A race for ice discharge between ice streams on glaciated continental shelves

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RATIONALE

Ice-streaming is one the most efficient mechanism through which ice can be exported from the interior of ice sheets to the ocean[1].

Changes in the activity and the velocities of ice streams can therefore have a significant impact on ice sheet mass balance and global sea level[2].

Changes in the drainage network of ice streams usually results into ice streams switching trajectory and/or shutting down[3].

While some hypotheses for reorganization of ice streams have emerged recently[3], the mechanisms that control flow-switching remain poorly understood.

Here, we report the flow-switch of an ice stream that occurred within the former Laurentide Ice Sheet that was active during the last glaciation on the northeastern Baffin Island shelf (Arctic Canada) through glacial erosion and overdeepening of marginal troughs.

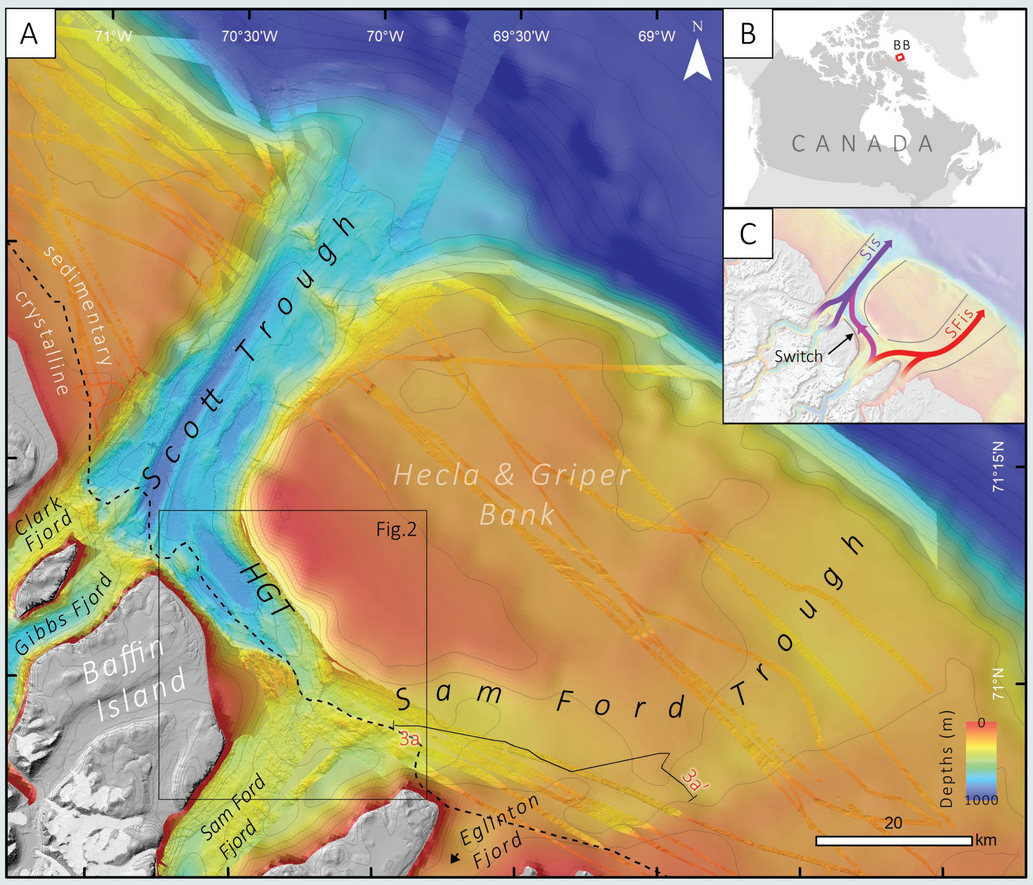

Figure 1. A. The map show the high-resolution bathymetric data collected by ArcticNet program draped on the International Bathymetric Chart of the Arctic Ocean data (IBCAO40) map on the northeastern Baffin Island shelf. The black dashed-line shows the approximate limit between sedimentary and crystalline bedrock. HGT: Hecla & Griper Trough. Light-gray lines: 100 m contours. B. Location of the study area. BB: Baffin Bay. C. Schematic representation of ice streams that existed in the study area and the location of the ice stream switch. Sis: Scott Ice Stream. SFis: Sam Ford Ice Stream.

METHODS

High resolution swath bathymetry imagery was collected over a period of 13 years onboard the CCGS Amundsen, using Kongsberg Simrad EM-300 and EM-302 (30 kHz) multibeam echosounders. The multibeam data were processed using the Caris Hips & Sips and MB-System softwares.

Archived seismic reflection profiles were collected by the Geological Survey of Canada; they were extracted and analysed using the LizardTech GeoViewer software.

International Bathymetric Chart of the Arctic Ocean data was used for the analyze of the morphology of Sam Ford Trough.

EVIDENCE FOR ICE-STREAM SWITCHING AND PIRACY

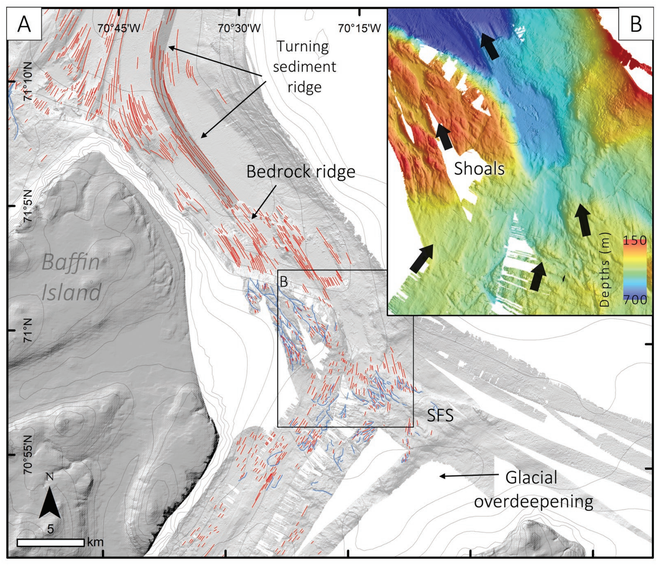

Figure 2. A. Ice-flow landforms (lineations, crag-and-tails, drumlins, grooves) and meltwater channels interpreted from bathymetric data. SFS: Sam Ford Fjord Sill. B. Close-up on bathymetry showing the direction change in both ice-flow landforms and meltwater channels. Black arrows show general direction of the features.

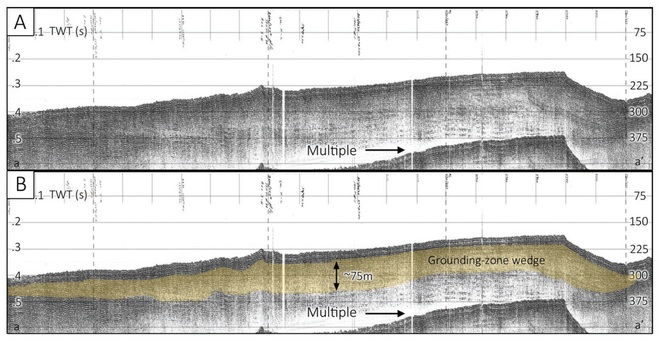

Figure 3. Airgun profile (A) and interpretation (B)showing a major 75 m-thick grounding-zone wedge (red) in inner-middle Sam Ford Trough (Profile 80028_AG_RAYT_257_0200; NRCan).

The swath bathymetry imagery shows glacial lineations both in Scott and Hecla & Griper troughs, while none is observed in Sam Ford Trough (Figs. 1-2)[4].

Although Hecla & Griper Trough has a structural origin (eroded along the crystalline-sedimentary fault; Fig. 1) the lineations observed within the trough and on Sam Ford Fjord Sill support the erosion by an ice stream (Fig. 2).

The presence of a grounding-zone wedge (Fig. 3) and an overdeepened basin in Sam Ford Trough suggest that an ice stream once flowed in and excavated Sam Ford Trough[5].

Scott and Sam Ford ice streams have equivalent ice-drainage basins areas[6], so what happened?

Over repeated glaciation episodes, the erosional effect of ice streams spreading upstream along Hecla & Griper Trough has eventually led the marginal trough (HGT) to extend to Sam Ford Fjord mouth where ice-streaming could already have been active.

The changes in bathymetry associated with the upstream propagation of Scott Ice Stream in the Sam Ford system has led to: the reorganization of the ice drainage system; the switching of Sam Ford Ice Stream from Sam Ford Trough to Scott Trough; and ultimately, the shutdown of Sam Ford Ice Stream.

The erosion and the subsequent morphology of the shelf of NE Baffin is therefore a function of this competition for ice drainage network.

SIMILAR SYSTEMS ON OTHER CONTINENTAL SHELVES

Similar transverse troughs following coast orientation and aligned with faulting in bedrock are also observed along the Greenland (e.g., Godthaab, Sukkertop and Melville troughs; Figs. 4a-b), continental shelves and probably result from the same formation mechanism.

An ice drainage piracy mechanism could explain the presence of other abandoned cross-shelf troughs on most high latitude shelves that are not connected to the coast or to fjords (e.g., Pine Island-Twaites West Trough (Fig. 4d) on West Antarctica shelf, or, Unamed Trough on Disko Bank in West Greenland (Fig. 4c).

During the retreat of the ice margin, flow-switching of ice streams on continental shelves provided more efficient and rapid pathways for ice to reach the ocean, thus possibly leading to a more rapid drawdown of ice sheets.

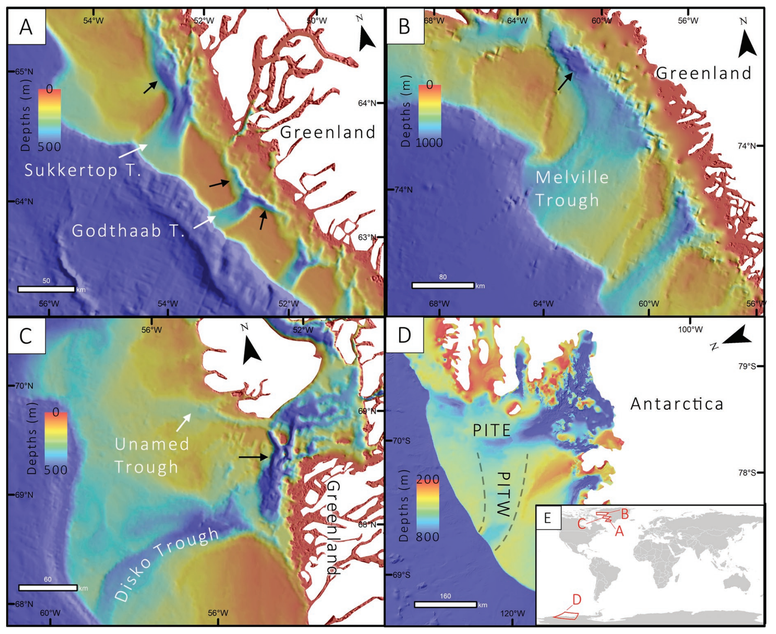

Figure 4. A. Bathymetry (IBCAO) of Sukkertop and Godthaab troughs off West Greenland. B. Bathymetry (IBCAO) of Melville Trough off Northwest Greenland. C. Bathymetry (IBCAO) of Unamed and Disko troughs off West Greenland. D. Bathymetry (Intenational Bathymetric Chart of the Southern Ocean data) of Pine-Island-Thwaites troughs off West Antarctica. E. Location of figures.

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