GROUND ICE IN UTOPIA PLANITIA: A LATE AMAZONIAN MARINE ORIGIN G. P. Pearce[1], D. Veillette[1] and R. J. Soare[1,2] [1]Dept. of Geography, Planning and Environment, Concordia University, 1455 De Maisonneuve W., Montreal, Canada, H3G 1M8; [2]Dept of Geography, Dawson College, 3040 Sherbrooke St. W., Montreal, QC H3Z 1A4, Canada. E-mail: geoffreypearce@hotmail.com,

Introduction: The inability to identify pale-shorelines in the northern hemisphere, for example, in Utopia Planitia, is an important constraint on the viability of a northern ocean hypothesis. Here we identify periglacial features consistent with two things: 1. the occurrence of near-surface ice-rich ground; and, 2. the antecedent saturation of near-surface regolith by marine processes, possibly in the late Amazonian. We suggest that the marine transgression-recession hypothesis associated with the formation of massive ice at Ellesmere Island in the Canadian high arctic [1] is a good analogue for the late Amazonian emplacement of water and the formation of ice-rich regolith in the mid-latitudes of Utopia Planitia.

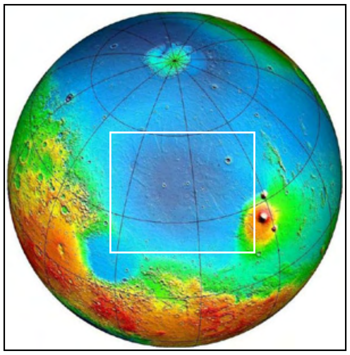

Figure 1:MOLA topographic map centered on area in Utopia Planitia in which thermokarst-like depressions have been identified

Periglacial features in Utopia Planitia: Scalloped depressions ranging in diameter from a few hundred metres to 1–2 kms are widespread in Utopia Planitia (between 255 and 282 degrees longitude and 32 and 50 degrees latitude, see Figure 1) [2-3]. From the zero datum of the surrounding plains, MOLA tracks show that these depressions are tens of metres deep [4]. The depressions lack raised rims and are flat-floored (Figure 2). Some of them are isolated, others appear to have coalesced. Step-like features, suggestive of multiple growth cycles, occur in the depressions. The morphology and general characteristics of these depressions are very similar to drained thermokarst-lakes (alases) in terrestrial periglacial environments, where ice-rich permafrost dominate the landscape.

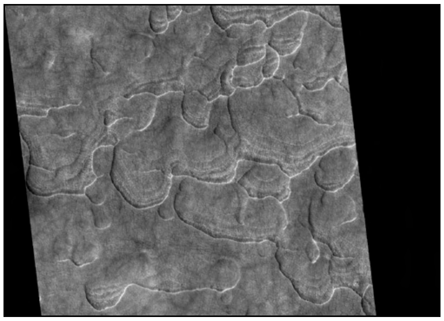

Figure 2: Scalloped depressions, Utopia Planitia; (HiRise PSP-001331-2260, 45.6^{0}N, 93.7^{0}E). Image is ~10 km across and illuminated from the west. North is up.

Other features that point to formation by periglacial processes include: a. gullies that form at or near the rim of some impact craters [5]; b. destabilized-lobate terrain (possibly solifluction lobes) on crater walls and in the surounding plains [6]; and, c. small-sized polygonal patterned-ground (perhaps underlain by ice wedges) [7-8] are ubiquitous in this region.

Ice-rich is a term used to describe sediments with ice content values that range between 50 and 150% by volume [9]. Often, the formation of a terrestrial thermokarst lake is induced by unusual and regional rises of temperature. This disturbs the thermal equilibrium of the ice-rich permafrost, leading to thaw conditions and the ponding of meltwater [10]. The eventual loss of ponded water by evaporation or drainage leaves an exposed basin or alas in its wake.

A number of authors have argued that the formation of periglacial and glacial landscapes is consistent with boundary conditions at high obliquities [11-13]. The possible emplacement processes associated with the near-surface ice-rich regolith in the target region are understood less well.

We hypothesise that an emplacement mechanism associated with marine or lacustrine recession, followed by aggradation of permafrost in the previously-saturated sediments, could be responsible for the formation of near-surface ice-rich sediments in our target region.

Ice-rich sediments and beds of massive ice are ubiquitous on Ellesmere Island and in the Tuktoyaktuk Peninsula, in the Canadian arctic. Explaining the origin of these periglacial landforms could be of analogical value in trying to understand the origin of the ice-rich sediments in Utopia Planitia.

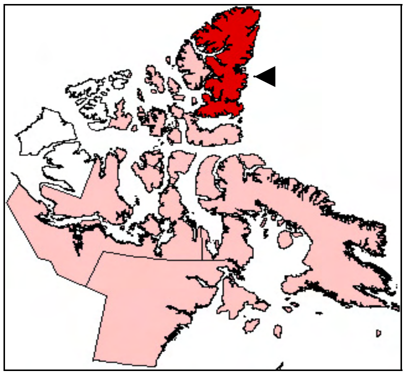

Figure 3: Ellesmere Island highlighted in red

Ground-ice formation at Ellesmere Island, Canada (Figure 3)**:** Pollard [14] explains the formation of ground ice on Ellesmere Island by tying an early Holocene episode of marine recession in the low-lying regions of the island with a subsequent episode of permafrost aggradation.

His hypothesis comprises two phases: 1. saturation of fine-grained sediments during submergence (~prior to 8 ka BP); and, 2. the downward aggradation of permafrost and the formation of massive ice (Figure 4) in the previously saturated sediments when areas below the marine limit emerge .

The chemistry and structure of the massive ice in the region, as well as its universal distribution below the Holocene maximum, suggest that the ground ice is of intrasedimental origin. Although the submergence duration was brief (4000-7000 years), Pollard hypothesises that it was sufficient to emplace layers of ice-saturated of marine sediments which are typically 20-30 meters in depth, reaching heights of 36 meters in some areas.

Figure 4: Massive ice exposure, Peninsula Point, Tuktoyaktuk Peninsula, NWT, Canada (summer 2006)

Discussion: The occurrence of possible periglacial landforms and ice-rich sediments in the near-surface regolith of the mid-latitudes in Utopia Planitia is easier to document empirically than it is to explain by models or theory. Gamma-ray spectrometry data suggest that this region is relatively poor in near-surface water-equivalent hydrogen [15-16]. This is to be expected as water-ice is not thought to be stable in the top few metres, presently. In the recent past, the obliquity driven migration of water from the northern pole to the northern mid-latitudes could have deposited significant amounts of snow/ice in the region [17]. In turn, if temperatures rose and led to thaw, not sublimation, a large body of standing water could have ensued. Over time, the underlying regolith would have become saturated. With the eventual loss of water as high obliquity faded, the saturated sediments would have undergone permafrost aggradation. This would have coincided with the formation of the periglacial features and landscape identified by us in Utopia Planitia.

Further modeling is urged, in order to narrow the divide between the observed geological data and our understanding of Martian boundary conditions in the late and possibly recent Amazonian.

References: [1] Pollard, W.H. (2000). Geol. Surv. Can. 529, 325-333. [2] Costard, F.N., Kargel, J.S. (1995) Icarus 114, 93-112. [3] Soare, R.J. Wan Bun Tseung, J.M., Peloquin, C. (2005). LPSC XXXVI Abstract # 1103. [4] Soare, R.J., Wan Bun Tseung, J.M., Osinski, G.R. (2006). LPSC XXXVII, Abstract # 1666.
[5] Soare, R.J., Kargel, J.S., Osinski, G.R., Costard, F.N. (2007). Icarus, in press. [6] Mustard, J.F. Cooper, C.K. Rifkin, M.K. (2001). Nature 412, 411-414. [7] Mellon, M.T. (1997). JGR. 102 (E11) 25,617-25,628. [8] Seibert, N.M., Kargel, J.S. (2001). GRL. 28 (5), 899-902. [9] French, H.M. (1996) The Periglacial Environment. Longman, England. [10] Ibid. [11] Costard, F.N., Kargel, J.S. (1995) Icarus 114, 93-112. [12] Kargel, J.S. (2004). Mars: a warmer, wetter planet, Springer-Praxis, New York. [13] Soare, R.J., Kargel, J.S., Osinski, G.R., Costard, F.N. (2007). Icarus, in press. [14] Pollard, W.H. (2000). Geol. Surv. Can. 529, 325-333. [15] Feldman, W.C. et al. (2002). Science 297 (5578), 75-78. [16] Mitrofanov, I.G. et al. (2002). Science 5578 (297), 78-81. [17] Kargel, J.S. (2004). Mars: a warmer, wetter planet, Springer-Praxis, New York.

Acknowledgements: Grants provided by the Canadian Space Agency and the Aurora Research Institute {ARI] facilitated our fieldwork in the Tuktoyaktuk Peninsula and Mackenzie River delta (June 2006). Access to the land was permitted by: the ARI; Parks Canada (western Arctic office); the Inuvialuit Land Administration, and; the Hunters and Trappers Associations of Inuvik and Tuktoyaktuk. Ongoing discussions with J. Kargel have been particularly valuable.