TERRESTRIAL BRAIN TERRAIN AND THE IMPLICATIONS FOR MARTIAN MID-LATITUDES. S. M. Hibbard[1], G. R. Osinski[1], E. Godin[1] and A. Kukko[2], [1]University of Western Ontario (1151 Richmond St, London, ON N6A 3K7, shibbard@uwo.ca), [2]Finnish Geospatial Research Institute (Helsinki, Finland).

Introduction: Periglacial features, such as polygonally patterned ground and brain terrain, are widely distributed across the mid-latitudes of Mars [e.g. 1-5]. The origin of polygonally patterned ground and its relationship to ice on both Earth and on Mars remains debated, although a wide range of possible terrestrial analogues have been documented [e.g. 2]. However, very little is known about the origin of so-called brain terrain and suitable Earth analogues have not been identified.

Brain terrain occurs in the mid-latitudes of Mars and is characterized by an anastomosing complex of ridges and troughs arranged in a "brain-like" pattern (Fig. 1). There have been only a handful of studies on brain terrain; most workers suggest it is periglacial in origin [1,5,6] but its relationship with ice is unknown. The leading hypothesis suggests dry periglacial processes cause localized sublimation of the ice-bearing latitude dependent mantle (LDM) [1].

We recently identified a landform, referred to here as terrestrial brain terrain (TBT), in the Canadian High Arctic [7]. In this study, we report on further occurrences of TBT documented in summer 2019 that may provide insight into brain terrain formation mechanisms on Mars.

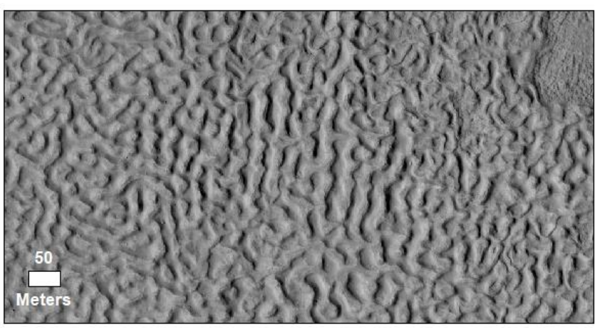

Figure 1: *Example of brain terrain on gently sloping lobate debris apron (LDA) moraine in Protonilus Mensaeat 40°N. HiRISE image ESP_045507_2200.*

Terrestrial Brain Terrain: Since our first identification of a possible terrestrial analogue for martian brain terrain at Dundas Harbor on Devon Island, Nunuvut, Canada [7], we have discovered several other sites on Axel Heiberg Island in our 2019 field season (Fig. 2). These landforms have strikingly similar morphological characteristics to Martian brain terrain. TBT is characterized by a sinuous network of ridges and troughs that form amorphous to well-defined open or closed circles (Fig. 2). We are now continuing our search across the Canadian Arctic by mapping out their distribution using high resolution World Imagery (down to 30 cm resolution).

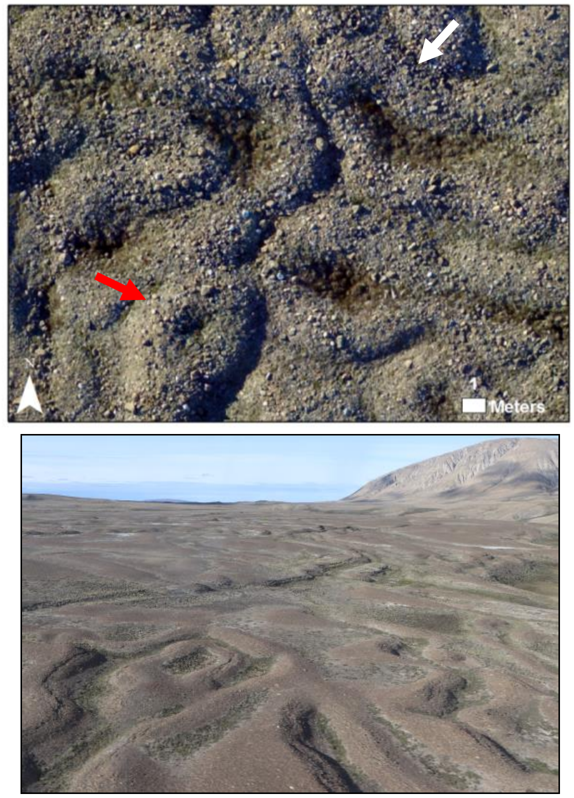

Figure 2: *Top: Example of terrestrial brain terrain (TBT) on gently sloping glacial till moraine in Dundas Harbor, Devon Island. Amorphous (white arrow) to well-defined (red arrow) open and closed circular features. Bottom: TBT field view on Axel Heiberg Island on gently sloping glacio-fluvial plains material.*

Field Methods. We collected a combination of drone imagery (Using DJI Phantom 3 and DJI Mavic Pro), sediment samples, ground penetrating radar (GPR; using Sensors and Software 250 Noggin) and laser scanning (using AkhkaR4DW Backpack mobile laser scanning system) of TBT in the Arctic 2018 [7] and 2019 field seasons.

Observations. Initial observations made by [7] included TBT in an active periglacial environment forming in cobbley glacial till on a gentle slope of ≤ 9°. The presence of relatively fresh axial cracks on ridges, minimal grain sorting, and absence of massive ice are also notable observations.

We have found similarities in scale, morphology, grain size and depositional environment in the additional 4 sites identified in the 2019 field season. All sites have similar ridge width (1–2 m) and height (< 2 m). In some cases, open or closed ridges are much more localized or isolated (Fig. 3c). TBT consistently occurs in larger grained, cobbley material either in glacial till or glacio-fluvial deposits. All TBT occurrences are on gentle slopes less than 10°. Multiple sites also show thermal contraction cracks of polygons cross cutting TBT (Fig. 3) suggesting TBT formation may predate polygon formation.

Figure 3: *Aerial image examples of terrestrial brain terrain on Axel Heiberg Island (a, b) and Devon Island (c). Thermal contraction polygons (arrows).*

Possible Formation Mechanisms. As we continue to process data from the 2019 field season, we are currently exploring two potential end-member hypotheses for the formation of TBT:

(1) TBT formed periglacially through stone circle sorting and solifluction processes [cf., 7]. The presence of relatively fresh cracks in the ridges of TBT suggests differential uplift in the ridges and a possible mechanism for post-depositional sorting. Thermal cracking cross cutting TBT may indicate more than one periglacial process is occurring. This would indicate that TBT is a currently active periglacial phenomenon. More field experiments can be done to test hypothesis. The installation of long term rods to measure ground uplift across a series of ridges and troughs could give us rate and direction of uplift [e.g. 8].

(2) TBT formed due to glacial processes, such as differential melting of an ice-cored moraine or a type of kettle and kame topography. Polygonal cracking would then have come later during the present-day periglacial-dominant conditions overprinting any glacial deposits. This would suggest TBT formed in the past when conditions were icier.

A combination of these two processes is also being considered.

Implications for Mars: Brain terrain can be found across the LDM in the mid-latitudes of Mars. It can be found on concentric crater fill [1], at the base of LDA (Fig. 1), and on flat-lying plains [5]. Two hypotheses for brain terrain formation have been proposed both of which are periglacial in nature. (1) Frost heave mechanisms similar to stone circle sorting processes [6], and (2) Differential interstitial ice sublimation of LDM material [1,5]. These hypotheses suggest brain terrain forms under either strictly wet or dry periglacial processes.

Although TBT is not fully understood, it is morphologically similar to Martian brain terrain and occurs in the cold polar desert environment in the Canadian High Arctic. If TBT is a presently active periglacial landform, then it is forming under wet periglacial conditions, suggesting brain terrain on Mars may be a relict landform.

TBT may be the first appropriate terrestrial analogue and continued studies on TBT may help us better understand brain terrain on Mars.

References: [1] Levy J. S. et al. (2009a) *Icarus, 202*, 462-476. [2] Levy J. S. et al. (2009b) *JGR, 114*. [3] Balme M. R. and Gallagher C. (2009) *EPSL, 285*, 1-15. [4] Zanetti M. et al. (2010) *Icarus, 206*, 691-706. [5] Williams N. R. et al. (2017) *LPS XLVIII*, Abstract #2852. [6] Dobrea E. Z. N. et al. (2007) *7th Intl. Conference on Mars*, Abstract #3358. [7] Hibbard S. H. and Osinski G. R. (2019) *LPS L*, Abstract #2126. [8] Hallet B. and Prestrud S. (1986) *Cambridge, 26*, 81-99.