ABIOTICALLY FORMED REDOX INTERFACES IN BASALT SAND – A "MARS HABITAT OF INTEREST".

R. Popa[1], M.R.Fisk[2], P-Y Meslin[3], J. Lasue[3], R. Léveillé[4], W. Goetz[5], M.B. Madsen[6], N. Bridges[7], N. Renno[8], D. Rubin[9], and R. Wiens[10]

[1]University of Southern California, Los Angeles, CA 90089-2910, USA, radu.popa@usc.edu). [2]Oregon State Univ. [3]Institut de Recherche en Astrophysique et Planetologie, CNRS-UPS, Toulouse, France., [4]Space Science and Technology, Canadian Space Agency, St-Hubert, QC, Canada, [5] Max-Planck-Institut für Sonnensystemforschung, Germany; [6]Niels Bohr Institute, University of Copenhagen, Denmark;[7]Johns Hopkins Univ., Applied Physics Laboratory, Laurel, MD, [8]Dept. Atmospheric, Oceanic and Space Sciences, Univ. of Michigan, Ann Arbor, MI, [9]US Geological Survey, Santa Cruz, CA, [10]Los Alamos National Lab, Los Alamos, NM, MSL Science Team

Introduction. The main criteria for establishing whether a habitat may support life are nutrients, energy and liquid water. We have used these criteria to ascertain potential, past and present Mars habitats that are accessible to the Mars Curiosity rover. The habitats we have analyzed are in the near surface aphotic zone of Mars soil and sand, containing basalt-derived silicate minerals. We discuss two potential energy sources: redox reactions between Mars surface oxidants and ferrous iron (FeII), and energy rich Fe(II):Mn(III-IV) redox interfaces. In both these cases, the primary source of energy is abiotic; i.e. chemical disequilibrium produced by sunlight.

Alternative sources of Energy in Mars Soil: The Mars soil at the site called Rocknest is derived primarily from weathered basalts and is rich in micronutrients but poor in nitrogen, phosphorus and organic materials. Potential sources of energy for microorganisms in this habitat are solar energy (i.e. phototrophy), decay of extraplanetary-derived organic matter (i.e. organotrophy), and inorganic redox reactions (i.e. lithotrophy). Based on irradiance measurements, solar energy is rich on Mars (590 W m^{-2}), about 44% of the Earth's solar constant. Yet, photosynthesis is an unlikely source of energy on the present Mars because it requires sunlight and liquid water in the same habitat. Furthermore, no colors indicative of photosynthetic pigments were found on Mars. The input of organic matter on Mars is about 5 ng per square meter per sol [1]. In reference to carbohydrates, using O_2 as an electron acceptor and assuming about 40% energy transduction efficiency for chemiosmotic phosphorylation, the maximum amount of bioavailable energy in extraplanetary organics is but about$1.6 \bullet 10^{-9}$ cal m^{-2} sol^{-1}. This energy is only sufficient to support a 1 micrometer microorganism per square meter dividing once per sol and with a respiration rate of $9 \bullet 10^{-10}$ cal sol^{-1}.

Olivine oxidation as energy source: Redox reactions between surface oxidants (such as O_2 or perchlorate) and basalt-contained reductants (such as Fe(II)) are a more likely source of bio-available energy on Mars. Recently, is has been shown that microorganisms capable of extracting energy from O_2 and olivine-iron inhabit lava tubes on Earth [2]. These microorganisms are neutrophilic iron-oxidizers, cryotolerant and oxidize olivine at low oxygen partial pressure (e.g. 16 mbar O_2, however the lowest oxygen partial pressure at which these microorganisms can grow has not yet been determined). On Mars, such habitats may be (or have been) present in soil and sand dunes. X-ray diffraction analyses of the Rocknest sand shadow in Gale crater revealed the presence of various igneous minerals, including olivine and pyroxene [3] (both containing Fe(II)). Both mass spectrometery (SAM) [4] and laser ablation spectroscopy (Chemcam) of Mars sand [5] indicated that H is, and water may be, present below the surface. The surface temperature of Mars often reaches habitable temperatures (i.e. above -20^{o}C).

Light band in sand as an energy-rich habitat: MSL's Mastcam and MAHLI images have shown a light layer flanked by dark layers in scooped trenches made in an aeolian sand shadow at Rocknest. This layering may be due to depositional history or chemical changes within the sand. Chemical analyses of vertical chemical gradients indicate that the light band has lower H and higher Fe, Mn (and possibly Cr) than the dark layers above and below it. We hypothesize that this layering is a consequence of redox differentiation (i.e. iron photooxidation and manganese photoreduction) combined with displacement of soluble chemicals following periodic accumulation and diffusion of subsurface moisture (i.e. cycles of condensation and evaporation or sublimation). The resulting energy rich interfaces (i.e. Fe(II):Mn(III-IV)) would be available to microorganisms.

Conclusions: Two potential habitats for life have been identified in Mars' soil and sand: redox interfaces between olivine and surface oxidants; and light bands in the subsurface, hypothesized to be redox interfaces. These habitats could support (or may have supported) chemolithotrophic autotrophs, capable of obtaining energy by neutrophilic oxidation of metals (iron and manganese). Habitability in these environments also depends on the presence of liquid water. The path of Curiosity will likely permit the analysis of these habitats by scooping and analyzing olivine-bearing dunes. Chemical measurements and images taken with the Mastcam and MAHLI will help verify if life relevant chemical anomalies are associated with layers in sand dunes where water is also present. The probability of finding such habitable environments is expected to increase in the vicinity of Mount Sharp in Gale Crater, where aquifers are likely to have been close to the surface.

References: [1] Flynn G. J. (1996) *Earth Moon Planet, 72,* 469–474. [2] Popa R. et al. (2012), *Astrobiology*, *12*, 9-18. [3]. Mahaffy, P.M. et al Fall AGU 2012. [4] Blake, D.F. et al (2013) this mtg. [5]. Wien R. et al. 2013 this mtg.