SHALLOW MELTING AND UNDERGROUND DRAINAGE IN UTOPIA PLANITIA, MARS.

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Introduction: The mid-latitudes of Mars show a range of landforms similar to those observed in periglacial regions on Earth. These include debris flows [1], networks of small-sized polygonal patterned ground [2, 3], scalloped pits [2-6] and small pingo-like mounds [6]. Recently, we have used HiRISE images to study the geomorphology of western Utopia Planitia (UP; 80°-100°E, 40°-47°N) and to understand the processes responsible for the formation of the possible periglacial landforms. Under current atmospheric conditions on Mars that are below the triple point of water, the occurrence of meltwater at or near the surface must be uncommon. Some studies have suggested that sublimation is the dominant process by which the putative periglacial landforms have developed [2, 7]. Here, we address questions concerning the influence of meltwater on the UP landscape using analogues of near-surface melting and drainage along ice-wedge troughs in the Tuktoyaktuk Coastlands [8] and Bylot Island, northern Canada [9]. Mars-wise, we use this terrestrial analogue to develop a thermal model that comprises a thick insulating dusty layer during a period of slight climatic warming relative to today's climate (but still severe periglacial conditions by Earth standards).

The polygon junction pits: Numerous elongated pits are found at the junctions of the small-sized polygons. The pits range from tens to hundreds of meters in diameter, 5-36 m deep and possess a circular to elliptical-shape (Fig. 1) [5-8]. Inside the pits, the polygonal crack is observed [7]) 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 [7]. The preferential direction could underline an aeolian control or a regional slope [6].

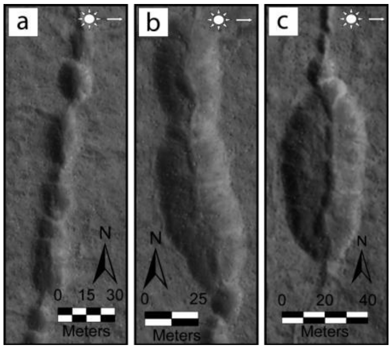

Fig. 1: Morphology of the polygon junction pits in UP. The sinuous rill and elongated pits are possibly indicative of an underground drainage by thermal erosion along ice wedges (HiRISE PSP_002202_2250)

Formation of tunnels in ice wedges network: On Earth, 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 ponds at the junctions of polygons (Fig. 2) [9, 11]

On Bylot Island (Canada), thermal erosion of permafrost by surface water runoff can initiate internal tunnelling [9] and gullying in ice-rich permafrost along the well-developed system of ice wedges, leading to the rapid development of an underground drainage network of tunnels (Fig. 2). Most often, collapse pits oriented along fracture-controlled drainage ways are observed in the field.

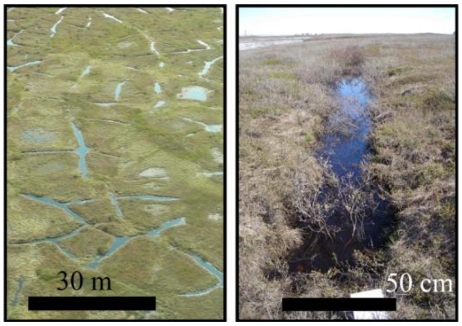

Fig. 2: Polygon junction ponds in the Tuktoyaktuk Coastlands, Canada (July 2009).

In UP, sinuous rilles inside elongated pits suggest an evolution by collapse and coalescence. We did not observe any run-off or flow features inside the pits supporting the sublimation of ground ice. However, we surmise that the process includes the melting of ground ice at depth and transient accumulation of water. Here, we suggest that these sinuous rills and associated elongated pits are indicative of an underground melting and collapse with the formation of tunnels along ice wedges networks by thermal erosion. The lack of terminal deposits (e.g., a fan) at the end of the network remains unexplained. One possibility is that transient or episodic flows without enough power for solid transport during the thermal erosion process occurred and the main cavity volume produced was by removal of ice.

Thermal model with an insulating dust layer: Figure 3 shows two sets of simple models of heat conduction; in **panel A**, the thermal profiles through a single layer of dust is shown for different surface temperatures. **Panel B** gives results for two-layer models of a porous, dry dust layer overlying ice-cemented nonporous dust. In both cases the thermal conductivity is temperature dependent. The thermal conductivity of dry dust (both models) is set at 10% that of nonporous basalt, as is consistent with typical fine-grained powders. The icy dust layer has the thermal conductivity values of nonporous basalt. The Martian heat flow is set at 0.03 $W m^{-2}$. The two-layer model of a porous dust blanket or other low-conductivity blanket over an ice-rich dust deposit has been proposed [11, 12]. In the model (Fig. 3B), the low conductivity surface layer provides insulation sufficient to enable melting of the underlying icy-dust layer at depths of 150-250 m. Melting could occur with extensive erosion and collapse of the underlying dusty ice. After melting, the dry surface layer might blow away to reveal the thermokarstic terrain of the substrate layer.

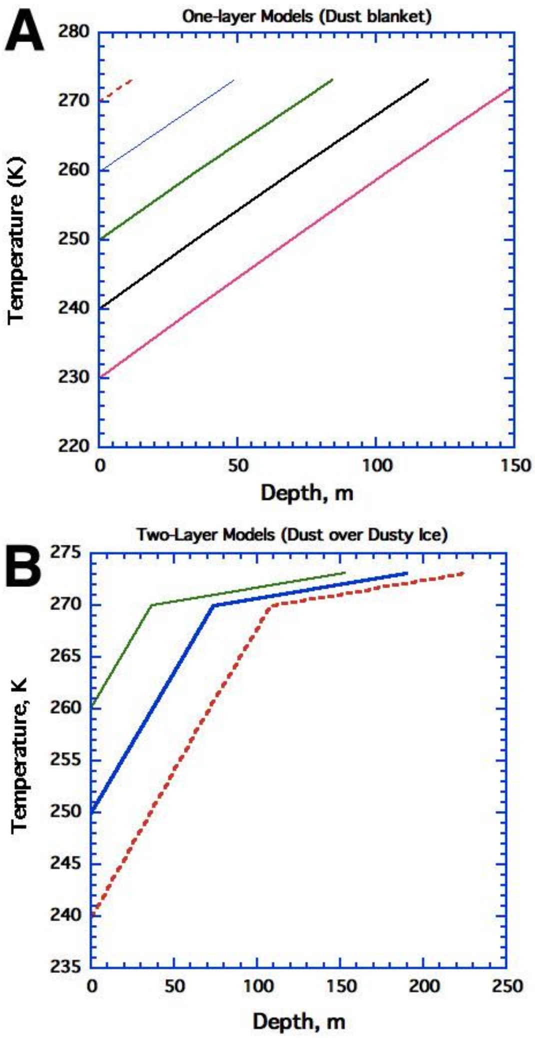

Fig. 3: One- and Two-layer thermal models of heat conduction through a dust layer (3A) and a dust layer overlying an icy dust deposit (3B). Colour (different surface temperatures).

The minimum thickness of the icy dust deposits over UP, which corresponds to the deepest scalloped depression depth and depth of filled craters, ranges between 40 and 70 m thick [13-14].

Results and discussion: Achievement of melting at such a shallow depth requires some special conditions: 1) exceptional low thermal conductivity, 2) exceptional high heat flow, 3) exceptional low melting point compositions, or 4) climate modified to allow much warmer surface temperatures. These four things can work separately if the values chosen for the system are very special (presumably rare). However, moderate/unexceptional values of 2 or more parameters may have occurred together. Some of the models could involve buried ice, and others buried salt hydrates. Periods of high obliquity have occurred in the past suggesting previous permafrost thaw periods.

These hypothesized underground drainages might be just thousands to millions of years, formed when obliquity was different. If the features are a few million years old then they have existed through many obliquity cycles, some of which might have made the Martian climate more conducive to thaw.

Conclusion: Using HiRISE images in Western UP, we found that the polygonal network inside depressions is possibly an ice-wedge network that has subsequently evolved by sublimation or thawing. Based on the identification of sinuous and elongated pits within supposed thermokarst depressions in UP, we suggest that episodic underground channel-like forms and melting are possible under severe periglacial conditions. Testing that hypothesis with a thermal model, we propose that the underground flow was possible in UP by melting of ice rich permafrost along polygonal network during high-obliquity periods of Mars and the formation of tunnels along ice wedges networks.

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