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SEARCH FOR MARTIAN FOSSIL COMMUNITIES: SCIENCE STRATEGIES, SEDIMENT SITES, AND SAMPLE HANDLING. David J. Des Marais, NASA, Ames Research Center, Moffett Field, CA 94035, U.S.A.

The strategy for locating and sampling possible fossilized Martian organisms benefits from our experience with fossil microbial ecosystems on Earth. Evidence of early life is typically preserved as stromatolites in carbonates and cherts, and as microfossils in cherts, carbonates and shales. Stromatolites, which are laminated flat or domal structures built by microbial communities, are very likely the oldest and most widespread relics of early life. These communities flourished in supratidal to subtidal coastal benthic environments, wherever sunlight was available and where incoming sediments were insufficient to bury the communities before they became established. A logical site for such communities on Mars might be those areas in an ancient lake bed which were furthest from sediment input, but were still sufficiently shallow to have received sunlight. Therefore, although some sites within Valles Marineris might have contained ponded water, the possibly abundant sediment inputs might have overwhelmed "stromatolite-like" communities. Localized depressions which acted as catchment basins for ancient branched valley systems (see S. Squyres' abstract, this volume) might be superior sites. Perhaps such depressions received drainage which, because of the relatively modest water discharges implied for these streams, was relatively low in transported sediment. Multiple streams converging on a single basin might have been able to maintain a shallowwater environment for extended periods of time.

Although stromatolites are recognized as such by their striking laminated fabric, this fabric can resemble nonbiogenic deposits such as travertine, tufa, varves, etc. In order to identify conclusively a "Martian stromatolite" by its morphology, it might be necessary to bring back an intact rock or sediment sample measuring at least several centimeters in dimension. With such a size, fabrics such as those formed by microbial activity (e.g., phototaxis, the light-seeking migration of cells) might be identified.

Perhaps most valuable will be the chemical and isotopic criteria employed for identifying any Martian fossil life. Either organic matter or the minerals affected by biological activity could offer important clues about such life. Archean-age (>2.5 Ga old) Martian sediments probably have experienced less heating and pressure than have Archean sediments on Earth. If Martian microbial communities indeed ever existed, their remains have very likely been preserved in exquisite detail. Therefore during sampling and return to Earth, fossil material must be shielded from light, high temperatures, oxidation, etc., which might damage this evidence.

Below are summarized the basic science objectives as well as sampling requirements.

Science questions. We should seek to understand, in the most general sense, the low temperature (<200^{o}C) chemistry of the "biogenic" elements (C, H, O, N, S and P) on the surface of Mars. Special emphasis is given to those chemical processes which occurred early in the planet's history. A search for organic matter should receive special effort. By interpreting the chemical and isotopic signatures imposed by nonbiological physico-chemical Martian processes, we will help to define the planet's early environment. This effort clearly will assist any reconstruction of a putative ancient biosphere. We would then look for distinctive recurring patterns, among the biogenic elements and their compounds, which might reflect biological processes. Examples of such evidence are those obvious features (cells, stromatolite-like structures, organic matter) which on Earth constitute classical expressions of fossil life.

Nature of Samples. Most interesting are materials which have contacted water and reflect aqueous chemical processing. Accordingly, desirable samples contain minerals precipitated from aqueous solutions at ambient temperatures. Examples include carbonates, silica, and other evaporitic minerals occurring either as whole rocks or as cements. Samples should have experienced low thermal histories subsequent to their deposition, because compounds and minerals indicative of life are temperature sensitive. Ideal are samples derived from shallowwater environments which had received minimal inputs of clastic material.

Sample Masses. This requirement reflects the need to obtain a sample sufficiently large to examine the textures and other physical relationships between the various minerals. For chemical and isotopic studies, a 1 to 5 g sample is desirable. For studies of morphologic features (e.g., stromatolite-type fabrics) 10's of g are necessary.

Optimal sample sites. This requirement follows from the above requirement that the sample should have experienced liquid water. Any site which evidences the effects of liquid water is desirable. Ideal are sites of ancient, shallowwater pools, or sites where low-temperature aqueous chemical precipitation had occurred.

Sample collection procedure. It is critical to circumvent surface dust and crater ejecta which have been heavily altered by weathering and other processes presently active on the planet. This might be achieved either by coring or by sampling ancient strata exposed by weathering or crustal movement. Because the roving sampler must discard most of the samples it inspects, it must be able to screen samples based upon visual appearance, light element content and how well they represent the local rock types. The original in situ sample orientation must be recorded.

Curation. To preserve potentially well-preserved features of biological interest, the samples should be stored at ambient temperatures and be sealed in the ambient atmosphere. Physical disruption must be minimized.

General References

J. W. Schopf, ed. (1983) Earth's Earliest Biosphere, Its Origin and Evolution. Princeton University Press, Princeton.

M. R. Walter, ed. (1976) Stromatolites. Elsevier, New York.