LIFE IN VOLCANIC ROCKS: USING ANALOG BASALTIC ENVIRONMENTS ON EARTH TO ASSEMBLE A HISTORY OF MARTIAN HABITABILITY

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Introduction: Determining the extent to which Mars supported habitable conditions in its past and how those conditions might have changed over time to the present day requires that we understand the association between life and volcanic environments and how geochemical factors influence the suitability of basaltic terrains for life. One approach is to select basaltic terrains on the Earth and investigate their microbial communities under a range of conditions from active fumaroles to largely unaltered rocks. Using field sites in Hawai`i and Idaho under the auspices of the BASALT project funded through the NASA PSTAR program, we propose a timeline of changing Martian habitability based on the microbial communities that inhabit these diverse volcanic environments on the Earth today.

Methods: Samples, collected from field sites at the Craters of the Moon National Monument and Preserve (COTM) in Idaho and the Hawai'i Volcanoes National Park (HVNP), were placed into sterile Whirlpak bags and kept frozen until processing. Samples were obtained from a range of environments that represent general gradients of alteration and volcanic activity: unaltered, cold and hot alteration conditions, and relic and active fumaroles. All sample sets were collected in triplicate from each environment type. Upon return to the laboratory, samples were crushed under aseptic conditions, and DNA was extracted [1]. DNA was sequenced for archaea and bacteria, and the sequence data subjected to clustering analysis to determine groups of phylogenetically related environments.

Results: Hawaiian fumaroles hosted a thermophilic population of organisms including cyanobacterial genera (*Chlorogloeopsis* and *Chroococcidiopsis*) and chemoorganotrophs including *Meiothermus* and *Thermobaculum*. Archaea contained chemolithotrophs such as Nitrososphaera. Cold and hot altered volcanic rocks in Idaho hosted a similar microbial community consisting primarily of heterotrophic, oligotrophic organisms some of which have known desiccation resistance [2]. They included, in the bacterial domain, *Rubrobacter*, *Pseudonocardia*, *Deinococcus*, *Segitibacter*, *Conexibacter*. In many samples unclassified Thaumarchaeota dominated the archaeal population. In general, old, both and hot and cold altered, rocks with little present-day hydrological activity, particularly Idaho rocks, hosted populations of oligotrophic heterotrophs. Organisms capable of chemolithotrophy using plausible redox couples of iron and sulfur were not detected in these terrains.

Discussion: Samples of cold and hot altered volcanic rocks, but no longer within hydrologically active regions, were populated by heterotrophic organisms dependent on an external source of organics or photosynthetically-derived organics, showing that without a flow of water to release electron donors such as reduced iron, volcanic rocks likely primarily act as mere surfaces for microbial growth. The organisms that do inhabit these rocks contain genera adapted to life at low organic concentrations. We explain the results by the fact that without extensive water flow, the kinetic availability of rock-entrained redox couples is low. Without allochthonous organic input, the rocks would have extremely low biomass or be uninhabited [3]. In hydrothermally active regions, such as active fumaroles, we found distinctive thermally adapted communities [4]. These communities contain chemolithotrophic organisms using inorganic compounds such as ammonia generated within the hydrologic system. The breakdown of volcanic rocks and their reaction with hot water generates energy supplies.

These results suggest that we can assemble a putative history of habitability on Mars where active fumaroles and hydrothermal systems on early Mars would have provided sufficient inorganic compounds to sustain chemolithotrophic organisms, but as the hydrological cycle retreated in intensity, so many exposed basaltic terrains became only surfaces for any potential life, even despite availability of redox couples in the bulk state of the rocks. As organic input would have been low from the lack of a photosynthetic biosphere and relegated to meteoritic input, much of the surface of Mars would have been largely uninhabitable, with habitable locations restricted to local regions with active sustained hydrothermal systems. These data show that bulk analysis of Martian rocks does not necessarily provide an indication of the kinetic accessibility of those minerals and thus habitability of the environment.

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