

Investigation of a Magma-Sediment Hydrothermal Dike System in Utah: Constraints on the Habitability Potential of Martian Noachian Hydrothermal Systems. R. A. Slank¹, J. Filiberto², J. R. Crandall³, V. Tu⁴, G. L. Eggers⁵ ¹The Lunar and Planetary Institute/USRA, 3600 Bay Area Blvd. Houston, TX 77058, rslank@lpi.usra.edu, ²Astromaterials Research and Exploration Science (ARES) NASA Johnson Space Center, ³Eastern Illinois University, Department of Geology & Geography, ⁴Jacobs JETS Contract at NASA Johnson Space Center, ⁵Department of Earth and Environmental Sciences, Wesleyan University.

Introduction: The martian crust is predominantly composed of basalt [1] and hosts a large variety of alteration materials produced by wide-ranging processes from volcanic hydrothermal processes to sedimentary and post-magmatic (e.g., see [2] and reference within). High temperature hydrothermal systems from volcanic processes, as well as meteorite impacts, should have occurred through time [3, 4]. However, finding evidence of high-temperature hydrothermal activity has been challenging. To better understand how to detect such a system on Mars, Earth analogs can be used to constrain mineral changes in such a system, then applied to locations on Mars. Here we investigate a mafic dike and the surrounding metamorphic contact zone that has been hydrothermally altered from contact with ground water as it was emplaced.

Geologic Field Site: DC Dike (DCD) is located on the Colorado Plateau, in south-central Utah. A mafic dike, DCD is part of the San Rafael volcanic field intruding between 3.8 and 4.6 Ma [7] into the Jurassic Entrada Sandstone. The Entrada Sandstone is an iron silty sandstone deposited in an eolian to tidal environment [8]. The earthy Entrada Sandstone varies in color from red to tan. Throughout the gray black dike, there were large xenolith sections of baked Entrada Sandstone, some of which contained crystal pockets.

Other dikes in this area have been explored, including Robbers Roost Dike, which also intruded the Entrada Sandstone, and generated a potentially habitable hydrothermal system [5, 6]. We will compare our results here with those previous results, which investigated a more porous, and less earthy portion of the Entrada Sandstone.

Methods: At our sampling location, the dike was exposed at the surface in an arch shape, with Entrada Sandstone in between the exposed mafic rock (Fig. 1). Multiple rock samples were collected from DCD at six different locations. The first three samples were collected on the left part of the dike arch, with samples 67 and 69 being the altered contact rock and 68 a sample of the dike. The other three samples were from the thicker right side of the dike arch, with sample 70 being the altered contact rock, and 71 and 72 from the dike. Sample 71 had small xenolith pockets in the

sample of mafic rock. Sample 72 was predominately the xenolith rock with crystal pockets, with some of the surrounding dike attached.



Figure 1: Field site of DCD. Six samples were collected, with sample location seen above. 67, 69, and 70 are contact rock. 68 and 71 are from the dike, and 72 has xenolith crystals inside the right side of the dike.

We have chosen Mars analog instrumentation to make our results directly applicable to those on Mars: Visible-Near Infrared reflectance spectroscopy, X-Ray Diffraction, and optical microscopy.

Twenty-one splits of the 6 samples were analyzed with an oreXpress Hi-Res Visible-Near Infrared Spectrometer (wavelengths from 350-2500 nm). Each location on the sample was analyzed twice to minimize movement errors. Every side of the sample was analyzed, as well as any spots that had variation in color or texture. Mineralogy was determined from the spectra using Spectral Geologist following previous procedures [5, 6].

X-Ray Diffraction (XRD) was conducted on the six samples using a multitude of techniques: Bulk XRD, spiked XRD with corundum, 4 sizes of soil separation and clay fractionation, and in a few samples glycolated clays were run on the Panalytical and Rigaku XRD at the Astromaterials Research and Exploration Science (ARES) NASA Johnson Space Center.

VNIR and XRD Results: VNIR spectral analyses for each sample's location were averaged and the mean spectra per location was plotted for comparison (Fig. 2). The contact rock samples are depicted in shades of blue (Fig. 2, A), whereas the mafic dike samples are depicted shades of pink, and the xenolith sample in purple (Fig. 2, B). The contact rocks all have very similar spectra, especially samples 67 and 69. The dike samples are also fairly similar. All 6 locations show strong features at the water absorption bands, 1.4 and 1.9 μm .

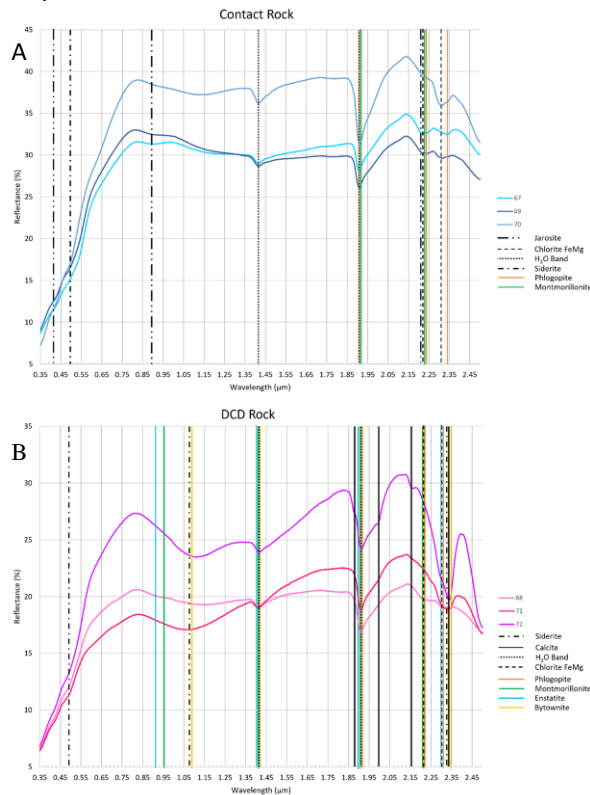


Figure 2: Averaged VNIR spectra from each of the 6 samples collected at DCD. A: The altered Entrada sandstone contact rock. B: The mafic dike, including the xenolith crystals. The sample numbers correspond with the locations depicted in Figure 1.

Eight different minerals were detected by VNIR. Spectral absorptions for jarosite were detected at $\sim 0.41 \mu\text{m}$, $\sim 0.89 \mu\text{m}$, and $\sim 2.21 \mu\text{m}$ for all three contact rock samples, but the signature was stronger for DCD_67 and DCD_69. Siderite, phlogopite, and montmorillonite were detected in all 6 samples. Chlorite FeMg was detected in all of the rock samples, except the one with xenolith crystal pockets. Calcite, enstatite, and bytownite were detected in all three mafic dike samples.

The XRD results are broadly similar to the VNIR results, but revealed more details, especially the

corundum spiked approach (giving mineral proportions) and the clay fraction XRD. Sample 67 was composed of quartz, montmorillonite, andesine, and calcite. The other two contact rocks were composed of quartz, montmorillonite, and andesine. However, the other XRD runs did detect other minerals including jarosite, biotite, and vermiculite. The mafic dike rocks had a more complex mineralogy. Sample 68 was composed of montmorillonite, andesine, pyroxene, biotite, calcite, and quartz. Sample 71 was composed of montmorillonite, andesine, pyroxene, biotite, and vermiculite. Sample 72, the one with the xenolith crystal pockets, was composed of calcite, montmorillonite, andesine, pyroxene, biotite, and quartz. All the minerals detected by VNIR and cristobalite were also detected in other XRD analysis.

Preliminary Conclusions: Vermiculite is consistent with hydrothermal alteration of a mafic protolith, suggesting fluid mobility in the system as it formed and cooled. This also led to mineralogical changes observed including the formation of jarosite, carbonates, and other clay minerals, as the system cooled and evolved. Based on the mineralogy, and detection of vermiculite and jarosite, this system could be a good analog for Mars where jarosite was detected at multiple locations including from orbit at Mawrth Vallis [9] and in situ at Meridiani Planum [10] and vermiculite has been detected at Jezero Crater [11] and has been suggested to widespread on Mars [12]. Ongoing optical microscopy will help reveal the sequence of alteration mineral formation, which is needed to determine how the fluid evolved upon cooling and whether the fluid could have been a habitable environment. Finally, we will use the mineral changes seen in the analog system to locate similar locations on Mars.

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