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Physical controls on speleothem formation and growth in volcanic (lava tube) caves

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Speleothem formation is a complex mechanism consisting of physical, chemical, and microbiological processes. Analysis of speleothems and water chemistry from volcanic caves at Lava Beds National Monument (N. California, USA) showed enrichment of $SiO_{2(am)}$ and Ca-Mg-CO_3 in speleothems, and slightly acidic cave water (pH 6.7) with average concentrations of $SiO_{2(aq)}$ (22 mg/L), Ca^{2+}, (4 mg/L) and HCO_3^- (35 mg/L). Geochemical calculations suggested that $SiO_{2(am)}$ and calcite were undersaturated (SI of -0.72 and -2.49, respectively) in cave waters and could not have precipitated spontaneously to form speleothems. Cave waters had depleted $\delta^{18}O$ and $\delta^{2}H$ signatures indicative of moderate evaporation compared to local meteoric water. A forward reaction model developed to simulate the evaporation of cave waters, revealed that $SiO_{2(am)}$ precipitation started at ~65% evaporation. Our initial assessment showed several speleothem morphologies such as mineral crust (sub-mm to 0.5 mm thick deposition of secondary minerals), polyps (1-2 cm oblong upward-pointing secondary mineral growths), cauliflower (2-5 cm diameter knob-like features), coralloids (mm to cm scale features resembling to ocean corals) and gours (cm scale flowstone-like features). We hypothesize that both physical factors (including the type and volume dimensions of cave water – i.e., water as a single ceiling drop, a group of connected drips, a thin film of water over the smooth cave walls and ceilings, and aerosols) and active processes (e.g., water drip rate, evaporation rate, surface tension, and cave wind velocity) influence the speleothem morphology. For example, the evaporation of thin film of water would form a mineral crust, whereas a water droplet at cave ceiling with fast dripping rate would form a gour. On the basis of our calculations, we cannot characterize the role of microbial activity in speleothem formation, although microbial communities were found in close contact with these mineral formations. Geochemical modeling is underway to better constrain speleothem formation, growth rate, and morphology. This work is part of the multi-disciplinary NASA project, Biologic and Resource Analog Investigations in Low Light Environments (BRAILLE), funded by the PSTAR Program (NNH16ZDA001N).