MINERALOGICAL DIVERSITY OF THE LUNAR SOUTH POLE: CRITICAL CONTEXT FOR FUTURE SAMPLE RETURN GOALS AND INTERPRETATION. D. P. Moriarty III[1,2] and N. E. Petro[1], [1]NASA GSFC, 8800 Greenbelt Road, Greenbelt MD [Daniel.P.Moriarty@nasa.gov], [2]USRA, 7500 Columbia Gateway Drive, Columbia MD.

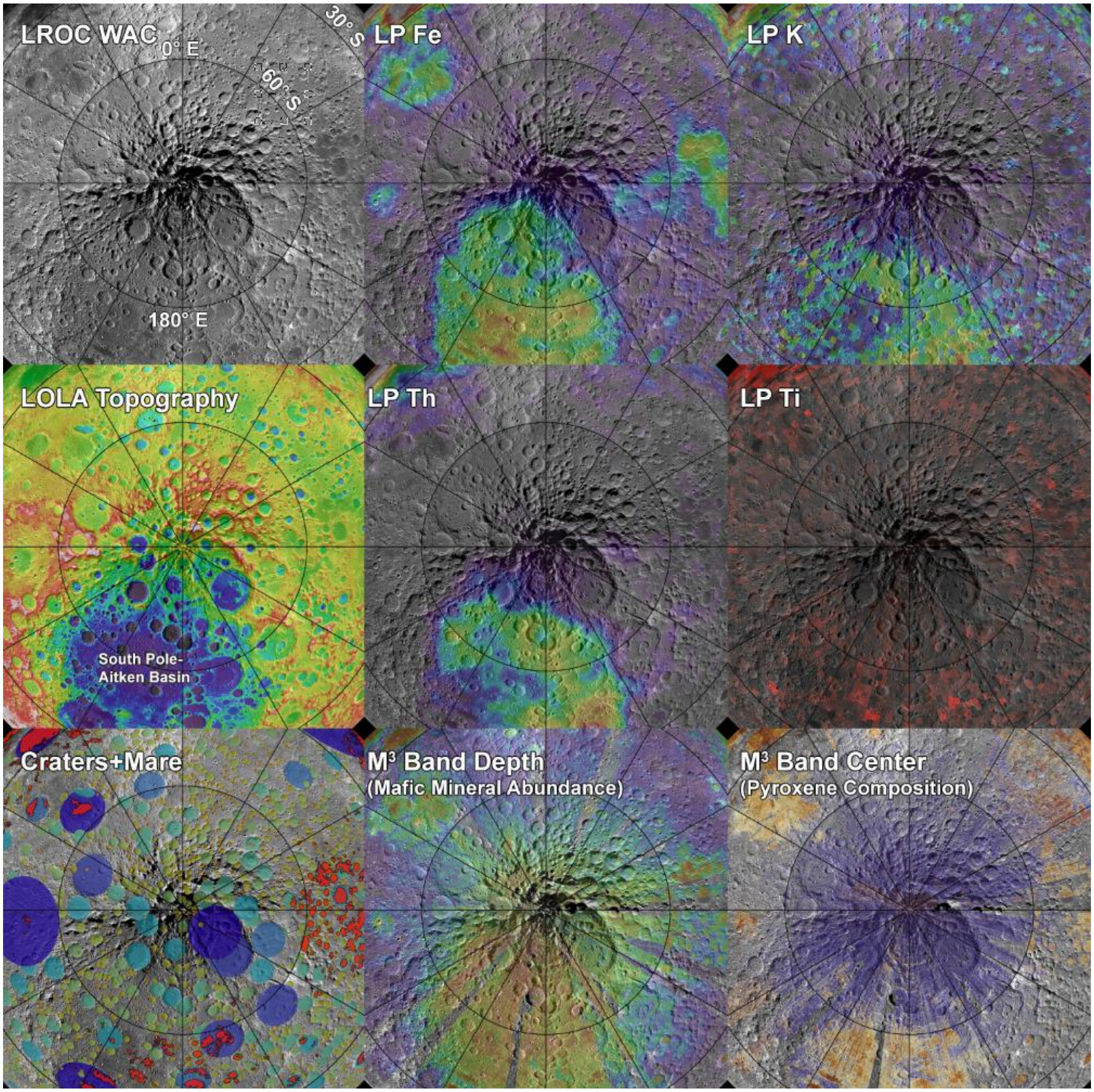

Fig. 1: Integrated remote sensing analyses of the lunar south pole (including imagery, topography and elemental abundances) enrich the interpretation of spectroscopic data. Moon Mineralogy Mapper data reveal the south polar region to be enriched in mafic minerals relative to the highlands crust. These mafic minerals exhibit short-wavelength band centers indicative of a noritic, Mg-pyroxene-bearing composition. The south pole is also associated with regional enhancements in elemental Fe, Th, and K abundance (Lunar Prospector), suggesting the presence of lower crust / upper mantle ejecta from the nearby ~2000 km-diameter South Pole – Aitken Basin.

Introduction: The lunar South Pole is a high-priority target for future exploration, with broad relevance to a range of critical science questions, including lunar geology and geophysics, the volatile cycle, and the distribution of potential resources for future *in situ* utilization to support exploration deeper into the Solar

System. For these reasons and others, the lunar South Pole has been identified as the destination for the upcoming Artemis campaign, an effort to support sustainable human presence on the lunar surface through a series of landed missions, both robotic and crewed.

The first crewed Artemis mission in 2024 aims to return at least 20 kg of lunar samples to Earth for detailed laboratory analyses. These samples have the potential to address several high-impact science questions driving planetary science priorities. South Pole materials may include mantle-derived ejecta and impact melt from the enormous South Pole – Aitken Basin, as well as crustal materials far-removed from the geochemical terranes explored by the Apollo missions. However, the utility of these samples may be limited if their local and regional geologic context is poorly understood. Therefore, to identify the most desirable samples, and to maximize the science return from samples collected at the South Pole, it is essential to characterize its regional geology and mineralogy.

Initial Results from Integrated Remote Sensing Analyses: Moon Mineralogy Mapper (M^3) hyperspectral images are ideally-suited for this task, as they provide rich mineralogical information in spatial context at high combined spatial and spectral resolution. However, mineralogical analyses of M^3 data have not been widely conducted at the poles. This is in part due to the low-illumination environment (due to a low sun angle near the poles), resulting in poor signal-to-noise.

To improve signal-to-noise, we have performed an initial M^3 analysis on global mosaics of M^3 data with 10x reduced spatial resolution. Each pixel is a 10x10 pixel average of full-resolution M^3 images (resulting in a spatial resolution of just over 1 km/pixel), significantly reducing random noise. From these global mosaics, mineralogically-sensitive spectral parameter maps were generated using the Parabolas and two-part Linear Continua (PLC) technique developed and validated for use with M^3 data [1].

Two relevant parameter maps are shown in Fig. 1. To first order, the 1 μm band depth (bottom center) is sensitive to the abundance of mafic minerals. The south polar region is associated with an enhancement in absorption band depths, suggesting that it is relatively mafic in composition compared to the feldspathic highlands crust. The map of 2 μm band center (bottom right) is sensitive to pyroxene composition. In general, short-wavelength absorption bands are associated with Mg-rich orthopyroxenes, while long-wavelength absorption bands are associated with more Fe,Ca-rich clinopyroxenes. The south polar region exhibits primarily short-wavelength absorption bands consistent with relatively Mg-rich pyroxenes.

The elevated mafic abundance and noritic mineralogical signatures observed across the south polar region suggest a widely-distributed mafic anomaly. This may be related to ejecta from the vast South Pole – Aitken Basin (SPA) on the southern lunar farside. The SPA interior exhibits a largely noritic character associated with impact melt and ejecta likely derived from the lower crust and upper mantle [2,3].

The relationship between the south pole mafic anomaly and SPA is further supported by elemental abundance data from Lunar Prospector (Fig. 1). Regional enhancements in iron, thorium, and potassium associated with SPA extend into the south polar region.

Further M^3 Analysis in Support of Future Exploration: Further evaluating the origin and possible link between south polar materials and SPA ejecta will require spectral analysis at higher spatial resolution, which is challenging at high latitudes. We will overcome this challenge using two independent approaches. First, protruding and sloped surfaces at the poles often receive higher insolation than flat surfaces due to differing illumination geometries. Leveraging Lunar Orbiter Laser Altimeter (LOLA) illumination models [4] with supplemental M^3 files that provide illumination and signal information, we will identify well-illuminated surfaces in M^3 images from the south pole. These regions will be extracted and analyzed with the PLC technique [1] to characterize optical maturity and mineralogical diversity of the region.

Our second approach will leverage the high density of M^3 observations at the poles due to its polar orbit. Recent analyses have employed data stacking techniques to look into permanently-shadowed craters using M^3 data, with the goal of detecting surface frosts [Li et al., *2018]*. We will adapt these stacking techniques to perform mineralogical analyses across the south polar region. These approaches offer independent assessments of mineralogical properties than previous analyses of Kaguya Spectral Profiler data, which are rooted in spectral unmixing models constrained by Fe abundance [6].

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References: [1]Moriarty D. P. and Pieters C. M. (2016) *MAPS 51(2)* 207-234. [2]Melosh H. J. et al. (2017) *Geology 45(12)* 1063-1066. [3]Moriarty D. P. and Pieters C. M. (2018) *JGR 123(3)* 729-747. [4]Mazarico E. et al. (2011) *Icarus 211(2)* 1066-1081. [5]Li S. et al. (2018) *PNAS 115(36)* 8907-8912. [6]Lemelin, M. et al. (2017) *LPSC 48,* #2479.