LARGE-SCALE ASSESSMENT OF POLYGON-EDGE BOULDER CLUSTERING IN THE MARTIAN NORTHERN LOWLANDS Don R. Hood[1], C.I. Fassett[2], S. Karunatillake[1], S. F. Sholes[3], R.C. Ewing[4], [1]Louisiana State University, Department of Geology and Geophysics (dhood7@lsu.edu), [2] NASA Marshall Space Flight Center, Huntsville, AL, [3]Depts. of Earth and Space Sciences & Astrobiology, University of Washington, Seattle, WA., [4]Texas A&M University, Department of Geology and Geophysics

Introduction: Two features evident in many images of the martian northern lowlands are small-scale (<10m) polygonal fractures (especially northwards of 60°N) and meter-scale surface boulders. Since first observed, studies have classified these polygons (e.g. [1]), examined potential causative mechanisms, and tried to explain how the polygons 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. Prior 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 determine image-wide boulder locations and sizes, enabling boulder sampling representative of the underlying populations. To directly compare boulder locations with the underlying polygons, we modified the 2-D Fourier analysis described by Orloff in 2013 [7] to operate on boulder density maps. With a method to calculate the characteristic length of boulder clusters, results of each method can be compared in the 100+ images analyzed in the original work. This comparison would represent the first large-scale, quantitative assessment of boulder cluster correlation with martian polygons.

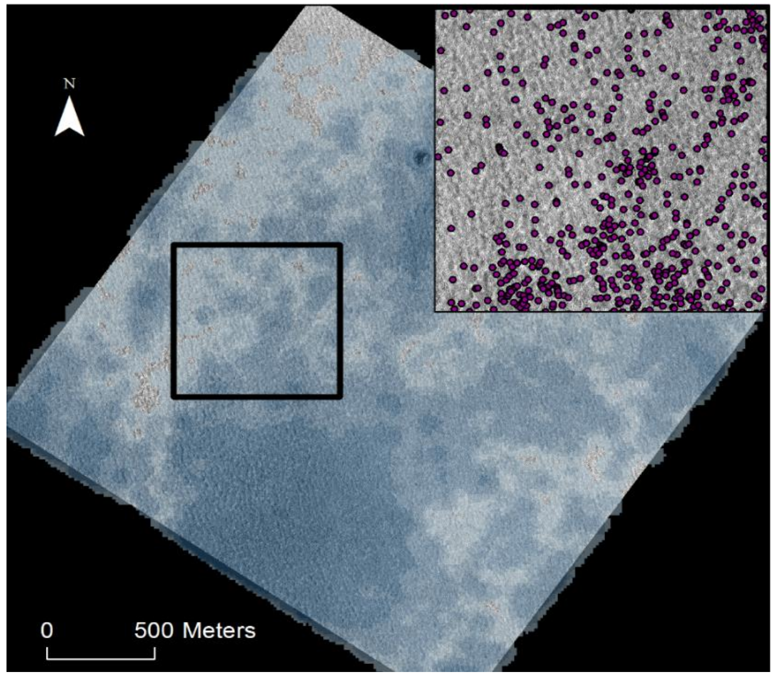

Figure 1. *Boulder populations in HiRISE image PSP_001415_2470, located north of Acidalia Planitia. The boulder density (blue shading, dark colors = high density) is shown in the main image and ranges from 0-30 boulder/hectare. Individual boulders are marked as purple dots in the inset. The entire image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

Methodology: MBARS is a key tool used here to identify and measure boulders in the chosen HiRISE image. Boulder detection and verification of the algorithm have been described previously [4]–[6]. Summarily, MBARS measures boulders using their cast shadows, similar to previous boulder detection methods [8], [9]. However, MBARS is more automated and user-independent than previous methods, making it easier to apply to large image sets. In addition, MBARS will be made open-source once it is complete, making it accessible to the planetary science community. In MBARS, 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 (Figure 1), 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 fractures in HiRISE images. The 2-D Fourier transform of a HiRISE image containing polygonal fractures is used to determine a characteristic length (λ) of polygons in the image. From the 2-D power spectrum of the image, λ can be calculated as:

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

Where k_x and k_y are the x- and y-frequencies, and $P(k_x, k_y)$ is the spectral power at a given x and y frequency. 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, and the 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 (~130m and ~160m respectively), the results of which were similar except where multiple polygon scales were present. Because boulder density maps are 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 (Figure 1) for the characteristic boulder cluster length calculation method (Figure 2). 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. A general correlation of these characteristic lengths would suggest that boulders across the northern lowlands are sorted along polygon edges, and that the polygons play a role in creating this sorting effect. If this sorting is found along the 3-6m polygons that are consistent with modern ice table estimates [11], it would further suggest that this sorting process is active and ongoing. This would provide data to support investigation into the mechanisms by which the sorting may occur, which is a subject of current investigation e.g. [11], [12].

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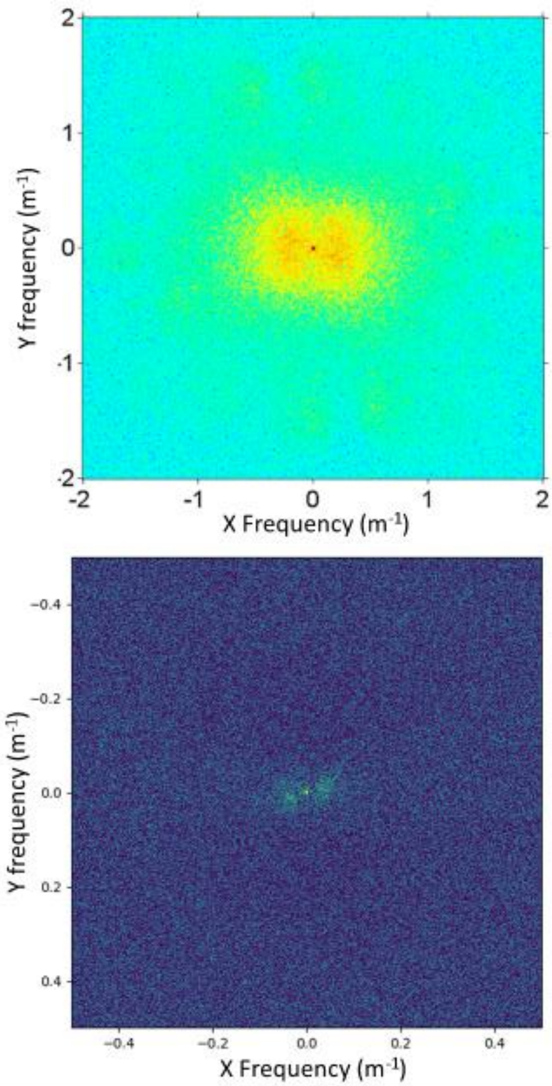

Figure 2. *Examples of 2-D power spectra from HiRISE images (top) [7] and from boulders interpreted from HiRISE images (bottom). Note the difference scale between the two images. The same method applied to boulder data generates a similar power spectrum and a similar λ of 3.9m. The overall fainter appearance of the central lobe is likely due to the lower information density in the boulder density map*

References: [1] J. S. Levy, et al. *J. Geophys. Res. E Planets*, 2009. [2] T. C. Orloff, et al. *J. Geophys. Res.*, 2011. [3] A. M. Barrett, et al. *Icarus*, 2017. [4] D. R. Hood, et al. *49th Lunar and Planetary Science Conference*, 2018. [5] D. R. Hood, et al. in *50th Lunar and Planetary Science Conference*, 2019. [6] D. R. Hood and S. Karunatillake, *48th Lunar and Planetary Science Conference*, 2017. [7] T. C. Orloff, et al. *J. Geophys. Res. Planets*, 2013. [8] M. P. Golombek *et al.*, *J. Geophys. Res.*, 2008. [9] Y. Li and B. Wu, *J. Geophsical Res. Planets*, 2018. [10] R. L. Kirk *et al.*, *J. Geophys. Res.*, 2008. [11] M. T. Mellon, et al. *J. Geophys. Res. E Planets*, 2008. [12] T. C. Orloff, et al., *Icarus*, 2013.