EJECTA LOCALITIES OF INTERMEDIATELY SHOCKED AND SHOCK MELTED IMPACTITES IN TERRESTRIAL CRATER EJECTA AND MODELING CONSTRAINTS ON THEIR FORMATION AND DEPOSITION

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Introduction: Fieldwork at two well-preserved, simple, bowl-shaped impact craters reveals a double-layer ejecta (DLE) structure consistent with observations at larger impact structures such as Ries [1] and perhaps an analog for DLE craters observed on Mars [2,3]. Field observations at Lonar Crater, India are described here and related to Shoemaker's well-known descriptions of the Meteor Crater, Arizona ejecta blanket [4]. Constraints on the process(es) responsible for the deposition of the upper suevite ejecta layer are discussed and suggestions for modeling communities are given.

Lonar Crater ejecta structure and comparsions to Meteor Crater: Whereas field data of any preserved terrestrial ejecta blanket is relevant to understanding the impact process and products, studies of Lonar Crater have implications for Mars [5-8]. The target Deccan basalt provides an opportunity to examine terrestrial shocked basalt similar to shergottites from Mars [8,9]. Further, Deccan basalt has been labeled as an excellent analog for Surface Type 1, a thermal infrared spectral type identified from orbital and Rover observations [10]. Field geology at Lonar Crater (diameter = 1.8 km) reveals a DLE structure with two distinct layers of ejecta [5,11] (**Figure 1**). The lower unit is lithic breccia extending to the limits of the continuous ejecta blanket (CEB), or 1.4 km (~1 ½ crater radii) from the crater rim and measuring ~8 m at maximum thickness. The clasts in the lithic breccia are angular, highly fractured, and either unshocked (mineralogically) or Class 1 shocked basalt (0-20 GPa) [5], which consists of fractured grains but no melting or mineral phase changes [5]. As shock pressures are typically 1-2 GPa near the crater rim, no intense shock metamorphism has occurred. From comparisons to basalt flows exposed in the crater walls, the clasts originated from both the oldest flows that have more secondary mineralization of groundmass and from the youngest flows that lack this feature. This is attributed to the level of the pre-impact water table of the ~65 Ma Deccan basalts [11]. The matrix consists of finely pulverized basalt. In theory, this unit grades into what would be overturned or inverted strata near the crater rim, but the crater has degraded since its initial diameter (1.7 km, based on gravity surveys [6]), meaning that ~50 m of the original crater rim has eroded to contribute to the post-crater fill. The upper ejecta unit is a suevite breccia containing clasts shocked to all degrees of shock pressure from unshocked up to Class 5 (> 80 GPa) of Kieffer *et al.* [5]. The suevite layer measures ~1 m in thickness and extends to ~0.5 km (~½ crater radii) from the rim. The matrix is finely pulverized basalt but with the addition of local glass spherules, beads, and dumbbells [5,6] reportedly not found in the lithic breccia unit.

This DLE structure described for Lonar Crater is similar, if not identical, to the "throw out" and "fall out" layers observed at Meteor Crater [4] or the Bunte Breccia and Suevite at Ries Crater [1], and suggests that two processes are responsible [3] for the ballistic emplacement of the lithic breccia moments before the "falling out" of the fall-out suevite layer. Shoemaker [4] identified a suevite layer within Meteor Crater, then later surmised that this unit likely used to be thicker in near-rim regions of the CEB, but has eroded, as the fine matrix of this unit is easily transported by the SW winds of the Colorado Plateau to leave behind the clasts of the suevite layer as a lag [4].

Whereas the lower, more weathered basalt flows have not been identified as protoliths for Classes 2 through 5 in the suevite breccia, heavily fractured basalt corresponding to these basalt flows is observed that are either unshocked or Class 1, implying that these deeper strata are incorporated into the suevite layer. At Meteor Crater, the Coconino Sandstone serves as a lithologic tracer, as highly shocked lechatlerite is distributed in the Meteor Crater fall-out layer [4], suggesting material deep in the target sequence is incorporated into this unit. This provides data to "ground truth" modeling of Lonar Crater, Meteor Crater, and similar small (1-2 km diameter) craters.

Modeling: The potential ground-hugging flow of the lithic breccia unit at Lonar Crater [7] and other craters needs to be understood, but a model that explains the emplacement of both ejecta units should be the goal of impact modeling. Several objectives can be placed on the modeling based on observations at Lonar Crater:

1.) Because the shock wave weakens as it expands, the disparity in the shock levels of the clasts in the two ejecta layers tell us their location in the transient crater. It is obvious that the clasts in the lithic breccia were ballistically emplaced and are from the "curtain" or "flap" [7] and originate towards the outer edges of the expanding sphere. Some of the clasts currently in the suevite ejecta layer must have been located further towards the center of the sphere, although it cannot be said that all of the suevite layer is from this region.

2.) It has been noted that the number of cells and variables in modeling is limited [12], but perhaps more

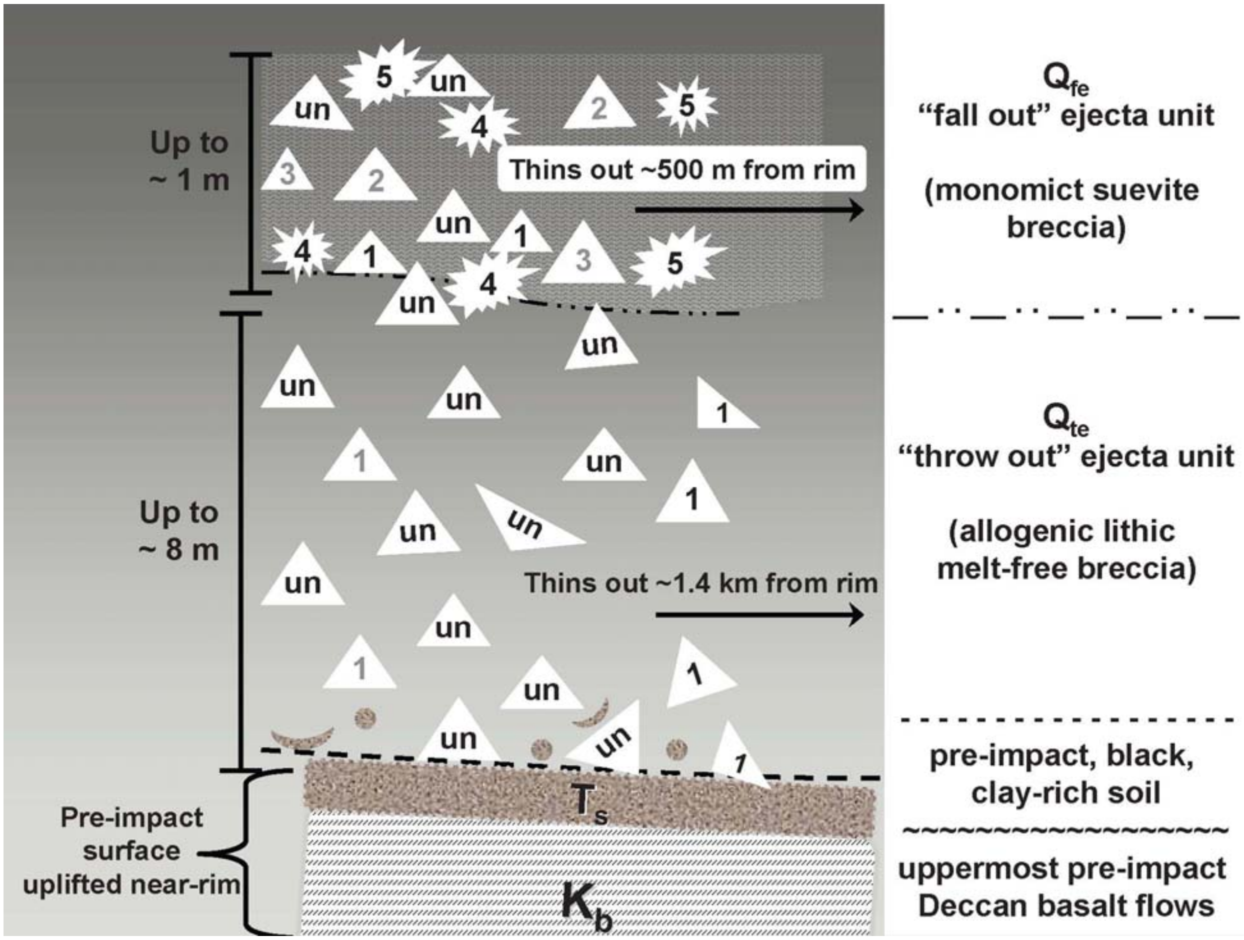

Figure 1. Structure of the Lonar Crater, India ejecta blanket. The figure represent a stratigraphic cross section viewed as a slice through the Lonar ejecta. The number on the clasts represents the class of shocked basalt, and thus the shock level, with "un" representing unshocked basalt. It is suggested that early modeling attempts to duplicate the overall structure seen here.

emphasis should be directed at understanding the deposition of the suevite layer. One problem is that the volume of the lithic breccia comprises roughly ~96% of the total Lonar ejecta. Further, as discussed at Meteor Crater and seen at Lonar, the ~4% of ejecta volume that is the upper suevite unit, with its location and friability, is likely amongst the 1st materials to be eroded/transported after crater formation. However, whereas the process, although not the details, responsible for the deposition of the lithic breccia is constrained, little is known about the deposition and formation of the suevite layer. It is hypothesized that a portion of the target is thrown to high heights in a plume and emplaced is a base surge-like process [13].

3.) Whereas a complete geologic map, including the exact thicknesses and distances of both units in all directions, may provide for an accurate model of various parameters such as impact angle, it suggested that early models of Lonar attempt to reproduce the general thicknesses, distances, and shock levels of both units circum around the crater.

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