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POSTGLACIAL BASIN SEDIMENTATION ON LABRADOR SHELF

GUSTAVS VILKS

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L. Carter
R.H. Fillion

Author's Address

Atlantic Geoscience Centre
Bedford Institute of Oceanography
Dartmouth, Nova Scotia B2Y 4A2

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POSTGLACIAL BASIN SEDIMENTATION ON LABRADOR SHELF

Abstract

The postglacial marine environment of the Labrador Shelf is influenced by a southeasterly flow of Arctic water via the Labrador Current, by winter sea ice, and by the frequent presence of icebergs. The Arctic ***Neogloboquadrina pachyderma*** *is the only planktonic foraminifer present in the Labrador Current. The assemblage of the major benthonic foraminifera in the basins is very similar to the Hudson Bay faunas, suggesting a strong influence of Hudson Bay waters in the Marginal Channel of the Labrador Shelf.*

A series of piston cores collected in the basin of Cartwright Saddle contain well-preserved sedimentary and faunal sequences. The lateral coherence of these features indicate a low-energy depositional environment within the basin and a minimal postdepositional downslope movement of sediment. ^{14}*C dates of organic carbon between the ages of 3000 and 21 000 years B.P. correlate well with depth in sediment cores.*

A series of piston cores in the basin of Hawke Saddle indicate a different sedimentary environment. Sedimentary and faunal features do not correlate between the cores and ^{14}*C dates do not show a persistent increase in age of deposition in subsurface sediments. Here the sedimentation is dominated by episodes of slumping and nondeposition.*

The well-preserved faunal and sedimentary sequences of the Cartwright Saddle cores indicate that prior to 15 000 years B.P. and in sediments as old as 22 000 years B.P. the benthic environment in the basins was marginal marine with salinities between 20-25‰, and temperatures close to freezing. The extent of summer ice was similar to modern times, implying that off Hamilton Inlet the Laurentide ice sheet did not extend beyond the Marginal Channel during the Late Wisconsinan.

Résumé

L'environnement marin post-glaciaire du plateau continental du Labrador subit l'influence d'un écoulement sud-est des eaux arctiques dû au courant du Labrador, au mouvement des glaces marines formées pendant l'hiver et des icebergs fréquents. L'espèce arctique ***Neogloboquadrina pachyderma*** *est le seul foraminifère planctonique présent dans le courant du Labrador. Dans les bassins l'assemblage des principaux foraminifères benthoniques est très semblable à celui de la baie d'Hudson, ce qui semble indiquer que les eaux de la baie d'Hudson exercent une profonde influence sur le chenal marginal du plateau continental du Labrador.*

Une série d'échantillons prélevés à l'aide d'un carottier à piston dans le bassin de Cartwright Saddle contiennent des successions sédimentaires et fauniques bien conservées. L'uniformité latérale de ces successions indique que la sédimentation s'est faite dans un milieu de faible énergie dans le bassin, et qu'après la sédimentation, les sédiments se sont peu déplacés par glissement. La datation au radiocarbone, indiquant que les sédiments ont entre 3000 et 21 000 B.P., correspond bien avec la profondeur des prélèvements de sédiment.

Une série d'échantillons prélevés par carottier à piston dans le bassin de Hawke Saddle indiquent un milieu sédimentaire différent. Les successions sédimentaires et fauniques ne coïncident pas avec les carottes, et les dates données par le carbone 14 (C_{14}) *ne montrent pas d'augmentation d'âge continue pour les sédiments de subsurface. Ice, la sédimentation est dominée par des épisodes de glissements de terrain et de non déposition.*

Les successions sédimentaires et fauniques bien conservées, représentées par les carottes de Cartwright Saddle indiquent que, dans l'intervalle de temps compris entre 15 000 et 22 000 B.P. avant la période actuelle, le milieu benthonique des bassins était une mermarginale dont la salinité variait entre 20 et 25‰ et dont la température était proche du point de congélation. L'extension de la glace d'été était la même qu'actuellement, ce qui semble indiquer qu'au large de l'inlet Hamilton, la nappe glaciaire Laurentide n'avait pas dépassé le chenal marginal pendant le Wisconsin supérieur.

INTRODUCTION

During the last glaciation, lobes of continental ice extended offshore in the region of Nova Scotia and Labrador (King, 1969; Fillon, 1975). The marine environment along the glacial margins would have fluctuated in response to the dilution of seawater and changes in circulation patterns. The preservation of fossil evidence for these changes in continental shelf sediments is, however, seldom of sufficient quality to provide an adequate time-stratigraphic record. As a result, the exact age of glacial marine deposits and the chronology of glacial retreat on the Labrador and Scotian shelves is not well established, although a Wisconsinan age has been suggested on the basis of morphological criteria (e.g. King, 1969; Grant, 1972; Fillon, 1975; Van der Linden et al., 1976).

Occasionally proglacial deposits in small basins at depths below the high energy zones of shelf sedimentation contain continuous sedimentary records. The combination of a good fossil environmental indicator, if one can be found, and ^{14}C dates from these basins could provide a time-stratigraphic framework for glacial marine deposits nearby. This report describes textural characteristics of sediments and the distribution of major foraminifera in piston cores from two basins and adjacent areas on the Labrador Shelf. Against the background of existing oceanographic and sedimentary setting, the sedimentological-micropaleontological information is used to describe possible late-glacial to recent changes in the marine environment. The chronology of events is based on ^{14}C dates of organic carbon present in the muds.

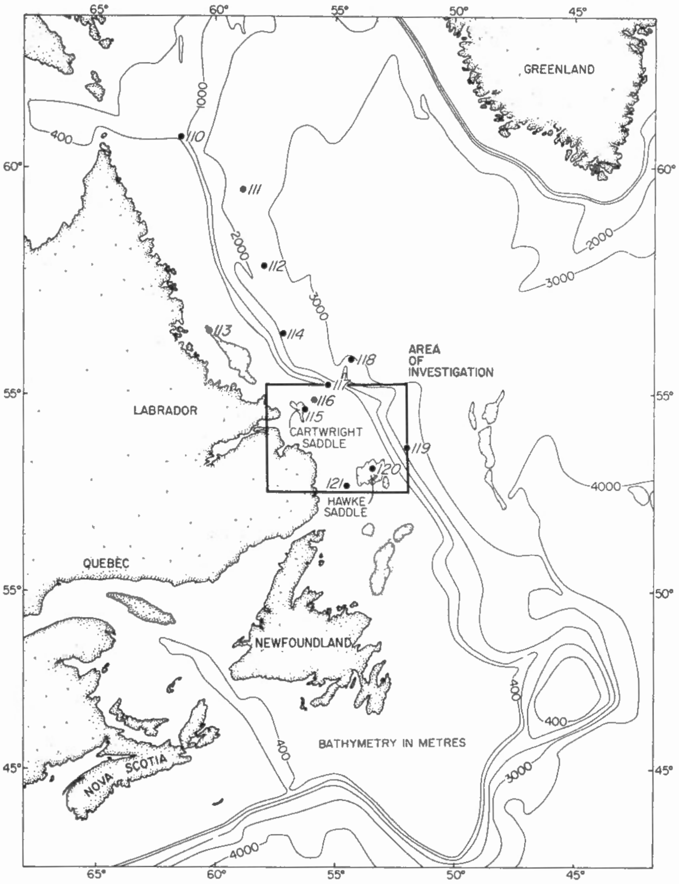

Figure 1. Index map also showing 1977 plankton stations.

Previous Work

Most investigations dealing with unconsolidated sediments on Labrador Shelf have depended on surface samples, continuous seismic profiles, side-scan sonograms and bottom photographs. The description of sediment cores has been a comparatively minor contribution.

Relying mainly on the interpretation of seismic profiles Grant (1966, 1972) outlined the major types of unconsolidated sediment on the Labrador Shelf. McMillan (1973) used piston cores from the banks of the Labrador Shelf to determine the age of bedrock and concluded that a considerable part of the unconsolidated sediments are locally derived. Slatt and Lew (1973) reported on textural and petrographic analysis from the same cores and indicated that the sediment is relict and of glacial origin. According to Van der Linden (1974), Hamilton Bank and the basins nearby are covered with a thin veneer of muds and sands on top of the poorly sorted glacial drift. The mud in the basins may contain up to 16 000 ppm methane (Vilks et al., 1974).

Fillon (1976) maintained that on Hamilton Bank and nearby the reworked surface sediments overlie glacial debris and Van der Linden et al. (1976) indicated that the postglacial sediment dynamics consist largely of winnowing and local redeposition of glacial deposits. Deonarine and Vilks (1977) gave a quantitative account of foraminifera in sediment cores.

Methods

This report deals with 21 piston cores and 30 plankton tows collected during September-October of 1973 and October, 1977. The sampling was carried out between latitudes 55°N and 53°N and longitudes 57°W and 52°W from

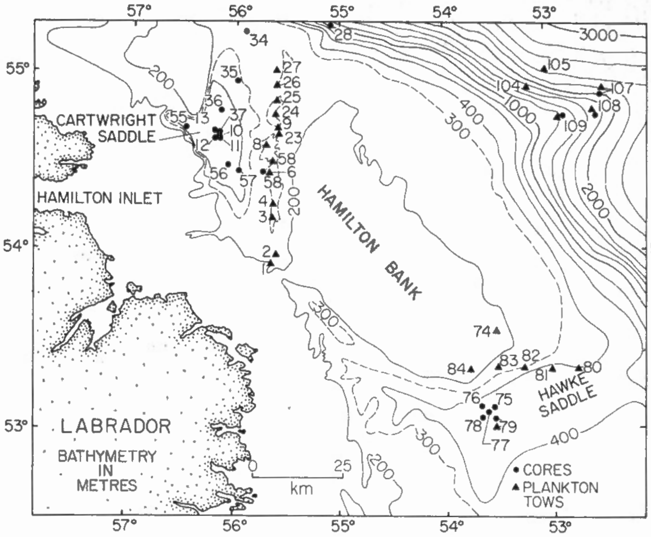

Figure 2. Location of stations.

CSS Dawson, Bedford Institute of Oceanography (Fig. 1; Table 1). The sediments were collected with a 700 kg Alpine piston corer equipped with a 5.5 cm ID core barrel containing a plastic liner. Plankton was taken in a series of vertical tows through the upper 200 m of water with a 202 μm[1] net. The collected plankton was preserved in 5% formalin buffered with hexamethylene tetramine.

Sediment cores were subsampled at 25 cm intervals, each subsample consisting of a vertical section 5 cm long and containing one quarter of the core by volume ($35\ cm^3$). The relative percentages of sediment grain sizes were determined at one phi interval using the pipette method for the finer fractions. Samples for foraminiferal analysis were sieved through a 0.063 mm sieve and the fauna collected from the fraction greater than 0.125 mm.

^{14}C dating of total organic carbon was carried out by Kreuger Enterprises, Inc., and Geological Survey of Canada, Ottawa.

Sediments were cored in the deepest areas of Cartwright and Hawke Saddles, along the margins of the two basins and at three localities on the continental slope. In each of the two basins a series of five cores were taken within a radius of 8 km (Fig. 2). To resolve variability caused by sampling error, patchiness, etc., and from fluctuations reflecting changes in environment, the pattern of sediment and foraminiferal record that was recognized in all five cores of a series was used to describe the postglacial marine environment on the Labrador Shelf. Features of the pattern recognized as typical for the area were also used to interpret the sedimentary record of single cores taken outside the series.

ENVIRONMENT

Bottom Topography

The surface physiography of Canadian Eastern continental shelves is dominated by a complex system of banks and basins, the result of glacial erosion and deposition (Emery and Ushupi, 1972; King, 1969; Fillon, 1976). Characteristically, the basins occupy the inner shelf, and along the coast of Labrador a series of basins form a longitudinal depression known as the Labrador Marginal Channel (Grant, 1972). Cartwright Saddle is one of the deeper basins that extends across the shelf in a saddle-shaped depression between the banks.

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[1] 1 μm (micrometre) = 1 micron

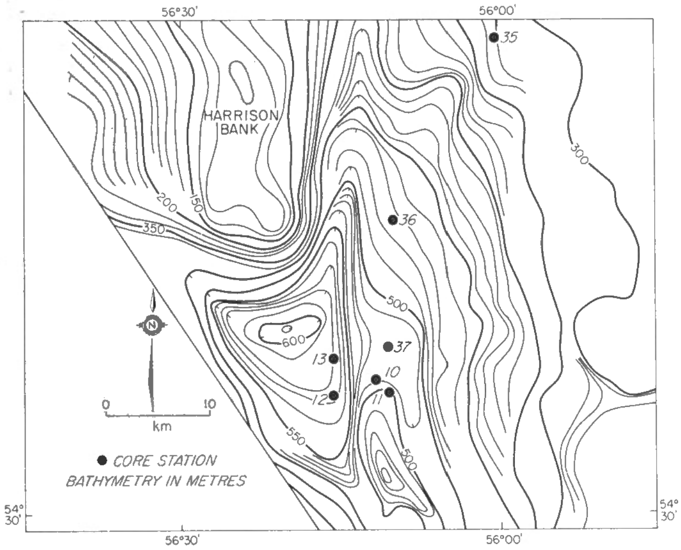

Figure 3. Core stations and bottom topography in Cartwright Saddle.

Details of the seafloor in the Hamilton Bank area have been mapped by Van der Linden et al. (1976). Bathymetric features analogous to glaciated landforms found elsewhere on Labrador mainland indicate that the limit of subaqueous glacial or proglacial features are well preserved, and a late Wisconsinan glaciation was suggested by Fillon (1975).

The postglacial muds in Cartwright Saddle do not obliterate the uneven glacial topography (Fig. 3). For example, Core 11 was taken close to the northern tip of a local rise in seafloor identified by Van der Linden et al. (1976) as a large subaqueous kame. From the 130 m isobath on Harrison Bank to the 600 m isobath at the bottom of Cartwright Saddle maximum slopes are in the order of 2 degrees and between coring sites 11 and 12, the slope is 0.9 degrees.

Topographic variations of this magnitude do not favour the deposition of sediments in laterally continuous sequences in the presence of bottom currents or where turbidite sedimentation is a dominant process. The lack of flat basin floors in depressions suggest lack of sediment ponding.

Oceanography

By far the most dominant oceanographic feature on the Labrador Shelf is the Labrador Current. It is a southeasterly current of arctic water and is confined to the continental shelf and upper slope to a depth of 500 m with the exceptional depth of 1200 m off Hamilton Inlet (Dunbar, 1951). The Labrador Current waters are derived by the mixing of the West Greenland Current, polar waters and the waters from Hudson Bay (Fig. 4). The mixing is not complete and the dominance of the various components varies across the shelf (Smith et al., 1937). Local runoff, Hudson Bay waters, and waters originating in the Arctic Basin, dominate the inner shelf and the Marginal Channel. The West Greenland waters are more prominent along the outer shelf. The mixing is enhanced in the basins between the banks, especially in the Hawke Saddle where Andersen (1968) reported a small cyclonic gyre. It is evident that the bottom topography of the shelf influences the course of the Labrador Current.

The waters of the Labrador Current are characterized by low temperatures (-1.5°C – +2.5°C and salinities 32.0-34.5 ‰) (Dunbar, 1951). Deviations from the typical Labrador Current TS "envelope" are common, especially in the nearshore zone (Nutt, 1953) where the deviations are normally more pronounced in terms of warmer temperature. A typical summer profile off Hamilton Inlet has a surface temperature up to 6°C, a core of cold water (less than 0°C) between 50 and 150 m and water warmer than 0°C below these depths (Andersen, 1968). The salinities range from 30 ‰ at surface to 34 ‰ at bottom, with a halocline at approximately 40 m. The deeper basins in the marginal channel may trap the warmer and more saline water, over 2°C in the vicinity of Hamilton Inlet (Kolimayer, 1965) and over 3°C in Hawke Saddle (Andersen, 1968).

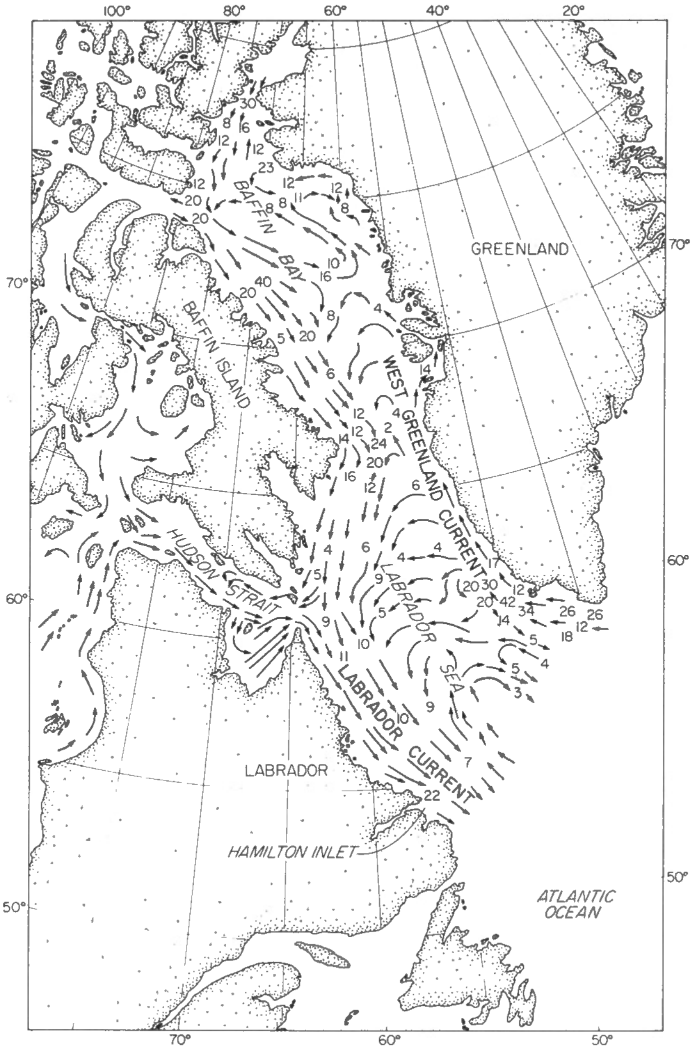

Figure 4. Surface currents in Baffin Bay (after Dunbar, 1952). Numbers indicate cm/s.

The Labrador Current is responsible for the transport of ice along the coast of the western North Atlantic as far south as 45°N latitude (Dinsmore, 1972). By December the Arctic ice has normally reached the Strait of Belle Isle and in March close pack ice covers the whole shelf as far south as the northern Grand Banks. Westerly winds drive the pack into the warmer offshore waters cleaning the Strait of Belle Isle by the end of May and the northern Labrador Shelf by end of July (Dinsmore, 1972).

In addition to the extensive annual sea ice, the environment of the Labrador Shelf is modified by the presence of icebergs. The coast of West Greenland is a major

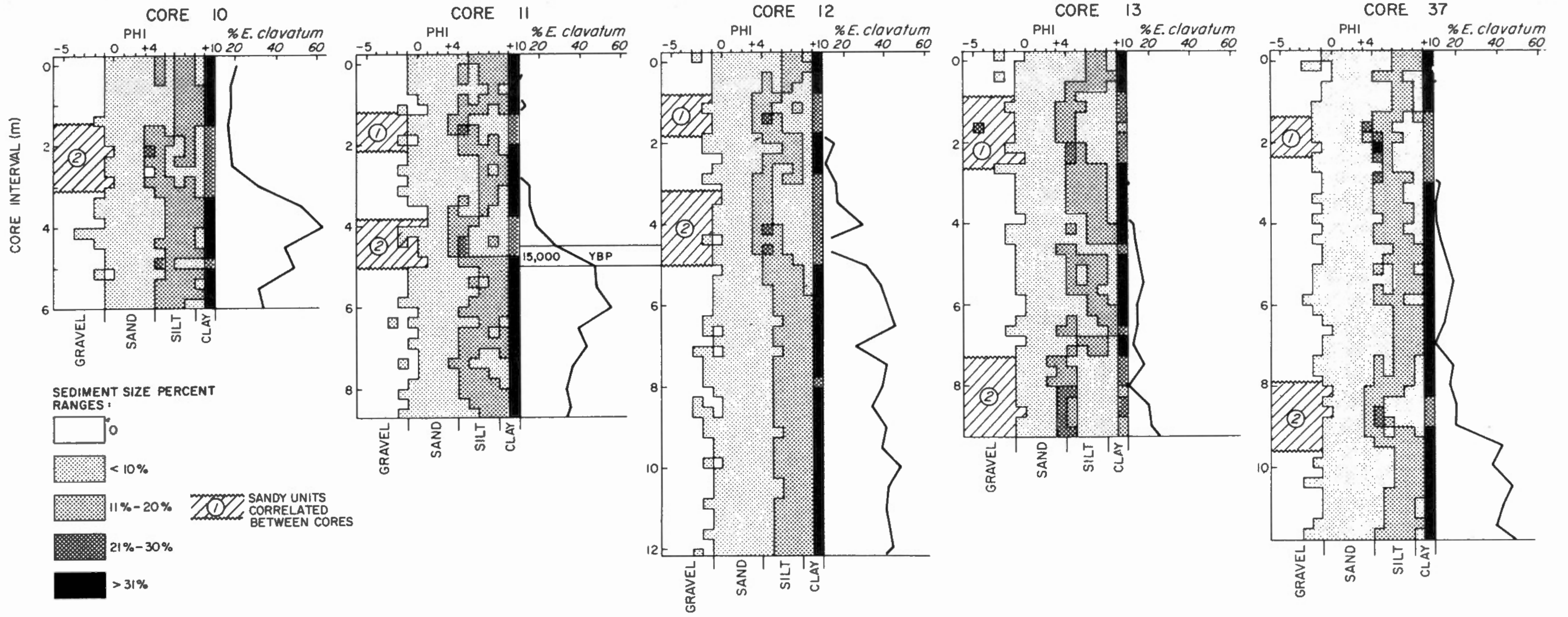

Figure 5. *Sediment size distribution and relative abundance of* ***E. clavatum*** *in Cartwright Saddle cores. (Approximately 1.5 m were lost from core 10 during handling.)*

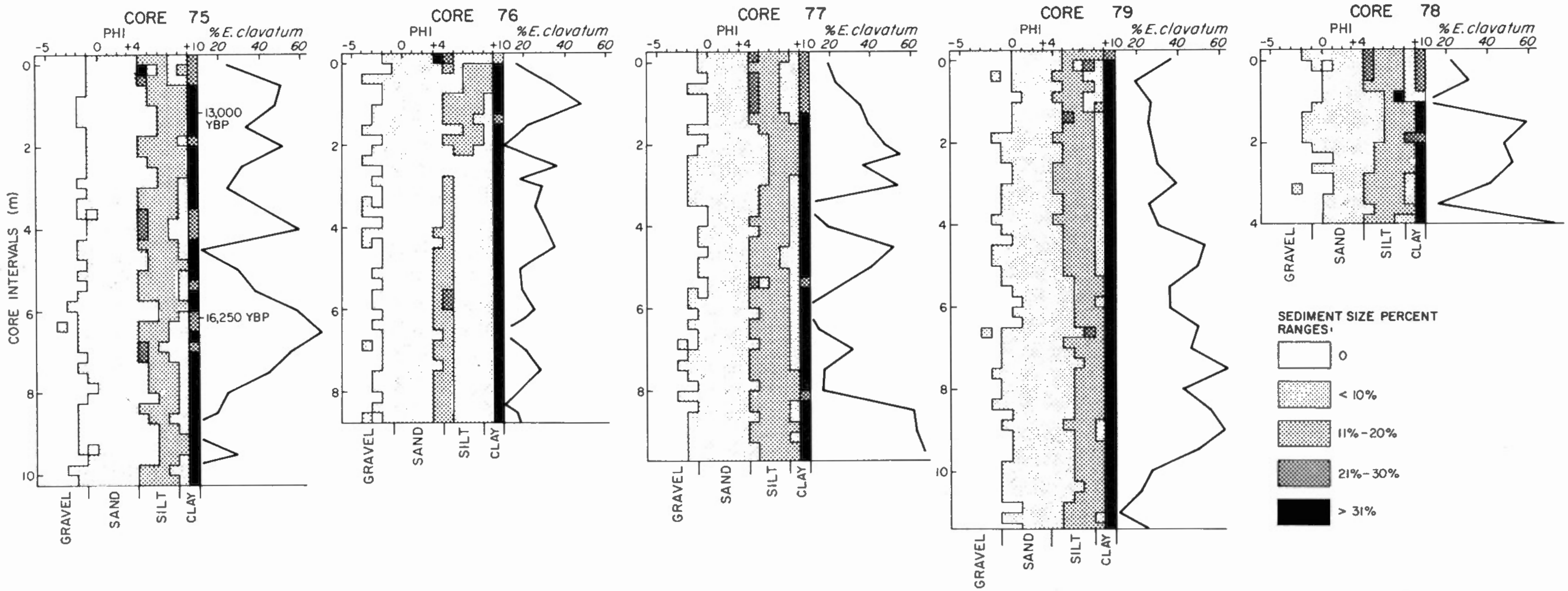

Figure 6. *Sediment size distribution and relative abundance of* ***E. clavatum*** *in Hawke Saddle cores.*

source and approximately 1000 bergs per year reach the region offshore Belle Isle via Labrador Current (Dinsmore, 1972). The larger icebergs frequently touch the bottom (Van der Linden et al., 1976).

Information on current velocities on the Labrador Continental Shelf is not available and water mass movements have been deduced from geostrophic calculations. Surface currents on the Labrador Shelf are southeasterly and in the order of 20 cm/s off Hamilton Inlet (Dunbar, 1951). Along the continental margin, the calculated velocity was 18 cm/s above the 1500 decibar reference level during 1968 (Andersen and Moynihan, 1968). Between 1948 and 1968, the mean volume transport of the Labrador Current in summer was 5.5×10^6 m^3/s measured along the section between Labrador Shelf and Cape Farewell, Greenland (Dinsmore and Moynihan, 1969). The variability of the annual values is considerable (standard deviation of the mean is 1.74) and reflects the multiplicity of the source. The southeasterly flowing water on the Labrador Shelf contains contributions from the Arctic Ocean, Hudson Bay and the Atlantic and the variations in the climate and meterological conditions in each of these distant areas may influence the transported volumes.

In addition to the fluctuations in water mass transport, variability in local current velocities is influenced by the bottom topography as a result of shoaling and diversion of flow between the banks. These currents are difficult to predict and reliable information can only be obtained from moored current meters.

Sediments in General

Unconsolidated Quaternary deposits of the Labrador Shelf are thickest in basins (over 300 m) but vary from a few metres to 100 m on the banks (Grant, 1972; Van der Linden et al., 1976). The sediment in Cartwright Saddle is approximately 200 m thick, according to a reflection profile (Vilks et al., 1974). The internal reflectors within the unconsolidated unit indicate the presence of coarser sediments that are below the reach of piston cores and were not sampled.

Surficial sediments in the region of Hamilton Bank have been described by Van der Linden et al. (1976). Sand dominates both Harrison and Hamilton banks. The outer edge of Hamilton Bank is covered by gravelly sand and the remainder by silty sand or sandy silt. Gravel or gravelly sand most commonly covers the sills between the banks and between the inner shelf and Hamilton Bank. Clayey silt is found in the basinal parts of Hawke Saddle and silty clay in Cartwright Saddle. The sediment distribution pattern suggests that in the process of postglacial redistribution, the fine sediments accumulated in the basins and the coarser material remained on banks and sills, a conclusion also reached by Van der Linden (1974) and Fillon (1976).

The typical frequency distribution curves of sediments on the Labrador Shelf are polymodal. Tables 2, 3, 4, and 5 indicate the phi intervals at which modes occur throughout the cores, showing both the primary and secondary modes. The basin sediments also contain large percentages of clays finer than 10 phi and because the analysis does not differentiate sediment at this size range, the 10 phi modes are not shown in the tables.

The polymodal nature of sediments strongly suggest the influence of several transport mechanisms (e.g. Smith and Hopkins, 1972) and multiple source. With very little new sediment being added to the shelf, recent processes modify the distribution characteristics of glacial deposits. Thus, because of the low rates of sediment supply, rugged seafloor topography has been maintained allowing exposure of old sediment. As a result, the frequency distribution of sediment sizes contains evidence of both historical and present-day sedimentary environment.

Sediment in Basins

The basin piston cores collected mostly silts and clays with a few pebbles (Fig. 5 and 6). Several layers of distinct textural characteristics are recognized in all Cartwright Saddle cores; however, the surface metre of sediment is low in coarse silts (5 phi) and is barren of **Elphidium clavatum** (a nearshore species to be discussed later). Below the surface a sequence of sandy (4 phi) and silty (5 phi) sediments is present in all five cores (Fig. 5). The upper sandy unit (1) is missing from core 10, but is present in all the other cores between 1-2 m below surface. The lower sandy unit (2) occurs in core 10 at 2-3 m level, at 4-5 m in cores 11 and 12, at the bottom of core 13 and between 8-9 m in core 37. The bottom of unit 2 coincides with an increase of the nearshore foraminifera **E. clavatum** to relative percent of more than 30 (Fig. 5). This level of the cores is considered to represent a major environmental change associated with the deglaciation of the shelf (Vilks and Mudie, 1978) and is defined as the Wisconsinan and Holocene contact. The general dominance of fine grain size modes in cores taken in Cartwright Saddle suggest a low energy depositional environment with sediments arriving from suspension. According to Table 2, most principal modes are in silt and clay fractions, with a secondary mode in either a coarser or finer size intervals. Disregarding the fine clay fractions, Holocene sediments are dominated by principal modes in coarse silts (5 phi) and Wisconsinan sediments by fine silts (Table 6). The table also shows that on the average, 15 per cent of core intervals representing Holocene sediments contained principal modes in sand fraction, while during Wisconsinan sedimentation sand was not sufficiently dominant to produce a principal mode in the distribution curve.

Despite the relatively uneven seafloor, the cores show that in Cartwright Saddle laterally continuous sedimentary sequences, extending for at least 10 km, were preserved. The five cores taken from Hawke Saddle (Fig. 6) do not show a similar lateral continuity with respect to sediment and faunal characteristics. In comparison to Cartwright Saddle, the sediments contain more gravel, but less sand. The extreme fluctuations of **E. clavatum** suggest sediment redeposition.

A high resolution reflection profile through Hawke Saddle (R. Fillon, pers. comm., 1978) shows a relatively thin (10 m) cover of stratified sediment on top of unstratified deposits probably of glacial origin. The seismic line also indicates that the slope to the north of the coring site is incised with steep-sided gulleys not shown in Figure 7.

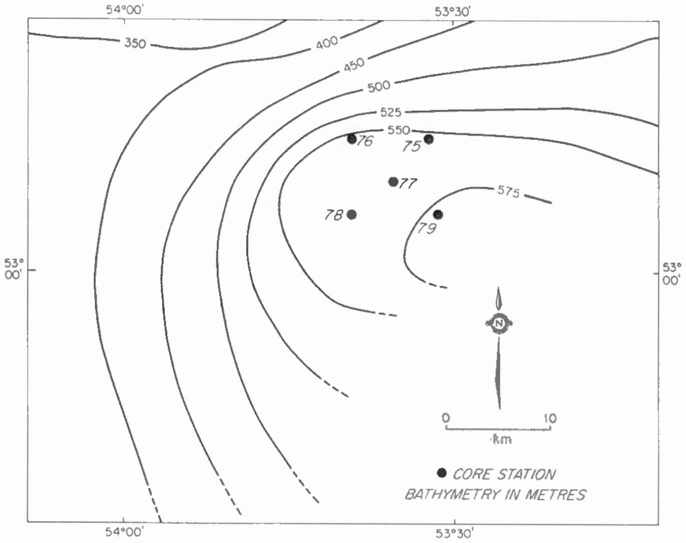

Figure 7. Core stations in Hawke Saddle.

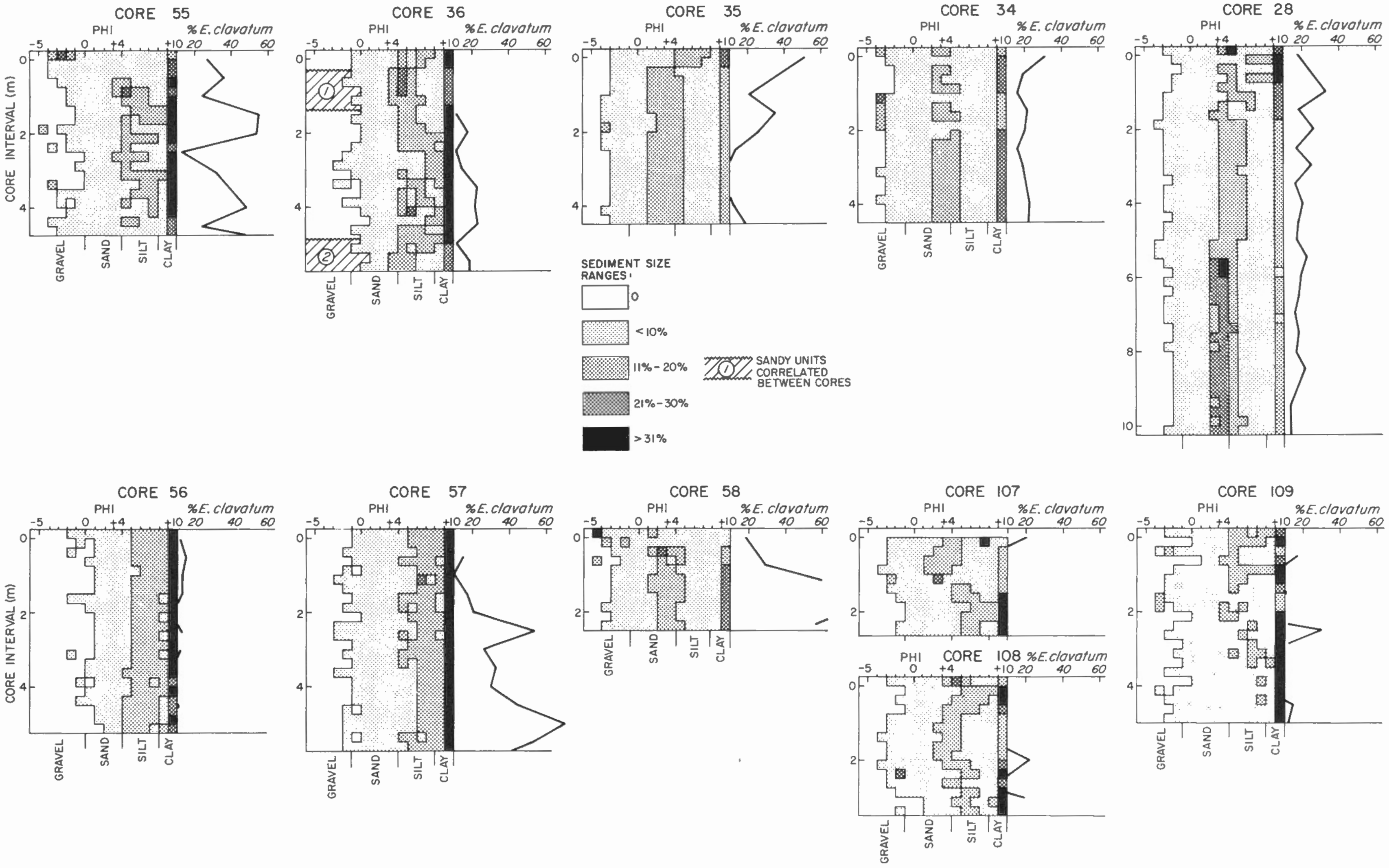

Figure 8. *Sediment size distribution and relative abundance of* ***E. clavatum*** *in cores taken outside the basins.*

Except for core 76, the Hawke Saddle sediment distribution patterns are bimodal within the silt size fractions. Core 76 contains up to 4 modes per interval, with most of the secondary peaks occurring in the gravel size range (Table 3). The occurrence of abundant Paleogene-Miocene fossil foraminifera mixed with recent faunas suggest the presence of rock outcrop nearby. The polymodal character of the sediments and the excellent condition of the fossils indicate multiple source and a short distance of sediment transport, most likely downslope, with very little winnowing.

The summary of principal mode distribution (Tables 6 and 7) shows that Holocene sediments are dominated by 5 phi fraction and the Wisconsinan sediments by 8 phi fraction. In both Cartwright and Hawke basins the coarse silts produce most principal modes in Holocene sediments and fine silts in Wisconsinan sediments.

The modal analysis of sediments supports the model of sediment redistribution from banks to basins. The sediment distribution curve of the glacial drift on Hamilton Bank contains a secondary 5 phi grain size mode (Fillon et al., 1978) and therefore is a source for the Holocene sediments in Cartwright Saddle. The finer sands of the Groswater Unit that covers the central Hamilton Bank (Van der Linden et al., 1976) is characterized by a primary mode in the 4 phi size range. As a result of secondary reworking of the Hamilton Bank sands, the Groswater sediments could be the source for the sandy beds 1 and 2 in Cartwright Saddle.

Shelf Sediments

Single cores taken at various localities along the margin of the Cartwright Saddle basin vary in sediment characteristics, depending on depth and proximity to a topographic high. Sediments in waters deeper than 450 m (cores 36, 56, 57, Fig. 2 and 8) show features that can be correlated with the Cartwright Saddle cores of Figure 5. In core 36, sandy unit 1 and the top of sandy unit 2 can be recognized. The upper half of core 36 contains mainly unimodal (5 phi) deposits and in the lower half the distribution of principal modes is typical of Holocene sediments with a low fine silt (8 phi) contribution (Tables 4, 5 and 8).

Most of core 56 is low in both 5 phi sediments and **E. clavatum** and therefore correlates with the sediments above sandy unit 1 of the "series" cores. The sandy units are missing from core 57 and the sediments are low in the coarse silt fraction (5 phi). However, the **E. clavatum** profile is similar to the "series" cores below the sandy units. Core 57 was taken 20 km from the "series" cores and may be beyond the lateral extent of the sandy beds.

Core 55 penetrated a sequence of gravels and muds on a steep slope towards Harrison Bank at a water depth of 439 m. The surface gravel is 0.5 m thick, below which there is 0.5 m of sand that grades to silty sand and silty clay at a level of 1.8 m. Most of the gravelly sediment below 2 m also contains large percentages of fine clay. The sediment size distribution is basically polymodal with -2 phi primary modes dominating the gravel. The high -2 phi peak is probably due to the removal of silt by currents along the rise of Harrison Bank.

Three sediment cores were taken at a water depth of close to 300 m in gravelly sediment (cores 34, 35, and 58, Fig. 2 and 8). Sediments below 2 m in cores 34 and 35 are suspect in being sucked in during coring and the size distribution in Figure 8 may be incorrect. Core 58 contains well sorted sand under a surface layer of gravel.

Continental slope cores (28, 107, 108 and 109, Fig. 2 and 8) are rich in pebbles and as a rule, clays and silts are more dominant below the sands and gravels at the surface. A thick sequence of well sorted sand is present in the upper slope core 28 below 500 cm of sediment. The deeper cores taken below 1000 m show frequent alterations of texture and colour.

FORAMINIFERA

Planktonic Foraminifera in the Water Column

The Labrador Current is dominated by the Arctic planktonic foraminifera **Neogloboqudrina pachyderma** (Tables 9 and 10). Few specimens of **Globigerina bulloides, Globogerinita uvula** and **G. guingueloba** were found mainly along the continental slope, in Hawke Saddle and at station 113 in Hopedale Saddle (Fig. 1). Dextrally coiled **N. pachyderma** occur on the average of 3.4% in Labrador Shelf water and 13.4% along the continental slope. The higher dextral percentages and the presence of the **Globigerina** species indicate a slight influence of lower latitude waters in the offshore Labrador Current.

Planktonic foraminifera play a relatively minor role in the food chain of the oceans and by weight they add little to the total biomass. Exclusive of coastal waters, planktonic foraminifera occur in greater numbers where production rates are higher and in our samples higher numbers seem to correlate with greater weights of total biomass (Fig. 9).

The Arctic Shelf waters that are rich in **N. pachyderma** also contain a large population of the normalform ecophenotypes of this species (Vilks, 1974). Normalform tests are characterized by a constant growth with each additional chamber larger than the previous one. On the Labrador Shelf the correlation between foraminiferal numbers and percent normalforms is sufficient (Fig. 10) to be useful in sediment core studies. In terms of the total biomass and normalforms, Hawke Saddle is richest in both (Table 9) and is most productive, assuming a correlation between the standing stock in the water column and organic productivity.

Planktonic Foraminifera in Surface Sediments

The sediments deposited in the Arctic waters contain only a fraction of total foraminiferal tests produced in the water column as a result of dissolution of calcareous material before burial. Most normalform **N. pachyderma** are thin-walled and are more readily destroyed in comparison to the other forms. On the Labrador Shelf the percent of normalform tests in the sediment is therefore lower than in the water column (Table 11).

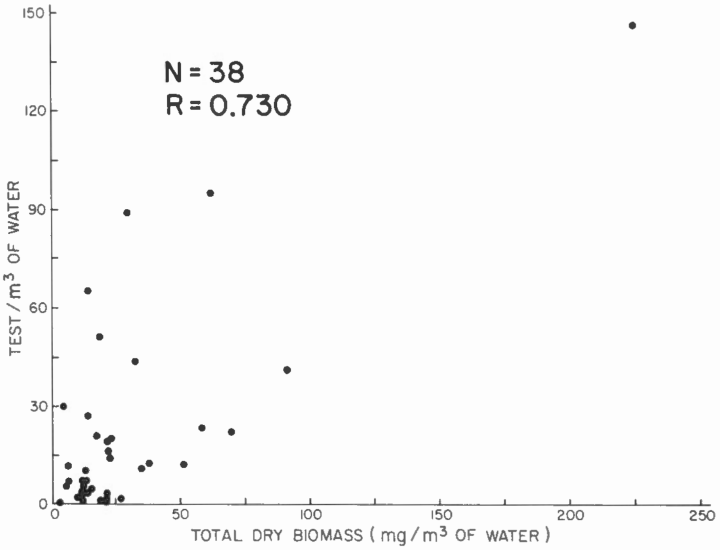

Figure 9. Relationship of planktonic foraminiferal and total biomass abundances.

By assuming that only normalforms are being destroyed, it is possible to calculate the number of tests each sediment sample should contain for a given normalform percentage in the water column (Table 11). After the correction, the Hawke Saddle sediment samples are still the poorest in planktonic foraminifera by several orders of magnitude despite the greater production.

The tests of planktonic foraminifera become sediment particles and in offshore areas the unconsolidated deposits may consist almost entirely of biogenic calcareous material. How much of the test material produced is actually preserved in the sediment is difficult to estimate mainly because of insufficient information on rates of production. However, dealing with a single species from high latitudes where production is distinctly seasonal and short, one generation per year may exist and the summer standing stock may be the total annual supply to the seafloor. On this basis the number of planktonic tests collected in plankton tows may be used to estimate the number that will be deposited on one cm^2 of seafloor during one year.

If F is the total number of foraminiferal tests deposited per year per cm^2 and S is the number of tests found in one cm^3 of sediment, then 1/S is the volume of sediment deposited for each test preserved. It follows that the rate of total sedimentation $R = \frac{F}{S}$ cm/a[1] (Vilks, 1972). On the basis of average counts of tests in the water column and the estimated numbers in sediment, R values were calculated in the three sampling areas (Table 11). Considering the possible errors, the R value for the Cartwright Saddle is close to the rate of sedimentation based on ^{14}C dates in two sediment cores (Fig. 11). Although ^{14}C dates are not available for the other sampling areas for comparison, the calculated rate of sedimentation is higher than could be expected in Hawke Saddle and lower on the continental shelf.

The deviation of R values from the ^{14}C rates of sedimentation indicates processes not accounted for in the simple model of $R = \frac{F}{S}$. Vilks (1972) suggested lateral transport of tests before landing on the seafloor on the Beaufort Shelf of the Canadian Arctic as an explanation for extremely high or low R values. However, the main reasons for deviations are probably patchiness of plankton and that the high standing stock in Hawke Saddle may not be representative of a long term average for the area. The low R values on the continental slope may be close to being correct in that sediment reworking may be responsible for the removal of fine fractions and the concentration of foraminiferal tests in the sediments.

Benthonic Foraminifera

Faunal reports on 21 cores collected in the area is given by Deonarine and Vilks (1977), where 175 benthonic foraminifera species were identified. The distribution of major species in Cartwright and Hawke saddles are discussed here. The ranking species that add up to 70 per cent in each sample are defined as major (Fig. 12).

On the basis of species distribution in the top metre of the cores, the environment in the two basins is similar to that of Hudson Bay and the Gulf of St. Lawrence (Table 12). It is less similar to the Beaufort Shelf in the vicinity of Mackenzie Delta and the Canadian Arctic Archipelago and there are no common major species with Emerald Basin on Scotian Shelf.

The two localities to which the Labrador Shelf fauna is most similar are characterized by large influx of runoff and on the basis of salinity and circulation, can be considered as large estuaries. However, the two Labrador Shelf basins lack any obvious present-day estuarine circulation, and the similarity of faunas may be due to a combination of the Hudson Bay influence extending along the coast and a historical effect, i.e. the species are relict from earlier periods of estuarine environment associated with shallower water.

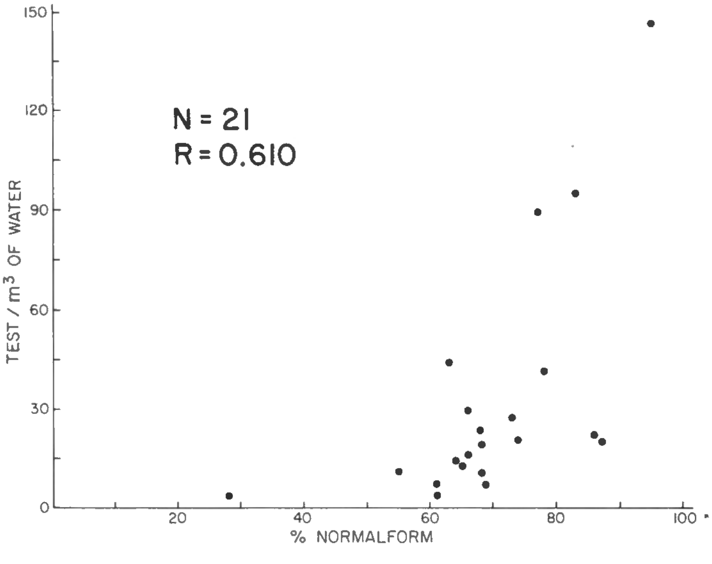

Figure 10. Relationship between total numbers and percent normalform N. ***pachyderma.***

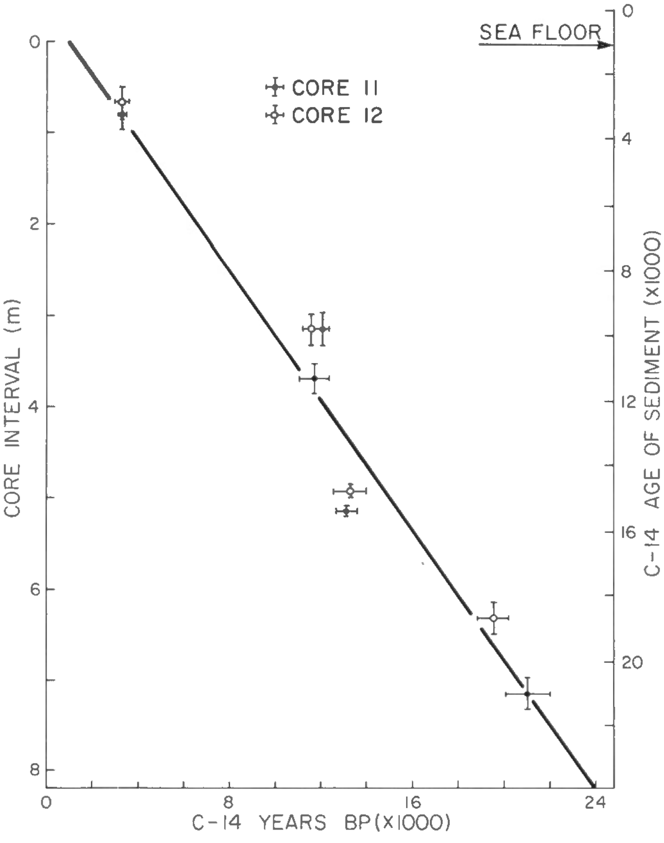

Figure 11. ^{14}C dates related to core intervals of two cores.

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[1] a is the SI abbreviation for years.

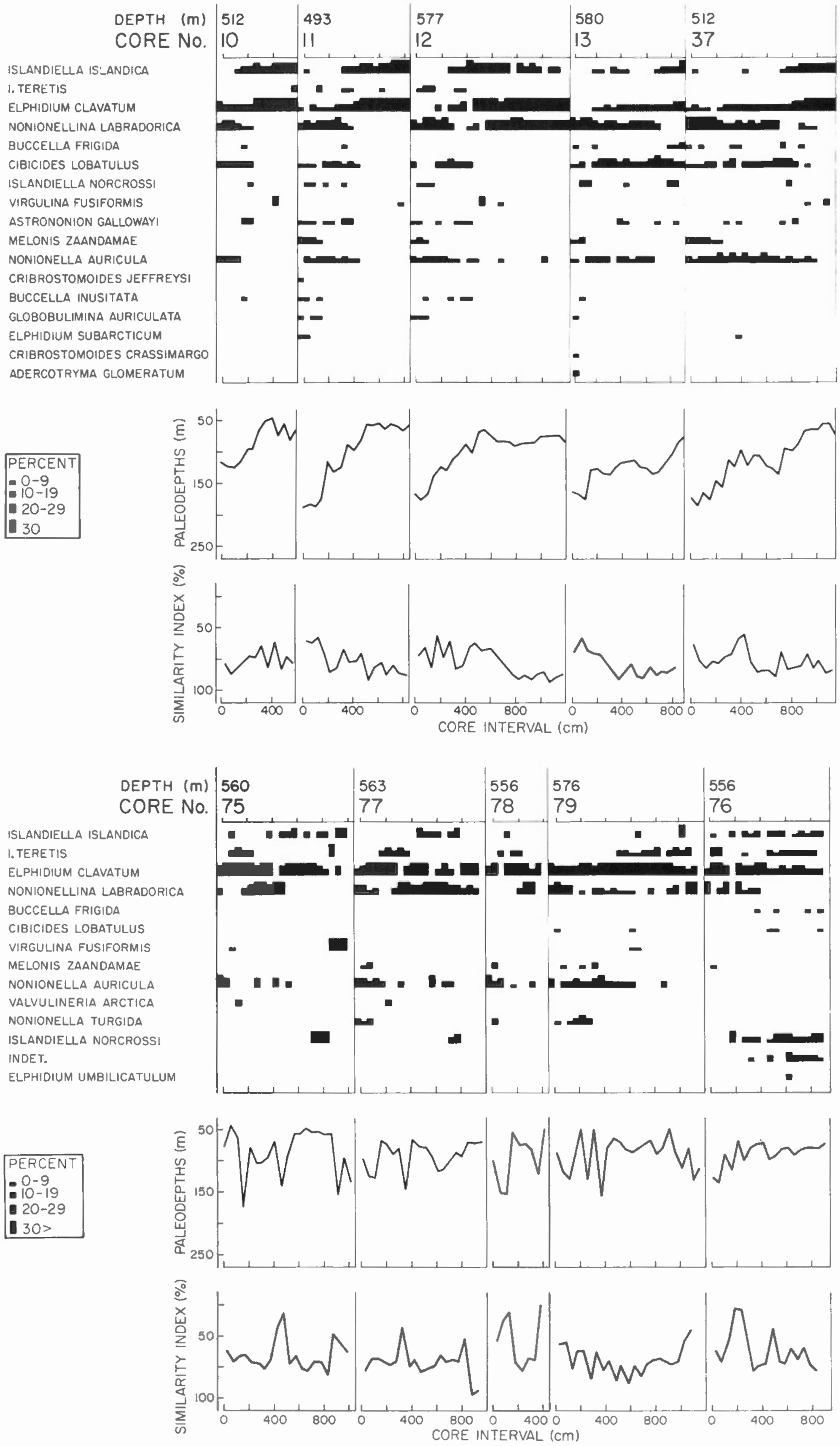

Figure 12. Distribution of major species in Cartwright Saddle and Hawke Saddle cores. Paleodepths defined in text. Similarity index defined by Ruddiman et al. (1970).

Possible water depths of earlier times (paleodepths) can be estimated by summing the product of mean depth of water at which species are commonly found (specific depths) and the abundances of these species in sediment cores. Thus the paleodepth (PD) at any core interval is $PD = \sum_{i=A}^{S} SD_i f_i$ where SD_i are the specific depths of species from A to S occurring at frequencies f_i. Vilks et al. (1978) calculated specific depths for a number of species found in surface sediments of the Beaufort Shelf by using the following relationship: $\mathrm{Ln}\, SD_a = \sum_{i=1}^{N} f_{a_i} \ln D_{a_i}$; $SD_a = e^{\ln SD_a}$ where SD_a is a specific depth of species A and D_{a_i} are water depths at stations where species A is occuring at frequencies fa_i. These specific depths are used in this report to indicate possible changes in apparent paleodepths in sediment cores (Fig. 12).

The undisturbed cores of Cartwright Saddle show a change from a relatively shallow paleodepth at the bottom to deeper waters at the top of the cores. In the Hawke Saddle cores, the calculated paleodepths fluctuate without any trend. However, the calculated depths in both basins are much shallower than the range of water depths at which the cores were taken. For example, foraminifera found in surface sediments of the Cartwright Saddle cores are typical of water depths in the order of 160 m on the Beaufort Shelf. On the Labrador Shelf they are found in waters that average 530 m in depth. The discrepancy is significant and suggests a basic difference in the environmental setting and recent history of the two areas. From the historical point of view, it is possible that the present Labrador Shelf faunas are relict not only of a more estuarine paleoenvironment, but also of shallower paleodepths, in the order of 100 m during the Pleistocene (e.g. Hardy and Umpleby, 1976).

POSTGLACIAL SEDIMENTATION AND PALEOCEANOGRAPHY

Core Stratigraphy

The stratigraphy of sediment in Cartwright Saddle is defined by two sandy intervals and a faunal discontinuity. In each core below the lower sandy layer the fine sediments contain less diverse benthonic foraminifera with **E. clavatum** the dominant species. The lateral coherence of the sedimentary and faunal discontinuities indicate that the change has a time stratigraphic connotation and most likely coincides with a change in the environment.

The time framework of these changes is established by ^{14}C dates of cores 11 and 12 (Fig. 11; Table 13). Sediments below 8 m of core 12 gave younger ages, suggesting intrusion of surface sediments during the coring operations. The nine good dates correlate linearly with depth in the cores (r = 0.884, significant at 0.99 probability level). The calculated straight line through the points is used to estimate the age of sediment in cores 11 and 12 at any depth between the surface and 8 m.

According to the ^{14}C dates, the lower contact of sandy layer 2 in cores 11 and 12 is 15 000 years old and the age of the lower contact of sandy layer 1 is close to 7000 years. The age of sediment in the remainder of the cores is determined whenever these contacts are recognized.

The stratigraphy of sediment in Hawke Saddle is not defined because of the complex faunal and sediment records. Down the core, faunal assemblages fluctuate irregularly as shown by the low similarity indices (percentage overlap values of Ruddiman et al., 1970) (Fig. 12). As a result, distinct sediment and faunal features could not be recognized between cores.

The poor lateral continuity of sediments in Hawke Saddle is also reflected in the lack of correlation between ^{14}C dates and core intervals (Fig. 13). The correlation is improved by separate lines through points of cores 76 and 77. The bottom of core 75 closely agrees with 77. The dates suggest a wide difference in ages between the cores with the Holocene interval missing on the top of 76. However, ^{14}C stratigraphy based on organic carbon should not be considered dependable without the support of biostratigraphy at least within a basin. Good biostratigraphy provides the assurance of sequential deposition and minimizes the possibility of wrong dates as a result of sediment mixing.

Sedimentation

Sediment texture and distribution of foraminifera in cores suggest the presence of several different environments of sedimentation within the area of study. The basin of Cartwright Saddle is characterized by a relatively low energy sedimentary environment where resuspended debris from the banks is being deposited. The sedimentation has been continuous for at least the last 20 000 years at an average rate of 36 cm/1000 a. The basin seafloor is reminiscent of abyssal hills where continuous sequences of fine sediments blanket the uneven topography. The uneven bottom of the basin and the well preserved stratigraphy suggest very little redeposition in the form of slumping or turbidity currents.

The basin sedimentation in Hawke Saddle is different from that of Cartwright Saddle, despite the reasonably similar bathymetric setting. The lack of lateral coherence of textural and faunal sequences between closely spaced cores and the poor correlation between ^{14}C dates and core intervals indicates a mixing of organic matter of different ages. The evidence suggests a highly localized and short distance transport along the seafloor, most likely downslope in the form of slumping. Sediment reworking by currents and suspension redeposition would destroy old organic matter by a prolonged exposure to the oxidizing environment in the water column. The lack of ages younger than 10 000 years B.P. suggests a minimal deposition from suspension during the postglacial period.

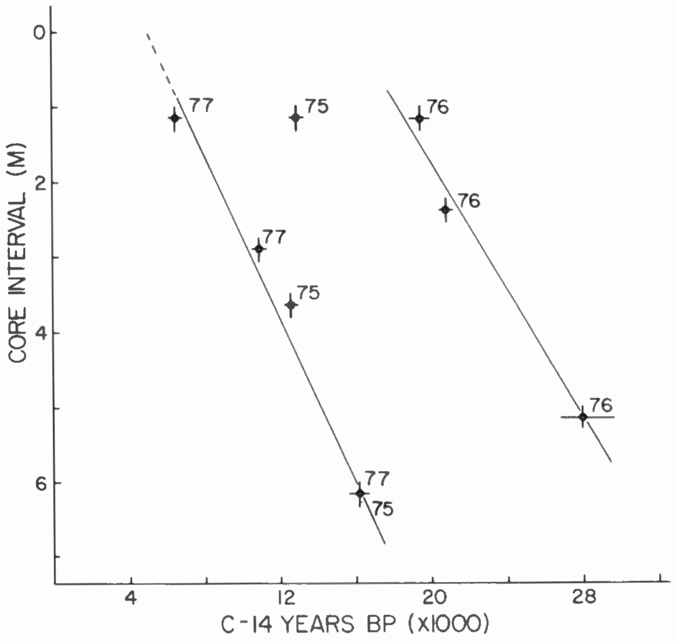

Figure 13. ^{14}C dates in cores 75, 76 and 77 of Hawke Saddle.

In shallower water outside the basins the sediments are basically gravels and gravelly sands. The size distribution is characteristically polymodal and most likely due to the presence of ice rafted gravel. As a rule, the gravelly sands are overlain by sediment containing more gravel and associated with lesser amounts of mud. The decrease of mud suggests higher currents and lower sedimentation rates during recent times, assuming that the rate of ice rafting has remained constant since deglaciation.

Paleoceanography

Biostratigraphy in Cartwright Saddle is based on the decrease of species diversity with depth of sediment and concurrent increase in dominance of **Elphidium clavatum** (Williamson). **E. clavatum** is a highly variable species with a complex synonomy (see faunal reference list). The most commonly used names are **Elphidium incertum clavatum** (e.g. Feyling-Hanssen, 1964), **E. incertum** (e.g. Vilks, 1969), **E. excavatum** forma **clavata** (e.g. Schafer and Cole, 1978). The species is most abundant in nearshore waters and has a large temperature tolerance (Sen Gupta, 1972; Murray, 1973). It is one of the major species in Arctic waters that are free of summer ice for at least several months (R.W. Smith, unpublished report; Leslie, 1965; Vilks et al., 1978) but is not common in the Arctic Archipelago where sea ice remains during the summer (Vilks, 1964, 1969, 1976). Although **E. clavatum** is also found in warm waters, it is normally associated with arctic conditions and when abundant, it is a useful indicator for cold paleoenvironments (Feyling-Hanssen, 1972b). As a nearshore species, **E. clavatum** tolerates relatively large salinity ranges and low amounts of dissolved oxygen (Wefer, 1976).

Elphidium clavatum is ubiquitous in late glacial sediments along both sides of the North Atlantic. Several small basins on the Canadian continental shelf contain stratified late Wisconsinan — early Holocene muds with well preserved **E. clavatum.** In the Emerald Basin of Scotian Shelf a low-diversity **E. clavatum** assemblage is replaced by high diversity outer shelf foraminiferal assemblages towards the surface of two cores (Vilks and Rashid, 1976). A similar change was recorded in one core in the Gulf of Maine (Schnitker, 1976) and Grand Manan Basin at the entrance of Bay of Fundy (Vilks and Rashid, 1977). The late Wisconsinan sediments resulting from the marine incursion of the Champlain Sea, contain large numbers of **E. clavatum** (Wagner, 1970; Fillon, 1974; Cronin, 1976) and across the Atlantic, in Norway, the late glacial strata are characterized by the abundance of **E. clavatum** (Feyling-Hanssen, 1964; Knudsen, 1971).

Along the Atlantic coast of eastern Canada the change from a low-diversity **E. clavatum** assemblage to the diverse faunas in the surface layers took place approximately 15 000 years B.P. on the Labrador Shelf and in Gulf of Maine and as late as 8000 years B.P. in Emerald Basin of the Scotian Shelf. The faunal evidence suggests that during the late Wisconsinan, marginal marine conditions existed in some of the present day basins of the continental shelf. As a result of excessive runoff and limited circulation, bottom salinities were probably in the range of 25-30%. Normal marine conditions returned to the Gulf of Maine and Emerald Basin when the sill depths to the basins were sufficient to allow the entrance of offshore slope waters.

The factors responsible for the return of normal marine conditions to the Labrador Shelf basins are complex. The sediments in Cartwright Saddle cores are sufficiently old to include evidence of late Wisconsinan fluctuations in sea level. The world eustatic minimum sea level has been estimated at approximately -130 m occurring 17 000 years B.P. (e.g. Müller-Beck, 1966; Milliman and Emery, 1968). During the last 6000 years very little eustatic change in sea level has been recorded (Walcott, 1972). It is certain that the seafloor on the Labrador Shelf must have readjusted isostatically in response to the coastal glaciation. Along the coast of Hamilton Inlet the maximum isostatic rebound is in the order of 150 m above the present sea level (Andrews, 1973). It is difficult to extrapolate the isostatic movements from land to the Labrador Shelf nearby, without knowing more about ice margins and chronology of ice ablation on the shelf. To date no direct evidence has been presented showing Wisconsinan emergence of any of the banks seaward of marginal channel. Seafloor morphology and sediments suggest that seas did not transgress Hamilton Bank (Fillon, 1976).

Deeper waters along the continental shelf may have been one of the factors responsible for the return of normal marine conditions to Cartwright Saddle 15 000 years B.P. The sea level rise at this time was out of phase with the eustatic sea level fluctuations and the deeper water may have been due to isostatic readjustment of the outer continental margin. Change in the dynamics of the Labrador Current are another possibility. However, the ratio of planktonic to benthonic foraminifera is only slightly higher in the surface sediments indicating a slight recent increase in offshore influence. **Globigerina bulloides** and the other indicators of West Greenland Current waters occur in small numbers throughout the cores, suggesting that the oceanographic setting of surface waters did not change significantly at 15 000 years B.P. As a result of global warming towards the end of glaciation, the formation of deep water in Labrador Sea may have changed and consequently, more saline slope waters have been entering the deep basins since 15 000 years B.P.

The Extent of Glaciers and Sea Ice

The sedimentary record in the cores of Cartwright Saddle show very little evidence for the presence of continuous continental glaciers during the last 20 000 years. Both Wisconsinan and Holocene muds of the basins contain comparatively little ice-rafted debris. The inclusion of coarser sediments in the cores along the continental margin indicates that the ablation of floating sea ice took place at the continental margin or in deep sea to the southeast where it contacted warmer waters. Deposition of sediments from icebergs was bypassed because of the shallower water surrounding the basins.

The faunal record in the Cartwright Saddle sediments suggests that the cover of sea ice during the last 20 000 years has been similar to the present conditions on the Labrador Shelf, Hudson Bay and Gulf of St. Lawrence. During the winter, the ice was almost continuous but the waters were free of ice during the summer. At present, the ice begins to break up on the Labrador Shelf in early summer and is driven to the southeast by winds. Melting takes place either in nearshore bays or offshore, where the floes meet warmer currents.

The summer open water during the Late Wisconsinan is postulated mainly on the dominance of **Elphidium clavatum** below the sandy layers of the cores. The foraminiferal number is high throughout the cores and the sediments in the bottom half of each core contain methane up to 25 000 ppm of the sediment volume (Vilks et al., 1974). The organic production rates were therefore at least as high as under the present seasonal regime.

The hypothesis of open seasonal water is also supported by pollen profiles from core 12 of Cartwright Saddle (Vilks and Mudie, 1978). These indicate the presence of a sedge-tundra environment near the basin as early as 21 000 years B.P. The glacial limit of Late Wisconsinan may have been close to the shore, leaving some of the headlands or islands exposed where vegetation could have established.

SUMMARY

Labrador Current brings Arctic water and ice to the Labrador Shelf and maintains subarctic environment at comparatively low latitudes. It is being fed by waters from several independent sources, which influence the distribution of foraminifera. The waters contributed by the West Greenland Current reflect the presence of several cold-temperate **Globigerina** species in addition to greater percentages of dextral **Neogloboquadrina pachyderma**. The Baffin Bay source (Canada Current) contains close to 100% sinistral **N. pachyderma** and the Hudson Bay component may be responsible for the high similarity of the Labrador Shelf benthonic foraminifera with the Hudson Bay assemblages.

The dynamics of the Labrador Current, the migrating ice fields and bergs and to a lesser extent wind-induced surface waves influence the textural characteristics of surficial sediments. Because of the low rates of sediment supply to the continental shelf, a major process is sediment redistribution, followed by ice rafting. As a result, the deeper basins are dominated by silty clays with a trace of ice-rafted debris and the shallower areas between the banks by a mixture of gravelly sands and clays. Lateral coherence of sediment features in the Cartwright Saddle indicates low energy depositional environment during the last 20 000 years. Absence of lithostratigraphy, biostratigraphy and the mixed ^{14}C dates in Hawke Saddle cores suggests sedimentation in episodes of slumping and periods of nondeposition.

The well-preserved sedimentary and faunal sequences of the Cartwright Saddle cores are used to establish a paleoceanographic model of the area. Prior to 15 000 years B.P. the benthic environment in the basins was marginal marine with salinities between 20-25 and temperatures close to freezing. The surface circulation was similar to that of the present time. The exchange of bottom waters may have been slower as a result of lesser sill depths, thus lower salinities in the basins. The area was free of summer ice as early as 20 000 years B.P.

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APPENDIX

Table 1

Station Locations

Stat.	1973 Day	Time (Z)	Latitude (N)	Longitude (W)	Water Depth (m)	Core Length (m)	Plankton (m)	
							Vertical	Surface
1	264	2230	55° 55'	55° 38'			0-200	0-5
2	264	2346	53° 58.5'	55° 35.7'			0-200	0-5
3	265	0130	54° 09.4'	55° 37.7'			0-200	0-5
4	265	0230	54° 14.7'	55° 37.3'			0-200	
5	265	0326	54° 19.9'	55° 38.2'			0-200	
6	265	0429	54° 24.8'	55° 39.8'			0-200	
7	265	0532	54° 29.8'	55° 37.3'			0-200	
8	265	0645	54° 34.7'	55° 39.4'			0-200	
9	265	0754	54° 40.0'	55° 35.0'			0-200	
10	265	1140	54° 36.9'	56° 11.3'	512	6.0		
11	265	1345	54° 36.3'	56° 10.1'	493	8.8		
12	265	1745	54° 36.3'	56° 15.0'	577	12.2		
13	265	1905	54° 38.2'	56° 15.2'	580	9.3		
23	266	0704	54° 40'	55° 35'			0-200	
24	266	0800	54° 45'	55° 35.0'			0-200	
25	266	0915	54° 50'	55° 35'			0-200	
26	266	1022	54° 55'	55° 35'			0-200	
27	266	1123	55° 59.4'	55° 35.5'			0-200	
28	266	1408	55° 12.3'	55° 9.3'	713	10.3		
34	268	1100	55° 12.0'	55° 55'	282	4.5		
35	268	1315	54° 55.2'	56° 0.3'	310	4.6		
36	268	1520	54° 45.2'	56° 9.6'	472	5.8		
37	268	1635	54° 38.7'	56° 10.0'	512	11.9		
55	270	1535	54° 39.7'	56° 28.6'	439	4.8		
56	270	1820	54° 27.2'	56° 4.6'	525	5.3		
57	270	1932	54° 25.3'	55° 58.3'	512	5.7		
58	271	0033	54° 24.9'	55° 44.6'	347	2.5		
74	272	1447	53° 32.7'	53° 30.0'			0-200	
75	272	1605	53° 07.1'	53° 32.8'	560	10.3		
76	272	1755	53° 07.1'	53° 40.0'	556	8.9		
77	272	1917	53° 05.0'	53° 36.2'	563	9.6		
78	272	2050	53° 03.0'	53° 40.0'	556	4.1		
79	272	2144	53° 03.0'	53° 32.0'	576	11.5		
80	273	0206	53° 19.5'	52° 45.9'			0-200	
81	273	0331	53° 20.0'	53° 01.4'			0-200	
82	273	0501	53° 20.2'	53° 15.1'			0-200	
83	273	0635	53° 20.4'	53° 30.4'			0-200	
84	273	0811	53° 20.0'	53° 45.0'			0-200	
104	274	1315	54° 53.2'	53° 15.0'			0-200	
105	274	1453	55° 00'	53° 00'			0-200	
107	274	1935	54° 53.3'	52° 29.8'	2,012	2.7	0-200	
108	274	2117	54° 45.00'	52° 30.0'	1,637	3.6	0-200	
109	274	2332	54° 44.7'	52° 49.9'	1,189	5.1	0-200	
110	290	1300	60° 39'.57	61° 21'.13			0-200	
111	293	1445	59° 31'.57	58° 48'.55			0-200	
112	294	1445	57° 50'.05	57° 58'.58			0-200	
113	299	1230	56° 23'.3	60° 12'.8				
114	301	1015	56° 21'.6	57° 06'.9			0-200	
115	302	1645	54° 39'.23	56° 24'.44			0-200	
116	302	2145	54° 55'.0	55° 51'.9			0-200	
117	303	1240	55° 11'.4	55° 21'.0			0-200	
118	303	0915	55° 43'.3	54° 20'.38			0-200	
119	304	0030	53° 40'.55	51° 58'.89			0-200	
120	304	0940	53° 07'.6	53° 22'.4			0-200	
121	304	1524	53° 41'.21	54° 29'.35			0-175	

Table 2

Relationship of sediment distribution modes and phi intervals in cores of Cartwright Saddle (X = primary mode, - = secondary modes)

Core Interval (cm)	Core 10 Sediment Size Ø														Notes
	-5	4	3	2	1	0	+1	2	3	4	5	6	7	8	
0-5											-			X	All core olive green
25-30											X		-		
50-55											-		X		Abundant diatoms 0-100 cm
75-80														X	
100-105											-			X	
125-130											-			X	
150-155											-			X	Ostracods from 100-500 cm
175-180											X			-	
200-205											X			-	
225-230										X				-	
250-255										X			-		
275-280										X				-	
300-305											X			-	
325-330											X		-		
350-355														X	
375-380														X	
400-405														X	
425-430			-											X	
450-455												X		-	
475-480													X		
500-505											X				
525-530													X		
550-555											X			-	
575-580												-		X	
600-605											X				
Core 11															
5-10														X	All core olive green
25-30											X				
50-55											X		-		Abundant diatoms 0-300 cm
75-80											-			X	
100-105											-		X		Radiolarians, worm tubes
120-125											X				
145-150											X				0-5 cm
175-180											X				
200-205											X			-	
225-230											X				
250-255														X	
275-280											-		X		
300-305											-			X	
325-330										-				X	
350-355											X		-		
375-380										X			-		
400-405											X				
420-425										X			-		
450-455											X			-	
475-480											X				
500-505											X		-		
525-530														X	
550-555												-		X	
570-575														X	
600-605														X	
620-625											X		-		
650-655				-							-			X	
675-680													X		
700-705												-		X	
720-725											X				
750-755											X			-	
775-780											X		-		
800-805											X			-	
820-825											X		-		
850-855													X		
875-880											-		X		

Core Interval (cm)	Core 12 Sediment Size Ø														Notes
	-5	4	3	2	1	0	+1	2	3	4	5	6	7	8	
0-5				-							-			X	Diatoms 0-400 cm
25-30											-		X		
50-55											X			-	
75-80											X		-		
100-105											X				
125-130										X				-	
150-155											X				
175-180											X				
200-205														X	
225-230											-			X	
250-255											-			X	
275-280											X			-	
301-306											X			-	
326-331										X				-	
351-356											X				
376-381											X			-	
399-404										X			-		
425-430											X				
450-455										X					
475-480											X				
501-506											X				
525-530												X			
550-555												-		X	
575-580													X		
601-606													X		
625-630														X	
650-655														X	
675-680														X	
700-705														X	
725-730				-				-						X	
745-750										-				X	
775-780														X	
800-805														X	
825-830														X	
850-855				-									X		
875-880				-										X	
900-905														X	
925-930														X	
950-955														X	
975-980														X	
1,000-1,005														X	
1,025-1,030														X	
1,050-1,055													X		
1,075-1,080													X		
1,100-1,105														X	
1,125-1,130													X		
1,150-1,155														X	
1,180-1,185														X	
1,200-1,205													X		
1,211-1,220				-									X		

Table 2 (cont.)

Core Interval (cm)	Core 13 Sediment Size Ø														Notes
	-5	4	3	2	1	0	+1	2	3	4	5	6	7	8	
0-5				-							-			X	All core olive-gray
25-30											-			X	
50-55											-			X	
75-80											X			-	
100-105											X			-	0-500 cm abundant diatoms
125-130											X				
150-155										X					
175-180		X								-					
200-205											X				
225-230											X				
250-255											X				
275-280				-							X				
300-305												X			Shell fragments
325-330														X	
350-355											-			X	
375-380											-			X	
400-405										-			X		
425-430										-				X	
450-455														X	
475-480										X					
500-505											-			X	
525-530											X			-	
550-555											-			X	
575-580											X			-	
600-605														X	
625-630													X		
650-655											-			X	
675-680										X			-		
700-705													X		
725-730									-		-			X	
748-753								X						-	Shell fragments
775-780											X				
800-805										X				-	
825-830										X				-	
850-855										X				-	
875-880											X				
900-905										X				-	
925-930										X					

Core Interval (cm)	Core 37 Sediment Size Ø														Notes
	-5	4	3	2	1	0	+1	2	3	4	5	6	7	8	
0-5													X		All core light olive-gray
25-30				-									X		
50-55											X		-		Abundant diatoms 0-100 cm
75-80											-			X	
100-105													X		
125-130													X		
150-155											X				
175-180										X					
200-205											X				
225-230											X				
250-255											X				
275-280											X				
300-305											X				
325-330											X				
350-355											X		-		
375-380											X		-		
400-405													X		
425-430											-		X		Worm tubes
450-455													X		Shells
475-480											-		X		
500-505												-		X	Abundant diatoms
525-530											-		X		
550-555											-			X	
575-580											-			X	
600-605											X		-		
625-630														X	
649-654														X	Large shell
675-680													X		
700-705														X	
725-730										-				X	
750-755											X			-	
775-780											-			X	
800-805											X			-	
825-830											X			-	
850-855											X				
875-880											X			-	
900-905											X				
925-930											X			-	
950-955											-			X	
975-980														X	
1,000-1,005														X	
1,025-1,030													X		
1,050-1,055														X	
1,075-1,080													X		
1,100-1,105												X		-	
1,125-1,130														X	
1,150-1,155													X		
1,177-1,185									-			X			

Table 3

Relationship of sediment distribution modes and phi intervals in cores of Hawke Saddle

Core Interval (cm)	Core 75 Sediment Size Ø														Notes
	-5	4	3	2	1	0	+1	2	3	4	5	6	7	8	
0-5											X		-		All core olive-gray
25-30											X		-		
50-55											X				0-300 cm diatoms
75-80													X		
100-105														X	
125-130											-			X	
150-155														X	
175-180														X	
200-205													X		
225-230													X		
250-255													X		
275-280														X	
300-305											-		X		
325-330											X			-	
350-355											X		-		brocken tests, diatoms
375-380											X				
400-405											X				400-750 cm diatoms
425-430											X		-		
450-455												X			
475-480													X		
500-505													X		
525-430											X				
550-555											X				
575-580													X		
600-605														X	
625-630							-							X	
650-555			-								X				
675-680											X				
700-705											X				
725-730											X				
750-755													X		
775-780													X		
800-805													X		
825-830													X		
850-855											X		-		diatoms
875-880													X		shell
900-905				-									X		
925-930														X	
950-955														X	
975-980													X		
1,000-1,005											X		-		
1,025-1,030											-		X		
Core 76															
0-5					-					X					Light gray 0-280 cm
25-30											-		X		dark gray 280-650 cm
50-55			-											X	
75-80											-			X	
100-105											X			-	
130-135											X			-	
155-160								-			X				
175-180			-											X	
200-205													X		
225-230				-								X			
250-255			-		-						-			X	
276-281					-						X			-	Abundant Tertiary fossils from 300 cm to bottom of core
300-305				-							X				
325-330											X				
350-355			-		-						X			-	
375-380			-								X		-		
400-405					-						X			-	
425-430			-								X			-	
450-455			-								X				

Core Interval (cm)	Core 76 (cont.) Sediment Size Ø														Notes
	-5	4	3	2	1	0	+1	2	3	4	5	6	7	8	
475-480											X			-	
500-505											X			-	
525-530				-							X		-		
550-555											X		-		
575-580											X				
600-605				-							X				
625-630											X			-	
650-655				-							X		-		
676-681											X			-	
700-705			-								X		-		
725-730					-						X			-	
750-755					-						X				
776-781				-							X			-	
800-805				-							X		-		
825-830											X			-	
850-855				-							X			-	
880-885			-								X				
Core 77															
0-5											X		-		All core olive gray
25-30											X		-		
50-55											X				
75-80											X				
100-105											X				
125-130											X		-		
150-155											X		-		
175-180														X	
200-205														X	
225-230														X	
250-255														X	
275-280								-						X	
300-305													X		
325-330														X	
350-355														X	
375-380													X		
400-405													X		Diatoms, pyrite
425-430													X		
450-455											-		X		
475-480												X			
500-505											X				
525-530											X				
550-555											X				
575-580												X			
600-605											X			-	
625-630													X		
650-655											X				
675-680												-	X		
700-705												X			
725-730												X			
750-755											X		-		
775-780												X			
800-805														X	
825-830											X			-	
850-855													X		
875-880												X			
900-905												X			
925-930											X		-		
950-955													X		
970-975													X		

Table 3 (cont.)

Core Interval (cm)	Core 78 Sediment Size Ø														Notes	Core Interval (cm)	Core 79 Sediment Size Ø														Notes
	-5	4	3	2	1	0	+1	2	3	4	5	6	7	8			-5	4	3	2	1	0	+1	2	3	4	5	6	7	8	
0-5											X				0-110 cm dark gray	0-5													X		
25-30											X			-		25-30												-		X	
50-55											X				110-318 Olive gray, dark gray below	50-55											X		-		
75-80											X					75-80													X		
100-105														X		100-105													X		
125-130														X		125-130													X		
150-155						-							X		Diatoms present in all core	150-155												X			
175-180												-		X		175-180													X		
200-205						NO MODE										200-205											X				
225-230														X		225-230													X		
250-255													X			250-255													X		
275-280													X			270-275													X		
300-305												X		-		300-305													X		
325-330				-								X				325-330													X		
350-355												X				350-355													X		Pyritized worm tubes
375-380														X		375-380													X		Sponge spicules
400-405											X					400-405													X		
																425-430													X		
																450-455													X		
																475-480							-						X		
																500-505													X		
																525-530													X		
																550-555														X	
																575-580														X	
																600-605														X	
																625-630														X	
																650-655														X	Fecal pellets
																675-680				-								X			
																700-705													X		
																725-730														X	
																750-755														X	
																775-780														X	
																800-805														X	
																825-830														X	
																850-855														X	
																875-880														X	
																900-905														X	
																925-930													X		
																950-955													X		
																975-980													X		
																1,000-1,005														X	
																1,025-1,030														X	
																1,050-1,055														X	
																1,075-1,080													X		
																1,100-1,105													X		
																1,125-1,130													X		
																1,142-1,147														X	

Table 4

Relationship of sediment distribution modes and phi intervals in cores from basin margins.

Core Interval (cm)	Core 34 Depth 282 m Sediment Size Ø														Notes
	-5	4	3	2	1	0	+1	2	3	4	5	6	7	8	
0-5			-							X					All core olive gray
25-30				-								X		-	
50-55				-					X						
75-80				X					-				-		
100-105				X					-		-				
125-130			X						-						large pebble
150-155			X						-						
175-180			X						-						
200-205			X			-			-						
225-230				X						-					
250-255									X						
275-280				-					-		X				
300-305				-					X					-	
325-330			-						X						
350-355				-					X		-				
373-378				-					X						
400-405				-					X						
425-430				-					X		-				
450-455				-					X						
	Core 35 Depth 310 m														
0-5					-						X			-	Olive gray 0-45 cm
25-30				-							X				
50-55				-					X						Dark grayish brown 45-450 cm
75-80				-							X		-		
100-105									X						
125-130				-					X						pebble, 50 mm diam. (anorthosite)
150-155			-						X		-				pebble, 50 mm diam. (gneiss)
175-180			-						-		X				
200-205		-							X		-				
225-230		-							X						
250-255									X		-				
275-280									X						
300-305									X						
325-330					-				X		-				
350-355				-					X						
375-380				-				-			X			-	
400-405				-				X			-				
425-430			-					X			-				
450-455								X							

Core Interval (cm)	Core 36 Depth 472 m Sediment Size Ø														Notes
	-5	4	3	2	1	0	+1	2	3	4	5	6	7	8	
0-5											-		X		All core olive gray. Abundant diatomes 2-250 cm. Ostracods present throughout core.
25-30											X		-		
50-55											X				
75-80											X				
100-105											X				
125-130											X				
150-155											X				
175-180											X			-	
200-205											X				
225-230											X				
250-255												-		X	
275-280											-			X	
300-305											X			-	
325-330											-			X	
350-355												X			
375-380											X		-		
400-405											X		-		
425-430												X			shells
450-450												-		X	
475-480											X		-		
500-505											-			X	
525-530											X			-	pebble
550-555											X				
575-580										X					
	Core 55 Depth 439 m														
0-5				X				-			-				All core olive gray
25-30				X				-					-		pebbles igneous, few carbonates
50-55				X							-			-	
75-80				-				-			X		-		
100-105											X		-		
125-130											X		-		
150-155														X	
175-180											-		X		
200-205		X									-			-	
225-230											X		-		
250-255			-		-						X			-	
275-280											X				
300-305								-			X				
325-330												X		-	
350-355			-								-			X	
375-380				-								-		X	
400-405				-							X			-	
425-430														X	
450-455			-				-				X				Sea urchin spines
475-480				-			-				X			-	Gastropod shell (eroded)

Table 4 (cont.)

Core Interval (cm)	Core 56 Depth 525 m Sediment Size Ø														Notes
	-5	4	3	2	1	0	+1	2	3	4	5	6	7	8	
0-5					-								X		All core olive gray, abundant diatoms
25-30													X		
50-55													X		
75-80													X		
100-105													X		
125-130													X		
150-155														X	
175-180													X		
200-205												-		X	
225-230														X	
250-255													X		
275-280														X	
300-305												X		-	
325-330													X		
350-355												-		X	
375-380													X		
400-405												X			
425-430													X		
450-455													X		
475-480													X		
500-505												X			
523-528													X		
	Core 57 Depth 512 m														
0-5	NO MODE														
25-30													X		All core gray green and and extensive pyritization. Abundant diatoms 0-200 cm
50-55														X	
75-80											-			X	
100-105														X	
125-130				-									X		
150-155											-			X	
175-180											-			X	
200-205											-		X		
225-230														X	
250-255														X	
275-280				-							-			X	large pebble, limestone 40 mm (diam)
300-305														X	
325-330											-			X	
350-355											-			X	
375-380														X	
400-405														X	
425-430													X		
450-455											-			X	
475-480														X	
500-505														X	clay pebbles
525-530								X							
550-555												-		X	
567-572													X		

Core Interval (cm)	Core 58 Depth 347 m Sediment Size Ø														Notes
	-5	4	3	2	1	0	+1	2	3	4	5	6	7	8	
0-5		X						-			-				0-15 olive gray
25-30			-		X				-		-				
50-55				-					X						150-254 dark grayish brown
75-80		X					-		-		-				
100-105					-				X						
125-130				-					-		X				
150-155									X		-				
175-180				-					X		-			-	
200-205			-						X						
225-230					-				X					-	
249-254			-						X						

Table 5

Relationship of sediment distribution modes and phi intervals in cores from continental margin and slope.

Core Interval (cm)	Core 28 Depth 713 m Sediment Size Ø														Notes
	-5	4	3	2	1	0	+1	2	3	4	5	6	7	8	
0-5				-							X		-		Gray green 0-480 cm
25-30														X	diatoms, ostracods 0-450
50-55											X			-	
75-80											X		-		
100-105										X				-	
125-130											X		-		
150-155					-					X			-		gray sandy band
175-180					-					X			-		brown band
200-205				-			-				X				gray band
225-230				-						X				-	
250-255				-							X				
275-280									X						
300-305											X			-	
325-330										X					
350-355										X					
375-380										X					
400-405				-							X				large pebble 40 mm diam. granite
425-430											X				
450-455				-							X				
475-480											X				
500-505											X				dark green to bottom of core
525-530				-							X				
550-555				-							X				
575-580			-							X					
600-605					-					X					
625-630										X					
650-655					-					X				-	
675-680					-					X					
700-705					-					X					
725-730					-					X					
750-755						-				X				-	
775-780										X					
800-805										X					
825-830										X					
850-855										X					
875-880										X				-	
900-905						-				X					
925-930										X					
950-955										X					
975-980										X					
1,000-1,005										X					
1,025-1,030				-						X				-	

Core Interval (cm)	Core 107 Depth 2,012 m Sediment Size Ø														Notes
	-5	4	3	2	1	0	+1	2	3	4	5	6	7	8	
0-5	NO SAMPLE														0-37 light olive gray
25-30				-							-			X	ostracods
50-55										X					37-57 dark olive gray
75-80									X						
100-105			-						X					-	57 bottom light olive gray
125-130				-					X			-			
150-155				-					-		X				
175-180									-		X				
200-205									-		X				
225-230												X		-	
265-270									-			X			
	Core 108 Depth 1,637 m														
0-5						-					X				All core olive gray
25-30												-		X	
50-55					-								X		
75-80											X		-		
100-105				-							X				
125-130				-						X					
150-155			-			-				X					
175-180				-						X					
200-205				-					X					-	
225-230			-		-						X				light olive gray band
250-255				-							X				
275-280				-							X				
300-305					-								X		
325-330												X			
350-355												X			
	Core 109 Depth 1,189 m														
0-5											X				All core brown with light
25-30											-		X		and dark banding
50-55				X		-					-		-		
75-80										X					
100-105												X			
125-130				-								X			
150-155						-					X		-		
175-180									X		-				
200-205			X							-		-			
225-230											X		-		
250-255													X		
275-280				-								X			
300-305												X			
325-330					-						-		X		350-500 semi consolidated
350-355													X		clay fragment
375-380				-									X		
400-405												-		X	
425-430			-										X		
450-455				-										X	
475-480					-										
500-505				-									X		

Table 6

Per cent of Cartwright Saddle core intervals containing primary sediment distribution modes in size classes from phi = -5 to +8.

							Sediment Size Ø							
	Core	-5	4	3	2	1	0	+1	2	3	4	5	6	7	8
	10										20	33		7	40
Holocene	11										10	55		10	25
Sediments	12										19	57		5	19
	13		3		3						21	29	3	8	34
	37										3	47		26	24
Average %			1		1						15	44	1	28	28
Wisconsin	10											30	10	20	40
	11											44		19	38
Sediments	12												3	28	69
	13	No Wisconsin													
	37												20	30	50
Average %												25	8	24	49

Table 7

Per cent of Hawke Saddle core intervals containing primary sediment distribution modes in size classes from phi = -5 to +8.

							Sediment Size Ø							
	Core	-5	4	3	2	1	0	+1	2	3	4	5	6	7	8
	75											33	6	44	17
	76										4	82	4	7	4
Holocene	77											42	21	26	11
Sediments	78											57	14		29
	79											11	6	61	22
Average %											1	45	10	28	17
	75											42		33	25
	76											63			38
Wisconsin	77											33	14	24	29
Sediments	78											11	22	33	33
	79												3	48	48
Average %												30	8	28	35

Table 8

Per cent core intervals containing primary sediment distribution modes in cores outside the basins

		Sediment Size Ø															Depth
	Core	-5	4	3	2	1	0	+1	2	3	4	5	6	7	8		(m)
Marginal Basin	36										4	63	8	4	21	H	472
	55		5		14							52	5	5	19	H	439
	56												14	64	23	R	525
	57								4					22	74	W	512
Average %			1		1				1		1	29	7	24	34		
	34			21	16					47	5	5	5				282
Shelf	35								16	58		26					310
	58		18			9				64		9					347
Average %			6	7	5	3			5	56	2	13	2				
	28									2	62	33			2		713
	107									30	10	30	20		10		2,112
Slope	108									7	20	40	13	13	7		1,637
	109			5	5					5	5	14	19	33	10		1,189
Average %				1	1					11	24	29	13	12	7		

Table 9

Planktonic foraminifera in the water column, fall, 1973, Samples 1-27 – Cartwright Saddle, 74-84 – Hawke Saddle and 104-109 – Continental Slope. N = perçent normalform **N. pachyderma**, X = less than 1 per cent of total planktonic foraminifera

	Neogloboquadrina pachyderma		**Globigerina bulloides**		**Globigerina quinqueloba**		Totals/m^3 of water		
Sample	Number	% Dextral	No.	%	No.	%	Foraminifera	Dry Biomass (mg.)	N
1	314	4					3.4	21.8	28
2	2,880	3					44.0	32.7	63
3	864	1					16.1	21.6	66
4	500	2					11.1	34.8	55
5	446	4					7.3	13.1	61
6	1,506	3					27.3	14.3	73
7	626	4	2	X			14.0	22.9	64
8	1,270	2	4	X			29.7	4.5	66
9	262	3					3.7	13.9	61
23	2,008	2	4	X	4	X	23.3	58.4	68
24	706	3					6.9	6.6	69
25	510	2					10.5	13.4	68
26	1,258	2					20.8	17.6	74
27	990	3					12.6	37.8	65
Means		2.7					16.48	22.4	63
74	916	3			8	X	22.2	69.7	86
79	2,072	4	8	X	120	5	41.4	91.3	78
80	2,600	2	8	X	24	1	95.0	61.7	83
81	4,160	2			8	X	89.3	29.6	77
82	1,168	3			4	X	19.2	20.9	68
83	8,016	3			16	X	146.0	224.5	95
84	1,596	2					20.0	23.0	87
Means		2.7					61.87	74.4	81
104	2,992	3	2		128	4	51.1	18.5	94
105	60	0			42	41	0.7	21.3	75
107	116	17	4	3	4	3	1.7	21.4	60
108	74	8	10	11	2	2	1.2	11.8	71
109	256	5	12	4	12	4	3.4	12.2	53
Means		6.6		3.6		11	11.62	17.0	71

Table 10

Planktonic foraminifera in the water column, fall, 1977, S = Continental Slope samples

Sample	**Neogloboquadrina pachyderma** Number	**Neogloboquadrina pachyderma** % Dextral	**Globigerina bulloides**	**Globigerina quinqueloba**	**Globigerinita uvula**	Totals/m^3 of water Foraminifera	Totals/m^3 of water Dry Biomass (mg.)	N
110	337	4				7.3	11.8	85
S 111	1,396	11	X		1.1	65.2	14.4	93
S 112	273	21	X	3	6	11.7	5.8	97
113	41	17	4.7			1.5	19.2	85
S 114	164	21		7.8	6.8	5.7	5.4	95
115	149	5			X	4.6	15.4	89
116	67	4				2.3	9.8	85
117	28	0				1.8	26.7	93
S 118	14	29			7	0.3	3.0	93
S 119	173	19	X	6.8	8.7	5.8	12.5	63
120	214	6		X		3.9	12.1	90
121	264	3	X	X	X	12.1	50.9	96
Means		11.7				10.2	15.6	89

Table 11

Comparison of **Neogloboquadrina pachyderma** in sediment and water column

	% Normalform Core Tops	% Normalform Plankton Tows	Test/m^3 Water	Tests per 35 cm^3 sed. Counted	Tests per 35 cm^3 sed. Estimated	R(cm/1000 yrs.)
Cartwright Saddle	35	63	16	264	464	24.1
Hawke Saddle	33	81	62	17	250	173.6
Continental Slope	34	71	12	33 403	76 021	0.1

Note: The calculated number per sediment sample is derived by assuming that only normalform are destroyed in the sediment, thus $N_s = K_s \frac{N_w}{K_w}$ where N_s and N_w are normalforms in sediment and water, respectively and K are other than normalforms. R is defined in text.

Table 12

Comparison of the occurrence of major species on Labrador Shelf basins with Canadian Arctic and eastern shelf

Major Species in Cartwright & Hawke Saddles (493-580 m)	Hudson Bay 26-230 m	Canadian Arctic Archipelago 21-458 m	Emerald Basin Scotian Shelf 240-251 m	St. Margaret's Bay, Bay of Fundy 64-199 m	Gulf of St. Lawrence 24-369 m	Beaufort Shelf 16-2031 m
Islandiella islandica	X	X			X	X
I. teretis	X	X		X	X	X
I. norcrossi	X			X		
Elphidium clavatum	X			X	X	X
Nononellina labradorica	X			X	X	
Buccella frigida	X				X	X
Cibicides lobatulus	X				X	X
Virgulina fusiformis				X		X
Astrononion gallowayi	X			X	X	X
Melonis zaandamae	X					X
Nonionella auriculata	X					
Cribrostomoides jeffreysi	X	X			X	
Globobulimina auriculata				X	X	
Elphidium subarticum	X				X	
Cribrostomoides crassimargo	X	X			X	
Adercotryma glomeratum	X				X	
Percent common occurrences with Labrador Shelf basins	78	22	0	39	67	44

Table 13

^{14}C dates of sediment cores taken from Cartwright and Hawke Saddles

Core	Interval (cm)	Age C-14 Years BP	Laboratory Number	Laboratory
11	65 - 100	3,370 ± 160	GX - 4942	Geochron
	300 - 335	12,055 ± 405	GX - 5235	Geochron
	465 - 475	11,700 ± 490	GSC - 2560	Geological Survey
	500 - 535	13,140 ± 440	GX - 5074	Geochron
	700 - 735	21,050 ± 1,050	GX - 4944	Geochron
12	50 - 85	3,320 ± 165	GX - 4935	Geochron
	300 - 335	11,495 ± 455	GX - 5236	Geochron
	490 - 500	13,300 ± 770	GSC - 2565	Geological Survey
	615 - 650	19,660 ± 710	GX - 5075	Geochron
	* 800 - 835	11,695 ± 415	GX - 5237	Geochron
	* 1,001 - 1,036	12,520 ± 540	GX - 4945	Geochron
75	100 - 135	13,035 ± 490	GX - 5238	Geochron
	350 - 385	12,710 ± 300	GX - 5390	Geochron
	600 - 635	16,250 ± 540	GX - 5239	Geochron
76	102 - 137	19,440 ± 560	GX - 5391	Geochron
	225 - 260	20,940 ± 660	GX - 5392	Geochron
	500 - 535	28,010 + 1,640 - 1,360	GX - 5393	Geochron
77	100 - 135	6,440 ± 195	GX 5394	Geochron
	275 - 310	10,980 ± 350	GX 5395	Geochron
	600 - 635	16,310 ± 430	GX 5396	Geochron

* Dates not reliable because of mixed sediments.