



HAL
open science

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

Paula Hilger, Reginald L Hermanns, Bernd Etzelmüller, Kristin Saeterdal Myhra, Florence Magnin, John C Gosse

► To cite this version:

Paula Hilger, Reginald L Hermanns, Bernd Etzelmüller, Kristin Saeterdal Myhra, Florence Magnin, et al.. Do deformation patterns and initial failure timing of rock-slope instabilities in Norway relate to permafrost dynamics?. 5th European Conference on Permafrost, Jun 2018, Chamonix, France. hal-03337514

HAL Id: hal-03337514

<https://hal.science/hal-03337514v1>

Submitted on 8 Sep 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

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

Paula Hilger^{1,2}
Reginald L. Hermanns^{1,3}
Bernd Etzelmüller²
Kristin Sæterdal Myhra⁴
Florence Magnin²
John C. Gosse⁵

¹Geological Survey of Norway, Trondheim, paula.hilger@ngu.no

²Department of Geosciences, University of Oslo, Norway

³Norwegian University of Science and Technology, Trondheim, Norway

⁴Western Norway University of Applied Science, Sogndal, Norway

⁵Department of Earth Sciences, Dalhousie University, Halifax, Canada

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 ¹⁰Be, ²¹Ne, or ³⁶Cl, 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).

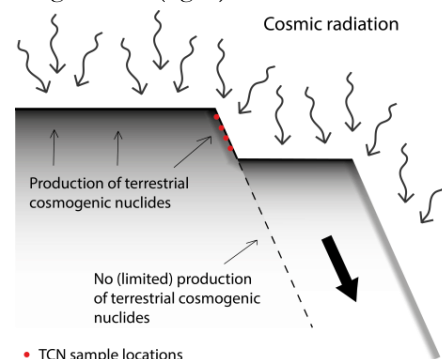


Figure 1. Schematic illustration of TCN production on the cross section of a mountain plateau and slope with a gravitationally moving block. Theoretical sample locations are indicated in red.

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.

References

- Blikra, L.H. & Christiansen, H.H., 2014. A field-based model of permafrost-controlled rockslide deformation in northern Norway. *Geomorphology* 208: 34-49.
- Blikra L.H., Majala, G., Anda, E., Hallvard, B., Eikenæs, O., Helgås, G., Oppikofer, T., Hermanns, R.L. & Böhme, M. 2016. Fare- og risikoklassifisering av ustabile fjellparti. *NVE-Rapport nr 77-2016* 47.
- Gosse, J.C. & Phillips, F.M., 2001. Terrestrial in situ cosmogenic nuclides: theory and application. *Quaternary Science Reviews* 20: 1475-1560.
- Hermanns, R.L., Redfield, T.F., Bunkholt, H.S.S., Fischer, L. & Oppikofer, T., 2012. Cosmogenic nuclide dating of slow moving rockslides in Norway in order to assess long-term slide velocities. In: Eberhardt et al. (eds.), *Landslides and Engineered Slopes: Protecting Society through Improved Understanding*. Taylor & Francis Group, London, 849-854.
- Hermanns, R.L., Oppikofer, T., Anda, E., Blikra, L.H., Böhme, M., Bunkholt, H., Crosta, G.B., Dahle, H., Devoli, G., Fischer, L., Jaboyedoff, M., Loew, S., Sætre, S. & Yugsi Molina, F., 2013a. Hazard and risk classification system for large unstable rock slopes in Norway. In: Genevois R. & Prestininzi A., (eds.) *International conference on Vajont - 1963-2013. Italian Journal of Engineering Geology and Environment, Book series 6*, Rome, Italy, 245-254.
- Hermanns, R.L., Oppikofer, T., Dahle, H., Eiken, T., Ivy-Ochs, S. & Blikra, L.H., 2013b. Understanding long-term slope deformation for stability assessment of rock slopes: The case of the Oppstadhornet rockslide, Norway. In: Genevois R. & Prestininzi A., (eds.) *International conference on Vajont - 1963-2013. Italian Journal of Engineering Geology and Environment, Book series 6*, Rome, Italy, 255-264.
- Oppikofer, T., Nordahl, B., Bunkholt, H., Nicolaisen, M., Jarna, A., Iversen, S., Hermanns, R.L., Böhme, M., & Molina, F.X.Y., 2015. Database and online map service on unstable rock slopes in Norway - From data perpetuation to public information. *Geomorphology* 249: 69-81.