QUANTITATIVE MINERAL ABUNDANCES IN GALE CRATER USING THEMIS.

R. J. Smith[1] and P. R. Christensen, School of Earth and Space Exploration, Arizona State University (rebecca.jean.smith.1@asu.edu).

Introduction and science objectives: The Mars Science Laboratory (MSL) rover is on its way toward the central mound of Gale Crater where orbital data has confirmed the presence of aqueous weathering products such as mono- and polyhydrated sulfates and phyllosilicates [1]. It is important to have knowledge of mineral abundances before MSL reaches the central mound so that we might be able to guide the rover to locations that would be important for detailed analysis.

The mineralogical diversity of Gale Crater has been heavily studied using high spectral and spatial resolution visible-near infrared spectral (VNIR) datasets collected by the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) instrument [1], [2]. However, it is extremely difficult to derive quantitative mineral abundances in the VNIR due to complex scattering and absorption of energy at these wavelengths [3]. Quantitative abundance analyses are much less complicated in the thermal infrared (TIR) as it can be assumed, with some caution, that surface emissivity combines in a linear fashion at these wavelengths such that the emitted energy is proportional to the areal percentage of the minerals present [3].

Mineral abundance in Gale Crater has been quantified using Thermal Emission Spectrometer (TES) data, but only for the relatively flat crater floor where the mineralogy is similar to that of TES surface type 1 [4]. Determining mineralogy from the central mound is difficult because the slopes are steep enough that each TES pixel covers a significant change elevation which makes atmospheric correction much more complex. Yet, the slopes are where CRISM has detected secondary minerals making it important to attempt to analyze this region with TIR

The objective of this study is to obtain quantitative abundances of weathering products in Gale Crater in order to aide MSL to sulfate and phyllosilicate hot spots. We use high spatial resolution Thermal Emission Imaging System (THEMIS) data (~100 m/pixel) in conjunction with TES data (3 x ~8 km/pixel) to study the mineralogy of the mound.

Atmospheric correction*:* We selected a region of daytime infrared THEMIS observation I18380009 from which to model quantitative mineral abundances (figure 1). ROIa corresponds to a ~48 km^2 area in which CRISM has detected sulfate and phyllosilicate minerals, and ROIb is a ~0.1 km^2 area within ROIa.

We then performed atmospheric corrections of the THEMIS data by first atmospherically correcting TES data (ock 5733) (figure 2a), which were selected because they were near ROIa and covered a similar elevation range (figure 2b). It was then assumed that the thickness of the atmosphere, and thus the spectral contribution of atmospheric components in both locations was roughly the same.

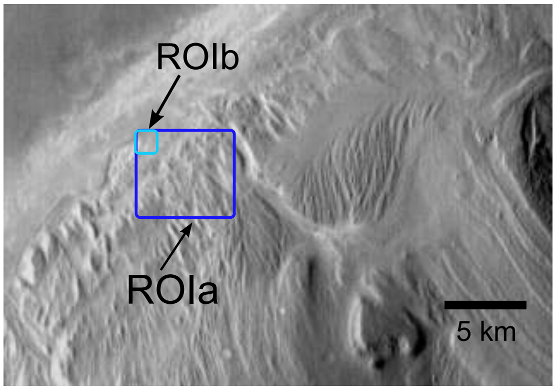

Figure 1: THEMIS observation I18380009 with areas ROIa and ROIb selected for analysis.

Next, THEMIS spectra from the region of I18380009 underlying ock 5733 were forced to match the atmospherically corrected TES spectrum, and the difference between the measured and atmospherically corrected THEMIS spectra was subtracted from the rest of the image.

Spectral analysis*:* Atmospherically corrected THEMIS spectra were averaged in order to create manageable datasets for preliminary analysis. ROIa is the average spectrum of a 65 x 74 pixel rectangle, and ROIb is the average spectrum of a 3 x 3 pixel square.

The two spectra were analyzed using a non-negative least squares algorithm which models the measured spectrum using lab spectra. This algorithm limits the lab spectral library to n - 1 endmembers, where n is the number of bands available for spectral analysis. THEMIS is limited to bands 3 – 9, thus we are allowed only 6 endmembers. The accuracy of each mineral abundance model was judged by the root-mean square (RMS) error (the lower, the better) and goodness of fit of the model to the measured spectrum.

Atmospheric correction results: Both ROIa and ROIb spectra are very similar in shape. The spectra differ near band 9, centered at 12.57 µm, a region that can be affected by CO_2 which has a strong absorbtion centered around 15 µm. The downturn in the spectrum of ROIb around 11.75 µm suggests that there is some residual CO_2 absorption, possibly due to a thicker atmosphere since this region is at a lower elevation than the average used in the atmospheric correction. This is further supported by the absence of a downturn in ROIa, indicating that the CO_2 was averaged out over the larger area.

Preliminary spectral analysis results: The 11.75 µm downturn in ROIb makes it difficult to accurately model the spectrum (figure 2a). However, an excellent fit can be attained for ROIa (figure 2c), which indicates that a better atmospheric correction could lead to more accurate modeling.

The models that provide the least RMS error and best fit to the data always include sulfates and plagioclase. Both of the spectra show a strong absorption feature around 9.4 µm, and sulfates are known to have deep, well-defined features in the 8.3 to 10 µm region [7] (figure 2 a and b). Phyllosilicates were not required to accurately model the spectra.

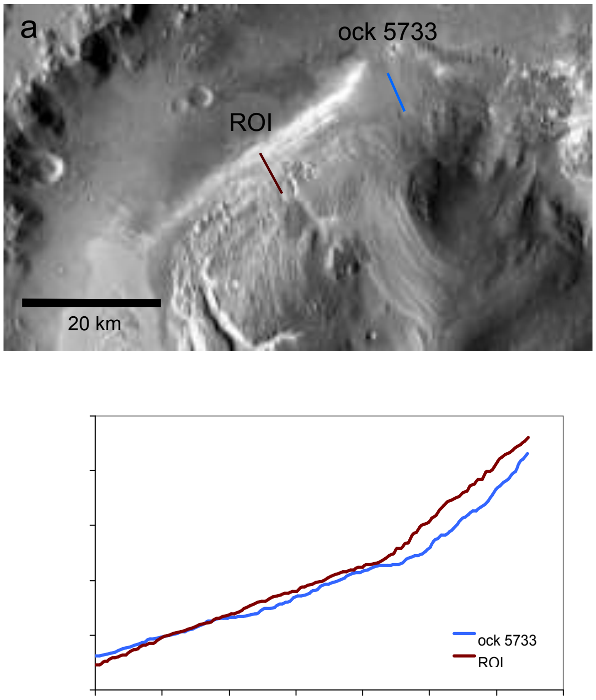

Figure 2: (a) THEMIS day IR global mosaic [5] with positions of elevation profiles shown in (b). (b) Elevation profiles of region of interest compared to region used in atmospheric correction (ock 5733).

Conclusions: THEMIS indicates a significant amount of sulfate minerals (above the detection limit of the instrument ~ 10 – 15%) in a region where sulfates have been reported from CRISM. Phyllosilicates are not required to accurately model the surface, thus they are either present in abundances below the detection limit, or have been averaged out over the ROI footprint. The refinement of atmospheric correction methods will allow reliable models to be obtained. Once this is achieved, smaller parcels of averaged spectra can be analyzed, yielding high spatial resolution quantitative mineral abundance maps of this region in Gale Crater.

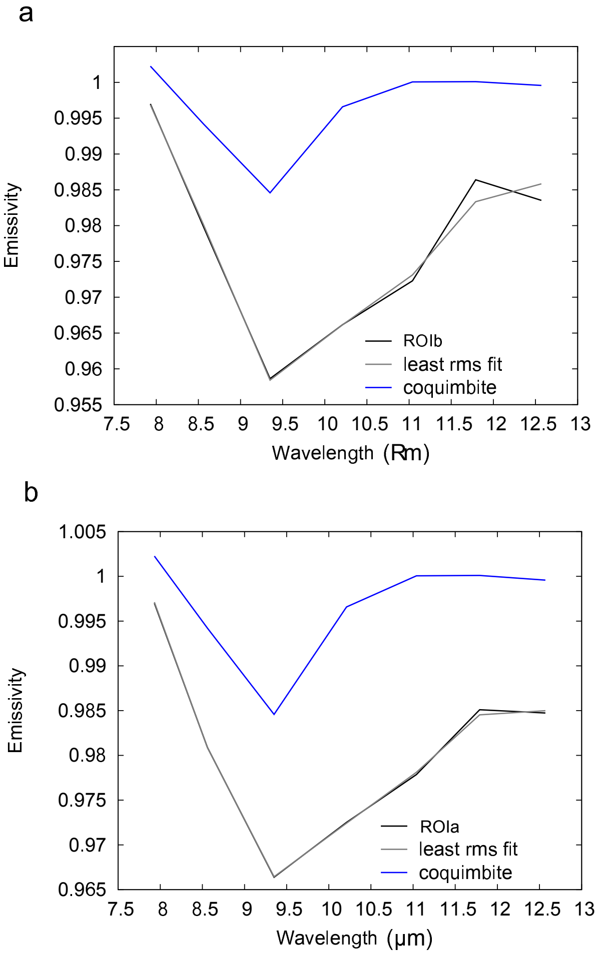

Figure 3: ROIb spectrum and modeled fit. (b) ROIb spectrum and modeled fit with no sulfates in endmember library (c) ROIa spectrum and modeled fit. Sulfate spectrum shown in (a) and (c) is offset for clarity.

References: [1] Milliken, R.E. et al. (2010) *GRL*, 37, L04201. [2] Murchie, S. et al. (2007) *JGR*, 112, E05S03. [3] Ramsey, M.S. and Christensen, P.R. (1998) *JGR*, 103, 577-596. [4] Rogers, A.D. and Bandfield, J.L. (2009) *Icarus*, 203, 437-453. [5] Edwards, C.S. et al. (2011) *JGR*, 116, E10008. [7] Christensen, P.R. et al. (2004) *Space Science Rev.*, 110, 85-130.