Quantification of rockfall processes on recently deglaciated rock slopes, Gepatsch glacier, Tyrol (Austria)

GeoZentrum Nordbayern

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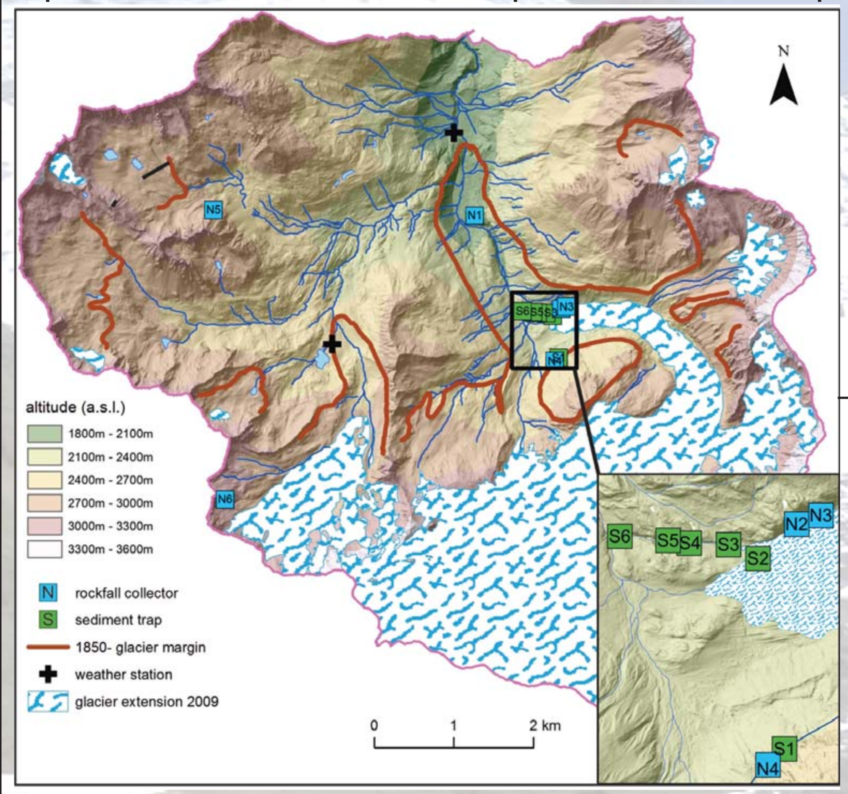
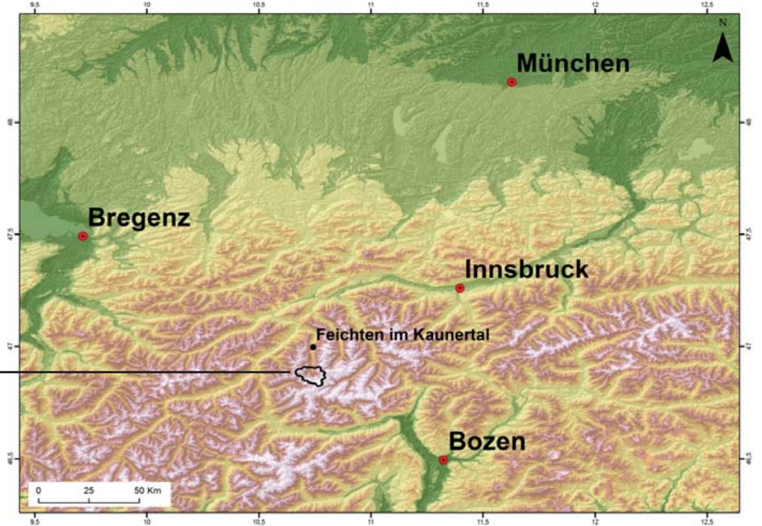
PROSA

1. Introduction and study area

Rockfall is an increasingly serious natural hazard in steep alpine areas, in particular in the areas adjacent to recently shrinking glaciers. However the process is difficult to assess as its intensity is governed by numerous factors which vary in time and space.

Due to the rapid deglaciation since 1850, lithological structures and topoclimatic factors, rockfall processes are important contributors to sediment transport and modification of the earth's surface in the steep, 62 km² large high mountain catchment of the Gepatsch reservoir. The study is carried out in the Frame of the PROSA-joint-project by the Department of Applied Geology, University Erlangen-Nuremberg, and will be continued for two additional years.





The study area:

- Mean altitude: 2800m a.s.l.
- 20% of the planar study area is covered by rockfall or rock avalanche deposits, 30% of the planar area is glaciated
- Most frequent rock types: Biotite-plagioclase paragneiss, granitic orthogneiss, amphibolite, mica schist
- Mean annual precipitation: 1000-1300mm
- Mean annual air temperature: -0,4°C (2540m a.s.l.)

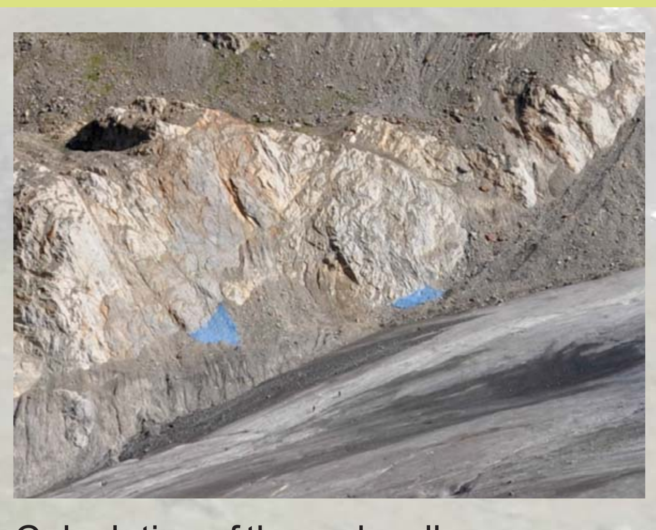
Aims of the study

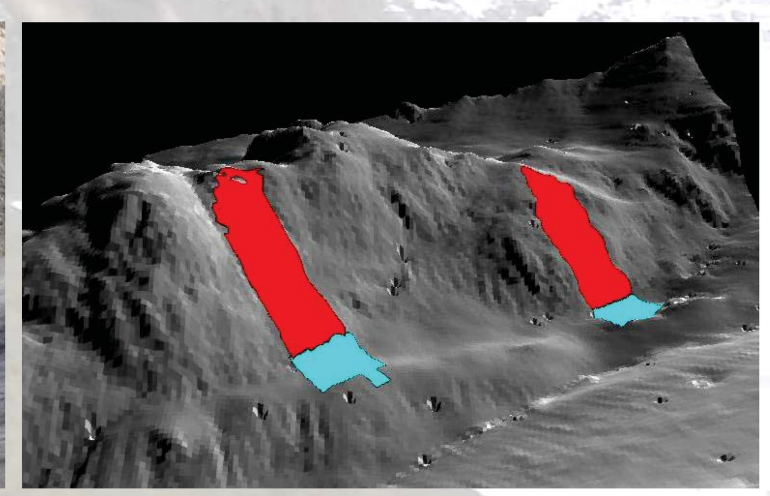
- Quantifying rockfall intensity in the light of recent deglaciation
- Determination of the controlling factors of rockfall intensity
- Providing data for the regionalization of rockfall

2. Methods

Quantifying rockfall intensity: Rockfall collector nets & natural sediment traps
Determining the controlling factors of rockfall intensity: Geomorphological mapping, rock mass mapping, Schmidthammer measurements, meteorological data, high resolved data-logging of rock temperature and jointing

Weighting & grainsize analysis of rockfall



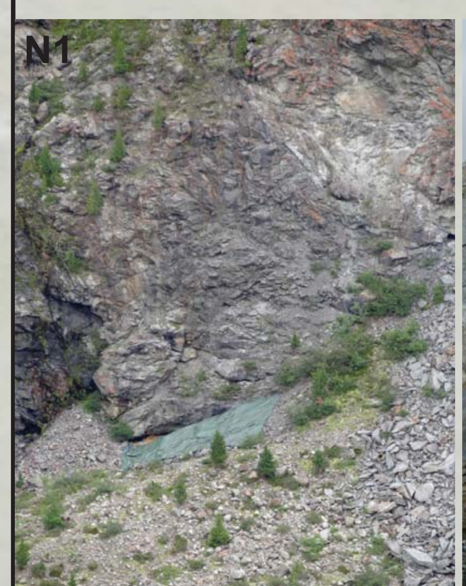


Calculation of the rockwall source area on a DEM1 (blue: rockfall collector nets)

rockfall masses (g) / rockfall source-area (m²) / observation interval (d) = rockfall intensity (kg/m²/d)

Impressions of the rockfall collectors

N1

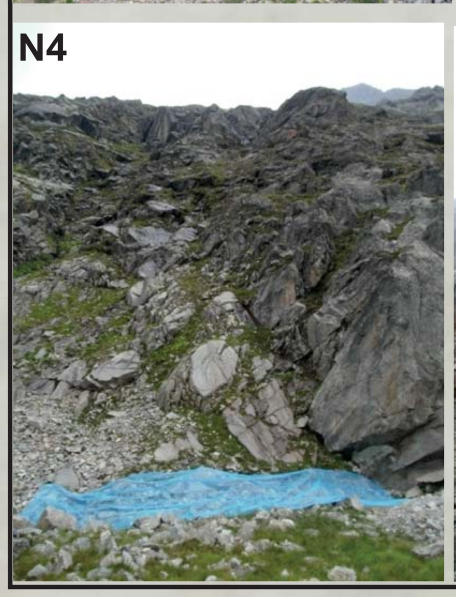


N2

N3

collector nets: mesh size: 2mm; net area: 80-230m², fixed by iron hooks at the base of the rockwall

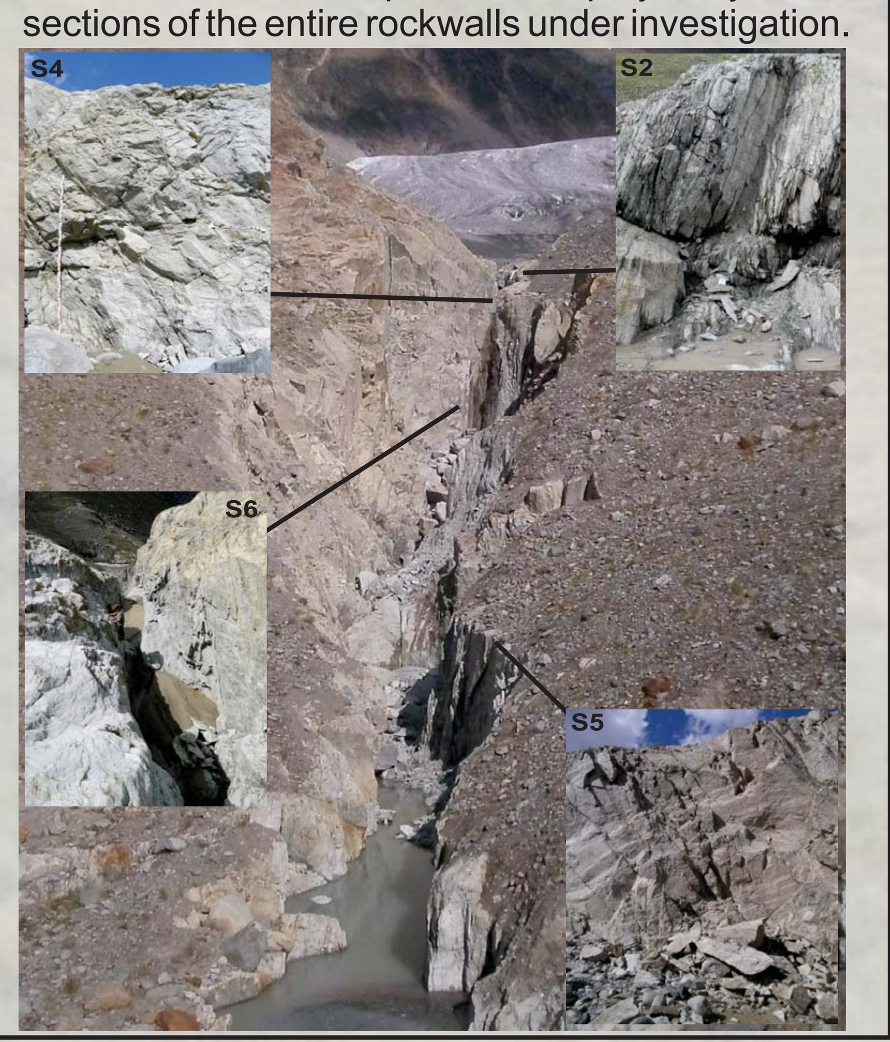
N4



N5

N6

Fault zone in the proglacial area (below): The sediment traps encompass several hundreds of m², each. The four pictures display only small sections of the entire rockwalls under investigation.



3. Results and discussion

Rockfall intensities at the rockfall collectors, supplemented by geomorphological data. For pictures and locations of the rockfall collectors see left part.

name	net area (m²)	rockfall intensity (g/m²/d)	back weathering rate (mm/a)	rock type, geology	altitude (m a.s.l.)	exposition	slope > 45° (area - %)	onset of deglaciation	joint spacing (m)	joint aperture (cm)	RMS (Selby, 1980)
N1	84	**2,4**	**0,32**	fine grained paragneiss	2020	W	95	1891	0,3	0,5-2	66
N2	230	**3,9**	**0,52**	coarse grained paragneiss, massive orthogneiss	2250	SE	58	2009	0,3	0,1-0,5	67
N3	187	**6,9**	**0,94**	massive orthogneiss	2250	SE	39	2010	0,2	0,5-2	68
N4	120	**0,05**	**0,0068**	orthogneiss, coarse grained paragneiss	2380	NW	66	>10000	0,45	0,01-0,1	77
N5	150	**0,38**	**0,048**	amphibolite, orthogneiss	2750	N	100	>10000	0,8	0,01-0,1	86
N6	200	**0,049**	**0,0066**	finegrained paragneiss	3125	S	93	>10000	0,25	0,1-0,5	70
S1		**0,023**	**0,0031**	orthogneiss, coarse grained paragneiss	2380	NW	69	>10000	1	0,1-0,5	82
S2		**137,7**	**18,6**	phyllit, fault zone	2190	E	48	2012	0,05	0,1-0,5	42
S3		**71**	**9,6**	splintery orthogneiss, fault zone	2190	S	65	2009	0,05	0,1-0,5	46
S4		**58,7**	**7,9**	blocky orthogneiss, fault zone	2190	S/N	74	2009	0,15	0,5-2	57
S5		**109,8**	**14,8**	mica-rich orthogneiss, fault zone	2140	S/N	98	1997	0,3	0,5-2	61
S6		**5,3**	**0,71**	massive orthogneiss	2170	S/N	79	2003	0,9	0,1-0,5	74

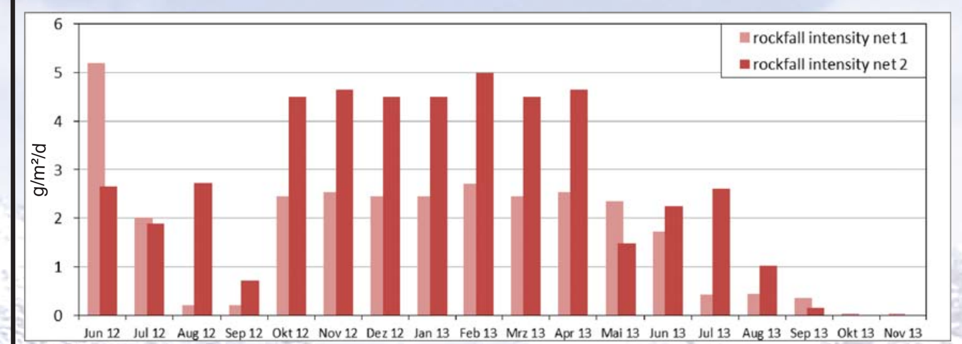
Green: Medium to high rock mass strength, degaciated before 10000 BP, ‚equilibrium slope'

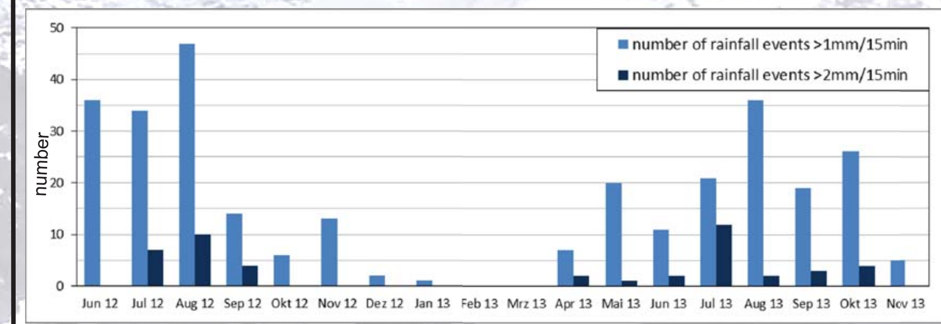
Yellow: Medium rock mass strength, deglaciated since 1850

Orange: Low rock mass strength, recently deglaciated, fault zone

3A: Short term perspective: Rockfall intensity, frost action and meteorological events

Rockfall intensity and rainfall intensity



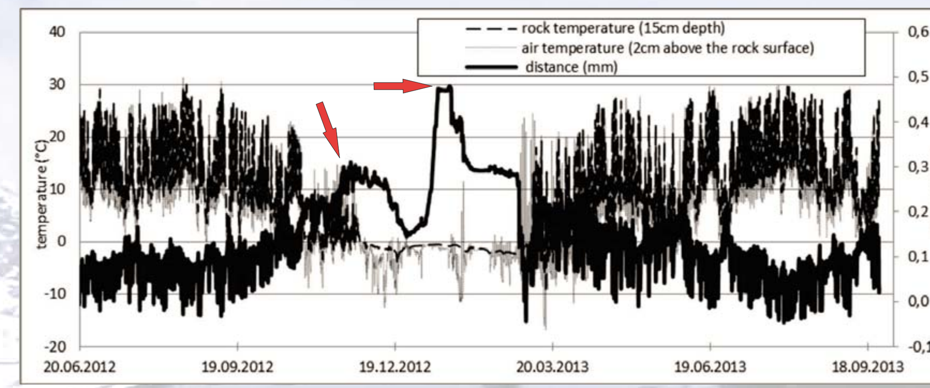


Rockfall intensity at collector N1 and N2 and the absolut number of rainfall events for the corresponding months.

There is no connection between rainfall and rockfall intensity, indicating that these two rockwalls are mainly weathering-limited.

Rockfall intensity and the cold climate weathering

Rock temperature fluctuations and ‚frost cracking'

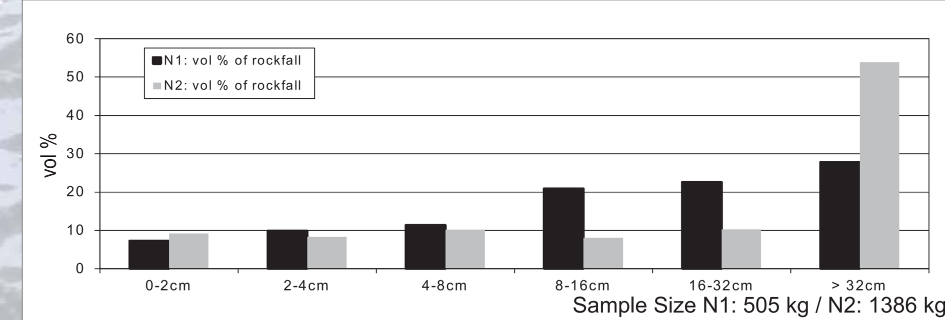


Frost cycles:

- rock surface: 113 (below -2°C: 82)
- 15 cm depth: 40
- 40 cm depth: 10

Two mayor frost-cracking events can be identified during winter 2012/13 (red arrows). These events lead to disintegration of the rock mass along predefined fractures.

Grain size distribution of rockfall



Percentage of rockfall particles > 4cm:

- N1: 82%
- N2: 83%
- N4: 82%
- N5: 85%
- N6: 91%

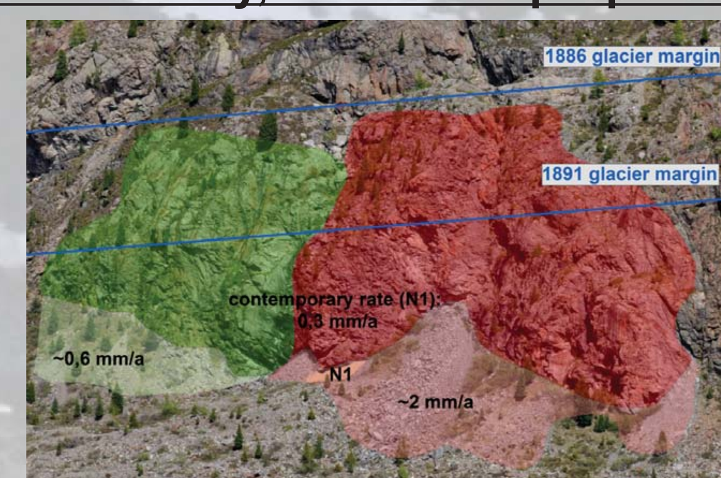
The grain size distribution suggest that frost action is an important contributor to rockfall, as particles are mostly larger than 4 cm in the diameter and have sharp-edged fracture surfaces.

3B: Outlook: Long-term perspective: Rockfall intensity, rock mass properties and geomorphic history

In spite of providing clear high resolved rockfall intensities for different rock slopes, rockfall collector nets fail to reveal long-term rockwall erosion rates as they are not able to detect high magnitude infrequently occurring large rockfall events. Rockfall activity varies as a response of regional climate fluctuations, which exceed the possible timespan of direct observations. Rock mass strength is also suposed to act as a controlling factor of rock slope erosion on longer time-scales (MOORE et al. 2009). To close these gaps, the implementation of additional methods will be neccessary:

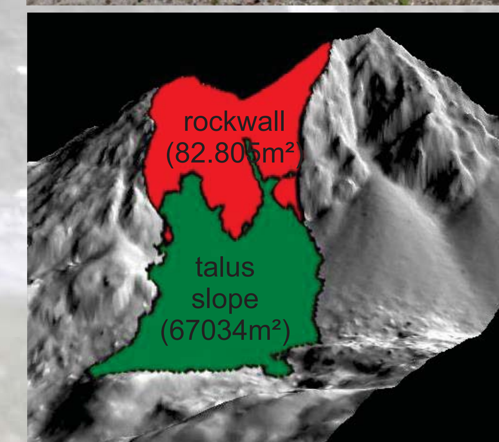
- **Multitemporal laserscanning** (See poster B437)
- Mapping of rockfall deposits & **volumetric estimations** (right figure) to calculate back-weathering rates
- Catchment-wide calculations of **‚talus production ratios'** (COE & HARP 2007) employing the digital geotechnical map (lright figure)

These method combination allows us to investigate rockfall intensities on multiple time- and space-scales. The results can also be implemented to regionalization of rockfall processes on catchment scale (HECKMANN et al. 2014).



Back-weathering rate based upon volumetric calculations, compared with the actual back-weathering rate.

Rockfall activity has been declining since the deglaciation. The data from the other rockfall collectors shows the same trend because there is a huge gap in rockfall intensity between recently deglaciated rock sopes and rock slolpes deglaciated during the late Pleistocene.



Example of the ‚talus production ratio' (after COE & HARP 2007) on the base of a DEM5. The talus production ratio is the area ratio between talus slope and rock wall. It gives an impression of the rockfall susceptibility of different rock masses on a larger scale, as long as talus slopes under similar conditions (e.g. unconstrained deposition, similar talus production timeframe) are compared.

4. Conclusions

The conclusions which can be drawn from these preliminary results are:

- *Rockfall intensity is in average two orders of magnitude higher at the proglacial rockwalls compared to the rockwalls that have been deglaciated at the Pleistocene-holocene transition, indicating a clear ‚paraglacial signal' on recently deglaciated rockwalls*
- *Highest rates are detected on rock slopes with low rock mass strength adjacent to mayor faults*
- *The comparison of rockfall intensity and mayor precipitation events results no relationship, as the investigated rockwalls are ‚weathering limited'*
- *Frost action seems to be a mayor control of rockfall intensity, as ‚frost-cracking' can be observed along joints during the winter and the grain size distribution of rockfall suggests the dominance of ‚frost-cold climate weathering'*

References

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