CRATERING IN BLOCKY REGOLITHS. K. A. Holsapple[1] and K.R. Housen[2],
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Introduction: Analysis of crater populations on asteroids Eros and Itokawa have demonstrated a significant depletion of small craters, those less than about 100m diameter, relative to the expected equilibrium population [1, 2]. Chapman *et al.* [1] considered various explanations for this depletion on Eros including infilling of small craters by subsequent larger craters, erasure of small craters by seismic jolts that occur during large impacts, a depetion of the impacting population by the Yarkovsky effect, and "armoring" of the surface due to numerous boulders that are part of the blocky regolith. They note that the target aurface area occupied by the boulders is a small part of the total surface area, arguing aginst the armoring idea. They further presented qualitative arguments against the infilling and seismic shaking mechanisms. Subsequent modeling [3-5] suggests that the Yarkovsky effect cannot produce the needed depletion of small impactors and that seismic shaking is consistent with the observed crater populations. Holsapple [6] suggested that the blocks may be outcomes of the domination of spall cratering mechanisms on small bodies less than a few tens of km diameter with strength.

In any case, the question of the influence of large rocks and blocks on a surface, to the point of dominating the surface, is an important question. Güttler *et al.* [6] presented a recent study. They impacted targets consisting of mono-size glass spheres ("grains") and varied the size of the spheres relative to that of the impactor. They found that craters became irregular-shaped and relatively flatter when the impactor size was comparable to the size of the spheres making up the target. Additionally they found in repeated experiments that when the target grains were ~3x larger than the projectile the scatter in the measured crater size was about a factor of 2. Impacts into targets where the particle size was a factor of 10x larger than the projectile did not produce recognizable craters.

However, those experiments were conducted at impact speeds of only a few hundred m/s. In that case, an impact may little more than the energy to shatter a single large grain. They noted the possibility that cratering at the ~5 km/s impact speeds relevant to asteroid collisions might produce different results.

We agree with that assessment. One should compare the impactor *energy* with that to shatter a largest grain, and not just the ratio of *dimensions* of the projectile to the largest grain.

Here we summarize the results of experiments that reveal how crater size is affected by the size of the impactor relative to the size of the particles that constitute a granular target, at hypervelocity speeds for which the energy is much greater. The results are surprising.

Experiments: The impact experiments were a part of a study of momentum transfer in hypervelocity collisions performed using the vertical gas gun at the AVGR facility at NASA Ames. A description of the experimenal setup can be found in [8]. The targets consisted of either a fine quartz sand or gravel. Three sizes of gravel were used (Fig 1) with largest (and relatively uniform) particle sizes of approximately 5mm, 15mm and 55mm. The projectile in each experiment was a 6.35 mm diameter aluminum sphere at normal incidence at 5.35±0.20 km/s. That provided a ratio of projectile diameter to particle diameter of about 30:1 for the fine sand, down to 1:8 for the coarsest gravel. An experiment was also performed in a roughly 50/50 mix of the fine (5 mm) gravel and the coarse (55 mm) gravel.

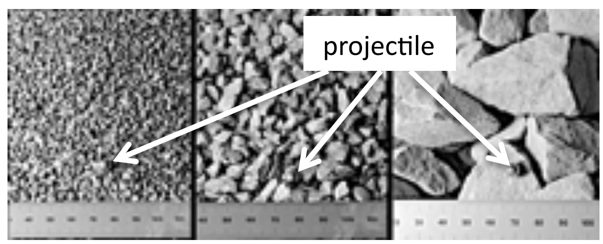

Fig 1. The three gravels used in the present experiments.

The pre- and post-impact targets with the 55mm gravel is shown in Fig. 2.

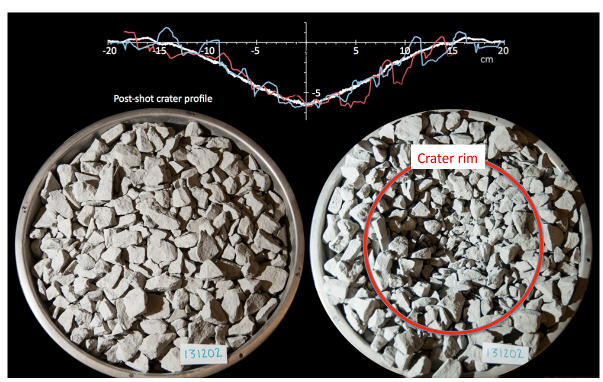

Fig. 2. The pre-impact targe of coarse gravel and the post-impact target. The resulting crater rim is outlined in red.

Crater profiles were measured with a 3D laser scanner with a spatial resolution of 300µm. The crater volume and linear dimensions were determined from those scans and the pre-shot target surface elevation.

Results: The crater volumes and the radii can be compared to lots of data for other material using the groups π_V or π_R and gravity-size parameter π_2 dimensionless parameters commonly used by the authors and others [9]. Here we compare it to representative data for common sand materials. Fig. 3 presents the scaled radius data, and Fig. 4 the scaled volume values.

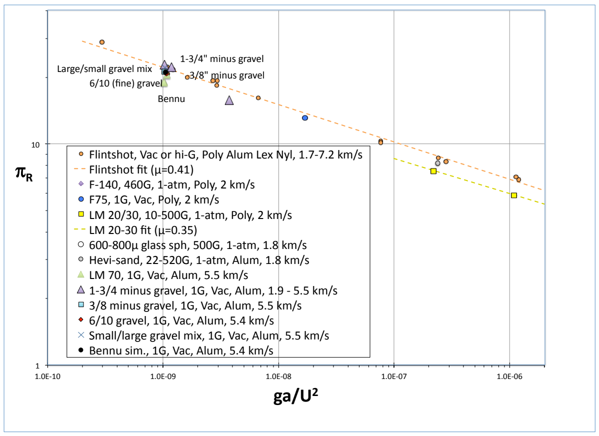

Fig. 3. Scaled radius versus gravity-size parameter π_2.

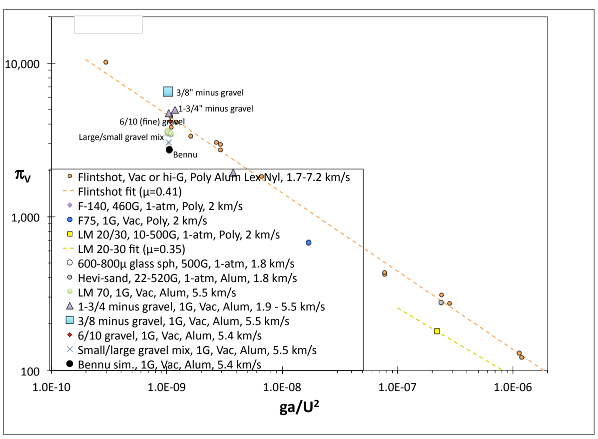

Fig. 4. Scaled volume versus gravity-size parameter π_2.

Surprisingly, the data for the crater radii falls right on the curve for the dry sand data. That is, the craters in the coarsest gravel were the same size as in dry sand: they all fall on the curve for the point-source results with the scaling exponent μ=0.41. Considering that for the coarsest target the projectile was tiny compared to the grain size, that was not expected. We conclude that, when the impactor energy is much larger than that to shatter a single particle, then the grain size has no effect. In the present experiments, the energy is on the order of 50-100 times that required to break the largest particle. That implies that, at 5 km/s, the largest particle size compared to the impactor size could be on the order of 4 times larger than in these experiments, or with a size ratio of 30:1, before suppressing cratering. A 1m impactor hitting a rocky rubble-pile asteroid shielded with continuous 30 m rocks may have the same cratering as a fine granular surface. And that size ratio would be greater at higher impact speeds.

For the volume, that simple result is not quite so true, there is some small scatter depending on the grain size, but the data centers on the dry sand data. Further experiments are appropriate to sort out the details. However, it appears that the effect of grain size on crater dimensions, at least for the cases studied here, is surprisingly small or absent.

References:

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