EROSION OF SMALL CRATERS ON RUBBLE PILE ASTEROIDS BY SUBSEQUENT LARGE IMPACTS: SHAKING OR EJECTA INFILLING ? C. Busuttil[1], P. Cornwall[1] and M. J. Burchell[1]. [1]School of Physical Sciences, Univ. of Kent, Canterbury, Kent CT2 7NH, United Kingdom. Email: M.J.Burchell@kent.ac.uk.

Introduction: Impact craters are observed on exposed solid surfaces throughout the solar system. Small impacts are more frequent than larger ones, so generally, smaller craters dominate on any surface. There are exceptions to this rule of thumb: overwriting can occur when surfaces are saturated with craters, and a single large impact can overprint not just small craters where it hits, but also in the surrounding region.

Asteroids are just as prone to impacts as any other bodies. Imaging of asteroid surfaces during spacecraft encounters or flybys has provided high resolution images showing detailed surface morphology. The asteroid Itokawa was observed by the Japanese Hayabusa mission [1] and is considered to have a rubble pile like composition as a result of catastrophic disruption [2, 3]. It is suggested by several authors that the surface morphology of Itokawa implies that granular flow as a result of seismic activity has occurred resulting in resurfacing, and that the origin of this is impact jolting [1, 4]. By contrast, earlier work concerning observations of craters on other asteroids, e.g. Mathilde reported that large impacts have had relatively little effect in modifying the pre-existing topography [5].

Laboratory impact experiments have previously been carried out into porous, granular materials but have mostly been concerned with crater shape, size, amount of ejecta etc., e.g. [6]. Here we report on new laboratory experiments which aim to look not so much at the impact crater, but the influence of the impact on surrounding surfaces of a finite target. In particular we use target surfaces which are already dimpled to simulate the presence of pre-existing impact craters and then observe how they alter as a result of a large, high speed impact on the target which produces a crater with a dia. of approx. half the target width.

Method: To obtain the impacts we used the two stage light gas gun at the Univ. of Kent [7] with 1 mm dia. stainless steel 420 projectiles and impact speeds of ~5 km s^{-1}. Targets were made of one of two materials. The first was sand, with semi rounded grains (90 – 150 µm dia.) and a coef. of friction corresponding to an angle of repose (θ) = 33.5º. The second material consisted of glass beads, dia. 127±14 µm and θ = 25.0º. The granular materials were placed in trays (35 x 14 x 6 cm) which represented bodies with aspect ratio 5.8 x 2.3 x 1, similar to elongated shaped asteroidal bodies with a rubble pile (non solid) nature. The Kent gas gun fires horizontally, so the angle of impact could not be at normal incidence (the targets would have fallen out of a vertical tray). Instead the targets were placed at initially 20º and later 15º to the horizontal. It should be noted that in space the typical impact angle is 45º so having an inclined impact is not atypical. The projected impact direction was along the main axis of the target.

Two types of crater-like indentations were made in the targets pre-shot and their dia. and depth were measured individually both pre and post-shot. They were arranged in a grid across the whole surface. Type 1 were narrow (14 mm dia., 2 mm deep) bowl shaped indentations arranged in 7 rows of 3 across the target surface. Type 2 were larger indentations (21 mm across, 5 mm deep) arranged in 5 rows of 3. In one shot the central region of the target was filled with a disk of red sand (grain size dia. 100 – 300 µm) some 9.2 cm in dia. and 2m deep and in this shot the larger indentations were made pre shot in a slightly modified grid arrangement

A total of 6 shots were carried out. One was a test shot onto a smooth surface sand target at 20º to determine the size and shape of the resulting large impact crater. Three more shots were then carried out at 20º, all onto sand targets, one with a Type 1 target, one Type 2, and one with a modified Type 2 target with the red sand present. The use of the red sand in a central region where the large impact crater formed permitted study of whether or not it was ejecta from the main crater which was causing any in-filling of the surrounding pre-existing features. Two shots were also carried out at 15º, both with Type 2 targets, but one was made of sand and the other glass beads, allowing an investigation of the influence of friction on the results.

Results: At 20º incidence the large crater in the sand arising from the shot still appears circular, with a mean diameter of 7.6±0.3 cm (peak to peak) and depth below the original surface of 8.4±1.3 mm (averaged over the shots). The crater is thus 54% of the width of the target. The deepest point in the crater was offset from the centre towards the impact direction by about 5% of the crater diameter. Examples of impacts are shown in Figs. 1 and 2.

There were several ways the impact effected the pre-existing depressions. The indentations immediately adjacent to the large crater were deformed by sideways bulk flow of the target material as the crater rim walls formed. These craters were thus no longer circular in appearance and the surface they were on was raised.

The other indentations had suffered loss of depth of (57±11)%. It was typically more severe (63±9)% in the downrange compared to uprange direction (51±10)%, compatible with shock asymmetries reported previously [8]. In some shots at 20º (e.g. Fig. 1b) there is evidence that some collapse of the indentation rims has occurred on the right side of the indentations (note the impact was from the left). This results in slightly tear-drop shape craters and accounts for some of the loss of depth. This was not due to the tilting of the targets pre-shot nor due to handling when moving in and out of the gun (photographs were taken in-situ before and after each shot) and is taken as evidence that some impact induced shaking of the target has occurred. The right-hand walls of the indentations are steeper than the left-hand walls, due to the tilt of the target. Shake induced flow may thus be expected to be more severe here as is indeed the case. However, this flow from the down-range walls does not appear in all shots and is not of sufficient magnitude to explain the total loss of depth in the indentations, indicating that some other mechanism (flow from all sides of the indentation or emplacement of an ejecta blanket) is also playing a role in erosion of the features. Apart from those immediately adjacent to the larger crater, the rim to rim diameters of the indentations increased slightly (5 - 10% effect) as a result of the impact. This is compatible with shaking causing relaxation of the rims of the features.

The shot with red sand (Fig. 2b) clearly shows that whilst the indentations immediately adjacent to the main crater rim wall have had a blanket of ejecta superimposed on them, the next rows of craters have had only minor (if any) ejected material superimposed on top of them. Yet they have undergone a significant loss of depth. This is not therefore due to emplacement of an ejecta blanket from the large impact.

The shots at 15º provided similar results to those at 20º. There were slight differences in the size of the central crater (both compared to 20º and between the sand and glass bead targets). However, indentation in-filling had again occurred, with substantial reduction in depth observed, once again more severe in the down-range direction.

Overall, impact induced shaking appears to have substantially infilled features over the whole target, even some 4.5 crater radii away from the impact point.

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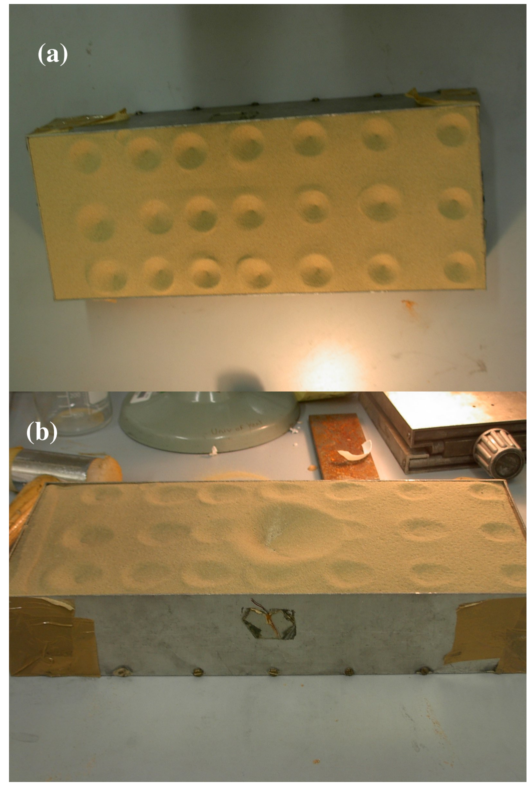

Fig. 1. Type 1 sand target. (a) pre-shot (b) post shot. The impact was from the left at 20º.

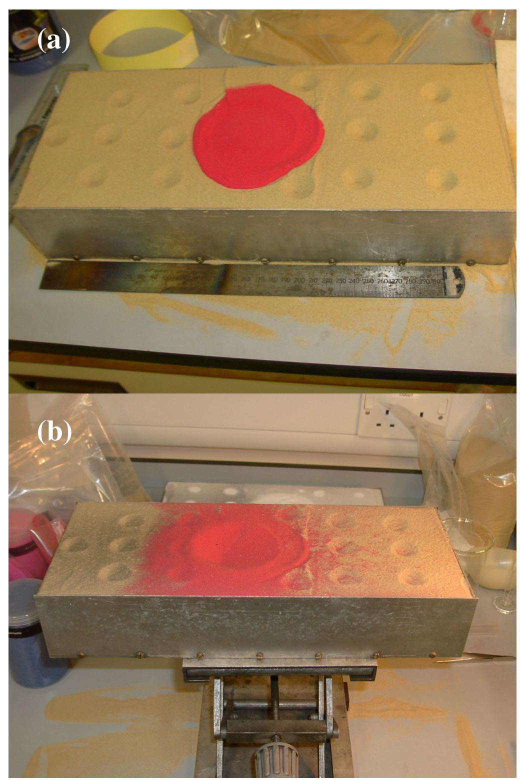

Fig. 2. Coloured sand modified target. (a) pre-shot, (b) post-shot. The impact was from the left at 20º.