RADIOLYTIC HYDROGEN PRODUCTION ON NOACHIAN MARS, J.D. Tarnas¹, J.F. Mustard¹, B. Sherwood Lollar², M.S. Bramble¹ ¹Brown University Department of Earth, Environmental, and Planetary Sciences (jesse_tarnas@brown.edu), 324 Brook Street, Box 1846, Providence RI, 02906, ²University of Toronto Department of Earth Sciences.

Introduction: Radiolytic hydrogen production sustains deep subsurface microbial communities on Earth [1,2] and is estimated to produce $[1.6-4.7] \times 10^{10}$ moles $H_2$ per year in the Precambrian cratons [2], based on measurements of $H_2$ concentrations in deep groundwaters [1,3]. It has also been proposed as a precursor to current methane production on Mars [4]. Here we model $H_2$ production on Noachian Mars.

Modeling: Our model of Noachian $H_2$ production includes radioactive element concentrations extrapolated from measurements of modern Mars by Mars Odyssey’s GRS [5], a spatially resolved cryosphere depth model based on Noachian heat flux [6,7] and surface temperature [8] models, and modeled Mars porosity [9] using parameter values derived from GRAIL [10] scaled to Mars gravity. Subsurface $H_2$ of greatest biological interest is produced beneath the cryosphere and megagregolith bases as megagregolith contains high fracture apertures, permeability, and porosity relative to underlying bedrock [11], making it the region of highest groundwater content and subcryospheric $H_2$ production. We define this region as the subcryospheric hypermegagregolith-base zone (SHZ). $H_2$ may be dissolved in SHZ groundwaters in concentrations $>0.05$ nM, which is sufficient to sustain microorganisms [12], depending on the $H_2$ diffusion rate through water, ice, and megagregolith rock, as well as its solubility in water in the low temperature, high pressure conditions immediately beneath the cryosphere.

Results: We find the Noachian cryosphere and subcryosphere both produce the same order of magnitude total $H_2$ as the Precambrian craton estimates $[(0.72-2.40) \times 10^{10}, (2.63-6.23) \times 10^{10}$ moles per year, respectively]. As shown in Figure 1, the SHZ contributes $[0.35-1.13] \times 10^{10}$ moles per year to the total subcryospheric $H_2$ production, assuming a 3 km depth megagregolith base. Using a brine-filled pore space increases $H_2$ production [13,14], as does assuming an alternative porosity model [11]. Cryospheric $H_2$ may diffuse through the surface, or be trapped beneath impermeable layers of ice or rock, or potentially stored in $H_2$ clathrates [15].

Discussion: Dissolution of $H_2$ into groundwater was likely highest in the SHZ, which has high porosity, permeability, and fracture aperture. The concentration of $H_2$ dissolved in this groundwater depends on Noachian groundwater volume and distribution, the diffusion rate of $H_2$ through water, ice, and megagregolith, and the solubility of $H_2$ under high pressure, low temperature conditions. The best locations for deep subsurface life on Noachian Mars would therefore be regions in which radioactive element concentrations are high and the thickness of the SHZ is minimized, which equates to higher dissolved $H_2$ concentrations. Alternatively, if there exists a mechanism for trapping large volumes of $H_2$ gas in the subsurface, these gas traps would have significant biological potential.

Conclusions: During the Noachian, radiolysis of pore water in the martian crust produced $H_2$ in volumes potentially sufficient to sustain microbial communities in the SHZ, depending on the diffusion of $H_2$ through water, ice, and megagregolith, as well as the solubility of $H_2$ under low temperature, high pressure conditions. Though it has received limited attention from the community, post-production behavior of $H_2$ is also important to consider in the context of serpentinization-derived $H_2$. Here we have demonstrated that radiolysis produced $H_2$ in biologically significant quantities during the Noachian. Comprehensive models of subsurface Noachian $H_2$ availability must therefore include radiolytic and serpentinization-derived $H_2$, as well as characterization of post-production $H_2$ behavior, which will determine concentration scenarios for both dissolved and gaseous subsurface $H_2$.