BRAIN TERRAIN ON EARTH? A POTENTIAL PERIGLACIAL ANALOGUE IN THE CANADIAN HIGH ARCTIC. S. M. Hibbard[1] and G. R. Osinski[1], [1]Centre for Planetary Science and Exploration / Dept. Earth Sciences, University of Western Ontario, London, ON N6A 5B7, Canada (shibbard@uwo.ca).

Introduction: The mid-latitudes of Mars are characterized by ice-related processes and landforms [1–5]. Glacial landforms, such as lineated valley fill, lobate debris aprons, and concentric crater fill indicate significant water-ice deposition in the past [3–6]. Periglacial features, such as patterned ground, can be found across the mid-latitudes of Mars [7–9]. Brain terrain, also referred to as brain coral terrain [10] and crenulated terrain [7], has been proposed to be as a periglacial landform characterized by a series of sinuous ridges and troughs [7,11]. It has been separated into two categories: (1) closed-cell and (2) open-cell brain terrain (Fig. 1; 11). In this study, we have identified comparable crenulations in the Canadian High Arctic for the first time that may have significant implications for understanding the origin of brain terrain and for Mars' past climate.

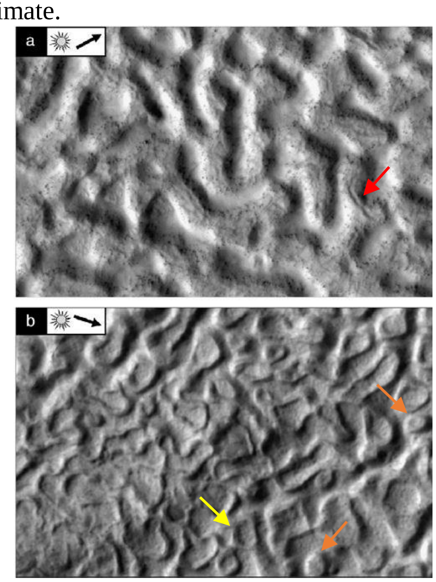

Figure 1: Examples of brain terrain in concentric crater fill in Utopia Planita, Mars. (a) Closed-cell brain terrain with grooves along the axial trace of some ridges (red arrow). Ridges are 20 m wide and up to 100 m long. Boulders rest on top of and along the margins of the ridges. (b) Open-cell brain terrain with closed and open circular ridges. Ridges are 4–6 m wide and ~2 m high. Example of a closed circle with trough indicated by a yellow arrow. Example of a closed circle without trough indicated by an orange arrows. Images from PSP_002175_2210. Modifed from [11].

Field Site and Methods: Crenulated terrain was found and imaged along the coast of Devon Island near Dundas Harbour, in Nunavut, Canada (74°31'45.5" N 82°21'02.9" W). Aerial images were captured using a DJI Phantom 3 drone at 20–30 m above the ground. Images are 12 megapixels captured using the Pix4Dcapture application. An orthomosaic and digital elevation model were produced using Agisoft Photoscan Professional 1.4.4 with a WGS 1984 UTM 16N projection.

Results: Crenulations found at Dundas Harbour are characterized by anastomosing ridges and troughs that occur in an active periglacial environment (Fig. 2). These occur on a very gentle regional slope of approximately 5–10° and exist in a ground moraine of till deposits from a once extant valley glacier. A 10–20 cm layer of organic soil blankets the surface of the glacial diamict. Depth to permafrost roughly follows surface topography with an active layer between ~0.5–1.5 m thick.

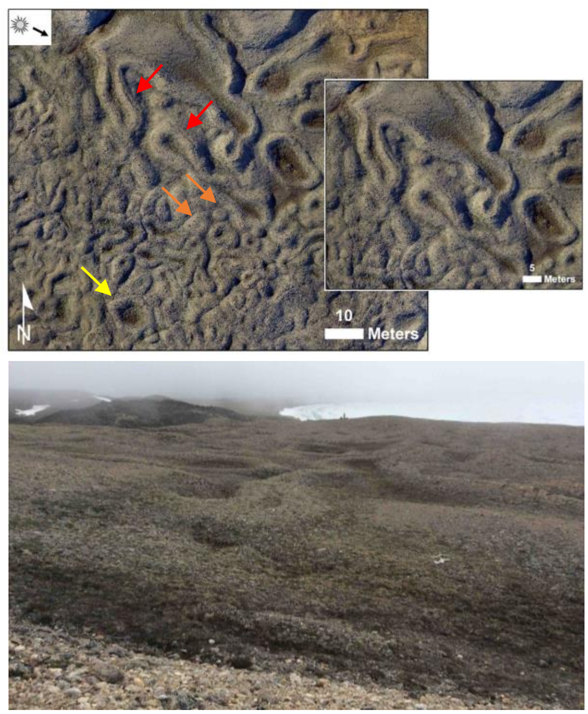

Figure 2: (top) Orthomosaic of Dundas Harbour crenulations from aerial drone imagery. Ridges are up to 4 m wide and 1.5 m high. Cracks are visible along the axial trace of the ridges (red arrows). Closed and open sinuous ridges. Closed circle with trough (yellow arrow). Closed circle without trough (orange arrows). (bottom) Field perspective of crenulated terrain. Person in the distance for scale.

The ridges form a sinuous network of closed and open circles. Ridges are convex-up that grade into concave or flat-floored troughs. Ridges are no greater than

1.5 m in height and 2–4 m wide. Closed circles typically have a concave floor and have a diameter around 4–10 m from ridge-to-ridge and can contain ponds of water. Some ridges form small (< 4 m diameter) closed circles with no trough, likely due to larger grain sizes (Fig. 2). Spacing between ridges ranges from 1 to 10 m. Large cobbles and small boulders rest on the crests of the ridges and occasionally within troughs. Trenches dug to the permafrost layer of a ridge and two adjacent troughs revealed that the largest grain sizes were found in the ridges (up to 42 cm long) while the largest grain found in the trough was 21.5 cm long.

Some crenulations are intersected by thermal contraction cracks that are not quite forming polygonal patterns. Cracking occurs along or just below the axial trace of some ridges. These cracks appear to be fresh (a few years old) by the absence and splitting of vegetation.

Discussion: Fresh cracks along the crests indicate dilation cracking from recent localized doming from periglacial aggradation-degradation processes [12]. The possible presence of sorting within an original glacial diamict suggests post-depositional sorting may be occurring, likely due to frost heave [12]; similar to the self-organization of stone circles [12,13]. The sinuous and circular nature of the crenulations may be the result of subsurface topographic controls, microtopograpic controls [14], discontinuous frost-heave [12], or surface slope solifluction processes [12].

In the Devon Island study area, we only observed this terrain in glacial diamict and were not present in other local sediments, such as raised beach deposits or blocky bedrock mass waste products. This confines the landform formation to occur in poorly sorted loose sediment ranging from silty sand to cobbles and boulders. We are currently investigating the exact formation mechanism, however, there is clearly periglacial modification of the original moraine in which crenulations occur. Whether its morphology is entirely the result of periglacial activity, or if it is due, in part, to the original morphology of the glacial deposits is an important unanswered question that we are investigating further. The timescale at which these features form is also unknown, but they can be constrained to the retreat of the glacial ice in the region approximately 8,000 kyr ago [15].

Implications for Mars: There is an undeniable resemblance between the crenulations found in the Arctic and the crenulations that make up brain terrain on Mars. The width, height and range of shapes of the ridges are comparable [e.g., 11]. Open-cell brain terrain consists of completely closed circles and detached sinuous ridges, as well as smaller circular ridges that do not appear to have developed a trough. Closed-cell brain terrain ridges have grooves along the long axis of the crest of ridges that appear to be similar to the cracks seen along the crenulations in Dundas Harbour. Boulders present along the margins of Martian crenulations on concentric crater fill may indicate large grain sizes in the material, or simply mass wasting contribution from the crater walls [11]. Brain terrain has been documented within ice-rich deposits interpreted to be similar to rock glaciers [3,16]; but also in mid-latitude flat plains dominated by patterned ground [7].

The formation mechanism for brain terrain on Mars is still unknown and remains debated. It has been suggested that brain terrain is analogous to stone circles in Spitsbergen, Svalbard, and may have formed from periglacial processes in a previously warmer and wetter environment in the past [10]. Levy et al. [11] has provided a schematic process for the development of brain terrain suggesting a topographic inversion model produced by cold-desert processes.

Cold-desert processes currently dominate Mars' climate; however the climate may have been different during the early Amazonian. Levy et al. [11] suggest these are an active cold-desert process, while [10] suggests these are relict landforms produced by a wetter climate in the past. Although we do not know the exact formation mechanism of Arctic crenulations, we can infer these are active periglacial processes due to wet soil conditions near freezing temperatures.

Dundas Harbour crenulations may not have formed in the same way as the brain terrain seen on Mars; however, it is possible. This would have huge implications for Amazonian climate on Mars. This would mean that Mars climate would have had to have been warmer and wetter than observed today.

References: [1] Head J. W. et al. (2003) *Nature*, 426, 797–802. [2] Pathare A. V. et al. (2017) *LPSC XLVIII*, Abstract #2543. [3] Mangold N. (2003) *JGR*, 108, 8021–8033. [4] Squyres S. W. (1979) *JGR*, 84, 8087–8096. [5] Plaut J. J. et al. (2009) *GRL*, 36, 2. [6] Head J. W. et al. (2010) *EPSL*, 306–320. [7] Williams N. R. et al. (2017) *LPSC XLVIII*, Abstract #2852. [8] Mellon M. T. et al. (2008) *JGR*, 113, E3; [9] Levy J. S. et al. (2010) *Icarus*, 206, 229–252. [10] Dobrea E. Z. N. et al. (2007) *7th International Conference on Mars*, Abstract #3358. [11] Levy J. S. et al. (2009) *Icarus*, 202, 462–476. [12] Washburn A. L. (1980) *Wiley*. [13] Hallet B. (2013) *Phil. Trans. R. Soc. A*. [14] Kessler M. A. and Werner B. T. (2003) *Science*, 380–383. [15] Dyke A. S. (1999) *Quaternary Science Reviews*, 393–420. [16] Mangold N. and Allrmand P. (2001) *GRL*, 28, 3, 407–411. [17] Levy J. S. et al. (2007) *JGR*, 112, E08004.

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