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PermaSense

Acoustic Emission Measurement System to Investigate Rock Damage Driven by Freezing

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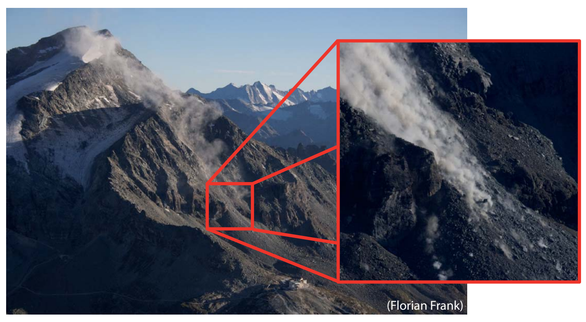
Motivation

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


(Florian Frank)

Goals

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


(Max Maisch)

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

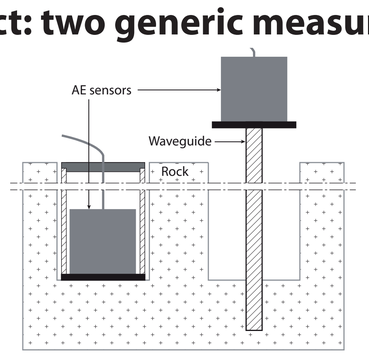
Preliminary experiments

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

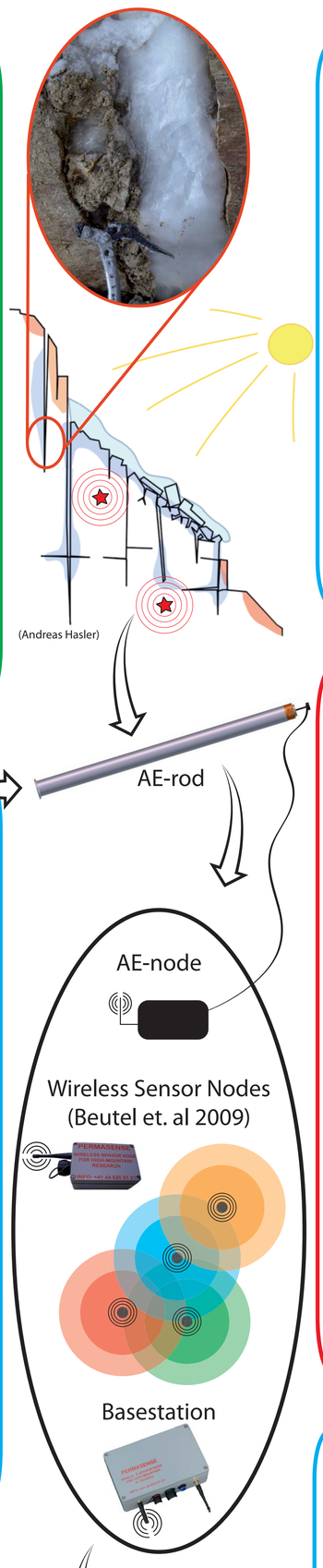
+ good coupling
+ raised data quality
+ protection of AE sensor
- alteration of field site
- difficult to install



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

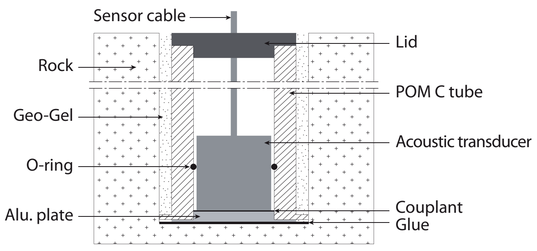
+ easier to install
- reduced data quality
- not protected
- alteration of field site
- no constant coupling

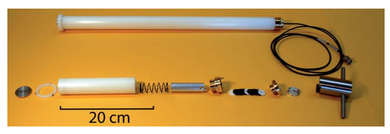
Preliminary and laboratory experiments were done with *Physical Acoustics Corp.* equipment.



AE Measurement System

AE-rod: direct insertion with casing



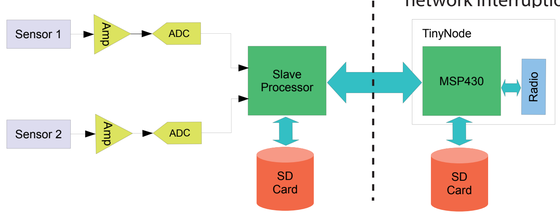


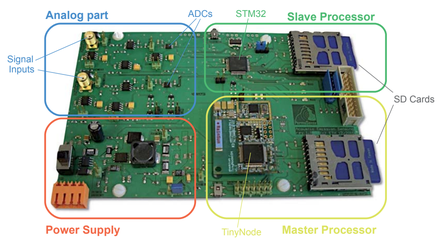
- Acquires reliable and consistent data
- Arbitrary depth mounting
- Replacement of sensor (piezoelectric sensor: R6alpha)
- Compatible to *Physical Acoustics Corp.*

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

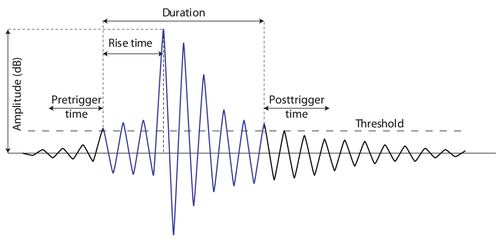




AE = Acoustic Emission

Powerful technique to track the evolution of damage

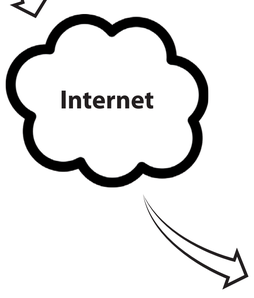
Acoustic emission
- Form of microseismicity
- Transient elastic waves produced by a sudden redistribution of stress in a material
- AE monitoring = technique to track the evolution of damage



AE detection = passive system

Frequency content of source
- source size
- elastic wave velocity

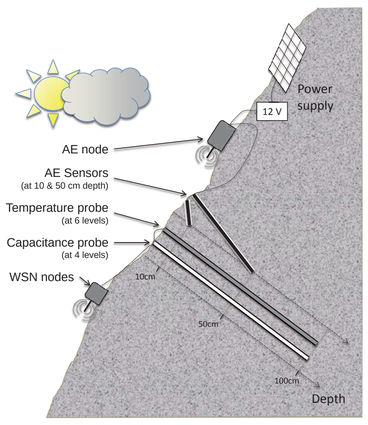
Frequency reaching the sensor
- distance of propagation
- attenuation



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)



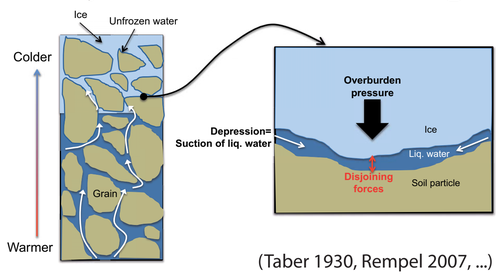
Which Processes can Cause Rock Damage?

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

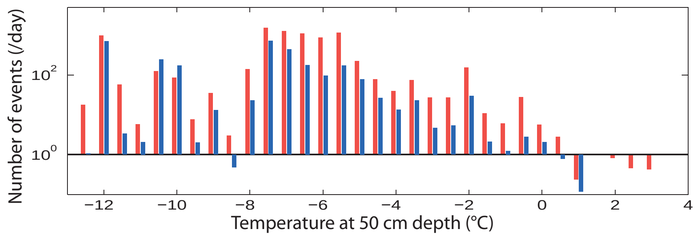
5) Punctual load
- earthquakes
- rock falls

Results

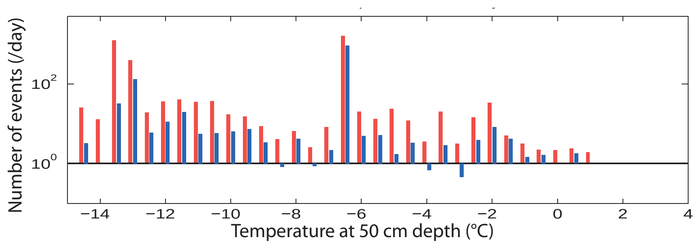
Rate of AE event (/day) detected at 50 cm depth for bins of the temperature

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.

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QR-Code

Acknowledgments

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