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Regional-scale controls of periglacial rockfalls (Turtmann valley, Swiss Alps)

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Rockfalls are among the most hazardous processes in mountain regions and of major importance for landform evolution and sediment budgets. The rockfall activity varies significantly in space and time, driven by the complex interplay between locally dynamic variables (i.e. discontinuities, freeze-thaw processes) as well as system inherent predisposing factors dominating at a regional scale. Many studies focus on small-scale triggering conditions for rockfalls, but the effects of regional-scale controls leading to a basic instability of alpine rockwalls, such as topo-climatic settings, lithology and i.e. tectonic structures as well as paraglacial adjustments, are poorly understood.

In this study, we aim to understand the role of regional-scale controls of rockfalls in the Turtmann Valley, which covers 110 km^2 in the Swiss Alps. Based on an inventory of 220 talus slopes (Otto et al. 2009), rockfall source areas were determined and their causal relationship between ten different prediction variables was assessed. By combining two multivariate statistical models, we (i) explained the spatial pattern of rockfalls, (ii) evaluated the relative importance of potential predisposing factors (iii) and discuss these regional-scale controls in the light of the local-scale geomorphic and rock mechanical settings. Major finding are:

(i) A stepwise logistic regression (LR) based on principal components and a random forests (RF) model were performed and validated using a 75%-subset of the rockfall source areas. Given the area under the ROC curves for both approaches, LR: 0.92, RF: 0.99, respectively, the RF model performs slightly better to explain the large-scale variability of rockfalls in our study area.
(ii) Both, the LR and RF model reveal that lithology and joint orientation have the strongest causal influence on rockfalls at regional scale. In contrast, topo-climatic factors (elevation, slope, solar radiation) might be of secondary importance. Additionally, the regional pattern of rockfalls seems to be linked to the paraglacial adjustment time since LGM, conceptualised by the ergodic principle (space-time-substitution).
(iii) The modelling results are in good agreement with local geomorphic and rock mechanical surveys performed on different rockwalls. Rockfall events dominate locally on steep, comparatively recently deglaciated, anaclinal slopes consisting of amphibolite rocks with high rock mass strength (RMS: 50-70). Nevertheless, it must be supposed that the regional-scale controls differ in their relative importance from small-scale factors, due to emergent system behaviour and the increasing system complexity with increasing spatial scale.

In contrast to many other large-scale statistical studies underestimating the importance of rock mass properties, our results indicate that the rock mechanical parameters in combination with the paraglacial response process of alpine rockwalls have to be considered as key predisposing factors for rockfall activity at regional scales.

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.