Bedrock erosion rates in the Antarctic Dry Valleys

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We made a comprehensive study of sandstone bedrock erosion rates throughout the Antarctic Dry Valleys, using cosmic-ray-produced ^{10}Be and ^{26}Al. Concentrations of these nuclides in bedrock surfaces are much lower than expected from a) millions-of-years-old volcanic ashes that have resided at the surface since emplacement, or b) similarly old exposure ages on resistant surface clasts. By measuring both ^{10}Be and ^{26}Al in bedrock surfaces, we excluded ice cover as an explanation for this discrepancy. The only remaining explanation is that sandstone surfaces are eroding at slow but geomorphically significant rates of 1-3 m/Myr. In the photo above, dolerite erratics with ^{3}He exposure ages of 2-7 Ma overlie sandstone that must have been eroding at 1-1.5 m/Myr for at least ~2-3 Myr. Erosion has significantly lowered this bedrock surface since it was originally exposed by ice, without destroying the resistant glacial erratics that record past ice cover. This observation is relevant to interpretations of small-scale bedrock topography as geomorphic evidence for subglacial processes. In addition, many of the sandstone surfaces we sampled were colonized by cryptoendolithic lichens. Past research has suggested that these organisms may be significant agents of rock weathering via secretion of organic acids, and thus that their distribution may conrol the distribution of rock weathering rates in the Antarctic landscape. Although we did not design the present study specifically to test this hypothesis, we observe that surfaces with lower erosion rates are more likely to show evidence for lichen colonization. This suggests that lichens may preferentially colonize surfaces that weather slowly because of geologic factors, rather than themselves exerting a primary control on weathering rates.

Multiple-cosmogenic-nuclide isochron methods

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Measuring multiple cosmogenic nuclides with different decay constants in the same sample tells more about its exposure history than a single-nuclide exposure age. The main terrestrial application of this idea is `burial dating' of a sample that has experienced only steady erosion followed by abrupt deep burial. Two measurements of ^{10}Be and ^{26}Al yield unique solutions for two unknowns: the erosion rate and the burial age. This simple approach, however, fails in many common situations where samples have experienced a complex exposure-burial history. Here we describe two related approaches that exploit an isochron method – measuring ^{10}Be and ^{26}Al concentrations in a set of samples that share the same burial age, but vary in other aspects of their exposure history – to address this deficiency and expand the range of geologic applications of burial dating.

First, Pleistocene terrestrial glacial sequences include paleosols that were exposed during soil formation and then buried by till during glaciations. Their ^{10}Be-^{26}Al burial ages should date ice sheet advances, but simple burial dating fails here because paleosol parent materials have large and unknown inventories of inherited ^{10}Be and ^{26}Al. However, one can collect samples from different depths in the paleosol that have the same inheritance, but different production rates during soil formation. ^{10}Be and ^{26}Al concentrations in these samples will lie on a line in ^{10}Be-^{26}Al space. The slope of this line depends only on the burial age of the soil, so the age can be determined without knowing the inherited nuclide concentrations.

Second, simple burial dating often fails for fluvial or alluvial sediment sections because their burial history is not well known, so their inventory of postdepositional ^{10}Be and ^{26}Al is likewise unknown. However, one can analyse a set of individual clasts that arrived at the site with different inherited nuclide concentrations, but share the same burial history. Again, ^{10}Be and ^{26}Al concentrations in these clasts will lie on a line whose slope depends only on the burial age, so the age can be determined without knowing the postdepositional nuclide inventory.