Terrestrial Cosmogenic Nuclides as Paleoaltimeters: New Approaches and Future Potential

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The elevation dependence of terrestrial cosmogenic nuclide (TCN) production has long been noted by researchers, along with the suggestion that TCNs might hold the key for deducing climate-independent paleoaltimetry. If all other variables affecting both modern and ancient TCN concentrations can be constrained, the average elevation for a specific time period of surface exposure can be calculated. Paleoaltimetry requires careful evaluation of exposure time (usually via Ar-Ar dating) and measurement of at least one TCN. The ratio of TCN concentration to exposure time gives a production rate that can be compared to known attenuation of cosmic ray flux (and hence TCN production) as a function of elevation. Although radionuclides are quite useful for studying modern surfaces, stable TCNs, such as ^{3}He or ^{21}Ne, are more commonly used for evaluation of pre-Holocene paleosurfaces. Proof of concept of single isotope TCN paleoaltimetry has been documented by Blard et al. [1] for Quaternary basalts, although the difficulties of applying this technique to older paleosurfaces should not be underestimated. Erosion, even small amounts, effectively wipes out the TCN signal. In addition, changes in magnetic field intensity will significantly alter TCN production, and paleointensity is poorly constrained for rocks older than ~5 Ma. Ultimately, paleoelevation uncertainty is constrained by TCN production rates which are generally known to ~10% for radionuclides and ~20% for stable TCNs (2σ). Additional uncertainty related to TCN measurement, rock density, and atmospheric attenuation coefficients implies a best-case uncertainty of one km for single isotope paleoaltimetry. This uncertainty depends greatly on geographic locality and lithology as well as the ability to clearly identify a paleosurface, quantitatively differentiate TCNs produced during modern exposure from paleoTCNs, and accurately measure exposure time. Theoretical consideration of approaches for limiting uncertainty related to exposure time, erosion and paleointensity suggests that measurement of two or more TCNs may provide a cosmogenic paleoaltimeter that is applicable in a wider range of settings and timescales than is feasible for a single TCN.

References

[1] Blard P., Lave J., Pik R., Quidelleur X., Bourls, D., and Kieffer, G. (2005) *EPSL* **236,** 613-631.