BIOSTRATIGRAPHIC DATING OF LATE NEOGENE SEDIMENTATION ON THE WESTERN SHELF, GREAT BAHAMA BANK

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ABSTRACT

Biostratigraphic analysis of planktonic foraminifera from two long cores on the west shelf and platform margin of the Great Bahama Bank provided a detailed record of contemporaneous continuous and noncontinuous late Neogene sedimentation within a lateral distance of 4 n. mi (7.5 km). Cored slope sediments range in age from latest Miocene to early Pleistocene, whereas those on the shelf range from middle middle Miocene to late middle Pliocene. In the deeper slope sediments, the presence of successive foraminiferal zones in the core sediments attests to relatively continuous sedimentation. On the shelf, however, the absence of foraminiferal zones of late middle and latest Miocene, and earliest and early middle Pliocene age indicates hiatuses in sedimentation that correlate with missing global sequence and downlap-surface boundaries. These hiatuses and the presence of interpreted alternating highstand- and lowstand-wedge deposits at and below 1,000 ft (300 m) of core depth on the slope imply sea-level fluctuations of variable frequency, amplitude, and duration. The sea-level history includes at least four pre-Pleistocene lowstands that exposed the shelf for periods spanning 0.4 to 2.6 million years. Six pre-Pleistocene cycles of fluctuation are recognized and constrained, resulting in development of a late Neogene (12.9-0.9 Ma) sea-level curve for the region. The greatest amplitude sea-level fall, relative to present level, occurred at the end of the late middle Miocene, when a lowstand is inferred to have been close to 2,400 ft (730 m) below present. Deposition of the inferred Pleistocene seismic facies, derived from assigning the planktonic foraminiferal zonation for the Quaternary to the facies, corresponds to four of the eight known Pleistocene interglacials.

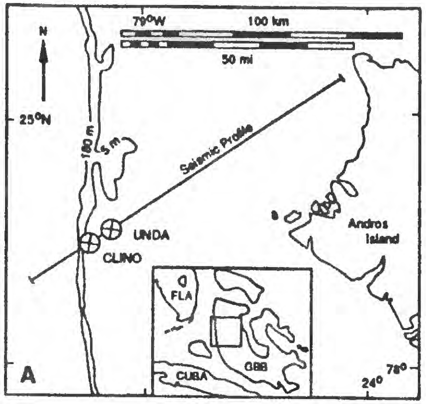
INTRODUCTION

Multichannel seismic profiles of northwestern Great Bahama Bank revealed that the bank developed through the infilling and coalescence of two small initial banks, followed by westward lateral accretion into the Straits of Florida (Eberli and Ginsburg, 1987). The accretionary process is seen as a series of prograding, conformable clinoforms (Fig. 1). Sequence stratigraphic analysis of the seismic boundaries led to the interpretation that individual units, or clinothems, record rise and fall of sea level (Eberli and Ginsburg, 1989). Two long cores, CLINO (2,222 ft, 677 m; 76.52% recovery) and UNDA (1,489 ft 454 m; 76.58% recovery), were obtained from 24°36'07"N, 79°10'41"W and 24°38'47"N, 79°06'42"W, respectively, on the west slope and inshore-shelf edge. The cores were collected in order to determine age, lithology, sedimentation rate, and diagenesis of the units seen in the seismic profiles and to define the timing of sedimentation and sea-level fluctuations. This report includes, in two sections, results of the planktonic biostratigraphic analyses (Part I) and depositional environments as indicated by the benthic species (Part II).

METHODS

Samples of friable material were washed in water over 250-, 125-, and 63-µm mesh screens, were oven dried, and were placed in vials by size fraction marked by sample number. The 250-µm fraction for each sample was examined several times under a binocular light microscope and specimens of all identifiable species of both benthic and planktonic foraminifera were picked. Where possible, specimens were picked from ~0.5 gram of the 125-µm fraction, although not all of this size fraction was examined due to the generally poor preservation of the component grains. The 63-µm fraction was not examined. Diagenetic alteration and cementation limited the number of usable samples (CLINO:40; UNDA:27) for foraminiferal analyses. Many marker species could not be identified due to poor preservation as a result of either dissolution or diagenetic camouflage and because some species were apparently absent. Thus, the core intervals addressed in this report, in feet and inches to conform with the terminology used by other researchers conducting other analyses, pertain only to those portions that could be sampled for biostratigraphic analyses.

Planktonic species were identified by using the criteria and terminology of Blow (1969) and Bolli and Saunders (1985) for low-latitude Cenozoic planktonics, supplemented where necessary by those of Bolli (1957) for species from type sections in Trinidad, Postuma (1971) and



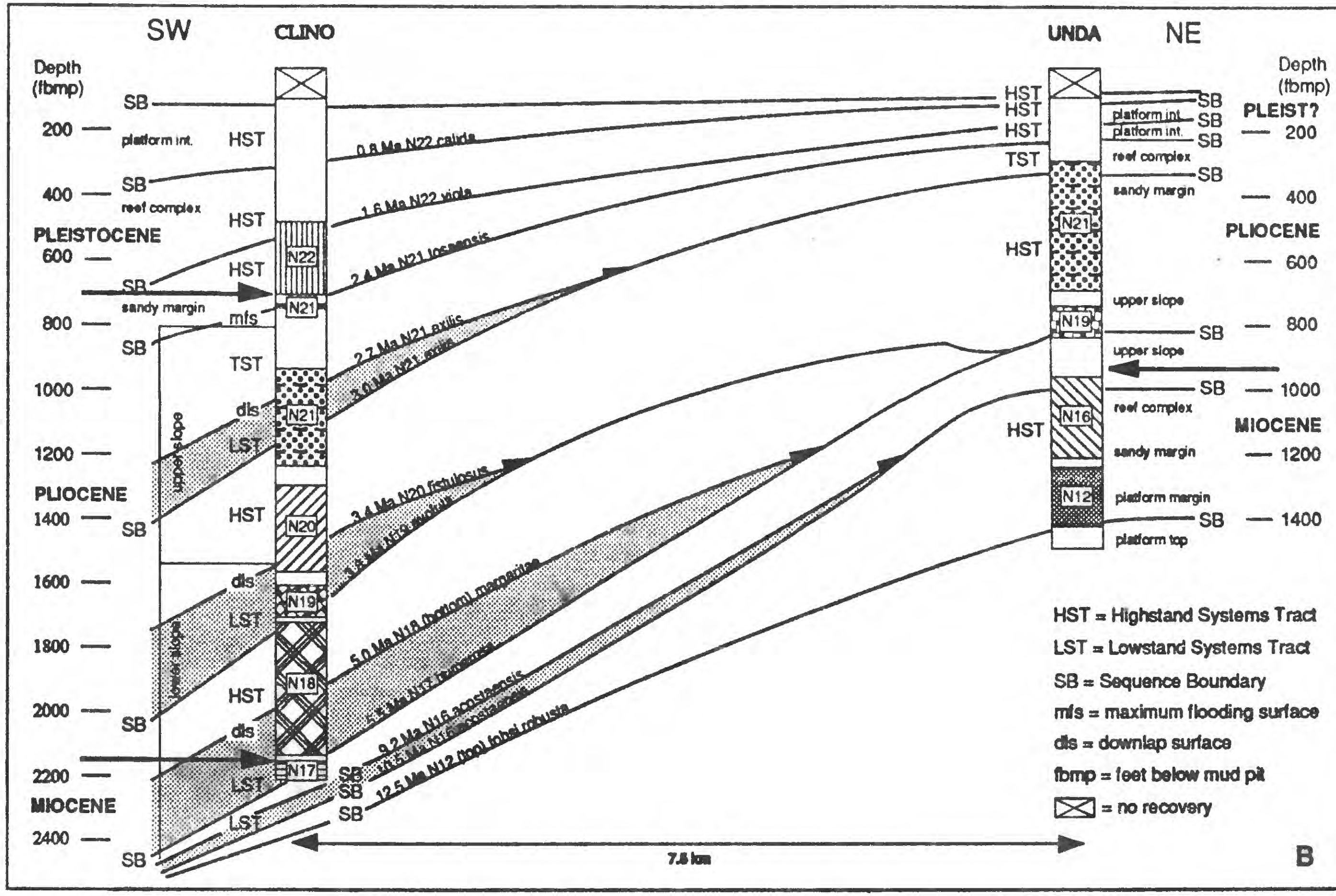


Figure 1. (A) Index map showing relation of the Great Bahama Bank (GBB) to Florida and Cuba. Small inset indicates area of study. (B) Simplified seismic interpretation of cored area showing correlation of sequence boundaries (ages in Ma) and core intervals assigned to foraminiferal zones (patterns; zonal numbers and names on boundaries) within CLINO and UNDA. White spaces in cores could not be dated biostratigraphically due to cementation. Note pinching out of lowstand wedges (shaded areas) between cores. Lowstand units indicate sea level fell at least four times within a 7.8-my time period (the difference between 10.5-Ma and 2.7-Ma boundaries). Also note that sediments corresponding to two of the lowstand wedges and representing foraminiferal Subzones N18 and N20 were not identified in UNDA; sediments assigned to Zone N17 time are presumed to be present in UNDA but were not identified in the material sampled (see text for discussion). Sediments assigned to Zones N13, N14, N15, and early N16 are presumed missing from both cores (see text), which would imply that the entire platform margin was subaerially exposed for at least 2.5 million years during the late middle Miocene. Ages for sequence boundaries are from Haq et al. (1988). Note that they fall within the age ranges, shown in Tables 1 and 2, for identified foraminiferal zones. The global sequence boundary dated at 4.2 Ma and downlap surface dated at 4.0 Ma also do not occur in either core. Seismic interpretation after Eberli and Ginsburg (1989).

Stainforth *et al.* (1975) for index species, and Lidz (1982, 1984) for species from St. Croix in the Virgin Islands. Where necessary, specimens were compared with type section material, on file with the author, from Venezuela, Java, Trinidad and DSDP cores. Foraminiferal zones were determined following the definitions of Bolli and Saunders (1985). Where foraminiferal zone could not be determined, correlation of the presumed age of the sediments with the ages of Haq *et al.* (1988) for major sequence and downlap-surface boundaries enabled zonal determination. Because coiling direction of four particular groups of planktonic species can be stratigraphically significant in certain geologic times and strata, direction of coil was correlated with foraminiferal zone where applicable.

RESULTS

Tables 1 and 2 summarize the interpreted foraminiferal zonations, zonal thickness, age

Table 1. Summary of Planktonic Biostratigraphy in CLINO

Sample Interval	Sample Interval Thickness		Lithologic Units
1) C504'9"-C714'1"	209'	(63.7 m)	8-10
2) C771'8"	1"	(2.5 cm)	11
3) C946'4"-C1273'4"	327'	(99.7 m)	13A-B
4) C1310'3"-C1587'6"	278'	(84.7 m)	13B-15
5) C1602'6"-C1745'	128'	(39.0 m)	15-16
6) C1776'-C2136'4"	391'	(119.2 m)	17
7) C2161'3"-C2214'3"	51'	(15.5 m)	17

Foraminiferal Zones/Subzones	Epoch	Age (Ma)
1) Globorotalia crassaformis viola Subzone N22	Early Pleistocene	~1.9-1.4
2) Globorotalia tosaensis tosaensis Zone N21	Late Pliocene	~2.5-1.9
3) Globorotalia exilis Subzone N21	L. Mid-Pliocene	~3.2-2.5
4) Globigerinoides trilobus fistulosus Subzone N20	E. Mid-Pliocene	~3.8-3.2
5) Globorotalia margaritae evoluta Subzone N19	L. Early Pliocene	~4.5-3.8
6) Globorotalia margaritae margaritae Subzone N18	E. Early Pliocene	~5.1-4.5
7) Globorotalia humerosa Zone N17	L. Late Miocene	~8.2-5.1

Table 2. Summary of Planktonic Biostratigraphy in UNDA

Sample Interval	Sample Interval Thickness		Lithologic Units
1) U288'8"-U687'	398'	(121.3 m)	4-5A
2) U742'9"-U830'7"	88'	(26.8 m)	5A-B
3) U911'8"-U1208'8"	297'	(90.5 m)	5B-8
4) U1263'5"-U1420'7"	158'	(48.2 m)	8-9

Foraminiferal Zones/Subzones	Epoch	Age (Ma)
1) Globorotalia exilis Subzone N21	L. Mid-Pliocene	~3.2-2.5
2) Globorotalia margaritae evoluta Subzone N19	L. Early Pliocene	~4.5-3.8
3) Globorotalia acostaensis Zone N16	E. Late Miocene	~11.3-8.2
4) Globorotalia fohsi robusta Zone N12	Mid-Mid-Miocene	~12.9-12.5

ranges, and the relation of the lithologic units, described by Ginsburg *et al.* (1990), to the foraminiferal zones in cores CLINO and UNDA. The zonations and age ranges are shown in diagram format in Table 3 along with the core intervals to which zonal ages have been assigned, and the preferred coiling directions for planktonic groups. Figure 2 shows a comparison of the middle and late Neogene foraminiferal zones of Bolli and Saunders (1985), followed in this study, with the nannofossil zonation of Martini (1970, 1971) and magnetic polarity and chrons developed by Berggren *et al.* (1985).

Age		Planktonic Foraminiferal Zones and Subzones		N Zones	Globorotalia menardii s.l.	*Menardiform Species	†Globorotalia crassaformis	øGloborotalia acostaensis	Pulleniatina Species
HOL.		*Globorotalia truncatulinoides truncatulinoides*	*Gr. fimbriata*	N 23	S	X	S	S (R,D)	D
PLEISTOCENE			*Gg. bermudezi*	N 23					
			Gg calida calida	N 22					
			Gr. crassaf. hessi	N 22					
			Gr crassaf. viola	N 22					
PLIOCENE	L	*Globorotalia tosaensis tosaensis*		N 21	D		D		F
	M	*Globorotalia miocenica*	*Gr. exilis*	N 21		D	S		X
			Gs. trilob. fistulosus	N 20			D		
	E	*Globorotalia margaritae*	*Gr. marg. evoluta*	N 19					D
			Gr. marg. margaritae	N 18			S		
MIOCENE	L	*Globorotalia humerosa*		N 17	F	X	X	I	X
		Globorotalia acostaensis		N 16				S	
	M	*Globorotalia menardii*		N 15	S			X	
		Globorotalia mayeri		N 14					
		Globigerinoides ruber		N 13					
		Globorotalia fohsi robusta		N 12	R				

Ma	Core Intervals (ft) CLINO	Core Intervals (ft) UNDA
0		
0.4		
0.9		
1.4	505'-714'	
1.9	772'	
2.5	946'-1273'	289'-687'
3.2	1310'-1588'	
3.8	1603'-1731'	743'-831'
4.5	1745'-2136'	
5.1	2161'-2214'	
8.2		912'-1209'
11.3		
11.7		
12.1		
12.5		1263'-1421'
12.9		

Table 3. Foraminiferal zonation and age ranges of Bolli and Saunders (1985, p. 163), assignments to foraminiferal zone by biostratigraphically dated core intervals, and preferred coiling directions for planktonic groups whose directions of coil can, in some strata, have stratigraphic significance. Core intervals rounded to nearest foot. S=Sinistral; D=Dextral; F=Fluctuating; I=Irregular; R=Random. *=Globorotalia multicamerata -pertenuis-pseudomiocenica-miocenica, excluding the Gr. tumida lineage, which, with few exceptions, coils sinistrally throughout its range. †=Globorotalia crassaformis cf. viola-crassaformis s.l.-oceanica-ronda. ø=Globorotalia acostaensis-humerosa-Neogloboquadrina deutertrei. Cross in box indicates period of time when group was absent from Atlantic realm.

Offshelf/Onshelf Diagenesis

Core CLINO was described on site as containing portions of 17 lithologic units (Ginsburg *et al.*, 1990). Core UNDA contained portions of 10 lithologic units. The units in both cores were interpreted to represent proximal- and distal-slope deposits. Sediments sampled for biostratigraphic analyses were thought to be unconsolidated to semiconsolidated muds, but examination under the light microscope showed many particles were moldic, lithified, or completely altered calcitized or dolomitized grains of undetermined origin. The lithologic units from which the samples were analyzed included mudstone, wackestone, packstone, grainstone, and coarse sand.

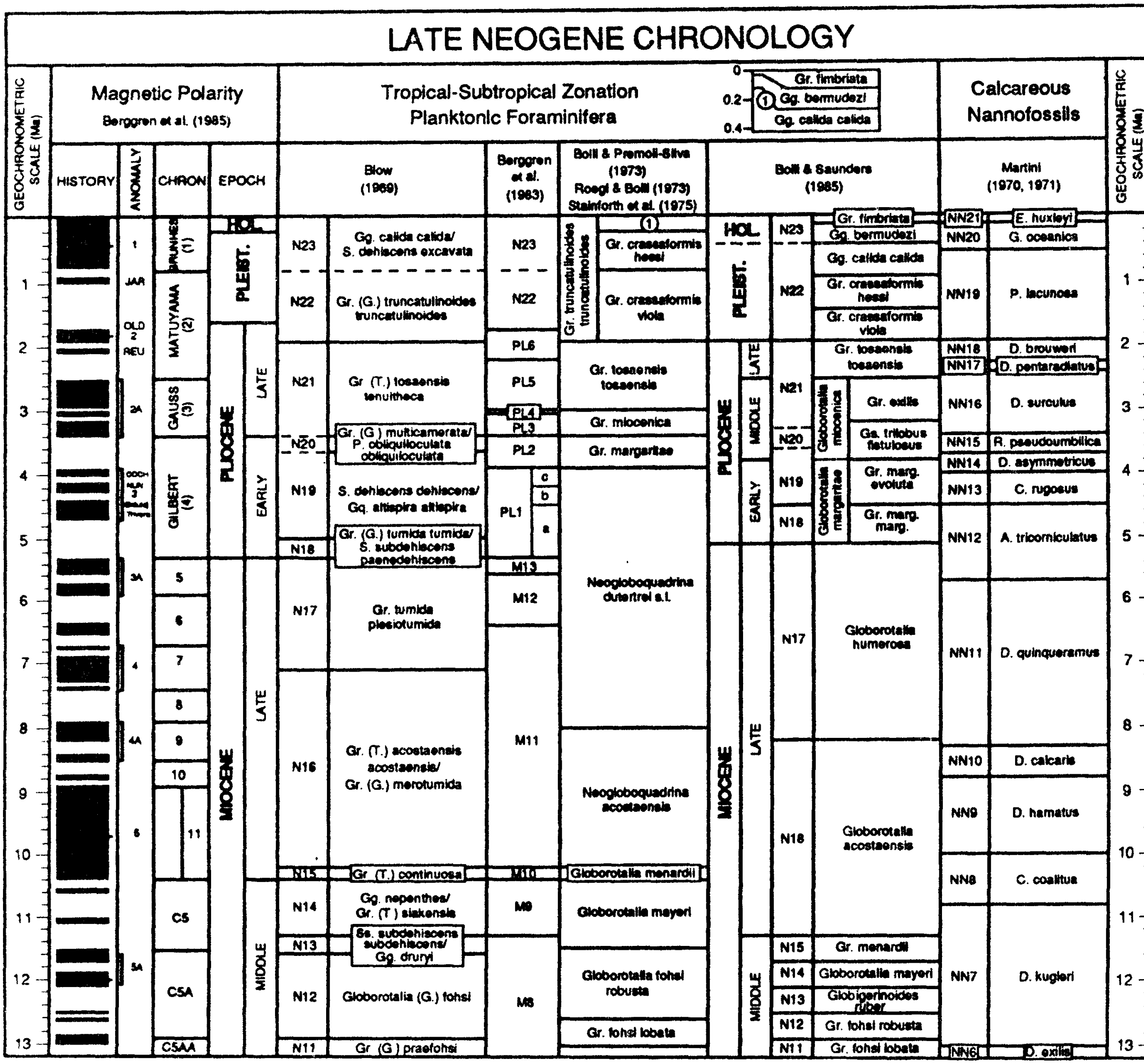


Figure 2. Comparison of magnetic polarity and chrons, foraminiferal zones, and calcareous nannofossil zones. Position of zonal boundaries is based upon direct correlation between biostratigraphic datum levels as determined in deep-sea cores or continental marine sediments. Extent (duration) of standard time-stratigraphic units and their boundaries is estimated on the basis of their relation to standard plankton biostratigraphic zones. Chart after Berggren et al. (1985, fig. 6). Data for Bolli and Saunders (1985), based on their foraminiferal-zone age ranges and followed in this study, have been adapted to the geochronometric scale of Berggren et al. (1985).

In spite of generally poor preservation, 59 planktonic species were identified in CLINO (Table 4) and 42 in UNDA (Table 5; Appendix A; Pls. 1-6). The larger number from CLINO is likely a result of less diagenetic alteration of the deeper slope strata than of the shallow-water sediments in UNDA. Most species identified were long ranged (Table 6), particularly in UNDA, and thus were unsuitable for biostratigraphic dating of much of the core. However, together with three other marker species (Pl. 1:6-8, 11; Pl. 2:29-31), a single internal-cast specimen of a key index

CLINO	Biostratigraphic Age	Globigerina venezuelana	Globigerinoides trilobus trilobus	Globigerinoides trilobus sacculiferus	Globigerinoides ruber	Globoquadrina altispira globosa	Globoquadrina dehiscens	Globoquadrina altispira altispira	Globoquadrina altispira conica	Globigerinita incrusta	Globigerinoides obliquus obliquus	Orbulina universa	Orbulina bilobata	Orbulina suturalis	Globorotalia scitula scitula	Globigerinoides bollii	Sphaeroidinellopsis multiloba	Hastigerina siphonifera	Globorotalia menardii 'A'	Globigerina nepenthes	Globigerina eamesi
C504'9"	N22 crassa viola											x									
C555'9"	N22 crassa. viola											x									
C576'4"	N22 crassa. viola		x		x							x									
C714'1"	N22 crassa. viola		x	x	x							x						x			
C771'8"	N21 tos. tosaensis		x	x	x							x						x			
C834'9"	No data	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C946'4"	N21 exilis		x	x	x							x									
C984'9"	N21 exilis			x	x							x						x			
C1042'8"	N21 exilis		x		x							x						x			
C1110'	N21 exilis		x	x	x							x			x			x			
C1121'	No data	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C1215'2"	N21 exilis		x	x	x							x						x			
C1273'4"	N21 exilis		x	x	x							x						x			
C1310'3"	N20 tril. fistulosus		x		x							x	x					x			
C1445'6"	N20 tril. fistulosus		x	x	x							x									
C1488'9"	N20 tril. fistulosus		x	x	x							x						x			
C1567'5"	N20 tril. fistulosus		x	x	x							x						x			
C1587'8"	N20 tril. fistulosus		x		x							x						x			
C1598'7"	N20 tril. fistulosus		x	x	x							x						x			
C1602'6"	N19 marg. evoluta		x		x							x	x					x			
C1664'9"	N19 marg. evoluta											x						x			
C1710'5"	N19 marg. evoluta		x	x	x							x			x			x			
C1710'8"	N19 marg. evoluta		x	x	x			x		x		x						x			
C1731'	N19 marg. evoluta		x		x					x		x		x				x			
C1745'	N19 marg. evoluta	x	x	x	x			x	x		x	x			x						x
C1778'	N18 marg. marg.	x	x	x	x			x			x	x		x	x			x		x	
C1778'	N18 marg. marg.	x	x	x	x	x		x			x	x			x	x		x	x	x	
C1781'8"	N18 marg. marg.	x	x	x	x	x		x			x	x									
C1803'4"	N18 marg. marg.	x	x	x		x		x	x		x	x	x	x	x	x		x	x	x	
C1804'2"	N18 marg. marg.	x	x	x	x	x	x	x			x	x	x	x	x		x	x	x		
C1870'3"	N18 marg. marg.	x	x	x	x		x	x			x	x	x					x	x		
C1891'5"	N18 marg. marg.	x	x	x	x			x			x	x	x					x	x	x	
C1899'5"	N18 marg. marg.		x	x			x	x			x	x									
C1951'	N18 marg. marg.	x	x					x				x	x				x	x	x		
C2083'	N18 marg. marg.		x	x	x	x	x	x				x	x	x			x	x	x	x	
C2138'4"	N18 marg. marg.		x					x			x	x					x	x	x	x	
C2181'3"	N17 humerosa	x	x	x		x		x	x		x	x	x		x			x	x	x	
C2171'	N17 humerosa		x	x		x		x	x		x	x					x	x	x	x	
C2198'6"	No data	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C2214'3"	N17 humerosa		x	x		x	x	x	x		x	x	x				x	x	x	x	

CLINO	Globigerinoides ruber seiglei	Globorotalia acostaensis acostaensis	Globigerinoides conglobatus canimarensis	Globorotalia menardii 'B'	Globigerinoides elongatus	Globorotalia humerosa humerosa	Turborotalia humilis	Globigerinoides obliquus extremus	Sphaeroidinellopsis seminulina	Globorotalia pseudomiocenica	Sphaeroidinellopsis sphaeroides	Globorotalia merotumida/plesiotumida	Candeina nitida	Sphaeroidinellopsis hancocki	Globorotalia margaritae margaritae	Globorotalia pertenuis	Globorotalia tumida flexuosa	Neogloboquadrina dutertrei	Globorotalia tumida tumida	Hastigerina pelagica
C504'9"																				
C555'9"		x																		
C576'4"																				
C714'1"					x														x	x
C771'8"																		x		x
C834'9"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C946'4"		x				x												x		
C984'9"		x			x															x
C1042'8"																		x		
C1110'		x				x												x	x	x
C1121'	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C1215'2"		x				x												x		x
C1273'4"																				
C1310'3"		x			x	x		x					x					x		x
C1445'6"								x												x
C1488'9"								x												
C1567'5"								x												
C1587'8"		x			x			x										x		
C1598'7"								x												
C1602'6"					x	x		x						x						
C1664'9"		x						x												x
C1710'5"					x	x				x	x							sl	x	
C1710'8"		x			x	x		x	x	x						x		x		
C1731'		sl			x	x		x	x		x					x				x
C1745'	x	x		x	x	x		x	x	x		x		x	x	x	x		x	
C1778'		x	x						x	sl		sl								
C1778'		x						x	x	x	x	x								
C1781'8"		x							x	x		x				x				
C1803'4"	x	x			x	x	x		x	x		x				x				x
C1804'2"		x							x			x								
C1870'3"										x		x								x
C1891'5"		x										x								
C1899'5"									x	x										
C1951'		x		x					x	x		x								x
C2083'	x	x				x	x	x		x		x	x		x					x
C2138'4"		x							x		x	x								x
C2181'3"		x						x			x	x								
C2171'	x	x			x	x			x			x								
C2198'6"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C2214'3"	x	x			x	x		x	x		x	x	x							

CLINO	Globigerinoides conglobatus conglobatus	Globorotalia crassaformis ronda	Globorotalia crassaformis oceanica	Globorotalia crassula	Pulleniatina obliquiloculata primalis	Globorotalia multicamerata	Globorotalia menardii cultrata	Globorotalia marg. marg./evoluta transition	Globorotalia crassaformis crassaformis	Globigerinoides trilobus fistulosus	Globorotalia miocenica	Globorotalia exilis	Globorotalia crassaformis cf. viola	Sphaeroidinella dehiscens	Globorotalia inflata	Globorotalia tosaensis tenuitheca	Pulleniatina obliquiloculata obliquiloculata	Pulleniatina obliquiloculata finalis	Globorotalia truncatulinoides truncatuli-
C504'9"																			
C555'9"																			
C576'4"					x														
C714'1"					x									x			x	x	x
C771'8"					x														
C834'9"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C946'4"	x				x		x		x			x					x		
C984'9"									x			x					x	x	
C1042'8"												x		x					
C1110'																	x		
C1121'	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C1215'2"							x		x			x							
C1273'4"														x					
C1310'3"	x	x	x						x	x				x		x			
C1445'6"									x					x					
C1488'9"																			
C1567'5"	x																sl		
C1587'8"					x				x					x			x		
C1598'7"	x								x			x		x					
C1602'6"	x	x	x		x				x	x				x			x		
C1664'9"		x								x	x								
C1710'5"	x		x			sl			x	x	x		x						
C1710'8"	x	x	x	x			x		x	x	x	x	x	x					
C1731'	x	x	x	x		x			x	x	x	x	x	x	x				
C1745'	x	x	x	x		x		x		x	x	x		x					
C1778'																			
C1778'	x																		
C1781'8"	x																		
C1803'4"							x												
C1804'2"																			
C1870'3"																			
C1891'5"																			
C1899'5"																			
C1951'																			
C2083'																			
C2138'4"																			
C2181'3"																			
C2171'																			
C2198'6"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C2214'3"																			

Table 4. Middle middle Miocene to Pleistocene low-latitude planktonic foraminifera, their occurrence in CLINO, and bi ostratigraphic ages of core intervals (in ft and in.). sl = sensu lato (in a broad sense).

UNDA	Biostratigraphic Age	*Globigerina venezuelana*	*Globorotalia mayeri*	*Globigerinoides trilobus trilobus*	*Globigerinoides trilobus sacculiferus*	*Globigerinoides ruber*	*Globigerinita incrusta*	*Globoquadrina altispira conica*	*Globoquadrina altispira globosa*	*Globoquadrina dehiscens*	*Globoquadrina altispira altispira*	*Globigerinoides obliquus obliquus*	*Orbulina universa*	*Orbulina bilobata*	*Orbulina suturalis*	*Globorotalia praemenardii*	*Globorotalia fohsi robusta*	*Globigerinoides bollii*	*Sphaeroidinellopsis multiloba*	*Hastigerina siphonifera*	*Globorotalia menardii 'A'*	*Polyperibola christiani*	*Globigerina camesi*	*Globorotalia acostaensis acostaensis*	*Globigerinoides conglobatus canimarensis*	*Globorotalia menardii 'B'*	*Globigerinoides elongatus*	*Globigerina bulloides*	*Globorotalia humerosa humerosa*	*Globigerinoides obliquus extremus*	*Sphaeroidinellopsis seminulina*	*Globorotalia pseudomiocenica*	*Globorotalia merotumida/plesiotumida*	*Globorotalia menardii menardii*	*Globorotalia menardii cultrata*	*Neogloboquadrina dutertrei*	*Hastigerina pelagica*	*Globigerinoides conglobatus conglobatus*	*Globorotalia crassaformis ronda*	*Globorotalia tosaensis tenuitheca*	*Pulleniatina obliquiloculata primalis*	*Globorotalia crassaformis crassaformis*	*Globorotalia miocenica*
U288'8"	N21 exilis			x	x	x																		x										x	x								
U361'9"	N21 exilis			x																				x	x		x									x		x		x			
U393'2"	N21 exilis			x																				x			x									x					x		
U427'10"	N21 exilis			x		x																							x														
U471'5"	N21 exilis			x	x	x	x						x							x				x			x	x	x							x						x	
U499'5"	N21 exilis			x																				x										x									
U549'10"	N21 exilis			x	x								x											x			x								x				x	x			x
U560'6"	N21 exilis					x							x																							x							
U599'	N21 exilis			x		x							x														x										x					x	x
U645'6"	N21 exilis			x	x	x														x				x						x				x									x
U687'	N21 exilis			x									x																	x					x								
U742'9"	N19 marg. evoluta			x	x	x		x	x		x		x						x	x				x		x	x		x		x	x	x	x	x			x				x	x
U774'6"	N19 marg. evoluta			x	x						x									x				x		x				x		x	x		x								x
U830'7"	N19 marg. evoluta	x		x	x	x					x	x	x												x		x		x	x	x	x	x	x				x			x		
U881'10"	No data	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U911'8"	N16 acostaensis	x		x	x				x		x							x							x		x			x	x			x									
U940'3"	No data	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U969'	N16 acostaensis			x																																							
U1094'	No data	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U1119'8"	N16 acostaensis			x									x		x																												
U1162'	No data	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U1174'4"	N16 acostaensis			x	x				x				x		x							x																					
U1208'8"	N16 acostaensis			x		x				x	x	x	x						x		x	x	x																				
U1263'5"	N12 robusta			x		x					x		x			x	x	x																									
U1315'3"	N12 robusta			x					x		x		x			x				x	x																						
U1395'3"	N12 robusta	x	x	x	x	x			x	x	x	x	x	x	x	x		x	x	x	x																						
U1420'7"	N12 robusta		x	x	x	x			x	x	x	x	x	x	x	x				x																							

Table 5. Middle middle Miocene to late Pliocene low-latitude planktonic foraminifera, their occurrence in UNDA, and biostratigraphic ages of core intervals (in ft and in.).

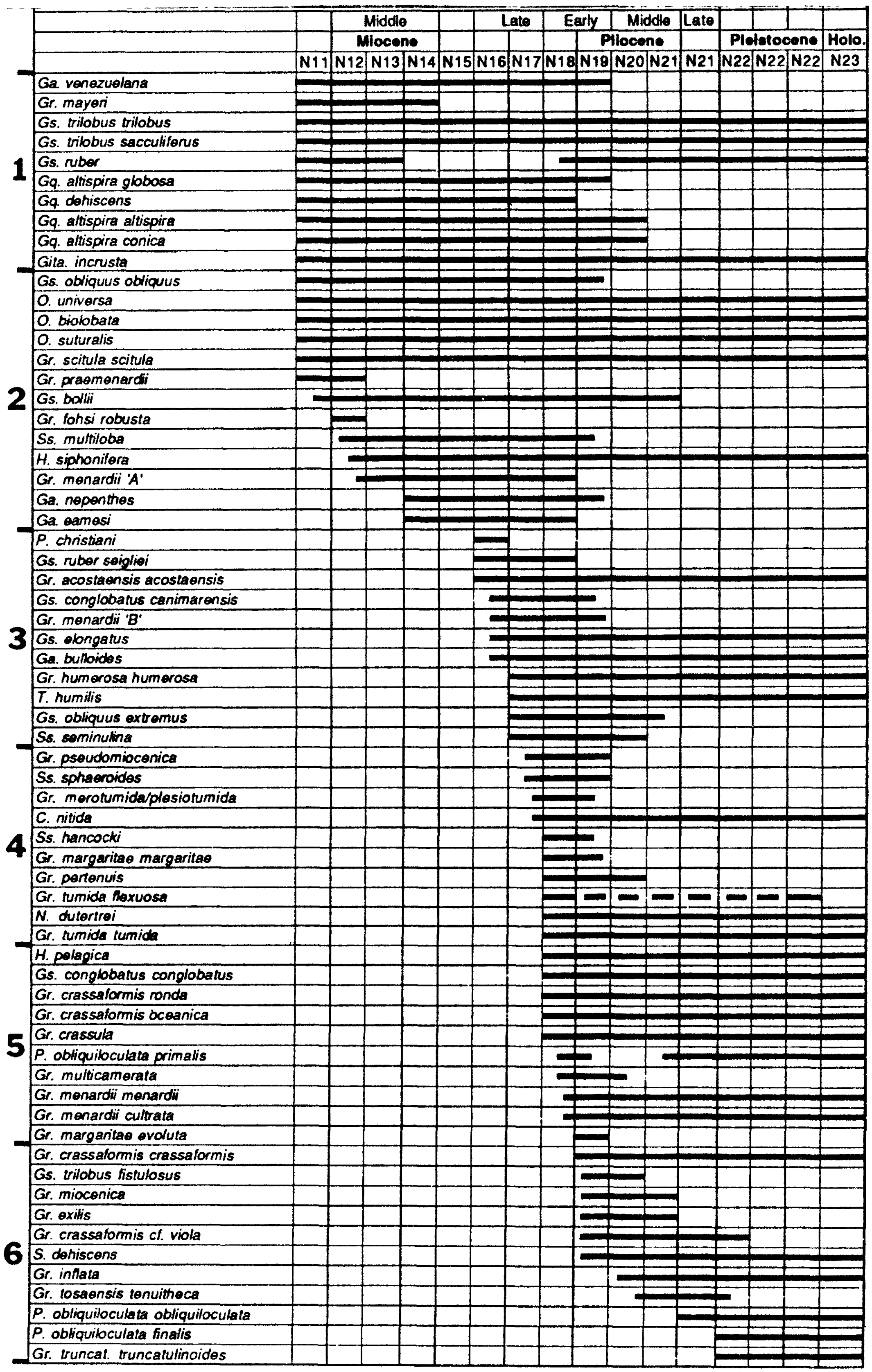


Table 6. Range chart showing distribution of middle Miocene to Holocene planktonic foraminifera identified in cores CLINO and UNDA in order of first stratigraphic occurrence. Numbers at left correspond to Plates 1-6, on which the taxa are figured.

species and nominate taxon (Pl. 2:35) from the lowermost samples in UNDA cinched the zonal age for the bottom of that core. The presence of several marker species (Pl. 4:80-82; Pl. 5:113-115; Pl. 6:116-118, 129-130, 133-134, 138-139) at the deeper site (CLINO) provided relatively good control in zonal determination for the slope sediments. Biostratigraphic criteria for zonal determination are given in Appendix B for CLINO and Appendix C for UNDA.

Contemporaneous Continuous and Noncontinuous Sedimentation

Analyses of planktonic foraminifera in CLINO allowed division of the core sediments into seven biostratigraphically distinct intervals of varying thickness (Fig. 3) and age (Table 3). Thickness of the intervals ranged from 1" (2.54 cm) in a single sample, assignable to late Pliocene *Globorotalia tosaensis tosaensis* Zone N21, to as much as 391 ft (119.2 m) of sediments belonging to early Pliocene *Globorotalia margaritae margaritae* Subzone N18. Ages ranged in sequential foraminiferal zones from late Miocene to early Pleistocene.

Age		Zone	CLINO	UNDA
PLEIST.		N22	63.7	?
PLIOCENE	L	N21	?*	?
	M	N21	99.7	121.3
		N20	84.7	0
	E	N19	39.0	26.8
		N18	119.2	0
MIOCENE	L	N17	15.5	?
		N16	?	90.5
	M	N15	?	0
		N14	?	0
		N13	?	0
		N12	?	48.2

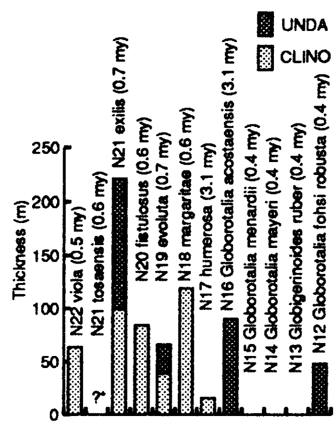


Figure 3. Thickness (m) of deposits by core and foraminiferal zone. Zonal duration given in parentheses on histogram. *Thickness could not be determined on basis of single sample.

Analyses of planktonic species in UNDA produced four biostratigraphic intervals. The thinnest (94 ft, or 26.8 m; Fig. 3) was assigned to *Globorotalia margaritae evoluta* Subzone N19. The thickest, representing *Globorotalia exilis* Subzone N21 (Fig. 3), was 397 ft (121 m). Zonal ages ranged in broken sequence from middle middle Miocene to late Pliocene.

The biostratigraphic interpretations resulted in cross-correlation of (a) the interpreted seismic sequence boundaries in both cores, (b) the age ranges of biostratigraphically determined and inferred foraminiferal zones, and (c) the global sequence boundaries as dated by Haq *et al.* (1988). The correlation revealed three types of sedimentary evidence that support a sea-level derivation for clinoform morphology (Eberli and Ginsburg, 1989). (1) Sediments corresponding to two of the lowstand sediment wedges present (downlap-surface boundaries at 5.0 and 3.4 Ma; Fig. 1) and dated to foraminiferal *Globorotalia margaritae margaritae* Subzone N18 and *Globigerinoides trilobus fistulosus* Subzone N20 in CLINO did not occur in UNDA. (2) Sediments assignable to *Globigerinoides ruber* Zone N13, *Globorotalia mayeri* Zone N14, and *Globorotalia menardii* Zone N15, also not identified in UNDA, were likely not present on the shelf, or on the shelf margin (Fig. 1, Table 3; see later discussion). (3) Three late middle Miocene to early Pliocene global sequence boundaries, dated at 8.2 Ma, 6.3 Ma, and 4.2 Ma, and four downlap-surface boundaries, dated at 11.6 Ma, 7.0 Ma, 5.8 Ma, and 4.0 Ma (Haq *et al.*, 1988), did not occur in either core (Fig. 1).

The smooth, convex morphology of the interpreted clinoform sequence boundaries, showing typical seaward-sloping, aggrading, platform-margin profiles (Fig. 1), implied that erosion of these sediments likely had not played a significant role. Indeed, it is improbable that sediments representing entire foraminiferal zones would be removed by erosion in a shallow-platform setting. On the other hand, dissolution was likely a formidable process and could have resulted in the removal of as much as 33 to 330 ft (10-100 m) of sediment per million years (Trudgill, 1985). In addition, nondeposition may have been important, i.e., sea level may have been high, but currents may have swept sediments away, as is occurring off Bimini in the Bahamas today (Wilber *et al.*, 1990). Despite the probable effects of dissolution and nondeposition, however, the fact remains that sediments assignable to the missing foraminiferal zones and sequence boundaries in (2) and (3) above were most likely never deposited either on the shelf or slope due to lowstands of sea level.

Together, these data support the conclusions that the shelf, and slope in the area of CLINO, were subaerially exposed at least during the major time intervals (12.5-10.0 Ma, 8.3-5.7 Ma, and 4.3-3.9 Ma) represented by the missing sequence boundaries and zonal sediments, and that the clinoforms were thus formed by sea-level-controlled sedimentary processes. A late middle Miocene period of exposure (12.5-11.3 Ma) correlates with a dolomization phase of the same age on the Little Bahama Bank (Vahrenkamp *et al.*, 1991).

DISCUSSION

Rates of Sedimentation

Rates of sediment accumulation, calculated in meters by foraminiferal zone (Fig. 4), show that between periods of exposure shelf sedimentation in UNDA *apparently* increased from a late Miocene Zone N16 low of 29.2 m/my through an early Pliocene Subzone N19 median (38.2 m/my) to a middle Pliocene *Globorotalia exilis* Subzone N21 peak of 173.3 m/my. These rates *apparently* imply a sufficiently high sea-level stand, especially during the middle Pliocene, to accommodate a relatively significant amount of carbonate-sediment production on the shelf. An abundance of planktonic species in the four assigned foraminiferal zonal intervals in UNDA indicates that a near

Age		Zone	CLINO	UNDA
PLEIST.		N22	127.4†	?
PLIOCENE	L	N21	?*	?
	M	N21	142.4	173.3†
		N20	141.2	0
	E	N19	55.7†	38.2†
		N18	198.7	0
MIOCENE	L	N17	?†	?
		N18	?	29.2†
	M	N15	?	0
		N14	?	0
		N13	?	0
		N12	?	?†

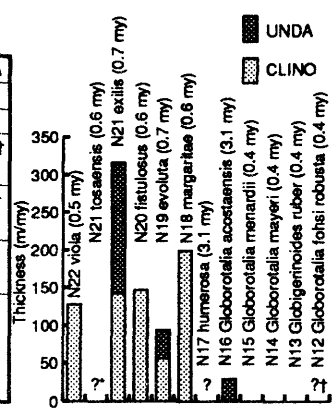


Figure 4. Sedimentation rate (m/my) by core and foraminiferal zone. Rates were determined by dividing 1 my by the zonal duration (in parentheses on histogram), as calculated from age ranges in Tables 1 and 2, and multiplying the result by zonal thickness given in Figure 3. *Rate not determined because single sample is not representative of extent of zone. †Not all of zone in cores, thus real rate could not be determined. See text for discussion.

hemipelagic environment prevailed during each time of shelf sedimentation. Since the uppermost limits of the assigned deposits occur at core depths of U1263'5", U911'8", U742'9", and U288'8" (Table 5), sea level had to have been at a stand higher than these core depths for hemipelagic conditions to have existed. These core depths are dated, respectively, as middle and late Miocene, and late early and late middle Pliocene. Three species (*Globigerinoides trilobus trilobus,* Pl. 1:9-10; *G. trilobus sacculiferus,* Pl. 1:4-5; and *Orbulina universa,* Pl. 2:24) identified in each interval have been shown by Jones (1967) to have observed habitats from 0 to 246 ft (75 m) in the equatorial Atlantic. Oxygen isotopic ratios of selected species from a Pleistocene core from the central Caribbean indicate that these three species had calculated depth habitats ranging from 65 to 265 ft (20-81 m) during postglacial time (Lidz *et al.,* 1968). The depth habitats for these species and the hemipelagic nature of the faunas in UNDA imply either that water depth on the shelf was near a minimum of 265 ft (81 m) at some time during Zones N12, N16, and Subzones N19 and N21 (*Globorotalia exilis*) time, or, if considerably shallower, that the hemipelagic faunas were rafted onto the shelf by upwelling. The apparent rates of sedimentation on the shelf, the interpreted highstands for at least a part of these zones (see later discussion), and the depositional environments interpreted from the benthic assemblages (see Part II) favor near hemipelagic conditions during much of those times. Although influence of paleocurrents on influx of deeper waters onto the shelf cannot be excluded, the few modern planktonic species found by Todd and Low (1971; see Part II) to be present solely in samples near the outer shelf edge, versus the abundance of planktonics throughout UNDA, further support a near hemipelagic-environment interpretation.

On the slope, rate of sedimentation generally decreased through time (Fig. 4). The highest rate (198.7 m/my) occurred during earliest Pliocene Subzone N18 time, when the shelf was exposed. The *apparent* lowest rate (55.7 m/my) followed during late early Pliocene Subzone N19 time, when shelf sedimentation was also at its apparent lowest (38 m/my). From middle Pliocene *Globorotalia exilis* Subzone N21 time when the rate of slope sediment production again increased to a median of 142.4 m/my, to the Pleistocene, the rate appears to have declined gradually to 127.4 m/my.

At first glance, the high offshelf rates in CLINO during N18 and N20 times might imply there was comparatively more sediment production during the lowstands that exposed the shelf than during Zone N16 and Subzone N19 time when the shelf was flooded, and that sea level was sufficiently high to permit accumulation of relatively thick (~650 ft, or 200 m) lowstand wedges on the slope. As will be shown later, however, lowstands of sea level that exposed the slope occurred during significant portions of the times represented by Zones N16, N17, and N19. Hence, sediments assignable to those zones are thinner than if deposition had occurred under uninterrupted highstand conditions, and the actual rates of sedimentation thus cannot be computed. The absence of the top or bottom of a zone in the cores also precludes obtaining actual sedimentation rates. What we have left, then, are believed to be accurate sedimentation rates for Zones N18 (~199 m/my) and Zones N20/N21 (~141 m/my) on the slope in CLINO. It stands to reason that, through time, there is a direct relation between the decrease in sedimentation rate on the slope and the simultaneous post-middle Pliocene increase in frequency and amplitude of sea-level fluctuation, recognized by Beach and Ginsburg (1980).

Clinothems, Hiatuses, and Sea-Level Fluctuation

Examination of discontinuity surfaces within the Plio-Pleistocene Lucayan Limestone on the northwestern Great Bahama Bank led Beach and Ginsburg (1980) to conclude that there is strong evidence for higher frequency and greater amplitude sea-level fluctuations in the late Pliocene and throughout the Pleistocene than earlier in time. The exposure surfaces interpreted from the lithology in CLINO and UNDA support this hypothesis. Although more interpreted seismic sequence boundaries and lowstand wedges occur in the lower half (late Miocene through middle Pliocene) than in the upper half (late Pliocene and early Pleistocene) of core CLINO (Fig. 1), which seemingly contradicts the hypothesis, some of the boundaries have been shown to be a result of differential cementation, rather than a sea-level-controlled facies change (Eberli *et al.*, 1991). According to Eberli *et al.* (1991), the pattern of cementation in the cores is common to intervals that coincide with an interpreted transgressive-surface reflector.

The uppermost 2,395 ft (730 m) of sediment on the platform-margin slope, represented in core CLINO, are characterized on the seismic profile as a sequence of late Miocene to middle Pliocene, alternating, highstand and lowstand systems tracts; a late middle Pliocene transgressive-system tract with a late Pliocene maximum flooding-surface boundary; and a series of early Pleistocene (to Holocene?) highstand systems tracts (Eberli and Ginsburg, 1989). On the basis of interpreted lithology, the sediments grade upcore from lower-slope, through upper-slope, to reef-capped sandy-margin, to platform-interior deposits (Ginsburg *et al.*, 1992). Determination of seven successive foraminiferal zones, ranging from N17 to the earliest of three subzones of N22 age (Tables 1, 3), indicates deposition in the area of CLINO had been relatively continuous, at least from the late Miocene through early Pleistocene.

The planktonics present in the lowermost core interval in CLINO ranged across the Mio-Pliocene boundary, and no index species were identified to resolve which of three possible zones (N19, N18, or N17) was represented. However, the presence of four marker species *(Globorotalia mayeri,* Pl. 1:6-8; *G. fohsi robusta,* Pl. 2:35; *G. praemenardii,* Pl. 2:29-31; and *Globigerinoides ruber,* Pl. 1:11) of middle Miocene Zone N12 age at the bottom of UNDA required upward adjustment of the ages of middle and late Miocene global sequence and downlap-surface boundaries (Haq *et al.*, 1988) until the appropriate sequence boundary age (12.5 Ma) corresponding to Zone N12 time (12.9-12.5 Ma) was attained. The adjustment (1) placed the age of the sequence boundary at the bottom of CLINO as being equivalent to Late Miocene *Globorotalia humerosa* Zone N17 time, which "fits" with relatively continuous sedimentation on the slope during the time represented by the sediments recovered in CLINO, and (2) revealed the apparent absence of three late middle Miocene to early Pliocene sequence boundaries (at 8.2 Ma, 6.3 Ma, and 4.2 Ma) and four downlap-surface boundaries (at 11.6 Ma, 7.0 Ma, 5.8 Ma, and 4.0 Ma) on the bank and slope. That both cores penetrated the Miocene is supported by the presence of benthic species commonly associated with the Miocene (see Part II).

The 1,490-ft-thick (454-m) section on the platform edge, represented in core UNDA, is interpreted on the seismic profile as being composed of sediments equivalent to six highstand system tracts, ranging in age from middle middle Miocene to Pleistocene(?), and the late middle Pliocene transgressive-system tract (Eberli and Ginsburg, 1989). Lithologic data indicate the sediments grade upcore from deep-water platform-top and margin deposits capped by a reef community, through reef-capped upper-slope and sandy-margin deposits, to shallow-water platform-interior accumulations (Ginsburg *et al.*, 1992). Biostratigraphic analyses enabled determination of four nonconsecutive foraminiferal zones (Tables 2, 3): *Globorotalia fohsi robusta* Zone N12, *Globorotalia acostaensis* Zone N16, *Globorotalia margaritae evoluta* Subzone N19, and *Globorotalia exilis* Subzone N21. Sediments assignable to the later part of *Globorotalia humerosa* Zone N17 are probably also present, as determined by correlation of the zonal-age range (8.2-5.1 Ma) with the age (5.5 Ma) of the corresponding sequence boundary, but were too cemented for biostratigraphic analysis. As discussed later, presumably the early part of Zone N17 is missing, which would account for the absence of the global sequence boundaries dated at 8.2 Ma and 6.3 Ma and downlap-surface boundaries dated at 7.0 Ma and 5.8 Ma.

Dissolution, nondeposition, or erosion may have occurred on the shelf at the sequence boundary dated at 3.8 Ma, which shows a distinct dip in its surface just seaward of UNDA (Fig. 1). If sediments had not been deposited or had been removed from this region, they would have belonged to *Globorotalia margaritae margaritae* Subzone N19, not the underlying, presumably N17-age, *Globorotalia humerosa* Zone. Since the age for Subzone N19 deposition ranges from 4.5 to 3.8 Ma, removal or nondepostion of middle Subzone N19 sediments would explain the absence of the global sequence boundary dated at 4.2 Ma and downlap-surface boundary (dls) dated at 4.0 Ma. Sediments belonging to *Globorotalia margaritae margaritae* Subzone N18 (dls at 5.0 Ma; Fig. 1) and *Globigerinoides trilobus fistulosus* Subzone N20 (dls at 3.4 Ma) form lowstand wedges on the slope and thus were never deposited on the shelf. Biostratigraphic data did not reveal their presence.

No biostratigraphic evidence was found in UNDA to indicate deposition of sediments belonging to Zones N13, N14, N15, or early N16 on the shelf, which would also explain the absence of the 11.6-Ma global sequence boundary. From study of the interpreted seismic profile (Fig. 1), the close proximity (~50 ft, or 15 m) of the lowermost two sequence boundaries (at 12.5 and 10.5

Ma) 198 ft (60 m) beneath the TD (2,222 ft, or 677 m) of CLINO on the slope leads to the inference that sediments from the same zones are probably thin or also absent there. If true, their thinness or absence would imply that sea level fell relatively rapidly (~1,200 ft, or 365 m) at the end of N12 time and prior to N13 time to at or below the 2,222-ft (677-m) TD of CLINO and that the carbonate-platform margin may have been exposed to a depth of close to 2,400 ft (730 m) below present sea level for 2.5 million years, the duration of Zones N13 through early N16 time.

Using the detailed interpreted seismic profile and the planktonic-analyses data, we can construct a series of diagrams showing the stands of sea level from the middle middle Miocene to early Pleistocene and the gradual accumulation of foraminiferal zonal deposits through time (Fig. 5A-D). Tables 7 and 8 summarize the duration of the lowstands and highstands and the amplitudes of the sea-level changes shown in Figure 5A-D.

In order for hemipelagic Zone N12 deposits to have been deposited in UNDA on the shelf, sea level at 12.9 Ma could have been approximately 1,200 ft (365 m) below present and still would have provided the backreef/mid-shelf depositional environment interpreted from the benthic fauna (see Part II) for the region of UNDA (Fig. 5A). After that time, sea level fell, as sediments assignable to Zones N13, N14, N15, and early N16 were not identified in UNDA. Sea level remained at this 2,400-ft (730-m) lowstand until it began rising at about 10.0 Ma, after the beginning of Zone N16 time, to about 1,000 ft (300 m) below present. Hemipelagic late N16 deposits accumulated both on the slope, as interpreted from the seismic profile, and shelf, as determined biostratigraphically. Although sediments assignable to Zone N17 were not identified on the shelf from the material sampled, those belonging to at least the later part (5.7-5.1 Ma) of the zone are presumed to be present from examination of the seismic facies (Fig. 5B). Removal or nondeposition of early (8.3-5.7 Ma; Fig. 5A) Zone N17 sediments would account for the four missing global boundaries that fall within that age range, as previously discussed. Nondeposition due to platform exposure is the more likely cause and would have required a lengthy (2.6 my, the duration of early N17 time)

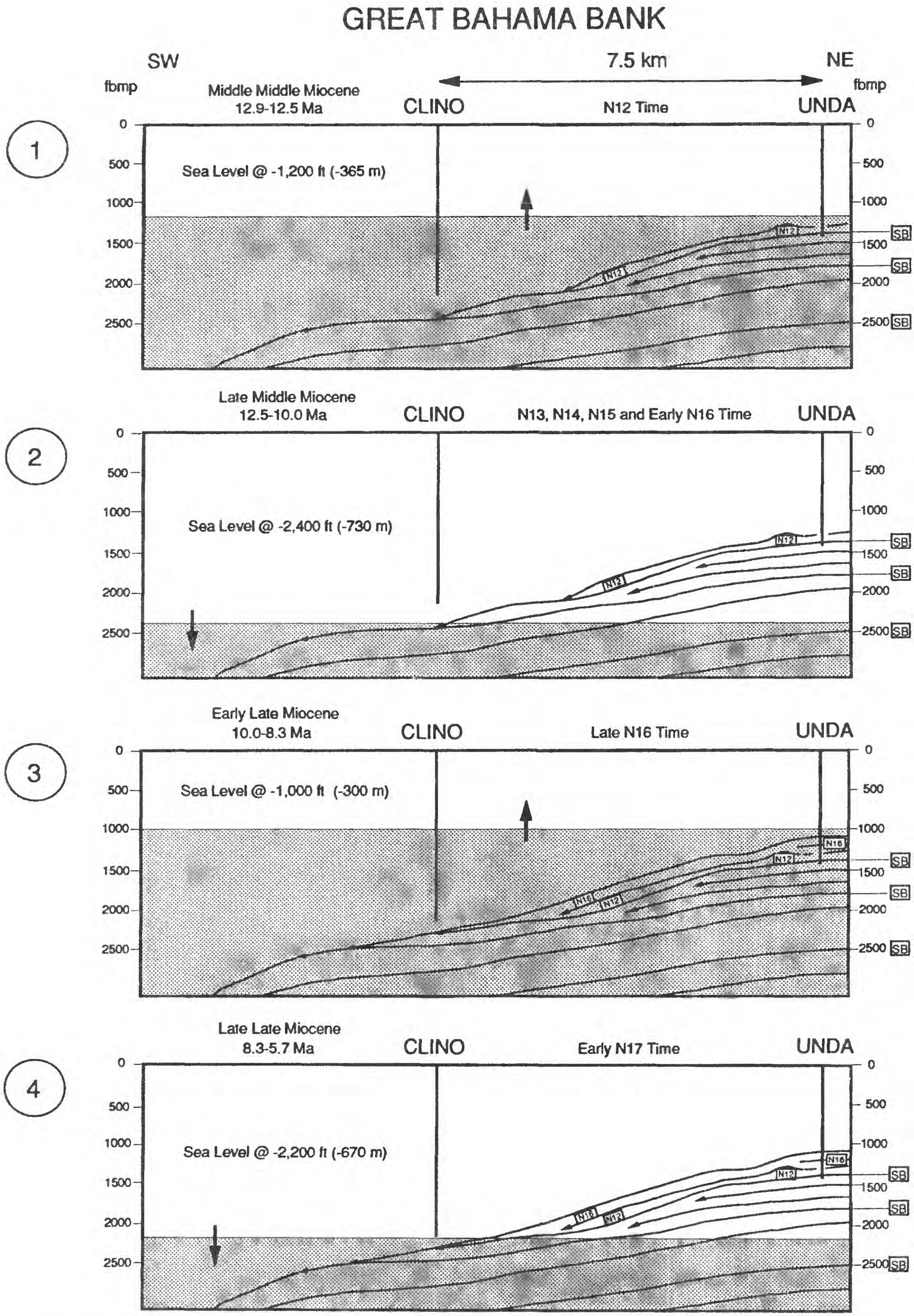


Figure 5A. Middle and late Miocene sea-level fluctuations between 12.9 and 5.7 Ma, during which time foraminiferal Zones N12 and late N16 were deposited. A significant fall in sea level during N13, N14, and N15 time and during the beginning and middle of N17 time would account for the absence on both the shelf and slope of the late middle Miocene foraminiferal zones and late Miocene global sequence boundaries dated at 8.2 Ma, 7.0 Ma, 6.3 Ma, and 5.8 Ma. Sea-level rise in top frame interpreted from lithology (see Fig. 7B and D, Part II). All other fluctuations based on planktonic analyses and interpreted seismic facies. Circled numbers at left represent a change in sea level and correspond to the same circled numbers on Figures 6 and 7. Seismic interpretation after Eberli and Ginsburg (1989). fbmp = feet below mud pit.

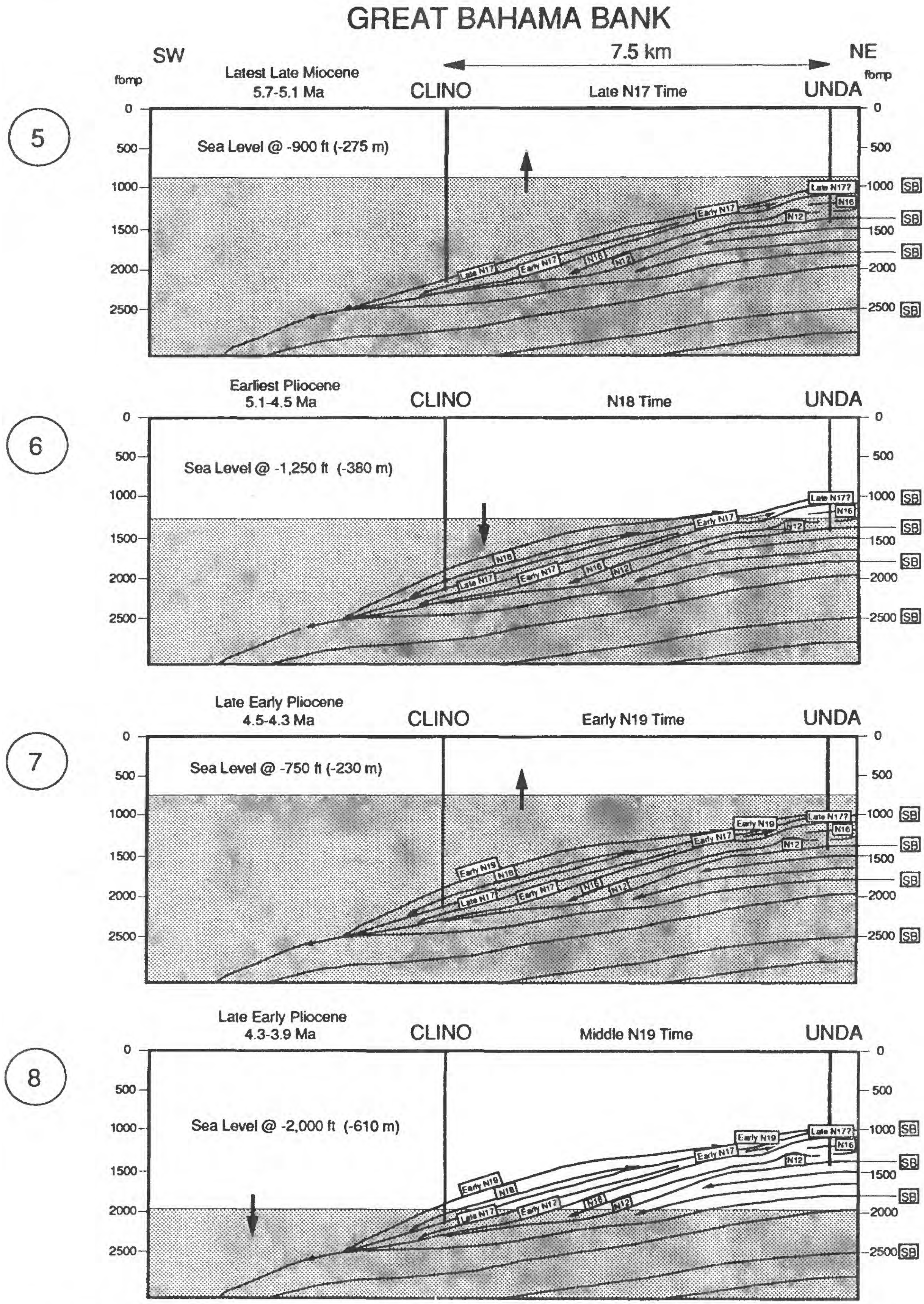


Figure 5B. Latest Miocene to late early Pliocene sea-level fluctuations between 5.7 and 3.9 Ma, during which time foraminiferal Zones late N17, N18, and early N19 were deposited. A significant fall in sea level during middle N19 time would account for the absence on both the shelf and slope of the early Pliocene global sequence boundaries dated at 4.2 and 4.0 Ma. Circled numbers at left represent a change in sea level and correspond to the same circled numbers on Figures 6 and 7. Seismic interpretation after Eberli and Ginsburg (1989). fbmp = feet below mud pit.

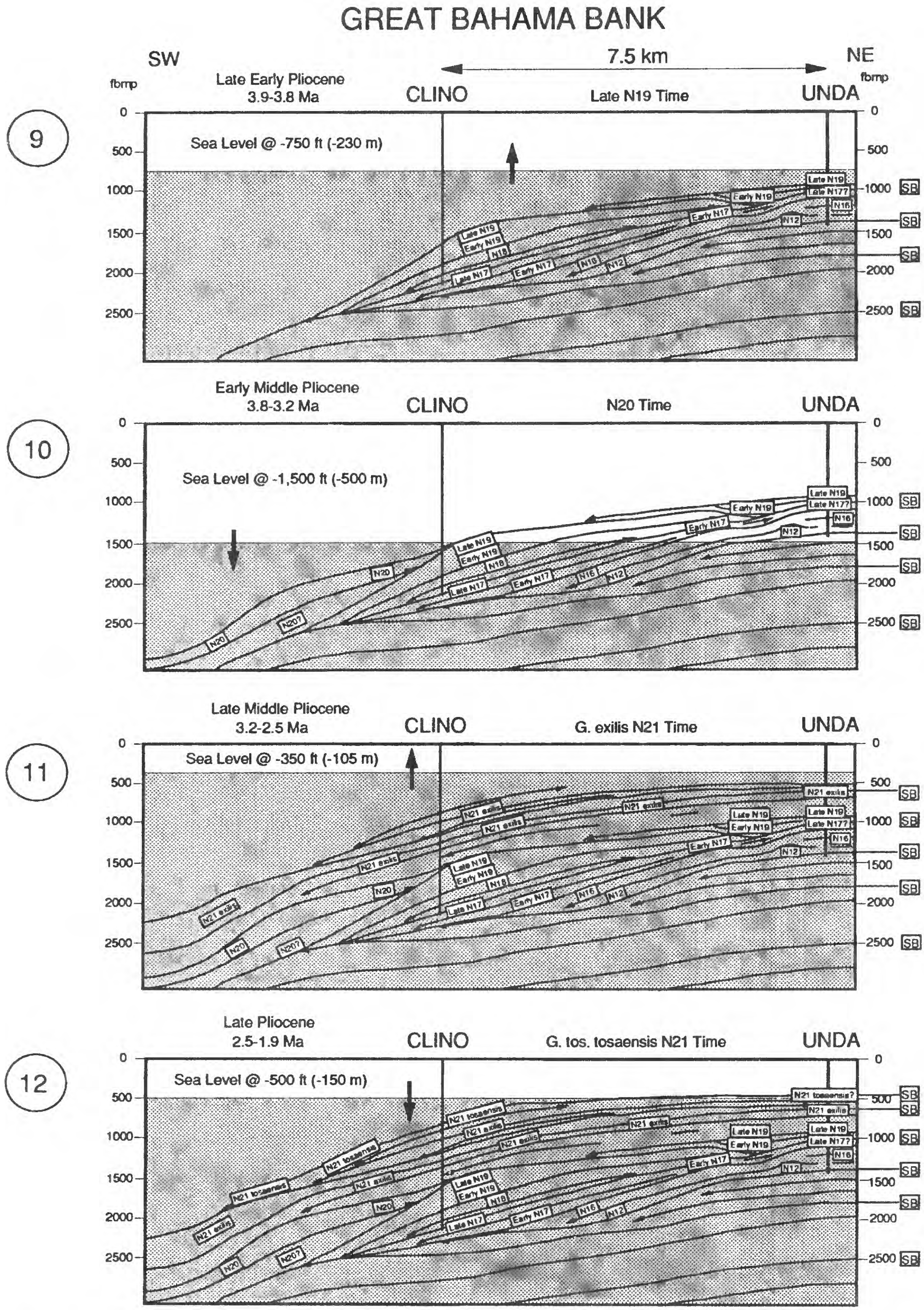


Figure 5C. Late early Pliocene to Late Pliocene sea-level fluctuations between 3.9 and 1.9 Ma, during which time foraminiferal Zones late N19, N20, Globorotalia exilis N21, and Globorotalia tosaensis tosaensis N21 were deposited. Circled numbers at left represent a change in sea level and correspond to the same circled numbers on Figures 6 and 7. Panel number 12 represents the Nebraskan lowstand at the end of the Pliocene. Seismic interpretation after Eberli and Ginsburg (1989). fbmp = feet below mud pit.

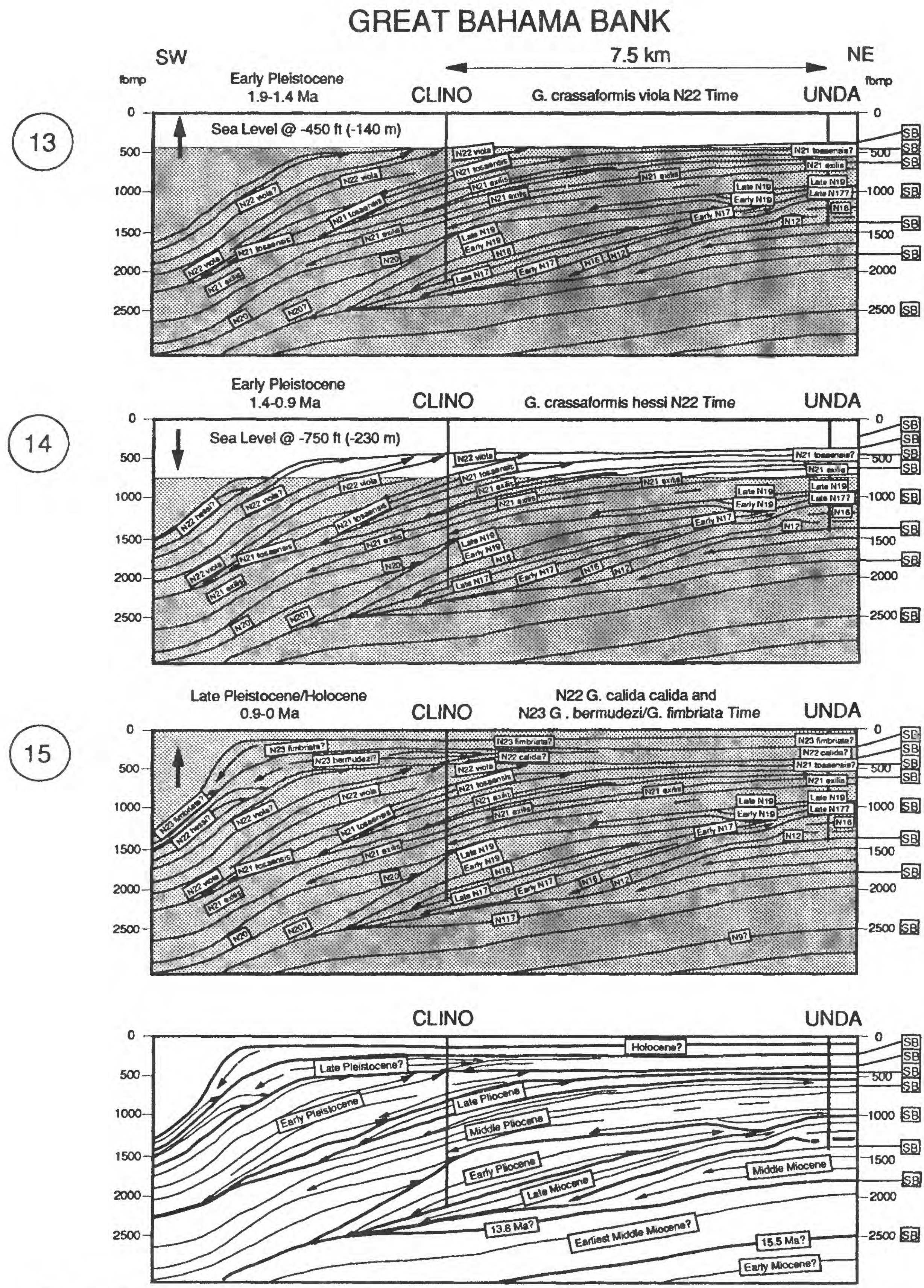


Figure 5D. Early Pleistocene to Holocene sea-level fluctuations between 1.9 Ma and today, during which time foraminiferal Zones Globorotalia crassaformis viola N22 and younger were deposited. See Figure 2 for foraminiferal zonation. Panel number 13 represents a rise in sea level following the Nebraskan glacial at the end of the Pliocene and corresponds to the same rise indicated by the circled 13 on Figures 6 and 7. Panel number 14 represents the Kansan glacial lowstand. Panel number 15 includes the Illinoian and early and main Wisconsinan glacials and the interglacial deposits. The last panel summarizes the ages of the sediments as determined by planktonic analyses and seismic facies. Seismic interpretation after Eberli and Ginsburg (1989). fbmp = feet below mud pit.

Table 7. Duration (my) of Highstands and Lowstands

Highstand		Lowstand	
G. crassa. viola N22	0.5	G. crassa. hessi	0.5
G. exilis N21	0.7	G. tos. tosaensis N21	0.6
Late N19	0.1	N20	0.6
Early N19	0.2	Middle N19	0.4
Late N17	0.6	N18	0.6
Late N16	1.7	Early N17	2.6
N12	0.4	N13 to early N16	2.5

Table 8. Amplitude (ft) of Sea-Level Fluctuation

Rise		Fall	
G. crassa. viola N22	50	G. crass. hessi N22	300
G. exilis N21	1150	G. tos. tosaensis N21	150
Late N19	1200	N20	750
Early N19	500	Middle N19	1250
Late N17	1300	N18	350
Late N16	1400	Early N17	1200
N12	?	N13 to early N16	1200

stillstand in sea level followed by a rise to above the 1,000-ft (300-m) depth at 5.7 Ma to accommodate late Zone N17 deposition on the shelf. Sea level then receded again at 5.1 Ma to expose the shelf briefly during Subzone N18 time (0.6 my; Fig. 5B, Table 7). Subzone N19 time (4.5-3.8 Ma) experienced a rise, a fall, and a second rise that flooded the shelf to a depth of approximately 750 ft (230 m) below present. The middle Subzone N19 lowstand precluded deposition of sediments that would have contained the global boundaries dated at 4.2 and 4.0 Ma. The last major Pliocene regression was to 1,500 ft (500 m) below present, which allowed accumulation of lowstand wedge Subzone N20 sediments on the slope (Fig. 5C). During the next 0.7 million years, a transgression to a depth of about 350 ft (105 m) below present again inundated the shelf, allowing accumulation of hemipelagic *Globorotalia exilis* Subzone N21 sediments at both core sites. A relatively minor fall to a depth of 500 ft (150 m) occurred at the end of the Pliocene during *Globorotalia tosaensis tosaensis* Zone N21 time (2.5-1.9 Ma), which exposed the shelf for a fourth time. The timing of this fall corresponds to the timing of the well-documented glacial period that occurred from 2.0 to 1.75 Ma (Ericson and Wollin, 1968).

Application of the Pleistocene foraminiferal zonation to the interpreted detailed seismic facies that overlie the Pliocene, shown in the first two panels of Figure 5D, also allows correlation of the inferred Pleistocene facies ages with the timing of Pleistocene glaciations and interglacial periods of deposition. From study of the profiles in Figure 5D, one notes that from 1.9 to 1.4 Ma, sea level rose to about 450 ft (140 m) below present, which allowed deposition of *Globorotalia crassaformis viola* Subzone N22 sediments, identified in CLINO, on the slope but not on the shelf. The sea-level rise and age range (1.9-1.4 Ma) for *Globorotalia crassaformis viola* Subzone N22 correspond to the interglacial that lasted from 1.75 to 1.4 Ma. A subsequent sea-level fall from 1.4 to 0.9 Ma to about 750 ft (230 m) below present fully exposed the shelf and permitted lowstand wedges likely assignable to *G. crassaformis hessi* Subzone N22 time to accumulate on the slope. The fall corresponds to the glacial that spanned precisely the same time period. The third panel in Figure 5D combines the remaining Pleistocene sea-level fluctuations and clearly shows that the shelf was subsequently (1) flooded during early *Globigerina calida calida* Subzone N22 time (0.9-0.4 Ma), the time of the interglacial dated at 0.9 to 0.55 Ma, (2) exposed during the latter part of *G. calida calida* time, equivalent to the glacial dated at 0.55 to 0.4 Ma, and (3) partially flooded during *Globorotalia bermudezi* Subzone N23 time (0.4-0 Ma), the equivalent of the 0.4- to 0.15-Ma interglacial. Because there is no discernible evidence on the interpreted seismic profile for later fluctuations in sea level, we can only infer that the shelf was exposed during the early and main Wisconsinan glacials at 0.15 and 0.05 Ma and that the sediments likely assignable to *Globorotalia fimbriata* Subzone N23 were deposited between these periods of exposure. The shelf became flooded for the final time during the postglacial.

Late Neogene Sea-Level Curve for the Region of the Great Bahama Bank

Using the sea-level data shown schematically in Figure 5A-D, we can construct a late Neogene sea-level curve for the region of the Great Bahama Bank. Comparison of the sea-level curve developed in this study with the eustatic curve of Haq *et al.* (1988), shown in Figure 6, required modification of their curve to accommodate the apparent absence of sequence boundaries and foraminiferal zones in the cores. Whereas relatively little correlation is at first apparent between the data presented here and the unmodified eustatic curve (Fig. 6A, B), 74% of the interpretations expressed in this paper are shown to correlate with similar interpretations as proposed by Haq and his colleagues when the data points representing the missing boundaries are removed from the

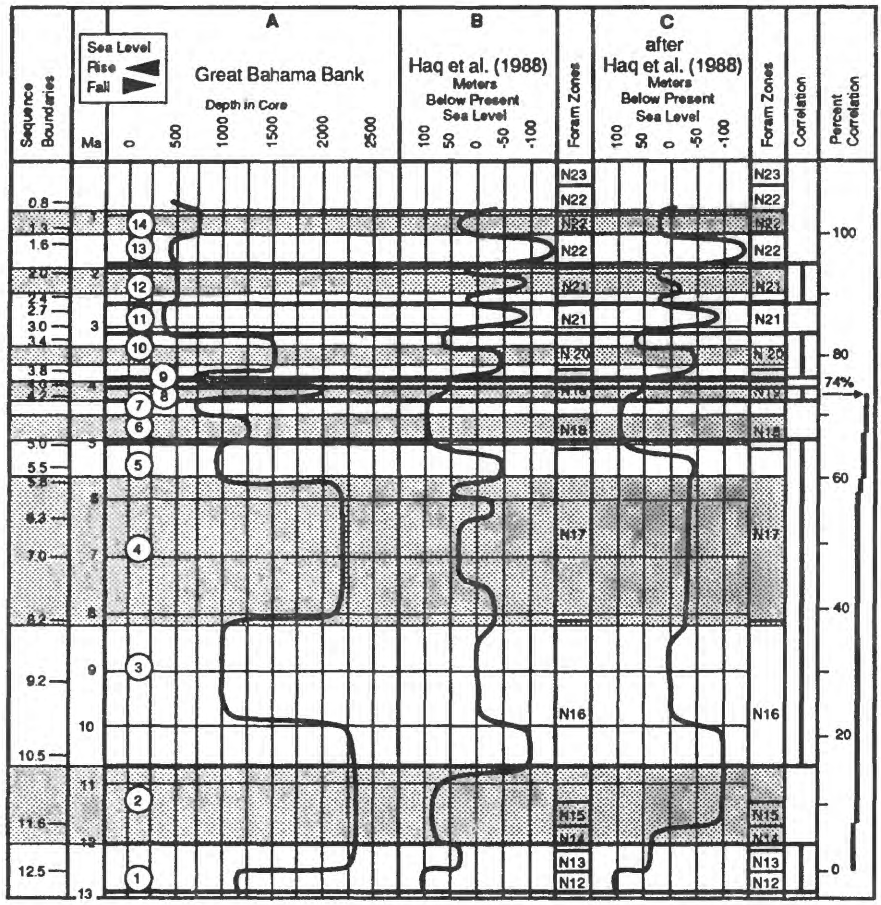


Figure 6. Comparison of the sea-level curve for the Great Bahama Bank (A), constructed from interpreted planktonic analyses and seismic facies shown in Figure 5A-D, with the eustatic curve of Haq et al. (1988) for the late Neogene (B), and the modified eustatic curve (C). Curves plotted against time (Ma). Circled numbers correspond to numbered panels in Figure 5A-D. Shaded areas indicate portions of curves where sediments and sequence boundaries appear to be absent on the shelf. The modified curve of Haq et al. in (C) has had those portions of the curve in the shaded areas removed and the remaining portions connected. Regardless of the amplitude of the sea-level fluctuations, note the areas of otherwise matching sinuosity in curves (A) and (C). Their comparison shows relatively good correlation from 12.9 to 12.0 Ma (Zones N12-early N14), 10.7 to 4.9 Ma (middle and late Zone N16 to within Subzone N18), 4.3 to 4.0 (middle Subzone N19), 3.9 to 3.2 Ma (Subzone N20), and 2.6 to 1.8 Ma (Globorotalia tosaensis tosaensis Zone N21). The correlative intervals are indicated by bold vertical lines at right and total 74% of the data among both curves.

eustatic curve (Fig. 6B, C). In particular, the following five scenarios are expressed in both curves: a middle Miocene sea-level fall encompassing Zones N12 and N13, a late Miocene episode of transgression-regression-transgression during most of Zone N16 to within Subzone N18 time, a late early Pliocene fall in sea level within the middle of Subzone N19 time, an early middle Pliocene lowstand and highstand during Subzone N20 time, and another complete cycle of fall and rise during late Pliocene *Globorotalia tosaensis tosaensis* Zone N21 time. Speculation on why there is a 26% discrepancy between the two curves is beyond the scope of this paper.

Based on foraminiferal zonation and seismic facies, therefore, at least six cycles of sea-level fluctuation and four periods of shelf exposure are recognized to have occurred on the west Great Bahama Bank from the middle middle Miocene at 12.9 Ma through the early Pleistocene at 1.75 Ma. The duration of lowstands ranged from 0.4 million years during the late early Pliocene (Fig. 5B) to 2.6 million years during the late late Miocene (Fig. 5A, Table 7). Highstands ranged from 0.1 million years near the end of the late early Pliocene (Fig. 5C) to 1.7 million years during the late early Miocene (Fig. 5A). The amplitude also varied and ranged from approximately 50 ft (15 m) at the Plio-Pleistocene transition (Fig. 5C, D) to as much as 1,400 ft (430 m) at the middle to late Miocene transition (Fig. 5A, Table 8). The foraminiferal data and seismic facies of the Pleistocene correspond to the timing of four of the well-known and well-documented cycles of Quaternary sea-level fluctuation.

CONCLUSIONS

Biostratigraphic analyses of sediments from the western Great Bahama Bank show that sedimentation was relatively continuous on the platform-margin slope from the late Miocene (*Globorotalia humerosa* Zone N17) to early Pleistocene (*Globorotalia crassaformis viola* Subzone N22), but was noncontinuous 4 n. mi (7.5 km) inshelf from the middle Miocene (*Globorotalia fohsi robusta* Zone N12) to middle Pliocene (*Globorotalia exilis* Subzone N21). At least two (N18 and N20) and probably as many as five (N13, N14, and N15) foraminiferal zones are missing from shelf deposits. It is also likely that sediments assignable to the latter three zones are thin or absent on the slope. Portions of Zones N16, N17, and N19 are absent from the shelf and slope. Sediments belonging to late Zone N17 are presumed to be present on the shelf from study of the interpreted seismic sequence boundaries, but were not identified in the material sampled. Correlation of the age ranges for the foraminiferal zones identified on the slope with ages of the interpreted seismic sequence and downlap-surface boundaries on the shelf and with those of matching global sequence boundaries for the last 3.8 million years supports the biostratigraphic interpretations in both cores. Upward adjustment of ages of the global boundaries in the lower parts of the cores, to accommodate the presence of middle Miocene Zone N12 deposits at the bottom of UNDA, reveals the absence of three late Miocene to early Pliocene global boundaries (at 8.2 Ma, 6.3 Ma, and 4.2 Ma) and four downlap-surface boundaries (at 11.6 Ma, 7.0 Ma, 5.8 Ma, and 4.0 Ma) on both the bank and slope. Dissolution, rather than erosion, was likely the primary cause of any sediment removal. Nondeposition may also have been an influence. Rate of deposition generally decreased on the slope through time and is not known for the shelf sediments.

Six cycles of sea-level fluctuation and four periods of shelf exposure are recognized based on biostratigraphy to have occurred from the middle middle Miocene at 12.9 Ma through the early Pleistocene at 1.75 Ma. The six cycles correlate with the six highstand systems tracts on the shelf interpreted from the seismic profile. On the basis of the planktonic foraminifera and seismic facies, the amplitude and timing of the frequency and duration of each fluctuation have been constrained, and a late Neogene sea-level curve has been developed that shows at least a 74% correlation with the well-known eustatic curve. The foraminiferal zonation inferred for the Pleistocene seismic facies is analogous to the timing of four well-known and well-documented cycles of Quaternary sea-level fluctuation. Together, the data conclusively support the earlier hypothesis of sea-level-controlled deposition on the west Great Bahama Bank.

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PART II - BENTHONIC FORAMINIFERAL ANALYSES

ABSTRACT

Analyses of the benthic foraminifera indicate depositional environments on the shelf (UNDA) ranged from shallow inner-shelf to upper-slope depths and those on the slope (CLINO) from mid-shelf to outer-shelf depths. Comparison of the environmental data interpreted from the benthic faunal assemblages and those interpreted from lithology show an apparent 75% and 55% correlation, respectively, in CLINO and an apparent 63% and 69% correlation, respectively, in UNDA. Integration of these two data sets with those interpreted based on planktonic analyses and seismic facies provides more accurate correlation percentages. Assimilation of all four data sets yields a 90% correlation of interpretations based on benthic analyses and a 90% correlation of those based on lithology in CLINO, whereas 90% of the benthic data and 81% of the lithologic data were correlative with all other data in UNDA. The number of depositional environments varies more on the shelf than on the slope, reflecting a greater influence of changing sea level on the shelf than on the slope, as would be expected.

A series of alternating backreef/mid-shelf, forereef/outer-shelf, forereef, and outer-shelf/upper-slope environments on the shelf during the 0.7 million years of late middle Pliocene *Globorotalia exilis* Subzone N21 time correlates with a series of alternating onlapping and offlapping seismic facies that are dated biostratigraphically to Subzone N21 age. This apparently "sudden" increase in frequency of sea-level fluctuation over that earlier in time may redefine the previously determined post-middle Pliocene onset of increased fluctuation.

INTRODUCTION

When compared to literature on planktonic foraminifera in the Caribbean, that on the benthic taxa, other than taxonomic works, is relatively scant. D'Orbigny (1839) and Cushman (1921, 1922) conducted three classic studies on systematic paleontology of Caribbean faunas, with Cushman having made the first effort to interpret the significance of environment and distribution in relation to depth, wave energy, and bottom growth. Norton (1930) examined samples from random localities in Florida and the West Indies, and recognized four environmental zones based on depth and temperature limits. In two short papers, Illing (1950, 1952) discussed transport effects on foraminifera in the Bahamas, emphasizing the effectiveness of currents in concentrating and redistributing tests. She recognized differences between faunas from exposed platform margins, quiet protected banks, highly saline areas, and brackish localities. Todd and Low (1971, p. C6) carried out a taxonomic study of samples collected from the Great Bahama Bank west of Andros Island and presented a very generalized review of gross distribution. In their study, only six planktonic species were identified and were from samples collected near the outer edge of the bank, where they "might be expected to have originated from the oceanic water of the adjacent Straits of Florida."

The Bahamas faunas, although less varied, have much in common with faunas reported from Florida. Some of the Florida faunal studies include those by Stubbs (1940, Biscayne Bay), Parker (1954, Florida west coast), Bandy (1956, Florida west coast), Moore (1957, northern Florida Keys), Lynts (1962, 1965, upper Florida Bay), and Bock *et al.* (1971, Florida Bay and adjacent waters). Rose and Lidz (1977) compared ecologic faunal assemblages across the carbonate platforms of the Florida Keys and off west Andros Island and concluded that species on a platform occur in an orderly seaward succession and are subdivided into faunas typical of each of the many subenvironments inherent to a shallow-platform setting.

METHODS

A qualitative analysis of the benthonic foraminifera was performed on 26 samples from CLINO and 25 from UNDA, following the criteria and terminology of Barker (1960), Cushman (1932), and Parker (1954). (The number of samples is less than the number examined for planktonic analyses because only planktonic species were picked from the preliminary samples examined.) Of 151 species identified (Appendix D), only six were tentatively identified as to species level (Appendix E); 63 species were common to both cores. Besides the recognizable species, many specimens were tentatively identified as to genus, family, superfamily and phylum levels. Many fragments could not be determined to be of foraminiferal origin.

The poor state of preservation required that the method of picking specimens for analysis be random. Because the specimens picked were dependent solely upon the likelihood of identification, any quantitative analyses were precluded. The interpretations of depositional environments were therefore based upon faunal composition and associations. Nine environments were recognized, given in an offshore direction: inner shelf; mid-shelf; backreef/mid-shelf; reef; forereef; forereef/outer shelf; outer shelf; outer shelf/upper slope; and upper slope.

RESULTS

Diagnostic Species and Their Environments

Inner Shelf

The inner shelf is characterized by species commonly attached to sea grasses (*Articulina mucronata, Cibicides lobatulus* and *Rosalina concinna*) or to individual quartz grains, carbonate grains or shells subject to movement by current or wave action (*Asterigerina carinata, Cibicides protuberans* and *Rosalina concinna*; Pl. 7). Grass beds usually are limited to a zone of sufficient light penetration, about 26 ft (11 m). Other indicators of an inner-shelf environment are large numbers of *Quinqueloculina* spp. and other miliolids.

Mid-Shelf

The mid-shelf environment (here referred to as the zone between the inner and outer shelf, or between the inner shelf and back reef) is characterized by *Anomalina globulosa, Asterigerina carinata, Cibicides* aff. *C. floridanus, Cribroelphidium poeyanum, Elphidium sagrum, Globulina inaequalis, Gypsina vesicularis, Hanzawaia strattoni, Nonionella atlantica, N. pizzarense, Planorbulina mediterranensis, Planulina exorna, Quinqueloculina* spp., *Rosalina bahamaensis, Rosalina floridana,* and *Trifarina occidentalis* (Pls. 7, 8).

Backreef/Mid-Shelf

The backreef/mid-shelf zone (here referred to as the zone between the mid-shelf and reef zones) is dominated by *Amphistegina gibbosa* and *Asterigerina carinata* with *Baggina* spp., *Elphidium sagrum, Eponides antillarum, Hanzawaia strattoni, Nonionella atlantica, Planulina exorna, Pyrgo subsphaerica* and *Rosalina bahamaensis* (Pl. 9). Many of the mid-shelf species also occur in this zone, but never in dominant numbers.

Reef

The reef zone is completely dominated by *Amphistegina gibbosa* (Pl. 9).

Forereef

The forereef zone is completely dominated by *Amphistegina gibbosa* and *Asterigerina carinata* (Pl. 9). Other common species are *Eponides repandus, Planulina foveolata* (Pl. 9) and some textularids.

Forereef/Outer Shelf

The forereef/outer-shelf zone is characterized by *Amphistegina gibbosa, Asterigerina carinata, Cassidulina curvata, Cibicides corpulentus, Cibicides* aff. *C. floridanus, Cibicides protuberans, Cibicides wuellerstorfi, Eponides antillarum, Gyroidina soldanii altiformis, Planulina foveolata* and *Reussella atlantica* (Pl. 10), along with many specimens transported from shallower zones.

Outer Shelf

The outer shelf is characterized by *Anomalina globulosa, Brizalina plicatella, Bulimina inflata, Cibicides corpulentus, Cibicides* aff. *C. floridanus, Dentalina* spp., *Eponides antillarum, Globobulimina affinis, Globocassidulina subglobosa, Guttulina hirsuta, Guttulina laevis, Gyroidina soldanii altiformis, Lenticulina* spp., *Marginulina subaculeata glabrata, Planulina ariminensis,* *Planulina depressa, Planulina foveolata, Saracenaria italica, Sigmoilina* spp., *Sigmoilopsis schlumbergeri, Trifarina carinata, Uvigerina flintii, Uvigerina laevis* and *Uvigerina peregrina* (Pls. 11, 12), along with many specimens transported from shallower zones.

Outer Shelf/Upper Slope

The outer-shelf/upper-slope zone contains all the species of the outer shelf plus *Ehrenbergina trigona, Gaudryina (Pseudogaudryina) atlantica, Gyroidina orbicularis, Lenticulina atlantica, Pseudonodosaria comatula* and *Uvigerina auberiana* (Pl. 13).

Upper Slope

The only reason for differentiating the upper-slope zone from the outer-shelf/upper-slope zone is the presence of *Bulimina marginata* (not figured), which has a reported depth range of 985 to 2,230 ft (300-680 m), placing it on the upper slope. Other species characteristic of this zone are *Cibicides corpulentus, Gaudryina (Pseudogaudryina) atlantica, Globocassidulina subglobosa, Gyroidina soldanii altiformis, Marginulina subaculeata glabrata, Planulina foveolata, Rosalina bertheloti, Saracenaria italica, Textularia* spp. and *Trifarina carinata* (Pl. 13).

DISCUSSION

Environments in Core CLINO

Table 9 lists the species identified and depositional environment interpreted by sample number in CLINO (also see Appendix F). The changes in environments are shown as "sea-level curves" by core in Figure 7. In CLINO, the lower part of the core from C2214'3" through C1781'8" contained an outer-shelf fauna. At C1745' and C1710'8", the fauna indicated an outer-shelf/upper-slope environment, the deepest depositional environment in the core. Two specimens that are very similar to the genus *Operculinoides* Hanzawa, which is a late Eocene form, also occurred at C1745'. However, the poor state of preservation and the associated fauna made this interpretation doubtful. Sample C1664'9" was completely dominated by the reef

CLINO	Depositional Environ.	*Ammonia beccarii tepida*	*Ammonia translucens*	*Ammobaculites sp.*	*Amphistegina gibbosa*	*Amphycoryna separans*	*Anomalina globulosa*	*Archaias angulatus*	*Articulina lineata*	*Astacolus crepidulus*	*Asterigerina carinata*	*Bigenerina floridana?*	*Bigenerina irregularis*	*Brizalina goesii*	*Brizalina paula*	*Brizalina plicatella*	*Brizalina sp.*	*Bulimina inflata*	*Bulimina marginata*	*Bulimina spp.*	*Buliminella curta*	*Cancris oblonga*	*Cancris sagra*	*Cassidulina carinata*	*Cassidulina crassa*	*Cassidulina laevigata*	*Chrysalidinella dimorpha*	*Cibicides corpulentus*	*Cibicides aff. C. floridanus*	*Cibicides lobatulus*
C504'9"	Mid-shelf				x						x																		x	
C555'9"	Backreef/mid-shelf				x																									
C576'4"	Backreef/mid-shelf				x						x																		x	
C714'1"	Forereef/outer shelf		x		x																		x		x					x
C771'8"	Mid-shelf				x								x										x							
C834'9"	No data	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C946'4"	Mid-shelf										x																			x
C984'9"	Mid-shelf				x		x		x		x								x			x	x						x	
C1042'8"	Mid-shelf										x											x								
C1110'	Mid-shelf							x			x												x							x
C1215'2"	Mid-shelf				x								x										x						x	
C1273'4"	Mid-shelf				x						x																		x	
C1310'3"	Outer shelf				x	x	x			x	x						x			x		x						x	x	
C1587'6"	Outer shelf	x			x		x						x									x								
C1602'6"	Outer shelf				x		x						x							x		x							x	
C1664'9"	Reef			x	x																							x	x	
C1710'8"	Outer shelf/up. slope			x		x					x			x			x			x				x					x	
C1745'	Outer shelf/up. slope												x					x						x		x	x	x	x	
C1781'8"	Outer shelf																	x										x	x	
C1803'4"	Outer shelf													x			x	x	x					x					x	x
C1951'	Outer shelf																	x											x	
C2136'4"	Outer shelf																	x						x				x	x	
C2161'3"	Outer shelf					x					x	x				x		x	x	x								x	x	x
C2171'	Outer shelf											x						x										x		
C2198'6"	Outer shelf																											x		
C2214'3"	Outer shelf														x	x		x		x	x			x				x	x	x

Table 9. Benthonic foraminifera, their occurrence in CLINO, and their depositional environment. Core intervals in ft and in.

CLINO	Depositional Environ.	*Cibicides protuberans*	*Cibicides wuellerstorfi*	*Cibicides spp.*	*Cribroelphidium poeyanum*	*Dentalina advena*	*Dentalina communis*	*Dentalina subsoluta*	*Discorbis mira*	*Dyocibicides biserialis*	*Eggerella bradyi*	*Ehrenbergina trigona*	*Elphidium advenum*	*Elphidium incertum*	*Elphidium sagrum*	*Eponides antillarum*	*Eponides regularis*	*Eponides repandus*	*Fissurina spp.*	*Fursenkoina complanata*	*Fursenkoina compressa*	*Fursenkoina sp.*	*Gaudryina (Pseudogaudryina) atlantica*	*Globobulimina affinis*	*Globocassidulina subglobosa*	*Globulina inaequalis*	*Guttulina hirsuta*	*Guttulina laevis*	*Gypsina vesicularis*	*Gyroidina orbicularis*
C504'9"	Mid-shelf									x																			x	
C555'9"	Backreef/mid-shelf															x														
C576'4"	Backreef/mid-shelf			x												x		x												
C714'1"	Forereef/outer shelf		x	x										x	x	x		x		x										
C771'8"	Mid-shelf			x										x					x										x	
C834'9"	No data	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C946'4"	Mid-shelf	x	x	x	x									x				x				x							x	
C984'9"	Mid-shelf			x	x										x	x			x											
C1042'8"	Mid-shelf									x																			x	
C1110'	Mid-shelf			x	x				x						x								x					x	x	
C1215'2"	Mid-shelf			x														x	x									x		
C1273'4"	Mid-shelf	x		x					x							x									x			x	x	
C1310'3"	Outer shelf	x		x	x	x	x	x	x				x	x	x	x		x			x				x		x	x		
C1587'6"	Outer shelf	.		x															x			x								
C1602'6"	Outer shelf			x																					x			x		
C1664'9"	Reef			x																					x					
C1710'8"	Outer shelf/up. slope		x								x	x				x	x		x	x			x		x				x	
C1745'	Outer shelf/up. slope			x								x		x				x			x				x					x
C1781'8"	Outer shelf			x																				x	x					
C1803'4"	Outer shelf	x		x																x		x			x					x
C1951'	Outer shelf			x																						x				
C2136'4"	Outer shelf			x																		x		x						
C2161'3"	Outer shelf																	x				x			x					
C2171'	Outer shelf																	x							x					
C2198'6"	Outer shelf																													
C2214'3"	Outer shelf			x														x						x						

Table 9 (cont.)

CLINO	Depositional Environ.	Gyroidina soldanii altiformis	Hanzawaia strattoni	Karreriella bradyi	Lenticulina americana	Lenticulina americana spinosa	Lenticulina atlantica	Lenticulina calcar	Lenticulina orbicularis	Lenticulina spp.	Marginulina dubia	Marginulina subaculeata	Marginulina subaculeata glabrata	Marginulina sp.	Melonis barleeanum	Melonis formosum	Miliolid spp.	Miliolinella subsphaerica	Nodosaria pyrula	Nodosaria spp.	Nonion depressulum	Nonionella atlantica	Nonionella pizarrense?	Nonionella sp.	Nubeculina divaricata	Operculinoides? sp.	Osangularia cultur	Peneroplis carinatus	Peneroplis proteus	Planorbulina mediterranensis
C504'9"	Mid-shelf																			x										
C555'9"	Backreef/mid-shelf																					x		x						
C576'4"	Backreef/mid-shelf																x			x		x						x		
C714'1"	Forereef/outer shelf																			x	x	x								x
C771'8"	Mid-shelf																x			x				x						
C834'9"	No data		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C946'4"	Mid-shelf		x														x		x			x								
C984'9"	Mid-shelf		x	x					x	x							x					x						x	x	
C1042'8"	Mid-shelf		x														x	x		x		x		x						
C1110'	Mid-shelf									x							x			x	x	x		x					x	x
C1215'2"	Mid-shelf																x			x		x		x						
C1273'4"	Mid-shelf														x		x			x		x			x					x
C1310'3"	Outer shelf		x				x	x	x			x	x	x	x				x			x					x			x
C1587'6"	Outer shelf									x							x							x						x
C1602'6"	Outer shelf									x		x																		
C1664'9"	Reef																x													x
C1710'8"	Outer shelf/up. slope		x	x			x			x		x		x			x			x										
C1745'	Outer shelf/up. slope	x	x		x		x			x		x		x			x			x		x				x				x
C1781'8"	Outer shelf	x								x		x			x															
C1803'4"	Outer shelf	x	x		x	x			x		x	x				x				x		x		x						
C1951'	Outer shelf		x									x										x								
C2136'4"	Outer shelf	x	x		x																	x								
C2161'3"	Outer shelf	x			x							x			x					x										
C2171'	Outer shelf				x																	x								
C2198'6"	Outer shelf									x												x		x						
C2214'3"	Outer shelf	x										x		x	x					x			x							

Table 9 (cont.)

CLINO	Depositional Environ.	Planulina ariminensis	Planulina depressa	Planulina exorna	Planulina foveolata	Planulina spp.	Pseudonodosaria comatula	Pyrgo depressa	Pyrgo elongata	Pyrgo jugosa	Pyrgo subsphaerica	Pyrgo vespertilio	Quinqueloculina agglutinans	Quinqueloculina lamarckiana	Quinqueloculina poeyana	Quinqueloculina spp.	Reophax scorpiurus	Reophax spp.	Reussella atlantica	Rosalina bahamaensis	Rosalina concinna	Rosalina floridana	Rosalina floridensis	Rosalina rosea	Rosalina spp.	Rotaliid spp.	Sagrina pulchella primitiva	Saracenaria italica	Sigmoilina tenuis	Sigmoilopsis schlumbergeri
C504'9"	Mid-shelf					x														x						x				
C555'9"	Backreef/mid-shelf																			x						x				
C576'4"	Backreef/mid-shelf																			x	x	x	x		x	x				
C714'1"	Forereef/outer shelf				x	x										x			x		x					x	x			
C771'8"	Mid-shelf															x			x		x	x	x		x	x				
C834'9"	No data		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C946'4"	Mid-shelf				x											x										x				
C984'9"	Mid-shelf									x	x			x		x			x	x	x					x				
C1042'8"	Mid-shelf					x					x			x	x	x				x	x	x			x	x				
C1110'	Mid-shelf					x					x		x	x	x	x		x	x	x		x			x	x				
C1215'2"	Mid-shelf				x	x										x	x			x	x	x			x	x		x		
C1273'4"	Mid-shelf	x			x											x				x	x	x				x				
C1310'3"	Outer shelf	x		x	x													x	x	x			x	x	x	x		x		
C1587'6"	Outer shelf				x			x					x			x	x	x	x		x	x		x	x				x	x
C1602'6"	Outer shelf				x	x		x	x			x						x												
C1664'9"	Reef																	x												
C1710'8"	Outer shelf/up. slope				x		x									x		x	x									x		x
C1745'	Outer shelf/up. slope				x		x											x					x			x		x		x
C1781'8"	Outer shelf	x			x																							x		
C1803'4"	Outer shelf		x															x										x		
C1951'	Outer shelf		x			x																			x					
C2136'4"	Outer shelf		x			x										x									x			x		
C2161'3"	Outer shelf		x																									x		
C2171'	Outer shelf		x																											
C2198'6"	Outer shelf					x																								
C2214'3"	Outer shelf		x																										x	

Table 9 (cont.)

CLINO	Depositional Environ.	*Siphonina pulchra*	*Sphaeroidina bulloides*	*Spiroloculina planulata*	*Textularia agglutinans*	*Textularia conica*	*Textularia spp.*	*Tretomphalus atlanticus*	*Trifarina bella*	*Trifarina carinata*	*Trifarina jamaicensis*	*Trifarina occidentalis*	*Trifarina spp.*	*Triloculina bassensis*	*Triloculina fiterei meningoi*	*Triloculina linneiana*	*Triloculina trigonula*	*Triloculina trigonula multistriata*	*Triloculina rotunda*	*Triloculina spp.*	*Uvigerina auberiana*	*Uvigerina flintii*	*Uvigerina laevis*	*Uvigerina peregrina*	*Uvigerina laevigata*	*Valvulineria minuta*
C504'9"	Mid-shelf																									
C555'9"	Backreef/mid-shelf																									
C576'4"	Backreef/mid-shelf																									
C714'1"	Forereef/outer shelf	x									x															
C771'8"	Mid-shelf																			x						
C834'9"	No data	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C946'4"	Mid-shelf							x																		
C984'9"	Mid-shelf			x	x	x	x	x						x		x		x		x						
C1042'8"	Mid-shelf					x									x	x	x			x						
C1110'	Mid-shelf					x	x				x			x			x		x	x						
C1215'2"	Mid-shelf								x																	
C1273'4"	Mid-shelf		x						x																	
C1310'3"	Outer shelf	x						x		x	x											x	x		x	
C1587'6"	Outer shelf							x																		
C1602'6"	Outer shelf							x														x				
C1664'9"	Reef						x																			
C1710'8"	Outer shelf/up. slope						x	x			x		x								x	x		x		x
C1745'	Outer shelf/up. slope									x	x		x													
C1781'8"	Outer shelf										x		x													
C1803'4"	Outer shelf	x					x		x		x	x	x													
C1951'	Outer shelf																									
C2136'4"	Outer shelf											x														
C2161'3"	Outer shelf	x						x				x														
C2171'	Outer shelf							x																x		
C2198'6"	Outer shelf																									
C2214'3"	Outer shelf							x					x													

Table 9 (cont.)

indicator, *Amphistegina gibbosa*. From C1602'6" to C1310'3", the taxa indicated an outer-shelf environment. A mid-shelf fauna, indicating the shallowest environment in the core, dominated from C1273'4" to C771'8" and in the uppermost sample at C504'9". The presence of *Cibicides wuellerstorfi* in sample C946'4" was somewhat confusing as it is a deeper water form, which does not fit with the rest of the fauna. Its known depth range is 2,065 to 14,600 ft (630-4,450 m). However, there is at least one reference (Flint, 1897) reporting it as shallow as 150 ft (46 m). Sample C714'1" contained a forereef/outer-shelf fauna and again a few specimens of *Cibicides wuellerstorfi*, seemingly out of place. The fauna from C576'4" to C555'9" indicated a mid-shelf/backreef environment.

Environments in Core UNDA

Table 10 lists the identified taxa and interpreted environments in UNDA (also see Appendix G). Sample U1420'7" contained an inner-shelf fauna that indicated the shallowest environment of deposition in the core, with such species as *Articulina mucronata, Neoconorbina orbicularis* and

UNDA	Depositional Environ.	*Ammonia beccarii tepida*	*Amphistegina gibbosa*	*Anomalina globulosa*	*Archaias angulatus*	*Articulina mucronata*	*Articulina pacifica?*	*Asterigerina carinata*	*Baggina n. sp.*	*Bifarina decorata*	*Bigenerina floridana?*	*Bigenerina irregularis*	*Bolivinita rhomboidalis*	*Brizalina goessi*	*Buccella hannai*	*Bulimina marginata*	*Bulimina spicata?*	*Cancris oblonga*	*Cancris sagra?*	*Cassidulina curvata*	*Cibicides corpulentus*	*Cibicides aff. C. floridanus*	*Cibicides io?*	*Cibicides lobatulus*	*Cibicides protuberans*	*Cibicides spp.*
U288'6"	Mid-shelf			x				x				x							x			x				x
U361'9"	Fore reef/outer shelf		x					x						x								x	x	x	x	x
U393'2"	Back reef/mid-shelf		x		x			x										x								x
U427'10"	Back reef/mid-shelf		x					x													x		x	x		x
U471'5"	Fore reef/outer shelf		x	x				x	x	x			x		x			x		x		x			x	
U499'5"	Fore reef		x					x																		
U549'10"	Fore reef/outer shelf		x					x	x											x		x			x	x
U560'6"	Back reef/mid-shelf		x					x																	x	x
U599'	Back reef/mid-shelf		x					x	x																x	x
U645'6"	Fore reef/outer shelf		x	x																	x				x	x
U687'	Outer shelf	x		x				x	x								x				x				x	x
U742'9"	Fore reef/outer shelf		x					x										x		x	x	x				
U774'6"	Fore reef/outer shelf		x																		x	x	x			x
U830'7"	Upper slope		x					x				x				x		x		x	x		x			
U881'10"	Upper slope																									x
U911'8"	Upper slope		x																		x	x	x			
U969'	Upper slope		x																		x					x
U1119'8"	Back reef/mid-shelf		x						x																	x
U1162'	No data	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U1174'4"	Mid-shelf		x				x	x	x																x	
U1208'8"	Back reef/mid-shelf		x					x	x			x													x	
U1263'5"	Back reef/mid-shelf		x					x												x						x
U1315'3"	Back reef/mid-shelf		x					x				x													x	
U1395'3"	Back reef/mid-shelf		x					x	x		x							x						x	x	x
U1420'7"	Inner shelf		x			x		x																x	x	x

Table 10. Benthonic foraminifera, their occurrence in UNDA, and their depositional environment. Core intervals in ft and in.

UNDA	Depositional Environ.	*Clavulina tricarinata*	*Cribroelphidium poeyanum*	*Cyclogyra planorbis*	*Discorbis mira*	*Dorothia pseudoturris*	*Dyocibicides biserialis*	*Elphidium advenum*	*Elphidium fimbriatulum*	*Elphidium incertum*	*Elphidium sagrum*	*Elphidium translucens*	*Elphidium spp.*	*Eponides antillarum*	*Eponides regularis*	*Eponides repandus*	*Fissurina spp.*	*Fursenkoina compressa*	*Fursenkoina mexicana*	*Fursenkoina pontoni*	*Globobulimina affinis*	*Globocassidulina subglobosa*	*Globulina gibba*	*Globulina inaequalis*	*Guttulina australis*	*Guttulina laevis*
U288'8"	Mid-shelf																				x					
U361'9"	Fore reef/outer shelf				x			x					x	x		x										
U393'2"	Back reef/mid-shelf															x							x			
U427'10"	Back reef/mid-shelf				x									x									x			
U471'5"	Fore reef/outer shelf		x		x			x	x		x	x					x		x	x		x	x			x
U499'5"	Fore reef															x										
U549'10"	Fore reef/outer shelf															x									x	
U560'6"	Back reef/mid-shelf			x									x	x		x							x			
U599'	Back reef/mid-shelf				x						x					x							x			
U645'6"	Fore reef/outer shelf																									
U687'	Outer shelf						x						x													
U742'9"	Fore reef/outer shelf						x											x				x				
U774'6"	Fore reef/outer shelf																					x				
U830'7"	Upper slope																					x				
U881'10"	Upper slope																									
U911'8"	Upper slope							x																		
U969'	Upper slope							x								x										
U1119'8"	Back reef/mid-shelf							x			x			x		x						x				
U1162'	No data	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U1174'4"	Mid-shelf				x					x	x		x										x	x		
U1208'8"	Back reef/mid-shelf										x												x	x		
U1263'5"	Back reef/mid-shelf															x										
U1315'3"	Back reef/mid-shelf				x	x		x		x	x			x		x							x			
U1395'3"	Back reef/mid-shelf	x									x		x			x								x		
U1420'7"	Inner shelf							x		x					x	x										

Table 10 (cont.)

UNDA	Depositional Environ.	*Gyroidina soldanii altiformis*	*Gypsina vesicularis*	*Hanzawaia strattoni*	*Lenticulina orbicularis*	*Lenticulina spp.*	*Liebusella soldanii*	*Marginulina subaculeata glabrata*	*Marginulina sp.*	*Melonis barleeanum*	*Miliolid spp.*	*Neoconorbina orbicularis*	*Nonion depressulum*	*Nonionella atlantica*	*Nubeculina divaricata*	*Orbiculinoides? sp.*	*Peneroplis carinatus*	*Planulina exorna*	*Planulina depressa*	*Planulina foveolata*	*Planulina spp.*	*Planorbulina mediterranensis*	*Pseudoeponides umbonatus*	*Pseudopolymorphina rutila?*	*Pyrgo elongata*	*Pyrgo subsphaerica*	*Quinqueloculina agglutinans*
U288'8"	Mid-shelf													x				x	x							x	
U361'9"	Fore reef/outer shelf			x						x				x				x					x				
U393'2"	Back reef/mid-shelf																x	x		x			x			x	
U427'10"	Back reef/mid-shelf			x		x						x						x								x	
U471'5"	Fore reef/outer shelf									x				x				x		x						x	
U499'5"	Fore reef													x						x					x	x	
U549'10"	Fore reef/outer shelf	x		x							x			x				x		x		x				x	
U560'6"	Back reef/mid-shelf		x											x						x				x		x	
U599'	Back reef/mid-shelf										x			x				x		x		x					
U645'6"	Fore reef/outer shelf			x				x						x				x		x							
U687'	Outer shelf			x										x				x		x							
U742'9"	Fore reef/outer shelf			x				x						x						x							
U774'6"	Fore reef/outer shelf			x	x	x		x										x		x							
U830'7"	Upper slope		x	x	x		x	x	x	x										x	x						x
U881'10"	Upper slope					x	x													x							
U911'8"	Upper slope	x		x												x				x	x						
U969'	Upper slope	x																			x						
U1119'8"	Back reef/mid-shelf										x	x					x									x	
U1162'	No data	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U1174'4"	Mid-shelf			x								x	x	x													
U1208'8"	Back reef/mid-shelf										x			x					x			x					
U1263'5"	Back reef/mid-shelf																										
U1315'3"	Back reef/mid-shelf			x						x			x	x					x			x					
U1395'3"	Back reef/mid-shelf			x										x	x				x				x		x	x	
U1420'7"	Inner shelf			x								x		x	x			x	x			x			x	x	

Table 10 (cont.)

UNDA	Depositional Environ.	*Quinqueloculina spp.*	*Reophax? spp.*	*Reussella atlantica*	*Rosalina bahamaensis*	*Rosalina bertheloti*	*Rosalina concinna*	*Rosalina floridana*	*Rosalina floridensis*	*Rosalina rosea*	*Rosalina spp.*	*Rotaliid spp.*	*Saracenaria italica*	*Sigmavirgulina tortuosa*	*Sigmoilina distorta*	*Siphonina pulchra*	*Spiroloculina sp.*	*Spiroplectamina? sp.*	*Textularia candeiana*	*Textularia conica*	*Textularia gramen?*	*Textularia mayori*	*Textularia spp.*	*Textulariella barrettii*	*Tretomphalus atlanticus*	*Trifarina bella*	*Trifarina carinata*
U288'8"	Mid-shelf	x			x						x					x											
U361'9"	Fore reef/outer shelf	x		x	x					x		x				x											
U393'2"	Back reef/mid-shelf	x								x	x	x							x				x		x		
U427'10"	Back reef/mid-shelf	x		x	x				x	x	x	x							x				x				
U471'5"	Fore reef/outer shelf			x	x	x			x	x	x			x		x									x	x	
U499'5"	Fore reef										x									x			x				
U549'10"	Fore reef/outer shelf	x		x		x					x	x				x									x		
U560'6"	Back reef/mid-shelf	x		x	x			x				x															
U599'	Back reef/mid-shelf				x			x			x							x									
U645'6"	Fore reef/outer shelf	x		x				x				x						x	x			x			x		
U687'	Outer shelf	x		x	x		x				x	x								x			x				
U742'9"	Fore reef/outer shelf			x		x	x						x		x					x			x				x
U774'6"	Fore reef/outer shelf	x													x	x	x										
U830'7"	Upper slope		x		x							x	x		x			x			x	x	x	x			
U881'10"	Upper slope			x								x															
U911'8"	Upper slope											x				x											x
U969'	Upper slope	x										x								x							
U1119'8"	Back reef/mid-shelf											x				x											
U1162'	No data	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U1174'4"	Mid-shelf								x	x		x													x		
U1208'8"	Back reef/mid-shelf																										
U1263'5"	Back reef/mid-shelf										x	x															
U1315'3"	Back reef/mid-shelf	x		x				x	x		x	x				x											
U1395'3"	Back reef/mid-shelf	x	x	x	x		x			x																	
U1420'7"	Inner shelf	x	x		x		x	x	x																		

Table 10 (cont.)

UNDA	Depositional Environ.	*Triloculina bassensis*	*Triloculina tricarinata*	*Triloculina trigonula*	*Triloculina trigonula multistriata*	*Triloculina spp.*	*Uvigerina? sp.*	*Valvulina? sp.*	*Valvulineria? sp.*	*Carpenteria proteiformis*	*Gaudryina (Pseudogaudryina) atla*
U288'8"	Mid-shelf			x							
U361'9"	Fore reef/outer shelf			x							
U393'2"	Back reef/mid-shelf		x								
U427'10"	Back reef/mid-shelf			x							
U471'5"	Fore reef/outer shelf										
U499'5"	Fore reef			x							
U549'10"	Fore reef/outer shelf										
U560'6"	Back reef/mid-shelf			x							
U599'	Back reef/mid-shelf										
U645'6"	Fore reef/outer shelf										
U687'	Outer shelf								x		
U742'9"	Fore reef/outer shelf										
U774'6"	Fore reef/outer shelf						x				
U830'7"	Upper slope									x	x
U881'10"	Upper slope										
U911'8"	Upper slope										
U969'	Upper slope										
U1119'8"	Back reef/mid-shelf			x							
U1162'	No data	-	-	-	-	-	-	-	-	-	-
U1174'4"	Mid-shelf										
U1208'8"	Back reef/mid-shelf										
U1263'5"	Back reef/mid-shelf					x		x			
U1315'3"	Back reef/mid-shelf										
U1395'3"	Back reef/mid-shelf			x	x	x					
U1420'7"	Inner shelf	x		x							

Table 10 (cont.)

Rosalina concinna, which are normally found on sea grasses. The core interval U1395'3" through U1119'8" contained typical backreef/mid-shelf faunas with the exception of sample U1162', which had a fauna too poorly preserved for specific identifications. Samples U964' through U836'7" contained an upper-slope fauna, indicative of the deepest environment in the core, with such diagnostic species as *Bulimina marginata, Gaudryina (Pseudogaudryina) atlantica, Gyroidina soldanii altiformis, Marginulina subaculeata glabrata* and *Trifarina carinata*. Some fragments similar to the genus *Operculinoides* were found at U911'8". Forereef/outer-shelf faunas dominated from U774'6" through U645'6" with all but sample U687' containing abundant *Amphistegina gibbosa*, which would indicate a forereef habitat. The faunas at U599' and U560'6" indicated backreef/mid-shelf conditions, whereas sample U549'10" contained a fauna indicative of a forereef/outer-shelf environment. The taxa at U499'5" were typically forereef species with the fauna dominated by *Amphistegina gibbosa* and *Asterigerina carinata* along with the forereef indicators *Eponides repandus, Planulina foveolata* and *Textularia* spp. Sample U471'5" contained a forereef/outer-shelf fauna that was dominated by *Amphistegina gibbosa*, but also contained species indicative of deeper water than the mid-shelf fauna. Some of these were *Bolivinita rhomboidalis, Cassidulina curvata, Cibicides* spp. and *Reussella atlantica.* A typical backreef/mid-shelf fauna was found at U427'10" and U393'2". Sample U361'9" contained forereef indicators along with such species as *Melonis barleeanum* and *Pseudoeponides umbonatus,* which, although reported from waters as shallow as 138 ft (42 m), are usually indicative of deeper waters. Thus, this interval was classified as fore reef/outer shelf. At U288'8", the fauna indicated a mid-shelf environment of deposition.

Correlation of the Changing Depositional Environments with the Sea-Level Curve

Depositional environments interpreted based on benthic-foraminifera faunal composition and on lithology can be expressed as "sea-level curves" and compared with the sea-level curve derived for the area of the Great Bahama Bank from the planktonic analyses and seismic facies in Part I (Fig. 6A). As plotted in Figure 7, with the deepest core depth and deepest interpreted environment to the right, the environmental curves are inverse to the sea-level curve. Thus, a rise in sea level will show a deepening environment, whereas a fall will show a shoaling environment. Since no actual depths are assigned to either set of environments, the terms used in Figure 7 and discussed earlier in Part II by environment are relative, not absolute. Percentages are calculated by counting the numbered circles, which represent changes in sea level indicated by the planktonic-analyses and seismic-facies interpretations and which match the illustrative panels in Figure 5A-D, and lettered circles, which represent changes in depositional environment interpreted from the benthic analyses and lithology.

Without careful comparison with (a) the timing of sea-level fluctuations, (b) the changes in and sequence of the foraminiferal zonation, (c) the shelf-margin clinoform morphology, and (d) the presence of sequence boundaries illustrated in Figure 5A-D, the percentages derived from study of the curves alone (Fig. 7) are not real. The interpreted sea-level rise, fall, or stillstand, represented by the black numbered circles on Figure 7, show a 75% correlation of the benthic-

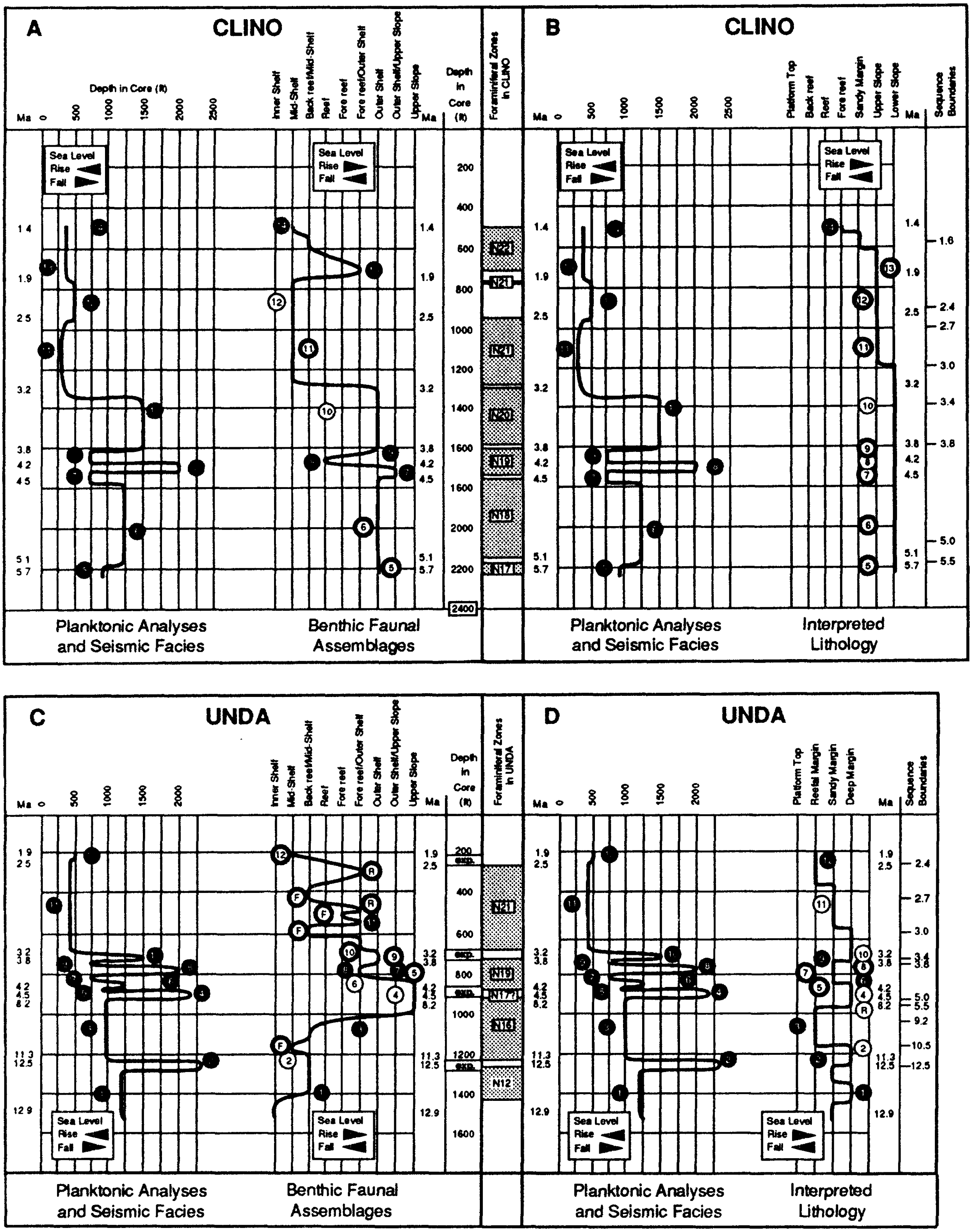

Figure 7. Comparison of depositional-environment "sea-level curves" for CLINO and UNDA interpreted from (A, C) benthic foraminiferal assemblages and (B, D) lithology with sea-level curve derived from planktonic foraminiferal analyses and seismic-profile interpretations. Curves plotted against depth in core. Foraminiferal zones based on planktonic analyses. Note that where the curves correlate, the depositional-environment curves are opposite the curve determined from planktonic analyses and seismic facies. Numbered circles match panels in Figures 5A-D and 6 (Part I) that show fluctuations in sea level through time as determined from foraminiferal zonation and seismic facies. Black circles = data clearly correlate with those of planktonic analyses and seismic facies. Bold-outline circles = data correlate when integrated with data shown in Figure 5A-D. White circles = data apparently do not correlate with those of planktonic analyses and seismic facies. R = sea-level rise interpreted from depositional environment. F = Sea-level fall interpreted from depositional environment. exp. = periods of shelf exposure determined from foraminiferal zonation.

analyses environments with the sea-level curve and a 55% correlation of the lithologic environments in CLINO (Table 11). In UNDA, without further analysis, 63% of the faunal-assemblage and 69% of the lithologic interpretations correlate with the sea-level curve. Both sets of environmental data average to an apparent 65% correlation of the environmental interpretations in CLINO and 66% correlation in UNDA with those derived from the planktonics and seismic profile.

	CLINO			UNDA	
	avg.				avg.
apparent	65%	75%	faunal	63%	66%
		55%	lithologic	66%	
actual	90%	90%	faunal	90%	85.5%
		90%	lithologic	81%	

Table 11. Percentage of correlation of depositional-environment interpretations with those based on planktonic analyses and seismic facies.

These percentages are shown to be low when correlating these data sets with all other information derived from the planktonic analyses and seismic-facies interpretations (Fig. 5A-D). In Figure 7, all environments in curve format that do not appear to correlate with the sea-level curve are indicated by bold or white numbered or lettered circles. Keep in mind that the numbered circles on the curves match the numbered panels in Figure 5A-D and represent changes in sea-level, here called events. In CLINO, the benthic-analyses curve of Figure 7A appears noncorrelative in five places: at events 5, 6, 10, 11, and 12. Events 5 and 6 represent a sea-level rise in late Zone N17 time and a fall that exposed the shelf during N18 time (Fig. 5B). The faunal analyses show no change in environment, however, and indicate that the region of CLINO remained at outer-shelf depths during those times. Examination of the panels numbered 5 and 6 in Figure 5B and calculation of the interpreted lowstand water depth in the area of CLINO shows that the water depth and low-gradient slope were indeed sufficient to maintain what might have been an outer-shelf environment. Therefore, the bold circles numbered 5 and 6 on Figure 7B can be considered black, thereby increasing the benthic-analyses correlation from 75% to 85%.

Within the core interval in CLINO that encompasses events 5 through 9 is a faunal assemblage that is interpreted to indicate reef conditions that may have occurred on the slope during event 8 time (middle N19 time). Study of panel 8 in Figure 5B shows the position of sea level interpreted from the planktonic analyses and seismic facies and indicates that indeed a reefal environment might have existed in the area of CLINO either before or after the lowstand that characterized event 8. Although it is possible that the diagnostic reef taxa could represent downslope transport of material that once formed an inshore reef complex, the onlapping seismic clinoforms suggest otherwise, i.e., that components of a mid-Subzone N19 *in-situ* reef probably became mixed with hemipelagic sediments deposited during early and late N19 time.

Circles 10, 11, and 12 in CLINO (Fig. 7A) represent a sea-level fall during Subzone N20, a rise during *Globorotalia exilis* Subzone N21 and a fall during *G. tosaensis tosaensis* Zone N21 time. No change in environment is indicated by the faunal analyses for event 10 until at the end of N20 time. Examination of the seismic facies in Figure 5C during the N20 lowstand shows that outer-shelf conditions likely did not exist in the area of CLINO, which translates to a white circle for event 10. Using the same approach to decipher whether the environments interpreted for events 11 and 12 are likely to have existed near CLINO during the times of those events, one can determine that a mid-shelf environment is probable for event 11 (= a black circle), but may be questionable for event 12 (white circle) -- questionable because of the 500-ft (150 m) water depth and increasing slope gradient in the region of CLINO, yet a distance of about 2 n. mi (3.75 km) from the lowstand strandline. Thus, at least 90% of the benthic-environment interpretations actually correlates with those derived from the planktonic analyses and seismic facies (Table 11).

The deviations in depositional environments interpreted from lithology are resolved in the same manner as those for the benthic analyses. In CLINO, the interpreted lithology for the bottom half of the core remains unchanged at a lower-slope environment (circles 5-10, Fig. 7B). Examination of the panels in Figure 5B and C indicates that this interpretation is correct for events 5 through 7 and 9 (= black circles), but incorrect for the lowstands depicted for events 8 and 10 (= white circles). For much of the top half of the core, the environment is interpreted to be of upper-slope depths. Comparison of these relative depths with the interpreted sea levels of Figure 5C and D indicates the depositional-environment interpretation is probably correct. Thus, using all four data sets, at least 90% of the depositional environments based on lithology are correlative in CLINO.

Averaging both data sets yields a 90% correlation of all environmental data with the interpretations derived from the planktonic analyses and seismic facies.

Three areas on the benthic-analyses curve for UNDA apparently do not correlate with the other data. The earliest is event 2. Although the curve indicates a fall in sea level occurred during event 2 (bold-circle F on Fig. 7C), the backreef/mid-shelf and mid-shelf interpretations for event 2 time are probably not correct as event 2 represents a lowstand of significant amplitude (Fig. 5A) that exposed the shelf for some 2.5 million years. The next discrepancy is the faunal-analyses interpretation of an upper-slope environment (events 4 and 6, Fig. 7C) for early N17 and N18 times, which is contraindicated by the planktonics and seismic-facies data that show events 4 and 6 represent periods of shelf exposure (Fig. 5A, B). An upper-slope environment may have been possible during event 5 time, however (Fig. 5B). Although no indications of platform exposure are given by the benthic-faunal interpretations during events 8 and 10 (Subzones mid-N19 and N20), the number 8 and 10 circles are bold because the benthic-analyses interpretations do indicate that a shallowing occurred at those times, which agrees with the data shown on the sea-level curve.

The last series of questionable interpreted changes in environment occurred during event 11 (*Globorotalia exilis* N21 time). Event 11 was a sea-level rise that flooded the shelf (Fig. 5C). After initial shallow backreef/mid-shelf conditions, five alternating environments (from deep forereef/outer shelf, to shallow forereef, and back to deep forereef/outer shelf, then shallow backreef/mid-shelf, and finally to deep outer shelf/upper slope) are indicated by the faunal analyses to have occurred during the 0.7-million-year duration of *G. exilis* time. Examination of the interpreted seismic facies, alternating onlapping and offlapping clinothem morphology, and interpreted water depths for event 11 in Figure 5C indicates that these various environments could have existed. Therefore, the Rs and Fs on Figure 7C are in bold circles (= black), and the circled 11 is black. If true, this episode of multiple fluctuations in sea level occurring in such a relatively short time might not just be a precursor to the increased sea-level frequency noted by Beach and Ginsburg (1980) to have occurred during the late Pliocene and Pleistocene, but instead may be an extension of it. If so, the timing of onset of such increased frequency should be revised to the late middle Pliocene.

Event 12 (late Pliocene *G. tosaensis tosaensis* Zone N12 of 0.6-million-year duration), also showing at least two fluctuations on the interpreted seismic facies (although only a single sample was obtained for analyses and therefore only one environment was determined), is also in a bold circle, because the benthic fauna does indicate a fall in sea level, although no shelf exposure. Thus, recalculation of the correlation percentage of the interpreted depositional environments in UNDA, based on benthic analyses, yields a 90% correlation between all data (Table 11).

Periods of platform exposure also are not evident based on interpreted lithology in UNDA, although falls in sea level are indicated for those times (Fig. 7D). The earliest deviation from indications of the other data occurs in event 2 time, when the shelf was exposed (Fig. 5A). The interpreted lithology indicates deep-margin conditions for the shelf at that time, which were unlikely. At the end of event 3 time and into event 4 time, the lithology indicates a rise in sea level, also unlikely as all other data indicate the shelf was again exposed (Fig. 5A). Numbers 5, 7, and 8 are in bold circles because they match indications for two sea-level rises and a fall, respectively, also shown by the other data (Fig. 5B), but are slightly "off" in time in their position on the lithology curve. Events 10 and 11 clearly do not match the fall and rise, respectively, indicated by the other data (Fig. 5C) and remain as white circles. Thus, recalculation of the correlation percentage for the lithologic interpretations yields 81% (Table 11), with an average of both environmental-data sets of 85.5% that matches the same fluctuations at the same core intervals as interpreted from the planktonic analyses and seismic profile.

CONCLUSIONS

The benthonic foraminiferal faunas in CLINO and UNDA reflect changes in sea level. In CLINO the taxa indicate a lengthy stillstand at outer-shelf depths from C2214'3" to C1781'8", a fall in sea level to outer-shelf/upper-slope depths from C1745' through C1710'8", a rise to outer-shelf conditions from 1602'6" to C1310'3", then to another long standstill at mid-shelf depths from C1273'4" to C771'8", a fall to forereef/outer-shelf conditions at C714'1", a rise to backreef/mid-shelf conditions from C576'4" to C555'9" and again to mid-shelf depth in the topmost core sample (C504'9"). The reef-indicator taxa at C1664'9", of Subzone N19 age (event 8), probably represent an *in-situ* reef complex that grew before and after the mid-Subzone N19 lowstand. The deepest (outer-shelf/upper-slope) interval is within the bottom half of the core (C1745'-C1710'8") and the shallowest (mid-shelf) within the top half (C1273'4"-C771'8" and at C504'9"). Changes in the taxa in CLINO show a 90% correlation with the same changes indicated by the planktonic-analyses and seismic-profile interpretations.

In UNDA more fluctuations are noticeable with backreef/mid-shelf, forereef, and forereef/outer-shelf conditions prevailing at all intervals except at U1420'7", U969' through U836'7", at U687' and at U288'8". Sample U1420'7" at the bottom of the core represents the shallowest (inner-shelf) water depth, with the deepest (upper-slope) depth occurring from U969' through U836'7". Outer-shelf conditions prevailed at U687' and mid-shelf conditions at the top of the core (U288'8). The changes in sea level interpreted based on benthic assemblages show a 90% correlation with those based on the planktonic analyses and seismic profile. Thus, in both cores, the majority of the benthic data supports the timing of sedimentation and changes in sea level as determined biostratigraphically.

In UNDA, the interval from U645'6" through U471'5", representing 0.7 million years of *Globorotalia exilis* Subzone N21 time (event 11), contains six alternating changes of environment that correlate with alternating onlapping and offlapping seismic facies. These changes and facies most likely represent an earlier onset (late middle Pliocene) of increased frequency and amplitude in sea-level fluctuation than previously thought (post-middle Pliocene).

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APPENDICES

APPENDIX A

PLANKTONIC FORAMINIFERA FAUNAL LIST

1. Candeina nitida d'Orbigny
2. Globigerina bulloides d'Orbigny
3. Globigerina eamesi Blow
4. Globigerina nepenthes Todd
5. Globigerina venezuelana Hedberg
6. Globigerinita incrusta Akers
7. Globigerinoides bollii Blow
8. Globigerinoides conglobatus canimarensis Bermudez
9. Globigerinoides conglobatus conglobatus (Brady)
10. Globigerinoides elongatus (d'Orbigny)
11. Globigerinoides obliquus extremus Bolli and Bermudez
12. Globigerinoides obliquus obliquus Bolli
13. Globigerinoides ruber (d'Orbigny)
14. Globigerinoides ruber seigliei Bermudez and Bolli
15. Globigerinoides trilobus fistulosus (Schubert)
16. Globigerinoides trilobus sacculiferus (Brady)
17. Globigerinoides trilobus trilobus (Reuss)
18. Globoquadrina altispira altispira (Cushman and Jarvis)
19. Globoquadrina altispira conica Bronnimann and Resig
20. Globoquadrina altispira globosa Bolli
21. Globoquadrina dehiscens (Chapman, Parr, and Collins)
22. Globorotalia acostaensis acostaensis Blow
23. Globorotalia crassaformis crassaformis (Galloway and Wissler)
24. Globorotalia crassaformis oceanica Cushman and Bermudez
25. Globorotalia crassaformis ronda Blow
26. Globorotalia crassaformis cf. viola Blow
27. Globorotalia crassula Cushman and Stewart
28. Globorotalia exilis Blow
29. Globorotalia fohsi robusta Bolli
30. Globorotalia humerosa humerosa Takayanagi and Saito
31. Globorotalia inflata (d'Orbigny)
32. Globorotalia margaritae evoluta Cita
33. Globorotalia margaritae margaritae Bolli and Bermudez
34. Globorotalia mayeri Cushman and Ellisor
35. Globorotalia menardii 'A' Bolli
36. Globorotalia menardii 'B' Bolli
37. Globorotalia menardii cultrata (d'Orbigny)
38. Globorotalia menardii menardii (Parker, Jones, and Brady)
39. Globorotalia merotumida/plesiotumida Banner and Blow
40. Globorotalia miocenica Palmer
41. Globorotalia multicamerata Cushman and Jarvis
42. Globorotalia pertenuis Beard
43. Globorotalia praemenardii Cushman and Stainforth
44. Globorotalia pseudomiocenica Bolli and Bermudez
45. Globorotalia scitula scitula (Brady)
46. Globorotalia tosaensis tenuitheca Blow

47. Globorotalia truncatulinoides truncatulinoides (d'Orbigny)
48. Globorotalia tumida flexuosa (Koch)
49. Globorotalia tumida tumida (Brady)
50. Hastigerina pelagica (d'Orbigny)
51. Hastigerina siphonifera (d'Orbigny)
52. Neogloboquadrina dutertrei (d'Orbigny)
53. Orbulina bilobata (d'Orbigny)
54. Orbulina suturalis Bronnimann
55. Orbulina universa d'Orbigny
56. Polyperibola christiani Liska
57. Pulleniatina obliquiloculata finalis Banner and Blow
58. Pulleniatina obliquiloculata obliquiloculata (Parker and Jones)
59. Pulleniatina obliquiloculata primalis Banner and Blow
60. Sphaeroidinella dehiscens (Parker and Jones)
61. Sphaeroidinellopsis hancocki Bandy
62. Sphaeroidinellopsis multiloba (LeRoy)
63. Sphaeroidinellopsis seminulina (Schwager)
64. Sphaeroidinellopsis sphaeroides Lamb
65. Turborotalia humilis (Brady)

APPENDIX B

PLANKTONIC FORAMINIFERAL BIOSTRATIGRAPHY: CLINO

The numbers in parenthesis preceding the core intervals refer to the numbered core interval and its corresponding assigned, numbered, foraminiferal zone shown in the summary in Table 1.

(1) Sample Interval C504'9"-C714'1"

Lithology: Units 8 (Halimeda-bearing sand), 9 (plant-bearing skeletal sand), and 10 (mudstone)

Environment: Hemipelagic

Zone: ***Globorotalia truncatulinoides truncatulinoides*** **Zone,** ***Globorotalia crassaformis viola*** **Subzone (N22, lower part).** The subzone is defined by Bolli and Saunders (1985) as:

> "Category: Interval zone
>
> Age: Pleistocene
>
> Author: Bolli and Premoli Silva (1973)
>
> Definition: Interval with subzonal marker, from first occurrence of *Globorotalia truncatulinoides truncatulinoides* to first occurrence of *G. crassaformis hessi.*
>
> Remarks: *Globorotalia tosaensis tosaensis* and *G. tosaensis tenuitheca* disappear within the subzone and *G. crassaformis* cf. *viola* together with the zonal marker at the top."

Interpretation: Sediments from the 209-ft-thick (63.7 m) core interval belong to the earliest Pleistocene *Globorotalia crassaformis viola* Subzone N22 based on the occurrence of the zonal marker and absence of *Globorotalia crassaformis hessi* (Table 2). The age is supported by the presence of *Pulleniatina obliquiloculata finalis,* whose first occurrence datum is at the base of the zone (Table 4). Neither the subzonal marker nor the subspecies of *G. tosaensis* was identified.

A dextral coiling direction for the *Pulleniatina* group and sinistral direction for the *G. acostaensis* group (Tables 3, 12) are consistent with those for the groups during the Pleistocene.

CLINO	Biostratig. Age	Menardiform Grp*	Gr. crassaformis Grp	Gr. acostaensis Grp	Pulleniatina Spp
C504'9"	N22 crassa. viola				
C555'9"	N22 crassa. viola			Sinistral	
C576'4"	N22 crassa. viola				Dextral
C714'1"	N22 crassa. viola				Dextral
C771'8"	N21 tos. tosaensis				Dextral
C834'9"	No data	------	------	------	------
C946'4"	N21 exilis	1 Sinist., 1 Dextral	Sinistral	Dextral	Dextral
C984'9"	N21 exilis	Sinistral	Sinistral	Dextral	
C1042'8"	N21 exilis	Sinistral			
C1110'	N21 exilis	Sinistral		Dextral	Dextral
C1121'	No data	------	------	------	------
C1215'2"	N21 exilis	Sinistral	Dextral	Dextral	
C1273'4"	N21 exilis				
C1310'3"	N20 tril. fistulosus		Sinistral	Dextral	
C1445'6"	N20 tril. fistulosus		Sinistral		
C1468'9"	N20 tril. fistulosus				
C1567'5"	N20 tril. fistulosus				Dextral
C1587'6"	N20 tril. fistulosus		Sinistral	Dextral	Dextral
C1587'6"	N20 tril. fistulosus	Dextral	Sinistral		
C1602'6"	N19 marg. evoluta		Predom. Sinistral	Dextral	Dextral
C1664'9"	N19 marg. evoluta	1 Sinist., 1 Dextral		Dextral	
C1710'5"	N19 marg. evoluta	Dextral	Predom. Dextral	Dextral	
C1710'8"	N19 marg. evoluta	Dextral	Predom. Sinistral	Dextral	
C1731'	N19 marg. evoluta	Dextral	Predom. Dextral	Predom. Dextral	
C1745'	N19 marg. evoluta	Predom. Dextral	Predom. Dextral	Dextral	
C1776'	N18 marg. marg.	Sinistral		Sinistral	
C1778'	N18 marg. marg.	Sinistral		Sinistral	
C1781'8"	N18 marg. marg.	Sinistral		Sinistral	
C1803'4"	N18 marg. marg.	Predom. Sinistral		Sinistral	
C1804'2"	N18 marg. marg.	Sinistral		Predom. Sinistral	
C1870'3"	N18 marg. marg.	Sinistral			
C1891'5"	N18 marg. marg.	Sinistral		Sinistral	
C1899'5"	N18 marg. marg.	Sinistral			
C1951'	N18 marg. marg.	Sinistral		Sinistral	
C2083'	N18 marg. marg.	Sinistral		Sinistral	
C2136'4"	N18 marg. marg.	Sinistral		Sinistral	
C2161'3"	N17 humerosa	Sinistral		Sinistral	
C2171'	N17 humerosa	Predom. Sinistral		Sinistral	
C2198'6"	No data	------	------	------	------
C2214'3"	N17 humerosa	Sinistral		Predom. Sinistral	

Table 12. Coiling direction of significant planktonic foraminiferal groups in CLINO. *Excludes *Globorotalia tumida tumida*.

The age range given by Bolli and Saunders (1985, p. 163) for *Globorotalia crassaformis viola* Subzone N22 (~1.9-1.4 Ma) correlates with the 1.6-Ma age given by Haq *et al.* (1988) for the global sequence boundary that matches the one in this core interval in CLINO (Fig. 1).

(2) Sample C771'8"

Lithology: Unit 11 (graded sand and mudstone)

Environment: Hemipelagic

Zone: *Globorotalia tosaensis tosaensis* Zone (N21, upper part)

"Category: Interval zone

Age: Late Pliocene

Author: Bolli (1970), renamed in Bolli and Saunders (1985)

Definition: Interval with zonal marker, from extinction of *Globorotalia miocenica/G. exilis* to first occurrence of *G. truncatulinoides truncatulinoides.*

Remarks: The zonal marker is often not typically developed or may be very rare or even absent, as is the case in many of the investigated sections in the Caribbean region. Identification of the zone then rests largely on negative criteria, that is on the absence of *G. miocenica, G. exilis,* and *G. truncatulinoides truncatulinoides.*"

Interpretation: Sediments in the core interval belong to the Late Pliocene *Globorotalia tosaensis tosaensis* Zone N21 based on the absence of the zonal marker, *G. miocenica, G. exilis,* and *G. truncatulinoides truncatulinoides.*

Direction of coil for the *Pulleniatina* group fluctuates in the late Pliocene and therefore is non-indicative.

The age range given by Bolli and Saunders (1985) for *Globorotalia tosaensis tosaensis* Zone N21 (~2.5-1.9 Ma) correlates with the 2.4-Ma age given by Haq *et al.* (1988) for the global sequence boundary that matches the one in this core interval in CLINO.

Sample C834'9" - No Data

Lithology: Unit 11 (graded sand and mudstone)

Comments: The material was composed of angular fragments, completely altered to sparry calcite and coated with limestone matrix. Benthics were picked solely based on suggestive shape. Miliolids appeared to be abundant and planktonics appeared to be absent. It is doubtful identification to genus could be made.

(3) Sample Interval C946'4"-C1273'4"

Lithology: Units 13A (foraminiferal packstone to wackestone) and 13B (skeletal packstone to grainstone)

Environment: Hemipelagic

Zone: *Globorotalia miocenica* Zone, *Globorotalia exilis* Subzone (N21, lower part)

"Category: Interval zone

Age: Middle Pliocene

Author: Bolli & Premoli Silva (1973)

Definition: Interval with zonal marker, from extinction of *Globigerinoides trilobus fistulosus* to extinction of *Globorotalia miocenica* or *G. exilis.*

Remarks: The subzonal marker may extend slightly above *Globorotalia miocenica*, which is usually fairly common up to the point of its extinction while *G. exilis* becomes scarce, in particular when it is found above *G. miocenica. G. crassaformis viola* appears at the base of the subzone and *Globigerinoides obliquus extremus* last occurs within it."

Interpretation: Sediments of the 327-ft-thick (99.7 m) core interval belong to the late middle Pliocene *Globorotalia exilis* Subzone based on the occurrence of the subzonal marker. The age is supported by absence of the distinctive *Globigerinoides trilobus fistulosus*, whose extinction datum occurs at the top of Zone N20. The zonal marker, *Globorotalia crassaformis viola,* and *Globigerinoides obliquus extremus* were not identified.

A predominantly sinistral coiling direction for the *G. crassaformis* group is consistent with the group's coiling direction in the lower half of Zone N21 (= *G. exilis* Subzone). The dextral direction of coil for the *Pulleniatina* group is consistent with that found by Bolli (pers. commun., 1991) in the uppermost part of the *G. miocenica* Zone (= *G. exilis* Subzone) of DSDP Sites 29 and 31 and in the same stratigraphic position in the Gulf of Mexico. The predominantly sinistral coil for the menardiform group is inconsistent with the direction of coil for the group during this time interval and may indicate downhole mixing of sediments. According to Bolli (pers. commun., 1991), however, coiling change from sinistral to dextral in the menardiform group has to be checked in type sections available and thus should not be used as a criterion for biostratigraphic dating of this subzone. A dextral direction of coil for the *G. acostaensis* group may or may not be consistent for the group during Subzone N21 time; the direction is mainly sinistral in the Caribbean but with occasional excursions to random or dextral. Timing of these excursions has not been associated with a foraminiferal zone. Direction of coil is insignificant for the *Pulleniatina* group as it fluctuates throughout Zone N21 time.

The age range given by Bolli and Saunders (1985) for *Globorotalia exilis* Subzone N21 (~3.2-2.5) correlates with the 3.0- and 2.7-Ma ages given by Haq *et al.* (1988) for the global sequence boundary and downlap surface, respectively, that match those in this core interval in CLINO.

(4) Sample Interval C1310'3"-C1587'6"

Lithology: Units 13B (skeletal packstone to grainstone), 14 (fractured mudstone), and 15 (fine-grained foraminiferal packstone to mudstone)

Environment: Hemipelagic

Zone: *Globorotalia miocenica* Zone, *Globigerinoides trilobus fistulosus* Subzone N20

"Category: Interval zone

Age: Middle Pliocene

Author: Bolli and Premoli Silva (1973)

Definition: Interval with subzonal marker, between last occurrence of *Globorotalia margaritae evoluta* and last occurrence of the subzonal marker.

Remarks: *Globorotalia inflata* first appears within the subzone while *G. multicamerata* last occurs within it. *Globorotalia pertenuis, Globoquadrina altispira altispira*, and *G. altispira conica* last occur at or near the top of the zone, at about the level of extinction of the zonal marker."

Interpretation: Sediments of the 278-ft-thick (84.7 m) core interval belong to the early middle Pliocene *Globigerinoides trilobus fistulosus* Subzone N20 based on the occurrence of the zonal and subzonal markers; the extinction datum of the latter occurs at the top of the subzone. A Subzone N20 age is supported by the absence of the large and distinctive *Sphaeroidinellopsis hancocki*, whose extinction datum occurs within Subzone N19. *Globorotalia multicamerata, G. pertenuis, G. inflata, Globoquadrina altispira altispira,* and *G. altispira conica* were not identified.

A predominantly dextral direction of coil for the menardiform group and a sinistral direction for the *G. crassaformis* group are consistent with an early middle Pliocene age. A dextral direction of coil for the *G. acostaensis* group may or may not be consistent for the group during Subzone N20 time; the direction is mainly sinistral in the Caribbean but with occasional excursions to random or dextral. Timing of these excursions has not been associated with a foraminiferal zone. The *Pulleniatina* specimens are probably contaminants from overlying younger sediments. The *Pulleniatina* group does not occur in the Atlantic province from within the top of the *Globorotalia margaritae evoluta* Subzone N19 to within the top of the *Globorotalia exilis* Subzone N21.

The age range given by Bolli and Saunders (1985) for *Globigerinoides trilobus fistulosus* Subzone N20 (~3.8-3.2 Ma) correlates with the 3.4-Ma age given by Haq *et al.* (1988) for the global downlap boundary that matches the one in this core interval in CLINO.

(5) Sample Interval C1602'6"-C1731'

Lithology: Units 16 (foraminiferal coarse sand with lithoclasts) and 17 (foraminiferal packstone to grainstone)

Environment: Hemipelagic

Zone: *Globorotalia margaritae* Zone, *Globorotalia margaritae evoluta* Subzone N19

"Category: Taxon range zone

Age: Early Pliocene

Author: Cita (1973)

Definition: Range of zonal marker, from its development from *Globorotalia margaritae margaritae* to its extinction.

Remarks: Together with the presence of the nominate subspecies, the following events characterize the subzone: at or near the base appears *Globorotalia crassaformis crassaformis*, within the subzone appear *G. miocenica* and *G. exilis* (both mainly in the Atlantic realm), *G. crassaformis* cf. *viola, Globigerinoides trilobus fistulosus, Sphaeroidinella dehiscens*, and *Pulleniatina spectabilis* (restricted to upper part of the subzone in the Pacific realm). *Globigerina venezuelana* and *G. nepenthes* become extinct at or near the top of the subzone."

Interpretation: Sediments of the 128-ft-thick (39.0 m) core interval belong to the uppermost early Pliocene *Globorotalia margaritae evoluta* Subzone N19 based on the presence of the zonal and subzonal markers along with *Globorotalia crassaformis crassaformis, G. miocenica, G. exilis, G. crassaformis* cf. *viola, Globigerinoides trilobus fistulosus, Globigerina venezuelana, Sphaeroidinella dehiscens*, and *Globigerinoides ruber,* a species that is extinct from the middle middle Miocene to early Pliocene when it reappears within Subzone N18. A Subzone N19 age is supported by the presence of *Globigerinoides obliquus obliquus, Globorotalia menardii 'B', G. pseudomiocenica, G. merotumida/plesiotumida, Sphaeroidinellopsis sphaeroides*, and *S. hancocki*, whose first occurrence datums occur at the base of, or within, Subzone N19. *Globigerina* *nepenthes* was not identified. A single specimen of *Globorotalia inflata* is a downhole contaminant. Most of the species identified range across the Miocene/Pliocene (N17/N18) boundary and into Subzone N19. Thus, based on the planktonic species identified from this core interval, the sediments could belong to Subzone N19, Subzone N18 or Zone N17. The presence of *G. ruber*, however, supports a Subzone N19 or N18 age.

A predominantly dextral coiling direction for the menardiform, *Pulleniatina*, and *G. crassaformis* groups is consistent with those of the species for the time represented by the upper half of Subzone N19, thus constraining the age to that zone. A predominantly dextral direction of coil in the *G. acostaensis* group may or may not be consistent for the group during Subzone N19 time; the direction is mainly sinistral in the Caribbean but with occasional excursions to random or dextral. Timing of these excursions has not been associated with a foraminiferal zone.

The age range given by Bolli and Saunders (1985) for *Globorotalia margaritae evoluta* Subzone N19 (~4.5-3.8 Ma) correlates with the 3.8-Ma age given by Haq *et al.* (1988) for the global sequence boundary that matches the one in this core interval in CLINO, thus supporting a Subzone N19 age.

(6) Sample Interval C1745'-C2136'4"

Lithology: Unit 17 (foraminiferal packstone to grainstone)

Environment: Hemipelagic

Zone: *Globorotalia margaritae* Zone, *Globorotalia margaritae margaritae* Subzone N18

"Category: Lineage zone

Age: Early Pliocene

Author: Cita (1973), redefined by Bolli and Premoli Silva (1973)

Definition: Interval with zonal marker, from first occurrence of *Globorotalia margaritae* s.l. (sensu lato) to the first occurrence of *G. margaritae evoluta*.

Remarks: At the base of the subzone, approximately at the level of the first occurrence of *Globorotalia margaritae* s.l., appear the following characteristic taxa: *G. crassaformis* s.l., *G. pertenuis* (Atlantic realm), *G. tumida tumida* (mainly in the Pacific realm), *Neogloboquadrina dutertrei, Globigerinoides conglobatus* and *Sphaeroidinellopsis hancocki.* Within the subzone appear *Globorotalia multicamerata* (Atlantic realm), *G.* cf. *bononiensis, Pulleniatina primalis* (Atlantic realm) and *P. praespectabilis* (Pacific realm). *Globoquadrina dehiscens* s.l. becomes extinct at about the upper boundary of the subzone."

Interpretation: Sediments of the 391-ft-thick (119.2 m) interval are assignable to *Globorotalia margaritae margaritae* Subzone N18 based on the presence of the subzonal marker, *G. pertenuis, G. menardii cultrata, Globigerinoides conglobatus* subspecies, *G. ruber,* and *Hastigerina pelagica,* whose first occurrence datums are at the base of, or within, Subzone N18, and *Globigerina eamesi, Globoquadrina dehiscens, Globorotalia menardii 'A',* and *Globigerinoides ruber seigliei,* whose extinction datums are at the top of the subzone. *Globorotalia margaritae evoluta, G. multicamerata, G.* cf. *bononiensis, G. crassaformis* s.l., *Neogloboquadrina dutertrei, Sphaeroidinellopsis hancocki,* and *Pulleniatina primalis* were not identified.

The sinistral coiling direction for the menardiform group is inconsistent with that for the group in the earliest Pliocene and points to a slightly older age (basalmost *G. margaritae margaritae* Subzone N18 or *G. humerosa* Zone N17). However, according to Bolli (pers. commun., 1991), the coiling change of the menardiform group from sinistral to dextral has to be checked in type sections available and thus should not be relied upon as an age indicator for this time. A predominantly sinistral direction for the *G. acostaensis* group may or may not be consistent for the group during Subzone N18 time; the direction is mainly sinistral in the Caribbean but with occasional excursions to random or dextral. Timing of these excursions has not been associated with a foraminiferal zone. Coiling direction for this species is irregular in the lower half of the *G. margaritae margaritae* Subzone and throughout the *G. humerosa* Zone.

The age range given by Bolli and Saunders (1985) for *Globorotalia margaritae margaritae* Subzone N18 (~5.1-4.5 Ma) correlates with the 5.0-Ma age, as adjusted upward, given by Haq *et al.* (1988) for the global downlap-surface boundary that matches the one in this core interval in CLINO. An upward adjustment of Miocene boundary ages was made to accommodate the presence of mid-Miocene species *(Globorotalia mayeri, G. fohsi robusta, G. praemenardii, and Globigerinoides ruber)* at the bottom of UNDA and resulted in discovery of the apparent absence of the 4.2-Ma sequence and 4.0-Ma downlap-surface boundaries in both cores (Fig. 1).

(7) Sample Interval C2161'3"-C2214'3"

Lithology: Unit 17 (foraminiferal packstone to grainstone)

Environment: Hemipelagic

Zone: ***Globorotalia humerosa*** **Zone N17**

"Category: Interval zone

Age: Late Miocene

Author: Bolli and Bermudez (1965), renamed in Bolli and Saunders (1985)

Definition: Interval with zonal marker, from its first occurrence to first occurrence of *Globorotalia margaritae* s.l.

Remarks: Developing from *Globorotalia acostaensis, G. humerosa* appears first at the base of the zone to continue throughout the zone, with typical *Neogloboquadrina dutertrei* developing from it only in the *Globorotalia margaritae* Zone. The zone marks the beginning of an explosive appearance of new taxa that becomes even more spectacular in the Early Pliocene. Along with the zonal marker, the following diagnostic taxa appear at about the base of the zone: *Globigerinoides obliquus extremus* and *Sphaeroidinellopsis seminulina*. Within the zone appear *Globorotalia merotumida/plesiotumida, G. pseudomiocenica, G. pseudopima, Sphaeroidinellopsis sphaeroides, Pulleniatina primalis* (Pacific realm) and *Candeina nitida*.

Sphaeroidinellopsis disjuncta and *Globorotaloides variabilis* disappear at or near the top of the zone."

Interpretation: The zonal marker was identified. The age of this 51-ft-thick (15.5 m) core interval is supported by the presence of *Globigerinoides obliquus extremus, Sphaeroidinellopsis seminulina, Globorotalia merotumida/plesiotumida,* and *Candeina nitida* and absence of *Neogloboquadrina dutertrei. Globorotalia pseudomiocenica, G. pseudopima, Sphaeroidinellopsis sphaeroides, S. disjunta,* and *Globorotaloides variabilis* were not identified.

Coiling directions of the menardiform and *G. acostaensis* groups cannot be used as criteria for dating sediments in the late Miocene. The direction fluctuates in the former and is irregular in the latter.

The age range given by Bolli and Saunders (1985) for *Globorotalia humerosa* Zone N17 (~8.2-5.1 Ma) correlates with the 5.5-Ma age, as adjusted upward, given by Haq *et al.* (1988) for the global sequence boundary that matches the one in this core interval in CLINO.

APPENDIX C

PLANKTONIC FORAMINIFERAL BIOSTRATIGRAPHY: UNDA

The numbers in parenthesis preceding the core intervals refer to the numbered core interval and its corresponding numbered, assigned foraminiferal zone shown in the summary in Table 2.

(1) Sample Interval U288'8"-U687'

Lithology: Units 4 (coral-bearing packstone and grainstone) and 5A (skeletal grainstone-packstone)

Environment: Hemipelagic

Zone: *Globorotalia miocenica* Zone, *Globorotalia exilis* Subzone (N21, lower part; see subzonal definition for core interval 3 in CLINO)

Interpretation: Sediments from the 398-ft-thick (121.3 m) core interval belong to late middle Pliocene *Globorotalia exilis* Subzone N21 based on the presence of the zonal marker, *Globorotalia miocenica* (Table 3). Although the subzonal marker was not identified, a *Globorotalia exilis* Subzone N21 age is supported by the occurrence of *Pulleniatina obliquiloculata primalis, Globorotalia tosaensis tenuitheca,* and *Globigerinoides obliquus extremus*, whose extinction datums occur within the subzone; absence of *Pulleniatina obliquiloculata obliquiloculata*, whose first occurrence is at the base of the late Pliocene *Globorotalia tosaensis tosaensis* Zone N21; and absence of the *Globoquadrina altispira* complex, *Sphaeroidinellopsis seminulina, Globorotalia pertenuis, G. pseudomiocenica*, and *Globigerinoides trilobus fistulosus*, whose extinction datums occur before onset of *Globorotalia exilis* time (Table 4). *Globorotalia crassaformis viola*, whose first occurrence datum is at the base of the subzone, was not identified.

A predominantly dextral coiling direction for the menardiform group and predominantly sinistral direction for the *G. crassaformis* group are consistent with those in the groups for a *Globorotalia exilis* Subzone age (Tables 3, 13). A predominantly dextral direction of coil for the *G. acostaensis* group matches that of the group for the interval in CLINO assigned to the *G. exilis* Subzone but may or may not be consistent for the group during Subzone N21 time; the direction

UNDA	Biostratig. Age	Menardiform Grp*	Gr. crassaformis Grp	Gr. acostaensis Grp	Pulleniatina Spp
U288'8"	N21 exilis	1 Sinist., 1 Dextral		Dextral	
U361'9"	N21 exilis			Dextral	
U393'2"	N21 exilis			Dextral	Dextral
U427'10"	N21 exilis			Sinistral	
U471'5"	N21 exilis		1 Sinist., 1 Dextral	Dextral	
U499'5"	N21 exilis	Dextral		Dextral	
U549'10"	N21 exilis	Dextral	Sinistral	Dextral	
U560'6"	N21 exilis				
U599'	N21 exilis				
U645'6"	N21 exilis	Predom. Dextral	Sinistral	Dextral	
U687'	N21 exilis	Dextral			
U742'9"	N19 marg. evoluta	Dextral	Sinistral	Dextral	
U774'6"	N19 marg. evoluta	Dextral		Dextral	
U830'7"	N19 marg. evoluta	Predom. Dextral		Predom. Sinistral	Dextral
U881'10"	No data	------	------	------	------
U911'8"	N16 acostaensis	Dextral			
U940'3"	No data	------	------	------	------
U969'	N16 acostaensis				
U1094'	No data	------	------	------	------
U1119'8"	N16 acostaensis				
U1162'	No data	------	------	------	------
U1174'4"	N16 acostaensis				
U1208'8"	N16 acostaensis	Predom. Sinistral			
U1263'5"	N12 fohsi robusta	Sinistral			
U1315'3"	N12 fohsi robusta	Sinistral			
U1395'3"	N12 fohsi robusta	Sinistral			
U1420'7"	N12 fohsi robusta	Sinistral			

Table 13. Coiling direction of significant planktonic groups in UNDA. *Excludes *Globorotalia tumida tumida.*

is mainly sinistral in the Caribbean but with occasional excursions to random or dextral. Timing of these excursions has not been associated with a foraminiferal zone. Direction of coil is insignificant for the *Pulleniatina* group as it fluctuates throughout Subzone and Zone N21 time.

The age range given by Bolli and Saunders (1985) for *Globorotalia exilis* Subzone N21 (~3.2-2.5 Ma) correlates with the 3.0-Ma sequence boundary age given by Haq *et al.* (1988) for the global sequence boundary that matches the one in the top of this core interval in UNDA (Fig. 1).

(2) Sample Interval U742'9"-U830'7"

Lithology: Units 5A (skeletal grainstone-packstone) and 5B (skeletal grainstone-packstone)

Environment: Hemipelagic

Zone: *Globorotalia margaritae* Zone, *Globorotalia margaritae evoluta* Subzone N19 (see subzonal definition for core interval 5 under CLINO)

Interpretation: Neither the zonal nor subzonal markers were identified. Sediments of the 94-ft-thick (28.7 m) core interval belong to the late early Pliocene *Globorotalia margaritae evoluta* Subzone N19 based on the coeval occurrence of *Globoquadrina altispira globosa, Globigerina venezuelana, Sphaeroidinellopsis multiloba, Globorotalia menardii 'B', G. pseudomiocenica, G. merotumida/plesiotumida, Globigerinoides conglobatus canimarensis,* and *G. obliquus obliquus,* all of whose extinction datums occur at or near the top of the subzone. *Globorotalia crassaformis crassaformis, G. crassaformis* cf. *viola, G. exilis, Globigerinoides trilobus fistulosus,* and *Sphaeroidinella dehiscens*, which appear within the subzone, and *Globigerina nepenthes*, which disappears at or near the top of the subzone, were not identified.

A predominantly dextral coiling direction for the menardiform and *Pulleniatina* groups and sinistral direction for the *G. crassaformis* group are consistent with those for the groups in the time interval represented by Subzone N19. A dextral direction for the *G. acostaensis* group matches that of the group in sediments in CLINO assigned to Subzone N19 age and may or may not be consistent for the group during Subzone N19 time; the direction is mainly sinistral in the Caribbean but with occasional excursions to random or dextral. Timing of these excursions has not been associated with a foraminiferal zone.

The age range given by Bolli and Saunders (1985) for *Globorotalia margaritae evoluta* Subzone N19 (~4.5-3.8 Ma) correlates with the 3.8-Ma age given by Haq *et al.* (1988) for the global sequence boundary that matches the one in this core interval in UNDA.

Sample U881'10" - No Data

Lithology: Unit 5B (skeletal grainstone-packstone)

Comments: Sample material was heavily replaced with crystallized sparry calcite and was not picked. Most components could not be identified as to origin.

(3) Sample Interval U911'8"-U1208'8"

Lithology: Units 5B (skeletal grainstone-packstone), 6 (alternation of wackestone and dolomitized coral rudstone, 7 (skeletal grainstone-packstone with coral and laminated crusts) and 8 (skeletal to non-skeletal packstone with benthic foraminifera)

Environment: Hemipelagic

Zone: *Globorotalia acostaensis* Zone N16

"Category: Interval zone

Age: Late Miocene

Author: Bolli and Bermudez (1965)

Definition: Interval with zonal marker, from its first occurrence to first occurrence of *Globorotalia humerosa*.

Remarks: The lower and upper boundaries of the zone are not always easy to determine. Early *Globorotalia acostaensis* as, for example, those present in the basal part of the zone in Bodjonegoro-1 of Java, are somewhat atypical in that they possess only 4 chambers in the last whorl compared with 5 in the holotype. The upper boundary of the zone is based on the first occurrence of *G. humerosa*, which gradually evolves from *G. acostaensis*; this makes the placing of the boundary somewhat subjective. Where conditions are favorable, *Globorotalia juanai* and *Polyperibola christiani* may be present in the zone, at least in the Atlantic province."

Interpretation: The 297-ft-thick (90.5 m) core interval was inferred to be of *Globorotalia acostaensis* Zone N16 age based on the 10.5-Ma age, as adjusted upward, of the major global sequence boundary that cuts the interval. The zonal marker species was not identified. A Zone N16 age is supported by the presence of *Polyperibola christiani.* *Globorotalia juanai* was not identified.

Coiling direction of the menardiform group fluctuates in Zone N16 time and thus cannot be used as a criterion for age identification.

The age range given by Bolli and Saunders (1985) for *Globorotalia acostaensis* Zone N16 (~11.3-8.2 Ma) correlates with the 10.5-Ma age, as adjusted upward, given by Haq *et al.* (1988) for the global sequence boundary that matches the one in this core interval in UNDA.

(4) Sample Interval U1263'5"-U1420'7"

Lithology: Units 8 (skeletal to non-skeletal packstone with benthic foraminifera) and 9 (skeletal to non-skeletal wackestone and packstone)

Environment: Hemipelagic

Zone: *Globorotalia fohsi robusta* Zone N12

"Category: Taxon range zone

Age: Middle Miocene

Author: Bolli (1957)

Definition: Range of zonal marker.

Remarks: The only characteristic event in addition to the presence of the marker throughout the zone is the appearance of larger sized *Sphaeroidinellopsis multiloba* with up to 5 chambers in the last whorl."

Interpretation: Sediments in this 158-ft-thick (48.2 m) core interval are assignable to middle middle Miocene Zone N12 based on the presence of the nominate taxon and zonal marker *Globorotalia fohsi robusta.* A Zone N12 age is supported by the presence of *G. praemenardii* and the large 5-chambered *Sphaeroidinellopsis multiloba.*

A sinistral coiling direction for the menardiform group is consistent with that for the group in the upper half of Zone N12.

The age given by Bolli and Saunders (1985) for the top of Zone N12 (~12.5 Ma) matches precisely that given by Haq *et al.* (1988) for the age, as adjusted upward, of the global sequence boundary that cuts this core interval in UNDA.

APPENDIX D

BENTHONIC FORAMINIFERA FAUNAL LIST

1. Ammonia beccarii (Linne) tepida (Cushman)
2. Ammonia translucens (Phleger and Parker)
3. Amphistegina gibbosa d'Orbigny
4. Anomalina globulosa Chapmann and Parr
5. Archaias angulatus (Fichtel and Moll)
6. Articulina lineata Brady
7. Articulina mucronata (d'Orbigny)
8. Articulina pacifica? (Cushman)
9. Astacolus crepidulus (Fichtel and Moll)
10. Asterigerina carinata d'Orbigny
11. Baggina n. sp.
12. Bifurina decorata Phleger and Parker
13. Bigenerina floridana Cushman and Ponton
14. Bigenerina irregularis Phleger and Parker
15. Bolivinita rhomboidalis (Millet)
16. Brizalina goesii (Cushman)
17. Brizalina paula (Cushman and Cahill)
18. Brizalina plicatella (Cushman)
19. Buccella hannai (Phleger and Parker)
20. Bulimina inflata Sequenza
21. Bulimina marginata d'Orbigny
22. Bulimina spicata? Phleger and Parker
23. Buliminella curta Cushman
24. Cancris oblonga (Williamson)
25. Cancris sagra (d'Orbigny)
26. Carpenteria proteiformis Goes
27. Cassidulina carinata Silvestri
28. Cassidulina crassa d'Orbigny
29. Cassidulina curvata Phleger and Parker
30. Cassidulina laevigata d'Orbigny
31. Chrysalidinella dimorpha (Brady)
32. Cibicides corpulentus Phleger and Parker
33. Cibicides aff. C. floridanus (Cushman)
34. Cibicides io? Cushman
35. Cibicides lobatulus (Walker and Jacob)
36. Cibicides protuberans Parker
37. Cibicides wuellerstorfi (Schwager)
38. Clavulina tricarinata d'Orbigny
39. Cribroelphidium poeyanum Cushman and Bronnimann
40. Cyclogyra planorbis Schultze
41. Dentalina advena (Cushman)
42. Dentalina communis d'Orbigny
43. Dentalina subsoluta (Cushman)
44. Discorbis mira Cushman
45. Dorothia pseudoturris (Cushman)
46. Dyocibicides biserialis Cushman and Valentine
47. Eggerella bradyi (Cushman)
48. Ehrenbergina trigona Goes
49. Elphidium advenum (Cushman)

50. Elphidium fimbriatulum (Cushman)
51. Elphidium incertum (Williamson)
52. Elphidium sagrum (d'Orbigny)
53. Elphidium translucens Natland
54. Eponides antillarum (d'Orbigny)
55. Eponides regularis Phleger and Parker
56. Eponides repandus (Fichtel and Moll)
57. Fursenkoina complanata (Egger)
58. Fursenkoina compressa (Bailey)
59. Fursenkoina mexicana (Cushman)
60. Fursenkoina pontoni (Cushman)
61. Gaudryina (Pseudogaudryina) atlantica (Bailey)
62. Globobulimina affinis (d'Orbigny)
63. Globocassidulina subglobosa (Brady)
64. Globulina gibba d'Orbigny
65. Globulina inaequalis Reuss
66. Guttulina australis (d'Orbigny)
67. Guttulina hirsuta (Terquem)
68. Guttulina laevis d'Orbigny
69. Gypsina vesicularis (Parker and Jones)
70. Gyroidina orbicularis d'Orbigny
71. Gyroidina soldanii d'Orbigny altiformis R.E. and K.C. Stewart
72. Hanzawaia strattoni (Applin)
73. Karreriella bradyi (Cushman)
74. Lenticulina americana (Cushman)
75. Lenticulina americana (Cushman) spinosa (Cushman)
76. Lenticulina atlantica (Barker)
77. Lenticulina calcar (Linne)
78. Lenticulina orbicularis (d'Orbigny)
79. Liebusella soldanii (Jones and Parker)
80. Marginulina dubia Neugeboren
81. Marginulina subaculeata Cushman
82. Marginulina subaculeata Cushman glabrata Cushman
83. Melonis barleeanum (Williamson)
84. Melonis formosum (Sequenza)
85. Miliolinella subsphaerica (Mantagu)
86. Neoconorbina orbicularis (Terquem)
87. Nodosaria pyrula d'Orbigny
88. Nonion depressulum (Walker and Jacob)
89. Nonionella atlantica Cushman
90. Nonionella pizzarense? Berry
91. Nubeculina divaricata (Brady)
92. Osangularia cultur (Parker and Jones)
93. Peneroplis carinatus d'Orbigny
94. Peneroplis proteus d'Orbigny
95. Planorbulina mediterranensis d'Orbigny
96. Planulina ariminensis d'Orbigny
97. Planulina depressa d'Orbigny
98. Planulina exorna Phleger and Parker
99. Planulina foveolata (Brady)
100. Pseudoeponides umbonatus (Reuss)
101. Pseudonodosaria comatula (Cushman)
102. Pseudopolymorphina rutila? (Cushman)
103. Pyrgo depressa (d'Orbigny)

104. Pyrgo elongata (d'Orbigny)
105. Pyrgo jugosa (Cushman)
106. Pyrgo subsphaerica (d'Orbigny)
107. Pyrgo vespertilio (Schlumberger)
108. Quinqueloculina agglutinans d'Orbigny
109. Quinqueloculina lamarckiana d'Orbigny
110. Quinqueloculina poeyana d'Orbigny
111. Reophax scorpiurus Montfort
112. Reussella atlantica Cushman
113. Rosalina bahamaensis Todd and Lowe
114. Rosalina bertheloti (d'Orbigny)
115. Rosalina concinna (Brady)
116. Rosalina floridana (Cushman)
117. Rosalina floridensis (Cushman)
118. Rosalina rosea (d'Orbigny)
119. Sagrina pulchella primitiva (Cushman)
120. Saracenaria italica Defrance
121. Sigmavirgulina tortuosa (Brady)
122. Sigmoilina distorta Phleger and Parker
123. Sigmoilina tenuis (Czjzek)
124. Sigmoilopsis schlumbergeri (Silvestri)
125. Siphonina pulchra
126. Sphaeroidina bulloides d'Orbigny
127. Spiroloculina planulata (Lamarck)
128. Textularia agglutinans d'Orbigny
129. Textularia candeiana d'Orbigny
130. Textularia conica d'Orbigny
131. Textularia gramen? d'Orbigny
132. Textularia mayori Cushman
133. Textulariella barrettii (Jones and Parker)
134. Tretomphalus atlanticus Cushman
135. Trifarina bella (Phleger and Parker)
136. Trifarina carinata (Cushman)
137. Trifarina jamaicensis (Cushman and Todd)
138. Trifarina occidentalis (Cushman)
139. Triloculina bassensis Parr
140. Triloculina fitterei Acosta meningoi Acosta
141. Triloculina linneiana d'Orbigny
142. Triloculina tricarinata d'Orbigny
143. Triloculina trigonula (Lamarck)
144. Triloculina trigonula (Lamarck) multistriata Cushman
145. Triloculina rotunda d'Orbigny
146. Uvigerina auberiana d'Orbigny
147. Uvigerina flintii Cushman
148. Uvigerina laevis Goes
149. Uvigerina peregrina Cushman
150. Valvulinaria laevigata Phleger and Parker
151. Valvulineria minuta Parker

APPENDIX E

TAXONOMIC NOTES

Because of the poor state of preservation of many of the samples, the following format was used:

1) ? after the species name indicates a possible identification of that species.
2) ? after the genus name indicates a possible identification of that genus.
3) Identifications such as miliolid sp., rotaliid sp., and textulariid sp. indicate identification to superfamily level.
4) Unidentified foram indicates identification only to phylum level.
5) Unidentified possible foram indicates a possible identification to phylum level.
6) Unidentified fragment indicates no identification to any level.

In this report, *Amphistegina gibbosa* is used as the dominant reef species. Many investigators have followed Fornasini (1903) in regarding *Amphistegina lessonii* as the only valid Recent species of *Amphistegina*. However, d'Orbigny (1839) described and figured *A. gibbosa* from Cuba, which is regarded as the same species as occurs in the eastern Gulf of Mexico and the Caribbean region generally.

The *Baggina* sp. in this report is probably an undescribed species. There are enough specimens (it is found in eight samples in UNDA) to erect a new species, but time contraints preclude visiting museums to study comparative material, and thus puts it outside the scope of this study.

The specimens placed in *Anomalina globulosa* are, in the opinion of W. D. Bock, identical to type material. However, the reported habitat for this species is usually deeper water than most of the material encountered in this study. The species is identical to one that is commonly found on the outer shelf of the eastern Gulf of Mexico.

Many of the specimens reported as *Quinqueloculina* spp. and other mioliolids were represented by internal casts, in most cases with none of the original shell material preserved, making specific identifications extremely difficult. Although benthonics are not very reliable age indicators (except for some of the larger foraminifera), faunal associations existed in CLINO from

C1745' to the bottom of the core, and to a lesser extent in UNDA in the lower levels of the core, both of which have a Miocene character. These include the following species: *Buliminella curta, Globulina inaequalis, Lenticulina americana, Lenticulina americana spinosa, Nonionella pizzarense, Planulina depressa* and *Trifarina occidentalis.* All of these species range into the Pleistocene and even Recent, but where they appear together in abundance, they are characteristic of a Miocene assemblage. However, where they appear in the cores, the majority of the benthonic fauna is represented by extant species.

APPENDIX F

DEPOSITIONAL ENVIRONMENT AND SPECIES BY CORE INTERVAL

CLINO

Sample C504'9"

Environment: Mid-shelf

1. Amphistegina gibbosa
2. Asterigerina carinata
3. Cibicides aff. C. floridanus
4. Dyocibicides biserialis
5. Gypsina vesicularis
6. Nodosaria spp.
7. Planulina spp.
8. Rosalina bahamaensis
9. Rotaliid spp.

Sample Interval C555'9"-C576'4"

Environment: Backreef/mid-shelf

1. Amphistegina gibbosa
2. Asterigerina carinata
3. Cibicides aff. C. floridanus
4. Cibicides spp.
5. Dentalina? sp.
6. Eponides antillarum
7. Eponides repandus
8. Miliolid fragment
9. Nodosaria spp.
10. Nonionella atlantica
11. Nonionella? fragment
12. Peneroplis carinatus
13. Rosalina bahamaensis
14. Rosalina concinna
15. Rosalina floridana
16. Rosalina floridensis
17. Rosalina spp.
18. Rotaliid spp.
19. Unidentified fragments

Sample C714'1"

Environment: Forereef/outer shelf

1. Ammonia translucens
2. Amphistegina gibbosa
3. Cancris sagra
4. Cassidulina crassa
5. Cibicides lobatulus
6. Cibicides wuellerstorfi
7. Cibicides spp.
8. Elphidium incertum
9. Elphidium sagrum
10. Elphidium sp.
11. Elphidium fragment
12. Eponides antillarum
13. Eponides repandus
14. Eponides fragments
15. Fursenkoina complanata
16. Nodosaria fragment
17. Nonion depressulum
18. Nonionella atlantica
19. Planorbulina mediterranensis
20. Planulina foveolata
21. Planulina? spp.
22. Quinqueloculina fragment
23. Reussella atlantica
24. Rosalina concinna
25. Rotaliid fragments
26. Sagrina pulchella primitiva
27. Siphonina pulchra
28. Trifarina jamaicensis
29. Unidentified fragments

Sample Interval C771'8"-C1273'4"

Environment: Mid-shelf

1. Amphistegina gibbosa
2. Anomalina globulosa
3. Archaias angulatus
4. Articulina lineata
5. Asterigerina carinata
6. Bigenerina irregularis
7. Bulimina marginata?
8. Cancris oblonga
9. Cancris sagra
10. Cancris? sp.
11. Cibicides aff. C. floridanus
12. Cibicides lobatulus
13. Cibicides protuberans

14. Cibicides wuellerstorfi
15. Cibicides spp.
16. Cribroelphidium poeyanum
17. Dentalina? sp.
18. Discorbis mira
19. Dyocibicides biserialis
20. Elphidium incertum
21. Elphidium sagrum
22. Elphidium spp.
23. Eponides antillarum
24. Eponides repandus
25. Fissurina spp.
26. Fursenkoina? sp.
27. Gaudryina (Pseudogaudryina) atlantica
28. Globocassidulina subglobosa
29. Guttulina laevis
30. Guttulina sp.
31. Gypsina vesicularis
32. Hanzawaia strattoni
33. Karreriella bradyi
34. Lenticulina orbicularis?
35. Lenticulina spp.
36. Melonis barleeanum
37. Miliolid fragments
38. Miliolinella subsphaerica
39. Nodosaria pyrula?
40. Nodosaria spp.
41. Nonion depressulum
42. Nonion? sp.
43. Nonionella atlantica
44. Nonionella sp.
45. Nubeculina divaricata
46. Peneroplis carinatus
47. Peneroplis proteus
48. Planorbulina fragment
49. Planorbulina mediterranensis
50. Planulina ariminensis
51. Planulina foveolata
52. Planulina spp.
53. Pyrgo jugosa
54. Pyrgo subsphaerica
55. Quinqueloculina agglutinans
56. Quinqueloculina lamarckiana
57. Quinqueloculina poeyana?
58. Quinqueloculina spp.
59. Reophax scorpiurus
60. Reophax spp.
61. Reussella atlantica
62. Rotaliid sp.
63. Rosalina bahamaensis
64. Rosalina concinna
65. Rosalina floridana
66. Rosalina floridensis
67. Rosalina spp.

68. Rotaliid spp.
69. Saracenaria italica?
70. Saracenaria sp.
71. Sphaeroidina bulloides
72. Spiroloculina planulata
73. Textularia agglutinans
74. Textularia conica
75. Textularia spp.
76. Tretomphalus atlanticus
77. Trifarina bella
78. Trifarina jamaicensis
79. Triloculina bassensis
80. Triloculina fitterei meningoi
81. Triloculina linneiana
82. Triloculina rotunda
83. Triloculina trigonula
84. Triloculina trigonula multistriata
85. Triloculina spp.
86. Unidentified fragments
87. Many internal casts

Sample Interval C1310'3"-C1602'6"

Environment: Outer shelf

1. Ammonia beccarii tepida
2. Amphistegina gibbosa
3. Amphycoryna fragment
4. Anomalina globulosa
5. Astacolus crepidulus
6. Asterigerina carinata
7. Bigenerina irregularis
8. Brizalina fragment
9. Bulimina spp.
10. Cancris oblonga
11. Cibicides corpulentus
12. Cibicides aff. C. floridanus
13. Cibicides protuberans
14. Cibicides spp.
15. Cribroelphidium poeyanum
16. Dentalina advena
17. Dentalina communis
18. Dentalina subsoluta
19. Discorbis mira
20. Elphidium advenum
21. Elphidium incertum
22. Eponides antillarum
23. Eponides repandus
24. Fissurina spp.
25. Fursenkoina compressa
26. Globocassidulina subglobosa
27. Guttulina hirsuta

28. Guttulina laevis
29. Hanzawaia strattoni
30. Lenticulina atlantica?
31. Lenticulina calcar
32. Lenticulina orbicularis
33. Lenticulina spp.
34. Marginulina subaculeata
35. Marginulina subaculeata glabrata
36. Marginulina? sp.
37. Melonis barleeanum
38. Miliolid fragments
39. Nodosaria pyrula
40. Nonionella atlantica
41. Nonionella sp.
42. Osangularia cultur
43. Peneroplis? sp.
44. Planorbulina mediterranensis
45. Planulina ariminensis
46. Planulina exorna
47. Planulina foveolata
48. Planulina sp.
49. Pyrgo depressa
50. Pyrgo elongata
51. Pyrgo internal cast
52. Pyrgo vespertilio
53. Quinqueloculina agglutinans
54. Quinqueloculina internal cast
55. Quinqueloculina spp.
56. Reophax scorpiurus
57. Reophax spp.
58. Reussella atlantica
59. Rosalina bahamaensis
60. Rosalina concinna?
61. Rosalina floridana
62. Rosalina floridensis
63. Rosalina rosea
64. Rosalina spp.
65. Rotaliid spp.
66. Saracenaria italica
67. Sigmoilina tenuis
68. Sigmoilopsis schlumbergeri
69. Siphonina pulchra
70. Tretomphalus atlanticus
71. Trifarina carinata
72. Trifarina jamaicensis
73. Uvigerina flintii
74. Uvigerina laevis
75. Uvigerina sp.
76. Unidentified fragments
77. Valvulineria laevigata
78. Valvulineria sp.

Sample C1664'9"

Environment: Reef

1. Ammobaculites sp.
2. Amphistegina gibbosa
3. Cibicides corpulentus
4. Cibicides aff. C. floridanus
5. Cibicides spp.
6. Cibicides fragment
7. Globocassidulina subglobosa
8. Miliolid fragment
9. Planorbulina mediterranensis
10. Reophax spp.
11. Textularia fragment
12. Unidentified fragments

Sample Interval C1710'8"-C1745'

Environment: Outer shelf/upper slope

1. Ammobaculites sp.
2. Amphycoryna separans
3. Anomalina? sp.
4. Asterigerina carinata
5. Bigenerina fragment
6. Bigenerina irregularis
7. Brizalina goesii
8. Brizalina sp.
9. Bulimina inflata*
10. Bulimina? spp.
11. Cassidulina carinata
12. Cassidulina laevigata
13. Chrysalidinella dimorpha
14. Cibicides corpulentus
15. Cibicides aff. C. floridanus
16. Cibicides spp.
17. Cibicides wuellerstorfi
18. Eggerella bradyi
19. Ehrenbergina trigona
20. Elphidium incertum
21. Elphidium sp.
22. Eponides antillarum
23. Eponides regularis
24. Eponides repandus
25. Fussurina spp.
26. Fursenkoina complanata
27. Fursenkoina compressa
28. Gaudryina (Pseudogaudryina) atlantica
29. Globocassidulina subglobosa
30. Gypsina vesicularis

31. Gyroidina orbicularis
32. Gyroidina soldanii altiformis
33. Hanzawaia strattoni
34. Karreriella bradyi
35. Lenticulina americana*
36. Lenticulina atlantica
37. Lenticulina spp.
38. Marginulina fragment
39. Marginulina sp.
40. Marginulina subaculeata
41. Melonis? sp.
42. Miliolid spp.
43. Nodosaria spp.
44. Nonionella atlantica
45. Operculinoides? sp.
46. Planorbulina mediterranensis
47. Planulina foveolata
48. Pseudonodosaria comatula
49. Quinqueloculina spp.
50. Reophax spp.
51. Reussella atlantica
52. Rosalina floridensis
53. Rotaliid spp.
54. Saracenaria italica
55. Sigmoilopsis schlumbergeri
56. Siphonella? sp.
57. Textularia spp.
58. Tretomphalus atlanticus
59. Trifarina carinata
60. Trifarina jamaicensis
61. Trifarina spp.
62. Uvigerina auberiana
63. Uvigerina flintii
64. Uvigerina fragments
65. Uvigerina peregrina
66. Uvigerina fragment
67. Unidentified fragments
68. Valvulineria minuta

Sample Interval C1781'8"-C2214'3"

Environment: Outer shelf

1. Amphycoryna? fragment
2. Asterigerina carinata
3. Bigenerina floridana?*
4. Brizalina goesii
5. Brizalina paula
6. Brizalina plicatella*
7. Brizalina sp.
8. Bulimina inflata*
9. Bulimina marginata

10. Bulimina spp.
11. Buliminella curta*
12. Cassidulina carinata
13. Cibicides corpulentus
14. Cibicides aff. C. floridanus
15. Cibicides fragment
16. Cibicides lobatulus
17. Cibicides protuberans
18. Cibicides spp.
19. Elphidium sp.
20. Eponides repandus
21. Fursenkoina complanata
22. Fursenkoina sp.
23. Globobulimina affinis
24. Globocassidulina subglobosa
25. Globulina inaequalis*
26. Gyroidina orbicularis
27. Gyroidina soldanii altiformis
28. Hanzawaia strattoni
29. Lenticulina americana*
30. Lenticulina americana spinosa*
31. Lenticulina fragment
32. Lenticulina orbicularis
33. Marginulina dubia*
34. Marginulina fragment
35. Marginulina subaculeata
36. Melonis barleeanum
37. Melonis formosum
38. Nodosaria spp.
39. Nonionella atlantica
40. Nonionella pizzarense?*
41. Nonionella sp.
42. Planulina ariminensis
43. Planulina depressa*
44. Planulina foveolata
45. Planulina spp.
46. Quinqueloculina spp.
47. Reophax spp.
48. Rosalina spp.
49. Saracenaria italica
50. Sigmoilina tenuis
51. Siphonina pulchra
52. Sphaeroidina? sp.
53. Stilostomella? fragment
54. Textularia spp.
55. Tretomphalus atlanticus
56. Trifarina bella
57. Trifarina jamaicensis
58. Trifarina occidentalis*
59. Trifarina spp.
60. Uvigerina peregrina
61. Vaginulinopsis? sp.

*Typically found in Miocene sediments.

APPENDIX G

DEPOSITIONAL ENVIRONMENTS AND SPECIES BY CORE INTERVAL

UNDA

Sample U288'8"

Environment: Mid-shelf

1. Anomalina globulosa
2. Asterigerina carinata
3. Bigenerina irregularis
4. Cancris sagra?
5. Cibicides aff. C. floridanus
6. Cibicides spp.
7. Globobulimina affinis
8. Nonionella atlantica
9. Planulina exorna
10. Planulina depressa
11. Pyrgo subsphaerica
12. Pyrgo sp.
13. Quinqueloculina spp.
14. Rosalina bahamaensis
15. Rosalina sp.
16. Siphonina pulchra
17. Triloculina trigonula
18. Unidentified fragments
19. Unidentified foram spp.

Sample U361'9"

Environment: Fore reef/outer shelf

1. Amphistegina gibbosa
2. Asterigerina carinata
3. Brizalina goesii
4. Cibicides aff. C. floridanus
5. Cibicides io?
6. Cibicides lobatulus
7. Cibicides protuberans
8. Cibicides spp.
9. Discorbis mira
10. Elphidium advenum
11. Elphidium spp.
12. Eponides antillarum
13. Eponides repandus
14. Eponides sp.
15. Hanzawaia strattoni
16. Melonis barleeanum

17. Nonionella atlantica
18. Planulina exorna
19. Pseudoeponides umbonatus
20. Quinqueloculina spp.
21. Reussella atlantica
22. Rosalina bahamaensis
23. Rosalina rosea
24. Rosalina? sp.
25. Rotaliid spp.
26. Siphonina pulchra
27. Triloculina trigonula
28. Unidentified fragments

Sample Interval U393'2"-U427'10"

Environment: Back reef/mid-shelf

1. Amphistegina gibbosa
2. Archaias angulatus
3. Asterigerina carinata
4. Cancris oblonga
5. Cibicides corpulentus
6. Cibicides io?
7. Cibicides lobatulus
8. Cibicides spp.
9. Discorbis mira
10. Eponides antillarum
11. Eponides repandus
12. Globulina gibba
13. Hanzawaia strattoni
14. Lenticulina spp.
15. Neoconorbina orbicularis
16. Peneroplis carinatus
17. Planulina exorna
18. Planulina foveolata
19. Pseudoeponides umbonatus
20. Pyrgo subsphaerica
21. Quinqueloculina spp.
22. Reussella atlantica
23. Rosalina bahamaensis
24. Rosalina floridensis
25. Rosalina rosea
26. Rosalina spp.
27. Rotaliid spp.
28. Textularia candeiana
29. Textularia? spp.
30. Tretomphalus atlanticus
31. Triloculina tricarinata
32. Triloculina trigonula
33. Unidentified fragments

Sample U471'5"

Environment: Fore reef/outer shelf

1. Abnormal foram
2. Amphistegina gibbosa
3. Anomalina globulosa
4. Asterigerina carinata
5. Baggina n. sp.
6. Bifurina decorata
7. Bolivinita rhomboidalis
8. Buccella hannai
9. Cancris oblonga
10. Cassidulina curvata
11. Cibicides aff. C. floridanus
12. Cibicides protuberans
13. Cribroelphidium poeyanum
14. Discorbis mira
15. Elphidium advenum
16. Elphidium fimbriatulum
17. Elphidium sagrum
18. Elphidium translucens
19. Fissurina spp.
20. Fursenkoina compressa
21. Fursenkoina mexicana
22. Fursenkoina pontoni
23. Globocassidulina subglobosa
24. Globulina gibba
25. Guttulina laevis
26. Melonis barleeanum
27. Nonionella atlantica
28. Planulina exorna
29. Planulina foveolata
30. Polymorphinid? sp.
31. Pyrgo subsphaerica
32. Pyrulina? sp.
33. Reussella atlantica
34. Rosalina bahamaensis
35. Rosalina bertheloti
36. Rosalina floridensis
37. Rosalina rosea
38. Rosalina spp.
39. Sigmavirgulina tortuosa
40. Siphonina pulchra
41. Tretomphalus atlanticus
42. Trifarina bella
43. Unidentified foram spp.
44. Unidentified fragments

Sample U499'5"

Environment: Fore reef

1. Amphistegina gibbosa
2. Asterigerina carinata
3. Eponides repandus
4. Nonionella atlantica
5. Planulina foveolata
6. Pyrgo elongata
7. Pyrgo subsphaerica
8. Rosalina spp.
9. Textularia conica
10. Textularia spp.
11. Triloculina trigonula
12. Unidentified fragments

Sample U549'10"

Environment: Fore reef/outer shelf

1. Amphistegina gibbosa
2. Asterigerina carinata
3. Baggina n. sp.
4. Cassidulina curvata
5. Cibicides aff. C. floridanus
6. Cibicides protuberans
7. Cibicides spp.
8. Eponides repandus
9. Guttulina australis
10. Gyroidina soldanii altiformis
11. Hanzawaia strattoni
12. Miliolid spp.
13. Nonionella atlantica
14. Planorbulina mediterranensis
15. Planulina exorna
16. Planulina foveolata
17. Pyrgo subsphaerica
18. Quinqueloculina spp.
19. Reussella atlantica
20. Rosalina bertheloti
21. Rosalina spp.
22. Rotaliid spp.
23. Siphonina pulchra
24. Tretomphalus atlanticus
25. Unidentified fragments

Sample Interval U560'6"-U599'

Environment: Back reef/mid-shelf

1. Amphistegina gibbosa
2. Asterigerina carinata
3. Baggina n. sp.
4. Cibicides protuberans
5. Cibicides spp.
6. Cyclogyra planorbis
7. Discorbis mira
8. Elphidium sagrum
9. Elphidium spp.
10. Eponides antillarum
11. Eponides repandus
12. Globulina gibba
13. Gypsina vesicularis
14. Miliolid spp.
15. Nonionella atlantica
16. Peneroplis? sp.
17. Planorbulina mediterranensis
18. Planulina exorna
19. Planulina foveolata
20. Pseudopolymorphina rutila?
21. Pyrgo subsphaerica
22. Quinqueloculina spp.
23. Reussella atlantica
24. Rosalina bahamaensis
25. Rosalina floridana
26. Rosalina spp.
27. Rotaliid spp.
28. Spiroplectammina? sp.
29. Triloculina trigonula
30. Unidentified foram sp.
31. Unidentified fragments

Sample U645'6"

Environment: Fore reef/outer shelf

1. Amphistegina gibbosa
2. Anomalina globulosa
3. Cibicides corpulentus
4. Cibicides protuberans
5. Cibicides spp.
6. Cibicides? sp.
7. Hanzawaia strattoni
8. Marginula subaculeata glabrata
9. Nonionella atlantica
10. Planulina exorna
11. Planulina foveolata

12. Planulina? sp.
13. Quinqueloculina spp.
14. Reussella atlantica
15. Rosalina floridana
16. Rotaliid spp.
17. Spiroplectammina? sp.
18. Textularia candeiana
19. Textularia mayori
20. Tretomphalus atlanticus
21. Unidentified fragments

Sample U687'

Environment: Outer shelf

1. Ammonia beccarii tepida
2. Anomalina globulosa
3. Asterigerina carinata
4. Baggina n. sp.
5. Bulimina spicata?
6. Cibicides corpulentus
7. Cibicides protuberans
8. Cibicides spp.
9. Dyocibicides biserialis
10. Elphidium spp.
11. Hanzawaia strattoni
12. Nonionella atlantica
13. Planulina exorna
14. Planulina foveolata
15. Quinqueloculina spp.
16. Reussella atlantica
17. Rosalina bahamaensis
18. Rosalina concinna
19. Rosalina spp.
20. Rotaliid spp.
21. Textularia conica
22. Textularia spp.
23. Tretomphalus? sp.
24. Unidentified foram sp.
25. Unidentified fragments
26. Valvulineria? sp.

Sample Interval U742'9"-U774'6"

Environment: Fore reef/outer shelf

1. Amphistegina gibbosa
2. Asterigerina carinata
3. Cancris oblonga
4. Cassidulina curvata

5. Cibicides corpulentus
6. Cibicides aff. C. floridanus
7. Cibicides io?
8. Cibicides spp.
9. Dyocibicides biserialis
10. Fursenkoina compressa
11. Globocassidulina subglobosa
12. Hanzawaia strattoni
13. Lenticulina orbicularis
14. Lenticulina spp.
15. Marginulina subaculeata glabrata
16. Nonionella atlantica
17. Planulina exorna
18. Planulina foveolata
19. Quinqueloculina spp.
20. Reussella atlantica
21. Rosalina bertheloti
22. Rosalina concinna
23. Saracenaria italica
24. Sigmoilina distorta
25. Siphonina pulchra
26. Spiroloculina sp.
27. Textularia conica
28. Textularia mayori?
29. Textularia sp.
30. Trifarina carinata
31. Trifarina? sp.
32. Unidentified fragments
33. Uvigerina? sp.

Sample Interval U836'7"-U969'

Environment: Upper slope

1. Amphistegina gibbosa
2. Asterigerina carinata
3. Bigenerina irregularis
4. Bulimina marginata
5. Cancris oblonga
6. Carpenteria proteiformis
7. Cassidulina curvata
8. Cibicides corpulentus
9. Cibicides aff. C. floridanus
10. Cibicides io?
11. Cibicides spp.
12. Elphidium advenum
13. Eponides repandus
14. Eponides sp.
15. Gaudryina (Pseudogaudryina) atlantica
16. Globocassidulina subglobosa
17. Gypsina vesicularis
18. Gyroidina soldanii altiformis

19. Gyroidina? sp.
20. Hanzawaia strattoni
21. Hanzawaia sp.
22. Lenticulina orbicularis
23. Lenticulina spp.
24. Liebusella soldanii
25. Marginulina subaculeata glabrata
26. Marginulina sp.
27. Melonis barleeanum
28. Nonionella? sp.
29. Operculinoides? sp.
30. Planulina foveolata
31. Planulina spp.
32. Quinqueloculina agglutinans
33. Quinqueloculina spp.
34. Reophax? spp.
35. Reussella atlantica
36. Rosalina bertheloti
37. Rotaliid spp.
38. Saracenaria italica
39. Sigmoilina distorta
40. Siphonina pulchra
41. Siphonina? sp.
42. Spiroplectammina? sp.
44. Textularia conica
45. Textularia gramen?
45. Textularia mayori
46. Textularia spp.
47. Textulariella barrettii
48. Trifarina carinata
49. Unidentified foram spp.
50. Unidentified fragments

Sample U1119'8"

Environment: Back reef/mid-shelf

1. Amphistegina gibbosa
2. Baggina n. sp.
3. Cibicides spp.
4. Elphidium advenum
5. Elphidium sagrum
6. Eponides antillarum
7. Eponides repandus
8. Globocassidulina subglobosa
9. Miliolid spp.
10. Neoconorbina orbicularis
11. Peneroplis carinatus
12. Pyrgo subsphaerica
13. Rotaliid spp.
14. Siphonina pulchra
15. Triloculina trigonula

Sample U1162'

Environment: Unknown

1. Miliolid spp.
2. Rotaliid spp.
3. Unidentified fragments

Sample U1174'4"

Environment: Mid-shelf

1. Ammoscalaria? sp.
2. Amphistegina gibbosa
3. Articulina pacifica?
4. Asterigerina carinata
5. Baggina n. sp.
6. Cancris? sp.
7. Cibicides protuberans
8. Discorbis mira
9. Elphidium incertum
10. Elphidium sagrum
11. Elphidium spp.
12. Globulina gibba
13. Globulina inaequalis*
14. Hanzawaia strattoni
15. Neoconorbina orbicularis
16. Nonion depressulum
17. Nonionella atlantica
18. Rosalina floridensis
19. Rosalina rosea
20. Rotaliid spp.
21. Tretomphalus atlanticus
22. Unidentified foram spp.
23. Unidentified fragments
24. Unidentified possible foram

*Typically found in Miocene sediments.

Sample Interval U1208'8"-U1395'3"

Environment: Back reef/mid-shelf

1. Amphistegina gibbosa
2. Anomalina? sp.
3. Asterigerina carinata
4. Baggina n. sp.
5. Bigenerina floridana?
6. Bigenerina irregularis
7. Cassidulina curvata

8. Cancris oblonga
9. Cibicides lobatulus
10. Cibicides protuberans
11. Cibicides spp.
12. Clavulina tricarinata
13. Discorbis mira
14. Dorothia pseudoturris
15. Elphidium advenum
16. Elphidium incertum
17. Elphidium sp.
18. Elphidium sagrum
19. Eponides antillarum
20. Eponides repandus
21. Eponides sp.
22. Globulina gibba
23. Globulina inaequalis*
24. Hanzawaia strattoni
25. Melonis barleeanum
26. Miliolid spp.
27. Nonion depressulum
28. Nonionella atlantica
29. Nonionella? sp.
30. Nuberculina divaricata
31. Planorbulina mediterranensis
32. Planulina depressa*
33. Pseudoeponides umbonatus
34. Pyrgo elongata
35. Pyrgo subsphaerica
36. Pyrgo sp.
37. Quinqueloculina spp.
38. Reophax? spp.
39. Reussella atlantica
40. Rosalina bahamaensis
41. Rosalina concinna
42. Rosalina floridana
43. Rosalina floridensis
44. Rosalina rosea
45. Rosalina spp.
46. Rotaliid spp.
47. Siphonina pulchra
48. Triloculina trigonula
49. Triloculina trigonula multistriata
50. Triloculina spp.
51. Unidentified fragments
52. Valvulina? sp.

*Typically found in Miocene sediments.

Sample U1420'7"

Environment: Inner shelf

1. Ammobaculites? sp.
2. Amphistegina gibbosa
3. Articulina mucronata
4. Asterigerina carinata
5. Cibicides lobatulus
6. Cibicides protuberans
7. Cibicides spp.
8. Cyclogyra? sp.
9. Elphidium advenum
10. Elphidium incertum
11. Eponides regularis
12. Eponides repandus
13. Hanzawaia strattoni
14. Neoconorbina orbicularis
15. Nodosaria? sp.
16. Nonionella atlantica
17. Nonionella? sp.
18. Nubeculina divaricata
19. Planorbulina mediterranensis
20. Planulina depressa*
21. Planulina exorna
22. Planulina? sp.
23. Pyrgo elongata
24. Pyrgo sp.
25. Pyrgo subsphaerica
26. Quinqueloculina spp.
27. Reophax? spp.
28. Rosalina bahamaensis
29. Rosalina concinna
30. Rosalina floridana
31. Rosalina floridensis
32. Triloculina bassensis
33. Triloculina trigonula
34. Unidentified fragments

*Typically found in Miocene sediments.

PLATES

PLANKTONIC FORAMINIFERA

OF THE GREAT BAHAMA BANK

Plate 1

1 - 3 ***Globigerina venezuelana*** Hedberg. 1. Umbilical view from C1745'. Scale 100 μm. 2. Axial view from C1745'. Scale 100 μm. 3. Spiral view from C1745'. Scale 50 μm. The species is characterized by 3.5 to 4 appressed chambers in a low trochospiral whorl, a smooth test, a low-arch aperture and poorly depressed sutures.

4 - 5 ***Globigerinoides trilobus sacculiferus*** (Brady). 4. Spiral view from C1803'4". 5. Umbilical view from C1803'4". Note characteristic elongate, sack-like (sacculiferid) ultimate chamber. Scales 100 μm.

6 - 8 ***Globorotalia mayeri*** Cushman and Ellisor. 6. Umbilical view from U1420'7". 7. Axial view from U1395'3", showing fairly uniform chambers. 8. Spiral view from U1395'3". Scales 100 μm. Species has oblique, distinctly curved intercameral sutures on spiral side and a narrow umbilicus.

9 - 10 ***Globigerinoides trilobus trilobus*** (Reuss). 9. Umbilical view from U1315'3". 10. Spiral view from C1310'3". Scales 100 μm. Species is morphologically similar to *G. trilobus sacculiferus* except for the shape of the ultimate chamber.

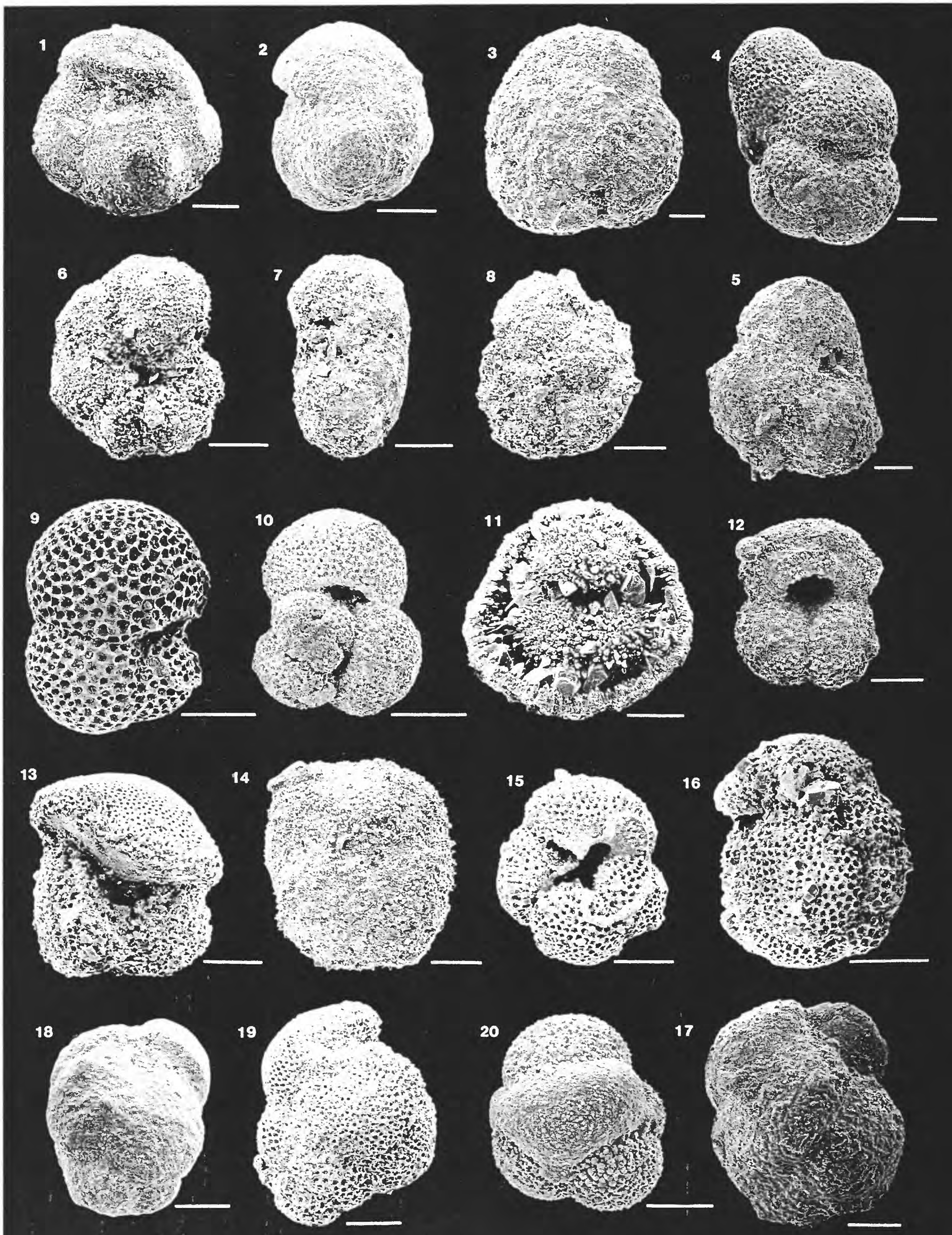
11-12 ***Globigerinoides ruber*** (d'Orbigny). 11. Umbilical view of juvenile within broken later chamber from U1420'7" (middle middle Miocene *Globorotalia fohsi robusta* Zone N12). Energy-dispersive X-ray spectrometry determined the crystals replacing the calcium-carbonate test are sparry calcite. 12. Umbilical view from C1710'8" (early Pliocene *Globorotalia margaritae evoluta* Subzone N19). Scales 100 μm. The species is morphologically similar to *G. trilobus trilobus* except for the higher arched apertures and their symmetrical position above the sutures between earlier chambers.

13-14 ***Globoquadrina dehiscens*** (Chapman, Parr and Collins). 13. Umbilical view from U1420'7" showing distinctive smooth face on ultimate chamber, open umbilicus, and angular, ventrally pointed chambers. Note apertural flap, characteristic of the genus, in umbilicus. 14. Spiral view from C2083' showing distinct quadrate shape. Spiral side is flat. This species shows highly variable monospecific morphology, noted by Stainforth and others (1975) to occur along with intergrading forms in most normal assemblages. Scales 100 μm.

15-17 ***Globoquadrina altispira altispira*** (Cushman and Jarvis). 15. Umbilical view from U1315'3". Note triangular tooth-like apertural flaps extending into umbilicus. 16. Axial view from U1315'3". 17. Umbilical view from C1745'. Scales 100 μm. The *G. altispira* subspecies differ from *G. dehiscens* in having a less angular test without a flattened spiral side and more globose chambers with usually more than 4 in the last whorl.

18-19 ***Globoquadrina altispira conica*** Bronnimann and Resig. 18. Umbilical view from C1803'4". 19. Axial view from U742'9". Note high spire and drawn out, laterally compressed later chambers relative to those of *G. altispira altispira*. Scales 100 μm.

20 ***Globigerinita incrusta*** Akers, ventral view from U471'5". Species is a globigerinid in which the last chamber extends back over the umbilicus and a series of apertures are restricted to prolongated tips of inflated bulla along infralamellar sutures. Note tips are rimmed. Scale 50 μm.



MIDDLE AND LATE MIOCENE AND EARLY PLIOCENE FAUNA

Plate 2

21-23 ***Globigerinoides obliquus obliquus*** Bolli. 21. Umbilical view from U1208'8". Scale 50 µm. 22. Oblique axial view in elongated-spire specimen with immature ultimate chamber from C1745'. Scale 100 µm. 23. Spiral view from U836'7". Scale 50 µm. The species is distinguished from *G. trilobus trilobus* (Pl. 1) in having the ultimate chamber slightly compressed laterally and obliquely and a slightly higher and wider primary aperture.

24 ***Orbulina universa*** d'Orbigny from C714'1". Scale 100 µm. When broken, the spherical test shows internal early globigerinid chambers. Apertural pores are widely scattered over surface.

25-26 ***Globorotalia scitula scitula*** (Brady). 25. Spiral view from C1110'. 26. Umbilical view from C2161'3". Scales 100 µm. The species differs from *G. margaritae* in having thicker walls, a more circular outline in equatorial view, being more biconvex, lacking a peripheral keel, and in its dextral coil.

27-28 ***Orbulina suturalis*** Bronnimann. 27. View from C2083' shows early 3 chambers (arrows) of globigerinid stage of development breaking outline of sphere. 28. View from U1420"7" shows 2 of 3 globigerinid chambers (arrows) in outline. In well-preserved tests, sutural as well as areal apertures can be seen. Scales 100 µm.

29-31 ***Globorotalia praemenardii*** Cushman and Stainforth. 29. Umbilical view from U1420'7". 30. Axial view from U1420'7". 31. Spiral view from U1420'7". Scales 100 µm. Species has a distinctly lobate peripheral outline.

32-33 ***Globigerinoides bollii*** Blow. 32. Umbilical view from U1263'5", showing rather small, nearly circular, rimmed primary aperture. 33. Axial view from C1803'4", showing smaller supplementary aperture and strongly embracing nature of chambers. Scales 100 µm.

34 ***Globorotalia menardii 'A'*** Bolli, spiral view from C1951', showing strongly developed keel and limbate sutures. The subspecies has 5-6 chambers in the last whorl versus the 7-7.5 chambers in the larger *G. menardii 'B'* (Pl. 3). Scale 100 µm.

35 ***Globorotalia fohsi robusta*** Bolli, umbilical view of moldic specimen from U1263'5". The end-form of the *G. fohsi* lineage, the subspecies is the nominate taxon for the middle middle Miocene *G. fohsi robusta* Zone N12. Scale 100 µm.

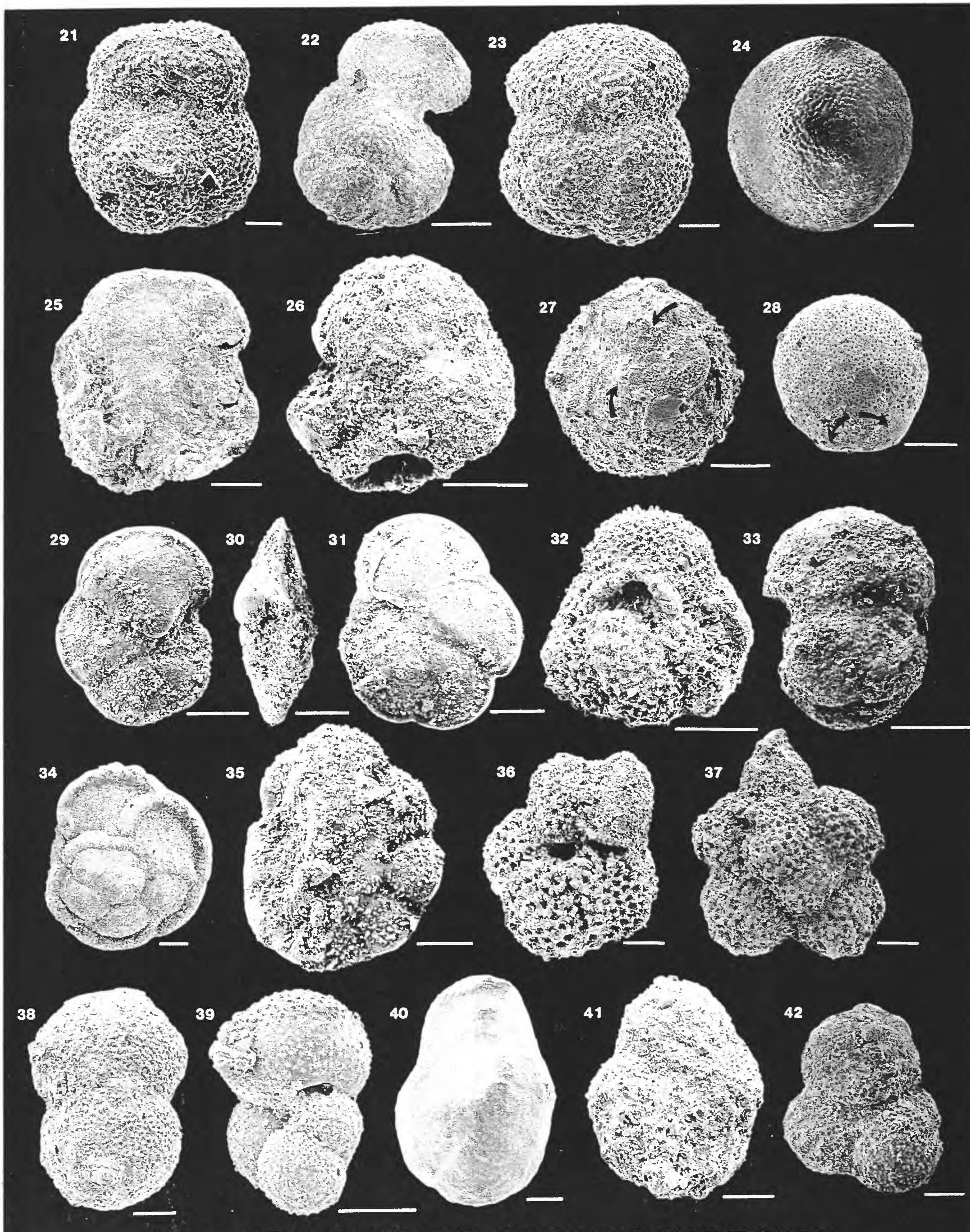
36-37 ***Sphaeroidinellopsis multiloba*** (LeRoy). 36. Umbilical view from U742'9". 37. Spiral view from U1395'3". Scales 100 µm. Having a coarsely perforate wall structure, strongly depressed sutures, and a large irregular aperture with crenulated edge, the species is distinguished from *S. hancocki* (Pl. 4) by radial sutures. Early forms have 3-4 greatly inflated chambers. Later forms have 5 or 6 chambers, the ultimate chamber usually being sacculiferid.

38 ***Orbulina bilobata*** (d'Orbigny) from C2214'3". Scale 100 µm. When broken, bilobate test shows internal early globigerinid chambers. Apertural pores are scattered over surface.

39 ***Hastigerina siphonifera*** (d'Orbigny), axial view from U471'5". The species differs from *H. pelagica* (Pl. 5) by having an involute asymmetrical coil. Scale 100 µm.

40-41 ***Globigerina nepenthes*** Todd. 40. Umbilical view from C2136'4", showing large aperture bordered by thickened rim in cap-like last chamber. 41. Spiral view from C1803'4'. Scales 100 µm. The species shows considerable morphological variation throughout its range.

42 ***Globigerina eamesi*** Blow, umbilical view from C1745'. Scale 100 µm. The species has a tight, low trochospiral coil with low-arch umbilical aperture in last chamber.



MIDDLE AND LATE MIOCENE AND EARLY PLIOCENE FAUNA

Plate 3

43-45 ***Globorotalia menardii 'B'*** Bolli. 43. Umbilical view from C1951'. 44. Spiral view from C1951'. 45. Spiral view from U774'6". Scales 100 µm.

46 ***Turborotalia humilis*** (Brady), umbilical view from C2083'. Scale 100 µm. Last chamber is modified to wrap over umbilicus and extend in a series of finger-like projections over sutures. The projections in this poorly preserved specimen have been dissolved.

47-49 ***Globorotalia acostaensis acostaensis*** Blow. 47. Umbilical view from C1803'4". Scale 100 µm. 49. Axial view from U1395'3". Scale 50 µm. 50. Spiral view from C1803'4". Scale 100 µm. The subspecies varies from early, small, 4-chambered forms to later, larger, 5-chambered forms.

50 ***Polyperibola christiani*** Liska from U1208'8". The species is similar to *Candeina nitida* (Pl. 4) in its general chamber arrangement, closed umbilical area, delicate type of wall structure and presence of tiny sutural apertures, but differs from that species in the presence of bullae and a generally smaller test size. Scale 100 µm.

51-52 ***Globigerinoides conglobatus canimarensis*** Bermudez. 51. Axial view from U836'7". 52. Umbilical view from U836'7". Scales 100 µm. Ancestral to *G. conglobatus conglobatus* (Pl. 5), the subspecies differs from it in its smaller test size and higher arched primary and secondary apertures.

53-54 ***Globigerinoides ruber seiglei*** Bermudez and Bolli. 53. Umbilical view from C1745'. 54. Axial view from C1803'4". Scales 100 µm. The subspecies differs from *G. ruber* (Pl. 1) in having a larger primary aperture that, as in *G. ruber*, is symmetrically placed over the suture between the last two chambers.

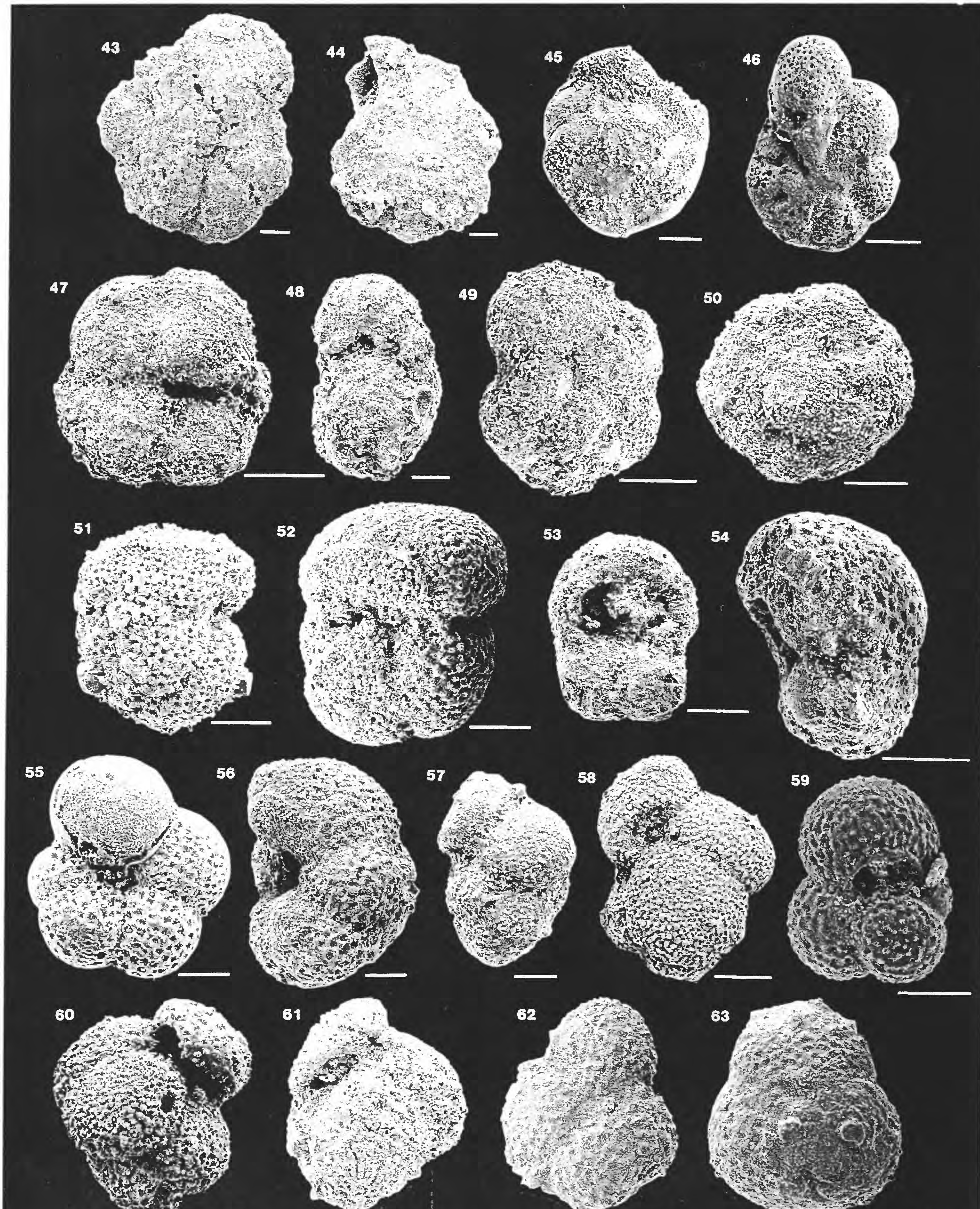
55-56 ***Globorotalia humerosa humerosa*** Takayanagi and Saito. 55. Umbilical view of juvenile from U471'5". 56. Axial view from C2171'. Scales 50 µm. The subspecies differs from *G. acostaensis acostaensis* in its larger test size, open umbilicus, and greater number of chambers (6-7 versus 4-5 in *G. acostaensis*).

57-58 ***Globigerinoides elongatus*** (d'Orbigny). 57. Umbilical view from C1310'3". 58. Spiral view from C1745'. Scales 100 µm. Species differs from *G. ruber* (Pl. 1) in the elongate spire. Both species have symmetrical apertures over sutures.

59 ***Globigerina bulloides*** d'Orbigny, umbilical view from U471'5". Scale 50 µm. Object to right of aperture is debris. Species is highly variable in wall structure and may be hispid, spinose, cancellate, smooth, or pitted.

60-61 ***Globigerinoides obliquus extremus*** Bolli and Bermudez. 60. Umbilical view from C1310'3". 61. Umbilical view from C1745'. Scales 100 µm. The subspecies is distinguished from *G. obliquus obliquus* (Pl. 2) by elongated spire, extremely oblique ultimate chamber and more assymetrical primary aperture, and from *G. ruber* (Pl. 1) and *G. elongatus* (Pl. 3) by assymetrical apertures.

62-63 ***Sphaeroidinellopsis seminulina*** (Schwager). 62. Umbilical view from C1745'. 63. Umbilical view from C1745' . Scales 100 µm. The species differs from *Ss. multiloba* (Pl. 2) in having a thickened cortex, which results in less incised, occasionally barely distinguishable sutures, and by a more irregular and more slit-like aperture bordered by a thin, irregularly edged flange.



MIOCENE-PLIOCENE TRANSITION FAUNA

Plate 4

64-66 ***Globorotalia pseudomiocenica*** Bolli and Bermudez. 64. Spiral view from C1710'8". 65. Axial view from C1710'8". 66. Umbilical view from C1710'8". Scales 100 µm. The species differs from *G. menardii 'A'* (Pl. 2) in having a flatter spiral side, more convex umbilical side, and more delicate wall and keel.

67-68 ***Candeina nitida*** d'Orbigny. 67. Umbilical view from C1310'3". 68. Spiral view from C2214'3". Scales 100 µm. Test is tightly coiled, usually with 3 chambers per whorl and a completely closed umbilicus. Numerous small circular to elongate apertures, often rimmed, are aligned along sutures of last whorl and commonly along those of penultimate whorl.

69-71 ***Globorotalia merotumida*** Banner and Blow. 69. Spiral view from C1745'. 70. Axial view from C1745'. 71. Umbilical view from C1745'. Scales 100 µm. The species differs from *G. plesiotumida* in having a smaller test at the same growth stage as measured by the number of chambers, a slower increase in whorl height as seen dorsally, more uniformly enlarging chambers, more consistently oblique dorsal intercameral sutures, a thinner and more finely perforate wall, a thinner keel, a relatively greater ventral convexity, and a relatively broader apertural face.

72-73 ***Sphaeroidinellopsis sphaeroides*** Lamb. 72. Spiral view from C2136'4". 73. Ventral view from C1710'5". Scales 100 µm. The species has 3 chambers in the final whorl, is close to spherical, has only faintly incised sutures, a cortex and a single narrow apertural slit.

74-76 ***Globorotalia plesiotumida*** Banner and Blow. 74. Spiral view from C1803'4". 75. Axial view from C1781'8". 76. Umbilical view from U774'6". Scales 100 µm.

77-79 ***Neogloboquadrina dutertrei*** (d'Orbigny). .77. Spiral view from C1310'3". 78. Axial view from C1310'3". 79. Umbilical view from U471'5". Scales 100 µm. The species is variable and may exhibit a low to high trochospire with an open umbilicus with or without tooth-like flaps extending from the last chambers into the umbilical area. The last chamber is often smaller and more laterally compressed than the penultimate chamber.

80-82 ***Globorotalia margaritae margaritae*** Bolli and Bermudez. 80. Umbilical view from C2083'. Scale 50 µm. 81. Axial view from C1745'. Scale 100 µm. 82. Spiral view from C1745'. Scale 100 µm. A widely recognized index species for the Pliocene, the subspecies differs from the end-form *G. margaritae evoluta* (Pl. 5) in its smaller size, more elongated equatorial outline, greater increase in chamber height, and less symmetrical axial profile.

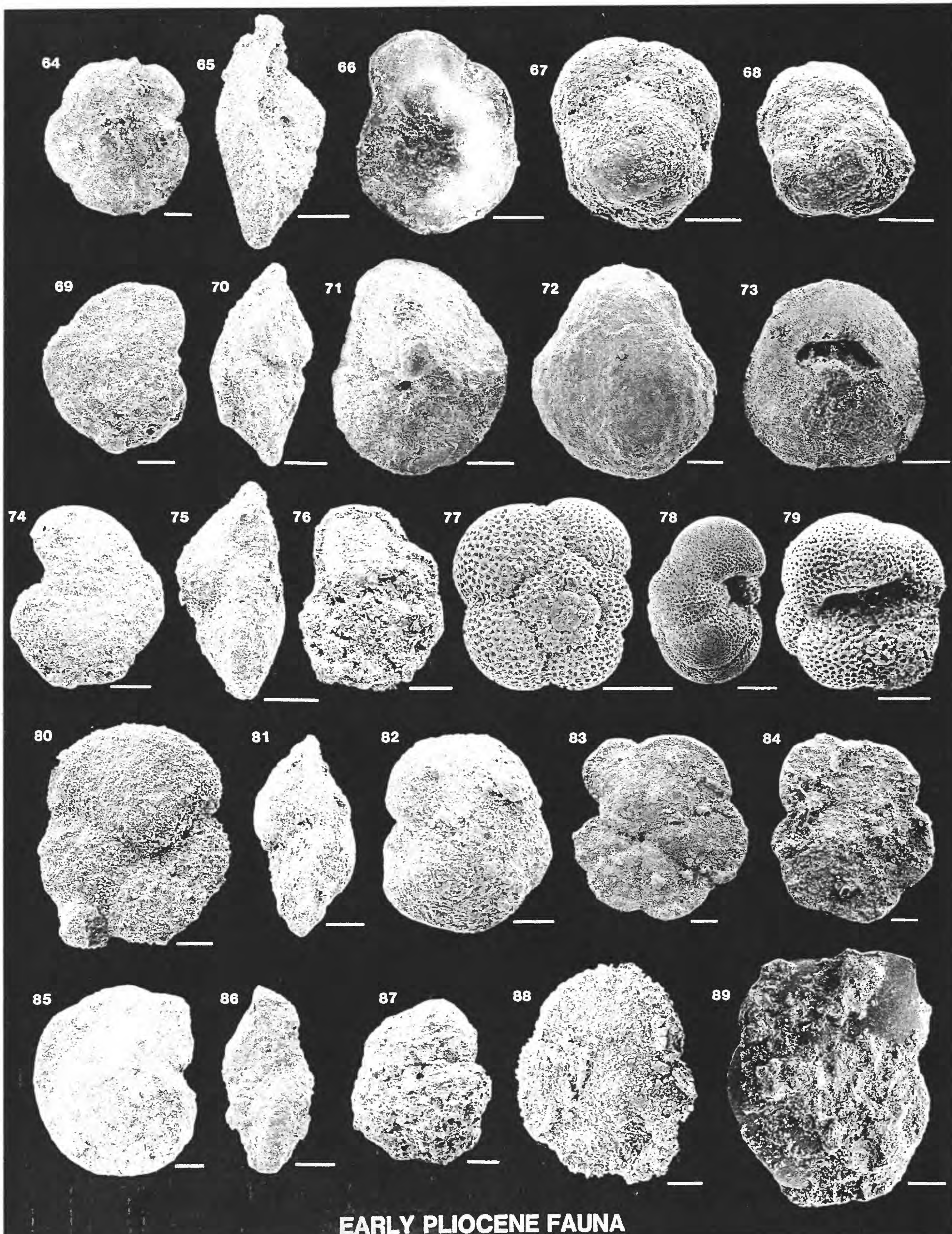
83-84 ***Globorotalia pertenuis*** Beard. 83. Umbilical view from C1731'. 84. Spiral view from C1781'8". Scales 100 µm. Species differs from *G. multicamerata* (Pl. 5) in having distinctly more delicate walls, less developed keels, and fewer chambers in the last whorl (6-8 versus 8-10 in *multicamerata*).

85 ***Globorotalia tumida flexuosa*** (Koch), spiral view from C1745'. Scale 100 µm. The subspecies is a variant of *G. tumida tumida* with the last chamber or two strongly flexed toward the umbilical side.

86 ***Globorotalia tumida tumida*** (Brady), axial view from C1110'. Scale 100 µm.

87 ***Sphaeroidinellopsis hancocki*** Bandy, spiral view from C1602'6". Scale 100 µm. The species differs from *Ss. seminulina* (Pl. 3) in having a greater number of chambers (as many as 7 versus 3.5-4 in *seminulina*) and *Ss. multiloba* (Pl. 2) by having oblique, rather than radial, sutures.

88-89 Unidentified recrystallized menardiform from U288'8" and moldic menardiform specimen from U645'6" with portion of keel on earlier chambers. Scales 100 µm.



EARLY PLIOCENE FAUNA

Plate 5

90-91 ***Globorotalia conglobatus conglobatus*** (Brady). 90. Spiral view from U361'9". Scale 50 µm. 91. Umbilical view from C1710'8". Scale 100 µm.

92-93 ***Hastigerina pelagica*** (d'Orbigny). 92. Umbilical view from C2136'4". 93. Umbilical view from C1310'3". Scales 100 µm. Test is symmetrically planispiral, tightly coiled and nearly involute, with chambers of the last whorl distinctly broader than high. Aperture is equatorial.

94-95 ***Globorotalia crassula*** Cushman and Stewart. 94. Spiral view from C1745'. 95. Axial view from C1710'8". Scales 100 µm. Test is tightly coiled with closely appressed chambers.

96-97 ***Globorotalia crassaformis ronda*** Blow. 96. Axial view from C1745'. 97. Umbilical view from C1745'. Scales 100 µm. The species is virtually identical to *G. crassaformis oceanica* except that its thickened test is formed of densely packed sclerites.

98-99 ***Globorotalia crassaformis oceanica*** Cushman and Bermudez, spiral views from C1710'8". Scales 100 µm.

100-104 ***Pulleniatina obliquiloculata primalis*** Banner and Blow. 100. Spiral view from C714'1". 101-102. Axial views from C714'1". 103. Umbilical view from C714'1". 104. Umbilical view from U393'2". Note peeling of sparry-calcite coating and breakage of earlier chambers, revealing moldic interior. Scales 100 µm. The earliest of the *Pulleniatina* lineage, the subspecies differs from *P. obliquiloculata obliquiloculata* (Pl. 6) in its smaller size with the last chambers only slightly streptospirally arranged, and by lack of overlap of the oppositely placed chamber on the umbilical end of the last chamber in such a way that the two chambers are joined by a point (arrow), rather than a straight line.

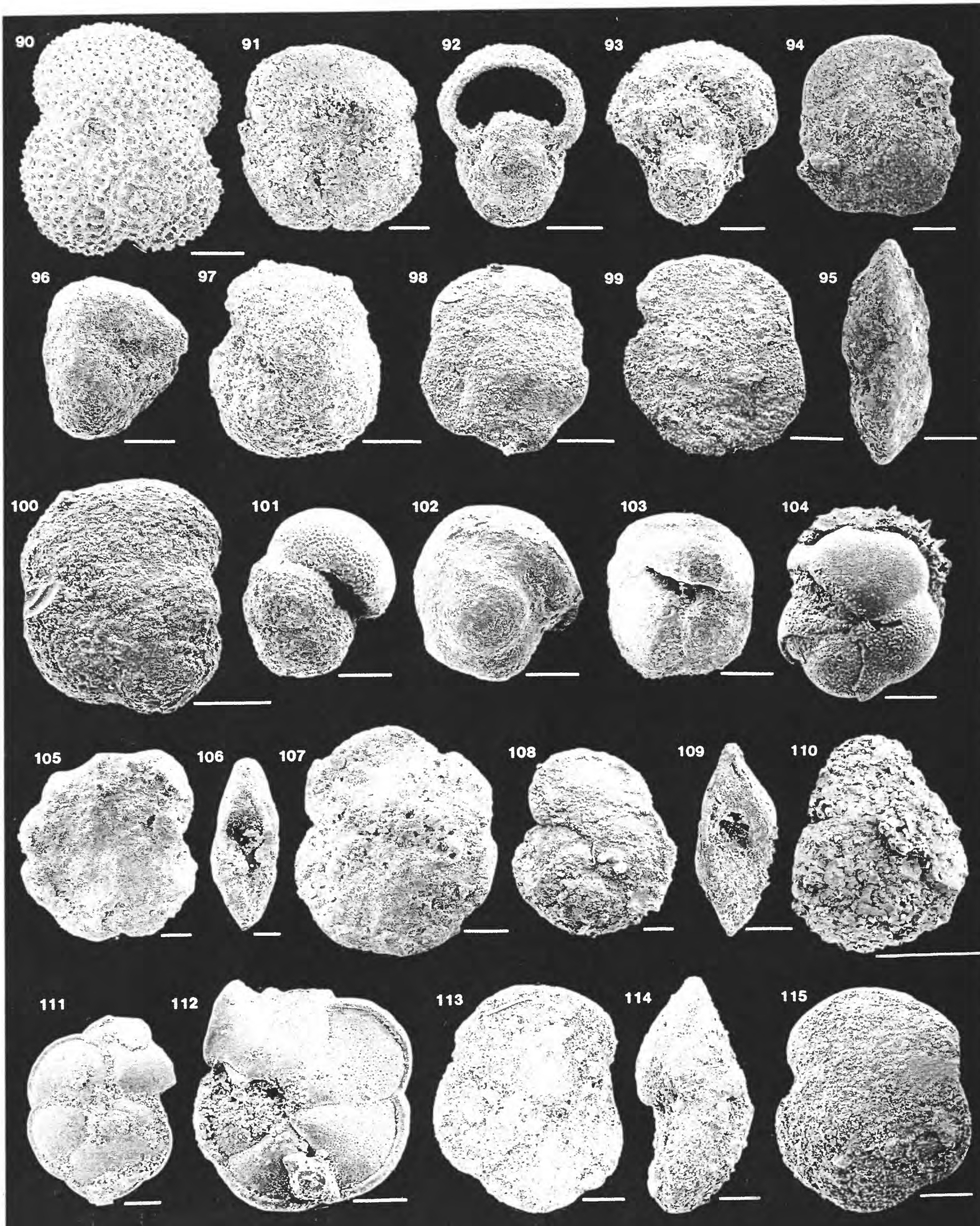
105-107 ***Globorotalia multicamerata*** Cushman and Jarvis. 105. Spiral view from C1745'. 106. Axial view from C1745'. 107. Umbilical view from C1745'. Scales 100 µm. The species differs from its assumed ancester, *G. menardii 'B'* (Pl. 3) by having more chambers (8-10) in the last whorl and a more robust test and keel. Intermediate forms difficult to assign to either of the taxa are frequent.

108-109 ***Globorotalia menardii cultrata*** (d'Orbigny). 108. Spiral view from C946'4". 109. Axial view from U742'9". Scales 100 µm. The species differs from *G. menardii menardii* by its thinner, more delicate wall, less pronounced keel, and more elongate outline in equatorial view.

110 Unidentified crystallized menardiform specimen from U1162'. Energy-dispersive X-ray spectrometry determined crystals are dolomite. Scale 500 µm.

111-112 ***Globorotalia menardii menardii*** (Parker, Jones, and Brady). 111. Spiral view from U499'5". 112. Umbilical view from U836'7". Scales 100 µm. Note nearly circular equatorial outline.

113-115 ***Globorotalia margaritae evoluta*** Cita. 113. Umbilical view from C1745'. 114. Axial view from C1745'. 115. Spiral view from C1745'. Scales 100 µm.



EARLY PLIOCENE FAUNA

Plate 6

116-118 ***Globigerinoides trilobus fistulosus*** (Schubert). 116. Spiral view from C1310'3". 117. Umbilical view from C1310'3". 118. Spiral view from C1710'5". Scales 100 µm. Considerable variation exists in numbers and shapes of characteristic fistules, from knobs to distinct finger-like fistules with rounded ends, one to several in the last chamber, often also present in the penultimate but seldom in earlier chambers. Chambers that possess more than three are usually distinctly flattened and cockscomb shaped. Where several fistules occur, they are usually in a line along the chamber periphery.

119-120 ***Sphaeroidinella dehiscens*** (Parker and Jones). 119. Axial view from C1710'8". 120. Umbilical view from C1310'3". Scales 100 µm. The species varies considerably in size and shape of chambers and in development of apertures and flanges.

121-122 ***Globorotalia crassaformis* cf. *viola*** Blow. 121. Umbilical view from C1710'8", showing characteristic peripheral keel and pustulose early parts of test near umbilical area. 122. Spiral view from C1710'8", showing limbate sutures and keel. Scales 100 µm.

123-124 ***Globorotalia crassaformis crassaformis*** (Galloway and Wissler). 123. Umbilical view from C1310'3". 124. Axial view from C1710'8". Scales 100 µm. Subspecies is characterized by highly vaulted, conical-shaped umbilical side and has an acute or subacute periphery or a trace of an imperforate rim.

125 ***Globorotalia inflata*** (d'Orbigny), umbilical view from C1731'. Scale 100 µm. Species has curved intercameral sutures and reniform-shaped chambers in spiral view. Specimen is a downhole contaminant in the sample as the species ranges from the late Pliocene to Recent.

126-128 ***Globorotalia miocenica*** Palmer. 126. Spiral view from C1710'8". 127. Axial view from C1731'. 128. Umbilical view from C1710'8". Scales 100 µm. Species differs from *G. pseudomiocenica* in having an absolutely flat to slighly concave spiral side, a higher umbilical side, and a more circular, less lobate equatorial outline.

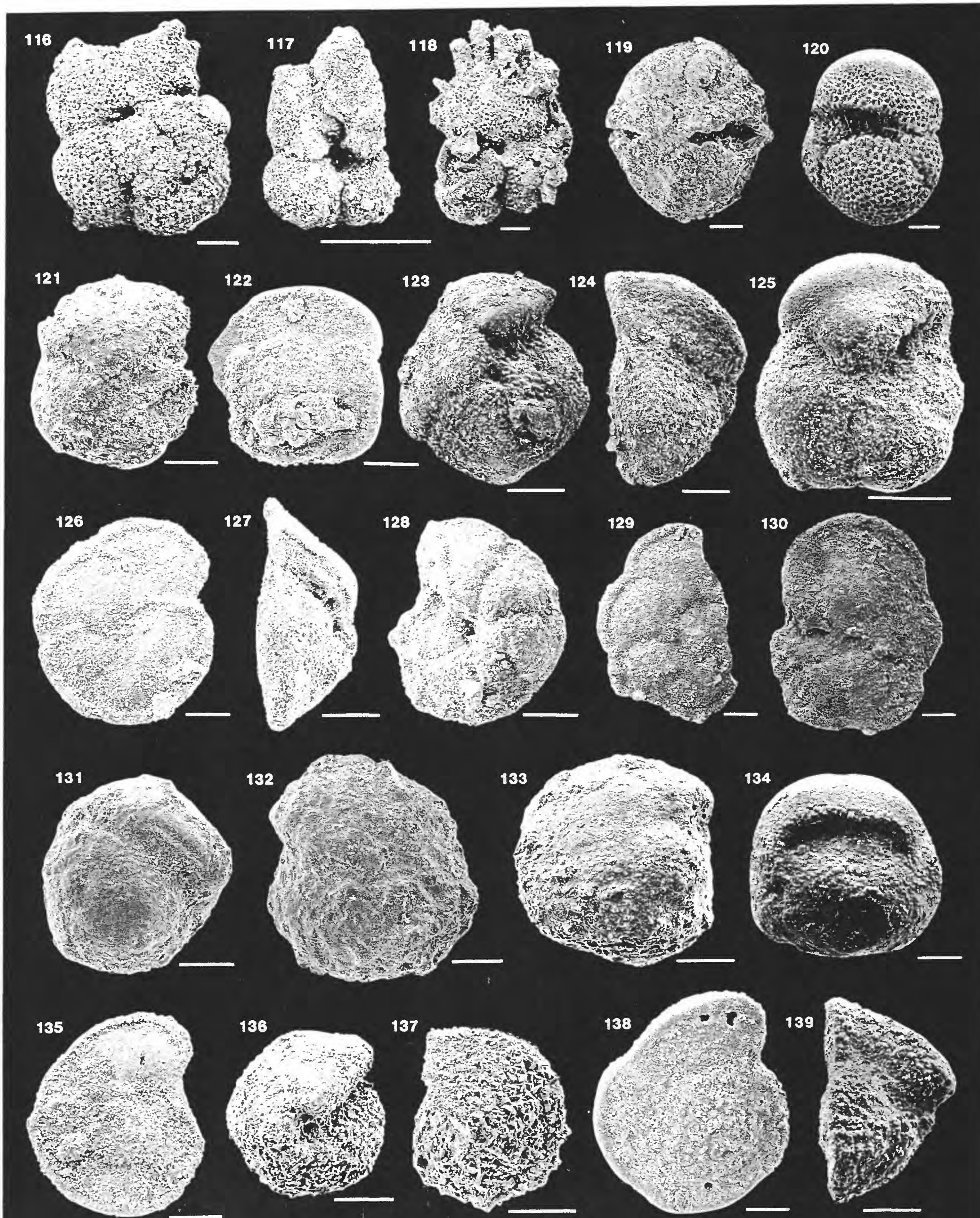
129-130 ***Globorotalia exilis*** Blow. 129. Spiral view from C1710'8". 130. Umbilical view from C1731'. Scales 100 µm. The species is closely related to *G. pertenuis* (Pl. 4) and differs from it in having 5-6 chambers in the last whorl, versus 6-8 in *pertenuis*. A diagnostic characteristic of *G. exilis* is the slightly inflated chambers on the spiral side, making the non-limbate sutures appear distinctly incised. The sutures also become partially overlapped by succeeding chambers. Later sutures may be limbate near the keel.

131-132 ***Pulleniatina obliquiloculata obliquiloculata*** (Parker and Jones). Axial views from C1602'6". Scales 100 µm.

133-134 ***Pulleniatina obliquiloculata finalis*** Banner and Blow. 133. Axial view from C984'9". 134. Umbilical view from C714'1". Scales 100 µm.

135-137 ***Globorotalia tosaensis tenuitheca*** Blow. 135. Spiral view from U549'10". 136. Umbilical view from C1310'3". 137. Umbilical view from U361'9". Scales 100 µm. The species differs from *G. truncatulinoides truncatulinoides* in being non-carinate, although some specimens may have a clear area over the subacute dorso-marginal periphery, giving the appearance of a keel. The species is characterized by its compact, relatively non-lobate test and distinct, non-fused pustules in the umbilical area.

138-139 ***Globorotalia truncatulinoides truncatulinoides*** (d'Orbigny). 138. Spiral view from C714'1" showing characteristic imperforate keel. Scale 50 µm. 139. Axial view from C714'1". Scale 100 µm. The species is characterized by an acute peripheral margin, laterally compressed chambers in the final whorl, a widely open umbilicus, and radial dorsal intercameral sutures.



LATE PLIOCENE AND EARLY PLEISTOCENE FAUNA

BENTHONIC FORAMINIFERA

OF THE GREAT BAHAMA BANK

Plate 7

Species commonly found attached to sea grasses include:

140-142 ***Cibicides lobatulus*** (Walker and Jacob). 140. Umbilical view from U1395'3". 141. Axial view from C2161'3". 142. Spiral view from C2161'3". Scales 100 µm. Test trochospiral, spiral side evolute, umbilical side involute with sharply angled apertural face and nonporous keel. Aperture a low interiomarginal opening with narrow lip that may extend along spiral suture on spiral side.

143-144 ***Articulina mucronata*** (d'Orbigny). 143. Side view from U1420'7". 144. Axial view from U1420'7", showing rounded terminal aperture with everted margin. Scales 100 µm. Test in early stage milioline, later rectilinear, may be longitudinally costate.

145-147 ***Rosalina concinna*** (Brady). 145. Umbilical view from U687'. 146. Axial view from U687'. 147. Spiral view from U1395'3". Scales 50 µm. Test plano-convex, all chambers visible from spiral side, only those of last whorl visible on umbilical side. Aperture a low interiomarginal arch at base of final chamber near periphery on umbilical side, with broad chamber flap just beneath aperture extending into open umbilicus and secondary sutural opening at opposite of flap.

Species commonly found attached to individual quartz grains, carbonate grains, or other shells include *Rosalina concinna* and:

148-150 ***Asterigerina carinata*** d'Orbigny. 148. Spiral view from U393'2". 149. Axial view from U471'5". 150. Umbilical view from U393'2". Scales 100 µm. Test unequally biconvex with chambers arranged in flat turbinoid spiral with oblique sutures. Dorsal chambers all visible, alternating on ventral side with small secondary chambers arranged in rosette form around umbilical plug and with less oblique sutures. Surface smooth. Primary aperture on inner side of ventral face of last chamber alternates with loop-shaped aperture of secondary chambers leading into primaries.

151-153 ***Cibicides protuberans*** Parker. 151. Ventral view from U361'9". Scale 100 µm. 152. Axial view from U549'10". Scale 100 µm. 153. Spiral view from U471'5". Scale 50 µm.

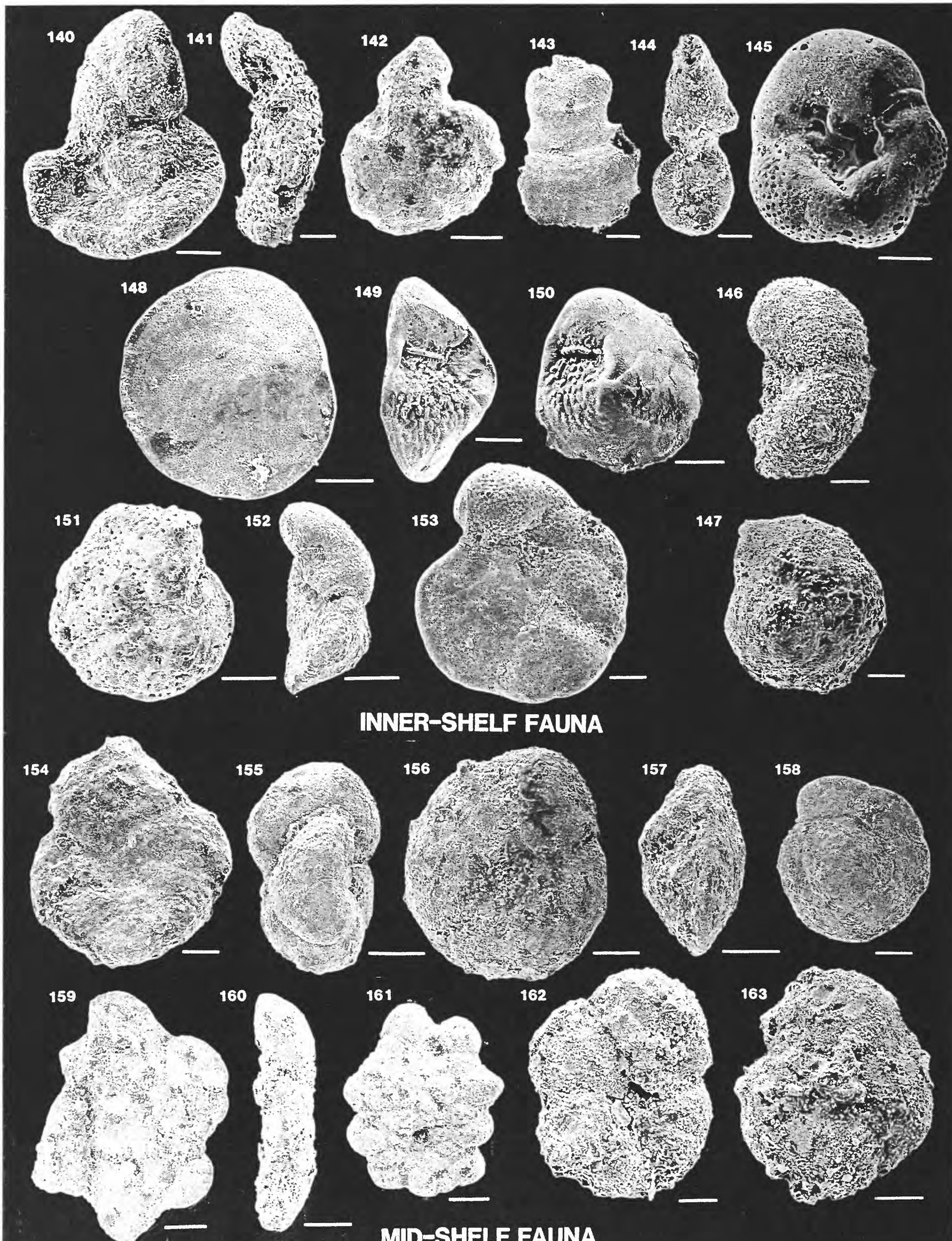
Species characteristic of a mid-shelf environment include:

154-155 ***Anomalina globulosa*** Chapmann and Parr. 154. Umbilical view from U288'8". Scale 50 µm. 155. Axial view from C984'9". Scale 100 µm. Test with low trochospiral, nearly planispiral coil, spiral side with umbonal boss, ventral side with depressed umbilicus, rounded periphery. Chambers few with radiate sutures. Aperture interiomarginal equatorial, extending slightly to umbilical side.

156-158 ***Cibicides aff. C. floridanus*** (Cushman). 156. Umbilical view from C1310'3". 157. Axial view from C1310'3". 158. Spiral view from C1215'2". Scales 100 µm.

159-161 ***Planorbulina mediterranensis*** d'Orbigny. 159. Umbilical view from C1310'3". 160. Axial view from U549'10". 161. Dorsal view from C714'1". Scales 100 µm. Test attached, early stage trochospiral, later with numerous chambers forming discoidal, cylindrical, conical, or subglobular adult. Aperture single or multiple, commonly oval to semilunar openings on each chamber of final whorl, each with narrow bordering lip.

162-163 ***Rosalina floridana*** (Cushman). 162. Umbilical view from C1215'2". Scale 50 µm. 163. Spiral view from U599'. Scale 100 µm.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INNER-SHELF FAUNA
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MID-SHELF FAUNA

Plate 8

Species characteristic of a mid-shelf environment
include *Asterigerina carinata* (Pl. 7) and:

164-166 ***Elphidium sagrum*** (d'Orbigny). 164. Side view from C714'1". 165. Axial view from U471'5". 166. Axial view from C984'9". Scales 100 μm. Test planispiral and bilaterally symmetrical, involute, with sutural pores and retral processes projecting across sutures. Chambers numerous. Aperture a row of pores at base of septal face or areal pores, or both. Surface commonly with grooves (fossettes) or ridges paralleling periphery (striped crenulation) and commonly coinciding with retral processes, or surface may be smooth and finely pustulose.

167-168 ***Cribroelphidium poeyanum*** Cushman and Bronnimann. 167. Axial view from C946'4". Scale 100 μm. 168. Side view from U471'5". Scale 50 μm. Test planispiral and involute with few chambers to whorl. Sutures distinct, depressed and may be crossed by solid pillars or septal bars but without retral processes. Large sutural pores may be present between septal bars. Aperture multiple with one or more pores at base of septal face and one or more areal pores.

169-172 ***Nonionella atlantica*** Cushman. 169. Side view from C1310'3". 170. Axial view from C1310'3". 171. Axial view from C1310'3". 172. Side view from C714'1". Scales 100 μm. Test trochospiral, slightly compressed, spiral side partially evolute with umbonal boss, opposite side involute with final chamber overhanging umbilical region, possibly appearing to form distinct umbilical flap. Chambers relatively numerous, broad, low. Aperture interiomarginal, a low arch near periphery extending somewhat onto umbilical side.

173-174 ***Planulina exorna*** Phleger and Parker. 173. Umbilical view from C1310'3". 174. Axial view from C1310'3". Scales 100 μm. Test trochospiral to nearly planispiral, compressed, spiral side evolute, umbilical side partially evolute, periphery truncate with thick, imperforate marginal keel. Sutures strongly arched, thickened. Secondary lamellae cover umbilical region. Aperture an equatorial interiomarginal arch with narrow bordering lip extending somewhat onto less evolute umbilical side beneath the flap-like chamber margin.

175-177 ***Rosalina bahamaensis*** Todd and Lowe. 175. Umbilical view from C1273'4". Scale 50 μm. 176. Axial view from C1110'. Scale 50 μm. 177. Spiral view from C1310'3". Scale 50 μm.

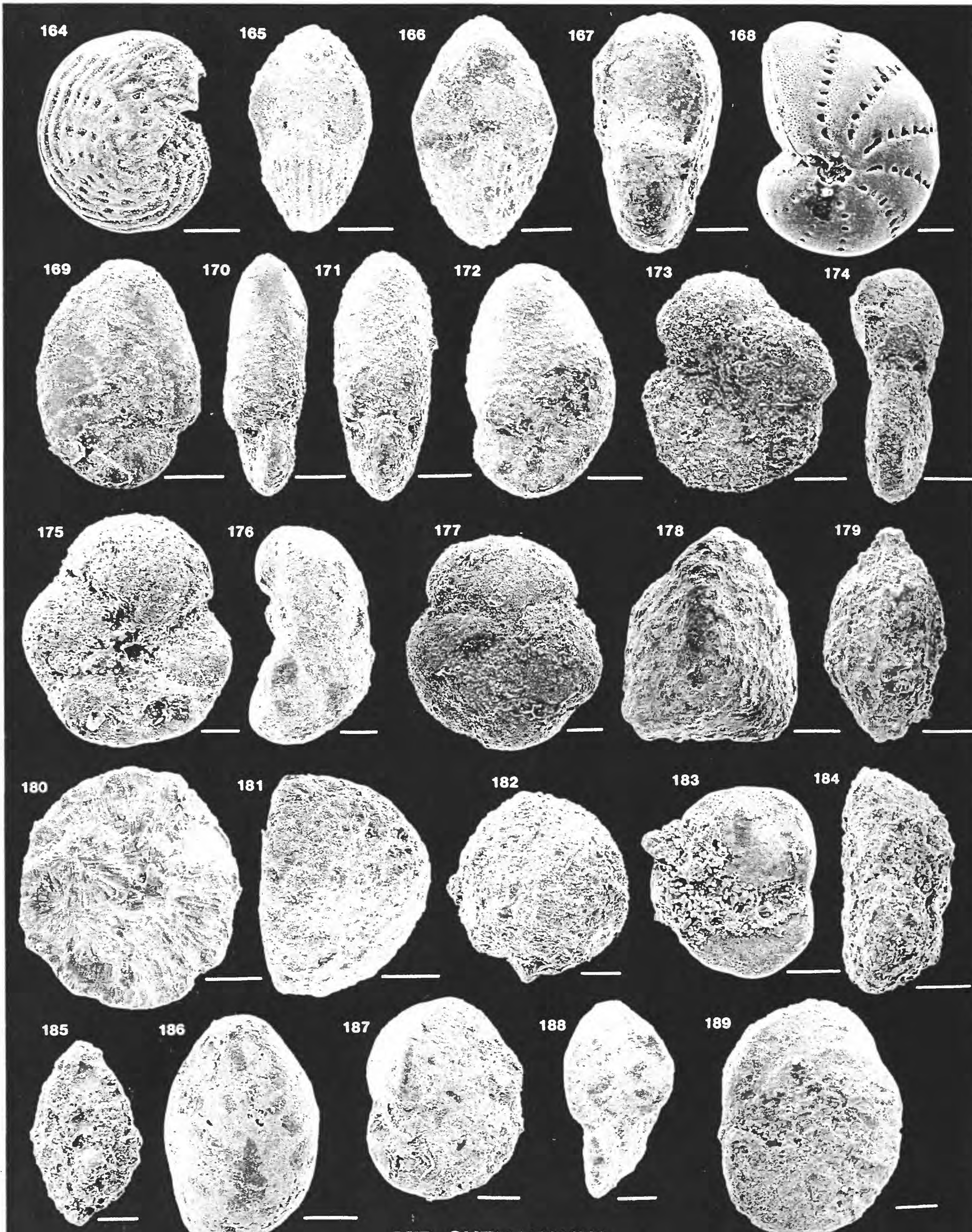
178-179 ***Trifarina occidentalis*** (Cushman). 178. Terminal-aperture view from C1803'4". Scale 50 μm. 179. Side view from C2161'3". Scale 100 μm. Test triserial to uniserial, elongate, triangular in section, commonly costate. Aperture ovate, on short neck with thickened rim, tooth plate with wing at dorsal side.

180-182 ***Gypsina vesicularis*** (Parker and Jones). 180. Umbilical view from C1273'4". 181. Axial view from U836'7". 182. Dorsal view from C504'9". Scales 100 μm. Test relatively large, attached. Chambers roughly circular to rectangular or polygonal in outline. May have irregular knobby projections of groups of chambers. No aperture other than large septal wall pores.

183-184 ***Hanzawaia strattoni*** (Applin). 183. Umbilical view from U361'9". 184. Axial view from U1315'3". Scales 100 μm. Test trochoid, plano-convex, periphery moderately angled with keel, flat side partially involute with elevated flaps on lower margin of chamber partly or completely overlapping chambers of previous whorl and commonly coalescing over central, clear, solid-calcite boss. Opposite side involute but without open umbilicus. Sutures strongly curved, thickened. Aperture an arch on periphery extending somewhat onto convex involute side but also laterally continuous with opening on flat side, with supplementary openings under umbilical flaps.

185-186 ***Globulina inaequalis*** Reuss. 185. Side view from C1951'. 186. Side view from U1174'4". Scales 100 μm. Test globular to ovate, chambers strongly overlapping, added in planes ~144° apart. Sutures flush. Aperture radiate, but commonly obscured by fistules.

187-189 ***Nonionella pizzarense(?)*** Berry. 187. Side view from C2214'3". 188. Axial view from C2214'3". 189. Side view from C2214'3". Scales 100 μm.



MID-SHELF FAUNA

Plate 9

Species characteristic of a backreef/mid-shelf environment include *Asterigerina carinata* (Pl. 7), *Elphidium sagrum* (Pl. 8), *Hanzawaia strattoni* (Pl. 8), *Nonionella atlantica* (Pl. 8), *Planulina exorna* (Pl. 8), *Rosalina bahamaensis* (Pl. 8), but not in dominant numbers, and:

190-192 ***Pyrgo subsphaerica*** (d'Orbigny). 190. Side view from U427'10". 191 Axial view from U499'5". 192. Apertural view from U427'10". Scales 50 µm. Test inflated, discoidal to ovate, proloculus followed by chambers one-half coil in length (biloculine). Aperture terminal near junction of 2 last chambers, rounded to elongate, with distinct and commonly bifed tooth.

193-195 ***Eponides antillarum*** (d'Orbigny). 193. Dorsal view from U1315'3". 194. Axial view from C714'1". 195. Umbilical view from U1315'3". Scales 100 µm. Test low trochospiral coil or may be uncoiled. Aperture basal or areal, single or multiple, and may be covered by plate or spongy material. Periphery angled to distinctly carinate with narrow to broad depression in umbilical region. Sutures curved on spiral side, nearly radial to curved or sigmoid on umbilical side. May have secondarily formed pustules or ridges formed on previous whorl below aperture. Primary aperture an interiomarginal arch without internal tooth plate.

196-198 ***Baggina* n. sp.** 196. Spiral view from U1174'4". Scale 50 µm. 197. Axial view from U1119'8". Scale 50 µm. 198. Ventral view from U1395'3". Scale 100 µm. Test trochospiral, subglobular, chambers few, rapidly enlarging and somewhat overlapping on spiral side. Aperture a broad umbilical opening below clear, nonperforate lunate area in face of final chamber.

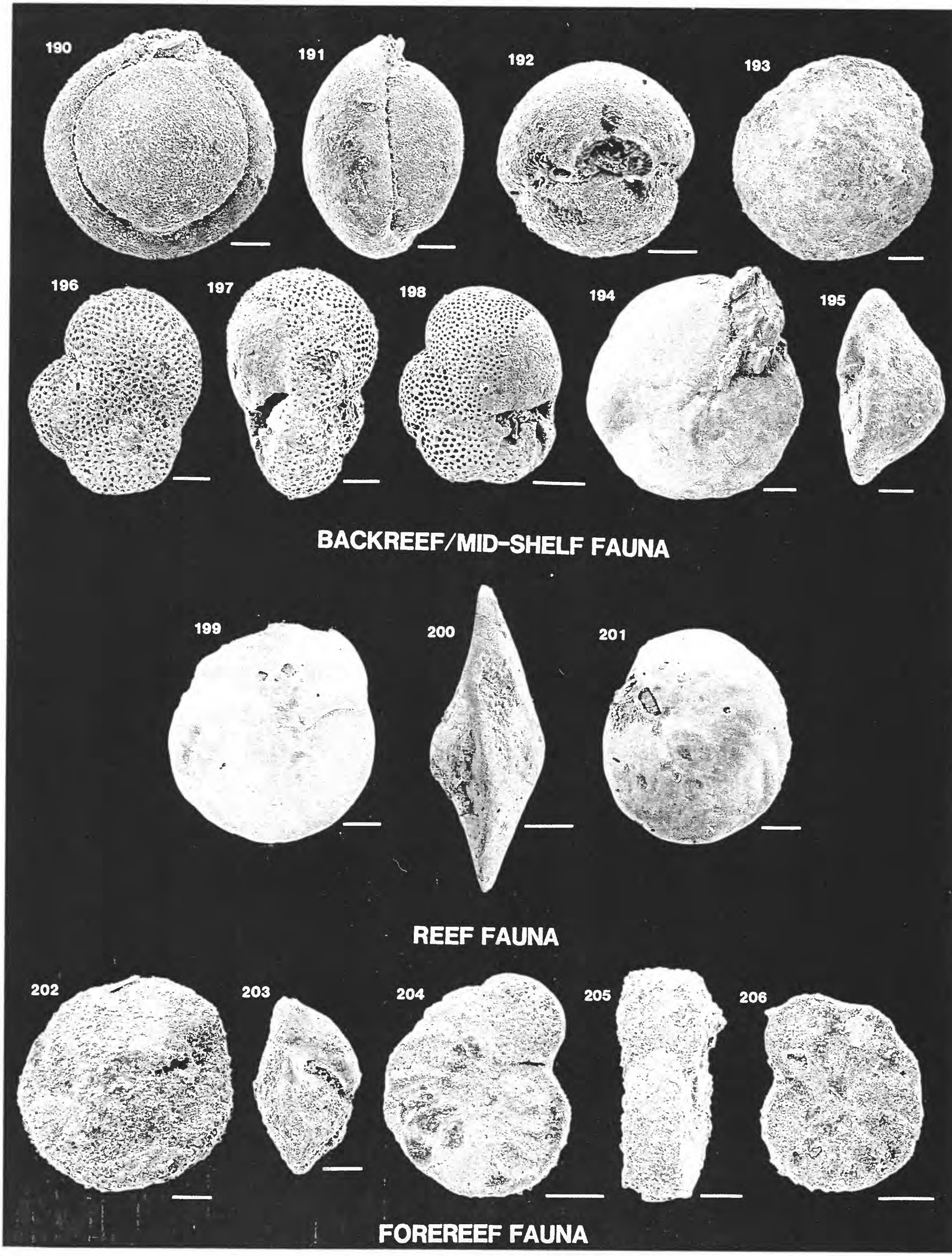
A reef environment is completely dominated by:

199-201 ***Amphistegina gibbosa*** d'Orbigny. 199. Umbilical view from U560'6". 200. Axial view from U471'5". 201. Spiral view from U1315'3". Scales 100 µm. Test lenticular, generally unequally biconvex, with low turbinoid spire. Biconvexity varies widely among individuals. Chambers in complex spiral that splits into chamberlets on ventral side or extends into peripheral flange. Aperture a narrow slit at inner margin of last chamber, usually with a thin lip and generally surrounded by a granulate area.

A forereef environment is dominated by *Amphistegina gibbosa*, *Asterigerina carinata* (Pl. 7), and:

202-203 ***Eponides repandus*** (Fichtel and Moll). 202. Umbilical view from U1263'5". 203. Axial view from U1420'7". Scales 100 µm.

204-206 ***Planulina foveolata*** (Brady). 204. Umbilical view from U645'6". Scale 100 µm. 205. Axial view from U836'7". Scale 50 µm. 206. Side view from U742'9". Scale 100 µm.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BACKREEF/MID-SHELF FAUNA
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REEF FAUNA
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FOREREEF FAUNA

Plate 10

Species characteristic of a forereef/outer-shelf environment include *Asterigerina carinata* (Pl. 7), *Cibicides* aff. *C. floridanus* (Pl. 7), *C. protuberans* (Pl. 7), *Amphistegina gibbosa* (Pl. 9), *Eponides antillarum* (Pl. 9), *Planulina foveolata* (Pl. 9), and:

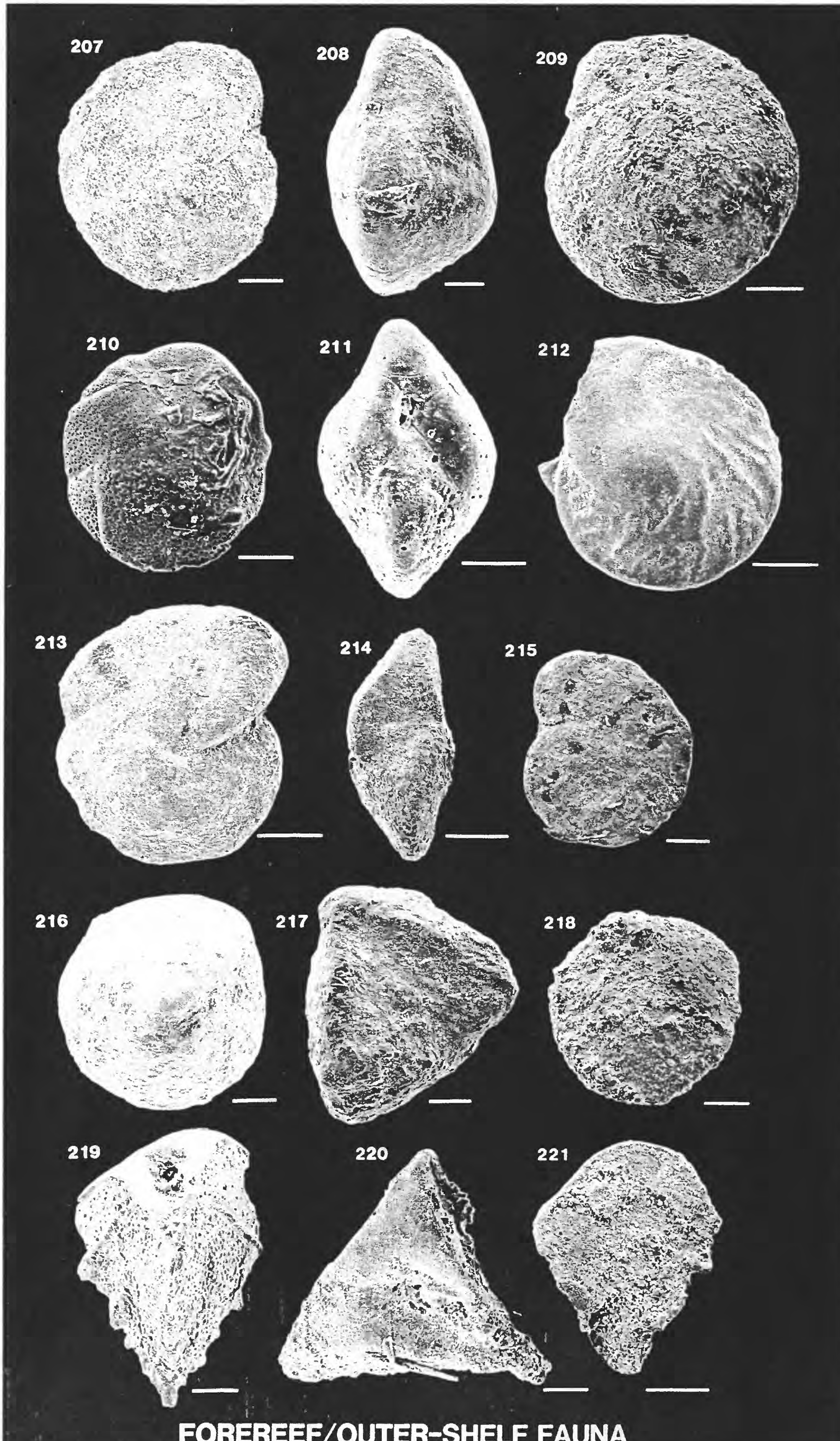
207-209 ***Cibicides corpulentus*** Phleger and Parker. 207. Ventral view from C1310'3". Scale 100 µm. 208. Apertural view from U836'7". Scale 50 µm. 209. Spiral view from C1310'3". Scale 100 µm.

210-212 ***Cassidulina curvata*** Phleger and Parker. 210. Side view from U471'5". 211. Axial-aperture view from U471'5". 212. Side view from U471'5". Scales 50 µm. Test lenticular, commonly biumbonate with clear central bosses. Biserial chambers alternate on each side of periphery, each reaching boss on one side and only extending part way to boss of opposite side. Aperture an elongate slit extending from base of final chamber upward in curve paralleling anterior margin of chamber with narrow bordering lip on lower margin.

213-215 ***Cibicides wuellerstorfi*** (Schwager). 213. Umbilical view from C714'1". 214. Axial view from C714'1". 215. Spiral view from C946'4". Scales 100 µm.

216-218 ***Gyroidina soldanii*** d'Orbigny ***altiformis*** R.E. and K.C. Stewart. 216. Umbilical view from C1803'4". Scale 100 µm. 217. Axial-aperture view from C2136'4". Scale 50 µm. 218. Spiral view from C1803'4". Scale 100 µm. Test trochospiral, periphery rounded to subtruncate, spiral side flat with all chambers visible, opposite side elevated and umbilicate with only chambers of final whorl visible. Chambers rhomboidal in section, with angled umbilical shoulder. Sutures radial to oblique, flush to depressed. Primary aperture a low interiomarginal slit restricted to mid-portion of apertural face, bordered by narrow lip. Small secondary apertures, umbilical in position against previous chamber wall with projecting umbilical flap extending backward over them, are not evident except when test is viewed obliquely.

219-221 ***Reussella atlantica*** Cushman. 219. Umbilical view from U471'5". Scale 50 µm. 220. Apertural view from C1310'3". Scale 50 µm. 221. Dorsal view from C1310'3". Scale 100 µm. Test triserial, triangular throughout, sharply angular, commonly carinate or spinose, gradually enlarging. Aperture basal in final chamber with complex internal tooth plate.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FOREREEF/OUTER-SHELF FAUNA

Plate 11

222-224 ***Planulina ariminensis*** d'Orbigny. 222. Side view from C1273'4". Scale 100 µm. 223. Axial view from C1781'8". Scale 50 µm. 224. Side view from C1310'3". Scale 100 m.

225-226 ***Marginulina subaculeata*** Cushman ***glabrata*** Cushman. 225. Side view from U774'6". Scale 500 µm. 226. Side view from U774'6". Scale 100 µm. Early portion of test slightly coiled but not completely enrolled, later rectilinear. Sutures oblique, especially in early portion. Aperture terminal, eccentric.

227 ***Brizalina plicatella*** (Cushman), side view from C2214'3". Scale 100 µm. Test elongate, tapering, commonly compressed and laterally carinate, biserial throughout, having straight or curved, commonly limbate sutures. May be costate or have apical chamber spines. Aperture loop-shaped, extending up from base of final chamber with trough-shaped internal tooth plate.

228-230 ***Planulina depressa*** d'Orbigny. 228. Spiral view from C2171'. 229. Axial view from C2161'3". 230. Ventral view from C1803'4". Scales 100 µm.

231-233 ***Trifarina carinata*** (Cushman). 231. Side view from C1310'3". Scale 100 µm. 232. Apertural view from C1310'3". Scale 50 µm. 233. Side view from C1310'3". Scale 100 µm. Test triserial, elongate, triangular in section, later chambers tending to become uniserial. Aperture terminal, ovate, on short neck with thickened rim, tooth plate with wing at dorsal side.

234-236 ***Bulimina inflata*** Sequenza. 234. Side view from C1803'4", showing costate test. Scale 100 µm. 235. Apertural view from C1951'. Scale 50 µm. 236. Side view from C1803'4". Scale 100 µm. Test triserial, may become uniserial, lacks strongly embracing chambers. Aperture extends up from base of apertural face with internal folded tooth plate with developed border, one side of which is not attached.

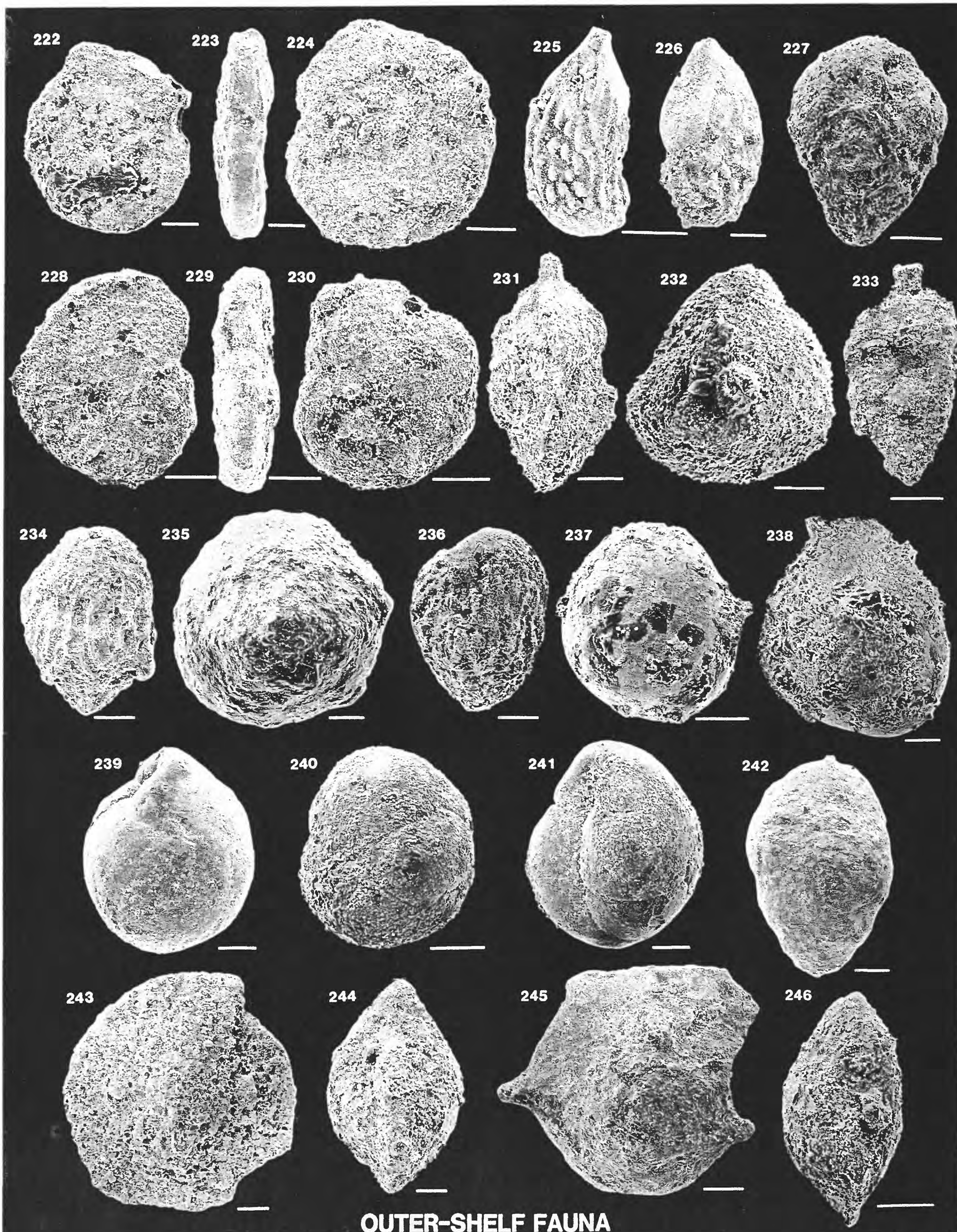
237-238 ***Guttulina hirsuta*** (Terquem). 237. Side view from C1310'3". Scale 100 µm. 238. Side view from C1310'3". Scale 50 µm. Test ovate to elongate. Inflated chambers added in quinqueloculine spiral in planes 144^{o} apart, each successive chamber extending farther from base but strongly overlapping. Sutures depressed. Aperture radiate.

239-241 ***Globocassidulina subglobosa*** (Brady). 239. Side view from C1310'3". Scale 50 µm. 240. Spiral view from C1310'3". Scale 100 µm. 241. Oblique-side view from C1273'4". Scale 50 µm. Test biserial, subglobular, peripheral margin rounded, umbilicus closed. Aperture a narrow slit extending up face of final chamber, may have narrow infolded rim but no tooth plate.

242 ***Globobulimina affinis*** (d'Orbigny), side view from C2136'4". Scale 100 µm. Test globular to ovate, triserial, with strongly overlapping chambers. Aperture loop-shaped with tendency to become terminal. Tooth plate doubly folded pillar-like trough joined to apertural border at one side, upper part with projecting fanlike tip, lower part extending into chamber cavity as arched trough, then curving forward.

243-244 ***Lenticulina americana*** (Cushman). 243. Side view from C2171'. 244. Axial view from C2136'4". Scales 100 µm. Test planispiral or rarely slightly trochoidal, lenticular, biumbonate, periphery angled or keeled. Chambers in general of greater breadth than height. Sutures radial, straight, or curved and depressed, flush or elevated. Surface may have thickened elevated sutures, bosses, or structural nodes. Aperture radial at peripheral angle.

245-246 ***Lenticulina americana*** (Cushman) ***spinosa*** (Cushman). 245. Side view from C1803'4". Tuberculate marginal spines have been partially broken off specimen. 246. Axial view from C1803'4", showing complete loss of spines. Scales 100 µm.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OUTER-SHELF FAUNA

Plate 12

247-249 ***Lenticulina atlantica*** (Barker). 247. Side view from C1310'3". 248. Apertural view from C1310'3". 249. Side view from C1310'3". Scales 100 µm.

250-251 ***Saracenaria italica*** Defrance. 250. Side view from C1710'8". 251. Apertural view from C1781'8". Scales 100 µm. Test planispiral in early stage, later with tendency to uncoil. Triangular in section with broad flat apertural face. The outer margin and two angles of face may be acute and keeled to somewhat rounded. Aperture at peripheral angle, radiate.

252-254 ***Sigmoilopsis schlumbergeri*** (Silvestri). 252. Side view from C1587'6". Scale 100 µm. 253. Terminal-aperture view from C1587'6". Note lipped aperture. Scale 50 µm. 254. Side view from C1587'6". Scale 100 µm. Test ovate with chambers one-half coil in length, at first quinqueloculine, then with increasing angle between plane of coil so that chambers are nearly opposing. Changing plane of coil results in early sigmoid curve, extremities of curve spiraling outward. Wall agglutinated with calcareous cement and calcareous particles. Aperture terminal, rounded, with small tooth.

255-256 ***Guttulina laevis*** d'Orbigny. 255. Side view from C1310'3". Scale 100 µm. 256. Terminal-aperture view from C1310'3". Scale 50 µm.

257-259 ***Uvigerina flintii*** Cushman. 257. Side view from C1710'8". Scale 100 µm. 258. Side view from C1310'3". Scale 100 µm. 259. Terminal-aperture view from C1710'8". Scale 50 µm. Note costate test and double-lipped neck. Test elongate, triserial, rounded in section, chambers inflated, surface smooth, hispid or costate. Aperture terminal, rounded with nonperforate neck and phialine lip and internal tooth plate with distinct wing at one side.

260-261 ***Uvigerina peregrina*** Cushman. 260. Side view from C1710'8". Scale 100 µm. 261. Terminal-aperture view from C1710'8", showing costate test and short neck. Scale 50 µm.

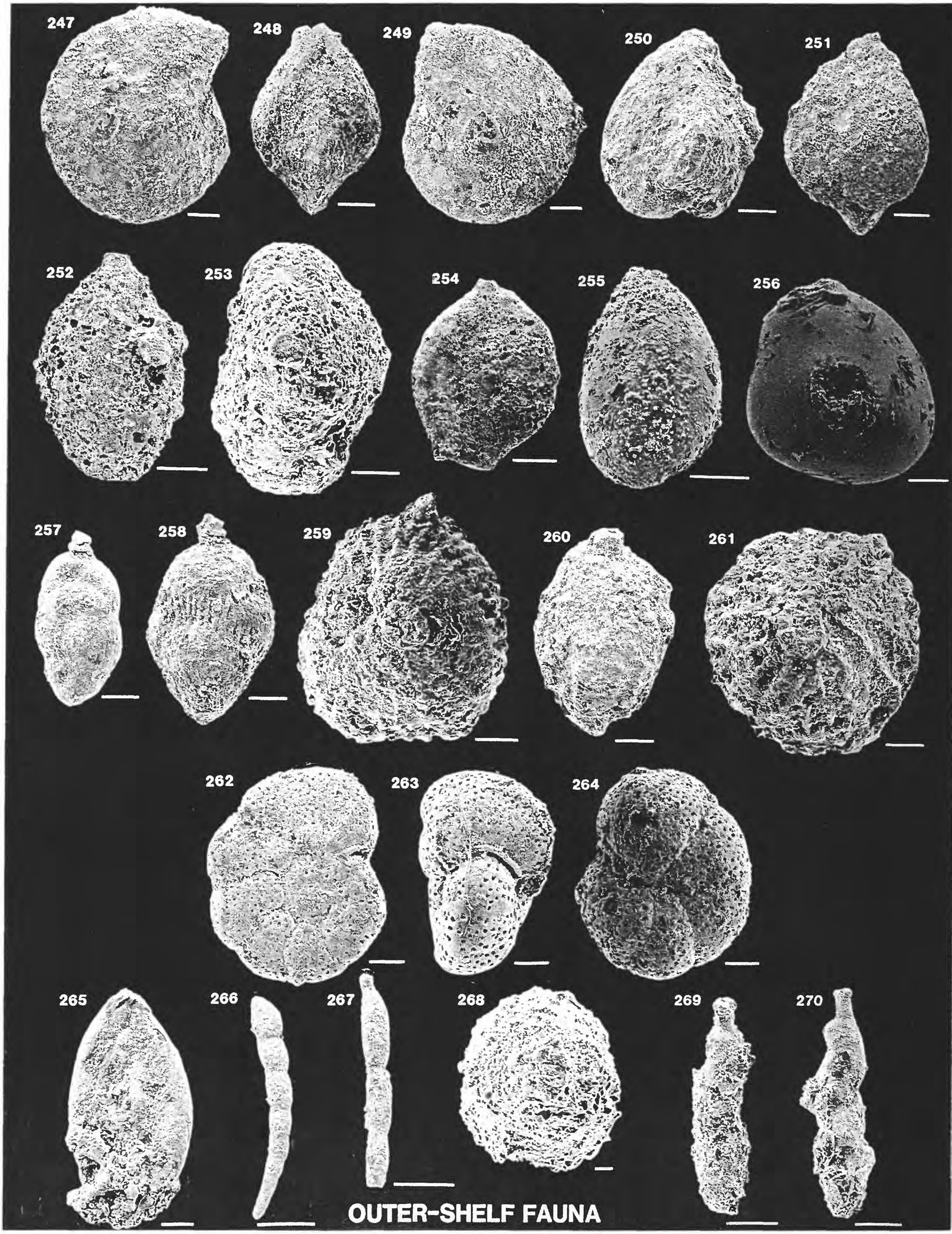
262-264 ***Anomalina globosa*** Chapmann and Parr. 262. Spiral view from C1310'3". 263. Axial view from C1310'3". 264. Umbilical view from C1310'3". Scales 50 µm. Test low trochospiral or nearly planispiral coil, spiral side with umbonal boss, opposite side with depressed umbilicus, periphery rounded. Chambers few, sutures radiate. Aperture an interiomarginal equatorial opening extending slightly to umbilical side.

265 ***Sigmoilina tenuis*** (Czjzek), side view from C1587'6". Scale 50 µm. Test ovate with earliest chambers opposite, then with plane of chamber addition changing so that it forms a sigmoid curve. Successive chambers added at first in planes about 120° apart but angle gradually enlarges to 180° in adult stage. Chambers have broad lateral extensions that obscure all preceding chambers except penultimate one, giving external biloculine appearance. Aperture terminal, rounded with tooth.

266 ***Dentalina advena*** (Cushman), side view from C1310'3". Scale 500 µm. Test elongate, arcuate, uniserial, assymetrical. Sutures commonly oblique. Aperture radiate, terminal, may be eccentric or nearly central.

267 ***Dentalina subsoluta*** (Cushman), side view from C1310'3". Scale 500 µm.

268-270 ***Uvigerina laevis*** Goes. 268. Terminal-aperture view from C1310'3". Scale 10 µm. 269. Side view from C1310'3". Scale 100 µm. 270. Side view from C1310'3". Scale 100 µm.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OUTER-SHELF FAUNA

Plate 13

Species characteristic of an outer-shelf/upper-slope environment include all species found on the outer shelf (Pls. 11 and 12) plus the following:

271 ***Ehrenbergina trigona*** Goes, ventral view from C1710'8". Scale 100 µm. Test flat, compressed perpendicular to plane of coiling, periphery carinate. Chambers broad, low, biserial, enrolled but somewhat uncoiled. Surface smooth or with pustules or ridges. Aperture an elongate curved slit perpendicular to base of apertural face and paralleling peripheral keel.

272-274 ***Rosalina bertheloti*** (d'Orbigny). 272. Ventral view from U742'9". 273. Axial view from U742'9". 274. Spiral view from U742'9". Scales 100 µm.

275 ***Gyroidina orbicularis*** d'Orbigny, side view from C1745'. Scale 50 µm.

276-277 ***Pseudonodosaria comatula*** (Cushman). 276. Side view from C1710'8". Scale 100 µm. 277. Apertural view from C1710'8". Scale 50 µm. Test uniserial and rectilinear throughout. Chambers embracing strongly in early portion, later ones may be inflated and less embracing. Sutures horizontal. Aperture terminal, radiate.

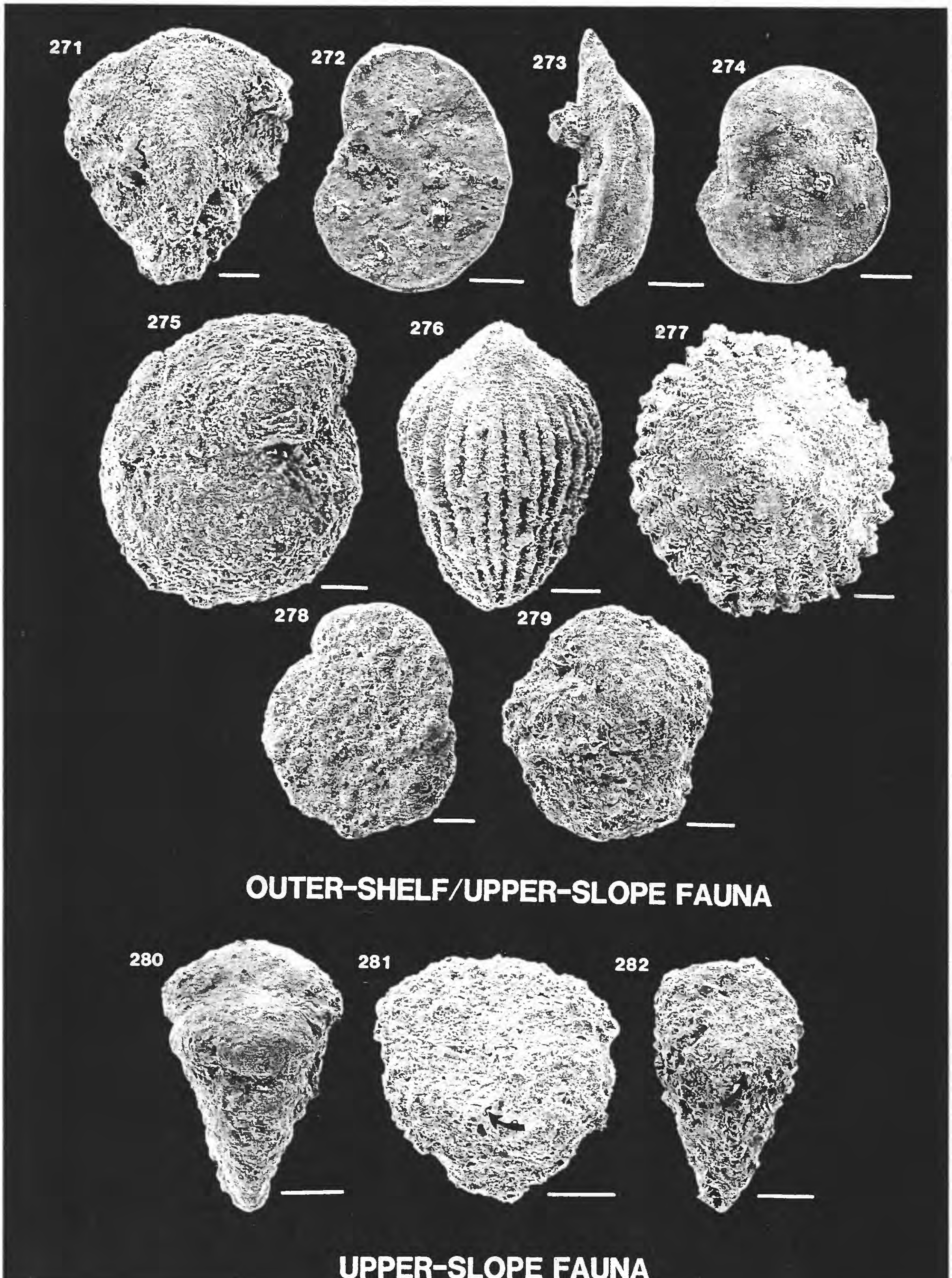
278-279 ***Gaudryina (Pseudogaudryina) atlantica*** (Bailey). 278. Spiral view from C1710'8". 279. Ventral view from C1710'8". Scales 100 µm. Test elongate, early stage triserial and commonly triangular, later portion biserial. Aperture interiomarginal.

Species characteristic of the upper slope include those of the outer shelf (Pls. 11 and 12) and agglutinated, biserial textularids:

280 ***Textularia agglutinans*** d'Orbigny, oblique axial view from C984'9". Scale 100 µm. Test elongate, biserial, generally more or less compressed in plane of biseriality or rarely oval to circular in cross section. Chambers numerous, generally closely appressed. Aperture single low arch at base of last chamber.

281 ***Textularia conica*** d'Orbigny, oblique axial view from U687', showing broad, wide, flat apertural surface from point of arrow to top of micrograph. Scale 100 µm. Side view of perfect specimen would show a wide "stubby-cone" shape.

282 ***Textularia mayori*** Cushman, oblique axial view from U836'7", showing broad, relatively narrow apertural surface from point of arrow to top of micrograph. Scale 100 µm. Side view would show greater height relative to that of *T. conica*.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