Inventory of flow features on Martian layered ejecta. Joseph M. Boyce, Peter Mouginis-Mark, and Sarah Fagents, Hawaii Institute of Geophysics and Planetology, University of Hawaii, Honolulu, HI 96822.

Introduction: High-resolution images of ejecta layers of Martian craters show a broad range of ridges, striations and grooves produced by ejecta flow. While these features are morphologically similar to features formed in granular flows, such as landslides and debris flow, the Mars cratering community typically has remained unconvinced that studying these features provides any useful information about ejecta flow. However, we suggest that ejecta flow, like other geophysical flows composed of fragmented debris, is controlled by the physics of granular flow, and hence, the flow features on ejecta record intrinsic processes of free-surface granular flows [1 - 5].

Table 1

Morphologic Characteristics of Flow Features on Layered Ejecta		
Inner Ejecta Layer	**DLE**	**MLE and SLE**
Straight Radial Grooves and Ridges	Broad, undeflected by topography. Terminates abrupt, no Curving or Fanning at Layer Edge.	Deflected by topography. Commonly terminate abruptly at Layer Edge, but can curve and Fan.
Transverse Troughs and Ridges	Sets in Wave-like Patterns	Same as DLE craters
Transverse Graben-like Troughs and Scarps	Frequently Segments Intersect in V-shapes Patterns	Same as DLE craters
Layer Termination	Relatively Broad Rampart	Relatively Narrow Rampart
Smooth Pitted Material	No	Small Patches on MLE ejecta, Mostly Beyond SLEs' Rampart
Outer Ejecta Layers	**DLE**	**MLE**
Straight Radial Grooves and Ridges	No	Yes, Can Fan out at Ramparts and be Deflected by Topography
Radial Sinuous grooves and ridges	Yes, Deflected by Topography	No
Transverse Troughs and Ridges	No	Sets in Wave-like Patterns
Layer Termination	Low, Relatively Broad Rampart	Relatively Narrow Rampart
Smooth Pitted Material	No	Mostly blanketing outer ejecta layer and surrounding surface

Results: Here, summarized are results from our survey of these features on the ejecta layers of different types and sizes of Martian layered ejecta (Table 1). We have found that the flow features of layered ejecta show systematic differences with crater type, ejecta layer, and distance from the rim, but generally not crater size. To a first order, the flow features on single layer ejecta (SLE) craters are similar to those of multi- layer ejecta (MLE) craters, but both are different than those on double layer ejecta (DLE) craters.

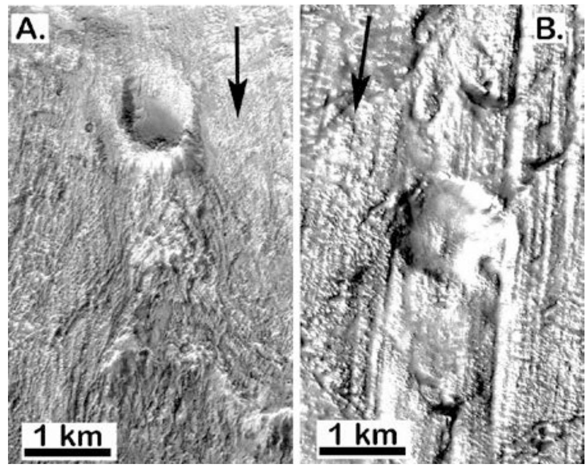

Fig. 1: The effects of small pre-existing crater on radial grooves development. A) 8.7 km dia. SLE crater at 27°N, 319°E. B) 30 km dia. DLE crater at 40°N, 315°E. Arrows show direction of ejecta flow.

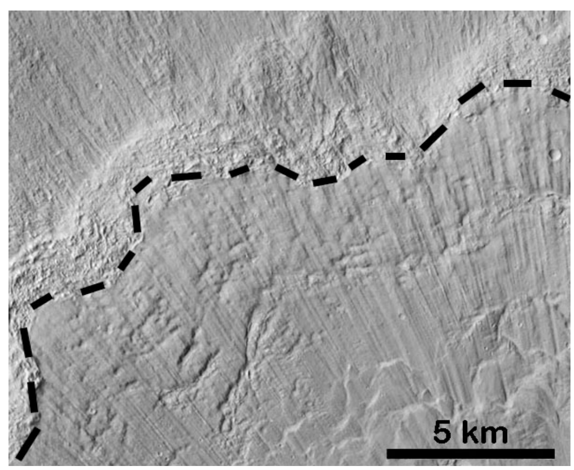

Fig. 2: Northwest edge of the inner layer (black line) of Bacolor crater (32°N 118°E) showing radial grooves orientation is not effected by intersect with the lobes.

Radial Features: All ejecta layers are crossed by radial grooves and ridges that differ with crater type and layer. The grooves of inner layers of DLE craters are straight; appear to be insensitive to most obstacles (Fig. 1B), and show no fanning at lobe edges (Fig. 2). The radial grooves on MLE and SLE of all ejecta layers are generally straight, but can be deflected around topographic obstacles (Fig. 1, left). Some of these grooves fan at the edges of lobes (Fig. 3). In contrast, the radial grooves of DLE craters outer ejecta layers are typically long and sinuous (Fig. 4). These features can be deflected by pre-existing topography (Fig. 5).

Transverse Features: All ejecta layers, except the outer ejecta layer layers of DLE craters, have closely spaced sets of transverse ridges and troughs (Fig. 5). These have been interpreted by [7, 8] to be roll waves.

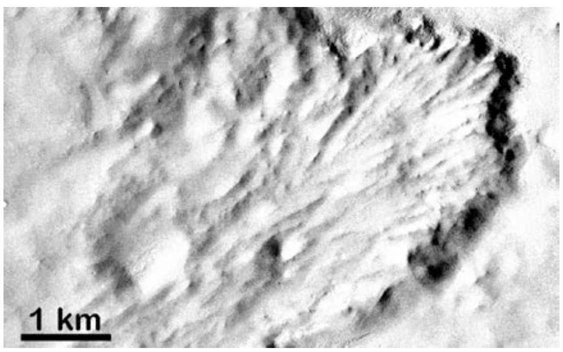

Fig. 3: Fanning of radial grooves as they intersect edges of a MLE ejecta lobe (crater at 29°N, 13°E, 17 km dia.).

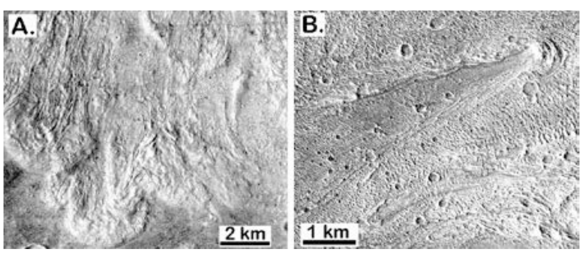

Fig. 4: A) Curves, sinuous radial grooves and ridges on the outer ejecta of this 13.8 km dia. crater (41°S, 197°E). B) Pile-up of ejecta and shadow area on 10 km DLE crater caused by flow around a small hill (23°N, 320°E).

Smooth Pitted Deposits: Extensive smooth pitted deposits are common on, and around fresh MLE and SLE craters. These deposits are found on, and beyond the outer layer of MLE craters (Fig. 6), and outward of SLE craters ejecta layer. These deposits appear to be similar to those on the floors of fresh craters [9].

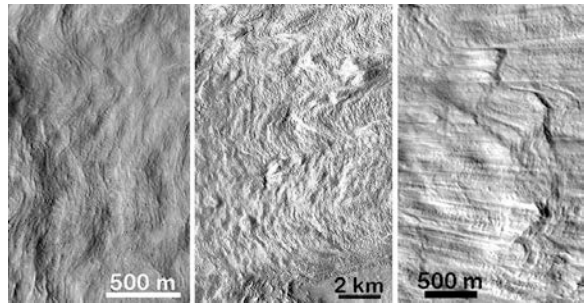

Fig. 5: Transverse ridges and troughs on SLE (left), MLE (center), and the inner layer of DLE (right) craters.

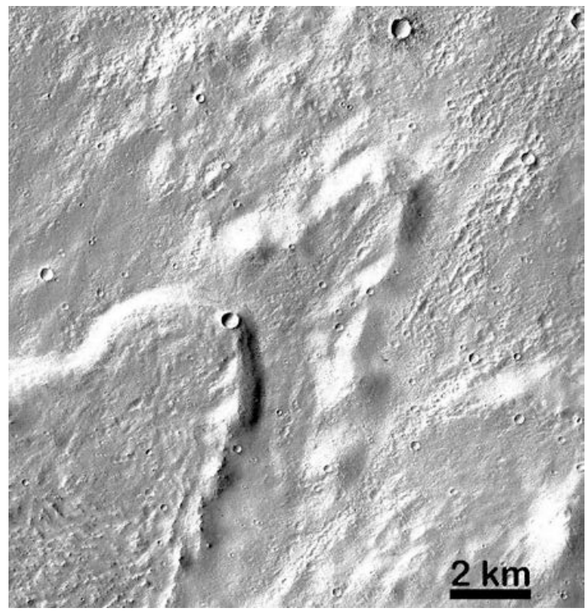

Fig. 6: Outer two ejecta layers on the 28 km dia. MLE crater (10°N, 193°E) showing smooth pitted material.

References: [1] Shreve, R. (1966). *Science* 154, 1639-1643; [2] Marangunic, C. and Bull, W. (1968). *Nat. Acad. Sci*. 383-394; [3] Barnouin-Jha, O., *et al*. (2005). *JGR*, EO4010, doi:10:1029/2003 JE002214; [4] Dufresne, A., and Davis, T. (2009). *Geomorph*. 105, 171-181; [5] DeBlasio, F. (2014). *Geomorph*. 213, 88-89; [6] Boyce *et al*. (2014). *8th Mars Conf.*, abs. 1428; [7] McKean, J. and Roering, J. (2004). *Geomorph*. 57, 331-351; [8] Baloga, S. *et al*. (2005). *JGR*, 110. E10001doi: 10.1029/2004 JE002338; [9] Tornabene, L. *et al*. (2012). *Icarus*, 220, 2, 348-368.