

EFFECTS OF MAGMATIC VAPOR MINERAL DEPOSITION ON IR SPECTRA OF MARTIAN SOIL CONSTITUENTS. N.J. DiFrancesco¹, M. Yant¹, H. Nekvasil¹, Rogers, A.D¹, and D.H. Lindsley¹. ¹Stony Brook University Department of Geosciences, Stony Brook, NY 11794. Nicholas.difrancesco@stonybrook.edu

Introduction: Several workers have suggested that parts of the Martian surface have been shaped by magmatic vapor, or fumarole alteration [1,2]. On Mars, these vapors are derived from magmas that can be quite rich in volatiles such as H₂O, S and Cl. As these melts approach the surface, the volatile components become supersaturated and begin to exsolve as a gas. When these vapors reach the surface and cool, the regolith and rock exposed to them can be altered or new material can be directly deposited from the vapor. Sample observations may be able to resolve the nature of these deposits, however, much of the surface has only been observed remotely (e.g.- spectroscopically). Therefore, it is important to understand how the interaction of surface minerals with magmatic vapor changes their spectral signature.

As shown by DiFrancesco et al. [4], vapors from magmas containing high Cl/H₂O ratios can transport a variety of cations with Cl. Such magmatic vapors can condense onto cool surfaces and form deposits or coatings of salts. Rock that is near the source of the vapors will become coated in salts precipitated from the primary vapor stream. Rock further from the vapor source could be coated by smaller particulate material from aerosols carried by wind. These salts can react with moisture at the surface to form brines, or, through UV irradiation, form perchlorate salts. However, the primary deposits could also persist unmodified at the surface for extended periods of time. Developing criteria for identifying igneous vapor deposits on the surface could prove useful for locating paleo-volcanic systems which could have developed into sites of hydrothermal activity.

Remote infrared spectroscopy is a primary vehicle for inferring the composition and mineralogy of the Martian surface. Thus, it is important to determine if a signature of vapor deposits can be determined from orbit. This study attempts to show how magmatic vapor deposition affects the infrared spectra of various common crustal materials.

We have simulated a magma with a composition reflective of a typical Martian basalt into which the volatiles sulfur, water and chlorine were doped at different concentrations. Upon heating above the solidus temperature, the source magma began to boil and exsolve vapor. A silicate glass or mineral “target” was suspended in the path of these vapors to allow interaction with the gases and to provide a substrate for deposition of mineral phases directly from vapor. The properties of these

deposits and changes in mineral spectra were investigated.

Detailed Methods: A source magma with a composition of a well-studied Martian basalt Irvine [5] was synthesized from a variety of oxides, silicates and iron metal, with variable amounts of brucite (as a source of water), magnesium chloride (as a source of chlorine), magnesium sulfate and pyrite (as a source of sulfur). The powder was loaded into capsules as is, or in some cases, was first melted at elevated pressure in a piston cylinder experimental press, rapidly quenching to a glass (to simulate production of a magma at depth), then recovered, crushed, and loaded into capsules. For the degassing, Au₈₀Pd₂₀ capsules were used to minimize Fe loss from the source magma to the capsule. This container was welded shut at one end, but left open at the opposite end, allowing vapors to be released while the magma was boiling.

The source capsule was placed at the bottom of a long silica glass tube. Above the capsule, the tube was heated by torch, and stretched to form a “neck” (Fig. 1). The target material, wrapped in Pt wire, or encased in a gold mesh bag, was placed at this point, so that vapors produced from the source would be concentrated, and forced through/past the target. The tube was then evacuated and sealed shut by heating. Because the tube was placed inside a vertically-oriented furnace with a measured temperature gradient, varying the height of the “neck” allowed us to keep the target material at different temperatures.

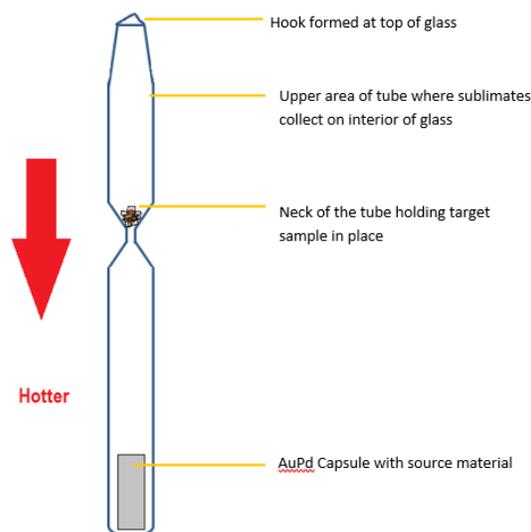


Figure 1: Experimental setup.

Four different target materials were used for these experiments - three natural terrestrial minerals, olivine, plagioclase, and pyroxene, as well as a synthetic glass with a composition identical to the source magma, however with no volatiles. These materials were chosen primarily because they are prevalent at the Martian surface, and because these mineral phases have very distinctive IR signatures, making it easy to identify changes to their spectra after deposition of magmatic vapor deposits. Target materials were either in the form of sand-sized grains or >1 mm “chunks”.

Vapor deposits were first characterized by scanning electron microscopy and dispersive spectroscopy, to understand the mineralogy and chemistry of deposits. Infrared spectroscopy was carried out on the target material before and after exposure to magmatic vapors. Spectra were collected using a Thermo Fisher Nicolet 6700 FTIR spectrometer. TIR spectra were acquired in the range of 350-2000 cm^{-1} .

Results: At the end of the experiments the target materials were visibly discolored or appeared to have surficial crusts or coatings of other minerals. SEM study of the target material and inner walls of the glass tubes demonstrated that chlorides and sulfides were deposited onto these surfaces from vapor that degassed from the source magma. The specific chlorides halite, sylvite, and molysite were identified from SEM analyses. Sulfur was deposited in elemental form, as well as in the iron sulfide, pyrrhotite. A nickel sulfide was also identified on the surface of the olivine target, suggesting that some reaction of vapor and the target was taking place. In addition, minerals of unknown stoichiometry containing Mg, Al and Ca were also seen. An unknown form of silica was found in small rounded clusters of crystals.

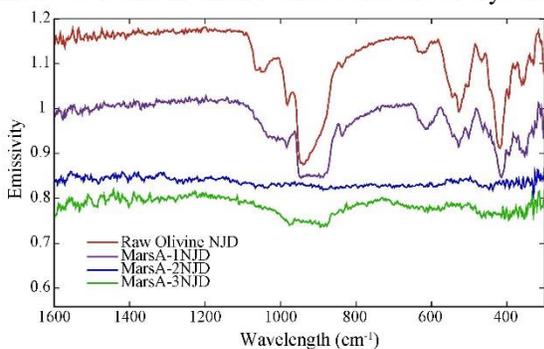


Figure 2: Spectra of unaltered olivine (red), compared to olivine exposed to magmatic vapor in various experiments, which differ in volatile content and temperature. Spectral differences between altered samples could be due to either the proportion of vapor deposits or the particle size of the target material.

TIR spectra of the materials after vapor deposition revealed that there was significant change in the spectral

signature of the silicates as a result of deposits. The most noticeable feature of the spectra when compared to their unaltered analyses was the intense loss of signal, or shallowing of the the spectral features for the altered materials.

Spectra collected of olivine (Fig. 2), before and after the experiments, showed the loss of a major absorption feature at 1100 cm^{-1} after exposure to vapor. Plagioclase and pyroxene also demonstrate this (Fig. 3).

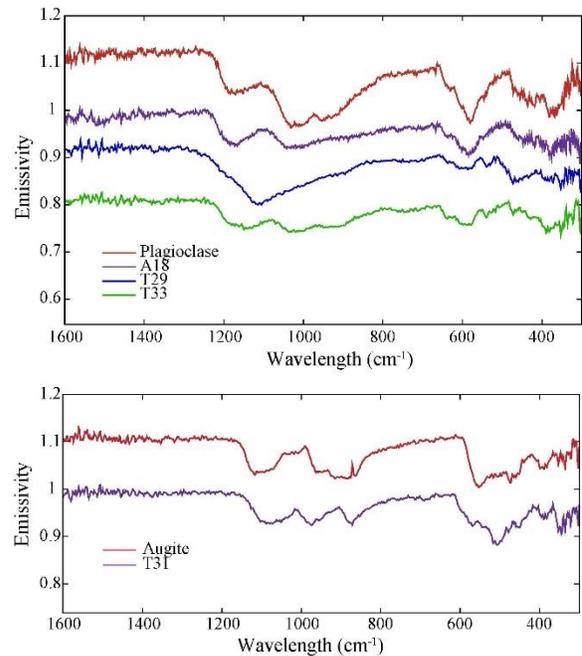


Figure 3: Plagioclase (above) and pyroxene TIR spectra before (red) and after exposure to magmatic vapors.

Discussion: These results confirm the effects of halide coatings on TIR spectra that other workers have noted, which is that spectral features of the substrate can be reduced, modified or obscured [6,7]. However, it also shows that such coatings can be produced magmatically without aqueous activity. Further work to discriminate the spectral differences of evaporative coatings from lacustrine sediments and those from magmatic sources is also needed. Such information may help to discern locations of recent volcanic outgassing on the Martian surface.

References: [1]Mcollom and Hynek 2005 Nature. [2]Syquers et al. 2008 Science. [3]Wanke et al. 1994 Roy. Soc. [4]DiFrancesco et al. 2015 LPSC. [5]McSween et al. 2006 JGR. [6] Jensen and Glotch 2011 JGR. [7] Berger et al. 2015 JGR.

Acknowledgements: This work was supported by NASA MFR NNX13AG82G to H. Nekvasil. and A.D. Rogers.