Acoustic Emission Monitoring of Laboratory Scale Hydraulic Fracturing Experiments

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Abstract

Hydraulic Fracturing type experiments on cube shaped blocks with 150 mm edge length and a 13 mm diameter central borehole under different true-triaxial confining pressures of up to 7.5 MPa have been conducted in this study. The tests lead to the initiation and propagation of new fractures and the interaction of those with pre-existing zones of weakness. Rock types that have been tested within this study are potential geothermal reservoir rocks. These are rhyolites and sandstones with generally low porosity and permeability and in the case of rhyolite with pre-existing (healed) fractures. Fracturing has been conducted via pressurization of an elastic polymer sleeve in the borehole to eliminate poroelastic effects. Main focus was the non-destructive mapping of the fracture development. Acoustic Emission (AE) was monitored using an AE acquisition system from Vallen Systeme GmbH, Germany with 10 transducers. Data were evaluated using a self-written program based on actual AE-data processing techniques. A total of 30 experiments containing different true-triaxial loading conditions have been evaluated. During far-field stress loading pre-existing fractures within the samples started to emit AE. These localizations revealed the structure of the pre-existing fractures that yield important information benefit for the interpretation of the subsequent fracture propagation. The sleeve fracturing process could be monitored very precise due to the low fracture propagation velocity that is caused by stable fracture propagation. AE monitoring also revealed the 'trapping' of induced propagating fractures by pre-existing fractures. Successive borehole pressurization also forced pre-existing fractures to become active. Branching and deviation of the induced fracture away from the supposed orientation as well as fracture propagation parallel to the borehole became visible in some experiments. AE monitoring of hydraulic fracturing experiments revealed the complexity of this kind of experiments. This knowledge is very relevant for interpretation of the hydraulic and deformation data. The ability to measure the fracture-front position and geometry in time delivers important information for modelling purposes and model verification that are also a part of this project.

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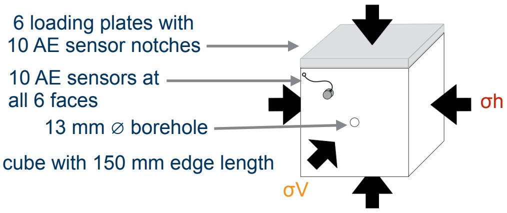
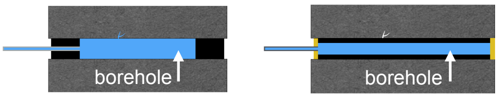
Introduction

The research project aims at optimizing the stimulation design for geothermal reservoirs (hydraulic fracturing) based on an improved understanding of the interaction of pre-existing fractures.

Within this project the non-destructive monitoring of the activation of pre-existing fractures via Acoustic Emission, as well as the investigation of the propagation of induced fractures in the experiments is anticipated.

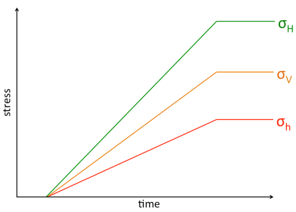
Experimental Setup



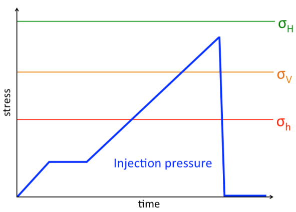


Procedure

A) applying the pre-defined true triaxial far-field stress; σh < σV < σH up to 7.5 MPa

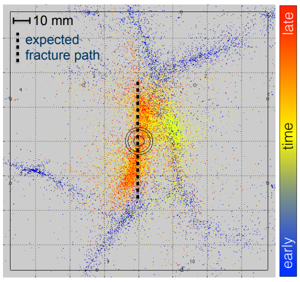


B) increase the injection pressure by 0.1 ml/min (≈ 0.3 MPa/s) up to 105 MPa



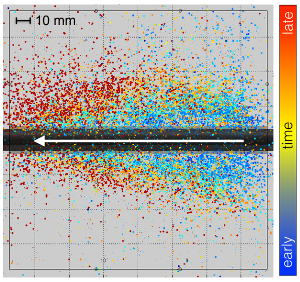
Results - main observations

Sandstone



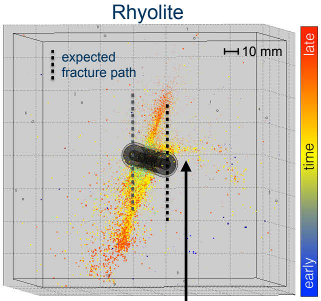
Pre-existing fractures became visible as soon as the confining stresses raise (blue). Successive raise of the injection pressure yield the reactivation of pre-existing fractures near the borehole (yellow) and afterwards the expected fracture (orange).

Sandstone



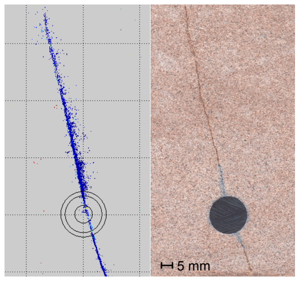
Fracture propagation starting at one end of the borehole and propagating in the direction of the borehole was observed (see time-color-coding from blue-early to red-late).

Rhyolite



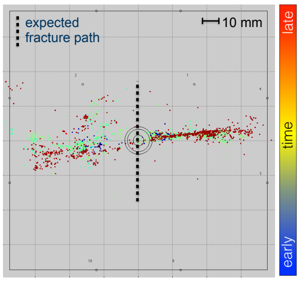
'Trapping' of the fracture within a weak pre-fractured zone. Successive fracture growth within this zone perpendicular to the expected fracturing direction. Pre-fractured zones lying horizontally in this case.

Sandstone



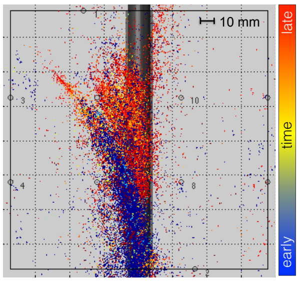
Localization accuracy example referenced to a scan of the fracture. High quality events are localized within 5 mm uncertainty.

Slate



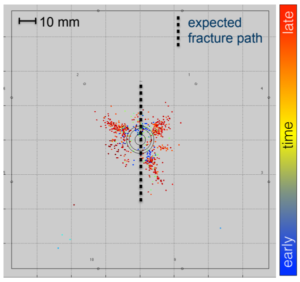
Opening of a schistose layer in the direction of the smallest principle stress perpendicular to the expected fracture path. Schistosity is aligned horizontally.

Sandstone



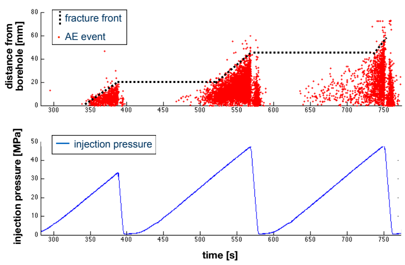
Curved deviation away from the expected fracture path into the rock within several branches following pre-existing fractures.

Sandstone



Fracture-initiation part of an experiment. Three rather then two fractures at the borehole wall developed.

Sandstone



Fracture propagation distance from the borehole can be displayed vs. time and/or injection pressure. Onset of further fracturing within several injection cycles are clearly distinguishable.

Conclusion

- Water-fracs develop way to fast to be monitored properly (not shown here)
- Sleeve-fracs allow for partly stable fracture propagation and precise localizations
- Fracture interaction with pre-existing weaknesses is present and observable
- Induced stress field may differ from the (basic) expected one
- Velocity anisotropy/inhomogeneity can be handled quite well (via pulsing)

4D AE fracture propagation monitoring yield relevant information for the interpretation of each single experiment and serves as an important tool for model verification.

Acknowledgements

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