Do deformation patterns and initial failure timing of rock-slope instabilities in Norway relate to permafrost dynamics?

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Abstract

Deep-seated and slow moving rock-slope instabilities are common in the Norwegian valley and fjord system. While many sudden rock-slope failures happened shortly after deglaciation, there is still a number of recently deforming unstable rock slopes. We have dated several slip surfaces using cosmogenic nuclide exposure dating, which provides the duration of time that a rock surface has been exposed to cosmic rays. The chronologies reveal that rock-slope deformation can be active during most of the Holocene, and that creep velocities have varied during this period. The principal objective is to evaluate the reason of these velocity variations, including if thermal processes in the rock slopes may have influenced the rock slope dynamics.

Keywords: Rock-slope instabilities; TCN-dating; deformation pattern; thermal processes; permafrost.

Introduction

More than 300 active rock slopes demonstrating post glacial deformation are mapped in Norway (Oppikofer et al., 2015). Seven are classified as high-risk objects because of the advanced deformation of the rock mass, the sliding rates and other parameters checked in the norwegian hazard and risk classification for unstable rock slopes, e.g. potential loss of life (Hermanns *et al.,* 2013a; Blikra *et al.,* 2016).

In addition to post-glacial stress increase, we expect water pressure and altitudinal permafrost dynamics to significantly impact these gravity driven slope processes along complex pre-existing bedrock structures. In this presentation we discuss the possible reasons for the different deformation patterns along unstable rock-slopes.

Methods and study sites

High energy cosmic ray particles will interact with atoms in exposed minerals on the rock surface to produce terrestrial cosmogenic nuclides (TCN). The concentration of a specific nuclide, such as ^{10}Be, ^{21}Ne, or ^{36}Cl, can therefore be used to calculate the apparent exposure duration of the surface (Gosse & Phillips, 2001). This can be used to reproduce the movement history of unstable rock slopes, gradually exposing the sliding surface (fig. 1).

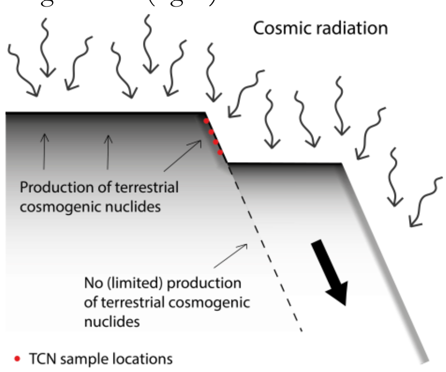

Figure 1. Schematic illustration of TCN production on the cross section of a mountain plateau and slope with a gravitationally moving block. Theoretical sample locations are indicated in red.

We present updated ages and slip rates for two rockslides in western Norway: Skjeringahaugane slide in Sogn og Fjordane (Hermanns *et al.,* 2012), and the Oppstadhornet rockslide in Møre og Romsdal (Hermanns *et al.,* 2013b). The former is a complex instability, where the unstable slope is broken up with several secondary sliding surfaces. In addition to these recalculations, we sampled along vertical transects over the sliding surfaces of three different active rock-slope instabilities. While one is located ca. 5.5 km SE of Oppstadhornet in western Norway, two adjacent instabilities are located at Revdalsfjellet in the Troms county in northern Norway.

Preliminary results and discussion

Preliminary TCN ages of the Mannen and Revdalsfjellet 2 instabilities suggest that sliding started close to the Holocene Thermal Maximum (HTM), when mountain permafrost presence was at a minimum. This indicates that permafrost thawing may have contributed to the timing of these rock-slope instabilities. The preliminary results of Revdalsfjellet 1, which is an adjacent but independently moving rock body to Revdalsfjellet 2, suggest a movement onset during strong temperature fluctuations in the mid Holocene.

The new results of the Skjeringahaugane rock-slope instability differ greatly from the ages published previously and imply ages affected by inheritance. While the main sliding surface indicate early deformation following deglaciation, deformation at a secondary sliding surface started during the mid Holocene. The onset of Oppstadhornet seems to coincide with the local deglaciation.

Deformation measurements at the Mannen rockslide, compared to the dating results, indicate a recent acceleration of deformation. This could be influenced by late stage permafrost thawing at the lower boundary of altitudinal permafrost. The different timing of the initial failure and deformation velocities at the two adjacent instabilities at Revdalsfjellet demonstrate the importance of local settings. Although the instabilities at present lie below the lower boundary of continuous altitudinal permafrost in the area, thermal processes under specific local conditions (isolated permafrost) cannot be excluded, as demonstrated at the nearby Jettan rock-slope instability, where thermal processes and permafrost in open cracks are monitored in connection with recent deformation (Blikra & Christiansen, 2004).

Acknowledgments

This research was carried out within the CryoWALL project (243784/CLE), which is mainly funded by the Research Council of Norway with co-financing by the Geological Survey of Norway (NGU) and the Department of Geosciences, University of Oslo.

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