17. LATE EOCENE TO RECENT DEEP-SEA BENTHIC FORAMINIFERS FROM THE CENTRAL EQUATORIAL PACIFIC OCEAN[1]

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ABSTRACT

Benthic foraminifers were studied in upper Eocene to Recent core-catcher samples from DSDP Sites 573, 574, and 575. The sites are on a north–south transect from the equator to about 05°N at about 133°W, water depth 4300 to 4600 m. At Site 574 additional samples were used to study the Eocene/Oligocene boundary in detail. About 200 specimens were counted per sample.

The fauna is highly diverse (about 50 to 70 species per sample) and is of low dominance. The diversity is not related to age or sub-bottom depth. Many species are cosmopolitan and probably have wide environmental tolerances. Fluctuations in frequency of some taxa (e.g., *Nuttallides umbonifera*, *Epistominella exigua*, and *Uvigerina* spp.) cannot be correlated from one site to another.

Several common species (e.g., *Oridorsalis umbonatus* and *Globocassidulina subglobosa*) range from late Eocene to Recent. First and last appearances are generally difficult to define precisely because many species are rare. For some species these datums differ from one site to another, but several datum levels are within 1 m.y. at all sites. First and last appearances are most numerous in two intervals, the late Eocene to early Oligocene (about 32 to 37 Ma) and the early to middle Miocene (about 13 to 18.5 Ma).

Isotopic events occur within each of these periods of benthic faunal change, but the isotopic events have a shorter duration and start after the initiation of the changes in the fauna. Changes in deep-sea benthic faunal composition are not directly related to short-term oceanographic changes as expressed in isotopic records.

INTRODUCTION

The knowledge of deep-sea benthic foraminifers has increased rapidly since 1968, when the Deep Sea Drilling Project began to recover Cenozoic abyssal sediments. Several review papers have been published recently on deep-sea benthic foraminifers, such as those by Douglas and Woodruff (1981), who include many previously unpublished data on Pacific faunas; Schnitker (1980), who covers Quaternary faunas; and Miller (1982). Only a few papers, notably those by Woodruff and Douglas (1981) and Tjalsma and Lohmann (1983), have quantitatively described the benthic foraminiferal fauna in long sections (spanning more than a few millions of years).

Benthic faunas from the eastern Pacific (Nazca Plate) have been described by Ingle (1973), Resig (1976, 1981), Coulbourn (1980), and Boltovskoy (1981b); from the western Pacific by Boltovskoy (1980a,b, 1981b), Woodruff and Douglas (1981), and Culp-Burke (1981); and from the central Pacific by Douglas (1973). An important discussion of Miocene benthic faunas from 25 sites distributed over the entire Pacific Ocean is presented by Woodruff (in press). The comparison of results of different authors is generally complicated by varying taxonomic concepts. Deep-sea benthic foraminiferal faunas are extremely diverse and contain many rare species, and taxonomic confusion is rampant.

The use of deep-sea benthic foraminifers in biostratigraphy is under current investigation. Detailed zonations comparable to those of planktonic microorganisms are not possible using benthic foraminifers. Boltovskoy (1976, 1978, 1980a,b, 1981a,b) found that abyssal benthic foraminifers are of limited value in biostratigraphy; his arguments were based on his work on hundreds of samples (late Eocene to Recent) from the Pacific, Indian, and south Atlantic oceans. Miller (1982) stressed that biozones based on benthic foraminifers tend to be diachronous because of the relationship between benthic faunas and the local environment. Several authors (e.g., Douglas and Woodruff, 1981; Tjalsma and Lohmann, 1983), however, agree that during times of relatively rapid change in benthic faunas, these faunas can be used for biostratigraphy, although their use is limited by geographic and depth migration of species and by taxonomic problems.

Studies of benthic foraminifers have contributed significantly to paleoclimatic and paleoceanographic reconstructions. Benthic foraminifers are rare in most samples from the deep ocean (mainly because of dilution with the skeletons of more numerous planktonic organisms), but they are generally the only bottom dwellers found in significant numbers in deep-sea cores. Therefore, they are the most important fossil group used in the reconstruction of bottom-water movements and changes in deep-water circulation (e.g., Boltovskoy et al., 1980).

Assemblages of benthic foraminifers were found to be correlated with specific water masses in the present oceans (see Boltovskoy, 1959; Streeter, 1973; Schnitker, 1974; Boltovskoy, 1976; Lohmann, 1978, for the Atlantic Ocean; Belanger and Streeter, 1980, for the Norwegian–Greenland Sea; Corliss, 1979a, for the Indian Ocean; Boltovskoy, 1976; Ingle et al., 1980, for the southeast Pacific Ocean). Unfortunately, exact relationships between

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benthic species and properties of the water masses are not yet clear. For instance, Miller (1983) and Tjalsma and Lohmann (1983) describe that *Nuttallides umbonifera* is abundant in old, sluggish, oxygen-poor bottom waters, whereas Woodruff and Douglas (1981) conclude that this species (*Epistominella umbonifera* in their nomenclature) is indicative of young, oxygenated bottom waters in the western Pacific.

The records of carbon and oxygen isotopic ratios, which are based on analyses of tests of benthic foraminifers, also document changes in bottom-water conditions. The relationships, however, between the carbon and oxygen isotopic records and the record of changes in the composition of benthic faunas are not straightforward.

A major shift in oxygen and carbon isotopic ratios in planktonic and benthic foraminifers occurred worldwide in the earliest Oligocene, just above the Eocene/Oligocene boundary (e.g., see Kennett and Shackleton, 1976; Keigwin, 1980; Keller, 1983; Keigwin and Keller, 1984; Miller and Thomas, this volume). Corliss (1981) documents that changes in the benthic faunas at that time were minor. Schnitker (1979) used DSDP material from the Bay of Biscay and concluded that a faunal turnover in the benthic foraminifers did occur at the Eocene/Oligocene boundary, but Miller (1983) studied material from the same sites and found that major changes took place between the middle Eocene and the Oligocene. These changes, however, cannot be dated unequivocally in the Bay of Biscay because of hiatuses in the upper Eocene. Tjalsma and Lohmann (1983), Tjalsma (1983), and Clark and Wright (1984) studied material from the Atlantic Ocean. They concluded that there was no major crisis in abyssal benthic faunas close to the Eocene/Oliogocene boundary, but that there were gradual changes from the middle Eocene through the early Oligocene (i.e., mainly before the major shift in isotopic ratios). In agreement with the conclusions of the papers cited above are reports by Miller (1983), Miller et al. (in press), and Snyder et al. (1984) who describe deep-sea benthic faunas from the southwest Atlantic Ocean and the Bay of Biscay. Wood et al. (in press) come to similar conclusions in their paper on the benthic faunas from the Oceanic Formation on Barbados.

A major increase in oxygen isotopic ratios of benthic and planktonic foraminifers at high latitudes occurred in the middle Miocene. The increase in benthic foraminiferal oxygen isotopic ratios is recognized worldwide (Savin et al., 1981) and is well documented in the Pacific Ocean (Shackleton and Kennett, 1975; Woodruff and Douglas, 1981). The latter authors report that a major change in benthic faunal composition occurred at the same time as the isotopic shift. Woodruff (in press) describes that migratory and evolutionary changes in benthic faunas from 25 sites all over the Pacific Ocean occurred at the same time as the shift in oxygen isotopic ratios. However, the "main phase of benthic evolution" occurred between 16.5 and 13.2 Ma (Woodruff, in press), whereas the main shift in oxygen isotopes started later and had a much shorter duration (14.0 to 14.8 Ma, Woodruff et al., 1981; see also Pisias and Shackleton, this

volume; Vincent and Killingley, this volume). Berggren (1972) noted a change in the benthic faunal composition in the middle Miocene in the Atlantic Ocean, but he does not present isotopic data, nor does he give a more precise age for the event than "middle Miocene."

A worldwide increase in carbon isotopic ratios in benthic and planktonic foraminifers predates the shift in oxygen isotopic ratios (Savin et al., 1981; Vincent and Berger, 1984; Vincent et al. 1983; Vincent and Killingley, this volume). No comparison between the time of this shift and the composition of benthic faunas has been made as yet.

The late Miocene shift in carbon isotopic ratios has likewise been recognized worldwide (Savin et al., 1981; Haq et al., 1980; Keigwin, 1979; Bender and Keigwin, 1979; Vincent et al., 1980). None of the authors describing the shift gives details concerning the composition of the benthic faunas before and after the event, although Vincent et al. (1980) report a sharp peak in abundance of *Uvigerina* spp. just below the shift.

In summary, there appears to be a general relationship between changes in the composition of benthic faunas and changes in carbon and oxygen isotopic ratios, but the relationship is not straightforward: faunal changes have a longer duration and start earlier. Several authors describe the isotopic events at the Leg 85 sites (Miller and Thomas, this volume, late Eocene and Oligocene; Vincent and Killingley, this volume, early Miocene; Pisias and Shackleton, this volume, middle Miocene; Prell, this volume, Pliocene). This makes it possible to compare the isotopic records at Sites 573, 574, and 575 with the composition of the benthic fauna.

MATERIAL AND METHODS

I used material from DSDP Sites 573 (00°29.91′N, 133°18.57′W, 4301 m water depth), 574 (04°12.52′N, 133°19.81′W, 4561 m depth), and 575 (05°51.00′N, 135°02.16′W, 4536 m depth) (Fig. 1). The basement age at all sites is late Eocene. At Sites 573 and 574 basement was recovered, but at Site 575 the oldest sediment recovered was lower Miocene. Assuming that the initial depth of deposition at the ridge crest was approximately 2700 m (Berger, 1973), Sites 573, 574, and 575 backtrack (see Berger and Winterer, 1974, for methodology) from their present positions to about 3900 m depth in the early Miocene.

The sediments at all sites are siliceous nannofossil oozes and chalks. The preservation of benthic foraminifers varies from good to poor. Calcite overgrowth is rare or absent, but some dissolution does commonly occur. In many samples, especially in the older sediments, specimens show etching of the walls and detached last chambers (see Plates 1 to 15). Some samples (upper part of Holes 574 and 575) do not contain sufficient calcareous microfossils for study because of strong dissolution.

At Sites 573 and 574 core-catcher samples (about 20 cm³) were used from one HPC hole and from the deeper rotary-drilled hole (573B and 574C, respectively). At Site 575 core-catcher samples were used from two HPC holes (575 and 575A). All core-catcher samples from these holes were studied, except those from the lower part of Hole 575A in which cores are shorter than 4 m. In this interval every second core-catcher sample was used. The sampling interval is about 0.5 m.y. averaged over the complete section, but the use of equally spaced samples does not mean that the samples are equally spaced in time. At Site 574 (Hole 574C), the lower part of the section, which spans the Eocene/Oligocene boundary, was studied in detail. From Core 574C-29 down to 547C-32 one sample per section was used, and from Core 574C-33 downward as many as five samples per section were used. The volume of these additional samples was 10 cm³.
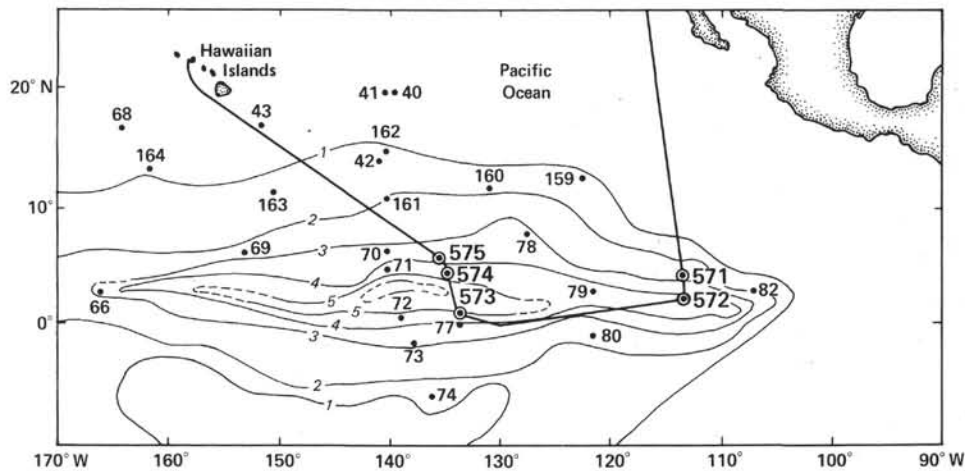
Figure 1. Track and locations of sites drilled on DSDP Leg 85 (⊚) in relationship to sediment thickness (contours in tenths of seconds of two-way traveltime) and to DSDP holes drilled previously (Legs 5, 8, 9, and 16).

All samples were dried and washed through a 63-μm sieve. Samples from the indurated chalks in the lower part of the section were dried and then soaked in kerosene. The kerosene was poured off and the sample heated in water.

Species–specimen plots were constructed for several samples by plotting the number of species versus the number of specimens while counting the specimens (Fig. 2). The species–specimen curves start to become parallel to the species axis at about 180 specimens; in other words, many extra specimens have to be counted to find a few extra species. Therefore, I decided to obtain about 200 specimens per sample and not use samples in which considerably fewer specimens were present. I made a strewing on a 5 × 9 cm picking tray to determine how abundant benthic foraminifers were in each sample. If fewer than five specimens were present in the strewing, the sample was not used. If more than five specimens were found, the amount of sample needed to obtain 200 specimens was estimated and a split of that size was made. If not enough specimens were found in the split, extra splits were made as needed. In the additional samples from Hole 574C, I counted all benthic foraminifers present, and samples with fewer than 180 specimens (total) were excluded from the analysis. All specimens counted were picked and mounted on Cushman slides.

Most core-catcher samples contained sufficient specimens for study (200), with the exception of samples from the upper 95 m at Site 574 and the upper 30 m at Site 575, which represent the latest 10.9 and 12.4 m.y., respectively. These sediments show strong dissolution.

The entire size fraction larger than 63 μm was used, mainly because inconsistent results were obtained when the fraction larger than 125 μm was separated. Some samples have numerous specimens of *Pleurostomella* spp. and *Stilostomella* spp., and these linear specimens can pass through the 125-μm sieve. The number of specimens that ac-

tually pass, however, turned out to depend on the way in which the sieve is shaken (how vigorously and for how long). Since the majority of the benthic foraminifers are larger than about 120 μm, the results of this study can be compared with studies in which the larger than 125-μm fraction was used, but not with studies in which the larger than 250-μm fraction was studied.

RESULTS AND DISCUSSION

The counts of benthic foraminifers for all sites are presented in Appendix A, and the taxonomy is discussed in Appendix B. The relative abundances (percent frequencies) of the most common species and species groups are shown plotted versus sub-bottom depth in Figures 3 (Site 573), 4 (Site 574), and 5 (Site 575). Figure 6 shows some of the data on Figures 3, 4, and 5 plotted versus time for the three sites combined. The time scale used to construct this figure was taken from the sedimentation rate curves in Barron et al. (this volume), and is based on the time scale by Berggren et al. (in press). (Note that a correlation of Anomaly 5 with Chron 11 has been assumed.)

Figure 7 shows stratigraphic ranges for selected species at all three sites plotted versus time. Figures 8 and 9 show relative abundances and stratigraphic ranges for selected species for the interval in Hole 574C that was studied in more detail.
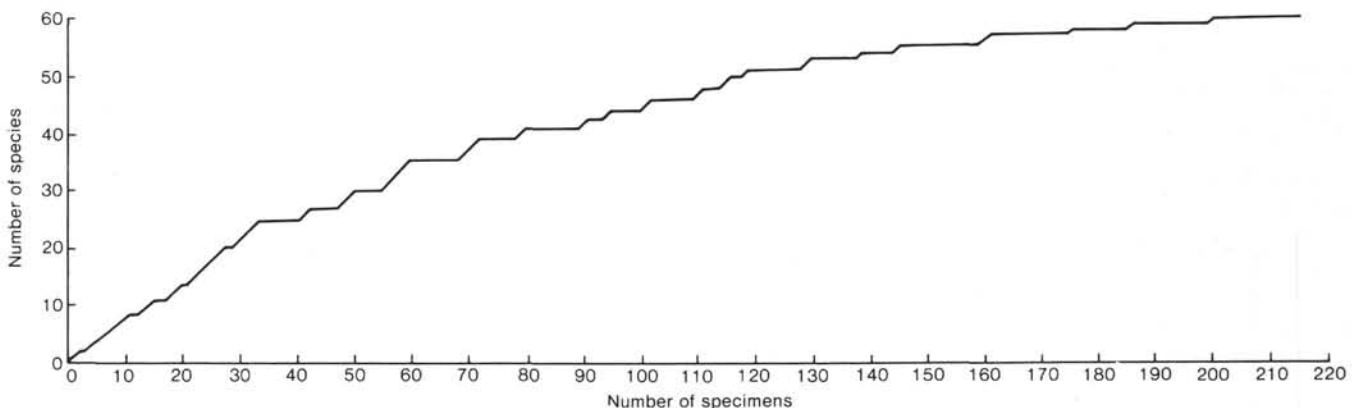

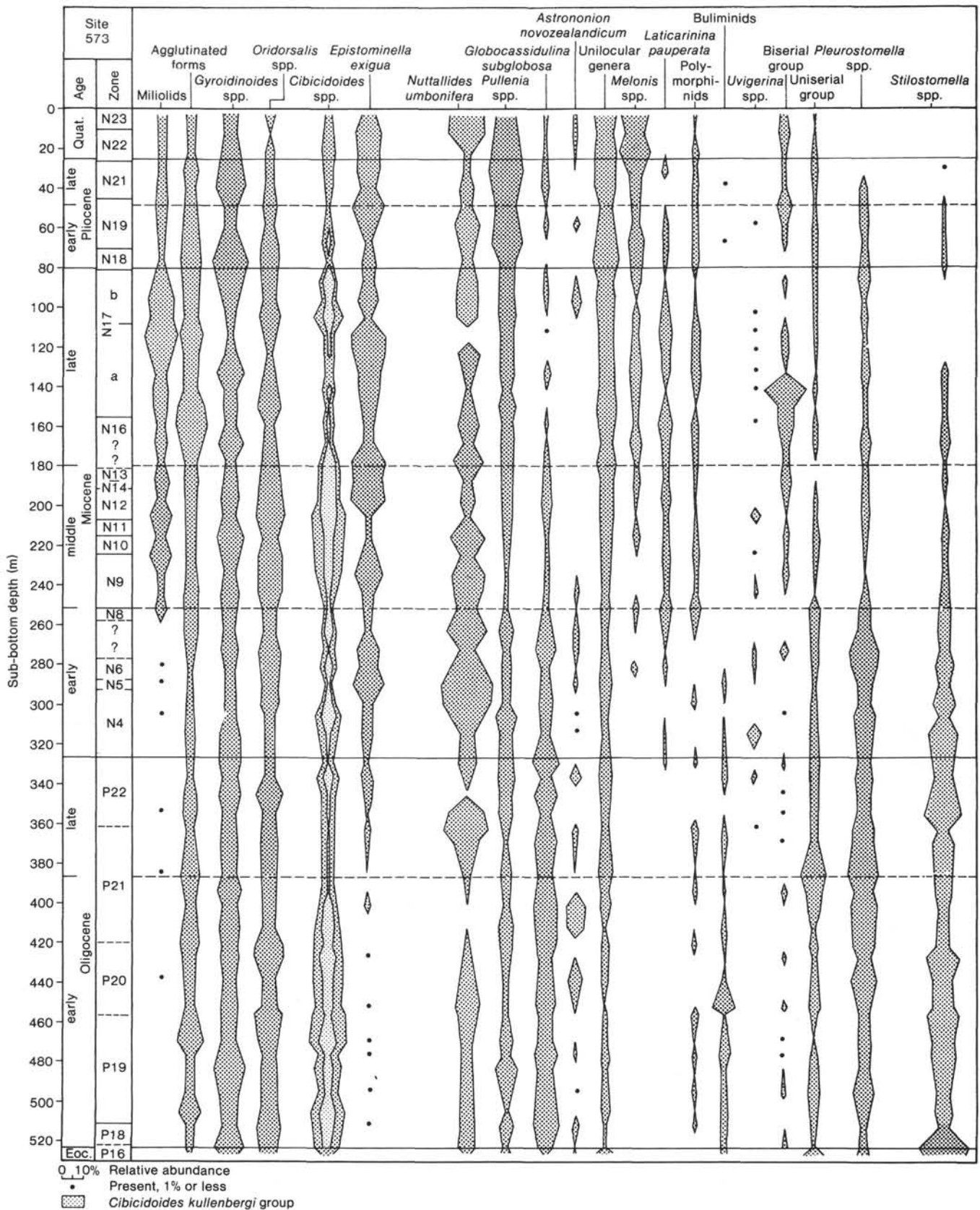Figure 2. Species–specimen plot for Sample 573-4,CC.

Figure 3. Relative abundances of selected species and species groups plotted versus sub-bottom depth, Site 573. Biserial group consists of *Bolivina* spp., *Fursenkoina* spp., *Stainforthia complanata*, and *Francesita advena*. Buliminids consist of *Bulimina* spp. and *Buliminella* spp. Uniserial group consists of uniserial lagenids.

Figure 4. Relative abundances of selected species and species groups plotted versus sub-bottom depth, Site 574. Biserial group consists of *Bolivina* spp., *Fursenkoina* spp., *Stainforthia complanata*, and *Francesita advena*. Buliminids consist of *Bulimina* spp. and *Buliminella* spp. Uniserial group consists of uniserial lagenids.
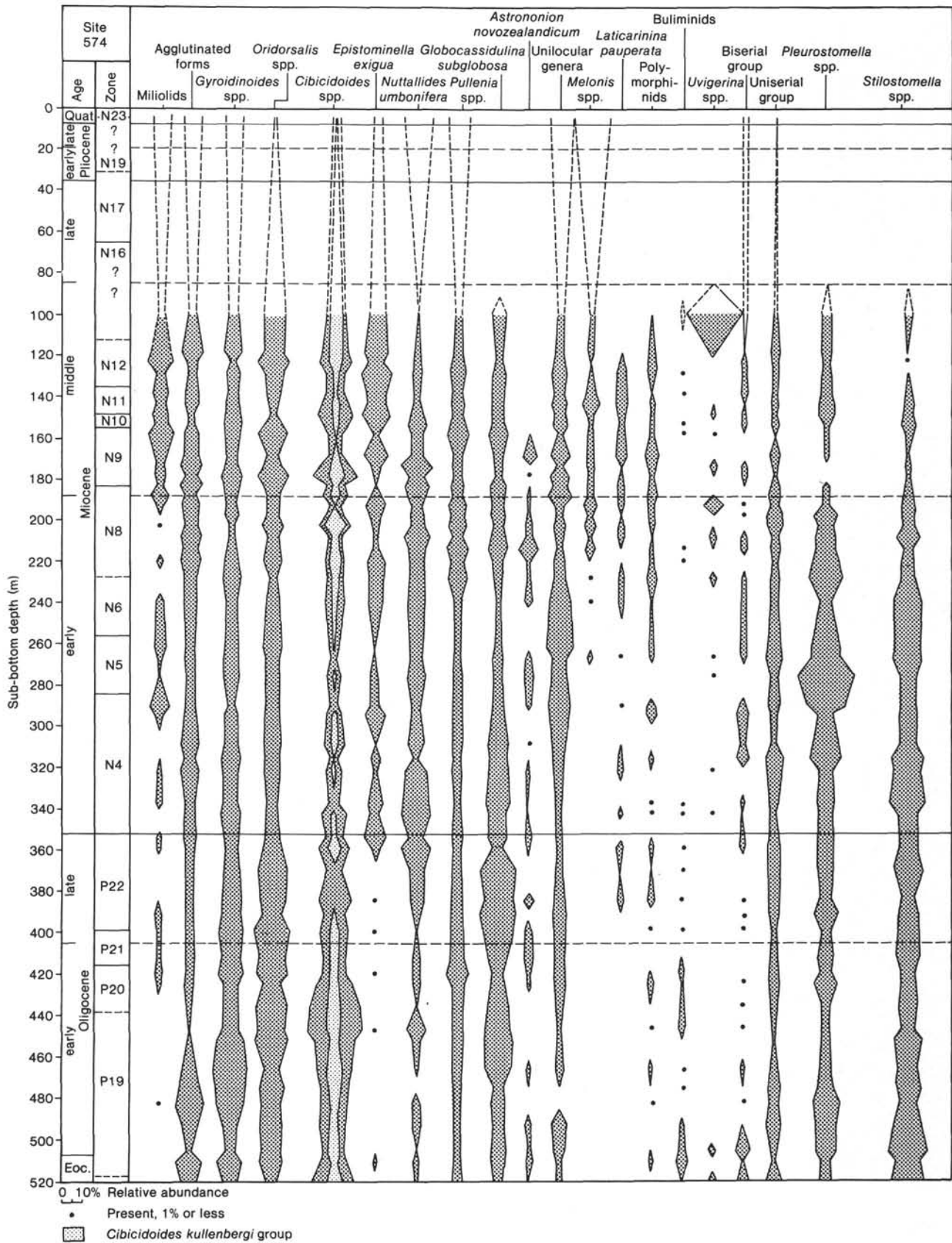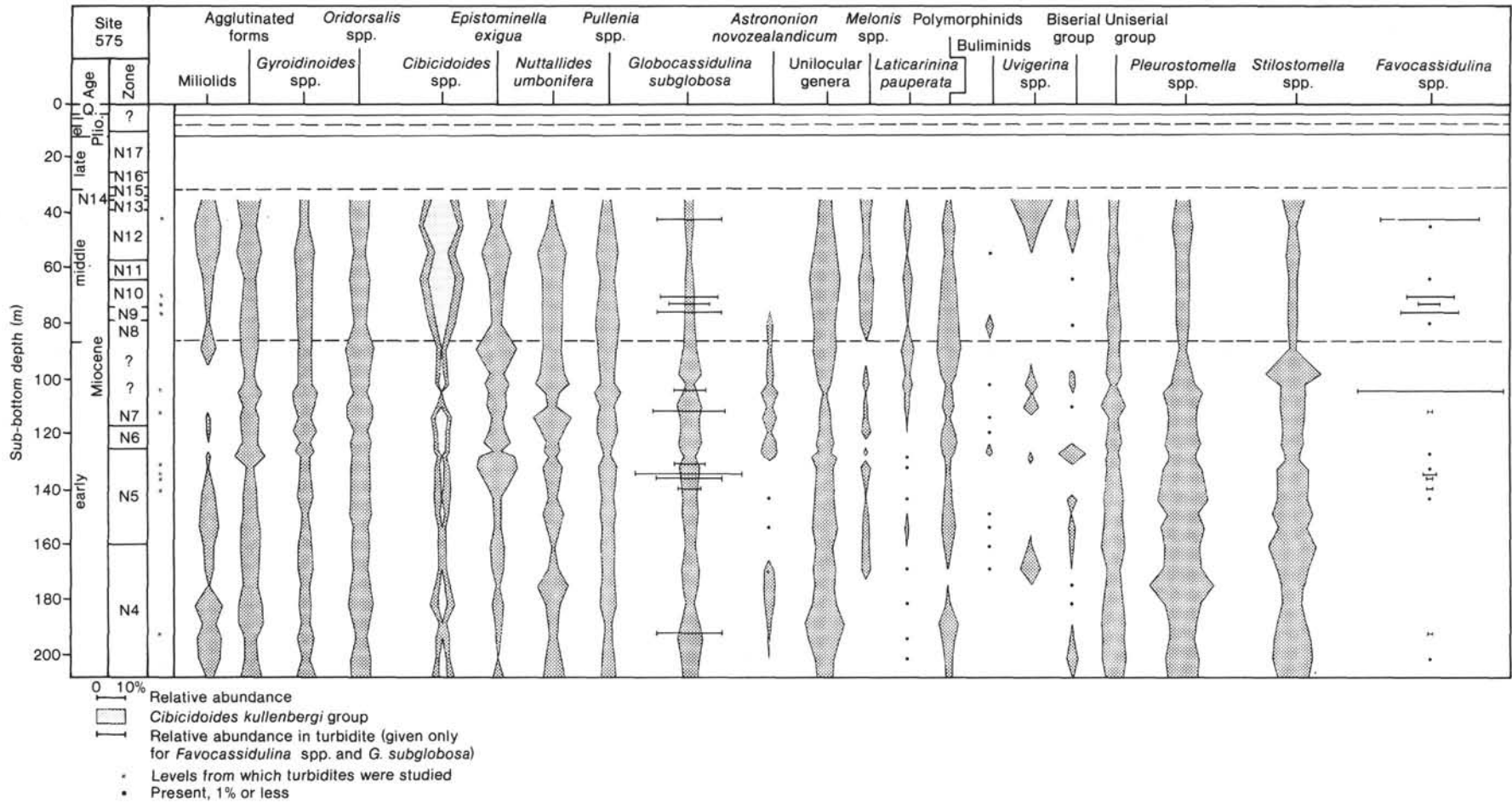
Figure 5. Relative abundances of selected species and species groups plotted versus sub-bottom depth, Site 575. Biserial group consists of *Bolivina* spp., *Fursenkoina* spp., and *Francesita advena*. Buliminids consist of *Bulimina* spp. and *Buliminella* spp. Uniserial group consists of uniserial lagenids.

Diversity

At all sites the benthic foraminiferal faunas are similar and highly diverse, as expected for deep-sea faunas (e.g., Douglas and Woodruff, 1981). Generally, between 50 and 70 taxa are recognized in a sample if about 200 specimens are counted. Usually the single most common species makes up less than 15% of the total fauna. The average number of species is 58.0 (±6.1) at Site 573, 58.8 (±6.7) at Site 574, and 63.4 (±5.5) at Site 575. These numbers are not significantly different.

The number of species does not show a clear trend if plotted against sub-bottom depth (Fig. 10) or time (Fig. 11). The diversity does not markedly decrease in more indurated sediments (Fig. 10). On the contrary, the youngest samples (573-1,CC and 574-1,CC) have relatively low diversities. The data from Site 573 (Fig. 11) suggest that the diversity might decrease overall from about 6 Ma to present. The data, however, show considerable fluctuation, and this recent decrease in diversity is not unequivocal.

It is improbable that the fluctuations in the number of species are caused completely by the slight differences in the number of specimens counted per sample. Figure 12 shows that there is no significant correlation between the number of species and the number of specimens in each sample if more than 200 specimens are counted. Of course, counting more specimens gives more species, but only very few additional species are found for many extra specimens counted over 200 (Fig. 2).

Samples with a low diversity (less than 50 species found) are 574-11,CC, 574-18,CC, 574C-9,CC, 574C-28,CC, 573B-3,CC, 573B-16,CC, and 573B-29,CC. These samples have little in common. Sample 574-9,CC contains abundant *Pleurostomella* spp. (27.1%), and Sample 573B-16,CC has abundant *Nuttallides umbonifera* (24.5%). Both samples have similar ages (19 to 20 Ma). Sample 574-11,CC contains abundant *Uvigerina graciliformis* (28.6%), a species that is also common in Sample 575-4,CC (14.6%). These two samples are the first samples below the interval with severe dissolution. The other relatively less diverse samples do not have a low diversity because of the dominance of a single species, but many species that are rare in other samples are absent. Sample 573B-9,CC is just below a hiatus (Barron et al., this volume), and the sediments were apparently deposited at a slow sedimentation rate. This sample and Sample 574-28,CC show severe dissolution in planktonic foraminifers (see site chapters, this volume); in those samples the low diversity may be caused by dissolution. None of the samples with a relatively low diversity has an extraordinarily low CaCO₃ content.

Generally speaking, there does not seem to be any one single cause for relatively low diversity. Both dissolution and primary environmental effects appear to be causes.

Composition of the Fauna

Abundant Taxa

Several species and species groups are common throughout the interval studied at all sites. These include *Oridorsalis umbonatus*, *Gyroidinoides* spp., *Pullenia* spp., and unilocular genera. *Globocassidulina subglobosa* is common at all sites, most abundant in the Oligocene, and decreases in abundance irregularly throughout the Miocene. The species is not common at Site 573, but it is present in most samples above 573B-5,CC (at about Zone N16 and upsection) (Fig. 3).

Miliolids are common to (rarely) abundant, with a maximum relative abundance of 16.1% in 573-14,CC, but they are absent (except for single specimens in a few samples) at Site 573 below Sample 573B-12,CC (about 16.5 Ma, at the top of Zone N8). They are extremely rare at Site 574 from Sample 574-29,CC through 574C-4,CC (about 18 to 16.5 Ma, Zones N6 to N8) and below Sample 574C-25,CC (Zone P20). At Site 575 miliolids are all but absent from Sample 575A-1,CC through -10,CC (about 18 to 16 Ma, Zone N6 through the lower part of Zone N8). (All zonal assignments are from Barron et al., this volume.) In the interval between 16 and 18 Ma in which the miliolids are absent or extremely rare at all sites there is strong dissolution of planktonic foraminifers at all sites. Miliolids are reportedly less resistant to dissolution than hyaline species (Corliss and Honjo, 1981), and thus the first appearances of miliolids may be dependent on preservation rather than immigration or evolution.

Agglutinant taxa are rare to common, generally between 5 and 15% of the total fauna. They do not show major fluctuations in relative abundance (Figs. 3 to 5). The most common species are *Eggerella bradyi*, *Trochammina globigeriniformis*, *Textularia agglutinans*, and *Siphotextularia catenata*.

Both *Epistominella exigua* and *Nuttallides umbonifera* show strong fluctuations in relative abundances. *E. exigua* is present throughout the section, from upper Eocene to Recent. The species is extremely rare below Sample 573B-22,CC and 574C-19,CC (upper Oligocene, Zone P22). Higher in the section its maximum abundance is 16%. The increase in abundance of *E. exigua* in the late Oligocene may be related to the depth increase at the sites, since this species is mainly described from the deep ocean (although it has been found in shallow, brackish water by Boltovskoy et al., 1980).

N. umbonifera, with a maximum abundance of 25%, is fairly common to abundant throughout the section at Site 573, with strong fluctuations in relative abundance in the upper lower and upper Oligocene. The species is generally less abundant at Sites 574 and 575 (Fig. 6). At Site 574 *N. umbonifera* is rare in the lower Oligocene and upper Eocene. A modest peak in abundance occurs in Samples 573B-33,CC and -34,CC (10.6 and 9.4%, respectively) and in Sample 574C-27,CC (9.6%). These samples are approximately coeval (about 32 to 33 Ma). There is no evident correlation between the relative abundance of *N. umbonifera* and the paleodepths of the sites.

Pleurostomella spp. and *Stilostomella* spp. are common to abundant in the lower part of the section at all sites. Both taxa decrease in abundance from Sample 573B-10,CC upward, from 574-25,CC upward, and from 575-10,CC upward (14.8 to 15.8 Ma). *Pleurostomella* spp. is most abundant at Site 574 in the lower Miocene (Zone N5).
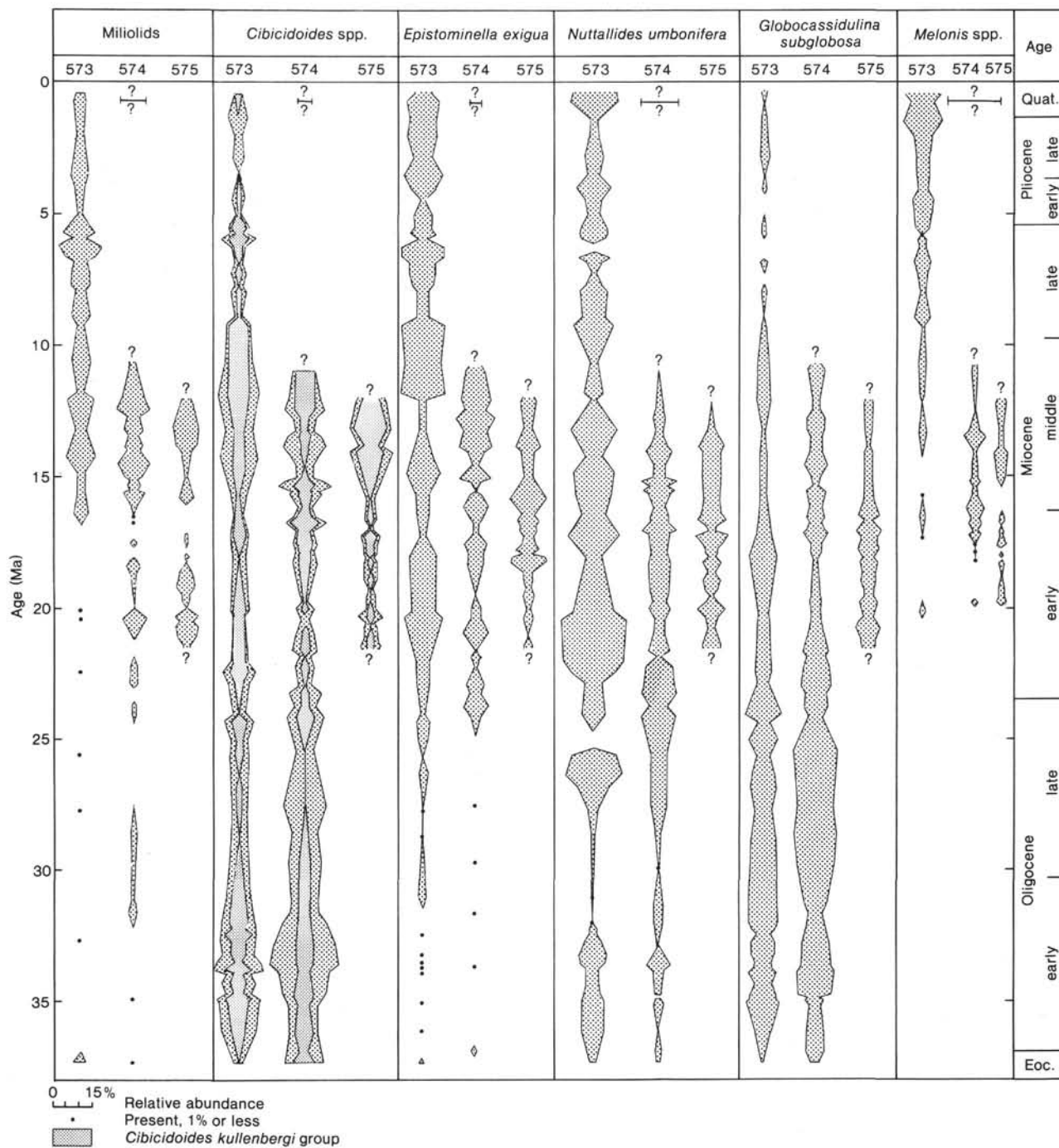
Figure 6. Relative abundances of selected species and species groups plotted versus time, Sites 573, 574, and 575. Data from Barron et al. (this volume) were used to construct the age model. Biserial group consists of *Bolivina* spp., *Fursenkoina* spp., *Stainforthia complanata*, and *Francesita advena*. Buliminids consist of *Bulimina* spp. and *Buliminella* spp.

The *Cibicidoides kullenbergi* group is present throughout the section at all sites. It decreases in abundance at Sites 573 and 574 in the upper Oligocene and increases again in the Miocene (Fig. 6). Other fluctuations in abundance of the *Cibicidoides* group cannot be correlated between the sites. The taxon is common to abundant at all sites, but it is the most abundant at Site 574 in the upper Oligocene (upper Zones P19 to P20).

Uvigerina spp., *Bolivina* spp., and *Bulimina* spp. are generally rare but common to abundant in a few sam-

ples. Abundant *Uvigerina graciliformis* occurs just below the level of strong dissolution at Sites 574 and 575; no other fluctuations in abundance of these taxa can be correlated between the sites.

Stratigraphic Ranges

The first appearances (FAs) and last appearances (LAs) of selected species at all sites are plotted versus time in Figure 7, and the timing of these events is given in Table 1. Data are given for all species with fairly continuous
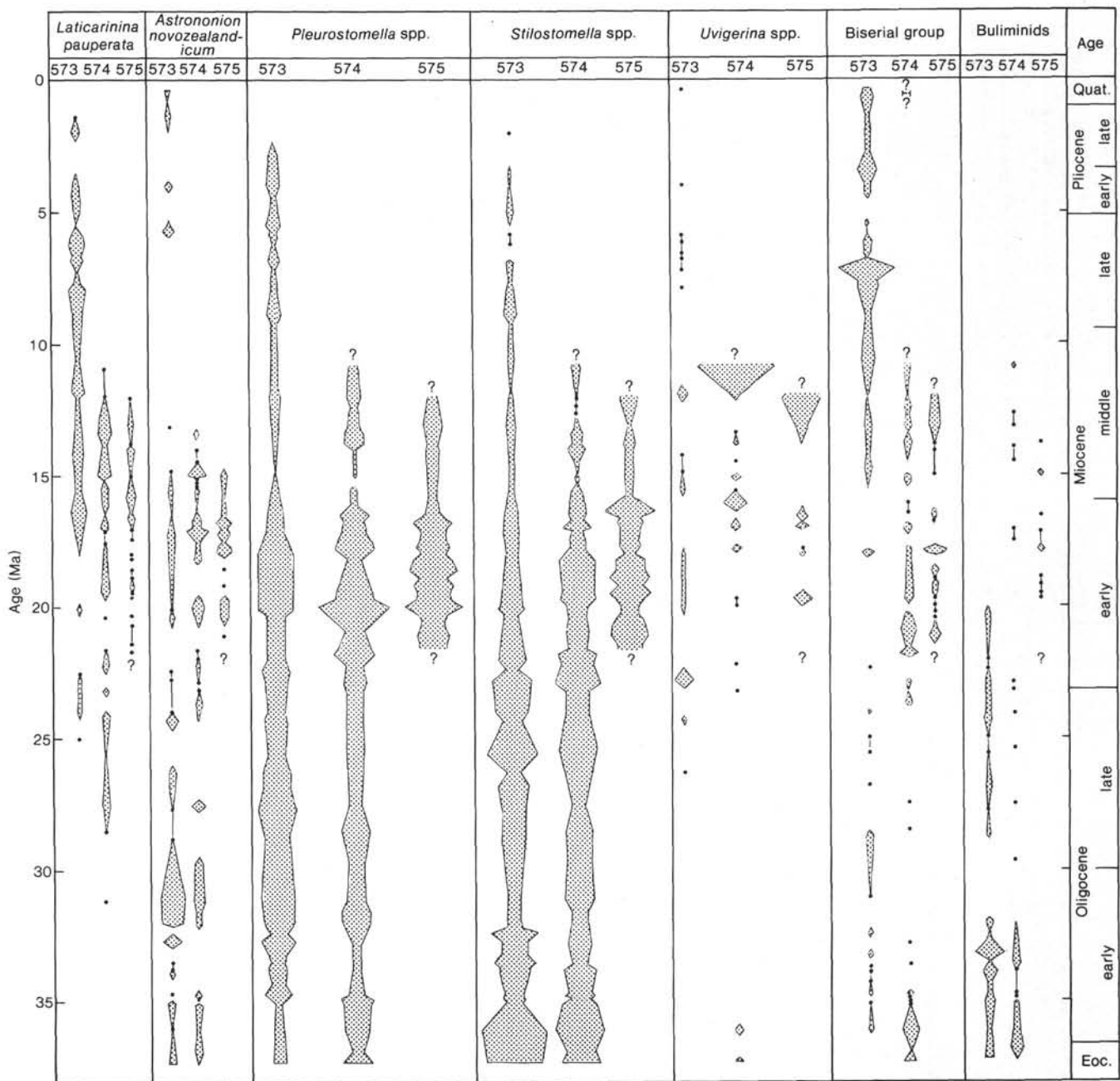
Figure 6. (Continued).

ranges of occurrence. Determining the FAs and LAs is problematic in deep-sea benthic foraminiferal faunas because many species that have FAs or LAs are rare and thus have discontinuous occurrences (Fig. 7, Appendix A). Chance may be the main determinant for the exact range of rare species.

FAs and LAs can be either evolutionary (evolution–extinction) or migratory (immigration–emigration). Migration can be either geographic migration or depth migration (or both). Evolution, extinction, and depth migration may be worldwide (although not necessarily synchronous), but study of sites in a small area cannot give information on geographic consistency of datum levels. It is not clear which of the observed FAs and LAs are local and which ones (if any) are useful for correla-

tion over a larger area. Clustering of events (FAs and LAs) at specific levels, however, suggests that major changes in the environment of the deep sea occurred at those times, either on a local or more widespread scale.

Many species do not have similar occurrences at the three sites, and thus their FAs or LAs are not consistent even within a relatively small area in the equatorial Pacific. Some species have a continuous occurrence at one of the sites and are rare or absent at the other sites (e.g., *Bulimina microcostata* occurs at Site 573 only, and *Cibicidoides* aff. *mundulus* is common at Site 574 but extremely rare at Site 573). Probably some differences in LAs and FAs from one site to another are caused by uncertainties in biostratigraphic correlation, but there is no consistent offset in ages between the sites. Some of the
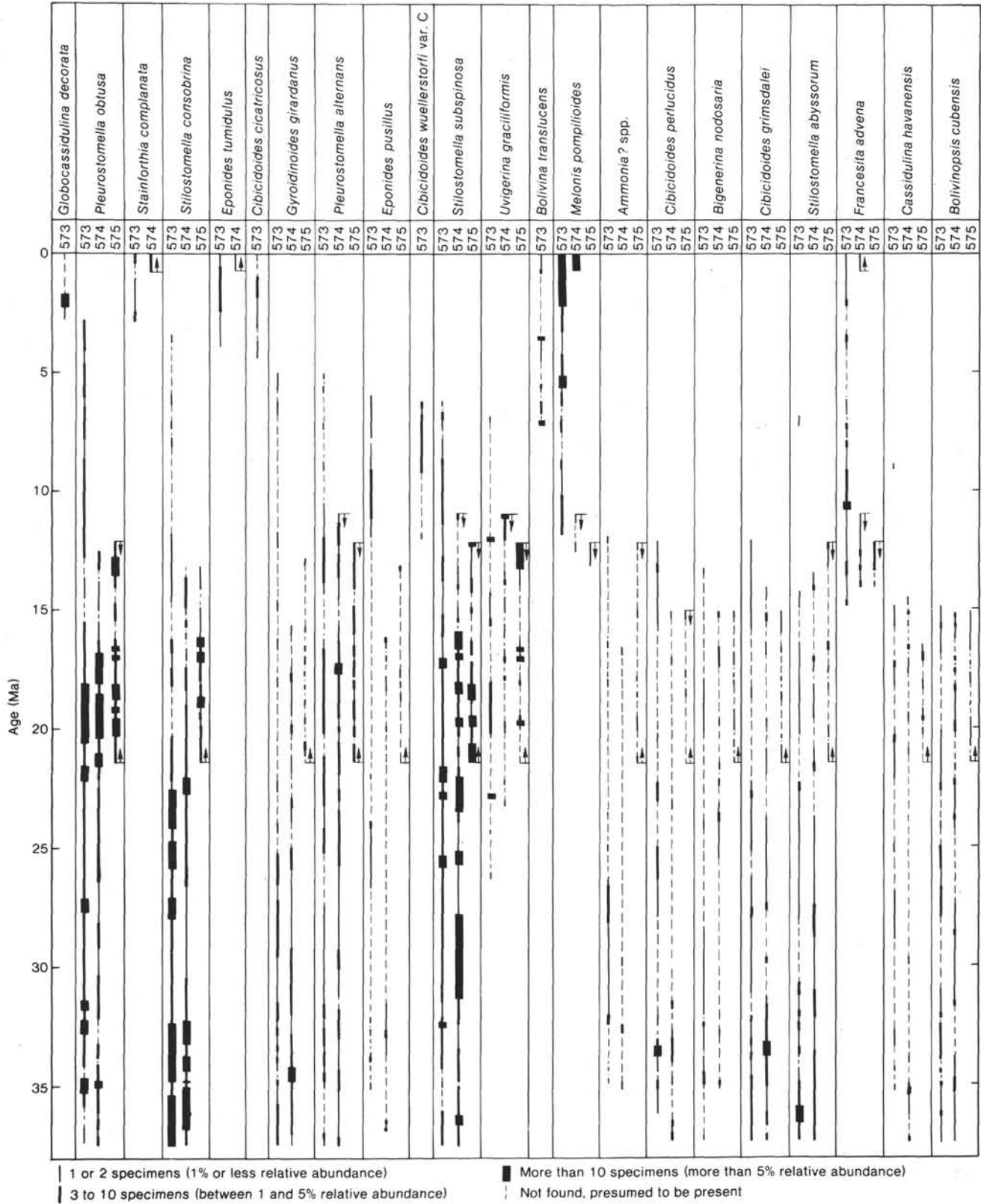
Figure 7. Stratigraphic ranges of some species tabulated in Table 1. Plotted versus time, Sites 573, 574, and 575. Age model derived from data in Barron et al. (this volume).
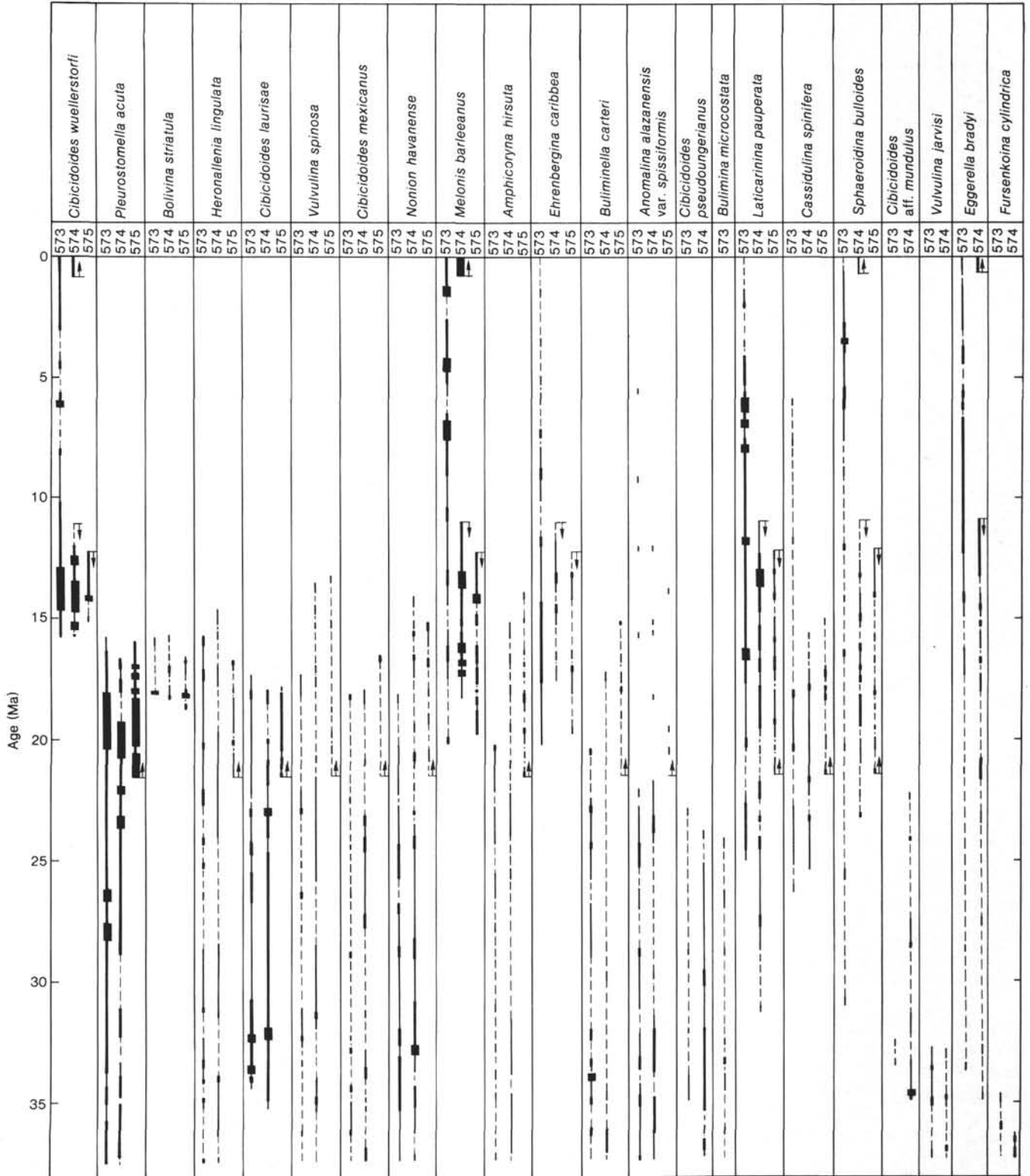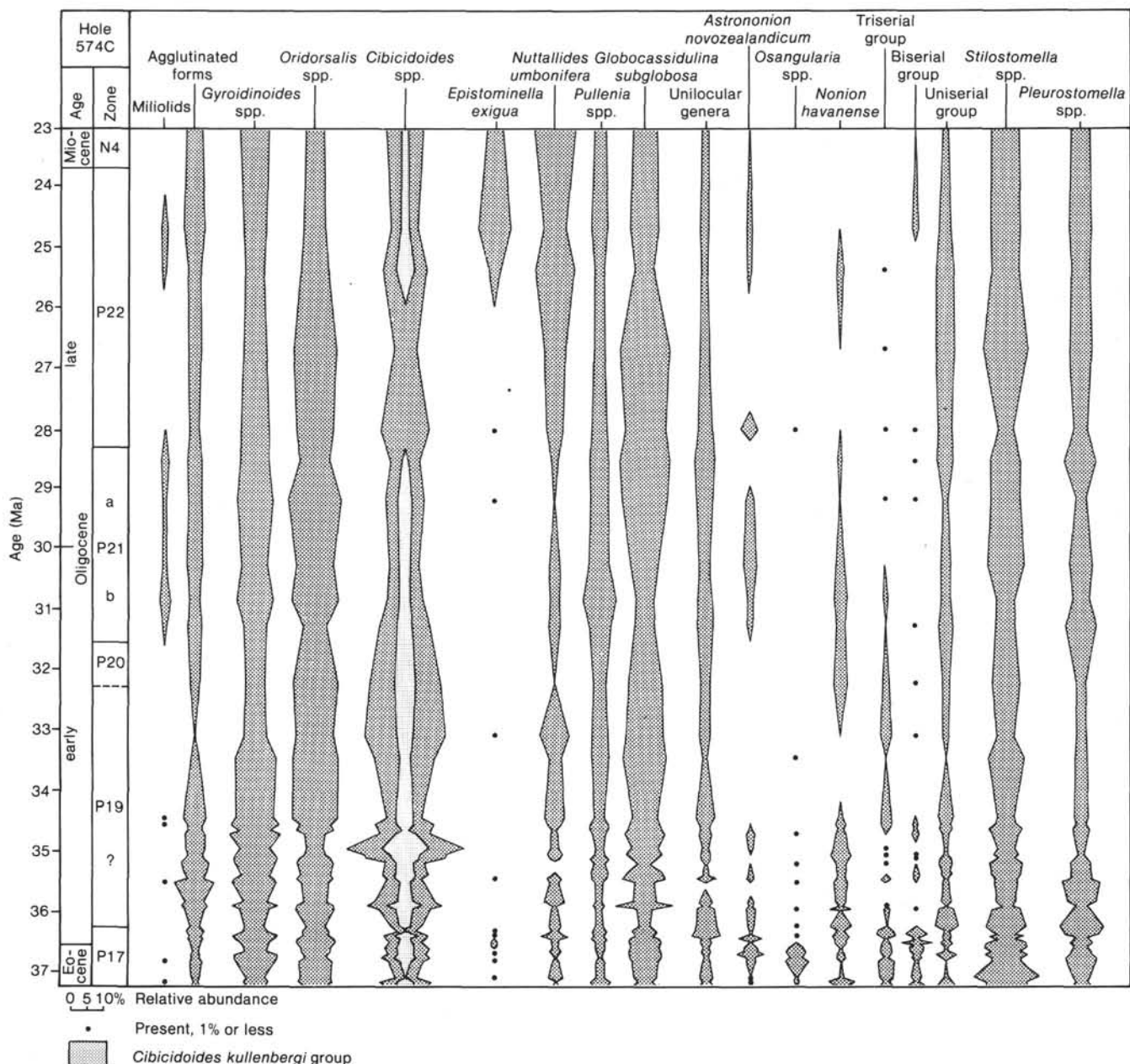
Figure 7. (Continued).

Figure 8. Relative abundances of selected species and species groups in the upper Eocene and Oligocene (Hole 574C), plotted versus time. Biserial group consists of *Bolivina* spp. and *Fursenkoina* spp. Triserial group consists of *Bulimina* spp., *Buliminella* spp., and *Uvigerina* spp. Uniserial group consists of uniserial lagenids.

LAs are apparently caused by local processes, because they appear to be related to dissolution. Several species (e.g., *Stilostomella lepidula* and *Pleurostomella obtusa*) disappear below the interval showing strong dissolution at Sites 574 and 575 but extend into much younger sediments at Site 573, where dissolution is less severe (Fig. 7). Possibly the disappearance of these species at Sites 574 and 575 was caused by the same changes in the environment that later caused strong dissolution and not by differential dissolution, as is shown by the species not appearing to be solution-prone in samples lower in the section.

Although there is no evident correlation between diversity and time or sub-bottom depth (as described above),

the total number of species decreases with time. At all sites there are more LAs than FAs (32 LAs versus 19 FAs at Site 573, 29 LAs versus 15 FAs at Site 574, and 16 LAs versus 6 FAs at Site 575); thus, there is a net loss of species. Since more than 200 taxa were recognized, the number of species per sample may appear to remain constant even when the total number of species declines.

Stratigraphic Events

Late Eocene to Oligocene

At Site 574 datum levels (FAs and LAs) cluster between 32 and 37 Ma (Figs. 8 and 13). At Site 573 few data are available for this period, because there is a fora-
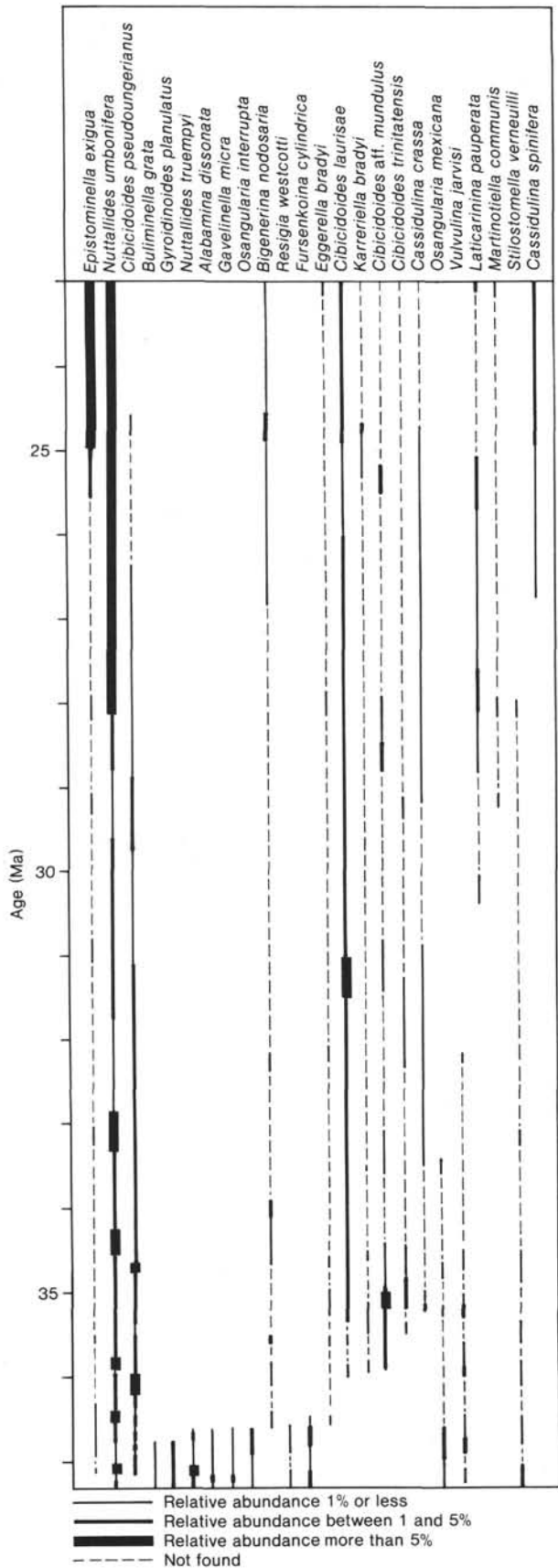
Figure 9. Stratigraphic ranges of selected species in the upper Eocene–Oligocene (Hole 574C). See also Table 1.
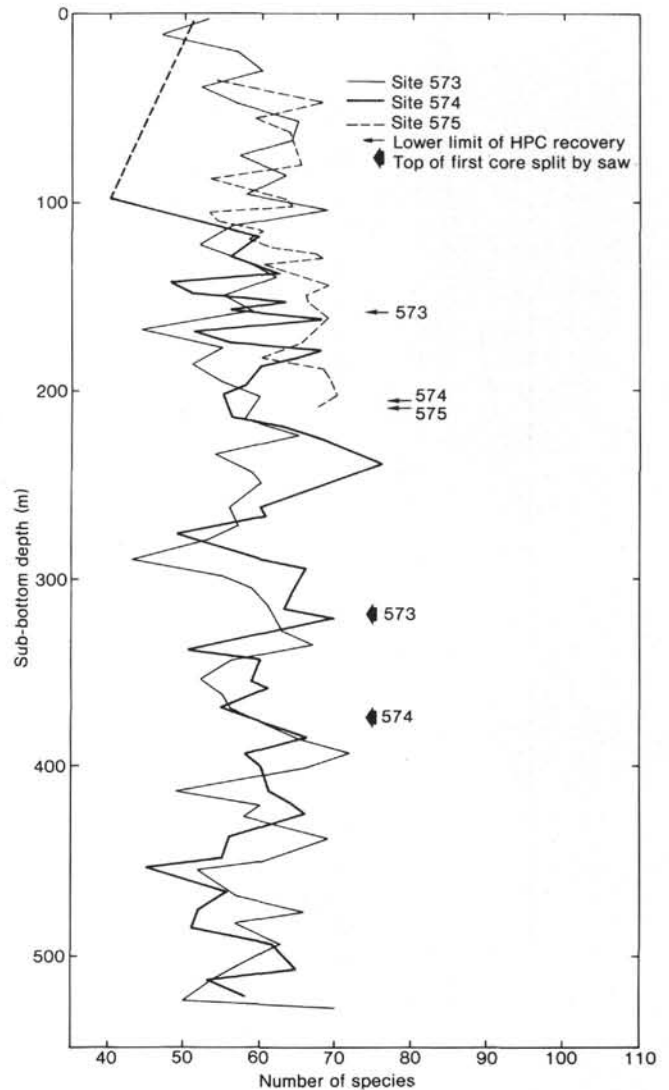

Figure 10. Diversity (number of species) plotted versus sub-bottom depth for Sites 573, 574, and 575.

minifer-barren interval spanning the Eocene/Oligocene boundary (see site chapter, this volume). Relative abundances of the most common taxa are shown in Figure 8 and stratigraphic ranges of selected species in Figure 9.

The most common taxa in Eocene and Oligocene are *Globocassidulina subglobosa* and *Oridorsalis umbonatus*, both present throughout this period. Other common taxa are the *Cibicidoides kullenbergi* group (see Appendix B for taxonomy), *C. pseudoungerianus, C. grimsdalei, Anomalina spissiformis, Nonion havanense, Pullenia* spp., *Gyroidinoides* spp., *Pleurostomella* spp., and *Stilostomella* sp. *Epistominella exigua* is rare below Sample 574C-18,CC but present throughout the interval. *Nuttallides umbonifera* is likewise found throughout the interval but is most common (relative abundance 6 to 14%) above Sample 574C-19,CC. Below this level its relative abundance is generally less than 6%, except in Samples 574C-27,CC (9.6%), 574C-32-1, 102–104 cm (6.6%), and 574C-33-4, 39–41 cm (9.5%). *Uvigerina senticosa, Bulimina alazanensis*, and *Fursenkoina cylindrica* (tri-
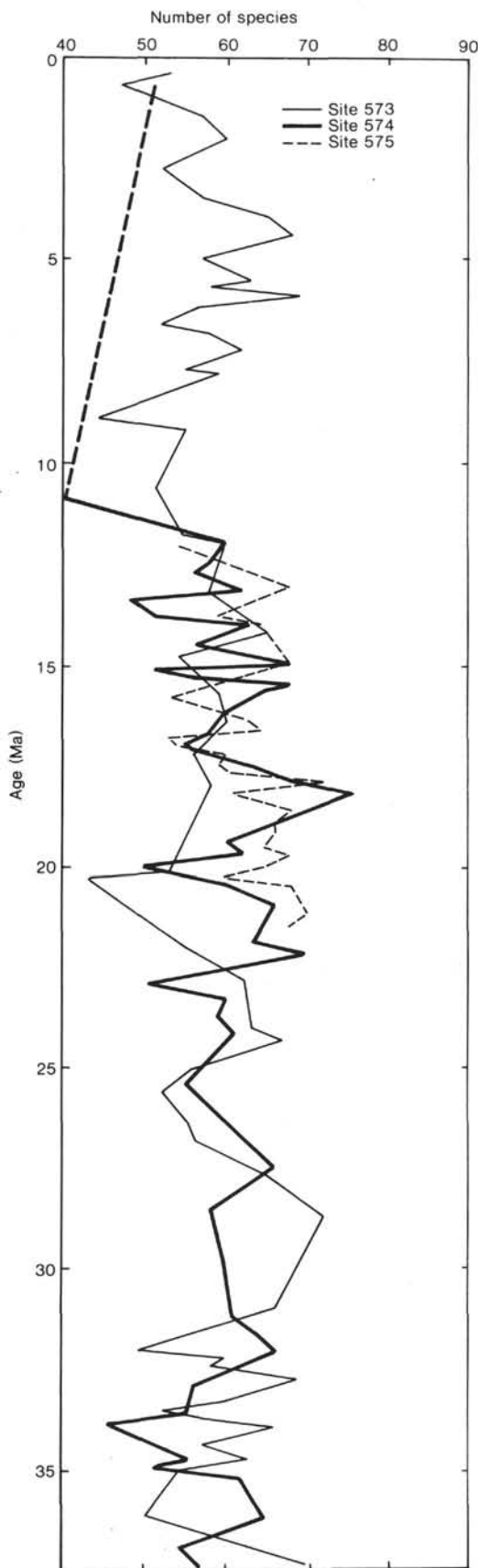
667

Number of species

Figure 11. Diversity (number of species) plotted versus time for Sites 573, 574, and 575.

serial group and biserial group in Fig. 8) are relatively common (1 to 5%) below Sample 574C-33-5, 26–28 cm.

From the upper Eocene through Oligocene in Hole 574C, 168 taxa were recognized. Of these, 85 range throughout the interval; all the most common taxa are among these 85. In total, 60 taxa are too rare to establish a range, and 11 taxa have a LA. *Nuttallides truempyi* has its LA in Sample 574C-33-4, 141–143 cm and does not occur from Sample 574C-33-4, 90–92 cm upward. The LA of this species is generally considered to be a reliable marker for the Eocene/Oligocene boundary (Tjalsma and Lohmann, 1983; Miller, 1983; Snyder et al., 1984). The relative abundance of *N. truempyi* is less than 8% in all samples. Seven other species have LAs relatively close to the LA of *N. truempyi*, i.e., between about 35 and 37 Ma: *Buliminella grata, Gyroidinoides planulatus, Alabamina dissonata, Gavelinella micra, Osangularia interrupta, Resigia westcotti*, and *Fursenkoina cylindrica*. *Osangularia mexicana* has its LA in Sample 574C-20,CC, *Stilostomella verneuilli* in Sample 574C-20,CC and *Cibicidoides pseudoungerianus* in Sample 574C-17,CC. All of these species, except *C. pseudoungerianus*, are rare (less than 6% relative abundance, but usually less than 1 to 3%). The two *Osangularia* species together have a maximum abundance of 9.5% (in Sample 574C-34,CC). Most of the LAs are of local significance only, given that the species occur in the Oligocene elsewhere (Douglas, 1973; Corliss, 1981). *Gyroidinoides planulatus* extends into the Oligocene at Site 573 (Appendix A). At Site 574 the clustering of FAs and LAs between 32 and 37 Ma might have been influenced by a relatively rapid water-depth increase during this period when the site was close to the ridge. The extinction of *N. truempyi* and *Resigia* spp., however, represents the extinction of endemic abyssal taxa that were important constituents of the earlier Eocene abyssal faunas in the Atlantic Ocean (Tjalsma and Lohmann, 1983; Miller, 1983).

Several species have a FA in the period between 35 and 37 Ma: *Bigenerina nodosaria, Eggerella bradyi, Cibicidoides laurisae, C.* aff. *mundulus, Karreriella bradyi,* and *Cassidulina crassa. Cibicidoides laurisae* and *C.* aff. *mundulus* are the only species in this group that attain relative abundances of greater than 5% in some samples.

The high-diversity, low-dominance fauna at Site 574 resembles the coeval deep-water faunas described by Tjalsma and Lohmann (1983) from the Caribbean and south Atlantic and by Miller (1983) and Miller et al. (in press) from the Bay of Biscay. This fauna was called the *Globocassidulina subglobosa–Gyroidinoides* spp.–*Oridorsalis* spp. fauna by these authors. In the Atlantic this assemblage replaced the middle Eocene *N. truempyi* fauna near the end of the middle Eocene. The transition was not found at Site 574 because no middle Eocene sediments were recovered.

At Site 574 *N. umbonifera* is not as abundant as in the Oligocene in the Bay of Biscay (as much as 25% relative abundance; Miller, 1983). The species is present throughout the section, but it has only modest peaks in abundance (9.5%) in Sample 574C-27,CC (Zone P19)
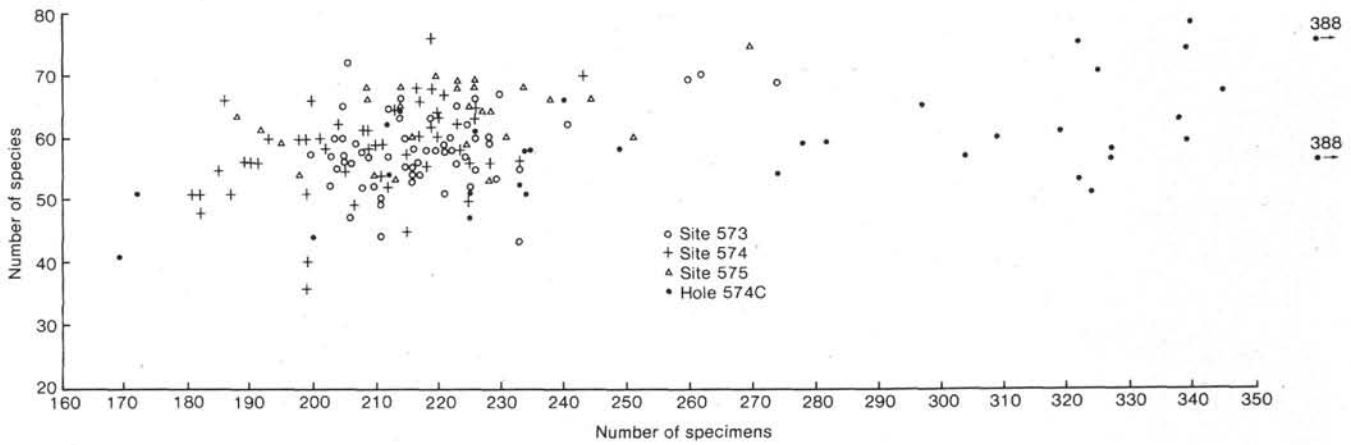
Figure 12. Scatter diagram of the number of species versus the number of specimens for all samples (Sites 573, 574, and 575). Data are included from the additional samples used in the detailed study of the Eocene/Oligocene boundary in Hole 574C.

Table 1. Timing of first and last appearance datums.

|	Event	Sample, Site 573	Approximate age (Ma)	Sample, Site 574	Approximate age (Ma)	Sample, Site 575	Approximate age (Ma)	Age range (Ma)
FAD	Globocassidulina decorata	573-5,CC	2.8					
LAD	Pleurostomella obtusa	573-5,CC	2.8	574-14,CC	12.5			2.8–12.5
FAD	Stainforthia complanata	573-5,CC	2.8					
LAD	Stilostomella consobrina	573-6,CC	3.5	574-17,CC	13.2	575-5,CC	13.1	3.5–13.2
FAD	Eponides tumidulus	573-7,CC	3.9					
FAD	Cibicidoides cicatricosus	573-8,CC	4.4					
LAD	Gyroidinoides girardanus	573-9,CC	5.0	574-27,CC	15.6	575-6,CC	13.8	5.0–13.7
LAD	Pleurostomella alternans	573-9,CC	5.0					
LAD	Eponides pusillus	573-12,CC	5.9	574-28,CC	16.1	575-5,CC	13.1	5.9–16.1
LAD	Cibicidoides wuellerstorfi, var. C	573-13,CC	6.2					
LAD	Stilostomella subspinosa	573-13,CC	6.2					
LAD	Uvigerina graciliformis	573-15,CC	6.8					
FAD	Bolivina translucens	573-16,CC	7.2					
FAD	Melonis barleeanus	573B-6,CC	11.8	574-14,CC	12.5	575-5,CC	13.1	11.8–13.1
LAD	Cibicidoides perlucidus	573B-7,CC	12.0	574-23,CC	15.0	575-9,CC	15.0	12.0–15.0
FAD	Cibicidoides wuellerstorfi, var. C	573B-7,CC	12.0					
LAD	Bigenerina nodosaria	573B-8,CC	13.2	574-23,CC	15.0	575-9,CC	15.0	13.2–15.0
LAD	Cibicidoides grimsdalei	573B-9,CC	14.2	574-20,CC	14.0	575-9,CC	15.0	14.0–15.0
LAD	Stilostomella abyssorum	573B-9,CC	14.2	574-18,CC	13.4			12.1–14.2
FAD	Francesita advena	573B-10,CC	14.8	574-20,CC	14.0	575-7,CC	14.0	14.0–14.8
LAD	Cassidulina havanensis	573B-10,CC	14.8	574-21,CC	14.5	575A-1,CC	16.4	14.5–16.4
LAD	Bolivinopsis cubensis	573B-10,CC	14.8	574-24,CC	15.1	575-9,CC	15.0	14.8–15.1
FAD	Cibicidoides wuellerstorfi	573B-11,CC	15.6	574-18,CC	15.6	575-9,CC	15.0	15.0–15.6
LAD	Pleurostomella acuta	573B-11,CC	15.6	574-29,CC	16.5	575-10,CC	15.8	15.6–16.5
LAD	Bolivina striatula	573B-11,CC	15.6	574-26,CC	15.5	575A-1,CC	16.4	15.5–16.4
LAD	Heronallenia lingulata	573B-11,CC	15.6	574-21,CC	14.5	575A-2,CC	16.6	14.5–16.6
LAD	Cibicidoides laurisae	573B-13,CC	17.2	574C-4,CC	17.8	575A-7,CC	17.7	17.2–17.8
LAD	Vulvulina spinosa	573B-13,CC	17.2	574-18,CC	13.4	575-5,CC	13.1	13.1–17.2
LAD	Cibicidoides mexicanus	573B-14,CC	18.0	574C-4,CC	17.8			16.4–18.0
LAD	Nonion havanense	573B-14,CC	18.0	574-20,CC	14.0	575-9,CC	15.0	14.0–18.0
FAD	Bolivina striatula	573B-14,CC	18.0	574C-5,CC	18.2	575A-13,CC	18.6	18.0–18.6
FAD	Melonis barleeanus	573B-15,CC	20.1	574C-5,CC	18.2	575A-21,CC	19.7	18.2–20.1
LAD	Amphicoryna hirsuta	573B-15,CC	20.1	574-26,CC	15.5	575-6,CC	13.8	13.8–20.1
FAD	Ehrenbergina caribbea	573B-15,CC	20.1	574C-3,CC	17.5	575A-21,CC	19.7	17.5–20.1
LAD	Buliminella carteri	573B-16,CC	20.3					
LAD	Anomalina alazanensis, var. spissiformis	573B-17,CC	22.0	574C-12,CC	21.6			21.6–22.0
LAD	Cibicidoides pseudoungerianus			574C-17,CC	23.7			
LAD	Bulimina microcostata	573B-20,CC	24.0					
FAD	Laticarinina pauperata	573B-22,CC	25.0	574C-23,CC	31.2			25.0–31.2
FAD	Cassidulina spinifera	573B-24,CC	26.3	574C-19,CC	25.4			25.4–26.3
FAD	Uvigerina graciliformis	573B-24,CC	26.3	574C-16,CC	23.2			23.2–26.3
FAD	Sphaeroidina bulloides			574C-16,CC	23.2			
LAD	Cibicidoides aff. mundulus			574C-14,CC	22.2			
LAD	Vulvulina jarvisi	573B-34,CC	32.7	574C-26,CC	32.8			32.7–32.8
FAD	Cibicidoides aff. mundulus			574C-32-1, 102–104 cm	34.9			
FAD	Cibicidoides laurisae	573B-37,CC	34.3	574C-32,CC	35.1			34.3–35.1
LAD	Fursenkoina cylindrica			574C-33-3, 113–115 cm	36.3			
FAD	Cibicidoides pseudoungerianus	573B-39,CC	34.9	574C-35-1, 126–128 cm	37.2			
FAD	Ammonia? sp.	573B-39,CC	34.9	574C-35-2, 99–100 cm	37.3			34.9–37.3
FAD	Eponides pusillus	573B-40,CC	35.0	574C-35-1, 97–98 cm	37.2			35.0–37.2
LAD	Buliminella grata	573B-42-4, 140–144 cm	36.6	574C-34-1, 138–140 cm	36.8			
LAD	Nuttallides truempyi	573B-42-4, 140–144 cm	36.6	574C-33-5, 141–143 cm	36.6			
LAD	Resigia westcotti			574C-33-4, 139–140 cm	36.5			
LAD	Gavelinella micra			574C-33-4, 139–140 cm	36.5			
LAD	Alabamina dissonata	573B-42-4, 140–144 cm	36.6	574C-33-5, 90–92 cm	36.6			
LAD	Osangularia mexicana	573B-42-4, 140–144 cm	36.6	574C-28,CC	33.8			
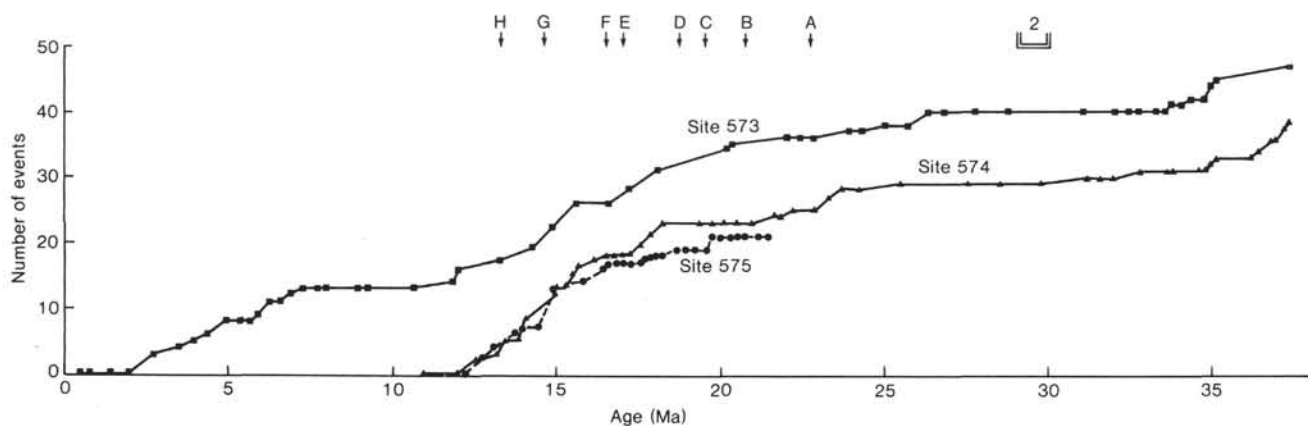
Figure 13. Cumulative plot of first and last appearances at Sites 573, 574, and 575. The letters A through H indicate events in the isotopic and CaCO₃ records of Sites 573 to 575 described by Vincent and Killingley (this volume). An interval of relatively heavy $\delta^{13}C$ occurs between 22.7 and 20.7 Ma (events A and B); a warming trend begins at 19.5 Ma (event C); more severe dissolution and a lower CaCO₃ content begin at 18.7 Ma (event D); a shift to heavier $\delta^{13}C$ values is centered at 17 Ma (event E); the peak of a warming trend (i.e., the lightest $\delta^{18}O$ value) is at 16.5 Ma (event F); a shift toward heavier $\delta^{18}O$ values is centered at 14.6 Ma (event G); strong dissolution begins at 13.3 Ma (event H). Events 1 and 2 are shifts in oxygen isotopic values described by Miller and Thomas (this volume); 1 is shift to heavy values of $\delta^{18}O$, and 2 indicates period of enrichment in $\delta^{18}O$.

and just above the LA of *N. truempyi* (Zone P17). *Stilostomella* spp. and *Pleurostomella* spp. are more abundant at Site 574 than in the Bay of Biscay.

The fauna at Site 574 also resemble the fauna described by Corliss (1981) from DSDP Site 277 (southwest Pacific). A notable difference is the abundance of *N. umbonifera*, which at Site 277 has a peak in abundance (25 to 30%) at about the same level as a shift in oxygen isotopic ratios. The modest peak in abundance of this species at Site 574 is just below the shift in oxygen isotopic ratios (Miller and Thomas, this volume).

Coeval faunas described by Tjalsma (1983) from DSDP Site 516 in the south Atlantic (paleodepth less than 1700 m) resemble the Site 574 faunas in that they contain abundant *Cibicidoides* spp. and *Oridorsalis umbonatus* and common *Pullenia* spp. and *Gyroidinoides* spp. *Bulimina* spp. and *Uvigerina* spp., however, are much more common at Site 516, whereas *Pleurostomella* spp. and *Stilostomella* spp. are more abundant at Site 574.

Generally, the observations at Site 574 agree well with Corliss (1981), Miller (1983), Clark and Wright (1984), Snyder et al. (1984), Miller et al. (in press), and Wood et al. (in press) in that no major changes occurred at the Eocene/Oligocene boundary in the dominant species of benthic foraminifers, although some relatively rare species have FAs or LAs close to the boundary.

The dominant species do not show large variations in relative abundance between 32 and 37 Ma. There were, however, considerable shifts in oxygen and carbon isotopic ratios (Miller and Thomas, this volume): 0.9 and 0.6‰, respectively, between Samples 574C-33-1, 113–115 cm and 574C-33-3, 113–115 cm, which corresponds to a period of about 0.4 m.y. (Fig. 13, event 1). There was no change in composition of the benthic fauna in the late Oligocene (29 to 30 Ma), which is the time of another shift toward heavier oxygen isotopic ratios (Keigwin and Keller, 1984; Miller and Thomas, this volume). This suggests that the fauna had wide environmental tolerances, which is also indicated by the dominant species being long ranging and cosmopolitan and occurring over

a large depth range in the present-day oceans. The tolerant character of the fauna is also shown by the lack of change in the dominant species while the water depth increased by more than 1000 m.

Some of the fluctuations in relative abundance may be the effect of differential dissolution. According to Corliss and Honjo (1981), *Gyroidinoides* spp. is more solution resistant than *C. kullenbergi, O. umbonatus*, and *N. umbonifera*, which are about equally resistant. *Globocassidulina subglobosa* is also resistant (Woodruff and Douglas, 1981). However, dissolution effects probably do not completely obscure the faunal compositional fluctuations. The abundance of *Gyroidinoides* spp., a resistant group, is similar to the abundance of this taxon in the Bay of Biscay (Miller, 1983). Furthermore, the less resistant *Cibicidoides* spp. are abundant throughout the lower Oligocene, where dissolution of planktonic foraminifers is usually severe (Saito, this volume). *Stilostomella* spp., described as "least preservable" by Woodruff and Douglas (1981), is common in all samples.

Early to Middle Miocene

Many FAs and LAs cluster in the upper lower to middle Miocene. The exact limits of this period of change in the benthic faunal composition are not easy to locate. At Site 573 the upper limit is at about 13 Ma, the lower limit between 18.0 and 20.1 Ma (no data are available between these data points). The lower limit is at about 18.2 Ma at Site 574, where the precise position of the upper limit cannot be determined because of strong dissolution in the upper part of the section. At Site 575 the upper limit cannot be determined because of strong dissolution, and the position of the lower limit is not clear. The changes appear to start more gradually here than at Site 574, between 20.5 and 18.5 Ma (Fig. 13). When the data for the three sites are combined, it appears that the majority of the FAs and LAs occur between 13 and 18.5 Ma. The event rates, that is, the number of FAs and LAs per time unit, are comparable at the three sites at about 4 events/m.y.

Since many FAs and LAs occur in the period between about 13 and 18.5 Ma, faunas from before and after that period are easily distinguished (Fig.6 and Table 1), although many abundant and common species have ranges extending from Eocene to Recent. "Modern" species, that is, species that have FAs between about 13 and 18.5 Ma, include *Cibicidoides wuellerstorfi* (FA at 15.0 to 15.6 Ma), *Francesita advena* (FA at 14.0 to 14.8 Ma), and *Melonis pompilioides* (FA at 11.8 to 13.1 Ma). A less common "modern" species is *Ehrenbergina caribbea* (FA at 17.5 to 20.1 Ma). *M. barleeanus* (FA at 18.2 to 20.1 Ma), *Sphaeroidina bulloides* (FA at about 23 Ma), and *Laticarinina pauperata* (FA at 25.0 to 31.2 Ma) might be included in the "modern" group, but have earlier FAs.

"Old" species that have their LAs in the early to middle Miocene include *Cibicidoides grimsdalei* (LA at 14.0 to 15.0 Ma), *C. mexicanus* (LA at 16.4 to 18.0 Ma), *C. perlucidus* (LA at 12.0 to 15.0 Ma), *Vulvulina spinosa* (LA at 13.1 to 17.2 Ma), *Nonion havanense* (LA at 14.0 to 18.0 Ma), *Bolivinopsis cubensis* (LA at 14.8 to 15.1 Ma), and *Pleurostomella acuta* (LA at 15.6 to 16.5 Ma). The LAs are not all precise, since the "old" species decline in abundance and become very rare before they finally disappear. *Anomalina spissiformis* is extremely rare in the interval younger than 21.6 to 22.0 Ma; the rare occurrences higher in the section might be due to reworking. Typically, *Pleurostomella* spp. and *Stilostomella* spp. are much more common in the "old" than in the "modern" fauna at these Pacific sites (Fig. 6, decrease in abundance at about 16.5 Ma). *Bolivina striatula* is found only in the interval of maximum change in benthic faunal composition (FA at 18.0 to 18.6 Ma; LA at 15.5 to 16.4 Ma).

From the range of ages found for the first and last appearances, it is evident that detailed benthic foraminiferal biostratigraphy using the present data set is not possible within the interval between 13 and 18.5 Ma. The detailed sequence of FAs and LAs is somewhat different at all sites (Table 1 and Fig. 7) (see also Barron et al., this volume). Detailed patterns in the relative abundances can generally not be correlated between the sites because the time resolution as given by the sampling interval is not precise enough. The fauna at the three sites is similar, but many details are different, such as the fluctuations in the abundance of *Epistominella exigua* and *Nuttallides umbonifera* and some fluctuations in the abundance of *Pleurostomella* spp. (Fig. 6). Therefore, fluctuations in abundance observed at one site must be interpreted with care and cannot be seen as results of general changes in bottom-water circulation.

It must also be emphasized that the total relative abundance of specimens belonging to species that have FAs and LAs is generally between 20 and 40% of the total fauna and that between 60 and 80% of all specimens in the fauna belong to long-ranging species. Thus, Boltovskoy (e.g., 1980a,b) was able to conclude that the benthic deep-sea fauna has a stable character and shows hardly any changes since the late Eocene. Woodruff and Douglas (1981) and Woodruff (in press), on the other hand, emphasize the less abundant taxa and conclude

that a major faunal turnover in benthic faunas occurred in the middle Miocene. The "turnover" is definitely observed at Sites 573 to 575, but it affects less than half of the fauna. In addition, the "old" species are not completely replaced by "modern" species, as is seen from an increase in the relative abundance of the long-ranging species from an average of about 62% to an average of about 75% between about 18 and 17 Ma. A maximum of 80% of the specimens in present-day faunas and about 50% of the species in the deep equatorial Pacific belong to species that have been around since the late Eocene.

During the interval from 13 to 18.5 Ma, several isotopic events were recognized. A shift in oxygen isotopic composition of benthic foraminifers occurs at 155 m subbottom depth at Site 574 (Pisias and Shackleton, this volume). The duration of the event is about 30,000 yr., and the age is estimated as 14.6 Ma, using data from Barron et al. (this volume). This agrees well with the estimate of Woodruff et al. (1981) for the age of the largest shift in oxygen isotopic ratios at 14.0 to 14.8 Ma.

Vincent and Killingley (this volume) recognize several events in the isotopic and calcium carbonate records from Sites 573 to 575. They describe a period of $\delta^{13}C$ enrichment in planktonic foraminifers between 22.7 and 20.7 Ma (see events A and B on Fig. 13); the beginning of a warming trend. i.e.. lighter values of $\delta^{18}O$ at 19.5 Ma (event C, Fig. 13); the beginning of increasing dissolution and lower $CaCO_3$ content at 18.7 Ma (event D); a major shift toward heavier $\delta^{13}C$ values centered at 17 Ma (event E); the peak in the warming trend (i.e., the lowest values of $\delta^{18}O$ at 16.5 Ma; event F); a shift toward heavier $\delta^{18}O$ values at 14.6 Ma, which is the shift also recognized by Pisias and Shackleton (this volume) (event G); and stronger dissolution at 13.3 Ma (event H).

The isotopic events (a carbon shift at 17 Ma and an oxygen shift at 14.6 Ma) postdate the beginning of the changes in the benthic faunas and are within the period of change in the faunas. The beginning of the faunal changes seems to be best correlated with (i.e., slightly later than) the increase in dissolution (event D, Fig. 13) at 18.7 Ma, which reflects a change in bottom-water properties.

Woodruff and Douglas (1981) describe a major change in benthic faunas in the western Pacific (Site 289) that is coeval with the shift in oxygen isotopes at 14.0 to 14.8 Ma. The benthic fauna at Sites 573 to 575 resembles the fauna at Site 289 in overall characteristics, although Site 289 was considerably shallower (paleodepth 2300 to 2400 m, Woodruff [in press], versus 3900 to 4100 m at Sites 573 to 575). *Epistominella exigua* is much more common in the lower Miocene section at Sites 573 to 575 than at Site 289, as are *Pleurostomella* spp. and *Stilostomella* spp. The events in most species of the *Cibicidoides* group are difficult to compare because of the complicated taxonomy, but *C. wuellerstorfi* has a FA at 16 Ma at Site 289, which agrees well with a FA at 15.0 to 15.6 Ma at Sites 573 to 575. *Melonis barleeanus* has a FA at about 14.3 Ma at Site 289, much later than at Sites 573 to 575, where it has a FA at 18.4 to 21.1 Ma.

In general, the faunal events described for Site 289 by Woodruff and Douglas (1981) and for the deep Pacific

in general by Woodruff (in press) are similar to the events as described in this paper. Woodruff and Douglas, however, conclude that the timing of the faunal changes correlates well with the timing of the shift in oxygen isotopic ratios, although the greatest isotopic change (14.0 to 14.8 Ma, Woodruff et al., 1981) predates and is of shorter duration than the main faunal change (13.2 to 16.5 Ma, Woodruff, in press). The difference in opinion as to the beginning of the main faunal change (at about 18.5 Ma in this paper) may be caused by several factors, including the difficulty in determining the precise level of FAs and LAs of rare species. Furthermore, not all age models for the sites described by Woodruff (in press) are well restrained. In addition, the part of the section deposited at Site 289 between 16.9 and 18.5 Ma was apparently deposited at very low sedimentation rates (about 6.3 m/m.y.) (data from Savin et al., 1981, p. 445), and Woodruff and Douglas do not present data from this time interval. Similarly, Woodruff (in press) presents relatively few data from the interval between 16 and 19 Ma: for paleodepths of more than 3 km, she gives data on 40 samples between 13 and 16 Ma and on 11 samples between 16 and 19 Ma.

In conclusion, data from Sites 573 to 575 suggest that changes in the benthic fauna occur roughly in the same time interval as changes in isotopic ratios, but the faunal changes start earlier and have a longer duration. The beginning of the faunal changes may be related to the beginning of increased dissolution at about 18.7 Ma. Keller (1981) suggests that a major change in bottom-water circulation occurred at about 20 Ma: after the opening of the Drake Passage, Antarctic Bottom Water reached the equatorial Pacific. Either this event occurred later than suggested by Keller (1981), or the benthic foraminifers took about 1.5 m.y. to react to the changes in the bottom-water masses, which seems unlikely when contrasted with the fast reactions of benthic faunas to glacial–interglacial events (Schnitker, 1980). It is also possible that another event caused the faunal changes and increased dissolution. The short-term changes in isotopic ratios may represent a sudden adjustment to changes in ocean circulation resulting from positive feedback processes (Berger et al., 1981). However, these sudden adjustments do not seem to occur at the same time as major changes in bottom water as perceived by deep-water benthic foraminifers.

Post–Middle Miocene

Data on the last 12 Ma are available from Site 573 only because of strong dissolution at the other two sites. The data from Site 573 cannot be compared with the data from Site 289 (Woodruff and Douglas, 1981), where an important change in the benthic fauna occurred around 9 to 10 Ma. At this time *Uvigerina* spp. increased sharply in abundance, probably because the site fell under the influence of the deep oxygen-minimum zone.

At Site 573 the number of FAs and LAs per time unit is relatively low between 12 and 7 Ma (Fig. 13), is higher between 7 and 5.5 Ma, and remains relatively high until the Recent. These data suggest that further research on benthic foraminifers from this period could prove inter-

esting, because the increase in the event rate of the benthic fauna at 7 Ma occurs close to the time of an important shift in carbon isotopic ratios (e.g., Savin et al., 1981) at 6.2 Ma.

Foraminiferal Turbidites

At Site 575 a number of distinctive, coarse-grained, fining-upward foraminiferal turbidites were recognized (see Site 575 chapter, this volume) which were probably derived from a nearby seamount with a present-day elevation of about 1000 m above the seafloor (water depth at the top of the seamount about 3500 m). Benthic faunas in samples from the turbidites are distinct from the *in situ* faunas (Fig. 5 and Appendix A).

Most of the turbidites contain abundant large, thick-walled specimens. The abundance of these large specimens is apparently the result of size sorting in the turbidites, but the specimens of some species in the turbidites are much larger than any specimen found in the pelagic samples (e.g., *Globocassidulina subglobosa*, *Favocassidulina favus*, and *Eggerella bradyi*). These observations suggest that these species attained larger sizes at shallower depths on the seamount. A similar depth-size correlation in *G. subglobosa* has been observed by Corliss (1979b,c) in the Indian Ocean. The hypothesis that some species of benthic foraminifers are smaller at greater depths (more than 4000 m) is supported by the observation that the specimens at Sites 573 to 575 are overall smaller than specimens of the same species from shallower depths (e.g., Douglas, 1973).

In most turbidites *G. subglobosa* is more abundant (relative abundance up to 38.6%) than in pelagic samples (Fig. 5), and *F. favus* and *F. subfavus* are abundant (relative abundance up to 53.4%) in turbidites from Sample 575A-3-2, 142–144 cm upward (above 110 m subbottom depth). *E. caribbea* is common (11.8%) in a turbidite sampled at 575A-8-5, 110–112 cm. Several species are absent or extremely rare in the pelagic samples but are frequent in the turbidites, including species that have been described from stratigraphic intervals lower than the ones in which they are found. These include *Bulimina jarvisi* (Oligocene), *Hanzawaia cushmani* (Eocene), *Planulina renzi* (Eocene–Oligocene), and *Buliminella* sp. (Oligocene) (all from Douglas, 1973). All these species were found in lower to middle Miocene turbidites at Site 575. *Eggerella propinqua* and *Uvigerina spinulosa* were found only in the turbidites.

CONCLUSIONS

1. Many common to abundant species in deep-sea benthic foraminiferal faunas in the equatorial Pacific have long ranges and probably wide environmental tolerances. Taxa with limited stratigraphic ranges generally make up between 20 and 40% of the total fauna.

2. Diversity is high (50 to 70 species per 200 specimens) and not correlatable with time or sub-bottom depth, although the total number of species decreases with time; in other words, there are more last appearances than first appearances.

3. First and last appearances of taxa (whether they are evolutionary or migratory) are concentrated in two

periods: in the late Eocene to early Oligocene (32 to 37 Ma) and in the early to middle Miocene (13 to 18.5 Ma).

4. "Old" species are partly replaced by "modern" species and partly by long-ranging species. The latter increase in abundance from about 62 to 75% between 17 and 18 Ma.

5. Post–middle Miocene faunas are readily distinguished from early Miocene and older faunas, but the transition is slow (about 6 m.y.). Characteristic "modern" species are *Melonis barleeanus, Francesita advena, M. pompilioides*, and *Cibicicodes wuellerstorfi*. "Old" species include *C. grimsdalei, C. mexicanus, C. laurisae, Bolivinopsis cubensis*, and *Pleurostomella acuta. Stilostomella* spp. and *Pleurostomella* spp. are more abundant in the "old" fauna.

6. First and last appearances of the above taxa are within 1 to 2 m.y. at the three sites, but the first and last appearances of many other species differ widely in age at the different sites. No data are available to assess whether some of the events are correlatable on a larger scale. Some events (FA of *C. wuellerstorfi*) correlate well with the western Pacific, while others do not (FA of *M. barleeanus*).

7. Carbon and oxygen isotopic events occur within the periods of relatively high rates of change in the benthic faunal composition, but the isotopic events start after the initiation of the faunal changes and have a shorter duration. The beginning of the faunal change can possibly be correlated with a period of increased dissolution of $CaCO_3$.

8. Data from foraminiferal turbidites (Site 575) suggest that several species (e.g., *Globocassidulina subglobosa*) attain a larger size at shallower depths (about 3,500 km versus 4,500 km).

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APPENDIX A
Counts of Benthic Foraminifer Specimens for All Samples Studied, Sites 573, 574, and 575[3]

APPENDIX B
Taxonomy

Alabamina dissonata (Cushman and Renz). *Pulvinulinella atlantisae* Cushman, var. *dissonata* Cushman and Renz, 1948, *Spec. Publ. Cushman Lab. Foraminiferal Res.*, v. 24, p. 35, pl. 7, figs. 11, 12.

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

Allomorphinella contraria Reuss, 1841, *Haidinger's Naturwiss. Abh.*, v. 4, p. 43.

Alveolophragmium subglobosum (Cushman). *Haplophragmoides subglobosum* Cushman, 1910, *Bull. U.S. Nat. Mus.*, v. 71, p. 105, figs. 162–164.

Ammonia? sp. Plate 15, Figs. 1, 2. Test free, calcareous, perforate, generally between 300 and 500 μm, trochospiral with slightly evolute ventral side, 5–7 chambers in last whorl. Flattened with almost parallel sides, slightly depressed umbo, and broadly rounded, somewhat lobulate to smooth periphery. Sutures flush to slightly depressed, generally indistinct. Chambers increase in size gradually. Wall thick, hyaline, extremely smooth. Primary aperture is an elongate, low slit bordered by a narrow lip, extending from just outside the umbo to the periphery. Secondary apertures (rounded or L-shaped) along the spiral suture on the dorsal side and on the junctions of spiral and cameral sutures. On slightly evolute ventral side secondary apertures are on cameral sutures close to umbo or on spiral suture. The species superficially resembles an indistinct species of *Eponides* and has a close resemblance to *Gyroidinoides lamarckianus* in its flattened shape. Its actual affinity is unknown

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[3] This appendix is in the back pocket.

until a more detailed study of the internal structure is completed. For the time being it is tentatively assigned to the genus *Ammonia* because of its similarity to juvenile *A. tepida* or *A. beccarii*, in which the spiral fissure system is not yet fully developed. If the species belongs in the genus *Ammonia*, its abyssal habitat is remarkable, since *Ammonia* species are generally shallow-water dwellers.

Stratigraphic Range. Late Eocene–early middle Miocene.

Amphicoryna hirsuta **(d'Orbigny).** Plate 1, Fig. 12. *Nodosaria hirsuta* d'Orbigny, 1826, *Ann. Sci. Nat., Ser. 1*, v. 7, p. 87, no. 7.

Anomalina alazanensis, **var.** *spissiformis* **Cushman and Stainforth, 1945.** Plate 12, Figs. 4, 5. *Spec. Publ. Cushman Lab. Foraminiferal Res.*, v. 14, p. 77, pl. 14, fig. 5.

Anomalinoides acutus **(Plummer).** Plate 12, Figs. 10, 11. *Anomalina anomalinoides* (Reuss), var. *acuta* Plummer, 1947, *Univ. Texas Bull.*, no. 2644, p. 149, pl. 10, fig. 2.

Anomalinoides dorri, **var.** *aragonensis* **(Nuttall).** *Anomalina dorri* Cole var. *aragonensis* Nuttall, 1930, *J. Paleontol.*, v. 4, p. 291, pl. 24, fig. 18.

Anomalinoides globulosus **(Chapman and Parr).** Plate 12, Figs. 6, 7. *Anomalina globulosa* Chapman and Parr, 1937, *Rep. Australasian Antarctic Exped.*, C, v. 1, p. 119, pl. 9, fig. 27.

Anomalinoides semicribratus **(Beckmann).** Plate 12, Figs. 8, 9. *Anomalina pompilioides* Galloway and Heminway var. *semicribrata* Beckmann, 1953, *Eclogae Geol. Helv.*, v. 10, pp. 400–401, pl. 27, fig. 3, text figs. 24, 25.

Astacolus crepidulus **(Fichtel and Moll).** *Nautilus crepidulus* Fichtel and Moll, 1798, *Test. Microsc.*, p. 107, pl. 19, figs. g–i.

Astacolus reniformis **(d'Orbigny).** *Cristellaria reniformis* d'Orbigny, 1846, *Foraminifères fossiles du Bassin Tertiaire de Vienne*, pp. 88–89, pl. 3, figs. 39, 40.

Astrononion novozealandicum **Cushman and Edwards, 1937,** Plate 4, Fig. 9. *Contrib. Cushman Lab Foraminiferal Res.*, v. 13, pt. 1, p. 35, pl. 3, fig. 18.

Bigenerina nodosaria **d'Orbigny, 1826,** Plate 1, Fig. 6. *Ann. Sci. Nat., Ser. 1*, v. 7, p. 261, pl. 11, figs. 9–12.

Bolivina capitata **Cushman, 1933,** Plate 3, Fig. 2. *Contrib. Cushman Lab. Foraminiferal Res.*, v. 9, pt. 4, p. 80, pl. 8, figs. 12a,b.

Bolivina huneri **Howe, 1939,** Plate 3, Fig. 1. *Geol. Bull. Louisiana Geol. Surv.*, v. 14, p. 66, pl. 9, figs. 3, 4.

Bolivina silvestrina **Cushman, 1936,** *Spec. Publ. Cushman Lab Foraminiferal Res.*, v. 6, p. 56, pl. 8, fig. 5.

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,** Plate 3, Fig. 3. *Carnegie Inst. Washington Publ. 311*, p. 27, pl. 3, fig. 10. Resembles *B. subaenariensis* Cushman, but the latter species has parallel sides and an angular periphery, whereas *B. striatula* is a flattened oval in cross section.

Bolivina tectiformis **Cushman, 1926,** *Contrib. Cushman Lab. Foraminiferal Res.*, v. 1, p. 83, pl. 12, fig. 6.

Bolivina translucens **Phleger and Parker, 1951,** Plate 3, Fig. 4. *Mem. Geol. Soc. Am.*, v. 46, pt. 2, p. 15, pl. 7, figs. 13, 14. *B. translucens* is flat in cross section and has a narrow aperture. *B. seminuda* Cushman is round in cross section. *B. pseudopunctata* Hoeglund has a wide aperture.

Bolivinopsis cubensis **(Cushman and Bermudez).** *Spiroplectoides cubensis* Cushman and Bermudez, 1937, *Contrib. Cushman Lab. Foraminiferal Res.*, v. 13, pt. 1, pl. 1, figs. 44, 45.

Bolivinopsis trinitatensis **(Cushman and Renz).** *Spiroplectammina trinitatensis* Cushman and Renz, 1948, *Spec. Publ. Cushman Lab. Foraminiferal Res.*, v. 24, p. 11, pl. 2, figs. 13, 14.

Bulimina alazanensis **Cushman, 1927,** Plate 2, Fig. 6. *J. Paleontol.*, v. 1, p. 161, pl. 25, fig. 4. There is considerable confusion between *B. alazanensis* and *B. rostrata* Brady. *B. alazanensis* has a reticulate pattern of costae, whereas in *B. rostrata* the costae do not touch. *B. semicostata* resembles *B. alazanensis* closely, but the costae do not cover the last chamber.

Bulimina fijensis **Cushman, 1933,** *Contrib. Cushman Lab. Foraminiferal Res.*, v. 9, p. 79, pl. 8, figs. 7a–c.

Bulimina jarvisi **Cushman and Parker, 1936,** *Contrib. Cushman Lab. Foraminiferal Res.*, v. 12, p. 39, pl. 7, fig. 1. Found mainly in turbidites, Site 575.

Bulimina macilenta **Cushman and Parker, 1939,** *Contrib. Cushman Lab. Foraminiferal Res.*, v. 15, p. 93.

Bulimina microcostata **Cushman and Parker, 1936,** Plate 2, Fig. 5. *Contrib. Cushman Lab. Foraminiferal Res.*, v. 12, p. 39, pl. 7, figs. 2a–c. Resembles *B. alazanensis*, but has less well-developed costae.

Bulimina simplex **Terquem, 1882,** *Mem. Soc. Geol. Fr.*, ser. 3, v. 2, p. 109, pl. 11, figs. 23, 24.

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

Bulimina translucens **Phleger, Parker and Peirson, 1953,** *Rep. Swed. Deep Sea Exped. 1947–1948*, v. 7, p. 33, pl. 6, figs. 30, 31.

Bulimina trihedra **Cushman, 1926,** *Am. Assoc. Pet. Geol. Bull.*, v. 10, p. 591, pl. 17, figs. 6a,b.

Buliminella carteri **Bhatia, 1955,** Plate 2, Fig. 7. *J. Paleontol.*, v. 29, p. 678, pl. 66, fig. 10. Resembles *B. grata* Parker and Bermudez, but the sutures are not scalloped.

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

Buliminella **sp. Douglas, 1973,** *Init. Repts. DSDP*, v. 17, p. 634, pl. 7, fig. 5. Found only in turbidites, Site 575.

Cassidulina crassa **d'Orbigny, 1846,** *Foraminifères fossiles du Bassin Tertiaire de Vienne*, pp. 212–213, pl. 21, figs. 42, 43.

Cassidulina havanensis **Cushman and Bermudez, 1936,** Plate 7, Figs. 1, 2. *Contrib. Cushman Lab. Foraminiferal Res.*, v. 12, p. 36, pl. 6, fig. 11.

Cassidulina laevigata **d'Orbigny, 1826,** *Ann. Sci. Nat., Ser. 1*, v. 7, p. 282, pl. 15, figs. 4, 5, 5b.

Cassidulina spinifera **Cushman and Jarvis, 1929,** Plate 7, Fig. 3. *Contrib. Cushman Lab. Foraminiferal Res.*, v. 5, pt. 1, p. 17, pl. 3, figs. 1a,b.

Cassidulina translucens **Cushman and Hughes, 1925,** *Contrib. Cushman Lab. Foraminiferal Res.*, v. 1, pt. 1, p. 15, pl. 2, figs. 5a–c.

Cassidulinoides bradyi **(Norman).** *Cassidulina bradyi* Norman, 1881, *Q. J. Microsc. Sci.*, new ser., v. 21, p. 59.

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

Chrysalogonium tenuicostatum **Cushman and Bermudez, 1936,** *Contrib. Cushman Lab. Foraminiferal Res.*, v. 12, pt. 2, p. 27, 28, pl. 5, figs. 3–5.

Cibicidoides alleni **(Plummer).** *Cibicides alleni* Plummer, 1927, *Univ. Texas Bull.*, no. 2644, p. 144, pl. 10, fig. 4.

Cibicidoides bradyi **(Trauth).** Plate 10, Figs. 7, 8. *Truncatulina bradyi* Trauth, 1884, *Denkschr. K. Akad. Wiss. Wien, Math. Naturwiss. Kl.*, v. 95, p. 235, pl. 4, figs. 7–9.

Cibicidoides cicatricosus **(Schwager).** *Anomalina cicatricosa* Schwager, 1866, *Novara Exp. Geol. Theil.*, v. 2, p. 260, pl. 7, fig. 108. Not the same as *C. cicatricosus* in Resig, 1981, *Mem. Geol. Soc. Am.*, v. 154, pl. 8, figs. 13, 14. These figures show a more acute periphery.

Cibicidoides dickersoni **(Bermudez).** *Cibicides dickersoni* Bermudez, 1937, *Mem. Soc. Cubana Hist. Nat.*, v. 11, p. 244, pl. 21, figs. 8, 9.

Cibicidoides grimsdalei **(Nuttall).** Plate 9, Figs. 1, 2. *Cibicides grimsdalei* Nuttall, 1930, *J. Paleontol.*, v. 4, p. 291, pl. 25, figs. 7, 8, 11.

Cibicidoides havanensis **(Cushman and Bermudez).** *Cibicides havanensis* Cushman and Bermudez, 1937, *Contrib. Cushman Lab. Foraminiferal Res.*, v. 13, pt. 1, p. 28, pl. 3, figs. 1–3.

Cibicidoides kullenbergi **(Phleger, Parker and Peirson).** Plate 8, Figs. 1, 2. *Cibicides kullenbergi* Phleger, Parker and Peirson, 1953, *Rep. Swed. Deep Sea Exped., 1947–1948*, v. 7, p. 49, pl. 11, figs. 7, 8. This species shows considerable variability. In my opinion, it is closely related to *C. mundulus* (Brady, Parker, and Jones), *C. mollis* (Phleger and Parker), *C. kullenbergi*, var. *S.* (this study), *C.* aff. *mundulus* (this study), and *C. pseudoungerianus* (Cushman). This classification does not take into account bi- or planconvexity of the test, since this varies considerably in type material of *C. kullenbergi*. I call specimens *C. kullenbergi* if they have a keel and if the sutures on the involute side are curved strongly and thus join the keel tangentially. *C. kullenbergi*, var. *S.* also has strongly curved sutures on the involute side, but there is a kink in each suture close to the umbo, and the sutures do not join the keel tangentially. The species is keeled. *C. mundulus* also has a keel, but the sutures on the involute side are not or hardly curved. In *C. mollis* the later chambers of the last whorl are not keeled, but inflated; the sutures on the involute side in these inflated chambers are not curved. *C. pseudoungerianus* does not have a keel. *C.* aff. *mundulus* resembles *C. mundulus*, but the keel tends to be lobate and very thick; the specimens are larger. Generally, *C. kullenbergi* has more cham-

bers per whorl (about 13) than the other species (9 to 11). *C. wuellerstorfi* juveniles strongly resemble *C. kullenbergi*. I include in *C. wuellerstorfi* all forms that have strongly curved sutures on the evolute side. Although problematic individuals certainly occur, this taxonomic scheme proved to be useful.

Cibicidoides kullenbergi, **var. S.** Plate 8, Figs. 3, 4. See *C. kullenbergi.*

Cibicidoides laurisae **(Mallory).** Plate 10, Figs. 3, 4. *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. This is probably the same species as *Anomalinoides* sp. 1, Douglas, 1973, *Init. Repts. DSDP,* v. 17, pl. 19, figs. 4, 5.

Cibicidoides mexicanus **(Nuttall).** Plate 9, Figs. 3, 4. *Cibicides mexicanus* Nuttall, 1932, *J. Paleontol.,* v. 6, p. 33, pl. 9, figs. 7–9. *C. mexicanus* resembles *C. perlucidus* in its thickened, glassy wall on the evolute side, but has a much more highly convex involute side.

Cibicidoides mollis **(Phleger and Parker).** Plate 8, Figs. 7, 8. *Cibicides mollis* Phleger and Parker, 1951, *Mem. Geol. Soc. Am.,* v. 46, pt. 2, p. 30. See *C. kullenbergi.*

Cibicidoides mundulus **(Brady, Parker and Jones).** Plate 8, Figs. 5, 6. *Truncatulina mundula* Brady, Parker and Jones, 1888, *Trans. Zool. Soc. London,* v. 12, p. 228, pl. 45, fig. 25. See *C. kullenbergi.*

Cibicidoides aff. *mundulus.* Plate 8, Figs. 9, 10. See *C. kullenbergi.*

Cibicidoides perlucidus **(Nuttall).** Plate 9, Figs. 5, 6. *Cibicides perlucida* Nuttall, 1932, *J. Paleontol.,* v. 6, p. 33, pl. 8, figs. 10–12. See *C. mexicanus.*

Cibicidoides pseudoungerianus **(Cushman).** Plate 11, Figs. 5, 6. *Truncatulina pseudoungeriana* Cushman, 1922, *U.S. Geol. Surv. Prof. Pap.,* v. 129E, p. 97, pl. 20, fig. 9.

Cibicidoides robertsonianus **(Brady).** Plate 10, Figs. 5, 6. *Truncatulina robertsoniana* Brady, 1881, *Q. J. Microsc. Sci.,* new ser., v. 21, p. 65.

Cibicidoides trinitatensis **(Nuttall).** Plate 10, Figs. 1, 2. *Truncatulina trinitatensis* Nuttall, 1928, *Q. J. Geol. Soc. London,* v. 84, p. 97, pl. 7, figs. 3, 5–6. This species is the same as *C. trincherasensis* Beckmann, not Bermudez, *Eclogae Geol. Helv.,* 1953, v. 46, p. 656, pl. 18, figs. 4–6; the species that Beckmann names *C. trinitatensis* is completely different.

Cibicidoides wuellerstorfi **(Schwager).** Plate 11, Figs. 1, 2, 3, 4. *Anomalina wuellerstorfi* Schwager, 1866, *Novara Exp. Geol. Theil.,* v. 2, p. 258, pl. 7, figs. 105–107. See *C. kullenbergi.*

Cibicidoides wuellerstorfi, **var. C.** Plate 11, Figs. 7, 8. This form resembles the nominate species in overall shape and chamber arrangement, but the evolute side does not show the thick ridges. On the involute side the sutures are less thickened and glassy.

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

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

Dentalina intorta **(Dervieux).** *Nodosaria intorta* Dervieux, 1893–94, *Boll. Soc. Geol. Ital.,* v. 12, p. 610.

Dentalina reussi **Neugeboren, 1856,** *Denkschr. K. Akad. Wiss. Wien, Math. Naturwiss. Kl.,* v. 12 (Abt. 2), p. 85, pl. 3, figs. 6–7.

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

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

Dorothia scabra **(Brady).** *Gaudryina scabra* Brady, 1884, *Rep. Voy. Challenger, Zool.,* v. 9, pl. 46, figs. 7a,b.

Eggerella bradyi **(Cushman).** Plate 1, Fig. 4. *Verneullina bradyi* Cushman, 1911, *Bull. U.S. Nat. Mus.,* v. 71, pt. 2, p. 54, text figs. 87a,b.

Eggerella propinqua **(Brady).** *Verneuillina propinqua* Brady, 1884, *Rep. Voy. Challenger, Zool.,* v. 9, p. 383, pl. 47, figs. 8–12. Only in turbidites, Site 575.

Ehrenbergina caribbea **Galloway and Heminway, 1941,** Plate 7, figs. 7, 8. *N.Y. Acad. Sci., Scientific Surv. Porto Rico and Virgin Islands,* v. 3, pt. 4, p. 426, pl. 32, figs. 4a–d.

Eilohedra weddellensis **(Earland).** Plate 13, Figs. 5, 6. *Eponides weddellensis* Earland, 1936, *Discovery Repts.,* v. 13, p. 57, pl. 1, figs. 65–67. This species closely resembles *Eponides pusillus* Parr in chamber arrangement and small size. However, the aperture in *E. pusillus* is at the base of the last chamber. In *E. weddellensis* it extends into the apertural face parallel to the periphery. *Epistominella levicula* Resig was designated as the type species of the genus *Eilohedra* by Lipps (1965). However, I consider *E. levicula* to be a

junior synonym of *E. weddellensis,* which makes *E. weddellensis* the type species of *Eilohedra.*

Ellipsobulimina **sp.** Resembles *E. seguenzai* Silvestri, but is much more slender.

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

Ellipsoglandulina exponens **(Brady).** *Ellipsoidina exponens* Brady, 1892, *Q. J. Geol. Soc. London,* v. 48, p. 198.

Ellipsoglandulina laevigata **Silvestri, 1900,** *Mem. R. Accad. Sci., Lett. Arti degli Zelanti, Cl. Sci.,* Nuova Ser., v. 10, p. 12.

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

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

Ellipsoglandulina **sp.** Very strongly depressed sutures, inflated chambers.

Ellipsopolymorphina **sp.** Last chamber more enveloping than in *E. fornasinii,* first chambers more elongate than in *E. schlichtii.*

Epistominella exigua **(Brady).** Plate 13, figs. 3, 4. *Pulvinulina exigua* Brady, 1884, *Rep. Voy. Challenger, Zool.,* v. 9, p. 696, pl. 103, figs. 13a–c, 14a–c.

Eponides pusillus **Parr, 1950,** *BANZ Antarctic Res. Exp.,* v. 5, pt. 6, p. 360, pl. 14, figs. 16a–c. See *Eilohedra weddellensis.*

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

Eponides tumidulus **(Brady).** *Truncatulina tumidula* Brady, 1884, *Rep. Voy. Challenger, Zool.,* v. 9, p. 666, pl. 95, figs. 8a–d.

Favocassidulina favus **(Brady).** *Pulvinulina favus* Brady, 1877, *Suppl. Notes Foram. Chalk, New Britain Group, Geol. Mag. London,* new ser., v. 4, no. 12, p. 535.

Favocassidulina subfava **Resig, 1982,** Plate 7, Figs. 6. *J. Paleontol.,* v. 56, pp. 979–980, pl. 7, figs. 6–8.

Francesita advena **(Cushman).** Plate 2, Fig. 8. *Virgulina(?) advena* Cushman, 1922, *Bull. U.S. Nat. Mus.,* v. 104, pt. 3, p. 120, pl. 25, figs. 1–3.

Fursenkoina bradyi **(Cushman).** Plate 3, Fig. 7. *Virgulina bradyi* Cushman, 1922, *Bull. U.S. Nat. Mus.,* v. 104, pt. 3, p. 115, pl. 24, fig. 1.

Fursenkoina ciperana **(Cushman and Stainforth).** Plate 3, Fig. 6. *Virgulina ciperana* Cushman and Stainforth, 1945, *Contrib. Cushman Lab. Foraminiferal Res.,* v. 14, p. 46, 47, pl. 7, fig. 10.

Fursenkoina compressa **(Bailey).** *Bulimina compressa* Bailey, 1851, *Smithsonian Contrib.,* v. 2, art. 3, p. 12, pl. 12, figs. 35–37.

Fursenkoina cylindrica **(Cushman and Bermudez).** Plate 3, Fig. 8. *Virgulina cylindrica* Cushman and Bermudez, 1936, *Contrib. Cushman Lab. Foraminiferal Res.,* v. 12, pt. 2, p. 30, 31, pl. 5, figs. 15a–c.

Fursenkoina pauciloculata **(Brady).** Plate 3, Fig. 5. *Virgulina pauciloculata* Brady, 1884, *Rep. Voy. Challenger, Zool.,* v. 9, p. 414, pl. 52, figs. 4, 5.

Gavelinella micra **(Bermudez).** Plate 11, Figs. 11, 12. *Cibicides micrus* Bermudez, 1949, *Spec. Publ. Cushman Lab. Foraminiferal Res.,* v. 25, p. 302, pl. 24, figs. 34–36.

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

Globocassidulina decorata **(Sidebottom).** Plate 7, Fig. 5. *Cassidulina decorata* Sidebottom, 1910, *J. Quekett Microsc. Club,* ser. 2, v. 11, no. 67, p. 107, pl. 4, figs. 2a–c.

Globocassidulina subglobosa **(Brady).** Plate 7, Fig. 4. *Cassidulina subglobosa* Brady, 1884, *Rep. Voy. Challenger, Zool.,* v. 9, p. 430, pl. 54, figs. 17a–c.

Globulina minuta **(Roemer).** *Polymorphina minuta* Roemer, 1838, *Neues Jahrb. Mineral.,* v. 20, p. 386, pl. 3, fig. 35.

Gravellina narivaensis **Brönnimann, 1953,** Plate 1, Fig. 7. *Contrib. Cushman Found. Foraminiferal Res.,* v. 4, pt. 1, p. 88, text fig. 1, pl. 15, fig. 8.

Gyroidinoides acutus **(Boomgaart).** Plate 6, Figs. 4, 5, 6. *Gyroidina neosoldanii* Brotzen var. *acuta* Boomgaart, 1949, Univ. Utrecht doctoral dissert., p. 124, pl. 9, figs. 1a–c. I think that this species is closely related to *G. soldanii* (d'Orbigny). Probably this species is the same as *G. zealandica* (Finlay) in Resig, 1981, *Mem. Geol. Soc. Am.,* v. 154, pl. 8, figs. 3–4, and as *G. zealandica* in Douglas, 1973, *Init. Repts. DSDP,* v. 17, p. 644, pl. 12, partim, figs. 7–9,

not figs. 4–6. The type figure of *G. zealandica* Finlay, 1939, *Trans. R. Soc. N.Z.*, v. 67, p. 323, pl. 28, figs. 138–140, shows much more convex sides and the periphery is less acute. I use the name *G. acutus* for forms with somewhat concave evolute side, acute periphery, and about triangular on cross section.

Gyroidinoides girardanus (**Reuss**). Plate 6, Figs. 1, 2, 3. *Rotalina girardana* Reuss, 1851, *Dtsch. Geol. Ges.*, v. 3, p. 73, pl. 5, fig. 34.

Gyroidinoides globosus (**Hagenow**). Plate 5, Figs. 7, 8. *Nonionina globosa* Hagenow, 1842, *Neues Jahrb. Mineral.*, p. 574.

Gyroidinoides lamarckianus (**d'Orbigny**). Plate 5, Figs. 1, 2. *Rotalina lamarckiana* d'Orbigny, 1839, *Hist. Nat. Iles Canaries*, v. 2, pt. 2, p. 131, pl. 2, figs. 13–15. *G. lamarckianus* is a flat form, in which the involute side is not strongly convex and the periphery is broadly rounded. The species is probably the same as that named *G. orbicularis* by Corliss, 1979, *Micropaleontology*, v. 25, p. 9, pl. 5, figs. 1–3 and by Pflum and Frerichs, 1976, *Spec. Publ. Cushman Found. Foraminiferal Res.*, v. 14, pl. 5, figs. 5–7. *G. orbicularis* d'Orbigny, 1826, *Ann. Sci. Nat.*, v. 7, p. 278, no. 1, modelès no. 13 has a much more acute periphery and a more convex involute side.

Gyroidinoides mediceus (**Emiliani**). Plate 5, Figs. 5, 6. *Gyroidina medicea* Emiliani, 1954, *Paleontographica Italiana*, v. 48, p. 136, pl. 24, fig. 6.

Gyroidinoides planulatus (**Cushman and Renz**). Plate 5, Figs. 3, 4. *Gyroidina planulata* Cushman and Renz, 1941, *Contrib. Cushman Lab. Foraminiferal Res.*, v. 17, p. 23, pl. 4, fig. 1.

Gyroidinoides soldanii (**d'Orbigny**). Plate 6, Figs. 7, 8. *Gyroidina soldanii* d'Orbigny, 1826, *Ann. Sci. Nat.*, v. 7, p. 298, no. 5, modelès no. 36. This is probably the same species as *G. zealandica* (Finlay), Douglas, 1973, *Init. Repts. DSDP*, v. 17, p. 644, pl. 12, partim, figs. 4–6, not figs. 7–9 (see *G. acutus*).

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

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

Hanzawaia cushmani (**Nuttall**). *Cibicides cushmani* Nuttall, 1930, *J. Paleontol.*, v. 4, p. 291, pl. 25, figs. 3, 5, 6.

Heronallenia lingulata (**Burrows and Holland**). Plate 13, Fig. 7. *Discorbina lingulata* Burrows and Holland, 1896, *in* Jones, *Foram. Crag*, pt. 3, p. 297, pl. 7, fig. 33.

Involutina tenuis Brady, 1884, *Rep. Voy. Challenger, Zool.*, v. 9, pl. 38, figs. 5, 6.

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

Laticarinina pauperata (**Parker and Jones**). Plate 11, Fig. 10. *Pulvinellina repanda* var. *menardii* subvar. *pauperata* Parker and Jones, 1865, *Philos. Trans. R. Soc. London*, v. 155, p. 395, pl. 16, figs. 50–51.

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

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

Lenticulina sp. **juv.** This includes all juvenile specimens having only 2–3 chambers present that cannot be assigned to a species.

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

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

Marginulina suberecta **Franke**, 1927, *Dan. Geol. Unders.*, v. 2, Raekke nr. 46, p. 19, pl. 1, fig. 28.

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

Martinotiella petrosa (**Cushman and Bermudez**). *Listerella petrosa* Cushman and Bermudez, 1937, *Contrib. Cushman Lab. Foraminiferal Res.*, v. 13, p. 5, pl. 1, figs. 24–26.

Melonis barleeanus (**Williamson**). Plate 12, Fig. 3. *Nonionina barleeana* Williamson, 1858, *Recent Foraminifera of Great Britain*, p. 32, pl. 3, figs. 68–69.

Melonis pompilioides (**Fichtel and Moll**). Plate 12, Figs. 1, 2. *Nautilus pompilioides* Fichtel and Moll, 1798, *Test. Microsc.*, p. 31, pl. 2, figs. a–c.

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

Nodosaria filiformis d'Orbigny, 1826, *Ann. Sci. Nat.*, v. 7, p. 2543, no. 14.

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

Nodosaria lamnulifera Boomgaart, 1950, *Contrib. Cushman Found. Foraminiferal Res.*, v. 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.*, v. 7, p. 253, no. 13.

Nodosaria vertebralis (**Batsch**). *Nautilus (Orthoceras) vertebralis* Batsch, 1791, *Conchyl. Seesandes*, p. 3, no. 6, pl. 2, fig. 6.

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

Nonion havanense **Cushman and Bermudez**, **1937**, Plate 4, Figs. 10, 11. *Contrib. Cushman Lab. Foraminiferal Res.*, v. 13, p. 19, pl. 2, figs. 13, 14.

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

Nuttallides truempyi (**Nuttall**). *Eponides truempyi* Nuttall, 1930, *J. Paleontol.*, v. 4, p. 271, pl. 8, figs. 9, 13, 14.

Nuttallides umbonifera (**Cushman**). Plate 13, Figs. 1, 2. *Pulvinulinella umbonifera* Cushman, 1933, *Contrib. Cushman Lab. Foraminiferal Res.*, v. 9, pt. 4, pl. 9, figs. 9a–c.

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

Oridorsalis tener (**Brady**). Plate 4, Figs. 5, 6. *Truncatulina tenera* Brady, 1884, *Rep. Voy. Challenger, Zool.*, v. 9, p. 665, pl. 95, figs. 11a–c.

Oridorsalis umbonatus (**Reuss**). Plate 4, Figs. 7, 8. *Rotalina umbonata* Reuss, 1851, *Z. Dtsch. Geol. Ges.*, v. 3, p. 75, pl. 5, figs. 35a–c.

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

Orthomorphina doliolaris (**Parr**). *Nodosaria doliolaris* Parr, 1950, *BANZ Antarctic Res. Exp.*, ser. B, v. 5, p. 290, pl. 12, fig. 2.

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

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

Osangularia interrupta (**Cushman**). *Pulvinulinella interrupta* Cushman, 1927, *Contrib. Cushman Lab. Foram. Res.*, v. 3, p. 115, figs. 10a–c.

Osangularia mexicana (**Cole**). *Pulvinulinella culter* Parker and Jones var. *mexicana* Cole, 1927, *Bull. Am. Paleontol.*, v. 14, no. 51, p. 31, pl. 1, figs. 15, 16.

Planulina marialana Hadley, 1934, *Bull. Am. Paleontol.*, v. 20, no. 70A, p. 27, pl. 4, figs. 4–6.

Planulina renzi **Cushman and Stainforth**, **1945**, Plate 11, Fig. 9. *Spec. Publ. Cushman Lab. Foraminiferal Res.*, v. 14, p. 72, pl. 15, fig. 1.

Planulinoides biconcavus (**Jones and Parker**). *Discorbina biconcava* Jones and Parker, 1861, *in* Carpenter, Parker, and Jones, *Intro. Study Foram.*, p. 201, fig. 32g.

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

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

Pleurostomella acuta Hantken, 1875, Plate 14, Figs. 1, 2. *K. Ungar. Geol. Anst. Mitt.*, v. 4, pt. 1, p. 44, pl. 13, fig. 18.

Pleurostomella alternans Schwager, 1866, Plate 14, Fig. 5. *Novara Exp. Geol. Theil.*, v. 2, p. 238, pl. 6, fig. 79.

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

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

Pleurostomella fusiformis Reuss, 1860, *Sitzungsber. Kais. Akad. Wiss. Wien, Math. Naturwiss. Kl.*, v. 40, p. 205, pl. 8, fig. 1.

Pleurostomella obtusa Berthelin, 1880, Plate 14, Figs. 3, 4. *Mem. Soc. Geol. Fr.*, ser. 3, v. 1, pt. 5, p. 29, pl. 1, fig. 9.

Pleurostomella rimosa **Cushman and Bermudez, 1937,** *Contrib. Cushman Lab. Foraminiferal Res.,* v. 13, pt. 1, p. 17, pl. 1, figs. 62–63.

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

Pseudoparrella **sp.** This species resembles *P. subperuviana* (Cushman) closely in 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. See Lipps (1965).

Pullenia bulloides **(d'Orbigny).** *Nonione bulloides* d'Orbigny, 1846, *Foraminifères fossiles du Bassin Tertiaire de Vienne,* p. 107, pl. 5, figs. 9, 10. 4–4½ chambers, spheroid, smooth outline.

Pullenia quadriloba **Reuss.** Plate 4, Fig. 1. *Pullenia compressiuscula* Reuss var. *quadriloba* Reuss, 1867, *Denkschr. K. Akad. Wiss. Wien, Math. Naturwiss. Kl.,* ser. B, v. 55, p. 87, pl. 3, fig. 8. 4–4½ chambers, flattened, lobate periphery.

Pullenia quinqueloba **(Reuss).** Plate 4, Fig. 2. *Nonionina quinqueloba* Reuss, 1857, *Z. Dtsch. Geol. Ges.,* v. 3, p. 47, pl. 5, fig. 31. 5–5½ chambers, flattened, lobate periphery.

Pullenia salisburyi **Stewart and Stewart, 1930,** Plate 4, Fig. 4. *J. Paleontol.,* v. 4, p. 72, pl. 8, figs. 2a–b. 6–8 chambers, more flattened than *P. quinqueloba,* lobate periphery.

Pullenia subcarinata **(d'Orbigny).** Plate 4, Fig. 3. *Nonionina subcarinata* d'Orbigny, 1839, *Voy. Amer. Merid.,* v. 5, p. 28, pl. 5, figs. 23, 24. 5–5½ chambers, lenticular, smooth outline.

Pullenia trinitatensis **Cushman and Stainforth, 1945,** *Spec. Publ. Cushman Lab. Foraminiferal Res.,* v. 14, p. 66, pl. 12, fig. 11. 6–7 chambers, outline pronounced lobate, chambers inflated, umbo depressed.

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

Pyrgo murrhina **(Schwager).** Plate 1, Fig. 10. *Biloculina murrhina* Schwager, 1866, *Novara Exp. Geol. Theil.,* v. 2, p. 203, pl. 4, figs. 15a–c.

Pyrulina angusta **(Egger).** *Polymorphina (Globulina) angusta* Egger, 1857, *Neues Jahrb. Min. Geogn. Geol. Petrof.-kunde,* p. 290, pl. 13, figs. 13–15.

Pyrulina cylindroides **(Roemer).** *Polymorphina cylindroides* Roemer, 1838, *Neues Jahrb. Min. Geogn. Geol. Petrof.-kunde,* p. 385, pl. 3, figs. 26a–b.

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

Pyrulina fusiformis **(Roemer).** *Polymorphina fusiformis* Roemer, 1838, *Neues Jahrb. Min. Geogn. Geol. Petrof.-kunde,* p. 386, pl. 3, figs. 37a–b.

Quadrimorphina allomorphinoides **(Reuss).** *Valvulina allomorphinoides* Reuss, 1860, *Sitzungsber. Kais. Akad. Wiss. Wien, Math. Naturwiss. Kl.,* v. 40, p. 223.

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. Naturwiss. Kl.,* v. 1, p. 384, pl. 50, fig. 3.

Quinqueloculina venusta **Karrer, 1868,** *Sitzungsber. Kais. Akad. Wiss. Wien, Math. Naturwiss. Kl.,* v. 58, Abt. 1, p. 147, pl. 2, fig. 6.

Quinqueloculina **cf. *weaveri* Rau.** Plate 1, Fig. 11. *Quinqueloculina* cf. *weaveri* Phleger, Parker and Peirson, 1953, *Rep. Swed. Deep Sea Exped. 1947–1948,* v. 7, p. 28, pl. 5, figs. 13, 14.

Reophax dentaliniformis **Brady, 1884,** *Rep. Voy. Challenger, Zool.,* v. 9, p. 299, pl. 30, figs. 21, 22.

Reophax nodulosus **Brady, 1879,** *Q. J. Microsc. Sci.,* v. 19, p. 52, pl. 4, figs. 7, 8.

Resigia westcotti **Schnitker and Tjalsma, 1980,** *J. Foraminiferal Res.,* v. 10, p. 240, pl. 1, figs. 22–27.

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

Robertina subcylindrica **(Brady).** *Bulimina subcylindrica* Brady, 1879, *Q. J. Microsc. Sci.,* v. 19, p. 56.

Saracenaria arcuata var. *ampla* **Cushman and Todd.** *Saracenaria arcuata* d'Orbigny var. *ampla* Cushman and Todd, 1945, *Spec. Publ. Cushman Lab. Foraminiferal Res.,* v. 15, p. 31, pl. 5, figs. 5, 6.

Saracenaria italica **de France, 1824,** *Dict. Sci. Nat.,* v. 32, p. 177.

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

Siphotextularia catenata **(Cushman).** *Textularia catenata* Cushman, 1911, *Bull. U.S. Nat. Mus.,* v. 71, pt. 2, p. 23, figs. 39–40. I agree with Corliss, 1979, *Micropaleontology,* v. 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.,* v. 7, p. 267, modèles no. 65.

Spiroloculina canaliculata **d'Orbigny, 1846,** *Foraminifères fossiles du Bassin Tertiaire de Vienne,* pp. 269–270, pl. 16, figs. 10–12.

Spiroplectammina biformis **(Parker and Jones).** *Textularia agglutinans* d'Orbigny var. *biformis* Parker and Jones, 1865, *Philos. Trans. R. Soc. London,* v. 155, p. 370.

Stainforthia complanata **(Egger).** Plate 2, Fig. 9. *Virgulina schreibersiana* Czjzek var. *complanata* Egger, 1893, *Abh. Bayer. Akad. Wiss., Math-Phys. Naturwiss. Kl.,* p. 292, pl. 8, figs. 91, 92.

Stilostomella abyssorum **(Brady).** Plate 14, Fig. 9. *Nodosaria abyssorum* Brady, 1881, *Q. J. Microsc. Sci.,* new ser., v. 21, p. 63.

Stilostomella consobrina **(d'Orbigny).** Plate 14, Figs. 6, 7. *Dentalina consobrina* d'Orbigny, 1846, *Foraminifères fossiles du Bassin Tertiaire de Vienne,* p. 46, pl. 2, figs. 1–3. There consists considerable confusion in the nomenclature within *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 lower edge of each chamber, and *S. subspinosa* for forms with rounded chambers, covered with spines. *S. consobrina* may have delicate spines randomly distributed over its chambers.

Stilostomella lepidula **(Schwager).** Plate 14. Fig. 8. *Nodosaria lepidula* Schwager, 1866, *Novara Exp. Geol. Theil.,* v. 2, pp. 210–211, pl. 5, figs. 27, 28. See *S. consobrina.* I think that *S. antillea* (Cushman), 1923, *Bull. U.S. Nat. Mus.,* v. 104, pt. 4, p. 91, pl. 14, fig. 9 is a junior synonym.

Stilostomella subspinosa **(Cushman).** Plate 14, Fig. 10. *Ellipsonodosaria subspinosa* Cushman, 1943, *Contrib. Cushman Lab. Foraminiferal Res.,* v. 19, p. 92, pl. 16, figs. 16, 17. See *S. consobrina.*

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,** Plate 1, Fig. 5. *In* de la Sagra, *Hist. Phys. Pol. Nat. Cuba,* p. 136, pl. 1, figs. 17, 18, 32, 34.

Textularia leuzengeri **Cushman and Renz, 1941,** *Contrib. Cushman Lab. Foraminiferal Res.,* v. 17, p. 3, pl. 1, fig. 2.

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

Textularia pseudogramen **Chapman and Parr, 1937,** *Sci. Rep. Australian Antarctic Exp.,* v. 1, p. 153.

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

Trochammina globigeriniformis **(Parker and Jones).** Plate 1, Figs. 2, 3. *Lituola nautiloidea* Lamarck, var. *globigeriniformis* Parker and Jones, 1865, *Philos. Trans. R. Soc. London,* v. 155, pl. 17, fig. 96.

Trochammina squamata **Jones and Parker, 1860,** *Q. J. Geol. Soc. London,* v. 16, p. 304.

Trochamminoides proteus **(Karrer).** *Trochammina proteus* Karrer, 1865, *Sitzungsber. Kais. Akad. Wiss. Wien,* v. 52, Abt. 1, p. 494, fig. 8 (not figs. 1–7).

Unilocular genera. I did not try to assign specific names to any of the occasionally common unilocular specimens. However, I grouped them and counted the number of species to which they belonged. This number was used in counting the total number of species.

Uvigerina cylindrica **(d'Orbigny).** Plate 2, Fig. 4. *Clavulina cylindrica* d'Orbigny, 1852, *Prodr. Pal. Strat.,* v. 3, p. 94. For discussion of taxonomy, see Thomas (1980).

Uvigerina graciliformis **Papp, 1953,** Plate 2, Fig. 3. *Jahrb. Geol. Bundesanst.,* v. 16, p. 122, pl. 5A, figs. 5–7.

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

Uvigerina senticosa **Cushman, 1927,** Plate 2, Fig. 1. *Scripps Inst. Techn. Ser. Bull.,* v. 1, p. 159, pl. 3, fig. 14.

Uvigerina spinulosa **Hadley.** Plate 2, Fig. 2. *Uvigerina canariensis* d'Orbigny var. *spinulosa* Hadley, 1934, *Am. Paleontol. Bull.,* v. 20, p. 18, pl. 2, fig. 17. Occurs only in turbidites, Site 575.

Vaginulina advena **Cushman, 1923,** *Bull. U.S. Nat. Mus.,* v. 104, pt. 4, p. 134–135, pl. 39, figs. 1–4.

Vaginulina elegans **d'Orbigny, 1826,** *Ann. Sci. Nat.,* v. 7, p. 257, no. 1, modèles no. 54.

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

Vaginulina pacifica **Cushman and Hanzawa.** *Polymorphinella pacifica* Cushman and Hanzawa, 1936, *Contrib. Cushman Lab. Foraminiferal Res.,* v. 12, pt. 2, p. 47.

Vaginulina subelegans **Parr, 1950,** *BANZ Antarctic Res. Exp.,* ser. B, v. 5, pt. 6, p. 326, pl. 11, figs. 20a–b.

Vaginulina sublegumen **(Parr).** *Vaginulinopsis sublegumen* Parr, 1950, *BANZ Antarctic Res. Exp.,* ser. B, v. 5, pt. 6, p. 325, pl. 11, figs. 18a–b.

Vulvulina jarvisi **Cushman, 1932,** Plate 1, Fig. 8. *Contrib. Cushman Lab. Foraminiferal Res.,* v. 8, p. 84, pl. 10, fig. 10. In *V. jarvisi* the biserial portion is flat-sided, whereas *V. spinosa* is biconvex (see Douglas, 1973).

Vulvulina spinosa **Cushman, 1927,** Plate 1, Fig. 9. *Contrib. Cushman Lab. Foraminiferal Res.,* v. 3, pt. 2, p. 111, pl. 23, fig. 1. See *V. jarvisi.*
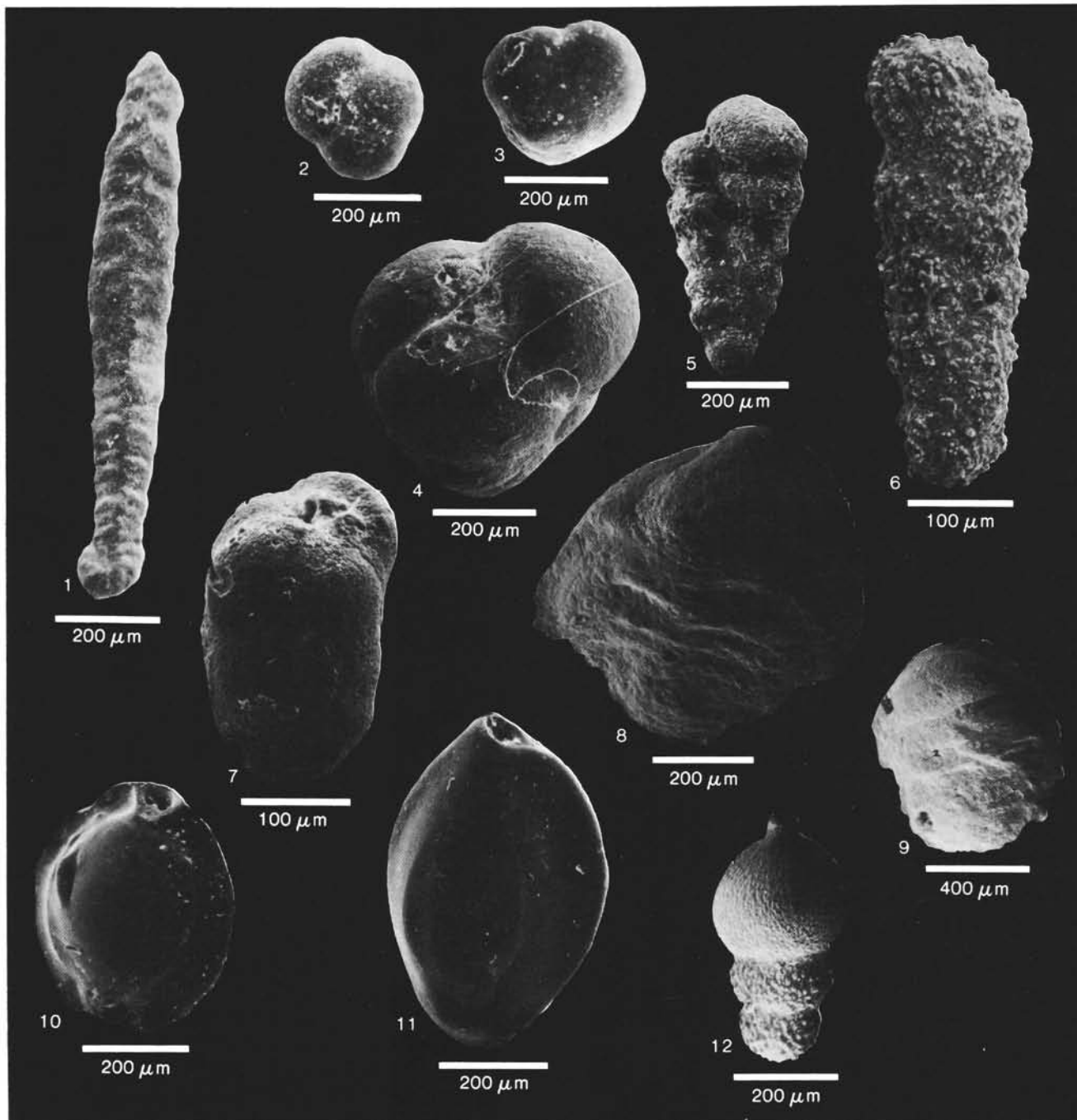
Plate 1. **1.** *Bolivinopsis cubensis*, Sample 573B-15,CC. **2–3.** *Trochammina globigeriniformis*, Sample 573-15,CC. **4.** *Eggerella bradyi*, Sample 574-25,CC. **5.** *Textularia agglutinans*, Sample 573-13,CC. **6.** *Bigenerina nodosaria* (juv.), Sample 574C-17,CC. **7.** *Gravellina narivaensis*, Sample 574C-30-1, 110–112 cm. **8.** *Vulvulina jarvisi*, Sample 574C-30,CC. **9.** *V. spinosa*, Sample 573B-30,CC. **10.** *Pyrgo murrhina*, Sample 573-16,CC. **11.** *Quinqueloculina* cf. *weaveri*, Sample 572A-14,CC. **12.** *Amphicoryna hirsuta*, Sample 573B-15,CC.
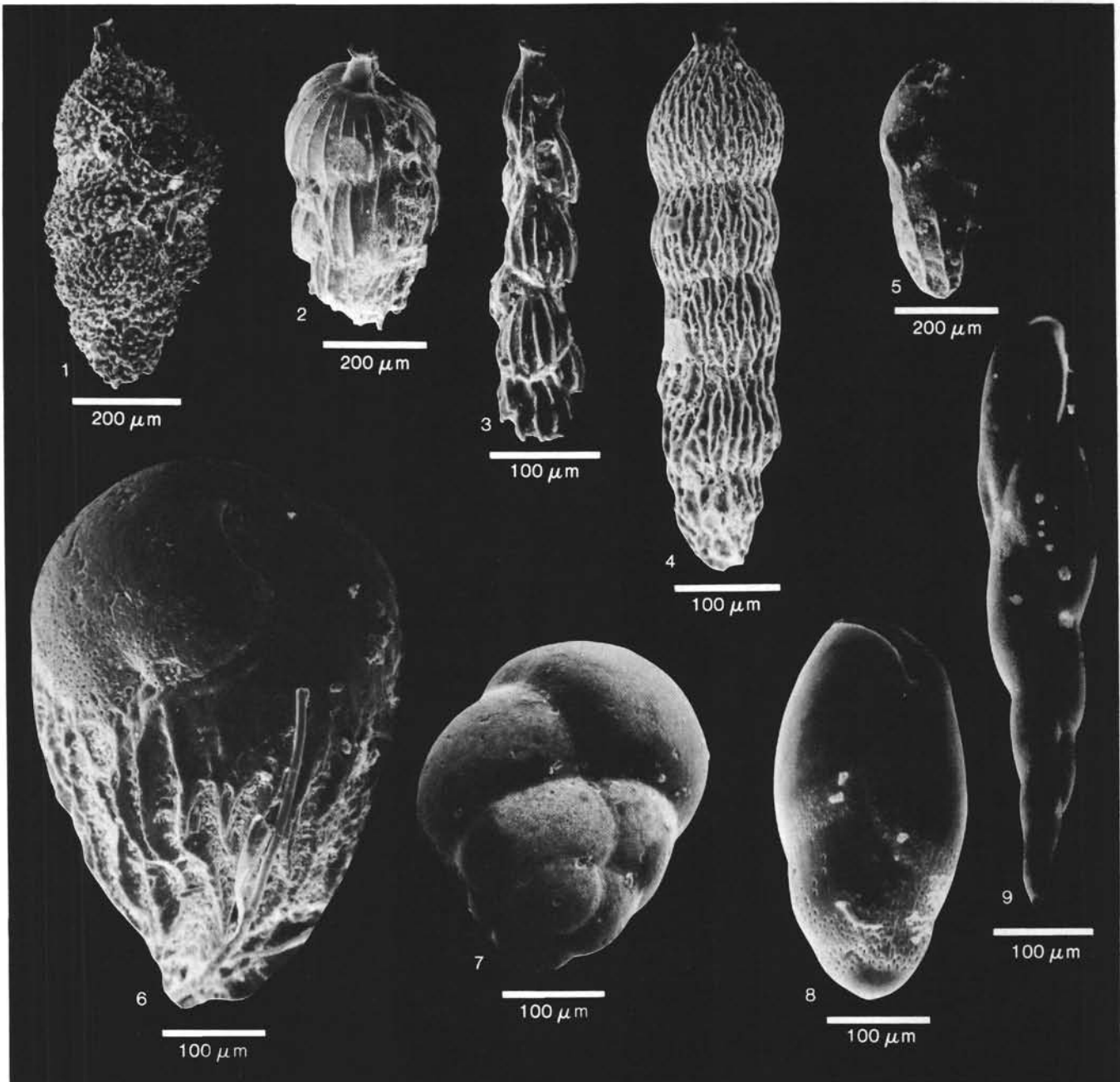
Plate 2. **1.** *Uvigerina senticosa*, Sample 572A-14,CC. **2.** *U. spinulosa*, Sample 575A-11-3, 109–111 cm. **3.** *U. graciliformis*, Sample 574-11,CC. **4.** *U. cylindrica*, Sample 573B-2,CC. **5.** *Bulimina microcostata*, Sample 573B-33,CC. **6.** *B. alazanensis*, Sample 574C-34-1, 138-140 cm. **7.** *Buliminella carteri*, Sample 575A-8,CC. **8.** *Francesita advena*, Sample 573-1,CC. **9.** *Stainforthia complanata*, Sample 573-1,CC.

Plate 3. **1.** *Bolivina huneri*, Sample 573B-31,CC. **2.** *B. capitata*, Sample 575A-8,CC. **3.** *B. striatula*, Sample 573B-14,CC. **4.** *B. translucens*, Sample 573-16,CC. **5.** *Fursenkoina pauciloculata*, Sample 573-1,CC. **6.** *F. ciperana*, Sample 574C-30-2, 110–112 cm. **7.** *F. bradyi*, Sample 573-17,CC. **8.** *F. cylindrica*, Sample 574C-35-1, 6–8 cm.
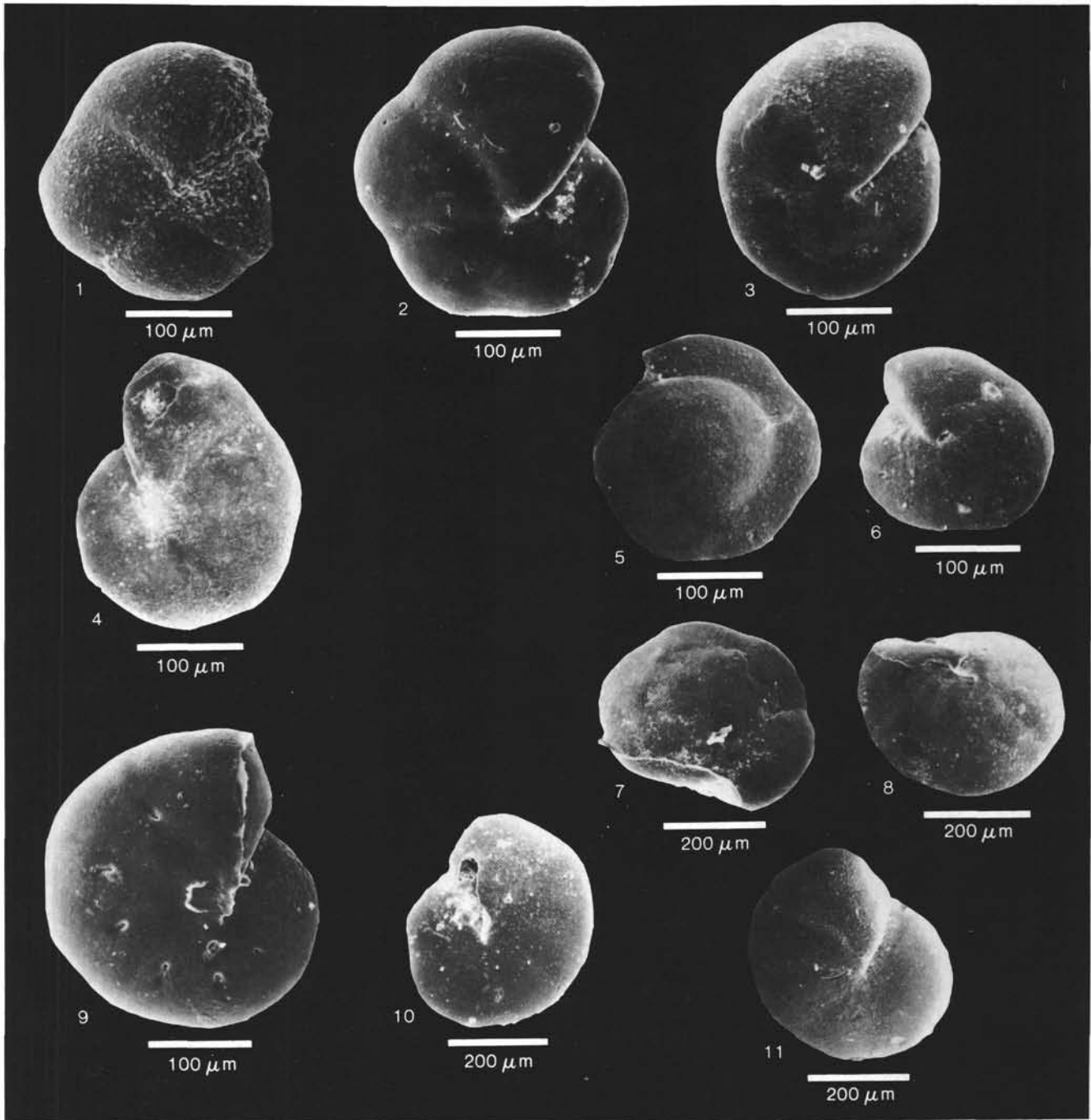
Plate 4. **1.** *Pullenia quadriloba*, Sample 574C-30-2, 110–112 cm. **2.** *P. quinqueloba*, Sample 574C-29-3, 96–98 cm. **3.** *P. subcarinata*, Sample 574C-29-3, 96–98 cm. **4.** *P. salisburyi*, Sample 573B-13,CC. **5–6.** *Oridorsalis tener*, Sample 573-17,CC. **7–8.** *O. umbonatus*, Sample 572A-14,CC. **9.** *Astrononion novozealandicum*, Sample 573-2,CC. **10–11.** *Nonion havanense*, (10) Sample 573B-37,CC, (11) Sample 573B-38,CC.
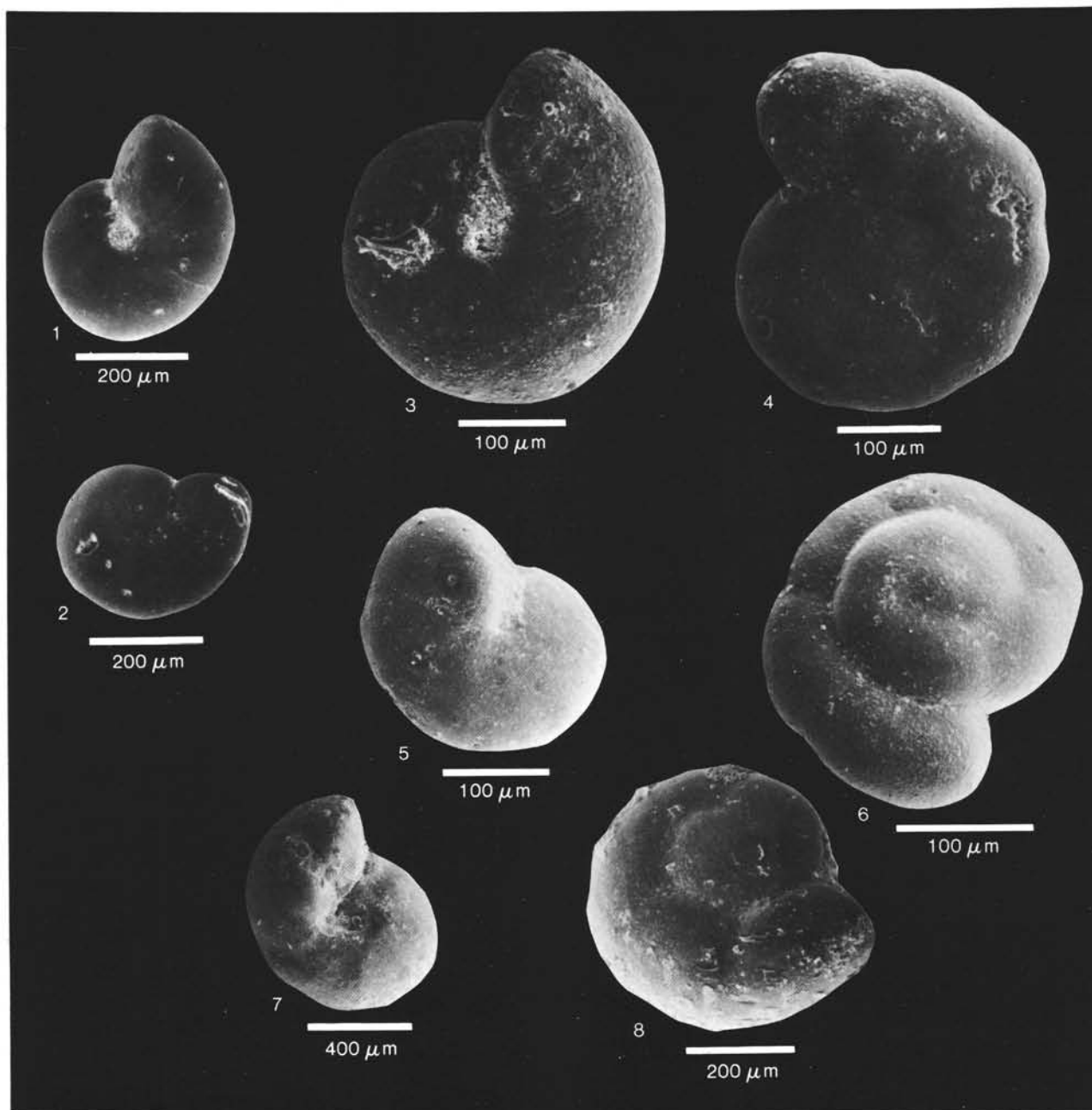
Plate 5. **1–2.** *Gyroidinoides lamarckianus*, Sample 573B-37,CC. **3–4.** *G. planulatus*, Sample 574C-34-1, 138–140 cm. **5–6.** *G. mediceus*, Sample 573B-9,CC. **7–8.** *G. globosus*, Sample 573B-40,CC.
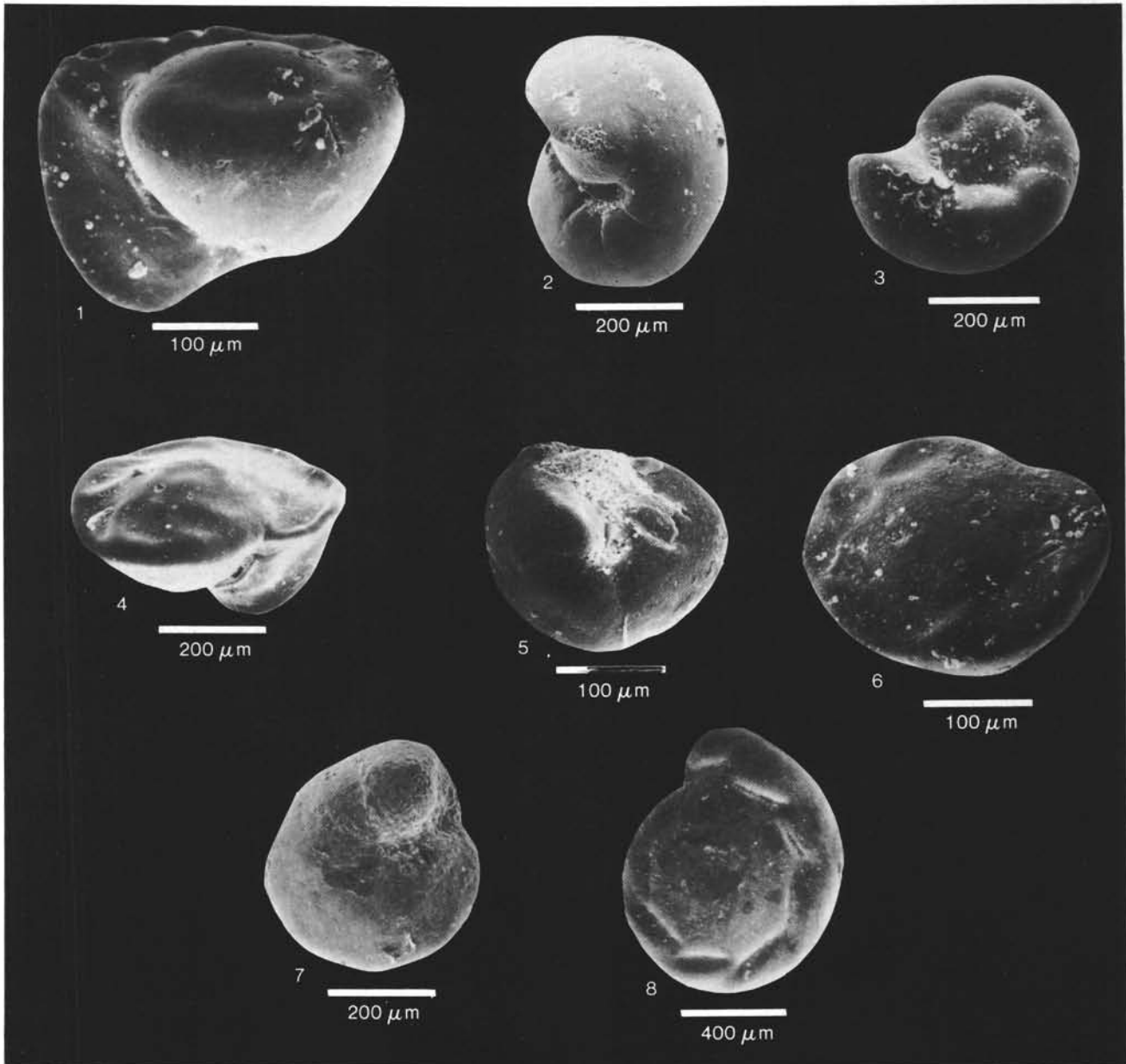
Plate 6. **1–3.** *Gyroidinoides girardanus*, Sample 574C-30-2, 110–112 cm. **4–6.** *G. acutus*, (4) Sample 573-2,CC, (5) Sample 573B-37,CC, (6) Sample 573B-37,CC. **7–8.** *G. soldanii*, Sample 573B-9,CC.
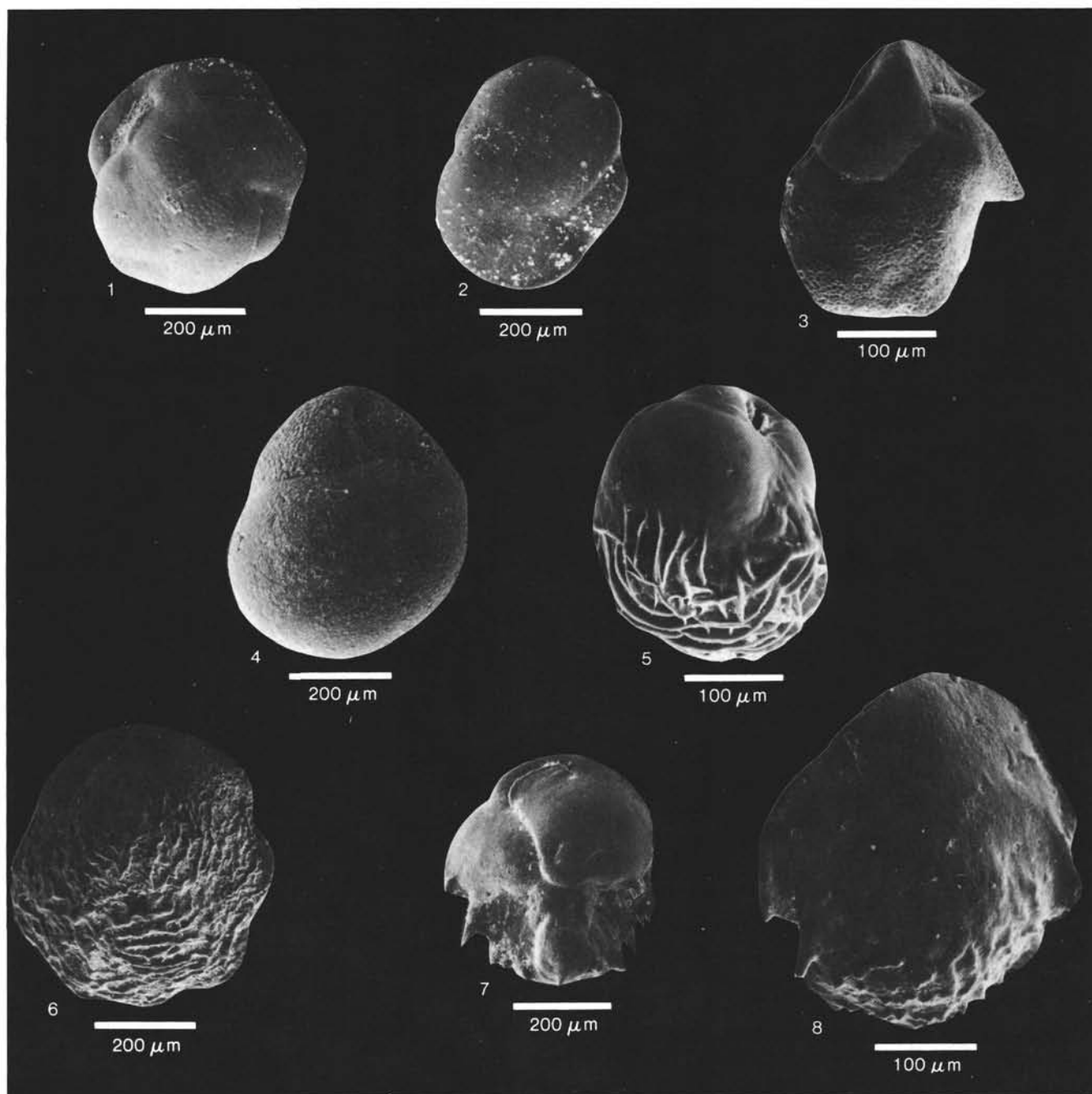
Plate 7. **1–2.** *Cassidulina havanensis*, Sample 573B-37,CC. **3.** *C. spinifera*, Sample 573B-16,CC. **4.** *Globocassidulina subglobosa*, Sample 573B-13,CC. **5.** *G. decorata*, Sample 573-4,CC. **6.** *Favocassidulina subfavus*, Sample 574-25,CC. **7.** *Ehrenbergina caribbea*, Sample 573-16,CC. **8.** *E. caribbea*, Sample 573B-13,CC.
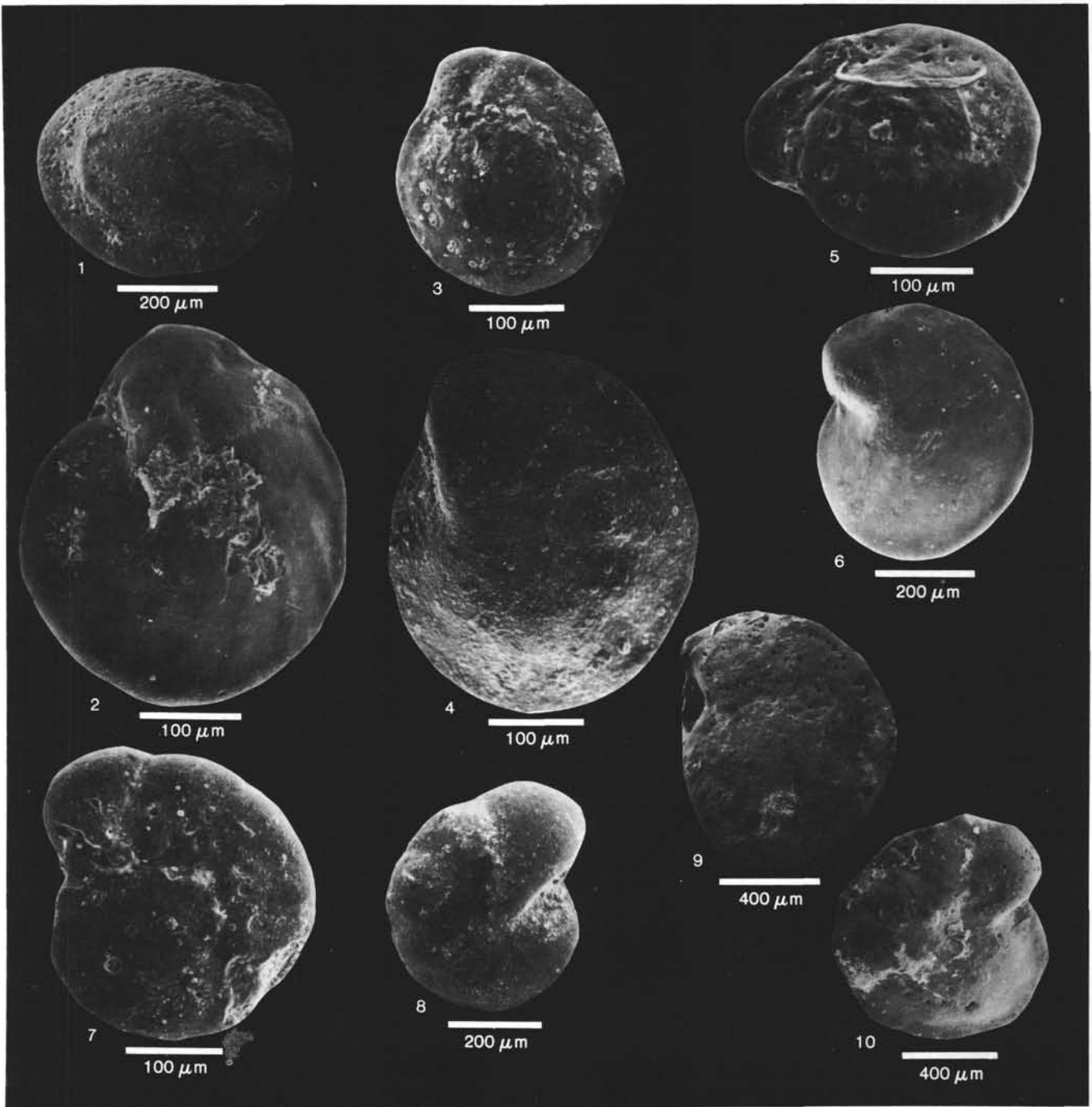
Plate 8. **1–2.** *Cibicidoides kullenbergi*, Sample 574C-30-1, 110–112 cm. **3–4.** *C. kullenbergi* var. *S.*, Sample 574-25,CC. **5–6.** *C. mundulus*, Sample 573-13,CC. **7–8.** *C. mollis*, Sample 574-23,CC. **9–10.** *Cibicidoides* aff. *mundulus*, Sample 574C-30-1, 110–112 cm.
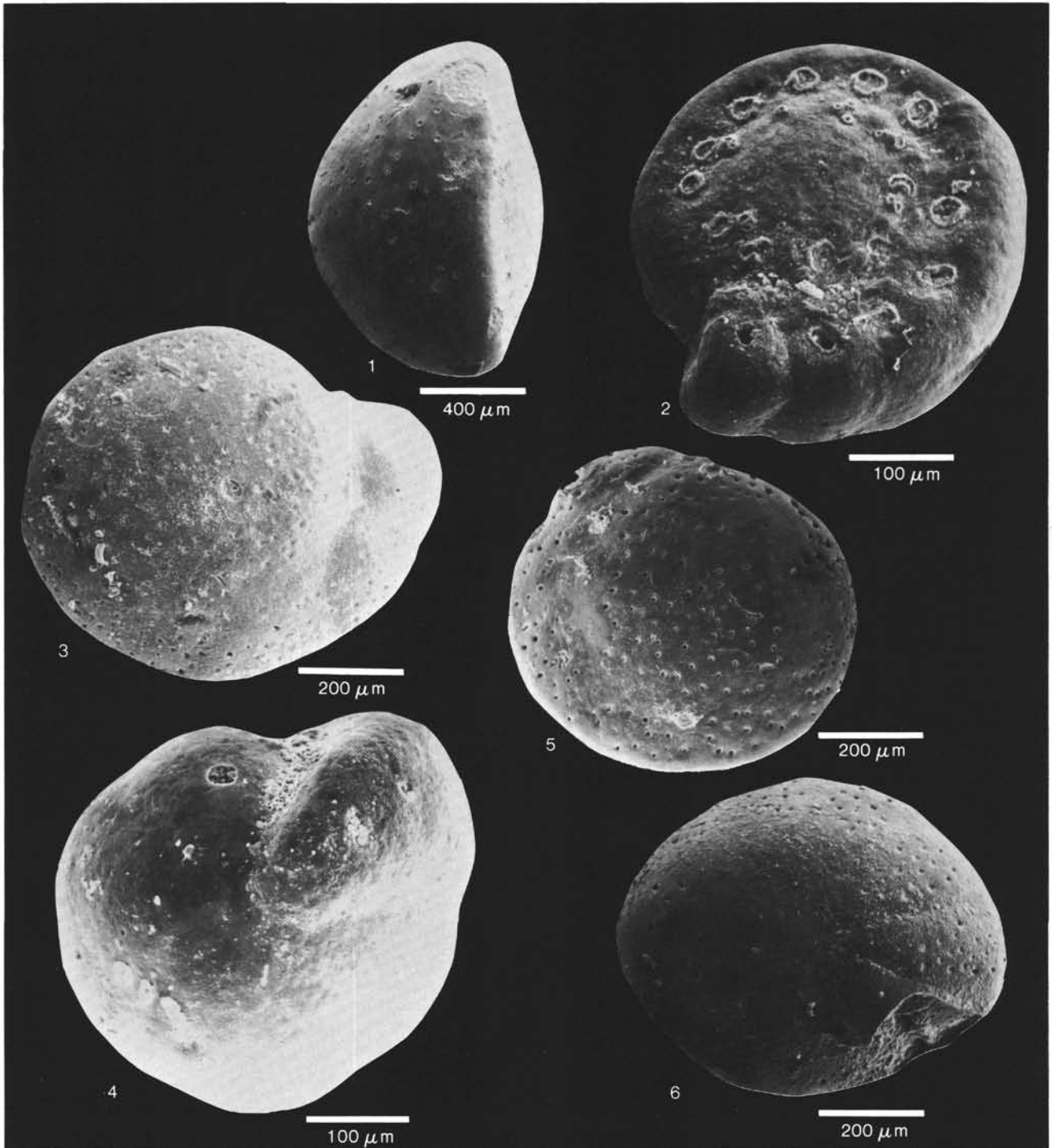
Plate 9. **1–2.** *Cibicidoides grimsdalei*, (1) side view, Sample 573-9,CC, (2) juvenile, Sample 574C-30-3, 110–112 cm. **3–4.** *C. mexicanus*, Sample 573B-37,CC. **5–6.** *C. perlucidus*, (5) Sample 574C-30-1, 110–112 cm, (6) Sample 574C-35-1, 109–111 cm.
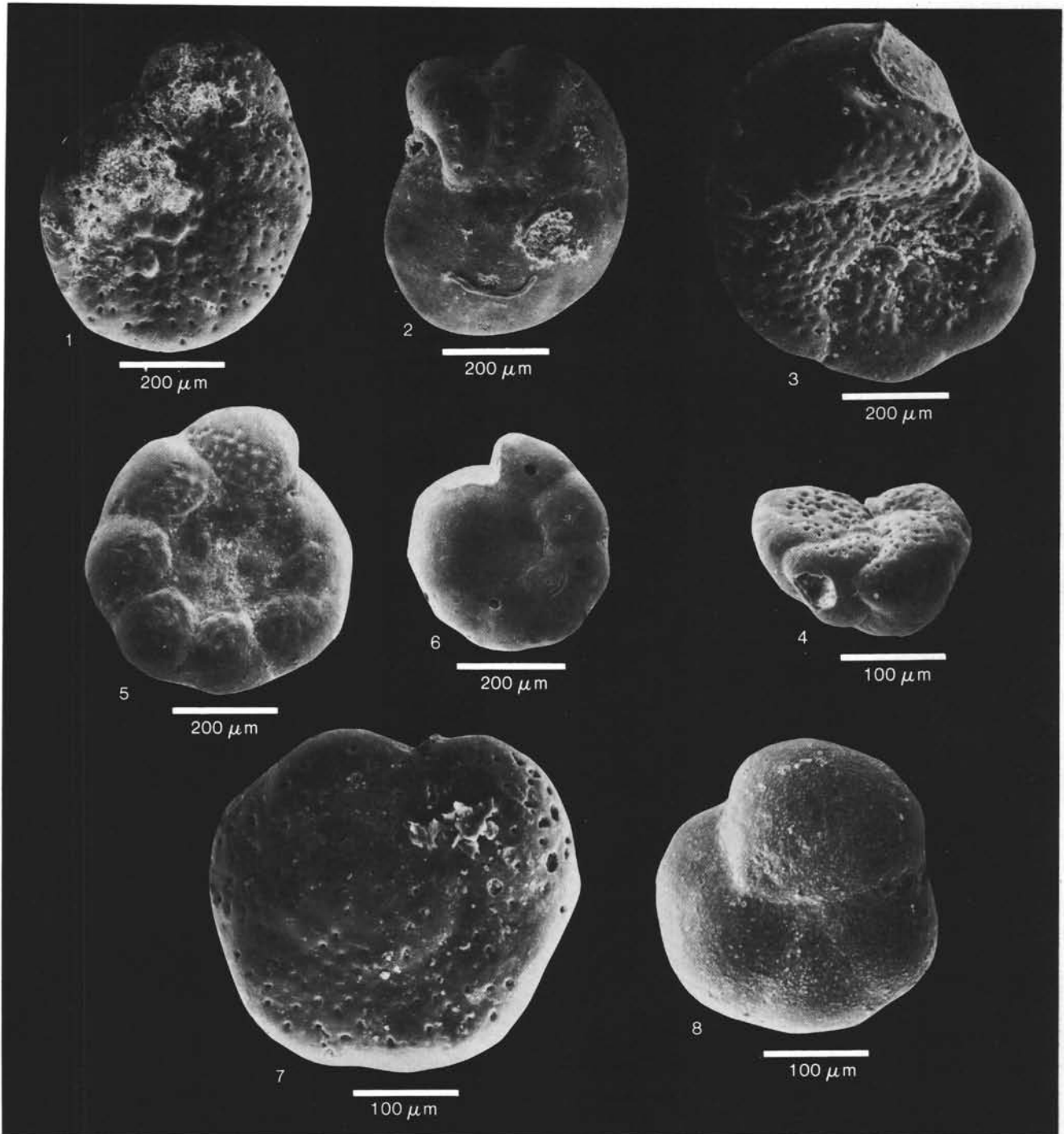
Plate 10. **1–2.** *Cibicidoides trinitatensis*, Sample 574C-30-1, 110–112 cm. **3–4.** *C. laurisae*, Sample 574C-30-2, 110-112 cm. **5–6.** *C. robertsoni-anus*, Sample 574C-30-2, 110–112 cm. **7–8.** *C. bradyi*, Sample 572-14,CC.
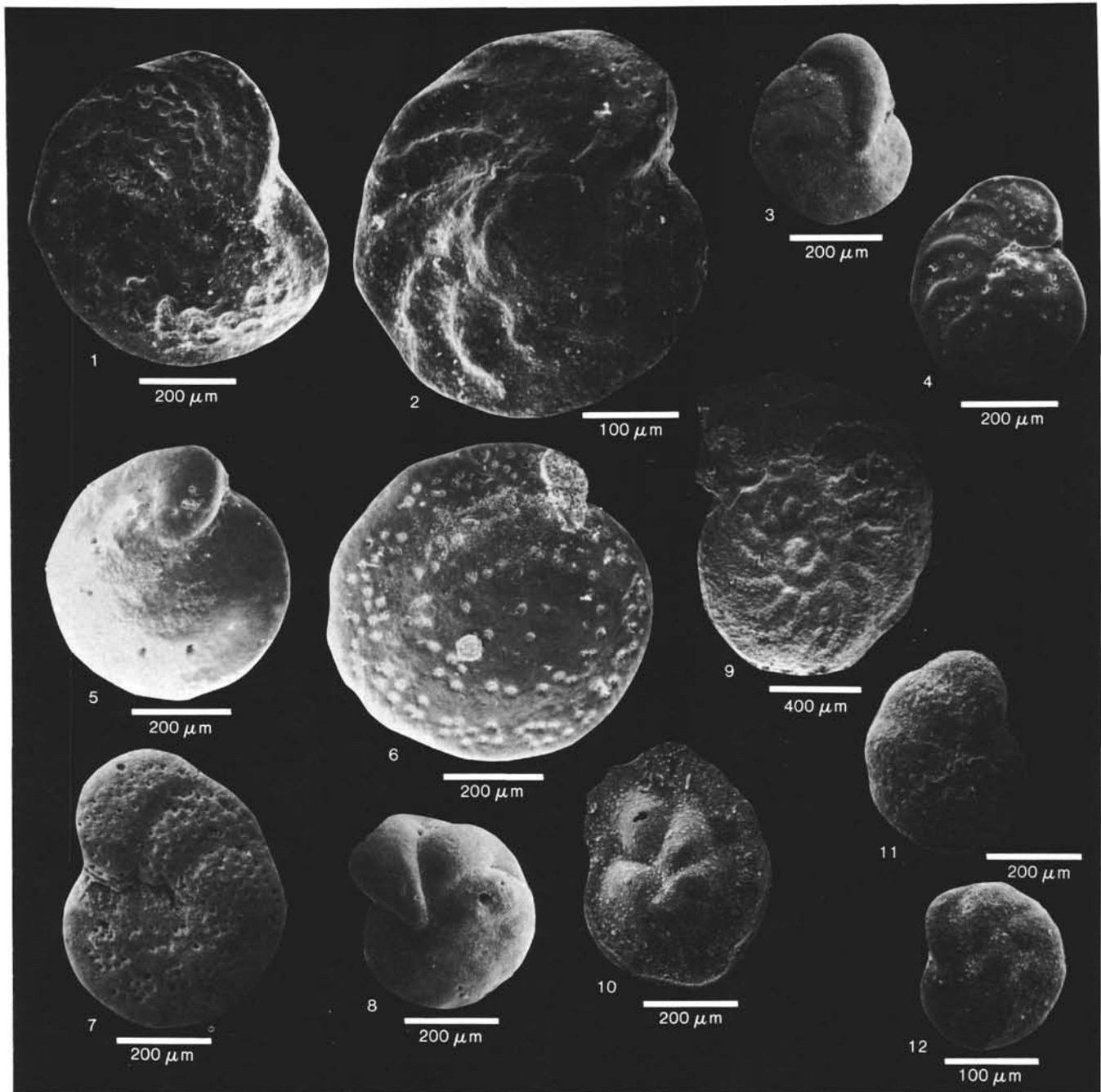
Plate 11. **1–2.** *Cibicidoides wuellerstorfi* (specimens from indurated sediments), Sample 574-25,CC. **3–4.** *C. wuellerstorfi* ("clean" specimen), Sample 573-3,CC. **5–6.** *C. pseudoungerianus*, Sample 573B-37,CC. **7–8.** *C. wuellerstorfi* var. *C.,* Sample 573-14,CC. **9.** *Planulina renzi*, Sample 575A-29-2, 128–130 cm (turbidite). **10.** *Laticarinina pauperata*, Sample 574-17,CC. **11–12.** *Gavelinella micra*, Sample 574C-35-1, 109–111 cm.
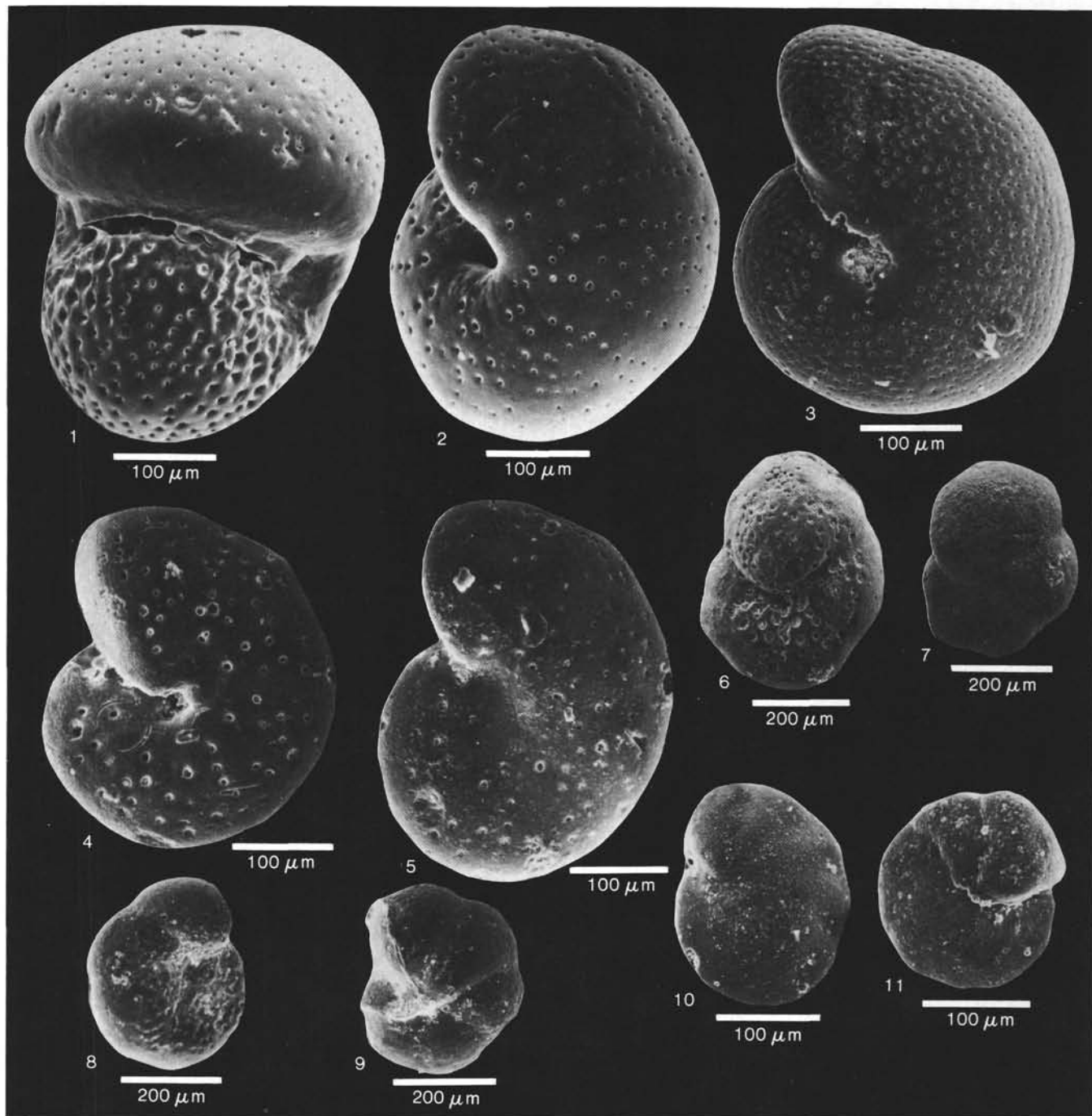
Plate 12. **1–2.** *Melonis pompilioides*, Sample 573-1,CC. **3.** *Melonis barleeanus*, Sample 572A-14,CC. **4–5.** *Anomalina alazanensis* var. *spissiformis*, Sample 574C-30-2, 110–112 cm. **6–7.** *Anomalinoides globulosus*, Sample 574C-34-1, 138–140 cm. **8–9.** *A. semicribratus*, Sample 573-9,CC. **10–11.** *A. acutus*, Sample 573B-28,CC.
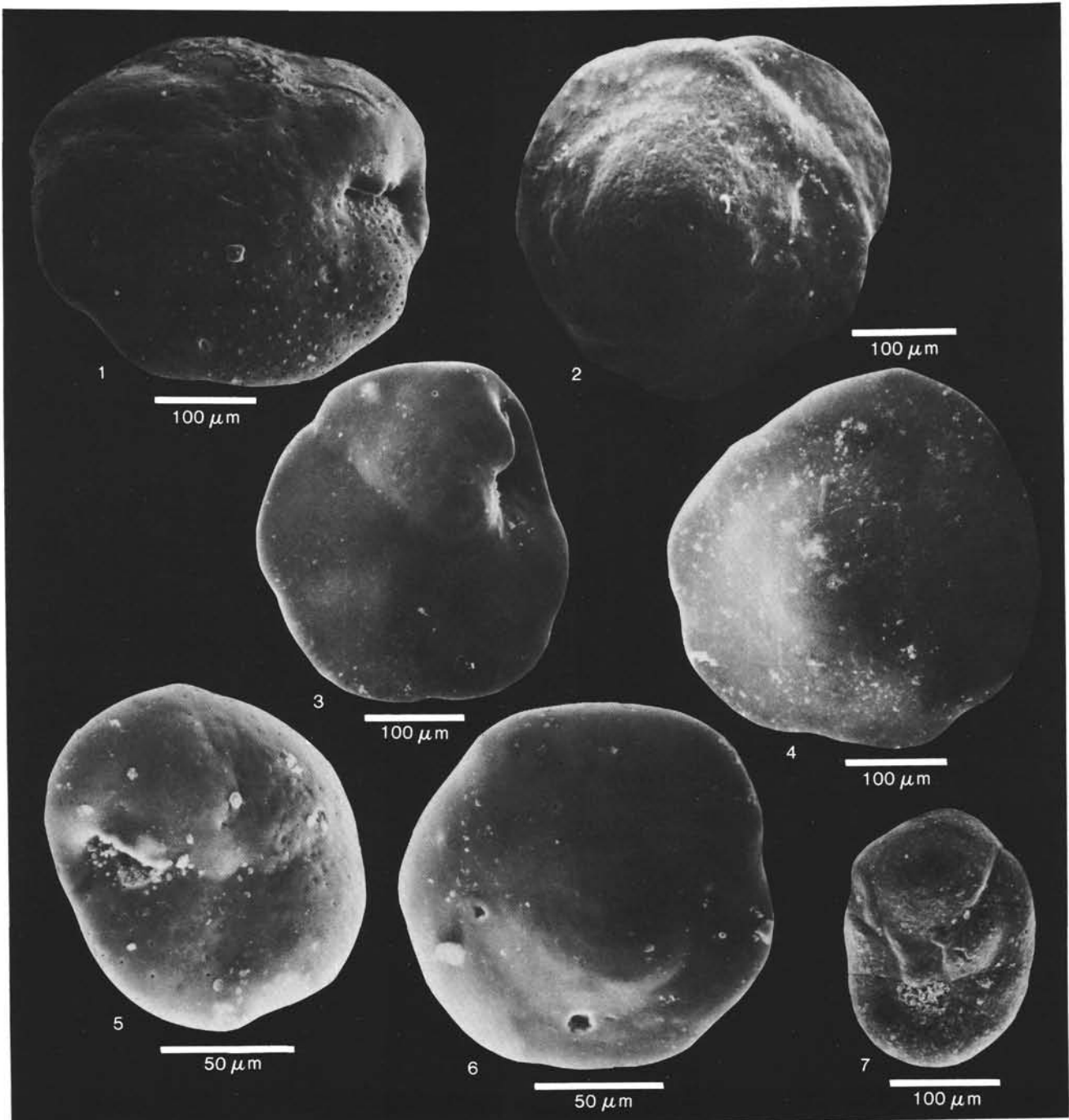
Plate 13.   **1–2.** *Nuttallides umbonifera*, Sample 573-3,CC.   **3–4.** *Epistominella exigua*, Sample 573-3,CC.   **5–6.** *Eilohedra weddellensis*, Sample 573-3,CC.   **7.** *Heronallenia lingulata*, Sample 573B-13,CC.
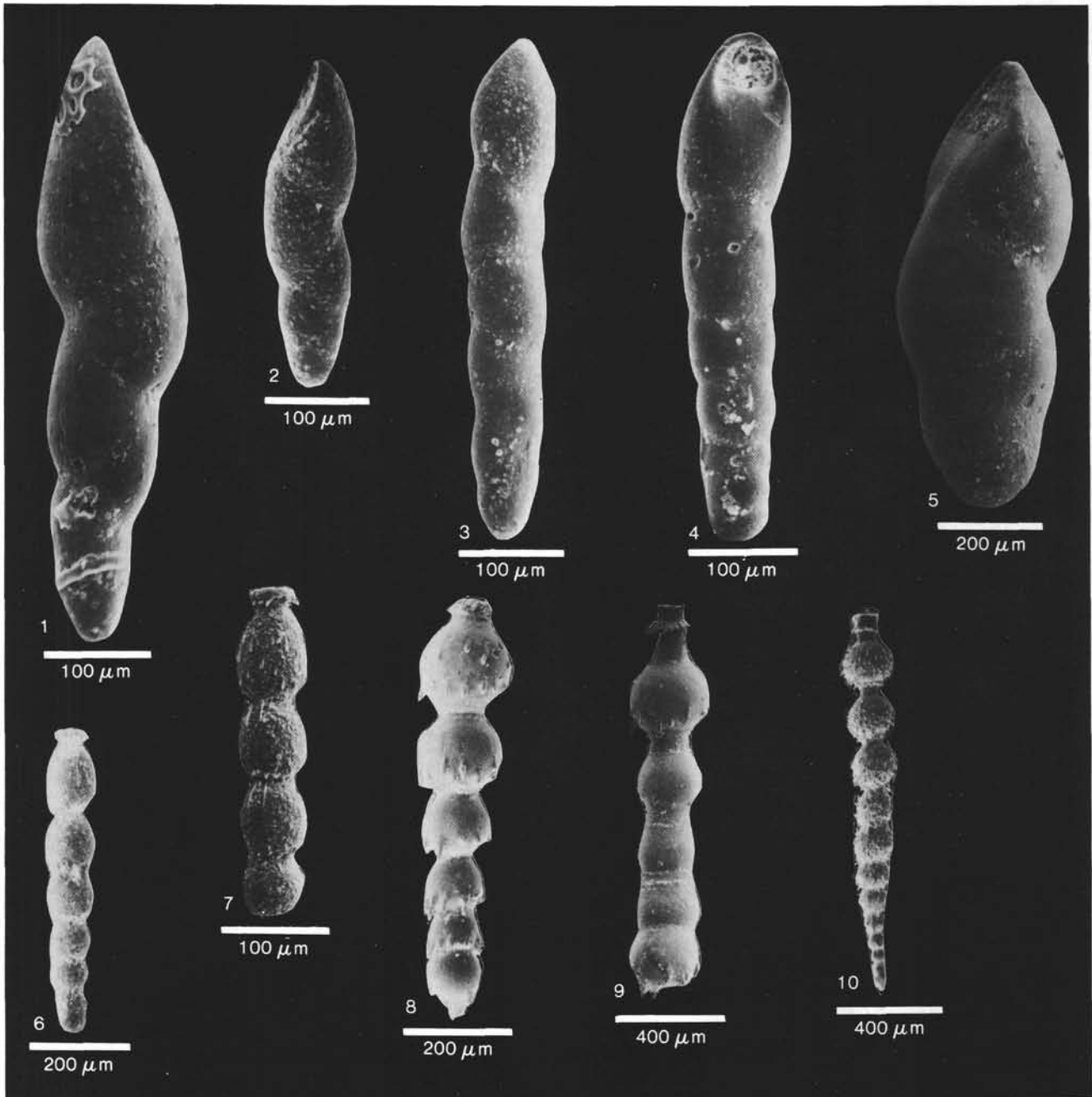
Plate 14. 1–2. *Pleurostomella acuta*, Sample 573B-14,CC. 3–4. *P. obtusa*, Sample 573B-37,CC. 5. *P. alternans*, Sample 574-17,CC. 6–7. *Stilostomella consobrina*, Sample 573-15,CC. 8. *S. lepidula*, Sample 575A-19,CC. 9. *S. abyssorum*, Sample 574C-35-1, 6–8 cm. 10. *S. subspinosa*, Sample 574-11,CC.
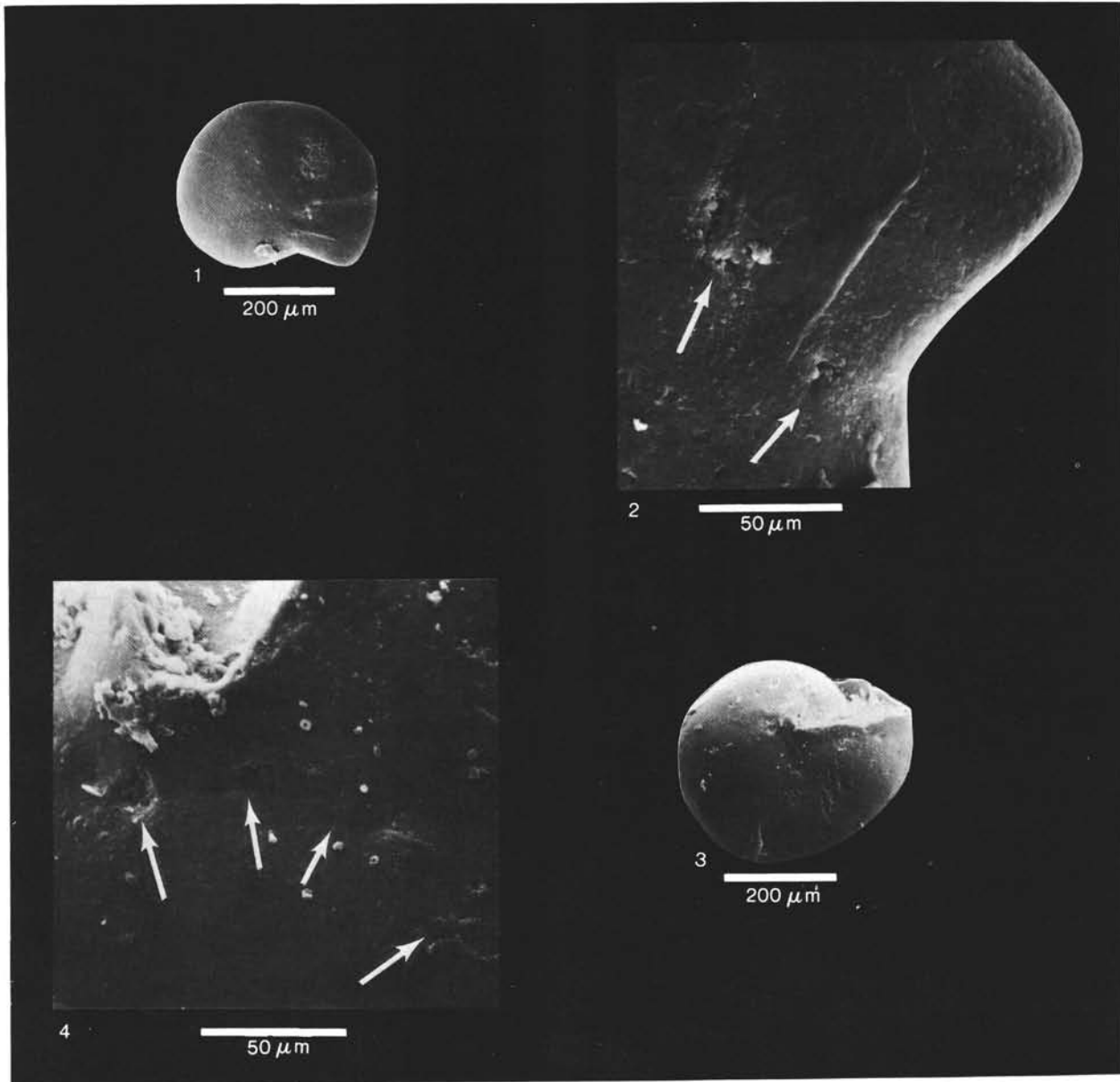
Plate 15.   1–2. *Ammonia*(?) sp., Sample 574C-35-2, 51–53 cm, (1) dorsal side, (2) detail from (1). Arrows indicate secondary apertures.   3–4. *Ammonia*(?) sp., Sample 574C-22,CC, (3) ventral side, (4) detail from (3). Arrows indicate secondary apertures.