MARTIAN LARLE EJECTA: EMPLACEMENT MECHANISM, J. M. Boyce[1], N. G. Barlow[2], and L. Wilson[3], [1]Hawaii Institute of Geophysics and Planetology, University of Hawai'i, Honolulu, HI 96822, (jboyce@higp.hawaii.edu), [2]Department of Physics and Astronomy, Northern Arizona University, Flagstaff, AZ. 86011, [3]Lancaster Environment Centre, Lancaster University, Lancaster LA1 4YQ, U.K.

Introduction: The unique physical characteristics of LARLE, or low-aspect ratio layered ejecta craters [1] suggests that their outer *LARLE* layer is emplaced by a mechanism that differs from those responsible for emplacement of other types of Martian ejecta layers. In addition, the ejecta layers inward of the LARLE layer on these craters are morphologically similar to those of the other common types of layered ejecta craters (i.e., single, double and multi-layer ejecta craters). This suggests that LARLE craters are just layered ejecta craters with the addition of the LARLE layer. However, LARLE craters preferentially form in areas mantled by fine-grain deposits, suggesting a possible genetic connection [1].

LARLE layers are characterized by (1) long run out distances (i.e., the ejecta mobility ratio or *EM* averages > 6 [1]), (2) nearly uniform thinness (< ~ 10 m), (3) feathery shaped outer edges, with occasional long, narrow jet-like prominences (4) no distal rampart ridges, (5) surface textured mainly by curved, low-relief, sometimes overlapping, radial ridges (i.e., commonly have dune-like appearances), and (6) a composition of fine-grain particulates (suggested by THEMIS IR and HiRise images). These characteristics are consistent with emplacement of fine-grain particulate material from dilute, suspension driven, low-viscosity (i.e., gas) density currents [1-5] such as base surges like those produced in high- explosion and nuclear cratering tests [6]. However, they are not consistent with dense flows of particles where the stresses that resist motion arise as a consequence of interactions between individual particles and the boundaries (e.g., granular flow) [7].

Background: The mechanism of emplacement of the LARLE layer is controversial. Wrobel et al., [8] proposed that this layer is not ejecta at all, but a “duricrust-like” erosion-resistant surface produced by extreme winds, lingering high temperatures, and water vapor generated by the impacts that melt near-surface volatiles, causing them to migrate upward through the regolith to form a duricrust. However, this model requires that LARLE craters < 5 km not only form in pure water ice or water, but that it all be transformed to vapor in order to produce the required blast.

In contrast, we [1-4] propose that the LARLE layer is a base surge deposit emplaced like those observed in all high-explosion and nuclear crater tests [9]. Base surges are predicted for large impact structures on planets with atmospheres [10], including on Earth where evidence of base surges has been found in the ejecta from the Chicxulub [11] . Base surge also can be produced by explosive volcanic eruptions [12], but such surges can range in physical characteristics and flow mechanism [7].

Boyce et al. [3] performed a simple test to assess the reasonableness of their proposal that base surge is responsible for LARLE emplacement. In that test, they compared the observed run out distance of LARLE ejecta of two test craters (i.e., Lonar, an 11.5-km-D. crater at 72.99°N, 38.30°E, and an unnamed 4.2-km-D crater at 44.3º S., 139.3º E) with that predicted by a physics-based fluid dynamics model by [13, 14]. This model describes flow of radially spreading, dilute, turbulent, suspension driven, density currents. Results of this test showed remarkable agreement between predicted values and actual run-out distances (i.e., 99%).

Excess volume and its source: The thicknesses (i.e., volumes) of base surge deposits formed by high-explosions and nuclear test craters in rocky materials are nearly an order of magnitude less than the thickness of the outer layer of equivalent-sized LARLE craters (scaled-up linearly). However, there appears to be no mechanical reason for this difference because, to a first order, both types of craters of equivalent size should generate similar amounts of fine ejecta [4, 10]. However, the distribution of LARLE craters may provide a clue to this difference in volume. LARLE crater primarily occur in regions mantled by tens of meters of fine-grain clastic deposits. We suggest that LARLE ejecta layers may contain substantial amounts of material excavated from those mantles.

Valuable insight into how the materials from these mantles can be incorporated into impact-generated base surge on Mars comes from studying high-explosions and nuclear cratering tests. These impact-generated surges form in an environment relatively similar to Mars (i.e., rocky planet with an atmosphere). Nuclear explosion tests in shallow sea water (i.e., Baker events) were found to produce base surge in two components, a (1) *primary* surge which formed by spill-out of seawater jets, and (2) *secondary* surge caused by column collapse of the explosion column [15]. In contrast, tests in rocky targets produced mainly *primary* surges, with secondary surge only of minor importance [16], and in extreme cases, such as the Danny Boy Event (in dense, dry basalt), no secondary surge component formed because no explosion column formed [17].

Partly based on these experiments, impact theory, and Mars geology, Knauth et al [18] outlined details of mechanisms that generate primary impact surge on Mars. These include (1) secondary debris mobilized by ballistic ejecta, (2) winnowing of fine ejecta from the ballistic curtain, (3) secondary vapor explosions caused by interaction of residual impact melt and saturated target rocks, and (4) density currents formed from impact breccia and late-stage or distal ejecta. In particular, generating base surge on Mars by mobilizing secondary debris by impact of primary ejecta has important implication to the origin of the excess volume of LARLE layers. This is because the operation of this process in regions covered by tens of meters of fine-grain clastic materials, as where LARLE craters are found, should easily erode, entrain and incorporate such material in the base surge and its deposit.This provides a straightforward mechanism for generating base surges with the characteristics required to produce the observed relatively thick deposits.

Conclusions: We suggest that emplacement of the LARLE layer is by base-surge, unlike the mechanisms responsible for emplacement of the other types of ejecta layers. We also propose that, while all Mars impact craters produce thin, base-surge deposits, LARLE layers are thicker because their craters form in regions mantled by fine-grain, clastic materials. Furthermore, we suggest that these materials are excavated by primary ejecta, entrained in the surges, and the deposited.

References: [1] Barlow N., and Boyce J., (2012) 3rd *PCC*, abst. 1204. [2] Barlow N. and Boyce J. (2012) *LPSC. XXXXII*, abst. 1263; [3] Boyce, J., et al., (2012) *LPSC XXXXII*, abst. 1017; [4] Boyce J. M. et al. (2008) *LPSC XXIX*, abst. #1164. [5] Boyce J. M. et al. (2012) *3rd PCC* Abst. #1210. [6] Young, G., (1965) NOLTR 64-103, AD-618733, 294 p.; [7] Branney, M. and Kokelaar, P. (2002). *Mem. Geol Soc. London*, 152 p. [8] Wrobel K. et al. (2006) *MAPS*, *41*, 1539-1550. [9] Nordyke, M., and Willianson, M. (1965) *PNE-242F*, 103 p; [10] Melosh, J. (1989). *Oxford Press*;[11] Dressler, et al., 2004; *MAPS*, 39, 857-878; [12] Fisher R. (1966) *Am. J. Sci., 264*, 350-363.; [13] Dade W. and Huppert H. (1995) *Nature, 381*, 509-510. [14] Dade W. (2003*) JGR*, *108*, B4, 2211.; [15] Brinkley S. et al., (1950) LANL Rept.; [16] Carlson, R., and Roberts W., (1963) *Boeing Co. PNE-217F*, 144p.; [17] Nordyke M. & Wry, G., (1964), JGR, 69,4, 675-689 [18] Knauth et al., (2005), Nature;20, 1123-1128.