POSSIBLE PINGO & ICE WEDGE/ThERMOKARST COMPLEXES IN UTOPIA PLANITIA, MARS. R.J. Soare,1 S.J. Conway,2 J-P. Williams,1 C. Gallagher,4 and L.E. Mc Keown.3 1Geography Dept., Dawson College, Montreal, QC, Canada (rsoare@dawsoncollege.qc.ca); 2CNRS UMR 6112, LPG, Nantes, France; 3Dept. of Earth, Planetary & Space Science, UCLA, Los Angeles, CA, USA; 4School of Geography, University College Dublin, Belvedere, Dublin 4, Ireland.; 5Geography 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°N; ~80-115°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° 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-latitude 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°N; 95.528°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°N; 87.904°E). Note the summit cracks that intercept the polygonised cracks in surrounding 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 response 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 (lcp/hcp) 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 devolatisation and of thermokarstically-driven surface deformation [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 devolatisation of the near-surface excess ice that forms the thermokarstic depressions [8-9, 13-19]. This notwithstanding, the freeze-thaw cycling of meltwater is the only known process that can generate excess ice to decametres of depth [8-9, 13-19].

Modelling [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.