The STIMTEC experiment at the Reiche Zeche Underground Laboratory

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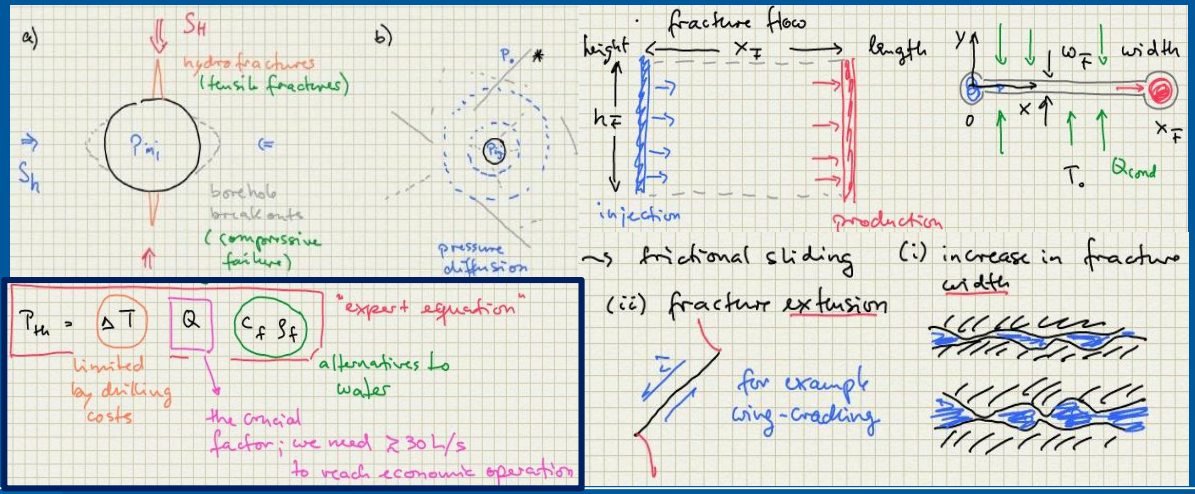


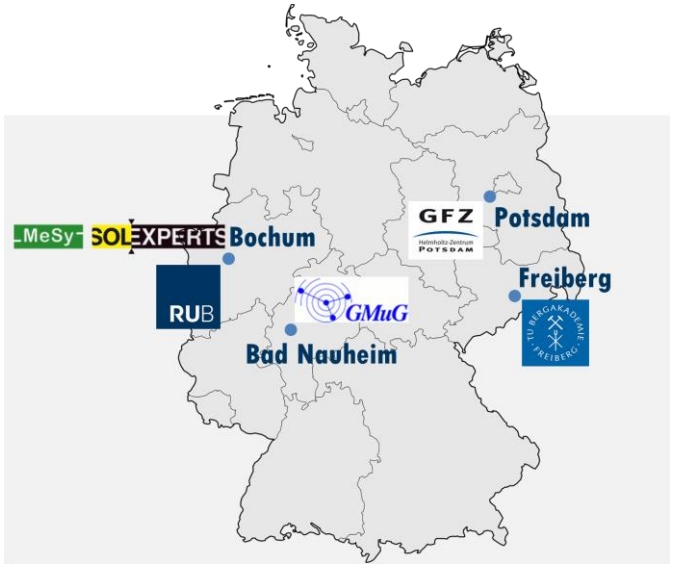
Outline

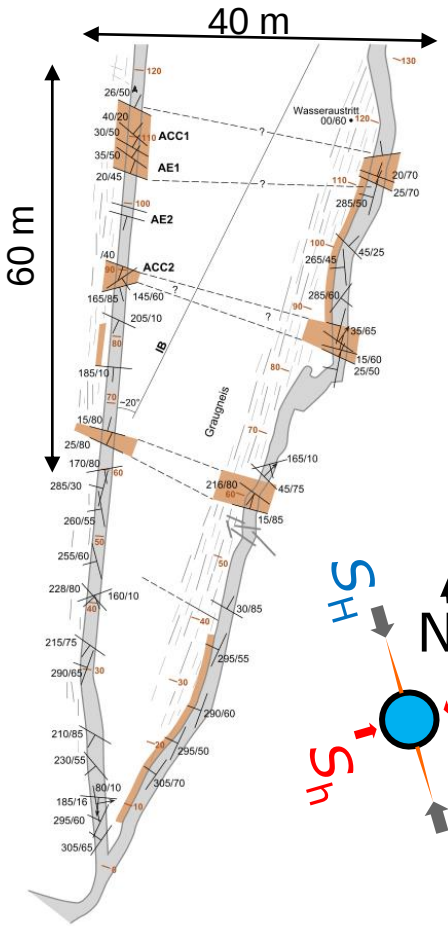
- Introduction STIMTEC experiment
- Reiche Zeche URL / Infrastructure
- Overview of field and lab measurements
  - Anisotropy characterisation
  - Stimulation
  - Stress measurements
- Summary & Conclusions

Introduction: STIMTEC experiment

STIMTEC hydraulic stimulation experiment at Reiche Zeche mine

- involves real-time monitoring technologies and 3-D numerical modelling
- **aims** to understand hydro-mechanical processes that occur during hydraulic stimulation, by associating and correctly identifying them through their seismic and hydraulic fingerprints
- comprised three phases that were **completed in December 2019**:
  - Pre-stimulation characterisation phase
  - Stimulation phase
  - Post-stimulation validation & characterisation phase
- a joint effort of an **inter-disciplinary team**





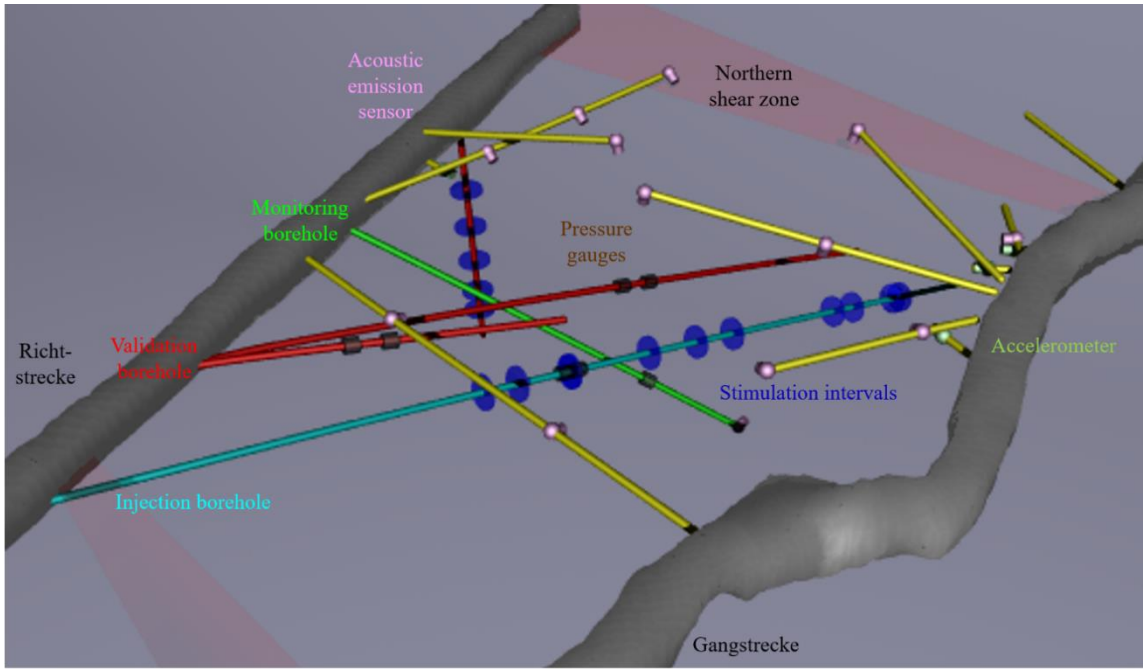
Freiberg
Eastern
Erzgebirge

~283 ASL
120-130 m depth

Reiche Zeche Underground Lab

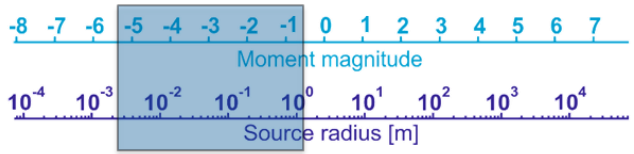
- Target volume ~60 x 30 x 20 m^3 of strongly foliated metamorphic Freiberg gneiss between two access tunnels
- comprises steeply dipping deformation zones
- foliation is sub-horizontal

Instrumentation & Borehole Monitoring Network



- 17 boreholes (Ø=76 mm)
- 12 AE sensors (1-100 kHz)
- 3 accelerometers (0.05-25 kHz)
- 1 broadband seismometer (0.01-100 Hz)
- 1 AE-type hydrophone (1-40 kHz)
- Up to 7 hydraulic pressure gauges

Target acoustic emissions (AE)



Overview of field measurements

Dataset/ measurement (Unit)	Acoustic TV/Sonic log (length in m)		Impression packer (no. of intervals)	Pressure (no. of gauges)
Time relative to	before stimulation	after stimulation	after stimulation	during stimulation
Injection BH	60	60/49	10	continuous (5)
Hydraulic monitoring BH	25	-	-	continuous (2)
Vertical validation BH	-	15	3	-
Horizontal validation BH	-	64	-	-
Cable BH	-	-	-	-

Dataset/ measurement (Unit)	Ultrasonic transmission (points along well)		Hydraulic testing (no. of intervals)		Acoustic emission (events located)
Time relative to	before stimulation	after stimulation	before/after drilling of validation BH	after	during stimulation
Injection BH	30 x 2 orient.	67	6/9	7	11000
Hydraulic monitoring BH	-	26	-	-	-
Vertical validation BH	19	19	2	5	140
Horizontal validation BH	-	70	-	-	-
Cable BH	-	26	-	-	-

The field campaigns produced high-quality sets of hydraulic, seismic and logging data.

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Overview of field measurements

Dataset/ measurement (Unit)	Acoustic TV/Sonic log (length in m)	Impression packer (no. of intervals)	Pressure (no. of gauges)
Time relative to	before after stimulation	after stimulation	during stimulation
Injection BH			
Hydraulic monitoring BH			
Vertical validation BH			
Horizontal validation BH			
Cable BH	- -	-	

To identify and characterise pre-existing and new fractures

To monitor the effect of the stimulation in real time

Dataset/ measurement (Unit)	Ultrasonic transmission (points along well)	Hydraulic testing (no. of intervals)	Acoustic emission (events located)
Time relative to	before after stimulation	before/after drilling of validation BH after	during stimulation
Injection BH			11000
Hydraulic monitoring BH			-
Vertical validation BH			140
Horizontal validation BH			-
Cable BH	- 20	- -	-

To character-ise seismic anisotropy

To characterise enhancement in hydraulic properties

The field campaigns produced high-quality sets of hydraulic, seismic and logging data.

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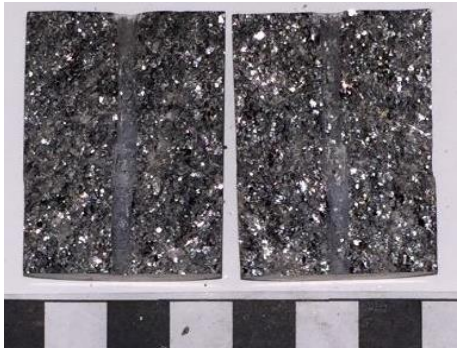
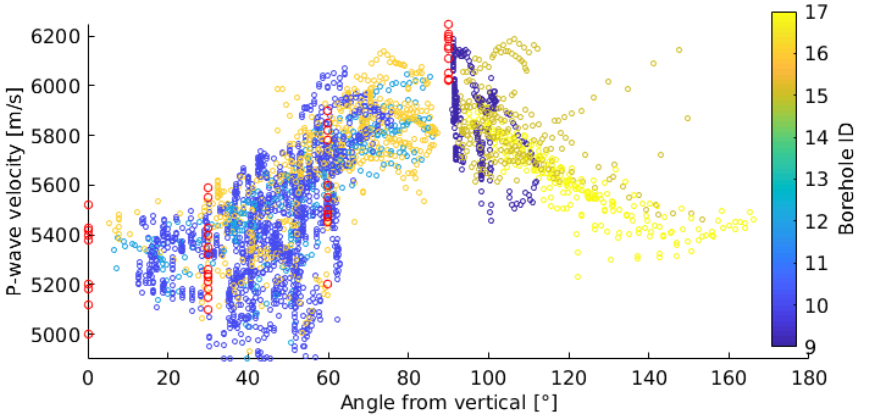
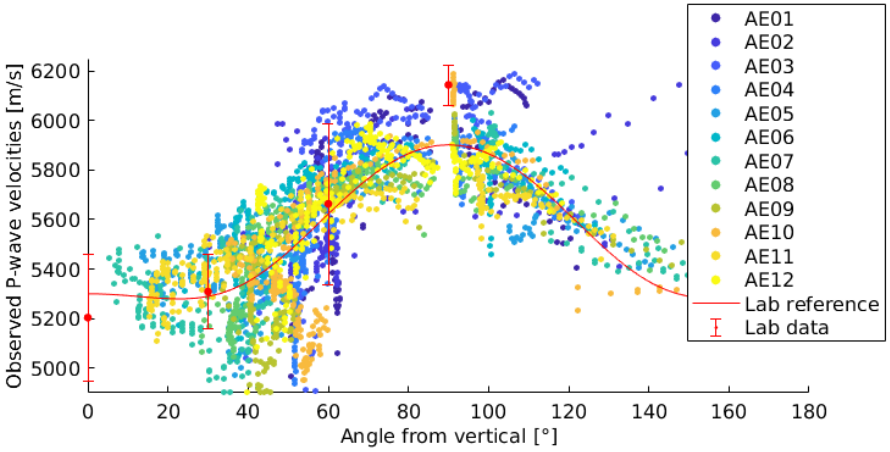
Overview of lab measurements

- 3-point bending tests
- laboratory mini-frac tests (confining pressures of 1–7 MPa, injection rate of 0.1 ml/s)
- triaxial compression experiments (3–5 MPa)



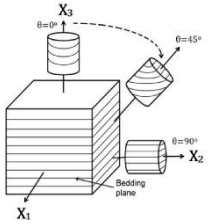
90° 30° 0°



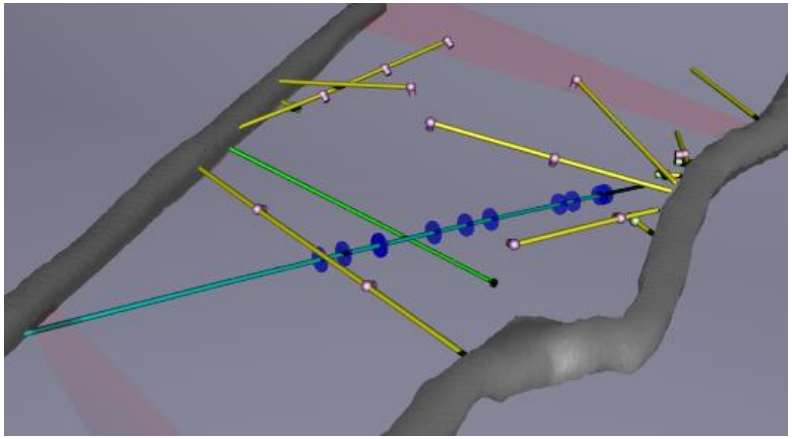


Anisotropy: Comparison lab and field

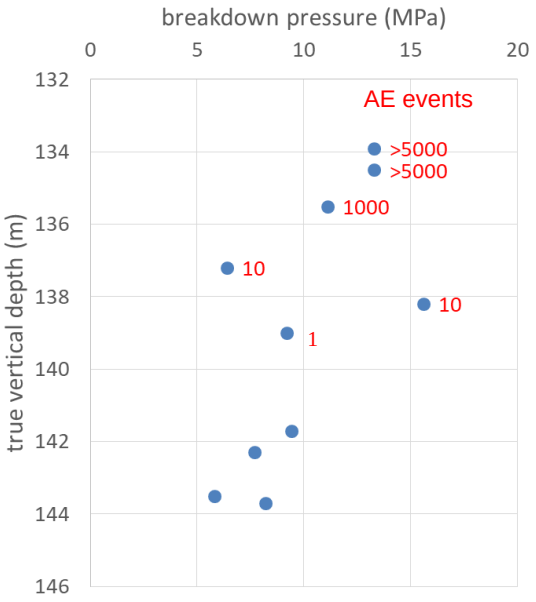
- Lab and field P-wave velocity measurements display same means and ranges
- Elastic wave anisotropy (12% on average), best described by vertical transverse isotropy, is caused by the sub-horizontal foliation

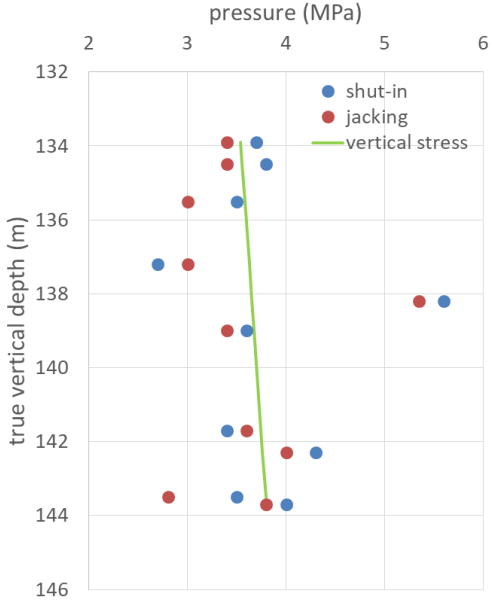


Hydraulic Stimulation (16-18 July 2018)

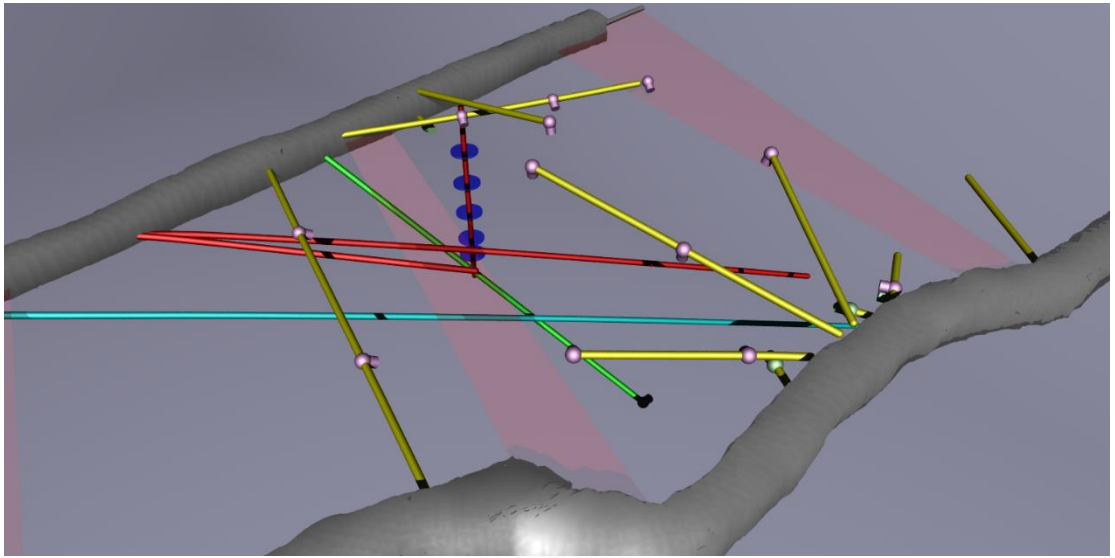


10 stimulation intervals along a 63 m long, 15° inclined injection borehole, real-time monitoring of acoustic emission activity and periodic pumping tests





Stress measurements in vertical validation borehole



HF5	HF4	HF3	HF2	HF1
4.0 m	6.7 m	9.3 m	11.7 m	13.2 m
21/8	21/8	21/8	21/8	20/8
11:00-11:45	10:05-10:46	9:00- 9:45	8:10-8:40	13:10-14:00
22 l	19 l	21 l	18 l	33 l
11.07 MPa	14.95 MPa	7.95 MPa	14.73 MPa	7.46 MPa
303 AEs	188 AEs	52 AEs	56 AEs	9 AEs

- 5 minifrac intervals
- Horizontal hydrofracs created in three intervals
- Variable breakdown pressures (7-15 MPa)
- Seismic activity decreases with depth

Summary & conclusions

- In July 2018, a mine-scale hydraulic stimulation experiment with 10 stimulated intervals was conducted at the Reiche Zeche underground lab in Freiberg, Germany.
- The metamorphic gneiss formation exhibits moderate to strong elastic wave anisotropy (2–30%, average 12%) with fast and slow propagation parallel and perpendicular to the foliation, according to active seismic measurements and lab measurements.
- The seismic and hydraulic responses to stimulation vary significantly along the length of the injection borehole with many AE events and high breakdown pressures at the shallowest injection intervals (22.4-28.1 m depth), few AE events and a range of breakdown pressures at intervals at intermediate depth (33.7-40.6 m depth) and low breakdown pressures and no seismic activity at the deepest injection intervals (49.7-56.6 m depth).
- Three validation boreholes were drilled in mid-2019 into seismically active and inactive areas and confirmed enhancement of hydraulic properties.
- Stress measurements through minifracs in the vertical validation borehole yield as variable seismic and hydraulic characteristics as in the injection borehole.
- The evaluation of the hydraulic testing and validation phases of the experiment is ongoing.

More Info: http://stimtec.rub.de/
Next ARMA newsletter 2020

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Thank you for your attention!

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