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Photogrammetric analysis of slope failures feeding the head of the Illgraben debris flow channel

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Our understanding of slope failure is restricted by a lack of inventories of sufficient size and directly measured volumes. We used digital photogrammetry to produce a multi-temporal record of erosion of a rock slope in the Illgraben. From this we extracted an inventory of ∼2500 slope failures for 3 epochs of 6/7 years between 1986 and 2005 ranging over 6 orders of magnitude in volume. Through analysis of their magnitude-frequency, volume-area and depth-slope gradient relations we aimed to understand the characteristics of slope failure at the head of this active alpine debris-flow catchment.

The slope failure volumes follow a characteristic magnitude-frequency distribution with a roll-over at $50m^3$ and a power-law tail between $\sim 200m^3$ and $1.6x106m^3$ with an exponent of 1.65. We compared different methods to estimate the power law scaling exponent and found the maximum likelihood estimator to be the most accurate. Conversely, least squares regression on the probability density function consistently underestimated the exponent. Slope failure volume scales with failure area as a power law with an exponent of 1.1. This exponent is low for the bedrock nature of the slope in comparison with worldwide studies of bedrock and soil landslides and likely results from the highly fractured and incohesive nature of the quartzitic bedrock of the study slope. Comparing the results for different epochs we find that the magnitude-frequency and volume-area relationships are reasonably time-invariant demonstrating their general nature for the setting.

We interpret the magnitude-frequency distribution of slope failure volumes as the result of two separate slope failure processes. Type (1) failures are frequent, small slides and slumps within the weathered layer of highly fractured rock and loose sediment. These make up the roll-over of the distribution. Type (2) failures are less frequent rockslides and rockfalls within the internal bedded and fractured slope along pre-determined potential failure planes. These make up the power-law tail of the distribution and generate ∼99% of the failure volume. In contrast to Type (1) failures, Type (2) failures occur mostly on slopes with gradients above 45°, thus limiting the relief of the slope.

Our study lends empirical support to the hypothesis that the characteristic probability distribution of landslides contains two separate processes: shallow earth-slides and slumps and deeper rockslides and rockfalls. Additionally it gives support to the concept of a threshold slope angle for landsliding in landscape evolution models.