LARGE-SCALE ASSESSMENT OF POLYGON-EDGE BOULDER CLUSTERING IN THE MARTIAN NORTHERN LOWLANDS

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Introduction: Two features evident in many images of the martian northern lowlands are polygonal fractures (especially northwards of 60°N) and meter-scale surface boulders. Since their first observation, several attempts have been made to classify and study these polygons (e.g. [1]) as well as how the forces that form these polygons may modify the surface. Surface boulders have been used as a potential indicator of such modification, though current studies find evidence both for [2] and against [3] their association with the underlying polygons. Both these investigations are limited by the same fundamental challenge: mapping the location of surface boulders manually is not practical at large scales. Here, we use the Martian Boulder Automatic Recognition System (MBARS, [4]–[6]) to provide image-wide assessments of boulder location and size, enabling large-scale assessment of boulder populations. To compare these boulder locations with the underlying polygons, we modified the 2-D Fourier analysis described by Orloff in 2013 [7] to analyze boulder locations. When compared with Orloff's observations of polygon scales, this provides an avenue for large-scale comparison of boulder-cluster scale and polygon scale.

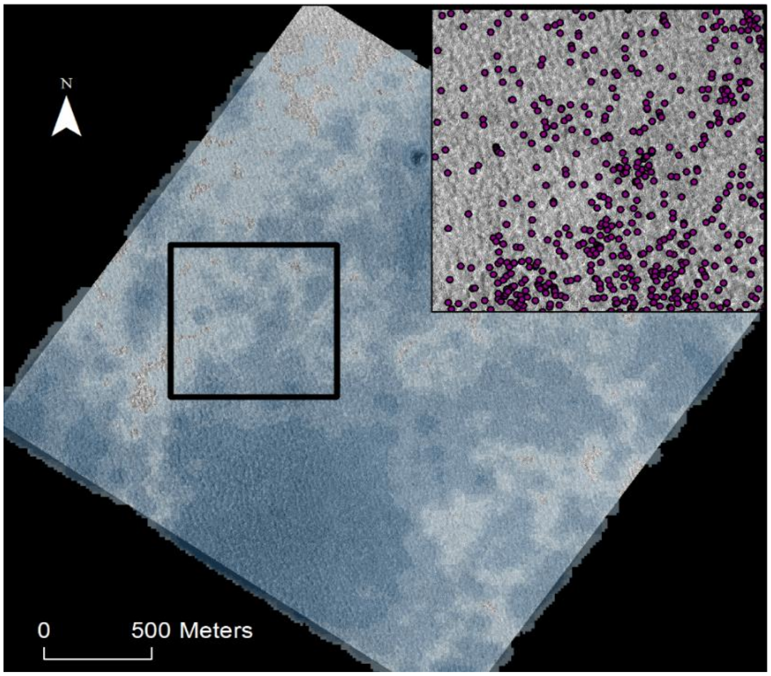

Figure 1. *Boulder populations in HiRISE image PSP_001415_2470, located north of Acidalia Planitia. The boulder density (blue shading, dark colors = high density) is shown in the main image and ranges from 0-30 boulder/hectare. Individual boulders are marked as purple dots in the inset. The entire image contains ~16,000 boulders.*

Methodology: MBARS is a key tool used here to identify and measure boulders in the chosen HiRISE image. Details on the boulder detection methodology and verification of the algorithm have been discussed in previously published work [4]–[6]. In short, MBARS measures boulders using their cast shadows, similar to previous boulder detection methods [8], [9]. Shadow boundaries are modeled based on image statistics and the HiRISE point-spread function [10]. After boundaries are determined, images are segmented along the shadow boundary and shadows are isolated, delineated, and measured. The result of this analysis is a list of boulder locations, morphometry, and fit confidence for each boulder in a HiRISE image. Processing time depends greatly on image size, boulder density, and image brightness. For a small image with moderate boulder densities, processing time is less than a few hours.

The 2-D Fourier transform method [7] was first applied to calculate objective length scales for polygonal fracturs in HiRISE images. In short, this method uses the 2-D Fourier transform of a HiRISE image containing polygonal fractures to determine a characteristic length (λ) of polygons in the image. From the power spectrum, λ can be calculated as:

$$\lambda = \frac{\sum_{k_x}\sum_{k_y} P\left(k_x, k_y\right)}{\sum_{k_x} k_x \sum_{k_y} P\left(k_x, k_y\right)}$$

This λ is calculated after the power spectrum above 1m^{-1} and close to 0 are set to zero, as these frequency windows are dominated by sub-pixel noise, and large-scale features respectively. To apply this method to boulder locations instead of HiRISE images, few fundamental modifications are required. For consistency, the power spectrum is set to zero in the same ranges, but the

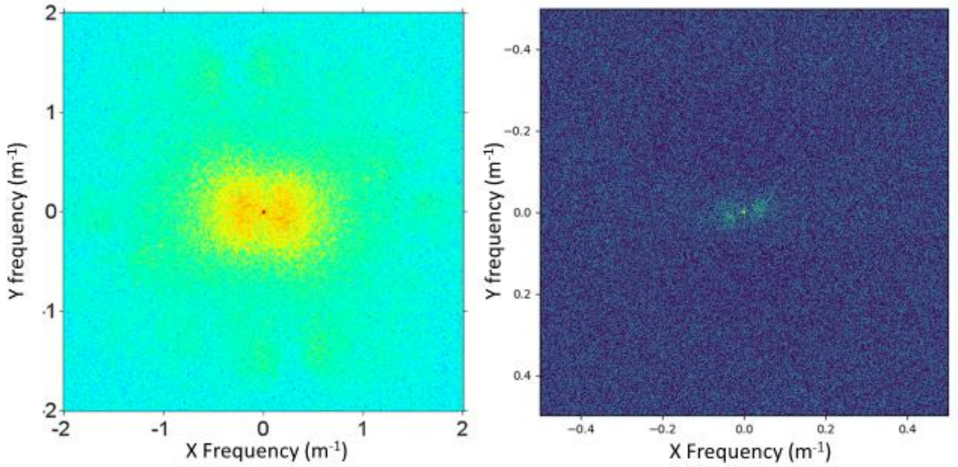

Figure 2. *Examples of 2-D power spectra from HiRISE images (left) and from boulders interpreted from HiRISE images (right). Note the difference scale between the two images. The same method applied to boulder data generates a similar power spectrum and a similar λ of 3.9m. The overall fainter appearance of the central lobe is likely due to the lower information density in the boulder location data.*

calculation remains the same. One major change is the analysis scale. The original method was applied to 512 × 512 pixel image panels and 1024 × 1024 image panels, the results of which were similar except where multiple polygon scales were present. Because the boulder location data is less information-dense, the transform was applied over larger areas (1.5km × 1.5 km) to ensure robust statistics.

Results: We chose PSP_1415_2470 as a test image for the characteristic boulder cluster length calculation method. Applying this methodology to boulder locations in this image yielded a λ of 3.9 m. The polygon-derived λ for this image is 4.9m [7], and while our result is not identical, it is within the range of expected values for polygon-aligned clustering (~3-10m).

Interpretations: This investigation provides preliminary evidence in favor of polygon-aligned clustering of surface boulders, at least in the vicinity of this image. Analyses of other images will demonstrate if there is a general correlation between λ derived from boulder locations and those from polygon images.

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