HABITABILITY OF SAPONITE-RICH HYDROTHERMAL SYSTEMS OF EARLY MARS AND A MODERN EARTH-BASED ANALOGUE IN ICELAND. R. E. Price[1], H. R. Rucker[2], A. M. Sanchez[1], L. M. Barge[3], T. Ely[4], A. A. Fraeman[3], D. Giovannelli[5], D. LaRowe[6]. [1]Stony Brook University (roy.price@stonybrook.edu), [2]University of Arizona, [3]NASA Jet Propulsion Laboratory, California Institute of Technology, [4]University of Minnesota; 39 Alpha Research (Tempe, AZ), [5]University of Naples, [6]University of Southern California.

Introduction: This presentation will provide an overview and summary of progress for our NASA Habitable Worlds funded project "*Habitability of saponite-rich hydrothermal systems of early Mars*". The overarching goal for this work is to evaluate how, and to what extent, energy generated by ancient, saponite-rich, alkaline hydrothermal settings on Mars, specifically Eridania Basin [1], could have supported biological processes. Our Earth analog, the Strytan Hydrothermal Field (SHF), an alkaline shallow-sea vent located in Eyjafjord, Iceland (Fig 1), is an exceptional terrestrial analogue for past hydrothermal systems on Mars because of its basaltic setting, and associated water-rock chemistry. It is also one of the only places on Earth where massive, hydrothermal saponite is being deposited in an anoxic, alkaline environment, making it an ideal locality for investigating the habitability of similar clay-rich deposits on Mars [2].

Broadly, the targeted goals of our project are to: 1) model the Gibbs energy of the SHF and compare to the putative hydrothermal system thought to have existed on Noachian Mars in Eridania Basin; 2) evaluate the electrical energy generated by Strytan vent precipitates and laboratory simulated precipitates that could support habitability via direct electron transfer to/from precipitates; and 3) evaluate the amount of trapped organic matter in natural and synthetically generated laboratory vent precipitates and relate the results to the energy available for heterotrophic metabolisms.

Quantifying the potential energy yield: For the first objective, we 1) calculated the energetic yield of the SHF using existing and new fluid geochemical data at 10 % and 90 % seawater:vent fluid mixtures, 2) used EQ3/6 to model the expected hydrothermal fluid composition on Noachian Mars in an Eridania vent system during the Noachian (using olivine-rich (16%) and olivine-poor (5%) basalt and rainwater equilibrated with ancient Martian atmosphere), and estimated the basin fluid composition into which the vent fluids would discharge, and 3) calculated the energetic yield of the ancient Martian vent system as vent fluids mix with overlying basin fluids upon discharge (like the SHF calculations, using 10 % and 90 % mixing ratios). The water-rock reaction model was 'ground-truthed' using known SHF vent fluid and subsurface rock compositions [3].

Results: Our model reveals that of the 86 relevant redox reactions that were considered, the most energy yielding reactions in the Eridania hydrothermal system were CH_4 producing, indicating potential for some form of methanogenesis. Four of the top five reactions suggest Eridania basin could have been a habitable environment for methanogens using some form of nitrogen, e.g., N_2 or NH_4^+. In contrast, Gibbs energy calculations carried out for SHF indicate that the most energetically favorable reactions are CO_2 and O_2 reduction coupled to H_2 oxidation, e.g., hydrogenotrophic methanogenesis and H_2S oxidation.

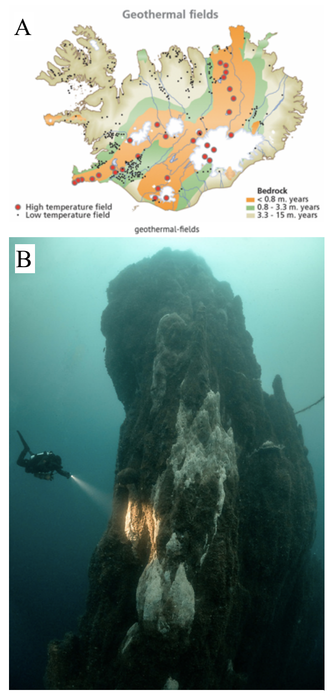

Fig 1. Underwater photograph of the top of Big Strytan (image courtesy of Steve Jones, millionfish.com).

Eridania consistently had a higher potential yield when considering the top five most favorable reactions. This is most likely because the reactions that are favorable at Eridania utilize reactants that are much higher in concentration than at SHF (specifically N-bearing species). Furthermore, differences in Gibbs energies were greatly impacted by the oxic conditions of present-day Earth as compared to ancient Mars. Based on these calculations alone, SHF may not appear to be a good analog for an Eridania Basin saponite-rich hydrothermal system. However, Strytan can serve as a useful analogue for Eridania in many other ways, particularly when studying methane producing reactions that do not involve O_2, e.g., the deep subsurface biosphere of the basalt-hosted, anaerobic "hot aquifer" in northern Iceland. Broadly, it is crucial to understand that modern hydrothermal systems on Earth have too much O_2 to serve as good analogs for early Mars, or even early Earth. Future investigations would be better served to focus on the geochemistry and microbiology of the subsurface, O_2-poor environments.

Vent precipitates, natural and artificial: The three types of chimneys are being evaluated for geochemical and mineralogical characteristics include: 1) numerous natural chimney samples collected from "Big Strytan" in Eyjafjord (Fig 1). 2) chimneys grown in the laboratory at JPL [4], and 3) chimneys grown in our in-situ chimney growth chambers (IGCs) [5]. In particular, selected chimneys are being analyzed with instruments equivalent to the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) and Chemistry and Mineralogy (CheMin) on the Mars Reconnaissance Orbiter and Curiosity rover, respectively. Broadly, this work may provide important implications for the potential habitability of Eridania Basin during the Noachian. For more information, please see abstract #2286 "*Investigating hydrothermal saponite precipitates on Mars using an Icelandic vent analog*" from Sanchez et al, this conference.

In situ artificial chimney growth chambers

IGC chimneys are precipitated by mixing hot, mineral- rich fluids with seawater to replicate the chemical gradients in hydrothermal vents (Figs 2A and 2B; [5]). Thus, the artificial chimney apparatus requires diversion of a natural vent fluid source through the device and into large (2x2x1 m) reservoirs of flowing seawater. The custom- built apparatus consists of PVC pipes with vent fluids continuously discharging out of an outlet. A screen fabric (1 mm mesh size) is overlain on the outlet to provide a surface for precipitates to accumulate. Valves controlling fluid flow determine the rate of chimney growth. By coupling the apparatus with various in situ probes or loggers, chimney properties and their astrobiological implications can be evaluated in several ways. For example, the red wires in Fig 2A are connected to voltage loggers, which record the voltage across the vent chimney as the precipitate forms [6]. This can be used as an indirect proxy for the potential of the chimney to receive or give electrons, e.g., to a microbe [7].

In the future, manipulating the chemistry of natural vent analogues could also enable investigations of habitability in early Earth and extraterrestrial hydrothermal systems. Iron reactivity, for example, is potentially important in the abiotic synthesis of organic compounds on Earth billions of years ago [8]. Conducting iron amendment experiments using IGCs can shed light on the role of iron during the onset of life. Thus, IGCs provide an unparalleled opportunity to advance our understanding of the potential geological and prebiotic chemistry of early Earth and other planetary bodies, wherever aquatic chemical gradients exist. They can drastically improve efforts to constrain or manipulate biogeochemical conditions of vent systems in a laboratory setting. Furthermore, growing chimneys using IGCs with natural vent fluids and seawater are an alternative for long- term sampling, which can prevent damage to natural vents and their ecosystems.

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References: [1] Michalski J. R. et al. (2017) *Nature Communications*, 8, 15978. [2] Price R. E. et al. (2017) *Geology*, 45, 1135-1138. [3] Rucker H.R. et al (*submitted to Astrobiology, Jan 2022*). [4] Barge et al., J. *Vis Exp*, 105. [5] Sanchez A. M. (2021) *Nature Reviews Earth & Environment*, 2, 590. [6] Barge et al. (2015b) *Angewandte Chemie*, 54, 28:8184-8187, DOI: 10.1002/anie.201501663. [7] Ishii et al. (2015) *Front Microbiol*. 2015; 6: 994. [8] Barge et al (2019) *Proc. Natl. Acad. Sci.,* 116 (11) 4828-4833.

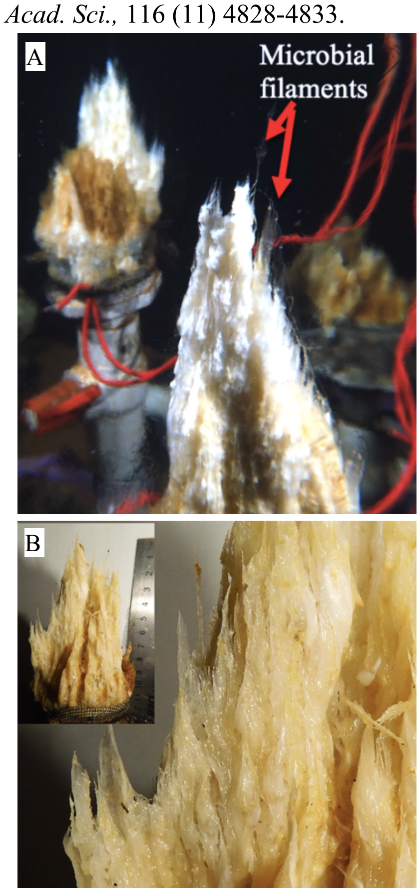

Fig 2. A) Underwater photograph of chimneys growing in our in-situ growth chambers. Note abundant microbial filaments, and red wires recording voltages across the precipitates as they form. B) Close-up view of ICG vent chimney removed from the tank.