Measurement setup to investigate near surface failures in steep bedrock permafrost

Conference Poster

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Samuel Weber, Jan Beutel, Jerome Faillettaz, Stephan Gruber, Tonio Gsell, Andreas Hasler, Andreas Vieli

The main goals are:

• to gain better *process understanding* of *near surface failures* in permafrost

• to *assess stability* of rock-slopes in alpine environments

• to work towards an *early warning system* to prevent a catastrophic event

Assessing rupture in natural media remains a challenge because:

• natural media are *heterogeneous*

• the heterogeneity is difficult to *quantify and measure*

• rupture is a *nonlinear process* involving these hetereogeneities

BUT heterogeneity is a chance - taking advantage of it

During rupture process, weakest zones will break first!

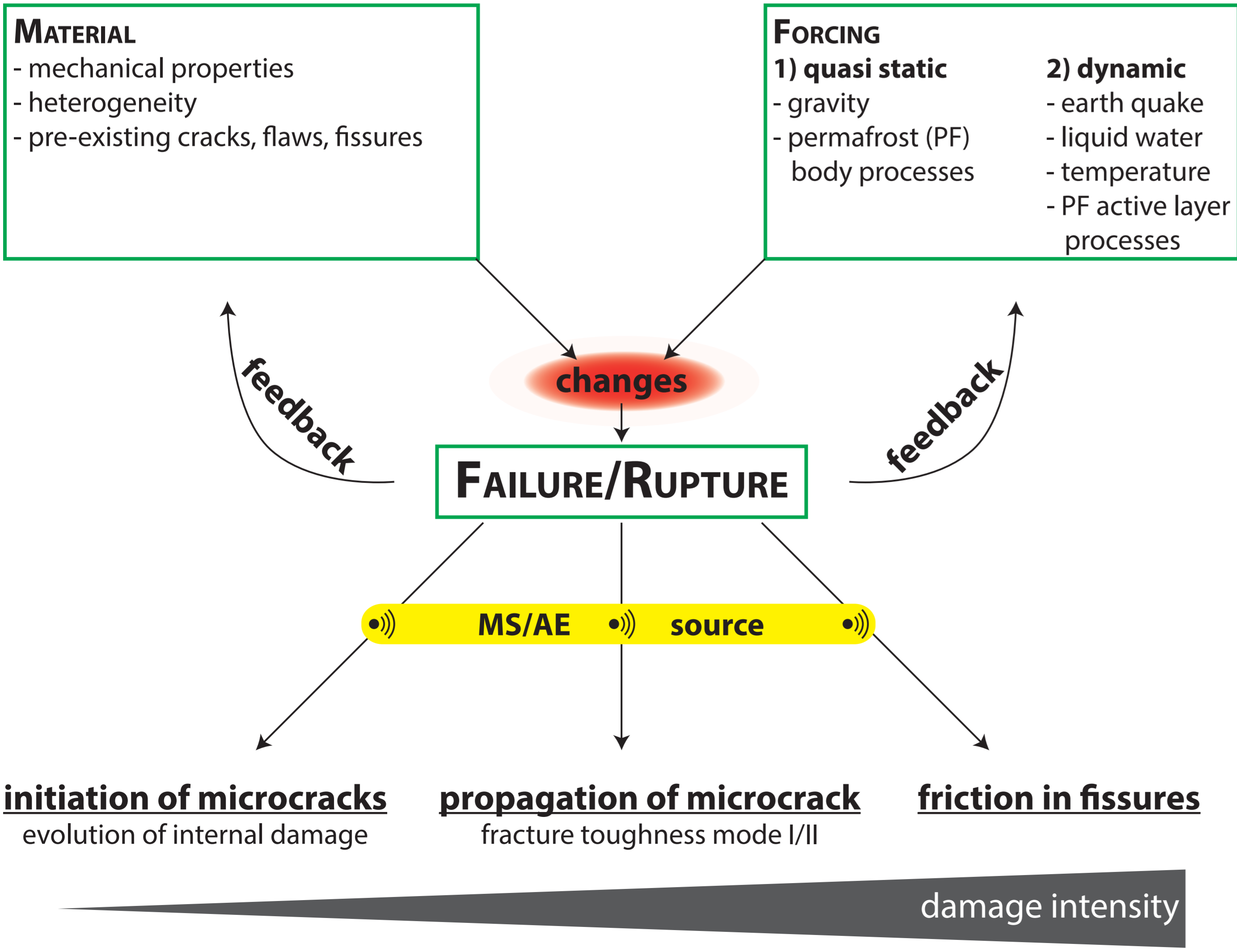→ *precursory signs are expected before final rupture!*

Assessing slope stability requires to...   ...these precursors.

• monitor
• identify
• analyse/interpret

Assessing stability = monitor changes & detect precursory signs

	External changes		Internal changes
	geometry	*th. regime*	*damage/cracks*
Monitoring	displacement	temperature	acoustic/micro-seismic activity
Instrumentation	crackmeter, GPS	thermistor	piezo, accelerometer, geophone
	──── *scale* ⟶		──── *scale* ⟶

Gravitiy driven instabilities in high-alpine rock-slopes

MATERIAL
- mechanical properties
- heterogeneity
- pre-existing cracks, flaws, fissures

FORCING
1) quasi static
- gravity
- permafrost (PF) body processes

2) dynamic
- earth quake
- liquid water
- temperature
- PF active layer processes

feedback → **changes** ← feedback

FAILURE/RUPTURE

))) **MS/AE**))) **source**)))

initiation of microcracks
evolution of internal damage

propagation of microcrack
fracture toughness mode I/II

friction in fissures

damage intensity

Field site: Hörnli-Ridge of Matterhorn

**Matterhorn, Hörnligrat
(Zermatt, Switzerland)**
• 3500 m a.s.l. (permafrost)
• Ice-containing clefts
• Large temperature gradients
• Rock fall 2003 (approx 1500 m³) with ice-containing scarp
○ = measurement point

detachment zone

basestation

north side

Sensor setup

Displacement sensors

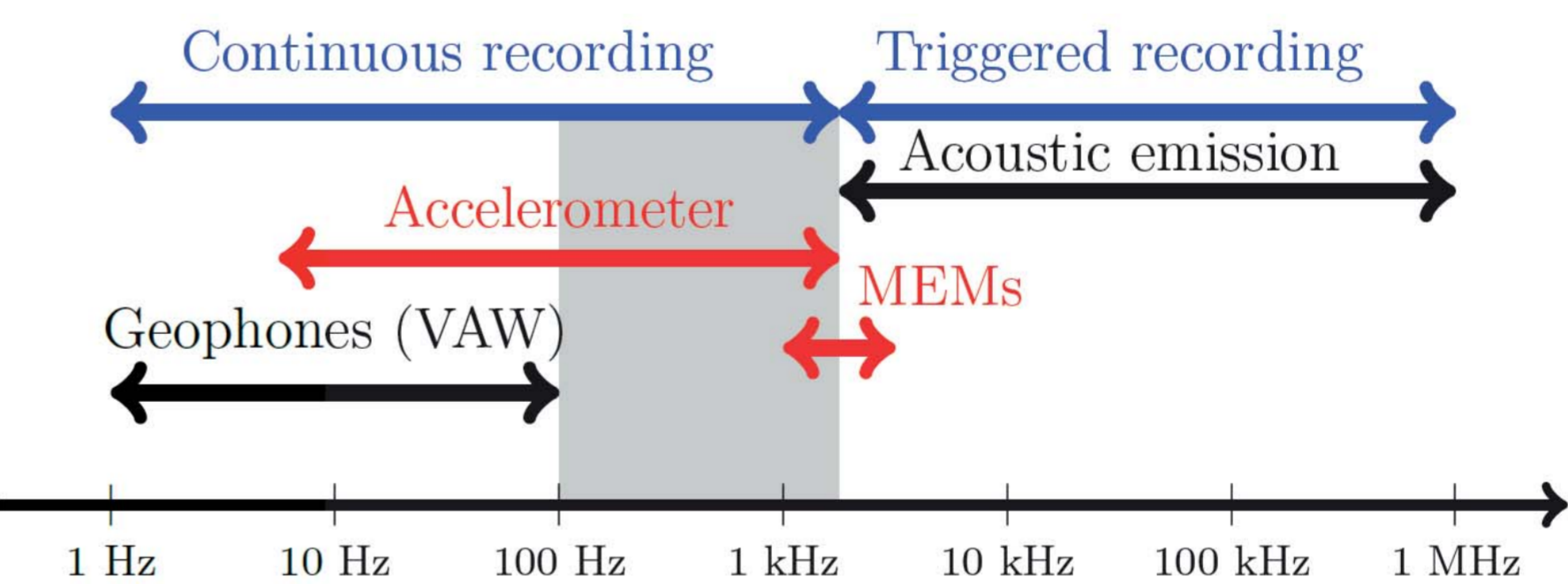*PermaSenseL1-GPS* (large scale)
• daily position accuracy:
  • 1-2 mm horizontal
  • 3-5 mm vertical
• ublox LEA-6T receiver
• wireless communication
• all-inside mast design
• remote configurable

ForaPot crackmeter (small scale)
• potentiometric measurement principle
• very high accuracy (≤ 0.01 mm)
• temperature-compensated
• multiple axes possible

Acoustic/micro-seismic sensor (scale freq. dependent)

Continuous recording   Triggered recording

Accelerometer

Acoustic emission

Geophones (VAW)   MEMs

1 Hz   10 Hz   100 Hz   1 kHz   10 kHz   100 kHz   1 MHz

Temperature
• rock surface
• at depth
Camera
• Nikon D-300
• Axis
Weather station
• Vaisala WXT520

Outlook

How to analyse/interpret data?

surface displacment

MS/AE source   ? interaction ?
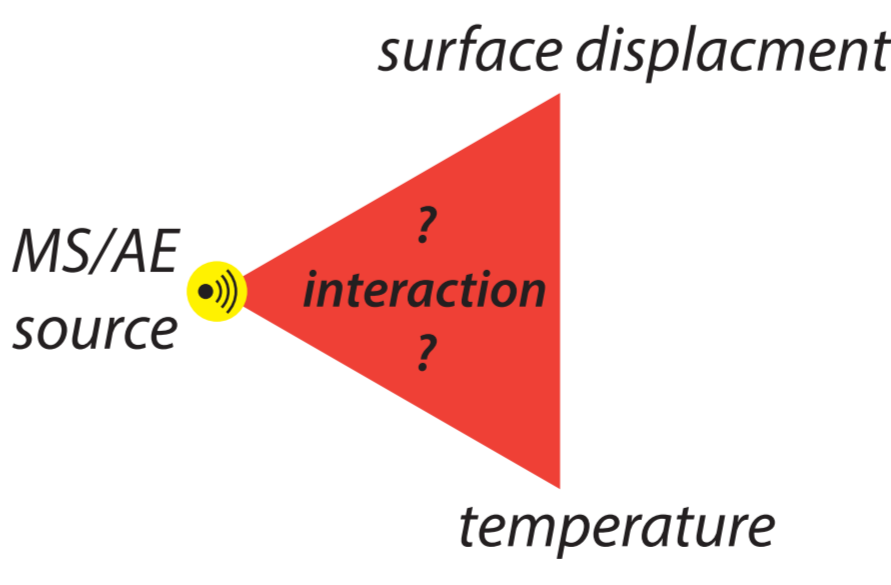
temperature

Need for a tool to investigate link between
• MS/AE activity, temperature & displacement
• acoustic data and rupture imminence!

→ using *numerical models* as tool to investigate and test parameters sensitivity

Complementary lab test

1) conventional lab tests
to characterize the AE waveform and spectrum of *initiation* vs. *propagation* of microcracks

2) unconventional lab tests
to simulate friction at different conditions (frozen, not frozen, wet, dry...)

characteristic waveform?

? attenuation ?   MS/AE source

characteristic spectrum?