Late Stage Flow of Ejecta Across the Boundary Between Ejecta Layers of Martian Double Layered Ejecta Craters: Implications: Joseph M. Boyce and Peter J. Mouginis-Mark, Hawaii Institute of Geophysics and Planetology, University of Hawaii, Honolulu, Hi 96822.

Boyce and Mouginis-Mark (2006) [1] proposed that the emplacement of ejecta around Double Layered Ejecta (DLE) craters on Mars ended with a base surge that carved the groove on the inner ejecta layer and deposited the erosional products on (or as) the outer ejecta layer. Later, [2-4] disputed the observations on which these observations are based and offered alternative origins and emplacement mechanisms for these ejecta. This abstract present one of the most important observations for resolving this controversy.

Recently, high quality topographic data derived from HiRISE and CTX stereo images reveal that, in places, thin ejecta deposits containing the curvilinear grooves that characterize the surface of the outer ejecta layer are draped over and superposed on the boundary between the ejecta layers of large DLE craters (Figs. 1a and 2). These thin deposits and their grooves extend outward from the rampart of the inner ejecta layer on to the surface of outer ejecta layer. This superposition relationship indicates that these grooves and the material in which they formed developed after the emplacement of the ejecta layers. Furthermore, it also suggests that the process that formed the grooves on the outer ejecta layer operated across the boundary between ejecta layers.

In places, there appears to be gaps in the thin groove deposits on the outer ejecta layer (Fig. 1b), exposing a lower surface a few meters (<~10 m) below (on our test crater Bacolor) where the radial grooved texture of the thin grooved deposit is absent. We suggest that this is the actual surface of the outer layer ejecta deposit. This lower surface is topographically above the surrounding region by ~15 m suggesting that the volume of grooved material above is <0.5 of the layer. This is consistent with our estimates of the volume of grooves on the inner ejecta layer of Bacolor as, at most, 25 % of the total volume of the outer ejecta layer.

Our observations are inconsistent with evidence presented by [2-4] that the inner ejecta layer formed after the emplacement of the outer ejecta layer, and even overrode it in places. This is also inconsistent with [5] who suggested that emplacement of the outer ejecta layer occurred after the inner ejecta layer. However, the surge model [1, 6-10] offers a viable resolution to the inconsistency between these observations and models. This model supports the idea that the straight grooves on the inner ejecta layer of DLE craters formed by erosion (possibly deeply incising pre-surge landslide-like grooves) from a high-velocity surge after formation of both ejecta layers. The erosion products were deposited on (or, as) the outer ejecta layer as the velocity of the surge decrease and its flow regime transitioned from erosion to deposition [11], hence this event would have obscured straight grooves on both layers like those on single and multilayer ejecta craters [see 12]. This model is consistent with the erosion model of [13] that requires the observed shape of the inner ejecta layer [1] in order to form vortices that erode the straight grooves in the inner ejecta layer.

In conclusion, we suggest that thin grooved material flowed off the inner ejecta layer of DLE craters onto their outer ejecta layer after both were emplaced, and is probably the result of a surge like that proposed by [2, 7-11].

References: [1] Boyce, J., Mouginis-Mark, P., 2006 *JGR*, 111, E10005, doi:10.1029/2005 JE2638; [2] Weiss, D., Head, J., 2013, *GRL*, 40, 3819-3824; [3] Weiss, D., Head, J., 2014, *Icarus* 233, 131-146; [4] Wulf, G., Kenkmann, T., 2015, *MAPS* 50, Nr, 173-200; [5] Mouginis-Mark, P., 1981, *Icarus*, 45, 60–76; [6] Boyce, J. et al., 2014. *PCCC*, abs. # 1404; [7] Boyce, J. et al., 2015, *LPSC* XXXXV, Abs.# 1043 [98 Boyce, J. et al., 2016, *LPSC*, abs. 1327; [9] Boyce and Mouginis-Mark, 2017, *PCCC*, abs. # 1705; [10] Boyce, J. et al., 2010, *MAPS* 45, 661; [11] Wohletz, K., 1998, ed. A. Freundt, pp. 247–312, Elsevier, NY; [12] Carr, M. et al., 1977, *JGR*, 82:4055–4065; [13] Kieffer, S. et al., 2017, *GSA* Natl. Mtg, abs.

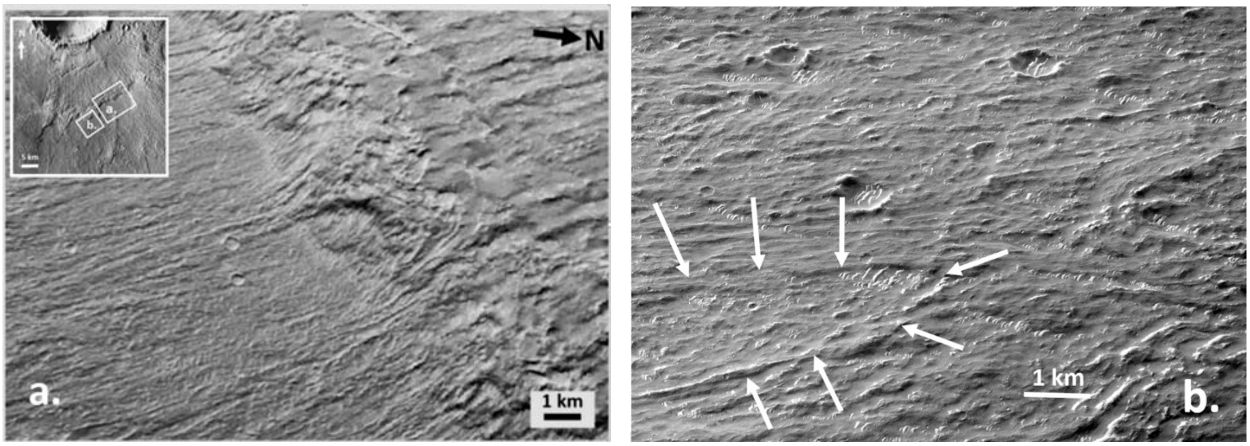

Fig. 1. (a.) Oblique view of southern boundary between the inner (right) and outer (left) ejecta layers of Bacolor crater (33.4ºN, 118.6ºE), the 21.7 km dia. DLE crater showing a thin sheet of grooved material draped over the boundary and extending onto the outer ejecta. (b.) Oblique view of a portion of the southern outer ejecta layer of Bacolor crater showing an elongate lower area (~10 m lower than the surrounding thin flows) that exhibits no flow features like those found on the thin grooved material around it. Inset at top left in (a) shows location of images a and b. HiRISE DEM from images PSP_006750_2130 and PSP_007462_2130.

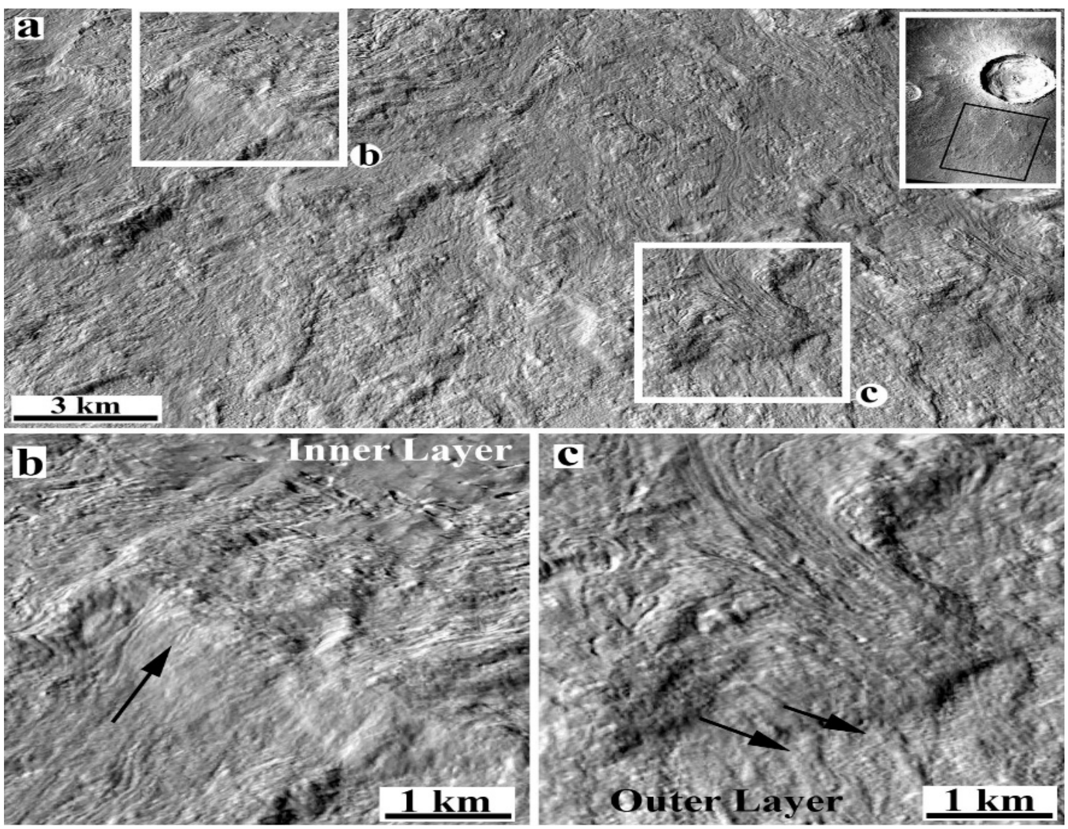

Figure 2: Oblique view (looking north) of Jaisalmer crater (~14 km dia.) located at 33º30'N, 84º10'E. (a) Southern portion of the ejecta blanket, inset at top left shows location, and boxes indicate areas shown at higher resolution below. (b) Shows the straight grooves on the inner ejecta layer terminating at the jumbled zone between ejecta layers with curvilinear grooved material draped over that zone and on to the outer ejecta layer where in (c) the grooves can be traced around clots of ejecta and draped over the outer ejecta rampart onto the terrain beyond. Digital elevation model derived from CTX images F23_044886_2136 and J01_045229_2136.