DIVINER OBSERVATIONS OF PURE PLAGIOCLASE REGIONS AS IDENTIFIED BY SELENE AND THE MOON MINERALOGY MAPPER. M. B. Wyatt[1], K. L. Donaldson Hanna[1], D. A. Paige[2], B. T. Greenhagen[2], J. Helbert[3], and A. Maturilli[3]. [1]Brown University, Department of Geological Sciences, Providence, RI 02912, [2]University of California, Los Angeles, Department of Earth and Space Sciences, Los Angeles, CA 90095, [3]Institute for Planetary Research, German Aerospace Center DLR, Rutherfordstr. 2, Berlin-Adlershof, Germany.

Introduction: Recent near-infrared 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 in Orientale Basin [3]. Shocked plagioclase had been previously inferred on the Moon from a lack of Fe^{2+} absorptions [4,5,6] in near-infrared measurements of high albedo locations as plagioclase can become sufficiently disordered with shock to lose its absorption bands [7]. The new SELENE and M^3 observations are significant because they validate these earlier near-infrared observations of plagioclase. The identification of Fe-bearing crystalline plagioclase in the near-infrared comes from a broad absorption band at ~ 1.3 μm due to electronic transitions of Fe^{2+}. Near-infrared laboratory studies of this feature have suggested its band depth and center position may vary with Fe and An content respectively [8, 9, 10]. The regions where pure crystalline plagioclase has been identified with SELENE and M^3 are ideal locations on the Moon to investigate the utility of Diviner data to distinguish between plagioclase compositions.

The Diviner Lunar Radiometer Experiment (DLRE) on NASA's Lunar Reconnaissance Orbiter (LRO) was launched on June 18, 2009 and is making the first global coverage maps of thermal-infrared derived compositions and physical 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) [12]. The CF is an emission maximum that results from minimum scattering (maximum transmission and penetration) in silicate minerals and occurs at a frequency at which the refractive index (real part) of the particles is equal to that of the surrounding medium (vacuum on the Moon). The wavelength position of the CF is diagnostic of composition and changes with the change in bond strength and molecular geometry associated with changing mineralogy [13]. The CF shift to shorter wavelengths for particulate materials in a vacuum environment is also well constrained [14, 15]. Of the known silicate minerals on the Moon, plagioclase feldspars, which have little Fe and higher Al and Ca, have higher CF frequencies than pyroxenes and olivines which have high Fe and/or Mg and no Al.

We take two approaches in this study for Diviner data analysis. First, laboratory emissivity spectra of the full plagioclase solid solution series measured at the Planetary Emissivity Laboratory [16] are analyzed to determine how the shift of the CF in vacuum conditions affect Diviner's ability to identify plagioclase composition. Second, Diviner emissivity maps of previously identified pure plagioclase regions are analyzed to (1) identify plagioclase and (2) look for variations in plagioclase composition within and across these regions. Here, we examine the extent to which Diviner derived plagioclase compositions provide new insights into recent near-infrared measurements.

Data and Methods: Laboratory emissivity spectra of < 25 μm and > 90 μm grain size fractions of the plagioclase solid solution series used in this work are from the Berlin emissivity database (BED) and are measured under ambient temperature and pressure conditions (Figure 1). The CF is identified for each plagioclase spectrum and Salisbury and Walter's [15] linear relationship between the CF measured in vacuum and air is then applied.

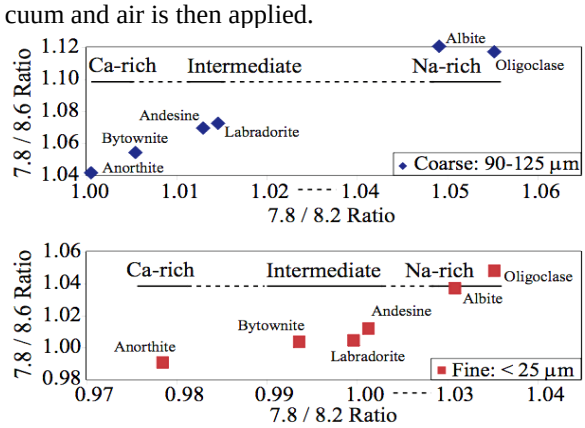

Figure 1. Spectral band ratios (7.8/8.6 vs. 7.8/8.2) of the plagioclase solid solution series for coarse- and fine-grain size fractions [17]. The coarse- and fine-grained fields are distinguished from one another due to the unique position and shape of the CF for each mineral composition. They are separated into two different plots to maximize the differences for each grain size fraction.

Available Diviner image cubes for the three mineralogical bands in pure plagioclase rich regions are converted from integrated radiance values ($Wm^{-2}Sr^{-1}\mu m^{-1}$) to emissivity by finding the maximum measured brightness temperature in one of the one mineralogical channels. A planck function is calculated for the maximum brightness temperature and then all pixels values in the mineralogical channels are divided by it. Previous laboratory studies of minerals and lunar highland and mare soils indicate that ratios of Diviner's mineralogical spectral channels can be used to distinguish between: (1) mineral groups, (2) different compositions of the same mineral, and (3) lunar lithologies [17]. Spectral ratios will thus be used to identify minerals and lithologic units as well as to constrain compositional differences across the pure plagioclase regions.

Results: On the Moon small grain size fractions, vacuum conditions, and thermal gradients complicate the analysis of lunar thermal infrared spectra. It has been shown for fine-particulate materials that a vacuum environment can introduce thermal gradients that will alter the spectral emissivity of a surface [14]. As pressure decreases, the spectral contrast increases, and the increased absorption in the Reststrahlen bands (8 – 12 μm region) cause the CF to shift to shorter wavelengths. Salisbury and Walters measured the linear shift of the CF between air and vacuum conditions. When this shift is applied to laboratory emissivity spectra of the plagioclase solid solution series the measured ambient CF of anorthite shifts to a vacuum position similar to the CF position of ambient labradorite and andesine (Figure 2). Therefore spectra of pure plagioclase regions as measured by Diviner will have spectra similar in shape to ambient condition measured labradorite and andesine.

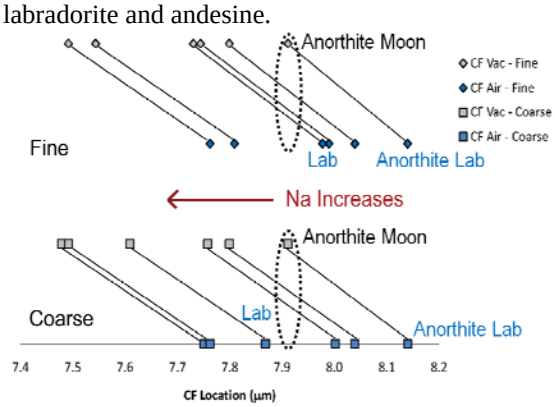

Figure 2. The CF position for fine- and coarse-grain size fractions for measured ambient conditions and shifted to vacuum conditions. Na-rich compositions plot to the left and Ca-rich plot to the right.

Pure plagioclase regions as identified by near-infrared spectra are analyzed with Diviner data including Jackson crater. Spectral band ratios were taken to identify the pure plagioclase regions and regions of plagioclase mixed with some mafic component (low- and high-Ca pyroxene, and olivine). SELENE's MI identified pure plagioclase, plagioclase mixed with low-Ca pyroxene, and plagioclase mixed with high-Ca pyroxene units in Jackson crater. In Figure 3 the spectral band ratio of 7.8/8.2 is plotted in color to identify different compositional units. Red units are spectrally consistent with pure plagioclase regions, meaning their spectra are similar in shape to a labradorite spectrum. The blue and green units in Figure 3 are likely mixtures of plagioclase and mafic minerals. Using the same analysis techniques, we find similar results for the Inner Rook mountains and Tycho crater.

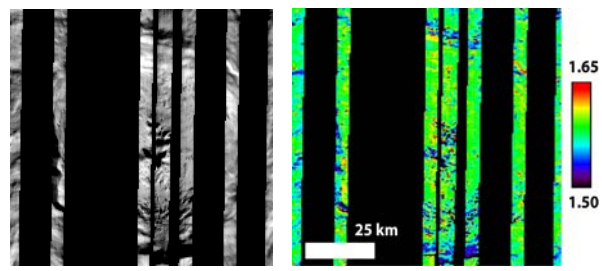

Figure 3. (left) Jackson crater Diviner temperature map derived from spectral channel 8 and **(right)** spectral band ratio 7.8/8.2. Red regions are consistent with pure plagioclase regions as identified by SELENE.

Future Work: The integration of new spectral measurements from Diviner with high-spatial and spectral resolution near-infrared data sets will further constrain plagioclase compositions. More insightful comparisons will be made as Diviner coverage of the regions of interest increase. Future laboratory spectral measurements of minerals, rocks and lunar soils under lunar-like conditions will provide direct comparisons for measured Diviner spectra.

References: [1] Ohtake et al. (2009) *Nature, 461*. [2] Matsunaga et al. (2008) *GRL, 35*. [3] Pieters et al. (2009) *40th LPSC*, Abs no. 2052. [4] Spudis et al. (1984) *JGR, 89*, C197-210. [5] Hawke et al. (2003) *JGR, 108*. [6] Tompkins and Pieters (1999) *MAPS, 34*, 25-41. [7] Johnson and Horz (2003) *JGR, 108*. [8] Adams and McCord (1971) *2nd LSC*, 2183. [9] Bell and Mao (1973) *GCA, 37*, 755-759. [10] Cheek et al. (2009) *40th LPSC*, 1928. [11] Paige et al. (2009) *Space Sci. Rev.*. [12] Greenhagen and Paige (2006) 37th *LPSC*, 2406. [13] Conel (1969) *JGR, 74*, 1614-1634. [14] Logan et al. (1973) *JGR, 78*, 4983-5003. [15] Salisbury and Walters (1989) *JGR, 94*, 9192-9202. [16] Maturilli et al. (2008) *Planet. & Space Sci., 56*, 420-425. [17] Donaldson Hanna K et al. (2009) *40th LPSC*, 2286.