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Coupled processes in clay during tunnel excavation

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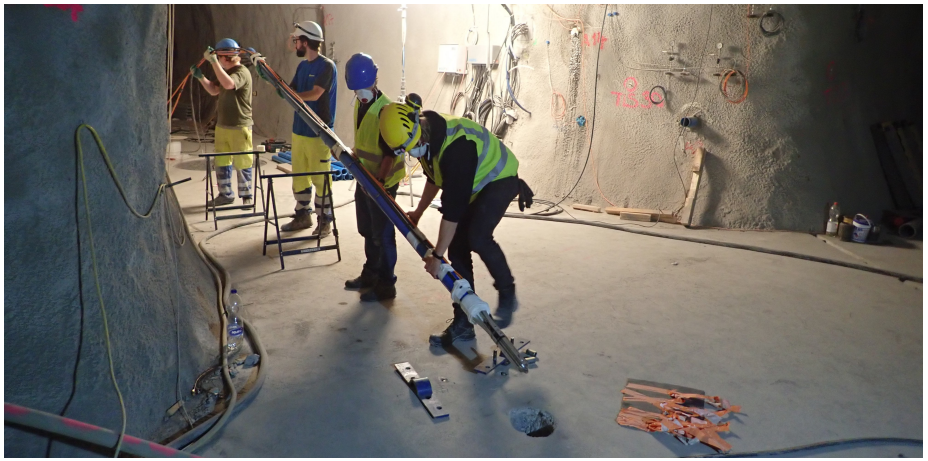
EGU General Assembly 2020

EGU2020-18041

The CS-D experiment

Flow through faults, potential leaks through a caprock:

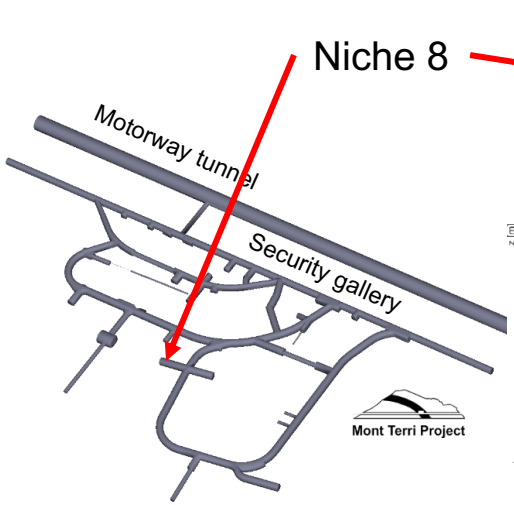
Representing CO_2 (dissolved in formation water) leaking trough a fault in a caprock

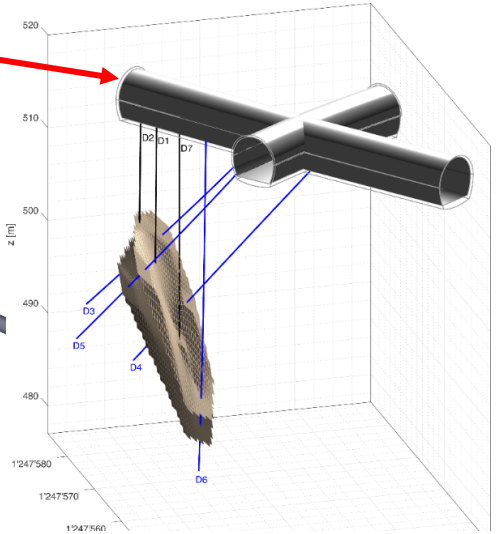


"Long" term injection of CO_2-saturated formation water and tracers in Mont Terri main fault at a scale of 1-10 m^3 rock volume

Monitor injection effects:

- Electrical conductivity, tracers, fluid samples
- Recording flow rates and pressures
- Strain (Potentiometer chain, FO)
- Seismic velocity changes
- Microseismic events





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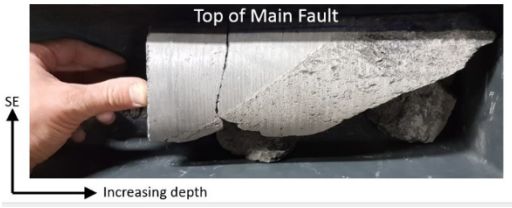
ELEGANCy

Partners CS-D
swisstopo TOTAL Chevron BERKELEY LAB Mont Terri Project



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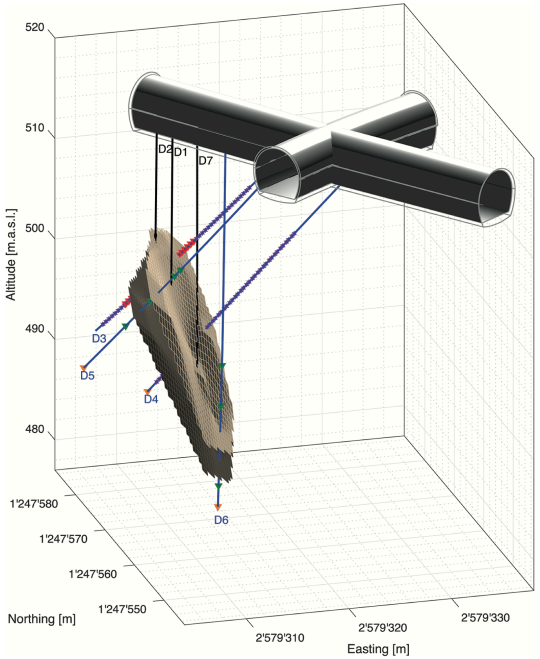
CS-D instrumentation

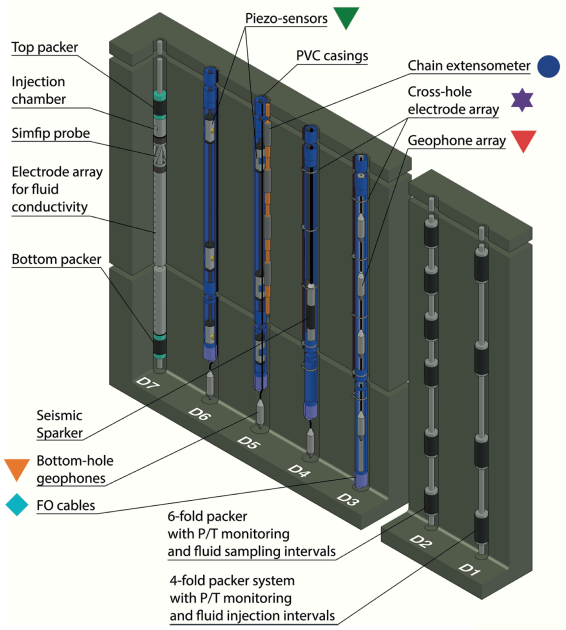
Geophysical borehole monitoring

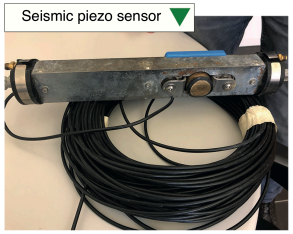
- 27 Borehole Geophones each with 3-components (0.1-2 kHz)
- 8 Piezosensors in the boreholes (1-200 kHz)
- Chain extensometers: 12 measuring sections for axial deformation and temperatures
- DSS FO in all boreholes

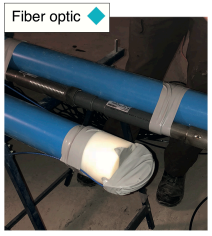
Hydrualic borehole monitoring

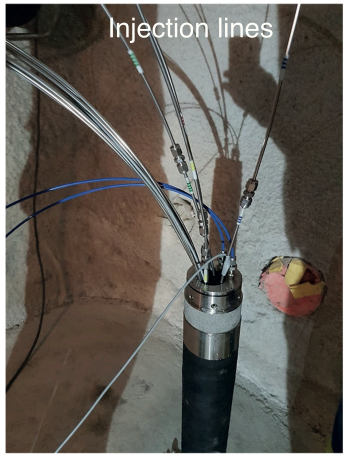
- Injection borehole with 4-fold packer system
- Fluid monitoring borehole with 6-fold packer system, and two circulation lines for fluid sampling and analysis











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The FS-B experiment

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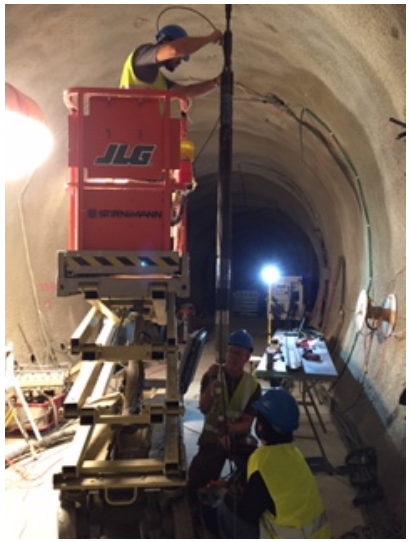
Imaging the long-term loss of faulted host rock

FS-B

Studying of coupled processes in 3D during and after fault activation by injection

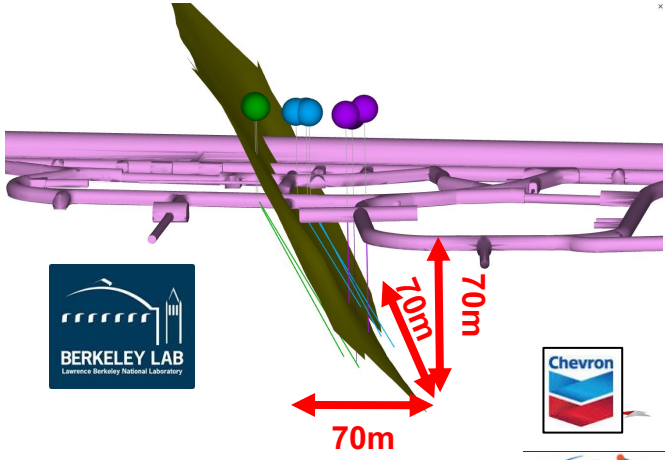


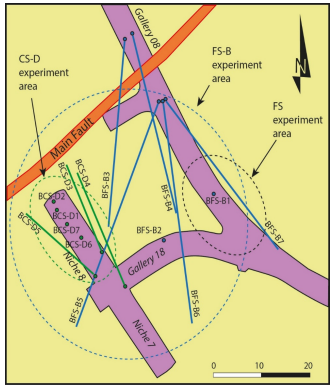
Optical Fibers Installation
Behind casing in Inclined wells

Activation of main fault at a scale of ~100 m^3 rock volume

- During Activation: How do leakage pathways organize in the rupture zone?
- After Activation: Can a Fault heal/seal in Clay Materials?
- Can we improve the monitoring? *Through the imaging of aseismic rupture…*
- Can we improve fault leakage prediction and induced seismicity?

SIMFIP probe installation in BCS-D7





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JAEA IRSN ENSI ETH

BGR Bundesanstalt für Geowissenschaften und Rohstoffe GEOZENTRUM HANNOVER swisstopo

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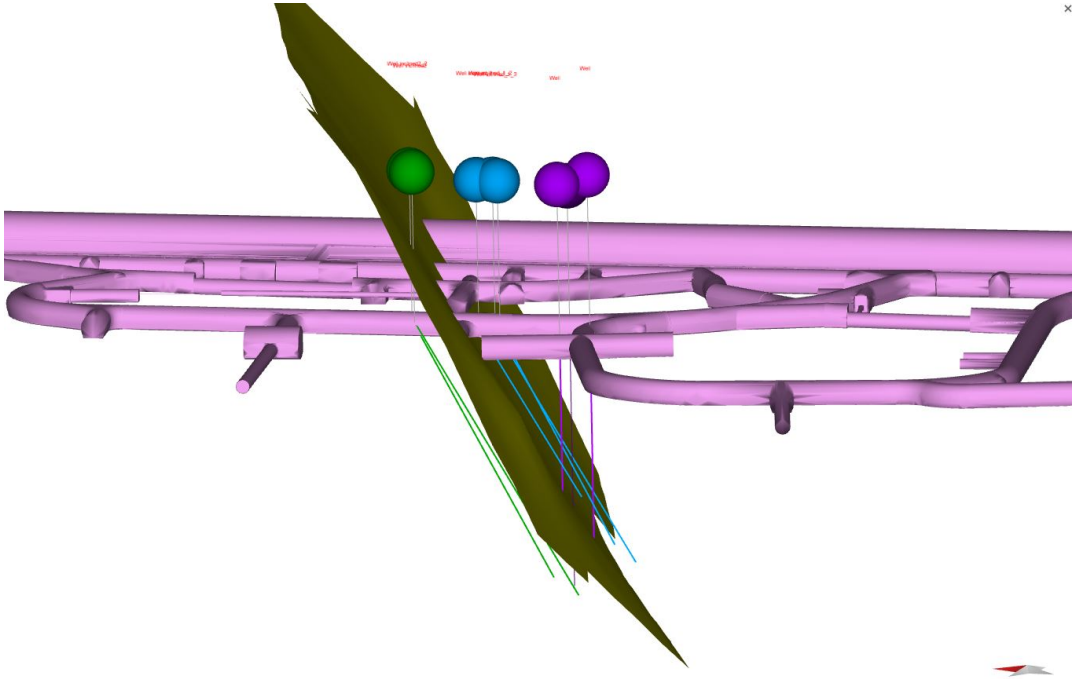
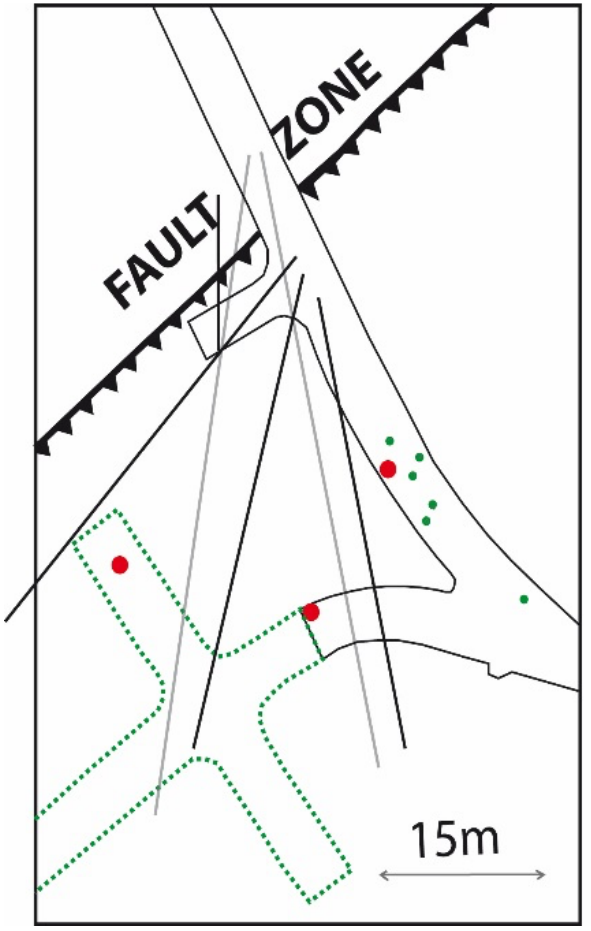
FS-B instrumentation

Coupling downhole hydro-mechanical tests with active seismic monitoring

Experiment Scale: about 70m x 70m x 70m





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FS-B instrumentation

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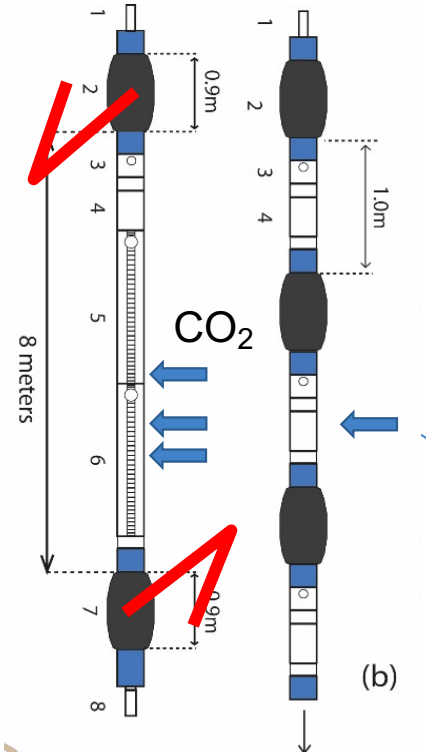
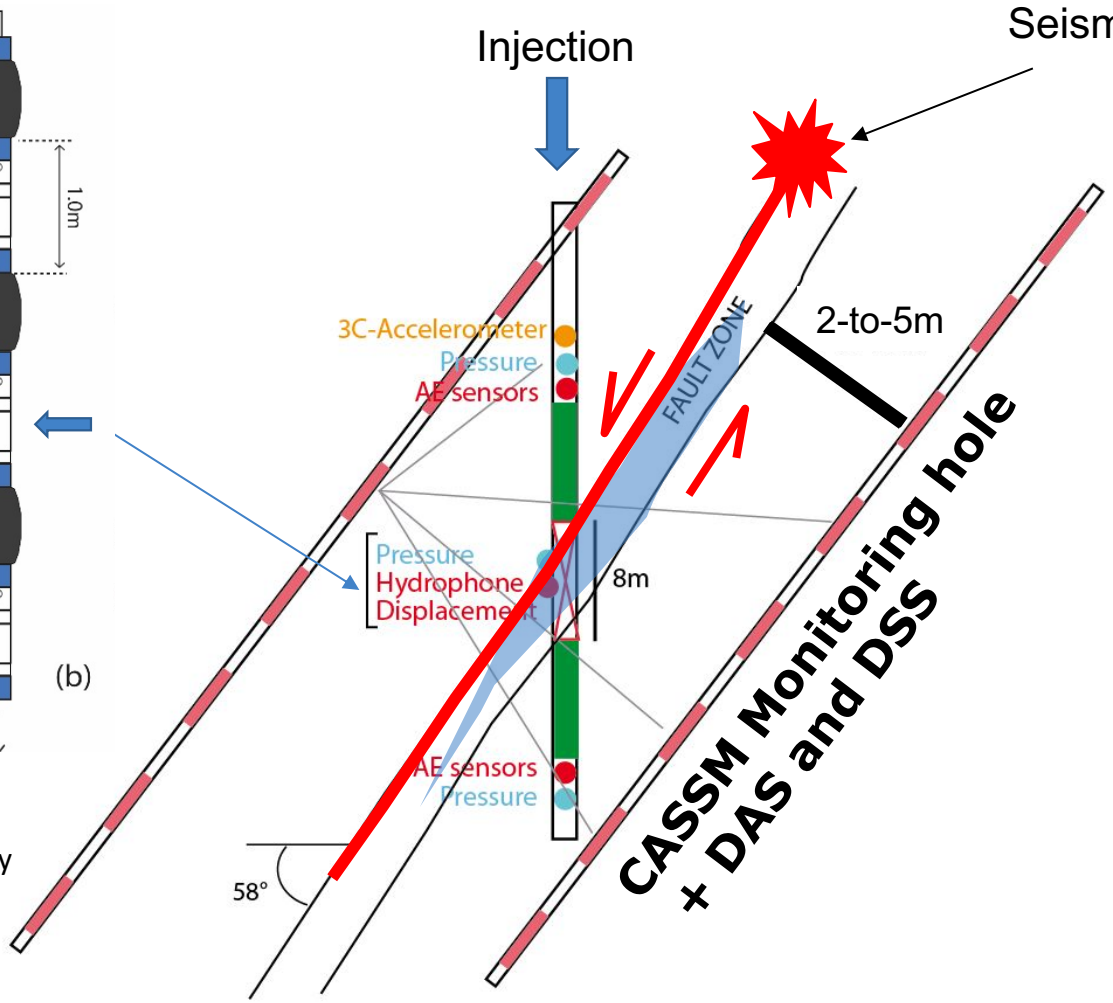
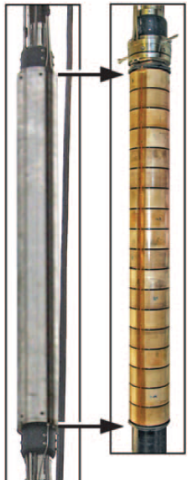


SIMFIP

Displacements accuracy
~ 5 10^{-6}m





Hydrophone array

For one-hour stacking, standard error only ~ 6ns.

Custom piezoelectric borehole source

[Daley et.al. 2007]
[Silver et al. 2007]
[Ajo-Franklin et al. 2011]
[Marchesini et al. 2017]

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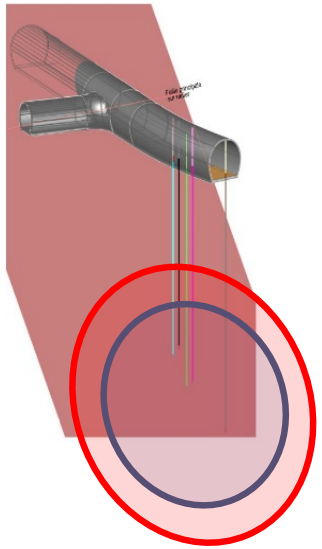
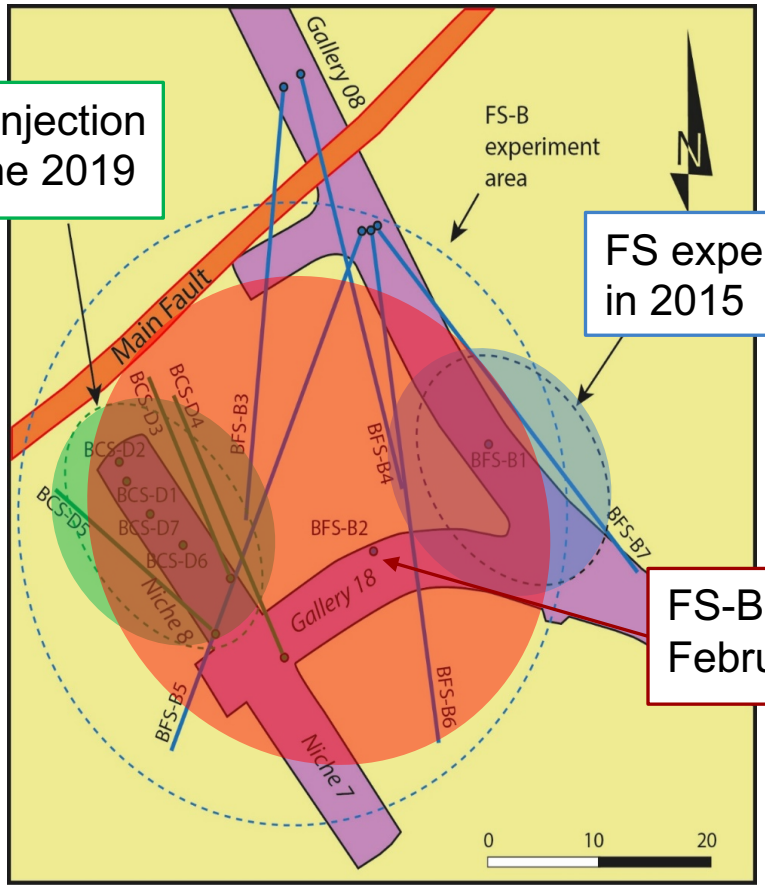
CS-D/FS-B collaboration

- CS-D is focusing on a long term, small volume injection of CO_2-saturated formation water in the fault and long term geochemical/geomechanical evolution
- FS-B involves a relatively large fault activated volume, and will conduct long term post activation monitoring to study eventual sealing





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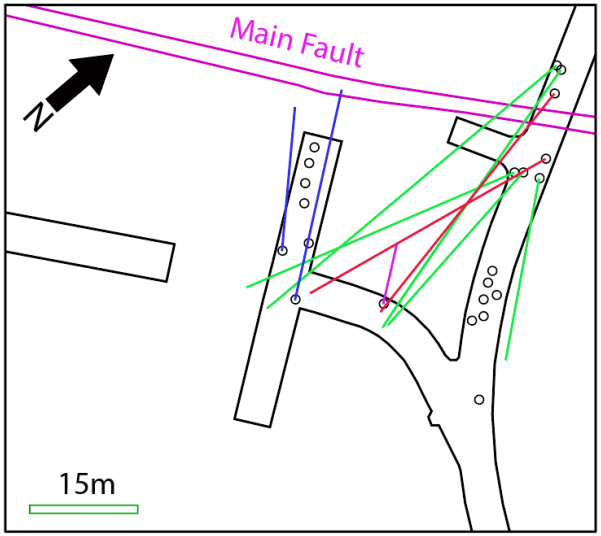
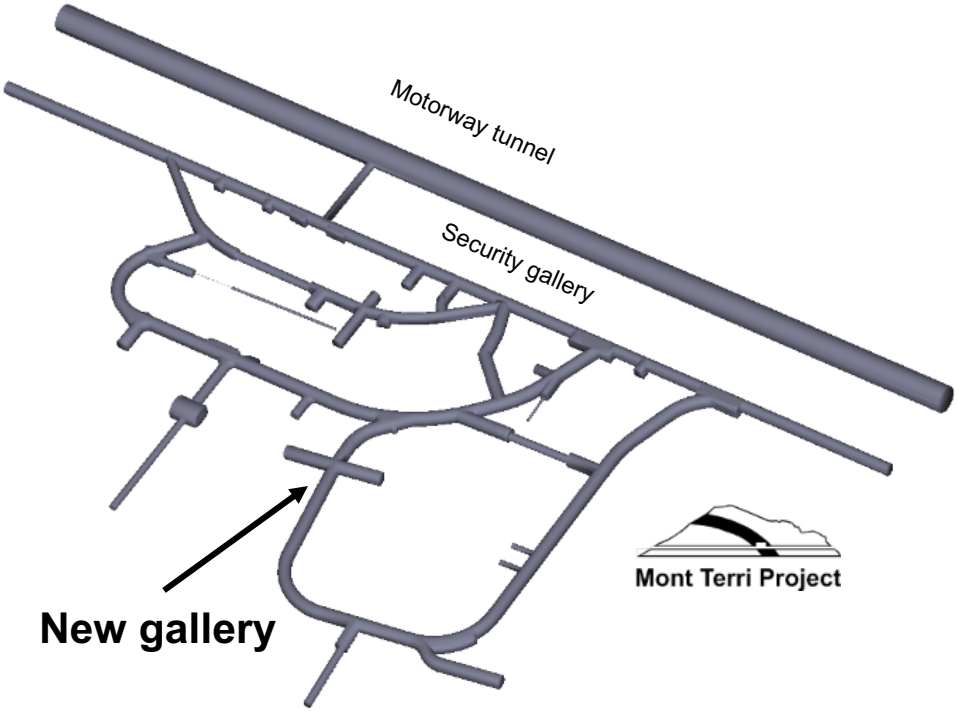
First collaboration results

Monitoring fault response during tunnel excavation





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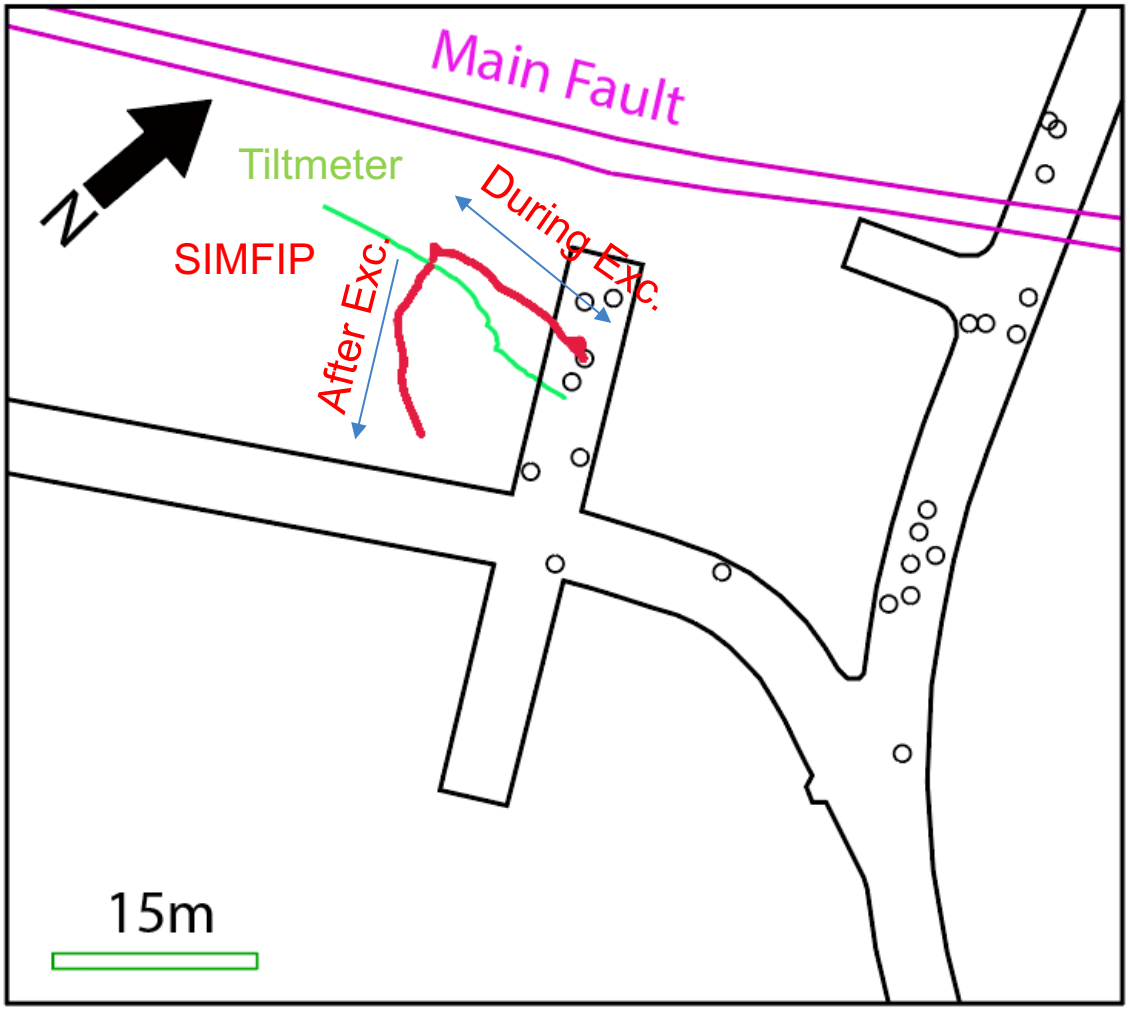
Monitoring fault response during tunnel excavation: SIMFIP vs tiltmeter



- Reverse shear to the NW during excavation
- **About 150 microns shear**
- Normal opening after gallery breaktrough

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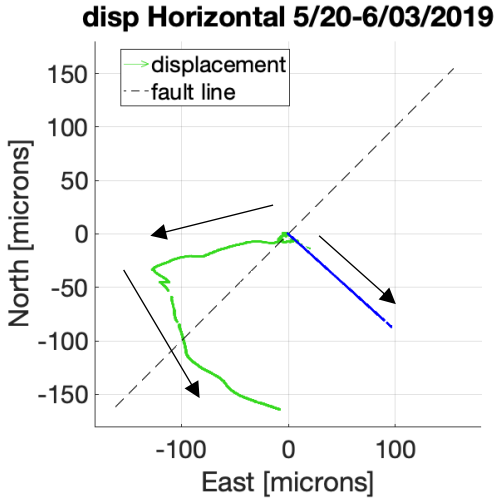
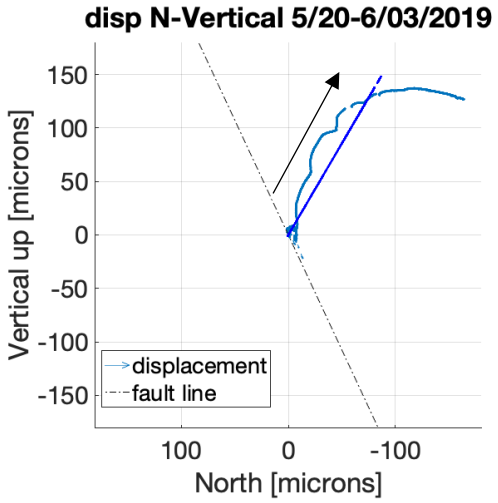
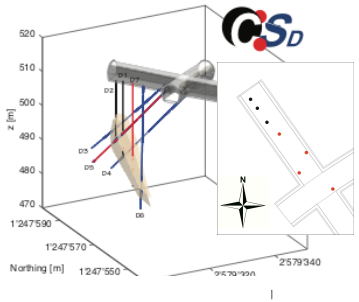
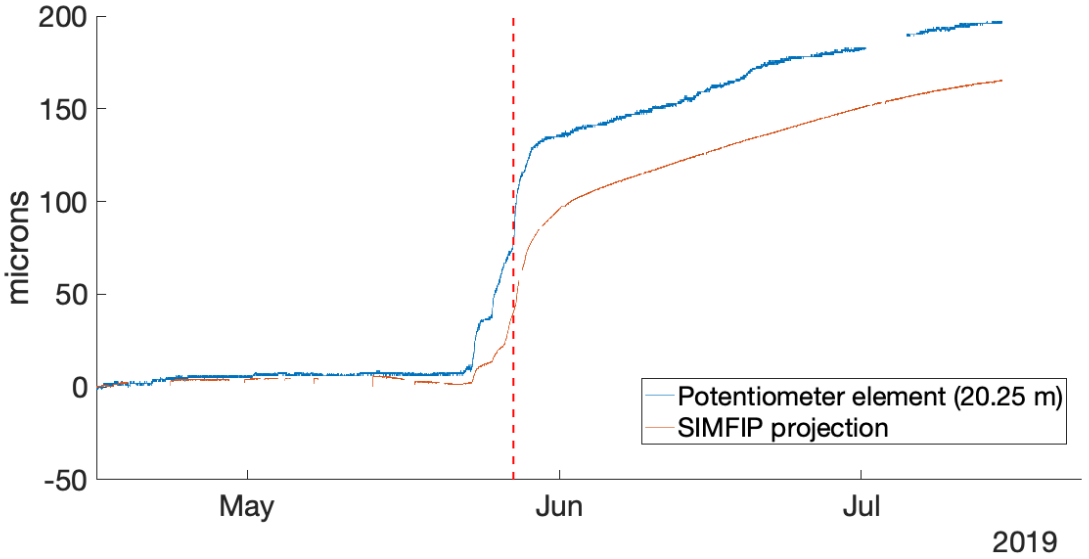
Monitoring fault response during tunnel excavation: SIMFIP vs potentiometer









- Fault slip up to 0.1 mm
- Extension of rock mass (from fault toward tunnel) with initial slip toward excavation front
- No "clear" seismicity

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Monitoring fault response during tunnel excavation: fiber optic response

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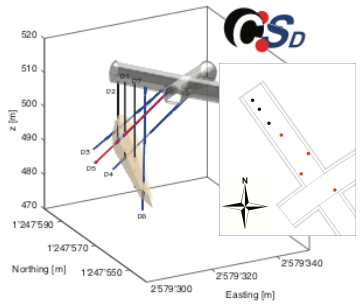

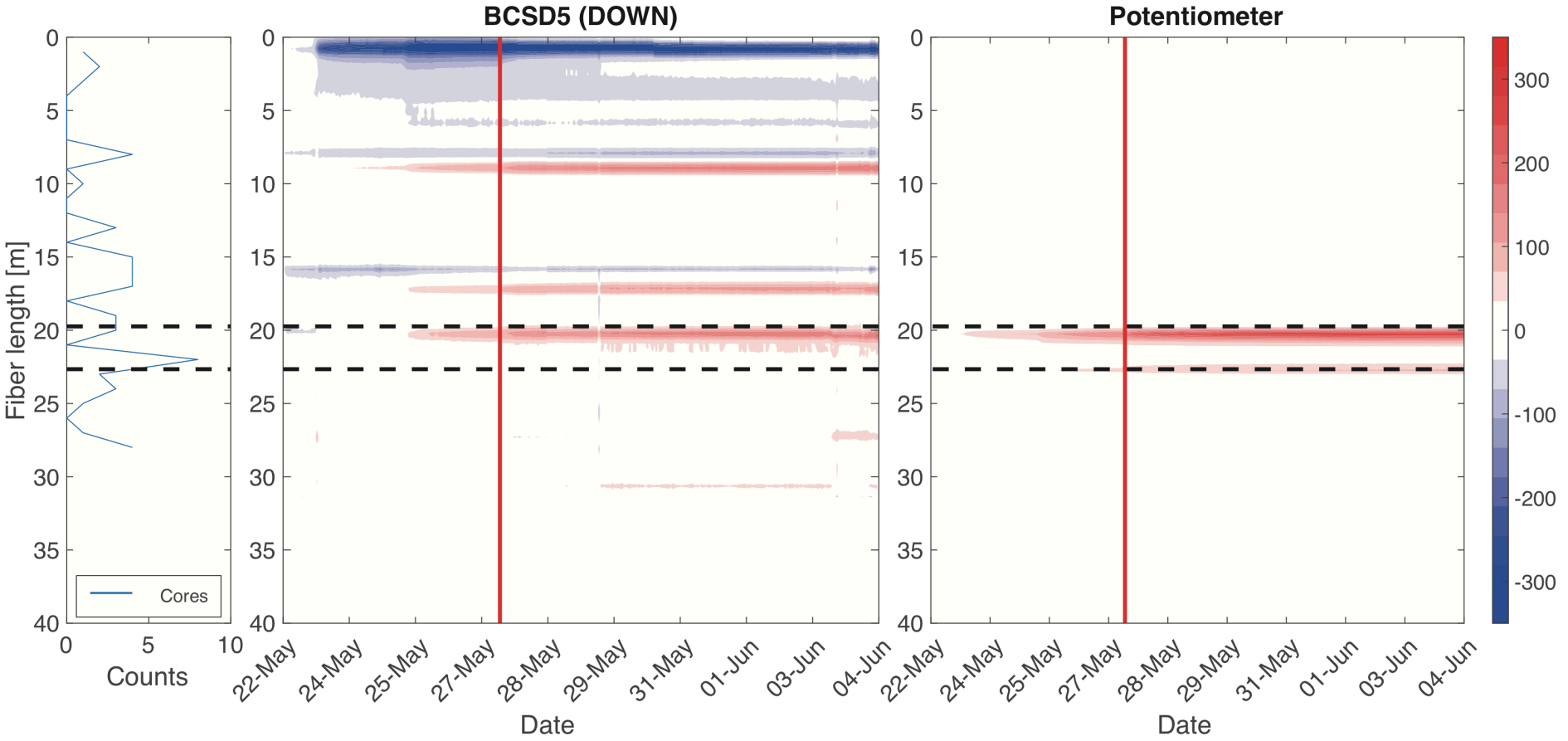

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Monitoring fault response during tunnel excavation: pressure and deformation

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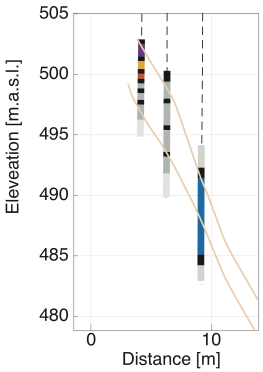

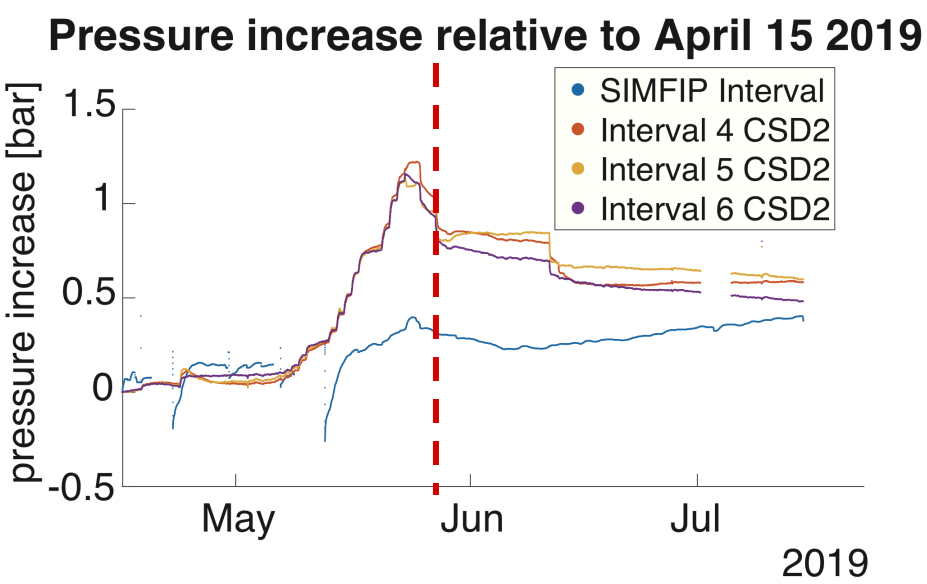

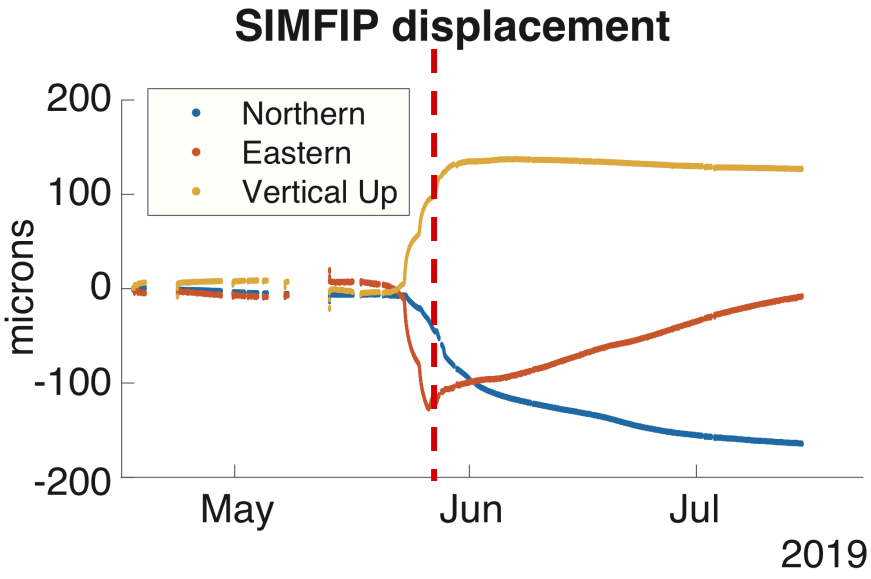

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Concluding remarks

- **Tunnel excavation affects the fault zone.** Poroelastic effects visible on pressure (increase of about 1 bar).
- Deformation up to **hundreds of microns**.
- An analysis of the slip direction and distributed deformation shows the **fault zone moving toward the tunnel and the excavation front**

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Acknowledgements

CS-D/FS-B Team: Jens Birkholzer (LBNL), Paul Cook (LBNL), Sem Demir (ETHZ), Melchior Grab (ETHZ), Yves Guglielmi (LBNL), Chet Hopp (LBNL), Maria Kakurina (UNINE), Claudio Madonna (ETHZ), Christophe Nussbaum (swisstopo), Anne Obermann (ETHZ), Katrin Plenkers (ETHZ), Dorothee Rebscher (BGR), Antonio P. Rinaldi (ETHZ), Michelle Robertson (LBNL), Florian Soom (LBNL), Alba Zappone (ETHZ), Quinn Wenning (ETHZ), Stefan Wiemer (ETHZ)

ACT ELEGANCY, Project No 271498, has received funding from DETEC (CH), BMWi (DE), RVO (NL), Gassnova (NO), BEIS (UK), Gassco, Equinor and Total, and is cofunded by the European Commission under the Horizon 2020 programme, ACT Grant Agreement No 691712.

This project is supported by the pilot and demonstration programme of the Swiss Federal Office of Energy (SFOE). It is conducted within the Swiss Competence Center for Energy Research – Supply of Electricity (SCCER-SoE / Innosuisse)

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