POLYGONS OVERLYING MASSIVE ICE: A CANADIAN HIGH ARCTIC ANALOGUE. S. M. Hibbard[1], G. R. Osinski[1], A. Kukko[2], E. Godin[3], S. Chartrand[4], A. Grau[5], M. Jellinek[6], and C. Andres[1]. [1]Institute for Earth and Space Exploration / Dept. Earth Sciences, University of Western Ontario, London, ON, CA (shibbard@uwo.ca). [2]Finnish Geospatial Research Institute, Helsinki, FI. [3]Centre d'Études Nordiques, Université Laval, Québec, Canada. [4]School of Environmental Science, Simon Fraser University, Burnaby, BC, CA. [5]School of Earth and Space Exploration, Arizona State University, Tempe, AZ, US. [6]Dept of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver, CA.

Introduction: Evidence of an ice-rich layer, known as the latitude dependent mantle (LDM), has been observed poleward of 30° on Mars. The LDM shows a range of periglacial features, with polygons being one of the most prominent [1]. Polygons are a common periglacial landform that are commonly thought to be produced from the thermal contraction and subsequent cracking of frozen ground [2]. Polygons can occur in the presence and absence of ice. Despite wet or dry environmental conditions, polygons can appear morphologically similar at the surface.

Excess ice, defined as ice that exceeds the total pore volume of the ground, has been detected in the flat-lying plains of Arcadia Planitia [3,4]. However, no distinct morphological difference in the polygonised terrain has been identified where excess ice has been detected [5].

The factors that drive polygon morphology are not well understood and it is unclear what influence the subsurface ice content and geometry have on the surface expression [6]. As we search for near-surface ice on Mars for future in-situ resource utilization, it is pertinent to understand the relationship that surface morphology has with subsurface ice content.

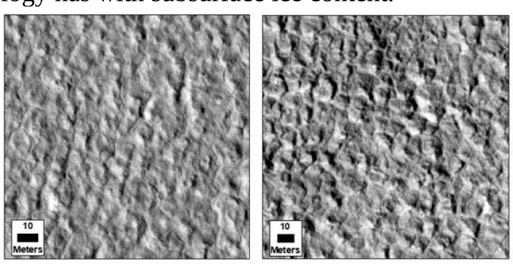

Figure 1: *Polygons in Arcadia Planitia at ~40.5°N. Left: Polygons in surrounding terrain. Right: Polygons overlying possible excess ice.*

Analogue Study: Antarctic periglacial terrain is frequently compared to the LDM due to its cold, dry, and stable conditions, as is the case for Amazonian Mars based on global climate models [7]. However, the Canadian High Arctic is a polar desert and another potential analogue that has received little attention. Accordingly, we investigate polygons on Axel Heiberg Island with a presently active thaw slump exposing a meters-thick formation of massive ice (Fig. 2). We use a combination of high resolution (cm-scale) lidar and near-subsurface (m-scale) ground penetrating radar (GPR) data to investigate relationships between subsurface ice and surface morphology. In particular, we 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?

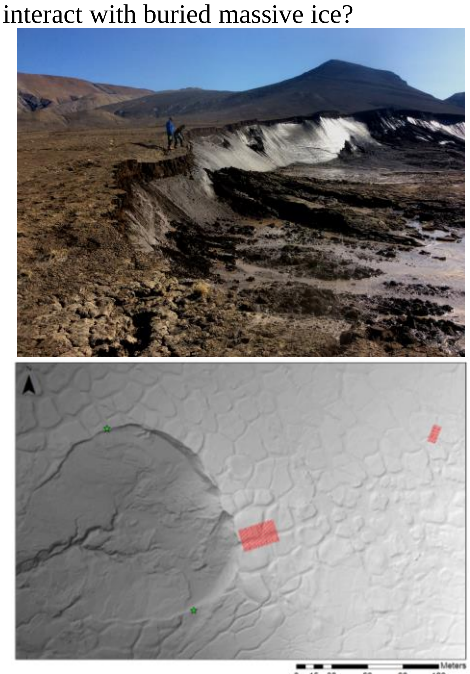

Figure 2: *Top: Field perspective of an active thaw slump exposing a massive unit of ice with overlying polygonal terrain. People for scale. Bottom: Digital elevation model of the thaw slump. GPR line taken along the edge of the thaw slump to and from green stars. GPR grid sites in red.*

Field Site and Methods: High-centered polygons (HCPs) located on Axel Heiberg Island (~80°N), Nunavut, Canada, overlie a massive ice deposit. A ~100 m long outcrop of ice is exposed by a presently active thaw slump (Fig. 2).

High-resolution laser scanning (using AkhkaR4DW backpack mobile laser scanning system) and GPR (using Sensors and Software 250 MHz Noggin) were used to analyze the overlying HCPs in the 2019 Arctic field season. A GPR line along the entire edge of the thaw slump was collected to identify changes in ice thickness (Fig. 2). Two GPR grids were analyzed to locate changes in depth to ice and search for possible ice or sand wedges within troughs. A 30 x 19 m grid (grid site 1) was analyzed near the edge of the thaw slump and a 14 x 7 m grid (grid site 2) ~200 m NE of the thaw slump (Fig. 2).

Results and Interpretations: Polygons have an average diameter of 20 m with a pattern ranging from random-orthogonal to hexagonal [6] (Fig. 2). Soil overlying the buried ice outcrop ranges from 0.55 to 1.3 m thick, which is similar in range to the estimated local active layer depth. Soil is thicker at polygon centers compared to troughs. Sub-rounded to sub-angular cobbles lie on the surface of polygon centers with evidence of substantial wind abrasion suggesting long-term cold and dry conditions. The soil is comprised of dry clay-rich silty material which attenuated the signal of the GPR.

A 2 m long trench was dug at grid site 1 crossing the polygon trough, shoulder and center. The polygon trough has 68 cm of soil overlying the ice, with little to no coarse grains (~1%) and 7 YR 3/2 hue value and chroma. The polygon shoulder is 70 cm thick and 7 YR 3/2. The polygon is 83 cm thick with 2-3% coarse material and 7 YR 3/1 (Fig. 3).

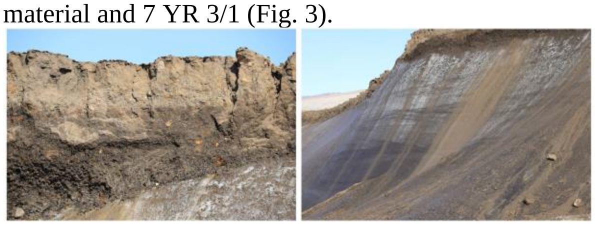

Figure 3: *Left: ~1 m of overlying soil where polygon center overlies ice. Severely weathered cobbles visible in soil. Right: Close-up of ice outcrop. White ice overlying banded/fractured ice overlying dark ice.*

GPR depth slices show evidence of a wedge beneath the trough that penetrates into the massive ice body (Fig. 4). Stronger signals are apparent in the trough at the soil-ice interface. We interpret these wedges to be sediment-rich ice and different from the massive ice unit.

The buried ice outcrop is ~6 m thick; however, the thickness of the massive ice unit may extend deeper into the subsurface. GPR signal was attenuated and the depth to the base of the ice unit was not reached. White-colored ice is visible just beneath the soil layer and is ~0.7 m thick. This overlies ~3 m of banded and fractured ice, followed by ~1.7 m of dark-colored ice (Fig. 3). Ice outcrop thickness decreases towards the lower flanks of the thaw slump until ice is no longer visible. However, this may not reflect the actual thickness of the ice.

The extent, thickness and origin of the buried ice unit is unknown. However, buried ice appears to be present at both GPR grids suggesting massive ice extends NE. Buried ice along the flanks of the thaw slump are present but ice thickness is unknown. Ice samples were collected to determine its origin.

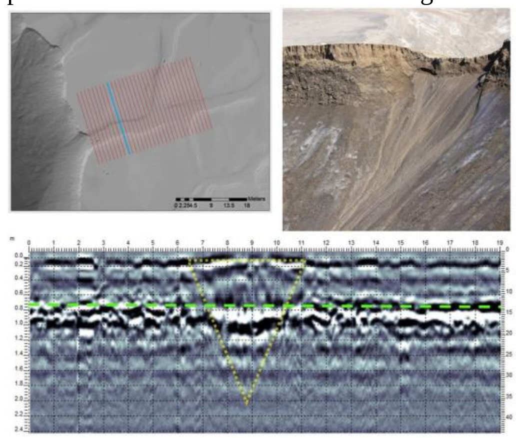

Figure 4: *Left: Lidar DEM of grid site 1. GPR transect below located along blue line. Right: Field outcrop view of the trough analyzed with GPR. Bottom: GPR transect not corrected for topography. Soil/ice interface outlined in green. General wedge shape outlined in yellow.*

Implications for Mars: Arcadia Planitia is a flat lying region in the northern plains of Mars with widespread polygons. There is abundant geomorphological evidence, and supporting shallow radar data [3,4], that suggest massive ice in the near sub-surface [3, 8–10]. Morphological evidence of viscous flow was identified on three sinuous features in Arcadia that may indicate these are potentially buried glaciers with an overlying polygonized layer of loose sand and dust [5]. However, polygons in the surrounding terrain are nearly indistinguishable from polygons over the sinuous features. This leads us to ask what is controlling the surface morphology of polygons if not buried ice? If we can better understand what relationship, or lack thereof, subsurface ice has with the overlying soil in Axel Heiberg, we may be able to better understand why we see little difference in polygon morphology at Arcadia and what other factors may be driving polygon morphology.

References: [1] Levy J. S. et al. (2009) *JGR*, 114. [2] Washburn A. L. (1980) *Wiley*. [3] Bramson A. M. et al. (2015) *GRL, 34*, 6566-6574. [4] Plaut J. J. et al. (2009) GRL, 36. [5] Hibbard S. M. et al. (2018) 49th *LPSC*, Abstract #2606. [6] French H. M. (2017) *Wiley*. [7] Marchant D. R. and Head J. W. (2007) *Icarus, 192(1), 253-271.* [8] Byrne S. et al. (2009) Science, 325, 1674-1676. [9] Dundas C. M. et al. (2014) JGR, 119, 109-127. [10] Viola D. et al. (2015) Icarus, 248, 58-61.