An investigation into morphology and dynamics of thermal contraction cracks polygons found at Mimelia in the Jutulssessen, Antarctica

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Abstract

Introduction

Seasonal and diurnal freeze-thaw cycles of the permafrost and active layer yield circular, labyrinthine, polygonal, and striped patterns of stones and soil in the polar environments. Patterned ground diversity is due to a variety of mechanisms. Thermal contraction polygons form as a result of thermal contraction cracking of the frozen ground or seasonal frost cracking of the permafrost. Thermal contraction crack polygons in the permafrost found at Mimelia in the Jutulssessen were identified and measured. These features are closed, roughly quadrilateral, and bounded by more or less straight sides or troughs, forming orthogonal or hexagonal networks. Although some studies have been conducted for the region in the geological and biological fields, limited work has been done on the geomorphology of the area. A series of measurements by Dallmann et al. (1990) suggest that polygonal patterns in the area have diameters between 5 m and 10 m, one up to 2 m in height, exhibit poor sorting and have stone pits subcircular to them. The project is the first in depth and summative study of these features for the region. Polygon morphology, particle distribution analyses of cell vs. trough samples, temperature dynamics of cell vs. trough sample locations, and polygon progression down slope is investigated and discussed. Findings provide insight into the role these features have in terms of habitat provision to microorganisms, their role in the hydrological cycle, as well as an indication of age.

Setting

Troll research station (72°01'S, 02°32'E) is located in the Jutulssessen of Dronning Maud Land. Within this larger region the Jutulssessen is the only site that has significant sediment cover present and on moraine slopes of less than 15° patterned ground is observed. The site was visited during the austral summers of 2009/10 and 2013/14 and a total of 65 polygons were measured. Measurements of polygon (the 'cell' sample) and one along the trough walls and infilling of contraction cracks between polygons (the 'trough' sample) were taken. Measurements were conducted on average at a month intervals. The polygon field is about 700 m long and 300 m wide and lies along the north-north-west direction (Fig. 2).

Findings

• Polygon sizes range from 6.5m-30m in size. A-axes are on average 13.4m long, with b-axes on average 7.5m smaller than the equivalent a-axes. On average polygons have a perimeter of 62.3m and a mean diameter of 1.2m.
• Prolonged elongation is common with only 29% of polygons having an elongation ratio (a/b) of less than 1.0:0.83% exhibit an elongation ratio exceeding 1.0: 15% exceed that of 1.5.
• Average trough width is 20 cm. Primary polygon cracks appear fully developed with app. angles of 67°-120° at the confluence of polygons. A network of secondary and tertiary polygons is in evidence.
• The average slope measured in the field is 13.7° and polygons occur on slopes from 8°-27°.
• 86.2% of all samples are oriented in a north-south direction with the 90.7% of the observed slope orientation being similar.
• Samples where a west-northwest slope orientation differ and are located toward the northern extent of the field, i.e. the area next to the permanent ice of Sætet.
• Rayleigh tests show that the mean orientation for both a-axes (n=65) and slope orientation (n=45) approaches north (n=100).

Discussion & Conclusion

Gravitational sorting of larger clasts into troughs is apparent. The large mean diameters, primary-secondary/tertiary polygon formation, well-developed troughs, predominantly sandy matrix, and seasonal and annual thermal changes in the active layer indicate that polygons and macro-scale unsorted thermal contraction polygons. A temperature change of app. -4.2°C below mean annual temperatures is sufficient to lead to thermal cracking (Lee et al., 2006). Since this threshold is achieved for the region permafrost is seen as the primary mechanism for polygon development. The variability of trough width measurements suggests continuous and simultaneous development of troughs along the borders of polygons, i.e. the preferential trough development along a specific path in present. Polygon distributions have implications on moisture-permeability and holding capacity. The presence of stone in troughs and higher VWC [%] supports findings by Lee et al. (2013) and has been identified as a crucial component for microorganisms colonisation. Polygon formation is also shown to occur on slopes exceeding the 15° as proposed by Dallmann et al. (1990), suggesting that slope gradient is not the only limiting factor in polygon formation. The regular and non-oriented polygon network, the large number of fully formed polygons and hexagonal angles of polygon boundaries suggest that the polygon field is in its mature stage.

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REFERENCES


Box plot for VWC (%) for all cell vs. trough samples.

Fig. 4

For all cell vs. trough samples.