Raymo, M.E., Jansen, E., Blum, P., and Herbert, T.D. (Eds.), 1999
Proceedings of the Ocean Drilling Program, Scientific Results, Vol. 162

2. *DATA REPORT:* PLANKTONIC FORAMINIFERS FROM THE SUBPOLAR NORTH ATLANTIC AND NORDIC SEAS: SITES 980–987 AND 907[1]

Benjamin P. Flower[2]

ABSTRACT

During Ocean Drilling Program (ODP) Leg 162, five sites were drilled in the subpolar North Atlantic (Sites 980–984), three sites in the Nordic Seas (Sites 985–987), and two holes at Iceland Sea Site 907 (first drilled during ODP Leg 151). Carbonate sediments at the subpolar sites have generally common to abundant and well-preserved planktonic foraminifers, especially at Feni Drift Sites 980/981 and Rockall Plateau Site 982. Gardar Drift Site 983 and Bjorn Drift Site 984 featured greater concentrations of clay material and ice-rafted debris, diluting carbonate material in some intervals (particularly before ~1.8 Ma at Site 984). Nordic Seas Sites 907 and 985–987 feature generally rare to common and moderately well-preserved planktonic foraminifers only within the past 1 m.y., although Pliocene taxa are sparsely recorded at Site 986 on the Svalbard margin.

Planktonic foraminifer datum levels are located to the section level where possible for the subpolar North Atlantic sites. Comparison to an integrated magnetostratigraphy and calcareous nannofossil stratigraphy shows that several datum levels are synchronous to within 5% of their published ages. In particular, the start of the *Neogloboquadrina pachyderma* (sinistral) Acme Zone (1.8 Ma), the first occurrence (FO) of *Globorotalia inflata* (2.09 Ma), the last occurrence (LO) of *Globorotalia* cf. *crassula* (3.3 Ma), and the FO of *Globorotalia puncticulata* (4.5 Ma) are judged synchronous in eastern sections of the subpolar North Atlantic. The LO of *Neogloboquadrina atlantica* (sinistral) occurs ~100–200 k.y. later relative to its mid-latitude North Atlantic age (2.41 Ma).

INTRODUCTION AND PREVIOUS WORK

The subpolar North Atlantic is an important region in which to study late Neogene paleoceanographic and climatic change. The region is among the most sensitive to glacial–interglacial sea-surface temperature variations (e.g., CLIMAP, 1981) and has a major influence on conversion of surface waters to deep waters and, hence, the global thermohaline circulation (e.g., Broecker and Denton, 1989). Documenting tectonic- to millennial-scale paleoceanographic changes in this region associated with the late Neogene evolution of Northern Hemisphere glaciation is a major goal of Ocean Drilling Program (ODP) Leg 162.

The North Atlantic and Nordic Seas region sampled during Leg 162 ranges from temperate to polar waters. A southeast-northwest transect of subpolar North Atlantic sites (Jansen, Raymo, Blum, et al., 1996) includes high sedimentation-rate locations on Feni Drift, Bjorn Drift, and Gardar Drift (Fig. 1; Table 1). These high sedimentation-rate sites (drilled with the advanced hydraulic piston corer) allow for detailed comparison of geographic synchroneity and asynchroneity among planktonic foraminifer datum levels. Site 982 on the Rockall Plateau reached lower Miocene sediments, providing a nearly complete Neogene sediment sequence for the subpolar North Atlantic. Together with sites from the Nordic Seas, these sites provide insights on subpolar North Atlantic paleobiogeography during the Neogene and the (a)synchroneity of planktonic foraminifer datum levels across the subpolar North Atlantic.

Previous work in this region includes sites drilled on Deep Sea Drilling Project (DSDP) Leg 12 (Hayes, Pimm, et al., 1972), Leg 38 (Talwani, Udintsev, et al., 1976), Leg 81 (Roberts, Schnitker, et al., 1984), and Leg 94 (Ruddiman, Kidd, Thomas, et al., 1987). Neogene planktonic foraminifer paleobiogeography of the subpolar North Atlantic shows progressive reduction in diversity and development of endemic subpolar faunas in the late Miocene and continuing in the late Pliocene (Berggren, 1972; Poore and Berggren, 1975; Poore, 1979; Huddlestun, 1984; Weaver, 1987; Raymo et al., 1987; Spencer-Cervato et al., 1994). These changes are associated with the progressive cooling of the high northern latitudes during the Neogene and the development of Northern Hemisphere glaciations (e.g., Shackleton et al., 1984; Ruddiman, Kidd, Thomas, et al., 1987; Jansen et al., 1988; Raymo et al., 1990).

Whereas the subpolar North Atlantic featured the accumulation of calcareous sediments throughout the Neogene, calcareous sediment preservation in the Nordic Seas (Greenland, Iceland, and Norwegian Seas) began much later, by ~1 Ma (Jansen et al., 1988; Spiegler and Jansen, 1989; Spiegler, 1996). Because calcareous sediment preservation commenced within the Quaternary, planktonic foraminifer faunas are dominated by *Neogloboquadrina pachyderma* (sinistral), although rare incursion of warmer water species is documented in the Pliocene sediments of the Nordic Seas and Arctic Gateway region (Spiegler and Jansen, 1989; Spiegler, 1996).

The progressive development of cold surface-water conditions in the high-latitude North Atlantic has led to the need for two planktonic foraminifer zonation schemes for the late Miocene to Holocene, one for the subpolar North Atlantic (Weaver and Clement, 1986) and one for the Nordic Seas (Spiegler and Jansen, 1989). The tropical and subtropical zonations (Blow, 1969, 1979; Bolli and Saunders, 1985) have limited value in middle to high latitudes because many of the warm-water forms on which these zonations are based are not found at higher latitudes. Zonations for the upper Miocene to Holocene sediment sequence in the subpolar North Atlantic and Nordic Seas are based mainly on species within the neogloboquadrinid and globorotalid groups (Berggren, 1972; Poore and Berggren, 1975; Poore, 1979; Weaver and Clement, 1986, 1987; Weaver, 1987; Hooper and Weaver, 1987; Spiegler and Jansen, 1989). In this study, the subpolar zonation of Weaver and Clement (1986) is used for Sites 980–984, including the upper Miocene to Holocene at Site 982. The Nordic Seas zonation of Spiegler and Jansen (1989) is used for Sites 985–987 and 907.

[1]Raymo, M.E., Jansen, E., Blum, P., and Herbert, T.D. (Eds.), 1999. *Proc. ODP, Sci. Results,* 162: College Station, TX (Ocean Drilling Program).

[2]Department of Marine Science, University of South Florida, St. Petersburg, FL 33701, U.S.A. bflower@marine.usf.edu

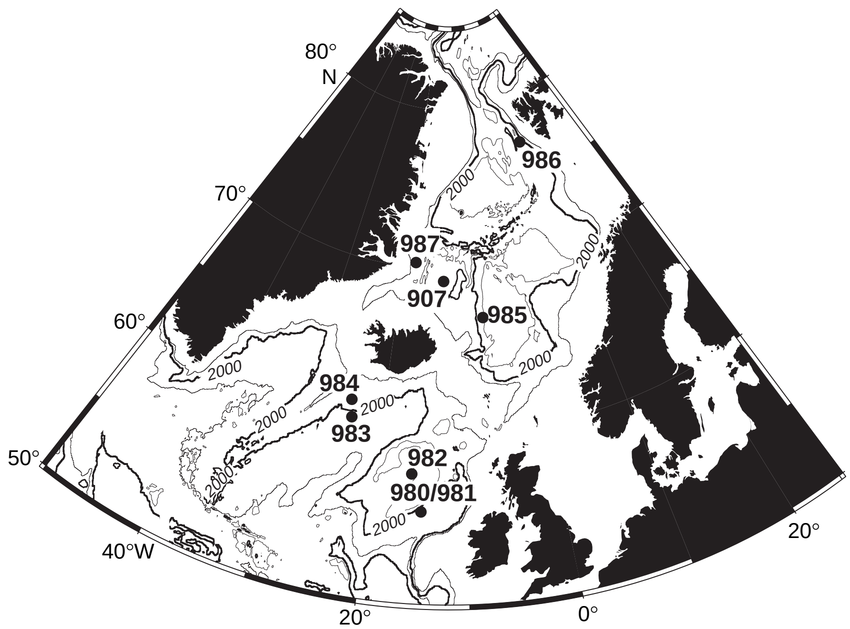

Figure 1. Location map of sites drilled during Leg 162 in the subpolar North Atlantic and Nordic Seas. Contour interval is 1000 m.

Table 1. Leg 162 site locations.

Site	Latitude (°N)	Longitude (°W)	Water depth (mbsl)
907	69°15.0′	12°41.9′	1802
980	55°29.1′	14°42.1′	2168
981	55°28.6′	14°39.0′	2173
982	57°31.0′	15°52.0′	1134
983	60°24.2′	23°38.4′	1983
984	61°25.5′	24°04.9′	1648
985	66°56.5′	6°27.0′	2788
986	77°20.4′	9°04.7′E	2052
987	70°29.8′	17°56.2′	1672

Note: mbsl = meters below sea level.

The generally high abundance and good preservation, plus the continuous sequences obtained in the subpolar North Atlantic, provide excellent material for planktonic foraminifer studies at Feni Drift Sites 980 and 981, Gardar Drift Site 983, and Bjorn Drift Site 984. The oldest age reached among these drift deposits is ~4.8 Ma at Feni Drift Site 981 (~320 meters below seafloor [mbsf]). However, Rockall Plateau Site 982 reached an age of ~18.4 to 19.2 Ma at ~605 mbsf. Feni Drift Site 981 (early Pliocene to Holocene) and Rockall Plateau Site 982 (early Miocene to Holocene) are, therefore, particularly useful for studies that focus on the Neogene.

METHODS

Preliminary age determinations were based on shipboard analysis of planktonic foraminifers from core-catcher samples, in conjunction with other microfossil biostratigraphy and magnetostratigraphy (Shipboard Scientific Party, 1996a). Additional samples were then used to refine the planktonic foraminifer biostratigraphy. Abundance and preservation data were recorded throughout the study to assess surface-water environments and sediment dissolution. Biostratigraphic zonal assignments are correlated with the geomagnetic polarity time scale (GPTS) directly where possible (see Channell and Lehman, Chap. 8, this volume) or correlated indirectly based on calcareous nannofossil data (Jansen, Raymo, Blum, et al., 1996). Placement of epoch boundaries relative to paleomagnetic chrons and biostratigraphic zones followed Berggren et al. (1985, 1995). Age assignments of individual planktonic foraminifer datum levels are from Weaver and Clement (1986), Raymo et al. (1989), and Berggren et al. (1985, 1995), updated to the Cande and Kent (1995) time scale.

Planktonic foraminifers were obtained by disaggregating a 10-cm^3 sample and washing it over a 63-µm sieve. Disaggregation methods for well-indurated sediments included ultrasonic treatment and sodium hexametaphosphate solution. Between samples, sieves were soaked in methylene blue carbonate stain to identify potential contamination. The samples were dried and examined under a binocular microscope, and planktonic foraminifers from the >150-µm fraction were identified to species level where possible. Planktonic foraminifer relative abundance (based on ~200 specimens) was recorded as follows:

D (dominant) = >60%,
A (abundant) = >30%–60%,
C (common) = >10%–30%,
F (few) = >5%–10%,
R (rare) = >1%–5%,
T (trace) = <1%, and
B (barren) = no specimens observed.

Preservation (absence of dissolution and/or calcite overgrowth) was recorded as G (good), M (moderate), and P (poor).

SITE SUMMARIES

Site 907

Two holes were drilled at Iceland Sea Site 907 (Shipboard Scientific Party, 1996b). Hole 907B was selected for planktonic foraminifer biostratigraphy (Table 2) and confirms the information obtained from Hole 907A drilled on ODP Leg 151 (Myhre, Thiede, Firth, et al., 1994). Planktonic foraminifers are found only in the upper part of the section. Assemblages are dominated by *N. pachyderma* (sinistral), indicating cold subpolar conditions. The start of the *N. pachyderma* (sinistral) Acme Zone is not recorded at this location because samples are nearly barren of planktonic foraminifers below Sample 162-907B-3H-CC, 37–40 cm (26.63 mbsf). The trace last occurrence (LO) of *Neogloboquadrina atlantica* in Sample 162-907B-5H-1, 39–41 cm, immediately below rare *N. pachyderma* (sinistral) in Sample

Table 2. Stratigraphic ranges of planktonic foraminifers in selected samples from Hole 907B, Iceland Sea.

Core, section, interval (cm)	Depth (mbsf)	Depth (mcd)	Abundance	Preservation	*Globorotalia inflata*	*Neogloboquadrina atlantica* (sinistral)	*Neogloboquadrina pachyderma* (dextral)	*Neogloboquadrina pachyderma* (sinistral)	Zone	Epoch
162-907B-										
1H-CC, 24-27	7.24	7.46	C	G			T	D	*N. pachyderma* (s.)	Pliocene
2H-CC, 22-25	17.08	17.41	C	G				D		
3H-CC, 37-40	26.63	28.20	R	G				D		
4H-CC, 17-20	36.20	38.35	T	M	R			D		
5H-1, 39-41	36.19	39.26	T	M		D				Pleistocene
5H-3, 39-41	39.19	42.26	T	M		D				
5H-CC, 22-25	45.87	48.94	B							
6H-CC, 32-35	55.33	59.40	B							
7H-CC, 23-26	64.67	69.24	B							
8H-CC, 24-27	74.09	79.36	B							
9H-CC, 35-38	83.96	89.64	B							
10H-CC, 23-26	93.24	99.26	B							
11H-2, 35-37	94.65	101.28	B							
11H-CC, 20-23	102.84	109.47	B							
12H-CC, 27-30	112.24	118.80	B							
13H-CC, 15-18	121.77	129.00	B							
14H-CC, 22-25	131.20	139.59	B							
15H-CC, 25-28	140.50	149.21	B							
16H-CC, 28-31	150.19	159.66	B							
17H-CC, 24-27	159.88	170.12	B							
18H-CC, 24-27	169.14	181.06	B							
19H-CC, 21-24	178.76	191.95	B							
20H-CC, 22-25	188.12	202.89	B							
21H-CC, 0-1	197.38	212.51	B							
22H-CC, 1-3	206.86	223.65	B							
23H-CC, 15-18	216.55	234.07	B							

Note: D = dominant, A = abundant, C = common, F = few, R = rare, T = trace, B = barren, G = good, M = moderate, P = poor, s. = sinistral.

4H-CC, 17–20 cm, is consistent with previous observations in the Nordic Seas where the LO of *N. atlantica* approximates the Pliocene/Pleistocene boundary (Spiegler and Jansen, 1989; Spiegler, 1996).

Site 980

Three holes were drilled at Feni Drift Site 980 (Shipboard Scientific Party, 1996c); Hole 980A was selected for planktonic foraminifer biostratigraphy. Planktonic foraminifers are abundant and well preserved throughout the lower Pleistocene to Holocene sediment sequence (Table 3). Common taxa include *Globigerina bulloides, Globigerina quinqueloba, Globigerinita glutinata*, *Globorotalia inflata, Globorotalia scitula,* and *Neogloboquadrina pachyderma* (both sinistral and dextral forms). Assemblage composition is dependent upon whether the sample happened to fall within a glacial or interglacial interval; sample resolution is insufficient to resolve glacial–interglacial cycles. Inferred glacial samples feature abundant *N. pachyderma* (sinistral), whereas inferred interglacial samples feature common *Gg. bulloides* and *Gr. inflata*. Paleoenvironmental conditions range from warm subpolar to cold subpolar. Hole 980A lies entirely within the *N. pachyderma* (sinistral) Acme Zone, which is Pleistocene in age.

Site 981

Three holes were drilled at Feni Drift Site 981 (Shipboard Scientific Party, 1996c); Hole 981A was selected for planktonic foraminifer biostratigraphy. Planktonic foraminifers are abundant and well preserved throughout the lower Pliocene to Holocene sediment sequence (Table 4). Pleistocene taxa include *Gg. bulloides*, *Gg. quinqueloba*, *Ga. glutinata*, *Gr. inflata*, *Gr. scitula*, and *N. pachyderma* (both sinistral and dextral forms). As in Hole 980A, assemblage composition is dependent upon whether the sample happened to fall within a glacial or interglacial interval. Inferred glacial samples feature abundant *N. pachyderma* (sinistral), whereas inferred interglacial samples feature common *Gg. bulloides* and *Gr. inflata*. Paleoenvironmental conditions range from warm subpolar to cold subpolar. The base of the Pleistocene sediments is approximated by the start of the *N. pachyderma* (sinistral) Acme Zone between Samples 162-981A-11H-5, 9–11 cm, and 11H-6, 130–132 cm (98.09–100.80 mbsf).

The Pliocene is subdivided into four zones, following Weaver and Clement (1986): the latest Pliocene *Gr. inflata* Zone, the late Pliocene *Gg. bulloides* Zone, the mid-Pliocene *N. atlantica* Zone, and the early Pliocene *Gr. puncticulata* Zone (also the latest part of the latest Miocene to early Pliocene *Gr. margaritae* Zone). Common taxa in the *Gr. inflata* Zone include the nominate species, *Gg. bulloides*, *Gg. quinqueloba*, *Ga. glutinata*, *Gr. scitula*, *N. pachyderma* (dextral), and *Orbulina universa*. Common taxa in the *Gg. bulloides* Zone include the nominate species, *Gr. crassaformis*, *Gr. scitula*, *N. pachyderma* (dextral), and *O. universa*. Common taxa in the *N. atlantica* Zone include the nominate species, *Gg. bulloides*, *Gr. crassaformis*, *Gr. scitula*, *N. pachyderma* (dextral), and *O. universa*. Common taxa in the *Gr. puncticulata* Zone include the nominate species, *Gg. bulloides*, *N. atlantica* (sinistral), and *N. pachyderma* (dextral). Common taxa in the *Gr. margaritae* Zone include *Gg. bulloides*, *N. atlantica* (sinistral), *N. pachyderma* (dextral), and *O. universa*.

Several Pliocene planktonic foraminifer datum levels are recorded in Hole 981A. The first occurrence (FO) of *Gr. inflata* (2.09 Ma) is recorded between Samples 162-981A-13H-CC, 14–17 cm, and 14H-1, 49–51 cm (120.82–120.99 mbsf). The LO of *N. atlantica* (sinistral; 2.41 Ma) is recorded between Samples 162-981A-16H-4, 19–21 cm, and 16H-5, 19–21 cm (144.19–145.69 mbsf). The LO of *Gr. puncticulata* (2.41 Ma) is recorded between Samples 162-981A-16H-6, 19–21 cm, and 16H-7, 19–21 cm (147.19–148.69 mbsf). The LO of *Globorotalia* cf. *crassula* (3.3 Ma) is recorded between Samples 162-981A-23H-2, 30–32 cm, and 23H-CC, 9–12 cm (207.80–215.63 mbsf). Lastly, the FO of *Gr. puncticulata* (4.5 Ma) is recorded between Samples 162-981A-30H-4, 70–72 cm, and 30H-5, 70–72 cm (277.70–279.20 mbsf). The absence of both *Gr. puncticulata* and *Neogloboquadrina acostaensis* at the base of Hole 981A indicates an age between 4.5 and 5.29 Ma.

Site 982

Four holes were drilled at Rockall Plateau Site 982 (Shipboard Scientific Party, 1996d). A limited number of samples was examined in Hole 982A (Table 5); Hole 982B was selected for planktonic foraminifer biostratigraphy (Table 6). Planktonic foraminifers are generally abundant from the top of the section to Sample 162-982A-20H-CC, 15–18 cm (188.86 mbsf); common from Sample 162-982A-21H-CC, 24–27 cm (198.54 mbsf), to Sample 162-982B-58X-CC, 30–33 cm (541.58 mbsf); and few to the base of the section. Preservation is generally good from the top of the section to Sample 162-982A-20H-CC, 15–18 cm (188.86 mbsf), and moderate from Sample 162-982A-21H-CC, 24–27 cm (198.54 mbsf), to the base of the section (Tables 5, 6). Moderate preservation (numerous planktonic foraminiferal fragments) in the Miocene section significantly reduces the reliability of datum levels, as well as species richness.

The subpolar zonation of Weaver and Clement (1986) is applicable in the upper Miocene to Holocene sediment sequence, and the temperate zonation of Poore and Berggren (1975) is applicable in the lower to middle Miocene. The base of the Pleistocene sediments is approximated by the start of the *N. pachyderma* (sinistral) Acme

Table 3. Stratigraphic ranges of planktonic foraminifers in selected samples from Hole 980A, Feni Drift.

Core, section, interval (cm)	Depth (mbsf)	Depth (mcd)	Abundance	Preservation	*Globigerina aequilateralis*	*Globigerina bulloides*	*Globigerina quinqueloba*	*Globorotalia crassaformis*	*Globorotalia inflata*	*Globorotalia scitula*	*Globorotalia truncatulinoides*	*Globigerinita glutinata*	*Globigerinita uvula*	*Neogloboquadrina pachyderma* (dextral)	*Neogloboquadrina pachyderma* (sinistral)	*Orbulina universa*	Zone	Epoch
162-980A-																		
1H-2, 67-69	2.17	6.28	A	G		A			R	R			T	C	A		*N. pachyderma* (s.)	Pleistocene
1H-5- 39-41	6.39	10.50	A	G		A			R	R			T	R	A			
1H-5, 137-139	7.37	11.48	A	G		A			C	F		F		F	R			
1H-6, 80-82	8.30	12.41	A	G		A			F	F	R	R		R	F	R		
1H-CC, 14-17	9.36	13.47	A	G		A	F		F	F		F		F	F			
2H-CC, 15-18	18.95	24.09	A	G		C	R		F	F	R	F		F	C	F		
3H-CC, 15-18	28.61	35.33	A	G		A	R		F	F		R		C	C			
4H-4, 50-52	33.40	41.31	A	G		A	F		R	F	T	T		F	F/C	T		
4H-5, 50-52	34.90	42.81	A	G		C/A	F		C	F	R	R		F	T/R	T		
4H-6, 50-52	36.40	44.31	C	G		T				T				T	D			
4H-CC, 15-18	38.20	46.11	A	G		A			F	F				F	C	R		
5H-CC, 12-15	47.66	56.89	A	G		C			C	F	R			F	C			
6H-CC, 18-21	57.19	67.26	A	G		C	F		C	F		R	T	C	C			
7H-CC, 22-25	66.84	78.39	A	G		C	C/A		F	F		R		F	C			
8H-CC, 15-18	76.21	88.52	A	G		C	C		C	C			T	C	T	T		
9H-CC, 13-16	85.71	98.90	A	G	T/R	F	F		R	R		T		F	A	T		
10H-CC, 19-22	95.27	109.50	A	G		C	F		F	F		T		F	C/A			
11H-CC, 26-29	104.75	118.62	A	G		F/C	F		F	T		T		R/F	A			
12H-CC, 24-27	114.41	129.37	A	G		F/C	F/C	T	F	F		T	T	C	C			

Note: Abbreviations as in Table 2.

Zone between Samples 162-982B-5H-2, 110–112 cm, and 5H-3, 110–112 cm (36.60–37.76 mbsf). The start of this zone is located based on the first consistent (rare) appearance of the nominate taxon, rather than trace occurrences (Table 6).

The Pliocene is subdivided into four zones as in Hole 981A: the latest Pliocene *Gr. inflata* Zone, the late Pliocene *Gg. bulloides* Zone, the mid-Pliocene *N. atlantica* Zone, and the early Pliocene *Gr. puncticulata* Zone (also the latest part of the latest Miocene to early Pliocene *Gr. margaritae* Zone). The Miocene is subdivided into four zones: the latest Miocene *Gr. conomiozea* Zone, the late Miocene *N. acostaensis* Zone, the middle Miocene *Orbulina suturalis* Zone, and the latest early Miocene *Praeorbulina* Zone (Table 6).

Pliocene planktonic foraminifer datum levels recorded in Hole 982B include the FO of *Gr. inflata* (2.09 Ma) between Samples 162-982B-5H-5, 110–112 cm, and 5H-6, 104–106 cm (41.10–42.54 mbsf); the LO of *N. atlantica* (sinistral; 2.41 Ma) between Samples 162-982B-6H-2, 54–56 cm, and 6H-3, 65–67 cm (45.54–47.15 mbsf); the LO of *Gr. puncticulata* (2.41 Ma) between Samples 162-982B-7H-3, 18–20 cm, and 7H-4, 18–20 cm (56.18–57.68 mbsf); the LO of *Globorotalia* cf. *crassula* (3.3 Ma) between Samples 162-982B-8H-4, 140–142 cm, and 8H-5, 140–142 cm (68.42–69.9 mbsf); and the FO of *Gr. puncticulata* (4.5 Ma) between Samples 162-982B-12H-7, 20–22 cm, and 13H-1, 30–32 cm (109.70–110.30 mbsf).

In the lower to middle Miocene sediments (before ~7–10 Ma), some planktonic foraminifer datum levels from subtropical (Blow, 1969, 1979; Bolli and Saunders; 1985) to temperate (Berggren, 1972; Poore and Berggren, 1975; Poore, 1979; Berggren et al., 1983; Weaver and Clement, 1986) zonations are applicable. Datum levels recorded in Hole 982B include the LO of *N. acostaensis* (5.29 Ma) between Samples 162-982B-18H-3, 24–26 cm, and 18H-4, 24–26 cm (160.74–162.24 mbsf); dextral to sinistral *N. atlantica* (6.4 Ma) between Samples 162-982B-26H-3, 19–21 cm, and 26H-4, 19–21 cm (236.69–238.19 mbsf); the FO of *N. acostaensis* (10.03 Ma) and LO of *Paragloborotalia mayeri* (10.30 Ma) between Samples 162-982B-35X-CC, 33–36 cm, and 36X-1, 19–21 cm (323.03–326.49 mbsf); the FO of *O. suturalis* (15.1 Ma) between Samples 162-982B-53X-6, 19–21 cm, and 53X-CC, 34–37 cm (497.39–498.61 mbsf); and the LO of *Catapsydrax dissimilis* between Samples 162-982B-58X-CC, 30–33 cm, and 59X-CC, 67–70 cm (541.58–548.07 mbsf). Interestingly, the small, biserial form *Streptochilus globigerum* is abundant in Sample 162-982B-40X-CC, 33–36 (372.28 mbsf), of earliest late Miocene age.

Lower to middle Miocene sediments at subpolar North Atlantic Site 982 can be correlated with subtropical to temperate zonation schemes, consistent with low meridional sea-surface temperature gradients. In particular, the latest early Miocene *Praeorbulina* Zone and the early part of the middle Miocene *Orbulina suturalis* Zone (Blow, 1969, 1979; Bolli and Saunders, 1985) are recognized. Use of the temperate late Miocene *N. acostaensis* Zone and the latest Miocene *Gr. conomiozea* Zone (Poore and Berggren, 1975) at Site 982 is consistent with increased meridional sea-surface temperature gradients in the subpolar North Atlantic after the middle Miocene.

Site 983

Three holes were drilled at Gardar Drift Site 983 (Shipboard Scientific Party, 1996e); Hole 983A was selected for planktonic foraminifer biostratigraphy. Planktonic foraminifers are generally common and well preserved throughout the uppermost Pliocene to Holocene sediment sequence (Table 7). Faunal assemblages indicate distinctly cooler conditions than at Feni Drift Sites 980/981 and Rockall Plateau Site 982. Fauna are frequently dominated by *N. pachyderma* (sinistral), although *Gg. bulloides*, *Gr. inflata*, *Gr. scitula*, *Ga. glutinata*, *Gg. quinqueloba*, and *N. pachyderma* (dextral) are also recorded. Two barren intervals are recorded in Samples 162-983A-16H-CC, 20–23 cm (150.24 mbsf), and 25H-3, 20–22 cm (229.10 mbsf; near the base of the Pleistocene sediments). The base of the Pleistocene is approximated by the start of the *N. pachyderma* (sinistral) Acme Zone between Samples 162-983A-25H-4, 20–22 cm, and 25H-5, 20–22 cm (230.60–232.10 mbsf).

Table 4. Stratigraphic ranges of planktonic foraminifers in selected samples from Hole 981A, Feni Drift.

Core, section, interval (cm)	Depth (mbsf)	Depth (mcd)	Abundance	Preservation	*Globigerina aequilateralis*	*Globigerina bulloides*	*Globigerina falconensis*	*Globigerina quinqueloba*	*Globigerina decoraperta*	*Globigerinoides ruber*	*Globigerinoides conglobatus*	*Globorotalia crassaformis*	*Globorotalia* cf. *crassula*	*Globorotalia inflata*	*Globorotalia margaritae*	*Globorotalia puncticulata*	*Globorotalia scitula*	*Globorotalia truncatulinoides*	*Globigerinita glutinata*	*Globigerinita uvula*	*Neogloboquadrina atlantica* (dextral)	*Neogloboquadrina atlantica* (sinistral)	*Neogloboquadrina pachyderma* (dextral)	*Neogloboquadrina pachyderma* (sinistral)	*Orbulina bilobata*	*Orbulina universa*	*Streptochilus tokelauae*	Zone	Epoch
162-981A-																													
1H-CC, 17-20	6.45	7.52	A	G		C		F						R			F	T	T/R				F	C		T		*N. pachyderma* (s.)	Pleistocene
2H-CC, 13-16	16.24	17.43	A	G		C		R									F	T	T				R	T		T			
3H-CC, 19-22	25.74	27.64	A	G		C		F/C						F			F/C						F	F		T/R			
4H-CC, 15-18	35.36	38.59	A	G		C		C						F/C			R/F		R	T			C	F/C		T			
5H-CC, 72-75	44.59	48.70	A	G		F		R						R/F			R		R				C	C					
6H-CC, 23-26	54.38	59.90	A	G	T	F		T/R				T		C			F		T/R				R	R	T	R			
7H-CC, 16-19	63.81	70.91	A	G		F		F						R			R		R				F	C					
8H-CC, 21-24	73.43	81.23	A	G		C			T	T				C			F	F/C	R				F	F					
9H-CC, 24-27	82.93	92.69	A	G	F	A								A			F		F				F	R		C			
10H-CC, 26-29	89.22	100.15	A	G	C	C								C			F		F				R	R					
11H-1, 49-51	92.49	104.05	A	G	T	C		R						C/A					F				R	C	T	R			
11H-2, 49-51	93.99	105.55	A	G		A						F		C			F		R				R	R					
11H-3, 49-51	95.49	107.05	A	G	T	A		R						C			F		R				R	C		F			
11H-5, 9-11	98.09	109.65	A	G		A		R						C			F		R				R	F		R			
11H-6, 130-132	100.80	112.36	A	G		C								A			R						F			R		*G. inflata*	late Pliocene
11H-CC, 19-22	101.67	113.23	A	G		A								C			F						R			F			
12H-CC, 24-27	111.47	123.57	A	G		A						F		C			F		F				F			C			
13H-CC, 14-17	120.82	134.18	A	G								T		R			F						C						
14H-1, 49-51	120.99	135.01	A	G		A											R						C	R	T	F		*Gg. bulloides*	
14H-2, 49-51	122.49	136.51	A	G	T	A											R		F				C			R			
14H-CC, 25-28	130.48	144.50	A	G	T	A						F					F		F				C			A			
14H-CC, 18-21	139.80	153.82	A	G		C						C				T	F						C			F			
16H-1, 13-21	139.63	154.69	A	G	T	A						C											C			F			
16H-2,19-21	141.19	156.25	A	G		A						C					F		R							C			
16H-3,19-21	142.69	157.75	A	G		A						C					F						F			C			
16H-4, 19-21	144.19	159.25	A	G		A						C				T			R				C			C			
16H-5, 19-21	145.69	160.75	A	G		A						R					R					C	F			F		*N. atlantica* (s.)	
16H-6, 19-21	147.19	162.25	A	G		C															D		C			R			
16H-7, 19-21	148.69	163.75	A	G		A						C				R	R					A	F			R			
16H-CC, 20-23	149.42	164.48	A	G	R	F										R	F		R			C				F			
17H-CC, 21-24	158.81	173.77	A	M		C											R		R			A				F			
18H-CC, 28-31	168.42	184.20	A	G	T	F													F			A				F			
19H-CC, 25-28	177.86	194.32	A	G	R	F						R				R	F		F							F			
20H-CC,15-18	187.29	204.68	A	G	T	C										F			R			A				C			
21H-CC, 17-20	196.71	214.44	A	G	T	C										A	F		F			F				F			
22H-CC, 14-17	206.30	225.49	A	G	T	C										C	F					C			T	F			
23H-1, 30-32	206.30	226.47	C	M		A						F			R	C						F		F		C			
23H-2, 30-32	207.80	227.97	A	G	T	C							T		T	C	T									R		*Gr. puncticulata*	early Pliocene
23H-CC, 9-12	215.63	235.80	A	G		A	T						R		R	R	F		F			R				F			
24H-CC, 8-11	225.11	245.28	A	G		C/A							T				T		R			F				T/R			
25H-CC, 7-10	234.80	254.97	A	G	R	A							R				F					F/C				F			
26H-CC, 15-18	244.19	264.36	A	G		C						R	T			R	T		T			R	R						
27H-CC, 23-26	253.80	273.97	A	G		C			T				T/R			A	R		R			F	R			R			
28H-CC, 8-11	263.12	283.29	A	G		C			F/C				R				T/R		R			R	R			T/R			
29H-CC, 19-22	272.81	292.98	A	G		C		T/R					T/R			F	T/R		T			C	R						
30H-2, 80-82	274.80	294.97	A	G	A							F				C						A	F	R		F			
30H-3, 70-72	276.20	296.37	A	G		C										A	F						F			F			
30H-4, 70-72	277.70	297.87	A	G		C										A	R					C	F	R		F			
30H-5, 70-72	279.20	299.37	A	G		A																A	F			C		*Gr. margaritae*	
30H-6, 70-72	280.70	300.87	C	M		A							R				T					A				C			
30H-CC, 11-14	282.31	302.48	A	M/G		C		R			T		T				T					F	R/F			F			
31H-CC, 20-23	291.84	312.01	A	M/G		F		F					R				R		T		F	C/A	R				R		
32H-CC, 14-17	301.24	321.41	A	G		C		T/R					T				T		T			C				T			
33H-CC, 12-15	310.66	330.83	A	G		C							R						T/R			C	F			T			
34H-CC, 37-40	320.28	340.45	A	G		F		F/C					R				R			R		F	F						

Note: Abbreviations as in Table 2.

Site 984

Four holes were drilled at Bjorn Drift Site 984 (Shipboard Scientific Party, 1996f). Hole 984A is entirely within the *N. pachyderma* (sinistral) Acme Zone; Hole 984B was selected for planktonic foraminifer biostratigraphy (Table 8). Planktonic foraminifers were generally common from the top of the section to Sample 162-984B-23H-CC, 8–11 cm (217.68 mbsf), and rare to barren from Sample 162-984B-24H-CC, 0–2 cm (226.94 mbsf) to the base of the section (Sample 162-984B-53X, 43–46 cm; 500.73 mbsf). Faunal assemblages indicate cooler conditions than at Gardar Drift Site 983 and the other subpolar North Atlantic sites. Fauna are generally dominated either by *N. pachyderma* (sinistral), *N. pachyderma* (dextral), or *N. atlantica* (sinistral). The base of the Pleistocene sediments is approx-

Table 5. Stratigraphic ranges of planktonic foraminifers in selected samples from Hole 982A, Rockall Plateau.

Core, section, interval (cm)	Depth (mbsf)	Depth (mcd)	Abundance	Preservation	*Globigerina aequilateralis*	*Globigerina bulloides*	*Globigerina quinqueloba*	*Globigerinoides* spp.	*Globorotalia conomiozea*	*Globorotalia* cf. *crassula*	*Globorotalia inflata*	*Globorotalia juanai*	*Globorotalia puncticulata*	*Globorotalia scitula*	*Globorotalia* spp.	*Globigerinita glutinata*	*Globigerinita uvula*	*Neogloboquadrina acostaensis*	*Neogloboquadrina continuosa*	*Neogloboquadrina atlantica* (dextral)	*Neogloboquadrina atlantica* (sinistral)	*Neogloboquadrina pachyderma* (dextral)	*Neogloboquadrina pachyderma* (sinistral)	*Neogloboquadrina* spp.	*Orbulina universa*	*Orbulina bilobata*	*Sphaeroidinellopsis paenedehiscens*	Zone	Epoch
162-982A-																													
1H-CC, 6-9	8.20	8.20	A	G		A					F			F		F						C	C		F			*N. pachyderma* (s.)	Pleistocene
2H-CC, 9-12	17.92	19.22	A	G		F					F			R		F						F	A						
3H-CC, 10-13	26.51	28.59	A	G		C					F					R						F	C						
4H-CC, 10-13	36.98	39.48	A	G		A					C			F								F	C						
5H-CC, 17-20	46.53	50.46	A	G		C/A								T		C						C	R		T/R				
6H-CC, 23-26	55.99	62.52	A	M		C/A	R						T								F							*N. atlantica* (s.)/ *Gg. bulloides*	Pliocene
7H-CC, 14-17	65.29	73.26	A	G	T	A							T			T					R				T				
8H-CC, 10-13	74.95	83.73	A	G	T/R	A							R			T					F/C				T				
9H-CC, 21-24	83.59	93.42	A	G	T/R	C				T			F								F				T	T		*Gr. puncticulata*	
10H-CC, 11-14	93.99	105.42	A	G		A				T			R												R				
11H-CC, 14-17	103.30	115.65	C	M/G		C	R			T			F			R/F	R				F				R				
12H-CC, 17-20	112.99	126.48	A	M		C				T			F/C								F								
13H-CC, 12-15	122.35	137.27	A	G		C									T						R				R			*Gr. margaritae*	
14H-CC, 17-20	131.93	147.75	A	G		C/A	T										T	T/R							T				
15H-CC, 24-27	141.32	158.60	A	G		C				T										F	F			C	T				
16H-CC, 24-27	151.00	169.12	A	M		C				T										R/F	T/R				T				
17H-CC, 15-18	161.31	180.31	A	M		C										F	T	T			F				T				
18H-CC, 17-20	170.01	189.51	A	G						T																			
19H-CC, 17-20	179.51	200.29	A	G		C										T				F	F				T				
20H-CC, 15-18	188.86	209.20	A	G		C						T						R			R/F				T	T		*N. acostaensis*	Miocene
21H-CC, 24-27	198.54	219.59	C	M		C				R		T						R			F								
22H-CC, 25-28	207.71	229.64	C	M		F/C						T			T	T	T	R/F			R/F								
23H-CC, 20-23	217.55	240.75	A	G		C		T						T				C			R				F		T		
24H-3, 26-28	220.46	244.65	A	P		R										R		R											
24H-CC, 18-21	226.91	251.10	C	M		C			T					F	T	F	T				F								
25H-CC, 18-21	236.38	261.76	C	G		A			C							F	R	F			F				F				
26H-CC, 16-19	245.93	271.31	C	M		A										F	R	C	R						F				

Note: Abbreviations as in Table 2.

imated by the start of the *N. pachyderma* (sinistral) Acme Zone between Samples 162-984B-21H-3, 35–37 cm, and 21H-4, 35–37 cm (192.35–193.85 mbsf).

The FO of *Gr. inflata* is not recorded at this location because of sparse occurrences. The LO of *N. atlantica* (2.41 Ma) in the lower part of Hole 984B (between Sample 162-984B-33X-1, 35–37 cm [302.15 mbsf] and 33X-2, 35–37 cm [303.65 mbsf]) provides an important age control point because of the absence of magnetostratigraphic data and calcareous nannofossil data in this interval. This datum level allows informal subdivision of the Pliocene into a latest Pliocene *Gr. inflata/Gg. bulloides* zone and a late Pliocene *N. atlantica/Gr. puncticulata* zone.

Site 985

Holes 985A and 985B drilled at Iceland Sea Site 985 (Shipboard Scientific Party, 1996g) were examined for planktonic foraminifers (Table 9). Planktonic foraminifers are found only in the upper part of the Site 985 section. Assemblages are dominated by *N. pachyderma* (sinistral), indicating cold subpolar conditions. The start of the *N. pachyderma* (sinistral) Acme Zone is not recorded at this location because samples are generally barren of planktonic foraminifers below Samples 162-985A-3H-CC, 20–23 cm (26.94 mbsf), and 985B-2H-CC, 20–22 (13.13 mbsf).

Site 986

Four holes were drilled at Site 986 on the Svalbard margin (Shipboard Scientific Party, 1996h). Holes 986A, 986C, and 986D were examined for planktonic foraminifers (Table 10). Planktonic foraminifers are found sporadically throughout the Site 986 section but are often common from the mid-Pleistocene to present. Specimens are generally few to rare from the top of the section to Sample 162-986A-17X-CC, 59–62 cm (137.73 mbsf), and often barren from Sample 162-986A-19X-CC, 21–24 cm (155.02 mbsf), to the base of the section, except for certain intervals. For example, rare *N. pachyderma* (sinistral) is recorded in Samples 162-986D-16R-CC, 9–12 cm (541.48 mbsf), and 17R-CC, 15–18 cm (546.57 mbsf), and rare *N. atlantica* is recorded in the interval from Sample 162-986D-34R-CC, 44–46 cm (705.94 mbsf), to 38R-CC, 9–11 cm (749.86 mbsf), and 43R-CC through 48R-CC (795.39–865.92 mbsf). Most of these rare specimens are well preserved and do not seem to be reworked. These occurrences provide limited age control for the sequence, together with limited magnetostratigraphic data and additional planktonic foraminifer data (Channell et al., Chap. 10, this volume; Eidvin and Nagy, Chap. 1, this volume).

Neither the start of the *N. pachyderma* (sinistral) Acme Zone nor the LO of *N. atlantica* (sinistral) is recorded at this location because of generally sparse planktonic foraminifers and poor core recovery from Samples 162-986D-18R-CC, 12–15 cm, to 34R-CC, 44–46 cm (558.92–705.44 mbsf). Significantly, the presence of *N. atlantica* below Sample 162-986D-34R-CC, 44–46 cm (705.94 mbsf), suggests an age >1.8 Ma for the lower part of the section. The LO of *N. atlantica* is significantly younger in the Nordic Seas (~1.8 Ma) than in the North Atlantic and approximates the Pliocene/Pleistocene boundary (Spiegler and Jansen, 1989; Spiegler, 1996).

Results from the Nordic Seas sites are consistent with previous findings that carbonate sediment preservation increased within the

Table 6. Stratigraphic ranges of planktonic foraminifers in selected samples from Hole 982B, Rockall Plateau.

Core, section, interval (cm)	Depth (mbsf)	Depth (mcd)	Abundance	Preservation	*Catapsydrax dissimilis*	*Catapsydrax stainforthi*	*Globigerina aequilateralis*	*Globigerina bulloides*	*Globigerina eamesi*	*Globigerina nepenthes*	*Globigerina praebulloides*	*Globigerina quinqueloba*	*Globigerina woodi*	*Globigerinoides obliquus*	*Globigerinoides quadrilobatus*	*Globigerinoides subquadratus*	*Globigerinoides triloba*	*Globigerinoides* spp.	*Globoquadrina dehiscens*	*Globoquadrina baroemoenensis*	*Globorotalia conoidea*	*Globorotalia conomiozea*	*Globorotalia* cf. *crassula*	*Globorotalia crassaformis*	*Globorotalia inflata*	*Globorotalia juanai*	*Globorotalia margaritae*	*Globorotalia miozea*	*Globorotalia puncticulata*	*Globorotalia praescitula*	*Globorotalia scitula*	*Globorotalia zealandica*	*Globigerinita glutinata*	*Globigerinita uvula*	*Neogloboquadrina acostaensis*	*Neogloboquadrina continuosa*	*Neogloboquadrina humerosa*	*Neogloboquadrina atlantica* (dextral)	*Neogloboquadrina atlantica* (sinistral)	*Neogloboquadrina pachyderma* (dextral)	*Neogloboquadrina pachyderma* (sinistral)	*Neogloboquadrina* spp.	*Orbulina suturalis*	*Orbulina universa*	*Orbulina bilobata*	*Paragloborotalia mayeri*	*Praeorbulina glomerosa glomerosa*	*Praeorbulina glomerosa circularis*	*Sphaeroidinellopsis disjuncta*	*Sphaeroidinellopsis kochi*	*Streptochilus globigerum*	Zone	Epoch
162-982B-																																																					
3H-6, 12-14	22.62	24.78	A	G			R	C				R													F						R									F	C			R								*N. pachyderma* (s.)	Pleistocene
4H-2, 124-126	26.12	29.20	A	G				C																F	A/D						R									R				R									
4H-5, 124-126	31.74	34.82	A	G				F																	D						R									R				R									
5H-1, 110-112	35.10	39.18	A	G				C				R												C	F						R		F							R	R			R									
5H-2, 110-112	36.60	40.68	A	G				C				R													C						R		R							F	R			R									
5H-3, 76-78	37.76	41.84	A	G				A				R												F	C						R									F	T											*Gr. inflata*	late Pliocene
5H-4, 126-128	39.76	43.84	A	G				C																	C						R									C	T			F									
5H-5, 110-112	41.10	45.18	A	G				A																	A						R		R							R													
5H-6, 104-106	42.54	46.62	A	G				C				T																			F									F				T								*Gg. bulloides*	
6H-1, 60-62	44.10	49.61	A	G				C																R							F		R							C				F									
6H-2, 54-56	45.54	51.05	A	G			T	A																T							T		T							C	T			R									
6H-3, 65-67	47.15	52.66	A	G				F																	T						R								D			T										*N. atlantica*	
6H-5, 68-70	50.18	55.69	A	G			T	C																															A					F									
7H-2, 18-20	54.68	60.45	A	G				A																							R								F					F									
7H-3, 18-20	56.18	61.95	A	G				C																					T/R				F						A					F									
7H-4, 18-20	57.68	63.45	A	G				C																					F										A					R									
7H-5, 18-20	59.18	64.95	A	G				A																					F										C					F									
8H-2, 142-144	65.42	72.25	A	G			R	C																					C		F								C					F									
8H-4, 142-144	68.42	75.25	A	G			F	F	C																				T		F								D					F									
8H-5, 140-142	69.90	76.73	A	G			T	C	T														R								R								D					F								*Gr. puncticulata*	early Pliocene
8H-6, 140-142	71.40	78.23	A	G				C															R						R		R								D					F									
9H-1, 84-86	72.84	80.78	A	M			R	F																							R								D					F									
9H-3, 84-86	75.84	83.78	A	G			C	A																					C										C					F									
9H-5, 84-86	78.86	86.80	A	G				C				R																	C		R		R						C					F									
10H-2, 30-32	83.30	92.51	A	G				C													R								C		R								C														
12H-7, 20-22	109.70	120.19	A	G																							R		D										C														
13H-1, 30-32	110.30	121.84	A	G				C																							R								A		F			F								*Gr. margaritae*	
13H-2, 30-32	111.80	123.34	C	G				A																															R		T			C									
13H-5, 30-32	116.30	127.84	C	G				A																									R						C					C									
14H-2, 29-31	121.29	133.89	C	G				D																															C		R												
14H-5, 29-31	125.79	138.39	C	M				A																															F	F	T			F									
15H-2, 29-31	130.79	144.85	C	M				A																															F					F									
17H-2, 24-26	179.74	195.33	C	G				A					R										R				T						R		C		R		F		R			R									
17H-5, 24-26	154.24	169.83	A	M				C																							R				R				C	R				F									
18H-2, 24-26	159.24	175.82	C	M				C																							R		C						C					F									
18H-3, 24-26	160.74	177.32	A	G				C																			F						F		T				C					F									
18H-4, 24-26	162.24	178.82	A	G				C																									F		F				C					F								*Gr. conomiozea*	
18H-5, 24-26	163.74	180.32	A	G				A	R														R								T				F				C					F									
24H-CC, 6-9	224.02	243.47	C	M				C					T								F		R												R	F			F														
25H-CC, 9-12	233.33	253.92	C	M				A	R														F												F				C					F									
26H-2, 19-21	235.19	255.78	C	M				C	T													R													C	R			R					F									
26H-3, 19-21	236.69	257.28	A	G				A				R															F								C				C														

Table 6 (continued).

Core, section, interval (cm)	Depth (mbsf)	Depth (mcd)	Abundance	Preservation	*Catapsydrax dissimilis*	*Catapsydrax stainforthi*	*Globigerina aequilateralis*	*Globigerina bulloides*	*Globigerina eamesi*	*Globigerina nepenthes*	*Globigerina praebulloides*	*Globigerina quinqueloba*	*Globigerina woodi*	*Globigerinoides obliquus*	*Globigerinoides quadrilobatus*	*Globigerinoides subquadratus*	*Globigerinoides triloba*	*Globigerinoides* spp.	*Globoquadrina dehiscens*	*Globoquadrina baroemoenensis*	*Globorotalia conoidea*	*Globorotalia conomiozea*	*Globorotalia* cf. *crassula*	*Globorotalia crassaformis*
26H-4, 19-21	238.19	258.78	A	G				A	R															
26H-5, 19-21	239.69	260.28	C	M				A															F	
26H-CC, 19-22	242.95	263.54	C	M				C	R				R									F		
27X-2, 19-21	244.69	265.28	A	G			R	D				R												
27H-4, 19-21	247.69	268.28	A	G				D		T											F			
27X-CC, 18-21	249.48	270.07	C	M				A	F															
28X-CC, 19-22	256.47	277.06	C	M				D	R															
29X-CC, 16-19	264.62	285.21	C	M				A																
30X-CC, 5-8	268.55	289.14	B																					
31X-CC, 18-21	287.75	308.34	F	M				C																
32X-CC, 33-36	293.61	314.20	C	M				C				T/R												
33X-CC, 34-37	305.52	326.11	A	M				A				F						T						
34X-CC, 32-35	315.15	335.74	C	G				C																
35X-4, 19-21	321.39	341.98	C	M				C																
35X-CC, 33-36	323.03	343.62	C	M				C																
36X-1, 19-21	326.49	347.08	A	G				A																
36X-2, 19-21	327.99	348.58	C	M				R																
36X-CC, 33-36	333.32	353.91	C	M				C																
37X-CC, 17-20	343.91	364.50	C	M				C/A																
38X-CC, 32-35	353.79	374.38	C	M				F/C																
39X-CC, 32-35	362.60	383.19	C	M				C																
40X-CC, 33-36	372.28	392.87	C	M				C																
43X-CC, 24-27	399.88	420.47	F/C	M				C				F												
45X-CC, 32-35	422.72	443.31	C	M				C																
47X-CC, 44-47	438.64	459.23	C	G								C									C			
48X-CC, 37-40	450.12	470.71	C	M				C													F			
49X-CC, 27-30	458.37	478.96	C	G				C							C						F			
50X-CC, 26-29	467.67	488.26	C	M		T		C							F		T			T				
51X-CC, 31-34	478.96	499.55	C	M							C					F								
52X-2, 19-21	481.89	502.48	A	M								F					R		R	F				
52X-5, 19-21	486.39	506.98	A	M					R			R			R				F	F	R			
52X-CC, 37-40	488.67	509.26	C	M		T		C				R								F	F			
53X-2, 19-21	491.39	511.98	A	G											F		R		T	C				
53X-4, 19-21	494.39	514.98	C	M																				
53X-5, 19-21	495.89	516.48	C	M				F			R				C		R			C				
53X-6, 19-21	497.39	517.98	A	G											F					C				
53X-CC, 34-37	498.61	519.20	C	M											C		F		T					
54X-1, 40-42	499.70	520.29	A	M							F									C				
54X-2, 21-23	501.01	521.60	F	M											C									
54X-CC, 34-37	506.20	526.79	C	M		R							F		C									
55X-CC, 22-25	518.54	539.13	C	M							C				C		F			F				
56X-CC, 42-45	528.32	548.91	C	M											C		C							
57X-5, 19-21	534.29	554.88	A	M							C								A	C				
58X-3, 25-28	531.35	551.94	A	M							C		F							F				
58X-CC, 30-33	541.58	562.17	C	M							C				C				R	F				
59X-CC, 67-70	548.07	568.66	F	M	R																			
60X-CC, 33-36	561.17	581.76	F	M																T				
61X-CC, 29-32	570.22	590.81	F	M	T						R			T	R									
62X-CC, 28-31	577.12	597.71	F	M							F								F					
63X-CC, 35-38	586.35	606.94	F	M							F								F					
64X-CC, 44-47	596.04	616.63	F	M							F													
65X-CC, 18-21	605.48	626.07	F	M							F													

Core, section, interval (cm)	*Globorotalia inflata*	*Globorotalia juanai*	*Globorotalia margaritae*	*Globorotalia miozea*	*Globorotalia puncticulata*	*Globorotalia praescitula*	*Globorotalia scitula*	*Globorotalia zealandica*	*Globigerinita glutinata*	*Globigerinita uvula*	*Neogloboquadrina acostaensis*	*Neogloboquadrina continuosa*	*Neogloboquadrina humerosa*	*Neogloboquadrina atlantica* (dextral)	*Neogloboquadrina atlantica* (sinistral)	*Neogloboquadrina pachyderma* (dextral)	*Neogloboquadrina pachyderma* (sinistral)	*Neogloboquadrina* spp.	*Orbulina suturalis*	*Orbulina universa*
26H-4, 19-21											R			C						F
26H-5, 19-21									R		R			R						R
26H-CC, 19-22									F		F			R						
27X-2, 19-21									R											R
27H-4, 19-21									F		R									
27X-CC, 18-21		R					F		F		F			F						
28X-CC, 19-22														F						
29X-CC, 16-19		F									R	F						R		
30X-CC, 5-8																				
31X-CC, 18-21		T					T		T		C			C						T
32X-CC, 33-36		T									C			C						F
33X-CC, 34-37						R					R			F						F
34X-CC, 32-35							T		T		C					C				
35X-4, 19-21							F				C	C				F				
35X-CC, 33-36							R		R		C			C		C				
36X-1, 19-21		R				R			R											
36X-2, 19-21							R		R	F										
36X-CC, 33-36															T	A				
37X-CC, 17-20							T							A						
38X-CC, 32-35																D				
39X-CC, 32-35																D				
40X-CC, 33-36																A				
43X-CC, 24-27							T											A		
45X-CC, 32-35																		A/D		
47X-CC, 44-47																				
48X-CC, 37-40							R											F		
49X-CC, 27-30																				
50X-CC, 26-29																				F
51X-CC, 31-34				C																
52X-2, 19-21				C																
52X-5, 19-21						R														
52X-CC, 37-40							R													T
53X-2, 19-21						F														
53X-4, 19-21																				
53X-5, 19-21						F														
53X-6, 19-21																			C	
53X-CC, 34-37						F														
54X-1, 40-42																				
54X-2, 21-23																				
54X-CC, 34-37																				
55X-CC, 22-25																				
56X-CC, 42-45																				
57X-5, 19-21				T		R			T											
58X-3, 25-28								T												
58X-CC, 30-33						R														
59X-CC, 67-70												C								
60X-CC, 33-36																				
61X-CC, 29-32						R		C				R								
62X-CC, 28-31												C/A								
63X-CC, 35-38												C								
64X-CC, 44-47												C								
65X-CC, 18-21												C								

Core, section, interval (cm)	*Orbulina bilobata*	*Paragloborotalia mayeri*	*Praeorbulina glomerosa glomerosa*	*Praeorbulina glomerosa circularis*	*Sphaeroidinellopsis disjuncta*	*Sphaeroidinellopsis kochi*	*Streptochilus globigerum*	Zone	Epoch
26H-4, 19-21								*N. acostaensis*	late Miocene
26H-5, 19-21									
26H-CC, 19-22									
27X-2, 19-21									
27H-4, 19-21									
27X-CC, 18-21									
28X-CC, 19-22						R			
29X-CC, 16-19									
30X-CC, 5-8									
31X-CC, 18-21	T								
32X-CC, 33-36									
33X-CC, 34-37									
34X-CC, 32-35									
35X-4, 19-21									
35X-CC, 33-36									
36X-1, 19-21		C						*O. suturalis*	middle Miocene
36X-2, 19-21		C							
36X-CC, 33-36	T	F				R			
37X-CC, 17-20									
38X-CC, 32-35									
39X-CC, 32-35									
40X-CC, 33-36							A		
43X-CC, 24-27									
45X-CC, 32-35		T							
47X-CC, 44-47		C							
48X-CC, 37-40									
49X-CC, 27-30									
50X-CC, 26-29									
51X-CC, 31-34									
52X-2, 19-21			R						
52X-5, 19-21		F	C						
52X-CC, 37-40									
53X-2, 19-21				C					
53X-4, 19-21									
53X-5, 19-21			R						
53X-6, 19-21									
53X-CC, 34-37			T					*Praeorbulina*	early Miocene
54X-1, 40-42		C	F						
54X-2, 21-23									
54X-CC, 34-37		F							
55X-CC, 22-25		F							
56X-CC, 42-45									
57X-5, 19-21					C				
58X-3, 25-28		T	F		C				
58X-CC, 30-33									
59X-CC, 67-70									
60X-CC, 33-36		C/A							
61X-CC, 29-32		C							
62X-CC, 28-31		F							
63X-CC, 35-38									
64X-CC, 44-47									
65X-CC, 18-21									

Note: Abbreviations as in Table 2.

Table 7. Stratigraphic ranges of planktonic foraminifers in selected samples from Hole 983A, Gardar Drift.

Core, section, interval (cm)	Depth (mbsf)	Depth (mcd)	Abundance	Preservation	*Globigerina aequilateralis*	*Globigerina bulloides*	*Globigerina quinqueloba*	*Globorotalia crassaformis*	*Globorotalia inflata*	*Globorotalia scitula*	*Globorotalia truncatulinoides*	*Globigerinita glutinata*	*Neogloboquadrina pachyderma* (dextral)	*Neogloboquadrina pachyderma* (sinistral)	*Orbulina universa*	Zone	Epoch
162-983A-																	
1H-CC, 13-16	7.39	7.39	C	G		C				R				A		*N. pachyderma* (s.)	Pleistocene
2H-CC, 18-21	17.28	18.47	A	G		D			R	F				A	R		
3H-CC, 26-29	26.86	29.52	C	G					R	F				D			
4H-CC, 15-18	36.34	40.30	F	G		R	R			R			R	D			
5H-CC, 21-24	45.94	51.75	C	G		C			F	T		T	T	A	T		
6H-CC, 16-19	55.35	61.31	F	G		C	R	R	A	R				F			
7H-CC, 21-24	64.82	72.12	A	G		A	T	R	A	R			F	F			
8H-CC, 23-26	74.30	82.17	A	G		C			A	R			R	C			
9H-CC, 25-28	83.83	92.68	A	G		C			A	R			C	R			
10H-CC, 22-25	93.29	102.63	C	G	T	C	R	R	C	R			R	C	R		
11H-CC, 21-24	102.78	113.07	C	G		R			R				F	D			
12H-CC, 21-24	112.35	123.17	C	G	R	A			C	R				C			
13H-CC, 21-24	121.79	133.40	A	G		C			A	T	R			F			
14H-CC, 23-26	131.32	143.63	C	G		C			T				C	C/A			
15H-CC, 23-26	140.93	153.74	F	M		F	F			T				C/A			
16H-CC, 20-23	150.24	164.14	B														
17H-CC, 18-21	159.68	174.40	C	G		C			C					C			
18H-CC, 22-25	169.28	184.96	C	M		C	F		T				C	A			
19H-CC, 22-25	178.88	195.53	F	M		R	T							D			
20H-CC, 19-22	188.27	205.70	R	M										D			
21H-CC, 23-26	197.72	215.51	R	M		T								D			
22H-CC, 0-2	207.06	226.10	F	M		C	F					F		F/C			
23H-CC, 17-20	216.67	236.89	C	G		C			C			F	C	C			
24H-CC, 0-3	226.00	247.96	C	G		C			C	T		F	C	L			
25H-2, 20-22	227.60	250.41	F	G		C	R		C	T		R		A			
25H-3, 20-22	229.10	251.91	B														
25H-4, 20-22	230.60	253.41	R	G					T				R	D			
25H-5, 20-22	232.10	254.91	F	G		F	F		R	R			A			*Gr. inflata*	Pliocene
25H-CC, 14-17	235.44	258.25	R/F	M/G									D				
26H-CC, 0-3	244.99	269.03	C	M		C			C	R		F	C				
27H-CC, 24-27	254.78	279.47	C	M		F			F				C/A				

Note: Abbreviations as in Table 2.

Quaternary at ~1 Ma. However, increased carbonate accumulation was delayed in the Arctic Gateway region; Svalbard margin Site 986 exhibits a distinct increase in planktonic foraminiferal abundances within approximately the past half m.y. (Table 10).

Site 987

Four holes were drilled at Site 987 on the Greenland margin (Shipboard Scientific Party, 1996i). Hole 987A was examined for planktonic foraminifers (Table 11). Planktonic foraminifers are abundant from the top of the section to Sample 162-987A-3H-CC and rare from Sample 162-987A-4H-CC to 10H-CC. Preservation is moderate to good. Samples are generally barren from Sample 162-987A-11H-CC to the base of the section. Assemblages are dominated by *N. pachyderma* (sinistral), although rare occurrences of *Globigerina quinqueloba* were recorded in Sample 162-987A-18X-CC. The start of the *N. pachyderma* (sinistral) Acme Zone is not recorded at this location because of barren samples and poor recovery.

SYNCHRONEITY/DIACHRONEITY OF SELECTED DATUM LEVELS

High sedimentation rate (~4–7 cm/k.y.) sites in the North Atlantic drilled with the hydraulic piston corer on Leg 94 (Ruddiman, Kidd, Thomas, et al., 1987) have provided particularly useful biostratigraphic and magnetostratigraphic data for calibration of many important datum levels to the GPTS. In particular, calibration of several planktonic foraminiferal datum levels at these sites has demonstrated synchroneity and diachroneity for several species in the mid-latitude North Atlantic from ~37°N–53°N (Weaver and Clement, 1986, 1987; Raymo et al., 1989).

An integrated magnetostratigraphy (Channell and Lehman, Chap. 8, this volume) and calcareous nannofossil biostratigraphy for Leg 162 drill sites (Jansen, Raymo, Blum, et al., 1996) allows independent calculation of planktonic foraminiferal datum level ages for subpolar North Atlantic Sites 981–984 (~55°N–61°N). Ages were calculated by linear interpolation between age control points. Polarity reversals were used as age control points from core top to the Matuyama/Gauss boundary at Sites 981 and 982. Calcareous nannofossil datum levels were used below the Matuyama/Gauss boundary, with the working hypothesis that they are nearly synchronous (e.g., Backman and Shackleton, 1983). Datum levels include the FO of *Pseudoemiliania lacunosa* at 3.7 Ma, the LO of *Amaurolithus primus* at 4.7 Ma, the FO of *Discoaster surculus* at 7.3 Ma, the LO of *Calcidiscus miopelagicus* at 10.9 Ma, the LO of *Sphenolithus heteromorphus* at 13.6 Ma, and the FO of *S. heteromorphus* at 18.2 Ma (Shipboard Scientific Party, 1996b, 1996c). At Site 983, polarity reversal age control points were used down to the base of the Olduvai Chron. At Site 984, polarity reversals were used down to the base of the Re-

Table 8. Stratigraphic ranges of planktonic foraminifers in selected samples from Holes 984A and 984B, Bjorn Drift.

Core, section, interval (cm)	Depth (mbsf)	Depth (mcd)	Abundance	Preservation	*Globigerina bulloides*	*Globigerina quinqueloba*	*Globorotalia crassaformis*	*Globorotalia inflata*	*Globorotalia scitula*	*Globigerinita glutinata*	*Neogloboquadrina atlantica* (sinistral)	*Neogloboquadrina pachyderma* (dextral)	*Neogloboquadrina pachyderma* (sinistral)	*Orbulina universa*	Zone	Epoch
162-984A-																
1H-CC 14-17	5.06	5.11	C	G									D		*N. pachyderma* (s.)	Pleistocene
2H-CC 12-15	13.31	15.44	A	G	F/C	R			R			F	D			
3H-CC 15-18	24.30	26.53	C	M	T				T				D			
4H-CC 11-14	33.81	36.35	R	M	R							R	D			
5H-CC 19-22	42.66	46.41	R	G	C	R		F				R	C			
6H-CC 22-25	52.83	57.17	R	G	C			F	R			F	A			
7H-CC 26-29	62.46	68.53	C	G	R	R		T/R				R	D			
8H-CC 20-23	71.96	78.76	F	M	R	R							D			
9H-CC 15-18	81.41	88.96	C	G	A	T		C		R		R	C			
10H-CC 19-22	91.03	99.14	C	G	A			R	T				A			
11H-CC 21-24	100.41	110.53	A	G									D			
12H-CC 13-16	110.03	119.92	R	G								R	D			
13H-CC 19-22	119.39	130.49	C	G	F			R	T				D			
14H-CC23-26	129.03	141.37	R/F	M									D			
15H-CC 26-29	138.46	151.59	C	M	F			T	R			T	D			
16H-CC 26-29	147.97	161.82	F/C	M	T/R			D	T			T				
17H-CC 23-26	157.45	172.29	F/C	M	T			T		T			D			
18H-CC 23-26	166.91	182.98	R	M									D			
19H-CC 23-26	176.43	193.29	R	M									D			
162-984B-																
17H-CC, 5-8	160.56	174.39	R	M				T					D		*N. pachyderma* (s.)	Pleistocene
18H-CC, 20-23	170.26	184.91	F	M				T				F	D			
19H-CC, 0-2	179.55	195.84	A	G	T			T/R		R			A/D	T		
20H-CC, 9-12	189.16	204.99	F	M									D			
21H-2, 35-37	190.85	209.25	R	G		R	T					R	D	T		
21H-3, 35-37	192.35	210.75	R	M							T		D			
21H-4, 35-37	193.85	212.25	B												*Gr. inflata/Gg. bulloides*	Pliocene
21H-6, 35-37	196.85	215.25	B													
21H-7, 35-37	198.35	216.75	R	G	D							R	T			
21H-CC, 7-10	198.59	216.99	F	M							D					
22H-CC, 1-4	208.01	226.81	C	G	R				T			D				
23H-CC, 8-11	217.68	237.76	C	G	C	F		R		T		A				
24H-CC, 0-2	226.94	247.21	R	M		D						T				
25H-CC, 14-17	236.58	258.30	R	M		D										
26H-CC, 1-4	246.11	268.70	R	M	T							C				
27H-CC, 14-17	255.79	278.29	R	M					F			A/D				
28H-CC, 37-40	264.85	287.35	T	P												
29H-CC, 1-4	274.29	296.79	R	M					T							
30H-CC, 0-2	283.50	306.00	R	M								D				
31H-CC, 38-41	293.43	315.93	R	M/G		D										
32X-2, 35-37	295.35	317.85	B													
32X-6, 35-37	301.35	323.85	B		T	T										
32X-CC, 36-39	303.33	325.83	R	M	T							D				
33X-1, 35-37	302.15	324.65	T		T	T						D				
33X-2, 35-37	303.65	326.15	C						T		D				*N. atlantica/Gr. puncticulata*	
33X-CC, 39-42	311.66	334.16	B													
34X-2, 35-37	313.25	335.75	B								D					
34X-CC, 40-43	320.40	342.90	R	M							T					
35X-2, 35-37	322.85	345.35	C		R					T	D					
35X-CC, 40-43	330.88	353.38	T		T											
36X-2, 95-97	333.05	355.55	R	M							D					
36X-CC, 26-29	336.76	359.26	F	M	R					T	C					
37X-CC, 35-38	349.99	372.49	B													
38X-CC, 39-42	359.74	382.24	T	M	T						T					
39X-CC, 20-23	369.07	391.57	A	G	F						D		R	T		
40X-CC, 34-37	378.91	401.41	B							T						
41X-CC, 34-37	387.86	410.36	B		T											
42X-CC, 21-24	397.07	419.57	B								T					
43X-CC, 35-38	407.82	430.32	R	M	D											
44X-CC, 33-36	417.36	439.86	F	G	R						D	T				
45X-CC, 33-36	427.07	449.57	F	M	F						D					
46X-CC, 24-27	436.50	459.00	R/F	M							D					
47X-CC, 41-44	446.35	468.85	F	M							D					
53X-CC, 43-46	500.73	523.23	R	M	R						D					

Note: Abbreviations as in Table 2.

Table 9. Stratigraphic ranges of planktonic foraminifers in selected samples from Holes 985A and 985B, Iceland Sea.

Core, section, interval (cm)	Depth (mbsf)	Depth (mcd)	Abundance	Preservation	*Globigerina bulloides*	*Globigerina quinqueloba*	*Neogloboquadrina atlantica* (sinistral)	*Neogloboquadrina pachyderma* (dextral)	*Neogloboquadrina pachyderma* (sinistral)	*Orbulina universa*	Zone	Epoch
162-985A-												
1H-1, 0-0	0.00	0.00	A	G	R	F		R	D		*N. pachyderma* (s.)	Pleistocene
1H-CC, 17-20	7.67	7.89	A	G				R	D			
2H-CC, 19-22	17.50	18.67	F	G					D			
3H-CC, 20-23	26.94	28.11	R	M			T		D			
4H-7, 59-61	36.29	37.66	T	M	T					T		
4H-CC, 26-29	36.41	37.78	T	M					D			
5H-1, 59-61	36.79	38.47	T	M	T							
5H-CC, 24-27	46.13	47.81	B									
6H-CC, 21-24	55.49	57.96	B									
7H-CC, 20-23	65.02	68.93	B									
8H-CC, 29-32	74.25	78.96	B									
9H-CC, 23-26	83.90	88.82	B									
10H-CC, 23-26	93.44	98.98	B									
11H-CC, 23-26	103.01	109.35	T	M					T			
12H-CC, 16-19	112.46	119.44	B									
13H-CC, 25-28	121.96	129.45	B									
14H-CC, 28-31	131.01	138.85	B									
15H-CC, 47-50	141.25	149.09	B									
16H-CC, 22-25	148.91	156.75	B									
17H-CC, 27-30	155.17	163.01	B									
18X-CC, 38-41	165.02	172.86	B									
19X-CC, 22-25	174.41	182.25	B									
20X-CC, 10-13	179.49	187.33	B									
21X-CC, 36-39	193.61	201.45	B									
22X-CC, 35-38	203.21	211.05	B									
23X-CC, 42-45	212.92	220.76	B									
24X-CC, 11-14	219.04	226.88	B									
25X-CC, 23-26	231.91	239.75	B									
26X-CC, 29-32	241.30	249.14	B									
27X-CC, 23-26	249.92	257.76	B									
28X-CC, 34-37	258.42	266.26	B									
29X-CC, 35-38	269.68	277.52	B									
44X-CC, 45-48	415.00	422.84	B									
50X-CC, 32-35	472.59	480.43	B									
54X-CC, 40-43	510.94	518.78	B									
162-985B-												
1H-CC, 11-14	3.39	3.39	C	G		R			D	T	*N. pachyderma* (s.)	Pleistocene
2H-CC, 20-23	13.13	14.97	F	G					D			
3H-CC, 23-26	22.46	24.30	B									
4H-CC, 33-36	31.73	33.89	T	M					D			
5H-CC, 15-18	41.66	44.34	T	M					D			
6H-CC, 15-18	50.97	54.38	B									
7H-CC, 22-25	60.72	64.67	B									
9H-CC, 17-20	79.69	84.95	B									

Note: Abbreviations as in Table 2.

union Event; the FO of *P. lacunosa* at 3.7 Ma was not reached, so the age of the LO of *N. atlantica* cannot be accurately determined using biostratigraphy at this site.

Planktonic foraminiferal datum levels from Sites 981 to 984 are located to the section level. This resolution is insufficient to resolve glacial–interglacial variations; high-resolution, quantitative data are needed to refine the placement of datum levels. However, resolution is adequate to address broad-scale synchroneity/diachroneity. Several Pliocene–Pleistocene planktonic foraminiferal datum levels judged synchronous in the mid-latitude North Atlantic (Weaver and Clement, 1986; Raymo et al., 1989) are found to be within 5% of their published ages in at least two subpolar sites (Table 12). These include the start of the Acme Zone *N. pachyderma* (sinistral), the FO of *Gr. inflata*, and the FO of *Gr. puncticulata*. However, the LO of *N. atlantica* (sinistral) somewhat lags its mid-latitude age (2.41 Ma), by ~200 k.y. at Site 981 and by ~100 k.y. at Site 982. Interestingly, the LO of *Gr. puncticulata* coincides with the LO of *N. atlantica* (sinistral) at Site 981 (~2.2 Ma) but precedes it at Site 982 (by ~500 k.y.). The LO of *Gr. puncticulata* is clearly time-transgressive, generally (but not entirely) disappearing earlier at the more northerly sites, consistent with its preference for subtropical/temperate latitudes (Kennett and Srinivasan, 1983; Raymo et al., 1989).

Based on nannofossil biostratigraphy, three Miocene datum levels at Site 982 (Table 12) are found to be within 5% of their published ages (Berggren et al., 1995): the LO of *N. acostaensis* (5.29 Ma), the FO of *O. suturalis* (15.1 Ma), and the LO of *C. dissimilis* (17.3 Ma). Diachroneity is observed for other species datum levels. The dextral to sinistral transition in *N. atlantica* precedes its published age (6.4 Ma, Weaver and Clement, 1986) by ~700 k.y. The LO of *P. mayeri* and FO of *N. acostaensis* pair are both somewhat younger than their published ages. Factors such as sample resolution and preservation complicate the interpretation of these results, and more work is needed to address patterns of diachroneity related to climate.

SUMMARY

Miocene to Holocene planktonic foraminifers from Leg 162 in the subpolar North Atlantic and Nordic Seas reflect the progressive establishment of southeast-northwest surface-water temperature gradients. Lower to middle Miocene sediments in the subpolar North Atlantic can be correlated with subtropical to temperate zonation schemes, consistent with relatively low meridional sea-surface temperature gradients. Increased meridional gradients are indicated since the middle Miocene by the requirement of subpolar zonations. Results from the Nordic Seas sites agree with previous findings that carbonate sediment preservation increased within the Quaternary.

Planktonic foraminiferal datum levels from Sites 981 to 984 are located to the section level, insufficient to resolve glacial–interglacial variations. However, these data are consistent with previous suggestions that several Pliocene–Pleistocene neogloboquadrinid and globorotalid datum levels are synchronous throughout the mid-latitude to subpolar North Atlantic. These include the start of the Acme Zone *N. pachyderma* (sinistral) at 1.8 Ma, the FO of *Gr. inflata* at 2.09 Ma, and the FO of *Gr. puncticulata* at 4.5 Ma (within 5% of their mid-latitude ages). The LO of *N. atlantica* (sinistral) is delayed relative to its mid-latitude age (2.41 Ma) by 100–200 k.y. The LO of *Gr. puncticulata* may generally (but not entirely) occur earlier at more northerly sites. During the Miocene at Rockall Plateau Site 982, the LO of *N. acostaensis* (5.29 Ma), the FO of *O. suturalis* (15.1 Ma), and the LO of *C. dissimilis* (17.3 Ma) may be synchronous (within 5% of their published ages) with these events at mid-latitudes.

ACKNOWLEDGMENTS

This work was funded by the JOI/USSSP, along with partial support from NSF (OPP-9423485). I thank the Ocean Drilling Program for providing samples, M. Flower and J. Hobson for laboratory assistance, T. Whalen for technical assistance, and C. Anderson and M. Raymo for thoughtful reviews. I also thank the captain, crew, and scientific party of Leg 162 for an excellent cruise.

REFERENCES

Backman, J., and Shackleton, N.J., 1983. Quantitative biochronology of Pliocene and early Pleistocene calcareous nannofossils from the Atlantic, Indian and Pacific oceans. *Mar. Micropaleontol.,* 8:141–170.

Berggren, W.A., 1972. Cenozoic biostratigraphy and paleobiogeography of the North Atlantic. *In* Laughton, A.S., Berggren, W.A., et al., *Init. Repts. DSDP,* 12: Washington (U.S. Govt. Printing Office), 965–1002.

Berggren, W.A., Aubry, M.P., and Hamilton, N., 1983. Neogene magnetostratigraphy of Deep Sea Drilling Project Site 516 (Rio Grande Rise, South Atlantic). *In* Barker, P.F., Carlson, R.L., Johnson, D.A., et al., *Init. Repts. DSDP,* 72: Washington (U.S. Govt. Printing Office), 675–713.

Berggren, W.A., Hilgen, F.J., Langereis, C.G., Kent, D.V., Obradovich, J.D., Raffi, I., Raymo, M.E., and Shackleton, N.J., 1995. Late Neogene chronology: new perspectives in high-resolution stratigraphy. *Geol. Soc. Am. Bull.,* 107:1272–1287.

Berggren, W. A., Kent, D. V., and Flynn, J. J., 1985. Neogene geochronology and chronostratigraphy, *In* Snelling, N.J. (Ed.), *The Chronology of the Geological Record.* Geol. Soc. London Mem., 10:211–260.

Blow, W.H., 1969. Late middle Eocene to Recent planktonic foraminiferal biostratigraphy. *In* Brönnimann, P., and Renz, H.H. (Eds.), *Proc. First Int. Conf. Planktonic Microfossils, Geneva, 1967:* Leiden (E.J. Brill), 1:199–422.

Blow, W.H., 1979. *The Cainozoic Globigerinida:* Leiden (E.J. Brill).

Bolli, H.M., and Saunders, J.B., 1985. Oligocene to Holocene low latitude planktic foraminifera. *In* Bolli, H.M., Saunders, J.B., and Perch-Nielsen, K. (Eds.), *Plankton Stratigraphy:* Cambridge (Cambridge Univ. Press), 155–262.

Broecker, W.S., and Denton, G.H., 1989. The role of ocean-atmosphere reorganizations in glacial cycles. *Geochim. Cosmochim. Acta,* 53:2465–2501.

Cande, S.C., and Kent, D.V., 1995. Revised calibration of the geomagnetic polarity timescale for the Late Cretaceous and Cenozoic. *J. Geophys. Res.,* 100:6093–6095.

CLIMAP Project Members, 1981. Seasonal reconstructions of the Earth's surface at the last glacial maximum. *Geol. Soc. Am., Map and Chart Ser.,* MC36.

Hayes, D.E., Pimm, A.C., et al., 1972. *Init. Repts. DSDP,* 14: Washington (U.S. Govt. Printing Office).

Hooper, P.W.P., and Weaver, P.P.E., 1987. Late Neogene species of the genus *Neogloboquadrina* Bandy, Frerichs and Vincent in the North Atlantic: a biostratigraphic, palaeoceanographic and phyologenetic review. *In* Hart, M.B. (Ed.), *Micropalaeontology of Carbonate Environments:* Chichester (Ellis Horwood), 21–43.

Huddlestun, P.F., 1984. Planktonic foraminiferal biostratigraphy, Deep Sea Drilling Project Leg 81. *In* Roberts, D.G., Schnitker, D., et al., 1984. *Init. Repts. DSDP,* 81: Washington, D.C. (U.S. Govt. Printing Office), 429–438.

Jansen, E., Bleil, U., Henrich, R., Kringstad, L., and Slettemark, B., 1988. Paleoenvironmental changes in the Norwegian Sea and Northeast Atlantic during the last 2.8 m.y.: Deep Sea Drilling Project/Ocean Drilling Program Sites 610, 642, 643, and 644. *Paleoceanography,* 3:563–581.

Jansen, E., Raymo, M.E., Blum, P., et al., 1996. *Proc. ODP, Init. Repts.,* 162: College Station, TX (Ocean Drilling Program).

Kennett, J.P., and Srinivasan, M.S., 1983. *Neogene Planktonic Foraminifera: A Phylogenetic Atlas:* Stroudsburg, PA (Hutchinson Ross).

Myhre, A.M., Thiede, J., Firth, J.V., et al., 1995. *Proc. ODP, Init. Repts.,* 151: College Station, TX (Ocean Drilling Program).

Poore, R.Z., 1979. Oligocene through Quaternary planktonic foraminiferal biostratigraphy of the North Atlantic: DSDP Leg 49. *In* Luyendyk, B.P., Cann, J.R., et al., *Init. Repts. DSDP,* 49: Washington (U.S. Govt. Printing Office), 447–517.

Poore, R.Z., and Berggren, W.A., 1975. Late Cenozoic planktonic foraminifera biostratigraphy and paleoclimatology of Hatton-Rockall Basin: DSDP Site 116. *J. Foraminiferal Res.,* 5:270–293.

Raymo, M.E., Ruddiman, W.F., and Clement, B.M., 1987. Pliocene–Pleistocene paleoceanography of the North Atlantic at DSDP Site 609. *In* Ruddiman, W.F., Kidd, R.B., Thomas, E., et al., *Init. Repts. DSDP,* 94 (Pt. 2): Washington (U.S. Govt. Printing Office), 895–901.

Raymo, M.E., Ruddiman, W.F., Backman, J., Clement, B.M., and Martinson, D.G., 1989. Late Pliocene variation in Northern Hemisphere ice sheets and North Atlantic deep water circulation, *Paleoceanography,* 4: 413–446.

Raymo, M.E., Ruddiman, W.F., Shackleton, N.J., and Oppo, D.W., 1990. Evolution of Atlantic-Pacific $\delta^{13}C$ gradients over the last 2.5 m.y. *Earth Planet. Sci. Lett.,* 97:353–368.

Roberts, D.G., Schnitker, D., et al., 1984. *Init. Repts. DSDP,* 81: Washington (U.S. Govt. Printing Office).

Ruddiman, W.F., Kidd, R.B., Thomas, E., et al., 1987. *Init. Repts. DSDP,* 94 (Pts. 1 and 2): Washington (U.S. Govt. Printing Office).

Shackleton, N.J., Backman, J., Zimmerman, H., Kent, D.V., Hall, M.A., Roberts, D.G., Schnitker, D., Baldauf, J.G., Desprairies, A., Homrighausen, R., Huddlestun, P., Keene, J.B., Kaltenback, A.J., Krumsiek, K.A.O., Morton, A.C., Murray, J.W., and Westberg-Smith, J., 1984. Oxygen isotope calibration of the onset of ice-rafting and history of glaciation in the North Atlantic region. *Nature,* 307:620–623.

Shipboard Scientific Party, 1996a. Explanatory notes. *In* Jansen, E., Raymo, M.E., Blum, P., et al., *Proc. ODP, Init. Repts.,* 162: College Station, TX (Ocean Drilling Program), 21–45.

Shipboard Scientific Party, 1996b. Site 907 (revisited). *In* Jansen, E., Raymo, M.E., Blum, P., et al., *Proc. ODP, Init. Repts.,* 162: College Station, TX (Ocean Drilling Program), 223–252.

Shipboard Scientific Party, 1996c. Sites 980/981. *In* Jansen, E., Raymo, M.E., Blum, P., et al., *Proc. ODP, Init. Repts.,* 162: College Station, TX (Ocean Drilling Program), 49–90.

Shipboard Scientific Party, 1996d. Site 982. *In* Jansen, E., Raymo, M.E., Blum, P., et al., *Proc. ODP, Init. Repts.,* 162: College Station, TX (Ocean Drilling Program), 91–138.

Shipboard Scientific Party, 1996e. Site 983. *In* Jansen, E., Raymo, M.E., Blum, P., et al., *Proc. ODP, Init. Repts.,* 162: College Station, TX (Ocean Drilling Program), 139–167.

Shipboard Scientific Party, 1996f. Site 984. *In* Jansen, E., Raymo, M.E., Blum, P., et al., *Proc. ODP, Init. Repts.,* 162: College Station, TX (Ocean Drilling Program), 169–222.

Shipboard Scientific Party, 1996g. Site 985. *In* Jansen, E., Raymo, M.E., Blum, P., et al., *Proc. ODP, Init. Repts.,* 162: College Station, TX (Ocean Drilling Program), 253–285.

Shipboard Scientific Party, 1996h. Site 986. *In* Jansen, E., Raymo, M.E., Blum, P., et al., *Proc. ODP, Init. Repts.,* 162: College Station, TX (Ocean Drilling Program), 287–343.

Shipboard Scientific Party, 1996i. Site 987. *In* Jansen, E., Raymo, M.E., Blum, P., et al., *Proc. ODP, Init. Repts.,* 162: College Station, TX (Ocean Drilling Program), 345–387.

Spencer-Cervato, C., Thierstein, H.R., Lazarus, D.B., and Beckmann, J.-P., 1994. How synchronous are Neogene marine plankton events? *Paleoceanography,* 9:739–763.

Spiegler, D., 1996. Planktonic foraminifer Cenozoic biostratigraphy of the Arctic Ocean, Fram Strait (Sites 908–909), Yermak Plateau (Sites 910–912), and East Greenland Margin (Site 913). *In* Thiede, J., Myhre, A. M., Firth, J.V., Johnson, G.L., and Ruddiman, W.F. (Eds.), *Proc. ODP, Sci. Results,* 151: College Station, TX (Ocean Drilling Program), p. 153–167.

Spiegler, D., and Jansen, E., 1989. Planktonic foraminifer biostratigraphy of Norwegian Sea sediments: ODP Leg 104. *In* Eldholm, O., Thiede, J., Taylor, E., et al., *Proc. ODP, Sci. Results,* 104: College Station, TX (Ocean Drilling Program), 681–696.

Talwani, M., Udintsev, G., et al., 1976. *Init. Repts. DSDP,* 38: Washington (U.S. Govt. Printing Office).

Weaver, P.P.E., 1987. Late Miocene to Recent Planktonic foraminifers from the North Atlantic: Deep Sea Drilling Project Leg 94. *In* Ruddiman, W.F., Kidd, R.B., Thomas E., et al., *Init. Repts. DSDP,* 94: Washington (U.S. Govt. Printing Office), 703–727.

Weaver, P.P.E., and Clement, B.M., 1986. Synchroneity of Pliocene planktonic foraminiferal datums in the North Atlantic. *Marine Micropaleontology,* 10: 295—307.

————, 1987. Magnetobiostratigraphy of planktonic foraminiferal datums, DSDP Leg 94, North Atlantic. *In* Ruddiman, W.F., Kidd, R.B., Thomas, E., et al., *Init. Repts. DSDP,* 94: Washington (U.S. Govt. Printing Office), 815–829.

Date of initial receipt: 17 September 1998
Date of acceptance: 5 October 1998
Ms 162SR-038

Table 10. Stratigraphic ranges of planktonic foraminifers in selected samples from Holes 986A, 986C, and 986D, Svalbard margin.

Core, section, interval (cm)	Depth (mbsf)	Depth (mcd)	Abundance	Preservation	*Globigerina bulloides*	*Globigerina quinqueloba*	*Neogloboquadrina atlantica* (sinistral)	*Neogloboquadrina pachyderma* (dextral)	*Neogloboquadrina pachyderma* (sinistral)	Zone	Epoch
162-986A-											
1H-1, 0	0.00	0.00	A	G		T		R	D	*N. pachyderma* (s.)	Pleistocene
1H-CC, 6-9	4.56	4.56	F	G		T		T	A/D		
2H-CC, 21-24	14.49	15.85	A	G		T			D		
3H-CC, 19-22	23.95	26.01	R	G					D		
4H-CC, 27-30	33.43	36.37	R	G					D		
5H-CC, 24-27	42.93	46.19	R	G					D		
6H-CC, 26-29	52.76	56.56	T	M					D		
7H-CC, 21-24	62.75	62.15	C	G				T	D		
8H-CC, 45-48	71.96	71.36	R	G		T			D		
9H-CC, 34-37	78.72	78.12	R	P/M					D		
10H-CC, 45-48	89.14	88.54	R/F	P/M					D		
11H-CC, 60-63	96.11	95.51	R	M					D		
12H-CC, 22-25	102.75	105.19	R	M					D		
13H-CC, 31-34	105.60	110.24	F	M				T	D		
14H-CC, 23-26	114.31	118.95	R	M					D		
15X-CC, 17-20	119.83	125.83	C	M/G		T			D		
16X-CC, 26-29	124.96	131.69	R	M					D		
17X-CC, 59-62	137.73	144.73	R	M					D		
19X-CC, 21-24	155.02	162.26	B								
20X-CC, 22-25	164.66	171.90	B								
21X-CC, 37-40	176.89	184.13	B								
22X-CC, 0-2	177.20	184.44	R	M					D		
23X-CC, 35-38	193.02	197.05	B								
24X-CC, 28-31	205.67	209.70	B								
162-986C-											
17X-CC, 23-26	156.67	161.03	B								Pleistocene
18X-CC, 19-22	157.99	162.35	B								
19X-CC, 15-18	170.36	174.72	B								
20X-CC, 7-10	179.66	184.02	B								
21X-CC, 21-24	193.43	197.79	R	M					D		
22X-CC, 49-52	201.29	207.44	B								
26X-CC, 0-2	235.54	241.69	T					T	T		
27X-CC, 15-18	245.80	251.95	B								
28X-CC, 20-23	256.44	262.59	B								
29X-CC, 23-26	265.08	271.23	B								
33X-CC, 6-9	292.46	298.61	B								
34X-CC, 24-27	304.55	310.70	B								
35X-1, 44-46	312.14	318.29	B								
35X-2, 44-46	313.64	319.79	B								
35X-CC, 35-38	314.30	320.45	T	P					D		
36X-CC, 33-36	322.26	328.41	B								
37X-CC, 98-101	340.89	347.04	B								
42X-CC, 34-37	385.12	391.27	B								
162-986D-											
2R-CC, 6-9	402.95	402.95	B							*N. pachyderma* (s.)	Pleistocene
3R-CC, 27-30	408.09	408.09	B								
5R-CC, 27-30	426.57	426.57	B								
11R-CC, 38-41	484.28	484.28	B								
16R-CC, 9-12	541.48	541.48	R	G		R		A	A		
17R-CC, 15-18	546.57	546.57	R	G	R				D		
18R-CC, 12-15	558.92	558.92	B								
19R-CC, 11-14	564.85	564.85	B								
20R-CC, -1	570.30	570.30	B								
21R-CC, 1-4	584.65	584.65	B								
27R-CC, 33-36	638.03	638.03	B								
28R-CC, 0-2	655.84	655.84	B								
29R-CC, 13-16	662.58	662.58	B								
30R-CC, 19-22	672.22	672.22	B								
31R-CC, 10-13	682.75	682.75	B								
32R-CC, 10-13	694.17	694.17	B								
33R-CC, 9-12	696.85	696.85	B								
34R-1, 44-46	705.44	705.44	B								
34R-2, 44-46	705.94	705.94	T	M	C		F		F	*N. atlantica* (s.)	Pliocene
34R-CC, 0-2	707.30	707.30	R	M	C		C	C			
35R-CC, 14-17	724.38	724.38	B								
36R-CC, 0-1	724.20	724.20	T	M	A		R				
38R-CC, 9-11	749.86	749.86	T	M	D		T	T			
43R-CC, 15-18	795.39	795.39	T	M			T				
44R-CC, 17-20	806.85	806.85	T	M	C		R				
45R-CC, 7-10	820.41	820.41	T	M			T				
47R-CC, 24-27	833.50	833.50	T	M			T				
48R-CC, 20-23	842.19	842.19	T	M			T				
50R-CC, 0-3	865.92	865.92	B								

Note: Abbreviations as in Table 2.

SPECIES LIST

Planktonic foraminifer taxonomy largely follows Kennett and Srinivasan (1983) and Bolli and Saunders (1985). An exception is *Paragloborotalia mayeri*, where the genus of Cifelli (1982) was assigned. The original citation for each species is given in the following list, although most are not included in the references. Complete citations are given in Kennett and Srinivasan (1983) and Bolli and Saunders (1985).

Catapsydrax dissimilis Cushman and Bermudez

Globigerina dissimilis Cushman and Bermudez, 1937, p. 25, pl. 3, figs. 4–6.
Catapsydrax dissimilis (Cushman and Bermudez) Kennett and Srinivasan, 1983, p. 22, pl. 2, figs. 1, 3–8.

Catapsydrax stainforthi Bolli, Loeblich, and Tappan

Catapsydrax stainforthi Bolli, Loeblich, and Tappan, 1957, p. 37, pl. 7, figs. 11a–11c.
Catapsydrax stainforthi (Bolli, Loeblich, and Tappan) Kennett and Srinivasan, 1983, p. 27, pl. 3, figs. 4–6.

Globigerina bulloides d'Orbigny

Globigerina bulloides d'Orbigny, 1826, p. 3, pl. 1, figs. 1–4.
Globigerina (Globigerina) bulloides (d'Orbigny) Kennett and Srinivasan, 1983, p. 36, pl. 6, figs. 4–6.

Globigerina decoraperta Takayanagi and Saito

Globigerina eamsi Takayanagi and Saito, 1962, p. 85, pl. 28, figs. 10a–10c.
Globigerina eamsi (Takayanagi and Saito) Kennett and Srinivasan, 1983, p. 48, pl. 9, figs. 4–6.

Globigerina eamsi Blow

Globigerina eamsi Blow, 1959, p. 176, pl. 9, figs. 39a–39c.
Globigerina eamsi (Blow) Kennett and Srinivasan, 1983, p. 34, pl. 5, figs. 7–9.

Globigerina falconensis Blow

Globigerina falconensis Blow, 1959, p. 177, pl. 9, figs. 40a–40c, 41.
Globigerina falconensis (Blow) Kennett and Srinivasan, 1983, p. 40, pl. 7, figs. 1–3.

Globigerina nepenthes Todd

Globigerina nepenthes Todd, 1957, p. 3-1, figs. 7a–7b.
Globigerina (Zeaglobigerina) nepenthes (Todd) Kennett and Srinivasan, 1983, p. 48, pl. 9, figs. 1–3.

Globigerina praebulloides Blow

Globigerina praebulloides Blow, 1959, p. 180, pl. 8, figs. 47a–47c; pl. 9, fig. 48.

Globigerina (Globigerina) praebulloides (Blow) Kennett and Srinivasan, 1983, p. 38, pl. 6, figs. 1–3.

Globigerina quinqueloba Natland

Globigerina quinqueloba Natland, 1938, p. 149, pl. 6, figs. 7a–7c
Globigerina (Globigerina) quinqueloba (Natland) Kennett and Srinivasan, 1983, p. 32, pl. 5, figs. 4–6.

Globigerina woodi Jenkins

Globigerina woodi Jenkins, 1960, p. 352, pl. 2, figs. 2a–2c.
Globigerina (Zeaglobigerina) woodi (Jenkins) Kennett and Srinivasan, 1983, p. 43, pl. 7, figs. 4–6.
Globigerina (Turborotalita) woodi woodi (Jenkins) Chaproniere, 1988, p. 124, pls. 1–2.

Globigerinella aequilateralis Brady

Globigerina aequilateralis Brady, 1879, p. 285 (figs. in Brady, 1884, pl. 80, figs. 18–21).
Globigerinella aequilateralis (Brady) Kennett and Srinivasan, 1983, p. 238, pl. 59, fig. 1; pl. 60, figs. 4–6.

Globigerinita glutinata Egger

Globigerina glutinata Egger, 1893, 371, p. 13, figs. 19–21.
Globigerinita glutinata (Egger) Kennett and Srinivasan, 1983, p. 224, pl. 56, figs. 1, 3–5.

Globigerinita uvula Ehrenberg

Pylodexia uvula Ehrenberg, 1861, 371, pl. 2, figs. 24–25.
Globigerinita uvula (Ehrenberg) Kennett and Srinivasan, 1983, p. 224, pl. 56, figs. 6–8.

Globigerinoides conglobatus Brady

Globigerinoides conglobatus Brady, 1879, p. 28b.
Globigerinoides conglobatus (Brady) Kennett and Srinivasan, 1983, p. 56, pl. 12, figs. 4–6.

Globigerinoides obliquus Bolli

Globigerinoides obliquus Bolli, 1957, p. 113, pl. 25, figs. 10a–10c.
Globigerinoides obliquus (Bolli) Kennett and Srinivasan, 1983, p. 56, pl. 11, figs. 7–9.

Globigerinoides ruber d'Orbigny

Globigerinoides rubra d'Orbigny, 1839, p. 82, pl. 4, figs. 12–14.
Globigerinoides ruber (d'Orbigny) Kennett and Srinivasan, 1983, p. 10, fig. 6; pl. 17, figs. 1–3.

Globigerinoides subquadratus Brönnimann

Globigerinoides subquadratus Brönnimann, 1954, p. 680, pl. 1, figs. 8a–8c.
Globigerinoides subquadratus (Brönnimann) Kennett and Srinivasan, 1983, p. 74, pl. 16, figs. 1–3.

Globigerinoides triloba Reuss

Globigerina triloba Reuss, 1850, p. 374, pl. 447, figs. 11a–11c.
Globigerinoides triloba (Reuss) Kennett and Srinivasan, 1983, p. 62, pl. 10, fig. 4; pl. 13, figs. 1–3.
Globigerinoides triloba (Reuss) Bolli and Saunders, 1985, p. 196, fig. 20.15.

Globigerinoides quadrilobatus d'Orbigny

Globigerina quadrilobata d'Orbigny, 1846, p. 164, pl. 9, figs. 7–10.
Globigerinoides quadrilobatus (d'Orbigny) Kennett and Srinivasan, 1983, p. 66, pl. 14, figs. 1–3.

Globoquadrina baroemoenensis LeRoy

Globigerina baroemoenensis LeRoy, 1939, p. 263, pl. 6, figs. 1–2.
Globoquadrina baroemoenensis (LeRoy) Kennett and Srinivasan, 1983, p. 186, pl. 6, figs. 1–3.

Globoquadrina dehiscens Chapman, Parr and Collins

Globorotalia dehiscens Chapman, Parr and Collins, 1934, p. 569, pl. 11, figs. 36a–36c.
Globoquadrina dehiscens (Chapman, Parr and Collins) Kennett and Srinivasan, 1983, p. 184, pl. 44, fig. 2; pl. 45, figs. 7–9.

Globorotalia conoidea Finlay

Globorotalia miozea Finlay, 1939, p. 326, pl. 29, figs. 159–161.
Globorotalia conoidea (Finlay) Kennett and Srinivasan, 1983, p. 113, pl. 26, figs. 4–6.

Globorotalia conomiozea Kennett

Globorotalia conomiozea Kennett, 1966, p. 235, pl. 29, text figs. 10a–10c.
Globorotalia conomiozea (Kennett) Kennett and Srinivasan, 1983, p. 114, pl. 26, figs. 7–9.

Globorotalia crassaformis Galloway and Wissler

Globigerina crassaformis Galloway and Wissler, 1927, p. 41, pl. 7, fig. 12.
Globorotalia (Truncorotalia) crassaformis (Galloway and Wissler) Kennett and Srinivasan, 1983, p. 146, pl. 34, figs. 6–8.
Globorotalia crassaformis crassaformis (Galloway and Wissler) Bolli and Saunders, 1985, p. 230, figs. 36.6–7.

Globorotalia cf. *crassula* Weaver

Globorotalia cf. *crassula* Weaver, 1987, p. 727, pl. 3, figs. 12–15.

Globorotalia juanae Bermudez and Bolli

Globorotalia juanae Bermudez and Bolli, 1927, pp. 171–172, pl. 14, figs. 1–6.
Globorotalia (Hirsutella) juanae (Bermudez and Bolli) Kennett and Srinivasan, 1983, p. 134, pl. 31, figs. 6–8.
Globorotalia juanae (Bermudez and Bolli) Bolli and Saunders, 1985, p. 216, figs. 30.20–21a–21c and 30.22–24.

Globorotalia margaritae Bolli and Bermudez

Globorotalia margaritae Bolli and Bermudez, 1965, p. 138, pl. 1, figs. 1–9.
Globorotalia (Hirsutella) margaritae (Bolli and Bermudez) Kennett and Srinivasan, 1983, p. 136, pl. 32, figs. 4–6.
Globorotalia margaritae (Bolli and Bermudez) Bolli and Saunders, 1985, p. 216, figs. 30.1–5, 30.9–14.

Globorotalia miozea Finlay

Globorotalia miozea Finlay, 1939, p. 326, pl. 29, figs. 159–161.
Globorotalia (Globoconella) miozea (Finlay) Kennett and Srinivasan, 1983, p. 112, pl. 24, fig. 2; p. 26, figs. 1–3.

Globorotalia praescitula Blow

Globorotalia scitula (Brady) subsp. *praescitula* Blow, 1959, p. 221, pl. 19, figs. 129a–129c.
Globorotalia (Globoconella) praescitula (Blow) Kennett and Srinivasan, 1983, p. 108, pl. 24, fig. 1; p. 25, figs. 4–6.

Globorotalia puncticulata Deshayes

Globigerina puncticulata Deshayes, 1832, p. 170; Banner and Blow, 1960, p. 15, pl. 5, figs. 7a–7c (lectotype).
Globorotalia (Globoconella) puncticulata (Deshayes) Kennett and Srinivasan, 1983, p. 116, pl. 27, figs. 4–6.

Globorotalia scitula Brady

Pulvinulina scitula Brady, 1882, p. 27, pl. 5, fig. 5 (lectotype).

Globorotalia (Hirsutella) scitula (Brady) Kennett and Srinivasan, 1983, p. 134, pl. 31, figs. 1, 3–5.

Globorotalia truncatulinoides d'Orbigny

Rotalia truncatulinoides d'Orbigny, 1839, p. 132, pl. 2, figs. 25–27.
Globorotalia truncatulinoides (d'Orbigny) Lamb and Beard, 1972, p. 56, pl. 24, figs. 1–4; pl. 25, figs. 1–7; pl. 26, figs. 1–3; Jenkins and Orr, 1972; p. 1104, pl. 33, figs. 4–6; Stainforth et al., 1975, figs. 209–211.
Globorotalia truncatulinoides truncatulinoides (d'Orbigny) Bolli and Saunders, 1985, p. 234, figs. 37.4–37.5.
Globorotalia truncatulinoides (d'Orbigny) Kennett and Srinivasan, 1983, p. 148, pl. 34, fig. 2; pl. 35, fig. 2; pl. 35, figs. 4–6.

Globorotalia zealandica Hornibrook

Globorotalia zealandica Hornibrook, 1958, p. 667, figs. 18, 19, 30.
Globorotalia (Globoconella) zealandica (Hornibrook) Kennett and Srinivasan, 1983, p. 108, pl. 25, figs. 1–3.

Neogloboquadrina acostaensis Blow

Globorotalia acostaensis Blow, 1959, p. 208, pl. 17, figs. 106a–106c.
Neogloboquadrina acostaensis (Blow) Kennett and Srinivasan, 1983, p. 196, pl. 47, fig. 1; pl. 48, figs. 1–3.

Neogloboquadrina atlantica Berggren

Neogloboquadrina atlantica Berggren, 1972, pl. 1, figs. 7–9.

Neogloboquadrina continuosa Blow

Globorotalia opima Bolli subsp. *continuosa* Blow, 1959, p. 218, pl. 19, figs. 125a–125c.
Neogloboquadrina continuosa (Blow) Kennett and Srinivasan, 1983, p. 192, pl. 47, figs. 3–5.

Neogloboquadrina humerosa Takayanagi and Saito

Globorotalia humerosa Takayanagi and Saito, 1962, p. 78, pl. 28, figs. 1a–2b.
Neogloboquadrina acostaensis (Takayanagi and Saito) Kennett and Srinivasan, 1983, p. 196, pl. 28, fig. 1; pl. 48, figs. 1a–2b.

Neogloboquadrina pachyderma Ehrenberg

Aristospira pachyderma Ehrenberg, 1861, pl. 3, figs. 8, 9, 11–13; Banner and Blow, 1960, p. 4, pl. 3, figs. 4a–4c (lectotype).
Neogloboquadrina pachyderma (Ehrenberg) Kennett and Srinivasan, 1983, p. 192, pl. 47, figs. 6–8.

Orbulina bilobata d'Orbigny

Globigerina bilobata d'Orbigny, 1846, p. 164, pl. 9, figs. 11–14.
Orbulina bilobata (d'Orbigny) Kennett and Srinivasan, 1983, p. 88, pl. 20, figs. 7–9.

Orbulina suturalis Brönnimann

Orbulina suturalis Brönnimann, 1951, p. 135, text fig. IV, figs. 15, 16, 20.
Orbulina suturalis (Brönnimann) Kennett and Srinivasan, 1983, p. 86, pl. 20, figs. 1–3.

Orbulina universa d'Orbigny

Orbulina universa d'Orbigny, 1839, p. 3, pl. 1, fig. 1.
Orbulina universa (d'Orbigny) Kennett and Srinivasan, 1983, p. 86, pl. 20, figs. 4–6.

Paragloborotalia mayeri Cushman and Ellisor

Globorotalia mayeri Cushman and Ellisor, 1939, p. 11, pl. 2, figs. 4a–4c.
Globorotalia siakensis LeRoy, 1939, p. 262, pl. 4, figs. 20–22.
Paragloborotalia mayeri Cifelli, 1982, p. 108, pl. 1, fig. 5; p. 111, pl. 2, figs. 1–2.
Globorotalia (Jenkinsella) mayeri (Cushman and Ellisor) Kennett and Srinivasan, 1983, p. 174, pl. 43, figs. 4–6.
Globorotalia (Jenkinsella) siakensis (LeRoy) Kennett and Srinivasan, 1983, p. 172, pl. 42, figs. 1, 68.

Sphaeroidinellopsis disjuncta Finlay

Sphaeroidinella disjuncta Finlay, 1940, p. 467, pl. 67, figs. 224–228.
Sphaeroidinellopsis disjuncta (Finlay) Kennett and Srinivasan, 1983, p. 206, pl. 51, figs. 3–5.

Sphaeroidinellopsis kochi Caudri

Globigerina kochi Caudri, 1934, text figs. 8a–8b.
Sphaeroidinellopsis kochi (Caudri) Kennett and Srinivasan, 1983, p. 210, pl. 52, figs. 1–3.

Sphaeroidinellopsis paenedehiscens Blow

Sphaeroidinellopsis subdehiscens paenedehiscens Blow, 1969, p. 386, pl. 30, figs. 4, 5, 9.
Sphaeroidinellopsis paenedehiscens (Blow) Kennett and Srinivasan, 1983, p. 211, pl. 52, figs. 4–6.

Streptochilus globigerum Brönnimann and Resig

Textilaria globigera Schwager, 1866, p. 252, pl. 7, fig. 100.
Streptochilus Brönnimann and Resig, 1971, p. 1288, pl. 51, figs. 14.
Streptochilus globigerum (Brönnimann and Resig) Kennett and Srinivasan, 1983, p. 21, pl. 1, figs. 2, 6–8.

Streptochilus tokelauae Boersma

Bolivina tokelauae Boersma, 1969, p. 329, pl. 1., figs. 1a–1c.
Streptochilus tokelauae (Boersma) Kennett and Srinivasan, 1983, p. 21.

Table 11. Stratigraphic ranges of planktonic foraminifers in selected samples from Hole 987A, East Greenland margin.

Core, section, interval (cm)	Depth (mbsf)	Depth (mcd)	Abundance	Preservation	*Globigerina bulloides*	*Globigerina quinqueloba*	*Neogloboquadrina pachyderma* (dextral)	*Neogloboquadrina pachyderma* (sinistral)	*Neogloboquadrina* spp.	Zone	Epoch
162-987A-											
1H-CC, 16-19	8.54	8.68	A	G				D		*N. pachyderma* (s.)	Pleistocene
2H-CC, 21-24	18.17	19.74	A	M	T		R	D			
4H-CC, 23-26	37.36	40.71	R	G				D			
5H-CC, 22-25	45.48	49.97	R	G				D			
6H-CC, 24-27	52.19	57.20	T	M				D	T		
7H-CC, 22-25	59.70	65.75	T	G				D			
9H-CC, 30-33	76.22	83.28	T	G				D			
10H-CC, 71-74	84.13	91.92	R/F	G				D			
11H-CC, 6-9	88.80	97.55	B								
12H-CC, 62-65	95.42	100.81	B								
13H-CC, 14-17	112.62	120.49	B								
14H-CC, 45-48	122.33	130.98	B								
15H-CC, 39-42	131.18	139.83	B								
16H-CC, 28-31	140.12	149.59	B								
17H-CC, 31-34	150.89	160.36	B								
18H-CC, 45-48	159.50	169.49	F/C	M		D					
19H-CC, 34-37	170.37	181.22	B								
20H-CC, 46-49	180.04	190.89	B								
21H-CC, 34-37	187.11	197.96	B								
22H-CC, 41-44	199.33	210.18	B								

Note: Abbreviations as in Table 2.

Table 12. Synchroneity/diachroneity of planktonic foraminifer datum levels (Sites 981–984).

		Hole 981A			Hole 982B			Hole 983A			Hole 984B		
Datum level	Age (Ma)	Depth (mbsf)	Age (Ma)	Average age (Ma)	Depth (mbsf)	Age (Ma)	Average age (Ma)	Depth (mbsf)	Age (Ma)	Average age (Ma)	Depth (mbsf)	Age (Ma)	Average age (Ma)
S, acme *N. pachyderma* (s.)	1.80	98.09 100.80	1.79 1.83	1.81	36.60 37.76	1.79 1.86	1.83	227.60 230.60	1.78 1.80	1.79	192.35 198.35	1.74 1.79	1.77
FO *Gr. inflata*	2.09	120.82 120.99	2.13 2.13	2.13	41.10 42.54	2.06 2.13	2.09						
LO *N. atlantica*	2.41	144.19 145.69	2.21 2.22	2.22	45.54 47.15	2.26 2.34	2.30				302.15 303.65	2.57 2.58	2.57*
LO *Gr. puncticulata*	2.41	147.19 148.69	2.22 2.23	2.23	56.18 57.68	2.78 2.85	2.81						
LO *Gr.* cf. *crassula*	3.30	206.30 207.80	3.12 3.14	3.13	68.42 68.42	3.15 3.20	3.17						
FO *Gr. puncticulata*	4.50	277.70 279.20	4.33 4.36	4.34	109.70 110.30	4.29 4.33	4.31						
LO *N. acostaensis*	5.29				160.74 162.24	5.44 5.47	5.45						
d. to s. *N. atlantica*	6.40				236.69 238.19	7.10 7.13	7.12						
FO *N. acostaensis*	10.03				323.05 326.49	9.42 9.51	9.46						
LO *P. mayeri*	10.30				323.05 326.49	9.42 9.51	9.46						
FO *O. suturalis*	15.10				498.60 499.70	14.93 14.98	14.95						
LO *C. dissimilis*	17.30				540.95	16.99	17.01						

Notes: Ages in the second column are after Berggren et al. (1995). S = start, d. = dextral, s. = sinistral, FO = first occurrence, LO = last occurrence. **N. atlantica* datum level in Hole 984B is calculated on extrapolation of sedimentation rate between base of Olduvai Chron and top of Reunion Event.