TOWARDS A REPEATABLE CRATER COUNTING METHOD FOR UNDERGRADUATE CRATER COUNTERS. K. S. Martin-Wells[1], L. Powers[1], B. Barker[1], J. Cayetano[1], and A. Edwards[1], [1]Ursinus College (Pfahler Hall, 601 E. Main Street, Collegeville, PA 19426, kmartinwells@ursinus.edu).

Introduction: Recent work has identified distal impact melt from Tycho crater [1, 2]. This distal Tycho melt is located as near to Tycho as on the edge of the continuous ejecta blanket and as far away as 460 km. The distal Tycho melt is concentrated to the northwest and southeast of Tycho crater, consistent with existing work that indicates that Tycho impacted from the west-southwest [e.g., 3]. Martin-Wells et al. (2021) determined that the Tycho distal melts developed prominent flow morphologies on slopes between 10 and 20 degrees. On shallower slopes, flow morphologies such as cracks and blocky margins were not observed. High-resolution image data revealed that melt was often present on shallow slopes near melt deposits with more prominent flow morphologies [1, 2]. However, it is more difficult and time-intensive to conclusively identify distal melts on shallow slopes than on steep slopes.

These observations raise a number of questions: Are distal impact melts typical for lunar craters of Tycho's size, or are they a product of potentially unique impact conditions? For example, is the production of the distal melt a result of the early-time interaction between the target and projectile in a moderately oblique impact? If so, are the size-frequency distributions of Tycho secondary craters in the directions of the distal impact melts distinct from the size-frequency distributions in the directions without melt? Additionally, what is the effect of distal impact melt deposits on existing crater populations? Are smaller Tycho secondary craters also removed? Preliminary work suggests that there may be fewer small Tycho secondary craters in areas where distal melt was observed than in areas where it was not [4].

In order to address these questions, it will be necessary to conduct extensive counts of both primary and secondary craters around Tycho and other lunar Copernican craters. A repeatable, systematic, and transparent method for both counting and classifying small craters will be essential to the usefulness of any such investigation. Due to the large number of craters to be counted and classified, it would also be ideal if the method were suited to counters at a range of experience levels, in order to broaden the pool of potential counters.

The problem of variability in crater counts across individuals, methods, and even for individual counters across counting sessions is known [e.g., 5]. Before we embark on significant counting as a group, we would like to develop a repeatable, transparent, and easy to learn method of counting that suits our group needs. Our counters will be primarily undergraduate researchers, with a high degree of turn-over and limited opportunity for any one counter to develop the experience that comes from completing very large numbers of counts.

Therefore, our group is working toward a repeatable method for identifying craters that is accessible to counters of all levels of experience. Specifically, we want a method that will generate preliminary counts that agree within statistical counting error on the number and size of craters counted across multiple counters. We are also aiming for preliminary counts with a high degree of completeness. The candidate craters that are identified by this method could then be more rapidly verified by a combination of experienced human counters and semi-automated computational methods.

By carefully documenting the development of our procedure, we hope to make the results of our counts and classifications more easily comparable to those of other crater counters.

Method and Preliminary Results: We have been developing our method using sixteen regions around Tycho crater. These regions extend radially away from Tycho to the west-northwest, northwest, southeast, and south-southeast, along the directions in which the distal Tycho melts have been identified. Four 20 km x 20 km regions were selected at 150 km, 250 km, 350 km, and 450 km from the Tycho central peak in each of the four directions. Our counts were completed using the JMARS software program [6]. For our preliminary counts, the Lunar Reconnaissance Orbiter Camera (LROC) Wide Angle Camera (WAC) Global 100m/pixel Mosaic was used as the base layer.

Craters with diameters between 1.25 km and 2.5 km were first marked in each of the sixteen 20 km x 20 km regions. In order to judge the size of the craters to be counted at this scale, circular templates with these minimum and maximum diameters were placed in the region to guide the eye.

Using the JMARS five-point ellipse tool, craters with diameters between the size of the small circle and the large circle were marked in each of the sixteen regions. Work is ongoing to determine the ideal level of zoom relative to the diameter range of craters being marked. A high level of zoom should result in more accurately marked planforms. However, these markings are only preliminary and will be refined during subsequent verification. Therefore, a high degree of planform accuracy is not essential at this stage in the procedure. A lower level of zoom tends to result in the marking of shallower craters, craters with more degraded rims, and other circular features with relatively low rim contrast. While marking more of these features may increase the number of false positives that are identified at this stage, false positives will be removed during subsequent verification. However, craters that are *missed* at this stage would not be recovered at a later point. A failure to include features at this stage could therefore adversely affect the completeness of the counts.

Once all of the crater candidates with diameters between 1.25 – 2.5 km were marked in each of the sixteen regions, each region was subdivided into four sub-regions, each of which was 10 km x 10 km in size. Small and large circle templates with diameters between 625 m and 1.25 km were placed in each grid and the marking procedure described above was repeated. The procedure was repeated again for 5 km x 5 km grids (resulting in 16 sub-regions for each of the 16 regions) and 2.5 km x 2.5 km grids (resulting in 64 sub-regions for each of the 16 regions). In this manner, craters with diameters between 156 m and 2.5 km were marked for each of the sixteen original regions.

At this stage of the marking, no attempts were made to distinguish between primary and secondary craters. All potential craters were marked and will be classified during subsequent verification. The preliminary test of our method resulted in 138 craters counted in the sixteen regions to the northwest of Tycho crater, with 327 to the west-northwest, 397 to the southeast, and 257 to the south-southeast. Our preliminary results also suggest that in order to improve both completeness and the accuracy of the measured planform shape, high-resolution LROC Narrow Angle Camera (NAC) images should be used as the base layer for craters marked on the 5 km x 5 km grids and below (e.g., for all craters with diameters less than 625 m).

Future Work: As we continue to refine this method, we will improve our counts at small diameters by marking on high-resolution LROC NAC images for grid sizes of 5 km and below. For each of the crater candidates, we also plan to automatically extract additional data that will make the subsequent verification and classification more systematic. For example, we plan to extract elevation profiles across each crater candidate. These elevation profiles can be averaged to generate refined diameter measurements for each crater, as well as depth-to-diameter ratios. Depth-to-diameter ratios could then be used to reject any false positive candidates that are too shallow to be confidently classified as impact features. The depth-to-diameter ratios could also aid in more systematic classification of primary vs. secondary craters within the dataset. In addition to elevation profiles, we will also calculate nearest similarly-sized-neighbor distances, as quantitative measurements of the degree of clustering will also make primary vs. secondary classification more systematic. We also plan to extract average radar circular polarization ratio and Diviner Rock Abundance values, where available. These data can be used—along with the nearest-neighbor analysis, planform shape, and depth-to-diameter ratio—to generate automatic preliminary recommendations for primary vs. secondary classification for each crater in the dataset. While any such classification would require verification by a human counter, it is our hope that these procedures will make our counts and classifications more systematic, repeatable, transparent, and accessible to counters at a broad range of experience levels. In addition to verification of the preliminary dataset by an experienced human counter, the craters marked by this method could also be used as a "starter set" for semi-automated computational methods of measuring crater sizes and planforms.

Once it has been refined, we intend to apply this method to radial counts of secondary craters at large Copernican impacts other than Tycho in order to better understand the production and distribution of lunar distal impact melts.

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References: [1] Martin-Wells K. S. et al. (2021) *LPS LII*, Abstract #2636. [2] Martin-Wells, K. S. (2021) *PCC XII*, Abstract #2038. [3] Krüger, T., van der Bogert, C.H. and Hiesinger, H. (2016) *Icarus*, *273*, 64-181. [4] Powers, L. T. and Martin-Wells K. S. (2021) *PCC XII,* Abstract #2027. [5] Robbins et al. (2014), *Icarus, 234,* 109-131. [6] Christensen P. R. et al. (2009) *AGU, Abstract #IN22A-06.*