CHARACTERIZATION OF GULLIES AND THEIR CONTROLS AT THOMAS LEE INLET, DEVON ISLAND, NUNAVUT, AND CONSIDERATIONS AS ANALOGUES TO MARS. E. Godin[1], A. Pontefract[2], T. N. Harrison[3], G. R. Osinski[1,4]. [1]Dept. of Earth Sciences / Centre for Planetary Science and Exploration, University of Western Ontario, London, ON, Canada, N6A 5B7, egodin5@uwo.ca. [2]Dept. of Earth, Atmospheric and Planetary Science, Massachusetts Institute of Technology, Cambridge, MA. [3]NewSpace Initiative, Arizona State University, Tempe, AZ. [4]Dept. of Physics and Astronomy, University of Western Ontario, London, ON, Canada, N6A 5B7

Introduction: Erosion by way of gullies is widespread on Earth, within polar deserts [1] such as within the continuous permafrost zone of the Canadian high-Arctic, throughout the Antarctic Dry Valleys [2], and beyond Earth, are found commonly in the mid-latitudes on Mars [3], many of which are located within impact craters [4]. Gullies, defined as an alcove-channel-apron system [5], vary in their erosional dynamics, aspect and shape depending on the geologic and geomorphologic context such as the nature of the underlying rocks, the orientation in relation with maximal sun exposure, the slope angle, the surface drainage capacity and especially the ground ice content. Gully maturity [6] (early or mature) or dominating erosional processes [7] (block flow or liquid) can be assesed from their morphology aspect. The presence of gully landforms in a landscape indicate the possible presence (ancient or recent) of liquid water as a medium facilitating landslides, rockflows and overall channel development [5]. The likely increased presence of water in these channels may also serve as a favorable microenvironment to microorganisms, which has specific importance when considering extreme environments such as polar deserts, and may have important implications for Mars [8]. These factors, in a context of exploration for in-situ resource utilization and a better understanding of the origins of life, place the gullies as an obvious landform to explore.

The objectives of this study are to present the characteritics, geometry and context of gullies located in distinct geologic units in close proximity at Thomas Lee Inlet, Devon Island (NU, Canada), as a Mars analogue study. This site is located 15 km east of the Haughton impact structure where gullies were previously studied as analogues to Mars in the impact melt breccia [9]. The proximity of this site to the impact structure is ideal to compare out-of-crater and in-crater gully dynamics, which is the subject of ongoing work by our group.

Site and methods: Thomas Lee Inlet (75°23’35” N - 89°06’49” W) on Devon Island (Fig. 1.A, red square) penetrates the north-central littoral as a 2 km wide fjord connecting a few incised inland valleys. In Fig 1B, the fjord is located inside the red circle and appears dark gray/black, with plateaus as light gray/white.

The Thomas Lee Inlet area (and most of Devon Island) was covered by the Laurentide/Innuitian Ice Sheet during the Wisconsinian; the study area was deglaciated around 8.5 ka BP [10]. Facing southwest, contiguous gullies G1 and G2 (Fig. 1B, white dots) are eroding a 360 m altitude plateau composed of allochtonous sedimentary rocks: limestone of the Thumb Mountain Formation at the base of the slope, overlain by Bay Fjord Formation dolomite. On the opposite side of the fjord 1 km southwest, gully G3 (Fig. 1B, yellow dot) is facing east on a 350 m altitude plateau, consisting of the Lower Allen Bay Formation (limestone) overlying Thumb Montain Formation [11]. Thus gullies G1 and G2 have formed in dolomite and limestone and gully G3 formed solely in limestone.

LIDAR surveys were performed during July of 2016 using a Optech ILRIS Terrestrial Laser Scanner. The resulting datapoint cloud was imported in ESRI’s ArcGIS (ver. 10.4.1) and converted to Triangular Irregular Networks (TIN) topographic surface model. Gully dimensions, profiles and metrics were obtained over the TIN surface using ArcMap 3D Analyst.

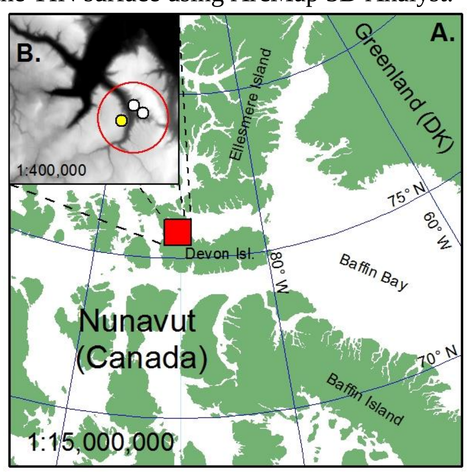

Figure 1: (A) Devon Island is located in the Eastern Canadian Archipelago, as indicated by the red square on the map. (B) Gullies sampled at Thomas Lee Inlet are located within the red circle and represented as white dots (G1 and G2) and a yellow dot (G3).

Gullies were characterized in the field for the nature of their colluvial deposits, whether or not they were actively eroding if water was running in the channel, and what the source of any water was. Water was sampled in the gully channels and the small river downstream for temperature, pH and conductivity (units for conductivity is siemens ‘S m^{-1}’) using a Fisher Scientific Accumet model AP85 portable probe. Classification scheme for gullies

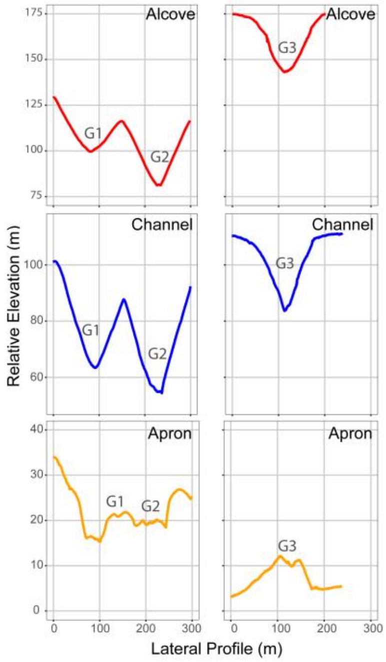

Figure 2: G1 and G2 are next to each other, in the Bay Fjord formation plateau's slope. G2 is much more incised along its profile compared to G1, either in the alcove or the channel section. G3 is higher and steeper than G1 – G2, incised through layers of in the alcove area; the apron has a well formed conical shape.

Results: *Gully G1 and G2:* G1 (length = 435 m) and G2 (length = 521 m) facing south-west are separated by a ridge. (Fig. 1.B, white dots and middle peak in Fig. 2, between G1 and G2). There was no perennial snow patches for G1 and G2 alcoves. The alcove for G1 did not show evidence of retrogressive channeling; whereas G2 had a more incised alcove connecting to the plateau level. Using a gully evolution classification scheme [6] G1 would be classed as type B1 as not reaching the slope line, thus immature where G2 would fall in the B2 type, as reaching slope line and cutting backwards in the bedrock. Snowmelt flow input from the plateau seem to be limited for G1 where G2 had dendritic channeling connecting the plateau to its incised alcove. G2 channel, a few metres across is well represented in the cross-section (Fig. 2). G1 apron is larger and thicker than G2's apron (Fig. 2) and both gullies sedimentary composition are a mix of clasts, gravel and sands, typical of colluvial and slope processes deposits. Concavity is more important in the system likely draining the most water (G2 over G1) as suggested by a previously published morphometric model [7].

Gully G3: G3 (length = 559 m) is different in many aspects from G1 and G2 other than the differences in underlying geology and orientation. First, a multi-annual snow patch is featured in the upper section of the alcove. In addition, a 200 m wide amphitheater in a terrace over the plateau (300 m upstream of the alcove) enables the accumulation of snow as a source of water thus adding input to the alcove and the gully network. Fines (clay size) were found in this amphitheater and transported downstream, which was not the case with G1 and G2. Following the gully classification scheme, G3 would be a B2 class [6]. G3 is quite incised, the alcove eroding through a clear contact layer in the Allen Bay/Thumb Moutnain limestone. The apron is very large compared to G1 and G2 and cone shaped as shown in Fig. 2.

Implications and conclusions: *Role of water:* Different water input regimes were observed: late spring snowmelt and snow bank up to later summer for G3 and to a lesser degree to G1 and G2. A thin active layer confines the water circulation close to the surface during snowmelt through which the bulk of the annual discharge will circulate in the gullies. G3 on the other hand has a steady water input following the maximum due to the multiple snow banks (alcove and upstream). Furthermore, both plateaus were relatively ice-rich as sorted polygons were observed near G3 and ice-wedges polygons upstream of G1/G2 on the plateau. Ground ice, prone to thermal-erosion during snowmelt runoff, is vulnerable to channeling and gullying.

Analogue: The few gullies covered in this study had almost indistinguishable long profiles between each other, but lateral profiles were useful to understand and differentiate active processes. Classifications [6,7] are useful to understand the evolution, active and past processes of gullies; lateral profiles could be an option to further refine gully dynamics when long profiles fail to account for differences between gully systems. Finally, the environment proximal to the alcove (on the crests or plateaus) can reveal critical features which could explain why a gully formed there and and its intrinsic processes.

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