DISCREPANCIES BETWEEN CRATER SIZE-FREQUENCY DISTRIBUTIONS ON EJECTA AND IMPACT MELT POOLS AT LUNAR CRATERS: AN EFFECT OF DIFFERING TARGET PROPERTIES?

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Introduction: Data from the Lunar Reconnaissance Orbiter Narrow Angle Camera (LROC NAC) [1,2] provide an unprecedented new view of lunar impact craters. Of particular interest are Copernican-aged craters, because they are the youngest craters on the Moon. The determination of absolute model ages for these craters will help to more clearly understand the impact rate of the last billion years.

We measured crater size-frequency distributions (CSFDs) and derived absolute model ages (AMAs) for impact melt pools and ejecta materials (e.g., Fig. 1) of the 71 km diameter crater Jackson, using LROC NAC images collected during the mission's commissioning phase. Jackson is a Copernican-aged crater located in the northern lunar far side at 22.4°N 163.1°W. Similar to Tycho [3,4], we found discrepancies between the CSFDs of the melt pools and ejecta blanket.

Data and Methods: We analyzed two LROC NAC image pairs: M103209479R/L and M103216633R/L (~1.5 meters/pixel). The image data were processed using ISIS 3 and imported into ArcGIS. The counting areas and craters were generated using CraterTools [5]. The CSFDs were plotted and fit with CraterStats [6], using the techniques described in [7,8]. The derived absolute model ages (AMAs) are based on the chronology function (CF) of [9] and production function (PF) of [10]. The technique is valid for lunar craters >0.01 and <300 km in size.

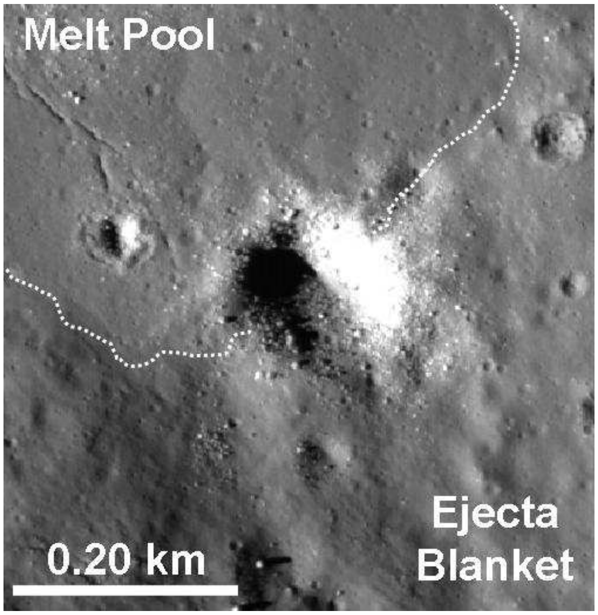

Figure 1. *Typical impact melt pool and proximal ejecta on the SE rim of Jackson crater in LROC NAC M103216633L. A crater at the boundary between this melt pool and the ejecta blanket is ~20% larger on the ejecta blanket than on the melt pool. This suggests a difference in the target properties of these two units.*

CSFDs were generated from all primary craters on each unit. There were very few obvious secondary craters on the melt pools. CSFDs of several impact melt pools were combined to improve the statistics. The ejecta CSFDs were heavily contaminated with secondary craters. Crater clusters and chains with matching degradation states, in addition to oblique craters, were removed from the final ejecta CSFD.

Results: The impact melt pools have a CSFD indicating they are younger than the proximal ejecta of Jackson. The AMA of the impact melt pools is ~85 Ma, whereas the ejecta is ~150 Ma (Fig. 2a).

Interpretation and Discussion: If we interpret the difference between the CSFDs at Jackson as reflecting a real age difference between the units, we must consider that the melt pools are not impact melt, but represent later volcanic activity.

Indeed, initial studies of the crater Tycho [3,11], using Surveyor VII and Lunar Orbiter V data, also showed a large difference between CSFDs on "lunar playas" and surrounding "volcanic flow" units. Strom and Fielding (1968) [3] estimated a 160 Ma age difference between the playas and flows. They concluded the age difference could only be explained by the multi-phase volcanic development of Tycho.

However, Shoemaker et al. (1968) [11] suggested that the flows were (1) volcanic (possibly triggered by the Tycho impact), (2) cold debris flows, or (3) hot debris flows associated with the impact formation of Tycho. They also suggested that the difference in the CSFDs could be caused by the formation of self-secondaries on the "older" flow units, immediately prior to the emplacement of the playas.

Given our current understanding of impact crater formation, and strong arguments against impact-induced volcanism [12], we think, in most cases, the lunar playas do represent impact melt that formed contemporaneously with the ejecta (formerly interpreted as "volcanic flows"). Thus, the CSFDs differ for a reason other than age.

We considered the suggestion of [11] that self-secondaries could cause the difference. However, we carefully removed the obvious secondaries from our CSFDs, and a ~65 Ma discrepancy remains. If self-secondaries explain this discrepancy, then their size-frequency distribution must be similar to the lunar PF. However, a population of circular secondaries, unrecognized as such, could help explain the greater variability of our ejecta versus melt pool CSFDs.

The observation of a crater at the boundary between an impact melt pool and the ejecta provides a clue to the puzzle (Fig. 1). Assuming the crater is not oblique, the diameter of the portion of the crater in the ejecta is about 20% larger than in the melt pool. Impact melt pools might be expected to be more consolidated, stronger targets than ejecta, which could affect the crater morphology. Indeed, using Holsapple's impact crater calculator [13], a 10 m impactor with an impact velocity of 15 km/s at 45° creates a 227 m crater in dry sand, versus a 183 m crater in hard rock. So, could the CSFD discrepancy be explained by differences between the material properties of the impact melt pools and ejecta?

We did a simple calculation to show the effect that 20% larger craters would have on the CSFD we measured for the impact melt pools (Fig. 2b). A 20% increase in crater size, as a proxy for a weaker and/or more porous ejecta target, could explain a ~70 Ma difference in the CSFDs. As a result, this effect likely plays a major role in the ~65 Ma AMA difference between the impact melt pools and proximal ejecta. Modeling is currently underway to more accurately assess this effect for lunar conditions, because this effect is not linear (in contrast to our simple calculation). Such an effect has also been observed and modeled for small craters on Martian lava flows [14].

Conclusion: For Jackson, multi-phase development of the melt pools and ejecta is not required to explain the difference between the CSFDs of each unit. The difference may be explained by the differences in target properties between melt pools and ejecta.

References: [1] Chin et al. (2007) Space Sci. Rev. 129, 391. [2] Robinson et al. (in press) Space Sci. Rev. [3] Strom, Fielder (1968) *Nature* 217, 611. [4] Hiesinger et al. (2010) LPSC XLI. [5] Kneissl et al. (2010) LPSC XLI. [6] hrscview.fu-berlin.de/craterstats.html. [7] Neukum (1983) *Meteoritenbombardement und Datierung planetarer Oberflächen*, Habil. Thesis, Univ. Munich, 186pp. [8] Michael, Neukum (2007) *LPSC* XXXVIII, #1825. [9] Neukum, Ivanov, Hartmann (2001) *Space Sci. Rev.* 96, 55. [10] Ivanov (2001) *Space Sci. Rev.* 96, 87. [11] Shoemaker et al. (1968) *in* Surveyor VII Mission Report Part II. *NASA Tech Rept* 32-1265, 9. [12] Ivanov, Melosh (2003) *Geology* 31, 869. [13] keith.aa.washington.edu/craterdata/scaling/index.htm. [14] Dundas et al. (in prep.) GRL.

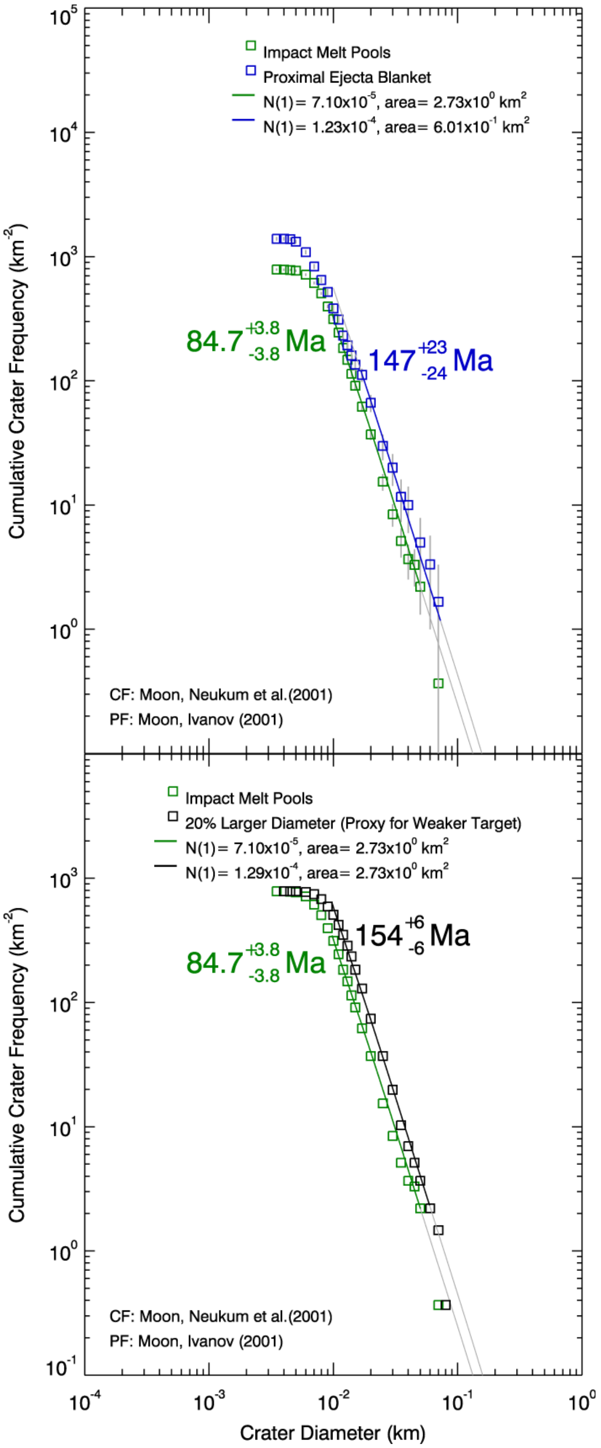

Figure 2. (a) Crater size-frequency distributions (CSFDs) and absolute model ages (AMAs) for impact melt pools and proximal ejecta of Jackson. (b) A 20% increase in crater size (black curve)—a proxy for a relatively weak target (e.g. ejecta)—relative to the impact melt pool CSFD, yields an AMA of ~70 Ma greater for a weaker, more porous target. Differences in target properties may help explain the discrepancy between CSFDs on impact melt pools and ejecta.