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2. OLIGOCENE TO PLEISTOCENE BENTHIC FORAMINIFER ASSEMBLAGES AT SITES 754 AND 756, EASTERN INDIAN OCEAN[1]

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ABSTRACT

Oligocene to Pleistocene bathyal benthic foraminifers at Broken Ridge (Site 754) and Ninetyeast Ridge (Site 756), eastern Indian Ocean, were investigated for their stratigraphic distribution and their response to paleoceanographic changes. Q-mode factor analysis was applied to relative abundance data of the most abundant benthic foraminifers.

At Site 754, seven varimax assemblages were recognized from the upper Oligocene to the Pleistocene: the *Gyroidina orbicularis–Rectuvigerina striata* Assemblage in the uppermost Oligocene; the *Lenticulina* spp. Assemblage in the upper Oligocene to lower Miocene, and in lower Miocene to lowermost middle Miocene; the *Burseolina* cf. *pacifica–Cibicidoides mundulus* Assemblage in the lower Miocene; the *Planulina wuellerstorfi* Assemblage in the upper middle Miocene; the *Globocassidulina* spp. Assemblage in the upper Miocene; the *Gavelinopsis lobatulus–Uvigerina proboscidea* Assemblage in the Pliocene; and the *Ehrenbergina* spp. Assemblage in the Pleistocene. The major faunal changes are complex, but exist between the *Lenticulina* spp. Assemblage and the *P. wuellerstorfi* Assemblage at ~13.8 Ma, and between the *Ehrenbergina* spp. Assemblage and the *G. lobatulus* Assemblage at ~5 Ma. The development of the *P. wuellerstorfi* and *Globocassidulina* spp. Assemblages after 13.8 Ma is correlated with the decrease in temperature of the intermediate waters of the ocean, in turn related to Antarctic glacial expansion. The faunal changes at ~5 Ma are related to the development of low oxygen intermediate water, formed in the presence of a strong thermocline.

At Site 756, six varimax assemblages are distributed as follows: the *Cibicidoides* cf. *mundulus–Oridorsalis umbonatus* Assemblage in the lower Oligocene; the *Epistominella umbonifera–Cibicidoides mundulus* Assemblage from the upper Oligocene to the lower Miocene; the *Cibicidoides mundulus–Burseolina pacifica* Assemblage from lower Miocene to the lower middle Miocene; the *Globocassidulina* spp. Assemblage from the upper lower Miocene to the Pliocene; the *Uvigerina proboscidea* Assemblage in the upper Miocene and the Pliocene; and the *Globocassidulina* sp. D Assemblage in the Pliocene. The main faunal change at this site is between the *E. umbonifera* Assemblage and the *Globocassidulina spp.* Assemblage, at ~17.1 Ma. The timing of this faunal change is coeval with faunal changes in the North Atlantic and the Pacific. The change is related to a change in bottom water characteristics caused by an increased influence of carbonate corrosive water from the Antarctic source region, and a change in surface productivity. A low oxygen event at Site 756, which started at about 7.3 Ma, occurred about 2.3 m.y. before that at Site 754.

The different response to global paleoceanographic changes is not yet explained, but may be due to the difference of marine topography and the degree of upwelling.

INTRODUCTION

Recent studies in Oligocene and Neogene deep-sea paleoceanography have shown several steps in benthic foraminiferal turnover occurring on a global scale (e.g., Douglas and Woodruff, 1981; Boltovskoy, 1987; Culver, 1987). The tempo and mode of the faunal turnovers and the paleoecological response of benthic foraminifers to oceanographic and climatic changes have been discussed in detail by many workers (e.g., Kennett, 1977; Schnitker, 1980, 1986; Woodruff and Douglas, 1981; Thomas, 1985, 1986a, 1986b; Thomas and Vincent, 1987, 1988). Woodruff (1985) identified a stepwise faunal turnover, related to the development of Antarctic glaciation, as one of the significant foraminiferal events in the Miocene. Species origins and extinctions between 16 and 13 Ma are believed to be related to the expansion of Antarctic glaciation which caused an intensification of atmospheric-ocean circulation and upwelling (Woodruff, 1985). The late Miocene change in species abundance and depth distribution between 10 and 8 Ma is considered to have resulted from an increase of organic carbon, intensification of the low oxygen zones, and an increase in deep ocean dissolution. Other changes in Miocene faunas were caused by an increase of primary productivity which initiated at 19—~17 Ma (Thomas and Vincent, 1987, 1988; Miller and Katz, 1987).

Despite these discussions, detailed information on the response of faunal change to such paleoceanographic changes in the Indian Ocean is very limited. Most original source data on paleoceanography are from the Atlantic and Pacific Oceans, except for Boltovskoy's work in the Indian Ocean (Boltovskoy, 1977, 1978). Therefore, the purpose of this study is (1) to report species ranges and their quantitative distribution, (2) to distinguish the assemblages based on quantitative analysis, and (3) to clarify the timing and the cause of faunal change in the Indian Ocean and to compare it with equivalent events at other ocean sites.

METHODS

ODP Site 754 (30°56.439′S; 93°33.991′E) is located on the crest of Broken Ridge and Site 756 (27°21.330′S; 87°35.805′E) is located near the crest of the southern end of Ninetyeast Ridge (Fig. 1). The present water depths are 1074 and 1518 m, respectively. A nearly complete Pleistocene to upper Oligocene section of foraminiferal nannofossil ooze was recovered by the advanced piston corer (APC) at Site 754. Recovery at APC Hole 756B consists of a complete section of lower Oligocene to Pliocene nannofossil ooze containing foraminifers. Cores from Hole 756C sampled lower Oligocene to upper Eocene nannofossil ooze with foraminifers.

The samples were processed by two methods: loose sediments were washed only, whereas slightly consolidated sediments were treated with a <3% hydrogen peroxide solution. In both cases, samples were washed on a 63 μm sieve. In order to measure

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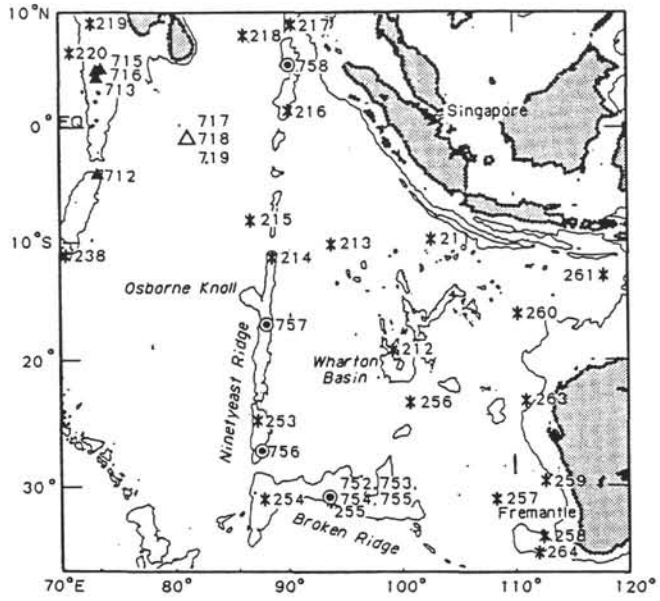

Figure 1. Locations of Site 754 (Broken Ridge) and Site 756 (Ninetyeast Ridge). ✱ = DSDP sites. ▲ = ODP Leg 115 sites. Δ = ODP Leg 116 sites. ◉ = ODP Leg 121 sites.

sample volume (cm^3), samples were put into a graduated cylinder with water before washing. Foraminiferal specimens were picked from aliquots of the >149 μm size fraction. This size fraction is the same as that of Miller and Katz (1987). The planktonic to benthic ratio is based on a count of over 100 individuals of both benthic and planktonic foraminifers.

Statistical analysis using a Q-mode factor analysis (CABFAC; Klovan and Imbrie, 1971) was applied to obtain statistically independent assemblages. The selection of species for this analysis was based on the taxa which occurred as >4% in each sample, and were found in more than two samples. Age estimation of samples is based on nannofossil biostratigraphy (Peirce, Weissel, et al., 1989). Taxonomy is principally based on Boltovskoy (1977), Corliss (1979b), and van Morkhoven et al. (1986).

RESULTS

Site 754

Hole 754A recovered the uppermost Eocene, uppermost Oligocene, and almost complete sections from the lower Miocene to Pleistocene. In this study, 30 samples from the upper Oligocene to the Pleistocene were analyzed for the stratigraphic distribution of benthic foraminifers (Fig. 2; Table 1).

The stratigraphic distribution of the most common species is shown in Figure 3. The species restricted to the uppermost Oligocene to lower Miocene are *Bulimina impendens, Uvigerina graciliformis, Pullenia subcarinata, Planulina renzi,* and *Cibicidoides* cf. *mundulus*. The following species are common to the Oligocene and lower Miocene: *Anomalinoides semicribratus, Bulimina tuxpamensis, Rectuvigerina striata,* and *Nonion havanensis,* but they disappear in the planktonic foraminifer N9 Zone. Species that are not present in the upper Miocene, but reported frequently from modern deposits of the Pacific and Atlantic Oceans, are: *Burseolina pacifica, Valvulineria laevigata, Astrononion stelligerum, Bulimina rostrata, Trifarina bradyi, Gyroidina lamarckiana,* and *Uvigerina schencki*. Therefore, the composition of deep-sea benthic faunas did not intrinsically change after the late Miocene to the Present as suggested by Berggren and Miller (1989).

Relative abundance of the main species is plotted against sub-bottom depths and nannofossil zones in Figure 4. *Globocassidulina spp.,* comprising smaller-sized *G. globosa,* is characteristically abundant in the Oligocene (up to 27% of the fauna). *Globocassidulina subglobosa,* with a larger test, is abundant in the upper Miocene and the Pleistocene. Owing to external similarity of these species, except for the test size, both are assigned to one group in this study. *Lenticulina* spp. are abundant in the lower Miocene, but decrease in relative abundance upward from the middle Miocene. A similar trend is observed in *Sphaeroidina bulloides. Cibicidoides mundulus* occurs commonly in the lower Miocene, though its peak relative abundance is found in the upper middle Miocene to upper Miocene. *Burseolina pacifica* and *B.* cf. *pacifica* are commonly found through the lower and middle Miocene, but *B.* cf. *pacifica* rapidly decreases in relative abundance within the lower middle Miocene (Samples 121-754A-8H-5, 70–75 cm, to -8H-1, 70–75 cm). *Uvigerina proboscidea* frequently occurs through the Miocene and dominates in the upper Pliocene. *Bulimina mexicana* occurs commonly in the upper Miocene and Pliocene, but its relative abundance is much reduced from in the uppermost Miocene and lower Pliocene. *Planulina wuellerstorfi* has a first appearance in the upper Miocene (nannofossil Zone CN4) and increases rapidly in relative abundance in the middle Miocene to 18%, with the highest peak abundance (26%) found in the nannofossil Zone CN9b–10a of the late Miocene. *Karreriella bradyi* occurs continuously at Site 754 and its relative abundance tends to increase from the middle Miocene to Pleistocene, but it is rare in the Pleistocene. The following species do not have continuous stratigraphic occurrences, but are prominent members of the fauna: *Ehrenbergina carinata* and *E.* spp. in the Pleistocene (up to 38%) and *Gavelinopsis lobatulus* and *Astrononion echolsi* in the Pliocene (up to 25%) and the uppermost middle Miocene (up to 11%).

Species diversity calculated by the Shannon-Wiener Information Function (H') reveals three stages (Fig. 5). The diversity of the lower Miocene assemblage is in the range of 4.5–5.0 (average 4.81). A characteristic drop in diversity is found in the lowermost middle Miocene assemblage between Samples 121-754A-9H-1, 70–75 cm, and -8H-5, 70–75 cm. Most samples from the middle Miocene and upper Miocene to Pliocene show diversities of 4.0–4.5 (average 4.26). Lower diversity (<4.0) is observed in Oligocene and Pleistocene samples. The samples show a rapid decrease in diversity from the upper Pliocene to the Pleistocene at this site and the diversity in the Pleistocene is particularly low.

Site 756

Holes 756B and 756C recovered almost complete sections of the Oligocene to Pliocene. Forty-four samples were analyzed for the species range and frequency distribution (Fig. 2; Table 2).

Stratigraphic distribution of the most common species is shown in Figure 6. The stratigraphic ranges of some species are compared with the range reported by van Morkhoven et al. (1986) and Berggren and Miller (1989). *Cibicidoides laurisae* is known up to P22, but it disappeared in Zone CP17 (P18) at this site. Three species, *Uvigerina spinulosa, Cibicidoides mexicanus,* and *Bulimina impendens,* are known to disappear in N5 (van Morkhoven et al., 1986). At Site 756, *Uvigerina spinulosa* is rare and ranges only through Zone CP18 (or P18–19). *Cibicidoides mexicanus* and *B. impendens* occur up to Zone CN1 (N4) at this site. *Anomalinoides pseudogrosserugosus, Cibicidoides alazanensis, Siphonina tenuicarinata,* and *Bulimina tuxpamensis* have been recorded up to N9, whereas *A. pseudogrosserugosus* occurs from CP16–18 (or P16–P18/19). *Cibicidoides alazanensis* and *S. tenuicarinata* disappeared in Zone CN3/4, which is similar to its range as reported by van Morkhoven et al.(1986). *Bulimina jarvisi,* with its last appearance in N10, is restricted to the upper Oligocene to

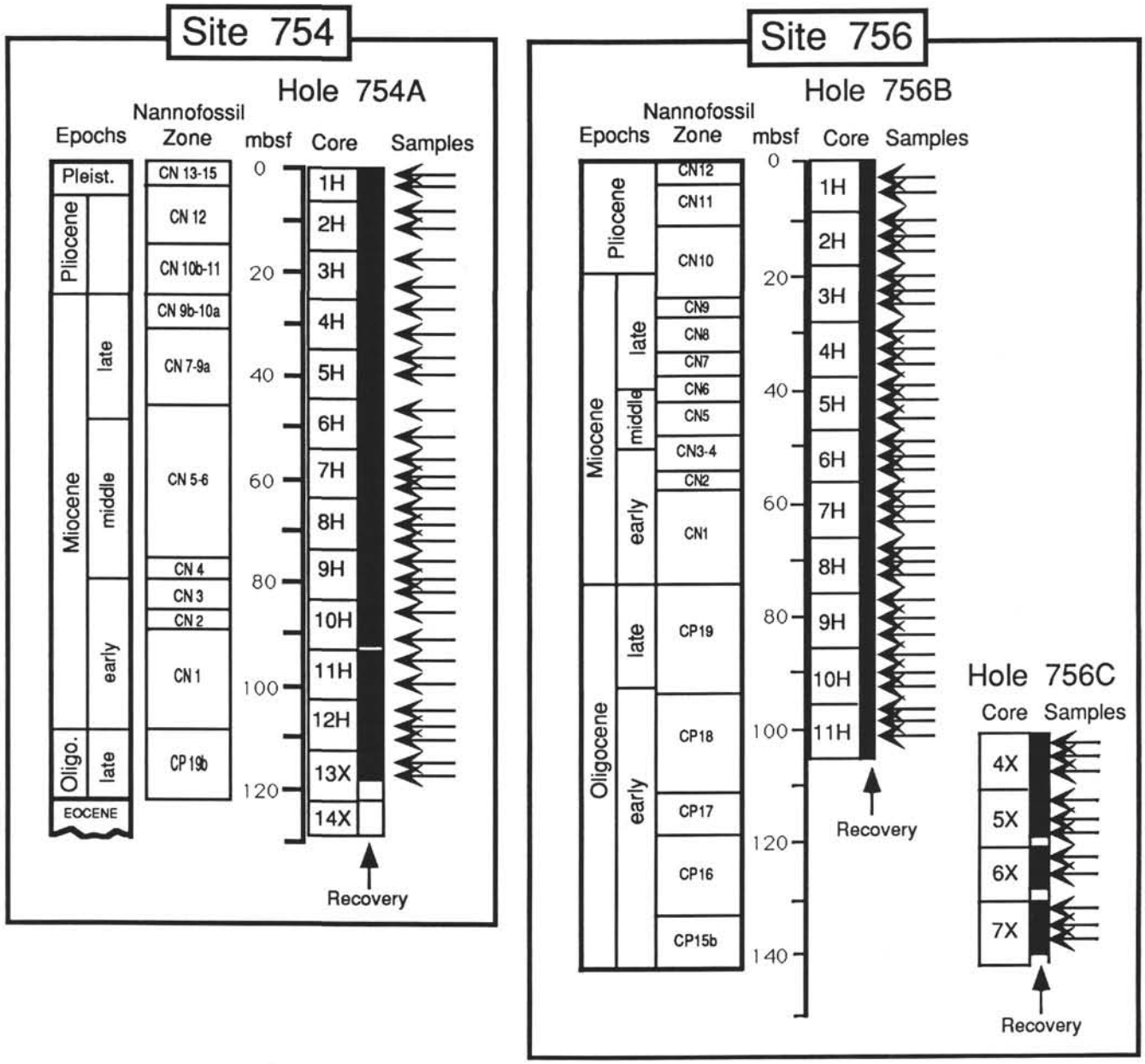

Figure 2. Samples analyzed in this study.

lowermost Miocene (CP9-CN1 or P21-N4) at this site. *Hanzawaia ammophila* ranges from lower Eocene to Miocene (P6a-N11), but is found only in the lower Oligocene at Site 756. The limited occurrence of *H. ammophila* at this site may be related to the rifting event of Broken Ridge. According to van Morkhoven et al. (1986), *H. ammophila* has its optimum occurrence in outer neritic to upper bathyal environments. *Anomalinoides semicribratus,* with known ranges from P12 to N12, disappears in Zone CN3/4 (or P10-13) at this site. *Planulina renzi* is known to occur in the range of P16/17-N17, but it ranges from the Oligocene to the lower Miocene (CP17-CN2 or P18-N4) at Site 756.

Anomalinoides globulosus first appears in Zone CN6 or Zone N15, consistent with the known first appearance of this species (van Morkhoven et al., 1986). *Planulina wuellerstorfi,* with its first appearance in Zone N9, occurs at Site 756 in the lower middle Miocene (CN3/4 or N10-13), suggesting almost coeval appearance with its known first appearance (van Morkhoven et al., 1986; Miller and Katz, 1987; Thomas and Vincent, 1987). *Uvigerina hispida* is recorded from the early Miocene to Pleistocene (van Morkhoven et al., 1986), though it appears from the Pliocene at Site 756.

The relative abundances of the most common species are plotted vs. sub-bottom depths and nannofossil zones in Figure 7. *Globocassidulina* spp., consisting of *G. subglobosa* and *G. globosa,* are abundant and occur almost continuously at this site, with wide fluctuations of abundance. A marked change in abundance of this taxon occurs within the middle Miocene, where its relative abundance falls rapidly from 18% (Sample 121-756B-6H-3, 70–75 cm) to 1% (Sample 121-756B-6H-1, 70–75 cm). *Cibicidoides* cf. *mundulus,* characterized by a small and thin-shaped test, dominates in the lower Oligocene. Instead of *C.* cf. *mundulus, Cibicidoides mundulus* is abundant from the upper Oligocene. *Epistominella umbonifera* is abundant in the Oligocene, making up to 21% of the fauna. *Astrononion echolsi* is common through

Table 1. Occurrence of benthic foraminifers at Site 754.

Hole	754A -												
Sections	1H-1	1H-3	2H-1	2H-3	3H-1	3H-5	4H-1	4H-5	5H-1	5H-5	6H-1	6H-5	7H-1
Intervals (cm)	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75
Amphicoryna scalaris											1		
Anomalinoides flintii													
Anomalinoides globulosus		2		5	2							1	
Anomalinoides semicribratus													
Anomalinoides sp. A					8								
Astrononion echolsi			8	20	8	9	1		1				
Astrononion cf. echolsi													
Astrononion stelligerum									1	3	1		
Astrononion sp. indet.													
Bolivina pseudoplicata								1					
Bolivinopsis cubensis													
Brizalina albatrossi					1		5	2	16	6	16	10	2
Brizalina cf. pacifica							2						
Brizalina petterssoni													
Brizalina silvestriana			7										
Brizalina sp.		1											
Bulimina cf. thalmanni													
Bulimina impenedens													
Bulimina mexicana				22	2	2	2			24	3	10	
Bulimina cf.mexicana													
Bulimina rostrata									1				7
Bulimina tuxpamensis													
Bulimina cf. tuxpamensis													
Bulimina sp.												1	1
Bulimina sp. indet.													
Burseolina pacifica											2		21
Burseolina cf. pacifica													
Burseolina sp. A							1						
Cibicides ? sp.	1				1								
Cibicides lobatulus		9				3	2	9	26	16	9	8	
Cibicidoides dutemplei													
Cibicidoides grosseperforatus													
Cibicidoides herricki													
Cibicidoides mundulus	11	4	1	7	16	19	3	5		2	19	9	11
Cibicidoides cf. mundulus													
Cibicidoides pachydema				7									
Cibicidoides robertsonianus													
Cibicidoides spp.	2	2	21	0	0	4	4		1	3			3
Dentalina communis											1	1	1
Dentalina hircicornua													
Dentalina cf. hircicornua													
Dentalina intorta					1								
Dentalina sp. A									1				
Dentalina spp.	1			6	1		2		1				1
Dyocibicides spp.													
Eggerella bradyi													
Eggerella sp.													
Ehrenbergina carinata			1			24	11	11					
Ehrenbergina spp.	22	47											
Epistominella exigua				1				1					
Epistominella umbomifera		1									2		2
Epistominella cf. umbomifera													
Epistominella sp. A													
Fissurina spp.	4	2	7	7	5	5	3	2		2	3		2
Fursenkoina squammosa				3		1							
Fursenkoina sp. B													
Fursenkoina spp.							1						
Gauduryina spp.			1		9	2	4	9	2			1	1
Gavelinopsis lobatulus	1		24	16	54		1				29		
Globobulimina spp.													
Globocassidulina alternans													
Globocassidulina crassa				6		2		2		6	4		1
Globocassidulina decorata			1		15								5
Globocassidulina havanensis													
Globocassidulina cf. havanensis													
Globocassidulina reflexa			13		9								
Globocassidulina sp. B				1				1					
Globocassidulina sp.E													
Globocassidulina spp.	77	2	1	1	11	16	45	42	21	50	39	6	7
Globocassidulina sp. indet.					1								
Guttulina spp.													
Gyroidina laevigata													
Gyroidina lamarckiana								2		6	2		
Gyroidina cf.lamarckiana							1						1
Gyroidina orbicularis	1		3	4	1		2		2	12	2		2
Gyroidina soldanii					2	6	11		13		3	6	
Heronarellina sp. "A"			1								1	1	
Karreriella bradyi	3		13	20	2	23	15	12	16	9	15	4	7
Kyphopyxa sp. A													
Lagena spp.	4	1	4	2	2	4	2	1	1	5	3		3
Laticarinina pauperata		5	10	2	6	7	15	9		4	1	7	5
Lenticulina spp.					1	2	1	4		1	1	1	2
Marginulina sp. 2													

Table 1 (continued).

7H-3	7H-5	8H-1	8H-3	8H-5	9H-1	9H-3	9H-5	10H-1	10H-5	11H-1	11H-5	12H-1	12H-3	12H-5	13X-1	13X-3
70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75
1		1	2	2	1 1	1	1 3	3 1 8	3 11	2 2	7 1	2	6 1	3		1
1		1	1 1			1		2	1		1	2	1			1
2	1	6	12	1	1	1	1	2	1 8	4	1		3	3		
	1											3	11	1	1 6 4	1
		4	7	4	2	2	1	1	2 1	2 2	5 14	28	55	1 1 1	40	26
6 1	7	18	5	1 40	6 6	9 7	5 6	1 16	19 43	12 59	21	2	2 13	8 31	1 25	3
9	17	1		1	1	7	4	6 12	2 56	34	43	4	31	16	87	30
3 1		7 1 3	1		1 1	1 7 2	1 4	6 2	2	16 4	7 4 1	2 2	20 3	5 3	14	3
	1	1		3	1 3	1				1	4	1 4	1 11	4	2	
						1		2		2		1				
1	3	3	1 1	5 2	4 2	12 2		7 1	5	12	10 3	2	1	10 1 1	1 8	4
3					3 3	1	2	2		1		3				
	1	1				2			1 1		2				1	
52	6	2	24	19	10		1	40	1	3 2	12	23	51	15	176	71
4 1	2	1	5	3	1	1 1	2		5			1			2	4 3 1
2 6 2	3 1 7 1	4 5	5 1	1 2	2 1 2 5	2 1 6	2 2	5 2 6	10 5 4 2	9 2 1 5	7 4 3 11	4 2 2 1 1	6 3 3 9	4 2 5 2	15 5 5	10 1 5 1
2 6	4 1	2 7	7 8	2 4	2 17	1 18	10	1 12	17	3 31	4 20	3 21	2 44	6 34 2	5 30	14

Table 1 (continued).

Hole	754A -												
Sections	1H-1	1H-3	2H-1	2H-3	3H-1	3H-5	4H-1	4H-5	5H-1	5H-5	6H-1	6H-5	7H-1
Intervals (cm)	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75
Marginulina sp. A									1				
Marginulina sp. B													
Marginulina spp.													
Marginulinopsis spp.													
Martinottiella scabra								2					
Neoconorbina sp. A													
Nodoraria pyrula			2		1					4			1
Nodosaria cf. pyrula													
Nodosaria spp.										1			
Nodosaria sp. indet.													
Nodosariella pacifica						3					1		
Nodosariella spp.													1
Nonion affine									1				
Nonion havanensis													
Nonion spp.	1												
Oolina spp.	1	3	1	2	2	2	4		1	3	2	1	1
Ophthamidium sp.			3	1			4	2					
Oridorsalis umbonatus	11	1	5	10	9	12	15	3	17	11	16	3	5
Orthomorphina antillea				2				10					
Orthomorphina cf. antillea								8	5			1	
Orthomorphina challengeriana		1	3			5		1	1	1		2	
Orthomorphina columnaris							1			1			
Orthomorphina glandigena										2			
Orthomorphina himerensis		1	1	4	3	2	2	3	1	14		3	
Orthomorphina modesta					1								
Orthomorphina richardsi		1	2										
Orthomorphina spp.			2										
Osangularia mexicana				1						3			1
Paracassidulina minuta	9												
Paracassidulina neocarinata													1
Paracassidulina sulcata		12											
Paracassidulina spp.			1										
Parafissurina spp.		3		4			1	1	1	1		1	
Planulina costata													
Planulina renzi													
Planulina wuellerstorfi	22	8	10	2		21	69	6				14	11
Plectfrondicularia spp.													
Pleurostomella acuminata						3	1	1					
Pleurostomella acuta			2										
Pleurostomella alternans			4	4					1			1	
Pleurostomella bierigi													
Pleurostomella sp. A						1			2	6	5	1	
Pleurostomella sp. B													
Pleurostomella spp.		1										1	
Pleurostomella sp. indet.													
Pseudonodosaria laevigata								2					
Pseudonodosaria sp. A													
Pullenia bulloides		1		4	16	7	3	18	13		1	11	10
Pullenia osloensis					1	1	7	4			1		5
Pullenia quinqueloba	1	1		1	1	3	2	2	4	3	8	4	3
Pullenia subcarinata													
Pullenia cf. subcarinata													
Quinqueloculina sp.	5	2	3		3		1	1					
Ramulina globulifera													
Rectuvigerina striata													
Rectuvigerina sp. A												2	1
Saracenaria latifrons													
Saracenaria latifrons jamaicensis													
Saracenaria spp.									1				
Siphonina pozonensis													
Sphaeroidina bulloides		1		1	4		2	1					
Sphaeroidina cf. bulloides													
Spiroplectammina sp. A					2								
Spiroplectammina spp.	1		1	7					1				
Stilostomella aculeata													
Stilostomella annulifera									16	3	5	1	
Stilostomella cf. annulifera		1	1										11
Stilostomella lepidula		2	4	5	3	5	2	1		3	3	2	
Stilostomella subspinosa		1								2			
Textularia flintii													
Textularia halkyardi													
Textularia milletti	2				1	2						10	
Textularia sp. A													
Textularia spp.	1												
Trifarina bradyi									1				
Trifarina sp. A													
Trifarina sp.			1									1	
Uvigerina graciliformis													
Uvigerina hispidula	3	1						3		6			
Uvigerina mexicana													
Uvigerina miozea					2								
Uvigerina peregrina			2										

Table 1 (continued).

7H-3	7H-5	8H-1	8H-3	8H-5	9H-1	9H-3	9H-5	10H-1	10H-5	11H-1	11H-5	12H-1	12H-3	12H-5	13X-1	13X-3
70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75
										2 3						
1			1			2	1	1	3 1	5	3 3 1	1	3 1	1	1 1	1 1
	2					2							1 2			
				2			1					2		1	1	2
1	1	3 2	3	9 1	4 8 1	2	3	5 2	2	2	1	1	1	2	3	3 1
31 2	11 1	4 2	3 7 2	4 6 2	5 2 1	11 4	7 1 1	17 2	17 12 1	14 4	5 2	1 2	14 8	18 2	24 1 4	10
1	1	3 2	3 2		1 1		5	1 3	1 2	1 1	2 1	1 1	1	2 1	3	
		3	2	1	4	2	1	1 1	7	4	8	3	5	7	2	
28	20	13	1 39	19	10 3	1	1 5	13	6 11	9 6	5 3	9 3	7 3 1	2 2	1	2
3	5 1	1 3		2 1	1	2				1 1	1	1	1	4	1	
1	1				1				1			1				
15 1	18 4	10 1	21 4	3 1 2	7 3 1	5 2 1	5 2 7	15 6 7	4 4 5 3	22 3 4	14 3 4	19 3 4	7 11 8	8 6 1	104 3	33 3
			1			1 11	3	8	15 1	14 1	1	1	2	8	8	2
4	1	2	1		3		3	1	4	13	10	1 9	35	15	1 18 19	6
11			1	1		1 7		1	5 1		6	3	1 10	8	1 16	2
2 3	11 3	8 1	5	3 1	4 2	13	3 1 2	9 7	11 7 1	3 1	12 8	9 2	6 6	7 3 1	1 3	2
		3	17	24				4		1 1			2		3	1
			1									5	17	3	3	10

Table 1 (continued).

Hole	754A -												
Sections	1H-1	1H-3	2H-1	2H-3	3H-1	3H-5	4H-1	4H-5	5H-1	5H-5	6H-1	6H-5	7H-1
Intervals (cm)	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75
Uvigerina proboscidea		1	42	1	5	2		5	4	12	3	10	1
Uvigerina schencki							8	2			1		
Uvigerina sp. A							5		12				
Uvigerina spp.				1									
Uvigerina striatula			2										
Vaginulina legumen													
Vaginulina spp.													
Valvulina spinosa													1
Valvulineria spp.			1				1						
Valvulineria laevigata										1			
Agglutinated misc.						1						1	
Calcareous misc.	2	3		4	2	2	2	1	1	2	1		1
Total number of specimens	186	121	209	184	214	201	264	190	187	228	204	136	139

the Oligocene and upper Pliocene, but is almost absent in the Miocene. *Burseolina pacifica* is at its peak abundance (15%) in the earliest middle Miocene (CN3/4). *Lenticulina* spp. are common in the Oligocene and lower Miocene, but decrease in abundance after the middle Miocene, as reported by Woodruff and Douglas (1981). *Uvigerina proboscidea* is common in the upper Miocene and Pliocene, forming 22% (Sample 121-756B-2H-3, 70–75 cm) of the assemblage in the lower Pliocene (CN10).

Species diversity (H′) at Site 756 is generally constant and in the range of 4.0–5.0, except for the upper middle Miocene (Samples 121-756B-5H-3, 70–75 cm, and -5H-4, 70–75 cm) and upper Pliocene (Samples 121-756B-1H-3, 70–75 cm), which show the lowest values of diversity (<4.0) for this site (Fig. 8).

A change of planktonic percentage is found between Samples 121-756B-8H-3, 70–75 cm, and -8H-5, 70–75 cm (Fig. 8). The planktonic percentage in the Oligocene averages 93.3%, but varies widely. The Neogene planktonic percentage, however, is higher than that of the Oligocene (>98%) (Fig. 8). If the sedimentation rate is assumed constant, the numbers of benthic foraminifers/cm^3 are reduced throughout the middle Miocene (Fig. 8).

Comparison between Site 754 and Site 756

Site 754 and Site 756 are situated in the same water mass, i.e., the Indian Central Water (Sverdrup et al., 1942), and both are situated at bathyal depths, but some differences in the composition and frequency of the most common species are clear within the Neogene. *Globocassidulina* spp. characteristically dominated the fauna at both sites, and the occurrence pattern during the Neogene is more or less similar at both sites. The relative abundance of *Globocassidulina* spp., however, in the upper Pliocene (CN12 Zone) at Site 754 is much lower than that at Site 756. *Cibicidoides mundulus* dominated the fauna after the early Miocene at Site 754, whereas at Site 756 *C. mundulus* became dominant in the late Oligocene and earliest Miocene. *Cibicidoides* cf. *mundulus* was abundant at Site 754 in the late Oligocene and earliest Miocene. At Site 756, *C.* cf. *mundulus* dominated in the early Oligocene. *Astrononion echolsi* was common in the Oligocene and the Neogene; its peak abundance was in the Pliocene at Site 754 and the early Oligocene at Site 756.

The following Neogene species, recognized as the most common elements at Site 754, are less important at Site 756: *Karreriella bradyi, Gyroidina orbicularis, Burseolina* cf. *pacifica, Trifarina bradyi, Sphaeroidina bulloides, Rectuvigerina striata, Gavelinopsis lobatulus, Ehrenbergina carinata, Bulimina tuxpamensis, Bulimina mexicana, Pullenia bulloides,* and *Planulina wuellerstorfi*. On the contrary, the following species are important at Site 756, but they are not abundant at Site 754: *Stilostomella lepidula, Orthomorphina antillea, Oridorsalis umbonatus, Gyroidina soldanii, Globocassidulina* sp. D., and *Epistominella umbonifera*.

The following species show a similar occurrence through the Neogene at both sites: *Lenticulina* spp., *Burseolina pacifica,* and *Uvigerina proboscidea*.

FAUNAL ANALYSIS

Site 754

The result of a factor analysis with a varimax rotation shows that the first seven factors account for 79% of the faunal variation of the Site 754 data set (Tables 3, 4). The stratigraphic distribution of the factor loading for each factor is shown in Figure 9.

Globocassidulina spp. Varimax Assemblage (Factor 1; 20.95% of the total variance) is well developed in the Neogene. Factor loadings higher than average (0.35) occur in the Oligocene (CP19; Sample 121-754A-13X-3, 70–75 cm), lower Miocene (CN3; Sample 121-754A-10H-1, 70–75 cm), middle Miocene (CN5-6, Sample 121-754A-7H-3, 70–75 cm), upper Miocene (CN7–CN10b/11, Sections 121-754A-3H-5 to -6H-1; 26–45.2 mbsf), and uppermost Pleistocene (CN13-15, Sample 121-754A-1H-1, 70–75 cm). This assemblage is dominated by *Globocassidulina subglobosa* and *G. globosa*.

Burseolina cf. *pacifica–Cibicidoides mundulus* Varimax Assemblage (Factor 2; 12.06% of the total variance) is distributed in the middle lower Miocene. This assemblage was typically found at 89.9–99.6 mbsf (from Sections 121-754A-10H-5 to -11H-5).

Planulina wuellerstorfi Varimax Assemblage (Factor 3; 14.39% of the total variance) is mainly found in the middle Miocene (51.2–67.5 mbsf). A smaller loading peak appears in the uppermost Miocene (Sample 121-754A-4H-1, 70–75 cm; 26 mbsf). *Pullenia bulloides* and *Burseolina pacifica* are included in this assemblage.

Gavelinopsis lobatulus–Uvigerina proboscidea Varimax Assemblage (Factor 4; 9.31% of the total variance) occurs in the Pliocene. This assemblage is most common from 6.8 to 16.4 mbsf (Sections 121-754A-2H-1 to -3H-1). Small peaks of this assemblage are also found in the lower upper Miocene (Sample 121-754A-6H-1, 70–75 cm). *Astrononion echolsi, Bulimina mexicana,* and *Karreriella bradyi* dominate this assemblage.

Lenticulina spp. Varimax Assemblage (Factor 5; 13.55% of the total variance) develops in two horizons: the lower Miocene (103.3–109.3 mbsf, Sections 121-754A-12H-1 to -12H-5) and the lowermost middle Miocene (Sections 121-754A-9H-1 to -9H-5; 74.2–80.2 mbsf). This assemblage includes the following species: *Bulimina tuxpamensis, Cibicidoides* cf. *mundulus, Planulina dohertyi,* and *Sphaeroidina bulloides*.

Gyroidina orbicularis–Rectuvigerina striata Varimax Assemblage (Factor 6; 3.96% of the total variance) is recorded only in Sample 121-754A-13X-1, 70–75 cm of Oligocene age.

Ehrenbergina carinata Varimax Assemblage (Factor 7; 5.12% of the variance) is distributed in the lowermost Pliocene (Sample

Table 1 (continued).

7H-3	7H-5	8H-1	8H-3	8H-5	9H-1	9H-3	9H-5	10H-1	10H-5	11H-1	11H-5	12H-1	12H-3	12H-5	13X-1	13X-3
70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75
1	1		2			3	8	4	4					1	1	
13	10	1	1		1						1					
1					1	2	1	5		1				1		1
2		1 3			1	1	1	4	18	3	3	1	11	4	1	
			7	4	9	1		6	5		2					
1			1					2	13	6	6		5	6		
1		3		1		5	5	3	1	4	1		3	3	4	
226	147	135	206	177	151	166	115	268	366	341	291	197	449	276	656	259

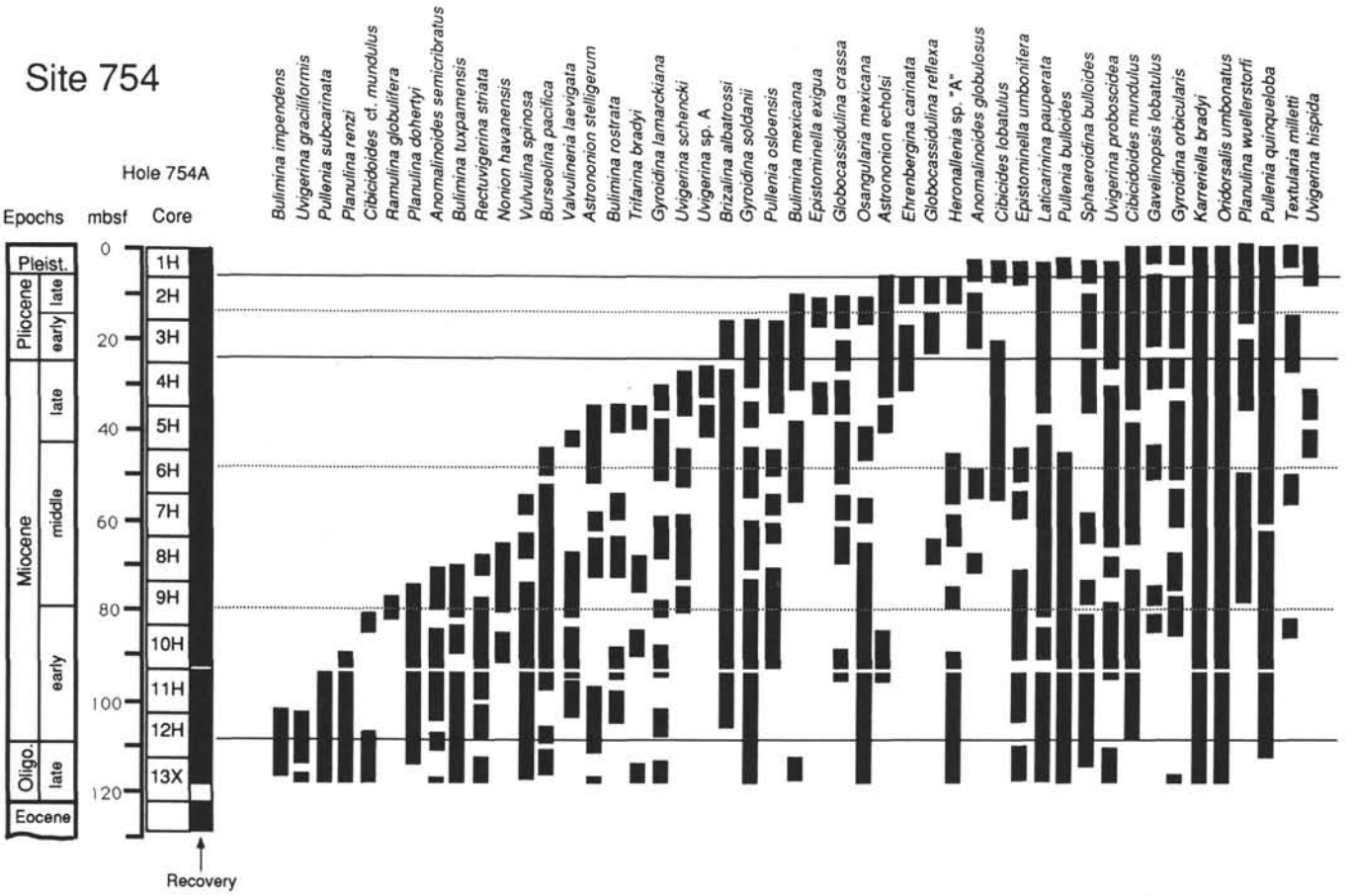

Figure 3. Stratigraphic range chart of selected benthic foraminifers at Site 754. Ranges shown by planktonic zones are based on van Morkhoven et al. (1986).

121-754A-3H-5, 70–75 cm) and Pleistocene (Sample 121-754A-1H-3, 70–75 cm).

In addition to the stratigraphic distribution of each varimax assemblage (= assemblage hereafter), factor loadings of >0.5 for each assemblage are interpreted as indicating a significant stratigraphic interval of each assemblage in this paper. The stratigraphic interval of these assemblages is summarized in Figure 11.

Site 756

The result of factor analysis with a varimax rotation is shown in Figure 10, in which six factors explain 83% of the faunal variance at Site 756 (Tables 5, 6).

Globocassidulina spp. Varimax Assemblage (Factor 1; 29.28% of the variance) generally occurs within the Neogene, but shows particularly drastic changes after the middle Miocene. Higher factor loadings (>0.45) are found in eight horizons: Section 121-756B-1H-1 (0.7 mbsf), Section 121-756B-1H-5 (6.7 mbsf), Sections 121-756B-2H-5 to -3H-3 (15.2–21.8 mbsf), Sections 121-756B-4H-1 to -5H-5 (28.4–44.0 mbsf), Sections 121-756B-6H-3 to -6H-5 (50.6–53.6 mbsf), Section 121-756B-7H-3 (59.9 mbsf), Section 121-756B-8H-3 (69.3 mbsf), and Section 121-756B-10H-3 (88.6 mbsf). This assemblage is dominated by *G. subglobosa* above the middle Miocene, and *G. globosa* dominates this assemblage below the middle Miocene.

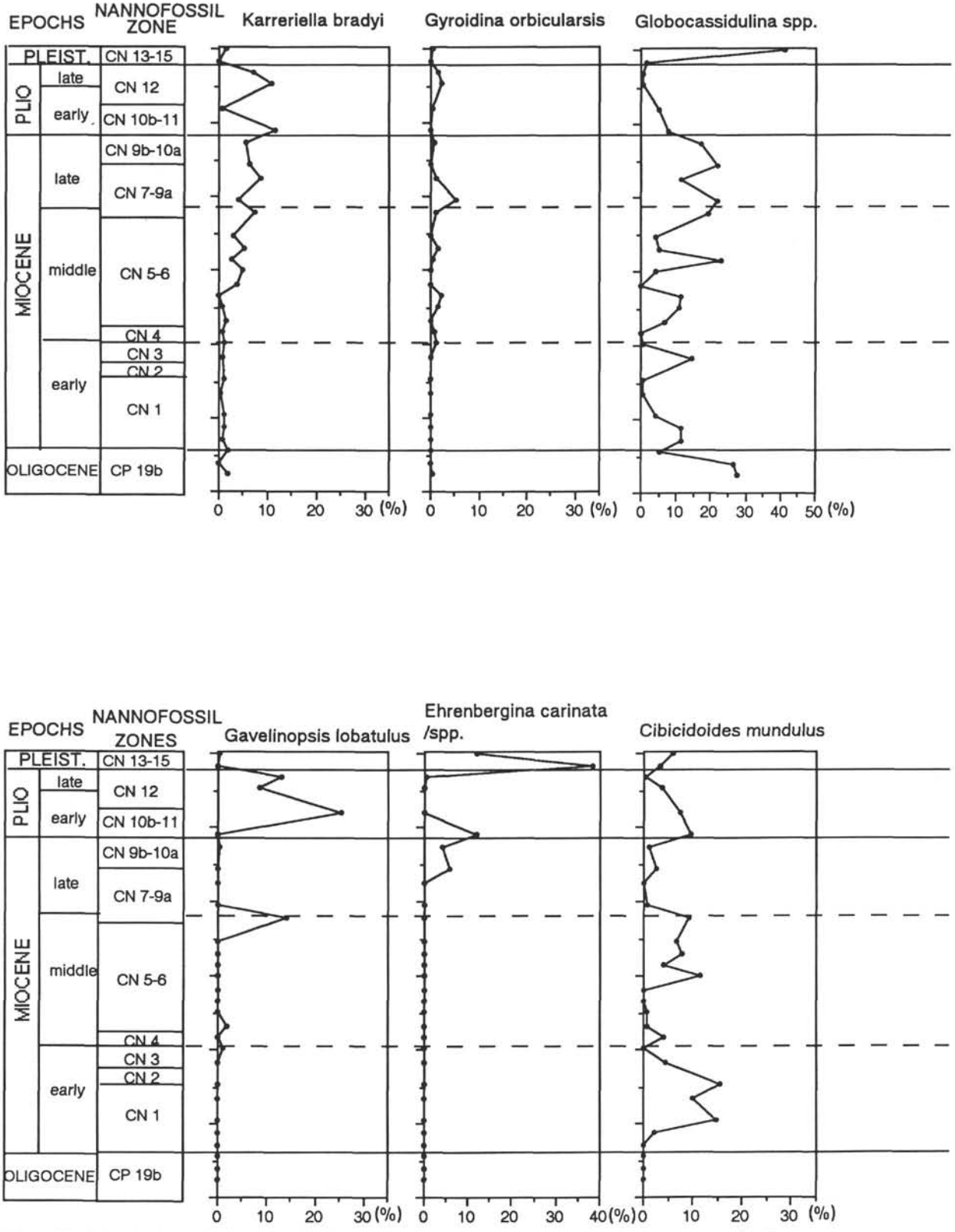

Figure 4. Relative abundance of selected benthic foraminifers plotted vs. sub-bottom depth and referred to nannofossil zones.

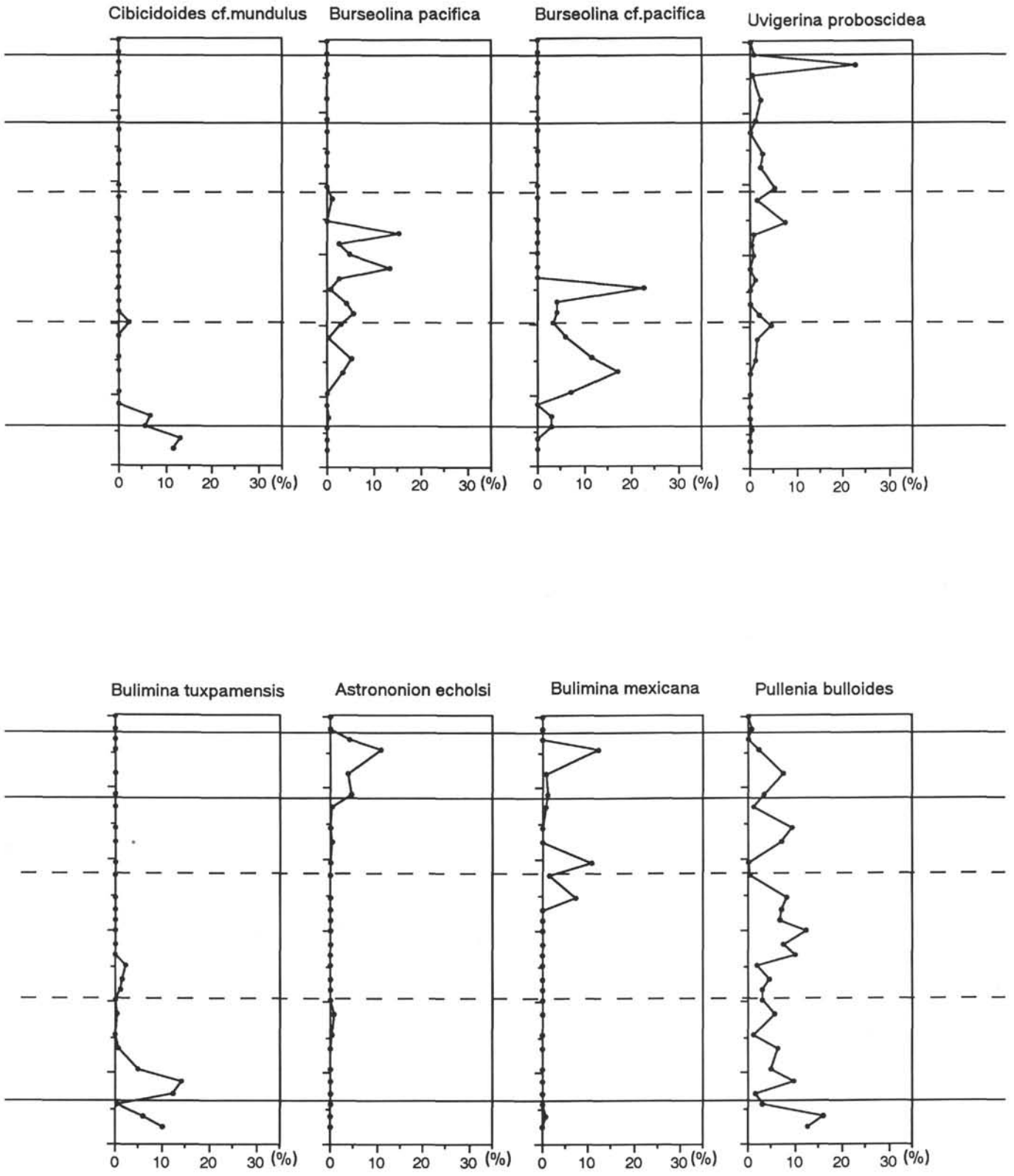

Figure 4 (continued).

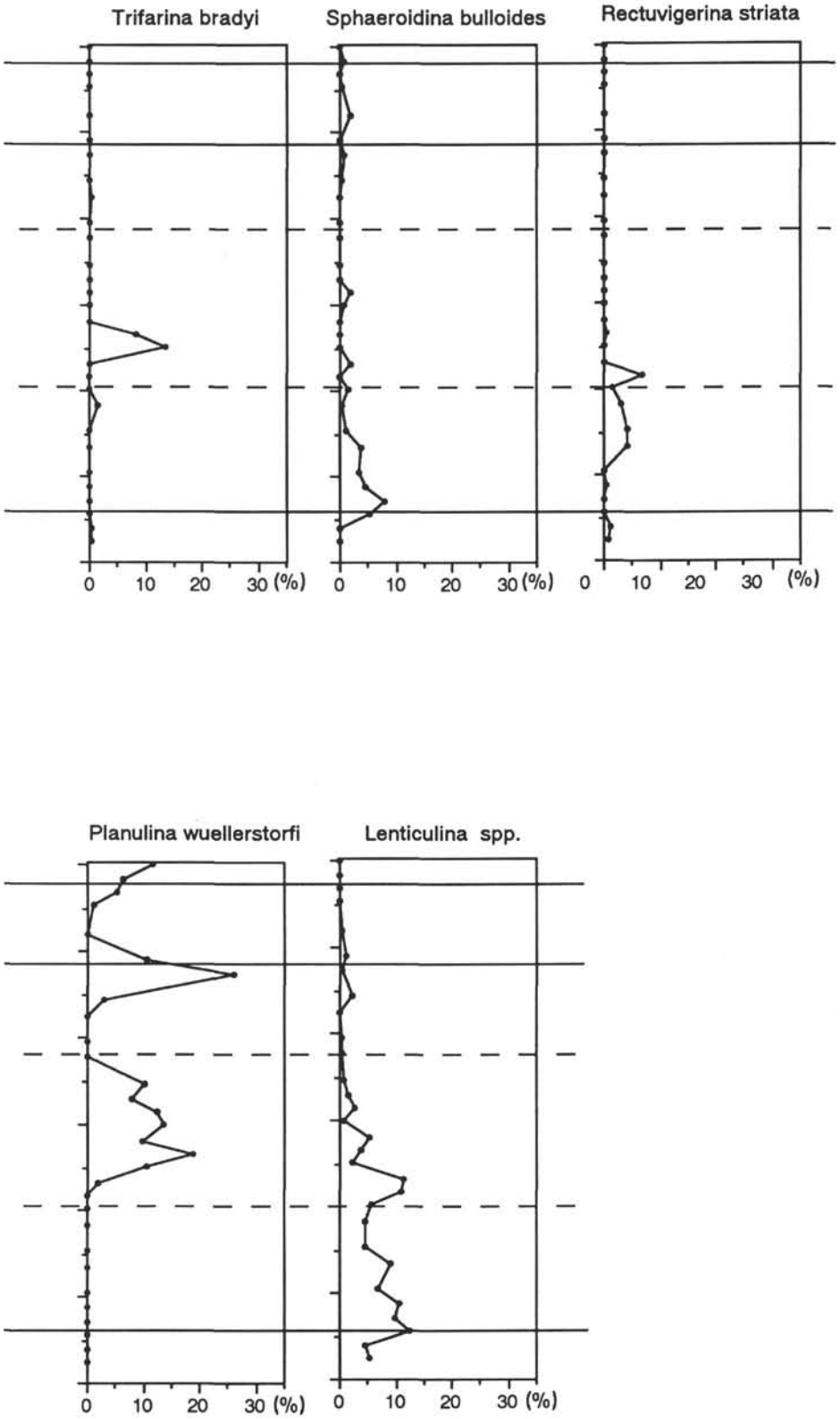

Figure 4 (continued).

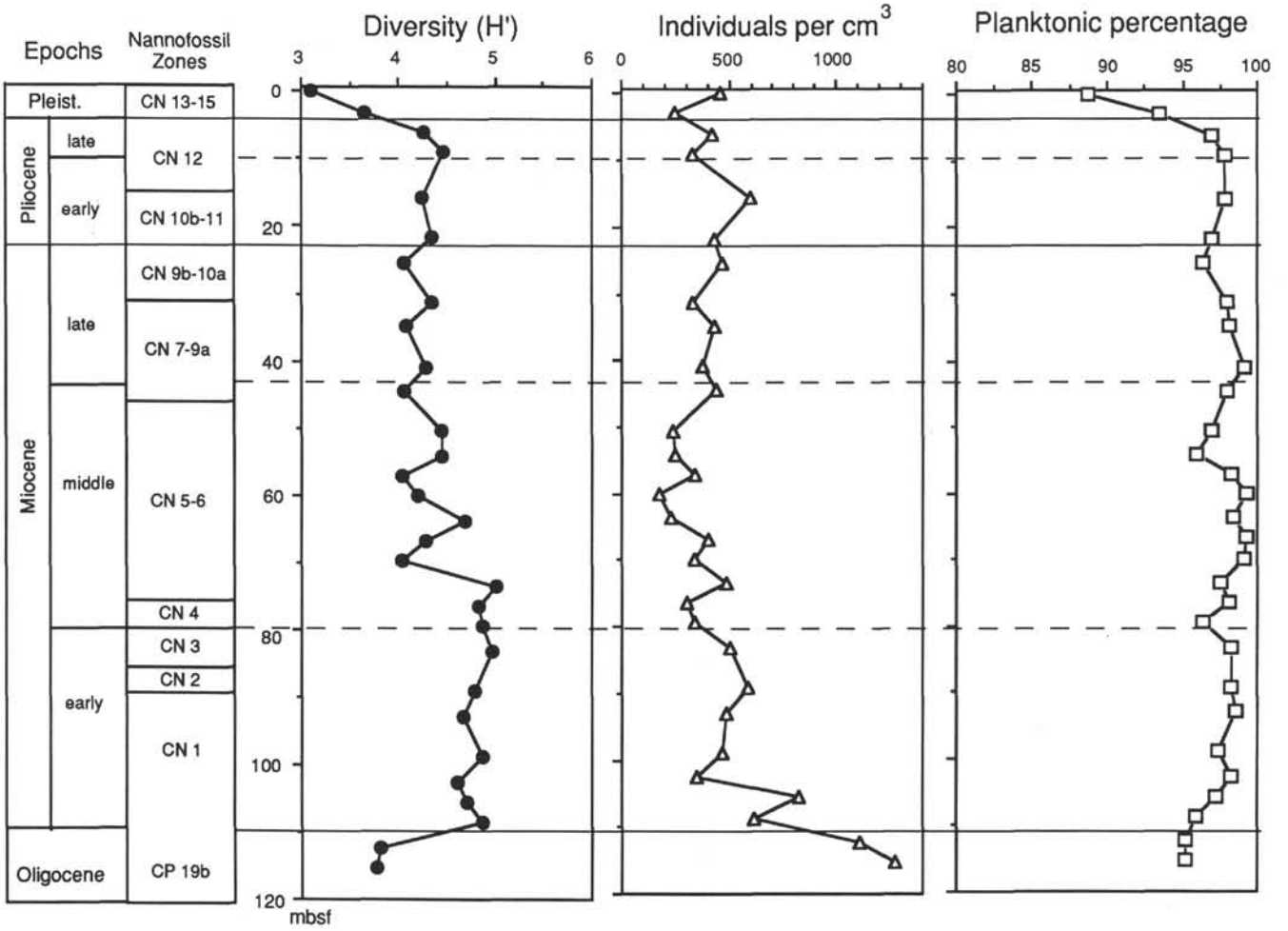

Figure 5. Species diversity, foraminifer number/cm^3, and planktonic to benthic percentages plotted vs. sub-bottom depth and referred to nannofossil zones.

Cibicidoides cf. *mundulus–Oridorsalis umbonatus* Varimax Assemblage (Factor 2; 22.59% of the total variance) is best developed in the lower Oligocene (Sections 121-756B-11H-1 to -7X-5; 95.3–136.5 mbsf). This assemblage is also associated with *Lenticulina* spp.

Epistominella umbonifera–Cibicidoides mundulus Varimax Assemblage (factor 3; 17.62% of the total variance) occurs mainly in the upper Oligocene and lower Miocene (Sections 121-756B-7H-1 to -10H-5; 56.9–91.6 mbsf) and also is found in Sample 121-756C-4X-1, 70–75 cm (101.6 mbsf).

Globocassidulina sp. D Varimax Assemblage (Factor 4; 7.20% of the total variance) is mainly found in the Pliocene (Samples 121-756B-1H-3, 70–75 cm, and -2H-1, 70–75 cm). This assemblage is also present in the middle Miocene (Sample 121-756B-6H-1, 70–75 cm).

Cibicidoides mundulus–Burseolina pacifica Varimax Assemblage (Factor 5; 3.80% of the total variance) is found through the lower Miocene to the lowermost middle Miocene.

Uvigerina proboscidea Varimax Assemblage (Factor 6; 5.19% of the total variance) occurs through the upper Miocene to the Pliocene, but most typically is developed in two horizons in the lower Pliocene (Section 121-756B-3H-5; 24.8 mbsf) and the upper Pliocene (Section 121-756B-2H-3; 12.2 mbsf). *Stilostomella lepidula* is included in this assemblage.

The stratigraphic interval of these assemblages is summarized in Figure 12, where the five assemblages are represented by samples having varimax factor loadings of >0.5. Although the *Cibicidoides mundulus–Burseolina pacifica* Assemblage explains 3.80% of the total variance, the factor loadings are <0.5, which are less significant in comparison with those of other assemblages.

Relationship between the Main Species and Known Water Masses

Of 148 species recognized at Sites 754 and 756, about 30 deep-sea species are reported from the Recent sediments of the Indian Ocean by Corliss (1979a, 1979b, 1983) and Peterson (1984). Although these authors investigated mainly foraminifers occurring deeper than ~2000 m, several species closely related to certain deep water-mass characters were found in the fossil assemblages defined by this study.

Globocassidulina globosa is the most characteristic species for the Indian Deep Water (IDW), which is known to be largely of Atlantic origin (North Atlantic Deep Water (NADW)), derived from the South Atlantic (Lohmann, 1978; Corliss, 1979a, 1979b, 1983; Peterson, 1984). *Planulina wuellerstorfi, Astrononion echolsi,* and *Pullenia bulloides* are reported as the representative species associated with warm and high-salinity NADW in the southwest Indian Ocean (Corliss, 1983). *Uvigerina* and *Eggerella bradyi* are strongly associated with IDW (Peterson, 1984). The occurrence of *Uvigerina* in the Southeast Indian Ocean further indicates the presence of Circumpolar Deep Water (Corliss,

Table 2. Occurrence of benthic foraminifers at Site 756.

Hole	756B-											
Sections	1H-1	1H-3	1H-5	2H-1	2H-3	2H-5	3H-1	3H-3	3H-5	4H-1	4H-3	4H-5
Intervals (cm)	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75
Allomorphina pacifica	1											
Allomorphina sp												
Amphicoryna scalaris												
Amphicoryna spp.												
Anomalina flintii												
Anomalina spp.												
Anomalinoides cf. flintii												
Anomalinoides globulosus				1								
Anomalinoides pseudogrosserugosus												
Anomalinoides semicribratus												
Anomalinoides spp.						1						
Astacolus spp.												
Astrononion echolsi	21	11	3	2		1	1			7	2	
Astrononion sterigerum						1					1	
Astrononion spp.												
Bolivina spp.												
Bolivinopsis cubensis							1					
Brizalina albatrossi		9						2	9	11	5	7
Brizalina byramensis												
Brizalina pseudoplicata			1		4	7				6	2	2
Brizalina pusilla												
Brizalina cf. pusilla						1	1					
Brizalina thalmanni	1		3		5	1	6	9			1	
Brizalina spp.			1									
Bulimina carteri												
Bulimina impedens												
Bulimina jarvisi												
Bulimina macilenta							4	5	2			1
Bulimina mexicana					1							
Bulimina cf. mexicana								1				
Bulimina rostrata	5	2	3	1	2	6	3	1	2	2	3	2
Bulimina sp. B												
Bulimina spp.												
Bulimina tuxpamensis												
Buliminella sculpturata								2	1		1	
Buliminella cf. sculpturata							1					
Burseolina pacifica												
Cassidulina carinata	2											
Cibicides spp.	1	1									1	
Cibicidina walli												
Cibicidina cf. wall i												
Cibicidoides alazanensis												
Cibicidoides bradyi												
Cibicidoides grosseperforatus			2									
Cibicidoides havanensis												
Cibicidoides incrassatus												
Cibicidoides laurisae												
Cibicidoides cf. laurisae												
Cibicidoides matanzasensis												
Cibicidoides mexicanus												
Cibicidoides mundulus	12	7	17	14	10	6	13	9	7	3	15	5
Cibicidoides cf. mundulus												
Cibicidoides spp.	1					3		8		3	3	5
Dentalina hircicornua												
Dentalina communis		1		2	4			1	2	2		
Dentalina spp.	1		1		1	2		2	2	2	1	2
Discorbis subvilardeboanus												
Dorothia brevis												
Dorothia cf. brevis												
Dorothia spp.												
Eggerella bradyi			2	11	3	1	2	6	3	1	2	2
Eggerella spp.												
Ehrenbergina carinata								3				
Ehrenbergina hystrix							11					
Ehrenbergina sp.					2							
Ellipsoidella spp.		3			2				3		1	
Ellipsoidina spp.	1											
Epistominella exigua	15	4	1		10	9	1	1		1	2	1
Epistominella cf. exigua												
Epistominella umbonifera				6	3	7		5	1	8		
Epistominella cf. umbonifera							1					
Epistominella spp.												
Fissurina spp.	7	2	14	4	4	1	3	4	3	4		3
Evolvocassidulina spp.												
Gaudryina sp.			1									
Gavelinopsis lobatulus	6	2		8				1			4	2
Glandulina spp.	2		1	1	2							
Glandulopleurostomella spp.												
Globocassidulina cf. decorata												
Globocassidulina subglobosa (s.l.) + globosa	56	11	44	19	10	17	26	71	20	40	54	18
Globocassidulina cf. moluccensis												
Globocassidulina crassa	6						1					
Globocassidulina gemma		6										

Table 2 (continued).

5H-1	5H-3	5H-5	6H-1	6H-3	6H-5	7H-1	7H-3	7H-5	8H-1	8H-3	8H-5	9H-1	9H-3	9H-5	10H-1	10H-3
70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75
			2	3	3				3	3						
3					1	1		2			2			2		
2 1	1		1		3 1		1	1	3		2	2 1	29	3	13	19
4 1	1	3			1	1	1		2	1						
				2	1	1	1	1	1 2				2	8 1	1 1	19
10	1							4	4 1	1	2 2	3 5		4	2	2
5	3		1 1 2		4	2		1 4	2 10	1 2	5 2 2	1 1 3	14 1	5 1	4 5 3	1 2
	1 3	3	23	28 1	1 4	4	1	2 4	2		2					10
				2		1 5 1	1			3		1				1
										5 6	9	5		11 14	1 8	3
3 3	5 3	3	11 1	7 3 2	20 4	16 22 1 2	31	26 4	32 2	17 2	55 13 1	37 2	31 6	30 3	24 1	10 12
1		1	2	4	1 2	1 1	2 1	1 3	3 6	2 1	4 2	9 4	6 1	1 1	3	1 3
2	3	1	1	8	4		4	2	2	1	5					
5				1	7	8	11	4	1 1		6	44	14	79	13	4
2		3	1	2					1	2	1	2	1	5	2	
1 39	2 54	44	1 1	29	43	17	52	20	25	35	19	21	12	40	22	37
			1				1									

Table 2 (continued).

Hole					756C-										
Sections	10H-5	11H-1	11H-3	11H-5	4X-1	4X-3	4X-5	5X-2	5X-5	5X-7	6X-1	6X-3	7X-1	7X-3	7X-5
Intervals (cm)	70-75	70-75	70-75	70-75	70-75	70-75	70-75	65-70	70-75	70-75	70-75	70-75	70-75	70-75	70-75
Allomorphina pacifica															
Allomorphina sp															1
Amphicoryna scalaris															
Amphicoryna spp.				1											
Anomalina flintii			4												
Anomalina spp.								3							
Anomalinoides cf. flintii											4	7		1	
Anomalinoides globulosus															
Anomalinoides pseudogrosserugosus			6	5						3	8	3			
Anomalinoides semicribratus		3					2		4			7	2	1	3
Anomalinoides spp.										1					
Astacolus spp.		3							1	4			2		
Astrononion echolsi	18	6	19	8	3	33	6	8	2	5					
Astrononion sterigerum															
Astrononion spp.															
Bolivina spp.															
Bolivinopsis cubensis															
Brizalina albatrossi															
Brizalina byramensis															
Brizalina pseudoplicata															
Brizalina pusilla					6	1					4				
Brizalina cf. pusilla															
Brizalina thalmanni															
Brizalina spp.			1												
Bulimina carteri															
Bulimina impedens	12	19	7	1	1		1	8	11	4		3	3	2	2
Bulimina jarvisi															
Bulimina macilenta															
Bulimina mexicana															
Bulimina cf. mexicana															
Bulimina rostrata	2	1	1		6	1		3	1	10	1				
Bulimina sp. B			2			3	3			1					
Bulimina spp.	2	1		4			1					1			
Bulimina tuxpamensis		3	2	9			9			6	4	1	2		5
Buliminella sculpturata															
Buliminella cf. sculpturata															
Burseolina pacifica															
Cassidulina carinata															
Cibicides spp.		14	1	1	6							1	2	1	
Cibicidina walli			1	5											
Cibicidina cf. wall i						15									
Cibicidoides alazanensis													3	2	5
Cibicidoides bradyi															
Cibicidoides grosseperforatus															
Cibicidoides havanensis	9	12	14	49				4	3	3	1	4		4	1
Cibicidoides incrassatus															
Cibicidoides laurisae								14	4	4		1	10	2	3
Cibicidoides cf. laurisae															
Cibicidoides matanzasensis															
Cibicidoides mexicanus		15			9		4			18	35	12	9	1	9
Cibicidoides mundulus	16			1	9										
Cibicidoides cf. mundulus.		51		32		14	31	26	29	30	24	45	3	20	14
Cibicidoides spp.	1		9	33	6	5		3	3	4	13		8	9	6
Dentalina hircicornua															
Dentalina communis															
Dentalina spp.	3	4	3	3		2	3	3	8	8	6	6	3	4	2
Discorbis subvilardeboanus															
Dorothia brevis					2	4	5					4	2		
Dorothia cf. brevis											3				
Dorothia spp.		1	4					2	1						
Eggerella bradyi	2				3										
Eggerella spp.			4	3		2	2			1				1	
Ehrenbergina carinata															
Ehrenbergina hystrix															
Ehrenbergina sp.															
Ellipsoidella spp.							3				3				
Ellipsoidina spp.													1		3
Epistominella exigua															
Epistominella cf. exigua															
Epistominella umbonifera	22			3	20		3	1							
Epistominella cf. umbonifera			2						1						
Epistominella spp.												2			
Fissurina spp.			1	1	1	3					2				
Evolvocassidulina spp.															
Gaudryina sp.															
Gavelinopsis lobatulus															
Glandulina spp.			3		1	2						1			
Glandulopleurostomella spp.		2													
Globocassidulina cf. decorata															
Globocassidulina subglobosa (s.l.) + globosa	15	26	23	51	13	33	32	36	34	24	29	17	13	17	24
Globocassidulina cf. moluccensis															
Globocassidulina crassa															
Globocassidulina gemma															

Table 2 (continued).

Hole	756B-											
Sections	1H-1	1H-3	1H-5	2H-1	2H-3	2H-5	3H-1	3H-3	3H-5	4H-1	4H-3	4H-5
Intervals (cm)	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75
Globocassidulina perumbonata												
Globocassidulina reflexa			12	3								
Globocassidulina sp. D		84	25	56	24	9	2	30	21	7	2	
Globocassidulina spp.		3				1						2
Gyroidina lamarckiana												
Gyroidina orbicularis	7	7	4	2	4	2						7
Gyroidina soldanii	1	2	8	2		5	10	11		13	2	
Gyroidina sp.A	2											
Gyroidina spp.	1				1			2	2		1	1
Hanzawaia ammophina												
Heronallenina sp. A			1				1	1	1		1	
Heronallenina spp.												
Karreriella bradyi			4		2		2					
Karreriella spp.					1							
Kyphophixa spp.												
Lagena spp.	3	1	3	2	5	3	1	3	1	5	2	4
Laticarinina pauperata	6	1	5	1		6	5	4	1	10	6	3
Lenticulina spp.			1	1		1	2	2	1	1		
Lenticulina subcarinata												
Lingulina spp.												
Marginulina spp.				1								1
Marginulinopsis spp.												
Martinottiella scabra												
Nodosaria cf. pyrula		1										
Nodosaria vertebralis		1		1								
Nodosaria spp.						1	2	2		1		5
Nodosariella spp.												
Nonion cf. affine										2		
Nonion havanensis			2									1
Nonion cf. havanensis												
Nonion spp.						2		1			1	
Nonionella spp.												
Oolina spp.		2	4	2	1	3	1			1	1	1
Ophthalmidium spp.	1							1				
Oridorsalis umbonatus	29	12	17	7	4	15	5	9	7	11	9	11
Orthomorphina challengeriana												2
Orthomorphina columnaris												
Orthomorphina glandigena			1									1
Orthomorphina himerensis	1	2		1			2	2	1		3	1
Orthomorphina perversa												
Orthomorphina richardsi												
Orthomorphina spp.			1							1		
Osangularia mexicana	8	2	1	5		5	9	6	7	9	5	8
Paracassidulina neocarinata												
Paracassidulina spp.											2	
Parafissurina spp.												
Planulina costata												
Planulina dohertyi												
Planulina cf. mexicana												
Planulina renzi												
Planulina subtenuissima												
Planulina wuellerstorfi	3		8					7		5		2
Planulina spp.												
Pleurostomella acuminata					1							5
Pleurostomella acuta												
Pleurostomella alternas	5		1	1		4		4	1		1	
Pleurostomella bierigi												
Pleurostomella obtusa					1							
Pleurostomella sp. F										1		
Pleurostomella spp.	2	1		1			1		2	6	1	1
Pseudonodosaria laevigata								1		1		
Pullenia bulloides	1	3		1		4	1	4		1	4	4
Pullenia osloensis	4	1		7	2			2			1	
Pullenia quinqueloba			1					1		1		
Pullenia riveroi												
Pullenia subcarinata		1			6	1	1		2	5	4	13
Pullenia spp.					1			1				
Pyrgo cf. murrhina			4				1					
Pyrgo serrata			1									
Pyrgo sp.	1		2		1							
Quinqueloculina sp.	1		1			1	1	1		1		
Ramulina spp.												
Rectuvigerina royoi								5	2	8	4	1
Rectuvigerina striata			4	1								
Rectuvigerina sp.										3		
Saracenaria latifrons								1				
Saracenaria spp.												
Siphonina tenuicarinata												
Siphotextularia catenata					2	2				1		
Sphaeroidina bulloides		8	6	3	2		5			2	1	4
Sphaeroidina spp.												
Spiroplectammina sp. A	2											

Table 2 (continued).

Hole																		
Sections	5H-1	5H-3	5H-5	6H-1	6H-3	6H-5	7H-1	7H-3	7H-5	8H-1	8H-3	8H-5	9H-1	9H-3	9H-5	10H-1	10H-3
Intervals (cm)	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75
Globocassidulina perumbonata				5	5	3	5										1
Globocassidulina reflexa																	
Globocassidulina sp. D	6			12													
Globocassidulina spp.	1		29	4	6	16	1	2		3		3	2	6	1	3	2
Gyroidina lamarckiana													6	1		1	
Gyroidina orbicularis	1	3					2		8	10	1	6					
Gyroidina soldanii	7		6	8			16	10	12	4	8	10	18	7	15	16	20
Gyroidina sp.A																	
Gyroidina spp.					3			1					6				
Hanzawaia ammophina																	
Heronallenina sp. A						2	1	3	4								
Heronallenina spp.				1						2	2	1	1		1	2	
Karreriella bradyi	4			3	1					2				3	5	4	6
Karreriella spp.		1											2				
Kyphophixa spp.																2	
Lagena spp.	1	2	3	2	3	4	4	1	3	1	3	4	2	4	1	1	2
Laticarinina pauperata		1	6	3			1		2		2	3	3	1		2	3
Lenticulina spp.		2	3		4	12	9	6	3	11	8	10	6	5	3	8	6
Lenticulina subcarinata																	
Lingulina spp.												2					
Marginulina spp.			1									2	1				
Marginulinopsis spp.						1		1					2		1		
Martinottiella scabra					2		1			1				1	1	2	
Nodosaria cf. pyrula																	
Nodosaria vertebralis															1		
Nodosaria spp.							1	2	1				2	1		1	
Nodosariella spp.					1								2	2			
Nonion cf. affine																	
Nonion havanensis		1	3	2	1				1	1			4				
Nonion cf. havanensis															4		
Nonion spp.	1				1								1	1			1
Nonionella spp.							1										
Oolina spp.	1	1		1				1	2		2	2	4	2			2
Ophthalmidium spp.																	
Oridorsalis umbonatus	14	5	10	10	5	8	10	7	3	19	3	15	9	27	25	15	9
Orthomorphina challengeriana									1			2		2	1		
Orthomorphina columnaris																1	
Orthomorphina glandigena			1				1										
Orthomorphina himerensis	1	3			1	1							3	2	1		4
Orthomorphina perversa															1		
Orthomorphina richardsi										3		3	2		2		4
Orthomorphina spp.																	
Osangularia mexicana			1	7		4	4	9	4	3	27	3			6	1	
Paracassidulina neocarinata						2											
Paracassidulina spp.																	
Parafissurina spp.																	
Planulina costata																	
Planulina dohertyi						1		8	4	6	1						
Planulina cf. mexicana																	
Planulina renzi							1			4	9	5	3	2	9	13	5
Planulina subtenuissima																	
Planulina wuellerstorfi	3	1		3													
Planulina spp.														1		2	
Pleurostomella acuminata					2				2			1			1		
Pleurostomella acuta																	
Pleurostomella alternas	3			1						1		3	2			2	2
Pleurostomella bierigi					1		1	1		1							
Pleurostomella obtusa																	
Pleurostomella sp. F																	
Pleurostomella spp.		1	1				1	1					1	1	1		
Pseudonodosaria laevigata			1											2			
Pullenia bulloides	4	4	3	2	3	3	2	6	1	6		3	1	6	10	6	1
Pullenia osloensis						1			2	2			4		5	3	
Pullenia quinqueloba		2			3		5	1	6	7	9	9	6	5	8	5	3
Pullenia riveroi																5	
Pullenia subcarinata	10			2	4	2	3	8			2						
Pullenia spp.								1									1
Pyrgo cf. murrhina																	
Pyrgo serrata																	
Pyrgo sp.																	
Quinqueloculina sp.		1		1				2				1	1				
Ramulina spp.																	
Rectuvigerina royoi	17	3	3		2												
Rectuvigerina striata						1	2			2							
Rectuvigerina sp.																	
Saracenaria latifrons																	
Saracenaria spp.								2		1		2					
Siphonina tenuicarinata							1						1				
Siphotextularia catenata						1		1									
Sphaeroidina bulloides	5	2	7	3		1	5	3	5	6				2			
Sphaeroidina spp.											1						3
Spiroplectammina sp. A																	

Table 2 (continued).

				756C-										
10H-5	11H-1	11H-3	11H-5	4X-1	4X-3	4X-5	5X-2	5X-5	5X-7	6X-1	6X-3	7X-1	7X-3	7X-5
70-75	70-75	70-75	70-75	70-75	70-75	70-75	65-70	70-75	70-75	70-75	70-75	70-75	70-75	70-75
	1													
3 20	25	32	27	7	17	15	20	19	19	13	20		12	14
	2	9	11 2	2		1 2		1 1	1	11 1	1	10	1	6
7 2 1	7 1	2 2	4 4	1 2	1	1 2 1	5	2	6 2	5	2	3 1	4	4
17	14 1	16 2	32 1	8	5	3 4	8 1	9 1 1	26	25	10 1 2	18 3	15 2 2	27
1 3 1	2 1 1	2 2 1	3 2 3	1	1 1		1	2 5	4 2	3 2	3 2	3 1 5	2 6	5 2 1
4	15	5	8		13 1	1	7	3	6 1	11	6	9	15	11 1
3	1 35 3	19	37	1 12	1 23 2	1 22 1	24	19 1	18 1	1 37 2	27	1 10	4 39	1 17
1	1 1	1	1	2	2	1 1	1 5 2			2 2	4	2	2 1	2
1	2 6	3	4		1	1	8 6 1	1 2		1 6		12	2	10
4 1	1				4	7	3							
1	5	2	3 5	1 1	2 3	1 1	2 2		1 1	3 1	7	1	1	1
1 8	1 23	2	11	4	6	1 4	1 1 3	1 5	2 14	6	8	1 4	2 18	15
5	12	9 1	3	2	2 1	3 5	3 2	2 6	4	2	6 6	9 2	6 2	1 6
						1								1
		2 1	5				3	1	2		2	1	1	1 4
3							3							

Table 2 (continued).

Hole	756B-											
Sections	1H-1	1H-3	1H-5	2H-1	2H-3	2H-5	3H-1	3H-3	3H-5	4H-1	4H-3	4H-5
Intervals (cm)	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75
Spiroplectammina spp.												
Stilostomella aculeata						3						
Stilostomella annulifera					2							
Stilostomella cf. annulifera		2	4				1	6	3	6	3	
Stilostomella antillea			1							1		
Stilostomella cf. antillea										1	3	11
Stilostomella capitata	2											
Stilostomella fistuca												
Stilostomella lepidula	10	8	11	7	7	9	6	8	6	6	2	2
Stilostomella modesta												
Stilostomella cf. modesta												
Stilostomella subspinosa	2			1	3		1	2	5	4	2	4
Stilostomella spp.												
Textularia milletti				3	1							
Textularia spp.												
Trifarina bradyi		1										
Trifarina occidentalis												
Trifarina sp. A												
Trifarina sp. B												
Trifarina sp.												
Triloculina spp.												
Turrillina spp.												
Uvigerina havanensis												
Uvigerina hispida		4		1								
Uvigerina miozea												
Uvigerina proboscidea	8	9	10	3	38	9	9	14	8	16	6	9
Uvigerina cf. proboscidea												
Uvigerina schencki										15		
Uvigerina spinulosa												
Uvigerina sp. A												
Uvigerina spp.			1					1	1			
Vaginulina spp.											1	
Valvulineria cf. laevigata												
Vulvulina spinosa											1	
Valvulineria sp.												
Agglutinated misc.												
Calcareous misc.	1	1	2	3	1			2	1	2	1	
Total number of specimens	239	216	240	185	173	150	144	265	128	237	168	154

1983). Thus the main species found at both Broken Ridge and Ninetyeast Ridge sites are clearly related to the direct or indirect influences of NADW. In contrast, *Epistominella umbonifera*, which occurred as a major taxon at Site 756, is known as an index of Antarctic Bottom Water (AABW), and it is also intimately related to water undersaturated in $CaCO_3$ (Bremer and Lohmann, 1982; Corliss, 1983; Corliss et al., 1986).

DISCUSSION

The stratigraphic distribution of Neogene benthic foraminiferal assemblages at Sites 754 and 756 reveals no major faunal turnover of a magnitude comparable to the Paleocene/Eocene boundary event; however, obvious changes occurred throughout the Oligocene to Pliocene epochs. The major faunal assemblages recognized here are similar to Atlantic faunas related to NADW, but also to Antarctic source water faunas. These faunal differences permit reconstruction of deep water changes with time at these sites, using standard benthic foraminiferal assemblage stratigraphy.

Although there are many changes of short- or long-ranged assemblages at Site 754 (Fig. 11), a major faunal change occurred between the development of the *Planulina wuellerstorfi* Assemblage and the decrease of the *Burseolina* cf. *pacifica–Cibicidoides mundulus* Assemblage at ~13.8 Ma. The change at 13.8 Ma is reflected in a decrease in species diversity. Other major faunal changes occurred in the decrease of the *P. wuellerstorfi* Assemblage in the late middle Miocene (~12 Ma) and the development of the *Gavelinopsis lobatulus–Uvigerina proboscidea* Assemblage in the earliest Pliocene (~5 Ma). The significant decrease of the *Burseolina* cf. *pacifica–Cibicidoides mundulus* Assemblage occurred in the early Miocene (~17 Ma). The most common species in these assemblages have a known ecological preference to specific water masses, as stated in the preceding section. The paleoceanographic significance of these short-ranged assemblages (e.g., the *Gyroidina orbicularis–Rectuvigerina striata* Assemblage) and the assemblages represented by various unidentified species, however, could not be clarified here, because of their limited ecological information.

At Site 756, major faunal changes occurred between the decrease of the *Cibicidoides* cf. *mundulus–Oridorsalis umbonatus* Assemblage and the development of the *Epistominella umbonifera–Cibicidoides mundulus* Assemblage during latest early Oligocene (~29.8–31.7 Ma), and in the decrease of the *Epistominella umbonifera–Cibicidoides mundulus* Assemblage during the late early Miocene (~17.1 Ma) (Fig. 12). The *Uvigerina proboscidea* Assemblage developed in the late Miocene (~7.3 Ma). Several short-term changes represented by the assemblages, also occurred during the Pliocene.

The faunal changes described above are apparently related to paleoceanographic changes; however, the timing of the faunal changes at Sites 754 and 756 is not synchronous. The reason why the exact timing of the faunal change is different between these two sites is not clear, but might result from the difference in water depths. Site 756 is located on a southeastern slope with irregular topography, thus upwelling of deeper water may easily occur at this site. On the other hand, Site 754, located at the center of the flat crest of Broken Ridge, may be far from direct upwelling. Similar diachronous faunal events resulting from local environmental differences between sites were noted by Thomas (1985) and Thomas and Vincent (1987, 1988).

The faunal change at about 30–31 Ma at Site 756 may correlate with the high benthic foraminiferal $\delta^{18}O$ event near the early/late Oligocene boundary that was recognized in many DSDP sites, e.g., Sites 366 and 558 (Miller and Fairbanks, 1985; Miller et al.,

Table 2 (continued).

Hole																	
Sections	5H-1	5H-3	5H-5	6H-1	6H-3	6H-5	7H-1	7H-3	7H-5	8H-1	8H-3	8H-5	9H-1	9H-3	9H-5	10H-1	10H-3
Intervals (cm)	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75
Spiroplectammina spp.																	
Stilostomella aculeata		1			3			7	5	4							
Stilostomella annulifera									2			3					
Stilostomella cf. annulifera			1			1				2				7	2		
Stilostomella antillea							1										
Stilostomella cf. antillea	3	3		3	6	3	3	4	13	6		17	11	10	10	10	5
Stilostomella capitata																	
Stilostomella fistuca	2										2	2				1	
Stilostomella lepidula	5	1	7	7	6	2	1	1	3	6	2	6	8	7	7	4	5
Stilostomella modesta			3	1					1	12		1	3	3		1	
Stilostomella cf. modesta																	
Stilostomella subspinosa	6	4	4	1	1	2	1	1		4	2	3		7	1		
Stilostomella spp.															5	6	6
Textularia milletti																	
Textularia spp.					1												
Trifarina bradyi						3											
Trifarina occidentalis																	
Trifarina sp. A				3													
Trifarina sp. B				5													
Trifarina sp.			2				13						3				
Triloculina spp.									1	1							
Turrillina spp.														1			
Uvigerina havanensis																	
Uvigerina hispida																	
Uvigerina miozea									4	14	7	5		3			
Uvigerina proboscidea	2	1	2	1	1	10	2	1	2	2			2		6	3	2
Uvigerina cf. proboscidea																	
Uvigerina schencki	14	10	2														
Uvigerina spinulosa															4	2	
Uvigerina sp. A									2	12	2	7	51	10	8	1	5
Uvigerina spp.						1	1	6									
Vaginulina spp.							1	1	2					1			
Valvulineria cf. laevigata		1			5			1	2	3		5	2			3	1
Vulvulina spinosa	1	1		3	1	4	3	1	3	6	4	3	1	5	10	4	3
Valvulineria sp.																	
Agglutinated misc.							1		1						1		2
Calcareous misc.	2	4	1	5		2	3	1	8	5	5	1	2	3	2	3	4
Total number of specimens	196	136	158	148	164	191	193	208	192	276	184	277	319	258	367	236	232

1989), Sites 77 and 574 (Keigwin and Keller, 1984; Miller and Thomas, 1985). This shift to more positive values of $\delta^{18}O$ was also detected between ~90 and 100 mbsf in Hole 756B (Rea et al., this volume). High oxygen isotopic values suggest the existence of significant continental ice at that time (Miller and Fairbanks, 1985). The common occurrence of *Epistominella umbonifera* in the upper Oligocene and lower Miocene suggests the involvement of Antarctic-source corrosive water in the intermediate water. The development of corrosive water, as indicated by the presence of E. umbonifera, is suggested to have occurred in the middle Oligocene in the Atlantic Ocean (Miller, 1983; Boersma, 1985), though *E. umbonifera* occurred abundantly from the middle Eocene at ODP Sites 689 and 690 (Thomas, 1990).

The faunal change at ~17.1 Ma may correlate with the faunal event at 17–15 Ma, reported by Thomas and Vincent (1987, 1988) from central Pacific Site 575 and North Atlantic Sites 608 and 610 (Thomas, 1986b), and close to that of North Atlantic Sites 558 and 563 (Miller and Katz, 1987). According to these authors, the timing of this faunal change pre-dates the middle Miocene Antarctic ice growth and cooling of the deep ocean water (Savin, 1977; Miller et al, 1987). The main cause of these changes may have been an increase of planktonic productivity. Thomas and Vincent (1988) noted that the benthic faunal changes may be related to development of corrosive bottom water, as a result of a large supply of biogenic silica. A decrease of the $CaCO_3$ content, from 50.80 to 53.80 mbsf (~2.24 m above the faunal change) at Site 756 (Peirce, Weissel, et al., 1989), agrees closely with the position of the faunal change at this site, and falls within the range of 17–15 Ma of Thomas and Vincent (1987, 1988). Therefore, the idea of a correlation between faunal events and $CaCO_3$ content (Thomas and Vincent, 1987; 1988), is in agreement with results of this study. Furthermore, a positive shift in $\delta^{13}C$ values of benthic foraminifers was detected from the lower to middle Miocene at this site (Rea et al., this volume).

The fauna after 17.1 Ma suggests a decrease in production of carbonate-corrosive intermediate water, because of the reduction of the *Epistominella umbonifera–Cibicidoides mundulus* Assemblage. A decrease in the volume of carbonate-corrosive water is also suggested by lower $\delta^{18}O$ values in the latest early Miocene (Rea et al., this volume). These isotopic data indicate that the faunal change at 17.1 Ma may have been caused primarily by the change in surface ocean productivity, in support of the view of Thomas and Vincent (1987, 1988) and Miller and Katz (1987).

The decrease of the *Burseolina* cf. *pacifica–Cibicidoides mundulus* Assemblage at ~17 Ma at Site 754 can be correlated with that of the *Epistominella umbonifera–Cibicidoides mundulus* Assemblage at Site 756, suggesting the decrease of carbonate-corrosive intermediate water. However, the development of the *Planulina wuellerstorfi* Assemblage during the middle Miocene (~14–12 Ma) is noted at Site 754. The isotopic data at DSDP Site 216 (Vincent et al., 1985) and at Site 754 show that the increase of $\delta^{18}O$ from Zone CN3/4 to CN5b is inversely related to the development of the *Planulina wuellerstorfi* Assemblage after 13.8 Ma. Similarly *P. wuellerstorfi* appeared in the middle Miocene at about 14 Ma at DSDP Sites 563, 608, and 610 in the North Atlantic Ocean (Thomas, 1986b; Miller and Katz, 1987). The timing of the development of the P. wuellerstorfi Assemblage in the Atlantic Ocean and the Indian Ocean seems to be almost synchronous, and is correlated with the timing of bottom water temperature drop at 14.8–13.5 Ma (Miller and Katz, 1987; Miller et al., 1987). According to Thomas (1986b), the first occurrence of Planulina wuellerstorfi corresponds to the increased value of oxygen isotope ratio in the middle Miocene of the North Atlantic Ocean (14.8–14.1 Ma; Thomas and Vincent, 1987), though it occurred earlier

Table 2 (continued).

Hole					756C-										
Sections	10H-5	11H-1	11H-3	11H-5	4X-1	4X-3	4X-5	5X-2	5X-5	5X-7	6X-1	6X-3	7X-1	7X-3	7X-5
Intervals (cm)	70-75	70-75	70-75	70-75	70-75	70-75	70-75	65-70	70-75	70-75	70-75	70-75	70-75	70-75	70-75
Spiroplectammina spp.					1										
Stilostomella aculeata															
Stilostomella annulifera															
Stilostomella cf. annulifera					9							3			
Stilostomella antillea							2								
Stilostomella cf. antillea	4		3	1		12	2	9	4		4			18	2
Stilostomella capitata															
Stilostomella fistuca			1											2	
Stilostomella lepidula	3	1	6	6	11		5	7	1	1	5	16	4	5	10
Stilostomella modesta				4		1	3	2	2						
Stilostomella cf. modesta			3												
Stilostomella subspinosa															3
Stilostomella spp.		8			3	2	1		1	7	3			21	2
Textularia milletti															
Textularia spp.		3													
Trifarina bradyi															
Trifarina occidentalis						1	3		3	1	6		1		1
Trifarina sp. A															
Trifarina sp. B															
Trifarina sp.				18											
Triloculina spp.															
Turrillina spp.															
Uvigerina havanensis													1		
Uvigerina hispida															
Uvigerina miozea															
Uvigerina proboscidea								1						5	
Uvigerina cf. proboscidea														46	1
Uvigerina schencki															
Uvigerina spinulosa			2	2		1									
Uvigerina sp. A	8	3	2		1										
Uvigerina spp.							1								5
Vaginulina spp.				2							2				
Valvulineria cf. laevigata									3						
Vulvulina spinosa	2	12	10	15	2	3	2	6	6	14	8	7	6	5	6
Valvulineria sp.													1		
Agglutinated misc.	2			1		2				2	3		3	1	2
Calcareous misc.	4	6	6	1	7		10	4	3	4	3	4			2
Total number of specimens	212	355	253	426	164	226	214	252	208	265	305	252	175	305	242

in the Pacific Ocean (16.1–15.7 Ma in the eastern Pacific and 15.0–14.9 Ma in the western Pacific; Thomas and Vincent, 1987). Therefore, the faunal change at 13.8 Ma at Broken Ridge may have been related to a decrease in the water temperature. Woodruff (1985) attributed the faunal change that occurred between 13 and 16 Ma in the Pacific to a cooling related to Antarctic glacial expansion. The *Planulina wuellerstorfi* Assemblage, however, does not indicate either the effect of Antarctic corrosive water, or an increase of organic carbon. More recently, Woodruff and Savin (1989) proposed an influence of Tethyan Indian Saline Water in the early Miocene Ocean. Their results suggest that the termination of this saline water event occurred at about 14 Ma. This timing is also apparently correlated with the faunal change at Site 754. The cause of the faunal change at such intermediate water depths is complex, but it may have been due to dynamic and chemical changes of oceanic water, such as the formation of a strong thermocline.

The faunal changes at ~12 Ma at Site 754 may correlate with the timing of a peak supply of NADW into the North Atlantic basins (Miller and Katz, 1987). The modern *Globocassidulina subglobosa* is related to the water derived from NADW. Therefore, I interpret that the Indian Ocean intermediate water during the late middle Miocene and the late Miocene was derived from the North Atlantic.

Other faunal changes recognized at ~5 Ma at Site 754 and 7.3 Ma at Site 756 suggest the intensification of the low oxygen zone as inferred from the development of the *Uvigerina* Assemblage. This may have led to the modern intermediate water characterized by low oxygen (Wyrtki, 1973). Woodruff (1985) suggested that the faunal changes after 8–10 Ma are related to the increase of organic carbon and intensification of the low oxygen zone, and this is supported by the observed development of the *Uvigerina* Assemblage in this study. The low oxygen event at Site 754 occurred ~2.3 m.y. later than that at Site 756. These paleoceanographic changes in the Indian Ocean are probably related primarily to the intensification of the thermocline.

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APPENDIX

Species Index

Allomorphina pacifica Cushman and Todd, 1949
Amphicoryna scalaris (Batsch) = *Nautilus (Orthoceras) scalaris* Batsch, 1791.
Anomalinoides flintii (Cushman) = *Anomalina flintii* Cushman, 1931.
Anomalinoides globulosus (Chapman and Parr) = *Anomalina globosa* Chapman and Parr, 1937
Anomalinoides pseudogrosserugosus (Colom) = *Anomalina pseudogrosserugosa* Colom, 1945.
Anomalinoides semicribratus (Beckmann) = *Anomalina pompilioides* Galloway and Heminway var. *semicribrata* Beckmann, 1953.
Astrononion echolsi Kennett, 1967.
Astrononion stelligerum (d'Orbigny) = *Nonion stelligera* d'Orbigny, 1839.
Bolivina cf. *villalverniensis* Martin, 1954.
Bolivina pseudoplicata (Heron-Allen and Earland) = *Bolivina pseudoplicata* Heron-Allen and Earland, 1930.
Bolivinopsis cubensis (Cushman and Bermudez) = *Spiroplectoides cubensis* Cushman and Bermudez, 1937.
Brizalina albatrossi (Cushman) = *Bolivina albatrossi* Cushman, 1922.
Brizalina byramensis (Cushman) = *Bolivina byramensis* Cushman, 1923.
Brizalina cf. *pacifica (Cushman and McCulloch)* = *cf. Bolivina acerosa* Cushman var. *pacifica* Cushman and McCulloch, 1942.
Brizalina petterssoni (Parker) = *Bolivina petterssoni* Parker, 1953.
Brizalina pusilla (Schwager) = *Bolivina pusilla* Schwager, 1866.
Brizalina silvestrina (Cushman) = *Bolivina silvestrina* Cushman, 1936.
Brizalina thalmanni (Renz) = *Bolivina thalmanni* Renz, 1948.
Bulava indica Boltovskoy, 1976.
Buliminella carteri Bhatia, 1955.
Bulimina impendens Parker and Bermudez, 1937.
Bulimina jarvisi Cushman and Parker, 1936.
Bulimina macilenta Cushman and Parker, 1936.
Bulimina mexicana Cushman, 1922.
Bulimina rostrata Brady, 1884.
Buliminella sculpturata Keijzer, 1953.
Bulimina tuxpamensis Cole, 1928.
Burseolina pacifica (Cushman) = *Cassidulina pacifica* Cushman, 1925.
Cassidulina carinata Silvestri, 1896.
Cibicides lobata (d'Orbigny) = *Truncatulina lobata* d'Orbigny, 1839.
Cibicidina walli Bandy, 1949.
Cibicidoides alazanensis (Nuttall) = *Anomalina alazanensis* Nuttall, 1937.
Cibicidoides mundulus (Brady, Parker and Jones) = *Truncatulina mundula* Brady, Parker and Jones, 1888.

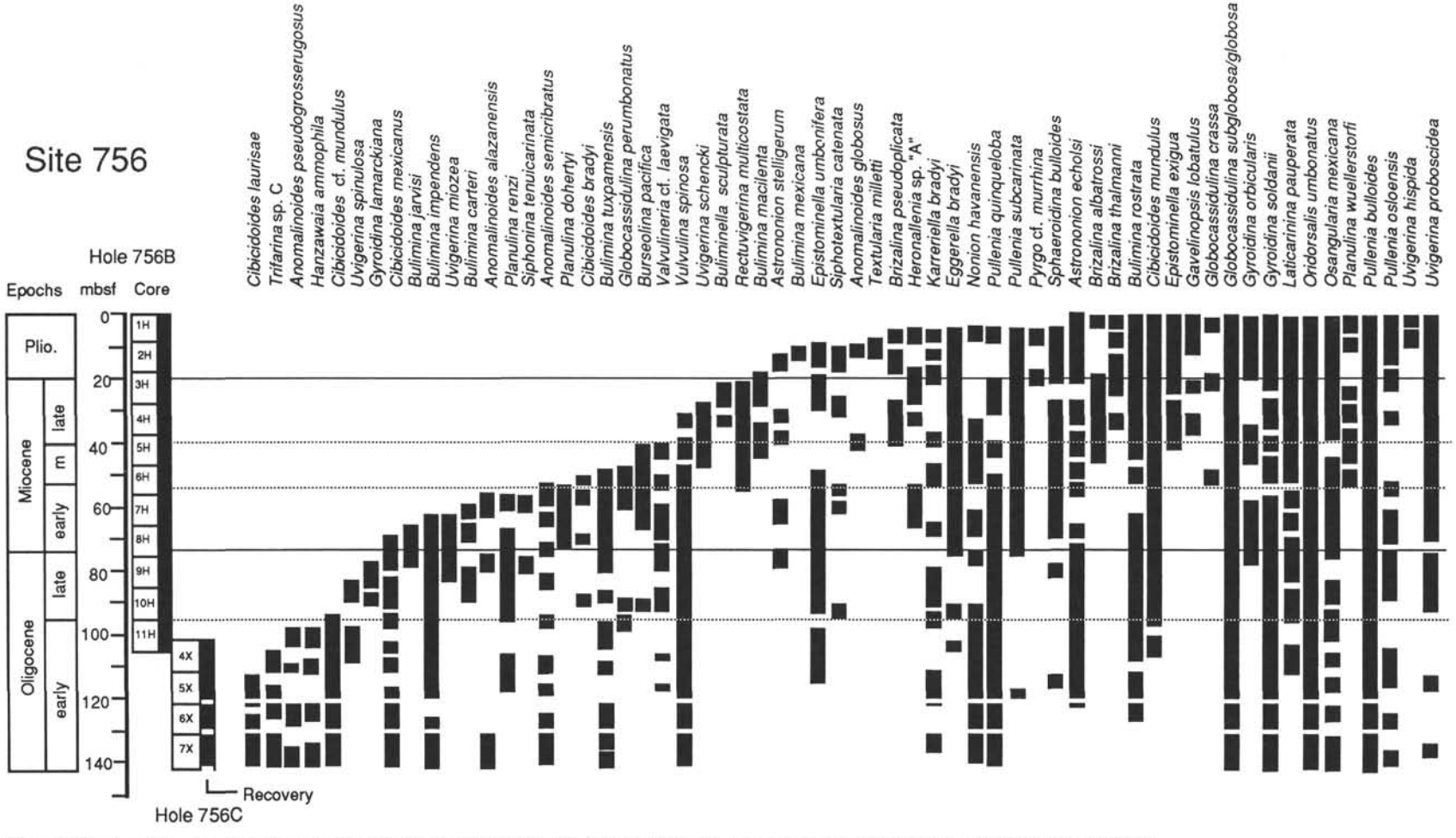


Figure 6. Stratigraphic range chart of selected benthic foraminifers at Site 756. Ranges shown by planktonic zones are based on van Morkhoven et al. (1986).

Cibicidoides laurisae (Mallory) = *Cibicides laurisae* Mallory, 1959.
Cibicidoides matanzasensis (Hadley) = *Planulina matanzasensis* Hadley, 1934.
Cibicidoides bradyi (Trauth) = *Truncatulina bradyi* Trauth, 1918.
Cibicidoides dutemplei (d'Orbigny) = *Rotalia dutemplei* d'Orbigny, 1846.
Cibicidoides grosseperforatus van Morkhoven and Berggren, *in* Van Morkhoven, Berggren, and Edwards, 1986.
Cibicidoides havanensis (Cushman and Bermudez) = *Cibicides havanensis* Cushman and Bermudez, 1937.
Cibicidoides incrassatus (Fichtel and Moll) = *Nautilus incrassatus* Fichtel and Moll, 1798.
Cibicidoides mexicanus (Nuttall) = *Cibicides mexicana* Nuttall, 1932.
Cibicidoides pachyderma (Rzehak) = *Truncatulina pachyderma* Rzehak, 1886.
Cibicidoides robertsonianus (Brady) = *Planorbulina (Truncatulina) robertsoniana* Brady, 1881.
Cibicorbis herricki Hadley, 1934.
Dentalina communis d'Orbigny, 1826.
Dentalina hircicornua (Schwager) = *Nodosaria hircicornua* Schwager, 1866.
Dentalina intorta (Dervieux) = *Nodosaria intorta* Dervieux, 1894.
Discorbis sub-vilardeboanus (Rzehak) = *Discorbis sub-vilardeboana* Rzehak, 1888.
Dorothia brevis Cushman and Stainforth, 1945.
Eggerella bradyi (Cushman) = *Verneuilina bradyi* Cushman, 1911.
Ehrenbergina carinata Eade, 1967.
Ehrenbergina hystrix Brady, 1884.
Epistominella exigua (Brady) = *Pulvinulina exigua* Brady, 1884.
Epistominella umbomifera (Cushman) = *Pulvinulinella umbonifera* Cushman, 1933.
Fursenkoina squammosa (d'Orbigny) = *Virgulina squammosa* d'Orbigny, 1826.
Gavelinopsis lobatulus (Parr) = *Discorbis lobatulus* Parr, 1950.
Globocassidulina crassa (d'Orbigny) = *Cassidulina crassa* d'Orbigny.
Globocassidulina decorata (Sidebottom) = *Cassidulina decorata* Sidebottom, 1910.
Globocassidulina horizontalis (Cushman and Renz) = *Cassidulina subglobosa* var. *horizontalis* Cushman and Renz, 1941.
Globocassidulina subglobosa (Brady) = *Cassidulina subglobosa* Brady, 1881.
Globocassidulina alternans (Yabe and Hanzawa) = *Cassidulina alternans* Yabe and Hanzawa, 1925.
Globocassidulina cf. *moluccensis* (Germeraad) = *Cassidulina moluccensis* Germeraad, 1946.
Globocassidulina gemma (Todd) = *Cassidulina gemma* Todd, 1954.
Globocassidulina havanensis (Cushman and Bermudez) = *Cassidulina havanensis* Cushman and Bermudez, 1936.
Globocassidulina perumbonata (Keyzer) = *Cassidulina perumbonata* Keyzer, 1953.
Globocassidulina reflexa (Galloway and Wissler) = *Cassidulina reflexa* Galloway and Wissler, 1927.
Gyroidina lamarckiana (d'Orbigny) = *Rotaliana lamarckiana* d'Orbigny, 1926.
Gyroidina orbicularis d'Orbigny, 1826.
Gyroidina soldanii d'Orbigny, 1826.
Hanzawaia ammophina (Gümbel) = *Rotalia ammophila* Gümbel, 1868.
Heronallenia sp. "A" of Boltovskoy, 1978, p. 10.
Karreriella bradyi (Cushman) = *Gaudryina bradyi* Cushman, 1911.
Kyphopyxa sp. A of Boltovskoy, 1978.
Laticarinina pauperata (Parker and Jones) = *Pulvinulina repanda* var. *menardii* subvar. *pauperata* Parker and Jones, 1865.
Lenticulina subangulata (Reuss) = *Cristellaria subangulata* Reuss, 1862.
Nodosarella pacifica Cushman, 1931
Nodosaria fistuca Schwager, 1866.
Nodosaria pyrula d'Orbigny, 1826.
Nodosaria vertebralis (Batsch) = *Nautilus (Orthoceras) vertebralis* Batsch, 1791.
Nonion havanensis Cushman and Bermudez, 1937.
Nonion affine (Reuss) = *Nonionina affinis* Reuss, 1851.
Oridorsalis umbonatus (Reuss) = *Rotalina umbonata* Reuss, 1851.
Orthomorphina modesta (Bermudez) = *Ellipsonodosaria modesta* Bermudez, 1937.
Orthomorphina antillea (Cushman) = *Nodosaria antillea* Cushman, 1923.
Orthomorphina challengeriana (Thalmann) = *Nodogenerina challengeriana* Thalmann, 1937.
Orthomorphina columnaris (Franke) = *Nodosaria columnaris* Franke, 1936.
Orthomorphina glandigena (Schwager) = *Nodosaria glandigena* Schwager, 1866.
Orthomorphina himerensis (de Amicis) = *Nodosaria himerensis* de Amicis, 1895.
Orthomorphina perversa (Schwager) = *Nodosaria perversa* Schwager, 1866.
Orthomorphina richardsi (McLean) = *Nodosaria richardsi* McLean, 1952.
Osangularia mexicana (Cole) = *Pulvinulinella culter* (Parker and Jones) var. *mexicana* Cole, 1927.
Paracassidulina minuta (Cushman) = *Cassidulina minuta* Cushman, 1933.
Paracassidulina neocarinata (Thalmann) = *Cassidulina neocarinata*, 1950.
Paracassidulina sulcata (Belford) = *Cassidulina sulcata* Belford, 1966.
Planulina costata (Hantken) = *Truncatulina costata* Hantken, 1875.
Planulina dohertyi (Galloway and Morrey) = *Cibicides dohertyi* Galloway and Morrey, 1929.
Planulina cf. *mexicana* Cushman, 1927.
Planulina renzi Cushman and Stainforth, 1945.
Planulina subtenuissima (Nuttall) = *Anomalina subtenuissima* Nuttall, 1928.
Planulina wuellerstorfi (Schwager) = *Anomalina wuellerstorfi* Schwager, 1866.
Pleurostomella acuminata Cushman, 1922
Pleurostomella acuta Hantken, 1875.
Pleurostomella alternans Schwager, 1866.
Pleurostomella bierigi Palmer and Bermudez, 1936.
Pleurostomella obtusa Berthelin, 1880.
Pullenia bulloides (d'Orbigny) = *Nonionina bulloides* d'Orbigny, 1846.
Pullenia subcarinata (d'Orbigny) = *Nonionina subcarinata* d'Orbigny, 1839.
Pullenia osloensis Feyling-Hanssen, 1954.
Pullenia quinqueloba Reuss, 1867.
Pullenia riveroi Bermudez, 1939.
Pyrgo cf. *murrhina* (Schwager) = cf. *Biloculina murrhina* Schwager, 1866
Pyrgo serrata (Bailey) = *Biloculina serrata* Bailey, 1861.
Ramulina globulifera Brady, 1879.
Rectuvigerina multicostata Cushman and Jarvis, 1929.
Rectuvigerina striata (Schwager) = *Dimorphina striata* Schwager, 1866.
Saracenaria latifrons (Brady) = *Cristellaria latifrons* Brady, 1884.
Saracenaria latifrons jamaicensis Cushman and Todd, 1945.
Siphonina pozonensis Cushman and Renz, 1941.
Siphonina tenuicarinata Cushman, 1927.
Siphotextularia catenata (Cushman) = *Textularia catenata* Cushman, 1911.
Sphaeroidina bulloides d'Orbigny, 1826.
Stilostomella aculeata (Cushman and Renz) = *Ellipsonodosaria nuttalli* Cushman and Jarvis var. *aculeata* Cushman and Renz, 1948.
Stilostomella annulifera (Cushman and Bermudez) = *Ellipsonodosaria annulifera* Cushman and Bermudez, 1936.
Stilostomella lepidula (Schwager) = *Nodosaria lepidula* Schwager, 1866.
Stilostomella subspinosa (Cushman) = *Ellipsonodosaria subspinosa* Cushman, 1943.
Textularia flintii Cushman, 1911.
Textularia halkyardi Lalicker, 1935.
Textularia milletti Cushman, 1911.
Trifarina bradyi Cushman, 1923.
Uvigerina graciliformis Papp and Turnovsky, 1953.
Uvigerina havanensis Cushman and Bermudez, 1936.
Uvigerina hispida Schwager, 1866.
Uvigerina mexicana Nuttall, 1932.
Uvigerina miozea Finlay, 1939.
Uvigerina peregrina Cushman, 1923.
Uvigerina proboscidea Schwager, 1866.
Uvigerina schencki Asano, 1950.
Uvigerina spinulosa Hadley, 1934.
Vaginulina legumen (Linnaeus) = *Nautilus legumen* Linnaeus, 1758.
Valvulineria laevigata Phleger and Parker, 1951.
Vulvulina spinosa Cushman, 1927.

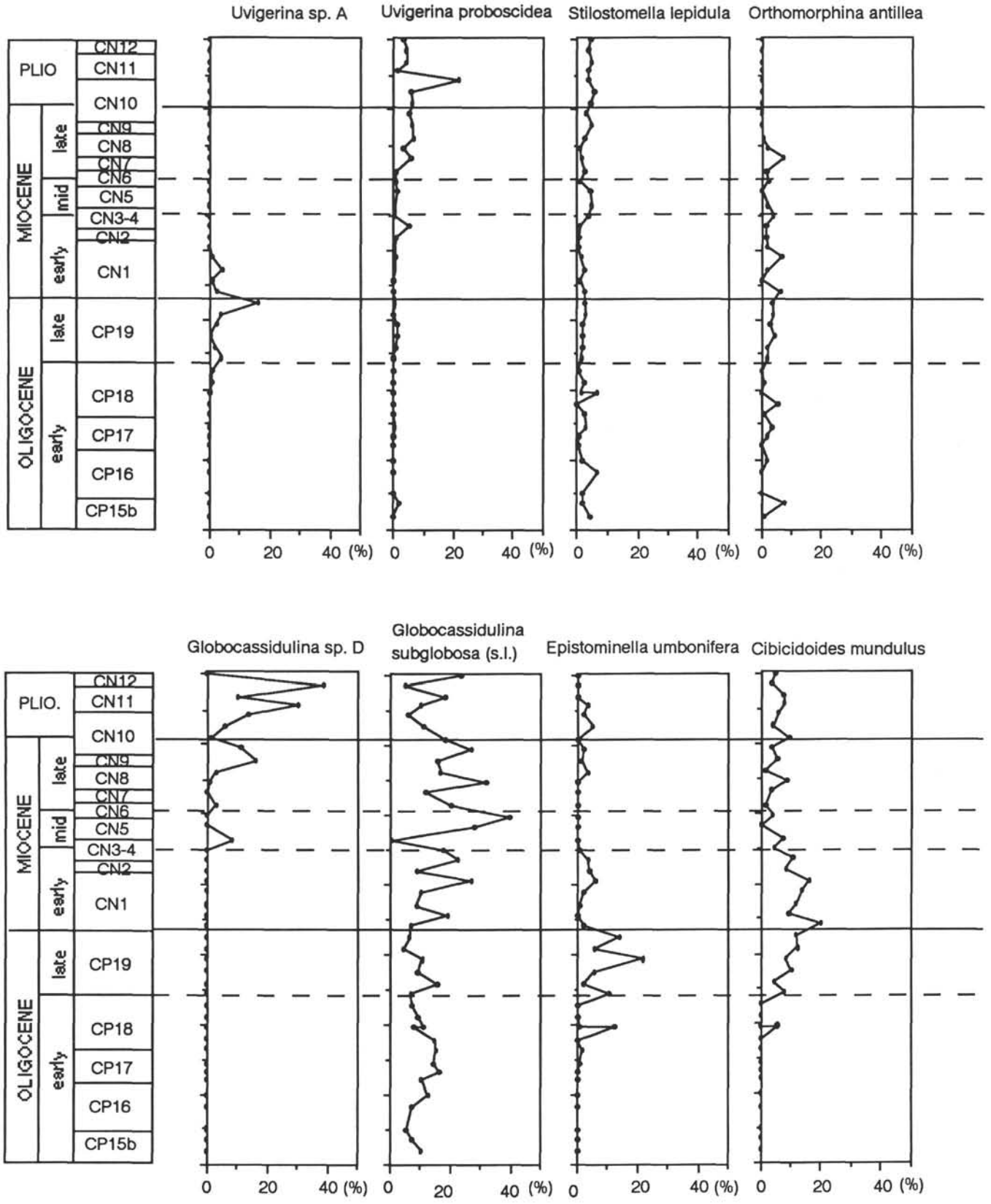


Figure 7. Relative abundance of selected benthic foraminifers plotted vs. sub-bottom depth and referred to nannofossil zone.

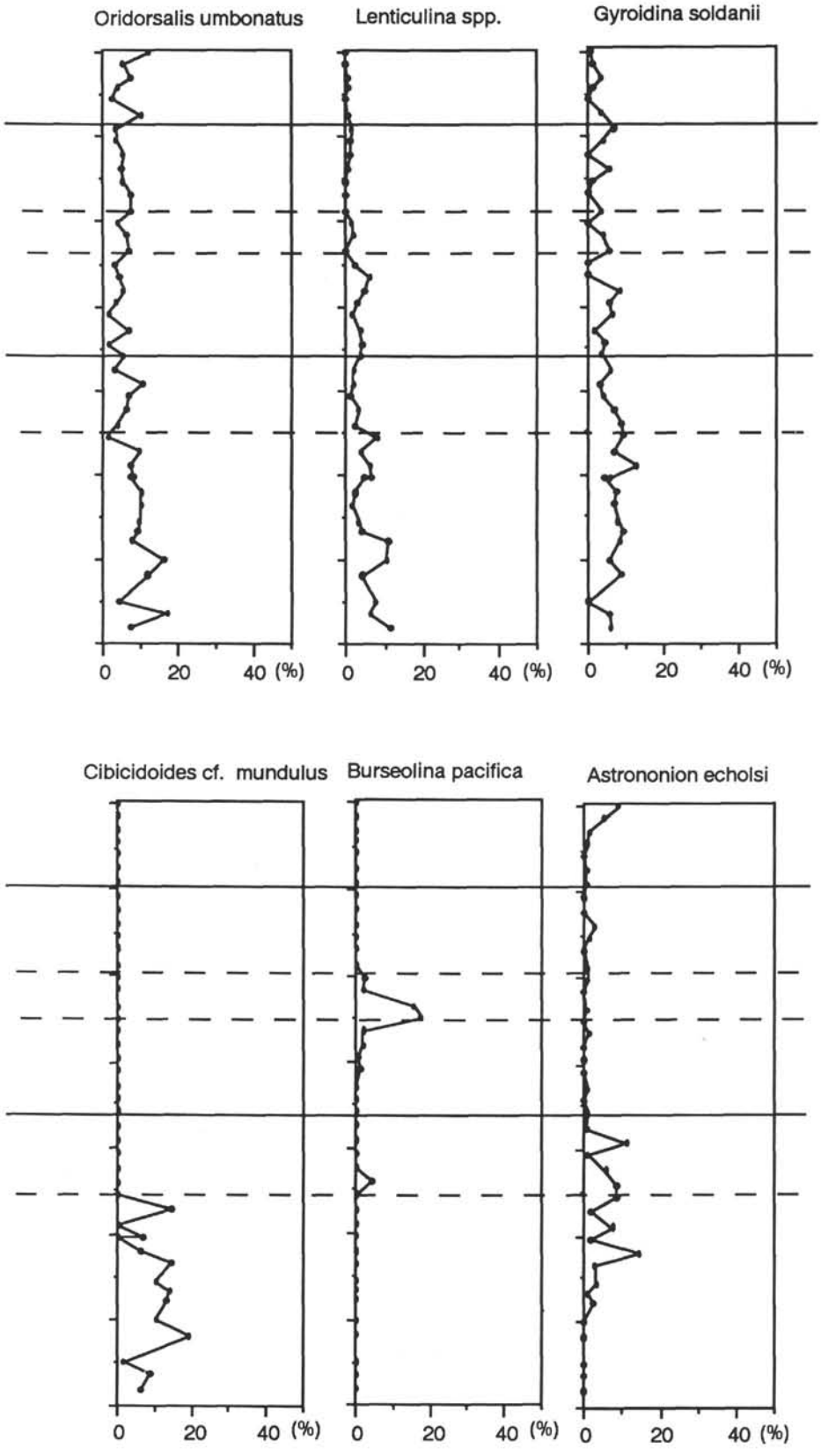


Figure 7 (continued).

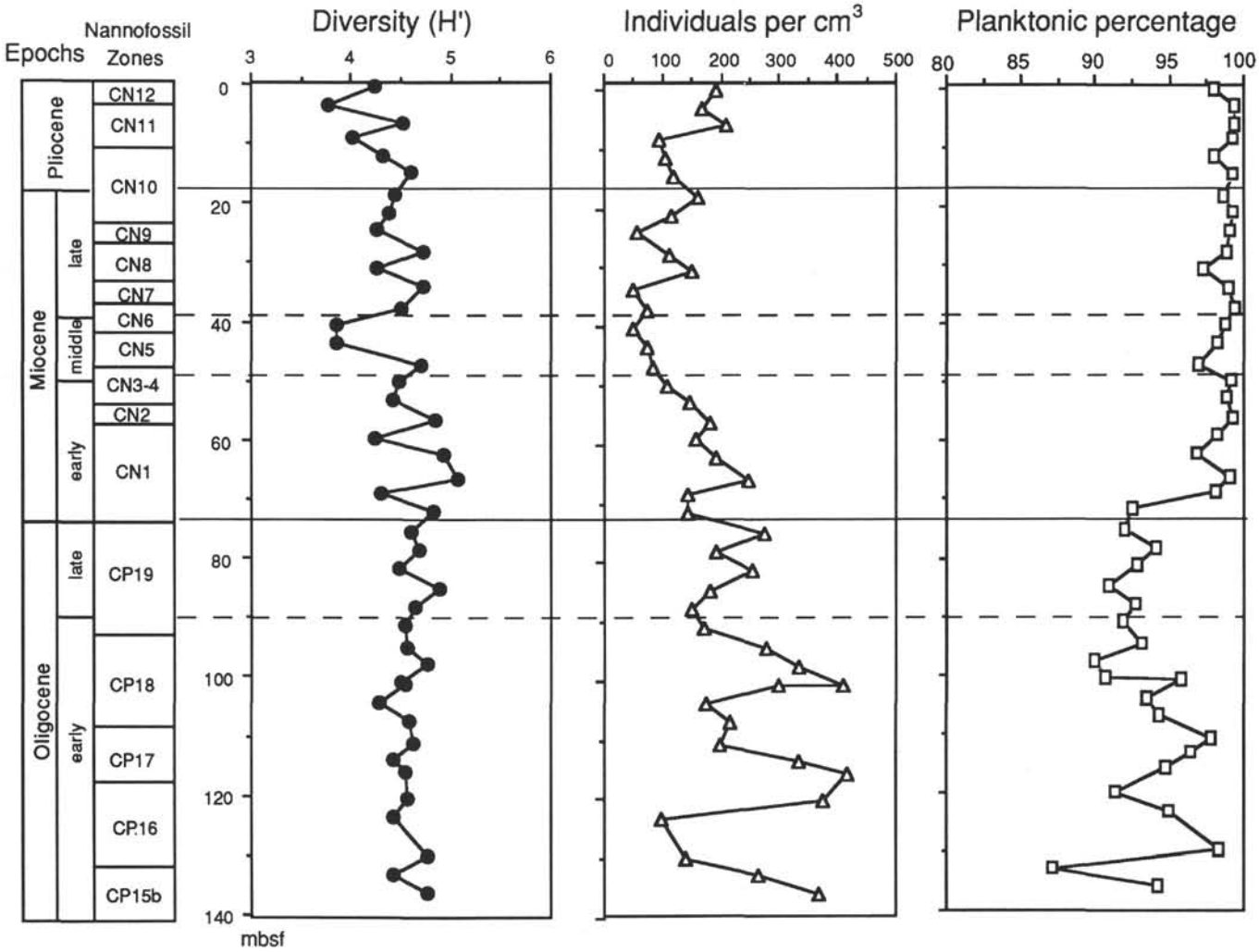


Figure 8. Species diversity, foraminifer number/cm^3, and planktonic to benthic percentages plotted vs. sub-bottom depth and referred to nannofossil zones.

Table 3. Varimax factor loadings from factor analysis of Site 754.

Section	Interval (cm)	Communality	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
754A-1H-1	70-75	0.9100	0.8943	0.0723	0.1783	-0.0034	0.0611	-0.0314	0.2617
754A-1H-3	70-75	0.9175	0.0922	0.0083	0.0752	0.0162	0.0179	0.0102	0.9501
754A-2H-1	70-75	0.6359	0.0122	-0.1168	0.2000	0.7342	0.1095	0.1629	0.0670
754A-2H-3	70-75	0.6383	0.1145	0.0925	0.1275	0.7715	0.0227	0.0265	0.0626
754A-3H-1	70-75	0.7099	0.1979	0.1568	0.0493	0.7760	0.1089	-0.1569	-0.0713
754A-3H-5	70-75	0.9132	0.4042	0.2181	0.4539	0.3238	0.0326	-0.0667	0.6212
754A-4H-1	70-75	0.8386	0.5877	-0.0173	0.6543	0.0348	-0.0238	0.0310	0.2491
754A-4H-5	70-75	0.8369	0.8073	0.0594	0.2508	0.1535	0.2087	-0.0389	0.2237
754A-5H-1	70-75	0.5114	0.5691	0.0358	0.2386	0.3060	0.1490	0.1124	0.0298
754A-5H-5	70-75	0.8190	0.8248	-0.0108	0.0598	0.2748	0.1184	0.2129	0.0119
754A-6H-1	70-75	0.8634	0.6872	0.2224	0.0872	0.5693	0.0801	-0.0564	-0.0178
754A-6H-5	70-75	0.6438	0.3066	0.1329	0.6051	0.3856	0.0384	0.0466	0.1170
754A-7H-1	70-75	0.6832	0.1381	0.2681	0.7282	0.1631	0.1813	-0.0241	0.0430
754A-7H-3	70-75	0.8572	0.7470	0.1294	0.4806	0.0852	0.2053	-0.0231	0.0387
754A-7H-5	70-75	0.8329	0.2213	0.3253	0.7671	0.2232	0.0831	-0.1407	0.1148
754A-8H-1	70-75	0.8632	-0.0605	0.0858	0.8575	0.0936	0.3283	0.0198	-0.0043
754A-8H-3	70-75	0.8469	0.4804	0.0466	0.7674	-0.0506	0.1177	0.0924	0.0097
754A-8H-5	70-75	0.5993	0.4005	0.5446	0.2754	-0.1650	0.0558	0.1860	-0.0384
754A-9H-1	70-75	0.7367	0.2729	0.3270	0.2963	0.0552	0.6802	0.0088	-0.0407
754A-9H-3	70-75	0.7778	-0.0833	0.5063	0.2315	0.1041	0.6206	0.2530	0.0306
754A-9H-5	70-75	0.8457	-0.0152	0.3124	0.2519	0.2802	0.7245	0.2836	-0.0256
754A-10H-1	70-75	0.8958	0.6786	0.4742	0.1596	0.0938	0.4134	0.0674	-0.0287
754A-10H-5	70-75	0.9103	-0.0088	0.9045	0.1741	0.1740	0.1609	0.0481	0.0582
754A-11H-1	70-75	0.9249	0.0031	0.8658	0.1423	0.0479	0.3795	0.0922	0.0151
754A-11H-5	70-75	0.8747	0.1904	0.7857	0.1393	0.1433	0.3672	-0.1966	0.0879
754A-12H-1	70-75	0.7948	0.4520	0.1385	0.1249	-0.0066	0.7166	-0.2051	-0.0091
754A-12H-3	70-75	0.8283	0.4793	0.1422	-0.0187	-0.0616	0.7467	-0.1291	-0.0011
754A-12H-5	70-75	0.6821	0.2058	0.1824	0.0960	0.0536	0.7692	0.0039	0.0524
754A-13X-1	70-75	0.7394	0.0457	0.0528	-0.0439	0.0330	0.0347	0.8545	0.0110
754A-13X-3	70-75	0.8714	0.7857	0.0176	0.1057	-0.0046	0.4778	-0.1082	-0.0508
Variance			20.956	12.063	14.385	9.309	13.55	3.956	5.122
Cumulative variance			20.956	33.019	47.405	56.714	70.263	74.219	79.341

Table 4. Factor score matrix from varimax factor analysis of Site 754.

Taxa	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
Astrononion echolsi	-0.023	-0.010	-0.022	0.253	-0.010	-0.014	0.056
Brizalina albatrossi	0.062	0.015	0.151	0.084	-0.044	0.063	-0.093
Bulimina mexicana	0.060	-0.020	-0.010	0.244	-0.055	0.067	-0.020
Bulimina rostrata	-0.028	0.007	0.116	-0.016	0.000	-0.017	-0.032
Bulimina tuxpamensis	0.079	-0.029	-0.094	-0.077	0.316	-0.204	-0.005
Burseolina cf. pacifica	0.014	0.660	-0.082	-0.117	-0.002	0.160	-0.048
Burseolina pacifica	-0.191	0.058	0.405	-0.014	0.147	0.044	-0.092
Cibicides ? sp.	-0.016	-0.058	-0.023	-0.001	0.162	-0.017	0.033
Cibicides lobatulus	0.129	-0.036	-0.018	0.106	-0.037	0.097	0.111
Cibicidoides cf.mundulus	0.027	-0.092	-0.050	-0.018	0.242	-0.019	0.007
Cibicidoides mundulus	0.017	0.648	0.050	0.233	-0.186	-0.241	0.145
Dentalina communis	-0.048	0.028	0.035	0.009	0.123	0.061	-0.001
Ehrenbergina spp.	0.015	-0.031	-0.077	-0.029	0.037	0.008	0.922
Epistominella umbonifera	-0.032	0.128	-0.014	-0.019	0.110	0.052	0.025
Gaudryina spp.	0.033	-0.007	0.009	0.051	0.009	-0.022	0.005
Gavelinopsis lobatulus	0.005	-0.022	-0.111	0.649	0.007	-0.104	-0.123
Globocassidulina reflexa	-0.030	-0.040	0.016	0.120	0.024	0.002	-0.013
Globocassidulina spp.	0.933	0.002	-0.017	-0.049	0.107	-0.035	-0.046
Gyroidina orbicularis	0.068	-0.024	-0.023	0.045	-0.003	0.689	-0.004
Gyroidina soldanii	0.020	0.053	0.092	0.035	0.062	-0.002	0.008
Karreriella bradyi	0.060	-0.035	0.130	0.334	0.008	0.006	0.123
Laticarina pauperata	0.003	-0.032	0.138	0.094	0.033	-0.009	0.111
Lenticulina spp.	-0.100	0.119	0.033	-0.059	0.668	0.023	0.030
Nonion havanensis	0.009	0.026	0.054	-0.044	0.033	0.028	-0.044
Oridorsalis umbonatus	0.104	0.115	0.112	0.202	0.163	0.094	0.013
Orthomorphina antillea	0.009	-0.001	-0.004	0.012	0.033	0.018	0.020
Orthomorphina cf. antillea	0.040	0.086	0.026	-0.016	-0.038	0.036	-0.016
Orthomorphina himerensis	0.033	-0.035	0.034	0.064	0.013	0.036	0.004
Planulina dohertyi	-0.011	0.061	-0.027	-0.008	0.185	0.011	-0.015
Planulina wuellerstorfi	0.086	-0.068	0.727	-0.111	-0.173	0.037	0.152
Pullenia bulloides	0.053	0.046	0.341	0.072	0.226	-0.130	-0.085
Rectuvigerina striata	-0.019	0.131	-0.044	-0.008	0.067	0.507	0.026
Sphaeroidina bulloides	-0.010	0.029	-0.055	0.004	0.239	-0.082	0.040
Stilostomella cf. annulifera	-0.023	0.019	0.064	-0.016	0.102	-0.017	0.008
Stilostomella lepidula	-0.035	0.052	0.132	0.072	0.117	-0.072	0.017
Textularia milletti	-0.011	-0.011	0.048	0.044	0.003	0.022	0.012
Trifarina bradyi	0.073	0.088	0.080	-0.102	-0.084	0.092	-0.082
Uvigerina proboscidea	-0.051	-0.122	0.051	0.361	0.132	0.218	0.023
Uvigerina schencki	0.019	0.001	0.102	-0.014	-0.026	-0.038	-0.020
Uvigerina sp. A	0.027	-0.014	0.009	0.015	-0.008	0.025	-0.008
Vulvulina spinosa	-0.012	0.088	-0.012	-0.004	0.047	-0.008	0.004
Valvulineria laevigata	0.017	0.047	0.029	-0.035	0.035	0.023	-0.036

Table 5. Varimax factor loadings from factor analysis of Site 756.

Section	Intervals (cm)	Communality	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
756B-1H-1	70-75	0.8354	0.7782	0.3206	0.2325	0.1290	-0.0519	0.1486
756B-1H-3	70-75	0.9128	0.1229	0.0365	0.0207	0.9124	-0.0721	0.2412
756B-1H-5	70-75	0.9318	0.7138	0.2353	0.2701	0.4765	0.0439	0.2547
756B-2H-1	70-75	0.8696	0.2838	0.0324	0.1470	0.8480	0.0192	0.2165
756B-2H-3	70-75	0.8473	0.2486	-0.0277	0.1270	0.4938	0.0226	0.7241
756B-2H-5	70-75	0.8377	0.5062	0.3134	0.3764	0.3452	-0.0099	0.4716
756B-3H-1	70-75	0.8883	0.7655	0.2319	0.3651	0.1611	0.1773	0.2404
756B-3H-3	70-75	0.9420	0.8295	0.2266	0.1768	0.3446	-0.0423	0.2252
756B-3H-5	70-75	0.7863	0.2216	0.0539	0.0852	0.2188	0.0138	0.8240
756B-4H-1	70-75	0.8763	0.7566	0.2773	0.2813	0.1682	-0.1407	0.3158
756B-4H-3	70-75	0.9624	0.9107	0.2147	0.2519	0.0714	0.0754	0.1128
756B-4H-5	70-75	0.7310	0.6625	0.2636	0.2348	0.0898	0.2192	0.3337
756B-5H-1	70-75	0.8656	0.8215	0.3297	0.1838	0.1748	-0.0823	0.1043
756B-5H-3	70-75	0.9465	0.9326	0.2373	0.1428	0.0044	0.0073	0.0042
756B-5H-5	70-75	0.9408	0.8885	0.3522	0.1356	0.0477	-0.0206	0.0784
756B-6H-1	70-75	0.7059	0.1003	0.1648	0.2637	0.6488	0.4207	-0.0343
756B-6H-3	70-75	0.6608	0.6762	0.2021	0.1798	0.1851	0.2941	-0.0981
756B-6H-5	70-75	0.9157	0.7873	0.2379	0.4132	0.0458	0.2089	0.1509
756B-7H-1	70-75	0.8774	0.4624	0.3696	0.6528	0.1507	0.2795	-0.0009
756B-7H-3	70-75	0.9281	0.7737	0.1878	0.4934	0.0533	0.2186	0.0136
756B-7H-5	70-75	0.8681	0.4973	0.1414	0.6355	0.1411	0.4203	-0.0196
756B-8H-1	70-75	0.7989	0.4224	0.2627	0.5850	0.1268	0.4365	0.0513
756B-8H-3	70-75	0.7720	0.6721	0.2504	0.3335	0.0198	0.3806	0.0338
756B-8H-5	70-75	0.8883	0.2754	0.1312	0.7319	0.1372	0.4901	0.0214
756B-9H-1	70-75	0.7453	0.1462	0.0720	0.8401	0.0287	0.0605	0.0924
756B-9H-3	70-75	0.7738	0.1727	0.2520	0.7996	0.2001	0.0316	0.0138
756B-9H-5	70-75	0.7872	0.2737	0.1923	0.7919	-0.0082	-0.0653	0.2096
756B-10H-1	70-75	0.9078	0.3837	0.3548	0.7757	0.1364	0.1172	0.0259
756B-10H-3	70-75	0.8147	0.6278	0.3551	0.4963	0.1599	-0.0842	-0.1241
756B-10H-5	70-75	0.8339	0.1836	0.3444	0.8126	0.0893	-0.0879	-0.0745
756B-11H-1	70-75	0.9024	0.1251	0.9224	0.1697	0.0815	0.0200	-0.0018
756B-11H-3	70-75	0.7307	0.3200	0.6344	0.4094	0.1605	-0.1230	-0.1317
756B-11H-5	70-75	0.7852	0.3664	0.7697	0.2226	0.0825	-0.0354	-0.0309
756C-4X-1	70-75	0.7918	0.2330	0.3677	0.7213	0.0217	-0.0404	0.2828
756C-4X-3	70-75	0.7829	0.4558	0.6082	0.3203	0.1646	-0.2310	-0.1487
756C-4X-5	70-75	0.8553	0.4390	0.7810	0.1979	0.0876	-0.0751	0.0083
756C-5X-2	65-70	0.8977	0.4747	0.7825	0.2210	0.1048	-0.0155	0.0088
756C-5X-5	70-75	0.9041	0.4650	0.8064	0.1673	0.0776	-0.0434	-0.0415
756C-5X-7	70-75	0.8912	0.1959	0.8965	0.2010	0.0318	0.0855	0.0199
756C-6X-1	70-75	0.8223	0.2309	0.8371	0.1808	0.0224	0.1445	0.1192
756C-6X-3	70-75	0.8711	0.0895	0.9087	0.1245	0.0891	0.0304	0.1134
756C-7X-1	70-75	0.6834	0.2628	0.6543	0.1355	-0.0464	0.3748	0.1590
756C-7X-3	70-75	0.5642	0.1133	0.6962	0.1549	0.0778	0.1405	0.1300
756C-7X-5	70-75	0.8842	0.3071	0.8263	0.2022	0.0203	0.2306	0.1126
Variance			27.284	22.591	17.62	7.195	3.795	5.191
Cumulative variance			27.284	49.875	67.495	74.69	78.485	83.676

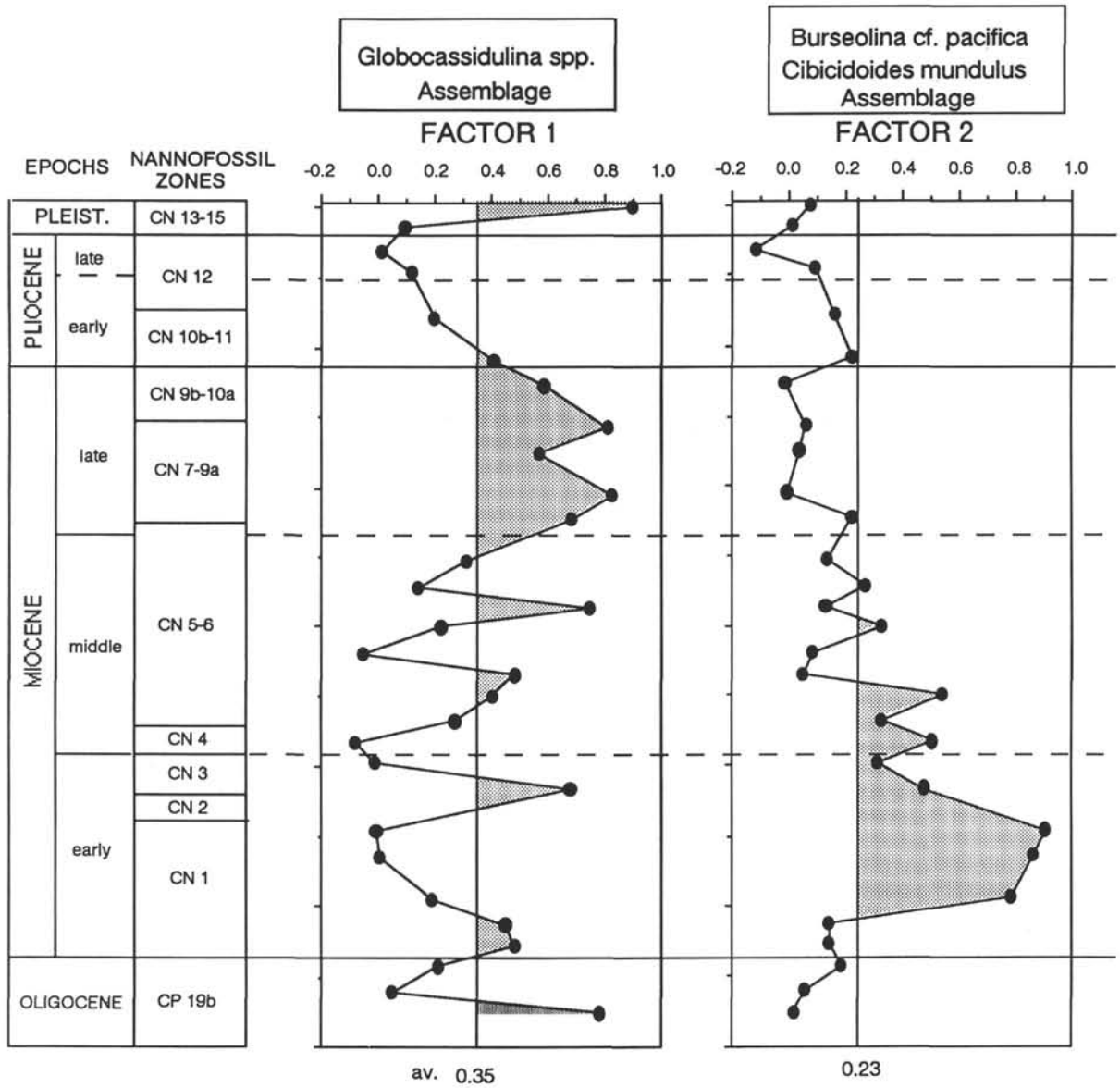


Figure 9. Factor loading vs. sub-bottom depth and referred to nannofossil zones at Site 754.

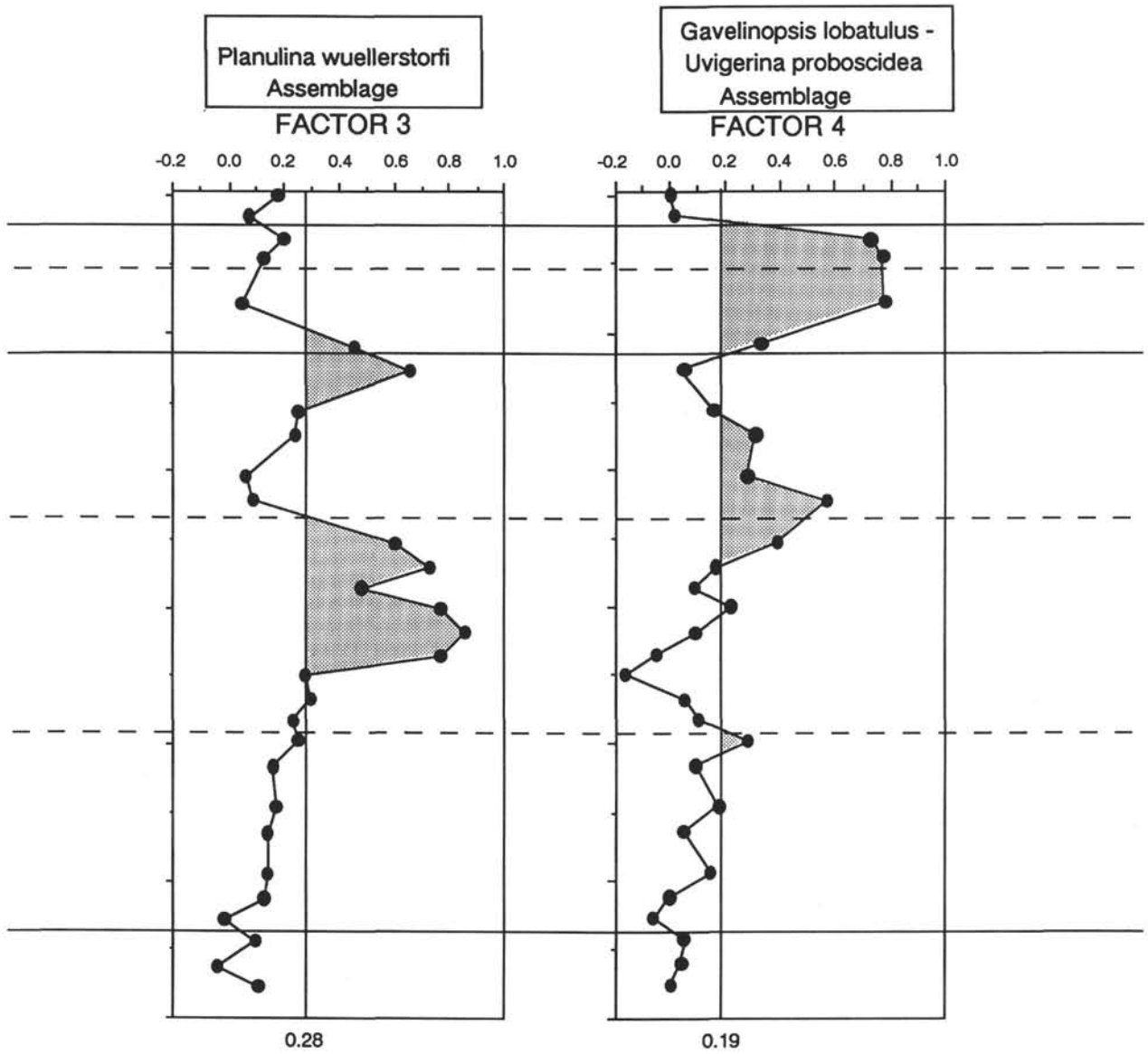
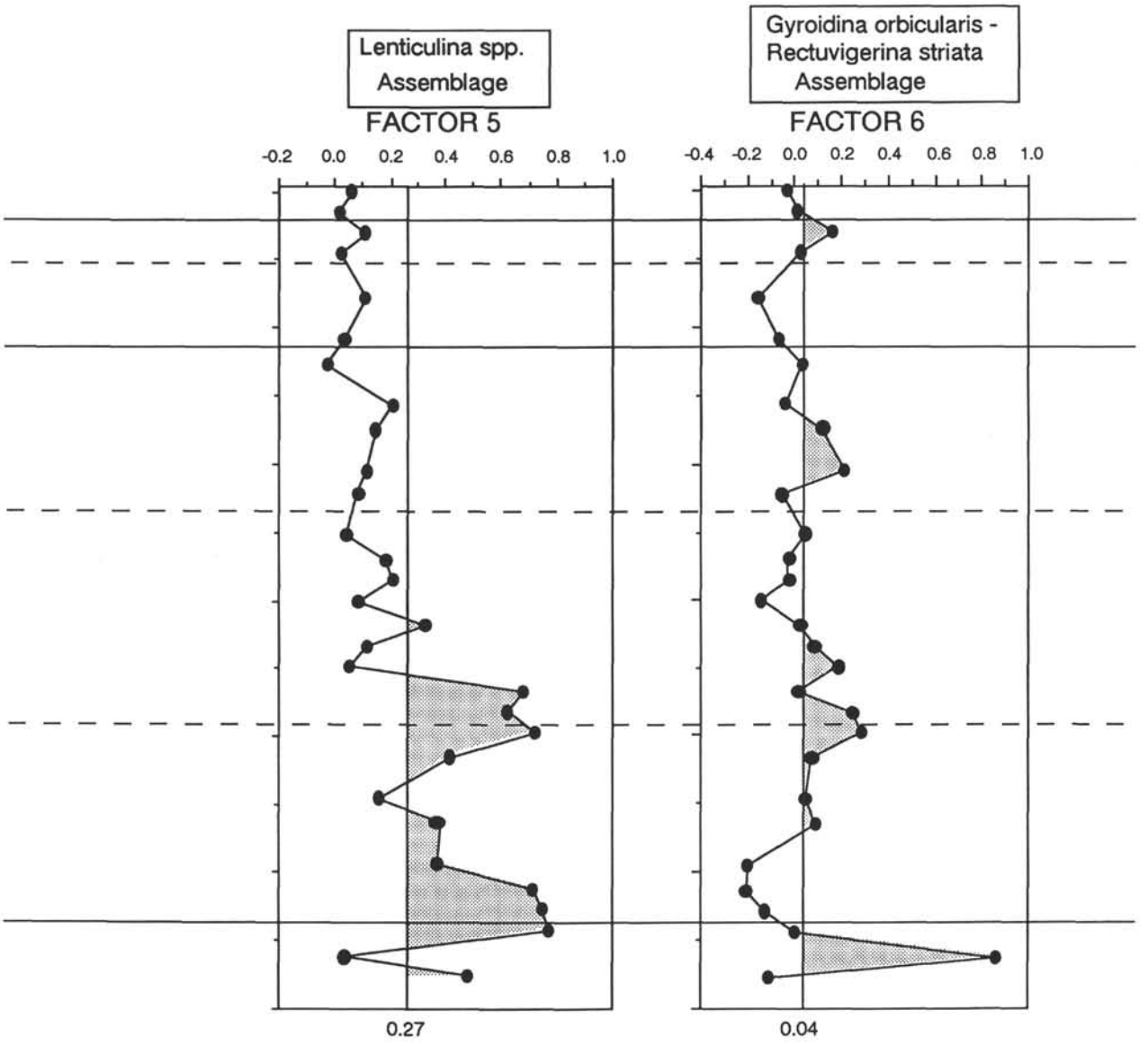


Figure 9 (continued).



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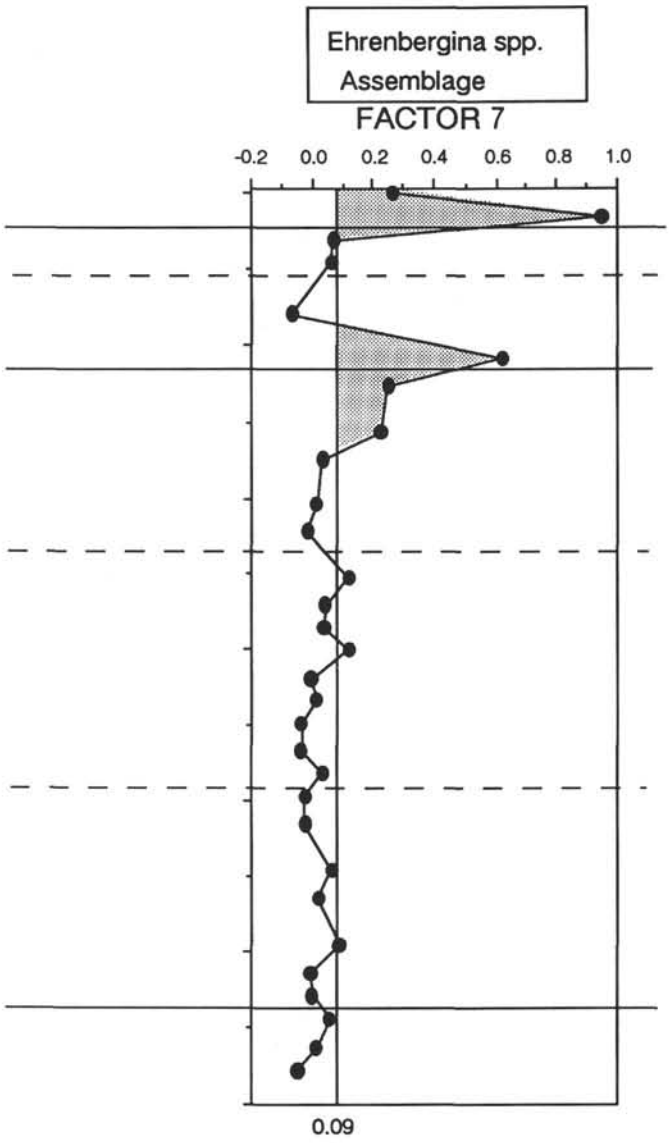

Figure 9 (continued).

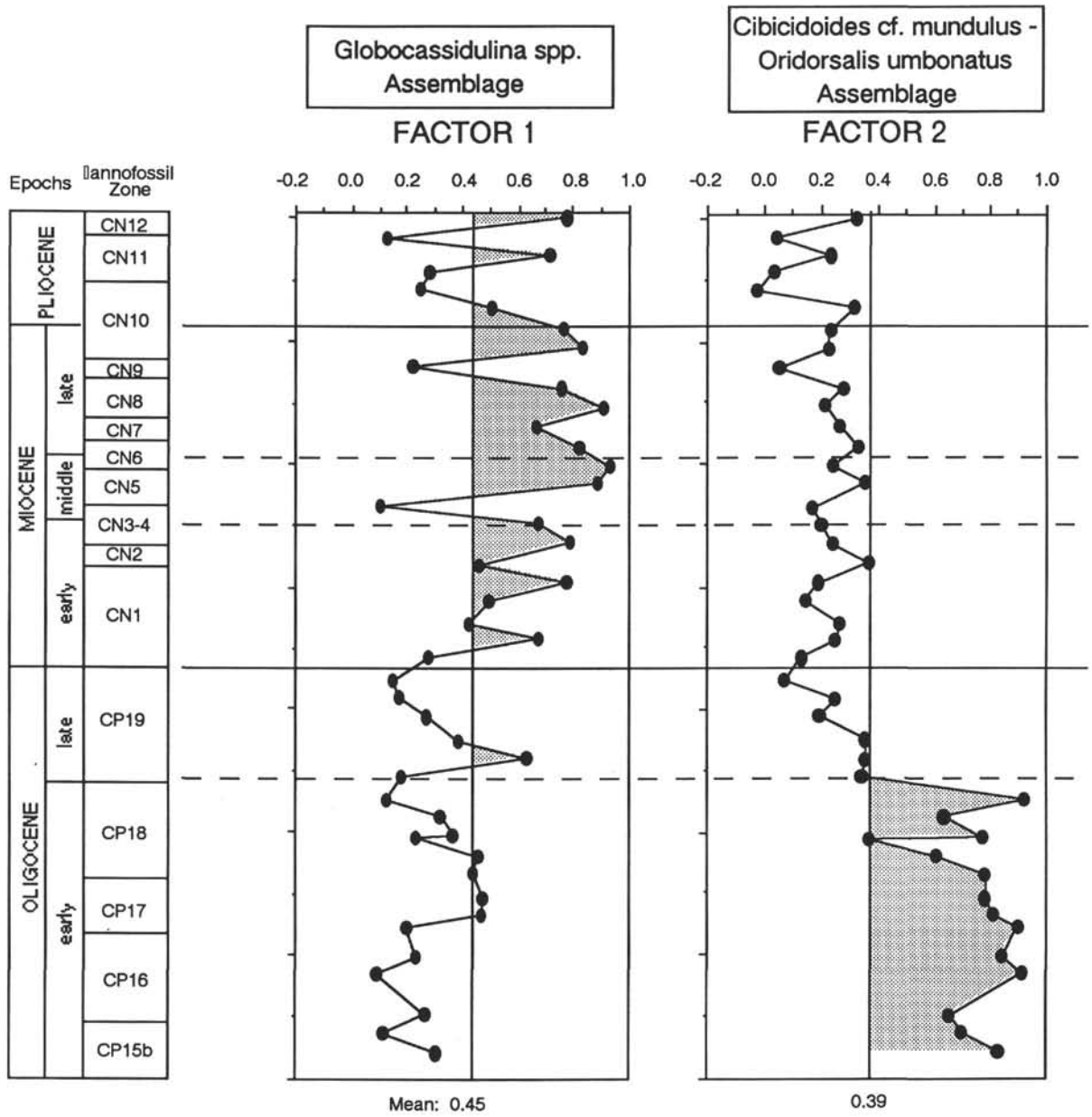

Figure 10. Factor loading plotted vs. sub-bottom depth and referred to nannofossil zones at Site 756.

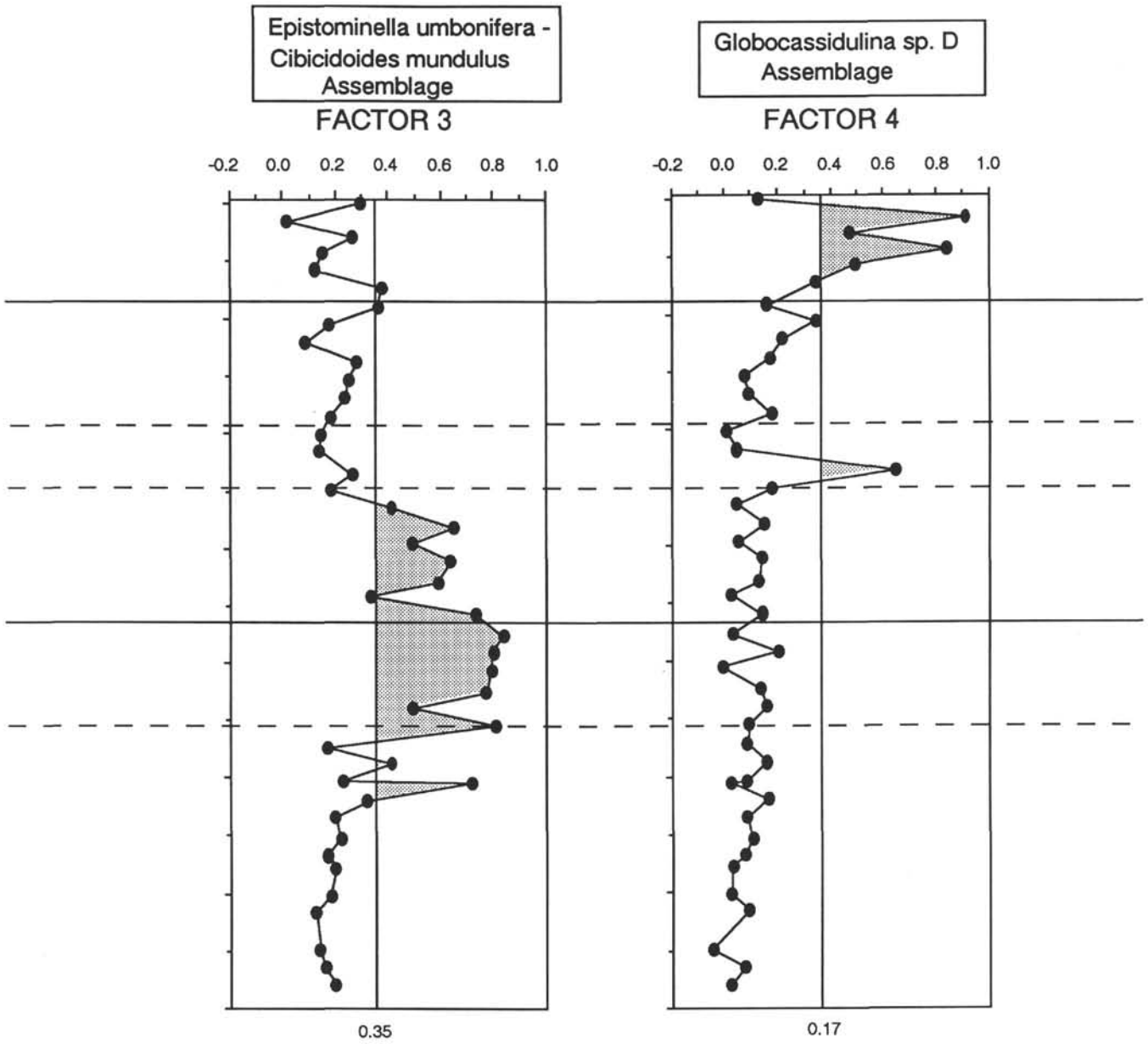

Figure 10 (continued).

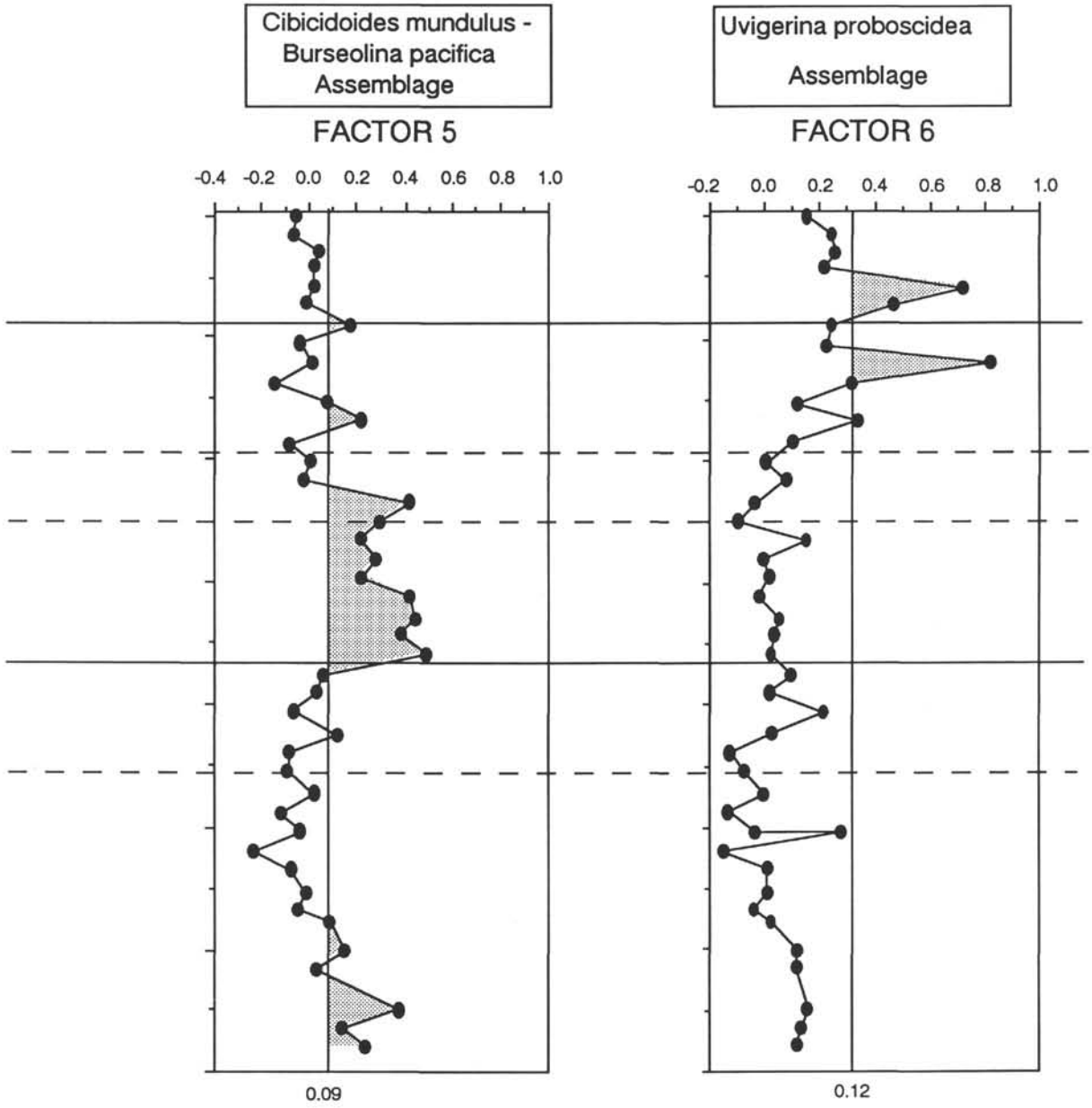

Figure 10 (continued).

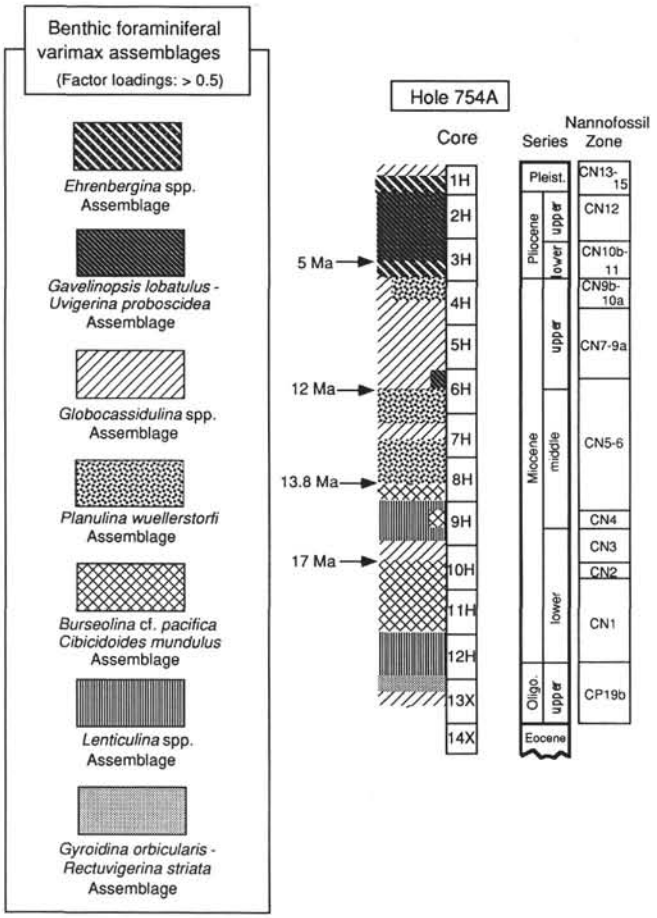

Figure 11. Stratigraphic distribution of varimax assemblages having the varimax factor loadings of >0.5 at Site 754.

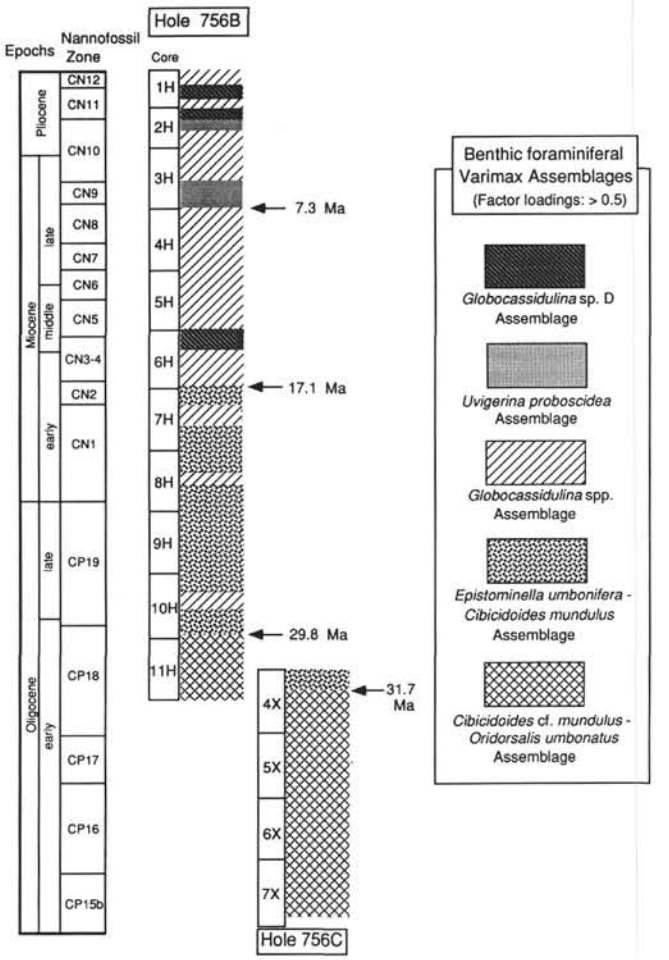

Figure 12. Stratigraphic distribution of varimax assemblages having the varimax factor loadings of >0.5 at Site 756. All the factor loadings of the *Cibicidoides mundulus–Burseolina pacifica* Assemblage are <0.5 and not included in this figure.

Table 6. Factor score matrix from varimax factor analysis of Site 754.

Taxa	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Astrononion echolsi	0.007	0.066	0.268	0.163	-0.414	-0.226
Brizalina albatrossi	0.058	-0.012	-0.026	-0.001	-0.028	0.083
Brizalina pseudoplicata	0.016	-0.005	0.001	0.000	-0.027	0.088
Brizalina pusilla	0.006	0.000	0.067	-0.008	-0.080	-0.018
Bulimina impendens	-0.042	0.097	0.066	0.007	-0.023	-0.041
Bulimina macilenta	0.044	-0.009	-0.015	-0.003	-0.018	0.013
Bulimina rostrata	0.000	0.012	0.095	0.012	-0.058	0.069
Bulimina tuxpamensis	-0.016	0.058	0.016	0.004	0.118	-0.017
Burseolina pacifica	0.058	-0.023	-0.050	0.256	0.299	-0.253
Cibicidina cf. walli	0.007	0.012	0.011	0.019	-0.052	-0.040
Cibicidoides cf. mundulus	-0.135	0.567	-0.146	0.014	-0.029	0.005
Cibicidoides havanensis	-0.035	0.121	0.028	0.032	-0.097	-0.066
Cibicidoides mundulus	0.066	-0.212	0.561	0.142	0.506	-0.035
Cibicidoides laurisae	-0.012	0.079	-0.038	-0.025	0.076	0.028
Cibicidoides mexicanus	-0.104	0.199	0.048	-0.092	0.139	0.133
Epistominella exigua	0.031	-0.011	-0.005	0.029	-0.053	0.124
Epistominella umbonifera	-0.113	-0.074	0.572	-0.109	-0.300	0.186
Fissurina spp.	0.049	-0.014	0.003	0.054	-0.026	0.056
Gavelinopsis lobatulus	0.019	-0.008	-0.011	0.044	-0.006	0.000
Globocassidulina subglobosa s.l.	0.941	0.193	0.060	-0.039	-0.071	-0.015
Globocassidulina sp. D	-0.023	-0.052	-0.103	0.893	-0.075	0.136
Gyroidina orbicularis	0.028	-0.025	0.015	0.036	0.120	0.041
Gyroidina soldanii	-0.021	0.288	0.276	0.141	-0.146	-0.191
Hanzawaia ammophila	-0.014	0.057	-0.006	0.002	-0.002	-0.007
Laticarinina pauperata	0.072	-0.024	0.021	0.016	-0.016	0.051
Lenticulina spp.	-0.087	0.328	0.100	-0.081	0.249	0.030
Nonion havanensis	-0.045	0.183	-0.031	0.006	0.071	0.003
Oridorsalis umbonatus	-0.003	0.444	0.144	0.141	0.020	0.119
Orthomorphina modesta	0.000	0.009	0.024	0.010	0.042	-0.022
Orthomorphina cf. antillea	0.017	0.018	0.144	0.016	0.148	-0.062
Osangularia mexicana	0.095	0.031	-0.039	-0.016	0.330	0.105
Planulina dohertyi	0.015	-0.014	0.014	-0.007	0.061	-0.015
Planulina renzi	-0.003	0.003	0.097	-0.005	-0.005	-0.043
Pullenia bulloides	-0.030	0.180	0.043	-0.008	0.066	0.047
Pullenia quinqueloba	-0.036	0.094	0.088	-0.021	0.155	-0.020
Sphaeroidina bulloides	0.059	-0.022	-0.003	0.071	0.079	-0.010
Stilostomella annulifera	-0.009	-0.001	0.056	-0.035	-0.060	0.181
Stilostomella lepidula	-0.011	0.083	0.072	0.070	0.037	0.364
Uvigerina cf. proboscidea	-0.039	0.072	-0.020	-0.005	0.058	0.048
Uvigerina miozea	0.002	-0.015	0.031	-0.004	0.125	-0.018
Uvigerina proboscidea	0.064	-0.047	-0.012	0.012	-0.017	0.721
Uvigerina schencki	0.092	-0.017	-0.023	-0.021	-0.087	0.008
Uvigerina sp. A	-0.066	-0.039	0.247	-0.025	-0.026	-0.007
Vulvulina spinosa	-0.046	0.153	0.044	0.009	0.091	-0.029

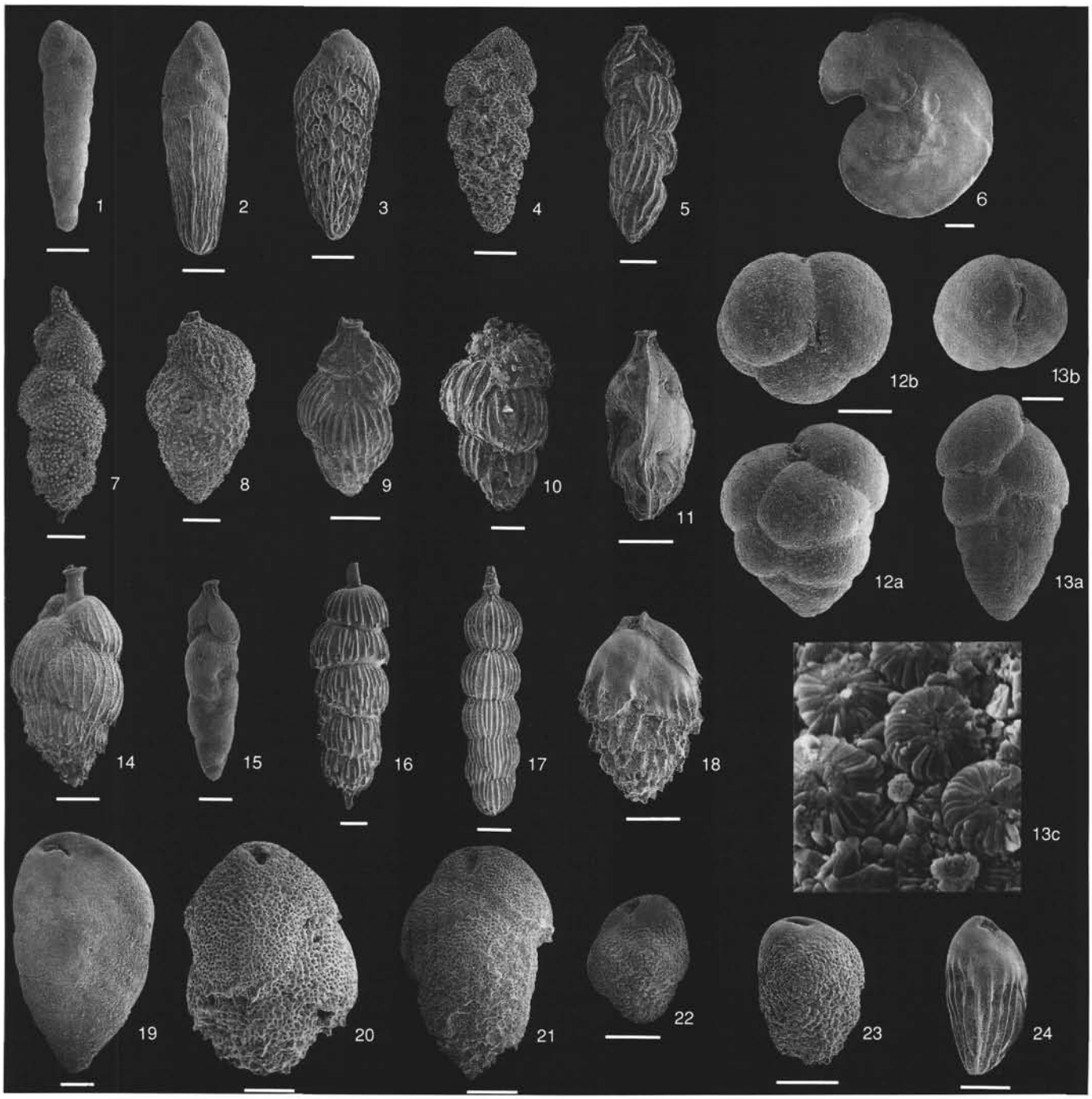

Plate 1. (Scale bar = 100 µm) **1.** *Brizalina pseudoplicata,* Sample 121-756B-2H-5, 70–75 cm. **2.** *Brizalina pusilla,* Sample 121-756B-10H-3, 70–75 cm. **3.** *Brizalina albatrossi,* Sample 121-756B-3H-5, 70–75 cm. **4.** *Brizalina* cf. *thalmanni,* Sample 121-756B-3H-1, 70–75 cm. **5.** *Uvigerina schencki,* Sample 121-756B-9H-1, 70–75 cm. **6.** *Laticarinina pauperata,* Sample 121-756B-4H-1, 70–75 cm. **7.** *Uvigerina proboscidea,* Sample 121-756B-2H-3, 70–75 cm. **8.** *Uvigerina* cf. *hispida,* Sample 121-756C-7X-3, 70–75 cm. **9.** *Uvigerina graciliformis,* Sample 121-754A-13X-3, 70–75 cm. **10.** *Uvigerina peregrina,* Sample 121-754A-2H-1, 70–75 cm. **11.** *Trifarina* sp., Sample 121-756B-9H-1, 70–75 cm. **12a–b.** *Eggerella bradyi,* Sample 121-756B-2H-1, 70–75 cm. **13a–c.** *Karreriella bradyi* (**13c** is detail of wall surface showing calcareous nannofossils, (×4900), Sample 121-754A-2H-3, 70–75 cm. **14.** *Uvigerina miozea,* Sample 121-756B-8H-1, 70–75 cm. **15.** *Uvigerina* sp. A., Sample 121-754A-5H-1, 70–75 cm. **16.** *Rectuvigerina multicostata,* Sample 121-756B-4H-1, 70–75 cm. **17.** *Rectuvigerina striata,* Sample 121-754A-10H-5, 70–75 cm. **18.** *Bulimina mexicana,* Sample 121-754A-2H-3, 70–75 cm. **19.** *Bulimina tuxpamensis,* Sample 121-756B-8H-1, 70–75 cm. **20.** *Bulimina macilenta,* Sample 121-756B-3H-3, 70–75 cm. **21.** *Bulimina impendens,* Sample 121-756B-11H-1, 70–75 cm. **22.** *Bulimina tuxpamensis,* Sample 121-756C-6X-1, 70–75 cm. **23.** *Bulimina tuxpamensis,* Sample 121-754A-12H-3, 70–75 cm. **24.** *Bulimina rostrata,* Sample 121-756B-1H-1, 70–75 cm.

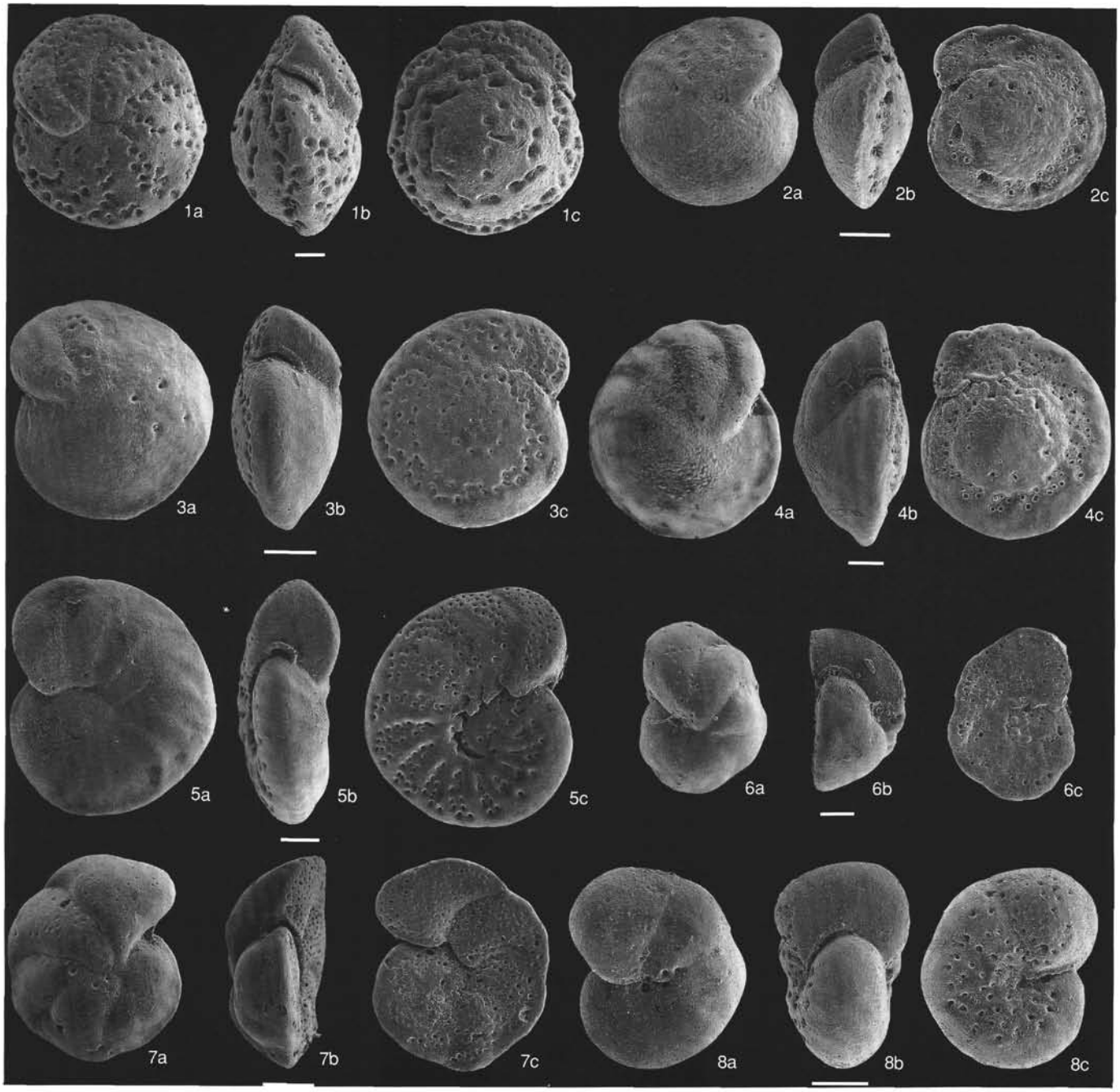

Plate 2. (Scale bar = 100 μm) **1a–c.** *Cibicidoides havanensis*, Sample 121-756B-10H-5, 70–75 cm. **2a–c.** *Cibicidoides* cf. *mundulus*, Sample 121-756C-7X-3, 70–75 cm. **3a–c.** *Cibicidoides* cf. *mundulus*, Sample 121-756C-6X-1, 70–75 cm. **4a–c.** *Cibicidoides mundulus*, Sample 121-756B-1H-1, 70–75 cm. **5a–c.** *Cibicidoides robertsonianus*, Sample 121-754A-8H-1, 70–75 cm. **6a–c.** *Cibicidoides laurisae*, Sample 121-756C-7X-1, 70–75 cm. **7a–c.** *Cibicidoides lobatulus*, Sample 121-754A-5H-1, 70–75 cm. **8a–c.** *Anomalinoides semicribratus*, Sample 121-754A-10H-5, 70–75 cm.

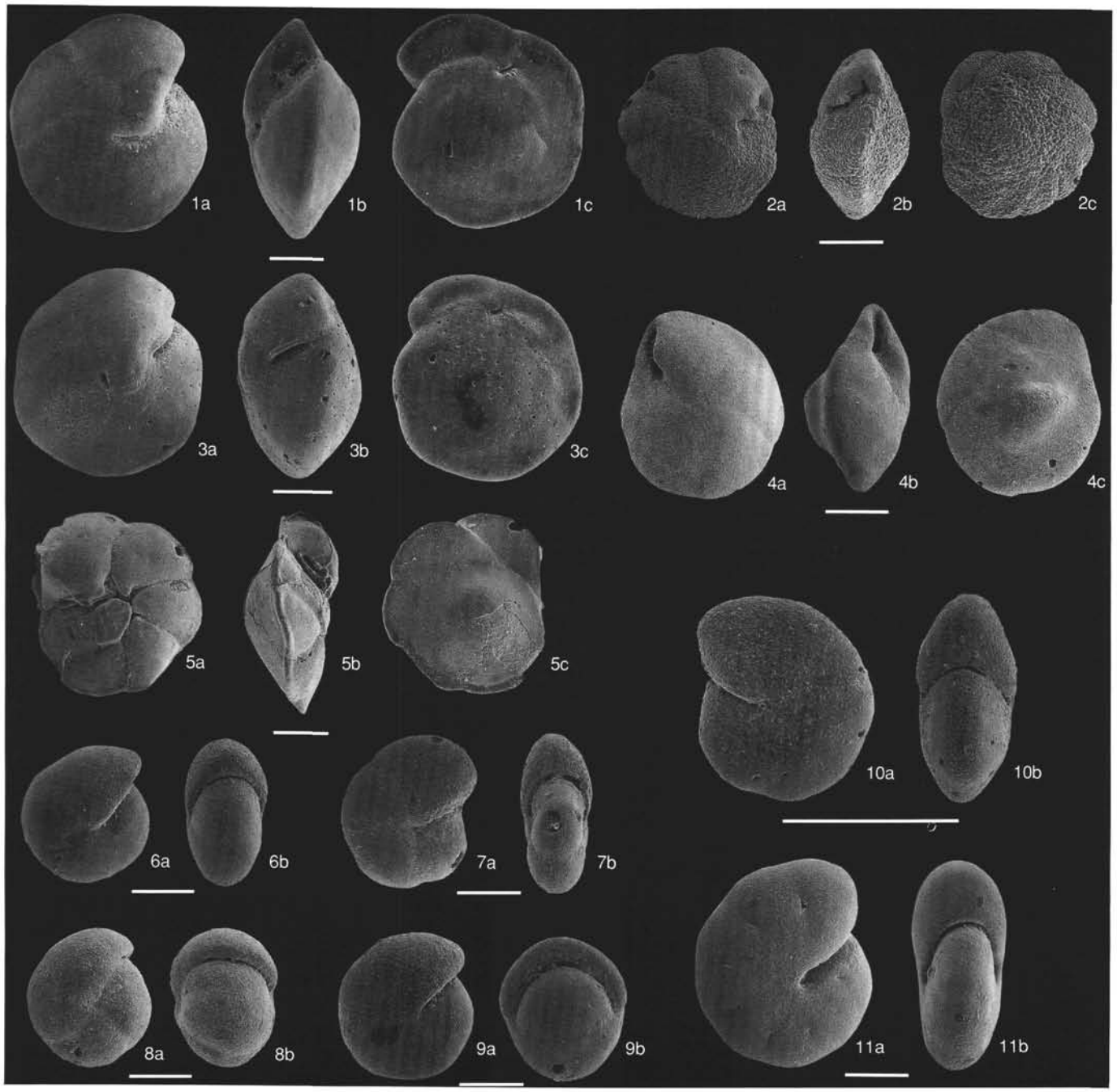

Plate 3. (Scale bar = 100 µm) **1a–c, 3a–c.** *Oridorsalis umbonatus,* Sample 121-756B-1H-1, 70–75 cm. **2a–c.** *Epistominella umbonifera,* Sample 121-756B-9H-1, 70–75 cm. **4a–c.** *Epistominella exigua,* Sample 121-756B-1H-1, 70–75 cm. **5a–c.** *Gavelinopsis lobatulus,* Sample 121-756B-11H-1, 70–75 cm. **6a–b.** *Pullenia subcarinata,* Sample 121-756B-4H-5, 70–75 cm. **7a–b.** *Pullenia quinqueloba,* Sample 121-756B-11H-5, 70–75 cm. **8a–b.** *Pullenia osloensis,* Sample 121-756-2H-1, 70–75 cm. **9a–b.** *Pullenia bulloides,* Sample 121-756B-4H-3, 70–75 cm. **10a–b.** *Nonion havanensis,* Sample 121-756B-11H-1, 70–75 cm. **11a–b.** *Astrononion echolsi,* Sample 121-756B-1H-1, 70–75 cm.

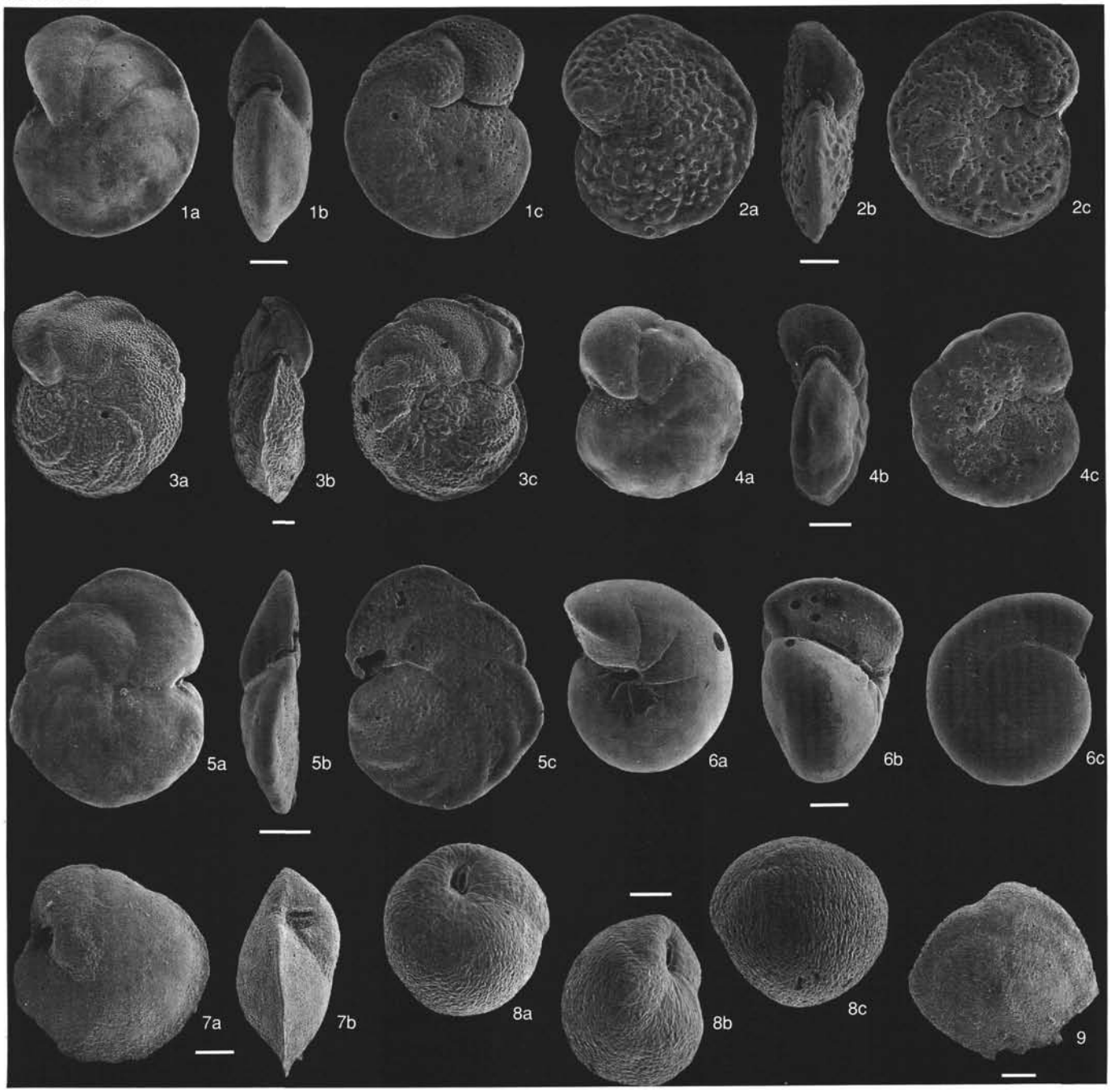

Plate 4. (Scale bar = 100 μm) **1a–c.** *Planulina wuellerstorfi* (smooth type), Sample 121-754A-4H-1, 70–75 cm. **2a–c.** *Planulina wuellerstorfi* (coarse type), Sample 121-754A-7H-3, 70–75 cm. **3a–c.** *Planulina renzi,* Sample 121-754A-10H-5, 70–75 cm. **4a–c.** *Cibicidoides* sp. A, Sample 121-754A-2H-1, 70–75 cm. **5a–c.** *Planulina costata,* Sample 121-754A-11H-1, 70–75 cm. **6a–c.** *Gyroidina soldanii,* Sample 121-754B-9H-1, 70–75 cm. **7a–b.** *Osangularia mexicana,* Sample 121-756B-11H-1, 70–75 cm. **8a–c.** *Globocassidulina* sp. C, Sample 121-754A-8H-1, 70–75 cm. **9.** *Vulvulina spinosa,* Sample 121-756B-8H-1, 70–75 cm.

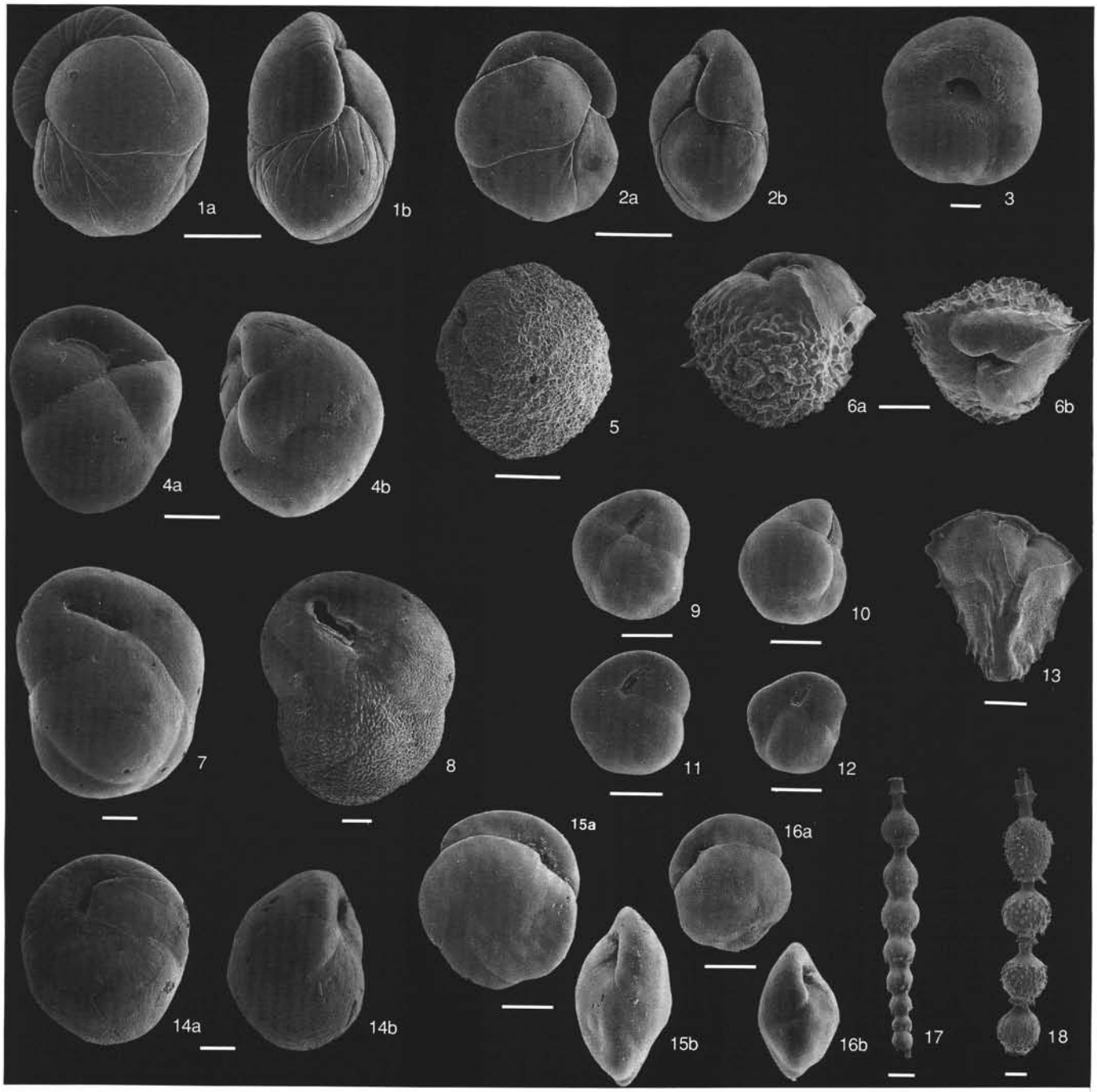

Plate 5. (Scale bar = 100 µm) **1a–b.** *Paracassidulina sulcata,* Sample 121-754A-1H-3, 70–75 cm. **2a–b.** *Paracassidulina minuta,* Sample 121-754A-1H-1, 70–75 cm. **3.** *Sphaeroidina bulloides* Sample 121-756B-1H-5, 70–75 cm. **4a–b.** *Burseolina pacifica,* Sample 121-756B-6H-1, 70–75 cm. **5.** *Globocassidulina reflexa,* Sample 121-756B-1H-5, 70–75 cm. **6a–b.** *Ehrenbergina hystrix,* Sample 121-756B-3H-1, 70–75 cm. **7.** *Globocassidulina horizontalis,* Sample 121-754A-3H-5, 70–75 cm. **8.** *Globocassidulina subglobosa,* Sample 121-754A-1H-1, 70–75 cm. **9.** *Globocassidulina globosa,* Sample 121-754A-12H-5, 70–75 cm. **10.** *Globocassidulina* sp. A, Sample 121-754A-5H-5, 70–75 cm. **11.** *Globocassidulina* sp. A, Sample 121-754A-5H-5, 70–75 cm. **12.** *Globocassidulina subglobosa,* Sample 121-754A-1H-1, 70–75 cm. **13.** *Ehrenbergina carinata,* Sample 121-754A-1H-1, 70–75 cm. **14a–b.** *Burseolina* cf. *pacifica,* Sample 121-756B-6H-5, 70–75 cm. **15a–b; 16a–b.** *Globocassidulina* sp. D, Sample 121-756A-2H-1, 70–75 cm. **17.** *Stilostomella lepidula,* Sample 121-756B-1H-5, 70–75 cm. **18.** *Stilostomella subspinosa,* Sample 121-754A-11H-1, 70–75 cm.