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

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Toward the Development of a ^{10}Be 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 ^{10}Be ages that are being used to develop the first chronology of glaciation in the Mosquito Range (Figure 1).

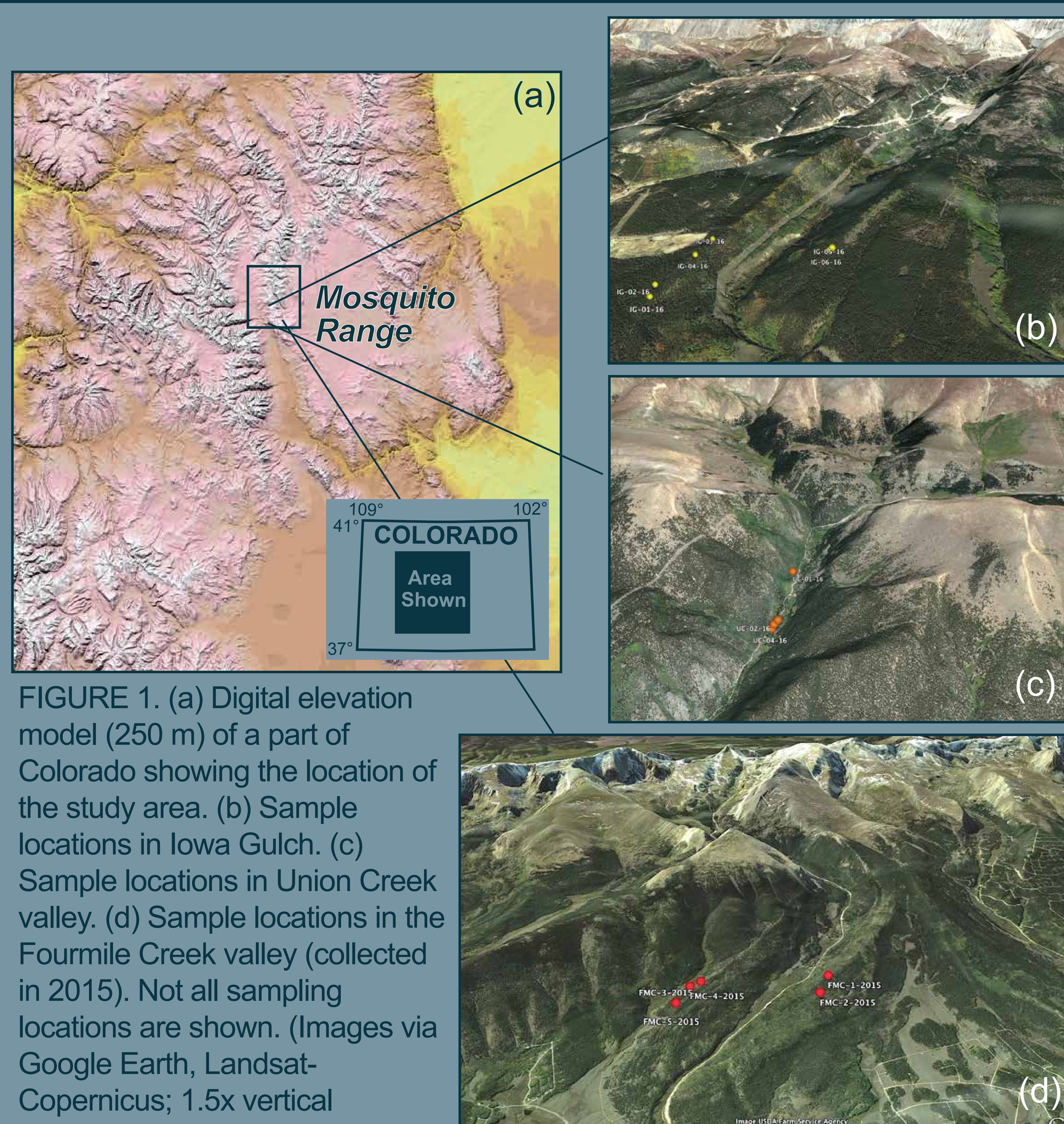

FIGURE 1. (a) Digital elevation model (250 m) of a part of Colorado showing the location of the study area. (b) Sample locations in Iowa Gulch. (c) Sample locations in Union Creek valley. (d) Sample locations in the Fourmile Creek valley (collected in 2015). Not all sampling locations are shown. (Images via Google Earth, Landsat-Copernicus; 1.5x vertical exaggeration.)

COSMOGENIC RADIONUCLIDE (CRN) DATING: Theory

- ^{10}Be is an isotope produced by cosmic ray bombardment (Figure 2) of the silicon in quartz (SiO_2).
- Given a known production rate of cosmogenically-produced ^{10}Be and its loss due to radioactive decay, the abundance of ^{10}Be in quartz is a measure of a rock's exposure time at the Earth's surface
- The application of CRN dating to glacial deposits assumes: (1) quartz-rich rocks (e.g. granite) are plucked from the bedrock by glacial erosion; (2) those rocks are abraded by the glacier during transport which removes any preexisting ^{10}Be due to prior exposure; (3) the rocks are deposited initially at the surface of a moraine and thereafter remain exposed.
- For this simple scenario, the calculation of a CRN age uses the equation

$$N = (P/\lambda)(1 - e^{-\lambda t})$$

where N is number of ^{10}Be atoms, P is the production rate of ^{10}Be, λ is the rate of decay, and t is time (or the age of the sample) (Zreda and Phillips, 2000).

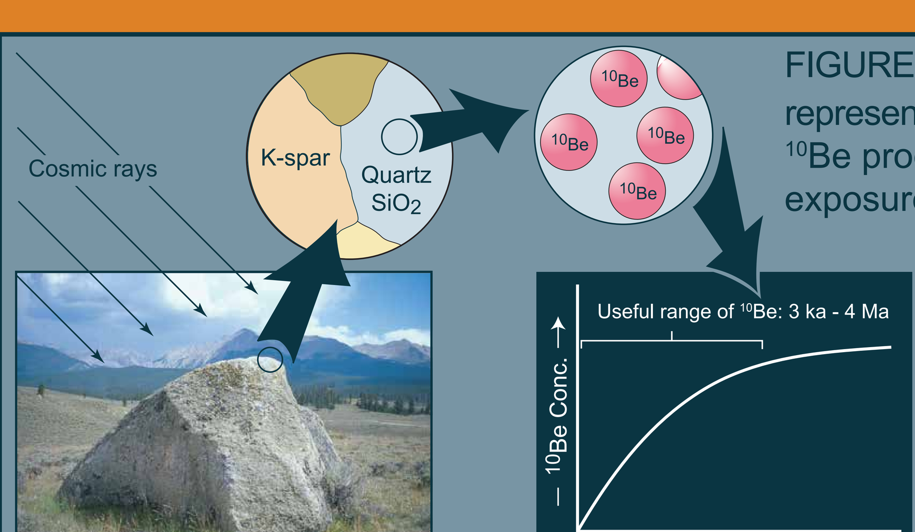

FIGURE 2. Schematic representation of cosmogenic ^{10}Be production and CRN exposure dating.

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 probably had been exhumed; and
  - Free from any signs of spalling (flaking) at the boulders surface that would remove the original surface exposed to cosmic rays, effectively resetting the exposure age.
- A ~2 cm 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 shielding.

FIGURE 3. Sampling of a moraine boulder in the Union Creek valley.

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).
- Grains were magnetically separated as a preliminary means of isolating the quartz from other minerals.
- Quartz grains were etched in HCl to remove contaminated grain surfaces.
- 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 HNO_3) to remove any remaining organic material and finish isolating pure quartz grains (SiO_2) that contain the ^{10}BeO target material.
- ^{10}BeO targets are sent to Purdue Rare Isotope MEasuring (PRIME) Lab for measurment of ^{10}Be concentrations using accelerator mass spectrometry (AMS).

ACCELERATOR MASS SPECTROMETRY (AMS)

- The principles of AMS are outlined below (Figure 4):
  - SiO_2 and ^{10}BeO molecules are ionized into anionic (negatively charged ionic) forms.
  - Anions are attracted to a positively charged electron stripping material, where electrons are removed.
  - Newly-formed cations (positively charged ions) 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.

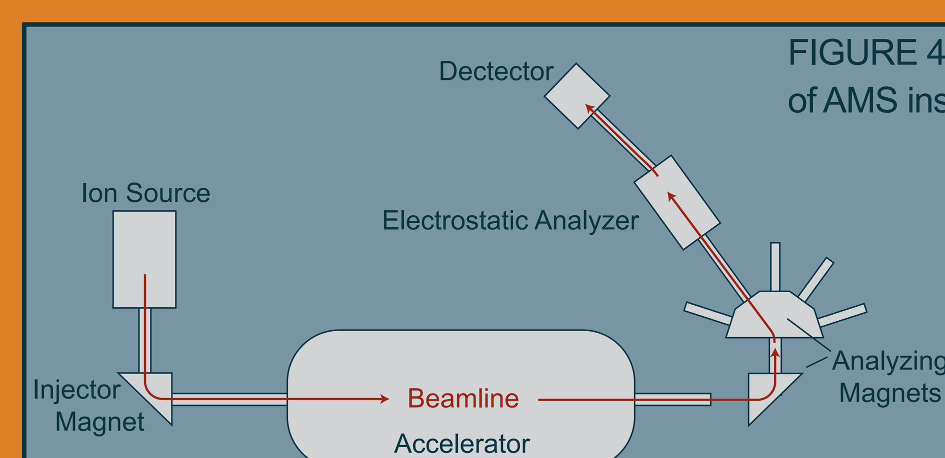

FIGURE 4. Schematic illustration of AMS instrumentation.

- AMS results are reported as a ratio of ^{10}Be atoms per gram of quartz in the sample that is then used to compute the exposure age.

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 ^{10}Be atoms per gram of quartz for each sample were submitted to the CRONUS-Earth online calculator (http://hess.ess.washington.edu/) for computation of exposure ages.
- Corrections were included for:
  - Sample depth to account for the exponential decrease in the production of ^{10}Be within the boulder;
  - Rock density to account for degree of penetration of cosmic rays;
  - Elevation, as ^{10}Be production increases with altitude;
  - Lattitude, 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	63.5 ± 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 ^{10}Be 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 are 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 asynchroneity - (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 ^{10}Be "inherited" from its previous exposure history as bedrock.

ACKNOWLEDGEMENTS

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REFERENCES

Brugger, K.A., 2007. Cosmogenic ^{10}Be and ^{36}Cl ages from late Pleistocene terminal moraine complexes in the Taylor River drainage basin, central Colorado, U.S.A. *Quaternary Science Reviews*, v. 26, 494-499.

Schweinsberg, A.D., Briner, J.P., Shroba, R.R., Licciardi, J.M., Leonard, E.M., Brugger, K.A., and Russell, C.M., 2016, Pinedale glacial history of the upper Arkansas River valley: New moraine chronologies, modeling results, and geologic mapping, in Keller, S.M., and Morgan, M.L., eds., *Unfolding the Geology of the West*: Geological Society of America Field Guide 44, p. 335–353, doi:10.1130/2016.0044(14).

Young, N.E., Briner, J.P., Leonard, E.M., Licciardi, J.M., and Lee, K., 2011. Assessing climate and non-climatic forcing of Pinedale glaciation and deglaciation in the wester United States. *Geology* 39, 171-174. doi:10.1130/G31527.1

Zreda, M.G., and Phillips, F.M., 2000. Cosmogenic nuclide buildup in surficial materials, in Noller, J.S., Sowers, J.M. and Lettis,W.R. eds., Quaternary Geochronology: Methods and Applications, AGU Reference Shelf 4, American Geophysical Union, 61-76.