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The Role of Obliquity-Driven Climate Change on the Formation of Martian Impact Crater Ejecta Deposits

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Abstract

The morphologic and morphometric characteristics of ejecta deposits surrounding craters at mid- to high-latitudes on Mars are distinctly different from ejecta around craters at lower latitudes. These unique characteristics result from crater formation in the fine-grained ice-rich latitude-dependent mantle deposited during periods of high obliquity.

1. Introduction

The ejecta deposits of Martian impact craters at latitudes poleward of about ±30° display morphologic and morphometric characteristics distinct from craters at lower latitudes. These mid- to high-latitude craters, which we preliminarily call Type 1 craters, are characterized a thick, approximately circular inner ejecta deposit and a thinner, more sinuous outer ejecta layer. The inner ejecta deposit terminates in a broad rampart while the outer ejecta deposit's rampart is narrower, although still broader than the ramparts for lower-latitude (Type 2) ejecta. A topographic depression (moat) occurs just beyond the crater rim. Radial grooves on the inner ejecta deposit widen with distance from the crater rim. The texture of the outer ejecta deposit is unique, consisting of radial, sinuous grooves and ridges which curve around pre-existing obstacles, similar to some features seen in terrestrial pyoclastic deposits eroded by base surges [1]. These characteristics are in contrast to the lower-latitude Type 2 ejecta craters, which display thin ejecta layers of approximately equal thickness terminating in narrow ramparts, no moat, and radial grooves whose widths remain approximately constant with distance from the crater rim. Our quantitative measurements of rampart width and groove width show that Type 1 craters are distinct from Type 2 craters (Fig. 1-2). This suggests the ejecta deposits of the two types of craters are formed in different ways.

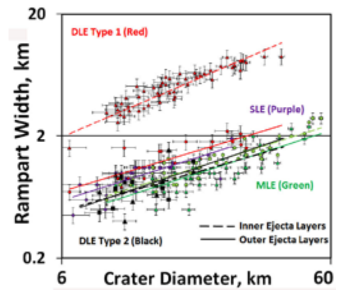

Figure 1: Width of ejecta ramparts for Type 1 DLE and Type 2 SLE, DLE, and MLE craters [2].

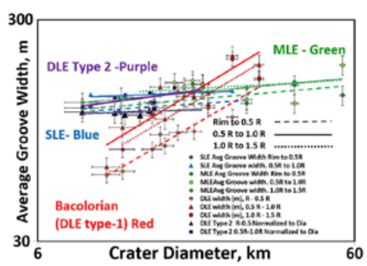

Figure 2: Average width of radial grooves for Type 1 DLE and Type 2 SLE, DLE, and MLE craters [3].

2. Type 1 Crater Morphologies

Traditionally all craters displaying the Type 1 characteristics were classified as Double Layer Ejecta (DLE) craters. However, some of these craters classified as DLE display more than two ejecta layers, meaning they are actually Multiple Layer Ejecta (MLE) craters [4]. One example is the 12.4-km-diameter Steinheim crater (54.57°N 190.65°E), which has been presented as an excellent example of a well-preserved Type 1 DLE crater [5]. Morphologic and morphometric analysis reveals it displays all the characteristics of a Type 1 crater, but CTX images of the northern part of the ejecta blanket clearly show the outer deposit is composed of multiple partial layers (Fig. 3). Hence Steinheim is a

Type 1 MLE crater. We also find that well-preserved pancake craters display the Type 1 characteristics and propose that these are Type 1 Single Layer Ejecta (SLE) craters rather than being erosional forms of Type 1 DLE craters as previously proposed [6, 7].

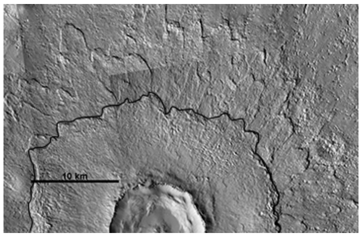

Figure 3: CTX mosaic of the northern part of the ejecta deposits surrounding Steinheim crater on Mars.

3. Formation of Type 1 Craters

We have previously reported that small craters (generally <5-10 km in diameter) forming entirely within the fine-grained ice-rich latitude-dependent mantle deposited at mid- to high-latitudes during periods of higher obliquity result in the creation of a base surge that armors the region surrounding the crater out to as much as 20 crater radii [8, 9]. These Low-Aspect-Ratio Layered Ejecta (LARLE) craters then undergo erosion as the obliquity decreases and ice sublimates from the surrounding terrain and the exposed edges of the LARLE deposit. This creates pedestal craters, where the crater and surrounding ejecta are elevated above the surrounding terrain. We propose that the larger Type 1 craters excavate through the decameters-thick mantle into underlying bedrock, but that the presence of the ice-rich mantle still influences the formation of the ejecta deposits. Our studies of the morphologic and morphometric characteristics of Type 1 craters lead us to the following scenario for ejecta deposit formation. The crater excavates through the decameter-thick mantle into underlying bedrock, forming the crater and emplacing the outer ejecta deposit as a ground-hugging debris flow. The crater rim contains large amounts of ice derived from the ice-rich mantle, which causes the rim to collapse and slide outward to create the thicker inner ejecta deposit [10]. The collapse of the rim also delivers large quantities of volatiles to the crater cavity where they interact with hot suevite filling the crater cavity to produce a steam explosion. This creates a base surge deposit which spills out of the crater cavity and across the ejecta deposit, forming the observed groove pattern [14].

4. Summary and Conclusions

We conducted detailed analyses of the layered ejecta deposits of Martian impact craters. We find that the high-latitude Type 1 craters have morphologic and morphometric characteristics distinct from the lower-latitude Type 2 craters, indicating different formation processes. We present evidence that Type 1 characteristics apply not only to DLE craters but also are expressed in MLE and SLE craters at mid- to high-latitudes. Our studies suggest that impact into and excavation through the obliquity-driven latitude-dependent mantle layer is responsible for the creation of the unique Type 1 ejecta deposits.

Acknowledgements

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References

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