ETH zürich

SCCER SoE

Fracture Transmissivity Development as a Response to Hydraulic Fracturing and Hydraulic Jacking at Grimsel Test Site

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In cooperation with the CTI

Energy funding programme
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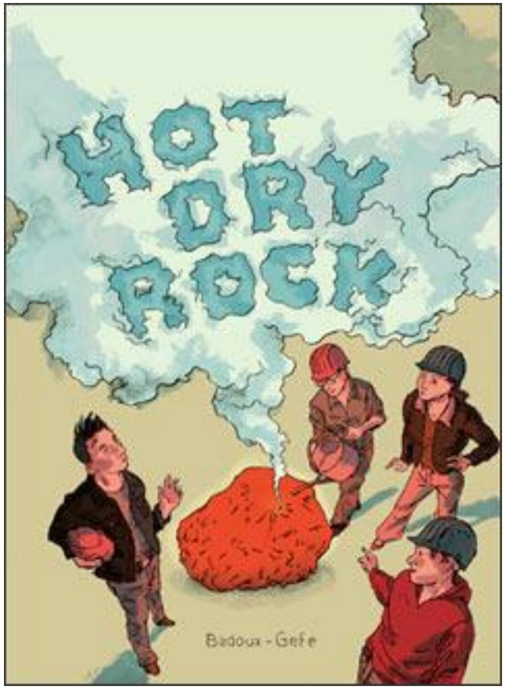
SWISS Road Map – Deep Geothermal Energy

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

(1) How do **we create an effecient 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 link to micro-seismicity is essential**
- **Calls for an initiative operating across many disciplines and scales**

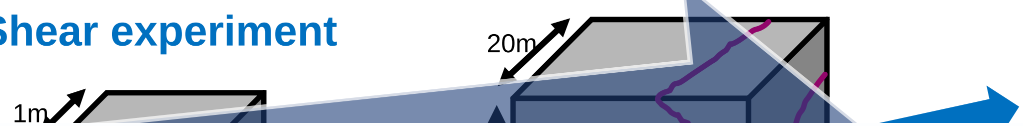
Multiscale Approach

Grimsel experiment

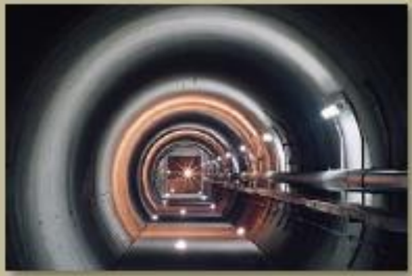
Shear experiment

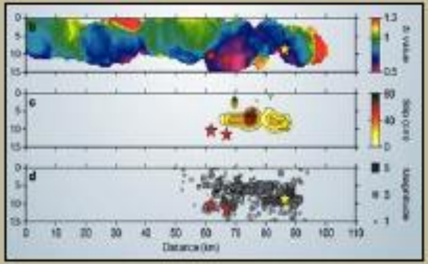
Flagship experiment

Lab experiment



10 cm | 10 m | 100 m | 1 km | 10 km





Laboratory Scale

Underground Lab Scale

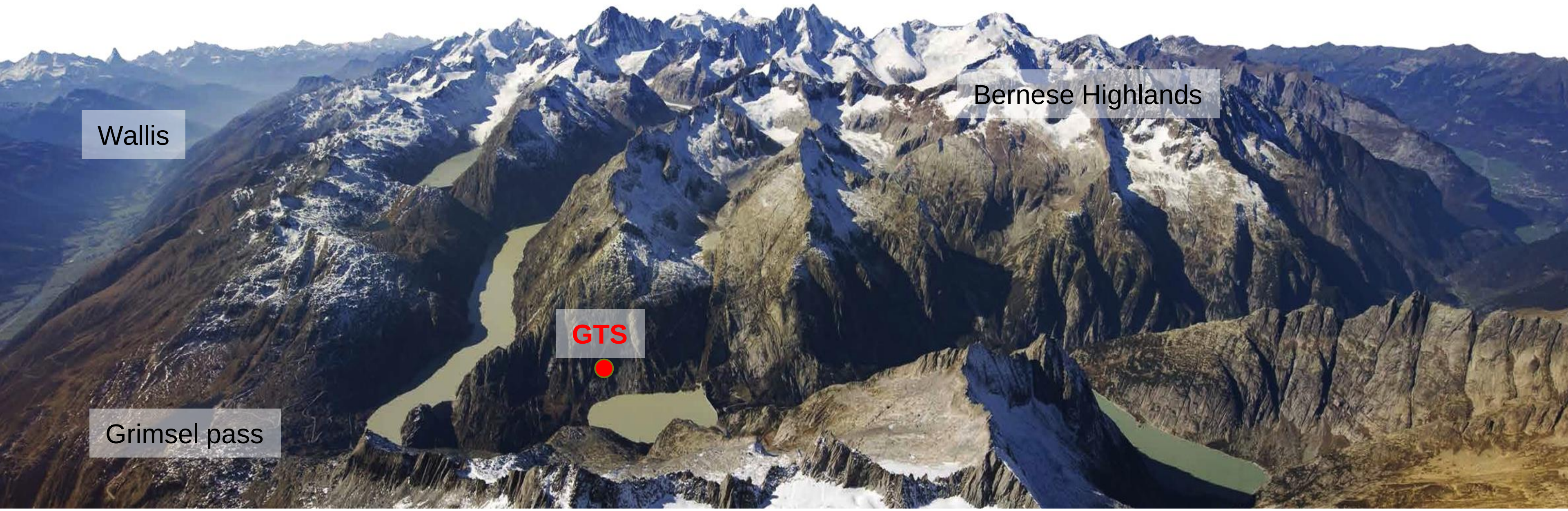
Natural Systems

- …

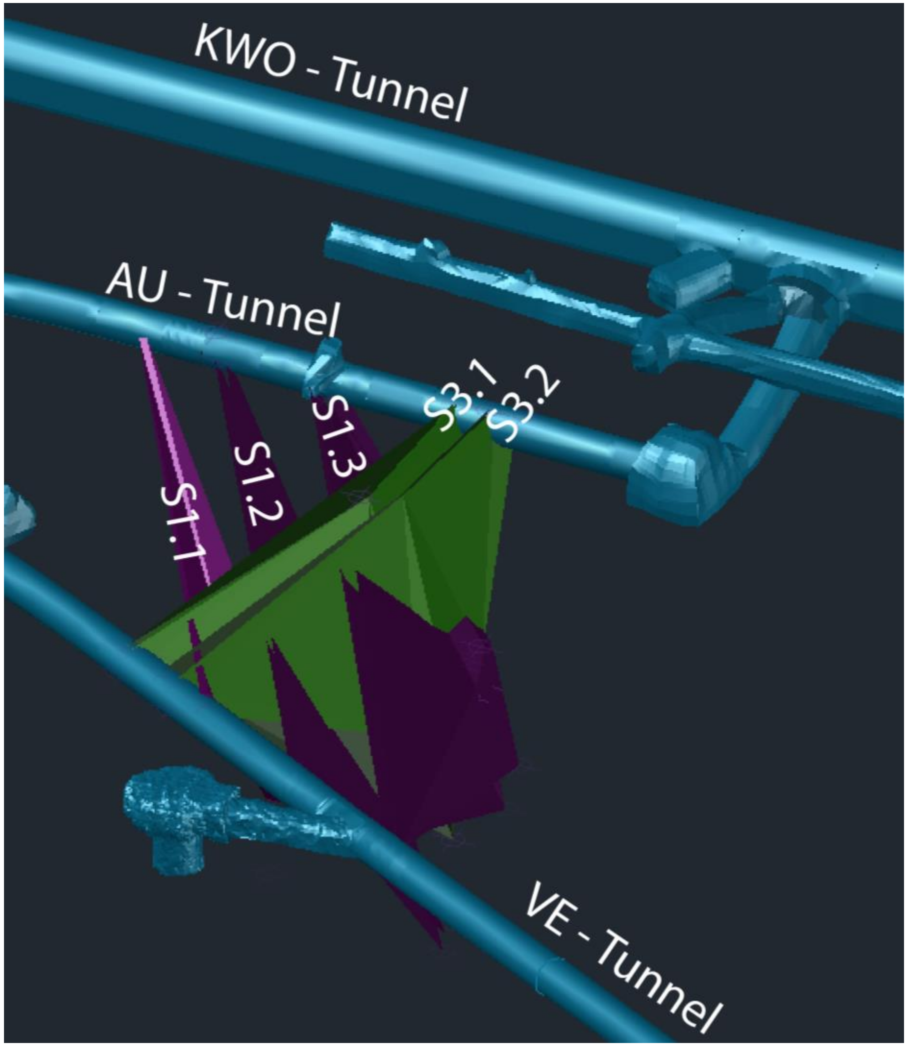
- HM fault/fracture properties
- …

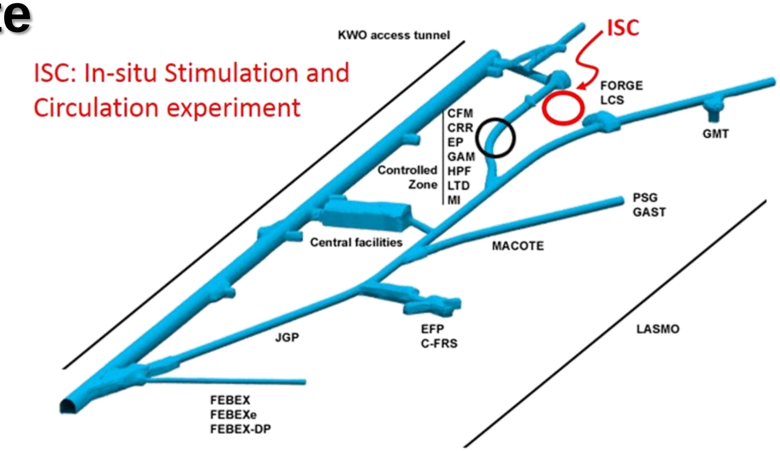
Grimsel Test Site (GTS) in the Swiss Alps

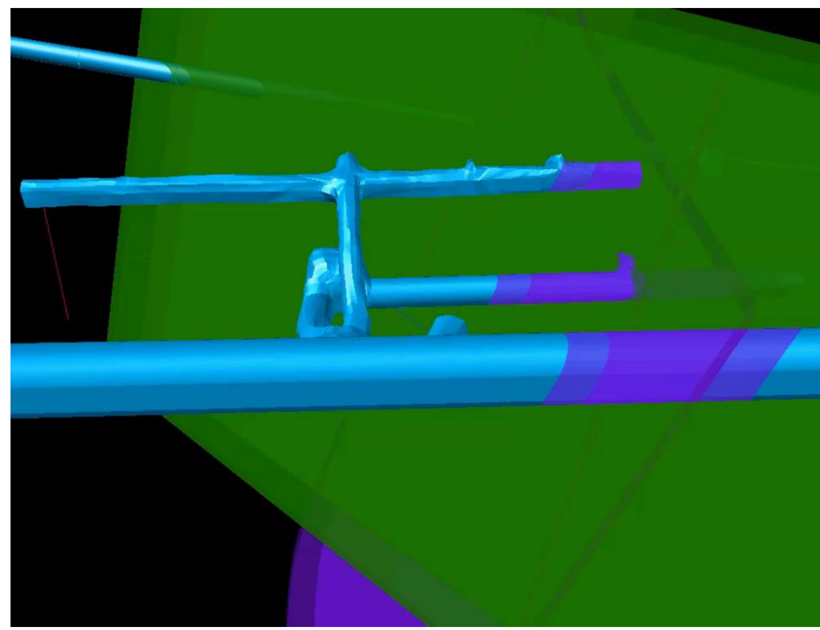
- GTS operated by nagra.
- Originally built for experiments concerning nuclear waste storage
- Now open to other projects



ISC Experiment at the Grimsel Test Site







Requirements for the Fault Slip Experiment

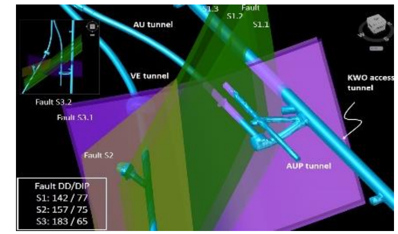
- Experimental rock volume that contains fault zones which is exceptionally well characterized (i.e. structures, in-situ stress and reservoir pressure, thermal and hydraulic properties, etc.)

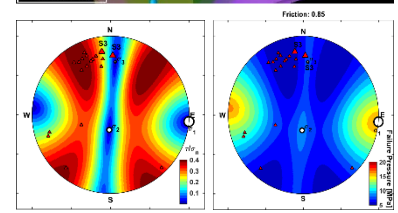
- Fractures which support shear stress and can be reactivated with reasonable injection pressures

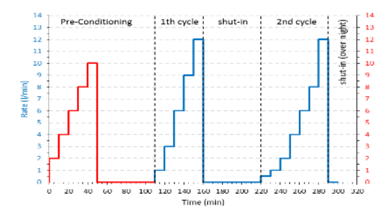
- A borehole probe that allows high pressure injection and simultaneous measurements of 3D dislocations, flow rate and pressure

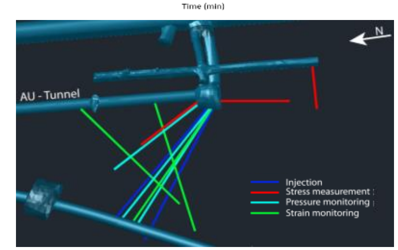
- Monitoring of key parameters in the rock volume during injection such as pore pressure and displacement, strain, tilt

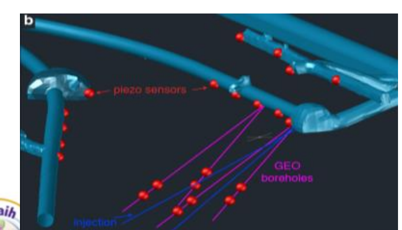
- Micro-seismic monitoring on various scales and frequency ranges; real time localization of micro-seismic events





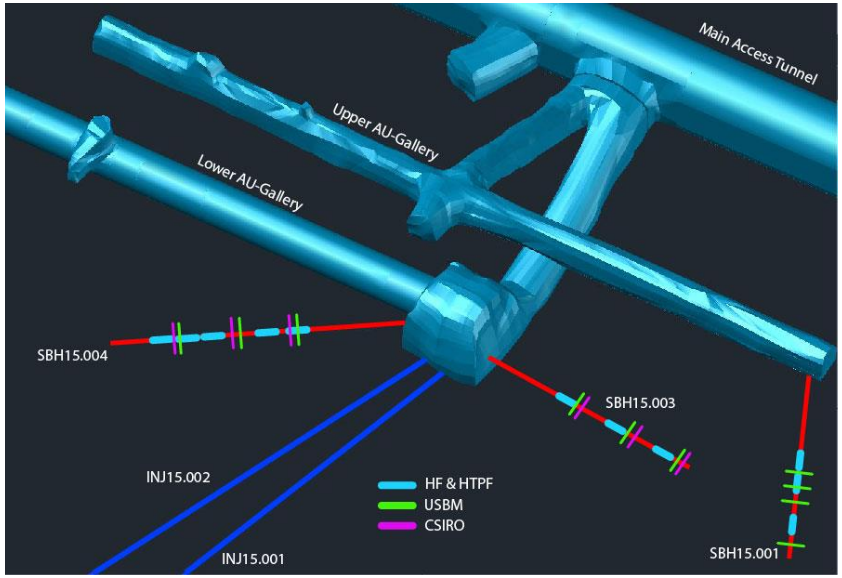




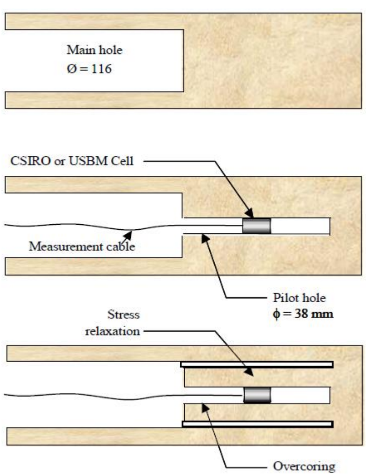


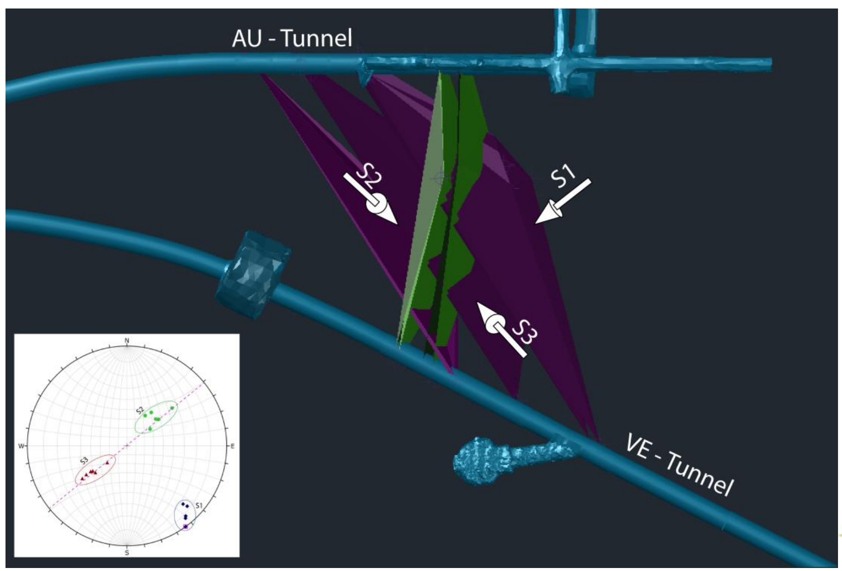
Stress Measurements

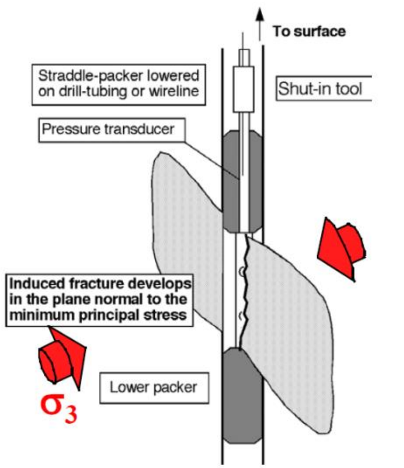
Overcoring



Hydraulic fracturing







25-29th September 2016
Montpellier, France
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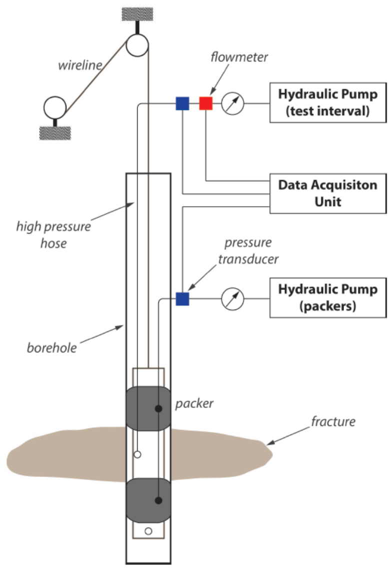
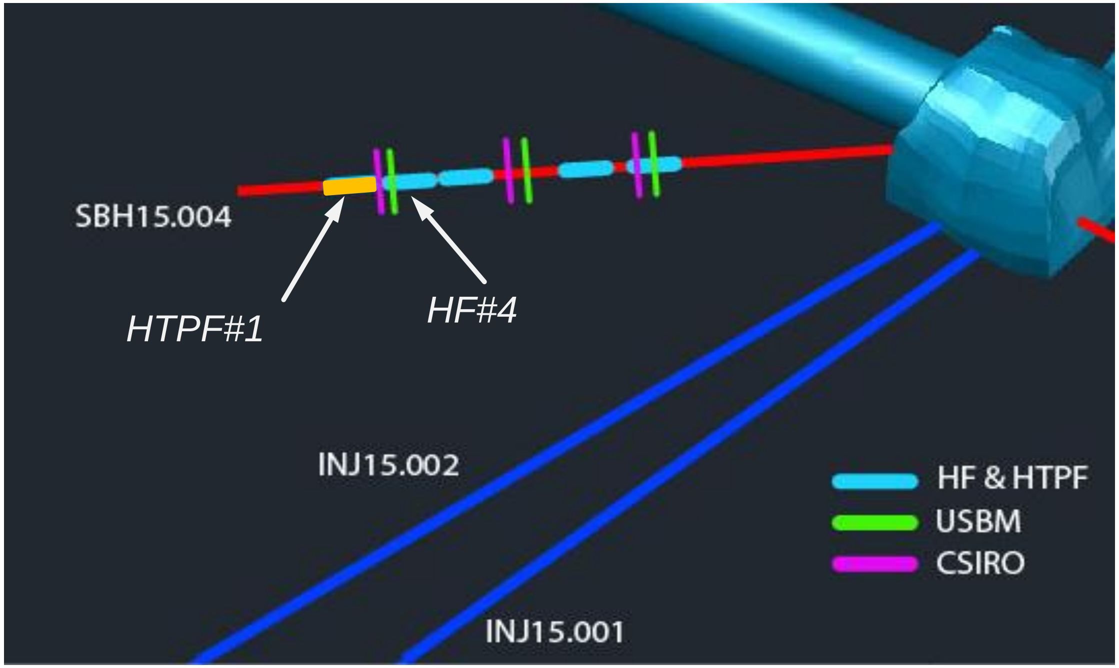
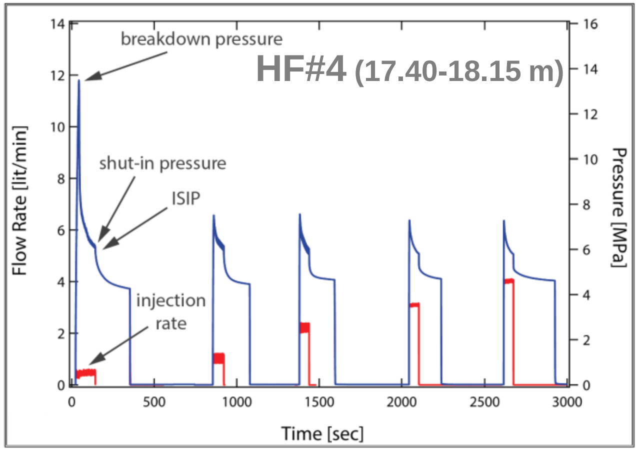
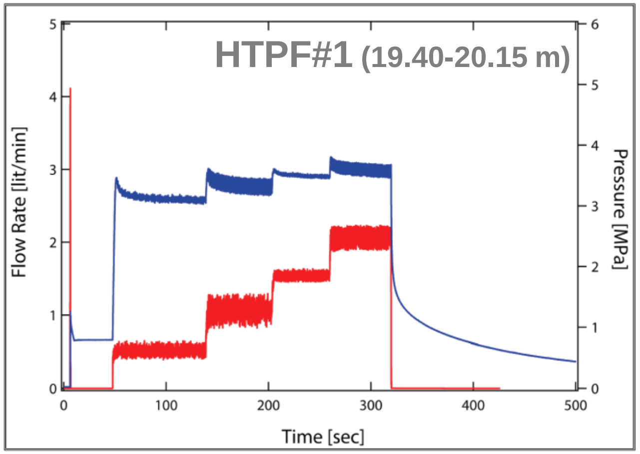
43rd IAH congress

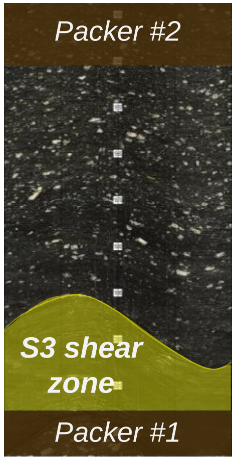
HF & HTPF in SBH15.004





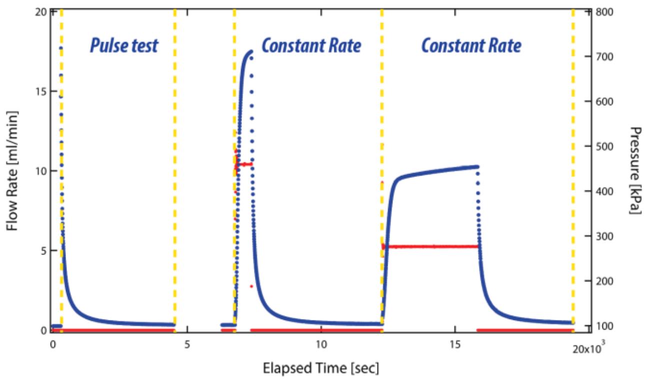


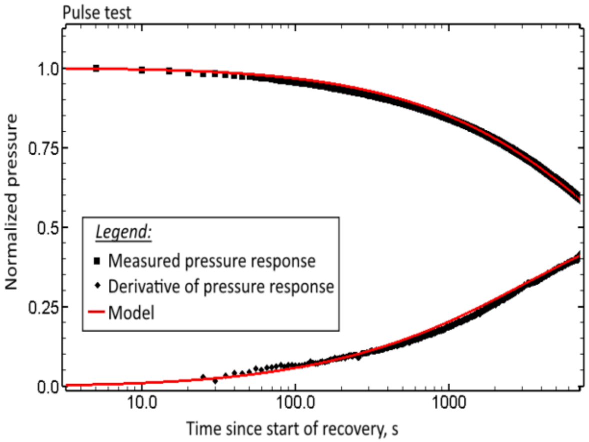


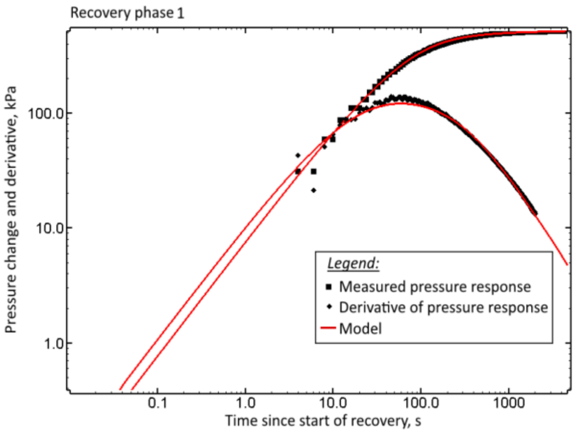


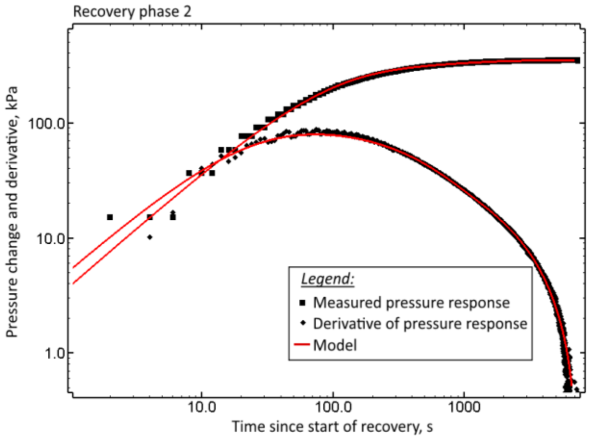
Hydraulic Characterization of SBH15.004

- A series of hydrogeological tests (*pulse injection* and *constant rate injection*) using a downhole triple packer system were conducted in stress measurement borehole (SBH15.004) *before and after HF and HTPF tests* (*maximum injection pressure < 7 bars*).
- The measured data was interpreted using existing analytical and numerical solutions in order to estimate ***T***, ***S***, ***Cz*** and ***n*** (flow dimension).
- Diagnostic plots was impletemened to understand the dynamic behavior of flow regime during each hydraulic test.

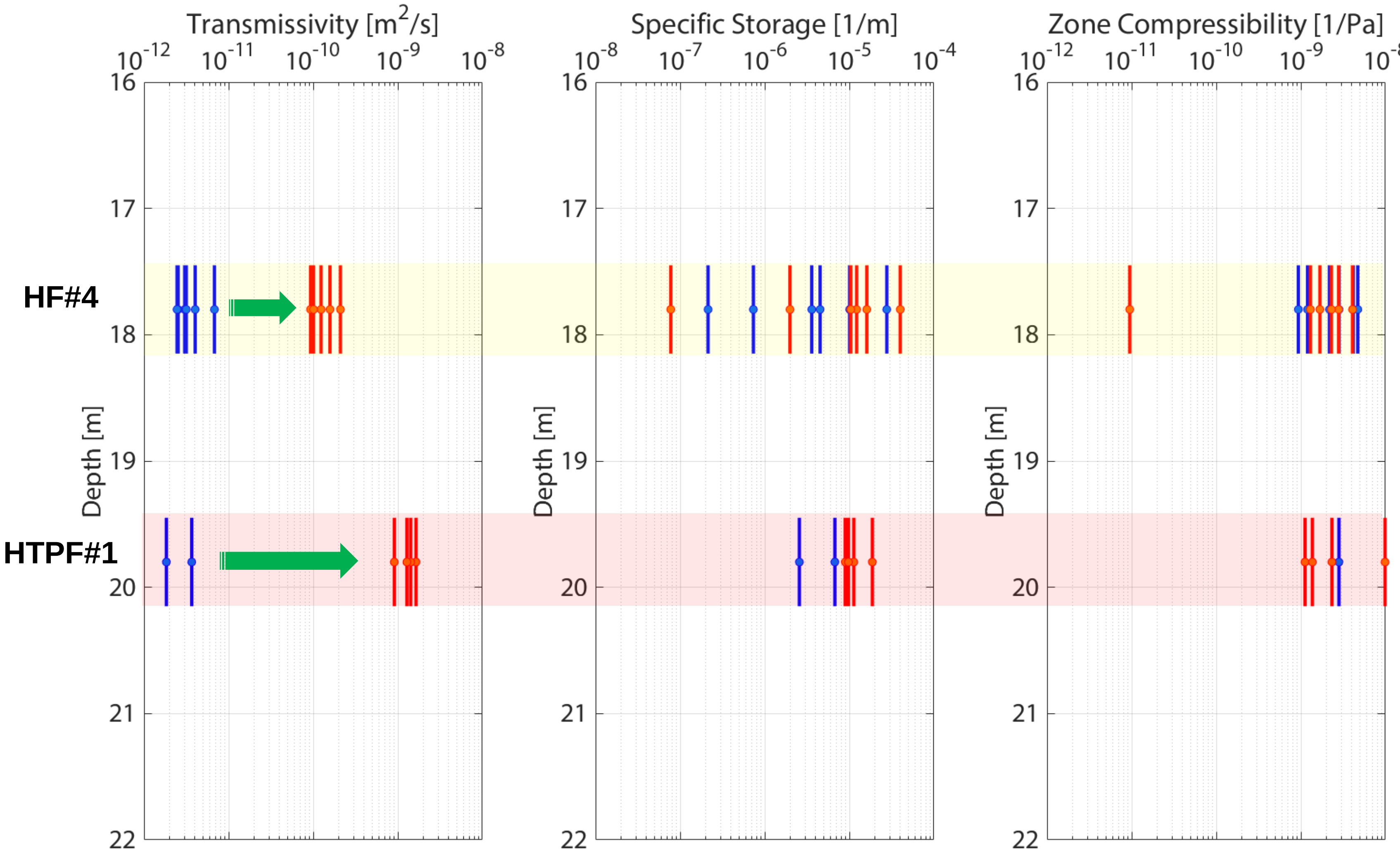






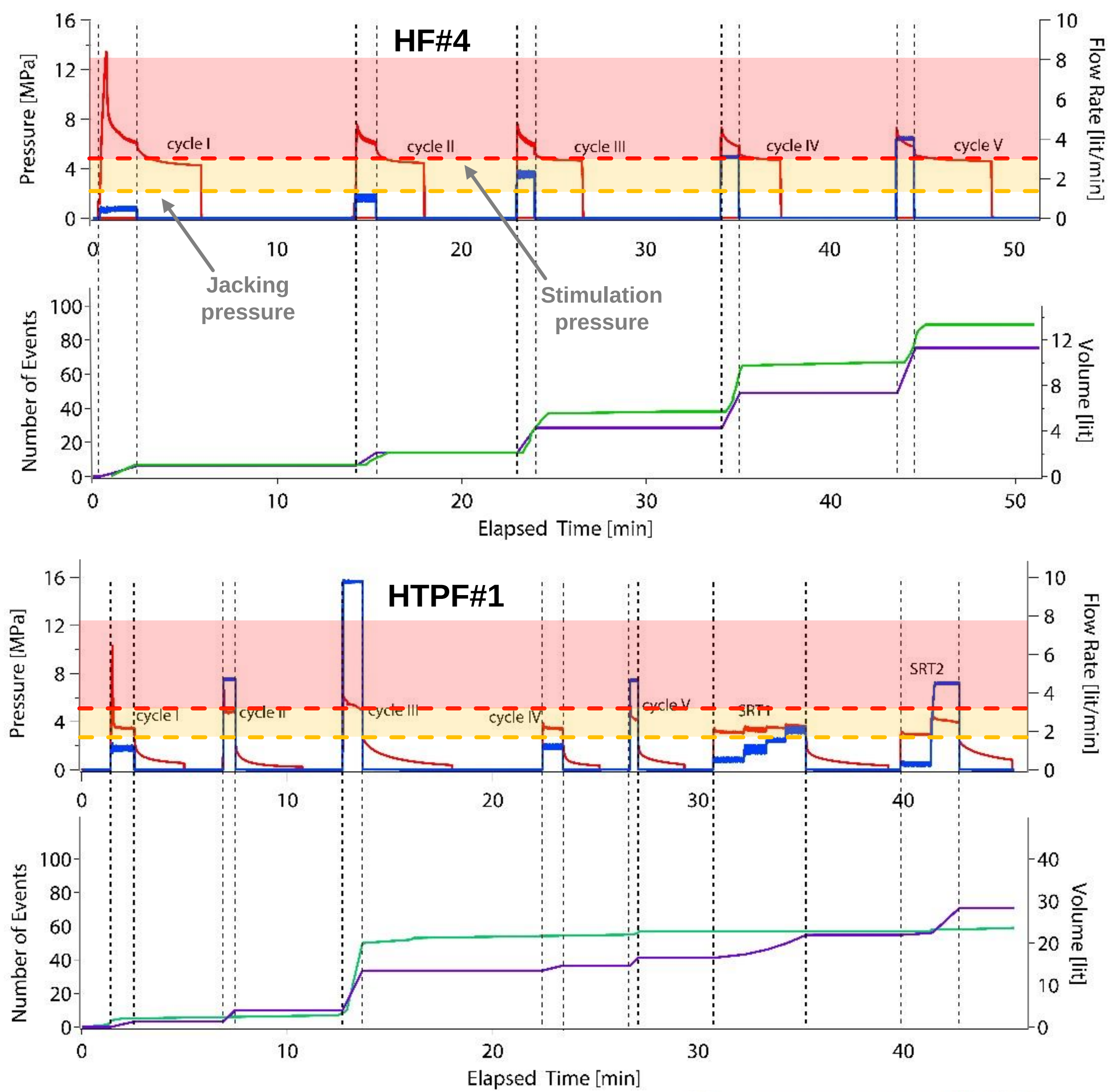


Evolution of Hydraulic Proeprties



Injection vs. Seismicity

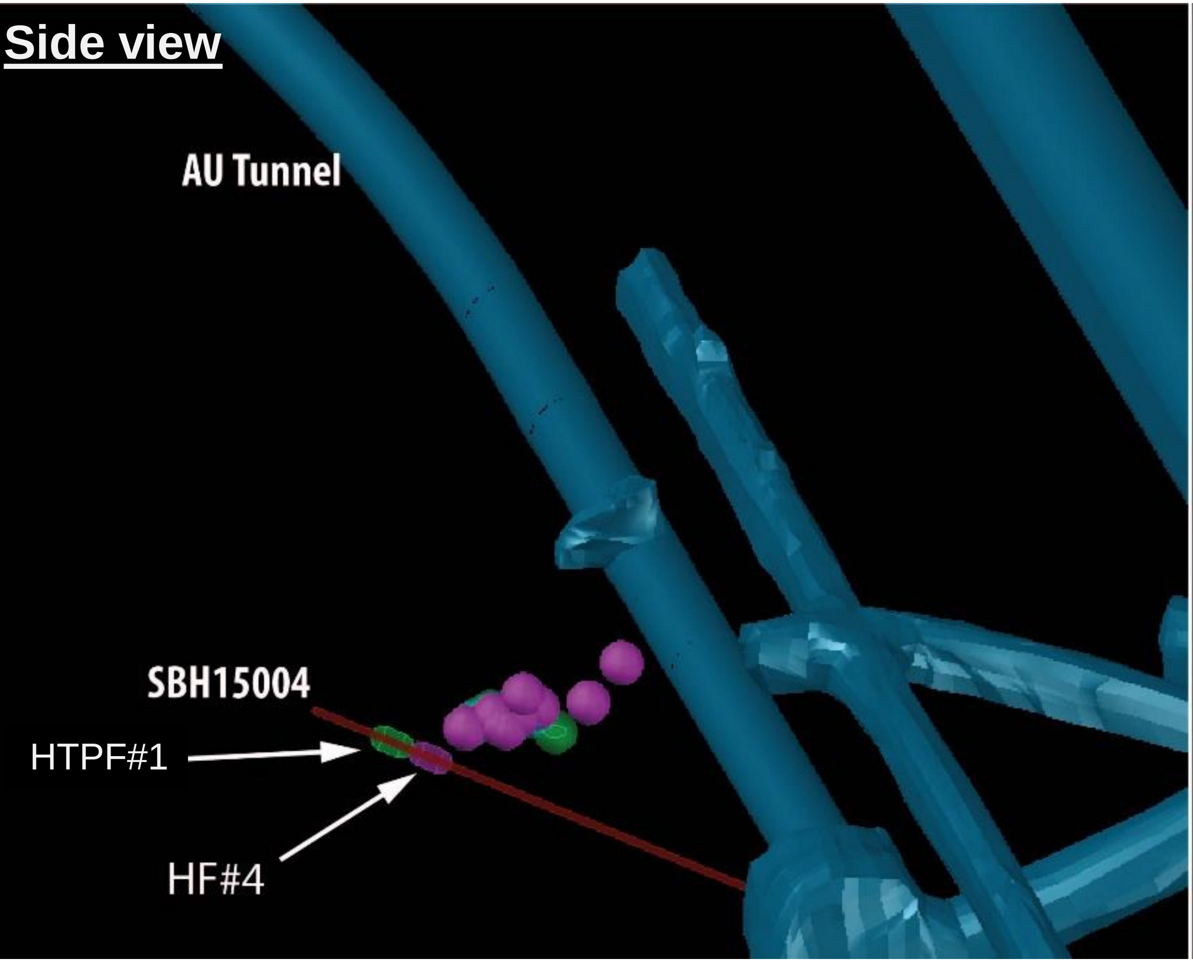
- Injection pressure
- Injection flow rate
- Cum. injected volume
- Cum. seismic events
- Normal opening
- Shear opening (seismic)

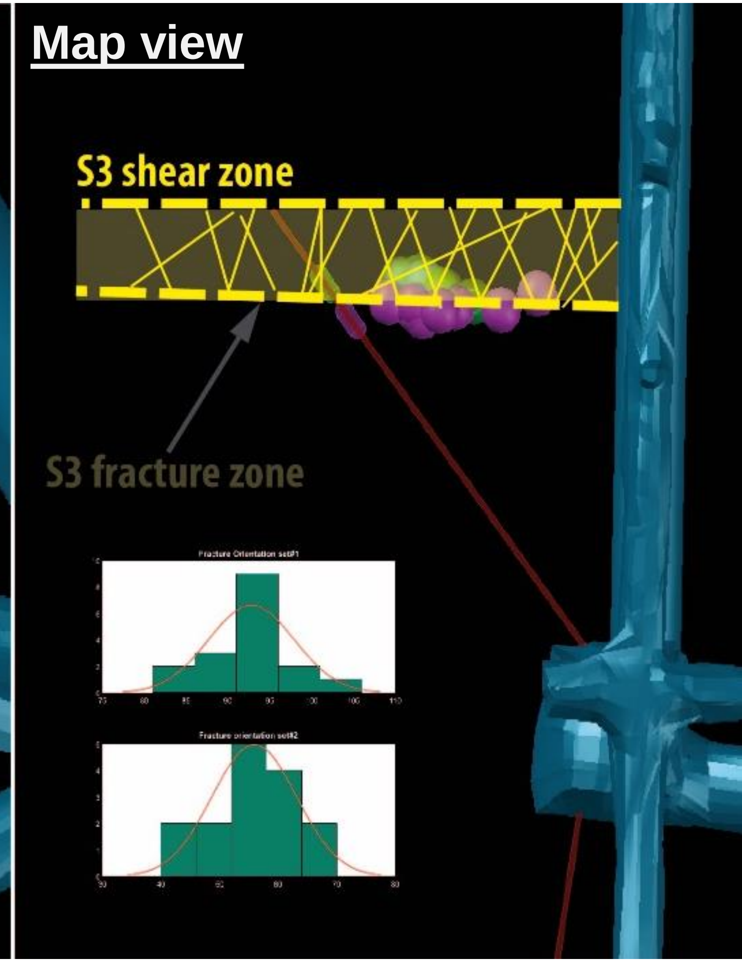


Jacking pressure is identical to ***normal stress on the fracture***.

Stimulation pressure is the pressure which is associated with ***shear opening*** with occuring ***micro-seismicity***.

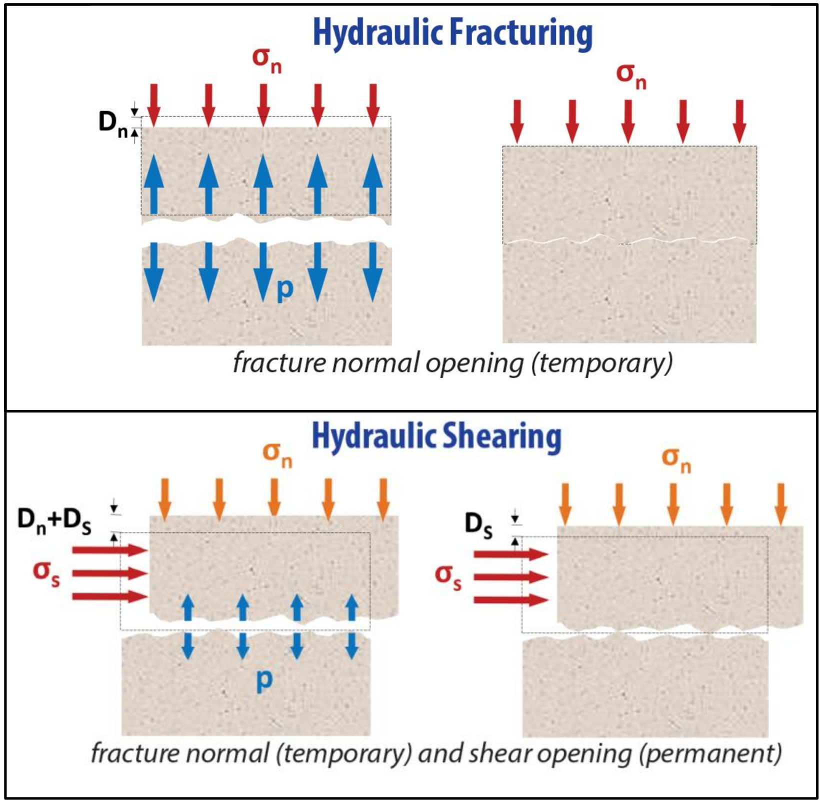
Spatial Distribution of Microseismicity



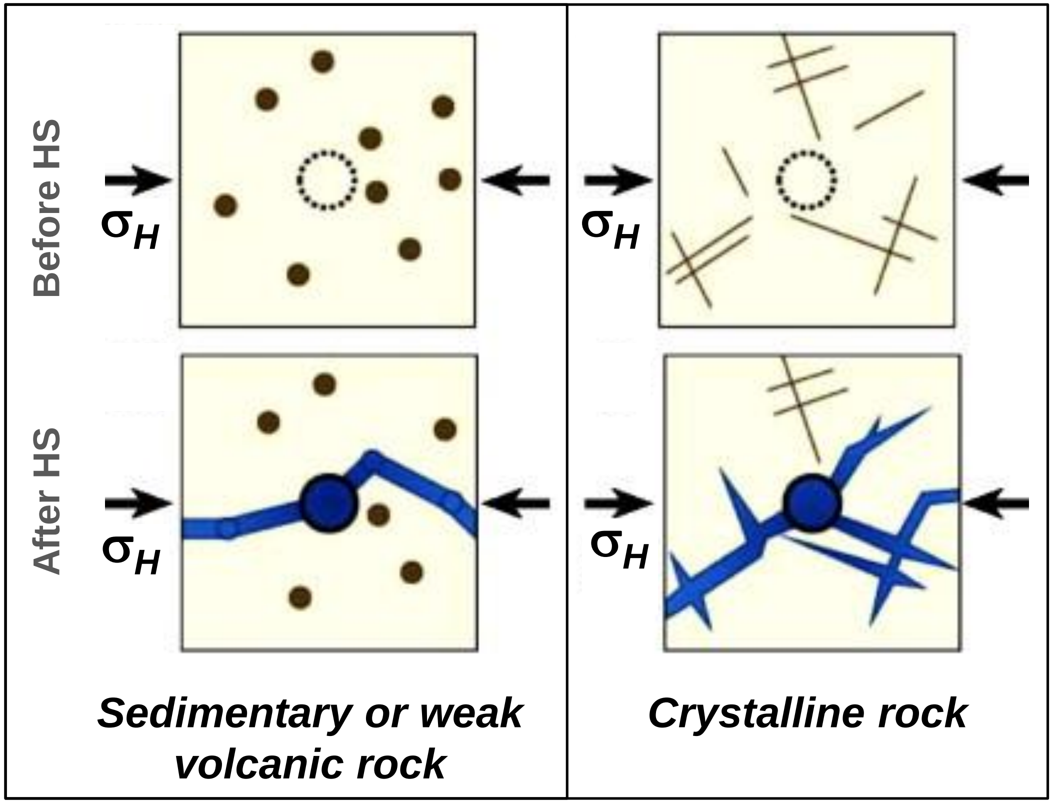


Dominant Fracturing Mechanisms

HF is dominated by fracture normal opening (mode I), whereas HS is mostly dominated by shearing (mode II)



HF in sedimentary rocks propagates in the direction of σ_H whereas in Crystalline rocks propagsates along the local fractures



Conclusion

- Hydraulic fracturing in crystalline rock in the absence of the pre-exisitng fractrures in the stimulation interval might be associated with hydro-shearing (mode II) in the cases where
  - Presence of high conductive features in the vicinity of stimulated volume
  - Critical stress state suitable for shearing

- Comparing hydraulic fracturing (HF) with hydraulic jacking (HTPF) in this study showed:
  - Higher order of transmissivity enhancement in the case of HTPF
  - Higher number of micro-seismic events in the case of HF

- Storativity estimated with conventional hydraulic tests presents a wide range of uncertaintiy before and after the hydraulic stimulation. Performing non-conventional hydraulic tests such as ***periodic pumping tests*** might provide a better insight to characterize such a heterogeneous fractured medium.

Thanks for your attention

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