Effects of snow cover on luminescence dating of glacial moraines

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ABSTRACT

Large glaciers and ice sheets in North America have melted as the climate warmed since the last ice age, exposing boulders that were once frozen inside the ice. Once exposed to sunlight, a boulder's surface begins to lose its luminescence signal, a measurable amount of blue light that can be stimulated by shining infrared light onto the mineral grains. With time this signal empties to greater depths. Thus, using luminescence dating, the date that the rock was exposed, and therefore the date the glacier melted at the boulder location, is revealed. To estimate how long the boulders have been exposed to sunlight, several important assumptions are involved. Previous research has overlooked how varying degrees of snow cover could influence the apparent exposure age of samples. In this study, we develop MATLAB codes to simulate fluctuating levels of snow cover through time to determine the effects on bleaching depth. Using these results, we can more accurately estimate when glaciers retreated from specific regions to better reconstruct past responses of glaciers to climate change. This helps us to better predict future melting of land ice in response to changing climate.

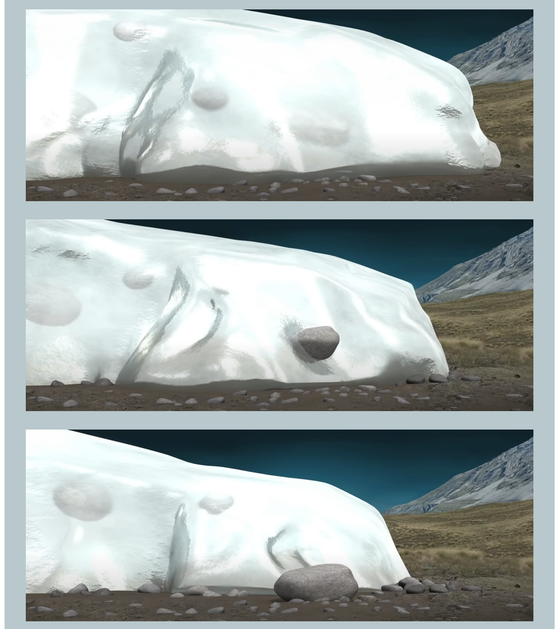

Figure 1: Boulder falling out of glacial moraine. (AMNH, 2012)

INTRODUCTION

Morainal boulders are chunks of rock that become frozen inside glaciers as they erode the underlying bedrock. As a glacier melts, those boulders fall out of the glacier onto the ground surface and are exposed to sunlight. The longer a boulder is exposed to sunlight, the deeper into that boulder interior the luminescence signal will bleach. By estimating the date that multiple boulders were exposed to sunlight, the timing and rate of glacial retreat can be found. Studying how glaciers behaved in the past helps scientists more accurately predict how modern glaciers will respond to future climate change.

OSL PROFILES INFORM SUNLIGHT EXPOSURE AGES

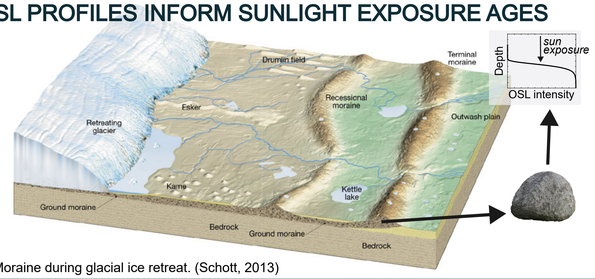

Figure 2: Moraine during glacial ice retreat. (Schott, 2013)

GEOMORPHOLOGY

Moraines form natural berms as they recede, leaving debris and piles of boulders behind.

Terminal moraines mark the furthest extent of the glacier, while recessional moraines indiciate the timing of glacial regression.

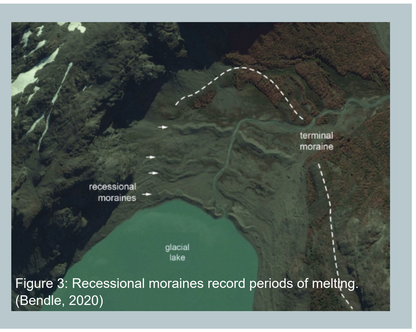

Figure 3: Recessional moraines record periods of melting. (Bendle, 2020)

RESEARCH QUESTIONS

- What if winter-time snow cover lasted longer in the past?
- Would this effect bleaching depth? If so, how?
- What if extended winters occured over thousands of years?

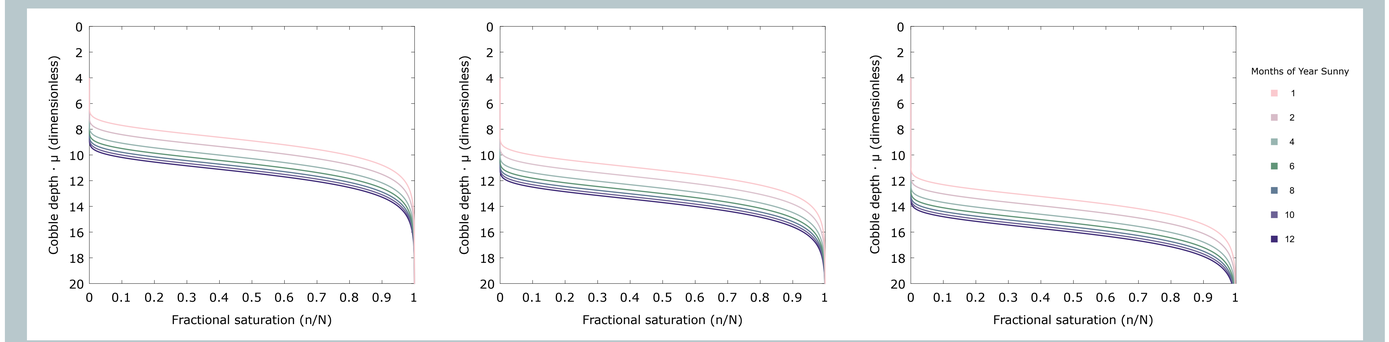

Figure 4: Simulated OSL depth profiles for 1 year.

Figure 5: Simulated OSL depth profiles for 10 years.

Figure 6: Simulated OSL depth profiles for 100 years.

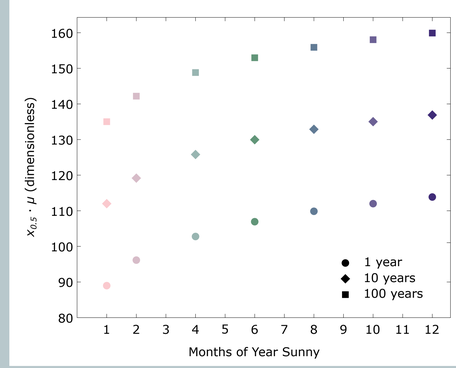

Figure 7: Comparison of 1, 10, and 100 year simulations by snow cover.

RESULTS

OSL profiles inform us how long each boulder was exposed to sunlight. Figures 4, 5, and 6 all show simulated OSL depth profiles for the same sample. In all three cases, the rock was exposed to sunlight for varying amounts of time each year, mimicking seasonal snow cover. Figure 4 shows data for a boulder exposed for 1 year, Figure 5 for 10 years, and Figure 6 for 100 years. Fractional saturation is the amount of luminescence signal the rock has accumulated, with 0 meaning the signal is completely empty, or the sample is fully bleached, and 1 meaning the signal is full. Rocks exposed to sunlight for more years have deeper bleaching depths. Rocks with more months of sun per year also have deeper bleaching depths. Figure 7 shows the distribution of each simulated OSL profile's bleaching depth, summarized as '$x_{0.5}$', which is the depth where the signal is halfway bleached.

TAKEAWAYS

Longer periods of snow cover each year contribute to a shallower bleaching depth. As longer periods of snow cover repeat continuously, bleaching depth increases.

For each simulation, the difference between the greatest and lowest hypothetical bleaching depths are equal.

FUTURE WORK

We will estimate the potential bias on exposure age calculations for if winters were significantly longer in the past.

If a significant difference is noted, then correcting or mitigating this effect is important for determining more accurate time estimates for glacial retreat.

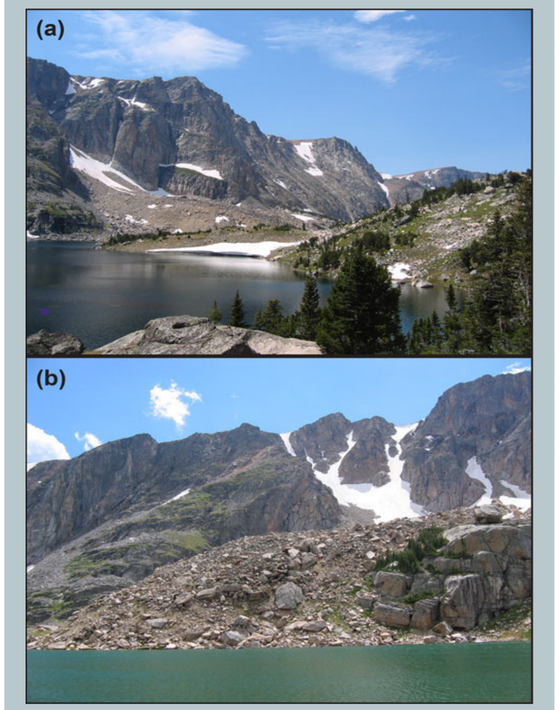

Figure 8: Pictured here are two moraines previously dated with cosmogenic ^{10}Be, which we will sample for OSL in the summer of 2024. (Barth et al., 2022)

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