Morphology and Age Relationships of Radial Grooves on Martian Layered Ejecta Deposits: Joseph M. Boyce, Peter Mouginis-Mark, Hawaii Institute for Geophysics and Planetology, University of Hawaii, Honolulu, 96822,

The radial grooves (and ridges) found on the inner ejecta layer of double-layered (DLE type-1) are morphologically different from those found on single, double type-2 and multilayer (SDM) crater ejecta [1, 2, 3]. This difference suggests likely differences in emplacement processes or environmental conditions during their formation. For example, the average width of these grooves (W_a) for all types of ejecta are plotted in Fig. 1 [2, 3] indicate that W_a of grooves on the inner ejecta layer of SDM craters remain nearly constant independent of the parent crater diameter, while W_a on DLE type-1 crater ejecta increase with parent crater size (i.e., exponent of exponential functions that describe them is ~0.09 compared with ~0.85, respectively). We suggest that these trends indicate that processes controlling groove width on SDM caters are unrelated to crater size, while those that control groove width on DLE type-1 ejecta may be related.

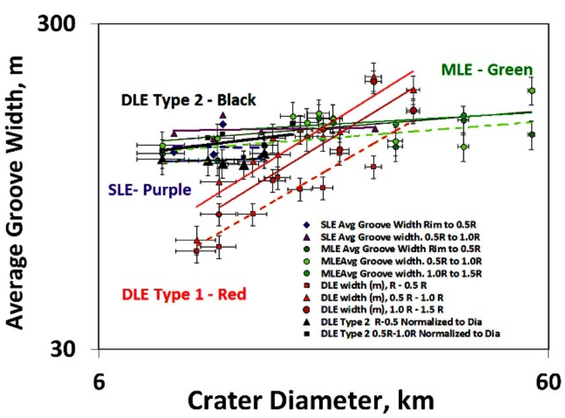

Figure 1. Average width of radial grooves (W_a) in layered ejecta: rim out to 1.5 R in 0.5 R increments.

Along individual grooves, variation in width is substantially less on inner ejecta layer of SDM craters compared with groove on DLE type-1 craters (typically variation of σ ~0.2 and σ ~0.5 of their W_a, respectively). Similar uniformity in groove width was noted by [4, 5, 6] for grooves on terrestrial long-runout landslides. Based on this observation and the trends in W_a with crater diameter, we suggest that the grooves on SDM ejecta originate in a similar manner as those found on geophysical flow (e.g., landslides), and in granular flow laboratory experiments involving phenomena occurring within the flows such as shear (e.g., see 4, 6 - 12), while those on DLE type-1 ejecta are in some way tied to process that controls crater diameter (e.g., impact energy) as suggested by [1].

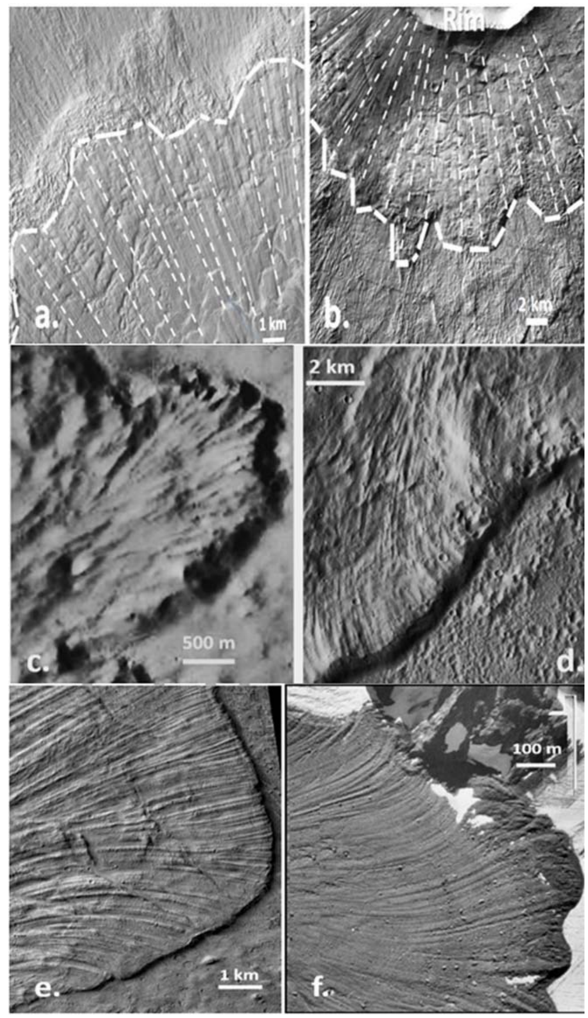

Figure 2. Grooves (white lines) on DLE craters Bacolor (THEMIS: V12453007) (a) and (b) a 13.7 km dia. crater located at 34°N 101°E (CTX: D18_034138_2142) remain straight and radial to the crater center in spite of intersection with ejecta lobes. Radial groove on MLE craters a 28 km dia. at 10°N, 193°E (c) (CTX: G04_019709_1905) and a 17 km dia. at 29°N, 13°E (d) (CTX: G19_025557_2096) fanning as they intersect with ejecta lobes. Images of (e) Martian (CTX: P22_000763_1690) and (f) terrestrial (Sherman glacier

USGS) landslides showing fanning of grooves as they intersect with flow lobes.

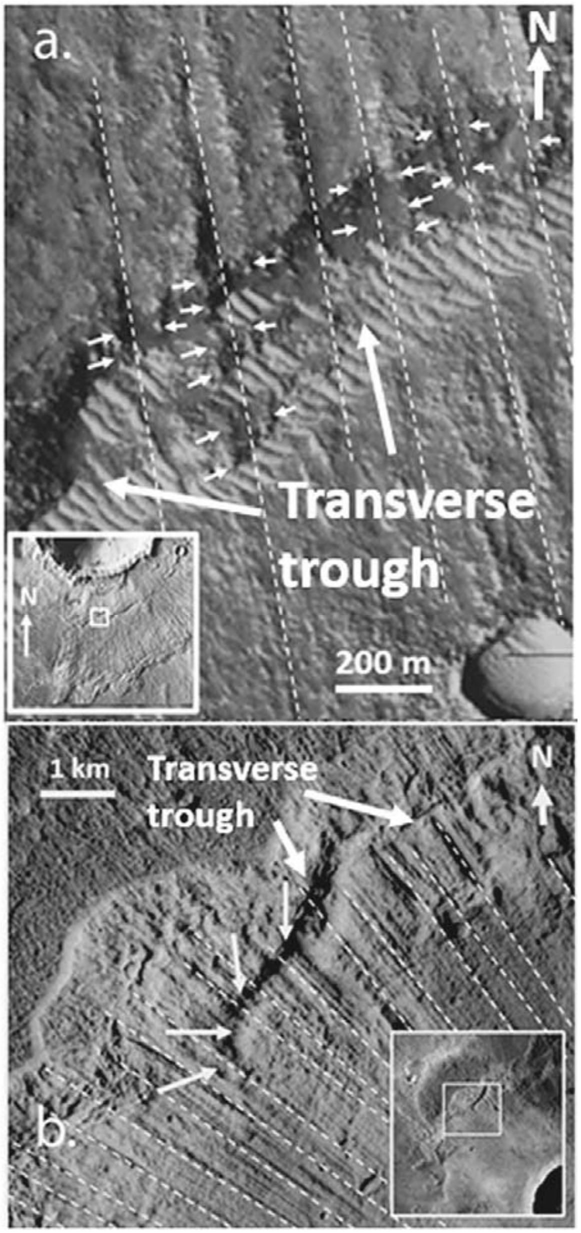

Fig. 3: Examples of radial grooves, highlighted by dashed lines, cutting troughs on the inner ejecta layer of (a) Bacolor and (b) a 12 km dia. DLE type-1 crater located at 34°S, 101°E (CTX: G23_027268_2131). Short arrow point to where grooves cut the scarps and floors of the transverse troughs they cross. Note that the grooves are straight and radial to the craters center. Inserts show context of main images.

Although, the radial groove on all types of Martian layered ejecta are generally straight and radial to the crater center, only grooves on SDM ejecta curve around obstacles and fan near the edges of individual ejecta flow lobes (Fig. 2) in a manner similar to those on geophysical flows produced in the direction of flow as the flowing debris moves forward, and expands to form lobes [4, 13].

Boyce and Mouginis-Mark, [1], noted that the radial grooves on the inner ejecta layer of DLE type-1 ejecta cut all types of flow features, but this is disputed by [14]. However, our ongoing planet-wide search of new images of DLE type-1 impact craters confirms the findings of [1]. For example, in Fig. 3, radial grooves clearly can be traces straight up to the edge of graben-like troughs on the inner ejecta layer of these DLE type-1 craters, down their interior slopes on each side of the troughs, and straight across their floors. This clearly indicates the trough formed before the radial grooves and that the trough had little, if any, effect on groove formation or their direction.

We suggest that there are two types of radial groove associated with layered ejecta craters: those on DLE-type-1 ejecta and those on SDM ejecta. The data suggest that the processes that governed flow of SDM ejecta were similar to those that govern terrestrial geophysical flows. However, the data also suggest that processes that govern flow of DLE type-1 ejecta are different and are consistent with the model for their formation proposed by [1].

References: [1] Boyce, J. and Mouginis-Mark, P., 2006, JGR, doi:10. 1029/2005JE2638; [2] Boyce, J. et al., 2014. PCCC, abs. # [3] Boyce et al., 2015, LPSC XXXXV Abs.# 1043; [4] Shreve, R., 1966, Science 154, 1639-1643; [5] DeBlasio, F., 2014, Geomorph., 213, 88-89; [6] Marangunic, C., and Bull, W., 1968, Nat. Acad. Sci., 383-394; [7] Savage S. B., Hutter K., 1989, J. Fluid Mech., 199, 177-215. [8] Barnouin-Jha, O., et al, 2005, JGR, EO4010, doi:10:1029/2003 JE002214; [9] Baloga S, and Bruno, B. (2005), JGR 110, doi: 10.1029/ 2004JE002381 [10] Aranson, I., and T. Tsimring, 2006, Reviews of Modern Physics 78: 641-687. [11] Iverson, R., et al., JGR, 115, doi:10.1029/2009JF001514; [12] Dufresne, A., and Davis, T., 2009, Geomorph., 105, 171-181; [13] Johnson, C. G., et al., 2012, JGR, 117, doi:101029/2011JF002185; [14] Wulf, G Kenkmann, T., 2015, MAPS 50, Nr, 173-20.