MORPHOLOGY AND IN-SITU MEASUREMENTS OF PATTERNED GROUND IN THE HAUGHTON IMPACT STRUCTURE AND IMPLICATIONS FOR MARS

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Introduction: Periglacial patterned ground is a morphological expression that has been observed in permafrost environments on Earth and Mars. While a combination of orbital and surface observations suggest that patterned ground on Mars today is driven primarily by dry processes (i.e. sublimation or thermal contraction) [1][2], some workers have proposed that wet processes (i.e. freeze-thaw) could have occurred in the past during periods of high-obliquity [3]. There is an extensive track record of analog field work that has examined patterned ground in regions of Antarctica [1][4] and Svalbard [5] to draw comparisons to both contemporary and high-obliquity processes on Mars. We have found that while other workers have looked at the patterned ground in HIS [6], it has not been thoroughly examined with the intent of informing on processes during high-obliquity on Mars.

The periglacial landscape inside the 23 km-wide Haughton Impact Structure (HIS) on Devon Island, Nunavut, Canada provides a unique setting among Earth-Mars analogs for observing patterned ground formed by an active wet layer. We discuss observations collected over the 2017 summer field season during the Mars 160 simulation (M160) of the various types of patterned ground encountered at HIS. Observations included monitoring the temperature and moisture content of the active layer, assessing the grain-size distribution of selected patterned ground morphologies, and the potential implications of these results in assessing martian patterned ground on Mars for evidence of past wet active layers.

Geological Setting: The HIS is thought have formed during an impact event approximately 39 Mya and has remained well preserved despite several periods of glaciation [7]. The intracratere environment provides both morphological and stratigraphic analogs to features observed on Mars that have proposed liquid water origins. These features include gullies around the crater rim, intra-crater channels, crater floor lake sediments, and an assortment of periglacial features including patterned ground, solifluction lobes, and thermokarst.

The three primary geological units that encompass the study area are the Neogene-aged Haughton Formation and the Ordovician/Silurian aged Upper and Lower members of the Allen Bay Formation [7]. Surface outcrops of the predominantly lacustrine Haughton Formation consist of post-impact silt, sand, and mud and surface material from the Allen Bay Formation consists of dolomitic gravels and cobbles.

Patterned Ground: Several types of patterned ground were observed over the course of M160, however due to mission-planning constraints only five sites were selected for detailed study. A summary of each site can be found in Table 1. Of note, Sites 2-4 represent non-sorted, hummocky patterned ground that were selected specifically for having surface morphologies similar to the Phoenix landing site [2].

Temperature and soil moisture dataloggers were deployed to the permafrost active layer contact at Site 1 on July 19 and were retrieved on August 14 prior to departure from the island. A portion of the results is presented in Figure 1. Most notably, the datalogger output details the diurnal variations in temperature throughout the period and demonstrate that the soils in the active layer remained saturated at around 37.5 mg/mg3 water content, which is estimated to be the saturation limit of the soil.

In-situ measurements were collected at each study site (Table 2) including soil pH, electrical conductivity, and temperature that were measured from the sidewall of trenches excavated at each site. The active layer-permafrost boundary was found to range between 0.3-0.7 meters below ground surface and active layer temperatures ranged from 0 C at the permafrost contact up to 7 C near the surface. The moisture content of the soil at each site is near predicted saturation limits for each soil type, reinforcing that patterned grounds featured in this study are undergoing modification through wet periglacial processes in the modern-era.

<table>
<thead>
<tr>
<th>Location ID</th>
<th>Patterned Ground Type</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 1 - A1/A2</td>
<td>Low-relief, non-sorted</td>
<td>Trenching, Samples, In-Situ</td>
</tr>
<tr>
<td>Site 2 - PHX-1</td>
<td>Hummocky, non-sorted</td>
<td>Trenching, Samples, In-Situ</td>
</tr>
<tr>
<td>Site 3 - PHX-2</td>
<td>Hummocky, non-sorted</td>
<td>Trenching, Samples, In-Situ</td>
</tr>
<tr>
<td>Site 4 - PHX-3</td>
<td>Hummocky, non-sorted</td>
<td>Trenching, Samples, In-Situ</td>
</tr>
<tr>
<td>Site 5 - POLY</td>
<td>Sorted polygons</td>
<td>Trenching, Samples, In-Situ</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location ID</th>
<th>pH</th>
<th>Percent Moisture</th>
<th>Temp (°C)</th>
<th>Conductivity (mS/cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 1A1</td>
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<td>59</td>
<td>4.8</td>
<td>0.06</td>
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<tr>
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<td>Site 5-POLY</td>
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<td>0.28</td>
</tr>
</tbody>
</table>

Tables 1 and 2 – Summarized description of each study site and averages from in-situ measurements.
Discussion Alteration by liquid water is thought to have shaped some of the features observed in intracrat environments on Mars, including evidence suggesting that volatiles can be released and brought closer to the surface during impact [8]. Post-impact gullies as well as polygonal terrain and other periglacial landforms that frequently form through aqueous processes on Earth are found to occur in Martian craters [4][9]. Soare et al [9] have suggested that while dry-periglacial processes can explain many of the patterned ground and large-scale polygons occurred in close proximity to fluvial channels, snow meltwater slope streaks, and gullies. The contextual association of polygons and other patterned grounds with fluvial features and gullies are also common in the Argyre and Elysium regions of Mars, among others (Figure 2). Therefore, we propose that our results from studying patterned ground in the HIS can be utilized as an analog for wet-periglacial processes during high obliquity periods on Mars.

Conclusion Through in-situ observations and an analysis of samples collected at 5 patterned ground sites on Devon Island, the current modification of patterned ground in the HIS through wet-periglacial processes was confirmed. Similarities in the morphological context of features on Mars could allow the HIS patterned ground to serve as an analog for wet-periglacial processes during high obliquity periods on Mars.


Acknowledgments: We would like to thank the Mars Society for monetary support and Robert Zubrin for his vision and direction to make Mars 160 possible. We would also like to thank Paul Sokoloff in his role as Co-PI for his assistance in helping navigate the logistical and regulatory process throughout M1602. A portion of this research was carried out on Inuit-owned land (IOL) and we thank the Qikiqtani Inuit Association for granting us an IOL access permit during the summer of 2017.

Figure 1 – Active layer soil moisture and temperature measurements recorded from the center (Probe 1) and margin (Probe 2) of a patterned ground feature.

Figure 2 – A) HiRISE image of sorted polygons on Mars creating circular pattern around topographic low. B) HiRISE photo of patterned ground forming at the terminus of a gully. C) GoogleEarth image of stream networks flowing into polygonal ground in the HIS.