GROUNDWATER-FED IRON-RICH MICROBIAL MATS IN A FRESHWATER CREEK: GROWTH CYCLES AND FOSSILIZATION POTENTIAL OF MICROBIAL FEATURES. J. Schieber, Department of Geological Sciences, Indiana University, Bloomington, Indiana 47405, jschiebe@indiana.edu.

Introduction: Much of earth's sedimentary iron deposits can be attributed to microbial activity either directly or indirectly. Precambrian Banded Iron Formations are characterized by extensive hematite laminae that may be due to blooms of photosynthetic algae [1], and also contain stromatolites with hematitic laminae and hematitic oncoids [2]. Benthic microbial mat deposits in Proterozoic carbonaceous shales can be heavily mineralized with pyrite [3], and concretionary pyrite from various periods in earth history contains mineralized microbial remains [4]. Microbial remains have also been recovered from Phanerozoic ironstones [5]. While in many instances iron precipitation may merely be a byproduct of microbial metabolism (e.g. BIF's), it is also well established that microbes can precipitate iron either within cells or in the sheaths surrounding microbial filaments [6].

It is this common association of microbes and iron deposition on earth that has spurred hopes that robot crafts exploring the hematite anomaly of Mars' Meridiani Planum might find evidence for ancient life. The hematite deposits of Meridiani Planum [7], regardless of their exact origin, are considered to be a favorable host for microorganisms that might have been associated with their formation [8].

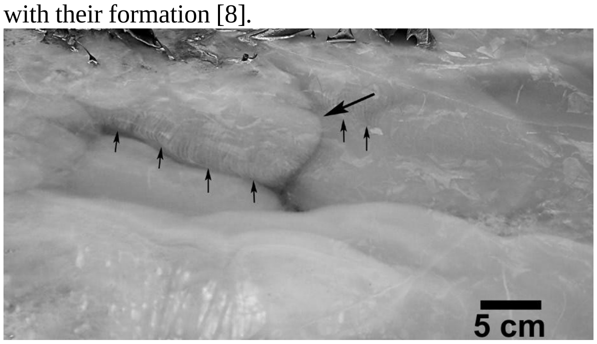

Figure 1: loaf-shaped microbial masses in creek bed (large arrow). Small arrows point out vertical microbial streamers.

Study Site Description: We have investigated a groundwater-fed tributary to Jackson Creek in SE Bloomington/Indiana which is characterized by prominent reddish-brownish deposits of iron hydroxides. Under typical conditions the water seeps into the creek from a sandstone horizon within the Mississippian Borden Formation, a succession of marine marls, carbonates, and sandstones. These sediments contain variable amounts of diagenetic pyrite that is oxidized as surface water percolate through the sediments. In the process the oxygen content of the water is utilized for sulfate formation, and the iron goes into solution as the Fe^{2+} ion. On first approximation one could assume that this iron simply is oxidized (to Fe^{3+}) and precipitated in the form of hydroxides ($Fe(OH)_3$) once it exits aquifers and comes in contact with oxygen.

Discharge of these iron-rich waters is intimately linked to an occurrence of masses of iron bacteria. The bacteria form loaf-shaped (Fig. 1) and bulbous buildups (Fig. 2) up to 20cm diameter, as well as undulose mats of a few cm thickness that cover the creek bed.

Figure 2: Bulbous microbial buildups (arrows) in faster flowing portion of creek.

The sheath forming bacterium *Leptothrix* dominates, but spiral stalks of *Gallionella* are commonly present, as well as other currently unidentified microbes.

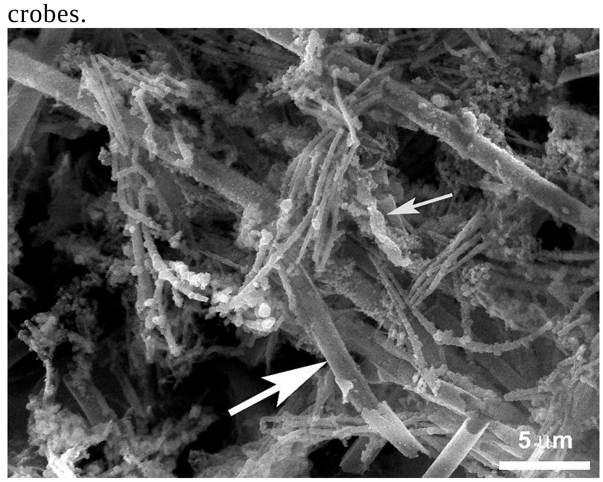

Figure 3: SEM image of mat fabric. Large arrow = *Leptothrix* sheath, small arrow = *Gallionella* stalk.

Microbial growth forms are fragile and are flushed out entirely during peak runoff associated with heavy rains. However, regrowth of microbial mats is vigorous and full mat coverage can be achieved within a weeks time.

Potential Relevance: In our case example storm-eroded mat material is flushed further down the creek and dispersed. Yet, if the material had for example been washed into a lake basin, it could potentially form distinct deposits of microbially precipitated iron that would become part of the geologic record.

An Experiment: Mat material was collected, filter dried, and subjected to increasing temperatures (100°C) over time and to compaction (simulating 1-2 km burial). We were curious how readily recognizable microbial features, such as sheaths and filaments, would change in appearance once they had been buried within a sedimentary succession. How difficult would recognition be for material that had undergone heating and compaction?

Observations: Figures 4 and 5 illustrate basic observations from this experiment (SEM images).

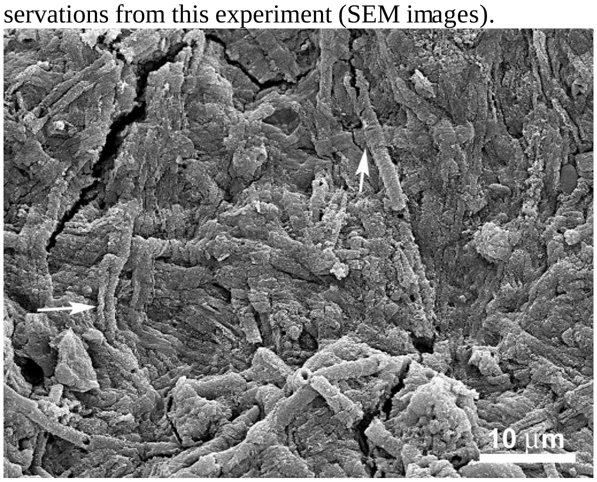

Figure 4: Mat material heated to 50°C for two weeks. Arrows point out flattened and collapsed sheaths.

Samples of sheath material that were kept in a moist state for several months and thus were subject to microbial breakdown of the organic sheath matrix still retained their overall appearance and texture after several months. After two weeks of heating (Fig. 4) an uncompacted sample still shows a dense network of sheaths. Fully Fe-mineralized sheaths retain their original tubular shape, partial or un-mineralized sheaths flatten out or collapse upon drying. The sheaths retain their granular surface texture that is due to clumps of amorphous Fe hydroxides incorporated into sheaths. After 5 weeks of heating and temperature increase to 100°C there was not much change - mineralized sheaths retain original structure, others show collapse and flattening. Application of pressure dramatically changes the appearance of the mat material. Most sheaths have now collapsed and produce a dense groundmass of granular appearance (Fig. 5). Only careful searching reveals in places still recognizable sheaths/filaments.

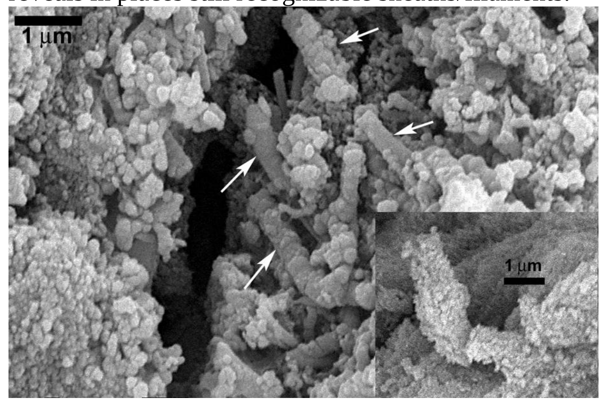

Figure 5: Granular groundmass of compacted material with rare remains of recognizable sheaths/filaments (arrows, inset) that still show granular surface texture.

Conclusion: Fe-mineralization of sheaths greatly enhances preservation potential of remains of iron precipitating bacteria. Fossil material will require early diagenetic mineralization to provide contrast between rock matrix and microbial remains after burial.

If Martian hematite deposits in Meridiani Planum were microbially mediated in a way similar to our terrestrial analog, detection of microbial remains should be possible. However, detection will require a lander equipped with a miniaturized SEM, because it seems not feasible that a miniaturized incident light optical microscope could provide the necessary resolution. The potential for detection will be best if the deposits have never undergone prior burial. Recognition in previously buried deposits will heavily depend on the nature of early diagenetic mineralization.

If apparent groundwater seeps on the modern Martian surface [9] were to support comparable microbial life, dried out crusts from spring deposits may contain recognizable microbial features. These can be transported over large distances by wind [10] and may be encountered and examined by landers that are engaged in a systematic study of surficial particles.

References: [1] Konhauser, K.O. et al. (2002) *Geology*, 30, 1079-1082. [2] LaBerge, G.L. (1973) *Econ. Geol.*, 68, 1098-1109. [3] Schieber, J. (1989) *Sedim. Geol.*, 64, 79-90. [4] Schieber, J. (2002) *Geology*, 30, 531-534. [5] Gerdes, G. and Krumbein, W.E. (1987) *Biolaminated Deposits*, Springer, 183p. [6] Konhauser, K.O. (1998) Earth-Science Reviews, 43, 91-121. [7] Christensen, P.R. et al. (2000) *J. Geophys. Res.*, 105, 9623-9642. [8] Allen, C.C. et al. (2003) *Sixth International Conference on Mars*, Abstract #3133. [9] Malin, MC. And Edgett, K.S. (2000) Science, 288, 2330-2335. [10] Krumbein et al. (1994) *Biostabilization of Sediments*, BIS Oldenburg, 526p.