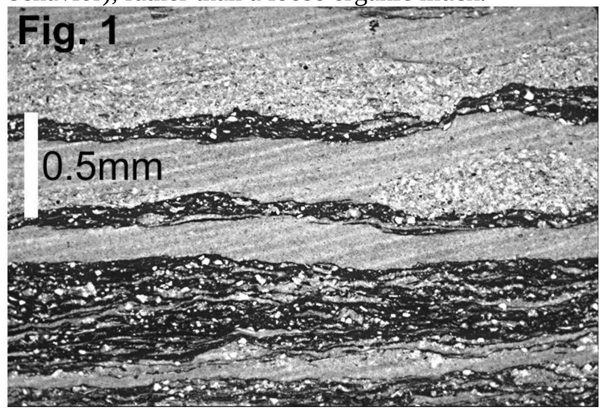
FINDING LIFE ON MARS: A MUDROCK GEOLOGIST'S PERSPECTIVE. J. Schieber, Department of Geology, The University of Texas at Arlington, Arlington, Texas 76019, schieber@uta.edu.

Introduction: On Earth we find two types of fossils in the early rock record: (1) stromatolites, the remains of microbial mats (±trace fossils) and (2) preserved remains of microbes (±body fossils). There is a bias in the literature, with all certified occurrences of Archean microbes having been reported from cherts [1]. Likewise, although Proterozoic microbial remains have also been found in shales, the literature is nonetheless skewed in favor of cherts and carbonates [2]. Because cherty carbonates are much more common in shallow water settings, it is inevitable that the current literature is biased in favor of microbes and microbial communities that live in shallow water carbonate environments and are associated with photosynthesis. Yet, whereas cherty carbonates only comprise a few percent of the sedimentary rock record, the lion's share (65% or more) consists of mudstones [3]. A drawback of mudstones is that microbial remains are compressed as well as more easily affected by near-surface processes (weathering etc.), and as such are more difficult to work with. If there were a way to effectively capture the microbial record in mudstones it would give us a much more comprehensive record of microbial life in the past.

Potential Places to Look: Just like has been done for cherty carbonates, [1,2] a good place to start a search for microbial remains in mudstones would be strata with microbial mat/stromatolitic laminae. In addition, however, mudstones can harbor a range of early diagenetic concretions/cementations that could potentially contain microbial inclusions.

Shales and microbial mats. Compared with carbonates, establishing microbial mat presence in mudstones poses a challenge [4]. The following sedimentological criteria can be utilized, however, as microbial mat indicators: (A) domal buildups; (B) cohesive behavior; (C) wavy-crinkly character of laminae; (D) irregular wrinkled bed surfaces; (E) laminae with mica enrichment; (F) irregular, curved-wrinkled impressions on bedding planes; and (G) lamina specific distribution of early diagenetic minerals (dolomite, ferroan carbonate, pyrite) [4].

The following picture (Fig. 1) shows bundles of wavy-crinkly carbonaceous laminae in a Mid-Proterozoic mudstone that have been interpreted as a microbial mat deposit [5]. Important considerations are: (1) the contrast in texture to other carbonaceous shales (with parallel laminae); and (2) the cohesive behavior of the carbonaceous layers during erosion and deformation. These layers basically behave like a tough leathery membrane (expected microbial mat behavior), rather than a loose organic muck.



Especially when found in combination, these features are highly suggestive of microbial mats and can serve as guides to sediments that may have accumulated under their influence.

Early diagenetic concretions in shales: Freshly deposited muds contain 80-90% water, plenty of pore space to be colonized by microbes. Early diagenetic concretions of carbonate, silica, phosphate and pyrite are common in mudstones. Pyritic concretions are the most common variety and among the earliest to form.

Sedimentary pyrite from rock units ranging in age from Archean to Devonian was examined for potential microbial remains by petrographic microscope (reflected light), SEM, and TEM. The search was successful, and the results are illustrated below.

Figure 2 is a TEM image from a pyrite nodule in Archean (2.7 b.y.) black shales from Australia. The rounded light colored bodies are amorphous and carbonaceous, have a crumbled texture suggestive of collapsed cell walls, and are interpreted as a fossilized bacteria. The surrounding matrix (dark gray mottled) consists of pyrite. Bacterial remains of this type range in size from 0.2-0.8µm.

Ovoid and filamentous microbial remains were observed in pyrite grains from the Proterozoic of Montana and India (Figs. 3, 4). Figure 3A shows ovoid bodies in a polycrystalline (etched) pyrite matrix (SEM image), and Fig. 3B (TEM image) shows a cross section of a carbonaceous (light) envelope with a complexly textured pyrite fill.

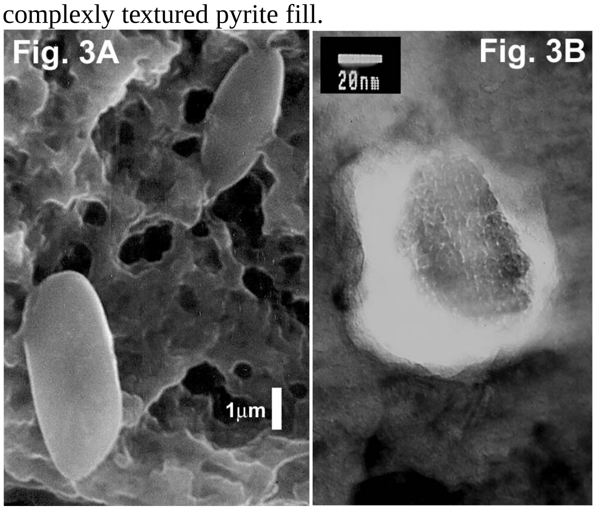


Fig. 4A shows what appears to be a preserved pyritic filament, and Fig. 4B shows filament molds on an etched surface, (both SEM images). The pyrite grains may have resided intermittently at the sediment surface, forming analogous to carbonate oncoids.

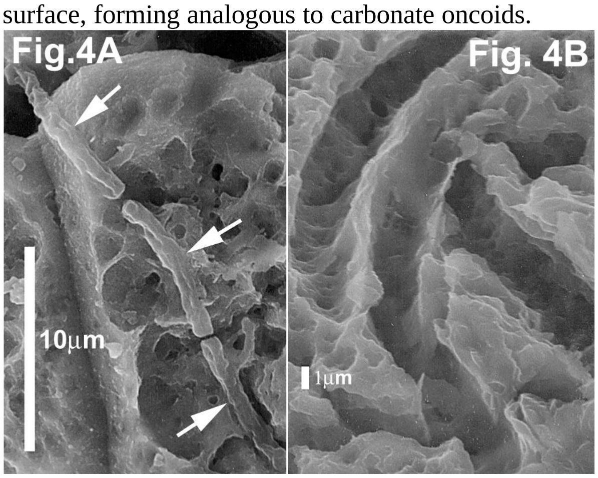
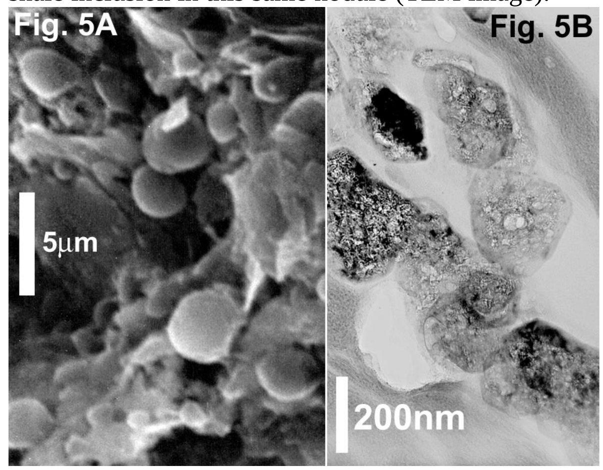


Figure 5 shows presumed microbial remains from an early diagenetic pyrite nodule in the Devonian Chattanooga Shale. Fig. 5A shows rounded bodies in a pyrite matrix (SEM image), and Fig. 5B shows rounded and somewhat deformed remains from a shale inclusion in this same nodule (TEM image).



These examples illustrate that microbial remains have a high preservation potential when sealed into early diagenetic sedimentary pyrite grains. Assuming a comparable early atmosphere for Mars and Earth, microbial life on Mars should have evolved using analogous metabolic pathways. Thus, sedimentary pyrite grains may be excellent prospects for finding microbial remains in Martian mudstones. Pyrite grains of the type illustrated also contain preserved amino acids [6], and may thus be a good source for Martian chemofossils as well. If early Mars was anything like Earth, mudstones are likely to dominate its sedimentary record, and pyrite grains within these may contain abundantly preserved evidence of Martian life.

Some Suggestions: To maximize our chance to find evidence of Martian life, we might want to adopt the following sampling strategy: (1) locate an area with a high chance to find mudrocks (orbiter photos: areas with well developed differential erosion); (2) sample mudrocks from landslide scars or make fresh exposures with explosives; (3) crush a portion of the material and pick out sedimentary pyrite grains that show a large degree of differential compaction (early formed grains); (4) if steps 2&3 not feasible, search for pyrite grains in eolian deflation lags at the planet surface and select hard/solid grains. Considering that bacterial remains seem ubiquitous in terrestrial sedimentary pyrite, this should optimize our chances to recover tangible evidence of past life from Mars.

References: [1] Schopf J.W. & Walter M.R. (1983) In: Schopf J.W. (Ed.), Earth's Earliest Biosphere, 214-239. [2] Horodyski et al. (1992) In: Schopf J.W. & C. Klein (Ed.), The Proterozoic Biosphere, 185-193. [3] Potter et al (1980) Sedimentology of Shale, 303p. [4] Schieber J (1999) *Palaios, 14*, 3-12. [5] Schieber J. (1986) *Sedimentology, 33*, 521-536. [6] Nardi S. et al. (1994) *Chemical Geology, 111,* 1-15.