THE DEVELOPMENT AND PRESERVATION OF FILAMENTOUS FABRICS AS MINERALOGIC BIOSIGNATURES, IRON MOUNTAIN, CALIFORNIA. A. J. Williams[1] and D. Y. Sumner[1], [1]University of California, Davis, One Shields Avenue, Davis, CA, 95616. amywill@ucdavis.edu.

Introduction: Sulfide-rich terrestrial oxidized ore bodies (gossans) have been proposed as an analog system for some Martian environments [1]. Advances in the understanding of microbial preservation through studies of ancient systems [2, 3] and modern analogs [4, 5, 6, 7] allow for the novel identification of microbial biosignatures in substrates, such as gossans, similar to those encountered on Mars. Recent studies of gossans have identified both chemolithotrophs [8, 9] and microbial fossils, preserved as hydrous ferric oxide (HFO) coated filaments [10, 11]. The purpose of this study is to investigate the formation of mineralogic biosignatures in gossans related to HFO precipitation in association with microbial communities. The goals of this work are to 1) explore the processes that allow chemolithotrophs to form biosignatures in terrestrial gossans, 2) determine how these biosignatures are distinct from similar abiotically formed morphologies, and 3) explore the relevance and detection of these biosignatures to possible Martian biosignatures.

Methods: We characterized microbially-associated HFO precipitation by identifying 1) mineral phases with XRD, transmitted and reflected light microscopy; 2) microbial textures and morphology with FEG-SEM and optical microscopy, using ImageJ to quantify diameters, mineral coating thicknesses, and tortuosity; and 3) microorganisms using Sanger sequencing techniques.

Results: Samples of Fe-sulfide and HFO gossan from Iron Mountain, CA, were collected during the wet season in November 2010 and March 2011. To date, mineral species identified include: pyrite, goethite, quartz, lepitocrocite, hematite, multiple Fe-SO_4 salts (e.g. rozenite, copiapite, coquimbite, rhomboclase, halotrichite/bilinite) and acanthite.

Multiple microbial textures have been identified, including mats of organic filaments, filamentous plexi, branching filament networks, and mineralized cylindrical filaments (Fig. 1). The first three textures are interpreted as filamentous organisms that are uncoated to lightly coated with mineral detritus (mostly HFO). The last texture, mineralized cylindrical filaments, form dense, goethite-coated overlapping filament networks. Cylindrical filaments are the only morphology that exhibits two interior textures. The first, botryoidal, infrequently preserves a central filament void. The second, concentric, preserves a central filament core that exhibits a texture distinct from the coating (Fig. 2). These features are interpreted as the heavily mineralized casts of filamentous organisms.

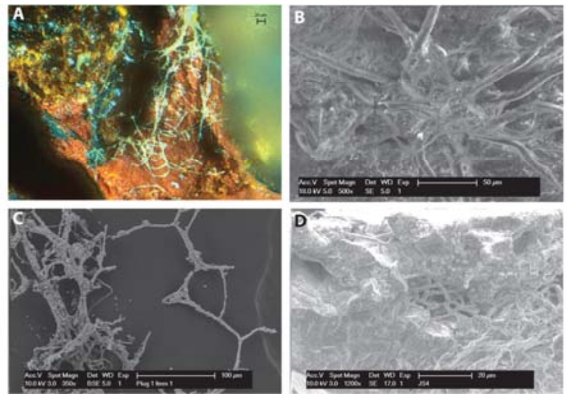

Figure 1. Microbial textures identified from the Iron Mountain surface gossan. A) Mats of organic filaments (white). B) Filamentous plexi. C) Branching filament networks. D) Mineralized cylindrical filaments.

Mats of organic filaments, filamentous plexi, and branching filament networks have filament or coat diameters >2μm, which is larger than many microbial filaments typically found in this environment (Fig. 3) [11]. However, the central voids of some botryoidal cylindrical filaments have ~1μm diameters. This is consistent with the size ranges of microbial filaments and coats determined from other gossans [10] and the Rio Tinto acid drainage system [12].

Previous work by Hofmann et al. (2008) established a likely biogenic origin for subsurface filamentous fabrics (SFF) of similar morphology to the mineralized cylindrical filaments described here. While abiotic fibers (e.g. halotrichite, volcanic glass fibers) are predominantly <1μm in diameter with a large diameter range, microbial filaments from [11] are predominantly 1 to 2 μm in diameter with a very limited diameter range. SFF were found to have a more similar diameter distribution to the microbial filaments than to the selection of general, filament-like abiotic fibers from [11]. This size distribution, along with measurements of filament bending, tortuosity, and direction changes, S and Fe isotope analyses, and bulk rock geochemistry, led Hofmann et al. (2008) to define SFF as biogenic in origin. Mineralized cylindrical filament diameters measured from Iron Mountain are consistent with diameter distributions measured by Hofmann et al., (2008), and the wide size distribution can be attributed to continued mineral coating leading to larger diameter coats on originally ~1μm diameter biogenic filaments (Fig. 3). Tortuosity measurements from mats of organic filaments and mineralized cylindrical filaments are consistent with tortuosity distributions measured from microbial filaments [11] (Fig. 4). Thus, we interpret the cylindrical filaments as mineralized microbial filaments. They are preserved as biosignatures, including macroscale (mm to µm scale) fabrics detectable by optical microscopy.

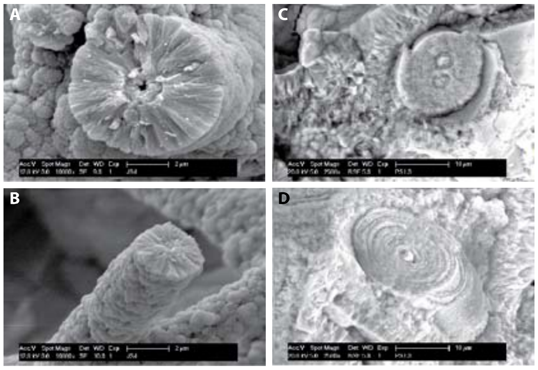

Figure 2. Mineralized cylindrical filament textures. A) Botryoidal filament with preserved central void. B) Botryoidal filament with no central void. C and D) Concentric filament with two and one preserved central cores, respectively.

Sanger sequencing was used to identify the closest genetic relatives of the organisms found in and on the goethitic surface gossan. Most organisms identified from the rock surface are related to psychrophilic soil bacteria. However, some organisms identified from inside the rock are related to organisms found in the Iron Mountain mine and Rio Tinto environments, such as *Edaphobacter* (family), *Acidiphilium* spp., and *Leptothrix* spp. *Leptothrix* is a filamentous bacterium which is often coated in iron oxides. Future work will confirm if *Leptothrix* spp. forms the mineralized cylindrical filaments identified with microscopy and place these organisms in a phylogenetic tree to better understand their relationship to other mineralogic biosignature-forming organisms in gossans.

Conclusions: Based on morphological measurements, mineralized cylindrical filaments are interpreted as mineralogic biosignatures composed of mineral-coated microbial filaments. Diameter and tortuosity comparisons suggest that these filaments served as the initial nucleation sites for HFO, and subsequent mineral-coating may be controlled geochemically. Future work will compare the filament curvature and tortuosity versus diameter to better elucidate the biological versus geochemical controls on filament mineralization and the diminishing preservation of filament characteristics during mineralization. The characterization of bacterial communities in the Iron Mountain gossan will provide analogs of mineralogical biosignatures within the detection window of the Mars Science Laboratory (MSL). Individual filament diameters are below the detection limit of MSL's Mars Hand Lens Imager (MAHLI) instrument (~14µm/pixel) unless they have thick coatings, but sinuous filaments forming mat-like textures are at to above MAHLI resolution and may be more readily identifiable as biogenic if present. The successful identification of Martian biosignatures would open up opportunities for future missions to the red planet in search of extraterrestrial life and the origin of life on Earth.

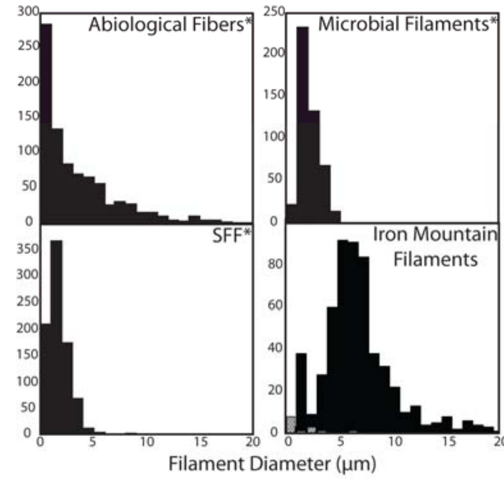

Figure 3. Measured diameters of abiological fibers, microbial filaments, SFF, and Iron Mountain mineralized cylindrical filaments. Gray bars are central filament void and core diameters. *from [11].

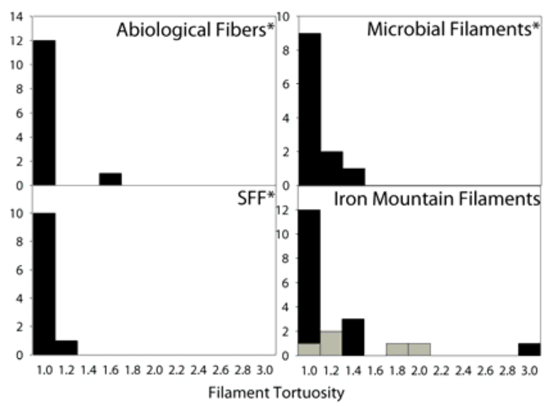

Figure 4. Filament tortuosity, measured as length of filaments between two points divided by the straight line distance, for filaments from Fig. 3. Gray bars are organic filaments, black bars are mineralized cylindrical filaments. *from [11].

References: [1] Burns, R.G. (1987) *LPSC* XVIII, 141-142. [2] Golubic, S. and Hofmann, H.J. (1976) *J. Paleo.* 50, 1074-1082. [3] Knoll, A.H. (1984) *Philo. Trans. R. Soc.* 311B, 111-122. [4] Ferris, F.G. et al. (1988) *Geology* 16, 149-152. [5] Farmer, J.D. and Des Marais, D.J. (1994) *NATO ASI series G35*, 61-68. [6] Cady, S.L. and Farmer, D.J. (1996) *Evol. Hydrothermal Ecosyst. On Earth (and Mars?),* 150-173. [7] Schultze-Lam, S. et al. (1996) *Chem. Geo.* 132, 171-181. [8] Bond, P.L. et al (2000) *App. Env. Microbiol.* 66, 4962-4971. [9] Druschel, G. K. et al (2004) *Geochem. Trans.* 5, 13-32. [10] Hofmann, B.A. and Farmer, J.D. (2000) *Planetary and Space Science* 48, 1077-1086. [11] Hofmann, B.A. et al. (2008) *Astrobiology* 8, 87-117. [12] Preston, L.J. et al. (2011) *Geobio.* 9, 233-249.