Meteoric $^{10}Be/^{9}Be$: A versatile tool for weathering and erosion estimates from small creeks to large rivers of varying lithology

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The ratio of meteoric ^{10}Be to stable ^{9}Be ($^{10}Be/^{9}Be$), a tracer for Earth surface erosion and chemical weathering, is set in the Critical Zone, where ^{10}Be that is a known atmospheric flux tracer mixes with ^{9}Be that is released from rocks by weathering. In rivers, millenial-scale erosion (E), denudation (D), and weathering (W) rates can be determined, assuming that due to their integrative nature, the geochemical properties and fluxes of particulate and dissolved material are diagnostic of the complex processes that set the Critical Zone. In this work, we focus on how the $^{10}Be/^{9}Be$ ratio is modified along spatial gradients, ranging from a single soil profile to the scale of the Amazon River, and how varying lithology may influence the ratio. We show that $^{10}Be/^{9}Be$ ratios from shale, mafic, and ultramafic rocks yield meaningful D´s obtained from sub gram-sized amounts of fine-grained sediment, or from river water. This independence from the presence of quartz provides a benefit over in situ ^{10}Be that has been used to quantify soil and sediment production in granitic landscapes, whereas in quartz-poor lithologies, such rates are largely unassessed.

We show the versatility of this new approach in three settings: 1) In three catchments in the Slavkov Forest, Czech Republic, underlain by felsic, mafic, and ultramafic rocks but otherwise having similar characteristics, equilibration between Be isotopes is indicated by agreeing ratios in ground- and creek water, top soil, and creek sediment. 2) In the Zhuoshui River, Taiwan, high erosion rates (4-8 mm/yr) of slate-dominated headwaters agree with million yr-scale exhumation rates. Denudation rates decrease downstream as more slowly eroding sandstone areas contribute. 3) In the Amazon Basin, the ^{9}Be-derived weathering rate is constant at 40% of the total denudation from the Andes to the river mouth, while ^{10}Be concentrations notably increase during millenial, channel-proximal lowland sediment storage.

In all these settings, meteoric- and in situ-derived denudation rates agree within less than a factor of 2, showing the potential of the $^{10}Be/^{9}Be$ system in a wide range of spatial scales, geomorphic conditions, and lithologies.