EXTREMOPHILE MICROORGANISM COMMUNITIES IN SULFATES AND OTHER SULFUR MINERALS AS SAMPLE RETURN TARGET MATERIALS.

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Introduction: The presence of various types of sulfates on the surface of Mars has generated much astrobiological interest in the biological contents of analogous materials on terrestrial arid environments. Numerous active sulfur transforming organisms live in sulfur rich environments in both Earth's surface and subsurface. Our team has studied organisms and their associated mineralogies in several salient environments: 1) a sulfuric acid dominated cave system where the biological activity is integral to the precipitation of sulfates [1] (Fig. 1), 2) microbial communities in a briny sulfur-rich iron mine environment that appear to be mediating the deposit of microcrystalline jarosite (Fig. 2), 3) organisms that utilize copper sulphides producing copper oxides and sulfates as byproducts of that transformation (Fig. 3), and 4) perhaps most saliently, the gypsum fracture microbial communities in the Gypsum Plain area of southeastern NM and west Texas (Fig.4).

The association of sulfate minerals with microbial communities can be seen in the physical proximity of organisms with mineral grains, and in the gradual transformation from amorphous to crystalline phases in the living materials. No transformations occur in killed controls. Such Earth-based microbial communities are of relevance to potential biology and mineralogy of Mars and useful as a comparison to materials that will be considered for collection as part of Sample Return Mission activities.

Methods: We analyze isotopic signatures of C, S, O, and H/D in both mineral and biological components and assess other geochemical biosignatures and bulk chemistry. To study the association of various elements with organisms, we construct elemental maps via electron microprobe of C, S, and other relevant elements. Organisms that are growable are maintained in culture and subjected to an array of experiments including those aimed at inducing the same or similar precipitation of minerals that we see in nature. Lastly, we analyze the DNA of both environmental and cultured samples to determine organism identities, or their closest relatives if they are unknown strains.

Mars Simulation Challenge Experiments: A selection of organism communities isolated from the environments mentioned here have been subjected to between 1 and 5 week simulations of significant Martian environmental conditions at the TechShot facility in Greenville , Indiana as part of a NIAC-funded (NASA Institute for Advanced Concepts) effort to test Earth organisms under Mars full spectrum sunlight (including UV) at Mars atmospheric pressures and low moisture. A plethora of organisms survived from these trials. Some of the most robust survivors were from the gypsum and other sulfur environments discussed here, including the black lineations seen in Figure 4. Such organisms can be used in ground based simulations of potential target material types that may be encountered on Sample Return.

Conclusion: Numerous microorganisms are involved in processes that either degrade or precipitate sulfates. The biology of these communites can serve as a comparison model for similar Martian minerals and environments. In order to meet the standards of proof for science in Earth extreme environments, we must employ a variety of labor-intensive analyses beyond the foreseeable scope aboard a Mars Sample Return Mission. As a byproduct, we are amassing a library of textures, microbial structures, and mineralogical compositions that can be associated on Earth unequivocally with biological activity. For the purposes of Sample Return Missions, such a field guide of properties can help guide the mission to select samples of potentially great astrobiological significance.

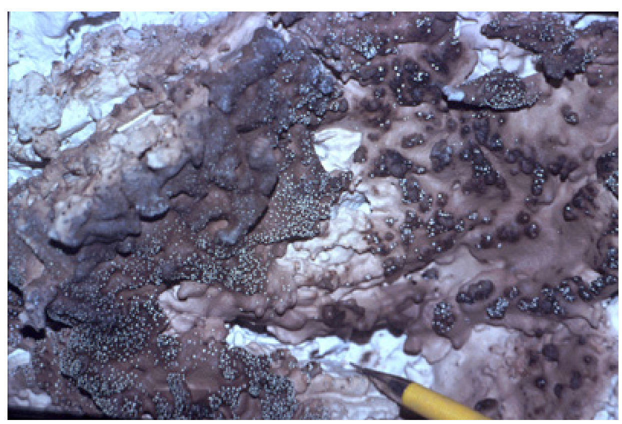

Figure 1: Gypsum paste soaked with sulfuric acid in Cueva de Villa Luz, an active sulfuric acid cave in Tabasco, Mexico. White dots on dark material are microbial colonies growing at pH 1.-2.5. Image courtesy of Kenneth Ingham.

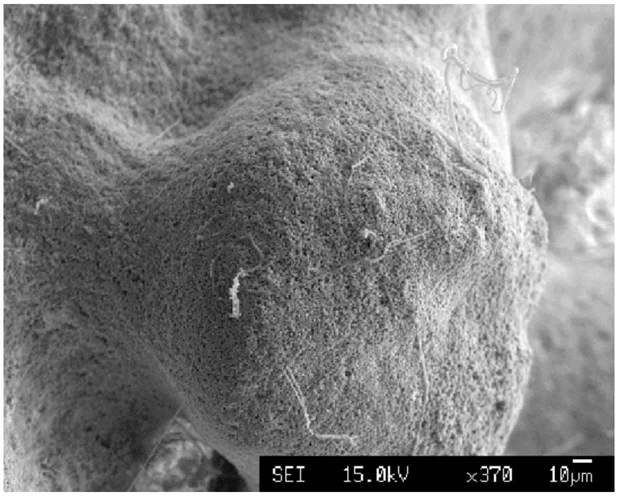

Figure 2: Jarosite and microbial filaments and cell bodies mound up in briny samples from the Soudan Iron Mine in northern Minnesota. SEM by Spilde and Boston.

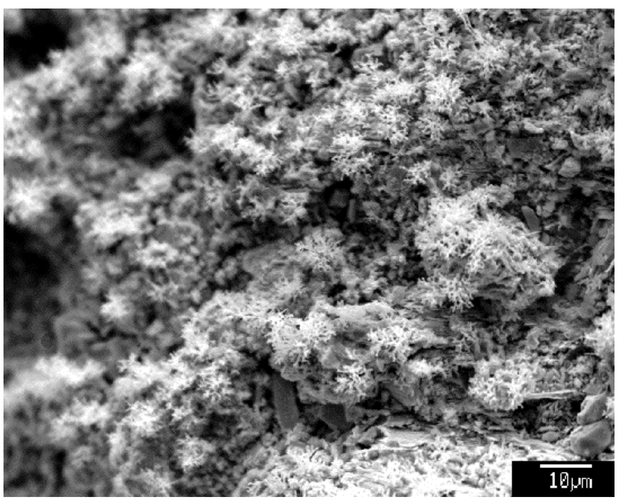

Figure 3: Cellular “bushes” coated with copper oxides derived from copper sulfides. SEM by Spilde and Boston.

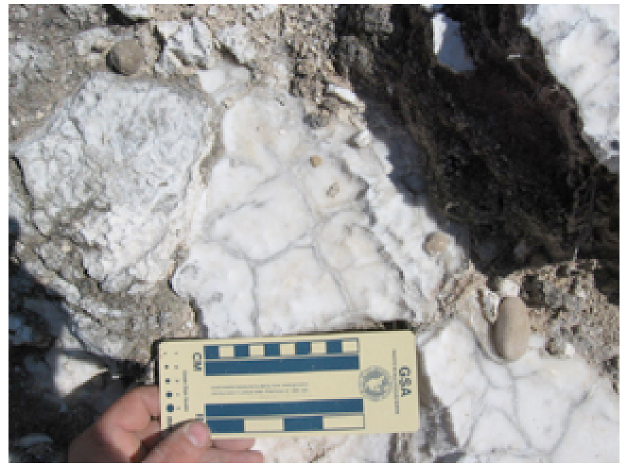

Figure 4: Dark hexagonal lines show gypsum fracture microbial communities in Permian age Gypsum Plain evaporates. These lines could be mistaken for mineral infilling in fractures but are actually densely populated black cyanobacteria, microcolonigal fungi, and bacteria. Image by K.W. Stafford.

References:

[1] Boston, P.J. et al. (2006) *GSA Sp. Pap. 404, 331-344*.