EPSC Abstracts
Vol. 11, EPSC2017-839, 2017
European Planetary Science Congress 2017

Quantitative Investigations of Polygonal Patterned Ground in Continental Antarctica: A Mars analogue

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Abstract

Polygonal fractured ground is widespread at middle and high latitudes on Mars. The latitude-dependence and the morphologic similarity to terrestrial patterned ground in permafrost regions may indicate a formation as thermal contraction cracks, but the exact formation mechanisms are still unclear. This study quantitatively investigates polygonal networks in ice-free parts of continental Antarctica to help distinguishing between different hypotheses of their origin on Mars.

1. Introduction

The study site is located in the Helliwell Hills in Northern Victoria Land (~71.73°S/~161.38°E; Fig. 1) and was visited during the austral summer of 2015/2016. The surfaces are covered by glacial drift consisting of clasts with diverse lithologies. In contrast to the ancient surfaces in the McMurdo Dry Valleys, the surfaces in the study area were deglaciated since the LGM and are, therefore, relatively young. No detailed climate data are available, but data from the closest permanent weather stations suggest that the air temperatures never exceed 0°C, and that the Helliwell Hills may be considered a hyper-arid polar desert environment.

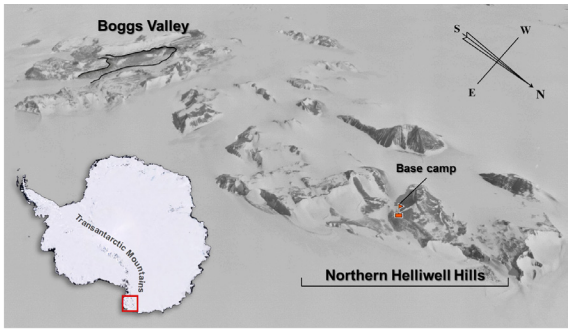

Figure 1: Location of Helliwell Hills (US Air Photo).

2. Data and Methods

Polygons were mapped in the northern part of Helliwell Hills in a GIS environment on the basis of high-resolution satellite images with a pixel size of 50 cm (Fig. 2). The measured spatial parameters include polygon area, perimeter, length, width, circularity and aspect. We also analyzed the connectivity of enclosed polygons within a polygon network and the type of polygon networks. During fieldwork, excavations were made in the center of polygons and across the bounding cracks. Soil profiles were recorded, and sediment samples were taken and analyzed for their grain size composition with laser diffractometric measurement methods.

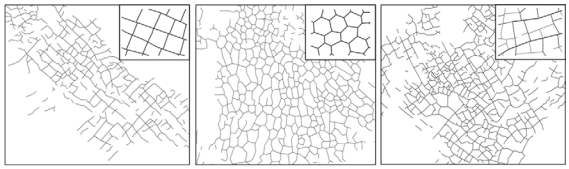

Figure 2: Examples of mapped polygon networks.

3. Observations

Thermal contraction cracks are ubiquitous in the Helliwell Hills. Polygons do not display significant local relief, but overall their centers are slightly higher than the bounding cracks (i.e. high-center polygons). Typically, the uppermost ~40 cm of regolith are dry and unconsolidated. Below that, there is commonly a sharp transition to ice-cemented material or very clear ice with few bubbles. No cracks could be identified in the ice-cemented substrate. Sizes of polygons can vary widely, dependent on the geographical location, between 10m² and >900m² (Fig. 3). In planar and level areas, thermal contraction cracks tend to be well connected as hexagonal or irregular polygonal networks (Fig. 2) without a preferred alignment. In contrast, polygonal

networks on slopes or near scarps form elongated, orthogonal primary cracks, which are either parallel or transverse to the steepest topographic gradient. Hexagonal polygon-nets tend to form smaller polygons, while polygons of orthogonal and random-orthogonal polygon-nets can form significantly larger polygons in respect to their area. Grain size analyses of the ice-free regolith (Fig. 4) show that silt dominates over clay and the coarse fraction is more abundant than the fine fraction.

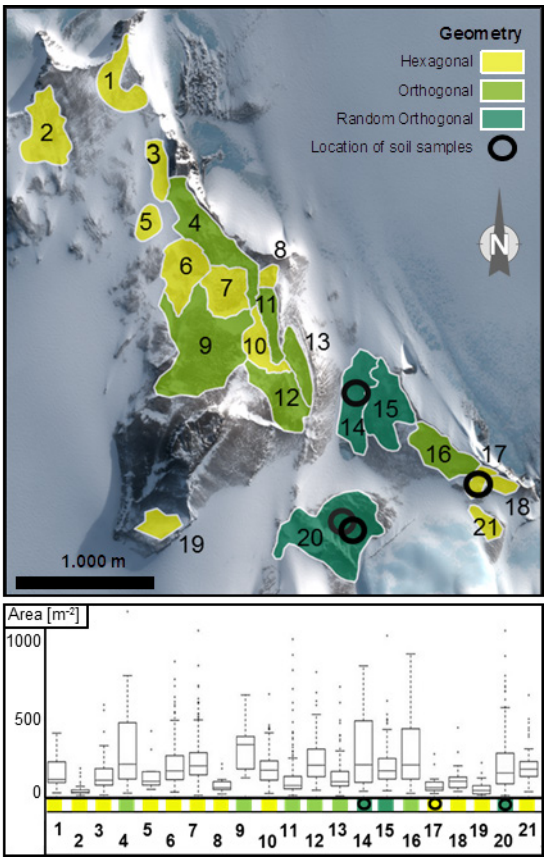

Figure 3: Different classes of polygon networks and their size sitribution (base map: WorldView-2).

4. Discussion

The geometry of the polygon-net and the geomorphometric parameters of single polygons within it correlate with the local topographic gradient. This is caused by a preferred direction of stress relief within orthogonal and random orthogonal networks, while stress release in hexagonal networks is equal in every direction. The ice cemented table does not show any visible cracks in the area below the polygon troughs. The analysis of the grain size distribution varies dependent on the locality of the excavation. There is no evidence found for some kind of sorting which would imply an ongoing process of thermal contraction within the soil.

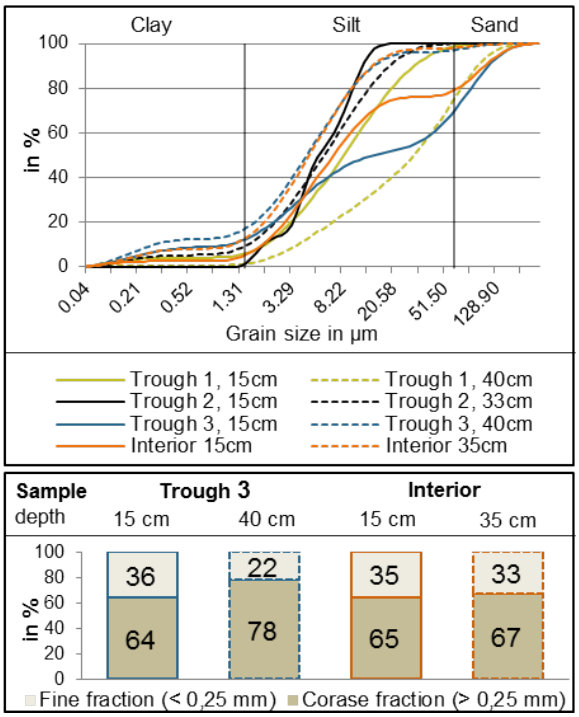

Figure 4: Grain size analysis. *(top)* Fine fraction *(bottom)* Coarse vs fine fraction within the regolith.

5. Summary and Conclusions

We conclude that the thermal contraction polygon morphometry is rather influenced by the local topography than the type of a polygon. Sublimation of ground ice, as well as minor availability of surface water, provided by melting snow, could have contributed to polygon formation in Helliwell Hills.

Acknowledgements

We thank the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) and A. Läufer as expedition leader, for inviting EH, JPdV and NS to the GANOVEX XI expedition in the austral summer 2015/2016. We appreciate the support by the DigitalGlobe Foundation which provided World View-2 images. Climate data from the Italian AWS network were kindly provided by Paolo Grigioni.