

THE MINERALOGIC VARIABILITY OF ICELANDIC PALAGONITES: AN ANALOG STUDY FOR MARS. S. Ackiss¹, B. Horgan¹, N. Scudder¹, J. Gudnason², C. Haberle³, and T. Thorsteinsson⁴, ¹Purdue University, Department of Earth, Atmospheric, and Planetary Sciences, West Lafayette, IN (sackiss@purdue.edu), ²University of Iceland, Department of Earth Sciences, Reykjavík, Iceland, ³Arizona State University, School of Earth and Space Exploration, Phoenix, AZ, ⁴Icelandic Meteorological Office, Reykjavík, Iceland.

Introduction: Palagonite is commonly misinterpreted as a weathering product of low-temperature alteration of volcanic rocks [1-6]; however, it has been conclusively shown that palagonite is a poorly crystalline, hydrated, and oxidized alteration product of glass [7-10] that is produced at low-temperatures and high water-to-rock ratios. Thus, palagonite only forms in specific environments, primarily subglacial and subaqueous volcanic eruptions.

Volcanism and alteration have been dominant processes on Mars, so it has been hypothesized that palagonite should occur on Mars [11-13]. Palagonite has recently been tentatively detected on Mars [14] via orbital VNIR spectroscopy; however, our ability to detect and interpret palagonite on Mars is limited because the range of palagonite compositions and spectral properties are both poorly constrained. In this study, we evaluate the compositional variability of palagonite on Earth in order to inform efforts to identify it on Mars.

On Earth, subaqueous volcanism typically produces a mineral assemblage containing glass, clays, sulfates, mafic minerals, and Fe-oxides, and the VNIR spectra of subaqueous palagonites are dominated by clay minerals [e.g. 16]. Subglacial volcanism produces a mineral assemblage containing the same minerals as well as zeolites, where zeolites and clays are the most prevalent spectral features in this environment [17, 18].

Methods: Iceland has abundant palagonite outcrops due to its long glaciovolcanic history. Subglacial and intraglacial volcanic rocks are found in the Western, Eastern, Northern, Snæfellsnes, and Örfafjökull Volcanic Zones [15]. The rocks within these zones are predominantly basaltic, often palagonitized, and formed during the Pliocene (0.01-0.78 Ma) [15]. Palagonite samples were collected in Iceland at subglacial volcanic sites (Figure 1) around Reykjavik in the Western Volcanic Zone (WVZ; 8 samples), on the Southern Coast in the Eastern Volcanic Zone (EVZ; 1 sample), and from the Herðubreið and Askja volcanoes in the Northern Volcanic Zone (NVZ; 3 samples).

Samples were dried out for 14 days in a fume hood. Visible and near infrared (VNIR) reflectance spectra were acquired of whole rock samples. Samples were also ground and sieved to <125 microns. The samples were also measured using thermal infrared emission (TIR) spectroscopy and quantitative X-ray powder diffraction (XRD). For TIR, samples (hand samples and pellets) were heated to 80°C prior to the measurements.

For XRD, sieved samples were spiked with 20% corundum and further mixed/crushed to ~10 microns for quantitative measurements.

Results: Below we discuss four samples (Lake03, Her01, SCoast01, and Ask01) and their variability.

Visible/Near-Infrared Spectroscopy. VNIR spectra show a strong red slope from ~350-700nm, with a strong reflectance peak between ~680-780nm. All samples also exhibit a broad absorption band near 1000 nm band generally consistent with glass, but with variable depth, width, and shoulder absorptions on the long wavelength side of the band likely due to other mafic minerals. Hydration bands at ~1400 and 1900 nm are observed in all samples, as well as a ~1780 nm band consistent with some sulfates and zeolites. The samples exhibit highly variable absorptions between 2200-2300nm, consistent with Si-OH or Al-OH stretches near 2200 nm, (Fe,Mg)-OH stretches near 2300nm, and Al,(Fe,Mg)-OH stretches between 2230-2270nm. This suggests the presence of complex clay assemblages within the rock samples. While most samples have their strongest clay band near 2200nm, SCoast01 is the only sample to exhibit a strong band at 2300nm (Figure 2).

Thermal-infrared Spectroscopy. TIR spectra exhibit broad absorptions at ~1000 and ~465 cm⁻¹ which are consistent with glass. Narrower absorptions at ~1050 and 530 cm⁻¹ are consistent with phyllosilicates. Linear deconvolutions of the mineral assemblage for these samples showed that >50% of the sample is composed of partially devitrified glass, along with clays and zeolites. All samples contain similar assemblages with the exception of the SCoast01 sample, which is modeled to have olivine, amphibole, and sulfate in addition to devitrified glass (Figure 3).

X-ray powder diffraction. XRD patterns for most samples show few clear peaks attributable to crystalline minerals (only the added corundum). In all of the samples, there is a large amorphous hump consistent with glass and other poorly crystalline phases. However, the SCoast01 sample that produced anomalous spectra in VNIR and TIR also has a unique XRD pattern. Even though the amorphous hump is much smaller than the other samples, Rietveld refinements of the SCoast01 sample still suggest >60% amorphous material as well as pyroxene. In addition, the SCoast01 sample is the only sample with large clay peaks, suggesting that these clays may be more crystalline than those in the other samples (Figure 4).

Conclusions and Future Work: Overall, the variability in the palagonite samples is hypothesized to be due to differences in environmental conditions during formation. Palagonite is dependent on magma composition and water conditions, thus we can relate the chemistry and mineralogy back to formation during eruption. Preliminary spectroscopic results show the sampled palagonites vary in mineralogy and contain partially devitrified glass, glass, clays, and zeolites. However, the SCoast01 sample shows a vastly different mineral assemblage in all sample techniques, including well-crystalline Fe/Mg-clays as opposed to the poorly-crystalline Al/Fe-clays observed in the other samples. Based on previous studies of subaqueous palagonites [19] and the sampling location, it is possible that the SCoast01 sample was formed in a submarine environment rather than subglacial. This suggests that it may be possible to differentiate submarine vs. subglacial palagonite from remote sensing observations on Mars. Definitively identifying palagonite on the martian surface would be vital in constraining the formation environment and history of the surface.

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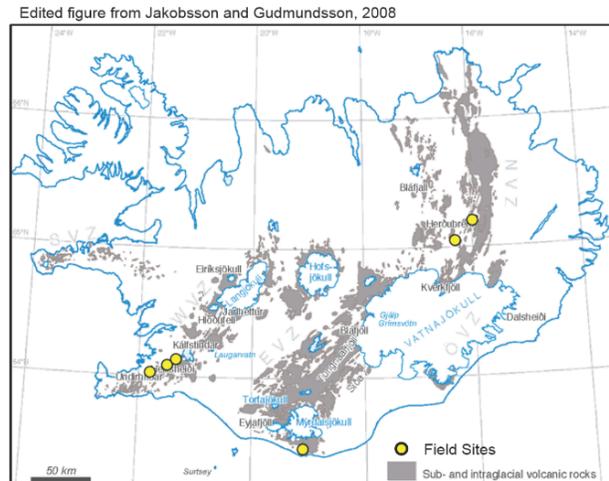


Figure 1 (above). Field context of samples in the NVZ, WVZ, and EVZ.

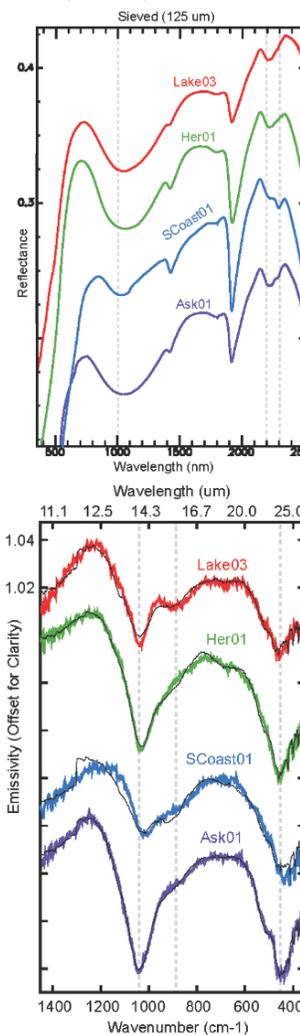


Figure 2 (left). VNIR spectra of Icelandic palagonite samples (Lake03, Her01, SCoast01, and Ask01)

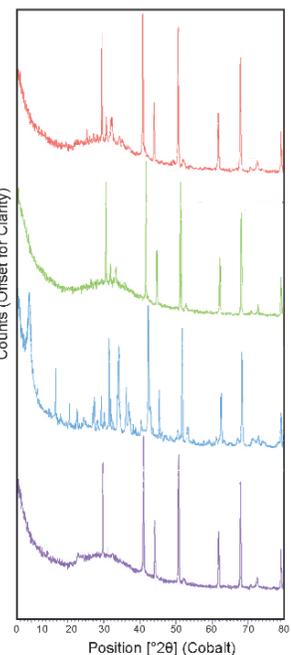


Figure 4 (above). XRD spectra of Icelandic palagonite samples (Lake03, Her01, SCoast01, and Ask01)

Figure 3 (above). TIR spectra of Icelandic palagonite samples (Lake03, Her01, SCoast01, and Ask01)