In situ investigations on the origin of seismic repeaters in a deep mine - Garpenberg mine (Sweden)

Thèse cofinancée par l'Ineris et la Région Grand Est

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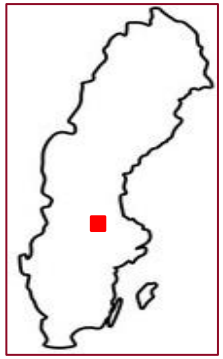
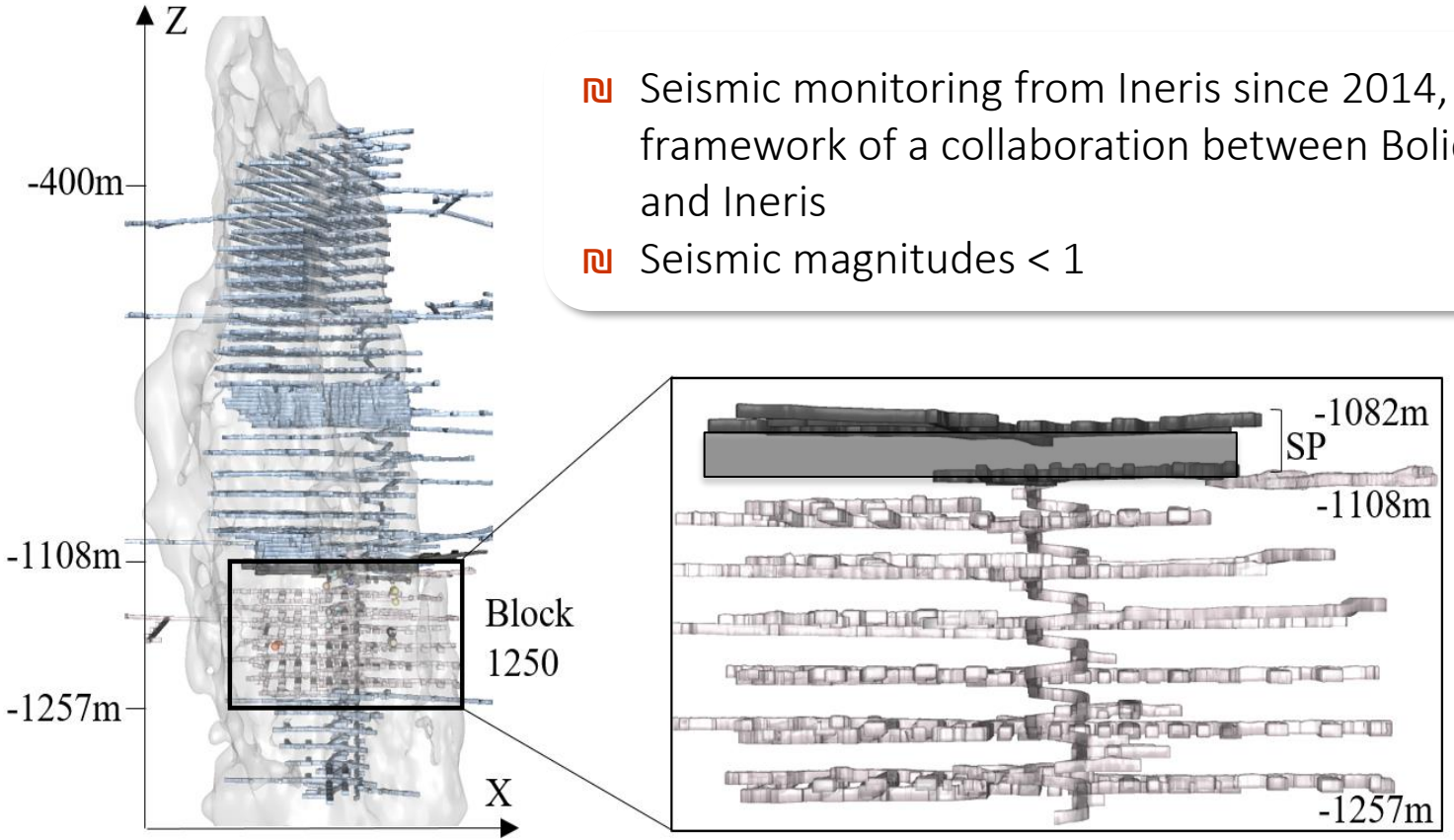
CFMR – 19th October 2023

Study area

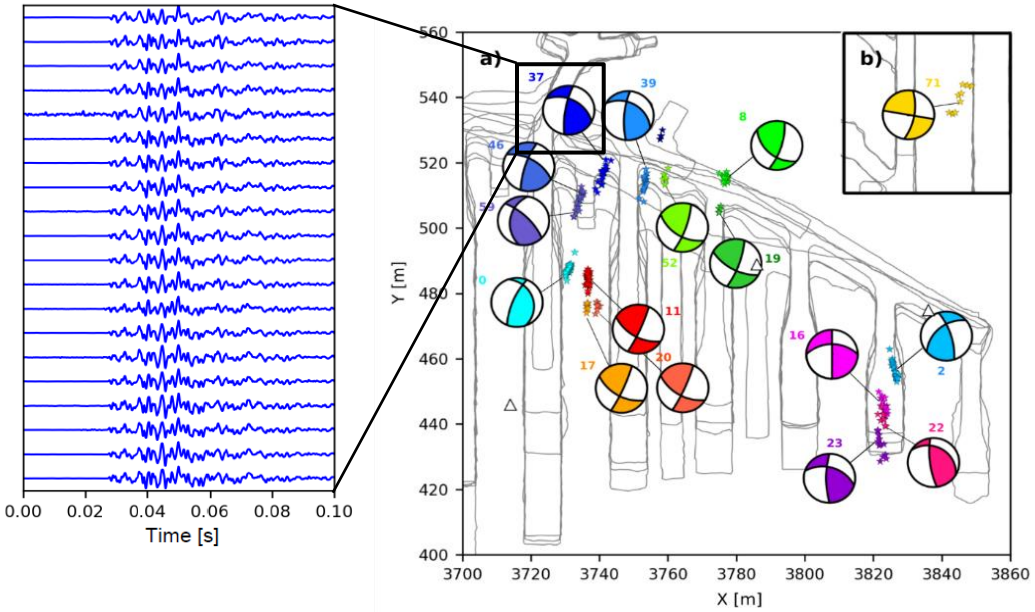




- Seismic monitoring from Ineris since 2014, in the framework of a collaboration between Boliden and Ineris
- Seismic magnitudes < 1

Seismic repeaters

- Definition: seismic events with highly similar waveforms, occurring repetitively at identical location



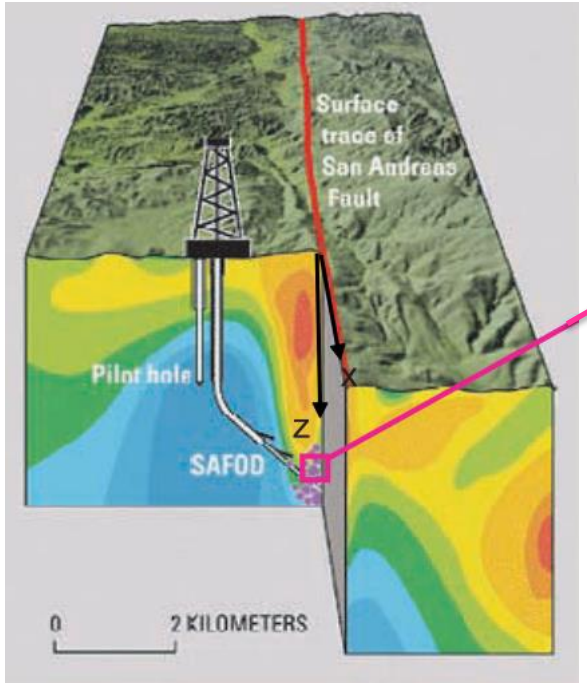
Kinscher et al. (2020)

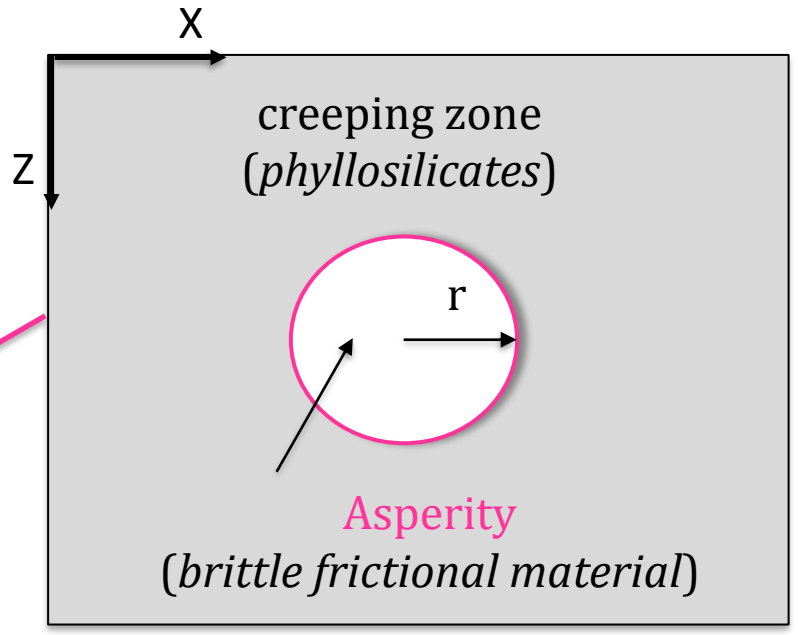
- Small-scale source sizes (1-10m)
- Alignment with same directions
- Repetitively reactivated over days, months, even years

- Repeaters are unexpected in a mining context

Theoretical model of repeaters

- Repeaters well studied at geodynamic scale
- Model preconizes seismicity driven by aseismic slip

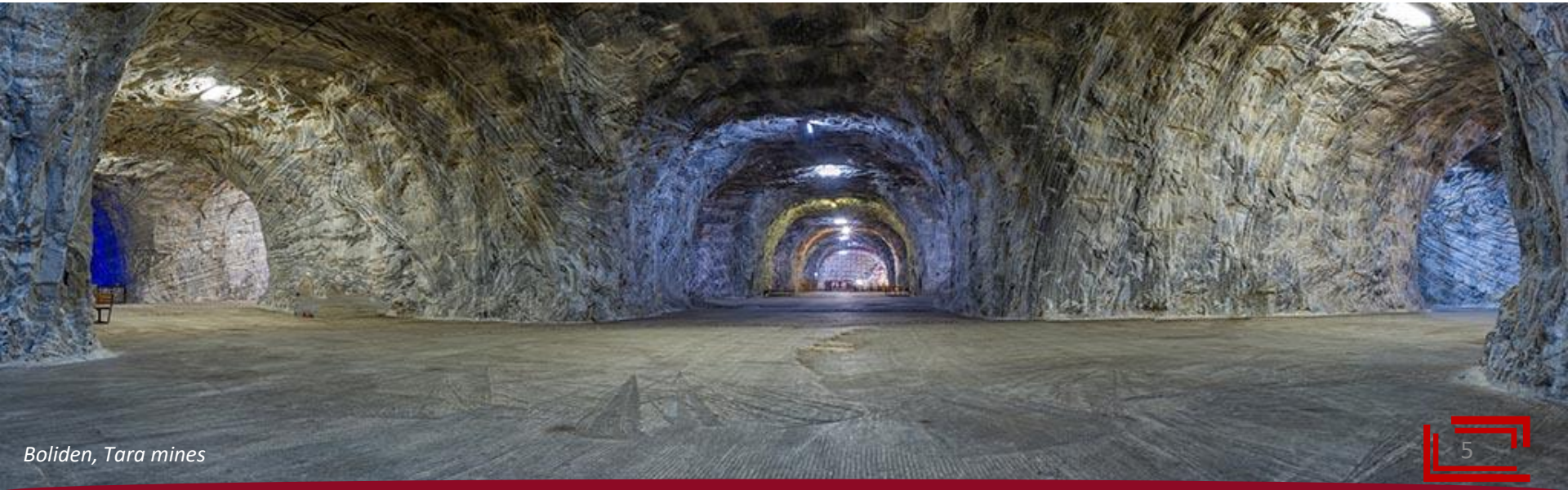




Adapted from Chen & Lapusta (2009)

Scientific questions

What is the geological and geomechanical origin of seismic repeaters in a deep mining context? Can we apply seismological models?



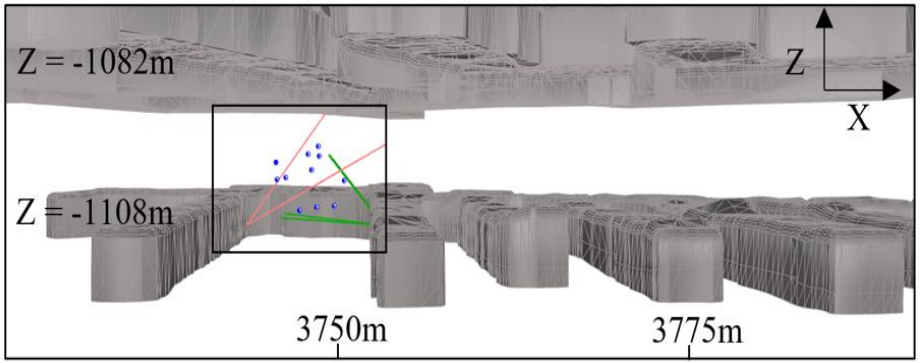
Boliden, Tara mines

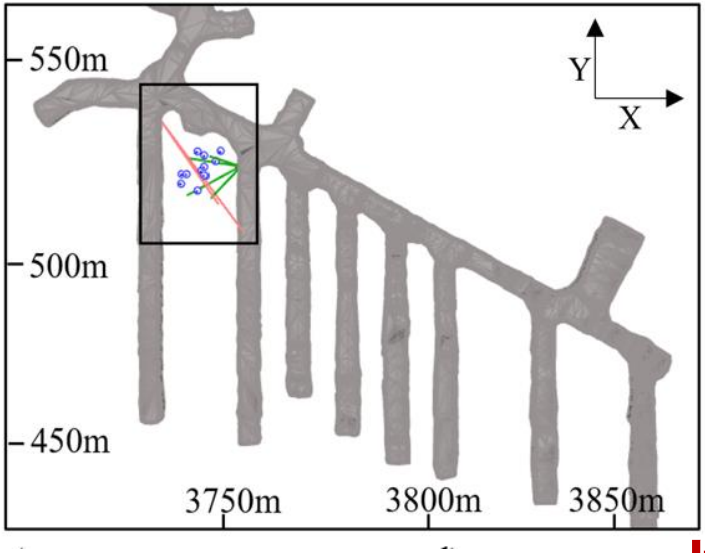
Installation in the sill pillar

Unique opportunity to :

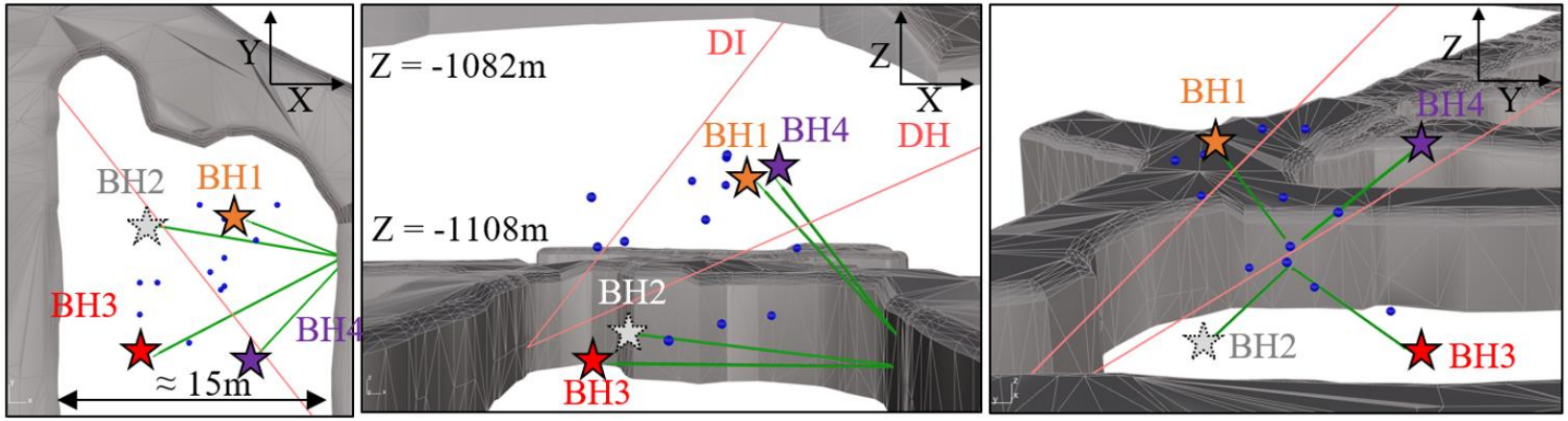
- Access a repeater source zone
- Test models built at geodynamic scale in a mining context

⇨ Opens perspectives on the understanding of induced and natural earthquakes, as well as micromechanisms of creep





Installation in the sill pillar



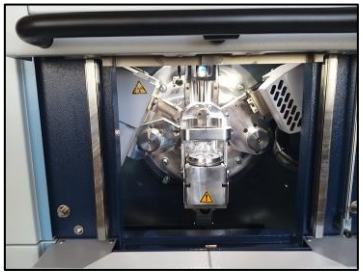
Csiro cells installed by Ineris

Boreholes drilled and sent by Boliden

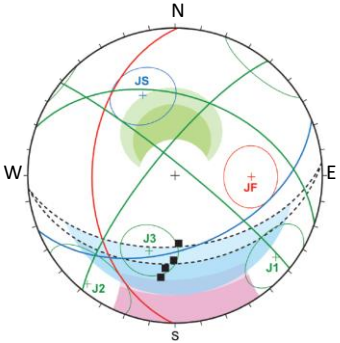
Geological and geomechanical origin of repeaters?

Geological markers (striation, fracture zones)

Mineralogy of infilling (DRX)

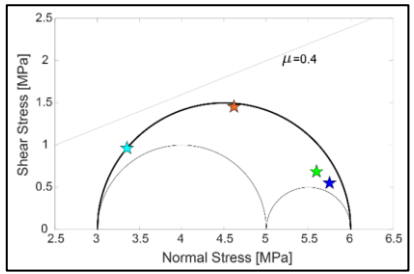


Fault orientation vs seismic data



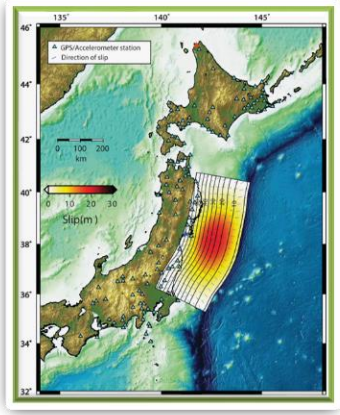
Schleier et al (2016)

Fault activation (stresses measurements)



DuBoeuf et al (2021)

Inversion model from strain data

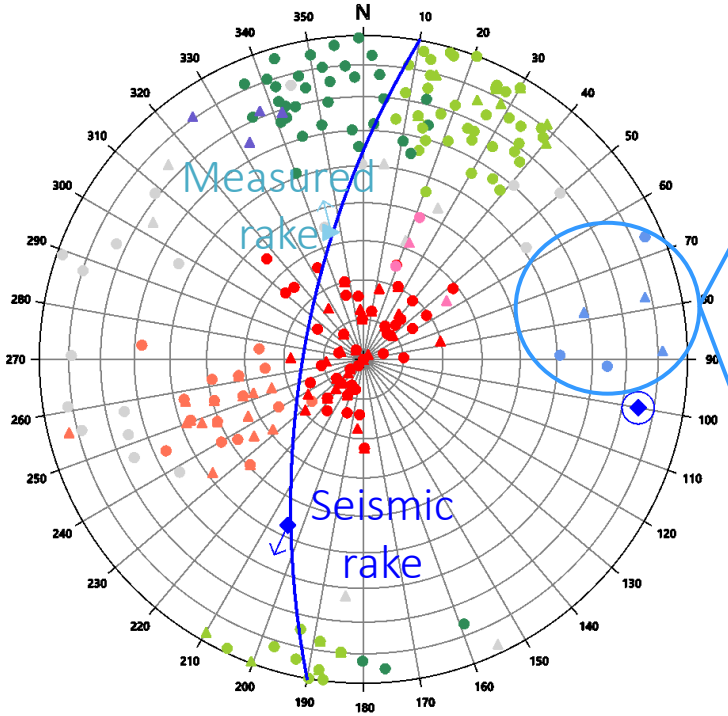


From Bock & Melgar (2015)

Comparison between fracture orientations and nodal plane

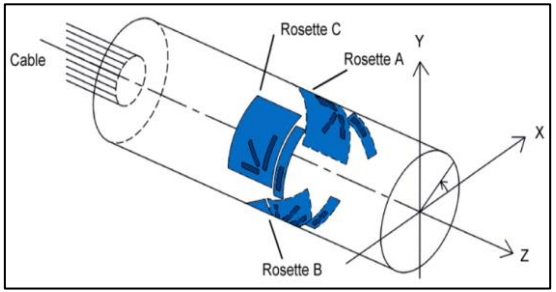
- F1: fractures parallel to foliation
- F2: sub-horizontal fractures
- ,,, : secondary sets
- F3: secondary set with similar orientation than seismic data

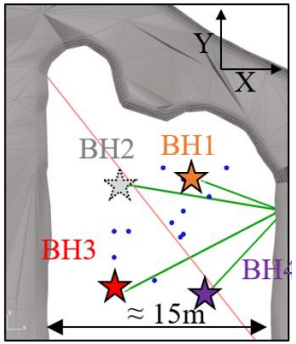
- Nodal plane given by seismic data



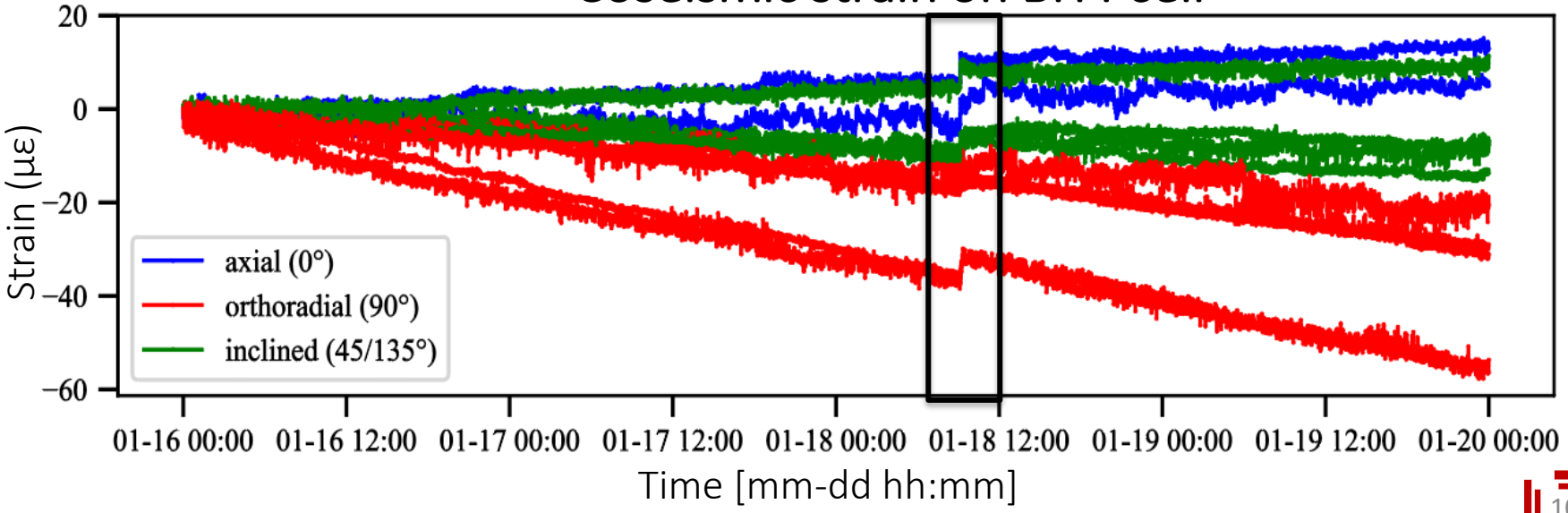
DRX analyses :
Muscovite and chlorite

Coseismic strain





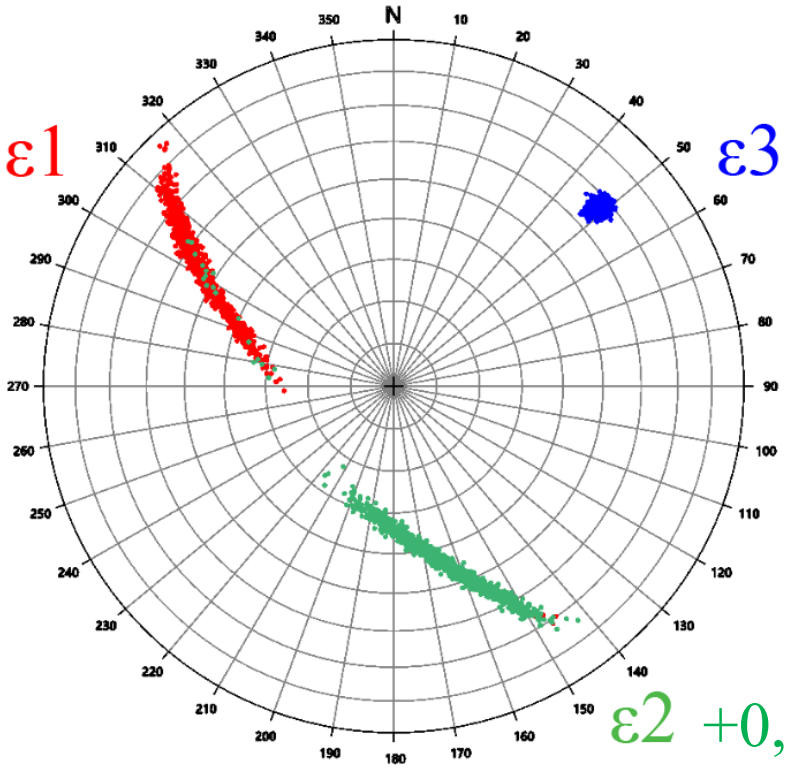
Coseismic strain on BH4 cell



Coseismic strain

+1,7με ε1

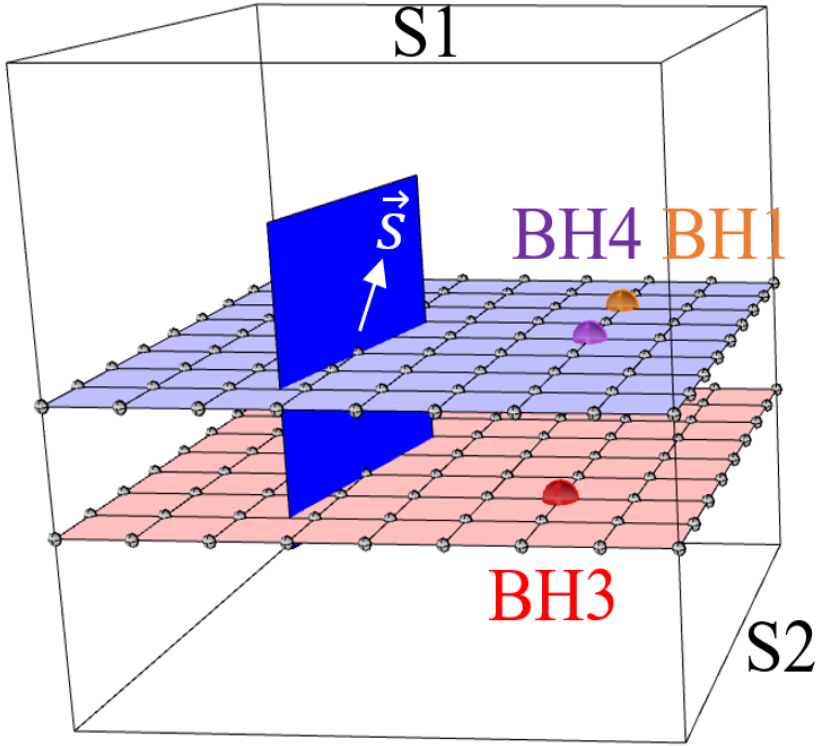
ε3 -6,6με

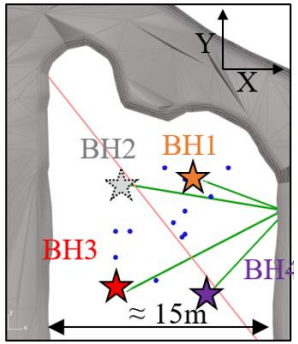


ε2 +0,94με

Inversion model

Elastic model of dislocation (Analytical model)



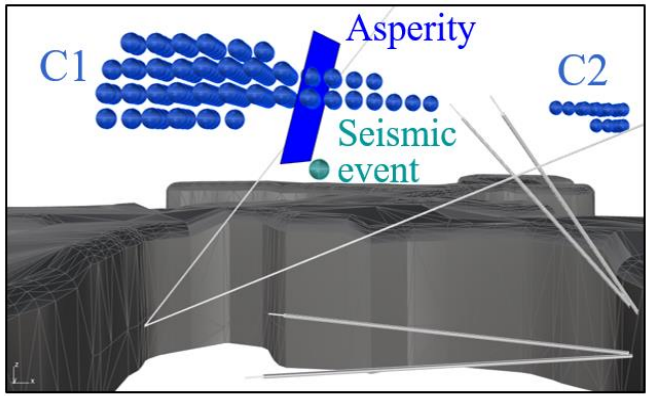


Strike	190°
Dip	75°
Rake	130°
Slip quantity	1mm (0.5mm-2mm)
Young's modulus	54GPa
Poisson	0.23
Length (= width) of the asperity	1- 10 meters

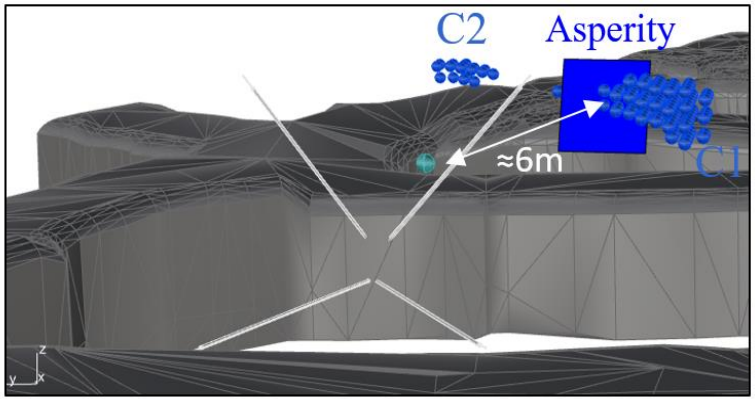
Results of inversion model

Possible localizations of the asperity

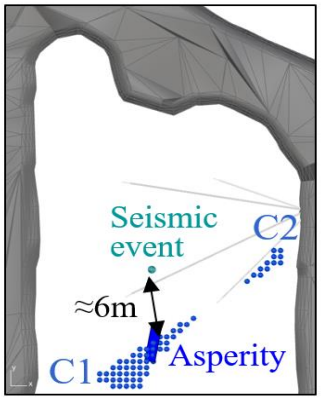
a) Front view



b) Side view



c) Plane view

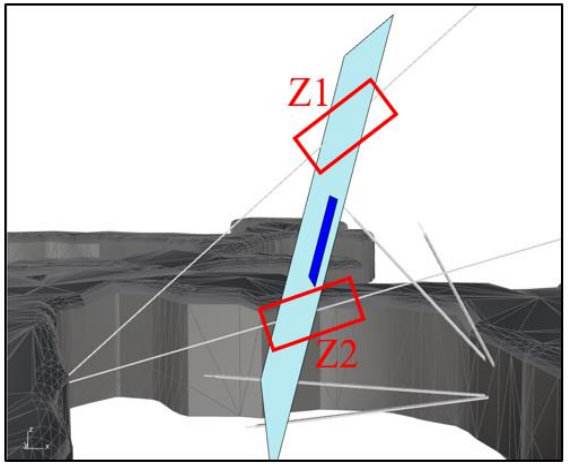


- Consistency between strain and seismic data
- The asperity seems to have been missed by the drillings

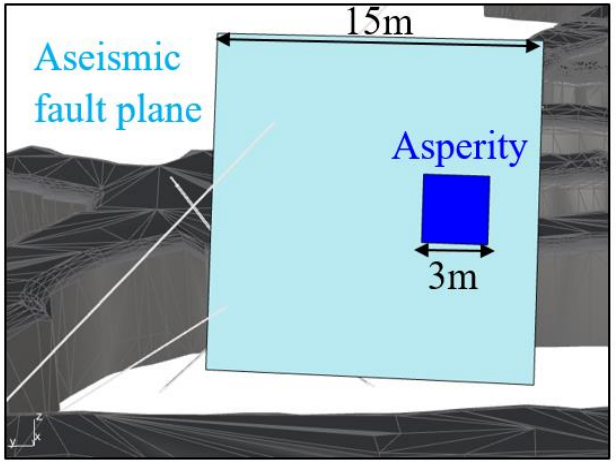
Extended fault plane

Possible localizations of the asperity

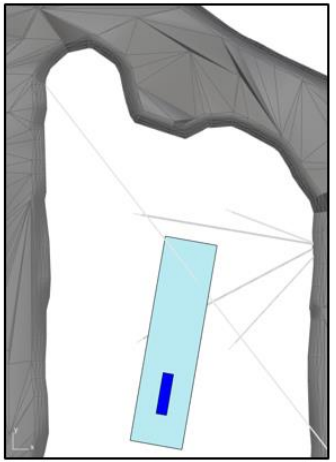
a) Side view



b) Front view



c) Plane view



- Consistency between geological, geomechanical and seismic data
- Interpretation : larger fault plane filled with phyllosilicates containing the asperity

Conclusions

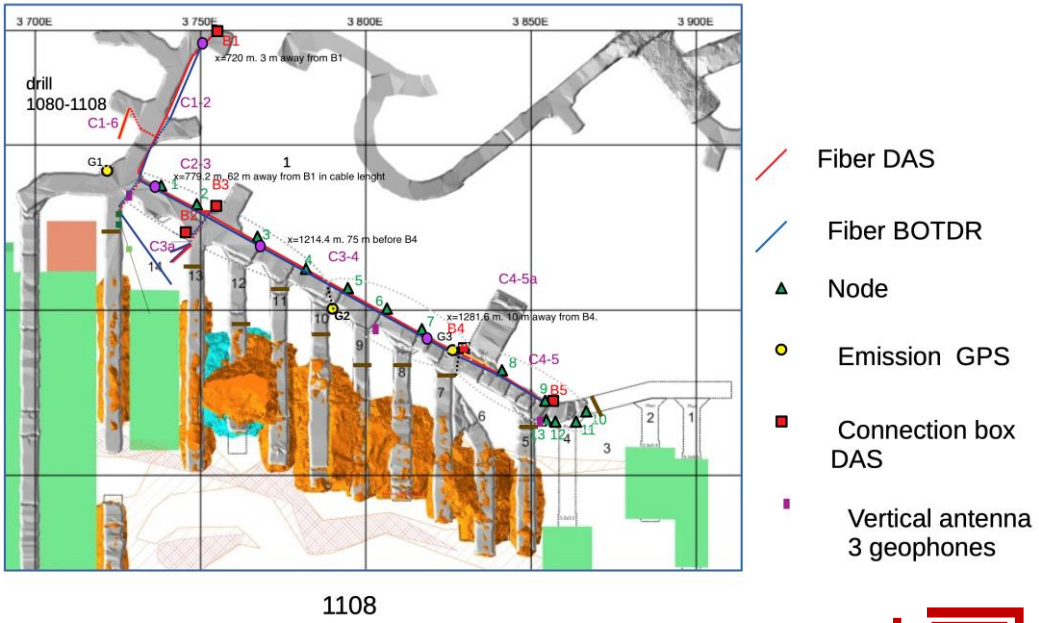
- Multidisciplinary method to study the origin of seismic repeaters
- Borehole analyses exhibit the presence of a fault plane with phyllosilicate infilling well oriented like seismic nodal plane
- Elastic model from inversion of strain data show possible localizations of the asperity
- Consistency between geological, geomechanical and seismic data
- Possibility we've reached aseismic portion of the fault plane

Open perspectives

On-going installation in the mine

- Installation of optic fibers to explore further triggering mechanisms of seismicity (existence of pre seismic creep?)

- Locate accurately the seismic events
- Acquisition of continuous strain measurements



Thank you for your attention !

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