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Rock avalanche and rock glacier: A compound landform study from Hornsund, Svalbard

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ABSTRACT

On the northern coast of the Hornsund fjord at SW Svalbard, numerous rock block accumulations flank the foot of Rotjesfjellet ridge. Whereas these accumulations are widely described as rock glaciers, this study shows that other factors also influence formation of these landforms. In this study, morphometric profiling and terrain analyses, lichenometry, optical granulometry, Schmidt hammer measurements, geophysical measurements using electric resistivity tomography, geodetic measurements using terrestrial LiDAR and rockfall modelling were used to clarify the formation of one unusual block accumulation. The morphometric analysis of a detailed (0.5 m) DEM and relief profiles showed distinctly different morphology of one of four studied block accumulations. The electric resistivity tomography revealed an ice core in the accumulation, the Schmidt hammer sampling helped to establish relatively younger age of the lobe-like left part of accumulation and finally, the lichenometry was employed to place the event on the approximate position on the timescale. In conclusion, the unusual block accumulation is a result of two consequent processes: first, a typical foothill rock glacier has developed, and consequently a large rock avalanche occurred, adding material and deforming the NW part of the accumulation. Based on the results of lichenometry, the rock avalanche was estimated to be 250 ± 50 years old. The study thus presents one of the few reported slope deformation events from the recently deglaciated Arctic areas.

1. Introduction

Generally, rock block foothill accumulations are very common on Svalbard and the Arctic generally, and these landforms are traditionally regarded as rock glaciers (e.g. Kääb et al., 2002, Deggenhardt, 2009, Czerny et al., 1993). Usually the rock glaciers in this position form simple, bench-like structures along the slopes, and are much more elongated along the slopes than along the dropline (e.g. André, 1994, Kääb et al., 2002).

At the foot of the Rotjesfjellet-Torbjørnsenfjellet Ridge (Fig. 1) on the north-western side of the Hornsund fjord (W. Spitsbergen), a set of such prominent landforms is situated. Previous studies by Karczewski et al. (1981a, 1981b, 1984) classify them as either rock glaciers or nival moraines (or protalus ramparts). Morphologically, they form steps at the base of the steep slopes, approximately 30 to 40 m high and 250 to 350 m long (Fig. 1). Whereas three of the four studied landforms appear as typical shelf-like rock glaciers, the fourth, situated under Mt. Rotjesfjellet, has a peculiar, lobe-shaped extension (Deggenhardt, 2009), which is very unusual among the foothill rock glaciers.

Studies of slope-related landforms often face the problem of differentiating the products of glaci- and periglacial processes and slope processes, both in the high mountains and Polar Regions. For example, Deline and Kirkbride (2009) find it difficult to distinguish some glacial-related landforms and rock avalanches. Similarly, Karczewski et al. (1984) states that there is a wide range of various shapes of the block accumulations occur at the foothills, some of them are difficult to explain how they formed.

Based on fieldwork, study of detailed aerial photographs and literature study, we have formulated a hypothesis that the unusual accumulation under Rotjesfjellet could be a product of combination of a classic foothill rock glacier sensu Deggenhardt (2009), and of a rock avalanche (Fig. 2). During the search for reference case studies, we have learned that the topic of gravity induced processes in the Arctic areas has been practically overlooked, with very few studies available.

The aim of this study was, therefore, to gather and analyse the available information on the studied landforms to formulate a conclusion concerning the above stated hypothesis. Two main objectives were:

i) verifying the hypothesis that the unusual shape of the accumulation is a result of a rock avalanche
ii) using relative dating to differentiate the two origins of the accumulated material

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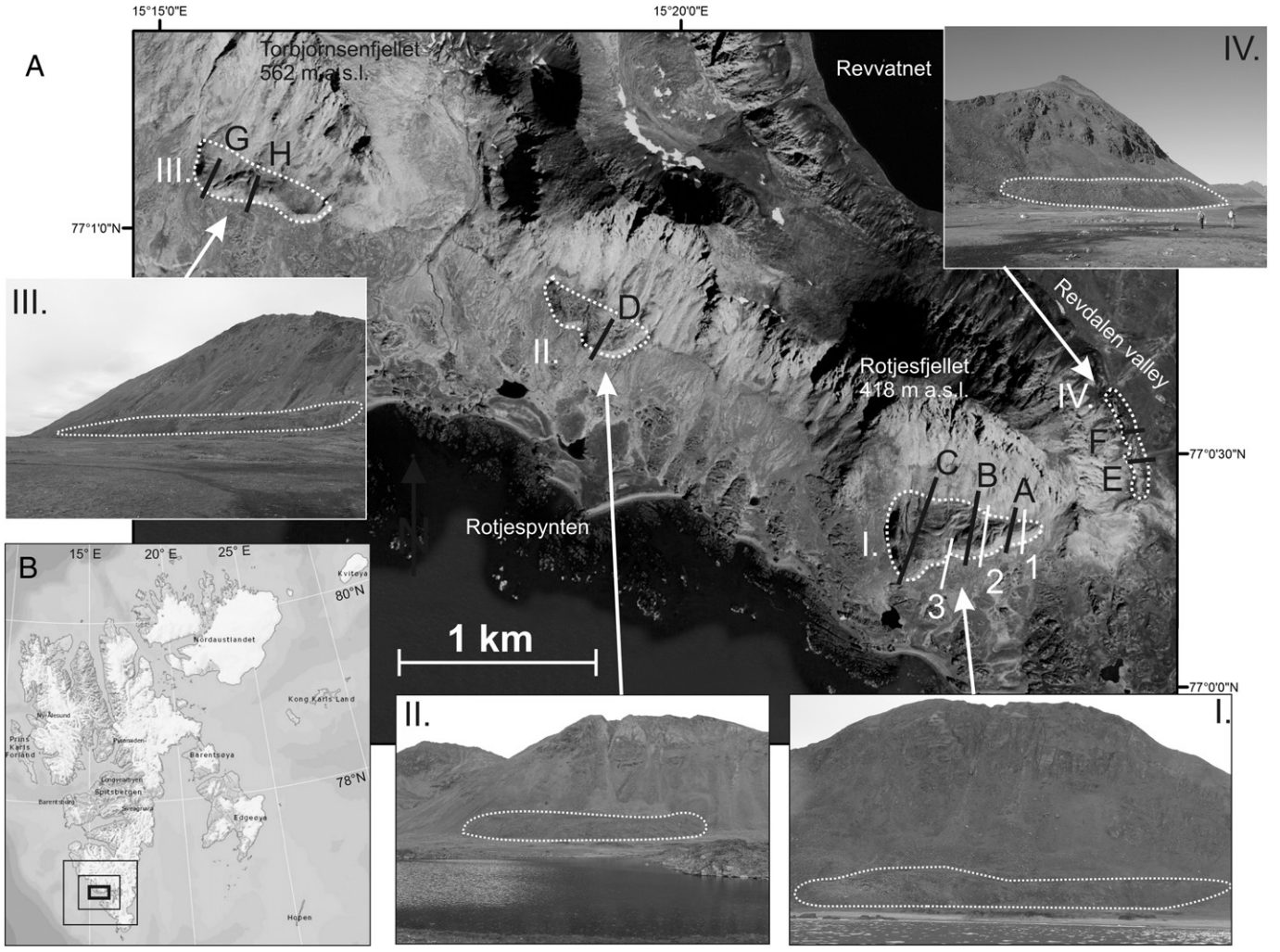

Fig. 1. A: Position and photographs of the studied block accumulations at the foot of the Rotjesfjellet - Torbjørnsenfjellet Ridge. The background is a satellite map of the studied area (captured 12.7.2012). The block accumulations are highlighted by white dotted line. Black full lines marked A-H represent the lichenometric and Schmidt hammer profiles, white full lines marked 1–3 are the ERT profiles. B: Position of the study area on the Svalbard Archipelago.

Aside from that, the combination of investigation methods allowing differentiating between monogenetic rock glaciers and related polygenetic landforms, was tested.

Finally, while in the mountain or mid-mountain regions, notably in the Alps (Soldati et al., 2006, Deline and Kirkbride, 2009), Scandinavia (Schleier et al., 2015) or Scotland (Jarman, 2006, Ballantyne and Stone, 2013, Ballantyne et al., 2014), the periods of significant activation of mass wasting after deglaciation are well-known and studied, although these events are generally 7–10 ka old. Some older events were dated in the Alps (Soldati et al., 2004), however, this proved problematic due to the lack of datable material (Borgatti and Soldati, 2010).

Surprisingly, little attention is given to these phenomena in the Arctic, where the deglaciation and consequent slope processes are occurring now or recently. The authors want, therefore, draw attention of fellow landslide researchers to the so far from underestimated field of slope processes research in the high Arctic.

2. Study area

2.1. Geological setting

The geological conditions and rock composition are varied in the Hornsund area because it covers rocks ranging from Late Precambrian to Mesozoic. In the valleys, coastal plains and at foothills, the bedrock is covered with varying layers of Quaternary sediments, predominantly of glacial and fluvio-glacial origin (Birkenmajer, 1990 and Czerny et al., 1993).

Major parts of the Rotjesfjellet ridge are formed by rocks of the Precambrian Ariekammen group. These consist of alternating layers of grey marbles and schists. The coastal outcrops are part of the Revdalen group, which are formed by garnet mica-schists (Birkenmajer, 1990).

With regards to the structural setting, the joint system on the Rotjesfjellet-Torbjørnsenfjellet Ridge corresponds to WNW-ESE striking faults recognised along the toe of the ridge and actually monitored using 3D extensometer (Stemberk et al., 2015). Joints are generally steeply (50–80°) sloping towards SSW, and are parallel to the slope orientation. This setting means that the SSW slopes are generally prone to slope deformations (Hartvich and Mentlík, 2010), which would in the rocky, steep slopes of Rotjesfjellet, be most likely manifested in the form of rock falls and debris taluses. Results of the analyses of Quaternary sediments in the Hornsund Fjord were summarized by Lindner and Marks (1990).

2.2. Geomorphological setting

The geomorphological evolution of the Hornsund fjord area during Quaternary is dominated by general glaciisostatic uplift of the area