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Crater formation in pre-existing target structures: Implications for small bodies

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Abstract

The influence of pre-existing target structures on the shape of craters have been observed at terrestrial craters, the most dramatic example being Meteor Crater [e.g., 1]. Such structures also influence the formation of craters on small bodies. For example, the formation of observed square craters on asteroid 433 Eros (Figure 1) were probably affected by the nearby presence of pre-existing tectonic ridges, while on 25143 Itokawa the paucity of observed craters (Figure 2) can be attributed in part to the presence of surface rubble. These surface blocks effectively armor the asteroid from small projectiles, hiding craters (Figure 3). Laboratory evidence [see 2] indicates that upon impact, pre-existing structure can also influence asteroid disruption.

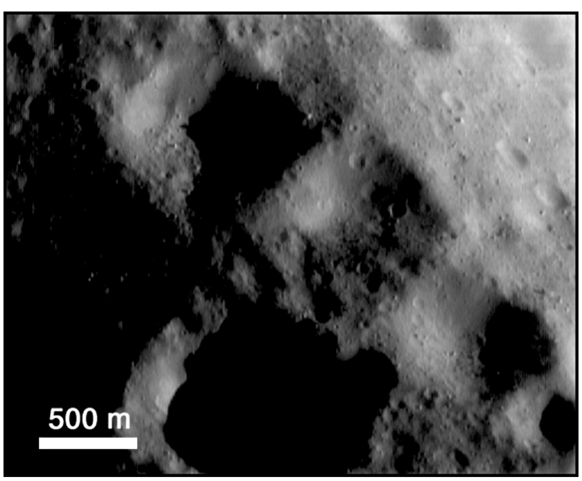

Figure 1: Square craters on 433 Eros.

This study compares and constrast the results from impact experiments in a coarse grained target with those in a fine grained one, where the target porosity and Coulomb friction properties are kept constant by using spherical glass beads of differing size. Measurements of crater growth and ejecta speeds are analyzed using non-intrusive laser-based techniques, and compared to preliminary 2 and 3D numerical calculations using CTH [3].

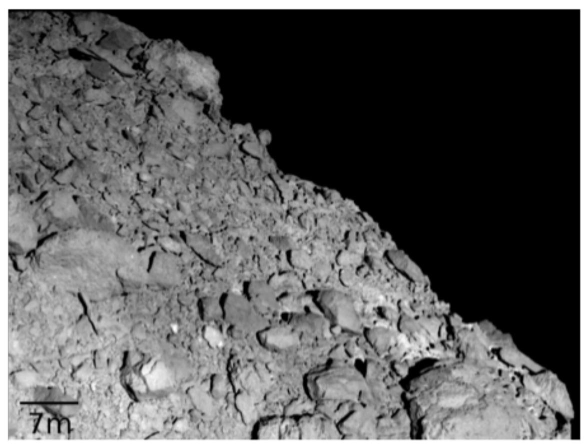

Figure 2: Surface rubble on 25143 Itokawa

1. Introduction

Often, target strength is declared the cause for any influence of pre-existing target structure on crater shape and/or the disruption process [e.g., 4]. Certainly zones of weakness due to fractures will affect crater modification to generate some of the observed morphologies seen in craters. However, prominent target structures will also influence the propagation of the impact shock wave, and thereby alter ejecta excavation, crater growth, and ultimately final crater shape. The thickness of the shock front relative to the average dimension of any pre-exiting structures could be a controlling factor. A long pulse, encompassing a large number of grains, would result in the target behaving as a continuum. Most current scaling rules consider this

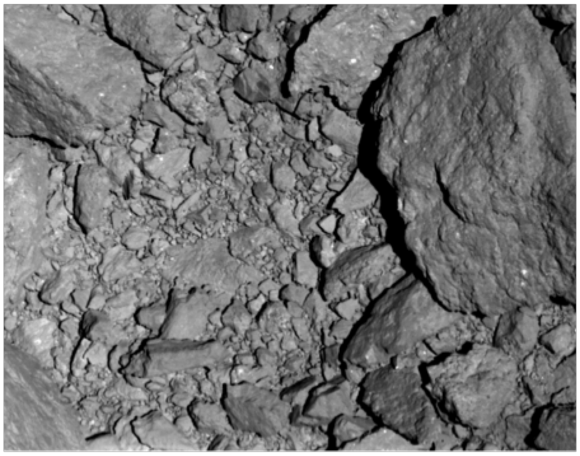

Figure 3: A 1-2m deep pit observed on 26143 Itokawa. Is this an impact crater as proposed in [4]? The image is 6m across.

type of medium. However, a pulse that is short relative to the grain size might concentrate the impact energy locally near the impact point leading to more efficient breakage or ejection of material near the impact point, while causing more rapid dissipation and slower propagation of the shock wave thereafter. Pre-existing structures could control crater shape and the likelihood of disruption, especially for asteroids.

2. Experiments

To investigate how such structures could play a role during the cratering process, we performed impact experiments at the U. Tokyo, NASA JSC, and Ames Vertical Gun Ranges. We measure crater growth, crater aspect ratio and excavation velocity using non-intrusive measurements [6, 7]. Our baseline experiments use fine uniform 220 and/or 350 μm glass beads for the target. The projectile is about 10x larger at 5-10mm diameter. Using a traditional normalization approach where gravity scaling is assumed, these experiments reveal that the rate of crater growth increases, while the transient crater depth-to-diameter ratio decreases with increasing velocity. A broad range of impact velocities from 80-5500m/s were investigated.

Preliminary results for impacts using the same projectiles and comparable speeds (0.8-5.5km/s) but a coarse 5mm uniform target show somewhat different behaviors relative to the fine-grained targets, especially at low impact velocities < 1.5km/s. As illustrated in Figure 4, ejecta were not all excavated near 45 °, nor did they follow nice ballistic trajectories. The

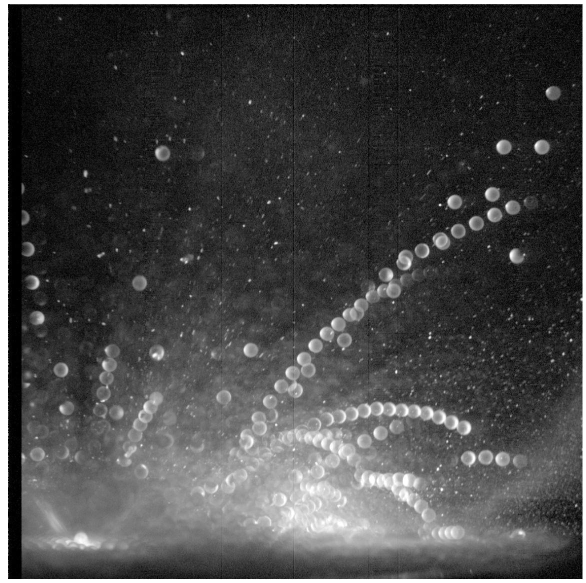

Figure 4: Trajectories of ejecta measured for 5mm projectile launched at 1.06km/s into 5mm spheres.

ejecta velocities also did decrease, but with significant variability as a function of distance from the impact point, and the final craters were often very asymmetric. All these effects seem to be reduced at higher impact velocities, but additional processing of our collected data is still required and will be performed for this presentation. We will present results for crater growth and crater aspect ratios as function of impact velocity for the coarse target beads relative to the fine ones in order to complete our assessment of the effects of impacts into pre-structured targets. These results will be complimented with preliminary impact calculations in 2 and 3D.

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