

# Glacier characteristics and sediment transfer system of Longyearbreen and Larsbreen, western Spitsbergen

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Bernd Etzelmüller, Rune Strand  
Ødegård, Geir Vatne, Rønnaug Sægrov  
Mysterud, Tore Tønning & Johan Ludvig  
Sollid

# Abstract

- Glaciological and hydrological conditions of the glaciers were studied.
- Goal: "[...] to reveal the dynamics and temperature regime of small glaciers in a high-Arctic environment, and its relationship to the material transport and sedimentation of these glaciers."

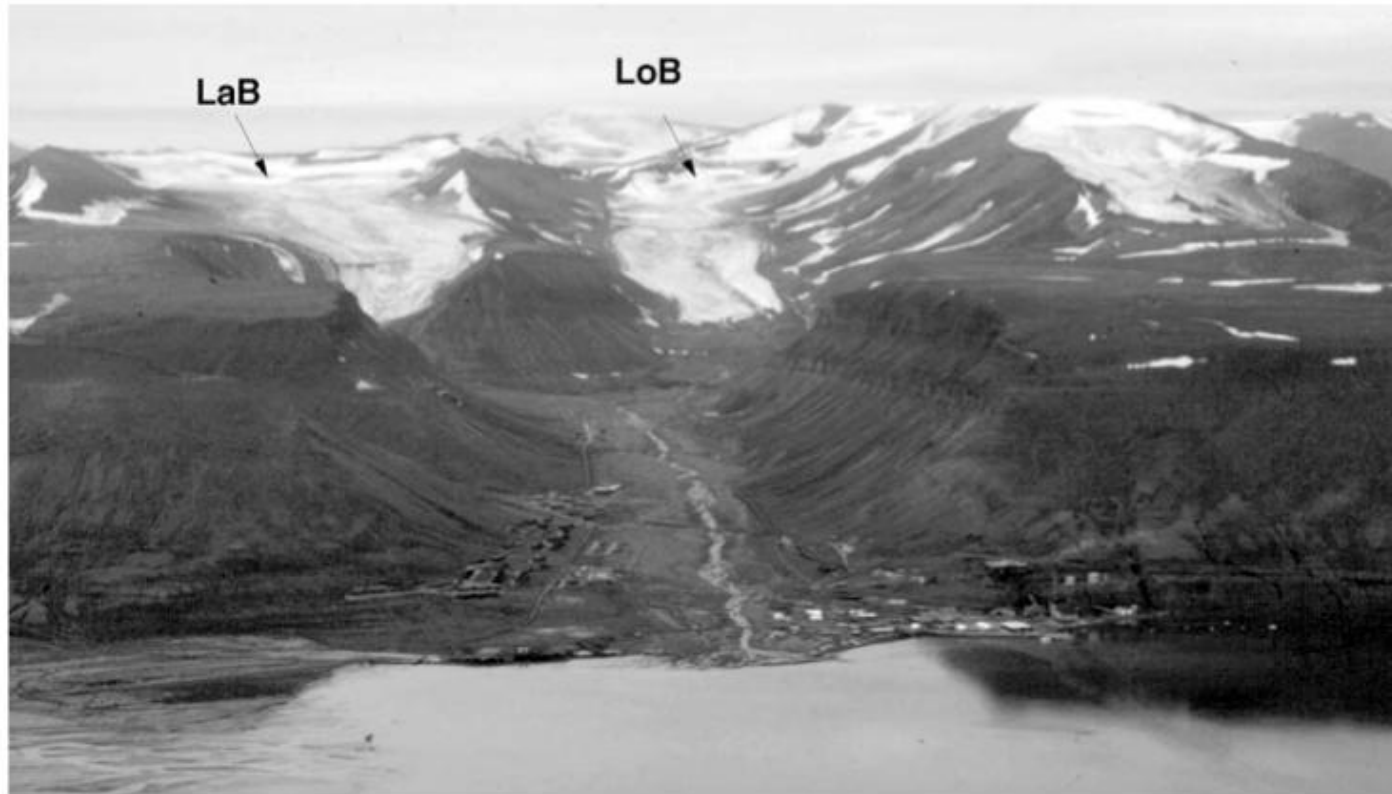
# Introduction

- Svalbard lies in the zone of continuous permafrost → cold-based glaciers.
- Small valley glaciers can give valuable information about the sediment transfer system in the Arctic regions.
- Trying to reveal the dynamics and temperature regime of small, high-Arctic glaciers, and their relationship to the material transport & sedimentation.

# Setting

- MAAT at sea level  $-6.1^{\circ}\text{C}$  (1976-1998)
- MAP 400mm at airport (underestimated)
- Permafrost thickness 200-450m
- Glacier size  $2.7\text{km}^2$  (Longyearbreen) and  $3.0\text{km}^2$  (Larsbreen)

# Setting



*Fig. 2.* The Longyear valley, western Spitsbergen, view towards south. LoB = Longyearbreen, LaB = Larsbreen (photo: Trond Eiken). The small glacier located west of Longyearbreen has no official name.

# Methods - Fieldwork

- Ice-flow velocity measured with theodolite.
- Glacier thickness & cold-temperate ice mapped with radio-echo sounding (error range  $\pm 4\text{m}$ ).
- Meltwater discharge, electrical conductivity and concentration of suspended sediments and solutes measured in glacier marginal area.

# Methods – DEM and glacier geometry

- DEM constructed with help of radio-echo profiles and manual digitizing of contours.
- Terrain parameters like slope and aspect calculated, used for map analysis.

# Methods – Map analysis

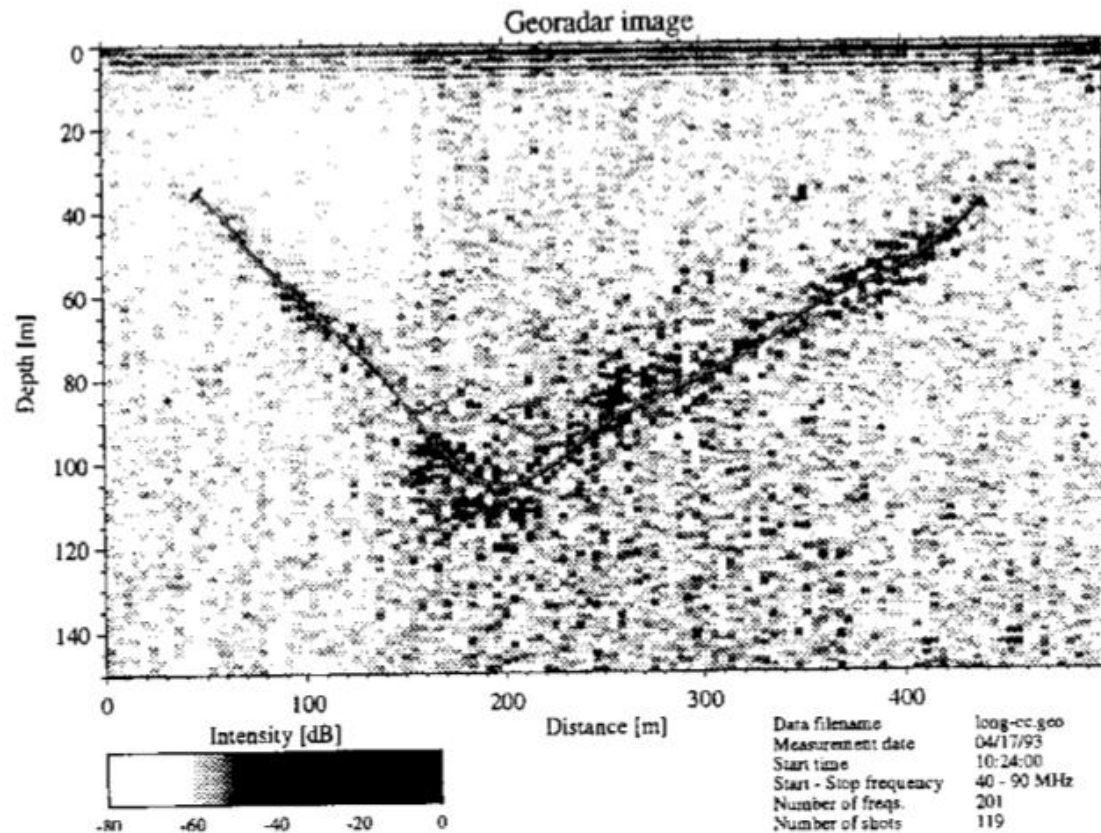
- Spatial analysis was used to calculate ice deformation velocities, basal shear stress and potential drainage system
- Basal deforming velocities calibrated with surface velocities.



# Results – mass balance and glacier geometry

- Loss of mass the last 25 years, in general - 0.5m w.e. Low turnover of mass due to mass-balance gradient of  $0.3\text{m (100m)}^{-1}$
- Longyearbreen has deep V-shaped channel profile (low F-value), Larsbreen U-shaped (higher F-value)

# Glacier geometry – subglacial relief



*Fig. 4.* Example of a radio-echo sounding profile with frequency bands of 30–80 MHz along a transect across the lower part of Longyearbreen. The bottom reflectors are indicated by the line of black pixels within the image. The gray solid line displays our interpretation of the subglacial relief.

# Results – Thermal regime

- Neither are polythermal.
- Radio-echo sounding shows cold-based or cold with temperate ice at the bed.

# Results - Dynamics

- Low ice-flow velocities, between 2-4  $\text{ma}^{-1}$
- Low basal shear stress, but due to low F-factors/greater glacial thickness for Larsbreen, velocities are higher in this glacier.

# Results - Hydrology

- Supraglacial drainage an important mode of drainage – mainly due to cold surface layer and lack of crevasses.
- Supraglacial meltwater routed to englacial/subglacial conduits, close to the marginal areas. Probably R-channels → transition clean/debris-rich basal ice.

# Results - Hydrology

- Spatial analysis show that both supraglacial drainage and channel pressure close to ice-overburden pressures are realistic as drainage patterns.
- Most of the meltwater drainage is believed to be supraglacial in the upper and central parts of the glaciers.
- Discharge varied from  $2 \text{ m}^3 \text{ s}^{-1}$  to  $4 \text{ m}^3 \text{ s}^{-1}$ , and ~60% came from Longyearbreen.

# Results – Sediment transport

- Suspended sediment transport was high from both glaciers, with a calculated value of  $1500 \text{ ta}^{-1} \text{ km}^{-2}$ .
- Grain size significantly finer on Larsbreen, reflects differences in till properties in the proglacial areas.
- Total solute transport was in the order of 20% to 30% of suspended transport.

# Results – Sediment transport

- Meltwater is in constant contact with solid material towards the end of the melting season (from change in solute concentration).
- Total material transport corresponds to denudation rate of  $0.2 \text{ mm a}^{-1}$



# Discussion

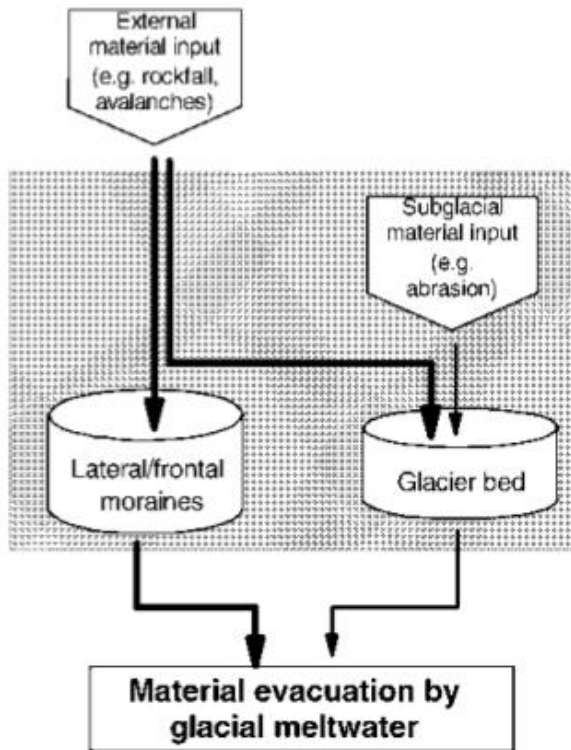
- The glaciology of small high-Arctic glaciers:
  - Limited sliding
  - Liestøl claims Surge type glaciers on Spitsbergen
  - No surge-type features identified on or around the glaciers

# Discussion

- Controls of sediment transfer in cold glaciers:
  - Meltwater drainage mostly supraglacial.
  - Material evacuation can contribute to decay of ice-cored moraines – thermal erosion.
  - Extra-glacial material input contribute to weathering, and might be the most important sediment transfer factor on small, high-Arctic glaciers.
  - High supraglacial input in cold-based glaciers, combined with low fluvial evacuation results in subglacial sediment magazines – giving high correlation between discharge and suspension transport.

# Discussion

(a) Cold or poly-thermal valley glacier system



(b) Temperate valley glacial system

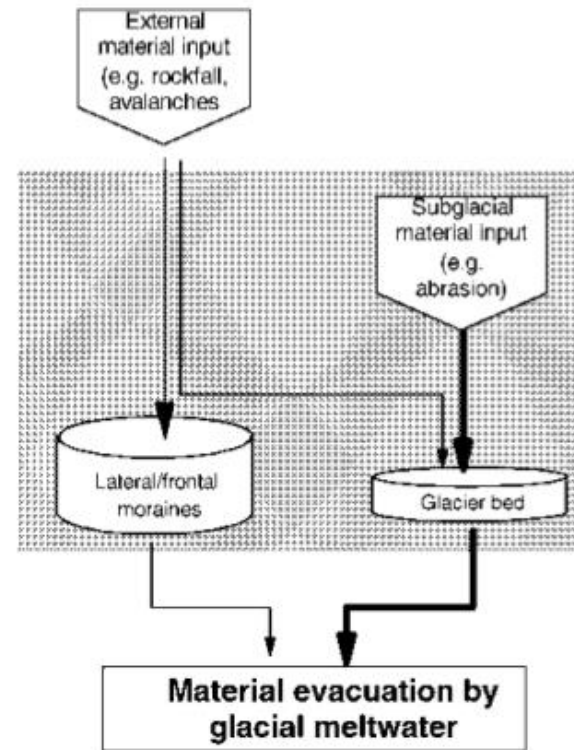


Fig. 9. Simplified sediment transport system for small valley glacier systems in a cold-polar and temperate environment, respectively. The thickness of the arrows indicates the relative importance of sediment transport paths.

# Discussion

- Significance of small polythermal and cold glaciers on landscape development:
  - The slope systems is coupled with the fluvial system through the glaciers → material production and storage more periglacial
  - Subglacial bedrock topography is preserved in the presence of cold ice

# Conclusions

- Longyearbreen and Larsbreen are low-activity glaciers, cold-based with temperate patches and a low potential for basal erosion.
- Transport of ions and suspended solids in the glacial meltwater implies storage of material in and around the glacier which comes into contact with the meltwater.

# Conclusions

- Small Arctic glaciers couple the Periglacial slope system with the fluvial system and therefore build a highly effective denudation system.
- V-shaped subglacial valley profiles beneath Longyearbreen indicate the low subglacial activity and the possibility of preglacial form preservation under cold thermal conditions.