

HIGH-SPEED, LOW-ANGLE EJECTA OBSERVED FROM IMPACTS INTO SAND+BOULDER TARGETS. C. J. Cline II¹, M. J. Cintala², ¹Jacobs Technology, NASA Johnson Space Center, Astromaterials Research and Exploration Science, ²NASA Johnson Space Center, Astromaterials Research and Exploration Science, Mail code X13

Introduction: For relatively small impact events, the target properties will have a substantial influence on the cratering process [1]. Boulders provide a means of introducing small-scale heterogeneities in cohesive strength, density, porosity, and friction into a target and are commonly observed on the surfaces of small bodies throughout the solar system [2-4]. Understanding the influence of these boulders on crater shape, size, as well as ejection characteristics is a formidable challenge, thus necessitating systematic laboratory experimentation.

Methods: Experiments were conducted in the Experimental Impact Laboratory at NASA Johnson Space Center. Targets were made by filling cylindrical PVC buckets (26.2 cm diameter, 12.2 cm depth) with a predominantly quart sand (< 0.5 mm) and generally included a coherent piece or pieces of synthetic sandstone. The shapes of blocks used in this study vary (cubes, irregular “rock-like” boulders, and rubble piles), but all synthetic sandstone was made by combining target media with an organic binder in specific quantities that, when cured, provided a precalibrated strength of either 0.5, 4.2, or 7.4 MPa. Tested target configurations include blocks placed directly on the preimpact surface, half-buried blocks, and cubes buried with the upper face level with the preimpact surface.

Impacts were conducted using 3/16” (4.76 mm) Al₂O₃ spherical projectiles accelerated to ~1.5 km s⁻¹ in an atmosphere of 1 torr. Ejecta was imaged using the Ejecta-Velocity Measurement System (EVMS) [5] and repeat experiments of certain configurations were conducted in order to capture high-speed video with a view orthogonal to the impactor trajectory.

Results: Using a crater created in a sand-only target as reference, the presence of blocky cohesive materials can have multiple effects on the characteristics of the ejecta plumes from the targets tested here. In general, the existence of any blocks on or near the surface generates heterogeneity in the ejecta plume and causes deviations from the classic ‘inverted lamp shade’ shape. Such heterogeneities take different forms depending on the arrangement, size, and burial depth of the block(s) in the target. When targets include cubic blocks placed on the surface, for example, increasing the size of the block depresses the maximum ejection angle of the sand substrate. Systematically reducing the strength of any surface block also seems to have the similar effect of decreasing the maximum observed ejection angle from the underlying sand.

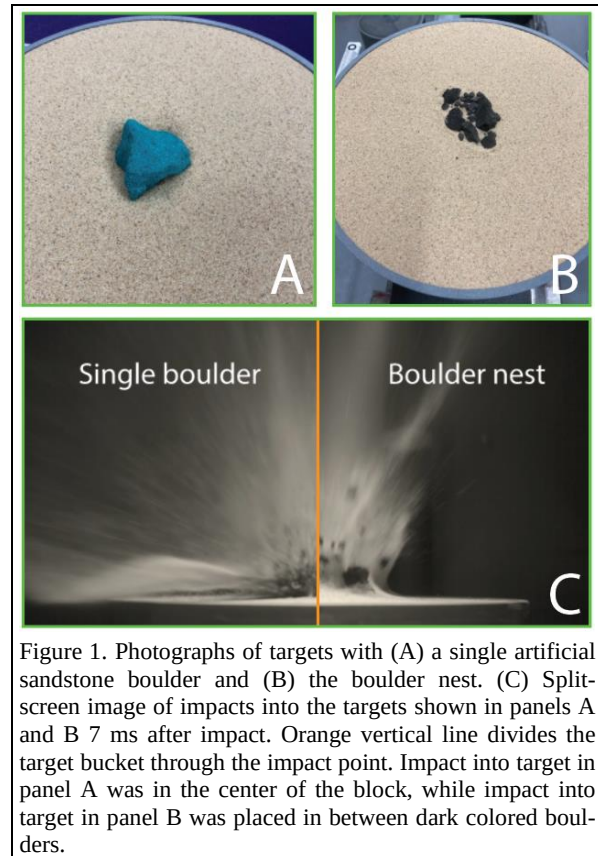


Figure 1. Photographs of targets with (A) a single artificial sandstone boulder and (B) the boulder nest. (C) Split-screen image of impacts into the targets shown in panels A and B 7 ms after impact. Orange vertical line divides the target bucket through the impact point. Impact into target in panel A was in the center of the block, while impact into target in panel B was placed in between dark colored boulders.

Disrupted block fragments, along with completely pulverized block material, can eject at extremely high speeds and low angles in certain configurations. Relative proportions of fragmented vs. pulverized block in these low-angle plumes were found to be a function of the block strength when the block was located on the surface. Other configurations, such as half-buried blocks, also produced these low-angle plumes, but the volume of ejecta was dominated more by the substrate sand launching at higher angles. One of the criteria for creating low-angle and high-speed ejecta was found to be the projectile directly striking a block. Impacts occurring immediately adjacent to a block(s) produced ejecta that was devoid of any high-speed, low-angle component (Fig. 1).

References: [1] Holsapple K.A. and Schmidt, R. M., (1979) *PLPSC* 10, 2757-2777. [2] Walsh *et al.* (2019) *Nature Geoscience*. 12, 242-246. [3] Arakawa, M. *et al.*, (2020), *Science*, 368, 67-71. [4] Daly *et al.* (2022) *Planet. Sci. J.*, 3(9). [5] Cintala *et al.* (1999) *MAPS* 34, 605-623.