GLOBAL DISTRIBUTION AND COMPOSITION OF LOW-CA PYROXENES ON THE MOON AS VIEWED BY THE MOON MINERALOGY MAPPER. R. L. Klima[1,2], C. M. Pieters[2], P. J. Isaacson[2], J. W. Head[2], M. Staid[3], L. A. Taylor[4], N. E. Petro[5] and J. M. Sunshine[6], [1]JHU/APL, Laurel MD (Rachel.Klima@jhuapl.edu); [2]Brown University, Providence RI; [3]PSI, Tucson, AZ; [4]University of Tennessee, Knoxville, TN; [5]NASA/GSFC, Greenbelt, MD; [6]University of Maryland, College Park, MD.

Introduction: New data from the Moon Mineralogy Mapper (M^3) onboard India's Chandrayaan-1 spacecraft is providing an excellent opportunity to expand our knowledge of the nature of the mineralogy and composition of the lunar surface. The 20-40 nm spectral resolution (in global mode) of the M^3 instrument allows diagnostic crystal field absorptions [1] to be mapped directly, providing an opportunity for quantitative mineralogic analyses at high spatial resolution.

Our goal is to first perform a survey of the moon, searching for immature exposures of pyroxenes within central peaks and in the walls of young craters. We then focus on modeling the spectra of low-Ca pyroxenes to determine where the low-Ca pyroxenes with the highest Mg-Fe ratios (or Mg#'s) are located on the surface. We hope to be able to distinguish candidate regions for Mg-suite pyroxenes from more ferroan norite deposits.

The crystalline structure of pyroxenes makes it possible to extract more than just compositional information from pyroxene spectra. The two octahedral cation sites in pyroxenes (M1 and M2) have geometries different enough that the absorption bands for the lower-energy crystal field transition occur at distinct wavelengths. Fe^{2+} in the M2 site produces the familiar 2 μm pyroxene band, and Fe^{2+} in the M1 site produces a weaker band near 1.2 μm. The relative strengths of these bands are proportionate to the amount of Fe^{2+} in each site, which varies based on the composition of the pyroxene and the cooling history [2]. We will examine the relative strengths of the 1.2 μm and 2 μm bands of selected pyroxenes, to explore their cooling history.

Methodology: An initial survey of the mineralogy of the lunar surface was conducted using two simple cylindrical global mosaics of M^3 data. The first, collected early in the mission, covers a large portion of the nearside of the Moon. The second, collected during the second optical period, spans the moon from about 150ºW to10ºW latitude. Shown in Fig. 1 are 0.75 μm albedo maps showing the coverage for each of the two optical periods (1b and 2a). All data for these mosaics are collected in global mode and spatially binned at 10x10. A correction (KRC1) has been applied to suppress residual calibration artifacts. Spectra presented here are not yet thermally corrected—thus many exhibit an increased signal at longer wavelengths caused by thermal emission. Similar investigations using thermally corrected data are underway and will be presented at LPSC.

To identify spectra that may be of high enough signal-to-noise for quantitative modeling, we limit our investigation to pyroxenes with continuum-removed band depths at 0.95 μm of at least 0.15. Pyroxene spectra from several latitudes on the near and far sides of the Moon have been selected and modeled using the Modified Gaussian Model (MGM), which allows a reflectance spectrum to be separated into its component absorption bands, each of which can be attributed to a specific crystal field transition [3]. If a spectrum represents a mixture of pyroxenes, the MGM can also be used to deconvolve the spectrum into its endmember pyroxenes, though the results are most accurate when the mixture is dominated by only two pyroxenes (either mechanically mixed or exsolved/inverted into a high and low-Ca phase) [4].

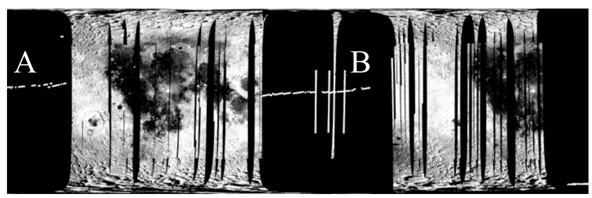

Fig. 1. 0.75 μm albedo in simple cylindrical projection for OP 1b (A) and 2a (B).

Preliminary Results: Although the calibration of M^3 data presented here does not include a thermal correction, the continuum-removed band depths at 1.9 and 2.3 μm still discriminate well between high and low Ca pyroxene. A color composite with R=1.9μm band depth (BD), G=2.3 μm band depth, and B= 1μm integrated band depth (IBD) was chosen to explore the diversity of pyroxene compositions. In this color composite, highlands appear black, fresh mare basalts and high Ca pyroxenes appear cyan and fresh low-Ca pyroxenes and norites appear magenta. Dark green is observed in highland areas near the equator because of the thermal upturn.

Outcrops dominated by low-Ca pyroxene (probably orthopyroxene) have been identified on both the near and far sides of the Moon. An example locality containing both low and high Ca pyroxenes is the region around the crater Bullialdus, shown in Fig. 2. The central peak of Bullialdus, located in Mare Nubium at about 20.7ºS and 22.2ºW, was identified previously [5,6] as being dominated by norite on the basis of telescopic and Clementine data. M^3 data confirms this identification. As illustrated in Fig. 3, the central peak of Bullialdus exhibits a 1 μm band near 0.9 µm and a 2 µm band near 1.9 µm, characteristic of low Ca pyroxene. This is in contrast to the surrounding material in Mare Nubium, which are dominated by high Ca pyroxenes. An example spectrum from one of the fresh mare craters near Bullialdus, Lubnietzky K, is also shown in Fig. 3.

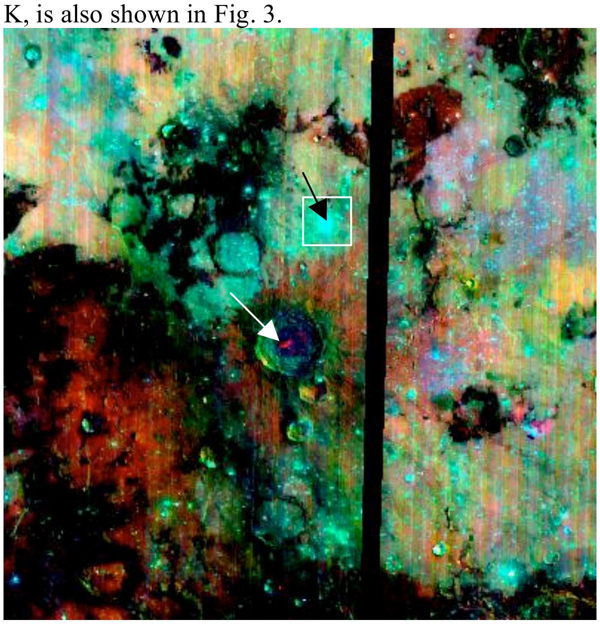

Fig. 2. False color image of region around Bullialdus. R=BD1.9µm, G=BD2.3µm, B=IBD1µm. The white arrow points to the central peak of Bullialdus and the black arrow points to Lubniezky K. Shades of cyan and yellow are mare basalts; magenta indicates a noritic composition.

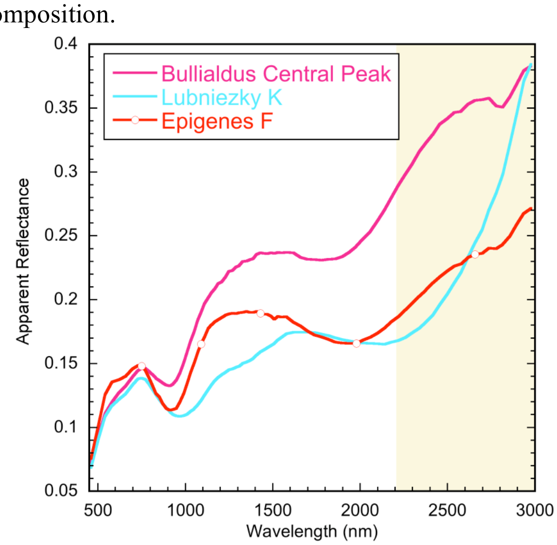

Fig. 3. Spectra from the central peak of Bullialdus and the crater Lubniezky K. Both spectra exhibit evidence of thermal emission longwards of 2.2 µm. Also shown is a spectrum from the small crater Epigenes F, located at 67.3ºN, 7.5ºW. This crater excavates noritic material comparable to that exposed by Bullialdus, and the spectrum exhibits significantly less thermally emitted component than do those near 20ºS.

The spectrum of Epigenes F makes it a good candidate for MGM analysis. An MGM fit was performed to this spectrum, using one band near 1µm, one at 1.2 µm, and one near 2µm. The results of the MGM, run with no parameters constrained and a continuum that is linear in wavenumber, are presented in Fig. 4. Compositional estimates based on the positions of the 1 µm and 2 µm band positions suggest that this is a norite of roughly Mg_{65} [7]. The 1.2 µm band at Epigenes F is quite weak, as expected for a well-ordered pyroxene. The 1.2µm intensity ratio is 0.17, suggesting that the pyroxenes excavated by Epigenes F are likely to have cooled quite slowly [2].

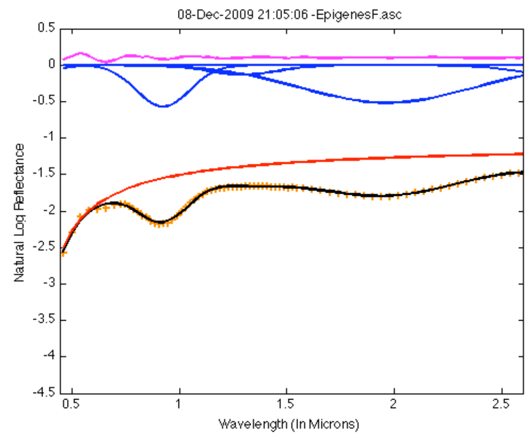

Fig.4. MGM fit to Epigenes F. The component absorption bands are shown as blue lines, the data are shown as orange plusses, the modeled fit is shown as a black line and the continuum slope is shown as a solid orange line. The magenta line indicates the residual error as a function of wavelength.

Conclusions and Ongoing Work: M^3 spectra are of sufficient quality to allow quantitative analysis of the character of pyroxene outcrops on the Moon. The 1.2 µm band provides additional information that can be used to validate compositional estimates and assess the cooling rate of deposits. Work is currently ongoing to map low Ca pyroxenes using full resolution global mode data and to repeat global analyses using thermally corrected data.

References: [1] Burns (1993) *Mineralogical Applications of Crystal Field Theory*. Cambridge University Press. 551. [2] Klima et al. (2008) *Meteoritics & Planet. Sci., 43,* 1591-1604. [3] Sunshine et al. (1990) *JGR, 95,* 6955-6966. [4] Sunshine and Pieters (1993) *JGR, 98*, 9075-9087. [5] Pieters (1991) *GRL, 18*, 2129-2132. [6] Tompkins and Pieters al. (1999) *Meteoritics & Planet. Sci., 34,* 25-41. [7] Klima et al. (2007) *Meteoritics & Planet. Sci., 42,* 235-253.

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