RECENT, LATE AMAZONIAN PINGOS, ICE-RICH LANDSCAPES AND PERIGLACIAL PONDING IN UTOPIA AND WESTERN ELYSIUM PLANITIA, MARS. R.J. Soare,[1,2] G.R. Osinski[3] and F.M. Costard.[4] [1]Dept. of Geography, Planning & Environment, Concordia University, 1455 De Maisonneuve W., Montreal, Qc., Canada H3G 1M8; [2]Dept. of Geography, Dawson College, 3040 Sherbrooke St. W, Montreal, Qc, Canada H3Z 1A4 (rsoare@colba.net); [3]Dept. of Earth Sciences, University of Western Ontario, London, Ont., Canada N6A 5B7; [4]CNRS/UPS UMR 8148 IDES, Interactions et Dynamique des Environnements de Surface, Université Paris-Sud, Bât. 509, 91405 Orsay Cedex, France.

Introduction: Recent work has identified circular and near-circular raised-rim landforms (usually < 1 km in diameter) throughout Utopia and western Elysium Planitia, Mars [1]. These landforms also have been identified in Athabaska Valles [2-3]. Some of the landforms in Utopia and western Elysium Planitia are nested in lobate, steeply-sided and flat-floored depressions (Fig. 1) [1]; the depressions are tens of metres deep and run from hundreds to several thousands of metres in diameter [4-6]. A few of the raised-rim landforms show inner mounds (Fig. 1) [1]. The mounds range in shape from roughly circular to crescentic and, in some instances, are fractured. Free-standing mounds similar in morphology and scale to the inner mounds

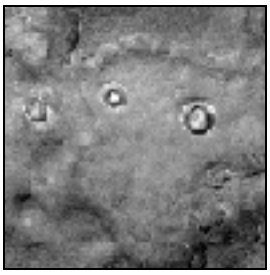

Fig. 1. Raised-rim depressions and mounds in thermokarst-like depressions. MOC image e0401 564 (41.8^{0}N, 277.4^0 W).

also have been identified throughout the region [7-8]. Within the depressions and in the surrounding outwash plains, small-sized polygonal patterned-ground (~25-250m in diameter) is ubiquitous [4-6,9].

Some workers point out that the raised-rim landforms and fractured-unfractured mounds (within and without the lobate depressions) are consistent with the morphology, scale and possible origin of terrestrial closed pingos (perennial, ice-cored mounds) in various stages of evolution and collapse [1-3,7-8]. A number of workers have surmised that the lobate depressions are alases (drained thermokarst lakes) whose occurrence marks the past and possibly very recent presence of near-surface ground (excess) ice [4-6,10-11] and of ponded water [4-5,10-11]. The widespread occurrence of small-sized polygonal patterned-ground, possibly formed by thermal contraction (freezing) processes and underlain by ice wedges, is consistent with the surmisal of a periglacial landscape in the region. In terrestrial landscapes, this type of patterned ground is a commonplace companion of pingos and alases [12-13].

Here we focus on the putative periglacial character of the landscape assemblage (described above) in Utopia and western Elysium Planitia and suggest that its origin is consistent with the presence of thawed ice-rich permafrost (ground-ice) and ponded water. Recent global climate models have shown that under conditions of high obliquity, abundant amounts of snow/ice could have been transported atmospherically and emplaced here [14-17]. Regional mean-temperatures only slightly above and then below the triple point of water would have been required for this snow/ice to have thawed, formed thermokarst lakes, saturated the underlying regolith and become ground ice [4,10].

Pingos, thermokarst landscapes and ponding on Earth: There are two type of pingos: 1. closed (hydrostatic); or, 2. open (hydraulic). Closed pingos can form when thermokarst lake-water drains, exposing the saturated sediments beneath the lake floor to freezing temperatures and permafrost aggradation. Constrained by permafrost aggradation, trapped pore water is placed under increasing hydrostatic pressure. This hydrostatic pressure, along with the volumetric expansion of the pore water as it freezes and forms an ice-core, gradually deforms the lake floor into a perennial periglacial mound [12].

On Earth, the greatest concentration of closed pingos (Fig. 2a) - growing, mature (Fig. 2b) or collapsed (Fig. 2c) - is located in the Tuktoyaktuk Coastlands of

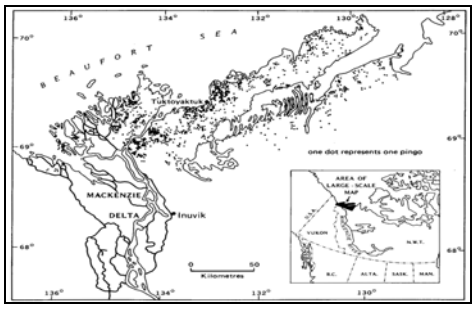

Fig. 2a. Distribution of closed pingos in the Tuktoyaktuk Coastlands, NWT, Canada [11].

northern Canada. Often, the pingos are nested in thermokarst lakes or alases. The lakes occur in ice-rich

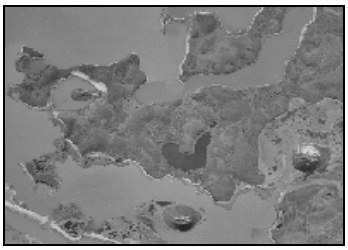

Fig. 2b. Air photo of pingo/thermokarst-lake assemblage, south of Tuktoyaktuk.

Fig. 2c. Collapsed pingo, Tuktoyaktuk Coastlands (Parks Canada).

(excess-ice dominated) permafrost. Excess ice is a volumetric term representing permafrost whose pore space is taken up fully and often exceeded by the presence of frozen water [13]. Alases are a product of ground-ice (permafrost) thaw and form when thermokarst lakes lose their water by evaporation, sometimes due to medium-term changes towards and above O^0C in regional mean-temperatures, or by drainage [12-13]. Small-sized polygonal patterned-ground, underlain by ice wedges, and exposures of excess ice also are widespread in the region (Fig. 2d).

Fig. 2d. Ice-wedges, overlying an exposure of excess ice, Peninsula Point, south of Tuktoyaktuk. Shallow troughs, immediately above the ice wedges, are indicative of small-sized polygonal patterned ground.

Pingos, thermokarst landscapes and ponding in Utopia and western Elysium Planitia, Mars: In the absence of regolith samples showing the presence of ground ice to metres of depth in the area of the lobate depressions, or of a remnant or extant ice-core beneath the Martian mounds, the alas and pingo hypotheses remain highly speculative. On the other hand, the Martian landscape assemblage comprising the alas-like depressions, nested raised-rim features and inner mounds, as well as that of the small-sized polygonal patterned ground, is similar in morphology, scale and possible origin to thermokarst- and pingo-based landscapes in terrestrial cold-climate landscapes such as the Tuktoyaktuk Coastlands. If the analogy is valid, then this points to periglacial processes involving frozen and liquid water having been at work in the surface and near-surface environments of Utopia and western Elysium Planitia, possibly in the very late, very recent Amazonian [4-5,10-11]. Equally, the analogue underlines two things: 1. ice-rich permafrost to metres of depth could have been widespread in this region; and, 2. temperatures at or slightly below O^0C must have been more or less concurrent with the ice-rich permafrost, otherwise permafrost thaw, the mobilisation of liquid water and the subsequent formation of the depressions, rim features and inner mounds, could not have taken place.

Although GCMs generally have shown that triple point conditions at or slightly below O^0C are unlikely to have occurred in this region even at high obliquities, the putative periglacial landscape of Utopia and western Elysium Planitia suggests otherwise.

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