GULLY FORMATION AND CLIMATE CHANGE IN THE CANADIAN ARCTIC: A POSSIBLE ANALOGUE OF NEAR-RIM, IMPACT-CRATER GULLIES IN UTOPIA AND WESTERN ELYSIUM PLANITIA, MARS. R.J. Soare[1] and G.R. Osinski. [1]Dept. of Geography, Planning & Environment, Concordia University, 1455 De Maisonneuve W., Montreal, Qc., Canada H3G 1M8 (rsoare@colba.net); [2]Dept. of Earth Sciences, University of Western Ontario, London, Ont., Canada N6A 5B7.

Introduction: The origin and development of Martian gullies remains a controversial topic within the planetary science community. Formation hypotheses are diverse. In earlier work [1], we hypothesised that the recent formation of some near-rim impact-crater gullies (Fig. 1) in Utopia and western Elysium Planitia was related to obliquity-driven rises in late-Amazonian mean temperatures and to the localised thawing of near-surface ice-rich regolith or permafrost (permafrost whose pore space is taken up if not exceeded by the presence of frozen water), perhaps even massive ice beds, that were emplaced during earlier obliquity cycles [2]. Possible geological markers of this ice-rich permafrost are lobate (alas-like) depressions [3-5], pingo-like mounds [6-8] and small-sized polygonal patterned-ground [3,9], all of which are ubiquitous in the region.

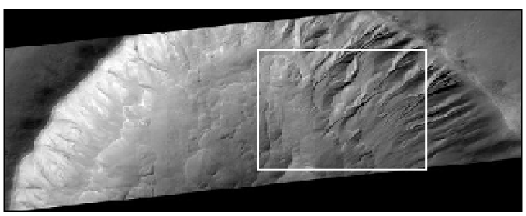

Fig. 1. Impact crater in Utopia Planitia. Notice gullies high on the crater wall near the crater rim. They superpose alas-like depressions [highlighted in the box] in the area of the gully debris aprons (MOC S04-00681, 50.5°N, 276.0°W). Image is ~3.1 km across.

Here we briefly discuss a possible terrestrial analogue of the Martian gullies: lakeside gullies in the Tuktoyaktuk Coastlands of northern Canada (Figs. 2a, 2b). We suggest that studying the origin and development of the Eskimo Lakes' gullies may further our understanding of climate-driven periglacial processes on Earth and, potentially, by analogy, of climate-driven periglacial processes and gully formation on Mars.

Fig. 2a. Air photo of lake-side gullies.

Fig. 2b. Air photo of lake-side gullies; grey-coloured sediment highlights active areas of massive ice thaw/ exposure and of discharge. Image is ~250 m across.

A periglacial landscape at Eskimo Lakes (Tuktoyaktuk Coastlands): Field work in June 2007 showed that gully formation at Eskimo Lakes (68°52' N, 133°19 W) is ongoing (Fig. 2b). The gullies occur in a region of deep, continuous and ice-rich permafrost. Permafrost depth ranges from ~400–600 m (Fig. 3) and attenuates to ~200 m around the margins of Eskimo Lakes [10]. The regional landscape is dotted with ice-rich periglacial landforms: thermokarst lakes (whose origin is tied closely to ground-ice thaw), alases (drained thermokarst lakes), pingos (perennial, ice-cored mounds) and small-sized, unsorted polygonal patterned ground (often underlain by ice wedges) [2,11]. Interestingly, the formation of the Eskimo Lakes gullies has exposed massive-ice beds in the near-surface permafrost that could be mid-Wisconsonian in age. The chronological gap between emplacement and exposure comprises thousands of years and numerous periods of terrestrial climate-change cycles.

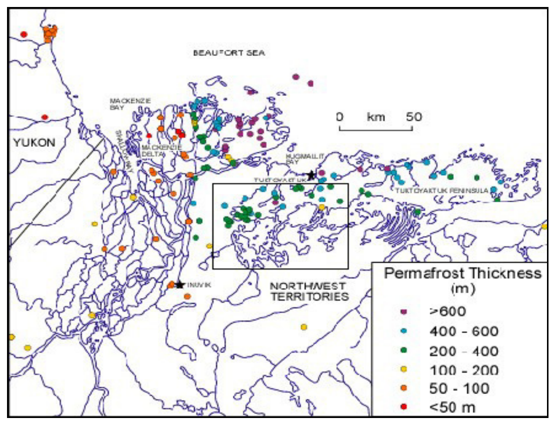

Fig. 3. Thickness of permafrost in the Delta Eskimo Lakes region (highlighted in box). Image: NRCan.

Massive ice and gully formation at Eskimo Lakes': Extensive sheets of massive ice are widespread in the region (often ≥ 13 m thick [12]). The sheets are most common at depths between 6 and 25 m

[13], although massive beds of ice are found at depths as shallow as 3-4 m (Fig. 4).

There is no consensus as to the origin of the massive-ice beds. Some researchers point to post-glacial ice segregation and permafrost aggradation; they argue that these processes were induced by the retreat of early- to mid-Wisconsonian glaciers and the subsequent freezing of basal meltwater in the glacial till [11,13-14]. Others suggest that the beds are buried basal ice [15-16].

Fig. 4. Ground-level view of massive-ice exposure. Notice overburden ~3-4 m thick.

Gully formation in the Tuktoyaktuk Coastlands: The ice-rich permafrost of the Tuktoyaktuk Coastlands is particularly sensitive to regional warming trends and to rises in mean temperatures (Fig. 4). Rises

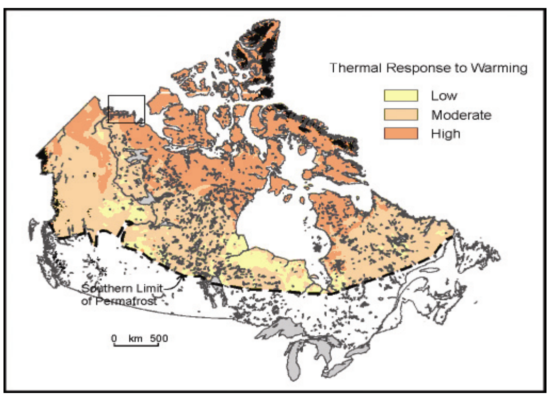

Fig. 4. The Tuktoyaktuk Coastlands are in a region of extreme thaw sensitivity, highlighted in a box. Image: NRCan.

in temperature deepen the active layer, mobilising and introducing melt-water that was previously frozen in the permafrost and unavailable for hydrological activity in the near-surface sediments. Figure 2b shows a three-tiered biogeographical gradient running from a sparse, small-hummock covered plain above the gully alcoves through to alder and willow-dominated slopes surrounding the gullies. Preliminary work suggests that the changes in vegetation type are the product of slight increases in the depth of the active layer as well as in the volume of thaw-related meltwater in the gully drainage basin. Further hydrological and biogeographical mapping will be carried out in order to evaluate the validity of this finding. Stable isotope studies are also underway in order to help constrain the relative environments and age associated with the emplacement of the massive-ice beds.

Discussion: The possible relevance of the Eskimo Lakes' gullies and the surrounding periglacial landscape to our understanding of gully formation on Mars - at least to the formation of near-rim impact crater gullies in Utopia and western Elysium Planitia - is three-fold. First, although regolith samples showing the presence of ground ice to metres of depth in the area of the Martian gully heads are not available, the occurrence of a regional landscape assemblage comprising alas-like depressions, small-sized polygonal patterned ground, nested raised-rim features and inner mounds, by analogy with the Tuktoyaktuk Coastlands, is suggestive of ice-rich ground on Mars. Second, if an adequately thick or deep overburden forms subsequent to the emplacement of a massive-ice body, then the integrity of the massive ice could be maintained through countless climate-change cycles, only to be exposed when temperature rises become particularly acute. Third, just as gully formation in areas of ice-rich permafrost on Earth can be driven by rises of mean temperature, similar rises may, therefore, play an important role in thawing ice-rich regolith on Mars and, subsequently, triggering gully formation high on the slope of some Martian impact craters.

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