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The Beryllium-10(meteoric)/ Beryllium-9 ratio as a new tracer of weathering and erosion rates

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A perfect clock of the stability of the Earth surface is one that combines a first isotope the flux of which depends on the release rate during erosion, and a second isotope produced at constant rate. The ratio of the meteoric cosmogenic nuclide ^{10}Be to stable ^{9}Be, suggested to serve as proxy for weathering and erosion over the late Cenozoic [1], is such a system. We provide a quantitative framework for its use.

In a weathering zone some of the ^{9}Be, present typically in 2ppm concentrations in silicate minerals, is released and partitioned between a reactive phase (adsorbed to clay and hydroxide surfaces, given the high partition coefficients at intermediate pH), and into the dissolved phase. The combined mass flux of both phases is defined by the soil formation rate and a mineral dissolution rate – and is hence proportional to the chemical weathering rate and the denudation rate. At the same time, the surface of the weathering zone is continuously exposed to fallout of meteoric ^{10}Be. This ^{10}Be percolates into the weathering zone where it mixes with dissolved ^{9}Be. Both isotopes may exchange with the adsorbed Be, given that equilibration rate of Be is fast relative to soil residence times. Hence a ^{10}Be/^{9}Be(reactive) ratio results from which the total denudation rate can be calculated. A prerequisite is that the flux of meteoric ^{10}Be is known from field experiments or from global production models [2]. In rivers, when reactive Be and dissolved Be equilibrate, a catchment-wide denudation rate can be determined from both sediment and a sample of filtered river water.

We have tested this approach in sediment-bound Be [3] and dissolved Be in water [4] of the Amazon and Orinoco basin. The reactive Be was extracted from sediment by combined hydroxylamine and HCl leaches. In the Amazon trunk stream, the Orinoco, Apure, and La Tigra river ^{10}Be/^{9}Be(dissolved) agrees well with ^{10}Be/^{9}Be(reactive), showing that in most rivers these two phases equilibrate. ^{10}Be/^{9}Be ratios range from 5×10^{-9} for the Brazilian shield rivers to 2×10^{-10} for the Beni river draining the Andes, corresponding to denudation rates of 0.01mm/yr for the shields and 0.5mm/yr for the Andes, compatible with denudation rates from in situ-produced cosmogenic ^{10}Be [3]. 10-50% of the ^{9}Be was mobilised from bedrock. Once delivered to the ocean, this riverine Be, be it dissolved or reactive, will eventually drive ^{10}Be/^{9}Be ratios of ocean water and disclose global denudation rates – at the present and in the sedimentary record from the past.

[1] Willenbring and von Blanckenburg, Nature 465, 2010

[2] Willenbring and von Blanckenburg, Earth Science Reviews 98, 2010

[3] Wittmann et al., Geol Soc. Am. Bull., 123, 2011

[4] Brown, E. et al., Geochim Cosmochim Acta 56, 1992