DEVELOPMENT AND PRESERVATION OF FILAMENTOUS MINERAL BIOSIGNATURES: IMPLICATIONS FOR DETECTION WITH THE MARS SCIENCE LABORATORY. A. J. Williams[1] and D. Y. Sumner[1], [1]University of California, Davis, One Shields Avenue, Davis, CA, 95616. amywill@ucdavis.edu.

Introduction: Microbe-mineral interactions and biosignature preservation in sulfidic oxidized ore bodies (gossans) are prime candidates for astrobiological studies, as gossans and oxidized iron systems have been proposed as analogs for some Martian environments [1]. Recent studies of gossans have identified both chemolithotrophs [2, 3] and microbial fossils preserved as hydrous ferric oxide (HFO) coated filaments [4, 5]. This study investigates surface gossan microbial communities, microbial community preservation via HFO precipitation and the formation of filamentous mineral biosignatures, as well as explores the relevance and detection of these biosignatures to possible Martian biosignatures. Observed filamentous biosignatures would be resolvable with the Mars Hand Lens Imager (MAHLI) onboard the Mars Science Laboratory (MSL) rover and may be identifiable as biogenic if present on Mars.

Methods: We collected samples of pyrite and goethite from the acidic and saline Iron Mountain, CA surface gossan during the winter of 2010/2011. We then characterized microbially-associated HFO precipitation by identifying 1) microorganisms in the gossan rocks using Sanger sequencing techniques; 2) mineral phases with XRD, reflected light microscopy, and energy dispersive x-ray spectrometry via SEM; and 3) mineral-coated microbial textures and morphology with SEM and optical microscopy.

Results:

Gossan Microbial Ecology. Phylogenetic trees were constructed to identify nearest genetic neighbors of organisms living in and on the gossan rocks. A majority of those identified are commonly found in non-acid mine drainage (AMD) soil, phyllosphere (subaerial plant surfaces), and water. Most organisms were associated with nitrogen or carbon cycling, with only six identified organisms participating in iron or sulfur cycling. Additionally, eukaryotic green algae and fungi were identified. As AMD systems commonly host acidophilic iron and sulfur cycling organisms, these results suggest that the surface gossan microbiome is very different from that observed in most AMD environments [2, 6, 7].

Multiple researchers have suggested that filaments similar to those in Fig. 1 are mineralized microbial filaments [4, 5, 8, 9]. Filamentous communities may be coated with minerals to form macroscopic structures identifiable as biosignatures (Fig. 1). Previous studies at Iron Mountain and in other gossans used morphological measurements of filament diameter, bending, and number of direction changes to demonstrate that mineralized filament morphologies are more consistent with microbial filaments than abiotically-formed fibers [4, 5, 10], and are likely mineral-coated microbial filaments. Organisms that form filament-like structures and are candidates for the mineralized filaments found in the Iron Mountain surface gossan include: *Comamonas denitrificans*, bacteria related to the *Ktedonobacterales* order, *Thermosporotrichaceae* family, *Microbacteriaceae* family, *Pseudonocardia* genus, *Rhodococcus* genus, and *Cyanobacteria* phylum. Additionally, filament-forming ekaryotic organisms that have been identified by the presence of their chloroplasts include *Physcomitrella patens* moss and some organisms related to the green algae phylum *Chlorophyta.* Given the limitations of Sanger sequencing techniques, many more organisms are expected to inhabit the gossan rocks than can be identified with this approach. However, calculated rarefaction curves and Good's Coverage (68 - 85%), suggests much of the diversity has been sampled.

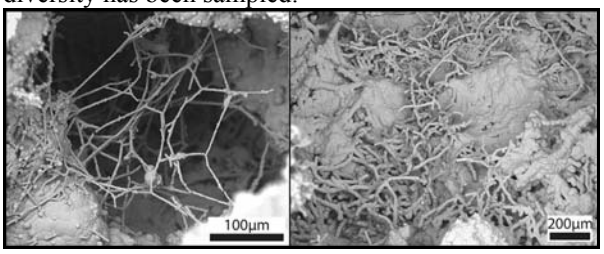

Figure 1. HFO-coated mineralized filaments.

Gossan Mineral Morphologies. Variations in HFO mineral morphology aid in the preservation and identification of mineralized filaments. Goethite is the dominant mineral, although less stable phases such as ferrihydrite may also be present.

Based on cross-cutting relationships of mineral morphologies, a model for mineralized filament preservation was developed (Fig. 2). In this model, microbial filaments are coated with <1µm wide HFO particles to form bumpy filaments that preserve the original structure. Bumpy filaments are 2.5 – 5.5µm in diameter, span voids in the rock and form overlapping, sometimes dense, filament networks. In some samples, smooth spheres coat bumpy filaments to form agglomerations of spheres that only vaguely preserve the original filament morphology (Fig. 2). Where bumpy filaments are not present, smooth spheres form agglomerations that fill voids. Smooth spheres accumulate by growing edge-on-edge to form dense layers of

spheres with two diameter populations (average 5.7µm and 20.5µm). Next, bladed structures form lamellar aggregations. Bladed fans, bowties, and pinwheels are composed of elongated and flattened crystals that radiate from bumpy filaments and smooth spheres. Many bladed features coalesce at different angles to form an extensive hatched surface (Fig. 2). In other areas, rough spheres (average diameter 9.9µm) coalesce to form knurled surfaces that overgrow bumpy filaments. Rough spheres are composed of 3 interlocking barbell crystals to form a hexagonal plate. Plates grow side by side to form spheres and spheres are truly oblate spheroids with crenulated edges with the hexagonal plate structure exposed on the sphere's top and bottom. Rough spheres accumulate by growing edge-on-edge to form an agglomeration of spheres, but do not form curvilinear, self-supported features and do not coat bumpy filaments directly. Some knurled surfaces are conchoidally fractured and exposed faces demonstrate that the knurled surface is a thin surficial veneer with a smooth material underlying it. Rough spheres and knurled surfaces can be overgrown by smooth spheres. In either case, the filament morphology is identifiable as a biosignature even when the surrounding pore space is infilled with other mineral morphologies.

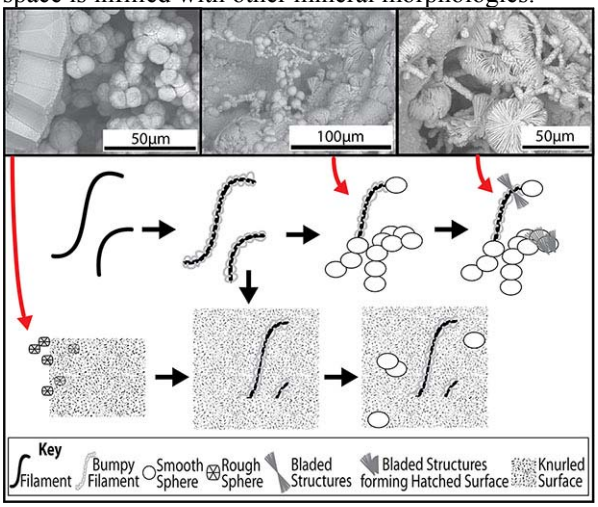

Figure 2. Mineralized filament preservation model.

Mineral Biosignature Identification on Mars. Understanding how biosignatures are formed and preserved is crucial for identifying similar mineral biosignatures on Mars if they exist. The MAHLI instrument would be capable of optical identification of mineral-coated filamentous textures observed in Iron Mountain gossan samples. Establishing the biogenicity of similar structures on Mars would require instrumentation not available on MSL. Fig. 3A shows an optical Z-stacked image of mineralized filaments from this study at a resolution of 0.77µm/ pixel. Fig. 3B shows the same image at MAHLI's highest resolution of 13.9µm/ pixel. At this resolution, the mineralized filaments are distinct. Although demonstrating biogenicity at this resolution would be problematic, textures such as this could be prime candidates for sampling.

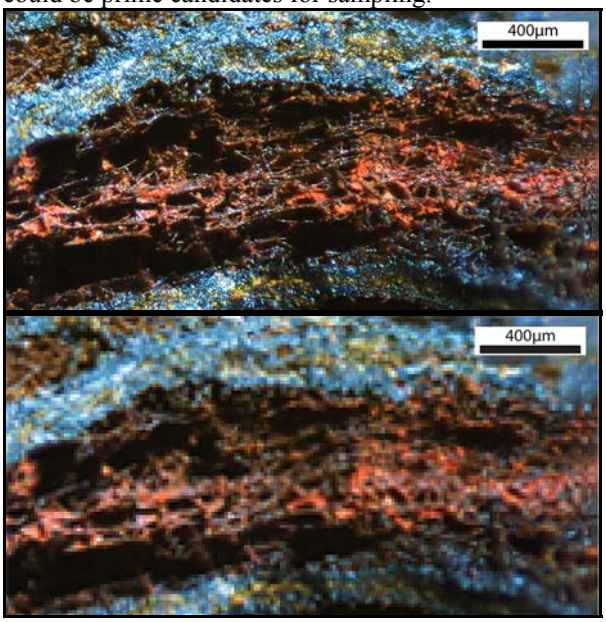

Figure 3A. Full resolution (0.77µm/ pixel) Z-stacked optical image of mineralized filaments. 3B. Same image at MAHLI resolution (13.9µm/ pixel).

Conclusions: The characterization of microbial communities and HFO filament preservation in the Iron Mountain surface gossan provides insight into mineral biosignatures within the detection window of MSL. Individual filaments are below MAHLI resolution unless they have thick coatings; however sinuous filaments forming mat-like textures are resolvable with MAHLI. With a suite of analyses acquired by the MSL instruments to define the geochemical and mineralogic environment, those features could be identified on Mars as similar to these filaments on Earth, and potentially biogenic. These features could be preserved in MSL's path in a crystalline hematite bearing ridge on Mt. Sharp, Gale Crater [11].

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