GRANULAR MICROBIAL HABITATS BUILT FROM IRON SULFIDES: ALTERNATIVE MICROBIAL LIFESTYLES? J. Schieber, Department of Geological Sciences, Indiana University, Bloomington, Indiana 47405, jschiebe@indiana.edu.

Introduction: Concentrically zoned pyrite grains of sand to pebble size occur in shallow marine sandstones of Ordovician and Proterozoic age. Though usually thought of as a product of post-depositional chemical processes, these particular pyrite grains participated in sediment surface processes for extended time periods. The observation of fossilized remains of filamentous and coccoid microorganisms within these pyrite oncoids indicates that they are the result of microbially driven chemical processes. Microbes initiated oncoid growth by encrusting and binding sediment grains, and then continued to grow on this nucleus until a size of a few millimetres was reached.

Laminae with radial fibrous iron sulfide morphology suggest marcasite as the original iron sulfide. This was confirmed through electron backscatter diffraction analyis with an SEM. Due to its preference for low pH conditions, marcasite might be a common iron sulfide in reducing Martian sediments and may enclose microbial remains during growth.

The concentric laminae of pyrite oncoids indicate frequent movement during growth and imply residence in the mobile surface sediment. Cross-bedding and ripples in these sandstones indicate an energetic environment that may have precluded establishment of mat-forming microbial communities. Microbial communities that constructed pyrite oncoids were pioneers in a dynamic environment that was adverse to more traditional microbial life styles, such as mat building.

Study Units: Samples come from three different locations: (1) The Mid-Proterozoic Purcell Supergroup of Alberta (Canadian Rockies); (2) The Mid-Proterozoic Kaladgi Supergroup of southwestern India; and (3) The Ordovician Winnipeg Formation of the Williston Basin. Purcell samples are from the lower Siyeh Formation, interbedded sandstones and carbonaceous shales that were deposited in a shallow marine setting [1]. Pyrite oncoids occur in medium grained quartz arenites with quartz cement, cross-bedding, current and wave ripples, indicative of high energy conditions. Kaladgi pyrite oncoids occur in interbedded sandstones and carbonaceous shales that were deposited in a shallow marine to nearshore environment [2]. Cross-bedding, mud rip-ups, current and wave ripples in the quartz arenites point to high energy conditions. Pyrite oncoids are 0.5-4mm in size and scattered through the sandstone or concentrated on bedding planes and foresets.

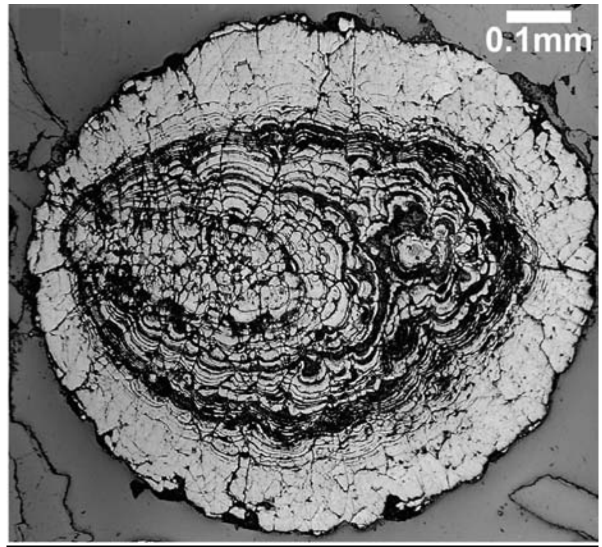

Figure 1: Pyrite oncoid from the Purcell Supergroup. Note wavy-crenulated laminae, suggestive of accretion as microbial laminae.

Coated iron sulfide grains from the Winnipeg Formation occur in shallow marine sandstones with indications of episodic wave reworking [3]. Horizons with strong enrichment of iron sulphide grains (up to 40%) indicate negative net sedimentation to facilitate geochemical “reworking” of iron. Sulphide-coated grains formed during intervals of maximum sediment starvation, when organic matter was enriched in surface sediments, and rare storm waves intermittently reworked the surface sediment [4].

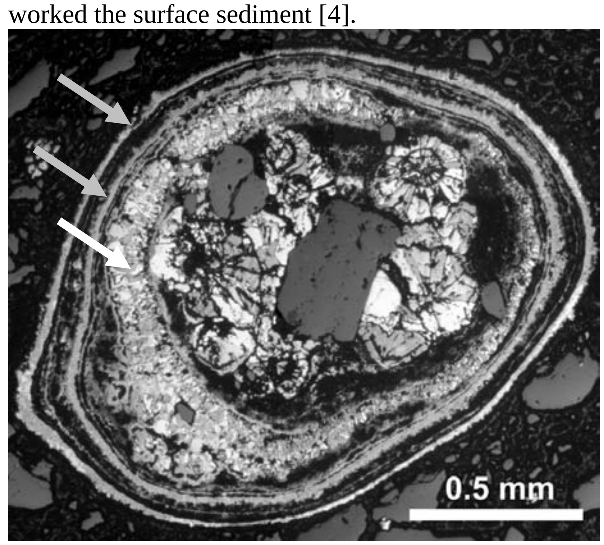

Figure 2: Pyrite oncoid from the Winnipeg Formation. Shows rhythmic accretion of pyrite amd marcasite cortices (arrows) on a core of reworked marcasite.

Microbial Remains: Wavy-crinkly laminae seen in Fig. 1 are similar to those from carbonate oncoids where irregular shape, wavy laminae, and domed projections reflect microbial growth on the oncoid surface [5,6]. If the cortices of grains like in Figs. 1 and 2 are examined at high magnification one finds that aside of areas that are covered with recrystallized pyrite (Fig. 3B), there are filamentous structures that may merge into what may be remains of biofilms (Fig. 3A), or clusters of iron sulfide encrusted ovoids (Figs. 3C&D). Encrusted ovoids have a smoothly curved exterior (Fig. 3C) and may show irregular perforations (Fig. 3D). They are the size of coccoid bacteria [7] and their perforations resemble those produced in experimental pyritization of microbes [8].

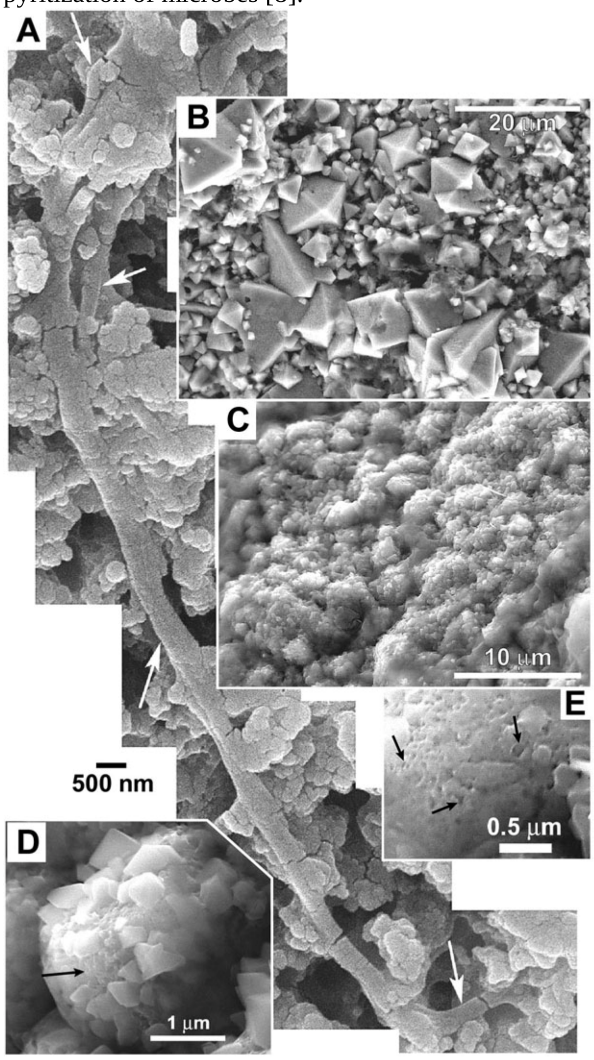

Figure 3: Microbial features in pyrite oncoids from the Winnipeg Formation. (A) filamentous features merging into potential biofilm (top). (B) cortex surface with recrystallized pyrite. (C, D, E) coccoid features with irregular perforations (E).

Origin of Pyrite Oncoids: Textural (SEM, TEM) and geochemical studies (EDS, electron microprobe, ion probe) support the view that pyrite oncoids are primary diagenetic grains, not a replacement of precursor carbonate, chamosite, or iron oxide grains. Sulfde minerals grew in the interior of oncoids and in the subsurface of cortices from multiple nucleation centers. Because of growth over extended time periods in the surficial sediment layer, it is possible that (1) clumps of microbes, possibly shreds of pioneer mats, bound together sands grains to form oncoid nuclei; (2) at the surface of the clump, cyanobacteria may have been primary producers of organic matter; (3) iron in the form hydroxide flocs and coatings was trapped and adsorbed by the EPS of this biofilm; (4) as lumps grew, decay of organic matter inside the oncoid produced H_2S due to anaerobic decay; (5) iron in the EPS reacted with H_2S to form iron sulfides; (6) iron sulfide formation in the EPS matrix enclosed and preserved bacterial remains; (7) as long as pyrite oncoids were small they were frequently remobilized by wave and current reworking, and when they got too large and heavy they became immobile and got buried.

Significance: The described grains represent microbial colonies that thrived in surface environments and produced iron sulfide mineralization instead of the more commonly observed calcite or phosphate.

Marcasitic grains of this type and their preserved microbial remains may have significance in the search for fossil life on Mars. The acidic nature of Martian surface waters, in combination with high abundances of dissolved sufate and iron [9], constitute a favorable environment for marcasite formation [10]. If life ever existed in Martian water bodies it should have at times produced carbonaceous sediments. Within these sediments marcasite grains of the type described here might have been preserved, including microbial remains that covered the surface of growing marcasite grains. Marcasite preservation of microbial matter may also be enhanced due to rapid growth of marcasite in low pH conditions.

References: [1] Binda, P. (1991) *Sask.Geol.Soc. Spec.Pub.* 11, p. 257-264. [2] Sarkar et al. (1997) *Indian Minerals*, v. 51, p. 137-148. [3] Binda. P., & Simpson, E. (1989) *European J. Min*., v. 1., p. 439-453 [4] Schieber, J. (2005) *J. Sed. Res*. in press. [5] Gerdes, G. and Krumbein, W.E. (1987) *Biolaminated Deposits*, Springer, 183p. [6] Carozzi et al. (1983) In: *Coated grains*, Peryt., T. (ed), Springer, p. 330-343. [7] Schieber, J. (2002) *Geology*, v. 30, p. 531-534. [8] Bubela, B. & Cloud, P. (1983) BMR J. Austr. Geol. & Geoph., v. 8, p. 355-357. [9] Squyres, S.W. et al. (2004) *Science*, v. 306, p. 1709-1714. [10] Schoonen, M.A.A., & Barnes, H.L. (1991) Geoch. Cosmoch. Acta, v. 55, p. 1495-1504.