THE COLORFUL MOON: SCIENCE DISCOVERIES FROM THE MOON MINERALOGY MAPPER ON CHANDRAYAAN-1.

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Introduction: Data from the Moon Mineralogy Mapper (M^3) onboard India's Chandrayaan-1 spacecraft provides an excellent opportunity to expand our knowledge of the nature of the mineralogy and composition of the lunar surface. The M^3 instrument is an imaging spectrometer which measures the spectral range of 0.4-3 μm, with just under 10 nm sampling at full resolution. In global mode, data are compressed to a sampling of 20-40 nm and ~140 m/pixel at a 100 km orbit. Over the course of the Chandrayaan-1 mission, >95% of the Lunar surface was imaged by M^3, though only a portion of these data were at nominal operating conditions, as described in detail by [1,2]. The spectral range and resolution of the M^3 instrument was chosen to allow diagnostic crystal field absorptions [3] to be mapped directly, enabling quantitative mineralogic analyses at high spatial resolution. The range was extended to 3 μm to search for any signs of water or hydroxyl on the lunar surface.

The Moon in 85 Dimensions: Shown in Fig. 1 is the nearside global mode coverage from optical period (OP) 1a, displayed using the 'M^3 standard' color composite. This composite is designed to incorporate a large number of bands in the regions of the spectrum that are sensitive to mafic mineralogy by displaying the continuum-removed integrated band depth (IBD) at 1 μm in red, the 2 μm IBD in green, and the IR reflectance at 1.5 μm in blue. In this depiction, highland crust appears blue, basalts and pyroxene-bearing units appear orange and yellow, and olivine-bearing units appear red.

Early Discoveries: Initial analyses performed by the M^3 science team to validate and calibrate the data immediately revealed surprises. Among the first data, a couple of discrete, small (<5 km) deposits were detected that exhibited an unexpected spectral character within the Moscoviense basin. These spectra contain an extremely strong 2 μm integrated band depth, without a corresponding 1 μm band. Such a spectral signature is typical of spinel group minerals [4], but is usually hidden by coexisting mafic silicates such as pyroxenes. Though spinel is not uncommon in lunar samples, these outcrops provide important constraints on the subsurface geology of the region, and perhaps of the Moon as a whole [5]. A global survey of the OP1 data revealed a similar spectral signature in only one other place—the pyroclastic deposits of Sinus Aestuum. The spectra of the deposits are most consistent with chromite [6]. These chromite-rich deposits are restricted to Sinus Aestuum, though many other pyroclastics have been measured, including those in Rima Bode to the North, providing new clues to the nature of late stage lunar volcanism in the region [6].

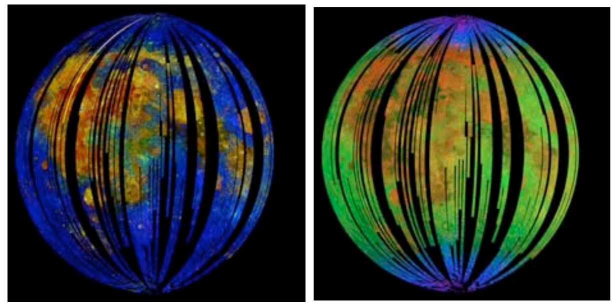

Fig. 1. Nearside of the moon as imaged in optical period 1 displayed using **(left)** the M^3 standard color composite and **(right)** B=3μm absorption associated with OH/H_2O, G=reflectance at 2.4μm, and R=absorption at 2μm [7].

Hydroxyl and Water: One of the biggest surprises encountered in the M^3 data was the presence of absorption features near 2.8 and 3 μm in much of the data [7]. Absorptions at these wavelengths are characteristic of OH^- and H_2O bearing minerals. Shown in Fig. 1 is the extent of the strongest 3μm absorptions as measured by M^3 and reported in [7]. Though the absorptions are strongest at the poles, they are not absent from the mid latitudes. The origin of the OH^- and or H_2O responsible for these absorptions is still under debate. Though the lunar samples have been generally considered anhydrous, recent studies suggest that the early Moon may have wetter than originally believed [8, 9]. It is thus possible that the water viewed by M^3 is internally sourced, though alternative hypotheses include delivery by water-rich impactors, or surficial chemistry induced by bombardment of the lunar surface by solar wind protons [10].

Basalts and Mafic Mineralogy: In addition to the more unexpected discoveries of M3, the quality of the data is enabling detailed reanalysis of mare basalt compositions [11], iron-magnesium content of deposits of lunar pyroxenes [12] and the compositions of olivine-rich deposits [13]. At the LEAG meeting, we will present an overview of the most recent new discoveries by M^3, and discuss how these discoveries can be used to inform and assist in planning future lunar exploration.

References: [1] Green et al. (2010) *LPSC 41*. [2] Boardman et al. (2010) *LPSC 41*. [3] Burns (1993) Cambridge Uni Press. [4] Cloutis et al. (2004) *MAPS.* [5] Pieters et al. (2010) *LPSC 41*. [6] Sunshine et al. (2010) *LPSC 41.* [7] Pieters et al. (2009) *Science*. [8] Saal et al. (2008) *Nature*. [9] McCubbin et al. (2010) *LPSC 41*. [10] McCord et al. (2010) *LPSC 41* [11] Staid et al. (2010) *LPSC 41*. [12] Klima et al. (2010) *LPSC 41*. [13] Isaacson et al. (2010) *LPSC 41*.

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