UNUSUAL ROCKY DEPOSITS AROUND LARGE IMBRIAN LUNAR IMPACT CRATERS. C. D. Neish[1], D. T. Blewett[2], Z. Morse[1], and Y.-C. Zheng[3], [1]The University of Western Ontario, London, ON, Canada (cneish@uwo.ca), [2]Johns Hopkins Applied Physics Laboratory, Laurel, MD, USA, [3]National Astronomical Observatories, Chinese Academy of Sciences, Beijing, China.

Introduction: The physical properties of the lunar surface can reveal important information about its structure and evolution over time. In particular, the distribution of rocks and boulders around large impact craters can provide significant insights into the impact cratering process, such as the production and emplacement of impact melt. Three instruments have recently provided new information about the block distribution on the lunar surface and in the near subsurface: the Diviner radiometer on the Lunar Reconnaissance Orbiter (LRO) [1], the Mini-RF synthetic aperture radar on LRO [2], and the Microwave Radiometer (MRM) on *Chang'E-2* [3].

In these data sets, two impact craters stand out as being exceptionally blocky for their age: Orientale [4] and Tsiolkovskiy [5]. Although both Late Imbrian in age, these craters share common attributes with Erastothenian and Copernican craters in similar data sets. In this work, we use new geologic maps from Morse *et al.* [6,7] to characterize the abundance of rocks in the surface and near surface for different ejecta facies around these two craters. We then use this data to make inferences about the source of the unusual block distributions observed there.

Observations: We use data from three different instruments in this work. Data from the Diviner radiometer on LRO has been used to infer the rock abundance (RA) of meter-sized boulders on the lunar surface [8]. Circular polarization ratio (CPR) data from the S-Band Mini-RF radar on LRO has been used to infer the distribution of decimeter-sized blocks on the lunar subsurface and in the top few meters of the lunar regolith [4]. Finally, brightness temperatures (TB) derived from the MRM on *Chang'E-2* (CE-2) have been used to determine the block distribution in the near surface (at 37 GHz) and in the top few meters of the subsurface (at 3 GHz) [3].

In Figure 1, we show the 3 GHz night time brightness temperatures for Orientale and Tsiolkovskiy. Orientale shows a distinct low TB anomaly in the southwestern portion of Facies A, described as a "thick impact-melt deposit mixed with large clasts" [6]. Tsiolkovskiy also shows a low TB anomaly, to the southeast of the crater, in the region where many impact melt ponds and flows have been mapped [7]. We compare these results to the MRM 37 GHz, Diviner RA and Mini-RF CPR data in Figures 2 and 3. Impact melt deposits at Orientale (Facies A and C) have slightly higher CPR values than the continuous ejecta blanket, and similar RA values. The 37-GHz values are relatively consistent across all facies. At Tsiolkovskiy, the impact melt deposits (Facies C and D) also have slightly higher CPR values than the continuous ejecta blanket. However, they also have lower TB values at 37 GHz and higher RA values. These properties are more similar to Copernican and Erastothenian craters than other Late Imbrian craters (Figure 4).

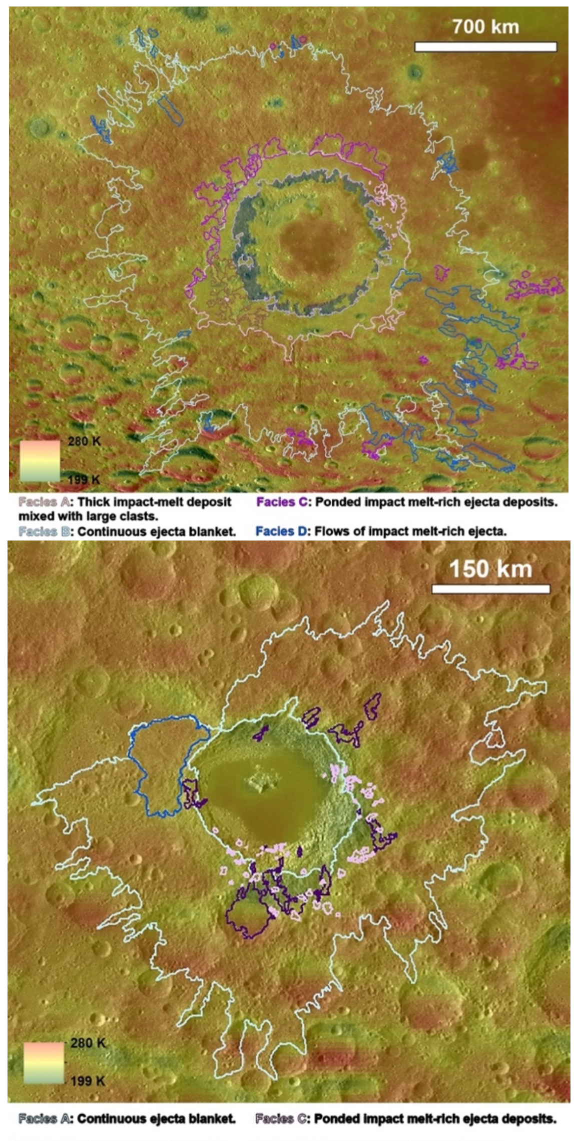

Figure 1: Facies map from [6] and [7] overlain on CE-2 3-GHz night time TB data of Orientale basin (top) and Tsiolkovskiy crater (bottom).

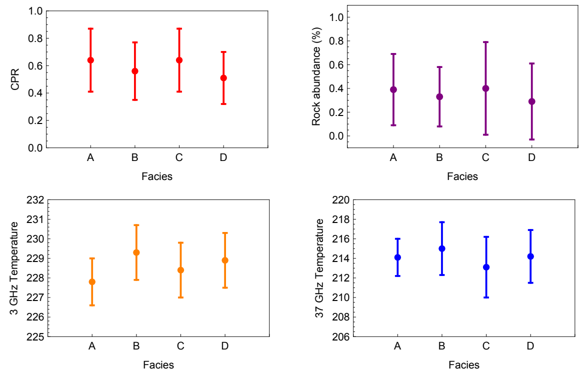

Figure 2: Values for Mini-RF CPR, Diviner RA, and CE-2 3-GHz and 37-GHz TB data for four facies mapped in [6] for Orientale basin.

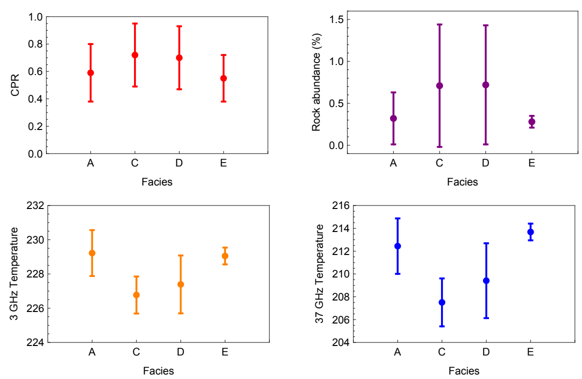

Figure 3: Values for Mini-RF CPR, Diviner RA, and CE-2 3-GHz and 37-GHz TB data for four facies mapped in [7] for Tsiolkovskiy crater.

Discussion: Unlike other large, late Imbrian impact craters, Orientale and Tsiolkovskiy have low TB anomalies at 3 GHz. These anomalies align with regions of impact melt deposits, as mapped by [6,7]. In the case of Orientale, there is little evidence for these anomalies in the Diviner rock abundance data, implying that the rocks are buried. This is consistent with the low TB values at 3 GHz and higher CPR values at 12.6 cm, which probe greater depths than the RA and 37-GHz data sets. The low TB values arise from the suppression thermal emission by rocks at depth. In the case of Tsiolkovskiy, there is a correlation between the low TB anomaly and higher rock abundance data. In addition, the low TB at 37 GHz implies the presence of near-surface rocks. These data suggest that the impact melt deposits at Tsiolkovskiy host a mix of buried and surficial rocks, perhaps due to a recent mass wasting event [5].

In general, these results suggest that Orientale and Tsiolkovskiy produced "rockier" impact melt deposits than other comparable craters. The deposits at Orientale have since been covered by a thick regolith layer, while those at Tsiolkovskiy have been recently exposed. There is no obvious differences in TiO_2 content in either crater compared to the background [9], so it is unlikely that the loss tangent (and hence the probing depth of Mini-RF and MRM) is affected in either case.

The origin of the blocky impact melt in these craters remains unknown at this time, but we note that there is evidence that both craters were created in oblique impacts [6,7]. We speculate that this may have assisted with the ejection of melt from these craters, as first described by Hawke and Head [10].

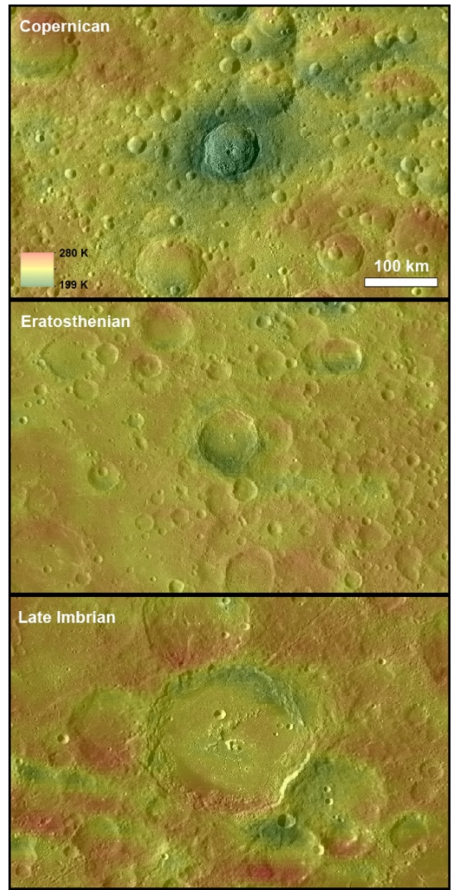

Figure 4: Chang'E-2 3-GHz night time TB data for three large craters of Copernican (Jackson), Eratosthenian (Olcott), and Late Imbrian age (Humboldt).

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