Geology, glacier changes, permafrost and related slope instabilities in a high-mountain rock face: Monte Rosa east face, Italian Alps

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The Monte Rosa east face, Italian Alps, is one of the highest flanks in the Alps (2200 - 4500m asl). Steep hanging glaciers and permafrost cover large parts of it. Since the end of the Little Ice Age (about 1850), the hanging glaciers and firn fields have retreated continuously. During the recent decades, the ice cover of the Monte Rosa east face experienced an accelerated and drastic loss in extent. Some glaciers have totally disappeared leaving large parts of the underlying rock unprotected against mechanical and thermal erosion. Enhanced rock fall and debris flow activity was observed (Haeberli et al., 2002; Kääb et al., 2004; Fischer, 2004).
Perennially frozen rock walls are highly complex systems that may react very sensitively on changes. Those changes in glacier extent, permafrost conditions, thermal and hydrological regimes, as related to present atmospheric warming, significantly affect the stability conditions of the Monte Rosa east face.
The exceptional rock fall activity during the hot summer 2003 has pointed to the relation of rock fall and climate change via permafrost thaw. These numerous smaller events stemmed mainly from enlarged active layer thickness during this extraordinary summer. Also the most recent event in the Monte Rosa east face, a 0.5 to 1 Mio. m^3 large ice/rock avalanche in August 2005, underlines the ongoing development of instabilities in ice and rock.

The scope of this study is to analyze the linkage between the glacier shrinkage and permafrost degradation, on the one hand, and the observed increasing slope instabilities in the Monte Rosa east face, on the other hand (Fischer, 2004). A number of amateur photos, air-photos and maps was compiled in order to reconstruct the development of the ice cover of the Monte Rosa east face. The geology of the Monte Rosa east face and the detailed extents of the hanging glaciers were mapped during fieldwork in summer 2003. The starting zones of rock fall, ice avalanches and debris flows were observed and localized as well. The permafrost distribution in the rock wall was computed with different models. Roughly one half to two thirds of the east face are estimated to be under permafrost conditions.
For the compilation and processing of these data, a Geographic Information System (GIS) was used. GIS technologies facilitate the integration of remote sensing and field data as well as modelled data for analysing and modelling instable and hazardous zones in a steep slope.
The investigated parameters are shown as separate layer in the GIS. The hazardous areas can be detected and classified by an overlay and intersection of the different layers.

It turned out that:

- Most of the active starting zones of rock fall and debris flow are located in parts of the rock wall, where surface ice disappeared recently.
- Most of the active starting zones are located in permafrost zones, mostly close to the estimated lower boundary of the permafrost occurrence.
- Many active starting zones are situated at the boundaries between two different lithologies.

In the view of ongoing or even enhanced atmospheric warming it is therefore very likely that the instabilities in the Monte Rosa east face will continue to represent a critical hazard source. Therefore some first-order modelling of rock fall events and ice avalanches has been conducted showing that particularly large events could endanger some parts of the upper part of the Valle Anzasca, especially in the current situation of an elevated Ghiacciaio del Bel-

vedere and an occasionally filled supraglacial lake on it.

This study shows the high suitability of the GIS technology for the processing and presentation of multi-temporal and multi-spatial data and related processes. It reveals as an important tool for the evaluation and prediction of natural hazards in general and the detection of possibly instable and hazardous zones in high alpine rock walls in detail.

REFERENCES

Fischer, L. (2004): Monte Rosa Ostwand – Geologie, Vergletscherung, Permafrost und Sturzereignisse in einer hochalpinen Steilwand. M.Sc.-Thesis, Department of Geography, University of Zurich.

Haeberli, W., Kääb, A., Paul, F., Chiarle, M., Mortara, G., Mazza, A., Deline, P. and Richardson, S. (2002): A surge-type movement at Ghiacciaio del Belvedere and a developing slope instability in the east face of Monte Rosa, Macugnaga, Italian Alps. Norwegian Journal of Geography 56, 104-111.

Kääb, A., Huggel, C., Barbero, S., Chiarle, M., Cordola, M., Epifani, F., Haeberli, W., Mortara, G., Semino, P., Tamburini, A. and Viazzo, G. (2004): Glacier hazards at Belvedere glacier and the Monte Rosa east face, Italian Alps: Processes and mitigation. International Symposium, Interpraevent 2004 – Riva/Trient.