LACK OF BOULDER SORTING IN THE MARTIAN NORTHERN LOWLANDS SUPPORTS DRY ENVIRONMENT, NO CO2 ICE RATCHETING.

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Introduction: The Martian Northern Lowlands are a low-relief landscape with prominent glacial and periglacial landforms. Patterned ground covers much of this landscape and overprints many other landforms as one of the youngest geologic features [1]. Shallowly buried H_2O ice known to exist at higher latitudes [2] supports the interpretation of these landforms as thermal contraction polygons. Initial investigations suggested that boulders are sorted into polygon margins, and that this was likely an ongoing process [3]. However later work suggested that boulder clusters and patterns were only sometimes statistically significant, and not preferentially aligned to polygon margins [4]. Sorting of clasts on Earth is associated with periglacial environments and generally requires the presence of liquid water [5]. On Mars, dry mechanisms for sorting have been propsed (e.g. [6]), but boulder sorting could imply the presence of liquid water.

To reconcile these results, we are carrying out a boulder survey across 60+ HiRISE images of the northern lowlands. In each image we are identify and measure boulders ~> 1m in diameter using our published automated boulder detection software: the Martian Boulder Automatic Recognition System (MBARS) [7]. Using the boulder maps for each image, we aim to answer a straightforward question: Are boulders sorted into polygon margins in the patterned ground of the martian northern lowlands? Boulder sorting in the current era of polygon formation would require either a dry sorting mechanism, or the presence of liquid water in the geologically recent past.

Data: We use HiRISE images in our survey for their unmatched resolution (25 cm/px) and coverage of the northern lowlands between 50°-70°N. The images were selected based on prior surveys that identified polygon morphology [1] and size [8]. Most of the images in our survey were included in both prior

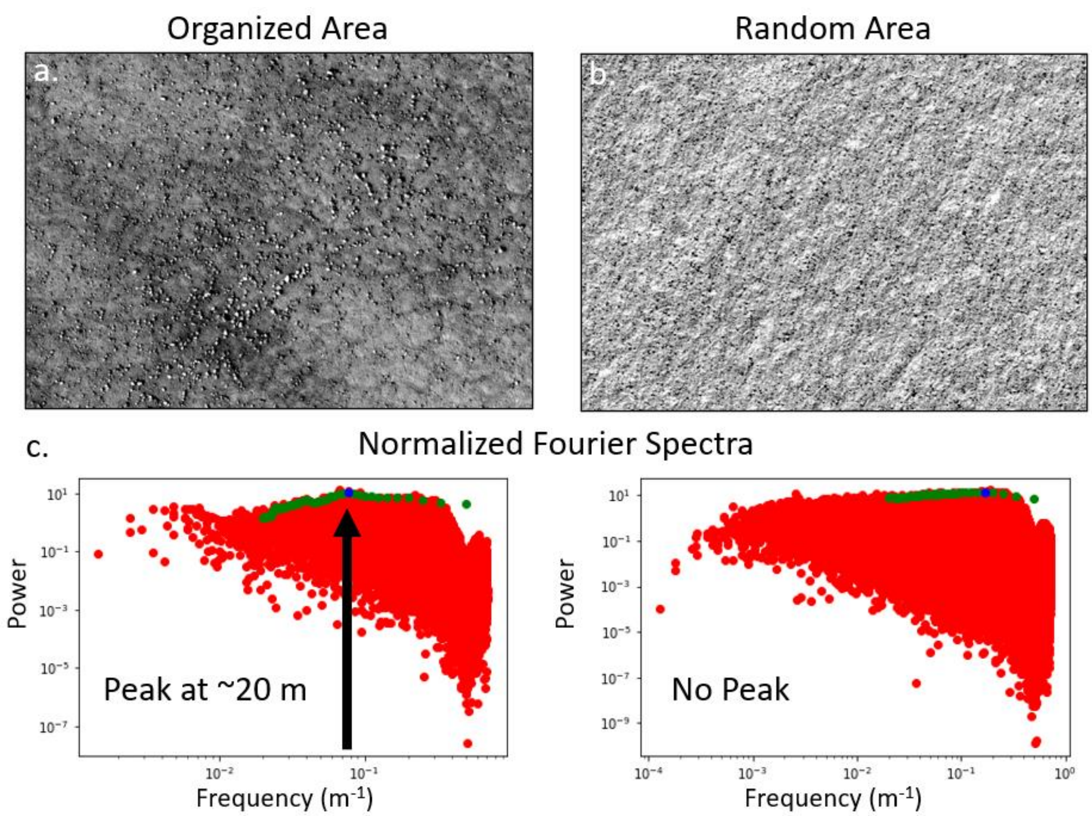

Fig. 1 *a,b) 300m image subsets representing test cases of organized (a) and random (b) boulder distributions. c) Normalized Fourier spectra of each image subset demonstrating the spectral features that indicate organization.*

surveys, and so we have information on the presence, morphology, and characteristic scale of polygons. We also include several images in the vicinity of Lomonosov crater in our survey, as these have been visually assessed for boulder sorting patterns [4]. Current results are based on images from the first 36 images of the survey, archived in the Texas Digital Repository [9].

Methods: We use several methods to characterize the spatial patterns of the boulder maps generated by MBARS [7] including Fourier Analysis (**Fig. 1**), and Hilbert-Huang transformations (**Fig. 2**). Our Fourier analysis builds on prior landform analysis code [10] and shares its heritage with the methods used to assess polygon wavelength [8]. After plane-fitting and windowing the boulder maps, we bin the Fourier spectra by radial frequency. We use both the peak in spectral power (**Fig. 1c**) and the power-weighted mean frequency [8] as possible metrics of the boulder sorting wavelength.

Hilbert-Huang transformations (HHTs) are a relatively new technique [11] that work well in isolating non-stationary signals and separating multiple superposed signals. HHTs involve two steps. First, Empirical Mode Decomposition (EMD) is applied to the input signal (boulder map), isolating the superposed signals. Then each mode is independently examined with Hilbert Spectral analysis (HSA). Similar to the Fourier analysis, we inspect the Hilbert spectral results binned by radial frequency looking for a peak in spectral power that corresponds to the polygon diameter. Here, we will only discuss Hilbert spectral analysis of image sections, as the EMD portion of our analysis is still under development.

Table 1. Correlation between polygon wavelength [8] and boulder-wavelengths determined in analogous fashion. Neither correlation is significant at $p<0.05$.

Parameter	Correlation to Polygon Wavelength
Peak wavelength	0.17
Power-weighted mean	0.34

Results:

Fourier Analysis: Peaks in the radial Fourier spectrum correspond to the scale of polygons in image subsets where organization is apparent (**Fig. 1**), suggesting that the analysis is sensitive to these boulder configurations. However, when applied to the entire images, only 6 images had a spectral feature that could possibly be associated with polygon-edge sorting. Further, neither the peak-determined wavelength nor the power-weighted mean wavelength correlates with the polygon wavelength as priorly determined [8] (**Table 1**).

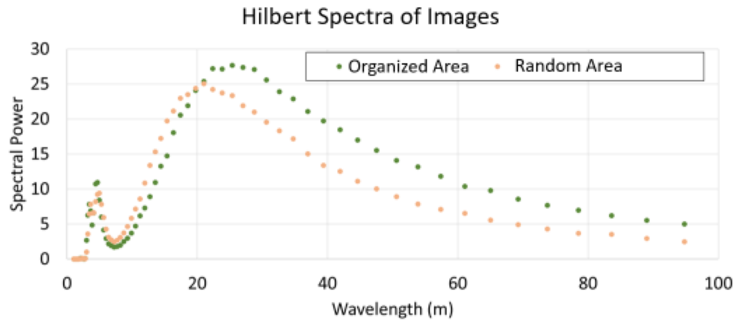

***Figure 2.** Hilbert spectra of the image subsets in Fig. 1 binned by radial wavelength. Two peaks are visible in the spectrum at ~5m and 20-30m in both images*

Hilbert Spectral Analysis: HSA has been carried out on a few image subsets, and initial tests do not demonstrate substantial differences between areas with organized and random boulder distributions (**Fig. 2**). Two features are apparent in the spectra: one at ~5m, which may be associated with the generation of the boulder density maps used in this analysis, and a second near 20m. The ~20m peak is present in both the organized and random areas and may not be indicative of organization. Further investigation will determine what these signals indicate about boulder distributions.

Conclusions: Our preliminary investigations based on 36 images (14.59×10^6 boulders over 1300 km^2) in the survey suggest that boulders are not sorted into a detectable polygonal pattern across the martian northern lowlands, though there is detectable local-scale organization. These results demonstrate that if any sorting occurs atop modern thermal contraction polygons, it does not occur ubiquitously across the lowlands. The lack of sorting also supports a lack of freeze-thaw cycling in the polygonal terrain, minimal cryoturbation, and no CO_2 ice driven sorting [6].

The next phase of our survey will confirm these findings and investigate whether the sites that show detectable sorting are fracture controlled. This may distinguish between local, recent freeze-thaw sorting or relict sorting from a prior era of polygon formation [5].

References:

[1] Levy, J. S., Head, J., & Marchant, D. (2009). *JGR: Planets*, **[2]** Mangold, et al., (2004). *JGR: Planets*, **[3]** Orloff, T. C., et al., (2011). *JGR*, **[4]** Barrett, A. M., et al., (2017). *Icarus*, **[5]** Soare, R. J., et al., (2015). *Icarus*, **[6]** Orloff, T. C., et al., (2013). *Icarus*, **[7]** Hood, D. R., et al., (2022). *Earth and Space Science*, **[8]** Orloff, T. C., et al., (2013). *JGR: Planets*, **[9]** Hood, Don, et al., (2022). *Texas Data Repository*, **[10]** Perron, J. T., et al., (2008). *JGR: Earth Surface*, **[11]** Huang, N. E., & Wu, Z. (2008). *Reviews of Geophysics*