# FRACTURE GROWTH AND COMPARISON TO ANALYTICAL SOLUTION FOR AN IN-SITU HYDRAULIC FRACTURING (HF) EXPERIMENT

SCCER-SoE Annual Conference 13.-14. September 2018, Horw (LU)

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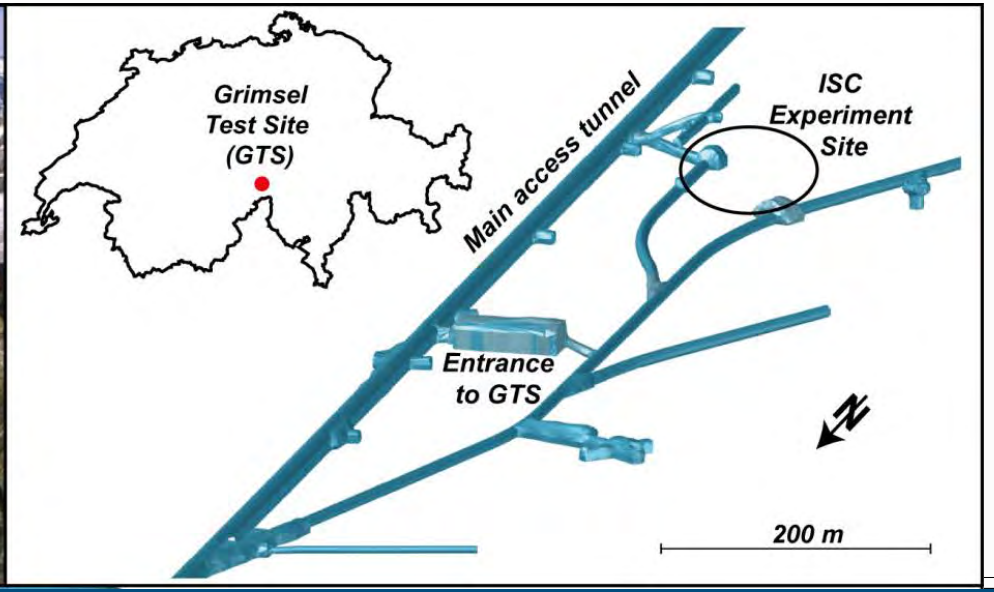
## CONTENT

- **Overview injection location and monitoring**
- **Seismic characteristics**
- **Overview of fracture growth**
- **Comparing fracture growth observations to analytical solutions**

**ISC - experiment**

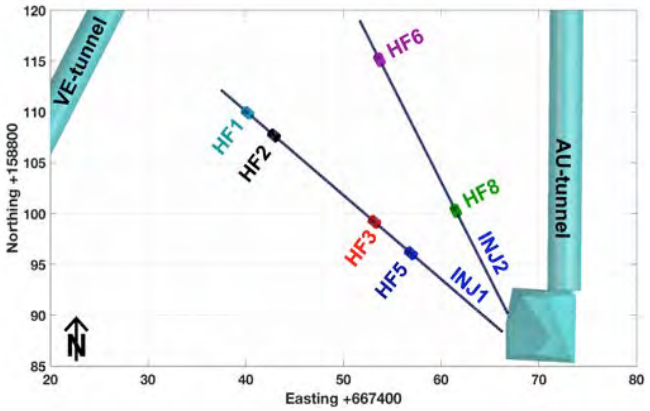
**I**n-situ **S**timulation and **C**irculation experiment

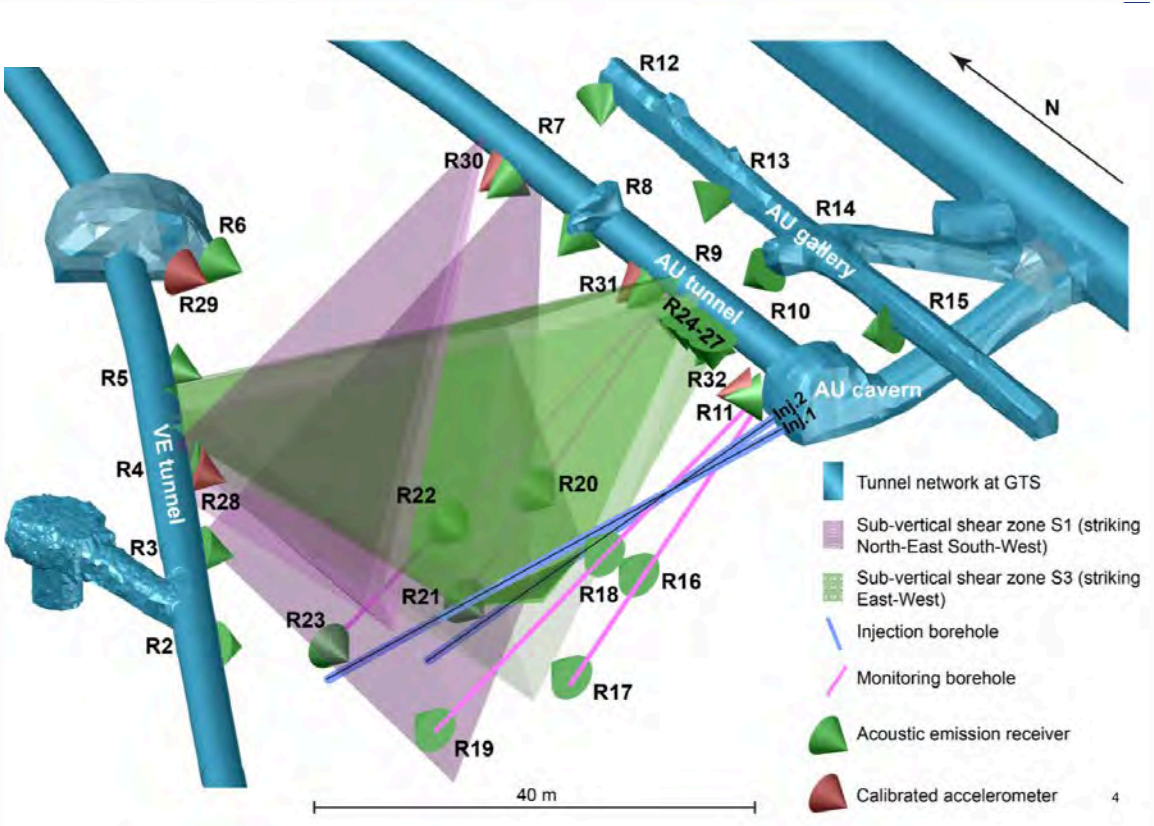
More in Amann et al. (2018), SE9, 115

# INJECTION LOCATIONS AND SEISMIC NETWORK

- 14 Piezo-electric acoustic emission receiver in tunnels
- 12 Piezos in monitoring boreholes
- 5 Calibrated Accelerometer



# EXECUTED INJECTION PROTOCOL

Injection fluid:

- 3x water
- 3x xanthan-salt-water with 35 times higher viscosity (non-newtonian!) than water at a shear rate of 1 Hz
- In total: 1000 l per injection

**Similar injection Protocol:**

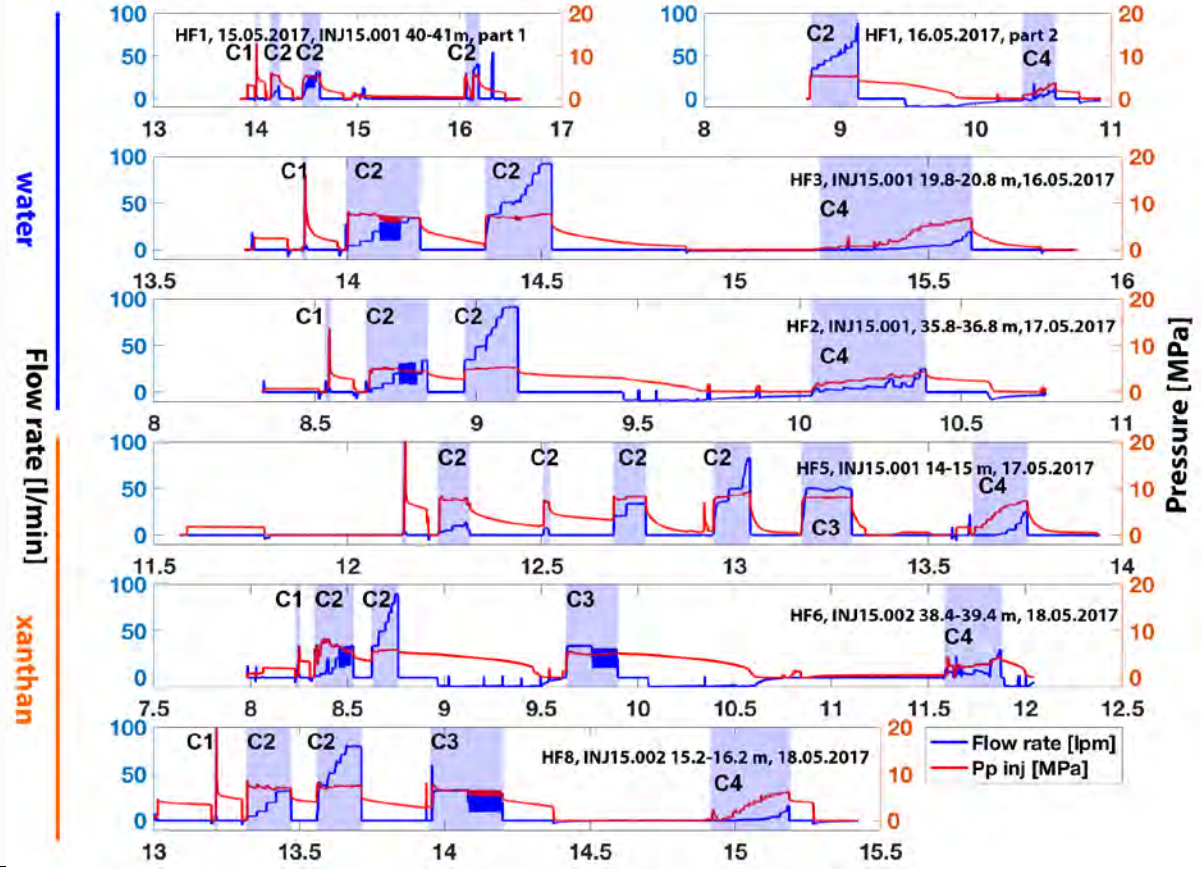
**C1 Break down cycle**

**C2 Fracture propagation cycle**

**C3 Flushing cycle (only when xanthan was injected)**

**C1-C3 are flow rate controlled cycles**

**C4 Pressure controlled step rate test**

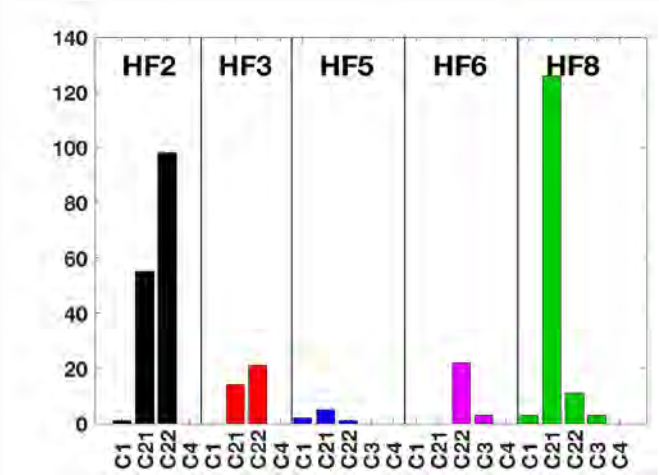


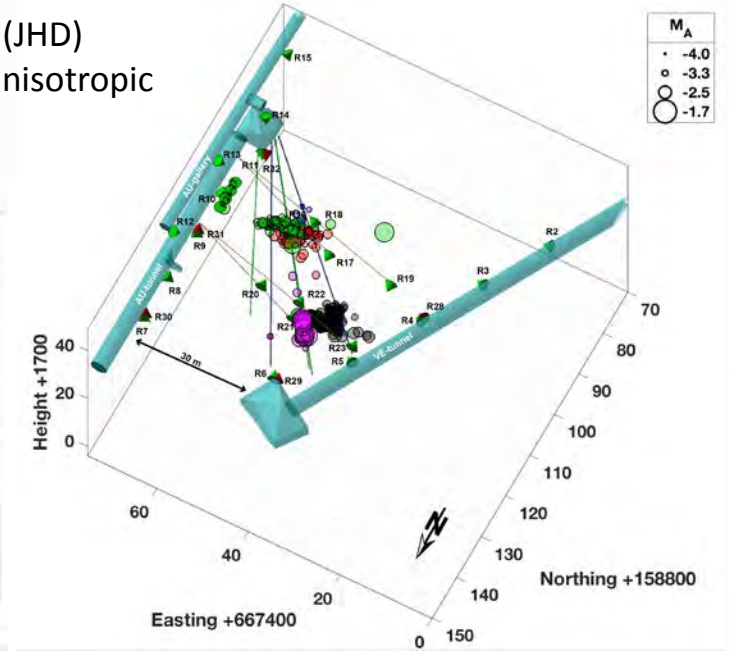
## SEISMIC CHARACTERISTICS

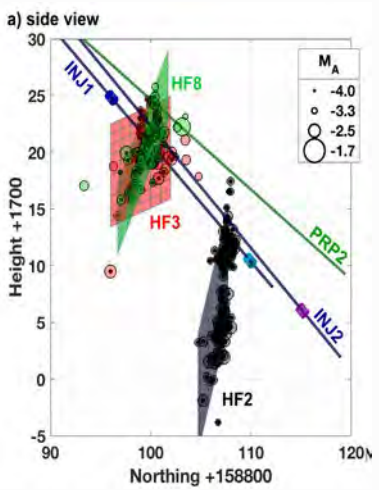
Absolute location procedure:

- Joint Hypocenter Determination (JHD)
- Velocity model: homogeneous, anisotropic

- Accuracy of location: ~ 0.5 m



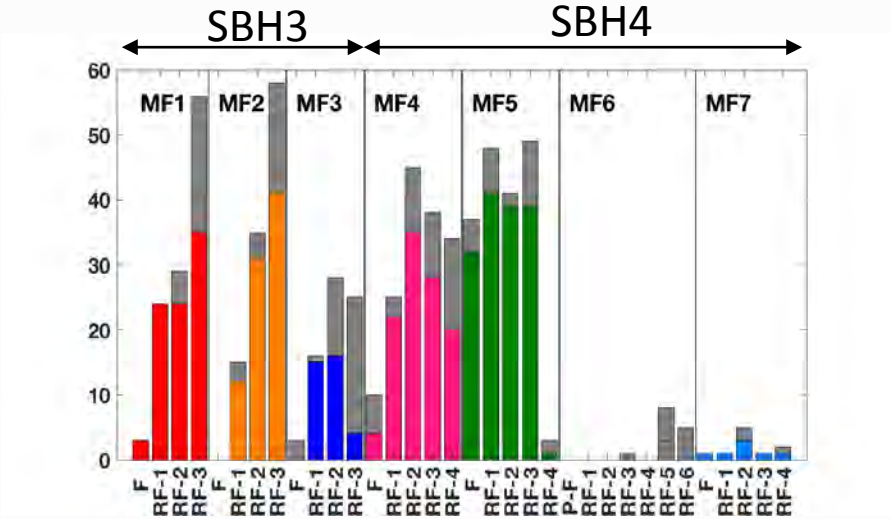



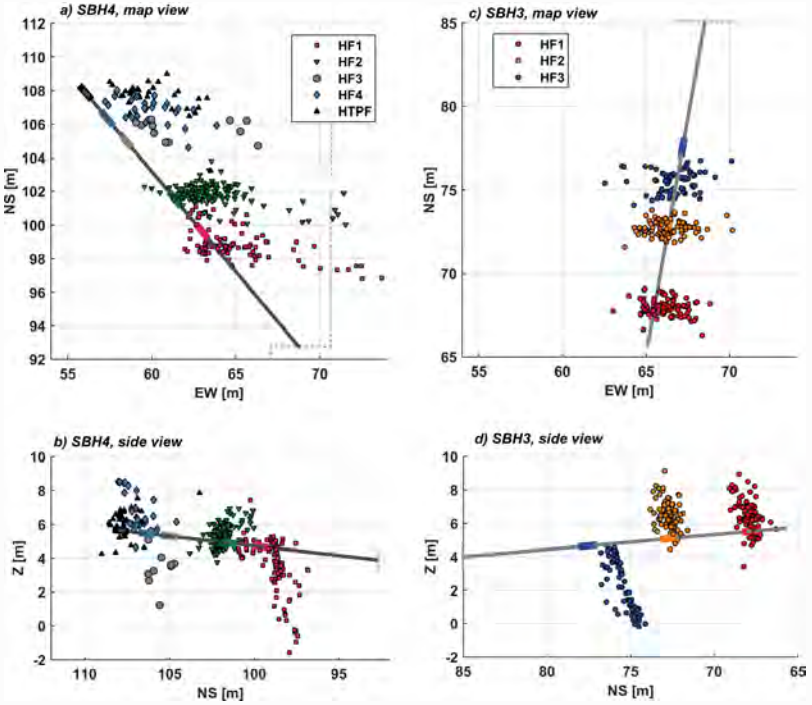




- In total 6986 seismic events are recorded and 367 events are located.
- Seismicity clouds and plane fit to the localized seismic events for HF2, HF3 and HF8.

# MINIFRACS FROM STRESS CHARACTERIZATION

- MF1-MF3 location error < 2 m
- MF4-MF7 location error < 3 m
- The bars are colored if the event occurred during injection. The bar is grey during shut-in or bleed-off.

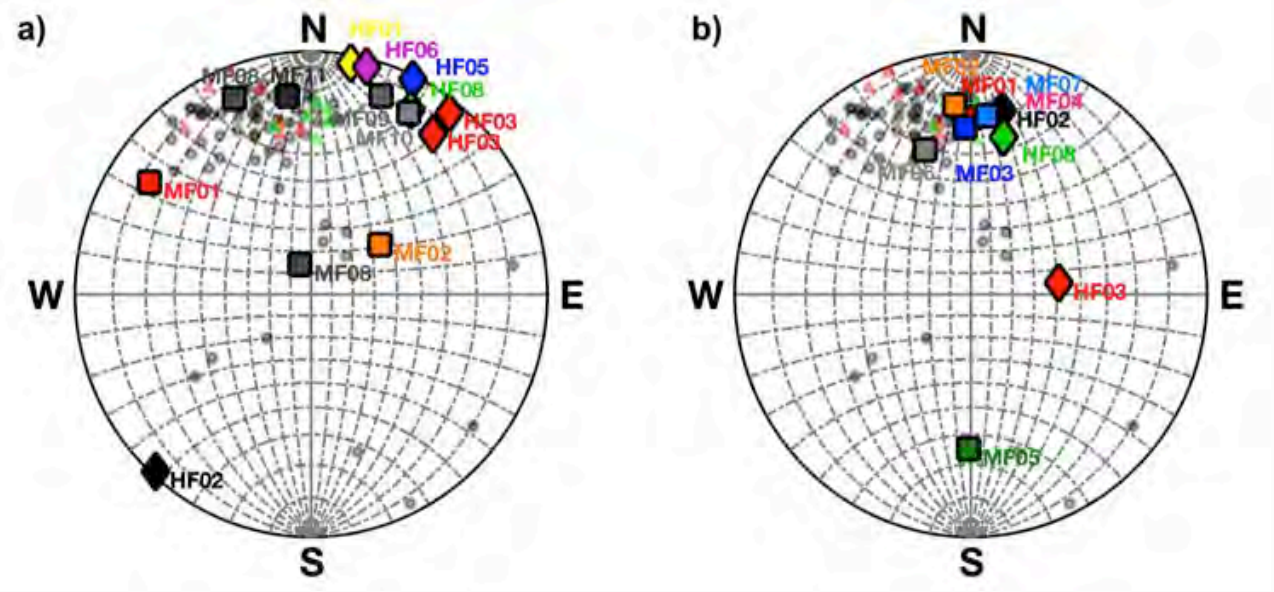




Gischig, V.S., et al., 2018, SE 9, 39–61.
Jalali, M., et al., 2018. Geophys. Res. Lett. 2017GL076781

# FRACTURE MAPPING AND GEOMETRY




*The new created fracture traces from geophysical borehole logging and impression packer are presented in a lower hemisphere stereonet.*

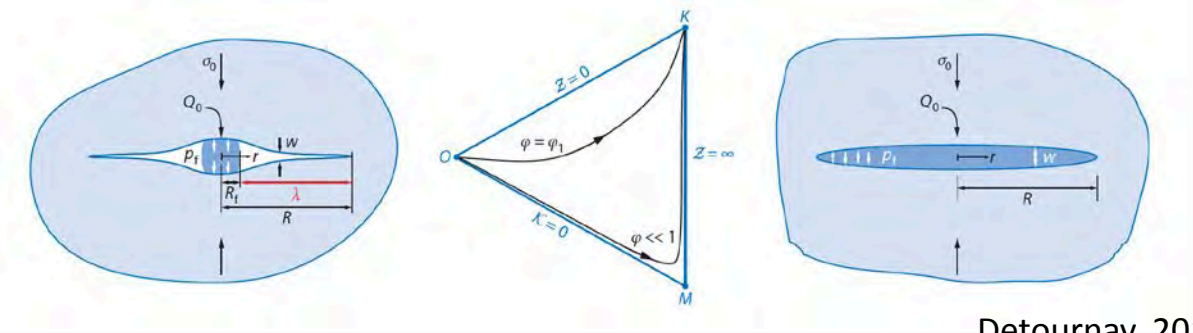
*The plane fits from the seismic events are indicated in a lower hemisphere stereonet.*

# PENNY-SHAPED FLUID DRIVEN FRACTURE

– **Definition of dimensionless toughness (Savitski & Detournay, 2002)**

$$K = K' \times \left(\frac{t^2}{E'^3 \mu'^5 Q^3}\right)^{\frac{1}{18}}$$

| *Energy dissipation mechanism* | | *Vertex* |
|---|---|---|
| $K \leq 1$ | corresponds to the viscous fluid flow | M |
| $K \geq 3.5$ | corresponds to the creation of new surfaces | K |



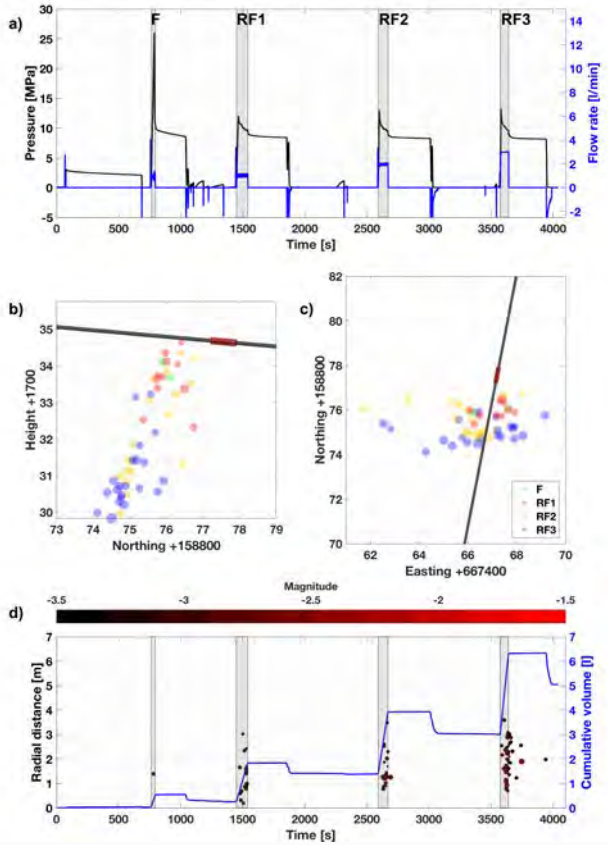

Detournay, 2016

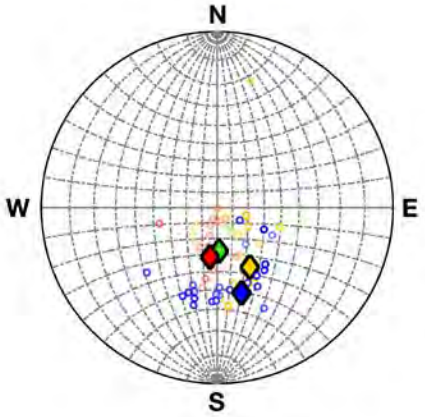
– **Length asymptote for small (M) and large (K) time**

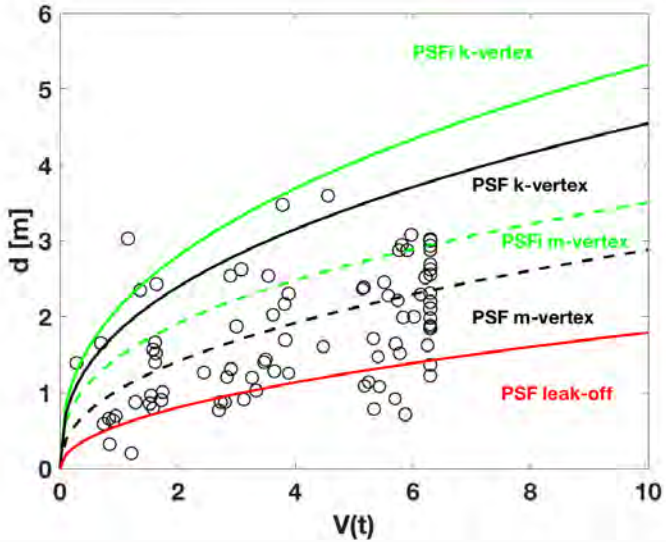
$$L_m = \left(\frac{E' Q_o^3 t^4}{\mu'}\right)^{1/9}, \quad L_k = \left(\frac{Q_o E' t}{K'}\right)^{2/5}.$$

**Equations to solve:**
Elasticity
Lubrication approximation
Boundary conditions

# MF: COMPARING FRACTURE GROWTH OBSERVATIONS TO ANALYTICAL SOLUTIONS

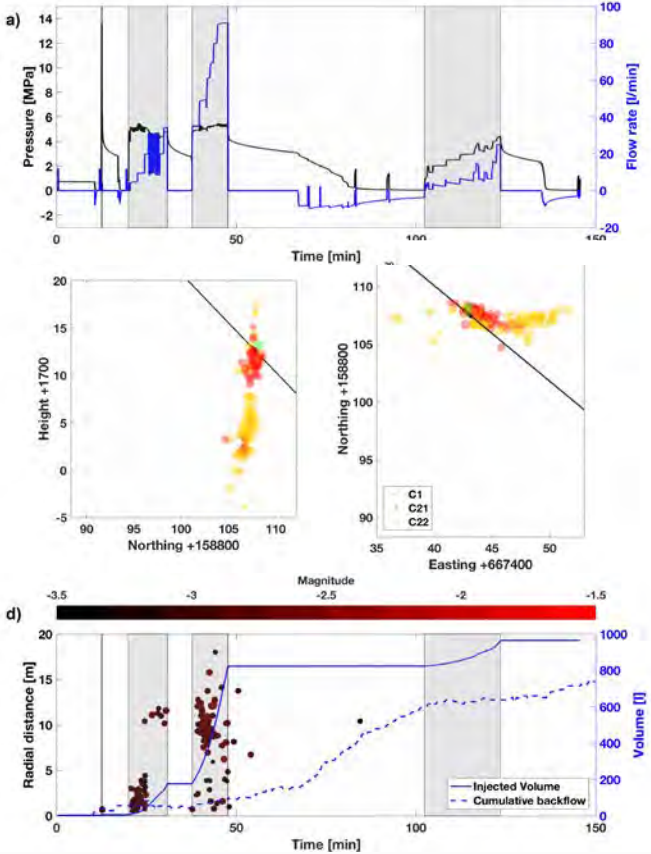


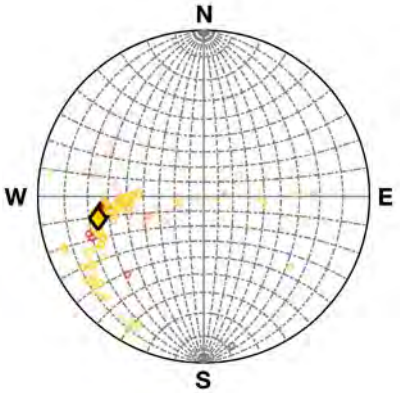



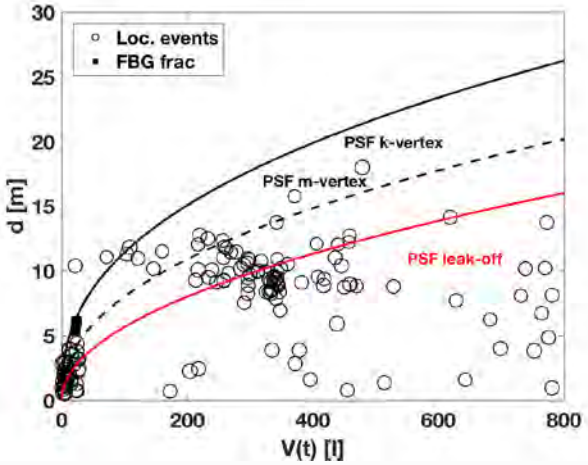




All events are located below the injection point and the fracture propagates downward. From the seismic cloud, only a partial penny-shaped fracture occur, whereby the error for small injection volumes is small.

# HF: COMPARING FRACTURE GROWTH OBSERVATIONS TO ANALYTICAL SOLUTIONS



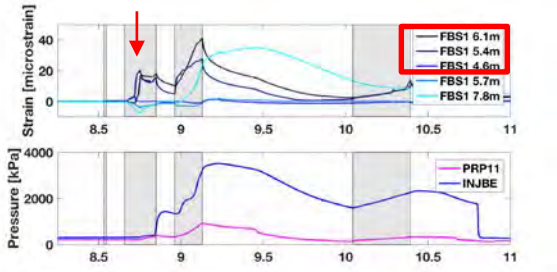



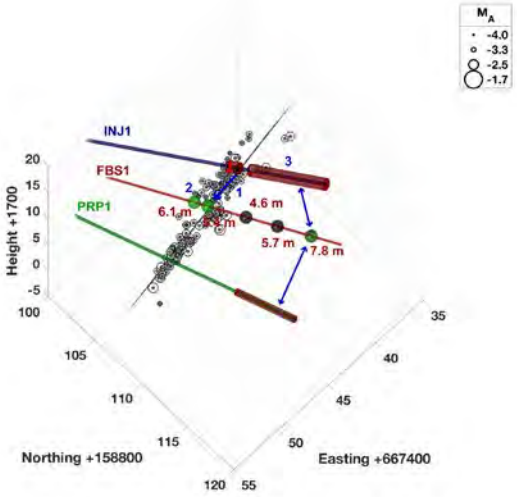



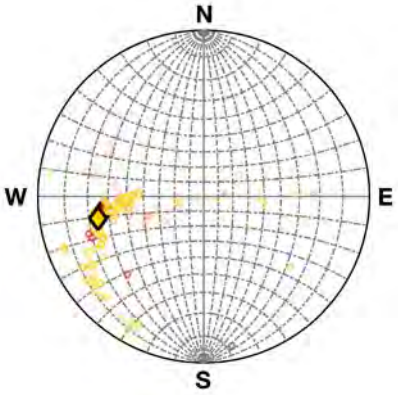

The fracture has a preferred seismic cloud growing downwards towards north.

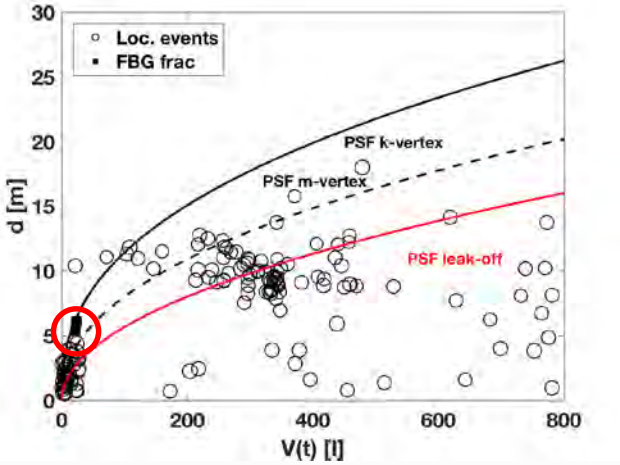
From the seismic cloud, only a partial penny-shaped fracture occur, whereby the error for small injection volumes is small. The error grows and it is necessary to account for permeable rock and leak-off.

# HF: COMPARING FRACTURE GROWTH OBSERVATIONS TO ANALYTICAL SOLUTIONS




The fibre bragg gratting (FBG) sensors are used to constrain the fracture geometry. Positive response indicate tension and negative response indicate compression.

## CONCLUSION

- The **seismic clouds indicate a preferential orientation** with a pole point towards sub-horizontal north (corresponds to minimum principal stress axis) and downwards in the HF experiment.
- The penny-shaped fracture geometry is able to reproduce the length of the minifracs. The **error of length increases due to the wrong approximation of the fracture geometry** with increasing fracture fluid volume. Changing the fracture geometry towards plane-strain is not an option, as this solution totally overestimate the fracture length.
- During the hydraulic fracturing experiment, seismic was observed up to 20 m away from the injection point. It seems, that network stimulation due to leak-off into pre-existing fractures takes over at early time.

# THANK YOU FOR YOUR ATTENTION !

Poster: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## REFERENCES


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