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Modular and evolutive rock slope instabilities detection and hazard assessment methods: new tools to compute instability factors and examples of application

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The challenge in rock instabilities detection and hazard assessment is to develop methods that are both modular (i.e. that can be adapted to the funding available for the study) and evolutive (i.e. that can be upgraded with the development of new tools and new digital documents) (Jaboyedoff et al., 2003a).

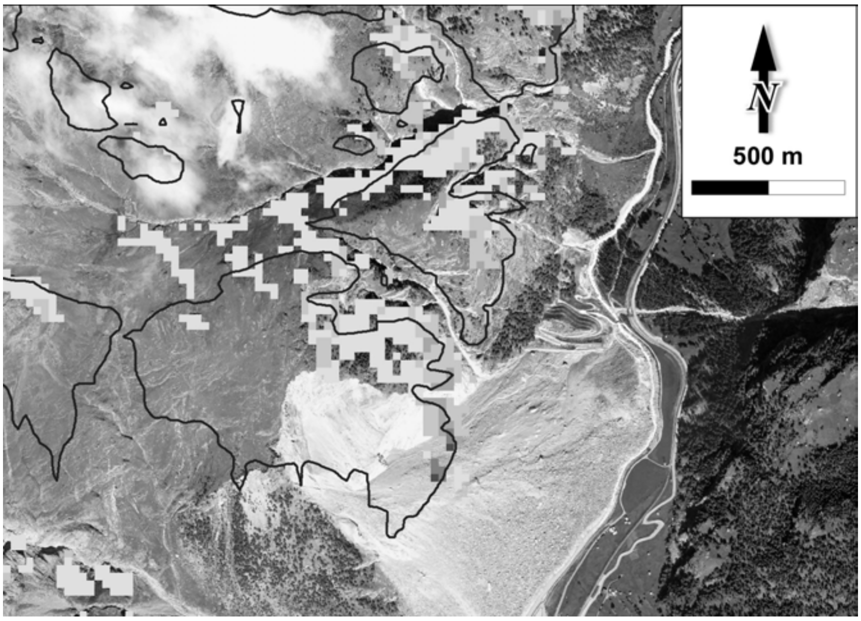

Figure 1: Surroundings of the Randa rockfall scar. The thickness above the sloping local base level isopach 50 m is contoured. The pixels indicate the density of J3 faults which can cross the topography (light grey = average; dark grey = high) (DHM25© 2004 swisstopo (BA045928)).

Basically, instability factors can be divided in two categories: intrinsic parameters (IP) that change with time, and external variables (EV), that cause these changes. Hazard assessment is based on two different ways of combining IP and EV: (1) by summing and weighing them together without introducing a hierarchy; (2) by assuming a simple physical based model which introduced a hierarchy, in the data and used parameters. A specific hazard scale for every case study can thus be defined, taking into account that some instability factors are lacking, or on the contrary that they are more detailed, i.e. depending on the scale of the study, the knowledge of IP and EV can be more or less accurate. The assessment methods are usually performed as a first step by combining geometrically IP and EV; and in further steps by introducing physical modelling and by field observations. Combinations as well as iterations can be performed along with theses steps.

A certain number of IP descriptors can be easily computed by analysing Digital Elevation Models (DEM): for instance, 1) slope angles, indicating whether slopes are near their equilibrium angle or not; 2) Sloping Local Base Level (SLBL) to calculate the volumes that are potentially erodible by landslide activity; 3) the main structural features shaping the topography that can be extracted using 3D topographic orientation histograms; 4) faults or discontinuities whose traces can be built with the help of known points; 5) hydrographic networks; 6) kinematics tests and factors of safety for different rockfall mechanism types; 7) rockfall activity that can be assessed by examining aerial photographs or vectorial topographic map to map cliffs and fresh rockfall deposits; and 8) geology; EV descriptors can be computed either by DEM analysis or with the help of external data such as 1) precipitation contribution to the watersheds; 2) hydraulic head index; 3) water table level estimated by a smoothed DEM or by data; 4) earthquake activity (Jaboyedoff et al., 2003b); 5) recent tectonic movements; 6) freeze and thaw cycles; 7) human activities and protection works; etc.

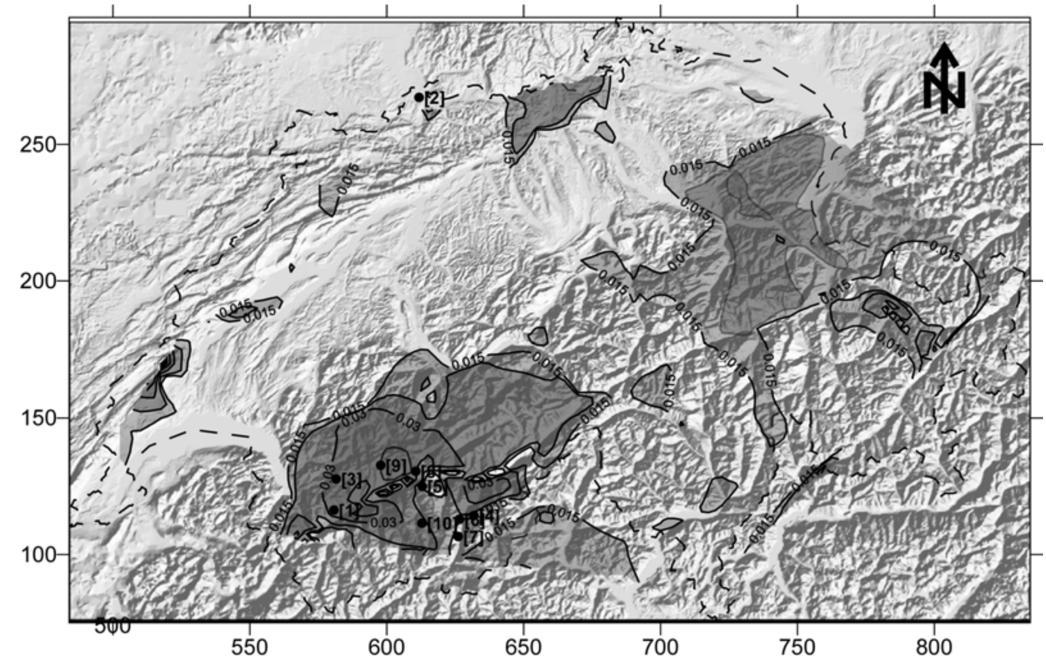

Figure 2: Significant instabilities are located in the southwest of Switzerland (according to Jaboyedoff and al. 2003b) and high gradients of uplift. The majority of instabilities are in zones, which have values of gradient of uplift higher than 0.015 mm km^{-1} $year^{-1}$ (in grey scale).

The above approaches were applied to linear elements at risk in Quebec and Switzerland (Baillifard et al., 2003). The rockfall hazard assessment along the Quebec City Promontory (Quebec, Canada) shows a good agreement with the observed data. Based on five instability factors, the rockfall hazard assessment along mountain roads in the canton of Valais appears efficient.
Applied to planar elements at risk, the hazard assessment of large rock instabilities was efficient in the area surrounding the 1991 Randa rockfall (30 M m3). The main instabilities were detected using instability factors extracted from a DEM, or deduced

from aerial photographs and field surveys. A simple mechanical modelling including pore water pressure improves the results. Moreover, such methods were tested on soil slopes, giving promising results.

References

Baillifard, F., Jaboyedoff, M. and Sartori, M. 2003: Rockfall hazard mapping along a mountainous road in Switzerland using an empirical approach. Natural Hazards and Earth System Sciences, Vol. 3, pp. 435-442.

Jaboyedoff, M., Baillifard, F., Kaufmann, J.F. et Labiouse, V. 2003a: Identification des versants rocheux potentiellement instables. Université Européenne d'Été sur les risques naturels 2002, Sion, Suisse. Quanterra, Short-Course – 03F.25 p.

Jaboyedoff M., Baillifard F. and Derron M.-H. 2003b: Preliminary note on uplift rates gradient, seismic activity and possible implications for brittle tectonics and rockslide prone areas: The example of western Switzerland. Bull. Soc. Vaud. SC. nat., Vol. 88, pp. 393-412.