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Fracture Dynamics In An Unstable, Deglaciating Headwall, Kitzsteinhorn, Austria

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Glacier retreat is one of the most significant consequences of 20th and 21st century temperature rise in the European Alps, most obvious at glacier tongues but also at glacier cirques. As cirque headwalls deglaciate, internal stress redistribution occurs and atmospheric forcing intensifies rendering deglaciating headwalls particularly prone to rock slope failure. Fractures intersecting these rock masses represent potential planes of weakness. Their dynamics may thus reveal information about the magnitude and timing of stability-relevant processes. The present study focuses on the need for quantitative data from unstable, recently deglaciated rock slopes, essential for better understanding the increasing risk on high-alpine infrastructure.

Here, we investigate the deformation regime of an open fracture, which is of direct geotechnical relevance for a popular cable car station at the Kitzsteinhorn (3203 m a.s.l.). The fracture is situated immediately up slope of the detachment zone of a recent rock slide (2012) and was glacially covered until the 1980s. Two crackmeters are operated to measure horizontal and vertical crack deformation with a resolution of ± 0.003 mm as well as crack top temperature. To decipher thermo-mechanical from cryogenic forcing, thermal expansion coefficients for both horizontal and vertical directions were calculated in order to model purely thermomechanical deformation. Based on a 2.5-year monitoring campaign, this study aims to decipher and quantify stability-relevant processes and their temporal occurrence, and addresses the following research questions: (i) Are fracture dynamics dominated by thermo-mechanical expansion/contraction of the inter-cleft rock mass? (ii) Do cryogenic processes, i. e. freeze-thaw dynamics and ice segregation, affect fracture opening/closing? (iii) Can irreversible crack deformation patterns and destabilisation be observed?

(i) Fracture dynamics are dominated by thermo-mechanical expansion and contraction of the inter-cleft rock mass during sustained snow-covered and snow-free periods. Calculated thermal expansion coefficients of 7E-006 along and 14E-006 perpendicular to foliation highlight material anisotropy of the calcareous micaschist.

(ii) Significant deviations from the thermo-mechanical deformation regime occur mainly during spring and autumn zero curtain periods due to freeze-thaw action. Peak vertical deformations are triggered by rainfall events providing liquid water onto the rock surface and into the fracture system. Subsequent refreezing rather than hydrostatic pressure build-up is assumed to cause the mechanical response of the rock. Lower magnitude deviations in the horizontal component arise in autumn and early winter, which are referred to segregation ice growth. Besides cryogenic processes, other mechanisms seem to affect fracture dynamics such as wedged rock fragments impeding maximum fracture-closing during snow-free periods.

(iii) Irreversible fracture opening, pointing towards acute, high magnitude rock slope instability, was not observed. However, enhanced cryogenic deformation in spring and autumn may lead to shallow, low magnitude rock detachments.

Our results highlight the importance of liquid water intake in combination with subzero-temperatures on the destabilisation of glacier headwalls. Randkluft systems may favour intense frost action and ice segregation, serving as important preparatory factors of paraglacial rock slope instability.