

Experimental Impacts into Strength-Layered Targets: Ejecta Kinematics and Crater Morphometry

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Impact craters can serve as probes of the subsurface structure of a planetary body and provide hints about a target's properties. Crater morphology, for example, can be used to estimate the thickness of a regolith layer above a more competent unit. Small lunar craters in the maria show a morphological progression from a simple bowl shape to flat-floored and concentric as crater diameter increases for a given regolith thickness. The final shape is a result of the subsurface flow-field initiated as the projectile transfers its energy and momentum to the target surface. In strength-layered targets, such as the lunar maria, the substrate modifies the flow field and thereby the excavation of the crater.

Here we report on a series of experimental impacts into targets composed of a layer of loose sand above a stronger substrate. As we varied the sand's thickness, we imaged individual ejecta trajectories as the craters grew, from which we derived ejection-speed scaling relationships. In addition, we used a 3D scanner to construct topographic maps of the substrate, pre-impact target, and post-impact surface. This permitted us to examine the final craters' morphologies and morphometries with respect to the original stratigraphy of the target.

As expected, craters became shallower and smaller as the sand's thickness decreased, transitioning from bowl-shaped to concentric as observed on the Moon. Subtle and important details show that the stronger substrate affected the subsurface flow-field by redirecting material upward and outward even when the interface was still well below the final crater's floor. Compared to the control target (loose sand only), the stronger substrate below the sand layer resulted in a much more complex pattern of ejecta. While most of the ejected material was still contained within a typical outward-moving curtain, a number of ejected particles moved along low-speed, high-angle (near 90°) trajectories. The number of these high-angle trajectories increased as the sand layer thinned, perhaps implying that self-secondary cratering would require the presence of a strong subsurface layer below the impact site. Such results refine our understanding of crater excavation in layered targets with implications for ejecta deposits and final crater shapes observed on the Moon.