Glacial erosion and till dispersion using the source and the sink: A new cosmogenic nuclide application

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Landscape morphodynamics can be recorded by both the bedrock surface and the deposits removed from the bedrock. In this work, we analyze both the source – the bedrock – and the sink – the till – to decipher the glacial system.

Terrestrial in situ cosmogenic nuclides (TCN) extracted from glaciated bedrock surfaces can be used to assess the relative stability of each part of the landscape, thus to determine the spatial variation of glacial erosion beneath polythermal ice. We adopt a field-constrained glacial erosion rule for the Torngat Mountains of northern Labrador for use in Baffin Island, which occupies similar setting. This rule correlates modeled ice velocities with TCN-derived erosion rates from bedrock for terrain once partially covered by slow-moving, non-erosive ice (Staiger et al., 2005).

Because the spatial variation of cold-based, non-erosive ice versus wet-based, erosive ice is recorded by the bedrock TCN concentrations, each individual grain within the till has a unique history as it was previously exposed to cosmic radiation then transported by ice. Together the grains give an areal average of the basal thermal regime of the ice that entrained the sediment. In this new method, we measure ^{10}Be and ^{26}Al concentrations in 25 surface till samples from Baffin Island and Labrador and can distinguish specific sediment packages. Till samples that were predicted by geomorphological context to have been deposited by non-erosive ice contain over 100 times the TCN contentration of till thought to be deposited by highly erosive ice. We interpret these data using a finite-element, time-dependent ice sheet model that includes basal temperature and basal water calculations (Johnson and Fastook, 2003) and a forward model that calculates possible TCN concentration scenarios.

We estimate ranges of englacial traveling distances for "short-distance tills" with high TCN values and "long distance tills" with low TCN values. This work has potential applications in arctic and sub-arctic drift exploration as well as a potential for assessing the effect of glacial erosion on a glaciated landscape with fewer samples.

References

Johnson, J. and Fastook, J. (2002) *Quat. Int.* **95-96**: 87-98.

Staiger, J.W., Gosse, J.C. Johnson, J., Fastook, J., Stockli, D., Stockli, L., and Finkel, R. (2005) accepted to *ESPL.*

Five ways to examine what isn't there with cosmogenic isotopes

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Terrestrial in situ cosmogenic nuclides (TCN) have been used in five ways to characterise the rates of exumation or incision by streams: (1) a maximum erosion rate can be calculated by measuring one or two isotopes on a bedrock surface; (2) basin-wide average erosion rates can be calculated with one isotope measured in stream sediment; (3) escarpment retreat rate can be attained by measuring remnents of the retreating cliff; (4) stream incision rates into bedrock can be attained by dating straths; and (5) vertical incision rates can be estimated from measurements of a single isotope down a near vertical wall of a canyon. The application of each approach is demonstrated and placed in a regional context. Erosion of Archean gneiss summits in the Torngat Mountains of Labrador, Canada are as low as 1.6±0.3 m/Myr. Basin-wide average erosion rates in the Clearwater Catchment, Olympic Mtns, Washington State range from 0.4±012 mm/yr in high relief regions to 0.2±0.1 mm/yr in low relief regions over the past 10^4 yrs, in close agreement with similar timescale strath incision rates, longer timescale thermochronology, and shorter timescale stream sediment discharge. Retreat rate of the Morrison Formation escarpment in NE Arizona has been measured at 15±5 mm/yr (n=3) in one basin and 2.5±0.5 mm/yr (n=2) in an adjacent basin, consistent with estimates from soils and other measurements. Chronology of mapped fill terrace surfaces in the eastern Grand Canyon provide constraints on the age of the underlying straths that are consistent with U-series and OSL ages of the same fills, and yield an average incision rate by the Colorado River of 100-150 m/Myr. Ages on straths in the Rio Diamante, Mendoza, Argentina have provided constraints on incision through a Quaternary fold (the initiation of an antecedent stream). Rates of incision based on single nuclide measurements in canyon wall bedrock samples within 20 m above 5000 cfs stage, average 0.08±0.01 mm/yr (n=3) for the past 20 kyr to more than 3 mm/yr on higher surfaces. Higher surfaces lacked fluvial polish.