Fracture propagation during fluid injection in reservoirs

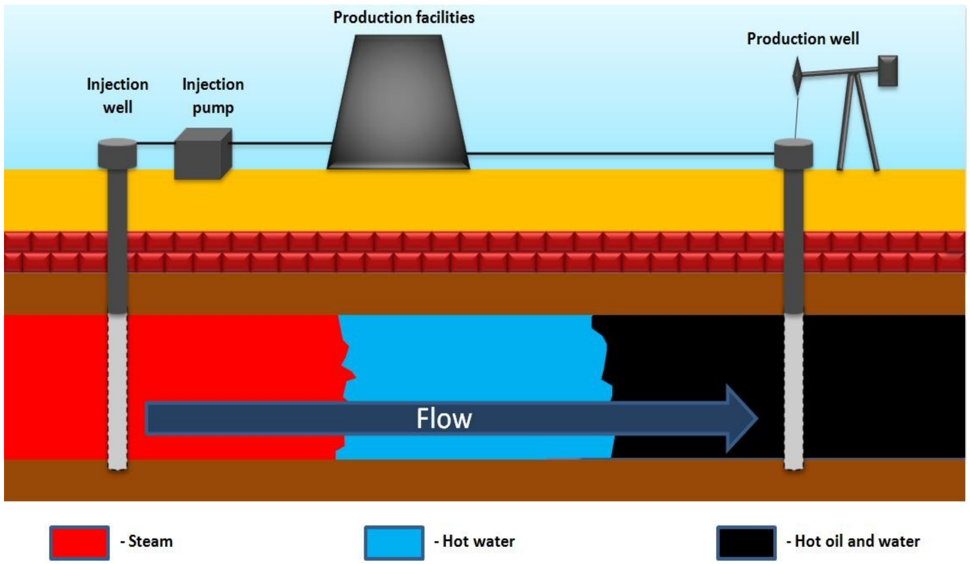
Srutarshi Pradhan
PoreLab, NTNU

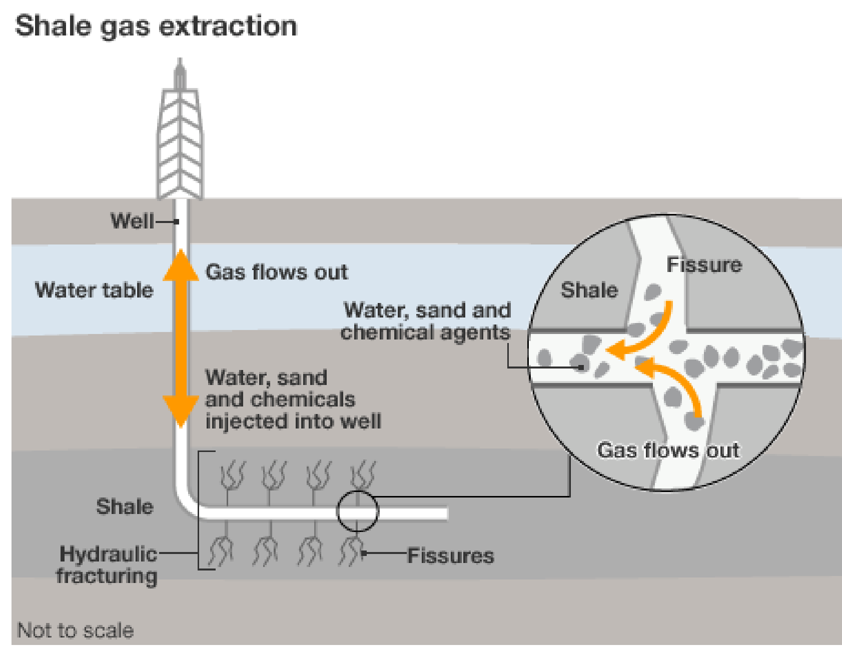
PoreLab Meeting, Soria-Moria, Oslo
06-08 September, 2017

Outline

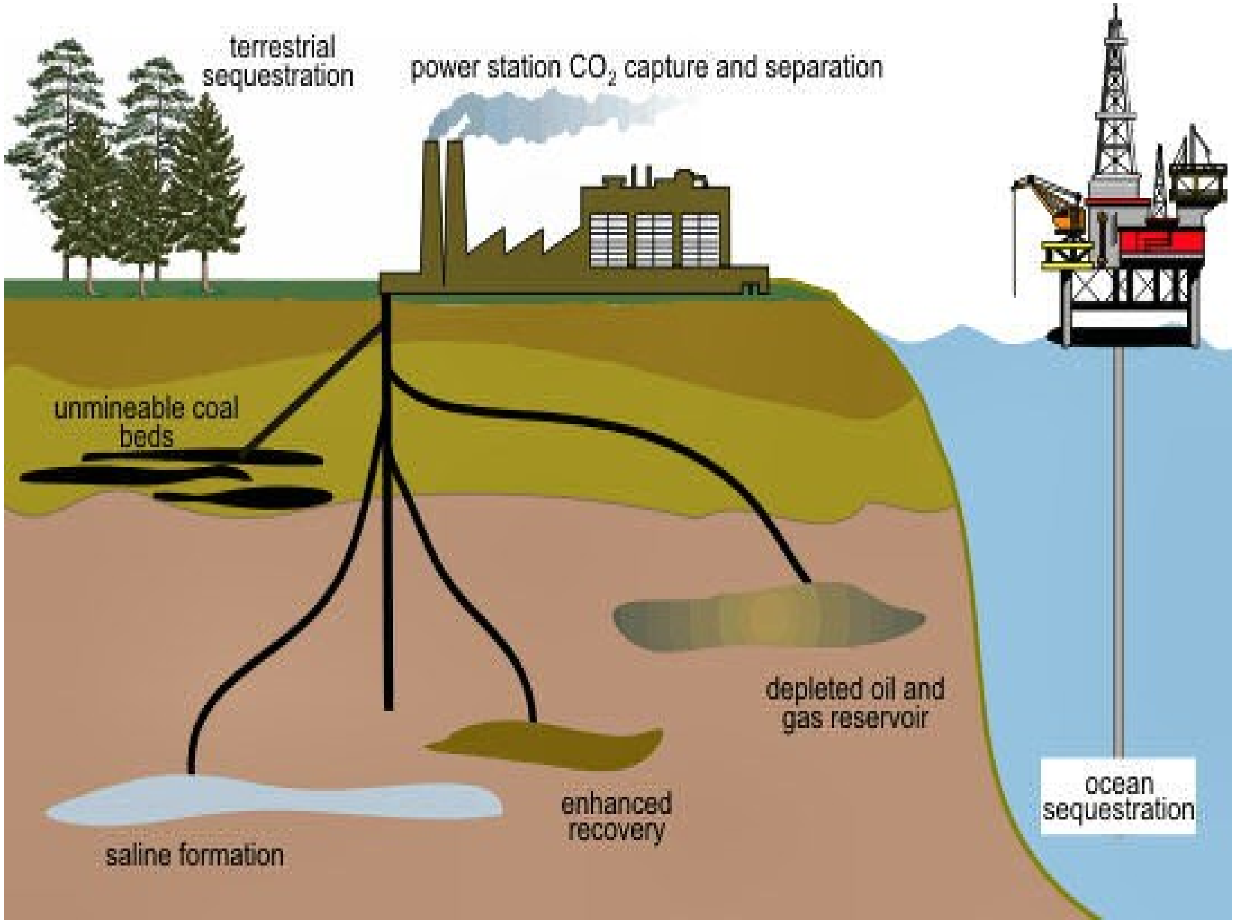
- Fluid injection scenarios
- Field problems during fluid injection
- Explanation and research targets
- Experiment and analysis
- Discrete element model simulation
- Conclusions

Oil & Gas production (EOR/EGR)

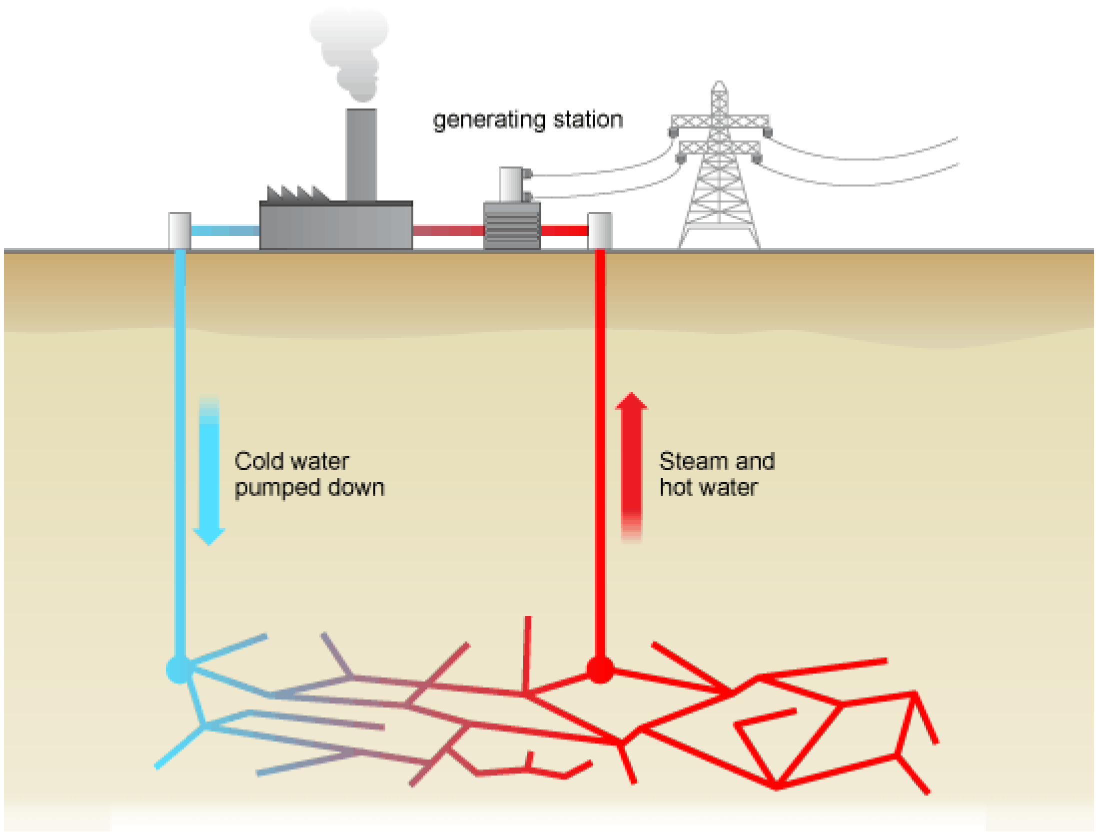




Underground CO2 storage



Geothermal energy production



Problems: Field cases

1. Injected water is coming directly to production well

2. Mud-loss events during drilling

3. Borehole collapse

4. Numbers of gas-well in Canada are leaking

5. A lot of activities (micro-seismic) have been recorded far from injection well (CO2 storage, US)

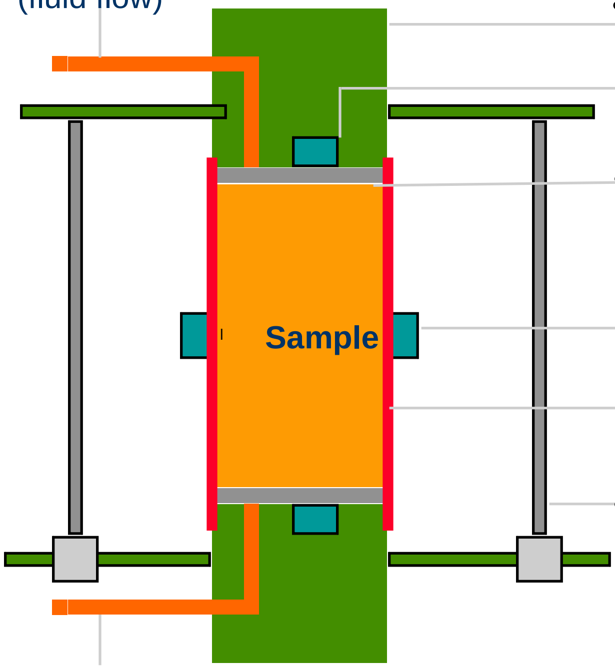
6. Field permeability is much higher (10 times or more) than estimated value (lab test + theory)

Solution/explanation

- How and when fracture opens up ?
- Is the fracture pattern different for different rock type?
- How important is porosity level?
- What is the role of pre-existing fractures/faults ?
- How can we characterize a fracture network inside rocks?
- Can we calculate fracture propagation velocity?
- Can we assess leakage possibility?
- How can we monitor fracture propagation?

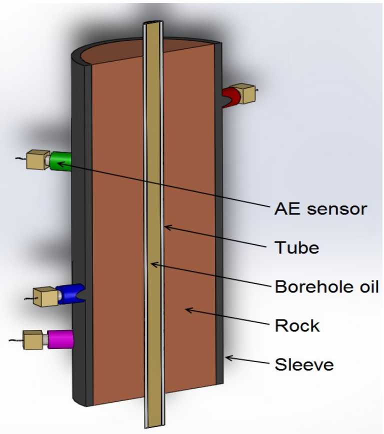
Experiments: Fracturing by fluid injection

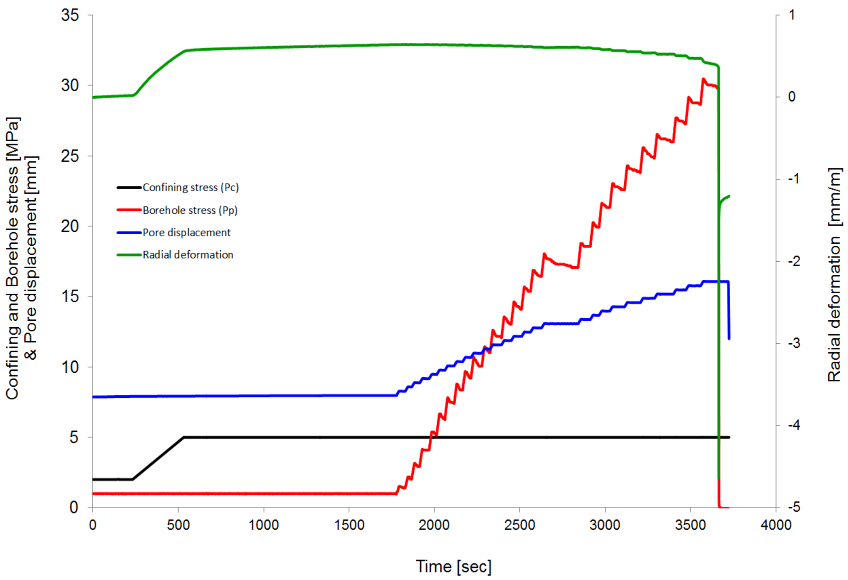
- Pore pressure
- (fluid flow)



- Steel piston
- Acoustic transducer
- Sintered plate
- Acoustic transducer
- Sleeve
- Axial strain LVDT

- Pore pressure
- (fluid flow)





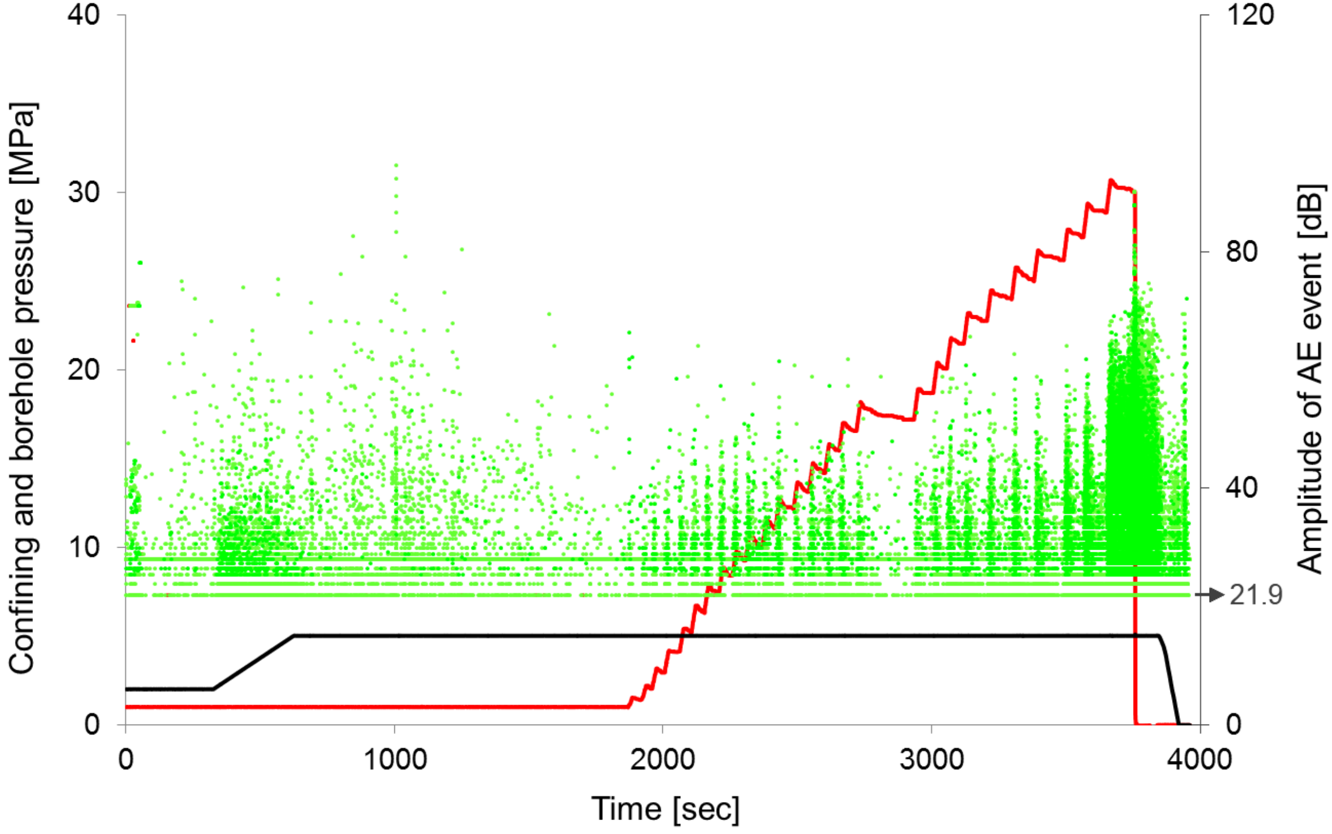
Pub. In ARMA 2013,2014,2015,2016

Findings from Lab-test

SAMPLE	Fracturing stress (MPa)	Peak axial stress (MPa)	Young's modulus (GPa)	Tensile strength (MPa)
Berea	30.6	82.3	13.8	4.7
Castlegate	25.8	20.4	3.4	1.0
R-wildmoor	25.5	19.3	3.4	0.9
Mons chalk	20.0	13.3	4.9	1.7
Saltwash-N	26.28	20.84	3.02	1.65
Saltwash-S	20.25	1.89	0.28	0.23
Lixhe Ch II	20.41	10.16	4.75	0.81
Lixhe Ch 90 degree	18.96	9.87	4.63	1.21

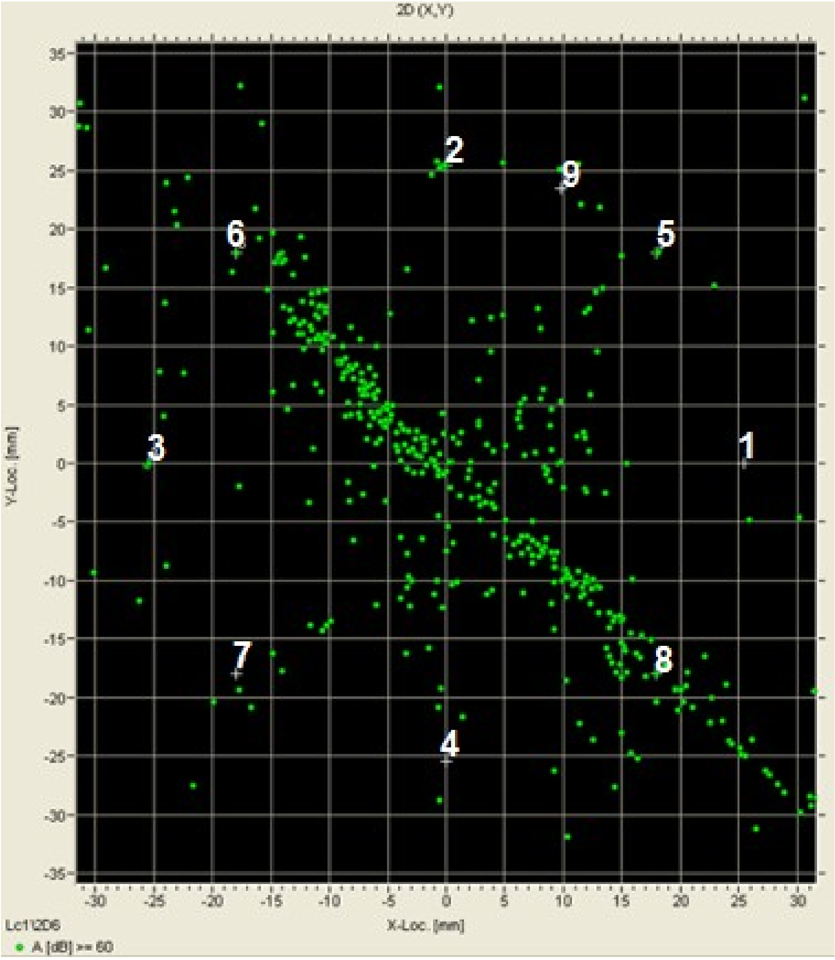
Pub. In ARMA 2013,2014,2015,2016; IJRMRE 2015

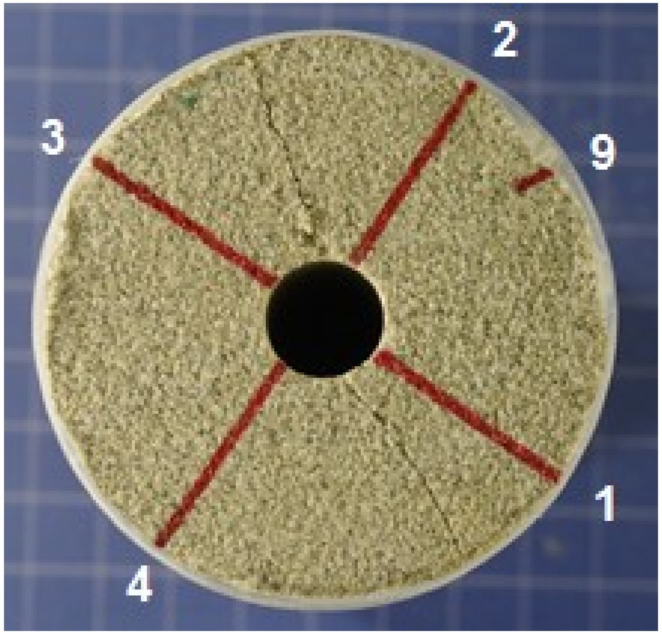
AE events during fracturing test



Pub. In ARMA 2015,2016; IJRMRE 2015

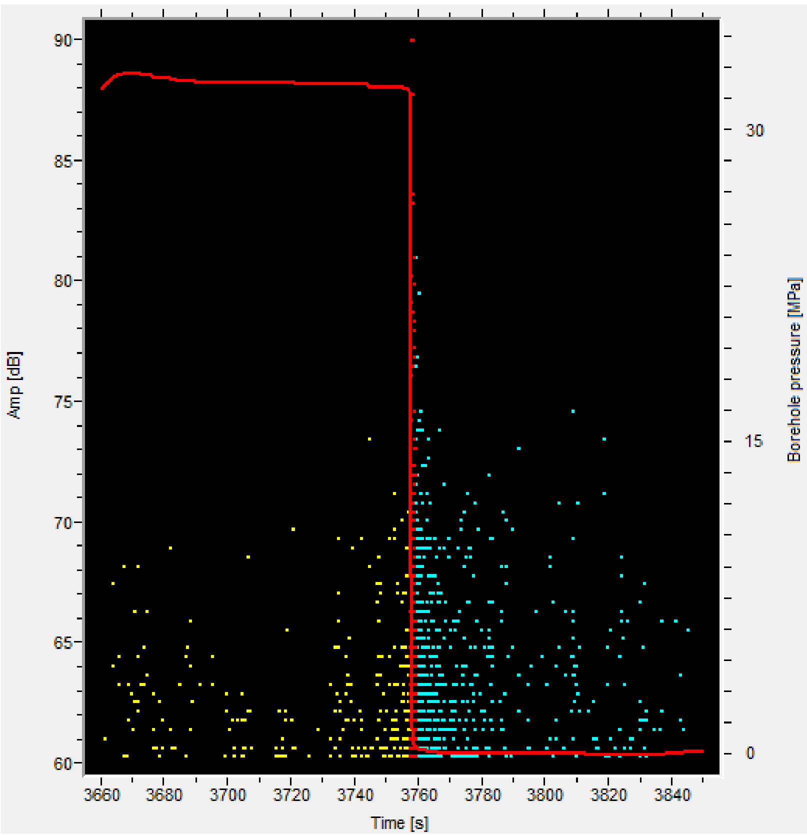
AE event locations

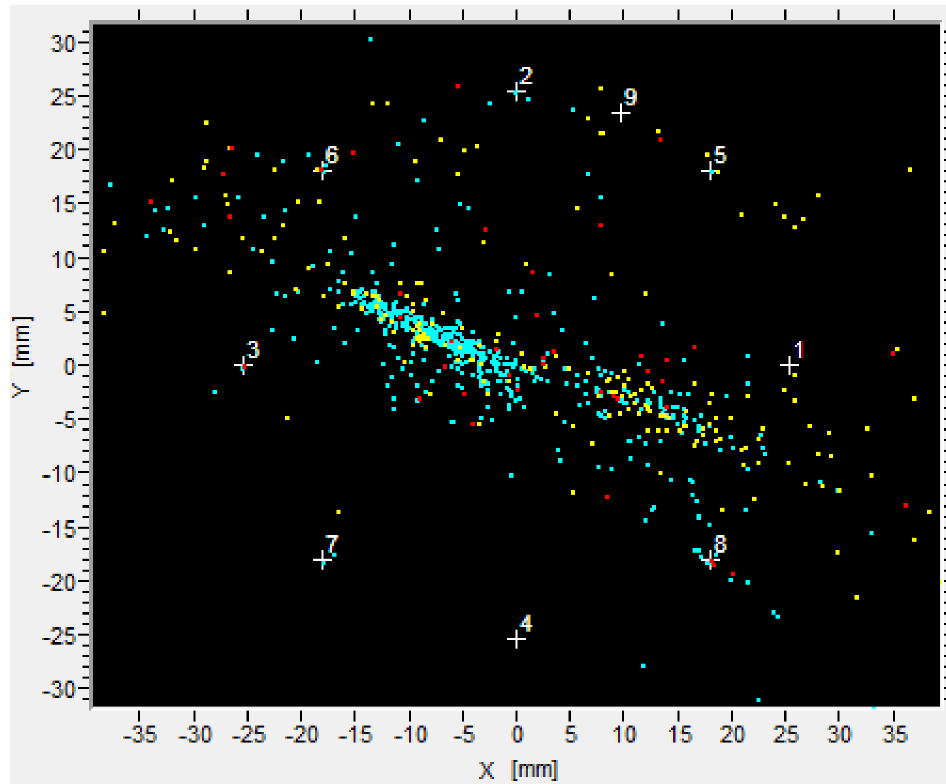




Pub. In ARMA 2014,2015; IJRMRE 2015

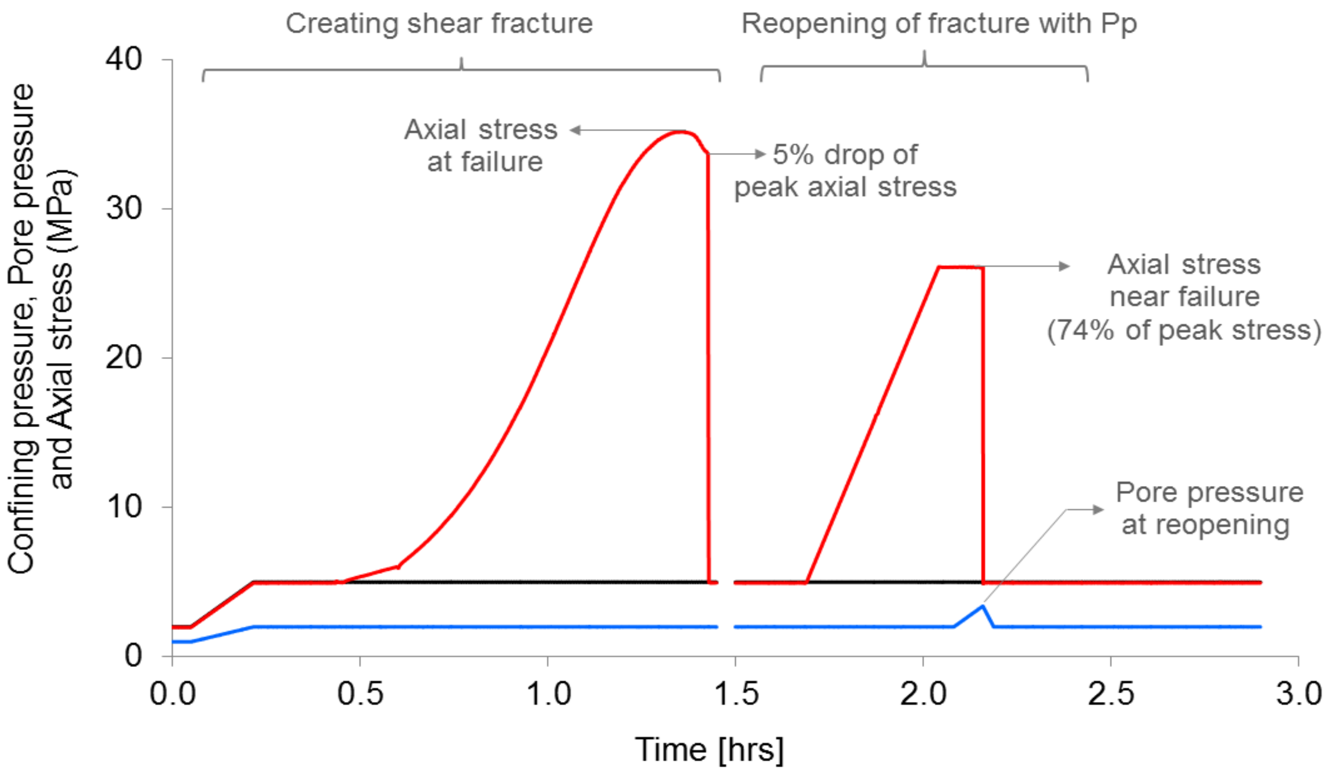
AE analysis near fracturing point





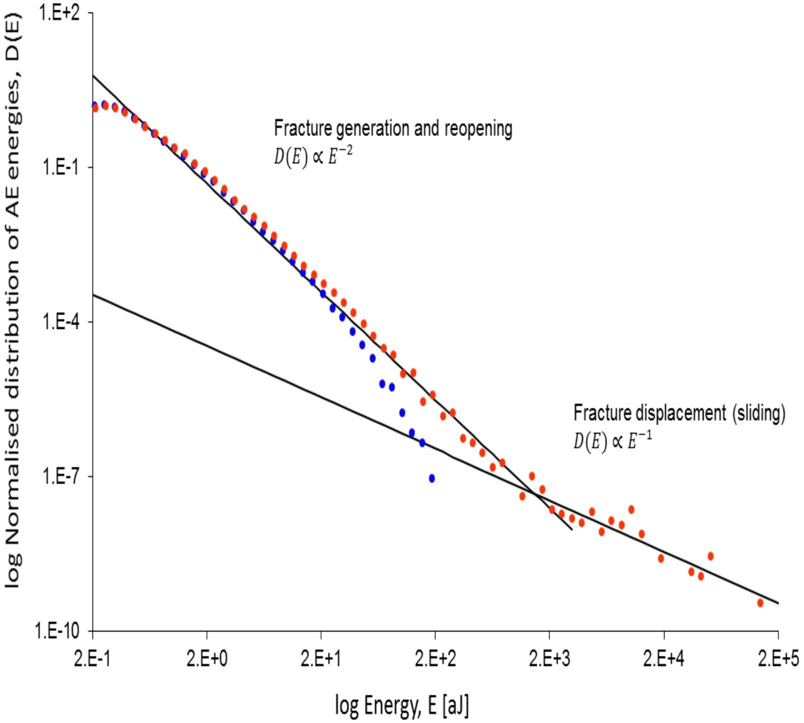
Pub. In ARMA 2015,2016; IJRMRE 2015

Fracture reactivation by pore-pressure inc.

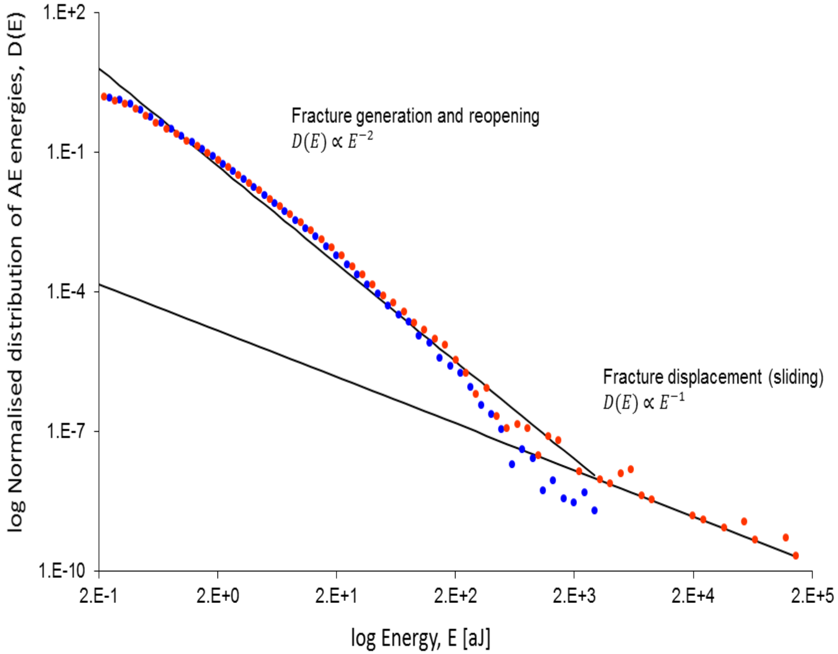


Pub. In ARMA 2016

AE energy distributions



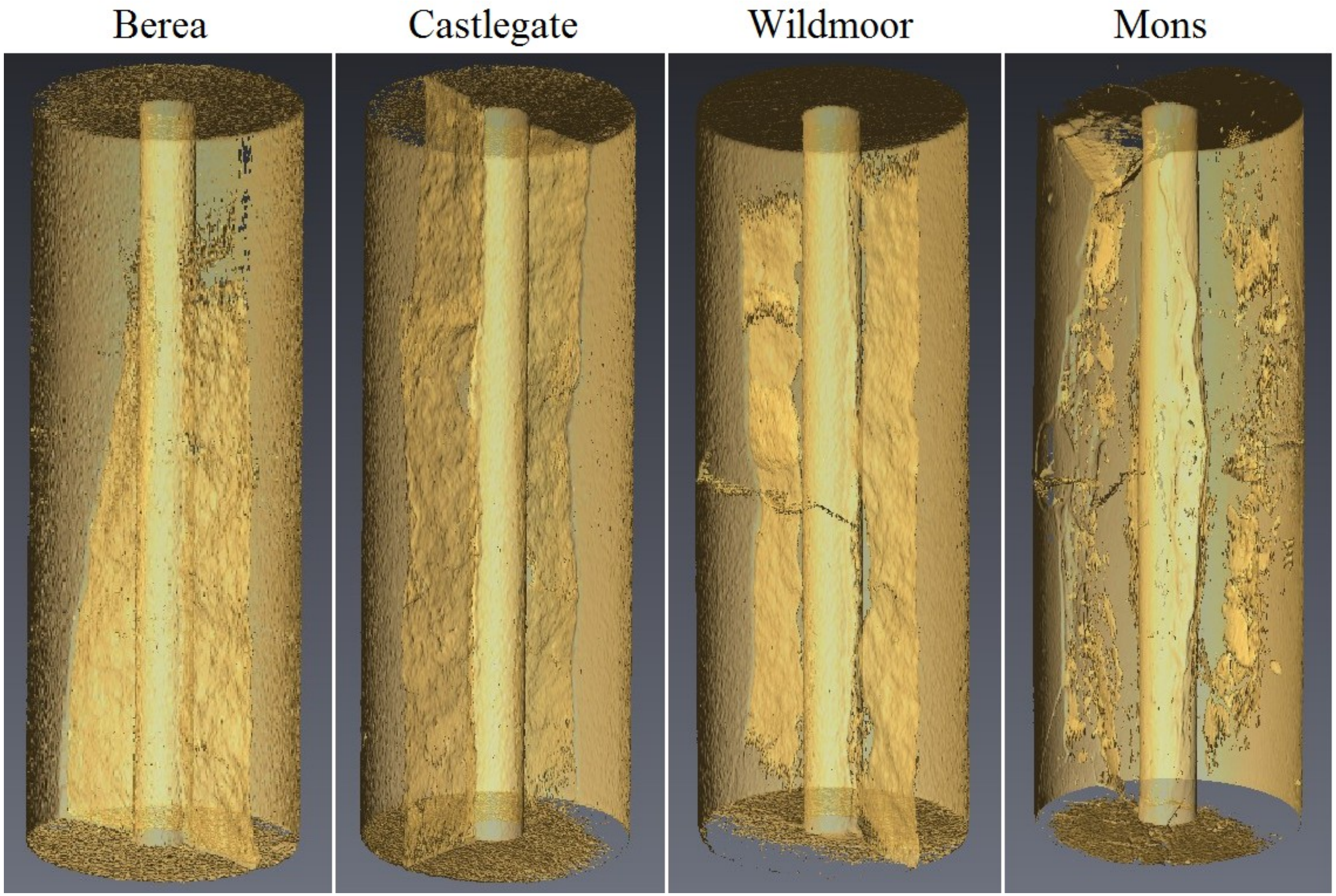
Castlegate Rock



Mount-Simon Rock

Pub. In ARMA 2016

Micro-CT image analysis



Pub. In ARMA 2014,2015; IJRMRE 2015

Reconstructed fracture plane (by AVIZO)

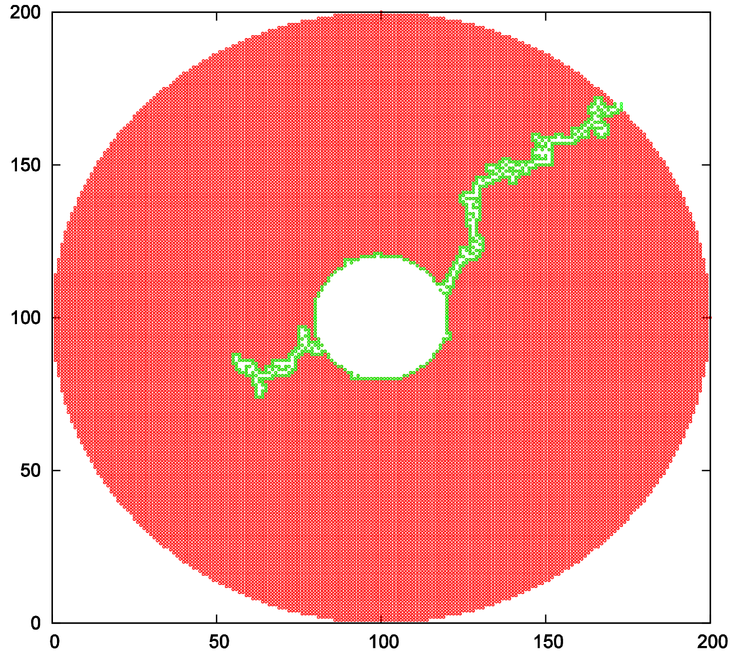
Mount-Simon Rock

Castlegate Rock

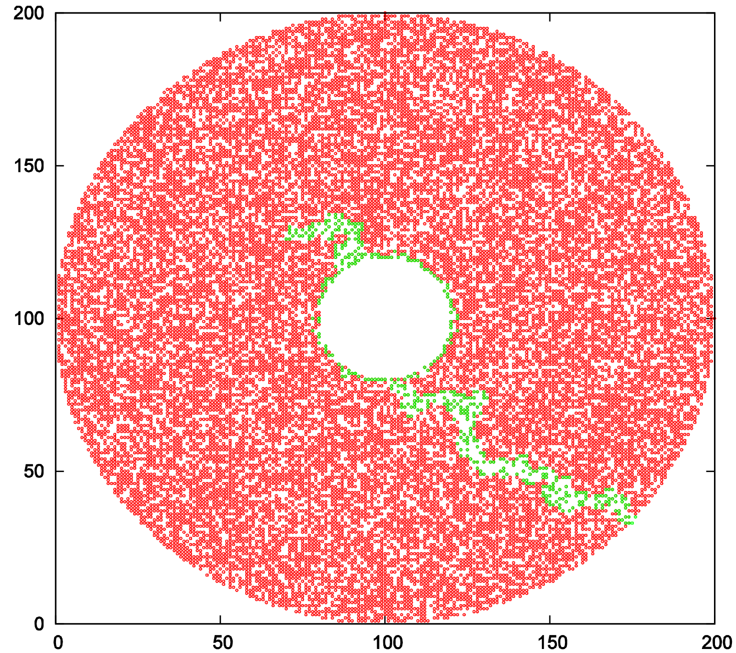
Pub. In ARMA 2016

DEM: Fracturing by fluid injection

Idea: Invasion percolation + distance dependent K
Inputs: Tensile strength dist.
breaking criteria, porosity, sample size, borehole pressure



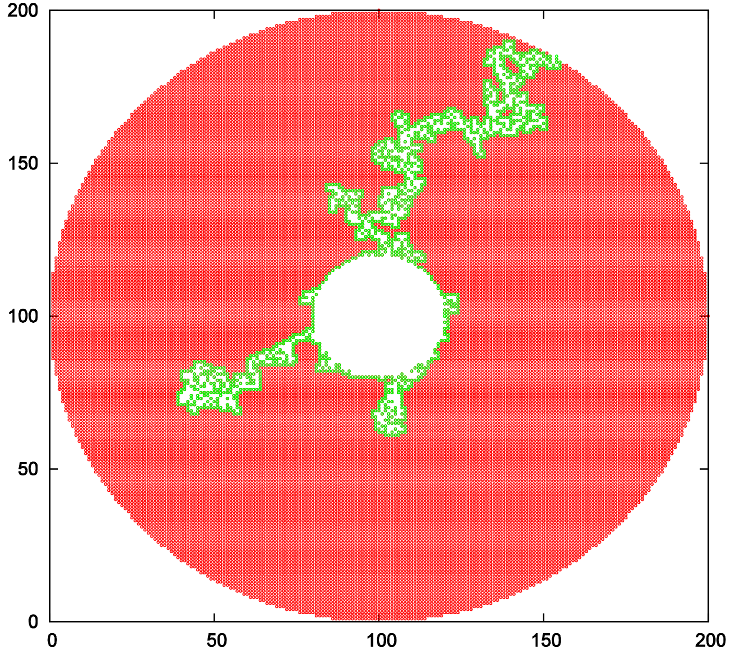
Porosity = 0



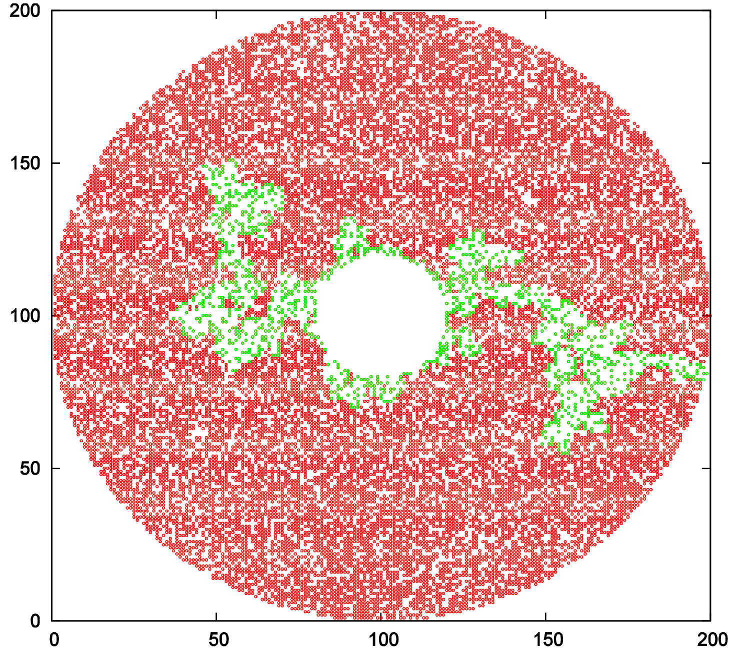
Porosity = 30 %

In Final Report to NFR on INDNOR Fracture-flow project 2015

DEM: Less brittle rocks



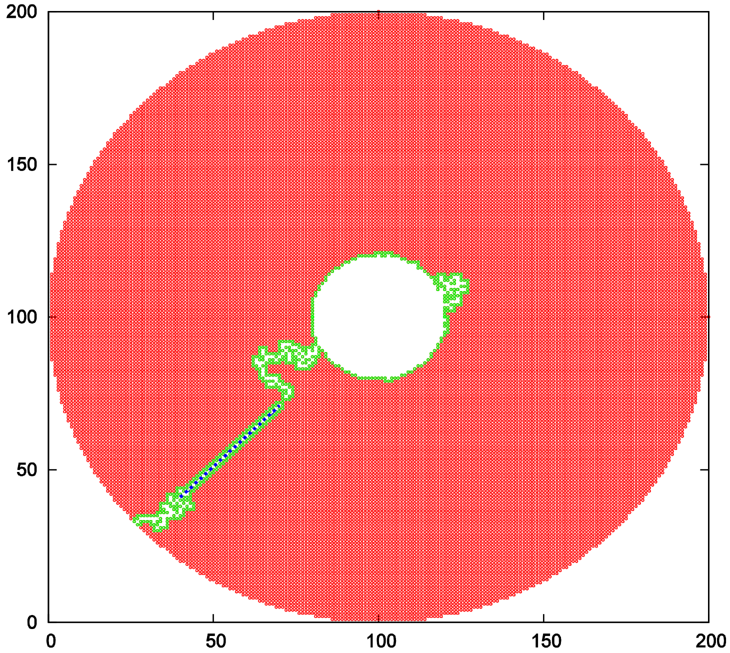
Porosity = 0

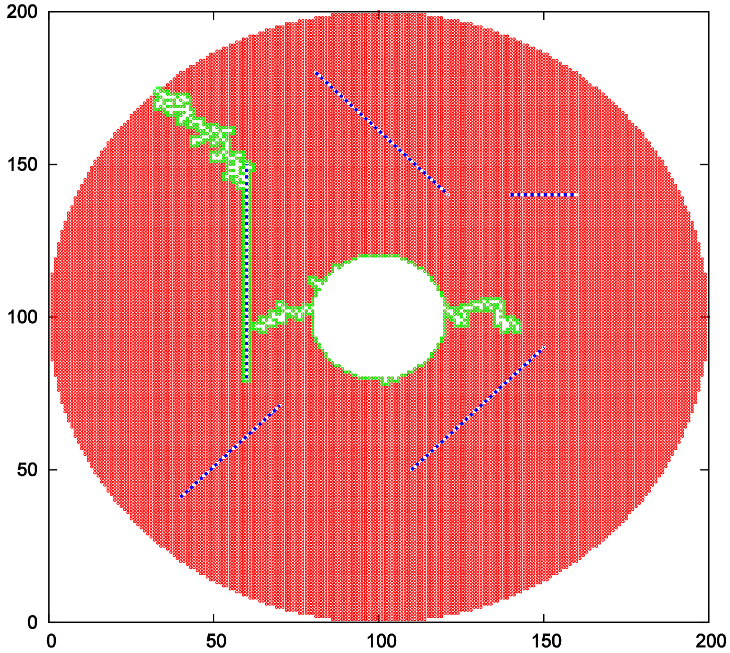


Porosity=30 %

In Final Report to NFR on INDNOR Fracture-flow project 2015

Pre-existing fractures





In Final Report to NFR on INDNOR Fracture-flow project 2015

DEM: Possible studies

- Properties of the fracture path- roughness, fractal dimen.
- Sample-size/hole-size effect
- Effect of pre-existing fractures in the sample
- Temperature effect
- Effect of mineralogy on fracture pattern & growth
- Anisotropic stress situations
- Fracture propagation velocity in different rocks
- 3D modelling

Conclusions

- Fluid injection can trigger rock-fracturing
- Induced fracture can reactivate existing fractures/faults
- We need better understanding of the dynamics
- Fractures are fatal for borehole stability
- EOR/EGR operations need more fractures (controlled ?)
- Fractures are safety issues (leakage) for CO_2 storage but they can help things by enhancing CO_2 absorption rate
- Geothermal energy production needs better flow channels – perhaps by controlled fracturing
- Research Challenges: Fracture characterization and active/passive monitoring of fracture propagation through porous rocks

Acknowledgment

- All the Lab tests were done in SINTEF Petroleum Research (Formation Physics Laboratory), Trondheim
- Micro-CT scans of the rock samples were taken by Numerical rocks and NTNU CT-scan center
- Major part of this work had been funded by NFR through CLIMIT (2010-2014) and INDNOR (2011-2015) Researcher projects
- DoE (US) funded the Fracture-reopening tests and analysis part through GSCO2 project (2015-2016)
- PoreLab funded travel,accommodation etc. for attending this PoreLab kickoff meeting