A Monte Carlo Investigation of Inherited Cosmogenic Nuclides in Moraine Boulders

Applegate, Patrick J.; Alley, Richard B.

Cosmogenic exposure dating is an important tool for determining the ages of moraines. However, cosmogenic exposure dates are often biased by geologic processes. Moraine degradation, which tends to bias exposure dates toward the young side, has been modeled in detail, but little modeling effort has been devoted to inheritance, which biases exposure dates toward the old side. Here, we present a Monte Carlo investigation of the revalence of inheritance in moraine boulders. We note that the production rates of most cosmogenic nuclides decrease exponentially with depth below rock surfaces. Therefore, in order for a boulder to give a spuriously old age, the boulder must have been exposed for a long time before it was moved by the glacier, and then deposited on the moraine with the side containing the maximum concentration of cosmogenic nuclides facing upward. The boulder also must not have been eroded appreciably during transport. In our model, the apparent age given by each boulder is the sum of the true age of the moraine and an inherited component, which is a well-defined function of the pre-depositional exposure time of the boulder, the size of the boulder, and the face of the boulder that was upright when the boulder was deposited on the moraine. The true age of the moraine is set by the user; the other variables are determined randomly for each boulder. Predepositional exposure times are drawn from either a uniform or exponential distribution, with the form and parameters of the distribution set by the user. Boulder sizes are drawn from a large data set of boulders actually sampled for cosmogenic exposure dating on last-glacial moraines in the western United States. The side of each boulder that faces upward has a 1 in 6 chance of being the side with maximum inheritance, a 1 in 6 chance of being the side with minimum inheritance, and a 4 in 6 chance of being a side with intermediate inheritance. Preliminary results suggest that most moraine boulders contain a relatively small amount of inherited cosmogenic nuclides, regardless of the distribution of preexposure times. We compare the distributions of apparent ages returned by the model to actual distributions from the literature, and we discuss the implications of this work for determining the ages of moraines using cosmogenic exposure dating.