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Saprolite Formation Rates using U-series Isotopes in a Granodiorite Weathering Profile from Boulder Creek CZO (Colorado, USA)

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Timescales of weathering profile formation and evolution are important kinetic parameters linked to erosion, climatic, and biological processes within the critical zone. In order to understand the complex kinetics of landscape evolution, water and soil resources, along with climate change, these parameters have to be estimated for many different contexts.

The Betasso catchment, within the Boulder Creek Critical Zone Observatory (BC-CZO) in Colorado, is a mountain catchment in Proterozoic granodiorite uplifted in the Laramide Orogeny ca. 50 Ma. In an exposure near the catchment divide, an approximately 1.5 m deep profile through soil and saprolite was sampled and analysed for bulk U-series disequilibria (238U-234U-230Th-226Ra) to estimate the profile weathering rate.

The (234U/238U), (230Th/234U) and (226Ra/230Th) disequilibria through the entire profile are small but vary systematically with depth. In the deepest samples, values are close to equilibrium. Above this, values are progressively further from equilibrium with height in the profile, suggesting a continuous leaching of U and Ra compared to Th. The (234U/238U) disequilibria remain < 1 along the profile, suggesting no significant U addition from pore waters. Only the shallowest sample ($\sim$20 cm depth) highlights a 226Ra excess, likely resulting from vegetation cycling.

In contrast, variations of Th content and (230Th/232Th) - (238U/232Th) activity ratios in the isochron diagram are huge, dividing the profile into distinct zones above and below 80 cm depth. Below 80 cm, the Th content gradually increases upward from 1.5 to 3.5 ppm suggesting a relative accumulation linked to chemical weathering. Above 80 cm, the Th content jumps to $\sim$15 ppm with a similar increase of Th/Ti or Th/Zr ratios that clearly excludes the same process of relative accumulation. This strong shift is also observed in LREE concentrations, such as La, Ce and Nd, and in Sr isotopic composition, which suggests an external input of radiogenic material such as dust from the western Colorado deserts or eroding landscapes. For the deeper part of the profile, the strong upward decrease of the (230Th/232Th) and (238U/232Th) activity ratio without generation of strong disequilibria could suggest a long history ($\sim$0.5-1 Ma) of U leaching with a very slow saprolite development ($\sim$1 m/Ma). Such a result is in agreement with slow weathering rates deduced from modern solute chemistry of rivers, but would be much lower than 10Be denudation rates on the same profile of $\sim$10-20 m/Ma. As the 10Be rates integrate denudation over a timescale of 40-80 ka, the apparent inconsistency between rates deduced by U-series data and Be data might suggest that erosion rates have increased during the 10Be integrating time.