DETERMINING THE PROVENANCE OF ALTERED BASALTIC CLASTICS BASED ON VNIR AND TIR SPECTROSCOPY: RELEVANCE FOR MARS. W.H. Farrand[1], S.P. Wright[2], and T.D. Glotch[3]. [1]Space Science Institute, 4750 Walnut St., #205, Boulder, CO 80301, farrand@spacescience.org, [2]Auburn University, Auburn, AL, [3]Stony Brook University, Stony Brook, NY.

Introduction: Mars is a planet dominated by basaltic volcanism. It has been suggested that its early volcanic history produced great quantities of clastic materials while later volcanic activity was largely effusive [1]. Flood basalt plains on Mars are riddled with craters and this cratering in turn produced ejecta of comminuted basalt. Superimposed on these primary materials is a history of aqueous alteration- nominally most active in Mars' early history. Spirit, Opportunity, and Curiosity have all found basaltic sandstones altered to varying extents [e.g., 2-4]. Disentangling the origin of these materials, (e.g., are they of volcanic or impact origin?) and what type of aqueous alteration they have experienced is a non-trivial task. This task is aided by examination of terrestrial analog materials. In our study, we have been examining clastic basaltic materials of hydrovolcanic, glaciovolcanic, and explosive eruptic origin and comparing them with basaltic ejecta from the Lonar Crater impact site [e.g., 5]. We have sought to use analysis techniques analogous to those available to the aforementioned Mars rovers focusing on VNIR and TIR reflectance and emittance spectroscopy with supporting information from thin section petrography and XRD analysis.

Alteration Pathways: There are several ways in which clastic basaltic materials can undergo alteration. These different alteration pathways can provide information on how the materials were formed and what type of environment was extant at the time. Some hydrovolcanic materials can undergo rapid alteration through the process of palagonitization in some tuff rings and tuff cones if they are emplaced "wet" with steam adhering to particles [6]. Unless subjected to some hydrothermal alteration, explosively generated basaltic ash tends to follow a pedogenic alteration pathway [7] leading to disaggregated tephras which when altered have been described as "palagonitic".

Field Sites: From past work, our team has samples from glaciovolcanic tuyas and tindars and from explosive volcanic basaltic ash from Haleakala. In addition, further sampling and field work was conducted in the summers of 2012 and 2013 at multiple hydrovolcanic eruption sites in Idaho, New Mexico, and Utah. In addition, one of our team has also conducted extensive field work at Lonar Crater [5].

Analysis Techniques: The 0.3 – 2.6 μm bidirectional and 0.83 – 25 μm biconical reflectance of a number of samples were measured at RELAB. MWIR emissivity was measured at Arizona State University and at Stony Brook University. Additionally, thin sections were prepared and examined using standard petrography and with a micro-FTIR reflectance spectrometer at the Stony Brook University Vibrational Spectroscopy Laboratory. XRD analysis of samples at Auburn University is on-going.

Differences Resulting from Modes of Formation and Alteration: In [7], Schiffman et al. described the differences in tephra altered through pedogenic and through palagonitic alteration. The former were disaggregated, lacking in smectites, but bearing poorly crystalline minerals such as allophane, imogolite, and ferrihydrite. The latter were well cemented with smectites and zeolites forming in the interstices between palagonitized glass grains. VNIR – MWIR reflectance spectra of pedogenically vs. palagonitically altered tephras were shown in [8] and VNIR spectra of our own examples of these alteration pathways are shown here in **Fig. 1**. In the VNIR, palagonitically altered tuffs have deeper 1.4 and 1.9 μm water absorption bands and can have a 2.29 μm Fe or Mg-OH overtone band. Even at the multispectral resolution of the MER Pancam differences were noted in spectral parameter plots of 754 to 1009 nm slope vs. 904 nm band depth between a suite of palagonitically altered hydrovolcanic ashes and tuffs from the Idaho field sites vs. pedogenically altered volcanic soils from Haleakala, Hawaii (**Fig. 2**).
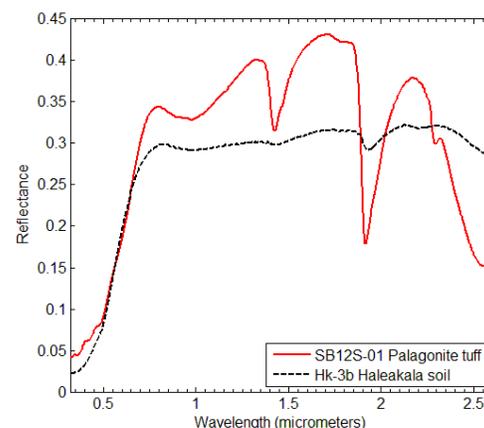

Fig. 1. Reflectance spectra of palagonitically altered hydrovolcanic tuff from Sinker Butte, ID (SB12S-01) and pedogenically altered tephra from Haleakala, HI.
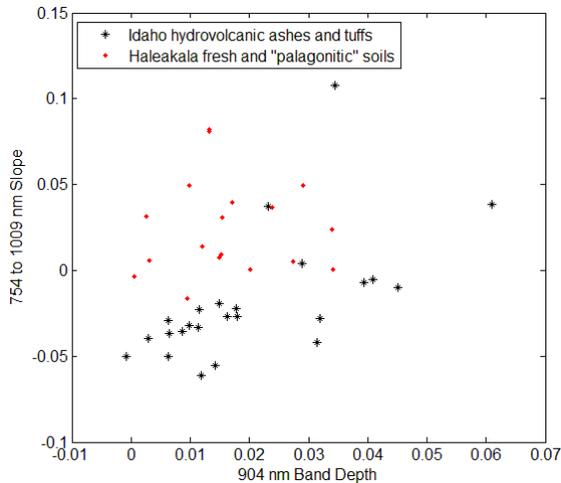
Fig. 2. Detectability of spectral differences between pedogenically and palagonitically altered basaltic glass.

Deconvolution of MWIR Spectra: The collection of micro-FTIR image cubes of a number of samples allowed for the isolation of pure spectra of basaltic glass and of palagonite rinds. Through application of Kirchoff's Law these were used as endmembers in a 30 endmember spectral library for application of linear deconvolution [9] to the bulk sample emissivity spectra of other samples. We had very few emissivity spectra of pedogenically altered samples but compared spectra of palagonite tuffs from tuff rings and tuff cones and of palagonitized glaciovolcanic hyaloclastites. These also represent different environments of formation depending on the mode of emplacement.

A sample measured and modeled deconvolution is shown in **Fig. 3** and **Fig. 4** shows estimated modal abundances of materials from hydrovolcanic palagonitically altered ash and subglacially emplaced partially palagonitized hyaloclastites. The latter are generally lacking in zeolites, a later stage alteration product of the palagonitization pathway, and have higher oxide (hematite and magnetite) abundances. Whether the latter is simply a product of differences in the magma or more rapid devitrification of the basaltic glass is unknown.

References: [1] Bandfield J.L et al. (2013) *Icarus*, *222*, 188-199. [2] Squyres S.W. et al. (2005) *JGR,111*, 10.1029/2005JE002562. [3] Squyres S.W. et al. (2009) *Science, 324*, 1058. [4] Grotzinger J.P. et al. (2013) *Science*, DOI: 10.1126/science.1242777. [5] Wright S.P. et al. (2011) *JGR, 116*, 10.1029/2010JE003785. [6] Wohletz K.H. and M.F. Sheridan (1983) *Am. J. Sci., 283*, 385-413. [7] Schiffman, P. et al. (2000) *G3, 1*, 2000GC000068. [8] Schiffman, P. et al. (2002) *Geol. Soc. London Spec. Pub. 202*, 395-405. [9] Ramsey M.R. and P.R. Christensen (1998) *JGR, 103*, 577-596. [10] Schopka, H.H. et al. (2006) *JVGR, 152*, 359-377.

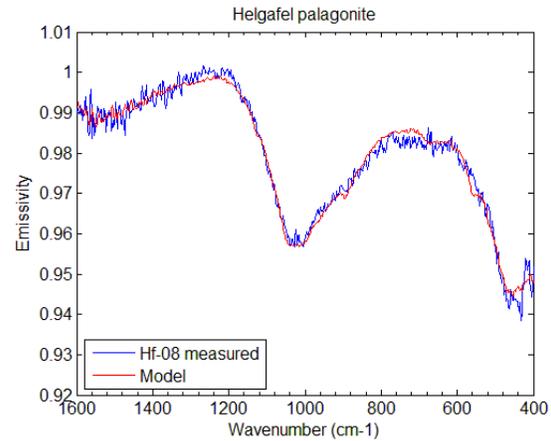**Fig. 3**. Measured (blue) and modeled (red) spectra of palagonitized hyaloclastite sample Hf-08 from Helgafel tindar Iceland [10].
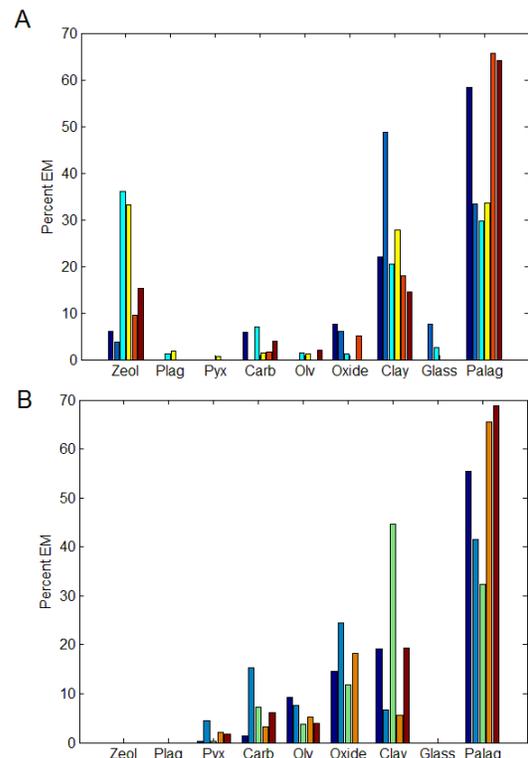

Fig. 4. Fractional abundances of mineral groups derived from (**A**) hydrovolcanic palagonite tuff samples and from (**B**) glaciovolcanic palagonitized hyaloclastite samples.