Production of H_2 on Mars Through Radiolysis and Implications for Habitability

JESSE D. TARNAS[1], JOHN F. MUSTARD[1], BARBARA SHERWOOD LOLLAR[2], MICHAEL S. BRAMBLE[1], KEVIN M. CANNON[3] , ANA-CATALINA PLESA[4] AND ASHLEY M. PLUMBO[1]

[1]Earth, Environmental and Planetary Sciences, Brown University, Providence, RI 02912 USA
[2]University of Toronto, Toronto, ON Canada
[3]University of Central Florida. Orlando FL, 32816 USA
[2]University of Toronto, Toronto, ON Canada
Institute of Planetary Research, Berlin, Germany

Protected from harmful radiation, subfreezing temperatures, and low pressures, subsurface rock-hosted habitats likely provide a sustainable refugia for microbial ecosystems inside small rocky planets, such as ancient Mars. On Earth, subsurface microbial ecosystems are widespread in both marine and terrestrial sediment and crust. Subsurface life requires energy to sustain metabolic activity. For many chemolithotrophic communities on Earth, water-rock alteration reactions have been shown to produce the key electron donors and acceptors necessary to sustain microbial life on geologic timescales. In this study we quantitatively demonstrate that radiolysis likely generated sufficient concentrations of dissolved H_2 to sustain microbial communities in the subsurface during Mars' early history prior to 3.5 Gyr. When considering an environment with H_2O groundwater, dissolved H_2 concentrations range from 0-253.9 μM in a cold early Mars climate scenario and 0-205.2 μM in a warm early Mars climate scenario, while when considering an environment with eutectic NaCl brine groundwater, dissolved H_2 concentrations range from 0-349.9 μM in a cold early Mars climate scenario and 0-282.9 μM in a warm early Mars climate scenario, with higher dissolved concentrations near the surface in both cases. Radiolytic H_2 likely produced [1.28-4.79] $\times 10^{10}$ moles H_2 per year globally during the Noachian depending on the assumed surface porosity and groundwater composition. We demonstrate that the region immediately beneath a cryosphere likely contained dissolved H_2 concentrations and temperatures suitable for life regardless of the background climate scenario, making it the most consistently habitable environment on ancient Mars in terms of reductant availability. Modern access to this zone in the ejecta and uplifts of relative recent impacts makes it an intriguing astrobiological target for testing the subsurface biosphere hypothesis