9. QUATERNARY BENTHIC FORAMINIFERS FROM DEEP SEA DRILLING PROJECT SITES 612 AND 613, LEG 95, NEW JERSEY TRANSECT[1]

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ABSTRACT

The Quaternary benthic foraminifers from Leg 95 Sites 612 and 613 were examined with respect to paleoceanographic trends. Data from the two sites indicate the presence of markedly different bottom-water masses, during both glacial and interglacial periods. The dominant interglacial species at Site 612 is *Uvigerina peregrina*, which is barely present in corresponding intervals at Site 613. Dominant glacial species are *Elphidium excavatum* and *Cassidulina reniforme* at Site 612 and *Epistominella takayanagii* at Site 613.

INTRODUCTION

The Baltimore Canyon trough is the most intensively investigated sedimentary basin along the U.S. Atlantic margin. Offshore studies began in the 1950s (e.g., Drake et al., 1959) and have intensified as interest built because of offshore petroleum leases. On the basis of an extensive published record of both geological and geophysical investigations, the New Jersey margin was selected as the most suitable location for constructing the first marginwide stratigraphic transect.

Leg 93 started the current phase of drilling on the New Jersey transect, at two shallow sites (604 and 605) on the upper rise and one at the extreme oceanward end of the transect (603). The Leg 95 holes reported on here (612 and 613) provide the link between the shelf and the rise.

The advent of the hydraulic piston corer (HPC) has made it possible to obtain from the soft, unconsolidated Quaternary deposits high-resolution results not previously possible with rotary drilling. This chapter focuses on the benthic foraminiferal record of the Pleistocene sections at Sites 612 (1404 m water depth) and 613 (2323 m water depth). At Site 612 this includes the upper 56 m of sediment; at Site 613 the Pleistocene appears to be 187 m thick. Site 613 was cored discontinuously, and approximately 120 m of section was not sampled. Data will be available, however, from nearby Site 604 (Moulotte and Blanc-Vernet, in press), which was cored continuously through the entire Pleistocene section.

The purpose of this investigation is to report on Quaternary benthic foraminiferal occurrences at Sites 612 and 613, using the assemblage characteristics to reconstruct the paleoceanography.

PREVIOUS WORK

There have been several investigations of modern faunas in this area, but most concentrated on the continental shelf rather than the slope. Cushman (1918–1931), in his studies of the Atlantic, included localities near this area but did not include quantitative data.

The first and most comprehensive of the early quantitative studies was that by Parker (1948), who investigated four transects off the New England coast, covering water depths of 15 to 700 m. Later studies (Murray, 1969; Gervirtz et al., 1971; Kafescioglu, 1975) employed more statistical techniques but lacked the coverage of Parker's study. More recently, Poag et al. (1980) did a comprehensive study on the shelf and upper slope off New Jersey.

Phleger (1942) examined many cores over a wide range of water depths in the same area, and his data provide a comparative base for the Holocene/Pleistocene boundary in our material.

Miller and Lohmann (1982) examined the New Jersey slope environment specifically, identifying *Uvigerina peregrina* as the dominant species between 1500 and 2400 m, which agrees fairly well with what we observed at the surface of our Leg 95 sites. However, their use of a large sieve size severely limits comparison with data presented here.

Streeter (1973) and Schnitker (1974, 1979) examined parts of this area in connection with much wider-ranging studies.

METHODS

Ten-cm^3 samples were processed for study of benthic foraminifers. All material was stored in a cold room before processing. Sediment was wet-sieved through a 63-μm (#230 mesh) screen.

After sieving, the samples were dried and, since most had excess amounts of fine sand, the sediment was sprinkled into carbon tetrachloride to float off the foraminifers. Foraminifers were split into fractions containing 300 to 500 individuals for quantitative counts. Planktonic foraminiferal and oxygen-isotope studies on the planktonic foraminifers are in progress (D. Smith, personal communication, 1985).

A total of 72 samples from Site 612 and 50 from Site 613 were studied. Samples were obtained at larger intervals from Hole 613, both because the Quaternary section was longer and because, since it was incomplete, high-resolution samples were of less interest.

A total of 115 species were found in samples from Site 612 (Fig. 1, Table 1) and 92 species were found in samples from Site 613 (Fig. 2, Table 2). Data are reported in both absolute abundance (total numbers per 10 cm^3) and relative frequency.

All depths given in the following sections are sub-bottom depths.

[1] Poag, C. W., Watts, A. B., et al., *Init. Repts. DSDP*, 95: Washington (U.S. Govt. Printing Office).

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SEDIMENTOLOGY

The sedimentology is adequately described in the site chapters (this volume), but a few brief comments are in order here. The sedimentological characteristics change little throughout the Pleistocene, except that large amounts of glauconite occur near the base of the Quaternary in both holes, particularly Hole 612. The origin of glauconite is suggested to be shallow marine, but may be controlled more by temperature and sedimentation rate than by water depth (McRae, 1972; Bell and Goodell, 1967). Glauconite is reported not to form where water temperatures are lower than 15°C and/or where sedimentation rates are high (McRae, 1972). Present-day distributions confirm this (Bell and Goodell, 1967). I suggest therefore, that any glauconite occurring at Sites 612 and 613 must have been transported from upslope and that reworked materials are present when glauconite is observed.

RESULTS

Hole 612

Total numbers of individuals vary significantly throughout the section from this hole, from almost 6000/10 cm^3 down to less than 500/10 cm^3. A large majority of these individuals are less than 250 μm and therefore were not observed in the shipboard studies (Site 612 chapter, this volume).

There are significant assemblage changes downcore (Fig. 1, Table 1). At the surface (0–1.00 m) a diverse fauna occurs; it is dominated by *Uvigerina peregrina* and *Pullenia subcarinata*, with lesser percentages of *Epistominella exigua* and *Bulimina marginata*. In a short sequence (1.00–2.00 m), the assemblage changes first to one dominated by *Fursenkoina fusiformis* (1.33 m), then to an *Islandiella teretis* assemblage (1.77 m), and below that a comparatively long (2.00–15.00 m) section is codominated by *Elphidium excavatum* f. *clavata* and *Cassidulina reniforme*. This long section is interrupted only at 4.83 m, where an assemblage identical to the surface one reappears in one sample. This sample is suspect, since it is from the top of a core section and does not match samples from just a few centimeters above (4.48 m) and below (5.08 m).

Below 15.00 m, a new type of fauna begins as *E. excavatum* f. *clavata* and *C. reniforme* are still codominant, and there are persistent percentages of *F. fusiformis* and *I. teretis* down to 35.00 m, but at several levels between 20.00 and 35.00 m, *E. exigua* is dominant, replacing the other codominants, *E. excavatum* and *C. reniforme*. Below 27.00 m, *I. teretis* and *F. fusiformis* replace *E. excavatum*; a peak occurrence of *F. fusiformis* at 32.00 m is similar to the one at 1.33 m. In a short sequence (34.00–36.00 m), *E. excavatum* becomes overwhelmingly dominant. *Elphidium subarcticum* also appears in significant percentages in this interval.

Below the 36.00 m level, down to the lowest level examined in this study (56.00 m), the fauna again changes dramatically to an assemblage dominated by *Uvigerina* spp., but this assemblage is very different from the one at the surface. Most of these uvigerinids, as well as a significant part of the rest of the assemblage (e.g., *Dentalina subsoluta, Bulimina aculeata*), appear to be Tertiary species, but there are still significant percentages of what appear to be glacial forms (*E. excavatum* and *F. fusiformis*), so that I believe the Tertiary forms are reworked into the section. Using nannofossils and planktonic foraminifers, this section was described as upper Tertiary, but at least with the planktonic foraminifers, there are also significant amounts of Pleistocene forms (Poag and Low, this volume), so that older planktonic species may also be reworked from older sediments. Further evidence of reworking is the presence of glauconite layers, the top of which is at 37.00 m. Some sedimentary structures also suggest disturbance in this section (Poag, personal communication, 1985, unpublished photos of core sections). Significantly, in the samples without glauconite (39.43 and 56.43 m), there are no diagnostic Tertiary benthic foraminifers.

Hole 613

As mentioned, the Pleistocene section was sampled discontinuously at this site. Samples were obtained from 0 to 1.00 m, 19.00 to 29.00 m, 59.00 to 61.00 m, 117.00 to 163.00 m, and 185.00 to 187.00 m. Total numbers are generally higher in this hole than in Hole 612 (20,000/10 cm^3 to 500/10 cm^3); many samples contained more than 2000/10 cm^3 (Fig. 2, Table 2). As with Hole 612, a majority of these species were less than 250 μm in size and were not observed in shipboard studies (Site 613 chapter, this volume).

The surface assemblage is significantly different from that at Hole 612. *U. peregrina* is present, but in low percentages. The three codominant species are *I. teretis, F. fusiformis*, and *E. excavatum* f. *clavata*. In the next sample below the surface (0.52 m), however, the fauna is completely different. The dominant species becomes *Epistominella takayanagii*, and the other species, except *F. fusiformis*, drop off. *E. subarcticum* increases in relative abundance, but *U. peregrina* disappears. Total numbers decrease just below the surface as well.

There is an 18-m gap between samples, but at 19 m a fauna similar to that at the surface recurs and persists for a longer length of section (19–22.02 m) than at the surface. At 23.32 m the fauna changes to an *E. takayanagii–E. subarcticum* fauna (similar to that at 0.52–1.00 m). *E. takayanagii* remains the dominant form down to 134.91 m, but *E. subarcticum* diminishes starting at 26.02 m, regains larger percentages at 59 to 61 m, and diminishes again below that. *E. excavatum* f. *clavata* remains in high relative abundance and actually codominates with *E. takayanagii* at 28.74 m, 59.51 to 61.01 m, and 117.32 to 118.81 m. After decreasing in abundance at 22.02 m, *I. teretis* again becomes prominent at 117.32 m. Also, at 120.31 m, *Bulimina marginata* becomes a significant species and remains significant to 134.91 m. *F. fusiformis* remains high in relative abundance (10–25%) throughout the entire upper sections (0–134.91 m).

At the 134.91 to 136.41-m level, *E. takayanagii* becomes a codominant with *Brizalina subaenariensis* (this is the only level in this sequence where *B. subaenariensis*

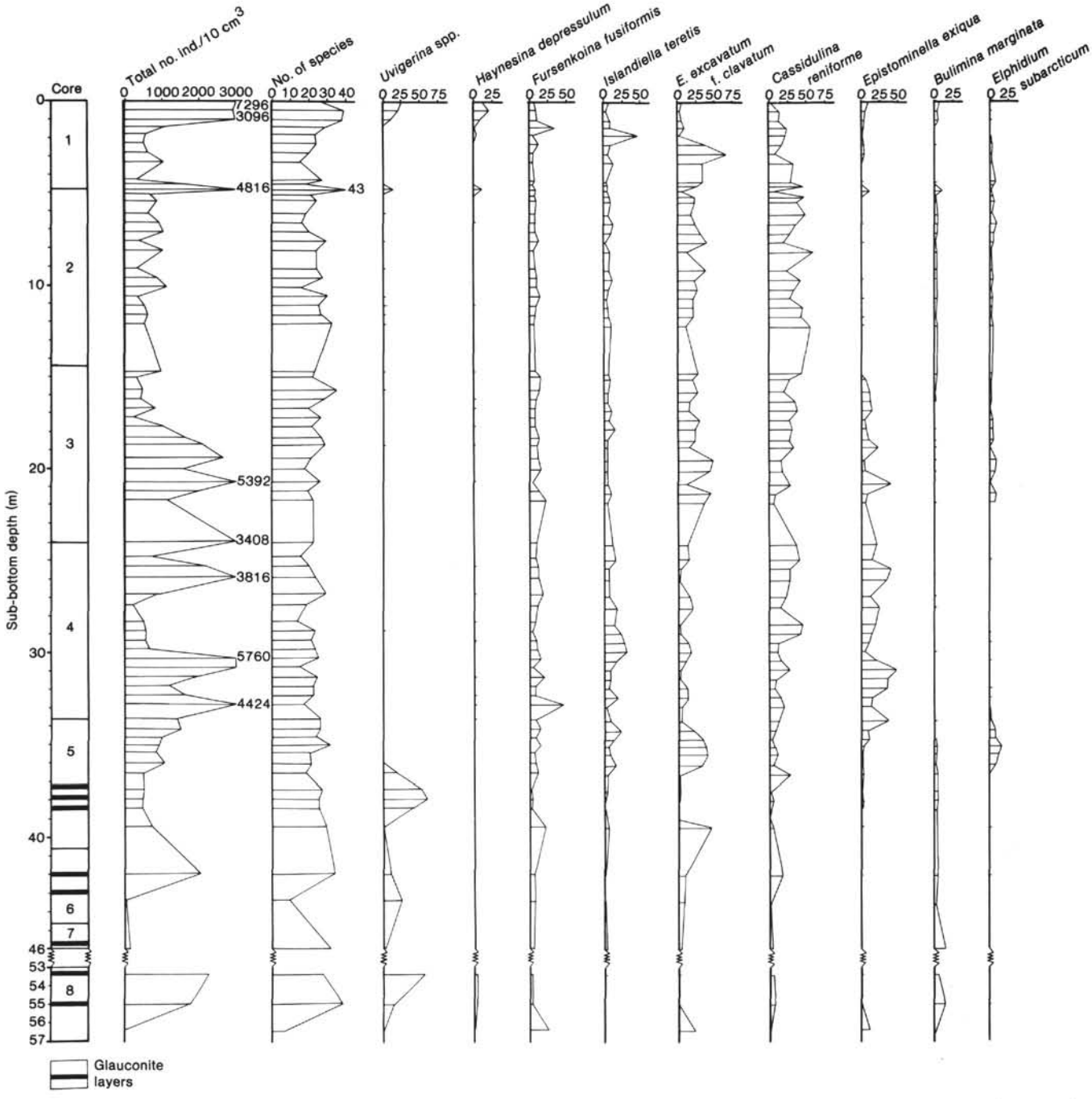

Figure 1. Percentage occurrences of selected species, Hole 612. Horizontal bars are values from corresponding level, vertical connecting lines are subjective averaging. *Haynesina depressulum* should be *Pullenia subcarinata*.

is prominent). Other species (*F. fusiformis, I. teretis*) drop in abundance, whereas some (*B. marginata, Nonionella turigida*) increase.

Just below this level, *E. takayanagii* recurs in overwhelming dominance (50–70%) down to 145.93 m. Other species all make up less than 10%, but total numbers are the highest at the site (5000–20,000/10 cm^3).

At 145.93 m, the assemblage changes abruptly to one codominated by *E. takayanagii, I. teretis*, and *E. excavatum* f. *clavata*. This fauna persists to the bottom of the section examined here.

There appear to be reworked Tertiary–Cretaceous species throughout the hole (Table 2), but they are most prominent in the lowest sample containing glauconite (185.23 m), where reworked species (*Heterohelix* spp., *Globigerinoides* spp., some *Dentalina* spp., *Guembelitria* sp.) make up as much as 25% of the total fauna.

BIOSTRATIGRAPHY

There are some interpretational discrepancies between the work presented here and that performed aboard ship (Poag and Low, this volume).

Table 1. Percentage occurrences of all benthic foraminiferal species observed in the Quaternary samples from Hole 612.

Depth of core (m)	0.3	0.5	1.00	1.33	1.77	2.33	2.88	3.33	4.33	4.48	4.83	5.08	5.33	6.13	6.60	7.13	7.63
Core-Section	1-1	1-1	1-1	1-1	1-2	1-2	1-2	1-3	1-3	1-3	2-1	2-1	2-1	2-1	2-2	2-2	2-2
No. of species	25	39	38	28	23	24	20	15	27	18	43	20	24	18	16	19	29
Total number of individuals/10 cm^3	7296	2912	3096	1034	536	508	590	1048	301	1468	4816	638	866	592	884	1028	339
Adercotryma glomerata				X	X												
Ammobaculites agglutinans		X															
Ammonia beccarii																	
Ammotium cassis		X									X						
Astrononion gallowayi	1	1	X		X	2	1		1		1		X				
Bolivina decussata		X	X			X											X
B. subspinescens	2	X	1								2						
Brizalina bradyi																	
B. pseudopunctata		2	6	8	14	7	1	4	6	5	X	6	5	6	4	6	3
B. spathulata	4	2	7	1					X	X	7	1	1	2		2	X
B. subaenariensis							X										X
Buccella frigida		X		X	X	2	2	1	3	X		1	1	2	3	2	1
Bulimina aculeata											1						
B. exilis											X						
B. gibba																	
B. marginata	5	2	4			1			1		8	X	X	2	1	1	X
B. striata	X	X	1		X					X	2	X				X	
Buliminella elegantissima						X				X							
Cassidulina laevigata			1	X							1						X
C. reniforme	1	14	12	24	21	16	8	31	28	46	5	47	36	48	35	27	18
Chilostomella oolina																	
Cibicides lobatulus			X	X		X		1	X		X		X	1	X	X	1
C. pseudoungerianus	1	X	5								1						
C. robertsonianus											X						
Cribrostomoides canariensis														1			2
Cyclogyra involvens																	
Dentalina ittae																	
D. subsoluta																	
D. subemaciata																	
Dentalina spp.							X										
Discorbis cf. *nitida*			X	X			X		X	X			X	X			
Eggerella advena						X	X						X	1			1
Elphidium excavatum f. *clavata*	4	2	4	9	1	37	66	33	34	27	4	21	22	17	23	30	39
E. excavatum f. *excavatum*				X									X				
E. excavatum f. *lidoensis*																	
E. excavatum f. *magna*									X								
E. excavatum f. *selseyensis*																	
E. subarcticum		X	X		X	2	1	2	7	4	X	2	4	1	8	4	5
Eoeponides pulchella						X							X				
Eponides bradyi	8	4	4		X		1		1		X	X		6			4
E. tumidulus																	
Epistominella exigua	8	4	3	1	X	2	3		1		10	1			X		X
E. takayanagii			X			2		1		1	X	1	4			4	
E. umbonifera				X													
Fissurina spp.	2	X	2	X	X		1	1	X	X	X		X		1	X	X
Frondicularia sp.																	
Fursenkoina fusiformis	6	9	10	35	3	12	5	3	6	4	9	6	9	6	7	8	12
Gavelinopsis lobatulus																	
G. translucens			X				X				4				X	X	
Glabratella wrightii																	
Glandulina sp.																	
Globobulimina auriculata	X	1	1	2	1		X				X						
Guembelitria sp. (T-K)																	
Gyroidina soldanii	3	2	4		2	X		2	1	2	2	1		X	X		X
Hayneşina depressulum[a]	11	20	7	X	2						10				X		
H. orbiculare									X								
Heterohelix sp. (K)											X						

Note: X = less than 1%, Tertiary and Cretaceous species are indicated by T or K next to the species name.
[a] *Haynesina depressulum* should be *Pullenia subcarinata.*

At Site 612, the Pliocene/Pleistocene boundary is placed at 37 m by shipboard scientists, but I believe the boundary cannot be above my lowest sample (56 m). I believe this discrepancy exists because of reworked material occurring in the Pleistocene. Reworking is indicated not only by the microfossils but also by the presence of glauconite. Reworking of Tertiary and Cretaceous microfossils is known to occur along glacially active margins, as this area must have been during former glacial periods. In some upper Pleistocene sediments off Nova Scotia, I have found up to 90% Tertiary–Cretaceous specimens, well preserved and easily identifiable, but in clearly identifiable upper Pleistocene sediment (from a seismically continuous section; Scott, unpublished data). The

Table 1 (continued).

8.13	9.13	9.57	10.13	10.63	11.07	11.63	12.13	14.75	15.03	15.73	16.25	16.73	17.23	17.75	18.27	18.73	19.37	19.93	20.73
2-3	2-3	2-4	2-4	2-4	2-5	2-5	2-5	3-1	3-1	3-1	3-2	3-2	3-2	3-3	3-3	3-3	3-4	3-4	3-5
24	24	27	15	30	25	26	32	23	21	35	28	19	26	21	26	28	21	17	26
1112	265	836	1100	305	493	574	481	944	276	461	412	780	185	1016	1580	2040	2648	1488	5392
	1			X			1									X			
							X												
X		X		1		X	X	1		X	1	X	2		X	X	X		1
										X									
					X									X					
4	9	4	20	12	6	12	6	2	6	1	4	4	2	2	3	4	1	3	2
1	1	X	X	1	X	1	X		X	X			X		X	X			
X													X						
1	1	1	1	X	X	X	1	X	1	3	2		2	3	4	X	4	1	X
1	2	1		2	1	X	1	1		X	1			1	X	X	1	X	
															X				
				X						X						1			
59	24	39	32	28	46	43	55	43	27	20	34	38	26	31	26	32	14	16	28
	X		X		1		X			X		X	2	X	X		2		X
																X			
	1			2			X			X									
							X						X						
																			X
X					X	X	X			1	1				X			X	X
X	1	X		X		X	X			1	X		X		X	X			
11	38	22	26	21	19	20	10	27	20	26	16	15	30	24	23	15	47	43	10
		X							1										
								X											
X	2	3	1	3	3	2	3	2	1	2	2	X	3	3	5	X	8	7	
											X								
				1		X	2			2	X		3	X	X	6			1
		X		X		X	X		6	12	13	14	5	7	9	22	2	5	40
3		2	1		5	3	X	2	1			X	X	2	X		X	X	X
1	X	X		1		1	X	1	X		X	X	1	1	X	X	X	X	1
6	8	9	9	13	8	6	5	8	14	13	9	7	6	8	11	9	11	14	5
		X																	
X											X		X		X				X
					X														
				X	X	X		X	X			X			X	X	1		X
														X					
3		X	X	2	1	1	X	X		X	1	X		1	6	1		X	X
					X			X			X	X		X		X			X
										X									

zonations assigned on board ship were based on nannofossils and planktonic foraminifers, but obviously the older species of these groups could have been transported together with the benthic foraminifers. It seems clear to me that more work must be done on this section to resolve the problem.

At Site 613 I have no samples from below 186 m, and the Pliocene/Pleistocene boundary is somewhere below that, perhaps at 190 m sub-bottom, according to shipboard studies. I would anticipate problems similar to those at Site 612, however, since reworked material was also found at the base of the Pleistocene at Site 613.

PALEOCEANOGRAPHY

The benthic foraminifers do not contribute a great deal of age information, but do indicate some strong paleoceanographic signals. Although the surface assemblages at the two sites are comparable (both have *Uvi-*

Table 1 (continued).

Depth of core (m)	21.23	21.73	24.03	24.83	25.33	25.87	26.83	27.37	28.33	28.83	29.33	29.83	30.35	30.83	31.33	31.83
Core-Section	3-5	3-5	4-1	4-1	4-1	4-2	4-2	4-3	4-3	4-4	4-4	4-4	4-5	4-5	4-5	4-6
No. of species	19	22	22	15	19	23	29	18	13	24	21	23	25	14	24	22
Total number of individuals/10 cm^3	1992	1092	3408	628	2148	3816	890	176	472	557	548	662	5760	2992	1908	1136
Adercotryma glomerata																
Ammobaculites agglutinans																
Ammonia beccarii			X													
Ammotium cassis																
Astrononion gallowayi					X	X	X	X		X	1	2	X	X	X	X
Bolivina decussata													X			
B. subspinescens																X
Brizalina bradyi	X	3	X													
B. pseudopunctata	2	2	3	2	8	12	6	1	8	3	4	5	2	1	2	2
B. spathulata							X				X	X				
B. subaenariensis	X															
Buccella frigida	2	4	1		X	X		2		X	1		X			
Bulimina aculeata																
B. exilis										X						
B. gibba							X									
B. marginata		1					X	X				X				
B. striata			X					1		X	7					4
Buliminella elegantissima																
Cassidulina laevigata				1	X							1				
C. reniforme	6	5	36	39	28	28	22	13	46	43	12	11	16	27	8	6
Chilostomella oolina																
Cibicides lobatulus	X	X		1	X	X	X	X		X	1	X	X			X
C. pseudoungerianus			X													
C. robertsonianus										X						
Cribrostomoides canariensis																
Cyclogyra involvens																
Dentalina ittae																
D. subsoluta																
D. subemaciata																
Dentalina spp.					X							X	X	X		
Discorbis cf. *nitida*	X		X				1		X			1	X		X	X
Eggerella advena						X										
Elphidium excavatum f. *clavata*	46	36	12	14	2	1	16	19	2	4	13	17	10	3	2	12
E. excavatum f. *excavatum*							X			X		1				
E. excavatum f. *lidoensis*																
E. excavatum f. *magna*																
E. excavatum f. *selseyensis*																
E. subarcticum	9	6		1						X	1		X			1
Eoeponides pulchella						X							X		X	
Eponides bradyi		X	X		3						X			X		
E. tumidulus													X			
Epistominella exigua	7	5	20	13	40	33	11	24	19	13	10	4	21	48	36	35
E. takayanagii							1		X	X			X		X	X
E. umbonifera																
Fissurina spp.	X	1	1			X	X			1			1		X	1
Frondicularia sp.																
Fursenkoina fusiformis	12	22	9	6	11	11	17	11	7	3	8	9	13	3	18	7
Gavelinopsis lobatulus																
G. translucens												1				
Glabratella wrightii																
Glandulina sp.																
Globobulimina auriculata	2	1	1	1	X			X		X	1	X			3	
Guembelitria sp. (T-K)																
Gyroidina soldanii		1		1	2	2				2	X		1	3	X	2
Haynesina depressulum[a]					X		X		X		X				1	
H. orbiculare																
Heterohelix sp. (K)																

gerina peregrina), the subsurface materials differ completely. Of course, the key problem in comparing the holes is the missing upper section of Hole 613. Despite the lack of a completely comparable section, however, there was sufficient overlap to suggest a major hydrographic boundary between the two sites. *U. peregrina* occurs in both surface assemblages but dominates at Site 612 and obviously is at its lower limit at Site 613, indicating that there is a hydrographic boundary presently in this location. The surface faunas compare favorably with reported modern faunas (e.g., Miller and Lohmann, 1982), except that *U. peregrina* is reported to occur commonly to depths of 2400 m.

In subsurface assemblages, however, there is less similarity. Instead of the *Cassidulina reniforme–Elphidium excavatum* fauna, prevalent throughout the Site 612 sequence, there is an *Epistominella takayanagii* fauna at Site 613 which has a strong *E. excavatum* component

Table 1 (continued).

32.33	32.83	33.63	34.10	34.60	34.93	35.37	35.93	36.43	37.41	37.93	38.37	39.43	41.93	43.43	45.93	53.43	54.93	56.43
4-6	4-6	5-1	5-1	5-1	5-1	5-2	5-2	5-2	5-3	5-3	5-4	5-4	6-1	6-2	7-1	8-1	8-2	8-3
22	17	26	27	23	31	20	21	18	27	25	25	29	34	9	31	27	38	7
1580	4424	1424	1508	936	890	812	1068	496	480	473	452	672	2162	16	129	2208	1776	9
2	X	X	1	2	1	X				3								
												X			2			
			X	1	X		X					X			7		X	
X	4	4	1	1	X	1	3	1		X		X	X		2	X	1	
			1		X							1						
		X					X				X							
		1	3	2	4	6	3	1	X	X			15					
		2		1				2	7		3	1			4			
													X					
		6			2	1	X	4	4	3	2	1	3		14	4	13	
6		X	3	10			9		2						5		X	
	X				X				X				6					
		X		X			1	1		2		X	X				2	
13	19	13	7	2	6	11	5	27	1	5	2	4	17		2	3	6	
												X						
2		1	2	X	2	2	1	1	1	X	X	1	4	6	9	X	1	
													X				X	
																X	1	
										1								
										1	4				6			
			X						5		1				14		6	
																	2	
	X				X			1	X		1	X	X		3	1	1	
X			1		1		1	1		X			1				X	
13	4	3	23	34	38	39	32	1	2	1		45	7	6	3	X	X	22
													X					
										X		1	3					
			X									1						
			X									2						
2		1	7	8	16	12	7					3	X		2		X	
					1	X	X								1			
					1			9			4		2		3	11	14	11
15	12	36	7	12	3	2	2	1	X	1	X	X	X			X		11
			1						1	4	1	1	12	31	2	5	3	
X		X	X	X	X	1		3	X		X			6		X	X	/
											X				1			
6	46	7	13	8	14	6	8	10	3	3	2	21	6	6	3	1	2	22
									1						2			
											X		4				1	11
				1		1							X					
										X								
4	1	4	X	1	1	X	2		1	1	1	X	X			X	1	
X	4	2	X		X				4	1	1	1			2			
X	X	X														1	1	
												X			1			

but very low relative abundances of *C. reniforme*. There also appears to be a less gradual transition between modern and glacial environments at Site 613 (i.e., surface fauna goes right into *E. takayanagii* fauna, whereas at Site 612 there are some intermediate steps).

The *C. reniforme–E. excavatum* fauna occurs very rarely in modern sediments, but has been reported in glacial marine sediments from all over the North Atlantic (e.g., Canada [Cronin, 1979; Vilks and Rashid, 1976; Scott and Medioli, 1980; Scott et al., 1984]; Europe [Feyling-Hanssen, 1972]). Scott and Medioli (1980) and Vilks (1981) characterize the fauna as a "warm" ice-margin fauna (as opposed to present-day "cold" ice margins around Greenland, which have 100% agglutinated faunas). Most of the previous reports of this fauna are from shallow (less than 500 m) water, suggesting that the *Elphidium* specimens observed in slope sediments are transported. However, the work of Schafer and Cole (1982)

Table 1 (continued).

Depth of core (m)	0.3	0.5	1.00	1.33	1.77	2.33	2.88	3.33	4.33	4.48	4.83	5.08	5.33	6.13	6.60	7.13	7.63
Core-Section	1-1	1-1	1-1	1-1	1-2	1-2	1-2	1-3	1-3	1-3	2-1	2-1	2-1	2-1	2-2	2-2	2-2
No. of species	25	39	38	28	23	24	20	15	27	18	43	20	24	18	16	19	29
Total number of individuals/10 cm^3	7296	2912	3096	1034	536	508	590	1048	301	1468	4816	638	866	592	884	1028	339
Hoeglundina elegans				X													
Hyperammina sp.	X	X	X								X						
Islandiella teretis	6	2	8	7	47	9	5	13	3	5	5	8	9	5	12	9	1
Karreriella bradyi											X						
Lagena spp.	X	1	1	X	X	1	X		X	X	1				1		X
Lenticulina denticulifera																	
Lenticulina spp.		X							X								
Miliolinella subrotunda																	
Nodosaria sp.		X															
Nonion auriculata																	
N. barleeanum		X	X		X	X		3	X		X	X				X	
Nonion sp.																	
Nonionella atlantica				4			1		X								X
N. turigida	3	4	4	2	4	5	2	2		2	5	2	2	X	3	3	2
Nonionellina labradorica					X				1				X				
Oolina borealis																	
O. globosa																	
O. hexagona				X													
Ophthalmidium acutimargo																	
Oridorsalis umbonatus	X										X						
Patellina corrugata																	
Parafrondiculeria helenae																	
Planulina wuellerstorfi						X					X						
Psammosphaera fusca	1	X	X														
Pseudopolymorphina novangliae						X					X		X				
Pullenia bulloides			X														
Pyrgo williamsoni		X														X	X
Quinqueloculina agglutinans																	
Q. cultrata			X														
Q. seminulum			X	X	X	X		2	1	1		1	1			X	1
Q. stalkeri																	
Rectoglandulina torrida		X			X												
Recurvoides turbinatus																	1
Reophax guttifer	X										X						
R. scottii				X													
Robertinoides charlottensis																	
Rosalina columbiensis																	
Saccammina difflugiformis		X		1									X				
Sphaeroidina bulloides											X						
Spiroplectammina biformis				X													
Stetsonia horvathi	2	1	1	2						X	X						
Stilostomella bradyi																	
Textularia conica																	
T. earlandi		X										1					
T. torquata																	
Tosaia hanzawai		X									X						
Trifarina fluens			X			X			1		X	1	1	X			X
Triloculina arctica		X	X					2				1					
T. carinata									X				X			X	1
Trochammina bullata	5	3	1	X	X						1						
T. "inflata"																	
T. lobata																	X
T. nitida																	
T. ochracea									1								1
T. squamata																	
Uvigerina asperula																	
U. peregrina	25	21	8								13			X			X
Valvulinera laevigata		X	1								1						

and some of our own work on the Nova Scotia slope (Williamson et al., 1984; Schroeder, 1986) shows that *Elphidium excavatum* can be a dominating species at slope depths, but not with *C. reniforme* as a subdominant. Although there is little doubt that the *Elphidium–Cassidulina* fauna represents glacial bottom-water conditions, an interglacial planktonic foraminiferal fauna has been noted from these "glacial" samples at Site 612 (Poag and Low, this volume), so that the question remains open whether the *Elphidium–Cassidulina* fauna is in place.

The *E. takayanagii* fauna appears to have no modern or fossil correspondent. Leslie (1965) reports finding *E. takayanagii* in Hudson's Bay, but usually in abundances of less than 10%. Schafer and Cole (1978) also report the species in Chaleur Bay (New Brunswick) in cold, sa-

Table 1 (continued).

8.13	9.13	9.57	10.13	10.63	11.07	11.63	12.13	14.75	15.03	15.73	16.25	16.73	17.23	17.75	18.27	18.73	19.37	19.93	20.73
2-3	2-3	2-4	2-4	2-4	2-5	2-5	2-5	3-1	3-1	3-1	3-2	3-2	3-2	3-3	3-3	3-3	3-4	3-4	3-5
24	24	27	15	30	25	26	32	23	21	35	28	19	26	21	26	28	21	17	26
1112	265	836	1100	305	493	574	481	944	276	461	412	780	185	1016	1580	2040	2648	1488	5392
8	6	11	6	2	4	6	9	6	9	5	5	11	5	14	4	3	4	4	5
X		1			X	X				X	X	X	X		X	X			
X		X	1	X		X	X	X		X	1		X	X		X 2			1
										X			2						1
X	X	1 X		1 1	1 X	X	X	1	5	2	1 X		1	1	2 X	X 1	2 1	2 X	X
		X																	
		X	1							X									
X		X							X		1	2			X		X		X
X	X	1	1	1	X	2	X		4	3	2	2		X	1	X	1	1	1
X	1			1			X			X			X						
						X		X	X					X					
				1				X	1	X 2	1	1	2						X
	X			X			X		1	X	X		X			X			
X	1			2	X	X		X			X	3	1				X X	X	
	X	X 1	X	1 1	1		X 1	1	1 1	X X 2									
	X X																		
	1				X		X			X	X						X		X
	X			1	X	X	X	X		X						X			X

line water of the Gaspé Current. Both of these reported occurrences are in shallow (less than 100 m) water. It is quite clear that, at least in the upper Pleistocene (0.5–25 m at Site 613), this fauna characterized the glacial bottom water at 2400 m, as opposed to the *Elphidium–Cassidulina* fauna at 1400 m. It appears that bottom-water conditions were less affected by glacial conditions at 2400 m than at 1400 m, but the *E. takayanagii* component certainly does not denote typical interglacial conditions as we know them today. The *E. takayanagii* fauna may be the high-salinity, cold-water counterpart of the slightly lower salinity, more tolerant *E. excavatum–C. reniforme* fauna.

Phleger (1942) studied a series of short cores (1–3 m) from this region, taken in water depths of from 500 to 5000 m. In many of his cores, he observed the same

Table 1 (continued).

Depth of core (m)	21.23	21.73	24.03	24.83	25.33	25.87	26.83	27.37	28.33	28.83	29.33	29.83	30.35	30.83	31.33	31.83
Core-Section	3-5	3-5	4-1	4-1	4-1	4-2	4-2	4-3	4-3	4-4	4-4	4-4	4-5	4-5	4-5	4-6
No. of species	19	22	22	15	19	23	29	18	13	24	21	23	25	14	24	22
Total number of individuals/10 cm^3	1992	1092	3408	628	2148	3816	890	176	472	557	548	662	5760	2992	1908	1136
Hoeglundina elegans																
Hyperammina sp.																
Islandiella teretis	9	4	11	15	3	5	5	16	11	23	26	31	14	7	8	4
Karreriella bradyi																
Lagena spp.		1	1	X	X	X	X						X	1	X	X
Lenticulina denticulifera																
Lenticulina spp.					X										X	
Miliolinella subrotunda							X									
Nodosaria sp.																
Nonion auriculata																
N. barleeanum			1	1		X		X	X		5	4	6	4	X	4
Nonion sp.																
Nonionella atlantica			1		3	1	1		1	2			12	X	1	2
N. turigida	1	2	1			1	1	3		X	2	2	X	1	4	8
Nonionellina labradorica	2	1		2		1	1	2				1			X	
Oolina borealis																
O. globosa																
O. hexagona					X											
Ophthalmidium acutimargo													X			
Oridorsalis umbonatus																
Patellina corrugata																
Parafrondiculeria helenae																
Planulina wuellerstorfi																
Psammosphaera fusca																
Pseudopolymorphina novangliae						X										
Pullenia bulloides						X	X			X						
Pyrgo williamsoni							X	X		X		X			X	
Quinqueloculina agglutinans			X				1					X				
Q. cultrata																
Q. seminulum	1	1	1			X	9	3	2	2	5	5	X		2	7
Q. stalkeri																
Rectoglandulina torrida																
Recurvoides turbinatus																
Reophax guttifer																
R. scottii																
Robertinoides charlottensis																
Rosalina columbiensis		X														
Saccammina difflugiformis																
Sphaeroidina bulloides																
Spiroplectammina biformis						X										
Stetsonia horvathi	X	X					3		1		1	1	X		11	1
Stilostomella bradyi																
Textularia conica																
T. earlandi																
T. torquata																
Tosaia hanzawai																
Trifarina fluens																
Triloculina arctica	X						X				X					
T. carinata			X					X								X
Trochammina bullata																
T. "inflata"																
T. lobata																
T. nitida																
T. ochracea		X				X										
T. squamata							X								X	
Uvigerina asperula																
U. peregrina										X						
Valvulinera laevigata							X									

rapid transition from a *Uvigerina* fauna to an *Elphidium* fauna in the upper 1 m. But he did not report subsurface faunas resembling the *E. takayanagii* fauna. His work does show, though, that the Holocene section is thin over a wide region, not just at our two Leg 95 sites.

In the lower Pleistocene sections of Sites 612 and 613, where we cannot compare between sites, there are some significant events as well. At Site 612, *Epistominella exigua* becomes common below 15 m, and this coincides with a general increase in total populations from 500 to over 2000/10 cm^3. *E. exigua* has been shown to be an indicator of North Atlantic Deep Water (NADW) and the Western Boundary Undercurrent (WBU) (e.g., Schnitker, 1979; Schafer and Cole, 1982). The WBU presently

Table 1 (continued).

32.33	32.83	33.63	34.10	34.60	34.93	35.37	35.93	36.43	37.41	37.93	38.37	39.43	41.93	43.43	45.93	53.43	54.93	56.43
4-6	4-6	5-1	5-1	5-1	5-1	5-2	5-2	5-2	5-3	5-3	5-4	5-4	6-1	6-2	7-1	8-1	8-2	8-3
22	17	26	27	23	31	20	21	18	27	25	25	29	34	9	31	27	38	7
1580	4424	1424	1508	936	890	812	1068	496	480	473	452	672	2162	16	129	2208	1776	9
																2		
18	1	6	22	12	5	7	15	3	1			4	X		2	1		
	X	X	X							1		X		6	2	1	1	
																	X	
								1	X		1							
11		4						14					2		1	1	6	11
	X	1	X		X								X					
5		3	1	2	1	1	4		2	1	X	2	2		1	X	X	
2					X	X	1											
						X					X			6			X	
										1			X					
					X												X	11
										X			X			X	1	
															1			
					X								X				X	
X		2		X					X								3	
X				X													X	
					X										1			
1	5	1	2	1	X	9	5		X			2				X		
					X													
									2		5					X		
	X																	
			X															
X		X											X					
									5	8	29		X		6	6	14	
										X		X	X					
				X														
					X	X	X											
					X							1						
																	X	
															1			
	X													6				
									47		34					51	2	
								19	4	60	5		11	25	1	5	11	
			X	X					X		1	X	X		1	X	X	

occupies a depth range below 2500 m, well below the water depth at Site 612. Ledbetter and Balsam (1985) report that the axis of the WBU has varied by as much as 500 m in the last 25 kyr. but has not been above about 3500 m. If *E. exigua* does indicate the presence of the WBU, then the WBU was significantly shallower in previous interglacial cycles. It is not likely that the WBU would have been present at Site 612 and absent at Site 613 in the same time interval. Hence, the absence of any *E. exigua* fauna in Site 613 samples indicates that the time-equivalent interval of the 15 to 35 m section at Site 612 was not sampled or was missing at Site 613. There is overlap at these hole depths between the two sites (we have 19–29 m in Hole 613), so obviously sedimentation

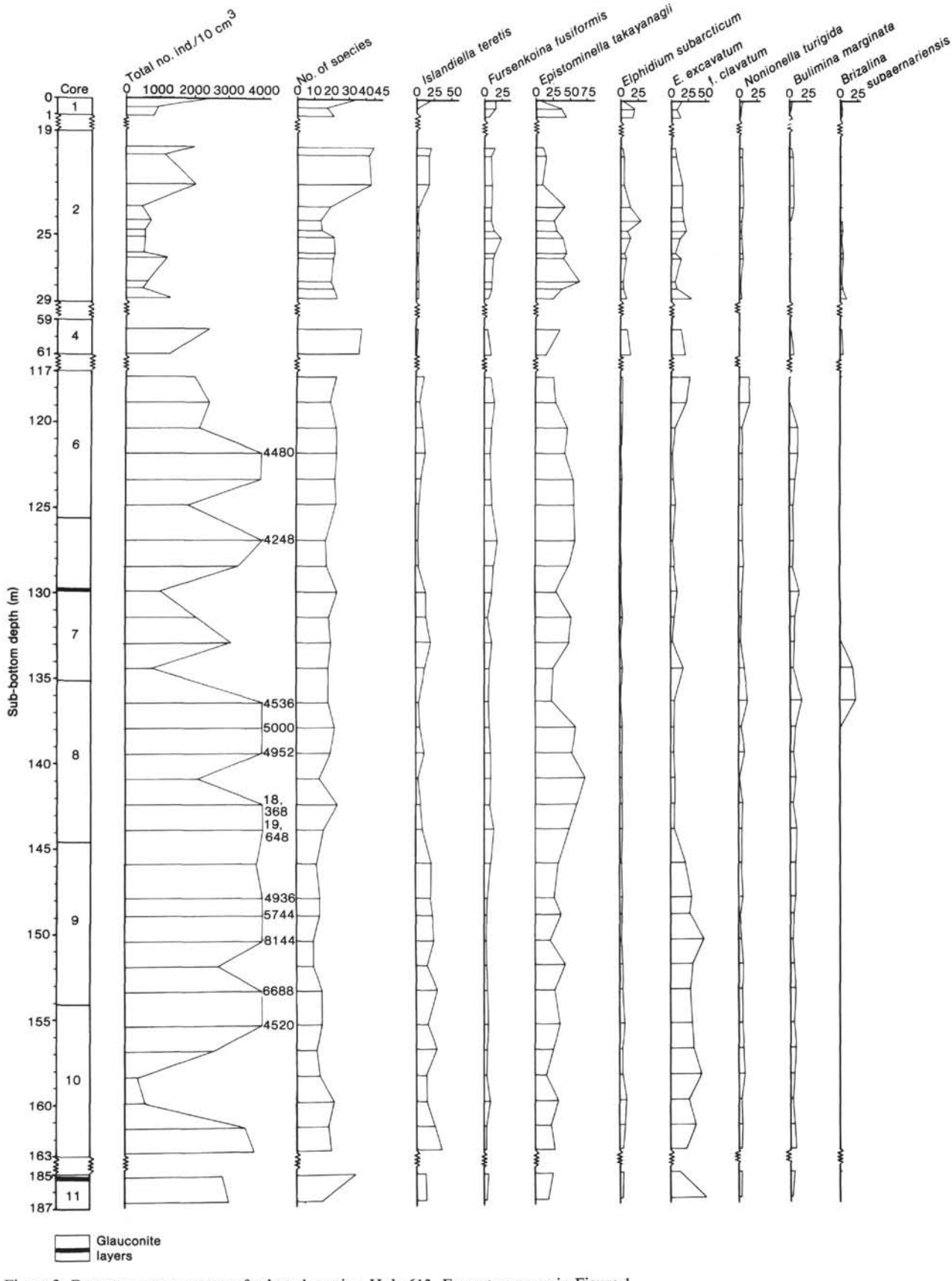

Figure 2. Percentage occurrences of selected species, Hole 613. Format same as in Figure 1.

rates were quite different between sites, and/or there are hiatuses (seismics at Site 613 show several hiatuses in the Pleistocene).

It is also of note that the surface fauna (i.e., present-day interglacial) does not recur downcore at Site 612 but does (19–22 m) at Site 613. In comparing the two sequences, it appears that major sections are missing from both sites, and without some absolute dating controls it will be very difficult to determine exactly how to correlate the Pleistocene records from the two sites.

The only characteristic common to both sites appears at the bases of both sections, where *Elphidium* faunas do occur with glauconite layers and reworked Tertiary–Cretaceous microfossils. But the basal faunas differ in many aspects (no *Uvigerina* at Site 613, low *Islandiella teretis* at Site 612, etc.), and it is unclear whether these sections are correlatable.

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APPENDIX
Systematic Taxonomy

Many of the most common species are illustrated in Plates 1 and 2. All species listed in Tables 1 and 2 are listed alphabetically here with their original references. Generic names are in accordance with Loeblich and Tappan (1964).

***Adercotryma glomerata* (Brady)**

Lituola glomerata Brady, 1878, p. 433, pl. 20, figs. 1a–c.

***Ammobaculites agglutinans* (d'Orbigny)**

Spirolina agglutinans d'Orbigny, 1846, p. 137, pl. 7, figs. 10–12.

***Ammonia beccarii* (Linné)**

Nautilus beccarii Linné, 1758, p. 10.

***Ammotium cassis* (Parker)**

Lituola cassis Parker, in Dawson, 1870, p. 177, 180, fig. 3.

***Astracolus crepidulus* (Fichtel and Moll)**

Nautilus crepidula Fichtel and Moll, 1798, p. 107, pl. 19, figs. g–i.

***Astrononion gallowayi* Loeblich and Tappan**

Astrononion gallowayi Loeblich and Tappan, 1953, p. 90, pl. 17, figs. 4–7.

***Bolivina decussata* Brady**

Bolivina decussata Brady, 1881, p. 58.

***Bolivina pseudoplicata* Heron-Allen and Earland**

Bolivina pseudoplicata Heron-Allen and Earland, 1930, p. 81, pl. 3, figs. 36–40.

***Bolivina subspinscens* Cushman**

Bolivina subspinscens Cushman, 1922a, p. 48, pl. 7, fig. 5.

***Brizalina bradyi* (Asano)**
(Plate 1, Fig. 8)

Bolivina bradyi Asano, 1938, p. 603.

***Brizalina pseudopunctata* (Hoeglund)**
(Plate 1, Fig. 9)

Bolivina pseudopunctata Hoeglund, 1947, p. 273, pl. 24, fig. 5, pl. 32, figs. 23, 24.

***Brizalina spathulata* (Williamson)**
(Plate 1, Fig. 10)

Textularia variabilis Williamson var. *spathulata* Williamson, 1858, p. 76, pl. 6, figs. 164, 165.

***Brizalina subaenariensis* (Cushman)**
(Plate 1, Fig. 11)

Bolivina subaenariensis Cushman, 1922a, p. 46, pl. 7, fig. 6.

***Buccella frigida* (Cushman)**

Pulvinulina frigida Cushman, 1922b, p. 144.

***Bulimina aculeata* d'Orbigny**
(Plate 1, Fig. 3)

Bulimina aculeata d'Orbigny, 1826, p. 269, no. 7.

***Bulimina exilis* Brady**

Bulimina elegans d'Orbigny var. *exilis* Brady, 1884, p. 399, pl. 50, figs. 5, 6.

***Bulimina gibba* Fornasini**

Bulimina gibba Fornasini, Barker, 1960, p. 102, pl. 50, figs. 1–4.

***Bulimina marginata* d'Orbigny**

Bulimina marginata d'Orbigny, 1826, p. 269, pl. 12, figs. 10, 12.

***Bulimina striata* d'Orbigny**
(Plate 1, Fig. 4)

Bulimina striata d'Orbigny, Barker, 1960, p. 104, pl. 51, figs. 10, 12.

***Buliminella elegantissima* (d'Orbigny)**

Bulimina elegantissima d'Orbigny, 1839, p. 51, pl. 7, figs. 13, 14.

***Cassidulina laevigata* d'Orbigny**
(Plate 2, Fig. 10)

Cassidulina laevigata d'Orbigny, 1826, p. 282, pl. 15, figs. 4, 5.

***Cassidulina reniforme* Norvang**
(Plate 2, Figs. 11, 12)

Cassidulina crassa d'Orbigny var. *reniforme* Norvang, 1945, p. 41, text figs. 6c–h.

***Chilostomella oolina* Schwager**

Chilostomella oolina Schwager, 1877, p. 10, pl. 1, fig. 16.

***Cibicides lobatulus* (Walker and Jacob)**

Nautilus lobatulus Walker and Jacob in Kanmacher, 1798, p. 642. pl. 14, fig. 36.

***Cibicides pseudoungerianus* (Cushman)**

Truncatulina pseudoungerianus Cushman, 1922c, p. 97, pl. 20, fig. 9.

***Cibicides robertsonianus* (Brady)**

Truncatulina robertsoniana Brady, 1881, p. 65.

***Cribrostomoides canariensis* (d'Orbigny)**

Nonionina canariensis d'Orbigny, 1839, p. 128, pl. 2, fig. 33.

***Cyclogyra involvens* (Reuss)**

Operculina involvens Reuss, 1850, p. 370, pl. 14, fig. 20.

***Dentalina hirsuta* (d'Orbigny)**

Nodosaria hirsuta d'Orbigny, 1826, p. 252, no. 7.

***Dentalina ittae* Loeblich and Tappan**

Dentalina ittae Loeblich and Tappan, 1953, p. 56, pl. 10, figs. 10–12.

***Dentalina subsoluta* (Cushman)**
(Plate 1, Fig. 14)

Nodosaria subsoluta Cushman, 1923, p. 74.

***Dentalina subemaciata* Parr**

Dentalina subemaciata Parr, 1950, p. 329, pl. 12, fig. 1.

***Discorbis* cf. *nitida* (Williamson)**

Rotalina nitida Williamson, 1858, p. 54, pl. 4, figs. 106–108.

***Eggerella advena* (Cushman)**

Verneuilina advena Cushman, 1921, p. 141.

***Elphidium excavatum* (Terquem) formae**
(Plate 1, Fig. 19)

For complete taxonomic review of this species and its formae we refer to Miller et al., 1982.

***Elphidium subarcticum* Cushman**
(Plate 1, Fig. 18)

Elphidium subarcticum Cushman, 1944, p. 27, pl. 3, figs. 34, 35.

***Eoeponides pulchella* (Parker)**

Pninaella? pulchella Parker, 1952b, p. 420, pl. 6, figs. 18–20.

***Eponides bradyi* Earland**
(Plate 2, Figs. 3, 4)

Eponides bradyi Earland, 1934, p. 187, pl. 8, figs. 36–38.

***Eponides tumidulus* (Brady)**

Truncatulina tumidula Brady, 1884, p. 666, pl. 95, figs. 8a–d.

***Epistominella exigua* (Brady)**
(Plate 2, Figs. 8, 9)

Pulvinulina exigua Brady, 1884, p. 696, pl. 103, figs. 13, 14.

***Epistominella umbonifera* (Cushman)**

Pulvinulina umbonifera Cushman, 1933, p. 90, pl. 9, figs. 9a–c.

***Epistominella takayanagii* Iwasa**
(Plate 2, Figs. 5–7)

Epistominella takayanagii Iwasa, 1955, pp. 16, 17, text figs. 4a–c.

***Fursenkoina fusiformis* (Williamson)**
(Plate 1, Figs. 12, 13)

Bulimina pupoides d'Orbigny var. *fusiformis* Williamson, 1858, p. 64, pl. 5, figs. 129, 130.

***Gavelinopsis lobatulus* (Parr)**
(Plate 2, Figs. 16, 17)

Discorbis lobatulus Parr, 1950, p. 354.

***Gavelinopsis translucens* (Phleger and Parker)**
(Plate 2, Figs. 14, 15)

"Rotalia" translucens Phleger and Parker, 1951, p. 24, pl. 12, figs. 11a, b, 12a, b.

***Glabratella wrightii* (Brady)**

Discorbina wrightii Brady, 1881, p. 413, pl. 21, fig. 6.

***Globobulimina auriculata* (Bailey)**

Bulimina auriculata Bailey, 1851, p. 12, pl. 1, figs. 25–27.

***Guembelitria* sp.?**
(Plate 1, Fig. 17)

***Gyroidina soldanii* (d'Orbigny)**

Rotalia soldanii d'Orbigny, 1826, p. 278, fig. 36.

***Haynesina orbiculare* (Brady)**

Nonionia orbiculare Brady, 1881, p. 415, pl. 21, fig. 5.

***Heterohelix* sp.?**
(Plate 1, Fig. 16)

***Hoeglundina elegans* (d'Orbigny)**

Rotalia elegans d'Orbigny, 1826, p. 276, no. 54.

***Islandiella teretis* (Tappan)**
(Plate 2, Fig. 13)

Cassidulina teretis Tappan, 1951, p. 7, pl. 1, figs. 30a–c.
This species also includes *I. helenae* and *I. norcrossi* of other authors, and grades into *Cassidulina laevigata*.

***Karreriella bradyi* (Cushman)**

Gaudryina bradyi Cushman, 1911, p. 67, fig. 107.

***Lenticulina denticulifera* Cushman**

Lenticulina denticulifera Cushman, 1913, p. 75.

***Lenticulina gibba* (d'Orbigny)**

Cristellaria gibba d'Orbigny, 1839, p. 63, pl. 7, figs. 20, 21.

***Miliolinella subrotunda* (Montagu)**

Vermiculum subrotundum Montagu, 1803, p. 521.

***Nonion barleeanum* (Williamson)**

Nonionina barleeana Williamson, 1858, p. 32, pl. 4, figs. 68, 69.

***Nonion auriculata*(Heron-Allen and Earland)**

Nonionella auriculata Heron-Allen and Earland, 1930, p. 192, pl. 5, figs. 68–70.

***Nonionella atlantica* Cushman**

Nonionella atlantica Cushman, 1947, p. 90, pl. 20, figs. 4, 5.

***Nonionella turigida* (Williamson)**
(Plate 1, Figs. 21, 22)

Rotalina turigida Williamson, 1858, p. 50, pl. 4, figs. 95–97.

***Nonionellina labradorica* (Dawson)**

Nonionina labradorica Dawson, 1860, p. 191, fig. 4.

***Oolina borealis* Loeblich and Tappan**

Oolina borealis Loeblich and Tappan, 1954, p. 384, no. 12.

***Oolina globosa* Montagu**

Oolina globosum Montagu, 1803, p. 523.

***Oolina hexagona* (Williamson)**

Entosolenina squamosa (Montagu) var. *hexagona* Williamson, 1848, p. 20, pl. 2, fig. 23.

***Opthalmidium acutimargo* (Brady)**

Spiroloculina acutimargo Brady, 1884, p. 154, pl. 10, figs. 12–15.

***Oridorsalis umbonatus* (Reuss)**

Rotalina umbonata Reuss, 1851, p. 75, pl. 5, figs. 35a–c.

***Patellina corrugata* Williamson**

Patellina corrugata Williamson, 1858, p. 46, pl. 3, figs. 86–89.

***Parafrondicularia helenae* Chapman**

Parafrondicularia helenae Chapman, 1941, pp. 154, 170, pl. 9, figs. 5a, b.

***Planulina wuellerstorfi* (Schwager)**

Anomalina wuellerstorfi Schwager, 1866, p. 258, pl. 7, figs. 105, 107.

***Psammosphaera fusca* Schulze**

Psammosphaera fusca Schulze, 1875, p. 113, pl. 2, fig. 8.

***Pseudopolymorphina novangliae* (Cushman)**

Polymorphina lactea (Walker and Jacob) var. *novangliae* Cushman, 1923, p. 146, pl. 39, figs. 6–8.

***Pullenia bulloides* (d'Orbigny)**

Nonionina bulloides d'Orbigny, 1826, p. 293.

***Pullenia subcarinata* (d'Orbigny)**
(Plate 1, Fig. 20)

Nonionina subcarinata d'Orbigny, 1839, p. 28, pl. 5, figs. 23, 24.
P. quinqueloba is a junior synonym of this species.

***Pyrgo williamsoni* (Silvestri)**

Biloculina williamsoni Silvestri, 1923, p. 73.

***Quinqueloculina agglutinans* d'Orbigny**

Quinqueloculina agglutinans d'Orbigny, 1839, p. 168, pl. 12, figs. 11–13.

***Quinqueloculina cultrata* (Brady)**

Miliolina cultrata Brady, 1881, p. 45.

***Quinqueloculina seminulum* (Linné)**

Serpula seminulum Linné, 1758, p. 786.

***Quinqueloculina stalkeri* Loeblich and Tappan**

Quinqueloculina stalkeri Loeblich and Tappan, 1953, p. 40, pl. 5, figs. 5–9.

***Rectoglandulina torrida* (Cushman)**

Nodosaria (Glandulina) laevigata var. *torrida* Cushman, 1923, p. 65.

***Recurvoides turbinatus* (Brady)**

Haplophragmium turbinatum Brady, 1881, p. 50.

***Reophax arctica* Brady**

Reophax arctica Brady, 1881, p. 405, pl. 21, figs. 2a, b.

***Reophax guttifer* (Brady)**

Lituola guttifer Brady, 1881, p. 49.

***Reophax scottii* Chaster**

Reophax scottii Chaster, 1892, p. 57, pl. 1, fig. 1.

***Robertinoides charlottensis* (Cushman)**

Cassidulina charlottensis Cushman, 1925, p. 41, pl. 6, figs. 6, 7.

***Rosalina columbiensis* (Cushman)**

Discorbis columbiensis Cushman, 1925, p. 43, pl. 6, fig. 13.

***Saccammina difflugiformis* (Brady)**

Reophax difflugiformis Brady, 1879, p. 51, pl. 4, figs. 3a, b.

***Sphaeroidina bulloides* d'Orbigny**

Sphaeroidina bulloides d'Orbigny, 1826, p. 267, no. 1.

***Spiroplectammina biformis* (Parker and Jones)**

Textularia agglutinans d'Orbigny var. *biformis* Parker and Jones, 1865, p. 370, pl. 15, figs. 23, 24.

***Stetsonia horvathi* Green**
(Plate 2, Figs. 1, 2)

Stetsonia horvathi Green, 1960, p. 72, pl. 1, figs. 6a, b.

***Stilostomella bradyi* (Cushman)**
(Plate 1, Fig. 15)

Nodogenerina bradyi Cushman, 1927, p. 79.

***Textularia conica* d'Orbigny**

Textularia conica d'Orbigny, 1839, p. 135, pl. 1, figs. 19, 20.

***Textularia earlandi* Parker**

Textularia earlandi Parker, 1952a, p. 458 (footnote).

***Textularia torquata* Parker**

Textularia torquata Parker, 1952b, p. 403, pl. 3, figs. 9–11.

***Tosaia hanzawai* Takayanagi**

Tosaia hanzawai Takayanagi, 1953, p. 30, pl. 40, fig. 7.

***Trifarina fluens* (Todd)**

Anglogerina fluens Todd in Cushman and Todd, 1947, p. 67, pl. 16, figs. 6, 7.

***Triloculina arctica* (Cushman)**

Quinqueloculina arctica Cushman, 1933, p. 2, pl. 1, figs. 3a–c.

***Triloculina trihedra* Loeblich and Tappan**

Triloculina trihedra Loeblich and Tappan, 1953, p. 45, pl. 4, fig. 10.

***Trochammina bullata* Takayanagi**
(Plate 1, Figs. 1, 2)

Trochammina bullata Takayanagi, 1960, p. 85, pl. 4, figs. 1a–c.

Trochammina "inflata"?

Trochammina inflata (Montagu), Williamson, 1983, p. 212, pl. 2, figs. 12, 13.

This species outwardly appears similar to Montagu's, except that *T. inflata* is a marsh species. The specimens observed here, and those of Williamson, lack the characteristic inner lining of the marsh forms. Cole (1981) also observed this form.

***Trochammina lobata* Cushman**

Trochammina lobata Cushman, 1944, p. 18, pl. 2, fig. 10.

***Trochammina nitida* Brady**

Trochammina nitida Brady, 1881, p. 52.

***Trochammina ochracea* (Williamson)**

Rotalina ochracea Williamson, 1858, p. 55, pl. 4, fig. 112, pl. 5, fig. 113.

***Trochammina squamata* Parker and Jones**

Trochammina squamata Parker and Jones, 1865, p. 407, pl. 15, figs. 30, 31a–c.

***Uvigerina asperula* Czjzek**
(Plate 1, Fig. 5)

Uvigerina asperula Czjzek, 1848, p. 146, pl. 13, figs. 14, 15.

***Uvigerina peregrina* Cushman**
(Plate 1, figs. 6, 7)

Uvigerina peregrina Cushman, 1923, p. 166, pl. 42, figs. 7–10.

***Valvulinera laevigata* Phleger and Parker**

Valvulinera laevigata Phleger and Parker, 1951, p. 28, pl. 13, figs. 11, 12.

Table 2. Percentage occurrences of all benthic foraminiferal species observed in the Quaternary samples from Hole 613.

Depth of core (m)	0.2	0.52	1.02	19.82	20.32	22.02	23.32	24.14	24.72	25.08	26.02	26.32	27.72	28.07	28.74	59.51	61.01
Core-Section	1-1	1-1	1-1	2-1	2-1	2-2	2-3	2-3	2-4	2-4	2-5	2-5	2-6	2-6	2-6	4-1	4-2
No. of species	34	17	21	45	42	43	19	14	14	21	22	21	20	21	23	38	36
Total number of individuals/10 cm^3	2344	900	790	1996	1076	2120	466	696	556	532	518	1172	604	478	1280	2384	1300
Astracolus crepidulus																	
Astrononion gallowayi	1			1							X						
Bolivina decussata				2	X						X						X
B. pseudoplicata					1		X										
B. subspinescens						1							X				
Brizalina bradyi				X													
B. pseudopunctata	4	1	X	3	1	2	X			X		X	X	X		1	1
B. spathulata	2	X	1	2	2	1	X		4	X	1	1			X		X
B. subaenariensis		2	X		X	X	X	X	1	X	1	1	X	1	8	1	2
Buccella frigida	1	2	2	1	1	2	4	3	5	2	2	3	1	X	2	1	1
Bulimina aculeata	1			X	X	1										X	
B. exilis						X											
B. marginata	1			1	3	3				X	X	X					3
B. striata		X		2	3	2		X		X	X	X	1	1	1	X	
Buliminella elegantissima			X	X							X						
Buliminoides sp. (T)																	
Cassidulina laevigata							X									X	1
C. reniforme	11	9	6	9	10	10	4	3	6	2	10	5	4	16	6	7	7
Cibicides lobatulus	1	X	X	X		1						X		X	1	X	X
C. pseudoungerianus						X											
Dentalina hirsuta																X	
D. subsoluta	X								1				X			X	X
D. subemaciata																	
Dentalina spp.					X												
Discorbis cf. *nitida*			1		X	X	X			1	2	X	1	1	1	1	2
Eggerella advena			X										X				
Elphidium excavatum f. *clavata*	14	7	12	5	6	14	14	17	21	11	5	13	5	7	29	15	20
E. excavatum f. *excavatum*		X	X												X	2	2
E. excavatum f. *lidoensis*																X	2
E. excavatum f. *magna*																	
E. excavatum f. *selseyensis*																X	1
E. subarcticum	2	19	17	2	3	3	12	30	9	13	5	8	3	3	7	9	16
Eoeponides pulchella	X														1	X	X
Eponides bradyi	X			4	1	1							X	1			1
Epistominella exigua	X	X	1	5	5	2	X				X	X	X	8	1	X	
E. takayanagii	4	37	45	10	14	8	43	26	31	40	44	41	64	38	25	36	15
E. umbonifera																	
Fissurina spp.	1			1	X	X	X			X	X	X	X		X	1	1
Frondiculeria sp.						X											
Fursenkoina fusiformis	14	15	5	15	9	10	10	8	12	24	14	12	11	10	4	5	10
Gavelinopsis lobatulus						X											
G. translucens	X	4	4	X	1		3	6	6	2	7	7	6	7	4	5	5
Glabratella wrightii					X	X										X	X
Glandulina sp.								X			X						
Globigerinoides sp. (T)																	

Note: X = less than 1%. Tertiary and Cretaceous species are indicated by T or K next to the species names.
[a] *Haynesina depressulum* should be *Pullenia subcarinata*.

Table 2 (continued).

117.32	118.81	120.31	121.81	123.31	124.81	126.91	128.41	129.91	131.41	132.91	134.91	136.41	137.91	139.41	140.91	142.41	143.91
6-1	6-2	6-3	6-4	6-5	6-6	7-1	7-2	7-3	7-4	7-5	7-6	8-1	8-2	8-3	8-4	8-5	8-6
23	20	23	23	22	23	17	18	24	19	20	19	19	22	20	13	24	16
2016	2468	2148	4480	3936	1796	4248	3280	1004	2040	3088	750	4536	5000	4952	2032	18368	19648
												1		X		X	
X	X		X		X		1	X	X	1		X		X		X	X
		X	X	X	1	X	1	1	X	X		1		X	1	X	X
X								2			17	24	X				
X	1	X						X	X				X				X
X								X									
X	2	11	12	6	4	4	4	14	6	6	4	18	8	5	9	5	10
								1			X						
		X	X			X			1	X							
X	2	6	6	6	4	3	6	5	7	2	4	2	5	4	X	3	5
			1	1	4	1	1	X	2	1		1	3	1	X	1	1
		X	X	X	X								X		X	X	
28	22	4	1	2	6	2	5	9	3	1	18	4	3	3	4	5	3
X					X					X			X			X	
				X	X												
1	1							X				X					
X											X						
2	2	1	X	1	1		1	X	1	X	1	X	1	1	X	2	1
			X											X			
														X			
27	29	48	43	54	58	61	50	30	53	51	26	24	60	53	73	61	50
X	1	1	1	2	1	X	X	1	1	1	1	X	1	1	X	1	X
														X			
8	14	10	9	10	11	19	15	11	5	10	6	6	7	9	8	6	14
X	2	X	1	1	X	X	1	X	X	X	X		X	X		X	
	X																

Table 2 (continued).

Depth of core (m)	145.93	147.43	148.93	150.43	151.93	153.43	155.43	156.93	158.43	159.43	161.43	162.93	185.23	186.73
Core-Section	9-1	9-2	9-3	9-4	9-5	9-6	10-1	10-2	10-3	10-4	10-5	10-6	11-1	11-2
No. of species	12	14	14	10	10	15	15	12	14	22	19	20	35	15
Total number of individuals/10 cm^3	3824	4936	5744	8144	2176	6688	4520	2584	332	567	3484	3840	2828	2984
Astracolus crepidulus													X	
Astrononion gallowayi									1		X			
Bolivina decussata														
B. pseudoplicata												X	X	
B. subspinescens														
Brizalina bradyi						X				X			1	
B. pseudopunctata		X								X	X	X	1	
B. spathulata	X				X	X				X		X	2	
B. subaenariensis													1	
Buccella frigida	X		X							2	X	X	X	2
Bulimina aculeata														
B. exilis														
B. marginata	7	6	4	3	3	6	3	7	5	2	4	6	5	2
B. striata													2	
Buliminella elegantissima										X	X			X
Buliminoides sp. (T)													1	
Cassidulina laevigata														
C. reniforme	2	1	X	X		X	1	X	2	X	X	X	1	X
Cibicides lobatulus	X											X	X	
C. pseudoungerianus														
Dentalina hirsuta														
D. subsoluta													2	
D. subemaciata													X	
Dentalina spp.														
Discorbis cf. *nitida*												X		
Eggerella advena														
Elphidium excavatum f. *clavata*	21	30	27	44	30	26	30	32	42	24	34	21	11	51
E. excavatum f. *excavatum*							X							
E. excavatum f. *lidoensis*														
E. excavatum f. *magna*														
E. excavatum f. *selseyensis*														
E. subarcticum	1	2	1	1	2	1	5	1	2	6	6	2	2	3
Eoeponides pulchella										X				X
Eponides bradyi							X						1	
Epistominella exigua														
E. takayanagii	33	28	37	21	42	27	35	25	13	33	23	27	24	18
E. umbonifera								X						
Fissurina spp.		X	1	X		X	X			1	X	X/	X	
Frondiculeria sp.														
Fursenkoina fusiformis	8	4	2	2	2	3	4	2	2	8	1	2	3	2
Gavelinopsis lobatulus														
G. translucens		X	X			X	X	1		1	X	1		1
Glabratella wrightii														
Glandulina sp.													6	
Globigerinoides sp. (T)													6	

Table 2 (continued).

Depth of core (m)	0.2	0.52	1.02	19.82	20.32	22.02	23.32	24.14	24.72	25.08	26.02	26.32	27.72	28.07	28.74	59.51	61.01
Core-Section	1-1	1-1	1-1	2-1	2-1	2-2	2-3	2-3	2-4	2-4	2-5	2-5	2-6	2-6	2-6	4-1	4-2
No. of species	34	17	21	45	42	43	19	14	14	21	22	21	20	21	23	38	36
Total number of individuals/10 cm^3	2344	900	790	1996	1076	2120	466	696	556	532	518	1172	604	478	1280	2384	1300
Globobulimina auriculata	3			X	1	X									2	X	X
Guembelitria sp. (T-K)														X		X	X
Gyroidina soldanii	X			1	X	X	X		1		X			X			1
Haynesina depressulum[a]	X	X		3	3	2										1	
Heterohelix sp. (K)			1	X	1	X			1		2	1		1	X	7	4
Hoeglundina elegans				X	X	X											
Islandiella teretis	18	X	X	19	18	17	2	X	2	1	1	X	1	1	1	2	X
Karreriella bradyi				X	X												
Lagena spp.	X			X	1	X						X				X	
Lenticulina gibba																	
Lenticulina spp.																	
Miliolinella subrotunda																X	
Nodosaria sp.																	
Nonion barleeanum				X	1	X											
Nonionella atlantica	X			1	1												
N. turigida	4	2	X	3	3	4	5	3	2	2	3	5	1	1	3	X	
Nonionellina labradorica				X	X	X	X								2		X
Oolina borealis				X													
Oolina spp.																	
Oridorsalis umbonatus				X	X												
Patellina corrugata	X																
Planulina wuellerstorfi	X			X						X							
Pseudopolymorphina novangliae								X									X
P. liqua																	
Pullenia bulloides				1	1	X										X	
Pyrgo williamsoni	X		X	X		X											
Quinqueloculina seminulum	5		2	X		5		1					X	1		X	X
Q. stalkeri					X												
Rectoglandulina torrida																	
Reophax arctica																	
Reusella sp.																X	
Robertinoides charlottensis																	X
Rosalina columbiensis				X	X	X											
Sphaeroidina bulloides				X		X											
Spirillina vivipara																	X
Stetsonia horvathi	X			X													
Textularia conica	X					1											
T. earlandi										X							
T. torquata																	
Tosaia hanzawai	X			1	X	X											
Trifarina fluens				1	X	X				X							1
Triloculina sp.																X	
Trochammina bullata					X					X							
T. macrescens															1		
Uvigerina asperula																X	
U. peregrina	3			2	2	4				X		X		X	X	X	X
Valvulinera laevigata	4			2	X	1										1	1

Table 2 (continued).

Depth of core (m)	117.32	118.81	120.31	121.81	123.31	124.81	126.91	128.41	129.91	131.41	132.91	134.91	136.41	137.91
Core-Section	6-1	6-2	6-3	6-4	6-5	6-6	7-1	7-2	7-3	7-4	7-5	7-6	8-1	8-2
No. of species	23	20	23	23	22	23	17	18	24	19	20	19	19	22
Total number of individuals/10 cm^3	2016	2468	2148	4480	3936	1796	4248	3280	1004	2040	3088	750	4536	5000
Globobulimina auriculata	X	X	1		1		X	X		X	X	X	1	X
Guembelitria sp. (T-K)														
Gyroidina soldanii			X											
Haynesina depressulum[a]														
Heterohelix sp. (K)							X							
Hoeglundina elegans														
Islandiella teretis	11	3	9	13	6	3	2	3	14	15	22	11	3	5
Karreriella bradyi														
Lagena spp.		X	1	X	X	X	X	X		X	X	X		X
Lenticulina gibba													X	X
Lenticulina spp.	X		X	X	X									
Miliolinella subrotunda														
Nodosaria sp.						X								
Nonion barleeanum									X		X			
Nonionella atlantica														
N. turigida	15	14	3	6	5	4	5	7	4	3	2	7	12	2
Nonionellina labradorica														
Oolina borealis														
Oolina spp.				X										
Oridorsalis umbonatus														
Patellina corrugata		X												
Planulina wuellerstorfi							X				X			
Pseudopolymorphina novangliae	X		1	X	X									X
P. liqua				X										
Pullenia bulloides									1					
Pyrgo williamsoni	1	2			X			1	X			X		X
Quinqueloculina seminulum	3	2	1		1	X		3	2			1		X
Q. stalkeri														
Rectoglandulina torrida	X	X		X		X						X		
Reophax arctica														
Reusella sp.														
Robertinoides charlottiensis														
Rosalina columbiensis			X		X	X								
Sphaeroidina bulloides														
Spirillina vivipara														
Stetsonia horvathi														
Textularia conica														
T. earlandi														
T. torquata			X											
Tosaia hanzawai														
Trifarina fluens			X	1	X		X	X	2	X	X	X	X	2
Triloculina sp.														
Trochammina bullata														
T. macrescens														
Uvigerina asperula														
U. peregrina						X			X	X			X	
Valvulinera laevigata														

Table 2 (continued).

139.41	140.91	142.41	143.91	145.93	147.43	148.93	150.43	151.93	153.43	155.43	156.93	158.43	159.43	161.43	162.93	185.23	186.73
8-3	8-4	8-5	8-6	9-1	9-2	9-3	9-4	9-5	9-6	10-1	10-2	10-3	10-4	10-5	10-6	11-1	11-2
20	13	24	16	12	14	14	10	10	15	15	12	14	22	19	20	35	15
4952	2032	18368	19648	3824	4936	5744	8144	2176	6688	4520	2584	332	567	3484	3840	2828	2984
	X	X						X	X			1	X X	X	X	X 2 X 14	
12	1	5	10	24	21	24	26	16	31	17	29	16	14	26	36	14	15
1		X	X						X	X	X		1		X		1
										X						X 1	
7	X	5	3	2	4	1 X	2	4	3	3 X	4	7 3	2 X	3 X X	1	1 X	3
					X					X		1			X	X	
X		X X X	X	X	X X	1	X				X	1 4	1 X	X	1 X	X 1	
																	X
																X	
		X	1			X											
		X							X							1	

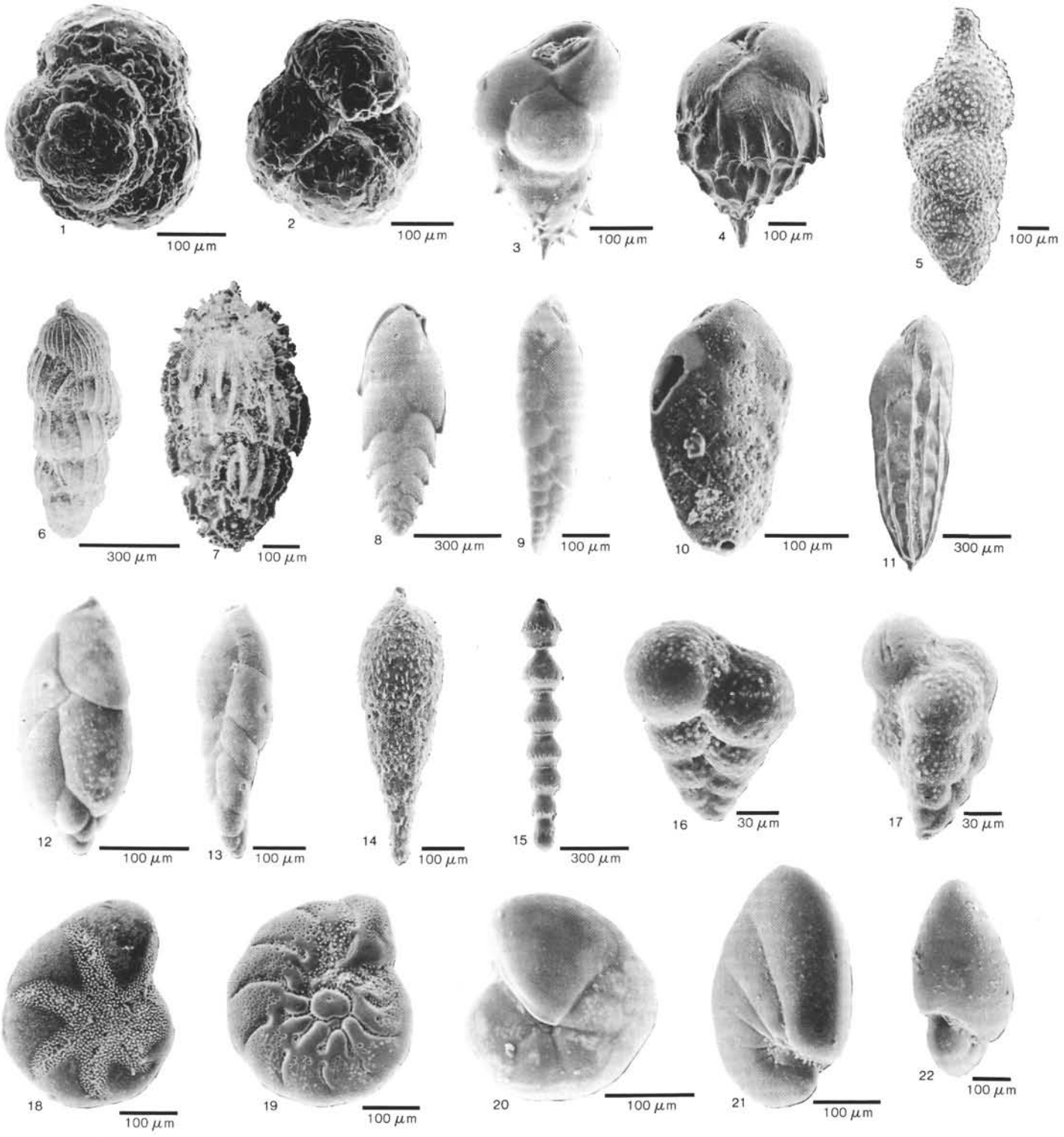

Plate 1. Benthic foraminifers. (All from Site 612 except 11, 16 and 17 from Site 613.) **1–2.** *Trochammina bullata*, (1) dorsal view, (2) ventral view. **3.** *Bulimina aculeata*. **4.** *Bulimina striata*. **5.** *Uvigerina asperula*. **6–7.** *Uvigerina peregrina*, (6) abraded form, (7) strongly costate form. **8.** *Brizalina bradyi*. **9.** *Brizalina pseudopunctata*. **10.** *Brizalina spathulata*. **11.** *Brizalina subaenariensis*. **12–13.** *Fursenkoina fusiformis*, (12) small typical form, (13) larger form. **14.** *Dentalina subsoluta*. **15.** *Stilostomella bradyi*. **16.** *Heterohelix* sp. **17.** *Guembelitria* sp. **18.** *Elphidium subarcticum*. **19.** *Elphidium excavatum* forma *clavata*. **20.** *Pullenia subcarinata*. **21–22.** *Nonionella turigida*, (21) umbilical view, (22) apertural view.

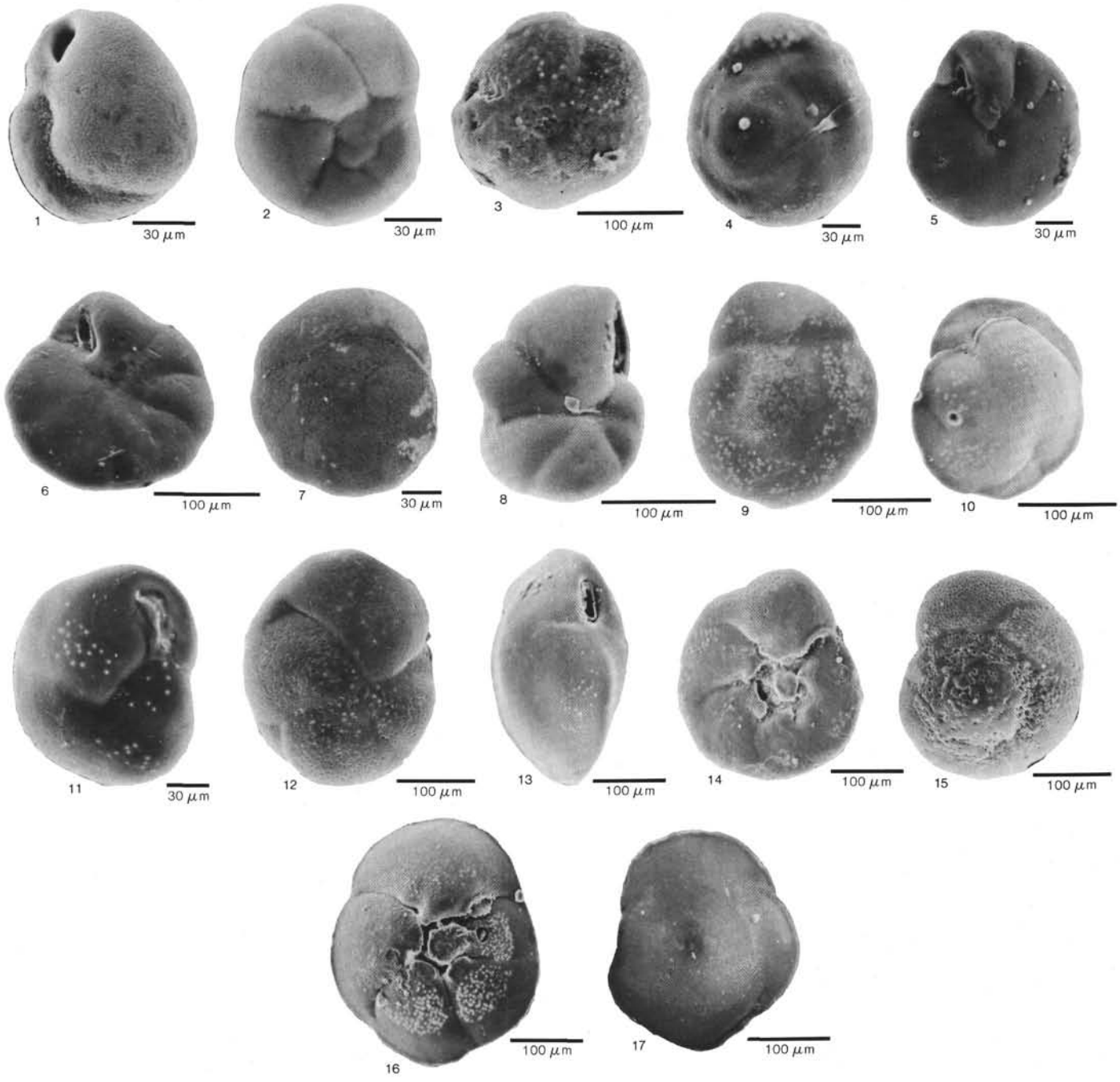

Plate 2. Benthic foraminifers. (All from Site 612 except 5, 6, 7, 14 and 15 from Site 613.) **1–2.** *Stetsonia horvathi*,(1) ventral view, (2) dorsal view. **3–4.** *Eponides bradyi*, (3) ventral view, (4) dorsal view. **5–7.** *Epistominella takayanagii*, (5) ventral view of small specimen, (6) ventral view of larger specimen, (7) dorsal view. **8–9.** *Epistominella exigua*, (8) ventral view, (9) dorsal view. **10.** *Cassidulina laevigata*. **11–12.** *Cassidulina reniforme*, (11) apertural view, (12) dorsal view. **13.** *Islandiella teretis*. **14–15.** *Gavelinopsis translucens*, (14) ventral view, (15) dorsal view. **16–17.** *Gavelinopsis lobatulus*, (16) ventral view, (17) dorsal view.