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Rates of carbonate soil evolution from carbon, U- and Th-series isotope studies: Example of the Astian sands (SE France)

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In carbonate rich soils, C-isotopes (14C, 13C) and carbonate mass budget may inform on centennial to millennial time scale dissolution/precipitation processes and weathering rates, whereas disequilibria between in the U- and Th-decay series provide tools to document high- (228Ra-228Th-210Pb) to low- (234U, 230Th, 231Pa, 226Ra) geochemical processes rate, covering annual to $\sim$ 1Ma time scales, governing both carbonate and silicate soil fractions. Because lithology constitutes a boundary condition, we intend to illustrate the behavior of such isotopes in soils developed over Astian sands formation (up to $\sim$ 30% carbonate) from the Béziers area (SE France). A >20 m thick unsaturated zone was sampled firstly along a naturally exposed section, then in a cored sequence. Geochemical and mineralogical analyses, including stable isotopes and 14C-measurements, were complemented with 228U, 234U, 230Th, 226Ra, 210Pb and 228Th, 232Th measurements. Whereas the upper 7 m depict geochemical and isotopic features forced by dissolution/precipitation processes leading to variable radioactive disequilibria, but overall deficits in more soluble elements of the decay series, the lower part of the sequence shows strong excesses in 234U and 230Th over parent isotopes (i.e. 238U and 234U, respectively). These features might have been interpreted as the result of successive phases of U-loss and gains. However, 226Ra and 230Th are in near-equilibrium, thus leading to conclude at a more likely slow enrichment process in both 234Th(234U) and 230Th, which we link to dissolved U-decay during groundwater recharge events. In addition, 210Pb deficits (vs parent 226Ra) are observed down to 12 m along the natural outcropping section and below the top-soil 210Pb-excess in the cored sequence, due to gaseous 222Rn-diffusion over the cliff outcrop. Based on C-isotope and chemical analysis, reaction rates at 14C-time scale are distinct from those estimates at the short- or long-lived U-series isotopes, but provide a specific insight into carbonate budgets when confronted with data on dissolved and gaseous phases as well as on solid matter, and possibly best integrate the overall soil behavior through time. It is concluded from this example that if first order estimates of long-term geochemical fluxes in soils can be obtained from disequilibria in the 238U-234U-230Th sequence or from C-isotope data. While insights into recent to "Anthropocene" processes require information on the shorter-lived isotopes of the U and Th series, adding specific information on physical and chemical erosion budgets from 232Th data. As also illustrated in the present example, a robust assessment of overall chemical and physical erosion rates must be based on measurements in cored sequences away from natural or recent man-made cuts.