THE VNIR SPECTRAL PROPERTIES OF IRON OXIDE/OXYHYDROXIDE MIXTURES AND APPLICATIONS TO IRON OXIDES IN THE MAWRTH VALLIS REGION OF MARS.

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Introduction: Iron oxides/oxyhydroxides (FeOx) are present nearly everywhere on the surface of Mars [e.g. 1,2]. They are characterized in the visible/near-infrared (VNIR) region by a strong electronic absorption centered near 0.85-0.95 µm and additional absorptions that shape the character of the visible reflectance spectrum and their color [3,4]. The objective of this study is to measure the spectral properties of mixtures of FeOx minerals in order to better constrain the types and abundance of FeOx on Mars. Of particular interest is understanding the spectral character of mixtures containing magnetic minerals, as the Martian surface soil is magnetic [5].

Samples: Mixtures were prepared by weighing aliquots of the components and gently stirring the particles then shaking them in a <125 µm sieve. Table 1 lists the mixture compositions of magnetite (Mt: finely particulate, from Aldrich, sieved <125 µm), maghemite (Mh: synthetic, finely particulate, sieved <125 µm), hematite (Hm: <5 µm particle size, from Aldrich; note that subsequent Mössbauer measurements have determined substantial maghemite in this sample [6]) and ferrihydrite (Fh: finely particulate, from Iceland [7] sieved <45 µm). VNIR spectra were measured using an ASD spectrometer under ambient lab conditions of the particulate samples poured onto a black Teflon dish.

Table 1 Mixture composition in wt.%

JB806	50% Mt	50% Mh		
JB807	50% Mt	50% Hm		
JB808	50% Fh	50% Mh		
JB809	75% Fh	25% Mh		
JB810	50% Fh	50% Mt		
JB811	75% Fh	25% Mt		
JB812	50% Fh	50% Hm		
JB813	75% Fh	25% Hm		
JB814	40% Fh	20% Hm	20% Mt	20% Mh

CRISM images: This study used the S detector images from MRO/CRISM that include 106 datapoints from ~0.4 to 1.04 µm across the extended visible region [8]. Images were processed as in previous studies [e.g. 9] and mineral detection parameters [10] were used for identification of interesting spectral units in several images. Maps were created using BDI1000VIS to highlight the 1000 nm integrated band depth, SH600 to measure the 600 nm shoulder that is characteristic of selected FeOx species, and BD530 to measure the spectral curvature from ~500-600 nm that is characteristic of some ferric minerals.

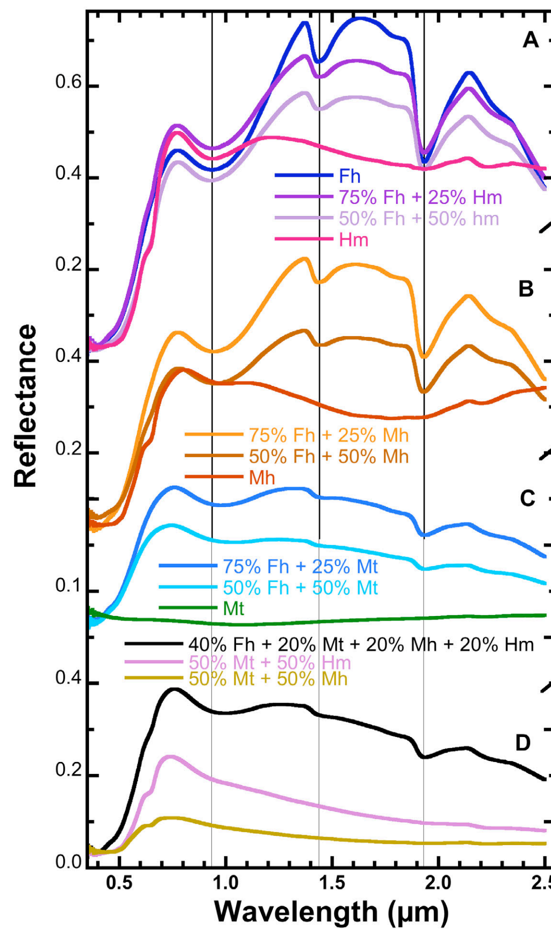

Fig. 1 VNIR reflectance spectra of FeOx minerals and mixtures.

Results: The spectral properties of FeOx minerals and mixtures were analyzed in order to better interpret the CRISM spectra of Mars.

Spectral properties of FeOx minerals. VNIR reflectance spectra are shown of ferrihydrite, hematite, magnetite, and maghemite and their mixtures (Fig. 1). This ferrihydrite spectrum (Fig. 1A) shows a prominent Fe^{3+} band near 0.93 µm, as well as strong water bands near 1.44 and 1.93 µm. The maghemite spectrum (Fig. 1A) displays a shoulder near 0.6 µm and a weak broad band near 0.97 µm. The hematite spectrum (Fig. 1B) exhibits a band near 0.9 µm with a shoulder near 0.6 µm, which show that this sample contains some maghemite as well. The magnetite spectrum (Fig. 1C) has a very low reflectance with a weak band near 1.1 µm.

Spectral analyses of FeOx mixtures. Adding hematite, maghemite and magnetite to ferrihydrite reduced the spectral contrast, with the greatest effect occurring for mixtures with magnetite. The magnetite mixtures also exhibit a decreasing slope with increasing wavelength.

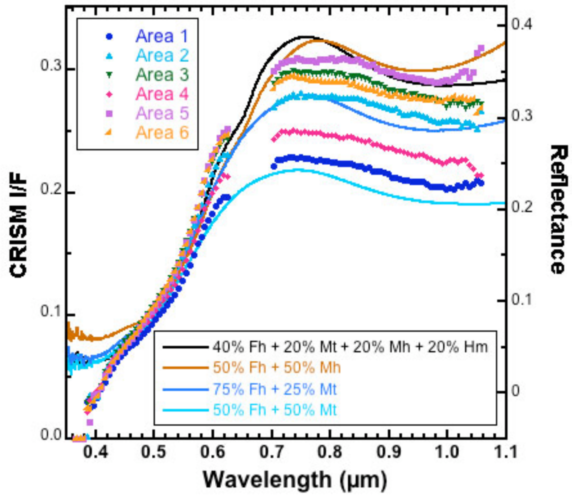

Fig. 2 CRISM spectra from areas 1-6 in image FRTB141 marked in Fig. 2 compared to lab spectra of FeOx mixtures from Fig. 1

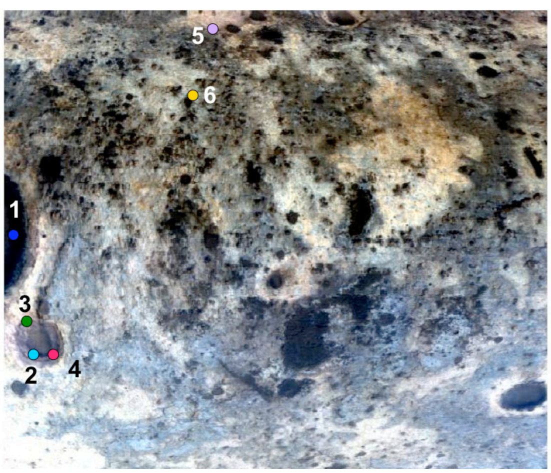

Fig. 3 CRISM image FRTB141 mapped with R 710, G 599, B 533 nm and spectral areas 1-6 marked.

Observations at Mawrth Vallis. Many CRISM images were studied, but two images in Mawrth Vallis (FRTB141 and HRL43EC) displayed particularly interesting mineralogy in the extended visible region. Spectra were collected and analyzed from several spots in these two images. FRTB141 exhibits subtle differences in the extended visible region spectra for spots inside craters and calderas compared with spectra of the caprock. Some of these spectral changes are consistent with variations in the iron oxide mineralogy. Selected Mawrth Vallis spectra from FRTB141 are shown in Fig. 2 for comparison with lab spectra. The locations of these spectra are shown in Fig. 3. The best spectral matches for the Mawrth Vallis spectra from our FeOx mixtures are the ferrihydrite-magnetite and/or ferrihydrite-maghemite mixtures.

Implications for Martian chemistry: Iron oxides have been identified in multiple locations on Mars [e.g. 11-12]. Ferrous iron (Fe^{2+}) is a large component of the primary silicates and minerals present on the surface of Mars. Ferric iron (Fe^{3+}) on the other hand is mostly found as a weathering product of the primary minerals. By studying the primary rocks (mostly Fe^{2+}) and the weathered/ oxidized product (Fe^{3+}) it is possible to constrain the processes that have occurred on Mars [11].

Ferrihydrite forms in the presence of water on Earth [3] and may have formed in the same way on early Mars. However, ferrihydrite is unlikely to be stable on Mars today due to the abundant H_2O in its mineral structure [7]. Alteration experiments were performed on ferrihydrite in order to better understand the FeOx products that might be present in the current environment on Mars [13]. Hematite is a thermodynamically stable end product of oxidation of ferrihydrite and is present in the Martian surface material today [2,11,12]. Additional reaction pathways including reduction by organics [14] or the presence of phosphates or silica [15] could have produced magnetite and/or maghemite instead of hematite. If ferrihydrite reacted with organics in the Martian soil to form magnetite/maghemite that could have used up a lot of organics and may explain why organics were not detected in the soil by Viking [16].

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References: [1] McCord T. B. et al. (1982) *JGR, 87,* 3021-3032. [2] Bell J. F. et al. (1990) *JGR, 95,* 14,447-14,461. [3] Cornell R. M., U. Schwertmann (1996), *The Iron Oxides* (VCH). [4] Morris R. V. et al. (1985) *JGR, 90,* 3126-3144. [5] Madsen M. B. et al. (1999) *JGR, 104,* 8761-8779. [6] Dyar M. D. et al. (2009) LPSC. [7] Bishop J. L., E. Murad (2002) in *Volcano-Ice Interactions on Earth and Mars* J. L. Smellie, M. G. Chapman, Eds. (Geological Society) pp. 357-370. [8] Murchie S. et al. (2007) *JGR, 112,* doi:10.1029/2006JE002682. [9] Bishop J. L. et al. (2008) *Science, 321,* doi: 10.1126/science.1159699, pp. 830-833. [10] Pelkey S. M. et al. (2007) *JGR, 112,* doi:10.1029/2006JE002831. [11] Morris et al. (2004) *Science*, 305, 833. [12] Bell et al. (2004) *Science*, 305, 800. Bishop et al. (2006) *LPSC XXXVII*, #1438. [14] Bishop et al. (2008) *Geophysical Research Abstracts, 10,* EGU2008-A-11557. [15] Torrent et al. (2007) *GRL, 33,* L02401. [16] Klein H. P. (1978) *Icarus, 34,* 666-674.