COMPARATIVE MORPHOLOGIC INVESTIGATION OF POLYGONS ON DEVON ISLAND, ARCTIC CANADA, WITH IMPLICATIONS FOR MARS ICE ACCESSIBILITY.

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Introduction: Thermal contraction polygons are a prevalent periglacial feature on Earth and Mars and vary widely in morphology in terms of size, shape, regularity, relief, and organization of rocks. There is ongoing discussion about the type of polygons present on Mars [e.g., 1–4], which has major implications for understanding past climate and near-surface ice, particularly at candidate human mission landing sites for in situ resource utilization (ISRU). For example, polygonal terrain has the potential to provide valuable information about the depth, volume, and geometry of near surface ice. However, polygons can appear surficially similar regardless of subsurface ice content. Thus, there is a need to further investigate the linkage between surface morphology and subsurface properties of polygonal terrain.

We investigate three polygon sites located on Devon Island in Nunavut, Canada, originally studied by [5], and characterize their surface and subsurface characteristics by combining geophysical measurements, adaptive thresholding, and statistical analysis. We use this study as a means of verifying the adaptive thresholding model and ultimately aim to use this method to address the following questions: (1) Can buried massive ice be identified from the surface morphology of polygons alone? (2) How does the formation of polygons interact with buried massive ice?

Study Sites: Three polygon sites were investigated on Devon Island, including (1) high centered ice-wedge polygons (IWP) in the Haughton Formation composed of Miocene lake sediments, (2) low centered polygons (LCP) at Orbiter Lake composed of well sorted glaciofluvial dolomitic sediment, and (3) high centered polygons (HCP) at Comet Lake comprised of dolomitic felsenmeer.

Methods: We collected LiDAR data, using the novel AkhkaR4DW Backpack mobile laser scanning system [6] in July 2017, to produce ultra-high resolution (2–5 cm-scale) digital elevation models (DEMs), and UAV imagery to produce orthomosaics of the surface. We also collected GPR data using a Sensors and Software Noggin 250 in July 2019, which includes a 250 MHz antenna on a towing system, to investigate the near-subsurface (ground surface to ~2–10 m max. depth) for pore-filling or massive water-ice.

We manually digitized polygons using DEMs in ArcGIS following methods described by [7] to extract surface morphometrics at each polygon site. However, our team (SC and JE) is developing an adaptive thresholding technique to automatically map the polygons and extract surface morphometrics. Many attempts to devise automatic systems for polygon detection usually involve the use of different machine learning techniques [e.g., 8–10]. Our approach requires minimal manual calibration and can be efficiently run on a laptop computer making it accessible to most scientific investigations of polygons. We are presently in the process of publishing the adaptive thresholding approach and can share more details after publication.

GPR grids were collected to identify ice in the subsurface and characterize its geometry. Pits were also dug at each site, where possible, to determine substrate characteristics.

Preliminary Results: Polygons from the Haughton Formation have been mapped both manually and using our automated method to test the efficacy of this new technique. The automated method shows promising comparative results to the manual mapping (Fig. 1). Over the same 200 m^2 area, we identified 85 polygons manually and 79 polygons automatically. Polygons had an average length (max dimension) and width (min dimension) of 20 m and 12 m, respectively, from manual mapping, and 25 m and 20 m, respectively, from our model. The reason for this relatively small discrepancy is due to the ability for the model to detect smaller secondary polygons and troughs. Additionally, it is possible to expand manual mapping to the edges of a LiDAR dataset (Fig. 2), whereas the automated model requires a rectangular area within the LiDAR dataset which limits the diversity in polygon shapes and sizes analyzed, and removes the affects local topography may have on substrate and subsurface ice content.

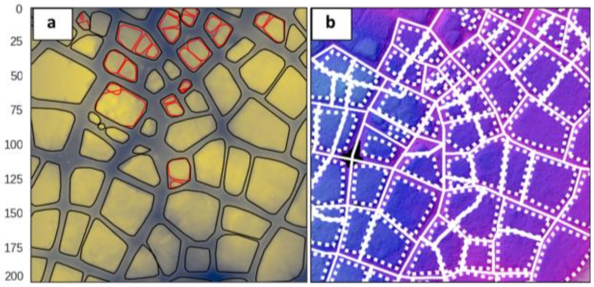

Figure 1. (a) Adaptive thresholding method for automatic mapping of polygons. y-axis in m. (b) Manual mapping of polygons and tough centerlines.

GPR data in the study area revealed a thaw depth in July 2019 to be around 0.5 m and massive ice wedges began around 1 m from the surface (Fig. 2). Ice wedges were generally around 2 m in height. We can use subsurface geometry and trough dimensions to estimate ice wedge volumes in the study areas.

Future Directions: We plan to use our automated model to map and extra surface polygon morphometrics on the other Devon Island polygon sites. GPR data will be used to locate and identify possible subsurface massive ice and estimate ice volumes.

As we continue to map the surface and subsurface, we can assess potential subsurface relationships with surface morphometrics using multivariate statistics.

Implications for Mars: Automated mapping of polygons will enable rapid and widespread characterization of potentially ice-rich terrains on Mars. Associating surface morphometrics with subsurface characteristics of the ice table will allow for generating more accurate estimates of buried ice content. This study will ultimately be used to characterize ice in the upper few meters of the subsurface at polygonal terrain sites on Mars.

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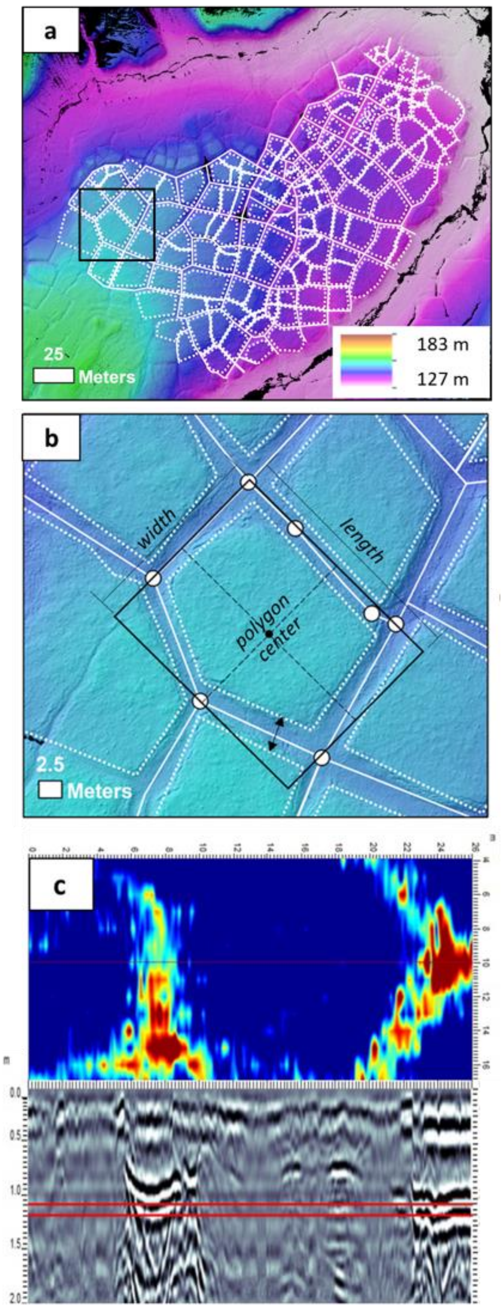

Figure 2. Surface morphometric extraction methods from Ulrich et al. (2011) and subsurface characteristic extraction. (a) Manual digitization of polygon networks using data from high resolution LiDAR DEMs. (b) Morphometrics to be extracted for each individual polygon. (c) 3D (top) and 2D (bottom) GPR data used to extract geometry and volume of wedges in troughs.