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Denudation and weathering rates of carbonate lithologies from meteoric $^{10}Be/^{9}Be$ ratios

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About 60% of the solute ocean input originates from weathering of carbonate rocks. The associated carbon sources and sinks are balanced over geologic time scales. However, the high solubility of carbonate rocks means that their weathering may compensate anthropogenic CO_2 emissions over centennial to millennial timescales. Knowledge of the rates of carbonate weathering and erosion over such timescales is hence of prime importance for constraining the feedbacks within this part of the carbon cycle.

To date carbonate rock denudation was quantified by 1) erosion using cosmogenic ^{36}Cl in pebbles; and 2) weathering using dissolved loads (e.g.[1],[2]). However, these rates are difficult to place into a joint context as they integrate over two distinct timescales. Hence, to constrain denudation rates in carbonate catchments, we developed a method that records weathering and erosion rates simultaneously: the cosmogenic meteoric ^{10}Be over ^{9}Be ratio ($^{10}Be/^{9}Be$). We adapted a framework[3] combining an atmospheric flux tracer, meteoric ^{10}Be ($T_{1/2}$=1.4 My), with stable ^{9}Be, a trace metal released from rocks during weathering, to the limestone-dominated French Jura Mountains. We analyzed river water, soil, sediment, and bedrock for $^{10}Be/^{9}Be$, major and trace elements, and Sr and C isotopes, to quantify i) the contribution of Be released from carbonate vs. silicate minerals and ii) primary vs. secondary carbonate phases in soils and sediments, iii) solid-solute load Be partitioning, and iv) deep (karstic system) vs. surficial (soils) weathering and erosion. Our results indicate average denudation rates (D, the sum of weathering W and erosion) are 300 t/km^2/yr. Denudation is dominated by the weathering flux (W/D ratios of 0.7-0.97). Importantly, we find a consistently high contribution from deep (below soil) weathering, accounting for 30-50% of total weathering at the catchment scale. Such a deep contribution may not have been accessible in previous cosmogenic nuclide studies that used solid material sampled at the surface. Overall, our rates agree with decadal-scale denudation rates from combined suspended and dissolved fluxes within <2x, highlighting the potential of this new method for future Earth's surface studies.

[1]Ott et al., JGR-ES, 2019.
[2]Ben-Asher et al., GSA-Bull., 2021.
[3]von Blanckenburg, F, Bouchez, J. and Wittmann, H., EPSL, 2012.