Using $^{26}Al/^{10}Be$ Cosmogenic Nuclides to Reveal LIS Erosivity and Behavior Near Historical Range of Quebec-Labrador Ice Dome

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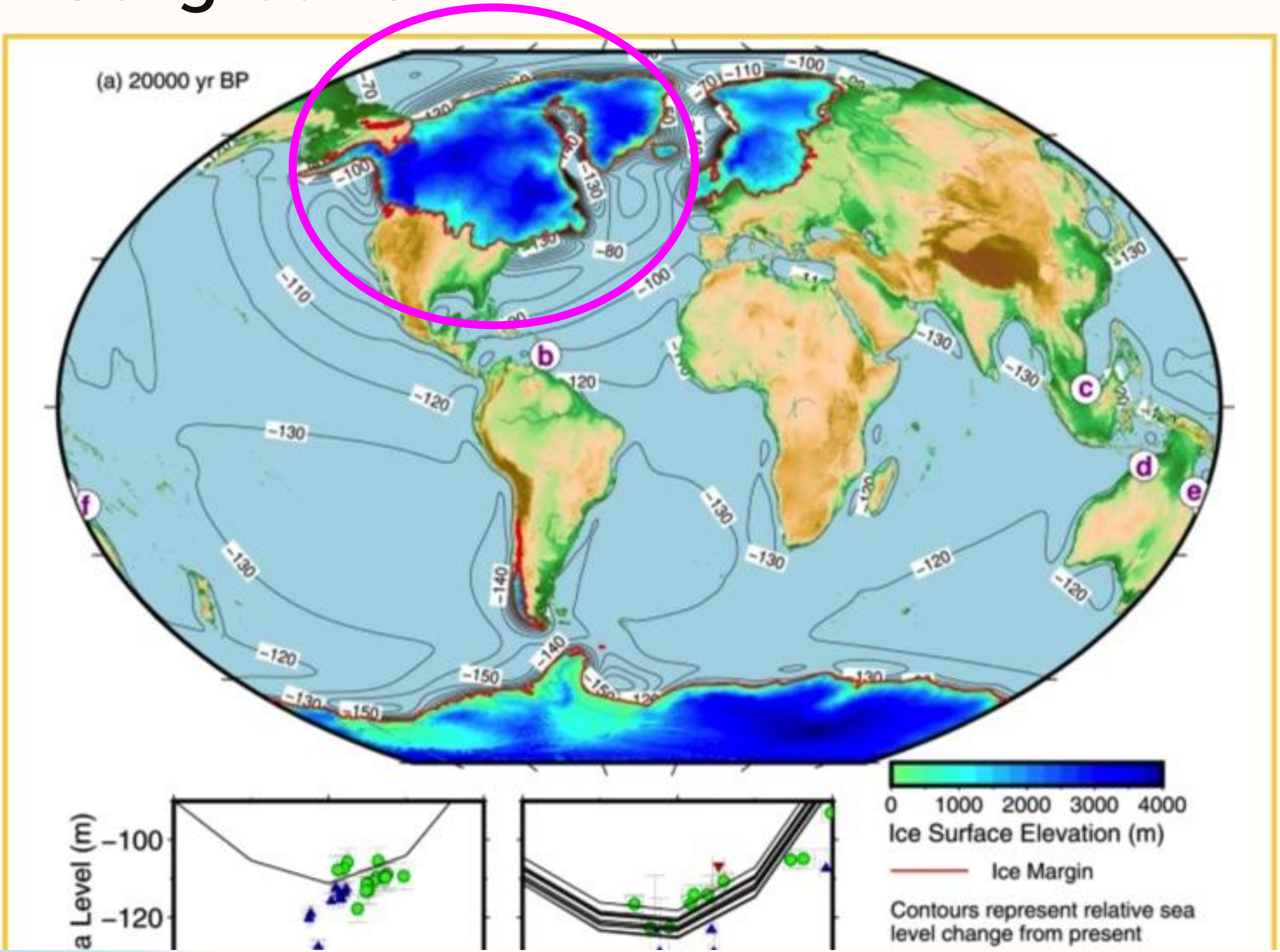
Background



LGM Ice Sheets

Figure Credit to Gowan et al., 2021 (Figure 3).

~2.6 Ma ebb and flow of continental ice sheets

~25,000 years ago for LGM and maximum LIS extent

Background

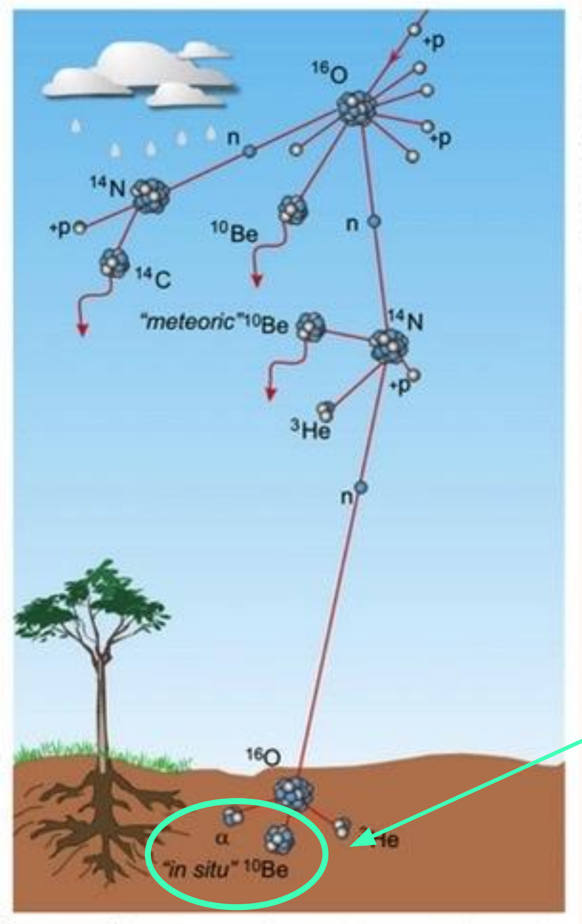


FIGURE 2 Cosmic rays, mostly energetic protons (+p), enter the upper atmosphere where they hit a target nucleus, such as ^{16}O. Its atom is converted into a cosmogenic nuclide, such as ^{10}Be, by a nuclear process called spallation. The collisions create showers of secondary particles, mostly neutrons (n), which are available for further reactions. In the atmosphere, these reactions produce meteoric cosmogenic nuclides. The few particles that reach the Earth's surface can produce cosmogenic nuclides, such as ^{10}Be and ^{3}He, in situ in the uppermost few meters of the surface.

Figure Credit: Blackenburg & Willenbring, 2014.

^{26}Al/^{10}Be

Problem

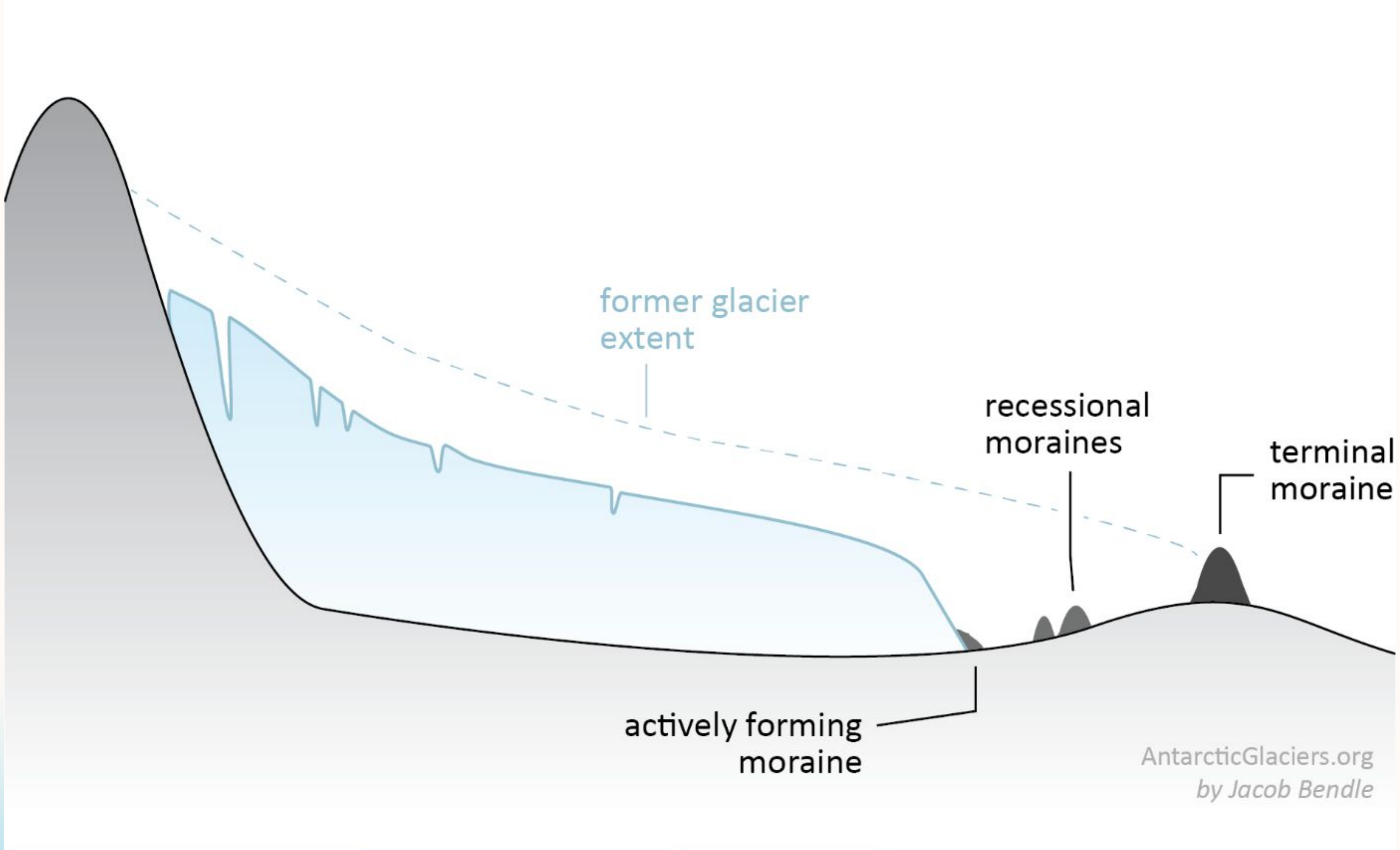


Figure Credit: Bendle 2020
https://www.antarcticglaciers.org

Problem

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https://doi.org/10.1130/G50820.1

Manuscript received 3 September 2022
Revised manuscript received 10 January 2023
Manuscript accepted 11 January 2023

Published online 22 March 2023

Laurentide Ice Sheet persistence during Pleistocene interglacials

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ABSTRACT

While there are no ice sheets in the Northern Hemisphere outside of Greenland today, it is uncertain whether this was also the case during most other Quaternary interglacials. We show, using *in situ* cosmogenic nuclides in ice-rafted debris, that the Laurentide Ice Sheet was likely more persistent during Quaternary interglacials than often thought. Low ^{26}Al/^{10}Be ratios (indicative of burial of the source area) in marine core sediment suggest sediment source areas experienced only brief (on the order of thousands of years) and/or infrequent ice-free interglacials over the past million years. These results imply that complete Laurentide deglaciation may have only occurred when climate forcings reached levels comparable to those of the early Holocene, making our current interglacial unusual relative to others of the mid-to-late Pleistocene.

yr^{-1} at high latitudes for ^{10}Be; 7.3x higher for ^{26}Al) and rapidly attenuates with depth, but low levels of production ($<10^{-1}$ atoms g^{-1} yr^{-1}) by muons extend several tens of meters into the subsurface (Gosse and Phillips, 2001).

During times of significant ice-sheet cover, most nuclide production halts because surface materials are shielded from cosmic rays. Because ^{26}Al ($t_{1/2} = 0.7$ m.y.) decays more rapidly than ^{10}Be ($t_{1/2} = 1.4$ m.y.), the ^{26}Al/^{10}Be ratio decreases below the production value during intervals of burial longer than ~10^5 yr. The long

Objectives

- Is there evidence for deep erosion by the LIS during the LGM (i.e., near-zero nuclide concentrations) and what does this suggest about its basal thermal conditions?

- Do different sources of sediment have different cosmogenic nuclides concentrations and $^{26}Al/^{10}Be$ ratios?

- Do depressed $^{26}Al/^{10}Be$ ratios in terrestrial sediments support LeBlanc et al.'s (2023) inference from marine sediments that the LIS rarely deglaciated during the last million years?

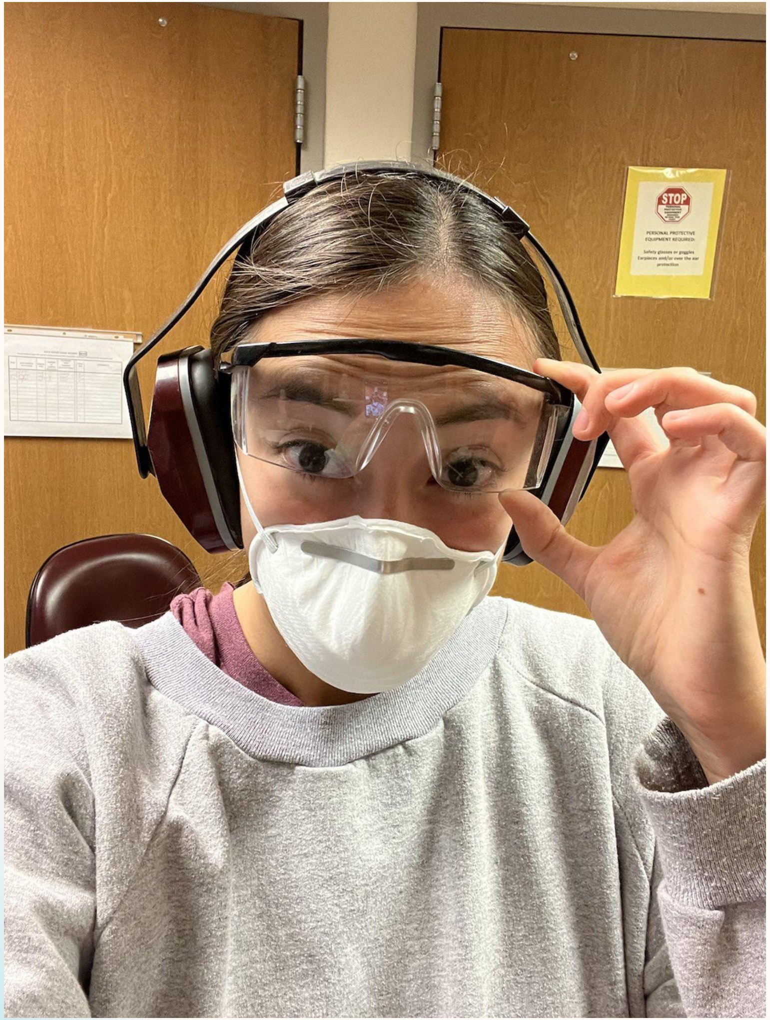
Approach

Figure 8: *We will measure cosmogenic nuclide concentrations in modern river sediments and deglacial deltas (e.g., Parent et al., 1988; Ashley et al., 1991; Lavoie et al., 2002; Occhieti et al., 2004; Peteet et al., 2009; Eyles et al., 2011; Nutz et al., 2015; Dietrich et al., 2019) in southeastern Canada and the northeastern United States to assess spatial variability at the end of the last glaciation and current interglacial. Our field campaign will take advantage of remote highway networks (yellow lines) to save travel costs and maximize spatial coverage across the former Labrador ice dome sector. Base map shows LIS deglacial margin ages in ^{14}C ka BP (Ruddiman, 2014).*



CF 01

Sample Processing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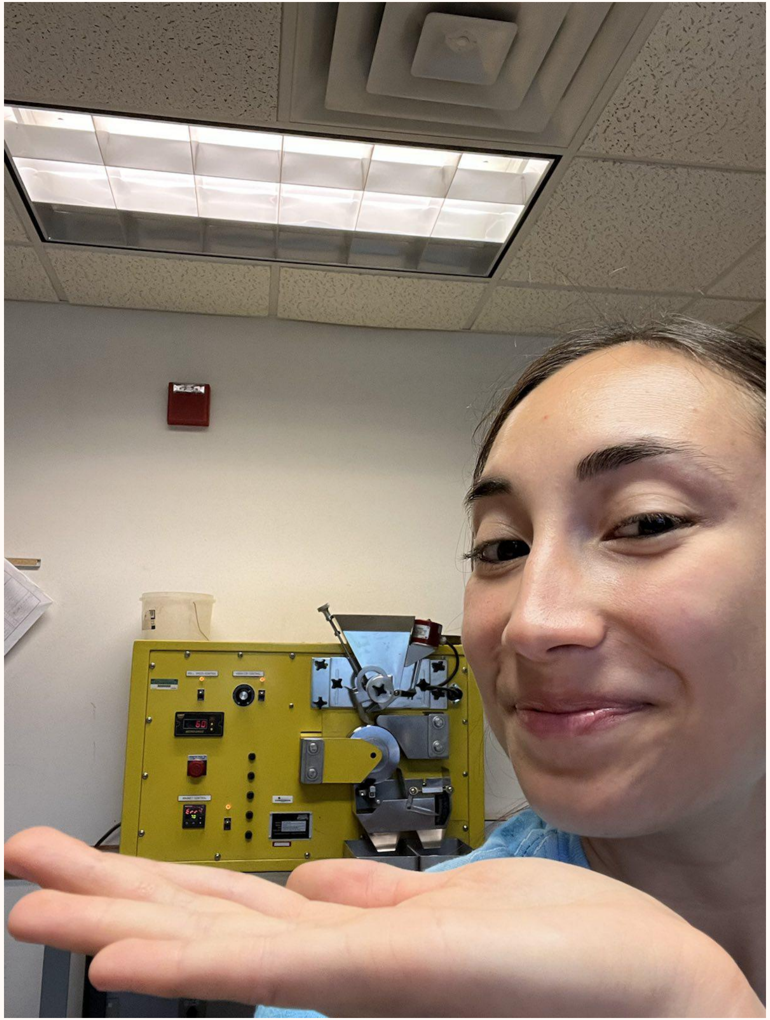
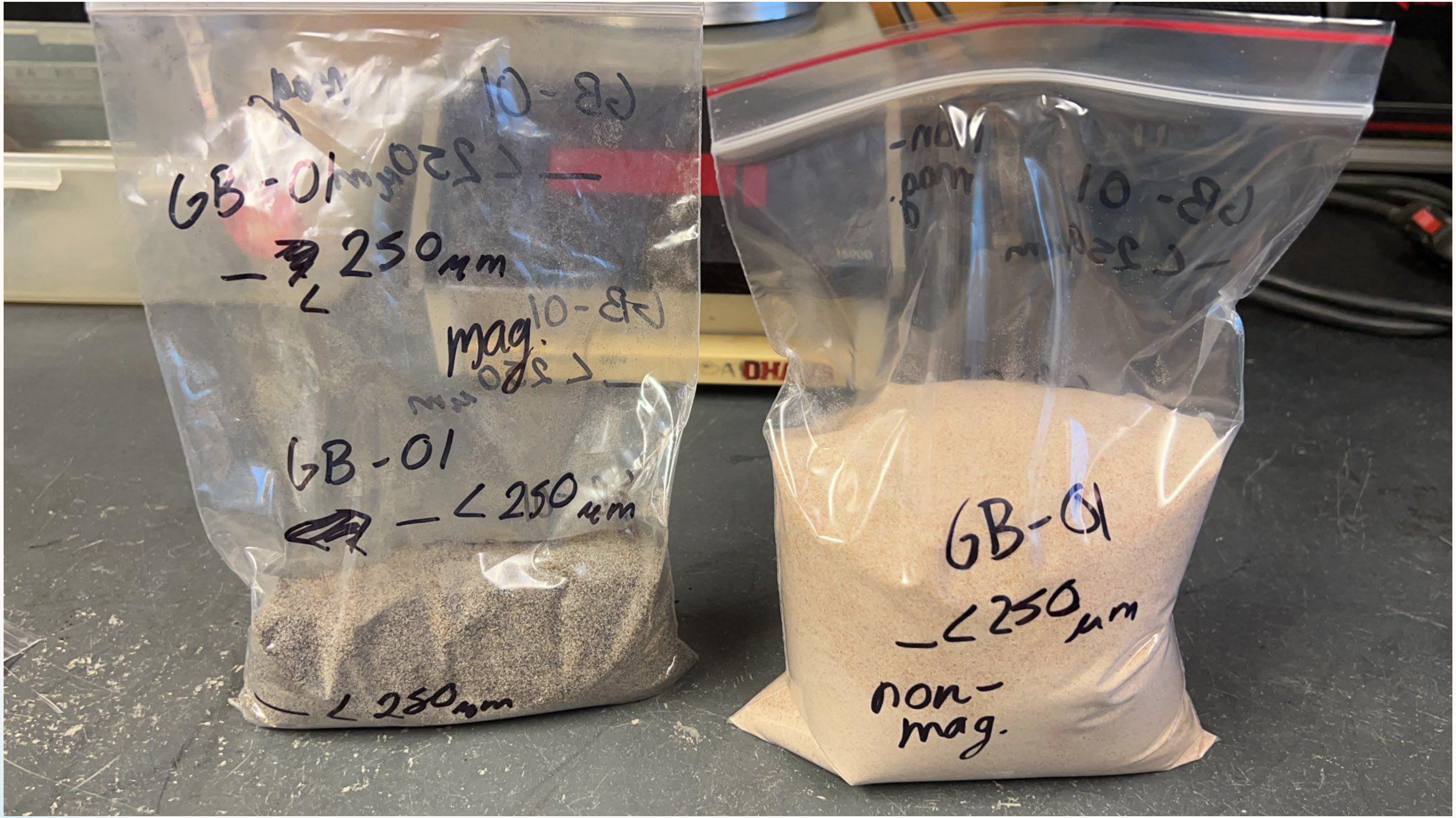
PERSONAL PROTECTIVE EQUIPMENT REQUIRED:
Safety glasses or goggles
Earpieces and/or over the ear protection

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DANGER
WEAR PROTECTIVE CLOTHING WHEN HANDLING CHEMICALS
CAUTION
WEAR YOUR GLOVES
WASHDOWN AFTER
EACH PERC EVAPORATION
PLENUM WASHDOWN
AUTION
AYS
ACID
WATER
SAFETY FIRST

Preliminary Results

Figure 1A: 2022 Sample Locations

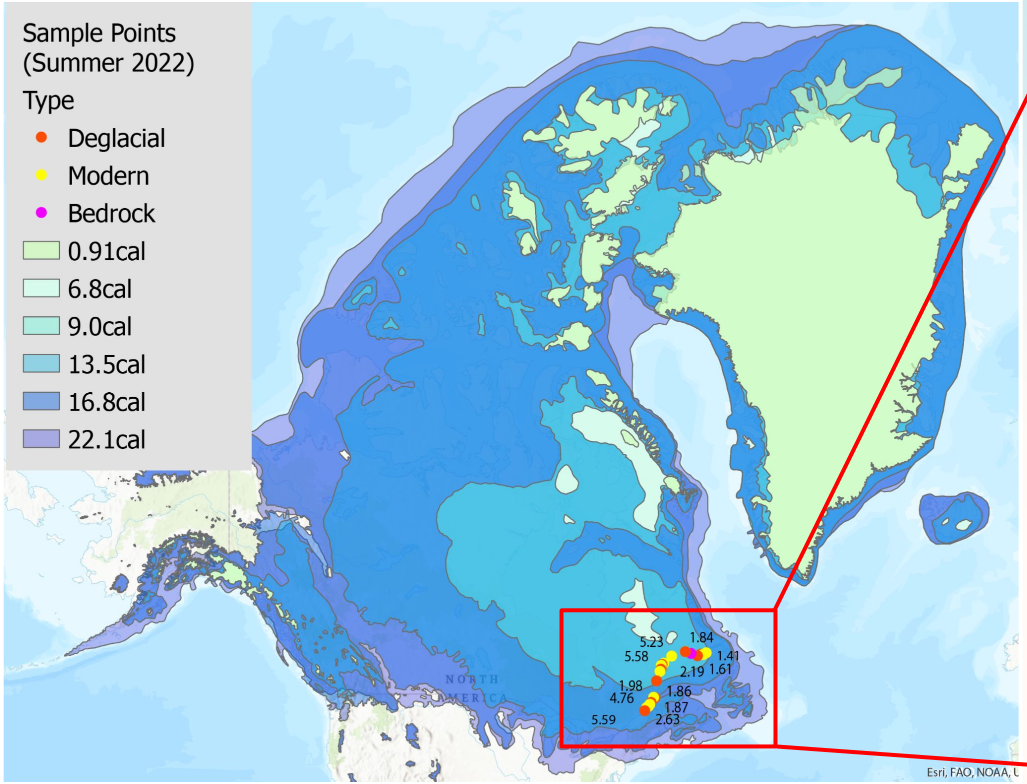
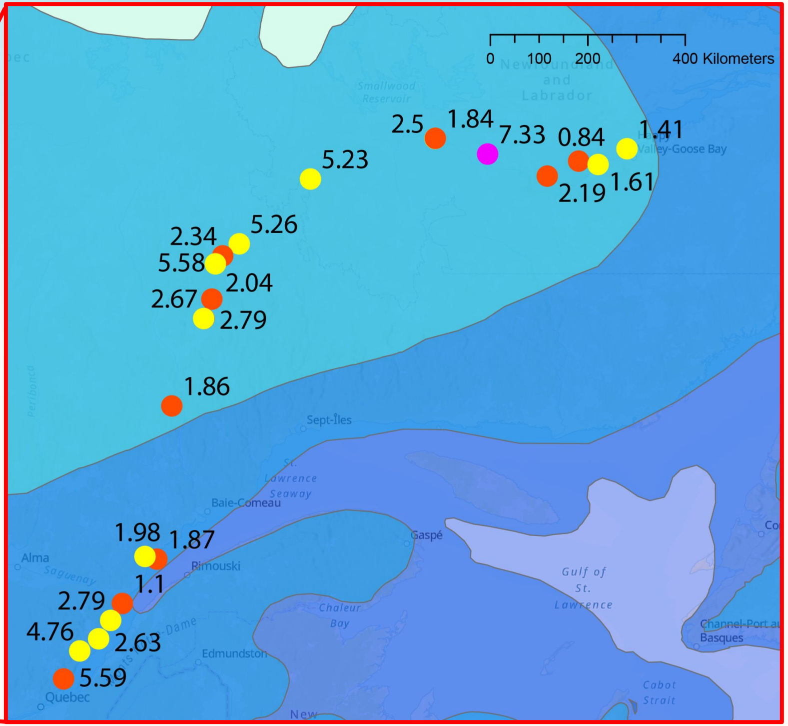


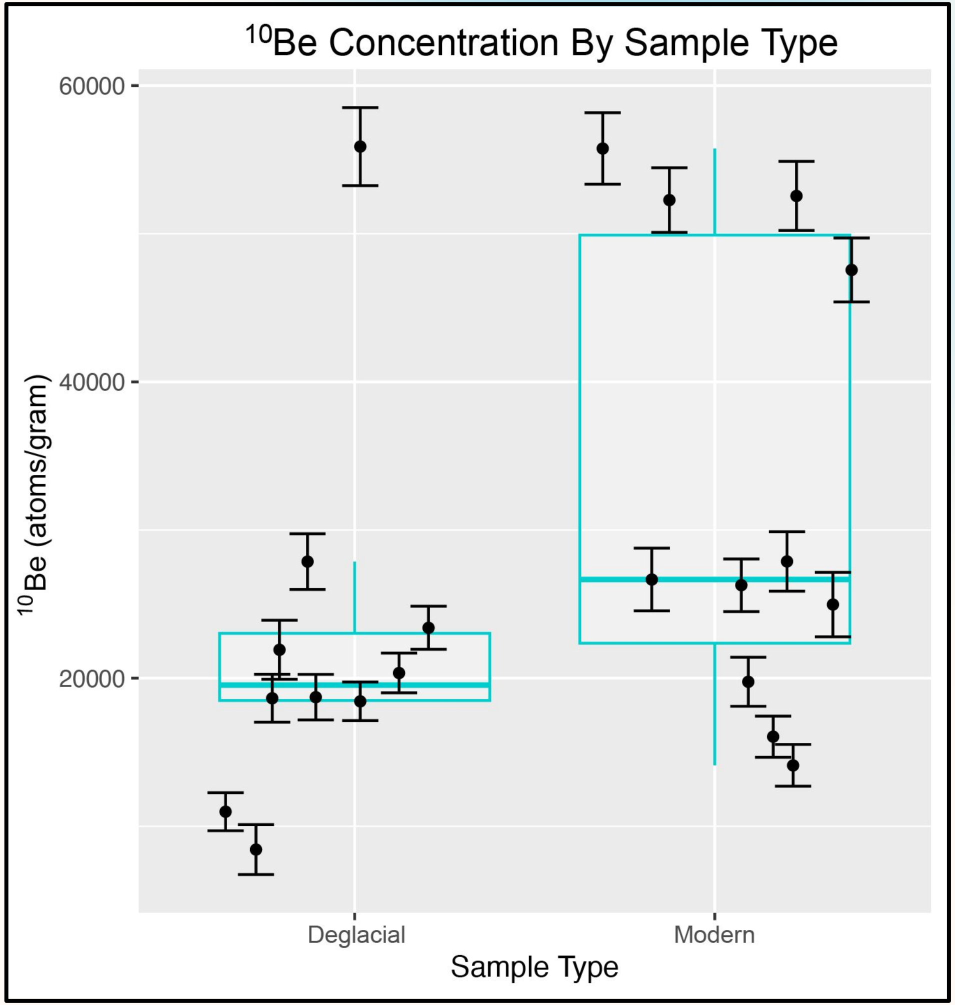
Figure 1B: Regional View



A. Location of sample sites in geographical span of historic LIS extent. Layers of LIS extent provided from findings in Dalton et al,. 2020. Each LIS extent layer corresponds to a different calibrated age in ka (see legend).
B. A closer view of sample sites and their overlaid historical LIS extent layers. Samples are color coded by type for both figures. Labels on each sample site show concentration of ^{10}Be (*10^{4}) in atoms/gram of quartz.

Figure 6. Concentration of ^{10}Be Sorted by Sample Type

Error bars represent 1 standard deviation analytical uncertainty.



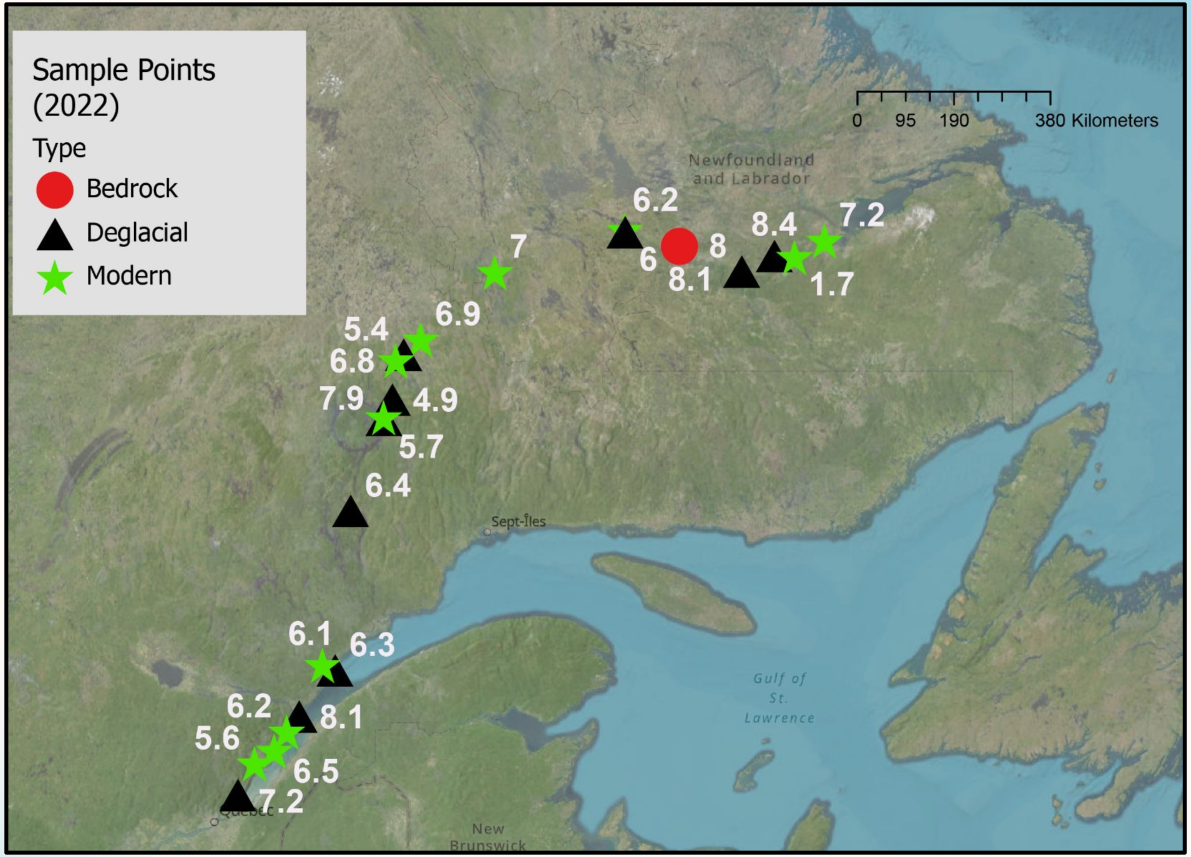


Figure 2. $^{26}Al/^{10}Be$ Ratios for Each Sample Site

Prior work suggests deglaciation between 10 and 8 ka (LeBlanc et al., 2023; Ullman et al., 2016; Couette et al., 2023).

Figure 3. Box and Whisker Plot of Nuclide Ratios

The red line indicates the nominal production ratio at high latitudes. Error bars show 1 standard deviation analytical uncertainty.

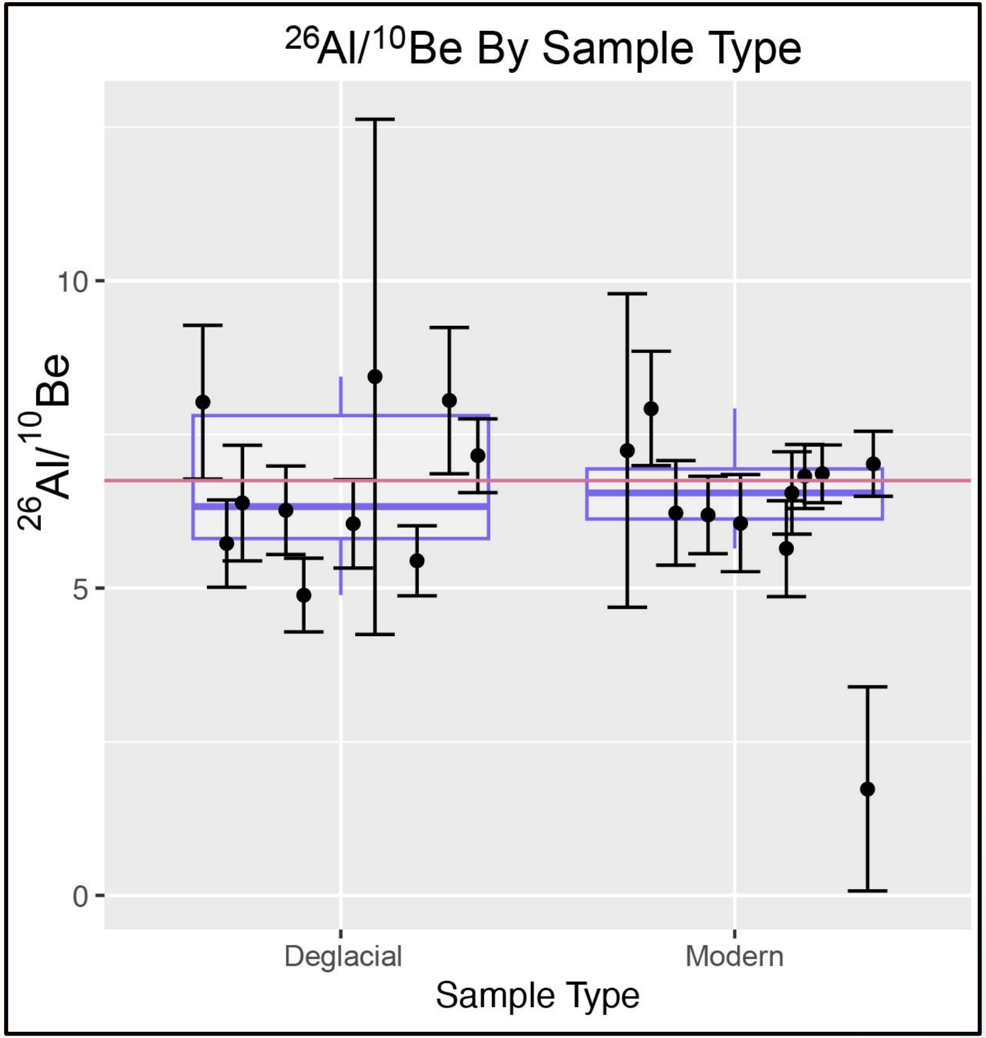
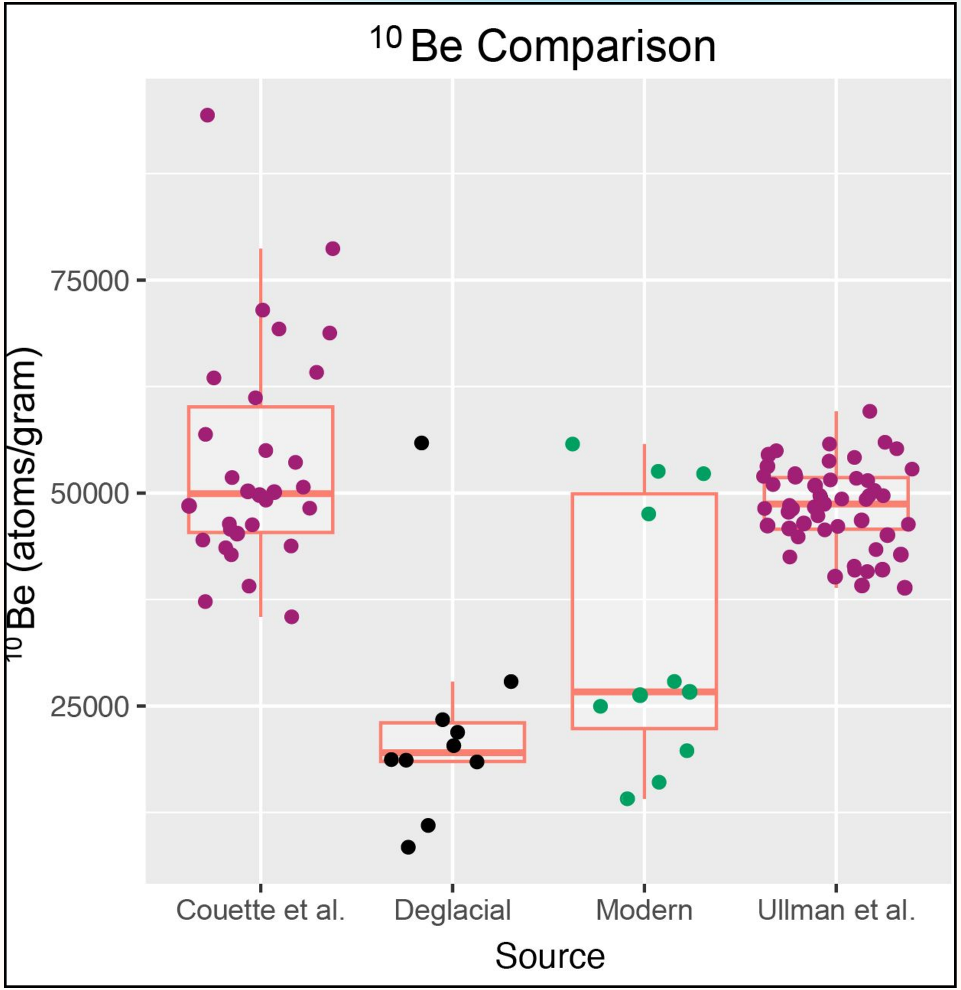


Figure 7. Comparison of My Data with Previous Publications

Couette et al.'s (2023) data comes from sampled bedrock outcrops within the historical range of the Quebec-Labrador Ice Dome (n=37).
Ullman et al.'s data (2016) data consists of ^{10}Be concentrations from glacial erratics on LIS moraine systems (n=50).



Summary

- No statistically significant difference between the means of deglacial and modern sample ^{10}Be concentration (ρ=0.14, $\boldsymbol{\alpha}$ = 0.05)
- 5 samples are below the nominal production ratio
- ^{10}Be concentrations are too high to be explained by production during this interglacial alone

Implications

Inheritance of ^{10}Be?

- If glacial erosion were deep, deglacial nuclide concentrations would be extremely low
- Since deglacial nuclide concentrations are higher, ^{10}Be was likely inherited from past interglacial exposures (before the final retreat of the LIS)
- These deglacial concentrations suggest that the LIS did not deeply erode sediment and bedrock exposed to cosmic radiation during prior interglacials
- Deglacial nuclide concentrations are too high at depth of sampling to be created after the final retreat of the LIS based on a production rate of ~5 atoms/(g*yr)

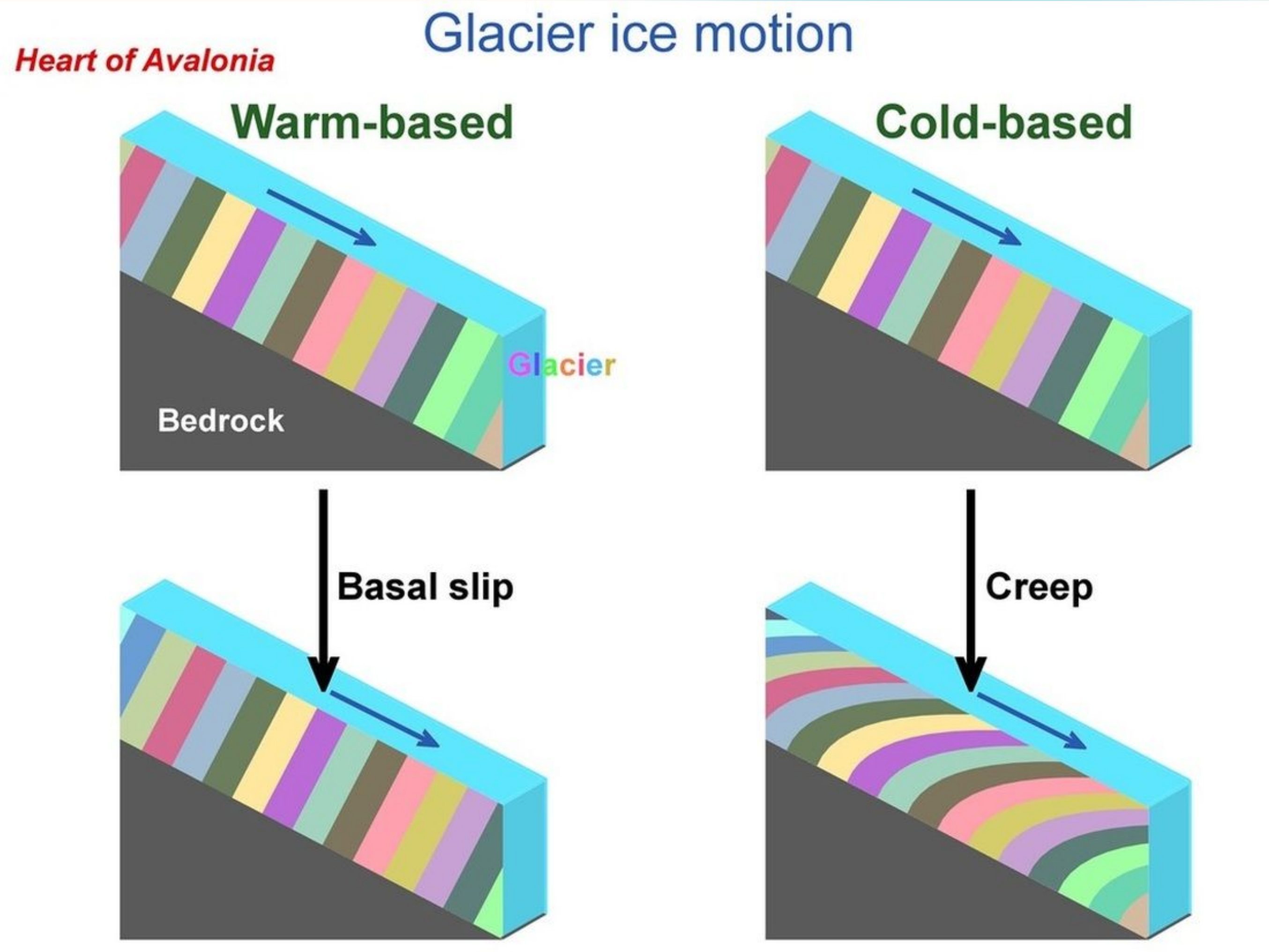
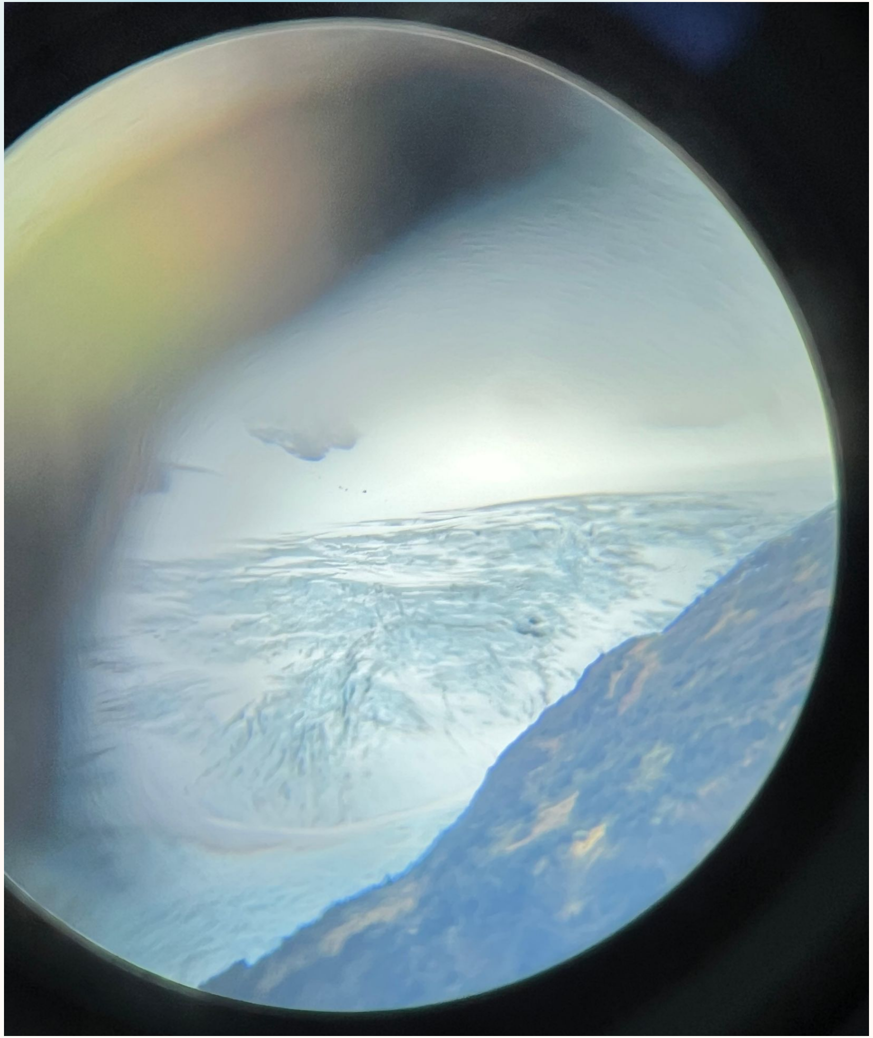


Figure Credit:
https://www.heartofavalonia.org

Next Steps

- Sampling challenges
  - Wildfires
  - New field site
- Alaska
- Extraction timelines
- Interpretation and writing
- Finding the story



Timeline

Semester	Tasks	Complete?
Summer 2022	– Collect field samples – Clean and start sample prep.	Yes
Fall 2022	– Complete sample cleaning and preparation	Yes
Spring 2023	– Sample extraction – Data analysis	Yes
Summer 2023	– Collect second round of samples – Continue data analysis	– Delayed field work due to wildfires – Partially
Fall 2023	– Complete analysis – Begin writing – Present Progress Report	– Partially – Yes
Spring 2024	– Continued data analysis (for new samples) – Complete writing	No
Summer 2024	– Finish and defend in summer	No

Thank You