RELATIONSHIPS BETWEEN BLOCK SIZE DISTRIBUTIONS AND TOPOGRAPHIC ROUGHNESS: AN EXPERIMENTAL APPROACH USING LIDAR SCANNING AND VARIOGRAM ANALYSIS.

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Introduction: Block size distributions on rocky planetary surfaces contain information regarding both the lithologic material properties and the geologic processes responsible for creating the deposit [1-3]. For example, studies of block size distributions have been used to assess landing site geology [4] and to determine processes occurring on active lava flow surfaces [1,2].

However, determining the size frequency distribution of irregularly-shaped rocks on a geologic surface is not straightforward even in field settings [1,2]. It is not practical or even possible in some situations to manually move and measure rocks in a number of directions and orientations. Therefore, Anderson et al. [1] developed a field measurement protocol where a line is stretched across 20-30m orthoganol transects. The length of the rock cut by the line (chord length) is measured and used as the rock size. This is analogous to the method used to determine crystal size distributions from thin sections, where any one-dimensional measurement of size should give an average size distribution for the sample if the items are randomly oriented [5,6].

Once block size measurements are acquired, data are typically reduced to cumulative size-frequency distributions that typically exhibit an exponential form. This behavior is noted for rock fields on Mars and in a number of geologic environments on Earth [1,2,3,7,8], and is expected from Griffith's fracture criteria where the likelihood of finding blocks without flaws that would lead to fragmentation decreases exponentially with increasing size [2]. The form of this function is:

$$f(D) = k \exp\{-qD\}$$

where f is the fraction of the transect covered by rocks greater than or equal to diameter D, and k and q are constants [2]. Least square curve fits are used to estimate k and q. The pre-exponential term (or intercept), k, is a function of the total percentage of the surface covered by rocks, if the rocks are measured down to very small sizes [2].

Although the Anderson et al. [1] method is a useful field protocol for determine block size distributions, it is difficult to apply the methodology to remotely-sense imagery because typically a large percentage of blocks are below the resolution of the data. Investigators are developing methodologies for estimating block size distributions from rover data (e.g. [9]), but determining block size populations from air- or space-borne remote sensing data is still problematic.

However, blocks provide a surface roughness component to the topography of an area [3], and topographic datasets are now approaching mm-scale resolution in terrestrial settings. Therefore, it may now be possible to resolve the block-size distribution of a rocky surface from analysis of detailed topography of the area. Here, we discuss a series of experiments designed to show relationships between topographic roughness and block size distributions.

LIDAR Scanning of Rock Boxes

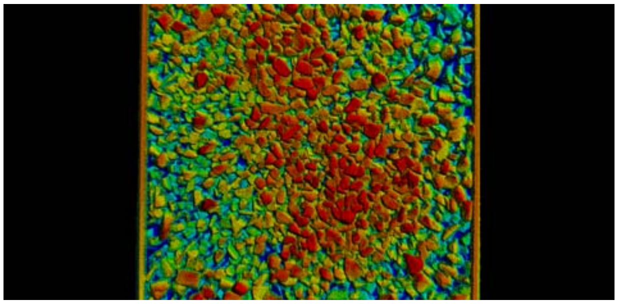
We are scanning rock boxes containing known block size distributions with a LIDAR setup capable of producing sub-cm DEMs. Although there are no comparable resolution planetary topographic scanners, any relationships between block size distribution and topography may extend to planetary settings. We use a Riegl LMS-Z420i laser scanner that captures topographic data by directing a near infrared (1550um) laser pulse at known angles and co-registers the x,y and z coordinates with the RGB values of true color high-resolution (12 megapixel) photographs from an externally-mounted camera to within ½ a pixel. We acquired topographic data at a rate of 12,000 points/second at a beam divergence of 0.25 mrad, permitting repeatable digital elevation model (DEM) generation with 5mm accuracy. The instrumentation is capable of scanning 360° horizontal and 80° in the vertical at an angular step of 0.00025°. If used from the ground, topographic highs give rise to line-of-sight restrictions and resultant data shadows, although these may be minimized by merging multiple scan positions through a process that combines fine-scanning of common tie point reflectors with leveling information provided by an internal inclination sensor. In our experiments, we mount the LIDAR system to an overhead beam to eliminate line-of-sight issues.

Above: Rock box containing natural samples of granite sieved to 6 inch minus size.

Below: Close up of same box showing the various shapes Possible in a single-sized deposit.

We are scanning both natural rock populations that have been sieved to a given size-range, and "synthetic blocks" consisting of a known size distribution of styrofoam and wooden cubes. In the first case, we restrict the size range but allow shape to vary according to the natural fracture tendencies of the rock. In the second case, we control the shape but can vary the size frequency distribution of the deposit.

Once scanning is complete, we measure the population of blocks by hand according to the field protocol of Anderson [1]. We also use the protocol to measure the block sizes from the overhead images supplied by the scanner in order to assess the difference in field versus image measurement accuracies. We then produce DEMs of each rock box.



Above: Sub-cm LIDAR DEM of 6 inch minus granite rock box.

Each DEM is run through a new program we developed to automatically produce semi-variograms reflecting the roughness of topography at various length scales. We can control where on the DEM variograms are produced, and at what scales. We are also investigating whether other topographic parameters are linked to the block size distribution in order to find a reliable topographic proxy for block size.

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