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Thermal and mechanical modelling of massive rock slope failure following fjord deglaciation

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During the last decade, more than 300 unstable rock walls have been systematically identified throughout Norway, of which five are classified as high-risk instabilities with respect to high hazard scores and anticipated casualties. At these five sites long-term permafrost degradation following glacial retreat seems to significantly influence large-scale rock instability. Here we combine thermal and mechanical modelling of extreme fjord topographies over the Pleniglacial / Lateglacial / Holocene to demonstrate how permafrost degradation controls long-term rock slope failure. Recent movement rates, however, show a strong link to hydraulic conditions such as hydraulic head and infiltration rates.

In this study, we investigate two of Norway's high-risk sites to model and evaluate thermal and hydraulic forcing on historic and recent rock slope instabilities. Critical rock mass parameters, such as uniaxial compressive strength, tensile strength and elasticity in frozen and unfrozen state were obtained by using over 100 specimens from site for rock mechanical testing. The results show a 15 to 20 % strength reduction upon thaw. These test results and results of a long-term transient heat flow model (CryoGrid2D) were transferred into a continuum mechanical model on a fjord scale level. Our thermal assumptions of recent rock wall temperature dynamics were confirmed by temperature-calibrated 3D electrical resistivity tomography. On a slope scale, 2D electrical resistivity tomography reveals hydraulic forcing since surface features such as large fissures can be attributed to zones of increased infiltration.

Here we show the first attempt on long-term stability modelling of steep fjord rock walls following deglaciation. This work helps understanding the often-observed time lag between deglaciation and rock wall failure by adding laboratory-tested rock mechanical implications of permafrost development and degradation to the picture.