PALAGONITIC MARS FROM ROCK RINDS TO DUST: EVIDENCE FROM VISIBLE, NEAR-IR, AND THERMAL EMISSION SPECTRA OF POORLY CRYSTALLINE MATERIALS. R.V. Morris[1], T. G. Graff[2], S. A. Mertzman[3], M. D. Lane[4], P. R. Christensen[2], [1]NASA Johnson Space Center, Houston, TX 77058 (richard.v.morris1@jsc.nasa.gov), [2]Dept. of Geol. Sci., Arizona State University, Tempe, AZ 85287, [3]Dept. of Geosci., Franklin and Marshall College, Lancaster, PA 17604, [4]Planetary Science Institute, Tucson, AZ 85705.

Introduction: Visible and near-IR (VNIR) spectral data for Martian bright regions are characterized by a general shape consisting of a ferric absorption edge extending from ~400 to 750 nm and relatively constant reflectivity extending from ~750 nm to beyond 2000 nm [e.g., 1-4]. Among terrestrial geologic materials, the best spectral analogues are certain palagonic tephras from Mauna Kea Volcano (Hawaii) [e.g., 5-10]. By definition [11], palagonite is "a yellow or orange isotropic mineraloid formed by hydration and devitrification of basaltic glass." The ferric pigment in palagonite is nanometer-sized ferric oxide particles (np-Ox) dispersed throughout the hydrated basaltic glass matrix [8-10]. The hydration state of the np-Ox particles is not known, and the best Martian spectral analogues contain allophane-like materials and not crystalline phyllosilicates [10].

Visible observations by the Hubble Space Telescope [e.g., 4] show that Martian dark regions are spectrally characterized (spatial scale ~20-50 km) by both a palagonite-like absorption edge and a ferrous band minimum near 950 nm. The ferrous band, which is also observed at the same spatial resolution in Phobos-2 spectra, is attributed to pyroxene in unaltered Martian basalts [e.g., 12]. Mars Global Surveyor thermal emission spectra show mid-IR evidence for andesitic and basaltic volcanic compositions concentrated in northern (Acidalia) and southern (Syrtis Major) hemispheres, respectively [e.g., 13-15]. The absence of a ferric-bearing component in the modeling of TES spectra is thus in apparent conflict with VNIR spectra of Martian dark regions. We note, however, that [16] have interpreted the andesitic spectra as oxidized basalt using phyllosilicate endmembers. We show here that laboratory VNIR and TES spectra of palagonitic alteration rinds developed on basaltic rocks are spectral endmembers that provide a consistent explanation for both VNIR and TES data of Martian dark regions.

Samples: Table 1 lists samples and major element compositions. Size fractions were obtained by mechanical grinding and sieving (ethanol wash). Three basaltic rocks with brown palagonitic alteration rinds were sawed to slabs ~1 cm thick. Rinds were ~100 μm thick, based on binocular examination of polished saw cuts normal to the rind. Some saw cuts were polished to give different surface textures. Thermal emission spectra were obtained using a modified Nicolet Nexus E.S.P. FT-IR spectrometer. VNIR spectra were obtained using a Cary-14 diffuse reflectance spectrometer. XRD and XRF data were obtained on fine powders of the same samples [e.g., 9].

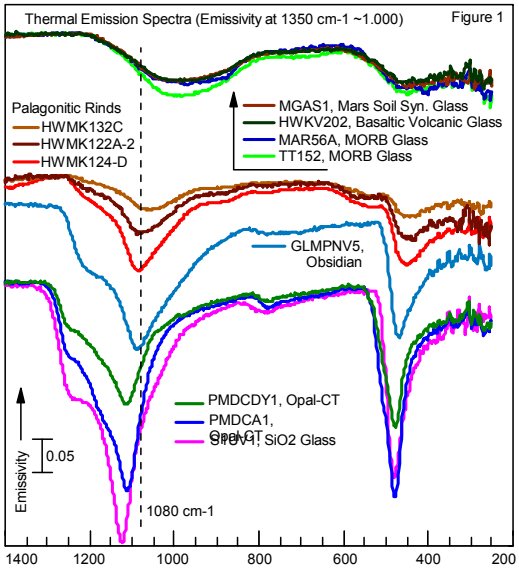
Results and Discussion: All samples except palagonitic rinds are amorphous or poorly crystalline on the basis of XRD analysis. We were not able to get XRD data for rinds, but XRD analysis of spectrally similar (VNIR) palagonitic tephra from the same location is poorly crystalline with respect to alteration products [10]. Fig. 1 shows that TES spectra for all samples are characterized by relatively broad and structureless silicate emissivity minima in the regions centered near ~1000 and ~500 cm^{-1}. The variation in the position of the silicate "10 μm" feature from ~1130 cm^{-1} (SiO_2 glass) to ~1090 cm^{-1} (obsidian) to ~950 cm^{-1} (basaltic glass) is a compositional effect [e.g., 18].

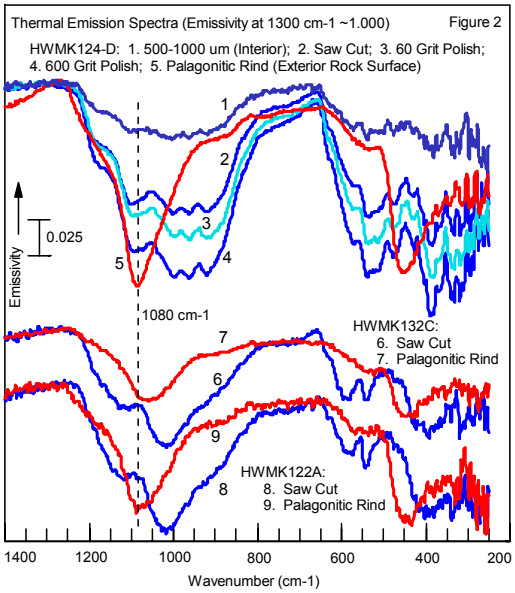
Note that TES spectra for anhydrous (S1UV1) and hydrous (PMDCA1) SiO_2-rich marerials are very similar. The similarity between the emissivity spectra of the palagonitic rinds and obsidian (an XRD-amorphous glass) is consistent with our interpretation that the rinds are poorly crystalline (palagonitic).

Table 1. Sample physical state, origin, and major element composition.

Sample	Size (um)	Description	SiO_2	TiO_2	Al_2O_3	Fe_2O_3T	MgO	CaO	Na_2O	K_2O	P_2O_5	Total	LOI
S1UV1	500-1000	SiO_2 glass (syn.)	100.0	UV grade SiO_2 glass. Presumed pure.									
PMDCA1	500-1000	Opal-CT, Prov. Mtns., NV	96.72	0.02	0.38	0.21	0.08	1.16	0.00	0.03	0.65	99.50	7.11
PMDCDY1	500-1000	Opal-CT, Prov. Mtns, NV	93.41	0.05	1.44	0.52	3.35	0.23	0.26	0.32	0.02	99.64	8.15
GLMPNV5	500-1000	Obsidian, Mineral, NV	75.64	0.10	13.17	0.79	0.08	0.57	4.33	4.80	0.01	99.75	0.14
MGAS1	500-2000	Mars global soil glass (syn.)	50.81	1.31	9.03	19.89	9.72	6.80	2.02	0.18	0.00	99.76	--
MAR56A	500-1000	MORB glass	50.51	1.13	14.80	10.21	8.93	11.31	2.22	0.20	0.12	99.73	0.78
TT152	500-1000	MORB glass	48.20	1.56	15.04	13.22	7.14	11.24	2.47	0.11	0.13	99.39	0.36
HWKV202	500-1000	Basaltic volcanic glass, HI	49.38	2.31	12.65	13.03	8.92	10.41	2.09	0.41	0.23	99.77	0.46
HWMK124	500-1000	Rock, from interior, HI	48.30	3.27	13.45	14.72	5.86	10.70	2.69	0.75	0.40	100.46	0.76
HWMK124	Slab_D	Rock with palagonitic rind, HI											
HWMK122A	Slab	Rock with palagonitic rind, HI											
HWMK132C	Slab	Rock with palagonitic rind, HI	49.64	2.83	16.91	12.12	4.02	6.71	4.31	1.81	0.85	99.63	0.98

Notes: All compositions in wt%. Rock compositions are from interior samples. Rocks were collected on Mauna Kea volcano at elevations above ~3000 m. MGAS1 from [17].





The vertical line at 1080 cm^{-1} in Fig. 1 corresponds to the position of the 10 μm emissivity minimum observed for Martian andesitic and basaltic surfaces [e.g., 13]. Note that both obsidian and palagonitic rinds spectra have minima in the same location. Significantly, the TES spectra for the andesitic surface can be modeled with a obsidian-like spectral endmember. [13, 15] both report ~25 modal % high-SiO_2 glass. Using a spectrally similar sheet silicate endmember, [16] report 30 modal % sheet silicate. Although we have not yet completed detailed liner mixing model calculations, we suggest that spectrum for palagonitic rinds, because it is also similar to the obsidian spectrum, is also a viable endmember for the andesitic composition. The nature and extent of weathering on Mars hinge on whether the obsidian-like spectral component is actually primary volcanic glass, sheet silicates, or palagonite.

In Fig. 2, emissivity spectra of palagonitic rinds (red traces) are compared to those for unaltered rock interiors (blue traces). The observation is that rinds on the order of ~100 μm thick can effectively mask detection of interior-rock mineralogical compositions.

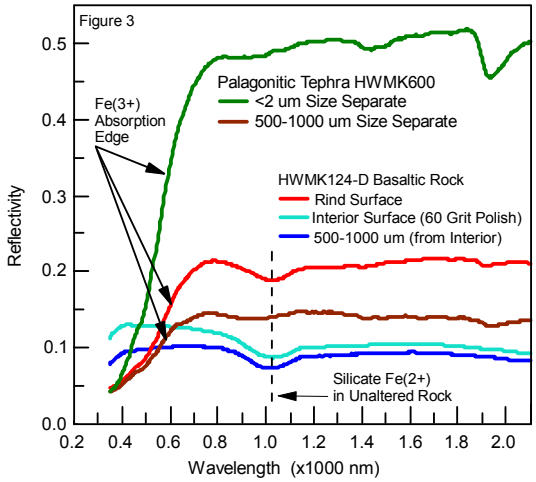


Fig. 3 shows VNIR spectra for the palagonitic rind on rock HWMK124-D, a polished interior saw cut, and 500-1000 μm powder obtained from interior rock as analogues for weathered and unaltered rock surfaces and unaltered basaltic "sand" on Mars. The spectra for the <2 μm and 500-1000 μm size fraction of palagonitic soil HWMK600 [from 9,10] are analogues for Martian dust and weathered basaltic sand. Note that the ferrous band present in the spectra of unaltered HWMK124 material is clearly present, along with a ferric absorption edge, in the VNIR spectrum of the palagonitic rind. Thus, palagonitic rock rinds provide a possible explanation for both the VNIR and TES spectra of Martian dark regions. Presumably, as weathering progresses with time, the relatively friable palagonitic rinds detach from rock surfaces, contributing to martian dust and soil and exposing fresh rock surfaces to alteration. Because palagonitic materials are formed by the hydration of basaltic glass, they can be an important reservoir for the water detected by the Odyssey neutron spectrometers [19] at low and mid latitudes.

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