DEPOSITION AND DEGRADATION OF A VOLATILE-RICH LAYER IN UTOPIA PLANITIA, MARS.

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Introduction: We investigate a region of about 92.000 km² in western Utopia Planitia, extending from about 80° to 85°E and from 40° to 50°N, where several morphological features like polygons and pits or depressions in a mantling deposit show close similarities to terrestrial permafrost structures. Their origin has been attributed to periglacial processes and permafrost degradation [e.g., 1], but aeolian processes [2] and structural control [3] have also been suggested. Our focus is on degradation features and their formation, and we compare the observations with our own field experience in Arctic Siberia [4,5].

Methods: We used High Resolution Stereo Camera (HRSC) and THEMIS-VIS images as a base for manually digitizing depressions in the mantling deposit attributable to permafrost degradation in a geoinformation system GIS (ArcGIS™ of ESRI™). The resulting vector layer was analyzed in GIS with respect to the latitudinal distribution of the depressions.

All Mars Orbiter Camera Near Angle (MOC-NA) images available for the study region were examined for comparisons with HRSC and closer analysis of permafrost degradation features, as they provide a better spatial resolution of down to 1.6 m. Topographic information was derived from individual tracks of the Mars Orbiter Laser Altimeter (MOLA).

Permafrost degradation and thermokarst on Earth: The degradation of permafrost is predominantly connected to externally forced changes in the thermo-physical range of permafrost stability at the land surface (e.g., climate warming; disturbance or removal of insulating cover layers). With the beginning of the Early Holocene climate warming (approx. 11.500 y ago), terrestrial permafrost landscapes were subject to major morphological changes due to permafrost instability and degradation. One of the most important and wide-spread degradation processes is the so called thermokarst, which is defined as the thawing of ice-rich permafrost or the melting of massive ice in the subsurface [6]. It results in surface subsidence and the formation of characteristic depressions due to the volume loss from ground ice melting.

Morphology of landforms: MOC images show several landforms that are typical for the study region (Fig. 1). Large depressions are observed where the mantling material is completely removed and the cratered floor of the underlying substrate is exposed (Fig. 1a and b). MOLA tracks indicate a depth of ~80 m for the depression shown in Fig. 1a. The depressions seem to be asymmetric: steep, north-facing scarps mark the southern margins of the depressions, while the remaining margins display a gently inclined slope of the bordering mantling deposit. Where the mantle is present, it is characterized by polygonal patterns (Fig. 1c-e). The cracks delineating the polygon areas show a more pronounced development in N-S direction, and smaller pits are aligned along the N-S trending cracks. Smaller depressions on the mantle, the depth of which is less than the thickness of the mantle, also show the same asymmetry as the larger ones (Fig. 1c). At several locations, the N-S-trending cracks are bordered by U-shaped troughs (Fig. 1f). Concentric and radial patterns mark the locations of impact craters buried by the mantling material (Fig. 1g and h).

Results: The region is generally affected by surface degradation. On scales of hundreds of meters, the flat terrain is interspersed with rampart craters and broad depressions of compound shape and a depth of several tens of meters. The depressions often have steep, north-facing cliffs at their southern margins, while the other margins display smoother slope angles. The percentage of the total surface covered by these depressions amounts to 24% of the study area (Fig. 2). Towards the south of the study region, the depressions seem to be larger in extent and their floors are populated by an abundance of small impact craters.

Conclusions: On the base of these observations we propose a model of landscape genesis for western Utopia Planitia. It assumes the subaerial deposition of a stack of probably ice-bearing sedimentary layers on a cratered basement and its post-sedimentary permafrost degradation. The dominant degradation process might be the sublimation of ice in the layers, leading to volume loss and subsequent collapse. We discuss several possible processes and factors of landscape evolution in the light of terrestrial periglacial analogues of permafrost degradation including surface fracturing, sublimation of ground ice, and other periglacial as well as aeolian activities.

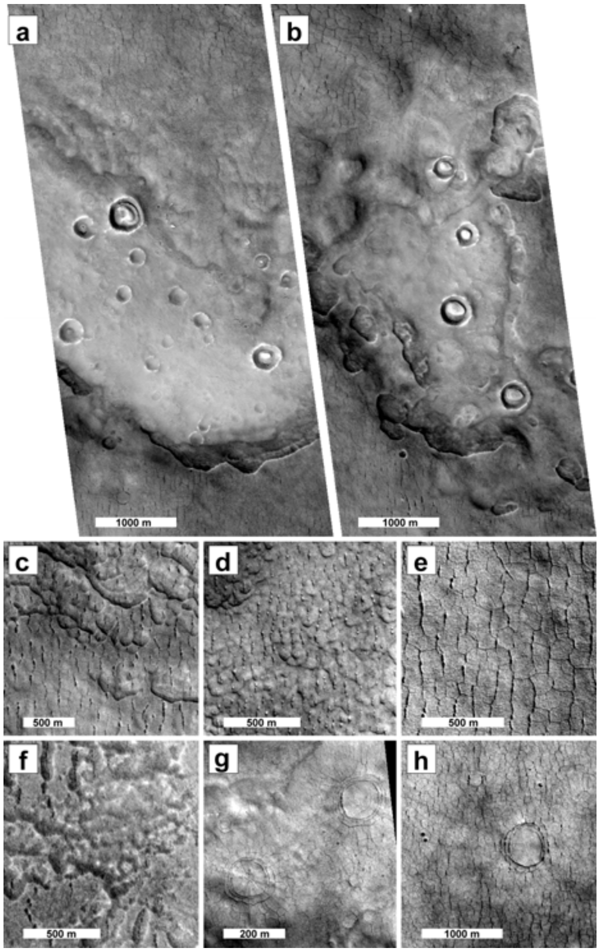

Figure 1: Examples of landforms in western Utopia Planitia. (a) Asymmetric topographic depression with steep southern scarp and more gradually rising northern margin. The floor of the depression displays impact craters, which are partly filled by layered material. The mantling material is characterized by polygons. Single MOLA track (nummer?) shows that the mantling material is about 80 m thick. The degraded appearance of the southern scarp in the lower left part of the image might indicate a gelifluction lobe (GFL). MOC E04-01564, center at 41.46°N, 82.92°E. (b) Very similar asymmetric depression, with steep southern and gently rising northern margin. MOC E04-01564, center at 42.08°N, 82.81°E. (c) Polygons with preferred N-S orientation of pits along cracks. Asymmetric small depressions have steep north-facing scarps (compare with Figs. 1a and 1b). MOC R11-00336, center at 45.47°N and 81.1°E. (d) Similar to Fig. 1c. MOC E11-02077, center at 45.4°N and 81.44°E. (e) Uniform polygons with preferred N-S orientation. MOC M04-02704, center at 44.08°N, 84.15°E. (f) Interior of x-km impact crater. Note the N-S-oriented cracks, which are bounded by U-shaped troughs (arrows in upper left and lower right parts of image). See text for details. MOC R17-00802, center at 47.62°N and 82.57°E. (g) Polygon pattern locally modified into concentric and radial pattern. The inhomogeneity of the mantling material might be caused by mantled impact craters, whose interior might have subsided more that the surroundings, causing the concentric cracks. MOC R05-00393, center at 42.02°N and 80.95°E. (h) Similar as in Fig. 1g, concentric cracks might indicate position of mantled impact crater. MOC E04-01564, center at 41.63°N, 82.89°E.

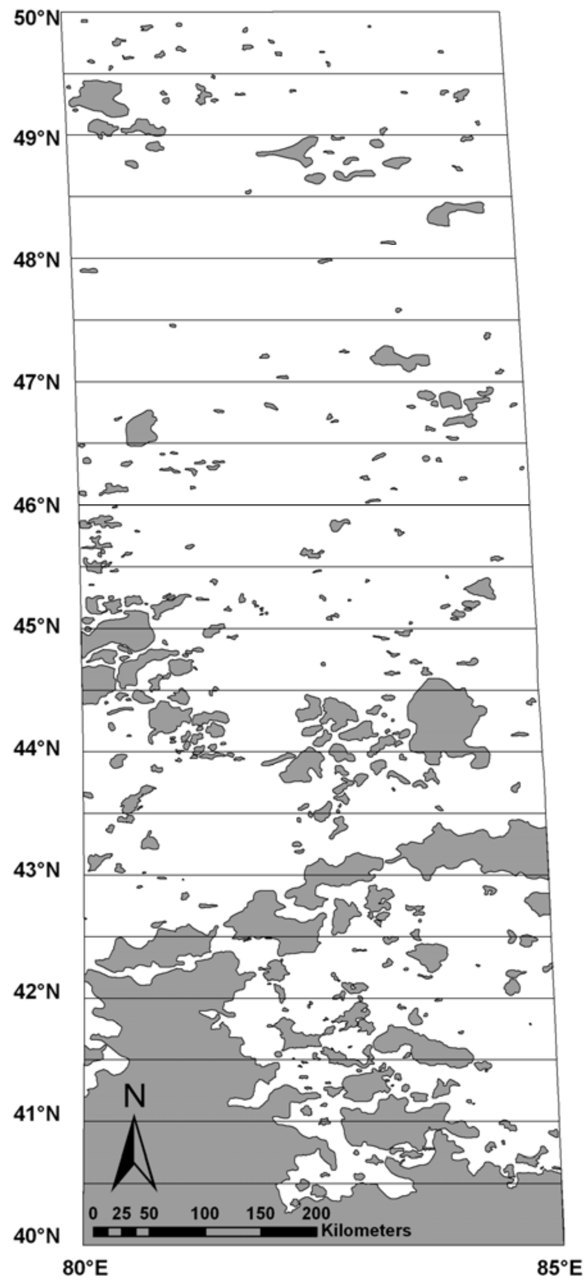

Figure 2: GIS-based map of topographic depressions (gray areas) in mantling material. Our results indicate an increasing area of depressions (=increasing degradation) from North to South, possibly indicating a climatic control of the degradation process.

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