

SPECTRAL AND CHEMICAL VARIATIONS IN ROCKS AND SOILS FROM ICELAND'S INTERIOR: IMPLICATIONS FOR SURFACE AND SUB-SURFACE WEATHERING PROCESSES IN THE MARTIAN NORTHERN PLAINS. U.N. Horodyskyj and M.B. Wyatt, Brown University, Dept. of Geological Sciences, Providence, RI 02912 (Ulyana_Horodyskyj@brown.edu).

Introduction: The barren interior of Iceland has been subjected to a variety of physical and chemical weathering conditions given its location within the rainshadow of the vast Vatnajökull icecap and along the path of glacial run-off and strong winds from the southwest [1]. Samples from basaltic sandy plains north of Vatnajökull icecap, light-colored tephra deposits from Askja volcano, and the Krafla volcanic system further north were collected during the 2008 and 2009 summer field seasons. Surface rocks and sediment cores (62 cm depth) from these regions were analyzed for mineralogy and chemistry. Our motivation for Icelandic studies comes from data returned from orbiting spectrometers and derived compositions in the northern lowlands of Mars.

In Acidalia Planitia, TES and OMEGA mineralogies are most consistent with the presence of basaltic rocks and aqueously derived Si-Al-Fe rich amorphous mineral phases [e.g., 2-4]. The GRS chemical dataset, however, reveals a basaltic crust with very little evidence for element mobility and aqueous alteration [5-6]. This apparent discrepancy is likely due to sampling depth differences between instruments as TES and OMEGA sample only the uppermost 10s to 100s μm of the surface while GRS samples the upper tens of centimeters. In this study, we seek to better understand the possible extent of aqueous alteration on Mars by characterizing the depth of alteration in terrestrial basalts from a Mars analog environment. We analyze surface and sub-surface materials from Iceland's interior to understand weathering processes at the different sampling depths of the TES, OMEGA and GRS instruments. We show that sampling depth matters and that it is an important factor to consider when interpreting Martian surface compositions.

Chemical Analyses: XRF data were collected down-core in samples from the sandy plains, Askja volcano, and Hverfjall (in Krafla). To obtain high-resolution chemical data, we utilized an Itrax core scanner at the University of Minnesota-Duluth, with a 0.4 x 2 mm footprint over 62 cm of core. Standard XRF measurements using fused beads from UMass-Amherst provide "control points" for converting element counts to weight percents from full-length XRF core scans. This is necessary to account for particle size effects encountered while using the scanning technique on unconsolidated samples.

Core scan averages are consistent with XRF control points in the sandy plains (A, B) and Hverfjall, indicating relatively homogeneous chemistry of a typical basaltic composition (Table 1). The core from Askja consists of a mixture of dacitic tephra deposits and basaltic sands, resulting in an average silica value of andesitic composition over the

scanned depth and, thus, a larger standard deviation from the control points.

To further examine the effects of averaging chemistry with depth in the presence of varying compositions, we use the obtained high resolution SiO_2 values, down-core, from the Askja sample. Total dacitic tephra (70 wt % SiO_2) makes up 35 cm of the core, with the remaining 27 cm composed of basaltic sands (50 wt % SiO_2). We find that an average basaltic chemistry signature can be generated if the original tephra layer is reduced to 6 cm in thickness. The result is significant, indicating if thin layers of enriched silica materials (either due to compositional differences or weathering) exist in the Martian Northern Plains, they may be effectively masked out by the GRS instrument over its sampling depth (tens of centimeters), over a 500 km footprint.

Samples	SiO_2	Al_2O_3	FeO^*	CaO	K_2O
Sandy plains A scan average	51.02	14.14	13.86	11.07	0.32
Standard deviation	0.34	0.08	0.19	0.16	0.02
Sandy plains B scan average	49.79	14.27	12.79	11.45	0.22
Standard deviation	0.15	0.12	0.12	0.07	0.01
Krafla (Hverfjall) scan average	49.28	13.78	15.37	10.19	0.29
Standard deviation	0.29	0.11	0.12	0.12	0.01
Askja tephra scan average	58.33	18.64	8.88	7.33	1.12
Standard deviation	9.67	2.04	3.50	3.54	0.87

Table 1. XRF core scan averages and standard deviation from control point chemistry data.

Mineralogical Analyses: Visible-near infrared (VNIR) spectra, with a wavelength range of 0.3 – 2.5 μm , were collected using Brown's RELAB facility. Thermal infrared (TIR) spectra were collected at ASU's thermal emissivity lab, with a 1600-200 cm^{-1} wavenumber range.

Samples from the sandy plains appear to be unaltered (Fig. 1), consistent with the chemistry data. Broad 1 and 2 micron bands in samples from the top, middle and bottom of the core are consistent with basaltic glass. Overlying rocks, however, show greater mineralogical diversity. While "plains rock 1" shows a negative blue slope with slight absorption at 1.9 μm , indicating some hydration, "plains rock 2" shows absorptions at 1, indicative of pyroxene, and 1.4, 1.9 and 2.21 μm , indicative of hydrated phyllosilicates. Results from the sandy plains region reveals a disconnect between surface and subsurface compositions. In a highly mobile environment such as Iceland's interior, soils have been transported and significantly reworked, resulting in a minimal amount of preserved secondary mineral phases. However, rocks and lava flows are more stable and can thus

form weathering products such as clays or coatings of Si-rich materials.

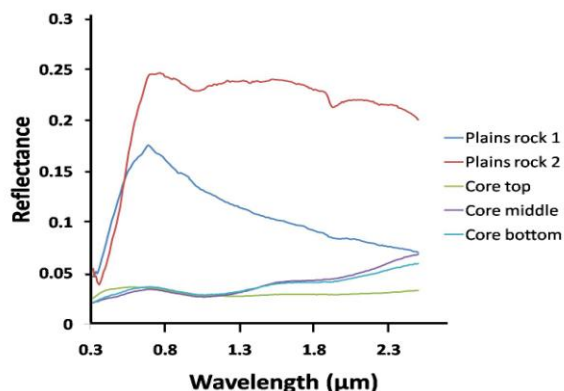


Figure 1. Rock and soil VNIR spectra from the sandy plains. Note the alteration in rocks and homogeneity in soils.

The near-infrared derived mineralogy with depth in core samples from Hverfjall is also consistent with basaltic glass (Fig. 2), although some grains reveal 1.9 μm absorption bands, indicating a level of hydration. A surface rock from the sampling region has a similar absorption at 1.9 μm , in addition to one at 1.4 μm . Average VNIR spectra across a 1.5 cm dish of grains from the same depth as a coated grain (15-17 cm, shown here as “core top”, Fig. 2), did not show alteration, indicating that grain orientation, grain size and surface areal coverage of coatings on individual grains are important factors to consider when taking measurements and making interpretations.

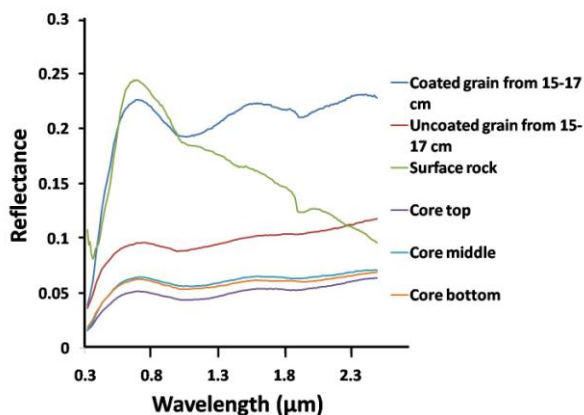


Figure 2. Rock and soil VNIR spectra from Hverfjall. Note the similar alteration features in the rock and coated grain.

From the Askja region, a rock's weathered surface and pristine interior were examined with VNIR and TIR data. The interior of the rock shows a 1 μm absorption in the VNIR and a box-shaped basaltic spectrum in the TIR, consisting of augite, forsterite and diopside phases, identified through a deconvolution algorithm (Fig. 3, with VNIR data inset). The weathered surface appears different, with a 1.9 μm absorption

in VNIR and a “v-shaped” spectrum in TIR, with (Si,Al)-O stretching at 1100 cm^{-1} and (Si,Al)-O bending features at 460 cm^{-1} . VNIR and TIR data agree on alteration, where VNIR indicates some level of hydration and TIR points to the presence of enriched Si phases.

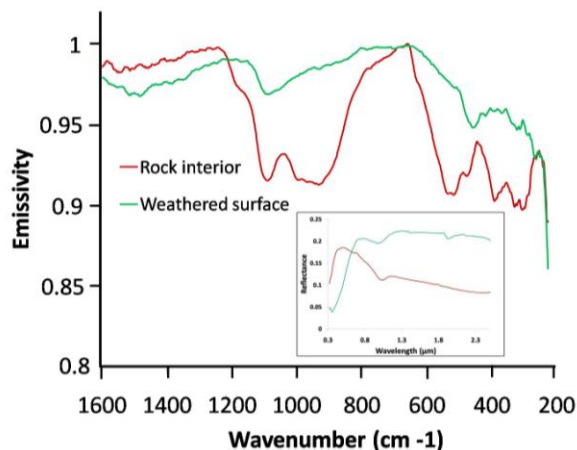


Figure 3. Interior and exterior (weathered) rock surfaces in TIR and VNIR (inset). Note the alteration features present on the weathered surface.

Conclusions: Alteration on surface rocks is apparent in VNIR and TIR data from Iceland, consistent with results from Mars orbiting spectrometers. Alteration with depth is however not readily apparent in the chemistry data, which is analogous to GRS observations of Mars. Isochemical alteration is a possibility that should be considered, as it would result in relatively homogeneous chemistry. But it is also important to keep in mind that depending on thicknesses of silica layers with depth, it is possible that GRS simply masks them out over its sampling range. We demonstrate this with our mixed dacitic tephra-basaltic sand core from Askja. While minimal alteration can be detected mineralogically with depth, as demonstrated in the samples from Hverfjall, it is important to note that this type of spectral analysis on Mars comes only in the form of “skin deep” TES and OMEGA measurements. It is possible that mineralogical alteration with depth is occurring, but it may be difficult to detect using only orbital spectrometer techniques.

References: [1] Arnalds et al (1997), *Soil Erosion in Iceland*. [2] Bandfield et al. (2000), *Science*, 287, 1626. [3] Wyatt et al. (2004), *Geology*, 32, 644-648. [4] Mustard et al. (2005), *Science*, 307, 1594-1597. [5] Karunatillake et al. (2006), *JGR*, 111. [6] Taylor et al. (2006), *JGR*, 111.

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