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8. MIDDLE PLIOCENE PLANKTONIC AND BENTHIC FORAMINIFERS FROM THE SUBARCTIC NORTH PACIFIC: SITES 883 AND 887[1]

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ABSTRACT

Diverse planktonic and benthic foraminifer assemblages exhibiting fair to good preservation were recovered from the middle Pliocene interval of Sites 883 and 887 in the subarctic North Pacific Ocean. The middle Pliocene planktonic assemblage at Site 883 is similar to late Pleistocene and modern assemblages in the region and probably represents paleoceanographic conditions approximately the same as those of today. The benthic assemblage from Site 883 indicates a middle Pliocene deepening of the oxygen minima. At Site 887 the planktonic assemblage is indicative of surface conditions slightly warmer than those of today while the benthic assemblage indicates conditions approximately the same as those of today.

INTRODUCTION

For several years the U.S. Geological Survey has been documenting the magnitude and variability of middle Pliocene (3.15–2.85 Ma) climate as part of the PRISM (Pliocene Research, Interpretation, and Synoptic Mapping) Project (Cronin and Dowsett, 1993). Examination of middle Pliocene sedimentary sequences from the Northern and Southern hemispheres by PRISM and other researchers reveals signs of significant surface water warming, reduced sea-ice cover, reduced global ice volume, elevated sea levels, and significant changes in vegetation patterns relative to today (Dowsett and Cronin, 1990; Webb and Harwood, 1991; Barron, 1992; Dowsett et al., 1992; Cronin et al., 1993; Shackleton et al., in press; Dowsett et al., 1994; Willard, 1994).

Ocean Drilling Program (ODP) Leg 145 represents a unique opportunity to examine complete, high-resolution sequences containing open-ocean calcareous microfossils from the North Pacific and to better understand the nature of the subarctic during the middle Pliocene. In this paper, we document the nature and variability of the planktonic and benthic foraminifer faunas from Sites 883 and 887 in the northwest and northeast Pacific, respectively.

The PRISM time interval is 3.15 to 2.85 Ma using the time scale of Berggren et al. (1985). Leg 145 workers have adopted the use of the Cande and Kent (1992) time scale, which places the PRISM time interval at 3.29–2.98 Ma. This interval is approximately coincident with the Kaena through Mammoth paleomagnetic subchrons.

METHODS

All samples were processed by first oven drying (≤50°C) and then soaking in dilute calgon solution for several hours to disaggregate the sediment. Disaggregated sediment was washed through a 150 µm mesh and oven dried at ≤50°C. Several methods were developed to separate foraminifer tests from siliceous material that dominates all samples. Procedures using controlled air and water currents to separate foraminifers from diatoms did not result in significantly faster separation, so samples were picked for foraminifers manually. For planktonic foraminifers, samples were placed on large 60-square micropaleontological picking trays, and foraminifers were removed from individual squares using a random number pattern until 300 individuals were obtained. In samples with less than 300 individuals, all planktonic foraminifers were obtained. For benthic foraminifers, samples were scanned to determine which contained abundant benthic foraminifers and all benthic foraminifers were removed from those samples. The average number of benthic formaminifers obtained ranged from 150 to 250.

Individuals were then fixed on a standard 60-square micropaleontological slide based upon their designation as species. For planktonic foraminifers, the taxonomies of Parker (1962, 1967), Blow (1969), and Kennett and Srinivasan (1983) were used whereas Loeblich and Tappan (1988) was used for the benthic foraminifers.

Scanning electron micrographs were obtained by coating specimens with 30Å of gold palladium and then viewing them on a JEOL JSM-35C. Specimens illustrated on Plates 1–3 are deposited at the U.S. National Museum in Washington D.C.

SITE 883

Site 883 is situated on the edge of the Detroit Seamount at 51°11.908′N and 167°46.128′E in 2384 m of water (Fig. 1). The core site is overlain by Pacific Deep Water and the surface Western Subarctic Gyre (Keigwin et al., 1992). Sea-surface temperatures average 1.5°C in February and reach 10.5°C in August (Schweitzer, 1993). Diatom and radiolarian biochronology and available magnetostratigraphy indicate that the PRISM time interval covers Cores 145-883B-14H to -16H. A 170-cm gap at the bottom of Core 145-883B-15H can be correlated to the upper portion of Core 145-883C-16H using the Gamma-Ray Attenuation Porosity Evaluation (GRAPE) density records of the two holes. Thus, by combining Holes 883B and 883C, we have a fairly complete record covering the PRISM time slab (3.29–2.98 Ma) at a sample spacing of approximately 10 k.y.

Planktonic Foraminifers

Planktonic foraminifers are common in most of the 49 samples examined from Site 883 (Tables 1 and 2). In all but 7 samples, more than 300 identifiable specimens were recovered. Preservation ranges from good to poor, with many samples showing signs of pervasive dissolution and recalcification of foraminifer tests.

The assemblage at Site 883 is dominated by *Globigerina bulloides* and cold-water *Neogloboquadrina* species, including *N. pachyderma* and *N. atlantica*. Other, less common, taxa include *Globigerina umbilicata* and *Globigerinita glutinata*. Rare occurrences of *Orbulina universa, Globorotalia scitula, Globigerina incisa,* and *Turborotalita quinqueloba* complete the assemblage. *Neogloboquadrina pachyderma* shows a preference for dextral coiling at Site 883 which along with other available age data suggests correlation to coiling interval CD15 of Lagoe and Thompson (1988).

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Table 1. Occurrences of planktonic foraminifers, Hole 883B.

Core, section, interval (cm)	Depth (mbsf)	Preservation	*Neogloboquadrina pachyderma* (s)	*Neogloboquadrina pachyderma* (d)	*Globigerina bulloides*	*Neogloboquadrina atlantica* (s)	*Neogloboquadrina atlantica* (d)	*Globigerina umbilicata*	*Globigerinita glutinata*	*Orbulina*	*Globigerina incisa*	*Globigerina quinqueloba*	*Globorotalia scitula*	Not identified	Total
14H-1, 5–10	121.95	G	10	6	86	20	28	135	18			20	1	4	328
14H-1, 45–50	122.35	F	1	42	45	84	70	10	7		3		1		263
14H-1, 85–90	122.75	G	1	83	24	57	96	8	5				2	2	278
14H-1, 121–126	123.11	F	5	35	24	117	117	15	3		5	3	2	1	327
14H-2, 15–20	123.55	F	3	28	49	79	126	3	10		2	1	1	1	303
14H-2, 55–60	123.95	F	4	3	20	44	44	12	9		2	2		4	144
14H-2, 90–95	124.30	F	1	20	46	100	122	18	18		5			1	331
14H-2, 135–140	124.75	F	6	12	46	98	102	19	12		3	6	1	3	308
14H-3, 25–30	125.15	F	3	14	98	75	59	29	15		3	2	1	3	302
14H-3, 65–70	125.55	F	1	10	52	95	99	15	24			2		3	301
14H-3, 102–107	125.92	F		23	171	16	41	12	22				2		287
14H-4, 35–40	126.75	P	1	5	34	20	62	13	33					1	169
14H-4, 110–115	127.50	F	5		63	34	30	22	7				1		162
14H-5, 45–50	128.35	F		11	201	11	48	21	16	1			1		310
14H-5, 125–130	129.15	P	2	12	116	28	75	22	52		1				308
14H-6, 55–60	129.95	P		12	170	15	58	27	23				5	1	311
14H-6, 136–141	130.76	F	1	17	98	36	104	42	24	2				7	331
14H-7, 65–70	131.55	F		9	185	13	44	78	16	2			2	1	350
15H-1, 45–50	131.85	F		40	124	61	37	32	13				1		308
15H-2, 15–20	133.05	G	6	28	39	94	113	20	17		6		1	2	326
15H-2, 135–140	134.25	F	3	18	188	13	65	65	9			1	1		363
15H-3, 25–30	134.65	F	2	19	71	96	85	16	15		1		1	1	307
15H-3, 102–107	135.42	F	4	9	78	112	84	20	2		4		7	6	326
15H-4, 35–40	136.25	F	3	5	105	64	81	28	17		2	2	5	4	316
15H-4, 111–116	137.01	F	1	8	102	92	97	18	11		1	1	3	5	339
15H-5, 46–51	137.86	F	1	2	130	99	91	26	11		1		1		362
15H-5, 126–131	138.66	F	1	1	117	111	83	23	7	4			2	3	352
15H-6, 50–55	139.40	F	1	9	175	32	54	17	21					1	310
15H-7, 35–40	140.25	F	1	6	87	67	99	17	28				1	1	307
16H-1, 5–10	140.95	G	1	7	203	11	42	42	3		1		1	1	312
16H-1, 85–90	141.75	F	1	10	193	35	13	32	8					3	295
16H-2, 15–20	142.55	F			77	127	84	16	9		2			1	316
16H-2, 90–95	143.30	F		1	242	17	15	52	4					1	332
16H-3, 25–30	144.15	F	2		182	54	28	32	8		2			5	313
16H-3, 101–106	144.91	F		3	219	25	40	44	3				1		335
16H-4, 35–40	145.75	F	1		201	24	32	64	7				2		331
16H-4, 111–115	146.51	F	2	3	162	22	36	68	17	1	3		2	1	317
16H-5, 45–50	147.35	F	4		189	31	26	50	4		3		1	3	311
16H-5, 120–125	148.10	F	3	3	163	27	33	72	7				4	1	313
16H-6, 50–55	148.90	F	2	5	152	23	21	108	14						325
16H-6, 135–140	149.75	F	1	1	145	27	19	111	4						308
16H-7, 64–69	150.54	F		1	143	34	22	55	43				4	2	304

Note: G = good, F = fair, and P = poor.

Table 2. Occurrences of planktonic foraminifers, Hole 883C.

Core, section, interval (cm)	Depth (mbsf)	Preservation	*Neogloboquadrina pachyderma* (s)	*Neogloboquadrina pachyderma* (d)	*Globigerina bulloides*	*Neogloboquadrina atlantica* (s)	*Neogloboquadrina atlantica* (d)	*Globigerina umbilicata*	*Globigerinita glutinata*	*Orbulina*	*Globigerina incisa*	*Globigerina quinqueloba*	*Globorotalia scitula*	Not identified	*Total*
16H-1, 5–10	136.1	F	1	39	197	6	31	28	13	1					316
16H-1, 85–90	136.9	F		10	196	24	53	34	6				4		327
16H-2, 15–20	137.7	F		5	130	33	66	73	4	1			3	2	317
16H-2, 95–100	138.5	F	2	7	209	18	33	31	5			1		1	307
16H-3, 25–30	139.3	F	1	18	170	38	44	26	9					4	310
16H-3, 105–110	140.1	F	1	1	192	30	33	40	15				2	2	316
16H-3, 145–150	140.5	F		8	197	7	25	80	13					1	331

Note: See Table 1.

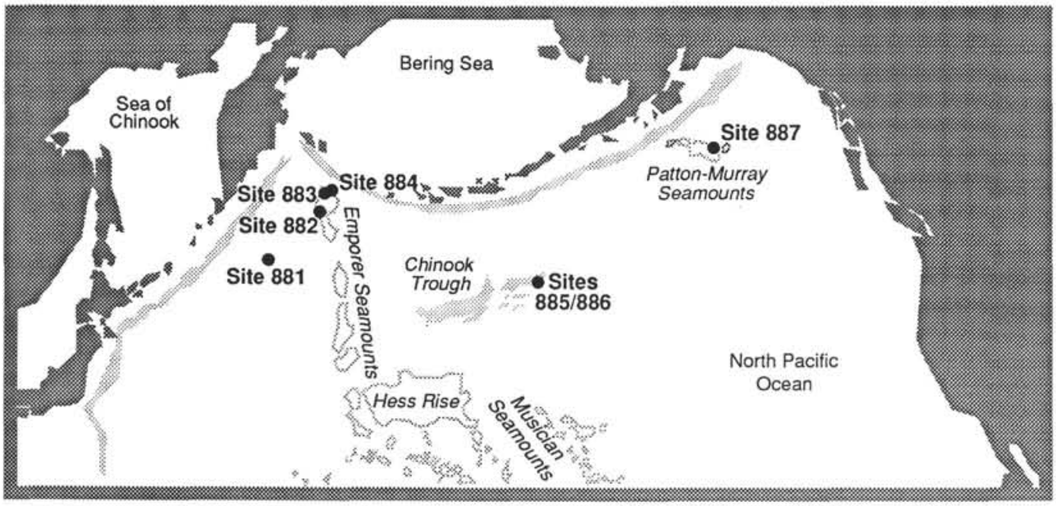

Figure 1. Location of Leg 145 sites in the North Pacific.

This is the first report of *Neogloboquadrina atlantica* from a high-latitude North Pacific Ocean sequence. We have found that dissolution and overgrowth of surface texture make it difficult to impossible to distinguish *N. atlantica* from *Globigerina bulloides* under the light microscope. A similar gradation between these taxa was observed by Dowsett and Poore (1990) in the North Atlantic. We estimate that as many as 15% of individuals identified as either *G. bulloides* or *N. atlantica* may be incorrectly assigned. For this reason, the counts (Tables 1 and 2) should be considered preliminary until further taxonomic work is performed on the assemblage. Nevertheless, sufficient numbers of unmistakable *N. atlantica* are recognized from the Site 883 material, thus firmly establishing the presence of this taxon at high latitudes throughout the Northern Hemisphere.

Figure 2 indicates two first-order cycles in the planktonic assemblage with broad peaks in the abundance of *Globigerina bulloides* centered at 128 and 145 m. Higher frequency variability in the planktonic assemblage is superimposed on these two primary cycles. In general, the abundance of cold-water *Neogloboquadrina* species (= *N. pachyderma* and *N. atlantica*) increases up the sampled interval whereas *Globigerina umbilicata* decreases up the section.

Pliocene-Pleistocene faunas from DSDP Leg 19, Site 192 (Echols, 1973), from the region immediately to the north of Site 883, are dominated by *N. pachyderma* with lesser amounts of *G. bulloides, Globorotalia scitula,* and *Globigerinita glutinata*. Site 883 Pliocene assemblages identified in this paper have approximately the same diversity and represent similar to possibly slightly warmer (because of higher percentages of *G. bulloides*) conditions than occurred during the late Pleistocene at DSDP Site 192.

Benthic Foraminifers

A total of 74 samples were analyzed for benthic foraminifers, of which 47 yielded quantitative counts (>100 specimens) (Table 3). We identified 51 species or species groups of calcareous benthic and agglutinated foraminifer taxa. Preservation was moderate to good, with some specimens displaying partial dissolution evident by enlarged pores and absence of the final chamber. The dominant agglutinated taxon, constituting up to 17% of the fauna, is *Eggerella bradyi*. Abundant calcareous benthic taxa include *Fontbotia wuellerstorfi, Globocassidulina subglobosa, Melonis barleeanum, Pyrgo* spp., and *Uvigerina proboscidea*. Minor components of this fauna are *Laticarinina pauperata, Oridorsalis* spp., *Quinqueloculina* spp., *Stilostomella lepidula, Ehrenbergina trigona,* and *Bulimina alazanensis*.

The benthic foraminifer fauna from Site 883 is similar to modern lower-middle to upper-lower bathyal (1000–2800 m) faunas from the Pacific (Echols and Armentrout, 1980; Ingle and Keller, 1980; Murray, 1991). Similar faunal associations are related to Deep Oxygen Minimum water in the Pacific (Murray, 1991). This fauna shows little significant variation in species abundances up to approximately 136.5 m, where the abundance of *Uvigerina proboscidea* increases significantly (up to 44% abundance) through 133.5 m (Fig. 3). The association of Uvigerinids with low-oxygen conditions may suggest a significant drop in the oxygen minima at this site. This event is followed by an increase in abundance of *Globocassidulina subglobosa* and relative decrease in the abundance of the agglutinated taxon *Eggerella bradyi* (Fig. 3).

SITE 887

Site 887 is situated on the eastern part of the Patton-Murray Seamount group in the Gulf of Alaska (54°21.921′N, 148°26.765′W) at a water depth of 3630 m (Fig. 1). The core site is situated under the center of the Alaskan Gyre and is overlain by Pacific Deep Water. Sea-surface temperatures average 3.5°C in February and 12.3°C in August (Schweitzer, 1993). High carbonate samples (based upon GRAPE density records) were selected for faunal analysis at this site.

The extraordinary magnetostratigraphic record at this site (Barron et al., this volume) indicates that the high carbonate levels partially coincide with the PRISM time interval. Our uppermost sample corresponds to the middle of the Kaena (C2An.2n), and our lowest sample falls just below the Gauss-Gilbert Chron boundary. Therefore, our samples cover the interval from 3.08 to 3.59 Ma at a sample spacing of approximately 12 k.y. As at Site 883, specimens of *Neogloboquadrina pachyderma* are predominantly dextrally coiled suggesting correlation to coiling interval CD15 of Lagoe and Thompson, 1988.

Planktonic Foraminifers

Planktonic foraminifers are common in 36 of the 52 samples examined from Site 887 (Tables 4 and 5). Preservation is consistently better than at Site 883.

The assemblage at Site 887 is dominated by *Globigerina bulloides*. Other less common taxa include *Neogloboquadrina pachyderma, Globigerina umbilicata, Neogloboquadrina atlantica, Orbulina universa*, and *Globigerina incisa*. Rare occurrences of *Globigerinita glutinata, Globorotalia scitula,* and *Turborotalita quinqueloba* complete the assemblage.

Globigerina bulloides is a larger component of the assemblage at Site 887 than at Site 883, suggesting warmer conditions (Fig. 2). Late Pleistocene assemblages from Gulf of Alaska DSDP Leg 18, Sites 179

Table 3. Occurrences and abundance of benthic foraminifers, Hole 883B.

Core, section, interval (cm)	Depth (mbsf)	Preservation	*Bolivina* sp.	*Bulimina alazanensis*	*Bulimina marginata*	*Chilostomella argentae*	*Cibicidoides cicatricosus*	*Cibicidoides kullenbergi*	*Cribrostomoides* sp.	*Eggerella bradyi*	*Ehrenbergina trigona*	*Epistominella exigua*	*Fontbotia wuellerstorfi*	*Fursenkoina* spp.	*Globobulimina auriculata*	*Globocassidulina subglobosa*	*Gyroidina lamarckiana*	*Gyroidina soldanii*	*Gyroidina zealandica*	*Hoeglundina elegans*	*Karreriella bradyi*	*Laryngosigma hyalascidia*	*Laticarinina pauperata*	*Lenticulina* sp.	*Melonis barleeanum*	*Melonis pompilioides*	*Nodosaria holoserica*	*Nodosariidae*	*Nuttallides umbonifera*
14H-3, 102–107	125.92	F								11		4	21			18		2	4		2			1	36			8	
14H-3, 145–150	126.35	F								1		1	2			8		6	1				1		23			4	1
14H-5, 45–50	128.35	F								1			1			3	1	1					4	1	1			2	
14H-5, 85–90	128.75	F											1			1					1		1		2				
14H-6, 55–60	129.95	F				1				3			5			9		1					2	1	2			3	
14H-6, 90–95	130.30	F								1		1	2			1		1			2				5			1	1
14H-6, 136–141	130.76	F											3			3		2						1	12			4	1
14H-7, 25–30	131.15	F		1						6	2		7			57		1			1		1		13			2	1
15H-1, 45–50	131.45	F						1		10		2	35			2	1						3		8			4	
15H-2, 51–56	133.41	F				5				10			60			120	4	2					3		57			13	
15H-2, 135–140	134.25	F				2				32			29			3	2	3	1		1		4	1	27			4	
15H-3, 25–30	134.65	F				2				40			24			9	8	2					4	1	44			9	
15H-3, 65–70	135.05	F				3				21			34			1	4	1					5		52			7	
15H-3, 102–107	135.42	F			1	2				38		2	31		1	3		17					5	2	47		1	4	
15H-3, 145–150	135.85	F				2				15		3	27			1		22			1		1		42			4	
15H-4, 35–40	136.25	F				1				11		2	27					5	1		5		4		37			9	
15H-4, 75–80	136.65	F								5		4	12		4			3			3				49			6	
15H-4, 111–116	137.01	F				3				17		7	16			2	5	2						1	30			3	
15H-5, 5–10	137.45	F				1				6		3	11	1		2	1	16		2			1		29			8	
15H-5, 46–51	137.86	F								15	2		14			1		25				1		1	34			5	
15H-5, 86–91	138.26	F		1						7	3		13			2		11					2		19			7	
15H-5, 126–131	138.66	F								1			11			1		19					1	1	16			10	1
15H-6, 15–20	139.05	F		1		2				28			35			13							3		62			10	
15H-6, 50–55	139.40	F		1		4				10			35				22	2					5	1	59			17	
15H-6, 91–96	139.81	F				2				21	3	5	33			40	24	2					2		69			8	
15H-7, 66–71	140.56	F				1				17			25			25		1					3		30			11	
16H-1, 5–10	140.95	F				2				7			14			17	5	2					1		15			4	
16H-1, 45–50	141.35	F								7			12			7	8								15			4	
16H-1, 85–90	141.75	F			1	3				12			33			28	3						4	1	57			7	
16H-1, 125–130	142.15	F				2				11		1	26			15		1					2	1	36			8	
16H-2, 15–20	142.55	F				2				11			32			8	2								44			4	
16H-2, 50–52	142.90	F			1	8				24	1	1	36			4	8						6		37			4	
16H-2, 135–140	143.75	F	1								17	1	13				3						2		12			7	
16H-3, 25–30	144.15	F								20			19				4								15			4	
16H-3, 65–70	144.55	F							1	15	2	2	36				3						3	1	36			14	
16H-3, 101–106	144.91	F				2				16			21				6						1		16			12	
16H-3, 145–150	145.35	F				2		4			1		26			1	8								14			13	
16H-4, 35–40	145.75	F				3				14		1	32				4	2					1	6	13			9	
16H-4, 111–116	146.51	F				2				12		2	20				11							2	12			11	
16H-5, 5–10	146.95	F								14	1	1	46				5	1					3	6	26			19	
16H-5, 45–50	147.35	F				5				15			56				13	2					4	5	23			54	
16H-5, 85–90	147.75	F								4			23				7	3					1	1	10			16	
16H-5, 120–125	148.10	F				2				6			27			1		6						1	30			20	
16H-6, 15–20	148.55	F				2				1			22			2	4	5							16			2	
16H-6, 50–55	148.90	F								11		3	9			9	15	3							9	5		9	
16H-6, 135–140	149.75	F						2		3		1	7					12							20			2	
16H-7, 25–30	150.15	F					3			2		3	9					24						1	22			1	

Table 3 (continued).

Core, section, interval (cm)	Depth (mbsf)	Preservation	*Oridorsalis* spp.	*Pleurostomella acuta*	*Pullenia bulloides*	*Pullenia quinqueloba*	*Pullenia salisburyi*	*Pyrgo* spp.	*Quinqueloculina oblonga*	*Quinqueloculina venusta*	*Rosalina* sp.	*Sigmoilina schlumbergeri*	*Silicosigmolina* sp.	*Siphonodosaria gracillima*	*Sphaeroidina bulloides*	*Spiroloculina pusilla*	*Spirosigmoilina* sp.	*Stilostomella lepidula*	*Stilostomella* sp.	*Trifarina angulosa*	*Triloculina tricarinata*	*Uvigerina peregrina*	*Uvigerina proboscidea*	*Valvulineria* sp.	Agglutinated sp. 1	Agglutinated sp. 2	Agglutinated sp. 3	Total
14H-3, 102–107	125.92	F	1				2	16													2		16					144
14H-3, 145–150	126.35	F					2	12														1	5					68
14H-5, 45–50	128.35	F	2				1	1									1											20
14H-5, 85–90	128.75	F					1	1																			1	9
14H-6, 55–60	129.95	F	3			1		2										1									1	35
14H-6, 90–95	130.30	F	3					11		3											1							33
14H-6, 136–141	130.76	F	1			2		4																				33
14H-7, 25–30	131.15	F	2		2	4		5							1			1					2					109
15H-1, 45–50	131.45	F	2	1		3		5											1				13	1				92
15H-2, 51–56	133.41	F	20		3	9		40		5								1	1				45					398
15H-2, 135–140	134.25	F	3		2	8		9									1	9			3		53	2				199
15H-3, 25–30	134.65	F	6	1	1	9	1	19		7							1	3					69				1	261
15H-3, 65–70	135.05	F	2	2		2		6						1									111				2	254
15H-3, 102–107	135.42	F			2	3		24		2		1		1									112	1				300
15H-3, 145–150	135.85	F	1					41	4														43					207
15H-4, 35–40	136.25	F				2		19	2					1									50				1	177
15H-4, 75–80	136.65	F			2	2		14										1					26					131
15H-4, 111–116	137.01	F	2	1	1		3	34							1								12	3				143
15H-5, 5–10	137.45	F	5		8	2	2	4					1										2	1			1	107
15H-5, 46–51	137.86	F	11	1	10		6	3					1					3					10				1	144
15H-5, 86–91	138.26	F	1	1	2		2	13		1								2			3		6					96
15H-5, 126–131	138.66	F	10		6		2	19		2					2						1		22				2	127
15H-6, 15–20	139.05	F	22		10			23		1					2			1			1		15		1			230
15H-6, 50–55	139.40	F	14				2	22		16					1					2	3		3	3				222
15H-6, 91–96	139.81	F	22		1			24		3								2		2			7	1		1		272
15H-7, 66–71	140.56	F	8				4	21															5			1		152
16H-1, 5–10	140.95	F	10		3			12		3					1			2					6					104
16H-1, 45–50	141.35	F	8				1	18		3																		83
16H-1, 85–90	141.75	F	15					18							2			1					3	7		2		197
16H-1, 125–130	142.15	F	11				2	17		3					1	1					2		2					142
16H-2, 15–20	142.55	F	18		7		2	7										1			3		3	1				145
16H-2, 50–52	142.90	F	19		15		1	14	1						2	1					1			7		1		192
16H-2, 135–140	143.75	F	15		7		7	31	1						2											1		120
16H-3, 25–30	144.15	F	5		2		1	41	1																	8		120
16H-3, 65–70	144.55	F	14		6		4	29		9													6			4		185
16H-3, 101–106	144.91	F	7	1	3	2	2	27							2						4					1		123
16H-3, 145–150	145.35	F	11	1	7	2		16							3					2	4		20			3		138
16H-4, 35–40	145.75	F	4		11	2		25												1	8		26					162
16H-4, 111–116	146.51	F	7		12			42		9													1		4	4		151
16H-5, 5–10	146.95	F	5		10	4		34		1								1		1	2		12	1	6	4		203
16H-5, 45–50	147.35	F	5		9	1	7	49								1		1		1	9		13		14	16		303
16H-5, 85–90	147.75	F	2		8	1		52							2			2			4		4		4			144
16H-5, 120–125	148.10	F	3	1	10		3	70										1			10							191
16H-6, 15–20	148.55	F	1		3	1	1	35																				95
16H-6, 50–55	148.90	F	2	1	14		4	25			2										1			2				124
16H-6, 135–140	149.75	F					1	6			2				2													58
16H-7, 25–30	150.15	F	1					12							2						1							81

Notes: See Table 1. Abundance = number of specimens.

Table 4. Occurrences of planktonic foraminifers, Hole 887A.

Core, section, interval (cm)	Depth (mbsf)	Preservation	*Neogloboquadrina pachyderma* (s)	*Neogloboquadrina pachyderma* (d)	*Globigerina bulloides*	*Neogloboquadrina atlantica* (s)	*Neogloboquadrina atlantica* (d)	*Globigerina umbilicata*	*Globigerinita glutinata*	*Orbulina*	*Globigerina incisa*	*Globigerina quinqueloba*	*Globorotalia scitula*	Not identified	Total
11H-7, 18–20	101.38	F	1	4	31	11	20	24	3			1			95
11H-7, 41–43	101.61	G			2		4	2					1		9
12H-1, 26–28	101.96	G	1	5	231	12	35	26	1	1				5	317
12H-1, 43–45	102.13	G		6	250	9	25	4	2		5		1	3	305
12H-1, 66–68	102.36	F		2	91	30	35	10						1	169
12H-1, 83–85	102.53	F		4	11	5	12								32
12H-1, 105–107	102.75	F		5	2	2	4		1						14
12H-1, 127–129	102.97	F	2	2	240	13	14	29			6			7	313
12H-1, 145–147	103.15	F			222	12	7	1		4			1		247
12H-2, 16–18	103.36	G		2	119	42	67	10						1	241
12H-2, 37–39	103.57	G				1	1								2
12H-2, 55–57	103.75	F			2										2
12H-2, 73–75	103.93	F	1	7	128	23	26	20	1				3	18	227
12H-2, 95–97	104.15	F	1	2	187	47	42	19						1	299
12H-2, 113–115	104.33	G	5		207	5	8	25					3	7	260
12H-2, 135–137	104.55	G	1	3	178	26	21	22			4		1	2	258
12H-3, 5–7	104.75	F			125	13	9							6	153
12H-3, 23–25	104.93	F		2	204	43	38	23	2				1		313
12H-3, 63–65	105.33	F	2	2	210	53	42	14	1		2				326
12H-3, 85–87	105.55	F		1	243	41	20	18						1	324
12H-3, 105–107	105.75	F		1	186	72	41	15						1	316
12H-3, 127–129	105.97	F	3		185	24	8	62	27					7	316
12H-3, 145–147	106.15	F			22	1	1	12	1				1		38
12H-4, 13–15	106.33	F			24			23							47
12H-4, 33–35	106.53	F			7				1						8
12H-4, 77–79	106.97	F			91	6	4	16						4	121
12H-4, 95–97	107.15	F	9	2	188	31	17	45			2			6	300
12H-4, 113–115	107.33	F			24	1	1	3							29
12H-4, 135–137	107.55	G			2										2
12H-5, 5–7	107.75	G		2	221	32	23	43	1					2	324
12H-5, 23–25	107.93	G			114	19	22	40	1		1				197
12H-5, 43–45	108.13	F	4	3	196	41	26	48		2	2			1	323
12H-5, 66–68	108.36	F	3		161	24	11	103			1			3	306
12H-5, 83–85	108.53	G			87	4	1	45							137
12H-5, 105–107	108.75	F	1	1	262	11	12	23		43					353
12H-5, 145–147	109.15	F			4		1			4					9
12H-6, 13–15	109.33	F			214	1	8	17		30					270
12H-6, 34–36	109.54	F	2	2	192	24	28	24		66	2		3	4	347
12H-6, 95–97	110.15	G			49	2	3	11		9					74
12H-7, 5–7	110.75	F			182	38	22	79		5	2		2	5	335
12H-7, 66–68	111.36	G			1	3	1		1				1		7

Note: See Table 1.

Table 5. Occurrences of planktonic foraminifers, Hole 887C.

Core, section, interval (cm)	Depth (mbsf)	Preservation	*Neogloboquadrina pachyderma* (s)	*Neogloboquadrina pachyderma* (d)	*Globigerina bulloides*	*Neogloboquadrina atlantica* (s)	*Neogloboquadria atlantica* (d)	*Globigerina umbilicata*	*Globigerinita glutinata*	*Orbulina*	*Globorotalia scitula*	Not identified	Total
12H-1, 45–47	93.75	G	6	5	262	19	10	13				1	316
12H-1, 65–67	93.95	G				2		1					3
12H-1, 125–127	94.55	F		11	195	29	52	3				1	291
12H-1, 145–147	94.75	F	5	38	143	22	115	14			1	2	340
13H-1, 5–7	102.85	G			170	27	19	2			2	0	220
13H-1, 25–27	103.05	G	3		45	29	29	29	1			3	139
13H-1, 45–47	103.25	F			3	8	6	9					26
13H-1, 65–67	103.45	F			18	10	8	22		1			59
13H-1, 85–87	103.65	F	5	1	127	40	25	23			1	7	229
13H-1, 105–107	103.85	F	2	2	110	8	6	16				2	146
13H-1, 145–147	104.25	F			118	19	4	45				3	189

Note: See Table 1.

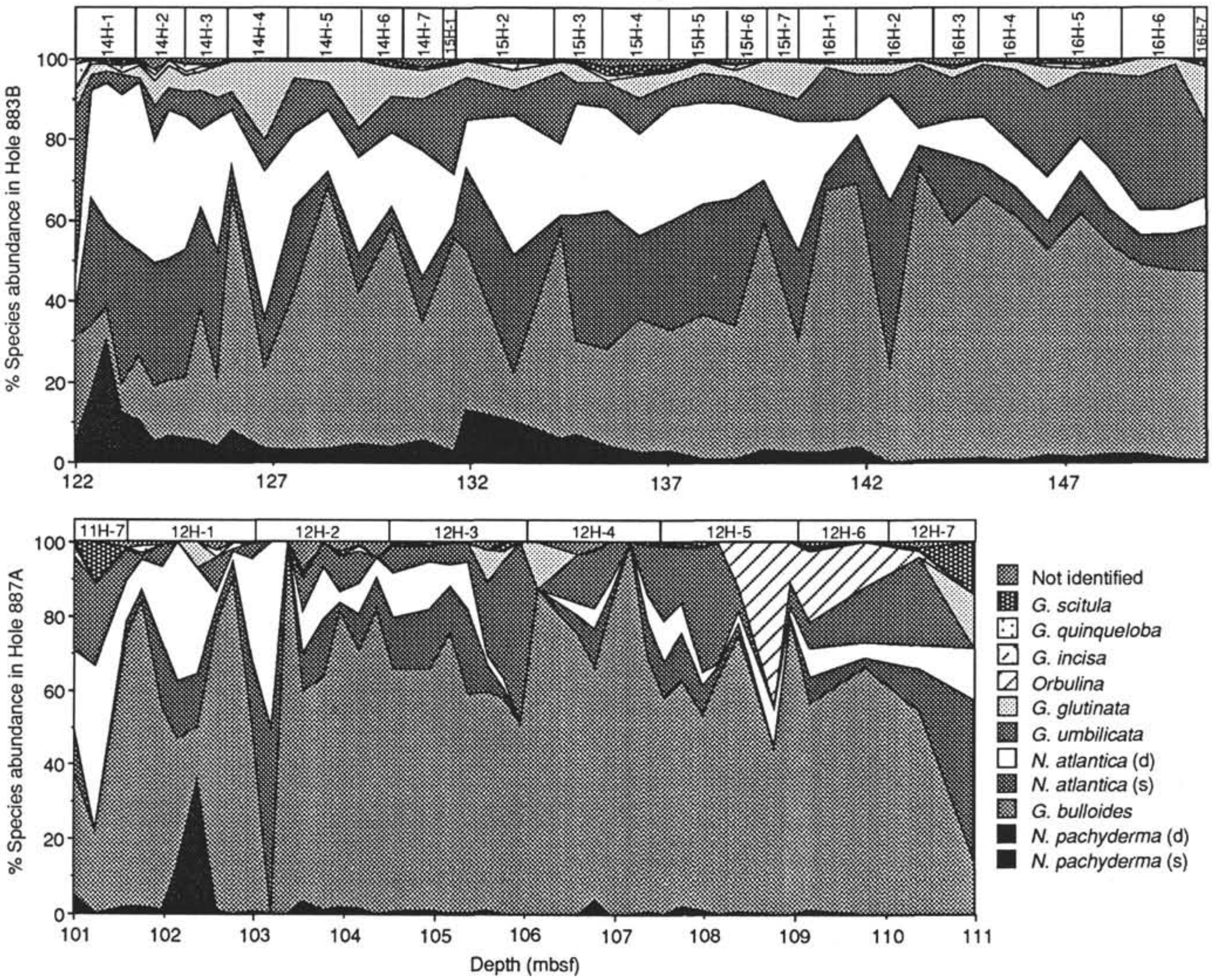

Figure 2. Planktonic foraminifer abundances at Sites 883 and 887.

and 180 (Ingle, 1973) are similar to Pleistocene assemblages in the western North Pacific and include predominantly *N. pachyderma*, with lesser amounts of *G. bulloides* and rare occurrences of *G. umbilicata*, *Globigerinita glutinata*, and *Turborotalita quinqueloba*. The Pliocene assemblage recovered from Site 883 has significantly greater numbers of *Globigerina bulloides* and indicates a warmer water assemblage. Near the base of Core 145-887A-12H, *Orbulina universa* is present for a short interval at abundances of just over 10%. Thus, the Pliocene assemblage at Site 887 represents warmer conditions than the Pleistocene assemblages of this region or western subarctic North Pacific.

Benthic Foraminifers

Benthic foraminifers were recovered from 46 samples from Holes 887A (31 samples) and 887C (15 samples) (Tables 6 and 7; Fig. 4). The fauna is dominated by calcareous benthic taxa with one prominent agglutinated taxon, *Eggerella bradyi*. Abundant calcareous benthic taxa include *Nuttallides umbonifera*, *Globocassidulina subglobosa*, *Oridorsalis* spp., *Melonis barleeanum*, *Pullenia bulloides* and *Epistominella exigua* (Tables 6 and 7). Minor components of this fauna are *Bolivina decussata*, *Cibicidoides kullenbergi*, *Fontbotia wuellerstorfi*, *Gyroidina* spp., *Laticarinata pauperata*, *Sphaeroidina bulloides*, *Trifarina angulosa*, and *Uvigerina proboscidea*. Preservation of the fauna is moderate to good, with some specimens displaying dissolution features such as enlarged pores and broken or missing final chambers.

The benthic foraminifer fauna recovered from Site 887 is typical of a Neogene Pacific Ocean abyssal benthic foraminifer fauna. The dominance of *Nuttallides umbonifera* associated with other deep-water benthic foraminifers such as *Oridorsalis* spp. and *Epistominella exigua* is similar to the deep-water Pliocene–Pleistocene assemblage described from the Gulf of Alaska, DSDP Site 178 (Ingle, 1973) and equatorial Pacific deep-sea benthic distributions described by Thomas (1985) and Ingle and Keller (1980). This fauna bears resemblance to the *Nuttallides umboniferus* association in the Pacific (Murray, 1991) that is related to Antarctic Bottom Water (AABW) near the lysocline-carbonate compensation depth (CCD) boundary. This fauna shows little variation throughout the section studied. However, an increase in the abundance of *Epistominella exigua* is observed from 102.97 through 101.75 m of the core. In addition, three distinct intervals (111.36–111.14 m, 110.33 m, and 109.93–109.75 m) have very low abundances or are barren of calcareous benthic foraminifers, indicating possible dissolution events.

DISCUSSION

Neogloboquadrina atlantica (Berggren)

Poore and Berggren (1975) reexamined the gross morphology and test surface ultrastructure of *Neogloboquadrina atlantica* (Berggren).

Table 6. Occurrences and abundance of benthic foraminifers, Hole 887A.

Core, section, interval (cm)	Depth (mbsf)	Preservation	*Astrononion gallowayi*	*Astrononion* sp.	*Bolivina decussata*	*Bolivina pseudopunctata*	*Bolivina silvestri*	*Bulimina alazanensis*	*Cassidulinoides* sp.	*Cibicidoides cicatricosus*	*Cibicidoides kullenbergi*	*Cibicidoides robertsiana*	*Eggerella bradyi*	*Ehrenbergina trigona*	*Epistominella exigua*	*Eponides tener*	*Eponides tumidulus*	*Fontbotia wuellerstorfi*	*Fursenkoina* spp.	*Globocassidulina subglobosa*	*Gyroidina lamarckiana*	*Gyroidina soldanii*	*Gyroidina zealandica*	*Haplophragmoides* sp.	*Hyperammina* sp.	*Karreriella bradyi*	*Laticarinina pauperata*
12H-1, 5–7	101.75	F			1	1					5		6	1	13			8		5	1		1				6
12H-1, 26–28	101.96	F			1		1			2	12		8	2	15					7			1				2
12H-1, 43–45	102.13	F				2	1		1		18		6		13			1		2	9		3				7
12H-1, 127–129	102.97	F			1	1		1	1	2	12				20			6		1	5						2
12H-2, 95–97	104.15	F			2			1			7		16		13					28			2				1
12H-3, 23–25	104.93	F			2					1	7		10	1	12	3		6		31	3		1				4
12H-3, 43–45	105.13	F			1						3		2	1	7			3		12	9						
12H-3, 63–65	105.33	F			3			2			11		13		12					28	4	2		1			4
12H-3, 85–87	105.55	F			1						8		1		2			4		12	3						1
12H-3, 105–107	105.75	F								2	7		2		13			6		22	2						2
12H-3, 127–129	105.97	F					1			2			8		27			8		42			2				
12H-4, 55–57	106.75	F									4				5			3		26		2					
12H-4, 77–79	106.97	F									3		5		4	1		7		27		2					1
12H-4, 95–97	107.15	F			1					3	4		3		12			9		61							2
12H-4, 113–115	107.33	F									3	1	3		3			1		18	2						3
12H-4, 135–137	107.55	F											10							36							1
12H-5, 5–7	107.75	F			1						5		14		6			10		54	2	3					3
12H-5, 23–25	107.93	F			1						6		20					3		37		3					1
12H-5, 43–45	108.13	F									3		7		2	1		5		26	3	4				1	
12H-5, 66–68	108.36	F			1			1					3		2			10		15	3						
12H-5, 83–85	108.53	F									1		4		1		2	4				1					
12H-6, 13–15	109.33	F		4							3		14					13		1	3	2	1				
12H-6, 34–36	109.54	F			2						7		13		6			12		1	8	2	2		1		3
12H-6, 55–57	109.75	F											4														
12H-6, 73–75	109.93	F											4														
12H-6, 95–97	110.15	F									3		7						2	2					1	3	
12H-6, 113–115	110.33	F											1														
12H-7, 5–7	110.75	F	1				1	1			15		35		3		1	5			21	4	3				1
12H-7, 23–25	110.93	F				4					2		16	1	8			4		1	7		4				
12H-7, 44–46	111.14	F											6														
12H-7, 66–68	111.36	F											6					1									

Table 6 (continued).

Core, section, interval (cm)	Depth (mbsf)	Preservation	*Lenticulina* sp.	*Melonis barleeanum*	*Melonis pompilioides*	*Nodosariidae*	*Nuttallides umbonifera*	*Oridorsalis* spp.	*Pleurostomella acuta*	*Pullenia bulloides*	*Pullenia quinqueloba*	*Pullenia salisburyi*	*Pyrgo* spp.	*Quinqueloculina oblonga*	*Quinqueloculina venusta*	*Rectuvigerina* sp.	*Sigmoilina schlumbergeri*	*Sphaeroidina bulloides*	*Stainforthia complanata*	*Stilostomella lepidula*	*Trifarina angulosa*	*Triloculina tricarinata*	*Uvigerina proboscidea*	*Valvulineria* sp.	Species 1	Species 2	Total
12H-1, 5–7	101.75	F		28			42	41		23			4			3				1			2				192
12H-1, 26–28	101.96	F		16		12	20	18	1	19		2	1					2		1							143
12H-1, 43–45	102.13	F		34	5	7	26	4		36	2		1							3			1				182
12H-1, 127–129	102.97	F		17		5	23	49		22	2	9	1					2		3	2	1	4				192
12H-2, 95–97	104.15	F	5	19	1	10	58	52	3	11		5	3	1	1				1	1	1		20				262
12H-3, 23–25	104.93	F	1	49		19	80	21	3	13	1	4	1					1		2			7				283
12H-3, 43–45	105.13	F	1	14		4	37	19	1	16					1			2		3							136
12H-3, 63–65	105.33	F	2	34		8	51	60		35			1					1					4				276
12H-3, 85–87	105.55	F	2	5		4	22	9	10	10		1	2		1			3			1						102
12H-3, 105–107	105.75	F		19		7	55	38		30		1	2		1			3		2							214
12H-3, 127–129	105.97	F	1	63		3	54	20		62		6	14		3			2									318
12H-4, 55–57	106.75	F		25		6	16	16	4	11		2						1					3				124
12H-4, 77–79	106.97	F		15	1	8	43	26		20	2												2				167
12H-4, 95–97	107.15	F		30		8	44	38	1	24		2	2							1	1		14				260
12H-4, 113–115	107.33	F		12		2	39	4		7		1	1							2			8				110
12H-4, 135–137	107.55	F		12		10	23	11		6								1					3				113
12H-5, 5–7	107.75	F		17		16	52	47	1	47	4	3						2		2	1				2	1	293
12H-5, 23–25	107.93	F		12		9	39	25		18	4	11						2			2						193
12H-5, 43–45	108.13	F		16		9	19	27	2	24		2	1		1			2	2	1			1				159
12H-5, 66–68	108.36	F		8	4	2	15	20		10	10												1				105
12H-5, 83–85	108.53	F	2	11	1	3	25	9		15		2					1										82
12H-6, 13–15	109.33	F	4	29		10	44	29	1	54	1	2	3					2									220
12H-6, 34–36	109.54	F	2	27	2	24	56	29	2	40	5	4	1	1	2			8									260
12H-6, 55–57	109.75	F																									4
12H-6, 73–75	109.93	F																									4
12H-6, 95–97	110.15	F		5		2	16	4		4								2									51
12H-6, 113–115	110.33	F																									1
12H-7, 5–7	110.75	F		22		29	79	37	2	35		7	2					4		2	1	1		1			313
12H-7, 23–25	110.93	F	1	9	3	19	73	44		24			5		1					5							231
12H-7, 44–46	111.14	F																									6
12H-7, 66–68	111.36	F				1																					8

Note: See Table 1. Abundance = number of specimens

Table 7. Occurrences and abundance of benthic foraminifers, Hole 887C.

Core, section, interval (cm)	Depth (mbsf)	Preservation	*Anomalina* sp.	*Anomalinoides* sp.	*Bolivina decussata*	*Bolivina pseudopunctata*	*Bulimina alazanensis*	*Cassdulina* sp.	*Cassidulina laevigata*	*Chilostomella argentae*	*Cibicidoides cicatricosus*	*Cibicidoides kullenbergi*	*Eggerella bradyi*	*Ehrenbergina trigona*	*Epistominella exigua*	*Fontbotia wuellerstorfi*	*Globocassidulina subglobosa*	*Gyroidina lamarkiana*	*Gyroidina soldanii*	*Gyroidina zealandica*	*Hyperammina* sp.	*Kareriella bradyi*	*Laryngosigma hyalascidia*	*Laticarinina pauperata*
12H-1, 5–7	93.35	F				1					1		9			5	3	3	2			1		4
12H-1, 22–24	93.52	F											2											
12H-1, 45–47	93.75	F			2						5	4	11	1	3	13	2		2					3
12H-1, 65–67	93.95	F						1					7				2			1				6
12H-1, 105–107	94.35	F			1		2					9	12		7	14	5							1
12H-1, 125–127	94.55	F			3								15		5	33	3	5		1				7
12H-1, 145–147	94.75	F			5						1	5	7	2	5	9				4				7
13H-1, 5–7	102.85	F		1							2		3		7	1	17	2			1			1
13H-1, 25–27	103.05	F			1								1	2	10	6	25		5	2				1
13H-1, 45–47	103.25	F							1				11		1		2	1						
13H-1, 65–67	103.45	F											12		2	1	7	1						
13H-1, 85–87	103.65	F								2	1		15		5	11	53	4		1		3		
13H-1, 105–107	103.85	F											6	1	3	1	9	4						2
13H-1, 125–127	104.05	F	1		8					1		5	11	2	24	16	49	3						4
13H-1, 145–147	104.25	F			4								17	1	30	6	35		6				1	1

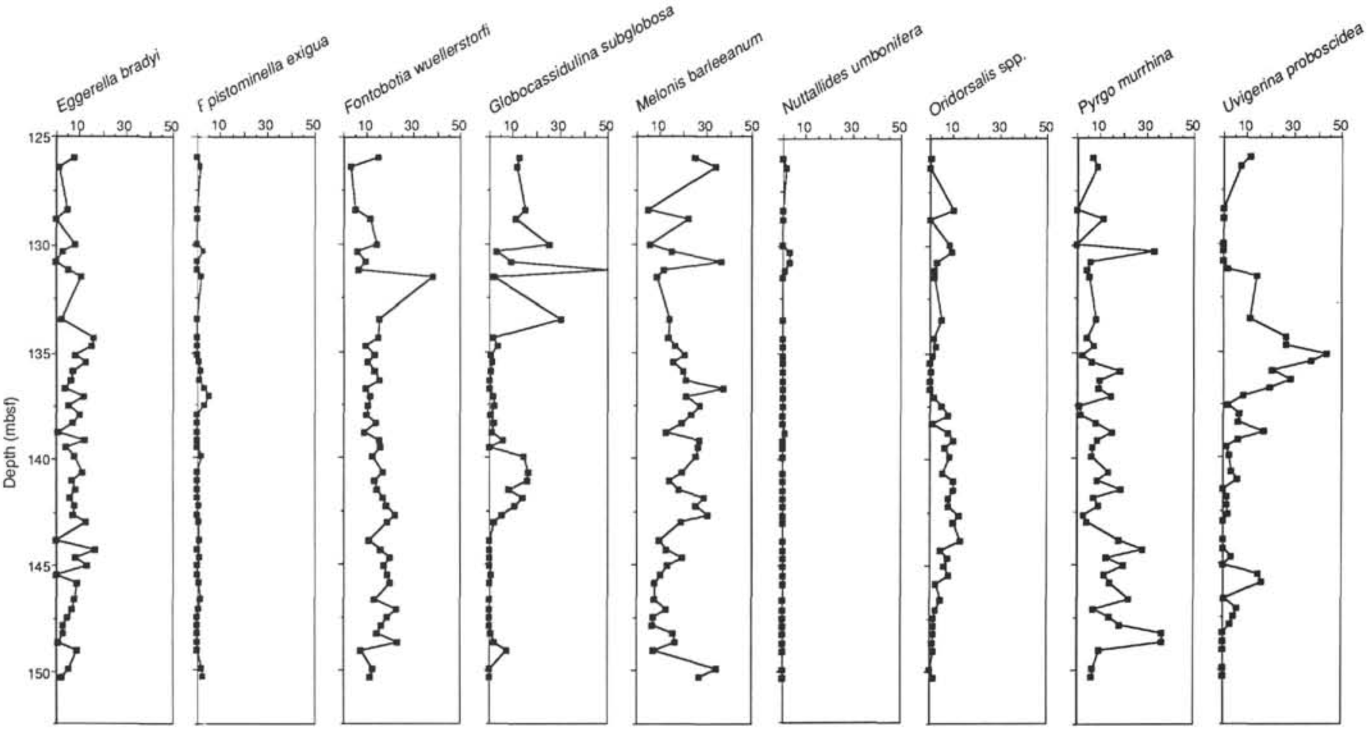

Figure 3. Percent abundance of selected benthic foraminifers vs. depth for Hole 883B (*Oridorsalis* spp. = *Oridorsalis tener* [Brady] and *Oridorsalis umbonatus* [Reuss]).

They noted that it is a highly variable species with four to five large chambers in the final whorl, reticulate microcrystalline and crystalline ultrastructure related to secondary calcification, and large apertural variability including the occasional development of an apertural lip. They indicated that small forms of *N. atlantica* with a kummerform final chamber intergrade morphologically with *Neogloboquadrina pachyderma*.

Poore (1981) documented the presence of *N. atlantica* in the foraminifer assemblages of DSDP Sites 467–471 in the North Pacific Ocean. Aside from being predominantly dextrally coiled, these specimens are essentially identical to those observed in the North Atlantic.

At DSDP Site 552, Dowsett and Poore (1990) noted that encrustation of tests sometimes made the distinction between *Globigerina bulloides* and *Neogloboquadrina atlantica* difficult. We find that the amount of secondary calcification occurring in many samples from Sites 883 and 887 makes it extremely difficult to distinguish between these two taxa. Plate 2 (Fig. 10) shows a *Globigerina bulloides* specimen showing recalcification of all but the ultimate kummerform

Table 7 (continued).

Core, section, interval (cm)	Depth (mbsf)	Preservation	*Lenticulina* sp.	*Melonis barleeanum*	*Melonis pompilioides*	*Nodosariidae*	*Nonionella* sp.	*Nuttallides umbonifera*	*Oridorsalis* spp.	*Osangularia* sp.	*Pleurostomella acuta*	*Pullenia bulloides*	*Pullenia quinqueloba*	*Pullenia salisburyi*	*Pyrgo* spp.	*Quinqueloculina venusta*	*Sphaeroidina bulloides*	*Stainforthia complanata*	*Stilostomella lepidula*	*Textularia abbreviata*	*Triferina angulosa*	*Uvigerina proboscidea*	*Valvulineria* sp.	Species 1	Total
12H-1, 5–7	93.35	F	2	3		10		24				2		1					1			18		1	91
12H-1, 22–24	93.52	F																							2
12H-1, 45–47	93.75	F		32	1	7		29	6			5		1						1		1			129
12H-1, 65–67	93.95	F		7		6		38	2					2					3			17			92
12H-1, 105–107	94.35	F	1	20	1	9		47	3			14		2				1	3			11			163
12H-1, 125–127	94.55	F		25		15		92	29			16	1			2						22	2		276
12H-1, 145–147	94.75	F		41		9		42	12	1	4	8			2	1			3			25	3		196
13H-1, 5–7	102.85	F		6		5		15	15			18		2	1		2	1							100
13H-1, 25–27	103.05	F		19		3		22	15		1	14			4		2				1	1			135
13H-1, 45–47	103.25	F		2	2	1		4	1			7		1	1										35
13H-1, 65–67	103.45	F		3		4		12	3			4			2			1							52
13H-1, 85–87	103.65	F		14	1	13	2	37	10		2	14	2									6			196
13H-1, 105–107	103.85	F			4			15	4			7	1	11	2		2								72
13H-1, 125–127	104.05	F		32		24	1	67	51		2	41	7		6		1		1			11			368
13H-1, 145–147	104.25	F		17		5		50	25			16		1	1		1				1	13			231

Note: See Table 1. Abundance = number of specimens.

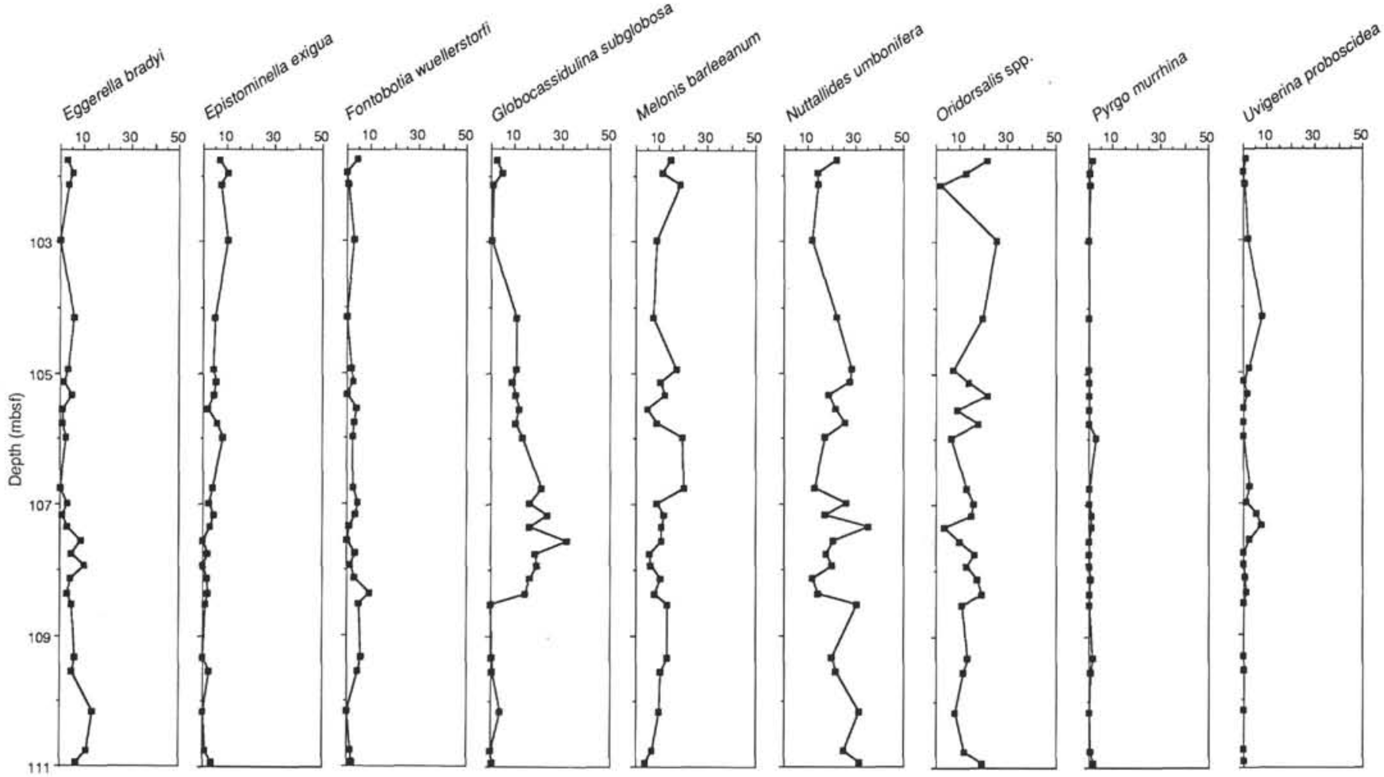

Figure 4. Percent abundance of selected benthic foraminifers vs. depth for Hole 887A (*Oridorsalis* spp. = *Oridorsalis tener* [Brady] and *Oridorsalis umbonatus* [Reuss]).

chamber. This obliterates the distinctive globigerine surface ultrastructure shown in Plate 2 (Fig. 12). Plate 3 (Figs. 1 and 2) shows the reticulate microcrystalline surface ultrastructure with pore pits typical of *Neogloboquadrina* spp. Fully crystalline structure can be found on many specimens from Sites 883 and 887.

No other workers have reported the presence of *N. atlantica* in the Pliocene assemblages of the subarctic North Pacific. We agree with Poore (1981) that *N. pachyderma* form 3 of Keller (1978a, 1978b), documented at DSDP Sites 173 and 310 and the Centerville Beach section of northern California (Keller and Ingle, 1981) as well as *Neogloboquadrina asanoi* (Maiya, Saito, and Sato) and *Neogloboquadrina kagaensis* (Maiya, Saito, and Sato), are referable to *N. atlantica*. We postulate that at higher latitudes, *N. atlantica* has been previously identified as *Globigerina bulloides* or *Neogloboquadrina pachyderma*, as a result of poor preservation and crystalline overgrowth.

Mid-Pliocene North Pacific Sea-surface Conditions

The lack of a sufficient number of high-latitude coretop carbonate-bearing samples for temperature calibration preclude the use of transfer functions or quantitative modern analog techniques of temperature estimation. However, late Pleistocene sequences from DSDP Legs 18 and 19 provide a semiquantitative summary of the planktonic foraminifer fauna near the position of ODP Sites 883 and 887. The late Pleistocene faunas are similar from these two regions and are similar to the Pliocene fauna recovered from ODP Site 883. This suggests that the Oyashio Current and Western Subarctic Gyre were in the same approximate positions during the middle Pliocene as they are today. The high-frequency variability seen in the Site 883 assemblages may indicate periodic migration of the path of the Oyashio bringing cooler Arctic water closer to Site 883. Additional work on the Site 883 material is necessary to improve the age model and sampling interval so as to address this question fully.

The Pliocene planktonic assemblages recovered from Site 887 generally show increased numbers of warmer taxa than have been recovered from Pleistocene DSDP Leg 18 material. A similar fauna dominated by *G. bulloides* is recorded by Lagoe et al. (1993) from the Yakataga Formation in the Gulf of Alaska. Barron (1992) documented warmer than modern conditions at DSDP Site 580 that coincided with warming documented in the North Atlantic by Dowsett and Poore (1991). Similar warming has been documented at DSDP Site 36 by Poore (in press). This warming in the North Pacific during the middle Pliocene most likely represents increased heat transport to the Eastern Pacific by way of the Kuroshio Current system.

Mid-Pliocene North Pacific Deep-water Conditions

The benthic foraminifer faunas described from Sites 883 and 887 represent distinct depth-related faunas. The Site 887 fauna shows relative stability and represents a deep-water, upper abyssal (2000–4000 m) fauna thus indicating no significant late Pliocene deep water change in the North Pacific. The fauna described from Site 883 represents a shallower water setting (lower bathyal) and shows greater variability in species abundance than the Site 887 fauna. A significant shift occurs at Site 883, with an increase in *Uvigerina proboscidea* indicating a deepening of the oxygen minima and marking a transition from a *Melonis barleeanum*-dominated assemblage to a *Globocassidulina subglobosa* dominated assemblage. We suggest a significant intermediate to upper deep water change represented by a deepening of the oxygen minimum in the North Pacific, possibly related to a global oceanographic change that also affected the preservation of $CaCO_3$ in the Pacific basin at about 2.9 Ma (Farrell and Prell, 1991).

SUMMARY

This preliminary study indicates that the mid-Pliocene foraminifer faunas at Sites 883 and 887 can be analyzed to estimate paleoceanographic and paleoclimatic conditions in the subarctic North Pacific.

No evidence for mid-Pliocene sea-surface warming can be found at Site 883; however, minor warming is associated with the planktonic faunas at Site 887. This warming is evident in the Yakataga Formation of Alaska and as far south as DSDP Site 36. This implies a greater transport of heat by way of the Kuroshio system during the mid-Pliocene. A look at the longer record from Site 887 may reveal a deep-water record of oceanographic changes associated with other climatic fluctuations recorded in the Yakataga Formation.

The planktonic assemblages at Sites 883 and 887 contain *Neogloboquadrina atlantica* (Berggren) and firmly establish the presence of this taxon in the high-latitude North Pacific. Because of the difficulty in separating some specimens of *N. atlantica* from recalcified specimens of *Globigerina bulloides* using light microscopy, extreme caution should be used when either of these taxa are incorporated into paleoenvironmental studies.

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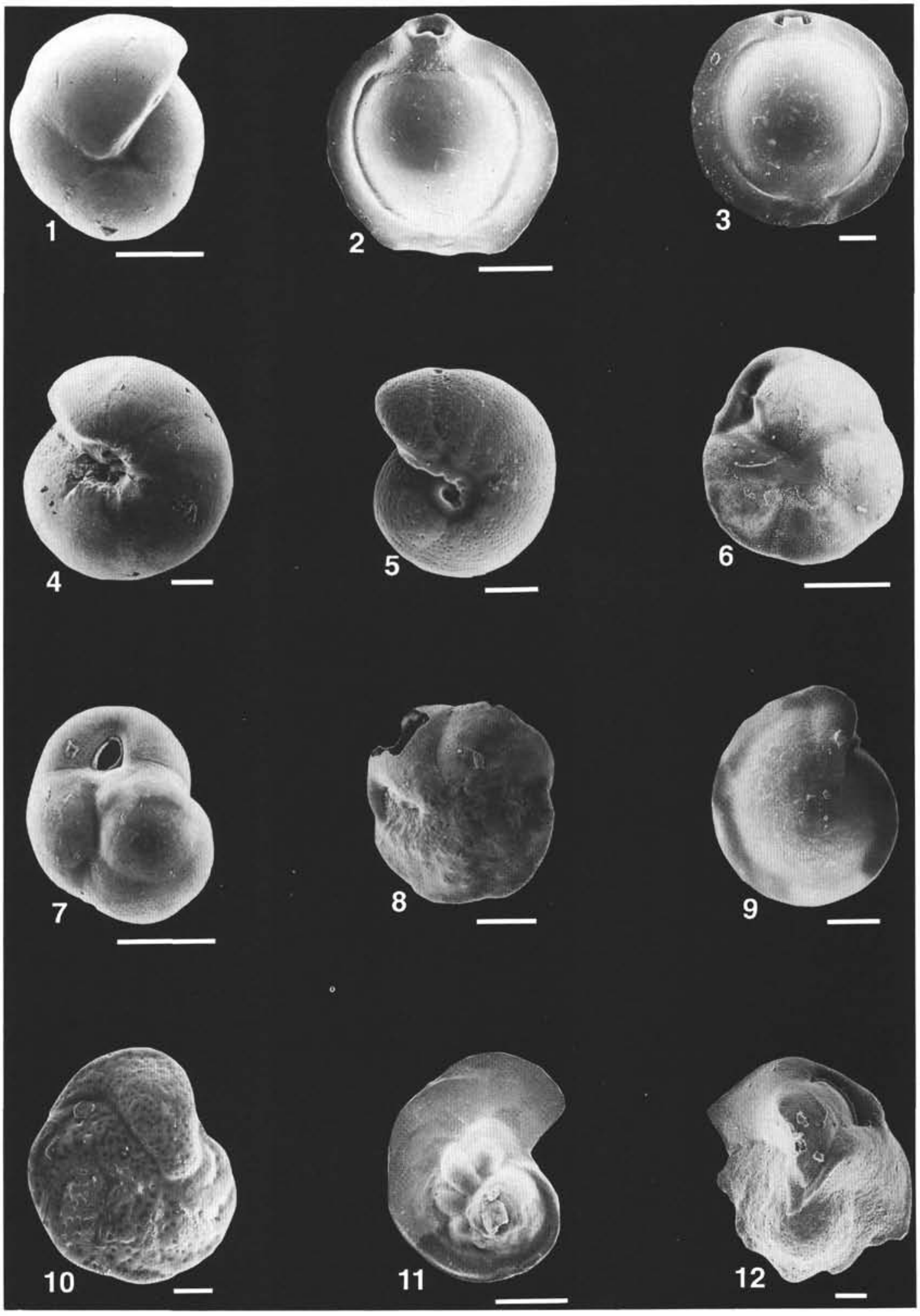

Plate 1. **1.** *Pullenia bulloides* (d'Orbigny); Sample 145-883B-16H-4, 35–40 cm; USNM 483280. **2.** *Pyrgo murrhina* (Schwager); Sample 145-887C-15H-3, 102–107 cm; USNM 483281. **3.** *Pyrgo depressa* (d'Orbigny); Sample 145-887C-15H-3, 102–107 cm; USNM 483282. **4.** *Gyroidina zealandica* Finlay; Sample 145-887C-12H-1, 105–107 cm; USNM 483283. **5.** *Melonis barleeanum* (Williamson); Sample 145-883B-16H-4, 35–40 cm; USNM 483284. **6.** *Epistominella exigua* (Brady); Sample 145-887C-12H-1, 45–47 cm; USNM 483285. **7.** *Globocassidulina subglobosa* (Brady); Sample 145-887A-12H-7, 5–7 cm; USNM 483286. **8.** *Nuttallides umbonifera* (Cushman); Sample 145-887A-12H-7, 5–7 cm; USNM 483287. **9.** *Cibicidoides kullenbergi* (Parker); Sample 145-887A-12H-3, 63–65 cm; USNM 483288. **10.** *Fontbotia wuellerstorfi* (Schwager); Sample 145-883B-16H-4, 35–40 cm; USNM 483289. **11.** *Laticarinina pauperata* (Parker and Jones); Sample 145-887A-12H-1, 43–45 cm; USNM 483290. **12.** *Ehrenbergina trigona* Goës; Sample 145-887A-12H-1, 26–28 cm; USNM 483291. Scale bar = 100 µm.

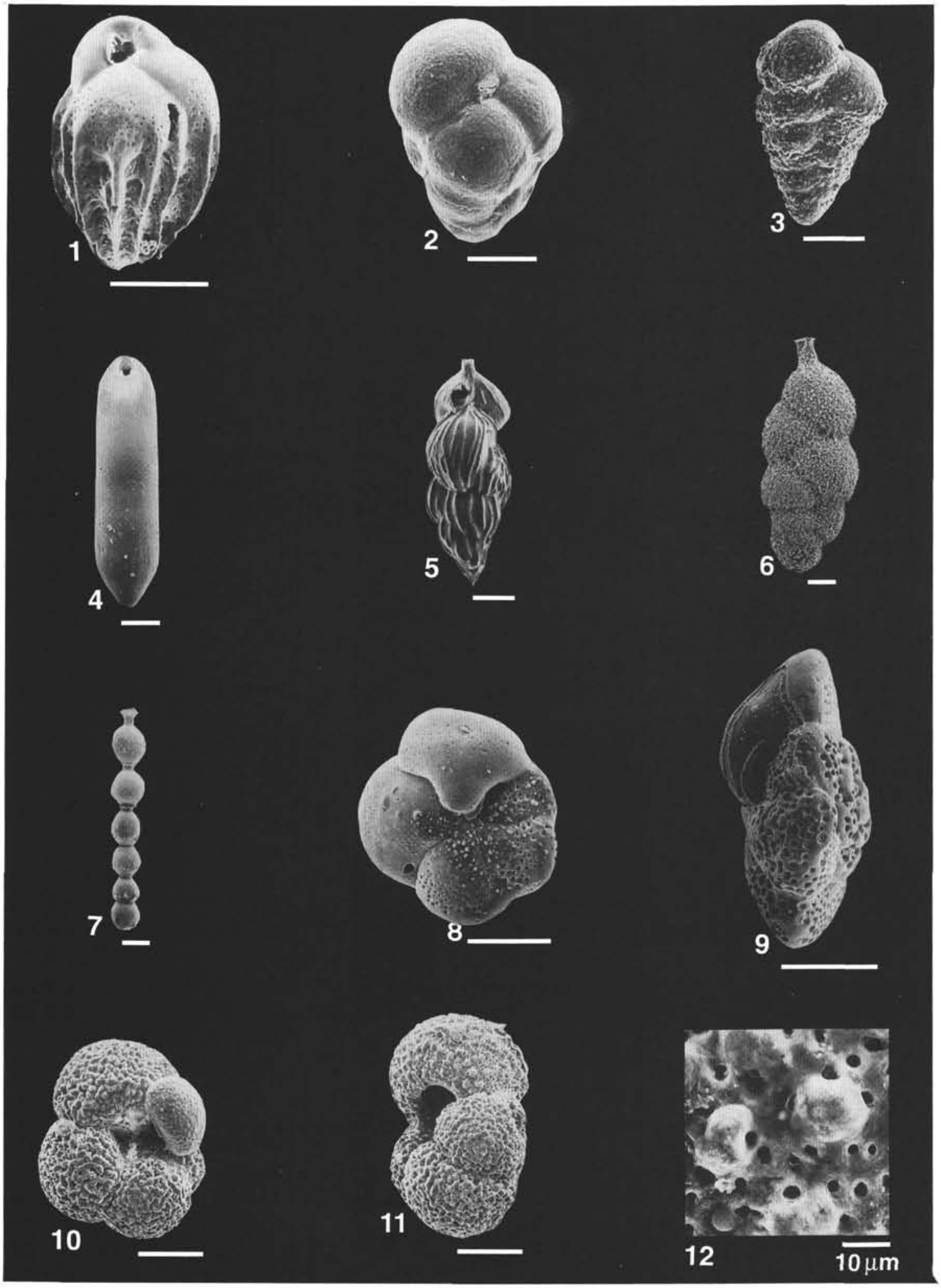

Plate 2. **1.** *Bulimina alazanensis* Cushman; Sample 145-887C-12H-1, 105–107 cm; USNM 483292. **2.** *Eggerella bradyi* (Cushman); Sample 145-887A-12H-1, 43–45 cm; USNM 483293. **3.** *Bolivina decussata* Brady; Sample 145-887A-12H-6, 13–15 cm; USNM 483294. **4.** *Pleurostomella acuta* Hantken; Sample 145-887A-12H-4, 95–97 cm; USNM 483295. **5.** *Trifarina angulosa* (Williamson); Sample 145-883B-16H-4, 35–40 cm; USNM 483296. **6.** *Uvigerina proboscidea* Schwager; Sample 145-887C-15H-3, 102–107 cm; USNM 483297. **7.** *Stilostommella lepidula* (Schwager); Sample 145-887A-12H-1, 43–45 cm; USNM 483298. **8.** *Globorotalia scitula* (Brady); Sample 145-887C-13H-1, 5–7 cm; USNM 483299. **9.** *Globorotalia scitula* (Brady); Sample 145-883B-14H-6, 55–60 cm; USNM 483300. **10.** *Globigerina bulloides* d'Orbigny; Sample 145-883B-14H-2, 15–20 cm; USNM 483301. **11.** *Globigerina bulloides* d'Orbigny; Sample 145-887C-12H-1, 125–127 cm; USNM 483302. **12.** Detail of ultimate chamber of Figure 11 showing globigerine test surface ultrastructure of pore pitted surface and pustules. Scale bar = 100 µm unless otherwise noted.

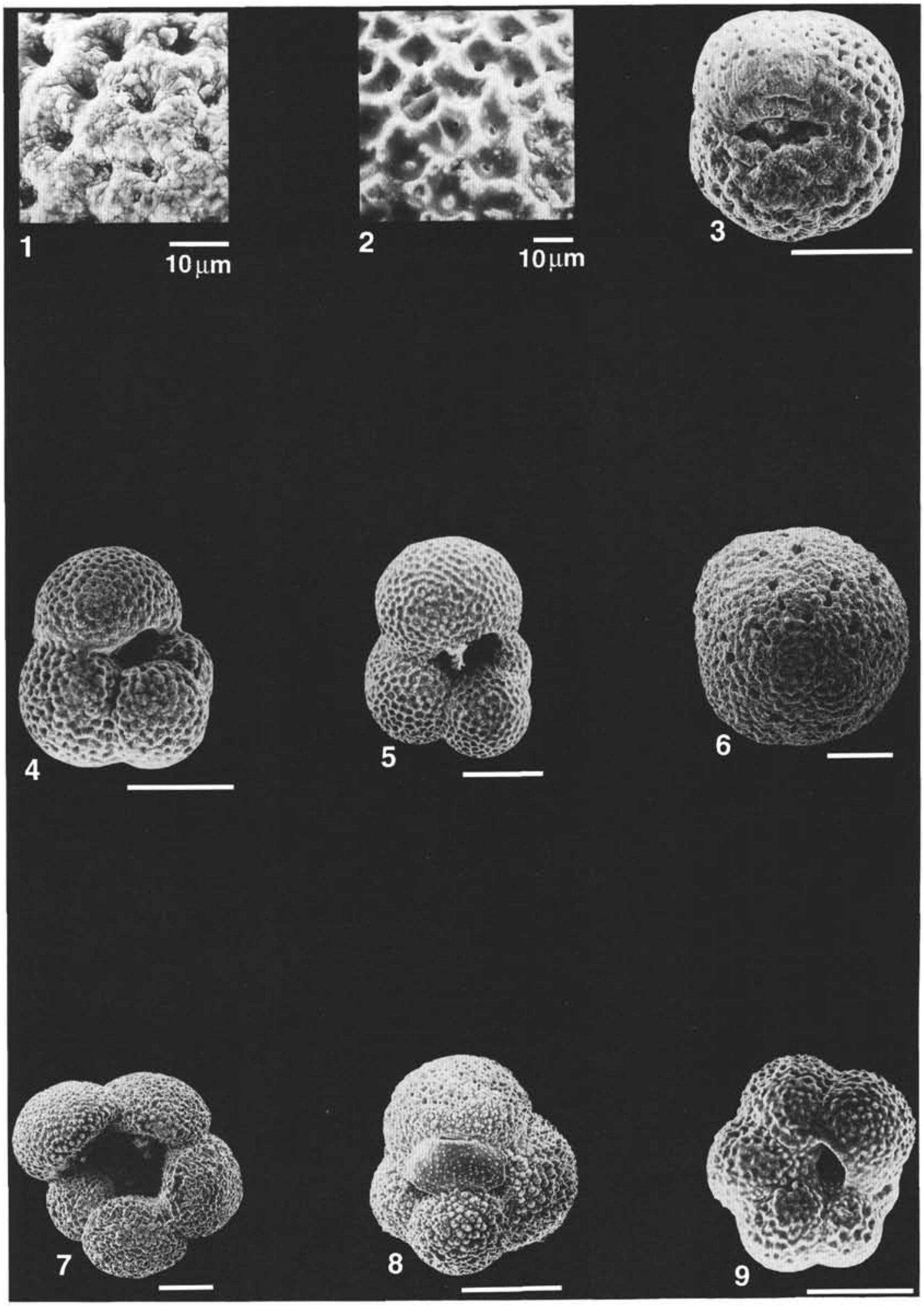

Plate 3. **1.** Detail of reticulate-microcrystalline test surface ultrastructure of ultimate chamber of Figure 4. **2.** Detail of reticulate-microcrystalline test surface ultrastructure of ultimate chamber of Figure 5. **3.** *Neogloboquadrina pachyderma* (Ehrenberg); Sample 145-883B-14H-2, 15–20 cm; USNM 483303. **4.** *Neogloboquadrina atlantica* (Berggren); Sample 145-883B-14H-2, 15–20 cm; USNM 483304. **5.** *Neogloboquadrina atlantica* (Berggren); Sample 145-887A-12H-3, 105–107 cm; USNM 483305. **6.** *Orbulina universa* d'Orbigny; Sample 145-887A-12H-6, 34–36 cm; USNM 483306. **7.** *Globigerina umbilicata* Orr and Zaitzeff; Sample 145-887A-12H-3, 127–129 cm; USNM 483307. **8.** *Globigerinita glutinata* (Egger); Sample 145-883B-15H-7, 35–40 cm; USNM 483308. **9.** *Turborotalita quinqueloba* (Natland); Sample 145-883B-14H-1, 5–10 cm; USNM 483309. Scale bar = 100 μm unless otherwise noted.