THE POLYGON JUNCTION PITS AS AN EVIDENCE OF A PARTICULARLY ICE-RICH AREA IN UTOPIA PLANITIA.

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Introduction: The western part of Utopia Planitia (UP) contains different landforms which are interpreted to be periglacial: thermokarst-like depressions [1-5], small-sized polygons [3-6] and thermokarst-like polygon junction pits [2;7]. The latter are particularly interesting due to a possible origin related to the ground-ice thaw and water accumulation [7]. We have studied the westernmost part of UP with HiRISE imagery (80°-90°E, 35°-50°N) and show that the pits have a specific geographic distribution coinciding with an ice-rich unit and a particular evolution of morphology similar to terrestrial thermokarst features.

The polygon junction pits in UP: Numerous elongated pits are found at the junctions of the small-sized polygons [2;4;7]. The pits range from tens to hundreds of meters in diameter, 5-36 m deep and possess a circular to elliptical-shape (Fig. 1a) [7]. They are present on the surface of the plain as well as inside scalloped terrains suggesting that they are younger than the latter [4]. As we did observe only few impact craters intersecting the pits assuming a very young age. We mapped the distribution of pits and found that they are concentrated to a particular area in UP (40°-47°N; 80°-90°E) where the Astapus Colles geological unit (ABa) occurs (Fig. 1a) [8]. Outside of that area, no polygon junction pits are observed (Fig. 1b).

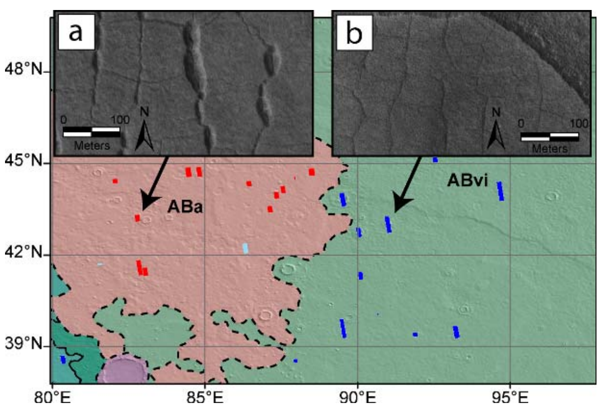

Fig. 1 : Localization of the HiRISE images showing the polygon junction pits (a) over the geologic map of UP [8]

Three classes of pits were distinguished based upon morphology and size (the elongation of pits is defined as major axis/minor axis) (Fig. 2). 1) The first class corresponds to small circular pits aligned along the polygon troughs (Fig. 2a). They are a few tens of meters in diameter for a mean elongation of 1.3 (number N = 73). 2) The second class includes medium-sized elongated pits with scalloped-edges (Fig. 2b). Their size ranges from a few tens to hundreds meters in diameter for a higher mean elongation of 4.1 (N = 75). The direction of the major axis is always N-S. 3) The third class represents large furrows with straight edges (Fig. 2c). They have the same range of size as class 2 but their mean elongation vary (2-5; N = 71). For every class, an enigmatic feature is their occurrence on the N-S troughs (70 %) while few pits occur at the junction of three polygons.

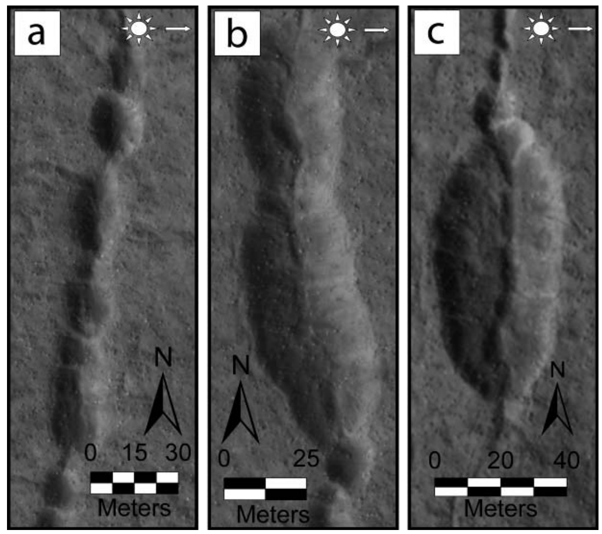

Fig. 2 : Classification of the polygon junction pits in UP (HiRISE PSP_002202_2250)

Possible origin: The concentration of polygon pits in UP could be explained by several hypotheses. In the Tharsis region, the alignments of depressions of several hundred meters in diameter are observed in volcanic area due to collapse of lavas tubes and inside grabens or along faults due to tectonic extension [9].

Others depressions produced by the collapse of the ground have a similar shape as the pits in UP. The dissolution of limestone or salt by ground-water forms underground caves. Their collapse can produce small depressions in the surface of a few tens of meters.

In periglacial environments on Earth, the highly localized thermal disturbance of an ice-rich permafrost produces thermokarst depressions [10]. The network of depressed polygon troughs underlain by ice-wedge is a favoured location for thermokarst (thawing of ice) to occur. The preferential surface water run-off and accumulation of water above ice-wedges induce the thermal-erosion of the latter and promote the subsidence of the ground, forming pits at the junctions of polygons [10;11]. The ponding of water acts like a thermal battery allowing the pits to deepen and expand rapidly into bigger furrows. Occasionally it was observed on Bylot Island (Canada) that the thermo-erosion of surface water run-off can initiate internal tunneling and gullying in ice-rich permafrost along the well-developed system of ice wedges, leading to the development of an underground drainage network of quickly progressing tunnels [10;12;13].

A link to a particularly ice-rich area in UP: The small size of the pits in UP, their presence at polygon junctions and absence of related volcanic/tectonic features rule out the volcanic/tectonic hypothesis [7]. Even if UP is thought to have received material from the nearby circum-Chryse outflow channels [14], the presence of limestone or salt has not been identified and is highly speculative. However, several evidences point out a thermokarst origin [2;7]. Firstly, the location of the pits coincides with the ABa unit which is interpreted to be ice-rich (Fig. 1) [8]. Moreover, a global climate model of water cycle predicted the atmospheric deposition of an icy mantle during the Late-Amazonian high obliquity period in the western UP region [15]. Secondly, they occur exclusively at the polygon junctions suggesting the possible presence of ice-wedges and are associated with other periglacial landforms. Because of the high concentration of pits in the western part of UP, we assume that the different classes distinguished could represent different "snapshots" of their development. We propose a sequence of evolution beginning with small individual pits along the troughs (class 1). At the same time of their expansion, more and more pits appeared along the troughs forming chains of pits. The coalescences of the pits produced elliptical pits with scalloped-edges resulting in the increase of elongation (class 2). With the expansion continuing, the pits acquired a more elliptical shape with straight edges inducing a resulting lower elongation (class 3). The evolution of pits appear to be similar to the evolution and formation of pits on Earth at the polygon junctions by thermal-erosion and water accumulation [10;13].

Discussion of processes: The pits seem to be the result of thermokarst processes but some observations point also toward the collapse processes. Their scalloped morphology suggests a coalescence with neighboring pits, there are fine semi-concentric cracks (~1.2 m width) around them and inside most of pits small dark holes (~5 m width) are observed aligned along the polygon crack suggesting new collapse. The collapse pattern and the possible pits evolution identified could suggest an evolution by collapse and coalescence. The key element is to know the processes that induce the collapse, whether the thawing or sublimation of ground ice is responsible. We did not observe any run-off or flow features inside the pits and no connections between them are visible supporting the sublimation of ground ice. But it is possible to assume the thawing of ground ice at depth and transient accumulation of water.

Unlike the thermokarst pits on Earth that occur at the junction of several ice-wedges, the pits in UP are observed mostly at the N-S polygon junctions (70 %) which is very enigmatic. The preferential direction could underline an eolian control [2].

We could envisage two scenarios. The first scenario implies that the sublimation of shallow ground ice induced the collapse of the ground forming the pits. The sublimation would have occurred particularly at the N-S polygon junctions due to prevailing N-S warm wind for example [2]. The second scenario assumes the localized thawing of ground ice at depth and the subsequent collapse of the void forming the pits. In both scenarios the process continuing, the pits evolved into bigger furrows by collapse and coalescence.

Conclusion: The study of the pits at the N-S polygon troughs in UP show that they are likely formed by the thermokarst modification of an ice-rich area. The possible evolution of morphology suggests the degradation of potential ice-wedges and the subsequent collapse of cavities formed. Further investigations are needed to evaluate the possibly of sublimation or thawing of ground ice. We also need to know if the pits in UP are the result of specific and local climatic conditions that disturbed the ground ice or a particularly ice-rich ground as predicted by the GCM that was thermally destabilized. Furthermore, mapping precisely the occurrence of the polygon junction pits in UP could help redefine the limit of the ice-rich unit of Astapus Colles.

References: [1] Costard, F. and Kargel, J.S. (1995). *Icarus* 114, 93-122. [2] Morgenstern, A. et al. (2007). *JGR* 112, E06010. [3] Soare, R.J. et al. (2007). *Icarus* 191, 95-112. [4] Lefort, A. et al. (2009). *JGR* 114, E04005. [5] Séjourné, A. et al. (2009). *40th LPS Abstract # 1733.* [6] Seibert, N.M. and Kargel, J.S. (2001). *GRL*. 28, 899-902. [7] Wan Bun Tseung, J.M. et al. (2006). *37th LPS Abstract # 1414.* [8] Tanaka, K. et al. (2005). *Atlas of Mars: Northern Plains Region*. [9] Wyrick, D. et al. (2004). *JGR, 109, E06005.* [10] French, H.M. (2007). *The periglacial environment, 3rd ed., J. Wiley & Sons. 458 pp.* [11] Washburn, A.L. (1973). *Perig. Processes and Environments. New York: St Mart. Press. 318 pp.*. [12] Seppälä, M. (1996). Geomorpho. 20, 313-319. [13] Fortier, D. et al. (2007). *Perm. And P. Proc. 18, 229-243.* [14] Lucchitta, B. (1986). *Proc. LPS 17th, JG. suppl., 91, E166-E174.* [15] Madeleine, J.B. et al. (2009). *Icarus* 203, 390-405.