Diviner and Moon Mineralogy Mapper integrated observations of plagioclase-rich regions on the Moon. K. L. Donaldson Hanna[1], M. B. Wyatt[1], C. M. Pieters[1], L. C. Cheek[1], P. J. Isaacson[1], D. A. Paige[2], and B. T. Greenhagen[3], [1]Department of Geological Sciences, Brown University, Providence, RI 02912, [2]Department of Earth and Space Sciences, University of California, Los Angeles, CA, [3]Geophysics and Planetary Geosciences Group, Jet Propulsion Laboratory, 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 (M^3) 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 [3]. The identification of Fe-bearing crystalline plagioclase in the NIR comes from a broad absorption band at approximately 1.3 μm due to electronic transitions of Fe^{2+}. NIR laboratory studies of plagioclase have also suggested that the band depth and center position of this feature may vary with Fe and An content, respectively [4-6]. The new SELENE and M^3 observations are thus significant because they validate earlier NIR identifications of shocked plagioclase on the Moon, which had been inferred from a lack of Fe^{2+} absorptions in high-albedo locations [7-9].

The regions on the Moon where nearly pure crystalline plagioclase has been identified with NIR observations are also ideal locations to investigate the utility of thermal infrared Diviner data to constrain plagioclase compositions (An#) [10]. In this initial study, we present Diviner and M^3 observations (in coordination with M^3 science validation) of a plagioclase-rich region in Proclus crater (a 28 km crater west of Mare Crisium and east of Palus Somni), which has been previously identified using SELENE data [1,2]. We compare Diviner data to laboratory thermal emission data of the plagioclase solid solution series measured under a simulated lunar environment to constrain An#. Our objectives for this ongoing work are to identify rock types (ferroan anorthosites versus Alkali-suite rocks), and examine their local and global distributions on the Moon, which may ultimately constrain methods of formation (lunar magma ocean crystallization versus pluton).

Background: M^3 is an imaging spectrometer that was launched on October 22, 2008 onboard India's Chandrayaan-1 and successfully collected data until August 2009. M^3 covers the 0.43 – 3.0 μm wavelength region and data were acquired in two modes across its 40 km field of view: target (260 spectral bands and 70 m/pixel spatial resolution) and global (85 spectral bands and 140 m/pixel spatial resolution) [3].

The Diviner Lunar Radiometer Experiment on NASA's Lunar Reconnaissance Orbiter (LRO) was launched on June 18, 2009 and has begun making the first global coverage maps of thermal infrared derived compositions [10] and thermophysical properties. Diviner has nine channels: two broadband solar reflectance channels, three mineralogy channels, and four broad thermal channels [11]. The three mineralogy spectral channels are centered at 7.8, 8.2, and 8.6 μm and were chosen to specifically measure the peak of the Christiansen Feature (CF) [10]. The CF shift to shorter wavelengths for particulate materials in a vacuum environment is well constrained [12,13]. Of the known silicate minerals on the Moon, plagioclase feldspars, which have little Fe and higher Al and Ca, have shorter CF positions than pyroxenes and olivines which have high Fe and/or Mg and essentially no Al.

Data and Methods: An M^3 data strip (M3G20090202T024131) collected during the instrument's first optical period (OP1B) was selected based on the presence of plagioclase-rich regions identified by [1,2]. The band depth at 1250 nm was calculated (BD = 1 – [R1249/(R1579-R749/1579-749) x (1249-749) + R749)] where R indicates the reflectance at the indicated wavelength) to highlight plagioclase-rich areas (high band depth values) within the data strip. Spectra were also extracted to confirm the identification of crystalline plagioclase. Diviner radiance data for the same regions were downloaded, converted to emissivity, and used to generate a CF map.

New laboratory spectral measurements of the plagioclase solid solution series measured under a simulated lunar environment demonstrate that varying compositions of plagioclase can be identified using only their CF position [14] (see Table 1). Therefore areas on the Moon having a CF value between 7.4 and 7.9 μm are identified as plagioclase-bearing and are examined in detail.

Table 1. The CF position for full resolution laboratory plagioclase solid solution series spectra measured under SLE conditions and their anorthite contents (An#).

Mineral	CF Position (μm) SLE	An# Ca / (Ca + Na)
Albite	7.6201	23
Oligoclase	7.6313	24
Andesine	7.9654	43
Labradorite	7.9838	52
Anorthite	8.1023	89

Results: An M^3 1250 nm band depth parameter map over Proclus crater clearly identifies crystalline plagioclase in this region (Figure 1). The 1.3 µm crystal-field band is well-developed (red spectrum in Figure 1) and shows very few shock effects in the near-infrared spectra. Also, plagioclase spectra are clearly distinguished from minor mafic-bearing units as well as from mature soil material in the floor and outside the crater.

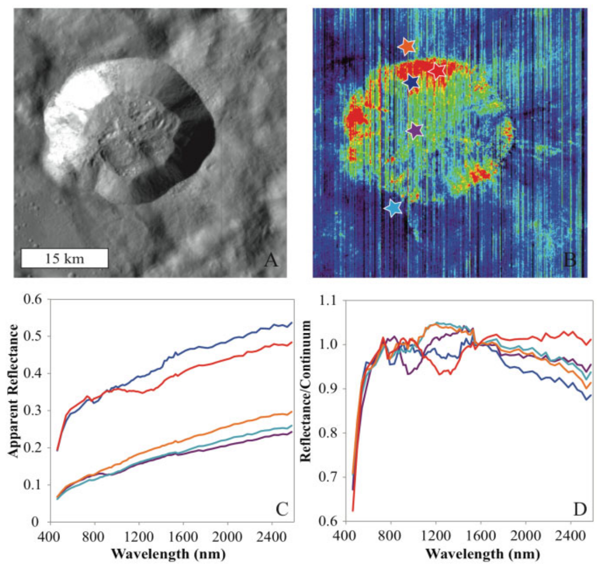

Figure 1. (A) M^3 image at 2936.3 nm of Proclus crater. **(B)** M^3 1250 nm band depth image where red areas indicate a high band depth value (plagioclase-rich regions) and purple areas indicate a low band depth value. Stars are color-coded and indicate 3 x 3 pixel locations at which spectra are extracted and plotted in **(C). (D)** Reflectance spectra where a continuum (anchored at 749 and 1579 nm) has been removed.

Analysis of Diviner data over Proclus crater shows a good correlation between the M^3 1250 nm band depth parameter map and the Diviner CF map. In the Diviner map, the lowest CF values indicating plagioclase (blue units) are identified in the same locations on the crater walls as the areas of highest 1250 nm band depth in the M^3 parameter map (red units) as shown in Figures 1 and 2. Focusing on these pixels, we find that the mean CF value is 7.83 µm with a standard deviation of 0.07 µm and that the minimum and maximum CF values are 7.61 and 7.89 µm respectively. Comparing these Diviner CF values to CF values for plagioclase minerals measured under laboratory simulated lunar environmental conditions indicates that there is very little variation in the An content of plagioclase within the crater walls of Proclus.

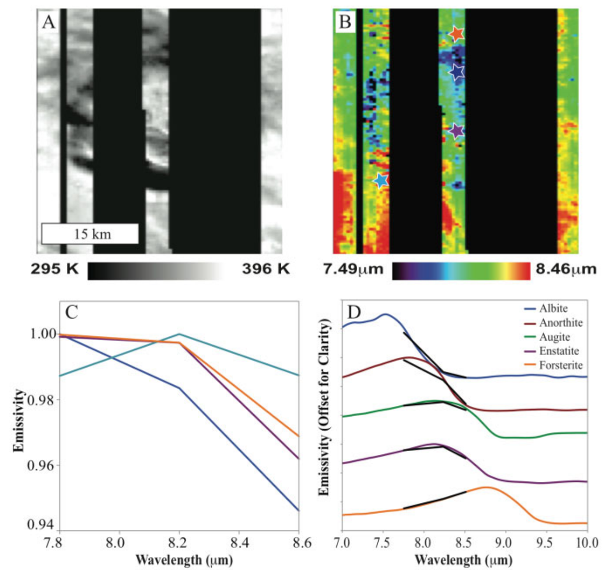

Figure 2. (A) Diviner band 5 temperature map. Black portions indicate no Diviner coverage. **(B)** Diviner CF map with color coded stars for locations of spectra extraction of 3 x 3 pixel areas (colors match the M3 data in Figure 1). Purple and blue areas indicate low CF values (plagioclase-bearing) while green to red areas indicate higher CF values (mafic-bearing). (C) Diviner spectra extracted from the 4 regions. (D) Full resolution and Diviner resolution mineral spectra.

Ongoing Work: Integrated Diviner-M^3 data analyses similar to the one performed for Proclus crater in this initial study are ongoing in an effort to conduct systematic analyses of additional pure plagioclase regions as identified by SELENE [1,2]. This work will enable plagioclase compositions to be mapped across the lunar surface and is significant for identifying rock types (ferroan anorthosites versus Alkali-suite rocks) and constraining methods of formation (lunar magma ocean crystallization versus pluton).

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