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Examining lunar impactor population evolution: Additional results from crater distributions on diverse terrains

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1. Introduction

Earth's Moon is the only solar system body for which we have both crater size-frequency distributions (SFDs) *and* ages of known terrains. These are keystones for understanding the impact rate through time. While there has been previous work attempting to constrain the lunar impact rate through time [e.g., 1, 2-4], these efforts are decades old. We have lately begun compiling crater SFDs for Birkhoff, Imbrium, and Orientale basins to understand the evolution of the impactor populations [5]. Our preliminary SFD results, plotted in R-plot format [6], indicated that overall our crater densities for these basins agreed with previous determinations [e.g., 7]. One exception was the Orientale melt pond (Im1), which was indicated to be older than the other regions examined (Fig. 1). This was hypothesized to be due to a combination of secondary craters and different material properties affecting the rate of crater degradation. A second result was that the examined maria (Imbrium-a and Orientale-M1) had different SFD slopes from those of the older Birkhoff basin, with more small craters and fewer large craters, implying a possible change in the impactor population SFD (Fig. 1). These differences, however, were also suggested to be consistent with contamination of the SFD by unrecognized small secondary craters (Fig. 2). In general, we found that many of our SFDs were likely influenced at small diameters by unrecognized secondaries.

While these results are intriguing, they are preliminary, only including crater measurements for a few regions and limited diameter ranges. Here we present data compiled from new regions within Imbrium and Orientale basin to further constrain the evolution of the impactor population relevant for the Moon, and the contribution of secondary cratering.

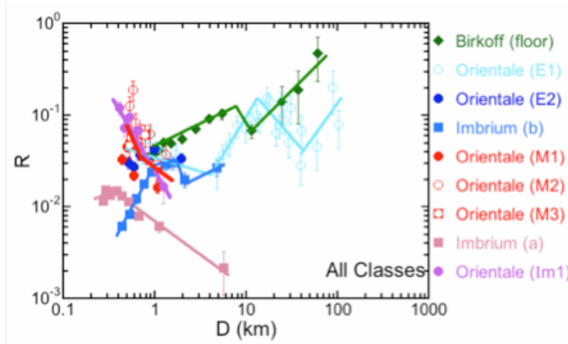

Figure 1. R-plot comparing SFDs of all regions. Previously examined regions: Birkhoff, Orientale (E2), Orientale (M1), Imbrium (a), and Orientale (Im1). Regions added in this work: Orientale E1, Imbrium (b), and Orientale (M1, M2).

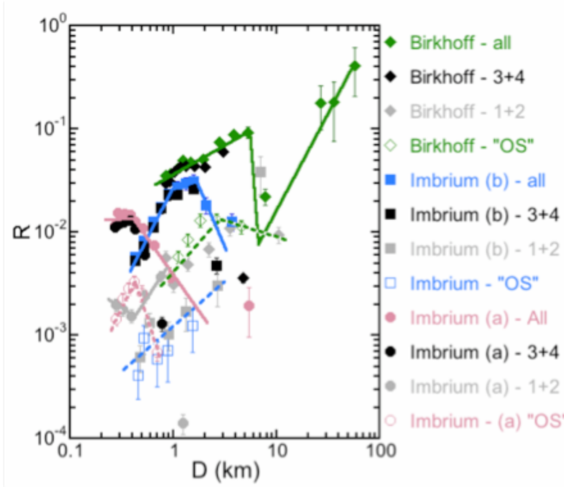

Figure 2. R-plot comparing Birkhoff and Imbrium SFDs (Fig. 1) with "obvious secondaries" ("OS").

2. Analyzed Terrains and Methods

The new regions analyzed in Imbrium and Orientale basins are shown in Fig. 3 (along with previous regions). For Imbrium, we added a small area of the ejecta blanket (Fig. 3a). For Orientale, we added a portion of the ejecta blanket at different resolutions and two new regions of the mare (Fig. 3b).

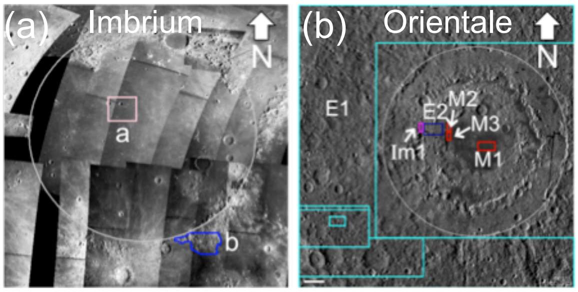

Figure 3. Regions. Basin Centers: (a) 35N, 17W; (b) 19S, 95W. Resolutions: (a) 40 and (b) 100 m/pix. Imbrium mosaic from Lunar Orbiter (LO) IV and V images, Orientale mosaic generated by LROC team (http://wms.lroc.asu.edu/lroc_browse/view/orient_100m). See Fig. 1 for list of regions analyzed in this work.

Methods are the same as in our previous work [5], which we briefly summarize here. Craters are measured manually by using a Perl add-on to SAOImage DS9. Ellipses are fitted to user-selected points along the crater rim. The script attaches coordinates to each crater outline, yielding the diameter (*D*) and center position. These data are then converted into SFDs [6]. A degradation class was assigned to each crater, ranging from 1 (fresh) to 4 (most degraded). A crater may also be identified as an "obvious secondary" ("OS") by being part of an obvious cluster or chain. Note that our term "All Classes" in this text refers to all degradation classes, excluding "OS"s.

4. New Results

Like the Orientale melt pond (Im1) analyzed previously the Orientale Mare regions examined here (M2, M3) are found to have a higher crater density than expected, given they are the same relative age or younger than the other terrains [e.g., 7] (Fig. 1). This supports our previous conclusion that the small crater SFDs in these regions likely contain unrecognized secondary craters (Fig. 2), and that craters in the stronger maria and melt take longer to erode than craters in the softer ejecta.

Fig. 1 also shows the Orientale Mare regions (M2, M3) have SFD slopes similar to those of the previously examined maria regions. Furthermore, the Orientale and Imbrium ejecta regions have SFD slopes similar to those of Birkoff basin. Finally, the maria SFD slopes are different from the ejecta regions and Birkhoff basin. These new results support the previous suggestions that either the impactor SFD has changed with time or the maria regions are effected by unrecognized secondaries.

5. Human Variation in Crater Measurement

Another element of our work is to better understand the human variation involved in identifying and measuring craters. Variations occur in indentifying the crater rim, the definition of what constitutes a crater, etc. Each coauthor manually outlined what they identified as craters in the Orientale melt pond (Fig. 4). Fig. 4 shows the craters identified and measured by CRC (expert crater counter), MRK (experienced crater counter), and KMS (novice crater counter). In general, CRC and MRK identified similar craters. The primary difference is that MRK identified craters lower than the resolution limit that CRC did not. KMS, however, identified several, chiefly large, degraded features, especially in a hillier region to center right that are not likely craters. These comparisons have resulted in further discussion of crater recognition and class identification.

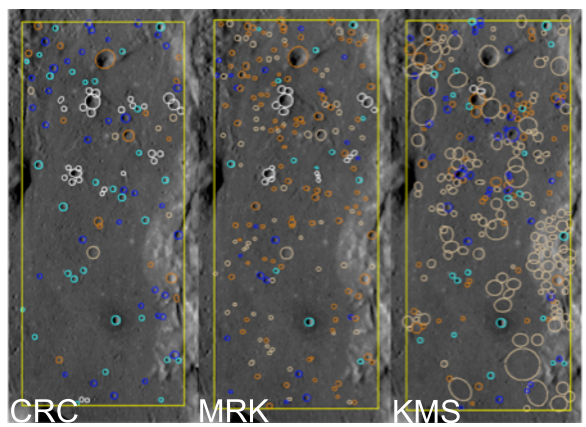

Figure 4. Comparison of crater measurements by CRC, MRK, and KMS. Yellow boxes outline the region. Ellipses mark crater rims and color denotes degradation class. Cyan – class 1; blue – class 2; brown – class 3; tan – class 4; white – obvious secondaries.

References

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