MODELING MODAL MINERALOGY OF LABORATORY MIXTURES OF NONTRONITE AND MAFIC MINERALS FROM VISIBLE NEAR-INFRARED SPECTRAL DATA.

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Introduction: The discovery of diverse phyllosilicates on Mars from visible near infrared (VNIR) spectral data from the CRISM and OMEGA instruments points to aqueous environments with long-lived water-rock interaction [1-3]. A key question is what was the geological environment of alteration? Mineral assemblage, modal mineralogy, and geologic setting provide important constraints on phyllosilicate formation environment.

Volumetric abundances of coarse grain size mineral constituents in surface units are possible to determine remotely via linear deconvolution of thermal emission data [e.g. 4] because the photon interactions are mostly singly scattered. In VNIR spectral data of particulate surfaces, multiple scattering dominates and spectral mixing is nonlinear. Radiative transfer models predict that the systematics can be linearized by converting reflectance data to single scattering albedo [5, 6]. Laboratory studies have shown the Hapke [5, 7, 8] and Shkuratov [6, 9] radiative transfer models predict modal abundance to within approximately 10% for well-controlled mixtures of mafic minerals. Applications of radiative transfer models to remotely sensed data show that more accurate understanding of geologic processes is gained relative to linear mixture models [10]. For Mars data, the Shkuratov model has been applied to estimate mineral abundances within phyllosilicate-bearing terrains using OMEGA data [11], providing a first comparison of variations from place to place in terms of modal mineralogy.

The performance of Hapke and Shkuratov models for determining phyllosilicate abundance in multi-component mixtures has not yet been evaluated using laboratory data, however. Because of the considerable compositional variability of phyllosilicates and changes in spectral properties related to hydration state, these alteration minerals may prove more challenging to model than mafic minerals. We are beginning a suite of laboratory experiments to assess the efficacy of both the Shkuratov and Hapke models in estimating modal abundances of phyllosilicates in multi-component mixtures. Here we report initial results from spectra of simple binary mixtures of nontronite-olivine and nontronite-basaltic glass. Additional results will be presented at the conference.

Materials and Methods: Our first experiments mix phyllosilicate with a relatively bright, transparent component and relatively dark, opaque component. The nontronite was obtained from the Clay Mineral Society, source clay NG-1. The olivine is San Carlos olivine, and the anhydrous basaltic glass was obtained from the Big Island of Hawaii. The samples were crushed and sieved into eight particle size fractions. Nontronite was dry sieved while olivine and basaltic glass were wet sieved. Each endmember was weighed and then mixed, resulting in mixtures containing 5%, 10%, 30%, 50%, 70%, and 90% nontronite in mixtures with olivine and basaltic glass endmembers. Reflectance spectra were measured in the RELAB bidirectional spectrometer at i=30º, e=0º. Here, we give results of Shkuratov modeling for the nontronite-olivine binary mixture for the 45-75 µm size fraction.

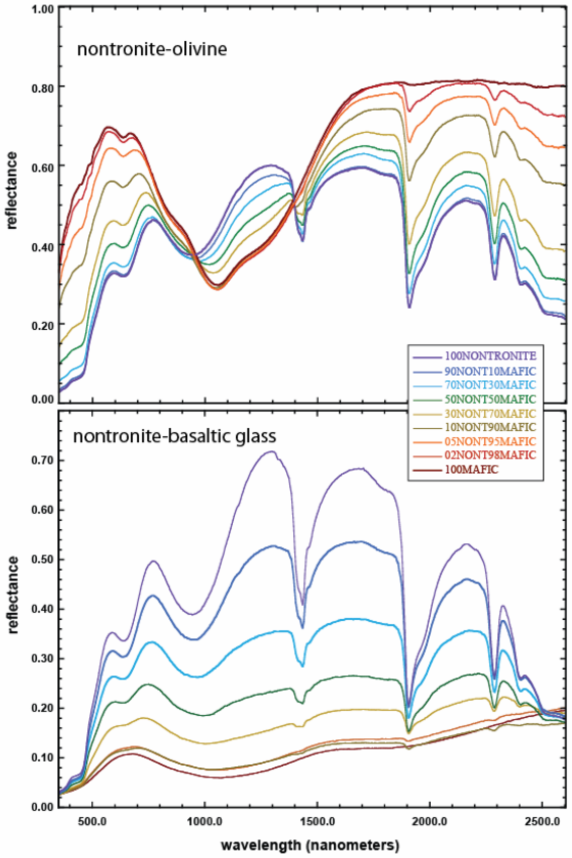

Figure 1. Nontronite-olivine (top) and nontronite-basaltic glass (bottom) for the 45-75 µm size fraction from 350 to 2600 nm. Abundances range from red 100% mafic (red) to 100% nontronite (purple).

The Shkuratov model simulates the reflectance of a particulate surface from the complex indices of refraction of each component, providing estimates of volumetric percentage, abundance and grain size of endmembers. Optical constants were estimated by using the Shkuratov model to iteratively determine the imaginary index of refraction for each endmember from reflectance spectra of the endmember particle size separates [9, 12]. Three particle size separates (<45, 45-75, 75-125μm) were available for initial model runs. Volumetric abundances output by the model were corrected to wt. % values using estimated densities of 1.7 g/cm^3 for nontronite and 3.3 g/cm^3 for olivine. These first analyses focused on the 1.0-2.6 μm region that is covered by the infrared detectors on CRISM and OMEGA.

Initial Results: Spectra of nontronite-olivine and nontronite-basaltic glass are shown in Fig. 1. As expected, phyllosilicate vibration band strength decreases with decreasing phyllosilicate abundance. This trend is more pronounced in the glass mixtures where dark, opaque components cause a lower apparent band strength compared to the olivine mixtures for equivalent phyllosilicate abundance. Low abundance mixtures of nontronite with the basaltic glass show some irregularities in the continuum (e.g. 10% nontronite mixture is darker than expected) perhaps related to inhomogeneous distribution of nontronite in the sample dish.

RMS errors in fit between measured spectra and modeled spectra are less than 0.01 in all cases. Model estimates of modal nontronite abundance in the nontronite-olivine mixtures are mostly within 10% of actual abundances (Fig. 2). These uncertainties are similar to those inferred in the case of mafic mixtures [9]. When the grain size parameter is variable, nontronite is mostly underestimated except at very low abundances. Nontronite grain size is overestimated and olivine grain size is underestimated for the 30-70% nontronite-olivine mixtures. (Fig. 3). A second model run with fixed nontronite grain size resulted in an overestimate of nontronite abundance rather than an underestimate.

Future model runs will assess the efficacy of the Shkuratov model on the nontronite-basaltic glass mixtures and compare these with the Hapke approach. Also, the full suite of eight particle size separates will be used to derive optical constants. In addition, we are preparing additional mixtures with more than two endmembers and mixtures of other phyllosilicates with mafic minerals to test and refine the models.

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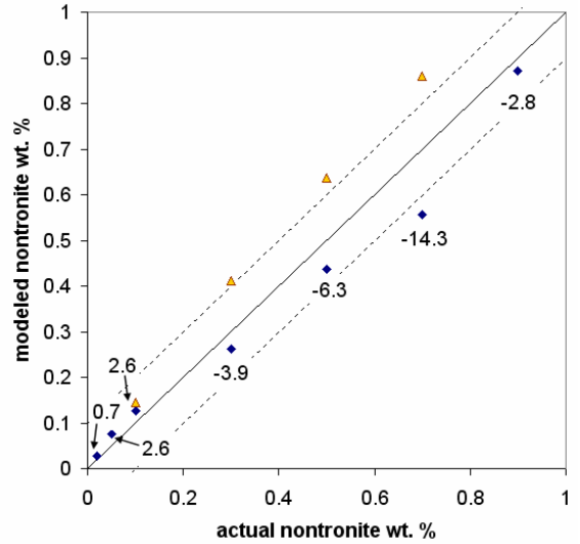

Figure 2. Shkuratov model estimates of abundance vs. actual abundance for nontronite in binary mixture with olivine. Weight % differences (modeled - actual) are indicated for the model run with variable grain size (blue diamonds) and fixed nontronite grain size (yellow triangles). Only the 1.0-2.6 μm range was used during the fit procedure. Dashed lines indicate ±10%.

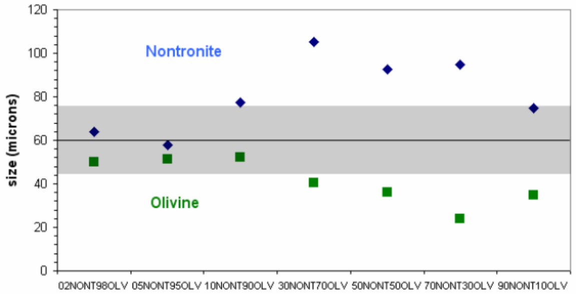

Figure 3. Shkuratov-based model estimates for endmember grain size for binary nontronite-olivine mixtures. The actual grain size range of the mixture, 45-75 μm, is indicated by the shaded box.