44. LATE PLIOCENE TO HOLOCENE PLANKTONIC 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. Holes 477, 477A, 477B, 481, and 481A were drilled in the two spreading rifts in the central part of the basin, and Hole 478 was drilled in the flat basin floor. The sediment dates from the Pleistocene to Holocene epoch. Sites 479 and 481 are on the continental slope within the depths of the present oxygen-minimum zone. The six basal cores from Hole 479 are from the late Pliocene epoch, and an unconformity seems to occur between the upper Pliocene and the overlying Pleistocene sequence. Hole 480 was drilled with a hydraulic piston corer and contains an upper Pleistocene to Holocene sequence of well-laminated diatomaceous mud.

Almost all specimens of *Neogloboquadrina pachyderma* are dextrally coiled in the upper Pliocene to Holocene sequence. Tropical and subtropical species occur in many samples but are not abundant. Such temperate forms as *Globigerina bulloides bulloides, G. bulloides quadrilatera, G. bulloides umbilicata, Globigerinita glutinata, Neogloboquadrina dutertrei* forma A, and *N. pachyderma* forma A and forma B are predominant in the Pleistocene to Holocene sequence. The late Pliocene fauna from the basal part of the Hole 479 is abundant in *Globigerinoides* and includes *Globigerinoides bollii, G. obliquus*, and sinistrally coiled *Pulleniatina obliquiloculata*. The upper Pleistocene to Holocene sequence is characterized by the abundant and continuous occurrence of *Globigerina bulloides quadrilatera* and *G. bulloides umbilicata*. Evidence for three cooler intervals occurring in the middle to late Pleistocene epoch is apparent, but the climatic fluctuation indicated by planktonic foraminifers differs from that of the northeast Pacific Ocean, probably because of the geography, geomorphology, and the special paleoceanographic conditions of the Gulf. The proto-Gulf sequence defined on the reflection profiles includes the uppermost Pliocene. The angular unconformity between the proto-Gulf sequence and the younger sediment was formed in the early Pleistocene epoch, during the opening of the Gulf, rather than at the beginning of the present spreading phase. Many of the planktonic foraminiferal species and morphotypes are illustrated in the plates. One species, *Turborotalita guaymasensis* n. sp., is new.

INTRODUCTION[2]

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. We studied planktonic foraminifers from the upper Pliocene to Holocene sections in the Guaymas Basin (Fig. 1).

The primary purposes of drilling were to investigate the nature of the ocean crust currently generated in the Gulf, where sedimentation rates are very high (Moore, 1973), and to study the paleoceanography and biostratigraphy of the laminated diatomaceous sediment on the continental slope in the central Gulf. The Guaymas Basin includes two spreading rifts separated by a 20-km transform fault. Sites 477 and 481 are in the south and north rifts, respectively. The sediment includes Quaternary diatom ooze and turbidites intruded by basalt, dolerite, and gabbro sills. Site 478 is on the basin floor —northwest of the south rift—over postulated young crust. Its sequence is similar to that of Sites 477 and 481. Sites 479 and 480 are on the northern continental slope of the Guaymas Basin within the present oxygen-minimum layer and over the presumed proto-Gulf sediment and crust (Moore, 1973). Hole 479 penetrated 444 meters of diatomaceous ooze to laminated mudstone. Sediment from the lowest part of the hole contains a late Pliocene planktonic foraminiferal fauna. Hole 480 duplicated the upper 152 meters of Hole 479 and was drilled with the newly developed hydraulic piston corer.

Bradshaw (1959), Bandy (1961), and Parker (1973) reported on the Recent distribution of planktonic foraminifers in the Gulf. Miocene to Pleistocene foraminifers from deposits exposed on islands and on the continental slope in the Gulf are included in the papers of Natland (1950) and Moore (1973), respectively. Smith (1970) and Ingle (1973c, 1974) studied planktonic and benthic foraminifers of upper Miocene to Pliocene land sections and wells in the northern extensions of the Gulf.

METHODS

We examined 258 sediment samples from Holes 477 to 481A in the Guaymas Basin; planktonic foraminifers occur in 129 samples. Each sample contained about 10 cm^3 of sediment. We disaggregated the samples by soaking them in warm water and by adding varying amounts of hydrogen peroxide, depending on the consolidation of the sediment.

We washed the disaggregated samples through a 250-mesh (0.063-mm) screen and allowed them to dry. Diatomaceous sediment samples, especially those from a few top cores of each hole, contained abundant diatom remains, which flocculated as they dried. We boiled these samples in a concentrated solution of sodium hydroxide to dissolve diatom silica. Before extracting the foraminifers, each sample was dry sieved through a 115-mesh (0.125-mm) screen, and the coarser fraction was analyzed for foraminifers. Where planktonic foraminifers were abundant, the samples were split into a workable size and 200 to 300

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

[2] For the geographic and hydrographic setting, see Matoba and Yamaguchi (this volume).

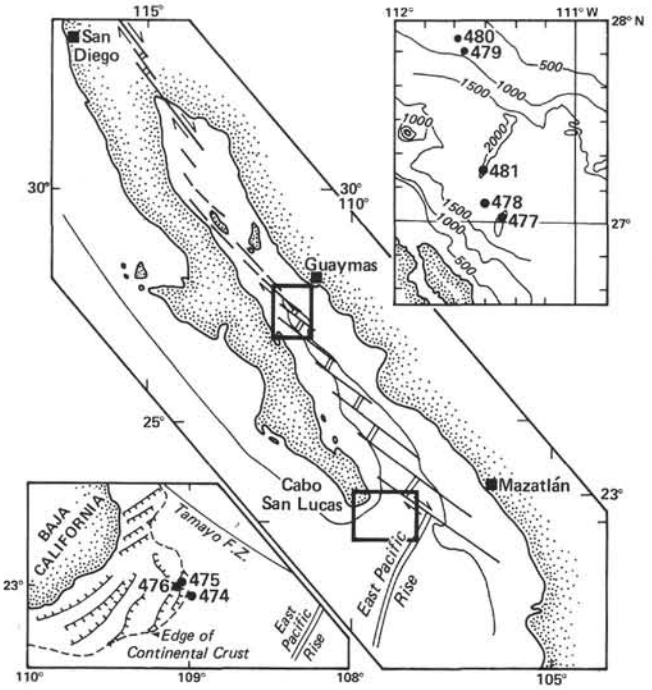

Figure 1. Guaymas Basin sites, Leg 64 (from Curray et al., 1979).

specimens were extracted. We extracted the benthic foraminifers from the same split.

We conducted quantitative analyses of planktonic foraminifers, and the results are given on Tables 1 through 5 (occurrence in percentages). Percentages were not calculated for samples containing fewer than 30 specimens. The stratigraphic occurrences of some selected species are shown in Figures 3 through 7. Most species and morphotypes are illustrated in SEM photographs on Plates 1 through 5.

PRESERVATION AND ABUNDANCE

Preservation, abundance of benthic and planktonic foraminifers, and the ratio of planktonic foraminifers to total foraminifers are shown in Figure 2. Preservation of foraminiferal tests is poor in many samples—and for two reasons: simple dissolution and thermal alteration.

The deeper sites (Sites 477, 478, and 481), are intruded by basaltic sills. Near the sills, there is a change in the foraminiferal tests: The test walls are brown or recrystallized. In samples from the upper part of each hole (above the sills), however, preservation is moderately good, except where strong dissolution has occurred; preservation is better than in the shallower sites (Sites 479 and 480). At Sites 479 and 480, which are within the present oxygen-minimum zone, preservation is generally poor throughout because of strong dissolution.

We calculated the abundance of benthic and planktonic foraminifers as the number of specimens in 10 ml of sediment. This abundance seems to be related to preservation; planktonic and benthic foraminifers are more abundant in the deeper holes. In these deeper holes, planktonic foraminifers are more abundant than benthic foraminifers. Nonetheless, in many samples from shallower holes, there are fewer planktonic than benthic foraminifers and in some samples, planktonic foraminifers are absent entirely. This may be the result of selective dissolution between benthic and planktonic foraminifers. Parker and Berger (1971), in their study of deep-sea sediment, noted that the ratio of planktonic to benthic foraminifers is a function of preservation. This ratio may also hold for continental slope and basin sediment in environments of strong dissolution, such as the bottom of the present oxygen-minimum zone in the Guaymas Basin.

GEOGRAPHICAL DISTRIBUTION

Planktonic foraminiferal species have different geographic distributions in the oceans, and this distribution generally accords with major hydrographic regions. Although the distribution is controlled physically, chemically, and biologically, temperature is probably the most important variable for most species. There are five major faunal provinces: the arctic and antarctic, subarctic and subantarctic, subtropical, tropical provinces, and the transition zones between subpolar and subtropical provinces (Bé and Tolderlund, 1971; Bé, 1977). To distinguish the paleoceanographic variations in the Gulf of California, we examined the occurrence of warm- and cold-water species in the fauna of the Guaymas Basin. Warm-water species (according to Bradshaw, 1959; Parker and Berger, 1971; Bé and Tolderlund, 1971; Bé, 1977) in the Basin fauna are as follows: *Globigerinella aequilateralis, Globigerinoides conglobatus, G. quadrilobatus* (s.l.), *G. ruber* (s.l.), *Globorotalia cultrata, G. fimbriata, G. hirsuta, G. tumida, Pulleniatina obliquiloculata*, and the fossil species of *Globigerinoides bollii* and *G. obliquus*. The characteristic arctic species, the left-coiling form of *Neogloboquadrina pachyderma*, is nearly absent in the Basin fauna. Therefore, the right-coiling form of *N. pachyderma*, which is distributed in the subarctic-to-transition area, is the relatively colder-water species in the Guaymas Basin samples.

SITE 477

The stratigraphic section at Site 477 consists of Holes 477 and 477A. The occurrence of planktonic foraminifers at Site 477 is shown in Table 1 and Figure 3. Statistically reliable occurrences of planktonic foraminifers were found only in the upper part of Sample 477-7-2, 17–19 cm, above the dolerite sill. *Globigerina bulloides bulloides, G. bulloides quadrilatera, G. bulloides umbilicata, Globigerinita glutinata, Neogloboquadrina dutertrei* forma A, and *N. pachyderma* forma B are common throughout most of this interval. *Neogloboquadrina pachyderma* (s.s.) and *N. dutertrei blowi* occur only in Sections 477-7-1 and 477-7-2. Warm-water species occur in Sections 477-5-1, 477-7-1, and 477-7-2 with frequencies of 6 to 17%.

SITE 478

In Hole 478, foraminifers are absent in two intervals between Cores 478-23 and 478-27 and below Core 478-40, where basalt and dolerite sills have intruded (Table 2; Fig. 4).

Globigerina bulloides bulloides, Neogloboquadrina dutertrei forma A, and *N. pachyderma* forma B are the most abundant nearly throughout the hole. *Globigerina* *bulloides quadrilatera* and *G. bulloides umbilicata* are abundant in the upper half of the hole. But *Neogloboquadrina pachyderma* forma A is generally abundant in the lower part of the hole and gradually decreases upward. Dextrally coiled specimens of *N. pachyderma* (s.s.), a cold-to-temperate-water form, occur in four intervals in Sections 478-36-4 and 478-36,CC, 478-28,CC through 478-31-2, 478-19-6 through 478-21,CC and 478-3-4 through 478-7-3. There are two distinct intervals of abundant warm-water species in Sections 478-7-6 through 478-10,CC and 478-1-1 through 478-3-4. *Neogloboquadrina dutertrei blowi* occurs in the lowest and upper sections of the hole. *Pulleniatina obliquiloculata* occurs sporadically throughout the hole and is dextrally coiled except for two samples in Sections 478-31-2 and 478-35-4. One specimen of *Pulleniatina obliquiloculata* is sinistrally coiled, but another is dextrally coiled in Section 478-31-2; one specimen of this species is sinistrally coiled in Section 478-35-4.

SITE 479

Table 3 and Figure 5 show the occurrence of planktonic foraminifers in Hole 479. There is a wide interval between Cores 479-28 and 479-42 where planktonic foraminifers are absent because of dissolution. There are also several other relatively wide gaps, which make it difficult to detect a continuous faunal change.

The fauna below Core 479-42 is different from that above Core 479-28. This basal fauna consists chiefly of *Globigerinita glutinata, Globigerinoides ruber ruber, G. ruber elongatus, Globigerina quinqueloba*, and *G. bulloides bulloides. Globigerinoides bollii, G. obliquus*, and *Globigerina* sp. A also occur only in this interval. We found four specimens of *Pulleniatina obliquiloculata* in Sample 479-42,CC, and all are sinistrally coiled (Plate 2, Figs. 14, 15), indicating that the fauna is from the late Pliocene epoch.

In the upper half of Hole 479, *Neogloboquadrina dutertrei dutertrei, N. dutertrei* forma A, and *Globigerina bulloides bulloides* are predominant. *Neogloboquadrina pachyderma* forma B is abundant in the middle–upper part (Sections 479-6-3–479-17-1) of the upper section. *Globigerina bulloides quadrilatera* and *G. bulloides umbilicata* occur continually above Sections 479-26-2 and 479-23-5, respectively. *Neogloboquadrina pachyderma* (s.s.) occurs in Sections 479-23-5 through 27-3 and 479-6-3 through 12-6 in the upper half of the hole.

SITE 480

Hole 480 was drilled using a hydraulic piston corer. Unusually well-preserved and undisturbed laminated diatomaceous mud was recovered. Unfortunately, foraminifers are not well preserved because of the strong dissolution effect under the depth condition of the present oxygen-minimum zone. Only seven core-catcher samples yielded planktonic foraminifers (Table 4, Fig. 6.).

Globigerina bulloides bulloides, G. bulloides quadrilatera, G. bulloides umbilicata, G. quinqueloba, and *Globigerinita glutinata* are abundant in most samples. *Neogloboquadrina dutertrei* forma A and *N. pachyderma* forma A and forma B are predominant in a few top samples. Warm-water species are abundant in the middle part of the hole (Sections 480-16,CC and 480-21,CC). *Globigerina pachyderma* (s.s.) occurs only at the top of the hole (Sections 480-3,CC and 480-4,CC).

SITE 481

The section at Site 481 is a composite of Holes 481 (Cores 481-1–481-11) and 481A (Cores 481A-1–481A-37). Table 5 and Figure 7 show the occurrence of planktonic foraminifers. There are two gaps in foraminiferal occurrence: Cores 481A-14 through 481A-17 and the part of the hole below Core 481A-31, where basaltic sills have intruded.

Globigerina bulloides bulloides and *Neogloboquadrina dutertrei* forma A are common throughout the section. *Globigerinita glutinata* and *Neogloboquadrina pachyderma* forma B are also abundant in many samples. *Globigerina bulloides quadrilatera* is abundant above Section 481A-12-1, and *G. bulloides umbilicata* is abundant above Section 481A-9-6. *Neogloboquadrina pachyderma* forma A is abundant in the middle section (Cores 481A-18–481A-22) and is less abundant upward in the hole. *N. pachyderma* (s.s.) occurs in three intervals: Sections 481A-18,CC through 481A-22-2, 481A-6-4 through 481A-12-1, and 481-6,CC through 481A-4-3. Warm-water species occur rather continuously throughout the hole, and, except for an interval in Sections 481-3,CC through 481-7-2 and in a few other samples, their composite frequency is not high. *N. dutertrei blowi* occurs sporadically between Cores 481-8 and 481A-22.

CORRELATION WITHIN THE GUAYMAS BASIN

Figure 8 shows the relation of the sites in the Guaymas Basin to the occurrence of selected planktonic foraminifers, including *Globigerina bulloides quadrilatera, G. bulloides umbilicata, Neogloboquadrina dutertrei blowi, N. pachyderma* forma A, *N. pachyderma* (s.s.), and some warm-water species.

The late Pliocene planktonic fauna in the basal part of Hole 479 do not occur in any other holes and seem to be the oldest fauna in the Basin. Except for this Pliocene fauna, there are no index species in the Quaternary sequence. Nevertheless, faunal variations of planktonic microfossils, caused by paleoclimatic and paleoceanographic changes, are usually very effective for correlation within Quaternary sediment. It is difficult, however, to make a precise correlation based on planktonic faunal changes, because there are several gaps in the planktonic foraminiferal record.

The most distinct and useful faunal data are the abundant and continuous occurrences of *Globigerina bulloides quadrilatera* and *G. bulloides umbilicata* in the upper half of the Quaternary sequence, although they are not distinct in Holes 479 and 480 because of several rather wide sample gaps. The first abundant and continuous occurrences of *Globigerina bulloides quadrilatera* and *G. bulloides umbilicata* are shown in Figure 8 with the correlation horizons C and B, respectively. Horizon A indicates the last occurrence of *Neogloboquadrina dutertrei blowi*. Moreover, this horizon nearly corresponds to the last occurrence of the dextrally coiled

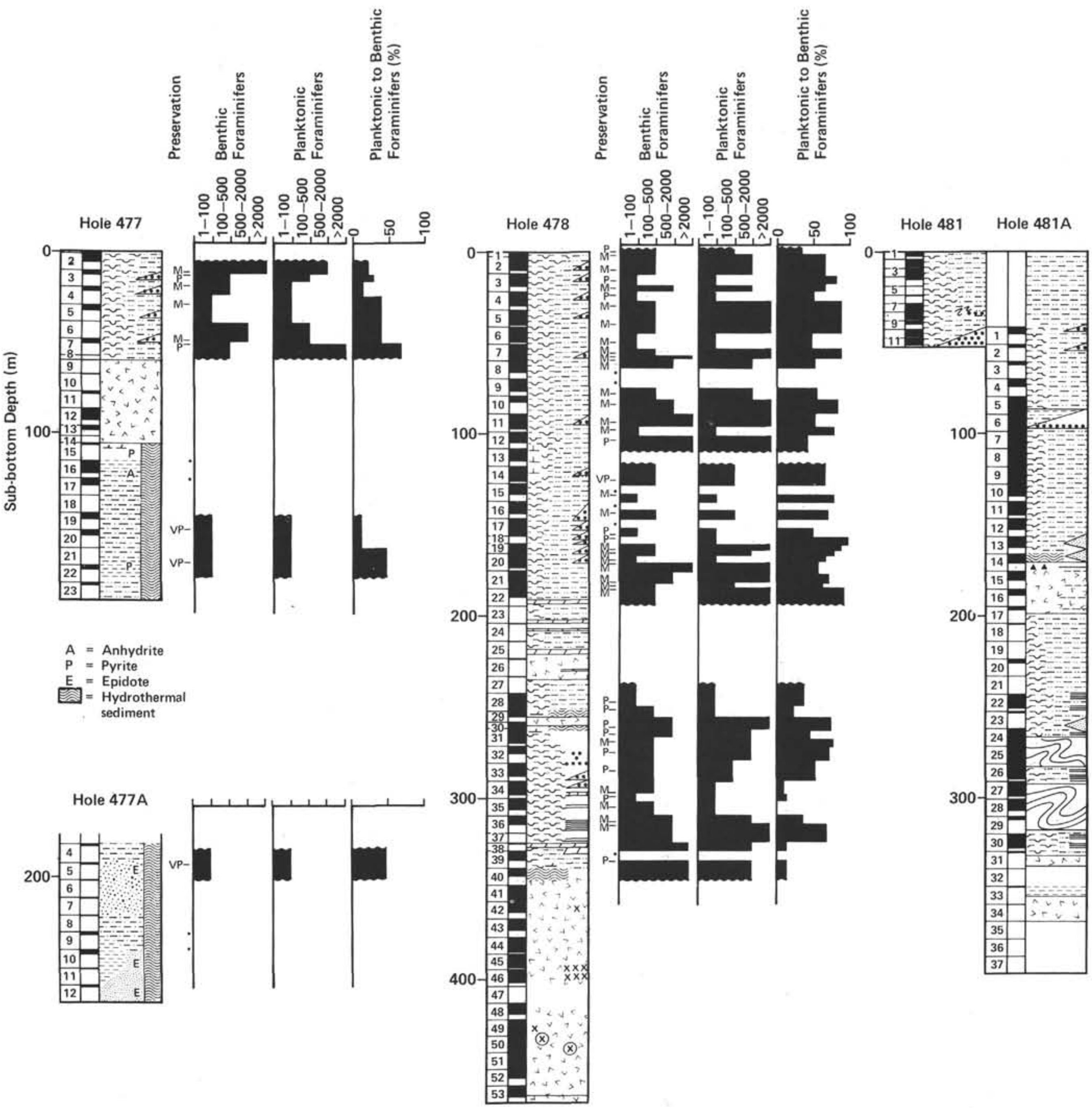

Figure 2. Preservation, abundance, and ratio of planktonic to benthic foraminifers, Guaymas Basin sites. (Preservation: M = moderate, P = poor, VP = very poor. Abundance was calculated for number of specimens per 10 ml of sediment.)

form of *Neogloboquadrina pachyderma* (s.s.), and the warm-water species become abundant above this horizon. The interval between horizons D and D′ is characterized by abundant occurrences of *Neogloboquadrina pachyderma* forma A and *N. pachyderma* (s.s.); *N. dutertrei blowi* also occurs in this interval.

GEOLOGIC AGE

The oldest fauna we found in the Guaymas Basin is in the basal part of Hole 479. According to Blow (1969), *Globigerinoides bollii* ranges from his Planktonic Foraminiferal Zone, N11 to the upper part of Zone N21 (middle Miocene to Pliocene); *G. obliquus* ranges from Zone N6 to the lower part of Zone N22 (early Miocene to earliest Pleistocene). In the eastern equatorial Pacific, Jenkins and Orr (1972) recorded the range of *G. bollii* from the *Globorotalia fohsi fohsi–G. peripheroacuta* zone (N10–11) to the *Sphaeroidinella dehiscens* zone (N19–N20; middle Miocene to Pliocene) and *G. obliquus* from the *Globigerinita dissimilis* zone (N5–N6) to the lower *Pulleniatina obliquiloculata* zone (N22–N23; early Miocene to early Pleistocene). Parker (1967), in a study of tropical Indo-Pacific deep-sea cores, recorded the tops of the ranges of the two species at the basal part

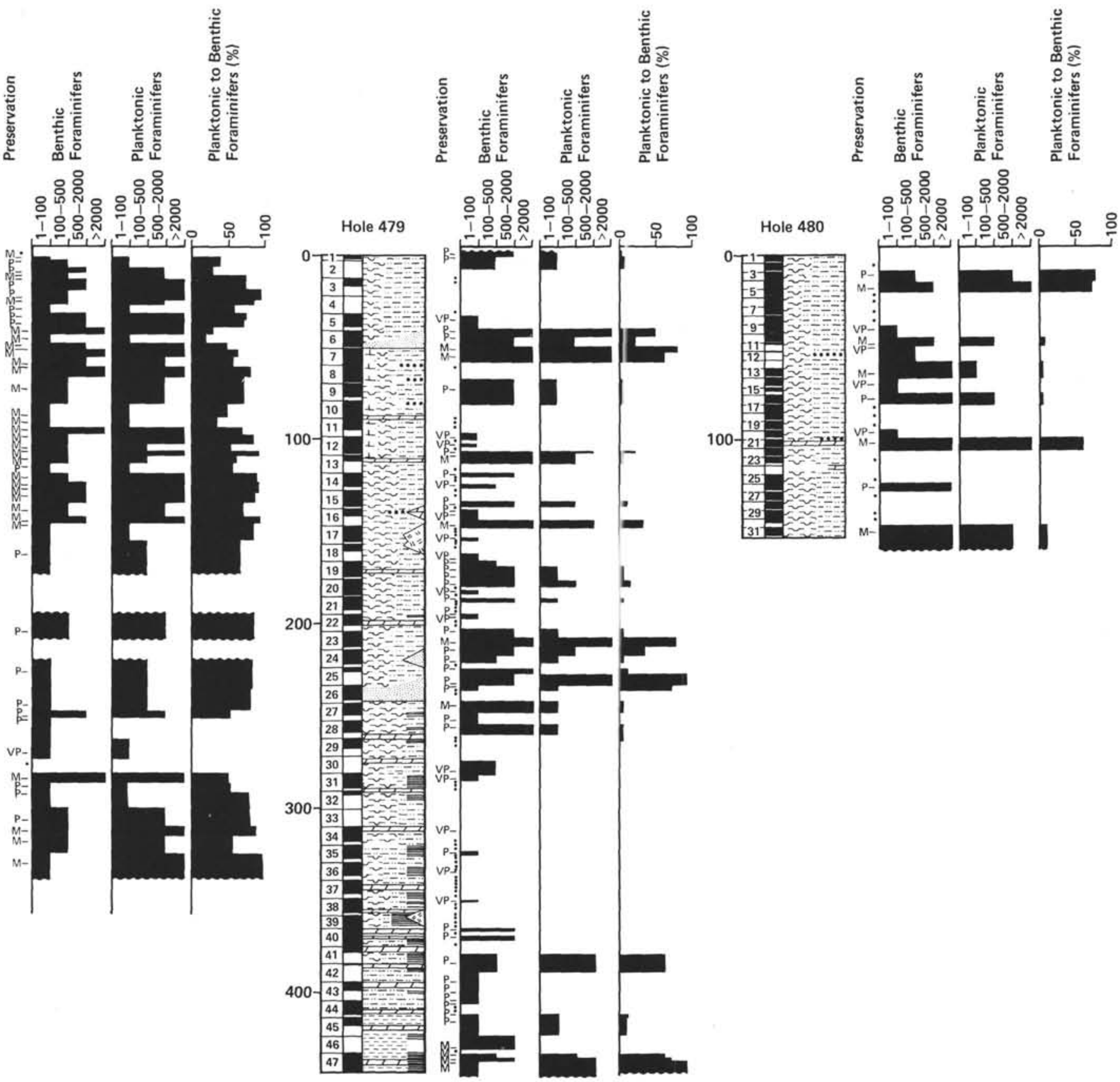

Figure 2. (Continued).

of Zone N21 as late Pliocene. But Brönnimann and Resig (1971) recorded the latest occurrences of the two species in N22 and N23, respectively, in the southwestern Pacific. Ingle (1974) reported on *Globigerinoides obliquus* from the Pliocene (N20–N21) Carmen Formation, Carmen Island, Gulf of California. Saito (1977) presented the extinction datum of *G. obliquus* at 1.76 Ma. Thompson and Sciarrillo (1978), on the basis of an examination of eight deep-sea cores from the equatorial Pacific (Fig. 9), proposed that the extinction datum of the species (1.63 Ma) be placed near the Pliocene/Pleistocene boundary.

Sinistrally coiled *Pulleniatina obliquiloculata* occurs in Section 479-42,CC and in two samples from the basal part of Hole 478. According to Hays et al. (1969), Saito et al. (1975), Saito (1976, 1977), and Thompson and Sciarrillo (1978), the coiling direction of *Pulleniatina* changed several times after its first appearance in the earlier paleomagnetic (Epoch 5; 6.1 Ma), which appearance included at least four major left-coiling intervals. The patterns of the coiling changes in this species are closely correlative within the Indo-Pacific regions. The occurrences of *Globigerinoides bollii, G. obliquus, Pulleniatina obliquiloculata* (s.s.) (middle Pliocene to Re-

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

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	477-22-1, 63-65	477A-5-1, 51-53
Globigerina bermudezi		3	3	4		1			
G. bulloides bulloides	43	39	28	22	40	43			X
G. bulloides quadrilatera	6	6	5	7	4	3			
G. bulloides umbilicata	7		8	13	3	4			
G. falconensis		6	8		6	5			
G. quinqueloba		3		2	2				
G. cf. *quinqueloba*	+	3	3	2	1				
G. rubescens	1								
G. spp.		1	3		1				
Globigerinita glutinata	16	21	23	17	4	1			X
G. uvula					3				
Globigerinoides quadrilobatus sacculifer						+			
G. quadrilobatus trilobus						1			
G. ruber ruber	1			4	4	4			X
G. tenellus	2								
G. sp. A	+								
Globorotalia cultrata				9	4	1			+
G. scitula				2					
Neogloboquadrina dutertrei blowi					3	1			
N. dutertrei dutertrei	+								
N. dutertrei forma A	13	7	3	4	14	12			
N. pachyderma (s.s.)					2	1			
N. pachyderma forma A			10		3	2			
N. pachyderma forma B	9	10	10	9	6	3	X		
N. spp.	+					+			X
Orbulina universa									X
Pulleniatina obliquiloculata	1	1		4	1				X
Turborotalita guaymasensis n. sp.					1				
T. spp.									
Miscellaneous						16		X	X
Total number examined	215	71	40	46	118	205	2	42	12

Note: Abundance is recorded as a percentage of total planktonic specimens counted (+ = < 1%). Percentages were not calculated for samples containing less than 30 specimens (X = presence of the taxon in the sample).

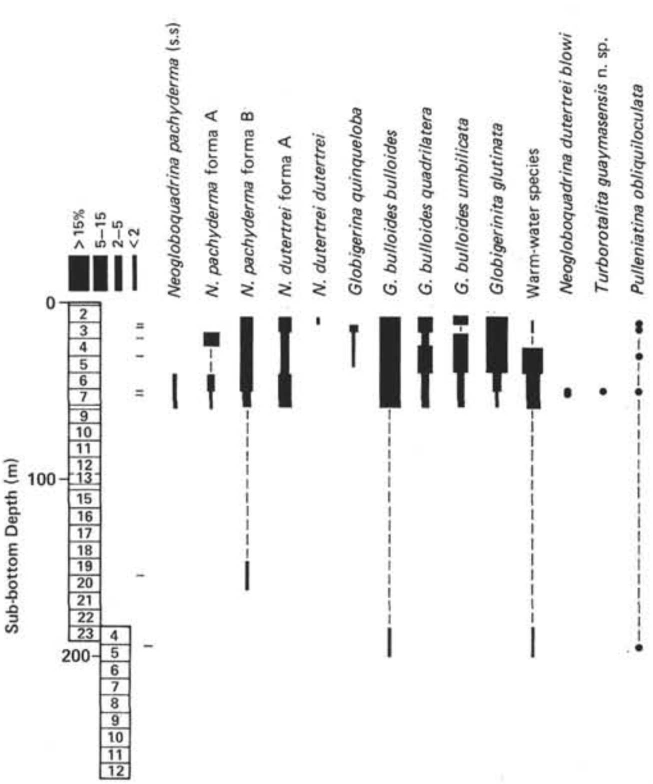

Figure 3. Stratigraphic occurrence of selected planktonic foraminifers, Site 477. (Solid circle denotes only the taxon's presence in a sample.)

cent; Blow, 1969), *Neogloboquadrina dutertrei blowi* (late Pliocene to Recent; Blow, 1969), and *Globigerinoides tenellus* (early Pleistocene to Recent; Blow, 1969) indicate that the basal fauna of Hole 479 (Sections 479-42,CC–479-47,CC) is latest Pliocene, and that the sinistral *Pulleniatina obliquiloculata* population in Section 479-42,CC may be correlated with the sinistral interval (numbered L5 or L6 in Fig. 9; Saito, 1976; Thompson and Sciarrillo, 1978) near the Olduvai Event of the Matuyama Reversed Epoch of the upper part of Zone N21. The coiling change of *Pulleniatina* is also evident and correlates with the middle latitude of the northwestern Pacific, where the warm Kuroshio Current flows northeastward (Matoba, 1967; Oda, 1977).

There are several studies of the late Cenozoic planktonic foraminiferal fauna off the west coast of North America (Bandy and Ingle, 1970; Olsson, 1971; Ingle, 1973a, 1973b, 1977a, 1977b; Keller, 1978a, 1978b, 1979a, 1979b). It is difficult, though, to correlate these studies with the Quaternary sequence of the Guaymas Basin, because characteristic species and faunal events in the Basin sequence are scarce, partly because of the special paleoceanographic conditions of the Gulf. Almost all variant specimens of *Neogloboquadrina pachyderma* in the Guaymas Basin holes are dextrally coiled, and the coiling change of the species—an important means of correlation in the northeastern Pacific—is of no use for this study.

Keller (1978a, 1978b, 1979b) distinguished three morphotypes within *N. pachyderma* in central and eastern North Pacific deep-sea cores and recorded the paleoceanographic oscillations during the Pliocene to Pleistocene epochs in the middle latitudes. As the morphologic variation of the species in the Pleistocene Guaymas Basin seems to be somewhat different from that of the California Current, our morphotypes may differ from Keller's. As we will discuss later, our *N. pachyderma* (s.s.) may correspond approximately to Keller's *N. pachyderma* form 1 and our forma A to Keller's form 2. Keller's *N. pachyderma* form 3 may be included in our *N. dutertrei blowi*. She found two horizons of *N. pachyderma* form 3 with form 2 in the middle part of the Pleistocene sequence at DSDP Site 173; she dated the two horizons 0.7 and 0.92 Ma, respectively (Keller, 1979b). Judging from the abundant and continuous occurrence of *N. pachyderma* forma A with *N. dutertrei blowi* at the interval D–D′ and the tendency of *N. pachyderma* forma A to decrease upward in the Guaymas Basin, we can approximately correlate the interval with the two horizons of *N. pachyderma* form 3 (Pleistocene) in Hole 173. The abundant and continuous occurrence of *Globigerina bulloides quadrilatera* and *G. bulloides umbilicata* above this interval also correlates with Hole 173. This correlation seems to be supported by the rare but significant occurrence of sinistrally coiled *Pulleniatina obliquiloculata*, suggesting that the interval can be correlated with the upper part of the Matuyama Reversed Epoch (Fig. 9). Horizon A, which is defined by the disappearance of *Neogloboquadrina dutertrei blowi*, seems approximately to correspond with the Pleistocene/Holocene boundary in the Guaymas Basin. *Neogloboquadrina pachyderma* (s.s.) nearly

Table 2. Abundance and occurrence of planktonic foraminifers, Hole 478.

Taxon \ Sample (interval in cm)	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	478-9,CC	478-10,CC	478-11-4, 38–40	478-11,CC	478-12-3, 139–141	478-14,CC	478-15,CC	478-16-5, 41–42	478-17,CC	478-18-1, 20–22	478-19-6, 95–97	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
Globigerina bermudezi	2	2			1		+	1		1	9								1								1													
G. bulloides bulloides	35	58	33	42	51	33	28	41	X	45	49	32	50	22	X	33	59	X	42	X	X	21	X	32	35	12	7		13	6	5	17	4	18	X	X		5	8	X
G. bulloides quadrilatera		13	9	9	20		7	20	X	9	9	16	11	9		9	12		10			6		9	8	2	1		.5	2										
G. bulloides umbilicata	6	11	17	6	12		6	3		5	1	11	13	9		3	11		8			1		4			1					6		2	X			1	1	
G. cf. *calida*								+											2			1																		
G. falconensis			4	9			8	20		8	3	4	3	5		4	9		11	X	X	6		6	3	1						2	1					1		
G. quinqueloba				6	1	3	2	1		3	4	15	2	5		6	1	X	8					5	3	1	2		3	4	2	12	1	19	X	X		14	5	
G. cf. *quinqueloba*					2	3	2			1		3		2		1			5			1		2	3	1				2	4	7	3	11				3	6	
G. rubescens					2			1			1										X				1	+	1				1				X					
G. sp. A																																		3					3	
Globigerinella aequilateralis											1		+													+	4													X
Globigerinita glutinata	7	5	8			11	+	4		3	3	5	4		X	4	1	X	2	X	X	1	X	2	3	1	10		3	1	1	2		4	X			1	1	X
G. uvula						3		1		+	1		+				1		1			1				+	3						1		X					
Globigerinoides conglobatus	1																																							
G. quadrilobatus sacculifer	1																										+													
G. quadrilobatus trilobus	2			3																							1													
G. ruber elongatus		3								+	1																													
G. ruber ruber	4	6	5							+	2	2	+	2		1	1					1		1	1	1	3					2	1	2		X			1	
G. tenellus											2								3						1	1	1		3			1	3	3		X				
G. sp. A																			1																					
G. spp.											1						1								1	1												1		
Globorotalia cultrata	37		7				+				1	5	+														+													
G. scitula					6	8		1		2	1																						1							
G. crassaformis var.																											+													
G. sp. A																																		2						
G. sp. B						3																																		
Globorotaloides hexagonus											1																+													
Hastigerinopsis riedeli																				X																				
Neogloboquadrina dutertrei blowi							+	1					2	1		2																				X				X
N. dutertrei dutertrei						6	2	9				1				1	3							1	8	2	2					1	7			X		2		X
N. dutertrei forma A			7	6	1	8	11	1	X	9	9		6	31		23			1	X		16	X	8	6	41	+	X	16	45	36	11	46	13				42	19	
N. pachyderma (s.s.)			1	3			9	4		4	2	1										6		3	4	4			11	8	8		2	1				8	10	X
N. pachyderma forma A							2	4		2	2	2	2	8		4						15	X	8	1	9			8	9	12	8	10	5				8	10	X
N. pachyderma forma B			6	9	1	8	19	14		7	6	2	2	8		8			1			21	X	15	6	17		X	26	24	24	24	21	5				16	34	X
N. spp.				6	1	10						4							2						3								1							
Orbulina suturalis										+																	+													
O. universa						6		1		+														+			2													
Pulleniatina obliquiloculata	7	2	3					+					1					X									+				2	2			X		X			
Turborotalita anfracta																											+													
T. iota																			1																					
T. iota vars																								1			2													
T. cf. *parkerae*																									1															
T. guaymasensis n. sp.										+														3	16	5	58				4	1		1						
T. spp.																								+	1															
Miscellaneous					1							1	2			3			1	X		2			1	+					3	3		2				1	1	X
Total number examined	125	213	144	33	155	36	320	160	8	281	201	139	246	128	4	157	184	11	155	16	6	214	17	292	106	252	316	2	38	161	135	130	150	102	23	10	1	147	146	156

Note: See note, Table 1.

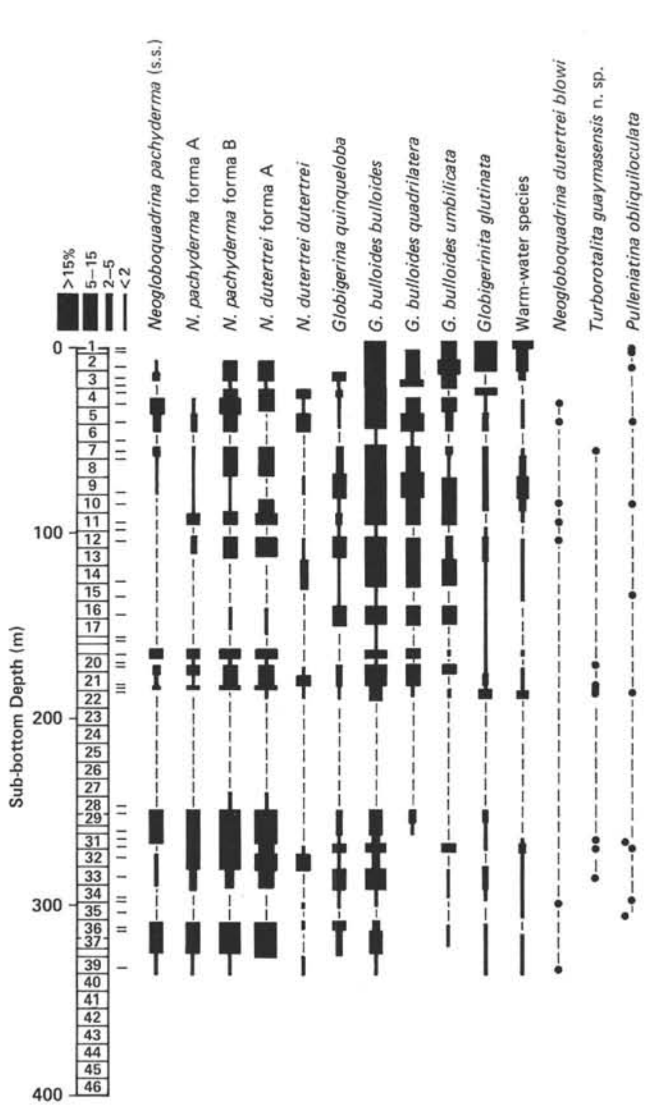

Figure 4. Stratigraphic occurrence of selected planktonic foraminifers, Site 478. (Solid circle denotes only the taxon's presence in a sample.)

disappears at this horizon, and warm-water species become abundant, indicating the relatively warmer-water condition of the interval above this horizon (Fig. 10).

Although planktonic foraminiferal evidence is lacking for the interval between Cores 479-29 through 479-41 (just above the upper Pliocene sequence), Schrader (this volume) recorded *Mesocena elliptica* (silicoflagellate) and placed its extinction datum at around 0.7 Ma for Section 479-32,CC and the Pleistocene first-occurrence datum at 0.93 Ma for Section 479-39,CC. This suggests an unconformity between Cores 479-39 and 479-42. On the other hand, the late Pliocene benthic foraminiferal fauna extends upward to Sample 479-40-3, 43–45 cm (Matoba and Yamaguchi, this volume). The possible unconformity, therefore, is limited to the upper part of Core 479-40. Based on the reflection profile passing near Hole 479 (Moore, 1973), an unconformity has been suggested for this depth. Our age assignment implies that the late Pliocene sediment at the basal part of Hole 479 belongs to the proto-Gulf of California sequence defined on the reflection profiles (Moore, 1973).

LATE CENOZOIC PALEOCEANOGRAPHY IN THE GULF OF CALIFORNIA

Magnetic-anomaly profiles indicate that the present phase of spreading in the Gulf of California probably began about 4 Ma in the early Pliocene (Larson et al., 1968). Prior to that, a proto-Gulf of California probably existed during the early to middle Miocene and early Pliocene epochs (Moore and Buffington, 1968; Karig and Jensky, 1972; Moore, 1973). Smith (1970) reported on a shallow-marine Pliocene foraminiferal fauna from the Bouse Formation along the lower Colorado River. Ingle (1973, 1974) recorded an upper bathyal foraminiferal fauna in the basal part of Pliocene (N19–21) Imperial Formation, Imperial County, California. Ingle (1974) also reported on a late Miocene (N16) planktonic foraminiferal fauna and an upper bathyal benthic fauna in a diatomite bed near San Felipe, Baja California, in the innermost part of the Gulf. He also suggested the possibility of a middle or even early Miocene initiation of the proto-Gulf. The seismic reflection profile in the Guaymas Basin, passing near Site 479, indicates that the proto-Gulf sediment is overlain with an angular unconformity of younger, nearly 400-meter-thick sediment (Moore, 1973). Siltstone, dredged from the faulted northeast wall of the Guaymas Basin, contains Miocene or early Pliocene planktonic foraminifers (Moore, 1973).

The latest Pliocene sediment at the basal part of Hole 479 may belong to the proto-Gulf sequence of Moore (1973). The late Pliocene planktonic foraminiferal fauna is similar to that of the upper Pliocene (predominantly *Globigerinoides*) on Carmen Island (Ingle, 1974). The unconformity may have been formed in the early Pleistocene epoch, during the course of the present phase of spreading, rather than during the initiation of spreading as described by Moore (1973). The unconformity between the upper Pliocene sediment that contains bathyal benthic foraminiferal fauna and the shallow Pleistocene marine deposits exposed on Carmen Island (Natland, 1950; Ingle, 1974) also indicates that the early Pleistocene tectonism caused a vertical movement of at least a few hundred meters in parts of the Gulf. The depth preference of the benthic foraminiferal fauna of the upper Pliocene interval at Site 479 is almost the same as the faunas in the Quaternary sequence above it. The surface water in late Pliocene was warmer than was indicated by the Quaternary sequence in the Guaymas Basin (Fig. 10).

The occurrence of the colder-water, dextrally coiled *Neogloboquadrina pachyderma* (s.s.) and the frequent occurrence of relatively colder forms of *N. pachyderma* forma B and A are evidence for three cooler intervals in the middle to upper Pleistocene sequence of the Basin. They occur in the interval D–D′, near the interval B–C, and in the upper part of the interval A–B (Fig. 10). Keller (1978a, 1978b, 1979a, 1979b) recorded two distinct cold intervals: a short interval in the lower Pleistocene and a long interval in the upper Pleistocene (Ingle's glacial Pleistocene [1973b]). Some fluctuations of warm and cold, as evidenced by the coiling ratios of *Neogloboquadrina pachyderma* and associated morphotypes, also occur in the middle Pleistocene sequence of

Table 3. Abundance and occurrence of planktonic foraminifers, Hole 479.

Taxon \ Sample (interval in cm)	479-1-1, 95-97	479-1,CC	479-6-2, 71-74	479-6-3, 106-108	479-7-2, 73-75	479-7-4, 46-48	479-9-3, 47-49	479-12-6, 32-34	479-13-1, 95-97	479-15-7, 4-6	479-17-1, 17-18	479-19-4, 37-39	479-20-1, 32-35	479-20-2, 29-31	479-21-2, 43-45	479-23-1, 45-47	479-23-5, 72-74	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	479-28-4, 49-51	479-42,CC	479-45-2, 73-75	479-45,CC	479-47-5, 47-49	479-47-6, 35-37	479-47,CC
Globigerina bermudezi					1						2						1												1	1
G. bulloides bulloides	28	X	40		19	15		3	16	7	11		X	7			3	2		1	3				+			5	15	+
G. bulloides quadrilatera			4	1	4	7		2	10		4			5			1			4		2							2	
G. bulloides umbilicata			12	1	3	4			1	3	2			3			1													+
G. falconensis			2			4			4		1			1							1									
G. quinqueloba			6		2	2		3			30		X			3	1								+			16	39	5
G. cf. *quinqueloba*			2		1	2		2			18	X					1											3	9	2
G. rubescens	3		3			1																								
G. sp. A																												2	19	1
G. spp.	3				1	2			2		2														+	X	X	3		63
Globigerinella aequilateralis			1						1					4																
Globigerinita glutinata	3		10		1	2		2	23		2		X	8		5	2			1	1				69		X	6	6	18
G. uvula			2						2					1		1													1	2
Globigerinoides bollii																									1			2		1
G. obliquus																												3		
G. quadrilobatus quadrilobatus														7																
G. quadrilobatus sacculifer														8															1	
G. quadrilobatus trilobus														7																
G. ruber elongatus			1	1																					11			30		4
G. ruber ruber			2					2	2		2			14											15		X	24	1	1
G. tenellus			3								1		X	4											2					
G. spp.									1																					
Globorotalia cultrata	42	X						5												1										
G. scitula						2																								
G. tumida																									1					
Hastigerinopsis riedeli																													1	
Neogloboquadrina dutertrei blowi					1	2		1		3				10			1			71	6		6						2	
N. dutertrei dutertrei				26	36	2		7	2	60				10		3	5	7	X	18	19	94	46	X					2	
N. dutertrei forma A		X	2	29		37	X	26	1	7	15		X	4	X	8	36	13			24							2	3	1
N. pachyderma (s.s.)				8	3	4		3		1							11	12			5		3							
N. pachyderma forma A		X	1	17	5	5		12		7			X			33	8	7		3	13		9							
N. pachyderma forma B		X	1	18	7	10	X	33		12	4		X	2		51	29	56			25	4	37					4		
N. spp.									1																			1		
Orbulina suturalis																				1										
O. universa			1											1	X	8					+									
Pulleniatina obliquiloculata	25	X																							2					
Turborotalita iota				1										1																
T. iota vars.			2								5		X																	
T. cf. *parkerae*		X																												
T. guaymasensis n. sp.			2		18	5			32					2																
T. spp.			3					1					X								1									
Miscellaneous																													1	1
Total number examined	36	24	101	168	136	135	8	117	82	81	84	1	24	99	5	39	145	83	8	78	240	47	35	15	275	1	3	132	102	279

Note: See note, Table 1.

DSDP Hole 173 off northern California under the California Current. The latest Pliocene through earliest Pleistocene epochs were distinctly warm, and the early through middle Pleistocene was generally warm except for the interval already mentioned. The lower Pleistocene faunal evidence, including the lower, short, cold event, is lacking in the Guaymas Basin sequence. The middle Pleistocene variations in Hole 173 are correlated with the interval D–D′ in the Guaymas Basin. The distinct, long, cold interval in the later half of Pleistocene sequence of Hole 173 cannot be recognized in the Guaymas Basin sequence, where two separate and cooler events are recorded. Thus, the Pleistocene climatic fluctuation patterns—as indicated by planktonic foraminifers—off northern California are quite different from those of the central Gulf of California.

The water character in the Gulf of California may have been primarily governed by the prevailing water masses at the entrance of the Gulf. Planktonic foraminifers, which are essentially oceanic, were introduced into the Gulf with these water masses. The present Gulf of California is at a critical location: The cool California Current flows southeastward toward the entrance of the Gulf, where it converges with the equatorial water. The Pleistocene climatic oscillation resulted in shifts of the convergence to the north and to the south, and such an oceanographic condition existed throughout the Neogene epoch (Ingle, 1973a, 1973b, 1977a, 1977b). Ingle (1973b, 1974) noted that a subarctic fauna invaded the Gulf of California during the glacial Pleistocene epoch and was trapped by the northward readjustment of isotherms in the Holocene epoch. This may have occurred not only during the glacial Pleistocene-to-Holocene transition, but also during the preceding similar transitions from cold to warm periods. Such a special geographic situation in the Gulf of California may have caused the different oceanographic records and the different climatic fluctuation patterns recorded by planktonic foraminiferal fauna between the Gulf of California and the open, northeastern Pacific. The benthic foraminiferal faunas also indicate that the water character or the depths of the oxygen-minimum zone changed

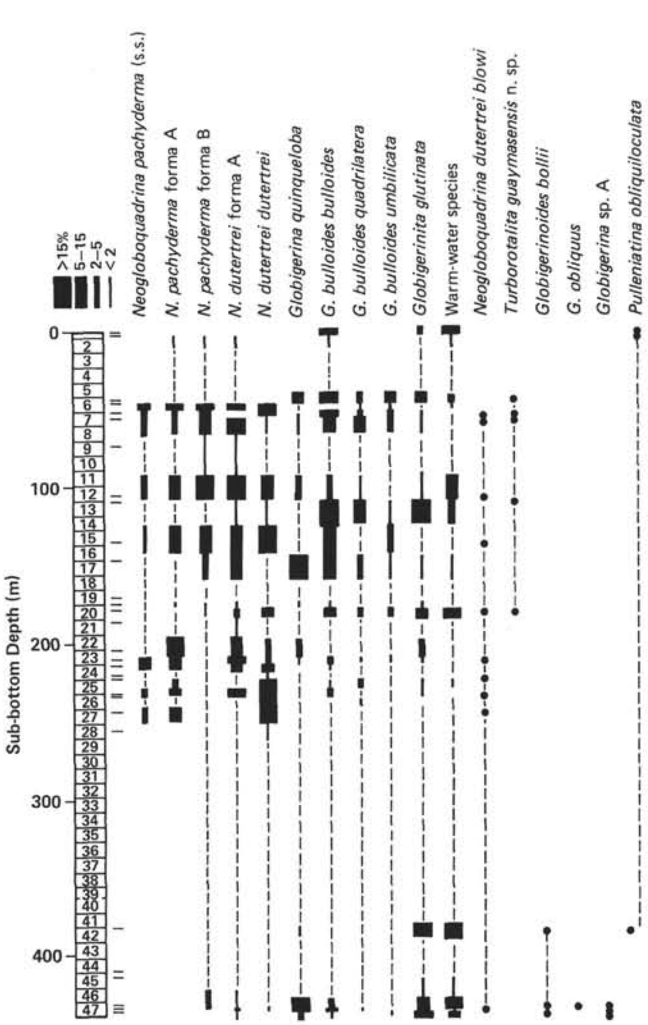

Figure 5. Stratigraphic occurrence of selected planktonic foraminifers, Site 479. (Solid circle denotes only the taxon's presence in a sample.)

Table 4. Abundance and occurrence of planktonic foraminifers, Hole 480.

Taxon \ Sample (interval in cm)	480-3,CC	480-4,CC	480-11,CC	480-13,CC	480-16,CC	480-21,CC	480-31,CC
Globigerina bermudezi					3	4	6
G. bulloides bulloides		13	31		12	10	16
G. bulloides quadrilatera		5	7		1	5	2
G. bulloides umbilicata		5	10		7	10	4
G. falconensis		1			5	1	1
G. quinqueloba			3		8	28	37
G. cf. *quinqueloba*					1	4	3
G. rubescens						3	
G. sp. B					6	13	15
Globigerinella aequilateralis						3	
Globigerinita glutinata			49		21	12	5
G. uvula					1		1
Globigerinoides quadrilobatus quadrilobatus					1		
G. ruber elongatus						1	
G. ruber ruber					28	5	1
G. tenellus					1	1	
G. spp.		1					
Globorotalia cultrata		2					
Neogloboquadrina dutertrei blowi		5					2
N. dutertrei dutertrei	10						2
N. dutertrei forma A	36	37		56			6
N. pachyderma (s.s.)	7	2					
N. pachyderma forma A	24	11		24			
N. pachyderma forma B	22	19		20			1
Pulleniatina obliquiloculata						1	
Turborotalita iota					1		
T. cf. *parkerae*					1		
T. guaymasensis n. sp.						1	
Total number examined	95	130	88	45	90	202	128

Note: See note, Table 1.

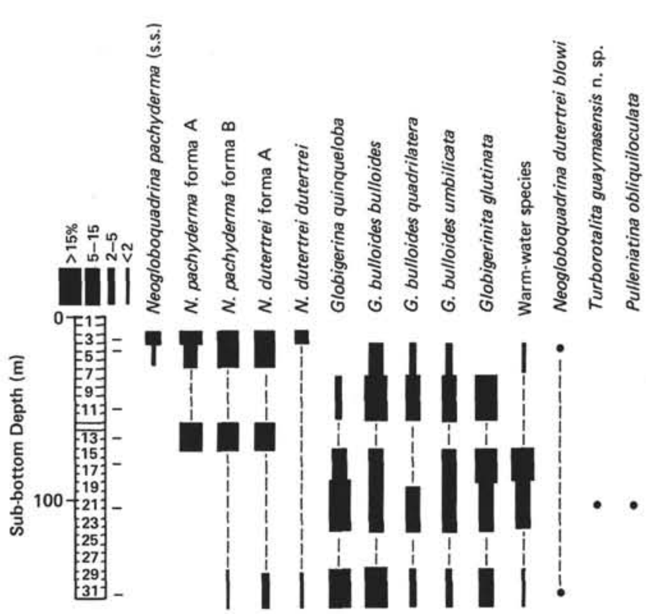

Figure 6. Stratigraphic occurrence of selected planktonic foraminifers, Site 480. (Solid circle denotes only the taxon's presence in a sample.)

during the Pleistocene epoch (Matoba and Yamaguchi, this volume).

FAUNAL REFERENCE LIST

Listed herewith are the species, subspecies, and morphotypes of planktonic foraminifers at Sites 477 through 481. We give the original references for all named taxa, a few subsequent references, and brief remarks for some. Most of the taxa are illustrated in Plates 1 through 5 by scanning electron microphotographs (JSM-U3). All the types are catalogued and deposited in the Institute of Mining Geology, Mining College, Akita University, Akita, Japan (AKMG numbers), except for the holotype and figured paratypes of a new species.

Globigerina bermudezi Seiglie (Plate 1, Figs. 1A, 1B). *Globigerina bermudezi* Seiglie, 1963, p. 90, pl. 1, figs. 1–8. Rögl and Bolli, 1973, p. 562, pl. 2, figs. 11–19, pl. 2, fig. 4. This species, characterized by the narrow and typically umbilical extension of the last few chambers, occurs sporadically at all the sites.

Globigerina bulloides bulloides d'Orbigny (Plate 1, Figs. 5, 6). *Globigerina bulloides* d'Orbigny, 1826, p. 277, no. 1 (no figure given; *fide* Ellis and Messina, 1940 *et seq.*). Brady, 1884, p. 593, pl. 79, figs. 7a–c. Banner and Blow, 1960, p. 3, pl. 1, figs. 1, 4 (lectotype). *Globigerina bulloides* (s.s.) is one of the predominant forms and occurs throughout the sequences at all the sites.

Globigerina bulloides quadrilatera Galloway and Wissler (Plate 1, Figs. 2A–C). *Globigerina quadrilatera* Galloway and Wissler, 1927, p. 44, pl. 7, figs. 11a–c. A *G. bulloides*-like form with the diminutive final chamber is separated from *G. bulloides* (s.s.) and is treated as its subspecies. This subspecies is common at all the sites but is continuously abundant in the upper Pleistocene and Holocene sequence.

Globigerina bulloides umbilicata Orr and Zaitzeff (Plate 1, Figs. 3A–C, 4). *G. umbilicata* Orr and Zaitzeff, 1971, p. 18, pl. 1, figs. 1a–3c. Keller, 1978b, pl. 2, figs. 10, 11. *Globigerina bulloides umbilicata* Orr and Zaitzeff, Rögl and Bolli, 1973, p. 563, pl. 1, figs.

Table 5. Abundance and occurrence of planktonic foraminifers, Holes 481 and 481A.

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-4-3, 41-43	481A-5-5, 108-110	481A-6-2, 116-118
Globigerina bermudezi		3	2	1		1	2				2	5		2	X	2	6	1		
G. bulloides bulloides	X	21	36	25	43	35	27	23	21	31	32	41	24	47	X	32	24	32	19	X
G. bulloides quadrilatera		3	19	8	17	16	13	5	8	10	16		6	6	X	5	8	13	14	X
G. bulloides umbilicata	X	9	13	16	28	13	17	43	25	16	21	11	29	9	X	21	16	22	19	X
G. cf. *calida*				3														1		
G. falconensis			20	8	1		5		5	1	4			9			3	6		
G. quinqueloba			1				5		2	6		1		1			2	1	3	
G. cf. *quinqueloba*							1											+		
G. rubescens							2		1	1	1		1	1		1		1		
G. sp. B								3												
G. spp.				3								1	1	1					3	
Globigerinella aequilateralis		3			1	1					1						+			
Globigerinita glutinata		44	7	9	6	13	8	5	5	3	9	23	15	6	X	23	5	3	14	X
G. uvula		3	2	3		1						1	1	1		+	1	1		
Globigerinoides conglobatus																				
G. quadrilobatus quadrilobatus																	+			
G. quadrilobatus sacculifer							+													
G. quadrilobatus trilobus												1								
G. ruber elongatus			2	2	2		1											1		
G. ruber ruber				3	3	1	2	5	3		2	3	5	1		4	2	2		
G. tenellus		3					1			1		3	1	2	X			1		
G. spp.											1			+		+				
Globorotalia cf. *bermudezi*												1	2	+	X	2				
G. cultrata				7	2			18	1				1	2		2		2	3	
G. fimbriata																				
G. hirsuta														+						
G. scitula									2									+		
G. cf. *scitula*																1				
G. sp. A																				
G. sp. B																				
Globorotaloides hexagonus													1							
Neogloboquadrina dutertrei dutertrei					1		1		4	4							1			
N. dutertrei blowi									+											
N. dutertrei forma A	X	6		2		14	8		11	19	7	6	10	7	X	5	18	8	19	X
N. pachyderma (s.s.)							+		+	2	1						1	+		
N. pachyderma forma A				2		2	3		1	2	2			1		+	9	2		X
N. pachyderma forma B		3		2		1	2		5	7	2	1	1	4			2	3	8	X
N. spp.																1				
Orbulina universa																				
Pulleniatina obliquiloculata						2	+		1		1			+		1	+			
Turborotalita anfracta				1																
T. iota				2													+	+		
T. iota vars							+													
T. cf. *parkerae*		3					+						1							
T. guaymasensis n. sp.				3					1	2							+			
T. spp.				2								1						+		
Miscellaneous																				
Total number examined	4	34	102	160	161	174	247	40	246	126	192	79	144	256	21	246	233	279	37	19

Taxon \ Sample (interval in cm)	481A-6-4, 110-112	481A-7-1, 92-94	481A-7-6, 136-138	481A-8-2, 26-28	481A-8-6, 135-137	481A-9-3, 97-99	481A-9-6, 117-119	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-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
Globigerina bermudezi	1					+	2																	
G. bulloides bulloides	37	62	44	30	38	26	22	44	34	47	15	X	48	42	33	59	X	68	X	X	52	58	62	42
G. bulloides quadrilatera	12	12	12	10	6	15	17	11	15	12	6		3	3	4	13		7		X	13	8	1	4
G. bulloides umbilicata	16	9	11	8		12	7															1	1	
G. cf. *calida*																								
G. falconensis				6	8	5	6	2	7	2			6			3		2		X		1		6
G. quinqueloba	3	1	4	2	8		+	5	4		2				3			2			3	2	7	10
G. cf. *quinqueloba*		1		1	2								1	1				1			3	3	2	1
G. rubescens	1	+	1						1									2					1	1
G. sp. B																								
G. spp.	1			1		1		1		1				1	1.	1	X	2	X		2	3	2	1
Globigerinella aequilateralis	1																							1
Globigerinita glutinata	3	2	5	2	4	9	12	4	4	5	2		2	8				7			10	1	7	1
G. uvula		1				+		1																
Globigerinoides conglobatus																	X							
G. quadrilobatus quadrilobatus		+									2		1	1								2		
G. quadrilobatus sacculifer								+						1								1		
G. quadrilobatus trilobus													1											
G. ruber elongatus																								
G. ruber ruber	2	3		1		1	1	1	3	1			1	1		3		6		X	2	2	1	
G. tenellus		1				+		1	2				2	3				1			3	3		1
G. spp.																								
Globorotalia cf. *bermudezi*																								
G. cultrata																		3				3	1	
G. fimbriata																		1						
G. hirsuta																		1						
G. scitula	2	1						4	5	16							X	1						
G. cf. *scitula*																								
G. sp. A	1																					3		
G. sp. B								1																
Globorotaloides hexagonus																								
Neogloboquadrina dutertrei dutertrei		2		3		3	2	7	2		9		3	3	13						1			4
N. dutertrei blowi				1		1	1		2					1	1									
N. dutertrei forma A	10	4	13	21	24	15	12		13	15	51		19	19	9	8	X	2	X		5	10		19
N. pachyderma (s.s.)	6	1	1	3		2	1	2	3	2	2		1	4	5									2
N. pachyderma forma A	3	1	5	8	2	4	4	4	4	2	2		6	6	20	6					3			5
N. pachyderma forma B	6	1	4	6	4	6	8	9	5	6	4		6	8	12	7	X	1			3	1		10
N. spp.							1																	
Orbulina universa	1							1		+														1
Pulleniatina obliquiloculata																								
Turborotalita anfracta																	X							
T. iota				1																				
T. iota vars																								
T. cf. *parkerae*																								
T. guaymasensis n. sp.			1		2																			
T. spp.					2	+	+																	
Miscellaneous												98												
Total number examined	177	340	140	214	50	252	245	284	124	319	47	121	178	120	101	119	12	164	6	9	116	90	138	182

Note: See note, Table 1.

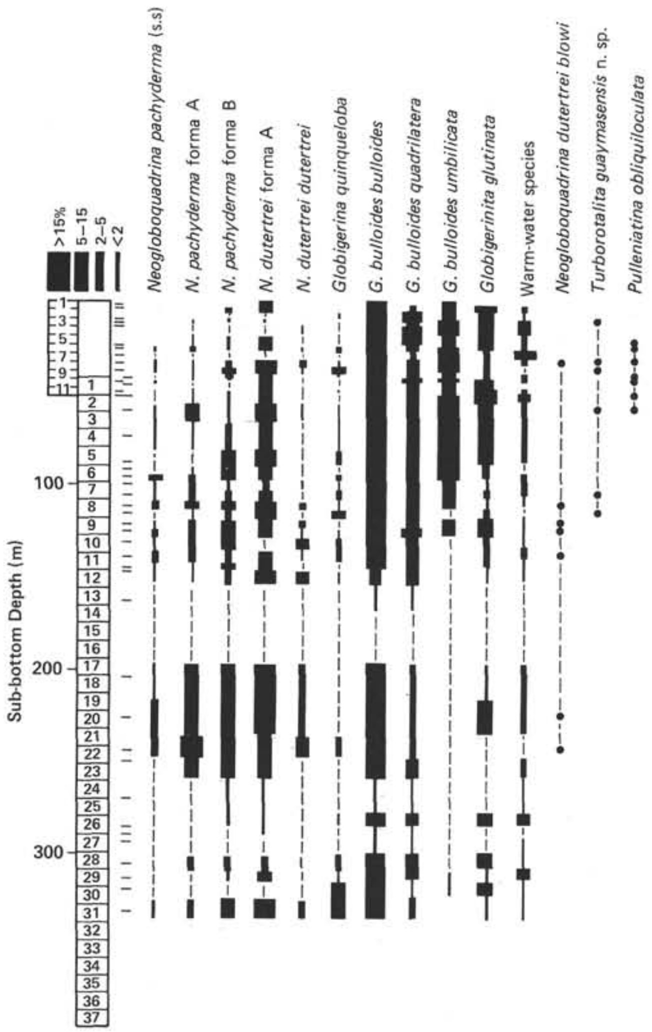

Figure 7. Stratigraphic occurrence of selected planktonic foraminifers, Site 481. (Solid circle denotes only the taxon's presence in a sample.)

19, 20, 22–24, pl. 11, fig. 13. This subspecies is characterized by a large umbilicus and the 5 to 6 large, well-developed chambers in the last whorl. It occurs at all the sites and is especially abundant in the upper Pleistocene to Holocene sequence above the horizon, somewhat higher than the horizon where *G. bulloides quadrilatera* becomes abundant.

Globigerina cf. *G. calida* Parker. Cf. *Globigerina* sp., Bradshaw, 1959, p. 38, pl. 6, figs. 19, 26–28. Cf. *G.* Parker, 1962, p. 221, pl. 1, figs. 9–13, 15. Some small or poorly preserved specimens are similar to this species.

Globigerina falconensis Blow (Plate 1, Fig. 10). *Globigerina falconensis* Blow, 1959, p. 177, pl. 9, figs. 40, 41. Parker, 1962, p. 224, pl. 1, figs. 14, 16–19.

Globigerina quinqueloba Natland (Plate 1, Figs. 7A, B). *Globigerina quinqueloba* Natland, 1938, p. 149, pl. 6, fig. 7.

Globigerina cf. *G. quinqueloba* Natland (Plate 1, Figs. 8A, B). This form is similar to *Globigerina quinqueloba*, but the last chamber is spherical and does not extend over the umbilicus, which is open and deep. This form is associated with *G. quinqueloba* and is rare in the sequences at all the sites.

Globiginera rubescens Hofker (Plate 1, Fig. 11). *Globigerina rubescens* Hofker, 1956, p. 234, pl. 35, fig. 18–21 (*fide* Ellis and Messina, 1940 *et seq.*).

Globigerina sp. A (Plate 1, Figs. 12A–C). This species is very similar to *Globigerina quinqueloba* but has a thicker, tightly coiled test with a less lobulate equatorial periphery and 4 chambers instead of 5 in the final whorl. It occurs only in the late Pliocene samples in the basal sequence of Hole 479.

Globigerina sp. B (Plate 1, Figs. 13–17). This species resembles *Globigerina quinqueloba* but in the typical form has 6 chambers instead of 5 in the final whorl. The shape and position of the last chamber varies. The typical form has a globular last chamber with a wide lip, but some others have somewhat elongate or reduced and elongate last chambers and often have a higher spired, tightly coiled test with 5 chambers in the last whorl. This species is abundant only in three samples in the lower section of Hole 480. A few specimens from Section 481-7-2 are tentatively included in this species. All are late Pleistocene.

Globigerinella aequilateralis (Brady) (Plate 2, Fig. 11). *Globigerina aequilateralis* Brady, 1879, p. 285 (*fide* Ellis and Messina, 1940 *et seq.*). Brady, 1884, p. 605, pl. 80, figs. 18–21. This species is rare and occurs sporadically in the Quaternary sequence.

Globigerinita glutinata (Egger) (Plate 2, Fig. 12). *Globigerina glutinata* Egger, 1893, p. 371, pl. 13, figs. 19–21 (*fide* Ellis and Messina, 1940 *et seq.*).

Globigerinita uvula (Ehrenberg) (Plate 2, Fig. 13). *Pylodexia uvula* Ehrenberg, 1861, p. 276, 277, 308. Ehrenberg, 1873, pl. 2, figs. 24, 25 (*fide* Ellis and Messina, 1940 *et seq.*). Banner and Blow, 1960, p. 5, 6, pl. 3, fig. 3. *Globigerina bradyi* Wiesner, 1931, p. 133 (*fide* Ellis and Messina, 1940 *et seq.*). Banner and Blow, 1960, p. 5, 6, pl. 3, fig. 1 (lectotype).

Globigerinoides bollii Blow (Plate 2, Figs. 1A, B). *Globigerinoides bollii* Blow, 1959, p. 189, pl. 10, figs. 65a–c. This species, characterized by a small, almost circular primary aperture, occurs in three Pliocene samples in the basal section of Hole 479.

Globigerinoides conglobatus (Brady) (Plate 2, Fig. 2). *Globigerina conglobata* Brady, 1879, p. 286 (*fide* Ellis and Messina, 1940 *et seq.*); Brady, 1884, p. 603, pl. 80, figs. 1–5, pl. 82, fig. 5. Banner and Blow, 1960, p. 6, 7, pl. 4, figs. 4a–c (lectotype).

Globigerinoides obliquus Bolli (Plate 2, Fig. 3). *Globigerinoides obliquus* Bolli, 1957, p. 113, pl. 25, figs. 9a–10c. A few specimens occur in one Pliocene sample in the basal sequence of Hole 479.

Globigerinoides quadrilobatus quadrilobatus (d'Orbigny) (Plate 2, Fig. 4). *Globigerina quadrilobata* d'Orbigny, 1846, p. 164, pl. 9, figs. 7–10. Banner and Blow, 1960, p. 17, 18, pl. 4, figs. 3a–c (lectotype).

Globigerinoides quadrilobatus sacculifer (Brady) (Plate 2, Figs. 5, 6). *Globigerina sacculifera* Brady, 1877, p. 535 (*fide* Ellis and Messina, 1940 *et seq.*). Brady, 1884, p. 604, pl. 80, figs. 11–17, pl. 82, fig. 4. Banner and Blow, 1960, p. 21–24, pl. 4, figs. 1a, b (lectotype). A single specimen from Sample 479-47-6, 35–37 cm, with a few slightly fistular projections of the last chamber (Pl. 2, Fig. 6), was included in this species.

Globigerinoides quadrilobatus trilobus (Reuss). *Globigerina triloba* Reuss, 1850, p. 374, pl. 47, figs. 11a–d (*fide* Ellis and Messina *et seq.*).

Globigerinoides ruber ruber (d'Orbigny) (Plate 2, Fig. 7). *Globigerina rubra* d'Orbigny, 1839, p. 82, 83, pl. 4, figs. 12–14. Banner and Blow, 1960, p. 19–21, pl. 3, figs. 8a, b (lectotype). This species occurs rather frequently at all the sites but is abundant only in a few Pliocene samples.

Globigerinoides ruber elongatus (d'Orbigny) (Plate 2, Fig. 8). *Globigerina elongata* d'Orbigny, 1846, p. 277 (*fide* Ellis and Messina, 1940 *et seq.*). Banner and Blow, 1960, p. 12, 13, pl. 3, figs. 10a–c (lectotype). This subspecies is rare and occurs only sporadically but is abundant in a few late Pliocene samples from Hole 479.

Globigerinoides tenellus Parker (Plate 2, Figs. 9, 10). *Globigerinoides tenella* Parker, 1958, p. 280, pl. 6, figs. 7–11. *G. tenellus* Parker, Parker, 1962, p. 232, pl. 4, figs. 11, 12. This species is rare and occurs in many samples in the Pleistocene to Holocene sequence in all holes; it also occurs in 1 upper Pliocene sample from Hole 479.

Globorotalia cf. *G. bermudezi* Rogl and Bolli (Plate 3, Figs. 1A–C). Cf. *Globorotalia bermudezi* Rogl and Bolli, 1973, p. 567, 568, pl. 6, figs. 16–20, pl. 16, figs. 1–3, fig. 6 (text). This form resembles *G. bermudezi* but differs from it in having a more inflated last chamber and a more broadly rounded axial periphery. A few specimens (latest Pleistocene) occur in 5 samples from Holes 481 and 481A.

Globorotalia crassaformis (Galloway and Wissler) (Plate 3, Figs. 10A–C). *Globigerina crassaformis* Galloway and Wissler, 1927, p.

41, pl. 7, figs. 12a–c. Only one specimen was found in Sample 478-22-1, 28–31 cm.

Globorotalia cultrata (d'Orbigny) (Plate 3, Figs. 14, 15). *Rotalina cultrata* d'Orbigny, 1839, p. 76 (plate published separately, pl. 5, figs. 7–9). Banner and Blow, 1960, p. 30, pl. 6, figs. 2a–c (neotype). This species is rare and occurs sporadically in the Quaternary sequence at all the sites. It is abundant, though (perhaps because of selective dissolution) in a few samples from the uppermost sections of Holes 478 through 481.

Globorotalia fimbriata (Brady) (Plate 3, Figs. 11A, B). *Pulvinulina menardii* (d'Orbigny) var. *fimbriata* Brady, 1884, p. 691, pl. 103, figs. 3a, b. Banner and Blow, 1960, p. 25, 26, pl. 5, figs. 2a, b (lectotype). One specimen from Sample 481A-26-3, 72–74 cm is identical to this species.

Globorotalia hirsuta (d'Orbigny). *Rotalina hirsuta* d'Orbigny, *in* Baker-Webb and Berthelot, 1839, p. 131, pl. 1, figs. 37–39 (*fide* Ellis and Messina, 1940 *et seq.*). A few small specimens in 2 samples from Hole 481A seem to be identical to this species.

Globorotalia scitula (Brady) (Plate 3, Figs. 2–4). *Pulvinulina scitula* Brady, 1882, p. 716 (*fide* Ellis and Messina, 1940 *et seq.*). Brady, 1884, p. 693, pl. 103, figs. 7a–c (as *P. patagonica*). Banner and Blow, 1960, p. 27, 28, pl. 5, figs. 5a–c (lectotype). This species is rare to common but occurs sporadically in the Quaternary sequence.

Globorotalia cf. *G. scitula* (Brady) (Plate 3, Figs. 5A–C, 6A–C). A few specimens assigned to this form differ from *G. scitula* in having an apertural flap extending toward the umbilicus. This form occurs only in Sample 481A-2-1, 75–77 cm.

Globorotalia tumida (Brady) (Plate 3, Figs. 12, 13). *Pulvinulina menardii* (d'Orbigny) var. *tumida* Brady, 1877, p. 535 (*fide* Ellis and Messina, 1940 *et seq.*). Brady, 1884, p. 692, pl. 103, figs. 4a–6 (as *P. tumida*). Banner and Blow, 1960, p. 26, 27, pl. 5, figs. 5a–c (lectotype). A few specimens of this species occur in 1 latest Pliocene sample from Hole 479.

Globorotalia sp. A (Plate 3, Figs. 7A–C). This form resembles *Globorotalia bermudezi* and *G.* cf. *G. bermudezi* (Pl. 3, Figs. 1A–C) but differs in having a distinctly coarse wall texture. Some specimens assigned to this form occur in 3 samples from Holes 478 and 481A.

Globorotalia sp. B[3] (Plate 3, Figs. 8A–C, 9A–C). This species is nearly identical to *Globorotalia* sp. of Rögl and Bolli (1973, p. 569, pl. 7, figs. 1–4) and is characterized by the high-spired test and coarsely perforate wall; it differs from the latter, though, in its dextrally coiled test. Some specimens of this form occur in 2 latest Pleistocene samples from Holes 478 and 481A.

Globorotaloides hexagonus (Natland) (Plate 2, Fig. 17). *Globigerina hexagona* Natland, 1938, p. 149, pl. 7, figs. 1a–c. *Globoquadrina hexagona* (Natland), Parker, 1962, p. 244, pl. 8, figs. 5–13. *Globorotaloides hexagona hexagona* (Natland), Blow, 1969, p. 373, 374. This species occurs only in 1 sample from Section 481-11,CC.

Hastigerinopsis riedeli (Rögl and Bolli). *Hastigerinella riedeli* Rögl and Bolli, 1973, p. 576, pl. 4, figs. 1–5, pl. 14, figs. 1–3, 5 (text). Two small specimens found in Section 478-17,CC and Sample 479-47-6, 35–37 cm may be identical to this species.

Neogloboquadrina dutertrei dutertrei (d'Orbigny) (Plate 4, Figs. 1A, B). *Globigerina dutertrei* d'Orbigny, 1839, p. 84, (plate published separately, pl. 4, figs. 19–21). Banner and Blow, 1960, p. 11, pl. 2, figs. 1a–c (lectotype). As discussed by Rögl and Bolli (1973), Srinivasan and Kennett (1976), and Thompson (1976), there is much controversy among investigators about the taxonomic treatment of *Globigerina dutertrei* d'Orbigny. In this study, we divided this group into three forms: *Neogloboquadrina dutertrei dutertrei*, *N. dutertrei blowi*, and *N. dutertrei* forma A. The form assigned to *N. dutertrei dutertrei* has 5 chambers in the final whorl and an umbilical aperture. Large specimens with 6 to 7 chambers in the final whorl, however, were also tentatively included in *N. dutertrei dutertrei*. This is one of the most important constituents of the Quaternary sequence in the Guaymas Basin.

Neogloboquadrina dutertrei blowi Rögl and Bolli (Plate 4, Figs. 5–8). *Neogloboquadrina dutertrei blowi* Rögl and Bolli, 1973, p. 570, pl. 9, figs. 19–22, pl. 17, fig. 12. *Globigerina subcretacea* Chapman, 1902, pl. 36, figs. 16a, b (*fide* Ellis and Messina, 1940 *et seq.*). *Globorotalia* (*Turborotalia*) *subcretacea* (Lomnicki), Blow, 1969, p. 392, pl. 4, figs. 18–20 (lectotype). This subspecies was introduced by Rögl and Bolli (1973) as a new name for *Globigerina subcretacea* Chapman, 1902 (not Lomnicki, 1901). It is characterized by a large, low trochospiral test with slightly more than 4 to 5 chambers in the final whorl and a flat or concave spiral side. The subspecies differs from *N. dutertrei dutertrei* in having an umbilical-extraumbilical aperture throughout ontogeny and from *N. dutertrei pseudopima* (Blow) in the wider umbilicus and more numerous chambers in the final whorl. This subspecies generally occurs in 4 intervals in the upper Pliocene to Pleistocene sequence in association with *N. pachyderma* forma A and almost disappears at the Pleistocene/Holocene boundary in the Guaymas Basin. A part of *N. pachyderma* form 3 of Keller (1978a, 1978b) may be included in this subspecies.

Neogloboquadrina dutertrei (d'Orbigny) forma A (Plate 4, Figs. 2–4). This form is trochospiral with 5 (or 6) chambers in the last whorl. The chambers increase gradually as they are added; the aperture is umbilical-extraumbilical with a distinct lip. This form differs from *N. dutertrei dutertrei* in that the aperture is umbilical-extraumbilical and the test is smaller. It differs from *N. dutertrei blowi* in having a higher spiral side, more lobulate equatorial periphery, and smaller size. This form is one of the most abundant of the upper Pliocene to Holocene sequence in the Guaymas Basin.

Neogloboquadrina pachyderma pachyderma (Ehrenberg) (Plate 4, Figs. 10, 11). *Aristerospira pachyderma* Ehrenberg, 1861, p. 276, 277, 303 (*fide* Ellis and Messina, 1940 *et seq.*). Ehrenberg, 1873, p. 386, pl. 1, fig. 4 (*fide* Ellis and Messina, 1940 *et seq.*). The typical form of the Guaymas Basin species has 4 chambers in the final whorl, a narrow umbilical aperture, and a small, quadrate, tightly coiled test, which is not lobulate. Encrustation is generally heavy, and the surface has a pitted, "sugar grain" texture. This form corresponds to *N. pachyderma* form 1 of Keller (1978a). It is a typical cold-water form (Bé, 1960) and is sinistrally coiled in the Arctic and Subarctic (Ericson, 1959; Keller, 1978a; Coulbourn et al., 1980). Nearly all Guaymas Basin specimens are dextrally coiled. This form is not abundant, but occurs, in general, in three Pleistocene intervals and nearly disappears in the Holocene sediment; however, it is possible that this form continued to survive, during the Holocene epoch in the northern Gulf.

Neogloboquadrina pachyderma (Ehrenberg) forma A (Plate 4, Figs. 12–14). This form has 4 globular chambers in the final whorl, with a quadrate outline and an umbilical-extraumbilical aperture with a faint rim-like lip. It differs from *N. pachyderma pachyderma* in that it is larger, more quadrate, and has a slightly lobulate equatorial outline. This form may correspond to *N. pachyderma* form 2 of Keller (1978a). All the specimens in the Basin are dextrally coiled. It is regarded as a temperate, transitional-water inhabitant and is one of the most predominant in the Basin Quaternary sequence; however, it seems to decrease in the upper Pleistocene and Holocene sequences.

Neogloboquadrina pachyderma (Ehrenberg) forma B (Plate 4, Figs. 15–19). This form has 4½ to 5 chambers in the final whorl, a lobulate equatorial periphery, and, frequently, an aberrant last chamber. It differs from *N. pachyderma pachyderma* in its larger, loosely coiled test and lobulate equatorial periphery. The test size is nearly the same as, or slightly smaller than, *N. pachyderma* forma A but differs in that it has more chambers in the final whorl, which shows a somewhat pentagonal appearance and a more lobulate periphery. Some authors' *Globigerina incompta* Cifelli may be included in this form. Nearly all specimens are dextrally coiled. It is one of the predominant forms in the Quaternary sequence of the Guaymas Basin.

Orbulina suturalis Brönnimann. *Orbulina suturalis* Brönnimann, 1951, p. 135, text fig. 2, figs. 1, 2, 5–8, text fig. 3, figs. 3–8, 11, 13–16, 18, 20–22, text fig. 4, figs. 2–4, 7–12, 15, 16, 19–22. Some specimens from a few Hole 478 and 479 samples are identical to this species.

Orbulina universa d'Orbigny (Plate 2, Fig. 16). *Orbulina universa* d'Orbigny, 1839, p. 2, pl. 1, fig. 1. This species is rare to common and scattered in the Quaternary sequence.

Pulleniatina obliquiloculata (Parker and Jones) (Plate 2, Figs. 14, 15). *Pullenia sphaeroides* (d'Orbigny) var. *obliquiloculata* Parker and Jones, 1865, p. 365, pl. 19, figs. 4a, b. Banner and Blow, 1960, p.

[3] Thompson (1980, p. 785, pl. 4, figs. 1–3) recently described this species as *Globorotalia wilesi*.

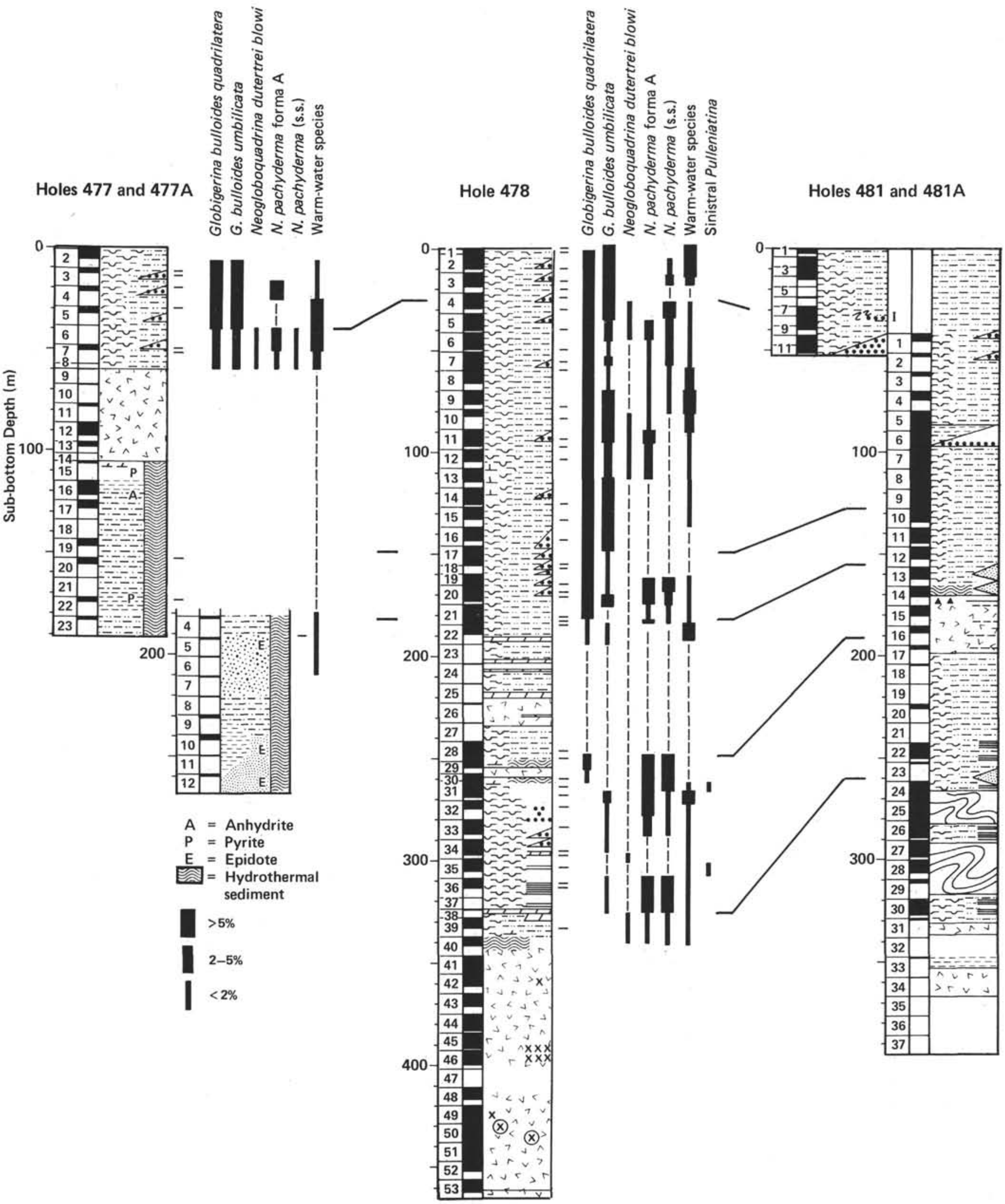

Figure 8. Correlation of the Guaymas Basin sites and the stratigraphic occurrence of some selected taxa. (Horizon A = last occurrence of *Neogloboquadrina dutertrei blowi* Rogl and Bolli; Horizon B = first abundant occurrence of *Globigerina bulloides umbilicata* Orr and Zaitzeff; Horizon C = first abundant occurrence of *Globigerina bulloides quadrilatera* Galloway and Wissler; Interval D-D′ = abundant occurrence of *Neogloboquadrina pachyderma* forma A.)

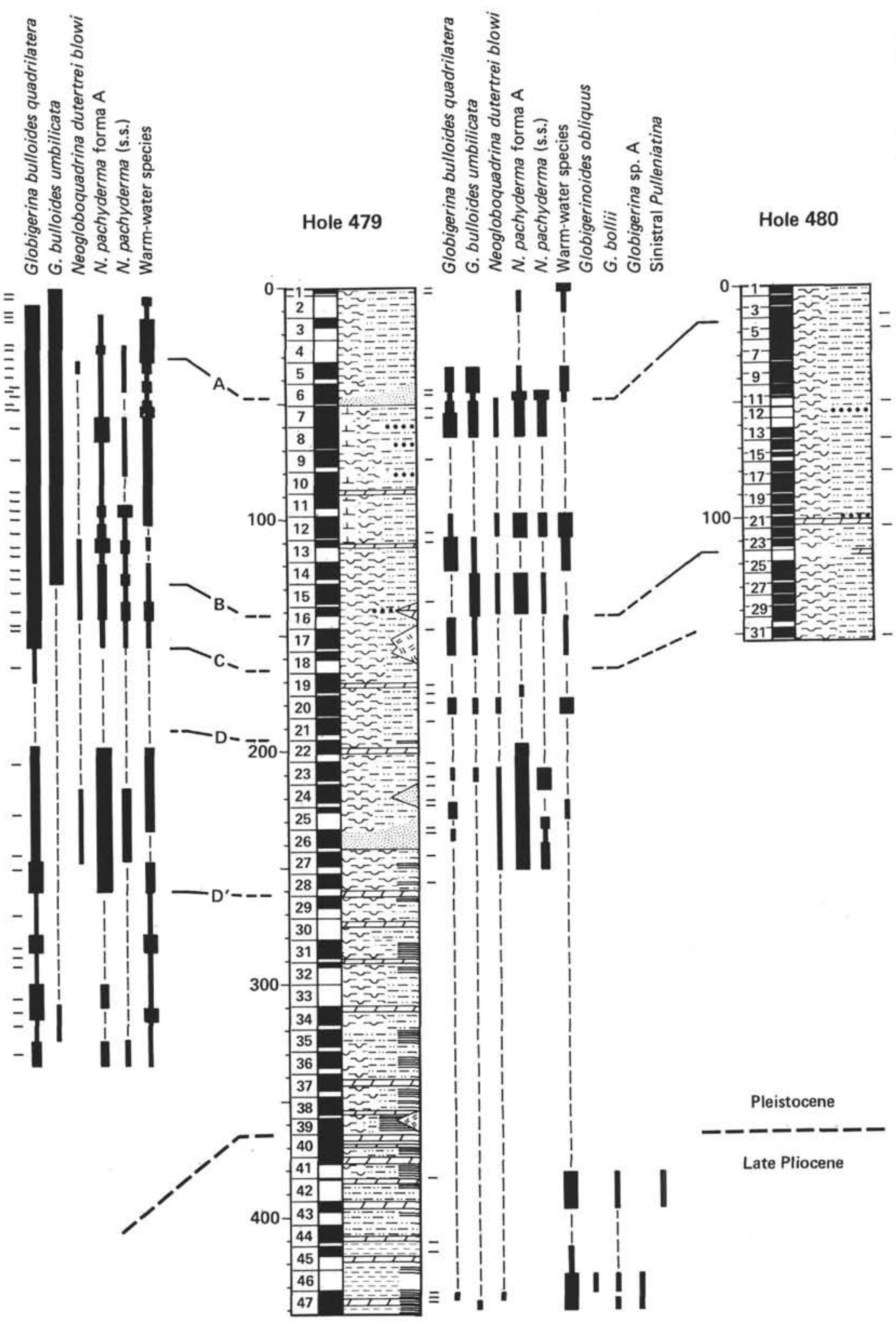

Figure 8. (Continued).

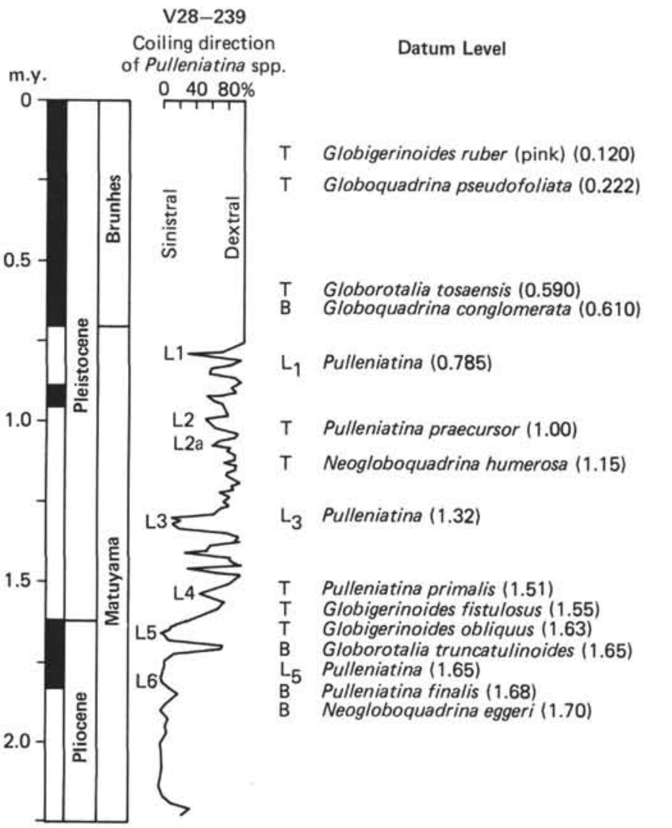

Figure 9. Coiling direction changes of *Pulleniatina* and planktonic foraminiferal datum levels dated by paleomagnetic time scale in the equatorial Pacific (simplified from Thompson and Sciarrillo, 1978).

25, pl. 7, figs. 4a–c (lectotype). All the specimens belong to typical *P. obliquiloculata* species. The occurrence of this species ranges from rare to few and is sporadic in the upper Pliocene to Holocene sequence. Nearly all specimens are dextrally coiled except for those in Section 479-42,CC, where all 4 specimens are sinistrally coiled, and Samples 478-31-2, 84–86 cm and 478-35-4, 18–20 cm, where each specimen is sinistrally coiled among 2 and 1 specimens of the species, respectively.

Turborotalita anfracta (Parker) (Plate 5, Figs. 14–15B). *Globorotalia anfracta* Parker, 1967, p. 175, pl. 28, figs. 3–8. *Turborotalita anfracta* (Parker), Rogl and Bolli, 1973, p. 571, pl. 8, figs. 1–7, pl. 16, fig. 9. Some specimens from a few samples at Sites 478 and 481 are identical to this species.

Turboratalita guaymasensis n. sp. (See Description of New Species, this chapter.)

Turborotalita iota (Parker) (Plate 5, Figs. 17–18B). *Globigerinita iota* Parker, 1962, p. 250, pl. 10, figs. 26–30. This species has a small, low trochospiral test and 4½ to 5 chambers in the final whorl. The umbilicus is covered by a bulla, which extends somewhat to the intercameral sutures. In this chapter, the specimens without bulla were distinguished from the typical form.

Turborotalita iota (Parker) vars. (Plate 5, Figs. 19A–20). Specimens similar to *G. iota*—but without bulla—were tentatively distinguished from the typical form. There are some morphologic variations, and the test size is often larger than in the typical form.

Turborotalita cf. T. *parkerae* (Bronnimann and Resig) (Plate 5, Figs. 16A–C) Cf. *Globorotalia (Turboratalia) parkerae* Bronnimann and Resig, 1971, p. 1280, 1281, pl. 43, figs. 7, 10, pl. 47, figs. 4, 6, pl. 48, figs. 2, 3. The very small test having the elongate final chamber and a bulbous appearance resembles *T. parkerae* but differs from it in having less radial elongation of the final chamber and slightly curved intercameral sutures on the umbilical side.

DESCRIPTION OF NEW SPECIES

Order FORAMINIFERIDA Eichwald, 1830
Family GLOBOROTALIIDAE Cushman, 1927
Genus *TURBORATALITA* Blow and Banner, 1962

***Turborotalita guaymasensis* Matoba and Oda, n. sp.**
(Plate 5, Figs. 1A–13B)

Description of Holotype. Test small, coiled in a trochospire with 15 globular chambers in all, arranged in 3 whorls, 5 in the final whorl; equatorial periphery fairly lobulate, somewhat pentagonal in outline; axial periphery broadly rounded. Chambers globular, inflated, gently embracing one another, increasing progressively in size as added, except for the ultimate chamber, which is slightly smaller than the penultimate chamber. Earlier 2 whorls very low trochospiral, forming the nearly flat spiral side; but the final whorl becomes a high trochospiral with a tendency to streptospiral. The last chamber tilts toward the umbilicus. Sutures on both spiral and umbilical sides radial to slightly curved and depressed. Umbilicus deep, open but small. Aperture interiomarginal; umbilical-extraumbilical in position, broad, low arch, bordered by a distinct, narrow lip. Wall is thin, finely perforate, and very finely pitted, without spines or spine bases. The wall of the ultimate chamber somewhat thinner and less densely perforate than the earlier chambers. Coiling sinistral.

Holotype. Plate 5, Figures 1A–D; deposited at the Institute of Geology and Paleontology, Tohoku University, Sendai, Japan (IGPS Coll. Cat. 96730).

Dimensions (holotype). Largest diameter = 0.22 mm; height of spire = 0.184 mm.

Type Locality. Deep Sea Drilling Project Leg 64, Site 478, Core 22, Section 1, 28–31 cm; Guaymas Basin, Gulf of California, 27°05.81′N; 111°30.45′W. Water depth = 1889 meters.

Type Level. Pleistocene.

Paratypes. Plate 5, Figures 2A–13B (IGPS Coll. Cat. 96731-96742). Unfigured paratypes (162 specimens) are deposited at the Institute of Mining Geology, Mining College, Akita University, Akita, Japan.

Dimensions (paratypes). Diameter = 0.162–0.242 mm; height of spire = 0.121–0.202 mm. Average diameter = 0.195 mm; average height of spire = 0.156 mm.

Number of Chambers (paratypes). 10–16; average = 13.6 chambers arranged in 2^+ to 3 whorls; 12 and 15 chamber forms are common. Number of chambers in ultimate whorl = 4–5, rarely 5½–6; 5–5½ in penultimate whorl.

Remarks. Characteristically becoming high trochospiral with a tendency to streptospiral coiling in the later stage of growth. Because of this coiling mode, the last chamber is usually tilted toward the umbilicus. The last chamber varies greatly in morphology, position, and wall character. In some specimens, the last chamber is normal in size and larger than the penultimate chamber, but often in others it is smaller than the penultimate chamber and is globose, elongate, reduced, or aberrant in shape. The wall of the last chamber is often thinner and less densely perforate than the wall of earlier chambers. In some specimens, the last chamber is completely umbilical and invisible from the spiral side (Plate 5, Figs. 8, 11); in an extreme case, the last chamber resembles a bulla (Plate 5, Figs. 6, 8) or shows an elongation onto the umbilicus (Plate 5, Fig. 9), as does *Globigerina quinqueloba*. A few specimens have an elongate last chamber toward the umbilicus as seen in *G. bermudezi*. The shape of the aperture varies because of the variation of the last chamber, but it is always bordered by a distinct lip. The morphology of the umbilicus varies from open to nearly closed, according to the shape and position of the last chamber and to the coiling mode, which ranges from rather loosely coiled to tightly coiled. A 4½–5 chambered, moderately coiled form such as the holotype seems to be typical, though the 4–4½ chambered, tightly coiled form with the umbilicus almost closed (Plate 5, Figs. 4–5B) and the 5-chambered form with a bulla-like or reduced last chamber on the umbilical side (Plate 5, Figs. 6–8) are also common. The 5½–6 chambered and rather loosely coiled form (Plate 5, Figs. 13A, B) is very rare. Sometimes, overlapping of lips of the previous apertures can be seen through the umbilicus when it is open.

Comparison. *Turborotalita guaymasensis* differs from *Globigerinita iota* Parker in the higher spired, thicker test, rougher wall, and

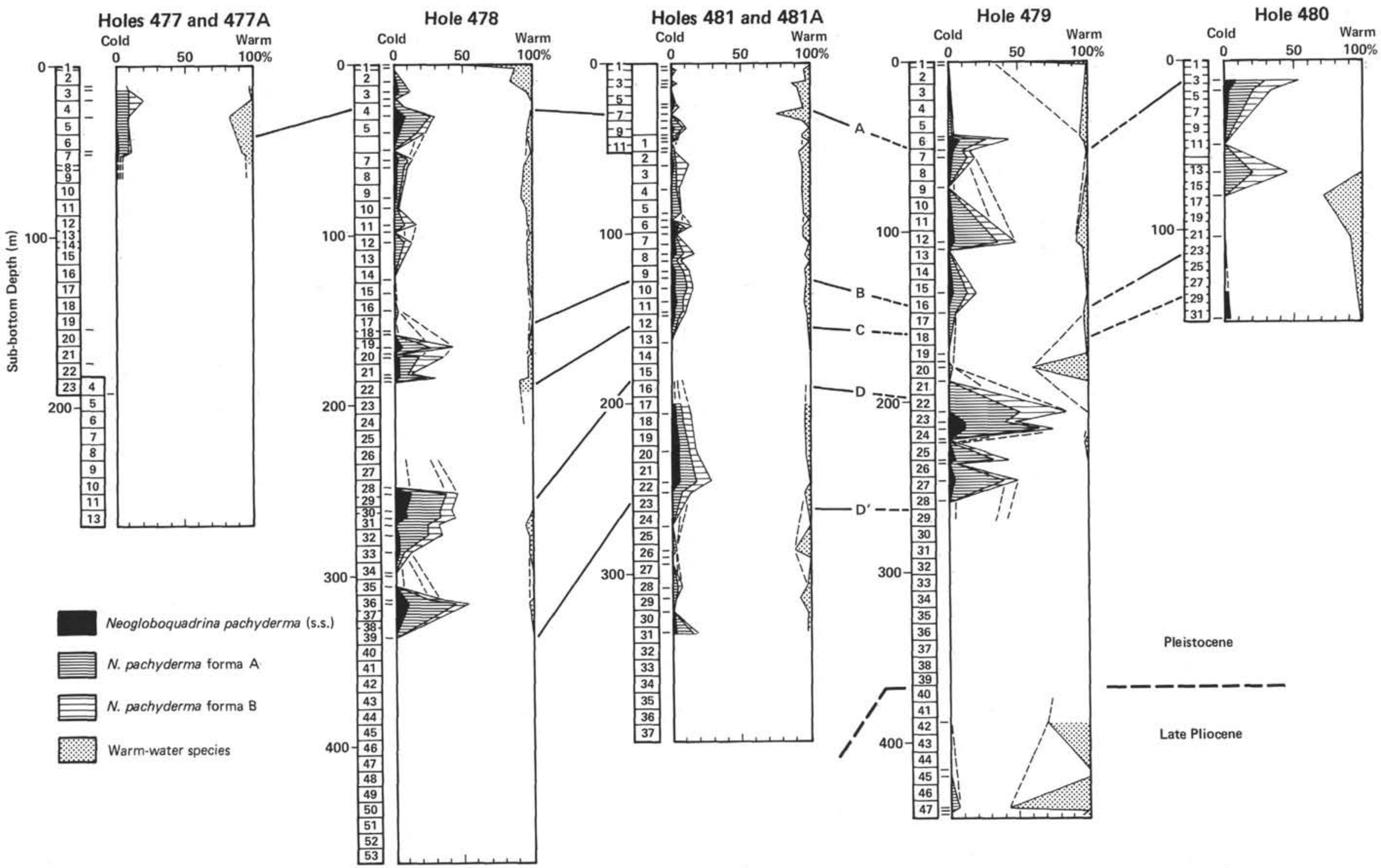

Figure 10. Vertical frequency distribution of warm and cold species, Sites 477 through 481. (Dashed line in the graphs indicates samples containing less than 30 specimens of planktonic foraminifers [disregarded]. See Fig. 8 for Horizons A–D′.

absence of true bulla. The senior author examined many paratypes of *G. iota* at the Scripps Institution of Oceanography (courtesy of Ms. F. L. Parker). *Turborotalita guaymasensis* resembles *Globigerina* sp. A of Poore (1979, p. 469, pl. 19, figs. 5-12), reported from the North Atlantic DSDP cores, which range from late Miocene to Quaternary. The form is thin-walled and nonspinose(?) having 4-6 chambers in the ultimate whorl and an open and deep umbilicus. Such a form is very rare and occurs at the end of the variation of our material from the Gulf. *Turborotalita guaymasensis* differs from *Globigerina tarchanensis* Subbotina and Khutsieva from the Miocene sequence of the Crimea-Caucasus, Soviet Union (1950) in having a higher trochospiral-to-streptospiral test. *Turborotalita guaymasensis* also differs from *Globigerina megastoma* Earland in its flat spiral side in earlier whorls, having chambers not as rapidly increasing in size as gradually added and has a much smaller test. It differs from *G. megastoma carinacoensis* Rögl and Bolli because of a lip, the absence of spines, and the much smaller size.

Occurrence. This species occurs only sporadically at all sites from Site 477 through 481, but is abundant in Cores 478-21, 478-22, 479-7, and 479-13. Pleistocene.

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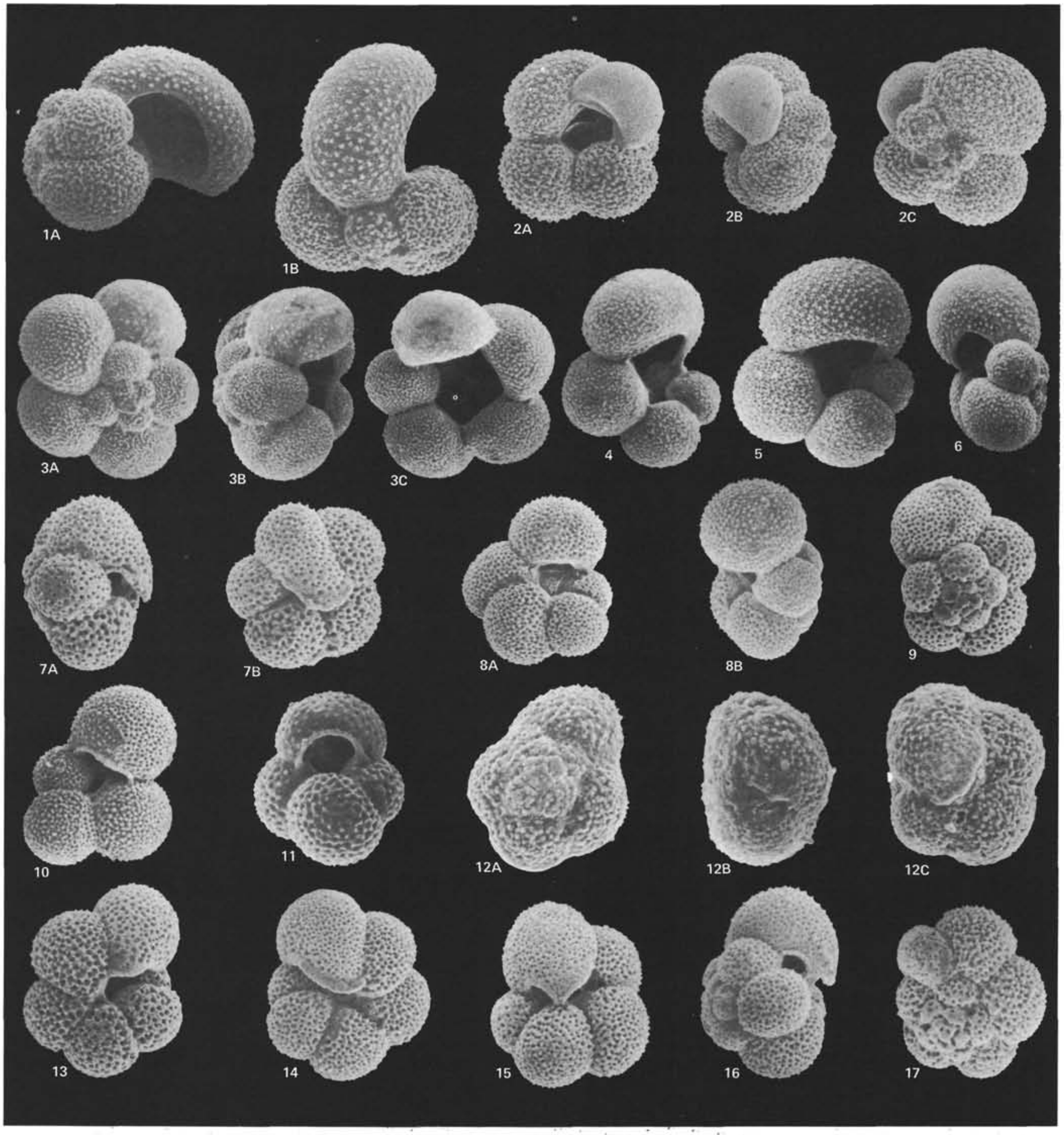

Plate 1. Late Pliocene to Holocene planktonic foraminifers. 1A, B. *Globigerina bermudezi* Seiglie. ×100. (1A) side view, slightly oblique. (1B) oblique spiral view (AKMG 11001). Section 481A-3,CC. 2A–C. *Globigerina bulloides quadrilatera* Galloway and Wissler. ×100. (2A) umbilical view. (2B) side view. (2C) spiral view (AKMG 11002). Section 478-10,CC. 3A–4. *Globigerina bulloides umbilicata* Orr and Zaitzeff. ×76. (3A) spiral view. (3B) side view. (3C) umbilical view (AKMG 11003a). (4) umbilical view (AKMG 11003b). Sample 481A-2-1, 75–77 cm. 5, 6. *Globigerina bulloides bulloides* d'Orbigny. ×88. (5) umbilical view (AKMG 11004a). (6) side view (AKMG 11004b). Section 478-2,CC. 7A, B. *Globigerina quinqueloba* Natland. ×125. (7A) side view. (7B) umbilical view (AKMG 11005). Section 480-21,CC. 8A–9. *Globigerina* cf. *G. quinqueloba* Natland. ×100. (8A) umbilical view. (8B) side view (AKMG 11006a). (9) spiral view (AKMG 11006b). Section 480-21,CC. 10. *Globigerina falconensis* Blow. ×100, umbilical view (AKMG 11007). Section 480-16,CC. 11. *Globigerina rubescens* Hofker. ×130, umbilical view (AKMG 11008). Section 481-11,CC. 12A–C. *Globigerina* sp. A. ×125. (12A) spiral view. (12B) side view. (12C) umbilical view (AKMG 11009). Sample 479-47-6, 35–37 cm. 13–17. *Globigerina* sp. B. ×125. (13–15) (AKMG 11010a–c), umbilical views. (16) oblique side view (AKMG 11010d). (17) spiral view (AKMG 11010e). Section 480-21,CC.

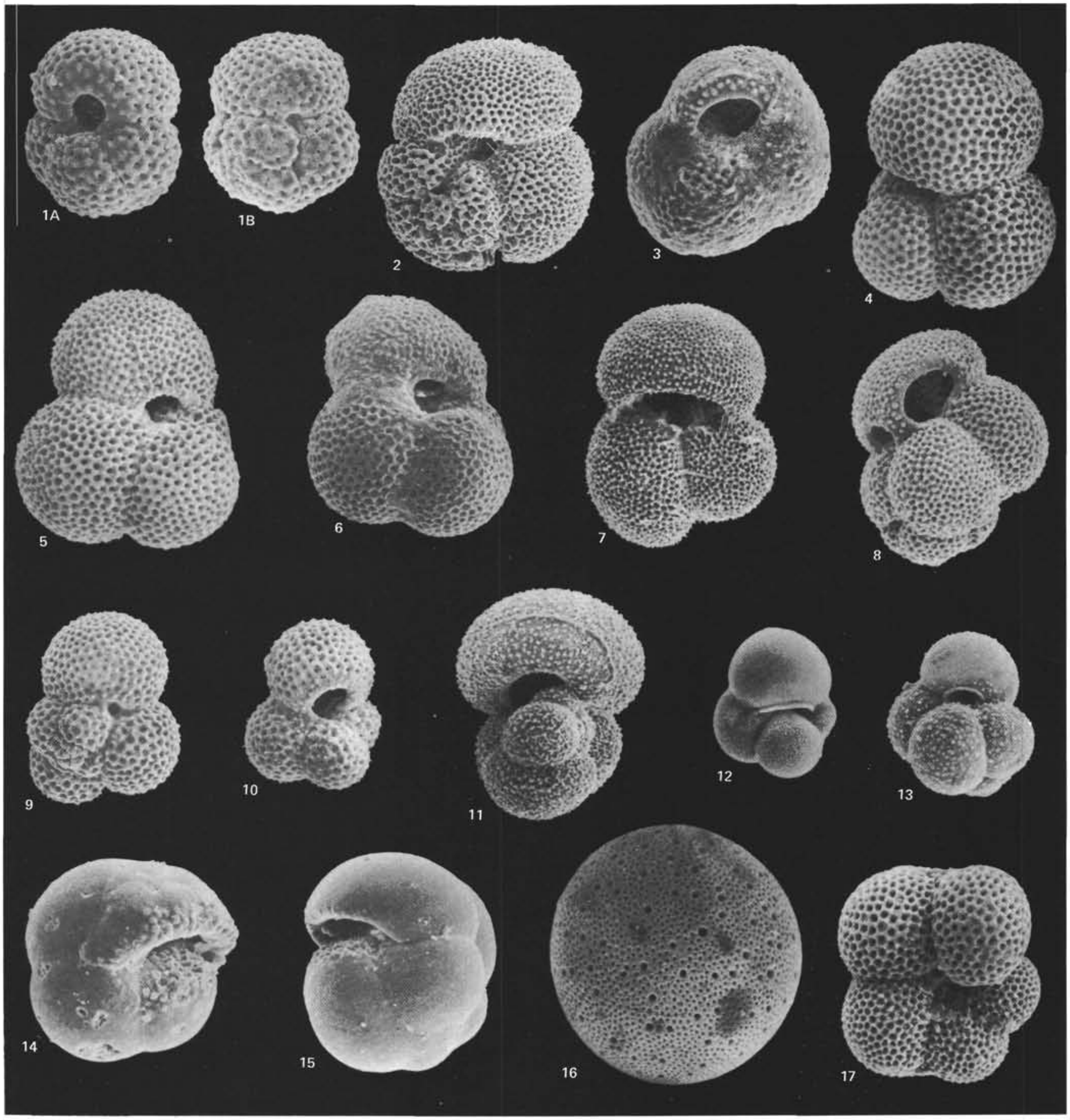

Plate 2. Late Pliocene to Holocene planktonic foraminifers. 1A, B. *Globigerinoides bollii* Blow, ×130. (1A) umbilical view, slightly oblique. (1B) oblique spiral view (AKMG 11011). Section 479-42,CC. 2. *Globigerinoides conglobatus* (Brady). ×70, oblique spiral view (AKMG 11012). Section 481A-3,CC. 3. *Globigerinoides obliquus* Bolli. ×100, umbilical view (AKMG 11013). Sample 479-47-5, 47–49 cm. 4. *Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny). ×88, umbilical view (AKMG 11014). Sample 479-20-2, 29–31 cm. 5, 6. *Globigerinoides quadrilobatus sacculifer* (Brady). ×88, umbilical views (AKMG 11015a, b). (5) Sample 479-20-2, 29–31 cm. (6) Sample 479-47-6, 35–37 cm. 7. *Globigerinoides ruber ruber* (d'Orbigny). ×75, umbilical view (AKMG 11016). Section 481-3,CC. 8. *Globigerinoides ruber elongatus* (d'Orbigny). ×88, oblique side view (AKMG 11017). Section 481-3,CC. 9, 10. *Globigerinoides tenellus* Parker. ×100. (9) spiral view (AKMG 11018a). (10) oblique umbilical view (AKMG 11018b). (9) Sample 478-7-6, 84–86 cm. (10) Sample 481A-1-1, 36–38 cm. 11. *Globigerinella aequilateralis* (Brady). ×75, side view (AKMG 11019). Section 478-10,CC. 12. *Globigerinita glutinata* (Egger). ×125, umbilical view (AKMG 11020). Section 478-2,CC. 13. *Globigerinita uvula* (Ehrenberg). ×125, umbilical view (AKMG 11021). Sample 479-6-2, 71–74 cm. 14, 15. *Pulleniatina obliquiloculata* (Parker and Jones). ×88. (14) umbilical view (AKMG 11022a). (15) side view (AKMG 11022b). Section 479-42,CC. 16. *Orbulina universa* d'Orbigny. ×88. (AKMG 11023). Sample 478-7-3, 80–82 cm. 17. *Globorotaloides hexagonus* (Natland). ×125, umbilical view (AKMG 11024). Sample 478-22-1, 28–31 cm.

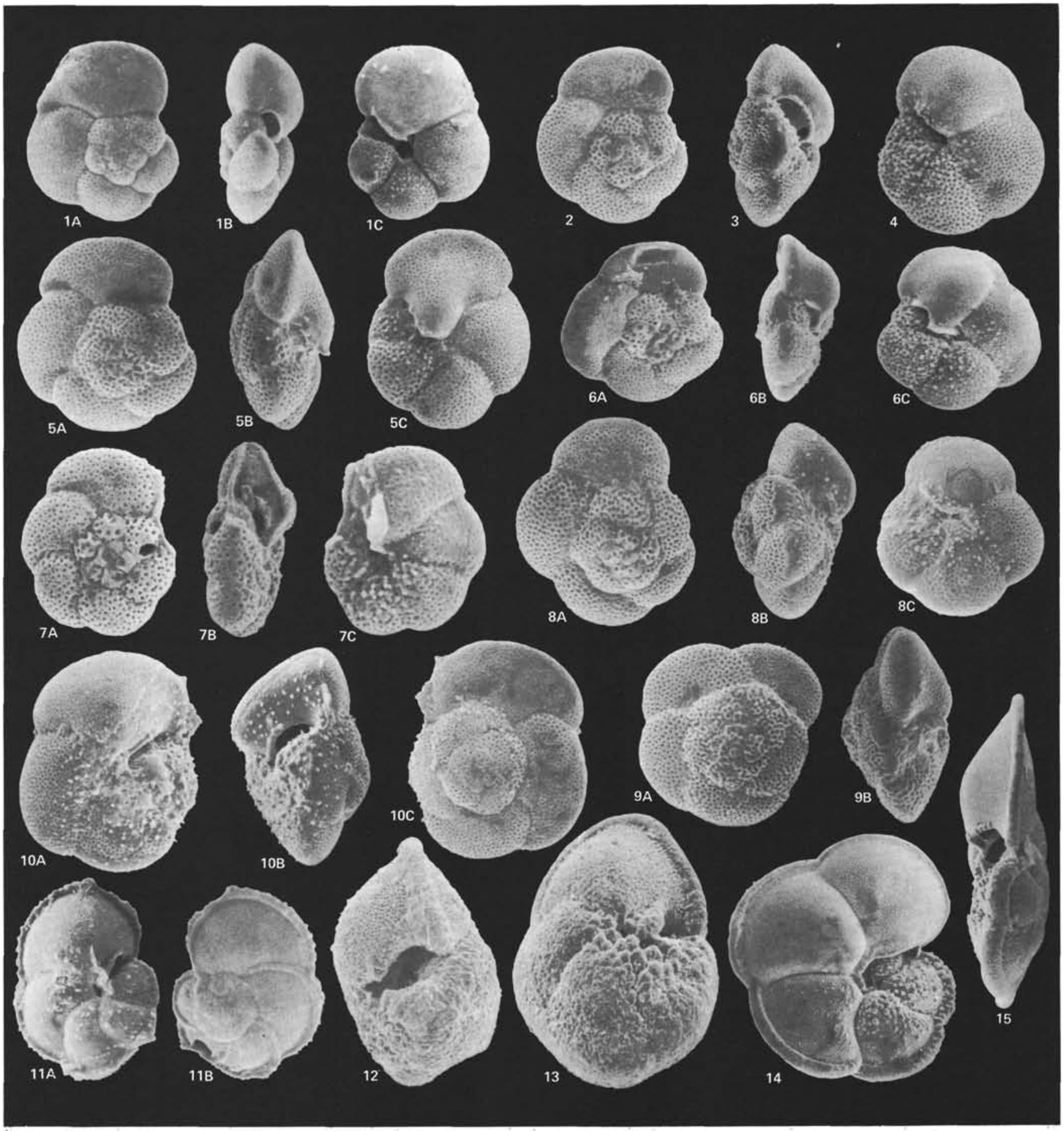

Plate 3. Late Pliocene to Holocene planktonic foraminifers. 1A–C. *Globorotalia* cf. *G. bermudezi* Rögl and Bolli. ×125. (1A) spiral view. (1B) side view. (1C) umbilical view (AKMG 11025). Sample 481A-2-1, 75–77 cm. 2–4. *Globorotalia scitula* (Brady). ×88. (2) spiral view (AKMG 11026a). (3) side view (AKMG 11026b). (4) umbilical view (AKMG 11026c). Section 478-3,CC. 5A–6C. *Globorotalia* cf. *G. scitula* (Brady). (5A, 6A) spiral views. (5B, 6B) side views. (5C, 6C) umbilical views. (5A–C) ×88. (AKMG 11027a). Sample 481A-10-3, 20–22 cm. (6A–C) ×113. (AKMG 11027b). Sample 481A-2-1, 75–77 cm. 7A–C. *Globorotalia* sp. A. ×125. (7A) spiral view. (7B) side view. (7C) umbilical view (AKMG 11028). Section 481A-29,CC. 8A–9B. *Globorotalia* sp. B. ×90. (8A, 9A) spiral views. (8B, 9B) side views. (8C) umbilical view. (8A–C) (AKMG 11029a). (9A, B) (AKMG 11029b). Sample 481A-10-3, 22–24 cm. 10A–C. *Globorotalia crassaformis* (Galloway and Wissler). ×88. (10A) umbilical view. (10B) side view. (10C) spiral view (AKMG 11030). Sample 478-22-1, 28–31 cm. 11A, B. *Globorotalia fimbriata* (Brady). ×100. (11A) umbilical view. (11B) spiral view (AKMG 11031). Sample 481A-26-3, 72–74 cm. 12, 13. *Globorotalia tumida* (Brady). ×75. (12) side view (AKMG 11032a). (13) umbilical view (AKMG 11032b). Section 479-42,CC. 14,15. *Globorotalia cultrata* (d'Orbigny). ×60. (14) umbilical view (AKMG 11033a). (15) side view (AKMG 11033b). Sample 481-10-2, 69–71 cm.

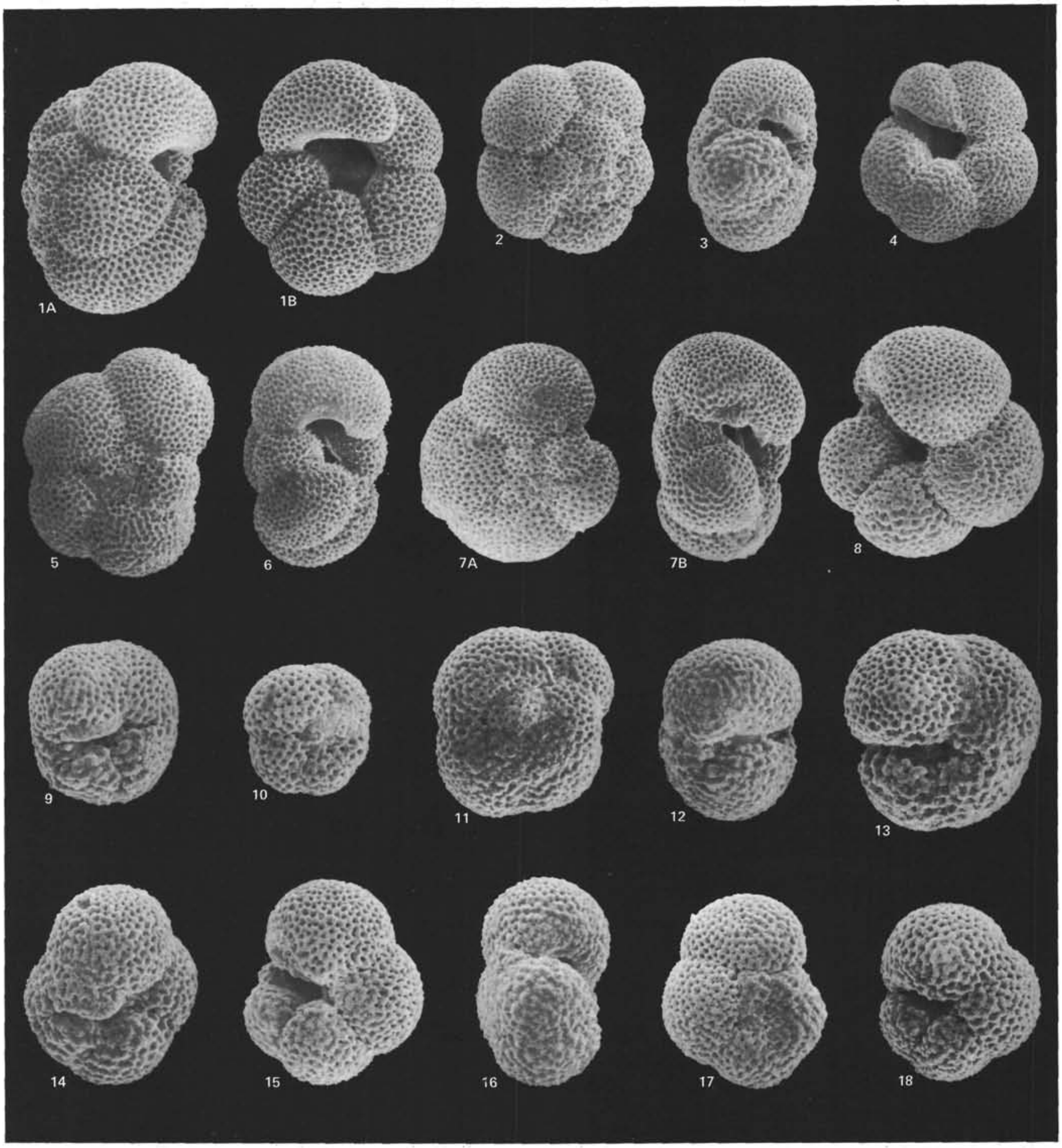

Plate 4. Late Pliocene to Holocene planktonic foraminifers. 1A, B. *Neogloboquadrina dutertrei dutertrei* (d'Orbigny). ×75. (1A) side view. (1B) umbilical view (AKMG 11034). Sample 478-12-3, 139–141 cm. 2–4. *Neogloboquadrina dutertrei* (d'Orbigny) forma A. ×88. (2) spiral view (AKMG 11035a). (3) side view (AKMG 11035b). (4) umbilical view (AKMG 11035c). Sample 479-7-2, 73–75 cm. 5–8. *Neogloboquadrina dutertrei blowi* Rögl and Bolli. ×75. (5, 7A) spiral views (AKMG 11036a,c). (6[AKMG 11036b], 7B) side views. (8) umbilical view (AKMG 11036d). (5) Sample 481A-8-2, 26–28 cm. (6) Sample 479-20-2, 29–31 cm. (7) Section 478-10,CC. (8) Section 478-28,CC. 9, 10. *Neogloboquadrina pachyderma pachyderma* (Ehrenberg). ×125. (9) umbilical view (AKMG 11037a). (10) side view (AKMG 11037b). Section 478-4,CC. 11–13. *Neogloboquadrina pachyderma* (Ehrenberg) forma A. ×88. (11) spiral view (AKMG 11038a). (12) side view (AKMG 11038b). (13) umbilical view (AKMG 11038c). Section 478-4,CC. 14–18. *Neogloboquadrina pachyderma* (Ehrenberg) forma B. ×125. (14, 15, 18) umbilical views (AKMG 11039a,b,e). (16) side view (AKMG 11039c). (17) spiral view (AKMG 11039d). (14–17) Sample 479-7-2, 73–75 cm. (18) Section 478-4,CC.

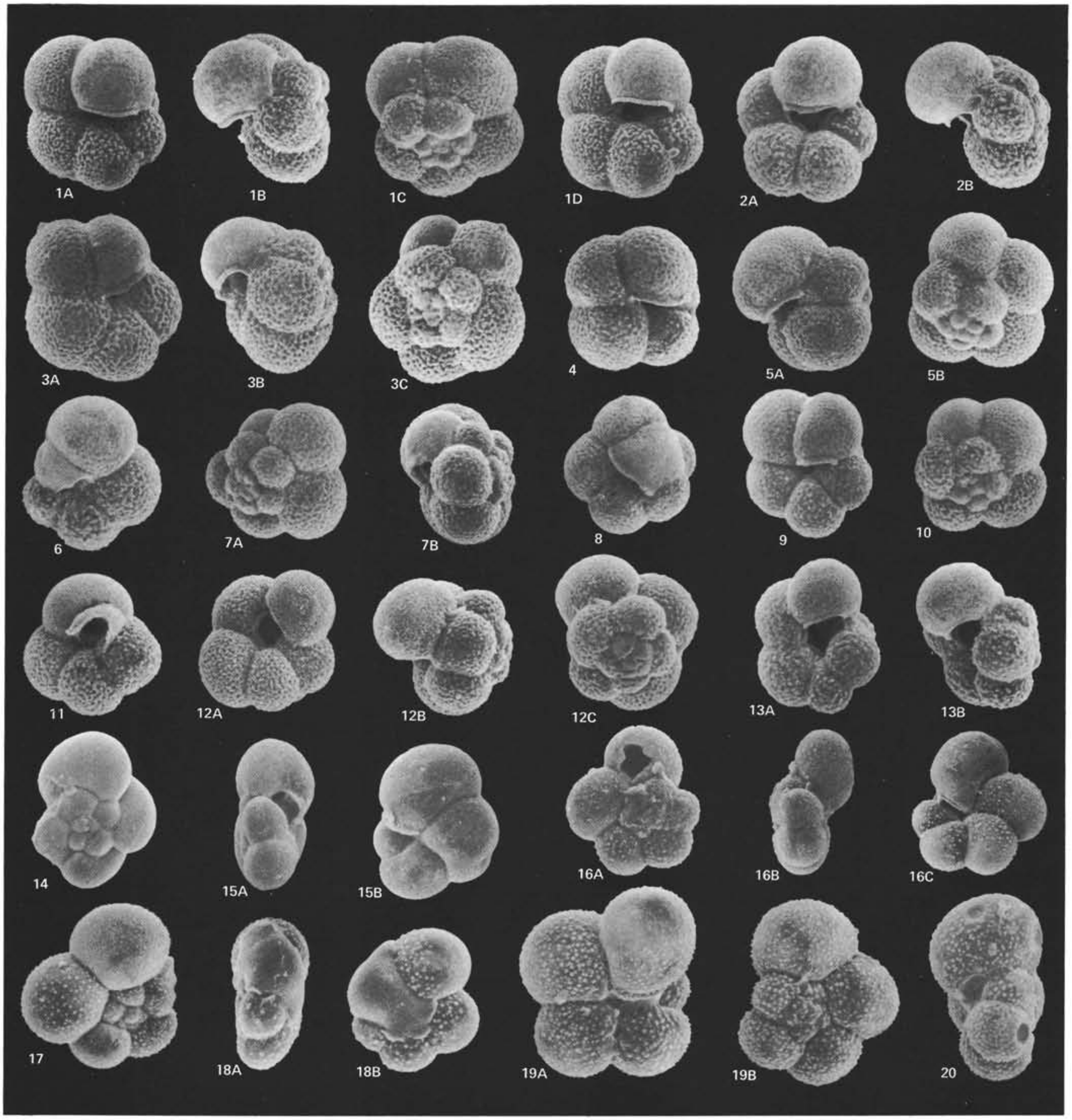

Plate 5. Late Pliocene to Holocene planktonic foraminifers. 1A–13B. *Turborotalita guaymasensis* Matoba and Oda n. sp. ×125. (1) holotype. (2–13) paratypes. (1A) umbilical view. (1B) side view. (1C) spiral view, slightly oblique. (1D) oblique umbilical view (IGPS Coll. Cat. 96730). (2A) oblique umbilical view. (2B) side view (IGPS Coll. Cat. 96731). (3A) umbilical view. (3B) side view. (3C) spiral view (IGPS Coll. Cat. 96732). (4) umbilical view (IGPS Coll. Cat. 96733). (5A) side view. (5B) oblique spiral view (IGPS Coll. Cat. 96734). (6) umbilical view (IGPS Coll. Cat. 96735). (7A) spiral view, slightly oblique. (7B) side view (IGPS Coll. Cat. 96736). (8, 9) umbilical views (IGPS Coll. Cat. 96737, 96738). (10) spiral view (IGPS Coll. Cat. 96739). (11) umbilical view (IGPS Coll. Cat. 96740). (12A) oblique umbilical view. (12B) side view. (12C) spiral view (IGPS Coll. Cat. 96741). (13A) umbilical view, slightly oblique. (13B) side view (IGPS Coll. Cat. 96742). (1–12) Sample 478-22-1, 28–31 cm. (13) Sample 479-7-4, 46–48 cm. 14–15B. *Turborotalita anfracta* (Parker). ×130. (14) spiral view (AKMG 11040a). (15A) side view. (15B) umbilical view (AKMG 11040b). Section 481-3,CC. 16A–C. *Turborotalita* cf. *T. parkerae* Brönnimann and Resig. ×130. (16A) spiral view. (16B) side view. (16C) umbilical view (AKMG 11041). Section 480-16,CC. 17–18B. *Turborotalita iota* (Parker). ×125. (17) spiral view (AKMG 11042a). (18A) side view. (18B) umbilical view (AKMG 11042b). Section 481-3,CC. 19A–20. *Turborotalita iota* (Parker) vars. ×130. (19A) umbilical view. (19B) spiral view (last chamber of Fig. 19A broken) (AKMG 11043a). (20) side view (AKMG 11043b). Sample 478-22-1, 28–31 cm.