Digital Elevation Models Aid the Analysis of DLE Impact Craters on Mars.

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Introduction: Considerable debate has recently taken place concerning the origin of the inner and outer ejecta layers of double layered ejecta (DLE) craters on Mars. The inner ejecta layer of DLE craters displays characteristic grooves extending from the rim crest, and has led investigators to propose Three hypotheses for their formation: (1) deposition of the primary ejecta and subsequent scouring by either atmospheric vortices or a base surge [1, 2],(2) emplacement through a landslide of the near-rim crest ejecta [3 - 5], and (3) instabilities (similar to Gortler vortices) generated by high flow-rate, and high granular temperatures [6]. Critical to resolving between these models is the topographic expression of both the entire ejecta layer as well as the groove geometry. To explore these topographic relationships, we have been using the NASA Ames Stereo Pipeline software to generate digital elevation models (DEMs) of Bacolor crater (33.0°N, 118.6°E). Bacolor is one of the freshest DLE craters, and is ~20 km in diameter.

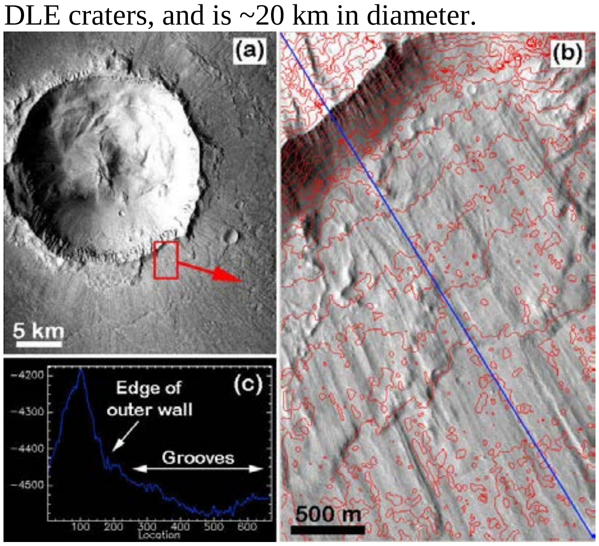

Fig. 1: Details of the topography of the southern rim of Bacolor crater. (a) Location of high resolution image, which is part of CTX image P16_007462_2133. Stereo pair is image P15_006750_2133. (b) 50 m contours for subscene indicated in (a). Blue line shows location of profile in (c). (c) Topographic profile from rim crest, showing the location of the grooves on the inner ejecta layer.

Topography of Bacolor Crater Ejecta Layers: A stereo pair of Context Camera (CTX) images allows the general topography of the southern ejecta layers to be investigated (Fig. 1) at a scale of ~24 m spatial resolution (thereby improving on the measurements of Boyce and Mouginis-Mark [2] by ~6x). These topographic data show that the southern rim is ~250 m high, and that the surface upon which the grooves can be seen has undulations on the scale of ~50 m.

Stereo images from the High Resolution Imaging Science Experiment (HiRISE) have also been used to better visualize the topographic expression of the inner and outer ejecta layers of Bacolor. Fig. 2 is a perspective view of the boundary between the inner and outer ejecta layers. Clearly visible is a series of grooves that cross from the inner layer onto the surface of the outer layer. In addition, material has flowed down the escarpment between these two layers.

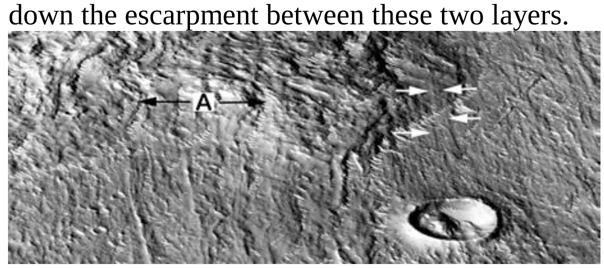

Fig. 2: Oblique view (looking north) of the southern ejecta blanket of Bacolor crater, showing the flow of ejecta from the inner layer (at top of image) on to the outer layer ("A"). Note the grooves (arrowed) that cross the boundary between these two units. DEM derived from HiRISE images PSP_006750_2130 and PSP_007462_2130.

The scale of topography of the grooves is also important to understanding their mode of formation. Fig. 3 illustrates part of the inner ejecta layer of Bacolor crater, along with a profile perpendicular to the long-axis of the grooves. Two different scales of relief are apparent from this profile: There are "deep-wide" grooves that have a width of ~200 m and a depth of ~10 m, and there are "shallow-narrow" grooves with a width of <50 m and depth <5 m. In several places, the shallow grooves are imprinted on top of the deeper grooves.

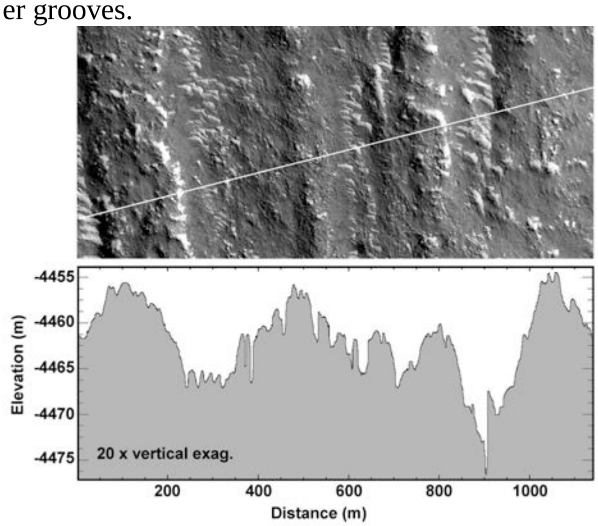

Fig. 3: Topographic profile (white line) across the grooves on the inner ejecta layer of Bacolor crater.

Insights into groove formation: The DEMs allow several key observations to be made that bear directly upon the origin of the grooves associated with DLE craters: (1) Grooves formed on the sloping ejecta layer surfaces up to the preserved crater rim (Fig. 1); (2) There is clear evidence that grooves traverse the boundary between the inner and outer ejecta layers (Fig. 2); and (3) There are at least two different sets of grooves, with smaller grooves imprinted upon the larger grooves (Fig. 3). All three of these observations can only be consistent with a model of groove formation by scouring of the ejecta surface after the layers were emplaced. The two scales of grooves is not consistent with their formation analogous to a landslide [3 - 5], or indeed other current models! The two different sets of grooves would imply that there was simultaneously two different depths to the flow if the grooves were formed by shear within the flow, something that is not physically possible.

Validation of DEMs: As the elevation data presented here are produced in-house, we have also spent time testing the validity of the Ames Stereo Pipeline software [7] compared to the the HiRISE Team's topographic products. To do this, we have generated a DEM from the same image pair that was used to produce one of the publically-available HiRISE DEMs. We use HiRISE images ESP_025801_2185 and ESP_025801_2185. In Fig. 4, we illustrate pixel-to-pixel comparisons of elevations derived from the two methods. In general, we find that our in-house topographic map differs from the publically-released HiRISE by <1 m on the terrain surrounding the crater (areas 3 and 4), <1 m on the crater rim (area 2) and <5 m on the ejecta blanket (areas 1 and 5). Because of this close comparison between our in-house produced DEMs and those that are made publically available by the HiRISE Team, we plan to produce additional topographic data sets of value to the Mars crater community to further investigate the geometry of DLE craters.

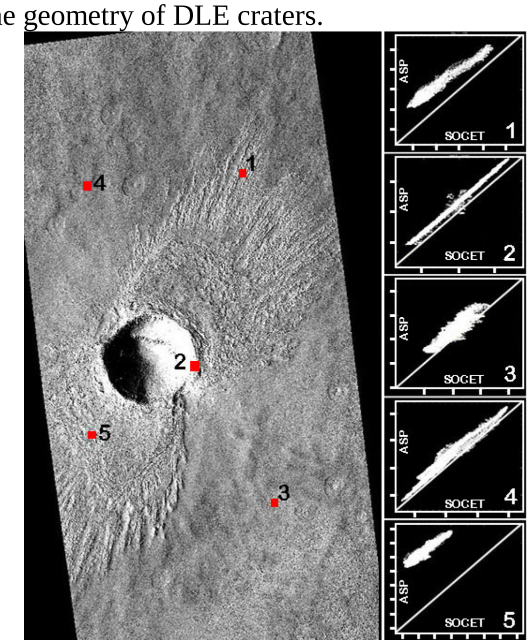

Fig. 4: Comparison of DEMs derived by using Ames Stereo Pipeline (ASP) and the HiRISE Socet Set. Five test areas have been selected and are shown at right. Horizontal and vertical scales on each scatterplot are in meters, and reveal that the greatest disparity (~5 m) is for test area #5. Other scatterplot show better correlation between the two data sets. Stereo pair is HiRISE images ESP_025735_2185 and ESP_025801_2185.

References: [1] Mouginis-Mark, P.J. (1981). *Icarus* 45, 60 – 76. [2] Boyce, J.M. and P.J. Mouginis-Mark (2006). *J. Geophys. Res*. 111(E10), doi:10.1029/2005JE002638. [Weiss, D.K. and J.W. Head (2013). *Geophys. Res. Lttrs*. 40: 3819 – 3824. [4] Wulf, G. and T. Kenkmann (2014). *Lunar Planet. Sci. XLV*, abstract #1792. [5] Weiss, D.K. and J.W. Head (2014). *Icarus* 233, 131 – 146. [6] Boyce, J.M. and P.J. Mouginis-Mark (2008). *11th Mars Crater Consort*. Abstract #1101. [7]. Moratto, Z.M. *et al*. (2010). *41st Lunar Planet. Conf*. Ab. #2364.