Permafrost Degradation and Natural Hazard Management in the Matter Valley, Swiss Alps

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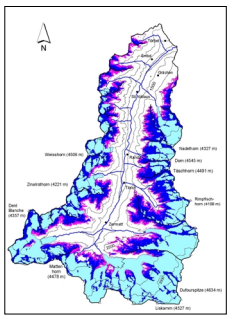


Figure 1: The Matter Valley (overview map); light blue = glaciers; dark blue = permafrost probable, pink = permafrost likely. Permafrost distribution according to mod2 (GRUBER 2000)

The Matter Valley is surrounded by some of the highest peaks of the Alps. In contrast to the numerous mountain peaks exceeding 4,000 meters, the valley bottom is located between 900 and 1,600 meters, resulting in extreme altitudinal differences and a continental character of the climate. Thus, a periglacial belt of considerable vertical extent is formed and underlain by discontinuous permafrost above 2,400 m a.s.l. (*cf. Figure 1*). The asymmetric shape of the Matter Valley is caused by the geological conditions and characterised by a comparatively steeper western flank. Due to the high relief energy, all kinds of natural hazards typical for high mountain environments occur: the steep western slope is dominated by rockfalls (*cf. Figure 2*), slope instabilities in bedrock and avalanches. A cover of unconsolidated sediments is widespread on the eastern slopes and induces landslides and debris flows, which often reach down to the valley bottom. Debris flow deposits can dam up the Matter Vispa in its deeply cut and narrow river bed. Consequently, lake outbursts can threaten the settlements downstream.

The local population has always been aware of these dangers. However, increasing population and modern forms of land use require a more sensitive attitude towards natural hazard potentials. Management of natural hazards has been much improved during the last fifteen years and increasing amounts of money are spent each year in order to safeguard settlements, traffic lines, and other objects of the technical infrastructure.

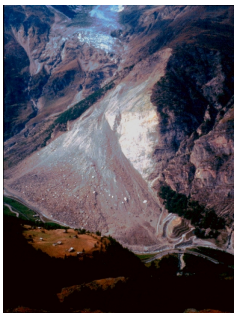


Figure 2: the Randa rockfall. In spring 1991 two rockfalls with twenty and ten million cubicmeter of material, respectively, went down from the steep western flank near Randa and buried parts of the BVZ railway track and the road

Planning, Management and Legislation of Natural Hazards in the Canton du Valais

Regional and local authorities (canton and communities) are officially in charge of treating natural risks. All cantons included regulations concerning natural hazards in their regional planning laws. The planning law of the Canton du Valais defines risk zones as areas, which are endangered by natural hazards according to former experiences or predictions. These hazards are divided into avalanches, rockfalls, landslides, floodings and others.

At first, risk assessment is done by overview maps ("*Sachplan Naturgefahren*", scale 1:25,000). Still at cantonal level, this overview is followed by detailed risk analyses consisting of registers and detailed maps (scale 1:2,000 to 1:10,000). These "*Object Sheets*" give exact cartographic positions as well as detailed information about location, kind and dimension of danger, information status, precautions and prophylactic investigations of each object.

The cantonal "Department for Land Use Planning" bears the administrative responsibility, while the "Department for Natural Risks" and the "Department for Street and River Construction" take the technical responsibility.

The communities are responsible for the compilation of risk analyses, which are regularly made by private planning offices. The elaboration of risk analyses is financed by federal (70%), cantonal (20%) and local funds (10%). These analyses are integrated in the land zoning at local level by defining zones of high, medium and low danger, associated with corresponding prohibitions, restrictions and conditions for utilisation.

At present, the incorporation of the avalanche (3,200 locations) and rockfall register (*cf. Figure 3*) in local zoning plans is completed in most communities of the Canton du Valais. An additional inventory of 200 slope instabilities was elaborated and must be considered in present and future local zonation updates. Zones threatened by floods, however, are indicated on maps of overview scale so far. A current pilot study is dealing with flood management methods and considers the debris flow activity of torrents, too.

Furthermore, the Canton du Valais carries out numerous projects of active disaster prevention comprising measurements and constructional precautions against avalanches and slope instabilities as well as different monitoring systems and early warning stations.

Planning and Management at Local Level – Case Study St. Niklaus / Matter Valley –

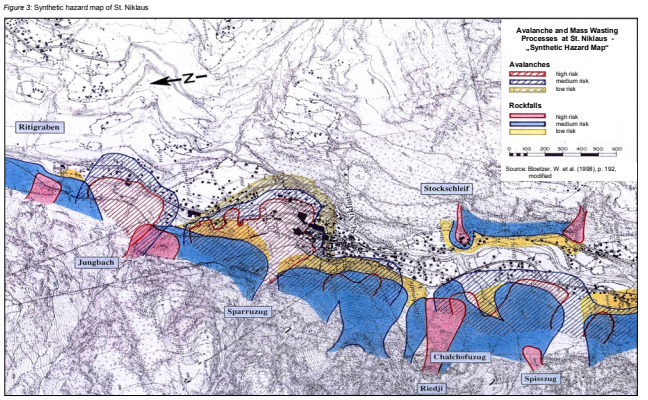
The community of St. Niklaus with its 2,419 inhabitants is located in the lower part of the Matter Valley (*cf. Figure 1*) and covers an area of almost 90 km². In contrast to Zermatt and Grächen, tourism is of secondary importance, as the main employer with 500 work places is a company, which produces saw blades. Due to its location St. Niklaus is endangered by catastrophic mass movements (avalanches, rockfalls, debris flows), floods and even earthquakes. In 1855 the last strong earthquake caused several rockfalls, which destroyed numerous buildings.

The actual planning is strongly influenced by the rockfall event of Randa in 1991 (*cf. Figure 2*) and (as in other communities of the Matter Valley) land use planning was completely revised, thereafter. Recent events confirmed the need of this decision: extremely heavy rainfalls in autumn 1993 and 2000, the avalanche-winter 1999, numerous debris flows at Ritigraben and last but not least the rockfall in September 2002, which resulted in the evacuation of two parts of the village and the controlled explosion of dangerous rock slopes. Areas threatened by avalanches are divided in different danger zones (*cf. Figure 3*) and integrated in the zoning plan. Numerous investigations concerning natural hazards have been made and the results are considered in the actual land use planning. The new zoning plan will also integrate danger zones for rockfalls and rock slides as well as activity areas of debris flows (*cf. Figure 5*). Even zones already declared for future build-up will be eliminated. This will probably entail conflicts with the land owners. Ongoing projects are the construction and drainage of safety dams and the monitoring in rockfall and debris flow areas.

In the 90ies the expenses for protection against natural hazards amounted to one million Swiss Francs per year. Due to a rockfall in autumn 2002 these costs will rise to over ten million Swiss Francs in 2003. The costs are shared as follows: 70 % federal state, 20 % Canton du Valais, 10 % community of St. Niklaus. In addition, the private railway company BVZ pays the costs for the protection of its railway track.

Due to the global warming St. Niklaus has to face an intensification of natural hazards, in particular of debris flows. Permafrost degradation will considerably raise the potential for debris flows, e.g. in the Ritigraben. Therefore, intensive investigations of the area is necessary.

Figure 3: Synthetic hazard map of St. Niklaus



Monitoring and Early Warning System at Ritigraben

Ritigraben torrent surmounts a vertical difference of 1,600 m on a length of 3,500 meters. From its starting point in 2,600 m a.s.l. to the confluence with the Matter Vispa (1,049 m a.s.l.) its longitudinal profile is characterized by two steep segments with a slope between 50 and 55% divided by a smoother section (terrace of Grächen, about 1,600 m a.s.l.). The catchment area between 2,600 and 2,900 meters consists of a block slope underlain by permafrost, which covers an area of about 1.4 km² (*cf. Figure 4*).

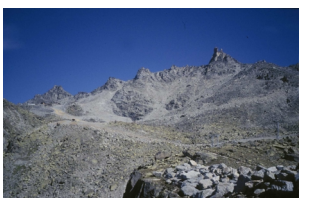


Figure 4: The catchment of the Ritigraben torrent with the peaks of Seetalhorn (3,037 m, left) and Gabelhorn (3,136 m, right)

During the last century, this torrent induced twelve debris flows with an increased frequency within the last 15 years. Heavy precipitation was the trigger event for most of these debris flows (REBETEZ et al. 1997). Events originating from the upper segment occured also in connection with high snow melt rates. The last larger event happened on 24th September 1993 and deposited a cone of 60,000 m³ (DIKAU et al. 1996). This blocked the main valley and dammed up a lake. Events of even bigger magnitude have to be expected, if ongoing climate warming leads to further permafrost degradation in the catchment area (*cf. Figure 5*). In contrast to avalanche hazards, no planning standards for the management of debris flow hazards exist in the Canton du Valais so far.

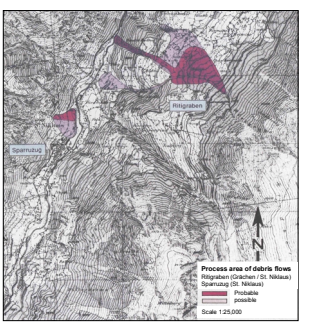


Figure 5: Example of a process area map (debris flow); dark pink indicates deposition areas of debris flow events that have occurred during historical times. Light pink indicates areas, that may be affected by future events, if changing conditions lead to a mobilisation of higher debris volumes.

Source: BLOETZER, W. et al. (1998), p. 195, modified

In March 2002, the Canton du Valais initiated the drilling of a 30 meter deep borehole in the Ritigraben catchment at an altitude of 2,615 meters (*Figure 6*). It was instrumented with thermistors for continuous monitoring of permafrost temperatures. A weather station collects hourly meteorological data, which can supply a real-time overview of meteorological conditions (especially precipitation rates). Ground temperatures are only slightly below freezing and the active layer reached a thickness of 3.5 meters in summer 2002.

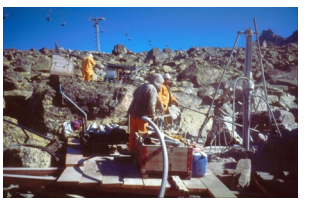


Figure 6: Drilling operations in the Ritigraben catchment at 2,615 m a.s.l. (October 2001)

The described installations were financed by federal (70%) and cantonal (30%) funds. In addition, an early warning station, which stops traffic on the cantonal road in case of a debris flow event, was installed in the lower steep section of the torrent.

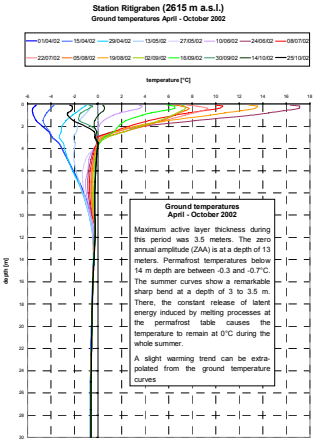


Figure 7: Ground temperatures at the Ritigraben station

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Further information:
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