ESTIMATING MODAL MINERALOGY OF THE MAWRTH VALLIS REGION, MARS USING VISIBLE-NEAR INFRARED RADIATIVE TRANSFER MODELS. K.M. Robertson¹, S. Li¹, and R.E. Milliken¹. Dept. of Geological Sciences, Brown University, Providence, RI, 02912. kevin_robertson@brown.edu

Introduction: Mawrth Vallis is a mineralogically diverse Noachian-age region of Mars with strong Fe/Mg–smectite, Al–smectite, kaolinite, hydrated silica, and sulfate signatures in CRISM reflectance spectra [1-3]. Distinct absorption bands in the 2.2 μm and 2.3 μm wavelength regions indicate phyllosilicates are an important component, but large absorption widths associated with the 2.2 μm feature and strong spectral slopes at short wavelengths suggests that additional minor phases could be present [2]. Qualitative mapping of hydrous minerals has been successful in interpreting many geochemical regimes; however, spectrally ambiguous signatures can result in loosely constrained hydrological models.

In this study, we use Hapke Radiative Transfer Modeling (RTM) [4-5] of CRISM data in the Mawrth Vallis region to 1) model subtle variations in OH and H₂O absorptions and 2) constrain modal mineralogy with respect to stratigraphic position and morphology.

Methods: Radiative transfer models are typically used to describe how light intensity changes as it enters, interacts with, and exits a specific medium. Hapke’s RTM is commonly used for spectral un-mixing for airless planetary surfaces [6-9]. The application of such models to OMEGA spectral data of clay-bearing deposits in Mawrth Vallis is promising [3], but RTM’s have not yet been fully examined using CRISM data. Recently, binary clay-igneous [10] and clay-sulfate [11] mixtures were analyzed using Hapke’s RTM.

The parameterization of the Hapke model used in this study is the same as that of [12]. The model inputs are the CRISM reflectance data after photometric correction, viewing geometry (i, e, g) from CRISM DDR data, and mineral endmember densities. The model outputs are the endmember abundances based on the least squares minimization. A horizontal spectral endmember is included to account for scaling effects (e.g., possibly due to dust, illumination or particle size); though this may limit the current method’s effectiveness for absolute abundances the results are expected to be effective for determining relative mineral contributions.

Endmember reflectance spectra used in the un-mixing were measured in RELAB at Brown University under ambient conditions with an ASD fieldspec3 spectrometer configured with a viewing geometry of: i = 30°, e = 0°, g = 30°. A total of 30 endmembers were simultaneously evaluated in the model, which included phyllosilicates, sulfates, zeolites, and hydrated glass.

Preliminary modeling was performed on image FRT0000A2C2 in Mawrth Vallis. Standard photometric and projection corrections from the CAT 6.6 tools in the ENVI software were applied to the full image. The corrected CRISM reflectance spectra are converted to single scattering albedo, and this is modeled as a linear combination of single scattering albedo spectra using mineral endmembers, weighted by their fractional contributions. The model is solved inversely and the combination of minerals that provide the best RMS error in the spectral fit is assumed to be the best representation of bulk mineralogy for each pixel.

Results: Preliminary mapping results indicate nontronite and montmorillonite are important components (Fig. 1b), consistent with previous interpretations [1-3] and simple band depth measurements (Fig. 1a). The similarity between the two maps is evident in regions marked 1 and 2 and suggests that the model is able to differentiate between the major phyllosilicate phases. The nontronite regions appear to have a higher correlation with the parameter map than the montmorillonite-rich regions, which may be attributed to the presence of hydrated silica in these locations and its influence on the BD2210 parameter.

Areas with low albedo and bland spectral features (right hand side of the image) include low abundances of nontronite and montmorillonite and likely represent uncertainty in the model results. The solid contiguous areas associated with regions 1 and 2 are much more representative of robust spectral fits.

Modeled spectra for two representative CRISM spectra are shown in Fig. 2. The blue spectrum is taken from region 1 and is dominated by nontronite whereas the red spectrum is taken from region 2 and is dominated by montmorillonite-like features. Spectral fits for both are excellent with average RMS ~ 10⁻⁶. An instrumental artifact is observed in the data at 1.65 μm (grey area) and is excluded in the modeling. The fit for the nontronite rich spectrum is excellent for all of the hydration features, whereas the shape of the broad 2.2 μm region in the montmorillonite spectrum is not modeled as accurately (arrow), suggesting phases outside of the input library may be present.

The modal abundances for all 30 endmembers are shown in Fig. 3 for both regions. The abundances and standard deviations for 200 spectra are presented, demonstrating very little variation over the target regions. This suggests mineral assemblages in these regions are relatively uniform at these spatial scales. It is observed that even with 30 endmembers the model only selects 3-5 phases with abundances greater than 5 wt%. Removing the phases with less than 5 wt% (grey shaded region) does not significantly decrease the quality of the spectral fits, therefore they are deemed unnecessary and not representative of the bulk mineralogy (i.e., they are likely modeling noise).
The nontronite rich region is also correlated with ferricopiapite, hexahydrite, opal and bloedite. While the presence of Fe$^{3+}$/Mg$^{2+}$ is consistent with the Fe$^{3+}$ phyllosilicates, the modeled sulfate components are difficult to reconcile. Spectra of these minerals exhibit broad spectral slopes, and it is likely that they are included by the model to provide a better fit to the overall shape of the CRISM spectra and the width of the 1.9 µm H$_2$O band. However, these phases are not modeled for montmorillonite regions (though botryogen is included), suggesting overall spectral shapes are different in these two regions.

Montmorillonite in region 2 is also associated with hydrated silica and kaolinite. Hydrated silica and kaolinite have been attributed to this unit previously [13] and thus are not unexpected, although kaolinite is modeled at very low abundances.

**Conclusions:** Our preliminary modeling results of CRISM data in Mawrth Vallis are encouraging in that major clay minerals are 1) identified, 2) modeled at abundances in rough agreement with previous work [3], and 3) match major spatial variations observed in spectral parameter maps. The poor fit in the 2.2 µm region for the montmorillonite rich zones suggest an additional endmember may be present.

Sulfates are modeled in both regions but the specific phases are unique to each; further work is required to understand the validity and implications of these modeled components. Ongoing work will include anhydrous phases (pyroxene, oxides) in the model to understand their spectral contributions and abundances. In addition, we will begin using spectral endmembers with variable hydration levels as measured in the lab under controlled Mars-like temperature, pressure and relative humidity conditions.

**References:**
[10] Ehlimann et al., (2011) *LPSC abstract #1704*

---

**Fig. 1.** a) Parameter map of CRISM image FRT000A2C2 in Mawrth Vallis highlighting the presence of hydrated clays. Red=BD2300 (Fe/Mg clays), green=BD2210 (Al clays and/or hydrated glass), blue=BD1900 (hydrated minerals). Regions 1 and 2 correspond to strong nontronite and montmorillonite signatures respectively. b) Abundance map for nontronite and montmorillonite as determined from the Hapke modeling (red=nontronite, blue=nontronite and green=montmorillonite).

**Fig. 2.** Comparison of representative corrected CRISM reflectance data with the corresponding modeled reflectance from Region 1 and Region 2 (Fig.1).

**Fig. 3.** Modal mineralogy of Regions 1 and 2 (Fig. 1). Data represent an average of 200 spectra collected in the two different regions with the standard deviations shown.