IMPACT MELT DEPOSITS ON TERRESTRIAL PLANETS. C. D. Neish1,2, 1The Planetary Science Institute, Tucson, AZ (cneish@psi.edu), 2The University of Western Ontario, London, ON.

Introduction: Flow-like deposits of impact melt are commonly observed on terrestrial planets, typically around young fresh craters [1] (Figure 1). Recent spacecraft observations have provided new data about these impact melt deposits at resolutions and wavelengths never before seen, revealing new insights about their emplacement processes and physical properties [e.g., 2] (Figure 2). This, in turn, provides strong constraints on the impact cratering process itself.

In this work, I will review the new discoveries made about impact melt deposits on the Moon, Mercury, Venus, and Mars using remote sensing data. I will focus on two areas of active research: (1) the mechanism(s) by which impact melt is emplaced on terrestrial planets, and (2) their resulting physical properties.

Figure 1: Waters crater on Mercury (15 km diameter), as imagined by the MESSENGER Narrow Angle Camera (NAC) of the Mercury Dual Imaging System (MDIS). A flow of impact melt is observed emerging from the southern rim of the crater. Image credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington.

Impact Melt Emplacement: Hawke and Head [3] noted that the melt distribution patterns on lunar crater exteriors tend to be asymmetric, and may relate to the pre-impact topography or the impact direction. On the Moon, most complex craters have melt directions that are coincident with the lowest point on the crater rim, implying that pre-existing topography plays a dominant role in melt emplacement on that world [2]. This may be a result of movement during the modification stage of crater formation, as the central uplift imparts an outward-directed flow to the melt, pushing it over a topographically low portion of the crater rim [1].

However, recent studies examining impact melt deposits on Venus [4] and Mercury [5] suggest a correlation between impact melt direction and the direction of impact. This suggests that on these worlds, melt is emplaced during the excavation stage, as the subsurface momentum-driven flow field is displaced downward. This in turn suggests that melt can be emplaced ballistically during excavation, and there is growing evidence for this on the Moon as well [6, 7].

The reasons for the difference in emplacement style on the Moon and Venus/Mercury are unclear. The higher gravity and impact velocities on Mercury and Venus tend to produce more melt in shallower craters, potentially allowing more melt to flow outward during excavation. On the Moon, smaller amounts of melt in deeper craters may require the extra momentum imparted during modification to over top their crater rims, flowing preferentially out of its lowest point. To study this process further, we are currently investigating impact melt emplacement on Mars, whose similar gravity but lower impact velocities provide an ideal counterpart to Mercury. Studying impact melt emplacement on terrestrial planets with a range of gravities and impact velocities provides a natural experiment in the impact cratering process.

Physical Properties of Melt Deposits: Impact melt deposits are observed to have a number of different forms, including ponds, veneers, and flows. In many cases, the morphologies of impact melt flows appear very similar to the morphologies of lava flows [e.g., 8]. However, despite their resemblance to lava flows in optical images, lunar impact melt deposits have a surface texture unlike any known terrestrial lava flow [9]. They are incredibly rough at decimeter scales, with radar returns similar to blocky lava flows on Earth, but appear quite smooth in high-resolution optical images (Figure 2). The reason for the unusual surface roughness of these flows is unknown, but may relate to the unique thermal conditions experienced by lunar impact melt deposits.

Melt surface texture is known to be strongly influenced by the efficiency of surface cooling [10], and the cooling conditions of lunar impact melt deposits differ markedly from terrestrial lava flows. Lunar impact melt deposits cool under vacuum with initial temperatures far in excess of their liquidus [11], while terrestrial lava flows cool under a convective atmosphere with initial
temperatures just above their liquidus. Lunar impact melts also incorporate clasts of broken rock from the impact event, which further alter their cooling conditions compared to terrestrial lava flows. In comparison, impact melt deposits on Mercury show similar surface textures to those on the Moon in radar data [12], while impact melt flows on Venus do not [13]. This supports the idea that cooling by radiation under a vacuum may produce different surface textures than cooling by convection under a thick atmosphere.

In Neish et al. [14], we propose that the unique cooling conditions experienced by lunar impact melt deposits cause them to form with a glassy surficial layer. This layer is then disrupted after formation to produce decimeter sized blocks covering an otherwise ‘smooth’ flow (Figure 2). To test this hypothesis, we used data from the Lunar Reconnaissance Orbiter’s (LRO) Mini-RF instrument to characterize the decimeter-scale texture of the deposits, data from the LRO Narrow Angle Camera (LRO NAC) to characterize their meter-scale morphology, and data from Chandrayaan-1’s Moon Mineralogy Mapper (M3) to characterize their composition. We looked for evidence in the M3 data for spectral signatures that are consistent with a glass-rich composition by using laboratory spectra acquired of a range of glass-bearing materials. We find that glass-crystalline mixtures are consistent with both the roughness observed by Mini-RF and the composition inferred from M3 data of impact melt deposits on the Moon.

**Concluding Thoughts:** The solar system presents a natural laboratory for the investigation of the impact cratering process. By studying impact melt deposits on worlds with differing gravities, impact velocities, and atmospheres, we are able to constrain the process by which impact craters form, and the properties of their resulting ejecta. Additional data returned from future orbital missions – including high-resolution radar data of Mercury, Venus, and Mars – would greatly aid in furthering our understanding of the impact cratering process.

**References:**


![Figure 2](image_url)

**Figure 2:** (a) A large melt deposit is observed to flow out of the southern rim of Korolev Z on the Moon in this Lunar Reconnaissance Orbiter (LRO) Wide Angle Camera (WAC) mosaic. The location of (c) is shown by a white box. (b) Radar data from Mini-RF on LRO indicate that this flow is blocky at the decimeter scale, yet a (c) close-up LRO Narrow Angle Camera (NAC) view of the melt flow and roughness analyses conducted by [9] suggests it is smooth at the meter scale. Neish et al. [14] suggest this is due to the presence of glassy blocks in the outermost layer of the melt flow.