**Acoustic Emission Measurement System to Investigate Rock Damage Driven by Freezing**

Samuel Weber¹, Stephan Gruber³, Lucas Girard¹, Jan Beutel²

¹Glaciology & Geomorphodynamics, Dep. of Geography, University of Zurich, Switzerland
²Computer 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 clefs can precondition rock fall
- Initial rock damage processes and dynamics can be studied by AE

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

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

**AE Measurement System**

**AE-node: customized, outdoor, low power, wireless**
- Acquires reliable and consistent data
- Arbitrary depth mounting
- Replacement of sensor (piezoelectric sensors, Microphonic)
- Compatible to Physical Acoustics Corp.

**AE-rod: direct insertion with casing**
- 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 intrusion
- AE-node
  - Wireless Sensor Nodes
  - BEUTEL et al. 2009
- AE node
  - AE-rod
  - Basestation
  - Internet

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**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)

**Results**

- Rate of AE event (i/day) detected at 59 cm depth for bins of the temperature
  - Weighted by the time spent in each temperature bin
  - Blue bars = cooling phases, red bars = warming phases

**Which Processes can Cause Rock Damage?**

1) Hydraulic pressure theory: volumetric expansion
   - Expansion of 9% when water turns to 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
   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
   - earthquakes

5) Punctual load
   - rock falls

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**References**


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**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

AE monitoring = technique to track the sudden redistribution of stress in a material

AE node: AE-rod: AE-sensor

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