SEEKING EVIDENCE OF PAST LIFE ON MARS: THE POTENTIAL EVIDENCE THAT MAY BE CONTAINED IN RETURNED SAMPLES. A.C. Allwood[1], [1]California Institute of Technology/Jet Propulsion Laboratory (4800 Oak Grove Drive, Pasadena, CA 93012).

Introduction: Returning samples for analysis on Earth is widely regarded as an essential step in the search for evidence of life on Mars. Accordingly, preparations are underway for a potential campaign to return samples from Mars, with primary science objectives centered on the search for evidence of past life [1]. However, the suite of material that would be returned from Mars would be limited to approximately 30 cores, weighing ~15-16g each—much less than the suite of materials typically involved in comparable life-detection studies on Earth [e.g. 2, 3]. The samples would also be selected under much more constrained field operational conditions. In light of these constraints, it is important to give considerable forethought to the types of evidence for past life that could potentially exist in such a sample suite and the types of in situ observations and approaches that could increase the chances that evidence of life would be captured in the samples.

Approaches developed in studies of Earth's earliest biosphere. A useful place to start this analysis is to look at studies of Earth's earliest biosphere. There are four different classes of biosignatures in the record of early life on Earth: microfossils, molecular fossils (biomarkers), chemical fossils (particularly isotopic abundances) and stromatolites (macroscopic sedimentary structures usually formed by microbes). To interpret a candidate biosignature, the general requirement is the same for all four classes: integrate multiple lines of evidence across multiple scales using combined field observations and sample analyses. This analysis includes documentation of the *inherent properties* of the particular candidate biogenic feature, as well as its *context*. Context consists of:

- The characteristics of the assemblage: a single biosignature is typically part of an assemblage
- The characteristics of the host rocks: environment of formation and subsequent history, based on a multitude of observations
- The spatial and temporal relationships between the candidate biosignatures, and between the biosignatures and the host rocks.

While the general approach described above is the same for all types of biosignatures, the specific approach is different for each class of biosignature. Because mission lifetime is highly constrained, understanding these differences is important for scientifically narrowing down the infinite possibilities for sample selection and performance of *in situ* measurements. The differences in approach come to light when certain key questions are posed:

- What are the *inherent* properties of the biosignature that would need to be observed?
- What *contextual* observations would be needed?
- Where is the necessary evidence likely to be detected: *in situ* or in returned samples, or both?
- Are the biosignatures likely to be contained within a single sample, or across multiple samples?

Two classes of biosignature are discussed and compared with regard to the questions posed above.

Microfossils: Cellular fossils are typically identified in thin section or through chemical separation of organic structures from the rock matrix of returned samples, and would almost certainly escape detection *in situ* with the instruments that are likely to be available on a rover. However, exceptions are possible, such as relatively large microfossils encased in large translucent crystals. These structures could potentially be seen, if not unambiguously interpreted, with a close-up imager on a rover. However, even if microfossils could be tentatively detected *in situ*, the inherent and assemblage characteristics of microfossils would need to be studied in returned samples.

The types of inherent properties that may help distinguish fossil cells from similar abiotic structures include such characteristics as cellular shape, signs of flexible but cohesive organic cell walls, nuclei, cell division, and isotopic abundances of organic material that make up the cell walls. At the assemblage scale, evidence of biogenicity may include community-like assemblages of cells, formation of microbial mats, deposits of draping biofilms, or remnants of extracellular polysaccharide (EPS) among the cells. Depending on the degree of preservation, typically at least several tens (if not hundreds) of candidate microfossils are studied in order to ascertain whether the structures are biogenic.

In addition to the inherent and assemblage properties of the microfossils, contextual information is needed. Some of that information would be derived from the microfossil-bearing samples themselves, but much of it would lie in the host rocks and would be acquired through both *in situ* observations and returned sample analyses. The measurements of context *in situ* would be done with no foreknowledge of the existence of microfossils, and would therefore need to focus on a general determination of the nature of the geologic deposit being sampled (e.g. chemical sediments, clastic sediments, or vein fills?) through multiscale observa-

tions of visible features, mineralogy and chemistry. These *in situ* interpretation of context would be verified through analyses of returned samples.

In summary, microfossils could exist in returned samples and multiple microfossils could exist within one sample. However, to confidently interpret them, morethan a single sample is needed. Multiple samples bearing microfossils would need to be collected to enable robust observations of inherent and assemblage properties. In addition, detailed *in situ* measurements supported by analyses of returned samples (not necessarily containing microfossils) would be needed to allow interpretation of the geologic setting.

Stromatolites: Stromatolites could be detected *in situ* with the instruments that are likely to be available on a rover. Both the inherent and assemblage characteristics of stromatolites could be studied extensively in the field through analysis of morphology and texture, and variability therein. Indeed, because stromatolites are large, many of their characteristics are only possible to study in the field and would not be captured in returned samples. However, critical detail is gained through laboratory analyses of returned samples, including thin section studies and geochemical analyses of minerals and organic deposits. On Earth, those samples are often large enough to contain a whole stromatolite, but smaller samples carefully selected from key locations within a stromatolitic deposit could encapsulate critical information on microtextures, geochemistry and organic deposits. Thus, samples would ideally be collected with these properties in mind, and *in situ* observations should focus on those properties that are too large to observe in a single sample, such as morphology, macroscopic textures, assemblage characteristics and the larger geologic context.

Stromatolites have few inherent properties that may help distinguish biogenic stromatolites from similar abiotic structures, for example, certain morphological and textural characteristics may be indicators of biogenicity. However, assemblage scale properties measurable *in situ* can be a rich source of information: morphological and textural variations correlated through space and time can provide evidence of biological influence on physical or chemical sedimentary processes occurring in the environment. Some of the most compelling properties of stromatolites, however, can be inherent properties that are not measured *in situ*, such as the distribution and character of organic deposits, isotopic abundances or microfossils.

Because the stromatolites are observable in situ, it is much easier to study them within their larger context. But, as with microfossils, the interpretation of context would rely on a combination of in situ observations and returned sample analyses. Insights to the origin of stromatolites lie in the correlation of stromatolite variations with variations in past environmental conditions.

Summary: Many different types of evidence for life may exist in returned samples. However, returned sample analysis alone is almost certainly insufficient for confident identification of past life and must be combined with *in situ* analyses to guide sample selection and provide geologic context. The process of selecting samples and providing context involves infinite possibilities, and consideration of the types of biosignatures that may be likely to occur in a given setting would help to significantly narrow down the range of possibilities.

References: [1] McLennan, S., et al., 2011, Planning for Mars Returned Sample Science: Final report of the MSR End-to-End International Science Analysis Group (E2E-iSAG), in prep, to be posted by the Mars Exploration Program Analysis Group (MEPAG) at http://mepag.jpl.nasa.gov/reports [2] Allwood, A.C., Walter, M.R., Kamber, B.S., Marshall, C.P., Burch, I.W., 2006: Stromatolite reef from the Early Archaean era of Australia, Nature, 414: 714-718. [3] Schopf, J.W., 2006, Fossil Evidence of Archean Life. Phil, Trans. Royal Soc B. 361: 869–885