Hidden in Plain Sight: Spinel-Rich Deposits on the Nearside of the Moon as Revealed by Moon Mineralogy Mapper (M^3). J. M. Sunshine[1], S. Besse[1], N. E. Petro[2], C. M. Pieters[3], J. W. Head[3], L. A. Taylor[4], R. L. Klima[3,5], P. J. Isaacson[3], J. W. Boardman[6], R. C. Clark[7] and the M^3 Team. [1]University of Maryland, Department of Astronomy, College Park, MD, 20742. [2]Brown University, [3]NASA Goddard, [4]Univ of Tenn., [5]JHU/APL, [6]AIG LLC, [7]USGS [jess@astro.umd.edu].

Introduction: Investigation of spectral anomalies in global data acquired with the Moon Mineralogy Mapper (M^3) [1] has revealed a new, unique, and unexpected spinel-rich lithology on the central nearside. These spinel-rich deposits are found only among the Sinus Aestuum pyroclastic/dark mantle deposits (DMD) and are notably absent from the adjacent Rima Bode DMD. While these deposits are spatially extensive (10000's km^2) [2], the most spinel-rich signatures occur at much smaller scales (<1 km). These newly identified regions are defined by their strong 2 µm absorptions and extremely weak or absent 1 µm absorptions as is characteristic of spinel-group minerals [3]. M^3's combination of high signal-to-noise, extended spectral range (both 1 and 2 µm), and spatial resolution (140 m/pixel) has enabled this unique, previously hidden, spinel-rich deposit to be uncovered.

Data and Methods: M^3 is a 0.43-3.0 µm imaging spectrometer on-board India's Chandrayaan-1 spacecraft. The M^3 data used here include 85 bands with 20-40 nm resolution and a spatial scale of 140 m/pixel. After radiometric and geometric calibration (including inflight darks and flatfields), the M^3 data are calibrated to apparent reflectance by dividing by the solar spectrum, correcting for the cosine of the incidence angle, and normalizing to account for cross-track photometric effects (±12° FOV). Thermal emission is significant at wavelengths longer than ~2.2 µm. These effects have not yet been removed from the image data presented here. However, thermal contributions are modeled for individual representative spectra.

Identification: The spinel-rich deposits were first recognized from analysis of global mosaics (spatially reduced by a factor of 10), where their strong 2 µm band and weak 1 µm band results in very high values in ratios of the integrated band depth (IBD) at 2 µm to that at 1 µm. They were also identified as spectral anomalies in statistical analyses of 85-dimensional space [4]. The only extensive spinel-rich deposits occur in DMDs on the central nearside. Additional small, isolated spinel deposits were found on the farside, but restricted to the inner ring of Moscoviense [5].

Dark Mantle Deposits: Pyroclastic or DMD deposits have been remotely studied with previous spectral and radar datasets [*e.g.*, 2, 6]. They consist of both glass and recrystallized beads as famously sampled at Tarus-Littrow by Ap. 17. Three of the largest regional DMDs on the Moon occur within very close proximity (Figure 1a). Of these only the eastern and western Sinus Aestuum DMD, separated by Sinus Aestuum mare, have very strong 2 µm IBD/1 µm IBD (Figure 1b).

Spatial Distribution: These spinel-rich units span the Sinus Aestuum DMDs, including more isolated craters between the two large deposits. The strong 2 µm/1 µm ratios occur throughout the rough topographic highs, however the strongest spinel signatures occur as small concentrations (*e.g.,* Figure 2) and are typically associated with small fresh craters and crater walls. While the darkest DMDs have the strongest spinel signatures, not all the strong spinel spectra are dark, and not all dark areas have strong spinel signatures, implying a complex relationship with DMDs.

Geologic setting: This region has undergone a complex geologic history, which includes the emplacement of Imbrium basin ejecta, pyroclastic eruptions, mare flooding, and modification by Copernicus ejecta. Preliminary analysis suggests that the pyroclastic glass deposits may be thin and that subsequent cratering may have exposed underlying spinel-rich deposits. The region as a whole was subsequently embayed by mare volcanism, with the spinel-rich and DMD deposits exposed only on topographic highs including isolated kipukas throughout the region. This suggests that the spinel-rich deposits are ancient.

Spectral Characteristics: Spectra for 3 locations with strong 2 µm/1 µm ratios are shown in Figure *3*). Even with strong thermal emissions near the equator (compare to nearby featureless soils), it is clear these spectra have very strong 2 µm and essentially no 1 µm bands. Spectral and thermal modeling is on-going, but preliminary results for these spectra (each from different location and at different temperatures) yield spectra that exhibit classic spinel-group features and are most consistent with chromite. This is in contrast to the farside spinels, which are more alumnious spinel-hercynites [5].

Conclusions: While spinel group minerals are common in lunar samples, they occur as accessory phases (abundances <10%). For the first time, M^3 has identified deposits on the lunar surface that have low mafic silicate abundances and are spectrally dominated by spinel, likely chromite. This composition and their association with DMDs are consistent with a volcanic origin, but distinct from that of the Rima Bode pyroclastics. Further understanding the detailed compositional and geologic origin of these surprising spinel-rich deposits will provide new insights the processes and source regions of early lunar volcanism.

References: [1] Pieters *et al*., *Current Science*, 2009. [2] Gaddis *et al*., *Icarus*, 1985; 2005. [3] Cloutis *et al.*, *MAPS*, 2004. [4] Boardman *et al.*, *LPSC 41*, *this vol.*, 2010. [5] Pieters *et al.*, *LPSC 41*, *this vol.*, 2010. [6] Weitz *et al.*, *J.G.R.*, 1998.

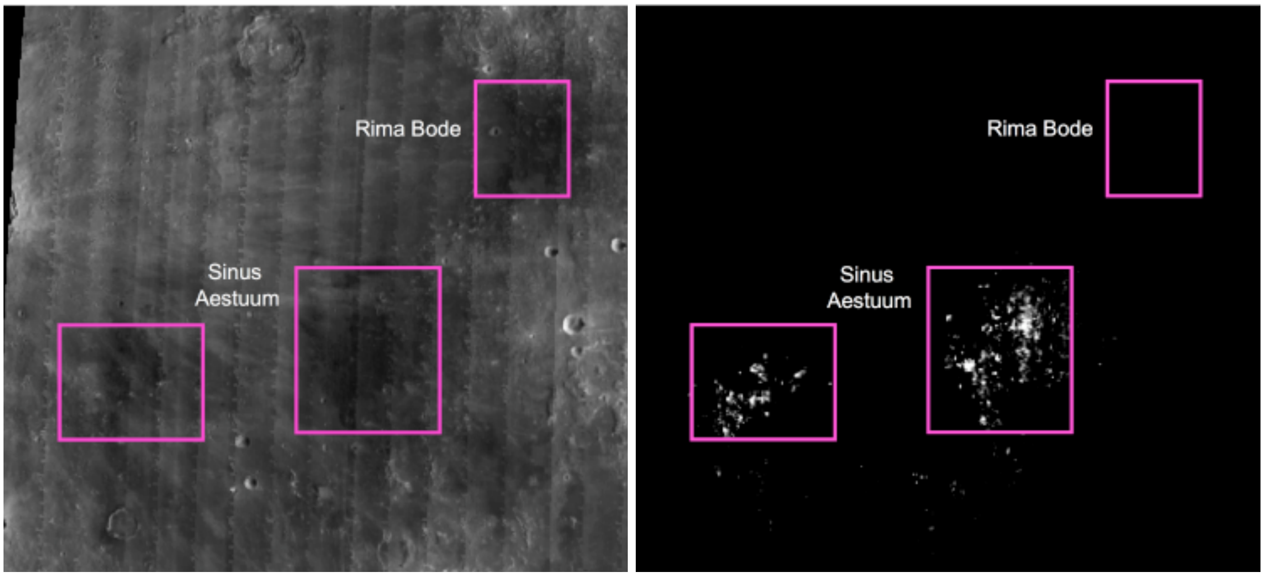

Figure 1: Very large dark mantle deposits (DMDs) on the central nearside. These pyroclastic deposits are cover 10,00s km^2. (a) 0.75 µm albedo image and (b) 2 µm IBD/1 µm IBD. While all three regions are dark, only the two Sinus Aestuum deposits have strong 2 µm relative to 1µm absorptions.

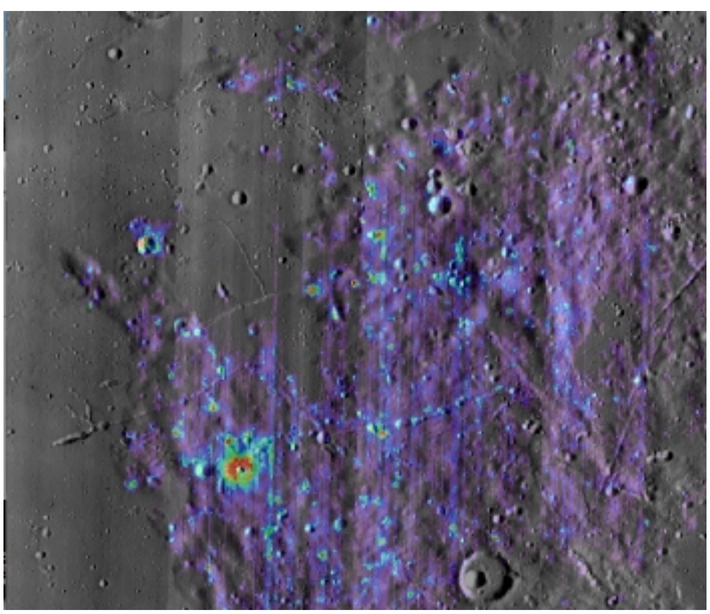

Figure 2: The strength of absorptions at 2 µm relative to the 1 µm overlain on a 2.9 µm image of eastern Sinus Aestuumm. 2.9 µm image is sensitive to thermal emission and thus topography. While the entire topographic high has strong 2 µm absorptions (purple), the highest concentration occurs at small (< 1 km; red/green) scales.

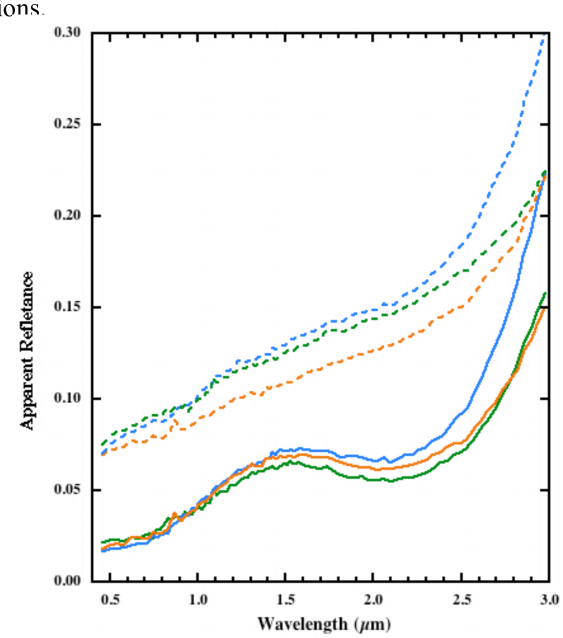

Figure 3: Representative spinel-rich spectra (solid lines) from Sinus Aestuum at 3 different locations and temperatures and nearby background soils (dashed lines). Despite the thermal emission (see background soils), the spinel-rich deposits clearly have very strong 2 µm features a weak or absent 1 µm bands as is characteristic of spinel [3].