Géographie physique et Quaternaire

The Quaternary History of Cumberland Sound, Southeastern Baffin Island: The Marine Evidence

Le Quaternaire de la baie de Cumberland, au sud-est de l'île de Baffin : les données marines

Die Quaternärgeschichte der Bucht von Cumberland im Südosten der Baffin-lnsel: Die marinen Belege

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Volume 47, Number 1, 1993

URI: https://id.erudit.org/iderudit/032929ar
DOI: https://doi.org/10.7202/032929ar

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Publisher(s)

Les Presses de l'Université de Montréal

ISSN

0705-7199 (print)
1492-143X (digital)

Explore this journal

Cite this article

Jennings, A. E. (1993). The Quaternary History of Cumberland Sound, Southeastern Baffin Island: The Marine Evidence. *Géographie physique et Quaternaire*, *47*(1), 21–42. https://doi.org/10.7202/032929ar

Article abstract

Acoustic and core data from Cumberland Sound show that glacial ice derived from the Foxe Sector (Amadjuak Dome) of the Laurentide Ice Sheet advanced to the continental shelf at the mouth of the sound during a late phase of the Foxe Glaciation. The basal lithofacies/acoustic unit (Ai/BUD) in the sound is a massive, black diamicton. On the basis of strati-graphic, acoustic, lithologie and faunal evidence, this unit is interpreted as till. The till is overlain by an ice proximal to ice distal glacial-marine sediment sequence termed the Davis Strait Silt (DSS). The influence of ice retreat is reflected in the foraminiferal assemblages of the DSS. Rapid sedimentation rates in the sound prevailed during deposition of the DSS as shown by the conformable geometry of the DSS. Accelerator Mass Spectrometry dates on molluscs and foraminifera and a single conventional 14C date on disseminated organic material from ice proximal sediment of the DSS (lithofacies B and lower lithofacies C) indicate that the ice retreated rapidly from its probable maximum position on the shelf no earlier than ca. 13,400 BP and into the fiords along the coast of the sound by ca. 8900 BP. Deposition of ice-distal glacial marine sediments (lower lithofacies D) continued in the sound until ca. 7600 BP as the ice margin rapidly retreated into the fiords. Between ca. 8900 BP and ca. 8000 BP, the foraminiferal fauna show that the influence of glacial ice is remote and that "Atlantic Water" impinges on the seafloor. Postglacial sedimentation began in the sound at ca. 7600 BP. Retreat of the ice margin onto land made the fiord basins available as sediment catchments. The reduced sedimentation rates in the sound during this interval are indicated by the change to onlapping basin fill geometry of the Tiniktartuq Silt and Clay (TS&C). Calcareous foraminifera disappear from the sediments by ca. 6300 BP and are replaced by agglutinated foraminifera reflecting "Arctic Water" conditions at the seafloor. The TS&C is presently being deposited in the sound.

Géographie physique et Quaternaire, 1993, vol. 47, n° 1, p. 21-42, 11 fig., 3 tabl.

THE QUATERNARY HISTORY OF CUMBERLAND SOUND, SOUTHEASTERN BAFFIN ISLAND: THE MARINE EVIDENCE

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ABSTRACT Acoustic and core data from Cumberland Sound show that glacial ice derived from the Foxe Sector (Amadjuak Dome) of the Laurentide Ice Sheet advanced to the continental shelf at the mouth of the sound during a late phase of the Foxe Glaciation. The basal lithofacies/acoustic unit (Ai/BUD) in the sound is a massive, black diamicton. On the basis of stratigraphic, acoustic, lithologic and faunal evidence, this unit is interpreted as till. The till is overlain by an ice proximal to ice distal glacial-marine sediment sequence termed the Davis Strait Silt (DSS). The influence of ice retreat is reflected in the foraminiferal assemblages of the DSS. Rapid sedimentation rates in the sound prevailed during deposition of the DSS as shown by the conformable geometry of the DSS. Accelerator Mass Spectrometry dates on molluscs and foraminifera and a single conventional ^{14}C date on disseminated organic material from ice proximal sediment of the DSS (lithofacies B and lower lithofacies C) indicate that the ice retreated rapidly from its probable maximum position on the shelf no earlier than *ca.* 13,400 BP and into the fiords along the coast of the sound by *ca.* 8900 BP. Deposition of ice-distal glacial marine sediments (lower lithofacies D) continued in the sound until *ca.* 7600 BP as the ice margin rapidly retreated into the fiords. Between *ca.* 8900 BP and *ca.* 8000 BP, the foraminiferal fauna show that the influence of glacial ice is remote and that "Atlantic Water" impinges on the seafloor. Postglacial sedimentation began in the sound at *ca.* 7600 BP. Retreat of the ice margin onto land made the fiord basins available as sediment catchments. The reduced sedimentation rates in the sound during this interval are indicated by the change to onlapping basin fill geometry of the Tiniktartuq Silt and Clay (TS&C). Calcareous foraminifera disappear from the sediments by *ca.* 6300 BP and are replaced by agglutinated foraminifera reflecting "Arctic Water" conditions at the seafloor. The TS&C is presently being deposited in the sound.

RÉSUMÉ *Le Quaternaire de la baie de Cumberland, au sud-est de l'île de Baffin: les données marines.* Les données acoustiques ou issues des forages en provenance de la baie de Cumberland démontrent que la glace du secteur de Foxe (dôme d'Amadjuak) de l'Inlandsis laurentidien est parvenue sur le plateau continental, à l'embouchure de la baie, au cours d'une phase tardive de la Glaciation de Foxe. L'unité de base est un diamicton massif noir identifiée comme étant un till. Le till est recouvert par une séquence de sédiments glacio-marins proximaux et distaux appelée Silt de Davis Strait. Le retrait glaciaire a eu des conséquences sur la nature des assemblages de foraminifères dans le Silt de Davis Strait. Des taux rapides de sédimentation ont caractérisé le dépôt de ce silt comme le montre sa géométrie concordante. Les datations obtenues par accélérateur de particules sur les mollusques et les foraminifères et une datation au ^{14}C conventionnelle sur du matériel organique disséminé dans le sédiment de contact glaciaire du Silt montre que la glace s'est retirée rapidement à partir de sa position maximale probable sur le plateau continental, à partir d'environ 13 400 BP, pour s'écouler dans les fjords le long de la côte vers 8900 BP. Le dépôt des sédiments glacio-marins distaux s'est poursuivi dans la baie jusque vers 7600 BP, alors que la marge glaciaire se retirait rapidement vers les fjords. Entre 8900 BP et environ 8000 BP, l'influence des glaciers s'est peu fait sentir sur les foraminifères, et l'eau de l'Atlantique a envahi les fonds marins. La sédimentation postglaciaire a commencé dans la baie vers 7600 BP. Le changement de géométrie des Silts et argiles de Tiniktartuk devenus chevauchants reflète la diminution des taux de sédimentation dans le détroit au cours de cette période. Les foraminifères à test calcitique n'apparaissaient plus dans les sédiments vers 6300 BP et ont été remplacés par les foraminifères à test agglutiné, témoignant ainsi de la présence des eaux arctiques.

ZUSAMMENFASSUNG *Die Quaternärgeschichte der Bucht von Cumberland im Südosten der Baffin-Insel: Die marinen Belege.* Akustische und durch Bohrungen gewonnene Daten von der Cumberland-Bucht zeigen, daß glaziales Eis vom Foxe-Sektor (Amadjuak Dom) der laurentischen Eisdecke zur kontinentalen Plattform am Mund der Bucht während einer späten Phase der Foxe-Vereisung vordrang. Die an der Basis befindliche Lithofazies/akustische Einheit (Ai/BUD) in der Bucht ist ein massives schwarzes Diamikton. Auf der Grundlage von stratigraphischen, akustischen, lithologischen und Fauna-Belegen wird diese Einheit als Till interpretiert. Das Till wird von einer Sequenz glaziomariner Eis-proximal bis Eis-distal-Sedimente überlagert, welche Davis Strait Silt (DSS) genannt wird. Der Einfluß des Eisrückzugs spiegelt sich in den Foraminiferen-Einhèiten des DSS. Schnelle Sedimentierungsraten herrschten in der Bucht während der Ablagerung des DSS vor, wie aus der gleich gelagerten Geometrie des DSS ersichtlich. Durch Teilchenbeschleuniger gewonnene Daten auf Mollusken und Foraminiferen und eine einzelne konventionelle ^{14}C-Datierung auf verstreutem organischem Material von dem proximalen Eissediment des DSS (Lithofazies B und niedrigere Lithofazies C) zeigen, daß das Eis sich rasch von seiner wahrscheinlichen maximalen Position auf der Plattform nicht vor *etwa* 13,400 v.u.Z. zurückzog und in die Fjorde entlang der Küste der Bucht um *etwa* 8900 v.u.Z. eindrang. Die Ablagerung der glazio-marinen distalen Sedimente (untere Lithofazies D) setzte sich in der Bucht weiter bis *etwa* 7600 v.u.Z. fort, als der Eisrand sich rasch in die Fjorde zurückzog. Zwischen *etwa* 8900 v.u.Z. und *etwa* 8000 v.u.Z. zeigt die Fauna der Foraminiferen, daß der Einfluß des glazialen Eises gering war, und daß "atlantisches Wasser" auf den Meeresgrund übergreift. Die postglaziale Sedimentierung begann in der Bucht um *etwa* 7600 v.u.Z. Die geringen Sedimentierungsraten in der Bucht während dieses Intervalls sind am Wechsel zu überlappender Geometrie der Beckenfüllung mit Tiniktartuq Schlamm und Lehm (TS&C) erkennbar.

Manuscrit reçu le 18 décembre 1991; manuscrit révisé accepté le 12 mai 1992

INTRODUCTION

The Late Wisconsinan configuration of the northeastern sector of the Laurentide Ice Sheet has been extensively revised during the past decade (*e.g.* Stravers, 1986; Lauriol and Gray, 1987; Miller *et al.*, 1988; Evans, 1990; Miller and Kaufman, 1990; Andrews *et al.*, 1991). This paper adds to this trend by revising the late Foxe (= Wisconsinan) margin of the Laurentide Ice Sheet in Cumberland Sound (Fig. 1). The marine geological data presented in this paper show that glacial ice from the Foxe sector of the Laurentide Ice Sheet filled much of Cumberland Sound *ca.* 13,400 BP and retreated to the fiords along the coast of the sound by *ca.* 8900 BP.

Previous interpretations of the glacial history of Cumberland Sound were based on the terrestrial glacial record without the benefit of data on sediments within the sound itself (Dyke, 1977, 1979; Miller, 1985). The terrestrial glacial record shows that during the Quaternary, Cumberland Sound served as a drainage route for regional ice on Baffin Island and for local ice-dispersal centers on the bordering peninsulas (Dyke, 1977, 1979; Miller, 1985; Stravers, 1986). But, based on the mapped glacial limits, glacier ice did not appear to have extended significantly beyond the head of Cumberland Sound for at least the past 70,000 yrs. (Dyke, 1977, 1979; Dyke *et al.*, 1982). The first information on the sediments within the sound was the acoustic data and cores. obtained in 1985 by the Geological Survey of Canada. Preliminary interpretation of these data showed that the late Quaternary sediment sequence overlying bedrock comprised a basal diamicton, interpreted as till, overlain by glacial

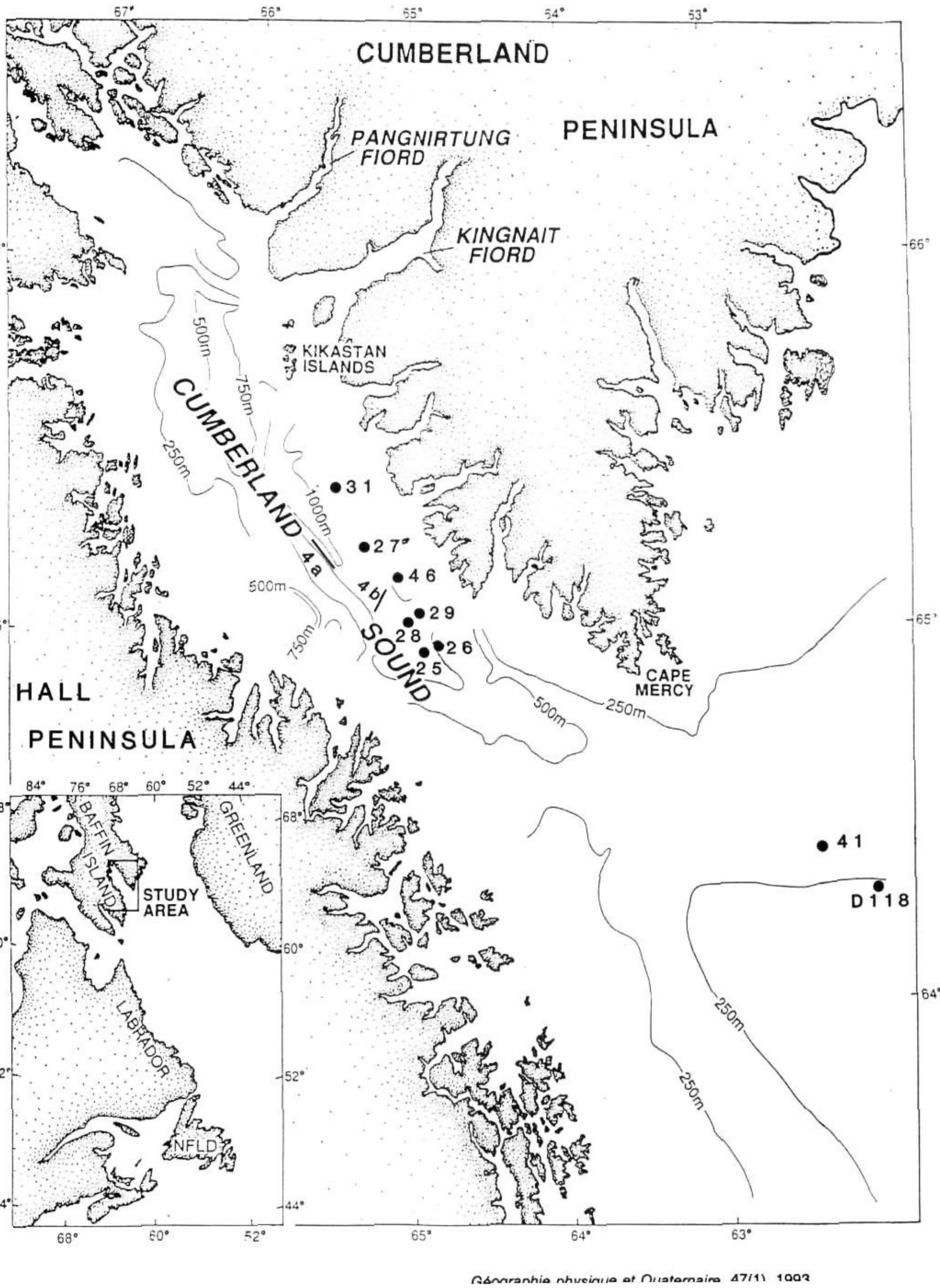


FIGURE 1. Location map showing bathymetry, core and bedrock sample sites and the position of the Huntec profiles shown in Figures 4A and B.

Carte de localisation montrant la bathymétrie, les sites de forage et l'emplacement des profils Huntec illustrés à la figure 4.

marine and postglacial sediments (MacLean *et al.*, 1986). In contrast to the terrestrial glacial record, this sequence suggested that Cumberland Sound was inundated by grounded glacial ice during a late phase of the Foxe Glaciation.

To resolve the conflicting terrestrial and marine interpretations, the acoustic and core data collected in 1985 were studied to determine the genesis of the sediment units in the sound. The next section of this paper contains a brief description of the bathymetry and onshore and offshore bedrock geology to provide background for interpreting the acoustic, sedimentologic, chronologic, mineralogic and foraminiferal data presented in subsequent sections. Finally, based on the data presented in this paper and on the previous work, the late Quaternary glacial and paleoceanographic history of Cumberland Sound is synthesized and an ice reconstruction for the area is presented.

PHYSIOGRAPHIC SETTING

Cumberland Sound is an elongate asymmetrical trough adjoining the broad platform of the southeastern Baffin shelf (Fig. 1). The sound shallows both landward and seaward. A narrow, deep basin with maximum water depths of 1100 m underlies the outer NE portion of the sound. The piston cores were taken from this subbasin.

The arrangement and composition of the bedrock in the region is extremely important in the interpretation of sediment provenance in the sound (Fig. 2). Onshore, Precambrian granite and granitic gneiss are the dominant lithologies (Riley, 1960; Jackson and Taylor, 1972).

Metasedimentary rocks including marble, quartzite and meta-arkose occur in subsidiary amounts, notably at the head of the sound and the outer third of Cumberland Peninsula. Marble outcrops are not extensive. They contain more than 85% calcite and no dolomite (Riley, 1960; Blackadar, 1967). Paleozoic limestone crops out on southern Baffin Island, in Foxe Basin and near the head of Frobisher Bay (Jackson and Taylor, 1972).

The Precambrian metamorphic rocks of southern Baffin Island extend offshore to form the bedrock of the southwestern half and inner third of Cumberland Sound (Fig. 2) (MacLean *et al.*, 1986). Ordovician limestone bedrock underlies the seafloor at the mouth of Cumberland Sound and extends from the shelf northwestward for 70 km into Cumberland Sound in a 10-to-15 km wide swath on the southwestern side (MacLean et *al.*, 1977; MacLean and Falconer, 1979; MacLean *et al.*, 1982, 1986). Cretaceous, semiconsolidated, black mudstone and siltstone occur beneath the northeastern half of Cumberland Sound (MacLean *et al.*, 1986). These strata are folded and truncated, yielding a smooth seafloor morphology. Lower Tertiary mudstone underlies the central and outer parts of the southeastern Baffin shelf seaward of the mouth of Cumberland Sound (Grant, 1975; MacLean *et al.*, 1982; MacLean, 1985).

MATERIALS AND METHODS

The geophysical data and sediment cores used in this study were collected during Bedford Institute of Oceanography cruises between 1977 and 1985. Acoustic and core data from within the sound were collected during cruise 85027 in 1985. Cruises prior to 1985 obtained data from the mouth of the sound and the shelf outside of the sound. Navigation was provided by BIONAV (the Bedford Institute of Oceanography Integrated Navigation System). BIONAV uses Loran C and Satellite systems assisted by radar fixing. The accuracy of the navigational positioning during the 1985 cruise was about 300 m.

GEOPHYSICAL DATA

Geophysical data were used to map acoustic stratigraphic units and to measure the thickness of the surficial sediments (Fig. 3). The geophysical systems included a Huntec, deep-towed, high-resolution, seismic system (Hutchins *et al.*, 1976), 14.25 kHz and 12 kHz echo-sounding systems, and an air-gun system (655 cm^3 compressed air source). Usually, the Huntec system provided stratigraphic data throughout the surficial sediment section with a resolution of 0.3-0.5 m. To define the edge of acoustic units beyond the resolution of the Huntec system the echo sounder systems were used. The air-gun data were used to confirm the top of the bedrock.

SEDIMENT CORES

Core data were used to verify the interpretations of the geophysical data. Seven piston and trigger-weight cores were collected during cruise 85027 from the main sedimentary basin in Cumberland Sound (Fig. 1, Table I). The core sites were chosen from the Huntec profiles to ensure sampling of the entire surficial sediment section. A piston core, 82034-041, from the shelf beyond the mouth of the sound was also used in this study (Fig. 1). The cores were split longitudinally while on board the ship. Each archive half was photographed, visually described, logged for magnetic susceptibility (MS) at 5-cm intervals and x-rayed. Each working half was sampled for geotechnical properties (water content, bulk density and shear strength), sediment properties (texture, organic matter content, and carbonate content), clay mineralogy and foraminifera at 20 to 40-cm intervals.

Radiocarbon Dating

Benthic foraminifera, molluscs and fish bones from the 1985 cores were radiocarbon dated at the accelerator mass spectrometry (AMS) laboratory at the University of Arizona. The radiocarbon date from the 1982 core was determined on organic matter by the Beta Analytic Laboratory. The dates were standardized by substracting an estimated 450-year reservoir effect so they could be directly compared to other dates from the region (*e.g.* Stravers, 1986; Miller *et al.*, 1988).

Sedimentological Analyses

The sedimentological analyses reported in this study were performed at the Sedimentology Laboratory at the Institute of Alpine and Arctic Research (INSTAAR). The particle size distributions of the sediment samples were measured using a combination of dry sieving (Ro-tap) and sedimentation (Sedigraph 5000D Particle Size Analyzer). A Chittick apparatus was used to quantify the carbonate content (Dreimanis, 1962). Potassium dichromate titration was used to measure the organic matter content of the sediments (Walkley, 1947).

X-Ray Diffraction Analysis

Conventional x-ray diffraction (XRD) techniques were used to determine the clay-sized mineralogy of sediments from four cores: 85027-029, 85027-031, 85027-025 82034-041, and two bedrock samples: Cretaceous bedrock from the base of 85027-031 PC, and Tertiary bedrock from a bedrock drill sample, 80028-D118 (Fig. 1). To prepare the sediments for XRD analysis the <2 μm fraction was isolated by suspension settling, and washed and centrifuged three times to remove salts. The clay slurry was deposited onto glass slides and allowed to dry overnight.

The mineralogy of the dried clay-sized material was analyzed at the Bedford Institute of Oceanography (B.I.O.) using a Siemens Diffrac 500 with Ni-filtered CuK radiation. Each slide was scanned 3 times under different conditions. The first scan was from 2 to 67° 2ø at 2° 2 ø/min. This scan provided the basic mineralogical data. The second scan was from 24 to 26° 2ø at 0.25° 2ø/min. This scan resolved the 3.54 A° chlorite and the 3.58 A° kaolinite peaks (Biscaye, 1965). The third scan was from 2 to 14° 2ø at 2° 2ø/min after the sediment had been placed in a glycol environment under vacuum for 24 hours. This scan was used to identify smectite. Two additional scans were done on 6 representative samples. These

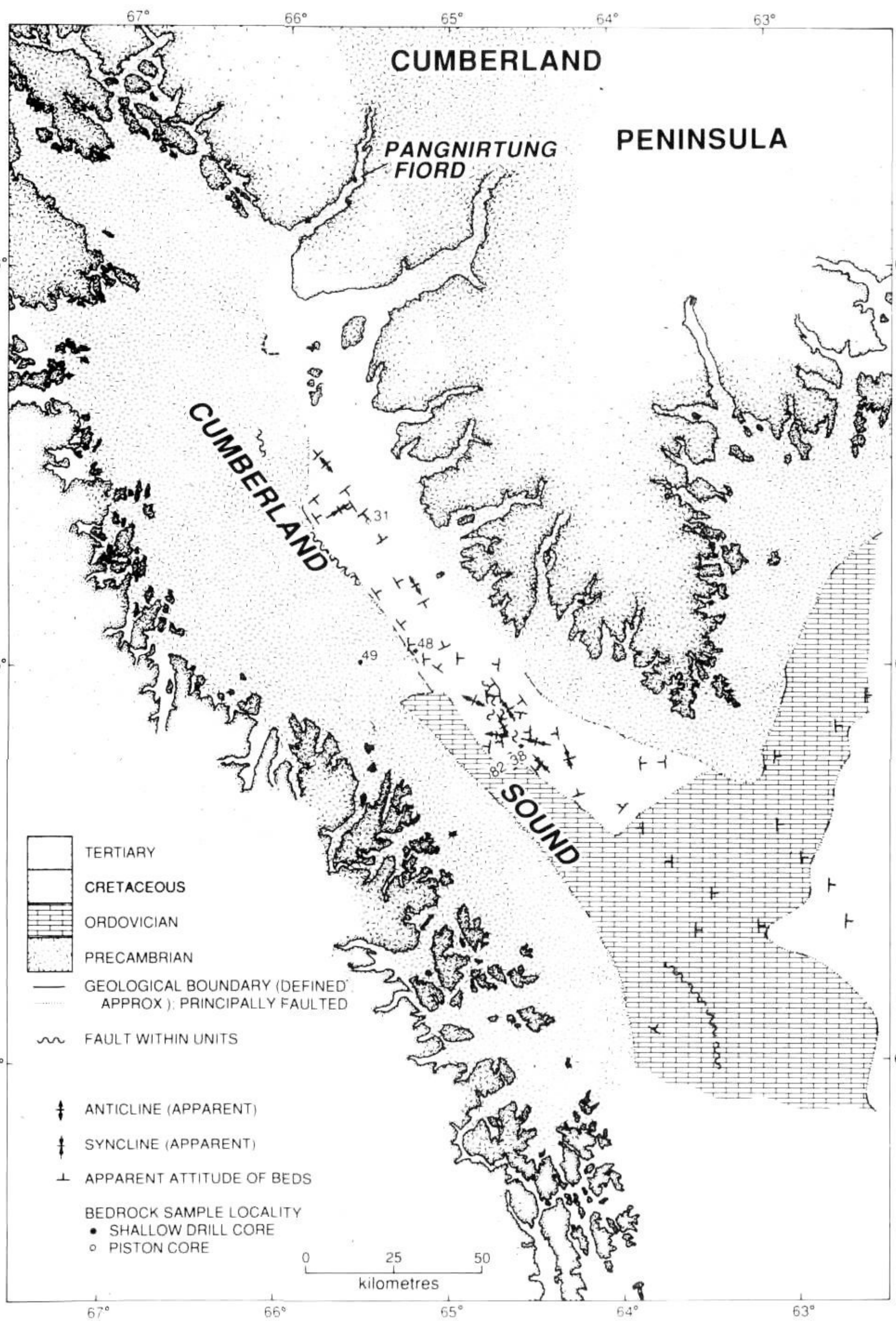


FIGURE 2. Bedrock map of Cumberland Sound. The Cretaceous mudstone underlies the deep basin along the north-eastern half of the sound (from MacLean *et al.*, 1986). Unmapped areas are shown in white.

Carte du substratum rocheux de la baie de Cumberland. La pélite du Crétacé constitue la base du profond bassin situé dans la partie nord-est de la baie (de MacLean et al., 1986). Les parties non cartographiées sont en blanc.

scans were heating tests at 300 and 550 °C from 2 to 16° 2ø at 2° 2ø/min. They were used to identify smectite and kaolinite, respectively. To obtain semiquantitative abundance data for the mineral assemblage the mineral intensity factors of Cook *et al.* (1975) were used, with the modifications reported in Andrews *et al.* (1989a).

Foraminiferal Analysis

To isolate foraminifera the sediment samples were wet-sieved at 63 μm; foraminifera were picked from the >63 μm fraction. To concentrate the foraminifera from sandy samples, the >63 μm fraction was floated in carbon tetrachloride. Samples from two cores were analyzed: 85027-025 PC (13 samples) and 85027-029 PC & TWC (20 samples). A split of each sample yielding approximately 300 individual foraminifera was examined under a binocular microscope. Foraminiferal species were identified using illustrated references (Loeblich and Tappan, 1964; Feyling-Hanssen *et al.*, 1971; Cole, 1981) and reference slides; F.E. Cole (B.I.O.) checked the identifications for several samples. The raw counts were converted to percentages to examine the foraminiferal assemblages. The Shannon-Weaver Information Function, H(S) (Shannon and Weaver, 1949; Buzas and Gibson, 1969) was used as a measure of species diversity. The age of the foraminiferal assemblage boundaries is based on the chronology established for 85027-029 PC & TWC.

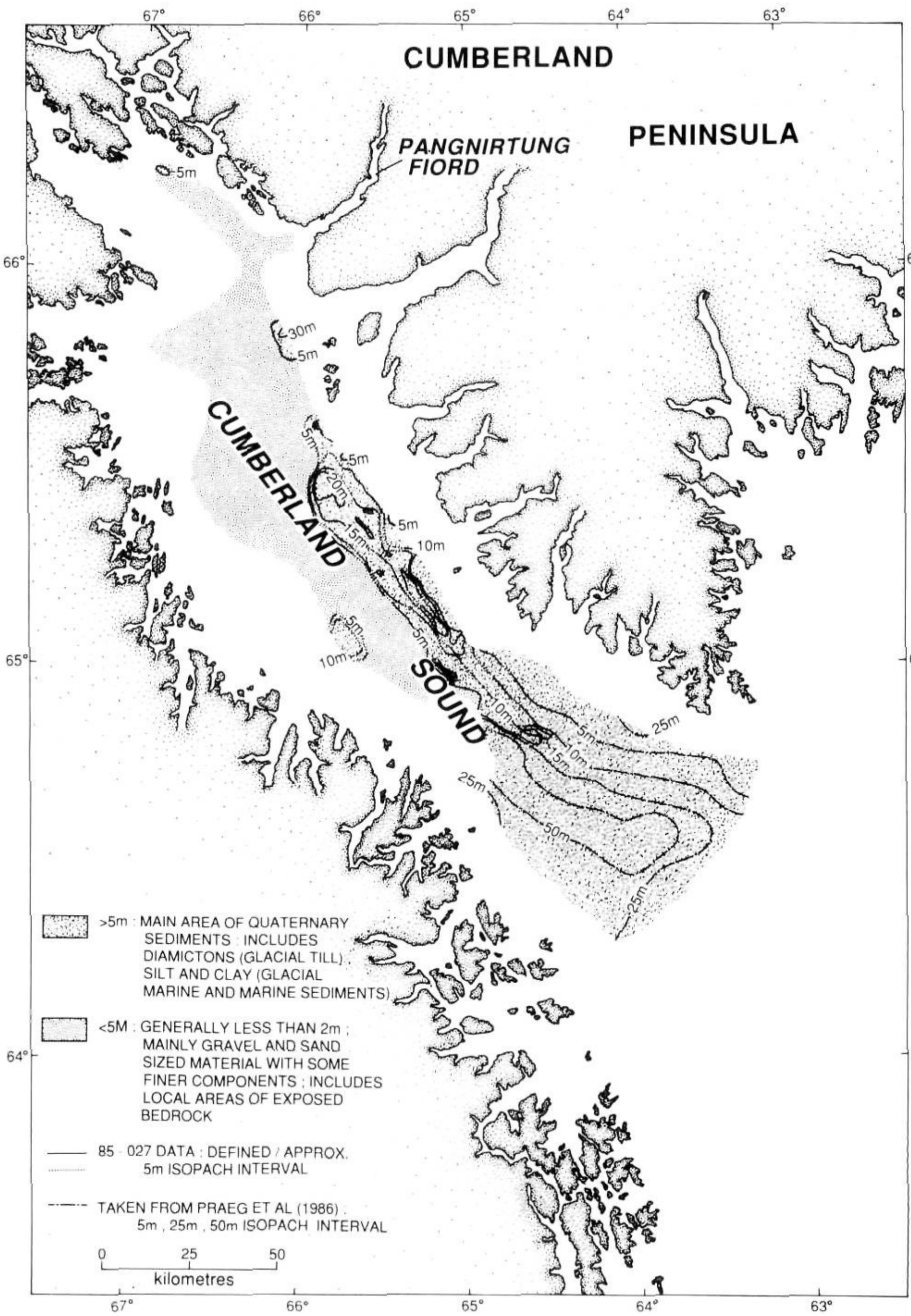


FIGURE 3. Isopach of total unconsolidated sediments in Cumberland Sound. The main accumulation of sediments occurs in the deep subbasin on the northern side of the sound, well beyond both the late and early Foxe glacial limits (from MacLean *et al.*, 1986).

Isopaques des sédiments non consolidés dans la baie de Cumberland. L'accumulation la plus importante se trouve dans le sous-bassin profond situé dans la partie septentrionale, bien au-delà des limites du Foxe supérieur ou inférieur (de MacLean et al.*, 1986).*

TABLE I

Sediment Cores Used in This Study

Cruise Number	Core Number	Latitude (°N)	Longitude (°W)	Water Depth (m)	Core Length (m)
85027	025 TWC	64 56.43	64 57.78	823	2.06
	025 PC				6.30
	026 TWC	64 57.16	64 52.19	816	1.46
	026 PC				8.60
	027 TWC	65 13.04	65 20.15	896	2.41
	027 PC				11.50
	028 TWC	65 01.88	65 03.36	850	1.98
	028 PC				10.20
	029 TWC	65 02.57	64 59.51	814	1.47
	029 PC				11.40
	031 TWC	65 23.34	65 30.53	896	2.60
	031 PC				8.00
	046 TWC	65 10.82	65 09.92	845	2.15
	046 PC				4.92
82034	041 PC	64 25.05	62 26.04	340	3.68

ACOUSTIC STRATIGRAPHY

The thickest unconsolidated sediments in Cumberland Sound coincide with the deepest water and with the distribution of sedimentary bedrock (Fig. 3) (MacLean *et al.*, 1986). They lie well beyond the maximum ice margins of the Foxe Glaciation (directly east of Pangnirtung Fiord) delineated from onshore data (Dyke, 1979). In the deeper northeastern half of the sound, up to 30 m of Quaternary sediments overlie the erosional surface on the Cretaceous mudstone. At the mouth of the sound, up to 50 m of sediments overlie Ordovician carbonate and Cretaceous mudstone. In the southwestern and inner parts of the sound, where the Precambrian gneiss forms a rough seafloor morphology, the surficial sediments occur as a thin (<1-2 m) discontinuous cover.

Three acoustic sediment units were identified from the geophysical profiles. The thickness, areal extent, acoustic character and genetic interpretation of each unit are described below.

BASAL UNSTRATIFIED DIAMICTON

The basal unstratified diamicton (BUD) is an acoustically unstratified unit that overlies bedrock. Within the deep, inner part of the sound, the BUD mainly is thin (< 5 m) and confined between the 750 and 1,000 m isobaths. At the mouth of the sound it thickens dramatically, especially offshore from Hall Peninsula where it exceeds 50 m. In the outer part of the sound, the areal extent and thickness of the BUD appear to be independant of bathymetry. The BUD usually has a strong, irregular surface reflection (Fig. 4), but in places it has a smooth surface and it thickens and thins laterally by infilling bedrock depressions, or it occurs in positive relief on the bedrock surface (Fig. 4). Do these acoustic characteristics suggest that the BUD is a subglacial deposit?

Subglacial sediments (*i.e.* tills) are identified as acoustic facies with a massive, dense acoustic signature, devoid of coherent internal reflections (*e.g.* Boulton *et al.*, 1980; Josenhans *et al.*, 1986; King and Fader, 1986; Bonifay and Piper, 1988; MacLean *et al.*, 1989). In addition, tills usually have a strong surface reflection; they can have an undulating or irregular surface resulting from iceberg scours and/or ice sheet sole marks; they may smoothly mantle the seafloor or vary in thickness. Moraines and other constuctional features composed of sediments interpreted as till have been recognized in acoustic profiles. Because the BUD displays many of these acoustic characteristics, it is interpreted to be till. This interpretation is supported by the lithological properties of this unit (lithofacies Ai) discussed later.

DAVIS STRAIT SILT

The Davis Strait Silt (DSS), defined originally by Praeg *et al.* (1986), is an acoustically well to poorly stratified conformable unit with moderate acoustic transparency (Fig. 4B). It overlies bedrock and the BUD and crops out at the seafloor beyond the onlapping edge of the Tiniktartuq Silt and Clay. The acoustic stratification of the DSS mimics the topographic irregularities on the surface of the underlying BUD (Fig. 4B). In places, the basal part of the DSS is characterized by a 2-3 m interval of very closely spaced wavy reflectors. In other instances, the base of the DSS is a thin interval lacking internal reflections (Fig. 4B). The DSS ranges between 0 and 7.5 m in thickness, except in the northwestern end of the main sedimentary basin and in subbasin off Kingnait Fiord, where it exceeds 10 m. Praeg *et al.* (1986) mapped the DSS elsewhere on the southeastern Baffin Shelf and interpreted it as a glacial-marine unit. No evidence of the iceberg scoured subunit of the DSS observed by Praeg *et al.* (1986) at the mouth of Cumberland Sound in water depths between 200 and 750 m was observed within the sound (Praeg *et al.*, 1986; Andrews *et al.*, 1991). The stratigraphic position and acoustic character of the DSS in Cumberland Sound support the interpretation that the DSS is glacial-marine in origin.

TINIKTARTUQ SILT AND CLAY

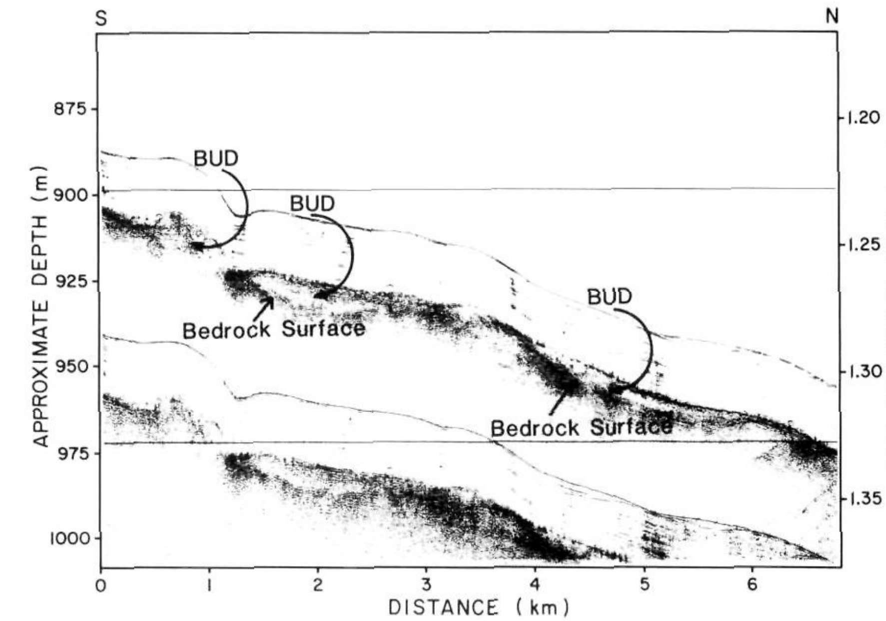
The Tiniktartuq Silt and Clay (TS&C) was defined by Praeg *et al.* (1986) as an acoustically stratified, moderately to highly transparent, onlapping basin-fill unit (Fig. 4B). It is the uppermost acoustic unit in Cumberland Sound. This unit is confined to water depths > 500 m at the mouth of the sound, but inside the sound it is restricted to > 750 m water depth. It varies in thickness between 0 and 17 m. The thickest sections occur in the deep axial basin of the sound, and in the sub-basin offshore from Kingnait Fiord. Elsewhere on the southeastern Baffin shelf, the TS&C has been interpreted as a postglacial sediment unit (Praeg *et al.*, 1986). The TS&C represents postglacial sedimentation in Cumberland Sound.

INTERPRETATION OF ACOUSTIC STRATIGRAPHY

Comparison of Quaternary sediment sequences on previously glaciated shelves, such as the Labrador Shelf (Josenhans *et al.*, 1986; Vilks *et al.*, 1984), the Scotian Shelf (King and Fader, 1986), the southeastern Baffin Shelf (Praeg *et al.*, 1986), the Arctic Island Channels (MacLean *et al.*, 1989), the coast of Maine (Kelley *et al.*, 1987), western Scotland (Boulton *et al.*, 1980) and the northern Norwegian shelf (Rokoengen *et al.*, 1979) shows that the principal acoustic sequences deposited during one glacial cycle are very similar. The generalized sequence produced when a grounded glacier retreats from a marine area consists of acoustically massive till (*e.g.* Scotian Shelf Drift, and Labrador Shelf Drift) overlain by an acoustically stratified, conformable glacial marine sediments (*e.g.* Emerald Silt, Scotian Shelf and the Qeovik Silt, Labrador Shelf) and capped by stratified, basin-fill postglacial marine sediments (*e.g.* LaHave Clay, Scotian Shelf and Makkaq Clay, Labrador Shelf). The acoustic facies sequence in Cumberland Sound strongly resembles this generalized deglacial sequence.

LITHOFACIES SEQUENCE

Five lithofacies, named A (base) through E (top), were defined using the visual and x-radiograph descriptions, magnetic susceptibility and sedimentological and geotechnical analyses of the sediment cores (Fig. 5, Table II). Sediment color, texture and the presence/absence of stratification were the most important variables for distinguishing lithofacies. The five lithofacies are described below, beginning with the lowermost lithofacies.



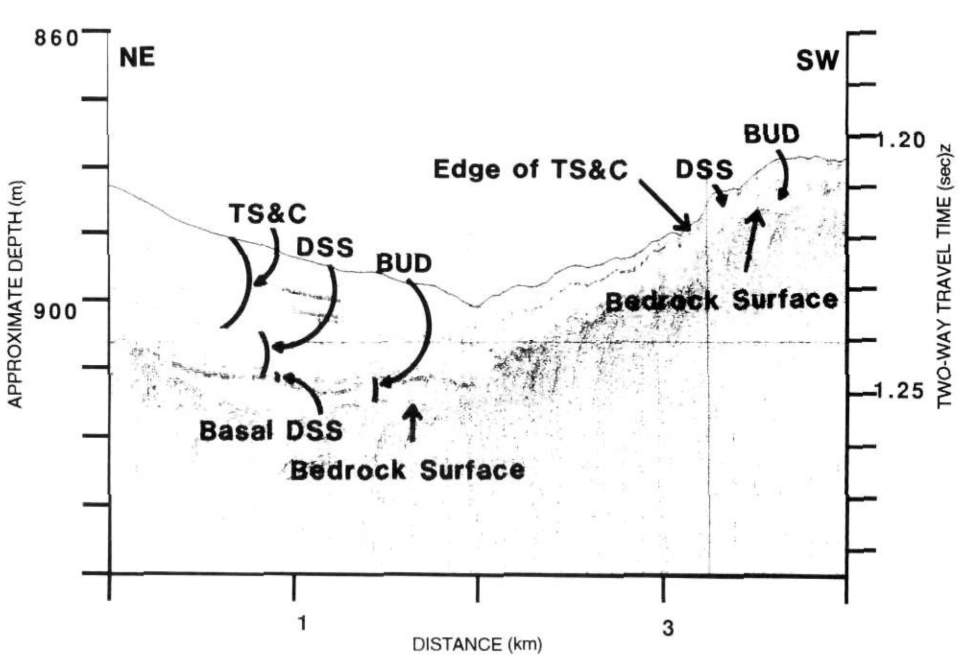


FIGURE 4. A) Huntec profile illustrating the Basal Unstratified Diamicton (BUD) infilling bedrock hollows and forming a mound or ridge on bedrock. B) Huntec profile illustrating characteristics of the acoustic units and their vertical relationships. The profile locations are shown in Figure 1. TS&C is the Tiniktartuq Silt & Clay, and DDS is the Davis Strait Silt.

Profil Huntec montrant le diamicton de base non stratifié (BUD) remplissant les dépressions du substratum et formant un monticule ou une crête sur le substratum. B) Profil Huntec montrant les caractéristiques des unités acoustiques et leurs relations verticales. Les emplacements sont indiqués à la figure 1. TS&C représente le Silt et l'Argile de Tiniktartuq et DDS, le Silt de Davis Strait.

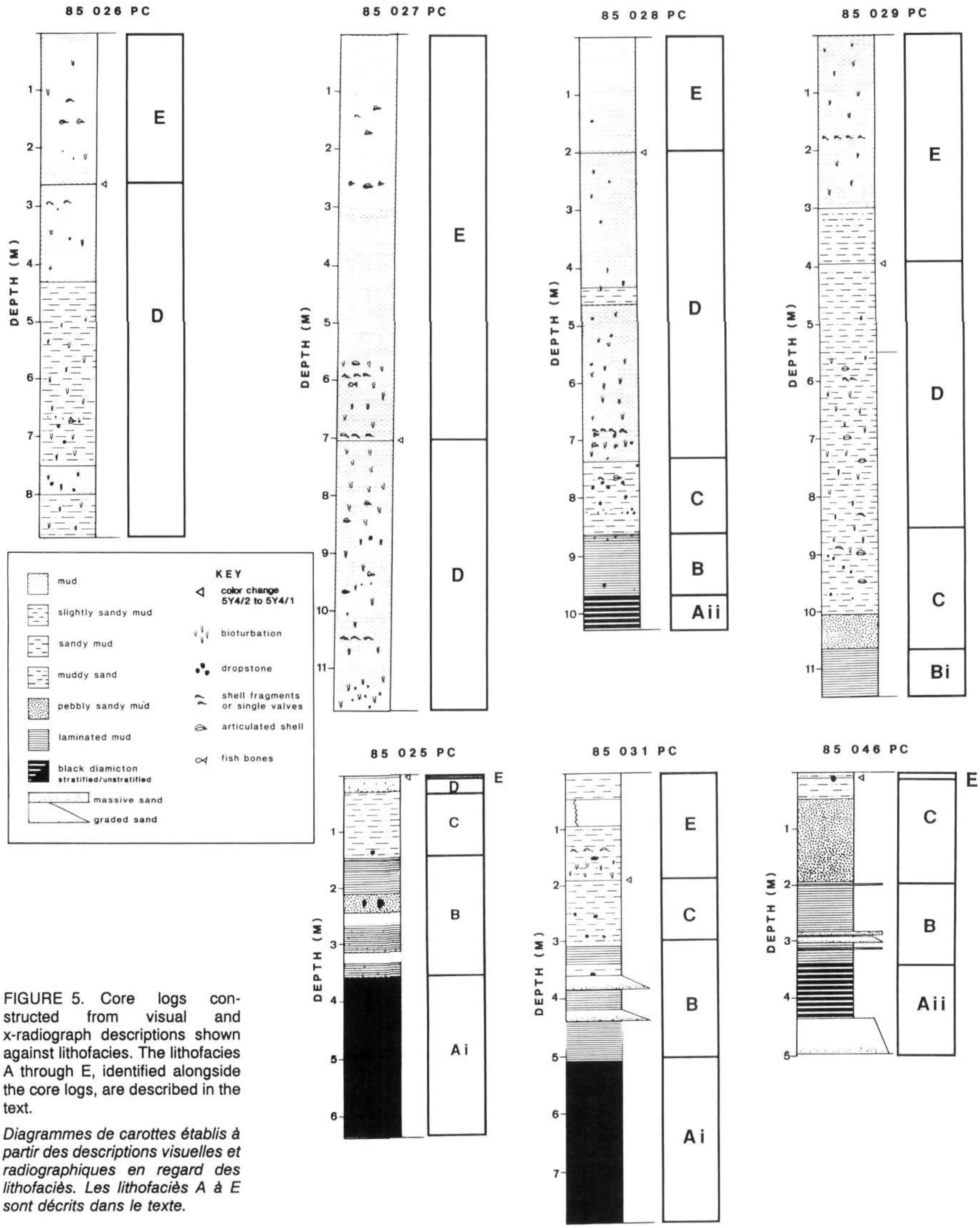


FIGURE 5. Core logs constructed from visual and x-radiograph descriptions shown against lithofacies. The lithofacies A through E, identified alongside the core logs, are described in the text.

Diagrammes de carottes établis à partir des descriptions visuelles et radiographiques en regard des lithofaciès. Les lithofaciès A à E sont décrits dans le texte.

TABLE II *Lithofacies*

Characteristics

Statistics	Lithofacies	Organic Carbon (%)	Calcite (%)	Dolomite (%)	Sand (%)	Silt (%)	Clay (%)	Phi Mean	Coefficient of Variation (CV)	Shear Strengt (kPa)	Dry Bulk Density (g/cc)	Water Content (% Dry Weight)	Volume MS (SI)
Mean	**E**	**1.62**	**0.63**	**2.14**	**6.86**	**47.08**	**46.06**	**8.06**	**0.38**	**4.25**	**0.60**	**145.92**	**38.06**
Standard Deviation	**E**	**0.40**	**0.24**	**0.69**	**5.05**	**5.93**	**8.72**	**0.67**	**0.05**	**2.23**	**0.18**	**46.27**	**31.88**
Maximum	**E**	**2.46**	**1.36**	**4.99**	**25.53**	**57.82**	**69.13**	**9.65**	**0.53**	**11.24**	**1.11**	**235.32**	**227.00**
Minimum	**E**	**0.75**	**0.08**	**1.00**	**1.08**	**29.79**	**24.14**	**6.09**	**0.27**	**0.54**	**0.36**	**55.00**	**6.00**
Mean	**D**	**0.90**	**0.97**	**3.60**	**11.42**	**50.68**	**37.90**	**7.45**	**0.42**	**8.85**	**1.05**	**61.10**	**121.84**
Standard Deviation	**D**	**0.23**	**0.37**	**0.92**	**5.45**	**3.96**	**6.62**	**0.52**	**0.04**	**3.09**	**0.17**	**15.06**	**33.59**
Maximum	**D**	**1.70**	**1.51**	**6.19**	**19.13**	**58.86**	**53.80**	**8.60**	**0.49**	**16.74**	**1.39**	**108.95**	**304.00**
Minimum	**D**	**0.62**	**0.08**	**1.74**	**2.97**	**40.84**	**28.65**	**6.88**	**0.35**	**2.54**	**0.64**	**26.16**	**47.00**
Mean	**C**	**0.80**	**1.04**	**4.18**	**14.54**	**40.02**	**45.44**	**7.73**	**0.45**	**5.08**	**1.09**	**58.47**	**184.90**
Standard Deviation	**C**	**0.19**	**0.43**	**1.27**	**6.33**	**7.59**	**7.16**	**0.50**	**0.05**	**2.46**	**0.15**	**13.70**	**47.16**
Maximum	**C**	**1.42**	**1.99**	**6.92**	**24.42**	**49.40**	**56.69**	**8.62**	**0.52**	**10.31**	**1.40**	**94.29**	**489.00**
Minimum	**C**	**0.55**	**0.39**	**2.69**	**5.14**	**27.59**	**31.14**	**6.76**	**0.35**	**2.01**	**0.77**	**39.57**	**84.00**
Mean	**B**	**1.50**	**1.17**	**2.21**	**10.53**	**28.01**	**61.25**	**8.82**	**0.34**	**6.00**	**1.03**	**62.24**	**99.80**
Standard Devistion	**B**	**0.70**	**0.92**	**1.26**	**19.90**	**7.28**	**17.26**	**1.55**	**0.12**	**1.53**	**0.11**	**9.05**	**29.72**
Maximum	**B**	**2.88**	**3.76**	**5.08**	**81.51**	**42.99**	**78.05**	**10.13**	**0.66**	**8.43**	**1.30**	**88.06**	**191.00**
Minimum	**B**	**0.08**	**0.33**	**0.75**	**0.23**	**10.17**	**8.32**	**3.75**	**0.22**	**3.61**	**0.80**	**41.66**	**38.00**
Mean	**A**	**2.56**	**1.03**	**3.49**	**22.39**	**33.73**	**43.89**	**7.34**	**0.50**	**7.37**	**1.42**	**34.81**	**64.69**
Standard Deviation	**A**	**1.50**	**0.77**	**1.88**	**12.80**	**5.89**	**12.10**	**1.15**	**0.13**	**2.37**	**0.15**	**8.36**	**27.93**
Maximum	**A**	**8.52**	**3.19**	**6.35**	**46.12**	**54.22**	**70.52**	**9.42**	**0.70**	**13.79**	**1.74**	**54.91**	**151.00**
Minimum	**A**	**1.21**	**0.07**	**1.34**	**1.96**	**21.49**	**24.02**	**5.32**	**0.27**	**4.15**	**1.11**	**19.97**	**19.00**

LITHOFACIES A: BLACK DIAMICTON

(Ai): Massive Subfacies. This lithofacies is a black (5Y2.5/1), matrix-supported diamicton composed of pebbles, granules and sand in a mud matrix. Some of the small pebbles and granules are fragments of black Cretaceous mudstone and coal. The black color and high organic matter content of this lithofacies probably comes from the presence of the reworked Cretaceous bedrock (Table II). Pebbles and granules of metamorphic rock derived from erosion of Precambrian terrain are also present. Visually, and on x-radiography, Subfacies Ai appears massive.

(Aii): Stratified Subfacies. Visually, the black stratified diamicton is almost identical to the black massive diamicton. Weakly to strongly developed stratification on x-radiographs of the stratified diamicton distinguish the two subfacies. Several types of stratification were noted on x-radiographs: interstratified pebbly mud and mud, interlaminated mud and sandy mud, and normally graded sand laminae. Mud-draped pebbles are common.

LITHOFACIES B: LAMINATED CLAY

The laminated clay overlies the black diamicton (Fig. 5). The contact between these two lithofacies is gradational, especially where the laminated clay overlies the stratified diamicton. In general, the laminae closest to the contacts between the over- and underlying lithofacies are coarser-grained than those in the central part of the lithofacies. In cores 85027-025, 85027-031 and 85027-046 lithofacies B is punctuated by graded sand beds (some with sharply defined bases), sand partings, coarse laminae, lone pebbles and scattered sand and granules. Sand beds become less frequent near the top of lithofacies B. Overall, lithofacies B is strikingly fine-grained (Table II). Lithofacies B always appears laminated on x-radiography, but may be massive visually. The visually massive sediments are slightly coarser in texture than are the visually laminated intervals and often occur at the lower and upper contacts of the laminated clay. Laminations alternate in color between very dark gray (5Y3/1) and black (5Y2.5/1), or between dark gray (5Y4/1) and very dark gray (5Y3/1) and range in thickness between 0.3 and 2.0 cm. The dark color and high organic matter content of this unit probably comes from reworking of the Cretaceous bedrock (Table II). X-radiographs show that individual color laminations comprise multiple textural laminations, with coarser darker layers and finer lighter layers. On x-radiographs, laminations range between 1 and 6 mm in thickness and packets of "thin" and "thick" laminations alternate. In general, the laminations tend to be thickest close to the contact with the black diamicton and they become thinner at the top of the unit.

LITHOFACIES C: PEBBLY MUD

Lithofacies C overlies the laminated clay with a gradational contact (Fig. 5). It is very dark gray (5Y3/1) pebbly muddy sand and dark gray (5Y4/1) pebbly sandy mud with very dark gray mottling attributed to bioturbation. On x-radiography, the burrows are sharply outlined or "bright"; they are pyritized. Pebbles are common and appear to lie both horizontally and vertically. In most cores this lithofacies is massive, but in core 85027-031 crude stratification was noted in the form of ungraded layers of coarse material. Articulated, small pelecypods and shell fragments are relatively common.

LITHOFACIES D: BIOTURBATED MUD

The bioturbated mud overlies the pebbly mud. The contact is gradational and marked by a significant decrease in coarse sand. Lithofacies D is massive, bioturbated, dark gray (5Y4/1) mud and sandy mud with few scattered pebbles and granules (Fig. 5). The number of pebbles decreases upward in the unit. Shells are less common than in lithofacies C. The lower part of this unit has abundant black (5Y2.5/1 and 2.5Y2/0) burrows that appear "bright" (pyritized) on x-radiographs. The burrows may be dispersed or concentrated in densely bioturbated horizons. Near the top of the unit, the sediment becomes softer and the black burrows give way to black banding and black discontinuous horizons. The sediments oxidize on exposure to air. Lithofacies D is very thin or absent in 85027-025 85027-031 and 85027-046 (Fig. 5).

LITHOFACIES E: OLIVE-GRAY MUD

The uppermost lithofacies in the sound, lithofacies E, overlies either lithofacies D or lithofacies C. Lithofacies E is very soft olive-gray mud to slightly sandy mud, with black horizons and blebs that give way with increasing depth in the sediment to black mottling (= pyritized burrows). The bioturbation is less pronounced and less abundant than that in lithofacies D. Sponge spicules, rare shells and scattered sand, granules and pebbles occur in this lithofacies. Silt stringers noted on x-radiographs indicate active bottom currents. The contacts between E and D and between E and C are marked by the color change from dark gray (5Y4/1) to olive gray (5Y4/2) (Fig. 5).

Thick sections of this lithofacies occur in 85027-026, 85027-027, 85027-028 and 85027-029; the same cores have thick sections of lithofacies D (Fig. 5). At the tops of these cores, lithofacies E becomes somewhat coarser grained. In 85027-025,85027-031 and 85027-046 lithofacies E is thinner and coarser grained than in the other cores, occurring as muddy sand and sandy mud. In addition, in the trigger weight cores of 85027-031 and 85027-046 there are color alternations between dark gray and olive gray within the lithofacies. The dark gray intervals tend to be thinner and coarser grained than the olive-gray intervals.

LITHOFACIES / ACOUSTIC UNIT CORRELATION

To verify the genetic interpretations of the acoustic units and to relate the acoustic features to sedimentological variations, the core locations had to be accurately placed within the acoustic profiles. Several types of information were used to do this, including: the lithofacies present in the core, the acoustic units present near each core site, whether or not the corer hit bedrock, the thickness of sediment, the length of the core, and the corrected vertical position of the piston core based on correlation with the trigger weight core and the apparent penetration of the corer. Given the accuracy of the navigation, the core locations are within one kilometer of the targeted sites on the acoustic profiles.

Consistent relationships emerged between the lithofacies and the acoustic units (Fig. 6). The BUD corresponds to lithofacies Ai, the massive, black diamicton. In addition to its color and texture, Ai differs from the other lithofacies in its relatively high "old" organic carbon content, high sand percentages, relatively poor sorting, high bulk densities, and low MS values (Table II). Several of these features are suggestive of a subglacial origin for this unit. First, the high "old" organic carbon content comes from erosion and incorporation of the underlying Cretaceous mudstone into lithofacies Ai. To the best of our knowledge, the Cretaceous bedrock is limited to the floor of the basin. Therefore, glacial erosion is the most likely mechanism to explain the abundance of Cretaceous fragments in Ai. Second, poor sorting is characteristic of tills (Boulton 1976; Dreimanis 1976). Third, the relatively high bulk densities in lithofacies Ai are similar to the bulk densities reported from tills identified from other marine areas (e.g. Kravitz, 1982a; MacLean era/., 1989). The sedimentological evidence indicates that Ai/BUD is till.

The basal unit of the Davis Strait Silt, a densely stratified or massive, thin, conformable unit above the BUD, corresponds to lithofacies Aii, the stratified diamicton, and lithofacies B, the laminated clay (Fig. 6). These lithofacies are distinguished by their stratification/lamination, black color, relatively high "old" organic carbon contents, relatively low carbonate contents (except in 85027-025), high clay contents (lithofacies B), relatively good sorting (lithofacies B) and relatively low MS values (Table II). As part of the Davis Strait Silt, these are glacial-marine sediments. If Ai/BUD is till, then the stratigraphic position and the composition of lithofacies B and Aii indicate that these lithofacies were deposited in an extremely ice-proximal environment, either proglacial or sub ice shelf. The origin of lithofacies B is tested further using mineralogical and foraminiferal data.

Both lithofacies C and D are characterized by pyritized burrows, organic carbon contents of <1 %, relatively high total carbonate contents, high sand percentages and high MS values (Table II). They differ in their stratigraphic position; lithofacies C occurs within the conformable Davis Strait Silt whereas lithofacies D straddles the contact between the DSS and the TS&C. Lithofacies C and the lower part of lithofacies D are glacial-marine sediments.

The upper part of lithofacies D forms the lower part of the Tiniktartuq Silt and Clay and coincides with the onset of onlapping basin-fill sedimentation (Fig. 6). It is somewhat finer grained than the lower part of the lithofacies and is less bioturbated. Based on its stratigraphic position, it represents the earliest phase of postglacial sedimentation.

Lithofacies E, the olive-gray mud, forms the upper part of the Tiniktartuq Silt and Clay. In general, it has relatively high organic carbon contents, low total carbonate percentages, and is silty clay to clayey silt in texture. It is a very soft sediment with low bulk density. However, in core 85027-031, lithofacies E bears evidence of reworking of darker-hued sediments richer in carbonate (especially dolomite), possibly lithofacies C.

CHRONOLOGY AND SEDIMENTATION RATES

Radiocarbon dates were used to assist correlation between cores, to calculate the sedimentation rates associa-

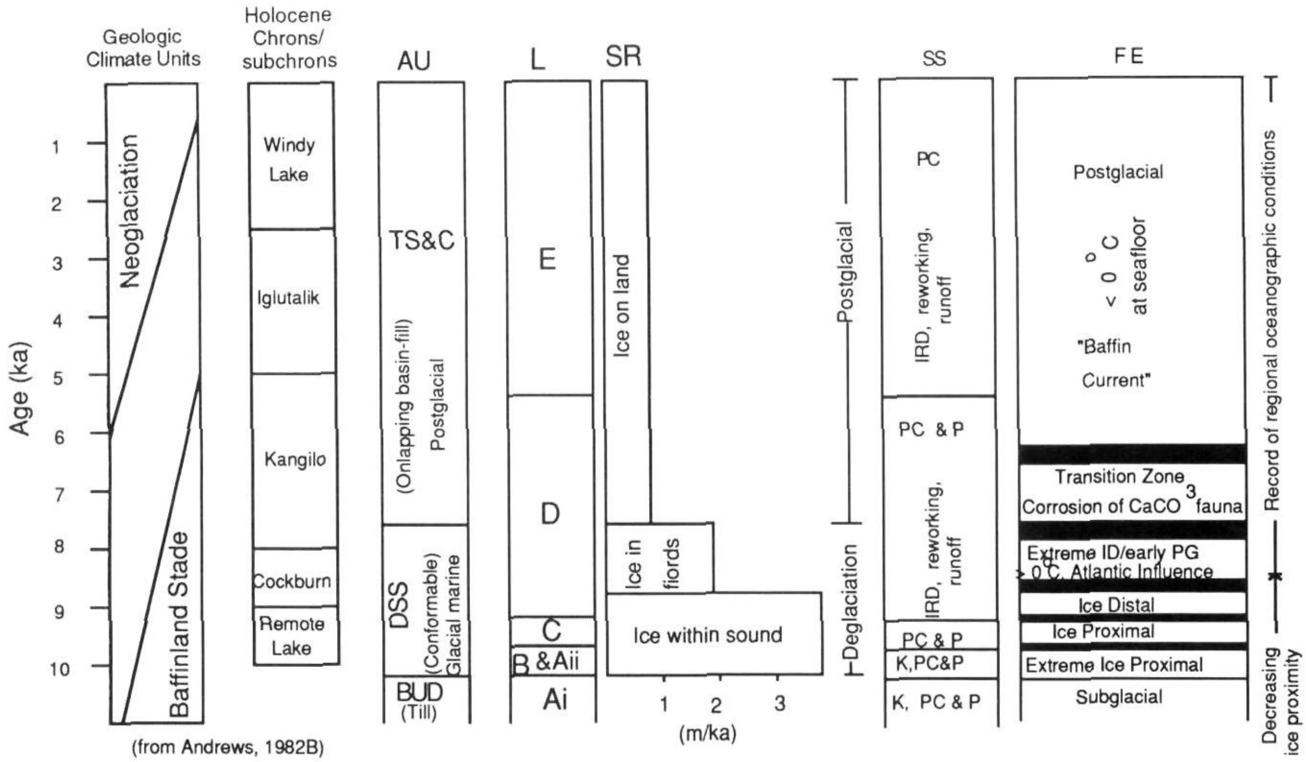


FIGURE 6. Summary diagram showing the timing of glacial and deglacial events in Cumberland Sound. AU = acoustic units; L = lithofacies; SR = average sedimentation rates derived from core 85027-029 PC & TWC; SS = interpreted sediment sources with PC = Precambrian, P = Paleozoic, and K = Cretaceous bedrock; and FE = paleoenvironment interepreted from foraminiferal assemblages.

Diagramme résumé montrant la chronologie des avancées et des retraits glaciaires dans la baie de Cumberland. AU = unités acoustiques; L = lithofaciès; SR = taux moyens de sédimentation établis à partir de la carotte 85027-029 PC & TWC; SS = sources des sédiments établis selon la nature du substratum: Précambrien (PC), Paléozoïque (P), Crétacé (K); FE = paléoenvironnements établis à partir des assemblages de foraminifères.

ted with lithofacies and acoustic units, and to relate changes in Cumberland Sound with the glacial and oceanographic history of the adjacent terrestrial and marine areas. Sediment flux data will be discussed in a future paper. Nine AMS ^{14}C dates on shells, foraminifera and fish bones from the 1985 cores and one conventional ^{14}C date on disseminated organic material from 82034-041 PC, constrain the chronology of the sediment sequence (Table III). Several of the dates were previously reported in Andrews *et al.* (1989b) and Praeg *et al.* (1986).

Three of the dates are considered unreliable indicators of sediment age. First, the >45000 BP date (AA-2632) from the Davis Strait Silt in 85027-028 PC was on chalky shell fragments. These fragments were probably reworked from older sediments, as substantially younger dates were obtained from stratigraphically older sediments in the sound (Andrews *et al.*, 1989). Second, the date of 10,255 ± 70 BP (AA 3940) in 85027-029 PC is out of stratigraphic order; it is the oldest date in core 029 though two younger dates (AA-1916 and AA-3885 & 6) occur as much as 5 m below it (Table III). AA-3940 was obtained on a mixed benthic foraminiferal assemblage containing corroded specimens. The stratigraphically deeper dates were on more reliable material: a mono specific foraminiferal sample (*Cassidulina reniforme*) and articulated shells. Third, AA-3941 was determined on a large broken valve of *Astarte*, from lithofacies E of 85027-031 PC. The date of 8265 ± 70 BP is significantly older than the other two dates on lithofacies E (AA-2631 and AA-1915), one of which, AA-2631, was determined on the articulated bones of a small fish and is considered to be highly reliable. Based on the evidence for reworking of older sediments into lithofacies E at site 031, and because younger dates on lithofacies E are present in the sound, AA-3941 is considered to have been reworked into younger sediment.

CHRONOLOGY

Shells and foraminifera were absent in the BUD and very rare in the basal unit of the DSS. Based on comparison with the lithofacies described within the sound, the bulk organic matter date from core 82034-041 PC is probably from lithofacies B, the basal unit of the Davis Strait Silt. Since the sediment contains coal fragments and reworked pre-Quaternary palynomorphs, the 20,180 ± 295 BP age is too old. The equation derived by Andrews *et al.* (1985) to convert organic dates to equivalent shell dates was applied, resulting in a corrected age of 13,400 ± 1700 BP. This date is of questionable reliability, but is in keeping with the timing of ice retreat on the shelf to the south (Andrews *et al.*, 1991). Inside the sound, two samples were obtained from near the base of lithofacies C; one was from 85027-029 (AA-3585&6) and the other was from 85027-031 (AA3939). The sample from 85027-029 consisted of the foraminifera *Cassidulina reniforme* plus a small articulated mollusc. It yielded an age of 9560 ± 110 BP. The

TABLE III

Radiocarbon Dates on Cumberland Sound Cores

Core	Interval (cm)	Lithofacies	Acoustic Unit	Material Dated	Reported Date (yr BP)	Corrected Date (yr BP)	Laboratory Number
85027-025 TWC	173-176	Upper C	DSS	Shell	9450 ± 95	9000 ± 95	AA-2633
85027-027 PC	629-631	E	TS&C	Fish Bones	5160 ± 60	4710 ± 60	AA-2631
85027-028 PC	684-685	Lower D	DSS	Shell Fragments	> 45,000	> 45,000	AA-2632
85027-029 PC	102	E	TS&C	Gastropod	2890 ± 115	2440 ± 115	AA-1915
85027-029 PC	495-499	Upper D	TS&C/DSS Boundary	Mixed Benthic Foraminifera	10,705 ± 70	10,255 ± 70	AA-3940
85027-029 PC	740	Lower D	DSS	Mollusc	9340 ± 84	8890 ± 84	AA-1916
85027-029 PC	996-998	Lower C	DSS	Benthic Foraminifera and Mollusc	10,010 ± 110	9560 ± 110	AA-3585&6
85027-031 PC	129-131	E	TS&C	Broken Mollusc	8715 ± 70	8265 ± 70	AA-3941
85027-031 PC	278-285	C	DSS	Benthic Foraminifera	10,920 ± 250	10,470 ± 70	AA-3939
82034-041 PC*	280-298	B?	DSS	Total Organics	20,180 ± 295	13,373 ± 1700	BETA-7405

Correction for reservoir age of 450 years.

* Corrected using equation modified from Andrews *et al.*, 1985: Corrected age = 706 + (.65)(Date)−450 ± 1700.

sample from core 85027-031 consisted of a mixed benthic foraminiferal assemblage. It yielded an age of 10,470 ± 250 BP. A shell from 85027-025 TWC gave an age of 9000 ± 95 BP in the upper part of lithofacies C. Stratigraphically above this level, a shell from the lower part of lithofacies D in 85027-029 PC yielded a slightly younger, but statistically identical age of 8890 ± 84 yrs BP. Near the base of lithofacies E in 85027-027 PC, articulated fish bones yielded an age of 4710 ± 60 BP. In 85027-029 PC, a gastropod in lithofacies E dated at 2440 ± 115 BP.

SEDIMENTATION RATES

Figure 7 shows the pattern of average sedimentation rates calculated from dates in 85027-029 PC & TWC. To evaluate the changes in sedimentation rates a number of assumptions and corrections were made. First, 81.5 cm were added to the depths in the piston core. This is the best estimate of the depth of sediment bypassed by the piston core during coring (Jennings, 1989). The sediment age at the top of the depth-corrected section was assumed to be modern. This assumption is supported by live biota observed in the trigger weight core top. The second assumption is that the age of the sediment at the boundary between the DSS and the TS&C (572 cm in 85027-029 PC & TWC) is well approximated by extrapolating the sedimentation rate of 75.2 cm/ka defined from the sediment surface (0 BP; 0 cm 85027-029 PC & TWC) to 183.5 cm in the corrected depth section (2440 BP) (Table III) to the DSS/TS&C boundary. By this method, the estimated age at the boundary is 7600 BP. Extrapolation of the slow sedimentation rate defined for the upper part of the TS&C to the base of the acoustic unit is justified based on the onlapping basin-fill style of the TS&C, which is consistent with a relatively slow sedimentation rate.

The highest sedimentation rate occurs from 9940 to 8890 BP. This time interval is represented by sediments in the lower portion of the DSS (lithofacies B and C), which were deposited at a rate of 3.8 m/ka. Such a rapid sedimentation rate is consistent with the conformable style of the Davis Strait Silt.

Sediments of the upper Davis Strait Silt (lithofacies C and D) were deposited at a slower rate of 1.9 m/ka over the interval 8890 to 7600 BP. This is the period when glaciers were rapidly retreating into the fiords and onto land, and based on previous glacial reconstructions, the ice was at least 80 km from the core site (Dyke, 1979; Miller, 1985). Though the fiords became available as sediment traps during this time, the sedimentation rate was still rapid enough to maintain the conformable style of the DSS.

The lower average sedimentation rate for the TS&C (lithofacies D and E) from 7600 BP to the present relates in time to the withdrawl of glaciers onto land and to the onset of non-glacial and neoglacial conditions (Dyke, 1979; Dyke *et al.*, 1982).

MINERALOGY AND PROVENANCE

Clay mineralogy was analyzed on core sediments and submarine bedrock samples to: 1) determine the mineral composition of the lithofacies/acoustic units; 2) identify changes in provenance and/or mechanisms supplying sediment through time; 3) gain insight into the depositional processes that produced different lithofacies/acoustic units. In particular, the link between mineralogical composition and bedrock source is used to evaluate whether or not the BUD is subglacial in origin.

BEDROCK MINERALOGY

The Cretaceous and Tertiary bedrock samples differ markedly in mineral composition (Fig. 8). The Cretaceous bedrock is dominated by kaolinite (62%) and mica (27%) with subsidiary amounts of chlorite (<1%), quartz (2%), orthoclase (5%) and plagioclase (2%). It does not contain smectite. In contrast, smectite (84%) dominates the Tertiary bedrock. Mica (12%), kaolinite (2%), chlorite (<1%) and quartz (<1%) occur in subsidiary amounts.

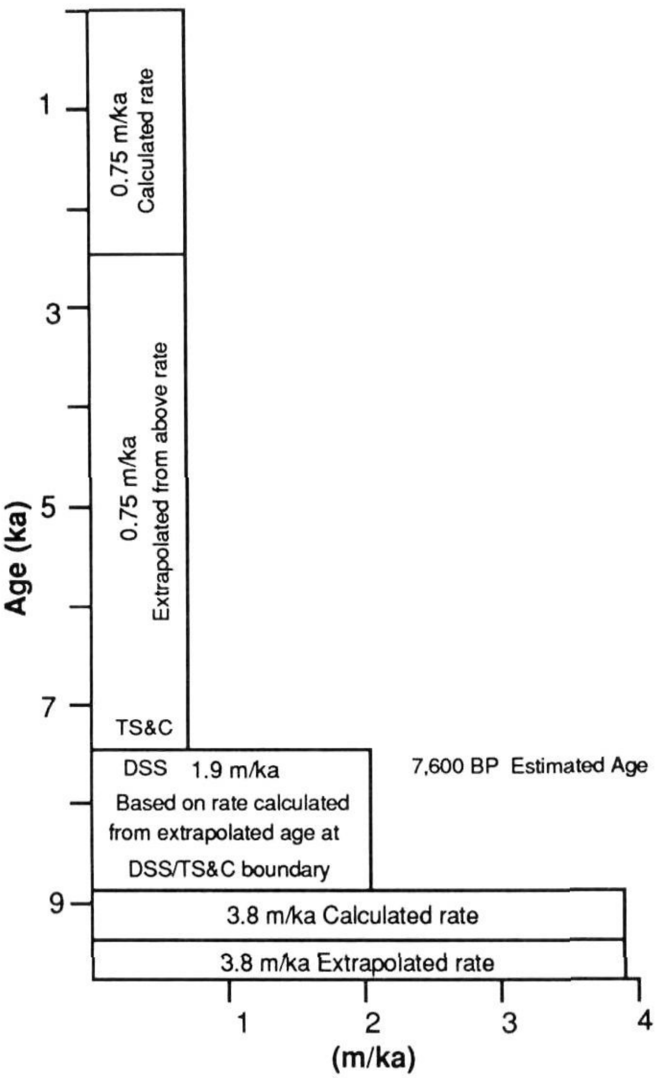


FIGURE 7. Average sedimentation rates through time in core 85027-029 PC & TWC. Table III contains information on the radiocarbon dates used to construct this diagram.

Taux de sédimentation moyens dans la carotte 85027-029 PC & TWC (établis à partir des renseignements contenus dans le tableau III).

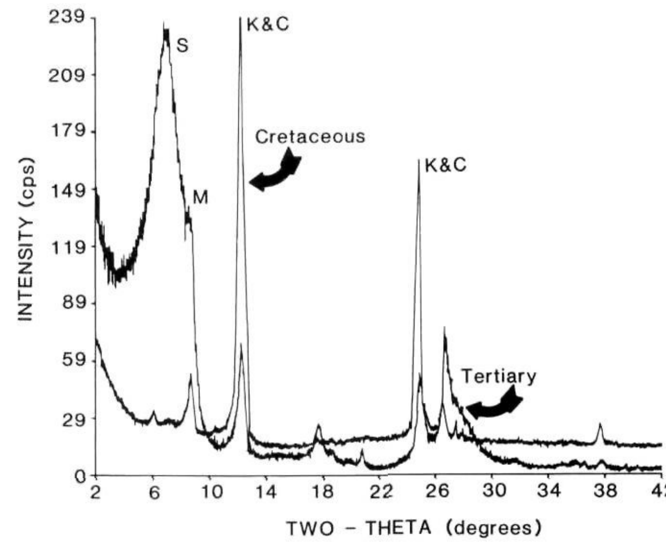


FIGURE 8. X-ray diffraction patterns of Tertiary and Cretaceous bedrock samples illustrating the compositional mineralogical differences of their clay-sized fractions. The Cretaceous bedrock is dominated by kaolinite and the Tertiary bedrock dominated by smectite. S = smectite, M = mica, K&C – kaolinite and chlorite.

Diffractométrie des échantillons du substratum du Tertiaire et du Crétacé illustrant les différences de composition minéralogique de leur fraction argileuse. Le substratum du Crétacé est dominé par la kaolinite et le substratum du Crétacé, par la smectite. S = smectite, M = mica, K&C – kaolinite et chlorite.

LITHOFACIES MINERALOGY AND PROVENANCE

This section discusses the possible sources of the main minerals in the assemblage. Other discussions of mineral provenance in the Baffin Bay region are found in Aksu (1981), Andrews *et al.* (1989), Jennings (1986), Boyd and Piper (1976) and Piper and Slatt (1977). The total mineral assemblage in the cores includes: smectite, mica, amphibole, kaolinite, chlorite, quartz, orthoclase, plagioclase, and dolomite (Fig. 9). Mica, chlorite, quartz, amphibole, and the feldspars are the main constituents of Precambrian Shield rocks. Individually, these minerals are non diagnostic in terms of source. However, as an assemblage, especially in the absence of smectite and kaolinite, they suggest erosion of Precambrian Shield rocks. Each of these minerals, however, could also have been derived from erosion of Mesozoic and Cenozoic sedimentary bedrock in the Sverdrup Basin (Aksu, 1981), from the Cretaceous strata around Pond Inlet, Baffin Island and the Disko Bay area of western Greenland (Aksu, 1981), from submarine erosion of the Cretaceous-Tertiary strata underlying portions of the Baffin Island shelf (MacLean and Falconer, 1979) or from reworking of Quaternary sediments. In essence, erosion of the Precambrian Shield rocks surrounding Cumberland Sound is the most likely source of these minerals in the sound. However, the same minerals could also be transported into the sound from numerous distal sources.

Smectite is variably present in all of the lithofacies (Fig. 9). There is no unique source for smectite in Cumberland Sound. However, the most likely sources of smectite in Cumberland Sound sediments are: 1) erosion of areas in the Arctic Archipelago, Greenland and parts of Baffin Island to the north of the study area that are underlain by smectite-bearing bedrock or sediments. Such sediments could be carried into Cumberland Sound by ice bergs, sea ice and currents (Aksu, 1981; Andrews, subm; Jennings, 1986); 2) glacial erosion and/or ice scouring of the Tertiary mudstone at the mouth of Cumberland Sound; 3) glacial erosion of possible smectite-bearing strata of the Cretaceous bedrock in Cumberland Sound; 4) reworking of smectite-bearing sediments from the shelf, or from the margins of the basin and concentration of the smectite in the basin-fill sediments.

The importance of kaolinite as an indicator of provenance in high latitude marine areas is well known (Biscaye, 1965; Darby, 1975; Aksu, 1981; Kravitz, 1982b). There are numerous sources of kaolinite in the Baffin Bay region in rocks

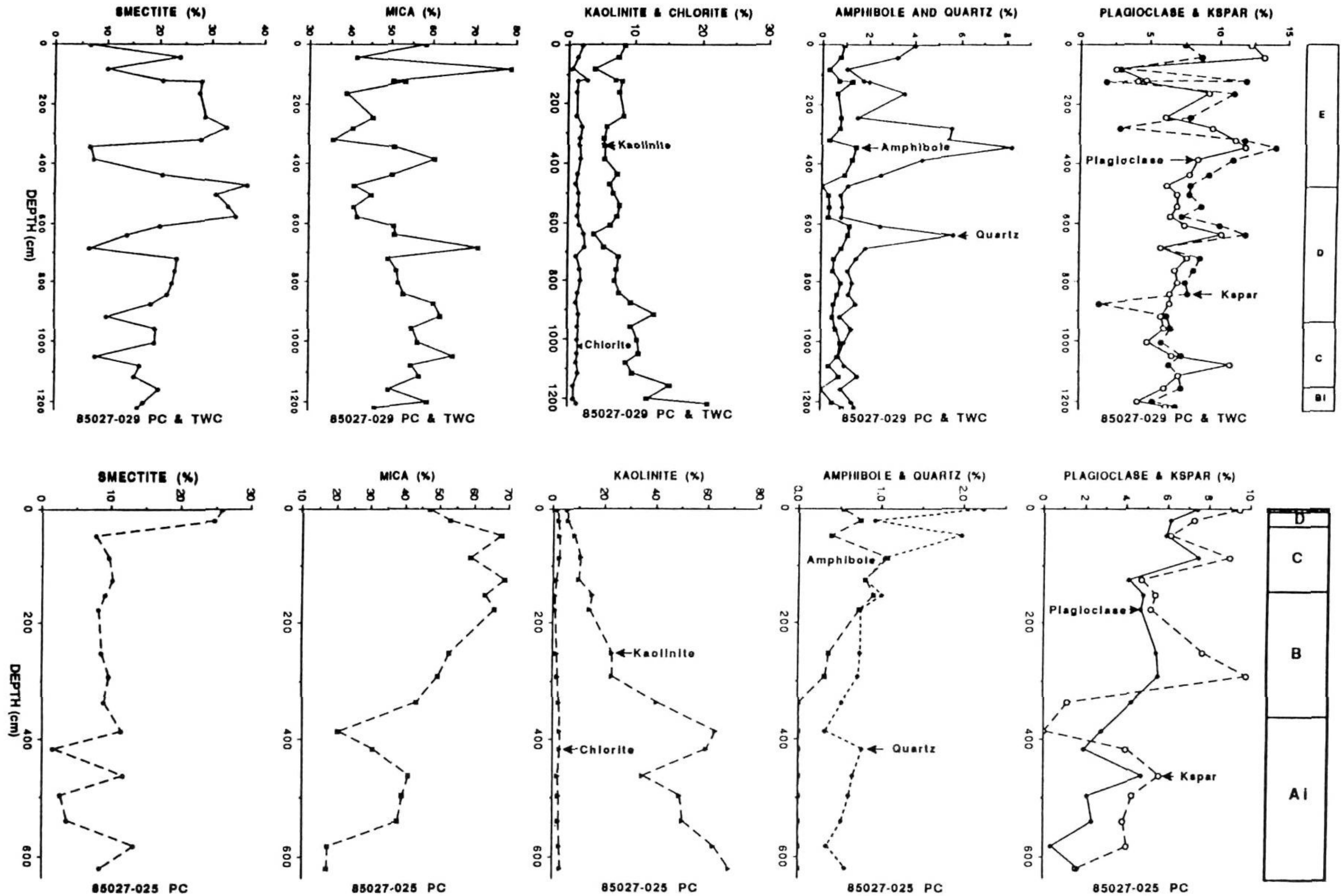


FIGURE 9. Downcore plots of clay-sized mineral percentages in cores 85027-025 PC and 85027-029 PC & TWC compared to the lithofacies defined in the text. Note that lithofacies A and B are dominated by kaolinite indicating that they derived from erosion of the Cretaceous bedrock.

Pourcentages des minéraux de la taille des argiles à la base des carottes 85027-025 PC et 85027-029 PC & TWC en comparaison avec les lithofaciès décrits dans le texte. À noter que la kaolinite domine dans les lithofaciès A et B montant ainsi qu'ils résultent de l'érosion du substratum du Crétacé.

deposited during the Mesozoic and Cenozoic eras: strata of the Baffin Island and Greenland shelves, fluvial sediments in the Disko area of western Greenland and sedimentary bedrock of Bylot Island and the Sverdrup Basin (Boyd and Piper, 1976; Piper and Slatt, 1977; Aksu, 1981; Kravitz, 1982b). Kaolinite is the dominant mineral in the Cretaceous bedrock underlying the main sedimentary basin of Cumberland Sound. As in the case of smectite, erosion of any of the distal sources by glacial and/or marine processes could provide some kaolinite via ice rafting and/or currents to Cumberland Sound. However, erosion of the Cretaceous bedrock at the floor of Cumberland Sound as a source of kaolinite can only be achieved by subglacial erosion.

Distinct mineralogical changes across lithofacies indicate that sediment sources and processes have changed during the different phases of sedimentation in the sound. Lithofacies Ai is extremely similar in terms of color and clay-sized mineralogy to the Cretaceous bedrock flooring the sound (Figs. 8 and 9). In addition, the abundant >2 mm fraction in lithofacies Ai contains fragments of the underlying Cretaceous bedrock as well as some Precambrian Shield clasts. Because there are no other sources of abundant kaolinite adjacent to the sound, the characteristics of lithofacies Ai are best explained by erosion and incorporation of the underlying Cretaceous bedrock. Because the Cretaceous bedrock lies in the deepest part of the sound, sediment gravity flows and ice berg ploughing are not likely origins. The only process that could have eroded the Cretaceous bedrock and deposited lithofacies Ai as a diamicton is subglacial erosion. Precambrian clasts and the slightly greater proportion of mica and feldspars in Ai relative to the bedrock indicate that erosion of the Precambrian Shield rocks probably also contributed to the lithofacies. The smectite in Ai must have originated either from the Cretaceous bedrock or possibly from glacial erosion of the Tertiary bedrock slightly beyond the mouth of the sound.

The mineralogical data provide evidence that lithofacies Ai/BUD is till. The glacier that deposited Ai probably overrode Precambrian, Ordovician and Cretaceous bedrock and may have extended onto the shelf to erode the Tertiary mudstone. There are no mineralogical data from lithofacies Aii, the stratified diamicton. Based on the similarities in color and coarse-fraction composition between Ai and Aii, it is likely that both subfacies were derived from the same sources. However, the stratification in Aii indicates that it must have been deposited through water. Its stratigraphic position directly overlying Ai/BUD, and its similar coarse- fraction composition to Ai/BUD indicate that Aii represents extremely ice-proximal sediment.

The mineral composition in lithofacies B is transitional between that of lithofacies Ai and lithofacies C. The percentage of kaolinite decreases dramatically from the base to the top of lithofacies B, suggesting that the source of kaolinite was diminishing during deposition of this lithofacies (Fig. 9). The decrease in kaolinite is interpreted to indicate sedimentation while ice was retreating. Proglacial and sub-ice shelf environments are both possible.

Lithofacies C shows no obvious mineralogical affinity to the Cretaceous bedrock. The abundance of clay minerals is relatively low. Erosion and transport of the Precambrian Shield rocks probably accounts for the greater proportion of the sediments entering the sound during deposition of lithofacies C.

Lithofacies D and E are similar mineralogically. The large fluctuations in smectite and kaolinite contents in these lithofacies may be due to ice rafting from distant source terrains. Another likely source of clay minerals is the reworking of glacial-marine sediments at the basin margins by tidal and other currents. The fine-grained clay minerals would be preferentially transported into the basin by such processes and thus concentrated in the basin-fill lithofacies. In lithofacies E, the Precambrian Shield mineral assemblage becomes more pronounced, possibly reflecting increased local glacier activity during the neoglacial interval.

FORAMINIFERAL ANALYSIS

Benthic foraminiferal assemblages have been used to infer paleoenvironmental changes related to the transition from glacial to interglacial conditions (*e.g.* Scott *et al.*, 1984; Hald and Vorren, 1987; Osterman and Nelson, 1989; Vilks *et al.*, 1989). The two cores chosen for analysis, 85027-025 PC and 85027-029 TWC & PC, span the entire sediment sequence from Ai/BUD through E/TS&C. Thus, analysis of these cores provides an additional test of the origin of Ai/BUD and a means of investigating the record of ice proximity and paleoceanographic conditions. The only modern faunal baseline data are the two core top samples both of which contain mainly agglutinated foraminifera. The paleoenvironmental significance of the foraminiferal faunas is inferred from reference to previous work on other high-latitude shelves. Figure 10 summarizes the foraminiferal zonations, relates them to lithofacies and acoustic facies, and shows the main environmental interpretations.

INTERPRETATION OF PALEOENVIRONMENTS

Ai/BUD is barren of foraminifera. Samples of till from other marine studies are either barren of foraminifera (*e.g.* Scott *et al.*, 1984; MacLean *et al.*, 1989) or contain mixed assemblages of foraminifera, such as mixed arctic and boreal assemblages (*e.g.* Hald and Vorren, 1987; Sejrup *et al.*, 1987). The Cumberland Sound foraminiferal analysis supports the acoustic and lithologic evidence that Ai/BUD is till.

The sediments of lithofacies B/Basal DSS are interpreted to represent deposition immediately in front of a glacier, or possibly beneath an ice ramp or ice shelf. The major species, *Cassidulina reniforme* and *Textularia earlandi*, reflect cold (<0 °C) arctic water (*e.g.* Schafer and Cole, 1986; Mackensen *et al.*, 1985; Sejrup and Guilbault, 1980). The minor species, *Fursenkoina fusiformis* and *Elphidium excavatum* forma *clavata* have been shown to dominate ice marginal environments (*e.g.* Nagy, 1965; Schafer and Cole, 1988). This extreme ice proximal environment occurred between at least 9.9 and 9.8 ka in Cumberland Sound. The presence of the same fauna in lithofacies B of core 82034-041 (Praeg *et al.*, 1986) suggests that as early as

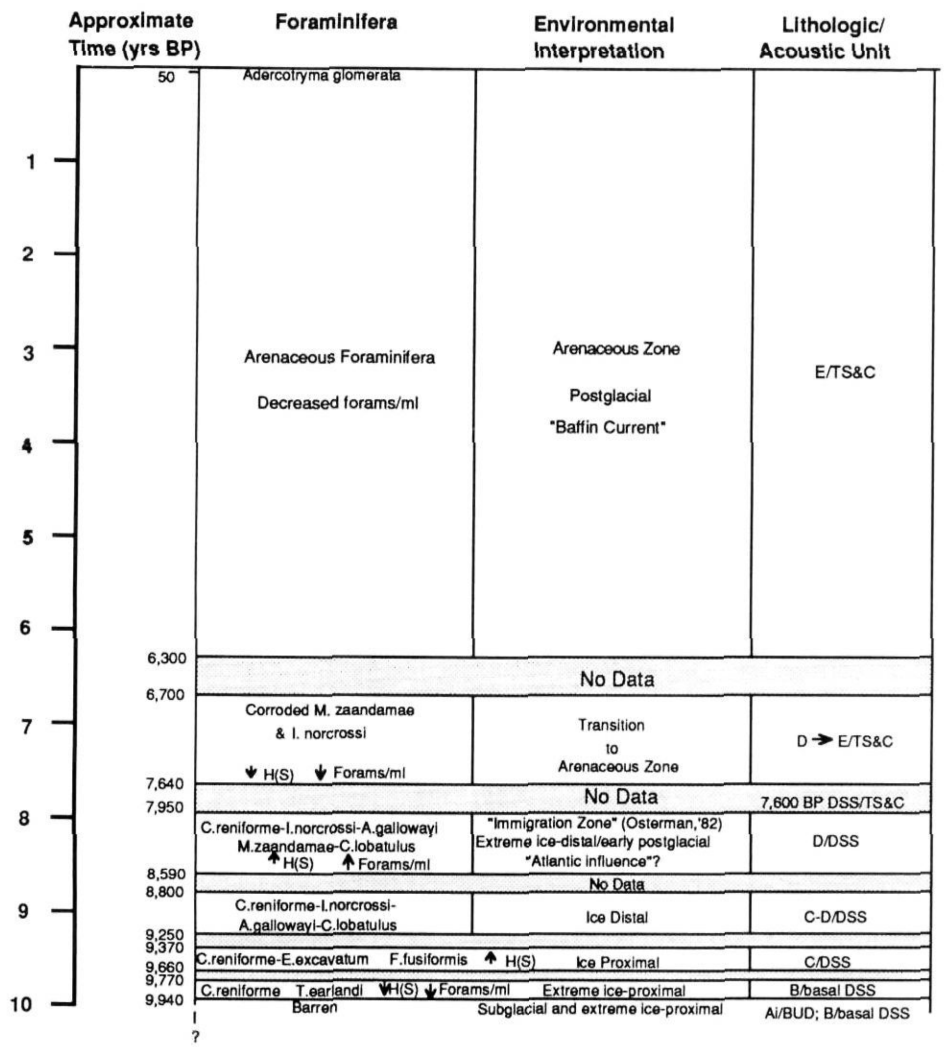


FIGURE 10. Paleoenvironmental interpretation of foraminiferal data in 85027-029 PC & TWC. Timing at the boundaries was extrapolated using radiocarbon control listed in Table III and illustrated in Figure 7. Up and down arrows with H(S) represent increasing and decreasing diversity, respectively. Up and down arrows with forams/ml represent increasing and decreasing foraminiferal concentrations, respectively.

Interprétation paléoenvironnementale des données sur les foraminifères de la carotte 85027-029 PC & TWC. Les dates aux limites ont été extrapolées à partir des datations au radiocarbone du tableau III et illustrées à la figure 7. La direction des flèches accompagnant «H(S)» indique l'augmentation ou la diminution de la diversité. Les flèches accompagnant «forams/ml» indiquent l'augmentation ou la diminution de la concentration de foraminifères.

13,400 BP the extreme ice proximal environment must have extended onto the Southeastern Baffin Shelf. Foraminiferal assemblages in cores from Resolution Basin to the south show ice proximal foraminiferal assemblages from about 13 to 10 ka (Evans, 1990).

The lower part of lithofacies C probably represents similar but slightly less extreme ice proximal conditions. This interpretation is based on the higher diversity of the assemblage, on the increasing percentages of *Fursenkoina fusiformis*, and on the introduction of *Islandiella norcrossi* into the assemblage. Based on the modern habitat preferences of the fauna, the bottom water in both the extreme ice proximal and the ice proximal environments was probably cold and turbid, with reduced salinities and, possibly, low oxygen content (Miller *et al.*, 1982; Scott *et al.*, 1984; Schafer and Cole, 1986; Hald and Vorren, 1987; Vilks *et al.*, 1989).

Osterman (1982; 1984) suggested that ice distal sediments in Frobisher Bay are characterized by a *Cassidulina reniforme-Islandiella helenae* Zone. In core 85027-029, a similar zone occurs from the upper part of lithofacies C through most of lithofacies D (9250-8800 BP). This interval is interpreted to represent ice-distal sedimentation. Though actual distances cannot be attached to the relative terms, "proximal" and "distal", glacial ice is known to have terminated in the fiords on the eastern side of Hall Peninsula during this time (Miller, 1985; Dyke, 1979). The increase in the percentage of *Cibicides lobatulus* over this interval in 85027-029 PC & TWC may reflect the coarsening of the substrate (*e.g.* Schafer and Cole, 1986) as ice rafting became more important relative to suspension settling.

Samples from the top of lithofacies D in core 85027-029 (8600-7950 yrs BP) and from the top of lithofacies C through D in 85027-025 do not reflect the influence of glacial ice. The faunal assemblage contains elements that occur at present on other shelves in the region. The percentage increase in *Melonis zaandamae* may reflect the fine-grained substrate and the relatively high organic content of the bottom sediments (Mackensen *et al.*, 1985; Caralp, 1989), and/or it may indicate the incursion of >0° C Atlantic water at depth in the sound (Schafer and Cole, 1986). This zone corresponds, in part, to the *Melonis* Zone of Osterman and Nelson (1989) which ranges from 8000 to 6000 BP. It also resembles the Immigration Zone of Osterman (1982). The assemblage is interpreted to represent extreme ice distal or early postglacial conditions (Fig. 10). The assemblage is partly reworked.

The upper 50 cm of 85027-025 have very low foraminiferal concentrations and extremely corroded calcareous specimens. The same is true of samples from 579-504 cm in 85027-029 PC & TWC (7600-6700 BP; uppermost D). The faunal compositions of these samples may have no paleoceanographic significance; they may result from differential dissolution of tests and/or from reworking of older deposits in the sound. Sediment reworking is expected based on the onlapping basin-fill geometry of the TS&C. The infaunal species such as *Melonis zaandamae* may be preserved more readily than epifaunal species such as *Cibicides lobatulus*. This zone corresponds in timing to the *Melonis* Zone of Osterman and Nelson (1989), but due to the low abundances of foraminifera, and their corroded appearance, the corroded calcareous zone is interpreted to be transitional to the overlying arenaceous zone.

Overlying the corroded calcareous zone in both cores is a zone of almost exclusively arenaceous foraminifera that corresponds to lithofacies E and ranges in age from 6300 BP to the present (Fig. 10). Abundant sponge spicules, large diatoms and some radiolarians occur in this zone. The concentration of foraminifera is very low. Whether the arenaceous zone represents a replacement of calcareous species by arenaceous species or poor preservation of calcareous tests, or both, is not clear. The beginning of the arenaceous zone in 85027-029 PC & TWC, somewhere between 579 and 474 cm, corresponds to the change from lithofacies D to E at 476.5 cm and to the boundary between the DSS and the TS&C at about 572 cm.

Arenaceous foraminifera are poorly preserved in subsurface sediments in some areas (*e.g.* Elverhoi *et al.*, 1980). However, areas that experience high sedimentation rates combined with reducing conditions, which inhibit bacterial action and bioturbation by macrobenthos, are ideal for the preservation of agglutinated tests (Vilks *et al.*, 1984). The Cumberland Sound sediments contain arenaceous foraminifera throughout, and the arenaceous species change through the record. This indicates that arenaceous foraminifera are well preserved and that the compositional changes are environmentally meaningful.

A change from calcareous to agglutinated assemblages of foraminifera during the Holocene, sometime between 6000 BP and 2500 BP, is reported along the inner eastern Canadian margin from Baffin Island, Labrador, Newfoundland and Nova Scotia (Scott *et al.*, 1984; Vilks *et al.*, 1984; Osterman *et al.*, 1985; Osterman and Nelson, 1989). Whether this change is due to an oceanographic effect, such as the incursion of Arctic waters (*cf.* the Baffin Current or the Inner Labrador Current), as suggested by Osterman (1982), Scott *et al.* (1984) and Vilks *et al.* (1984), or to a change in the preservation potential of arenaceous tests (Vilks and Deonarine, 1988) which actually may accompany environmental changes, is not clear. However, the very wide regional occurrence of the arenaceous zone does suggest paleoceanographic control (Vilks *et al.*, 1984).

Three conclusions are drawn from the foraminiferal data: 1) Faunal evidence supports a subglacial origin for lithofacies Ai; 2) The earlier portion of the record, from approximately 10,000 to 8800 BP, primarily records the local signal of ice retreat; 3) Regional oceanographic changes are probably reflected in the postglacial part of the record.

DATA SYNTHESIS

The acoustic, textural, chronological, compositional and faunal data in Cumberland Sound show that the sedimentary sequence records a Late Foxe ice advance that extended well beyond the previously mapped Late Foxe ice limits in the area (Fig. 11). This conclusion is based on the evidence for a subglacial origin for the lithofacies/acoustic unit, Ai/BUD. The evidence is: 1) Ai/BUD unconformably overlies bedrock and underlies a glacial-marine ice proximal to ice distal sequence. 2) Ai/BUD was derived from erosion of the underlying Cretaceous mudstone. 3) The acoustic, textural, geotechnical and faunal characteristics of Ai/BUD strongly resemble the same characteristics of tills identified on other shelves.

Based on the interpretation of Ai/BUD as subglacial sediment, the position of the maximum Late Foxe ice margin, as marked by the Ranger moraine, in Cumberland Sound, and the Late Foxe history preceeding the Ranger Stade are revised (Fig. 11). Events on land, from the Cockburn Substage, locally termed the Ranger Stade, through final deglaciation remain as presented by Dyke (1979) and Dyke *et al.* (1982).

POSSIBLE ICE SOURCES

There are four possible sources for the ice that inundated Cumberland Sound. Abundant evidence exists for three of these sources; Hall Ice flowing from Hall Peninsula, Penny Ice flowing from Cumberland Peninsula, and Amadjuak Ice flowing from southwestern Baffin Island and Foxe Basin (Fig. 11, inset; Dyke and Prest, 1987). A fourth, hypothetical source, an ice cap on the relatively shallow continental shelf seaward of the mouth of Cumberland Sound, will be considered below.

Mineralogical data do not support a shelf ice dome inundating the sound. The shelf seaward of Cumberland Sound is underlain by Paleozoic carbonates and Tertiary mudstone (MacLean *et al.*, 1982). Glacial erosion of these sources would have produced till and extreme ice-proximal sediments enriched in smectite and carbonates. 82034-041 PC lies >20 km inside of the zone of Tertiary bedrock, landward of the shallowest areas in this part of the shelf and is thus in a position to test the shelf-ice hypothesis. Smectite does not dominate the mineralogy of the extreme ice-proximal sediments of 82034-041 PC (Jennings, 1989). Instead, kaolinite and mica, products of erosion of the Cretaceous bedrock within Cumberland Sound dominate the sediment in this core. Although the possibility of a shelf ice dome based on these data cannot be precluded, the information available does not suggest ice flow from the shelf into the sound, but rather ice flow from the sound onto the shelf.

During the Ranger Stade, ice from the Amadjuak, Hall and Penny ice divides was flowing toward the head and the northwestern edge of Cumberland Sound (Fig. 11, inset; Dyke and Prest, 1987). All three of these sources probably contributed to the pre-Ranger ice advance into the sound. In contrast, on

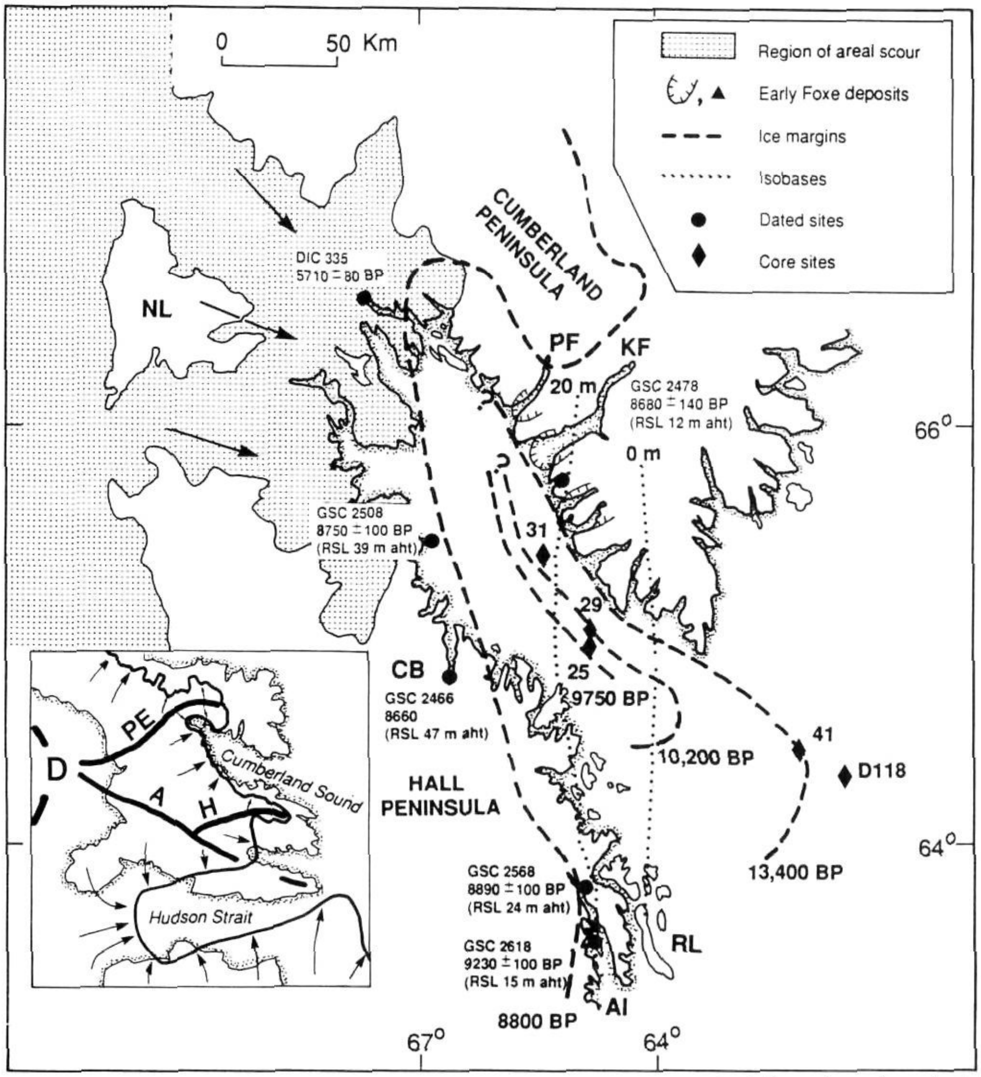


FIGURE 11. Ice reconstruction during maximum late Foxe ice advance and subsequent deglaciation. Margin at 8800 BP slightly modified from Dyke (1979), Miller (1985), and Stravers (1986). Radiocarbon dates shown relate to deglaciation and/or the Holocene marine limit (Miller, 1979; Dyke *et al.*, 1982) with aht denoting above high tide. Marine limits are given, not the elevation of the sample. The region of areal scour is marked by heavy stipple at the head of the sound. The 0 and 20 m isobases run N-S. Inset showing ice divides and ice margins during the Cockburn substage is from Dyke and Prest (1987); PE = Penny Ice; H = Hall Ice and A = Amadjuak Ice. CB = Chidliak Bay; AI = Allen Island; NL = Nettilling Lake; KF = Kingnait Fiord; PF = Pangnirtung Fiord; RL = Robinson Lake.

Reconstitution des glaciers pendant l'avancée maximale du Foxe supérieur et de la déglaciation subséquente. Les limites de 8800 BP sont légèrement modifiées par rapport à Dyke (1979), Miller (1985) et Stravers (1986). Les dates au radiocarbone correspondent à la déglaciation ou aux limites marines à l'Holocène (Miller, 1979; Dyke et al., *1982) (aht = au-dessus du niveau de la marée haute). On donne les limites marines, mais pas l'altitude des échantillons. La région de décapage aréolaire est soulignée par le tireté gras à la tête de la baie. Les isobases de 0 et 20 m sont de direction N-S. Le carton montre la ligne de partage glaciaire et des marges glaciaires au cours du sous-stage de Cockburn (Dyke et Prest, 1987); PE = glace de Penny; H = glace de Hall; A = glace d'Amadjuak. CB = Chidliak Bay; AI = Allen Island; NL = Nettilling Lake; KF = Kingnait Fiord; PF = Pangnirtung Fiord; RL = Robinson Lake.*

outer Cumberland Peninsula, local ice masses apparently did not expand significantly during the Late Foxe (Hawkins, 1980; Nelson, 1981; Locke, 1987).

Amadjuak Ice was probably the dominant ice source, Hall Ice the next most important, and Penny Ice contributed the least. This suppostition is based on the relative lengths of the ice divides and sizes of the drainages drawn by Dyke and Prest (1987) at 10,000, 9000 and 8400 yrs BP. This is also supported by the N-S isobase trend which shows that the main ice load was to the west (Fig. 11; Andrews, 1980) and by the evidence at Allen Island and Robinson Lake for the expansion of local ice on Hall Peninsula during the Late Foxe (Fig. 11; Miller, 1979; Sauer *et al.*, 1991). The heavily ice-scoured area at the head of the sound relates to glacial erosion beneath Amadjuak Ice (Fig. 11; Andrews *et al.*, 1986).

The presence of carbonate in ice-proximal sediments in 85027-029 PC & TWC also supports the conclusion that Foxe Basin was the dominant source of ice in the sound. Andrews and Miller (1979) suggested, on the basis of the paucity of limestone erratics on the saddles between Foxe Basin and the heads of Frobisher Bay and Cumberland Sound, that an ice divide lay east of the Precambrian/Paleozoic contact, close to the coast of western Baffin Island. This scenario was used to explain the supposed limited ice flow into Cumberland Sound during the Late Foxe (Dyke, 1979). This study shows that a major ice lobe did fill Cumberland Sound in the Late Foxe, and that there was a relatively large carbonate influx associated with melting of the ice (Jennings, 1989). Possibly, the ice divide lay to the west of the Precambrian/Paleozoic contact for part of its length or it migrated across that contact over some time intervals.

A MODEL OF DEGLACIATION AND ICE EXTENT

The data presented in this paper allow the timing and spot location of three ice margins to be determined, but do not uniquely define the orientations of the margins. Onshore glacial geological data strongly influenced my interpretations of the ice margins shown in Figure 11. Isobases across the area are not orthogonal to the axis of the sound (Fig. 11). They indicate that the major ice load was to the west, on Hall Peninsula and Foxe Basin. In support of the isobases, there is evidence for advances of Amadjuak and Hall ice during the Cockburn substage, but no evidence of extensive Late Foxe ice advances on Cumberland Peninsula southeast of the Penny Ice Cap.

The limited ice on Cumberland Peninsula has allowed the preservation of large, "early Foxe" deltas and moraines at the mouths of several of the major fiords that drain into southern Cumberland Peninsula (Fig. 11). The 99 m asl delta and associated moraine at the mouth of Kingnait Fiord is an example (Dyke, 1979). These deposits have been indirectly dated using stages of soil development (Birkeland, 1978), differences in the degree of horneblende etching (Locke 1979), amino acid analysis of shell fragments (Dyke *et al.*, 1982) and by their intrinsic relationships with glacial and sea-level chronologies on northern Cumberland Peninsula (*e.g.* Andrews, 1980; Nelson, 1981; Brigham, 1983). Because no *in situ* marine shells were recovered from these deltas, the associated moraines are not securely dated. It is therefore possible that the moraines and deltas are of Late Foxe age and were deposited during retreat of the ice that filled Cumberland Sound. If this were the case, then the 50 m elevational difference between the Duval marine limit and the 8700 BP shoreline (Dyke, 1979) would imply that the Duval moraines were deposited at about 9700 BP (5 m/century emergence rate) and that the Early Foxe limit of Dyke (1979) would represent the terrestrial Late Foxe limit (A.S. Dyke, pers. comm., 1992).

If the deltas and moraines are of early Foxe age, they constrain the positions of the Late Foxe ice margins because, presumably, they would not be preserved if overrun by Late Foxe ice flowing down the axis of Cumberland Sound. The ice margins on Figure 11 are oriented to avoid contact with these deltas and moraines. The resulting margins show ice flow oblique to bathymetric trends and extension of ice onto the shelf, without impingement on southern Cumberland Peninsula east of Pangnirtung Fiord (Fig. 11). The reconstruction does not *explain* how ice could have flowed onto the shelf without filling the inner part of Cumberland Sound, and overriding the "Early Foxe" deposits. Perhaps an ice shelf extended from the northeastern part of the margin and protected that area or, conversely perhaps the ice flowed over these deposits without destroying them as has been observed at Loks Land (Miller and Kaufman, 1990) and on Spitsbergen (Mangerud *et al.*, 1987). The ice margins drawn within Cumberland Sound (Fig. 11) are dashed throughout their length to highlight the uncertainty.

The late Quaternary geologic history of Cumberland Sound can be divided into five time intervals. The timing of events discussed below was extrapolated using the radiocarbon dates and sedimentation rates. The error bars on the extrapolated ages must be greater than the error bars on the original dates (about 100 yrs), but are not known. An error of about 200 yrs is implicit in the timing of each event discussed below.

13,400-10,200 BP

During this interval, ice was either at or near its maximum late Foxe position. Till (Ai/BUD) was being deposited over bedrock in Cumberland Sound, while extreme ice-proximal glacial-marine sediments (lithofacies B) charged with material derived from erosion of Cretaceous bedrock were being deposited on the shelf at 82034-041 PC. Two possible ice reconstructions could accomodate the data, one involving the presence of an ice shelf and the other with no ice shelf. Figure 11 depicts an ice shelf extending at least as far as 82034-041, releasing sediments derived from glacial erosion of Cretaceous bedrock to form lithofacies B at the site. The grounding line could have lain anywhere northwest of the northwestern edge of the Tertiary bedrock, 25 km away. As the ice advanced seaward of Cape Mercy, the lack of confinement by Hall and Cumberland peninsulas may have allowed the ice to spread laterally, thin and float, forming an ice shelf. There is no evidence of a former ice shelf other than extreme ice proximal lithofacies B with no Tertiary bedrock component at least 20 km from the supposed grounding line. If, on the other hand, no ice shelf existed, then sediments that were interpreted to be extreme ice proximal (lithofacies B) were probably deposited 20 km from the ice margin.

The orientation of the 13,400 BP margin implies that Amadjuak and Hall ice were both well beyond their previously mapped Late Foxe limits. The composition of the till at the base of 85027-025 PC reflects erosion of both the Cretaceous and Ordovician bedrock. The position of 85027-025 PC relative to the bedrock geology indicates that there must have been some downbay component to the ice-flow (Fig. 11), otherwise, the till in this core would not contain as much Cretaceous material as it does.

10,200-9750 BP

The date on ice-proximal sediments in 85027-031 indicates that the ice had retreated from that site prior to 10,450 yrs BP (Fig. 11). The 10,200 BP margin is placed at site 85027-029, where the age of deglaciation can be estimated by determining the age of the onset of glacial-marine sedimentation. The 10,200 BP age for the ice margin was determined by extrapolating the sedimentation rate in the ice-proximal sediments of 85027-029 PC and TWC (4 m/ka) to the top of BUD, 1 m below the base of the core.

Between 10,200 and 9750 BP lithofacies B was deposited at the site of 85027-029 PC and TWC. Ice proximity is indicated by the foraminiferal assemblage (Fig. 6). Glacial erosion of Cretaceous and Precambrian bedrock is reflected in the mineralogical composition of these sediments (Fig. 6). However, the Cretaceous component decreases over this interval indicating a decrease in the erosion of Cretaceous bedrock (Fig. 6). Glacial erosion of Cretaceous bedrock ceased after 9750 BP indicating the the grounding line had moved landward of the Cretaceous bedrock (Figs. 6 and 11).

Based on the interpretation of the terrestrial glacial evidence from Cumberland Peninsula (Dyke *et al.*, 1982), an almost shore-parallel ice margin was drawn slightly west of the edge of the Cretaceous bedrock, mainly between 500 and

750 m water depth (Fig. 11). The ice was no longer grounded in the deep trough but was mainly overriding the Precambrian bedrock. Based on this reconstruction, the ice retreated from site 85027-029 to the nearest southwestern edge of the Cretaceous bedrock at the relatively rapid rate of 220 m/a. Recent research on southern Hall Peninsula reported by Sauer and Miller (1991) indicates that Late Foxe ice had retreated from Brevoort Island by 9900 BP (Sauer, pers. commun., 1991).

9750-9150 BP

At 9750 BP, lithofacies B was replaced by lithofacies C. This textural change corresponds with a relative increase in the carbonate content, an increase in magnetic susceptibility, a decrease in organic carbon and a color change from black/gray to gray (Table II; Jennings, 1989). These changes are interpreted to reflect the retreat of the grounding line onto Precambrian bedrock (Fig. 6). Carbonate carried into the sound within Amadjuak Ice increased in importance because it was not diluted by erosion of local soft bedrock. The textural change occurred because glacial erosion of the hard Precambrian lithologies did not produce fine material as did glacial erosion of the Cretaceous mudstone. The magnetic susceptibility increased due to the relative increase in Precambrian erosion products.

Foraminiferal assemblages reflect ice-proximal conditions until 9250 BP. Sedimentation rates were still high, indicating that the ice margin had not yet retreated into the fiords along northern Hall Peninsula. At Allen Island, southern Hall Peninsula, the maximum Late Foxe marine transgression occurred at 9230 ± 100 yrs BP, but Miller (1979) suggested that Late Foxe ice did not reach this site (Fig. 11). An early Foxe ice-contact deposit that lies 25 km beyond the Late Foxe ice limit on Allen Island substantiates the restricted ice extent on southern Hall Peninsula (Osterman *et al.*, 1985).

If Allen Island was not inundated by ice, then this restricts the extent and thickness of ice that would have been available to flow into the sound from southeastern Hall Peninsula. As previously discussed, Amadjuak Ice had to supply much of the ice to the shelf by flowing across areas north of Allen Island. The main track of the Amadjuak Ice is probably marked by the region of intense areal scour shown on Figure 11.

9150-7600 BP

Glacial-marine sedimentation continued throughout this interval, though the sedimentation rate decreased substantially by 8900 BP (Fig. 6). The decrease in sedimentation rate probably relates to the rapid retreat of portions of the ice margin into the fiords as documented by the position of the Ranger and Chidliak moraines (Miller, 1985; Dyke, 1979). A retreat rate of 60 m/a was estimated by measuring the orthogonal distance between the 9750 BP margin to the site of GSC 2466 (8660 BP) in Chidliak Bay (Fig. 11). The mineralogical data suggest an influx of the erosional products of regional glaciation, runoff, local reworking of basinal sediments and influx of ice rafted and suspended sediment from distal sources (Fig. 6).

The foraminiferal data indicate ice-distal conditions until about 8900 BP. Between 8900 and 7950 BP the influence of glacial ice was very remote or absent, and the fauna may show evidence of >0 °C "Atlantic Water" at the seafloor (Fig. 6). By 7950 BP, the calcareous species began to be poorly preserved or replaced by agglutinated species (Fig. 6).

7600-0 BP

Postglacial sedimentation began in the sound by 7600 BP. By this time most glaciers had retreated onshore making the fiord basins available as sediment catchments. Decreased sedimentation rates are indicated by the change in the geometry of acoustic units from conformable to onlapping basin fill (Fig. 6).

During deposition of lithofacies D from 7600-5350 BP, there was no mineralogical change from the previous interval. However, some or all of the carbonate influx could be attributed to reworking of lithofacies C. During deposition of lithofacies E, 5350 to 0 BP, sediments were derived from local reworking and runoff plus ice-rafted detritus from distal sources. There may be an indication of increased erosion of Precambrian terrain at the top of the section corresponding to increased local glacier activity during Neoglaciation.

Calcareous foraminifera disappear from the sediments by 6300 BP and were replaced by an agglutinated fauna. The agglutinated fauna reflects <0 °C water at the seafloor. The Baffin Current had become established by this time.

ACKNOWLEDGEMENTS

Financial support for this research was provided by NSF Grant DPP-8619284 and ONR Contract # N00014-87-K-0026. The Atlantic Geoscience Centre provided the acoustic profiles and cores used in this study. I thank B. MacLean, P. Stoffyn, F. Cole, G. Sonnichsen, C. Powell and D. Praeg and others at the Atlantic Geoscience Center for their help in conducting the research. D. Kaufman, K. Williams, and J.T. Andrews carefully read and critiqued the manuscript. I appreciate the constructive reviews of B. MacLean and A. Dyke.

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