

GLOBAL IDENTIFICATIONS OF CRYSTALLINE PLAGIOCLASE ACROSS THE LUNAR SURFACE USING M³ AND DIVINER DATA. K. L. Donaldson Hanna¹, L. C. Cheek¹, C. M. Pieters¹, J. F. Mustard¹, M. B. Wyatt¹, and B. T. Greehangen², ¹Dept. of Geological Sciences, Brown University, Providence, RI 02912, (Kerri_Donaldson_Hanna@Brown.edu), ²Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA.

Introduction: Recent near-infrared (NIR) observations from the SELENE Spectral Profiler (SP) and Multiband Imager (MI) and the Chandrayaan-1 Moon Mineralogy Mapper (M³) have been used to uniquely identify Fe-bearing crystalline plagioclase in central peaks of several large highland craters [1,2] and the Inner Rook mountains of the Orientale Basin [1,3]. These results are significant because they validate earlier observations [4,5] as well as characterize the widespread distribution of crystalline plagioclase across the lunar surface. The identification of Fe-bearing crystalline plagioclase in the NIR comes from a broad absorption band at approximately 1.25 μm due to electronic transitions of Fe²⁺ in the crystal structure. While previous NIR lab studies have suggested that band depth and center position of the 1.25 μm feature may vary with Fe and An content [6,7], the relationship between NIR spectral properties of plagioclase and its composition (AN#) has yet to be quantified. Regions of nearly pure crystalline plagioclase (<5% olivine and pyroxene) as identified in NIR spectra are ideal areas to investigate the utility of thermal infrared (TIR) data to constrain plagioclase compositions [8,9].

The Diviner Lunar Radiometer Experiment onboard NASA's Lunar Reconnaissance Orbiter has three spectral bands near the 8 μm region chosen specifically to measure the peak of the Christiansen Feature (CF) [8], an emissivity maximum indicative of composition [10]. New lab measurements of varying compositions of the plagioclase solid solution series demonstrate that the CF position is diagnostic of composition and linearly related to AN# when measured under a simulated lunar environment [9].

Here we use M³ NIR global mosaics and individual data strips to identify the distribution of crystalline plagioclase and integrate those observations with Diviner TIR data to determine plagioclase composition. This integrated NIR and TIR approach is thus focused on relatively pure, crystalline plagioclase exposures across the lunar surface. Examining the local and global distribution of crystalline plagioclase is significant for (1) identifying rock types (ferroan anorthosites versus Mg-suite or Alkali-suite rocks) and (2) determining the crustal depth where crystalline plagioclase is observed. These results may ultimately constrain processes of formation (e.g. lunar magma ocean crystallization versus serial magmatism).

Data and Methods: Low resolution global mosaics of M³ data were prepared for each of the instrument's optical periods for evaluation within the team [11]. To identify crystalline plagioclase in the M³ data, an integrated band depth (IBD) at 1.25 μm was run on these mosaics as well as select full resolution data strips. The integrated band depth was calculated using the equation:
$$\sum_{n=0}^{26} 1 - R(1029 + 20n) / Rc(1029 + 20n)$$
 where R is the reflectance value at the given wavelength and Rc is the continuum reflectance at the same given wavelength. This integrated band depth parameter which sums 27 spectral bands across the broad 1.25 μm absorption was developed to specifically highlight plagioclase-rich areas (high IBD values) in the mosaics and data strips. M³ spectra were also extracted from each of the high IBD value regions to confirm the identification of pure crystalline plagioclase.

Diviner radiance data for lunar mid-day over the same regions were converted to emissivity and used to generate a CF map. TIR spectra were extracted from Diviner emissivity data and compared to laboratory emissivity spectra of the plagioclase solid solution

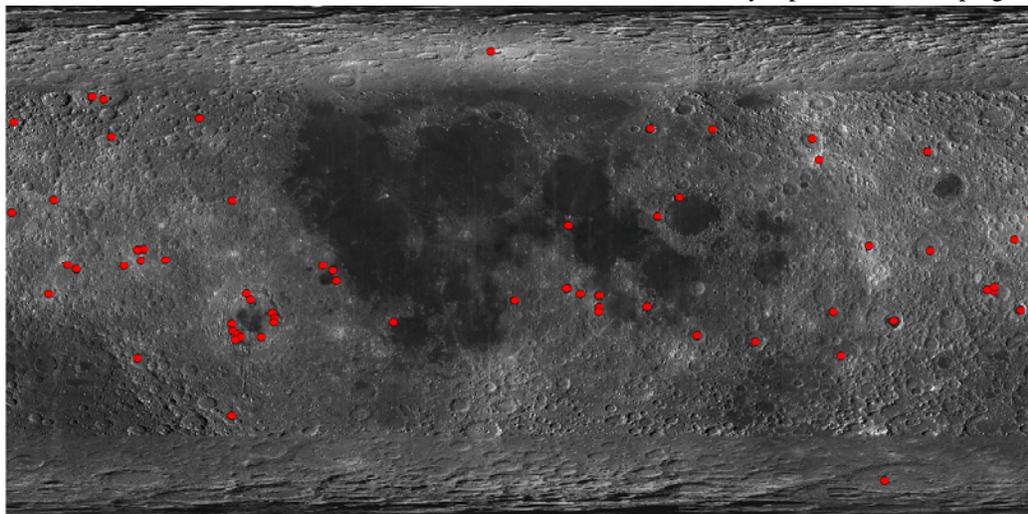


Figure 1. LROC WAC reflectance image of the lunar surface. Red dots indicate regions in which pure crystalline plagioclase has been identified using M³ NIR spectral data.

series to determine the plagioclase composition of those regions.

Results: In this global analysis of the M^3 NIR dataset we have identified crystalline plagioclase in: (1) the entirety of the Inner Rook mountain ring in Orientale Basin, (2) the walls and ejecta of simple craters surrounding basins and in the Feldspathic Highlands Terrane (FHT) on the lunar farside, and (3) in the central peaks and walls of complex craters (Fig. 1). Previously crystalline plagioclase had been identified only in a few isolated locations in the northern Inner Rook mountains [1,3], however this analysis shows that it is exposed extensively throughout the entire ring (see Cheek et al. [12] for further details). The exposure of crystalline plagioclase in the FHT by simple craters as well as the excavation of plagioclase by larger, complex craters can help estimate the range of crustal depths at which we see plagioclase. Simple craters have also exposed crystalline plagioclase in areas surrounding basins like Grimaldi where shocked plagioclase had previously been inferred from telescopic observations [4].

Our global survey identified crystalline plagioclase in many of the same large complex craters that [1] identified with two notable exceptions; we have made new identifications in the central peaks of Humboldt, Mercurius, Keeler, Theophilus, Fabry, and Aitken craters and we have yet to make identifications in Aristarchus, Copernicus, Kepler, and Tycho craters. Differences between our identifications and those of the recent SELENE MI survey could result from several factors including: (1) most of the crystalline plagioclase exposures are not large and with MI's higher spatial resolution it may make identifications that M^3 cannot (2) M^3 has more spectral bands across the broad 1.25 μm and its spectral range extends out to the 2.0 μm region making it easier to identify regions that have no mafic spectral signature, and (3) MI focused on specific immature, nearly regolith-free locations in craters and basins that

had high reflectances [1].

M^3 - Diviner Integration: An M^3 1.25 μm IBD parameter map over Humboldt crater clearly identifies crystalline plagioclase in several locations in the complex central peak structure (red units in Fig. 2B). The NIR spectra extracted from identified regions have strong 1.25 μm crystal-field bands and show no mafic signatures at 2.0 μm indicating these regions have not experienced shock pressures >25 GPa [13,14] and are free of mafic minerals. Analysis of Diviner data over Humboldt crater shows a good correlation between the 1.25 μm IBD parameter map and the Diviner CF map (plagioclase is identified as red units in each). The average CF value for the regions identified in the central peak of Humboldt crater is 7.84 μm with a standard deviation of 0.09 μm . Comparing these Diviner CF values to a CF value of 7.82 μm for anorthite (AN_{90}) measured under simulated lunar environment conditions [9] we find that the crystalline plagioclase in Humboldt crater is more Ca-rich than our terrestrial anorthite sample measured in the lab. These results are similar to those for Proclus, Jackson, and Petavius craters.

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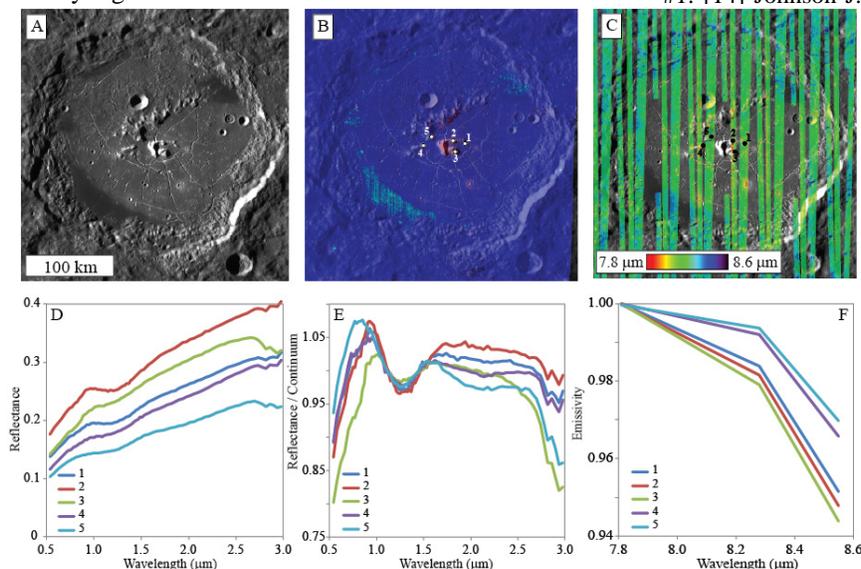


Figure 2. (A) LROC WAC reflectance image. (B) M^3 RGB image overlaid on the WAC image where R = IBD at 1.25 μm , G = IBD at 1.0 μm , and B = 2.0 μm . Red areas indicate regions identified as pure crystalline plagioclase. Circles indicate where 5 x 5 pixel locations were extracted for spectra. (C) Diviner CF map overlaid on the WAC image. Areas of short CF positions (red units) indicate plagioclase-rich areas. Circles indicate where 5 x 5 pixel locations were extracted for spectra. (D) M^3 reflectance spectra extracted from areas indicated in B. (E) M^3 reflectance spectra where a continuum (anchored at ~ 1.0 μm and 1.7 μm) has been removed (F) Diviner emissivity spectra extracted from areas indicated in C.