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High-resolution rock dilatation measurements from steep bedrock permafrost and implications for rock fall release mechanisms

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In fractured bedrock of steep alpine permafrost rock faces, cleft dynamics, creep and stability of rock masses is influenced by the thermal conditions within and around discontinuities. An increasing number of documented rock falls from periglacial environments in the last decade raise the question, how and where this thermal influence becomes a controlling factor of rock fall activity.

The mechanics of permafrost bedrock containing ice-filled clefts has rarely been investigated and only qualitative understanding of the processes interlinking temperature and stability in these situations exist. Here we present temperature, dilatation and translation measurements with high temporal resolution from six clefts at Matterhorn-Hörnligrat (3500m a.s.l.; Swiss Alps). Cleft opening / closing is recorded during cooling / warming at subzero temperatures in the upper cleft. This reversible dilatation is commonly explained by segregation ice formation within the cleft (cryogenic opening). Once temperatures reach the melting point (indicated by a zero curtain in cleft temperature records) an accelerated opening or shearing (depending on the geometrical setting) of the cleft takes place. We attribute this second slow mass movement to a sliding at a basal fracture plane of the rock mass that is introduced by melting conditions. We suspect this sliding mechanism to potentially culminate in the triggering of rock fall or rock avalanches.

The response time of the cleft movements to temperature changes is on the order of some hours for both cases (cryogenic opening and sliding). This is surprisingly short for the dimensions of the surveyed rock masses and can not be explained by conductive heat transport between the rock surface and the ice-rock interface within the cleft. Dilatation-temperature plots with the lower cleft temperatures show even a time lag of the cleft temperature in comparison to the movement. This finding is little understood at present but indicates the possible importance of rock hydrology (pore water pressure/expulsion and advective heat transport) as a coupling mechanism between the meteorological conditions and the mechanics of the fractures.