Mineral-water interactions in lava caves as proxies for Martian environments

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The NASA BRAILLE (Biologic and Resource Analog Investigations in Low Light Environments) project is a study of basaltic caves on Earth as analog testing environments for future robotic missions and the search for biosignatures on Mars and other planets; part of this work involves characterizing the geochemistry of the lava cave environment. Terrestrial lava caves exhibit morphologically and chemically diverse secondary mineral deposits (speleothems) that may form biotically or abiotically in the presence of liquid water [1-2]. Geochemical analysis of speleothems and associated drip waters from caves may help in unraveling their formation processes within these diverse cave environments. In this study, cave water and speleothem samples were collected from seven caves of different ages, temperature, moisture content, light intensity, and frequency of visitation at Lava Beds National Monument (N. CA, USA). Major inorganic and organic chemical constituents in the cave waters were measured. Mineralogy and chemical composition of speleothems were determined by x-ray diffraction, petrographic thin section, and fluorescence analysis. Results revealed that the cave water was enriched in Si, Na, K, Ca, Mg, Cl^-, NO_3^-, and organic matter (~15 mg/L as C); this aqueous chemistry may suggest an equilibrium between drip water and its basaltic host rock. Elevated NO_3^- levels detected in these waters may be due to agriculturally-influenced surface water percolating into the caves through fractures or in situ oxidation of nitrogenous organic matter. Speleothem samples contained ~29-79 wt% SiO_2 in crystalline, cryptocrystalline, and amorphous forms. Microstromatolitic-like structures within the speleothems were noted. Secondary minerals such as calcite, iron hydroxides, magnetite, hematite, vaughanite, apatite, and vanadium oxide were identified and contained significant concentrations of biologically-important elements (Ca, Mg, Fe, Mn, S and V) [3-4]. BRAILLE team results show a correlation between speleothem morphology and biological activity, making speleothems an important potential biosignature target that could persist over geologic time on Mars and other rocky planets.

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