13. PLIOCENE PLANKTONIC AND BENTHIC FORAMINIFERS FROM THE SOUTHEASTERN ATLANTIC ANGOLA MARGIN: LEG 75, SITE 532, DEEP SEA DRILLING PROJECT[1]

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INTRODUCTION

At Site 532 of Leg 75 (Fig. 1) hydraulic piston coring was used to drill three holes at a water depth of 1331 m. Holes 532 and 532B, discussed here, produced 61 and 73 cores, respectively. Core catchers from those two holes were provided to me through the courtesy of the shipboard paleontologist, Dr. Charles McNulty. In Hole 532, core catchers and an occasional extra sample in each core were studied from Cores 12 to 61; in Hole 532B only core catchers of most of Cores 12 to 71 were examined. Planktonic foraminiferal faunas and their biostratigraphic zonations are shown in Table 1 and Figure 2; benthic foraminiferal species are listed in Table 2.

PALEOGEOGRAPHIC SETTING

Site 532 was drilled on the continental margin of Angola near the easternmost end of the Walvis Ridge. At a bottom depth of 1331 m, the holes lay within the path of Antarctic Intermediate Waters (AAIW) flowing north along the continental slope of Africa. Overlying AAIW is the north-flowing, sluggish Benguela Current and its countercurrent system which produce a seasonally developing divergence zone in this region. The Benguela upwelling is thought to deliver AAIW to the surface in this area (Calvert and Price, 1971).

At Site 532, bottom sediments, which form the habitat of the benthic foraminifers, consist of marls dominated by: (1) terrigenous input deriving from the African continental margin, primarily from the embouchement of the Congo River; and (2) siliceous components produced in the fertile zone of the upwelling (Melguen, 1978). Leg 75 cores exuded significant amounts of biogenic gases on shipboard, attesting to bacterial activity and the high organic carbon contents (nearly 8%) of the sediments. Thorough bioturbation demonstrated, however, that the sediments were not anoxic (Dean, Arthur, Stow,this volume).

OBJECTIVES

The setting of Site 532 along a middle latitude continental margin within an active upwelling system provides an opportunity to document: (1) planktonic foraminiferal faunas and their fluctuations as the upwelling evolves with the distinct climatic variations of the Pliocene (Shackleton and Opdyke, 1977); (2) some effects of middle latitude upwelling sedimentation upon planktonic foraminiferal biostratigraphic zonations: (3) benthic foraminiferal faunas of the slope AAIW during these same distinct Pliocene climatic events; and (4) benthic faunas from areas with high sediment accumulation rates and in cycles which are themselves largely related to climate. The low sampling density for this study, however, allows only preliminary descriptions here of these faunas and their paleoecologies.

PLIOCENE PLANKTONIC FORAMINIFERS

Pliocene planktonic foraminifers from Hole 532B are listed in Table 1 along with a rating of their preservation and a tabulation of their diversities in each sample. Faunal lists include all species recognized in the >149 μm fraction.

Site 532 temperate planktonic foraminiferal faunas include high proportions of *Globigerina bulloides, Globorotalia puncticulata, G. inflata*, including a strongly pustulose morphotype, *G. conoidea, G. conomiozea*, and *Orbulina universa.* Less frequent are *Neogloboquadrina pachyderma, G. cultrata, Globoquadrina dutertrei*, and *Globorotalia crassaformis.* The characteristic Pliocene low-latitude biostratigraphic indices *G. multicamerata, G. miocenica, Sphaeroidinellopsis seminulina-subdehiscens, Globoquadrina altispira*, and *Globigerina nepenthes* were found only sporadically and in low abundance; their presence or absence is strongly correlated with sediment type.

Planktonic foraminiferal diversity, expressed simply as species richness, averages around 17 species; it is highest (20–23 species) in the well-preserved oozes of Cores 63–57 of early Pliocene age and is consistently relatively high again (17–13 species) in the latest Pliocene/earliest Pleistocene age samples above Core 19. The high values of the early Pliocene are never again recorded, even in the well-preserved sequence near the Pliocene/Pleistocene boundary; therefore, they cannot be attributed to sediment preservation, but reflect a proliferation of species during the early Pliocene immediately prior to the appearance of *Globorotalia crassaformis* (Fig. 3).

The presence of small amounts of the subtropical species *Globigerinoides ruber* and *G. sacculifer* throughout the sequence suggests the presence of warm, saline surface waters, while the presence of the keeled globorotaliids of the *Globorotalia conoidea–G. conomiozea* group, rather than the subtropical keeled globorotaliids, indicates substantial cooling and/or the absence of mixed-layer water through the thermocline in this area. It is assumed that the upwelling process has displaced

[1] Hay, W. W. Sibuet, J.-C., et al., *Init. Repts. DSDP*, 75: Washington (U.S. Govt. Printing Office).

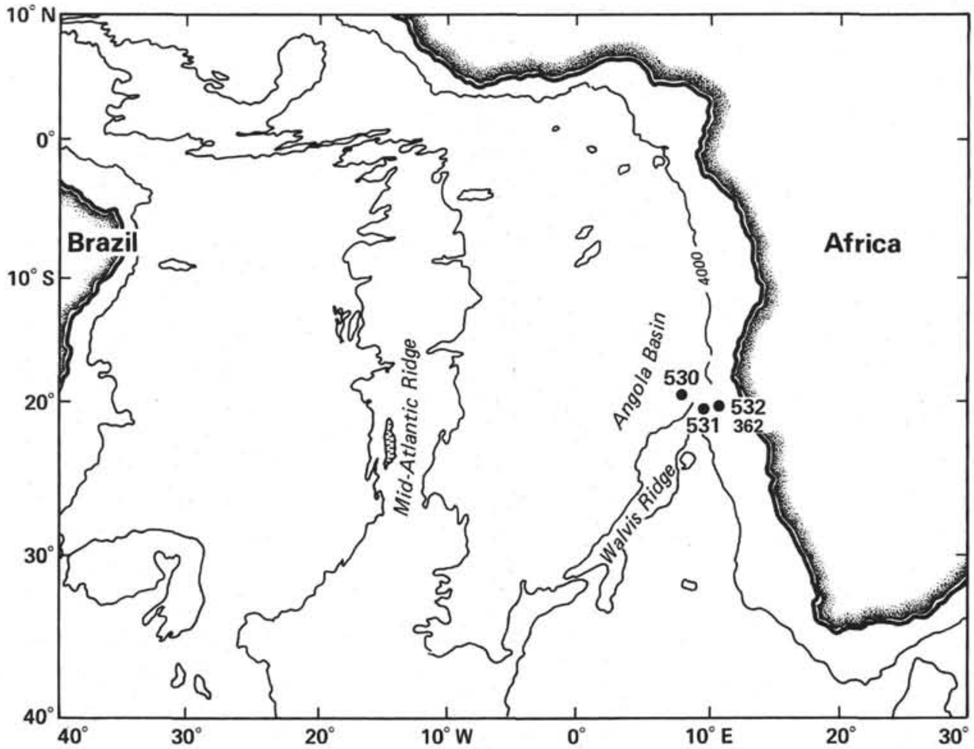


Figure 1. Location of sites drilled in the Angola Basin on Leg 75.

the mixed-layer water and replaced it with AAIW in the region of Site 532.

Preservation of the planktonic foraminifers fluctuated strongly through the section; the apparent degree of fluctuation here may be accentuated by the fact that only core catchers were examined. During episodes of good preservation in Cores 63-55, 44-38, and 13-12, the coarse fractions of the sediments contain primarily planktonic foraminiferal oozes with accessory clay, pyrite, benthic foraminifers, and planktonic siliceous fossils. Planktonic diversities reach maximum values and the rare keeled globorotaliids *G. miocenica* and *G. multicamerata* are found.

During the episodes of poor preservation from Cores 37-23 and within Core 19-18, diversity may drop to as low as five to six species, radiolarians may compose nearly 85% of the coarse fraction, and most of the planktonic foraminifers may be reduced to fragments. In such samples only the most resistant species such as *G. inflata* are preserved; benthics are also preserved and may equal 50% of the foraminiferal populations. These poorly preserved samples are always darker in color and have smaller >149 μm fractions.

PLANKTONIC FORAMINIFERAL BIOSTRATIGRAPHY

Despite the sporadic occurrences of the lower latitude index species, a rough subdivision of the Pliocene according to Berggren (1973) was possible (Fig. 2). As in other middle latitude areas, it was not possible to separate zones Pl1-2 and Pl5-6 because of the simultaneous use of *Globigerina nepenthes* and *Globorotalia margaritae* in the former case, and the absence of *G. miocenica* above Zone P14.

The Pliocene zones of Jenkins (1978) described at adjacent Site 362 and of Kennett (1973) and Srinivasan and Kennett (in press) were easily recognized by the presence/absence of the nominate species (Fig. 2). The *Globorotalia puncticulata* Zone was particularly short because of the appearance of *G. crassaformis* almost immediately above that of *G. puncticulata.*

Comparison of foraminiferal and nannofossil stratigraphy (Steinmetz et al., this volume) demonstrates offsets between the boundaries of foraminiferal and calibrated nannofossil zones. For example, the top of P13 should correspond to the top of *Reticulofenestra pseudoumbilica* Zone (NN15) (Berggren, 1973). Instead, the foraminiferal zonal top is found three cores lower. In a similar example at Site 532 the initial appearance of *G. truncatulinoides* occurs three cores above the top of NN18, rather than below it.

Solution susceptible foraminifer indices are most likely to be offset from calibrated nannofossil datums; most of the foraminifer datums of the mid-Pliocene at Site 532 are thus displaced by the intense dissolution of this time. The delayed appearance of the more solution-resistant species, *G. truncatulinoides*, (Berger, 1971) however, cannot be considered an artifact of dissolution, but must represent an ecologically induced delay in the appearance of *G. truncatulinoides* in the Site 532 area.

At Site 532 the *G. conoidea–G. conomiozea* and *G. sphericomiozea* groups, including morphotypes resembling *G. miozea*, range into the late Pliocene (Fig. 2). The *G. conoidea–G. conomiozea* plexus ranges through

Table 1. Ranges of all common planktonic foraminiferal species in the >149 μm fraction from Cores 70 through 12 at Hole 532B.

Epoch	Zone	Core, Section (level in cm)	*Neogloboquadrina acostaensis*	*Globoquadrina venezuelana*	*Globorotalia merotumida*	*Globigerina bulloides*	*Globorotalia cultrata*	*Globorotalia scitula*	*Orbulina universa*	*Globoquadrina dehiscens*	*Globorotalia conomiozea*	*Globigerina incisa*	*Globorotalia plesiotumida*	*Globigerinoides ruber*	*Globigerinoides obliquus*	*Neogloboquadrina pachyderma*	*Globigerinoides sacculifer*	*Orbulina bilobata*	*Globigerinoides trilobus*	*Sphaeroidinellopsis seminulina*	*Globigerinita glutinata*	*Globigerina foliata*	*Globoquadrina hexagona*	*Neogloboquadrina praehumerosa*	*Globoquadrina altispira*	*Globorotalia trans. puncticulata*	*Globorotalia margaritae*	*Globigerinoides bollii*	*Globigerina praecalida*	*Globigerinellopsis mitra*	*Globigerina nepenthes*	*Globigerinella aequilateralis*	*Neogloboquadrina humerosa*	*Globorotalia tumida*	*Globorotalia menardii*	*Globorotalia cf. cibaoensis*	*Globoquadrina dutertrei*	*Sphaeroidinellopsis subdehiscens*	*Globorotalia miocenica*	*Globorotalia crassaformis*	*Globorotalia multicamerata*	*Streptochilus tokelauae*	*Globorotalia puncticulata*	*Globorotalia hirsuta*	pustulose *Globorotalia inflata*	*Globorotalia tosaensis*	*Globorotalia pseudopima*	*Globigerinoides conglobatus*	*Globorotalia truncatulinoides*	Preservation	Diversity
Pleistocene	N22	12,CC				A			C					I	I	F	R																	R	R					C					A	F		R	I	G	13
Pliocene	Pl 5–6	13,CC				A			C					I	I	I	I																		R					C					C	R	F			G	12
		11,CC		R		A	I		C					I	I	C	R																		R					I					F	I		R		G	17
		19,CC				A		R	C																												F			I					A	I				P	7
		22,CC				A										A	I		R														R				C	R		I					A		F			M	12
		23,CC		R		A		I	F					I		F				R	I		R									R	R				F			I					A	I				M-G	16
		26,CC				A		I	I					I	I	F	I	I			R																F			I					A					M	13
		22-2, 106				A		I							I	I																					R			C	R				A					P	5
		25,CC				C			I					I		I																								I				I	A					M	8
		31,CC				C		R	I							F																					F			F			A	P						VP	1
	Pl 4	34,CC				C		R	R		F																													F			A							M-P	10
		36,CC				C	I	R	R		F				I	F						R											R				R			C			A							M-P	10
		37,CC				C		R	R																												I			I			A							M-P	6
		38-1, 48				C	I	I	R					I																							I			C			C							M-P	10
		40,CC				A			I		I			I	I		I								R							R					C			C			I							M	12
	Pl 3	41,CC				A	R	R	I		F				I		R	I																			I	I	I	C	I		R							M	10
		42,CC				A		R	F		I			F			F		F	F																	F	R	R	C										M	17
		43-1, 67				A	I	R	A					F	F			F	F	F					I												C			C	R	R								M	12
		44-2, 86				A	I		A					F	F			F	I														R				F			C										G	13
		96-1, 70		R		A	I	R						I	I		I								I												F			F										M-P	11
	Pl 1–2	47,CC				A	C	R	C					I	I		I										R										F			R										M-G	9
		52,CC				A	C		I					I						I	R						R						R		I		C			R										M-P	17
		54,CC		R		A	C		F		I			F	F		I	I							I										I		C	I												M	11
		55,CC				A	C	R	I		I			I	I					I					I										F		F		R											M	18
		55,CC		I		A	C		C		I			F	F	R	I	I	I	R	I													I	F		F	I	R											G	18
		57,CC		R	I	A	C	R	C		I			F	I	F		I		R							R		R				R	I	C	R	F	R												M	21
		58-3, 34		R	F	C	C	I	F		R			I	I	I	I	I	I	I						R	R				R		R	I	C	R	F	R												M	23
		59,CC			I	C	C	R	C		I			I	F	F	I	R	I							R	R						R	I	C		F	I												M	20
		60,CC			I	C	C	I	C		I	R		I	F		I	I	I	I			R		I								I	F	C		F	R												M-G	19
		62,CC	R		I	C	F	I	C		C			I	I		I	I	I			R		I	R						R		I		F	R	R													M-P	20
Miocene	N17	63-1, 48	R		R	C	F	I	C		C			F	F	F	F	F	F					I	F		R				R	R	I	I	F	R														G	22
		65,CC	I		I	C	F	I	F		C			R	R	R	R	R	R				F	I	R		R																							M-G	17
		66-1, 107	I		I	A	I	I	I	R	C			I		I	I	I	I			R		I	R	F					R																			M	19
		66,CC	F			A	F	F	I		A	I				I			R					F					R		R																			G	13
		67-1, 110		R	F	A	C	I	C					I	I	I		I	I			R	R	I	I	I		R	R		R																			VG	20
		67,CC	F		F	A	F	I	C			R		I	I	F		I	I				I	I	R	R	R	R	R	R																				G	21
		69,CC	I		I	C	I	I	I		F	I						I	I	R	I	I	F	F																										M	16
		70-2, 48	I	I	R	A	I	F	C		C	R				I		R	R																															M	13
		70,CC			I	I			I		I					I																																		P	5
		71-1, 132	C	I	I	A	C	R	C	I	I	I	R	R	R																																			G	13

Note: Species abundances are subjectively evaluated as Rare (R), Infrequent (I), Frequent (F), Common (C), and Abundant (A). Absence is indicated by a blank space. Preservation of the planktonic foraminiferal faunas is ranked as Poor (P), Moderate (M), or Good (G) or intermediate between two of these ranks. (V) Signifies *Very* poor, moderate, or good. The number of foraminiferal species in each sample is tabulated as species richness.

Core 34,CC in Hole 532B and into Core 32, Section 2 in Hole 532 (Table 3) and disappears immediately prior to the evolution of *G. inflata* (Fig. 3).

In most other temperate areas of the ocean, including nearby Site 362 (Jenkins, 1978), the ranges of these species are terminated in the early Pliocene. Similar forms listed from the Pliocene of the southwest Pacific Leg 21 sites by Kennett (1973) as *G.* cf. *miozea conoidea* and *G.* cf. *conomiozea* have recently been identified as *G. conoidea* and *G. conomiozea* and shown to disappear with the appearance of *G. inflata* in the Pliocene at DSDP Leg 74, Sites 525 and 527 in the Angola Basin (Boersma, in press). In future biostratigraphies, the ranges of these species should be extended into the late Pliocene.

BENTHIC FORAMINIFERAL FAUNAS

Benthic foraminifers were studied in core catchers from Cores 61 to 10 in Hole 532 and Cores 71 to 10 in Hole 532B. Ranges of the most common benthic foraminifers are shown in Table 2. Since my data set contains mainly core catcher samples, ranges are only approximate. In each sample the species in a 10 cm^3 sample from the >64 μm fraction were picked and identified.

Benthic faunas of the Pliocene section of Site 532 contain many species already well known from the literature (see the appendix to this chapter): from the Pliocene of Kar Nicobar (Schwager, 1866), the Buff Bay section of Jamaica (Cushman and Todd, 1945), and the Recent of the Pacific Ocean (Brady, 1884). It is difficult to compare with Pliocene faunas reported from nearby Site 362 (Cameron, 1978), since the taxonomy used there derived almost entirely from the New Zealand literature.

Faunas are dominated by long-ranging, geographically widespread species such as *Bulimina alazanensis, B. striata mexicana, Uvigerina auberiana, U. proboscidea, U. hispida, U. hispido-costata, U. schwageri, Hoeglundia elegans, Cibicidoides* (= *Heterolepa*) *kullenbergi, C. bradyi, Bolivina aenariensis, Planulina wuellerstorfi, Pullenia bulloides, Pleurostomella alternans, Textularia lythostrota,* and *Stilostomella lepidula.* Most faunas contain three to four species of agglutinated and miliolid foraminifers.

Although most species are long-ranging, there are two periods of benthic foraminiferal diversification, the

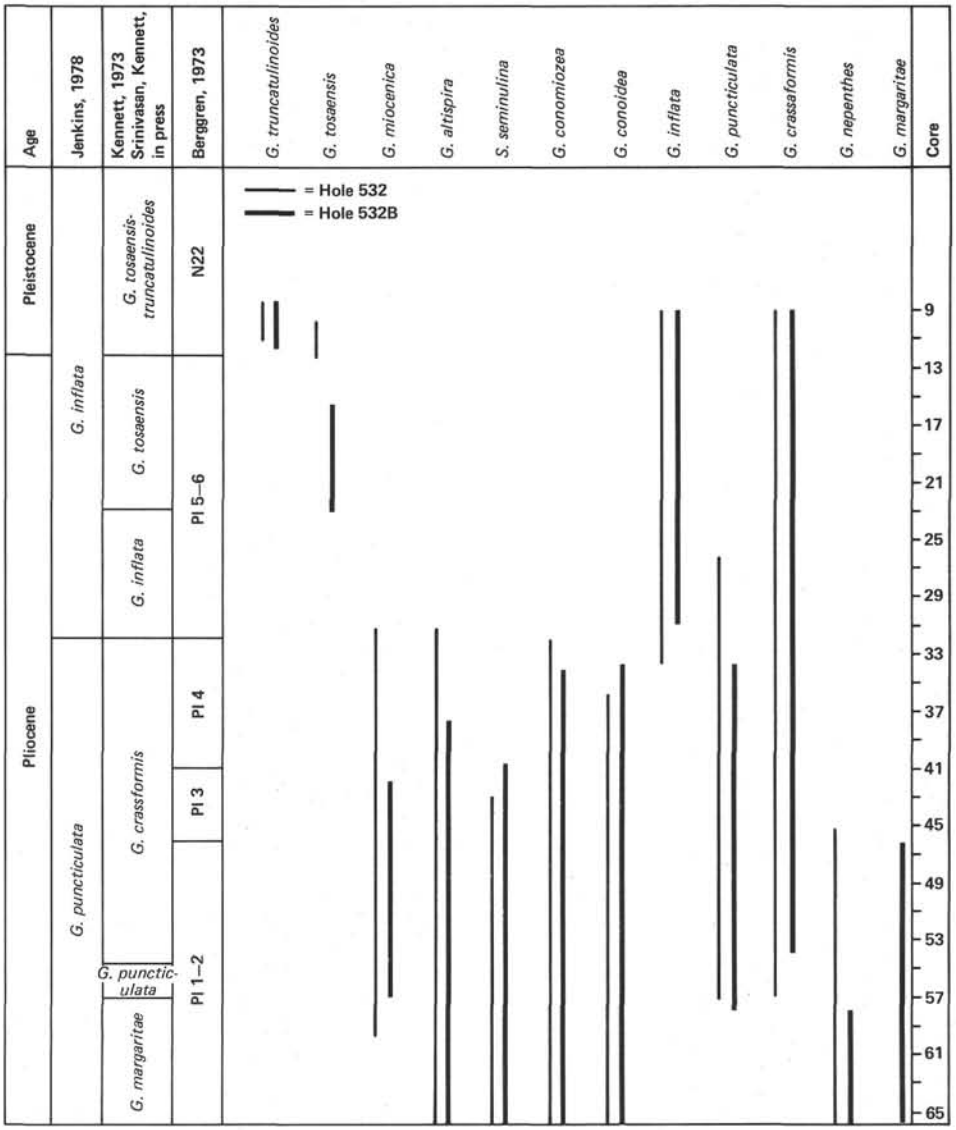


Figure 2. Biostratigraphic subdivision of the Pliocene section at Site 532 according to the zonation schemes of Kennett (1973, 1978) and Srinivasan and Kennett (in press) for temperate faunas; and Berggren (1973) for lower latitude sections. Ranges of key planktonic foraminiferal species used to make the zonal subdivisions were derived from the range chart (Table 1) and are listed in Table 3.

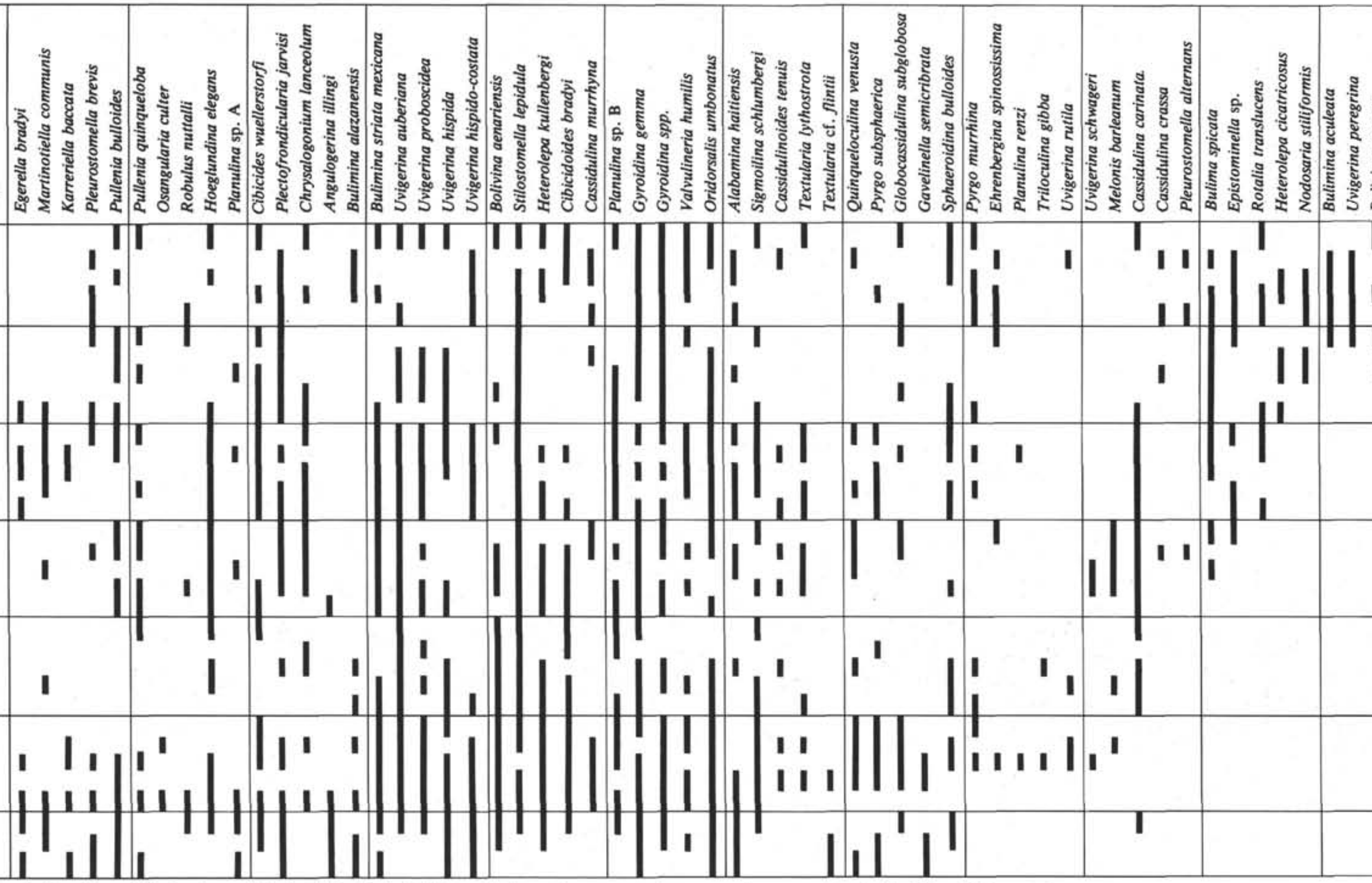
first in Cores 58–56 of the early Pliocene, and the second, which involves mainly pleurostomellids and bolivinids, in Core 31. Species which disappear through this section include: *Gavelinella semicribrata* and *Osangularia culter* in Core 54; *Planulina renzi* in Core 44; *Angulogerina illingi* in Core 39; *Uvigerina rutila* in Core 37; *U. schwageri* group in Core 35; and *Eggerella bradyi* and *Martinottiella communis* in Core 24.

Species indicative of the shallow depth (1331 m) and continental slope location of the site include: the *U. schwageri* group, *U. rutila, Robulus nuttalli, Rotalia translucens, Nodosaria stiliformis, Plectofrondicularia jarvisi*, and *Cassidulinoides bradyi.* Two other faunal aspects which signify an upper bathyal depth include the relatively low P:B ratio, benthics sometimes composing 20–30% of the foraminiferal populations, and the flooding of several species. Flood species are *Nodosaria stiliformis, U. rutila, P. alternans, R. translucens*, and *Albamina* spp.

Benthic abundance correlates directly with the preservation of planktonic foraminifers; benthic foraminifers constitute less than 10% of the total foraminiferal fraction in the well-preserved planktonic oozes of early Pliocene Cores 63–55, Cores 40–42, and of the Pliocene/Pleistocene transition from Cores 19–12. Poorly preserved sediments contain from 10–50% benthic foraminifers, usually accompanied by pyrite, clays, planktonic fragments, and siliceous plankton.

Benthic diversity varies from a low of eight species in a rich planktonic ooze (Hole 532, Core 42, Section 3 to

Table 2. Ranges of the most common benthic foraminifers through the Pliocene section at Hole 532B. Species richness (i.e., number of species in each sample) of each sample is also tabulated, but includes only the most common species; rare species were not counted in this preliminary study.



Epoch	Planktonic zone (Berggren, 1973)	Core-Section (level in cm)	Species richness
Pleisto-cene	N22	4-2, 11	26
		6-1, 18	22
		8-2, 64	20
		10-2, 72	23
		12-2, 32	22
Plio-cene	Pl 5-6	14-2, 114	17
		16-3, 95	13
		18-3, 49	18
		20-3, 50	15
		24-1, 116	22
		26-2, 134	30
		27-2, 106	30
		28-2, 83	22
		31,CC	26
		32-3, 10	23
	Pl 4	35-1, 67	20
		36,CC	28
		37-1, 87	19
		38-1, 84	26
		39-2, 7	18
	Pl 3	40-3, 11	12
		42-3, 58	8
		44-2, 86	19
		46-1, 40	19
		47-2, 54	17
	Pl 1-2	48,CC	
		52,CC	28
		54,CC	32
		56-1, 107	25
		58,CC	32
Miocene	N17	60-1, 100	27
		66,CC	22
		70-1, 11	24

Note: Species richness (i.e., number of species in each sample) of each sample is also tabulated, but includes only the most common species; rare species were not counted in this preliminary study.

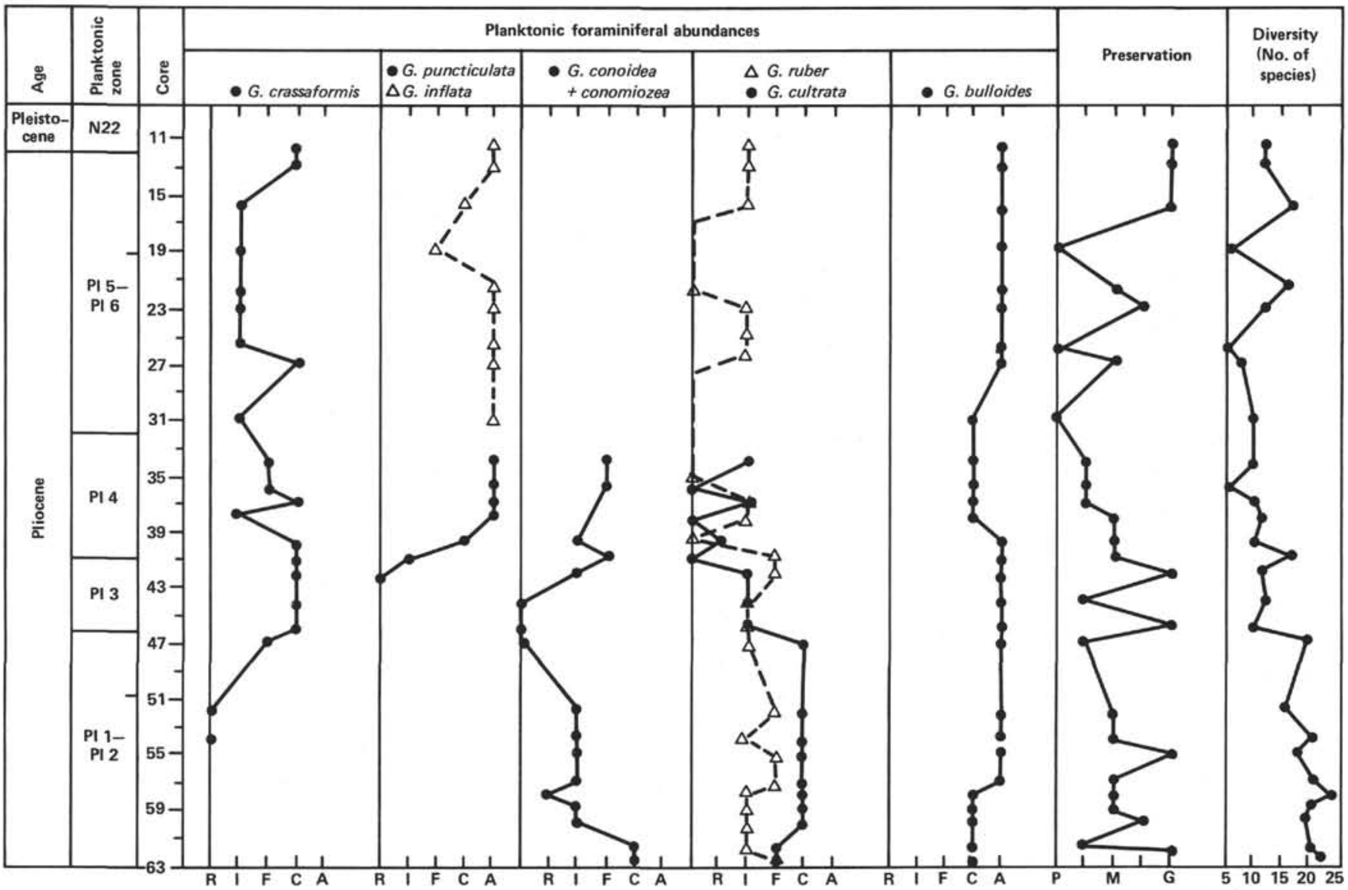


Figure 3. Abundances of key planktonic foraminiferal species through the Pliocene at Hole 532B. The bottom scale indicates the subjective estimates of species abundances as Rare (R), Infrequent (I), Frequent (F), Common (C), Abundant (A), or absent altogether (-). Preservation of the planktonic foraminiferal faunas is estimated for each sample as Poor (P), Moderate (M), or Good (G); these estimates were made to compare with the abundances of the more solution-susceptible species. Diversity of species, which is simply the number of species in each sample, was tabulated in order to demonstrate the relationship between preservation of the samples and foraminiferal species richness.

Table 3. Ranges of selected planktonic foraminiferal species in Holes 532 and 532B.

Species	Hole 532B	Hole 532
Globorotalia margaritae	69,CC to 60,CC	61,CC
Neogloboquadrina praehumerosa	67,CC to 58-3, 34	—
G. trans punticulata	67,CC to 46-1, 70	—
N. humerosa	63-1, 48 to 19,CC	61,CC
Sphaeroidinellopsis subdehiscens	60,CC to 40,CC	60-3, 47 to 31-3, 31
G. miocenica	57,CC to 42,CC	60-1, 106 to 32-3, 10
G. crassaformis	54,CC to Top	57,CC to Top
G. multicamerata	44-2, 86 to 41,CC	32-3, 10
G. puncticulata	42,CC to 34,CC	57,CC to 27-2, 82
G. inflata	31,CC to Top	34-2, 7 to Top
pustulose *G. inflata*	26,CC to Top	—
G. tosaensis	23,CC to 16,CC	12-1, 144 to 11-2, 63
Globoquadrina pseudopima	23,CC to 16,CC	—
Globorotalia truncatulinoides	12,CC to Top	11-21, 63 to Top
N. acostaensis	71,CC to 62,CC	—
G. conoidea	71,CC to 34,CC	61,CC to 36,CC
G. conomiozea	71,CC to 34,CC	61,CC to 32-3, 1–10
G. plesiotumida	71,CC to 71-1, 132	—
Orbulina biolobata	70-2, 48 to 26,CC	—
Sphaeroidinellopsis seminulina	69,CC to 41,CC	60-1, 106 to 39,CC
Globoquadrina altispira	69,CC to 38-1, 48	61,CC to 32-3, 10
Globigerina nepenthes	67-1, 110 to 58-3, 34	60-3, 47 to 45,CC
Globorotalia tumida	63-1, 48 to Top	60-3, 47 to Top
Globoquadrina dehiscens	71-1, 132	—

Note: Absence of species at Site 532 indicates only that their ranges were not followed through the section at that hole.

Core 58) to highs of 32 species in Cores 54 to 58 and near 30 species in poorly preserved samples of late Pliocene Cores 28 to 24.

Through the Pliocene section at Site 532, five ecologically controlled faunal episodes can be recognized:

1) Cores 70–60: Faunas contain the distinctive buliminids *B. alazanensis* and *B. spicata*, along with *Pleurostomella alternans*, as well as the derivative Miocene species *Textularia* cf. *flintii, Planulina renzi*, and *Bolivinopsis cubensis*—all of which disappear just after this episode;

2) Cores 58–38: Begins the major episode of benthic foraminiferal diversification of the Pliocene at this site; most of these species then range throughout the entire section.

3) Cores 37–27: Starts with a major change in species proportions; pleurostomellids and flat cassidulinids appear in greater abundances; *Pleurostomella alternans* and *Bulimina spicata* reappear, while the *Uvigerina schwageri* group disappears permanently from the sequence;

4) Core 24: Contains a substantial change in the cibicidid faunas; *Cibicidoides* (=*Heterolepa*) *kullenbergi* and *C. bradyi* are replaced by *C.* (=*Heterolepa*) *cicatricosus* and *Planulina* cf. *ariminensis*. Agglutinated spe-

cies decrease dramatically in abundance, and *Eggerella bradyi* and *Martinottiella communis* disappear permanently from the section.

5) Cores 18–19: Contain influxes of large costate nodosarids and floods of finely spinose uvigerinids; heavily limbate cibicidids and planulinids disappear from the section.

The Pleistocene faunas above Core 13 are more similar to the late-Miocene to early-Pliocene faunas; *Bulimina alazanensis* and *B. spicata* return to the samples and are joined by the new species *Uvigerina peregrina*, *Bulimina aculeata*, and *B. marginata.* Limbate planulinids and an increase in spinosity of several species were also noted in these samples.

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APPENDIX
Annotated List of Selected Benthic Species

Angulogerina illingi Cushman and Renz. Common only in early Pliocene samples.

Bolivina acerosa Cushman. Occurs only in the late Pliocene, but not accompanying the floods of uvigerinids and large costate nodosariids in Cores 18 and 19.

Bolivina aenariensis (Costa) (Plate 2, Figs. 9, 10). Although *Bolivina subaenariensis* has been listed from the Pliocene of the Mediterranean and Gulf of Mexico, specimens from Walvis have no keel on the final one or two chambers. In most samples the species is generally abundant.

Bulimina aculeata d'Orbigny (Plate 2, Figs. 7, 8). Individuals vary from very spiny as shown on Plate 2, to slightly longer forms with very reduced ornament.

Bulimina alazanensis Nuttall. Specimens are common in the late Miocene to early Pliocene, occur in lesser abundance during one episode of the mid-Pliocene, and become abundant again in the Pleistocene. They are medium in size for the species.

Bulimina spicata Phleger and Parker (Plate 2, Figs. 5, 7). Scanning photos demonstrate the porosity of this species, which is absent on the other species found in this study. Like *B. alazanensis*, the species occurs in three distinct episodes of the early Pliocene, middle Pliocene, and early Pleistocene.

Bulimina striata mexicana Cushman (Plate 2, Figs. 11, 12). Specimens vary markedly through the section; wider more robust forms resemble *Bulimina inflata*, more ornamented types resemble *Bulimina bleeckeri* (Bermudez, 1949). This species is particularly abundant in the early Pliocene.

Cassidulina carinata Cushman. The specimens at this site are small and delicate for the species. These flatter cassidulinids become abundant only during the mid-Pliocene.

Cassidulina murrhyna (Schwager). This species becomes more common from the mid- to later Pliocene.

Cassidulinoides bradyi (Norman) (Plate 4, Fig. 5). Occurs generally along with *Cassidulinoides tenuis*, but is never common.

Cassidulinoides tenuis Phleger and Parker. The species is rare; it generally occurs with other elongate cassidulinids.

Chrysalogonium lanceolum Cushman and Jarvis. The species is generally found fragmented; it is common when present.

Cibicidoides bradyi Cushman (Plate 5, Figs. 1–7). This is one of the two common cibicidids in most samples. There is marked variation in the degree of porosity, as demonstrated on the plate.

Cibicidoides cicatricosus. The species should probably be assigned to the genus *Heterolepa*, since it is consistently ventrally flat. It is common only at the end of the Pliocene.

Pullenia bulloides d'Orbigny. Forms at Site 532 are typical for the species, but somewhat below average in size.

Pullenia quinqueloba (Reuss). Individuals are small for the species.

Pyrgo murrhina (Schwager) (Plate 1, Fig. 6).

Pyrgo subsphaerica (d'Orbigny)

Quinqueloculina venusta (d'Orbigny)

Robulus nuttalli Cushman and Renz (Plate 2, Figs. 1, 2). The species tends to appear in floods, particularly at the very end of the Pliocene in Cores 18–19.

Rotalia translucens Phleger and Parker. The species appears in floods in the fine fractions, often along with *Epistominella* sp. Appearances, however, are sporadic.

Sigmoilina schlumbergeri Silvestri (Plate 1, Fig. 8). This is the only common miliolid; it occurs throughout the section and is common in the samples.

Sphaeroidina bulloides d'Orbigny. When present, the species is frequent; it is medium in size for the species.

Stilostomella lepidula Schwager (Plate 2, Figs. 13, 14). The species is common in many samples. Variation occurs in the degree of spinosity and in their tendency (or not) to be closely aligned.

Textularia lythostrota Schwager Cushman (Plate 1, Fig. 4). This is a common species which exhibits a large degree of morphologic variation. In most samples, specimens are intermediate in size for the species and less elongate than the holotype.

Triloculina gibba d'Orbigny (Plate 1, Figs. 9, 10).

Uvigerina auberiana d'Orbigny (Plate 3, Fig. 4). Specimens are large for the species. When present, the species is common.

Uvigerina hispida Schwager (Plate 3, Figs. 6, 7). The spinosity of individuals at Site 532 is less pronounced than on types from Kar Nicobar; it grades into *Uvigerina proboscidea* in both areas.

Uvigerina hispido-costata Cushman and Todd. This species is probably an ecophenotype of *Uvigerina peregrina* from which it can be differentiated by the fusiform test and the large number of small spines; it also lacks costae twisting to or around the base of its neck.

Uvigerina peregrina Cushman (Plate 3, Fig. 3). The species does not occur at this site until the Pliocene/Pleistocene transition when it is frequently found.

Uvigerina proboscidea Schwager (Plate 3, Figs. 5, 8). The species is commonly found; it is somewhat smaller than forms from Kar Nicobar where it was described.

Uvigerina schwageri Brady (Plate 3, Fig. 2). Like other large costate uvigerinids, this species demonstrates a marked variation in the degree of costate development and in their number. Forms from Site 532 have more costae than either typical *U. schwageri* from the Pacific, or *Uvigerina mitsogho*, a synonym, from onshore Angola. These variants in the late Neogene and Quaternary may need a new name.

Valvulineria humilis Phelger and Parker (Plate 4, Figs. 6, 7). The species is often common in the finer fractions, particularly in the early Pliocene.

NOTE TO PLATES

Original magnification is given here in each case. To meet publication specifications, however, each plate was then reduced as follows: Plate 1, reduced by 69%; Plate 2, reduced by 65%; Plate 3, reduced by 67%; Plate 4, reduced by 70%; Plate 5, reduced by 65%.

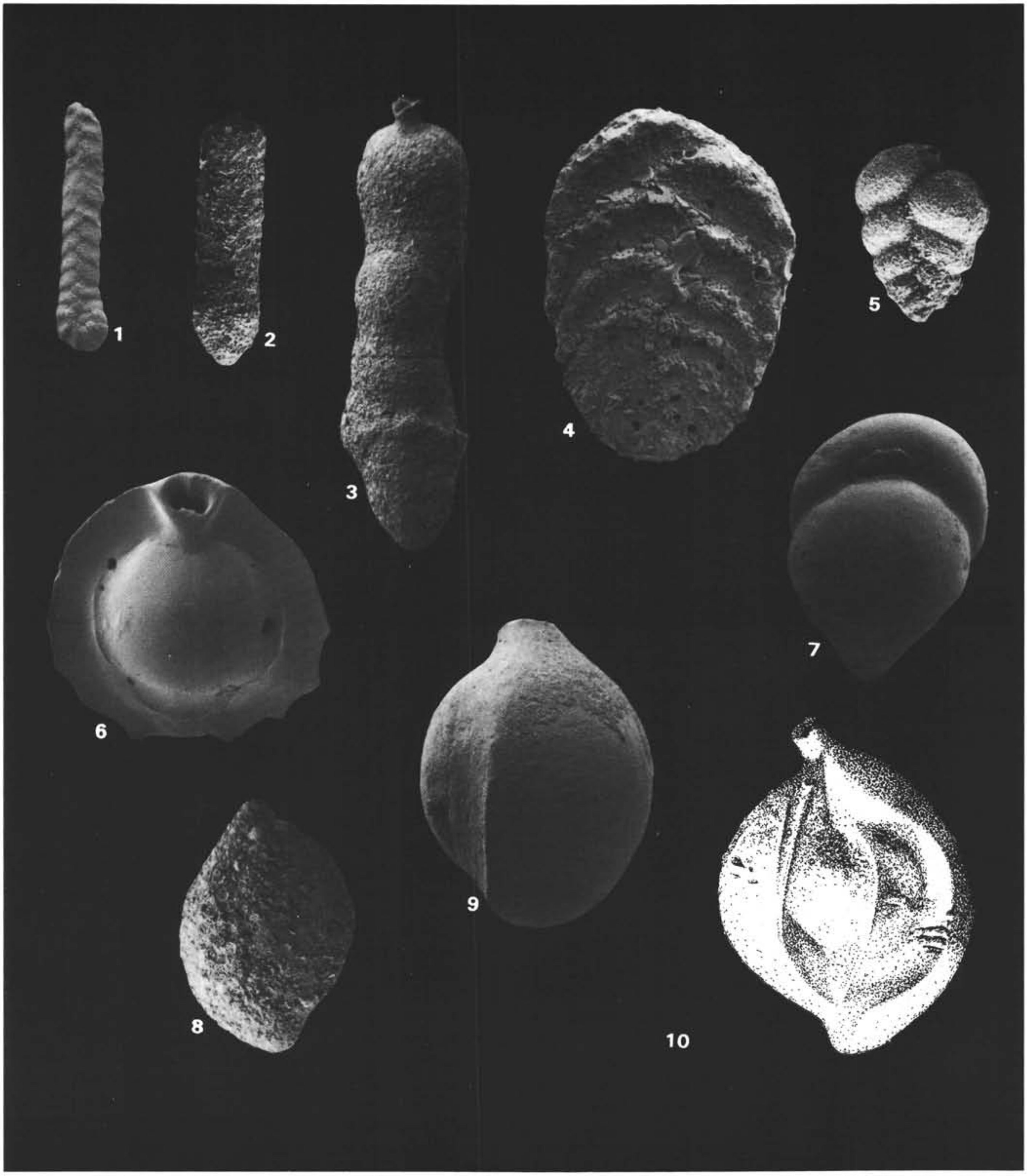

Plate 1. **1.** *Bolivinopsis cubensis*, ×55, Sample 68,CC. **2, 3.** *Martinotiella communis*, (2) ×55, Sample 14,CC; (3) ×110, Sample 68,CC **4.** *Textularia lythostrota*, ×55, Sample 13,CC. **5.** *Siphotextularia catenata*, ×55, Sample 68,CC. **6.** *Pyrgo murrhina*, ×110, Sample 26,CC. **7.** *Eggerella bradyi*, ×110, Sample 68,CC. **8.** *Sigmoilina schlumbergeri*, ×55, Sample 13,CC. **9, 10.** *Triloculina gibba*, ×110, Sample 42,CC.

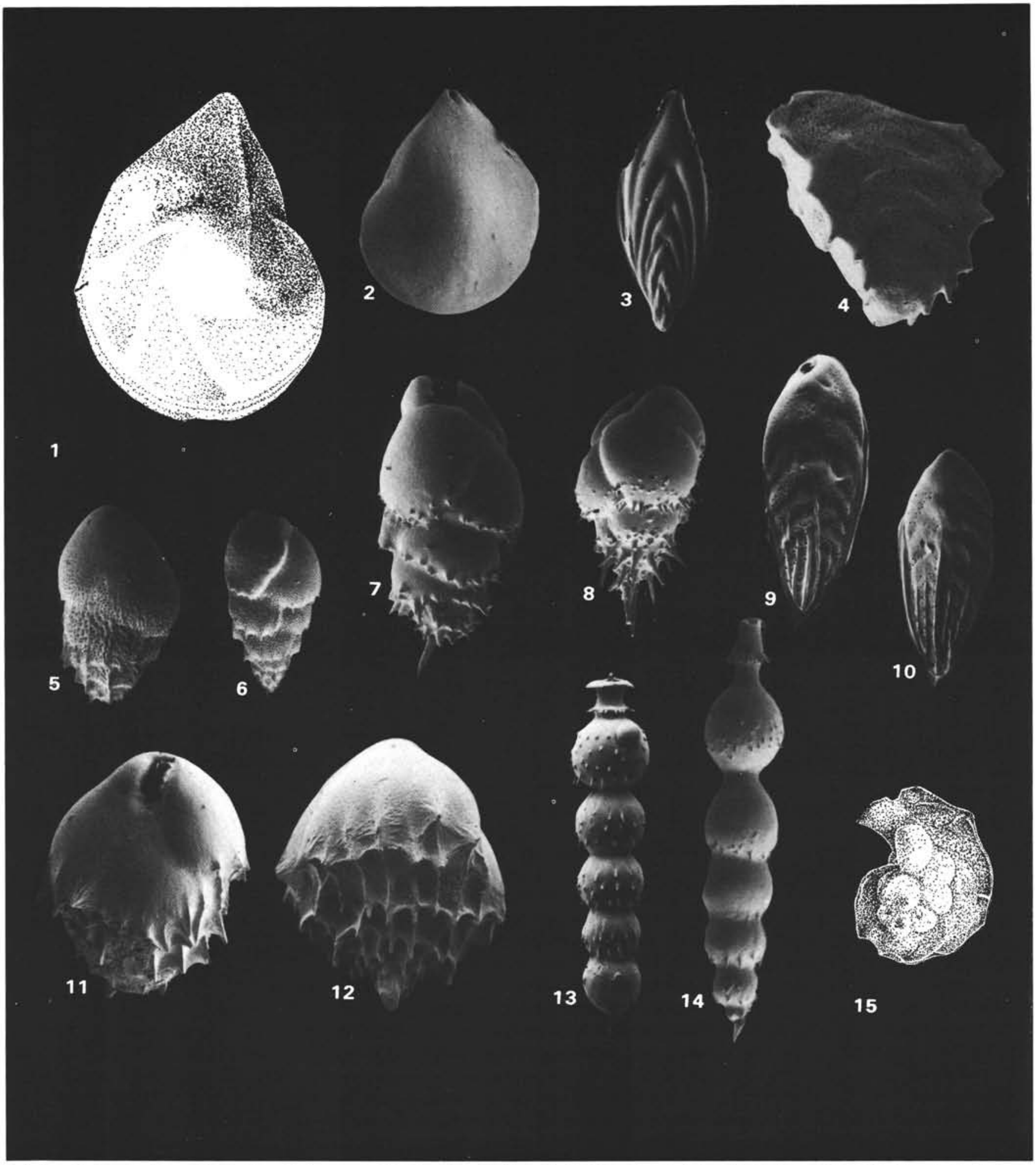

Plate 2. **1, 2.** *Robulus nuttalli,* (1) ×110, Sample 26,CC; (2) ×55, Sample 26,CC. **3.** *Plectofrondicularia jarvisi,* ×55, Sample 13,CC. **4.** *Ehrenbergina spinosissima,* ×110, Sample 36,CC. **5, 6.** *Bulimina spicata,* ×55; (5) Sample 34,CC; (6) Sample 13,CC. **7, 8.** *Bulimina aculeata,* ×110, Sample 5,CC. **9,10.** *Bolivina aenariensis,* ×55, Sample 13,CC. **11, 12.** *Bulimina mexicana striata,* ×110; (11) Sample 36,CC; (12) Sample 68,CC. **13, 14.** *Stilostomella lepidula,* ×55, (13) Sample 14,CC; (14) Sample 26,CC. **15.** *Laticarinina bullbroki,* ×55, Sample 42,CC.

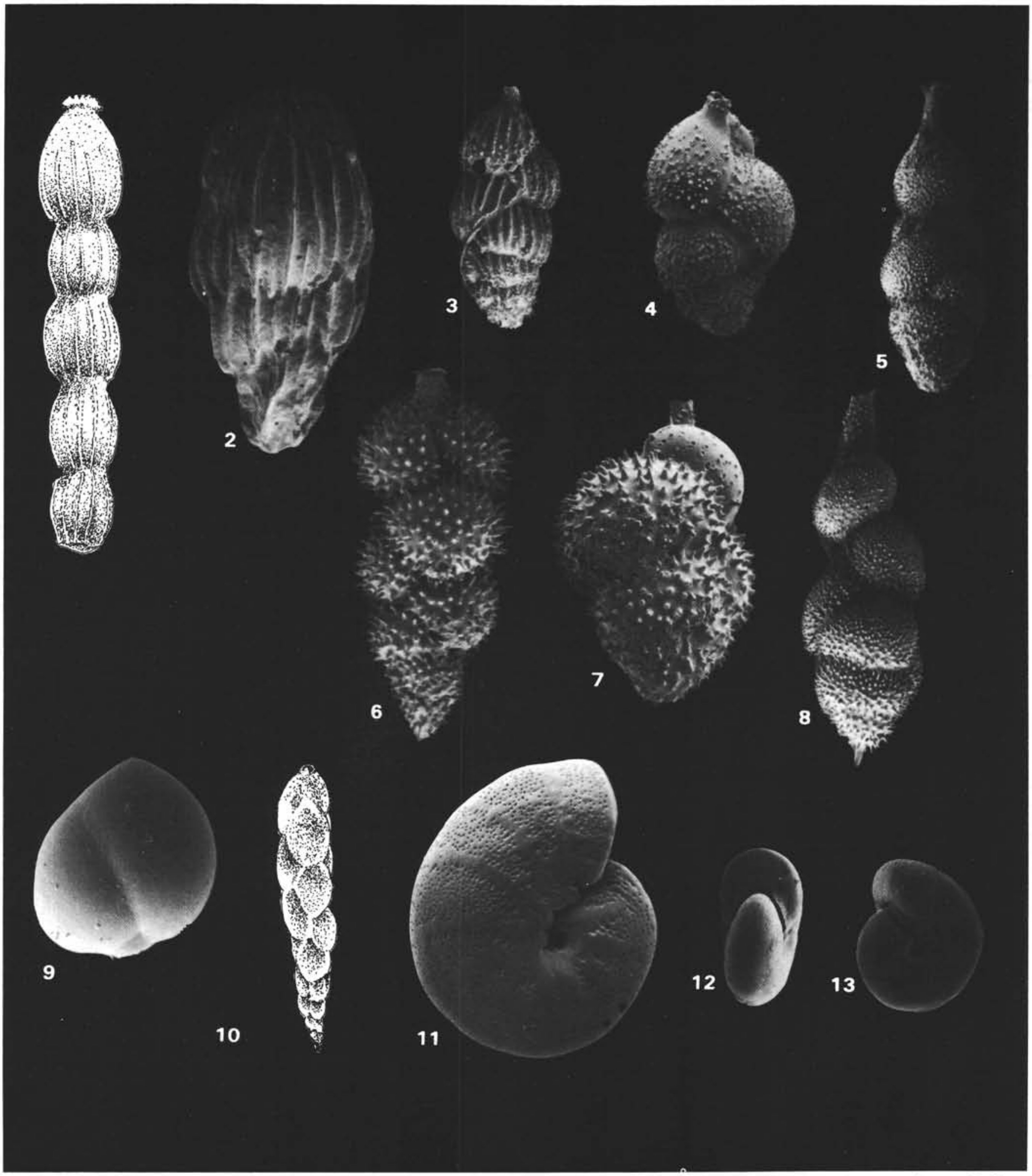

Plate 3. **1.** *Nodosaria stiliformis,* ×110, Sample 18,CC. **2.** *Uvigerina schwageri,* ×110, Sample 34,CC. **3.** *Uvigerina peregrina,* ×55, Sample 5,CC. **4.** *Uvigerina auberiana,* ×55, Sample 68,CC. **5, 8.** *Uvigerina proboscidea,* ×110, (5) Sample 34,CC; (8) Sample 14,CC. **6,7.** *Uvigerina hispida,* ×110, (6) Sample 68,CC; (7) Sample 42,CC. **9.** *Pleurostomella brevis,* ×55, Sample 5,CC. **10.** *Pleurostomella alternans,* ×110, Sample 5,CC. **11-13.** *Nonion barleanum,* (11) ×110, Sample 36,CC; (12, 13) ×55, Sample 36,CC.

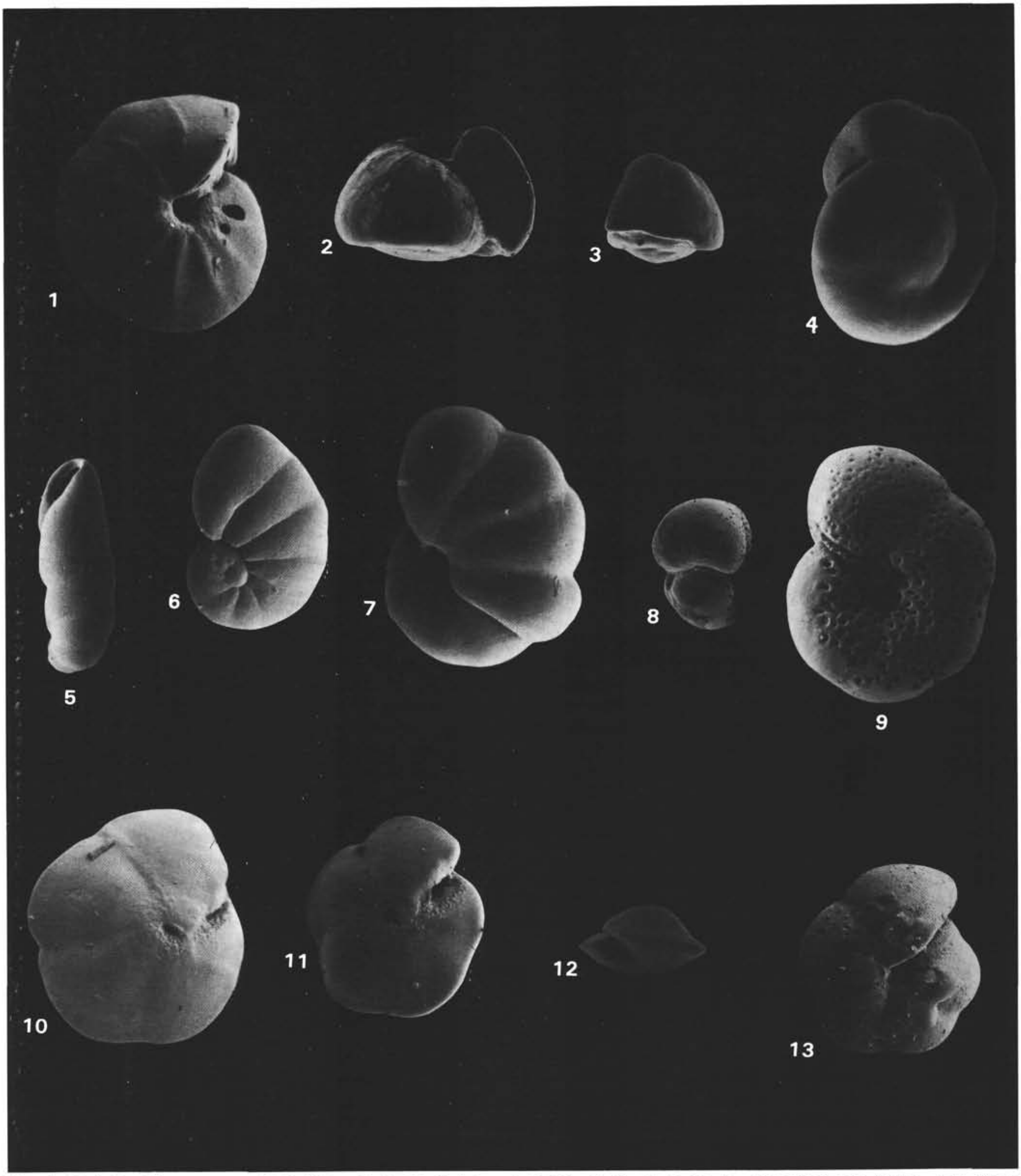

Plate 4. **1–4.** *Gyroidina gemma,* ×55; (1, 2) Sample 13,CC; (3, 4) Sample 26,CC. **5.** *Cassidulinoides bradyi,* ×55, Sample 42,CC. **6, 7.** *Valvulineria humilis,* (6) ×55, Sample 5,CC; (7) ×110, Sample 42,CC. **8, 9.** *Gavelinella semicribrata,* (8) ×45, Sample 5,CC; (9) ×55, Sample 5,CC. **10–13.** *Oridorsalis umbonatus,* ×55, (10) Sample 68,CC; (11, 12) Sample 13,CC; (13) Sample 5,CC.

Plate 5. **1–7.** *Cibicidoides bradyi,* (1) ×55, Sample 42,CC; (2) ×45, Sample 36,CC; (3) ×55, Sample 68,CC; (4) ×45, Sample 14,CC; (5) ×55 Sample 14,CC; (6, 7) ×55, Sample 68,CC. **8.** *Heterolepa kullenbergi,* ×110, Sample 42,CC. **9, 10.** *Planulina* sp. A., ×110, Sample 36,CC. **11, 12.** *Planulina* cf. *ariminensis,* ×55, Sample 26,CC.