DEGRADATION OF THE PERIGLACIAL LANDSCAPE OF UTOPIA PLANITIA UNDER GLOBAL WARMING : COMPARISON EARTH-MARS. A. Séjourné[1,2] , F. Costard[2], J. Gargani[2], R.J. Soare[3], A. Fedorov[4] and C. Marmo[2]. [1]WROONA Group, Institute of Geological Sciences PAS, Wrocław Research Centre, Poland (antoine.sejourne@u-psud.fr); [2]Univ. Paris-Sud XI, Laboratoire IDES, Orsay, France. [3]Dawson College, Montreal, Canada; [4]Permafrost Institute, Yakutsk, Russia

Introduction: In the last few years, evidences of Mars showing large quantities of ice in the permafrost have become increasingly abundant. The fate of this ground-ice reservoir is tied to dramatic global climate change during the recent history of Mars (< 10 Ma). The planet is thought to have undergone periodic variations of its orbital parameters deeply modifying the climate like Milankovitch's cycles on Earth.

The western Utopia Planitia (UP) in the northern mid-latitudes of Mars contains relatively young landforms (< 10 Ma): scalloped depressions [1-5], spatially-associated polygons [2-4, 6], polygon-junction pits [2-3, 6-7]. There is an agreement within the community that they are periglacial in origin and, derivatively, indicate the presence of an ice-rich permafrost. However, these landforms were studied individually and, many questions remain about their formation-evolution and climatic significance.

In contrast, we conducted a geomorphological study of all landforms in UP to : (i) propose model of their formation and evolution; (ii) cartography their geographical distribution and; (iii) discuss the climatic modifications of the ice-rich permafrost in UP. Our work combines a study of Martian landforms using HiRISE images and DEM, MOLA and a comparison with analogous periglacial landforms in Canada and Siberia.

The periglacial landforms of Utopia Planitia: The scalloped depressions are circular to elliptical with diameters of ~100-1,000 m for a depth < 70 m (Fig. 1) [1-5, 8]. They are flat-floored with an equator-facing slope that is gentler (1.2°) than the pole-facing slope (6°) [8]. The depressions are thought to be the result of sublimation or melting of ground-ice and subsidence of the ground [1-5]. Their NS asymmetric profile is thought to be due to an asymmetric insolation of their slopes [2-3].

Two types of polygons are observed in UP (Fig. 1) [2-4, 6]. Large polygons of 100 m in diam. occur on the plain between the depressions (inter-depression polygons). These large polygons are cross-cut by the calloped depressions showing that they are older than the latter. Smaller polygons of 6 m in diameter are observed inside the depressions (intra-depression polygons) [2, 8]. Both types of polygons are thought to be formed by thermal-cracking of a permafrost [6, 8].

Elongated pits are observed at the junction of some inter-depression polygons (Fig. 1) [2-3, 6-7]. They are ~10-100 m in diameter for a depth of 5-17 m [2, 7]. They are observed exclusively along the N-S polygonal troughs [7, 9]. The polygon-junction pits are thought to be due to sublimation or melting of ground-ice [3, 6-7].

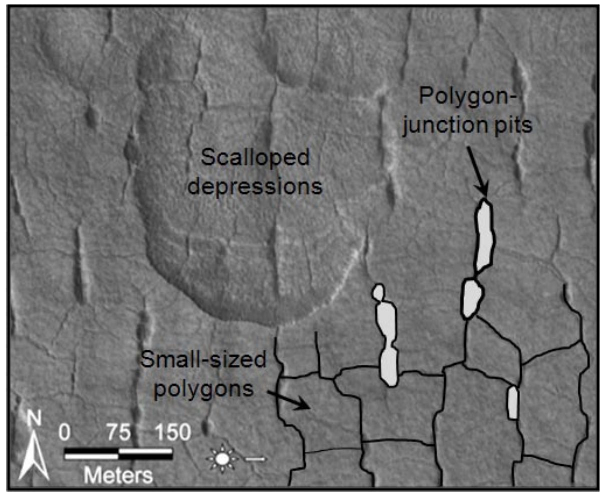

Fig. 1 : Periglacial landforms of Utopia Planitia (HiRISE image PSP_002202_2250).

The degraded periglacial landscape of Siberia and Canada: Abrupt climate-changes in the periglacial environments on Earth deeply modified the landscape. We conducted two field studies in Central Yakutia (Siberia) and in the Mackenzie Delta (Northern Canada). These regions are underlined by a continuous and ice-rich permafrost of 40-80% of ice by volume [10-11].

A unique assemblage of landforms possibly analogous to the Martian counterpart is observed there: thermokarst lakes, ice-wedge polygons and polygon-junction ponds (Fig. 2) [10-11]. The thermokarst lakes are the result of the subsidence of the ground following the localized thawing of excess-ice (Fig. 2). Most of thermokarst lakes were formed during the Holocene climatic optimum where higher temperatures induced the extensive thawing of the permafrost [10-11]. The ice-wedge polygons are formed by freeze-thaw cycles of an ice-cemented ground. Sometimes, the localized melting of the ice-wedges induces the formation of small ponds localized at the junction of the polygons (Fig. 2) [11].

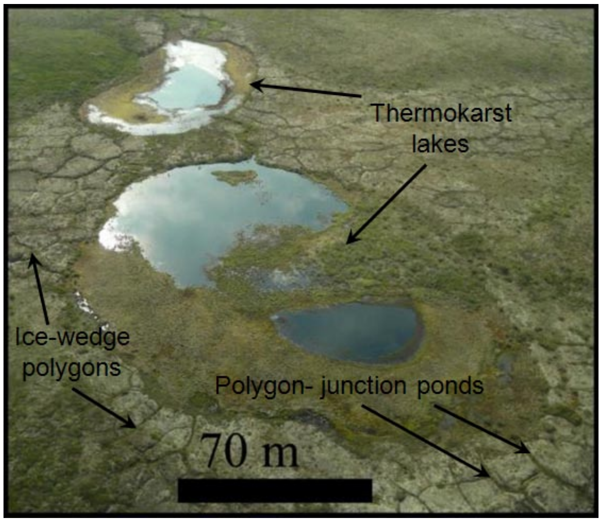

Fig. 2 : Periglacial landscape of Canada (aerial photo in the Tuktoyaktuk Coastlands, July 2009).

Degradation of an ice-rich permafrost during 45° obliquity of Mars: The landforms in UP are similar to the periglacial landforms of Canada or Siberia. We suggest that they are integrated in a complex landform assemblage indicating the presence of an ice-rich permafrost in UP [12].

From our study, we show that the ice-rich permafrost of UP were subject to important thermokarst degradation by sublimation. **1**) There is no fluvial-like connection between the scalloped depressions and no thaw-related features are observed inside of them [8]. **2**) There is no fluvial-like connection between the polygon-junction pits and no thaw-related features are observed inside of them [9].

We suggest that the ice-rich permafrost of UP were degraded during high-obliquity periods (~ 45°) of Mars. **1**) Several geomorphological observations show that the scalloped depressions have an equatorward development due to enhanced insolation-driven sublimation of their pole-facing slope during high-obliquity periods [8]. **2**) The exclusive occurrence of pits at the N-S junction of inter-depression polygons could underline an enhanced sublimation by the wind [9]. Only during high-obliquity periods, the wind has a dominant N-S direction in summer in UP [13].

According to [14], the crater-retention age of the surface showing the non-degraded inter-depression polygons is 1-10 Ma old. Therefore, the degradation of the permafrost in UP occurred before ~ 10 Ma during high-obliquity periods : three phases could be distinguished (Fig. 3 in red).

Degradation of an ice-rich permafrost during an increase of insolation on Mars: On Earth, the regional thermokarst in Canada and in Siberia was due to an increase of insolation at the early Holocene [15-16]. Similarly, in UP, the regional thermokarst was probably triggered by an increase of insolation during high-obliquity (~45°) periods of Mars. Variations in obliquity and eccentricity control the insolation and thus, the climate on Mars. The increase of temperature caused the thermal destabilization of the permafrost inducing the sublimation of ground-ice, deeply modifying the landscape of UP.

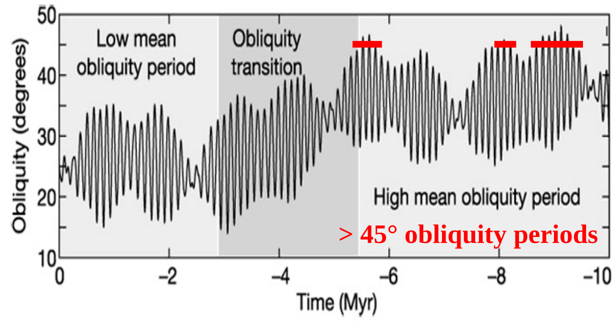

Fig. 3 : Possible degradation of the ice-rich permafrost of UP during high-obliquity periods of Mars, modified from [17].

Conclusion: Our results show that the assemblage of landforms in UP indicates the presence of an ice-rich permafrost like on Earth. This permafrost was degraded during a relatively recent high-obliquity period inducing a major climate change. The region of Utopia Planitia is probably a marker of the last major climate change that occurred on Mars.

This work improves significantly the understanding of the evolution of Utopia Planitia during the Late-Amazonian period (< 10 Ma) by studying the assemblage of landforms as an indicator of geomorphological evolution of the landscape.

References: [1] Costard, F. and Kargel, J.S. (1995) *Icarus* 114, 93-122. [2] Lefort, A. et al. (2009) *JGR* 114, E04005. [3] Morgenstern, A. et al. (2007) *JGR* 112, E06010. [4] Soare, R.J. et al. (2007) *Icarus* 191, 95-112. [5] Ulrich, M. et al., (2010) *JGR* 115, E10009. [6] Seibert, N.M. and Kargel, J.S. (2001) *GRL.* 28, 899-902. [7] Wan Bun Tseung, J.M. et al. (2006) *37th LPS Abs. #1414.* [8] Séjourné, A. et al. (2011) *PSS* 59, 412-422. [9] Séjourné, A. et al. (2010) *41th LPS Abs. #2113.* [10] Soloviev, P. (1973) *Biulet. Peryglac.* 23, 135-155. [11] Murton (2001), Global and Plane. Change 28, 175-192. [12] Soare et al. (2011) *Geolog. Soc. Am.* Special Issue 483. [13] Madeleine et al. (2009) *Icarus*, 203, 390-405. [14] McBride, S. et al. (2005) *36th LPS Abs. #1090.* [15] Rampton, V.N. (1988) Ph.D. thesis memoir v.423, 98p.. [16] Schirrmeister, L. et al. (2002) Quatern. Inter. 89 (1) 97-118. [17] Laskar, J. et al., (2004) *Icarus* 170(2).