CLIMATIC AND METEOROLOGICAL INFLUENCES ON ROCKFALL AND ROCKSLIDES ("BERGSTURZ")

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The **first part** discusses the climatic and meteorological boundary conditions, under which in the recent past smaller and larger rockfall und rockslide events have occurred. To do so, approximately 230 more or less well documented rockslides since the late Pleistocene Epoch in the Alpine region have been analysed. Additionally, approximately 800 rockfall and rockslide events, which occurred during the last 500 years for the most part on the north side of the Alps of Switzerland, have been investigated, focussing mainly on the influence of temperature and precipitation on the event frequency. The results of these analyses can be found in Gruner (2004, 2006).

The historical analysis of the rockslides shows the impossibility to correlate large events with warm climatic periods. Furthermore, the global warming since 1850 does not coincide with a significant increase of rockslide events. A majority of the large historical rockslides (since approximately 2000 years) are related to intensive and long-lasting precipitation during summer and autumn months. Looking at the examined 800 mainly smaller- or middle-sized rockfall events, the following conclusion can be drawn: winter- and spring-events are more frequent during generally cold periods than they are during warm periods. In the latter there is no reference to an accumulation of events; moreover it can be shown that during warm years the frequency of rockfall events is more likely to decrease during summer months. Besides there is no correlation between well-known extended humid periods and a accumulation of rockfall events.

In the **second part,** the historically documented climatic and meteorological influences on the triggering and mechanical processes will be discussed from a rock-mechanical point of view. Due to precise automatic deformation measurements in different rock areas, the mechanism of destabilization and decomposition of rock masses can be identified and correlated with meteorological data. For smaller- and middle-sized potential rockfall volumes such measurements show, that the clefts and fissures in the rock masses open continuously during cold periods , as a result of rock contractions, while they stagnate or even decrease during a warm-period. This cyclic process leads to a destruction of rock bridges, to an increase of the cleft depth and to a destabilization of the rock masses. The main movement thus takes place in the cold season. Snowmelt and the first intensive precipitation during spring causes water pressure in the cleft system to increase, which may trigger a rockfall. A frequent change of freezing and thawing can accelerate the process. Intensive or even extreme precipitation during warm periods as in August 2005 did not cause increased movements on most measuring points. This behaviour may explain, why such rockfall processes occur more frequently during cold seasons and spring time than during warmer seasons. A conclusion which corresponds also with dendrochronological findings on tree trunks, located on an alpine slope in the Valais, where it could be proved, that falling rocks arose almost exclusively during the winter growth phase of the trees (between October and end of May) and were not at all influenced by summer thun-

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derstorms. Otherwise deformation measurements taken on larger rock portions with impeded runoff (e.g. where high hydrostatic pressure can build up) show. while they are rather "cooling insensitive", also clear movements due to strong and/or long continuing precipitation.

In the **third part** some conclusions, which are to be considered e.g. for the evaluation and management of a rockslide danger, will be given:

- The most important cause for small- or middle-sized rockfall events is the extent of a cold period (cold climatic periods, cold winters, cold snap in the spring/autumn, frequent freezing and thawing cycles), which results in a destabilization of the rock masses (see figure 1).

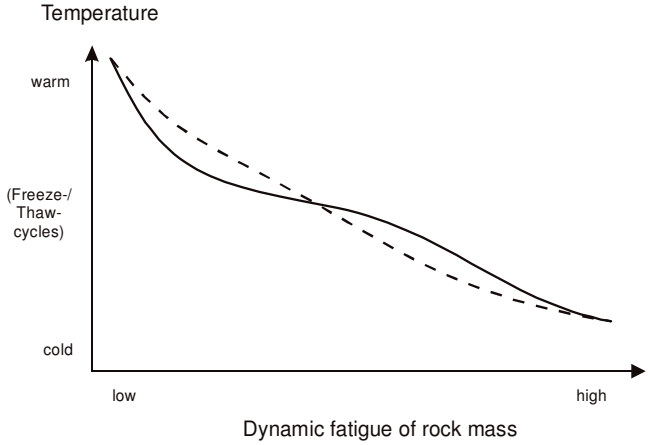

Fig.1: Extent of dynamic fatigue of rock masses depending on temperature

- The rockfall events are often triggered by precipitation and/or snowmelt following a cold period. Warm periods, especially warm summer months, cause however a sedation of the rock masses. During these periods generally less rockfall is to be expected. An exception are rock masses in permafrost zones, where during very hot summer months usually rather small rockfall from north walls of the high mountain may occur. They however hardly reach residential areas and infrastructure.
- In case of large rockslide and rockfall events (over 100'000 m^3) however, predominantly mountain water conditions ("mountain water pressure") and thus precipitation influences those events (figure 2).

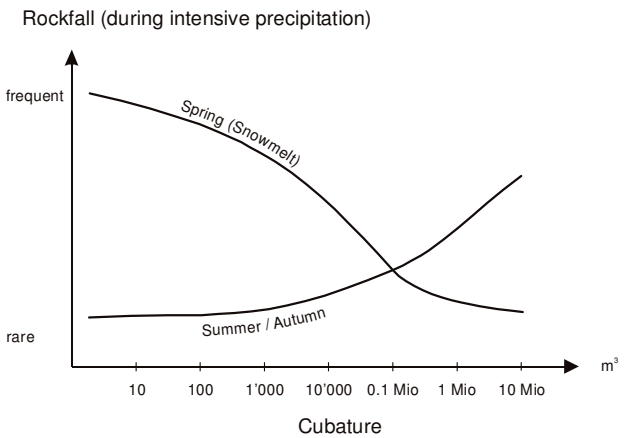

Fig. 2: Frequency of rockfall events versus cubature in case of intense precipitation

Keywords: Rockfall, Meteorological Influences, Event Frequency, Global Warming, Rockslide