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Orbital-scale relevance of speleothem $^{234}U/^{238}U$ hydrological proxy in a temperate Mediterranean area

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Despite pioneering hydrological analyses of $^{234}U/^{238}U$ in groundwaters decades ago, its application as a paleoclimatic proxy in stalagmites has been sporadic, despite uranium isotopes are readily available through U-Th dating. These isotopes have the potential to track water-rock exchange processes without being susceptible to kinetic fractionation. This study investigates uranium isotope ratios in 235 ^{230}Th datings gathered over the last ten years from six stalagmites in Ejulve cave, southwestern Europe, spanning the past 260 ka. The aim is to elucidate factors controlling $\delta^{234}U$ spatial variability within Ejulve cave and explore if there is a coherent long-term evolution in speleothem $\delta^{234}U$, with implications for paleoclimatic significance in different samples from the same cave system in a semi-arid climate setting.

The elevated ^{234}U compared to ^{238}U is attributed to ^{234}U preferential leaching and recoil-induced oxidation, with a noticeable accumulation of ^{234}U recoils resulting from α-decay after growth hiatuses. Leaching of other mineral phases and local variations in the bedrock and infiltration pathways may account for the spatial variability seen in the stalagmites.

Regarding to the long-term variation, $\delta^{234}U$ exhibits a consistent hydrological signal akin to Sea Surface Temperatures (SSTs) in the Atlantic Iberian Margin, showcasing lower (higher) $\delta^{234}U$ during warm (cold) SST periods. Generally, mechanisms for $\delta^{234}U$ hinge on infiltration frequency and surface/mineral exposure to the solution. Given the altitude of the study site and frequent winter frosts typical of continental climates, SST may track freeze/thaw cycles that the rock undergoes, exposing fresh rock surfaces to selective leaching. The physical fracturing of the rock may be efficient in the climate of the study area, characterized by significant day-night temperature fluctuations typical of a Mediterranean continental climate, compared to locations with permanent frost or prolonged periods above freezing temperatures. $\delta^{234}U$ reflects a balance between selective leaching and increased weathering and soil erosion, acting to increase $\delta^{234}U$ predominantly in stadials, countered by bedrock dissolution that tends to lower $\delta^{234}U$ during interstadials. Therefore, $\delta^{234}U$ serves as a powerful proxy for assessing water-rock interaction processes over orbital scales, being a potential indicator of bedrock dissolution intensity which, unlike growth rate, is unaffected by prior calcite precipitation.