POSSIBLE ICE-WEDGE POLYGONISATION IN UTOPIA PLANITIA, MARS, AND ITS POLEWARD LATITUDINAL-GRADIENT.

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Introduction: Here, we report, describe and evaluate: 1) the presence and widespread distribution in eastern Utopia Planitia (*UP*), Mars, of small-sized polygons, i.e. ~10-25 m in diameter, with low (*LCP*) or high centres (*HCP*) (relative to their margins); 2) the spatial if not periglacially-genetic association of these polygons and thermokarst-like depressions or basins; 3) the (poleward and statistically significant) latitudinal gradient of *LCP* distribution; and, 4) the possibility that this gradient is a geological marker of extant ice-wedging wherever the *LCPs* are observed.

Low/high-centred polygons on Earth: Geographically-expansive and morphologically-similar (late Holocene-epoch) assemblages of low/high-centred (ice-wedge) polygons and thermokarst-like basins (alases) are commonplace in cold climate, non-glacial landscapes on Earth, i.e. the Tuktoyaktuk coastlands of northern Canada and the Yamal peninsula of eastern Russia. Here, the permafrost is metres to decametres thick and *ice rich* [e.g. **1-4] (Fig. 1)**. Ice-rich permafrost comprises *excess ice,* i.e. "the volume of ice in the ground which exceeds the total pore-volume that the ground would have under natural unfrozen-conditions" **[5]**; ice lenses, veins, wedges or larger masses of consolidated ice are typical examples of excess ice **[5]**.

In the Tuktoyaktuk coastlands and Yamal peninsula assemblages of *LCPS/HCPs* and alases are geological bellwethers of transient or long-term rises of sub-aerial and thaw-generating mean temperatures [e.g. **6-7]**. Field observations and periglacial principles coalesce in support of these statements and suggest that this is as true today as it would have been in the past.

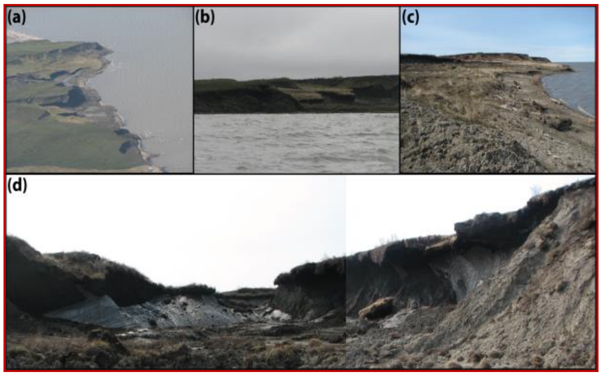

Fig. 1. Near surface massive ice and ice wedges at Peninsula Point, 6km SW of Tuktoyaktuk. Note, the terracing **(a-c)** induced by the thermal destabilisation of the coastline and the surface depressions immediately above degrading ice-wedges **(d)**. Image credit, R. Soare.

First, high-centred (ice-wedge) polygons are degradational landscape-features that form if and only if ice-wedge *LCPs*, i.e. polygons with uplifted shoulders or margins due to the aggradation of ice at the shoulders, thaw **[2, 8]**. Second, thermokarstic terrain is ice rich; an alas forms if and only when ice-rich terrain undergoes thermal destabilisation, meltwater pools locally and, subsequently, either evaporates or drains away **[6, 10]**. This leaves an emptied thermokarst basin, an alas, in its morphological wake.

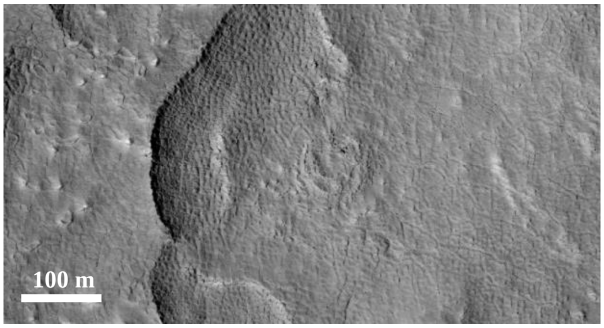

Fig. 2. A possible thermokarst/polygon complex in eastern *UP*. *LCPs* located adjacent to the depression scarp on the left side of the image; *HCPs* immediately to the right of the low-centred polygons. *HiRISE* ESP_026094_2250; 44.657° N, 111.415° E; 25 cm/pixel res. North is up. Image credit, NASA/JPL/University of Arizona.

Low/high centred polygons in eastern Utopia Planitia: The presence of *LCPs/HCPs* at the mid-latitudes of both Martian hemispheres, as well as the spatial and possibly genetic association of these polygons with alas-like landforms **(Fig. 2)**, has been noted in the literature **[**e.g. **9-12]**.

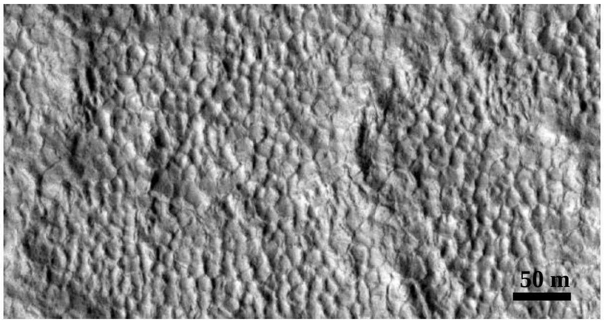

Fig. 3. Dense distribution of *LCPs* near the central peak of a large crater. *HiRISE* ESP_011523_2235; 42.953° N, 115.670° E; 25 cm/pixel res. North is up. Image credit, NASA/JPL/ University of Arizona.

However, in the case of the *LCPs/HCPs* themselves **(Figs. 3-4),** questions concerning the extent and density of their distribution, on a regional or a sub-regional scale, as well as the possibility of a poleward skew of distribution due to the greater stability of near-surface ice with increased latitude, have not been explored.

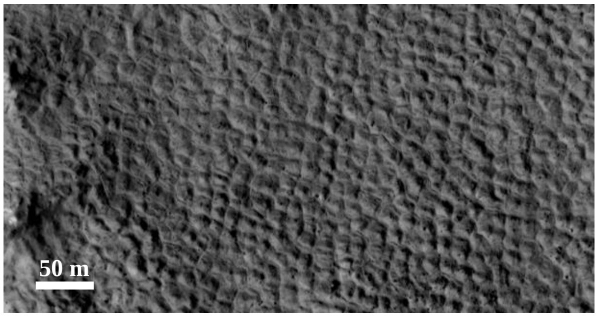

Fig. 4. Dense distribution of *HCPs* on a gullied and equator-facing crater-wall that also exhibits thermokarst-like depressions. *HiRISE* ESP_018960_2240; 43.468° N, 116.999° E; 25 cm/pixel res. North is up. Image credit, NASA/JPL/ University of Arizona.

In order to address these questions we have studied all of the available *HiRISE* images (25-50cm/pixel resolution) in a sub-region of eastern *UP* (40-50° N; 110-125° E). This area exhibits wide-ranging assemblages of polygonised terrain (clastically sorted or non-sorted), polygon-margin troughs and alas-like basins, all of which are thought to be periglacial in origin and possibly formed by means of the freeze-thaw cycling of water in the very Late Amazonian Epoch **[**e.g. **11, 13-14]**.

There are 101 *HiRISE* images in our study region. Other data sets comprised of lower-resolution images are not used because the elevated shoulders and depressed marginal-troughs associated with low/high polygon assemblages are metres to sub-metre in scale and can be resolved clearly only with *HiRISE* imagery.

Our data table comprises only those images (*n*=77) within this population (*N*=101) that exhibit polygons with distinctly low centres, high centres or with centres not distinguishably different in elevation from the polygon margins. Statistical analysis of disparate spatial and possible genetic-relationships amongst and between key landscape features, landforms and landscapes identified in our data table was performed using *PCA* (Principal Component Analysis) **[15]**.

Results: Our image analysis and statistical evaluation of *LCP/HCP* distribution produced five key findings:

1) *HCPs* occur more frequently than *LCPs.*
2) *LCPs* are widespread but occur only where *HCPs* also are observed.
3) The ratio of low to high-centred polygons increases polewardly with latitude.
4) *LCPs* occur if and only when they reside within or are adjacent to thermokarst-like depressions.
5) The latitudinal and statistically significant gradient of *LCP* distribution is consistent with the hypothesised increase of near-surface ground ice with latitude **[**e.g. **16-17]**

Discussion: Heretofore, hypotheses favouring the possible presence of ice-wedge *LCPs* on Mars have foundered because of the morphological similarity between *LCPs* on Earth whose margins are uplifted by sand and those uplifted by ice. Even when Martian *LCPs* exhibit spatial association with other possible *wet* periglacial landforms and landscape features, i.e. *HCPs* and thermokarst-like depressions, the *ice-rich* contextualisation of the *LCPs* has remained circumstantial.

We propose that the synonymity between the statistically-significant increase of *LCP* distribution with latitude in eastern *UP* and expectations of ground-ice stability at poleward latitudes enables one to conclude (with a relatively high degree of confidence) that the *LCP* margins are underlain by ground ice. In turn, this suggests that boundary conditions consistent with the freeze-thaw cycling of water ruled when the *LCPs* formed.

References: **[1]** Rampton, V.N. and Bouchard, M. (1975). *GSC*, Paper 74-53, 16 p. **[2]** Rampton, V.N. 1988. *GSC*, Memoir 423, 98 p. **[3]** Schirrmeister, L. et al. (2002). *IJES* 91, 154-167, doi. 10.1007/s005310100 205. **[4]** Schirrmeister, L. et al. (2013). Pleistocene ice-rich syngenetic permafrost of Beringia. eds. Elias & Mock, *Encycl. Quater. Sc.*, 3, 542-552. **[5]** Harris, S.A. et al. (1988). *Tech. Memo.* 142, Perm. Subcomm., NRC, 154 p. **[6]** Washburn, A.L. (1973). *Periglacial processes and environment*. New York, NY, St Martin's Press, 320 p. **[7]** Hill, P.R. et al. (2001). *Sedimentology* 48, 1047-1078. **[8]** Hallet, B. et al. (2011). *QR* 75, 347-355, dx.doi.org/10.1016/j.yqres.2010.12.009. **[9]** French, H.M. (2007). *The periglacial environment*, West Sussex, England, J. Wiley & Sons, 458 p. **[10]** Lefort, A. et al. (2009). *JGR* 114, E04005, doi:10.1029 /2008JE003264. **[11]** Séjourné, A. et al. (2011). *PSS* 59, 412-422, doi:10.1016/j.pss.2011.01.007. **[12]** Soare, R.J. et al. (2016). *Icarus* 264, 184-197, doi.10. 1016/j.icarus.2015.09.019. **[13]** Costard, F.. and Kargel, J. (1995). *Icarus* 114, 93-112. **[14]** Soare, R.J. et al. (2008). *EPSL* 1-2, 382-393, doi.org/10.1016/j. epsl.2008.05.010. **[15]** Joliffe I.T. (1986) Principal Component Analysis and Factor Analysis, in: *Principal Component Analysis*. New York, NY: Springer, 115-128. doi:10.1007/978-1-4757-1904-8_7. **[16]** Mellon, M.T. Jakosky, B.M. (1993). *JGR* 98, E2, 3345-3364. **[17]** Mustard, J.F. et al. (2001). *Nature* 412, 411-414, doi:10.1038/35086515.