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Erosion rates of moraine crests from *in-situ* and atmospheric cosmogenic nuclide accumulation in boulders and matrix

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Many techniques have been developed to quantify erosion on various temporal and spatial scales. Those based on accumulation of cosmogenic nuclides in surficial materials are particularly useful for determining long-term, integrated erosion rates. We describe the application of *in-situ* and atmospheric cosmogenic nuclides to determining erosion rates of moraines. It builds on our previous approach (Zreda et al., 1994) in which we measured ^{36}Cl in morainal boulders and in the matrix, and developed a statistical model to convert the variance of individual boulder ages into erosion rate. We improved that early approach by measuring *in-situ* ^{10}Be in the matrix and atmospheric ^{10}Be in the soil profile, and by including boulder erosion in the statistical model. The complete system consists of measurements of four nuclide inventories: *in-situ* ^{36}Cl in the boulders, *in-situ* ^{36}Cl in the matrix, *in-situ* ^{10}Be in the matrix, and atmospheric ^{10}Be in the matrix (in depth profile). Each measured inventory is a function of the same two variables: landform age and erosion depth.

We measured cosmogenic nuclides in samples from eleven moraines in Bishop Creek, in the Sierra Nevada, California, and determined time-integrated erosion rates and erosion-corrected ages of these landforms. The erosion rates of moraine crests range from 2 cm/ky to 10 cm/ky (ky = 1000 years), integrated over times between 100 ky and 170 ky. In general, the different combinations of measurements give erosion rates that are consistent within a factor of two or better. These combinations of erosion rates and ages result in the total lowering of the moraine crests between 2.5 m and 13 m, which is a reasonable magnitude in the arid climate of the Sierra Nevada. Accounting for lowering of moraine crests significantly reduces the uncertainty in the calculated

cosmogenic age of the moraine. For example, an uncorrected age of 109±33 ky becomes a corrected age range of 145-155 ky. Work in progress concentrates on two tasks: a rigorous error analysis, and combining a physical model of moraine erosion with accumulation of cosmogenic nuclides. Both will make the model more realistic and calculations more accurate.

Reference:

Zreda, M.G., F.M. Phillips and D. Elmore, 1994. Cosmogenic ^{36}Cl accumulation in unstable landforms, 2. Simulations and measurements on eroding moraines. Water Resources Research 30: 3127-3136.