TARGET PROPERTY CONTRASTS AS AN ORIGIN OF AGE AND SLOPE DISCREPANCIES BETWEEN CSFDS OF COEVAL UNITS.

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Introduction: Recent work on Lunar Reconnaissance Orbiter Camera (LROC) data re-encountered a curious discrepancy in crater size-frequency distribution (CSFD) measurements between impact units that was observed during the Apollo era [1-3]. For example, at Tycho, Copernicus, and Aristarchus, CSFDs of impact melt units give significantly younger relative [4,5] and absolute model ages (AMAs) [2,6] than the impact ejecta blankets, although these two units are coeval. This effect was also observed at the craters Jackson [1] and King [7,8] (e.g., ***Fig. 1***).

Two primary reasons for the discrepancies under recent investigation include (1) differing effects of target properties on the size distributions of small vs. large craters [1-3, 8], and (2) pollution of the primary crater population on impact ejecta units by self-secondary craters (SSCs)[9-14]. Here, we present an overview of our investigations of the possible roles of target property effects on CSFDs of small craters, along with new crater-scaling model results.

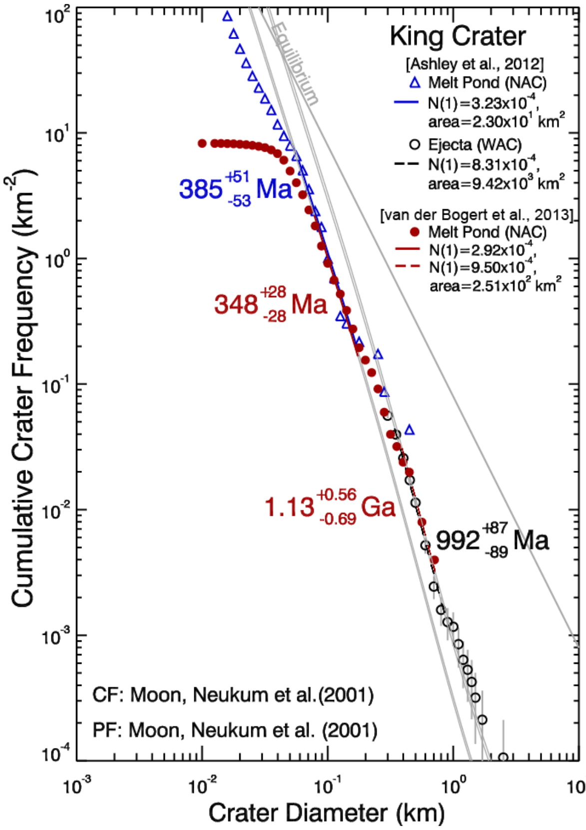

Figure 1. *CSFDs for King crater give different apparent AMAs for impact melt (blue) and ejecta (black) units. An updated CSFD for the melt pond (red) exhibits apparent AMAs similar to the melt pond at small crater diameters and ejecta at larger crater diameters, with a transition between the two isochrons, consistent with the diameter range where scaling shifts from strength- to gravity-dominated.*

Evaluating Target Effects: *Unusual Crater Morphometry and CSFD Measurements.* Earlier, we presented empirical and crater-scaling models evidence for effects of variations in target properties on CSFDs at Jackson crater [1, ***Fig. 2***]. These results led us to theorize that the discrepancies between impact melt and ejecta model ages could be primarily explained by differing target properties.

Our next step [3] was to use a novel approach (after [8]) to measure CSFDs across the strength- to gravity-scaling transition diameter range (>~300 m) on impact melt deposits large enough to contain craters >~300 m in diameter. If target properties indeed have an effect on CSFDs, we would expect the CSFDs of the different units to merge at larger crater diameters, where target strength no longer plays a dominant role in final crater diameter. Thus, we counted craters in a 251 km^2 area of the King crater melt pond, and we performed new measurements on the Tycho melt sheet [3]. The new measurements at King crater (***Fig. 1***) followed the previously measured impact melt pond isochron [7] at crater diameters <50 m, and at crater diameters >400 m are similar to the ejecta blanket. Craters with diameters from 50-400 m transition from the impact melt pond isochron to that of the ejecta blanket of [7]. AMAs and N(1) values for the new data are consistent with those of [7](***Fig. 1***). Similar trends are seen in new data from the Tycho melt sheet, where the impact melt CSFD converges to the ejecta blanket CSFD at crater diameters of ~500 m [3]. Thus, the

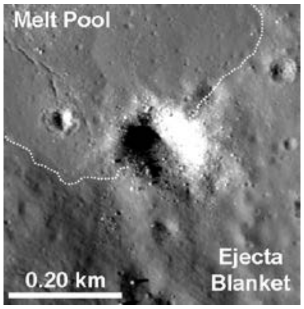

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Figure 2. *A crater at the boundary between a melt pool and the ejecta, on the SE rim of Jackson crater is ~20% larger on the ejecta blanket than on the melt pool, suggesting a difference in target properties between the two units.*

recent measurements at both King and Tycho craters show that target property effects are primarily responsible for the discrepancies in CSFDs for coeval geological units.

Crater Scaling Models. To investigate the possible range of discrepancies in final crater diameters generated by impacts on surfaces with different target properties, we modeled different scenarios using pi-group scaling [e.g., 15-18]. The impactors were assumed to have a velocity of 17.5 km/s, a density of 2500 kg/m, and an impact angle of 45°. The impactor size distribution was assumed to have a power law distribution with a cumulative exponent of -3. Target strength, density, and porosity were selected for a range of reasonable lunar values [19-22].

The CSFDs generated from the models show that target rock with higher density and strength generate smaller crater diameters than porous, weaker targets (***Fig. 3***). The results indicate that for the same impact conditions, a dense, strong target will give lower relative and absolute ages than a porous, weak target.

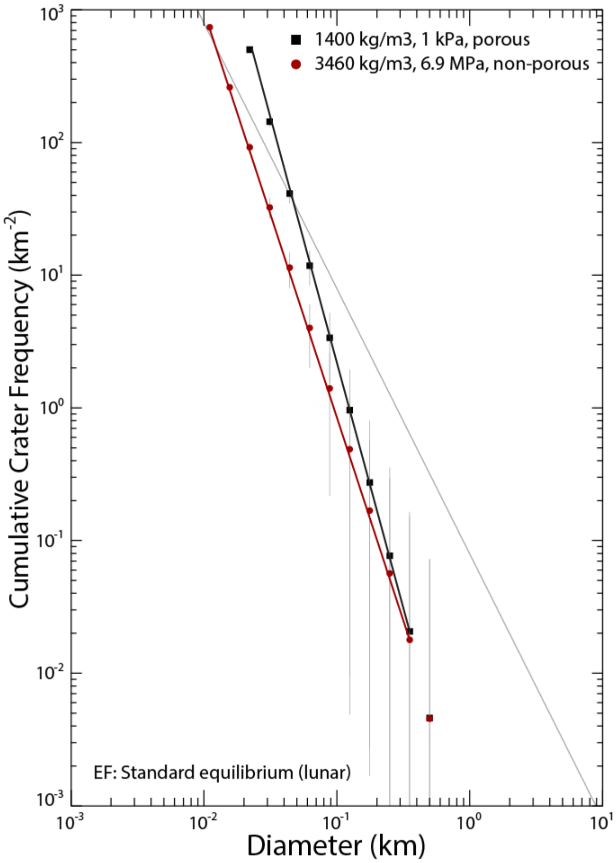

Figure 3. *CSFDs generated via pi-group scaling models of final crater diameters created by the same impactor population (with cumulative slope of -3) in two different theoretical lunar targets. Note that the slopes of the distributions are different – the red line has a slope of -3, whereas the black line is -3.6.*

However, not only do target property differences affect the final crater diameters, they also affect the resulting slope of the CSFD (***Fig. 3***). Slope differences mean that the final crater diameters differ more greatly at smaller diameters between different targets. In reality, such an effect may cause CSFDs for different targets to no longer have the same slopes as the production function (PF) [23], meaning that it is difficult, even impossible, to fit with an AMA.

Discussion: Beyond target property effects, one other possible origin for the discrepant CSFDs is self-secondary cratering. SSCs are postulated to cause an excess of craters on ejecta versus melt ponds, resulting in greater apparent ages relative to the melt [6,9-14, 24]. However, the results of both our CSFD measurements and scaling models suggest that the bulk of the discrepancy can be explained by target property effects alone. The count areas at the King crater and Tycho melt units are large enough to bridge the gap between the discrepant CSFDs, allowing us to observe that the CSFDs of the melt units transition to match those of ejecta units at larger crater diameters, so the effect must be unique to the properties of the melt units, rather than dependent on the occurrence of SSCs on the ejecta unit [3]. In addition, the scaling models we present illustrate significant discrepancies in final crater diameters between targets with different properties. Critically, the slopes of CSFDs determined for different targets differ from one another, despite having the same impactor SFD as input. As a result, small crater SFDs may be difficult or even impossible to fit with existing PFs [23]. This effect may explain the difficulty that [14] encountered in fitting a single age to their CSFDs at Aristarchus, and could explain small crater CSFDs with slopes in excess of the PF, as observed by [10, 11] at Giordano Bruno and Cone craters.

In summary, our work shows that target property effects may not only explain differences in relative/absolute ages, but may also cause differences in CSFD slope for small crater populations.

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