The STIMTEC-X In-Situ Hydraulic stimulation Experiment at the URL Reiche Zeche Mine, Germany

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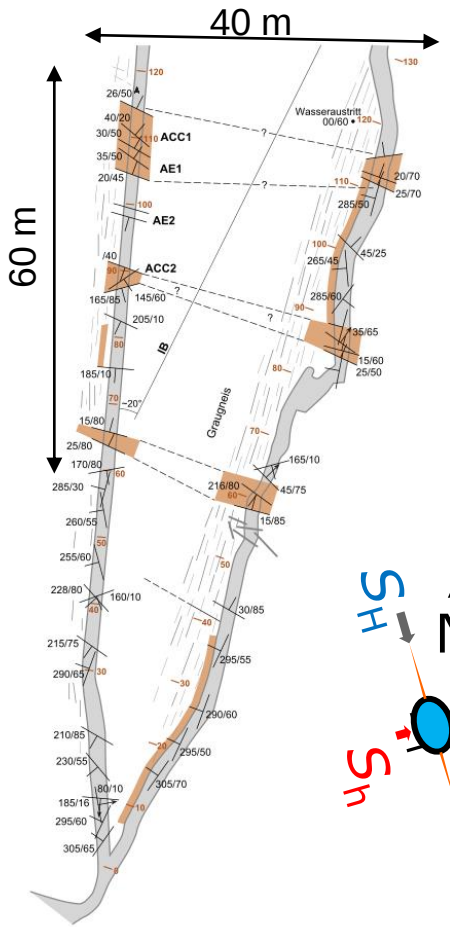
Reiche Zeche Underground Lab



Freiberg
Eastern
Erzgebirge

~283 ASL
120-130 m depth

- Target volume ~30 x 30 x 20 m^3 of strongly foliated metamorphic Freiberg gneiss
- comprises steeply dipping deformation zones
- foliation is sub-horizontal causing anisotropy

Introduction

STIMTEC

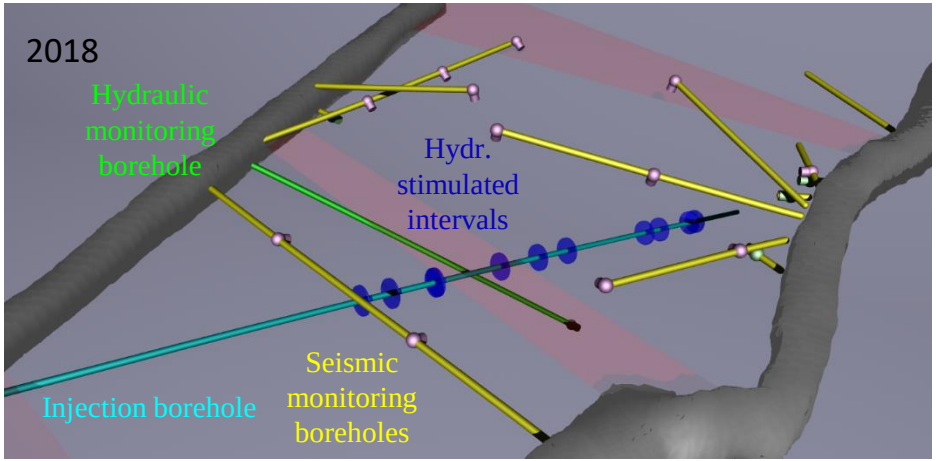
- Hydraulic stimulation experiments in 2018/2019 to investigate the role of hydro-mechanical processes associated with the enhancement of hydraulic properties in deep geothermal projects
- Characterisation of heterogeneity and anisotropy at the site
- Optimisation of real-time monitoring techniques

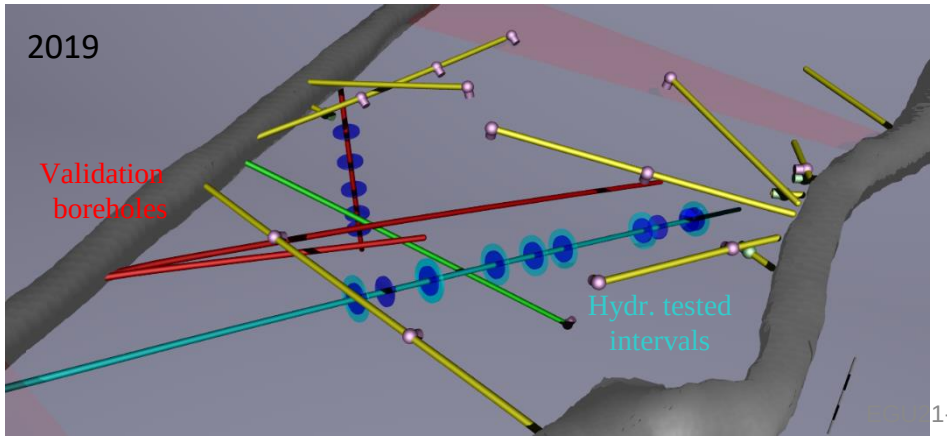
Renner & STIMTEC team, ARMA newsletter 2021

STIMTEC-X

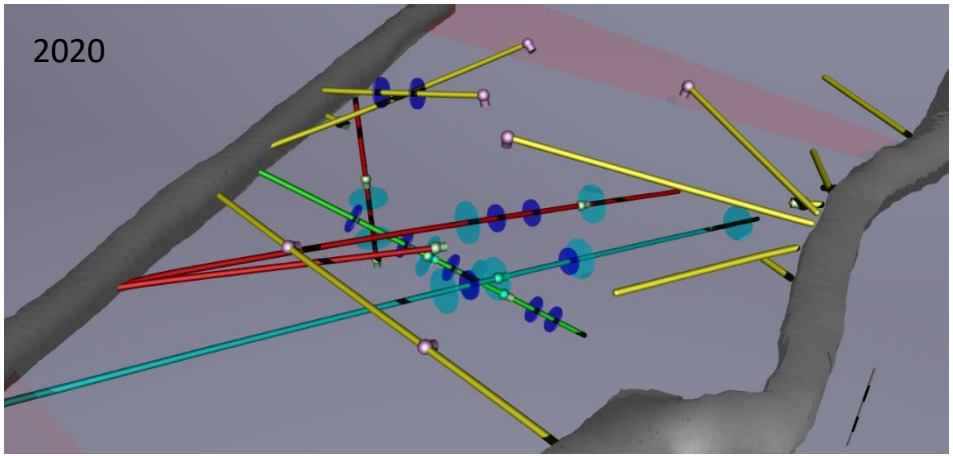
- Hydraulic stimulation experiments in late-2020/early 2021 to investigate the seismic and stress variability as well as their interrelation
- Dilatometer tests to determine deformation characteristics of induced hydrofracs and pre-existing fractures
- Long-term circulation experiment (pending)

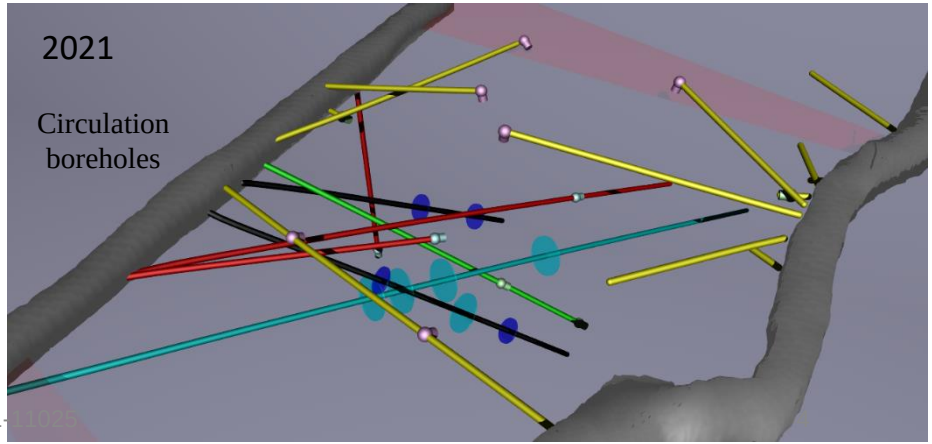
STIMTEC 2018/2019 campaigns





STIMTEC-X 2020/2021 campaigns





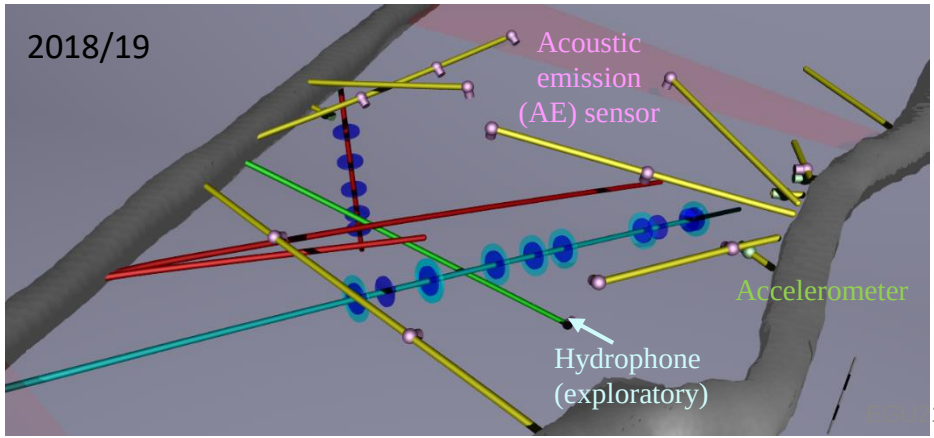
Seismic monitoring network comparison

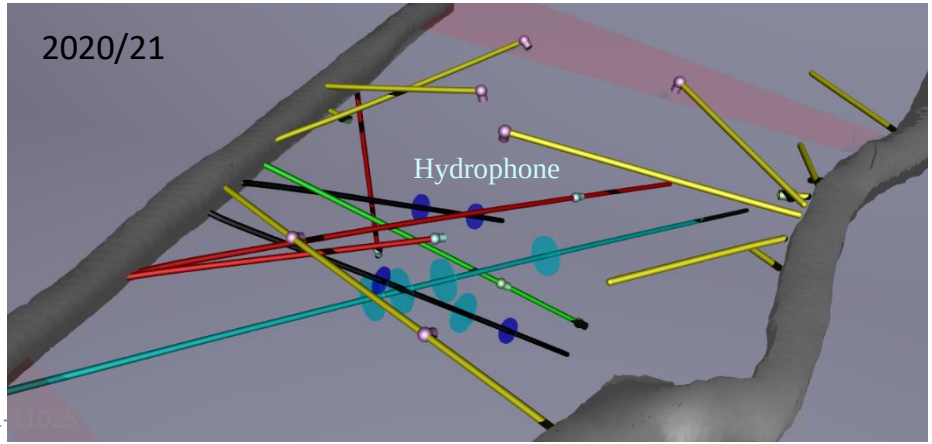
STIMTEC Stationary AE Network
- 12 AE sensors (1-100 kHz)
- 3 accelerometers (0.05-25 kHz)
- 1 AE-type hydrophone (1-40 kHz)
- 1 broadband seismometer (0.01-100 Hz)

Average interval–station distance 18-27 m

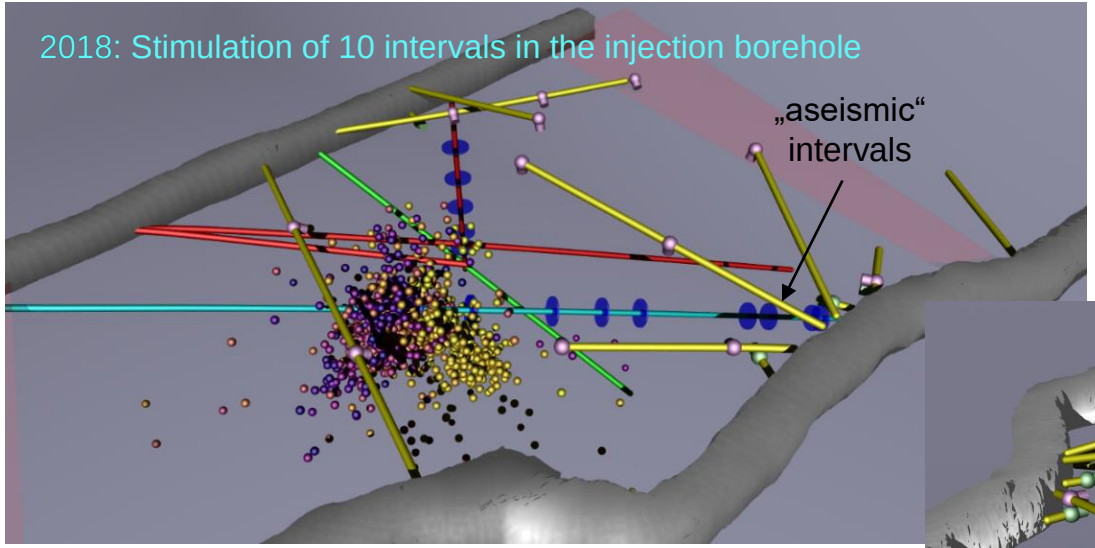
STIMTEC-X Adaptive AE Network:
- 6 AE sensors (1-100 kHz)
- 4 accelerometers (0.05-25 kHz)
- 6 AE-type hydrophone (1-40 kHz)
- 1 broadband seismometer (0.01-100 Hz)

Average interval–station distance 14-17 m

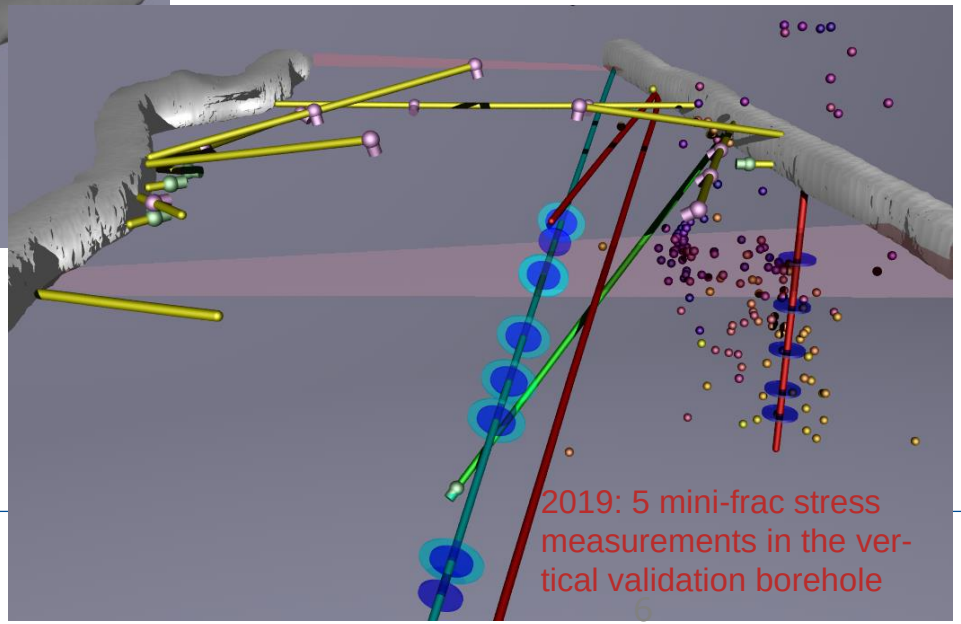




STIMTEC 2018/2019 seismic response to stimulation

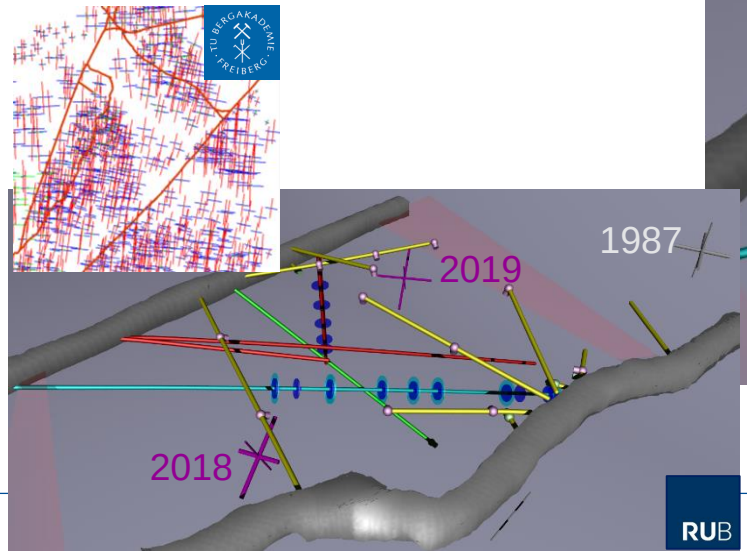


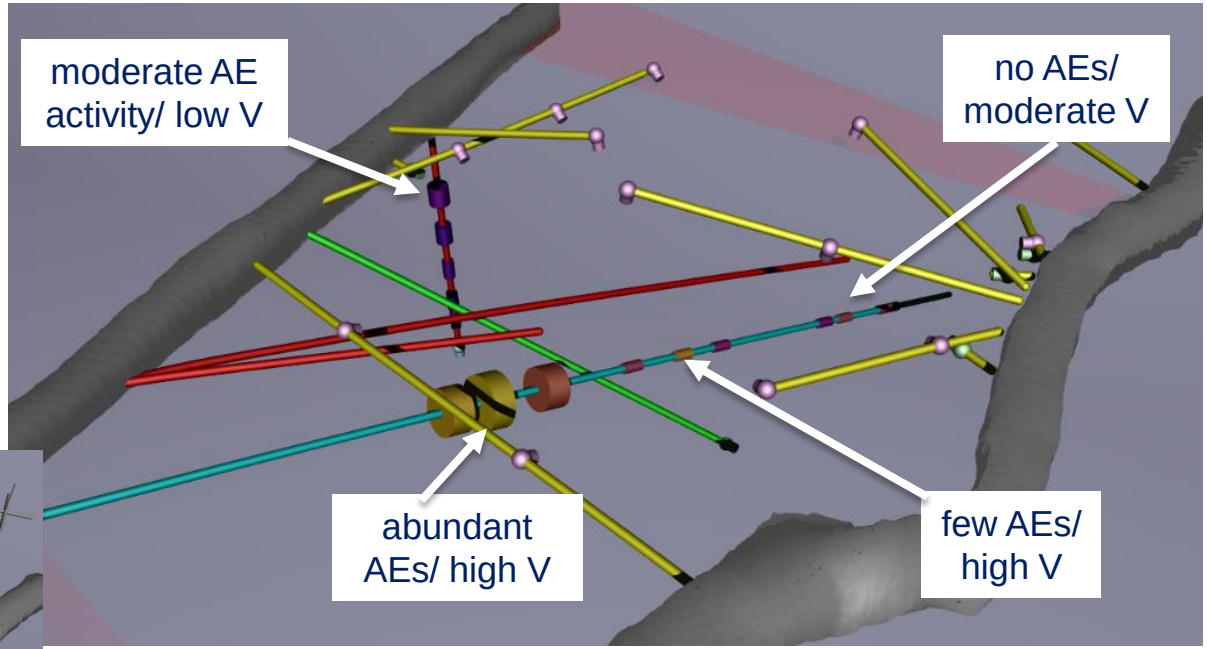
Same injection scheme in all intervals, markedly different seismic response



STIMTEC seismic and stress variability

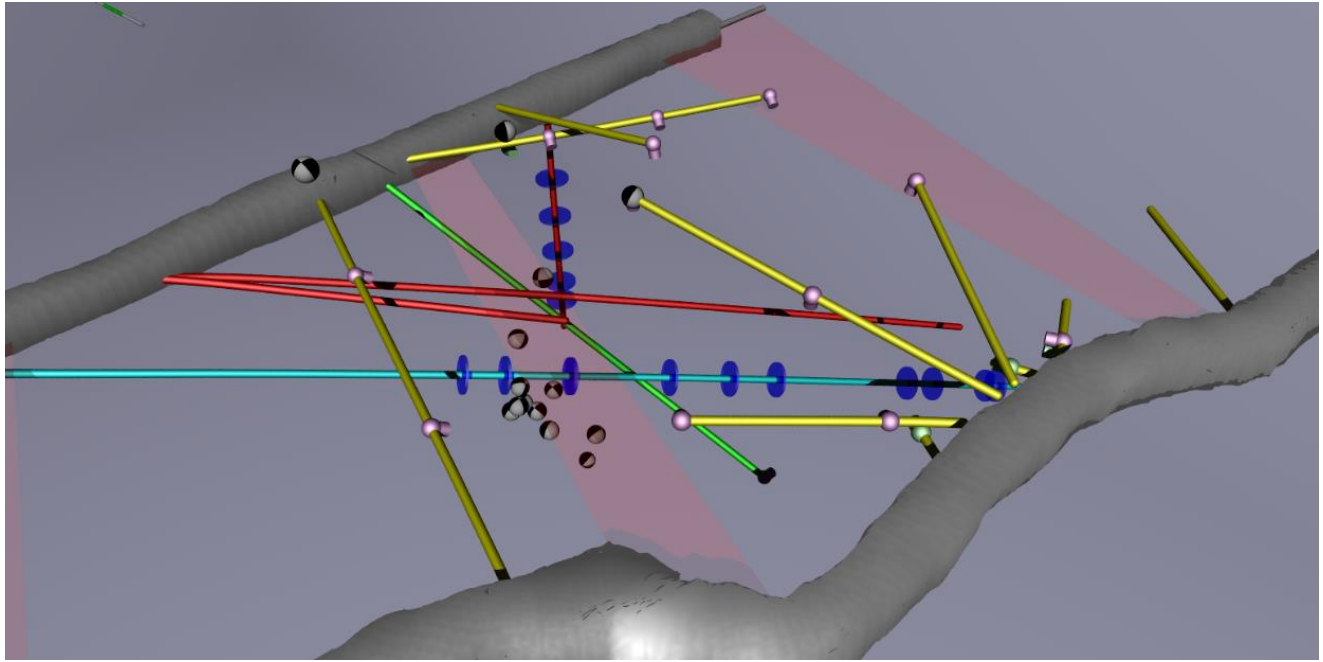
- Large variability in AE activity and stress magnitudes observed
- No simple correlation between injected volume and seismic activity

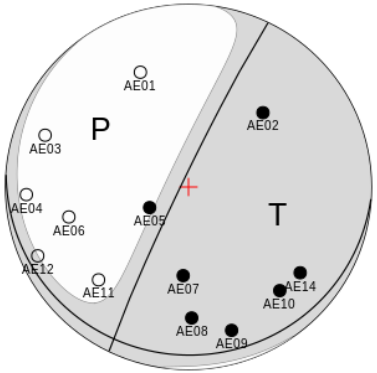


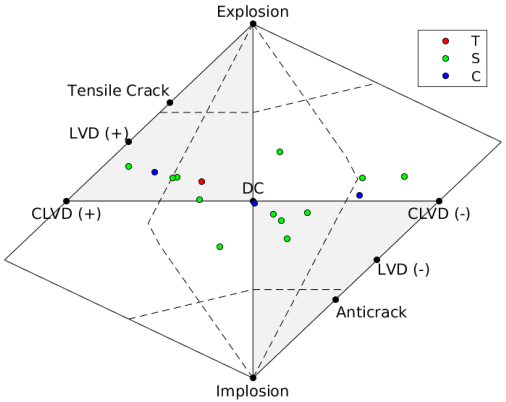


Size: number of located AE events
Color: total injected volume (V)

STIMTEC focal mechanism solutions of frac and refracs from stimulation interval 28.1





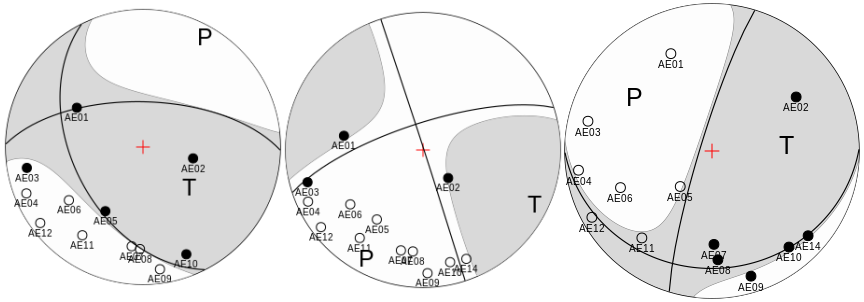


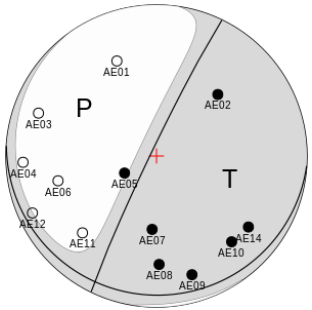
N-S to NE-SW trending nodal planes, dominated by shear faulting

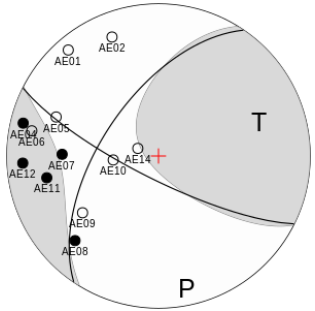
Focal mechanism solutions from different intervals

Representative FM for fracs & refracs in intervals

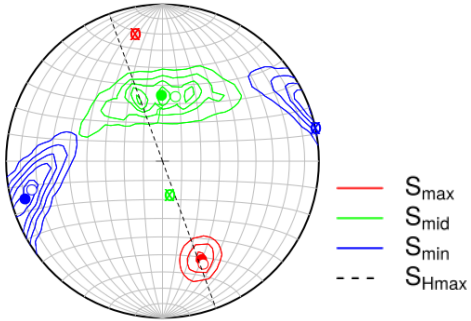
BH10: 22.4 24.6 28.1 BH17: 6.7

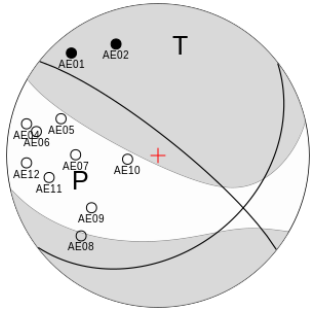






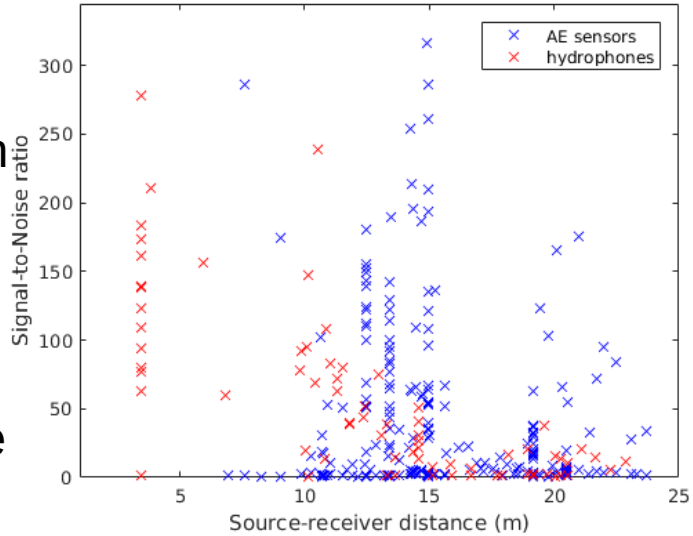
- Significant variability of FMs during periodic pumping tests
- FMs used to obtain stress field estimates between local stress measurement points in the boreholes

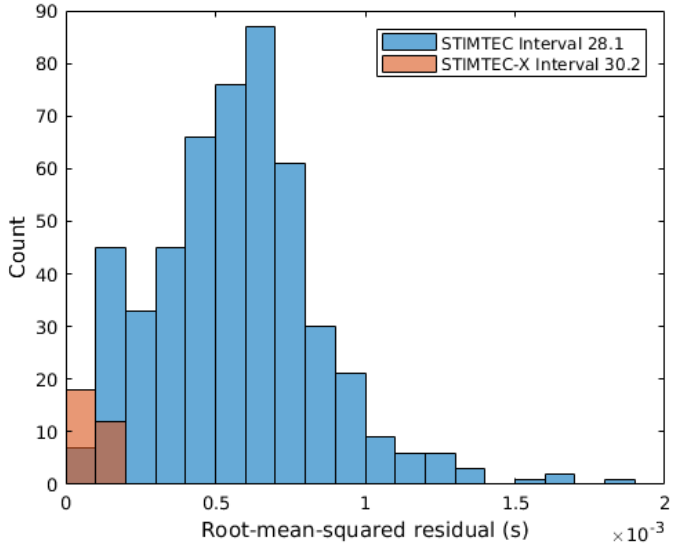




STIMTEC-X 2020 network performance

Hydrophones were optimally placed for each measurement configuration anew with at least one deployed in the direct vicinity (~3-4 m) of the injection interval



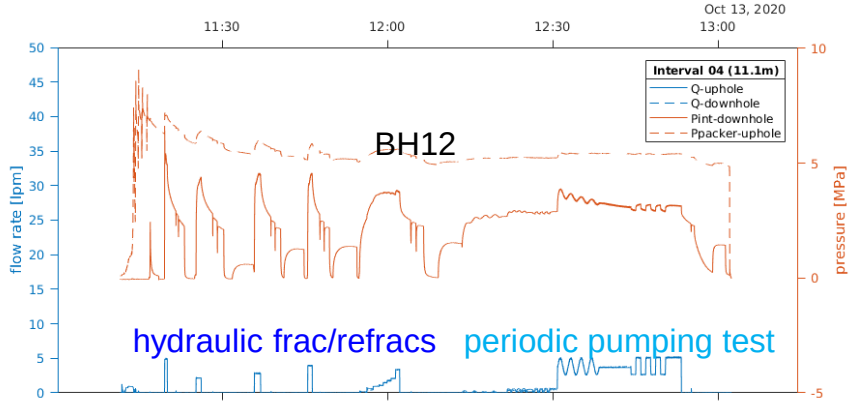


Hydrophone detection ranges are 15-17 m
Event locations improved significantly, uncertainty halfed
See EGU21-15326 Th. 11h GI5.1

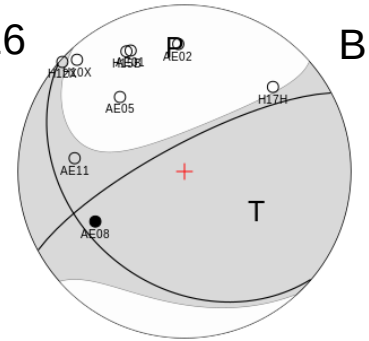
Boese et al. (in review), ARMA

STIMTEC-X 2020 pump sequence and seismicity

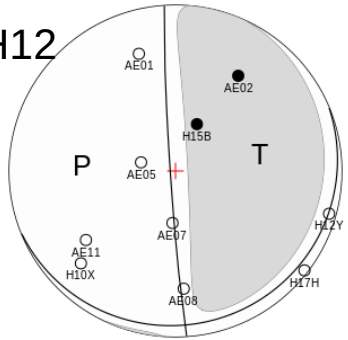
Same temporal characteristics of seismically active intervals as during STIMTEC:
some AEs during frac, most AEs during periodic pumping above fracture opening pressure

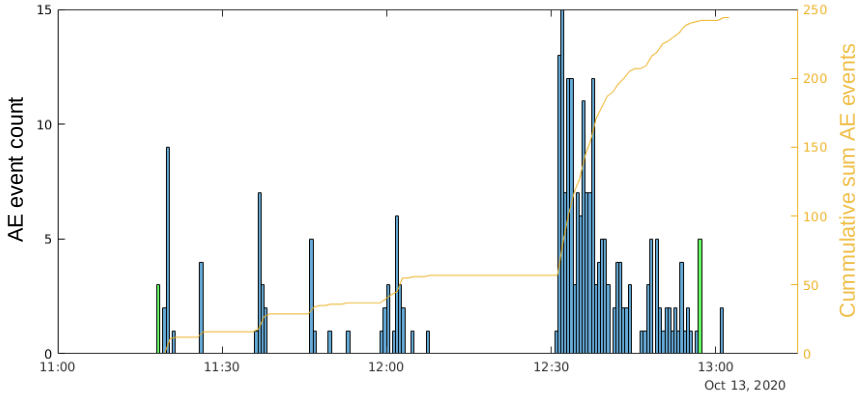


BH16



BH12

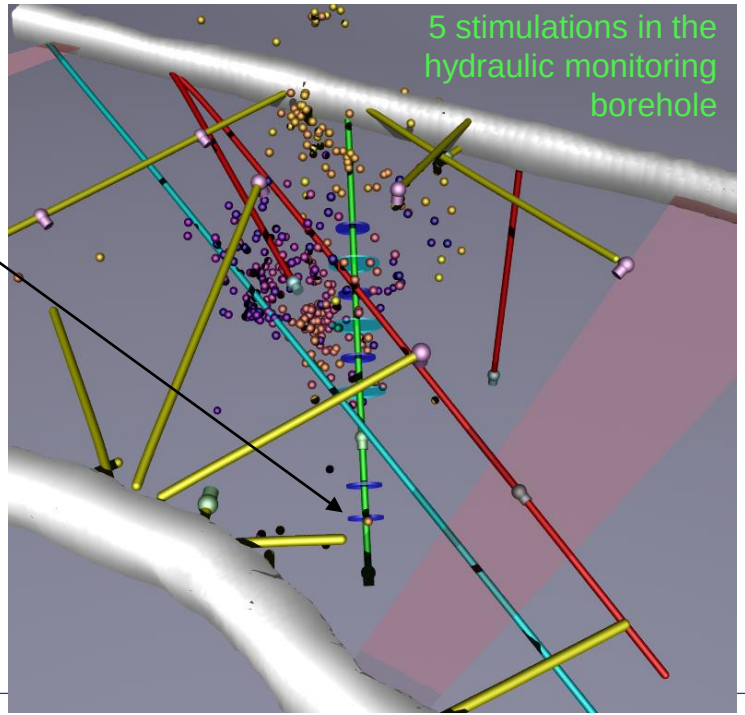


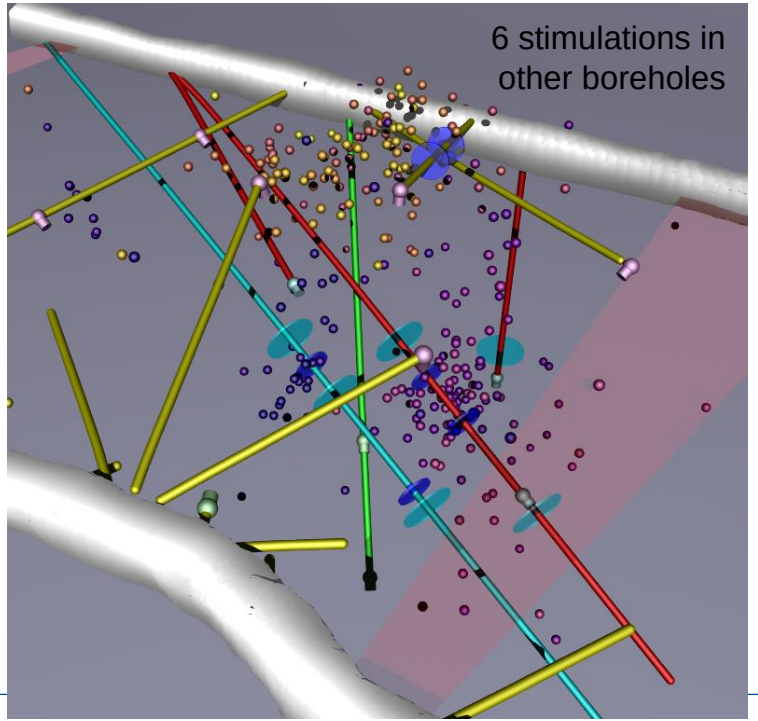


STIMTEC-X seismicity highlights

We doubled seismically active volume, spatially linking seismicity in the injection borehole and vertical validation borehole

We observed „aseismic“ intervals despite excellent monitoring coverage

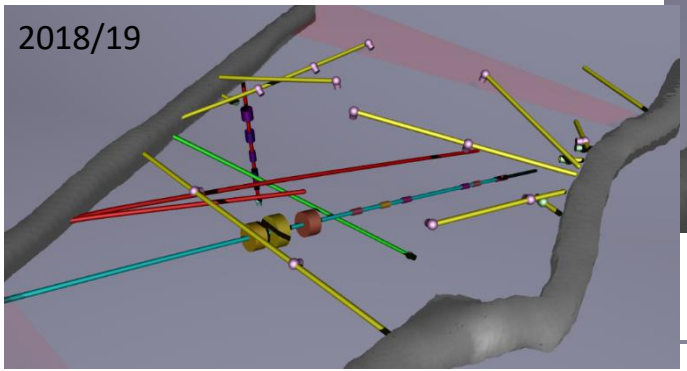


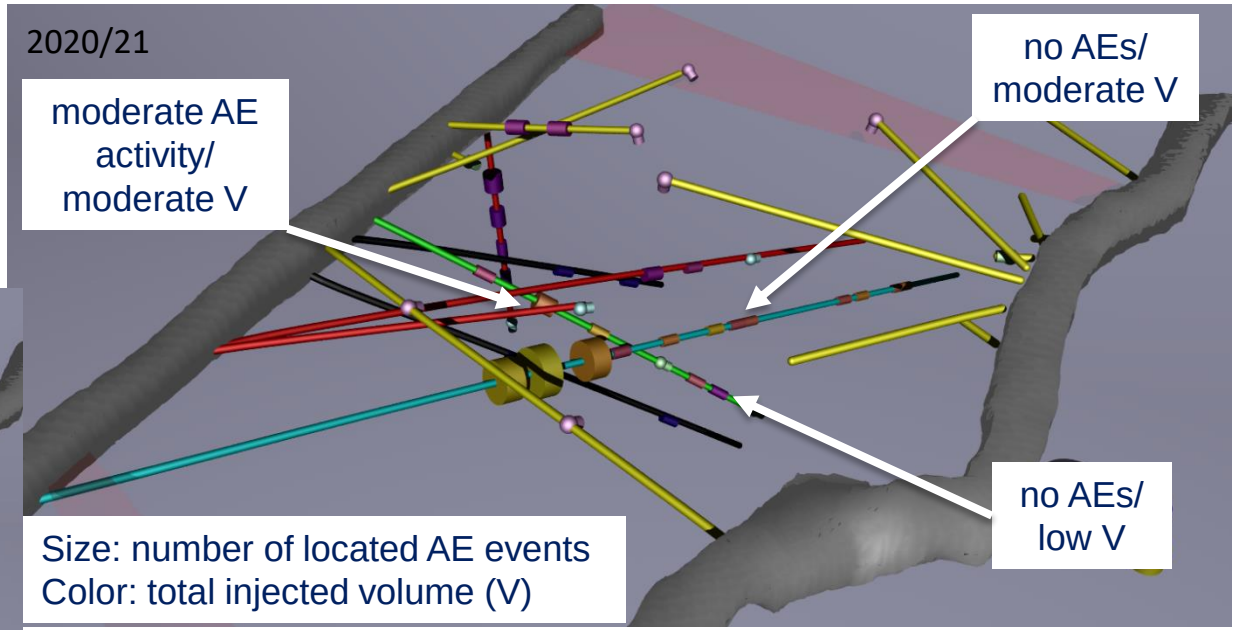


STIMTEC-X overview seismic response to stimulation

Less extreme seismic responses observed, most stimulated intervals showed moderate AE activity

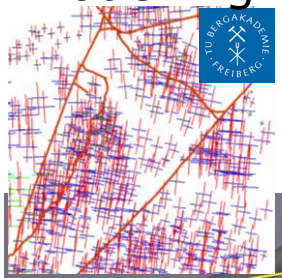
(See also STIMTEC/STIMTEC-X seismicity movie)

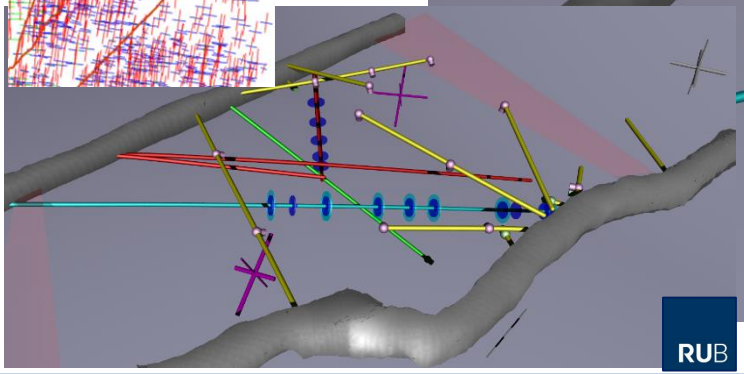


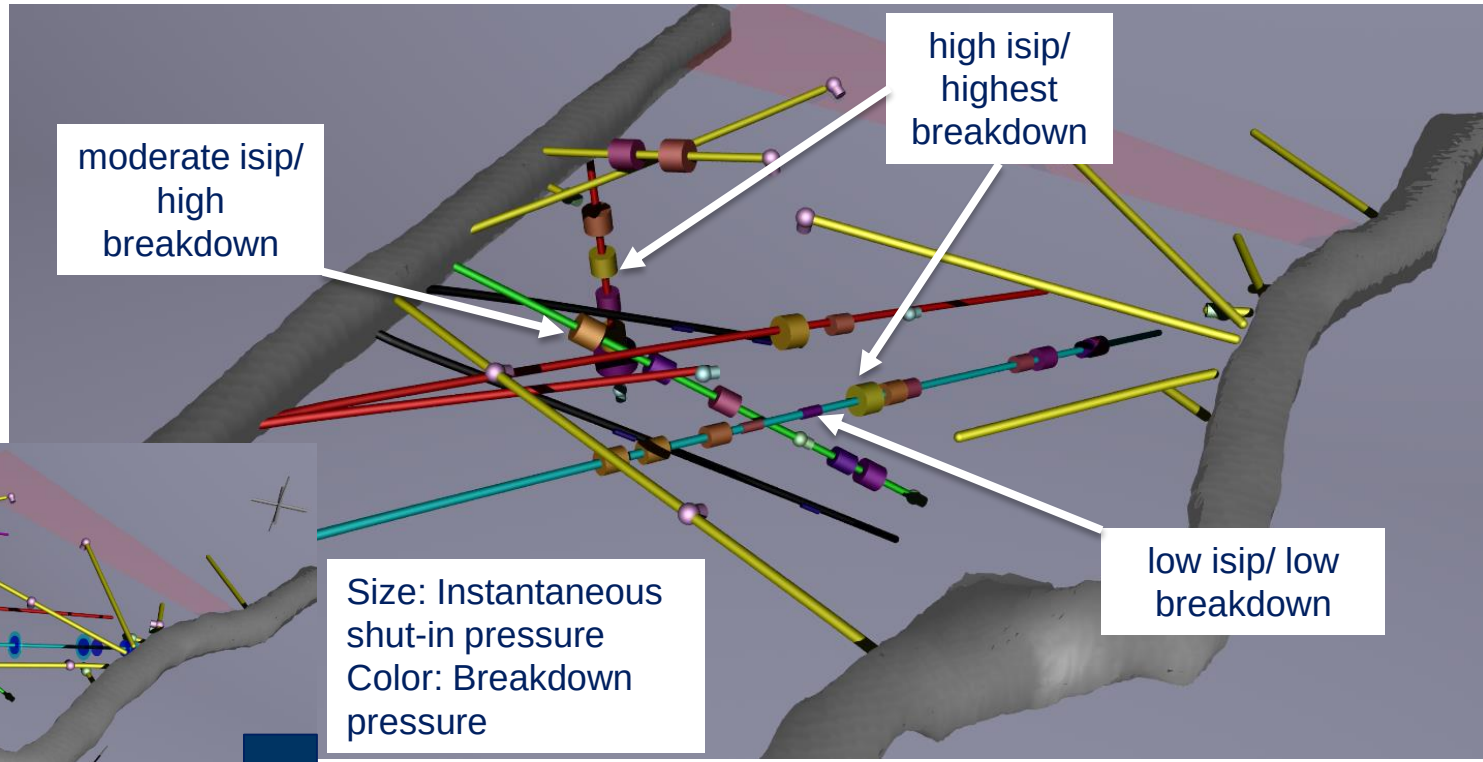


STIMTEC-X stress variability

Large stress variability not observed in modelling

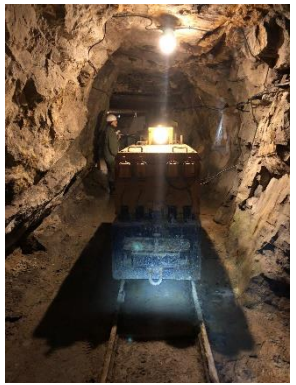






Summary & conclusions

- We achieved a significant improvement in locating AE activity during the STIMTEC-X experiment using an adaptive seismic monitoring network, comprising 6 hydro-phones
- The AE activity is spatially distributed between the distinct clusters observed during STIMTEC, the response to stimulation ranges from no AE activity to moderate AE activity
- Stress variability is high and there is no transition observed between the two stress regimes inferred from hydrofracs in the injection and vertical validation boreholes
- We started to invert focal mechanism solutions for the stress orientations and stress ratio with the aim to spatially link local minifrac stress measurements



Thank you for your attention!

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