PROTEROZOIC MICROFOSSILS AND THEIR IMPLICATIONS FOR RECOGNIZING LIFE ON MARS. D. Z. Oehler[1] and M. R. Walter[2], [1]Universities Space Research Association / NASA-JSC, Houston, TX 77058, doehler@ems.jsc.nasa.gov. [2]Australian Centre for Astrobiology, Department of Earth and Planetary Sciences, Macquarie University, Sydney, NSW 2109, Australia, malcolm.walter@mq.edu.au.

Introduction: An important element in the search for life on Mars involves efforts to detect evidence of past life – life that may have arisen during the early history of the planet (more than 2.5 billion years ago) when surface conditions are thought to have been more amenable to supporting living systems and not too dissimilar from conditions on the early Earth [1-2].

To guide such efforts, it is prudent to review our knowledge of early life on Earth [3]. Hundreds of deposits with Proterozoic to Archean microfossils are now known; they tell us of an early Earth exclusively inhabited by microscopic organisms, mainly algae and bacteria. While uncertainty may exist regarding biogenicity of some of the oldest Archean structures [4], many assemblages of Proterozoic age are well preserved and indisputably biogenic. It is these that we will use to illustrate biosignatures typifying ancient microbiotas.

Recent work has illustrated the difficulty of using morphology alone as an indicator of biogenicity [5-6], and certainly it is well recognized that the use of multiple lines of evidence (e.g., morphology, chemistry, isotopes, biology) is critical to interpretation of ancient microstructures. A number of authors have addressed the importance of defining criteria for biogenicity [7-10]. Our goal is to focus on several of the best-preserved examples of ancient life in order to clarify some of these criteria and enhance our ability to discriminate between biological and abiological origins for controversial structures, both on Earth and Mars.

Preservation: Typically**,** Proterozoic microfossils are organically preserved (Figs. 1-3, 6). That is, their remnant structures are composed of kerogen, the acid-insoluble, diagenetically altered product of original biological materials. Organic preservation can be recognized by a combination of optical microscopy, acid maceration, and various spectroscopic techniques. Grains of pryite may encrust cell walls or even replace entire cells (Figs. 4-5), but this is relatively rare.

Organic microfossils can be recovered from clastic rocks (shales, siltstones, mudstones), but some of the best preserved are entrapped in chert – a fine-grained chemical precipitate. Microfossils have been reported from other types of chemically precipitated sediments (e.g., phosphorites and ferricrete [11-13]), but the majority of our knowledge of Proterozoic life comes from assemblages preserved in chert or shale.

Proterozoic Microorganisms: Examples of well-preserved Proterozoic microbes are shown in Figures 1-6 [14-16]. Most have been compared to cyanobacteria. Spheroidal microfossils occur singly, in pairs, or in clusters which may be surrounded by enveloping sheaths or membranes. Walls are single or double-layered. Some spheroids look like spores or cysts, with apical caps or pores (Fig. 1R). Others (not shown) may have surface ornamentation or remnants of internal cellular contents. Mat-like colonies may be preserved and may exhibit "tops and bottoms" (polarity).

Filaments, usually unbranched, consist of stacked cells or may be hollow and ribbon-like. Many are mat-forming. Stacks of cells within filaments may be capped by terminal, dome-shaped cells and may be encased in mucilaginous sheaths.

Most cells likened to bacteria or cyanobacteria are smaller than about 20 *u*m in diameter and within single morphotypes, size ranges are narrow.

Ultrastructural detail is also preserved (Fig. 6) and may reflect biological precursors (e.g., cell wall layers, cell membranes [16]). This level of detail should aid interpretation of controversial organic forms where gross morphology is not distinctive enough to rule out possibilities that the structures are either artifacts of preservation or organic coatings on minerals [5-6].

Finally, the great majority of biotas in Proterozoic rocks appear to include diverse organisms, suggesting that, like their modern counterparts, ancient microbes lived in complex ecosystems.

Conclusions: By focusing on clearly biogenic Proterozoic assemblages, the following traits, typifying examples of early life on Earth, can be defined:

a. preservation, generally, as organic residues
b. simple to complex spheroidal or filamentous forms
c. organizational complexity – may show polarity
d. narrow range of size and shape per morphotype
e. ultrastructure reflecting biological precursors
f. association with a biodiverse community

None of these characteristics, by itself, is absolutely necessary to prove biogenicity and only "e" (and possibly "d" and "f") may be unique to biological systems. Yet together, these features describe some of the most primitive organisms on Earth and thus provide a set of criteria against which structures of uncertain origin can be compared.

References: [1] Walter M. (1999) *The Search for Life on Mars*, Allen & Unwin, NSW, 170 p. [2] Walter M.R. & Des Marais D.J. (1993) *Icarus 101*, 129-143. [3] Knoll A.H. & Walter M.R. (1996) *Evolution of hydrothermal ecosystems on Earth (and Mars?)*, Wiley, Chichester, 198-213. [4] De Gregorio B.T. & Sharp T.G. (2003) *LPS XXXIV*, Abs. # 1267. [5] García Ruiz J.M. *et al*. (2002) *Astrobiology 2* (3), 353-369. [6] García Ruiz J.M. *et al*. (2003) *Science 302*, 1194-1197. [7] Cady S.L. et al. (2003) *Astrobiology 3* (2), 351-368. [8] Schopf J.W. (2003) *GSA Prog. Abs*. Paper 156-6**.** [9] Walsh M.M. & Westall F. (2000) *LPS XXXI Abs. # 1932*. [10] Cady S.L. (1998) *Palaios 13*, 95-97**.** [11] Li C.-W. *et al*. (1998) *Science 279*, 879-882. [12] Xiao S. *et al*. (2000) *PNAS 97* (25), 13684-13689. [13] Allen C.C. et al. (2003) *LPS XXXIV*, *Abs. # 1005*. [14] Oehler D.Z. (1978) *Alcheringa 2***,** 269-309. [15] Oehler J.H. (1977) *Alcheringa 1*, 315-349. [16] Oehler D.Z. (1976) *J. Paleontology 50*, 90-106.

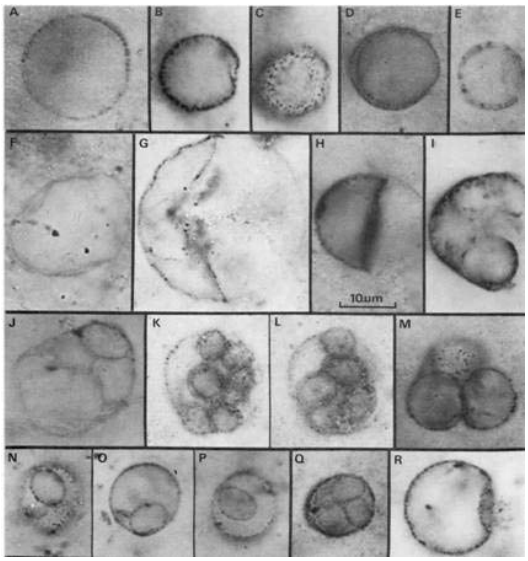

Figure 1. Organic spheroids in chert from the 1500 Ma Balbirini Dolomite, Australia [14]. Scale in H (10 *u*m) applies to all.

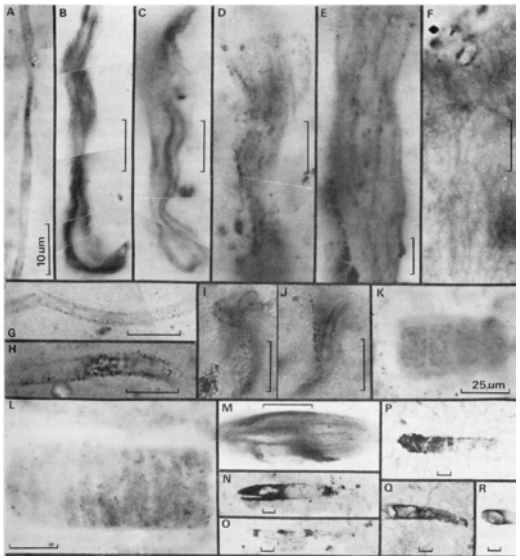

Figure 2. Organically preserved filaments in chert (Balbirini Dol.) [14]. Scales are 10 *u*m in A-J and 25 *u*m in K-R.

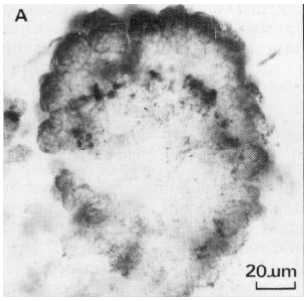

Figure 3. Organic, mat-forming colony in chert (Balbirini Dol.) [14]. Dark coloration on upper surface may be a remnant of photosynthetic pigment.

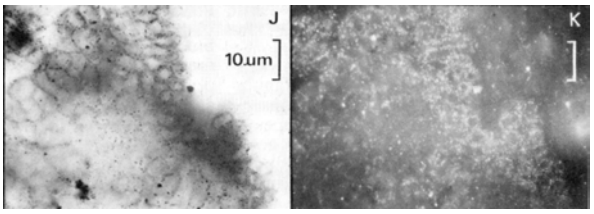

Figure 4. Transmitted (J) & reflected (K) light photo-micrographs of a polished thin section of the same colony in chert (Balbirini Dol.) showing cell walls encrusted with pyrite [14].

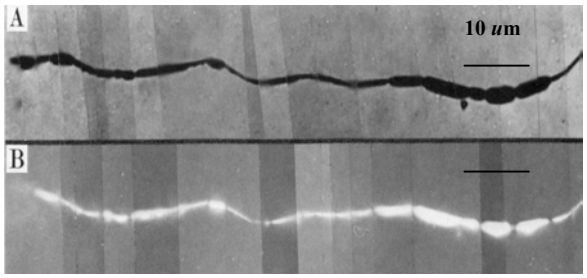

Figure 5. Transmitted (A) and reflected (B) light photo-micrographs of a bacterium in chert from the 1640 Ma HYC of Australia showing replacement of cells by pyrite [15].

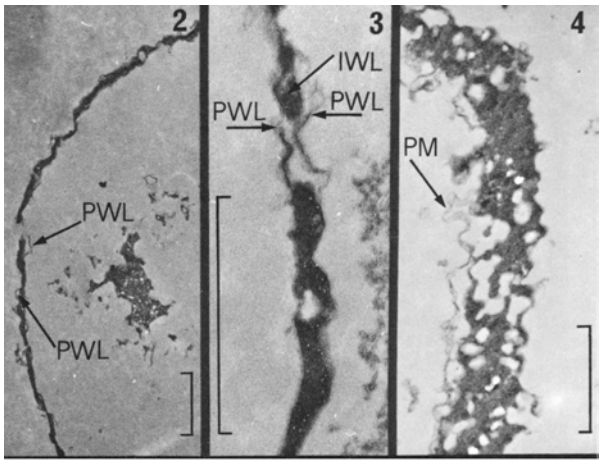

Figure 6. TEM of ultrathin sectioned unicells from the ~900 Ma Bitter Springs Fm. of Australia [16]. Scales = 1 *u*m. Pw = peripheral wall layer; iw = inner wall layer; pm = plasma membrane(?).