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Identification of thermo- and ice-mechanical stresses and their occurrence conditions in a steep permafrost rockwall

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Thermo- and ice-mechanical stresses can initiate and expand fractures in high alpine rockwalls, cause instabilities and, thus, natural hazards. In permafrost rockwalls, research focus traditionally on ice-mechanical stresses by frost weathering processes while thermo-mechanical stresses are paid little attention. We use Seismic Refraction Tomography (SRT) to quantify permafrost distribution as well as crackmeters and piezometer to monitor fracture expansions in a permafrost-affected rockwall between August 2012 and August 2014. The calculation of thermal expansion coefficients enables the differentiation of expansion into (i) thermal expansion and contraction, (ii) ice segregation as well as (iii) volumetric expansion and ice erosion during phase transitions.

In the Steintaelli at 3100 m a.s.l., mean annual rock surface temperature (MARST) ranges from -0.52°C to -4.47°C in 2012/13 and from -0.74°C to -4.42°C in 2013/14 indicating possible permafrost conditions on the crestline and probable permafrost conditons in the north face. Active-layer thawing and permafrost distribution is quantified by SRT (Krautblatter & Draebing, 2014). Permafrost is present in the north face and the crestline below 5 m depth and preserved by an up to 3 m high snow cornice in 2013 (Draebing et al., 2014) and 2014 while the south-face is permafrost-free. Water availability and fracture permeability are significantly altered by permafrost. Snow covers the rock surface between 119 and 312 days in 2012/13 and 0 to 365 days in 2013/14 with longer snow cover duration on the less-insolated north face and crestline. Snow cover controls the occurrence of thermo- and ice-mechanical stresses

(i) During snow-free conditions high-frequent rock surface temperature (RST) changes result in thermal expansion and contraction of the rockwall and, thus, in thermo-mechanical-induced fracture opening and closing up to 0.7 cm.

(ii) RSTs within the frost cracking window of -3 to -6°C are preserved by isolating snow cover and enable ice segregation. Fracture water pressure show negative values due to cryosuction with coincident fracture opening up to 0.9 cm. Due to enhanced water availability, ice segregation is emphasized in fractures close to permafrost-free areas of the crestline.

(iii) Volumetric expansion and ice erosion occur in the freeze-thaw window of -0.7°C. Due to unsufficient water saturation of fractures volumetric expansion occurs rarely, however, refreezing during snow melt periods results in fracture dilation up to 0.2 cm. Advected heat transported by snow meltwater erodes ice and decreases ice pressure with coincident fracture closing.

Here, we identified for the first time conditions enabling thermo- and ice-mechanical stresses in a permafrost rockwall and show how snow and permafrost control and influence these stresses.

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