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POST-GLACIAL PALEO-OCEANOGRAPHY, NORTHEAST NEWFOUNDLAND SHELF

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ABSTRACT

Forty-five sediment samples from three sediment cores (one trigger weight, two piston) from the northeast Newfoundland Shelf were analyzed for benthic and planktonic foraminifera, pollen and dinoflagellates.

Five benthic foraminiferal faunas were found in cores 07TWC and 07P (combined), four post-glacial and one glacial. These five assemblages are (down core): an agglutinated (Inner Labrador Current - late Holocene) assemblage; a *N. labradorica* (Outer Labrador Current - mid-Holocene) assemblage, a *M. barleeanum* - *Pullenia spp.* (" cold" Labrador Current - early Holocene) assemblage; an *I. helenae* - *C. reniforme* - *C. laevigata* ("warm" Labrador Current - early Holocene/late Pleistocene) fauna and an *E. excavatum* - *C. reniforme* ("warm" glacial ice-margin - late Pleistocene) fauna. Only two faunas were found in core 015P; the agglutinated assemblage and the "warm" ice-margin assemblage which directly overlies till or till - like material barren of foraminifera.

If the post-glacial sequence in cores 07TWC and 07P is complete, then most of the post-glacial sedimentary record (2500-10000 YBP) is missing from core 015P.

The planktonic foraminifera present with the agglutinated benthic fauna in core 015P indicates there has been mixing of Gulf Stream and Inner Labrador Current surface waters during the late Holocene, at this site.

INTRODUCTION

Petroleum exploration on the Canadian continental margin has helped spark interest in the Quaternary sedimentary records and paleo-oceanography of the Labrador, Newfoundland and Scotian Shelf areas. Detailed micropaleontological studies have been completed on relatively small areas along the Labrador and Newfoundland margins (i.e. Mudie et al., 1984; Vilks, 1980, 1981; Vilks and Mudie, 1978, 1983; Vilks et al., 1984) but very little has been done in the way of regional synthesis and correlations. The most recent work (Scott et al., 1984) employed benthic foraminifera, pollen and dinoflagellates to reconstruct the post-glacial record at four locations on the Canadian margin including Cartwright Saddle on the Labrador Shelf and Notre Dame Channel on the Newfoundland Shelf.

However, little has been done on the northeast Newfoundland Shelf, an area of particular interest for two reasons. One reason is the proximity to the Hibernia oil and gas field, the other reason is that some seismic records of this area and the area directly offshore of this show structures believed to be iceberg scours (M. Lewis, pers. comm.; Josenhans, 1983). Only by studying the post-glacial record of an area correlateable with this 'scoured' area can the age, and perhaps the nature, of these 'scours' be determined.

The purpose of this work, then, was to reconstruct the post-glacial record for an area on the northeast Newfoundland Shelf; determining the glacial - post-glacial and possibly Holocene - Pleistocene boundaries and the post-glacial

paleo-oceanography, using the benthic and planktonic foraminifera, pollen and dinoflagellates.

CORE LOCATIONS

Three cores were selected for study (Figure 1): cores 83-033-07P (from here on referred to as 07P) and 83-033-07TWC (07TWC) from 50° 52.97' N, 53° 18.0' W and a water depth of 457 m; just offshore of the Notre Dame Channel site extensively studied and reported on by Scott et al. (1984). Core 83-033-015 (015P) was from an area southeast of the first core site at 48° 53.75' N, 51° 49.18' W and a water depth of 338 m. This core site is directly north of the Grand Banks, and due east of Bonavista Bay.

The core sample intervals are recorded on Tables 1, 2 and 3 (along with the compilations of the foraminiferal, pollen and dinoflagellate percent occurrence data).

PRESENT ENVIRONMENT

Physiography

There are four major physiographic zones on the Labrador Shelf: the inner shelf, the marginal channel, the outer shelf and the transverse saddles; all described in detail by Vilks et al. (1984). The inner shelf has high uneven relief due to its development from the weathering of Pre-Cambrian granites and

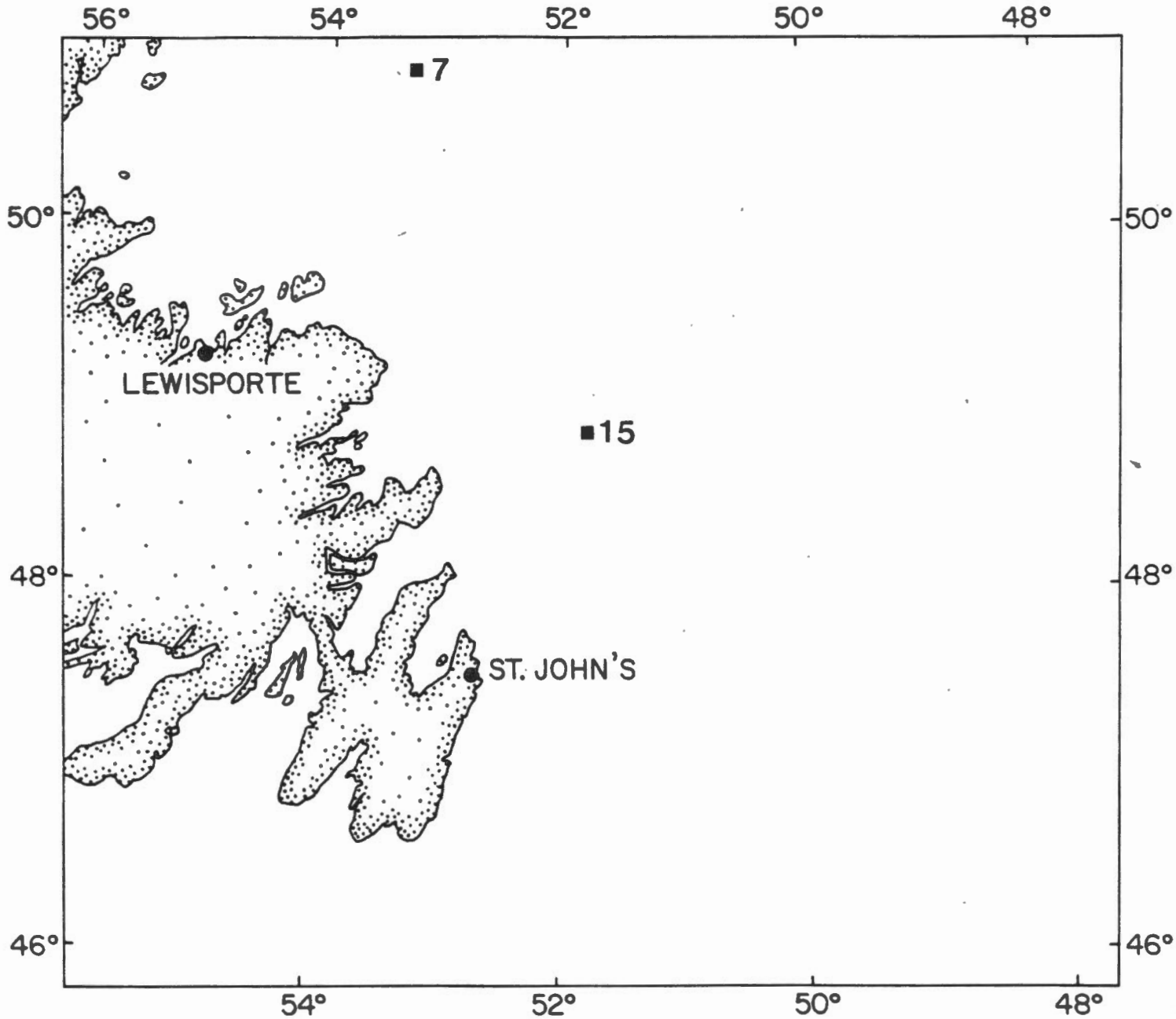


Figure 1: Location of the core 07 (TWC and P) and core 015 sites, cruise 83 - 033. Core 07 (TWC and P) from 50° 52.97' N, 53° 18.0' W, 457 m of water. Core 015 from 48° 53.75' N, 51° 49.18' W and 338 m of water (figure courtesy of G. Vilks, A.G.C.).

metasediments. In contrast is the smooth relief of the outer shelf, with a basement of Tertiary sandstone and siltstone (Vilks et al., 1984).

The surficial Quaternary sediments of the Labrador - Newfoundland Shelf are well summerized by Scott et al. (1984) and only brief mention of the salient features will be made here.

The Labrador - Newfoundland Shelf contains intra-shelf basins which have water depths ranging from 400-900 m. Grant (1972) attributes the origins of these basins to glacial erosions and the surficial deposits covering the banks and saddles to glacial deposition. Dale and Haworth (1979) reported till overlying the bedrock on the northeast Newfoundland Shelf. Some till - like deposits off Labrador have been identified as lateral moraines (Josenhans, 1983).

Little deposition is occurring on bank areas today (Scott et al., 1984) though reworking of the glaciogenic sediments by currents and waves is believed to be the cause of fine sediment accumulation in the basins and the remaining veneer of coarse sands and gravels on the banks (Parrott et al., 1980; Fillon, 1976). The sediments have been described lithologically and acoustically (Vilks et al., 1984) and will not be described here.

Oceanography

The oceanography of the Labrador - Newfoundland Shelf is thoroughly summerized by Mudie et al. (1984) and Scott et al. (1984) and again only major characteristics will be covered

here.

The continental shelf water off Labrador and Newfoundland is carried south by the Labrador Current. The major core of this current flows along the continental margin at a water depth of 600-800 m along the outer shelf and contains branches of the arctic Canada Current and the subarctic West Greenland Current. Mixing of the two water masses is limited and confined to the deep basins on the Labrador Shelf (Vilks, 1980, 1981; Mudie et al., 1984). The water on the inner shelf is colder (-1.5° to +2.5° C), slightly less saline (32-34 o/oo) and originates in northern Baffin Bay with a small but important Hudson Bay Current component. This Inner Labrador Current retains most of its arctic character until it reaches the Grand Banks (Scott et al., 1984).

The Labrador Current water has a relatively large seasonal surface variability due to winter cooling (Scott et al., 1984). Average temperature - salinity characteristics of two other study areas on the Labrador - Newfoundland Shelf are given in Scott et al. (1984, Figure 3).

The Labrador Current is responsible for the transport of ice, both pack ice and icebergs, along the Labrador - Newfoundland margin (Vilks, 1980; Mudie et al., 1984). Close pack ice covers the area from at least January through March and large icebergs are frequent until July (Mudie et al., 1984).

Foraminifera

Two benthic foraminiferal assemblages have been recognized in the surficial sediments on the Labrador - Newfoundland Shelf,

each controlled by the prevailing current. The large portion of the shelf influenced by the Inner Labrador Current contains an agglutinated assemblage that is also controlled by water depth. In waters less than 200 m deep there is an assemblage dominated by Spiroplectammina biformis, Reophax arctica, Eggerella advena and Islandiella helenae. In waters deeper than 250 m the dominant species are Reophax fusiformis, Adercotryma glomerata and Cribrostomoides crassimargo (Mudie et al., 1984; Scott et al., 1984; Vilks and Mudie, 1983; Vilks et al., 1982, 1984). In the deep basins influenced by the Outer Labrador Current the assemblage is calcareous and is dominated by Nonionellina labradorica, with subdominant species Cassidulina reniforme, Elphidium excavatum and Globobulimina auriculata (Mudie et al., 1984; Scott et al., 1984; Vilks, 1981; Vilks et al., 1982).

PREVIOUS WORK

Foraminifera

Details of previous work relevant to this study will be given in the Discussion as a comparison is made with the results of this work.

There is, however, substantial information on both modern and Quaternary foraminifera of the Newfoundland and Labrador margins (Scott et al., 1984).

Sen Gupta (1971) reported on 88 species found on the Tail of the Grand Banks, southeast of Newfoundland, the southern limit of the Labrador Current. Small areas along the Labrador margin

have been the subject of detailed studies, particularly Lake Melville (Mudie et al., 1984; Vilks et al., 1982); Makkovik Inlet (Mudie et al., 1984); the inner Labrador Shelf north and south of Lake Melville (Vilks et al., 1982) and a region directly offshore of Lake Melville encompassing two basins known as Cartwright and Hawke Saddles (Mudie et al., 1984; Scott et al., 1984; Vilks and Mudie, 1978; Vilks, 1980, 1981). In addition, distribution data from 25 grab samples collected on the same cruise as the three cores studied for this report have been made available (MacKinnon and Scott, unpublished data).

The modern assemblages have been sampled using Van Veen grab samples, box cores, trigger weight (gravity) core tops and piston core tops. Quaternary post-glacial sections have been taken by piston core. There are three areas where Quaternary sections have been retrieved that are of particular interest to this study. One is an area off Lake Melville known as Cartwright Saddle; Cartwright Saddle core 12 has been extensively described and the data from it used in reconstructing post-glacial environments (Mudie et al., 1984; Scott et al., 1984; Vilks and Mudie, 1978; Vilks, 1980, 1981). The data for this core is given in Scott et al. (1984).

Cartwright Saddle is a deep shelf basin (500-600 m) situated among Harrison Bank (to the northwest), Hamilton Bank (to the southeast) and Hamilton Inlet (to the west).

At the core 12 site there are about 40 m of pre-glacial and post-glacial sediments overlying glacial till and core 12 is 10 m of organic rich silty mud (Scott et al., 1984).

The second area of interest is just inshore (west) of

Cartwright Saddle, south of Groswater Bay. A series of 6 piston cores taken on the inner shelf contain basal till overlain by a mixture of clay and sandy - gravelly mud (Vilks et al., 1984).

Both the Cartwright Saddle location and the inner shelf southeast of Groswater Bay show evidence to suggest the absence of an offshore ice sheet during the Late Wisconsinan (Vilks and Mudie, 1978; Vilks, 1980; Vilks et al., 1984).

The third area of interest is on the Newfoundland, rather than the Labrador margin. One core from Notre Dame Channel (286 m of water) was obtained from an area where the sediments have been deposited in a uniform manner without truncations (Dale and Haworth, 1979). This core penetrated glacial till and has provided the most complete glacial - late-glacial marine record available from the Newfoundland Shelf (Scott et al., 1984).

There are three factors influencing the composition of the data sets both in this report and from the works cited above; that must be kept in mind when comparisons between data sets are made. One is the size of the core samples (before processing); for the works cited above they are either 10 cc or 35 cc. Another major factor is the lower limit sieve size (used in processing); for this study, the Notre Dame Channel core and the inner Labrador Shelf cores it was .063 mm; for the Cartwright Saddle cores it was .125 mm. This may account for differences in total numbers/percent occurrences of smaller sized species. Another discrepency may arise from the use of piston core tops as a source of surficial data; Vilks et al. (1982, 1984) have realized that often a surface layer of sediment and foraminifera is missing from a piston core top, when a comparison is made

between piston and box core/trigger weight core data taken at the same site.

LABORATORY METHODS

Foraminifera

Forty-seven wet sediment core samples were received, 23 from core 07P (20 samples - 35 cc volume, 3 samples - 10 cc volume), 10 samples from core 07TWC (all 10 cc) and 10 samples from core 015P (all 10 cc). All samples were wet sieved with a .5 mm (32 mesh) and .063 mm (230 mesh) brass sieves and all material of grain size greater than .063 mm retailed (only from core 015P was there material greater than .5 mm in size). Fine organic material was removed by decantation, the decant was examined to ensure that no foraminifera were lost. No mollusc fragments were found. All samples were then stored in a mixture of denatured alcohol and water (Scott and Medioli, 1980a).

Most 35 cc and some 10 cc samples contained large numbers of foraminifera and were split using a wet splitter that split to equal 1/8 portions. One sixteenth was the smallest split counted. Two samples from core 015P were barren (302-304 cm and 344-346 cm) and three samples from core 015P contained large amounts of sand; they were dried and the foraminifera concentrated by floation with CCl_4 (Scott and Medioli, 1980a). All samples were standardized to a volume of 10 cc. The foraminiferal species were identified as they were encountered; an abbreviated faunal synonymy (one reference for each species)

is given in Appendix A and two sets of key slides, each containing representatives of most species, were made : one set deposited with Dr. G. Vilks (A.G.C.) and the other with the senior author at Dalhousie University. A minimun of 200 benthic and the accompanying planktonic specimens were counted in each sample; counting the appropriate split where necessary. Planktonic fragments were also counted. The raw quantitative count data and calculated percent data for the benthic foraminifera in each sample are given in Appendix B (available from Dr. G. Vilks or the senior author). Percent data for the benthic species and count data for the planktonic species are tabulated on Table 1.

OBSERVATIONS

Foraminifera

Of the forty seven samples studied, two samples (core 015P:302-304 cm, 344-346 cm) were barren. The faunal list of species present is compiled in Appendix A. The benthic foraminiferal percent occurance data is given on Table 1.

The benthic foraminiferal assemblages will be discussed downcore.

Five faunal units were recognized in cores 07TWC and 07P (Figures 2 and 7): (1) an agglutinated assemblage (07TWC:0-98 cm; 07P:0-28.5 cm; (2) a *Nonionellina labradorica* dominated assemblage (07P:28.5-50 cm); (3) a *Melonis barleeanum* - *Pullenia spp.* (*P. bulloides*, *P. osloensis*, *P. subcarinata*) assemblage

(50-125 cm); (4) an Islandiella helenae - Cassidulina laevigata assemblage (125-200 cm); and (5) an I. helenae - E. excavatum assemblage (200-555 cm). Downcore percent occurrences of the dominant species are shown on Figure 2.

The agglutinated assemblage in both cores has very low total numbers (<225 specimens/10 cc) and is dominated by the agglutinated species Adercotryma glomerata, Reophax spp. (R. arctica, R. dentaliniformis, R. fusiformis, R. scottii), Saccammina spp. (S. atlantica and S. difflugiformis) accompanied by lower but consistant numbers of Silicosigmoilina groenlandica and Spiroplectammina biformis. Dominant calcareous species are Elphidium excavatum, Buccella frigida and Nonionellina labradorica, subdominant species are Cassidulina reniforme and Melonis barleeanum. There are lower (<7%) but consistant numbers of I. helenae present. The planktonic foraminifera are almost all Neogloboquadrina pachyderma left coiled, but Globigerina bulloides and Globigerina quinqueloba are also present.

The overlap between the two cores (07TWC and 07P) occurs at approximately 25-30 cm in core 07P. This is based on the absence of A. glomerata from 30 cm onwards downcore and the low total numbers in the first 30 cm of core 07P. It is interesting to note that the percent occurrences of I. helenae, C. reniforme, E. excavatum and N. labradorica do not match exactly. However, the top of core 07P appeared to be (previously) disturbed when the core was sampled.

The second assemblage (28.5-50 cm) is defined by a peak in the percent occurrence (42.3%) of N. labradorica. At this point

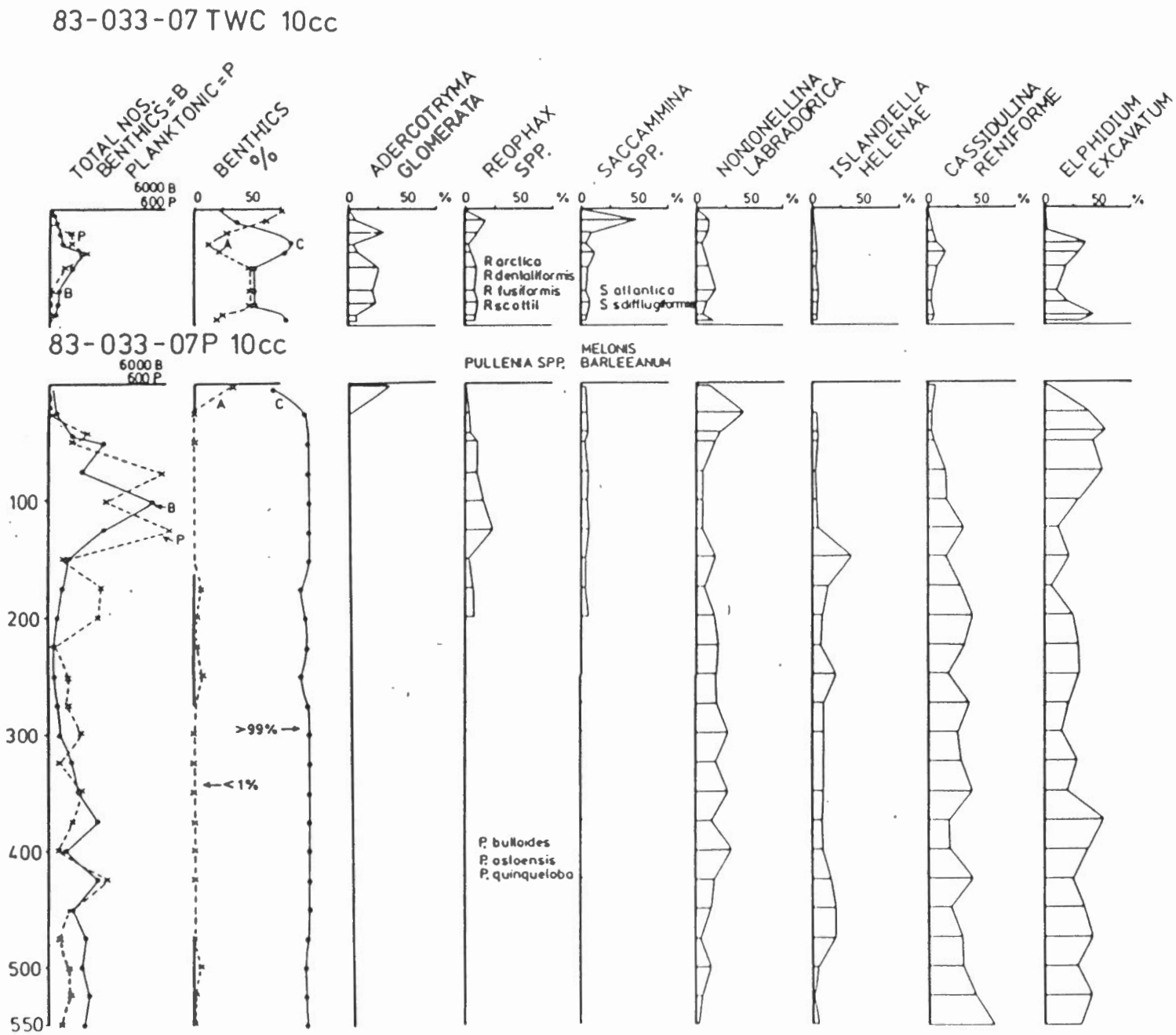


Figure 2: Downcore percent occurrences of the dominant benthic foraminiferal species, cores 07P and 07TWC.

the benthic assemblage becomes over 97% calcareous and remains that way downcore. E. excavatum is the co-dominant species; together at 28.5 cm they account for 80% of the benthic assemblage.

The Melonis barleeanum - Pullenia spp. assemblage (50-125 cm) is defined by the consistant presence (3-6%) of M. barleeanum. From 50-125 cm there is a steady increase in the percent occurrence of Pullenia spp. (7.6-20.7%) peaking at 125 cm; then lower percentages (.6-5.0%) of the same group. There are isolated occurrences of both genera downcore (200-555 cm), but both genera appear suddenly in significant amounts in the fauna at 200 cm and continue to the top of core 07P, though the Pullenia spp. numbers drop off towards the surface. Neither genera were present in 07TWC in any significant numbers, suggesting that they do not occur in the present day environment. The dominant species in this (50-125 cm) interval are E. excavatum and C. reniforme, with C. laevigata a noticeable component in the assemblage (7-18%). There are low numbers of N. labradorica and I. helenae in this interval.

This third faunal unit is also characterized by higher total numbers of benthic specimens (almost 6000/10 cc at 100 cm) and planktonic forms as well (just over 600/10 cc at 125 cm). Planktonic species include over 90% N. pachyderma left coiled and minor occurrences of N. pachyderma right coiled, G. bulloides and G. quinqueloba.

The fourth faunal unit (125-200) cm is marked by a peak in the I. helenae percent occurrence (29.5%) at 150 cm and in C. laevigata (23.8%) at 175 cm. Subdominant species are C.

reniforme, N. labradorica, Fursenkoina fusiformis and Stainforthia concava. Globobulimina auriculata is also present. Total numbers of benthic specimens dropped off sharply in this unit (<1700/10 cc).

The fifth faunal unit, from 200-555 cm, is characterized by low total numbers (<3000/10 cc benthics, <300/10 cc planktonics) and 45-83% (usually at least 60% E. excavatum and C. reniforme combined. The subdominant species are N. labradorica (up to 28.5%) and I. helenae (up to 21%).

Only two faunal units are recognized in core 015P (Figures 3 and 7). The top unit (0-40 cm), contains an agglutinated assemblage marked by a dominance of Spiroplectammina biformis and a subdominance of Recurvoides contortus, Textularia torquata and Trochammina nana. The dominant calcareous species is E. excavatum, subdominant is C. reniforme. The total numbers / sample peak in this unit (500/10 cc).

The planktonic numbers are also low, the major species are N. pachyderma left and right coiled.

The second faunal unit contains low benthic numbers (<125/10 cc) and contains 50-75% E. excavatum and C. reniforme combined. This is probably the same unit as the bottom unit in core 07P. The subdominant species in this unit (core 015P) are agglutinated species (not calcareous as in core 07P): Textularia earlandi and S. biformis. Planktonic forms are absent, except for one sample at 260 cm which contains mostly G. quinqueloba and Globigerinita uvula. The two bottom samples appeared to be glacial till or contain till - like material and were barren of foraminifera.

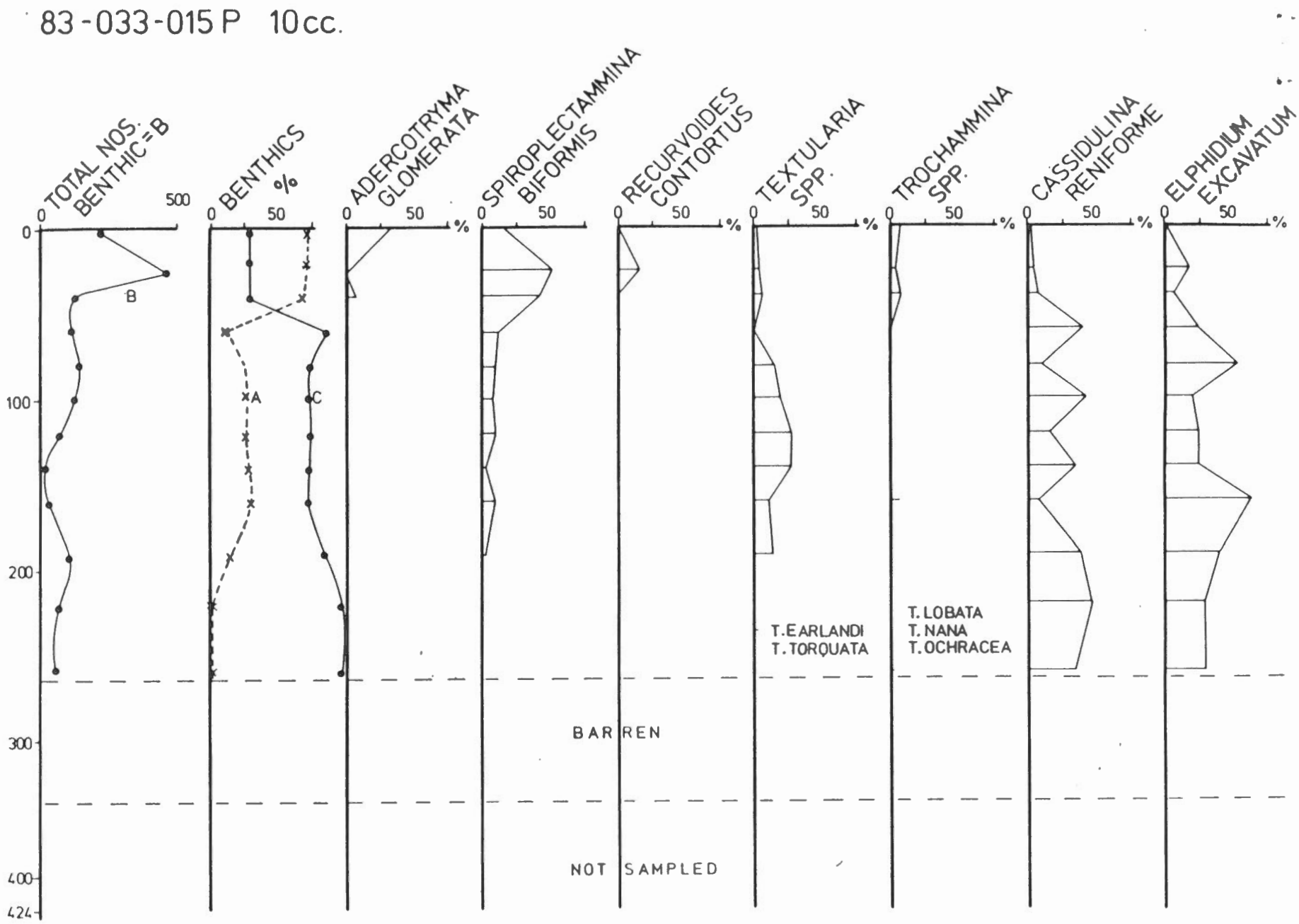


Figure 3: Downcore percent occurrences of the dominant benthic foraminiferal species, core 015P.

Pollen and dinoflagellates

The pollen and dinoflagellate data are given on Tables 2 and 3 (available from Dr. G. Vilks or the authors). Downcore percent occurrences of the dominant pollen genera and total numbers of dinoflagellates are shown on Figures 4 (core 07TWC), 5 (core 07P) and 6 (core 015P).

DISCUSSION

Environmental Interpretation - Foraminifera

The surface *A. glomerata* - *S. biformis* assemblage which continues throughout core 07TWC and appears at the surface of core 07P is interpreted as appearing in conjunction with the present day Inner Labrador Current. This assemblage corresponds well to the offshore agglutinated assemblage Vilks et al. (1982, 1984) find in the surficial sediments and the top portions of piston cores off Lake Melville and Groswater Bay. It also corresponds well to the fauna found in the surface of box cores taken at the same sites (MacKinnon and Scott, unpub. data). The Inner Labrador Current waters have a temperature of 0-3° C and a salinity of 31-34 o/oo (Scott et al., 1984).

The *N. labradorica* fauna is similar to what has been found in the surficial sediments of Cartwright and Hawke Saddles. In fact, faunal units two, three and five are similar to the sequence found in Cartwright Saddle core 12.

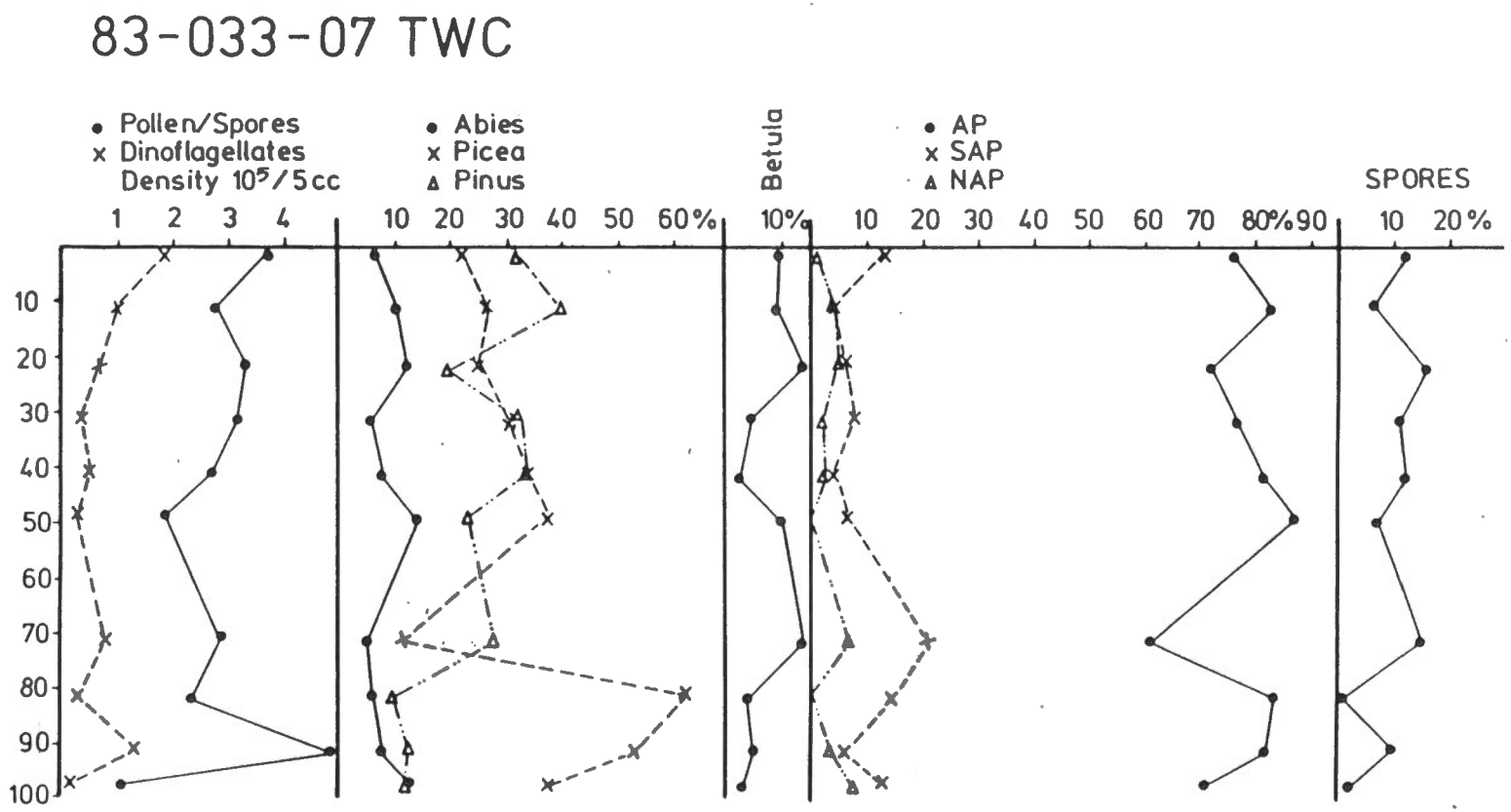


Figure 4 : Palynomorph abundances, core 07TWC. AP = aboreal pollen, SAP = sub-aboreal pollen, NAP = non-aboreal pollen.

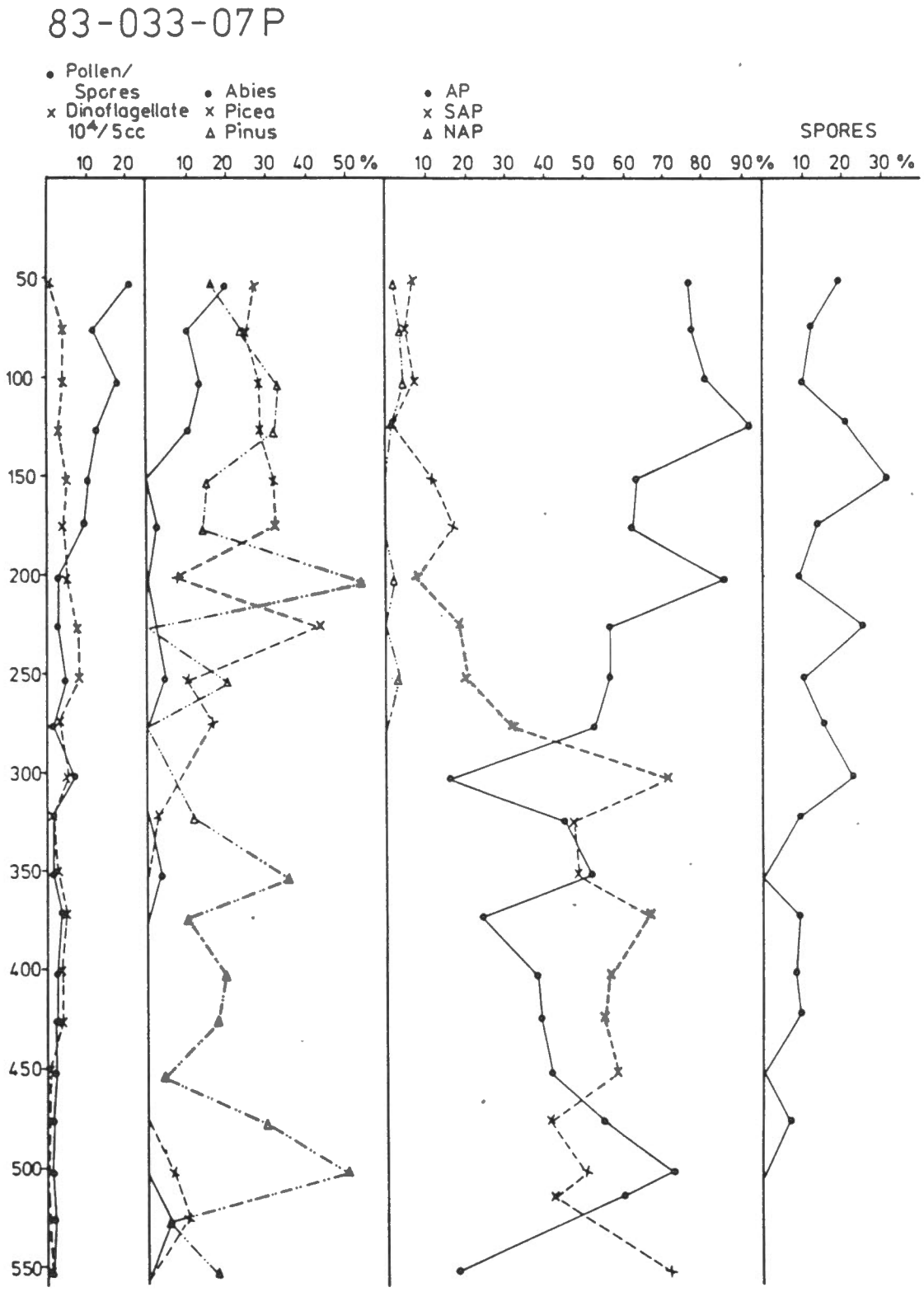


Figure 5: Palynomorph abundances, core 07P.

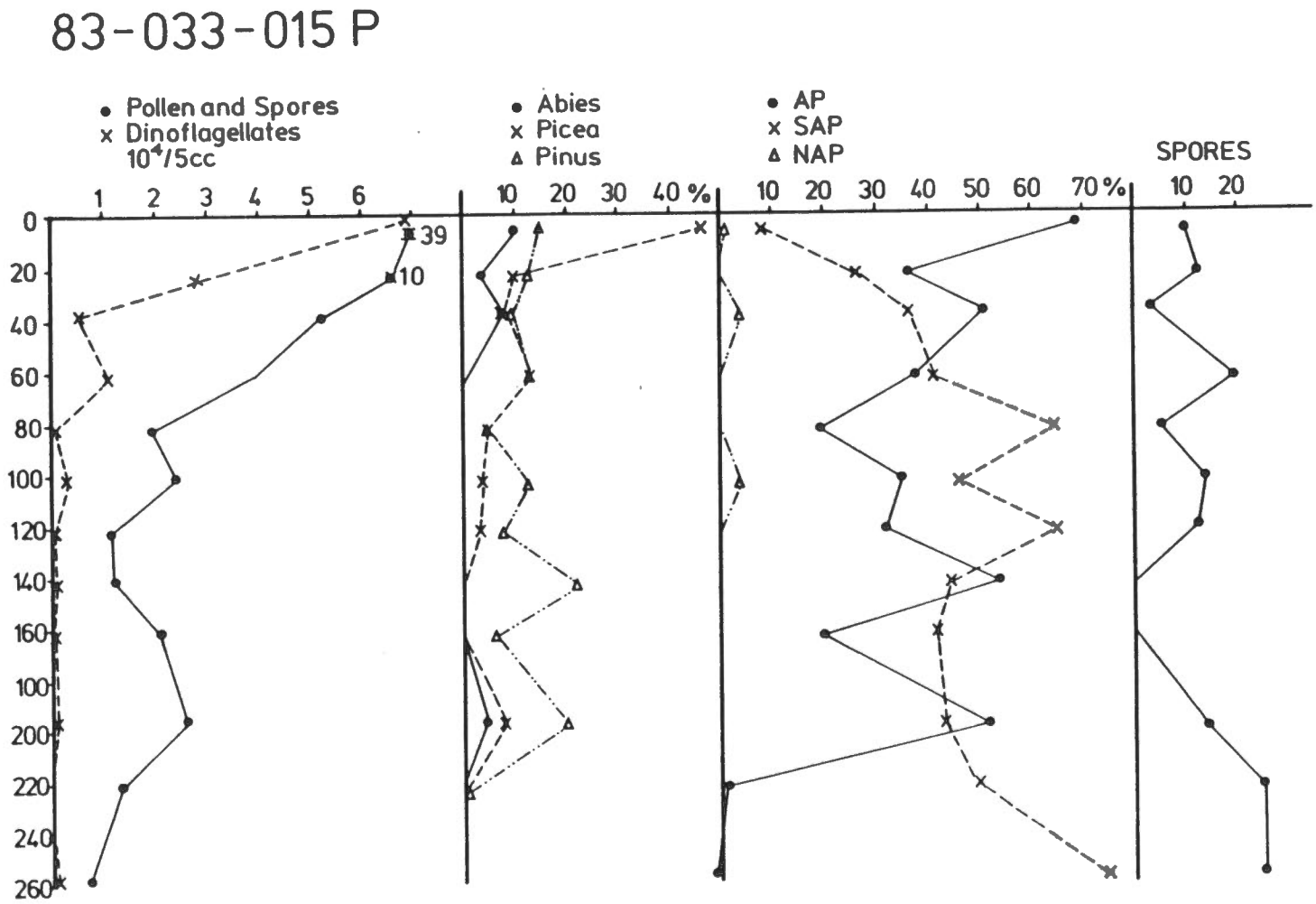


Figure 6: Palynomorph abundances, core 015P.

The Cartwright Saddle surface sediments are influenced by Outer Labrador Current waters. The surface assemblage is dominated by N. labradorica (40-50%) and also contains high total numbers of both benthic and planktonic specimens (Scott et al., 1984). As piston core tops were the source of surficial data it is possible that the true surface assemblage is missing. Another factor is the sieve size used in processing, for Cartwright Saddle cores it was .125 mm. Sieve fractions .063 mm. - .125 mm for three Cartwright Saddle core tops have been examined (Miller and Mudie, unpub. data) and the smaller fraction contains a noticeable portion of the fauna, which is small agglutinated/calcareous specimens, particulally data for core 12.

Beneath this N. labradorica fauna (at Cartwright Saddle) is a C. reniforme, I. teretis (=I. helenae) fauna with subdominant species E. excavatum. There is a noticeable decrease in the percent occurrence of N. labradorica. This fauna is interpreted as also being deposited beneath an Outer Labrador Current water mass during the early Holocene, but a current slightly colder than the present day current.

The oldest post-glacial fauna at Cartwright Saddle is the glacial marine fauna dominated by E. excavatum, C. reniforme and N. labradorica. This is a late Pleistocene fauna interpreted as being a "warm" ice margin fauna (Scott and Medioli, 1980b; Scott et al., 1984; Vilks, 1981). It is believed to have been deposited along a glacial ice margin, where sea water temperatures were relatively high compared with present day glacial marine environments (Scott et al., 1984).

The N. labradorica fauna in core 07P is also similar to the N. labradorica fauna found in the Notre Dame Channel core. This fauna in core 07P and in the Notre Dame Channel core are interpreted as being deposited in conditions similar to areas now under the influence of the present day Outer Labrador Current (i.e. Cartwright Saddle), areas in deep water basins on the outer Labrador Shelf where there is mixing of arctic and subarctic water (Mudie et al., 1984; Vilks, 1980, 1981).

The Melonis barleeanum - Pullenia spp. fauna is more difficult to explain, (1) because there is no present day equivalent on the Labrador Shelf, and (2) there is no similar Quaternary faunal unit in any of the Labrador - Newfoundland areas that have been subject to detailed study. Vilks (1981) finds comparible numbers of M. zaandamae (=M. barleeanum) in his top unit (N. labradorica fauna) on Cartwright Saddle (also Scott et al., 1984), but little mention is made of Pullenia spp. Vilks (1980) also reports that Feyling-Hanssen (1964) finds Pullenia osloensis abundant and N. barleeanum (=M. barleeanum) as common in specific zones of the Quaternary in northern Europe, but the two genera are not reported as occurring concurrently.

These two genera are currently found in an area offshore of this core 07P site, on the Newfoundland Slope (southeast of the core 07 site, northeast of core 015), an area studied by Cole (1981) and Schafer et al. (1981). Cole (1981) reports P. bulloides as common from 390-3210 m, and abundant from 600-1380 m; P. osloensis as scattered from 400-3000 m; and M. zaandamae (=M. barleeanum) as scattered from 390-3210 m and common from

500-1600 m. However, Schafer et al. (1981) place these genera in their thanatotype 1A, an area confined to a water depths of <2000 m and containing a diverse arenaceous - calcareous fauna with many deep water calcareous forms which are absent in core 07P faunal unit 3. This unit does show minor occurrences of Oolina, Lenticulina and Dentalina, genera found mainly in this unit. These are common arctic water (shelf) genera (Loeblich and Tappan, 1953). Schafer et al. (1981) are of the opinion that this fauna is governed by the Outer Labrador Current. This is an area of upwelling and mixing (Cole, pers. comm.), also indicated by the presence of diatoms in the samples (Appendix B). This faunal unit 3 is interpreted as occurring with a water mass similar, but colder and probably slightly more saline than the present day Outer Labrador Current.

Faunal unit 4 is the I. helenae - C. laevigata - C. reniforme fauna and is somewhat similar to the middle unit found in cores from Emerald Basin (Scott et al., 1984). Vilks (pers. comm.) suggests that this represents an "offshore" Labrador Current water mass, cold and more saline than the present day water mass.

Faunal unit 5 is the E. excavatum - C. reniforme glacial "warm" ice-margin fauna, will documented and discussed (Mudie et al., 1984; Scott and Medioli, 1980a; Scott et al., 1984; Vilks, 1980, 1981) and for which there is no known modern analogue.

Core 015 contains a different sequence than cores 07TWC and 07P, a sequence very similar to that found on the inner Labrador Shelf, off Groswater Bay (Vilks et al., 1984).

The sequence found on the inner Labrador Shelf southeast of

Groswater Bay, an area under the Inner Labrador Current water mass, is also quite different than that found at Cartwright Saddle. Six cores, taken from water depths of 95-335 m contain three distinct faunas downcore (Vilks et al., 1984). The core taken farthest offshore (core 82, a 335 m water depth) contains a short (0-5 cm) sequence characterised by a predominantly (80%) agglutinated assemblage of A. glomerata, C. crassimargo and S. biformis. Only core 92, taken closest to shore (109 m of water), contains a longer sequence (107 cm) with an agglutinated assemblage, though this 'inshore' assemblage is dominated by S. biformis, Reophax spp., Eggerella advena and I. helenae (Vilks et al., 1984). This inshore fauna is quite diverse and contains other agglutinated and calcareous species. Underlying this assemblage is the C. reniforme, I. helenae and E. excavatum "warm" ice-margin fauna (Scott et al., 1984), the same Late Wisconsinan post-glacial fauna found at the Cartwright Saddle location. The contact between these two faunas is sharp and coupled with acoustic and lithologic data is believed to represent an unconformity (Vilks et al., 1984).

The third "faunal" unit is barren of foraminifera except for the occasional occurrences of reworked tests and is interpreted as a period of relatively fast sedimentation of glacial material (Vilks et al., 1984). The boundary between the ice-margin fauna and barren zone is gradual (Vilks et al., 1984).

Core 015 contains an almost identical sequence of benthic foraminfera. The contact between the Inner Labrador Current (agglutinated) fauna and the post-glacial "warm" ice-margin fauna is sharp (between 40-60 cm) and must contain an

unconformity. The barren zone at the base of the core containing till or till - like material was probably deposited in glacial - fluvial conditions with high sedimentation rates.

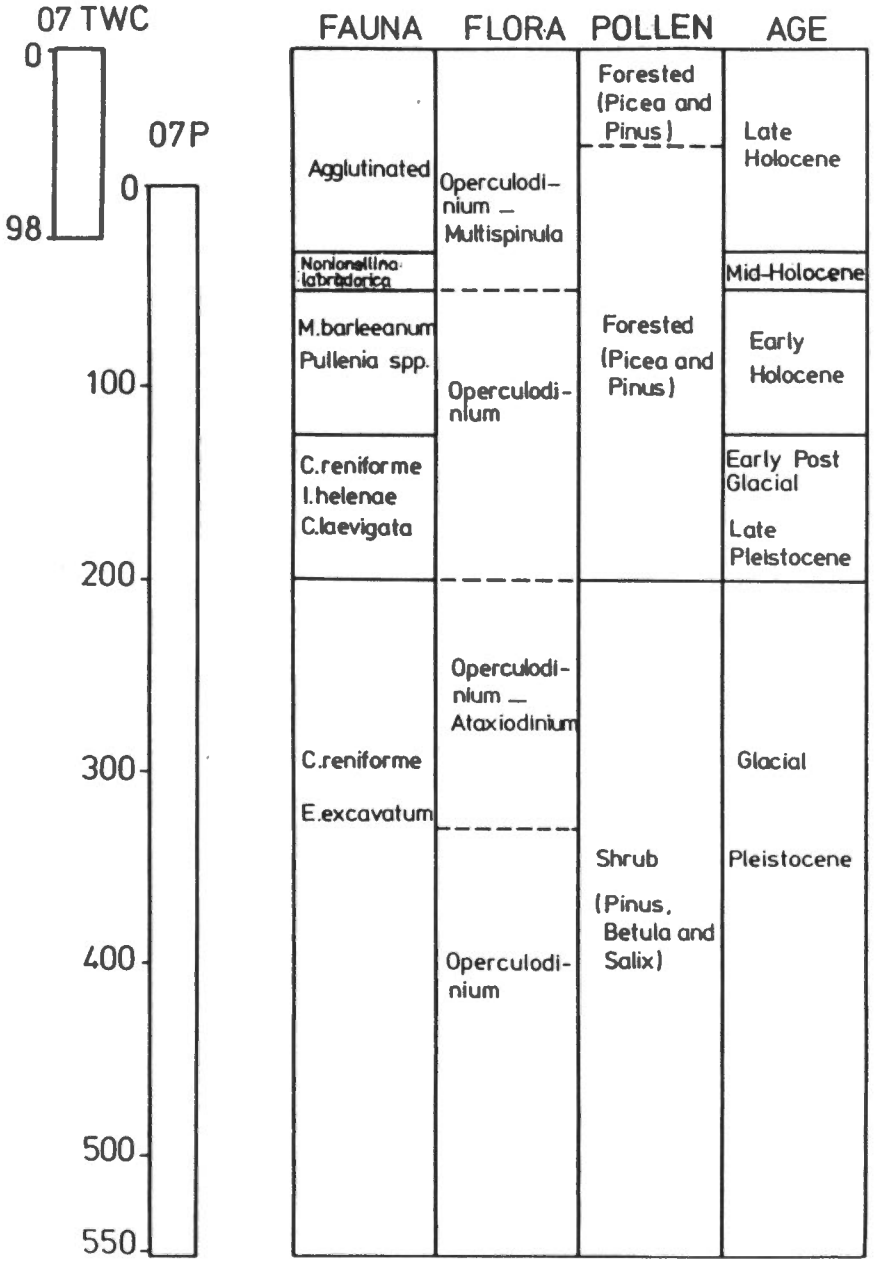
The planktonic foraminifera in core 015P are also different than those found in core 07P. The relatively diverse fauna (*N. pachyderma* left and right coiled, *G. quinqueloba* left and right coiled, *Globorotalia scitula*, *Glogigerinita uvula*, *Globigerinita glutinata*) occurring with the agglutinated benthic assemblage in core 015P only, are interpreted as being the product of mixing of Labrador Current waters with warm eddies of the Gulf Stream, mixing that does not occur at the core 07P site to the northwest.

Regional and Chronological Framework

There is little direct chronological control on these cores (i.e. no C_{14} dates); however, the time framework for the major oceanographic events documented here has been extrapolated to these two sites.

These events will be discussed here in chronological order, (i.e. oldest to youngest) and are shown on Figures 7 and 8.

If the barren unit in till - like material represents a similar sequence and similar events as those occurring off Groswater Bay, then this unit was deposited at least 10,000 YBP (Vilks et al., 1984). More likely this event occurred approximately 16,000 YBP, when taking into account the overlying *E. excavatum* - *C. reniforme* assemblage. This "warm" ice-margin fauna present above the "till" in core 015P and at the base in



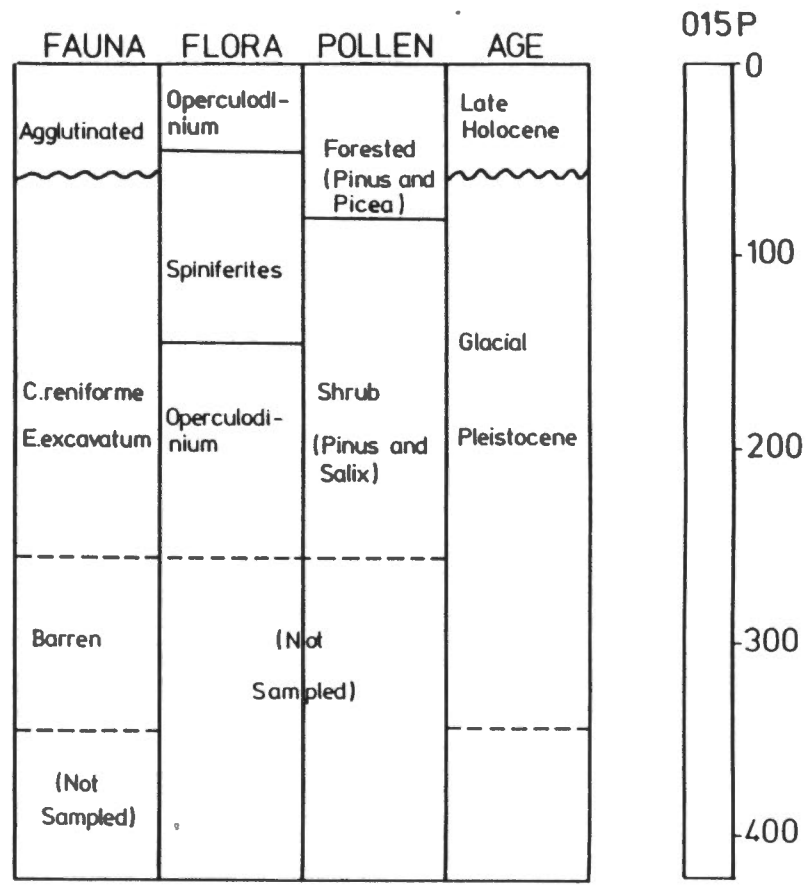


Figure 7: Summary chart showing the correlation between microfossil assemblages and paleo-environmental events recorded in cores 07TWC and 07P (left) and core 015P (right). See legend on Figure 7.

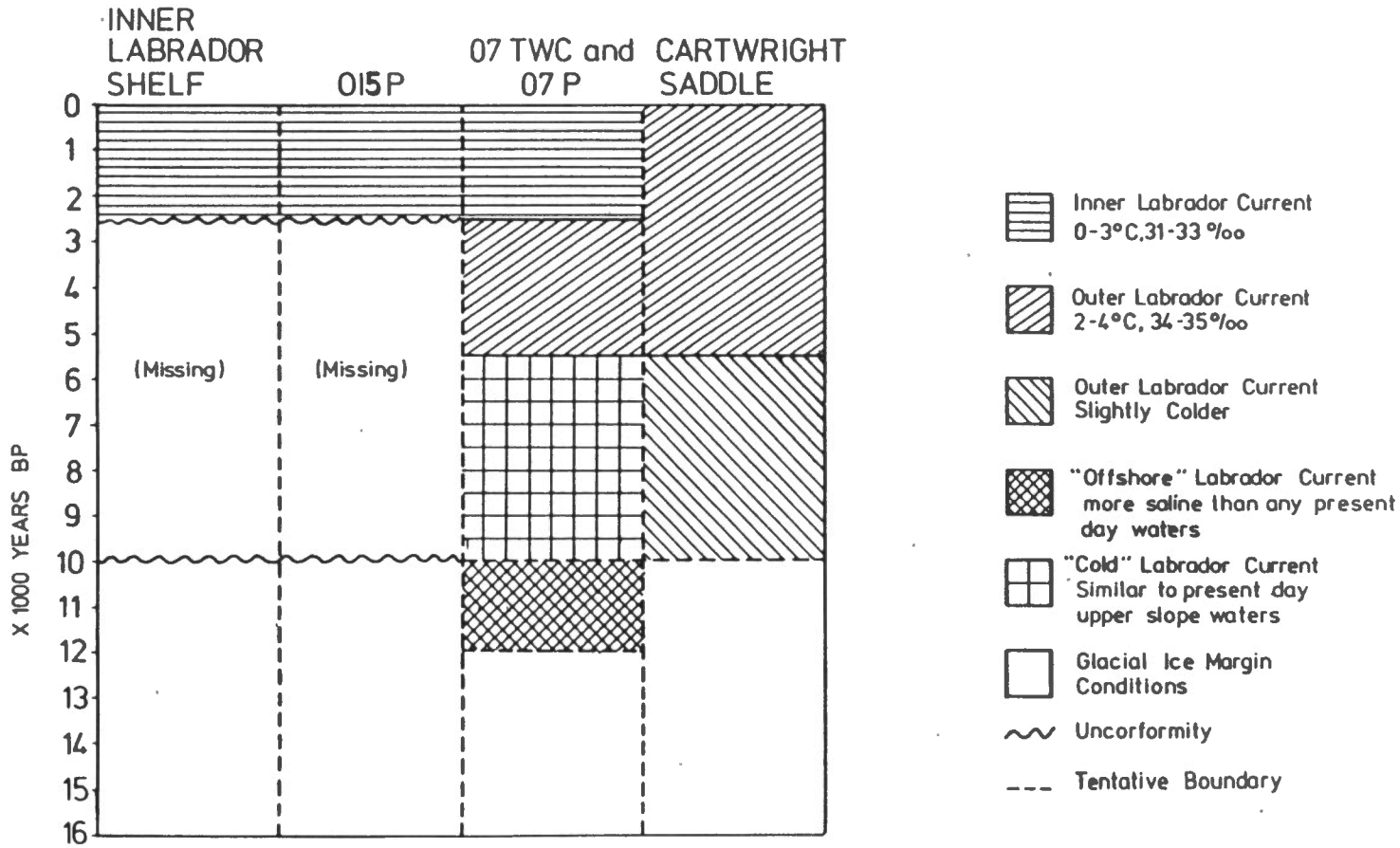


Figure 8: A summary of the history of bottom water mass distribution at the two core locations, inner Labrador Shelf (Groswater Bay, from Vilks et al., 1984) and Cartwright Saddle (from Scott et al., 1984).

core 07P, is observed in all marine shelf sediments dated at 16,000 - 12,000 YBP, from the Labrador Shelf to the Gulf of Maine (Schniter, 1976) and the Bay of Fundy (Scott and Medioli, 1980b). This is a late glacial ice-margin fauna. This fauna occurring on the Inner Labrador Shelf and on Cartwright Saddle is interpreted as not being glaciated during the Late Wisconsinan (Vilks and Mudie, 1978; Vilks, 1980, 1981; Vilks et al., 1984) though the same fauna at the Notre Dame site is interpreted as reflecting glacial meltwater/a permanent ice shelf during the Late Wisconsinan (Scott et al., 1984).

Overlying this unit in core 07P (absent from core 015P) is an "offshore" Labrador Current fauna (*I. helenae* - *C. laevigata* - *C. reniforme* dominated). The boundary between this fauna and the underlying *E. excavatum* - *C. reniforme* fauna is considered the post-glacial boundary but there is not enough control to determine if this is the Holocene - Pleistocene boundary too. This fauna could be very late Pleistocene or early Holocene; it is unlikely that it is older than 12,000 YBP.

The *M. barleeanum* - *Pullenia spp.* fauna above the *I. helenae* - *C. laevigata* - *C. reniforme* fauna, present only in core 07P is considered early Holocene. It represents a water mass colder and more saline than the two underlying faunas. This *M. barleeanum* - *Pullenia spp.* fauna is similar to the present day upper Newfoundland slope fauna occurring with the Outer Labrador Current and may indicate the early development of the Labrador Current. The *Nonionellina labradorica* fauna occurred on the inner shelf during the mid-Holocene (Scott et al., 1984) and occurs in outer shelf basins today (Vilks, 1980, 1981; Scott et

al., 1984); if indicative of present Outer Labrador Current conditions then it probably represents a drop in salinity and approximately the same temperature as the M. barleeanum - Pullenia spp. fauna as the Labrador Current continued to develop (5,000-7,000 YBP). The N. labradorica fauna is abruptly replaced by a late Holocene agglutinted fauna (in both cores) which appeared with the development of the Inner Labrador Current 2,500 YBP. This Inner Labrador Current is colder and less saline than the Outer Labrador Current waters.

In summary (Figures 6 and 7), the record in core 07P indicates a late glacial "warm" ice-margin fauna followed by an offshore, normal marine, post-glacial (late Pleistocene - early Holocene) shelf fauna. During the early Holocene there was a cooling and increase in salinity as indicated by the M. barleeanum - Pullenia spp. fauna. Cooling has continued and the salinity has decreased steadily since the mid-Holocene, the present day conditions are the coldest and least saline since the last glacial. The planktonic foraminifera occurring with the agglutinated fauna in core 015P indicate that the Inner Labrador Current surface waters are being mixed with Gulf Stream waters.

The stratigraphic sequence in core 07P appears to be complete and benthic foraminifera show no evidence of reworking. If this core 07P sequence is complete then most of the Holocene is missing in core 015P; there is part (or all) of the late Holocene overlying late Pleistocene glacial sediments; consequently, there is no sedimentary record here for the period 2,500-10,000 YBP, perhaps longer. The total numbers, lack of

planktonic forms and condition of the glacial fauna do not rule out the possibility of reworking in this section of the core.

CONCLUSIONS

1. Cores 07TWC and 07P (together) appear to contain a complete post-glacial record; core 015P contains only a late Holocene fauna overlying a glacial fauna; consequently most of the Holocene sedimentary record is absent at the core 015P site.
2. There are five distinct benthic foraminiferal faunas in cores o7TWC and 07P: an agglutinated (Inner Labrador Current - late Holocene) assemblage; a *N. labradorica* (Outer Labrador Current - mid-Holocene) fauna; a *M. barleeanum* - *Pullenia spp.* ("cold" Labrador Current - post-glacial - early Holocene/late Pleistocene) assemblage; and an *E. excavatum* - *C. reniforme* ("warm" ice-margin - glacial - late Pleistocene) assemblage.
3. The post-glacial record in cores of 07TWC and 07P indicates a warm interval of low salinity immediately following deglaciation, followed by cooling (which has continued to the present day) and an early Holocene increase in salinity. Salinity has than continued to decrease since early Holocene times, to present day conditions.
4. The planktonic foraminifera in core 015P indicate mixing of Inner Labrador Current - Gulf Stream surface waters during the late Holocene, at this site.

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APPENDIX A

Faunal List of Foraminifera

This is not a taxonomic report and synonymies will not be given here. However, it is important that an unambiguous concept of each species be conveyed to the reader, to that end the following references are given, with illustrations / synonymies of each species cited in this report. Where the name of the species in this report is not the same as the one cited in the given reference, the name immediately following in brackets is the one used in the reference given.

The generic classification is in accordance with Loeblich and Tappan (1964) except for *Haynesina* (Banner and Culver, 1978).

References are listed in reverse chronologic order (starting with the most recent). First agglutinated, then calcareous species are listed; within each group the listing is alphabetic. Planktonic foraminifera are listed at the end.

Benthic Foraminifera

Williamson et al., 1984

Cribrostomoides jeffreysii
Globobulimina auriculata
Trifarina angulosa

Kaminski, 1983

Saccammina tubulata

Miller et al., 1982a

Elphidium excavatum - mostly specimens of *E. excavatum* forma *clavata*, and a few specimens of forma *magna*. The numbers of

forma magna are so low that no environmental significance is attached to their occurrence.

Miller et al., 1982b

Ammotium cassis
Cribrostomoides crassimargo
Eggerella advena
Reophax arctica
Reophax scottii
Saccammina atlantica
Saccammina difflugiformis
Spiroplectammina biformis
Textularia torquata
Trochammina ochracea
Brizalina pseudopunctata
Buccella frigida
Buliminella elegantissima
Cassidulina reniforme
Elphidium bartletti
Elphidium subarcticum
Epistominella takayanagii
Fissurina marginata
Fursenkoina fusiformis
Glabratella wrightii
Haynesina orbiculare
Nonionellina labradorica

Vilks et al., 1982

Adercotryma glomerata
Recurvoides contortus (R. turbinatus)
Reophax fusiformis
Tritxis atlantica (Trochamminella atlantica)
Cibicides lobatalus
Islandiella helenae
Quinqueloculina seminulum

Cole, 1981

Textularia earlandi
Guttulina lactea
Gyroidina soldani
Pullenia osloensis
Stainforthia concava

Barker, 1960

Eggerella scabra
Hemisphaerammina bradyi
Psammosphaera fusca

Reophax dentaliniformis
Saccammina sphaerica
Astacolus crepidulus
Epistominella exigua
Lagena distoma
Lenticulina gibba
Nonionella turgida
Oolina globosa
Pullenia subcarinata

Loeblich and Tappan, 1953

Silicosigmoilina groenlandica
Trochammina nana
Astrononion gallowayi
Dentalina baggi
Dentalina frobisherensis
Dentalina ittai
Dentalina pauperata
Fissurina cucurbitasema
Lagena laevis
Laryngosigma hyalascidia
Laryngosigma williamsoni
Melonis barleeanum (Nonion zaandamae)
Milliolinella chukchiensis
Oolina lineata
Oolina squamosa
Parafissurina himatiostoma
Parafissurina tectulostoma
Quinqueloculina stalkeri
Robertinoides charlottensis
Scutuloris tegminis
Triloculina trihedra

Parker, 1952

Ammodiscus catinus
Haplophragmoides bradyi
Reophax gracilis
Eoeponidella pulchella (Prinaella(?) pulchella)
Nonionella turgida var. digitata

Phleger and Parker, 1951

Cassidulina laevigata
Gavelinopsis translucens ("Rotalia" translucens)
Islandiella islandica (Cassidulina subglobosa)
Islandiella norcrossi (Cassidulina norcrossi australis)
Pullenia bulloides
Valvulineria laevigata

Planktonic Foraminifera

Saito et al., 1981

Globigerina bulloides
Globigerina quinqueloba (both left and right coiled)
Globigerinita glutinata
Globigerinita uvula
Globorotalia scitula
Neogloboquadrina pachyderma (both left and right coiled)