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# FAULT INSTABILITY DETECTION USING FIBER OPTIC BASED MONITORING AT THE GARPENBERG ORE MINE, SWEDEN – FIMOPTIC PROJECT

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# FIMOPTIC project 2022-2025

**FIMOPTIC** Fault Instabilities Monitored by innovative OPTICal instruments

**Funding:** French agency of research

**Partner:**

**Strategical partner:**

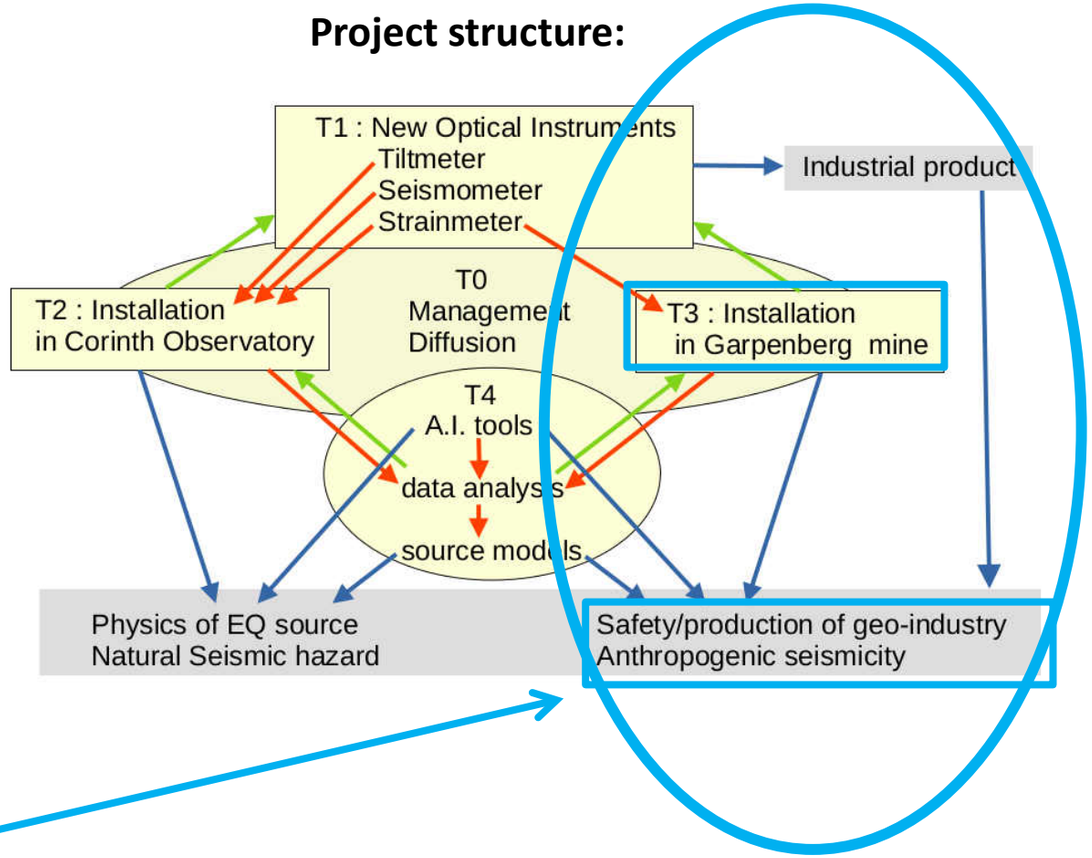
## Objectives:

Develop and demonstrate the potential of new, high resolution, innovative optical instruments, for:

1) Improving the detection, monitoring, and characterization of ***slow, transient mechanical processes*** involved in the ***preparation phase of earthquakes ruptures***

2) Evaluating its potential to mitigate ***anthropogenic seismic hazard*** (underground mining)

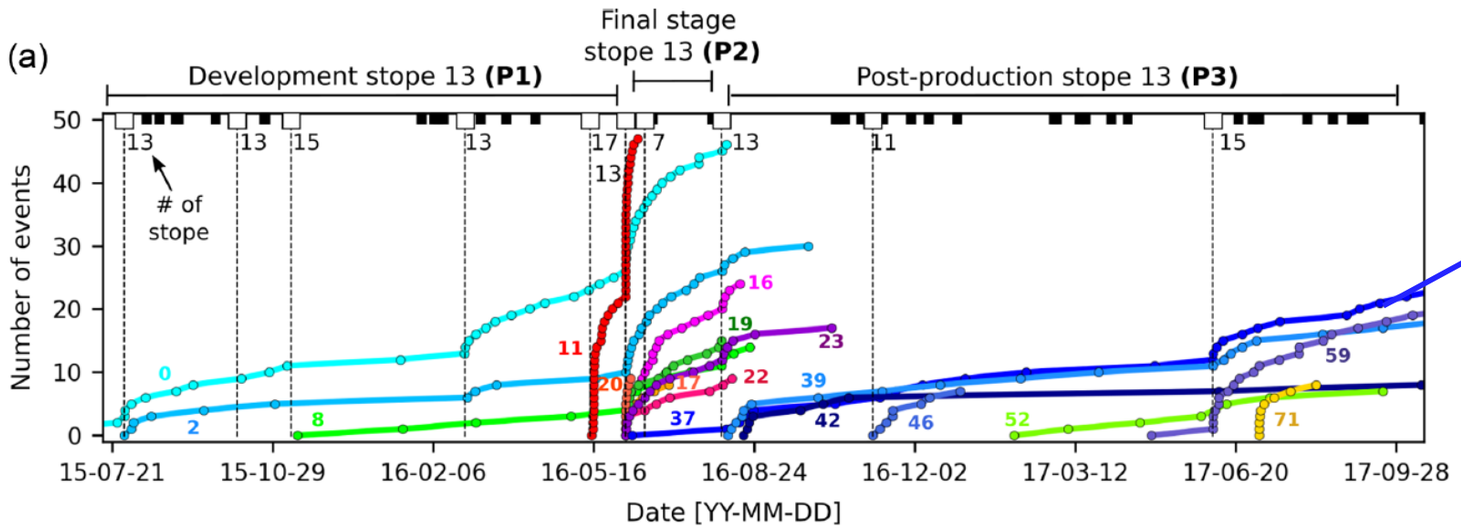
**Project structure:**



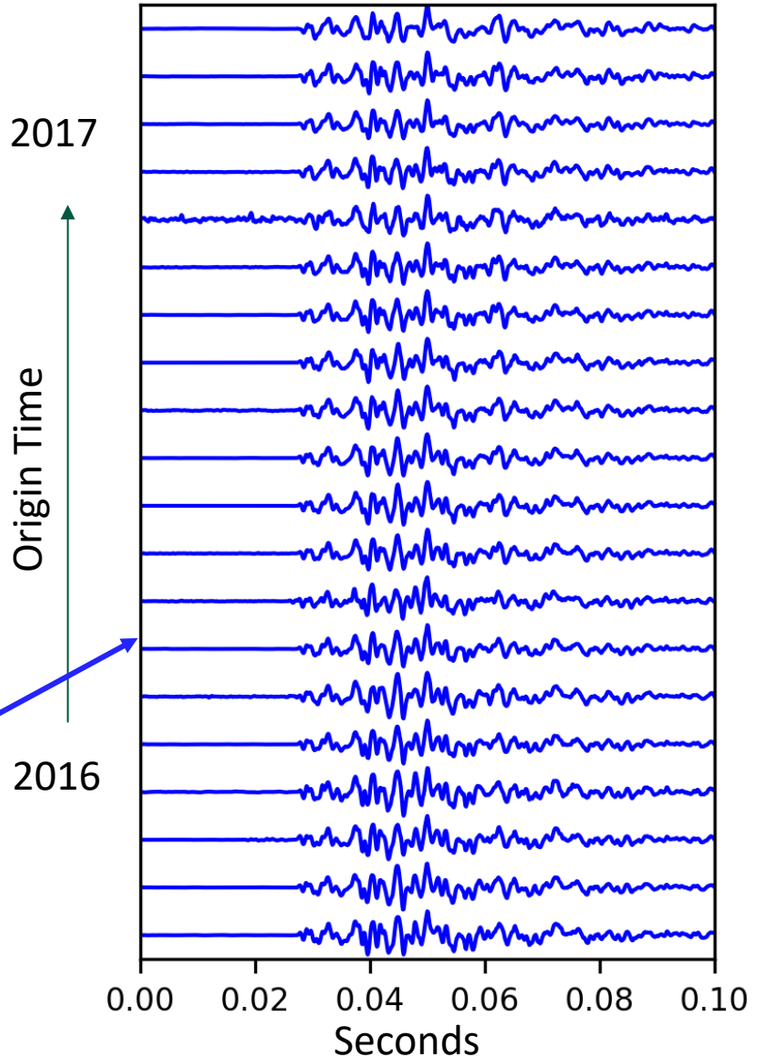
# Why Garpenberg ?

1) Observation of persisting, highly similar wave forms (multiplet families) induced from blasing

⇒ we «know» where and when seismicity will likely occur which allows for monitoring of the full seismic cycle




**Example of high coherency in wave forms**



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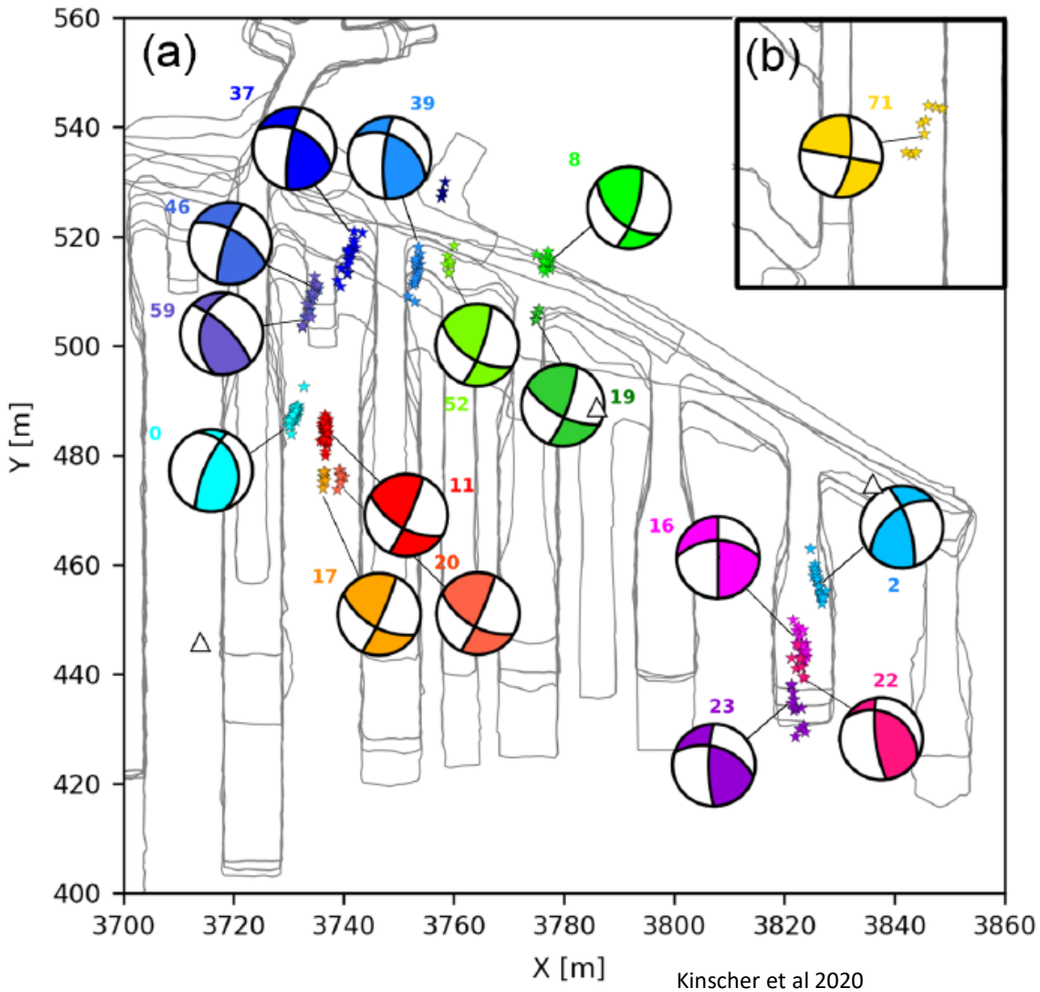
⇒ Faulting phenomena (even though forced/accelerated from excavation) is comparable to tectonic faults…

**Multiplet families**
**Source mechanisms and relocation**




Kinscher et al 2020

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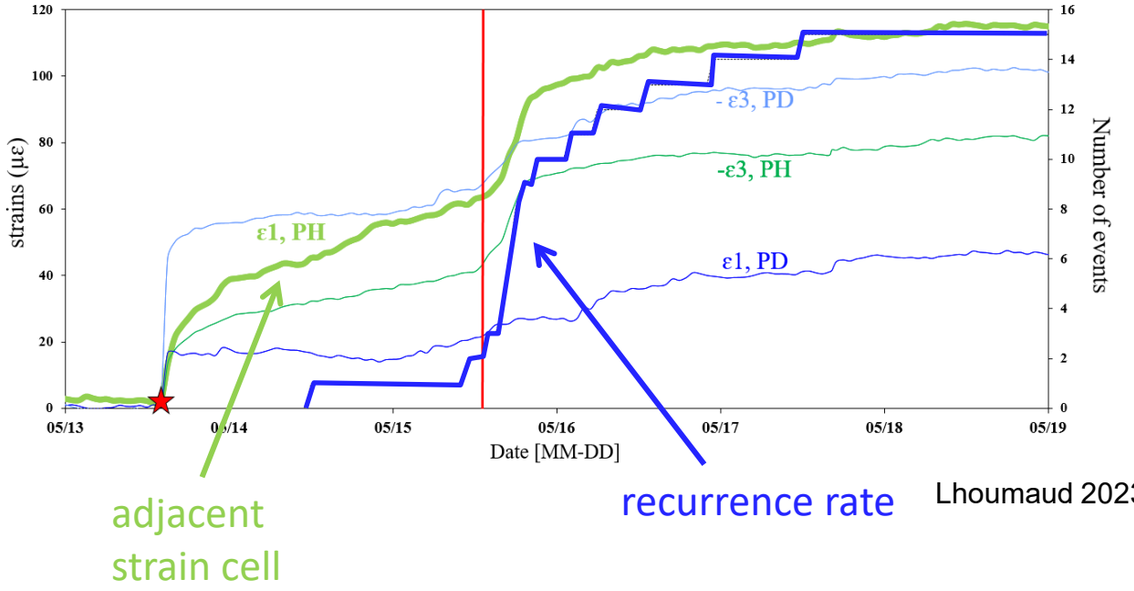
3) Evidence for presence of aseismic creep and potential link to seismic triggering

⇒ Slow transient mechanics and seismic-aseismic coupling processes involved in faulting dynamics

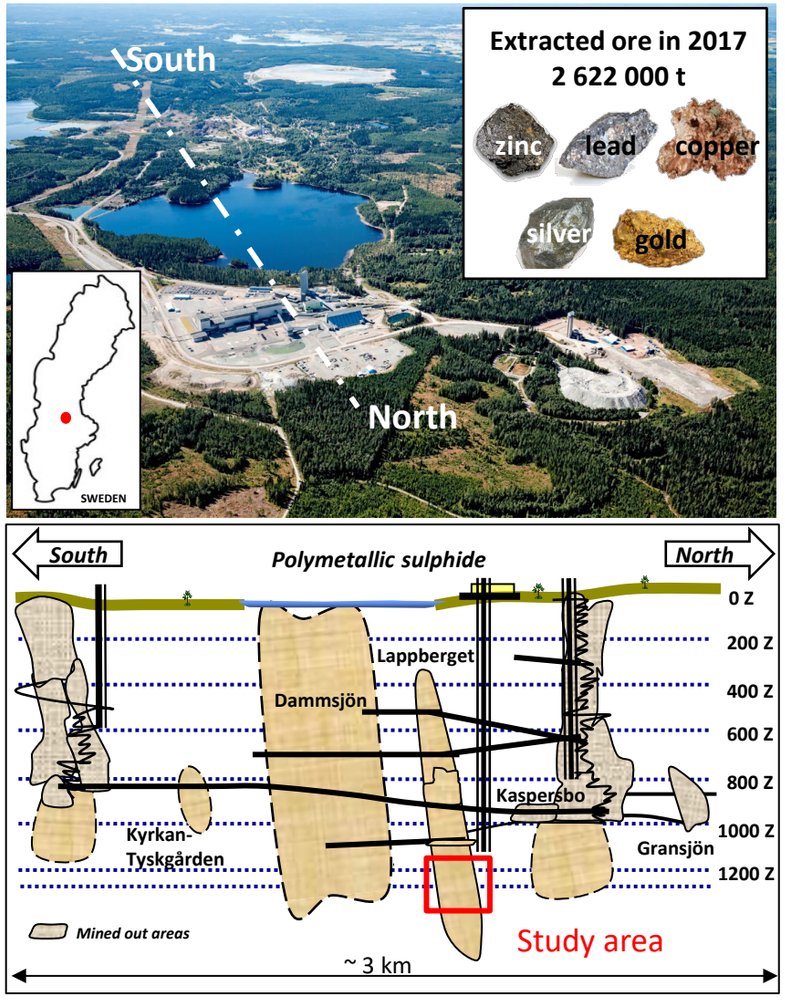
Post-blast creep sequence example

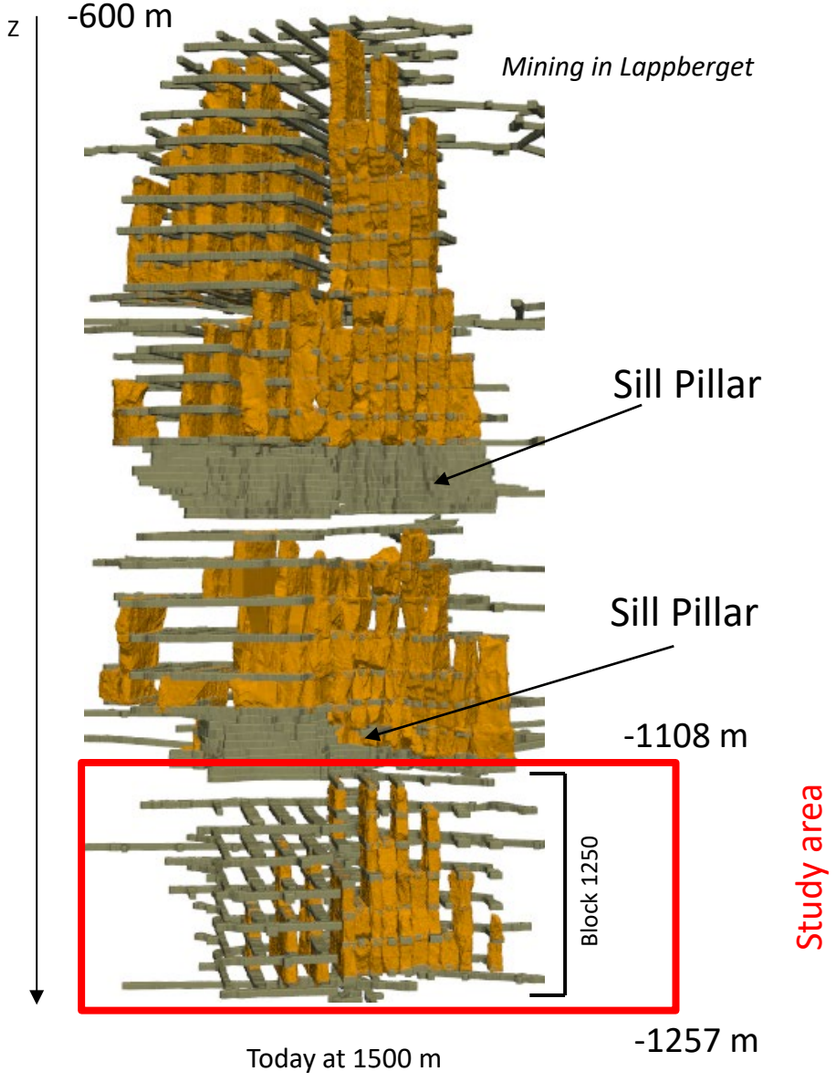
Post-blast creep vs multiplet transient




Lhoumaud 2023

# Garpenberg mine: Study site

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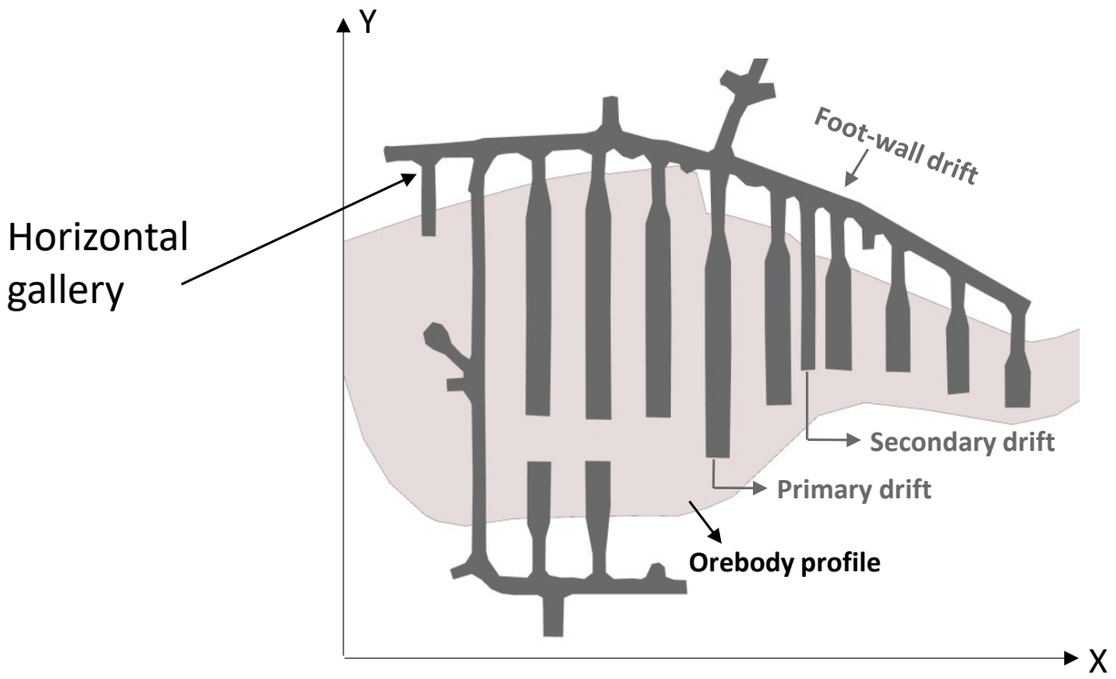
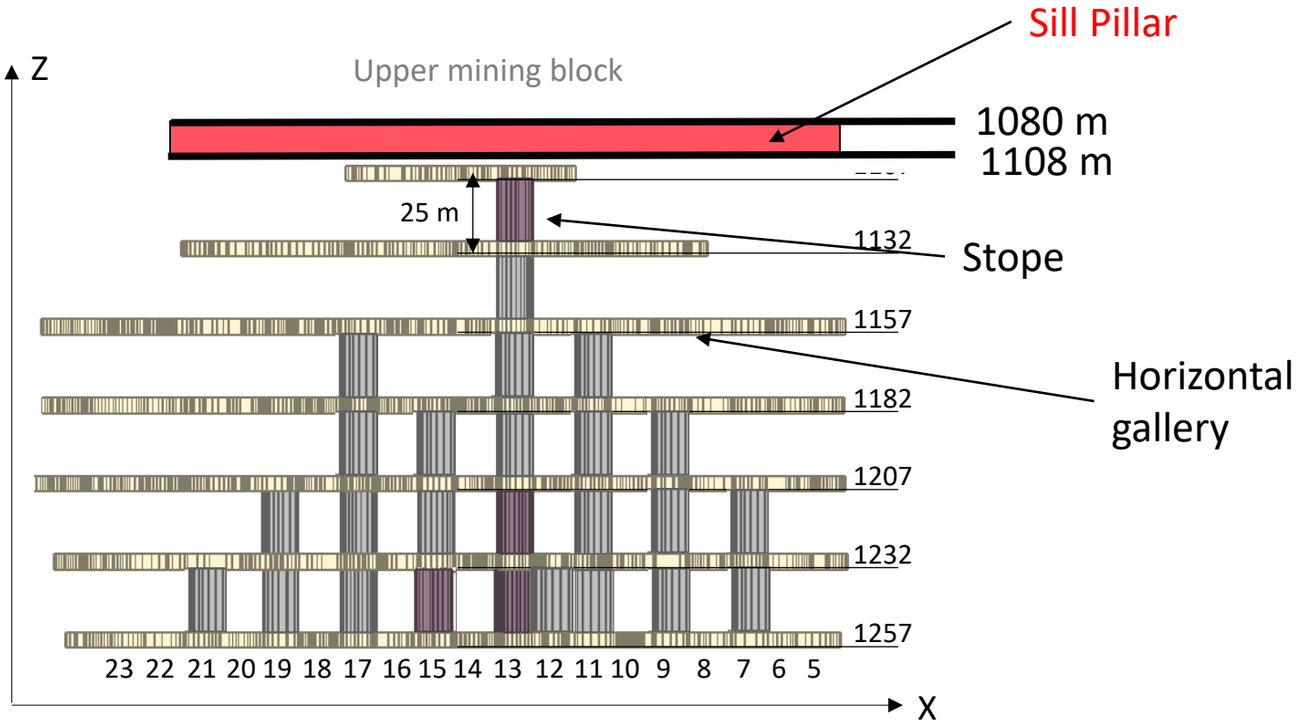
# Study site: Sill Pillar Block 1250

Sublevel Stoping with backfilling

*Horizontal section*




*Vertical section*




De Santis 2019

… Persistent multiplet families in the Sill-Pillar since 2017 …

# FIMOPTIC Project structure/strategy

## Phase1: locate and characterize repeater sources

## Phase 2 : local in-situ monitoring on target repeater

### Commercial fiber optic technologies:

**DAS (Distributed Acoustic Sensing)**

- Sensitivity: nano strain rate (>10 Hz)
- Sampling: 5 kHz

**DTSS (Distributed Temperature Strain Sensing)**
**Brillouin diffusion based interrogator (BOTDR)**

- Sensitivity: > 10 micro strain
- Min sampling: 1 min

⇒ *Monitor strain and seismicity of the compete seismic cycle*

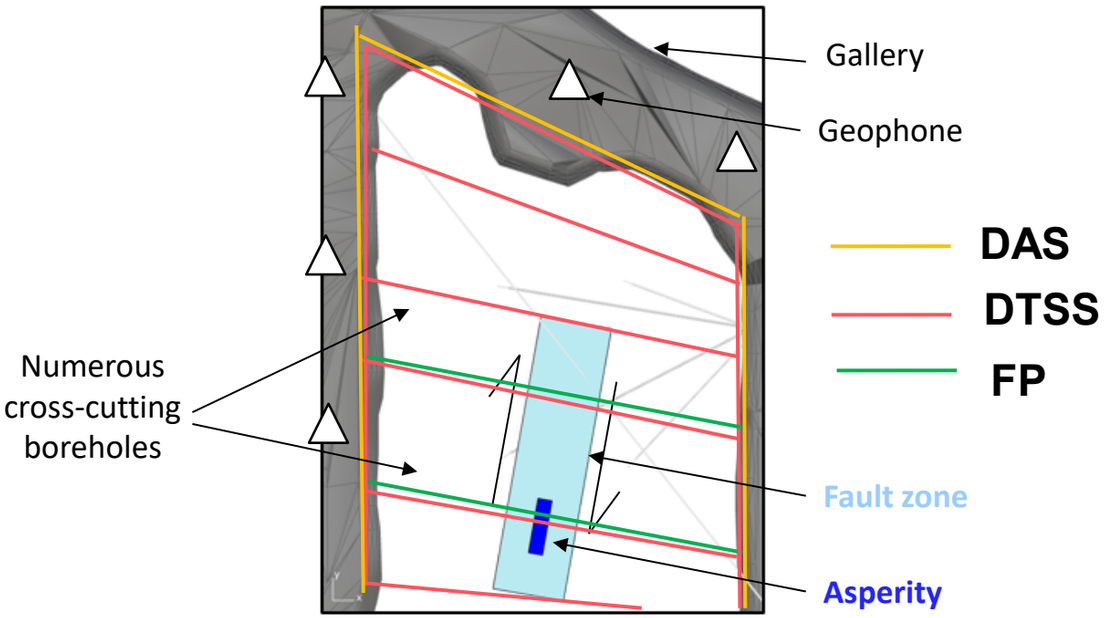
### Innovative fiber optic technologies:

**FP: (Fabry-Perot interferometry)**
**Optical strain meter developed by ESEO and IPGP**

- Sensitivity: 0.1-1 nanostrain (<10 Hz)

⇒ *Potential detection of (slow mechanic) rupture nucleation and loading phase of asperity*

**Possible design of optical fiber based repeater in-situ monitoring along galleries and boreholes**



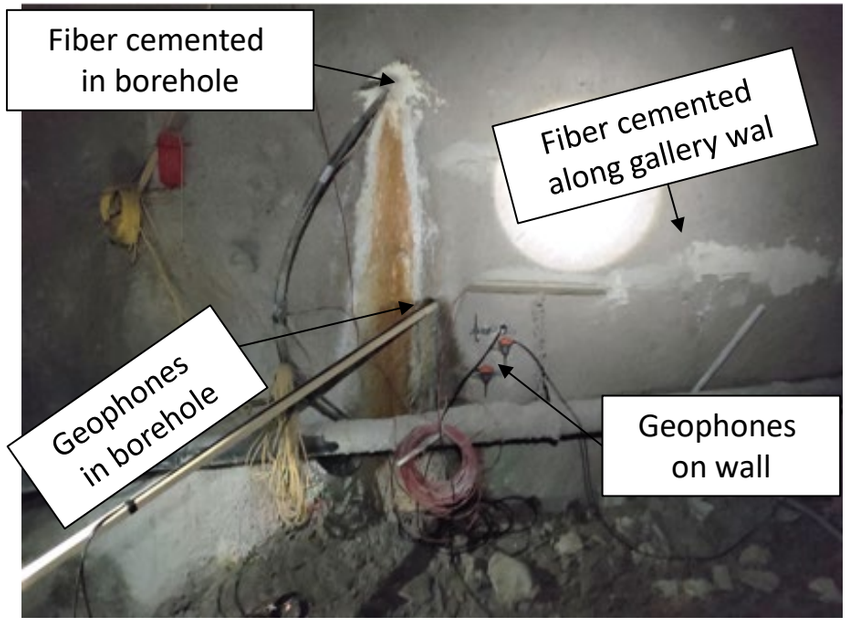
# Challenges during monitoring set up

Initial ambitious plan of extensive installation in Sill-Pillar:

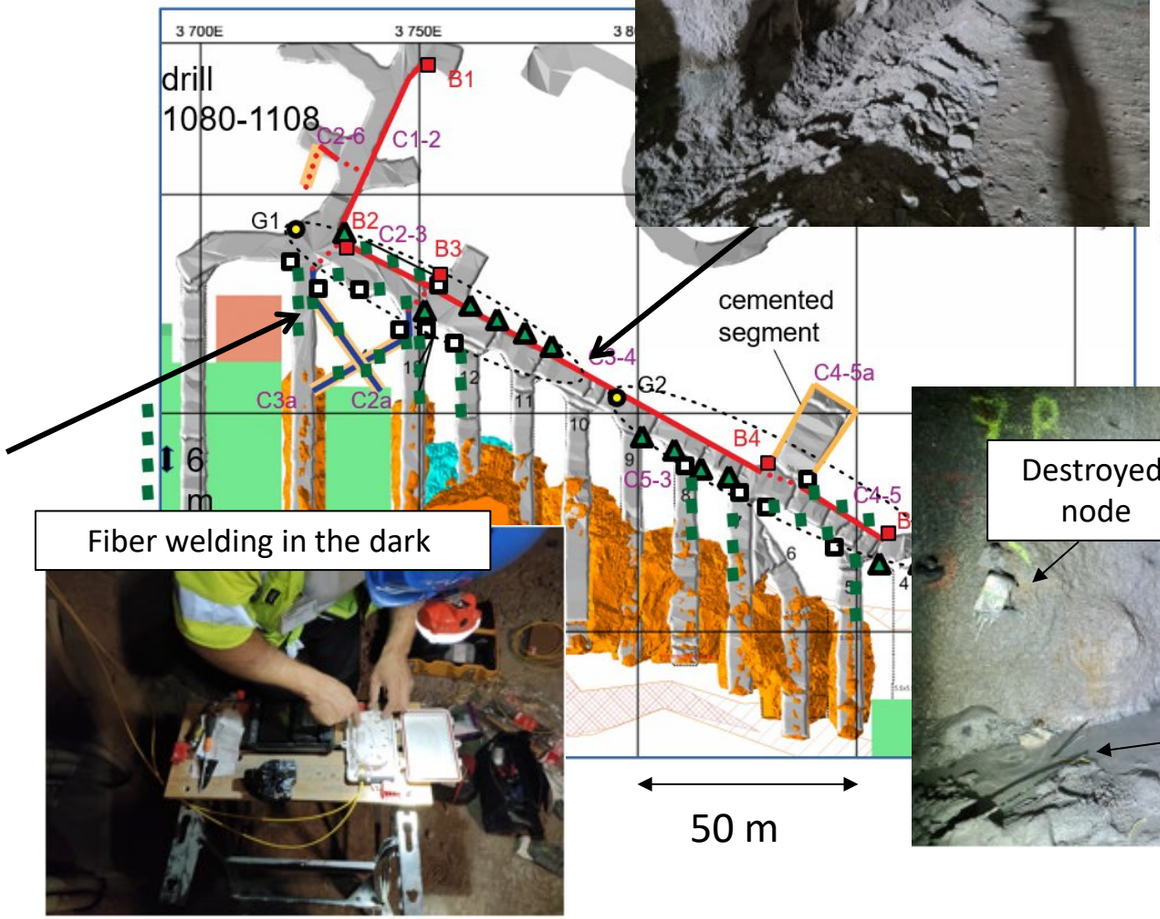
- Using DAS and ~ 60 geophones and nodes along two galleries (> 200 m)

=> Intervention in active mining environment is challenging and around 4 times more time-consuming compared to standard field missions (changes in production plan, destruction of equipment, security measurements etc.)

## Fiber in boreholes and gallery walls

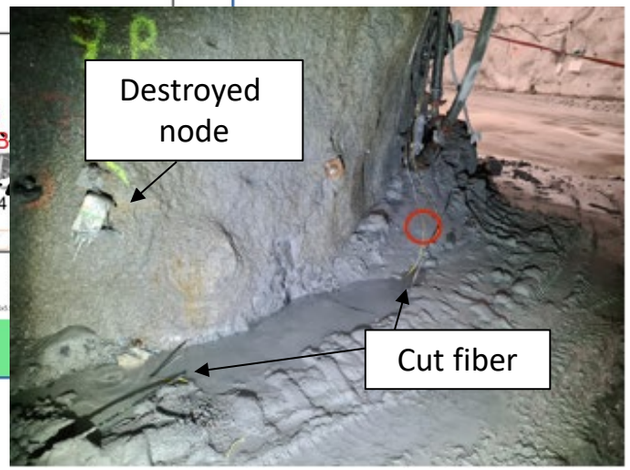



Fiber in trench along gallery

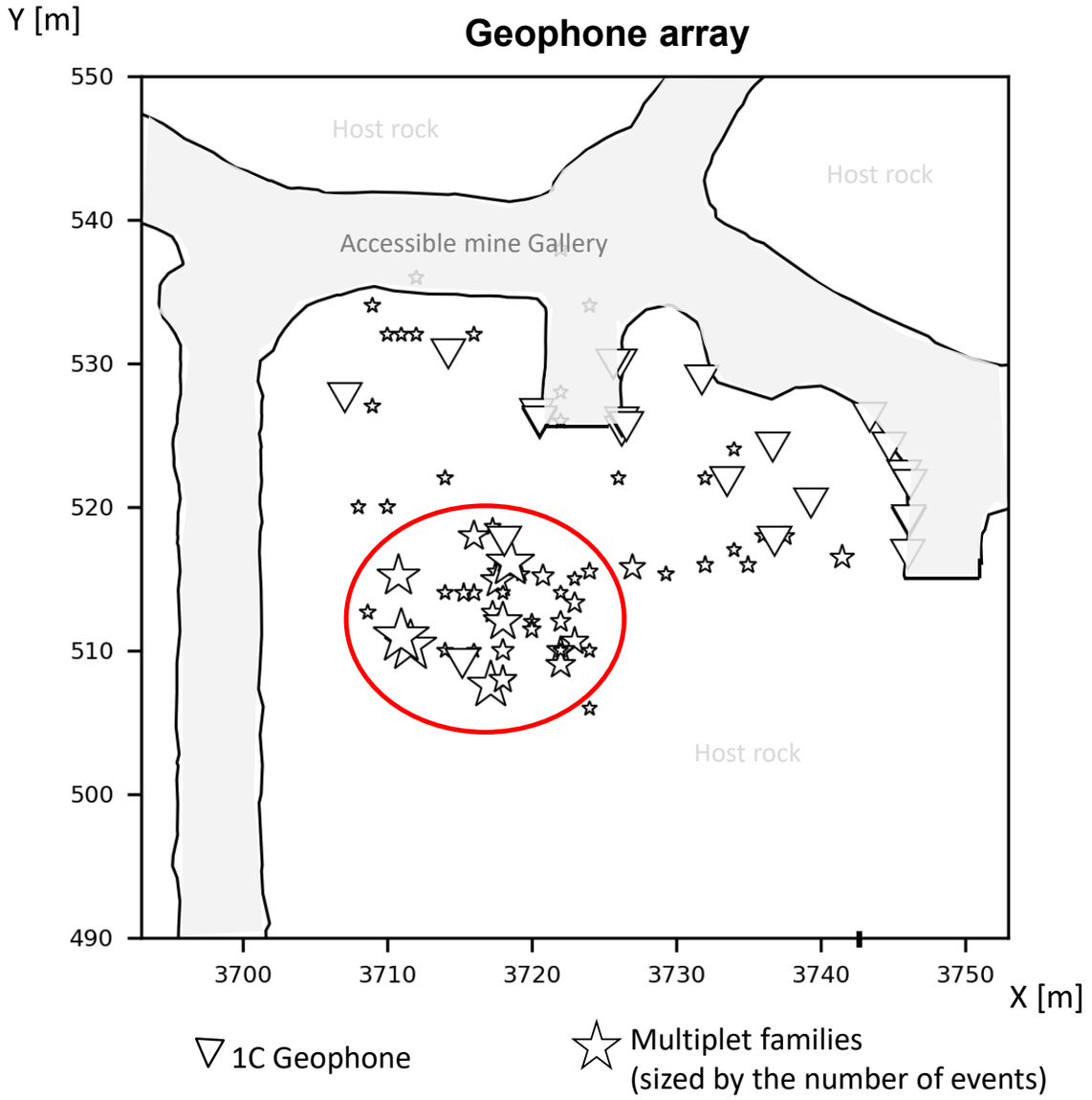



Fiber welding in the dark



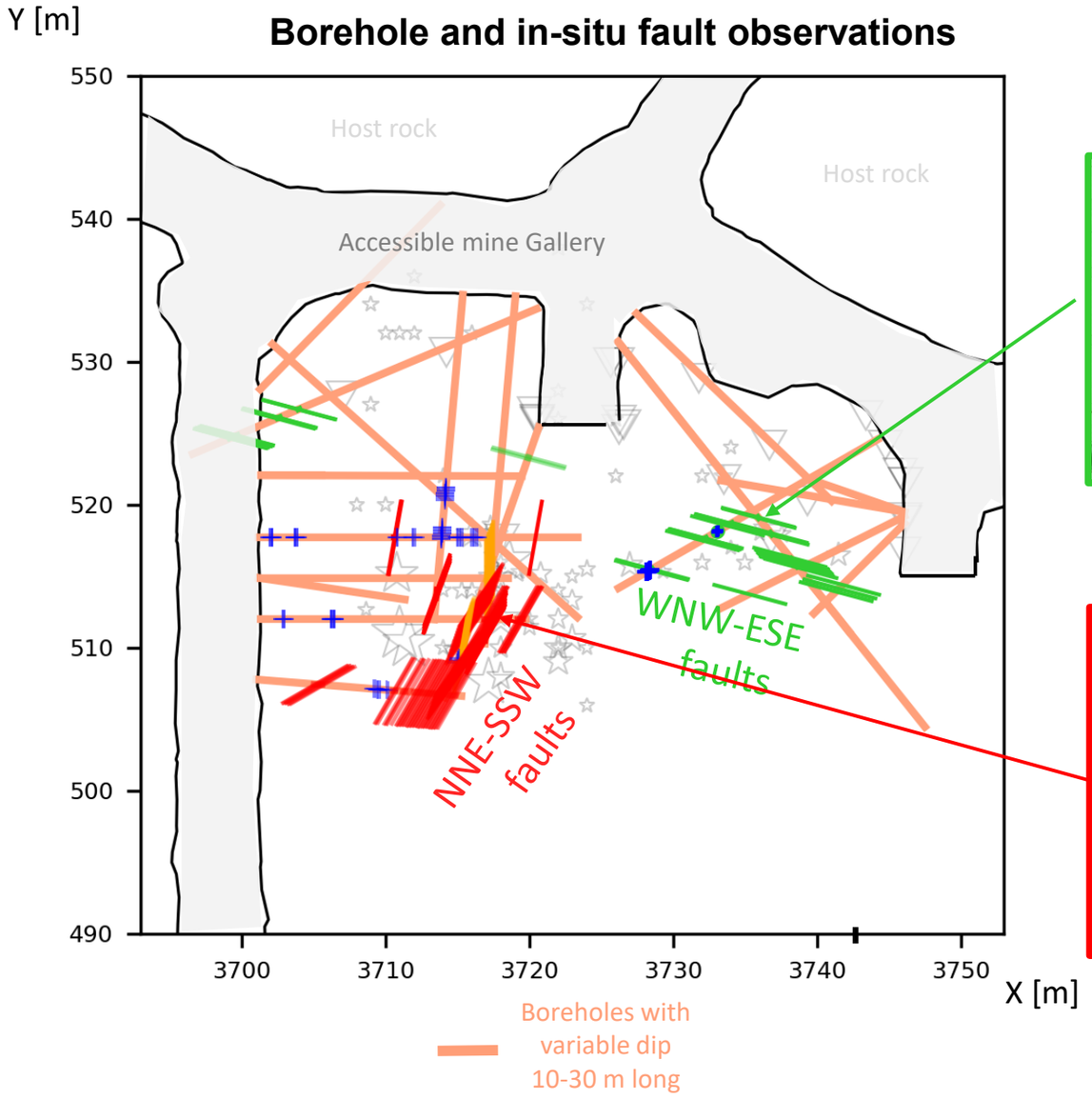


# Seismic monitoring




- Focus on area associated with long-term repeater occurrences (2016-2022)
- Installation (May – Sep 23) of > 20 geophones and nodes
- Identification of zone of major multiplet activity

# In-situ borehole observations



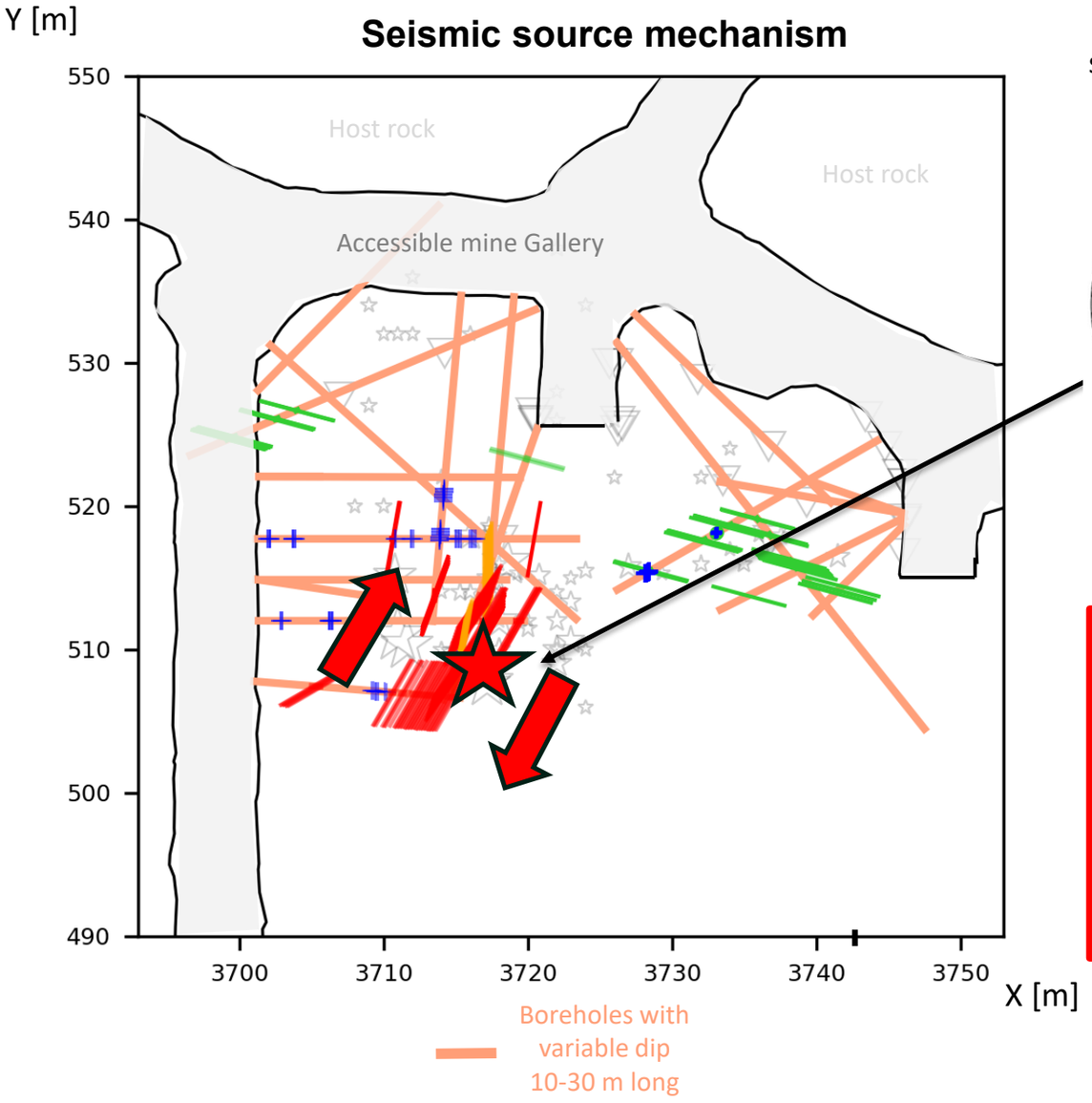

Borehole camera images

WNW-ESE strikings fauls

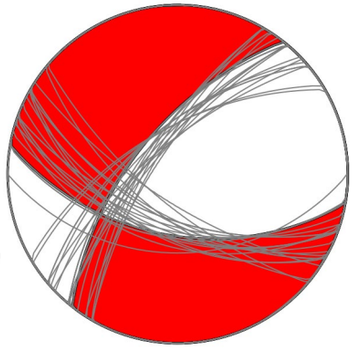
NNE-SSW stiking faults

- 2 main groups of “open” fault structures
- NNE-SSW Faults dominant in most active multiplet zone

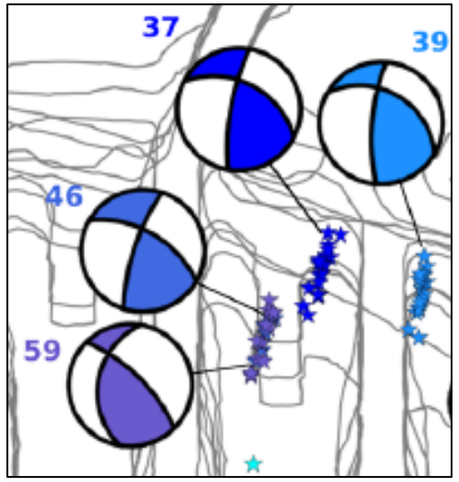
# Seismic source mechanism




Source mechanism of strongest event Mw ~ -1 (wave-form inversion)



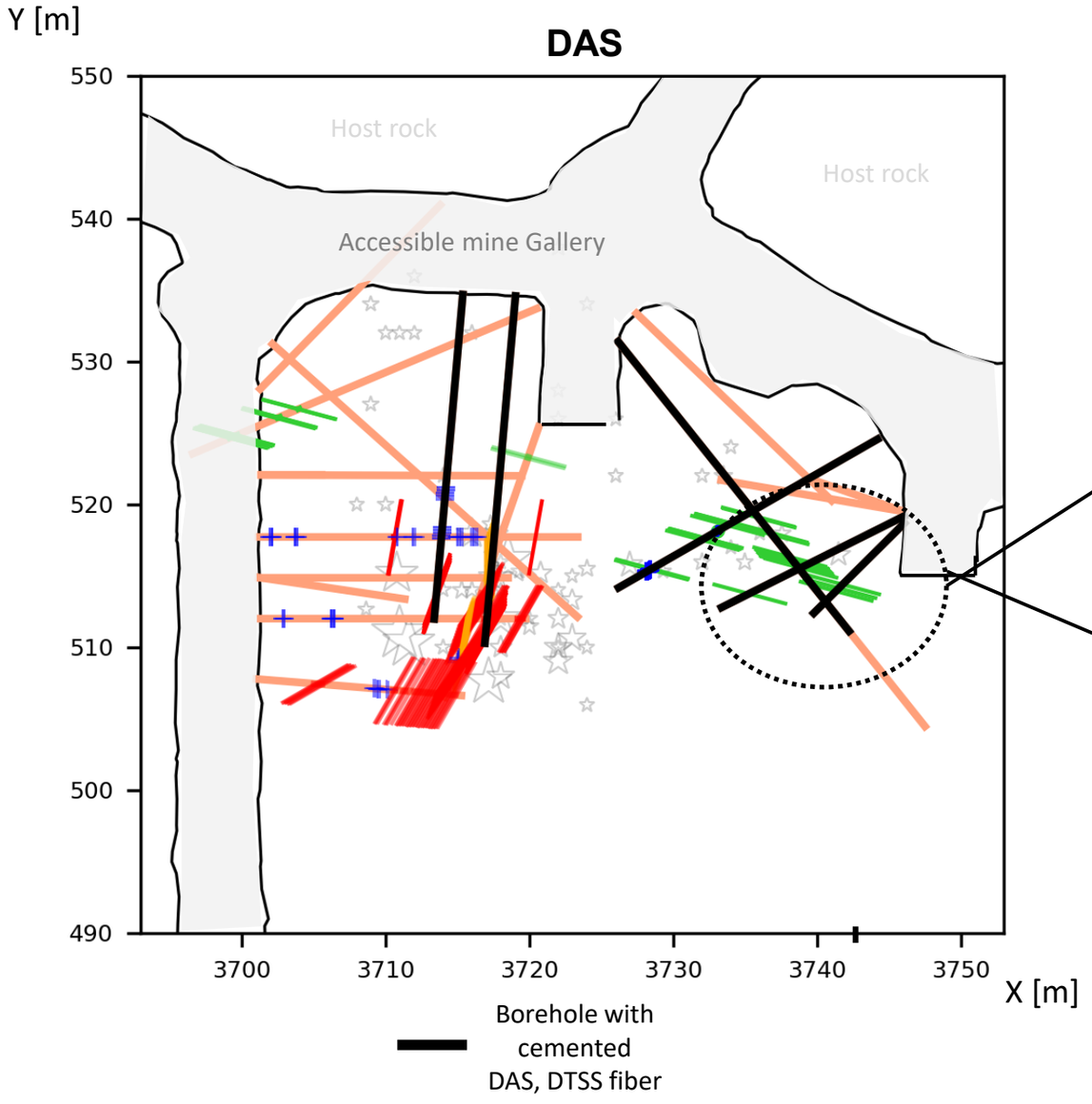
Link to repeaters 2016-2017

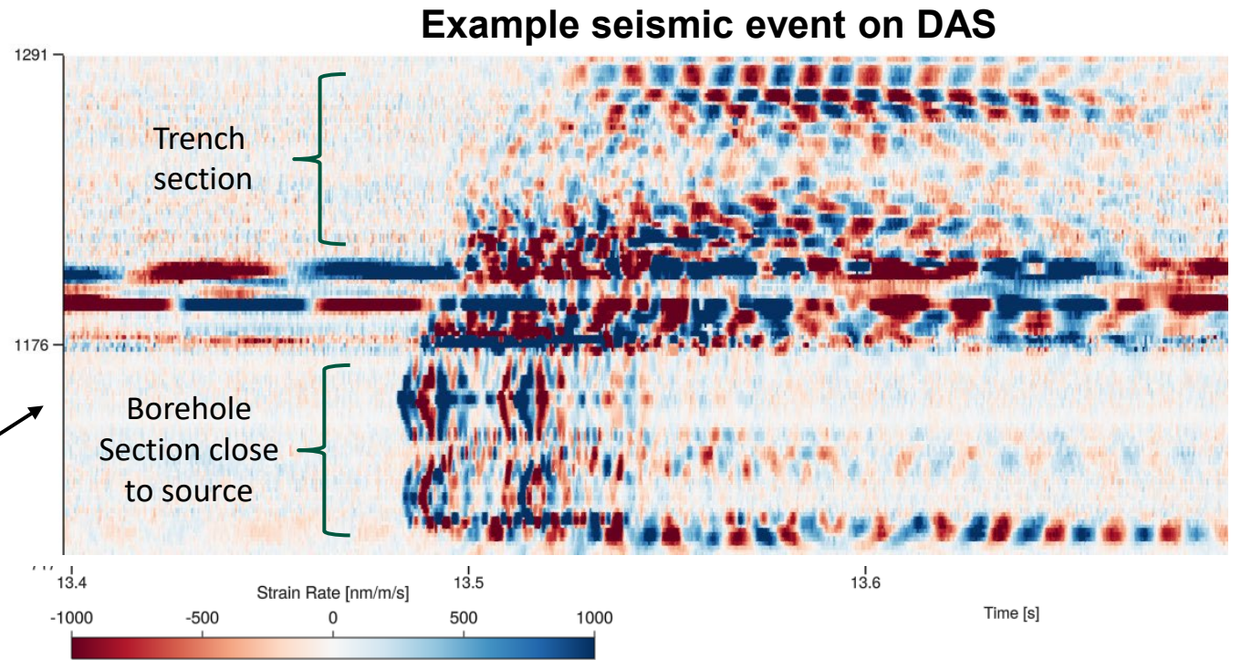


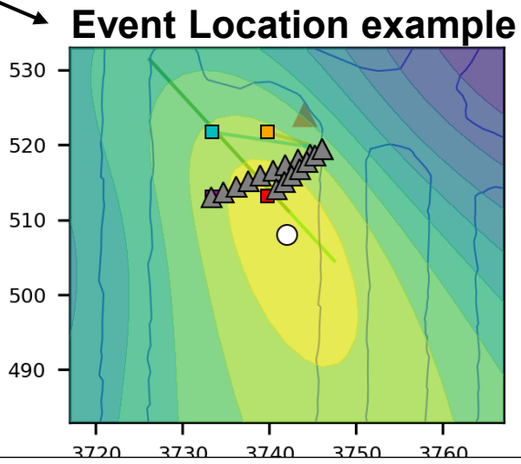

NNE-SSW Fault

- 2 main groups of “open” fault structures
- NNE-SSW Faults dominant in most active multiplet zone
- Fault trend consistent with source mechanisms of multiplets and long-term repeaters

# Seismic source characterization using DAS




- Best quality in cemented boreholes
- DAS useful for location of stronger events and study on wavefield radiation and propagation

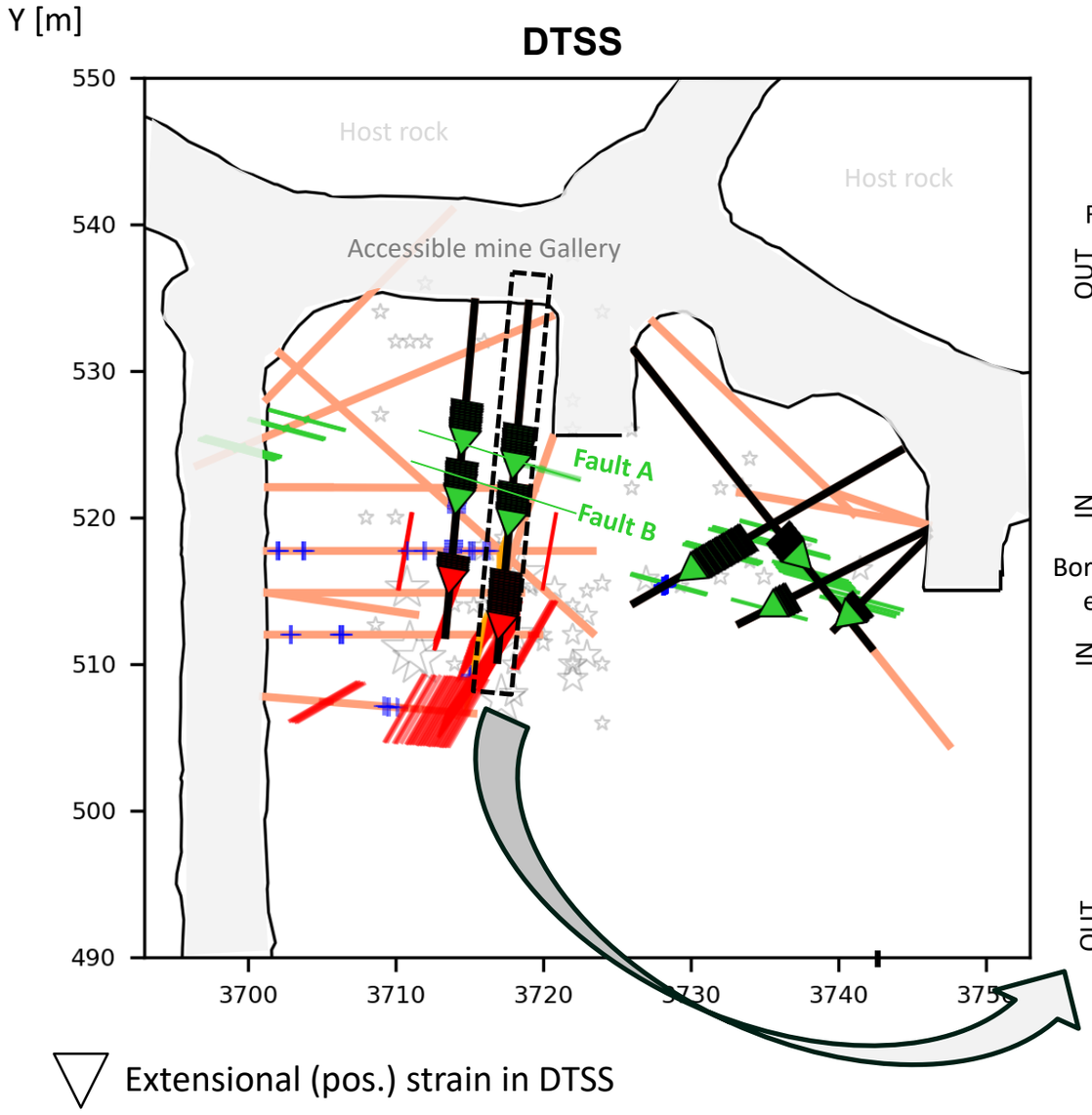
- Shortcomings/challenges:

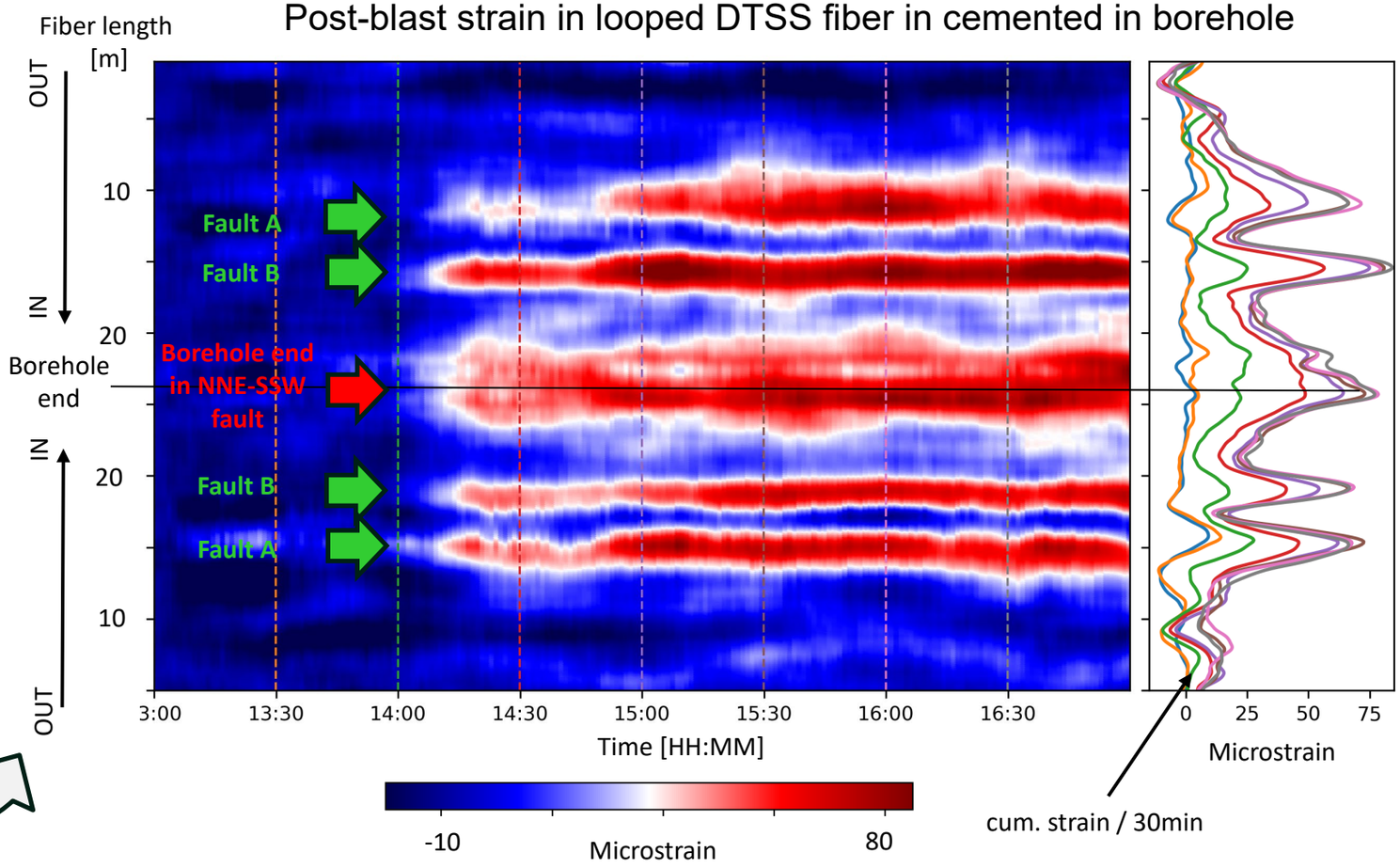
⇒ 10-100 less sensitive compared to geophone

⇒ Data volume (3 Gb/min) (5kHz sampling rate)

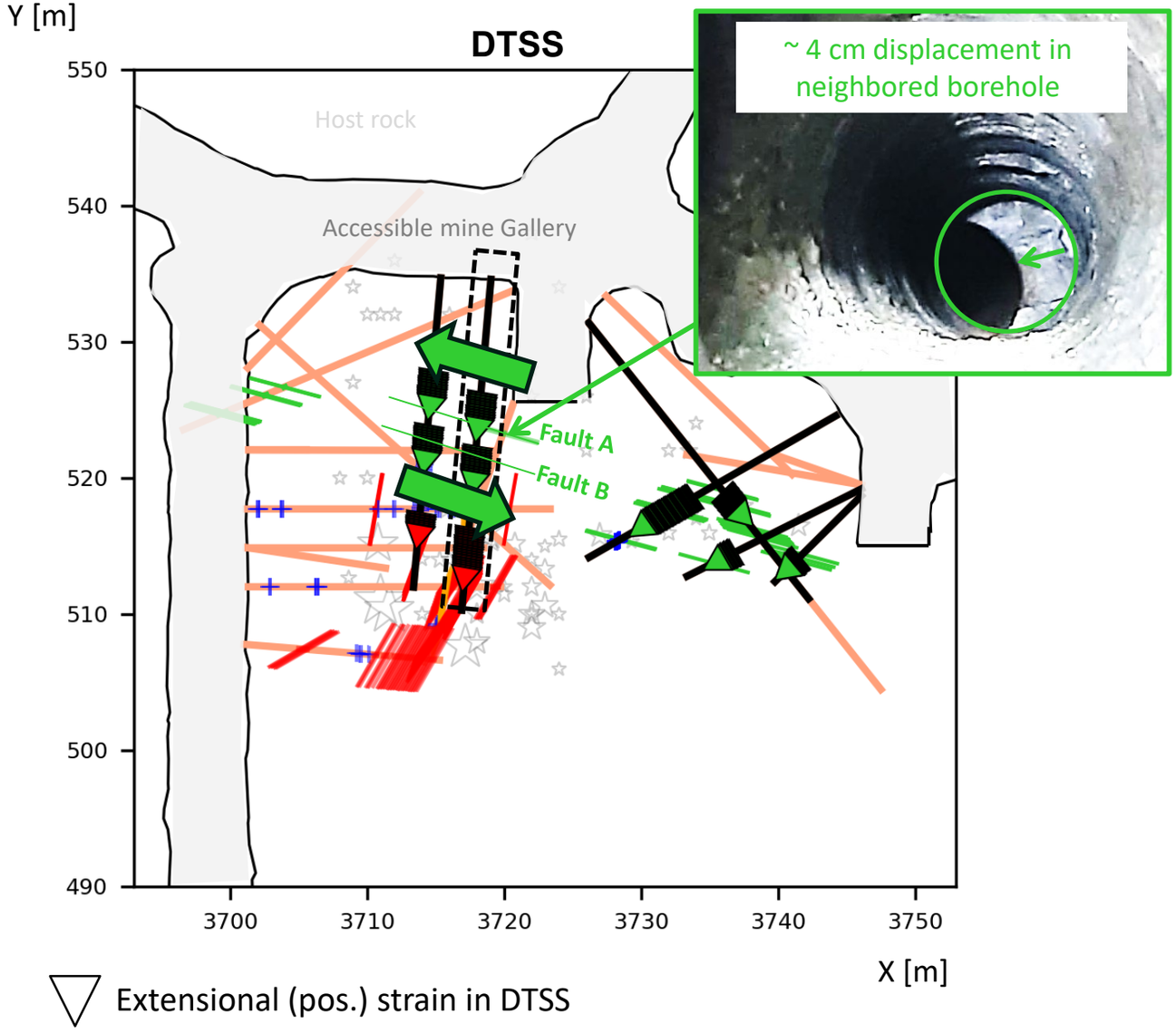
# Fault (creep) detection using DTSS

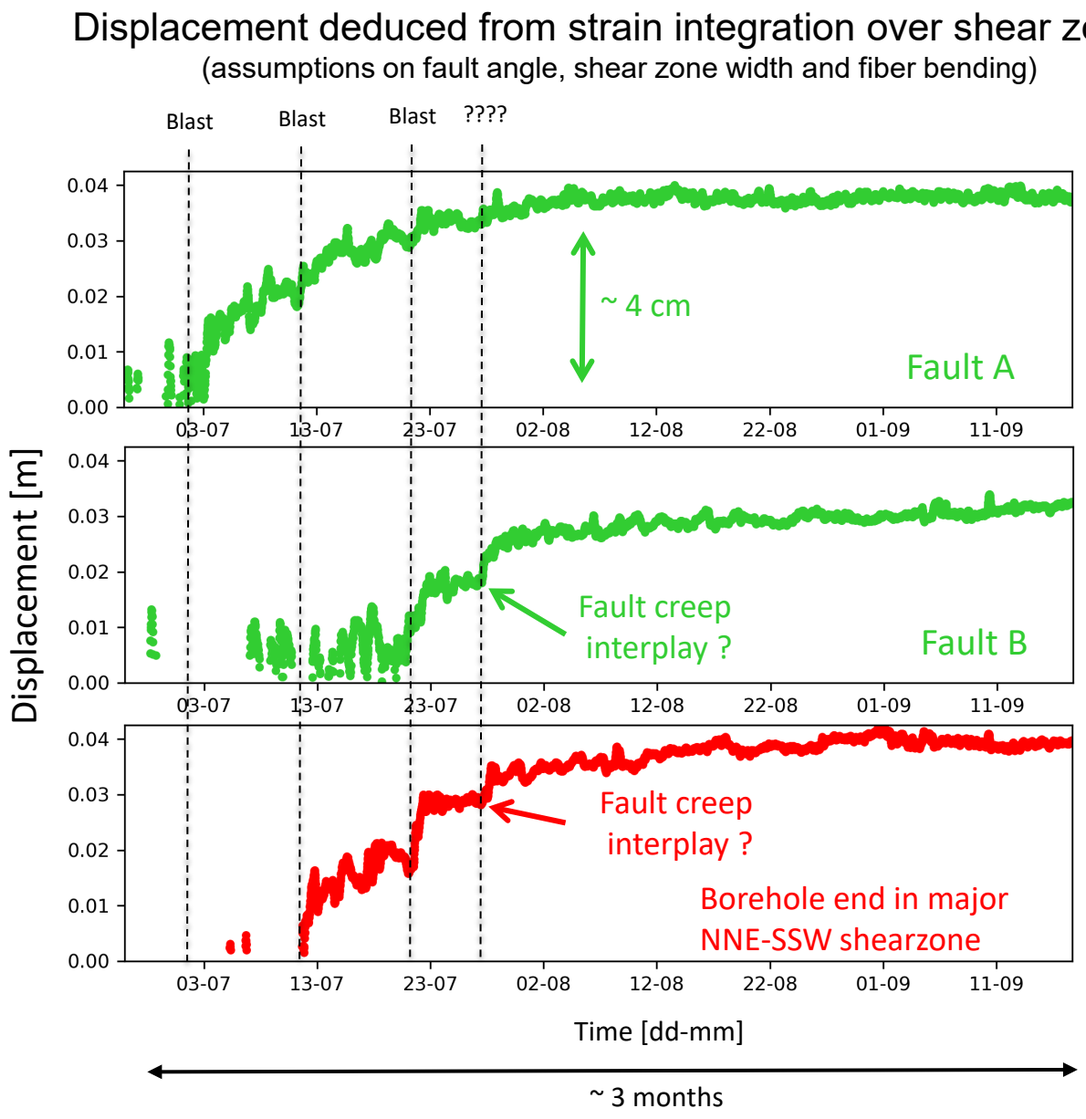
- Detection of 2-3 m thicks fault zones



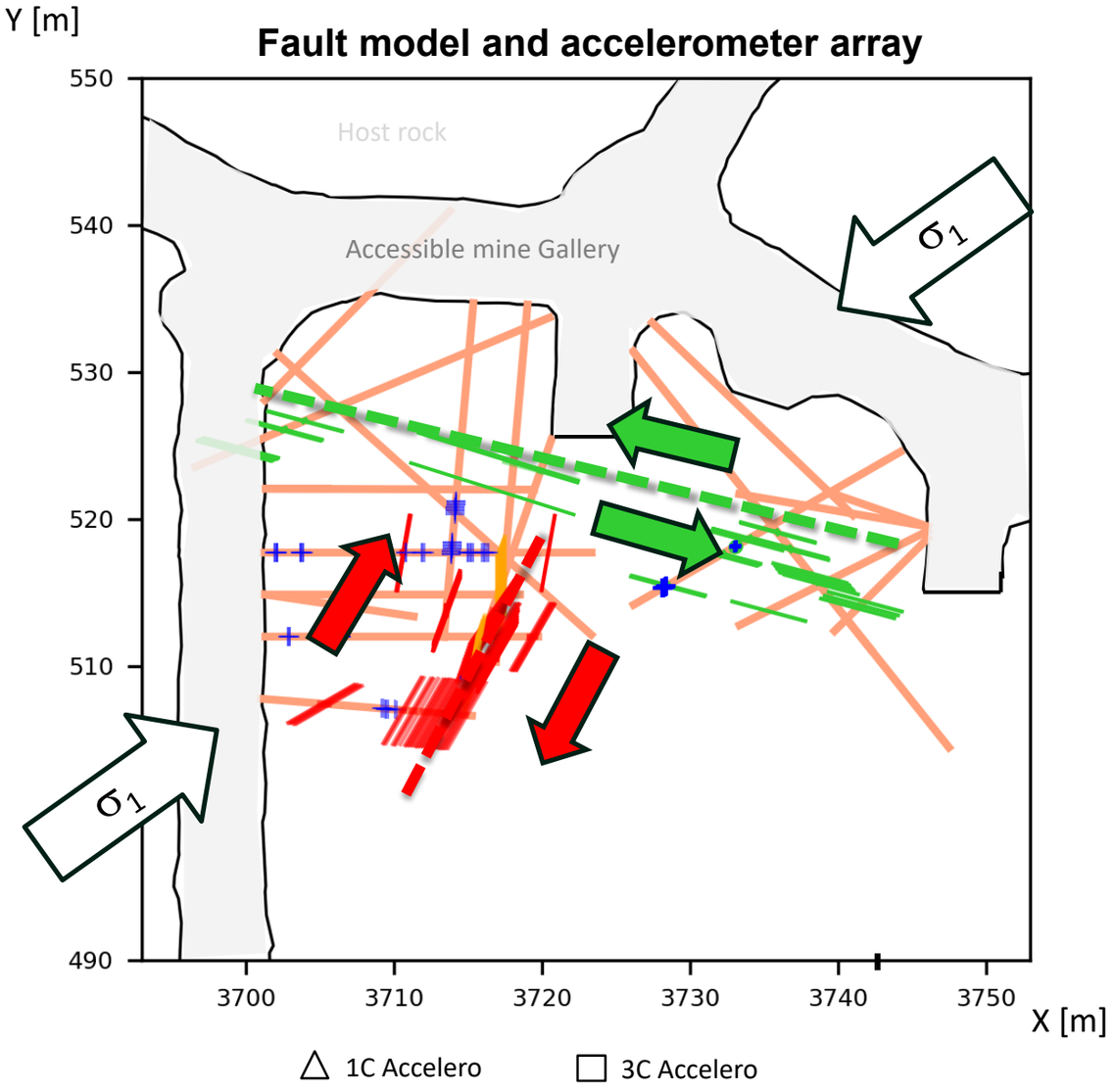



# Evidence for different long-term creep behaviors



# Fault model and repeater origin




Hypothetic fault/repeater model

- Post-blast stress redistribution widely accommodated by means of creep along (preexisting) fault structures opened subparallel to the main galleries

- Repeaters/multiplet represent parts in fault zones associated with higher friction loaded from fault creep

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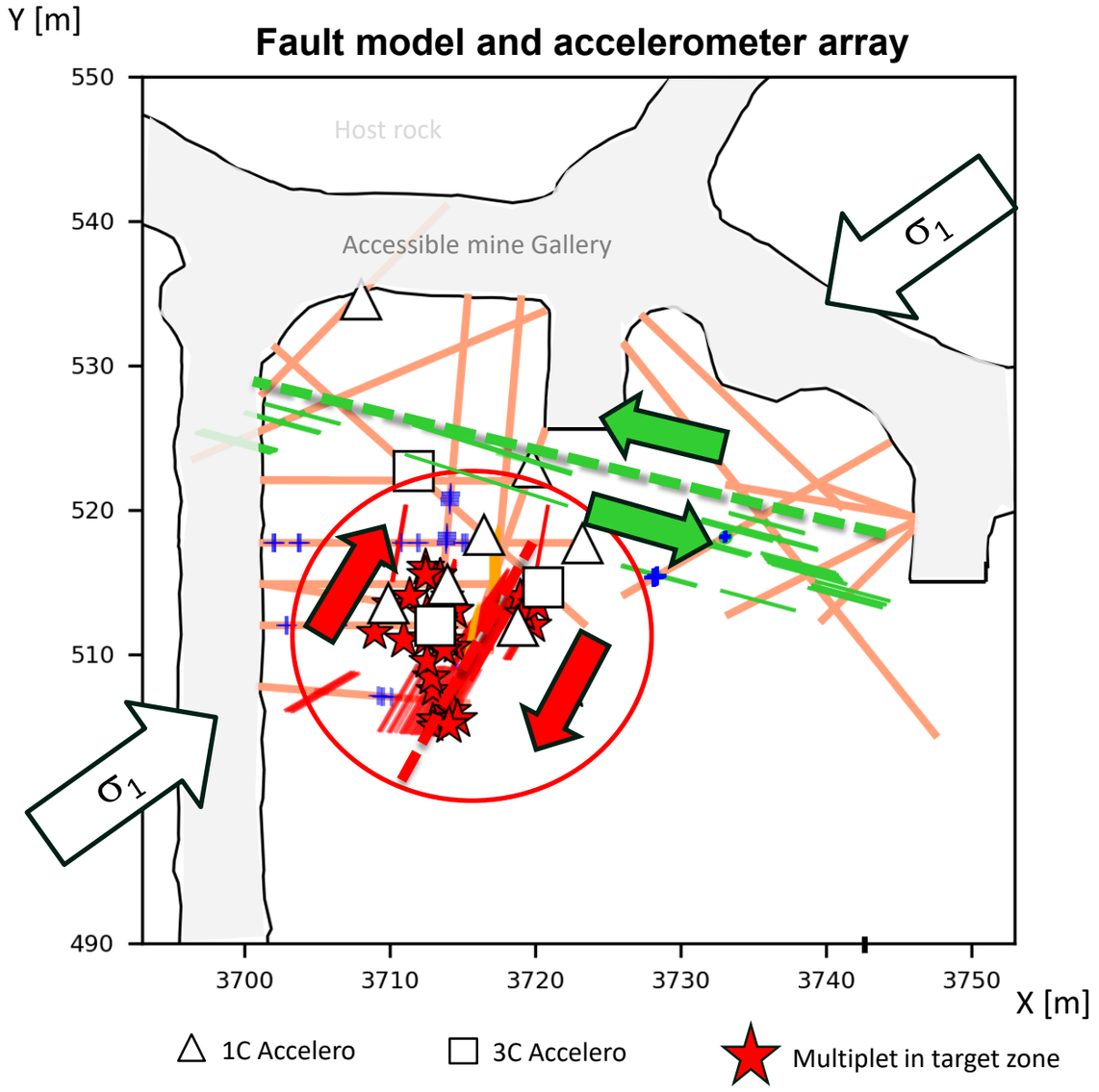


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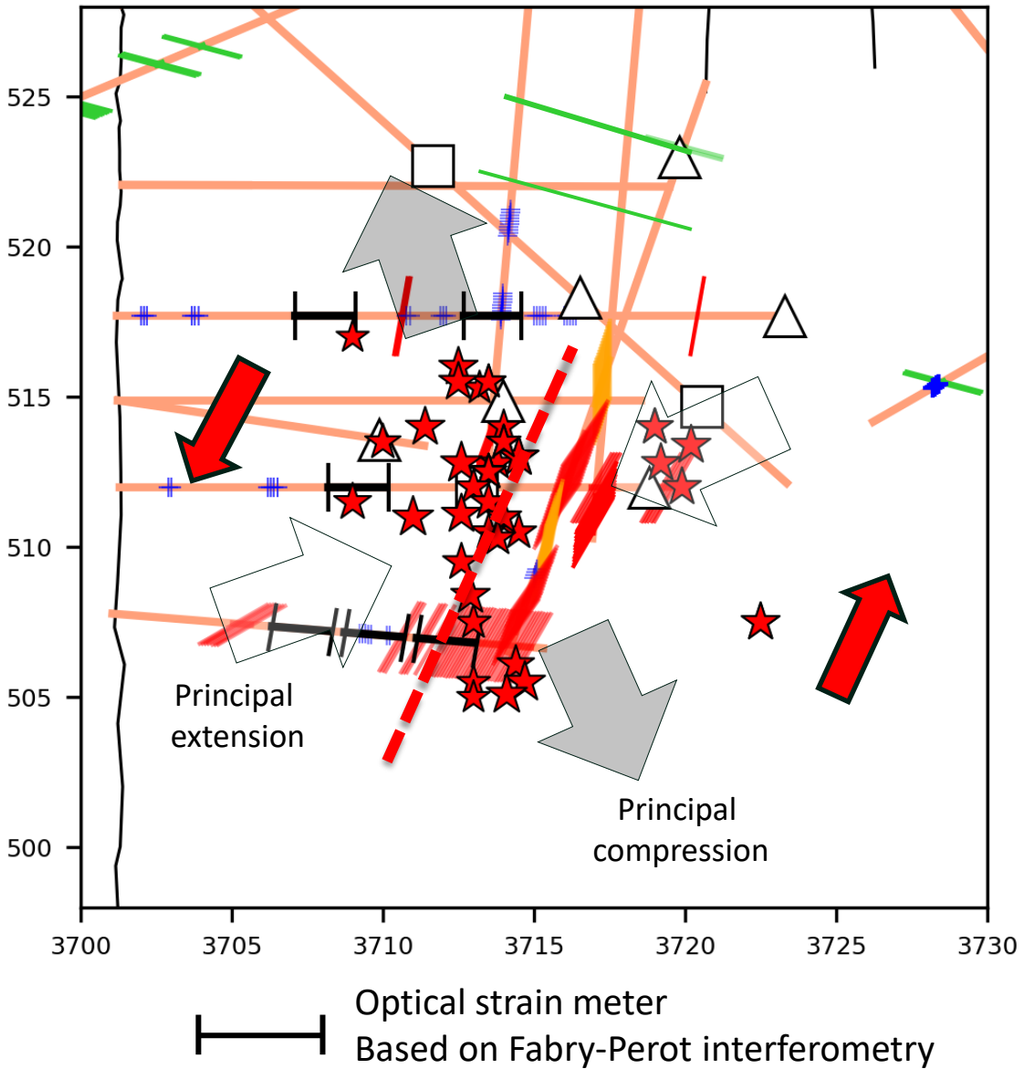
Current investigations:

- Focus on NNE-SSW fault

- Set up of very local accelerometer network to locate precisely (< 1 m) seismic asperities

# Co and inter-seismic slip detection




Current investigations:

- Focus on NNE-SSW fault
- Set up of very local accelerometer network to locate precisely (< 1 m) seismic asperities
- FP strainmeters placed next to seismic asperities and at the expected principal strain axis during inter-and co-seismic fault slip

# Conclusions

- Repeaters/multiplets are related to aseismic-seismic coupling processes in fault zones

- Fault creep is important mechanism for post-blast stress redistribution

- DTSS highly valuable tool for fault detection and creep monitoring

- DAS is promising for studies  on wave radiation and propagation but remains challenging when using high sampling rates (data volume)

- Inter- and co-seismic strain monitoring under investigation

# Merci

Particular thanks to