SIZE-FREQUENCY AND SPATIAL DISTRIBUTION OF EJECTA BLOCKS AT METEOR CRATER, AZ DETERMINED FROM LIDAR AND SATELLITE IMAGERY. D. D. Durda[1,3] and D. A. Kring[2,3], [1]Southwest Research Institute, 1050 Walnut Street Suite 300, Boulder, CO, 80302, [2]Lunar and Planetary Institute, 3600 Bay Area Blvd, Houston, TX, 77058, [3]NASA Solar System Exploration Research Virtual Institute (SSERVI).

Introduction: Studies of the size-frequency and spatial distributions of ejecta blocks surrounding impact craters provides crucial constraints on crater scaling laws and cratering physics, and information about the pre-impact subsurface structure of the target materials and geologic units.

Data Sets: Two independent sets of data were used to map the locations and dimensions of ejecta blocks at Meteor Crater, AZ.

A Digital Elevation Map (DEM) was generated from the point cloud data of an aerial LiDAR survey of the crater conducted by the National Center for Airborne Laser Mapping (NCALM) in March 2010 [1]. The survey was conducted with an Optech GEMINI Airborne Laser Terrain Mapper mounted on a twin-engine Piper PA-31. The crater rim, walls, and interior were surveyed with a point density of 5 pts/m^2, while the surrounding terrain was surveyed with a point density of 8 pts/m^2, at a flight altitude of 600 m. The point cloud data were gridded for a 5 km × 5 km collection area centered on the crater, sampled at 1 m resolution, and saved in GeoTiff format. The GeoTiff image was converted to JPEG format for display and direct comparison with other imagery in Photoshop for analysis.

A Google Earth overlay image covering approximately the same area around the crater as the LiDAR DEM image was constructed by screen grabbing a matrix of 25 images surrounding the crater and assembling them into a single large composite image in Photoshop. The Google Earth base map image (from March 2013) has a resolution of 0.5 m/pixel – comparable to the resolution of the LiDAR DEM image.

Figure 1 shows an example co-registered subsection of the LiDAR DEM and Google Earth overlay images, centered just off the eastern rim of the crater.

Methods: The image analysis workflow proceeds in two stages. Stage 1 consists of ‘blinking’ between the LiDAR DEM image and the co-registered Google Earth base map to identify candidate blocks and discriminate between positive relief features that are actual ejecta blocks versus Juniper and Pinyon Pine trees (these trees actually dominate the LiDAR positive relief features along the southern rim of the crater). Candidate blocks are identified by constrasting albedo and apparent shadow features in the Google Earth imagery that correspond to positive relief features in the LiDAR DEM data; large blocks are obvious but small blocks near the limit of resolution can appear similar to small bushes and there exists some ambiguity at these smallest sizes. At Stage 1 the positions of blocks are marked in a separate Photoshop image layer with dots corresponding in size to the apparent sizes of the blocks in the Google Earth base map.

Stage 2 consists of tagging each ejecta block with a placemark in Google Earth and making a note of its dimensions in the placemark note. Two roughly orthoganal dimensions are recorded corresponding to the maximum and minimum apparent projected diameters of the block. The Google Earth .kml file can be exported as a .xml file and then read in to Micrsoft Excel as spreadsheet data, thus then recording the latitude, longitude, and size information for each ejecta block in a manner amenable to various subsequent analyses.

Results and Discussion: The total search area covered 12.996 km^2 (a ~4.3 km × 3.0 km area roughly centered on the crater). The bottom panel of Fig. 1 shows an example of the Stage 1 mapping product, with the positions and sizes of ejecta blocks on the eastern rim of the crater marked by red dots.

The spatial distribution of ejecta blocks is not uniform around the crater. There are significant apparent azimuthal and radial variations that correspond with local topography and geologic units. The distribution at distances beyond about 1 crater radius from the rim is very thin on the west side of the crater compared to the north, east, and south sides. There are concentrated ‘rays’ of large ejecta blocks on the eastern and western rims of the crater, corresponding to the east and west boulder fields of [2]. There is a concentrated belt of boulders on the south side about one crater radius from the rim. Based on previous mapping, most of these blocks are dominated by Kaibab, with lesser amounts of Coconino and virtually no Moenkopi at the scale (~1 m) detectable with the methods used here. The dearth of large boulders on the south rim appears to correspond to a zone of Coconino ejecta that still covers Kaibab ejecta. Beyond that zone, however, is a concentrated zone of boulders that correspond to the appearance of exposed Kaibab ejecta. The distribution of boulders appears to be more homogeneous north and east of the crater than south of the crater.

The resulting ejecta block location map was then analyzed with the software package ImageJ to count the number of mapped block candidates and produce a very rough, ‘first look’ size-frequency distribution in advance of the more detailed analysis that will be

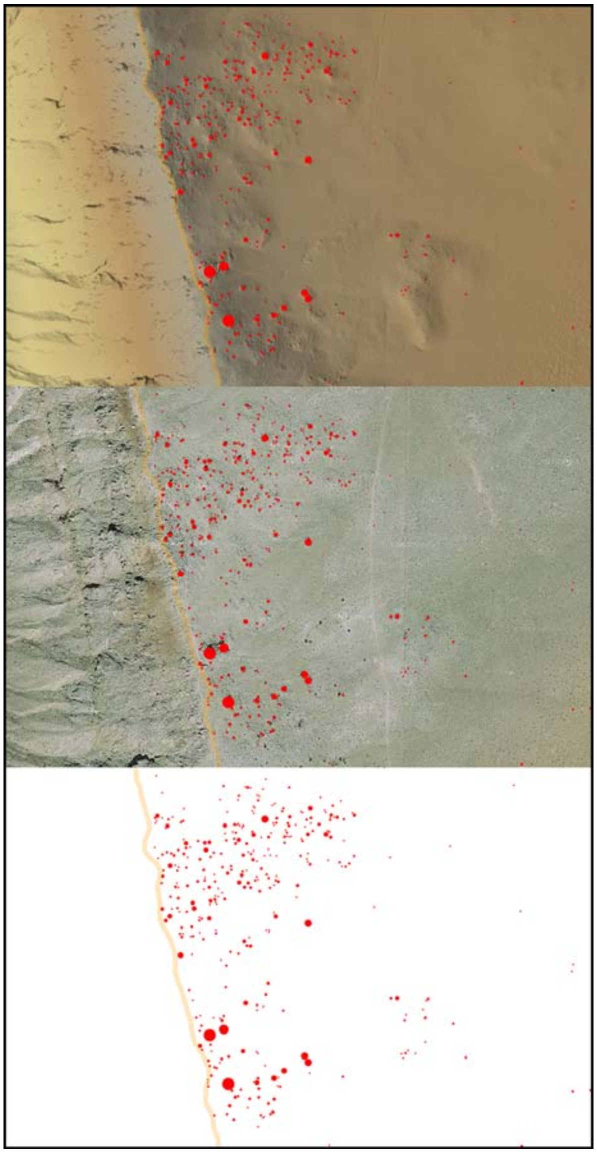

Figure 1. Comparison of co-registered examples of the LiDAR DEM image data (top panel) with Google Earth imagery (middle panel). Note that some positive relief features apparent in the LiDAR data correspond to Juniper and Pinyon Pine trees rather than actual ejecta blocks, thus necessitating the use of Google Earth imagery in 'blink comparitor' mode during Stage 1 of ejecta block candidate identification. The Stage 1 mapping product is illustrated by the ejecta block location map (bottom panel). The sizes of the red dots marking the mapped locations of identified ejecta blocks correspond to the apparent dimensions of the blocks in the Google Earth imagery.

available as Stage 2 mapping and measurements are completed. Figure 2 shows a log-log plot of the cumulative size-frequency distribution of the red dots marking the ejecta blocks in Stage 1, with data for ejecta blocks around similar-size lunar craters [3] for comparison [V-153-H2 (gray dots); Ap17-Pan-2345(a) (red dots); Ap17-Pan-2345(b) (green dots); Ap17-Pan-2345(e) (blue dots)]. The latter three craters are excavated in a mare unit, making them good comparisons for the solid but fractured rock layers target material at Meteor Crater.

The size-frequency distribution is a rather well-behaved power law very similar to those seen for ejecta blocks around lunar and fresh explosion craters. There is a 'hump' in the distribution for larger boulders in roughly the 5-12 meter diameter size range, but for the segment between about 2.5-5 meters there is a rather linear section; the slope index over that range is about -4.3. For comparison, the slope indices for the lunar crater data plotted in Fig. 2 range from -3.0 for crater V-153-H2 (excavated in an ejecta blanket deposit) to -4.0, -4.5, and -4.5 for craters Ap17-Pan-2345(a), Ap17-Pan-2345(b), and Ap17-Pan-2345(e), respectively, each excavated in a mare unit.

Stage 2 mapping is in progress; initial results will be reported at the conference.

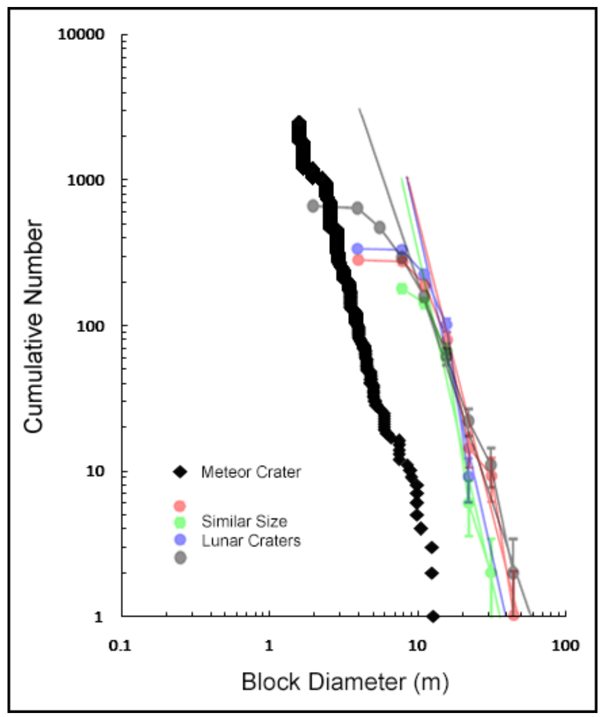

Figure 2. Size-frequency distribution of the red dots from Stage 1 mapping of ejecta blocks at Meteor Crater (black diamonds). Data for four similar-size lunar craters from [3] are shown for comparison.

References:

[1] http://www.lpi.usra.edu/publications/books/barringer_crater_guidebook/LiDAR/. [2] Barringer D. M. (1910) *Meteor Crater in Northern Central Arizona*. [3] Bart G. D. and Melosh H. J. (2010) *Icarus, 209*, 337–357.