# Timing and Extent of Glaciation on southern Baffin Island, N.W.T., Canada Determined Using *In Situ* Produced Cosmogenic Isotopes

A Proposal Presented

by

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to

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of

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# Abstract

There is a significant controversy in Quaternary science concerning the vertical and lateral extent of icesheets in the eastern Canadian Arctic during the late Wisconsinan (ca. 24,000 to 6,000 B.P.). Using *in situ* produced cosmogenic isotopes, $^{10}$Be and $^{26}$Al, I plan to determine the extent of glaciation and timing of deglaciation on Southern Baffin Island, Canadian Arctic. Specifically, I will collect field data delimiting ice extent in Pangnirtung Fiord and use isotopic data to determine if ice was present during the late Wisconsinan (< 12 ka).

I will focus my research on a nested set of moraines (the Duval moraines) along Pangnirtung Fiord which represent a significant glacial advance on southern Baffin Island. These moraines have been interpreted to be approximately 70 ka (Dyke, 1977, 1979); however, field evidence suggests that the area has been more recently covered by ice and recent work by Jennings (1993) shows evidence for late Wisconsinan till on the floor of nearby Cumberland Sound. Air photos and satellite images will be used to construct geomorphic maps (prior to field work) and to locate sample sites precisely in the field this summer. Samples will be collected for cosmogenic isotope measurement from polished and striated bedrock surfaces and from morainal boulders. Detailed investigations of the geomorphic and glacial features in the area, and their stratigraphic relationships will be used as the framework in which to interpret the cosmogenically estimated exposure ages. Sample preparation and analyses of $^{10}$Be and $^{26}$Al will continue throughout next year.

My field area is of interest to researchers working on the northeastern margin of the Laurentide Ice Sheet because of the stratigraphically important Duval moraines. Cosmogenic isotope measurements should provide the most direct age estimates to date for the timing of deglaciation on southern Baffin Island. This study will be one of the first to compare the exposure ages of morainal boulders to adjacent polished, striated bedrock surfaces. It will also be the first cosmogenic study in which detailed mapping of the sample sites is done prior to sampling.

## Introduction

The vertical and lateral extent of icesheets in the eastern Canadian Arctic during the late Wisconsinan has been the subject of much research and controversy during the past few decades. There are two general and extremely different models for the configuration of the northeastern sector of the Laurentide Ice Sheet during the late Wisconsinan (ca. 24,000 to 6000 B.P.). One reconstruction proposes that a large, extensive ice sheet with both land and marine-based domes existed during the late Wisconsinan (Hughes *et al.*, 1977; Denton and Hughes, 1981 a,b; Grosswald, 1984). This constitutes what is commonly referred to as the "big ice model". In contrast, many researchers (Miller, 1973; Miller and Dyke, 1974; Andrews, 1975; Dyke and Prest, 1987) believe that ice during the late Wisconsinan glaciation was limited to small, land-based icecaps, leaving the coastal zone of Baffin Island ice-free. This second theory is often referred to as the "small ice model". Figure 1 illustrates the difference in these two models, showing the maximum and minimum reconstructions of the Laurentide ice sheet in the late Wisconsinan, as compiled by Vincent and Prest (1987). Baffin Island (Figure 2) marks the northeastern margin of the former Laurentide Ice Sheet and is the focal point of most of the controversy concerning the late Wisconsinan configuration of the Laurentide.

Numerous authors have expressed concern regarding the accuracy of mapped limits of late Wisconsinan ice and the reliability of the current methods for determining such limits. One reason for questioning the reliability of mapped limits has been the lack of chronological control used in correlating units (Ives *et al.*, 1975). Mayewski *et al.* (1981, p. 121) emphasize that the minimum model of the late Wisconsinan reconstruction is based primarily on work done on eastern Baffin Island. Mayewski *et al.* (1981, p. 115) also emphasize that glacial chronologies used in Cumberland Sound, in particular, are questionable, as will be discussed later in this proposal.

Due to the discrepancies in the literature and among researchers, the glacial chronology on eastern Baffin Island, especially in the Cumberland Sound area, needs to be re-evaluated. I propose to refine the glacial chronology in the Pangnirtung area of Cumberland Sound (Figure 3).

I intend to delimit ice extent in this area and determine the timing of deglaciation using a combination of field reconnaissance, detailed surficial mapping, and exposure age determinations of polished, striated bedrock and morainal boulders using the *in situ* produced cosmogenic isotopes, $^{10}Be$ and $^{26}Al$.

**Significance of Research**

Determining exposure ages of glacial landforms in the Canadian Arctic should help resolve discrepancies in Wisconsinan glacial chronologies which have persisted for over two decades. The Duval moraines represent a significant glacial advance on southern Baffin Island and stratigraphically appear to separate two major weathering zones. The Duval moraines most likely represent the maximum advance of the Laurentide ice sheet in southern Cumberland Sound. However, the previously accepted early Wisconsinan age (ca. 60 ka) for the Duval moraines along Pangnirtung Fiord (Dyke, 1977, 1979) appears to be at odds with recent marine evidence for late Wisconsinan (ca. 10 ka) till on the floor of Cumberland Sound (Jennings, 1989, 1993). Cosmogenic isotope measurements should provide the most direct age estimates to date for the timing of deglaciation in southern Baffin Island. The age we establish for the Duval moraines may be used to revise existing glacial chronologies of Cumberland Sound. This is significant because the previous chronologies have been used in estimating the maximum extent of the Laurentide Ice Sheet, sea level histories, and implied climatic regimes for Cumberland Sound and the entire eastern portion of Baffin Island.

**Previous Work**

**-Glacial Chronologies in the Eastern Canadian Arctic**

The extent of the northeastern margin of the Laurentide Ice Sheet has been studied intensely, especially in Labrador and Baffin Island. At the late Wisconsin maximum, the northeastern margin of the Laurentide Ice Sheet extended from the Maritime Provinces to northern Baffin Island. Chronologies for the last major glaciation on Baffin Island, defined by Locke (1979) as the Foxe glaciation, have been developed through morphostratigraphic studies of moraines and shoreline features, relative dating by the degree of bedrock and surface boulder weathering, and soil development studies (Andrews and Miller, 1976; Nelson, 1980). Radiocarbon ages and amino acid racemization of fossil mollusks have also been used extensively in assigning ages to Quaternary deposits and landforms (Miller, 1980; Miller *et al.*, 1977; Miller *et al.*, 1985; Nelson, 1981, 1982; Brigham, 1983; Mode, 1980; Locke, 1987).

Fieldwork conducted over the past two decades has contributed to the modern view of Wisconsin ice extent which centers around the development of the "weathering zone concept" (Mayewski *et al.*, 1981). These weathering zones represent "units of the land surface which are distinguishable from each other on the basis of the distinct weathering features that record different lengths of time through which they have formed" (Dyke, 1977, p. 40). Three broad weathering zones have been recognized along the entire northeastern margin of the Laurentide Ice Sheet from Newfoundland to the northern Queen Elizabeth Islands (Ives, 1978). In the coastal mountains, three altitudinally different weathering zones have been defined, from highest to lowest, weathering zones I, II, and III (Figure 4). The boundaries between these zones are thought to reflect the former margins of fiord glaciers (Boyer and Pheasant, 1974) and the upper limit of weathering zone III is commonly believed to represent the maximum extent of ice during the Wisconsin glaciation (Mayewski *et al.*, 1981). Moraine systems within weathering zone III on eastern Baffin Island have been divided further; early Wisconsin moraines (EWM), mid Wisconsin moraines (MWM), and late Wisconsin moraines (Figure 4).

Figure 5 is a compilation of the previous glacial chronologies inferred along the eastern coast of Baffin Island (locations are indicated on Figures 2 and 3). From the time-distance diagrams it appears that the most extensive glaciations are believed to have occurred during the early Wisconsin glaciation (ca. 120,000 to 60,000 B.P.), with sequentially less extensive advances of the Laurentide and local ice masses during the latter part of the Wisconsinan. The outermost limit of late Wisconsin (ca. 8000 B.P.) ice is mapped roughly parallel to the fiord heads of the eastern coast of Baffin Island.

Dyke (1977, 1979) studied a large area, primarily southwest of the Penny Ice Cap (southern Cumberland Peninsula; Figure 5), and initially mapped what he termed the "Duval" moraines and related features along Pangnirtung Fiord and near the mouth of Kingnait Fiord (Figure 3). Based on relative dating, Dyke (1977,1979) proposed an older (more seaward) and younger (farther inland) weathering zone separated by the Duval moraines, which he believed to be approximately 100,000 to 60,000 years B.P. (based on correlation with amino acid data from a single mollusk fragment on a nearby glaciomarine delta). The Ranger moraines (Fig. 5), located at the fiord head, are believed to delimit the maximum extent of late Wisconsinan (ca. 8000 B.P.) ice in this area. This glacial chronology (progressively less extensive glaciations throughout the Wisconsinan) is consistent with the chronologies proposed for the northern side of Cumberland Peninsula (Miller, 1973; Boyer and Pheasant, 1974; Nelson, 1980; Brigham 1983.) and those shown in Figure 5.

Mayewski *et al.* (1981, p. 115) question the Cumberland Sound chronologies, based on the reliability of radiocarbon ages, and "would not restrict the extent of late Wisconsin glaciers to fiord heads on the basis of this [Cumberland Sound] chronology." Data from marine sediment cores from some areas adjacent to Baffin Island suggest that late Wisconsinan ice deposited till on parts of the continental shelves (MacLean, 1985; MacLean *et al.*, 1986; Praeg *et al.*, 1986). This type of evidence may support a late glacial maximum whieh is farther downfiord, or more extensive than the fiord heads. Recent work by Jennings (1989, 1993) suggests that late Wisconsinan till (ca. 10,000 B.P.) does lie on the floor of Cumberland Sound (Figure 6). Based on these data, a revision of the late Wisconsinan maximum ice extent and timing of deglaciation in Cumberland Sound is suggested. As mentioned earlier, the maximum extent of ice (interpreted as early Wisconsinan, ca. 60,000 B.P.) in the Cumberland Sound area was previously interpreted by the relative dating of the terrestrial surfaces (Dyke 1977, 1979; Miller, 1985). The discrepancies between the terrestrial record and the marine record emphasizes the difficulty in correlation studies, and the need for assigning accurate ages to these landforms.

**-*In situ* Produced Cosmogenic Isotopes**

The use of cosmogenically produced nuclides in geomorphic studies is becoming a useful tool for constraining landscape erosion rates as well as exposure ages of landforms. Recent advances in analytical chemistry and nuclear physics allow quantitative measurement of rare isotopes including those produced by the interaction of cosmic rays with rock and soil (Elmore and Phillips, 1987). Geomorphic studies have concentrated on six of these isotopes ($^{3}$He, $^{10}$Be, $^{14}$C, $^{21}$Ne, $^{26}$Al, and $^{36}$Cl). Recent studies have shown that, particularly in glaciated regions, the use of *in situ* produced cosmogenic isotopes provides helpful information about exposure ages and histories of the geologic surfaces (Cerling, 1990; Phillips *et al.*, 1990; Nishiizumi *et al.*, 1991; Brook *et al.*, 1993).

The three most important assumptions used when interpreting measured isotope abundance as model exposure ages are: (1) There is a known and constant rate of isotopic production (2) At the time of initial exposure, there is no isotopic inheritance (i.e. from prior exposure history) and (3) There has been no significant erosion of the sampled surface since exposure. Recent studies have shown that due to variations in the strength of the Earth's magnetic field, production rates of cosmogenie nuclides have fluctuated over time. However, the effect of field strength changes in polar regions is minimal for age determinations (Lal, 1991). Field based studies have been used to calibrate the production rates for $^{3}$He (Cerling, 1990; Kurz *et al.*, 1990), $^{21}$Ne (Hudson et. al., 1991), $^{10}$Be and $^{26}$Al (Nishiizumi et. al., 1989; Brown et. al., 1991; Larsen, in progress) and $^{36}$Cl (Zreda et. al., 1991).

The assumption of no isotopic inheritance has been investigated by few workers. Brook et. al. (1993) suggest that for Antarctic glaciers inheritance is not likely to be important. Work by Bierman (1993) also indicated that for boulders contained in Sierra Nevada moraines minimal isotopic inheritance has occurred.

The assumption of no erosion is easily testable on glaciated terranes. By sampling outcrops on which glacial polish and/or striated surfaces are preserved, the amount of rock surface degradation can be constrained to 1-2 cm which will have a minimal influence on calculated exposure ages (1-2%). Careful sample selection can avoid the problem of sampling surfaces which have not recently been covered by till and then exposed, which would result in calculated ages which are too low.

Based on the assumptions listed above, a model exposure age can be calculated using equation 1, where: N is the measured isotopic abundance after background correction (atom $g^{-1}$), P is the isotopic production rate (atom $g^{-1}$ $y^{-1}$), $\lambda$ is the decay constant for unstable isotopes ($y^{-1}$), and t represents the time of exposure (y):

$$N = \frac{P}{\lambda}(1-e^{-\lambda t}) \qquad \text{(Eq. 1)}$$

Phillips *et al.* (1990) calculated the exposure ages for 30 boulders on moraines in the Sierra Nevada of southern California using the abundance of *in situ* produced $^{36}$Cl. Chlorine-36 studies in Hawaii have also been used to calculate ages of glacially abraded lava surfaces and tillstones (Dorn *et al.*, 1992; Jull *et al.*, 1992; Zreda *et al.*, 1991; Zreda *et al.*, 1990). Studies in Antarctica (Brown *et al.*, 1991; Brook *et al.*, 1993) have used measurements of *in situ* produced $^{3}$He, $^{10}$Be, and $^{26}$Al to calculate model exposure ages of moraines. The Antarctic studies have correlated cosmogenic ages with accepted glacial chronologies and suggest an expanded Pliocene ice cap which is supported by $^{21}$Ne data (Staudacher and Allegre, 1991). Recent work by Gosse *et al.* (1992) and Evenson *et al.* (1994) suggest that $^{10}$Be and $^{26}$Al measurements from morainal boulders in the Wind River Mountains of Wyoming, when adjusted for mass loss from the boulder surfaces, provide reasonable estimates for the moraine ages.

Recent work by McCuaig *et al.* (1994) used $^{10}$Be and $^{26}$Al measurements to estimate the glacial history on South Bylot Island, northern Baffin Island, Canadian Arctic. The $^{10}$Be model ages of all the erratics (native and foreign origin) clustered around 60 ka, suggesting that the northeastern margin of the Laurentide reached its maximum during the early Wisconsinan. The $^{10}$Be ages were not consistent with $^{26}$Al ages (>2 ma) on the same rock samples, suggesting that McCuaig *et al.* 's determinations may not be robust.

Preliminary cosmogenic isotope analyses for the Pangnirtung area on Baffin Island have been carried out on samples collected by P. Thompson Davis. Samples have been prepared by myself and R. Finkel. Isotopic analyses have been made by accelerator mass spectrometry under the auspices of R. Finkel and M. Caffee, Lawrence Livermore National Laboratory. Stable Al in the samples has been favorably low, 60 to 120 ppm. The relatively low abundance of $^{27}$Al means that samples with exposure ages of only several thousand years can be measured reliably. Six striated bedrock surfaces from Pangnirtung Fiord have calculated cosmogenic exposure ages ranging from 5.5 to 8.5 ka (using currently accepted isotope production rates) suggesting that the floors of Pangnirtung Pass and Fiord were deglaciated after the late Wisconsinan. Samples collected from a bedrock surface exposed after Little Ice Age glaciers retreated have very low isotope abundances, indistinguishable from blanks, and suggest that even such short-lived advances are capable of removing isotopic evidence of prior cosmic ray exposure.

**Research Plan/Methodology**

**-Objectives**

In order to evaluate current models of the Laurentide Ice sheet and to understand better the glacial and climatic history of the low-middle Arctic, I have chosen the Pangnirtung area (Figure 7) on southeastern Baffin Island as the primary research area, with the goal of resolving the age of the Duval moraines. To evaluate the glacial history of the area, both field data and isotopic measurements will be used. Completing the following tasks will allow me to accomplish this goal.

(1) Prior to going into the field, I will perform air photo analysis. Black and white, stereo images at a scale of approximately 1:60,000 will be used to identify glaciated areas and prioritize field sites. I will attempt to distinguish the morainal designations identified by Dyke (1977,1979).

(2) In the field, data will be collected using topographic maps, air photos and satellite images as base maps. Nested moraines will be examined and mapped using the criteria of previous researchers. This criteria will include: moraine morphology and position, boulder weathering, boulder abundance, and possibly relative soil development. Boulder weathering will be estimated based on the preservation of striae and polish, frequency of macropits, micropits and evidence of felsenmeer development. Boulder abundance will be estimated by determining size classifications and eounting the number of each boulder size in a measured section. The time-stratigraphic relationships of moraines will be estimated using the criteria above, as well as any cross-cutting relationships.

(3) During primary field data collection, reconnaissance of sample location sites for isotopic measurements will also occur. Samples collected for analysis will be restricted to glacially polished and striated bedrock surfaces and morainal boulders with negligible weathering. Bedrock geometries will be carefully recorded in order to make geometric corrections for cosmic ray dosimetry. Detailed drawings, photographs and precise location of sample sites will be made in the field.

(4) Approximately 10 samples will be eolleeted from bedrock surfaces exposed in valley bottoms, fiord sidewalls and roche moutonees. Analysis of these samples should indieate the timing of deglaciation in the valley bottoms.

(5) Approximately 25 samples will be colleeted from boulders on nested sets of the Duval moraines above the valley bottoms in order to: **A.** Determine whether isotopic abundances reflect the relative ages of the moraines, **B.** Test the variability of exposure ages on a single moraine, and **C.** Determine whether mean or median exposure ages for the moraine boulders are similar to those measured on bedrock surfaces in the valley bottoms and sidewalls.

(6) In order to test the assumption that striated bedrock has no isotopic inheritance, several samples will be collected from striated bedrock at sites recently (< 200 years) deglaciated by withdrawal of ice following the Little Ice Age.

(7) A few samples will be collected from higher elevations, which are believed to represent significantly older glaciation (>120,000 B.P.), in order to: **A.** Establish a variability in the isotope abundances and **B.** Estimate the maximum erosion rate and minimum exposure age of these older surfaces.

**-Sample Preparation**

The lithology of the area is primarily granite and granite gneisses which are quartz bearing lithologies conducive to the measurement of *in situ* produced $^{10}Be$ and $^{26}Al$. Sample processing will occur at UVM. Samples will be prepared for mineral separation using jaw crushing, plate grinding and washing equipment within the department. After the initial acid etching to remove meteoric $^{10}Be$, mineral separation, using heavy liquids, will be performed to isolate quartz. "Clean-up" of the quartz and additional etching will be done ultrasonically. The final steps involve quartz dissolution, column separations, and preparation of the Be and Al targets for mass spectrometry. ICP analyses will be made at UVM or Middlebury College. Both replicate and blank samples will be run to ensure reliability of sample preparation. In addition, it may become necessary to use a third isotope, specifically *in situ* produced $^{14}C$, due to its much shorter half life (as compared to $^{10}Be$ or $^{26}Al$). Preparation and analysis of $^{14}C$ abundances would occur under the guidance of Dr. M. Caffee at the Lawrence Livermore National Laboratory and will be funded by Caffee.

## Possible Outcomes

My data could help resolve three issues: (1) whether the Duval moraines are young (late Wisconsin age) or old (early Wisconsin age), (2) whether the mean moraine ages correlate with topographic position and, (3) how large age variances on each moraine are.

If the calculated cosmogenic exposure ages are inconsistent with the previous chronologies for Cumberland Sound, re-evaluation of the extent of the late Wisconsinan maximum of the northeastern margin of the Laurentide will be necessary. Broadly speaking, the age determinations from the Duval moraines will either confirm or be at odds with the previous determination from relative dating, ca. 60,000 ka., or early to mid-Wisconsin age. Although some uncertainties remain in the interpretation of cosmogenic isotope data, particularly in the variability of production rates and altitude/latitude corrections, the isotopic systems are sufficiently robust to differentiate late Wisconsinan from mid or early Wisconsinan exposure ages.

By sampling nested moraines, I can test for stratigraphic trends in the calculated cosmogenic isotope ages. The mean calculated ages of the moraines should correlate with position along the fiord wall, if the variance is small enough on each moraine. The ages should be less, with decreasing elevation, as ice melts down.

If significant variances of calculated ages within any single moraine exist this may indicated that the samples have undergone erosion and/or have inherited nuclides from a prior exposure history.

## Time Table

March-June, 1995

- Preliminary analysis of air photos and TM images and construction of preliminary maps
- Continued isotopic processing and measurements of samples collected in 1994

June 7- July 26, 1995

- Fieldwork
  - 1 week reconnaissance
  - 3-4 weeks of field data collection including preliminary selection of sample sites
  - 1-2 weeks collecting samples

August, 1995

- Present data at the INQUA meeting in Berlin, Aug. 1-7
- Complete maps and begin sample preparation

September-December, 1995

- Continued sample processing and measurements of $^{10}$Be and $^{26}$Al
- Possibly conduct $^{14}$C measurements at Lawrence Livermore Laboratory with M. Caffee
- Present Progress Report
- Present data at National GSA meeting in New Orleans, November 6-9, 1995

January-May, 1996

- Final data reduction
- Thesis writing and final preparation
- Present data at annual Arctic & Alpine Research Workshop in Boulder, CO, March, 1996

## Potential Coursework

- Statistics
- Glacial Geology
- Geohydrology

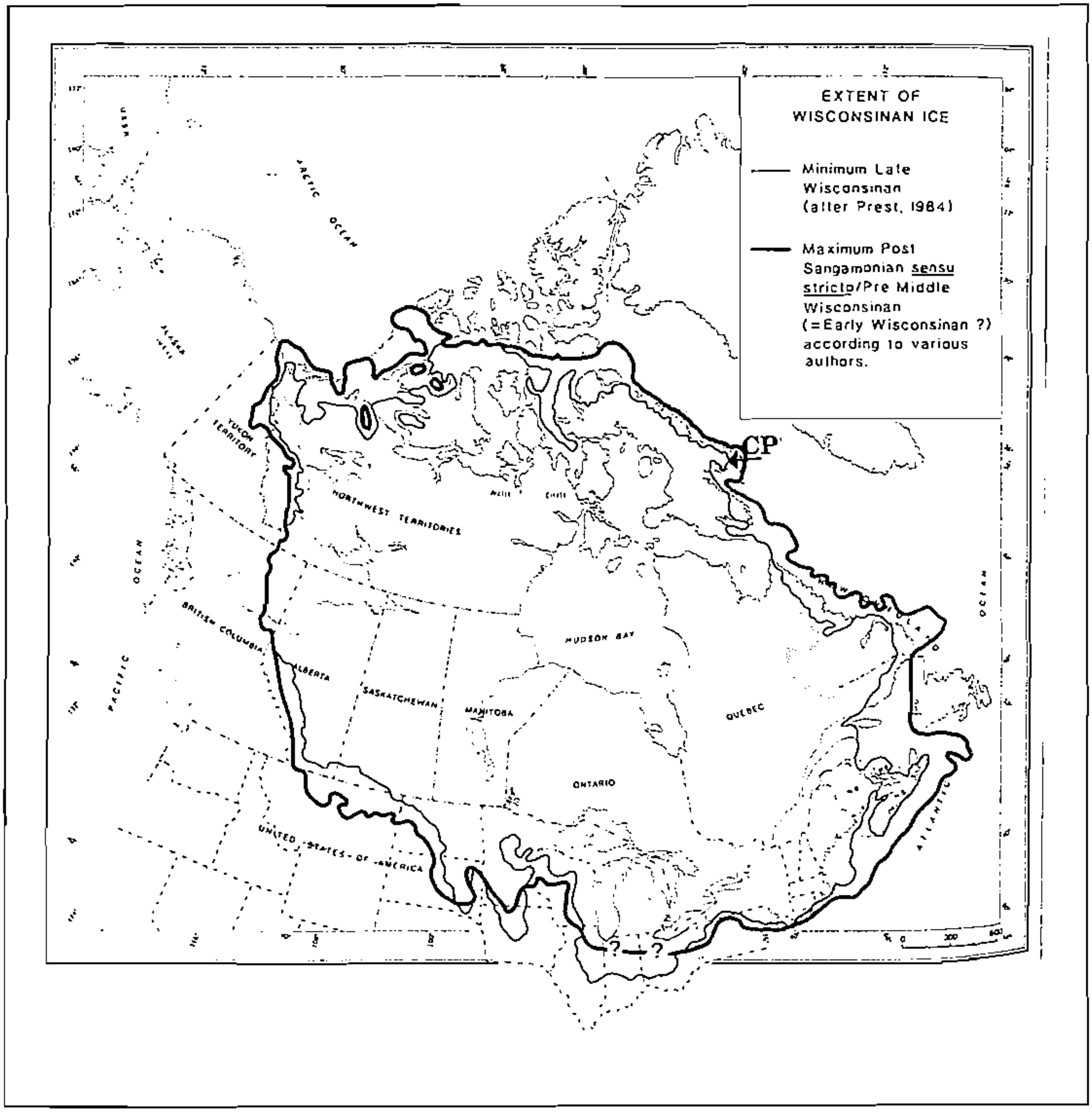


**Figure 1.** Overview map showing maximum and minimum extents of Laurentide Icesheet. Although Dyke *et al.* (1982) and Dyke and Prest (1987) proposed an early Wisconsinan age for maximum extent (thick solid line) and late Wisconsinan age for minimum extent (thin solid line), recent data suggest that the late Wisconsinan ice margin may have been more extensive in some areas than shown here. Cumberland Peninsula on Baffin Island labeled CP.

(adapted from Vincent and Prest, 1987)

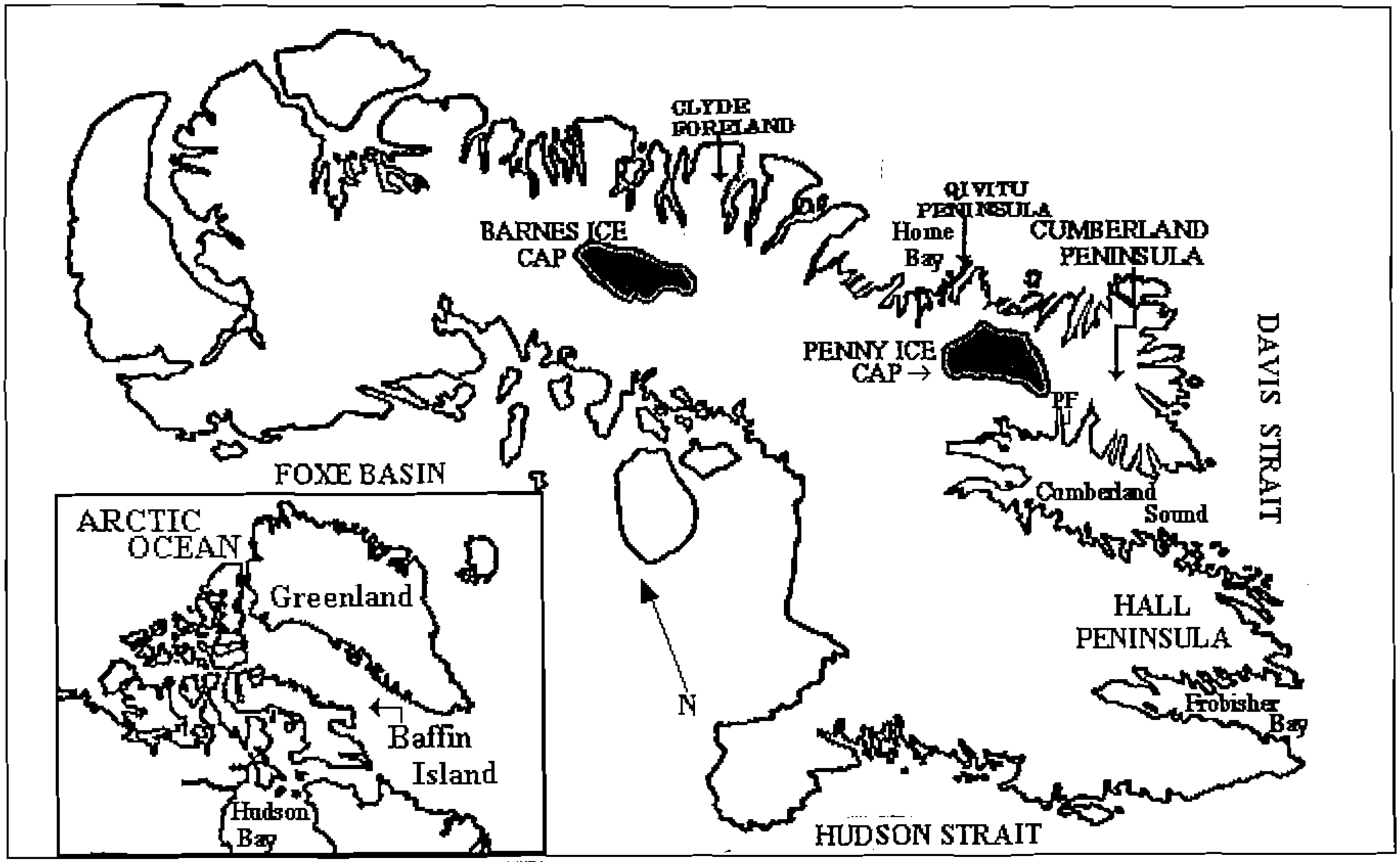


**Figure 2. Location map of Baffin Island. PF=Pangnirtung Fiord.**
**(adapted from Dyke, 1977)**

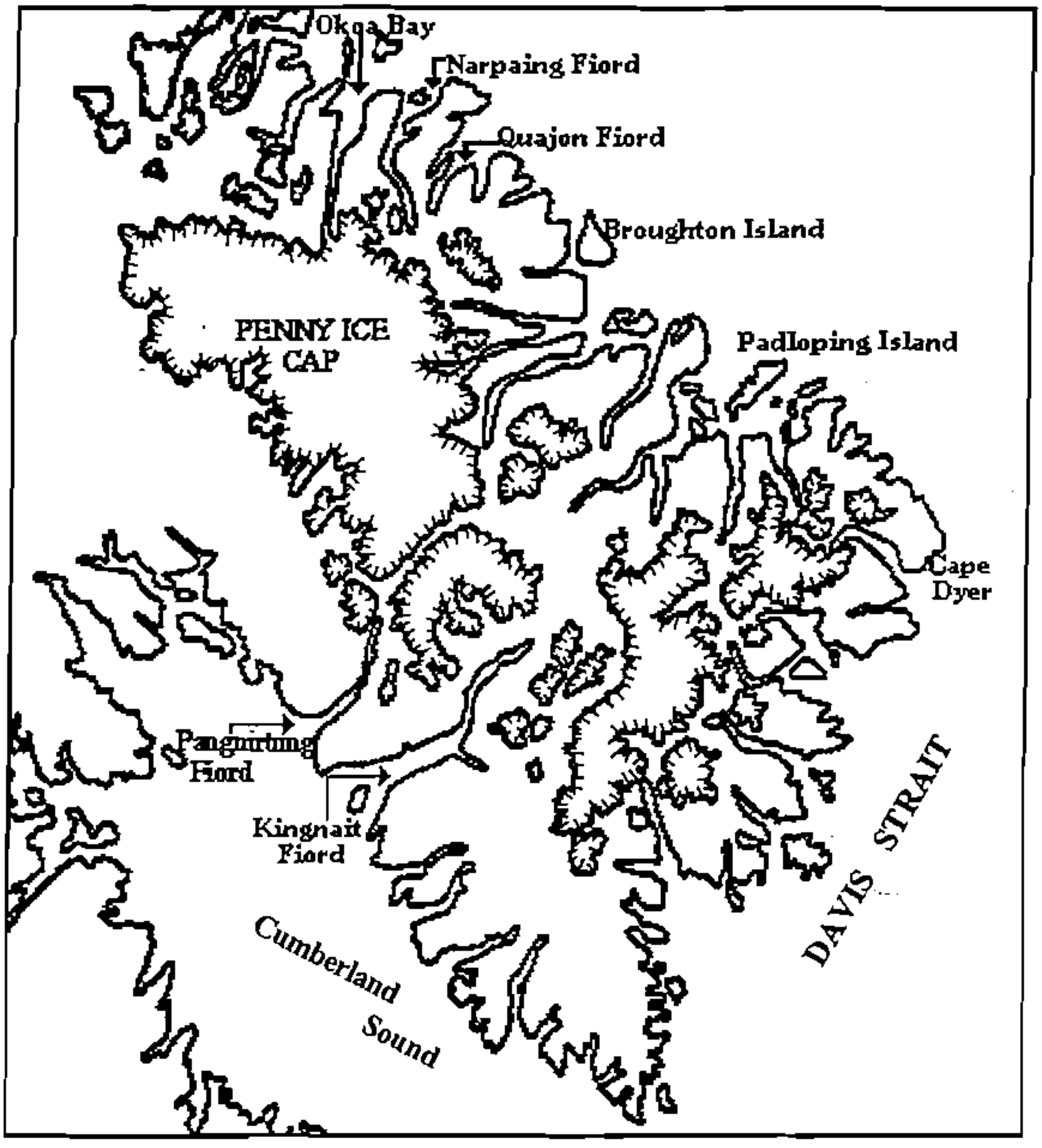


Figure 3. Index map of Cumberland Peninsula, Baffin Island.
(adapted from Dyke, 1977)

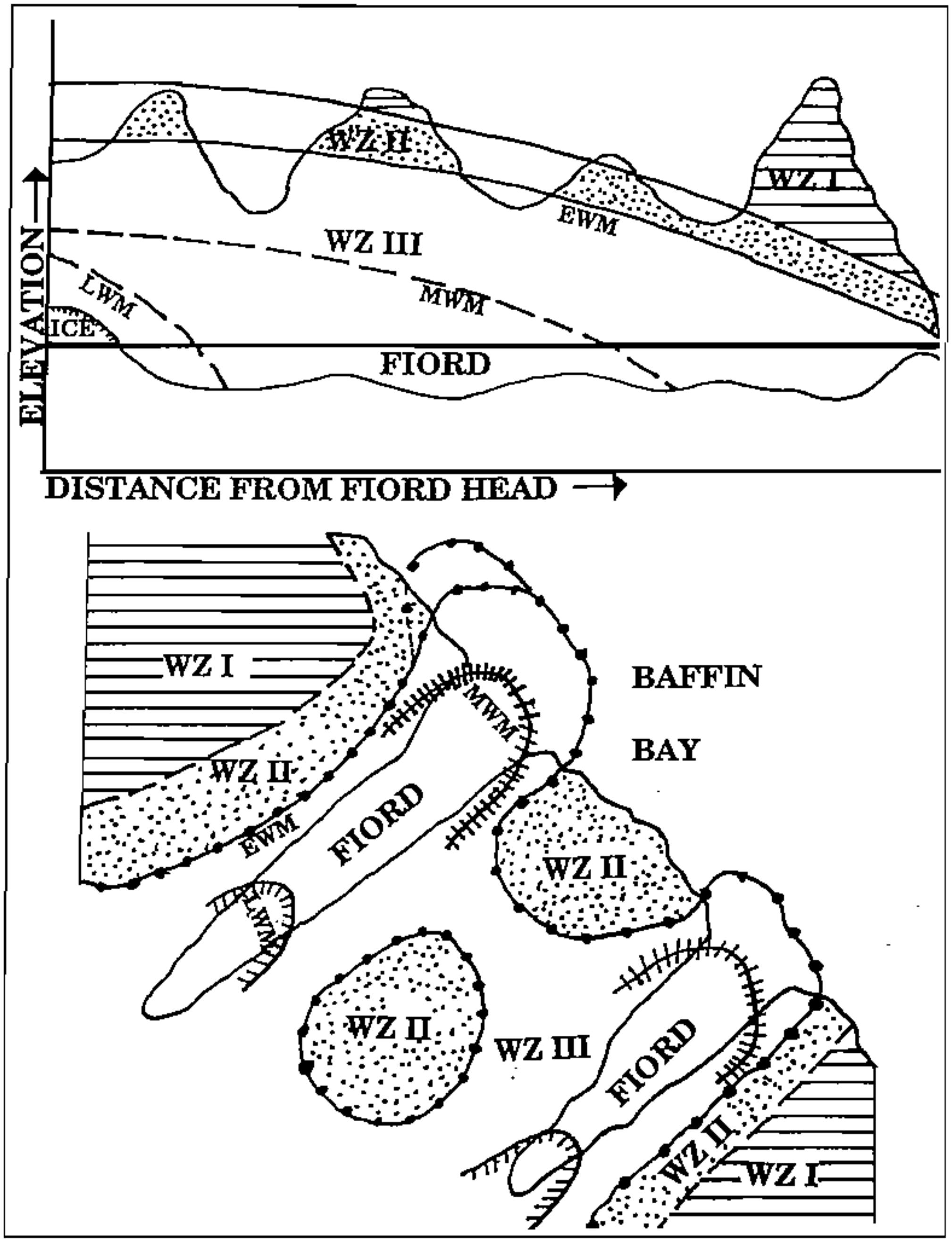


**Figure 4. A schematic portrayal of the Quaternary glaciation model for northern Cumberland Peninsula. The upper diagram shows the vertical distribution of lateral moraines and weathering zones on a longitudinal profile. The lower diagram shows the same in a planimetric view of highlands dissected by fiords.
WZ= Weathering Zone, EWM=Early Wisconsin moraine, MWM= Mid-Wisconsin moraine, and LWM=Late Wisconsin moraine.
(adapted from Dyke, 1977)**

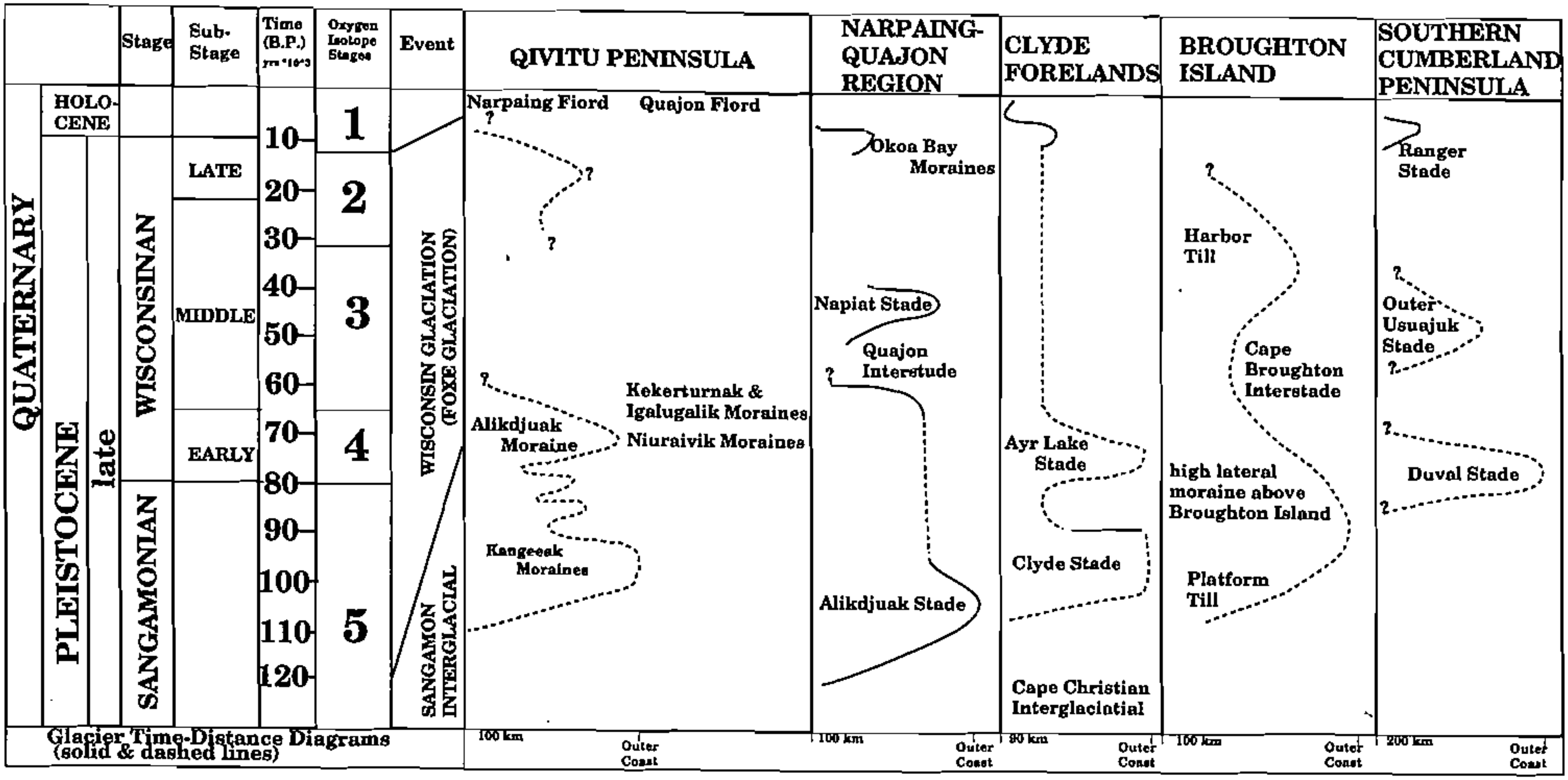


**Figure 5. Correlation of tills, moraines, and glacial events on eastern Baffin Island.**
**(adapted from Nelson, 1980; Pheasant & Andrews, 1973; Andrews et al., 1975; Miller et. al, 1977; Andrews et al., 1976; Dyke, 1977, 1979)**

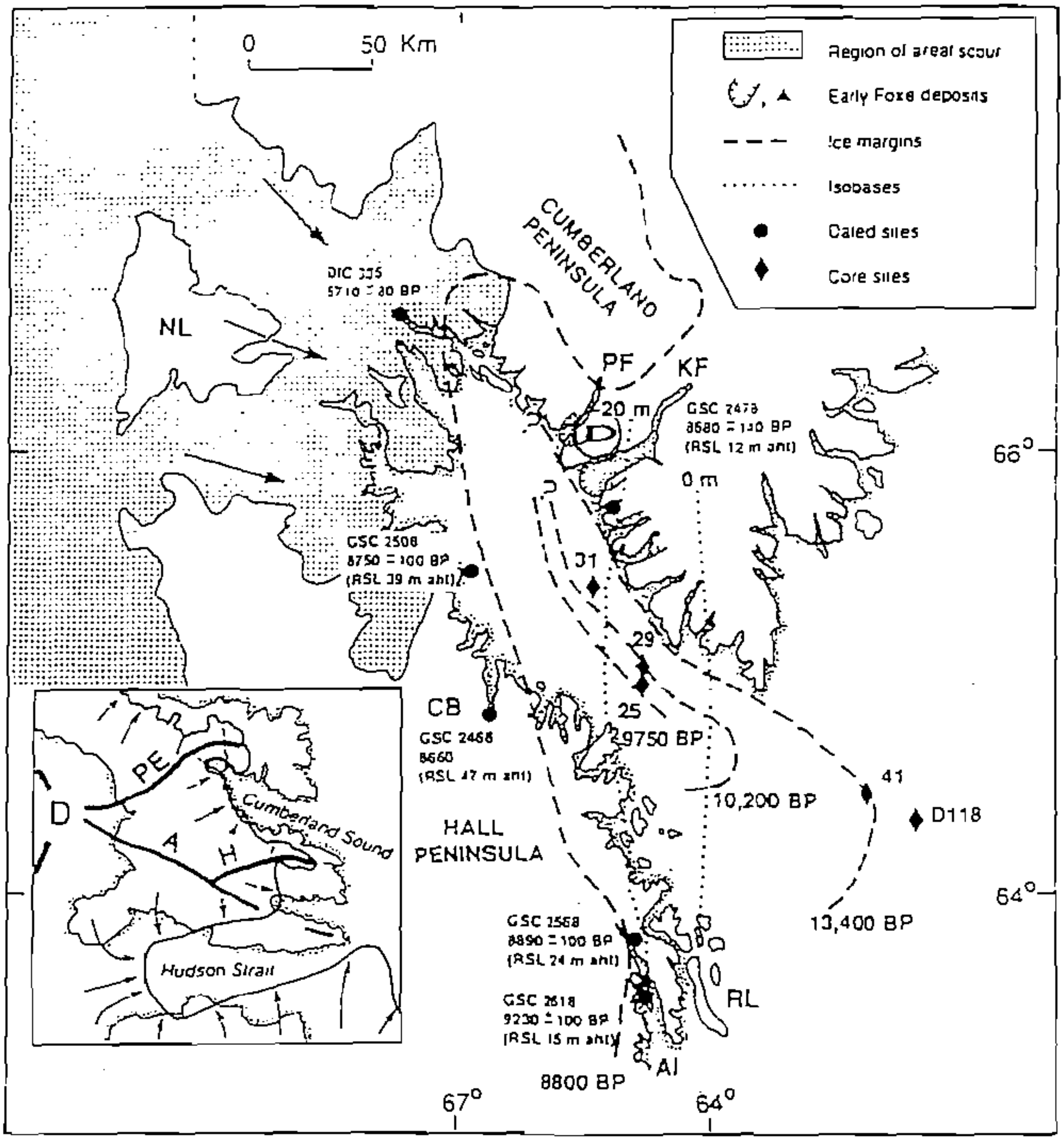


Figure 6. Jenning's (1989, 1993) ice reconstruction in Cumberland Sound area during the late Wisconsinan maximum and subsequent deglaciation. Ice margin at 8800 yrs BP slightly modified from Dyke *et al.* (1982). Radiocarbon ages shown related to deglaciation and/or Holocene marine limit (Dyke *et al.*, 1982; Miller, 1980). Region of areal scour shown by stippling. Isobases for 0 m and 20 m trend north-south. D= Duval moraines, mapped by Dyke (1977,1979) as early Foxe (early Wisconsinan) deposits; PF= Pangnirtung Fiord, KF= Kingnait Fiord.

(from Jennings, 1993)

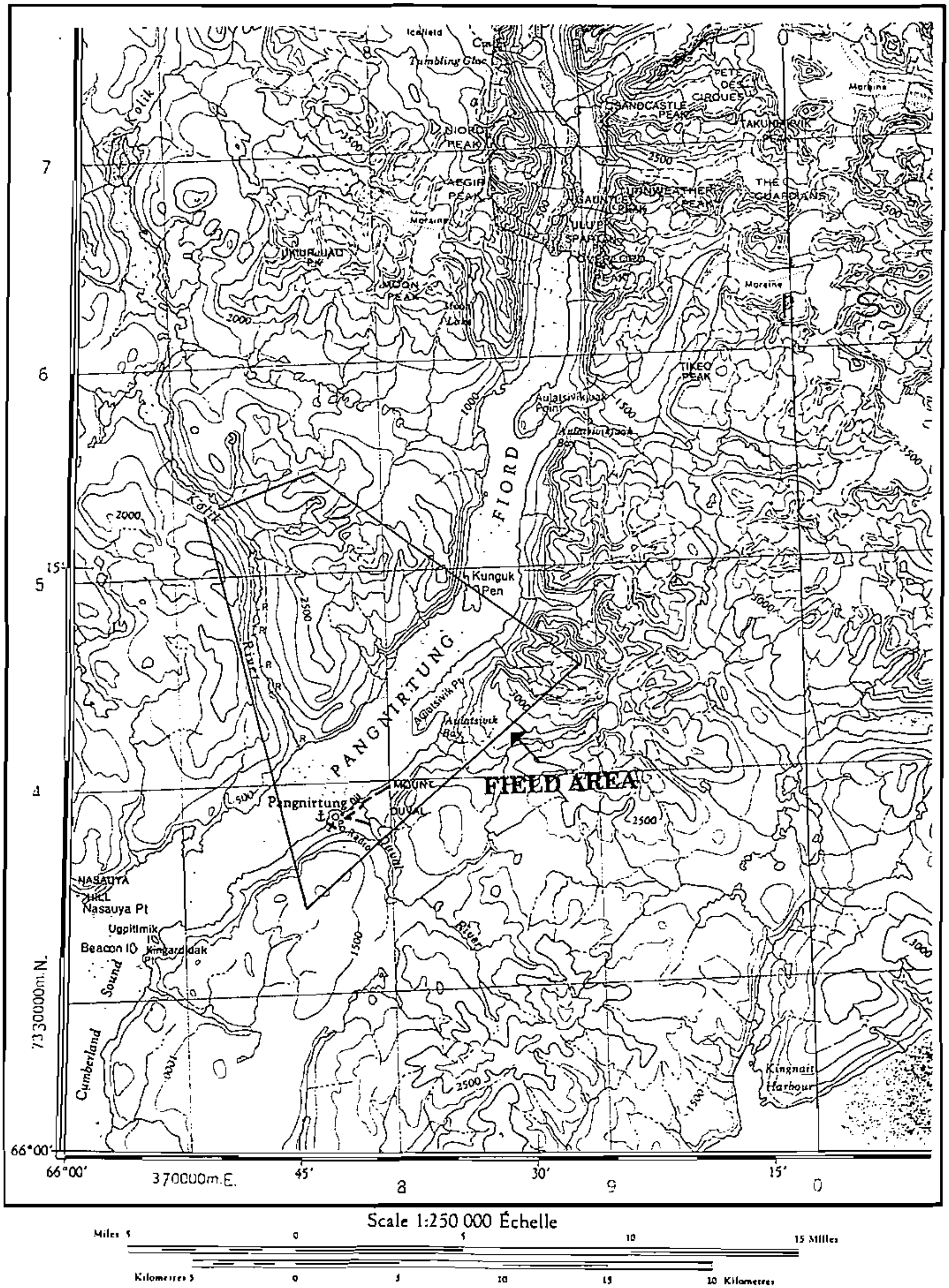


**Figure 7. Location map of Pangnirtung area, southern Cumberland Peninsula, showing field area. From part of Pangnirtung 1:250,000 map sheet 26-1, Department of Mines and Technical Surveys, Ottawa, compiled 1965, updated 1979.**

**Bibliography**

Andrews, J.T. and Ives, J.D., 1972, Late and postglacial events (<10,000 B.P.) in the eastern Canadian Arctic with particular reference to the Cockburn moraines and breakup of the Laurentide Ice Sheet, *in* , Vasari, U., Hyvarinen, H., and Hicks, S., eds, Climate Changes in Arctic Areas during the last Ten Thousand Years: Acta Universitatis Oulensis, Oulu, Finland, Series A, No. 3, p. 149-174.

Andrews, J.T. and Ives, J.D., 1978, "Cockburn" nomenclature and the late Quaternary history of the eastern Canadian Arctic: Arctic and Alpine Research, v. 10, p. 617-633.

Andrews, J.T. and Miller, G.H., 1979, Glacial erosion and ice sheets divides, northeastern Laurentide Ice Sheet, on the basis of limestone erratics: Geology, v. 7, p. 592-596. Andrews, J.T., 1975, Support for a stable Wisconsin ice margin (14,000 to about 9000 B.P.): A test based on glacial rebound: Geology, v. 3, p. 617-620.

Andrews, J.T., 1980, Progress in relative sea level and ice sheet reconstructions, Baffin Island, N.W.T., for the last 125,000 years, *in* Morner, N.A., ed., Earth rheology, isostasy, and eustasy: John Wiley and Sons, New York, p. 175-200.

Andrews, J.T., 1982, On the reconstruction of Pleistocene ice sheets: A review: Quatatemary Science Reviews, v. 1, p. 1-30.

Andrews, J.T., 1987a, The late Wisconsin deglaciation of the Laurentide Ice Sheet: Chronology and mechanisms, *in* Ruddiman, W.F. and Wright, H.E., Jr., eds., North America and adjacent oceans during the last deglaciation: Geological Society of America, vol. K-3, p. 13-37.

Andrews, J.T., 1987b, Postface; The Laurentide Ice Sheet: Research Problems: Geographie physique et Quaternaire, v. 41, p. 315-318.

Andrews, J.T., 1990, Fiord to deep sea sediment transfers along the northeastern Canadian c ontinental margin: Models and data: Geographie physique et Quaternaire, v. 44, no. 1, p. 55-70.

Andrews, J.T., Aksu, A.E., Kelly, M., Klassen, R.A., Miller, G.H., Mode, W.N., and Mudie, P.J., 1985a, Land/ocean correlations during the last interglacial/glacial transistion, Baffin Bay, northwestern North Atlantic: A review: Quaternary Science Reviews, v. 4., p. 333-355.

Andrews, J.T., Erlenkeuser, H., Evans, L.W., Briggs, W.M., and Jull, A.T.J., 1991a, Meltwater and deglaciation, SE Baffin Shelf (NE margin Laurentide Ice Sheet during the Younger Dryas chron: SE Baffin Shelf, Northwest Territories: Paleoceanography, v. 5, p. 921-935.

Andrews, J.T., Jennings, A.E., MacLean, B., Mudie, P.J., Praeg, D., and Vilks, G., 1991b, The surficial geology of the Eastern Canadian Arctic and polar continental shelves: Continental Shelf Research, v. 11, p. 791-819.

Andrews, J.T., Jull, A.J.T., Donahue, D.J., Short, S.K., and Osterman, L.E., 1985c, Sedimentation rates in Baffin Island fiord cores from comparitive radiocarbon dates: Canadian Journal of Earth Sciences, v. 22, p. 1827-1834.

Andrews, J.T., Laymon, C.A., and Briggs, W.M., compilers, 1989, Radiocarbon Date List III, Labrador and Northern Quebec, Canada, and Radiocarbon Date List IX, Baffin Island, N.W.T., Canada: Institute of Arctic and Alpine Research, University of Colorado, Occasional Paper No. 46, 85 pp.

Andrews, J.T., Matthews, R.K., Osterman, L.E., Miler, G.H., Hillaire-Marcel, C., and Williams, K.M., 1987b, Deglaciation and meltwater events in Hudson Strait, and the eastern Canadian Arctic: Geomarine Letters, v. 7., p. 23-30.

Andrews, J.T., Stravers, J.A., and Miller, G.H., 1985b, Patterns of glacial erosion and deposition around Cumberland Sound, Frobishier Bay, and Hudson Strait, and the location of ice streams in the eastern Canadian Arctic, *in* Waldenburg, M., ed., Models in Geomorphology: Allen & Unwin, Boston, p. 93-117.

Bard, E., Hamelin, B., Fairbanks, R.G., and Zindler, A., 1990, Calibration of the $^{14}C$ timescale over the past 30,000 years using mass spectrometric U-Th ages from Barbados corals: Nature, v. 345, p. 405-410.

Birkeland, P.W., 1978, Soil development as an indicator of relative age of Quaternary deposits, Baffin Island, N.W.T., Canada: Arctic and Alpine Research, v. 10, p. 733-747.

Bockheim, J.G., 1979, Properties and relative age of soils of southwestern Cumberland Peninsula, Baffin Island, N.W.T., Canada: Arctic and Alpine Research, v. 11, p. 289-306.

Boyer, S.J. and Pheasant, 1974, Delimitation of weathering zones in the fiord area of eastern Baffin Island, Canada: Geological Society of America Bulletin, v. 85, p. 805-810.

Brigham, J.K., 1983, Stratigraphy, amino acid geochronology, and correlation of Quaternary sea-level and glacial events, Broughton Island, eastern Baffin Island, Canada: Canadian Journal of Earth Sciences, v. 20, p. 577-598.

/Broecker, W.S. and Denton, G.H., 1989, The role of ocean-atmosphere reorganizations in glacial cycles: Geochemica et Cosmochimica Acta, v. 53, p. 2465-2501.

Brook, E.J., Kurz, M.D., Denton, G.H., and Ackert, R.P.J., 1993, Chronology of Taylor Glacier advances in Arena Valley, Antartica using *in situ* cosmogenic $^{3}He$ and $^{10}Be$: Quaternary Research, v. 39, p. 11-23.

Brook, E.J. and Kurz, M.D., 1993, Surface-exposure chronology using *in situ* cosmogenic $^{3}He$ in Antartie quartz sandstone boulders: Quaternary Research, v. 39, p. 1-10.

Brown, E.T., Edmond, J.M., Raisbeck, G.M., Yiou, F., kurz, M.D., and Brook, E.J., 1991, Examination of surface exposure ages of Antartic moraines using *in situ* produced $^{10}Be$ and $^{26}Al$: Geochemica et Cosmochimica Acta, v. 5, p. 2269-2283.

Brown, T.A., Nelson, D.E., Mathewes, R.W., Vogel,J.S., and Southon, J.R., 1989, Radiocarbon dating of pollen by accelerator mass spectrometry: Quaternary Research, v. 32, p. 205-212.

Bursik, M.I. and Gillespie, A.R., 1993, Late Pleistocene glaciation of Mono Basin, California: Quaternary Research, v. 39, p. 24-35.

Cerling, T.E., 1990, Dating geomorphic surfaces using cosmogenic $^{3}He$: Quaternary Research, v. 33, p. 148-156.

Craig, H. and Poreda, R.J., 1986, Cosmogenic $^{3}He$ in terrestrial rocks: The summit lavas of Maui: Proceedings of the National Academy of Science, v. 83, p. 1970-1974.

Davis, J.C., Proctor, I.D., Southon, J.R., Caffee, M.W., Heikkinen, D.W., Roberts, M.L., Moore, T.L., Turteltaub, K.W., Nelson, D.E., Loyd, D.H., and Vogel, J.S., 1990, LLNL/UC AMS facility and research program: Nuclear Instruments and Methods in Physics Research B52, p. 269-272.

Davis, P.T. and Fabel, J., 1988, Lichenometric dating of debris flow levees, Pangnirtung Pass, Baffin Island: More data and new interpretations: Geological Society of America, Abstracts with Programs, v. 20, no. 1, p. 14-15.

Davis, P.T. and Kihl, R., 1985, Late Holocene record of debris avalanche deposits interbedded with lake sediments, Baffin Island, Canada: Geological Society of America, Abstracts with Programs, v. 17, no. 1, p. 14.

Davis, P.T., 1980, Late Holocene glacial, vegetational, and climatic history of Pgnirtung and Kignait Fiord area, Baffin Island, N.W.T., Canada: Ph.D. dissertation, University of Colorado, 366 pp.

Davis, P.T., 1985, Neoglacial moraines on Baffin Island, *in* Andrews, J.T., ed., Quaternary Environments-Eastern Canadian Arctic, Baffin Bay, and western Greenland, Chapter 22: Allen & Unwin, Boston, p. 682-718.

Davis, P.T., 1988, Possible evidence for extensive late Wisconsin (late Foxe) glaciation in Pangnirtung Pass area, southern Cumberland Peninsula, Baffin Island: Geological Society of America, Abstracts with Programs, v. 20, p. A208.

Davis, P.T., Finkel, R.C., Caffee, M.W., Southon, J.R., and Koning, J., 1993, Cosmogenic $^{26}Al$ and $^{10}Be$ exposure ages for glacially eroded bedrock, Pangnirtung area, Baffin Island, N.W.T., Canada: Geological Society of America, Abstracts with Programs, v. 25, no. 2, p. 11.

Davis, P.T., Nichols, H. and Andrews, J.T., 1980, Holocene vegetation and climate record from Iglutalik Lake, Baffin Island: Abstracts with Program, Fifth International Palynological Conference, London, p. 105.

Davis, R. and Schaeffer, 1955, Chlorine-36 in nature: Annals of the New York Academy of Science, v. 62, p. 105-122.

Denton, G.H. and Hughes, T.J., eds., 1981a, The Last Great Ice Sheets: John Wiley and Sons, New York, 484 pp.

Denton, G.H. and Hughes, T.J., 1983, Milankovitch theory of ice ages: Hypothesis of ice-sheet linkage between regional insulation and global climate: Quaternary Research, v. 20, p. 125-144.

Denton, G.H., Hughes, T.J., and Karlen, W., 1986, Global ice-sheet system interlocked by sea level: Quaternary Research, v. 26, p. 3-26.

Dorn, R.I., Jull, A.J., Donahue, D.J., Linick, T., Toolin, L., Moore, R., Rubin, M., Gill, T. and Cahil, T., 1992, Rock varnish on Hualalai and Mauna Kea volcanoes, Hawaii: Pacific Science, v. 46, p. 11-34.

Dyke, A.S. and Prest, V.K., 1987, The Late Wisconsinan and Holocene history of the Laurentide Ice Sheet: Geographie physique et Quaternaire, v. 41, p. 237-263.

Dyke, A.S., 1977, Quaternary geomorphology, glacial chronology, and climatic and sea-level history of southwestern Cumberland Peninsula, Baffin Island, Northwest Territories, Canada: Ph.D. dissertation, University of Colorado, 185 pp.

Dyke, A.S., 1979, Glaeial and sea-level history of southwestern Cumberland Peninsula, Baffin Island, N.W.T., Canada: Arctic and Alpine Research, v. 11, p.179-202.

Dyke, A.S., 1993, Landscapes of cold-centered Late Wisconsinan ice caps, Arctic Canada: Progress in Physical Geography, v. 17, p. 223-247.

Dyke, A.S., Andrews, J.T., and Miller, G.H., 1982a, Quaternary geology of the Cumberland Peninsula, Baffin Island, District of Franklin: Geological Survey of Canada, Memoir 403, 32 pp.

Dyke, A.S., Dredge, L.A., and Vincent, J.S., 1982b, Configuration of the Laurentide Ice Sheet during the late Wisconsin maximum: Geographie physique ct Quaternaire, v. 36, p 5-14.

Elmore, D. and Phillips, F.M., 1987, Accelerator mass spectrometry for measurement of long-lived radioisotopes: Science, v. 236, p. 543-550.

Fowler, A.J., Gillespie, R., and Hedges, R.E.M., 1986, Radiocarbon dating of sediments: Radiocarhon, v. 28, p. 441-450.

Fulton, R.J. and Prest, V.K., 1987, The Laurentide Ice Sheet and its significance: Geographie physique et Quaternaire, v. 41, p. 181-186.

Gilbert, R. and Church, M., 1983, Contemporary sedimentary environments of Baffin Island, N.W.T., Canada: Reconnaissance of lakes on Cumberland Peninsula: Arctic and Alpine Research, v. 14, p. 1-12.

Gilbert, R., 1983, Sedimentary processes of Canadian Arctic fjords: Sedimentary Geology, v. 36, p. 147-175.

Gosse, J.C., Evcnson, E.B., Klein, J., Middleton, R., Lawn, B., and Dezfouly-Arjomandy, B., 1992, A test of cosmogenic radionuclide dating of moraines at the type-locality of the Pinedale glaciation, Fremont lake, Wyoming: Geological Society of America, Abstracts with Programs, v. 24, no. 3, p. 24.

Grosswald, M.G., 1984, Glaciation of the continental shelf (Part I): Polar Geography and Geology, v. 8, p. 196-258.

Hays, J.D., Imbrie, J., and Shackleton, N., 1976, Variations in the Earth's orbit; Pacemaker of the Ice Age: Science, v. 194, p. 1121-1132.

Hudson, B., Caffee, M., Beirger, B., Ruiz, B., Kohl, C.P., and Nishiizumi, K., 1991, Production rate and retention properties of cosmogenic $^{3}$He and $^{21}$Ne in quartz: EOS, v. 72, p. 575.

Hughes, T.J., Denton, G.H., and Grosswald, M.G., 1977, Was there a late-Wurm Arctic ice sheet?: Nature, v. 266, p. 596-602.

Jennings, A.E., 1993, The Quaternary history of Cumberland Sound, Baffin Island, arctic Canada: Ph.D. dissertation, University of Colorado.

Jennings, A.E., 1993, The Quaternary history of Cumberland Sound, southeastern Baffin Island: The marine evidence: Geographie physique et Quaternaire, v. 47, p. 21-42.

Jull, A.J., Wilson, A., Burr, G.S., Toolin, L.J., and Donahue, D.J., 1992, Measurements of cosmogenic $^{14}$C produced by spallation in high-altitude rocks: Radiocarbon, v. 34, p. 737-744.

Kurz, M.D., 1986a, Cosmogenic helium in a terrestrial igneous rock: Nature, v. 320, p. 435-439.

Kurz, M.D., Colodner, D., Trull, T.W., Moore, R., and O'Brien, K., 1990, Cosmic ray exposure dating with *in-situ* produced cosmogenic $^{3}$He: results from young Hawaiian lava flows: Earth and Planetary Science Letters, v. 97, p. 177-189.

Lal, D., 1988, In-situ produced cosmogenic isotopes in terrestrial rocks: Annual Reviews of Earth and Planetary Science, v. 16, p. 355-388.

Lal, D., 1991, Cosmic ray labeling of erosion surfaces. *In-situ* production rates and erosion models: Earth and Planetary Science Letters, v. 104, p. 424-439.

Lal, D. and Peters, B., 1967, Cosmic ray produced radioactivity in the earth, *in* Sitte, K., ed., Handbuch der Physik, Springer-Verlag, New York, p. 551-612.

Lemmen, D.S., Gilbert, R., and three others, 1988, Holocene sedimentation in glacial Tasikutaaq Lake, Baffin Island: Canadian Journal of Earth Sciences, v. 25, p. 810-823.

Locke, W.W., 1987, The late Quaternary geomorphic and paleoclimate history of the Cape Dyer area, easternmost Baffin Island, N.W.T.: Canadian Journal of Earth Sciences, v. 24, p. 1185-1198.

Locke, W.W., III, 1979, Etching of hornblende grains in arctic soils: An indicator of relative age and paleoclimate: Quaternary Research, v. 11, p. 197-212.

Locke, W.W., III, 1985, Weathering and soil development on Baffin Island, *in* Andrews, J.T., ed., Quaternary Environments; Eastern Canadian Arctic, Baffin Bay, and Western Greenland, chapter 12: Allen & Unwin, Boston, p. 331-353.

MacLean, B., 1985, Geology of the Baffin Island Shelf, *in* Andrews, J.T., ed., Quaternary Environments; Eastern Canadian Arctic, Baffin Bay, and Western Greenland, chapter 6: Allen & Unwin, Boston, p. 154-177.

MacLean, B., Williams, G.L., Jennings, A.E., and Blakeney, C., 1986, Cumberland Sound, N.W.T.: Investigations of bedrock and surficial geology: Geological Survey of Canada Paper 86-1B, p. 605-616.

McCuaig, S.J., Shilts, W.M., Evenson, E.B., and Klein, J., 1994, Use of cosmogenic $^{10}$Be and $^{26}$Al for determining glacial history of the South Bylot Island and Salmon River lowlands, N.W.T., Canada: Geological Society of America, Abstracts with Programs, v. 26, no. 7, p. A-127.

Mayewski, P.M., Denton, G.H., and Hughes, T.J., 1981, Late Wisconsin Ice Sheets in North America, *in* Denton, G.H., and Hughes, T.J., eds., The Last Great Ice Sheets: John Wiley & Sons, New York, p. 67-178.

Mayewski, P.M., Meeker, L.D., Whitlow, S., Twickler, M.S., Morrison, M.C., Alley, R.B., Bloomfield, P., and Taylor, K., 1993, The atmosphere during the Younger Dryas: Science, v. 261, p. 195-197.

McElhinny, M.W. and Senanayake, W.E., 1982, Variations in the geomagnetic dipole 1: The past 50,000 years: Journal of Geomagnetism and Geoelectricity, v. 34, p. 39-51.

McFadden, P.L. and McElhinny, M.W., 1982, Variations in the geomagnetic dipole 2: Statistical analysis of VDM's for the past 5 million years: Journal of Geomagetism and Geoelectricity, v. 34, p. 163-169.

Miller, G.H. and Dyke, A.S., 1974, Proposed extent of late Wisconsin Laurentide ice on Baffin Island: Geology, v. 2., p. 125-130.

Miller, G.H. and Kaufman, 1990, Rapid fluctuations of the Laurentide Ice Sheet at the mouth of Hudson Strait: New evidence for ocean/ice sheet interactions as controls on the Younger Dryas: Paleoceanography, v. 5, p. 907-919.

Miller, G.H., 1973, Late-Quaternary glacial and climatic history of northern Cumberland Peninsula, Baffin Island, N.W/T., Canada: Quaternary Research, v. 3, p. 561-583.

Miller, G.H., 1980, Late Foxe glaciation of southern Baffin Island, N.W.T., Canada: Geological Society of America Bulletin, Pt. 1, v. 90, p. 399-405.

Miller, G.H., Andrews, J.T., and Short, S.K., 1977, The last interglacial-glacial cycle, Clyde Foreland, Baffin Island, N.W.T.: Stratigraphy, biostratigraphy, and chronology: Canadian Journal of Earth Sciences, v. 14, p. 2824-2857.

Miller, G.H., Heary, P.J., and Stravers, J.A., 1988, Ice-sheet dynamics and glacial stratigraphy of southeasternmost Baffin Island and outermost Hudson Strait: Quaternary Research, v. 30, p. 116-136.

Mode, W.N., Nelson, A.R., and Brigham, J.K., 1983, A facies model of Quaternary glacial-marine cyclic sedimentation along eastern Baffin Island, Baffin Island, *in* Molina, B.F., ed., Glacio-marine Sedimentation: Plenum, New York, p. 495-534.

Nelson, A.R., 1980, Chronology of Quaternary landforms, Qivitu Peninsula, northern Cumberland Peninsula, Baffin Island, N.W.T., Canada: Arctic and Alpine Research, v. 12, p. 265-286.

Nelson, A.R., 1981, Quaternary glacial and marine stratigraphy of Qivitu Peninsula, northern Cumberland Peninsula, Baffin Island: Geological Society of America Bulletin, v. 92, Pt I, p. 512-518, Pt. II, p. 1143-1261.

Nelson, A.R., 1982, Aminostratigraphy of Quaternary marine and glaciomarine sediments, Qivitu Peninsula, Baffin Island: Canadian Journal of Earth Sciences, v. 19, p. 945-961.

Nishiizumi, K., Kohl, C.P., Arnold, J.R.,Klein, J., Fink, D., and Middleton, R., 1991, Cosmic ray produced $^{10}$Be and $^{26}$Al in Antarctic rocks: Exposure and erosion history: Earth and Planetary Science Letters, v. 104, p. 440-454.

Nishiizumi, K., Lal, D., Klein, J., Middleton, R., and Arnold, J.R., 1986, Production of $^{10}$Be and $^{26}$Al by cosmic rays in terrestrial quartz *in situ* and implications for erosion rates: Nature, v. 319, p. 134-136.

Nishiizumi, K., Winterer, E.L., Kohl, C.P., Klein, J., Middleton, R., Lal, D., and Arnold, J.R., 1989, Cosmic ray production rates of $^{10}$Be and $^{26}$Al in quartz from glacially polished rocks: Journal of Geophysical Research, v. 94, p. 17907-17915.

Osterman, L.E. and Nelson, A.R., 1989, Latest Quaternary and Holocene paleoceanography of the eastern Baffin Island continental shelf, Canada: Benthic foraminiferal evidence: Canadian Journal of Earth Sciences, v. 26, p. 2236-2248.

Osterman, L.E., Miller, G.H., and Stravers, J.A., 1985, Late and mid-Foxe glaciation of southern Baffin Island *in* Andrews, J.T., ed., Quaternary Environments; Eastern Canadian Arctic, Baffin Bay, and Western Greenland, chapter 18: Allen & Unwin, Boston, p. 520-545.

Phillips, F.M., Leavy, B.D., Jannik, N.O., Elmore, D., and Kubik, P., 1986, The accumulation of cosmogenic chlorine-36 in rocks: a method for surface exposure dating, Science, v. 231, p. 41-43.

Phillips, F.M., Zreda, M.G., Smith, S.S., Elmore, D., Kubik, P.W., and Sharma, P., 1990, Cosmogenic, chlorine-36 chronology for glacial deposits at Bloody Canyon, eastern Sierra Nevada: Science, v. 248, p. 1529-1532.

Praeg, D.B., MacLean, B., Hardy, I.A., and Mudie, P.J., 1986, Quaternary geology of the southeast Baffin Island continental shelf: Geological Survey of Canada Paper 85-14, 38 pp.

Raisbeck, G.M., Yiou, F., Klein, J., and Middleton, R., 1983, Accelerator mass spectrometer measurement of cosmogenic $^{26}$Al in terrestrial and extraterrestrial matter: Nature, v. 301, p. 690-692.

Sauer, P.E. and Miller, G.H., 1991, Continuous records of late Quaternary climate change in arctic lake sediments, Baffin Island, Arctic Canada: Geological Society of America, Abstracts with Program, v. 23, p. A406.

Short, S.K., Mode, W.N., and Davis, P.T., 1985, The Holocene record from Baffin Island: Modern and fossil pollen studies *in* Andrews, J.T., ed., Quaternary Environments; Eastern Canadian Arctic, Baffin Bay, and Western Greenland, chapter 22: Allen & Unwin, Boston, p. 608-642.

Stafford, T.W.J., Abbott, M., and Jull., A.J.T., 1990, Accelerator $^{14}C$ dating of organic carbon fractions in lake sediments from Baffin Island and Arctic Canada: Geological Society of America, Abstracts with Programs, v. 22, p. A310.

Staudacher, T. and Allegre, C.J., 1991, Cosmogenic neon in ultramafic nodules from Asia and in quartzite from Antarctica: Earth and Planetary Science Letters, v. 106, p. 87-102.

Sugden, D.E. and Watts, S.H., 1977, Tors, felsenmeer, and glaciation in northern Cumberland Peninsula, Baffin Island: Canadian Journal of Earth Sciences, v. 14, p. 2817-2823.

Sugden, D.E., 1977, Reconstruction of the morphology, dynamics, and thermal characteristics of the Laurentide Ice Sheet: Arctic and Alpine Research, v. 9, p. 21-47.

Swanson, T.W., Sharma, P., Phillips, F.M., and Zreda, M.G., 1992, Determination of 36-Cl production rates from the deglaciation of Whidbey Island, Washington: American Chemical Society, 203rd annual meeting, San Francisco, California.

Tric, E., 1992, Paleointensity of the geomagnetic field during the last 80,000 years: Journal of Geophysical Research, v. 97, p. 9337-9351.

Vincent, J.-S. and Prest, V.K., 1987, The early Wisconinan history of the Laurentide Ice Sheet: Geographis physique et Quaternaire, v. 41, no. 2, p. 199-213.

Watts, S.H., 1979, Some observations on rock weathering, Cumberland Peninsula, Baffin Island: Canadian Journal of Earth Sciences, v. 16, p. 977-983.

Watts, S.H., 1983, Weathering processes and products under arctic conditions: A study from Ellesmere Island, Canada: Geografiska Annaler, v. 65A, p. 85-98.

Watts, S.H., 1985, A scanning electron microscope study of bedrock microfractures in granites under high Arctic conditions: Earth Surface Processes & Landforms, v. 10, p. 161-172.

Watts, S.H., 1986, Intensity versus duration of bedrock weathering under periglacial conditions in high Arctic Canada: Biuletyn Peryglacjalny, v. 30, p. 141-152.

Zreda, M.G., Phillips, F.M., and Smith, S.S., 1990, Cosmogenic $^{36}Cl$ dating of geomorphic surfaces: New Mexico Institute of Mines and Technology, H90-1.

Zreda, M.G., Phillips, F.M., E.more, D., Kubik, P.W., Sharma, P., and Dorn, R.I., 1991, Cosmogenic chlorine-36 production rates in terrestrial rocks: Earth and Planetary Science Letters, v. 105, p. 94-109.