LOW VELOCITY EJECTION OF BOULDERS FROM SMALL LUNAR CRATERS: GROUND TRUTH FOR ASTEROID SURFACES. Gwendolyn D. Bart, H. J. Melosh, *Univ. of Arizona, 1629 E. University Blvd., Tucson, AZ 85721, USA, (gwenbart@lpl.arizona.edu)*.

Introduction

We are characterizing the size and ejection velocity of boulders distributed around lunar craters 100 m to 1 km in diameter using high resolution, low sun angle *Lunar Orbiter III* images. While much is known about the impact cratering process [1], the distribution of boulders ejected from an impact crater has not yet been characterized through direct observation. Studies by Vickery et. al. indirectly found the distribution of ejecta from large craters by analyzing the size and distribution of their secondary craters [2, 3]. Our preliminary results from observations of boulders around small craters are consistent with those results found for large craters.

Spacecraft are finally returning sufficiently high resolution images to allow us to see boulders on the surface of other solar system bodies, such as the asteroids Eros and Ida. We want to find out what these boulders can tell us about the history of those bodies. But on the asteroids, it is impossible to tell which boulders came from which craters, since the low gravity causes the boulders to be distributed all over the asteroid. In contrast, the Moon has a much more significant gravity, and boulders ejected from small craters stay close enough to the crater to be able to determine their original distribution from the crater. Furthermore, the Moon is the only massive body for which we have images with sufficient resolution to be able to see meter size boulders around small craters. Craters on the Moon remain relatively pristine on long timescales because there are no active geologic processes taking place on its surface. The Moon also lacks an atmosphere or liquid fluids that could erode the craters. Thus, we employ the Moon as our laboratory to determine the general boulder distribution to be expected around small craters. With this baseline we can analyze bodies with more complex cratering histories, such as asteroids, Mars, and perhaps even comets.

The asteroid Eros was imaged close-up by the NEAR Shoemaker spacecraft in 2000. The spacecraft spiraled around the asteroid, taking images as it got closer and closer until it crashed onto the surface of the asteroid on February 12, 2001. The NEAR Shoemaker images revealed that boulders dominate the small scale landscape on Eros, and that small craters are rare [4]. The size frequency statistics of the boulders on Eros were also investigated, but without knowing what the distribution should be, it is hard to arrive at useful conclusions. Another place where our work will be applicable is in characterizing the small secondary craters of a large rayed crater has been found on Mars [5]. Our work provides data with which to test various hypotheses regarding boulders ejected from small craters.

Procedure

Both *Apollo* and *Lunar Orbiter* images of the Moon were examined for fresh, small craters surrounded by boulder fields. The *Apollo* panoramic and metric cameras did not have sufficient resolution to see any but a few of the largest boulders. High resolution *Lunar Orbiter III* images, however, reveal dozens of craters with hundreds to thousands of boulders. We examined one of these craters (*Lunar Orbiter III* image 185H 3 of 3) in detail, finding 1547 boulders apparently ejected from it. This particular crater has a diameter of 145 m and is located at 45.0° W, 2.5° S.

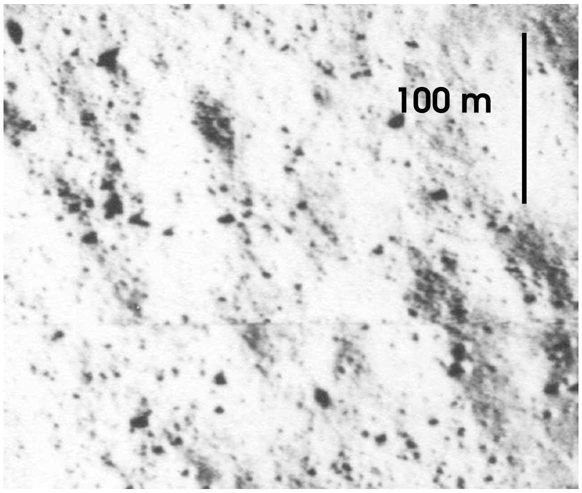

Figure 1: A few boulders in *Lunar Orbiter III* image 185H 3 of 3. Sun angle is from the right.

The image was converted to digital form by scanning the original image at the highest resolution necessary to preserve all the information. Next, the location of each boulder was marked so that each location could be easily identified at low resolution. The purpose of this step was to insure that no boulders would be missed when making measurements. The criterion used for marking a boulder was “a bright spot on the sunward side of a distinct shadow.” This criteria was rather strict in that there are many more shadows observed than have bright spots associated with them. Many of those shadows may in fact be boulders, but without a bright spot on their sunward side there is no way to distinguish them from craters, and therefore they were not counted. A few of the boulders can be seen in a small portion of the image in Fig. 1.

Once the boulders had been marked we used a modified version of ImageJ to measure the diameter of each boulder and its location. The boulder’s diameter is taken to be the width of the shadow near the bright spot, since the lighting would make a diameter measurement in the perpendicular direction uncertain. A very small ($\sim$10) number of additional boulders were found, and an even smaller number ($\sim$5) of marked boulders were determined upon re-examination not to be boulders by the previously stated definition. Therefore we are confident that our data represent the true boulder distribution around this

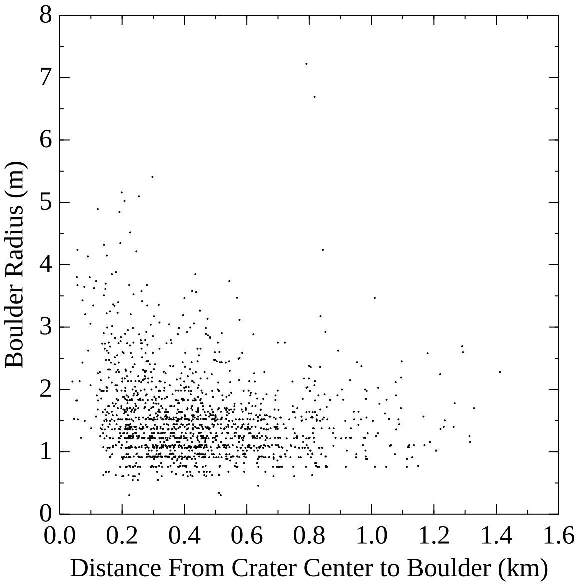

Figure 2: Distribution of 1547 boulders around a crater in *Lunar Orbiter III* image 185H 3 of 3.

crater with only ∼0.6% error.

The strip width of this particular image was 0.22 km [6], which, after scanning in the image, was equal to 724 pixels. This scale ratio was applied to the data from each boulder to convert boulder sizes to m, and to calculate the boulder's distance from the crater in km. Boulder radius as a function of distance from the crater center is plotted in Fig. 2.

Boulder diameters, which ranged in size from 2 to 20 pixels, were measured fairly accurately to the resolution of a pixel, resulting in diameters known to ± 0.30 m. This error in diameter, however, is the error in the width as described above. The actual boulder is likely not spherical, and due to shadow effects it is hard to know how closely this diameter reflects the true size of the boulder. The crater diameter is harder to find, with the value depending on where the rim was taken to be. Several measurements were made and the results were averaged, resulting in an error of ± 2 m for the crater center.

Discussion

The boulder distribution in Fig. 2 shows a general decrease in the maximum boulder radius with distance from the crater. Small boulders are observed at all distances from the crater. The horizontal lines result from the descrete number of pixels assigned to the boulder diameter.

Our survey results in a database that records the size of each boulder, its distance from the crater, and an angle to indicate where the boulder is located with respect to the crater. We assume that material ejected from the crater follows a ballistic path and lands a distance R_b from the crater. Thus, for short distances, the ejection velocity v_e can be found by

$$v_e^2 = R_b g/\sin(2\Phi)$$

where g is the planet's surface acceleration of gravity and Φ is the ejection angle [1]. Boulder radius as a function of ejection velocity is plotted in Fig. 3. The ejection angle was assumed to be 45°, since the distance the boulder was thrown from the crater is fairly insensitive to ejection angle. Furthermore, the distance the boulder was thrown was taken to be the distance from the crater rim to the boulder, since that is where most of the blocks are ejected from.

We will conduct this survey for several sizes of craters and for locations with varying regolith depths. Because we are conducting this study for very fresh craters, the statistics we develop should result in a better understanding of how much material is ejected from all small craters in the form of blocks.

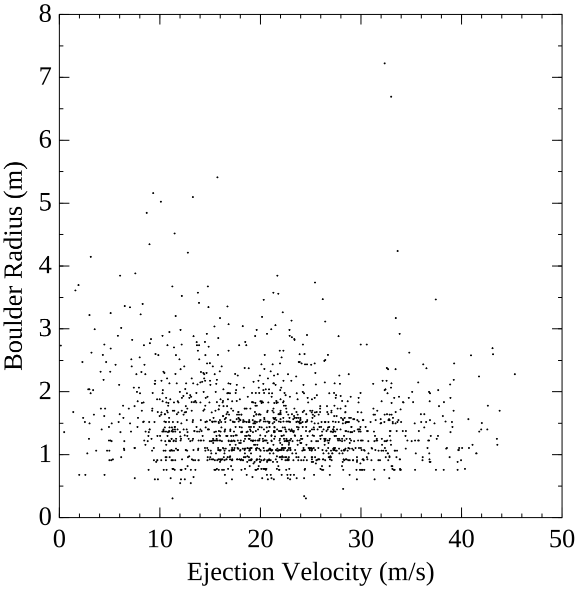

Figure 3: Boulder radius as a function of ejection velocity.

References

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