POSSIBLE PINGO & ICE WEDGE/THERMOKARST COMPLEXES IN UTOPIA PLANITIA, MARS. R.J. Soare,[1] S.J. Conway,[2] J-P. Williams,[3] C. Gallagher,[4] and L.E. Mc Keown.[5] [1]Geography Dept., Dawson College, Montreal, QC, Canada (rsoare@dawsoncollege.qc.ca); [2]CNRS UMR 6112, LPG, Nantes, France; [3]Dept. of Earth, Planetary & Space Science, UCLA, Los Angeles, CA, USA; [4]School of Geography, University College Dublin, Belfield, Dublin 4, Ireland.; [5]Geography Dept. Trinity College, Dublin, Ireland.

Introduction: Here, we report, describe and evaluate the presence and distribution of small-sized (sometimes domed) circular or sub-circular mounds (~100 m in diameter and metres in elevation) in Utopia Planitia (*UP*) (~35-50^0 N; ~80-115^o E, n = 513 *HiRISE* images) The mounds are observed: **a)** in the midst of or adjacent to rimless and sometimes scalloped, polygonised and metres to decametres-deep depressions; **b)** in areas where metres-deep polygon-margin pits or troughs are extensive; and, **c)** in a relatively-narrow latitudinal band (~40-45^0 N) **(Figs. 1-2)**. Some of the mounds exhibit summit depressions; some mounds display summit cracks that intercept the polygonal cracks in the surrounding terrain. We propose that the mounds are hydrostatic or closed-system pingos (*CSPs*).

Earlier work **[2-3]** discussed the possible presence of *CSPs* in paleo-lake (crater) basins at near polar Martian latitudes. We suggest that the *CSPs* occur in a mid-latitudinal region of Mars where possible ice wedge/thermokarst complexes dominate the landscape and near-surface ground ice is stable.

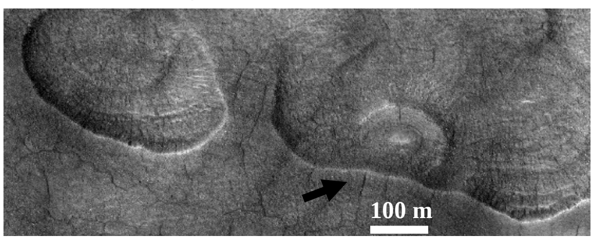

Fig. 1. Small, domed mound on floor of a polygonised and tiered thermokarst-like depression (*HiRISE* image PSP 008913_2255; 45.206^0 N; 95.528^0 E). North is up. Image credit: *NASA*/*JPL*/ Univ. of Arizona.

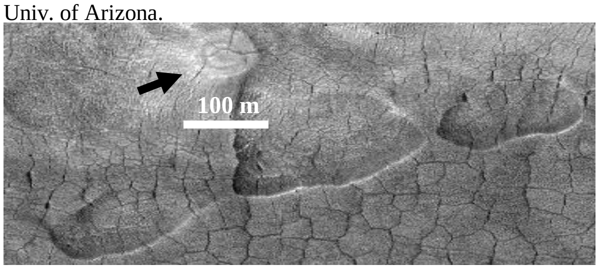

Fig. 2. Similar small, domed mound on floor of a polygonised and tiered thermokarst-like depression (*HiRISE* image ESP_016759_2235; 43.370^0 N; 87.904^0 E). Note the summit-cracks that intercept the polygonised cracks in surroundng terrain. North is up. Image credit: *NASA*/*JPL*/Univ. of Arizona.

Closed-system pingos on Earth: In regions of continuous, relatively-deep and ice-rich permafrost such as the Tuktoyaktuk Coastlands (*TC*) of northern Canada and northeast Siberia, *CSPs*, a type of perennial ice-cored mound, are commonplace **[1,4] (Fig. 3)**.

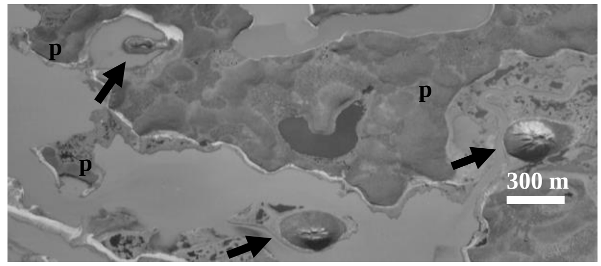

Fig. 3. Ice-rich and pingo-populated thermokarst landscape in the *TC* (aerial photo A27917-35-1993). Note: **a)** summit depressions and cracks on the two largest pingos, Split (centre-bottom) and Ibyuk (right); and, b) polygonised terrain [**p**]. North is to the left. Image credit: National Air Photo Library, Ottawa, Canada.

The mounds originate and evolve in response to the hydrostatic uplift of pore water pressured by aggrading permafrost **(Fig. 4)**. As the freezing front advances trapped pore-water uplifts the sedimentary overburden (i.e. the newly-exposed lake floor) and a mound begins to form. Radial-dilation cracks may propagate from the summit as the mound grows and tensile stresses within the overburden increase. Sometimes, these cracks grade into the surrounding polygonised terrain **[1]**.

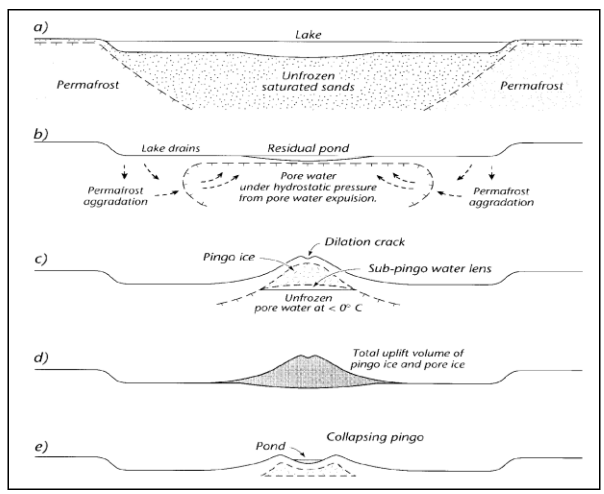

Fig. 4. Diagram of *CSP* development in the TC **[1]**.

Proposed geochronology of *CSP* formation in eastern Utopia Planitia:

1) Surface deposition and accumulation of atmospherically-precipitated ice/snow in respsonse to recent variances of obliquity and eccentricity**[e.g. 5-7]**.

2a) Freeze-thaw cycling of surface ice/snow; migration of meltwater into the near-surface regolith and the formation of excess ice **[8-9]**, i.e. "the volume of ice in the ground that exceeds the total pore-volume of the ground under natural unfrozen conditions" **[10-11]**.

2b) Specifically, ice veins, lenses or larger masses of consolidated ice develop in the near-surface regolith **[8]**. Here, at the northern mid-latitudes, the near-surface ice intermittently is stable **[12]**.

3a) Thermal-contraction cracking polygonises the local/regional landscape **[e.g. 13-14, also 15-18]**. **3b)** Episodic and localised sublimation and/or thaw volatilises the excess ice, degrading/deflating the terrain; this forms thermokarst-like depressions. In turn, the depressions incise the polygonised terrain **[14-19]**. **3c)** Depression-based low and high-centred polygons (*lcps/hcps*) develop subsequently. Together, the two polygon types could be geological markers of near-surface ice-wedge aggradation/*lcp*, degradation/*hcp* and of the transient freeze-thaw cycling of water **[20]**. In the adjacent terrain, connected linear polygon-troughs and corner pits are consistent with this transitional hypothesis and are morphologically synonymous with beaded-stream networks in ice-rich terrain on Earth **[18]**. **3d)** Depression tiers develop intermittently. They may be indicative of iterative devolatilisation and of thermokarstically-driven surface deflation **[e.g. 8, 15-17]**.

4) Meta-stable triple-point conditions, facilitated by recent changes of obliquity and eccentricity and, perhaps, by briny regolith [**e.g. 21-24**], produce the: **i)** thaw of near-surface excess-ice within the depressions; and, **ii)** meltwater pooling beneath the depressions.

5a) Subsequent freezing-conditions induce permafrost aggradation in the near-surface regolith, overburden uplift as the hydrostatic pressure of trapped meltwater increases and, the formation of an ice-core as the water freezes. **5b)** Dilation cracks form at the summit as the overburden stretches; some of the cracks radiate towards and eventually intercept the adjacent polygonised terrain.

Discussion: There are multiple pathways for explaining the devolatilisation of the near-surface excess ice that forms the thermokarstic depressions **[8-9, 13-19]**. This nowithstanding, the freeze-thaw cycling of meltwater is the only known process that can generate excess ice to decametres of depth **[8-9, 13-19]**.

Modelled **[e.g. 21-22]** and experimental findings **[e.g. 23]** as well as observational deductions **[e.g. 24]** suggest that briny freezing-point depressants at/near the Martian surface and diurnal temperatures/pressures above the triple point may be commonplace at all latitudes on Mars, at least diurnally and for relatively short periods of time.

It should also be noted that triple-point conditions need not be stable for expansive periods of time in order to promote the origin and development of ice complexes, let alone *CSPs.* Upon draining a thermokarst lake in the *TC,* Mackay observed the evolution of small pingo-like mounds within ~20 years of that event and through ~20 seasonally/diurnal cycles of freeze-thaw **[25]**.

Absent of boots on the ground and a pick or shovel, validating the *CSP* hypothesis by unearthing ice-cores physically is not possible. However, the geological consilience amongst a suite of diverse and Mars-based variables does point towards a frozen-water origin for the candidate *CSPs.*

First, multiple landscape-features and forms that collectively share the surface with the *CSPs* are synonymous with and are analogical to ice-rich terrain and the freeze-thaw cycling of water on Earth. Second, current work shows that the temperature/pressure requirements of the latter might have been present for periods of time sufficient for water-based periglaciation to evolve in our study region. Third, the mid-latitude location of the mounds is consistent with recent models of near-surface ice-stability.

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