CONTROLLED STUDY FOR QUANTITATIVE CLAY ABUNDANCE ON MARS. A. J. Brown[1] , J. L. Bishop[1,2], T. L. Roush[2,] L. Hunkins[2], T. Bristow[2,3], and D. Blake[2], [1]SETI Institute, 189 Bernardo Ave, Mountain View (abrown@seti.org), [2]NASA Ames Research Center, Moffett Field, CA 94035, [3]Oak Ridge Associated Universities, NASA Post-Doctoral Program, Oak Ridge, TN 37831

Introduction: Data obtained at visible and near-infrared wavelengths by OMEGA on MarsExpress and CRISM on MRO provide definitive evidence for the presence of phyllosilicates and other hydrated phases on Mars [1,2]. A diverse range of both Fe/Mg-OH and Al-OH-bearing phyllosilicates were identified including smectite, kaolinite chlorite, serpentine [e.g. 3,4] and possibly talc [5]. In order to constrain the abundances of these phyllosilicates spectral analyses of mixtures are needed.

We report on our effort to enable the quantitative evaluation of the abundance of hydrated-hydroxylated silicates when they are contained in mixtures. The study includes two component mixtures of hydrated/hydroxylated silicates with each other and with two analogs for other martian materials; pyroxene (enstatite) and palagonitic soil (an alteration product of basaltic glass). For the hydrated-hydroxylated silicates we include saponite and montmorillonite (Mg- and Al-rich smectites). We prepared three size separates of each sample for study: 20-45, 63-90, and 125-150 µm.

Scanning Electron Microscope (SEM) Characterization: Fig. 1 shows an example of our SEM imaging of the end-member samples. We used a Hitachi SEM to examine the particles at 50x, 100x, 500x, 1000x, and 2000x, resolving shape and surface features on the grains. We also captured digital images of well separated particles.

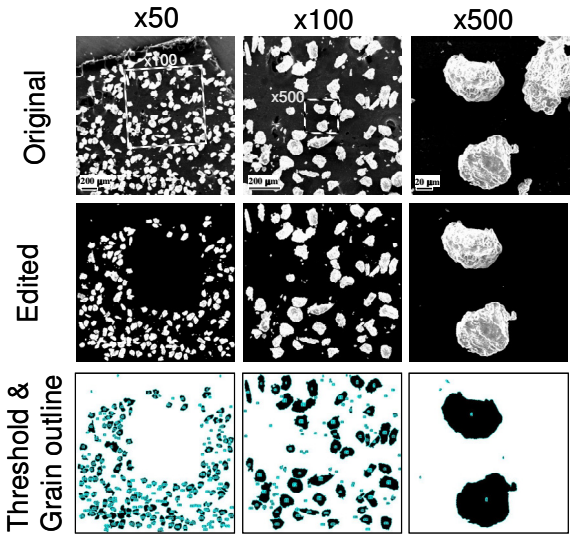

Figure 1. SEM images of 63-90 µm grain size of saponite, at different magnifications, used for particle size determination of saponite; original (top) and edited images (middle), and particle size numbers and outlines (bottom).

Particle Size Characterization: To determine the particle size distribution of the samples from the digital images we used ImageJ [6]. Fig. 1 shows the sequence for the 63-90 µm particle size separate of saponite.

The original image (Fig. 1 top row) contains a scale bar that can be used to determine the µm/pixel. Each image was edited to eliminate the region of scale bar, incomplete grains on the image border, grains contained in higher resolution images, and features associated with the carbon tape used to hold the samples in place. The results of these eliminations are shown in the middle row of Fig. 1. To isolate grains for further analyses, a threshold was applied while comparing to the original image and adjusting the threshold value. Particle size information was extracted using the ImageJ routine, *analyze particles*, and the results were displayed with an outline around each grain (Fig. 1, bottom row).

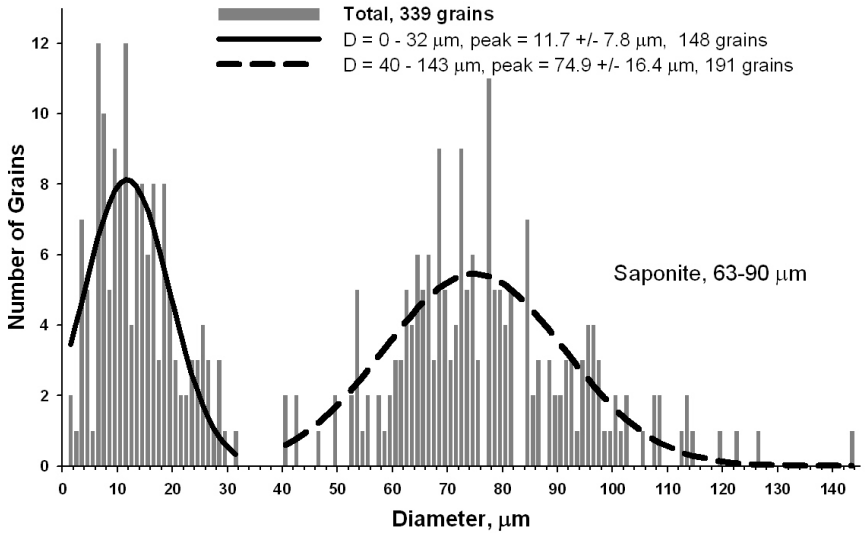

Figure 2. Histogram of the of the 63-90 µm grain size saponite sample using SEM images. The black lines represent separate Gaussian functions fit to each mode of the distribution, The center and widths are given in the legend.

The properties recorded for each grain and subsequently used to determine the particle size distribution include, each grain number, it's area (square pixels), and major and minor axes (pixels) of the fit ellipse.

Each grain area from the image analyses was used to calculate the equivalent spherical particle diameter, d, based upon the projected area, via: $A = \pi r^2$, where the sphere radius, r, is ½ d. A bimodal distribution resulted for this size fraction (Fig. 2) and each mode was fit with a Gaussian (black lines, Fig. 2).

Endmember Spectra: Fig. 3 shows the visible and near-infrared (VNIR) reflectance spectra of each sample as a function of particle size. The ensatite spectra in Fig. 3A exhibit broad reflectance features near 0.95- and 1.9 mm that are due to Fe^{2+} located in the pyroxene crystal structure. The spectra of the clays (Figs. 3B and 3C) and palagonitic soil (Fig. 3D) exhibit absorptions due to molecular water and hydroxyl groups. As Figs. 3 A-D show, there is an inverse relationship between particle size and overall refelctance level of the enstatite and palagonitic soil. However, this inverse relationship is not as clearly illustrated by the spectra of the saponite and montmorillonite, Figs. 3B and 3C, respectively.

Mixture Spectra: Fig. 4 shows the VNIR reflectance spectra of a mixture consisting of 95% enstatite and 5% saponite, along with spectra of the two end-members. Even at this low concentration, the presence of saponite introduces spectral features near 1.9, 2.32, and 2.38 μm when compared to the pure enstatite spectrum.

Future Work: In the coming two years of this project, we will: 1. Complete particle size determination of all end-members via the SEM imaging and procedures outlined here. 2. Carry out and analyze X-ray diffraction of end-member samples 3. Prepare additional mixtures and characterize them using SEM, X-ray diffraction and VNIR spectroscopy. 4. Derive optical constants, real and imaginary indices of refraction from the reflectance spectra 5. Calculate a forward model of reflectance spectra of the mixtures and compare these to the laboratory measurements.

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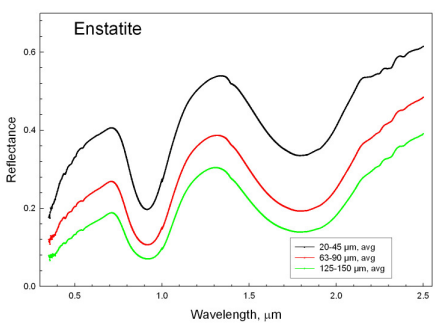
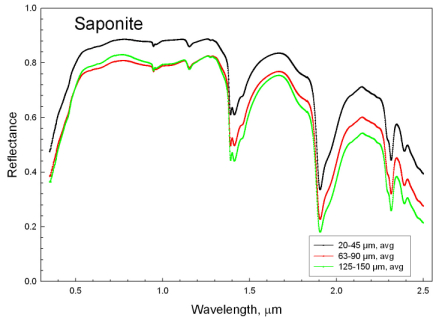
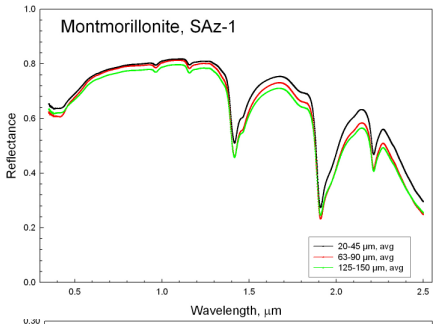
References: [1] Poulet, F. (2005) *Nature* **438** 623-627 [2] Bibring J.-P. et al. (2006) *Science* **312** 400-404 [3] Bishop, J.L. et al (2008) *Science* **321** 830-833 [4] Ehlmann B. et al. (2009) *JGR* **114** doi://10.1029/2009/JE003339 [5] Brown A.J. et al. (2010) *EPSL* **297** 174-182 [6] http://rsbweb.nih.gov/ij







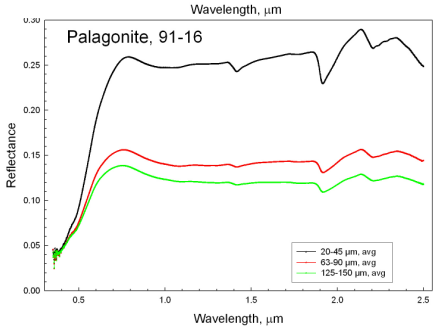


Figure 3. Average VNIR reflectance spectra for each grain size fraction of each sample: (A) enstatite, (B) saponite, (C) montmorillonite, and (D) palagonitic soil.

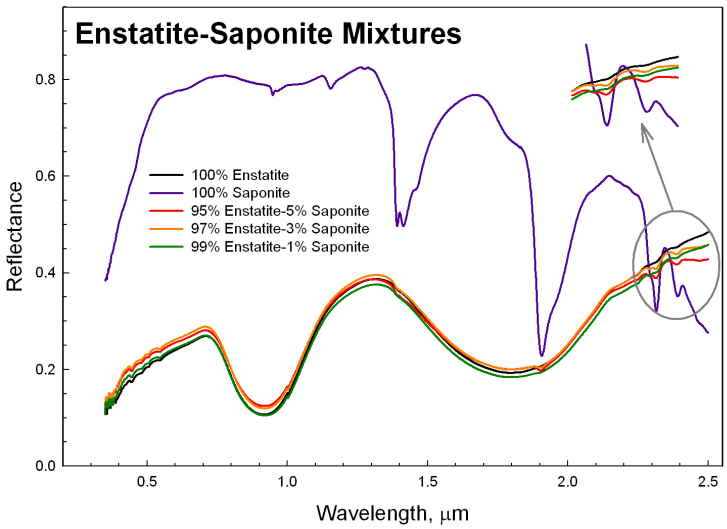


Figure 4. Average VNIR reflectance spectra of enstatite (black line), saponite (purple line) and a mxiture consisting of 95 wt.% enstatite and 5 wt.% saponite (red line) are shown for the 63-90 μm grain size fraction.