THE PITTED RAMPARTS OF LARGE MULTI-LAYERED IMPACT CRATERS ON MARS: THEIR POSSIBLE FORMATION MECHNISMS AND THEIR IMPLICATIONS: Joseph M. Boyce, Hawaii Institute of Geophysics & Planetology, University of Hawaii, Honolulu, HI 96822.

1.0: Introduction: The ramparts of the outer most ejecta layer of large (those > ~ 25 km diameter) multilayer ejecta craters (MLE) typically exhibit heavily pitted surfaces. These have been given little attention [1], but provide important information about rampart formation, cratering, and the distribution of subsurface volatiles on Mars. The close spacing of the pits and their morphology is reminiscent of the heavily pitted deposits found on the interior and ejecta blankets of Martian single layer ejecta (SLE) and MLE crater of all sizes [2] and are likely related.

2.0: Background: Ejecta ramparts resemble ridges at the terminus of some geophysical flows [3]. Most researchers assume that ejecta ramparts are formed by the same processes that form the geophysical ridges [4-6]. This is because both are composed of poly-dispersive rock fragments that rapidly moved across the surface, and both typically contain and enhance population of coarse grain particles compared with the rest of the flows [7-11]. While this mechanism generally requires kinetic sieving, transport and accumulation of the large particles at the front of a dense granular flow, the likely role of the Martian atmosphere and the abundant subsurface ice should not be ignored in ejecta emplacement [12-15]. Because of the likely participation of these volatile sources in the ejecta emplacement process, we envision, similar to some previous workers [12-15], that following impact of the ejecta curtain on the surface, ejecta emplacement may be similar to emplacement of many pyroclastic density currents flows [16]. In these flows, the concentration of fluid (i.e., mainly gas) increases upward resulting in the lower portion typically behaving as a dense granular flow where ramparts can form by particle-to particle interaction (e.g., Kinetic sieving and accumulation of coarse particles at the flow front), while the fluid behavior of the upper portion is as a dilute Newtonian flow.

3.0: Ramparts – Outer Ejecta Layer of Large MLE Craters: The morphology of Martian ramparts is a function of impact crater type [17-20]. In addition, in some cases, the morphology of ramparts is also different between individual layers, e.g., such as on double layer ejecta type-1 craters (DLE type-1) [9, 11].

In the case of relatively large (> ~ 25 km diameter) MLE craters (the focus of this study), the ramparts of the outer ejecta layer are typically heavily pitted, highly lobate ridges (Fig. 1, 2, 3). The density of pits in these ramparts appears to be higher with increased crater diameter (Note: detail measurement of the pits has just started). Based on preliminary analysis, the average size of the pits appears to scale with size of the parent crater. The sizes distribution of the pits on these rampart also appears to be unimodal, but skewed to small sizes from the average.

4.0: Conclusions: We suggest that, similar to the origin of the pits in the heavily pitted deposits [2], the closely-spaced rampart pits are formed by degassing of volatile-rich, impact melt-rich breccia in the ejecta. We suggest that these materials concentrate in the outer ejecta layer for two reasons. The first, the concentration of subsurface volatiles are most likely a function of depth. This means that the greatest volume of target material with the highest concentration of volatiles should be excavated early in the crater excavation process compared with material excavated later [21]. This material should be deposited furthest out. The second reason is that because the pressure levels in a growing crater is a function of crater size [21], a greater volume of impact melt and vapor, and hence volatile-rich, impact melt-rich breccia [21], should be produced in which pits can form.

References: [1] Mouginis Mark, P., Boyce, J., 2012, Geochemie der Erde Geochemistry, 72, 1, 1-23; [2] Tornabene, L., et al., 2012, Icarus, 220, 2, 348-368; [3] Shreve, R., 1966, Science 154, 1639-1643; [4] Pouliquen O., et al., 1997, Nature, V. 386, 816-817; [5] Felix and Thomas, 2004, Earth Planet Sci. Lett., 221, 197-213; [6] Iverson, R., et al., 2010, JGR, v. 115, FO03005, doi: 1029/2009 JF001514; [7] Barnouin-Jha, O., et al, 2005, JGR, EO4010, doi:10:1029/2003 JE002214; [8] Baratoux, D., et al., 2002, GRL., 29 (8), 1210; [9] Boyce, J. and Mouginis-Mark, P., 2006, JGR, doi:10. 1029/2005 JE2638; [10] Boyce, J., et al., 2010, MAPS 45; 661; [11] Wiess, D., Head, J., 2013, GRL, 40, 3819-3824; [12] Schultz P., Gault, D., 1979, JGR, 84:7669-7687;[13] Wohletz, K. Sheridan, M., 1983; Icarus, 56, 15-37; [14] Schultz, P., 1992, JGR, 97:11623-11662; [15] Barnouin-Jha, O., et al., 1999, JGR. 104: 27,117 – 27,131; [16] Branney M., and Kokelaar, P., 2002, Geol Soc London, 2003, 27, pNP; [17] Garvin, J., J. Frawley, J., 1998), GRL, 25, 4405–4408; [18] Barlow, N. *et al*., 2000, *JGR* 105, 26,733 – 26,738; [19] Mouginis-Mark, P., Baloga, S., 2006, *MAP* 41, 10, 1469-1482**;** [20] Robbins, S., Hynek, B., 2012, JGR, 117, E05004; [21] Melosh, J. (1989). Oxford Press

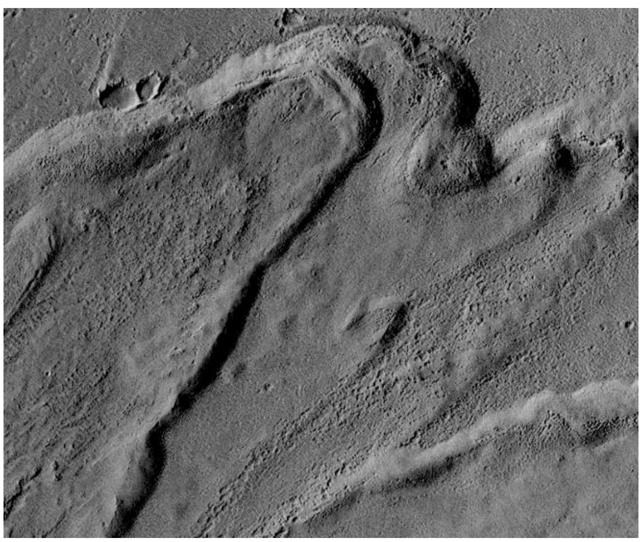

Fig 1. Outer rampart on the NE ejecta of the ~ 28 km diameter crater Tooting (23N, 208E). Image is a portion of CTX F21_044077_2043_XN.

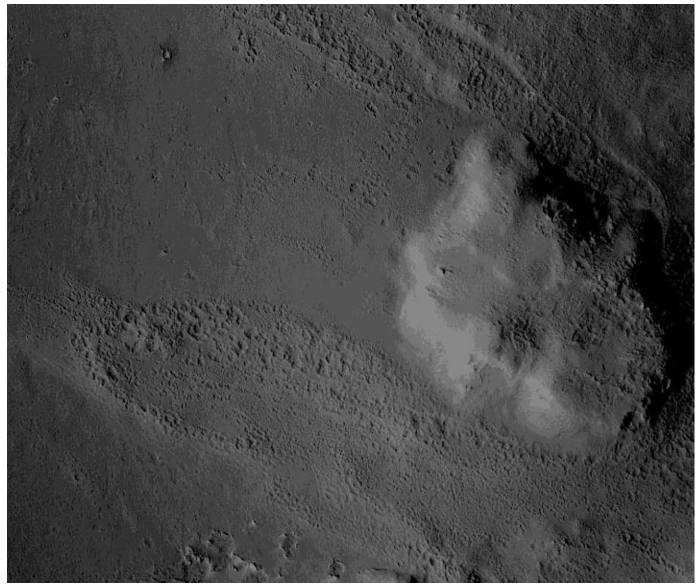

Fig. 2 Outer rampart on the NW ejecta of the 38 km diameter crater Kotka (19N, 169E). Image is a portion of CTX K05_055379_2008_XN.

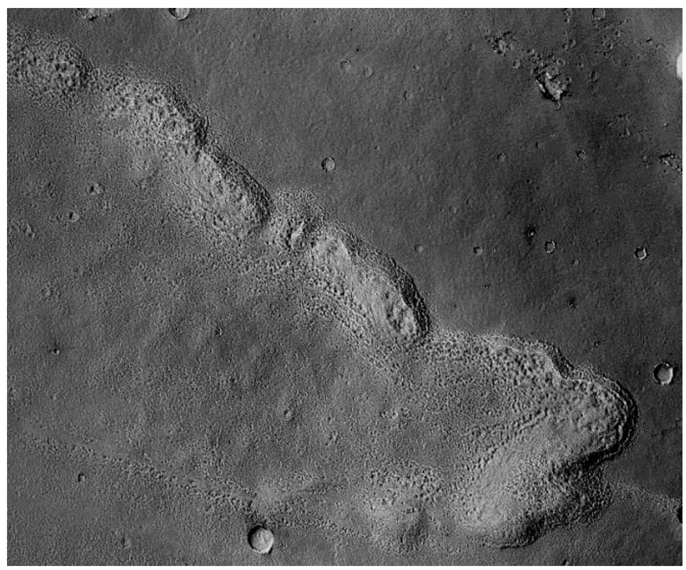

Fig. 3 Outer rampart (at 4 crater radii from the rim) on the west ejecta of the 500 km diameter crater Mojave. Image is a portion of CTX N02_063312_1869_XI.