Quaternary Stratigraphy and Paleoceanography of the Canada Basin, Western Arctic Ocean

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By Richard Z. Poore, Scott E. Ishman, R. Lawrence Phillips, and David H. McNeil

U.S. GEOLOGICAL SURVEY BULLETIN 2080

Climate and paleoceanography of the western Arctic Ocean for the last 1 million years interpreted from four marine sediment cores

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1994

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

ROBERT M. HIRSCH, Acting Director

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Box 25286, MS 306, Federal Center
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Published in the Eastern Region, Reston, Va.
Manuscript approved for publication December 7, 1993.

Library of Congress Cataloging in Publication Data

Quaternary stratigraphy and paleoceanography of the Canada Basin, western Arctic Ocean / by Richard Z. Poore ... [et al.].
p. cm. — (U.S. Geological Survey bulletin ; 2080)
Includes bibliographical references.
Supt. of Docs. no.: I 19.3:2080
1. Geology, Stratigraphic—Quaternary. 2. Paleoceanography—Canada Basin. I. Poore, Richard Z. II. Series.
QE75.B9 no. 2080
[QE696]
557.3 s—dc20
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CONVERSION FACTORS

Multiply	By	To obtain
	Length	
micrometer (μm)	0.000039	inch
millimeter (mm)	0.0394	inch
centimeter (cm)	0.3937	inch
meter (m)	3.281	foot
	Mass	
gram (g)	0.0353	ounce avoirdupois

Age designation.—Carbon-14 dates are expressed as yr B.P., meaning years before present (A.D. 1950).

Quaternary Stratigraphy and Paleoceanography of the Canada Basin, Western Arctic Ocean

By Richard Z. Poore,[1] Scott E. Ishman,[1] R. Lawrence Phillips,[2] and David H. McNeil[3]

ABSTRACT

Lithologic, paleontologic, and paleomagnetic analyses of sediment cores from Northwind Ridge in the western Canada Basin provide a stratigraphic framework for interpreting the upper Quaternary paleoceanographic record of the western Arctic Ocean. Analyses of the cores, which were taken over a depth range of 945 to 3,513 m, reveal distinct cycles in the abundance of planktic foraminifers that we interpret as glacial-interglacial cycles. Variations in preservation of foraminifers and changes in benthic foraminifer assemblages through time and along the depth transect show that the carbonate compensation depth became deeper during successive interglacial stages of the late Quaternary. The abrupt abundant appearance of *Oridorsalis* in benthic assemblages between 3,513 and 945 m depth during an interglacial stage that we correlate with oxygen-isotope stage 9 marks the development of near modern deepwater structure in the western Arctic.

INTRODUCTION

The Arctic Ocean is an extremely important component of the Earth's climate system, yet the paleoceanographic and paleoclimatic history of the Arctic is still poorly known and controversial. Documenting the Pliocene to Quaternary history of the Arctic Ocean has been hampered by lack of adequate material for study and by the perennial ice cover that limits access to many areas of the Arctic. Most coring in the central and western Arctic has been done from floating ice stations that cannot be directed toward a particular area or objective. In general, only short piston and gravity cores are available, and most cores from topographic highs in the central and western Arctic recovered sedimentary sections with extremely low average accumulation rates (about 1 to 2 mm/1,000 yr; for example, see Clark and others, 1980; Scott and others, 1989). Age and environmental interpretations of these cores are complicated by the low resolution of the records. The cores available from the deep Canada Basin sampled Holocene turbidites (Hunkins and Kutschale, 1967; Campbell and Clark, 1977; Goldstein, 1983), for which sediment accumulation rates range from 4 to 462 mm/1,000 yr, with an average of 83 mm/1,000 yr (Campbell and Clark, 1977). However, the turbidites contain much reworked material, and interpreting a paleoceanographic record from them is very difficult.

The U.S. Geological Survey obtained a suite of piston cores in 1988 from the U.S. Coast Guard Cutter *Polar Star* in the area of Northwind Ridge, which is a prominent feature extending from the Chukchi Sea continental slope into the Canada Basin of the western Arctic Ocean (fig. 1*A*, *B*). The cruise was part of an ongoing geologic sampling and geophysical program designed to understand the geologic evolution and oceanographic history of the western Arctic Ocean. Initial examination of the 1988 *Polar Star* cores indicated that they contained a relatively complete record of the last million years and that accumulation rates in some cores were higher (>4 mm/1,000 yr) than those for existing Arctic cores collected from topographic highs. Thus, these cores preserve a more detailed, yet still condensed, paleoclimatic and paleoceanographic record of the western Arctic Ocean.

This study presents the stratigraphy and environmental interpretations of four cores recovered from the crest and east flank (Northwind Escarpment) of Northwind Ridge in 1988 (fig. 1*C*; table 1). The cores form a transect that extends from 945 m down to 3,513 m depth. Cores 9 and 5 are from near the crest of Northwind Ridge on opposite sides of a central depression that extends along the ridge axis. Cores 3 and 7 are from the Northwind Escarpment. Cores 9 and 5 recovered relatively long and apparently undisturbed sections—626 and 476 cm, respectively. The sections recovered in cores 3 and 7 are complicated by

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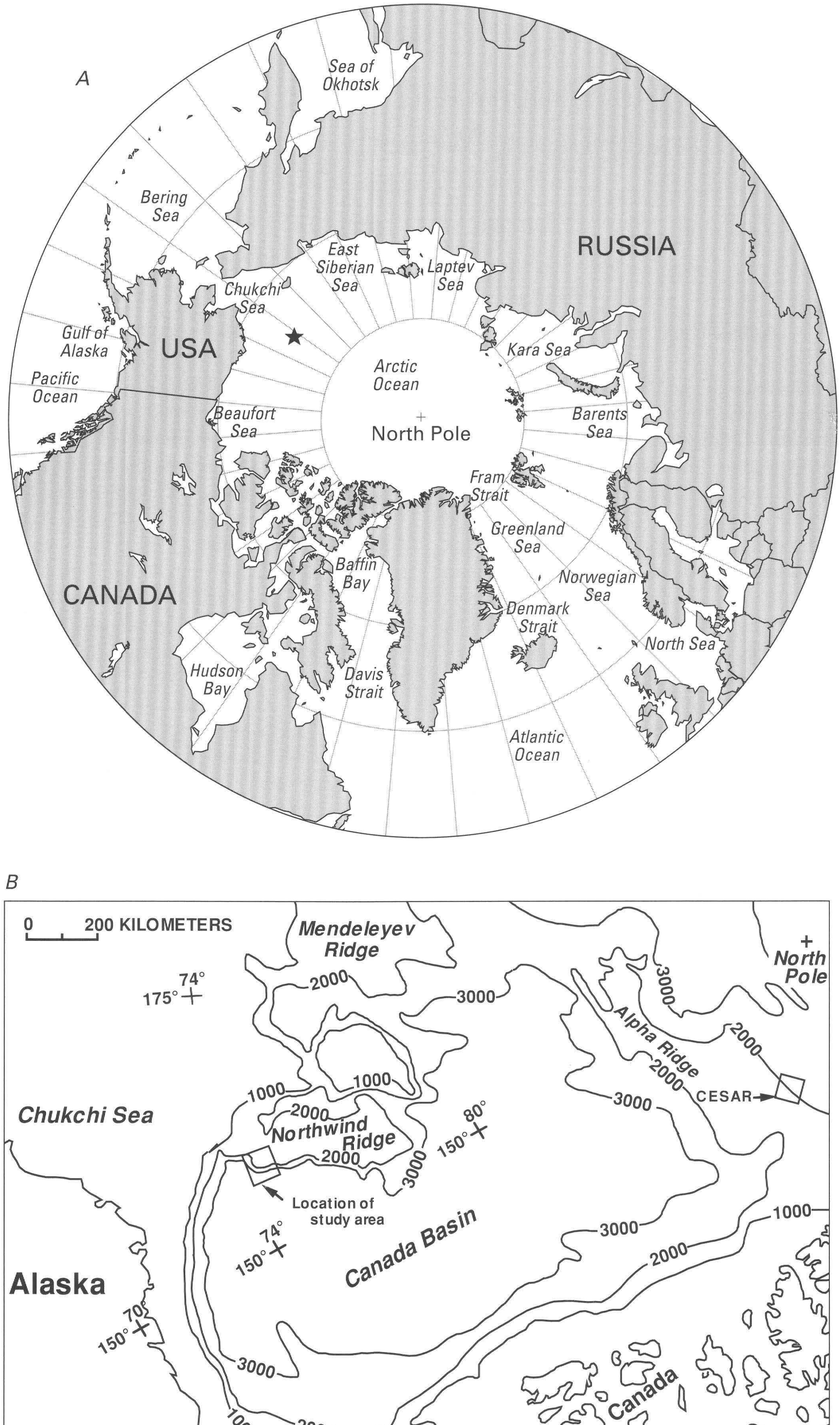
A
Sea of Okhotsk
Bering Sea
East Siberian Sea
Laptev Sea
RUSSIA
Chukchi Sea
Gulf of Alaska
USA
Kara Sea
Arctic Ocean
Pacific Ocean
Beaufort Sea
North Pole
Barents Sea
Fram Strait
Greenland Sea
Baffin Bay
CANADA
Norwegian Sea
Denmark Strait
North Sea
Hudson Bay
Davis Strait
Atlantic Ocean
B
0 200 KILOMETERS
Mendeleyev Ridge
North Pole
74°
175°
2000
3000
3000
Alpha Ridge
2000
2000
1000
1000
CESAR
Chukchi Sea
2000
80°
Northwind Ridge
150°
2000
3000
3000
Location of study area
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74°
150°
Canada Basin
3000
2000
Alaska
70°
150°
3000
Canada
1000
2000

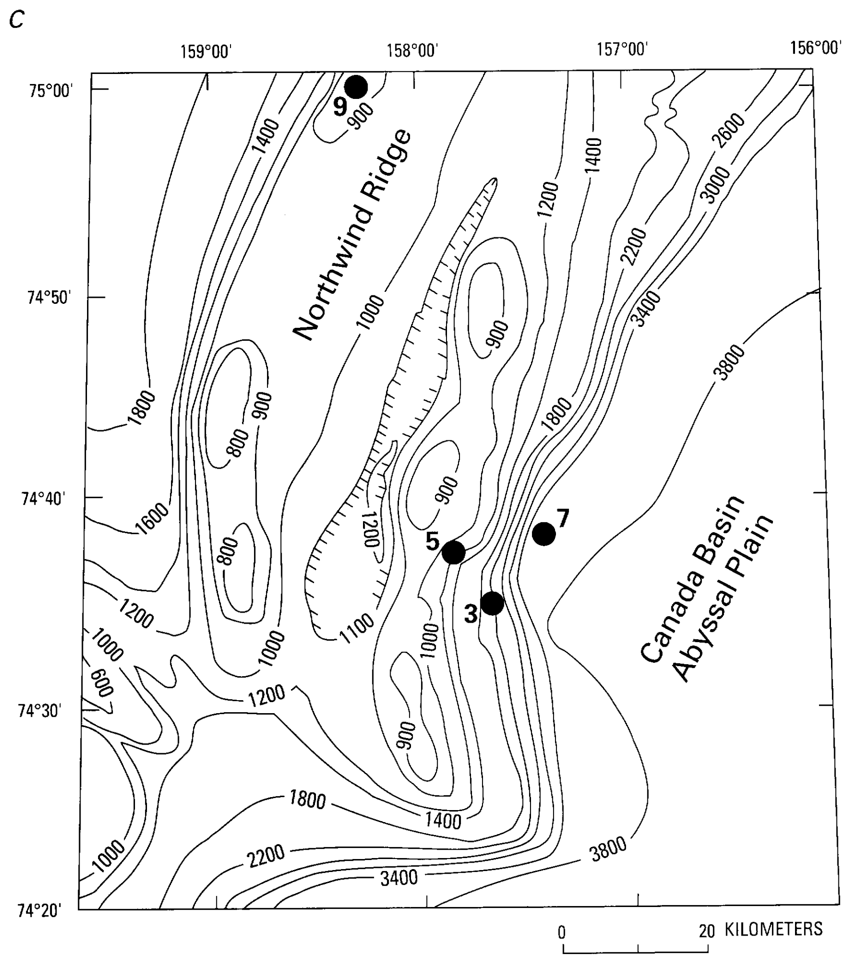

Figure 1. Location of study area *(A, B)* and four coring sites on Northwind Ridge in western Arctic Ocean *(C)*. Bathymetry contours in meters. *A*, Setting of the study area (at star) near the North Pole. Base map modified from MapArt Update 92 (MicroMaps Software, Lambertville, N.J.). *B*, Location of the study area on Northwind Ridge from which the U.S. Geological Survey collected the four cores described in this report. CESAR indicates area where cores were taken during the Canadian Expedition to Study the Alpha Ridge (CESAR) (Aksu, 1985; Scott and others, 1989). *C*, Location of Northwind Ridge coring sites (solid dots) discussed in text. *B* and *C* modified from Phillips and others (1992, fig. 1).

Table 1. Core designation, core length, water depth, and coordinates for Northwind Ridge cores 9, 5, 3, and 7 from the western Arctic Ocean.

Core designation		Core length (cm)	Water depth (m)	Coordinates	
Full	Brief			Latitude (N.)	Longitude (W.)
PI-88-AR-P9	9	626	945	75°01.38′	158°14.23′
PI-88-AR-P5	5	476	1089	74°37.35′	157°53.04′
PI-88-AR-P3	3	581	1909	74°35.60′	157°39.59′
PI-88-AR-P7	7	536	3513	74°37.76′	157°23.17′

internal erosional unconformities. However, most of core 3 and the upper part of core 7 do not contain discernible sediment gaps (Phillips and others, 1992). Pleistocene sediments recovered from Northwind Ridge consist of unconsolidated, interbedded mud, silty mud, sandy mud, and gravelly sandy mud. The cores exhibit distinct color banding due to intercalation of pinkish-white to white, clast-rich layers, dark-brown muddy and sandy mud beds, and gray to tan muds and silty muds. Calcareous microfossils are concentrated in the dark-brown beds, most of which are bioturbated and contain variable amounts of ice-rafted sediment.

ACKNOWLEDGMENTS

We thank Kevin Foley (U.S. Geological Survey, USGS) for technical assistance throughout this study and David L. Clark (University of Wisconsin) for discussions about the lithostratigraphy of our cores. The manuscript benefited from comments by Debra Willard, Paula Quinterno, and Arthur Grantz (all of USGS). We thank Meyer Rubin (USGS, Reston, Va.) for preparing graphite targets used for carbon-14 dating of upper layers of cores 9, 5, and 3. Dating of samples from core 5 was done at the National Science Foundation Accelerator Facility for Radioisotope Analyses at the University of Arizona, Tucson, Ariz. Dating of samples from cores 9 and 3 was done at the Center for Accelerator Mass Spectrometry, Lawrence Livermore National Laboratory, Livermore, Calif.

LITHOSTRATIGRAPHY

Clark and others (1980) defined informal standard lithostratigraphic units for the Arctic based on analyses of cores taken from the T3 Ice Island. These standard lithostratigraphic units have been recognized and used for correlation throughout the central and western Arctic Basin (Morris and Clark, 1986; Darby and others, 1989; Scott and others, 1989). The lithostratigraphic units of Clark and others (1980) have been identified in the Northwind Ridge sedimentary sequence (Phillips and others, 1992) and form a primary means for correlating between cores. Sediment texture, pinkish-white to white, clast-rich beds, and dark-brown muddy and sandy mud beds are important features for identifying these lithostratigraphic units. Figure 2 shows the percentage of coarse material (>63 μm) in Northwind Ridge cores and sand-sized content of selected cores used by Clark and others (1980) to define the lithostratigraphy for the central and western Arctic Ocean. The coarse material in Northwind Ridge cores is mostly sand. Detailed logs and photographs of cores 9, 5, 3, and 7 were provided by Phillips and others (1992).

UNIT J

Unit J, with its upper and lower sand peaks, is one of the keys to identifying the lithostratigraphic sequence. In cores from the central Arctic, the lower sand peak of unit J is characterized by a thin, but well-defined, pinkish-white, clast-rich layer (PW1 of Clark and others, 1980), and the upper sand peak typically contains scattered pinkish-white clasts (pink-white clast interval of Clark and others, 1980). At Northwind Ridge, near the edge of the Arctic Basin, PW1 is well developed at the base of unit J, and the pinkish-white clast interval is present as a well-defined bed at the top of unit J in cores 5 and 7. Pinkish-white clasts are not present in the coarse-fraction peak at the top of unit J in core 3. An unconformity occurs between units J and L in core 3, and the top of J and all of unit K are missing (see Phillips and others, 1992). The lower coarse-fraction peak and PW1 are well represented in core 3 (fig. 2).

UNIT M

Unit M is another key unit. As defined by Clark and others (1980), unit M commonly has an upper and a lower sand peak; the lower peak is marked by a pinkish-white, clast-rich layer. They noted that this clast-rich layer (PW2) is commonly distorted and intermixed with the surrounding sediment through an interval of up to 15 cm. In the relatively expanded sections recovered from Northwind Ridge, PW2 has been identified as two separate 1- to 2-cm-thick, clast-rich beds approximately 5 to 10 cm apart. Following consultation with D.L. Clark, the lower limit of unit M in Northwind Ridge cores has been placed at the top of the first dark-brown, foraminifer-rich muddy sand bed just below PW2. Thus, in Northwind Ridge cores, PW2 occurs near the bottom but not at the base of unit M. D.L. Clark (oral commun., 1993) placed the base of unit M on top of the brown bed below PW2 because the underlying unit L always has a dark-brown bed at its top. The split PW2 in our cores is readily traced among cores 9, 5, 3, and 7 (fig. 3). The split PW2 shows up as a double peak in the coarse-fraction plots for cores 9, 3, and 7 (fig. 2). No double peak is evident in the coarse-fraction plot of core 5 because of burrowing and the closer spacing of the PW2 beds (fig. 2).

The upper sand peak of unit M in central Arctic cores commonly contains one or two white layers that have been designated W2 and W3 (Clark and others, 1980; Minicucci and Clark, 1983). The white, clast-rich beds W2 and W3 are present in all four of our cores. The upper and lower coarse-fraction peaks, the presence of W2 and W3, and the split PW2 allow ready identification of unit M in cores 9, 5, 3, and 7 (see figs. 2 and 3).

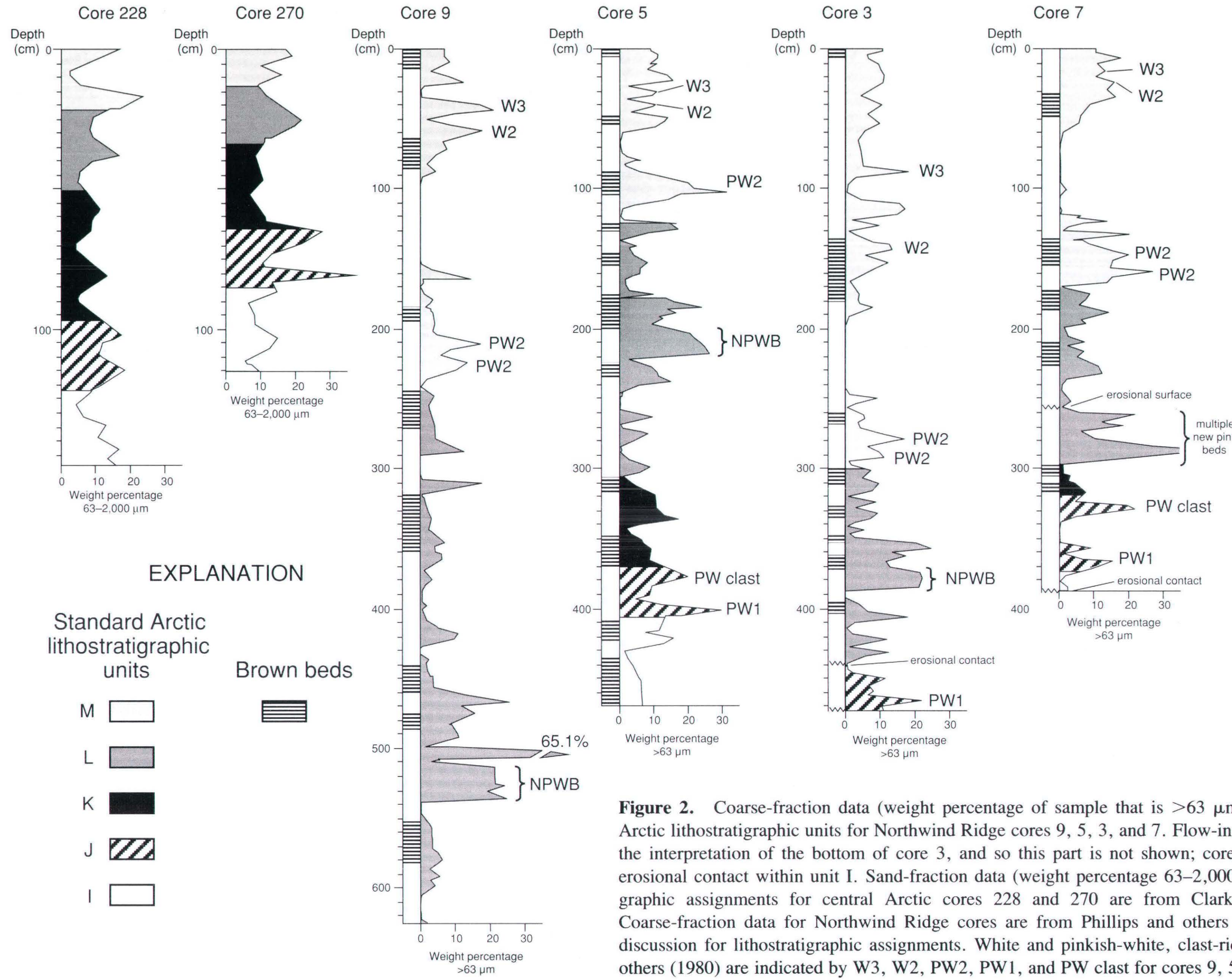

Figure 2. Coarse-fraction data (weight percentage of sample that is >63 µm) and assignment to Arctic lithostratigraphic units for Northwind Ridge cores 9, 5, 3, and 7. Flow-in problems complicate the interpretation of the bottom of core 3, and so this part is not shown; core 7 was cut off at an erosional contact within unit I. Sand-fraction data (weight percentage 63–2,000 µm) and lithostratigraphic assignments for central Arctic cores 228 and 270 are from Clark and others (1980). Coarse-fraction data for Northwind Ridge cores are from Phillips and others (1992). See text for discussion for lithostratigraphic assignments. White and pinkish-white, clast-rich beds of Clark and others (1980) are indicated by W3, W2, PW2, PW1, and PW clast for cores 9, 5, 3, and 7. NPWB is new clast unit identified in cores 9, 5, and 3. Clark and others (1980) did not plot the positions of clast-rich beds for cores 228 and 270, and so they are not indicated on the diagram for those cores. Cores 228 and 270 are plotted at expanded scales to clarify the condensed sections in those cores.

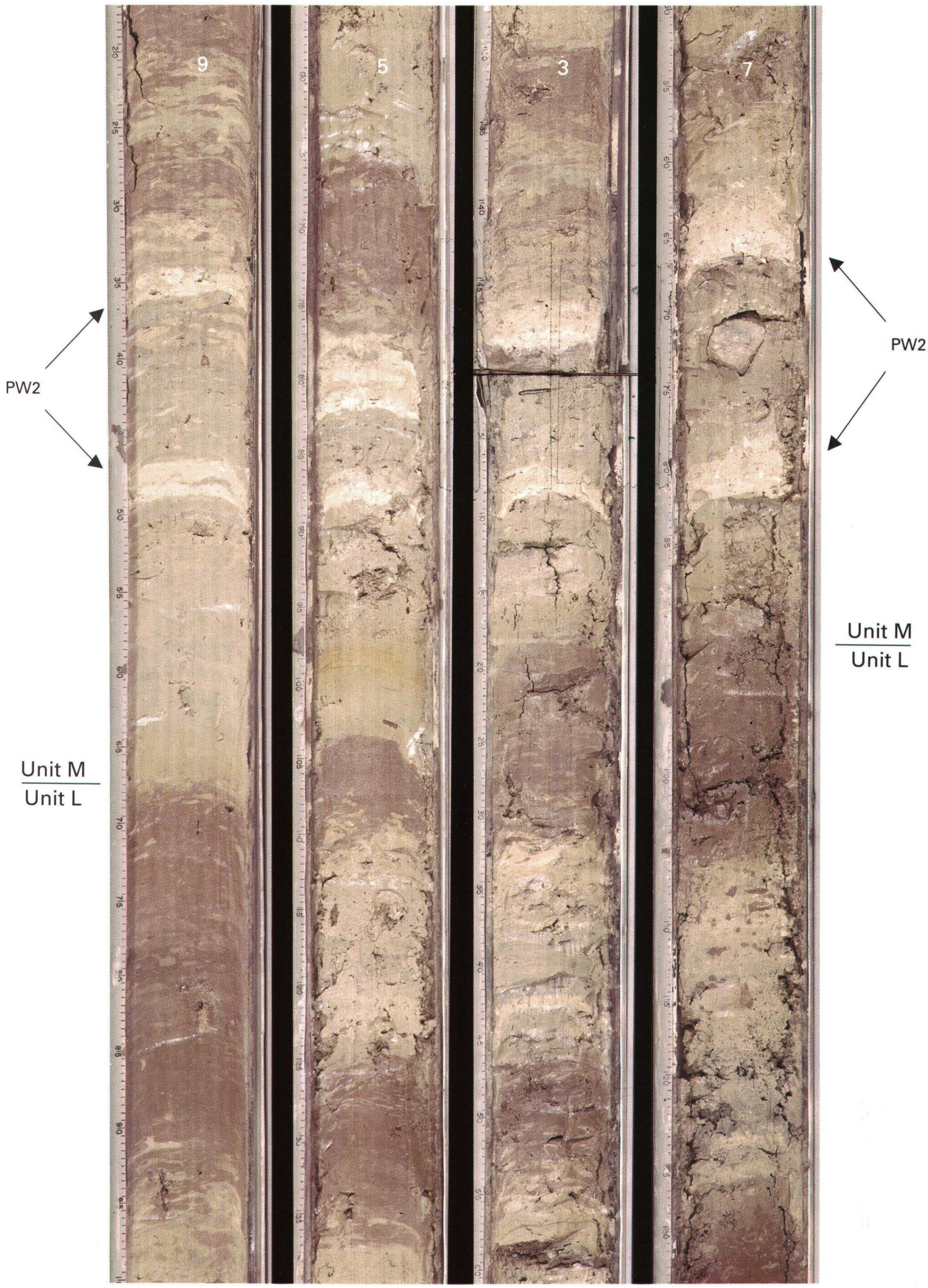

Figure 3. Parts of Northwind Ridge cores 9, 5, 3, and 7. In each core, the two light bands are the split PW2 bed, which is clast rich. Centimeter scales are visible along the cores.

UNITS L, K, AND I

A distinct, 20- to 25-cm-thick, pinkish-white to white, clast-rich bed, not recognized in previous Arctic cores, occurs within the interval we have assigned to unit L. This pinkish-white to white, clast-rich layer, labeled NPWB on figure 2, occurs near the middle of unit L in cores 9, 5, and 3. An alternative stratigraphy for our cores would be to interpret NPWB as PW2 and to consider the split, clast-rich beds discussed above as a new clast-rich unit. Interpreting NPWB as PW2 would change the lower boundary of unit M but would not change correlation among our cores.

Several thin, pink or pinkish-white, clast-rich beds are present in the lower part of unit L in core 7. However, unit L in core 7 is complicated by one or more unconformities, and the multiple pink to pinkish-white beds seen in core 7 were not observed in any of our other cores from Northwind Ridge. The multiple pink to pinkish-white beds in unit L of core 7 may represent very local depositional features.

Units L, K, and I do not have distinctive textural signatures like units M and J but can be identified from other characteristics and stratigraphic position. As delineated by Clark and others (1980), unit L has a high but variable sand content, and foraminifers can be abundant in the middle to upper part of L but are rare in the lower part of L. Unit K is characterized by a lower sand content than units J or L and commonly contains abundant planktic foraminifers.

Unit L, as identified at Northwind Ridge, shows a high but very variable coarse-fraction content. Dark-brown, foraminifer-rich beds occur in the upper part of L in cores 9, 5, and 3. Foraminifers are essentially absent below the top of unit L in core 7 because of dissolution (see discussion below). The expanded section recovered in core 9 ends in unit L.

Unit K is distinguished from units L and J in core 5 by the presence of upper and lower dark-brown, foraminifer-rich beds and a slightly lower average coarse-fraction content. Unit K is distinguished from units L and J in core 7 by a distinctly lower coarse-fraction content. Unit K is not present in core 3. The top of unit J in core 3 contains slightly inclined laminated beds that are truncated at the contact between J and L. Slumping or erosion probably removed unit K from the sequence recovered in core 3.

Unit I was identified in cores 5, 7, and 3 primarily on the basis of stratigraphic position below unit J. Unit I is complicated by flow-in problems in core 3 and is not plotted on figure 2.

MAGNETOSTRATIGRAPHY

Paleomagnetic data from core 5 (Poore and others, 1993) indicate that the polarity reversal horizon representing the Matuyama-Brunhes boundary occurs within unit K, and that the Jaramillo normal polarity event is in the lower part of unit J to the upper part of unit I (see fig. 4). These results match compilations of paleomagnetic results from Arctic cores, which show that the Matuyama-Brunhes polarity reversal horizon typically falls within the middle part of unit K and that the Jaramillo is associated with the lower part of unit J (for example, see Darby and others, 1989).

FORAMINIFERS

The abundance of foraminifers (in number per gram dry weight) and a census of planktic foraminifers were obtained from the >150-μm size fraction of samples from cores 9, 5, and 3 and the upper part of core 7 (fig. 5). We selected the >150-μm size fraction to make our planktic foraminifer census data consistent with published modern core-top data (for example, Kipp, 1976; Kellogg, 1977) and to minimize problems of juvenile and unidentifiable specimens in our census data. For samples containing abundant planktic foraminifers >150 μm, a split of the total sample containing approximately 300 planktic specimens was used for the faunal census and for calculating abundances of planktic and benthic foraminifers. For samples containing ≤300 planktic foraminifers, all planktic and benthic foraminifers were picked from the >150-μm fraction and used to calculate foraminifer abundances and for the planktic foraminifer census. Inspection of the 63- to 150-μm fraction of our samples indicates that the abundance data for the >150-μm size fraction accurately reflect changes in abundances of foraminifers in the >63-μm fraction.

Census data for planktic foraminifers were tabulated by Foley and Poore (1991, 1993). These data show that *Neogloboquadrina pachyderma* constitutes over 90 percent of the planktic assemblages in all samples; left-coiling *Neogloboquadrina pachyderma* usually exceeds 95 percent of the *N. pachyderma* population. The remainder of the fauna consists of intergrades between *N. pachyderma* and *N. dutertrei* (P-D intergrade of Kipp, 1976; dupac of Foley and Poore, 1991). Inspection of the 63- to 150-μm fraction shows that *Globigerina egelida* and *Turborotalita quinqueloba* are present in a few samples from the upper part of unit L and from unit M; however, *Neogloboquadrina pachyderma* is still the dominant member of the assemblages in the 63- to 150-μm size fraction. We observed no first or last occurrences of planktic foraminifers in the Northwind Ridge cores that would be considered standard biostratigraphic events.

Previous studies of benthic foraminifers in deep-sea sediments have used a variety of methods and size fractions. Our examination of benthic foraminifers in Northwind Ridge cores incorporated different faunal census methods as part of an effort to find an optimum procedure for future work. Splits of approximately 300 specimens >63 μm were

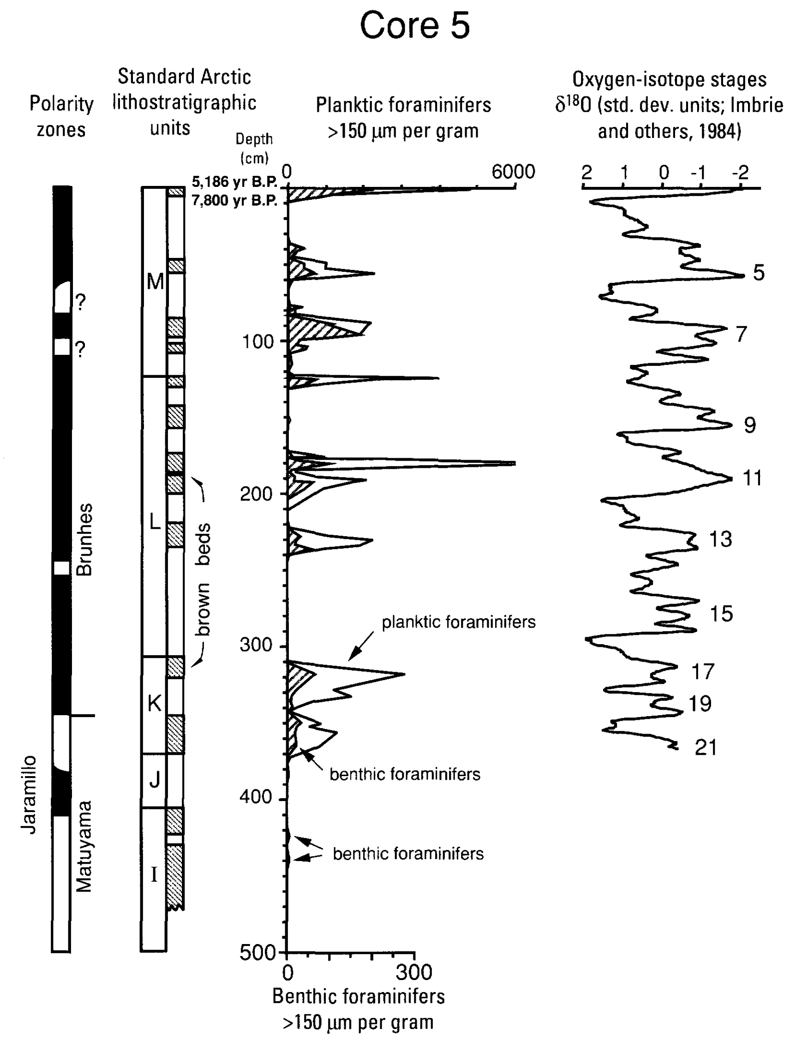

Figure 4. Magnetostratigraphy, lithostratigraphy, and foraminifer abundance data for core 5 and relation of foraminifer abundance to generalized deep-sea oxygen-isotope record. Composite deep-sea oxygen-isotope record is aligned so that the Matuyama-Brunhes polarity reversal horizon in core 5 coincides approximately with the stage 20-stage 19 transition. Figure modified from Poore and others (1993).

counted for selected samples in core 5 that contained abundant benthic foraminifers. Benthic census data for the remaining samples with abundant foraminifers in core 5 and all samples with abundant benthic foraminifers in core 3 were obtained by tabulating the first 200–300 specimens in strewn slides. Tabulation of specimens began with the >150-µm size fraction and extended to the 63- to 150-µm size fraction only when it was required to obtain >200 specimens. All benthic foraminifers were picked from the >63-µm fraction of samples, which contained rare benthic specimens. After cores 5 and 3 were completed, representative samples from cores 9 and 7 were scanned for comparison with the assemblages noted in cores 5 and 3.

Census data for benthic foraminifers in cores 5 and 3 are presented in tables 2 and 3, respectively. Work in progress on box core top samples from Northwind Ridge shows that the >106-µm and >125-µm benthic foraminifer census data provide the same basic oceanographic information as the >63-µm census data. Thus, we plan to use quantitative census of the >125-µm size fraction in our future studies of foraminifer assemblages from the Arctic Ocean.

The planktic foraminifer abundance data show that foraminifers are concentrated in distinctive layers (fig. 5) that generally coincide with dark-brown beds. Three intervals of abundant planktic foraminifers occur in unit M (M1, M2, and M3) and in unit L (L1, L2, and L3). The interval labeled L3 in core 3 contains relatively few foraminifers (<500/g) along with common iron manganese grains that are molds and internal casts of foraminifers. Thus, L3 in

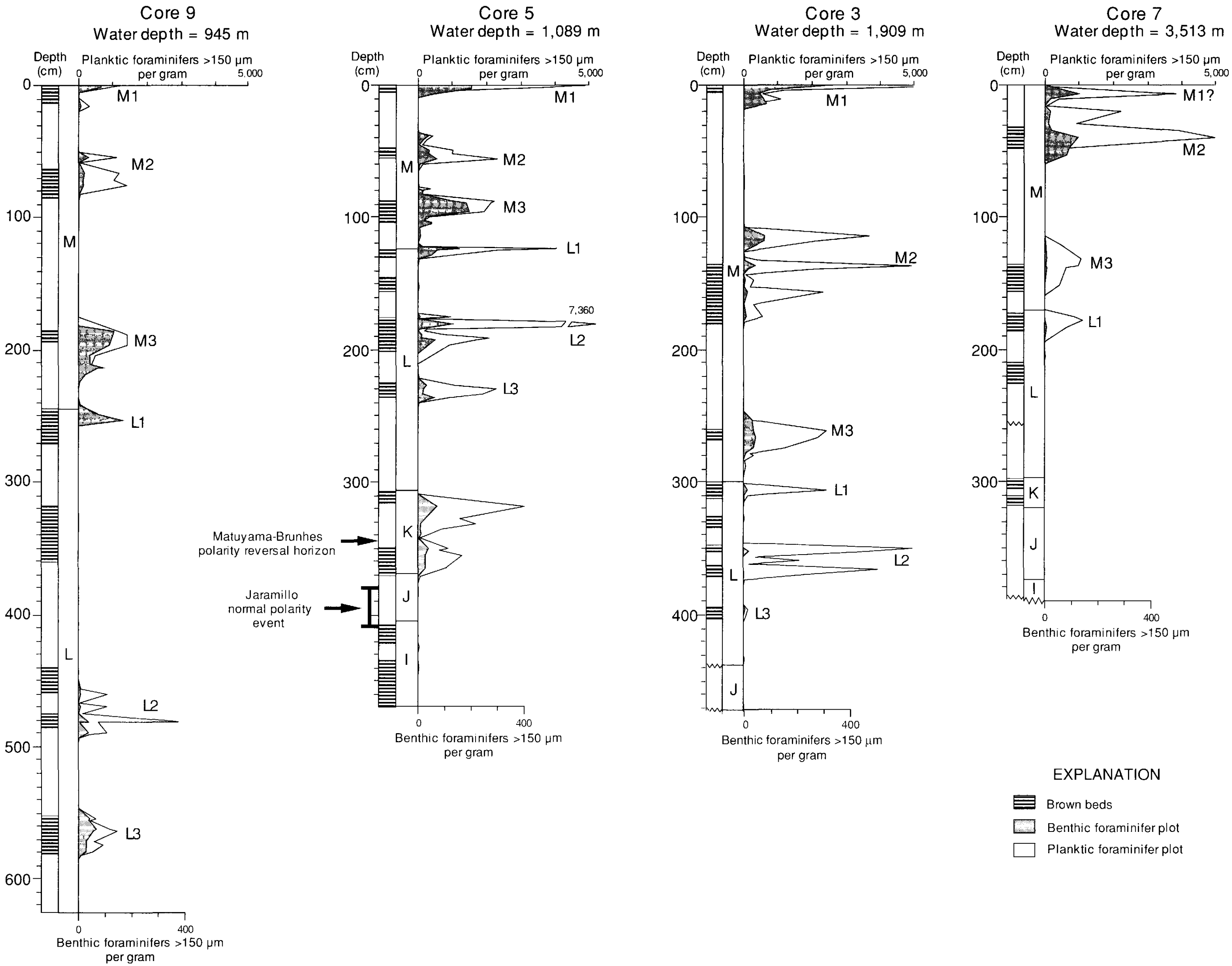

Figure 5. Foraminifer abundance data for Northwind Ridge cores 9, 5, 3, and 7. Abundance data are from Foley and Poore (1991, 1993). M, L, K, J, and I are Arctic lithostratigraphic units of Clark and others (1980) (see text and fig. 2). M1, M2, M3, L1, L2, and L3 designate planktic foraminifer abundance peaks within lithostratigraphic units. Matuyama-Brunhes polarity reversal horizon and Jaramillo normal polarity event for core 5 are from Poore and others (1993).

core 3 is the residue of a foraminifer abundance peak. Core 5 shows two foraminifer abundance peaks in unit K. Core 7, which was taken from a depth of 3,513 m, contains significant numbers of foraminifers in unit M and the top of unit L (L1). Foraminifers from deeper intervals in core 7 are rare and, where present, are corroded and pitted. The top of core 7 was lost during coring, and the upper foraminifer peak represents foraminifers in burrows that extended down from the unrecovered surface unit. Burrows with brown infilling are evident on the split face of the core. The peaks M2, M3, and L1 are well defined.

The stratigraphic distributions of the planktic foraminifer abundance peaks in units M and L are very similar in cores 9, 5, and 3. The poor preservation of L3 in core 3 and the absence of L2 and L3 in core 7 represent increased dissolution reflecting the deeper location of cores 3 and 7 (see following discussion). The similarity of the records in the shallow cores and the upper part of core 3 support the lithostratigraphic correlations and indicate that the foraminifer abundance variations reflect regional oceanographic events and are not features caused by localized sedimentary processes on Northwind Ridge.

PALEOCEANOGRAPHY

GLACIAL-INTERGLACIAL CYCLES

The environmental significance of foraminifer abundance variations in Arctic cores is controversial (see Herman and others, 1989, for summary). One interpretation concludes that foraminifer-rich intervals represent interglacial conditions reflecting seasonally absent or reduced ice cover leading to increased productivity; intervals barren or nearly barren of foraminifers are considered to represent glacial conditions with thicker ice cover and lower productivity (Clark, 1971; Aksu, 1985). An alternative interpretation concludes that foraminifer-poor intervals represent climates warmer than today when low-salinity surface waters due to increased river runoff or melting ice resulted in low productivity of planktic foraminifers (Herman, 1983). Foraminifer-poor intervals have also been interpreted as dissolution events occurring during interglacial and early glacial intervals (Morris and Clark, 1986). Many factors, including dissolution, surface-water productivity, downslope transport, and dilution by ice-rafted material, influence the abundance of foraminifers in Arctic sediments. Interaction of these factors is complex, and no single factor can explain all of the variability seen in Arctic sediments. We conclude that the foraminifer-rich intervals in the Northwind Ridge cores included in this study represent interglacial deposits for the following reasons.

Sediment-trap studies in the Fram Strait (Hebbeln and Wefer, 1991) and the Norwegian-Greenland Sea (William Curry, Woods Hole Oceanographic Institution, oral commun., 1993) show that ice cover eliminates or greatly curtails biogenic and lithogenic sedimentation and that sedimentation resumes as soon as open-water conditions return. Productivity is highest near the ice margin. The Northwind Ridge area of the western Arctic has 1 to 2 m of ice cover during most of the year but is near the northern margin of waters that are normally ice free for several months in the late summer (Untersteiner, 1990). Leads and polynyas of open water were observed over Northwind Ridge during the 1988 cruise, and brown, planktic-foraminifer-rich muddy sands were recovered in the tops of most piston and gravity cores from Northwind Ridge. Analyses of *Neogloboquadrina pachyderma* from the surface foraminifer-rich bed in core 5 yielded carbon-14 dates of 5,186±91 yr B.P. at 0–2 cm depth and 7,800±118 yr B.P. at 4.6–5.6 cm depth (fig. 4). The age of 5,186 yr B.P. for the top interval probably reflects the effects of burrowing and the loss of the uppermost sediment during piston coring. A carbon-14 date of 8,480±80 yr B.P. was obtained from the 3-cm level of core 9, and a date of 4,830±100 yr B.P. was obtained from the 1-cm level of core 3. Thus, the brown, planktic-foraminifer-rich surface sediments of Northwind Ridge were deposited during the current interglacial stage. Seasonally open water results in high productivity, abundant planktic foraminifers in the water column, and preservation of planktic foraminifers in the underlying sediments. By analogy with surface sediments, we infer that the repeated planktic-foraminifer-rich beds occurring at depth in Northwind Ridge cores record past interglacial stages.

The positive correlation of planktic and benthic foraminifer abundances throughout most of the shallow-water cores 9 and 5 and in core 3 (fig. 5) indicates that the major variations in planktic foraminifer abundances in these cores are not caused primarily by variable dissolution of sediment with a similar foraminifer content. *Neogloboquadrina pachyderma* is very resistant to dissolution (Berger, 1979; Malmgren, 1983), but many benthic foraminifers are even more resistant to dissolution (Berger, 1973, 1979). Abundance variations due primarily to differential dissolution of sediments having initially similar foraminifer components would result in variable ratios of planktic to benthic foraminifers and would include associations of common, robust benthic foraminifers with low numbers of planktic foraminifers. Additionally, no major changes in fragmentation were observed, which would be expected if the observed abundance fluctuations in the shallow cores were caused primarily by changes in dissolution intensity (Malmgren, 1983). Thus, we interpret the major variations in planktic foraminifer abundances in units M through K of cores 9, 5, and 3 to be primarily a function of productivity related to ice cover rather than a function of changes in dissolution.

The record from core 5 extends through the Brunhes into the Matuyama. The number and stratigraphic distribution of interglacial, planktic-foraminifer-rich horizons in core 5 (fig. 4) are similar to the number and stratigraphic distribution of oxygen-isotope minima (representing interglacial stages) recorded in the isotope records of the Brunhes interval of marine cores at lower latitudes. Most lower latitude records indicate that the Matuyama-Brunhes polarity reversal horizon is associated with the stage 20–19 transition and that interglacial stage 21 occurs near the end of the Matuyama (Imbrie and others, 1984; Shackleton and others, 1990). We infer that the foraminifer abundance peak just below 3.5 m in core 5 represents stage 21 and the foraminifer peak that begins just above the base of the Brunhes, around 3.4 m, represents stage 19 (Poore and others, 1993). We correlate the top four foraminifer abundance peaks with stages 1, 5, 7, and 9. Matching the remaining foraminifer abundance peaks with specific isotope stages is equivocal. Inspection of figure 4 indicates that several plausible correlations between the foraminifer peaks and interglacial stages are possible.

Previous records from the central and western Arctic indicated that foraminifers are generally abundant throughout most of unit M and in the upper third of unit L (Clark, 1971; Aksu, 1985; Scott and others, 1989). In contrast, the relatively expanded record in our cores demonstrates that foraminifers are concentrated in discrete layers that we correlate with global interglacial stages. Abundance variations of planktic foraminifers (>150 μm) in the relatively expanded section of T3–67–11 (Darby and others, 1989), from the slope of the Mendeleyev Ridge, also indicate that foraminifers occur in discrete beds separated by intervals that are barren or nearly barren of foraminifers. The differences between foraminifer occurrences reported by Clark (1971), Aksu (1985), and Scott and others (1989) and those found in our study may represent regional variations in the response of the Arctic to climate cycles or may be due to nonlinear sediment accumulation rates within and between cores. It is likely that bioturbation and low accumulation rates have blurred the foraminifer record in many central and western Arctic cores. For example, the combined thickness of unit M and unit L in CESAR (Canadian Expedition to Study the Alpha Ridge) core 14 from Alpha Ridge is about 42 cm (Scott and others, 1989), whereas the thickness of units M and L in Northwind Ridge core 9 is 626 cm.

Two foraminifer-rich beds occur in unit K of core 5 (fig. 4). The section below unit K in core 5 does not contain foraminifer-rich horizons, although the magnetostratigraphy shows that this interval includes the Jaramillo normal polarity event and thus spans several hundred thousand years, during which several glacial-interglacial cycles occurred. Apparently, interglacials are not represented by distinctive foraminifer-rich beds below unit K as they are in units M through K. However, the sparse planktic and calcareous benthic foraminifers at 425 cm and 440 cm in unit I could be dissolved remnants of foraminifer-rich beds representing interglacial events.

The Northwind Ridge data show that distinct cycles in the abundance of foraminifers occur throughout the Brunhes Normal Polarity Zone. Our interpretation of the foraminifer abundance variations as resulting from glacial-interglacial cycles implies that, with the exception of major interglacial stages, the Arctic Ocean since stage 21 has been covered by thick sea ice, which resulted in low productivity of foraminifers. The Northwind Ridge Brunhes record of foraminifer abundance fluctuations supports previous conclusions that unit M represents oxygen-isotope stages 1–8 and that stage 9 occurs at the top of unit L; these conclusions were based on variations in sand-fraction data (Clark and others, 1980) and limited oxygen-isotope data from Arctic cores (Aksu, 1985; Scott and others, 1989). Our results also support the conclusions of Boyd and others (1984) that climate variations in the Arctic are in phase with glacial-interglacial cycles observed in other proxy records of the Brunhes. The Northwind Ridge data are too limited to speculate on pre-Brunhes conditions and their relation to events within and outside of the Arctic Ocean.

DEEP WATERS

Changes in bottom-water conditions and structure through the late Pleistocene are indicated by differences in preservation of foraminifers and by changes in benthic assemblages within and between cores from different depths. Although most of the variation in foraminifer abundances seen in cores 9, 5, and 3 and the uppermost part of core 7 reflects changing productivity, significant dissolution is evident in much of core 7 and in the lower parts of cores 5 and 3. Dissolution effects are seen by comparing the foraminifer abundances in cores from different water depths (fig. 5). Foraminifer peaks M1, M2, M3, and L1 are in all four cores. Foraminifer peak L2 is present in cores 9, 5, and 3. Peak L2 is not recorded in core 7. However, L2 may be missing from core 7 because of erosion. L3 is well defined in cores 9 and 5 but is represented by a residual assemblage in core 3. Some calcareous specimens are present, but most of the foraminifers are preserved in core 3 as iron manganese molds and internal casts. No indication of L3 was observed in core 7. Thus, during deposition of L3, the carbonate compensation depth (CCD) was near but just below the depth of core 3. Unit K was identified in cores 5 and 7. Two large peaks of foraminifer abundance occur in unit K of core 5, whereas, in core 7, unit K is essentially barren of calcareous foraminifers. Unit I of core 5 contains two intervals with low abundances of benthic foraminifers (fig. 4) and rare planktic foraminifers that we interpret as dissolved assemblages. Unit I of core 3 yielded only a few agglutinated specimens. The short interval of unit I identified above an erosional contact in core 7 is barren of foraminifers. The pattern of preservation of foraminifers in Northwind Ridge cores documents a general increase in depth of the CCD of the Canada Basin with each successive (younger) interglacial stage through the late Quaternary. The changes in carbonate preservation seen in Northwind Ridge cores are in agreement with previous studies that show that the CCD in the central Arctic has progressively deepened during the Pleistocene (Morris and Clark, 1986).

Information in tables 2 and 3 and figures 6 and 7 on benthic foraminifer assemblages in cores 5 and 3 was obtained by quantitative and qualitative methods using several size fractions and cannot be used for detailed interpretations. However, the data (figs. 6 and 7) reveal several broad features that reflect changing deepwater characteristics. Assemblages from M1, M2, M3, and L1 of cores 5 and 3 are characterized by *Oridorsalis* and *Stetsonia horvathi*. *Stetsonia* is a very small form that is not found in the >150-μm size fraction, and it is well represented only in samples in tables 2 and 3 that were tabulated at >63 μm. Inspection of the <150-μm fraction, however, shows that *Stetsonia* is abundant in most samples that contain common to abundant foraminifers. Our general observation is that, where present, *Stetsonia horvathi* is the dominant taxon in the <150-μm size fraction.

Differences between benthic foraminifer assemblages in the upper part of unit L and in unit M of cores 5 and 3 are explained by the depth distribution of modern assemblages in Holocene Arctic sediments. For example, published distributional data (Lagoe, 1977; Scott and Vilks, 1991) and our data from Northwind Ridge box cores (Scott Ishman and Kevin Foley, unpub. data, 1993) show that *Cassidulina teretis* has its maximum abundance between 1,400 m and about 600 m depth throughout the entire Arctic and in the Norwegian-Greenland Sea (Belanger and Streeter, 1980; Mackensen and others, 1985). *Cassidulina teretis* is a common and consistent component of calcareous assemblages in the upper part of unit L and in unit M of core 5 (1,089 m water depth) but occurs sporadically and in much lower abundances in equivalent foraminifer-rich levels of core 3 (1,909 m water depth). Similarly, *Fontbotia wuellerstorfi* and *Eponides tumidulus*, which generally are more abundant below 1,500 m in the modern Arctic, are important components of core 3 assemblages in the upper part of unit L and in unit M but are poorly represented in equivalent assemblages from core 5.

Inspection of selected core 9 and core 7 assemblages from units L and M shows that core 9 assemblages are similar to core 5 assemblages and that core 7 assemblages are similar to core 3 assemblages. Core 7 assemblages, however, show distinct signs of dissolution below M2; fragments are much more common than in the other cores, and test surfaces are pitted and etched. *Bulimina aculeata* occurs in M3 in all four cores and in L1 of cores 9, 5, and 3 (assemblages found in L1 of core 7 are sparse and poorly preserved). *Bulimina aculeata* is not reported from Holocene sediments of the Arctic but is common in low-oxygen environments and areas of sediments with high organic-matter content in the North Atlantic (Burgess and Schnitker, 1990). The benthic foraminifer assemblages in the upper part of unit L and in unit M suggest that deepwater conditions in the area of Northwind Ridge were very similar to modern conditions during the last few interglacial stages. However, lower oxygen conditions prevailed during M3 and L1 (probably stages 7 and 9), perhaps reflecting increased productivity and thus greater supply of organic material to the sea floor.

A distinct change occurs between L1 and L2. Except for one sample in unit K of core 5, *Oridorsalis*, which is significant in assemblages in the upper parts of all cores, is absent below L1 (figs. 6 and 7). *Cassidulina teretis* continues to be common in the assemblages from L2 and L3 of core 5; *Bolivina arctica* is an important component of some assemblages. Core 3 assemblages from the lower part of unit L are slightly different from the core 5 assemblages. In core 3, the L2 assemblages contain abundant *Bolivina arctica* and *Stetsonia* with *Fontbotia wuellerstorfi* as an important accessory. L3 is represented by two samples in core 3 (table 3, 396.5 and 401.7 cm). The upper sample (fig. 7) has abundant *Stetsonia* and *Epistominella exigua*, whereas the lower sample yields a sparse assemblage dominated by *Bolivina arctica*. Thus, *Bolivina arctica* appears to have taken the place of *Oridorsalis* in L2 and L3 assemblages. *Epistominella exigua*, which is abundant between 2,000 and 3,000 m depth in modern benthic assemblages in the Norwegian-Greenland Sea (Belanger and Streeter, 1980; Mackensen and others, 1985), is essentially absent from L3 assemblages of core 5 (one specimen occurs at the top of L3 in the sample from 226.4 cm). The absence of *Epistominella exigua* from core 5, coupled with the abundance of *Epistominella exigua* in core 3, may reflect the presence of a water-mass boundary between cores 3 and 5 during L3 .

Cassidulina teretis and *Bolivina arctica* are consistent components of benthic assemblages in unit K of core 5 (fig. 6). *Fontbotia wuellerstorfi* occurs sporadically along with *Pullenia bulloides*. *Cassidulina reniforme*, which occurs in a few samples from unit L, is a common element in the assemblages from the lower part of unit K. A few specimens of *Oridorsalis* occur in one sample near the base of unit K.

The assemblages recovered from units J and I in core 5 generally contain *Cassidulina reniforme*, *Cassidulina teretis*, and *Bolivina arctica* (fig. 6). *Pullenia bulloides* dominates one sample (table 2, 439.6 cm), and the agglutinated foraminifer *Haplophragmoides obscurus* is abundant in several samples from unit I (fig. 6).

Studies of core tops from the Norwegian-Greenland Sea (Mackensen and others, 1985) indicate that *Cassidulina reniforme* is abundant in assemblages from water depths between 500 and 1,000 m, which is above and partially

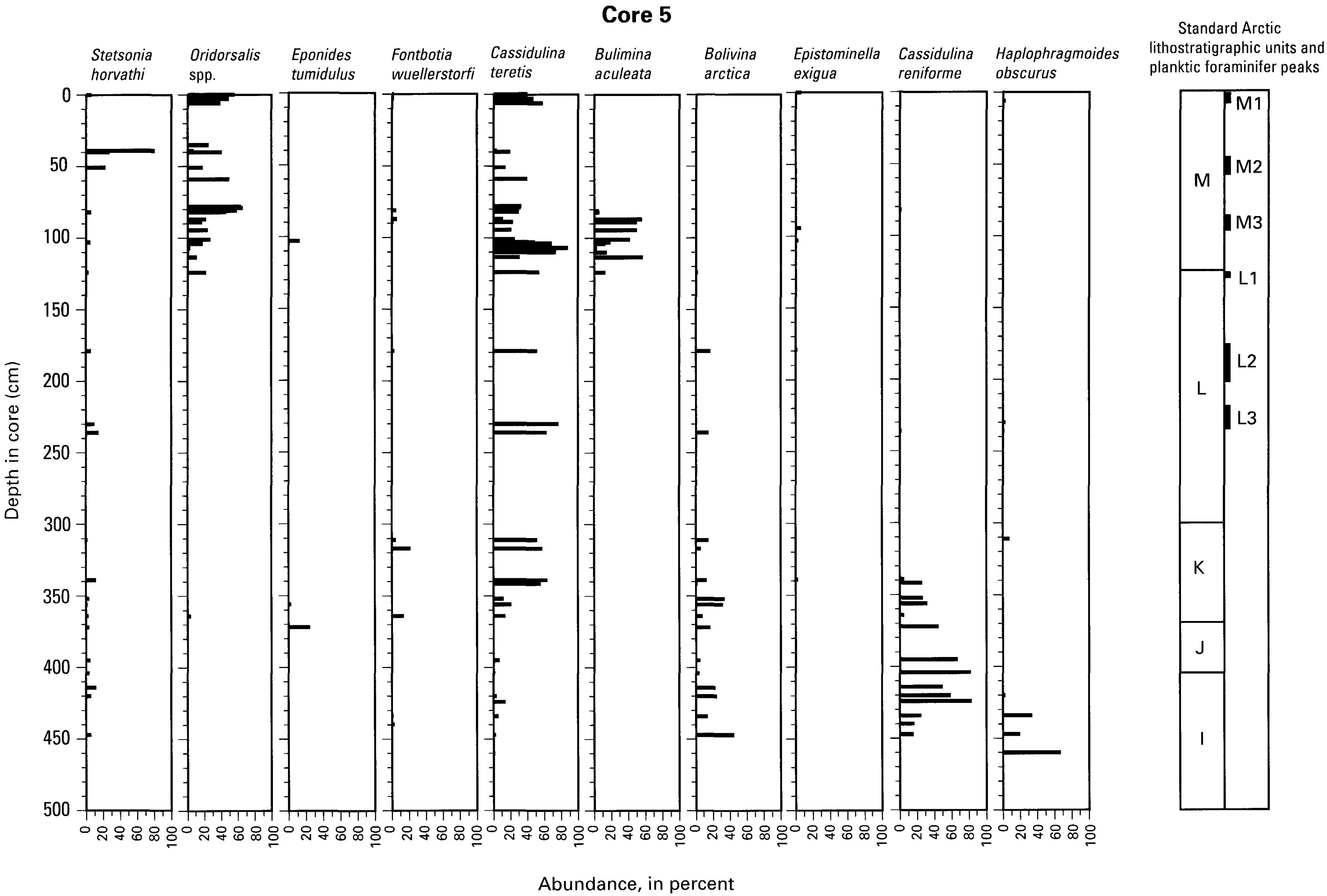

Figure 6. Abundance, in percent, of selected benthic foraminifers in samples from Northwind Ridge core 5. Abundances are plotted for samples yielding 30 or more specimens. Lithostratigraphy and location of planktic foraminifer peaks from figure 5. See text for explanation of methods for obtaining benthic foraminifer abundance estimates.

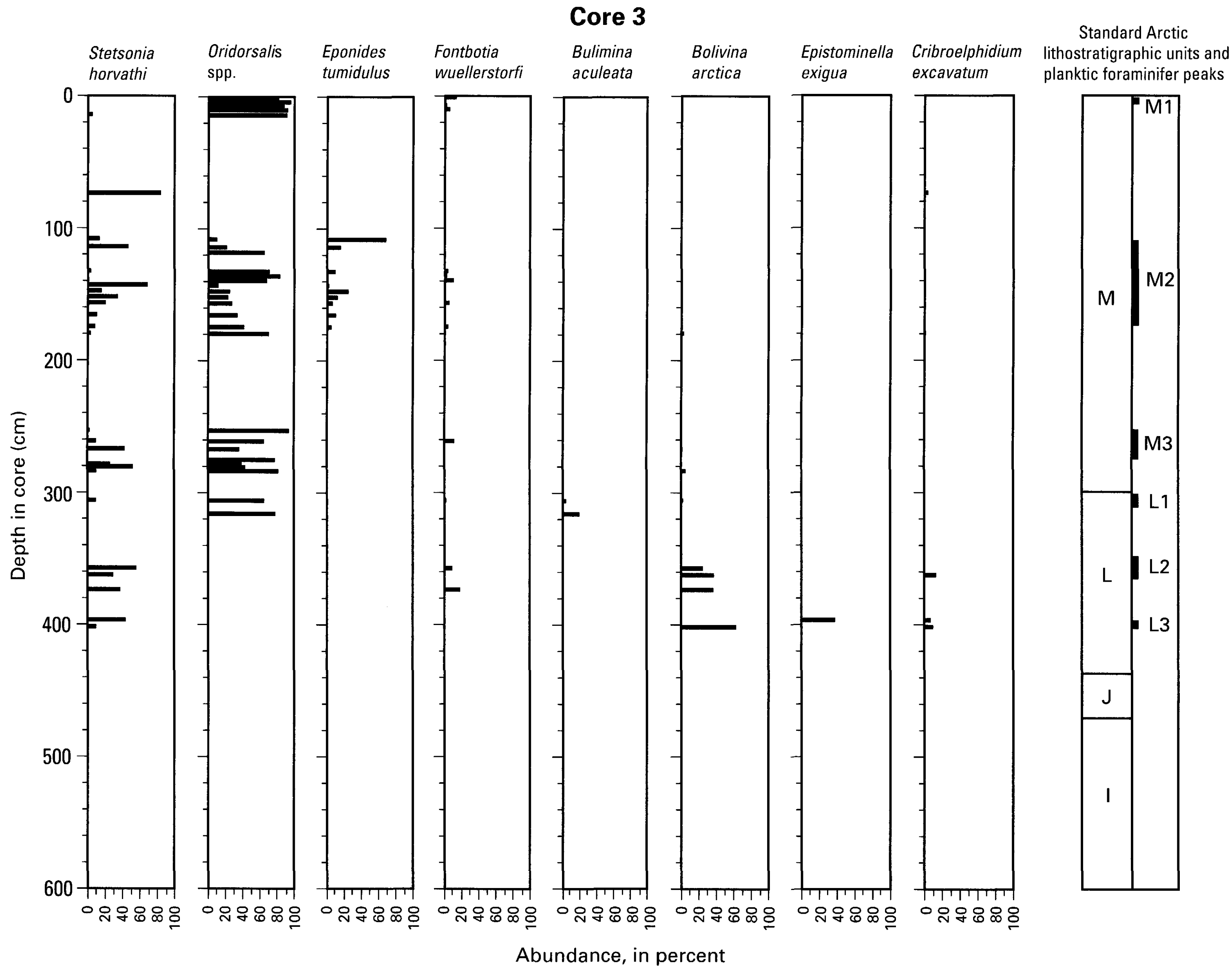

Figure 7. Abundance, in percent, of selected benthic foraminifers in samples from Northwind Ridge core 3. Abundances are plotted for samples yielding 30 or more specimens. Lithostratigraphy and location of planktic foraminifer peaks from figure 5. See text for explanation of methods for obtaining benthic foraminifer abundance estimates.

overlapping the zone of maximum abundance of *Cassidulina teretis*. However, the factors controlling the distribution of these taxa are unclear. The increase in abundance of agglutinated foraminifers in unit I of core 5 and the sparse agglutinated foraminifer assemblages found in unit I of core 3 represent increased dissolution in both cores.

Clark and others (1990) documented benthic assemblages from unit G in several Arctic cores. They concluded that increased exchange between the Arctic and the Norwegian-Greenland Sea through the Fram Strait occurred at the beginning of deposition of unit G and that the increased exchange caused lowering of the Arctic CCD and introduction of several North Atlantic taxa such as *Fontbotia wuellerstorfi* (as *Planulina wuellerstorfi*) and *Oridorsalis* (sparse and sporadic as *Eponides tener*) into the Arctic. Clark and others (1990) suggested that there is a general trend toward increasing diversity of Arctic benthic foraminifer assemblages through the Pleistocene and that variations in assemblages are common but that the controls and significance of the changes are unknown.

Scott and others (1989) conducted a detailed study of Quaternary benthic foraminifers in three CESAR cores recovered from a relatively narrow depth range of 1,370 to 1,555 m on Alpha Ridge of the central Arctic Ocean (fig. 1*B*). Benthic assemblages in these CESAR cores, of which one, core 14, extends through the entire Pleistocene, show changes that were interpreted to represent increased exchange between the Atlantic and the Norwegian-Greenland Sea. Scott and others (1989) found that the first significant (>1 percent) occurrences of North Atlantic benthic species in CESAR cores are within unit M and that the first North Atlantic taxon to appear is *Oridorsalis umbonatus* in the lower part of unit M, followed sequentially by *Eponides tumidulus* and *Planulina wuellerstorfi* (=*Fontbotia wuellerstorfi* in this study). Scott and others (1989) inferred that the changes they observed in CESAR benthic assemblages must have predated any similar changes in the western Arctic.

Aside from the sparse occurrence in unit K of core 5, the Northwind Ridge benthic data also show a dramatic first appearance of *Oridorsalis*, but the first appearance is in the upper part of unit L. In addition, *Fontbotia wuellerstorfi* forms a significant percentage of assemblages in units L (cores 5 and 3) and K (core 5) (see tables 2 and 3). The Alpha Ridge benthic data were tabulated from the >63-μm size fraction, whereas our data are a mixture of quantitative and qualitative data, some of which were based on the >150-μm size fraction. However, the basic differences between the sequence of events at Northwind Ridge and that at Alpha Ridge cannot be explained by differences in methodology. The first appearance of *Oridorsalis* at Northwind Ridge is very evident in all size fractions, and several of the significant occurrences of *Fontbotia wuellerstorfi* in unit K of Northwind Ridge core 5 are based on the total assemblage >63 μm and quantitative splits of the >63-μm size fraction. Similarly, placing the base of unit M lower in our cores (below the pinkish-white bed designated NPWB in figure 2) would not alter the fact that, in contrast to the CESAR core 14 record, significant occurrences of *Fontbotia wuellerstorfi* occur stratigraphically below the first significant occurrence of *Oridorsalis*. In addition, Clark and others (1990) reported significant occurrences of *Fontbotia wuellerstorfi* in assemblages from unit G.

Our data on benthic assemblages from Northwind Ridge indicate that the history of deepwater evolution in the western Arctic and its communication with the eastern Arctic and the world's oceans is complex. Substantial changes occur in both the abundance and composition of late Quaternary benthic assemblages from Northwind Ridge both within cores and between equivalent horizons in cores from different depths. The changes seen at Northwind Ridge by us and at Alpha Ridge by Scott and others (1989) cannot be completely explained by simple changes in connections of the Arctic Ocean with the North Atlantic through the Norwegian-Greenland Sea. Studies of core tops from the Arctic and the Norwegian-Greenland Sea show that *Oridorsalis* is more abundant in deeper waters than *Fontbotia wuellerstorfi*, but they have very similar upper depth limits. In addition, *Epistominella exigua*, which is strongly associated with *Fontbotia wuellerstorfi* in modern samples from the Norwegian-Greenland Sea (Mackensen and others, 1985), is absent from Holocene and unit M sediments from the central and western Arctic (Lagoe, 1977; Scott and others, 1989; this study).

Additional sampling and study of Pliocene and Pleistocene sections from Northwind Ridge and other Arctic areas that include careful documentation of benthic assemblages along depth transects are required to develop a better understanding of the four-dimensional history of the Arctic Ocean and its influence on global oceanic circulation.

CONCLUSIONS

1. Lithostratigraphic units established for the upper Quaternary of the central and western Arctic Ocean (Clark and others, 1980) are recognized in sediment cores from Northwind Ridge. However, the Northwind Ridge section is expanded and contains one or more coarse, clast-rich units that are not present in the central Arctic sequence.
2. Foraminifers are concentrated in discrete intervals within the Brunhes Normal Polarity Zone. Available age control and stratigraphic distribution of the foraminifer-rich beds indicate that they represent interglacial conditions.
3. Differential preservation of foraminifers within and between cores from different water depths indicates that the CCD became progressively deeper during successive (younger) interglacial stages of the last million years.

4. Changes in benthic foraminifer assemblages within and between cores of the Northwind Ridge depth transect indicate that the character and structure of deep waters in the western Arctic evolved substantially during the late Quaternary. The most striking change occurs at an interglacial stage we correlate with oxygen-isotope stage 9. At this change, *Oridorsalis* becomes a dominant component of benthic assemblages that were deposited between 3,513 and 945 m depth.

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Tables 2–3 begin on p. 18

Table 2. Abundance, in percent, of selected benthic foraminifers in samples from Northwind Ridge core 5.

[Total number of specimens in each sample is in the bottom row. Taxa that occurred in low abundances in only one or two samples are not included. Percentages may not add to 100 because of rounding or because of elimination of rare taxa. See text for identification of lithostratigraphic units I–M (Clark and others, 1980). Planktic foraminifer abundance peaks M1, M2, M3, L1, L2, and L3 are shown in figures 6 and 7. Abundance data for common benthic taxa from samples yielding 30 or more specimens are plotted in figure 6]

Lithostratigraphic unit	Unit M														
Planktic foraminifer peak	M1												M2		
Sample depth (cm)	0	3	6	9	12	13	17.1	21	26	29.2	32	35	39	40	44
Bolivina arctica	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Bulimina aculeata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buliminella elegantissima	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Cassidulina laevigata	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Cassidulina reniforme	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cassidulina teretis	40	47	58	0	0	0	0	0	0	0	0	0	4	20	0
Cribroelphidium excavatum	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0
Epistominella exigua	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eponides tumidulus	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Fontbotia wuellerstorfi	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Globocassidulina subglobosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haplophragmoides obscurus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oridorsalis spp.	56	49	39	0	0	0	0	0	0	0	0	25	7	41	100
Pullenia bulloides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Quinqueloculina arctica	0	0	0	0	0	0	0	0	0	0	0	75	0	2	0
Stainforthia concava	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Stetsonia horvathi	0	0	0	0	0	0	0	0	0	0	0	0	81	28	0
Triloculina frigida	1	1	0	0	0	0	0	0	0	0	0	0	3	6	0
Valvulineria arctica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total number of specimens	330	386	425	0	0	0	0	0	1	0	0	36	690	527	10

Table 2. Abundance, in percent, of selected benthic foraminifers in samples from Northwind Ridge core 5—Continued.

Lithostratigraphic unit	Unit M														
Planktic foraminifer peak	M2												M3		
Sample depth (cm)	47.6	50.8	54.5	59	65	69	73	75.4	78	79	81	82	87	89	94.4
Bolivina arctica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bulimina aculeata	0	0	0	0	0	0	0	0	1	1	5	6	56	50	50
Buliminella elegantissima	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0
Cassidulina laevigata	0	0	33	5	0	0	0	0	0	0	0	0	0	0	0
Cassidulina reniforme	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Cassidulina teretis	0	14	0	40	0	0	0	0	33	32	14	30	11	23	21
Cribroelphidium excavatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Epistominella exigua	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Eponides tumidulus	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Fontbotia wuellerstorfi	0	0	0	1	0	0	0	0	0	0	5	0	6	2	0
Globocassidulina subglobosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haplophragmoides obscurus	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Oridorsalis spp.	54	18	33	50	0	0	0	0	64	66	59	46	22	17	24
Pullenia bulloides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Quinqueloculina arctica	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0
Stainforthia concava	0	1	0	0	0	0	0	0	0	0	0	3	0	0	0
Stetsonia horvathi	0	23	0	0	0	0	0	0	1	0	0	6	0	0	0
Triloculina frigida	15	4	0	2	0	0	0	0	0	0	0	1	0	5	0
Valvulineria arctica	0	17	11	1	0	0	0	0	0	0	0	4	0	0	0
Total number of specimens	13	413	9	99	0	0	0	32	467	333	44	174	18	454	34

Table 2. Abundance, in percent, of selected benthic foraminifers in samples from Northwind Ridge core 5—Continued.

Lithostratigraphic unit	Unit M										Unit L				
Planktic foraminifer peak	M3										L1				
Sample depth (cm)	98	101	103	104	107	110	113.4	118	120	121.4	124	127.2	130.2	136	140
Bolivina arctica	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0
Bulimina aculeata	31	42	19	13	3	15	57	50	0	48	13	33	50	0	0
Buliminella elegantissima	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
Cassidulina laevigata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cassidulina reniforme	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Cassidulina teretis	15	25	49	69	88	74	31	50	0	9	54	53	30	0	0
Cribroelphidium excavatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Epistominella exigua	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Eponides tumidulus	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0
Fontbotia wuellerstorfi	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0
Globocassidulina subglobosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haplophragmoides obscurus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oridorsalis spp.	38	27	2	18	3	2	11	0	0	43	22	13	10	0	0
Pullenia bulloides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Quinqueloculina arctica	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0
Stainforthia concava	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0
Stetsonia horvathi	0	0	5	0	0	0	0	0	0	0	3	0	0	0	0
Triloculina frigida	15	2	4	0	0	0	0	0	0	0	3	0	0	0	0
Valvulineria arctica	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Total number of specimens	26	48	670	78	64	62	87	2	0	23	1265	15	10	0	0

Table 2. Abundance, in percent, of selected benthic foraminifers in samples from Northwind Ridge core 5—Continued.

Lithostratigraphic unit	Unit L														
Planktic foraminifer peak										L2					
Sample depth (cm)	141.2	146	151	155.3	160	161	163.2	167	171	174.4	177	179	183	185	187.5
Bolivina arctica	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0
Bulimina aculeata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buliminella elegantissima	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Cassidulina laevigata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cassidulina reniforme	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cassidulina teretis	0	0	0	0	0	0	0	0	100	100	67	52	57	67	100
Cribroelphidium excavatum	0	0	0	0	0	0	0	0	0	0	33	0	14	33	0
Epistominella exigua	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Eponides tumidulus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fontbotia wuellerstorfi	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Globocassidulina subglobosa	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Haplophragmoides obscurus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oridorsalis spp.	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0
Pullenia bulloides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Quinqueloculina arctica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stainforthia concava	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0
Stetsonia horvathi	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0
Triloculina frigida	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Valvulineria arctica	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Total number of specimens	0	0	0	0	0	0	0	1	1	3	3	540	7	3	7

Table 2. Abundance, in percent, of selected benthic foraminifers in samples from Northwind Ridge core 5—Continued.

Lithostratigraphic unit	Unit L														
Planktic foraminifer peak	L2									L3					
Sample depth (cm)	190	192	195.5	201.5	205	208.5	211	217	221	226.4	230	232.5	236	239	244
Bolivina arctica	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0
Bulimina aculeata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buliminella elegantissima	0	0	0	0	0	0	0	0	0	0	4	0	2	0	0
Cassidulina laevigata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cassidulina reniforme	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0
Cassidulina teretis	100	80	100	33	0	0	0	100	100	0	77	33	63	82	0
Cribroelphidium excavatum	0	0	0	67	0	0	0	0	0	33	0	0	0	0	0
Epistominella exigua	0	0	0	0	0	0	0	0	0	33	0	0	0	0	0
Eponides tumidulus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fontbotia wuellerstorfi	0	0	0	0	0	0	0	0	0	33	0	0	0	0	0
Globocassidulina subglobosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haplophragmoides obscurus	0	0	0	0	0	0	0	0	0	0	3	0	2	0	0
Oridorsalis spp.	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0
Pullenia bulloides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Quinqueloculina arctica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stainforthia concava	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0
Stetsonia horvathi	0	0	0	0	0	0	0	0	0	0	10	0	15	0	0
Triloculina frigida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Valvulineria arctica	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Total number of specimens	2	5	14	3	0	1	0	1	7	3	1954	3	1521	11	0

Table 2. Abundance, in percent, of selected benthic foraminifers in samples from Northwind Ridge core 5—Continued.

Lithostratigraphic unit	Unit L														
Planktic foraminifer peak															
Sample depth (cm)	247	247.3	251	253	255	257	262	267	270	274	279	283	286	287	290
Bolivina arctica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bulimina aculeata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buliminella elegantissima	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cassidulina laevigata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cassidulina reniforme	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cassidulina teretis	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0
Cribroelphidium excavatum	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0
Epistominella exigua	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eponides tumidulus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fontbotia wuellerstorfi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Globocassidulina subglobosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haplophragmoides obscurus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oridorsalis spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pullenia bulloides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Quinqueloculina arctica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stainforthia concava	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stetsonia horvathi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Triloculina frigida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Valvulineria arctica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total number of specimens	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0

Table 2. Abundance, in percent, of selected benthic foraminifers in samples from Northwind Ridge core 5—Continued.

Lithostratigraphic unit	Unit L					Unit K									
Planktic foraminifer peak															
Sample depth (cm)	292	297	302	304	308	311	317	327	332	335	339	341.6	348.8	352	356
Bolivina arctica	0	0	0	0	0	15	6	0	0	0	13	2	8	34	32
Bulimina aculeata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buliminella elegantissima	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Cassidulina laevigata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cassidulina reniforme	0	0	0	0	0	1	0	0	0	0	5	26	17	27	32
Cassidulina teretis	0	0	0	0	0	52	58	86	100	100	64	56	0	12	21
Cribroelphidium excavatum	0	0	0	0	0	1	0	0	0	0	0	0	17	2	0
Epistominella exigua	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
Eponides tumidulus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Fontbotia wuellerstorfi	0	0	0	0	0	5	22	0	0	0	0	0	0	1	0
Globocassidulina subglobosa	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0
Haplophragmoides obscurus	0	0	0	0	0	8	0	14	0	0	0	0	0	1	0
Oridorsalis spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pullenia bulloides	0	0	0	0	0	0	3	0	0	0	0	0	8	3	0
Quinqueloculina arctica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stainforthia concava	0	0	0	0	0	2	2	0	0	0	1	0	8	2	5
Stetsonia horvathi	0	0	0	0	0	2	0	0	0	0	12	0	0	4	2
Triloculina frigida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Valvulineria arctica	0	0	0	0	0	12	8	0	0	0	0	0	0	9	5
Total number of specimens	0	0	0	0	0	297	154	7	2	5	1053	57	12	394	2649

Table 2. Abundance, in percent, of selected benthic foraminifers in samples from Northwind Ridge core 5—Continued.

Lithostratigraphic unit	Unit K	Unit J								Unit I					
Planktic foraminifer peak															
Sample depth (cm)	364	372	375.5	383	389	392	395	399	403.2	404	414	415.4	420	424	428.8
Bolivina arctica	0	17	0	0	0	0	5	0	0	4	23	0	25	1	0
Bulimina aculeata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buliminella elegantissima	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Cassidulina laevigata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cassidulina reniforme	5	45	0	61	0	0	67	100	33	82	50	73	59	83	0
Cassidulina teretis	14	1	0	17	0	100	7	0	0	2	1	0	4	14	67
Cribroelphidium excavatum	0	0	0	0	0	0	0	0	33	0	0	0	0	0	0
Epistominella exigua	0	0	0	0	0	0	0	0	0	0	0	0	0	1	33
Eponides tumidulus	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0
Fontbotia wuellerstorfi	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Globocassidulina subglobosa	4	0	0	0	0	0	0	0	33	0	0	0	0	0	0
Haplophragmoides obscurus	1	0	0	0	0	0	0	0	0	0	1	18	3	0	0
Oridorsalis spp.	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pullenia bulloides	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Quinqueloculina arctica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stainforthia concava	0	1	0	0	0	0	8	0	0	2	1	0	1	0	0
Stetsonia horvathi	3	4	0	0	0	0	5	0	0	4	12	0	6	0	0
Triloculina frigida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Valvulineria arctica	3	1	0	0	0	0	1	0	0	3	10	9	1	0	0
Total number of specimens	73	1027	0	23	0	1	112	1	3	295	871	11	515	77	3

Table 2. Abundance, in percent, of selected benthic foraminifers in samples from Northwind Ridge core 5—Continued.

Lithostratigraphic unit	Unit I					
Planktic foraminifer peak						
Sample depth (cm)	434	439.6	447	449.8	460	465.7
Bolivina arctica	14	0	45	0	0	0
Bulimina aculeata	0	0	0	0	0	0
Buliminella elegantissima	1	0	0	0	0	0
Cassidulina laevigata	0	0	0	0	0	0
Cassidulina reniforme	25	17	16	100	1	25
Cassidulina teretis	6	0	3	0	2	25
Cribroelphidium excavatum	4	0	0	0	7	25
Epistominella exigua	0	0	0	0	0	0
Eponides tumidulus	0	0	0	0	0	0
Fontbotia wuellerstorfi	2	3	0	0	0	0
Globocassidulina subglobosa	0	0	0	0	0	0
Haplophragmoides obscurus	34	0	20	0	67	0
Oridorsalis spp.	0	0	0	0	0	0
Pullenia bulloides	4	81	2	0	1	0
Quinqueloculina arctica	0	0	0	0	0	0
Stainforthia concava	5	0	2	0	1	0
Stetsonia horvathi	1	0	6	0	0	0
Triloculina frigida	0	0	0	0	0	0
Valvulineria arctica	0	0	0	0	1	0
Total number of specimens	473	36	438	1	111	4

Table 3. Abundance, in percent, of selected benthic foraminifers in samples from Northwind Ridge core 3.

[Total number of specimens in each sample is in the bottom row. Taxa that occurred in low abundances in only one or two samples are not included. Percentages may not add to 100 because of rounding or because of elimination of rare taxa. See text for identification of lithostratigraphic units I–M (Clark and others, 1980). Planktic foraminifer abundance peaks M1, M2, M3, L1, L2, and L3 are shown in figures 6 and 7. Abundance data for common benthic taxa from samples yielding 30 or more specimens are plotted in figure 7]

Lithostratigraphic unit	Unit M																
Planktic foraminifer peak	M1																
Sample depth (cm)	1	4	7	10	14	19	24	33	39.5	46	52.5	59	65.5	73.5	83	88	91
Bolivina arctica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buccella frigida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bulimina aculeata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buliminella elegantissima	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Cassidulina reniforme	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cassidulina teretis	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cribroelphidium excavatum	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
Cribrostomoides sp.	0	0	0	1	0	80	0	0	0	0	0	0	0	0	0	0	0
Cyclammina sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Epistominella exigua	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eponides tumidulus	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Fontbotia wuellerstorfi	13	0	2	6	0	0	0	0	0	0	0	0	0	0	0	0	0
Globocassidulina subglobosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glomospira gordialis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haplophragmoides obscurus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oridorsalis spp.	82	96	88	92	92	0	0	0	0	0	0	0	0	0	0	0	0
Quinqueloculina akneriana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Quinqueloculina arctica	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reophax sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stainforthia concava	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0
Stetsonia horvathi	0	0	0	0	5	0	0	0	0	0	0	0	0	84	0	0	0
Textularia wiesneri	0	0	0	0	0	20	25	0	0	0	0	0	0	0	0	0	0
Triloculina frigida	1	3	8	1	2	0	0	0	0	0	0	0	0	0	0	0	0
Trochammina subglobigeriniformis	0	0	0	0	0	0	75	0	0	0	0	0	0	0	0	0	0
Valvulineria arctica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total number of specimens	314	421	743	381	313	5	4	0	0	0	0	0	0	96	0	0	0

Table 3. Abundance, in percent, of selected benthic foraminifers in samples from Northwind Ridge core 3—Continued.

Lithostratigraphic unit	Unit M																
Planktic foraminifer peak					M2												
Sample depth (cm)	93.5	97	102	107.5	114	118	125.5	130.5	132.5	136	139.5	143	147.5	152	156.5	165.5	174.5
Bolivina arctica	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	2
Buccella frigida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bulimina aculeata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buliminella elegantissima	0	0	0	0	0	0	0	0	4	0	0	4	7	8	4	3	19
Cassidulina reniforme	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cassidulina teretis	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0
Cribroelphidium excavatum	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
Cribrostomoides sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclammina sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Epistominella exigua	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eponides tumidulus	0	0	0	69	16	0	0	7	9	1	0	2	25	12	6	10	5
Fontbotia wuellerstorfi	0	0	0	0	0	0	0	3	4	3	10	0	0	0	6	1	4
Globocassidulina subglobosa	0	0	0	0	0	0	0	0	0	0	0	0	10	7	1	1	0
Glomospira gordialis	0	0	0	0	0	0	0	0	2	0	0	0	2	2	1	1	0
Haplophragmoides obscurus	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Oridorsalis spp.	0	0	0	10	22	66	21	31	72	84	69	12	25	23	28	34	42
Quinqueloculina akneriana	0	0	0	0	0	3	14	0	6	0	0	1	0	0	0	0	0
Quinqueloculina arctica	0	0	0	2	2	3	7	41	0	7	7	6	7	2	0	0	0
Reophax sp.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	17	0	0
Stainforthia concava	0	0	0	1	0	0	0	3	0	0	0	0	3	0	0	3	0
Stetsonia horvathi	0	0	0	14	47	0	36	3	4	0	0	69	16	34	21	11	9
Textularia wiesneri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Triloculina frigida	0	0	0	0	12	27	0	3	0	5	11	0	1	1	11	3	1
Trochammina subglobigeriniformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Valvulineria arctica	0	0	0	0	0	0	0	0	0	0	0	3	1	4	4	29	18
Total number of specimens	0	0	0	116	1591	314	14	29	53	355	351	283	319	300	307	290	332

Table 3. Abundance, in percent, of selected benthic foraminifers in samples from Northwind Ridge core 3—Continued.

Lithostratigraphic unit	Unit M																
Planktic foraminifer peak													M3				
Sample depth (cm)	179.5	184.5	190.5	196.5	202.5	209.5	216.5	223	231.5	238.5	246.5	253	261	267	275	278.5	280.5
Bolivina arctica	3	0	0	0	0	0	0	0	0	0	0	0	1	2	0	1	1
Buccella frigida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	21	0
Bulimina aculeata	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0
Buliminella elegantissima	15	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
Cassidulina reniforme	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cassidulina teretis	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0
Cribroelphidium excavatum	2	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
Cribrostomoides sp.	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclammina sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Epistominella exigua	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eponides tumidulus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fontbotia wuellerstorfi	1	0	0	0	0	0	0	0	0	0	0	0	12	1	0	0	0
Globocassidulina subglobosa	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0
Glomospira gordialis	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Haplophragmoides obscurus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oridorsalis spp.	71	0	0	0	0	0	0	0	0	0	100	94	66	37	79	40	44
Quinqueloculina akneriana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Quinqueloculina arctica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reophax sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stainforthia concava	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
Stetsonia horvathi	4	0	0	0	0	0	0	0	0	0	0	3	10	43	1	27	53
Textularia wiesneri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Triloculina frigida	0	0	0	0	0	0	0	0	0	0	0	0	2	1	5	7	0
Trochammina subglobigeriniformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Valvulineria arctica	4	0	0	0	0	0	0	0	0	0	0	0	2	8	0	1	0
Total number of specimens	131	1	0	0	0	0	0	2	0	0	11	345	313	2107	354	337	237

Table 3. Abundance, in percent, of selected benthic foraminifers in samples from Northwind Ridge core 3—Continued.

Lithostratigraphic unit	Unit M				Unit L												
Planktic foraminifer peak					L1										L2		
Sample depth (cm)	283.5	288.5	291.5	296.5	306	310	316	320	324	328	331.5	335	341	346.5	350	353	357.3
Bolivina arctica	5	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	25
Buccella frigida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bulimina aculeata	0	14	0	0	4	0	20	0	0	0	0	0	0	0	0	0	0
Buliminella elegantissima	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cassidulina reniforme	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Cassidulina teretis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cribroelphidium excavatum	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	50	0
Cribrostomoides sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclammina sp.	0	0	0	0	0	38	0	0	0	0	0	0	0	0	0	0	0
Epistominella exigua	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eponides tumidulus	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Fontbotia wuellerstorfi	0	0	0	0	2	38	0	0	0	0	0	0	0	0	0	0	9
Globocassidulina subglobosa	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	50	6
Glomospira gordialis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haplophragmoides obscurus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oridorsalis spp.	82	86	0	0	66	0	79	0	0	0	0	0	0	0	0	0	0
Quinqueloculina akneriana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Quinqueloculina arctica	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reophax sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stainforthia concava	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Stetsonia horvathi	10	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	56
Textularia wiesneri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Triloculina frigida	0	0	0	0	8	13	0	0	0	0	0	0	0	0	0	0	0
Trochammina subglobigeriniformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Valvulineria arctica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total number of specimens	39	7	0	0	222	8	85	0	0	0	0	0	0	0	0	2	32

Table 3. Abundance, in percent, of selected benthic foraminifers in samples from Northwind Ridge core 3—Continued.

Lithostratigraphic unit	Unit L																Unit J
Planktic foraminifer peak	L2									L3							
Sample depth (cm)	360	362.3	365.5	370	373.5	378.5	384.5	387.5	392.5	396.5	401.7	406	413.5	422.5	430.5	434	440
Bolivina arctica	0	38	0	0	37	0	0	0	0	0	63	0	0	0	0	0	0
Buccella frigida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bulimina aculeata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buliminella elegantissima	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cassidulina reniforme	0	8	0	0	2	0	20	0	0	0	0	0	0	0	0	0	0
Cassidulina teretis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cribroelphidium excavatum	0	14	0	0	0	0	40	0	0	8	10	0	0	0	0	50	0
Cribrostomoides sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclammina sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Epistominella exigua	0	0	0	0	0	0	20	0	0	38	0	0	0	0	0	0	0
Eponides tumidulus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fontbotia wuellerstorfi	0	0	0	0	19	0	0	0	0	0	0	0	0	0	0	0	0
Globocassidulina subglobosa	0	8	0	0	3	0	20	0	0	4	6	25	0	0	0	0	0
Glomospira gordialis	0	0	0	0	0	0	0	0	0	2	6	0	0	0	0	0	0
Haplophragmoides obscurus	0	0	0	0	0	0	0	0	0	0	0	75	0	0	0	0	0
Oridorsalis spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0
Quinqueloculina akneriana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Quinqueloculina arctica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reophax sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stainforthia concava	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0
Stetsonia horvathi	0	30	0	0	38	0	0	0	0	44	10	0	0	0	0	0	0
Textularia wiesneri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Triloculina frigida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trochammina subglobigeriniformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Valvulineria arctica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total number of specimens	0	37	0	0	129	0	5	0	0	131	49	4	0	0	0	2	0

Table 3. Abundance, in percent, of selected benthic foraminifers in samples from Northwind Ridge core 3—Continued.

Lithostratigraphic unit	Unit J						Unit I					
Planktic foraminifer peak												
Sample depth (cm)	445.5	449.5	454.5	461.5	465.5	469	482	492	493.8	515.5	541.5	569.5
Bolivina arctica	0	0	0	0	0	0	0	0	0	0	0	0
Buccella frigida	0	0	0	0	0	0	0	0	0	0	0	0
Bulimina aculeata	0	0	0	0	0	0	0	0	0	0	0	0
Buliminella elegantissima	0	0	0	0	0	0	0	0	0	0	0	0
Cassidulina reniforme	0	0	0	0	0	0	0	0	0	0	0	0
Cassidulina teretis	0	0	0	0	0	0	0	0	0	0	0	0
Cribroelphidium excavatum	0	0	0	0	0	0	0	0	0	0	0	0
Cribrostomoides sp.	0	0	0	0	0	0	0	0	0	0	0	0
Cyclammina sp.	0	0	25	0	0	100	93	0	0	0	9	0
Epistominella exigua	0	0	0	0	0	0	0	0	0	0	0	0
Eponides tumidulus	0	0	0	0	0	0	0	0	0	0	0	0
Fontbotia wuellerstorfi	0	0	0	0	0	0	0	0	0	0	0	0
Globocassidulina subglobosa	0	0	0	0	0	0	0	0	0	0	0	0
Glomospira gordialis	0	0	50	0	0	0	0	0	6	38	45	78
Haplophragmoides obscurus	0	0	0	0	0	0	0	0	0	0	9	0
Oridorsalis spp.	0	0	0	0	0	0	0	0	0	0	0	0
Quinqueloculina akneriana	0	0	0	0	0	0	0	0	0	0	0	0
Quinqueloculina arctica	0	0	0	0	0	0	0	0	0	0	0	0
Reophax sp.	0	0	0	0	0	0	0	0	12	0	0	0
Stainforthia concava	0	0	0	0	0	0	0	0	0	0	0	0
Stetsonia horvathi	0	0	0	0	0	0	0	0	0	0	0	0
Textularia wiesneri	0	0	0	0	0	0	0	0	0	0	0	0
Triloculina frigida	0	0	0	0	0	0	0	0	0	0	0	0
Trochammina subglobigeriniformis	0	0	25	0	0	0	7	0	82	63	36	22
Valvulineria arctica	0	0	0	0	0	0	0	0	0	0	0	0
Total number of specimens	0	0	4	0	0	28	14	0	17	8	11	9

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