EXCAVATION OF LIGHTLY SHOCKED DEEP LUNAR MATERIAL DURING CRATER COLLAPSE.

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Introduction: During an impact event, the passing shock and rarefaction waves initiate an excavation flow which generates a bowl-shaped transient crater in the target material and an ejecta curtain above the surface [1]. This flow pattern can eject deep material under high shock pressures from within the target. This framework reliably describes simple and complex crater formation but fails to adequately explain several aspects of cratering observations, including deep crustal compositions detected within a subset of Apollo-era lunar samples with unexpected compositions and low peak shock pressures [2]. The peak rings of Orientale Basin and Schrödinger Basin, which are likely excavated during collapse of a central uplift, have similar lightly shocked deep crustal compositions [2, 3] and may hint at the origin of these Apollo samples. Apollo 17 sample 76535 from the Serenitatis Basin illustrates a gap between the messy reality of basin formation and intuition. It is composed of olivine, plagioclase, and orthopyroxene [4] and formed 40-65 km deep in the lunar surface [5,6]. Interestingly, shock features within the rock indicate it experienced maximum shock pressures of 6 GPa [4,5,7] despite the sample having experienced at least one impact event. The petrographic signatures of lunar samples norite 78235 and dunite 72415-8 may indicate deep origin similar to 76535 [2,8]. Given these samples whose geologic history may not easily align with the current paradigm of excavation, we consider instead that these rocks were exhumed later in the impact process, during crater collapse instead of during excavation flow. If viable, this is a process whereby deep material may be displaced to the surface in response to an impact event.

Methodology: We use hydrocode iSALE-2D [9–13] to understand the genesis of lightly shocked ejecta. We model a 50-km radius dunite impactor striking a curved, 2-dimensional lunar-like target with 40 km thick crust at 12 km/s. Cell spacing is 1 km and model resolution is 50 CPPR. Because pre-impact thermal conditions affect final basin formation (e. g. [14]), we test lithospheric thermal gradients between 16 and 30 K/km. Models are evaluated by the presence of originally deep (45-65 km), unshocked material (< 6 GPa) at the surface at the end of basin formation.

Results: For all preimpact conditions, material analogous to sample 76535 is found on the surface at the end of basin formation. Figure 1 shows our best fit for Serenitatis Basin, replicating the average basin diameter and crustal thickness profile, with 76535-like tracers highlighted in red.

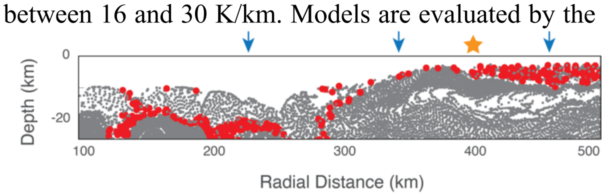

Figure 1: Tracer plot with 40 km crust and a 20 K/km thermal gradient. Tracer particles meeting both the preimpact depth and peak shock pressure are colored red and those which do not meet both are colored gray. Blue arrows denote approximate ring locations and the orange star marks where 76535 was found relative to the basin.

Discussion and Conclusions: We conclude that "excavation" during crater collapse is an integral component of basin formation based on some amount of deep, lightly shocked material reaching the surface in every model. We have initially focused on replicating sample 76535; moving forward, we will consider if this process provides a framework for understanding additional Apollo-era samples, further defining the role of crater collapse during large impact events. This process of displacing material to the surface during crater collapse of large basin-forming events has not been previously identified as producing "ejecta" during large crater formation and explains the petrographic history of lunar sample 76535. Upcoming analysis will consider the genesis of additional lunar samples to further determine the prevalence of excavation during crater collapse and the bounds of preimpact parameters where this process occurs.

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