GEOBIOLOGY OF ACID SALINE SYSTEMS: IMPLICATIONS FOR THE DEVELOPMENT AND PRESERVATION OF MINERALOGIC BIOSIGNATURES ON MARS. A. J. Williams[1] and D. Y. Sumner[1], [1]University of California, Davis, One Shields Avenue, Davis, CA, 95616, amywill@ucdavis.edu.

Introduction: The surface chemistry of modern Mars is rich in S and Fe minerals [1], and the weathering of these minerals have been integral to developing surface conditions [2] during the late Hesperian-Amazonian period from ~2 Ga to present. Variable water activity on Mars [3, 4] has greatly influenced weathering processes and alteration of these minerals. Terrestrial gossans, especially those formed from acid-saline solutions at low water-rock ratio, provide an important analog for understanding how S and Fe minerals may have weathered on Mars. Chemolithotrophs have been identified in these environments on Earth [5, 6], so they also comprise a model system for putative biosignature formation and preservation that is relevant to conditions on early Mars. The purpose of this study is to investigate 1) the role of biology in substrate weathering of acid-saline minerals and 2) microbial biosignature preservation in these systems. The goal of this work is to create a catalog of mineralogical biosignatures present in terrestrial gossans that can provide guidance for interpreting features observed by the Mars Science Laboratory.

The spatial variability of minerals in gossan environments and the extent of alteration provide the opportunity to study weathering gradients and mineral solution/reprecipitation in this system. Long-term preservation of organics in oxidizing environments indicated by the presence of iron oxides [7], such as those on Mars, is difficult. Thus, poor preservation of organic biomarkers might be expected even if microbial colonization of the Fe-rich substrate was present on Mars. However, if microbial activity influences local mineralogy or mineral morphology, this may provide evidence for microbial activity even in the absence of chemical biosignatures.

Methods: To investigate these questions, we explored the interactions between mineral precipitation/dissolution and extremophile microbiology. We determined 1) mineral phases with XRD; 2) spatial relationships with FEG-SEM; and 3) basic water chemistry in pyrite-dominated (JS3) and goethite-dominated (PS1.3) samples.

Preliminary Results: Samples of pyrite, goethite, and sulfate-rich gossan from Iron Mountain, CA, were collected during the dry season in late spring 2010. To date, mineral species identified with SEM-EDS, XRD, and optical microscopy include: pyrite, goethite, lepitocrocite, hematite, schwartmanite, gypsum, quartz, and acanthite. As yet unidentified soluble sulfate minerals formed by evaporative concentration are also present. Distilled water added to a pyrite-dominated sample with unidentified sulfate salts yielded a pH of ~2.5 once the evaporites dissolved.

Putative eukaryotic and bacterial filaments and eukaryotic spores have been observed on surfaces and in fractures in gossan samples when analyzed with FEG-SEM and optical microscopy.

Eukaryotic biosignatures: Detached filaments and plexi of filaments are sparse in the samples (Fig. 1).

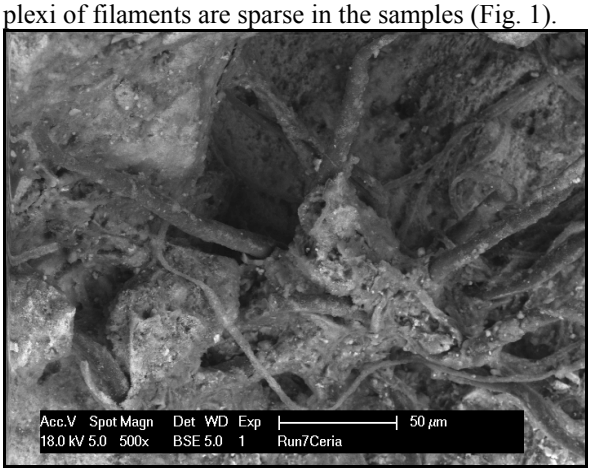

Figure 1. Backscatter SEM image of a plexus of fossilized filaments from sample PS1.3. Filaments have diameters ranging from ~5-10µm.

Detached filaments measure ~5 to >10µm in diameter and hundreds of microns long, tapering to one end. Fourteen regions on sample PS1.3 have one or more detached filaments. Five filament plexi, measuring ≤ 300 x 200µm were found in cavities. Attached filament plexi tend to emerge from a central area and extend into fractures in the rock, while unattached filaments are found alone or are intertwined with other filaments. Filaments are sometimes coated with <10µm thick layers of goethite, whereas others are uncoated. Filaments and plexi are found in a sparse distribution covering ~0.075% of the surveyed sample. Only two regions on JS3 exhibits a preserved detached filament, for a distribution of 0.002%. They are interpreted as fungal based on their large diameter, the tapering of filaments, and their organization into plexi. The coating of some filaments with goethite demonstrates that they were present during weathering of the gossan and mineral precipitation.

Ovoids measure ~50 x 30µm and are always found as sets of two egg-shaped structures, with differing percentages of surface-attached mineral crystals (Fig. 2). Nine regions on sample PS1.3 have one or more sets of ovoids in a sparse distribution covering ~0.005% of the surveyed sample. Only three regions

on JS3 exhibit sets of ovoids for a distribution of 0.003% but more may be present. Pairs of ovoids are interpreted as spore sets due to their regular geometry, narrow size range, and pairing. They were also present during mineralization.

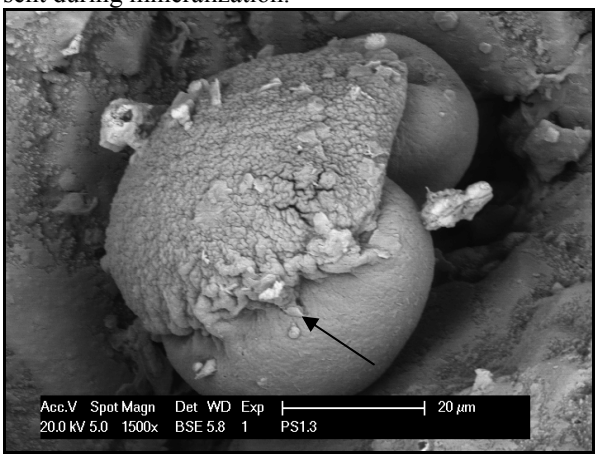

Figure 2. Fungal spores from sample JS3 measure ~50 x 30µm, with surficial mineral growth and a putative bacterial biofilm attached to the spores (arrow).

Bacterial biosignatures: Filament sizes range from ~1µm to ~10 µm in diameter and have uniform diameters along their length. These filaments functioned as nucleation sites for goethite, with concentric goethite rings around individual filaments (Fig. 3). Goethite first coated these filaments, then the void space between tubes was filled. When the adjacent goethite rings intersected, concentric goethite rings began growing around both filament rings. Filament cases are also filled with goethite. These relationships demonstrate that the filaments were present during various stages of goethite precipitation.

Although present, textural features interpreted to have formed associated with bacteria appear to be sparse. The filaments are interpreted as at least two distinct species of bacteria due to their size distributions, uniform diameter along their length, and the absence of evidence for branching. A putative bacterial biofilm (arrow) has been identified on a fungal spore (Fig. 2), based on the attachment between the ovoids and the capping material. The presence of this biofilm is the first indication of surficial bacterial life, as distinct cells have not yet been identified.

Future Research: Future work includes evaluating the relative abundance of bacterial cells using polymerase chain reactions (PCR) to qualitatively identify the presence of eukaryotic, archaeal, and bacterial cells. Based on the information from PCR, specific FISH (florescent *in situ* hybridization) probes will be used to identify cells located on the Fe and S minerals. $\delta^{34}S$ stable isotope geochemistry will also be used to evaluate biosignatures. SO_4 reducing bacteria preferentially reduce ^{32}S. Sedimentary and aqueous enrichment of ^{32}S relative to ^{34}S is therefore associated with microbial mediation of mineral morphologies and can be identified as a biosignature.

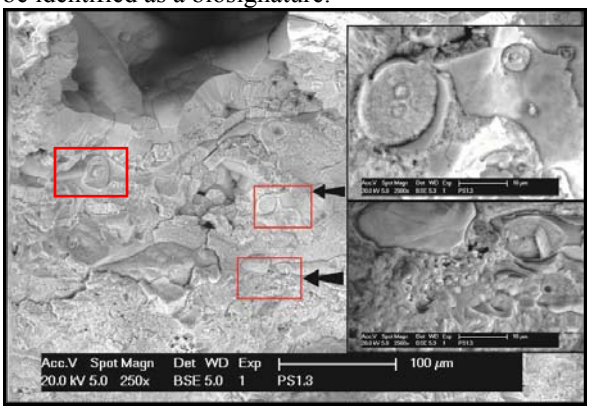

Figure 3. Backscatter SEM image of goethite-encrusted tubes in cross-section from sample PS1.3. Central filaments are distinct in goethite tube cores, with diameters ranging from 5-10µm (*upper right inset*) to ~1µm (*lower right inset*).

Conclusions: Some filaments and all spores have been identified as fungal based on their measured size and morphology. Some of these filaments are fossilized but not coated with goethite, while others are coated with ≤10µm of goethite. The relative paucity of bacterial morphologies in this analog acid-saline system combined with their heterogeneous spatial distribution presents a challenge for rover-based remote detection. Future research will elucidate the perceived absence of bacterial cells in this acid-saline system.

The characterization of bacterial communities in the Iron Mountain surface gossan will provide an important catalog of probable mineralogical biosignatures MSL may encounter. With this data, the MSL science team will be better equipped to recognize these biosignatures on Mars with MSL instruments. The successful identification of Martian biosignatures would open up opportunities for rovers and manned missions to the red planet in search of extraterrestrial life and the origin of life on Earth.

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References: [1] Burns, R. G. (1987) *LPSC XVIII*, 141-142. [2] Bibring, J.-P. et al (2006) *Science*, 213, 400-404. [3] Andrews-Hanna, J.C. et al (2007) *Nature* 446, 163-166. [4] Tosca, N.J. et al (2008) *Science* 320, 1204-1207. [5] Bond, P. L. et al (2000) *App. Env. Microbiol.* 66, 4962-4971. [6] Druschel, G. K. et al (2004) *Geochem. Trans.* 5, 13-32. [7] Sumner (2004) *J. Geophys. Res.* 109, E12007.