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A protocol for estimating accurate denudation rates based on terrestrial cosmogenic nuclides

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Terrestrial cosmogenic nuclides provide a crucial tool in geomorphology, however evaluation and correction of systematic uncertainties remains a challenge in estimating denudation rates of land surfaces. Subsurface nuclide production involves distinct processes by neutron and muons, which have different contribution ratios and attenuation lengths for accumulating any nuclides such as chlorine-36 in calcite in carbonate rocks and beryllium-10 or aluminum-26 in quartz in silicates. Therefore, at a given point in time, the nuclide amount present on an eroding ground surface has resulted from accumulation through each production path on different timescales. The muon contribution to the total nuclide abundance increases with the denudation rate, which accumulates the nuclide on a longer timescale. Generally, nuclide production rate changes with time with varying cosmic-ray flux, and hence different scaling factors apply for evaluating the local nuclide production rates on different timescales. However, the current scheme does not take temporal changes in the nuclide production rate into account for calculating denudation rates. In this report, we discuss the importance of this issue by comparing ordinary analytical solutions with quasi-analytical evaluation using time-integrated scaling factors for the denudation rates, as well as with results of numerical integration of nuclide accumulation under sequential changes in the nuclide production rate. An appropriate protocol is then presented for calculating accurate denudation rates based on the concentrations of terrestrial cosmogenic nuclides in various types of geomorphological samples.

Student Submission

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