USING CRATER SIZE-FREQUENCY MEASUREMENTS TO DISTINGUISH AGE UNITS WITHIN VOLCANIC SMOOTH PLAINS – A NEW APPROACH. L. R. Ostrach[1] and M. S. Robinson[1], [1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287. Correspondence: lostrach@ser.asu.edu.

Introduction: Unraveling relative and absolute ages for defined geologic units on planetary surfaces relies on crater counts and superposition relationships. Analyses of crater size-frequency distributions are a primary technique used to develop relative ages for geologic units, which can then be translated into absolute age estimates. Absolute age chronologies rely on crater counts calibrated to radiometric ages [e.g. 1,2], and with the exception of the Moon, samples of known surface provenance from other bodies do not exist.

It is well documented that the lunar maria were emplaced over an extended period of time [e.g. 1,3], and mare units exhibit marked color differences in multispectral data that correlate with distinct mineralogical compositions and ages [3-6]. Efforts using crater counts to age date the distinct spectral units identified within the lunar maria [3,5,6] provide a relative and absolute timeline of lunar mare emplacement. These efforts [3,5,6] relied on multispectral classification to distinguish geologic units prior to commencing crater counts, but not all planetary bodies exhibit multispectral differences within volcanic units (age and composition), as is the case on Mercury [e.g. 7].

Recent work by Michael *et al.* [8] used spatial clustering analyses of crater counts to help distinguish resurfaced areas in several study regions on Mars. Here, we applied a similar statistical method to test the applicability of using areal crater density as a novel approach to identify resurfacing boundaries in a region within Mare Imbrium on the Moon, as a test case for mercurian studies. Areal crater density as a measurement tool was recently successfully employed to investigate variations in crater retention age across the lunar surface [9] and to compare lunar and mercurian crater populations [10]. Thus, areal crater density measurements provide a reliable technique to distinguish relative ages amongst geologic units without employing spectral information.

Methods: Crater counting techniques assume that cratering is a random process and that accumulation of craters over time for a given surface reflects the age of that surface (older surfaces exhibit more craters than younger ones) [2]. For crater counting results to be valid, only primaries should be considered and the region in question should be comprised of one geologic unit and be uniform in age [2]. Since older surfaces have accumulated more craters than younger surfaces, a measure of areal crater density should reflect spatial variations in crater retention across volcanic plains, indicating differential regions of resurfacing, and thus age units.

By using published model ages for spectrally defined units in Mare Imbrium [5], we selected a region centered on a color boundary (4.5×10^4 km^2 at 45.0°N, 340.0°E, **Fig. 1**) between two areas with a large model age difference (Unit I22, ~2.96 Ga old; Unit I5, ~3.52 Ga old; as defined by Hiesinger *et al.* [5]). For each unit we utilized the CraterTools extension to ArcMap [11] to count all circular, non-overlapping craters in the study region using Lunar Reconnaissance Orbiter Camera (LROC) Wide Angle Camera 100 meter/pixel high and low incidence angle mosaics. Obvious secondary craters (crater chains, herringbone patterns, and overlapping clustered groupings) were excluded from the measurements.

For the two test units we determined the areal crater density for diameter (D) ≥0.5 km using a moving neighborhood method with a radius of 25 km and an output cell size of 1 km. When calculating areal crater densities, it is important to choose an appropriate neighborhood size because the moving neighborhood approach considers the number of craters within a defined circular region about each cell. We chose a 25 km radius because there were at least 30 craters within each neighborhood to provide robust sampling across the study area and emphasize regional density variations. Varying the neighborhood radius alters the spatial structure observed in the density plot; too-small neighborhood sizes emphasize local variations, as was the case with a 15 km radius, whereas overly large neighborhood sizes smooth both local and regional variation, in the case of a 30 km radius. Additionally, because areal crater density is calculated using a moving neighborhood, intermediate crater density values occur along sharp age boundaries due to smoothing. Moreover, our density map is buffered to one neighborhood radius (25 km) to minimize edge effects.

Discussion: In the study region of Mare Imbrium, the crater density map (**Fig. 2**) is congruent to previously mapped color units (each individual color unit was originally assumed to be of uniform age [5]). Crater density differences correspond to the contact visible in the spectral data to within ±one neighborhood radius (due to smoothing inherent in the density calculation).

Measures of areal crater density can be used as a method independent of spectral mapping to distinguish age units within lunar mare, subject to certain limitations. As with crater counts used to determine absolute model ages, identifiable crater rays and obvious secondary craters must be excluded from the study area, preventing contamination of the density measurement. The density measurement reflects the accumulation of craters over time and includes circular, non-overlapping spatial clusters of craters that are most likely far-flung secondaries [12] and will affect the density measurement (as well as model ages) since they do not truly represent the primary population. However, most absolute ages for the mare rely on D ≥1 km craters to limit inclusion of secondaries, so potential secondary contamination [e.g. 12-14] will be explored within the density measurements by examining small crater depth to diameter (d/D) ratios using LROC Digital Terrain Models. Secondaries have a shallower d/D than primaries at D <1 km [15], and many of these D <1 km craters may be "non-obvious" secondaries that could substantially affect crater densities and our ability to distinguish unit boundaries using crater densities alone. Furthermore, at this stage we have not established how large an age difference is required for successful unit identification through crater density mapping, however we can distinguish units that have an age contrast of 500 my. Future work will examine the age difference sensitivity by examining additional units with smaller age differences in Mare Imbrium.

Conclusions: Measures of areal crater density can be used to distinguish previously reported age units (defined with multispectral data) within lunar mare and the technique described here provides an effective method to determine relative ages of mare units independent of color boundaries. Moreover, the ability to distinguish surface units of different ages, without using spectral data, in Mare Imbrium show that this technique may be applied to other planetary bodies, such as Mercury, to search for age boundaries within contiguous smooth plains units. For example, the northern smooth plains on Mercury do not exhibit resolvable spectral variation, so our density method can be used to test hypotheses concerning timing of smooth plains emplacement [16].

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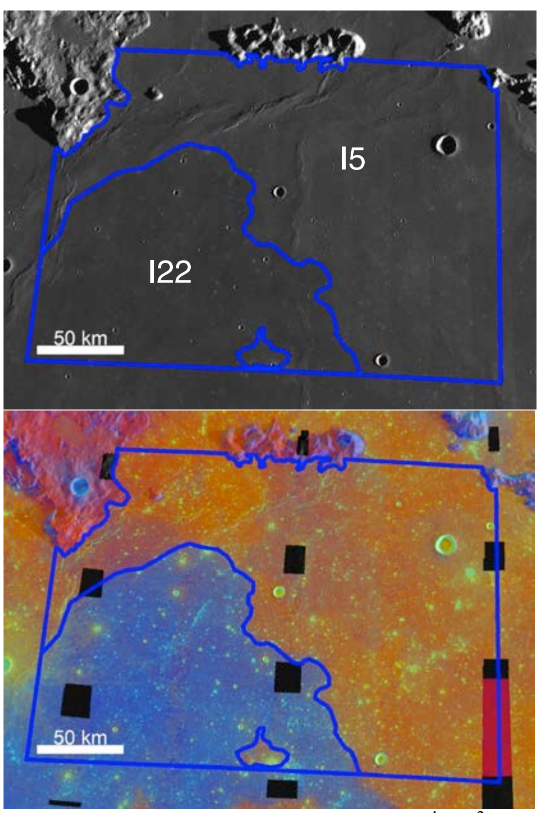

Fig. 1: Region in Mare Imbrium (4.5 × 10^4 km^2, centered 45.0°N, 340.0°E) at the boundary between two age units from [5]. (top) LROC WAC mosaic, (bottom) Clementine RGB mosaic (R=750/415, G=750/950, B=415/750). Crater counts of all circular, non-overlapping craters produced N(1) = 1978 ± 350 for the blue unit (I22) and 4177 ± 383 for the red unit (I5).

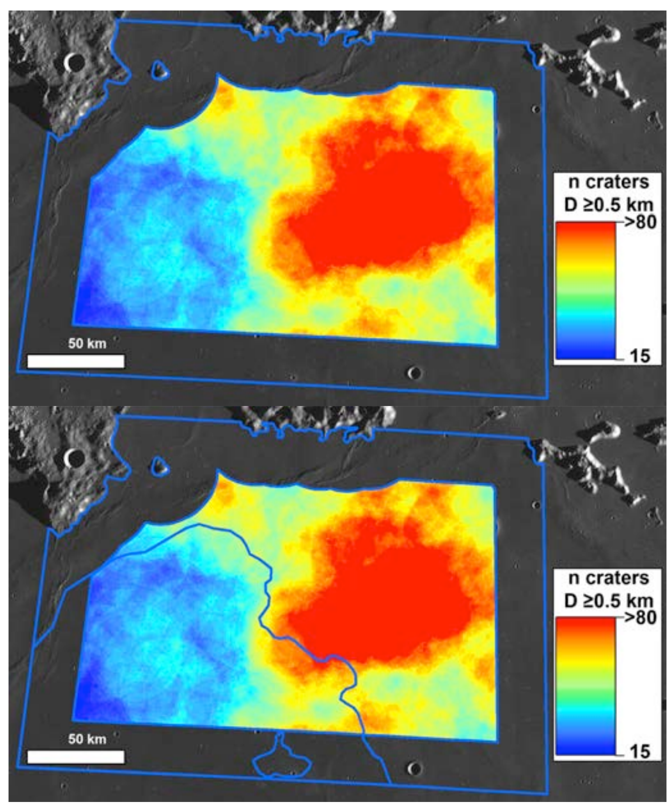

Fig. 2: (top) Areal crater density map derived from crater counts (output cell = 1 km, neighborhood radius = 25 km). (bottom) Same density map overlaid with the spectrally determined unit boundary from [5]. Measured crater densities demarcate the unit boundary with an accuracy of ±25 km due to smoothing.