The Canadian Arctic Archipelago As A Mars Wet-Based Glacial Analogue Site. A. Grau Galofre[1], G. R. Osinski[2], A. M. Jellinek[3], S. M. Chartrand[4] [1]School of Earth and Space Exploration, Arizona State University, Tempe, US (agraugal@asu.edu), [2]Department of Earth Sciences/Institute for Earth and Space Exploration, University of Western Ontario, London, Canada, [3]Department of Earth, Ocean, and Atmospheric Science, University of British Columbia, Vancouver, Canada, [4]School of Environmental Science, Simon Fraser University, Vancouver, Canada.

Introduction: Large-scale continental glaciation is responsible for some of the most arresting erosional landscapes on Earth. Ice masses such as Greenland, Antarctica, and the smaller ice caps of Iceland and the Canadian High Arctic accumulate meltwater at their bases, triggering the sliding motion of overlying ice at rates ranging from ~1 to up to 1000 m/yr. The motion of large glacial ice masses sliding on their bed results in the scouring and quarrying of the landscape, exposing upon ice retreat landforms such as striae, drumlins, moraines, glacial grooves, etc. (Fig. 1).

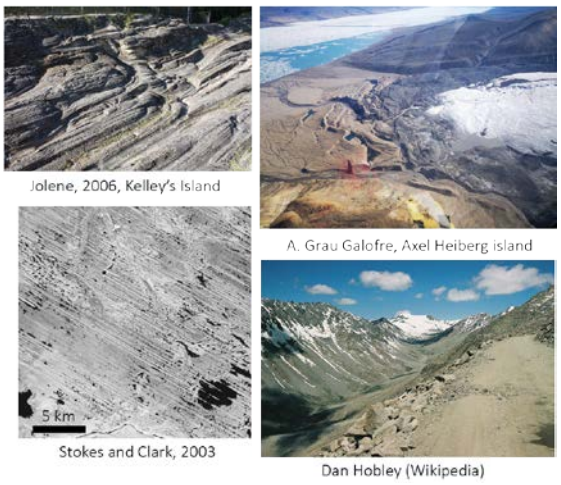

Figure 1: Landscapes eroded by sliding glaciers and ice sheets. Upper left: glacial grooves. Upper right: push moraine. Lower left: mega-scale lineations. Lower right: U-shaped valley.

The near absence of these characteristic kilometer scale features on Mars has largely dissuaded geomorphologists from considering that widespread wet-based glaciation occurred on Mars in the past. However, remains of the subglacial drainage system, such as sediment-filled conduits (eskers) and subglacial channels found in the Dorsa Argentea Formation [1], the Argyre basin [2], and in localized areas of the northern lowlands [3,4], provide evidence that water existed under Martian ice masses.

The unique landscapes of the Canadian High Arctic provide an excellent terrestrial analogue to help solve this conundrum. Here we present observations from field campaigns on Devon and Axel Heiberg islands to build understanding of the role of subglacial drainage and the influence of 'low gravity' on the fingerprints of wet-based glacial erosion.

The Arctic Archipelago as a glacial analogue: Devon Island and Axel Heiberg Island were under Innuitian glaciation until ~8 kyr ago [5, 6]. Although ice was likely cold-based (frozen to the ground) during most of the glaciation [5, 6], the Innuitian retreat was partially wet-based to polythermal (basal ice is at the pressure melting point). Both islands currently contain relict ice caps with basal conditions ranging from cold to wet-based: the Devon ice cap and the Stacie and Müller ice caps on Axel Heiberg [7]. These are excellent analogues for Early Mars ice sheets, mostly cold-based with episodes of punctuated melting. Owing to the cold temperatures and low precipitation rates typical of a polar desert climate [8], the landscapes of the Arctic Archipelago have received minimal fluvial overprint since ice retreat [9].

Figure 2: Context map showing the location of the Canadian Arctic Archipelago, highlighting our field sites. Southern: Devon Island by the Haughton Impact Structure. Northern: Axel Heiberg Island, southeastern coast.

Perhaps one of the most important characteristics that make both islands excellent Mars glacial analogues is the relatively small ice sheet thicknesses (~ 700 m). While it is irrelevant to consider the effects of the Earth-Mars difference in gravity when considering liquid water, the dynamics and motion of ice are largely affected by its weight and basal pressure. We argue that scaling ice thickness by a factor three when comparing Earth and Mars glacial analogue sites is a successful way to include the effect of gravity. A 2,100 m thick ice sheet on Mars would therefore behave similarly to the ~700 m thick Devon ice cap.

Devon Island: Our field site is located at the Eastern rim of the Haughton impact structure [8, 9] (Fig. 2). The plateaus we studied contain no evidence of any of the characteristic morphologies of sliding ice in Fig. 1 [5, 9]. Instead, the landscape contains

networks of channels displaying finger-like patterns, oriented towards the direction of Innuitian paleoflow (S-SE to N-NW, Fig. 3). Channels are organized into networks with 7-15 tributaries that are regularly spaced (~ 60-90 m), with cross-sections measuring on the range of 30-50 m [9]. Network interfluves are undissected by subsequent fluvial erosion and their morphology is dominated by periglacial processes.

The presence of uphill downflow sections (undulations), as well as other morphological differences to river systems in the island, lead to the interpretation that these channels (Fig. 3) formed subglacially [9].

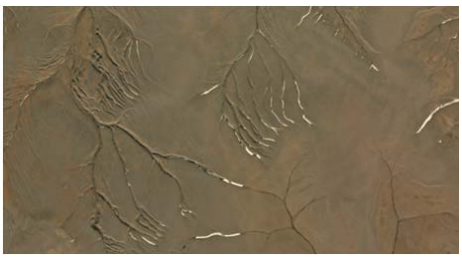

Figure 3: Subglacial channel networks (channel cross-section ~ 30 m) incised on dolomitic bedrock on Devon Island. Image is centered at 75°16'50.63"N, 89° 7'23.71"W. Credit: Landsat 8 (Arctic Views).

The striking morphological similarity of these subglacial channels to some small valley networks on Mars, as well as the finding of undulating sections within the Martian systems is suggestive that a fraction of Martian valley networks could have formed subglacially [10].

Axel Heiberg Island: Our field site is located ~15 km from the SE margin of the Stacie ice cap. The terrain here consists on flat plateaus dissected by U-shaped glacial valleys, with groups of channel networks similar to the Devon subglacial channels incising the upper flat areas (Fig. 4).

Figure 4: Subglacial channels incising the quartz arenite bedrock of the upper plateaus (bottom right), next to a piedmont style glacier on southern Axel Heiberg Island. Image credit: Anna Grau Galofre.

Whereas on Devon Island there was evidence for wet-based glaciation but not for glacial sliding, Axel Heiberg shows abundant glacial sliding signs (including moraines as shown in the figure) largely concentrated along the rugged, mountainous western coast, as well as funneled in steep valleys (Fig. 4). The flat plateaus are incised with clusters of channels that often are incised against the topographic gradient, with little to no signs of sliding or interfluve dissection in between.

Preliminary work shows small differences between the subglacial channels incised in the carbonate bedrock in Devon Island and the channels carved into the sandstone bedrock of Axel Heiberg. Sandstone channels have smaller cross-sections (20-30 m) and similar lengths (~ 1 km), and networks show relatively smaller Strahler orders (2-3 in Axel Heiberg, 3-4 in Devon Island). Anastomosing patterns such as those visible in the tributaries in Fig. 3 are also rarer.

Concluding remarks: The landscapes of the Canadian Arctic Archipelago, in particular those of Devon Island and eastern Axel Heiberg Island, record wet-based glaciations where the glacial drainage system is incised into bedrock, as opposed to the more common signs of glacial sliding erosion in Fig. 1. These landscapes provide valuable insight about Early Mars wet-based glaciation, suggesting that Martian glaciers may have shaped the landscapes beneath them in a fundamentally different manner to what most terrestrial ice sheets did during the last glacial maximum.

Acknowledgements: We thank the Polar Continental Shelf Program for logistical support and funding from the Natural Sciences and Engineering Research Council of Canada and the Canadian Space Agency.

References: [1] Head J. W. and Pratt S. (2001) J*GR: Planets*, *106*(E6). [2] Banks M. E. et al. (2009) *JGR: Planets*, *114*(E9). [3] Butcher, F.E.G. et al. (2017) *JGR: planets 122*(12), 2445-2468. [4] Gallagher C. and Balme M. (2015) EPSL *431*, 96-109. [5] Dyke, A. (1999). *Quaternary Science Reviews*, *18*(3), 393-420. [6] Dyke A. et al. (2002) *Quaternary Sci. Rev.*, *21*(1-3), pp.9-31. [7] Boon S. et al. (2010) *Arctic*, pp.13- 29. [8] Osinski G. et al. (2006) *Geoscience Canada*, *33*(4). [9] Grau Galofre, A. et al. (2018), *TC*, *12*(4), 1461 [10] Grau Galofre A., et al. (submitted).