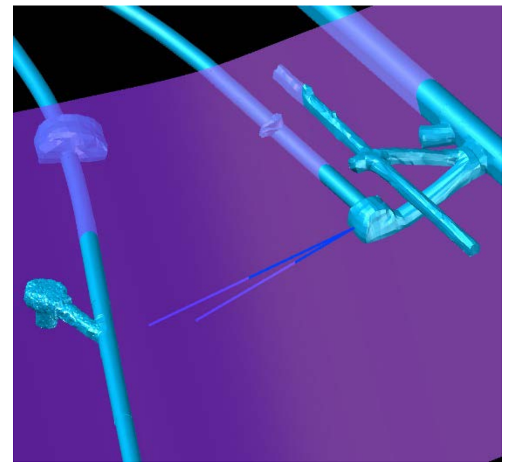
In-situ Stimulation and Circulation Experiment

SCCER-SoE, Annual Meeting
September 11, 2015



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Background

- The Swiss Energy Strategy 2050 (ES2050) plans to replace nuclear electricity production with an increase utilization of different sources of new renewable energy
- 7% of the national electricity supply shall be covered through Deep Geothermal Energy (DGE) by 2050, corresponding to 4.4 TWh per year and over 500 MWe installed capacity.
- To reach the ES2050 target, Switzerland will need to install on average 20 MWe per year between 2025 and 2050.
- A capacity of 20 MWe requires the circulation of over 220 l/s of water at temperatures of 170-190°C, commonly found at 4-6 km depths in Switzerland.
- As hydrothermal water is scares and difficult to locate, deep reservoirs will need to be created in hot crystalline basement rock (EGS), safely and at competitive costs.

Road Map - Deep geothermal Energy

To enable the **large-scale exploitation of deep geothermal energy** for electricity generation in Switzerland, solutions must be found for two fundamental and coupled problems:

(1) How do we **create an efficient heat exchanger** in the hot underground that can produce energy for decades while

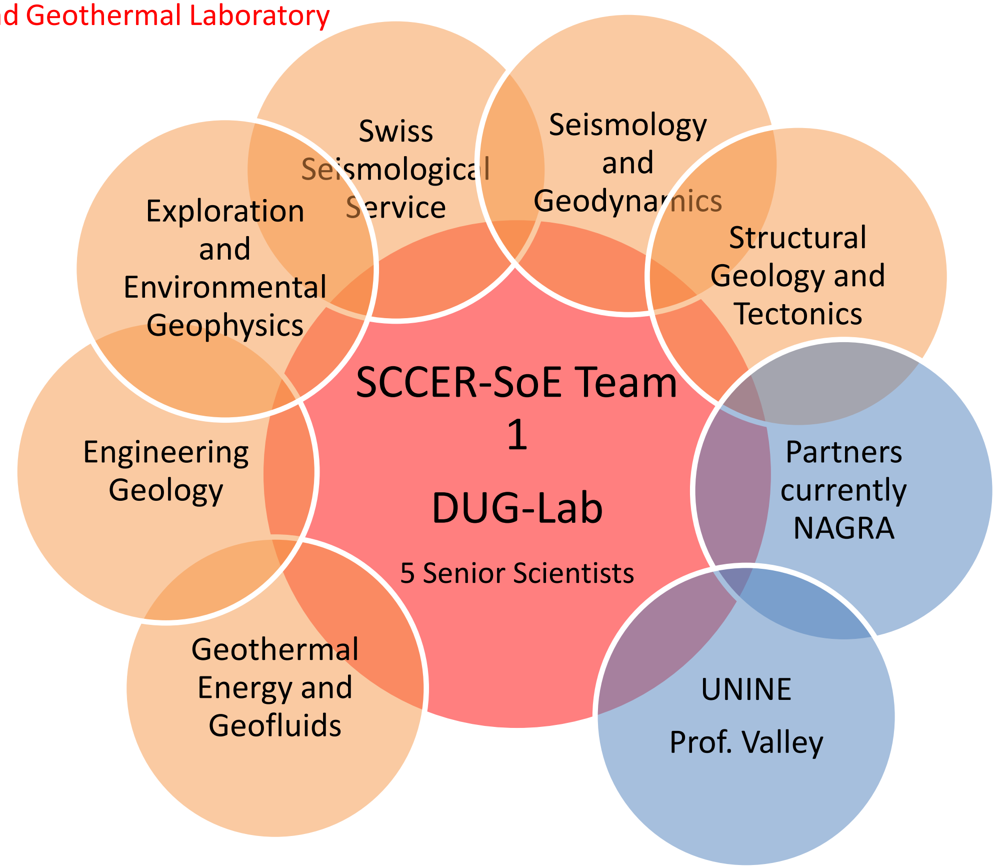
(2) at the same time keeping the nuisance and risk posed by **induced earthquakes to acceptable levels**?

→ **A fundamental understanding of key THM-coupled processes and its is link to micro-seismicity is essential**

→ **Calls for an initiative operating across many disciplines**

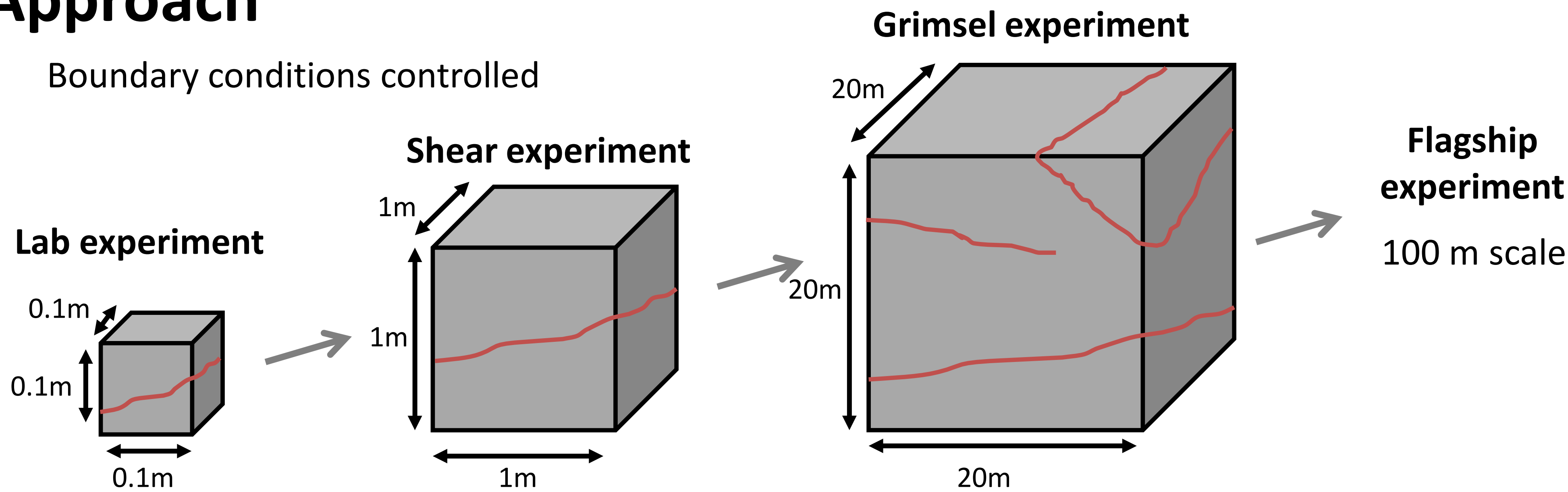
Collaborating chairs at ETH and partners

SCCER-SoE: Swiss Competence Center for Energy Research – Supply of Electricity
DUG-Lab: Deep Underground Geothermal Laboratory
ETH Chairs
Partners



Approach

Boundary conditions controlled



Laboratory Tests on intact rock and fractures

- THM properties
- Micro-seismicity
- Rate and state friction
- …

Large-scale Shear Tests

- Secondary fracture formation
- Dilatancy versus scale and permeability creation
- Anisotropic flow
- Micro-seismicity

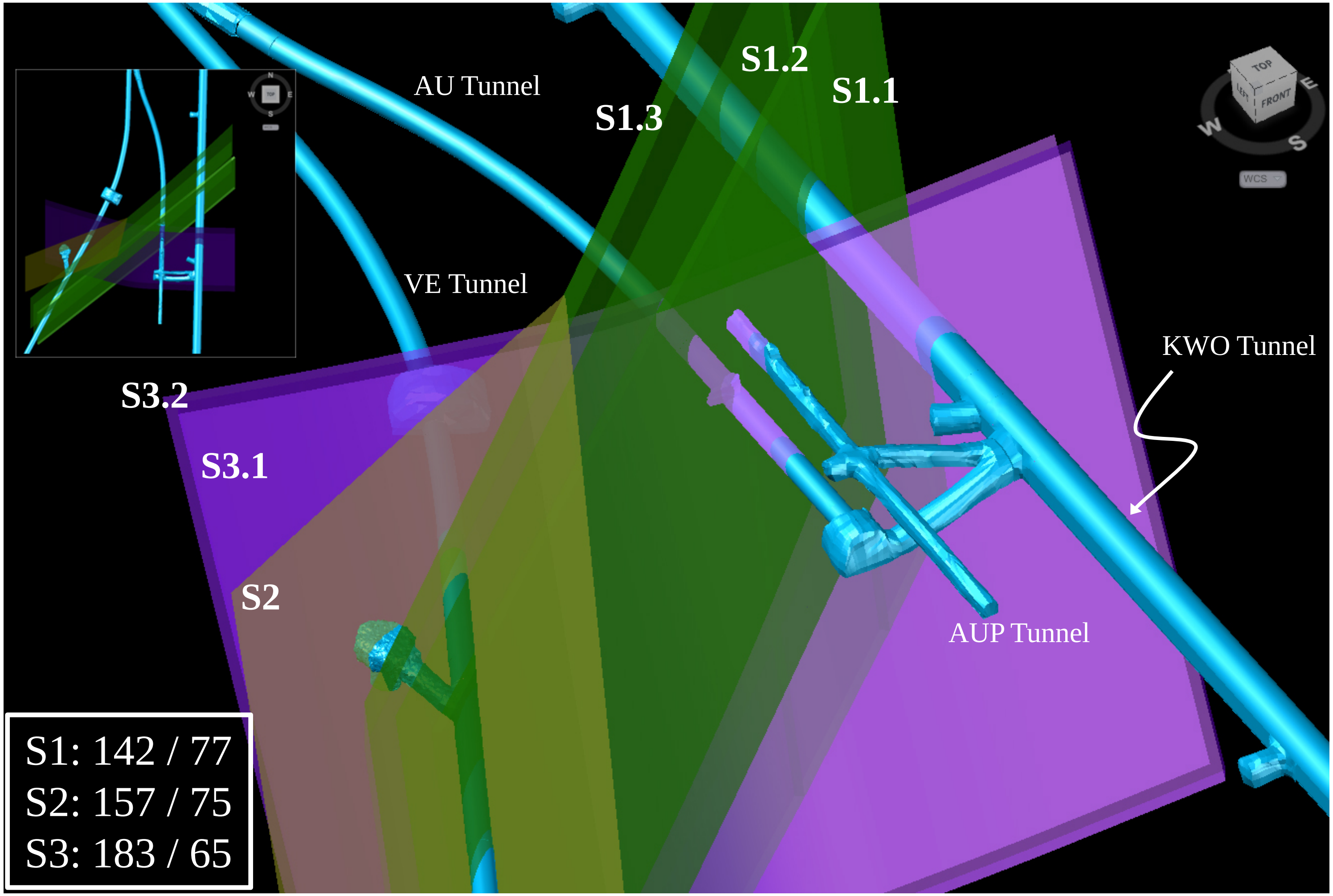
Stimulation & Circulation Experiment

- Hydro-shearing of faults
- Micro-seismicity
- Pressure propagation during shearing
- Permeability creation
- Thermal transport properties
- …

ISC- Objectives

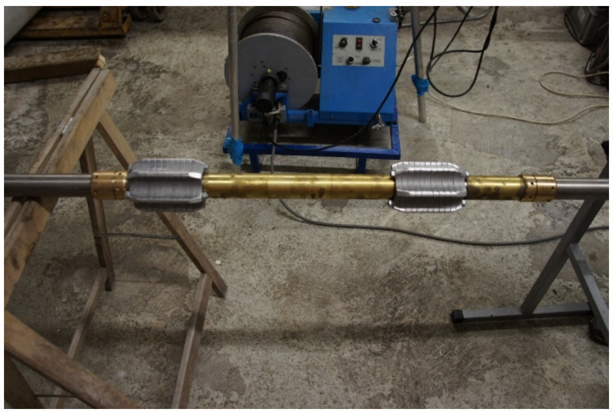
- High-resolution pre- and post-stimulation permeability, fracture connectivity and thermal transport properties of a set of interacting brittle shear zones.
- Real-time monitoring of 3D fault displacement, permeability changes, pore pressure propagation, and its relations to the transition between aseismic and seismic slip during hydraulic stimulation
- Physical constraints to spatio-temporal induced seismicity characteristics relevant for seismic hazard and risk estimation, such as the relative size distribution, the stress drop of earthquakes, the relevance of static and dynamic stress transfer as fault reactivation mechanism and the decay rate of activity.
- Apply and develop novel computational tools merging earthquake source physical and reservoir geomechanical modelling techniques to reproduce inferred physical processes underlying seismicity characteristics and aseismic slip.
- Develop novel imaging techniques so that multi-offset single-hole and cross-hole data can be processed into 3D images of the volume around the boreholes.
- Explore, if collocated GPR and seismic measurements can be processed jointly such that one data set can guide the migration of the other one.
- First phase demonstrator for traffic light system

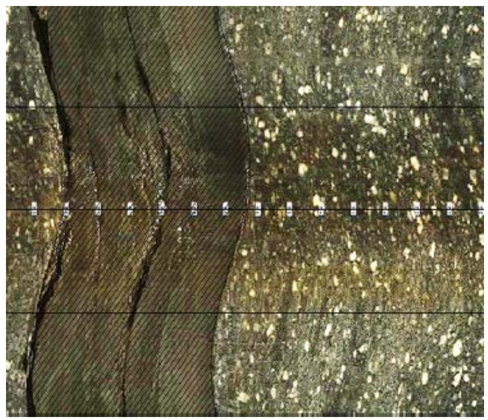
Experimental rock volume



Experimental rock volume

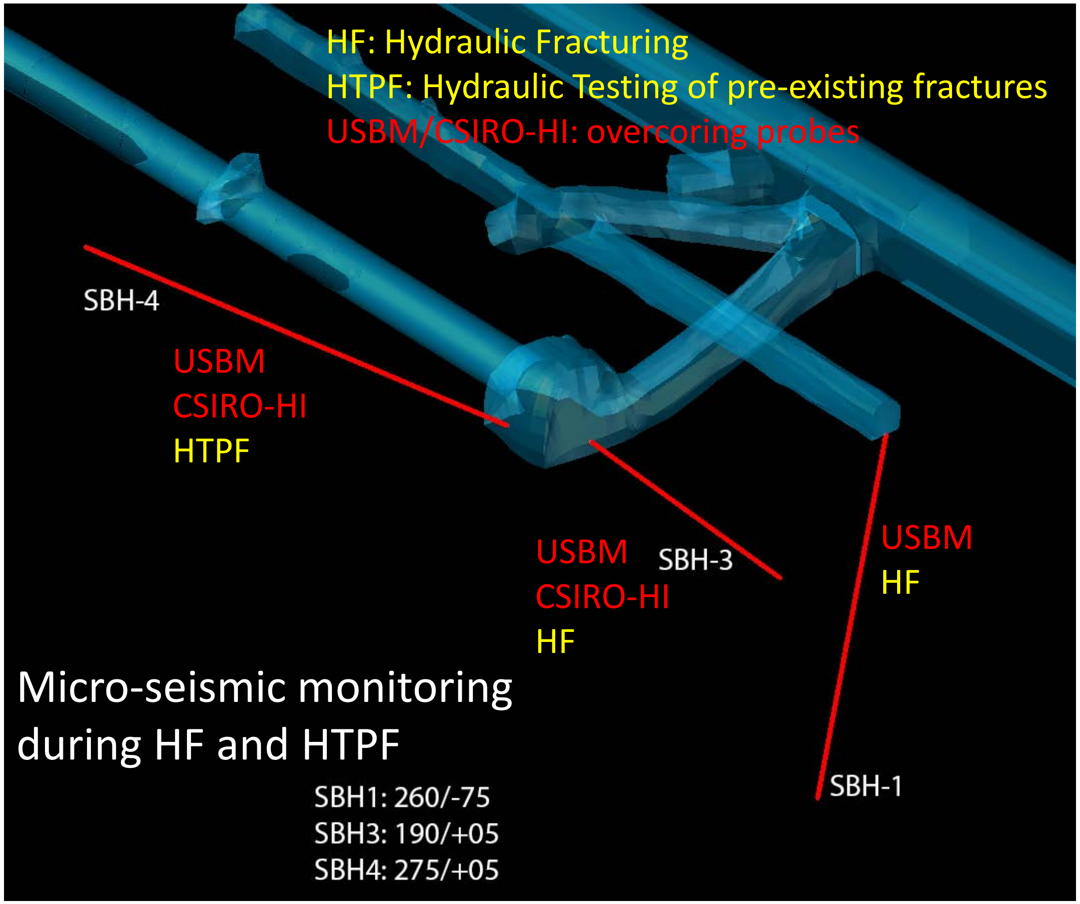
- X-hundred of meter cores and OPTV logs
- Exceptional well characterized rock volume (i.e. structures, hydraulics, stress, mechanics)
- 3D structural model is basis for feasibility analysis and risk assessment





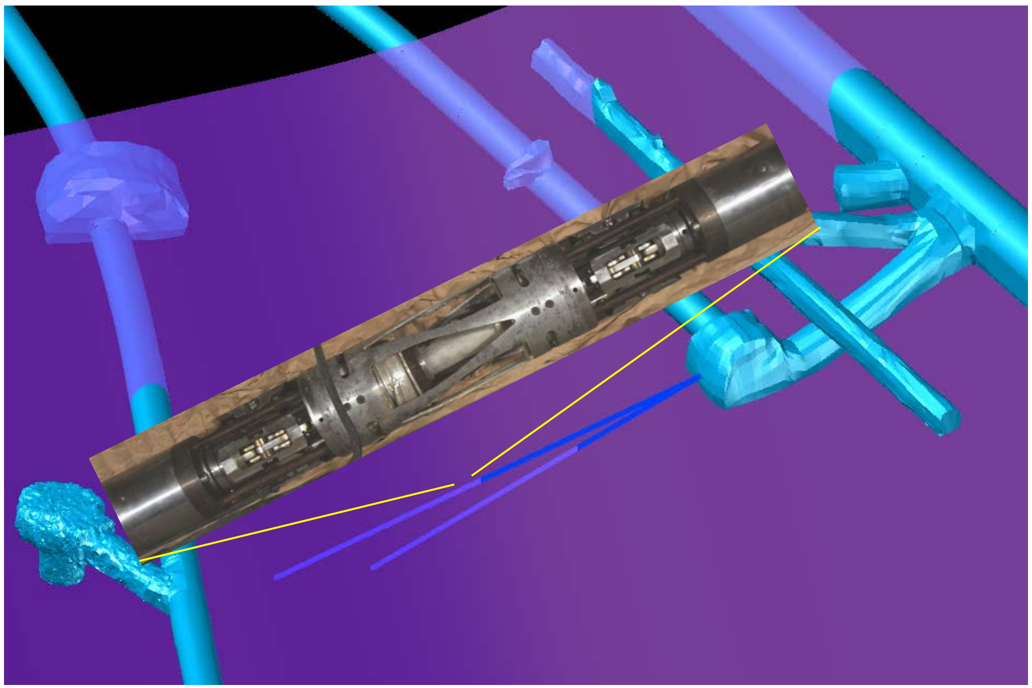
Stress measuments

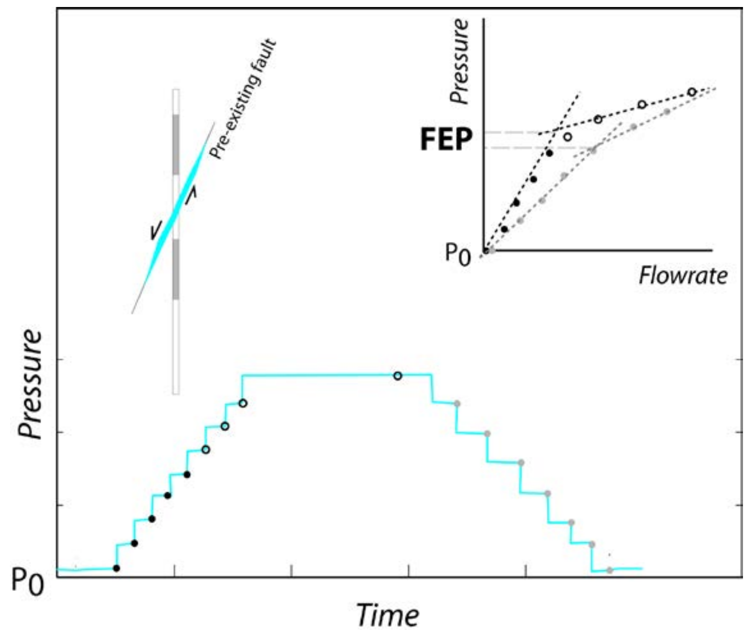
Phase 1 stress measurements



Fault Slip Experiment

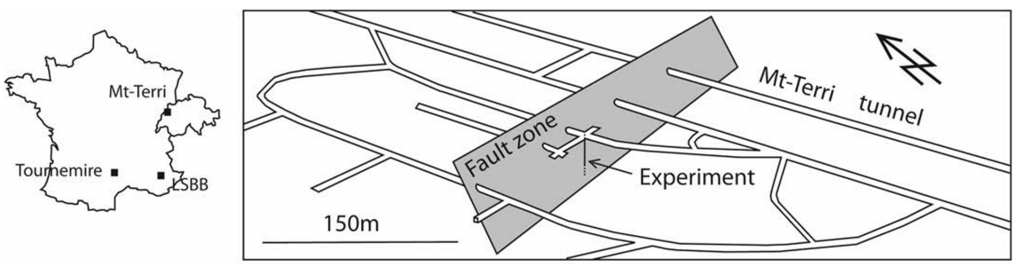
- **Controlled fault slip** (slip magnitudes in the range of 100 μm)
- SIMFIP probes allow measuring 3D displacements, pore pressure and flow rate in real time
- 2 Injectors, test procedure for stimulation and shut-in

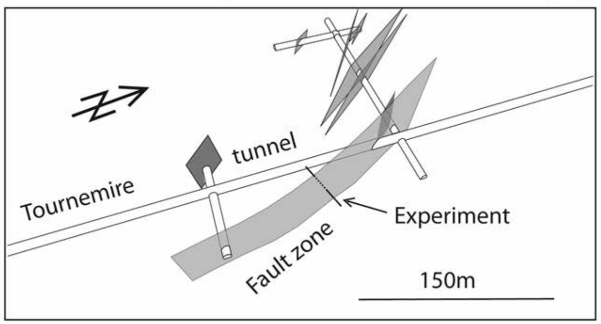


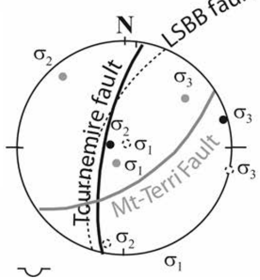


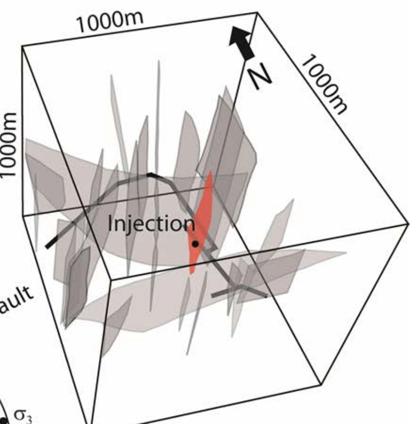
Guglielmi et al. 2014

Experience with Fault Slip experiments



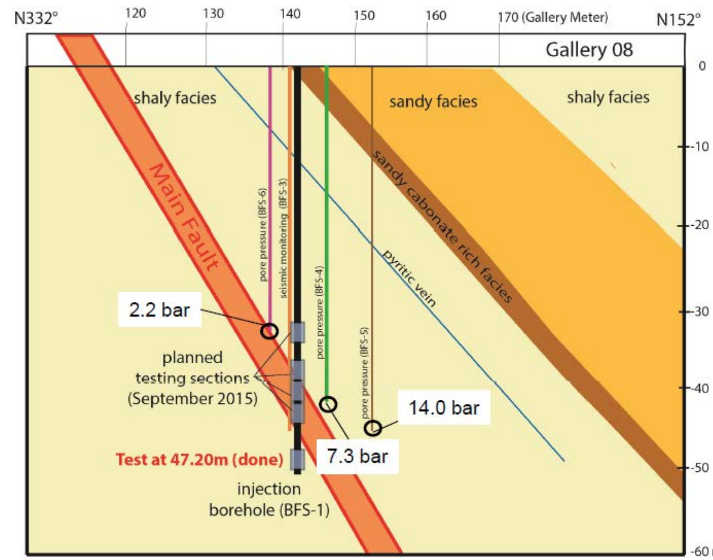






Tournemire, France (Shale)
→ events with M <<0

Low Noise Laboratory, France (Limestone)



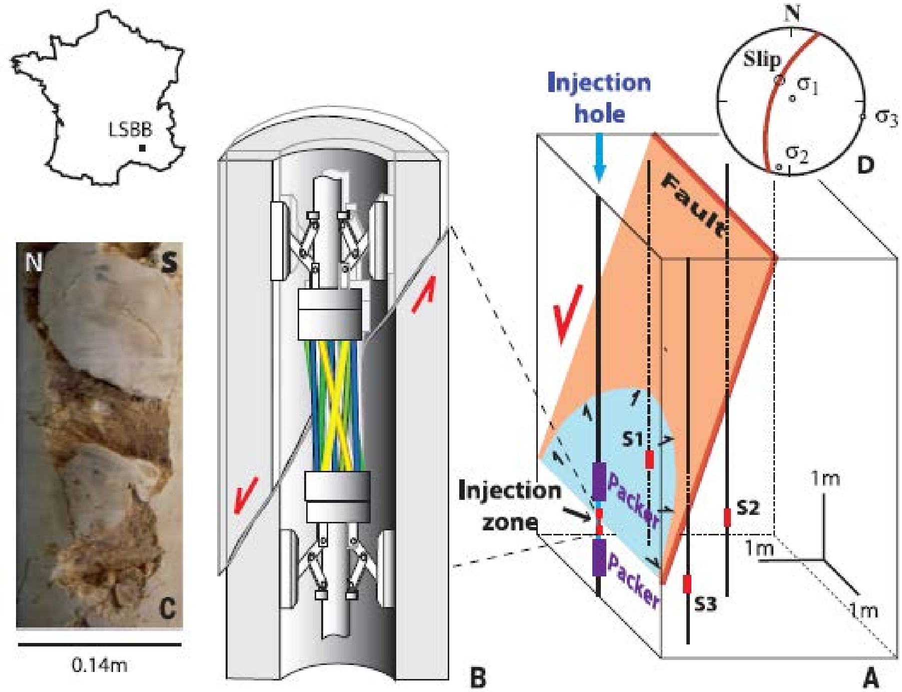
Underground research laboratory Mont Terri (Shale)

Guglielmi et al. 2014

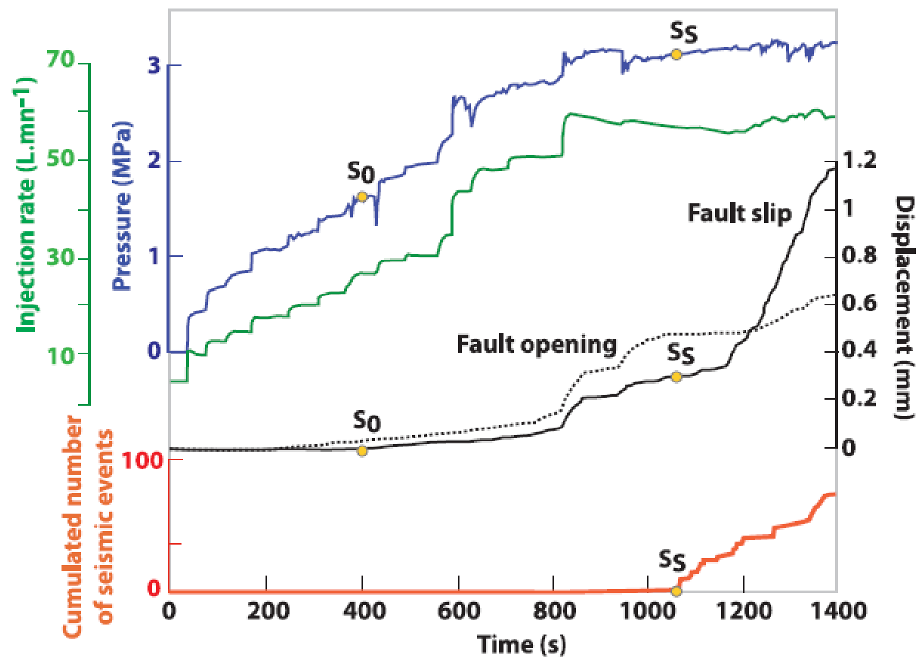
Guglielmi et al. 2015

Experience Low Noise Laboratory, France

Experimental Layout



Injection pressure, flow rate and seismicity

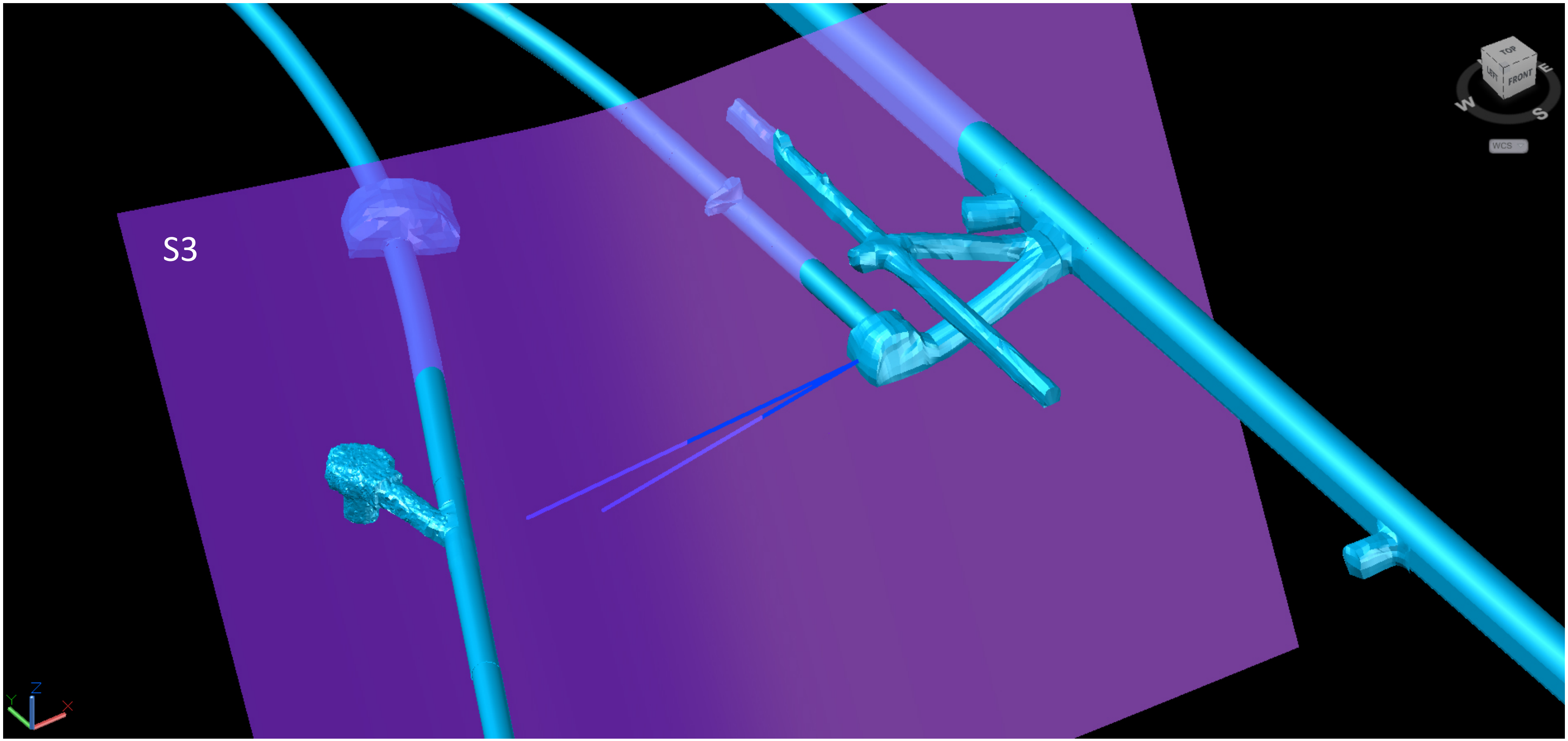


Guglielmi et al. 2015

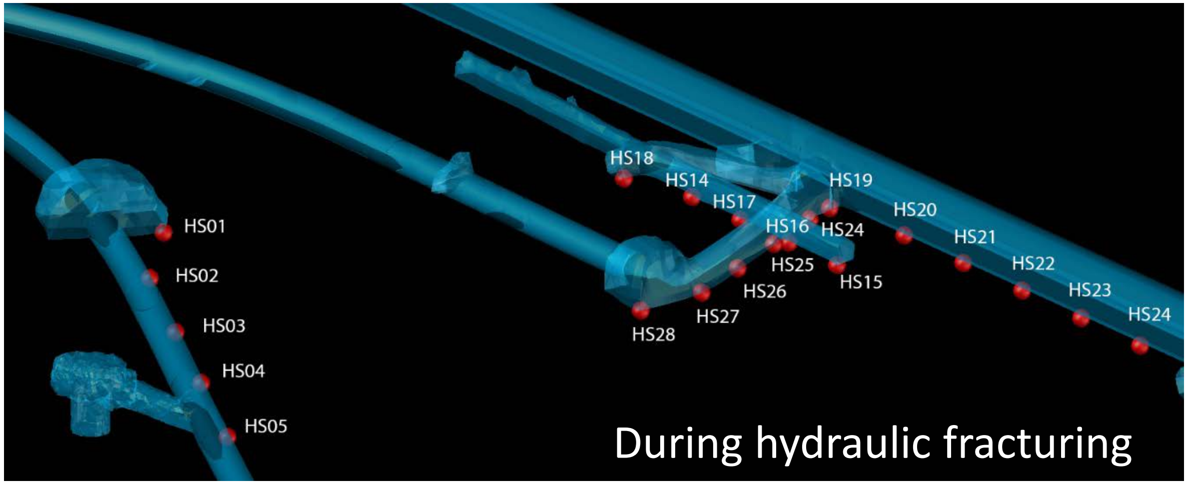
Monitoring borehole

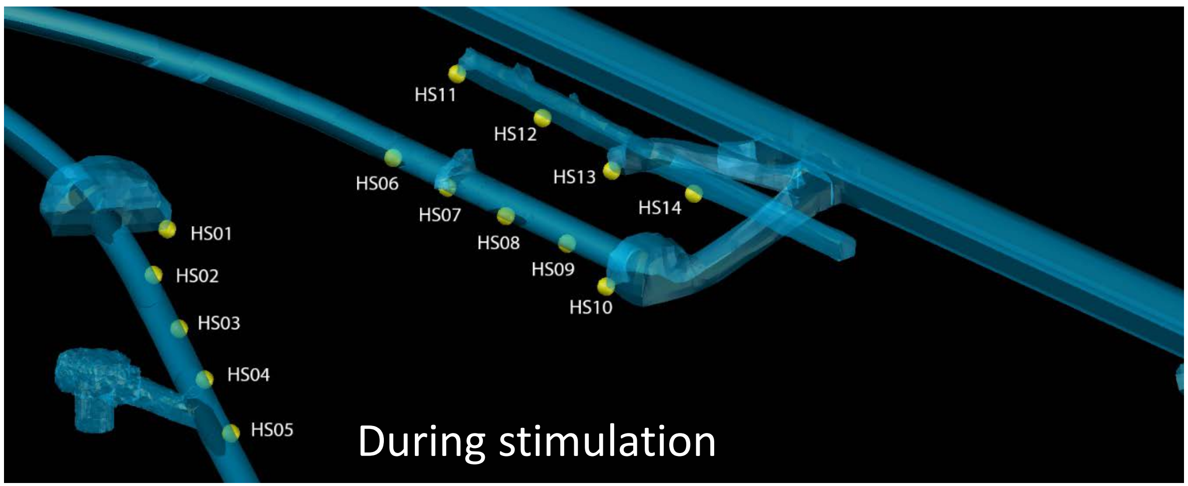
[illegible]

- Injection Borehole (BHINJ)
- Stress Measurement, Tilt-meter Borehole (SBH)
- GPR, Active Seismic Boreholes (BHAM)
- Passive Seismic Borehole (BHSM)
- Stress, Strain, Temperature (FBG) Borehole (BHST)
- Pressure, Temperature Borehole (BHPT)
- Strain, Temperature (DTS) Borehole (BHDS)

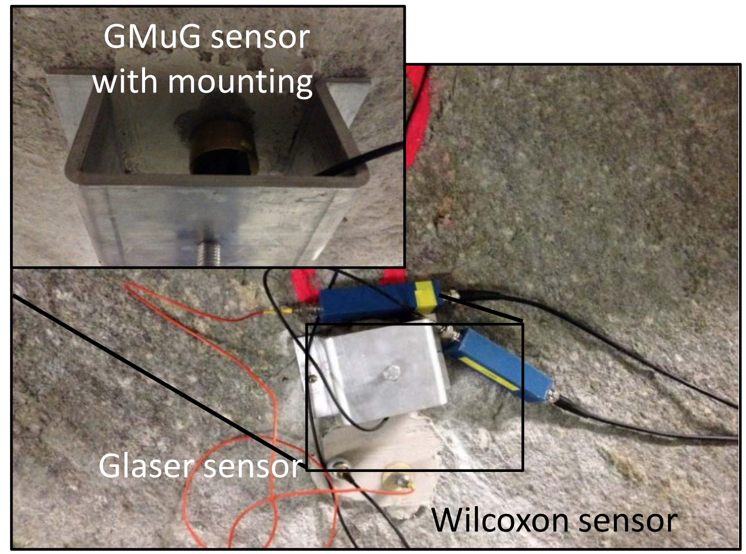


Laboratory-scale seismic Monitoring

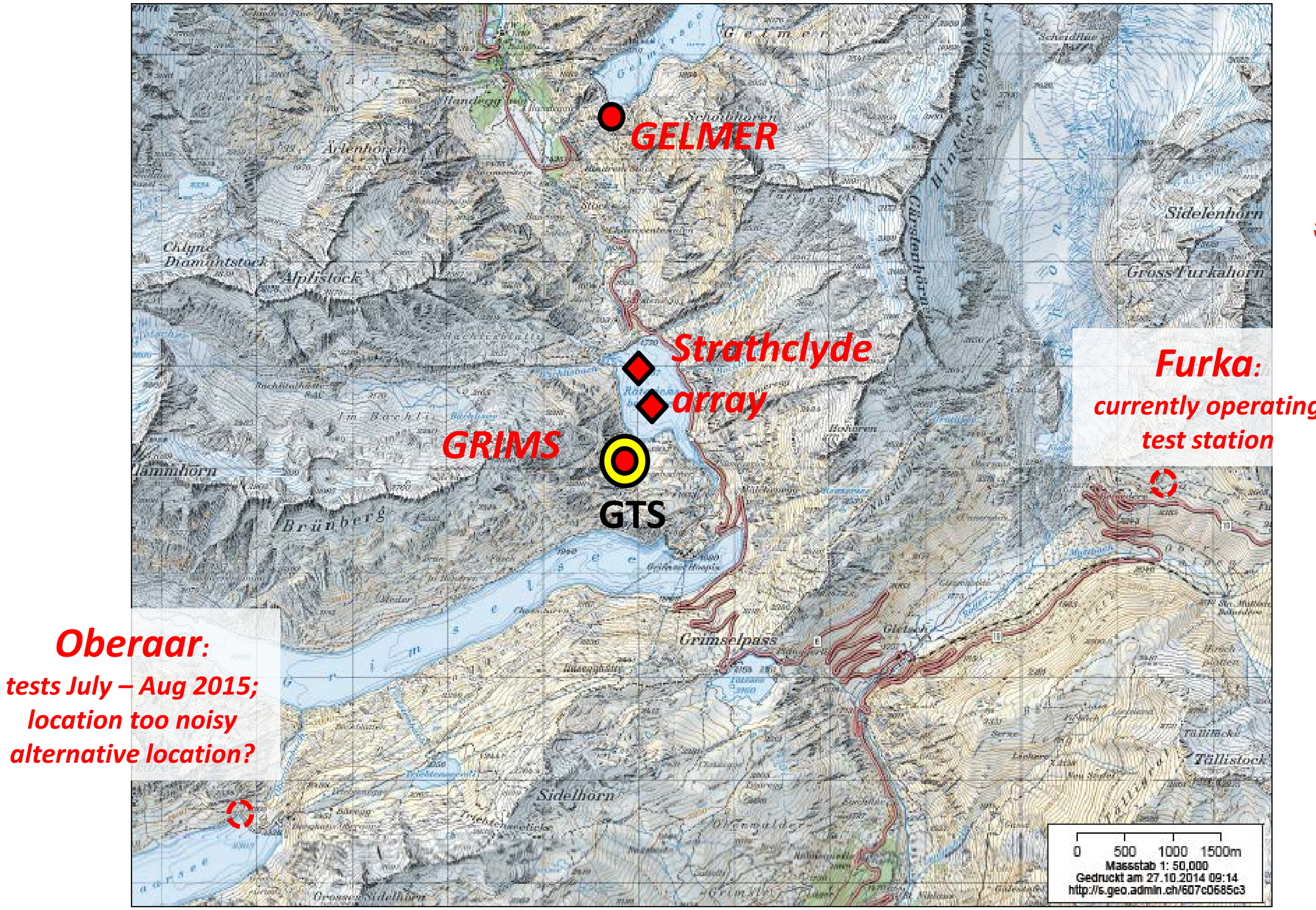




Optimized locations for optimal event localization
(Supplemented by borehole sensor arrays close to the faults; not shown)
→ Event localization in real time



Seismic Monitoring



Planned surface seismic network

Two installed stations

2 – 3 ? additional stations

Goal:

Lowering detection threshold of national seismic network

Distinguish natural from induced earthquakes in case of a significant event

Thanks for your attention