

HYDROTHERMAL ALTERATION OF MARTIAN BASALT: AN EXPERIMENTAL STUDY. N.J. DiFrancesco¹ H. Nekvasil and D.H. Lindsley, ¹Stony Brook University Department of Geosciences, Earth and Space Sciences Building, Stony Brook, NY 11794. Nicholas.Difrancesco@stonybrook.edu

Introduction: The precise history of water-rock interactions on the Martian surface is unclear. Undoubtedly in the past, there was a far greater volume of water at or near the surface, as evidenced by large amounts of phyllosilicates identified in situ and from orbit; as well as fluvial and lacustrine surface features¹. The presence of these alteration minerals is clear evidence of the interaction between water and rock over some extended period of time². Most of the hydrated silicates that are present are restricted to the early-mid Noachian crust (the earliest epoch on Mars), stratigraphically below most sulfates. These sulfates are presumed to have formed in the late Noachian through the Hesperian³ when there was less free water available. They are intermixed in some cases with carbonates.

While there is compelling evidence for at least isolated areas of standing water on the Martian surface during the Noachian⁴ some observed phyllosilicates require higher temperatures and pressures for formation. Minerals such as serpentine, illite, and prehnite are indicative of formation temperatures that could not be achieved reasonably at the surface².

Sulfates such as jarosite are also important indicators of water-rock interactions in the past. The vast majority of workers have identified jarosite as the product of low temperature precipitation from highly acidic and saline waters⁵, yet this mineral is capable of forming at other conditions not unique to the Martian surface. Identifying a mechanism for the production of jarosite that does not require highly acidic waters at the surface could help to satisfy problems of carbonate exposures in association with jarosite and other sulfates.

Evidence for hydrothermal alteration phases is present in some meteorites. MIL03346, for example, contains jarosite, as part of a melt inclusion within a clinopyroxene grain⁶. Figure 1 shows the nature of this inclusion, demonstrating that it has formed fully within a crystal that had formed as part of a silicate melt. Fluids trapped within the inclusion partitioned a vapor phase and silicate melt. The melt crystallized the mineral pyrrhotite, which reacted with the vapor phase, and precipitated the jarosite at temperatures as high as 200°C⁶. This is strong evidence that jarosite is capable of forming at hydrothermal conditions in the subsurface, independent of the planet's water cycle. Precipitation of the jarosite phase was enabled by several factors, but especially the presence of pyrrhotite, as it was

a source of sulfur, but also chlorine in the melt which helped to decrease the pH of the vapor/fluid⁶. These melt inclusions also provide evidence of fluid-saturated magmas on Mars, at least towards the end of their fractionation history. Thus magmatic water could be an important agent of element exchange, and therefore play a large role in subsurface alteration particularly once the activity of planetary water waned.

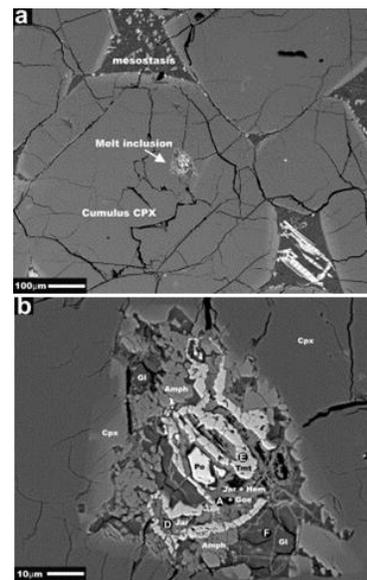


Figure 1: Back-scattered electron images of the jarosite-bearing melt inclusion (a) low-magnification image showing the cumulus clinopyroxene host and surrounding mesostasis. (b) High-resolution image of jarosite-bearing melt inclusion with phases identified. Phase abbreviations are indicated as follows: Jar, jarosite; Tmt, titanomagnetite; Hem, hematite; Goe, goethite; Amph, Cl-rich amphibole; Po, pyrrhotite; Gl, Fe-Si rich glass; and Cpx, clinopyroxene host. (from McCubbin et al. 2009)

Goals: The broad goal is to be able to distinguish areas on Mars that may have been compositionally modified by interaction with magmatic fluid, particularly during the latest/driest alteration history. Experiments were designed to evaluate the first order modification of subsurface wall rock and to determine the spectral “footprint” of the alteration products, specifically in the visible near infrared (VNIR) and mid infrared (MIR) wavelengths.

In order to evaluate compositional changes due to magmatic fluid/wall rock interaction, the experiments were designed in a manner as to allow fluid to be

exsolved from a magma and interact with a basaltic wall rock. The fluid source was supersaturated Irvine composition basalt, and the wall rock was partially crystallized Irvine basalt. The interaction takes place at low pressure, in a thermal gradient in order to simulate natural processes.

Preparation of Materials: MER Spirit identified the basalt Irvine as a good candidate for a “pristine” volcanic rock. It is fine-grained, appears to have a homogenous texture and has a chemical composition typical of basalt. This was chosen here for study.

A synthetic, powdered mixture of Irvine composition was produced using oxides, silicates and Fe^0 sponge. A second mixture was produced of identical composition, except sulfate was added (in the form of MgSO_4) to study the effects of sulfur during high temperature alteration. These mixtures are being used as “target rocks” for alteration experiments. Each mix was packed into graphite capsules, and loaded into a piston-cylinder press. The target rock was synthesized by pressurizing the sample to 0.5 GPa, initially heating to 1300-1400°C to completely melt it, then quickly dropping temperature (isobarically) to ~800°C to crystallize.

Two additional mixtures of Irvine composition were synthesized, however these were produced with 4% chlorine in one and 4.65% water in the other. These mixtures are being used as “source rocks” for the alteration experiments. The water-rich material was loaded into a graphite capsule, placed into a piston-cylinder press, pressurized to 1.0 GPa, and melted at 1400°C, then quenched to form a glass. An identical procedure was used for the Cl-rich composition, however to mitigate potential Cl-gas interactions with our thermocouple, and for the purposes of retaining the maximum amount of Cl in the glass, the mixture was loaded into a graphite-lined cobalt capsule that was sealed with a lid. The graphite liner was closed with a lid; these were used to prevent excessive diffusion of Co into our glass.

Experimental Design: After all materials have been initially synthesized, lightly ground crystalline target rock is loaded into a gold capsule, a spacer (cobalt tube or mesh) is then inserted, and finally the source rock glass is placed on top, and the capsule is welded shut. The entire capsule is then loaded into a hydrothermal pressure vessel (cold-seal bomb), that is then placed partially inside of a horizontal furnace. The end of the pressure vessel that is sticking out of the furnace is wrapped with copper tubing hooked up to a water chiller. This will cool the outer part of the pressure vessel creating a steep temperature gradient. By orienting our Au-capsule such that the end containing the “source rock” is deeper in the furnace allows this

glass to exsolve trapped fluids (Cl , H_2O , HCl) to interact with a much cooler “target” rock at the opposite end of the capsule (See figure 2). The entire system will be pressurized to 0.1 GPa.

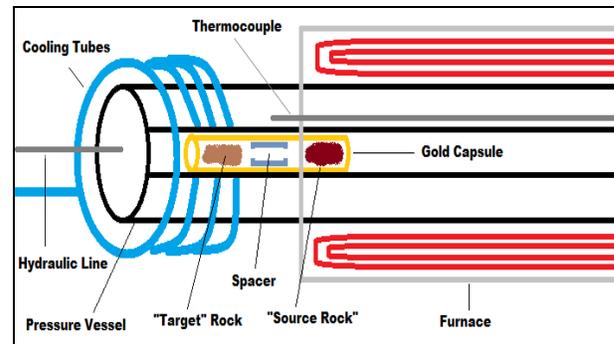


Figure 2: Cutaway of hydrothermal pressure vessel with capsule inside of horizontal furnace.

Different proportions of Cl and H_2O -bearing glasses will be studied at variable temperatures, pressures, and experiment durations. The spacer inserted allows separation between the source and target materials, while still allowing fluids to freely flow between either end of the capsule. Separation of each material will help alleviate any confusion when recovering the experimental products for analysis.

At the conclusion of each experiment, material will be carefully removed from the capsule for analysis. Electron microprobe studies will be conducted at the American Museum of Natural History, in NYC. This will allow us to gain chemical data of altered phases, and identification of new ones. X-ray diffraction data can be collected from the Scintag XRD at Stony Brook University, as well as VNIR and MIR analyses that can be performed at the vibrational spectroscopy laboratory at SBU. Preliminary results from this study will be presented.

References: [1] Mangold N. et al. (2012) *Icarus* 220.2 530-551. [2] Ehlmann B.L. et al. (2011) *Clays and Clay Minerals*, 59(4), 359-377. [3] Ehlmann B.L. et al. (2008) *Science*, 322(5909), 1828-1832. [4] Squyres S.W. et al. (2006) *Science*, 313(5792), 1403-1407. [5] Murchie S.L. et al. (2009) *J. Geophys. Res.*, 114 E2. [6] McCubbin et al. (2009) *GCA* 65(24), 4551-4565.