Hydrothermal carbonate-sulfate assemblages record the transition from a deep to a shallow hydrothermal system, Schwarzwald, SW Germany

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The majority of economic (or historically exploited) hydrothermal ore deposits occur close to the Earth's surface (e.g. Coeur d'Alene, the Anti Atlas or the Erzgebirge). However, prior to uplift and erosion these deposits originally formed at deeper crustal levels.

Late-stage hydrothermal (~20-70°C) mineral sequences consisting of calcite, dolomite, siderite and Ca-sulfates form the last generation of gangue assemblages in Jurassic/Tertiary Pb-Zn-fluorite-quartz-barite veins of the Schwarzwald, SW Germany. Mineral textures reveal that within these young sequences, mineral precipitation follows a recurring pattern: calcite is followed by Ca-sulfate, siderite and finally dolomite. This sequence may repeat up to three times.

In-situ U-Pb age dating of 15 carbonates yield robust ages between 20 to 0.6 Ma. The ages clearly relate these late-stage mineral phases to the youngest geological episode of the Schwarzwald, in which Cenozoic Rhinegraben rifting and basement uplift prevailed.

Hydro chemical modelling implies that the investigated mineral sequences are related to episodic injections of Mg-Fe-SO_4-rich fluids into a shallower Ca-HCO_3 aquifer. A similar process of discontinuous mixing formed the older (Jurassic/Tertiary) Pb-Zn-fluorite-quartz-barite assemblages in the same specific vein systems but at deeper crustal levels. However, due to the decrease in formation depth of the mostly Neogene carbonate-sulfate sequences, different fluids participated in the mixing process, which in turn caused a drastic change of the mineralogy from sulfide-quartz-fluorite-barite- to calcite-sulfate-siderite-dolomite veins as the system came closer to the surface. Consequently, the investigated carbonate-sulfate sequences reflect an intermediate stage of this hydrothermal system during its tectonic uplift from deep to shallow crustal levels.