Mineral to Microbe: Investigating the Continuum in Lava Cavesto Best Predict Life Detection Targets

Northup, Diana E.[1], Hathaway, Jennifer J.M.[1], Spilde, Michael N.[2], Moser, Duane P.[3], and Blank, Jennifer G.[4,5]

[1] Biology Department, University of New Mexico;[2]Institute of Meteoritics, University of New Mexico; [3]Division of Hydrologic Sciences, Desert Research Institute;[4] Division of Space Sciences & Astrobiology, NASA Ames Research Center; [5] Blue Marble Space Institute of Science

Microbial communities in lava caves create a variety of features visible to the unaided eye. These range from hard to soft—from mineral deposits to microbial mats that line cave walls. We investigated the bacterial and archaeal diversity of this continuum of features in Lava Beds National Monument (LABE, northern California, USA) in October-November 2018 as part of BRAILLE (Biologic and Resource Analog Investigations in Low Light Environments), a research project sponsored by NASA's Planetary Science and Technology in Analog Research program. One of BRAILLE's objectives is to characterize mineral biosignatures in lava caves, in orderto enhance remote capabilities for detection of life (past or present)on other planets such as Mars, where lava caves have been detected.In particular, the work aims to illuminatethe connection between secondary mineral deposits and microbial life in cavesfor the refinement of future robotic life detection strategies. We hypothesized that secondary mineral shape and texture would be predictive of the diversity and extent of potential microbial content.Samples were collected aseptically from two lava caves in LABE, distinct in age and human visitation intensity. Mineral samples were selected that encompassedrelatively pristine bare rock and a variety ofsecondary textures and shapessuch as mineral patina, polyps, round knobs, and cauliflower-like structures. Microbial mat samples were also sampled, distinguishedon the basis of color.

Scanning electron microscopy (SEM) revealed several common putative microbial forms, includingfuzzy and smooth filaments, spheroids, rods, and beads-on-a-string structures. Energy-dispersive X-ray spectroscopy (EDX) revealed that, silica-richfilms covered extensive portions of most of the samples examined. Secondary mineral samples displayedfewer microbial morphologies and contained a higher abundance of smooth filaments. In contrast, microbial mats exhibitedextensive microbial morphologies, with a greater proportion of fuzzy rods, fuzzy filaments, and beads-on-a-string shapes.

Microbial community structure was characterized on the Illumina platform using domain-specific primer sets targeting Bacterial and Archaea, using the bacterial specific primer 27F, and archaeal specific primer 519F.Both mineral and microbial mat samples exhibit extensive microbial diversity, with more DNA being recovered from microbial mat samples. In contrast to our previous studies of mineral versus microbial mat samples, composition at the bacterial phylum level was similar across mineral and mat samples. Actinobacteria, a dominant cave bacterial phylum, was present at moderate abundance across both mineral and mat samples. One bacterial phylum in particular, Nitrospirae, was more abundant in microbial mat samples than in mineral samples, however. On a finer scale, nonmetric dimensional scaling (NMDS) plots of diversity dissimilarities of both archaeal and bacteria sequences revealed that mat samples are more similar to each other than mineral samples are to each other.Microbial community assemblages of bare rock and patina samples are distinct from other mineral samples and cluster more closely to mat samples. The other mineral samples were very dissimilar to mat samples. Our results suggest that both secondary mineral deposits and microbial mats are worth investigating further as potential targets for life detection in Earth and extraterrestrial caves. Understanding which mineral textures, shapes, and compositions are most predictive of the presence and extent of microbial life will enhance future robotic life detection strategies.