GULLY FORMATION, PERIGLACIAL PROCESSES AND POSSIBLE NEAR-SURFACE GROUND-ICE IN UTOPIA PLANITIA. R.J. Soare,[1] J.M. Wan Bun Tseung[2] and G.R. Osinski.[3] [1] Dept. of Geog., Planning and Environment, Concordia Univ., 1455 de Maisonneuve Blvd. W., Montreal, Canada, H3G 1M8, rsoare@colba.net; [2] Dept. of Geog., Univ. of Calgary, 2500 University Drive N.W., Calgary, Canada T2N 1N4; [3] Canadian Space Agency, 6767 Route de l'aeroport, St-Hubert, Canada J3Y 8Y9.

Introduction: Speculation concerning the presence of near-surface ground-ice and of associated features on Mars dates back to the coarsely-resolved images of the Mariner missions in the late 1960s and early 1970s [1][2]. Recently, the identification of crater-wall gullies in polar and near-polar regions of Mars [3][4][5][6][7] and of high levels of water-equivalent hydrogen in these regions [8][9] has renewed debate about the presence of near-surface ground-ice and its possible influence on landform development.

Here, we show crater-wall gullies in Utopia Planitia [UP], point to landforms suggesting that near-surface ground-ice extends tens of metres to depth in the UP landscape and argue that gully formation could be related to the melting of this near-surface ground-ice during periods of high obliquity.

Gullies in Utopia Planitia: Small, sharply-incised gullies occur on the walls of some impact craters in UP (Fig. 1). They comprise three components: 1. narrow, elongated (~1.3-1.9km in length) and steeply-sided alcoves (~15-65m in diam.), indicative of strong topographic or stratigraphic control; 2. sinuous channels that anastamose on occasion; and, 3. depositional aprons that vary widely in shape and symmetry.

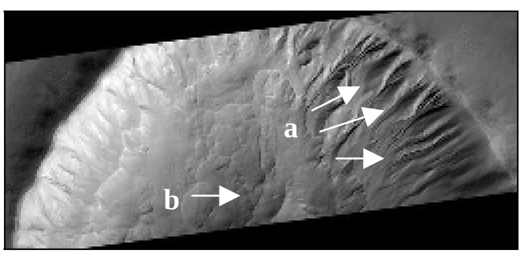

Fig. 1. a. Crater-wall gullies (poleward-facing); b. crater-floor, collapse-features. MOC image S04-00681 (276.02^{0}W, 50.52^{0}N; res: 3.29m/pixel). Image is ~9.1km across. North is to the left

The UP gullies, many of which lie on poleward slopes, differ from those that occur in the southern hemisphere in two important ways. First, the channel heads/alcoves of the Utopia gullies originate within metres of the crater rim or crest, not hundreds of metres downslope. This points to near-surface non-aquiferic sources of flow. Second, unlike the fully-formed and symmetrical deposition aprons associated with gullies in the heavily-cratered highlands, many of the UP crater-wall gullies break-up and disappear as they intercept areas of apparent crater-floor collapse.

We believe that the formation of the crater-wall gullies is the product of aqueous or mixed-debris flow that followed from the melting of near-surface ground ice just beneath the crater rim. There are no clear analogues for these near-rim cold-climate gullies on Earth.

We hypothesise that the areas of crater-floor collapse adjacent to the gullies also were formed by the melting of near-surface ground-ice. We suggest that terrestrial thermokarst landscapes are an analogical asset in trying to understand the development of collapse features and, derivatively, crater-slope gullies in UP. Here we describe the UP collapse features and compare them with terrestrial thermokarst-lake and -pond basins.

Collapse-feature description:

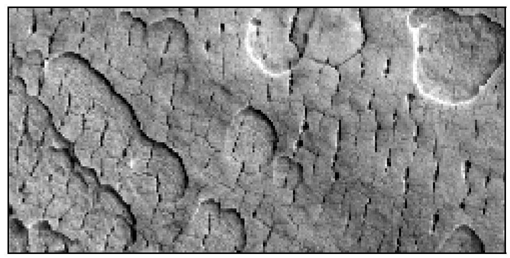

Fig. 2. Outwash-plain, collapse-features. MOC image R03-01203 (275.58^{0}W, 45.52^{0}N; res: 3.71m/pixel). Image is ~3.3km across. North is down.

South to mid-UP is dotted with small-sized, roughly circular collapse-features that are tens to hundreds of metres in diameter [10][11] (Fig.2). Some of these features are isolated; others are clustered; some of them appear to have coalesced. Many of them are scalloped or lobate. All of the features are rimless and have relatively flat floors (notwithstanding deposits of sand below the windward aspects). The collapse features are ubiquitous, occurring on impact-crater floors and slopes (Fig. 1), on impact crater ejecta-blankets and in the outwash plains beyond the craters themselves [12]. In some instances, they are 20-30m deep (unpublished data based on MOLA track overlays of MOC R03-01203).

Terrestrial arctic analogues: Thermokarst lake- and pond-basins in the arctic (Fig. 3) are rimless, relatively flat-floored and shallow, rarely being deeper than ~25m. The basins sometimes reach 1-2 km in diameter but usually are much smaller. Some of them are isolated; others are clustered; some of them have coalesced. Many of them are roughly circular to ovular, scalloped or lobate. The basins are found in areas of ice-rich permafrost, more specifically, excess ice, because the volumetric presence of frozen water exceeds the pore space available to it in the ground. The formation of thermokarst landforms takes place when the thermal equilibrium of permafrost is disturbed, inducing the thaw, melting and mobilisation of near-surface ground-ice. A variable often associated with the disturbance of ground-ice equilibrium is regional climate change [13].

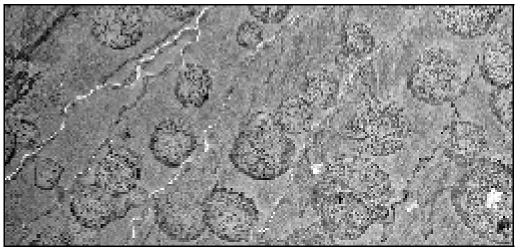

Fig. 3. Thermokarst lakes and drained basins, Baffin Island, Canada. Air photo 15358-58, National Air Photo Library, Ottawa, Canada (66.28^0N, 72.45^0W; scale-1:20:000). Image is ~1.8km across.

Possible thermokarst basins in UP: The morphology of the UP collapse features is consistent with that of terrestrial thermokarst-lake and pond basins. Hydrologically, a number of markers point to the region being ice-rich. High levels of water-equivalent hydrogen imply the possible presence of near-surface ground ice (perhaps excess ice) within a metre of the surface [14][15]. Collapse-feature depth of ~20-30m could be indicative of excess-ice extending tens of metres into the regolith that might have melted at high obliquity. The widespread presence of fluidised crater-ejecta points to the possible presence of ground-ice to hundreds of metres of depth [16][17].

Alternate hypothesis: Depressions roughly similar in shape to the UP collapse features are commonplace to the east, particularly in the area surrounding the Tharsis rise. Such features, called pit craters, form when surface material collapses into a sub-surface cavity created by endogenetic processes [18][19]. The pit craters occur within graben systems or near areas that display extensional or volcanic stresses such as fault lines, lava tubes and collapsed magma chambers [20][21]. A comparison between the pit craters and the UP collapse features reveals several important differences.

First, the mean diameter of the pit craters is ~0.255-1.76km [22], compared to ~10-20m for the collapse features (unpublished data). Second, the close association between pit craters and extensional or volcanic features is absent from the landscape where the UP collapse features occur. Third, the near-surface regolith found in UP is thought to be ice rich, much more so than the areas where the pit craters occur. Fourth, concurrent in the UP landscape with the collapse features are polygon-trough pits. The trough pits are thought to be relict markers of small-sized thermokarst-ponds [23]. Similar features are absent from the Tharsis region.

Discussion: Some scientists argue that even under optimum temperatures at high obliquity, the aridity of the Martian atmosphere would induce the sublimation of near-surface ground ice before the ground-ice reaches its melting point [24][25]. Accordingly, gully formation could not be the product of near-surface ground-ice melt. Others posit that under a protective layer of seasonal CO_2 [26] or snow [27], near-surface ground-ice melt and gully formation processes could occur.

We believe that the near-surface origin of the UP gullies points to the presence of near-surface ground-ice, perhaps excess ice, that could have been melted by a thermal wave at high obliquity [28]. The same process could have formed the collapse features on the crater floor of fig. 1. Both assumptions are consistent with the detection of near-surface, water-equivalent hydrogen in the area, the identification of widespread fluidised-ejecta in the region and analogically-derived thinking with regard to landscape evolution in UP. Further work needs to be done to reconcile our landscape interpretation with modeled data.

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