THEORETICAL PRECISION ESTIMATES FOR EXPOSURE-AGE AND EROSION-RATE DATA FROM ANALYSIS OF COSMOGENIC ISOTOPES

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Recently, efforts have been made to determine exposure ages based on analyses of ^{36}Cl, ^{3}He and other "cosmogenic" isotopes. These isotopes are created primarily by neutron reactions in the upper ~40 cm of rocks exposed at the earth's surface. The neutrons result from cosmic ray interactions in the atmosphere. One of the promising aspects of cosmogenic studies is the potential to determine both age and erosion rate, by analysis of two or more isotopes from the same sample. We present estimates of the achievable precision of exposure-age and erosion-rate estimates as a function of measurement uncertainty and age and erosion rate, for different isotopic systems.

The concentration C of cosmogenic isotopes at the exposed surface is related to the production rate P, the time of exposure t and the erosion rate ε, according to the equation: $C(P,t,\varepsilon) = P [\lambda + \varepsilon k]^{-1} [1 - e^{-(\lambda + \varepsilon k)t}]$ (where k is a characteristic value related to the density of the sample, λ is the decay constant of the cosmogenic isotope, and P is assumed to be constant). Calculating the precision of t (σ_t) from the measured uncertainty in C (σ_C) is straightforward, provided the value of ε is known. However, for many geologic problems neither t nor ε is known. In this general case, predicting precisions in t and ε is not straightforward, because σ_t and σ_ε depend strongly on the value of the unknowns, t and ε, as well as on σ_C. We analyze the systematics of the age/erosion-rate equation to map σ_t and σ_ε on the (t,ε) plane, and the correlation between σ_t and σ_ε, as a function of σ_C for different isotope pairs. Our results should be useful in constraining the interpretation of cosmogenic-isotope data, and in predicting the geologic situations for which cosmogenic studies may prove useful.