45. LATE PLIOCENE-TO-HOLOCENE BENTHIC FORAMINIFERS OF THE GUAYMAS BASIN, GULF OF CALIFORNIA: SITES 477 THROUGH 481[1]

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ABSTRACT

Eight holes were drilled at five sites in the Guaymas Basin in the central part of the Gulf of California during Deep Sea Drilling Project (DSDP) Leg 64. Most of the sediment from these holes is from the Pleistocene-to-Holocene epochs. As indicated by planktonic foraminifers, the lowest section from Hole 479 is from the late Pliocene epoch. An unconformity occurs above the section. We classified the holes at the five sites into two groups by water depth. Sites 477 and 481 lie over two distinct spreading rifts, and Site 478 lies over the smooth floor; all three sites are in the central part of the Guaymas Basin at depths of around 2000 meters. Sites 479 and 480 are on the continental slope of the Guaymas Basin at depths of about 700 meters in the present oxygen-minimum zone. Samples from each group of holes contain benthic foraminiferal fauna similar to the fauna currently found in the bottom sediment of the same depth in the Gulf of California. No significant faunal changes with depth occur in any hole. Downslope displacement of benthic foraminifers is frequent in deeper basin-floor holes, but is not significant in shallower slope holes. This evidence agrees with the sediment characteristics; turbidites are frequently intercalated in the sequences of deeper holes, whereas the sequences in shallower holes consist chiefly of laminated or homogenized ooze or mud. The vertical frequency distribution of some benthic foraminiferal species known to live in an anaerobic environment demonstrates the low-oxygen condition in Holes 479 and 480, which are in the present oxygen-minimum zone. The distribution also suggests that the oxygen-minimum zone at this depth in the Gulf of California reappeared in the early late Pleistocene epoch after its disappearance during an interval in the middle Pleistocene epoch. Magnetic-anomaly profiles indicate that the present phase of spreading in the Gulf of California probably began in the early Pliocene epoch. A proto-Gulf of California probably existed before the present phase of separation from Baja California. The upper Pliocene sediment at the lowest part of Hole 479 seems to belong to an earlier phase of Gulf history. The unconformity between the upper Pliocene and the younger sediments was formed during the early Pleistocene epoch and not during the beginning of the present phase of spreading. Previous reports on the foraminifers of Carmen Island in the Gulf also suggest that a vertical tectonic movement occurred in the early Pleistocene epoch in the Gulf of California.

INTRODUCTION

DSDP Leg 64 included two distinct drilling areas: off the tip of Baja California and the Guaymas Basin in the central part of the Gulf of California (Fig. 1). We studied late Pliocene-to-Holocene benthic foraminifers in samples from five sites in the Guaymas Basin. The samples also contained planktonic foraminifers (see Matoba and Oda, this volume). One of the purposes of drilling in the Guaymas Basin was to investigate the paleoceanography and paleoenvironment of the Gulf of California during its present phase of spreading. Magnetic-anomaly profiles indicate that spreading probably began about 4 Ma (Larson et al., 1968).

Sites 477 and 481 lie, respectively, over the south and north spreading rifts of the central Guaymas Basin and are separated by a 20-km transform fault. Site 478 lies over the smooth basin floor. The Quaternary sediment of these sites is intruded by basaltic sills. Sites 479 and 480 lie over the northern continental slope of the Guaymas Basin, within the water depth of the present oxygen-minimum layer and over the sediment of the proto-Gulf of California (Moore, 1973). The sediment is Quaternary, except for late Pliocene cores recovered from the lowest section of Hole 479 (Matoba and Oda, this volume).

Bandy (1961) and Phleger (1964, 1965) studied recent depth distribution of benthic foraminifers in the Gulf. Ingle (1967b) compared both data. Brenner (1962) and Phleger and Ayala-Castañares (1969) reported the areal distribution of shallow-water benthic foraminifers. Recent sediment samples from the Gulf of California were included in the taxonomic studies of Cushman and McCulloch (1939, 1940, 1942, 1948, 1950) and McCulloch (1977). Natland (1950), Smith (1970), and Ingle (1973c, 1974) reported on upper Miocene-to-Pleistocene foraminifers from land sections of islands in the Gulf of California and from land sections and wells in the northern extension of the Gulf. Moore (1973) studied the Miocene-to-Pleistocene foraminifers of some dredged rocks from the continental slope in the Gulf. Many studies have been made on the ecology and distribution of Recent benthic foraminifers off the west coast of North America. Among those, some of the important papers are as follows: Cushman (1927a), Natland (1933, 1938), Bandy (1953), Bandy and Arnal (1957a), Bandy and Chierici (1966), Walton (1955), Uchio (1960), Smith (1964), Lankford and Phleger (1973), Douglas and Heitman (1979), and Bergen and O'Neil (1979).

GEOGRAPHIC AND OCEANOGRAPHIC SETTING

The Gulf of California is a long, narrow marine basin approximately 1200 km long and 150 km wide. It is open to the Pacific at the southeastern end and closed at the northwestern end. Shepard (1950) and Rusnak et al.

[1] Curray, J. R., Moore, D. G., et al., *Init. Repts. DSDP*, 64: Washington (U.S. Govt. Printing Office).

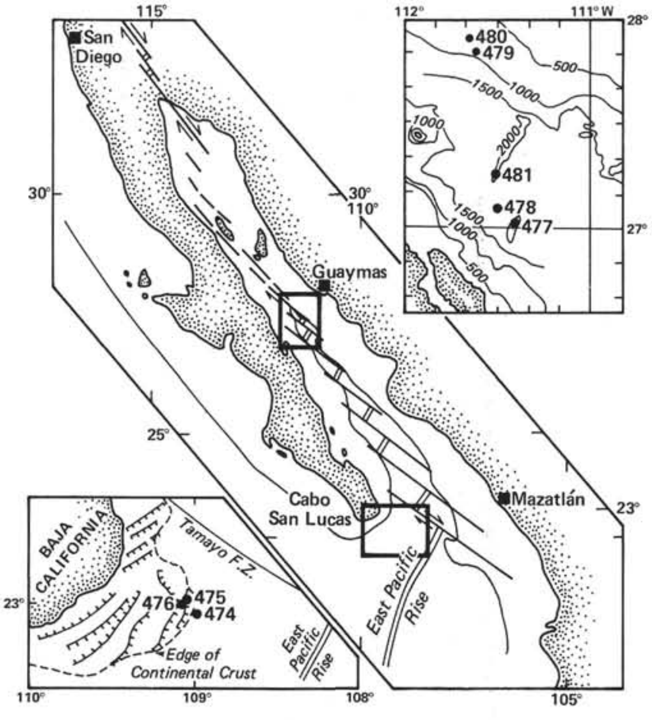


Figure 1. Guaymas Basin drilling sites, DSDP Leg 64.

(1964) reported on the bathymetry of the Gulf, and Bischoff and Niemitz (1979) published a bathymetry chart. Van Andel (1964) studied Recent sediment, and Roden and Groves (1959) and Roden (1964) reported the results of oceanographic observations.

The northern area of the Gulf is relatively shallow, mostly less than 200 meters. The Colorado River flows into the Gulf at the northwestern end. The central and southern Gulf is characterized by a series of deep basins along its axis, deepening from 980 meters in the northwest to 3700 meters at the entrance to the Pacific in the southeast. The basins are separated by sills, which also deepen southeastward from 880 to 3300 meters. The Guaymas Basin in the central Gulf is the largest, and the maximum depth exceeds 2000 meters, with the sill depth at about 1500 meters. The basin has a smooth floor, gently sloping to the central part where it encounters two rifts of a north–northeast trend (Fig. 1). Each rift is flat floored and has a depth of about 150 meters below the smooth basin floor.

Most of the adjacent land is arid, and runoff into the Gulf is small; hence, evaporation exceeds precipitation. The permanent streams are only on the mainland, southeast of Guaymas. The Colorado River, which once supplied the Gulf with abundant fresh water and sediment is now a negligible source. The surface-water salinities are thus higher than those near the entrance to the Pacific. In the northern Gulf, the annual range of the surface water temperature varies from approximately 15°C to 30°C. This is much warmer than that of the same latitude outside the Gulf in summer but nearly equal or colder in winter. In the southern Gulf, it ranges from about 21°C to 30°C. In the winter, considerable upwelling occurs along the northeastern side because of northwesterly winds; along the peninsula coast, the same occurs in summer with southeasterly winds (Roden, 1964). The result is extremely high plankton productivity (van Andel, 1964).

The surface of the Gulf is derived chiefly from the tropical equatorial Pacific water modified by evaporation. It contains tropical planktonic and benthic faunas in the southern Gulf. The cool California Current flows southeastward along the western side of the peninsula and converges with the northern equatorial water between 25°N and the tip of the Baja California peninsula (Sverdrup et al., 1946). In the central and southern Gulf, the water below the bottom of the thermocline is identical in salinity and temperature to the equatorial Pacific water. The oxygen-minimum zone (<0.2 ml/l) occurs between 400 and 800 meters (Roden, 1964).

METHODS

Benthic foraminifers occur in 164 of the 258 samples from Holes 477 through 481A. Each sample consists of about 10 cm^3 of sediment. We disaggregated the samples by soaking them in hot water. Depending on the consolidation of sediment, varying amounts of hydrogen peroxide were added. We washed the disaggregated samples through a 250-mesh (0.063-mm) screen and then dried them. Several samples, especially those from the upper few cores from each hole, contained abundant diatom remains and flocculated when dried. We boiled the samples in a concentrated solution of sodium hydroxide to dissolve the diatoms and then washed them again. Before extracting the foraminifers, we sieved each sample through a 115-mesh (0.125-mm) screen; the benthic foraminifers were taken from the coarser fraction. In instances where benthic foraminifers were especially abundant, the samples were split into workable sizes, and 150 to 250 specimens were removed.

We distinguished 154 taxa of benthic foraminifers, including named and unnamed species, subspecies, and morphotypes. The results are given in Tables 1 through 3, where the occurrence is presented in percentages (we calculated no percentages for samples containing less than 10 specimens). The stratigraphic occurrence of several selected species is shown in Figures 4 through 8.

PRESERVATION AND ABUNDANCE

Figure 2 shows preservation, abundancies of benthic and planktonic foraminifers, and ratios of planktonic to benthic foraminifers. There are two categories for poor or very poor preservation: dissolution and thermal alteration. All benthic foraminifers have calcareous tests, and we found no agglutinated foraminifers insoluble in acid. In the samples near basaltic sills, there is a change in the foraminiferal tests: The test wall changes to brown or, in extreme cases, is completely recrystallized. Except for the effect of alteration, preservation is generally better in the deeper holes than in the shallower ones (i.e., Holes 479 and 480). In Holes 479 and 480, within the present oxygen-minimum zone, preservation is poor or very poor because of strong dissolution.

All of the benthic foraminifers have calcareous tests, and no agglutinated foraminifers were found, although many agglutinated foraminiferal species have been recorded from the surface sediments in the Gulf of California (Phleger, 1964, 1965). Hydrogen peroxide, which was used to disaggregate the sediments, may have decomposed the organic cement and lining of most of the agglutinated tests; the result may have been the destruction of agglutinated foraminifers. Furthermore, several samples were boiled in a concentrated solution of sodium hydroxide to dissolve diatom silica. This treatment may have destroyed all the agglutinated tests. No faunal difference, however, occurs between samples treated or not treated in this manner. This suggests that all the agglutinated tests were destroyed before the sodium hydroxide treatment—probably a result of the hydrogen peroxide. Therefore, abundances of benthic foraminifers and ratios of planktonic to planktonic and benthic foraminifers in this study are different from those in the studies of surface sediments.

We calculated the abundance of benthic and planktonic foraminifers for each 10 ml of sediment. Abundance seems to be related to preservation. In the deeper holes, planktonic foraminifers are more abundant than benthic foraminifers. But in many samples from the shallower holes, there are fewer planktonic than benthic foraminifers, and in some samples planktonic foraminifers are absent entirely. Parker and Berger (1971) suggest that this is the result of selective dissolution of planktonic foraminifers—a function of preservation. Calcareous benthic tests were more resistant to solution than planktonic tests. In the lower sections of Hole 479, dissolution is especially significant. Of 35 samples from Cores 479-29 through 479-41, only 8 yielded benthic foraminifers and were very poorly preserved. We found no planktonic tests within the interval.

CORRELATION AND AGE BASED ON PLANKTONIC FORAMINIFERS

Planktonic foraminifer samples from the Guaymas Basin used by Matoba and Oda (this volume; Pt. 2) are the same as those of this chapter on benthic foraminifers. Figure 3 shows the results of correlation and age assignment. All the sequences are Quaternary, except for the late Pliocene cores in Hole 479 below Section 479-42,CC. The presence of benthic foraminifers indicates that the late Pliocene fauna extends upward to Sample 479-40-3, 43–45 cm, and an unconformity occurs just above the horizon. A comparison with changes in planktonic foraminiferal fauna which occurred during the Quaternary epoch in Hole 173 (off northern California and under the California Current) (Ingle, 1973a, 1973b; Keller, 1978) suggests that the interval D-D′ in the Guaymas Basin, which is characterized by abundant occurrences of *Neogloboquadrina pachyderma* forma A and *N. pachyderma* (s. s.), is correlated to a middle Pleistocene interval dated 0.7 to 0.92 Ma (Keller, 1979). But Schrader (this volume) discovered *Mesocena elliptica*, a silicoflagellate, in the interval between Sections 479-39,CC and 479-32, CC, dated 0.93 and 0.7 Ma, respectively, for the first and last occurrences of the species.

Cooler and warmer oceanographic fluctuations existed in the Guaymas Basin sequence, and we noted three cooler intervals in the middle-to-upper Pleistocene sections, although the faunal difference was not large. The late Pliocene epoch was generally warmer than was the middle to late Pleistocene and was dominated by species of *Globigerinoides*.

SITE 477

The occurrence of benthic foraminifers in Holes 477 and 477A is shown in Table 1, and Figure 4 shows the stratigraphic distribution of selected species. Only eight samples from Holes 477 and 477A yielded benthic foraminifers. The two basal samples (477-20-1, 90–92 cm and 477A-5-1, 51–53 cm) contained a small number of specimens, and we identified *Uvigerina peregrina curticosta, Buliminella tenuata, Bolivina seminuda*, and a few others. In the upper section of Hole 477, *Bolivina seminuda* is the most common, and *Buliminella tenuata, Bolivina pacifica, B. subadvena* forma A, *Brizaliba argentea* forma A, *"Islandiella" cushmani, Uvigerina peregrina curticosta, Epistominella smithi, Fursenkoina cornuta*, and *Cassidulina subcarinata* are abundant.

SITE 478

The occurrence of benthic foraminifers in Hole 478 is shown in Table 1, and the stratigraphic distribution of selected species is illustrated in Figure 5. *Uvigerina peregrina curticosta* and *Epistominella smithi* are the most common species nearly throughout the hole. *Epistominella* cf. *pacifica* and *Cassidulina subglobosa* are abundant only in the lowest section. *E.* cf. *pacifica* occurs only in this hole. *Oridorsalis umbonatus* is abundant in two intervals: the lower and uppermost sections of the hole. *Buliminella tenuata, Bolivina seminuda, "Islandiella" cushmani, Valvulineria araucana, Fursenkoina cornuta, Gyroidina*(?) *gemma* are abundant in some separate sections. Many species that commonly occur in one or two samples occur only sporadically in the other part of the section.

SITE 479

Table 2 shows the occurrence of benthic foraminifers in Hole 479, and Figure 6 shows the stratigraphic distribution of selected species. In the lowest part of this hole, below Sample 479-40-3, 25–27 cm, the benthic fauna differs somewhat from that in the upper section. The lowest part of the section, below Section 479-42,CC is upper Pliocene, as determined by planktonic foraminifers (Matoba and Oda, this volume), but planktonic foraminifers were absent in the interval between Cores 479-29 and 479-41. Therefore, the upper limit of the Pliocene is the horizon above Sample 479-40-3, 25–27 cm. *Buliminella curta basispinata* (this subspecies is included in *B. curta* in Table 2 and Fig. 6), *Bolivina* cf. *humilis, Pseudoparrella* sp. C, and *Hanzawaia*(?) sp. A are abundant but confined to the Pliocene cores. *Cassidulina tumida, Suggrunda eckisi, Gyroidina*(?) sp. A, and *Pseudoparrella bradyana* are abundant in these cores but rarely occur in the Quaternary section of the hole. *Bolivina seminuda, B. subadvena* forma A, and *"Islandiella" cushmani* are very abundant throughout the Pliocene and Quaternary parts of the hole. *Buliminella curta* (s.l.) and *Bolivina subadvena* forma B are abundant in the Pliocene and in the lower part of the Quaternary sections. *Buliminella tenuata, Brizalina ar-*

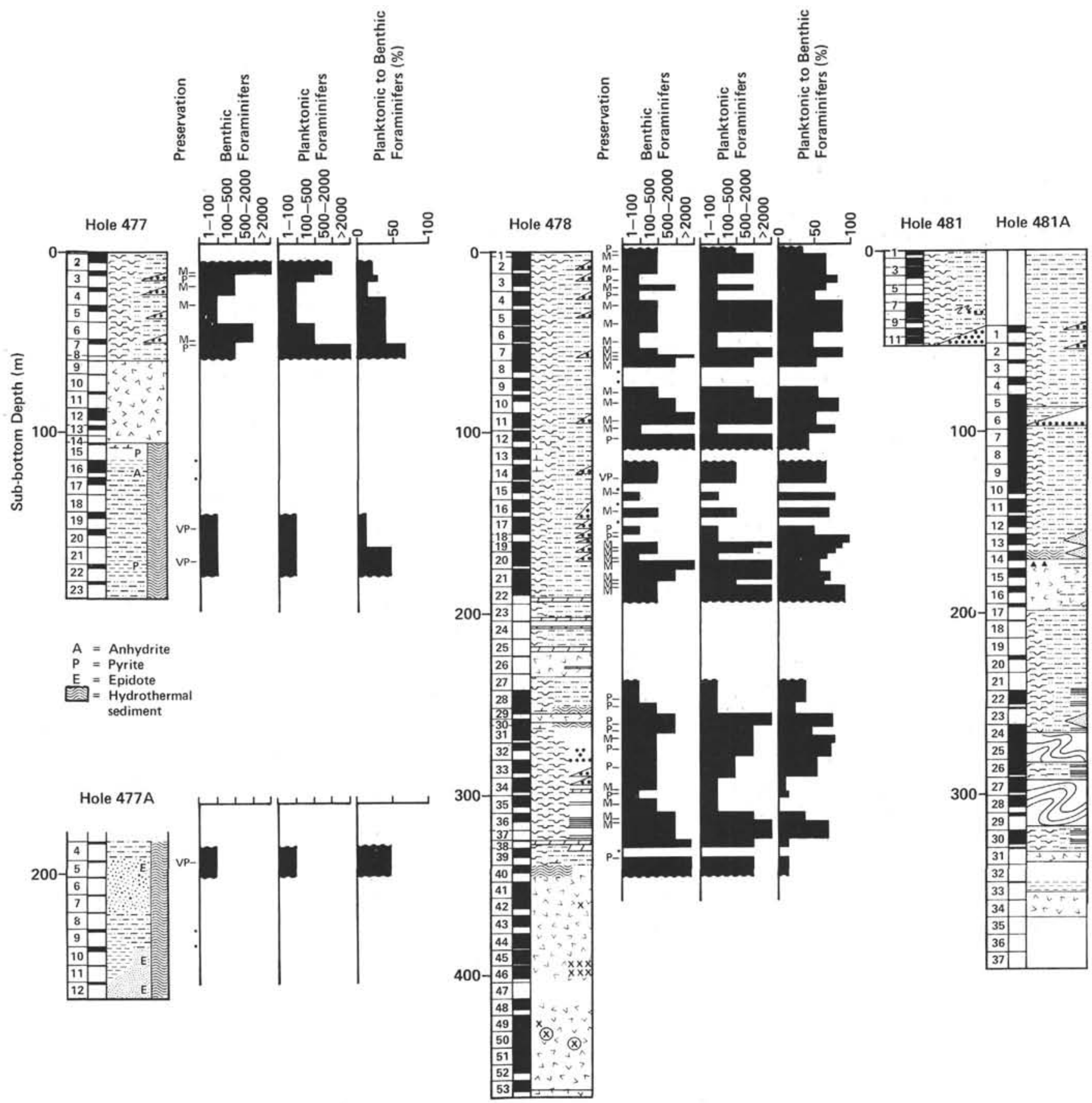


Figure 2. Preservation, abundance of benthic and planktonic foraminifers, and ratio of planktonic to benthic foraminifers at each site in the Guaymas Basin. (Preservation: M = moderate, P = poor, VP = very poor. Abundance calculated for number of specimens per 10 ml of sediment.)

gentea forma A and B, *B. spissa, B. semiperforata, Bolivina subadvena* forma C, *Uvigerina peregrina curticosta, "Loxostomum" pseudobeyrich*, and *Epistominella smithi* are abundant and generally confined to the Quaternary section, but some range downward to the Pliocene section.

SITE 480

The occurrence of benthic foraminifers in Hole 480 is shown in Table 2 and the stratigraphic distribution of selected species in Figure 7. *Bolivina seminuda* is common throughout the hole. *B. subadvena* forma A and C are abundant in the upper section. *Buliminella tenuata, Brizalina argentea* forma A and B, and *"Islandiella" cushmani* are also abundant in several samples. *Brizalina spissa* is abundant only in the upper portion of the hole.

SITE 481

Table 3 and Figure 8 show the occurrence and stratigraphic distribution of benthic foraminifers in Holes 481 and 481A. *Uvigerina peregrina curticosta, Epistom-*

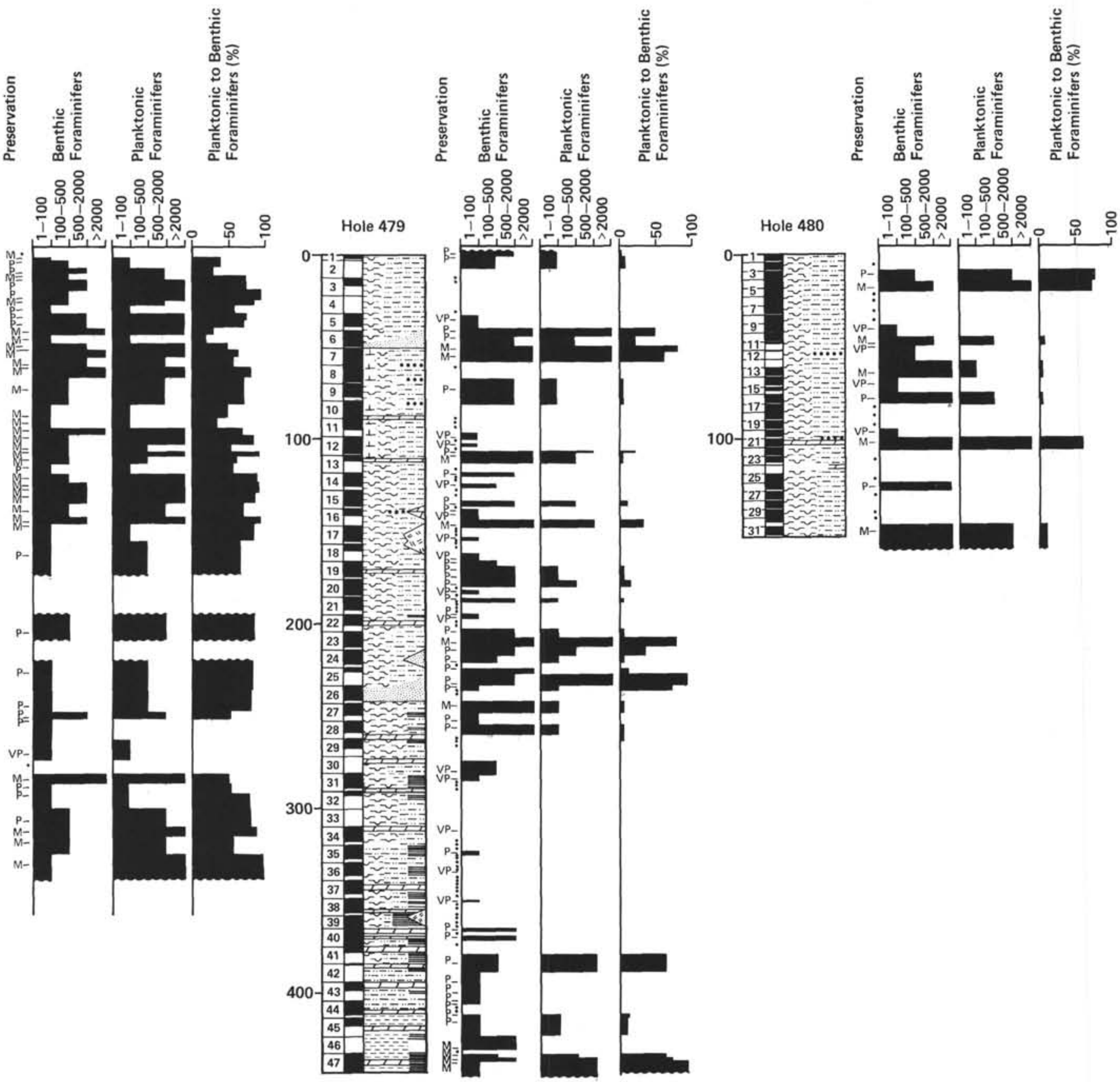


Figure 2. (Continued).

inella smithi, *Cassidulina* sp. A, *Buliminella tenuata*, and *Bolivina seminuda* are the dominant species in both holes. *Cassidulina* sp. A is more abundant in the lower-to-middle section of the holes, whereas *Bolivina seminuda* is abundant in the upper section. *"Islandiella" cushmani* occurs in the lower and upper parts of the holes and is nearly absent in the middle section. *Fursenkoina cornuta* occurs in the middle-to-upper section of the hole and is abundant in the upper section. *F. rotundata*, *Nonionella* sp. A, *Oridorsalis umbonatus*, *Cassidulina subcarinata*, and *C. tumida* all occur in the upper section.

COMPARISON WITH THE RECENT DISTRIBUTION IN THE GULF OF CALIFORNIA

Depths of Deposition

Figure 9 shows the Recent depth distribution of selected benthic foraminiferal species compiled from Bandy (1961) and Phleger (1964, 1965). The depth ranges indicated by "P" are from Phleger and are based on the living distribution. The others are from Bandy and are based on total (living and dead) distribution. The total distribution may include various amounts of tests displaced from a shallower- to a deeper-water bottom. It

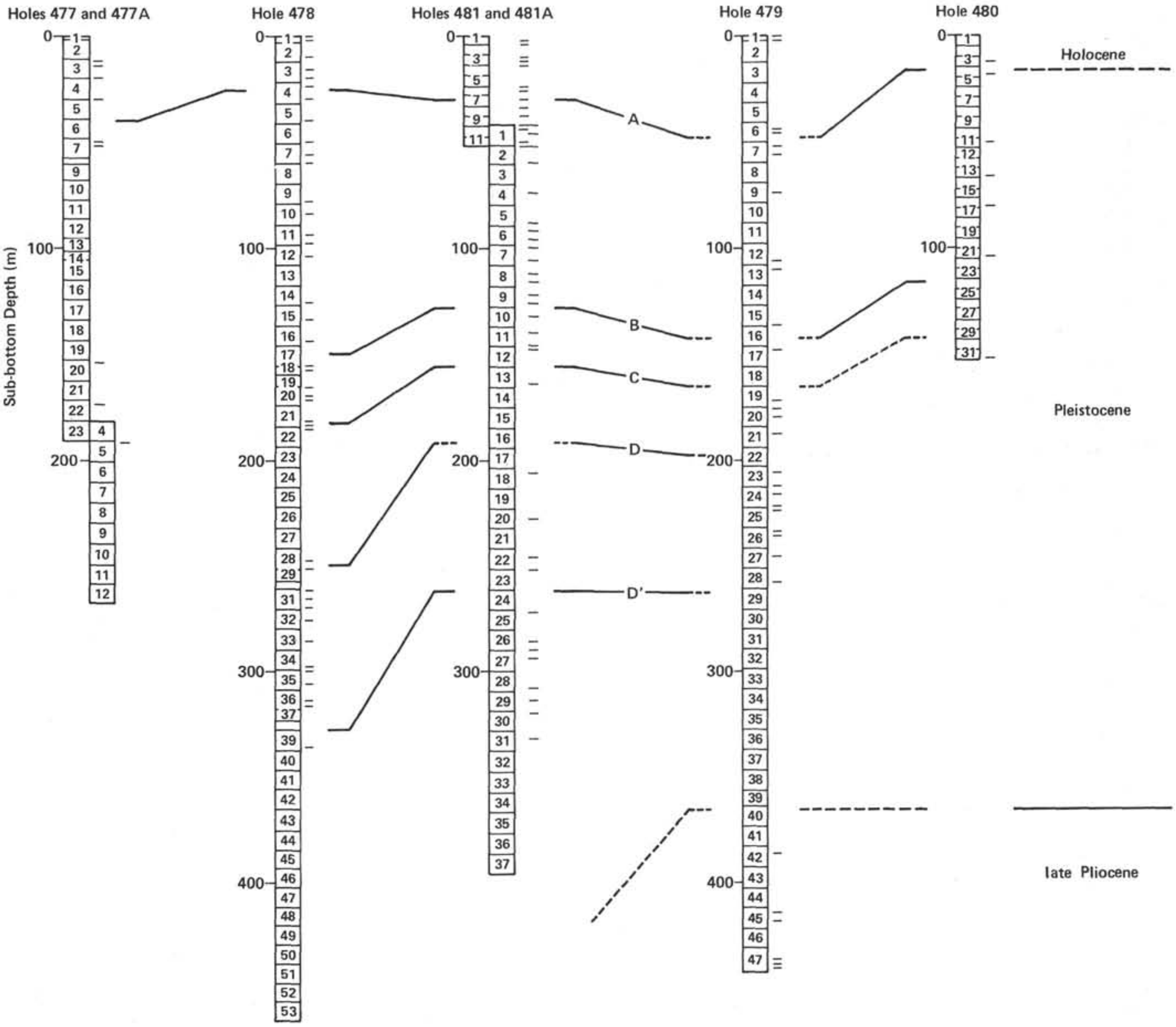


Figure 3. Guaymas Basin sites correlated by occurrence of planktonic foraminifers (after Matoba and Oda, this volume, Pt. 2).

generally has a wider depth range to the deeper part than the living distribution. The depth classification of marine benthic environments is after Bandy (1961).

In Holes 477, 477A, 478, 481, and 481A, *Uvigerina peregrina curticosta, Epistominella smithi, Bolivina seminuda*, and *Buliminella tenuata* are predominant, and *Gyroidina soldanii, G.*(?) *gemma, Oridorsalis umbonatus, Melonis parkerae, Pullenia bulloides*, and *Eilohedra levicula* occur in several samples. This fauna suggests that the depths of these holes were lower middle bathyal, similar to the present water depths of the holes. We detected no distinct depth changes in the benthic faunas within the sequences. Although several variations in occurrence and abundance of species exist within each hole, correlating them among Holes 477, 477A, 481, and 481A, is difficult. Displacement down along the slope and faunal mixing by turbidite currents are probably the major causes. The difference in bottom environment between the holes (i.e., two holes in two separate rifts and one on the basin floor) is also a possible cause.

In Holes 479 and 480, *Bolivina seminuda, B. subadvena* forma A, B, and C, *"Islandiella" cushmani, Buliminella tenuata*, and *Brizalina argentea* forma A and B are common. This fauna indicates that these holes were at the lower-upper to upper-middle bathyal depths similar to their present water depths. The upper Pliocene sequence at the lowest section of Hole 479 includes some species that do not occur in the Quaternary sequence. But predominant species in the upper Pliocene samples suggest no significant difference in depth of deposition between the upper Pliocene and the Quaternary sequences in Hole 479.

Displaced Fauna

On the basis of the Recent distribution of benthic foraminifers in the Gulf of California reported by Bandy (1961) and Phleger (1964, 1965), we examined the species in the Guaymas Basin samples, thereby determining their depth habitat and, thus, the displaced species. *Quinqueloculina* spp., *Buliminella elegantissima, Brizalina acutula, Bulimina marginata, Buccella frigida, B. tenerrima, Ammonia* spp., *Elphidium* spp., *Cibicides fletcheri, C. lobatulus, Montfortella bramlettei*, and *Hanzawaia nitidula* are defined as the shelf (0–150 m) species. *Sigmoilina tenuis, Buliminella curta, Brizalina acuminata, Bulimina denudata, Angulogerina angulosa, Cancris panamensis*, and *Planulina ornata* are the outer shelf (50–150 m) to upper bathyal (150–600 m) species. *Bolivina subadvena, Brizalina interjuncta bicosta, B. spissa, "Loxostomum" pseudobeyrichi, Angulogerina carinata, Cibicides mckannai, Fursenkoina cornuta, Suggrunda eckisi, Ehrenbergina compressa, Gyroidina altiformis*, and *Pseudoparrella bradyana* are grouped in the upper (150–600 m) to upper middle bathyal (600–1500 m) species. Figure 10 shows the vertical frequency distribution of these faunal groups in each hole in the Guaymas Basin.

Holes 477, 477A, 478, 481, and 481A are in the lower middle bathyal zone (about 2000 m), and some species included in the upper bathyal to upper middle bathyal fauna may extend to the depths of these holes. Attention should thus be given to the frequency occurrences of the shelf fauna and the outer shelf to upper bathyal fauna for the distinct downslope displacement. But Holes 479 and 480 are in depths of approximately 700 meters in the uppermost part of the upper middle bathyal zone; thus, it is possible to include the outer shelf to upper bathyal fauna in the depths of these holes. Only the shelf fauna, therefore, warrants our attention in these shallower holes. The data indicate that a considerable quantity of displaced fauna occurs in Holes 478, 481, and 481A in contrast to the shallower holes (479 and 480), where we detected scarcely any displaced fauna. This agrees with the nature of the sediment. Most of the sequences in the deeper-water holes consist of turbidites, whereas the shallower sequences are chiefly composed of laminated or homogeneous diatomaceous ooze or mud.

Low-Oxygen Environment

Along the margin of the eastern Pacific, some anaerobic benthic foraminiferal species live in waters of low-oxygen content of the continental slopes or in silled basins (Harman, 1964; Ingle, 1967a, 1967b; Phleger and Souter, 1973). *Bolivina humilis, B. seminuda, Globobulimina pacifica, G. ovula, Suggrunda eckisi, Chilostomella ovoidea*, and *Nonionella stella* represent such species. The combined frequency occurrence of these species may indicate the low-oxygen condition of the ancient sea bottom.

Figure 11 shows the combined vertical frequency distribution of the species, including *Bolivina* cf. *humilis*, in the holes of the Guaymas Basin. *Bolivina seminuda* forma A, B, and C are the most common, but *Suggrunda eckisi* (or *B.* cf. *humilis*) occurs in several samples. The fauna that indicates the low-oxygen condition is common in Holes 479 and 480 but occurs less frequently in Holes 477, 477A, 478, 481, and 481A. Holes 479 and 480 were drilled to depths within the present oxygen-minimum zone, and the drilling result suggests that a similar low-oxygen condition occurred in the past. A distinct change in frequency occurs between the middle and the upper sections in Hole 479. This faunal change suggests that an oceanographic change took place during the early late Pleistocene epoch, resulting in the reappearance of the oxygen-minimum zone (after its disappearance during an interval in middle Pleistocene epoch) at this same depth. The upper Pliocene section below Core 479-40, which is a part of the earlier Gulf history, is also indicative of the low-oxygen condition and include abundant *Suggrunda eckisi* in one sample. *Suggrunda eckisi* is common in the top sample from Hole 481, but this seems to be caused by downslope displacement, as inferred from the present depth distribution of the species.

GULF OF CALIFORNIA: PLIOCENE

Magnetic-anomaly profiles indicate that the present spreading phase of the Gulf of California probably began about 4 Ma in the early Pliocene epoch (Larson et al., 1968). A proto-Gulf of California probably existed during the early-to-middle Miocene and early Pliocene epochs, prior to the present phase of spreading (Moore and Buffington, 1968; Karig and Jensky, 1972; Moore, 1973). The presence of planktonic foraminifers indicates that the lowest part of the section in Hole 479 was deposited in the latest Pliocene epoch (Matoba and Oda, this volume). An unconformity is suggested between this section and the overlying Quaternary sequence, which has middle Pleistocene silicoflagellates at the base (Schrader, this volume). The reflection profile passing through near Hole 479 also suggests a low-angle unconformity near this depth below the bottom surface (Moore, 1973). The upper Pliocene sequence in Hole 479, therefore, seems to belong to the Pliocene phase of Gulf history. This conclusion implies that the unconformity between the late Pliocene Gulf sequence and the younger sediment was formed during the early Pleistocene epoch, not, as Moore (1973) infers, at the beginning of the present phase of spreading. The late Pliocene (N20 or N21) sequence, which is unconformably overlain by Pleistocene, shallow-marine deposits, exposed on Carmen Island in the southern Gulf of California (Natland, 1950; Ingle, 1974), contains upper bathyal benthic foraminifers (Natland, 1950). This suggests that a vertical tectonic movement occurred in the early Pleistocene epoch in the Gulf of California, probably during the present phase of spreading. If this is true, the proto-Gulf of California sediment defined in the reflection profile (Moore, 1973) also includes younger sediment deposited after the present phase of spreading began (4 Ma).

FAUNAL REFERENCE LIST

The species, subspecies, and morphotypes of benthic foraminifers from Sites 477 through 481 are listed herewith. The classification, with some exceptions, is after Loeblich and Tappan (1964, 1974). The original references are given for all named taxa, and a few subsequent references and brief remarks are added to some. Of the 154 taxa, 55 are illustrated by light microphotographs in Plates 1 through 4; all were

Table 1. Abundance and occurrence of benthic foraminifers, Holes 477, 477A, and 478.

Taxon \ Sample (interval in cm)	477-3-1, 86-88	477-3-2, 101-103	477-4-1, 17-19	477-5-1, 29-31	477-7-1, 73-75	477-7-2, 17-19	477-20-1, 90-92	477A-5-1, 51-53	478-1-1, 81-83	478-1,CC	478-2,CC	478-3-4, 110-112	478-3,CC	478-4-2, 128-130	478-4,CC	478-5,CC	478-6,CC	478-7-3, 80-82	478-7-6, 84-86	478-7,CC	478-9,CC	478-10,CC	478-11-4, 38-40	478-11,CC	478-12-3, 139-141
Pyrgo depressa																									
P. murrhina	1			2																					
P. sp.											2														
Pyrgoella sphaera																									
Quinqueloculina elongata																									2
Q. laevigata										5															
Q. lamarckiana																									2
Q. vulgaris																						1			
Q. sp. A																									1
Q. sp. B																									
Q. spp.																						1			6
Triloculina laevigata	1														1										
T. trigonula	1										2			3											
T. sp. A																									
T. sp. B																		1							
Biloculinella sp.																									
Miliolidae gen. sp. indet.													3	6							1		1		
Lagena elongata			1																						
L. mollis			1																						
L. cf. *striata*					1					1															
L. feildeniana																1					4				
Lenticulina spp.											2								1						
Fissurina spp.	1				1																				1
Parafissurina spp.		1									5											1			
Oolina melo															1										
O. lineata																									
Buliminella curta	3	1	1	2	2	3														2					
B. elegantissima	1																								
B. tenuata	16	9	10	3	13	8		23		1					1	5		7	8	34	5	2	2		1
Bolivina humilis																				2					
B. cf. *humilis*																									
B. pacifica		2	5	15						1			1							1					
B. peirsonae					1	1														1					
B. plicata					1			8												1					1
B. seminuda forma A	5	2	3	2	6	3												3	4	4					
B. seminuda forma B	8	14	12	7	9	5	21											2	3	19					2
B. seminuda forma C		10	15	10	9	4											X	2	2	7		1			
B. subadvena forma A	7	1	3	2	5	7										1		1	4	4		1			1
B. subadvena forma B						1																			
B. subadvena forma C					1																				1
B. sp. C																									
B. spp.						2	7	8																	
Brizalina acuminata					1																				
B. acutula			1																						
B. argentea forma A	5	5	4	2	9	9													4	2		1			
B. argentea forma B																			3	1		1	2		2
B. interjuncta bicostata			1		3	3			1							1			6	2					6
B. semiperforata					2													1	2						
B. spissa	1	1		2	2					1									2						2
"*Loxostomum*" *pseudobeyrichi*	2	5	3		1					1															
"*L.*" *limbatum*																									1
"*Islandiella*" *cushmani*	5	16	7	4	8	3			1						1	1			3	5	1	1			1
Bulimina denudata					1								1												7
B. marginata	1																		1						
B. mexicana														3	1										
B. pagoda			2		1				1														1		
B. spinosa										4												1			
B. sp. A															1	1									
B. spp.														3											
Globobulimina affinis forma A	2			3				8					1		3	3	X	2	3				2		
G. affinis forma B	2			2													X								
G. affinis forma C	2																X								
G. affinis forma D													1					1							
G. pacifica	1							8																	
G. ovula	1																				1		2		
Praeglobobulimina barbata																									
P. spinifera					1																				
"*Globobulimina*" spp.	2	1	1		1		14								3	1					1				
Reussella pacifica																									1
Uvigerina cf. *juncea*																									

Taxon \ Sample (interval in cm)	478-14,CC	478-15,CC	478-16-5, 41-42	478-17,CC	478-19-6, 95-97	478-19,CC	478-20-3, 76-78	478-20-4, 88-90	478-21-5, 78-80	478-21,CC	478-22-1, 28-31	478-28-4, 69-71	478-28,CC	478-30,CC	478-31-2, 84-86	478-31,CC	478-32,CC	478-33-4, 48-50	478-34-5, 6-8	478-34,CC	478-35-4, 18-20	478-36-4, 4-6	478-36,CC	478-39,CC
Pyrgo depressa									1	1														
P. murrhina						1									1			1	1					
P. sp.														1										
Pyrgoella sphaera										1														
Quinqueloculina elongata																								
Q. laevigata																								
Q. lamarckiana																								
Q. vulgaris															1									
Q. sp. A																								
Q. sp. B						15												10	12		6			
Q. spp.	1							1	1	4			3		1		4		11	4		+	4	
Triloculina laevigata								1	1					1										
T. trigonula								1		1														
T. sp. A														1										
T. sp. B																								
Biloculinella sp.										1														
Miliolidae gen. sp. indet.														2	1									
Lagena elongata																								
L. mollis																								
L. cf. *striata*	1							1																
L. feildeniana														1										1
Lenticulina spp.														1									2	
Fissurina spp.					1					1			3	1					3				6	
Parafissurina spp.										1					1	1			3		1			
Oolina melo														1										
O. lineata									1															
Buliminella curta	1		6		2	2		2	1						1		2	6		2				
B. elegantissima																								
B. tenuata				13		1		3		1	3			1	3		2	9	8	6	67	3	2	1
Bolivina humilis																								
B. cf. *humilis*								1																
B. pacifica																								
B. peirsonae				7							1													
B. plicata																						1		
B. seminuda forma A					1				1															
B. seminuda forma B				13									5									+		
B. seminuda forma C				13									8					3						
B. subadvena forma A					1			1							2			10		2	1			1
B. subadvena forma B									1						1									
B. subadvena forma C	1												10									1		
B. sp. C								1													1			
B. spp.									1						1			1	1					
Brizalina acuminata									1				3		1		2							
B. acutula																								
B. argentea forma A						1								1			2	3		2	1			1
B. argentea forma B									1						3							1		
B. interjuncta bicostata									2				3	1				7			1	+		1
B. semiperforata			1								10							3	9		1	+		
B. spissa														2	2		4							
"*Loxostomum*" *pseudobeyrichi*											9													
"*L.*" *limbatum*																								
"*Islandiella*" *cushmani*			1		1	1		1	6		16		3	1	2	1		4	1					1
Bulimina denudata									1				3											1
B. marginata									2						1									1
B. mexicana	1		1					1		10	3			2	1	12	6					+		
B. pagoda																			1					
B. spinosa					1																			
B. sp. A																								
B. spp.																								
Globobulimina affinis forma A																								
G. affinis forma B																								
G. affinis forma C																								
G. affinis forma D																								
G. pacifica																								
G. ovula		X																						
Praeglobobulimina barbata											3													
P. spinifera														1										
"*Globobulimina*" spp.														1			2	1						
Reussella pacifica																								
Uvigerina cf. *juncea*																1						+		

U. peregrina	3		1	12	6	17	29	23	32	35	39		8	38	34	31		30	25	1	16	9	61		11	3		3		17	9	X		6	4				5	3	2		3		2		39	44	
U. proboscidea vadescens																																			1														
U. senticosa																																			1														
U. spp.	1						7					X		6											1								7	2		1		10				2			2		1		9
Angulogerina angulosa			1					8																																									
Neoconorbina parkerae																																		1															
Cancris spp.																				1													1																
"Valvulineria araucana"	2			2		1				1	3'			6	1	1			3			1												1	16	5			9	3	1		4	27		1			
V. sp. A																			2						1											1													
Gaverinopsis avalonensis																									1																								
Rosalina spp.																									4								1	2		1		3		2									
Epistominella smithi	10	4	4	3	6	2			1	23	2	X	37	6	7	16		6	4	1	44	30	16		4	44	X	12		47	36	X	49	1	42	2	X	28	54	60	16	17	18	12	2	1	2		
E. cf. *pacifica*																																															43	39	42
Pseudoparrella bradyana		1			2	1							1						2	4	1				1			1	7	1				2				3					1			1			
P. cf. *exigua*		2	1		1	1													1																			10											
P. obesa	2	2		2	1															1																							1	1					
P. sp. A			1	2																1																			1										
P. sp. B		1																																															
Planulina limbata																																								1	15								
P. ornata																			1						2																								
P. spp.																																		4	1														
Cibicides fletcheri																									8									4															
C. cf. *lobatulus*																				1					4								1	1															
C. mckannai																																			4						2								
C. spp.			1			3				1					1										1								2	7						1							2		
Montfortella bramlettei																									2																								
Ammonia cf. *beccarii* vars.	2	2													1																		1							1		6	4						1
Buccella frigida																									1																								
B. mansfieldi																			1						3															1									
B. tenerrima	1														1										2								1	4															
B. sp. A		1																							2								1	2															
B. spp.						2						X		3																				3									1				1		
Elphidium crispum																									1																								
E. cf. *discoidale*															1										1																								
E. jensini																									1																								
E. lene	3																																																
E. translucens																																		1															
E. spp.						1										1			1	1					1								2	1			X						1						2
Fursenkoina cornuta	2	5	6	3	2	3				2	3				2	1	X	8			3	1	1		1	2		1	13	3		X	3	2		1				1		2	4			12	2	4	
F. rotundata		1	1	2	1					1	2				2	3		3										1			2		2			1			2									2	
F. sandiegoensis																																			1														
F. seminuda			2										3																																				
F. spp.			1	2		1																																											18
Sigmavirgulina torqueata																																											1						
Suggrunda eckisi			3	6		1														1																													
Cassidulina braziliensis						1													1	1																													
C. subcarinata	2	7	3		2	3			1	5	3		7		3						6	1				11					2	X	1	2	1	5		8		1	2			1			2		
C. subglobosa					1	1																															X			10	3		1		33				19
C. tumida	2	1	1			1													1	1					1																					1			
C. sp. A		4	1	2	4							X	37	13	27	22		23	9	1	11	47	11		6	54	X	78	13	27	28		18	14	2			5							2				
C. sp. B			1																																														
C. spp.	1		1	2	1	1							1					1	1			1			3	1							1	2									1		2		1		
"Cassidulinoides" cf. *tenuis*															1																																		
"C." sp. A																													7																				
Chilostomella ovoidea		1			1									6	1	6		4	1														3			3			5	1									13
Quadrimorphina glabra																													7							17													
Astrononion spp.																																		2															
Nonionella basiloba			1			1																							7																				
N. sp. A		3	3	2																									7				1																
N. spp.	1		1				7																	X																									
Pseudononion basispinatum						5		8								1		1							1					1			3																
Pullenia bulloides																																			1														
P. quinqueloba																																	1	2													+		
Gyroidina altiformis																																												11					
G. multilocula	1	1				1										1				1																													
G.(?) gemma		1									2				14	3		2	2	1	5	4	2												4	15			7										
G.(?) cf. *gemma*																																									4		1						
G.(?) rothwelli		1																					1		1									1									1	1					
G.(?) sp. A	1		1		1	2														1																1													
G.(?) sp. B	1		1																1																														
"G." spp.	1													6																																			
Oridorsalis umbonatus				7	1			8	63	22	35																													3	42	35			37	8			
Anomalina sp.																				1																													
Hanzawaia mexicana																									2																								
H. nitidula						1						X						1		1					6									10											2		+		
H.(?) sp. A																			2																														
Melonis parkerae																																			2														
Miscellaneous benthic foraminifers						2		8										1	1		1				1									1													2		
Total number examined	178	170	222	68	171	101	14	13	117	102	65	7	74	32	121	153	7	101	129	168	105	171	104	1	198	90	3	120	15	155	88	6	191	164	142	88	4	40	147	148	130	48	79	161	51	222	247	54	218

Note: Abundance is recorded as a percentage of total benthic specimens counted (+ = <1%); percentages were not calculated for samples containing less than 10 specimens (X = occurrence of the taxon in these samples).

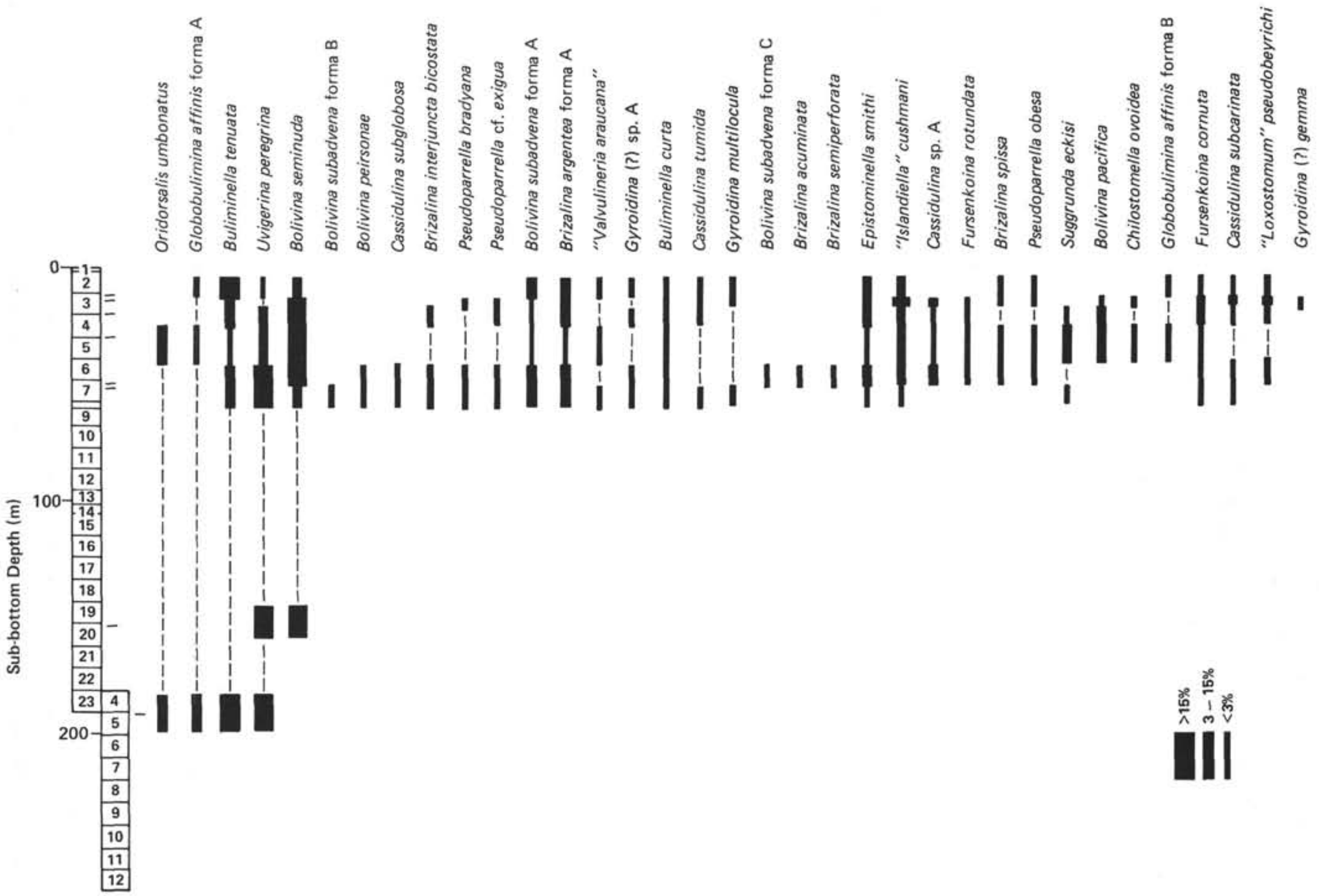


Figure 4. Stratigraphic occurrence of selected benthic foraminifers, Holes 477 and 477A.

retouched by the senior author. All the types are catalogued and deposited in the Institute of Mining Geology, Mining College, Akita University, Akita, Japan.

Ammonia cf. *beccarii* (Linné). Cf. *Nautilus beccarii* Linne, 1758, p. 710 (*fide* Ellis and Messina, 1940 *et seq.*).

Angulogerina angulosa (Williamson). *Uvigerina angulosa* Williamson, 1858, p. 67, pl. 5, fig. 140. Loeblich and Tappan (1964) included *Angulogerina* in *Trifarina*. The uvigerinid-like forms have a triangular cross section but lack a distinct uniserial portion: they are, however, distinguished from *Trifarina*.

Angulogerina carinata Cushman. Cushman, 1927a, p. 159, pl. 4, fig. 3.

Anomalina sp.

Biloculinella sp.

Bolivina humilis Cushman and McCulloch (Plate 1, Figs. 6A, B). Bolivina seminuda Cushman var. *humilis* Cushman and McCulloch, 1942, p. 211, pl. 26, figs. 1–6.

Bolivina cf. *humilis* Cushman and McCulloch (Plate 1, Figs. 7A, B). This species is distinguished from *B. humilis* in having narrower chambers and a shorter, relatively wider, and more compressed test. This is one of the characteristic species of the upper Pliocene sequence at the basal part of Hole 479. Some specimens from two Quaternary samples were questionably included in this species.

Bolivina pacifica Cushman and McCulloch (Plate 1, Figs. 8A–9). *Bolivina acerosa* Cushman var. *pacifica* Cushman and McCulloch, 1942, p. 185, pl. 21, figs. 2, 3. This species is variable in width of test. Wider and narrower forms are shown in Plate 1.

Bolivina peirsonae Uchio. Uchio, 1960, p. 63, pl. 7, figs. 3, 4.

Bolivina plicata d'Orbigny. D'Orbigny, 1839b, p. 81, pl. 8, figs. 4–7.

Bolivina seminuda Cushman. Cushman, 1911, p. 34, fig. 55 (text). This species varies greatly in test width and general test size; it is tentatively divided into three morphotypes.

Bolivina seminuda Cushman forma A (Plate 1, Figs. 10A–11). This form is the largest; compared with the specimens having similar test lengths, it has the widest test within the three morphotypes.

Bolivina seminuda Cushman forma B (Plate 1, Figs. 12A–13). The width of the test and general test size of this form is intermediate. The microspheric (Figs. 12A, B) and megalospheric (Fig. 13) forms are shown in Plate 1.

Bolivina seminuda Cushman forma C (Plate 1, Figs. 14A, B). This form has the narrowest and smallest test and is similar in appearance to *Bolivina pacifica* Cushman and McCulloch; it is distinguished, however, by the somewhat larger test and nearly horizontal sutures.

Bolivina subadvena Cushman. Cushman, 1926, p. 44, pl. 6, figs. 6a, b; Phleger, 1964, p. 382, pl. 3, figs. 14, 15. The peripheral condition of this species from the Guaymas Basin varies greatly from broadly rounded to acute and slightly keeled. On the basis of the peripheral condition, this species is tentatively divided into three morphotypes.

Bolivina subadvena Cushman forma A (Plate 1, Figs. 15A, B). This form has a broadly rounded periphery.

Bolivina subadvena Cushman forma B (Plate 1, Figs. 16A, B). The periphery of this form is narrowly rounded but is sometimes acute in larger specimens in the later part of growth.

Bolivina subadvena Cushman forma C (Plate 1, Figs. 17A, B). This form has an acute periphery throughout and is slightly keeled in the later part of growth. The cross section is lenticular.

Bolivina tongi filacostata Cushman and McCulloch. *Bolivina tongi* Cushman var. *filacostata* Cushman and McCulloch, 1942, p. 214, pl. 27, figs. 7–11.

Bolivina vaughani Natland. Natland, 1938, p. 146, pl. 5, fig. 11.

Bolivina sp. C

Brizalina acuminata (Natland). *Bolivina subadvena* Cushman var. *acuminata* Natland, in Cushman and Gray, 1946, p. 34, pl. 5, figs. 46a–c. Loeblich and Tappan's (1964) emendation restricted *Bolivina* to species with chamber retral projections or overlaps and placed species without chamber overlaps in *Brizalina*, which are commonly keeled and strongly compressed. It is sometimes diffi-

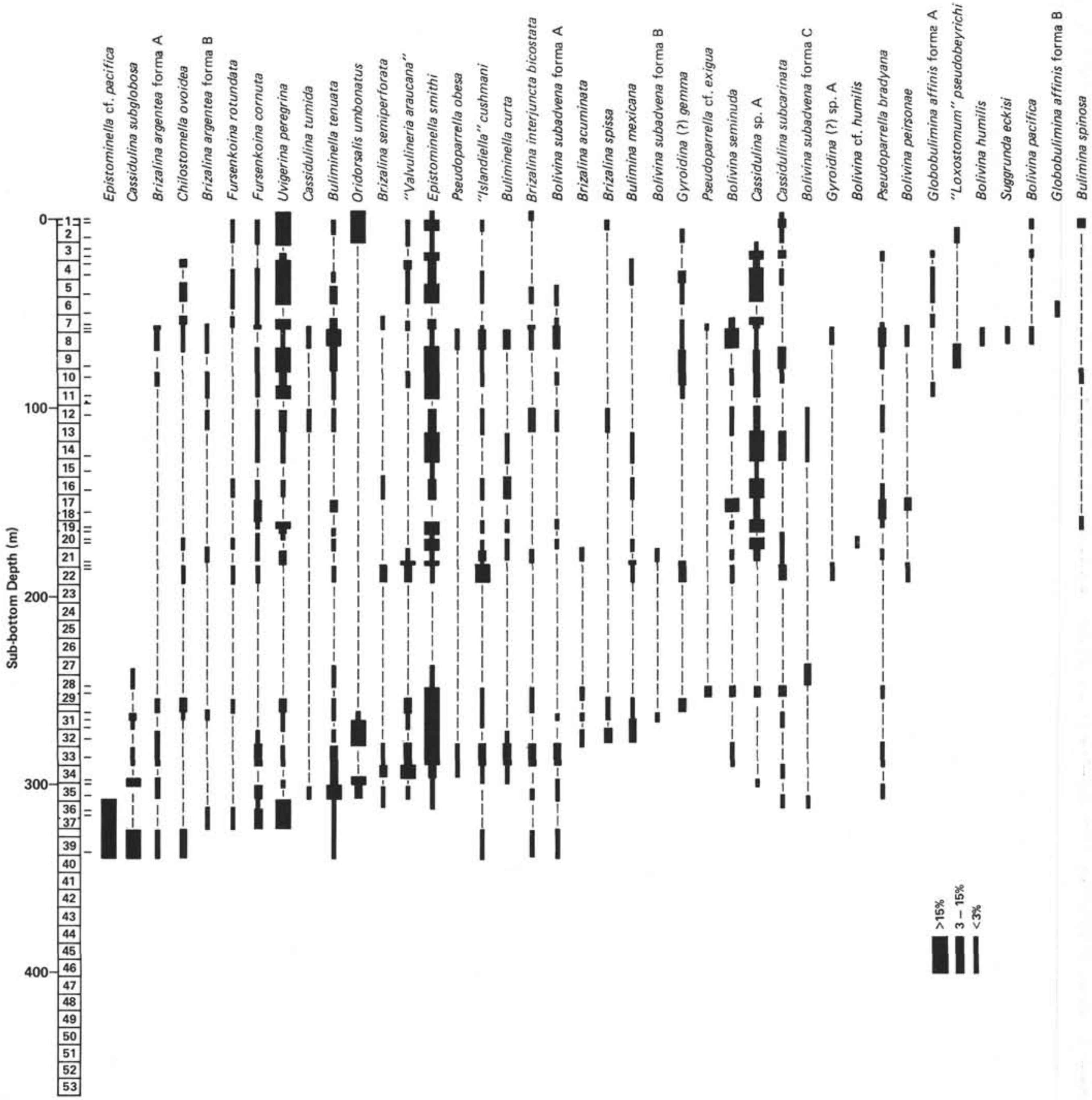


Figure 5. Stratigraphic occurrence of selected benthic foraminifers, Hole 478.

cult, however, to determine whether chamber overlaps occur in the bolivinid species, because in several species they occur only in the latest stage of ontogeny. Therefore, *Brizalina* is used in this study for species with a strongly compressed test and an acute, commonly keeled periphery.

Brizalina acutula (Bandy). *Bolivina advena* Cushman var. *acutula* Bandy, 1953, p. 180, pl. 24, figs. 7a, b.

Brizalina argentea (Cushman). *Bolivina argentea* Cushman, 1926, p. 42, pl. 6, fig. 5. *B. argentea* Cushman var. *monicana* Zalesny, 1959, p. 121, pl. 1, figs. 1a, b. *B. subargentea* Uchio, 1960, p. 64, pl. 6, figs. 21, 22. The senior author examined the holotype and paratype specimens of *B. argentea* Cushman, *B. argentea* var. *monicana* Zalesny, and *B. subargentea* Uchio at the U.S. National Museum. The periphery of the holotype of *B. argentea* is nearly acute and slightly keeled, rather than being "periphery subacute, and is usually not keeled" as in the original description. In the paratypes (two specimens) the periphery is subacute and not keeled, but the periphery of the latest chambers of one of the paratypes is acute. Therefore, the peripheral condition of the species seems to be variable. Both *B. argentea* var. *monicana* and *B. subargentea* have a distinct acute periphery with a keel but are considered to be conspecific with *B. argentea*. In this study, the two forms are distinguished as morphotypes.

Brizalina argentea (Cushman) forma A (Plate 1, Figs. 18A–19B). This form has a subacute periphery without keel and appears to fit the original description.

Table 2. Abundance and occurrence of benthic foraminifers, Holes 479 and 480.[a]

Taxon \ Sample (interval in cm)	479-1-1, 95-97	479-1,CC	479-5-3, 42-44	479-6-2, 71-74	479-6-3, 106-108	479-7-2, 73-75	479-7-4, 46-48	479-9-3, 47-79	479-12-1, 45-47	479-12-3, 72-74	479-12-6, 32-34	479-13-1, 95-97	479-14-2, 23-25	479-14,CC	479-15-7, 4-6	479-16-2, 115-117	479-16-3, 110-112	479-17-1, 17-18	479-17-5, 95-97	479-19-1, 32-34	479-49-2, 38-40	479-19-4, 37-39	479-20-1, 32-35	479-20-2, 29-31	479-20-6, 101-103	479-21-2, 43-45	479-22-2, 33-35	479-22-3, 39-41	479-23-1, 45-47	479-23-5, 72-74
Quinqueloculina spp.						1																								
Sigmoilina tenuis							1																							
Frondicularia sp.																														
Lagena cf. *striata*																														
Lenticulina spp.							1																							
Fissurina spp.				2			1					1																		
Oolina melo																														
Buliminella curta					1													10					3	1		5			1	
B. tenuata	5	25		7	9	6	1				12	10			8			7				+	32	28		1			4	5
Bolivinia humilis				6	3													1					+							
B. cf. *humilis*																														
B. pacifica																								1						
B. peirsonae				1																										
B. seminuda forma A	2	2	15		15		1	31			9	2		8	2			26		36	59	7				10				
B. seminuda forma B	17	11	51	6	9			41	X	X	21	20	9	85	20	54	80	31	82	62	35	53	2	1		15	X		7	7
B. seminuda forma C	30	6	4	11	1	1		4			2	2	1	6	9	21		3								2			5	2
B. subadvena forma A	20	22	13			2	2	22				1	24		1	7							16	7		25	X			
B. subadvena forma B					3							1						4						4		7			31	1
B. subadvena forma C	1		2	6	44						30	2			2	7						9							4	32
B. vaughani																								1						
B. sp. C																														
B. spp.													2						18			1			X			X		
Brizalina acuminata						1																								
B. acutula					1																									
B. argentea forma A	10	3	4		2			3				12			2	11		2					16	33		33			31	4
B. argentea forma B				16	2	26	22				8												+							
B. interjuncta bicostata																														
B. semiperforata			4	1							1	5			3								19	7					4	1
B. spissa					3	12	8								1								+							
"*Loxostomum*" *pseudobeyrichi*	2			2	1	1	2	2			2	4			4							1	1	1					3	5
Islandiella californica				1	1																									
"*I.*" *cushmani*	5	12		9	10	6	20				14	22			23			9				15	7	5					12	26
I. sp.																														
Bulimina mexicana				2											10															1
B. pagoda				2																										
B. spinosa																														
B. spp.												2	1		1															
Globobulimina affinis forma A															2															
G. affinis forma B						1																								
G. affinis forma C																														
G. affinis forma D				1	1		1								1							1								
G. pacifica					1	1												1												
G. ovula						1																								
Praeglobobulimina barbata															4															
"*Globobulimina*" spp.		2			1																									
Uvigerina excellence					1			1			2	1			2						5	2	2	1		2				1
U. hispida															1															
U. hispidocostata											1										2									1
U. peregrina			2	1	5	8	11				3											1	2	2		1			1	4
U. senticosa																						1								
U. spp.						2									3		20						+						4	
Angulogerina carinata				1																										
"*Valvulineria araucana*"							1															+								
Epistominella smithi				2		34	26								1															
Pseudoparrella bradyana								1				9						1					+							
P. cf. *exigua*				1																				3						1
P. obesa		2										2																		
P. sp. B								1				1																	1	
P. sp. C																														
Planulina limbata																														
P. ornata																						+								
P. spp.																														
Cibicides spp.																														
Buccella tenerrima																														
B. spp.	1																													
Fursenkoina cornuta	1			3			1																							1
F. rotundata						2																								
F. spp.																						1								
Suggrunda eckisi																		1												
Cassidulina brazilensis											+				4							4								1
C. subglobosa								1							3															
C. tumida	3																	3												
C. sp. A				1		1																		4						2
C. sp. B				2														2												
C. spp.								1					64									1								1
"*Cassidulinoides*" sp. B					2																									4
Chilostomella ovoidea				4	3	1																								1
Nonionella basiloba				2	1																									
N. sp. A	1	2		2																										
Pullenia sp. A																														1
Gyroidina multilocula	1																													
G. soldanii				5											3			2				+	1	5						3
G.(?) *rothwelli*											+				1			1											1	
G.(?) sp. A		3			1																									
G.(?) sp. B												1						1												
"*G.*" spp.																													1	
Oridorsalis umbonatus																														
Hanzawaia(?) sp. A																														
Miscellaneous benthic foraminifers														1				1		7										
Total number examined	189	65	47	101	148	129	155	187	1	6	227	130	220	101	166	28	10	213	11	29	63	223	231	142	2	101	4	1	99	170

[a] See note to Table 1.

Table 2. (Continued).

479-24-1, 114-116	479-24-6, 78-80	479-25-1, 70-72	479-26-1, 66-68	479-26-2, 22-24	479-27-3, 76-78	479-28-1, 35-37	479-28-4, 49-51	479-31-1, 101-103	479-34-3, 105-107	479-38-3, 123-125	479-40-3, 25-27	479-40-7, 28-30	479-42,CC	479-43-2, 43-45	479-43,CC	479-44-1, 19-21	479-44-3, 74-76	479-45-2, 73-75	479-45,CC	479-47-1, 70-72	479-47-5, 47-49	479-47-6, 35-37	479-47,CC	480-3,CC	480-4,CC	480-9,CC	480-11,CC	480-12,CC	480-13,CC	480-14,CC	480-16,CC	480-20,CC	480-21,CC	480-26,CC	480-31,CC
				6																															
																								1											
												1																							
					+																														
						X	48					10	5			X		X		9	2		5				5		1		15		1		3
11	22	1	5	6								1								2	5			6	3	6	1	2	2		20		3	1	4
		1									3		1			X				1							2		6		7		1		2
												2	74	23		X	61	X	50		35	8	14				5								
																													+						
11	6		3		1	X						6								16	2	13		18	8				7		27		2	23	15
30	10	3	6	12			11	1	X		10	12								8	22	9	3	6	13	56	18	77	5		14		14	55	24
		9			1		2													10	13						11		2					10	4
													4				4			25	1	1	3	2		39		19	14						
10	43	6	1				29				37	8												2			1						6	4	8
7	4	59																						19	12		11		53						9
																			4				3												
																															4				
							1	11		X			1	31	X				8			1	6							X		X	2	1	1
			3																8																
2	1	2	3	12									1			X					2		2										30	1	6
					4																2		9	1	21		9		2						1
																																	1		
	13	12	11		17																		3										8		
			16	6													4							25	8				1						
1		2	1		8							+								1					6		2		+		1		1		3
13		3	3	6	27		1				18	9		15					15	1			36	2	7		5		4		3		23	1	1
					13		8																												
1		1	2																																
																									1		2								
																																	1		
											9			15			4		4																
																								6											
																									2										
																								1											
																									2										
		1																																	
			2																										+						
1	1				+																												2		1
					1																														
																									1										
15			15	53	5						4													3	5										
			1																																
			4				1	85					1											4			4	2	+					2	
			1																																
			15		18														4					1	1										
													1			X	4				5		5												4
		1																																	
																													+						
													1					X													10				
											12	26	3	8					4	10		6													
																									1										
			3																																
												+												1											
			1										1	8									5	1											
													1																						
							1																												
			3																					1	7		6		1				2		
													4							1	4	28			2		1						1		10
	1		1		+		2																												
			1																								3								
					+							14							4		6	33											1		
1																									1						1				
																																	2		
					3								1							1							2		+						
			1																								7								
																											1								
																											2								
		1									1																								1
												3																					1		1
																											3						2		
											3	+															9		+						
1												+	1				9			5		1	11								1		2		
1											3	8																							
			3																																
													4				13																		
					+				3	X																					2				
152	149	155	145	17	229	4	159	103	1	8	119	269	159	13	2	9	23	9	26	210	85	87	64	109	175	18	105	62	223	1	116	1	131	138	138

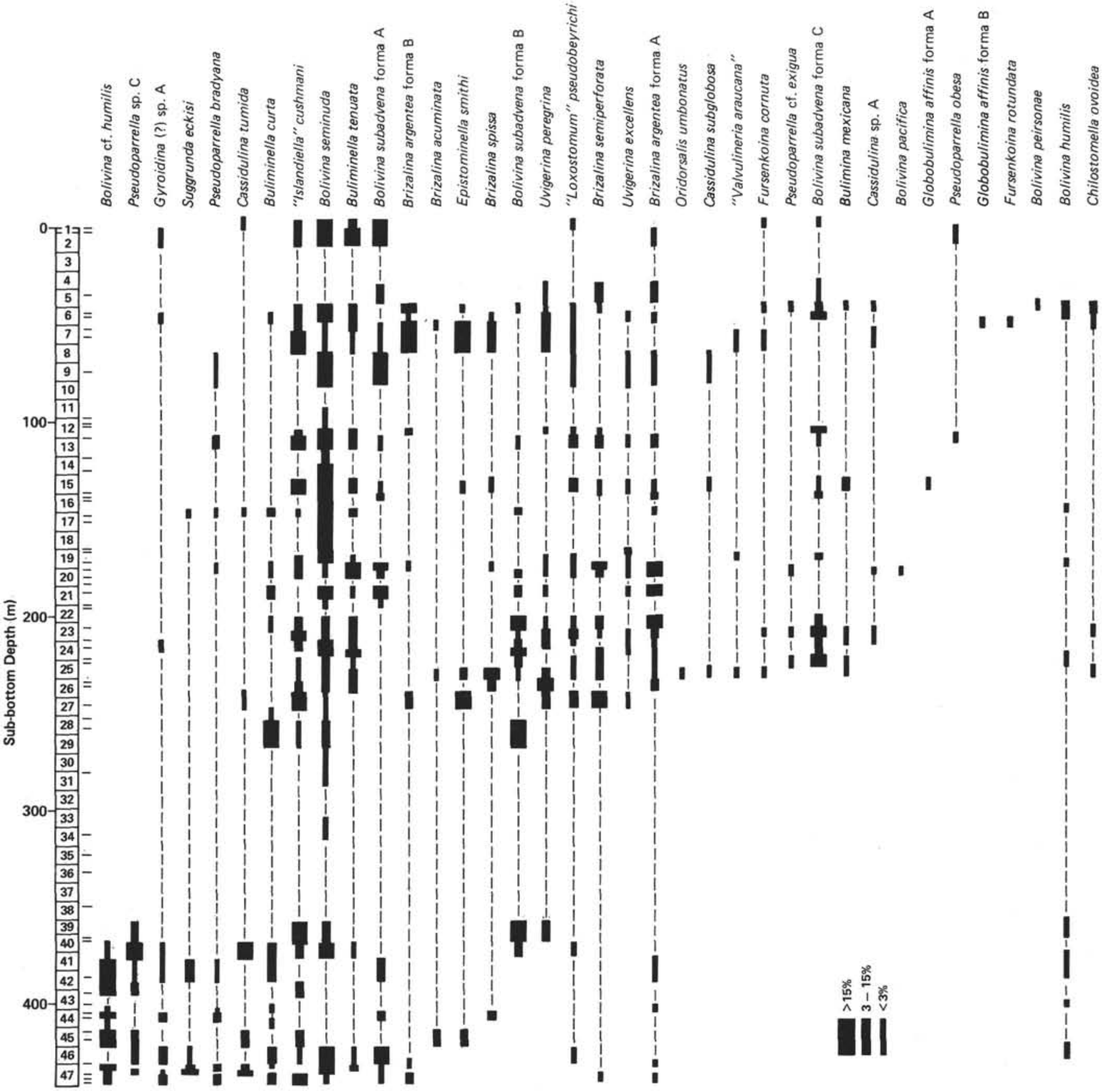


Figure 6. Stratigraphic occurrence of selected benthic foraminifers, Hole 479.

Brizalina argentea (Cushman) forma B (Plate 1, Figs. 20A, B). This is the acute, keeled form similar to *B. argentea* var. *monicana* and *B. subargentea*.

Brizalina interjuncta bicostata (Cushman) (Plate 1, Fig. 21). *Bolivina costata* d'Orbigny var. *bicostata* Cushman, 1926, p. 42. *B. interjuncta* Cushman var. *bicostata* Cushman, Cushman and McCulloch, 1942, p. 195, pl. 23, figs. 9–11, 13–16.

Brizalina semiperforata (Martin) (Plate 1, Figs. 23A–24). *Bolivina semiperforata* Martin, 1952, p. 129, pl. 21, figs. 10A–11B.

Brizalina spissa (Cushman) (Plate 1, Figs. 22A, B). *Bolivina subadvena* Cushman var. *spissa* Cushman, 1926, p. 45, pl. 6, figs. 8a, b.

Buccella frigida (Cushman). *Pulvinulina frigida* Cushman, 1922b, p. 144. *Buccella frigida* (Cushman), Andersen, 1952, p. 144, figs. 4a–6c.

Buccella mansfieldi (Cushman). *Eponides mansfieldi* Cushman, 1930, p. 54, pl. 11, figs. 1A–C (*fide* Ellis and Messina, 1940 *et seq.*).

Buccella mansfieldi (Cushman), Andersen, 1952, p. 148, figs. 12a–13c.

Buccella tenerrima (Bandy) (Plate 3, Figs. 7A–C). *Rotalia tenerrima* Bandy, 1950, p. 278, pl. 42, figs. 3a–c.

Buccella sp. A. This species has a compressed test, an acute periphery with a slight keel, and about 13 chambers in the final whorl.

Bulimina denudata Cushman and Parker. *Bulimina pagoda* Cushman var. *denudata* Cushman and Parker, 1938, p. 57, pl. 10, figs. 1a–2c.

Bulimina marginata d'Orbigny. D'Orbigny, 1826, p. 269, pl. 12, figs. 10–12 (*fide* Ellis and Messina, 1940 *et seq.*).

Bulimina mexicana Cushman (Plate 2, Fig. 2). *Bulimina inflata* Seguenza var. *mexicana* Cushman, 1922a, p. 95, pl. 21, fig. 2. *B. mexicana* Uchio, 1960, pl. 6, fig. 4.

Bulimina pagoda Cushman (Plate 2, Fig. 3). Cushman, 1927a, p. 152, pl. 2, fig. 16; Uchio, 1960, pl. 6, fig. 5.

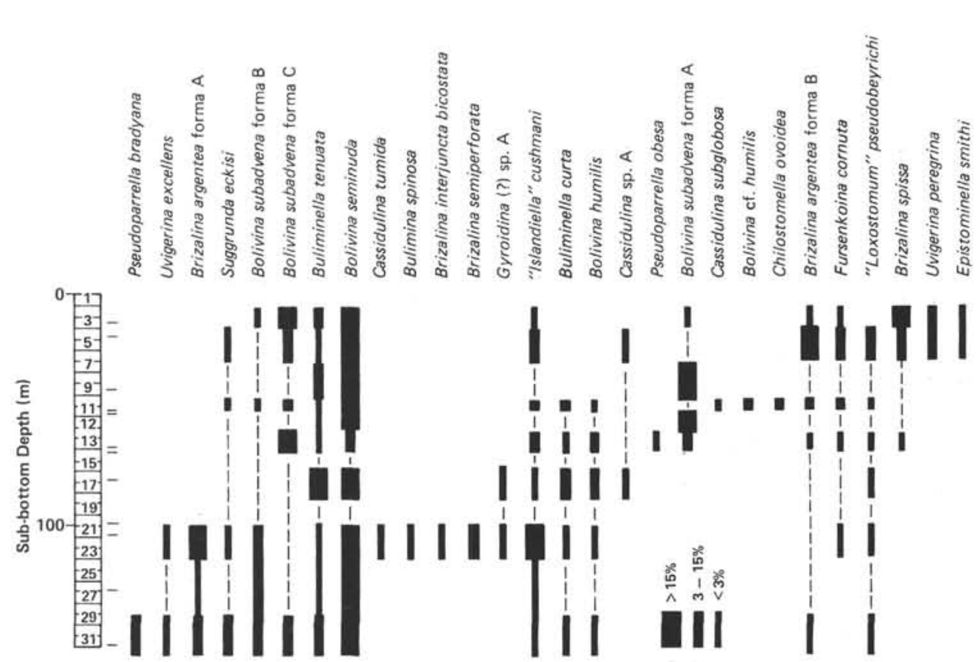


Figure 7. Stratigraphic occurrence of selected benthic foraminifers, Hole 480.

Bulimina spinosa (Heron-Allen and Earland) (Plate 2, Fig. 4). *Virgulina schreibersiana* Cžjžek var. *spinosa* Heron-Allen and Earland, 1932, p. 352, pl. 9, figs. 3, 4. *Virgulina spinosa* Heron-Allen and Earland, Bandy, 1961, p. 17, pl. 5, fig. 10. *Fursenkoina spinosa* (Heron-Allen and Earland), Phleger, 1964, p. 383, pl. 3, fig. 13. This species has a radial wall structure rather than the granular wall of *Fursenkoina* (= *Virgulina*) and is placed in *Bulimina*.

Bulimina sp. A This species is nearly identical to *Bulimina* sp. of Bandy (1961, pl. 5, fig. 3).

Buliminella curta Cushman (Plate 1, Fig. 2). Cushman, 1925, p. 33, pl. 5, fig. 13; Cushman and McCulloch, 1948, pl. 29, fig. 1.

Buliminella curta basispinata Stewart and Stewart (Plate 1, Fig. 3). *Buliminella curta* Cushman var. *basispinata* Stewart and Stewart, 1930, p. 63, pl. 8, fig. 6. Cushman and Parker, 1947, p. 65, fig. 23. *B. inconstans* (Egger) var. *basispinata* (Stewart and Stewart), Coryell and Mossman, 1942, p. 243, pl. 36, fig. 46. This subspecies occurs only in the upper Pliocene sequence at the basal part of Hole 479 (Sections 479-40-3, 479-40-7, 479-42,CC, 479-43-2, 479-45-2, 479-45,CC, 479-47-1). The occurrence of this subspecies, however, is included in *Buliminella curta* and *Bulimina* spp. in Table 3 and Figure 6. The illustrated specimen (Plate 1, Fig. 3) is immature; an adult form is about three times as long and is without surface spines in the middle and later stage of growth.

Buliminella elegantissima (d'Orbigny). *Bulimina elegantissima* d'Orbigny, 1839b, p. 51, pl. 7, figs. 13, 14.

Buliminella tenuata Cushman (Plate 1, Figs. 4A–5). *Buliminella subfusiformis* Cushman var. *tenuata* Cushman, 1927a, p. 149, pl. 2, fig. 9. *Bulimina exilis* Brady var. *tenuata* Cushman, Cushman and McCulloch, 1948, p. 248, pl. 31, figs. 2a–c. *B. exilis* (Brady) var. *tenuata* Cushman, Bandy, 1961, p. 14, pl. 4, fig. 10. *B. tenuata* Cushman, Uchio, 1960, pl. 6, fig. 1. This species varies greatly in the diameter of its test. The thick (Figs. 4A, B) and slender (Fig. 5) forms are shown in Plate 1.

Cancris panamensis Natland. Natland, 1938, p. 148, pl. 6, figs. 1a–c; Bandy, 1961, p. 14, pl. 3, figs. 15a–c.

Cassidulina braziliensis Cushman (Plate 3, Figs. 13A, B). Cushman, 1922a, p. 130, pl. 25, figs. 4, 5; Uchio, 1960, pl. 9, figs. 13, 14. Loeblich and Tappan (1964) included species with a tripartite aperture and globular, nonkeeled test in *Globocassidulina*. In this study these forms are tentatively included in *Cassidulina*.

Cassidulina subcarinata Uchio (Plate 3, Figs. 11A, B). Uchio, 1960, p. 68, pl. 9, figs. 15, 16. *Cassidulina laevigata* d'Orbigny var. *carinata* Silvestri (1896, p. 104, pl. 2, figs. 10a–c; *fide* Ellis and Messina, 1940 *et seq.*) and *Cassidulina laevigata* d'Orbigny var. *carinata* Cushman (1922a, p. 124, pl. 25, figs. 6, 7 [= *C. neocarinata* Thalmann, *nom. nov.*, 1950, p. 44]) are similar to this species. The senior author examined the holotypes of *C. laevigata* var. *carinata* Cushman and *C. subcarinata* Uchio at the U.S. National Museum and many specimens of *C. carinata* Silvestri—identified by F. L. Parker from cores of the Swedish Deep-Sea Expedition in the eastern Mediterranean and North Atlantic—at the Scripps Institution of Oceanography and found that *C. subcarinata* Uchio is a species distinct from the other two forms. In addition to Uchio's comparison, *C. subcarinata* differs from *C. neocarinata* in the aperture. *Cassidulina subcarinata* has an elongate aperture diagonal to the base of the apertural face; the aperture of *C. neocarinata* is a long slit at the base of the apertural face. *Cassidulina carinata* Silvestri has a larger test and a more coarsely perforate wall, but the aperture of its immature form resembles that of *C. subcarinata*.

Cassidulina subglobosa Brady. Brady, 1881, p. 60 *fide* Ellis and Messina, 1940 et seq.; Brady, 1884, p. 430, pl. 54, figs. 17a–c.

Cassidulina tumida Natland (Plate 3, Figs. 12A, B). Natland, 1938, p. 148, pl. 6, figs. 2–3b.

Cassidulina sp. A. This is a small species similar to *C. minuta* Cushman of Bandy (1961, p. 15, pl. 3, figs. 4a, b), *C.* sp 1 of Phleger (1964, p. 383, pl. 2, fig. 32), and *C. depressa* Asano of Uchio (1960, p. 68, pl. 9, figs. 18, 19).

Cassidulina sp. B

"Cassidulinoides" cf. *tenuis* Phleger and Parker. Cf. *Cassidulinoides tenuis* Phleger and Parker, 1951, p. 27, pl. 14, figs. 14a–17. This species has an optically granular wall but is tentatively placed in the genus.

"Cassidulinoides" sp. A

"Cassidulinoides" sp. B

Chilostomella ovoidea Reuss (Plate 4, Fig. 1). Reuss, 1850, p. 380, pl. 48, figs. 12a–e (*fide* Ellis and Messina, 1940 *et seq.*).

Cibicides fletcheri Galloway and Wissler. Galloway and Wissler, 1927, p. 64, pl. 10, figs. 8a–9c

Cibicides cf. lobatulus (Walker and Jacob). Cf. *Nautilus lobatulus* Walker and Jacob, 1978, p. 642, pl. 14, fig. 36 (*fide* Ellis and Messina, 1940 *et seq.*).

Cibicides mckannai Galloway and Wissler. Galloway and Wissler, 1927, p. 65, pl. 10, 5a–6c.

Ehrenbergina compressa Cushman. Cushman, 1927a, p. 168, pl. 6, fig. 7.

Eilohedra levicula (Resig). *Epistominella levicula* Resig, 1958, p. 304, fig. 16 (text).

Elphidium crispum (Linné). *Nautilus crispus* Linné, 1758, p. 709 (*fide* Ellis and Messina, 1940 *et seq.*).

Table 3. Abundance and occurrence of benthic foraminifers, Holes 481 and 481A.[a]

Taxon \ Sample (interval in cm)	481-1,CC	481-2-1, 90-92	481-3-2, 90-92	481-3,CC	481-4-1, 29-31	481-6-1, 8-10	481-6,CC	481-7-2, 72-74	481-8-1, 73-75	481-9-1, 44-46	481-10-2, 69-71	481-11-2, 70-72	481-11,CC	481A-1-1, 36-38	481A-1,CC	481A-2-1, 75-77	481A-3-1, 50-52	481A-3,CC	481A-4-3, 41-43	481A-5-5, 108-110	481A-6-2, 116-118	481A-6-4, 110-112	481A-6-5, 60-61	481A-7-1, 92-94	481A-7-6, 136-138
Pyrgo depressa																									
P. murrhina											1														
Pyrgoella sphaera																									
Quinqueloculina laevigata							2																		
Q. lamarckiana									1																
Q. vulgaris																								1	
Q. sp. A																									
Q. sp. B																									
Q. sp. C																						1			
Q. spp.						13			1	1			2					3		3				2	
Sigmoilina tenuis														1											
Triloculina laevigata													3					1	1						
T. trigonula						1																		1	
T. sp. A.						2																			
T. sp. B																								1	
Miliolidae gen. sp. indet.																1		1							
Lagena cf. *striata*							5					3	3			2									
L. amphora																									
L. feildeniana									1							1		1				1			
L. perlucida													2									1			
L. williamsoni																									
Lenticulina spp.										1		1	2						1			1			
Fissurina spp.							2												1						
Parafissurina spp.													3												
Oolina melo																									
Buliminella curta			4	2	6						1	1	3	4	60	12	2		1	3		1		3	4
B. elegantissima																1									
B. tenuata	10		11	5	27	1	5		5	8	11		6	5			5	5	9	6	3	6			4
Bolivina humilis					3					1	1	7		1	4	1	1	1	3			1			
B. pacifica			6	2	1					2			2								9	1			4
B. peirsonae		2	4		1		2				1	3		1		2			1	3					
B. plicata														1			1		1						
B. seminuda forma A			12	8	2				9		7	1	9		9	6	7		7			7			5
B. seminuda forma B		23	9	7	11		7		2	7	5	8	12	6		9		6	6			4		1	4
B. seminuda forma C	10	21	4		10		11		3			11		6	5	8	1	3		14	24	3			4
B. subadvena forma A									3		8			4				5	5	9		1			2
B. subadvena forma B		8			2		2		1	1	7	1		7	5	1	5							1	1
B. subadvena forma C									1																
B. tongi filacostata													2	1											
B. sp. C				1										1			1								
B. spp.				1															1						
Brizalina acuminata																	1								
B. acutula			1						1							1									
B. argentea forma A		2	2	2	4						10	1		5		2	2		2	6					
B. argentea forma B														2			1	1				3			
B. interjuncta bicostata				1						3	4			6			5		4	6		1			
B. semiperforata																	3					1			
B. spissa					2		2		1					1					1	3					1
"*Loxostomum*" *pseudobeyrichi*				2					1		2			5		1	1	3	1					1	2
"*L.*" *limbatum*										1															
"*Islandiella*" *cushmani*		12		2			2		8		5	3	2	9	2	4	5	8	7			11			2
I. sp.																			1						
Bulimina denudata										2				1	2		1		1			1			
B. marginata		2							1							1									
B. mexicana						2								2		1	1								
B. pagoda											1						2		1			1			
B. spinosa							11													3	18				
B. spp.																									
Globobulimina affinis forma A											1		4			7	1	1			3	3			
G. affinis forma B											3	1		1		1			1						3
G. affinis forma C											1					1									
G. affinis forma D																						1			
G. pacifica											1					1									
G. ovula									1	1									1					1	
Praeglobobulimina barbata														1		1									

Taxon \ Sample (interval in cm)	481A-7,CC	481A-8-2, 26-28	481A-8-6, 135-137	481A-9-3, 97-99	481A-9-6, 117-119	481A-9,CC	481A-10-3, 20-22	481A-11-2, 42-44	481A-11,CC	481A-12-1, 94-96	481A-13,CC	481A-18,CC	481A-20,CC	481A-22-2, 100-102	481A-22,CC	481A-23-1, 44-46	481A-24,CC	481A-26-3, 72-74	481A-26,CC	481A-27-2, 71-73	481A-28,CC	481A-29,CC	481A-30-1, 38-40	481A-31,CC
Pyrgo depressa																								
P. murrhina					1	1		1																
Pyrgoella sphaera								1																
Quinqueloculina laevigata																	3							
Q. lamarckiana						1																		
Q. vulgaris																								
Q. sp. A								1																
Q. sp. B					1	1																		
Q. sp. C																								
Q. spp.		1		1				1				4	8											
Sigmoilina tenuis																								
Triloculina laevigata	1				2	1																		
T. trigonula						1	1	2	2															
T. sp. A.	1																							
T. sp. B																						2		
Miliolidae gen. sp. indet.	1								2															
Lagena cf. *striata*			3																					
L. amphora							1																	
L. feildeniana																								
L. perlucida																								
L. williamsoni			3			1																		
Lenticulina spp.																		1						
Fissurina spp.			3	1		1																		
Parafissurina spp.				1																				
Oolina melo																						2		
Buliminella curta	2	1	5		5		1	1		X								6			4		1	
B. elegantissima																								
B. tenuata	4	4		1		1			6		2			4	1		19	3			12	6	1	27
Bolivina humilis			3															4				2		
B. pacifica			3			1																		
B. peirsonae																								
B. plicata																								
B. seminuda forma A		3						1			2		4								8			
B. seminuda forma B	2	5													1			7				2		
B. seminuda forma C			3		1												6	1						
B. subadvena forma A								2			2							4						
B. subadvena forma B		2													1			4						
B. subadvena forma C																								
B. tongi filacostata																								
B. sp. C																								
B. spp.			3								11						9				4			
Brizalina acuminata																								
B. acutula																								
B. argentea forma A																								
B. argentea forma B											2	2						6						
B. interjuncta bicostata		2					1	1										4				2		
B. semiperforata		2																1						
B. spissa							1				2											3		
"*Loxostomum*" *pseudobeyrichi*	1																							
"*L.*" *limbatum*																								
"*Islandiella*" *cushmani*	1				1		1											5		X	4	3		7
I. sp.																								
Bulimina denudata		1			1			1				2		4							4			
B. marginata																								
B. mexicana							1																	7
B. pagoda																		1						
B. spinosa			3		4																			
B. spp.													4				3							
Globobulimina affinis forma A	4	2					2	1																
G. affinis forma B																								
G. affinis forma C																								
G. affinis forma D																								
G. pacifica													4											
G. ovula						1															4			
Praeglobobulimina barbata	1																	1						

P. spinifera											1														
"*Globobulimina*" spp.	10						5		3	4		8			2					3					
Stainforthia complanata		2														1		1			6				
Uvigerina excellence																	1								
U. cf. *juncea*																	3								
U. peregrina			7	4		13	9	57	14	9	1			5		3	19	15	16	17		1	X	24	5
U. senticosa									1							1			1						
U. spp.		2				6			1			3							1						
Angulogerina angulosa									1	2	1								2						
A. carinata				1										1					1						
Cancris panamensis																									
C. spp.									1					1											
"*Valvulineria araucana*"		2						18	3	3	2	1				1		1	1			1			2
V. inflata														1											
V. sp. A																									
V. sp. B														1											
Rosalina spp.			1						1	4			2	1			1	1	1			2			
Eilohedra levicula																1									
Epistominella smithi		4		8		14			6	8	5	1	4	4		1	18	12	5	3		6		10	7
Pseudoparrella bradyana					1		2		2		2			1					1	3					1
P. cf. *exigua*		6	5						1		1	4		2			1	3	1			1			1
P. obesa											1	1	2	1		2		1							
P. sp. A				2										1											
Planulina limbata																	1								
P. spp.									1	1				1		1				3					
Cibicides mckannai																									
C. spp.									3	4								1							
Montfortella bramlettei									1																
Ammonia cf. *beccarii* vars.																2									
Buccella frigida																1									
B. mansfieldi																		1							
B. tenerrima										2								1	1						
B. spp.																									
Elphidium cf. *discoidale*																						1			
E. lene													4			2									
E. translucens																1									
E. spp.									1	1		3		1		1		4				1			1
Fursenkoina cornuta			22	31	6		5		2		11	9	15	4	3	1	1	1	3		12	1			9
F. rotundata		8				6	5	7	1	1			6	1		1			1	3		1		1	4
F. sandiegoensis												5									3				1
F. spp.							5	4																	
Suggrunda eckisi	50	4		3								4	2	1		1		3				1			1
Cassidulina braziliensis					1														1						
C. subcarinata		2		2		13		4	1		3	3	3	2		1	3	5	3						
C. tumida					4				2	1	5			4		2			1	3					
C. sp. A		2		2	7		14		10	17		3	2			4	5		3			28		54	32
C. sp. B														1					1						
C. spp.			4	1			2		1				2				1		1	6	12	1		2	
"*Cassidulinoides*" cf. *tenuis*																									
"*C.*" sp. A														1			1								
"*C.*" sp. B										1															
Ehrenbergina compressa										1															
Chilostomella ovoidea		2		1			2		4	4		4	4			1			1			1			
Quadrimorphina glabra																1									
Astrononion spp.																			1			1			
Nonionella basiloba		2										3		1		2									
N. stella													3			2		3	1			2			
N. sp. A		4		14	3		5				1	4				1					12				1
N. spp.	20						5		1	1															
Pseudononion basispinatum									1				2	1		1									
Pullenia quinqueloba																									1
Gyroidina multilocula					3						1			1					1						
G. soldanii																	1								
G.(?) *gemma*																				3					
G.(?) cf. *gemma*																			1						
G.(?) sp. A			1							2	1	1	2	1		2	1	3	1	3		1			
"*G.*" spp.					4				1																
Oridorsalis umbonatus						25		11	4	2	1			1	2		1	3	2						1
Hanzawaia nitidula										3				1		1		1	1						
Miscellaneous benthic foraminifers						1		4		1			2				1		1			1			
Total number examined	10	52	113	107	99	95	44	28	163	91	155	75	68	215	58	179	149	78	204	35	34	143	3	115	115

P. spinifera																								
"*Globobulimina*" spp.		1	3								46									X	12	2		
Stainforthia complanata																								
Uvigerina excellence																								
U. cf. *juncea*																								
U. peregrina	17	23		13	10	10	22	29	8	X		22	29	58	6	X	6	9			12	12	1	27
U. senticosa																								
U. spp.			5										4											
Angulogerina angulosa												2												
A. carinata																								
Cancris panamensis		2										2												
C. spp.																								
"*Valvulineria araucana*"								1	8															
V. inflata																								
V. sp. A																						2		
V. sp. B																								
Rosalina spp.																								
Eilohedra levicula																								
Epistominella smithi	14	15	5	14	17	18	17	20	2	X	2	34	29	21	8			5			4	5	2	
Pseudoparrella bradyana																								
P. cf. *exigua*																								
P. obesa																					4	2		
P. sp. A			3																					
Planulina limbata																								
P. spp.								2																
Cibicides mckannai			3																					
C. spp.																								
Montfortella bramlettei														4										
Ammonia cf. *beccarii* vars.		1						1	2			2												
Buccella frigida												2												
B. mansfieldi							1																	
B. tenerrima																								
B. spp.		1						1																
Elphidium cf. *discoidale*																								
E. lene		1	3																					
E. translucens																								
E. spp.		2					1	1					4											
Fursenkoina cornuta		2	3			3	5	1									3	1						
F. rotundata	2	3			1	2												1						
F. sandiegoensis																								
F. spp.											2						3							
Suggrunda eckisi												2						1						
Cassidulina braziliensis																								
C. subcarinata				1	2																			
C. tumida																		1						
C. sp. A	45	28	38	69	55	56	47	30	53	X		30		4			6	9	X		35	53	95	
C. sp. B																								
C. spp.			3		2						11		13		84									
"*Cassidulinoides*" cf. *tenuis*									2															
"*C.*" sp. A																								
"*C.*" sp. B																								
Ehrenbergina compressa																								
Chilostomella ovoidea	1					1			6						1			1	X			3		
Quadrimorphina glabra																								
Astrononion spp.																								
Nonionella basiloba																			X					
N. stella		1	3																					
N. sp. A																								
N. spp.																	28							
Pseudononion basispinatum					1		1																	
Pullenia quinqueloba																								
Gyroidina multilocula																								
G. soldanii																		1						
G.(?) *gemma*	1							2	11			2										2		13
G.(?) cf. *gemma*																								
G.(?) sp. A																	3					2		
"*G.*" spp.	1																							
Oridorsalis umbonatus		1																						
Hanzawaia nitidula		1					1							4										
Miscellaneous benthic foraminifers								1			23						9							
Total number examined	85	131	37	110	168	146	157	119	53	8	57	50	24	24	104	1	32	142	4	2	26	66	93	15

[a] See note to Table 1.

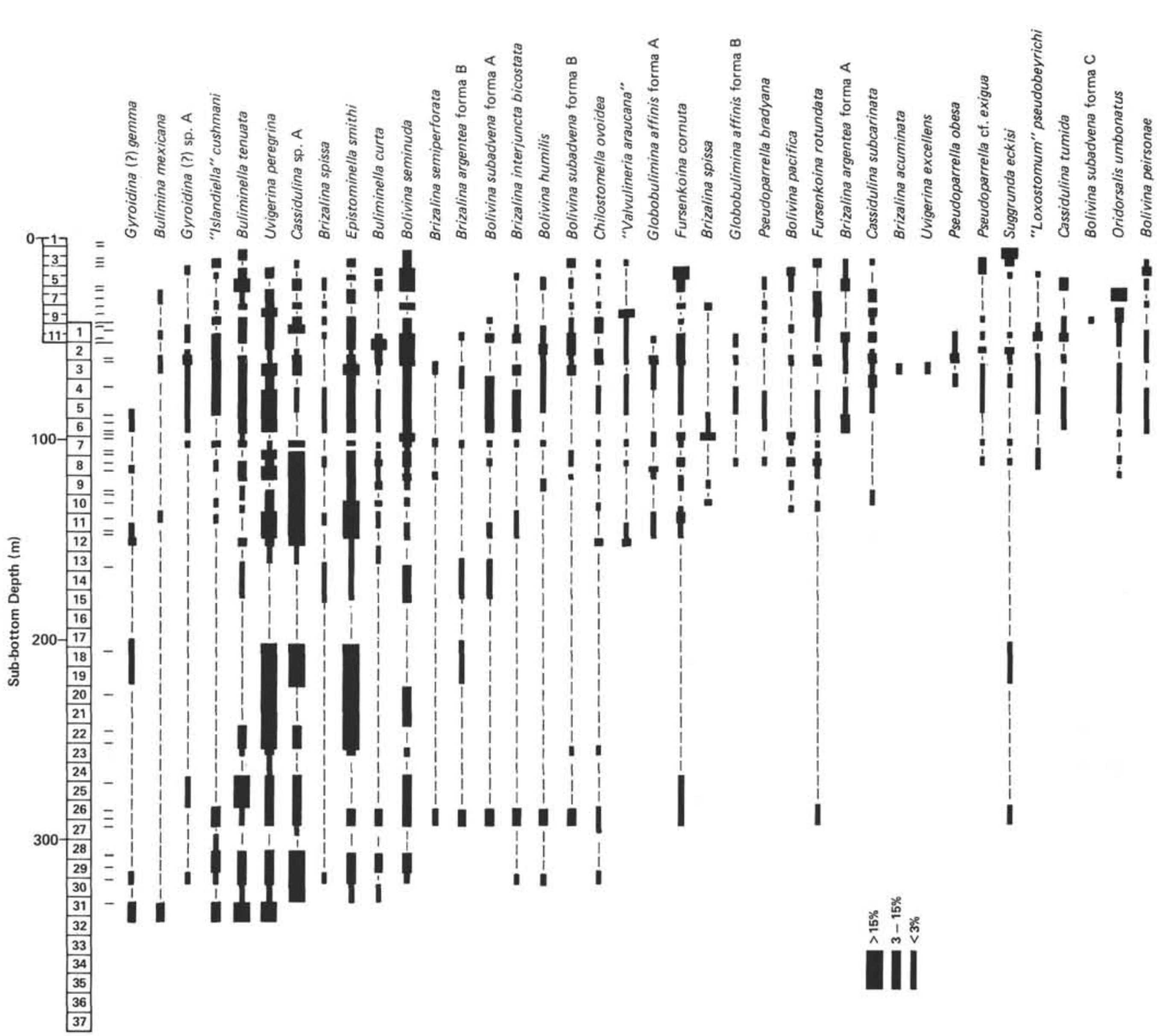


Figure 8. Stratigraphic occurrence of selected benthic foraminifers, Holes 481 and 481A.

Elphidium cf. *discoidale* (d'Orbigny). Cf. *Polystomella discoidalis* d'Orbigny, 1839a, p. 56, pl. 6, figs. 23, 24.

Elphidium jenseni (Cushman). *Polystomella jenseni* Cushman, 1924, p. 49, pl. 16, figs. 4, 6.

Elphidium lene Cushman and McCulloch. *Elphidium incertum* (Williamson) var. *lene* Cushman and McCulloch, 1940, p. 170, pl. 19, figs. 2a, b.

Elphidium translucens Natland. Natland, 1938, p. 144, pl. 5, figs. 3, 4.

Epistominella cf. *pacifica* (Cushman) (Plate 2, Figs. 14A–15C). Cf. *Pulvinulinella pacifica* Cushman, 1927a, p. 165, pl. 5, figs. 14, 15. This species resembles *E. pacifica* in its strongly convex umbilical side but differs in having the earlier whorls on the dorsal side, which is more convex and usually roughened (Plate 2, Fig. 14A). The roughness varies, and in several specimens the earlier part of the dorsal side is almost smooth, showing the appearance of typical *E. pacifica* (Plate 2, Fig. 15A). This species is only abundant in three samples at the base of Hole 478 (middle Pleistocene) and is not found in samples from other sites in the Guaymas Basin.

Epistominella smithi (Stewart and Stewart) (Plate 3, Figures 1A–C). *Pulvinulinella smithi* Stewart and Stewart, 1930, p. 70, pl. 9, figs. 4a–c; *Epistominella smithi* (Stewart and Stewart), Bandy, 1961, p. 15, pl. 5, figs. 6a–c.

Frondicularia sp.

Fursenkoina bramlettei (Galloway and Morrey). *Virgulina bramlettei* Galloway and Morrey, 1929, p. 37, pl. 5, fig. 14; Uchio, 1960, pl. 6, fig. 12.

Fursenkoina cornuta (Cushman) (Plate 3, Figs. 8A, B). *Virgulina cornuta* Cushman, 1913, p. 637, pl. 80, fig. 1.

Fursenkoina rotundata (Parr) (Plate 3, Figs. 9A, B). *Virgulina rotundata* Parr, 1950, p. 337, figs. 14a, b.

Fursenkoina sandiegoensis (Uchio). *Virgulina sandiegoensis* Uchio, 1960, p. 63, pl. 6, figs. 17, 18.

Fursenkoina seminuda (Natland). *Virgulina seminuda* Natland, 1938, p. 145, pl. 5, fig. 12.

Gavelinopsis avalonensis (Natland). *Rotalia depressa* Natland, 1938, p. 147, pl. 5, figs. 15a–c. *Rotalia avalonensis* Natland, *nom. nov.*, 1950, p. 30, pl. 8, figs. 4a–c.

Globobulimina affinis (d'Orbigny). *Bulimina affinis* d'Orbigny, 1839a, p. 105, pl. 2, figs. 25, 26. This species varies in inflation of test and is tentatively divided into four morphotypes.

Globobulimina affinis (d'Orbigny) forma A (Plate 2, Fig. 5). This is the most inflated form and is similar to *G. ovula*.

Globobulimina affinis (d'Orbigny) forma B (Plate 2, Fig. 6). This form is the intermediate between forma A and forma C.

Globobulimina affinis d'Orbigny) forma C (Plate 2, Fig. 7). This is the most slender form.

Globobulimina affinis (d'Orbigny) forma D. This form has a test shape similar to forma C but has more inflated chambers and is tentatively included in this species.

Globobulimina ovula (d'Orbigny). *Bulimina ovula* d'Orbigny, 1839b, p. 51, pl. 1, figs. 10, 11.

Globobulimina pacifica Cushman (Plate 2, Fig. 8). Cushman, 1927b, p. 67, pl. 14, fig. 12.

Gyroidina altiformis Stewart and Stewart. *Gyroidina soldanii* d'Orbigny var. *altiformis* Stewart and Stewart, 1930, p. 67, pl. 9, figs. 2a–c.

Gyroidina? gemma Bandy (Plate 4, Fig. 9A–C). *Gyroidina gemma* Bandy, 1953, p. 179, pl. 23, figs. 4a–c.

Gyroidina? cf. *gemma* Bandy.

Gyroidina multilocula Coryell and Mossman (Plate 4, Fig. 6A–C). *Gyroidina soldanii* d'Orbigny var. *multilocula* Coryell and Mossman, 1942, p. 237, pl. 36, fig. 20? *G. multilocula* Coryell and Mossman, Bandy, 1961, p. 15. *G. soldanii* var. *rotundimargo*, Natland (not Stewart and Stewart), 1950, p. 29, pl. 7, figs. 7a–c. Natland (1950) regarded *G. soldanii* var. *multilocula* as a junior synonym of *G. soldanii* var. *rotundimargo* Stewart and Stewart. The original figures of *G. soldanii* var. *rotundimargo*, however, are different from the species illustrated by Natland.

Gyroidina? rothwelli Natland (Plate 4, Figs. 7A–C). *Gyroidina rothwelli* Natland, 1950, p. 29, pl. 7, figs. 8a–c. Our specimens have a slightly convex dorsal side rather than the planoconvex test of the original figures.

Gyroidina soldanii d'Orbigny. D'Orbigny, 1826, p. 278 (*fide* Ellis and Messina 1940 *et seq.*).

Gyroidina? sp. A (Plate 4, Fig. 8A–C). This species resembles *Eponides* cf. *rosaformis* Cushman and Kleinpell of Natland (1950, p. 30, pl. 7, figs. 10a–c).

Gyroidina? sp. B

Hanzawaia mexicana Lankford. *In* Lankford and Phleger, 1973, p. 122, pl. 6, figs. 20a–c.

Hanzawaia nitidula (Bandy). *Cibicidina basiloba* (Cushman) var. *nitidula* Bandy, 1953, p. 178, pl. 22, figs. 3a–c.

Hanzawaia? sp. A (Plate 4, Figs. 10A–C). This species has a broadly rounded periphery and a nearly asymmetrically planispiral test. Because of the distinct flaps on the lower margin of the chambers on the dorsal side, this species is included in *Hanzawaia*.

Islandiella californica (Cushman and Hughes). *Cassidulina californica* Cushman and Hughes, p. 12, pl. 2, figs. 1a–c.

"Islandiella" cushmani (Stewart and Stewart) (Plate 2, Figs. 1A, B). *Cassidulina cushmani* Stewart and Stewart, 1930, p. 71, pl. 9, figs. 5a, b. Uchio, 1960, p. 68, pl. 9, fig. 17. *C. asanoi* Uchio, *in* Kawai et al., 1950, p. 190, fig. 13. Uchio, 1951, p. 39, pl. 3, figs. 2a, b. *C. delicata* Cushman, Uchio (not Cushman), 1960, p. 68, pl. 9, fig. 17. This species has a *Cassidulina* (not *Islandiella*) type of aperture as emended by Loeblich and Tappan (1964) but has an optically radial wall structure and is only tentatively included in *Islandiella*. The wall structure of the primary types of *C. cushmani* is also reported to be radial (Feyling-Hanssen and Buzas, 1976). The senior author examined the holotype and paratype specimens of *C. delicata* and *C. cushmani* and paratypes of *C. asanoi* at the U.S. National Museum. *Cassidulina delicata* differs from *C. cushmani* in having a larger test (approximately 1.5 times larger), very long aperture, and narrowly rounded, nonkeeled periphery; in the adult specimens, *C. cushmani* is acute to subacute and keeled. In addition, the paratypes (six specimens) of *C. delicata* have five pairs of chambers in the final whorl, although its holotype has four pairs. Therefore, *C. cushmani* is considered to be a distinct species from *C. delicata*, and *C. delicata* of some authors seems to be *C. cushmani*. *Cassidulina asanoi* appears to be conspecific with *C. cushmani*.

Islandiella sp.

Lagena amphora Reuss. Reuss, 1863, p. 330, pl. 4, fig. 57, (*fide* Ellis and Messina, 1940 *et seq.*).

Lagena elongata (Ehrenberg). *Miliola elongata* Ehrenberg, 1844, p. 274 (*fide* Ellis and Messina, 1940 *et seq.*).

Lagena feildeniana Brady. Brady, 1878, p. 434, pl. 20, fig. 4 *fide* Ellis and Messina, 1940 *et seq.* Brady, 1884, p. 469, pl. 48, figs. 38–39b.

Lagena mollis Cushman. *Lagena gracillima* (Segenza) var. *mollis* Cushman, 1944, p. 21, p. 3, fig. 3.

Lagena perlucida (Montagu). *Vermiculum perlucidum* Montagu, 1803, p. 525; pl. 14, fig. 3 (*fide* Ellis and Messina, 1940 *et seq.*).

Lagena cf. *striata* (d'Orbigny). Cf. *Oolina striata* d'Orbigny, 1839b, p. 21, pl. 5, fig. 12.

Lagena williamsoni (Alcock). *Entosolenia williamsoni* Alcock, 1865, p. 193 (*fide* Ellis and Messina, 1940 *et seq.*).

"Loxostomum" limbatum (Brady). *Bolivina limbata* Brady, 1881, p. 57 *fide* Ellis and Messina, 1940 *et seq.* Brady, 1884, p. 419, pl. 52, figs. 26–28. Bolivinid-like forms with a terminal aperture, but having a radial wall structure, are tentatively included in this genus.

"Loxostomum" pseudobeyrich (Cushman) (Plate 1, Figs. 25A, B). *Bolivina pseudobeyrich* Cushman, 1926, p. 45; 1927, p. 156, pl. 3, fig. 7.

Melonis parkerae (Uchio) (Plate 4, Figs. 12A, B). *Nonion parkerae* Uchio, 1960, p. 60, pl. 4, figs. 9, 10.

Montfortella bramlettei Loeblich and Tappan. Loeblich and Tappan, 1963, p. 213, figs. 7–9b.

Neoconorbina parkerae (Natland). *Discorbis parkeri* Natland, 1950, p. 27, pl. 6, figs. 11a–c.

Nonionella basiloba Cushman and McCulloch (Plate 4, Figs. 3A, B). Cushman and McCulloch, 1940, p. 162, pl. 18, figs. 3a–c.

Nonionella stella Cushman and Moyer (Plate 4, Figs. 4A, B). *Nonionella miocenica* Cushman var. *stella* Cushman and Moyer, 1930, p. 56, pl. 7, figs. 17a–c. *N. stella* Cushman and Moyer, Uchio, 1960, pl. 4, figs. 15, 16.

Nonionella sp. A (Plate 4, Figs. 5A–C). This species differs from *N. stella* in the thicker test, broadly rounded periphery, and deeply incised ventral sutures. This species resembles *N.*(?) *fragilis* Uchio (1960, p. 62, pl. 4, figs. 19–21), but differs in having finger-like processes at the lobate ventral end of the last chamber and not having sutural openings.

Oolina lineata (Williamson). *Entosolenia globosa* var. *lineata* Williamson, 1858, p. 9, pl. 1, fig. 17.

Oolina melo d'Orbigny. D'Orbigny, 1839b, p. 20, pl. 5, fig. 9.

Oridorsalis umbonatus (Reuss) (Plate 4, Fig. 11A–C). *Rotaliana umbonata* Reuss, 1851, p. 75, pl. 5, figs. 35a–c (*fide* Ellis and Messina, 1940 *et seq.*).

Planulina limbata Natland (Plate 3, Figs. 6A–C). Natland, 1938, p. 151, pl. 7, figs. 4a–5.

Planulina ornata (d'Orbigny). *Truncatulina ornata* d'Orbigny, 1839b, p. 40, pl. 6, figs. 7–9.

Praeglobobulimina barbata (Cushman). *Bulimina barbata* Cushman, 1927a, p. 151, pl. 2, fig. 11. Cushman and McCulloch, 1948, p. 248, pl. 31, figs. 3a–c. *Globobulimina barbata* (Cushman), Uchio, 1960, pl. 6, fig. 6.

Praeglobobulimina spinifera (Cushman). *Bulimina spinifera* Cushman, 1927a, p. 151, pl. 2, fig. 15. *Globobulimina spinifera* (Cushman), Uchio, 1960, pl. 6, fig. 10.

Pseudononion basispinatum (Cushman and Moyer). *Nonion pizarrensis* Berry var. *basispinata* Cushman and Moyer, 1930, p. 54, pl. 7, figs. 18a, b.

Pseudoparrella bradyana (Cushman) (Plate 3, Figs. 2A–C). *Pulvinulinella bradyana* Cushman, 1927a, p. 165, pl. 5, figs. 11–13.

Pseudoparrella cf. *exigua* (Brady). Cf. *Pulvinulina exigua* Brady, 1884, p. 696, pl. 103, figs. 13a–14c. Our specimens do not have so acute a periphery as Brady's species but instead are narrowly rounded and have six chambers in the final whorl instead of five. *Epistominella sandiegoensis* Uchio (1960, p. 68, pl. 9, figs. 6, 7) is tentatively included in this species, because the authors do not understand the variability of this species group.

Pseudoparrella obesa (Bandy and Arnal) (Plate 3, Figs. 3A–C). *Epistominella obesa* Bandy and Arnal, 1957b, p. 56, pl. 7, figs. 8a–c.

Pseudoparrella sp. A (Plate 3, Figs. 4A–C). This is a small species similar to *P.* cf. *exigua;* it differs in having seven chambers in the final whorl.

Pseudoparrella sp. B

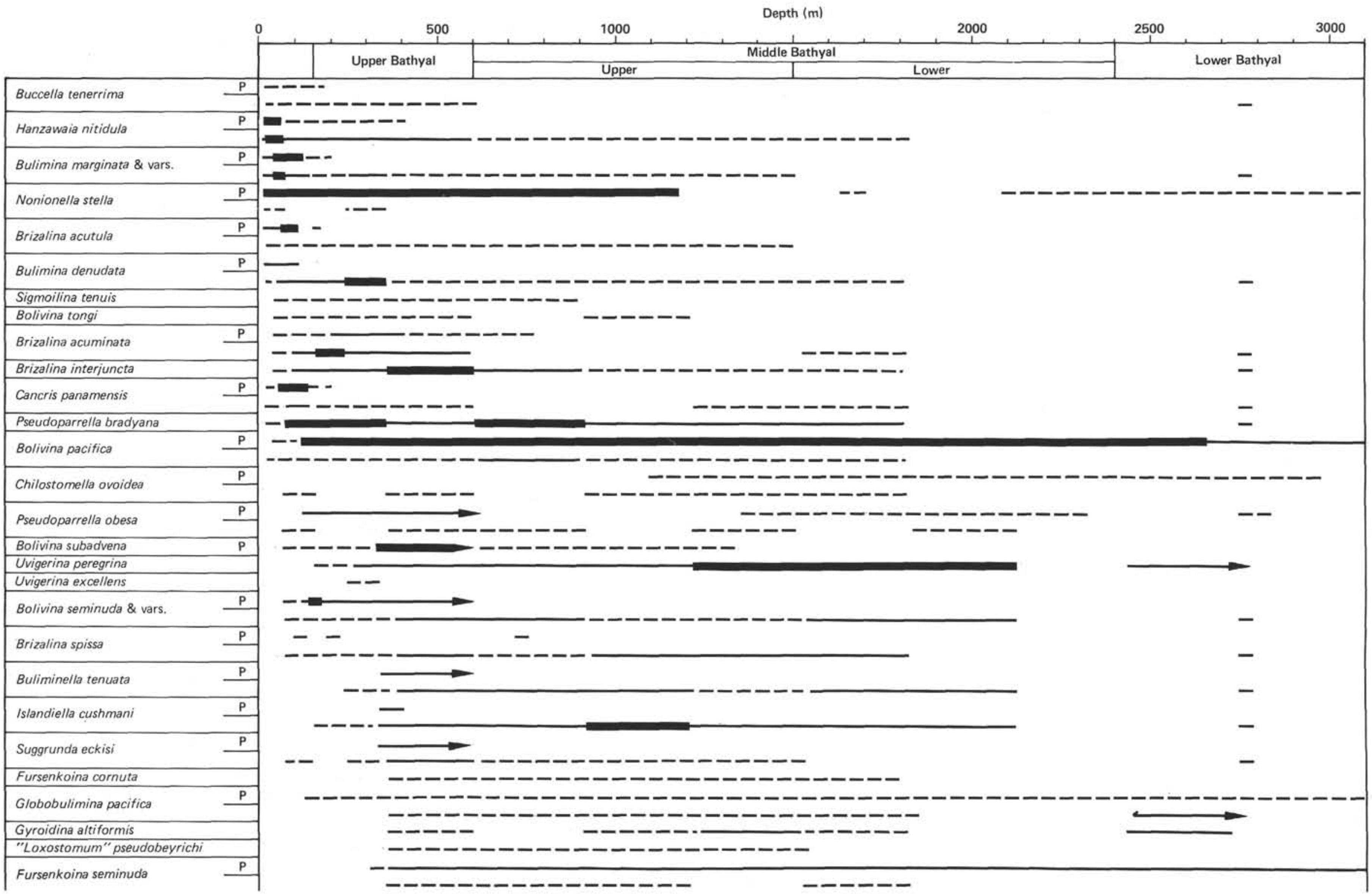
Pseudoparrella sp. C (Plate 3, Figs. 5A–C). This species, having eight chambers in the final whorl, differs from *P. bradyana* in the smaller test and rounded periphery; it differs from *P. obesa* in the smaller and thinner test and mode of convolution on the dorsal side.

Pullenia bulloides (d'Orbigny). *Nonionina bulloides* d'Orbigny, 1826, p. 293 (*fide* Ellis and Messina, 1940 *et seq.*).

Pullenia quinqueloba (Reuss). *Nonionina quinqueloba* Reuss, 1851, p. 71, pl. 5, fig. 31 (*fide* Ellis and Messina, 1940 *et seq.*).

Pullenia sp. A

Pyrgo depressa (d'Orbigny). *Biloculina depressa* d'Orbigny, 1826, p. 298, no. 7 (*fide* Ellis and Messina, 1940 *et seq.*).


Depth (m)
0
500
1000
2000
2500
3000
Upper Bathyal
Middle Bathyal
Upper
Lower
Lower Bathyal
Buccella tenerrima
Hanzawaia nitidula
Bulimina marginata & vars.
Nonionella stella
Brizalina acutula
Bulimina denudata
Sigmoilina tenuis
Bolivina tongi
Brizalina acuminata
Brizalina interjuncta
Cancris panamensis
Pseudoparrella bradyana
Bolivina pacifica
Chilostomella ovoidea
Pseudoparrella obesa
Bolivina subadvena
Uvigerina peregrina
Uvigerina excellens
Bolivina seminuda & vars.
Brizalina spissa
Buliminella tenuata
Islandiella cushmani
Suggrunda eckisi
Fursenkoina cornuta
Globobulimina pacifica
Gyroidina altiformis
"Loxostomum" pseudobeyrichi
Fursenkoina seminuda
P

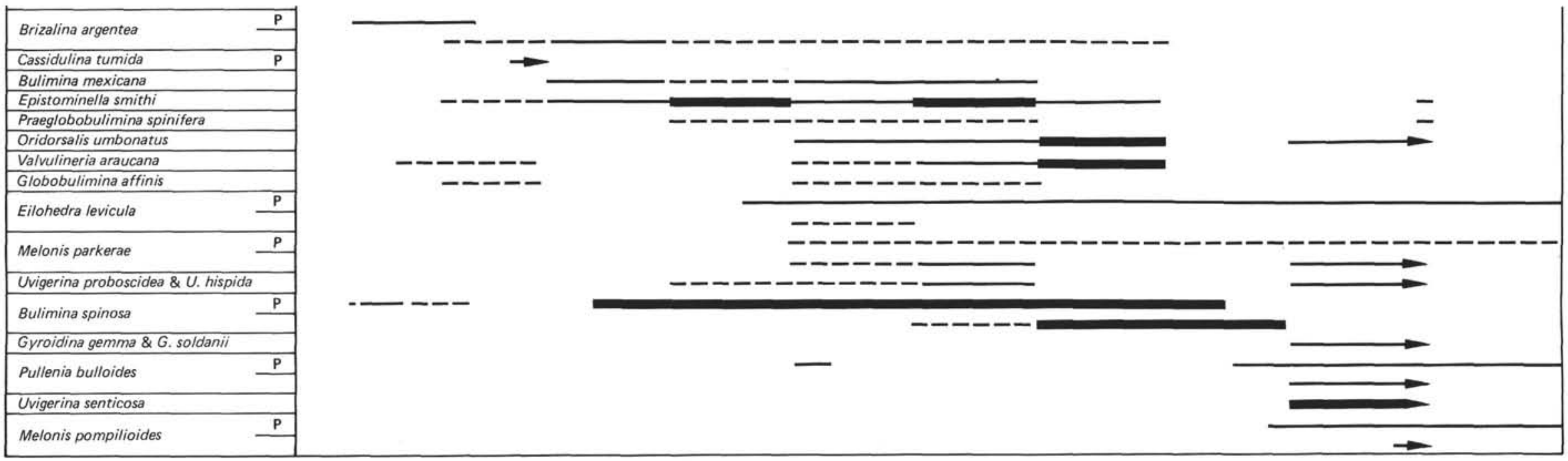


Figure 9. Recent depth distribution of selected benthic foraminifers in the Gulf of California (compiled from Bandy [1961] and Phleger [1964, 1965]; depth ranges indicated by "P" are from Phleger and are based on a living distribution).

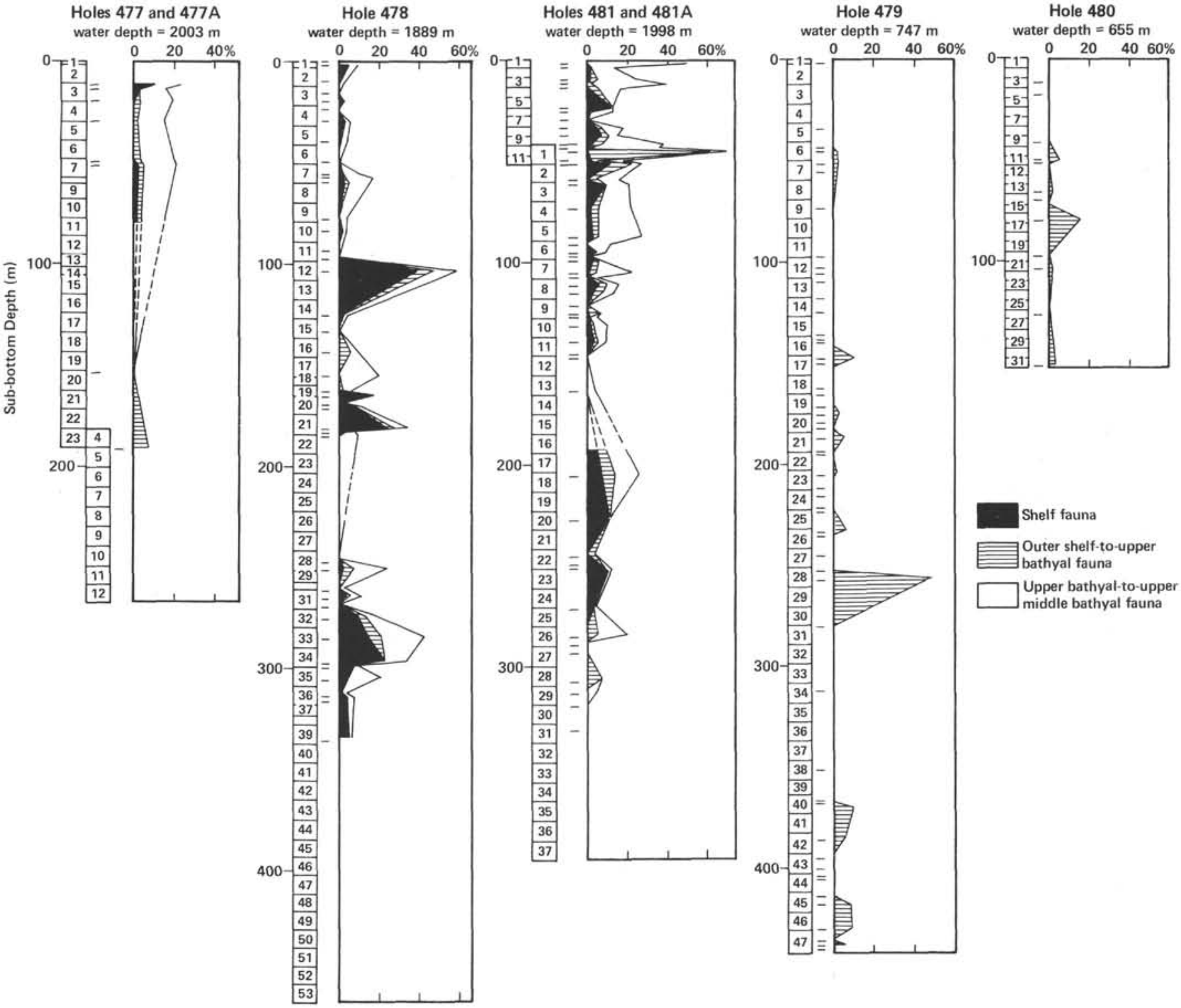


Figure 10. Stratigraphic frequency distribution of displaced fauna. (See text for species composition.)

Pyrgo murrhina (Schwager). *Biloculina murrhina* Schwager, 1866, p. 203, pl. 4, figs. 15a-c.

Pyrgo sp.

Pyrgoella sphaera (d'Orbigny). *Biloculina sphaera* d'Orbigny, 1839b, p. 66, pl. 8, figs. 13-16.

Quadrimorphina laevigata (Phleger and Parker) (Plate 4, Figs. 2a-C). *Valvulineria laevigata* Phleger and Parker, 1951, p. 25, pl. 13, figs. 11a-12b. Ingle et al., 1980, p. 146, pl. 8, figs. 5-7. *Rotamorphina laevigata* (Phleger and Parker), Parker, 1954, p. 537, pl. 11, figs. 10, 11. *Valvulineria glabra* Cushman, Uchio, 1960 (not Cushman), pl. 8, figs. 6, 7. Phleger, 1964, p. 384, pl. 2, figs. 16, 17. (This species is presented as *Quadrimorphina glabra* in the tables and figures of this chapter). This species was originally described under *Valvulineria;* Parker (1954) placed it in *Rotamorphina*. Loeblich and Tappan (1964) regarded *Rotamorphina* as a junior synonym of *Valvulineria*, which has a radial wall structure. We examined several specimens of this species (topotypes included) from both the Gulf of Mexico and the Gulf of California and found that this species has a granular wall. Therefore, this species was placed in *Quadrimorphina*. Specimens from the Gulf of California have a slightly more broadly rounded periphery and a wall very slightly and more coarsely perforated. Smith (1964) included Uchio's (1960) species in her *V. vilardeboana* (d'Orbigny), but d'Orbigny's species seems to be distinct from this species.

Quinqueloculina elongata Natland. Natland, 1938, p. 141, pl. 4, figs. 5a-c.

Quinqueloculina laevigata d'Orbigny. d'Orbigny, 1826, p. 301, no. 6 (*fide* Ellis and Messina, 1940 *et seq.*).

Quinqueloculina lamarckiana d'Orbigny. d'Orbigny, 1839a, p. 189, pl. 11, figs. 14, 15.

Quinqueloculina vulgaris d'Orbigny. d'Orbigny, 1826, p. 302, no. 33 (*fide* Ellis and Messina, 1940 *et seq.*).

Quinqueloculina sp. A

Quinqueloculina sp. B

Quinqueloculina sp. C

Reussella pacifica Cushman and McCulloch. Cushman and McCulloch, 1948, p. 251, pl. 31, figs. 6a, b.

Sigmavirgulina torqueata (Cushman and McCulloch). *Bolivina torqueata* Cushman and McCulloch, 1942, p. 215, pl. 27, figs. 5a-6.

Sigmoilina tenuis (Cžjžek) (Plate 1, Figs. 1a, b). Quinqueloculina tenuis Cžjžek, 1848, p. 149, pl. 13, figs. 31-34 (*fide* Ellis and Messina, 1940 *et seq.*).

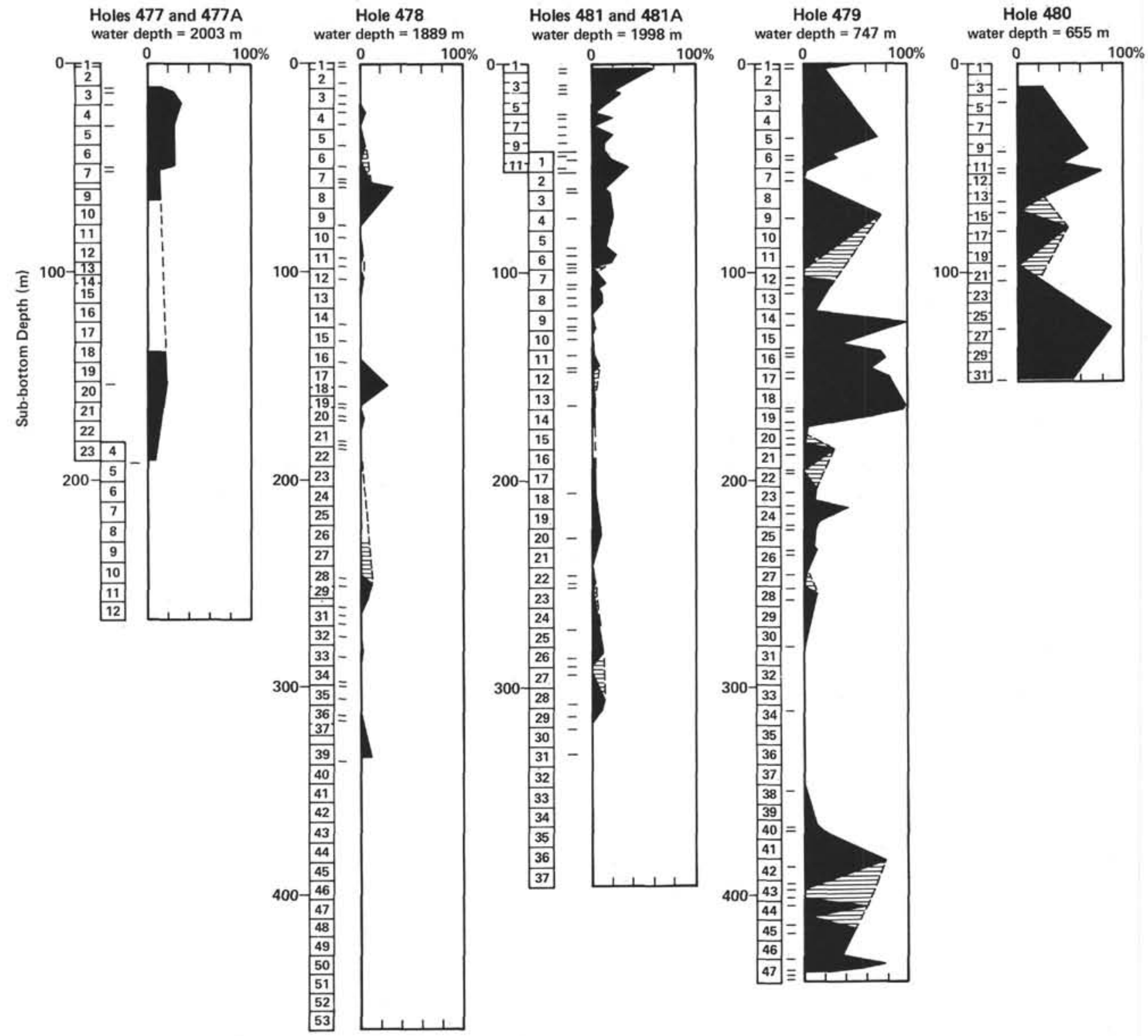


Figure 11. Stratigraphic frequency distribution of some species known to live under low-oxygen bottom conditions. (See text for species. Horizontal hatching indicates samples containing <20 benthic foraminiferal specimens disregarded.)

Stainforthia complanata (Egger). *Virgulina schreibersiana* Cžjžek var. *complanata* Egger, 1893, p. 292, pl. 8, figs. 91, 92 (*fide* Ellis and Messina, 1940 *et seq.*). *V. complanata* Egger, Uchio, 1960, p. 63, pl. 6, fig. 13.

Suggrunda eckisi Natland (Plate 3, Figs. 10a, b). Natland, 1950, p. 23, pl. 9, figs. 12a, b. *S.*(?) *eckisi* Natland, Uchio, 1960, pl. 7, figs. 5, 6.

Triloculina laevigata d'Orbigny. D'Orbigny, 1826, p. 300, no. 15 (*fide* Ellis and Messina, 1940 *et seq.*).

Triloculina trigonula (Lamarck). *Miliolites trigonula* Lamarck, 1804, p. 351. Lamarck, 1807, pl. 17, figs. 4a–c (*fide* Ellis and Messina, 1940 *et seq.*).

Triloculina sp. A

Triloculina sp. B

Uvigerina excellens Todd (Plate 2, Fig. 9). Todd, *in* Cushman and McCulloch, 1948, p. 258, pl. 33, figs. 2a–e.

Uvigerina hispida Schwager. Schwager, 1866, p. 249, pl. 7, fig. 95.

Uvigerina hispidocostata Cushman and Todd. Cushman and Todd, 1945, p. 51, pl. 7, figs. 27, 31.

Uvigerina cf. *juncea* Cushman and Todd. Cf. *Uvigerina juncea* Cushman and Todd, 1941, p. 78, pl. 20, figs. 4–11.

Uvigerina peregrina curticosta (Cushman) (Plate 2, Figs. 10–12). *Uvigerina pigmea* d'Orbigny var. *curticosta* Cushman, 1927a, p. 157, pl. 4, fig. 1. *U. pereglina* Cushman var. *curticosta* (Cushman), Todd *in* Cushman and McCulloch, 1948, p. 266, pl. 34, figs. 2a, b. *U. peregrina* Cushman var. *dirupta* Todd *in* Cushman and McCulloch, 1948, p. 267, pl. 34, figs. 3a–d. *U. curticosta* Cushman, Uchio, 1960, p. 65, pl. 7, figs. 12, 13. *U. peregrina* Cushman, Smith, 1964 (not Cushman), p. 34, pl. 2, figs. 15, 16. (This subspecies is presented in the tables and figures as *U. peregrina*).

Uvigerina proboscidea vadescens Cushman. *Uvigerina proboscidea* Schwager var. *vadescens* Cushman, 1933, p. 85, figs. 14a–15. Todd *in* Cushman and McCulloch, 1948, p. 268, pl. 34, fig. 5.

Uvigerina senticosa Cushman. Cushman, 1927a, p. 159, pl. 3, fig. 14; Todd *in* Cushman and McCulloch, 1948, p. 269, pl. 34, figs. 7a–c.

"*Valvulineria araucana* (d'Orbigny)" (Plate 2, Figs. 13A–C). Not *Rosalina araucana* d'Orbigny, 1839b, p. 44, pl. 6, figs. 16–18. *Valvulineria araucana* (d'Orbigny), Cushman, 1927a (not d'Orbigny), p. 160, pl. 4, figs. 7, 8. Walton, 1955, p. 1016, pl. 103, figs. 15, 20. Uchio, 1960, pl. 8, figs. 3–5. Ingle, et al., 1980, p. 146, pl. 8, figs. 9–11. *V. glabra* Cushman, Smith, 1964 (not Cushman), p. 44, pl. 5, figs. 3a, b. D'Orbigny's species is quite different from this form in that it has a very depressed, discoidal test with a subacute, subcarinate periphery. As authors have long used the species, d'Orbigny's species is tentatively adopted in this study. *Valvulineria sadonica* Asano (1951, p. 8, figs. 55–57) is very similar to this species. *Valvulineria vilardeboana* (d'Orbigny) var. *glabra* Cushman (1927, p. 161, pl. 4, figs. 5, 6) differs from this species in having only five chambers in the final whorl.

Valvulineria inflata (d'Orbigny). *Valvulina inflata* d'Orbigny, 1839b, p. 48, pl. 7, figs. 7–9.

Valvulineria sp. A

Valvulineria sp. B

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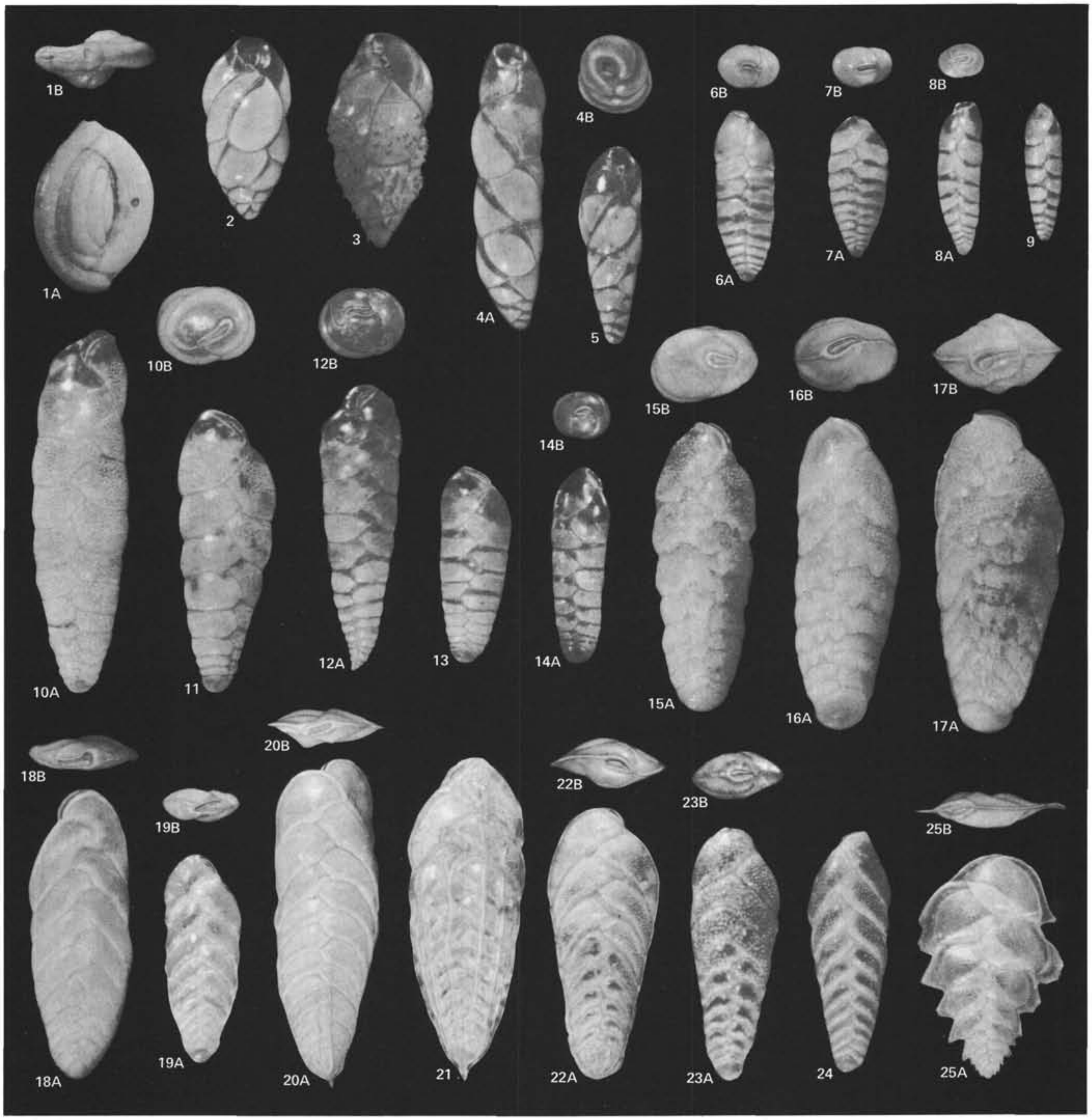

Plate 1. Late Pliocene to Holocene benthic foraminifers. 1A, B. *Sigmoilina tenuis* (Czjzek). ×60. AKMG 11044. Sample 479-7-4, 46–48 cm. 2. *Buliminella curta* Cushman. ×60. AKMG 11045. Section 478-7,CC. 3. *Buliminella curta basispinata* Stewart and Stewart. ×60. AKMG 11046. Sample 479-40-7, 28–30 cm. 4A–5. *Buliminella tenuata* Cushman. ×60. AKMG 11047a, b. Section 478-7,CC. 6A, B. *Bolivina humilis* Cushman and McCulloch. ×60. AKMG 11048. Sample 481A-4-3, 41–43 cm. 7A, B. *Bolivina* cf. *humilis* Cushman and McCulloch. ×60. AKMG 11049. Section 479-42,CC. 8A–9. *Bolivina pacifica* Cushman and McCulloch. ×60. (8A, B) AKMG 11050a. Section 478-7,CC, (9) AKMG 11050b. Sample 477-4-1, 17–19 cm. 10A–11. *Bolivina seminuda* Cushman forma A. ×60. (10A, B) AKMG 11051A. Sample 479-47-1, 70–72 cm, (11) AKMG 11051b. Sample 477-4-1, 17–19 cm. 12A–13. *Bolivina seminuda* Cushman forma B. ×60. AKMG 11052a, b. Sample 477-4-1, 17–19 cm. 14A, B. *Bolivina seminuda* Cushman forma C. ×60. AKMG 11053. Sample 477-4-1, 17–19 cm. 15A, B. *Bolivina subadvena* Cushman forma A. ×60. AKMG 11054. Section 479-1,CC. 16A, B. *Bolivina subadvena* Cushman forma B. ×60. AKMG 11055. Sample 481-10-2, 69–71 cm. 17A, B. *Bolivina subadvena* Cushman forma C. ×60. AKMG 11056. Section 480-31,CC. 18A–19B. *Brizalina argentea* (Cushman) forma A. ×40. (18A, B) AKMG 11057a, Sample 481-10-2, 69–71 cm, (19A, B) AKMG 11057b. Section 480-21,CC. 20A, B. *Brizalina argentea* (Cushman) forma B. ×40. AKMG 11058. Section 480-4,CC. 21. *Brizalina interjuncta bicostata* (Cushman). ×60. AKMG 11059. Sample 481A-4-3, 41–43 cm. 22A, B. *Brizalina spissa* (Cushman). ×60. AKMG 11060. Sample 479-7-2, 73–75 cm. 23A–24. *Brizalina semiperforata* (Martin). ×60. (23A, B) AKMG 11061a. Sample 478-34-5, 6–8 cm, (24) AKMG 11061b. Sample 479-13-1, 95–97 cm. 25A, B. *"Loxostomum" pseudobeyrichi* (Cushman), ×40. AKMG 11062. Section 480-4,CC.

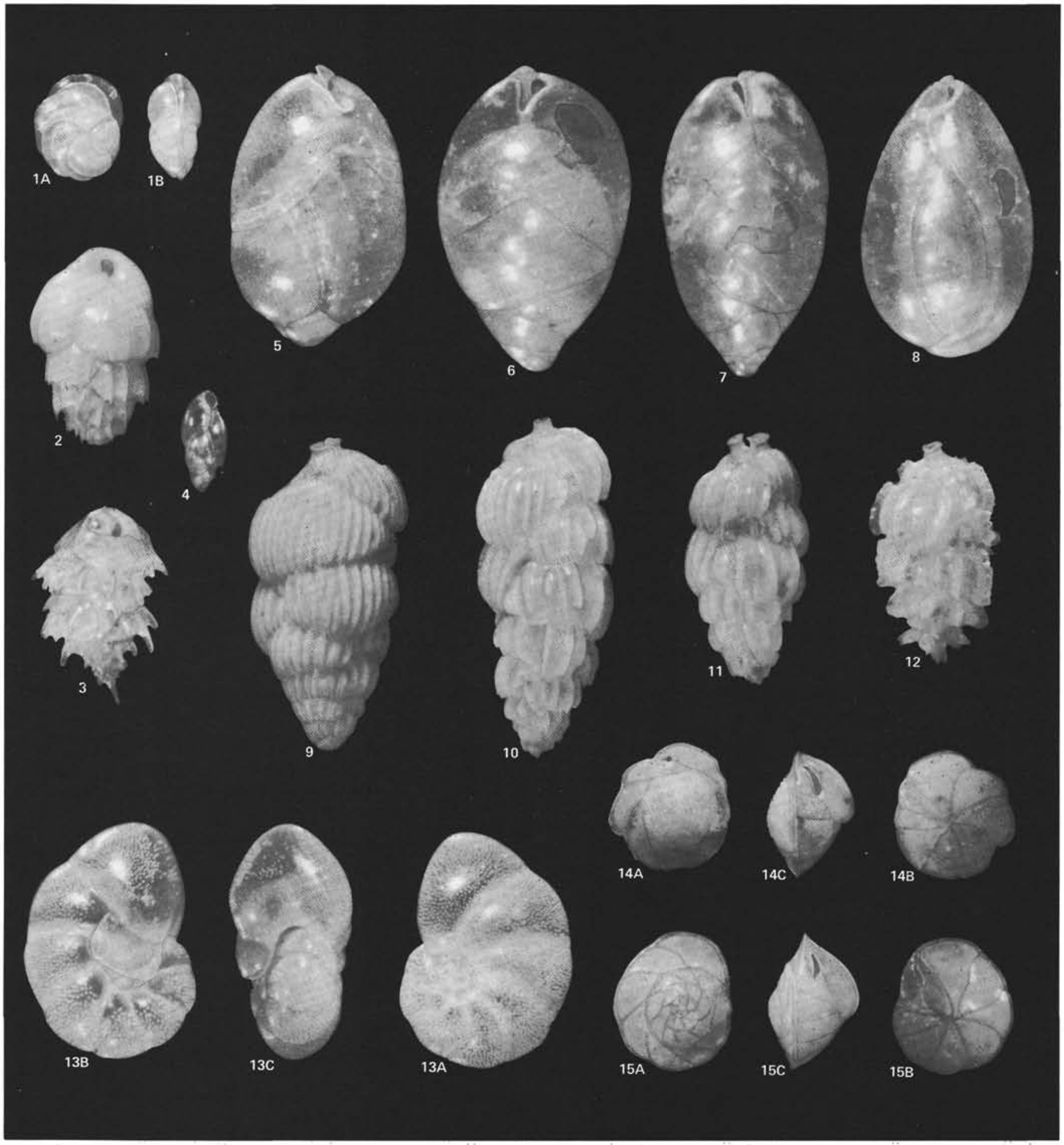

Plate 2. Late Pliocene to Holocene benthic foraminifers. 1A, B. *"Islandiella" cushmani* (Stewart and Stewart). ×60. AKMG 11063. Sample 477-3-2, 101–103 cm. 2. *Bulimina mexicana* Cushman. ×60. AKMG 11064. Section 478-30,CC. 3. *Bulimina pagoda* Cushman. ×60. AKMG 11065. Sample 481A-3-1, 50–52 cm. 4. *Bulimina spinosa* (Heron-Allen and Earland). ×80. AKMG 11066. Sample 481A-9-6, 117–119 cm. 5. *Globobulimina affinis* (d'Orbigny) forma A. ×60. AKMG 11067. Sample 477-3-1, 86–88 cm. 6. *Globobulimina affinis* (d'Orbigny) forma B. ×60. AKMG 11068. Sample 477-3-1, 86–88 cm. 7. *Globobulimina affinis* (d'Orbigny) forma C. ×60. AKMG 11069. Sample 477-3-1, 86–88 cm. 8. *Globobulimina pacifica* Cushman. ×60. AKMG 11070. Sample 477-3-1, 86–88 cm. 9. *Uvigerina excellens* Todd. ×60. AKMG 11071, Sample 479-6-3, 106–108 cm. 10–12. *Uvigerina peregrina curticosta* (Cushman). ×60. (10) AKMG 11072a. Sample 478-11-4, 38–40 cm, (11-12) AKMG 11072b, c. Sample 479-7-4, 46–48 cm. 13A–C. *"Valvulineria araucana* (d'Orbigny)". ×60. AKMG 11073. Sample 477-5-1, 29–30 cm. 14A–15C. *Epistominella* cf. *pacifica* (Cushman). ×60. AKMG 11074a, b. Section 478-36,CC.

Plate 3. 1A–C. *Epistominella smithi* (Stewart and Stewart). ×60. AKMG 11075. Section 478-10,CC. 2A–C. *Pseudoparrella bradyana* (Cushman). ×60. AKMG 11076. Sample 479-13-1, 95–97 cm. 3A–C. *Pseudoparrella obesa* (Bandy and Arnal). ×60. AKMG 11077. Sample 481-10-2, 69–71 cm. 4A–C. *Pseudoparrella* sp. A. ×80. AKMG 11078. Section 478-7,CC. 5A–C. *Pseudoparrella* sp. C. ×80. AKMG 11079. Sample 479-40-7, 28–30 cm. 6A–C. *Planulina limbata* Natland. ×40. AKMG 11080. Section 478-31,CC. 7A–C. *Buccella tenerrima* (Bandy). ×60. AKMG 11081. Sample 478-12-3, 139–141 cm. 8A, B. *Fursenkoina cornuta* (Cushman). ×60. AKMG 11082. Section 481-3,CC. 9A, B. *Fursenkoina rotundata* (Parr). ×60. AKMG 11083. Sample 478-16-5, 41–42 cm. 10A, B. *Suggrunda eckisi* Natland. ×80. AKMG 11084. Sample 477-5-1, 29–31 cm. 11A, B. *Cassidulina subcarinata* Uchio. ×80. AKMG 11085. Sample 477-3-2, 101–103 cm. 12A, B. *Cassidulina tumida* Natland. ×60. AKMG 11086. Sample 481-10-2, 69–71 cm. 13A, B. *Cassidulina braziliensis* Cushman. ×60. AKMG 11087. Sample 479-23-5, 72–74 cm.

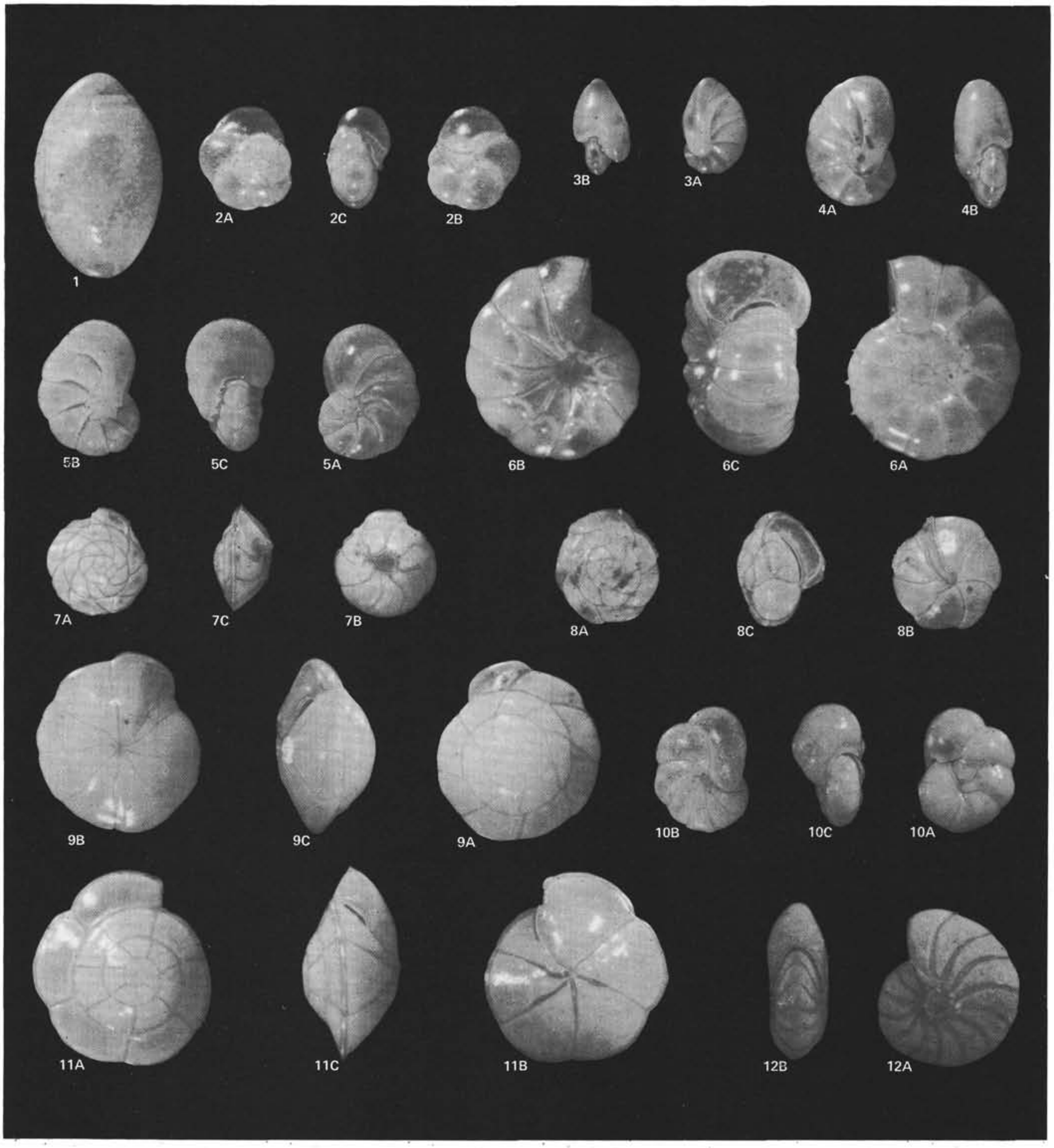

Plate 4. Late Pliocene to Holocene benthic foraminifers. 1. *Chilostomella ovidea* Reuss. ×60. AKMG 11088. Section 478-5,CC. 2A–C. *Quadrimorphina laevigata* (Phleger and Parker). ×60. AKMG 11089. Sample 478-22-1, 28–31 cm. 3A, B. *Nonionella basiloba* Cushman and McCulloch. ×60. AKMG 11090. Sample 481A-1-1, 36–38 cm. 4A, B. *Nonionella stella* Cushman and Moyer. ×60. AKMG 11091. Sample 481A-4-3, 41–43 cm. 5A–C. *Nonionella* sp. A. ×60. AKMG 11092, Section 481-3,CC. 6A–C. *Gyroidina multilocula* Coryell and Mossman. ×60. AKMG 11093. Section 478-7,CC. 7A–C. *Gyroidina*(?) *rothwelli* Natland. ×60. AKMG 11094. Sample 478-33-4, 48–50 cm. 8A–C. *Gyroidina*(?) sp. A. ×80. AKMG 11095. Sample 481A-6-4, 110–112 cm. 9A–C. *Gyroidina*(?) *gemma* Bandy. ×60. AKMG 11096. Section 478-4,CC. 10A–C. *Hanzawaia*(?) sp. A. ×60. AKMG 11097. Section 479-42,CC. 11A–C. *Oridorsalis umbonatus* (Reuss). ×60. AKMG 11098. Section 478-2,CC. 12A, B. *Melonis parkerae* (Uchio). ×60. AKMG 11099. Section 478-21,CC.