Determining the Importance of Different Scales of Isotopic Analysis for Identifying Glaciohydraulic Supercooling

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1) Introduction, Research Background and Aim

- Glaciohydraulic supercooling occurs as subglacial water at/or below the pressure melting point ascends from an overdeepening and consequently freezes (see figure 1).
- Some glaciologists have suggested that supercooling is the **primary mechanism** for basal ice formation[1,2,3,4,5,6].
- Other glaciologists have suggested it is only one of **several mechanisms**[7,8,9,10,11,12,13].
- Supercooling is an important process, e.g. entraining debris during Heinrich Events[2,5] and contributing to the slow down of Kamb Ice Stream, Antarctica [14].
- Ice formed from supercooled water under laboratory conditions has been suggested to have a distinctive herringbone crystal structure, termed '**herringbone ice**'[8,9].
- Methodological approaches differ across studies and sample sizes for isotopic analysis are often on a **bulk-scale**.
- Sample sizes of **basal ice** formed from supercooling range from **30mL**[15,16] to **250-300mL**[6,13], when sampled for isotopic analysis at glaciers.
- These bulk ice samples could potentially contain ice formed from different processes.
- This study has been designed to **micro-sample** ice formed from supercooled water to determine whether bulk-scale sampling is suitable.
- **Aim:** To determine whether bulk-scale sampling of ice formed from supercooled water is overlooking micro-scale isotopic differences.

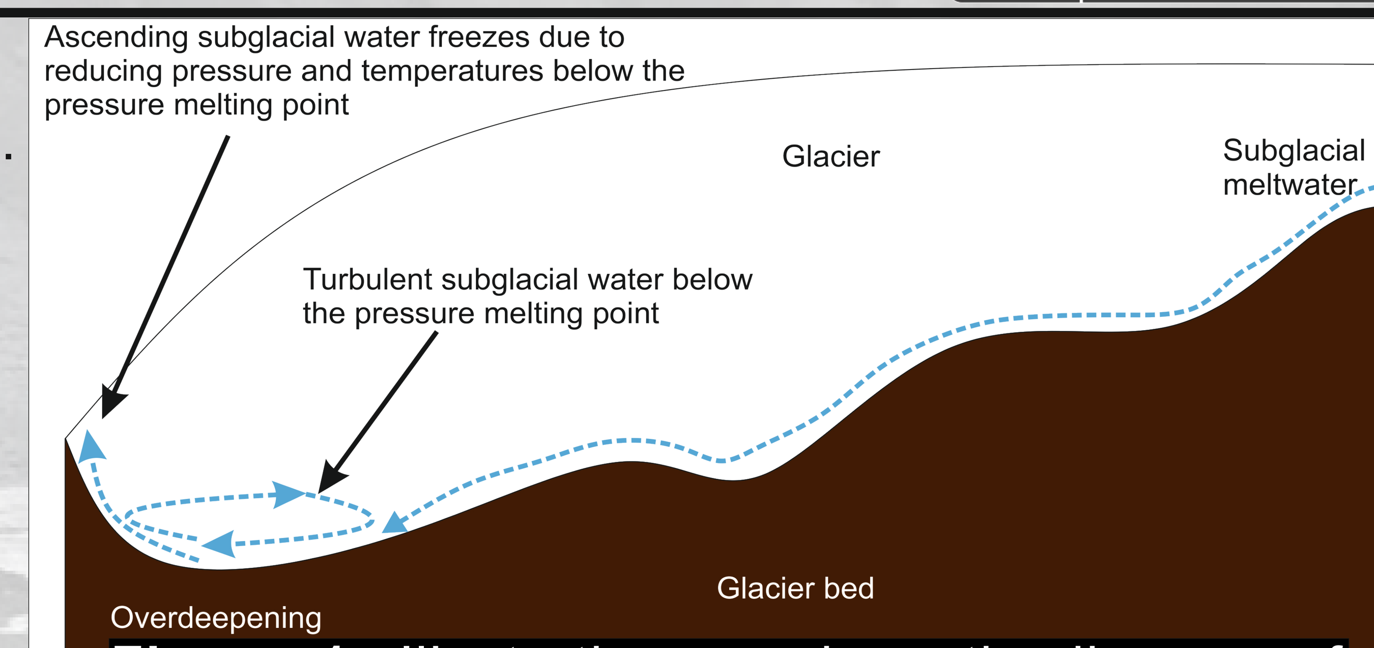

Figure 1. Illustrating a schematic diagram of glaciohydraulic supercooling.

2) Methodology

- This study followed **experimental laboratory** approaches by pilot papers[8,9,17].
- A container was placed in a **cold laboratory** at **-12°C** with a submerged **pump.**
- The turbulence caused by the pump allowed the water to remain **liquid, below 0°C**.
- The pump was turned off, freezing the supercooled water.
- 3 facies formed; 1) **clear ice**; 2) **herringbone ice** and 3) **bulk ice** (see figure 2).
- Facies 3 represents large-scale sampling, illustrated by earlier papers[6,13,15,16].
- The samples were melted on a **1.5mL** scale, **compared** to **30mL-300mL** collected by previous studies[6,13,15,16].

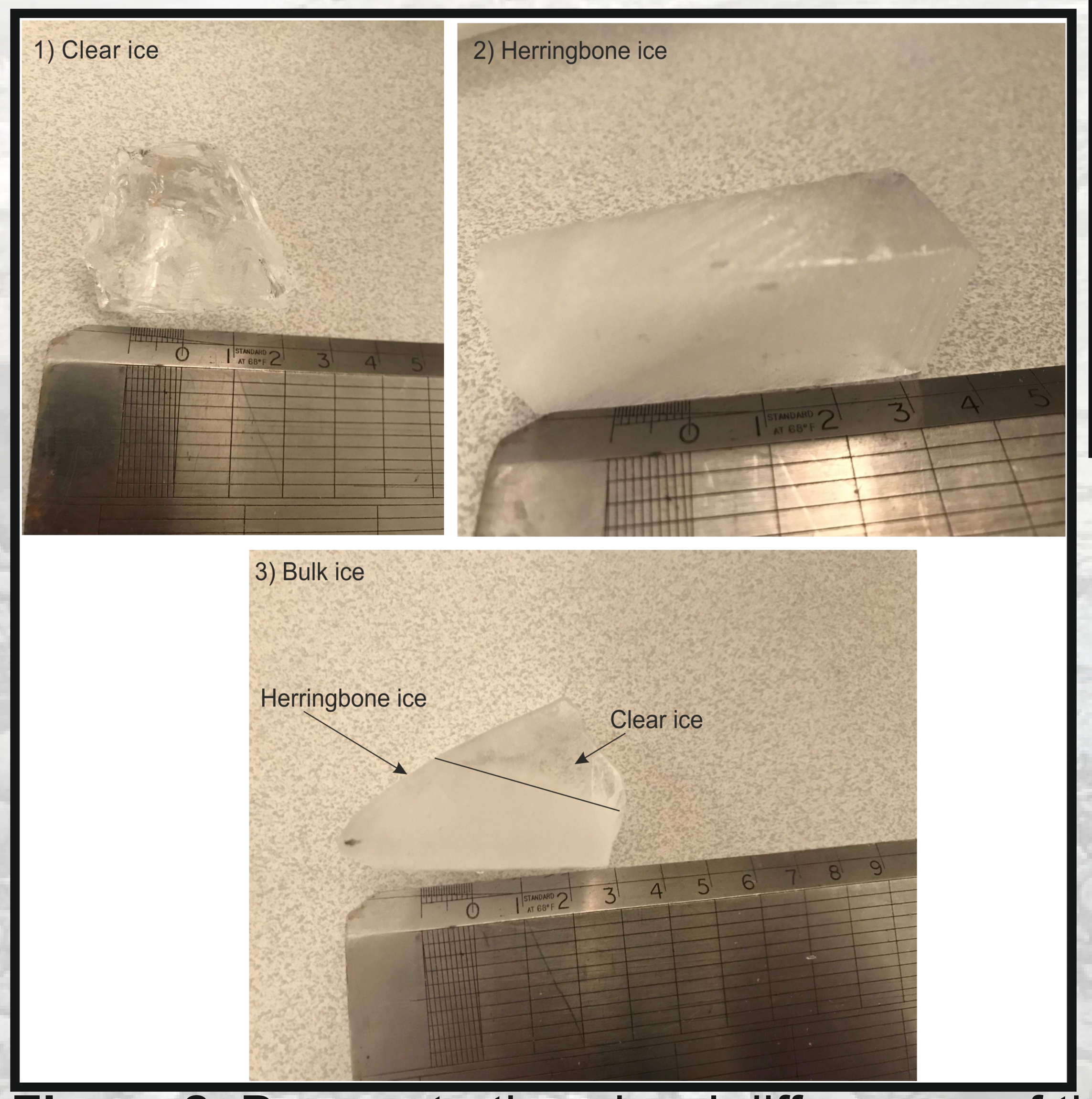

Figure 2. Demonstrating visual differences of the 3 facies in this study. 1) Clear ice: formed from regular freezing processes. 2) Herringbone ice: formed from supercooled water. 3) Bulk ice: contained both the clear and herringbone ice.

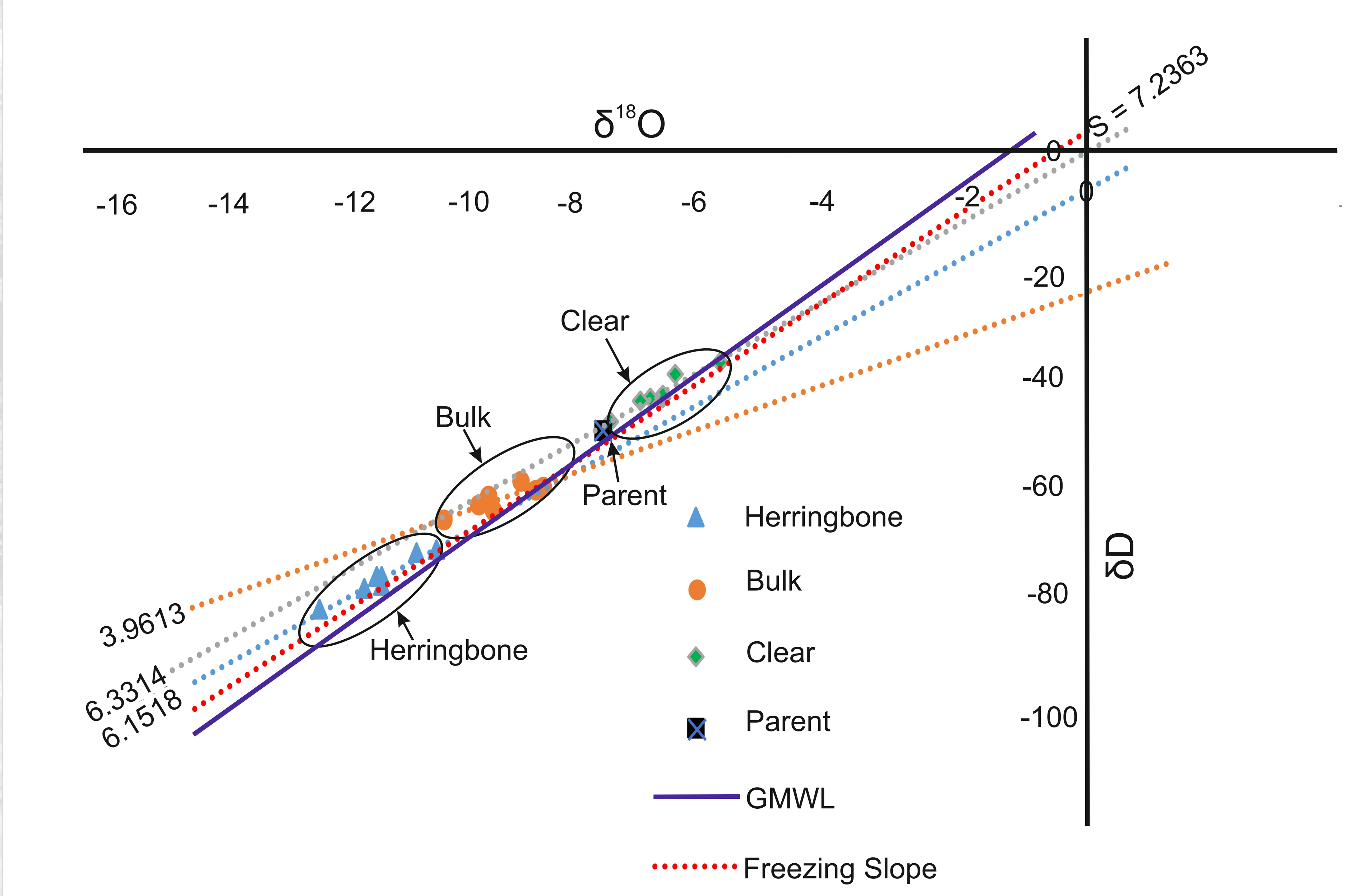

Figure 3. A δD/δ18O graph demonstrating the isotopic compositions of the ice facies, the Global Meteroic Water Line and the freezing slopes for each facies.

3) Results

- The isotopic composition for the **parent water** source was **~49.87756‰** for **δD** and **~7.674296‰** for **δ18O**. Table 1 shows the heaviest and lightest isotopic samples for each ice facies and figure 3 shows the results of the experiment.

Ice Facies	Heaviest Sample	Lightest Sample
Herringbone Ice	• δD: ~81.79‰ - δ18O: ~12.21‰	• δD: ~70.75‰ - δ18O: ~10.35‰
Bulk Ice	• δD: ~65.84‰ - δ18O: ~10.24‰	• δD: ~59.01‰ - δ18O: ~8.66‰
Clear Ice	• δD: ~48.27‰ - δ18O: ~7.59‰	• δD: ~37.51‰ - δ18O: ~5.84‰

Table 1. The heaviest and lightest isotopic samples for the 3 facies in this study.

4) Interpretations and Conclusions

- Supercooled glacier ice has been suggested to be isotopically enriched at glaciers[2,6,10,15].
- **Herringbone ice** in this study was **isotopically depleted**, because of experiments being in a **closed-system**.
- Ice which forms first is isotopically enriched, whereas ice which formed last is depleted[18].
- The clear ice facies formed first and the herringbone ice was last to form, due to the turbulence being spatially effective in the closed-system experiment.
- Freezing slopes in open and closed-systems should be relatively similar, unless the input has a significantly different isotopic composition, compared to the initial parent water source[19].
- The freezing slopes gradient range from **3.9613** to **7.2363**, because of **different stages of freezing**.
- The initial parent water had an isotopic composition of ~49.87756‰ for δD and ~7.674296‰ for δ18O.
- The water at the later stages had become **heavier** with the herringbone facies having isotopic compositions of ~81.79‰ for δD and ~12.21‰ for δ18O, explaining different freezing slopes for each facies[19].

5) Reference List and Acknowledgements

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Photography encouraged