HABITABILITY OF ERIDANIA LAKE: AN ANCIENT MARS LACUSTRINE HYDROTHERMAL VENT, COMPARED TO AN ICELANDIC ANALOGUE FJORD SITE. H. R. Rucker[1], R. E. Price[1], T. D. Ely[2], and D. E. LaRowe[3], [1]School of Atmospheric and Marine Sciences, Stony Brook University (roy.price@stonybrook.edu), [2]NASA Postdoctoral Fellow, University of Minnesota, [3]Department of Earth Sciences, University of Southern California

Introduction: Since their discovery in 1977, hydrothermal vents have been proposed as geochemical reactors for the origin of life on Earth and potentially life on other planetary bodies. The mixing of reduced hydrothermal fluid with oxidized seawater creates an environment of chemical disequilibria, which microbes can use to acquire metabolic energy. Putative hydrothermal systems on Noachian Mars are an exciting potential habitable environment for ancient Martian microbiology. If hydrothermal vents on ancient Mars were capable of hosting energetically favorable (i.e. negative Gibbs free energy) reactions that are relevant to microbial metabolism, the vents could have played a significant role in ancient Martian life. A saponite-rich area of interest is the Eridania basin, which once held the largest inland sea on Mars approximately 3.8 billion years ago, and evidence suggests that the basin could have once supported an ancient, alkaline hydrothermal system [1,2].

On planets such as Mars where seas and lakes have since abated, modern Earth analogs can be studied to better understand putative ancient hydrothermal vent systems. The iron-rich altered basalts of Iceland have been used as an analog for Noachian Mars 4.1-3.7 billion years ago. One particular Icelandic analog is the Strytan Hydrothermal Field (SHF), which is a basalt-hosted vent field that produces alkaline (pH ~10) vent fluids in which saponite precipitates, similar to the clay deposits found in the Eridania Basin on Mars [3].

The overall objective of this study is to model the fluid geochemistry of a putative hydrothermal vent in ancient Eridania and then calculate the amount of available energy for microbial metabolism upon hydrothermal fluid and sea-water mixing. The energetics calculations quantify the potential energy available for a given reaction that could be utilized by chemolithotrophic microorganisms. We aim to determine if saponite precipitating hydrothermal vents, such as SHF and our Eridania modeled vent, are capable of maintaining chemical gradients with energetically favorable reaction potentials. The results from this study will provide an assessment of the ability of basalt hosted, alkaline saponite-rich vents to support the metabolic activity of microbes, which is the most fundamental requirement for an environment to be considered habitable [4].

Methods:

Modeling Ancient Mars: To create a modeled rain water that could act as a source for the hydrothermal fluid in Eridania, we established a model of the atmosphere of Noachian Mars. The parameters for our atmospheric model were: 1.5 bar CO_2 at 273 K, with a composition of 92% CO_2, 3.5% H_2, 3.5% CH_4 and <1% trace gases such as CO, NO, N_2, and SO_2 [5]. The Van’t Hoff equation was used to obtain a Henry’s law constant for each gas at the specified temperature (273 K). Using Henry’s Law, we equilibrated our model atmosphere with pure water at a pH 4 to represent an acidic Noachian rainwater. Noble gases Ar, He and Ne were not included in the rainwater model used in EQ3 as these gases do not contribute to the ionic strength of the solution and are not redox active, and therefore not potential sources of energy.

In order to assess how hydrothermal water-rock interactions would influence the chemistry of rainwater, we estimated the composition of Martian basin rocks by varying the major oxide content of olivine using data collected from Backstay rock, located north of Eridania in the Columbia Hills, Gusev Crater [6]. Gusev Crater is a Noachian impact crater with late Noachian-Hesperian age basalts located close to our target location. Therefore, we chose Backstay rock because we consider water-rock reactions within the subsurface rock to be what created the saponite deposits at Eridania. The olivine (more specifically FeO) weight percents used were 5, 10 and 15%, to represent an olivine-poor (5%) to olivine-rich (15%) basalt sample.

Thermodynamics and Energetics: The modeled rainwater was used in the program EQ3/6, which speciates the rainwater, and then reacts it with increasing amounts of Backstay basalt while being heated from 0 to 150°C. To compare this method to our Icelandic analogue, the same process was repeated using an Icelandic rainwater and Icelandic basalt samples. It is important to note that unlike the Eridania fluid, SHF fluids are in contact with O_2-rich seawater on Earth, and therefore variation in atmospheric and seawater composition between SHF and Eridania will likely result in differences in their bioenergetic potentials. The modeled SHF fluid will also be compared to the in-field hydrothermal fluid measurements to verify that the thermodynamic model is working within our constraints.

Using the program SUPCRT [7], we will calculate log *K* for each metabolically relevant chemical reaction and then calculate the overall Gibbs free energy associated with the given reaction using:

$$\Delta G_r = -RT ln \frac{K_r}{Q_r}$$

The resulting values of ΔG_r will be normalized to energy per kg of H_2O, to reflect the amounts of electron donors and acceptors in solution, which tends to more accurately reflect the total amount of energy available in a particular system.

Results: The model calculations produced a Noachian rainwater with a high concentration of $CO_{2(aq)}$ and HCO_3^- at pH 4 (Table 1).

Table 1: *Noachian atmospheric composition and concentration of equilibrated aqueous species in Martian rainwater.*

gas	% in atmosphere	concentration in rainwater (M)
CO2	92.00	1.053e-01
H2	3.50	5.081e-05
CH4	3.50	1.314e-04
N2	0.25	3.771e-06
CO	0.07	1.556e-06
NO	0.10	5.163e-06
Ar	0.25	8.498e-06
He	0.25	1.608e-06
Ne	0.25	2.138e-06

While preliminary, our comparison of the hydrothermal fluid produced for our SHF model in EQ3/6 (orange) to the field data (black) validates our thermodynamic model (Figure 1). With our Eridania basin model constrained, we are currently calculating the energetics of Eridania, and both our SHF model and in-field data for SHF using SUPCRT. The Backstay rock used for our Eridania basin model has slightly more olivine than SHF, suggesting that we can anticipate a higher bioenergetic potential for Eridania. The bioenergetic potential is also a function of the basin fluids, which we know are different between Eridania and SHF due to the differences in atmospheric and seawater compositions.

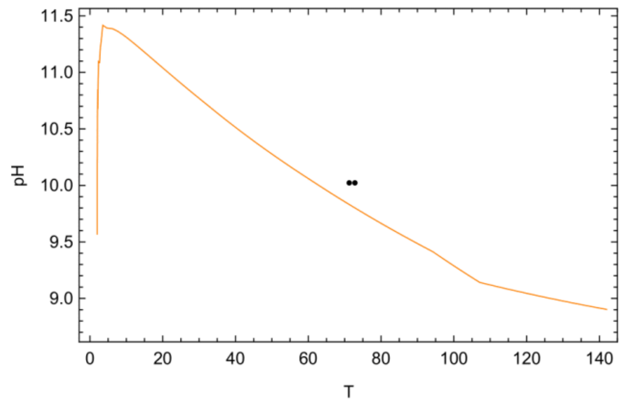

Figure 1: *SHF modeled pH as a function of increasing temperature using the EQ6 water-rock reaction model. Black dots represent field samples collected at Strytan [3,8].*

Conclusions and Implications: This study is the first to our knowledge to evaluate the potential energy available from water-rock reactions using Noachian olivine-rich basalts. The knowledge gained from this study provides insights into the habitability of ancient Mars and the bioenergetics of saponite-precipitating hydrothermal systems. The modeling design of this research could also be implemented for use in studies of hydrothermal vent habitability on other target planets/moons, such as Enceladus and Europa.

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