4. MONITORING AND WARNING SYSTEM FOR THE RANDA ROCKSLIDES

On the morning of **18 April 1991**, a major rock-slide of approximately 20 million m^3 occured in the Mattervalley near Zermatt (cf Figure 6). The Vispa River was dammed and parts of the town of Unterlärch near Randa were covered by 60 metres of debris, the Brig-Zermatt Railway line was closed and some horses and sheep were buried in the barns. Specialists came shortly after the event to make a first evaluation of the remaining hazards. After a careful examination of the site (with field observations and aerial photography), it was clear that the narrow alpine valley was still endangered by a large unstable rock volume in place.

A crisis committee was immediately set up; it was composed of representatives of communal authorities, the cantonal geologist, some specialists from Water Department and Public Works and the Army. They decided to install a monitoring and warning system in the unstable zone to detect the possible detachment of a second rockslide, to prevent fatalities and to start the rehabilitation work in the valley.

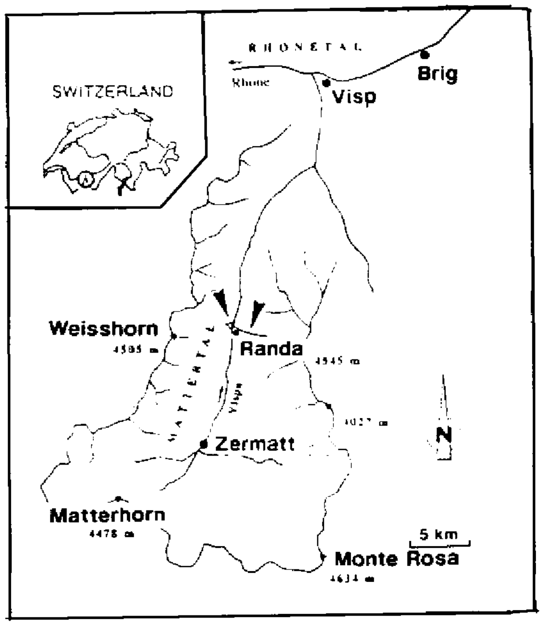
The monitoring and warning system was established, employing different methods with geodetic, hydrological, meteorological and seismic stations. After a close examination of the cliff by the geologists (analysis of dip and orientation of the main faults), **18 distance-metres** were established to measure, by hand, the opening of the active shearing and transverse cracks, twice a day. The results were transmitted to the scientific board of crisis (CSC).

A **geodetic network** was emplaced with 14 reflectors in the surrounding of the main scarp of the unstable cliff to know exactly the direction and speed of movement. The measurements took place twice a day with the help of electro-optic Tachymeter (infrared signals) from two differents points down the valley in Randa. The results were collected daily by the specialist and transmitted to the CSC.

Close to the main scarp, four seismometers were installed to detect ground vibrations and were linked to a **seismic station**, with visual and audible signals (warning system) under permanent control of an observer. On 22 April, this monitoring of the seismic signals allowed the prediction of an event (rockfall of 100'000 m^3) permitting evacuation of the workers from the endangered zone.

4.1 The second event

During the first days of May, geodetic displacement measurements recorded a strong acceleration of the movements in the unstable zone and high intensity tremors were also registered at an increased level (cf Figure 7). **On 9 May** the displacements amounted to more than 70 cm in 11 hours and the crisis committee decided to close the cantonal road leading from Visp to Zermatt and the population was kept away from this zone. Within 7 hours, 10 million m^3 of rock material fell down the valley. The loss of private property was limited to a few barns and 24 holiday residences in the hamlet of Lerch. There were no casualities. Some 20 ha of arable land were buried under a deep layer of debris. A giant cone formed a large barrier in the valley (20 meters above the lowest point of the plain) and a lake formed behind it. A volume of 3.5 million m^3 of water could have been dammed and the failure of this natural dam would cause severe damage by flash flooding in Visp (8000 inhabitants, 30 km downstream). Besides that, a large part of the town was threatened by the rising water-level of the new lake. The road and railway leading to Zermatt were closed; supplies for the local population and for thousands of tourists were stopped for 15 days.



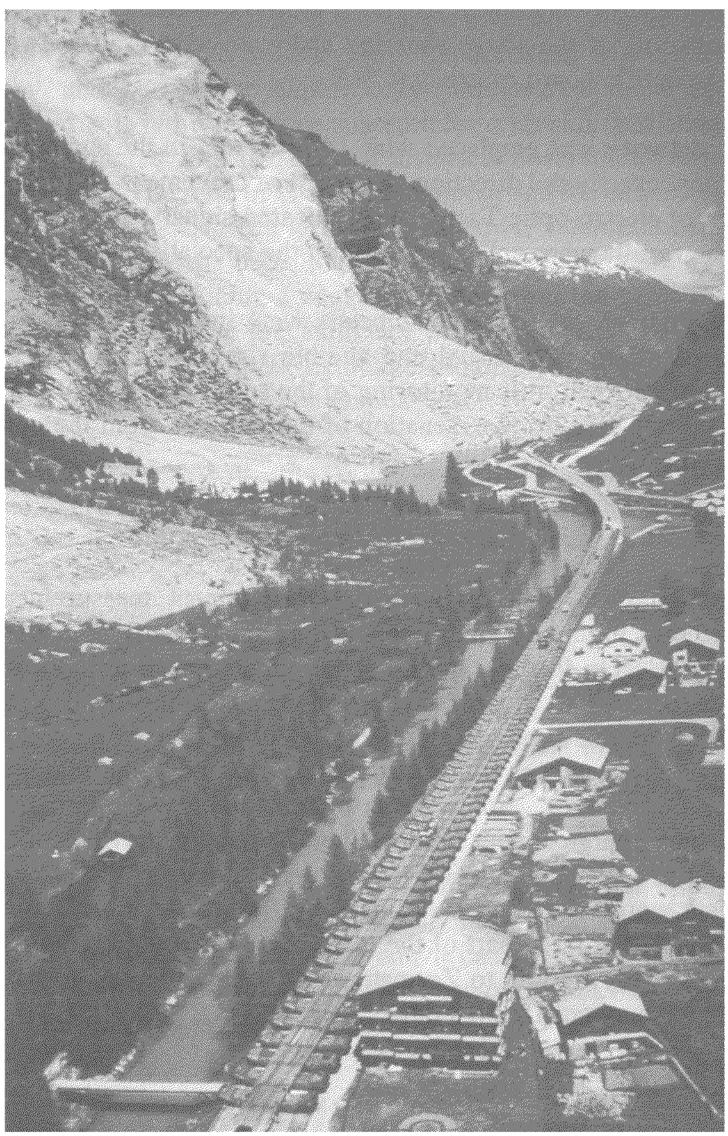


photo A. Goetz BWW-Bern

Figure 6 - Localisation of the Randa rockslides in Valais

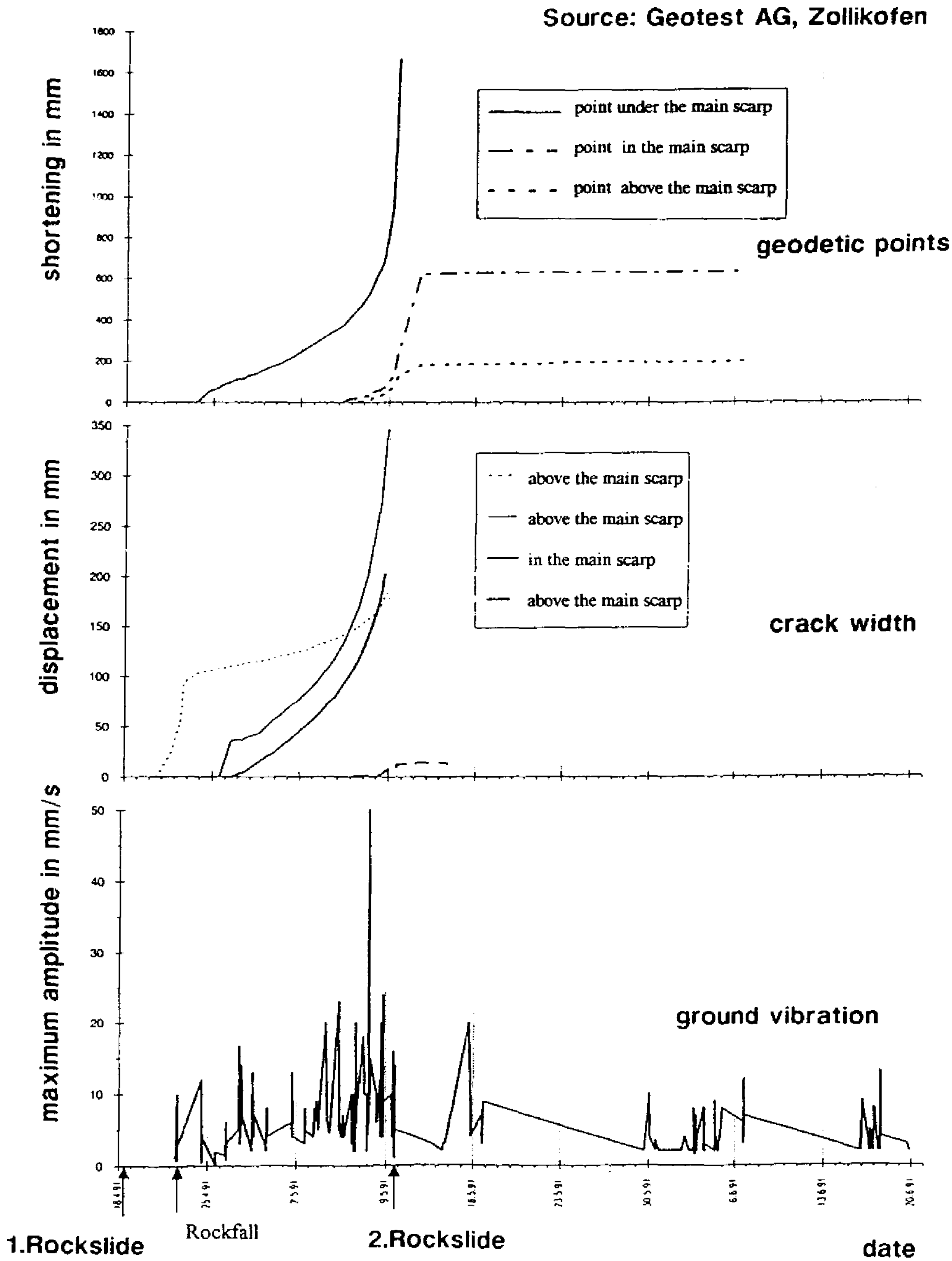


Figure 7 - Monitoring of the Randa rockslides

4.2 After the second event

After this second rockslide, the monitoring system was reorganized because some topographic datum points (with reflector) had disappeared. Since June, a **meteorological station** was installed above the main scarp, collecting data of temperature (air and ground), precipitation, air moisture and sun radiation. These data are sent with automatic teletransmitters to the specialists and will be used to understand the long term behaviour of meteorological events in connection with mass movements of the unstable zone. The **new geodetic network** is composed of 18 reflectors, dispersed around the main scarp and the measurements are made twice monthly from two different points down the valley. Periodically manual measurements (distance-meter) from 24 stations are made on top of active faults and 8 automatic stations with wire extensometers are linked to the meteorological network (with teletransmition of the results). This **network** is designed to detect the global movement (speed and orientation) and the possible rapid acceleration of parts of the unstable cliff. After the second event some **hydrological data** (water discharge, water level of the lake) were also collected to control the water level of the lake. The monitoring and warning systems were the main priority to keep rehabilitation workers safe. Today no more displacement is observed on the fissures. A geological study of the whole Mattervalley is underway in order to forecast a future event.

4.3 Rehabilitation

Efforts were made to keep the level of the lake as low as possible, preventing flooding of the town. A temporary by-pass for cars was constructed only four days after the second event. A new road (1,4 km long) and a railway line were built in the valley. A 25 meter deep channel was excavated through the toe of the rockslides in very coarse material. A very large pump system was able to take 12 m^3/s of the lake's water and ejected downstream into the Vispa river. Across the Randa plain, a military pontoon bridge of 500 metres served in case of flooding.

On 16 June, a thunderstorm associated with the melting of snow caused flooding of 1/3 of the village (rise of 5 metres of the water level in the lake) and again on 8 August the brand new railway line was under water. During the spring of 1991, more than 1000 soldiers accomplished 10'000 man/days for rehabilitation and reconstruction of the valley leading to Zermatt.

A maximum of 9 million m^3 of rock are expected to fall down in the future, causing a new dam of the Vispa river. To prevent the problem of flooding, a 3.7 km-long by-pass tunnel with a capacity of 200 m^3/s will be drilled at the toe of the rockslides for the river. The road and the railway line has to be restored in the future. The cost to repair the damaged caused by the rockslides, to restore the road and railway line (interim solution) and to guarantee a reasonable degree of safety for the local population against any further events amounted to 100 million Swiss francs.

4.4 Conclusions

Three years after, the unstable cliffs above Randa are still under close monitoring. The data are analysed monthly and a long term observation programme was established to predict any future events. A regional measurement programme of structural geology was set up, in order to identify further unstable zones in the valley. An event like the Randa rockslides occurs every 100 years in Switzerland. The knowledge of the processes involved in landslides is developed through a research programme called "Climate change and natural disasters" (budget 20 million Swiss francs, granted by the Swiss National Science Foundation). Prevention measures (monitoring, warning, evacuation, land-use regulations...)

require early recognition of the hazards. The case-study of Randa is a good example where a well designed monitoring system was able to predict a sudden massive rockfall in advance. A careful observation of nature, combined with accurate measurements at the site, prevented a major disaster in a very crowded valley with intense traffic and tourist facilities.

The Swiss IDNDR Committee also promotes studies of hazard and risk assessment for avalanches, floods, landslides, forest fires or earthquakes. Scientific findings must be transferred for practical use (structural measures of prevention) to legal implementation (land-use planning, regulations). The Randa event was also a good example of co-ordination at the communal, cantonal and federal level when a regional disaster appeared in a country where disaster prevention and management are mainly in the hands of regional authorities

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