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U and Th-series isotopes: a probe into time-dependent processes in carbonate-rich soils

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Since the early work of Rosholt, in the sixties, too little attention has been paid to the behavior of U- and Th-series isotopes in soils. If using such data in chemically open systems seems difficult, it remains that disequilibria in these series, in particular between 238U-234Th-234U-230Th-226Ra-210Pb-210Po, 235U-231Pa and 232Th-228Ra-228Th, offer probes into time dependent processes over time scales ranging Ma a to a few days, thus the means to document soil processes occurring over a large array of time scales and hydroclimatic forcings. Because lithology constitutes a boundary condition, we intend to illustrate the behavior of such isotopes in carbonate-rich soils, with examples from cool-temperate (St Lawrence Lowlands, Canada) or arid settings (Palmyre area, Syria) but special attention to Mediterranean environments (SE France). In this later case, a >12 m thick unsaturated zone has been sampled, near Beziers, in the recharge zone of the "Astian carbonate sand Aquifer", firstly along a naturally exposed section, then in a cored sequence. Geochemical and mineralogical analyses, including stable isotopes were complemented by 238U, 234U, 230Th, 226Ra, 210Pb and 228Th, 232Th measurements from soil surface, down to about 12 m below surface. Whereas the upper 7 m depict geochemical and isotopic features linked to dissolution/re-precipitation processes with highly variable radioactive disequilibria, the lower part of the sequence shows distinctive properties. In this deep horizon, strong excesses in 234U and 230Th over parent isotopes (i.e. 238U and 234U, respectively) are observed simultaneously whereas 226Ra and 230Th are in secular equilibrium. We interpret these features as an indication for a slow-process enrichment in 234Th(234U) and 230Th, linked to dissolved U-decay during groundwater recharge events. 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 222Rn-diffusion. It is concluded from this example that beside the strong impact on U- and Th-series disequilibria of fast chemical process occurring in the upper soil horizons, slower processes still leave an imprint with longer-lived disequilibria deeper in the sequence. In both cases, first order estimates of geochemical fluxes involved can be obtained. For a given lithology, they seem to respond essentially to the hydroclimatic conditions of the recent (interglacial) interval in the upper soil horizons, and to older interval conditions, deeper in the soil profile.