Ejecta Dynamics and Crater Topography during Experimental Impacts into Sloped Targets.

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Introduction: Impact cratering has been and continues to be the dominant macroscopic surface process on the majority of solid bodies in the solar system. Impacts form craters that act as subsurface probes, excavating subsurface material and depositing it outside of the crater, generating and mixing the regolith, and launching future meteorites. Current knowledge of the excavation and modification of impact craters from experiments and numerical models is limited primarily to cases of horizontal targets. Thus, existing experimentation and numerical modeling provide only first-order guidance when considering the effects of impact in more realistic planetary environments with actual topography.

Craters on planetary surfaces commonly form in regions with sloping topography. For example, Lowell H is a simple crater that formed on the rim of the larger Lowell crater [1]. As a result, Lowell H appears "normal" on the eastern side but smaller and deformed, with no obvious rim, on the western side (Figures 1 and 2).

We are taking the next logical step in experimental impact-cratering studies by investigating the effects of regional target topography on the impact process. We have performed a suite of impact-cratering experiments in the Experimental Impact Laboratory at NASA Johnson Space Center, comparing impacts into sand targets with horizontal surfaces to those with a surface slope of 10°. Ejecta leaving the target was imaged with the Ejection-Velocity Measurement System (EVMS, [2]). A 3D laser scanner was used to record the original surface topography of the target and the final crater shape and dimensions after impact.

Here we present initial results comparing an impact into a sloped target and a near-identical impact into a horizontal one. These results will be used to adapt and modify existing crater-scaling relationships to describe the behavior of more complex and realistic target surfaces.

Experiment Design: For consistency, all of the experiments performed for this study were completed under conditions as similar as possible, changing only the target slope from horizontal (0^o) to 5^o and 10^o. We used 3.15 mm glass projectiles with a density of 2.50 g/cm^3, similar to that of the target sand (1.52 g/cm^3). Impact speeds were near 1.7 km/s. Impact chamber pressures were held to ~1 torr. Projectile trajectories were vertical (i.e., parallel to the gravitational acceleration vector) for all experiments.

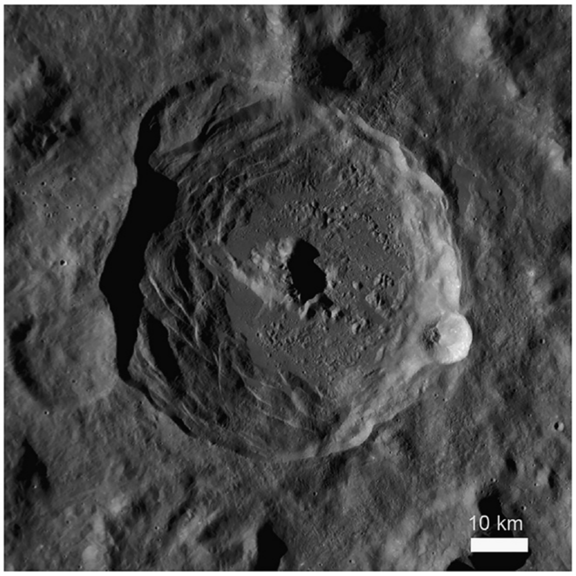

Figure 1. Example of a crater in a target with topography. Lowell crater, Orientale Basin, the Moon, with Lowell H superimposed on the east-southeast rim. North is to the top. [1]

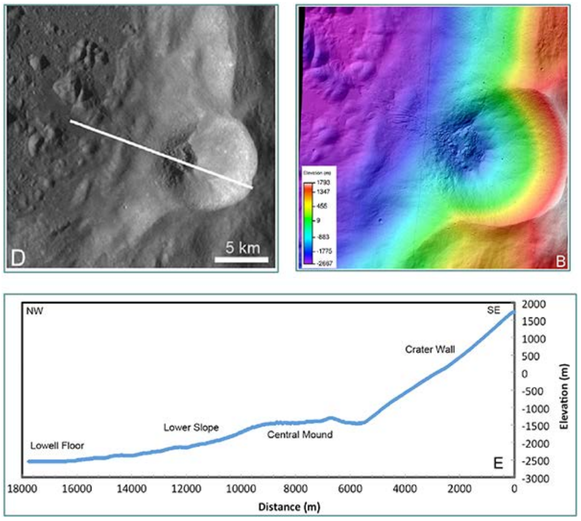

Figure 2. Close-up of Lowell H with topographic profile location (top left). Topographic map of Lowell H (top right). Topographic profile from Lowell H's crater rim and onto the floor of Lowell crater (bottom). [Modified from [1]].

Ejection-Velocity Measurement System (EVMS, [2]): To observe the ejecta particles in flight, a vertical laser plane, passing through the impact point, is strobed while a CCD camera records the impact. Ejecta particles can then be tracked along their ballistic trajectories to determine the particle's ejection position, speed, and angle (Figure 3). These data can then be compared to ejection-speed scaling relationships.

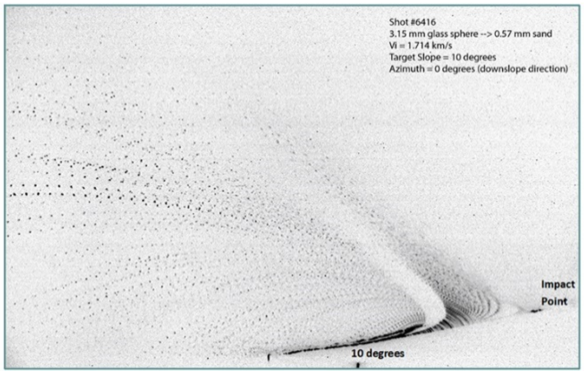

Figure 3. EVMS image showing ejecta trajectories from an impact into a 10^{o} slope.

Three-Dimensional Crater Scanner: Prior to and following the formation of the crater, a NextEngine 3D laser scanner is inserted at the top of the impact chamber to record the initial target topography and the final crater morphometry. This results in very accurate measure-ments of the shape of the crater in all azimuths around the impact point and with respect to any topography in the original target (Figure 4). Initial results demonstrate that enhanced slumping of material off the upslope wall occurs even at very shallow slopes [3].

Toward a Comprehensive View of the Effects of Regional Topography: We have just begun our study of the effects of topography on crater excavation, modification, and final morphometry. At this point, we are focused on targets with regional topography where the entire surface is at a constant slope and the topography's length scale is much larger than the final crater diameter. The data reported here showcase the differences between a horizontal surface and the excavation of material in the downslope direction for two gently-sloping surfaces with 10^{o} and 5^{o} slopes. We will continue to increase the target slope until just below the angle of repose of our target material, approximately 33^{o}. Our goal is to build a comprehensive understanding of the effects of regional topography on the excavation, modification, and morphometry of an impact crater. This will provide fundamental new information to be used in refining scaling relationships, tuning numerical models, and examining impact craters and their deposits on Earth, the Moon, and other planets.

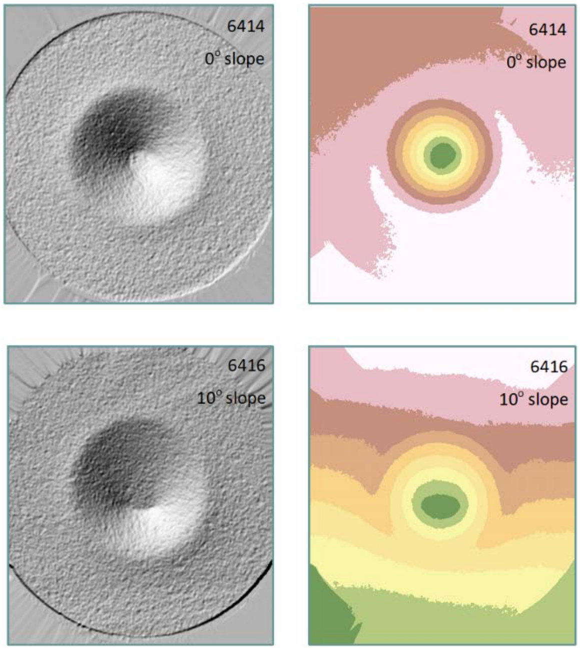

Figure 4. Digital elevation models of final craters comparing an impact into a horizontal target (top) with an impact into a target with a 10^{o} slope (bottom). Black and white images are hill-shaded DEMs while colored images show measured elevations (white is highest elevation, dark green is lowest, scales are not the same). Upslope is to the top of the images. There is a slight slope (1.6^{o}) to the flat target surface (top right, from lower right to top left) from a minor realignment of the impact chamber; this will be corrected and these shots redone.

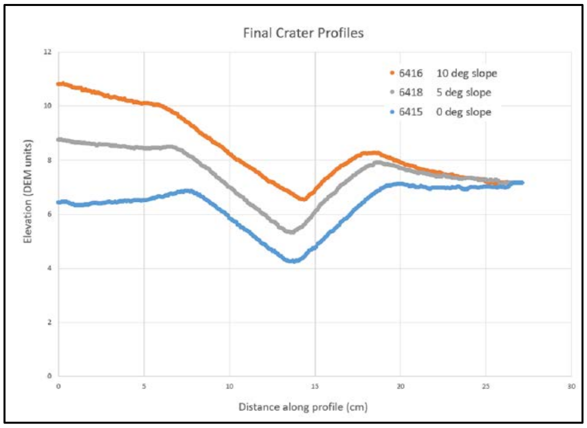

Figure 5. Crater profiles along original target slope for final craters from impacts into horizontal, 5^{o}, and 10^{o} sloped targets.

References: 1] Plescia, J.B., and Spudis, P.D. (2014) *Planetary & Space Sci.* **103,** 219-227. [2] Cintala, M.J., Berthoud, L., and Hörz, F. (1999) *Meteoritics and Planetary Sci.* **34,** 605-623. [3] Gault, D.E., Quaide, W.L., and Oberbeck, V.R. (1968) in *Shock Metamorphism of Natural Materials*, 87-99.