Influence of snow cover on luminescence dating of glacial moraines

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UT ARLINGTON LUMINESCENCE LAB

INTRODUCTION

Morainal boulders are chunks of rock that become frozen inside advancing glaciers as underlying bedrock erodes. As glaciers melt, those boulders fall out of the glacier onto the ground surface and are exposed to sunlight. Luminescence dating can be used to estimate the date that multiple boulders were exposed to sunlight, revealing the timing and rate of glacial retreat. This study considers important assumptions ignored in previous research, such as variable seasonal snow cover and changes in weather patterns through time, using data from the Northwestern United States. We use MATLAB to simulate fluctuating levels of snow cover to determine its effects on apparent exposure age, testing also if varying seasonal snow cover changes exposure duration. Then, we complete luminescence analyses on samples from Beartooth Mt., comparing our results with pre-existing Be-10 data. Using these results, we can more accurately estimate glacial retreat, reconstruct past responses of glaciers to variable climate, and better predict future melting scenarios due to climate change.

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

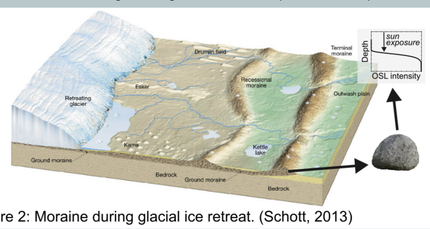


Figure 2: Moraine during glacial ice retreat. (Schott, 2013)

THEORETICAL RESULTS

For simulated OSL depth profiles for 1, 10, and 100 years:

- 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

For Holocene temperature and snow cover day histories:

- Yearly average temperature varies significantly through time
- SCDs per year and the average temperature each water year show a negative correlation
- Holocene temperatures combined with the relationship between SCDs and average temperature can create a simulated Holocene SCD history

For varying exposure age simulations:

- Simulations completed using a variable SCD history and a constant SCD history yield similar ages
- This includes exposure ages ranging from hundreds to thousands of years
- Apparent and "true" age ratios equal ~1 for each simulation

TAKEAWAYS

Since no significant difference was noted, correcting or mitigating this effect seems to prove unnecessary for determining accurate time estimates for glacial retreat.

More simulations in glacial areas besides the Northwestern U.S. could be completed to ensure the results in this study were not anomalous.

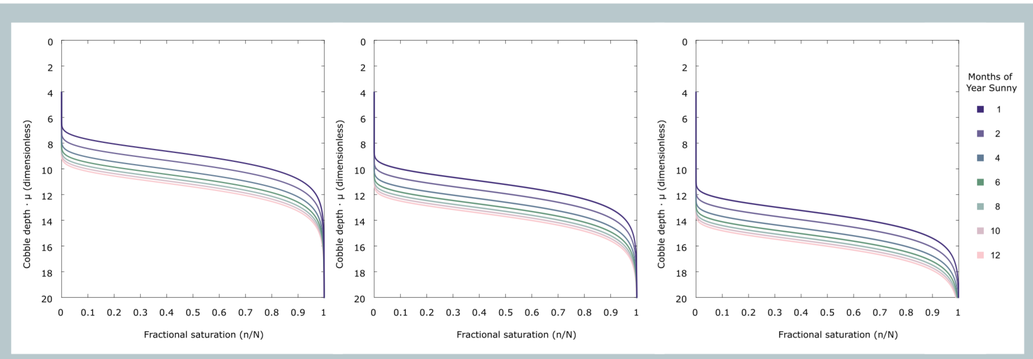


Figure 3, 4, 5: Simulated OSL depth profiles for 1 year, 10 years, and 100 years.

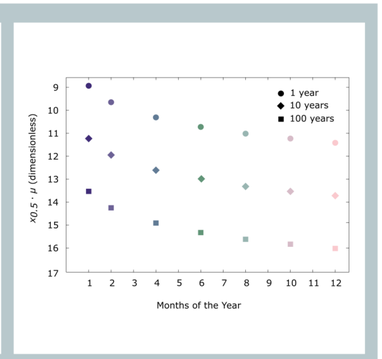


Figure 6: Comparison of 1, 10, and 100 year results.

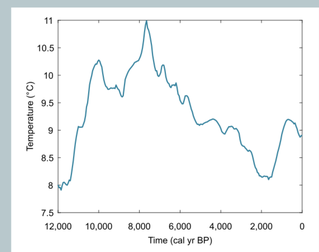


Figure 7: Holocene semi-centennial avg. temp. record reconstructed from pollen cores collected from both Yellowstone and the Bighorn Mountains. (Kelly et al., 2012)

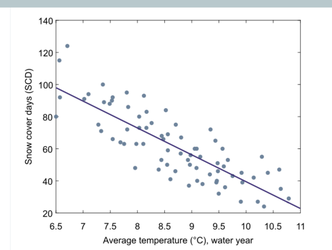


Figure 8: Annual SCD compared to avg. temp., collected from 1948 to 2024 at Billings International Airport, MT. (IVSL, 2022)

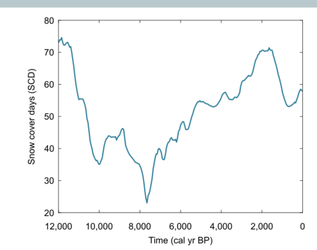


Figure 9: Simulated Holocene SCD history utilizing data from Figures 7 and 8.

Simulated Exposure Age (yr)	"True" Age (ka)	Apparent Age (ka)	Apparent Age/ "True" Age
500	0.423251	0.421096	0.9949
5,000	4.150309	4.175441	1.006055
10,000	8.470654	8.266463	0.975894

Figure 10: Summarized results comparing simulations of different exposure ages using a variable SCD history (Figure 9) vs. a constant SCD history (modern day SCD data assumed from the past).

The "true" age is simulated from a variable SCD history, and apparent age is simulated from a constant SCD history.

THE THEORY IN PRACTICE

Be-10 accumulation is not affected by mild snow cover, thus agreement shown between Be-10 and OSL measurements would indicate luminescence signals at the same site are also unaffected.

Samples were collected in Summer 2024 in the Beartooth Mountain Range from:

- Boulders dated in a previous study using Be-10 (Barth et al., 2022)
- Locations with large, stable, relatively flat boulders without excessive shade
- New boulders additionally sampled to expand the previous data set

The sampled rock cores were sliced into ~1 mm wafers and individually crushed in the UTA Luminescence Lab. We collected OSL measurements using a Risø TL/ OSL Reader Model DA-20.

"REAL LIFE" RESULTS

Samples UTA0507, UTA0511, and UTA0505 all have similar IR50 and pIRIR225 depth profiles.

- UTA0507 IR50 and pIRIR225 ages are less than the expected age based on Be-10 data, 357 years and 624 years respectively.
- UTA0511 IR50 and pIRIR225 ages are more than the age theorized based on the location of the boulder sampled, 1,800 years and 2,308 years, respectively.
- UTA0505 pIRIR225 age of 2,234 years is approximately the same Be-10 age, however the IR50 age, 854 years, is not in agreement.

IR50 and pIRIR225 ages do not show strong correlation with predicted ages, either from Be-10 data or based on location within recessional moraine.

FUTURE WORK

Additional sampling, specifically from Triangle and Emerald Lakes, would allow us to more thoroughly analyze the correlation between ages found using Be-10 and OSL. A tentative trip to the field is scheduled for Summer 2025.

Figure 11: Little Glacier Lake moraine from a distance, slightly blocked by the foreground. Still visible is the remaining snowpack from the preceding winter; image taken in Summer 2024. State outlines showing field site location in upper left corner.

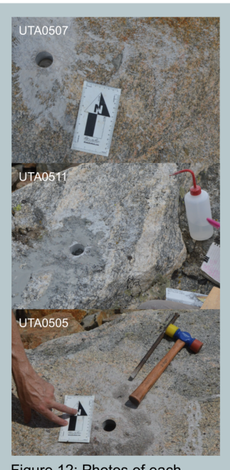
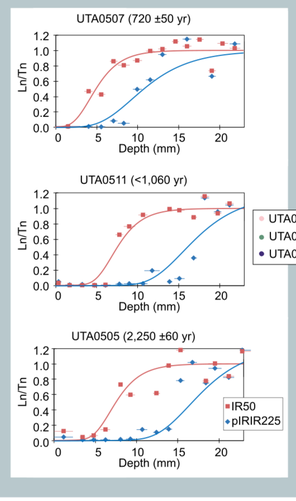


Figure 12: Photos of each sample site.



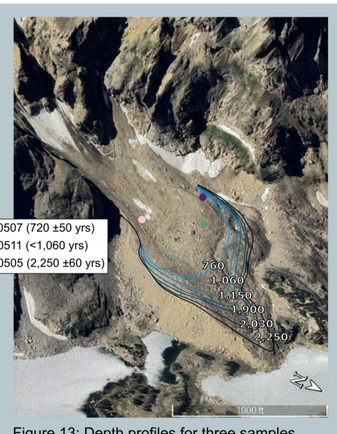


Figure 13: Depth profiles for three samples, marked on a satellite image of Little Glacier Lake moraine with possible recessional moraine outlines and ages.

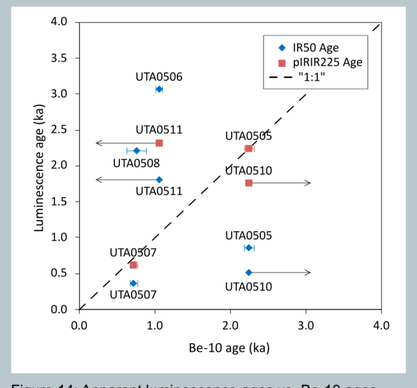


Figure 14: Apparent luminescence ages vs. Be-10 ages from Barth et al., 2022. Samples UTA0510 and UTA0511 are hypothesized to be older than 2,250 years and younger than 1,060 years respectively, indicated by the black arrows.

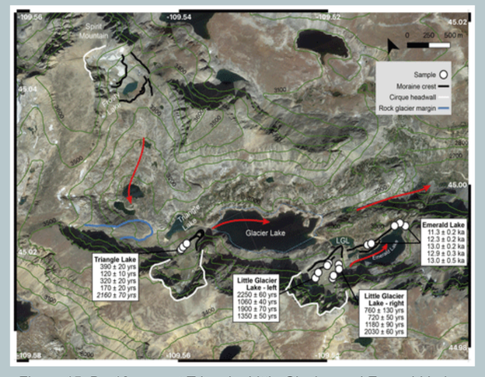


Figure 15: Be-10 ages at Triangle, Little Glacier, and Emerald Lakes, and generalized ice flow direction through time (Barth et al., 2022).

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