IMPACT MELT MOVEMENT IN LUNAR CRATERS.

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Introduction: Impact melt-bearing deposits in lunar craters are observed to possess different forms, including ponds, viscous flow features and relatively thin veneers draping crater rims, walls and central uplifts [e.g. 1, 2]. A more detailed assessment of the morphologic characteristics of these deposits is now possible with the high-resolution (~0.5-2.0m/pixel) images acquired with the Lunar Reconnaissance Orbiter Camera Narrow Angle Camera (LROC-NAC, [3]) We are conducting mapping and analysis of small-scale flows, ponds and veneers in several craters to help us piece together the distribution, timing of emplacement, and cooling histories of different types of melt deposits. Our mapping enables comparison of impact trajectory (as inferred from ejecta patterns when possible), azimuth of maximum wall slumping, and melt distribution to determine the main factors controlling the emplacement of interior and exterior melt.

Factors affecting initial melt emplacement: Interior melt deposits in complex craters are influenced by the presence of modification features such as central peaks and wall-terraces [e.g 1, 2] (Fig. 1). Pools of melt and melt-breccia mixtures are observed to embay and pond on these structural features. Distributions of exterior melt deposits are more complex. Although ejecta from oblique impacts are typically distributed downrange and/or perpendicular to the impact trajectory [4], Our preliminary work indicates that the most voluminous deposits of external impact melt do not always follow this relationship suggesting that exterior melt distribution may not simply be controlled by impact trjectory.

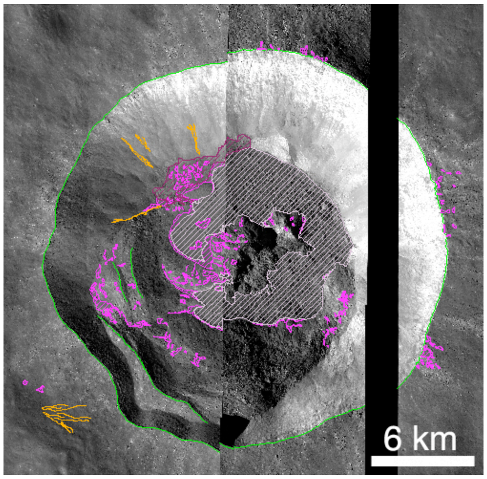

Figure 1: Melt distribution map of Moore F. North is up. Impact melt units include: hummocky floor melt (pink stripes) to the NE, smooth melt ponds (magenta), and channeled melt flows (orange). (M105664582, M103302202 and M105657409)

Fig. 1 shows extensive terracing in the SW portion of Moore F (D=24.5km; 185.0E, 37.25N). Impact direction was not obvious from examination of ejecta patterns and so a correlation between slumping azimuth and impact trajectory cannot be made for this example. Analysis of a DTM of the area indicates that pre-existing topography may have influenced the slumping. External melt deposits are not more voluminous on the NE side of the crater, which suggests that, in this example, the wall collapse was not violent enough to eject interior melt onto the rim. Previous suggestion that central uplift and large-scale terrace formation in complex craters can influence the placement of external impact melt deposits [1] is thus not supported by our results at this crater. However, control from pre-existing topography (also suggested by [1]) may still offer an explanation for the observed difference in impact trajectory and external melt emplacement.

Movement of melt after initial emplacement:

A) Flows: Fig. 2 shows a prominent slump block in the SSE section of Thales (D=29km; 50.25E, 61.7N), highlighting melt flows cutting down the footwall and spreading onto the upper surface of the slump block. This observation suggests that impact melt was still fluid after rim failure and after the initial melt emplacement on the crater rim. The viscous flow features in Fig. 2 have two main sections. Melt on the upper most section runs down the crater wall, creating poorly defined erosional channels. Once the melt reaches the lower gradient of the slump block surface, the flows form well-defined channels and levees as melt accumulates into a thicker deposit. Given the short run out, and as the formation of these flow features is likely a single event rather than a sustained flow, the levees are not likely of depositional origin, but may represent stabilization along the margins of the full lobate flow front, within which the central melt remained fluid and flowed out to form a central channel. The presence of

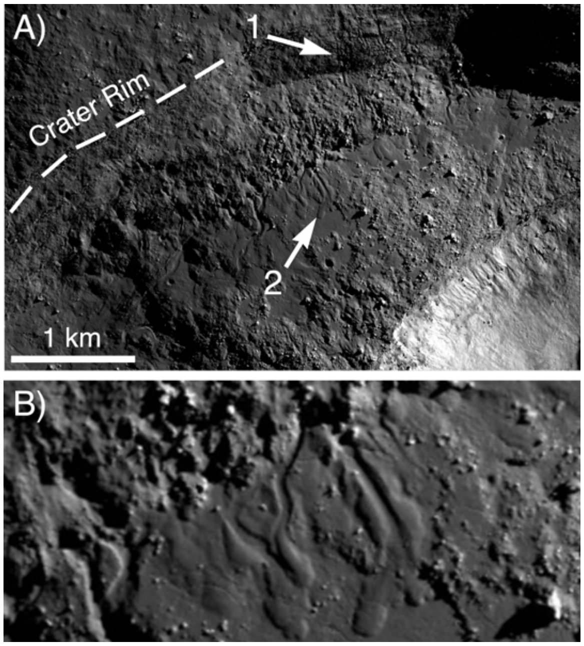

Figure 2: (A): Flows of melt on the SE slump block of Thales. '1' notes the thin channels on the hanging wall, '2' marks the leveed channels on the surface of the slump block. North is down. (B) Close-up of the leveed channels. (LROC-NAC M104182009L)

levees and distinct flow lobes suggests that, at the time of terrace formation, the melt had an increased viscosity due to cooling, possibly aided by entrainment of cold lithic clasts from the flow down the crater wall or while stalled at the break in slope [5] and from fall-back ejecta and mass wasting.

B) Veneers: A section of the Thales crater wall, close to the crater floor, shows melt veneer that continued downslope after its initial emplacement (Fig. 3). This observation suggests that melt veneers are not immediately quenched, and that slumping/wrinkling of the melt deposit can occur, either though basal-detachment slump, or ductile, ropey pahoehoe-style folding. Estimate of veneer thickness will be sought once a DTM of the area is derived.

C) Ponds: A melt pool is located on the western portion of Giordano Bruno (D=22km; 102.9E, 36.0N), where the crater wall slumps transition into to the crater floor (Fig. 4). The pond surface possesses a distinctive spiral pattern of dark and light debris that is suggestive of circulation within the melt pond prior to its solidification, providing an example of the low viscosity nature of impact melt after its emplacement. Debris appears to be entrained and lying on top of an otherwise smooth solid crust. A lack of fractures in the central region of the pool indicates that during the melt circulation, the solid crust remained warm enough to deform in a ductile manner. Circulation within the melt pool may have been prompted by a supply of material (perhaps descending melt veneer) from the crater walls, creating an instability in the melt pool. Creation of a DTM for this region is underway; the crust thickness and melt pool depth will be estimated once it becomes available.

Nature of melt during crater modification: Peripheral pools and wall veneers display ductile behavior and possess a smooth surface suggesting them to be relatively debris/clast poor (Fig. 4). This is in contrast to crater floor melt deposits which often have hummocky appearances produced by the inclusion of decimeter-scale blocks of fall-back and mass wasting debris, suggesting that melt that coated the transient cavity walls was not immediately a mix of melt and debris or a partial-melt, but a relatively pure melt (few clasts). Upon collapse of the transient cavity, the melt at the crater center likely mixed with debris, creating the clast-rich hummocky floor melt pools. The remaining clast-poor melt further up the transient crater walls then settled as melt veneers or progressed downwards, creating relatively clast-poor floor-periphery pools.

References: [1] Hawke & Head (1977), Impact and Explosion Cratering p815-884. [2] Cintala & Grieve (1998), MAPS 33:889-912. [3] Robinson M. et al. (2005) *36th LPSC,* Abstract #1576. [4] Melosh (1989), Impact Cratering: a geological process. Oxford U. Press, London. [5] Gregg T.K.P. and J. Fink (2000) *JGR*, 145-159.

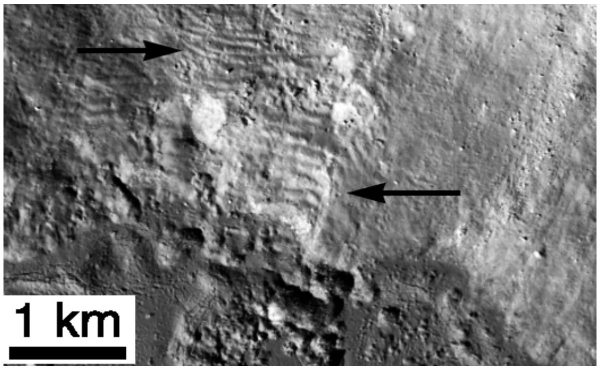

Figure 3: Slumping of melt veneers in Thales. North is up, crater centre to the bottom left (LROC-NAC M104182009L).

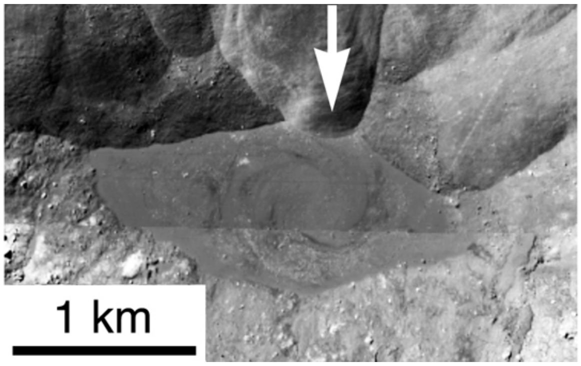

Figure 4: Swirled melt pool on the floor of Giordano Bruno. Arrow marks the slump direction of material from the crater wall, a possible trigger for circulation in the melt pool. North is right.