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Characterization of magnesite-nontronite-forsterite mixtures and implications for phyllosilicate and carbonate detections on Mars

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Abstract

Mineral detection on Mars largely relies on lab data of minerals and mineral mixtures. This study provides reflectance spectra in the visible/near-infrared (VNIR) and mid-IR regions, X-ray diffraction (XRD) data and Mössbauer spectra of a suite of carbonate, phyllosilicate and olivine mixtures [1]. Through analyses of mineral mixtures using multiple datasets, this study seeks to provide ground truthing that will enable better coordination of carbonate detections in the dust and rocks of Mars.

1. Introduction

Remote sensing observations indicate that combinations of carbonate, Fe/Mg-phyllosilicates, and olivine are present in the ancient rocks on Mars around the Isidis Basin [2,3] and in Gusev crater [4]. Mixtures of magnesite, nontronite and forsterite size fractions <125 µm were prepared for this study in binary and tertiary mixtures with a range of abundances [1]. XRD was run on all endmembers to test the purity of the samples and on the mixtures to test modelling of these components [1].

2. Reflectance spectra of the mixtures

Results of the VNIR reflectance analyses illustrate the complexity of VNIR spectra of mixtures (Figure 1). Analyses of the NIR band depths at ~2.3, 2.5, 3.4 and 4 µm showed clear trends with carbonate abundance, although the data are not linear. Mixtures of magnesite and nontronite exhibited a band near 2.3 µm much closer to that observed for nontronite than that of magnesite (Figure 2). VNIR analyses of the mixtures indicated that a small amount of forsterite in any of the mixtures contributed a large increase in the broad ~1 µm band and hence the red slope characteristic of Fe^{2+}-bearing minerals. Mid-IR mixture spectra were dominated by magnesite and forsterite, and nontronite was much more difficult to detect by mid-IR spectra in the mixtures. This could be related to why phyllosilicates are detected in many locations on Mars using data collected by the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM), but not detected using data collected by the Thermal Emission Spectrometer (TES).

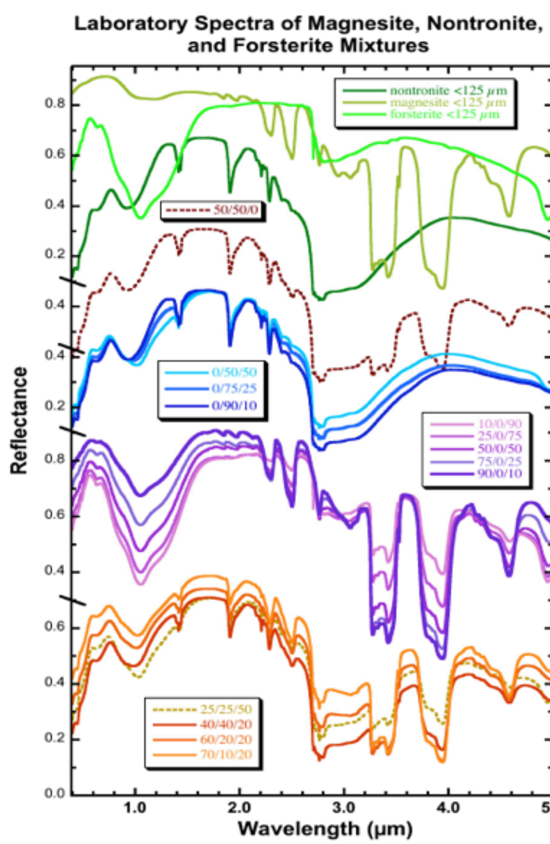

Figure 1: VNIR reflectance spectra of endmembers and mixtures with wt.% components given as magnesite/nontronite/ forsterite. Endmember spectra are shown at the top and mixture spectra are offset for clarity.

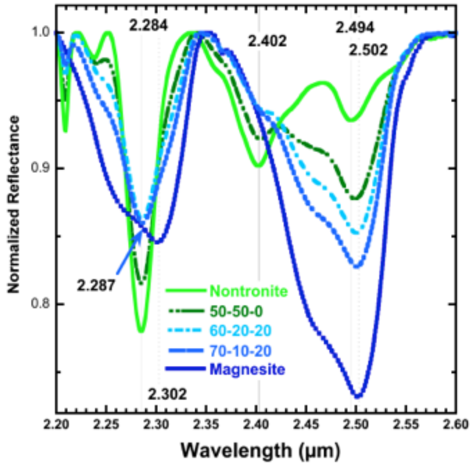

Figure 2: Continuum-removed reflectance spectra for magnesite-nontronite sample suite across the range 2.20-2.65 µm. Sample abundance is expressed as wt. % magnesite – wt.% nontronite – wt.% forsterite.

3. Mössbauer spectra of the mixtures

Mössbauer spectroscopy is well suited for analyses of Fe^{2+}- and Fe^{3+}-bearing minerals and modeling of the peak areas gave well correlated trends for nontronite and forsterite abundances where abundant Fe was present [1]. This study provides experimental data to assist in identification of carbonate, phyllosilicate and olivine on Mars using Mössbauer spectroscopy.

4. Summary and Conclusions

This study presents the spectroscopic and XRD properties of physical mixtures of magnesite, nontronite and forsterite in order to better understand the capabilities of these techniques in identifying carbonates on the surface of Mars. The VNIR spectral analyses indicate that the spectral properties of these mixtures exhibit nonlinear trends with mineral abundances and that different spectral features were affected to different degrees by the varying mixture components. Mössbauer peak areas correlated well in general with IR band depths for nontronite in the nontronite-bearing mixtures and with magnesite in the magnesite-forsterite mixtures. XRD full-pattern fitting analyses were performed on the magnesite-forsterite series giving results within 6 wt.% of the actual values, with a mean difference between actual and calculated values of 2.4 wt.% [1]. Magnesite determinations in these mixtures compare well for the 3 techniques, but the IR band depths are stronger than expected for low abundances and weaker for high abundances (Figure 3).

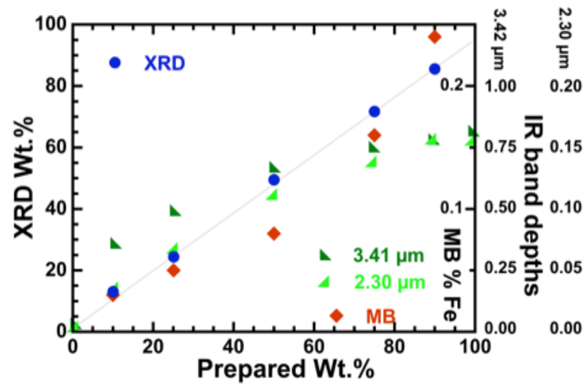

Figure 3: Comparison of magnesite abundance determined for magnesite-forsterite mixtures from XRD, IR and Mössbauer measurements. The IR band depths are from the continuum-removed spectra for two carbonate bands. The Mössbauer data represent the Fe attributed to magnesite in the fits.

The presence of phyllosilicates versus phyllosilicates plus carbonates likely indicates a change in the geochemical environment. Thus, identification of carbonates, even at low abundance, could provide important information about aqueous processes on Mars. This study provides data for ground truthing identification of phyllosilicates and carbonates in a basalt matrix on Mars through orbital and surface instruments.

Acknowledgements

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