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Inferring moraine age and depth of glacial erosion from cosmogenic exposure dates using geomorphic process modeling

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Cosmogenic exposure dating provides insight into the timing of glacial fluctuations at high latitudes, but collections of exposure dates from isochronous surfaces often show unexpectedly large scatter. Here, we show that the structure of a recently published set of cosmogenic exposure dates from eastern Greenland (Kelly et al., 2008, Quaternary Science Reviews, v. 27, p. 2273) is distinctly different from the structures of selected data sets from the midlatitudes. Specifically, histograms of the eastern Greenland dates are right-skewed, whereas histograms of exposure dates from the mid-latitude sites are left-skewed. We infer that this difference in structure reflects a difference in the geomorphic processes active in eastern Greenland, as compared to the mid-latitude sites. Further, we fit the eastern Greenland data with a process model that relates moraine age, landscape age, and depth of glacial erosion to the observed distributions of cosmogenic exposure dates.

Our model treats inherited nuclides in moraine boulders in a Monte Carlo framework. The unknown parameters for each boulder are 1) the amount of time it was exposed to cosmic rays before being incorporated into the moraine, and 2) the depth to which the sampled point on the boulder was buried during this predepositional exposure time. Neither of these parameters is known, so we assume that all values from zero up to some maximum are equally likely. We draw random values from these uniform distributions for a large number of synthetic boulders, calculate an apparent exposure time for each synthetic boulder, and histogram the apparent exposure times.

The histograms produced by the inheritance model are right-skewed, consistent with the eastern Greenland data set. In contrast, the left-skewed structure of the other data sets is well reproduced by a model of moraine degradation.

We present fits of the inheritance model to the eastern Greenland exposure dates, and discuss the implications of the resulting moraine age, landscape age, and glacial erosion depth estimates.