MORPHOLOGY AND MORPHOMETRY OF FLUIDIZED EJECTA BLANKETS: NEW RESULTS FROM THE MARS EXPRESS HIGH RESOLUTION STEREO CAMERA.

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Introduction: Impact craters on Mars often exhibit features that are not observed on the Moon. The most unusual is the ejecta blanket morphology (**Fig. 1**) [1]. Martian ejecta blankets are in general characterized by a terminal low concentric ridge (rampart) or a flat-topped plateau (pancake), or radial grooves and scouring. This type of ejecta morphology collectively called "layered ejecta structures" [2] is in general attributed to various ejecta displacement processes due to involvement of volatiles derived from the subsurface [3] or of atmosphere [4].

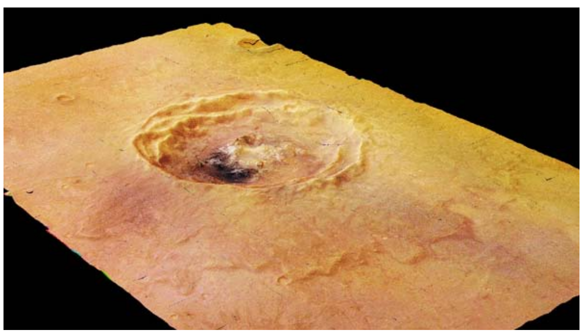

Figure 1. A Martian impact crater with a layered ejecta structure. This three-dimensional view was produced from the HRSC data set.

Methods: We utilized images and stereo-derived topographic data acquired by the HRSC (High Resolution Stereo Camera) onboard Mars Express in order to study geology of Martian impact crater ejecta blankets. We examined more than a dozen impact craters with possible evidence for water involvement during the formation by constructing 3-dimensional views and deriving various parameters. The high precisions of the HRSC data set ensure quantitative analyses of such impact craters better than previously possible.

Morphology: The investigated relatively pristine impact craters are distributed in the eastern Tharsis, but examples from other regions are also included. We examined various geomorphology and geomorphic parameters of Martian layered ejecta structures. The layered ejecta structures on Mars have been classified into different types including single lobe, multi lobate and double lobate [5]. Representative topographic profiles from our study clearly show a wide range of morphology. **Figure 2a** shows an example of typical single-lobed layered ejecta structure having a thick flat-topped plateau and a terminal rampart. The double lobate type is characterized by clearly separate inner thick lobes and much thinner outer lobes (**Fig. 2b**).

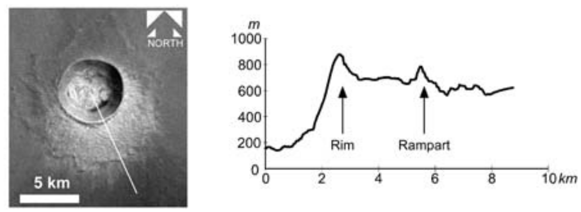

Figure 2a. HRSC topographic profile of a single-lobed layered ejecta structure.

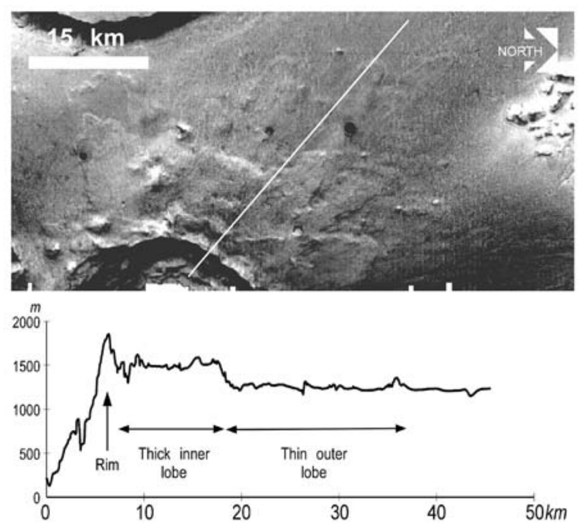

Figure 2b. HRSC topographic profile of a double-lobe type layered ejecta structure.

Morphometry: The ejecta radius has a strong correlation with crater cavity radius and volume, implying that the ejecta formation is primarily a function of impact energy. However, the thickness of ejecta appears to be a function of rim height, implying a gravity-driven process that contributed to the ejecta material movement together with the excavation-derived momentum.

Discussion:

Formation mechanism. The ejecta geomorphology and morphometric properties indicate the origin as water-related ejecta emplacement and liquefaction/fluidization.

We think that the morphology of the thick inner lobes is consistent with the formation mechanism by liquefaction and fluidization. Liquid water in the ejecta would greatly enhance the mobility of the ejecta debris [6]. Water-saturated sediment flows can take forms of turbidity current, dense currents, and debris flow depending on the sediment concentration and grain size [7]. The thick ejecta blankets with steep edges can be explained by the halting of mass flow with relatively low turbulence, although post-impact erosion can not be ruled out for the production of this morphology. The terminal rampart morphology likely resulted from the accumulation effect at the front of the lobe as it comes to stop.

Water either in a liquid or ice form stored in the subsurface was liberated because of the excavation. Ice was likely melted because of impact-induced shock [8]. Simulations [9] show that the water-brecciated rock mixture is ejected at angles higher than the pure rock depending on the amount of the original ground ice. This results in a knee (corresponding to the edge of melted water) in the thickness of the emplaced materials, possibly explaining the thicker inner lobe within the range of approximately 1.5–3 times the cavity radius and the edge of the rampart ejecta. Some layered ejecta structures have asymmetrical patterns and varying ejecta thickness. This is possibly due to the angle of impact, pre-existing surface topography, and the crustal structure including heterogeneous distributions of water reservoirs.

How about the thinner outer lobes? The majority of rampart craters are of single lobate type (e.g., [10]). However, a detailed study on the most pristine rampart craters found that the double lobate type is the majority [11], implying the double lobate type is the most likely original form. Our observations indicate that the outer lobes can also have rampart morphology although the thin nature of the lobes makes it difficult to identify such features to confirm the rampart for all the cases. We hypothesize that also the thin outer lobes were formed by liquefaction and fluidization. Flowing either due to the shockwave propagation through the near-surface materials or after the ejecta fallout are the possibilities. In the former case, the term “ejecta” may not apply. In the later case, the Ries impact structure suevites [12] that was formed over the Bunta Breccia and was emplaced as surface flows may be a terrestrial analog. The atmosphere-related turbulent flow probably contributed to some fraction of the ejecta.

Depth of cryosphere. A compilation by [13] found that the depth to the top of the Martian volatile layer is about 100–400 m globally using the onset diameter of rampart craters (1–7 km) and, whereas [14] obtained a different result (20–60 m deep) in Chryse Planitia. Our observation of selected examples of layered ejecta structures craters with the minimum size of 5 km implies that a volatile layer has or had existed at the depth of 400–600 m, taking account that the ratio of the excavation depth to the crater diameter can be around 0.08–0.12 as summarized by [15]. A theoretical approach argues that the cryosphere in the equatorial region of Mars is not stable over a geologically long period of time [16]. The presence of fresh impact craters with well-defined fluidized ejecta blankets in the equatorial region may require that there was a single or multiple episodes of water-recharging events in recent Martian history. Recent glaciation [17] or short-lived active hydrological cycles [18] may explain those events.

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