The modeler's perspective of habitability: key factors and insights from the field. S. M. Som[1,2], K.E. Fristad[3,4], and T.M. Hoehler[1] [1]NASA Ames Research Center, [2]Blue Marble Space Institute of Science (1200 Westlake Ave N Suite 1006, Seattle, WA 98109 – sanjoy@bmsis.org), [3]ORAU/NASA Postdoctoral Program, [4]Western Washington University.

Introduction: We present results of an ongoing project that surveys H_2 concentrations from springs sourced in rock types of varying silica content and in parallel investigate habitability numerically by coupling an equilibrium geochemical model of serpentinization with a single-cell bioenergetic model. Methanogenesis is the metabolism of focus. In particular, we will bridge field work and theoretical work to quantify the concept of habitability and present the necessary field data that enables the numerical assessment of habitability.

Water-rock chemistry in astrobiology: Geological settings dominated by hydrothermal activity are natural targets for astrobiological investigations. The rich geochemical diversity that characterize such sites provide abundant energy to support microbial life. Hydrogen oxidizers are of particular interest because H2-based metabolisms are widespread and deeply rooted throughout the phylogenetic tree of life, implying they may have emerged extremely early in the evolution, and possibly even the origin, of life on Earth and potentially any other rocky body bearing liquid water. Dihydrogen (H2) can be lithogenically produced by the hydrolytic oxidation of the ferrous iron component in Fe-bearing minerals as well as by radiolytic cleavage of water by α, β, or γ radiation produced during the decay of radioactive isotopes. Initial work on lithogenic H2 production has focused on ultramafic serpentinization, as it is occurring on Earth, is known to have occurred on Mars, and is likely occurring on icy satellites such as Europa. Lithogenic H2 production mechanisms, however, can operate across a range of rock types thus increasing the diversity of potential habitats on planetary bodies.

Hydrogen Survey: In order to assess the potential importance of H2-based metabolisms in geologic environments other than serpentizing systems, a field sampling campaign was undertaken in 2013 and 2014 to assess the variation in lithogenic H2 abundance across a range spring waters hosted in non-ultramafic rocks. Aqueous H2 concentrations were measured in spring waters across the western U.S. at sites including Yellowstone National Park, Lassen Volcanic National Park, Idaho Batholith, Oregon Cascades, California's Long Valley Caldera, and Iceland. The springs at these sites are hosted in rocks ranging in composition from mixed alluvial sediments to rhyolite to andesite to basalt. Sampling of dissolved gases was accompanied by measurements of physicochemical parameters including pH, temperature, dissolved inorganic carbon, and major ion chemistry. These field measurements are used in the bio-energetic model to quantitatively assess the habitability index for the various sites. This survey reveals that dissolved hydrogen concentration can vary across several orders of magnitude irrespective of host rock type, and absolute values overlap those found in serpentinizing ultramafic sytems. Thus, this initial survey suggests the possibility for supporting H_2-based metabolisms in a range of geologic environments beyond ultramafics.

Bio-energetic Modeling: Assessment of Gibbs Free Energy change (ΔG) alone is not sufficient to robustly assess habitability. Geochemical assessments of ΔG only describes the energetical potential of a site to host life, but ignores the fact that microbes require a minimum maintenance energy - the energy spent by cells to fix what the environment damages - in addition to any excess energy for growth. This maintenance energy requirement is expected to vary with environmental conditions, such as temperature and pH. From this, we define habitability index as the ratio of the catabolic energy yield available through metabolism (H_2-consuming methanogenesis is considered here) to the energy required for maintenance for the microbe within the physicochemical environment in question. As such, it is both the energy made available by geochemistry and the energy required for biochemistry that define habitability. To efficiently investigate a large array of environmental parameters and their effect on habitability, we numerically couple a geochemical model of water-rock interaction (e.g., serpentinization) with that of single-cell methanogenesis and compute a habitability index for the given environment. In particular, we investigate the control that temperature, rock composition, water composition and water to rock ratio (dilution) has on biological potential.

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