

PHYLLOSILICATE DETECTION AND UNCERTAINTY FROM THERMAL INFRARED DATA IN THE VICINITY OF THE NILI FOSSAE. M. L. McDowell¹ and V. E. Hamilton¹, ¹Hawai'i Institute of Geophysics and Planetology, University of Hawai'i, 1680 East-West Rd, Honolulu, HI 96822 (mcdowell@hawaii.edu).

Introduction: OMEGA, the visible-near-infrared (VNIR) spectrometer on the Mars Express spacecraft has detected phyllosilicates, specifically clay minerals, in a limited number of locations on Mars [e.g. 1-3]. These detections in the VNIR offer the opportunity to increase our knowledge of how these materials appear in the thermal infrared (TIR) wavelength range.

Clay minerals are detected in the VNIR by reflectance minima at ~ 1.4 , 1.9 , and $2.2 - 2.4 \mu\text{m}$ resulting from O-H, H-O-H, and metal-OH bonds. Determining the abundance of the material identified is more complicated, however, due to non-linear mixing. From TIR data abundances are determined assuming that all components mix linearly, which has been shown to be a good approximation in most cases [e.g. 4,5]. It must also be considered, however, that the clay minerals mapped by OMEGA may be present as thin coatings, in which case linear mixing is not valid [e.g. 6]. Nonetheless, linear deconvolution of TIR spectra acquired over these locations may return identifications of phyllosilicates, but the uncertainties associated with these values and the detection limits above which values are believable have not been well studied for phyllosilicates. Some phyllosilicate minerals have broad features and low spectral contrast, suggesting that their identification at low abundances may be more difficult than for minerals with stronger, narrower features (e.g. olivine [7]). Phyllosilicate abundances of $\sim 15\%$ have been reported for much of the Martian surface, but the values have been considered unreliable due to the possibility that they are only surface coatings resulting in erroneously high abundance values [e.g. 8] or may be confused with silica or poorly crystalline phases [9,10]. The lack of widespread identification of phyllosilicates by OMEGA suggests that modeled abundances of $\sim 15\%$ phyllosilicates in the TIR may be below the reliable detection limit for these minerals [11].

We use the identification of phyllosilicates from an independent source (i.e. OMEGA) to establish their presence and inspect TIR data in these areas for spectral characteristics (both qualitative and quantitative) that can be used to differentiate phyllosilicate-bearing material from non-phyllosilicate-bearing material. These characteristics, especially difference in abundance, will be used to better constrain the detection limits and uncertainty of these minerals in the thermal infrared.

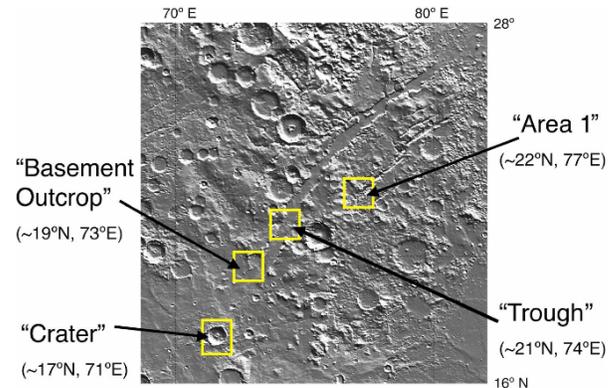


FIGURE 1: Shaded relief map of the area surrounding the Nili Fossae. The yellow boxes show the four study areas to date.

Study area. One of the largest exposures of phyllosilicates detected by OMEGA is in the vicinity of the Nili Fossae [1,2], the concentric grabens northwest of the Isidis impact basin. Currently we are investigating four areas in this region (Fig. 1) that are shown to be locations with phyllosilicate spectral features (those of Fe- and Mg-rich clays such as nontronite) in OMEGA data [1,3,12]. The ‘trough’ study area is a proposed landing site for the Mars Science Laboratory [12].

Michalski et al. [13] have previously reported an initial investigation of the ‘basement outcrop’ area in this region. Their study suggests that subtle compositional differences may be present, but TIR data indicates that the material is dominantly basaltic.

Approach: Data from both the Thermal Emission Imaging System (THEMIS) and the Thermal Emission Spectrometer (TES) are used in this work. THEMIS is a multispectral TIR spectrometer with a visible imaging subsystem onboard Mars Odyssey [14], and TES is a hyperspectral TIR spectrometer included on the Mars Global Surveyor spacecraft [15].

We selected THEMIS daytime infrared images for each of the study areas and analyzed them for spectral variation related to the presence or absence of phyllosilicates by performing a decorrelation stretch (DCS) [16]. This stretch uses three specified wavelength bands and redefines each axis in the way that maximizes variation and removes correlated information between bands. We removed atmospheric contributions to the images following the process outlined in [17]. We then averaged atmospherically corrected THEMIS surface spectra from the area mapped by OMEGA as phyllosilicate-bearing and compared this

average to the average spectrum of a similarly sized area of nearby spectrally homogeneous plains material.

Our analysis of TES data from these areas is currently in progress. Multiple techniques are being used to investigate the TES spectra to ascertain how the presence of the phyllosilicate material is manifested in thermal infrared hyperspectral data. One approach is to calculate ratios of TES spectra [18] on and adjacent to areas of interest from the same orbit to detect differences in surface composition. We are using linear deconvolution to remove atmospheric components and derive modeled abundances for the surface components. Additionally, we will apply factor analysis and target transformation, as described in [19], to help retrieve uniquely varying spectral shapes in the region, thus avoiding the constraints of spectral models relying on the use of laboratory spectra.

A complementary investigation of detection limits and uncertainty will help to better understand the significance of any differences observed in the TES data. Using laboratory spectra we will create numerical mixtures by linearly adding varying amounts of a phyllosilicate spectrum (e.g., nontronite) to the spectra of well characterized basalts [e.g. 20]. We will resample the data to TES spectral resolution and add TES-comparable noise to more realistically mimic measurements at Mars. These numerical mixtures will then be deconvolved and the actual and reported abundances for the range of mixtures will be analyzed.

Preliminary Results & Discussion: Three of the study areas analyzed to date show spectral variation in THEMIS DCS images in the area where clay minerals are expected. Atmospherically corrected THEMIS spectra from these areas exhibit differences in shape when compared to nearby spectrally homogeneous plains (Fig. 2). To better understand these shape differences, we created a range of numerical mixtures of nontronite and surface type 1 spectra at THEMIS resolution. As the nontronite abundance in the mixture increases, the emissivity decreases in band 5 (B5) while increasing in B4 and B7. This results in a relative increase in slope between B5-B6 and B7 with increasing nontronite abundance. The differences we observe in the THEMIS spectra of the three study areas appear to follow this pattern.

The fourth study area, the ‘trough’, does not appear to exhibit much of a difference between the area where phyllosilicates are reported and other nearby areas (Fig. 2). The shapes of these spectra are more broad and shallow than those of the other phyllosilicate areas. This result may indicate that the amount of phyllosilicates is too low to be distinguished by this method.

Summary and Ongoing Work: Areas where OMEGA detects phyllosilicates are observed as exhib-

iting spectral variation in THEMIS TIR images in most cases. Atmospherically corrected spectra from the images are consistent with the presence of a small abundance of clay minerals in addition to the modally dominant regional basaltic material. The recognition of these compositional variations as due to phyllosilicates in the TIR from THEMIS data is ambiguous, however. More confidence is placed in mineral identification with the higher spectral resolution of TES data. The examination of TES spectra from these areas is necessary to quantify the amount of phyllosilicate material present and use that information, along with the analysis of numerical mixtures, to help understand the detection limits and uncertainty of phyllosilicates in TES data.

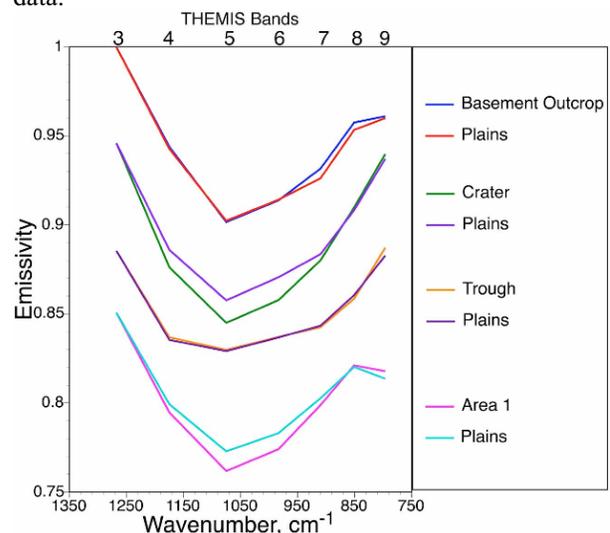


FIGURE 2: THEMIS spectra from the areas where phyllosilicates have been reported along with spectra from nearby non-phyllosilicate-bearing material. Spectra are offset by 0.05.

- References:** [1] Poulet F. et al. (2005) *Nature*, 438, 623-627. [2] Poulet F. et al. (2006) LPSC XXXVII, Abst. #1698. [3] Mustard J.F. et al. (2006) LPSC XXXVII, Abst. #1683. [4] Ramsey and Christensen (1998) *JGR*, 103, 577-596. [5] Feely and Christensen (1999) *JGR*, 104, 24195-24210. [6] Kraft M.D. et al. (2006) LPSC XXXVII, Abst. #2457. [7] Hamilton V.E. et al. (2003) *M&PS*, 38, 871-886. [8] Bandfield J.L. et al. (2000) *Science*, 287, 1626. [9] Wyatt and McSween (2002) *Nature*, 417, 263-266. [10] Michalski J.R. et al. (2006) *JGR*, 111, doi:10.1029/2005JE002438. [11] Hamilton and Schneider (2005) LPSC XXXVI, Abst. #2212. [12] Mustard J.F. et al. (2006) First MSL Landing Site Workshop. [13] Michalski J.R. et al. (2006) LPSC XXXVII, Abst. #1242. [14] Christensen P.R. et al. (2004) *SSR*, 110, 85-130. [15] Christensen P.R. et al. (2001) *JGR*, 106, 23823-23871. [16] Gillespie A.R. et al. (1986) *Rem. Sens. Env.*, 20, 209-235. [17] Bandfield J.L. et al. (2004) *JGR*, 109, doi:10.1029/2004JE002289. [18] Ruff and Christensen (2002) *JGR*, 107, 5127. [19] Bandfield J.L. et al. (2000) *JGR*, 105, 9573-9587. [20] Hamilton and Christensen (2000) *JGR*, 105, 9717-9733.