A Model for Layered Ejecta Emplacement on Mars: Joseph M. Boyce, and Peter J. Mouginis-Mark, Hawaii Institute of Geophysics and Planetology, University of Hawaii, Honolulu, Hi 96822.

In this abstract we propose a model for emplacement of layered (i.e., fluidized) ejecta on Mars. This model is based on results of the findings of our studies of Martian ejecta flow features [1 thru 7] and the shape attributes of these ejecta deposits (e.g., ejecta mobility {EM}, ejecta blanket profiles {i.e., ETF}, Sinuosity) from previous studies [e.g., see 6, 8, and 9]. Similar to many other previous models, the foundation of this model proposes that during crater formation on Mars, the ejecta initially travels in ballistic arcs, striking the surface as describe by [10] with some minor effects to this flight from the atmosphere [11, 12]. Upon striking the surface of Mars, the ejecta flows across it in a manner similar to debris in long run-out landslides and debris flows, but very different than the way ejecta flows on the Moon.

In a major variant of this model, in areas mantled by thick layers of ice-rich materials (e.g., the Vastitis Borealis formation), we propose a different type of ejecta morphology develops. Previously, Wiess and Head [13, 14] suggested ejecta flow across the surface is altered by sliding on this icy material resulting in piling up of ejecta into broad ramparts at the outer edge of each ejecta layer. Our research shows that in these areas, as the rims of the transient craters collapse into the transient crater cavities, they carry this ice-rich surface material into the hot crater cavity lined with impact melt and hot melt-rich breccia. The interaction between these volatiles and the hot impactite in the crater generates a fuel-coolant type interaction. This explosive interaction generates a base surge of particles and expanding gas, like that at Mount St Helens [1, 15] and in a manner similar to suevite genesis at Ries Crater in Germany [16, 17]. This surge forms ground-hugging Görtler vortices induced by concavity (caused by the broad rampart) in the surface of the inner ejecta layer that erode the radial grooves into the surface of those deposits by vortex scouring [15]. The relative straightness of the grooves and their crosscutting relationships with the other features on this ejecta layer suggest these surges were high velocity, likely internally supersonic and occurred after the ejecta layer had stabilized (see [1]). In addition, this event likely masked the presence of SDM-type radial grooves as the vortices scoured the surface in the long-axis direction of these furrows. As the speed of this surge decreases outward, at the outer edges of the broad rampart of the inner ejecta layer (which likely serves as a hydraulic jump) deposition begins to dominate. At this point, the surge begins to deposit much of its erosion products removed from the inner ejecta layer onto the outer ejecta layer (as much as 20% to 40% of the volume of outer ejecta layer [1]). This material forms many of the flow features found on that layer. There is no direct evidence for how long between the time of stabilization of the surface of the ejecta and groove formation. However, the interval likely was only a few minutes to hours (or, at most, a few days or weeks) because rim collapse was likely soon after crater formation [10].

We suggest that there is new morphometric evidence that water likely was involved in the fluidization of these ejecta. Although, most geomorphic features of/on layered ejecta suggest flow behavior similar to debris in long run-out landslides and other granular flows, these features provide little quantitative information about volatiles in the ejecta. We suggest that the relatively low ratio of rampart height (h_r) to the body of ejecta thickness behind the rampart (h_b), (i.e., h_b/h_r ratio) provide such evidence. In essence, ramparts form at the leading edge of multi-dispersive granular flows as the coarse debris that accumulates there is pushed up and along by the body of the flow behind. Field and laboratory observations show that after flowing water-rich, poly-dispersive granular debris (e.g., debris flows) halts, the debris in the bodies of these flows deflates as water leaks out, but their terminal ramparts do not deflate because they tend to be dry during flow [18, 19, 20]. In completely dry flows like the Tsiolkovskiy landslide on the Moon, the h_b/h_r ratio is ~ 0.75. However, the h_b/h_r ratio for the outer ejecta layer rampart on DLE type-1, DLE type-2, and MLE craters ejecta are nearly the same at ~ 0.30 ± 0.15 suggesting that substantial deflation of this ejecta layer occurred after emplacement. The most reasonable cause of this deflation is loss of water, and suggest substantial water in the flowing ejecta of these craters during their emplacement. This also suggests substantial water in the subsurface of Mars where these craters formed. Remarkably, the h_r/h_b ratio for SLE ramparts (~ 0.65 ± 0.10) is nearly that of dry ejecta indicating little deflation. These trends are also consistent with the EM of ejecta of ~ 3.5 for DLE type-1, DLE type-2, and MLE craters, which substantially exceeds the ~ 2.35 of ballistic ejecta [10], and the ~ 1.5 of SLE ejecta, which is similar to the EM of the inner ejecta layers of the other layered ejecta craters [6, 9]. This may suggest that less water was involved in the fluidization of SLE ejecta compared with the other layered ejecta craters [8]. Alternatively, SLE ejecta may be a composite of wet fluidized ejecta from the rim out to ~1.5 R, and outward of that, dry ejecta where ballistically emplaced ejecta produces thin and discontinuous deposits. This likely requires a dry upper layer in the target with a water rich layer beneath as suggested by [9].

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