Toward the Development of a 10Be Chronology of Glaciation in the Mosquito Range, Colorado: A Progress Report

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INTRODUCTION

• Glacier behavior is a valuable record of present and past climate change.
• Precise chronologies (e.g. Young et al., 2011) of the advance and retreat of glaciers during the Last Glacial Maximum (LGM) in the Rocky Mountain region have provided insights regarding the mechanisms of climate change and the influence of local microclimate on glacier behavior.
• However, additional glacial chronologies need to be developed in order to better understand the nuances of regional climate change.
• Presented here are the results of sampling, sample preparation, and calculations of ¹⁰Be ages that are being used to develop the first chronology of glaciation in the Mosquito Range (Figure 1).

FIELD METHODS

• 12 boulders were sampled from the LGM terminal moraine complexes (those associated with the maximum extent of the glaciers) in several valleys.
• Boulders selected for sampling needed to be:
  – Large: to minimize the chance it had been recently exhumed by surface erosion and also minimize shielding by winter snowpack;
  – At the apex of a moraine ridge, thus avoiding the possibility of the boulder having rolled downhill to potentially expose a different side of the boulder to the cosmic rays since its deposition; this also precluded sampling boulders on the slopes of moraines that most likely had been exhumed; and
  – Free from any signs of spalling (flaking) at the boulder surface that would remove the original surface exposed to cosmic rays, effectively resetting the exposure age.
• A 2×2 m deep grid was cut into the surfaces of boulders meeting these criteria (Figure 3) and samples were subsequently chipped out using a hammer and chisel.
• Boulder location and elevation were measured using GPS. Elevation of the surrounding horizon was taken every ten degrees azimuth to later correct for topographic shading.

LABORATORY METHODS

• Rock samples were crushed to disaggregate constituent mineral grains.
• Crushed samples were then sieved to obtain the optimal grain size (400-800 µm).
• Quartz grains were etched in HCl to remove contaminated grain surfaces.
• Grains were magnetically separated as a preliminary means of isolating the quartz from other minerals.
• Further separation of the quartz was done by floating the grains in a dense (heavy) liquid.
• Final purification of the grains uses a stronger acid etch (HF and HNO₃) to remove any remaining organic material and finish isolating pure quartz grains (SiO₂) that contain the ¹⁰Be target material.
• ¹⁰BeO targets are sent to Purdue Rare Isotope MEasuring (PRIME) Lab for measurement of ¹⁰Be concentrations using accelerator mass spectrometry (AMS).

ACCELERATOR MASS SPECTROMETRY (AMS)

• The principles of AMS are outlined below (Figure 4):
  – SiO₂ and ¹⁰BeO molecules are ionized into anionic (negatively charged ion) forms.
  – Ions are attracted to a positively charged electron stripping material, where electrons are removed.
  – Newly-formed cations (positively charged ion) are magnetically repulsed down an accelerating column.
  – A strong magnet at the end of the accelerating column bends the path of the cations.
  – The mass and identity of the cations are determined based on their speeds and deflection angles.

RESULTS: Calculation of Exposure Ages

• Samples collected in the summer of 2016 are still being processed and therefore no exposure ages can be determined at this time.
• However, processing and AMS analyses of four samples collected in the previous summer are complete and were used to compute exposure age of the LGM moraine complex in the Fourmile Creek valley (Figure 1).
• Ratios of ¹⁰Be atoms per gram of quartz for each sample were submitted to the CRONUS/Earth online calculator (http://cronus.ess.washington.edu) for computation of exposure ages.
• Corrections were included for:
  – Sample depth to account for the exponential decrease in the production of ¹⁰Be within the boulder;
  – Rock density to account for degree of penetration of cosmic rays;
  – Elevation, as ¹⁰Be production increases with altitude;
  – Latitude, as production varies according to the Earth’s magnetic field;
  – Topographic shielding from cosmic ray bombardment at sample locations; and
  – The sampled surface’s orientation, which affects the degree of exposure to cosmic rays.
• The assumption was made that no weathering of the boulder surfaces occurred. This is a standard assumption made in order to facilitate comparison of chronologies in different regions.
• Based on the foregoing, the following exposure ages were obtained:
  • FMC-1-2015 14.0 ± 0.5 ka
  • FMC-2-2015 21.9 ± 0.9 ka
  • FMC-3-2015 63.6 ± 2.4 ka
  • FMC-4-2015 24.6 ± 0.9 ka
• Analytical uncertainties are shown; no other uncertainties are included.

DISCUSSION AND PRELIMINARY CONCLUSIONS

• Samples FMC-2-2015 and FMC-4-2015 are reasonably consistent, with a mean exposure age of 23.2 ka.
• These are also in good agreement with ¹⁰Be exposure ages determined for LGM moraines in the region:
  – On the eastern flank of the Sawatch Range, ~40 km to the east of Fourmile Creek, exposure ages in three different glaciated valleys were 21.8 ± 0.3, 20.5 ± 0.2, and 23.6 ± 1.4 ka (Schweinsberg et al., 2015).
  – In the Taylor Park area, ~50 km to the southwest, (recalculated) exposure ages on an LGM moraine average 19.2 ± 1.7 ka (Brugger, 2007).
• Lacking a statistically robust data set, it is not possible to speculate whether LGM advances in the Mosquito Range were synchronous with those in the broader region, or asynchronous. If the latter, the question is what caused the asymmetry - micro-climate differences in the dynamic response of individual glaciers to the same climate forcing, or both?
• The substantially younger exposure age of sample FMC-1-2015 is most likely due to the boulder having been deposited during the construction of a recessional moraine during retreat of the glacier.
• Sample FMC-3-2015 is problematic in being much too old. A reasonable interpretation of this is that the boulder was not completely abraded during glacial transport, and thus has ¹⁰Be “inherited” from its previous exposure history as bedrock.

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REFERENCES