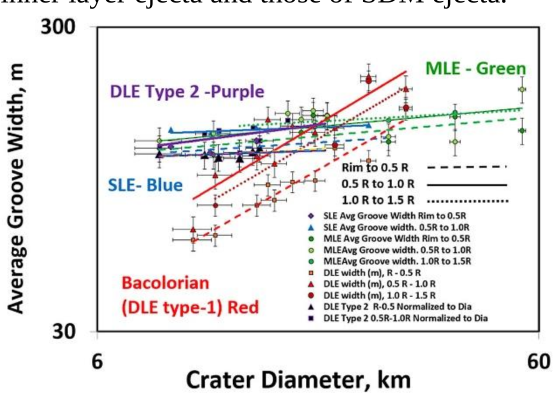
RADIAL GROOVES ON MARTIAN LAYERED EJECTA DEPOSITS: Joseph M. Boyce, and Peter Mouginis-Mark, Hawaii Institute for Geophysics and Planetology, University of Hawaii, Honolulu, 96822, jboyce@higp.hawaii.edu>

1.0 <u>Introduction</u>: Similar to furrows on terrestrial landslides, the radial grooves (RG) on Martian layered ejecta crater deposits provide a sensitive record of flow style and history [1]. From crater type to crater type, these closely-spaced sets of RG superficially resemble each other, but in detail, they exhibit important morphologic differences that suggest possible different formation processes [2 - 5]. We adopt here the nomenclature suggested by [3], i.e., single layer ejecta [SLE], double layer ejecta [DLE] type-2 and multi-layer ejecta [MLE] craters. However, we combine SLE, DLE type-2, and MLE craters as SDM craters, and DLE type 1 craters as Bacolorian craters [BC].

2. <u>Morphology</u>: RGs on SDM and BC ejecta can be discontinuous, and start/end at any distance from the rim. On SDM ejecta, RG typically begin near the base of the crater rim slope and extend outward, but on BC (Fig. 1) they can start at the crater rim crest [5 - 7].

RG range from a few tens of meters to > ~10 km long, a few meters to a few hundred meters wide, and up to tens of meters deep with the longest and widest RG typically found on the ejecta of the largest craters. This is shown in Fig 2 where the average width, and average length of RGs are plotted for 32 test craters of different type, of different sizes, from their rims to 1.5 crater radius [R] from the rim, in 0.5 R increments. These data show that the RG fall into two major morphometric groups, i.e., those of BC inner layer ejecta and those of SDM ejecta.



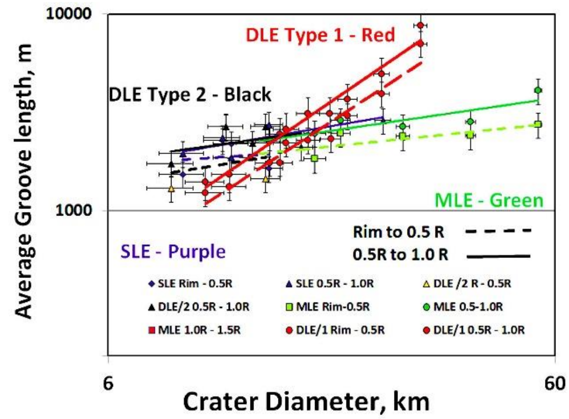


Fig. 2. Average RG width is shown on the top and average RG length is shown on the bottom.

While the RG on all types of ejecta are typically straight throughout their length, there are important exceptions. For example, RG on SDM ejecta (and outer layer of BCs) commonly curve around obstacles or bend outward (and widen) to form fans at ejecta lobes in the direction of ejecta flow (Fig. 3a, and b) This suggests that these features are formed "in" the flowing ejecta, similar to transverse grooves (TG) found on long run-out landslides [1, 8, 9] (Fig. 3d and e).

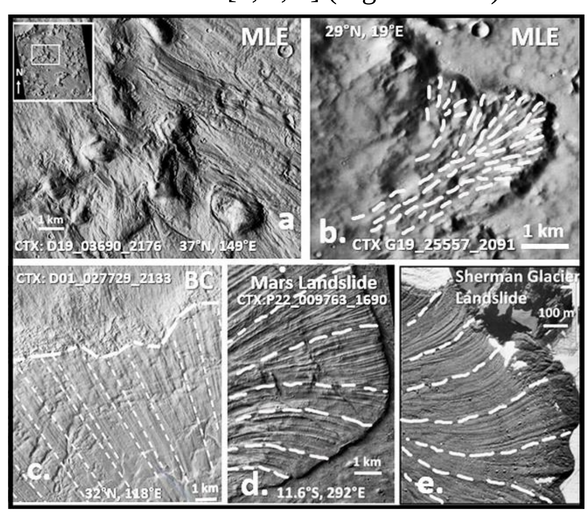


Fig. 3 (a.) on the left shows RG on ejecta of the inner ejecta layer of Bree (27.5 km dia.) curving around preexisting obstacles. (b.) shows an example of RG that fans toward the edges of flow lobes (on a 17.4 km dia. MLE crater). (c.) shows intersection without curving of RG with flow lobes Bacolor inner ejecta layer. (d.) shows fanning of TGs at distal edge of a landslide in Valles Marineris. (e.) shows the same relationship as (d.) but on the Sherman Glacier slide. White dashed lines show position of the RGs.

In contrast, [5] observed that RG on the inner ejecta layer of BC rarely show curving behavior anywhere along their extent, including at obstacles and the edges of ejecta lobes (Figs. 3c, and Fig. 4 d.), as well as cut across all other ejecta flow features and pre-existing topography without deflection (Fig. 4d and e). We have extended these observations using all available high-resolution images of BC [10] and found the same trend.

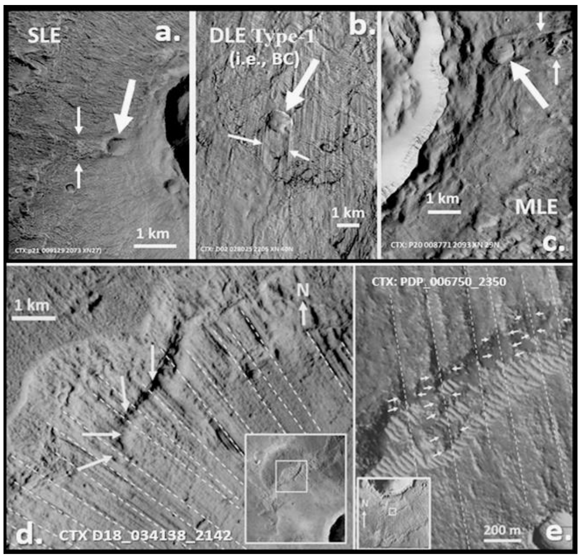


Figure 4. (a, b, and c) Effects of preexisting topography on RG development and ejecta flow. In a. and c. ejecta has flowed around small craters (large arrow) curving the RGs. In b., RGs cut straight across a small crater. (d. and e) RG crossing transverse-trending, graben-like troughs on the inner ejecta layer of BC. Arrows in d. and e. point to RG that cut across the interior of the troughs. In addition, note that the RG maintain their radial direction on BC ejecta.

Proposed Origin of RG: The morphology of RGs on SDM ejecta are most like transverse grooves on long run-out landslides suggesting that both types of grooves are likely produced by the same mechanism (shearing and pulling apart). However, the RG on the inner ejecta layers of BCs show important morphologic differences that are most consistent with formation by the mechanism proposed by [5], i.e., erosion by a Mt. St. Helens (MSH)-like blast surge. Kieffer [11] suggested that a fuel/coolant explosion was generated at MSH during the May 1980 eruption when dome collapse allowed magma to mix with surface and near surface ice and water. The resultant steam explosion generated a supersonic surge that eroded furrows that crossed local topography without defection. As the surge expanded and its speed dropped to subsonic, the surge flowed around topography and as a result the furrows it carved were also curved.

We suggest that if BC grooves are caused by this mechanism, then a substantial volume of ice on the Martian surface is required to mix with hot rock in BCs to produce a steam explosion. This is not an extraordinary requirement because recent climate models by [6] propose that the profile of the inner ejecta layer of BCs is the result of sliding of ejecta on thick icy surface materials during emplacement. We suggest that grooves like those on SDM ejecta would likely form initially as the ejecta flowed outward and then halted. However, we also propose that if the ice of [6] existed, then rim collapses of BC immediately after their formation would result in sliding of ice-rich material into the crater where it mixes with the substantial volume of hot impactite that would be present (i.e., similar to the crater suevite at Ries basin [12]). We propose that this mixing of ice and hot rock in BSs produces steam explosions that generate supersonic blast surges like the one at MSH. These surges would sweep radially outward from the crater interior, eroding RG into the surface from the rim crest out to the edge of the inner ejecta layer and obscuring the SDM type grooves. At the inner rampart [5], this surge hit a hydraulic jump (i.e., the broad, relatively high inner rampart) causing the surge to slow to subsonic and begin deposition of its material. We suggest that this deposition is the cause of the unique surface morphology of the outer ejecta layer of BC [5].

Acknowledgements: Sponsored by a contract from ASU for THEMIS Team Participation.

References: [1] DeBlasio, F., 2014, Geomorph., 213, 88-89: [2] Barlow, N., et al. 2000, *JGR.* 105: 26,733 - 26,738: [3] Barlow, N., 2015, GSA SP 518, 31-63: [4] Barlow. N., et al. 2017, LPSC this volume; [5] Boyce, J., Mouginis-Mark, P., 2006 *JGR*., 111, E10005, doi:10.1029/2005 JE2638; [6] Wiess, D., Head, J., 2013, GRL, 40, 3819-3824: [7] Wulf, G., Kenkmann, T., 2015, MAPS 50, Nr, 173-200: [8] Shreve, R., 1966, Science 154, 1639-1643: [9] Marangunic, C., Bull, W., 1968, Nat. Acad. Sci., 383-394: [10] Barlow. N., 2016, crater catalog USGS website: [11] Kieffer, S., 1981, *USGS, PP*, 1250, 379-400; [12] Stoffler, D., et al., 2013, MAPS, 48, Nr 4, 515-58.