MICROMORPHOLOGY OF RELIC TERRESTRIAL PATTERNED GROUND AS A MARS ANALOG

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Introduction: Patterned ground and polygonal features identified across the Martian mid- to high-latitudes share similarities in surface and subsurface morphology to terrestrial patterned ground [1, 2, 3]. While subsurface water ice was detected by Phoenix, freeze-thaw processes as seen on Earth were not observed. It has been hypothesized that under a warmer environment during periods of high obliquity, freeze-thaw may be possible, which carries important implications regarding the nature of liquid water on Mars in the recent past [4, 5, 6]. Thermal contraction is thought to be possible under present Mars surface conditions, although there are few accessible terrestrial analogs [7].

Determining if patterned ground on Mars is presently active or relic will help to constrain the dominant formation mechanism. This can be accomplished in part by working with existing HiRISE data in conjunction with terrestrial photogrammetry of patterned ground, incorporating both active and relic sites without present-day active layers.

Description: Two field sites were selected to study the micromorphological characteristics of relic patterned ground: a previously characterized relic patterned ground site in the Uinta Mountains in Utah [8] and an uncharacterized patterned ground site located in the Westfjords of Iceland (Fig. 1).

The genesis of hummocky patterned ground in Utah is estimated to have occurred during the Last Glacial Maximum (LGM) [8]. The selected survey locations are in an alpine tundra on a 3720 m elevation plateau that was surrounded by valley glaciers but remained ice-free during the LGM. While alpine permafrost is predicted to exist in the Uinta Mountains today, none has been observed at the site.

Alpine patterned ground in the Westfjords consists of sorted circles and hummocky terrain at 600 m elevation. In-situ measurements revealed a similar temperature profile as observed in the Utah patterned ground (Table 1). As with the Utah site, patterned ground in the Westfjords is situated on a mountain plateau that would have been surrounded but not covered by valley glaciers during the LGM. The subarctic location, presence of nearby active patterned ground at elevations above 800-900 m [9], and the proximity of the site to the Drangajökull ice cap 60 km away suggests that the relative inactivity of the site is a more recent condition.

A DJI MavicPro unmanned aerial vehicle (UAV) was used to rapidly image each site at altitudes ranging from 7.6 to 85 m above ground surface along programmed transects. A series of 7 flights were conducted at different locations across the Uinta Mountains site and 14 flights were conducted across the Westfjords site. Flight locations were chosen to collect a representative sample of the types of patterned ground observed at each site.

Agisoft Metashape/PhotoScan was then used to generate orthoimagery and digital terrain models (DTM) that were imported into ESRI ArcGIS and used to further characterize the micromophology of each site. Results were compared to DTM's of the Phoenix landing site to make predictions regarding the present activity of Martian patterned ground.

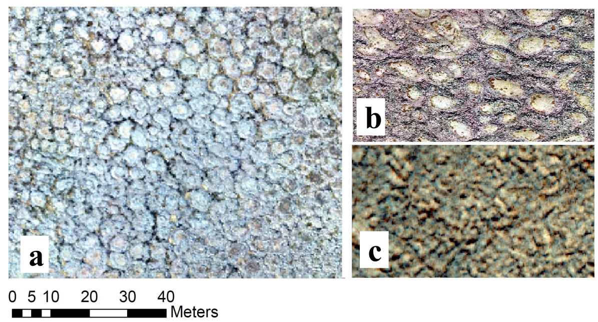

Figure 1: UAS-acquired orthoimagery of patterned ground in (a) Iceland, (b) Utah, and (c) HiRISE image of patterned ground at Phoenix landing site.

Patterned Ground Characteristics				
Site	Depth to Water Ice (m)	0.5m Temp (°C)	Avg. Feature Area (m²)	Sorting
Westfjords, Iceland	NA	5.47	9.11	Well sorted
Uinta Mountains, Utah	NA	4.37	70.6	Poorly sorted
Devon Island, Canada	0.6[10]	1.25[10]	23.54	Well sorted
Phoenix Landing Site	0.05[3]	NA	50.67	Well sorted

NA = Not available or not applicable

Table 1: Selected characteristics of patterned ground in Iceland, Utah, and the Phoenix landing site. Characteristics of active patterned ground on Devon Island [10] for reference.

Results: The micromorphology of terrestrial and Martian patterned ground sites were compared by examining their average dimensions, slope, aspect, and surface roughness. Slope and aspect were derived using the respective spatial analyst tools in ArcGIS. Surface roughness was derived by calculating the standard deviation of height in the raster DTM for each site.

Selected physical characteristics are detailed in Table 1. The average slope of the Iceland and Utah sites are similar at around 16 degrees and the Phoenix landing site has an average slope of 2 degrees. The aspect of all sites lies between 183-199 degrees (to the south-southwest), demonstrating a strong solar influence in patterned ground evolution among all possible modes of formation. Surface roughness is tabulated in Table 2 and visualized in Fig. 2. The surface roughness across all sites averages between 1.0×10^{-4} m and 2.0×10^{-4} m, with the Phoenix landing site trending closer to the roughness of the Utah site.

Surface Roughness				
Site	**Min**	**Max**	**Mean**	**Standard Deviation**
Iceland Sorted Circles	-0.827	0.825	0.000207	0.193
Utah Patterned Ground	-0.929	0.922	0.000133	0.139
Phoenix Landing Site	-0.814	1.000	0.000101	0.124

Table 2: Summary of surface roughness of height in meters between relic terrestrial patterned ground and the Phoenix landing site.

Discussion: The work conducted through this scope is the first step in developing a litmus test that can determine patterned ground activity using morphological indicators derived from existing and future HiRISE imagery in tandem with higher resolution terrestrial data collected via UAV of previously understudied relic sites. The collection of very high resolution terrestrial datasets allows for the establishment of baseline metrics across the spectrum of patterned ground types. These terrestrial baselines can be compared to lower resolution HiRISE data by converting terrestrial data to spatial resolutions that better correlate with HiRISE products from which predictions can be made regarding Martian patterned ground.

The results suggest there are some similarities between terrestrial relic patterned ground and the Phoenix landing site, however a larger survey of sites is needed. In order for this litmus test to be the most effective, additional field work will be conducted at terrestrial field sites where permafrost and seasonal active layers are present. Although they are remote, sites where thermal contraction is possible are desirable in the long term.

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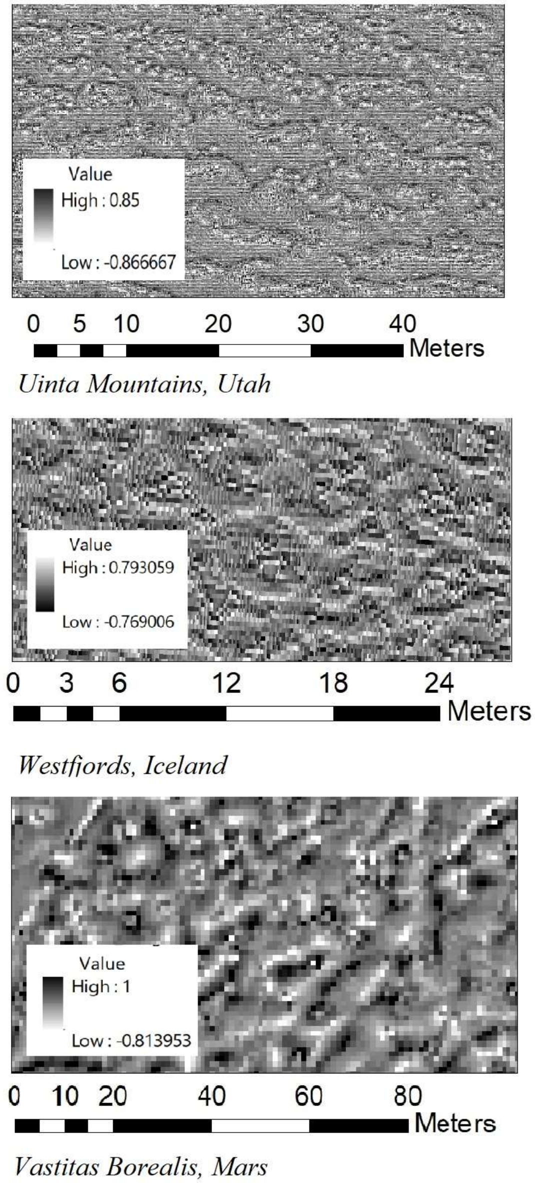

Figure 2: Surface roughness raster images of relic terrestrial patterned ground and the Phoenix landing site.

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