HIGH FIDELITY MINERAL MAPS OF MOSCOVIENSE BASIN INTEGRATING THERMAL AND NEAR INFRARED MULTISPECTRAL IMAGING.

B.T. Greenhagen[1], P.G. Lucey[2], M. Lemelin[2], E. Song[2], P.J. Isaacson[2], K.L. Donaldson Hanna[3], I.R. Thomas[3], and N.E. Bowles[3], [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA; [2]Hawaii Institute of Geophysics and Planetology, University of Hawaii, Manoa, Honolulu, HI; [3]Atmospheric, Oceanic, and Planetary Physics, University of Oxford, Oxford, UK.

Introduction: Moscoviense Basin is a Nectarian Age multiringed impact basin on the lunar farside. Much of the floor of Moscoviense has been filled with mare basalts, including basalts with variable Fe and Ti compositions [1]. Morota et al. [2] crater ages of the mare units suggest sequential basaltic eruptions between 3.9 and 2.6 Ga. Additionally, Pieters et al. [3] identified several areas within the peak ring with exposures of olivine, orthopyroxene, and Mg-rich spinel. These exposures are exceptional in that they are not clearly associated with impact craters. The large mineralogical variations present within Moscoviense, coupled with the suspected abnormally thin crust [e.g. 4] make the Moscoviense Basin a compelling target for future exploration and sample return.

Here we use Lunar Reconnaissance Orbiter (LRO) Diviner Lunar Radiometer maps of the thermal-infrared (TIR) Christiansen Feature (CF), a spectral feature sensitive to silicate mineralogy [e.g. 5], and multispectral near-infrared (NIR) data from the Kaguya Multiband Imager (MI) to create high fidelity mineral maps of the Moscoviense Basin.

Benefits of Integrating TIR and NIR: The mineral sensitivities of the NIR and TIR datasets used in this study are nearly orthogonal. NIR data are most sensitive to the relative abundances of the mafic minerals but less sensitive to the abundance of plagioclase when mafic minerals are moderately abundant. On the other hand, Diviner CF values are close to the average of the CFs of the constituent minerals, weighted by their modal abundances. However, using the CF alone, specific minerals are not uniquely detected, except at extremely high abundances. Incorporating the CF as a constraint greatly increases confidence in plagioclase-mafic ratios over using NIR data alone [6].

Data: A mosaic of local CF values for Moscoviense was produced by topographically projecting and binning Diviner TIR data at 128 pixels per degree. The data were radiometrically normalized to equatorial noon to remove local time and topographic effects using the method of Greenhagen et al. [7]. The CF value for each bin was estimated from a quadratic fit to Diviner's three 8-micron channels' data using the method of Greenhagen et al. [8]. We used topographically corrected NIR data from the Kaguya MI, with 9 spectral bands between 0.415 and 1.55 microns [9,10]. The MI data were down sampled to match the Diviner resolution.

Mineral Map Methodology: This study uses a model methodology based on Lucey et al. [6] and recently updated by Lemelin et al. [11]. The core of this process is the calculation of large lookup tables of NIR spectra computed from Hapke theory and CF values from linear mixing of endmembers over the system plagioclase, olivine, orthopyroxene, and clinopyroxene. The NIR data provide the essential pyroxene-olivine ratio and final compositions are selected only from compositions that have model CF values within 0.04 microns of the observed Diviner CF value for each data bin. [6,11]

The NIR spectral modeling incorporates corrections for space weathering. To correct for the effects of space weathering on TIR CF values (~0.1 micron from immature to mature on average), we use the relationship described in Lucey et al. [6].

Results: Preliminary mineral maps are presented in Figures 1C-1F. The feldspathic highlands terrain that surrounds Moscoviense is unsurprisingly dominated by plagioclase, while the mare-filled inner basin is dominated by mafic minerals. Olivine abundances are highest in Kormarov crater and adjacent areas, with additional hot spots in the peak ring. Orthopyroxene is limited to the mare-fill areas and a few isolated areas in the peak ring. Clinopyroxene dominates the mare-fill and is most abundant in the eastern areas of Mare Moscoviense surrounding Titov crater.

Conclusions and Future Work: Although the modeling and analysis of the NIR datasets in this study is quite mature, there are much higher uncertainties with regards to the TIR data. Additional laboratory work in simulated lunar environment is urgently required to understand the relative CF values of mixtures of the pure endmembers used in this study. Arnold et al. [12] performed a trailblazing study and demonstrated non-linearity of the CF in the mixture of Ca-rich plagioclase and forsterite, especially in proximity to the endmembers. However, Arnold et al. [12] used "~An 80-90" in their mixtures and work by Donaldson Hanna et al. [13] showed a strong dependence of CF with An#, which could result in a ~0.1 micron offset from real lunar compositions (same order of magnitude as space weathering effects). We find that our model is extremely sensitive to the CF value of the anorthite endmember and will require mixtures with a lunar-like plagioclase endmember (An_{94-96}).

To validate this study and improve the quality of the laboratory data used to interpret Moscoviense Basin, we plan to first use Moon Mineralogy Mapper data to determine the dominate pyroxene and olivine compositions found in the basin [14,15]. Then we will perform targeted laboratory experiments on mixtures of the locally derived endmembers along with the lunar-like plagioclase ($An_{94\text{-}96}$). These results will feed back into an improved model to produce the highest fidelity mineral maps of Moscoviense currently possible with these data, an important tool for planning future sample return missions.

References: [1] Kramer et al. (2008) *JGR, 113,* E01002. [2] Morota et al. (2009) *GRL, 36(21),* L21202. [3] Pieters et al. (2011) *JGR*, *116*, E00G08. [4] Ishihara et al. (2009) *GRL*, *36*, L19202. [5] Logan et al. (1973) *JGR, 78*, 4983. [6] Lucey and Greenhagen (2012) *LPSC XLIII*, #1736. [7] Greenhagen et al. (2011) *LPSC XLII*, #2676. [8] Greenhagen et al. (2010) *Science*, *329*, 1507. [9] Ohtake et al. (2010) *SSR*, *154*, 55. [10] Kodama et al. (2010) *SSR*, *154*, 79. [11] Lemelin et al. (2014) *LPSC XLV*. [12] Arnold et al. (2013) *LPSC XLIV*, #2972. [13] Donaldson Hanna et al. (2012) *JGR*, *117*, E11004. [14] Klima et al. (2011) *JGR*, *116*, E00G06. [15] Isaacson et al. (2011) *JGR*, *116*, E00G11.

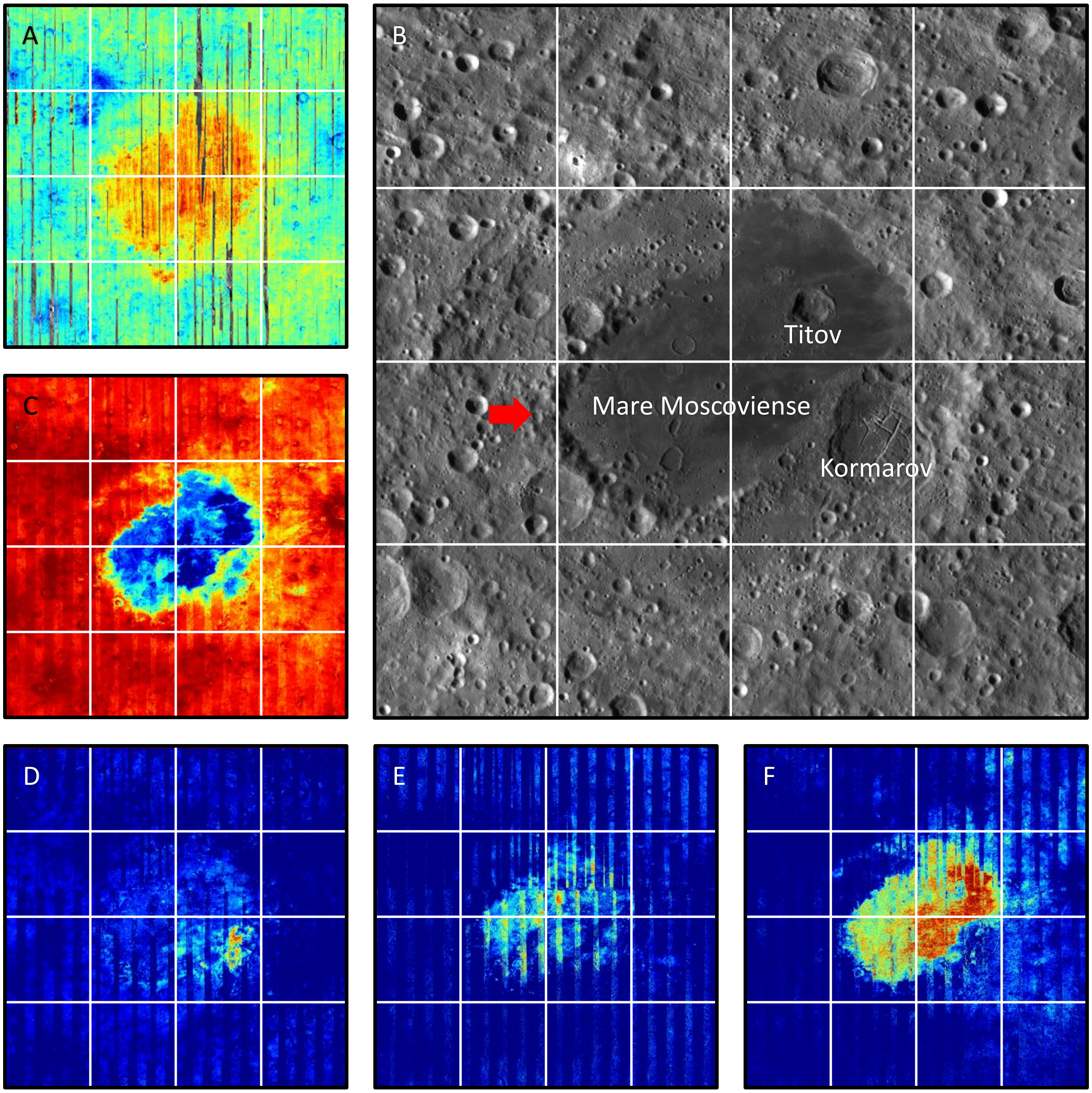

Figure 1: (A) Diviner CF Map for Moscoviense Basin, stretched 7.8 to 8.55 microns blue to red; (B) LROC WAC mosaic, red arrow indicates the peak ring; (C-F) preliminary mineral abundance maps of plagioclase (stretched 0.4 to 0.95), olivine, orthopyroxene, and clinopyroxene (each stretched 0.05 to 0.4) respectively. Maps cover 17-37N 138-158E. Preliminary maps at 64 ppd. Revised maps at 128 ppd will include new TIR constraints and updated methodology to reduce data striping.