THERMAL PROPERTIES OF WET PATTERNED GROUND IN HAUGHTON CRATER AND IMPLICATIONS FOR MARS.

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Introduction: Patterned ground is a periglacial landform that occurs in cold-weather terrestrial environments [1] and across the mid to high latitudes of Mars [2]. Most terrestrial patterned grounds form via freeze-thaw (wet) processes in which a seasonal active layer develops during local summer as the upper layer of permafrost melts [1]. In contrast, any evolution of patterned ground on Mars under present-day conditions is thought to occur via thermal contraction (dry) processes that do not require seasonal melting of the upper permafrost layer [3]. Constraining the probability of wet active layer development on Mars under warmer climates during past periods of high obliquity is a continuing subject of investigation [4]. Here we present the results of a terrestrial analog study examining the thermal properties of wet patterned ground in an impact crater and the implications for wet patterned ground development inside craters on Mars.

Figure 1. Data logger deployed in patterned ground in Haughton Crater, Devon Island, Canada.

Description: During the course of field operations funded by the Mars Society's Mars Arctic 160 simulation in 2017, a series of temperature and moisture data loggers were deployed in a wet patterned ground site in the Haughton Impact Crater on Devon Island, Canada (Fig. 1). The thermal properties of 4 additional sites were characterized through the collection of in-situ measurements and laboratory analyses across 60 sample locations. Previous efforts to characterize the thermal properties of patterned ground have been undertaken in Svalbard [5] and elsewhere, however no previously identified effort has examined the thermal properties of patterned ground in a periglacial impact crater – a common setting for Martian patterned ground [6, 7].

Field Results

Datalogger Observations

In-situ soil and atmospheric temperature and moisture observations were collected over a 27-day period at a study site immediately below the northwest rim of Haughton Crater. These observations were collected using a set of HOBO Micro Station Loggers collecting soil and atmospheric observations at 1 to 5 minute intervals respectively. With this data we were able to track the changing environmental conditions of the wet active layer/permafrost boundary during peak summer heating. At the initial active layer/permafrost boundary of around 0.45 meters below ground surface, an average soil temperature of 2.01°C was recorded throughout the monitoring period and an average soil moisture content of 37.42% was observed. The average recorded atmospheric temperature at the site was 4.58°C, with a range between -2.07°C and 16.34°C. Dew point temperatures averaged 3.17°C (69% atmospheric moisture).

In-Situ Measurements and Sample Analysis

In addition to the temperature and moisture data loggers, the scope of field work was designed to collect a terrestrial dataset comparable to patterned ground observations from the *Phoenix* landing site with specific interest in results returned by the Temperature and Electrical Conductivity Probe (TECP) [8, 9]. In-situ field measurements including soil temperature, moisture, pH, and electrical conductivity were collected to correspond with patterned ground margins and centers serving as terrestrial TECP analogs. The thermal conductivity, diffusivity, resistivity, and specific heat capacity of samples corresponding to field measurement points were recorded following the field campaign.

The patterned ground in Haughton Crater had an average thermal conductivity of 0.6711 $Wm^{-1}K^{-1}$ and an average heat capacity of 1.6200 x 10^6 $Jm^{-3}k^{-1}$. While *Phoenix* electrical conductivity readings were consistent with an open circuit due to a lack of soil moisture to provide accurate measurements ($2x10^{-6}$ mS/cm), the electrical conductivity of patterned ground in Haughton Crater was observed to be 0.13 mS/cm.

Martian Patterned Ground: TECP results provide an average thermal conductivity of 0.085 $Wm^{-1}K^{-1}$ and volumetric heat capacity of 1.05 x 10^6 $Jm^{-3}k^{-1}$ [8]. Collected during peak summertime heating at the

Phoenix landing site, the observations and subsequent analyses are consistent with near subsurface conditions that are unfavorable for developing a wet active layer under present-day conditions.

Beyond *Phoenix*, *Viking 2* landed in an area of patterned ground [10] and Martian patterned ground has also been characterized at several intra-crater locations including Lyot Crater [6] and the Argyre basin [7]. As with other localities on Mars, present-day environmental conditions in Lyot and Argyre are not expected to be conducive for the development of wet active layers. However, several morphological features in Argyre, including crater wall lobate features and gullies, are comparable to gullies [11, 12] and solifluction lobes (Fig. 2) observed within Haughton Crater that are formed in part due to the action of a seasonal wet active layer. In addition, we have previously described seasonal surface melt flows at Haughton as potential physical analogs for “wet-model” recurring slope linea (RSL) [13] that feed into an area adjacent to the data logger deployment site. The spatial relationship between polygons and gullies in Antarctica has also previously been described [14]. We observe an active relationship between these features in Haughton Crater today (Fig. 2).

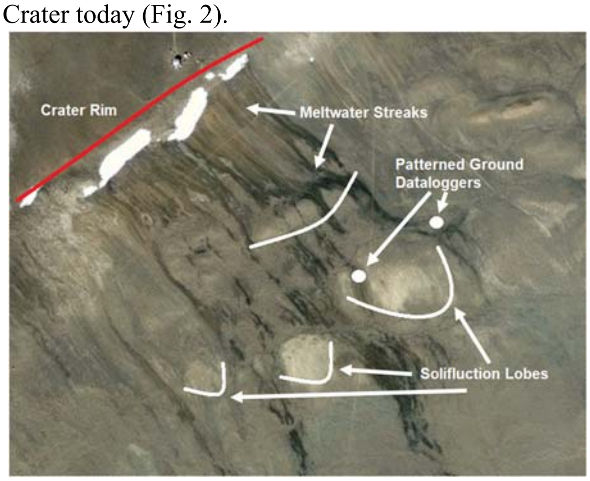

Figure 2. Location of patterned ground data loggers relative to other features in Haughton Crater.

Discussion: The results of our study paint a picture of the thermal and moisture conditions that exist in patterned ground presently shaped via wet active layer processes in a terrestrial intra-crater setting. We find that the average thermal and moisture parameters of intra-crater patterned ground in Haughton differed from those observed at the *Phoenix* landing site, thus supporting the widespread present consensus that the development of wet active layers on Mars today is highly unlikely.

However, we also observed throughout the field campaign that weather conditions did not need to be significantly above the freezing point of water for a wet active layer to develop and expand throughout the summer. It is possible that limited (but sustainable and recurring) excursions past the triple point on Mars could be sufficient for at least intermittent wet active layer development under favorable conditions. However additional modeling of these conditions on high obliquity Mars should be pursued to determine if these conditions are sufficient for patterned ground development and preservation.

Mars Analog Application: Terrestrial patterned ground from several locations around the world have been used in previous Mars-analog studies [14, 15]. The morphology of patterned ground in Haughton has been described previously [16, 17], however to our knowledge this is the first major effort to examine the thermal properties of the crater’s patterned ground. Places such as Argyre basin have a demonstrated connection with past liquid water processes and also contain patterned ground [9]. Therefore, we propose that the patterned ground in Haughton Crater can serve as a useful field analog to aid in future efforts to model high-obliquity wet active layer processes on Mars.

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