Geochemistry of Mineral-Water Interactions in Basaltic Lava Caves as Earth Analogs (Screen 4)

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Abstract

Basaltic lava caves are important Earth analogs in our search for life on Mars and other planets. Terrestrial lava caves exhibit morphologically diverse secondary mineral deposits (speleothems) often associated with liquid water. The detailed geochemical characterization of cave water and speleothems can provide valuable insights on potential biotic or abiotic mechanisms that lead to formation of these features. Our results showed that the cave water chemistry is consistent with basaltic host rock chemical composition. The water contained high levels of dissolved organic carbon and nitrogen, which could support microbial growth. The dissolved organic matter showed macromolecular structure and appears to be plant-derived, highly humified and microbially processed. Elevated nitrate in cave water may be due to agriculturally influenced regional surface water source or in situ oxidation of ammonia or organic N. Speleothems contained 29-79 wt% of crystalline, cryptocrystalline, or amorphous SiO2, and secondary minerals containing biosignature elements (Ca, Mg, Fe, Mn, S and V). This work complements the ongoing NASA BRAILLE (Biologic and Resource Analog Investigations in Low Light Environments) project to study basaltic lava tube caves as Earth analogs and ultimately provide insights for planning future missions to search for biosignature on Mars and other planetary bodies.

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Basaltic lava caves are important Earth analogs in our search for life on Mars and other planets. Geochemical investigation of secondary mineral deposits (speleothems) and associated water in terrestrial caves may help identify potential biotic or abiotic pathways for the formation of these mineral biomarkers, which could persist over geologic time. We collected water and speleothem samples from seven caves at Lava Beds National Monument (CA, USA) that varied in age, temperature, moisture content, light intensity, and frequency of visitation. Hydrochemical characterization of cave water was done by measuring dissolved inorganic and organic constituents. Mineralogical and chemical characterization of speleothems were determined via x-ray diffraction and fluorescence analyses and petrographic examination of corresponding thin sections. Results revealed that the cave waters contained elevated dissolved organic carbon (9-21 mg/L), total dissolved nitrogen (1-4 mg/L), as well as nitrate (3-21 mg/L). High DOC and TDN in basaltic cave waters are unusual and suggest influx of C and N that support microbial growth. Elevated nitrate in such waters may indicate an agriculturally influenced regional surface water source or in situ oxidation of ammonia or organic N within the caves by nitrifying bacteria. Moreover, the dissolved organic matter in cave waters was found to have macromolecular structure, being plant-derived, highly humified, and microbially processed. Major elements in cave waters include Si, Na, K, Ca, and Mg and represent basaltic host rock chemistry. Speleothems contained 29-79 wt% of crystalline, cryptocrystalline, or amorphous SiO_2, and secondary minerals such as calcite, iron-hydroxide, magnetite, hematite, vaughanite, apatite, and vanadium oxide. These findings complement an ongoing work of the NASA BRAILLE (Biologic and Resource Analog Investigations in Low Light Environments) project to study basaltic lava caves as Earth analogs and ultimately provide insights for planning future missions to search for biosignatures on Mars and other planetary bodies.

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