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# Is rock slope instability in high-mountain systems driven by topo-climatic, paraglacial or rock mechanical factors? - A question of scale!

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Due to the emergent and (often non-linear) complex nature of mountain systems the key small-scale system properties responsible for rock slope instability contrast to those being dominant at larger spatial scales. This geomorphic system behaviour has major epistemological consequences for the study of rockfalls and associated form-process-relationships. As each scale requires its own scientific explanation, we cannot simply upscale bedrock-scale findings and, in turn, we cannot downscale the valley-scale knowledge to smaller phenomena.

Here, we present a multi-scale study from the Turtmann Valley (Swiss Alps), that addresses rock slope properties at three different geomorphic levels: (i) regional valley scale, (ii) the hillslope scale and (iii) the bedrock scale. Using this hierarchical approach, we aim to understand the key properties of high-mountain systems responsible for rockfall initiation with respect to the resulting form-process-relationship at each scale.

(i) At the valley scale (110 $km^2$) rock slope instability was evaluated using a GIS-based modelling approach. Topo-climatic parameters, i.e. the permafrost distribution and the time since deglaciation after LGM were found to be the key variables causative for the regional-scale bedrock erosion and the storage of 62.3 - 65.3 x $10^6$ $m^3$ rockfall sediments in the hanging valleys (Messenzehl et al. 2015).

(ii) At the hillslope scale (0.03 $km^2$) geotechnical scanline surveys of 16 rock slopes and one-year rock temperature data of 25 ibuttons reveal that the local rockfall activity and the resulting deposition of individual talus slope landforms is mainly controlled by the specific rock mass strength with respect to the slope aspect, than being a paraglacial reaction. Permafrost might be only of secondary importance for the present-day rock mechanical state as geophysical surveys disprove the existence of frozen bedrock below 2600 m asl. (Messenzehl & Draebing 2015).

(iii) At the bedrock scale (0.01 mm - 10 m) the spacing, persistence and orientation of joints turned out to be the most causative bedrock properties for the higher-scale rock mass strength. Rock temperature data suggest that high-frequent, surficial thermal processes, daily freeze-thaw cycles and seasonal ice segregation coupled with a winter snow cover are the major rock breakdown mechanisms. By linking the rockwalls' joint geometric pattern to the size and shape of rockfall blocks lying on the corresponding talus slopes, different rockfall magnitudes and frequencies were identified.

Here we show, that the decrease in spatial scale is linked with a shift in variable importance, from topo-climatic and paraglacial factors at the largest scale to rock mechanical parameters at the smallest scale. Therefore, to understand the key destabilising factors of rock slopes in mountain systems and the resulting landforms, a holistic research approach is needed which considers the nested, hierarchical structure of geomorphic systems.

Messenzehl, K., Meyer, H., Otto, J.-C., Hoffmann, T., Dikau, R., 2015. Regional-scale controls on the spatial activity of rockfalls. (Turtmann valley, Swiss Alps) - A multivariate modelling approach. In: Geomorphology.

Messenzehl, K., Draebing, D., 2015. Multidisciplinary investigations on coupled rockwall talus-systems (Turtmann valley, Swiss Alps). Geophysical Research Abstracts, 17 (EGU2015-1935, 2015).