Eroding the Land: Steady State and Stochastic Rates and Processes Through a Cosmogenic Lens

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Quantifying erosion rates and processes remains a central focus of studying the Earth's surface. Measurement of *in situ* produced cosmogenic radionuclides (CRNs) enables a level of quantification that would otherwise be impossible or fraught with uncertainty and expense. Remarkable success stories punctuate the field over the last decade as CRN-based methodologies are pushed to new limits. Inherent to all is an assumption of steady-state rates and processes. This paper focuses on the use of cosmogenic ^{10}Be and ^{26}Al, extracted from quartz in bedrock, saprolite and detrital material to quantify sediment production or erosion rates and processes. Previous results from two very different field areas are reviewed to highlight the potential for non-steady-state processes in shaping soil-mantled landscapes. With this potential in mind, a numerical model is presented to test the effect of non-steady-state erosion rates and processes on CRN concentrations. Results from this model focus on ^{10}Be concentrations accumulated under modeled variations in erosion rates with different ranges, frequencies, and styles of variability. In general, the higher the maximum erosion rate, the higher the impact on the CRN concentration and, therefore, the more likely that point measurements will capture the variable signal. Conversely, the higher the frequency of erosional variation, the less likely point measures are to accurately determine rates, but the closer the inferred rate is to the mean of the long-term erosion rate. Modeling results are applicable for point-specific erosion rates, but endorse the catchment-averaged approach for determining average rates. Potentially large uncertainties emphasize the need for careful sample selection, with adequate numbers of samples collected for quantifying the processes eroding the land. The two field examples from the Oregon Coast Range, USA, and the southeasern Australian highlands, show how analyzing enough samples can define a clear soil production function despite the potential for non-steady-state processes. The model presented here is ready for application to catchment-averaged processes, as well as modeling the role of muons in variable erosion rate scenarios.