Permafrost degradation in West Greenland

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which is also shown by the ALOS PALSAR data. They are also related to clear source areas, facilitating material supply. Inactive rock glaciers are mapped based on the same criteria as the active rock glaciers, but where no surface movement is detectable. The active and inactive permafrost landforms were categorized as one group, namely intact landforms, because of difficulties in establishing whether a landform is moving or not based on singular aerial imagery, and also to expand the sample for statistical purposes. Relict rock glaciers, however, show distinct collapse structures and often have extensive vegetation cover. The formation of these landforms is discussed in relation to existing glaciers or creep in talus slopes, distinguishing between moraine-derived and talus-derived landforms. Ice-cored moraines are here characterized as over-sized moraines in front of small glaciers, and are stable geomorphic features in permafrost environments where the moraine sediment is thicker than the active layer. Ice-cored moraines are considered active features when they appear stable, but do not necessarily possess indications of creep.

This study will discuss present and relict permafrost distribution based on the mapped rock glacier and ice-cored moraines in Tröllaskagi. In addition, various characteristics of the landforms such as the state of activity are given. This study supports the previous inventory which indicated evidence of typical rock glacier formation at low elevations, indicating long ice-free and cold periods prior to the onset of the Holocene Atlanticum.

Reference

Guðmundsson, Á. (2000). Frerafjöll, urðarbingir á Tröllaskaga. MSc thesis. University of Iceland, Reykjavik. 322 pp.

EC3-3

Typology of sorted patterned ground sites in Skagafjörður (Northern Iceland) by using a factor analysis of mixed data

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Although scientists have been studying patterned ground features for a century, further works are needed for improving our knowledge about their formation mechanisms and their environmental conditions of development. Patterned ground is quite widespread in Iceland, though their observations are still lapidary, in particular in the Northern part. One of the queries needing deeper knowledge deals with the relationships between feature intrinsic characteristics and environmental conditions at site scale. Hence, we have decided to carry out fieldwork in Skagafjörður, attempting a typology of sorted polygon areas according to different environmental characteristics.

To fulfill this issue, we have investigated 75 polygon sites, equally distributed across the fjord between 20 m and 960 m a.s.l. Each site includes ten polygons, i.e. a total of 750 features were studied. Then, all polygon areas have been associated with three groups of explanatory variables (latitude, topography and soil variables), determined either with a regional DEM (resolution of 30 m), or during fieldwork, and in laboratory for grain-size analyses. To define homogeneous polygon sites as a function of the three groups of variables, we have used a factor analysis of mixed data and a complementary hierarchical classification of principal components, particularly suitable for this objective. In addition, we have analysed the variance of each so-defined class to test for significant differences in feature (mesh) diameter between each group.

Results reveal three homogenous areas of sorted polygon features. The first one is characterised by low altitude, high wetness index, low insolation, small clast length and kame terrace absence; the second one by high insolation, high valley depth, low latitude, low terrain ruggedness and kame terrace presence; finally the last cluster is associated with high altitude, low valley depth, low wetness index, large clast length, high terrain ruggedness, till deposits and high fine content. Altitude and type of drift appear to be the most discriminant factors for all three classes. In addition, ANOVA tests have shown that mean polygon diameter is significantly different by class: rather small in the two first clusters and large in the last one. We have highlighted that three variables are significantly correlated with the polygon size as well: proportion of fine material (r=0.35), altitude (r=0.51) and overall clast length (r=0.97). This positive correlation between polygon size and clast length is confirmed whatever the polygon area and scale considered (site and feature scales).

EC3-4

Permafrost degradation in West Greenland

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Important aspects of civil engineering in West Greenland relate to the presence of permafrost and mapping of the annual and future changes in the active layer due to the ongoing climatically changes in the Arctic. The Arctic Technology Centre (ARTEK) has worked more than 10 years on this topic and the first author has been involved since 1970 in engineering geology, geotechnical engineering and permafrost related studies for foundation construction and infrastructures in towns and communities mainly in West Greenland. We have since 2006 together with the Danish Meteorological Institute, Greenland Survey (ASIAQ) and the University of Alaska Fairbanks carried out the US NSF funded project ARC-0612533: Recent and future permafrost variability, retreat and degradation in Greenland and Alaska: An integrated approach.

This contribution will present data and observations from the towns Ilulissat, Kangerlussuaq, Sisimiut and Nuuk. They are situated in continuous, discontinuous and sporadic permafrost zones. We will show examples of detoriation of permafrost related to present local scale climate observations and large scale climate and permafrost simulations modeled numerically with the GIPL model driven by HIRHAM climate projections for Greenland up to 2075.

The engineering modelling is based on a risk assessment methodology based on a flow diagram which classify the risk of permafrost degradation causing settlement and stability problems for buildings and infrastructures based on relatively simple parameters. It is planned as decision and planning tool for town planners and engineers in local municipality governments and to consulting engineers and contractors in Greenland, which also may be used in other arctic regions. Risk is classified in four categories: Low, Limited, Medium and High based on environmental properties as surface conditions (rock or sedimentary basins), soil grain size classification (gravel, sand, silt and clay) and ice content in the ground. The model uses ground thermal conditions quantified as the Permafrost Thaw Potential, which is defined as the potential active layer increase due to climate warming and surface alterations.

Using this methodology it is expected that mapping of vulnerability in towns and construction areas together with proposed adaption and mitigation technologies will be of practical use to technical institutions and public as well as a general tool for the scientific community.

The presentation will focus on the application of the Risk Evaluation diagram used in the selected towns in different permafrost zones and is illustrated with present observations of permafrost detoriation in West Greenland.

EC3-5

Temperature measurements providing evidence for permafrost thickness and talik occurrences in Kangerlussuaq, West Greenland

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The present study is motivated by the requirement to understand the effect of permafrost and glaciation on the thermal and hydrological behavior of crystalline rock during long-term disposal of nuclear waste. Glacial conditions with growth of ice sheets and permafrost will likely occur in Fennoscandia and Canada during this time perspective. To advance the understanding of the impact of glacial processes on the long-term performance of a deep geologic repository, the Greenland Analogue Project (GAP) has been established by the Swedish, Finnish and Canadian nuclear waste management organizations (SKB, Posiva and NWMO). The GAP project is a field and modeling study utilizing the ice sheet and the sub-surface in West Greenland as an analogue of the conditions expected to prevail in Fennoscandia and Canada during future glacial cycles.

Within the GAP project three drillholes have been drilled during 2009-2011 and equipped with fiber optical Distributed Temperature Sensing (DTS) cable, in the Kangerlussuaq area, West Greenland. DTS is a technique where an optical laser pulse is transmitted through a passive optical fiber, which acts as temperature sensor.

One of the drillholes was drilled beneath a lake to study a presumed through talik. Given that taliks may provide hydraulic pathways through permafrost, they can potentially act as concentrated discharge points for radionuclides, in the case of release from the repository. The lake is located in a lineament structure and forms a 35 m deep elongated basin (1200 x 300 meters). Based on the results from the DTS-profiling the transition from permafrost to talik takes place at 20 m depth, i.e. at the shoreline of the lake. The two other drillholes were drilled near each other and approximately 0.5 km from the Greenland ice sheet, while the lake drillhole is situated 1 km from the ice sheet. The second and the third drillhole were drilled to measure permafrost depth, via installed DTS-cables, but also to take hydrogeochemical samples and monitor pressure from depths beyond the permafrost layer.

Our results suggest that in the study area, located about 350 - 500 m above sea level, 200 km from the sea and in the vicinity of the Greenland ice sheet, permafrost is about 300 m thick in areas distant from lakes and rivers. Forward conductive heat transfer modeling based on our temperature data and petrophysical information from the bedrock suggests that water bodies with diameters exceeding about 200 m would support the existence of through taliks. Given that about 20% of the surface area in Kangerlussuaq is covered by proglacial lakes larger than 500 m in diameter, the permafrost layer is abundantly perforated by through taliks. These taliks provide the only available pathways for water to be transported up or down through the permafrost, thus their distribution needs to be included in hydrogeological modeling of this Arctic landscape. Our study illustrates and confirms the usefulness of the DTS technique for temperature measurements in the Arctic environment, where drillholes are impossible to keep open for a long time, also allowing monitoring of permafrost depth over time.

EC3-6

Geophysical investigations of a pebbly rock glacier, Kapp Linné, Svalbard

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Pebbly rock glaciers (Ikeda & Matsuoka, 2006) differ from bouldery' rock glaciers with respect to lithological content, mean size of clasts and rock glacier dimensions; however few pebbly rock glaciers have been subjected to detailed investigations. This presentation reports on pebbly rock glaciers close to Isfjord Radio on Kapp Linné, Svalbard, and their internal structure based on a detailed DC resistivity profiling campaign and GPR measurements.

Kapp Linné is located on the northern part of the coast of Nordenskiølds land, western Svalbard. The pebbly rock glaciers have developed along Griegaksla at the transition between talus slopes and the strandflat area, similar to on Prins Karls Forland (Berthling et al. 1998, 2007) and further south on the coast of Nordenskiølds land (Kääb et al 2002).

The DC resistivity measurements were carried out in July 2007, and the GPR measurements in April, 2008 as part of the IPY project 'Permafrost Observatory Project: A Contribution to the