Composition Analysis of the Marius Hills Volcanic Complex using Diviner Lunar Radiometer Experiment and Moon Mineralogy Mapper. K. M. Lehman[1,2] , G. Y. Kramer[2], R. G. Mayne[1,3], W. S. Kiefer[2], [1]School of Geology, Energy, and the Environment, Texas Christian University, Fort Worth, TX (katelyn.lehman@tcu.edu), [2]Lunar and Planetary Institute, Houston, TX. [3]Monnig Meteorite Gallery, Fort Worth, TX.

Introduction:

The Marius Hills Volcanic Complex, located in Central Oceanus Procellarum at 13.3 N, 306.8 E , has an undoubtedly complicated volcanic history. Over 250 domes and complex surrounding volcanic geomorphologies suggest multiple volcanic episodes[1]. In light of this, many have investigated potential compositional differences using both Clementine and Chandryann-1's Moon Mineralogy Mapper (M3) and have identified the area as a high titanium basalt with glass features surrounding cones associated with pyroclastic [2,3,4]. Beyond subtle variation in FeO percent, TiO2 percent and olivine content, the complex has been deemed compositionally homogenous [2,3,5]. Recent geophysical research has shown a large gravity anomaly under the Marius Hills complex that can be best explained by a large magma chamber, large enough to allow for significant magma evolution [6]. This new evidence made it important to analyze possible compositional differences using data sets that have not been used before.

Our study makes use of two complementary spectral datasets. M^3 is an imaging reflectance spectrometer that can detect 85 channels between 460 to 3000 nm, and has a spatial resolution of 140 meter per pixel [7]. M^3 can determine mineralogy in reflectance spectra through diagnostic absorptions at specific wavelengths, which result from electronic transitions between an iron atom and its surrounding oxygens in a crystal structure [8]. The specific wavelengths at which these absorptions occur are dictated by the composition and crystal structure of a specific mineral. M^3 is particularly effective at detecting pyroxene and olivine, but can only detect plagioclase when it is verypure. Previous analysis of the near infrared spectrum of the Marius Hills used a preliminary calibration of M^3 spectroscopy [5], whereas our analysis uses the final calibration of the M^3 dataset.

The Lunar Reconnaissance Orbiter's (LRO) Diviner Lunar Radiometer Experiment has a spatial resolution of 950 m/pixel [10]. Diviner produces thermal emissivity data, and can provide compositional information from 3 wavelengths centered around 8 microns that are used to characterize the Christiansen Feature (CF) [9, 10]. Each CF value is indicative of a certain silicate mineral composition, with higher values being a more mafic material and lower values being felsic [9, 10]. This feature is not affected by vitrification and the value can be assumed to be based on linear mixing of the material [9, 10]. It is also important to note that a low CF value has a high correlation to high visual albedo, and that space weathering causes the CF value to move to longer wavelengths [10, 11]. All this makes the CF value very helpful in understanding the geology of an area. This value is complementary to M3 spectra, allowing for more felsic materials to be observed and for a deeper understanding of the entire compositional mixture as comparison between spectra compositions and Diviner compositions occur.

Methodology:

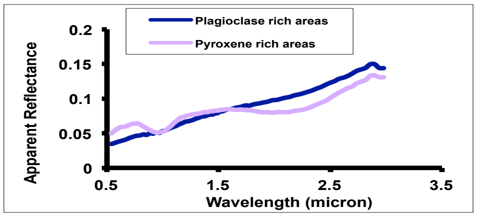
Three different data sets were used to analyze this region: Clementine, M3 spectral data, and the Gridded Level 3 Diviner Christiansen Feature map.

We initially used RGB (Band-Ratio Color Composite) [12], TiO2 [13], FeO [14] spectral image maps from the 5 channel UV VIS imager on the Clementine spacecraft. We also used M3 data to create spectral parameter maps, that were designed to highlight regions that are rich in particular materials such as olivine and high calcium pyroxene. The M3 maps were overlaid on to the Clementine data to differentiate chemically different areas. These areas were then analyzed using the M3 spectral profiles to see if there were actual notable changes in the spectra. We particularly focused on looking for possible spectral differences between the Marius Hills volcanic domes and the lava plains between the domes. Based on the geologic regions mapped out using these parameters we extracted representative M3 spectra for more detailed spectral analysis.

We also looked for possible differences in the location of Christiansen absorption frequency using Diviner radiometer results[9, 10]. Areas that displayed differences were then compared with their M3 spectral counterparts to see if there was a correlation between the two data sets. Finally, Lunar Reconnaissance Orbiter Camera (LROC) and WAC GLD 100 stereo topography model were used to try to understand the geomorphology of the areas that appeared chemically different.

M3 Analysis:

The analysis of the Marius Hills complex using the most recent M3 calibration bears similar results to previous studies. The complex appears relatively homogenous spectrally, with variations only seen in the absorption band depths and the reddening (ma-



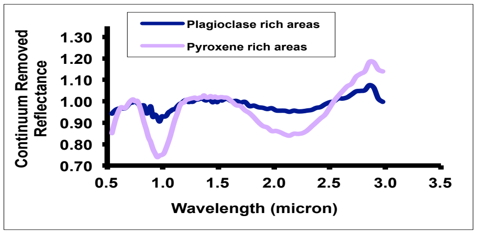


Figure 1: These graph displays the difference between the Plagioclase rich areas (purple) and the surrounding nonplagioclase-rich areas (blue). Top: Raw spectra Bottom: Continuum Removed spectra. Removing the continuum slope from the top spectra emphasizes the relative strength of the 1 and 2 micron absorptions for pyroxene. As can be seen, the Plagioclase-rich areas are brighter with muted absorptions.

turity) of the spectra. As seen in Figure 1, the spectra display classic pyroxene absorptions, primarily that of clinopyroxene, with its 1 and 2 micron absorptions shifted to longer wavelengths [15]. Previous studies had described an olivine rich flow within the complex [5], but we did not see this variation using the most recent M3 calibration.

Diviner Analysis:

Previous studies have used Diviner data to map more silica rich areas on the moon, but none of these have focused on the Marius Hills Complex [9, 10]. Although the area had an average CF value of 8.3 microns suggesting a pyroxene rich substance, there are areas across the complex that have CF values ranging 7.98.2 microns suggesting a more plagioclase rich area. These plagioclase regions are associated with many craters, rilles, possible volcanic vents and with 8 large domes. The largest of these lower CF value domes is made up of 65 diviner pixels covering approximately 62 km2. For each roughly km sized pixel, the CF value, and thus the composition, can be assumed to be based on linear mixing of the constituent minerals. For example, a CF value of An94-96 plagioclase is 7.9 microns. Therefore these km-sized areas with CF between 7.9 and 8.2 microns contain either a plagioclase rich basalt for the whole region or contain concentrated regions of exposed plagioclase surrounded by more mafic minerals [10].

These areas when compared to Clementine RGB and TiO2 parameters are shown to be surrounded by higher Ti materials. When spectrally analyzed using M3 data, these plagioclase rich areas displayed muted pyroxene absorptions and a brightening of the spectra.

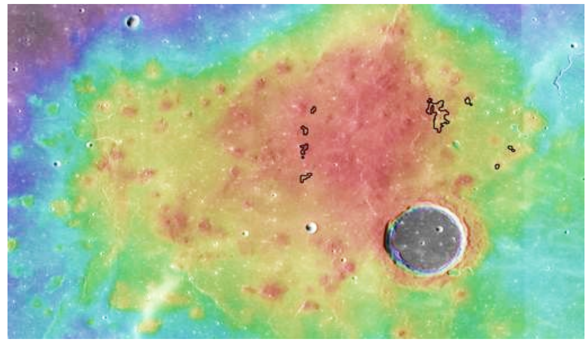


Figure 2: This map, which has a WAC image overlaid by a color relief map based on WAC GLD 100 topography as its base, displays the plagioclase rich domes. The 8 major domes that are observed as plagioclase rich by the Diviner Lunar Radiometer Experiment are outlined in heavy black.

Discussion:

The new Diviner data reveals the presence of plagioclase-rich regions within the Marius Hills. This conclusion was not possible using M3 data, because strong absorptions from even small abundances of pyroxene and olivine overwhelm the weak near-infrared absorption of plagioclase [16]. Bright craters and bright areas surrounding domes in the NAC images which are associated with low CF values are assumed to be the plagioclase-rich areas. These bright, plagioclase rich areas, are often surrounded by very low albedo which may be more ilmenite rich materials.

Conclusion:

By examining the Marius Hills complex using calibrated M3 data and Diviner CF value map, three important conclusions were made. First, the M3 spectra showed that the complex was relatively compositionally homogenous, supporting earlier observations. Second, the olivine-rich basalts previously observed [5] in the complex were not seen in the more recent M3 calibration nor the Diviner data. Finally, Diviner data made plagioclase rich areas observable, which might be suggestive of magma evolution of the large magma chamber observed geophysically.

References: [1]J.L. Whitford-Stark and J.W. Head (1977) Proc. Lun. Plan. Sci. Conf. 8, 2705-2724 [2] C.M. Weitz and J.W. Head (1999) JGR:104, 18933-18956 [3] D. J. Heather, S. K. Dunkin, L. Wilson (2003) JGR:108, 2002JE001938. [4] Prettyman et al.(2005) JGR:111, 2005JE002656 [5] S. Besse et. al. (2011) JGR: 116, 2010JE003725. [6] W. S. Kiefer. JGR 2012JE004111 [7] C.M. Pieters et al. (2009) Curr. Sci. 96(4), 500-505. [8] R. G. Burns (1993) Camb. Univ. Press, 551 [9] T. D. Glotch et al.(2010) *Sci.* 329, 1510 [10] B. T. Greenhagen et al.(2010) Sci. 329, 1507 [11] P. J. Lucey et al. (2010) Proc. Lun. Plan. Sci. Conf. 41, 1600 [12]A. S. McEwen (1994) Sci. 266, 1858-162 [13] P. G. Lucey et al. (2000) JGR 105, 20297-20305 [14] B. B. Wilcox et al (2005) JGR:110, 2005JE002512 [15] R. L. Klima et al. (2011) Met. Plan. Sci. 46, 37939 [16] C. M. Pieters (1983) JGR 88, 9534-9544