SPECTRAL ANALYSIS OF NONTRONITE-MAGNESITE-OLIVINE MIXTURES AND IMPLICATIONS FOR CARBONATES ON MARS.

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Introduction: Carbonates have been detected on Mars using spectral bands near 2.3, 2.5, and 3.4 µm [1,2] and near 6 µm [3]. Specific carbonate minerals can be identified by the wavelength positions of these bands in reflectance and emission spectra [e.g. 2-6]. Our study evaluates the character of magnesite (Mgs) in mixtures with nontronite (Non) and forsterite (Fo) using reflectance and Mössbauer spectroscopy and XRD. We discuss the implications for identification of carbonates on Mars using orbital and landed missions.

Methods: Carbonate, phyllosilicate and olivine minerals were chosen for this mixture study based on spectral features observed in CRISM data of the Libya Montes region on Mars [7-9]. We prepared laboratory mixtures of combinations of Mgs, Non and Fo (Table 1). The Mgs is from Brumado Bahia, Brazil and XRD indicates it is pure. The Non, NAu-1, is from the Uley Graphite Mine, South Australia and contains minor admixtures of kaolinite, quartz and goethite by XRD and IR. The Fo sample is from San Carlos, AZ (Fo_{70} from XRD). Samples were gently crushed and dry sieved to <125 µm. Mixtures were prepared by weight; particles were stirred and sieved for homogenization. Reflectance spectra were measured at RELAB, Mössbauer spectra at Mount Holyoke College, and XRD at NASA-Ames. A continuum was removed from the reflectance spectra for band center determinations.

Table 1 Mineral Mixtures by Wt.%

Mgs	Non	Fo
50	50	
90		10
75		25
50		50
25		75
10		90
	90	10
	75	25
	50	50
	25	75
	10	90
25	25	50
40	40	20
60	20	20
70	10	20

Results - NIR: Reflectance spectra of Mgs-Non-Fo mixtures show characteristic Fe phyllosilicate band centers at 2.29, 2.40, and 2.49 µm and characteristic carbonate band centers at 3.27, 3.42, and 3.94 µm (Fig 1). Spectra of Mgs-Fo mixtures show characteristic carbonate band centers at 2.30, 2.50, 3.27, 3.42, and 3.94 µm (Fig 2A). The depths of these band centers increase as %Mgs increases (Fig 2B) as expected; however, the trend is not linear. A relatively strong band is observed for only 10 wt.% Mgs for five bands in the mixtures. This band depth increases only gradually with increasing Mgs abundance. The bands near 3.3-4.0 µm are best for carbonate detection as they are the strongest and are not conflicted with phyllosilicate bands.

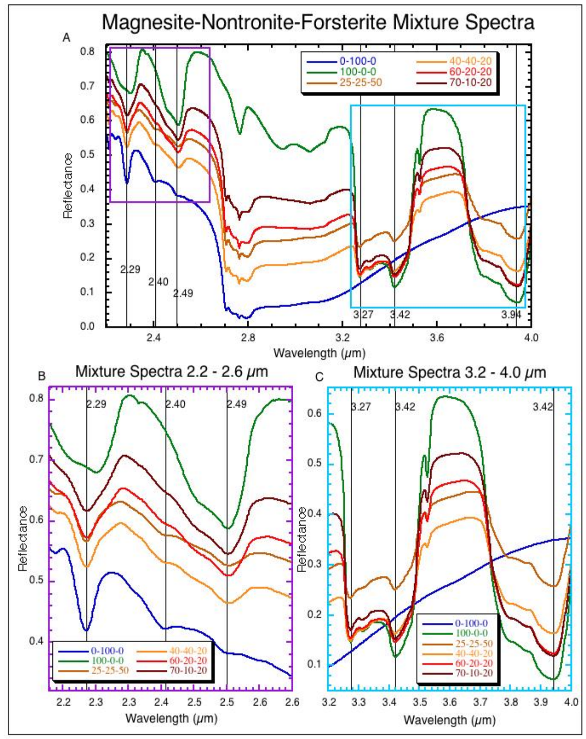

Figure 1. A. Reflectance spectra from 2.2-4.0 µm of mixures given in wt.%Mgs - wt.%Non - wt.%Fo. **B.** Enlarged view showing a carbonate band at 2.30 µm only in the pure Mgs spectrum, but a 2.29 µm band in the Non and mixture spectra. **C.** Enlarged view of carbonate bands at 3.27, 3.42, and 3.94 µm in all mixtures.

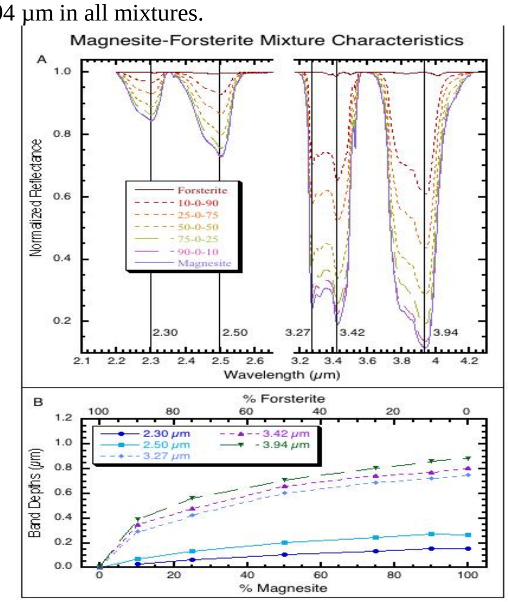

Figure 2. A. Continuum-removed reflectance spectra of mixures given in wt.%Mgs-wt.%Non-wt.%Fo. **B.** Carbonate band depths vs wt.%Mgs.

Results – Mid-IR: Reflectance spectra of Mgs-Non-Fo mixtures at longer wavelengths show characteristic carbonate bands near 5.5, 6.3, 11.4, and 13.2 µm (Fig 3) that remain constant in mixtures.

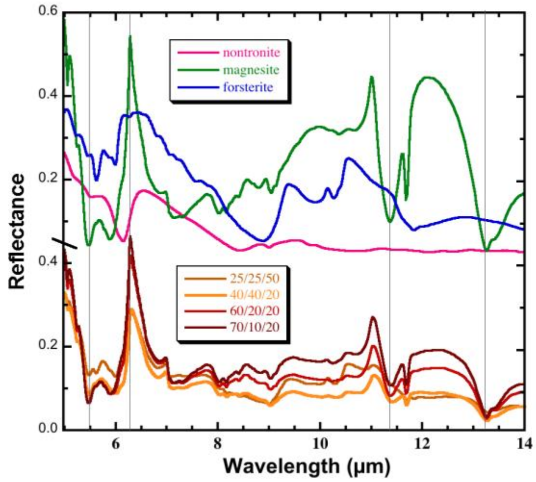

Figure 3. Mid-IR reflectance spectra with same mixture compositions and colors as Fig 1.

Results – Mössbauer Spectra and XRD: Mössbauer (MB) spectroscopy (Fig 4) and XRD were performed on all mixture samples to compare mineral detections using surface instruments and orbital spectroscopy. Note that MB doublet areas correspond to the atomic % of Fe atoms in each mineral. Mineral abundances for the Mgs-Fo series are shown in Fig 5. Analyses like this will enable ground truthing of CRISM mineral detections using CheMin on MSL and MB on MER.

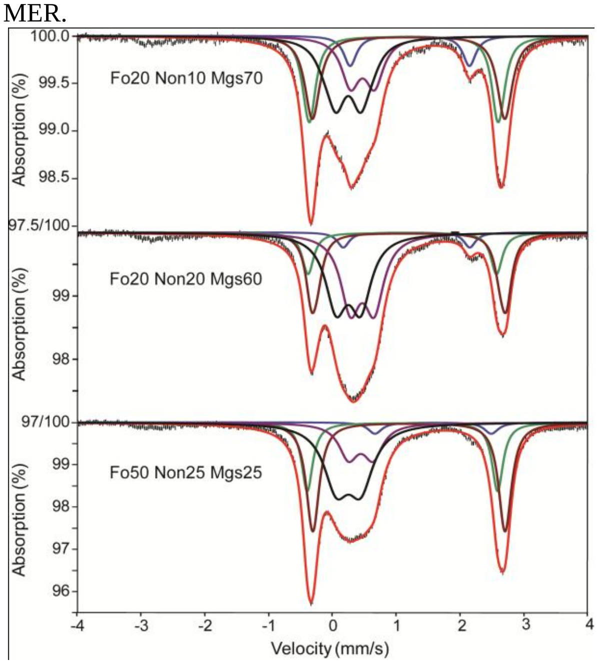

Figure 4. Mössbauer spectra of selected mixture samples. The red line is the envelope showing total contributions from all peaks. The peak areas reflect atomic distributions of Fe.

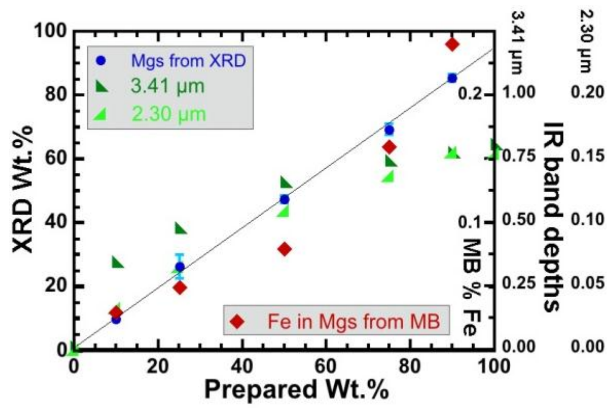

Figure 5. Measured vs prepared Mgs abundances in mixtures with Fo using wt.% from XRD, band depths from reflectance spectra, and atomic % Fe from MB spectra.

Summary: Analyses using XRD, reflectance and Mössbauer spectroscopy all were able to detect carbonate abundances well in mixtures. Band depths near 3.2-4.0 µm are preferred for carbonate-Non mixtures as band depths near 2.3 µm include contributions from both carbonate and Non. For spectral features ~2.2-2.5 µm, mixtures with ≥10% Non showed the dominate Non bands centered at 2.29, 2.40, and 2.49 µm, while bands centered at 2.30 and 2.50 µm are present only for pure Mgs. For spectral features ~3.2-4.0 µm, mixtures with ≥25% Mgs showed Mgs bands centered at 3.27, 3.42, and 3.94 µm. For spectral features ~5-14 µm, carbonate bands are visible in all mixtures.

Applications to Mars: These discoveries may have repurcusions for the interpretation of mineral spectra using CRISM. The CRISM instrument has a ground field of view of ~18 m per pixel [10]. At this resolution, it is likely that multiple minerals are present within each pixel. This study shows that with as little as 10% Non in the mixture, the ~2.3 µm band will closely resemble the Non feature obscuring indications of carbonate. This implies that there may be far more carbonates in Libya Montes and other Martian regions where phyllosilicates are found than previously estimated. Therefore, it is important to look for carbonate band detections at longer wavelengths on Mars.

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References: [1] Ehlmann, B.L. et al. (2008) *Science, 322*, 1828. [2] Brown A.J. et al. (2010) *EPSL*, *297*, 174. [3] Bandfield, J.L. et al. (2003) *Science, 301*, 1084. [4] Lane, M.D. (1999) *JGR, 104,* 14099. [5] Gaffey, S.J. (1987) *JGR, 92*, 1429. [6] Bishop J.L. et al. (1998) MAPS 33, 693.. [7] Mustand J.F. et al. (2009) *JGR, 114,* DOI: 10.1029/2009JE003349. [8] Bishop J.L. et al. (2010) *LPS IVI*, #2147. [9] Perry K. et al. (2010). *LPS IVI*, #2605. [10] Murchie S.L. et al. (2009) *JGR, 114*, doi:10.1029/ 2009JE003344.