PERENNIAL MOUNDS IN UTOPIA PLANITIA: (HiRISE) EVIDENCE OF A GLACIAL ORIGIN. R.J. Soare,[1-3] G. R. Osinski[3] and L. Thomson.[3] [1]Dept. of Geography, Planning & Environment, Concordia University, 1455 de Maisonneuve, Blvd. W., Montreal H3G 1M8, Canada. [2]Dept. of Geography, Dawson College, 3040 Sherbrooke St. W., Montreal, Canada H3Z 1A4. [3]Depts. of Earth Sciences & Physics and Astronomy, University of Western Ontario, 1151 Richmond Street, London, Canada N6A 5B7.

Introduction: "Closed" pingos are perennial ice-cored mounds that are formed by hydrostatic (pore-water) pressure induced by localised permafrost aggradation (Fig. 1). These mounds are commonplace features of periglacial landscapes on Earth such as the Tuktoyaktuk Coastlands of northern Canada. A number of studies have reported the occurrence of mounds in the middle to northern latitudes of Utopia Planitia (UP), Mars, whose morphology, size and geological characteristics - summit cracks and raised (collapse-like) rims - are suggestive of terrestrial pingos [1-6]. The mounds and the geological units upon which they reside are thought to be youthful, having formed in the late Amazonian period [7-11].

At least on Earth, the formation of closed pingos requires the presence of ponded water, soil saturation to metres of depth and the development of an ice core from injected and subsequently frozen pore-water [12-13]. Were the occurrence of pingos on Mars to be confirmed, current hypotheses about "dry" periglacial or glacial processes dominating relatively recent landscape modifications in UP [9,13] might have to be revised.

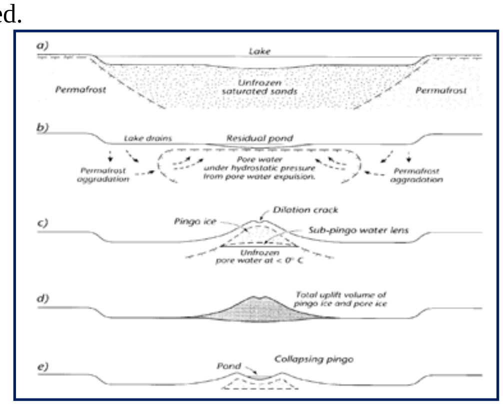

Fig. 1. Schematic evolution of a "closed" pingo in the Tuktoyaktuk Coastlands, northern Canada. The occurrence of ponded water is a necessary precursor of the process [12].

Here, we use HiRISE and high-resolution MOC images to discuss sub-kilometre pingo-like mounds in UP within circular raised-rim features (RRFs) [2,14-15]. The mounds show geological characteristics consistent with formation by glacial aggradation (accumulation), and with degradation (ablation) by "dry" sublimation-based processes. We do not discount the possibility that some mounds in the region are pingos; however, we suggest that caution be exercised in evaluating the possible link between mound development and periglacial processes.

Perennial glacial mounds in UP: Linking Martian global climate-change to water cycles, some workers have proposed that during relatively recent episodes of high orbital inclination, the accumulation of an atmospherically-deposited icy materials or an ice-rich mantle occurred in the western middle-latitudes of UP [16-17]. Astapus Colles (ABa, ~38^0-48^0N, 70^0-90^0 E) is a late Amazonian geological unit, thought to be ~80 m thick and comprised of icy materials, that is located in the midst of the hypothesized area of glacial accumulation [9,14]. Sub-kilometre mounds, nested in RRFs, are ubiquitous in the region [9,14]. In terms of their formation history or geochronology, the mounds exhibit an interesting array of morphologies and characteristics (Figs. 2a-e).

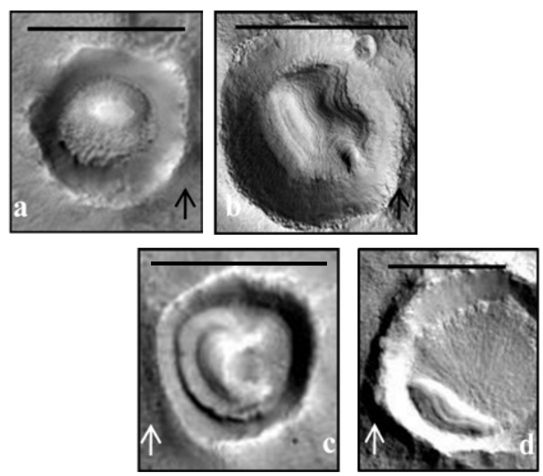

Fig. 2. **(a)** Mound with radial pitting **(**HiRISE PSP 008_162_2220_RED, 41.6^0 N; 82.9^0 E; res. 25 cm/pixel; NASA/JPL/Univ. of Arizona); **(b)** Mounds with slight u-shaped deformation and stratified layers or bedding **(**HiRISE PSP 004180_2165_RED; 36.2^0 N; 84.0^0 E; res. 25 cm/pixel; NASA/JPL/Univ. of Arizona); **(c)** Mounds with horse-shoe shaped deformation, missing central mass (MOC e0401564b; 41.8^{0}N, 82.6^{0}E, 5.99 m/pixel; USGS image archive); and, **(d)** Linear mound-remnant near raised-rim edge **(**MOC r0402182a; 38.8^{0}N, 97.6^{0}E; res: 4.62 m/pixel; USGS image archive). Scale bars are 500 m. Arrows point north.

Morphologically, the mounds range from circular to linear. Circular mounds, showing various degrees of pitting, often occur at or near the middle of the RRFs

(Fig. 2a). Slightly u-shaped to horseshoe-shaped mounds are located near the middle of the RRFs and seem to show a loss of mass near or at their summits (Figs. 2b-c). Linear or remnant mounds occur near or at the edge of the RRFs, and are the smallest of the mound types (Fig. 2d). We suggest that the range of morphologies - from circular to linear - and of mound types, is progressive and marks distinct stages of mass loss by sublimation.

Stratified layering or bedding is a key characteristic of some mounds**,** particularly those showing an absence of radial symmetry (Fig. 2b). The layering could be indicative of mantle aggradation by discrete episodes of atmospheric deposition. Moreover, the absence of radial symmetry and the exposure of the layering could be geological markers of mound degradation by sublimation. Contemporary boundary conditions of atmospheric aridity and low pressure, as well as mean temperatures that rarely cross 0^0 C, are inconsistent with ablation by evaporation in the region.

Many mounds also show pitting, radiating inwardly from the margins but not extending fully to the central area or summit (Fig. 2a). In ice-dominated landscapes on Mars, pitting is thought to be a geological marker of sublimating ice [11]. Thus, the marginal pitting of the mounds could be further evidence of ongoing degradation by sublimation and, just as intriguingly, of the relative youth of the mound and icy regional mantle [15].

A periglacial alternative?: Although evidence of late Amazonian periglacial modification of UP is abundant in the literature [1-11,14,17] we argue against a periglacial or pingo-related origin for the RRF mounds. First, many of the mounds display stratified layering or bedding. By contrast, (closed) pingo ice cores form by pore water pressure and hydrostatic injection. Their ice cores show no layering (Fig. 3). Second, there is no visible or unique separation between an overburden and the underlying mound material in the mound images, as there would be in closed pingos on Earth. Third, the RRF mounds often are ensconced in local landscapes dominated by an icy mantle. On Earth closed pingos tend to be nested in periglacial landscapes comprising thermokarst lakes or alases (drained thermokarst lakes) and small-sized polygonal patterned-ground [12-13]. Pingo-like mounds have been reported in the presence of alas-like depressions and small-sized polygons in UP [1-2,7,10-11]. However, many of these mounds display characteristics deemed by us to be synonymous with a glacial origin and, regardless of the periglacial surroundings in some instances, could not be linked genetically to them.

Fig. 3. Exposed pingo ice-core in the Tuktoyaktuk Coastlands [18]. Notice the absence of horizontal stratification in the ice.

Conclusion: Recent debate concerning the possibility of late Amazonian periglacial and glacial modification of UP has been strengthened by improvements in the resolution of Martian landscape images. Using HiRISE and MOC images, we have identified morphologies and characteristics associated with some sub-kilometre mounds in UP that are suggestive of an origin by glacial processes. The mounds occur in an area hypothesised by water-cycle models to have been subjected to glacial accumulation in the late Amazonian [16-17]. The concurrence between landscape formation hypotheses derived from the water-cycle models and the geological evidence supportive of the UP mounds being perennial glacial landforms is encouraging and worthy of further investigation.

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