HABITABILITY OF THE EARLY MARTIAN CRUST AS CONSTRAINED BY HYDROTHERMAL ALTERATION OF A MAFIC DIKE. Justin Filiberto[1], Lacey J. Costello[2], Jake R. Crandall[3], Sally L. Potter-McIntyre[2], Susanne P. Schwenzer[4], Daniel R. Hummer[2], Karen Olsson-Francis[4], Scott Perl[5], Michael A. Miller[6] and Nicholas Castle[1]. [1]Lunar and Planetary Institute, USRA, 3600 Bay Area Blvd., Houston, TX 77058, USA. jfiliberto@lpi.usra.edu, [2]Southern Illinois University, Department of Geology, 1259 Lincoln Drive, Carbondale, IL 62901, USA, [3]Eastern Illinois University, Department of Geology & Geography, 600 Lincoln Ave., Charleston, IL 61920, USA, [4]School of Environment, Earth, and Ecosystems Sciences, The Open University, Walton Hall, Milton Keynes MK7 6AA, UK, [5]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr, Pasadena, CA 91109, USA. [6]Materials Engineering Department, Southwest Research Institute, 6220 Culebra Road, San Antonio, TX 78238-5166, USA.

Introduction: The Martian crust is largely basaltic [1], with a wide range of alteration minerals observed in a wide diversity of settings (sedimentary, post-magmatic, volcanic-hydrothermal and impact generated hydrothermal). Secondary minerals have been observed from orbit, by ground based missions, and in Martian meteorites [2]. Therefore, the observed alteration minerals would have formed from a mafic protolith in a variety of conditions (P, T, and X_{fluid}).

Higher temperature hydrothermal systems, caused by both volcanic activity and impact processes [3, 4], likely dominated the formation of alteration mineralogy on an early Martian basaltic crust. Any potential biological activity would have had to deal with these conditions but, assuming they could survive the high temperatures, could have used the energy and nutrients in a similar manner as organisms inhabiting hydrothermal systems on Earth [5]. As an analog for these processes on the Martian crust, we have investigated a mafic dike that was hydrothermally altered from contact with ground water as it was emplaced. Here we report the alteration conditions of the altered dike and mineralogical constraints on the hydrothermal fluid. This allows us to constrain the potential alteration mineralogy present in the Early Mars crust from high-temperature hydrothermal systems and the habitability potential of such systems.

Field Site: Our field site is located in the Entrada formation on the Colorado Plateau. The investigation focuses on the 22 Ma Robbers Roost dike [6]. The dike intruded though the Jurassic Entrada Sandstone, an iron-cemented red silty-sandstone deposited in an eolian to tidal environment [7]. The dike can be separated into four visually distinct zones based on differences in colors and textures correlated to different degrees of alteration. Samples of each zone were collected and analyzed (**Figure 1**). Further, samples of the surrounding 'baked contact zone' of the Entrada sandstone (**Figure 1**), as well as bleached fractures distal to the dike (**Figure 2**) were collected to constrain the chemistry of the fluid.

Analytical Methods: Bulk composition was measured by an IXRF Systems (Model 550i) energy dispersive X-ray spectrometer attached to a Philips (Model XL-40) scanning electron microscope at Southwest Research Institute in San Antonio. Mineralogy was determined by X-Ray Diffraction and Visible-Near Infrared Spectroscopy. XRD was done for bulk mineralogy, as well as the clay (< 2 μm) fraction.

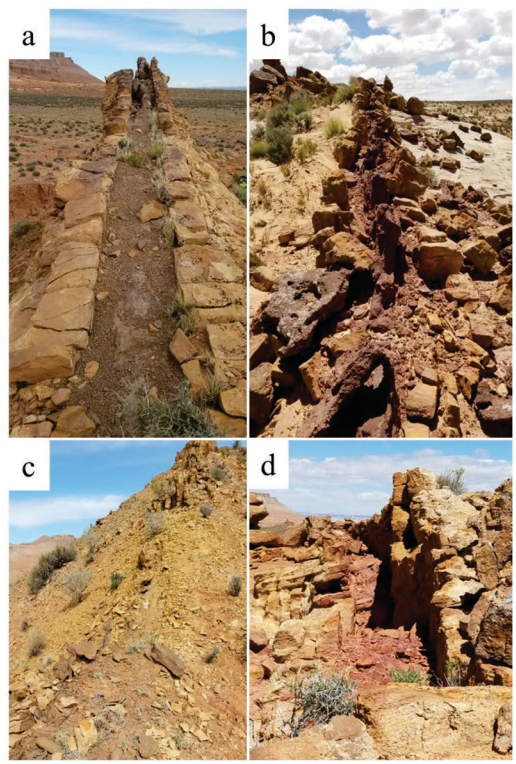

Figure 1. Field site showing each of the four visually distinct alteration zones of the dike. The alteration and oxidation of the dike changes from the 'darkest' zone (a), the 'green' zone (c), the 'purple' zone (b), and the 'red' zone (d).

Figure 2. Bleached zone along a fracture - parallel, but distal, to the dike in Figure 1.

Results: Samples contain calcite, hematite, and kaolinite, with minor goethite, gypsum, and halite. The alteration of the dike can be divided in four zones: a dark, a green, a purple and a red zone (Fig. 1). The mineralogy shows an increase in sulfate and iron-oxide minerals with increasing alteration. Interestingly, even the least altered sample contains alteration minerals.

The bulk chemistry of these four zones is consistent with fluid mobility removing Si and K but adding S, Fe, Ca, and possibly Mg as alteration progresses. Analyses of the contact and bleached zones are ongoing and will be reported at the meeting. These will track how the fluid cooled as it moved away from the dike and interacted with the sandstone. The presence or absence of specific minerals will allow us to put relative constraints on volumes of water that were isolated within secondary alteration products.

Conditions of Alteration of the Dike: Thermochemical models from [8] are used to constrain the alteration conditions. Based on the dominance of carbonates in the mineral assemblage, the fluid was near-neutral in pH [9]. In order for Si to be mobile in a near-neutral pH, high temperatures (>200 °C) would be required. As the system cooled (≥150 °C) carbonates, kaolinite, and hematite precipitated. Goethite would have been produced at lower temperatures. Finally, gypsum and halite would have precipitated from the fluid after formation of a more concentrated brine. Depending on their preserved locations and salinities, these minerals will show the longevity of fluid activity in the layered zones.

Implications for Habitability and Application to Mars: If the requirements for life on Earth are reasonable constraints for potential life on Mars [10], the hydrothermal system that formed during interaction of the magma and ground water would have been a habitable environment once the system cooled below ~120 °C [5]. The fluid within the system would have contained key elements used by microbial life (C, S, and Fe), which could have been utilized as an energy source for chemolithotophic microorganisms [11].

Similar alteration mineralogy has been analyzed at multiple landing sites and from orbit: carbonates with olivine, sulfates, and kaolinite and/or other clay minerals [12-14]. Therefore, this site is an ideal analog location for informing about alteration of the Early Martian crust and it is paramount that future missions, such as Mars 2020 and ExoMars [15, 16], look at the interface of sediments with magmas or impact melts where microbial life, if present, could have taken advantage of a selection of favorable conditions.

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