Acoustic emission measurement system to investigate rock damage driven by freezing

Conference Poster

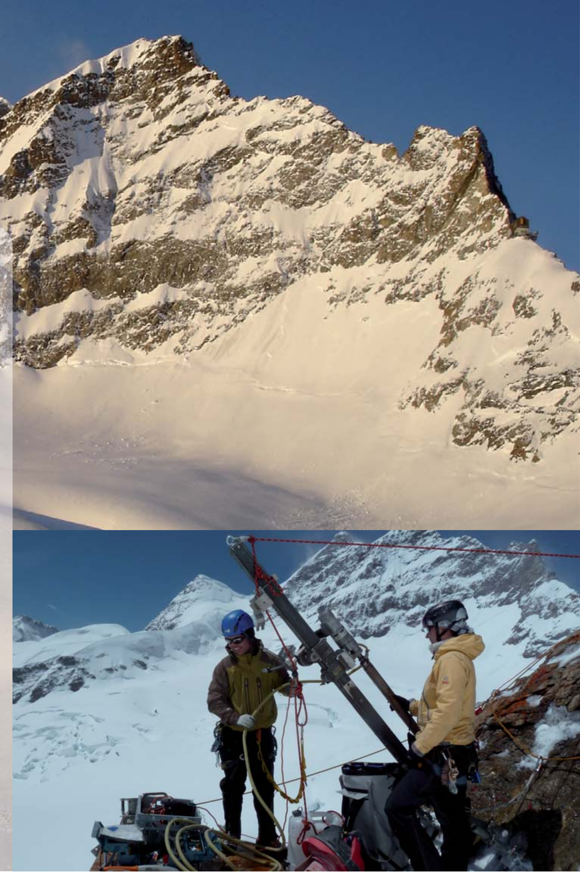
Author(s):
Weber, Samuel; Gruber, Stephan; Girard, Lucas; Beutel, Jan

Publication date:
2012

Permanent link:
https://doi.org/10.3929/ethz-b-000058264

Running for the PYRN award

Acoustic Emission Measurement System to Investigate Rock Damage Driven by Freezing



Samuel Weber[1,2], Stephan Gruber[1], Lucas Girard[1], Jan Beutel[2]

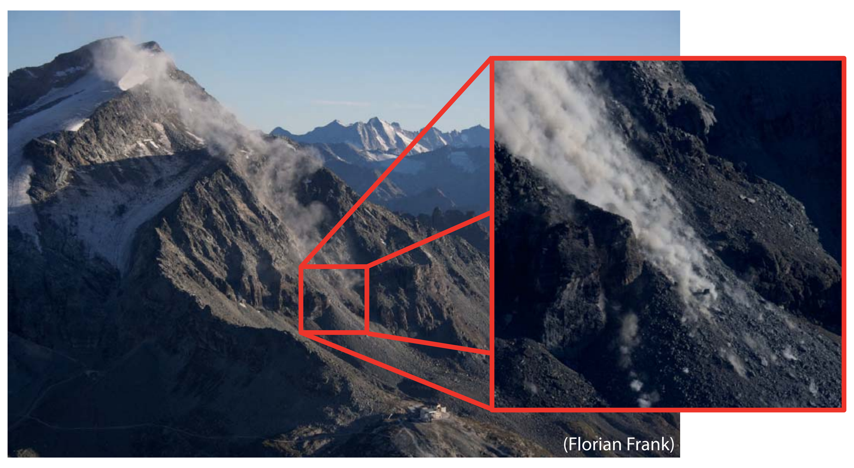
[1]Glaciology & Geomorphodynamics, Dep. of Geography, University of Zurich, Switzerland

[2]Computer Engineering and Networks Laboratory, Swiss Federal Institute of Technology Zurich, Switzerland

samuel.weber@tik.ee.ethz.ch, stephan.gruber@geo.uzh.ch, lucas.girard@geo.uzh.ch, janbeutel@ethz.ch

Motivation

- Formation of ice-filled clefts can precondition rock fall
- Initial rock damage processes and dynamics can be studied by AE



(Florian Frank)

(Max Maisch)

Goals

- Transfer theoretical and laboratory knowledge to real conditions
- Design a measurement system to capture AE at different depth

Main results

- Complete system to measure AE, temperature and pore water at depth in steep alpine rock-walls
- The system is installed on Jungfraujoch and runs since September 2011

What's next?

- Run the system for > 1 year
- Combine AE and crack meter measurements

Measurement System Evaluation

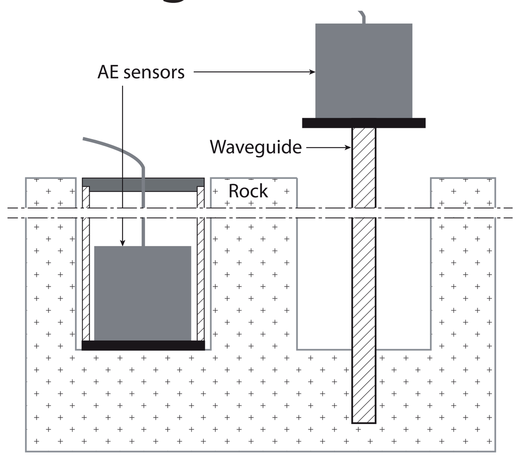
Preliminary experiments

April 2010, Jungfraujoch, Switzerland (Amitrano et al. 2012)
- Outdoor measurements with lab equipment during 4 days
- Piezoelectric sensors and six-channel high-frequency board
- Proved the potential and feasibility of AE measurements in *PermaSense*

Rock/sensor contact: two generic measurement assemblies

Casing: direct insertion of the sensor in the borehole
~2 dB loss

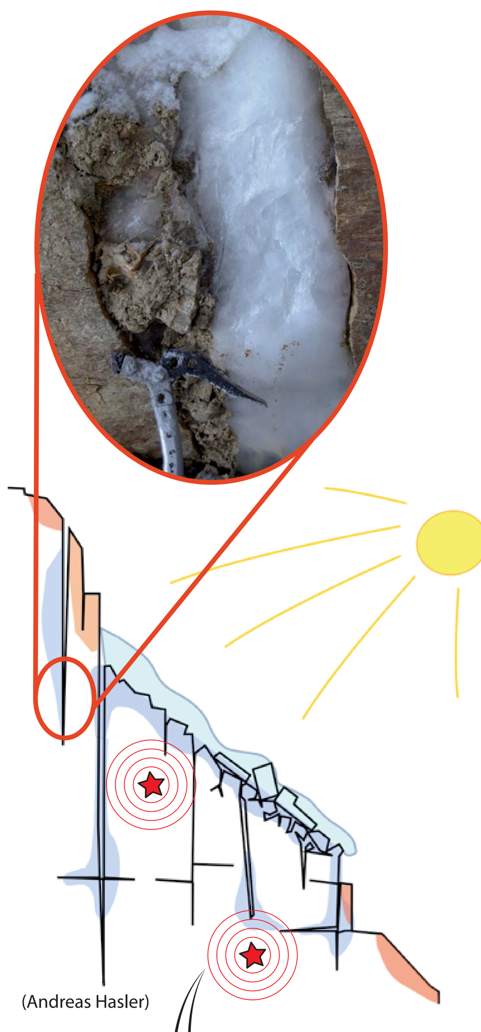
+ good coupling
+ raised data quality
+ protection of AE sensor
- alteration of field site
- difficult to install



Waveguide: thin rod transmits AE signal to sensor at surface
3-10 dB loss

+ easier to install
- reduced data quality
- not protected
- alteration of field site
- no constant coupling

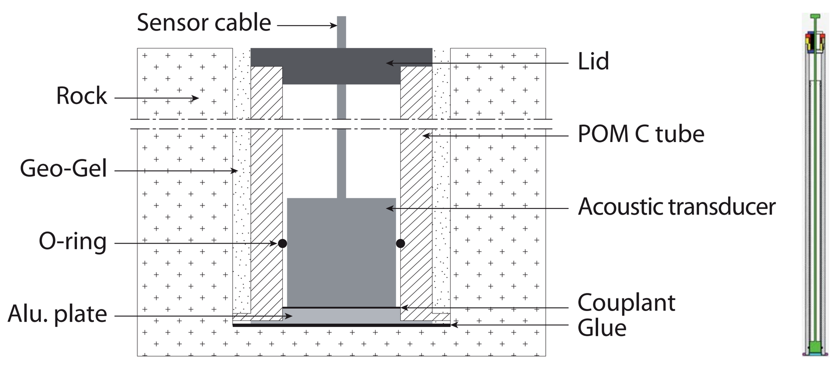
Preliminary and laboratory experiments were done with *Physical Acoustics Corp.* equipment.

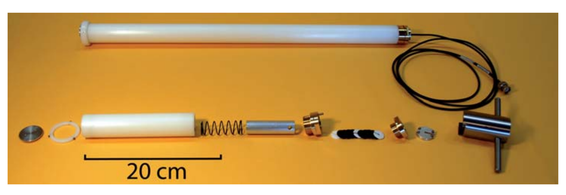


(Andreas Hasler)

AE Measurement System

AE-rod: direct insertion with casing





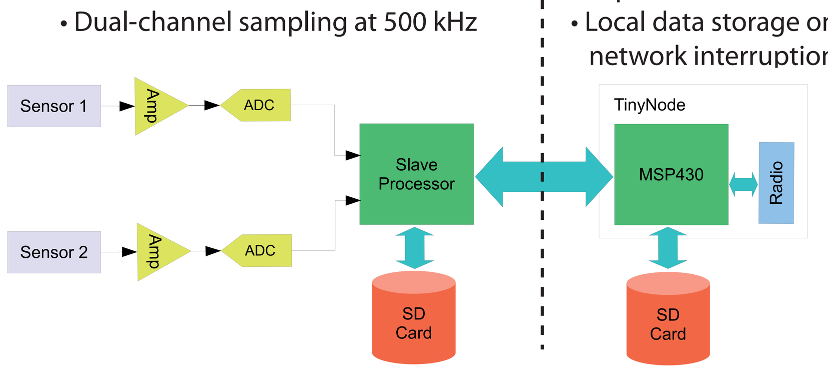
- Acquires reliable and consistent data
- Arbitrary depth mounting
- Replacement of sensor (piezoelectric sensor: R6alpha)
- Compatible to *Physical Acoustics Corp.*

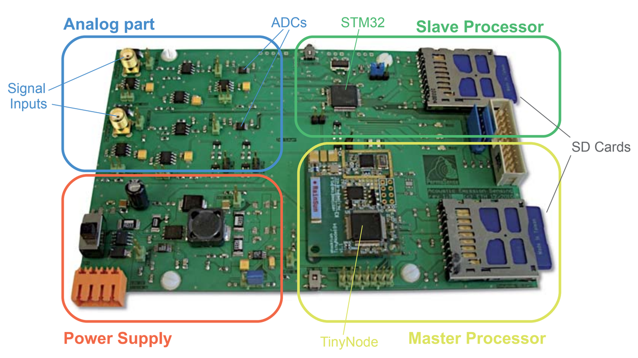
AE-node: customized, outdoor, low power, wireless

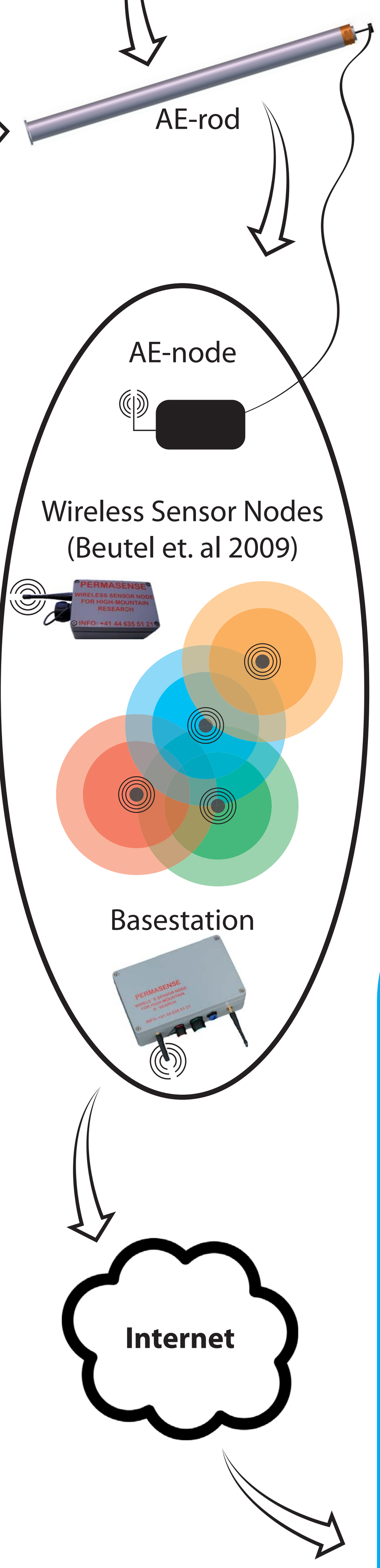
Data acquisition and preprocessing
- High-rate sampling and event characterization
- Dual-channel sampling at 500 kHz

Control and communication
- Transmission of captured event data
- Local data storage on network interruption

- Integration with wireless sensor network



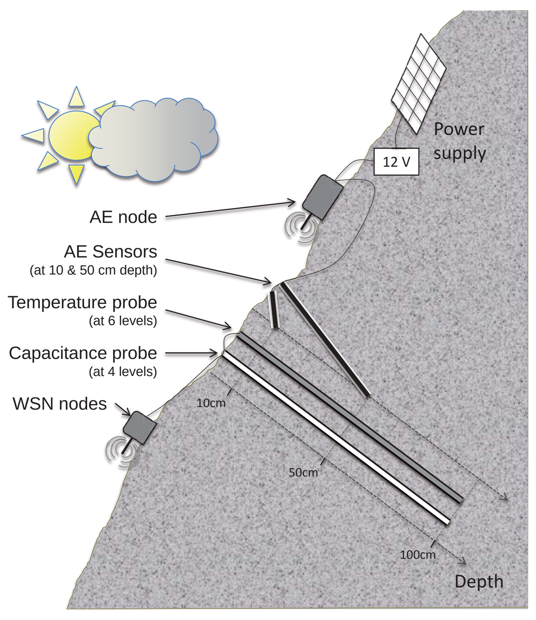




Field Installation

Switzerland, Bernese Alps, Jungfraujoch

3500 m a.s.l., facing south-east, slope 50 - 60°, granitic gneiss (~2% porosity)
2 locations with distinct characteristics (M1 = dry; M2 = wet)



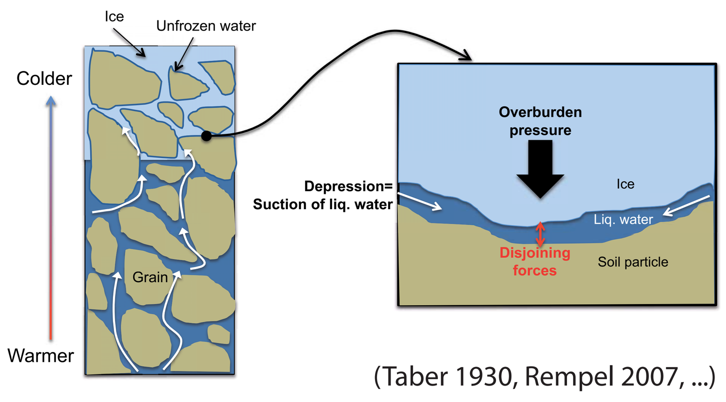
Which Processes can Cause Rock Damage?

1) Hydraulic pressure theory: volumetric expansion

- Expansion of 9% when water turns into ice (increase of the pressure)
- Liquid water is expelled from freezing sites

With high cooling rates, high saturation level, low drainage ability, the pressure build up could damage rock.

2) Cryo-suction and ice segregation



(Taber 1930, Rempel 2007, ...)

In sustained freezing conditions:
- Ice continues to grow and draws water through unfrozen layers and fine pores
- The ice is rejected from the pore walls by intermolecular forces.

This causes an inflow of liquid water into the pore: the cryo-suction effect.

3) Elastic-thermomechanical coupling between pore space and rock ‚skeleton'

4) Constant load
- gravity

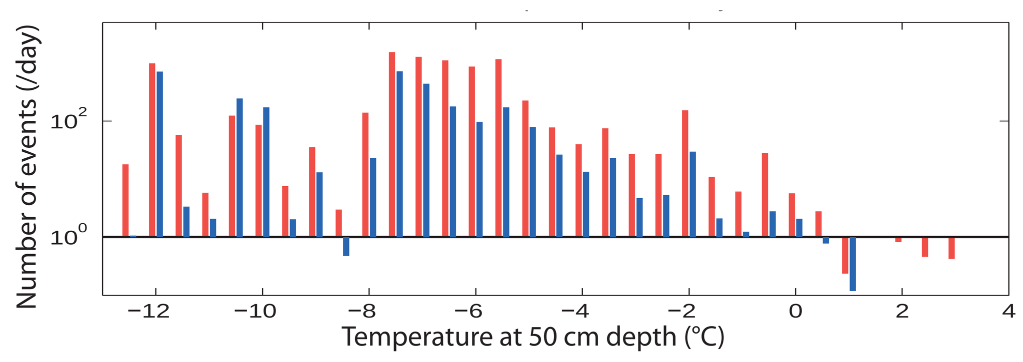
5) Punctual load
- earthquakes
- rock falls

Results

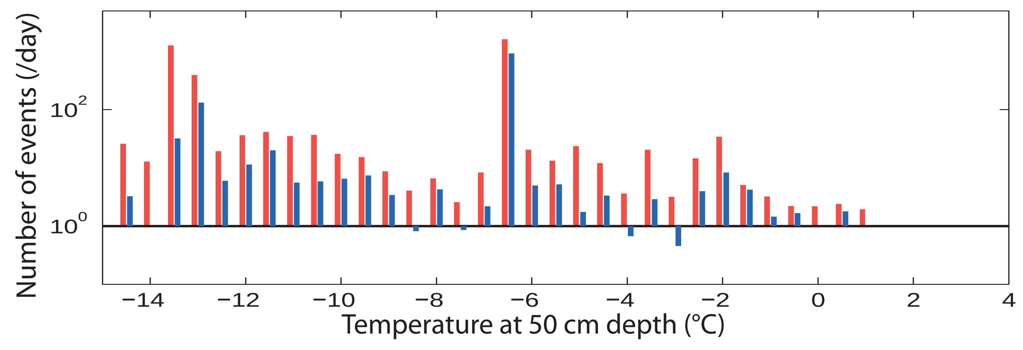
Rate of AE event (/day) detected at 50 cm depth for bins of the temperature

Weighted by the time spent in each temperature bin. Blue bars = cooling phases, red bars = warming phases.

Position M1
- dry location
- spur-like feature



Position M2
- wet location
- gully-like feature

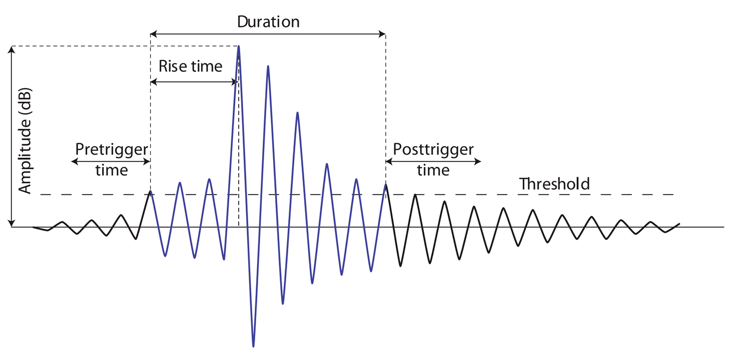


Blue bars are events detected during cooling phases (dT/dt<0 at 50cm depth) Red bars: dT/dt >0. 15-Sep-2011 - 10-May-2012.

AE = Acoustic Emission

Powerful technique to track the evolution of damage

Acoustic emission
- Form of microseismicity
- Transient elastic waves produced by a sudden redistribution of stress in a material
- AE monitoring = technique to track the evolution of damage



AE detection = passive system

Frequency content of source
- source size
- elastic wave velocity

Frequency reaching the sensor
- distance of propagation
- attenuation

References

- Amitrano, D., Gruber, S., Girard, L. 2012. Rock damage inferred from acoustic emissions in a partly frozen high-alpine rock-wall. Geosci. Intrum. Method. Data Syst. Discuss., 2, 267–300.
- Beutel, J., Gruber, S., Hasler, A., Lim, R., Meier, A., Plessl, C., Talzi, I., Thiele, L., Tschudin, C., Woehrle, M., Yuecel, M. 2009b. PermaDAQ: A scientific instrument for precision sensing and data recovery in environmental extremes. In: The 8th ACM/IEEE International Conference on Information Processing in Sensor Networks, San Francisco, California, USA.
- Murton, J., Peterson, R., Ozouf, J.-C. 2006. Bedrock fracture by ice segregation in cold regions. Science, 314(5802), 1127–1129.
- Physical Acoustics Corporation. Acoustic Emission Measurement Technologies. www.pacndt.com.
- Rempel, A. 2007. Formation of ice lenses and frost heave. Journal of Geophysical Research, 112, F02S21.
- Taber, S. 1930. The mechanics of frost heaving. Journal of Geology, 38(4), 303–317.
- Walder, J., Hallet, B. 1985. A theoretical model of the fracture of rock during freezing. Geological Society of America Bulletin, 96(3), 336–346.

QR-Code

Acknowledgments

The research presented was supported through the project PermaSense funded by the Swiss National Foundation (SNF) NCCR MICS as well as the International High Altitude Research Stations Jungfraujoch and Gornergrat. We are grateful for the technical support from the workshop of Physics Institute, University of Zurich, most specifically for the dedication, patience and creativity of Reto Maier and the work of numerous helpers from the PermaSense team, Tonio Gsell, Andreas Hasler, Josua Hunziker, Roman Lim, Jeannette Noetzli and Christoph Walser.