IMPACT MELT IN SMALL LUNAR HIGHLANDS CRATERS. J. B. Plescia[1] M. J. Cintala[2], M. S. Robinson[3], O. Barnouin[1], and B. R. Hawke[4], [1]Applied Physics Laboratory, The Johns Hopkins University, Laurel, MD; [2]NASA Johnson Space Center, Houston, TX; [3]School of Earth and Space Exploration, Arizona State University, Tempe, AZ, [4]HIGP, University of Hawaii, Honolulu HI.

Introduction: Impact-melt deposits are a typical characteristic of complex impact craters, occurring as thick pools on the crater floor, ponds on wall terraces, veneers on the walls, and flows outside and inside the rim [1]. Studies of the distribution of impact melt [2-6] suggested that such deposits are rare to absent in and around small (km to sub-km), simple imapct craters. [6] noted that the smallest lunar crater observed with impact melt was ~750 m in diameter. Similarly, theoretical models [7-10] suggest that the amount of melt formed is a tiny fraction (<1%) of the total crater volume and thus significant deposits would not be expected for small lunar craters.

LRO LROC images show that impact-melt deposits can be recognized associated with many simple craters to diameters down to ~200 m. The melt forms pools on the crater floor, veneer on the crater walls or ejecta outside the crater. Such melt deposits are relatively rare, and can be recognized only in some fresh craters. These observations indicate that identifiable quantities of impact melt can be produced in small impacts and the presence of such deposits shows that the material can be aggregated into recognizable deposits. Further, the present of such melt indicates that small craters could be reliably radiometrically dated helping to constrain the recent impact flux.

Data Collection: The LROC image data base [11] was searched for fresh craters and those craters were then examined for the presence of visible impact melt. The total archive of images is enormous and so random 10º x 10º latitude / longitude blocks of highland terrain were examined. Morphometric data were collected for those craters having recognizable melt.

Melt Recognition: A critical aspect of such an analysis is an accurate identification of actual impact melt. While most melt-containing craters have flat floors, not all flat-floored craters have impact melt (in some cases melt may be present but buried). Characteristics of impact-melt pools on the floor include: smooth surface, low albedo, tension cracks, festoons and swirls, and anomalous small-diameter impact crater morphology. Not all of the examples exhibit all characteristics and some of the larger pools have a complex morphology.

In addition to well-defined melt on their floors, the walls of some craters appear be covered with a veneer of material. This may be impact melt or it may be clastic debris moving downslope. In some cases the material has coalesced into flows that extend down the lower wall and onto the floor. This adds credence to the interpretation that the material is melt, but clastic material can also behave in this manner (e.g., North Ray Crater).

Figures 1 and 2 illustrate two examples of impact melt on the floors of simple lunar craters. In both of these cases the melt apparently formed a shallow pool on the crater floor. Boulders (up to 10-15 m) are only partially covered along the shallower margins of the pools, and are either not present or completely covered in the pools' deeper centers. In these cases, the melt is smooth and somewhat darker than the surrounding material. These crater also locally exhibit a veneer on the wall which may also be impact melt.

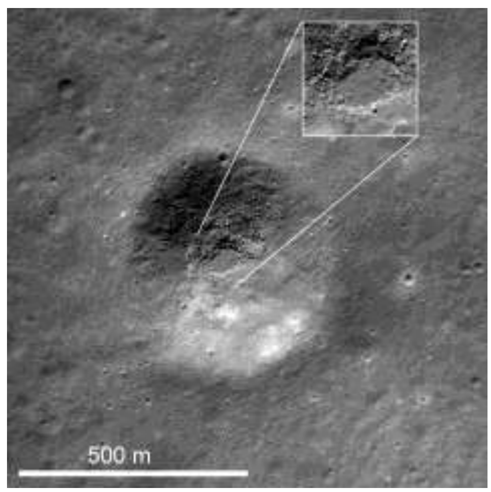

Figure 1. 470 m diameter simple crater with a small 72 x 40 m pool on the crater floor. (-51.5733ºS, 114.801ºE, LROC image M139158894LE).

Stringers of dark material are observed at some craters extending from the crater interior, across the rim, and out onto the ejecta (Figure 2). This material is interpreted be impact-melt ejecta.

Melt Volume: Estimating the melt volumes in very small craters is difficult. For craters at the km scale, the volumes can be estimated in a cases where topographic data are available, either as a DEM or a LOLA profile, using a technique developed by [12] in which a Gaussian function or a parabola are fit to the topography of the crater wall. The difference between this volume and that directly observed provides an estimate of the melt volume.

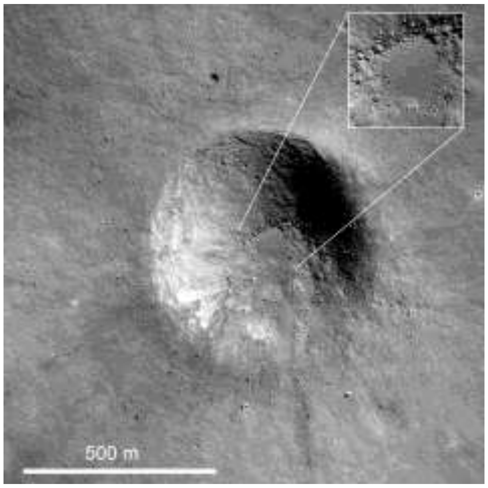

Figure 2. 600 x 680 m diameter simple crater with a 145 m diameter impact melt pool on the floor; veneer occurs locally on the crater walls. (-48.7336ºS, 207.153ºE, LROC image M143263845RE).

Estimates of the amount of melt present in craters with melt pools on the floor [10^{-3} to 10^{-5} km^3] are of the same order of magnitude as that estimated from the model of [7, 11] (Figure 3).

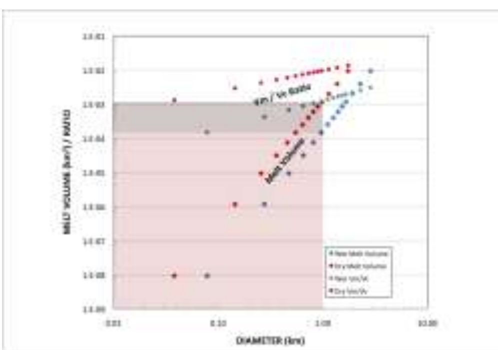

Figure 3. Amount of melt generated (km^3) as a function of transient crater diameter (km) and the ratio of the melt volume (Vm) to the excavated crater volume (Vc). Data based on model of [7] for dry (red) and wet (blue) sand targets. The shaded area is the diameter range of interest in this study (<1 km diameter).

Discussion: Only a fraction of small, fresh craters exhibit melt. While melt should be produced in almost any impact that will result in a crater hundreds of meters to kilometers in diameter - the question is why such small volumes are readily apparent on the floors of such small craters. A significant fraction of the generated melt should be ejected from the crater [9, 11] yet the volume on the crater floor is similar to that expected from the models.

The lack of a significant difference between the calculated and observed melt volumes may indicate that the models underestimate the melt volume, crater size is overestimated, or that in some cases, very little melt is ejected. Studies of larger diameter craters and melt volumes [12] indicate that the amount of melt observed is consistent with the amount expected to be retained in the crater (i.e., accounting for ejection loss).

Modeling studies illustrate that the target properties can have a significant influence on the amount of melt produced. Depending upon whether the target is solid rock (as might occur for a fresh, young mare surface) or regolith (for older mare surfaces and the highlands), the excavated volume and melt production will be different (all other aspects being equal). Figure 3 illustrates the results for dry sand target and the difference in melt volume and the ratio of melt volume to excavation volume (Vm/Vc).

It may be that the small craters for which well-defined melt pools are observed represent a special case - a vertical or near vertical impact. Under such conditions the bulk of the melting would be expected along the crater's axis of symmetry and thus might be less likely to be ejecta compared with the case of non-vertical impact, where the maximum heating and melt production would occur downrange of the crater's center [9] and would thus more likely be ejected.

Summary: Impact melt is observed to form pools, wall veneer and stringers of ejected material in and around fresh impact craters in the lunar highlands at diameters down to 200 m and perhaps smaller. Such craters, however, are relatively rare. The volumes of melt observed are similar to those expected from modeling studies and indicates that while small, they are sufficient to allow the melt to collect as pools on the crater floor. Given that a significant fraction of the melt should be ejected, it may be that the craters for which a well-defined melt pool is observed were the results of vertical or near-vertical impacts.

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