

THERMAL EMISSION SPECTRA OF SILICA-COATED BASALT AND CONSIDERATIONS FOR MARTIAN SURFACE MINERALOGY. M. D. Kraft, T. G. Sharp, and J. R. Michalski, Arizona State University, Tempe, AZ, 85287-1404, mdkraft@asu.edu

Introduction: Among the most important discoveries made during the Mars Global Surveyor (MGS) mission was that the rocky materials of Mars are broadly divisible into two distinct rock types [1]. The geological significance of this finding is dependent on the mineralogy of these rock types as well as their geographic and stratigraphic positions. Much work has yet to be done to understand these relationships and the small-scale variability of these units. For now, it is worth considering various scenarios that could have resulted in Mars' global-scale mineralogical dichotomy. Such work will make clearer what must be looked for in Thermal Emission Spectrometer (TES) and Thermal Imaging Spectrometer (THEMIS) data, what to test with other data sets, and what geological processes can be considered or ruled out as we advance with interpreting Martian geologic history. Here, we suggest that exogenic coatings of secondary silica on basaltic rocks may provide a plausible explanation for the newly discovered distribution of "rock types."

What Is At Issue?: The original TES report [1] referred to the distinct dark-region units as surface spectral types 1 and 2, which we will refer to as S1 and S2 for simplicity. The S1 unit is widely held to be basalt comprised of plagioclase feldspar and pyroxene [1-3]. However, the mineralogy of S2 is in dispute. S2 spectra have been deconvolved to plagioclase + high-silica glass (+ pyroxene) [1,2] interpreted to be basaltic andesite. S2 spectra have also been deconvolved to plagioclase + clay minerals + K-feldspar and is interpreted to be an aqueously altered basalt [3]. Finally, it has been suggested that the S2 spectrum could result from high-temperature oxidation of basaltic lava flows [4].

S2 occurs most prominently in the northern lowlands, particularly at high latitudes, but also is seen poleward in the southern hemisphere and in some near-equatorial localities [1,5]. The heavy concentration of S2 in northern high latitudes prompted Wyatt and McSween [3] to suggest that S2 may have been altered in a putative northern ocean or transported to a northern lowlands depocenter; however, this model does little to explain the southern hemisphere occurrences of S2. Also, the suggestion of oceanic weathering is inconsistent with geomorphological evidence [6]. However, the recognition of a latitudinally controlled distribution of S2 (or, conversely, the latitudinally controlled absence of S1, which occurs in equa-

torial regions) is probably of important significance in understanding the geological controls over the distribution of S1 and S2.

An additional concern with the weathered basalt model is that near-isovolumetric mass loss in aqueous weathering of rocks tends to produce mechanically weak weathering rinds. It is unlikely that such weathering rinds would remain intact for long under Martian eolian conditions.

The andesite model of [1] suffers from the lack of a petrologic model to explain how hemisphere-wide volumes of andesitic rocks could form on Mars. No andesitic or basaltic-andesitic Martian meteorites have been discovered. This fact by no means rules out the andesite model for S2, but the widespread occurrence of S2 leads one to question why this is the case. Furthermore, because S2 is widespread, eolian activity, mass wasting, and other processes should have mechanically weathered these materials to produce dust-sized particles. The upper dust layer of Mars appears to have been globally homogenized [7], so dust from silicic rocks should be reflected in the measured chemistry of Martian dust, i.e., the dust should be somewhat silicic. This is not the case. Dust chemistry from the Viking and Pathfinder landing sites suggests that the dust is either basaltic [8] or chemically derived from mafic to ultramafic rocks [7,9].

We question the ability of high-temperature oxidation to produce large quantities of S2. This seems to be a particular problem if oxidized rocks were to be comminuted to smaller particles.

While the above models cannot be ruled out on the basis of these observations—indeed they should be studied further—we suggest that other plausible geologic models for S2 should be explored.

Silica-coated Rocks on Mars: We suggest that a plausible explanation of S2-type spectra is silica coatings on basaltic rocks. This idea stems from the following observations: (1) S2 was modeled to include a silica glass component [1], which could be modeled as amorphous silica; (2) A small amount of silica may have a large effect on the thermal emission spectra [10]; (3) the occurrence of S2 has a latitudinal dependence, perhaps linked to atmospheric water; (4) S2 occurs most prevalently in the northern hemisphere, perhaps indicating a hemispherical or an elevation dependence that might also be linked to water; (5) S1 and S2 are observed to "mix" outside of their type localities [1], which could possibly be explained as S1-type

basaltic rocks and particles with various thicknesses of a silica coating; High silica concentrations measured for rocks at the Pathfinder landing site may be due to silica coatings [11], which could be consistent with the reportedly high water contents of those rocks [12].

Spectra of Silica-coated Basalt: We have begun to test the effect that silica coatings have in thermal emission spectra by obtaining spectral measurements of synthetically coated basaltic rocks. Using laboratory-produced samples allows the chemistry and thickness of silica coating to be controlled.

Slabs of a Columbia River basalt (CRB) were cut flat and polished to $\sim 1 \mu\text{m}$. Amorphous opaline silica was deposited onto the surface by applying a thin coating of a colloidal dispersion of silica in the form of a mist. The misted-on solution was evaporated at 50°C . Silica coatings were constructed layer by layer by repeating this method until a desired thickness (estimated by calibration experiments) was obtained. Silica thickness ranged from ~ 0.25 - $8.0 \mu\text{m}$. Its opaline character was confirmed by X-ray diffraction.

Thermal emission spectra of materials were collected using a fourier-transform infrared spectrometer at Arizona State University. The spectrum of coarse particles of the opaline material used to coat rocks is similar to silica glass and natural opal-A (Figure 1).

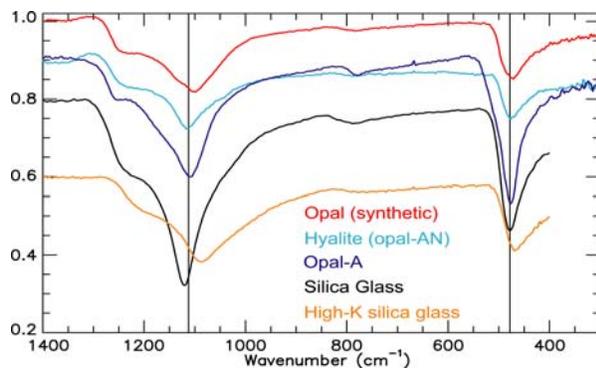


Figure 1. Emission spectra of synthetic opal, natural opals, and silica glasses. Y-axis is in emissivity.

Spectra were similarly obtained for the coated CRB slabs (Figure 2). The silica coatings produce a strong absorptions at 1120 cm^{-1} and 470 cm^{-1} . The spectra of CRB and opaline silica add non-linearly in the vicinity of the silica absorptions, with the silica features rapidly dominating these portions of the spectrum with increasing coating thickness. Measured trends in spectral features and simple visual inspection of the spectra suggest that a coating of amorphous silica $<10 \mu\text{m}$ thick will completely mask the underlying basalt, as speculated by Crisp and others [10] who studied ther-

mal reflectance spectra of natural silica-coated Hawaiian basalts.

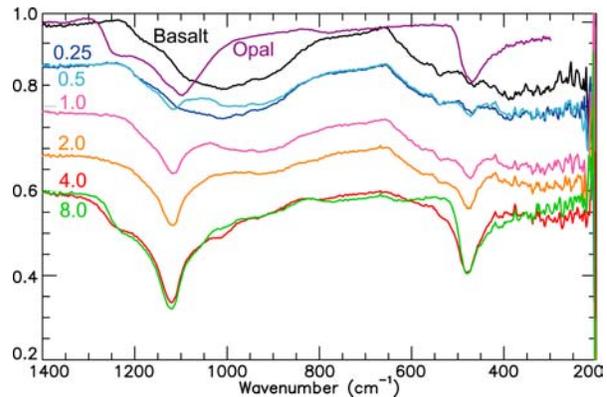


Figure 2. Thermal emission spectra of basalt coated with different thicknesses of opaline silica. Coating thickness are shown on the plot in μm . Y-axis is in emissivity.

Conclusions: The results show that silica and basalt add non-linearly to produce a composite spectrum of silica-coated basalt. Depending on the location of absorption features in a natural silica coating, we suspect that certain minerals in a coated rock could be masked preferentially, although this remains to be confirmed. Also, our experiment shows that continuous and thin, $<10 \mu\text{m}$ coatings of silica completely mask a basaltic substrate. We suggest that for Mars, regions of S2 and regions seen as mixtures of S1 and S2 may be the result of discontinuous and very thin ($<1 \mu\text{m}$) coatings of amorphous silica on basalt.

These results are for coatings of pure SiO_2 . The addition of other chemical constituents, principally Al, should shift spectral features and may be more appropriate for silica coatings on Mars and Earth, where silica coatings commonly have several weight percent Al [13].

References: [1] Bandfield J.L. et al. (2000) *Science*, 287, 1626-1630. [2] Hamilton, V.E. et al. (2001) *JGR*, 106, 14733-14746. [3] Wyatt M.B. and McSween H.Y. Jr. (2002) *Nature*, 417, 263-266. [4] Minitti M.X et al. (2002) *JGR*, 107(E5), 5030. [5] Bandfield J.L. (2002) *JGR*, 107(E6), 5042. [6] Malin M.C. and Edgett K.S. (2001) *JGR*, 106, 23429-23570. [7] McSween H.Y. Jr. and Keil K. (2000) *GCA*, 64, 2155-2166. [8] Baird and Clark B.C. (1981) *Icarus*, 45, 113-123. [9] Clark B.C. (1993) *GCA*, 57, 4575-4581. [10] Crisp J. et al. (1991) *JGR*, 95, 21657-21669. [11] Kraft M.D. and Greeley R. (2000) *JGR*, 105, 15107-15116. [12] Foley C. N. (2001), *LPSXXXII*, Abstract#1979. [13] Dorn R.I. (1998) *Rock Coatings*, Elsevier.

Acknowledgements: We thank Phil. Christensen for use of the thermal emission spectrometer and NASA Astrobiology (Grant NCC2-1051) for support.