POSSIBLE PINGOS AND CRATER-FLOOR PERIGLACIAL LANDSCAPES IN NORTHWEST UTOPIA PLANITIA: A RE-ASSESSED HYPOTHESIS BASED ON HI-RISE IMAGERY. R.J. Soare,[1] F. Costard[2] and G. Pearce.[1] [1]Dept of Geography, Dawson College, 3040 Sherbrooke St. West, Montreal, Canada H3Z 1A4 (rsoare@dawsoncollege.qc.ca); [2]UMR 8148, Université Paris-Sud 11, bat. 509, 91404 Orsay, Cedex, France.

Introduction: In 2005 [1-2] we discussed assemblages of small (10s of metres in diam.), irregularly-shaped mounds on the floors of two impact craters in nw Utopia Planitia (UP) (64.8^{0}N, 292.7^{0}W, MOC image e0300299, map scale=5.5m/pixel; 64.54^{0}N, 289.86^{0}W, MOC image e0500113, map scale= 6.03m/pixel). The mounds were offset slightly from the crater-floor centres and nested amidst integrated networks of small-sized polygons (≤250m in diam). Some of the polygons exhibited an orthogonal orientation around the mounds; others, cross-cut the mounds. A few of the mounds displayed summit depressions We proposed that the mounds were hydrostatic pingos and that the crater-floor landscape was reminiscent of drained thermokarst lakes (alases) on Earth.

Here we use HiRISE (i.e. Fig. 1) and MOC images (not available at the time of our earlier work) to do two things: (a) re-visit the hydrostatic-pingo hypothesis; and, (b) describe observations from four additional craters in nw UP that show crater-floor mounds and putative periglacial landscapes similar to the two craters in the region discussed by us in 2005. Also, we present an alternate mound-formation hypothesis not explored by other workers.

Description: Each of the newly identified craters display densely-clustered mounds (i.e. Fig. 1) near the crater centres. The mounds are nested in very fine (~10-15m diam.) polygonal-patterned ground (Fig. 2).

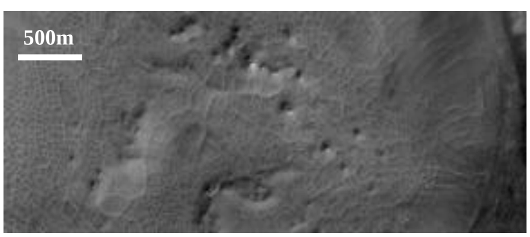

Fig. 1. HiRISE ESP_017090_2475; 67.2^{0}N, 47.8^{0}E; map scale = 31.7cm/pixel. Note the assemblage of mounds on the crater-floor.

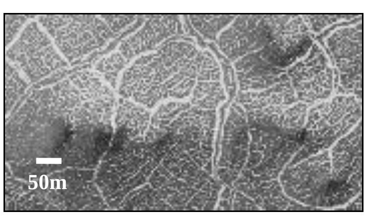

Fig. 2. Magnification of crater floor seen above. Note the finely scaled polygons that surround & cross-cut the mounds (HiRISE PSP_007372_2475; 67.2^{0}N, 47.8^{0}E; map scale = 31.7 cm /pixel).

Mound shape is irregular, ranging from elongate to circular/sub-circular; diameters are from tens to hundreds of metres. Mound elevation is a few tens of metres or less. Many mounds are cross-cut by crater-floor polygons; some mounds show summit depressions.

A periglacial origin: Since 2005, the possibility that pingos could have formed in UP late in the Amazonian period has been widely discussed in the literature [3-7]. This having been said, pingo formation, especially in the case of hydrostatic pingos, requires the occurrence of near-surface ice-rich regolith and pre-cursor boundary conditions above the triple point of water. Each of these constraints, in and of themselves, are hotly debated within the domain of planetary science.

On Earth, hydrostatic pingos are perennially ice-cored mounds produced by thaw-freeze cycling and permafrost aggradation. These landforms also are geological markers of ice-rich, near-surface permafrost [8-9]. Long-axes range in size from a few to hundreds of metres; shapes vary from circular/sub-circular to elongate. In places like the Tuktoyaktuk Coastlands, Canada, hydrostatic pingos occur in dense clusters (Fig. 3).

Fig. 3. Assemblage of four pingos at Eskimo Lakes, ~50km south of Tuktoyaktuk, Northwest Territories, Canada (late June, 2007). The two pingos in the foreground have been truncated by wave action. The small, circular pingo at the centre is ~7m in diam.

Most hydrostatic pingos form on the floor and at/or near the centre of thermokarst lakes that have, or are in the process of, losing their water (Fig. 4)[8-9]. The loss

Fig. 4. Twin (fried-egg) pingos (late June, 2009) south of Tuktoyaktuk. The pingos are nested in two partially-drained thermokarst lakes. Note the small-sized polygons in whose midst the pingos lie. Service road above the pingos provides scale.

of water in the lake basin and the subsequent exposure of saturated but previously unfrozen lake-floor sediments to new, colder boundary conditions induces these sediments to freeze (by permafrost aggradation) and then to deform the ground upwardly by means of hydrostatic pressure. Eventually, this forms a domed structure/mound underlain by an ice core.

Often, small-sized thermal-contraction polygons (≤50m in diam.) cross-cut the sedimentary overburden of the ice-core. If the loss of lake water in the surrounding basin is episodic, then polygons radial to the newly-formed pingos exhibit orthogonal orientation. As pingos begin to degrade, summit depressions form.

The Martian mounds and terrestrial hydrostatic pingos exhibit similarities of size, form and geological traits. Moreover, the Martian mounds are located near the centre of impact-crater floors, precisely where one would expect them to be were they formed in terrestrial thermokarst lakes. Based on the morphological affinity between (a) the Martian mounds and terrestrial hydrostatic pingos; and between (b) the putative periglacial features of the Martian crater-floor landscapes and terrestrial pingo, polygon thermokarst-lake complexes, we suggested that the Martian mounds could be hydrostatic pingos.

In hindsight, we recognize that the pingo analogy was tenuous, for three reasons. First, the Martian mounds were observed only in two craters; second, the two available narrow-angle MOC (Mars Orbiter Camera) images used by us in support of the pingo hypothesis presented only partial views of the relevant crater-floor landscapes; and, 3. landscape features that countervail our hypothesis could have been present but might not have been observed at MOC resolution.

A sedimentary origin: As noted above, the crater-floor mounds occur in dense clusters near impact-crater centres. In some instances, the mounds circumscribe mesa-like structures at the crater centre (Fig. 5). Could these structures and the spatially-associated mounds be weathered remnants of impact-generated central peaks?

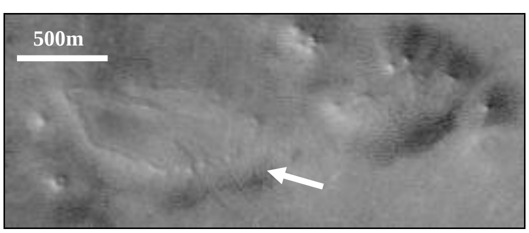

Fig. 5. HiRISE ESP_018078_2445; 64.5^0N, 70.1^0W; map scale = 31.8cm/pixel. Note the mesa-like structure at the centre.

Central peaks (Fig. 6.) are commonplace features that occur in complex Martian craters >8-10 kms (diam)[10]. Their elevation is below the datum of the original target material (i.e. the pre-impact planetary surface) and of the post-impact crater wall [11]. For

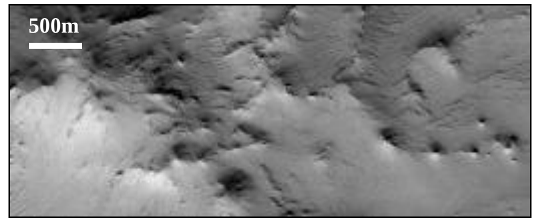

Fig. 6. Weathered and dust/debris-covered remnants of a central peak in a Martian impact crater **(**HiRISE PSP_009240_2055; 25.0^0N, 167.6^0E; map scale = 31.7cm/pixel).

example, ~10 km crater with an initial depth of ~1.1 km would show a central-peak height of 0.1 km [11].

Central peaks are dome shaped, although they may be highly deformed, and surrounded by breccias and impact melt rocks [12]. As the result of being within the region of central uplift, part of the final structure associated with the formation of a complex crater, the peaks are located at the crater-centres [12].

Were the crater-floor mounds and mesa-like structures eroded remnants of a central uplift region, their elevation would be lower than that of the surrounding plains. However, MOLA profiles of the crater-floor mounds in the HiRISE images show that the mounds are at an elevation equal to that of the surrounding plains. Based on the discrepancy between the predicted elevation of the landforms, according to the sedimentary hypothesis, and their actual elevation, we reject this hypothesis.

Discussion: The rejection of the alternate hypothesis does not necessarily validate the periglacial hypothesis. O the other hand, the HiRISE imagery of the putative pingos and surrounding crater-based landscapes provides no data that countervail the periglacial hypothesis. Thus, in the absence of countervailing geological data, we propose that the crater-floor mounds in nw UP are hydrostatic pingos.

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