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The nature of annual lamination in carbonate flowstones from non-karstic fractures, Vinschgau (northern Italy)

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The Vinschgau is an inneralpine valley in the Southern Alps, whose steep flanks are comprised of strongly sheared gneisses and schists affected by deep-seated gravitational slope deformations. The south-facing slope of the Vinschgau (Sonnenberg) hosts a fractured slope aquifer that is characterized by high amounts of dissolved solids, which reflect long residence times and water-rock interactions driven by sulphide oxidation. In the shallow parts of the aquifer calcite and aragonite flowstones form as a result of evaporation driven by high air and soil temperatures. Both unlaminated and regularly laminated (ca. 5%) flowstone types occur, the latter being a rare example in fracture-filling carbonates hosted in crystalline rocks.

A stable isotope, petrographic and trace element study combined with U-Th dating was undertaken to disentangle the processes controlling lamina formation in these unusual speleothems. A succession of darker and lighter laminae forms distinct macroscopic couplets (0.2-2 mm wide) in three of the samples, while one sample comprises alternating white and translucent laminae. Microscopically, the darker and white laminae show a higher abundance of opaque particles, whose organic origin is confirmed by their strong epifluorescence. The crystal fabric, dominated by the fascicular-optic type, shows no change across lamina boundaries, neither was any consistent correlation between the lamina couplets and the stable isotope values observed. The calcite exhibits regular δ18O oscillations with an amplitude of up to 1.2 ‰ while apart from one sample, δ13C lacks such a regular pattern. All samples exhibit regular, low-amplitude Mg, Sr, Ba and U cycles. In three samples Mg shows oscillations similar to the δ18O cycles in their frequency, but opposite in phasing. δ18O and Mg oscillations are primarily attributed to surface temperature variations that are transmitted to the shallow subsurface by thermal conduction. Low-amplitude trace element cycles (Mg, Sr, Ba and U) are most probably driven by intra-annual variations in the degree of prior aragonite precipitation.