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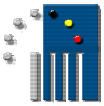
WORKSHOP

Dynamic Interaction between the Antarctic Ice Sheet and the Subglacial Environment

Brussels, 6-7 April 2004



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Science Policy Office (BELSPO)

Field observations and laboratory simulations of basal ice formed by freezing of supercooled subglacial water

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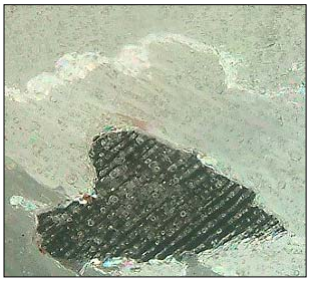
Key Question

Can the physical characteristics of basal ice facies provide a diagnostic signature of glaciohydraulic supercooling?

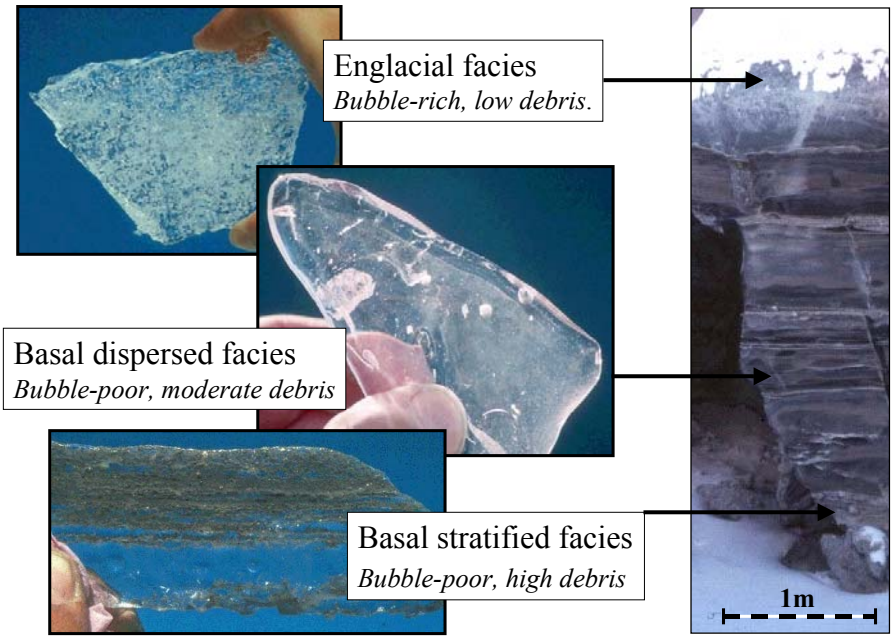
- **Background: What's the problem?**
- **Aim: What are we trying to find out?**
- **Results: Field and laboratory observations.**
- **Implications: Recognising supercooling.**

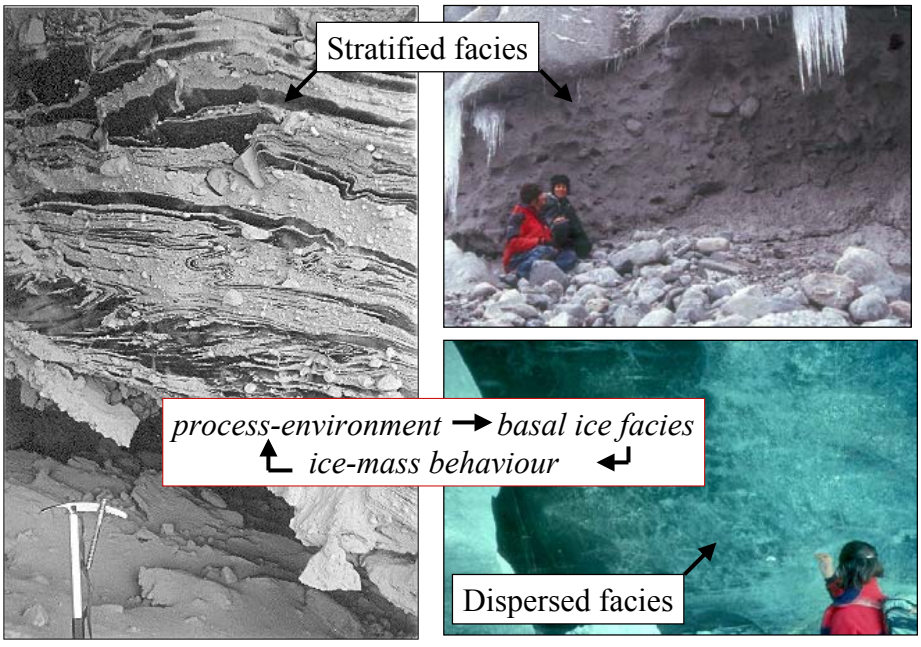


The debris-rich basal ice layer

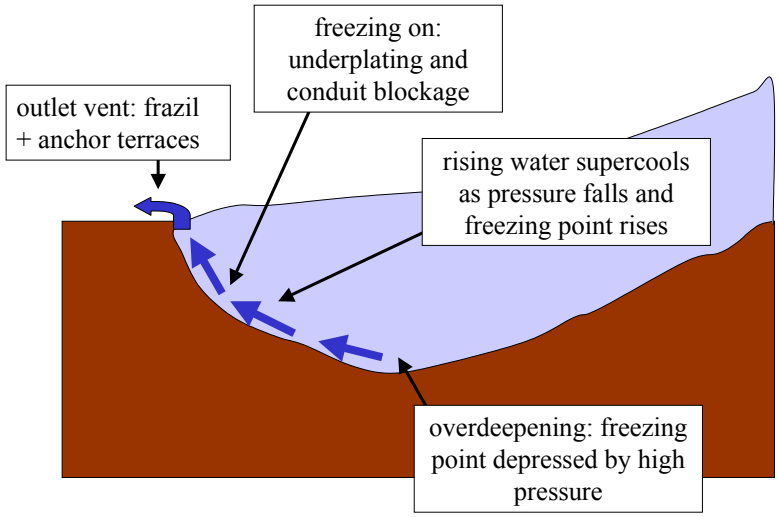
Starting points

- Ice facies reflect environment and process of formation:
  eg: thermal regime, strain history.
- Facies of different origin have different characteristics:
  eg: rheology, geomorphic potential.


Englacial facies
Bubble-rich, low debris.
Basal dispersed facies
Bubble-poor, moderate debris
Basal stratified facies
Bubble-poor, high debris
1m

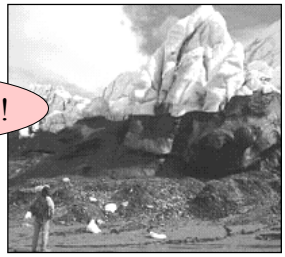

Stratified facies
process-environment → *basal ice facies*
ice-mass behaviour
Dispersed facies

Glaciohydraulic supercooling

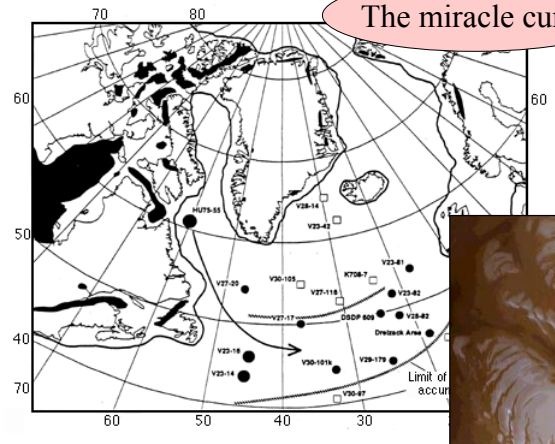


Basal ice derived from Supercooling

The miracle cure!



Matanuska Glacier



Heinrich Layers

Mars north polar ice cap

Controversial claims and assertions

"…established subglacial entrainment processes … cannot account for the appearance, location and geochemical composition of basal ice found at many glacier margins"

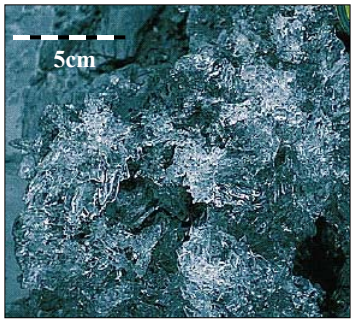
Roberts et al. *Geology* (2002)

"..referees urged us to accept that glaciohydraulic supercooling accounts for the extensive layers of basal ice. We believe that such certainty is premature."

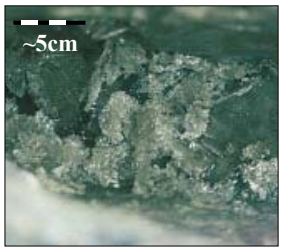
Spedding and Evans *Sedimentary Geology* (2002)

Previous Work

Ice associated with discharge vents at Matanuska Glacier



Aggregates of frazil ice



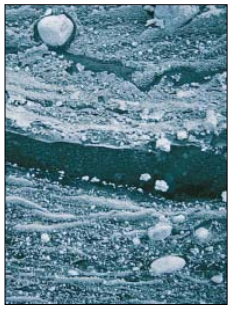
Large platy crystals

Anchor ice terraces

Photo's: Evenson et al., (1999) GSA Special Paper 337.

"…a genetic relationship between the modern anchor ice terraces and the stratified basal ice facies" (Evenson et al., 1999)





"…propose glaciohydraulic supercooling as the primary mechanism creating the debris-laden stratified facies of the glacier's basal zone"

(Lawson et al. *J.Glaciol.* 1998)

Photo's: Evenson et al., (1999) GSA Special Paper 337.

Recent work in Iceland

Subglacial overdeepenings

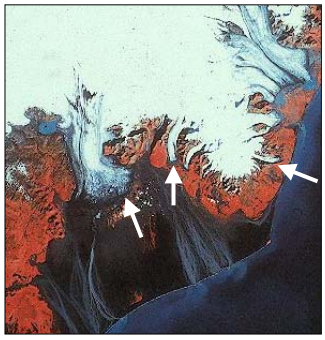
Subglacial meltwater outlets

Frazil ice

Anchor ice terraces

Fracture-fill ice

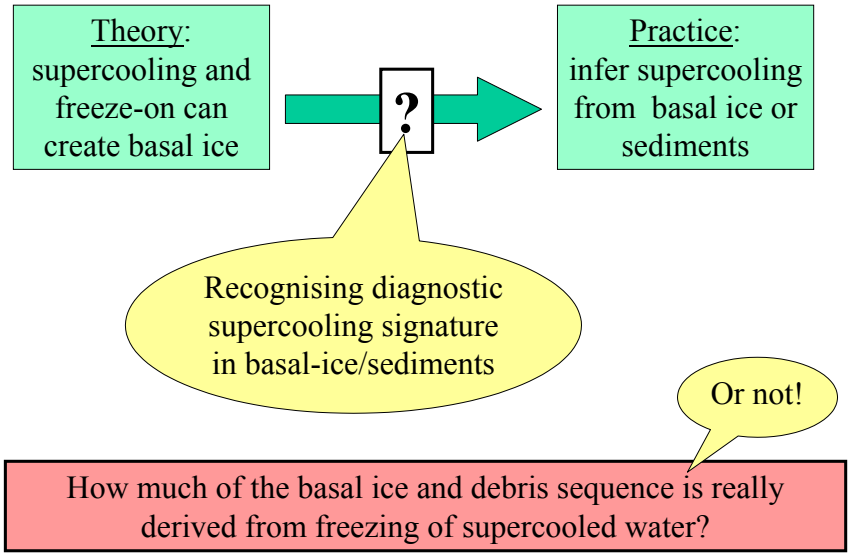
Just like Matanuska



"…bands of debris-rich frazil ice are crystallographically and sedimentologically similar to basal ice exposures at the margins of both glaciers, implying a process-form relationship between glaciohydraulic freeze-on and basal ice formation"

Roberts et al. *Geology* (2002)

Conceptual gap requiring evidence:



Our specific objectives

i) identify diagnostic characteristics of ice formed by freezing of supercooled water (in the field and in the lab)

ii) characterise the full range of basal facies at "supercool" sites to see how much of the basal ice is actually formed by freezing supercooled water.

To find out: how significant is supercooling in creating the basal ice sequences at "supercool" sites.

Part 1 of the project

Field observations in Iceland

Revisiting "supercool" sites of Roberts et al. (2002) and Spedding and Evans (2002).

1. <u>Outlet vents</u>: upwellings and frazil/anchor ice terraces

Outlet vents: frazil/anchor ice terraces

Agglomerations of "frazil floc" and large platy crystals

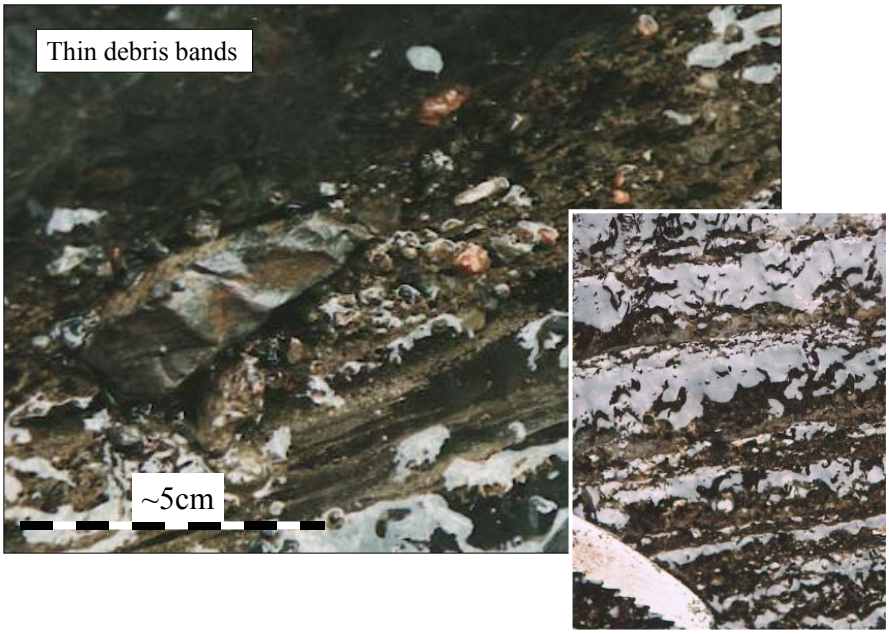
2. Basal ice sequences
<u>far from</u> outlet vents

Field and laboratory observations

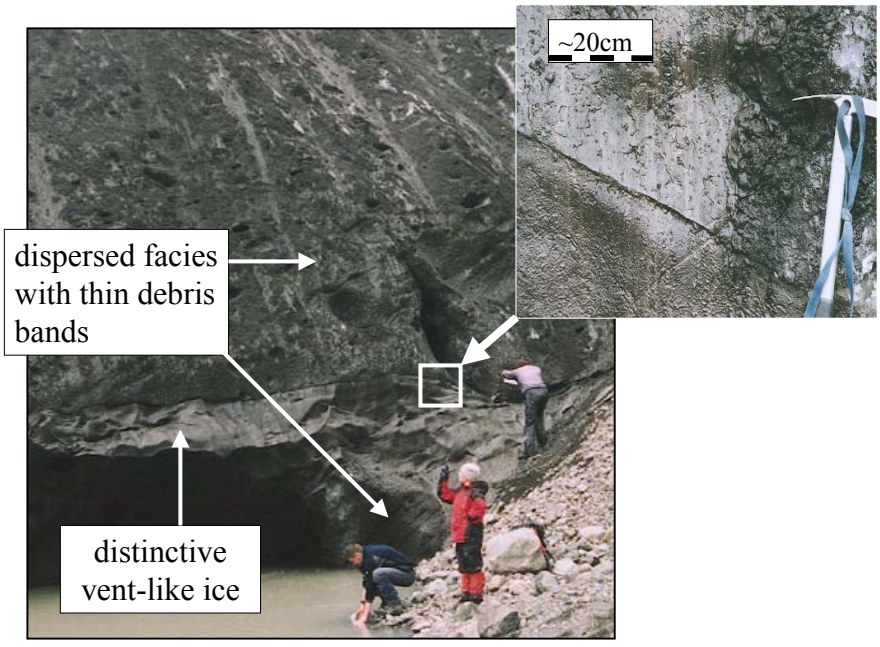
Clear / dispersed basal ice facies

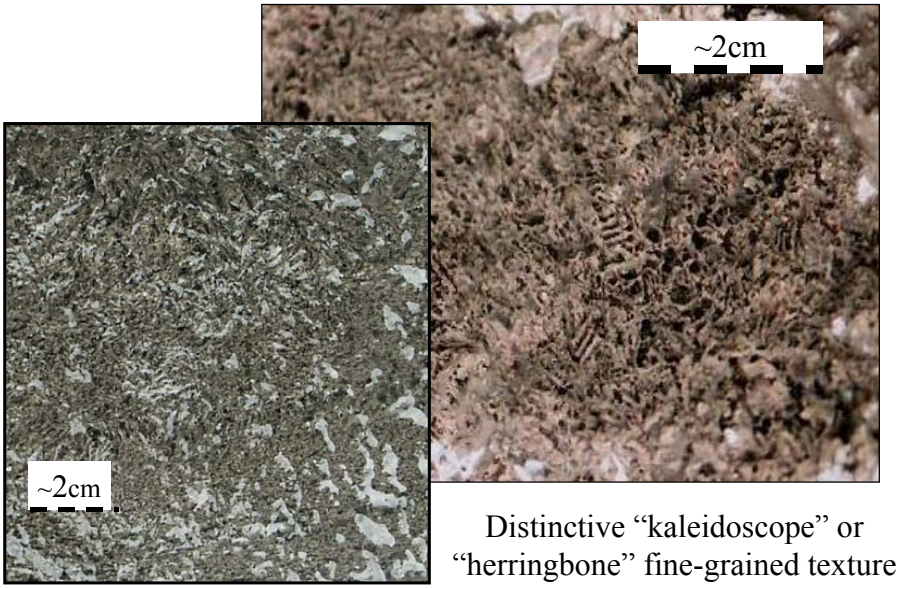
Field and laboratory observations

Thin debris bands



3. Basal ice sequences close to outlet vents





Distinctive “kaleidoscope” or “herringbone” fine-grained texture

Summary of our initial field observations:

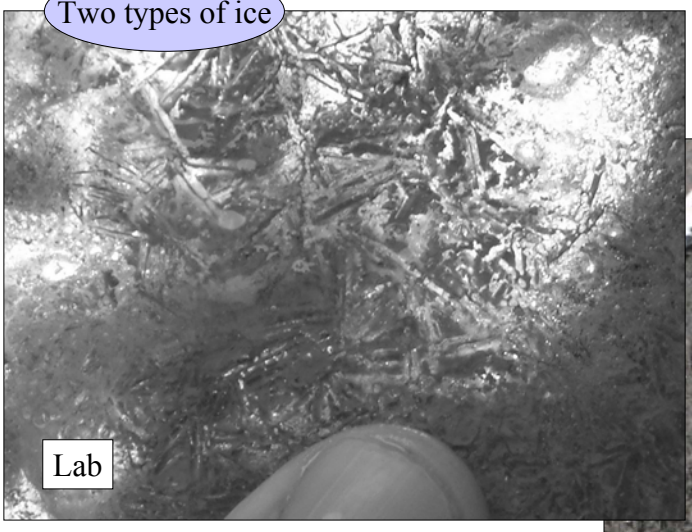
- Wide range of ice facies.
- Distinctive facies accreting at supercooled vents.
- Distinctive “vent” facies also within basal ice near vents.
- No “vent” facies distant from supercooled vents.
- Basal ice sequences dominated by *other* facies.
- Need more detailed measurements

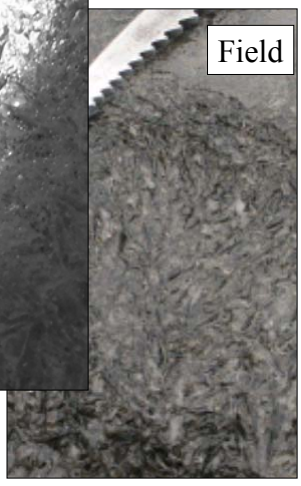
Part 2 of the project

Producing “supercooled” facies in the lab

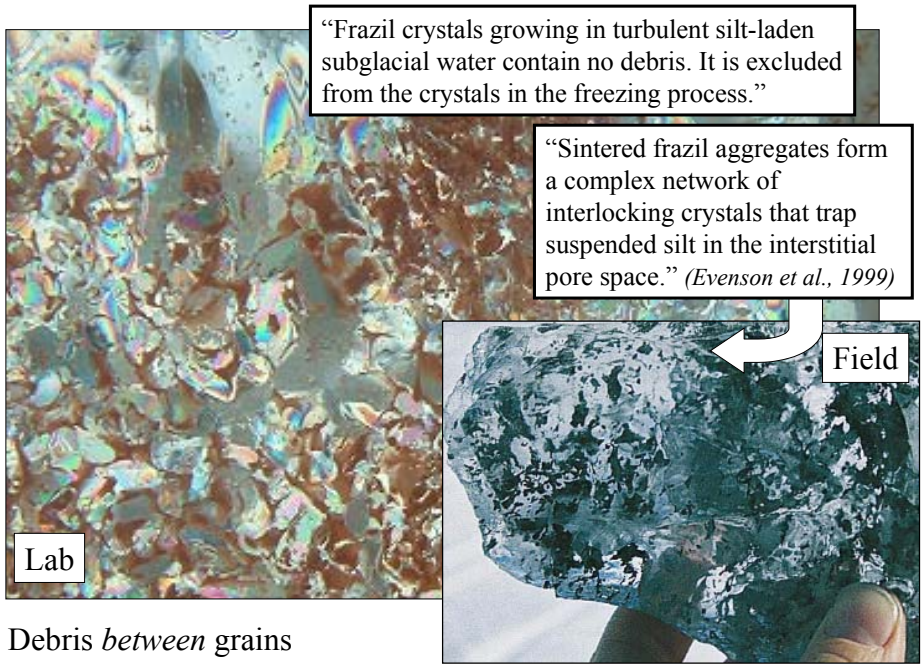
Two Methods: pressure and turbulence. Comparable results.

Two types of ice



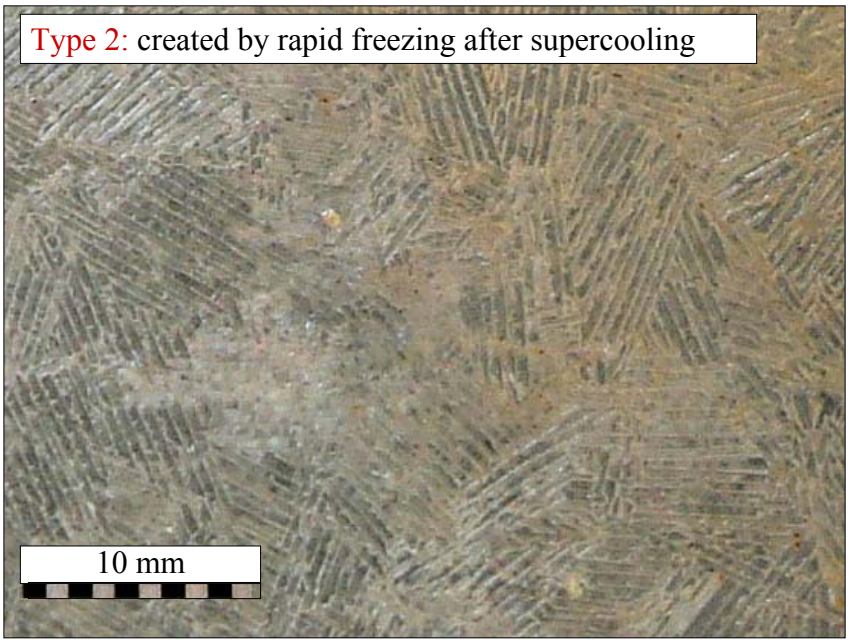


Type 1: Surface frazil ice

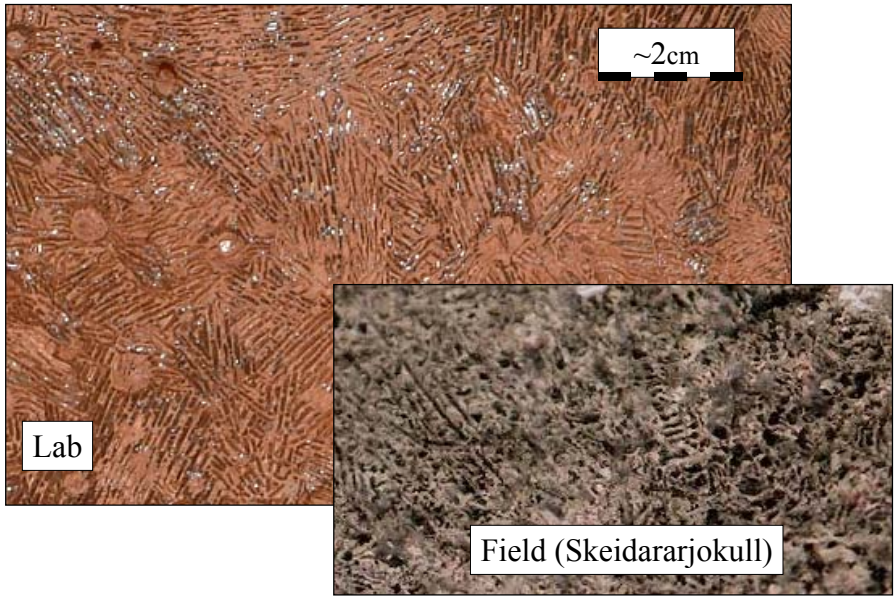


Debris *between* grains

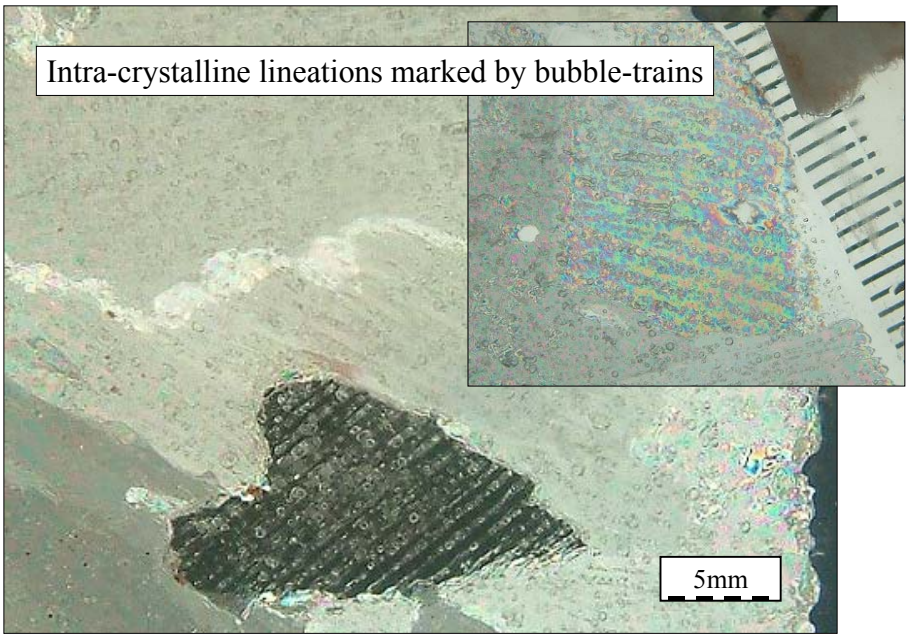
Field and laboratory observations

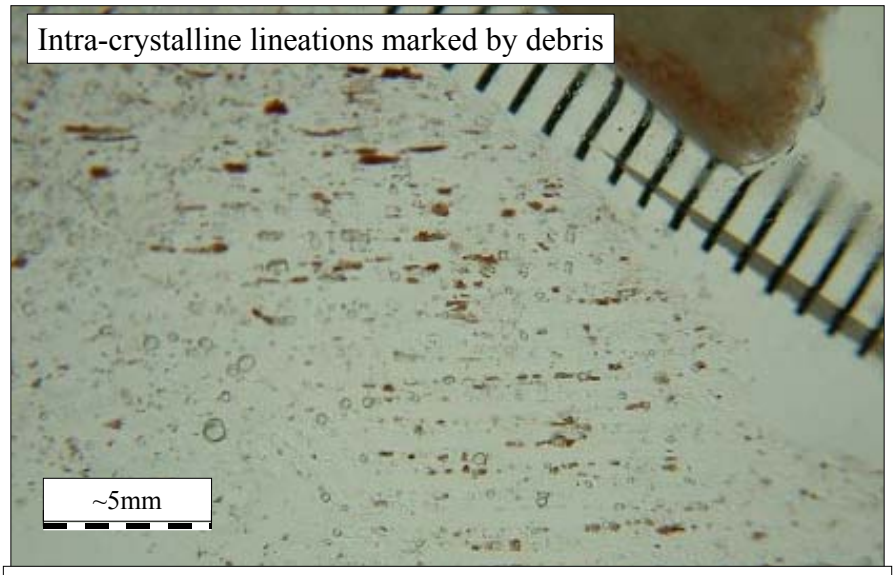


Field and laboratory observations



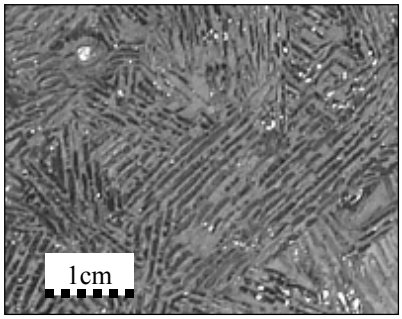
Field and laboratory observations

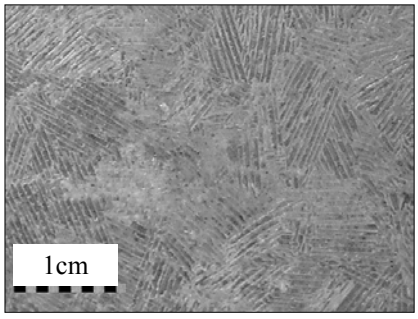




Debris and bubbles *within* grains (unlike frazil or dispersed facies)

Controls on crystal structure: Ambient temperature



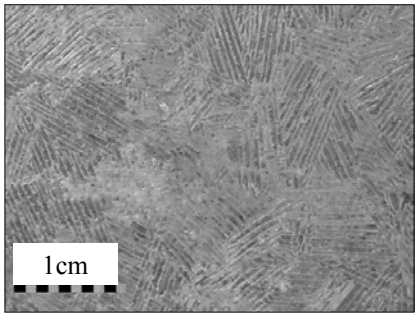


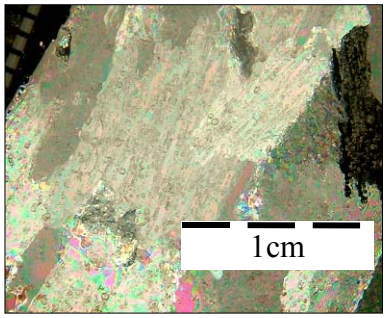
Ambient -3°C:
Mean area ~3cm^2

Ambient -9°C:
Mean area ~1cm^2

Supercooled to ~ - 0.2 °C before freezing in both cases

Ambient temperature control on crystal structure





Ambient -9°C:
Mean area ~1cm^2

Ambient -16°C:
Mean area ~0.25cm^2

Supercooled to ~ - 0.2 °C before freezing in both cases

Summary of initial laboratory observations

- Two distinctive facies related to freezing supercooled water:
  1. *Surface frazil ice*
  2. *Ice from rapid freezing upon supercooling*

- Distinctive crystallographically and in bubble / debris content

- Apparent thermal control on crystal size

- Further experiments required

Implications of field and laboratory observations: 1

Specific characteristic facies from "supercool" sites can be reproduced by supercooling in the laboratory, supporting the hypothesis that glaciohydraulic supercooling may be responsible for their origin in the field.

- Frazil/anchor ice at vents
- Distinctive "supercool" facies in basal ice close to vents

Laboratory experimentation can identify process-form relationships in facies characteristics, and hence provide a tool for interpreting field exposures in terms of subglacial conditions.

Implications of field and laboratory observations: 2

"Supercool" facies can be identified locally in basal ice close to the vents, are a clearly recognisable component of the basal ice.

However, "supercool" facies make up only a small part of the basal sequence even close to the supercooled vent outlets, and do not occur at all in the basal ice sequences that occur at non- "supercool" sites in S. Iceland

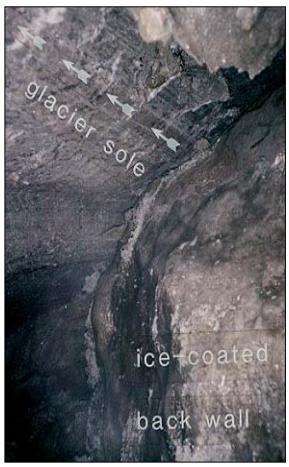
This leaves us with another question

Where do the other facies come from?

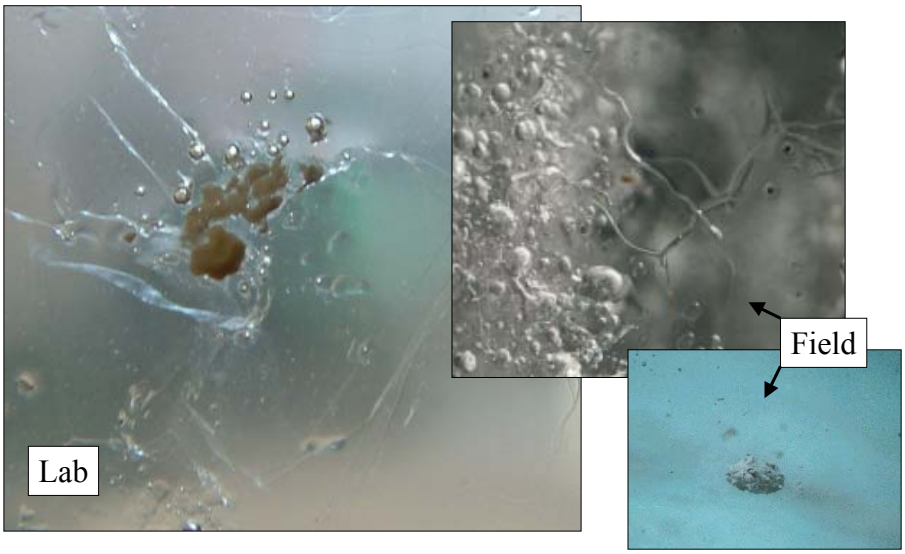
1. "Traditional" mechanisms?
2. Supercooling plus diagenesis?

Can we destroy the diagnostic signature?

"Traditional": regelation, deformation and intra-vein water flow?



"Traditional": turbulent freezing without supercooling?



Strain recrystallisation of supercooled facies?

Can this woman destroy the diagnostic signature of supercooled ice?

Unanswered questions and ways forward

For example…

- Diagenetic associations between facies?
- Multi-parameter approach!

Conclusions:

- Glaciohydraulic supercooling creates distinctive ice facies, but…
- …basal facies clearly related to supercooling are limited in extent even at "supercool" sites and not all facies are necessarily created by supercooling.
- Laboratory experiments provide an avenue for recognising diagnostic indicators of supercooling environments…

…more work required!