EVIDENCE FOR LATITUDE-DEPENDENT CHANGES IN BOULDER CLUSTERING IN THE MARTIAN NORTHERN LOWLANDS.

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Introduction: Boulders are ubiquitous at the surfaces of rocky worlds. Their presence and spatial distribution signal planetary processes [e.g., 1, 2]. Characterizing the abundance, size, and distribution of boulders provides insights into primary impact processes and secondary surface gradation processes to alter the boulder size or position. On Mars, boulders clustering occurs at different scales and patterns in the northern lowlands [3,4] and has been tenuously linked to surface polygons. However, the mechanism responsible for small-scale clustering of boulders remains unknown, particularly clustering along polygonal terrain edges. Possible mechanisms for the polygon-edge clustering include mass-wasting [5], cryoturbation [6], and ice-ratcheting [7]. To determine which of these possibilities is feasible, if any, it is necessary to (1) show that boulders distributions are patterned and (2) to associate these patterns with polygonal terrain edges.

This work presents spatial distribution analyses of boulders in the Martian northern lowlands. The objective is to evaluate boulder distributions (step 1 above). To that end, a boulders database has been compiled using an automated survey of high-resolution images and analyzed in GIS environment to identify spatial patterns. Presented are preliminary results from the first-year survey.

Data and Methods: A boulder survey of the northern lowlands of Mars (50-70°N) was done using the Martian Boulder Automatic Recognition System - MBARS [8]. Forty (40) HiRISE images were surveyed and analyzed. Data and results are archived and can be accessed from the Texas Digital Repository [9]. The spatial clustering of boulders was examined at various scales using Ripley's k-function (5-50m distances) and Average Nearest Neighbor (ANN) techniques. Getis-Ord Gi* was performed to identify and characterize boulder clusters for size and extent.

Results: The MBARS survey successfully detected a total of 14,849,853 boulders, 94.4% of which are <2.5m in diameter (mean and median of 1.32 and 1.19m respectively). The average rock abundance is 0.37, with an average image area of 40.6×10^6 m^2. Boulder sizes correlate moderately with latitudes (r=-0.315), meaning boulders diameters generally decrease from 70 to 50°N.

Ripley's k-function and ANN. Ripley's k indicate that boulders are clustered at all examined distances. All images showed observed k values larger than the upper confidence envelope for all distances, indicating statistical significance. Closer examination of the ratio and difference between the observed and expected k revealed grouping of images by clustering level, suggesting higher clustering degree for the larger distances in some of the images. Sorting the images by latitude shows that areas between 54-62°N tend to have a more clustered boulder distribution (Figure 1).

ANN also indicates clustered distribution of boulders in all images, except for two images where the ANN ratio (R) is slightly above random distribution of 1 (1.002 and 1.001 with p=0.02 and 0.04 respectively). Changes in ANN ratio also indicates a latitudinal band of increased clustering consistent with Ripley's K analysis (Figure 1). This latitudinal band is also characterized by a lower rock abundance (Figure 1). The fraction of boulders <2.5m both inside and outside the band is equivalent to that of the total database (~94%), as well as the mean and median diameter.

Getis-Ord Gi.* Getis-Ord Gi* analysis shows a distinct difference between the images inside and outside the clustering latitudinal band. On average, within the band there are more boulders contained in hot spots (large boulders surrounded by other large boulders – 26.5% vs. 4.5%) and more contained in cold spots (small boulders surrounded by other small boulders – 5.4% vs. 0.4%) than outside of the clustering band. Likewise, both hot and cold spots are bigger, i.e., contain more boulders and neighbors, inside the clustering band (Figure 2). However, the average size of boulders within the hot and cold spots does not change significantly. Larger hot and cold spots within the latitudinal band (54-62°N) may indicate clustering occurring coherently at larger spatial scales.

Conclusions: Spatial analyses of boulders in the Martian northern lowlands revealed a latitudinal band (54-62°N) where boulders tend to be more spatially clustered than elsewhere in the lowlands (<54 and >62°N). This increased clustering of boulders observed in this band is attributed to the larger spatial scale of the clusters and to the clustering of smaller boulders in addition to large boulders.

The scale of boulder clusters within the latitudinal band (100s of m) is too large to be associated with small scale polygons (10s of m). This suggests that the boulder clusters within the latitudinal band likely originated from impact craters or similar large-scale features.

Work is underway to examine the spatial relationship between boulders and polygon edges, especially outside the clustering band. Boulder-polygon associations may indirectly demonstrate fracture activity, providing a possible mechanism for boulders arrangement, like sorting processes well-known in preglacial terrain on Earth [10].

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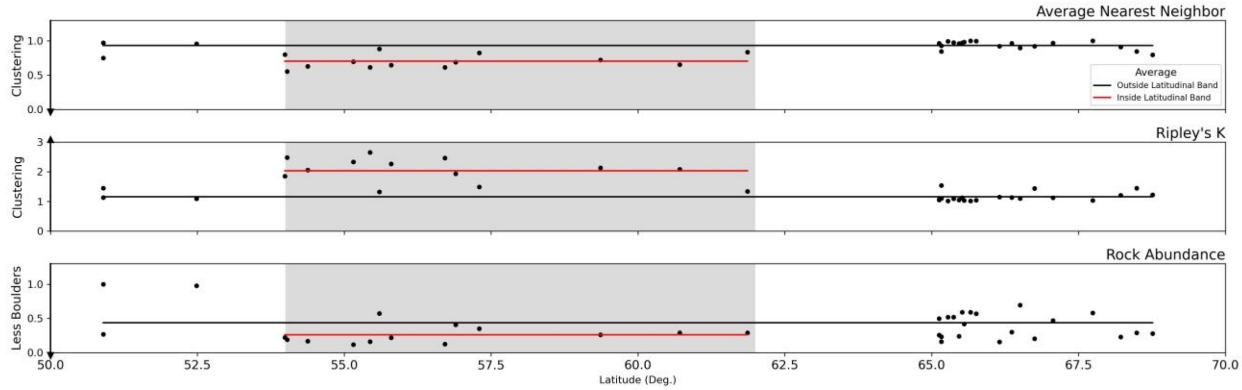

Figure 1: Spatial clustering of boulders in the Martian northern lowlands. Note that ANN R and Ripley's k-function ratio (K ratio) values interpret opposite to each other. The larger the K ratio (observed k divided by the expected k), the more clustered the distribution is, since clusters are indicated by larger observed k than expected k. On the other hand, ANN R=0 indicates maximum aggregation, R=1 is random distribution, and R>1 implies dispersion. Gray area marks the latitudinal band boundaries.

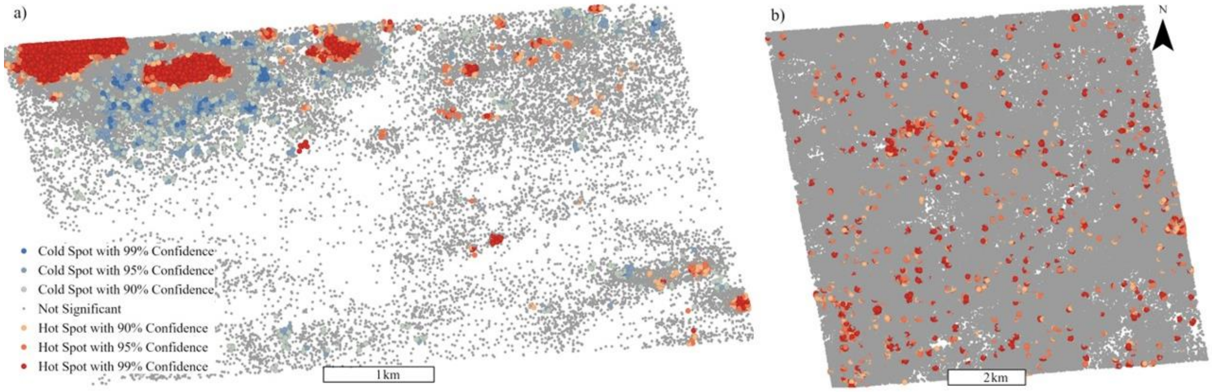

Figure 2: Getis-Ord Gi* maps of Martian boulders. This figure shows typical map of hot and cold spots for images (a) inside the latitudinal band and (b) outside the band.