CONSTRAINTS ON MARTIAN SURFACE MATERIAL FROM A STUDY OF VOLCANIC ALTERATION IN ICELAND AND HAWAII. J. L. Bishop[1], P. Schiffman[2], R. J. Southard[3], A. Drief[2], and K. L. Verosub[2], [1]SETI Institute/NASA-ARC, MS 239-4, Moffett Field, CA 94035 (jbishop@mail.arc.nasa.gov), [2]Dept. of Geology, UC Davis, Davis, CA, 95616, [3]Dept. of Land, Air & Water Resources, UC Davis, Davis, CA, 95616.

Abstract: Subaerial volcanic activity on Hawaii and subglacial volcanic activity on Iceland has led to the formation of a variety of silicate and iron oxide-rich alteration products that may serve as models for chemical alteration on Mars. Multiple samples have been collected from palagonitic tuffs, altered pillow lavas, altered tephra, and S-rich vents for study in the lab. Variations in the kinds of alteration products have been observed depending on the alteration environment of the sample. We are working on building associations between the alteration products and formation conditions that can be used to provide information about environmental conditions on Mars.

Introduction: The surface mineralogy on Mars holds information about the climatic and geochemical record that may provide clues to when water was present. The rock compositions are basaltic to andesitic [1, 2, 3] and many of the rocks near the Pathfinder lander contain surface coatings [4]. The soils contain elevated Fe and S levels compared to the rocks [5, 6] and definitive identification of specific minerals has been difficult because of the poorly-crystalline phases in the soils. The alteration processes that control which silicate and iron oxide/oxyhydroxide (FeOx) minerals form are directly linked to environmental conditions and physical factors on Mars. Spectroscopic analyses of terrestrial soils and alteration products with known weathering histories and formation conditions are essential for interpretation of the martian spectra.

Geochemical and mineralogical analyses were performed earlier [7, 8, 9] for some of the samples described here. New measurements have been made on an Icelandic sample from an active fumerole region and integrated analyses are underway in order to synthesize the chemical, mineralogical and spectroscopic data from these recent studies. Reflectance spectra, scanning electron microscopy (SEM), X-ray diffraction (XRD), <2 µm sediment fractionation, and dithionite iron dissolution have been performed on this new sample as in previous studies [8, 9]. Detailed high resolution transmission electron microscopy studies of selected samples are underway in order to characterize the grain morphology and intimate character of altered volcanic material from Hawaii and Iceland. Magnetic measurements for a number of these samples are also being performed in order to identify the magnetic minerals present and characterize the magnetic properties of volcanic alteration products from several environments.

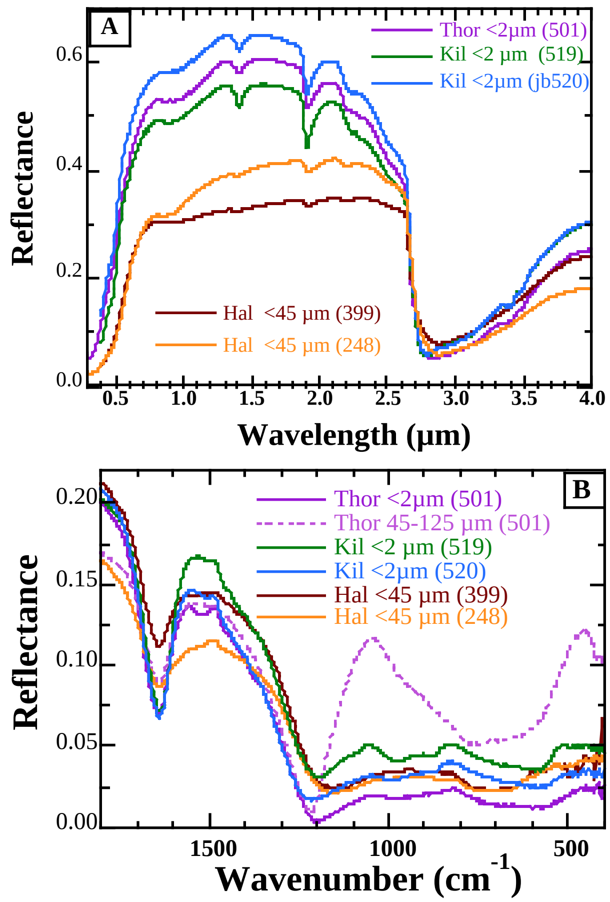

Fig. 1 Reflectance spectra of palagonitic tuffs (Thórólfsfell, Kilauea) and altered rind material (Haleakala): (A) VNIR and (B) mid-IR regions.

Palagonitized Tephra: Samples of palagonitized tephra from the Kilauea caldera, Hawaii, the Haleakala crater basin, Maui, and Thórólfsfell ridge, Iceland are compared in this study. The Kilauea and Thórólfsfell samples are palagonitic tuffs, whereas the Haleakala samples are the fine-grained material from the outer surfaces of loose tephra as it becomes altered. Reflectance spectra of these samples are shown in Fig. 1. The visible/near-infrared (VNIR) spectra in Fig. 1A show strong smectite and serpentine bands for the palagonitic tuff samples compared with the broadened and weaker OH and water bands observed for the altered rind material (Haleakala samples). Mid-IR spectra of the coarse-grained Thórólfsfell sample in Fig. 1B is characteristic of basaltic glass, while the fine-grained component of this and the other samples exhibit spectral features more characteristic of clays and amorphous material.

Pedogenically Altered Tephra: Samples of pedogenically altered tephra from the Kilauea caldera, Hawaii, are compared with a pillow lava from Hlödufell tuya, Iceland, that was altered in a high moisture environment. Reflectance spectra of these samples are shown in Fig. 2. The fine-grained fraction of altered material from Hlödufell tuya exhibits much stronger clay and nanophase iron oxide bands than do the samples from Kilauea. Both groups of samples contain large quantities of hydrated, amorphous iron oxide and silicate components. The <125 µm Hlödufell sample is magnetic and exhibits a broad ferric-ferrous band near 1 µm that is similar to the features observed for some rock coatings near Pathfinder.

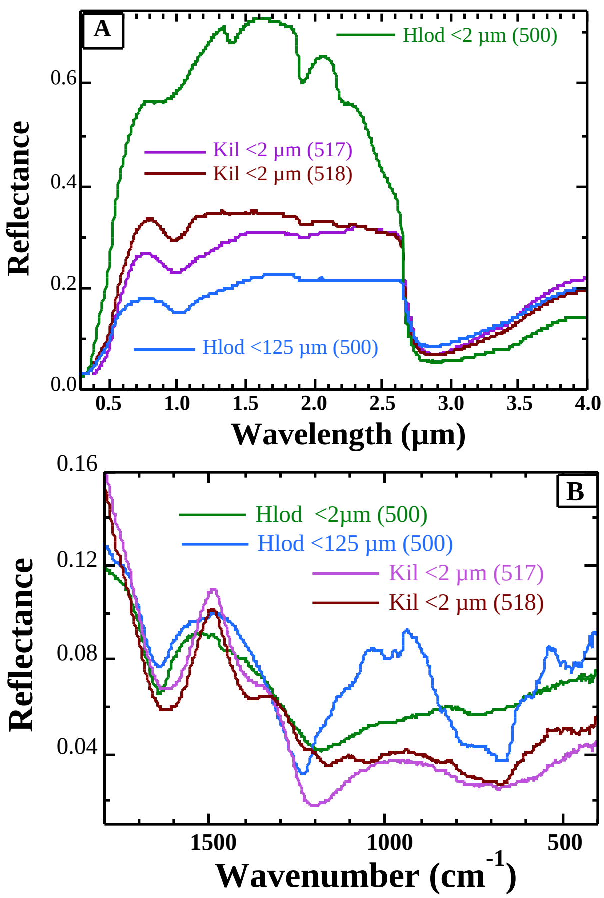

Fig. 2 Reflectance spectra of pedogenically altered volcanic material from Iceland (Hlödufell) and Hawaii (Kilauea): (A) VNIR and (B) mid-IR regions.

Solfatarically Altered Tephra: Samples of solfatarically altered tephra collected on (250, 394) and near (397) the rim of a cinder cone in the Haleakala crater basin, Maui, are compared with portions of a sulfur-crusted palagonitized tuff from an active fumarole/hot spring at Seltun Krysuvik on the Reykjanes Peninsula, Iceland. Images of the sample collection site and one of the rocks collected here are shown in Figs. 3 and 4. Samples 574 and 575 are the orange and white-ish layers, respectively of the rock in Fig. 4. These were further separated into <45, <125 µm and coarse chips by dry sieving. Sample 576 is a yellow crust on a small part of this rock (not shown). Preliminary XRD measurements indicate that the <2 µm fraction of both 574 and 575 are dominated by smectite-like material. The coarse chip components are glassy for both of these samples and contain fewer clay minerals. Bulk chemical analyses are given in Table 1 for the <125 µm fractions of samples 574 and 575. The outer orange layer (574) has higher amounts of Fe and Ti and sample 575 has higher Si, Al, Mg and Ca levels.

Fig. 3 An image of the Seltun Krysuvik hot springs collection site where there are active fumerols.

Fig. 4 An image of the solfatarically altered sample collected at the Seltun Krysuvik hot springs. The outer orange alteration layer (574) and light-colored layer directly under this (575) were separated for analysis.

Table 1 Chemical composition of the <125 μm fractions of the orange (574) and white-ish (575) layers of the Krysuvik sample by XRF and LECO.

Wt.%	574	575
SiO_2	43.1	46.5
Al_2O_3	9.7	12.8
Fe_2O_3	17.6	12.1
MgO	2.8	4.0
CaO	2.0	3.1
Na_2O	0.3	0.5
K_2O	tr	tr
P_2O_5	0.3	0.2
TiO_2	2.6	2.0
MnO	tr	tr
S total	1.6	1.6
SO_4	0.9	1.0
LOI	21.2	18.2

The data for sample 575 are an average of two measurements that are very similar. Amounts <1 wt.% are listed as tr.

Reflectance spectra of the solfatarically altered samples are shown in Fig. 5. VNIR spectra of the Haleakala cinder cone samples (250, 394) exhibit features due to smectite, hematite, maghemite and jarosite (Fig. 5A). Sample 397 was collected further from the cinder cone and containsfewer crystalline minerals. NIR spectra of the solfataric Iceland samples show the presence of clays, FeOx and hydrated components. Visible spectra are in the process of being measured and will provide more information about the FeOx species in these samples. XRD did not indicate any crystalline FeOx minerals, suggesting that only short-range ordered FeOx phases are present. Some sulfate is present in these Icelandic samples and features near 5 μm are attributed to this sulfate component that is under further study. The mid-IR spectrum of the coarse chips from the yellow crust layer from the active Icelandic spring (576) shows strong silica bands that are in contrast to the spectra of the fine-grained samples (Fig. 5B).

Aqueous processes on Mars: Direct evidence of liquid water on Mars has not been found; however, remote detection of alteration minerals may provide evidence of short- or long-term aqueous processes or hydrothermally active sites. Continued spectral analyses are underway that will provide VNIR spectral features to be used by CRISM and OMEGA and mid-IR spectral features to be used by TES and mini-TES to look for evidence of the clays, iron oxides, and sulfates indicative of volcanic alteration in either palagonitic, pedogenic or solfataric environments.

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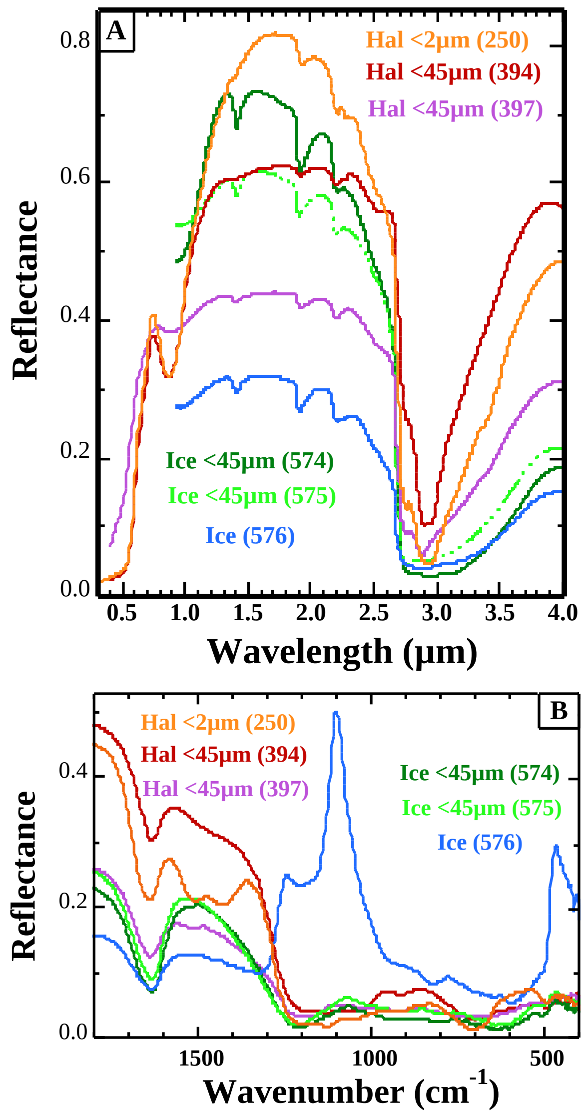

Fig. 5 Reflectance spectra of solfatarically altered volcanic material from near a cinder cone (Haleakala) and an active S hot spring (Iceland): (A) VNIR and (B) mid-IR regions.

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