CRATER-RIM GULLY FORMATION IN UTOPIA PLANITIA: HYDROLOGICAL SUPPORT OF THE PERIGLACIAL ORIGIN HYPOTHESIS. C.L. Roehm[1], R.J. Soare[2-4], G. R. Osinski[4] and F. Costard[5]. [1]Department of Geography & Planning and the Great Lakes Center, SUNY College at Buffalo, 1300 Elmwood Ave., 14222, Buffalo, NY 14222. [2] croehm@gmail.com. Department of Geography, Planning & Environment, Concordia University, 1455 de Maisonneuve, Blvd. W., Montreal H3G 1M8, Canada. [3]Department of Geography, Dawson College, Montreal, Canada H3Z 1A4. [4]Departments of Earth Sciences & Physics and Astronomy, University of Western Ontario, 1151 Richmond Street, London, Canada N6A 5B7. [5]UMR 8148 IDES, Université Paris-Sud XI, Orsay, France.

Introduction: Gullies are among the youngest and most enigmatic landforms identified on the Mars so far. In our earlier work we documented the occurrence of crater-based near-rim gullies in the middle latitudes of Utopia Planitia (UP)[1]. Near-surface, ice-rich regolith and periglacial landforms are thought to be widespread and commonplace in this region [1-6]. We proposed that gully origin was closely tied to the thaw of ice-rich regolith within the ejecta structure of some impact craters. Thaw conditions, in turn, were triggered by changes in the orbital inclination of Mars during the late Amazonian period [6].

In a number of instances, thermokarst-like depressions in the ejecta structure were identified close to crater-wall gully heads. We hypothesized that meltwater (thawed ice-rich regolith) could have ponded in these depressions during recent high obliquities and migrated through or over the ejecta-blanket mantle to the areas of gully formation.

This periglacial scenario is intriguing in as much as it uses readily observed and defined geological structures as a possible source of gully-forming material. Moreover, the scenario avoids having to hypothesise the origin and maintenance/presence of deep or perched (near-surface) aquifers and of related piping mechanisms wherever the near-rim gullies occur.

In this study, we present preliminary data derived from MOC imagery comparing the volumetric capacity of ejecta-based depressions with the volumetric dimensions of nearby crater-rim gullies. Questions about the permeability of crater-rim ejecta and ice-rich regolith are being addressed by ongoing research.

Volumetric data: A selection of seven crater ejecta depressions were identified from the MOC image E0301254 (Fig. 1). The depression volumes for each crater were determined by a modified approach of impact crater volume calculations we have adapted for depression structure. Ejecta blanket slopes in Utopia Planitia have been estimated to lie between 1.25 and 1.4 degrees [7]. This allows the inverted cone/parabola approximation to be used as the means of calculating volumetric content of water in the reference section. The volume of the depression represents the void volume of the ejecta mantle following sublimation and/or drainage. These voids are thought to have been ice rich and, hence, represent the potential volume of water-ice contained within the regolith.

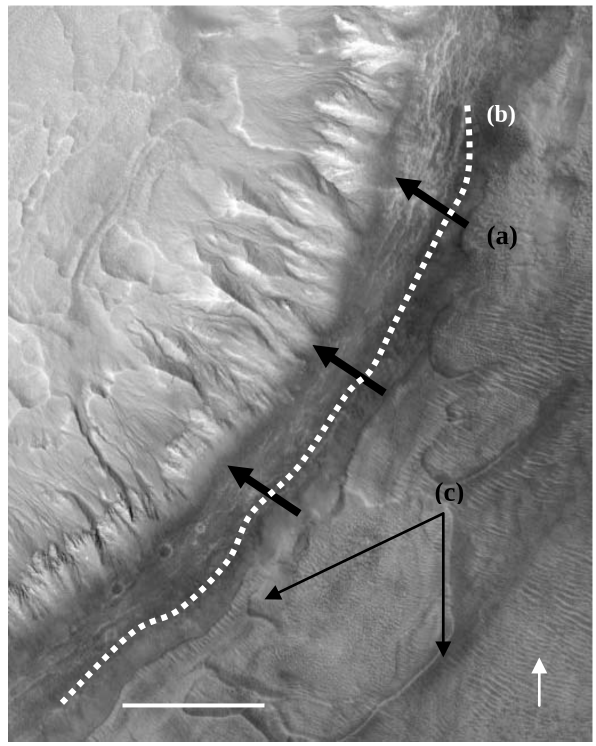

Fig. 1. Impact crater, western Utopia Planitia. (a) Potential direction of flow from ejecta depressions to gully heads. (b) Outline of crater summit. (c) Steep and shallow sides of scalloped depressions in ejecta structure (MOC e0301254; 47.1^{0}N, 89.8^{0}E; res: 5.97 m/pixel; USGS image archive). White arrow points north. Scale bar is 500 m.

The volume of the ejecta depressions varied between 77,389 m^3 and 4,214,150 m^3 with depression depths varying between 5 m and 20 m. Depression diameters ranged between 130 m and 570 m. Gullies on the crater wall are uniform in shape and in size with a typical v-shaped alcove. Given the orientation of the phase angle, measurements of width and length could be calculated. However, depth and true length were estimated given a range of minimum and maximum slope angles (30^o and 40^o). Gully alcoves measured on average between 207 m and 235 m in true length, 180 m in maximum width and between 20 m and 47 m in depth. Given these estimates, volumetric regolith displaced was calculated at between 502,793 m^3 and 210,652 m^3 for 30^o and 40^o angles, respectively. These data suggest that the volume of liquid displaced from the depression is up to 8.3 times greater than the volume of material removed from the gully alcove

Data interpretation: Boundary conditions sufficiently wet and warm to emplace, maintain and then thaw near-surface ground ice may allow for water to melt prior to sublimation [8]. Given a heating rate sufficient to warm ice to the melting point and overcome evaporative cooling, ice will transform into a metastable liquid as long as its vapor pressure does not exceed the ambient atmospheric pressure [9]. Under such circumstances, this liquid may be available for transport/flow through the regolith of the ejecta mantle towards a topographic/hydraulic low within the crater wall (a) in Fig. 1. This idea is supported in our study, whereby the volume of displaced material (volatiles) in the ejecta depressions can be up to 1.25 times greater than that displaced from the gully alcoves. Given that there are multiple depressions occurring on the ejecta regolith, it is feasible to assume that the amount of liquid required to cause gully erosion can be satisfied.

In dry regolith, heat transfer is limited by the contact between particles implying higher thermal inertia is expected in finer rather than coarse. Hence, to satisfy heating and flow, the higher thermal conductivity of ice relative to regolith would indicate higher capacity for heat flow and melting within ice-rich regolith. Additionally, in order to sustain gravitational potential for flow through regolith, near-saturation conditions need to be satisfied. Because the vapor-phase desiccation is constrained to the upper 10s of centimeters of the regolith [10], large portions of subsurface ice-rich regolith may be protected from sublimation. Further, the outer rims of the ejecta blanket depressions appear higher and sharper than the rims closer to the crater wall, suggesting possible flow of volatiles through the upper layers of the regolith mantle towards the inner crater wall (c in Fig. 2).

Conclusion: We have identified a geological structure (depressions on impact-crater ejecta blanket mantle), a possible source of gully forming fluids (near-surface ice-rich regolith in the ejecta) and a thermal mechanism (obliquity-driven thaw conditions) which, as a hydrological assemblage, could be used to explain the formation of some crater-rim gullies in UP.

We suggest that meltwater, generated by the thaw of ice-rich regolith, migrated to a lower topographic point and lower hydraulic potential. This explains two things: 1. flow through the ejecta blanket mantle to nearby crater walls; and, 2. the presence of gully alcoves high on the crater walls themselves. The absence of gullies on the crater walls where few or no depressions are observed within the outer ejecta blanket mantle, support this assumption.

Much work remains with regard to evaluating the possible permeabilities of crater-rim ejecta and ice-rich regolith. However, we believe that the volumetric calculations presented above, tied to a gully-forming pathway based on visible geological structures, may move debate concerning the origin of gullies on Mars one step further than hitherto.

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