The Late Pleistocene geology of the Labrador Shelf

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Josenhans, H. & Zevenhuizen, J. 1987: The Late Pleistocene geology of the Labrador Shelf. *Polar Research* 5 *n.s.*, 351–354.

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The Quaternary stratigraphic sequence on the Labrador Shelf records evidence of several glacial cycles and major climatic/environmental changes. This summary describes the major depositional episodes preserved on the Labrador Shelf and assigns ages and depositional interpretations to the last deglacial sequence. For a more detailed description of the seismic stratigraphy and sample analysis used to interpret this summary, the reader is referred to Josenhans et al. (1986).

Due to a lack of sample control in the lower part of the Quaternary section, paleoenvironmental interpretation for all the Pleistocene up to the last glacial advance is based only on seismic facies interpretation. Interpretation of Late Wisconsinan and Holocene sequence throughout the Labrador Shelf is based on seismic data tied to piston cores and bottom samples.

Fig. 1 diagrammatically summarizes the major depositional episodes since the Pliocene. The following text provides details pertinent to each of these 10 episodes.

1. A major regional erosional unconformity is developed on top of the Late Tertiary beds (as dated from exploration well cuttings). In some of the east-west trending depressions (saddles) this unconformity is smooth, but in the deeper saddles it is preserved as a fluvially cut erosion surface. The deepest recorded base level of this fluvial sequence is 650 m below present sea level. Based on paleontologically dated subsidence rates from exploratory well data, relative sea level was 650 m lower than present approximately 2 million years B.P. (Gradstein & Srivastava 1980). We therefore infer a Pliocene age for this erosional surface. The presence of these deep paleo drainage systems within the saddles suggests the major physiographic character of the shelf was formed at this time.

2. Subsidence of the shelf and/or global sea level rise resulted in infilling of the paleo channels within the deep saddles and development of a well stratified, conformably bedded sequence in the northern areas. Similar sediments may also have been deposited in the later stages of the deltaic development in the southern areas, but these are not preserved.

Considerable deltaic progradation occurred at the shelf edge and at the perimeter of the banks at this time.

3. The glacial episodes on the outer shelf have smoothed but not drastically altered the fluvial erosion surface. The symmetrical, streamlined shape of the east-west trending saddles and the removal of fluvial deposits in the western areas of the shelf are thought to have occurred during this and subsequent glacial advances. The smooth unconformity at the base of the glacial deposits suggests that erosion is the dominant process during advancement of the glacier, and deposition (*Labrador Shelf Drift*) occurs mainly during the retreat phase. Up to five superimposed, regionally correlable wedges of glacigenic sediments can be detected at the shelf edge and within the central areas of the saddles. Without chronologic control we do not know if these represent individual glacial episodes or local readvances at the ice margin. Based on the well developed unconformities between the till units and considering that deposition appears to occur during retreat of the ice, we suggest that the five units may represent major glacial episodes. In the marginal trough/inner shelf area only the latest glacial episode is preserved. Deposits from previous events were eroded in this area and are present only on the outer shelf and saddles.

Outbuilding of the shelf edge by a combination of proglacial sediments seaward of the ice margin and by massive till tongues to a (present) depth of 600 m at the shelf edge occurred during these glacial episodes. Glacial ice (as inferred from the presence of acoustically defined till) has covered the inner shelf to a depth of 800 m.

4. Isopach maps based on seismic character indicate thick till deposits interpreted as lateral moraines surrounding the bank margins. We infer ice streams in the latter part of ice retreat flowing out through the saddles as the mechanism for their formation. Stacked lateral morainal ridges at these margins suggest that this style of deglaciation has occurred for most of the glacial episodes. North-south trending ridges in the base of the saddles may represent recessional moraine ridges formed during final retreat of the ice margins.

On the outer banks numerous laterally consistent nick points which may represent former sea level terraces are cut into the till surface between a depth of 100 and 350 m. The age of these features is not known, although they must postdate retreat of the ice which deposited the till. An iceberg grounding line has also been proposed for these nick points (Fillon & Harmes 1982).

5,6. The upper till deposit is found only in depths greater than 100 m. In some places the unit pinches out along a feather edge against the bank tops and in others it terminates in the form of lateral moraine ridges. Over the inner shelf and in the marginal trough (to depths of 750 m) the upper till is found deposited directly on the bedrock surface, whereas further seaward it overlies the earlier till deposits. We infer increased erosion on the inner shelf/marginal trough where the ice was thicker and therefore had more erosive power. The upper till surface is undulating as a result of iceberg scouring. In the deeper water of the inner shelf/marginal trough (>450 m) the upper till surface is unscoured because icebergs calving from the retreating margin of the inner shelf did not exceed 450 m in draft. Piston core samples from the upper till unit indicate

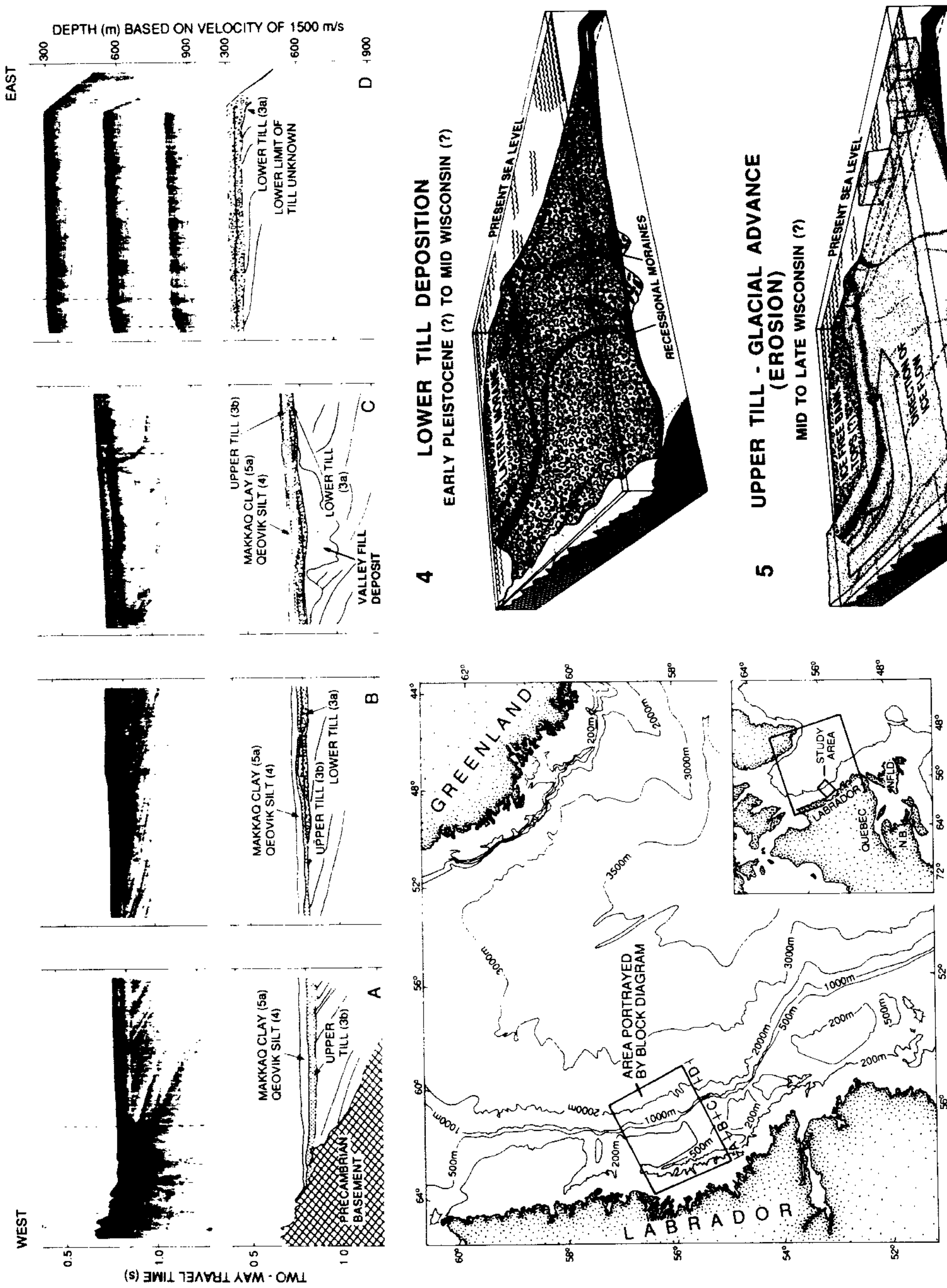
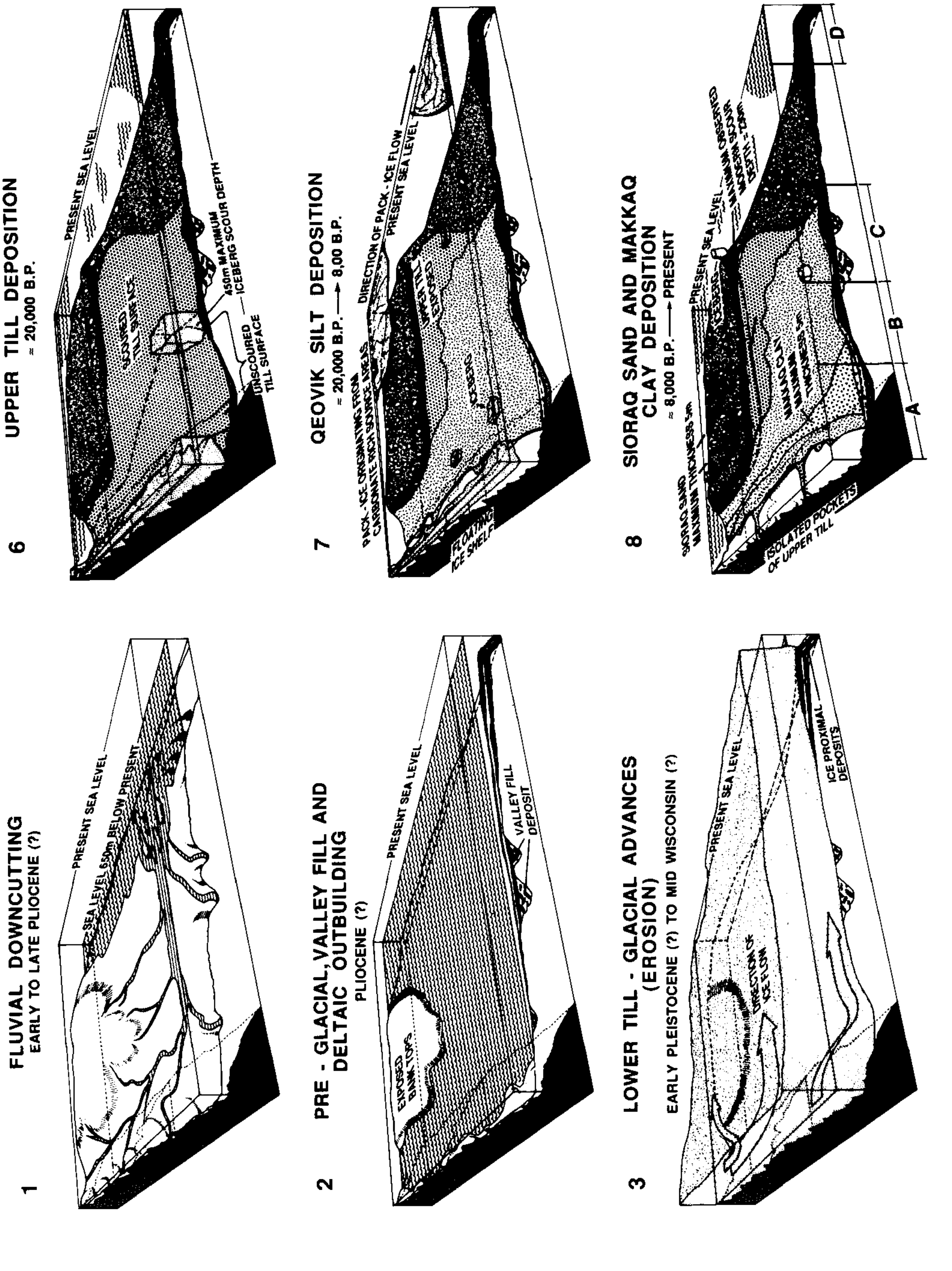


Fig. 1. Index map showing general bathymetry of the Labrador Shelf and location of the cross section and block diagrams illustrated. The block diagrams show the various phases (1–8) of Pleistocene development described in the text. The location of seismic section A-D is shown in block diagram 8.


1 FLUVIAL DOWNCUTTING
EARLY TO LATE PLIOCENE (?)
PRESENT SEA LEVEL
SEA LEVEL 650m BELOW PRESENT
2 PRE - GLACIAL, VALLEY FILL AND DELTAIC OUTBUILDING
PLIOCENE (?)
PRESENT SEA LEVEL
EXPOSED BANK TOPS
VALLEY FILL DEPOSIT
3 LOWER TILL - GLACIAL ADVANCES (EROSION)
EARLY PLEISTOCENE (?) TO MID WISCONSIN (?)
PRESENT SEA LEVEL
DIRECTION OF ICE FLOW
ICE PROXIMAL DEPOSITS
6 UPPER TILL DEPOSITION
≈ 20,000 B.P.
PRESENT SEA LEVEL
SCOURED TILL SURFACE
450m MAXIMUM ICEBERG SCOUR DEPTH
UNSCOURED TILL SURFACE
7 QEOVIK SILT DEPOSITION
≈ 20,000 B.P. → 8,00 B.P.
PACK - ICE ORIGINATING FROM CARBONATE ROCK SOURCE AREAS
DIRECTION OF PACK - ICE FLOW
PRESENT SEA LEVEL
FLOATING ICE SHELF
8 SIORAQ SAND AND MAKKAQ CLAY DEPOSITION
≈ 8,000 B.P. → PRESENT
PRESENT SEA LEVEL
ISOLATED POCKETS OF UPPER TILL
A
B
C
D

unsorted unstratified pebbly to bouldery mud with shear strengths ranging between 20–50 K Pa. Consolidation is generally normal. We suggest the normal consolidation of this marine till is a result of hydrostatic support on the ice, which consequently did not load the underlying till. Lithologically the unit is comprised of crystalline rock fragments originating from mainland Labrador, reworked earlier tills and the underlying Tertiary bedrock. Where sampled the till does not contain lithic carbonate fragments.

7. An acoustically well stratified, conformably draped unit (*Qeovik Silt*) overlies the upper till in water depths greater than 150 m. The unit contains up to 80% lithic carbonate in the sand and gravel size range. The nearest source for the carbonate debris is from the Paleozoic carbonates in the Hudson Strait; other sources include Hudson Bay, Foxe Basin and more northern areas. Paleontological analysis indicates cold water ice proximal conditions. We infer an environment with year round pack ice cover, abundant sediment (carbonate) rich glacial ice fragments and icebergs as the primary transport mechanism for the carbonate debris. The abundance of ice rafted fragments found in piston cores and the high percentage of carbonate debris indicate large amounts of ice rafting during this episode. Calculated sedimentation rates are approximately 150 cm/ 1,000 yrs. Pollen records from the *Qeovik Silt* indicate colder conditions than present which were similar to those found on Baffin Island today. Radiocarbon dates suggest an age spanning from approximately 20,000 to 8,000 years B.P. In the northern areas the acoustic evidence suggests undisturbed deposition occurred in areas which are now being intensely iceberg scoured. This may be due to greater water depth during deposition or deeper drafts of modern icebergs.

8. Deposition of the uppermost Holocene units started at 8,000 years B.P. In the deeper basins the *Makkaq Clay* unconformably overlies the *Qeovik Silt*. This unit is characteristically ponded in response to a marked increase in bottom current activity. The unit is an intensely bioturbated, acoustically weakly stratified silty mud with few ice rafted fragments. The unit is almost devoid of lithic carbonate fragments. Paleontological and pollen analyses indicate variable climatic conditions: 1) From 8,000 to about 6,500 years B.P. high arctic tundra and cool climatic conditions prevailed, 2) then gradual warming to about 4,000 years B.P., 3) hypsithermal warmer boreal forests 4,000-3,000 years B.P., 4) then deteriorating to the present cold conditions (Scott et al. 1984). Although the northern half of mainland Labrador is presently barren of trees, during the climatic optimum (4,000–3,000 years B.P.) mixed forests colonized the area.

The increased bottom current activity which has prevailed since 8,000 years B.P. has winnowed the bank tops and locally deposited a fine sand (*Sioraq Sand*) in depressions and behind morainal ridges. By the combined effects of bioturbation, winnowing bottom currents, and iceberg turbation, a considerable amount of material is eroded. Presently, the outer bank tops are intensely reworked by grounded icebergs to a depth of 220 m – the maximum draft of modern bergs.

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