Possible pingos and periglacial landscapes in northwest Utopia Planitia, Mars (II)

R.J. Soare,[1] D.M. Burr,[2] J.M. Wan Bun Tseung[1] and C. Peloquin.[1] Dept. of Geography, Planning and Environment, Concordia University, 1455 De Maisonneuve W., Montreal, Canada, H3G 1M8. E-mail: rsoare@colba.net. [2.]Astrogeology Program, 2255 N. Gemini Dr., Flagstaff, AZ 86001.

Introduction: Hydrostatic (closed-system) pingos are elongate to circular, ice-cored mounds that are perennial features of some periglacial landscapes. These perennial mounds range in size from a few to ~ 60 m in height; they may reach ~ 300 m in diameter [1]. The origin and growth of a hydrostatic pingo are contingent upon the availability of surface water, the work of freezing processes and the presence of deep, continuous permafrost [2]. As a hydrostatic pingo evolves and matures, mound cracks and crosses begin to appear. The final stage of pingo development is marked by summit collapse, leaving an annular rim behind.

The processes responsible for the formation of thermal contraction polygons - sharp, sub-zero losses of temperature - and of thermokarst - changes in the thermal equilibrium of ice-rich permafrost - differ from those associated with the formation of hydrostatic pingos. Despite these differences, the three landforms are frequent companions in periglacial landscapes on Earth

Possible Pingos and a Periglacial Landscape in northwest Utopia Planitia: In an earlier manuscript [3] we used a narrow-band, high-resolution Mars Orbiter Camera [MOC] image - EO300299 - and individual Mars Orbiter Laser Altimeter data tracks to identify possible pingos and a periglacial landscape on the floor of an impact crater in northwest Utopia Planitia - 64.8° N / 292.7° W. The landscape comprises a northern and southern set of small, roughly circular mounds, polygonal patterned ground and landforms that could have been formed by the work of water.

Mound size varies from ~ 25 - 50 m in diameter. Some of the mounds are crossed; a few of the mounds are low to the ground, rimmed and appear collapsed. The mounds are located on the crater floor, close to the centre of the crater, in areas of low elevation. Both mound groups are nested in patterned polygons whose trough-to-trough diameters are ~ 100 - 250 m. Dendritic, rill-like features that coalesce into a main trunk are visible to the west of the northern mound groups. This main trunk is connected to a basin-like feature that grades towards the east, away from the area of central uplift to the west. To the east of the northern mound group, some of the polygons are oriented orthogonally and overlie a curvilinear channel-like feature that grades southwardly in the direction of the basin-like feature noted above.

Lobe-like ejecta surround the main crater in MOC-EO300299 and others in northwest Utopia Planitia. They are visible in the Viking context image (M165N295) of MOC-EO300299 and in numerous Viking, MOC and Mars Odyssey wide and narrow-band images of this area.

Landscape Genesis: In general, the size of the crater-floor mounds is consistent with that of terrestrial hydrostatic pingos, as is the presence of mound crosses and possible collapse features. The average trough-to-trough diameter of the crater-floor polygons is slightly bigger than the trough-to-trough diameters of the largest thermal contraction polygons on Earth. The latter are found in the sea-side terraces of the Yamal peninsula, Siberia, and are ~ 100 m in diameter [4]. The size of the Martian crater-floor polygons, however, is consistent with the work of thermal contraction [5]. Polygon orthogonality could be indicative of water receding slowly, as it is in periglacial environments on Earth [6]. The dendritic, trunk and basin-like landforms also could be markers of fluvial geomorphology.

Lobe-like ejecta are thought to be the products of near-surface volatiles, possibly ground-ice, that were vaporised during crater formation [7]. The hypothesised presence of near-surface ground ice in this poleward region is consistent with the data delivered by the neutron spectrometer aboard the Mars Odyssey. [8].

A Terrestrial Analogue: Specifically, we argued that the genesis and development of the crater-floor features in MOC-EO300299 could be similar to the genesis and development of coastal, drained-lake landscapes such as those found in the Tuktoyaktuk peninsula of northern Canada. Hydrostatic pingos are commonplace amongst many of these drained lakes, as is small-sized, polygonal patterned-ground formed by thermal contraction and a number of associated fluvial landforms.

The Tuktoyaktuk peninsula is underlain by deep, continuous permafrost and is dotted by the presence of nearly 1400 hydrostatic pingos. The formation of these hydrostatic pingos is triggered mainly by the drained loss of water in shallow, thermokarst lakes [9]. As the water is lost, the floor of the lake basin is exposed to cold air temperatures for the first time. Permafrost aggradation ensues, from the edge of the former lake basin inwardly to the lowest point of elevation on the lake floor. Ahead of the freezing front, the pore water that is present in the lake-bed sediments becomes constrained in an increasingly small space. The hydrostatic pressure that results from this constraint eventually deforms and uplifts the frozen sediment above the pore water. A small mound arises. As the pore water begins to freeze an ice core is formed. The formation of thermal-contraction polygons often is concurrent with pingo formation in these landscapes.

We suggested that the higher average temperatures and atmospheric pressure associated with high obliquity [10] could have exercised a profound geomorphological influence on the crater-floor landscape in MOC-300299, inducing the thaw of near-surface ground-ice. In turn, this might have initiated a series of events - the ponding of crater-floor water near the centre of the crater, the subsequent loss of this water by drainage, evaporation or sublimation, permafrost aggradation, surface deformation due to pore-water pressure and the growth of an ice-cored mound.

If the crater-floor polygons are the product of thermal contraction and of acute, sub-zero drops of temperature, then the presence of liquid water and of boundary conditions that differ from contemporary ones are not required. Sharp sub-zero drops of temperature are not inconsistent with diurnal or seasonal meteorological changes in the sub-polar regions of Mars today. On the other hand, the orthogonality of patterned ground on the crater floor could be indicative of fluvial activity at a time when average temperature and atmosphere pressure were higher.

MOC image EO500113: Recently, we identified a second impact crater in northwest Utopia Planitia - 289.86^0 W, 64.54^0 N - (MOC-EO500113) with an assemblage of features similar to that which is found on the crater-floor of MOC-EO300299. The crater is ~ 7 - 8 km in diameter, approximately one-half of the diameter of the MOC-EO300299 crater and lies ~ 65 km to the east of the former. There are two groups of roughly circular mounds in MOC-EO500113. The group to the east of the crater centre comprises ~ 16 mounds, each of which is ~ 25 - 50 m in diameter. The group to the west of the crater centre comprises two mounds. Each of the western mounds is approximately the same size as the eastern mounds. Overall, the diameter of the crater-floor mounds in MOC-EO500113 is similar to that of the mounds on the crater floor of MOC-EO300299. As in the case of MOC-EO300299, some of the mounds in MOC-EO500113 are crossed [fig. 1A]; a few of the mounds are rimmed and appear to be collapsed [fig. 1B]. The location of the mounds near the centre of the crater follows the pattern of the crater-floor mounds in MOC-EO300299 and is consistent with the lake-basin floor location of pingos in the Tuktoyaktuk pensinula.

Intriguingly, the majority of the mounds on the crater floor of MOC-EO500113 are intact, as they are in MOC-EO300299. If the mounds are pingos, then this suggests that the core of ice underlying them may still be extant. The eastern mounds are terraced, possibly lying just above the areas in which the last vestige of residual water could have collected before having been lost. The trough-to-trough diameter of the polygons in MOC-EO500113 is ~ 50 - 200 m. This is broadly consistent with the trough-to-trough diameter of the polygons in MOC-EO300299 and with large, terrestrial polygons formed by thermal contraction. While no dendritic rills are apparent in this landscape, as they are in MOC-EO300299, the polygonal patterned ground immediately to the north of the eastern set of mounds is aligned orthogonally [fig. 1C]. As with MOC-EO300299, this pattern could be indicative of local water having receded slowly.

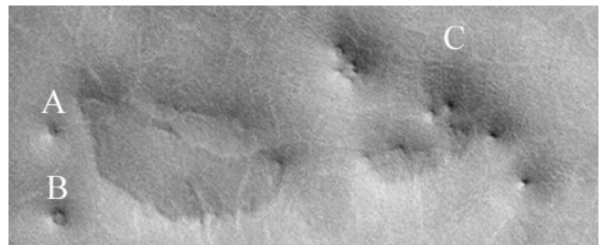

Figure 1. Crater-floor landscape, MOC-EO500113 (6.04m/pixel) A. crossed mounds; B. rimmed mounds; C. orthogonal polygons. Image is ~ 3.3 km across.

Discussion: Compared to the landforms of the equatorial and near-equatorial regions, the landforms of Utopia Planitia have tended to be deemed uninteresting. As a result, the number of narrow-band, high-resolution images of crater-floor features in Utopia Planitia is small.

We believe that the pingo-like mounds and associated crater-floor landforms identified by MOC-EO300299 and MOC-EO500113 may be commonplace in this area. If so, this could point to periglacial processes actively having shaped the landscape, perhaps as recently as the last episode of high obliquity.

We hope that our research will raise the geomorphological profile of northwest Utopia Planitia and turn the attention of planetary scientists more fully towards this near-polar area than has been the case heretofore.

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Acknowledgements : Thanks to M. Burelli and Dr. M. Burman for their friendship and support.