MINERALOGY OF THE LUNAR CRUST IN SPATIAL CONTEXT: FIRST RESULTS FROM THE MOON MINERALOGY MAPPER (M^3). C. M. Pieters[1], J. Boardman[2], B. Buratti[3], R. Clark[4], J-P Combe[5], R. Green[3], J.N. Goswami[6], J. W. Head III[1], M. Hicks[3], P. Isaacson[1], R. Klima[1], G. Kramer[5], S. Kumar[7], S. Lundeen[3], E. Malaret[8], T. B. McCord[5], J. Mustard[1], J. Nettles[1], N. Petro[9], C. Runyon[10], M. Staid[11], J. Sunshine[12], L. Taylor[13], S. Tompkins[14], P. Varanasi[3] [1]Dept. Geological Sciences, Brown University, Providence, RI 02912 (Carle_Pieters@brown.edu), [2]AIG, [3]JPL, [4]USGS Denver, [5]Bear Fight Center, WA, [6]ISRO-PRL, [7]ISRO-NRSA, [8]ACT, [9]NASA Goddard, [10]College of Charleston, [11]PSI, [12]Univ. MD, [13]Univ. Tenn., [14]DARPA.

Introduction: India's Chandrayaan-1 successfully launched October 22, 2008 and went into lunar orbit a few weeks later. Commissioning of instruments began in late November and was near complete by the end of the year. Initial data for NASA's Moon Mineralogy Mapper (M^3) were acquired across the Orientale Basin and the science results are discussed here. M^3 image-cube data provide mineralogy of the surface in geologic context. A major new result is that the existence and distribution of massive amounts of anorthosite as a continuous stratigraphic crustal layer is now irrefutable.

The Orientale data were acquired in M^3's reduced-resolution mode at 20 to 40 nm spectral resolution and 140 m/pixel across the 40 km field of view. The location of this M^3 image cube is shown in Fig. 1.

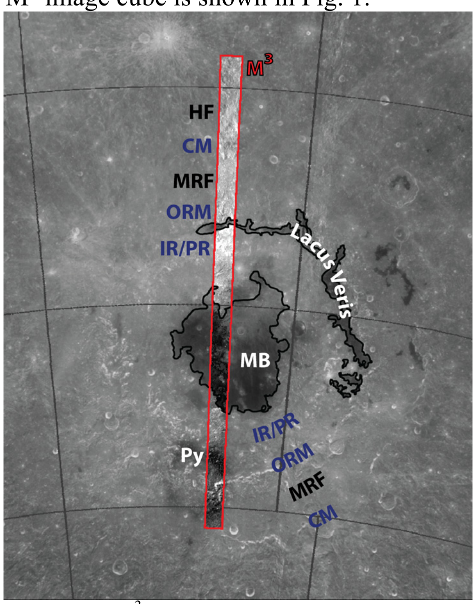


Fig 1. Extent of M^3 "warm" data-take across the Orientale Basin. The basemap is Clementine UVVIS 750 nm data and LAC chart locations. Basin rings are labeled in blue.

Although spacecraft thermal issues slowed operations, we expect conditions will allow normal operations to commence early 2009. The spectral content of these initial M^3 data is affected by quasi-random variations because the detector had not reached science temperature, but the instrument itself is in superb condition [1].

Science Background. The Orientale basin is one of the youngest impact multi-ringed basins on the Moon [2-4]; unlike most other basins it has not been significantly filled with mare basalt subsequent to its formation, and thus provides access to materials forming the basin interior and floor (including the melt sheet) and exposures of the bounding massifs forming the Cordillera, Outer Rook and Inner Rook mountain rings. These rings expose the uplifted crust and ejecta excavated by the basin event.

Recognition that several eastern massifs of the Inner Rook mountains are composed of shocked plagioclase was established with earth-based 4-20 km telescopic measurements [5,6]. More recently, near-infrared spectroscopic data from KAGUYA (SELENE) discovered crystalline plagioclase in the central peaks of several large highland craters [7] based on a diagnostic absorption near 1.3µm [e.g. 8].

The crystal-field basis for near-infrared spectral properties of lunar materials is documented extensively in the literature [e.g, 9]. Note that before KAGUYA, the diagnostic features of crystalline Fe-bearing anorthosites had only been seen in the laboratory. Anorthosite was previously identified remotely by high albedo and *lack* of Fe^{2+} absorptions [6,9] since plagioclase is the only mineral known to become sufficiently disordered with shock to lose its absorption bands [10].

M^3 Mineralogy. Mineralogy across Orientale is derived through combined spectral (Fig 2) and spatial information (Fig 3). We summarize principle findings here and encourage figure details to be viewed via zoom.

Hevelius Formation (**HF**: exterior): Feldspathic breccias with minor noritic mafic component; relatively homogeneous and well-mixed at M^3 scale (no distinctive blocks or mountains).

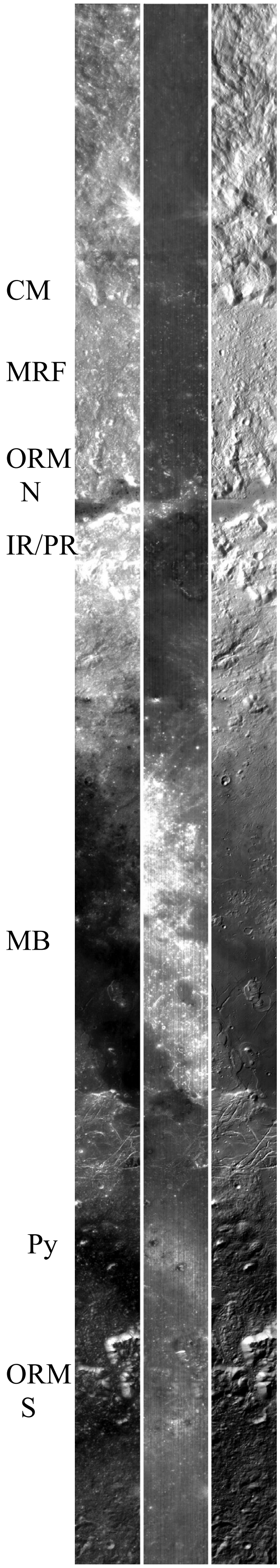
Cordillera Mountains (**CM**: outer ring): outcrop exposures of unweathered feldspathic breccias similar to HF

Montes Rook Formation (**MRF** between rings): Blocky and *not* well-mixed at M^3 scale; feldspathic breccias with some shocked anorthosite blocks.

Outer Rook Mountains (**ORM**: ring North and South): Distinctively more crystalline blocks of noritic anorthosite and anorthosite. Not well mixed at M^3 scale. All anorthosite blocks are of the shocked form.

Inner Rook/Peak Ring (**IR/PR**: inner ring). All massifs bordering Lacus Veris are pure anorthosite including discrete zones of the unshocked crystalline form; a few massifs toward the basin interior contain blocks with zones of mafic minerals.

Mare Basalts (**MB**). All contain abundant high-Ca pyroxenes; some have surfaces dusted with Orientale-derived debris from large craters. Diverse basalt types expected. Pyroclastics to the south (**Py**) have been weathered and are glass-rich only at small fresh craters.



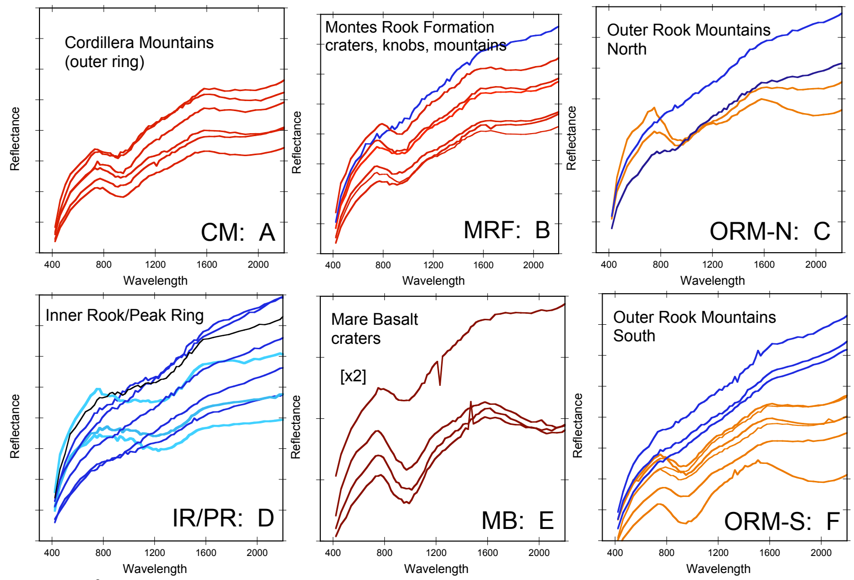


Fig 2. M^3 reflectance spectra for single pixel locations of unweathered areas (fresh craters, massifs, mountains) across six geologic terrains of the Orientale Basin indicated in Fig. 3. Crystalline anorthosite is identified (in D) by a prominent 1.3µm band and the shocked form by a bright featureless spectrum. OPX-CPX are discerned from the shape & position of 1 and 2 µm pyroxene ferrous bands (A,B,C,F vs E). All spectra are the same scale except E (expanded x2). Data are valid to 3 µm, but truncated at 2.2 µm since photometry and thermal corrections are not yet applied.

Fig 3. Three visualizations of M^3 data across the Orientale Basin: (left) 750 nm brightness. (middle) Integrated band depth derived from 28 spectral channels across the 1 µm band after continuum removal. Irregular striping is an artifact of higher detector temperature. (right) 2840 nm channel which contains reflectance and thermal flux and is very sensitive to local morphology.

Discussion/Conclusions. The overall regional crustal stratigraphy tapped by the basin forming event and varied shock history as inferred from observed Orientale mineralogy is (bottom to top): 1. Crystalline mafic-bearing anorthositic rocks (largely noritic) as seen as large blocks in the ORM, a remnant of the excavation cavity. 2. Pure anorthosite (all or some of which is Fe-bearing) as seen in the IR/PR, formed by lateral movement and uplift post impact, 3. Megaregolith of unknown thickness (removed, mixed). The two lower units (1&2) are consistent with that proposed by [6]. The MRF represents a large scale mixture of the excavated column including melt, and the HV represents a more finely mixed version. The Maunder Formation, representing presumed impact melt, is highly feldspathic and is discussed in companion abstracts [11, 12].

Discovery of crystalline Fe-bearing anorthosite within the IR/PR and its contiguous relations to inferred shocked plagioclase validates the near-infrared identification of plagioclase. Furthermore, the steeper continuum slope of shocked plagioclase suggests trace FeO in the crystalline form may be transformed to nanophase metallic iron ($npFe^0$), during shock.

In the coming months/years we look forward to full operation at M^3 science operating temperature. This will allow for global lunar coverage at this low resolution and targeted coverage at higher x4 spatial and 2-4x spectral resolution.

References: [1] R Green et al., these abstracts [2] D. Wilhelms (1987) USGS PP-1348. [3] J. Head (1974) *The Moon*, 11, 327-356; -- (1993) *JGR*, 98, 17149-17181 [4] P Spudis (1993) *Geology of Multi-Ring Impact Basins*, Cambridge. [5] P Spudis et al., (1984) *LPSC15 JGR* C197-C210 [6] BR Hawke et al. (2003) *JGR* 108 (E6) [7] T Matsunaga et al., 2008, *GRL 35,* L23201 [8] L. Cheek et al., these abstracts [9] C Pieters 1993, Cambridge Press; S Tompkins and C Pieters 1999 MaPS [10] Adams et al., 1979 LPSC10th,; J. Johnson & Horz (2003) JGR, 108, E11. [11] S. Kumar et al these abstracts [12] C. Pieters et al these abstracts.