DEBRIS FLOWS AND WATER TRACKS IN CONTINENTAL ANTARCTICA – A NEW TERRESTRIAL ANALOGUE SITE FOR INVESTIGATING THE ORIGIN OF GULLIES ON MARS. E. Hauber[1], C. Sassenroth[1], J.-P. de Vera[1], N. Schmitz[1], D. Reiss[2], H. Hiesinger[2], A. Johnsson[3], [1]Institute of Planetary Research, DLR, 12489 Berlin, Germany, Ernst.Hauber@dlr.de, [2]Institut für Planetologie, Westfälische Wilhelms-Universität, 48149 Münster, Germany, [3]Göteborg University, SE-405 30 Göteborg, Sweden.

Introduction: Gullies on Mars [1] may have formed by debris flows triggered by the melting of ice or snow [2,3], by dry granular flows [4-6], or by a combination thereof. Multi-year monitoring revealed present-day mass wasting at Martian gullies, most likely related to seasonal CO_2 activity [7] in environmental conditions that prohibit the stability of liquid water. It is debated, however, whether such "dry" processes can account for the full range of morphologic characteristics and the dimensions of the observed gully systems, or whether additional "wet" processes in the recent past and in a different climate may have been required. A better physical understanding of CO_2-related (flow) processes, for which there are no terrestrial analogues, is required to enable predicting the morphogenetic potential of such flows to generate gully-like landforms.

The study of terrestrial debris flow processes and their erosive and depositional records can help exploring the parameter space of (paleo)environments that may have been responsible for gully formation on Mars. Here we introduce a new analogue site in continental Antarctica that displays morphologic evidence for debris flows in a hyperarid polar environment. The site complements our previous analogue field site in Svalbard [8], where gullies and debris flows are morphologically remarkably similar to Martian gullies [9]. In addition, it hosts shallow underground pathways for liquid water on the top of the permafrost table that resemble water tracks observed elsewhere in Antarctica, which were suggested to be potential analogues for the so-called RSL (recurrent slope lineae [10]).

Location: The study area is located in the Transantarctic Mountains of Northern Victoria Land at the De Goes Cliff in the southernmost part of the Morozumi Range (~71°48.5S, 162°00.6`E; Fig. 1). The De Goes Cliff is a ~400 m-high, east-facing scarp oriented in NNW-SSE direction, and is composed of sediments belonging to the Beacon Supergroup and sills of Ferrar Dolerite. The lower sections are covered by talus.

The study area is very remote from any research station, and the closest weather stations are either located more towards the interior of East Antarctica or more towards the coast, respectively. Therefore, it can be reasonably assumed that the environmental conditions at the study area range between those measured at these stations. At none of them, the temperatures exceed 0°C anytime during the year. Summertime relative

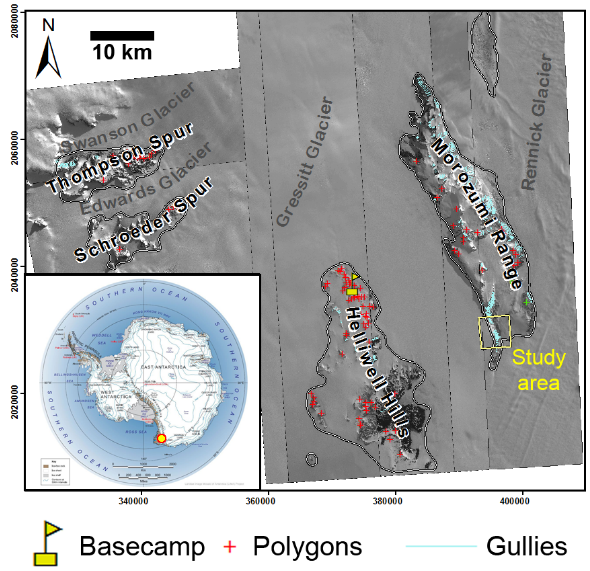

Fig. 1 | Study area in Northern Victoria Land.

humidity is ~55% at the closest weather stations (meteorological data from www.climantartide.it).

Observations: The geomorphology of the ice-free surfaces in the study area is characterized by glacial drift deposits and ubiquitous thermal contraction cracks. The largest ice-free area is Boggs Valley in the Helliwell Hills, a dry valley that measures about 5 × 2.5 km in size. Trenching showed that (in January 2016) relatively clear and bubble-free ice underlies most polygonally fractured terrain at a depth of 40 cm. Katabatic winds are common and mostly blowing northward along Rennick Glacier towards the coast.

Gullies. "Gullies" (consisting from top to bottom of an erosional alcove, transport channel(s), and a depositional fan or apron, following the terminology used to describe them on Mars [1]) transect the entire height of the De Goes Cliff (Fig. 2a). Alcoves are cut into both igneous and sedimentary bedrock, followed by long and thin single-thread channels which continue across relatively small depositional fans down to the foot of the cliff. The channels are about 2 m wide and have levées that are up to 1 m wide and ~30 cm high (Fig. 3a). Debris flow tongues consist of mostly angular clasts with diameters of centimeters to decimeters (Fig. 3b). Meltwater from snow patches in the channels began to flow down the lower parts of some gullies in the early afternoon (~14:30). The length of the channel section with water flowing in it reached >13 m at 16:45, but for ~4-5 m the water only flowed in the subsurface and the surface remained completely dry. The discharge was estimated at <0.1 liter per second.

Subsurface pathways. Immediately east of the gullies, some pathways for meltwater from snowbanks along the western margin of Rennick Glacier resemble fluvial channels in satellite images. Upon closer inspection however, it becomes clear that these landforms do not transport flowing surface water (Fig. 4a),. Instead, they represent only very shallow depressions (depth ~few cm; Fig. 4b), the surface of which is more or less wet (depending on the time since they were last active; Fig. 4a). Excavations show that the depth to ice-cemented, impermeable permafrost soil is ~40 cm. The irregular margin of the pathway (no erosion by flowing water) and the preservation of preexisting surface texture suggests that there is never any significant surface runoff in these depressions (Fig. 4c). Instead, they appear to be subsurface pathways for meltwater, just wetting the surface and darkening its albedo (analogous to *water tracks* in the McMurdo Dry Valleys [11] which, in turn, have been used as analogues to RSL [12]).

Discussion: We present a new field site in Antarctica that shows landforms analogous to Martian gullies. The observations presented here highlight the potential of hyperarid polar deserts to generate sufficient meltwater to produce debris flows and water tracks. It appears possible that only very small amounts of water may be able to produce gullies on Mars, too. Further modeling should attempt to predict better estimates of melt rates under Martian climatic conditions that are only slightly different that those prevailing today.

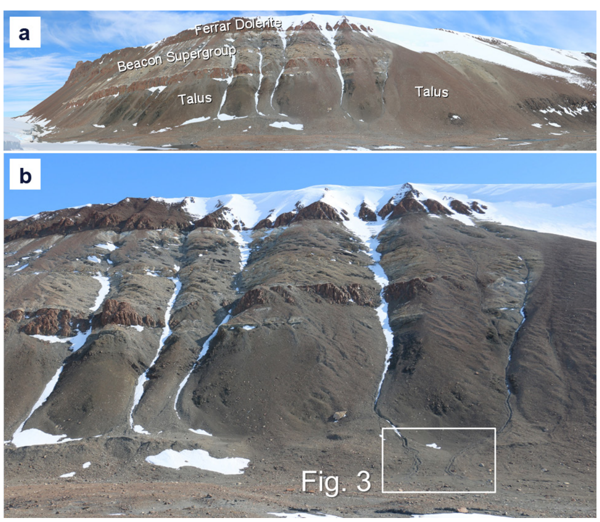

Fig. 2 | Context of gully landforms. (a) Panoramic view of central section of De Goes Cliff (view towards W), with labeled stratigraphy. (b) Gullies with tripartite morphology of (from top to bottom) alcoves, channels, and aprons (fans).

References: [1] Malin M.C. and Edgett K.S. (2000) *Science, 288,* 2330–2335. [2] Costard F. et al. (2002) *Science, 295,* 110-113. [3] Christensen P. R. (2003) *Nature, 422,* 45–48. [4] Shinbrot T. et al. (2004) *PNAS, 101,* 8542-8546. [5] Hugenholtz C. H. (2008) *Icarus, 197,* 65-72. [6] Diniega S et al. (2013) *Icarus, 225,* 526-537. [7] Dundas C. M. et al. (2015) *Icarus, 251,* 244-263. [8] Hauber E. et al. (2011) *GSA Spec. Pap., 483,* 177-201. [9] Johnsson A. et al. (2014) *Icarus, 235,* 37-54. [10] McEwen A. S. et al. (2011) *Science*, *333,* 2330-2335. [11] Levy J. S. et al. (2011) *GSA Bull., 123,* 2295-2311. [12] Levy J. S. (2012) *Icarus, 219,* 1-4.

Acknowledgements: We thank the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) in Hannover and the expedition lead, A. Läufer, for inviting EH, JPdV and NS to the GANOVEX XI expedition in the austral summer 2015/2016.

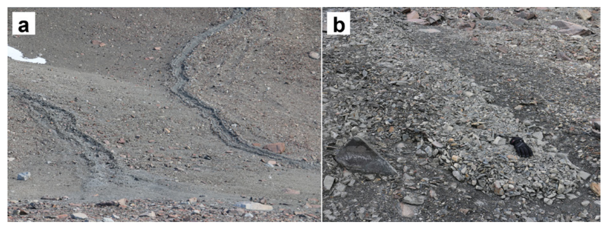

Fig. 3 | Morphological details of gully channels and fans. (a) Sinuous channels (width ~2 m) with lateral levees on fan deposit. (b) Debris flow tongue (black glove for scale).

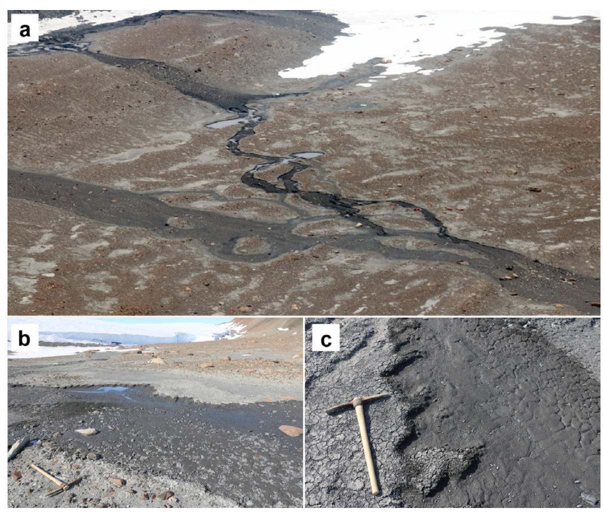

Fig. 4 | Shallow subsurface pathways for water. (a) Oblique aerial view (width ~400 m). Dark pathways are relatively wetter and fresher, bright pathways (bottom) are dry and inactive. (b) Close view of active pathway, with some ponding surface water. Note very small depth (only a few cm). (c) Detail of pathway margin and surface, neither of them showing any evidence for surficial flow of water (no streamlined eroded margin on left side, intact pre-existing desiccation cracks on right side). Pick for scale in b and c.