MORPHOMETRY OF RADIAL GROOVES ON THE INNER EJECTA LAYERS OF MARTIAN DOUBLE LAYERED EJECTA CRATERS.

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Introduction: The straight radial grooves on the inner ejecta layers of double layered ejecta (DLE) craters are some of the most enigmatic flow features on layered ejecta [1 - 7]. They are thought to be an indicator of flow conditions at the time of groove formation, and have been proposed to be produced by blast surge [7], high-speed granular flow described by [8], or low-speed flow like that common to landslides [9]. Here, we summarize the morphometry of these features and its possible implications.

Data: We measured the length and width of radial grooves on the inner ejecta layers of 10 Martian DLE craters that range in diameter from 9.9 km to 30 km (Table 1). The data were collected in rectangular strips (each a few km wide) from the rims to the edges of the inner ejecta layer. The strips were subdivided into sample areas of 0.5 crater radii (R) increments.

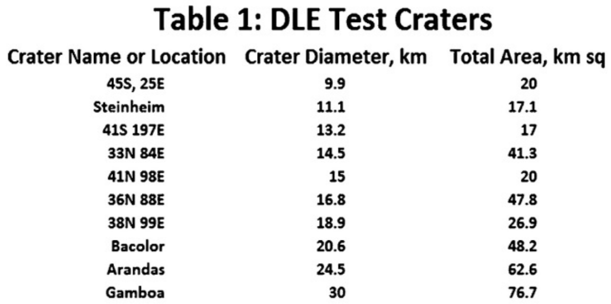

Table 1: DLE Test Craters

Crater Name or Location	Crater Diameter, km	Total Area, km sq
45S, 25E	9.9	20
Steinheim	11.1	17.1
41S 197E	13.2	17
33N 84E	14.5	41.3
41N 98E	15	20
36N 88E	16.8	47.8
38N 99E	18.9	26.9
Bacolor	20.6	48.2
Arandas	24.5	62.6
Gamboa	30	76.7

Results: The number of grooves/km^2 in each sample area is shown in Fig. 1. The average width and length of grooves is shown in Fig. 2. These data suggest that no matter the size of crater, the grooves are relatively narrower, shorter and more numerous per unit area inward of 0.5 R compared with those in sample areas further from the rim. Normalizing the total area of grooves in each zone to the area of that radial zone (Fig. 3) suggests that groove forming is more efficient near the rim.

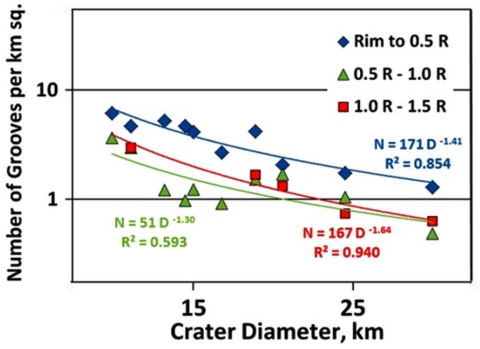

Fig. 1. The average number of grooves in each sample area on the inner ejecta layer of the DLE craters in Table 1.

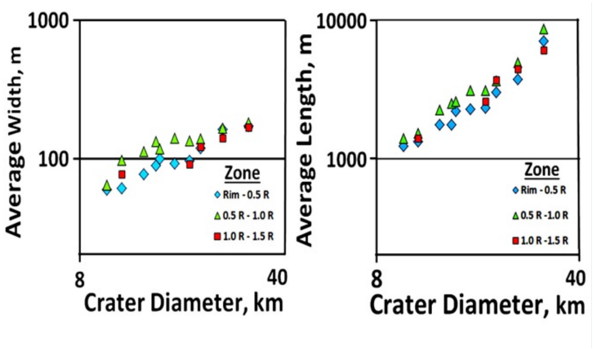

Fig. 2. Average groove width and length (from where the grooves start nearest the rim to their maximum radial extent, even if a groove extends across sample area boundaries) in each sample area.

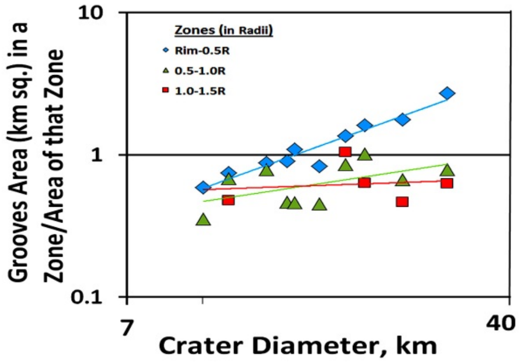

Fig. 3. Graph of the total area of grooves in radial increments (zones) of 0.5 R on the inner ejecta layer of the DLE craters in Table 1 normalized to the area of that zone. The grooves in the inner zone (blue diamonds) occupy relatively more area than grooves in the other zones.

This trend can be seen in images of these craters (Fig. 4, right). The abundant short, narrow grooves near the crater rim commonly coalesce outward with other small grooves to form larger grooves, disappear altogether, or in some cases are superposed on the larger grooves [10]. However, there are some relatively large grooves that occur near the rim and extend to the outer edge of the ejecta layer. In other places, large grooves develop abruptly further out from the rim. Boyce et al [10] noted that this trend is the reverse of those observed on some Martian (Fig. 4, left) landslides.

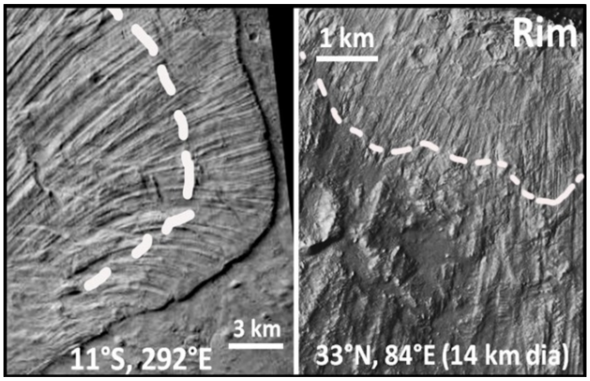

Fig. 4. Grooves on a long run-out landslide in Valles Marineris (left) and inner ejecta layer of a DLE crater (right). Grooves are narrowest near the rim of the crater and at the distal edge (average 1/3 narrower) of the landslide. Dashed lines are boundaries between areas of narrow and wider grooves.

In addition, the straightness of grooves on the inner ejecta layers of DLE craters appear never to be affected by intersection with the edges of flow lobes (Fig. 5 left). This is unlike grooves on some Martian (Fig. 6, left) and terrestrial [11] landslides (Fig. 6, right) and Multi-layered ejecta (MLE) craters (Fig. 5, right), where, in some cases, the grooves curve to intersect the edge of the lobes at near normal angles.

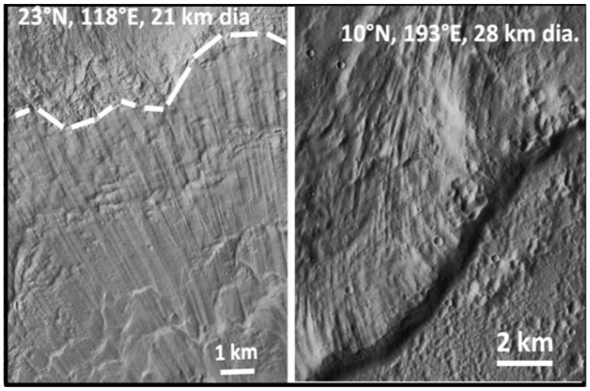

Fig. 5. Grooves intersecting with the distal edges of lobes on ejecta layers of a DLE (inner ejecta layer) crater (left) and a MLE (right). The grooves on the DLE crater remain radial to the crater center at all places along the lobes (marked with dash line), but on the MLE crater the grooves curve to intersect the edges at high angles.

Conclusions: The radial grooves on the inner ejecta layer of DLE craters show distinctive morphologic differences from the radial grooves on the inner ejecta layer on MLE crater ejecta or some long run out landslides. For example, the average width, and length of radial grooves of DLE craters systematically increase outward from the crater rim, while on some long run-out Martian landslides the trend is the opposite. This may be due to differences in formational mechanisms [7, 9], thickness of the deposits during groove formation [8, 11], or flow velocity with distance [8]. In addition, the radial grooves on DLE craters always intersect the outer edge of lobes on the DLE inner ejecta layers radial to the crater center, and not direction of flow that formed these lobes. This suggests the formation of these grooves was not associated with flow of ejecta that formed these lobes [7]. In contrast, the radial grooves on some landslides (Mars and Earth), and some MLE ejecta layers curve to intersect the edges of their flow lobes at high angles. This suggests that these grooves developed parallel to the flow direction, and as a result probably formed in the flowing debris.

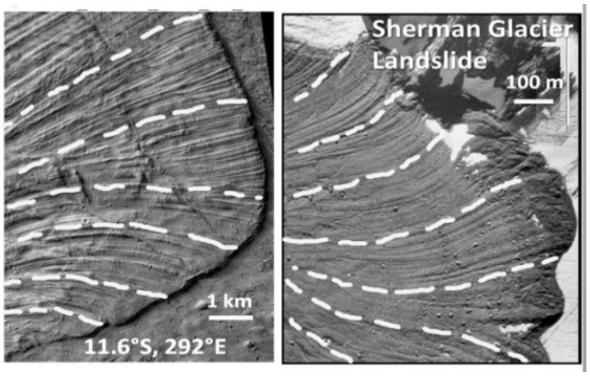

Fig. 6. Grooves curving (marked by dashed lines) at the distal edges of lobes on a Martian landslide (left) and the Sherman Glacier (Alaska) landslide (right) showing a tendency to intersect the edges at high angles (i.e., flow direction as lobe forms).

References: [1] Mouginis-Mark, P.J. (1981), *Icarus* 45, 60-76; [2] Schultz, P.H. and J. Singer (1981) *Proc. 11th LPSC*, 2243 – 2259; [3] Barlow, N. *et al*. (2000) *JGR* 105, 26,733 – 26,738; [4] Baloga, S. and B. Bruno (2005), *JGR* 110, doi: 10.1029/ 2004JE0 02381; [5] Baloga, S. *et al*. (2005), *JGR* 110, doi: 10.1029/2004 JE002338; [6] Barnouin-Jha, O.S. *et al*., (2005) *JGR* 110, doi: 10.1029/ 2003JE002214; [7] Boyce, J.M. and P.J. Mouginis-Mark (2006), *JGR 111*, doi:10.1029/2005JE2638; [8] Forterre, Y. and O. Pouliquen, (2002), *Fluid. Mech.*, 467, 361-387; [9] Wiess, D., and Head, J., 2013, *GRL*, 40, 3819-3824 [10] Boyce et al 2014, LPI, 8^{TH} *Mars Conf.*, abs. 142; [11] Dufresne, A., and Davis, T., 2009, *Geomorph.* 105, 171-181