocene	35,CC	328.71	15.9	204	55											8								1					
	36-1	329.70	16.0	208	47											7													
	36-2	331.20	16.1	210	64					1						6								1					
	36-3	332.70	16.2	253	41		10			1						3													
	36-4	334.20	16.4	213	52		1									5													
	36-5	335.70	16.6	225	64			3						1		3						1							
	36-6	337.20	16.7	213	63		11									3													
	36,CC	337.62	16.8	193	60		9									1						5	4						
	37-1	339.30	16.9	208	60		8			1						2						1							
	37-2	340.80	17.0	225	37											1													
	37-3	342.30	17.1	201	27																	1		2					
	37-4	343.80	17.4	245	12																								
	37-5	345.30	17.5	265	25											5													
	37-6	346.80	17.7	240	16		1																						
	37,CC	348.17	17.9	225	29											1							1						
	38-1	348.90	18.0	250	24		1																	1					
	38-2	350.50	18.2	209	41		2									5													
	38-3	351.90	18.3	211	44											7													
	38-4	353.40	18.4	211	47	1										7													
	38-5	354.90	18.6	213	47											9								1					
	38-6	356.40	18.7	219	51			4								4													
	38,CC	358.10	18.8	192	53		6				1		1			2													
	39-1	358.50	18.9	202	58											3								1					
	39-2	360.00	19.0	212	54					2						11													
	39-3	361.50	19.1	218	47											4													
	39-4	363.00	19.2	213	38											7													
	39,CC	364.34	19.4	190	71				1		1					9													
	40-1	368.95	19.6	220	55											20								1			2		
	40-2	369.20	19.7	203	54											4								1					
	40-4*	372.68	19.8	176	44				2							15								1					
	40,CC*	376.22	20.1	196	59					3						5		1						1					
	41-4	382.55	20.6	220	55											23								2					
	41-6	386.10	20.8	203	62					1						11													
	41,CC	386.90	20.9	211	66					1						8							2						
	42,CC	394.24	22.0	198	41					1						10													
Oligocene	43,CC	403.98	22.4	225	54					1						20							10	1			2		
	44,CC	411.62	22.8	204	46					1																			
	46,CC	431.05	24.6	228	48					2		1				2									1				
	48,CC	454.10	27.0	231	65				2		2					2	1												

Table 1 (continued).

Globobulimina ovata	*Globocassidulina subglobosa*	*Gravellina nariveansis*	*Guttulina problema*	*Guttulina seguenziana*	*Gyroidinoides acutus*	*Gyroidinoides girardanus*	*Gyroidinoides lamarckianus*	*Gyroidinoides mediceus*	*Gyroidinoides soldanii*	*Heronallenia lingulata*	*Hoeglundina elegans*	*Hopkinsina pacifica*	*Karreriella bradyi*	*Laticarinina pauperata*	*Lenticulina gibba*	*Lenticulina mexicana*	*Lenticulina* sp. juv.	*Marginulina glabra*	*Marginulina costata*	*Martinottiella communis*	*Martinottiella petrosa*	*Melonis affinis*	*Melonis barleeanus*	*Melonis pompilioides*	*Neoeponides hillebrandti*	*Nodosarella submodosa*	*Nodosaria albatrossi*	*Nodosaria filiformis*	*Nodosaria fusiformis*	*Nodosaria lamnulifera*	*Nodosaria longiscata*	*Nodosaria pyrula*	*Nodosaria vertebralis*	*Nonion havanense*	*Nonionella atlantica*	*Nonionellina labradorica*
	6				6			4	3		1			1			1							1											1
	8				3		5		2						1							1		5										
	14				8		3	7	1														6	1											
	10				6				4				2								2		1	1	3										
	8				4			4					1								1		4	4	4										
	16				8		1	3	2				2	3									6		1										1
	11				1		1	1	5				2										2		12										
	27				1				4						3								1		1										
	17				2		1		6														1	1	6										1
	33		2		3		1	3	9				2	3									3		1										
	14	1					3	2	5					1	1							1	10		1			1							
	21				2			4	6						1								9		4										
	31				2		4	7														1	10		2										
	15	1	2		3			1	4				3	2									6		1		2							1	
	6		1		1	1	1		9				3	2	1								5		1										
	31				2		1	1	5					4	3								7	3					1						1
	29	1					1	2	5				1										8		1										
	15		1		6		4	3	8	1			1	5								1	12		7										
	9				3		4	2	4	1			1	3									15								1				
	6				3		3	2															15		1				1						1
	7		2		2			4	3					5									22		4										
	9				6			6	5					1	1								17										2		
	19							1	5					1									49		1						1				1
	27						2	3	4					2	1								11					2					3		
	10				3			3	10					3									29									3		2
	4				1		4	2	6				1	5									20		2			1				1	3		2
	4	1	2		2	1	4	4	12				1								1		17					3					2		
	11				1		2	3	2														1												
	7	1			1	1	2	6	4					3								1	11		2			3							2
	10							6	8					3	1								13					1	3			1		6	
	11				3		2	1	8					1			2						18		1			2		1					1
1	8				5		6	4	9				1		2								28	1	1			1				2			1
	10				7		3		1					2	1				1				10					1	2		2			1	1
1	5				6	1	4	5	7						1								10					1	1						2
	3				10		3	5	4				1	3				1			1		14									1			5
	4				3	1	7	5	4					2	1							1	22				1	1	2						
	3				3		3	9	2						1								21				1	1							1
	9				2		6	9	3					1									10												7
	20	1	2		4		3	6	5	1					1			1					6						1						3
	4				3	2	4	3	1	1													18		1			1		1	1				4
	5				6	2	2	4	6						1								12		1				1				1		1
	3		1		2		5	2	4					1							1		24								1	1			
	8				3	3	10	4	7														20	2			2	1	4					3	
			1		9	2	4	2	2												4		8				1		1		2				
	18				5		5	1	5				1		1								18				1	1	3					3	
	3					2	6	3	6					1	2								8							1			5		2
	10		1		4	4	2	4	2	1													19				2	1						5	5
	8		1		3	3	7	8															9				1	1	2						1
	7				8	2	9	5	3						1								15		4							1	2		
	10		1		4	3	4	2	2				2								1		7												
	9				4	3	7	5	2	1					1								7		1		1		1				3		1
	15	2			6		3	5	2	1					1								2						1				1		1
	11				3	2	3		5						1							1	6				2								3
	15	1	2		3	2	3	3	4														5				2		2						2
	1		1		2	3	1		2														4					1	2						1
	1																						1												1
	1																																		
	5				1		1	2	2														1												
	1							1															1						1						1
					1			2															1					1							
	8				1	1		1															2												
	2				3		2	1	1	1													2												2
	5				1		1	2													1		1				1		1						2
	9				6		4	1	1						2								10	1					1						2
	10				3		1	4	3	1					1								1										2		2
	11				4		2	7															6				1	1					2		4
	1					2	2		5														3				2		1						3
	6	1		1	4	1		6	3				1		1								9						2						7
	8				1		7	12	2	1					1								2					1	1					2	
	2					1	5	8	4														13				1					1	2		1
	9	1			2	1			1														2									1		1
	26		1		3		1	4	1	1			1								1		2					1				2		2
	8				3			6	4	2					1								1									2		3
	12				3		2	5	1						1								1				1					1		2	
	3				1	1		4															1					2			1		1	
	19				4	3	4	2	6	1			1	1	1						1		1					2						4	
	20				2	5	1	3	2	1							1	2									2			1				2	
	35		1		3		4	6	2				1								2						1		1					6	
	16	1			6		5	4	1	1			2		1						1		1				1		2						
	28				2	1	5		3						3													1	2	2						
	10				4		4		4												2						1		6			2			4
	21				4		2		4	1				2	2											1				1					5
	5				4	8		3																		1		4							3
	15					2	2	3	3				1								3	1						1	2	1				1		

Table 1 (continued).

Epoch boundaries	Sample	Sub-bottom depth (m)	Age (Ma)	No. of specimens	No. of species	*Nuttallides umbonifera*	*Ophthalmidium pusillum*	*Oridorsalis tener*	*Oridorsalis umbonatus*	*Orthomorphina calomorpha*	*Orthomorphina challengeriana*	*Othomorphina doliolaris*	*Orthomorphina glandigena*	*Osangularia culter*	*Plectofrondicularia alazanensis*	*Planulina renzi*	*Pleurostomella acuminata*	*Pleurostomella acuta*	*Pleurostomella alternans*	*Pleurostomella bierigi*	*Pleurostomella bolivinoides*	*Pleurostomella brevis*	*Pleurostomella fusiformis*	*Pleurostomella obtusa*	*Pleurostomella rimosa*	*Pleurostomella* sp. A	*Polymorphina lactea*	*Pseudoparrella* sp.	*Pullenia bulloides*
Quaternary	1-1	0.00	0.0	208	48		3	13	3				1																
	1,CC	7.00	0.4	229	49	3	6	9	3			1																	
	2,CC	16.60	0.8	229	58		3	9	21																				1
	3,CC	26.20	1.1	196	53		1	9	25																				
	4,CC	35.80	1.3	199	51		6	4	19															1					1
	5,CC	45.40	1.5	193	66	30	1	1	7								1		2		1			1					3
Pliocene	6,CC	55.00	1.9	203	48	1	8	19	23	1			1																3
	7,CC	64.60	2.1	208	51	20	7	9	25	2							2												
	8,CC	72.96	2.2	206	41	47	12	1	24	1																			4
	9,CC	82.12	2.4	200	60	5	2	1	10				1								1								1
	10,CC	93.40	2.8	206	64	16	4	1	24								3		1	1				2					
	11,CC	102.42	3.0	194	57	1		3	17			1							2		1								
	12,CC	112.02	3.4	206	54	18		5	14	1											1								
	13,CC	121.41	3.7	187	60	14	2	1	5								4		1					3					1
	14,CC	130.55	4.6	204	64	10	1	2	34				1				2		1		1			1					
	15,CC	140.91	5.2	203	55	8	1	4	32				1				1							1					2
upper Miocene	16,CC	151.0	5.7	209	50	13	4	1	15			1											2						
	17,CC	156.52	6.0	220	54	19	5	4	9														1	8					5
	18,CC	164.91	6.4	233	60	17		3	19			1																	
	19,CC	175.70	7.0	202	49	7		4	12								3				2			4	2				
	20,CC	185.30	7.6	205	55	7			13								2				3			3					3
	21,CC	192.50	8.0	203	53	7			9				1				3	3			3		1	12					2
	22,CC	203.04	8.6	204	51			3	8				1							1	1			2					
	23,CC	214.20	9.2	200	57	9	1		16												2			4				1	1
	24,CC	223.70	9.7	217	53	2		5	16	1									1		2		2	5					
	25,CC	233.30	10.1	203	68	8		7	6				3				2		2		1		1	9					3
	26,CC	241.34	10.4	218	65	3	1	3	18								1		1		3		1	6					3
	27,CC	251.50	10.9	213	62	1	1	1	13			4	6				4		1		4			4					
	28,CC	260.32	11.4	218	63			3	15	2			4						2	1	2			5	1				1
middle Miocene	29,CC	271.20	11.9	196	65	1	2		17	1			1				2		2		2			2	3				4
	30,CC	279.32	12.3	218	53	1		2	34				1				1				5			10	3				
	31-4	286.20	12.6	211	60	1		4	27				1				2			1				10					2
	31,CC	290.46	12.9	213	62			1	24			1	1				1		5		1		1	12					3
	32-3	294.30	13.0	223	65			3	26	1			1				1							8					6
	32-4	295.80	13.1	203	65		1	8	29				2	1			2		4	1				2					3
	32,CC	299.09	13.4	210	56	1		1	22		1		3								1		1	4	1				
	33-1	301.00	13.5	209	57	1		7	27								2		4					1	2				3
	33-2	302.26	13.7	210	65	3	2	12	11			2		1			2		11	1	2			4					4
	33,CC	304.16	14.1	221	61	4	1	2	22			1	1	3					4		3		1	2					
	34-1	310.72	14.8	213	52	1		3	32										2	1				4	3				3
	34-2	311.85	14.9	209	59	8		2	21								1		3	1				2					5
	34-3	313.40	15.0	204	50	2		5	28				1				2	1	2		1			4					3
	34-4	315.50	15.2	217	52	4		3	22			1							3					12					4
	34,CC	318.99	15.4	199	65			2	14		1								8				2	4	1				9
	35-3	323.26	15.6	219	62	3		3	14			1							3					1	3			1	6
lower Miocene	35,CC	328.71	15.9	204	55	6		2	36	1			1				1		1		2			3					1
	36-1	329.70	16.0	208	47	4		4	32								2							2		2			9
	36-2	331.20	16.1	210	64	9		7	21								1	2		3				2					2
	36-3	332.70	16.2	253	41	5		6	26											1				1					
	36-4	334.20	16.4	213	52	4		4	12			1						3		1				3					2
	36-5	335.70	16.6	225	64	6		1	14			1					3	2	2					5				1	14
	36-6	337.20	16.7	213	63	5		1	18				1				1	1	4					2					8
	36,CC	337.62	16.8	193	60	2			18	1		2					4				1			2					4
	37-1	339.30	16.9	208	60	5		1	17								2		4		2			5					2
	37-2	340.80	17.0	225	37			1	10								1	1						1					4
	37-3	342.30	17.1	201	27				3	1							1								1				1
	37-4	343.80	17.4	245	12				4																				
	37-5	345.30	17.5	265	25	4			1				1							1				2					
	37-6	346.80	17.7	240	16	1			1																				
	37,CC	348.17	17.9	225	29	1			2			1									1			2					
	38-1	348.90	18.0	250	24	1		1	3								2							1					
	38-2	350.50	18.2	209	41	7			10										3					2				1	
	38-3	351.90	18.3	211	44	2		2	21			1							2				2	3				3	2
	38-4	353.40	18.4	211	47			3	20										2					2			1		1
	38-5	354.90	18.6	213	47	2		3	15										1		1			2					3
	38-6	356.40	18.7	219	51			2	16							1		3	1									3	
	38,CC	358.10	18.8	192	53			2	14							1	1		2		2			5					3
	39-1	358.50	18.9	202	58	2		2	10			2						3	4		1			3				2	1
	39-2	360.00	19.0	212	54			2	5	2		1	2						8	1	3			1					
	39-3	361.50	19.1	218	47	3		2	22				1				2			1				1				2	
	39-4	363.00	19.2	213	38	2		1	8									3						1					3
	39,CC	364.34	19.4	190	71	6		4	7				3						2		2			13	1				7
	40-1	368.95	19.6	220	55	9		2	20	1						1	2	1	2	2	2			6				1	6
	40-2	369.20	19.7	203	54	2		7	26			1						3	5					2					
	40-4*	372.68	19.8	176	44	1		13	22			3	1						1		1			3				1	3
	40,CC*	376.22	20.1	196	59	6		3	15				1					5	4					6					2
	41-4	382.55	20.6	220	55	7		4	32			1	5					6	1									2	6
	41-6	386.10	20.8	203	62	5		2	16									4	1	1				5					1
	41,CC	386.90	20.9	211	66	5		2	16								1	1	10	1	3			10				5	2
	42,CC	394.24	22.0	198	41			1	35										5	3				4					4
Oligocene	43,CC	403.98	22.4	225	54	6		1	24				5					1	5		2			3					
	44,CC	411.62	22.8	204	46				25								3		6					3				8	2
	46,CC	431.05	24.6	228	48	5		2	20				3				6	5	3					5					
	48,CC	454.10	27.0	231	65	2		6	21		3		3				5	2	7	1	1			3				1	

Table 1 (continued).

Pullenia quadriloba	*Pullenia quinqueloba*	*Pullenia salisburyi*	*Pullenia subcarinata*	*Pyrgo elongata*	*Pyrgo lucernula*	*Pyrgo murrhina*	*Pyrulina cylindroides*	*Pyrulina extensa*	*Pyrulina fusiformis*	*Quinqueloculina cf. compta*	*Quinqueloculina lamarckiana*	*Quinqueloculina pygmea*	*Quinqueloculina venusta*	*Qiunqueloculina cf. weaveri*	*Quinqueloculina sp. juv.*	*Rhabdammina sp.*	*Rosalina sp.*	*Sigmoilina tenuis*	*Sigmoilopsis schlumbergeri*	*Siphogenerina tubulosa*	*Siphonina bradyana*	*Siphotextularia catenata*	*Sphaeroidina bulloides*	*Stainforthia complanata*	*Stilostomella abyssorum*	*Stilostomella annulifera*	*Stilostomella consobrina*	*Stilostomella lepidula*	*Stilostomella subspinosa*	*Stilostomella verneuilli*	*Textularia agglutinans*	*Textularia aspera*	*Textularia porrecta*	*Textularia pseudogramen*	*Textularia sagittula*	*Trifarina bradyi*
5	1	1	2			5										1			1			2		1											
4		3	8	1		3		1		1		4		1				2	2			5		10											
1	1	2	9	5	1	4						2	5					1				2	1	8						2					
2	1	2	5	2		10		1		2	2	3		1								1		1											
3		1	6		2	2						2						1	4					1		1		1			4					
5	1	1	4	2		1			2	1				5				1	2			4	2	2		5		1			1				2	
2			2			3						1	7						1			5		4		3				4					
4		2	1	3		4		2	2		2	2	2									2	2				1			1		1			
3		1										1	2	1					1			3				5		1		4					
4			5	3	4	5			1		2	8		2					1			3	1			4				2					
7		1	8	1	1	3	3	1	1		1	6		3				1	1				1			2		2		1				3	
5			2			3				1		2		1					1			1	1					1		3					
1		2	1			5			1	2		7		4				2				1	1			2									
5	1		6			6	3	1	6	2		5		3									2	1		7		1		6					
4	2	2	5				2							5				2				2	1			1		3	6	3				1	
6	4		6			2					1	1		3				7						1		3			4	2					
9	5	3	9			2								2				1				2	1						1						
7	1	3				4	1							5				1					1					2		1				1	
6	3	4	7			1								1				2							1	12		6	3	1				1	
6	5	1	7				1		3					2				4				1			2	6		1							
18		3	6				1		1									4				1				3			2						
9	3	3	11				2		2									1							1	7		3	8		2				
9		2	20						4					1				3								3			1	3				1	
8	1	1	3				2											2				2			1	2			2	4					
17	3	2	6						4					1				1					1		1				4	2					
8	1	3	9						1									2							2	4	1	2	8						
9	2	3	8			1					2							3		1			1		7			2	3						
5	3		2					1	1									4							1	17		32	1						2
5			3			1				2	5							7				1			2			10							
2	1		6						1													1	2			2		5	2		7				
9	1	2	5						1		1														1		2	17	5						
6	1	4	3			1			1					1											1		1	4	2			1			
7		6	7						1	1															1	1		8	13		1				
7	2	4	2						1													1						6	1		1				
4		4	3			1						1										1	3				4	4			1				
6	6	3	7			1				1	1												1			1		5	6						
12		3	3						1				1													1		8	6						
9	1	6	8									1						1				3	1			6		3	5						
12		3	4																				3		1			8	7						
12	3	7	8																				1					20	7		1				
6	2	3	4																						1			7	6	1					
8	1	5	2																						1			28	9						
5		4	2																								1	40	2	1	1				
2			1			1								1									3			1	5	13	7						
5	2	7	8						1													3					1	5	3						
2		5	6																				4		1	1		3	1		2				
6	3	5	15															1										7	5						
9	1	4	7																						1			11	3		2				
4	4	5	3																			1	1		1			34	5						
3	4	4	6											1									1					5	3		1				
8	5	8	4						1																2			14	3						
7	3	4	4						2																1		1	16	5		1				
17		4	6						1													1	1				1	11	7						
5	4	2	6																				1					24	5					1	
1																							1		1		1	16	6						
2	3	2	3																								1	2							
	1																																		
1		3																							1	2									
1		2																										1							
1	1	1																					1			1			2						
2																																			
6	1		1						1																			7	6						
2			7					1	1														1					12							
4	1	3	3					1																	1			10	3						
1		1	5						1																2		1	3	8		1			1	
2	1		6																									5	2		2				
1	2	2	5																						1			5	2						
4	3	2	5																						2			3	5		1				
3	4	2	6						2							1									1			11			1				
7	3	2							3														2		2			23	3						
																							1					10	3						
		6	5						1					1								2						8	4		2				
5	1	2	5											1			3											42	2						
13	2	6	15			1								1								6						6	3		4				
2	1	4																				2			6		1	38	8	4					
6		5	11																									9	2						
1	3	1	7									1										2						20	4						
4	6	5	6									1															2	5	4						
6	2	1	18						2					8													4	6	1		2				
8	1	7	6																						7			8	5		1				
2	3	5	12															1							7		4	12	20						
10		14	11						2																			12	4						
5		6	9						1																7		1	67	2	1					
2	2	3	9																						6		8	4	17	1	1				

Table 1 (continued).

Epoch boundaries	Sample	Sub-bottom depth (m)	Age (Ma)	No. of specimens	No. of species	*Triloculina trigonula*	*Trochammina globigeriniformis*	*Trochamminoides proteus*	*Uvigerina auberiana*	*Uvigerina bononiensis*	*Uvigerina cylindrica*	*Uvigerina gaudryinoides*	*Uvigerina graciliformis*	*Uvigerina peregrina*	*Uvigerina rippensis*	Unilocular genera	*Vaginulina elegans*	*Vaginulina insolita*	*Vaginulina subelegans*	*Vaginulina sublegumen*	*Valvulineria laevigata*	*Valvulina jarvisi*	*Valvulina spinosa*
Quaternary	1-1	0.00	0.0	208	48		1									12							
	1,CC	7.00	0.4	229	49											12							
	2,CC	16.60	0.8	229	58		2							6		15							
	3,CC	26.20	1.1	196	53									18		11							
	4,CC	35.80	1.3	199	51									9		8							
	5,CC	45.40	1.5	193	66					3				2		13							
Pliocene	6,CC	55.00	1.9	203	48									6		11			1	1			
	7,CC	64.60	2.1	208	51									5		20	1						
	8,CC	72.96	2.2	206	41		4									7							
	9,CC	82.12	2.4	200	60											26							
	10,CC	93.40	2.8	206	64									1		17							
	11,CC	102.42	3.0	194	57		1			5			5	6		15							
	12,CC	112.02	3.4	206	54								4	1		21							
	13,CC	121.41	3.7	187	60								6			16							
	14,CC	130.55	4.6	204	64		1						1	34		17							
	15,CC	140.91	5.2	203	55					2			2	4		12			1				
upper Miocene	16,CC	151.0	5.7	209	50								6	12		11							
	17,CC	156.52	6.0	220	54											22			1			1	
	18,CC	164.91	6.4	233	60								2			13	3						
	19,CC	175.70	7.0	202	49								3			15							
	20,CC	185.30	7.6	205	55					1			1	1		21				1			
	21,CC	192.50	8.0	203	53		2						2			9			1				
	22,CC	203.04	8.6	204	51		2						1			9							
	23,CC	214.20	9.2	200	57								17	1		9							1
	24,CC	223.70	9.7	217	53								6	1		14	7						1
	25,CC	233.30	10.1	203	68								2	1		15	3		1				
	26,CC	241.34	10.4	218	65									1		13							2
	27,CC	251.50	10.9	213	62				8				1	2		6				1			
	28,CC	260.32	11.4	218	63								5			13	3						
middle Miocene	29,CC	271.20	11.9	196	65								7			22							
	30,CC	279.32	12.3	218	53								12			11	1	1					
	31-4	286.20	12.6	211	60								4			13			2				
	31,CC	290.46	12.9	213	62								13			9							
	32-3	294.30	13.0	223	65			1					3	2		26	9						
	32-4	295.80	13.1	203	65		2			1			1			14							
	32,CC	299.09	13.4	210	56								2			6	1		1				
	33-1	301.00	13.5	209	57		1						4			12							
	33-2	302.26	13.7	210	65								4			18	1		1				1
	33,CC	304.16	14.1	221	61								10			4	1						1
	34-1	310.72	14.8	213	52		1									3	1						
	34-2	311.85	14.9	209	59								1			13				1	2		1
	34-3	313.40	15.0	204	50				1				1			4							
	34-4	315.50	15.2	217	52								1			5			1				1
	34,CC	318.99	15.4	199	65								6			16							
	35-3	323.26	15.6	219	62				1				3			13							
lower Miocene	35,CC	328.71	15.9	204	55					1			4			3							3
	36-1	329.70	16.0	208	47											4							
	36-2	331.20	16.1	210	64		1		1				1			15				1			
	36-3	332.70	16.2	253	41																		1
	36-4	334.20	16.4	213	52				1				1			8							1
	36-5	335.70	16.6	225	64					2				1		12							
	36-6	337.20	16.7	213	63		1					1				6	1						2
	36,CC	337.62	16.8	193	60					2				1		7	1						1
	37-1	339.30	16.9	208	60								2			12	2						
	37-2	340.80	17.0	225	37											3							1
	37-3	342.30	17.1	201	27																		
	37-4	343.80	17.4	245	12																		
	37-5	345.30	17.5	265	25											3							
	37-6	346.80	17.7	240	16											1							
	37,CC	348.17	17.9	225	29					1				1		2							
	38-1	348.90	18.0	250	24											4							
	38-2	350.50	18.2	209	41								2			10	2						
	38-3	351.90	18.3	211	44								2			3							
	38-4	353.40	18.4	211	47		1			1			2			6							
	38-5	354.90	18.6	213	47								3			4	1			1		1	
	38-6	356.40	18.7	219	51								19			6			4			1	
	38,CC	358.10	18.8	192	53								9	6		7	1						
	39-1	358.50	18.9	202	58				2	1			8			13	1						1
	39-2	360.00	19.0	212	54											12	2						
	39-3	361.50	19.1	218	47								16			6							2
	39-4	363.00	19.2	213	38					1			3			7							
	39,CC	364.34	19.4	190	71		1							1		20	2						
	40-1	368.95	19.6	220	55								3			9							1
	40-2	369.20	19.7	203	54								4			15	1						
	40-4*	372.68	19.8	176	44								1										7
	40,CC*	376.22	20.1	196	59								1	2		10							
	41-4	382.55	20.6	220	55								2			12							
	41-6	386.10	20.8	203	62					1			6			17							
	41,CC	386.90	20.9	211	66								16			13			1				1
	42,CC	394.24	22.0	198	41								5			2							1
Oligocene	43,CC	403.98	22.4	225	54										6	4	1		1				
	44,CC	411.62	22.8	204	46											5	2		1				1
	46,CC	431.05	24.6	228	48								1		6	4							1
	48,CC	454.10	27.0	231	65										1	6			2	3			

Table 2. Counts of benthic foraminifers in samples from Site 610.

Epoch boundaries	Sample	Sub-bottom depth (m)	Age (Ma)	No. of specimens	No. of species	*Allomorphina trigona*	*Ammonia? sp.*	*Amphicoryna hirsuta*	*Angulogerina angulosa*	*Angulogerina carinata*	*Anomalina alazanensis var. spissiformis*	*Anomalinoides globulosus*	*Anomalinoides semicribratus*	*Asterigerinoides guerichi*	*Astrononion novozealandicum*	*Astrononion stelligerum*	*Bigenerina nodosaria*	*Bolivina capitata*	*Bolivina globulosa*	*Bolivina goësii*	*Bolivina pettersoni*	*Bolivina pseudoplicata*	*Bolivina spathulata*	*Bolivina striatula*	*Bolivina subspinescens*	*Bolivina translucens*	*Bolivinita quadrilatera*	*Bolivinopsis cubensis*	*Bulimina alazanensis*	*Bulimina elongata var. subulata*	*Bulimina jarvisi*	*Bulimina marginata*	*Bulimina microcostata*	*Bulimina tarda*	*Buliminella grata*	*Cassidulina crassa*	*Cassidulina havanensis*
Quaternary	610-1-1	0.00	0.0	209	60								1											5	3	1				2		1				3	
	610-1,CC	9.40	0.2	214	39																	1				1									3	
	610-2,CC	17.40	0.3	215	50	1																				2					2				3	
	610-3,CC	24.20	0.5	205	56				1					1												1					1				7	
	610-4,CC	37.50	0.7	239	49	1																		17						1	5				2	
	610-5,CC	47.60	0.8	195	51									1		3									5	13					1				6	
	610A-6,CC	56.80	0.9	215	68								1	8								2		1	6		1		1		1				2	
	610A-7,CC	66.20	1.1	212	53									10										2	1						1				1	
	610A-8,CC	75.90	1.3	220	53									4							2			3						1					1	
	610A-9,CC	85.40	1.4	215	45									16							1	1		1											1	
	610A-10,CC	95.00	1.7	227	57									17								6				3									6	
Pliocene	610A-11,CC	104.10	2.0	213	50									1	1							1	6												1	
	610A-12,CC	114.00	2.2	209	45									22							3					1	1								1	
	610A-13,CC	123.90	2.4	227	54									1												5									14	
	610A-14,CC	133.00	2.7	208	47																2	1				3						2				
	610A-15,CC	143.00	2.8	212	53		1							13							1	1	1			4									4	
	610-6,CC	154.80	3.0	196	61								1	5					1			3	1	1		1			1		1				3	
	610-7,CC	166.20	3.3	202	56								1									3		1		1									2	
	610-8,CC	175.60	3.7	211	58			1					1	2									2						2			1				
	610-9,CC	185.40	4.0	211	51															1		4				1						1			1	
	610A-20,CC	190.80	4.1	225	70									2							2	3	1					1				4			2	
	610A-21,CC	199.60	4.3	205	66		1	1					1								3			4								2				
	610-10,CC	239.0		208	51	1								2								5		2		23			18			1				
upper Miocene	610E-1,CC	294.8		215	72				2					3								5		12		8				3		5			1	
	610E-2,CC	305.7		205	68				3					10								7				7			6			1			1	
	610E-3,CC	318.6		223	60				2					5								7		5		4			9		1	1			2	
	610E-4,CC	327.2		198	51				3					14								1		1		1			2	1	2				2	
	610E-5,CC	337.7		208	65				1					14												2			1		1					
	610E-6,CC	343.7		198	57				1					3								4				4										
	610E-7CC	355.5		208	66																1	2							1		3				2	
	610-13,CC	361.5		197	65									1								4							25						2	
	610-14,CC	410.9		201	60									1								2		1		1			14						4	
	610-15,CC	462.8		213	60		1	1						1								8		1					2	7	2				1	
middle Miocene	610-16,CC	511.8		205	58						1																		9			1				
	610-17,CC	558.8		213	63				5		1			2										3				1	10							
	610-18,CC	605.7		214	49									2								2	1					4	14	5	1				1	
	610-19-1	637.15		226	50						7			3														1	1							
	610-19-2	639.16		226	51									5									2	2				6	1	5						
	610-19-3*	639.95		135	39			1						1									7					1							10	
	610-19,CC	640.48		202	64						1									1		6	1	1		2		3	1	6				1	2	
	610-20-1	646.72		226	57						4											4	2	2				1	4		1	1				1	
lower Miocene	610-20-2	648.71		222	51									3						1		1	1					2	1		1				2	
	610-20,CC	649.34		211	50						1											7	8						2		1				1	
	610-21-1	656.35		221	63									1								4	9					1	1						1	
	610-21-2	657.85		210	59																	2	45					2	1						4	
	610-21,CC	658.41		215	46			1	3													1	91					8	4						1	
	610-22-4	671.15		207	60					1	1			2								9	32					6	1							
	610-22-5	671.95		222	62								1	6								2	12						3			5	2			
	610-22-6	673.45		224	64						1											3	26					1	2						2	
	610-22,CC	675.05		210	51						1			2								2	48						2			2			3	
	610-23-1	657.55		218	49																	2	99						2							
	610-23-2	677.05		213	68						1			2								3	8	1				1	2						1	
	610-23,CC	677.17		213	54									3								8						1	13						4	
	610-24-1	685.05		213	58				1		2			1								42	2	2				1	18			2				1
	610-24-2*	687.55		109	41																		4						10						1	
	610-24-3	688.10		207	57						3			2							2	1							10							
	610-24,CC	688.26		221	55				1		7			2						1				1				1	8			5			1	
	610-25-2*	696.15		111	42																	1	3	13				1	5						1	
	610-25,CC	700.11		210	57																								6			1			1	
	610-26-2*	706.05		91	37																		2						1			8			3	
	610-26-3	707.55		214	50																	2		1					1			20				
	610-26-4	709.05		217	56																	2	2	5					1			3				
	610-26,CC	709.22		231	57	1					1					2						1							3		1	3				
	610-27-1	713.85		199	50											1						1	1	52					3			8				
	610-27-3*	716.85		79	33											1															1	1		2		
	610-27-5	719.85		221	54									1		1						1	2					2	1			9				
	610-27-6*	721.35		73	32											1															3	3				
	610-27,CC	722.40		211	53							2		2		1								5					3			1			1	

Note: Ages are extrapolated from the paleomagnetic data in Clement and Robinson (this volume). Ages are assigned for the upper part of the section only; in the lower part, the time control is too poor to assign ages. Samples marked with an asterisk contain insufficient specimens and were not used for analysis.

Table 2 (continued).

Epoch boundaries	Sample	Sub-bottom depth (m)	Age (Ma)	No. of specimens	No. of species	*Cassidulina teretis*	*Cassidulina transiucens*	*Cassidulinoides bradyi*	*Cassidulinoides tenuis*	*Chilostomella ovoidea*	*Chrysalogonium tenuicostatum*	*Cibicides lobatulus*	*Cibicides variabilis*	*Cibicidoides bradyi*	*Cibicidoides cicatricosus*	*Cibicidoides grimsdalei*	*Cibicidoides havanensis*	*Cibicidoides kullenbergi*	*Cibicidoides* cf. *kullenbergi*	*Cibicidoides laurisae*	*Cibicidoides mundulus*	*Cibicidoides perlucidus*	*Cibicidoides robertsonianus*	*Cibicidoides trinitatensis*	*Cibicidoides wuellerstorfi*	*Cibicidoides wuellerstorfi* var. C	*Cyclammina cancellata*	*Dentalina communis*	*Dentalina intorta*	*Dentalina reussi*	*Dentalina subsoluta*	*Dorothia brevis*	*Dorothia* cf. *brevis*	*Eggerella bradyi*	*Eggerella propinqua*	*Ehrenbergina caribbea*	*Ehrenbergina trigona*
Quaternary	610-1-1	0.00	0.0	209	60	2							5	2				1					2		10								3			
	610-1,CC	9.40	0.2	214	39	10							2		8										9											
	610-2,CC	17.40	0.3	215	50					2				1	6										11		2						2			
	610-3,CC	24.20	0.5	205	56	25							1	3	4								3		8		1				1		1			
	610-4,CC	37.50	0.7	239	49	1			1				1	10				27			1		5		23		1						2			
	610-5,CC	47.60	0.8	195	51	3				1	3				1										4					1	1		1			
	610A-6,CC	56.80	0.9	215	68						3			1	2										7								5			
	610A-7,CC	66.20	1.1	212	53						2		2	8	5										18		1				1		1			
	610A-8,CC	75.90	1.3	220	53	14					1				2										6		2						7			
	610A-9,CC	85.40	1.4	215	45									1	4										20		1						1			
	610A-10,CC	95.00	1.7	227	57									3	2			1							18								4			
Pliocene	610A-11,CC	104.10	2.0	213	50	20					1				3										12		3									
	610A-12,CC	114.00	2.2	209	45									2	2										10								8			
	610A-13,CC	123.90	2.4	227	54	2								3	6										16								7			
	610A-14,CC	133.00	2.7	208	47	77									2										7		2						3			
	610A-15,CC	143.00	2.8	212	53						12		1		1										15								5			
	610-6,CC	154.80	3.0	196	61	1					1			3	1			6			1				13		2				1		2			
	610-7,CC	166.20	3.3	202	56						4			1	6			6							22		1				1		3			9
	610-8,CC	175.60	3.7	211	58						5		1		1										10		1									
	610-9,CC	185.40	4.0	211	51										4			10							34		1									7
	610A-20,CC	190.80	4.1	225	70						1				6			5							10		4								1	1
	610A-21,CC	199.60	4.3	205	66						1			1	2			1							9						1		4			35
	610-10,CC	239.0		208	51						1		1					5			2		1		14		1						5			
upper Miocene	610E-1,CC	294.8		215	72			1	4		1			1				3						2	5		2			1				6		
	610E-2,CC	305.7		205	68									2	1			5	5		5				18		3						2	9		2
	610E-3,CC	318.6		223	60				4									6	1		1				17						1		1	5		1
	610E-4,CC	327.2		198	51									4	3			9	3		3				29								1	12		
	610E-5,CC	337.7		208	65									2	1			2			2		1	1	22		1				1		4	11		
	610E-6,CC	343.7		198	57						3			3				8	2		3				17								4	6		
	610E-7CC	355.5		208	66						4		1	7				7	2					1	18		1				4		7	9		
	610-13,CC	361.5		197	65					1	5			4				4	2						13		1				1		4	8		
	610-14,CC	410.9		201	60									3							2		2	1	25			1				2	3	2		
	610-15,CC	462.8		213	60				2	1	1							4			2			1	5								2			
middle Miocene	610-16,CC	511.8		205	58									4				3			1		1	1	20											
	610-17,CC	558.8		213	63					1	2							5	7		2			2	1		2									
	610-18,CC	605.7		214	49						1	1		4				9	5	3				4			1							7		
	610-19-1	637.15		226	50			13		2				2				17	4		2			7								1				
	610-19-2	639.16		226	51					1		1							2								2							14		
	610-19-3*	639.95		135	39									1				1	1					2												
	610-19,CC	640.48		202	64						2			1				4					1	1			2						1			
	610-20-1	646.72		226	57						1	1		3				10					1	1									1			
lower Miocene	610-20-2	648.71		222	51									3				10	11		1			1										3		
	610-20,CC	649.34		211	50													2	1		2		1	2												
	610-21-1	656.35		221	63				1					4				5	3		3		2	4			2					3		4		
	610-21-2	657.85		210	59						2			1				3	1		1		2	3			3						1	3		
	610-21,CC	658.41		215	46													8	1		3												1			
	610-22-4	671.15		207	60													1						1			2				1		1	2		
	610-22-5	671.95		222	62									3				11	3	1	1		1	2			1				1		4	1		
	610-22-6	673.45		224	64									1				10	1		1			5			2							1	1	
	610-22,CC	675.05		210	51						2							6	7	1	1						2					1		3		
	610-23-1	657.55		218	49													2	1				1	1			5									
	610-23-2	677.05		213	68					2				1				3	4		3						2					1		1	2	
	610-23,CC	677.17		213	54									4				3	6					1			1					1				
	610-24-1	685.05		213	58					1								4	1								4				3	2				
	610-24-2*	687.55		109	41					5				1																						
	610-24-3	688.10		207	57					6	2							1	1				1	1			4				1	1			2	
	610-24,CC	688.26		221	55					2	3			3				2						18			2				1					
	610-25-2*	696.15		111	42													2									1									
	610-25,CC	700.11		210	57				1		3			1				1						1			3					2				
	610-26-2*	706.05		91	37					2	2							1																		
	610-26-3	707.55		214	50				1	2	1							4		2							2					2		1		
	610-26-4	709.05		217	56					5	1			1				4						1			1			1		3		1		
	610-26,CC	709.22		231	57						1			1				14						4							1		1			
	610-27-1	713.85		199	50						1			1				4						1			2									
	610-27-3*	716.85		79	33													2																1		
	610-27-5	719.85		221	54					3	5			2													3					5		1		
	610-27-6*	721.35		73	32					1	2			1				1									1					2				
	610-27,CC	722.40		211	53									4				1									2									

Table 2 (continued).

Eilohedra weddellensis	*Ellipsodimorphina subcompacta*	*Ellipsoglandulina* aff. *fragilis*	*Ellipsoglandulina laevigata*	*Ellipsoglandulina multicostata*	*Ellipsoglandulina* sp.	*Ellipsopolymorphina* sp.	*Epistominella exigua*	*Eponides pusillus*	*Eponides regularis*	*Eponides repandus*	*Eponides tumidulus*	*Favocassidulina favus*	*Francesita advena*	*Fursenkoina bradyi*	*Fursenkoina ciperana*	*Fursenkoina cylindrica*	*Fursenkoina mexicana*	*Fursenkoina pauciloculata*	*Fursenkoina pontoni*	*Fursenkoina schreibersiana*	*Globobulimina ovata*	*Globocassidulina subglobosa*	*Gravellina nariaensis*	*Guttulina problema*	*Guttulina seguenziana*	*Gyroidinoides acutus*	*Gyroidinoides girardanus*	*Gyroidinoides lamarckianus*	*Gyroidinoides mediceus*	*Gyroidinoides soldanii*	*Heronallenia lingulata*	*Hoeglundina elegans*	*Hopkinsina pacifica*	*Karreriella bradyi*	*Laticarinina pauperata*	*Lenticulina gibba*	*Lenticulina mexicana*	*Lenticulina* sp. juv.	*Marginulina glabra*	*Marginulina costata*	*Martinotiella communis*	*Martinotiella petrosa*	*Melonis affinis*	*Melonis barleeanus*	*Melonis pompilioides*	*Neoeponides hillebrandti*	*Nodosarella subnodosa*	*Nodosaria albatrossi*	*Nodosaria filiformis*	*Nodosaria fusiformis*	*Nodosaria lamnulifera*	*Nodosaria longiscata*
12							24				2		5												10			8	5		1		1			2							16	11						
41							21				2		6									1			1		4	3	5			1		2								5						
9							4				1		10									1					2		3					1							2	21					
3							11				2		2					1							3			2	2												1		1	4	24					
1							10						4							2					13			5												3			3	25					
4			1			1	4			1														1	7	4	2	6			2		2									6	39					
1						1	14			2			1					1							4			3	6		1	1		1					1			5	12					
6							20				1		1								1				8		2		3		1								2			5	17					
8							9						1												3			2				10							2			6	7					
2							16				1		1							2					4			2	2			7							2				6					
3							5						1	4						1		2			4		2		5			2							2			10	7					
4							5						3							2								1	5					1								10	4					
12											2														4		1	3	2													17	23					
1							1															1	14						4		1	1	4								30	5					
1							1						4						11					1	2		2	6														10					
1							9											2	1				5		1		2	2	3					2								10	2					
							13						3										8					1	5	7					1	4						7		1				
							13						3						2				2						2	4	1				2							5		1				
1							13							2					3	1			12				3		1	5	1				3							6	2	1				1
1			2				14							1					1				4				1			10					6	1						8		4		1		
1							2						1	1									8						1	2	1				2	1			1			3		1				
1			1				5						1	6					2	3			5						2	3					1							6	1					
1							14						1				1						14						6	6				1	4	1			1		9	1				1	
2							2						1				3			1			4	1			3		2	1	6										1	3					1	1
							21										1	1					7				3			2	6				1							1	9					
							4										1						4					1		3	15				2		2					5	1					
							10						1				5							1				1	1	1	6	1				1						1	12	1				7	
	1						7						2	3			6						6	1						3	5				1	5						1	11			1	2		
	1						3						2				1		1				3			1		4	2	10						6	3				1	4					4	
2							8						2										9	1			4	1	2	4					2					1	1	6	1					
							16										5						11							4		1		1		1						10		1	2			
							40						2						1				10			1	1		6	12					2		1				4	12		1				
1			1	2			1						2				8						6						1	1	14				1						3	22		1	2		2	
							1										15		1				2					1	7	14					1						1	4		1	1	1		
							7												1				14	1			2		3	16	12				1						16				3	
			1														2						1	1			2	3	16		8				3		2			2	7			1			
							1										7	1					9				1	1	15	5	5					3		2				16			3	4	
																	12												14	4	6										7			2	1	
							13										8	1					3			1			13	11	1	1			1	4						7			3	1	
	1						10										17	1					9						24	9	3				2	1				1	7		1	1		2	
							3							4			9	6				16	1					3	12	6					1							11			2			
							13										30	1					9			1			12	5	2	1			1							9						
							2							6			5	1		3			5					1	9	2	3											7		1		1		
							2										7	2		1			8	2					5	1	4				1							4						
							3										6	3											3	2	12											2		2				
							17										24	6										1	1	5	5				3							6						
							19										17	1					8					3	4	1	7					2						7			3		2	
			1				17						3				15	14		1			2						6	3	10					3						3						
							19										13	1					2			2			2		1				2	1					8					3	
							3										2	2		3			2						13		4										11		2	2			
							12						4				9	2										2	9	6	10				2	5						3			3			
1							16										8	3					3						4	6	4				2						15			1			
							7										3	5		1								1	2	6	1				2						9		3	2		2	
	1						5										2	6		8			1						6		1										7			1			
			1				4							5				28		4						1	2	4	3	3				1							5		2	5	1		
							4							5			3	19		3			2			1	5	8		8					2						8			1	1			
							9										3	2					3						3	2	4					1						7			2		1	
1							10							1			25	18								1			6	6	4										11				1		
							3							2			2			5									1	2	1					1						4			1			
							24											31		5				2					1	2					1						3			2			
							17							2			12	6					4						4	6	4										6		4				
							4							5			9	44		4			1			2	2	5	5	4					1						7			2		1	
							1										17	9		2			2				1		3						2								1				
							4										4	2		1									4	2	2					1						6			4			
	1						26							2			5	17											10	1	1										12			2			
							4											2		2									1	2	1										8			5			
			1				17							3				3						1					2	7	4					1					2	25		1	1			

Table 2 (continued).

Epoch boundaries	Sample	Sub-bottom depth (m)	Age (Ma)	No. of specimens	No. of species	*Nodosaria pyrula*	*Nodosaria vertebralis*	*Nonion havanense*	*Nonionella atlantica*	*Nonionellina labradorica*	*Nuttallides umbonifera*	*Ophthalmidium pusillum*	*Oridorsalis tener*	*Oridorsalis umbonatus*	*Orthomorphina calomorpha*	*Orthomorphina challengeriana*	*Orthomorphina doliolaris*	*Orthomorphina glandigena*	*Osangularia culter*	*Plectofrondicularia alazanensis*	*Planulina renzi*	*Pleurostomella acuminata*	*Pleurostomella acuta*	*Pleurostomella alternans*	*Pleurostomella bierigi*	*Pleurostomella bolivinoides*	*Pleurostomella brevis*	*Pleurostomella fusiformis*	*Pleurostomella obtusa*	*Pleurostomella rimosa*	*Pleurostomella* sp. A	*Polymorphina lactea*	*Pseudoparrella* sp.	*Pullenia bulloides*	*Pullenia quadriloba*	*Pullenia quinqueloba*	*Pullenia salisburyi*
Quaternary	610-1-1	0.00	0.0	209	60					1	1	1	3																				1	1	3	9
	610-1,CC	9.40	0.2	214	39						3	1	13	2																			3	1		1
	610-2,CC	17.40	0.3	215	50				7		9		8	7																			1	7		4
	610-3,CC	24.20	0.5	205	56				1		4		5	1																			6	5		3
	610-4,CC	37.50	0.7	239	49				1			6	2	3																						2
	610-5,CC	47.60	0.8	195	51				2				1	1	1									1	2								1			4
	610A-6,CC	56.80	0.9	215	68					1	1	2	3	20	1		1					3											2		3	1
	610A-7,CC	66.20	1.1	212	53							4	3					1				4			1	3				2				2	4
	610A-8,CC	75.90	1.3	220	53								6	4				4				3								1		3	3		2
	610A-9,CC	85.40	1.4	215	45				2				4	36			1	2				1										6	8		1
	610A-10,CC	95.00	1.7	227	57							4		19			3	2				1				1		2				5	8	6	1
Pliocene	610A-11,CC	104.10	2.0	213	50									9				5				3		1						4	1	11	4	1	5
	610A-12,CC	114.00	2.2	209	45									13				1												1		2	5	2	1
	610A-13,CC	123.90	2.4	227	54					1	1	1	3		1		1					1		1					3		7	4		6
	610A-14,CC	133.00	2.7	208	47				1					3								1	1						3				1	2	
	610A-15,CC	143.00	2.8	212	53						5	1	2	4				3				2			1				3		2			1
	610-6,CC	154.80	3.0	196	61		1				2			15				2				3						1	1		1			2
	610-7,CC	166.20	3.3	202	56									23								4		1	1	1					4	1	1	
	610-8,CC	175.60	3.7	211	58									9	1		1	6				4			3			1			3	1		4
	610-9,CC	185.40	4.0	211	51						1			12				3								1		1			3			
	610A-20,CC	190.80	4.1	225	70			2			3		2	14				2				4						1			2			
	610A-21,CC	199.60	4.3	205	66					1	3	1	1	9	1			6	2			4			1						4			
	610-10,CC	239.0		208	51								3	6				2				1			2									1
upper Miocene	610E-1,CC	294.8		215	72					2	4		1	2								7			1			2	1			3	2		3
	610E-2,CC	305.7		205	68					1	4		3	12	1			2							2			1				4		1	
	610E-3,CC	318.6		223	60			1					7	9				3						1	2					1		6		2	
	610E-4,CC	327.2		198	51			1			1		4	7				6				2						1				6	5	4	
	610E-5,CC	337.7		208	65			3					2	1				3				2						8				9	11	2	3
	610E-6,CC	343.7		198	57					1			1	9	1			2				1			1							4	2	3	3
	610E-7CC	355.5		208	66			1						13				3	1					4				1				5	4	3	2
	610-13,CC	361.5		197	65			1					1	11	2			5				3			1			1				2	7	3	1
	610-14,CC	410.9		201	60			3		3			2	8				6					1	3		3						4	4		1
	610-15,CC	462.8		213	60			1					2	7	1							2		1		1		1				5	5		2
middle Miocene	610-16,CC	511.8		205	58			2		1	1			20				4						1	1	2						2			1
	610-17,CC	558.8		213	63					3	1			10				1			1	2		1	1	1		3					1		1
	610-18,CC	605.7		214	49			3			1		1	30					1	1	1	2						2				2	6		
	610-19-1	637.15		226	50						5		1	21					2			1		2		4						6	5	6	7
	610-19-2	639.16		226	51			4		3	2		2	5								1	2	5	2	4		4				5	16	3	1
	610-19-3*	639.95		135	39					1	2												4	5		1		4				2	8	1	2
	610-19,CC	640.48		202	64			6		2	5		1	4				1			1	2		1	2			2				5	4		8
	610-20-1	646.72		226	57			5		2	5		6	4				3				3	3	6				2				2	5		8
lower Miocene	610-20-2	648.71		222	51			2		1	8			15				3	1		1				1	3		3				7	9	3	8
	610-20,CC	649.34		211	50			2		6	3		5	10				1				2	4	1		5		2				6	8		4
	610-21-1	656.35		221	63				5	1	4		6	15				2					5	7	2			3				3	5		4
	610-21-2	657.85		210	59			4		3	5			9				2				4	2	2	2			6					7		2
	610-21,CC	658.41		215	46					1				9									1	1				2	1			3	3		
	610-22-4	671.15		207	60			2		4	4			1				4			2	1	5	2		3		1					5		3
	610-22-5	671.95		222	62			4		4	7			3			1				2	2		1	2	8		5				1	7	1	6
	610-22-6	673.45		224	64								1	11				3			1	1	4	2		2		2					3		2
	610-22,CC	675.05		210	51					3	1		1	10				1				2		2				4				4	6	3	5
	610-23-1	657.55		218	49					1				5				2				1		2		2		5				1	1	1	1
	610-23-2	677.05		213	68			1			3		1	9				3				4	4		1	3		4				5	5	2	5
	610-23,CC	677.17		213	54			2		3				26				1				2	3	1								4	7		3
	610-24-1	685.05		213	58			2						6				1					4					4				3	4		3
	610-24-2*	687.55		109	41					1	1		1	4				1				1						1							2
	610-24-3	688.10		207	57			1			1		1	11				3				2	5									3	7		1
	610-24,CC	688.26		221	55					5	2			5	1			6		1			5					7			1	7			9
	610-25-2*	696.15		111	42			2			3			1								2	5					4				1	2		1
	610-25,CC	700.11		210	57			3		4	2		3	5				6				5	6		1	2		6	1			3	4	1	7
	610-26-2*	706.05		91	37							2		4				1					2	1		1		4	1			1	2		3
	610-26-3	707.55		214	50						1		1	2				6					2			1		7	4			7	8		2
	610-26-4	709.05		217	56			2					5	2	4							9	4	1				5				1	6	1	7
	610-26,CC	709.22		231	57								5	8				5				3	3	1	2			2				1	3	2	6
	610-27-1	713.85		199	50			2						6				1				7	3		2	1		10				1	2		8
	610-27-3*	716.85		79	33			2					1									2						7							4
	610-27-5	719.85		221	54			3					3	5				1				2	6					4					6		7
	610-27-6*	721.35		73	32								1	4								5						1				1			
	610-27,CC	722.40		211	53					1	2		8	19				1					3			3	1	10					3	4	13

Table 2 (continued).

Pullenia subcarinata	*Pyrgo elongata*	*Pyrgo lucernula*	*Pyrgo murrhina*	*Pyrulina cylindroides*	*Pyrulina extensa*	*Pyrulina fusiformis*	*Quinqueloculina* cf. *compta*	*Quinqueloculina lamarckiana*	*Quinqueloculina pygmea*	*Quinqueloculina venusta*	*Quinqueloculina* cf. *weaveri*	*Quinqueloculina* sp. juv.	*Rhabdammina* sp.	*Rosalina* sp.	*Sigmoilina tenuis*	*Sigmoilopsis schlumbergeri*	*Siphogenerina tubulosa*	*Siphonina bradyana*	*Siphotextularia catenata*	*Sphaeroidina bulloides*	*Stainforthia complanata*	*Stilostomella abyssorum*	*Stilostomella annulifera*	*Stilostomella consobrina*	*Stilostomella lepidula*	*Stilostomella subspinosa*	*Stilostomella verneuilli*	*Textularia agglutinans*	*Textularia aspera*	*Textularia porrecta*	*Textularia pseudogramen*	*Textularia sagittula*	*Trifarina bradyi*	*Triloculina trigonula*	*Trochammina globigeriniformis*	*Trochamminoides proteus*	*Uvigerina auberiana*	*Uvigerina bononiensis*	*Uvigerina cylindrica*	*Uvigerina gaudryinoides*	*Uvigerina gracilliformis*	*Uvigerina peregrina*	*Uvigerina rippensis*	Uniocular genera	*Vaginulina elegans*	*Vaginulina insolita*	*Vaginulina subelegans*	*Vaginulina sublegumen*	*Valvulineria laevigata*	*Vulvulina jarvisi*	*Vulvulina spinosa*
1	2		1			1			1	7	2				6	6			2	2	2																			6		16	1						
12		3	1							12					10				2	3	8														5						4		4							
7		1	2			2			1	4					6				9	8	1													1						27		17							
3		5	7			1			2	6	2				6				1	1	2													3						16		9	1				1		
3		2	9			2				2					15						5													1					3	4		9	1						
5	5		3						1		1				7				2		2			7	7	2															2							
3	1	1	6	1		3			2	2				3	8				3					2	8	1														21		15		1					
		5	7			6			1	5	1								1		5		3	6	16														5		7							
4		1	9			2			4	1		1							3	12	5		15	9	12			11													14							
5		1	2						1							7			2	3	10		4	2	13														7		5							
1			3	1					4		1					7					9		6	2	8			8												2		19							
2	1	3	7			1			4	2					6			4			2		11	2	31			3													5							
8	5		3			1			1											1	6		6	3	12									1	2					6		10							
17		4	3			2				3					1						1		10	6	14																17							
3			1	1		1			1						3		5				3		6	2	11			1													9		10							
3			1			1					1				4		3				8		9	22	15			1													18		15							
		1	2			2								2	3								10	2	8			2							1					37	11	12							
			1		1	2					1				4		1				1		8	2	4			2	2								10				9	4	15							
			4	1		2					1				5					3	1		9	22	18			4									5				6	13	16							
						6									5		1		3	3	2		2	2	7												9				10	13	7		1					
1			2	1	1	3					2				1						2		6	6	10			7						1			3				28	2	21							
			1	1		1					1				3		3				1		9	2	16	1		3									10				4	3	21							1
1		1	3								1				4						6		8	7	10	3										18				1	6	1	1						
3									2		1			2	1			6	1			1	4	8	12	2		2									4					3	10	1		1				
4			1			1			2		1			4	3			4					9		9											2					3	12	1		1				
						2									3		2						3	1	3											10					19	22	1						
2						1									1					1			8													5					6	5	2						
5					1	3																	7	4	3			3								4						14	1	1				2	
5			1	2										1	1			1					15	8	10							1								4	6						1	
3						3			2														7	1	9	1		2						1		7				2	16						1	
5															1			1	1	1	1	1	4	2	2	3		5				1			4						1	13							
						1			1														7	5	5			3	3						3						1	17							
1									1									1					7	6	6			3	1						4	9	1		2		8	1						
1									1		2				6								5	7	7	3		5							2					9		9		1					
2						2			1		1	1			6		10		5				1	9	30	10		1	1						2				1	3		8							
3																							2		10	2															5							
3											1						2		2				4	2	20	15												2			2						2
3									1		2	1											3		21	8		2						1				1	2		7		1				
1									2		1														16	2								1					2		8						
4						5								2			1								19	2								1					4	1	8		3	2			
2																						1	2	27	2								2							5	2		1				
3									2											1			3		27									1							3		1					
1									1														4		19	1								2				1		9	1						
2						1			11					3						1			5	2	18				2					1					2		14							
2						3			9			3								1		1	3		10	3				1				1				3			7		1					
						1														1			1	1	13	2		3									2		1	11	1						
3						1			2		1			1								1		2	8	1															14	1						
2									1			2								5				4	3	1															12							
4						2			1										2	2				3	11			3								1	1				19							
4				1		1					2								1				2		12	1					2									1	7							
4									1											2				1	6			2										1		4		13							
4						2			2			1											2	3	10	2		4										2		5		15							
9									2											1		1		2	1	1	2										6					17		2					
6						1					3									1			2	4	13	1					1						2				2	13	1						
3						2			4											1					11											1				1	13	1						
4						2			2	1														2	35	2													2		11	3						
3															2					1					20	4															12	1						
1									2		3	2													5			2													10		1					
6						2			1			3													6	3		1											1		20							
4										1		6			1									2	10	2															2							
8						2					1				1							3		4	21	9		2												1		10							
6						5				3														2	21	3		4													29							
5						2				2					1									2	17	8														2	11		1					
2									1	2	1														10	1		3								1					18							
2												1			2										5			1								2						11							
8															1							1		3	25				1											1		29							
2						1																			4	2															10							
3									5		1													1	21									1						1	20							

APPENDIX B
Taxonomy

Allomorphina trigona **Reuss, 1850,** *Denkschr., K. Akad. Wiss. Wien, Math. Naturw. Kl.*, Vol. 1, p. 380.

Ammonia ? **sp.:** see Thomas, 1985, *Init. Repts. DSDP*, Vol. 85: pp. 655–694 for a discussion.

Amphicoryna hirsuta **(d'Orbigny).** *Nodosaria hirsuta* d'Orbigny, 1826. *Ann. Sci. Nat., Ser. 1,* Vol. 7, p. 87, no. 7.

Angulogerina angulosa **(Williamson).** *Uvigerina angulosa* Williamson, 1858, *Recent Foraminifera of Great Britain*, p. 67, pl. 1, fig. 140.

Angulogerina carinata **Cushman, 1927,** *Bull Univ. California, Techn. Ser.*, Vol. 1. p. 159, pl. 4, fig. 3.

Anomalina alazanensis **var.** *spissiformis* **Cushman and Stainforth, 1945,** *Spec. Publ. Cushman Lab. Foram. Res.*, Vol. 14, p. 77, pl. 14, fig. 5.

Anomalinoides globulosus **(Chapman and Parr).** *Anomalina globulosa* Chapman and Parr, 1937, *Rep. Australasian Antarctic Exped.*, C, Vol. 1, p. 119, pl. 9, fig. 27.

Anomalinoides semicribratus **(Beckmann).** *Anomalina pompilioides* Galloway and Heminway var. *semicribrata* Beckmann, 1953, *Eclogae Geol. Helv.*, Vol. 10, pp. 400–401, pl. 27, fig. 3, text figs. 24, 25.

Asterigerinoides guerichi **(Franke).** *Discorbina guerichi* Franke, 1912, *Verein. Preuss. Rheinlande Westfalens, Verhand.*, Vol. 69, pp. 271–273, pl. 3, figs. 1–3.

Astrononion novozealandicum **Cushman and Edwards, 1937,** *Contrib. Cushman Lab. Foram. Res.*, Vol. 13, pl. 3, fig. 18.

Astrononion stelligerum **(d'Orbigny).** *Nonionina stelligera* d'Orbigny, 1839, *Hist. Nat. Iles Canaries*, Vol. 2, *Pt. 2, Foraminifères*, p. 128, pl. 3, figs. 1, 2.

Bigenerina nodosaria **d'Orbigny, 1826,** *Ann. Sci. Nat., Ser. 1*, Vol. 7, p. 261, pl. 11, figs. 9–12.

Bolivina capitata **Cushman, 1933,** *Contrib. Cushman Lab. Foram. Res.*, Vol. 9, Pt. 4, p. 80, pl. 8, figs. 12a, b.

Bolivina goesii **Cushman, 1922,** *Bull. U.S. Nat. Mus.*, Vol. 104, Pt. 3, p. 34, pl. 6, fig. 5.

Bolivina globulosa **Cushman, 1933,** *Contrib. Cushman Lab. Foram. Res.*, Vol. 9, Pt. 4, p. 80, pl. 8, fig. 9.

Bolivina pettersoni **Phleger, Parker, and Peirson, 1953,** *Swedish Deep Sea Exped. 1947–1948*, Vol. 7, No. 1, p. 36, pl. 7, figs. 15–17.

Bolivina pseudoplicata **Heron-Allen and Earland, 1930,** *J. R. Microsc. Soc., Ser. 3*, Vol. 50, p. 81, pl. 3, figs. 38–40.

Bolivina spathulata **(Williamson).** *Textularia variabilis* var. *spathulata* Williamson, 1858, *Recent Foraminifera of Great Britain*, p. 76, pl. 6, figs. 164, 165.

Bolivina striatula **Cushman, 1922,** *Carnegie Inst. Washington Publ. 311*, p. 27, pl. 3, fig. 10. See Thomas, 1985, *Init. Repts. DSDP*, 85, pp. 655–694 for a discussion.

Bolivina subspinescens **Cushman, 1922,** *Bull. U.S. Nat. Mus.*, Vol. 104, Pt. 3, p. 48, pl. 7, fig. 5.

Bolivina translucens **Phleger and Parker, 1951,** *Mem. Geol. Soc. Am.*, Vol. 46, Pt. 2, p. 15, pl. 7, figs. 13, 14.

Bolivinita quadrilatera **(Schwager).** *Textilaria quadrilatera* Schwager, 1866. *Novara Exped., Geol. Theil.*, Vol. 2, p. 253, pl. 7, fig. 103.

Bolivinopsis cubensis **(Cushman and Bermudez).** *Spiroplectoides cubensis* Cushman and Bermudez, 1937, *Contrib. Cushman Lab. Foram. Res.*, Vol. 13, Pt. 1, pl. 1, figs. 44, 45.

Bulimina alazanensis **Cushman, 1927,** *J. Paleontol.*, Vol. 1, p. 161, pl. 25, fig. 4.

Bulimina elongata **var.** *subulata* **Cushman and Parker, 1937,** *Contrib. Cushman Lab. Foram. Res.*, Vol. 13, Pt. 2, p. 51, pl. 7, figs. 6–7.

Bulimina jarvisi **Cushman and Parker, 1936,** *Contrib. Cushman Lab. Foram. Res.*, Vol. 12, p. 39, pl. 7, fig. 1.

Bulimina marginata **d'Orbigny, 1826,** *Ann. Sci. Nat., Ser. 1,* Vol. 7, p. 269, pl. 12, figs. 10–12.

Bulimina microcostata **Cushman and Parker, 1936,** *Contrib. Cushman Lab. Foram. Res.*, Vol. 12, p. 39, pl. 7, figs. 2a–c.

Bulimina tarda **Parker and Bermudez, 1937,** *J. Paleont.*, Vol. 11, p. 514, pl. 58, figs. 6a–c.

Buliminella grata **Parker and Bermudez, 1937,** *J. Paleont.*, Vol. 11, p. 515, pl. 59, figs. 6a–c.

Cassidulina crassa **d'Orbigny, 1846,** *Foraminifères fossiles du Bassin Tertiaire de Vienne*, pp. 121–213, pl. 21, figs. 42, 43.

Cassidulina havanensis **Cushman and Bermudez, 1936,** *Contrib. Cushman Lab. Foram. Res.*, Vol. 12, p. 36, pl. 6, fig. 11.

Cassidulina teretis **Tappan, 1951,** *Contrib. Cushman Found. Foram. Res.*, Vol. 2, Pt. 1, p. 7, pl. 1, fig. 30.

Cassidulina translucens **Cushman and Hughes, 1925,** *Contrib. Cushman Lab. Foram. Res.*, Vol. 1, Pt. 1, p. 15, pl. 2, figs. 5a–c.

Cassidulinoides bradyi **(Norman).** *Cassidulina bradyi* Norman, 1881, *Q. J. Microsc. Sci.*, New Ser., Vol. 21, p. 59.

Cassidulinoides tenuis **Phleger and Parker, 1951,** *Mem. Geol. Soc. Am.*, Vol. 46, Pt. 2, p. 27, pl. 14, figs. 14–17.

Chilostomella ovoidea **Reuss, 1850,** *Denkschr. K. Akad. Wiss. Math. Naturw. Kl.*, Vol. 1, p. 380, pl. 48, fig. 12.

Chrysalogonium tenuicostatum **Cushman and Bermudez, 1936,** *Contrib. Cushman Lab. Foram. Res.*, Vol. 12, Pt. 2, pp. 27–28, pl. 5, figs. 3–5.

Cibicides lobatulus **(Walker and Jacob).** *Nautilus lobatulus* Walker and Jacob, 1798, *Adam's Essays on the Microscope*, Ed. 2, p. 642, pl. 14, fig. 36.

Cibicides variabilis **(d'Orbigny).** *Truncatulina variabilis* d'Orbigny, 1826, *Ann. Sci. Nat. Ser. 1,* Vol. 7, p. 279.

Cibicidoides bradyi **(Trauth).** *Truncatulina bradyi* Trauth, 1884, *Denkschr. K. Akad. Wiss. Wien, Naturw. Kl.*, Vol. 95, p. 235, pl. 4, figs. 7–9.

Cibicidoides cicatricosus **(Schwager).** *Amonalina cicatricosa* Schwager, 1866, *Novara Exped., Geol. Theil.,* Vol. 2, p. 260, pl. 7, fig. 108. Not the same as *C. cicatricosus* in Resig, 1981, *Mem. Geol. Soc. Am.*, Vol. 154, pl. 8, figs. 13, 14; these specimens have a more acute periphery.

Cibicidoides grimsdalei **(Nuttall).** *Cibicides grimsdalei* Nuttall, 1930, *J. Paleontol.*, Vol. 4, p. 291, pl. 25, figs. 7, 8, 11.

Cibicidoides havanensis **(Cushman and Bermudez).** *Cibicides havanensis* Cushman and Bermudez, 1937, *Contrib. Cushman Lab. Foram. Res.*, Vol. 13, Pt. 1, p. 28, pl. 3, figs. 1–3.

Cibicidoides kullenbergi **(Phleger, Parker and Peirson).** *Cibicides kullenbergi* Phleger, Parker, and Peirson, 1953, *Rep. Swedish Deep Sea Exped. 1947–1948*, Vol. 7, p. 49, pl. 11, figs. 7, 8. For a discussion see Thomas, 1985, *Init. Repts. DSDP*, Vol. 85, pp. 655–694. and see under *C. mundulus*.

Cibicidoides **cf.** *kullenbergi.* This taxon resembles *C. kullenbergi* in wall structure and chamber arrangement but is smaller, more compressed, and had less pronounced sutures; may be a juvenile form.

Cibicidoides laurisae **(Mallory).** *Cibicides laurisae* Mallory, 1959, *Lower Tertiary Biostratigraphy of the California Coast Ranges, Am. Assoc. Pet. Geol., Tulsa, Okla.*, p. 267, pl. 24, figs. 8a–c.

Cibicidoides mundulus **(Brady, Parker, and Jones).** *Truncatulina mundula* Brady, Parker, and Jones, 1888, *Trans. Zool. Soc. London*, Vol. 12, p. 228, pl. 45, fig. 25. The species was emended by Loeblich and Tappan, 1955, in *Smithsonian Inst., Misc. Coll., Washington, D.C.*, Vol. 128, No. 5 (Publ. 4214), p. 25, pl. 4, fig. 4; it resembles *C. kullenbergi* closely, and the two taxa may in reality be one species. According to the type figures of the two species (*op. cit.*), however, the ventral sutures of *C. mundulus* are radial and almost straight, whereas they are strongly curved and approximate the periphery tangentially in *C. kullenbergi.*

Cibicidoides perlucidus **(Nuttall).** *Cibicides perlucida* Nuttall, 1932, *J. Paleontol.*, Vol. 6, p. 33, pl. 8, figs. 10–12.

Cibicidoides robertsonianus **(Brady).** *Truncatulina robertsoniana* Brady, 1881, *Q. J. Microsc. Sci.*, New Ser., Vol. 21, p. 65.

Cibicidoides trinitatensis **(Nuttall).** *Truncatulina trinitatensis* Nuttall, 1928, *Q. J. Geol. Soc. London*, Vol. 84, p. 97, pl. 7, figs. 3, 5, 6. Note that this species is the same as *C. trincherasensis* Beckmann, not Bermudez, *Eclogae Geol. Helv.*, 1953, Vol. 46, p. 656, pl. 18, figs. 4–6.

Cibicidoides wuellerstorfi **(Schwager).** *Anomalina wuellerstorfi* Schwager, 1866, *Novara Exped., Geol. Theil.*, Vol. 2, p. 258, pl. 7, figs. 105–107.

Cibicidoides wuellerstorfi **var. C:** this taxon resembles *C. wuellerstorfi* in overall shape and chamber arrangement, but the evolute side does not have limbate sutures. On the involute side the sutures are less glassy and thickened.

Cyclammina cancellata **Brady, 1876,** *in:* Norman, *Proc. Roy, Soc. London*, Vol. 25, p. 214.

Dentalina communis **d'Orbigny.** *Nodosaria (Dentalina) communis* d'Orbigny, 1826, *Ann. Sci. Nat., Ser. 1,* Vol. 7, p. 254.

***Dentalina intorta* (Dervieux).** *Nodosaria intorta* Dervieux, 1893–1894, *Boll. Soc. Geol. Ital.*, Vol. 12, p. 610.

***Dentalina reussi* Neugeboren, 1856,** *Denkschr. K. Akad. Wiss., Math. Naturw, Kl.*, Vol. 12, Pt. 2, p. 85, pl. 3, 6–7.

***Dentalina subsoluta* (Cushman).** *Nodosaria subsoluta* Cushman, 1923, *Bull. U.S. Nat. Mus.*, Vol. 104, Pt. 4, p. 74, pl. 13, fig. 1.

***Dorothia brevis* Cushman and Stainforth, 1945,** *Spec. Publ. Cushman Lab. Foram. Res.*, Vol. 14, p. 18, pl. 2, fig. 5.

Dorothia* cf. *brevis: similar to *D. brevis* in wall structure and chamber arrangement, but more rounded in cross section, chambers more bulbous and flattened in the length direction of the test.

***Eggerella bradyi* (Cushman).** *Verneuillina bradyi* Cushman, 1911, *Bull. U.S. Nat. Mus.*, Vol. 71, Pt. 2, p. 54, text figs. 87 a, b.

***Eggerella propinqua* (Brady).** *Verneuillina propinqua* Brady, 1884, *Rep. Voy. Challenger, Zool.*, Vol. 9, p. 383, pl. 47, figs. 8–12.

***Ehrenbergina caribbea* Galloway and Heminway, 1941.** *N. Y. Acad. Scientific Survey Porto Rico and Virgin Islands*, Vol. 3, Pt. 4, p. 426, figs 4a–d.

***Ehrenbergina trigona* Goes.** *Ehrenbergina serrata* var. *trigona* Goes, 1896, *Bull. Harvard College Mus. Comp. Zool.*, Vol. 29, p. 49, pl. 6, figs. 184, 185.

***Eilohedra weddellensis* (Earland).** *Eponides weddellensis* Earland, 1936, *Discovery Repts.*, Vol. 13, p. 57, pl. 1, figs. 65–67. See Thomas, 1985, *Init. Repts. DSDP*, Vol. 85, pp. 655–694.

***Ellipsodimorphina subcompacta* Liebus, 1922,** *Lotos (Praga)*, Vol. 70, p. 57, pl. 2. fig. 13.

***Ellipsoglandulina* aff. *fragilis* Bramlette.** *Ellipsoglandulina* sp. aff. *fragilis* Bramlette, Beckmann, 1953, *Eclogae Geol. Helv.*, Vol. 46, p. 379, pl. 28, fig. 7.

***Ellipsoglandulina laevigata* Silvestri, 1900.** *Mem. R. Accad. Sci. Lett., e Arte degli Zelanti, Cl. Sci., Nuova Serie*, Vol. 10, p. 12.

***Ellipsoglandulina multicostata* Galloway and Morrey, 1929,** *Bull. Am. Geol.*, Vol. 15, No. 55, p. 42, pl. 6, fig. 13.

***Elliposglandulina* sp.:** a species with strongly depressed sutures, inflated chambers.

***Ellipsopolymorphina* sp.:** last chambers are more enveloping than in *E. fornasinii*, first chambers more elongated than in *E. schlichtii.*

***Epistominella exigua* (Brady).** *Pulvinulina exigua* Brady, 1884, *Rep. Voy. Challenger, Zool.*, Vol. 9, p. 696, pl. 103, figs. 13a–c, 14a–c.

***Eponides pusillus* Parr, 1950,** *BANZ Antarctic Res. Exped.*, Vol. 5, Pt. 6, p. 360, pl. 14, figs. 14a–c.

***Eponides regularis* Phleger and Parker, 1951,** *Mem. Geol. Soc. Am.*, Vol. 46, Pt. 2, p. 21, pl. 11, figs. 3a, b, 4a–c.

***Eponides repandus* (Fichtel and Moll).** *Nautilus repandus* Fichtel and Moll, 1798, *Testacea Microscopica*, p. 35, pl. 3, figs. a–d.

***Favocassidulina favus* (Brady).** *Pulvinulina fava* Brady, 1877, *Suppl. Notes Foram. Chalk, New Britain Group, Geol. Mag. London*, New Ser., Vol. 4, No. 12, p. 535.

***Francesita advena* (Cushman).** *Vaginulina(?) advena* Cushman, 1922, *Bull. U.S. Nat. Mus.*, Vol. 104, Pt. 3, p. 120, pl. 25, figs. 1–3.

***Fursenkoina bradyi* (Cushman).** *Vaginulina bradyi* Cushman, 1922, *Bull. U.S. Nat. Mus.*, Vol. 104, Pt. 3, p. 115, pl. 24, fig. 1.

***Fursenkoina ciperana* (Cushman and Stainforth).** *Virgulina ciperana* Cushman and Stainforth, 1945, *Contrib. Cushman Lab. Foram. Res.*, Vol. 14, p. 46, pl. 7, fig. 10.

***Fursenkoina cylindrica* (Cushman and Bermudez).** *Virgulina cylindrica* Cushman and Bermudez, 1936, *Contrib. Cushman Lab. Foram. Res.*, Vol. 12, Pt. 2, pp. 30–31, pl. 5, figs. 15a–c.

***Fursenkoina mexicana* (Cushman).** *Virgulina mexicana* Cushman, 1922, *Bull. U.S. Nat. Mus.*, Vol. 104, Pt. 3, p. 120, pl. 23, fig. 8.

***Fursenkoina pauciloculata* (Brady).** *Virgulina pauciloculata* Brady, 1884, *Rep. Voy. Challenger. Zool.*, Vol. 9, p. 414, pl. 52, figs. 4, 5.

***Fursenkoina pontoni* (Cushman).** *Virgulina pontoni* Cushman, 1932, *Contrib. Cushman Lab. Foram. Res.*, Vol 8, Pt. 1, No. 118, p. 17, pl. 3, fig. 7.

***Fursenkoina schreibersiana* Czjzek, 1848,** *Haidinger's Naturw. Abh., Wien*, Vol. 2, Pt. 1, p. 147, pl. 13, figs. 18–21.

***Globobulimina ovata* (d'Orbigny).** *Bulimina ovata* d'Orbigny, 1846, *Foraminifères fossiles du Bassin Tertiaire de Vienne*, p. 185, pl. 11, figs. 13, 14.

***Globocassidulina subglobosa* (Brady).** *Cassidulina subglobosa* Brady, 1884, *Rep. Voy. Challenger, Zool.*, Vol. 9, p. 430, pl. 54, figs. 17a–c.

***Gravellina narivaensis* Brönnimann, 1953,** *Contrib. Cushman Found. Foram, Res.*, Vol. 4, Pt. 1, p. 88, text fig. 1, pl. 15, fig. 8.

***Guttulina problema* d'Orbigny, 1826.** *Ann. Sci. Nat. Ser. 1,* Vol. 6, p. 266, no. 14.

***Guttulina seguenziana* (Brady).** *Polymorphina seguenziana* Brady, 1884, *Rep. Voy. Challenger, Zool.*, Vol. 9, p. 567, pl. 72, figs. 16, 17.

***Gyroidinoides acutus* (Boomgaart).** *Gyroidina neosoldanii* Brotzen var. *acuta* Boomgaart, 1949, Univ. Utrecht doctoral dissert., p. 124, pl. 9, figs. 1a–c.

***Gyroidinoides girardanus* (Reuss).** *Rotalina girardana* Reuss, 1851, *Zeitschr. Deutsche Geol. Ges.*, Vol. 3, p. 73, pl. 5, fig. 34.

***Gyroidinoides lamarckianus* (d'Orbigny).** *Rotalina lamarckiana* d'Orbigny, 1839, *Hist. Nat. Iles Canaries, Foraminifères*, Vol. 2, Pt. 2, p. 131, pl. 2, figs. 13–15.

***Gyroidinoides mediceus* (Emiliani).** *Gyroidina medicea* Emiliani, 1954, *Palaeontographica Italiana*, Vol. 48, p. 136, pl. 24, fig. 6.

***Gyroidinoides soldanii* (d'Orbigny).** *Gyroidina soldanii* d'Orbigny, 1826, *Ann. Sci. Nat., Ser. 1*, Vol. 7, p. 298, no. 5, model no. 36.

***Heronallenia lingulata* (Burrows and Holland).** *Discorbina lingulata* Burrows and Holland, 1896, *in* Jones, *Foram. Crag*, Pt. 3, p. 297, pl. 7, fig. 33.

***Hoeglundina elegans* (d'Orbigny).** *Rotalia (Turbinulina) elegans* d'Orbigny, 1826, *Ann. Sci. Nat., Ser. 1*, Vol. 7, p. 276, models no. 34.

***Hopkinsina pacifica* Cushman, 1933,** *Contrib. Cushman Lab. Foram. Res.*, Vol. 9, Pt. 4, no. 137, p. 86, pl. 8, fig. 16.

***Karreriella bradyi* (Cushman).** *Gaudryina bradyi:* Cushman, 1911, *Bull. U.S Nat. Mus.*, Vol. 71, Pt. 2, p. 67, fig. 107.

***Laticarinina paupertata* (Parker and Jones).** *Pulvinulina repanda* var. *menardii* subvar. *pauperata* Parker and Jones, 1865, *Philos. Trans. R. Soc. London*, Vol. 155, p. 395, pl. 16, figs. 50–51.

***Lenticulina gibba* (d'Orbigny).** *Cristellaria gibba* d'Orbigny, 1826, *Ann. Sci. Nat., Ser. 1*, Vol. 7, p. 292, no. 7.

***Lenticulina mexicana* (Cushman).** *Cristellaria mexicana* Cushman, 1925, *Bull. Am. Assoc. Pet. Geol.*, Vol. 9, p. 299, pl. 7, figs. 1, 2.

***Lenticulina* sp. juv.:** includes all *Lenticulina* specimens with 2–3 chambers only that cannot be assigned to a species.

***Marginulina costata* (Montagu).** *Nautilus costatus* Montagu, 1803, *Testacea Brittanica*, p. 199, pl. 14, fig. 5.

***Marginulina glabra* var. *obesa* Cushman.** *Marginulina glabra* d'Orbigny var. *obesa* Cushman, 1923, *Bull. U.S. Nat. Mus.*, Vol. 104, Pt. 4, p. 128, pl. 37, fig. 1.

***Martinotiella communis* (d'Orbigny).** *Clavulina communis* d'Orbigny, 1826, *Ann. Sci. Nat., Ser. 1*, Vol. 7, p. 268, no. 4.

***Martinotiella petrosa* (Cushman and Bermudez).** *Listerella petrosa* Cushman and Bermudez, 1937, *Contrib. Cushman Lab. Foram. Res.*, Vol. 13, p. 5, Pl. 1, figs. 24–26.

***Melonis affinis* (Reuss).** *Nonionina affinis* Reuss, 1851, *Zeitschr. Deutsche Geol. Ges.*, Vol. 3, p. 72, pl. 5, fig. 32. There is considerable confusion in the literature regarding this species, which closely resembles *M. barleeanus*. I use "*M. barleeanus*-group" for the two species together, and give the name *M. affinis* to specimens that have a smooth wall with less obvious large pores when viewed under the light microscope. These smoother specimens were not found in the samples from the equatorial Pacific (Thomas, 1985, *Init. Repts. DSDP*, Vol. 85, pp. 655–694).

***Melonis barleeanus* (Williamson).** *Nonionina barleeana* Williamson, 1858. *Recent Foraminifera of Great Britain* p. 32, pl. 3, fig. 68–69.

***Melonis pompilioides* (Fichtel and Moll).** *Nautilus pompilioides* Fichtel and Moll, 1798, *Testacea Microscopica* p. 31, pl. 2, figs. a–c.

***Neoeponides hillebrandti* Fisher, 1969,** *Palaeontology*, Vol. 12, Pt. 2, p. 197.

***Nodosarella subnodosa* (Guppy).** *Ellipsoidina subnodosa* Guppy, 1894, *Proc. Zool. Soc. London*, p. 650, pl. 61, fig. 12.

***Nodosaria albatrossi* Cushman.** *Nodosaria vertebralis* var. *albatrossi* Cushman, 1924, *Bull. U.S. Nat. Mus.*, Vol. 104, Pt. 4, p. 87, pl. 15, fig. 1.

***Nodosaria filiformis* d'Orbigny, 1826,** *Ann. Sci. Nat. Ser. 1*, Vol. 7, p. 254, no. 14.

***Nodosaria fusiformis* Silvestri, 1872,** *Atti Accad. Gioenia Sci. Nat. Catania,* Ser. 3, Vol. 7, p. 99, fig. 34.

***Nodosaria lamnulifera* Boomgaart, 1950,** *Contrib. Cushman Lab. Foram. Res.*, Vol. 1, p. 42.

***Nodosaria longiscata* d'Orbigny, 1846.** *Foraminifères fossiles du Bassin Tertiaire de Vienne*, p. 32, pl. 1, figs. 10–12.

***Nodosaria pyrula* d'Orbigny, 1826,** *Ann. Sci. Nat. Ser. 1*, Vol. 7, p. 253, no. 13.

***Nodosaria vertebralis* (Batsch).** *Nautilus (Orthoceras) vertebralis* Batsch, 1791, *Conchyl. Seesandes*, p. 3, nr. 6, pl. 2, fig. 6.

***Nonion havanense* Cushman and Bermudez, 1937,** *Contrib. Cushman Lab. Foram. Res.*, Vol. 13, p. 19, pl. 2, figs. 13, 14.

***Nonionella atlantica* Cushman, 1947,** *Contrib. Cushman Lab. Foram. Res.*, Vol. 23, p. 90, pl. 20, figs. 4, 5.

***Nonionella labradorica* (Dawson).** *Nonionina labradorica* Dawson, 1860, *Can. Naturalist*, Vol. 5, p. 191, fig. 4.

***Nuttallides umbonifera* (Cushman).** *Pulvinulinella umbonifera* Cushman, 1933, *Contrib. Cushman Lab. Foram. Res.*, Vol. 9, Pt. 4, pl. 9, figs. 9a–c.

***Opthalmidium pusillum* (Earland).** *Spiroloculina pusilla* Earland, 1934, *Discovery Repts.*, Vol. 10, p. 47, pl. 1, figs. 3, 4.

***Oridorsalis tener* (Brady).** *Truncatulina tenera* Brady, 1884, *Rept. Voy. Challenger, Zool.*, Vol. 9, p. 665, pl. 95, figs. 11a–c.

***Oridorsalis umbonatus* (Reuss).** *Rotalina umbonata* Reuss, 1851, *Zeitschr. Deutsche Geol. Ges.*, Vol. 3, p. 75, pl. 5, figs. 35a–c.

***Orthomorphina calomorpha* (Reuss).** *Nodosaria (Nodosaria) calomorpha* Reuss, 1886, *Denkschr. K. Akad. Wiss. Wien, Math. Naturw. Kl.*, Vol. 25, p. 129, pl. 1, figs. 15–19.

***Orthomorphina challengeriana* (Thalmann).** *Nodogenerina challengeriana* Thalmann, 1937, *Eclogae Geol. Helv.*, Vol. 30, p. 341.

***Orthomorphina doliolaris* (Parr).** *Nodosaria doliolaris* Parr, 1950, *BANZ Antarctic Res. Exped.*, Ser. B, Vol. 5, p. 290, pl. 12, fig. 2.

***Orthomorphina glandigena* (Schwager).** *Nodosaria glandigena* Schwager, 1866, *Novara Exped., Geol. Theil.*, Vol. 2, p. 219, pl. 5, fig. 46.

***Osangularia culter* (Parker and Jones).** *Planorbulina culter* Parker and Jones, 1865, *Philos. Trans. R. Soc. London*, Vol. 155, p. 421, pl. 19, fig. 1.

***Planulina renzi* Cushman and Stainforth, 1945.** *Spec. Publ. Cushman Lab. Foram. Res.*, Vol. 14, p. 72, pl. 15, fig. 1; 20, figs. 4, 5.

***Plectofrondicularia alazanensis* Cushman, 1927,** *Contrib. Cushman Lab. Foram. Res.*, Vol. 3, p. 113, pl. 22, fig. 12.

***Pleurostomella acuminata* Cushman, 1922,** *Bull. U.S. Nat. Mus.*, Vol. 104, Pt. 3, p. 50, pl. 19, fig. 6.

***Pleurostomella acuta* Hantken, 1875,** *Mitt. K. Ungar. Geol. Anst.*, Vol. 4, Pt. 1, p. 44, pl. 13, fig. 18.

***Pleurostomella alternans* Schwager, 1866,** *Novara Exped., Geol. Theil.*, Vol. 2, p. 238, pl. 6, fig. 79.

***Pleurostomella bierigi* Palmer and Bermudez, 1936,** *Mem. Soc. Cubana Hist. Nat.*, Vol. 10, p. 294, pl. 17, fig. 7, 8.

***Pleurostomella bolivinoides* Schubert, 1911,** *Abh. Geol. Reichsanst. Wien*, Vol. 20, Pt. 4, p. 57, pl. 4.

***Pleurostomella brevis* Schwager, 1866,** *Novara Exped., Geol. Theil.*, Vol. 2, p. 239, pl. 6, fig. 81.

***Pleurostomella fusiformis* Reuss, 1860,** *Sitzungsber. K. Akad. Wiss. Wien, Math. Naturw. Kl.*, Vol. 40, p. 205, pl. 8, fig. 1.

***Pleurostomella obtusa* Berthelin, 1880,** Mem. Soc. Geol. France, Ser. 3, Vol. 1, Pt. 5, p. 29, pl. 1, fig. 9.

***Pleurostomella rimosa* Cushman and Bermudez, 1937,** *Contrib. Cushman Lab. Foram. Res.*, Vol. 13, Pt. 1, p. 17, pl. 1, figs. 62, 63.

***Polymorphina lactea* (Walker and Jacob).** *Serpula lactea* Walker and Jacob, 1798, *Adam's Essays on the Microscope*, Ed. 2, p. 634, pl. 24, fig. 4.

***Pseudoparrella* sp.** This species resembles *P. peruviana* Cushman closely in the shape of the chambers on the evolute side, but it is more flattened and has a broadly rounded periphery. *p. garrisoni* Lipps has wider chambers and less curved sutures on the evolute side.

***Pullenia bulloides* (d'Orbigny).** *Nonionina bulloides* d'Orbigny, 1846, *Foraminifères fossiles du Bassin Tertiaire de Vienne*, p. 107, pl. 5, figs. 9, 10.

***Pullenia quadriloba* Reuss.** *Pullenia compressiuscula* var. *quadriloba* Reuss, 1867, *Denkschr. K. Akad. Wiss. Wien, Math. Naturw. Kl.*, Ser. B, Vol. 55, pl. 3, fig. 8.

***Pullenia quinqueloba* (Reuss).** *Nonionina quinqueloba* Reuss, 1857, *Zeitschr. Deutsche Geol. Ges.*, Vol. 3, p. 47, pl. 5, fig. 31.

***Pullenia salisburyi* Stewart and Stewart, 1930.** *J. Paleontol.*, Vol. 4, p. 72, pl. 8, figs. 2a, b.

***Pullenia subcarinata* (d'Orbigny).** *Nonionina subcarinata* d'Orbigny, 1839, Voy. Amer. Merid., Vol. 5, p. 28, pl. 5, figs. 23, 24.

***Pyrgo elongata* (d'Orbigny).** *Biloculina elongata* d'Orbigny, 1826, *Ann. Sci. Nat. Ser. 1*, Vol. 7, p. 298, no. 4.

***Pyrgo lucernula* (Schwager).** *Biloculina lucernula* Schwager, 1866, *Novara Exped., Geol. Theil.*, Vol. 2, p. 202, pl. 4, fig. 14.

***Pyrgo murrhina* (Schwager).** *Biloculina murrhina* Schwager, 1866, *Novara Exped., Geol. Theil.*, Vol. 2, p. 203, pl. 4, figs 5a–c.

***Pyrulina cylindroides* (Roemer).** *Polymorphina cylindroides* Roemer, 1838, *Neues Jb. Min. Geogn. Geol. Petrefaktenkunde*, p. 385, pl. 3, figs 26a–b.

***Pyrulina extensa* (Cushman).** *Polymorphina extensa* Cushman, 1923. *Bull. U.S. Nat. Mus.*, Vol. 104, Pt. 4, p. 156, pl.41, figs. 7, 8.

***Pyrulina fusiformis* (Roemer).** *Polymorphina fusiformis* Roemer, 1838, *Neues Jb. Min. Geogn. Geol. Petrefaktenkunde*, p. 386, pl. 3, figs. 37a–b.

***Quinqueloculina compta* Cushman, 1947,** *Contrib. Cushman Lab. Foram. Res.*, Vol. 23, p. 87, pl. 19, fig. 2.

***Quinqueloculina lamarckiana* d'Orbigny, 1839,** *in* de la Sagra, *Hist. Phys. Pol. Nat. Cuba*, p. 189, pl. 11, figs. 14, 15.

***Quinqueloculina pygmaea* Reuss, 1850,** *Denkschr. K. Akad. Wiss. Wien, Math. Naturw. Kl.*, Vol. 1, p. 384, pl. 50, fig. 3.

***Quinqueloculina venusta* Karrer, 1868,** *Sitzungsber. K. Akad. Wiss. Wien, Math. Naturw. Kl.*, Vol. 58, Abt. 1, p. 147, pl. 2, fig. 6.

***Quinqueloculina* cf. *weaveri* Rau.** *Quinqueloculina* cf. *weaveri* Phleger, Parker, and Peirson, 1953, *Rep. Swedish Deep Sea Exped.*, Vol. 7, p. 28, pl. 5, figs. 13, 14.

***Quinqueloculina* sp. juv.:** all specimens that have less than 6 chambers, and cannot be assigned to a species.

***Rhabdammina* sp.:** found as fragments only; I did not try to assign these to a species.

***Sigmoilina tenuis* (Czjzek).** *Quinqueloculina tenuis* Czjzek, 1848, *Haidinger's Naturw. Abh.*, Vol. 2, Pt. 1, p. 149, pl. 13, figs. 31–34.

***Sigmoilopsis schlumbergeri* (Silvestri).** *Sigmoilina schlumbergeri* Silvestri, 1904, Mem. Accad. Pont. Romani Nuovi Lincei, Vol. 22, pp. 267–269.

***Siphonina bradyana* Cushman, 1927,** *Proc. U.S. Nat. Mus.*, Vol. 72, no. 2716, art. 20, p. 11, pl. 1, fig. 4.

***Siphotextularia catenata* (Cushman).** *Textularia catenata* Cushman, 1911, *Bull. U.S. Nat. Mus.*, Vol. 71, Pt. 2, p. 23, figs. 39, 40. I agree with Corliss, 1979, *Micropalentology*, Vol. 25, p. 5, pl. 1, figs. 1, 2, that *S. rolshauseni* (Phleger and Parker) is a junior synonym of *S. catenata*.

***Sphaeroidina bulloides* d'Orbigny, 1826,** *Ann. Sci. Nat., Ser. 1*, Vol. 7, p. 267, model No. 65.

***Stainforthia complanata* (Egger).** *Virgulina schreibersiana* var. *complanata* Egger, 1893, *Abh. Bayer. Akad. Wiss., Math.-Phys. Naturw. Kl.*, p. 292, pl. 8, figs 91, 92.

***Stilostomella abyssorum* (Brady).** *Nodosaria abyssorum* Brady, 1881. *Q. J. Microsc. Sci.*, New Ser., Vol. 21, p 63.

***Stilostomella annulifera* (Cushman and Bermudez).** *Ellipsonodosaria annulifera* Cushman and Bermudez, 1936, *Contrib. Cushman Lab. Foram. Res.*, Vol. 12, Pt. 2, p. 28, pl. 5, figs. 8, 9.

***Stilostomella consobrina* (d'Orbigny).** *Dentalina consobrina* d'Orbigny, 1846, *Foraminifères fossiles du Bassin Tertiaire de Vienne*, p. 46, pl. 2, figs. 1–3. There is considerable confusion in the nomenclature within the genus *Stilostomella*. I use *S. consobrina* for forms in which the last chambers are elongated, *S. lepidula* for forms with rounded chambers with a ridge or ring of spines along the base of the chambers, and *S. subspinosa* for forms with rounded chambers covered with spines.

***Stilostomella lepidula* (Schwager),** *Nodosaria lepidula* Schwager, 1866. *Novara Exped. Geol. Theil.*, Vol. 2, pp. 210, 211, pl. 5, figs. 27, 28. *S. antillea* (Cushman), 1923, *Bull. U.S. Nat. Mus.*, Vol. 104, Pt. 4, p. 91, fig. 9 is a junior synonym in my opinion.

***Stilostomella subspinosa* (Cushman).** *Ellipsonodosaria subspinosa* Cushman, 1943, *Contrib. Cushman Lab. Foram. Res.*, Vol. 19, p. 92, pl. 16, figs. 16, 17.

***Stilostomella verneuilli* (d'Orbigny).** *Dentalina verneuilli* d'Orbigny, 1846, *Foraminifères fossiles du Bassin Tertiaire de Vienne*, p. 48, pl. 2, figs. 7, 8.

***Textularia agglutinans* d'Orbigny, 1839,** *in* de la Sagra, *Hist. Phys. Pol. Nat. Cuba*, p. 136, p. 1, figs. 17, 18, 32, 34.

***Textularia aspera* Brady, 1884,** *Rep. Voy. Challenger, Zool.*, Vol. 9, p. 366, pl. 44, figs. 9–11 (not figs. 12, 13).

***Textularia porrecta* Brady,** *Textularia agglutinans* var. *porrecta* Brady, 1884, *Rep. Voy. Challenger, Zool.*, Vol. 9, p. 364, pl. 364, pl. 43, fig. 4.

***Textularia pseudogramen* Chapman and Parr, 1937,** *Sci. Rep. Australasian Antarctic Exped.*, Vol. 1, p. 153.

***Textularia sagittula* Defrance, 1824,** *in* de Blainville, *Dict. Sci. Nat.*, Paris, Vol. 32, p. 177, pl. 13, fig. 5.

***Trifarina bradyi* Cushman, 1923,** *U.S. Nat. Mus.*, Vol. 104, Pt. 4, p. 99, pl. 22, figs. 3–9.

***Triloculina trigonula* (Lamarck).** *Miliolites trigonula* Lamarck, 1804, *Ann. Mus. Natl. Hist. Nat. Paris*, Pt. 5, p. 351, pl. 17, fig. 4.

***Trochammina globigeriniformis* (Parker and Jones).** *Lituola nautiloidea* var. *globigeriniformis* Parker and Jones, 1865, *Philos. Trans. R. Soc. London*, Vol. 155, pl. 17, fig. 96.

***Trochamminoides proteus* (Karrer).** *Trochammina proteus* Karrer, 1865, *Sitzungsber. K. Akad. Wiss, Wien, Math. Naturw. Kl.*, Vol. 52, Pt. 1, p. 494, fig. 8 (not figs. 1–7).

Unilocular genera: I did not assign specific or generic names to any of the occasionally common unilocular specimens, but I grouped these specimens and counted the number of species to which they belong. This number was used in the calculation of the total number of species per sample.

***Uvigerina auberiana* d'Orbigny, 1839,** *in* de la Sagra, *Hist. Phys. Pol. Nat. Cuba*, p. 106, pl. 2, figs. 23, 24.

***Uvigerina bononiensis* Fornasini, 1888.** *Boll. Soc. Geol. Ital.*, Vol. 7, Pt. 1, pl. 3, figs. 12, 12a.

***Uvigerina cylindrica* (d'Orbigny).** *Clavulina cylindrica* d'Orbigny, 1852, *Prodr. Paleont. Stratigr.*, Vol. 3, p. 94.

***Uvigerina gaudryinoides* Lipparini.** *Uvigerina tenuistriata* var. *gaudryinoides* Lipparini, 1932, *Giornale de Geologia, Bologna*, Ser. 2, Vol. 7, p. 65, pl. 6, figs. 7, 8.

***Uvigerina graciliformis* Papp, 1953.** *Jahrb. Geol. Bundesanst.*, Vol. 16, p. 122, pl. 5A, figs. 5–7.

***Uvigerina peregrina* Cushman, 1923,** *Bull. U.S. Nat. Mus.*, Vol. 104, Pt. 4, p. 166, pl. 42, figs. 7–10.

***Uvigerina rippensis* Cole, 1927,** *Bull. Am. Paleontol.*, Vol. 14, no. 51, p. 11, pl. 2, fig. 16.

***Vaginulina elegans* d'Orbigny, 1826,** *Ann. Sci. Nat. Ser. 1*, Vol. 7, p. 257, no. 1, model no. 54.

***Vaginulina insolita* (Schwager).** *Cristellaria insolita* Schwager, 1866, *Novara Exped., Geol. Theil.*, Vol. 2, p. 242, pl. 6, fig. 85.

***Vaginulina subelegans* Parr, 1950,** *BANZ Antarctic Res. Exped.*, Ser. B, Vol. 5, Pt. 6, p. 326, pl. 11, figs. 20a, b.

***Vaginulina sublegumen* (Parr).** *Vaginulinopsis sublegumen* Parr, 1950, *BANZ Antarctic Res. Exped.*, Ser. B, Vol. 5, Pt. 6, p. 325, pl. 11, figs, 18a, b.

***Valvulineria laevigata* Phleger and Parker, 1951,** *Mem. Geol. Soc. Am.*, Vol. 46, Pt. 2, p. 25, pl. 13, figs. 3–9.

***Vulvulina jarvisi* Cushman, 1932,** *Contrib. Cushman Lab. Foram. Res.*, Vol. 8, p. 84, pl. 10, fig. 10.

***Vulvulina spinosa* Cushman, 1927,** *Contrib. Cushman Lab. Foram. Res.*, Vol. 3, Pt. 2, p. 111, pl. 23, fig. 1.