Geophysical Research Abstracts
Vol. 16, EGU2014-410, 2014
EGU General Assembly 2014

Identification of critical factors for the instability of permafrost-affected rockwalls in the Turtmann valley (Swiss Alps)

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Rock slope instability, small-scale rockfalls and associated talus slopes are widespread phenomena in mountain environments. The heterogeneous spatial pattern, sediment properties and volume of talus deposits in alpine valleys reflect a complicated set of various variables governing the spatial and temporal occurrence of slope failure. However, the dynamic and non-linear interplay between environmental settings, the mechanical properties of the rock mass, its discontinuities and different weathering processes promoting rock degradation makes the identification of the dominant destabilizing factors a difficult task.

In our project we studied the instability of permafrost-affected rockwalls (Nyenhuis et al., 2005) in the high alpine Turtmann Valley in the Swiss Alps (110 km2). Here, we present a combination of (i) meso-scale spatial analyses and (ii) local-scale geotechnical investigations of critical factors on rockwall instability and (iii) incorporate the results into a theoretical concept with respect to abiotic and biotic weathering processes.

(i) To explain the spatial variability of talus deposits stored in 14 WE-oriented hanging valleys, a detailed geomorphological map of 220 talus slopes (Otto et al. 2009) was spatially combined with different key variables of the rockfall source area including topography, climate, lithology and rockwall morphometry. The talus slopes are strongly oriented towards north indicating reduced solar radiation. This aspect-driven trend appears to support the high significance of frost weathering processes as dominant mechanism for rock slope instability, in particular during thawing phases of rockwall permafrost.

(ii) To assess the role of mechanical properties of rockwalls at local scales, field surveys of rock discontinuities were performed at selected rockwalls with and without talus slopes based on ISRM standards. Geotechnical investigations reveal discontinuity orientations and spacings that might effectively promote rock slope failure during diurnal and annual freeze-thaw cycles.

(iii) To evaluate the effect of biotic processes on rockwall weathering, lichen species were identified and quantified at the selected rockwall areas (ca. 2x2m), representing the basis for a conceptual approach. Considering the lichens extensively covering the studied rockwalls, it seems reasonable that micro-scale biotic processes may lead to larger-scale impacts on the entire abiotic slope system through promoting or preventing the efficiency of freeze-thaw mechanisms.

Therefore, our multi-scale approach shows that the stability of permafrost-affected rockwalls in our study area is controlled by a combination of topoclimatic and rock mechanical variables that might cause synergetic and weakened weathering processes.

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Otto, J. C., L. Schrott, M. Jaboyedoff, and R. Dikau, 2009, Quantifying sediment storage in a high alpine valley (Turtmanntal, Switzerland), Earth Surface Processes and Landforms, 34(13), 1726-1742.