MID-LATITUDE PATTERNED GROUND ON MARS. EVIDENCE FOR ROCK SORTING ON MARS?

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Introduction: One of the key drivers of the Mars Exploration Program is the search for evidence of past or present life, and locations that experience periodic thawing of near-surface ice are attractive targets to search for extant life. Although liquid water is not stable on present day Mars at or near the martian surface, modeling studies of the atmosphere and climate system suggest recent and periodic occurrence of conditions conducive to transient thawing [1-3].

Multiple classes of young geomorphic features suggest that thawing may have occurred in the geologically recent past and may still be ongoing on Mars [4-6], although significant controversy remains [7-8].

Other intriguing candidate targets are young geomorphic features that resemble terrestrial periglacial landforms [*e.g.*, 9-16]. Of these, landforms interpreted as sorted stone circles and stripes are particularly interesting because they are relatively young and on Earth these types of landforms develop via freeze-thaw processes [e.g., 17]. On the basis of morphology and scale, [14] hypothesized that a terrain type, colloquially known as "brain coral", is the morphological equivalent of sorted stone circles on Earth (Figure 1). However, while their morphologies are similar, similarity in form does not necessarily imply the same underlying process. It is therefore important to compare available hypotheses by performing a careful and detailed study of this terrain.

The goal of this study is to assess whether "brain coral" is the martian equivalent of terrestrial sorted stone circles.

Approach: We consider the multiple alternative hypotheses and identify a set of characteristics that can be tested for using available data (Table 1). We are in the process of testing against the following hypotheses:

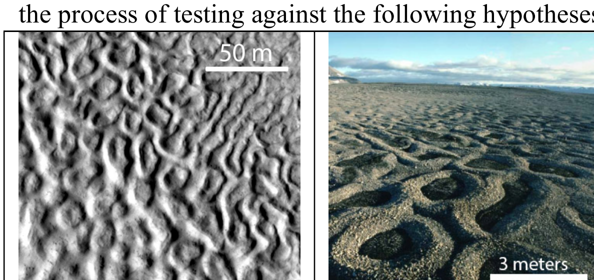

Figure 1. (Left) Transition zone between the polygonal terrain (upper right corner) and the "brain coral" texture (lower left corner). The transition band, running from the upper left corner to the bottom right, consists of closed-form ridges, which progressively thicken towards the bottom left to form mesas and knobs. (Right) Sorted stone circles in Spitsbergen, Norway exhibiting similar landforms.

H1. *Sublimation lag* [18]: complex patterns of small pits and buttes result from the sublimation of ice from a dust matrix cemented by interstitial ice, where the sublimation of the ice is especially initiated and accelerated by subsurface heterogeneities like fractures.

H2. *Topographic inversion of thermal contraction polygons* [19]*:* polygonally fractured terrain forms from thermal contraction and expansion cycles of the ground. Ice/Sand/rock wedges form at the fractures, and subsequent sublimation of the polygons' interiors and protection of the wedge by a lag deposit results in the formation of closed-cell brain coral. Further sublimation of the ice from the wedge creates narrow ridges, which constitute the ridges of open-cell brain coral.

H3. *Rock sorting processes akin to sorted stone circles* [14]: Cryoturbation caused by cyclic ground heave separates rocks from soil and causes the soil to convect in well-defined cells. The result is a series of soil plugs surrounded by rocky ridges that form circles and other irregular, labyrinthine patterns. Closed-form cells (mesas) result from higher rock-to-soil ratios and open-form cells (ridge-bounded hollows) result from lower rock-to-soil ratios (*e.g.*, Kessler *et al.*, 2003). On Earth the formation of sorted stone circles is constrained to areas known to exhibit freeze thaw cycles, independent of geology or surface composition although topographically higher terrains nearby provide hydraulic head to maintain groundwater at the sites of the stone circle formation.

Global distribution: We applied convolutional neural networks to the MRO/HiRISE dataset in order to detect images containing "Brain Coral" [20]. Given the large volume of the HiRISE dataset, we employed a hybrid approach, where the first pass used a classifier network at 1/16 resolution to flag potential candidates. In a second pass, a segmentation algorithm is used on each flagged image in order to produce a mask at the native resolution. The hybrid pipeline approach maintains ~96% accuracy while cutting down on ~80% of the total processing time compared to running the segmentation network at the full resolution on every image. Figure 2 shows the extent of our survey highlighting the positive detections in green (187), possible detections in orange (243), and negative detections in red (55886). We found that brain coral terrain is dominantly found in a narrow range of latitudes and elevations, with the largest fraction occurring around 40°N at the dichotomy boundary in the northern hemisphere.

Table 1. Observables used to distinguish between published hypotheses.

Observable	**H1. Sublimation lag**	**H2. Topographic inversion**	**H3. Stone sorting mechanisms**
Correlation to regions of episodic thaw	None expected	None expected	Yes
Correlation to local topography	Asymmetry in pole vs. equator-facing slopes.	None expected	At base of local topography
Mean cell-size vs. latitude	Potentially	Yes	Yes
Decameter Slopes	Unconstrained	Unconstrained	≤ 3º (Mangold, 2005)
Slopes of ridges	Unconstrained (material may be cemented)	≤ angle of repose	≤ angle of repose
Thermal inertia	Low – dust must protect ice from sublimation	Low – dust must protect ice from sublimation	Intermediate – rocky ridges, soil-rich cell-interiors
Rock distribution	Heterogeneous, potentially higher in troughs due to rolling of under-mined stones downhill.	Rocks and boulders concentrate on ridges.	1) Rock Concentration: close-cell > open-cell 2) Rocks and boulders concentrate on ridges and mesas.

Discussion: The relatively narrow band of latitudes and elevations in which brain coral terrain is found suggests that climate may be a driving mechanism Climate models suggest that above-freezing temperatures can occur at the mid to high latitudes in the near surface during periods of high obliquity [1, 3] or during periods in which periapsis coincides with northern summer [2]. Observations of shallow ice excavated by small impacts at mid-latitudes [21] and significant volumes of ice found to underlie lobate debris aprons [22] assure that ice is available for thawing. This latitudinal/elevation band could represent sweet spot between the lower-lying higher latitudes that may never see sufficient thawing and the higher elevation and lower latitude terrains where the ice instead sublimates.

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References: [1] Costard *et al.* (2002), *Science* 295; [2] Mischna and Richardson (2005), *Geophys res let*, *32*(3); [3] Kreslavsky *et al.* (2008), *Planet Space Sci*, *56*(2); [4] Malin and Edgett (2000), *J. Geophys Res*, 106(E10); [5] McEwen *et al.* (2011), *Science* 333; [6] Ojha *et al.* (2015), *Nature Geosci*, 8(11); [7] Dundas *et al.* (2017a), *Geol Soc, London, Sp Pubs*, 467; [8] Dundas *et al.*, (2017b), *Nature Geosci* 10; [9] Mangold (2005), *Icarus* 174; [10] Burr *et al.* (2009), *Planetary and Space Science*, *57*(5); [11] Dundas and McEwen (2010), *Icarus* 205; [12] Soare *et al.* (2013), *Icarus*, *225*(2); [13] Mellon *et al.* (2008), *J. Geophys. Res*, *113;* [14] Noe Dobrea *et al.* (2007), *7th Int Conf Mars, p.3358;* [15] Balme *et al.* (2009), *Icarus* 200; [16] Gallagher *et al.* (2011), *Icarus* 211; [17] Kessler and Werner (2003), *Science*, *299;* [18] Mangold, N. (2003) *J. Geophys. Res.*, VOL. 108, NO. E4 [19] Levy *et al.* (2009) *Icarus* 202 [20] Pearson *et al.* (2023) *IEEE IGARS 2023* [21] Dundas et al. (2014), *J. Geophys. Res.* 119; [22] Plaut et al. (2009), *Geophys. Res. Lett.* 36.

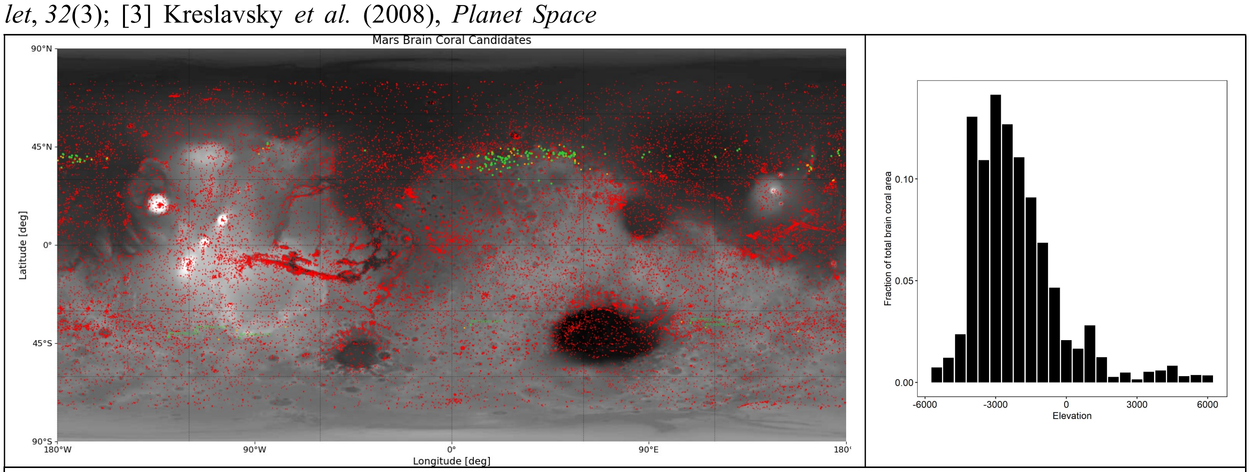

Figure 2. (Left) Detection of Brain Coral textures superimposed on MOLA topography [18]. Green: positive, manually vetted, Orange: potential, not manually vetted Red: no detection. (Right) Histogram showing range of elevations for positive and potential detections.