Environmental Context of Early Archean Stromatolites: Analog for Mars?

Bruce Runnegar, Department of Earth and Space Sciences and Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA 90095-1567, U.S.A.; runnegar@ucla.edu

Australian Archean stromatolites are arguably the best evidence for life on the early Earth, 3.5 billion years ago. These shallow-water sedimentary structures are plausible analogs for "biosignatures" on Mars, in that they are intimately associated with regularly layered deposits, crystalline sulfates, ferruginous materials, and small-scale cross lamination. But how useful is this comparison? Studies of the growth and environmental context of the stromatolites are the key to answering this question.

Stromatolites are self-organized mesoscale structures that result from various forms of accretionary growth in the generally vertical direction. Processes that contribute to stromatolitic growth include gravitational settling of sedimentary particles, surface-normal precipitation of mineral grains and fibers, upslope or downslope movement (diffusion) of previously deposited materials, and random natural effects best treated as noise (Grotzinger and Rothman, 1996). Most of these processes are equally characteristic of both abiotic and living systems and thus provide little or no evidence for a biogenic origin. However, sustained upslope diffusion is a process that is readily attributable to life but not to any other non-vital agents at anything larger than the atomic scale (Runnegar and Jögi, 2007).

The environmental context of stromatolitic structures provides another way to assess biogenicity. On Earth, early Archean stromatolites are commonly considered to have formed with gypsum, nahcolite ($NaHCO_3$), or aragonite evaporites, now pseudomorphed by barite ($BaSO_4$), quartz, and calcite (Buick, 2008; Tice and Lowe, 2004; Allwood et al., 2006); on Mars, prospective strata contain molds of sulfate crystals (possibly $MgSO_4.11H_2O$; Peterson and Wang, 2006) that have been attributed to evaporative processes (McLennan et al., 2005). Furthermore, an association of bacterial sulfate reducers with barite crystal growth surfaces has been claimed for the Australian Archean "evaporites" (Ueno et al., 2008; Shen et al., 2009). Our work on Australian Archean stromatolites and sulfates plus a new interpretation of Meridiani Planum "evaporites" (Niles and Michalski, 2009) suggests that early Earth may be a poor analog for early Mars.