Impact Melt Emplacement around an Unnamed Martian Impact Crater in Terra Cimmeria

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Introduction

A distinctive aspect of the impact cratering process is the production of impact melt (Grieve et al. 1977). The presence of impact melt-rich lithologies overlying ballistic ejecta deposits around terrestrial and lunar craters suggest emplacement during the last stages of crater modification (Osinski 2004). The positioning of melt may occur from the collapse of the central uplift and/or from the terracing of the crater rim (Osinski 2004; Hawke and Head 1977). A large coherent melt sheet is often located within the crater, with melt ponds occurring along and outside the crater rim, in addition to the surrounding area. Unlike the Moon, Mars has a crust of varied composition and potentially a large reservoir of volatiles (likely mostly in the form of ground ice). Thus, the study of impact melt deposits on Mars is a good way to determine the role of volatiles in the production and emplacement of melt (Tornabene et al. 2007).

Theory

Emplacement of melt along and beyond the crater rim occurs on top of the ballistic ejecta. Thus, melt emplacement and ponding must occur following the deposition of the ballistic ejecta blanket during the modification stage of crater formation (within minutes after the initial impact). As the impact melt has a tendency to follow topography, it will inevitably accumulate in areas of lowest elevation (Tornabene et al. 2007, 2008). Observational data of lunar craters suggests that the impact melt was emplaced as flows outwards from the crater centre during the modification stage of crater formation (Hawke and Head 1977).

It has been implied that the pitted material visible in and around the craters on Mars can be considered to be "suevites" (a mixture of impact melt rocks and rock fragments formed during the impact) (Tornabene 2007; Bray et al. 2009). Numerous Martian craters with such features have been carefully studied, and a description of how impact melt is identified has been given by Bray et al. (2009).

Method

In this study, we investigate the nature, origin, and emplacement of impact melt materials around a Martian impact structure, using a GIS database of Martian imagery coupled with terrestrial analogue studies. We focus mainly on the use of HiRISE images, as their high resolution allows an added certainty when identifying melt features (Bray et al. 2009). This is followed by a detailed mapping of melt distribution in and around the selected impact crater. Eventually we aim to have multiple craters mapped, to allow for a comparison between different Martian hemispheres and target materials (highlands vs. lowlands; volatile rich vs. volcanic) and to compare Martian and lunar craters.

Case Study

A small transitional crater (approximately 7 Km diameter) in Terra Cimmeria (near Hesperia impact crater), which has yet to be named, has been selected for a detailed study; this impact crater has relatively little dust cover and appears to be very well preserved. Additionally, the melt deposits inside the crater are well defined and impact melt ponds and flows are abundantly observable around the impact crater, atop the ejecta.

This crater appears to have a host of features (Figure 1) that are similar to the pitted ponds inside and surrounding craters such as Corinto (15Km diameter impact crater) (Bray et al. 2009), suggesting the presence of numerous melt flow features and melt ponds. The positioning of the melt appears consistent with theory where the melt seems to be flowing toward the lowest elevated areas as it follows topography (Tornabene 2007). Pitted melt ponds appear visible in many topographic lows all around the crater, with flow features partly visible in between. Unlike Corinto, however, there is far less melt ponds and melt flows in and around the unnamed crater and the overall amount of ejecta is considerably less (compare Figs. 1A and 1B). The melt ponds are also less defined and far smaller in size.

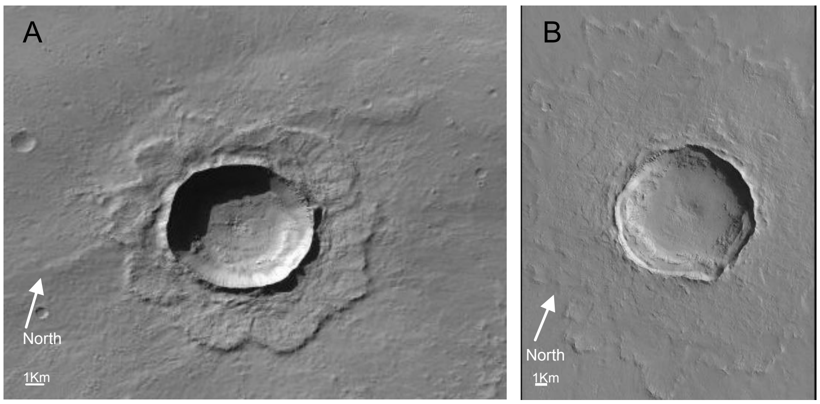

Figure 1A. CTX image P18_008135_1518 Unnamed Martian Crater (Image Credits NASA/JPL/MSSS); B. CTX image P07_003611_1971_XI_17N218W, Corinto impact crater (Image Credits NASA/LPI/University of Arizona)

Preliminary examination of the unnamed crater suggests that the melt is concentrated mostly along the west-southwest sector of the crater, with very little melt along the Eastern side. Melt along the northern boundary appears to be abundant as well; however, it appears to be mostly concentrated in only a few large areas (Figure 2).

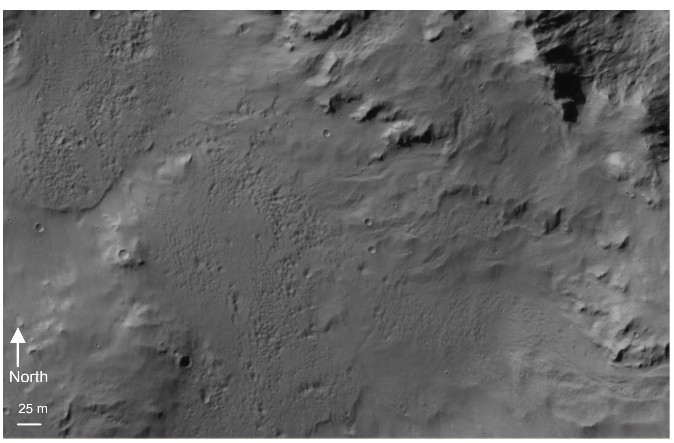

Figure 2a. HiRISE image PSP_008425_1520. Ponds and flows in the northern Rim (Image Credits NASA/LPI/University of Arizona)

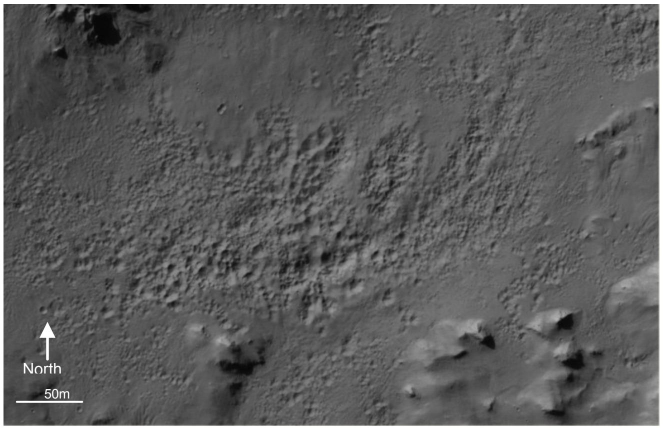

Figure 2b. HiRISE image PSP_008425_1520. Ponds and flows along the northern Rim (Image Credits NASA/LPI/University of Arizona)

Much of the impact melt appears to have flowed and collected into ponds, both in and around the crater (Figure 3). In general, the factors controlling where impact melt is distributed and ultimately ponded are numerous, yet the most significant would appear to be impact angle, and pre-impact topography (Mouginis-Mark and Garbeil 2007; Hawke and Head 1977). It is not clear at present whether either of these factors played a role in controlling the distrubution of melt at this crater. The volume of melt would be determined by velocity of impact, type of impacting body (Pierazzo et al. 2005) and type of rock into which the impact occurs (Osinski 2006).

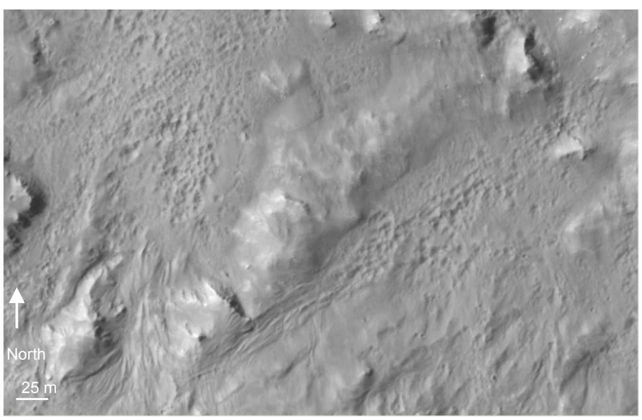

Figure 3. HiRISE image PSP_010772_1520 Flow and pond ((Image Credits NASA/LPI/University of Arizona)

It is notable that this crater, unlike many on Mars (e.g., Fig. IB with its fluidized ejecta blanket), resembles lunar craters. The melt ponds and flows are similar in appearance on both planetary bodies (Figure 5). Additionally, the impact area where the unnamed impact crater formed is also geologically similar to terrain where lunar impacts occur, as this portion of Terra Cimmeria consists of numerous superposed ejecta blankets from overlapping impacts that occurred early in Martian history; was well-weathered prior to impact; and had been exposed since the beginning of the Noachian (Scott and Carr 1978).

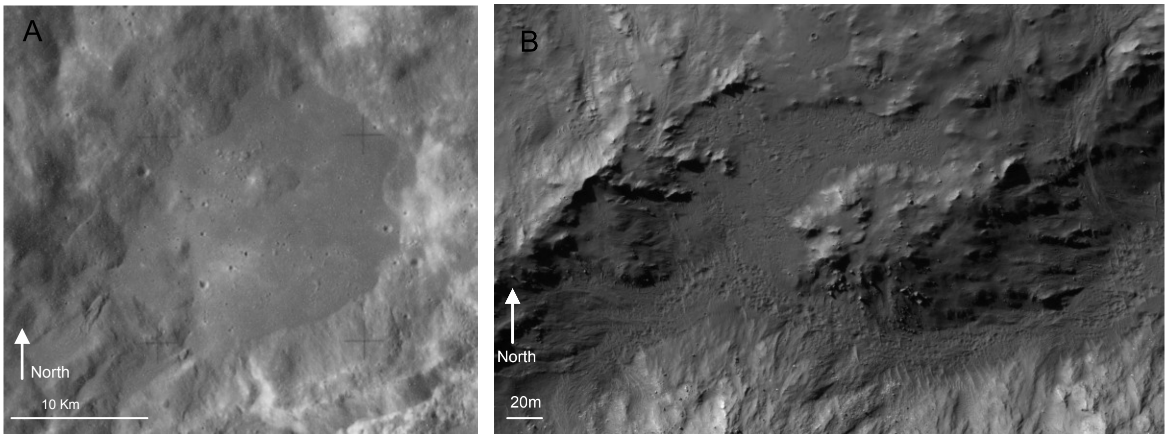

Figure 4 A. Apollo 16 Metric Photograph A16-metric-1580. King crater melt pond (Image Credits NASA/JPL/Apollo 16); B. HiRISE image PSP_008425_1520. Martian crater melt ponds (Image Credits NASA/LPI/University of Arizona)

Conclusion

Our preliminary study shows that this unnamed Martian crater provides an excellent case study to study the origin and emplacement of impact ejecta and the processes and products of melt emplacement. Not only is it a transitional crater, thus capable of being compared with both simple and certain complex craters, but also its relatively low dust cover and weathering is unusual for Mars and allows a detailed study to be made.

Acknowledgements

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