TOREVA-LIKE BLOCKS FORMED IN THE INNER EJECTA LAYER OF MARTIAN TYPE-1 DOUBLE LAYER EJECTA CRATERS: IMPLICATIONS.

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There is considerable evidence that Martian double layer ejecta (DLE) type-1 craters are morphologically different from single layer ejecta (SLE), DLE type-2, and multilayer ejecta (MLE) craters (i.e., SDM craters) [1-7]. Because differences in their morphologic characteristics suggest differences in emplacement processes and/or environmental conditions during their formation, a variety of models have been proposed for producing these differences (summarized by [5]),

Recently models for the origin of the unique shape of DLE type-1 inner layer ejecta deposit [2] propose that sliding, and/or slipping of ejecta across the surface is facilitated by surface ice (mixed with water) or by sliding from an initially over-steepened and high rim during emplacement [4, 5, 7]. While these models propose mechanisms for producing the unique profile of DLE type-1 ejecta, they are not underpinned by the presence of landforms that would be uniquely produced by these mechanisms. However, we suggest that this may no longer be the case.

Graben-like troughs oriented approximately transverse to ejecta flow are common on all types of layered ejecta (Fig. 1). These features are thought to be extensional features, similar to grabens, but developed in the ejecta as it flowed outward [2, 7]. Remarkably, on inner ejecta layers of some DLE type-1 craters these troughs are bound by inclined flat-surfaced blocks of ejecta that tilt back toward the crater rim (Fig. 3). These blocks typically form within ~ 0.2 R to 0.5 R of the rim and are relatively common on DLE type-1 crater ejecta located in southcentral Utopia Planitia. Their morphology is suggestive of terrestrial toreva blocks (Fig. 2). These features are thought to be an “end member” type of landslide formed by sliding and rotation of coherent blocks along log spiral-shaped rupture developed along steep slopes [8]. Movement along the rupture is attributed to slip on weaker surfaces, including those weakened by the presence of water [8, 9].

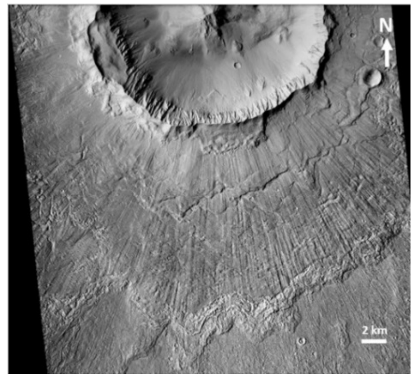

Figure 1. Bacolor crater (21.7 km dia. at 32.9°N, 118.6°E) exhibits sets of several hundred meters wide and a few kilometers long troughs that run transverse to ejecta flow. The surface that bound both sides of these trough are at about the same elevation. (CTX: P22_009677_2133_XN)

While the tilted-ridge morphology of these Martian features could be caused by over-thrusting as one mass of flowing ejecta overrides a slower moving ejecta mass, the lack of substantial narrowing or overriding of the troughs on the outer edges of these blocks is inconsistent with this mechanism.

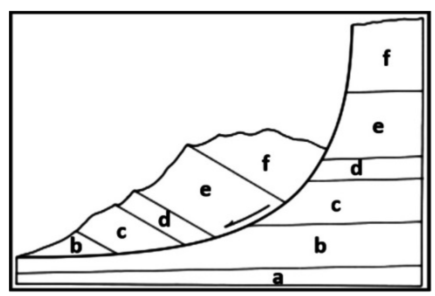

Figure 2. Sketch of model of Toreva block formation where a coherent block slides down a spiral-shaped fault (taken from Geol. of Grand Canyon 3rd 3d 1979).

The grooves on these blocks typically widen away from the rim in V-shape canyons toward the higher relief portions of the tilted blocks (Fig. 4a) suggesting their erosion into the blocks postdates surface stabilization and block rotation. In places, the grooves can be traced across the blocks, down the walls, and across the floors of the trough, indicating that the grooves formed after the blocks, the roll waves on them, and the troughs (Fig. 4b). This suggests a sequence of events that starts with ejecta emplacement similar to other DLE type-1 craters, (including transverse trough formation and roll waves), followed by detachment and rotation of near-rim ejecta blocks from the uplifted pre-impact surface, followed by formation of the radial grooves on the stable surfaces of the ejecta deposit.

We suggest that the fine-grained ice-rich mid-latitude mantle in which DLE type-1 craters are typically found provides the underlying weak layer. This mantle deposit, or possibly even thicker past ice layers, could have facilitated slip of the near-rim ejecta deposit in a manner that produced toreva blocks [8, 9].

References: [1] Barlow N.G., et al. (2000) *JGR 105*, 26733-26738. [2] Boyce J.M. and Mouginis-Mark P.J (2006) *JGR 111*, E1005. [3] Boyce J.M. et al. (2010) *MAPS 46*, 638-661. [4] Weiss D.K. and Head J.W. (2013) *GRL 40*, 3819-3824. [5] Weiss D.K. and Head J.W. (2014) *Icarus 233*, 131-146. [6] Barlow N.G. (2015) *GSA SP 518*, 31-63. [7] Wulf G. and Kenkmann T. (2015) *MAPS 50*, 173-203. [8] Reiche P. (1937) *J. Geology 45*, 538-548. [9] Elliot D.H. (2002) *GSA Abstract #104-12*.

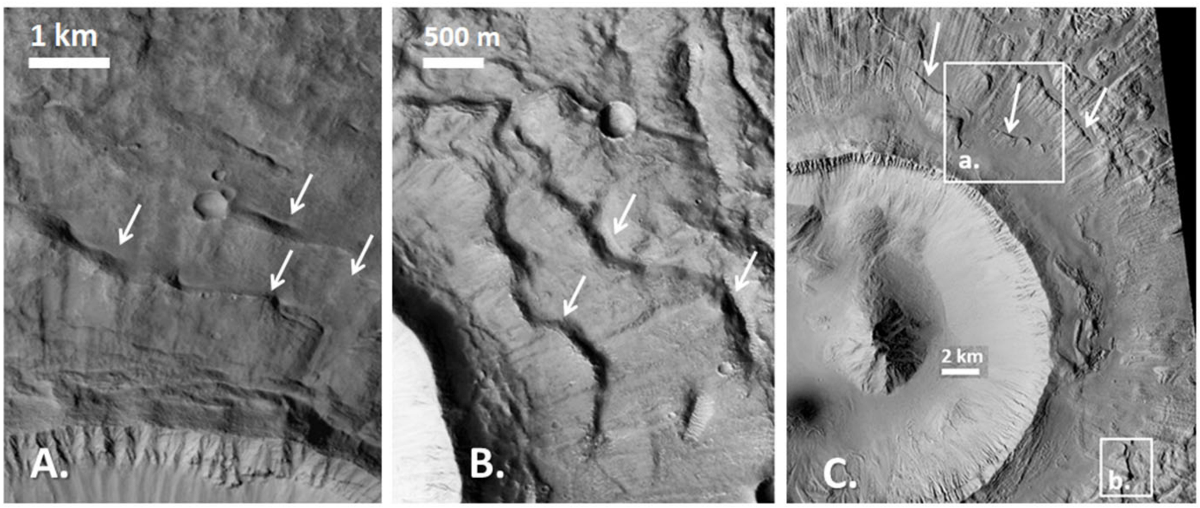

Figure 3: Examples of backward tilted ridges near the rims of DLE type-1 craters. Arrows point to scarps with transverse troughs outward of the tilted blocks. Image 3 C shows location of Figure a. and b. Image (A) is a 13 km dia. crater at 31°N, 105°E (CTX: P16_007212_2115_XN); image (B) of 14.8 km dia. DLE crater at 28°N, 116°E (14.8 km dia.) (CTX: P15+006916_2100_XI); image (C) is an 18.7 km dia. crater at 34°N, 120°E (P20_008833_2149_XN).

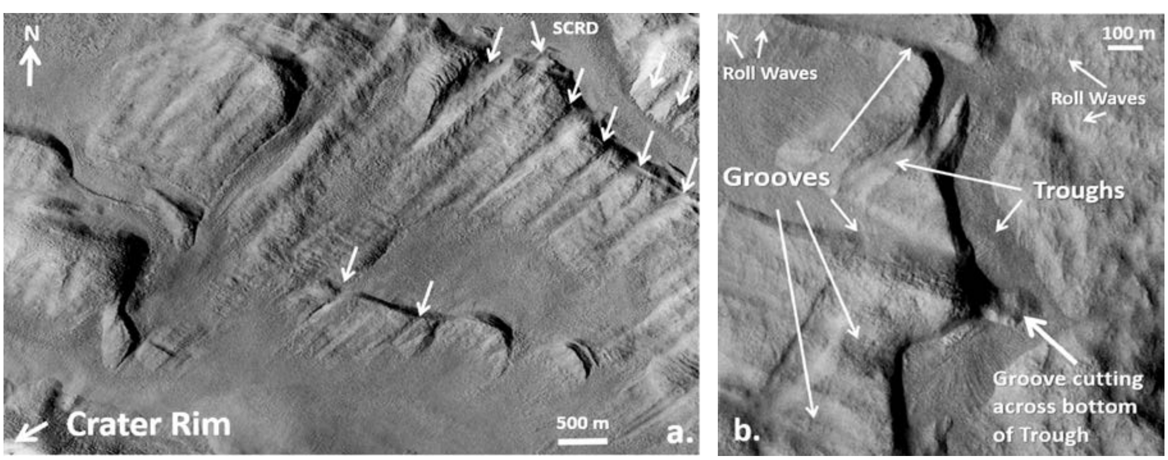

Figure 4. On the left (a.), tilted ejecta blocks flooded by post-impact deposits (SCRD) that help to accentuate the empression of tilt. The blocks are bound by troughs whose walls and floors (b.) have been cut by radial grooves (see Figure 3 C for locations).