Numerical simulation of a laboratory experiment testing hydraulic fracture initiation monitored by acoustic emission

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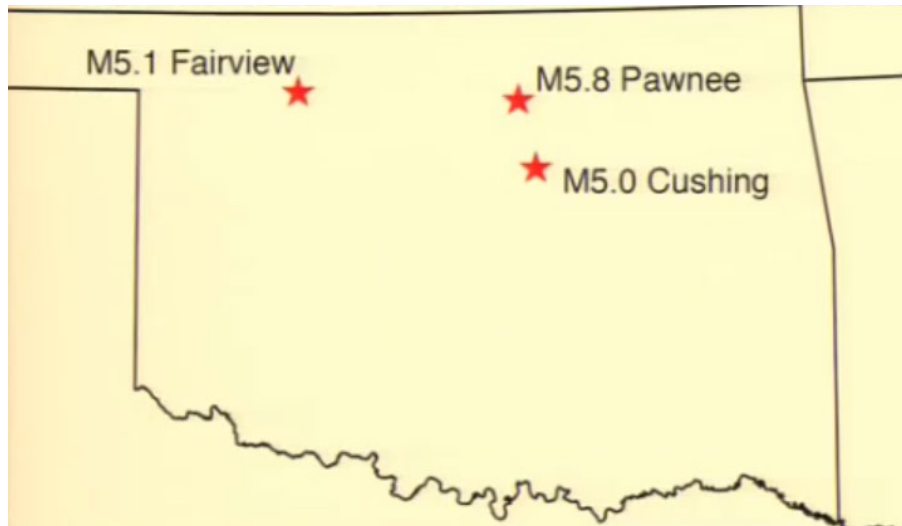
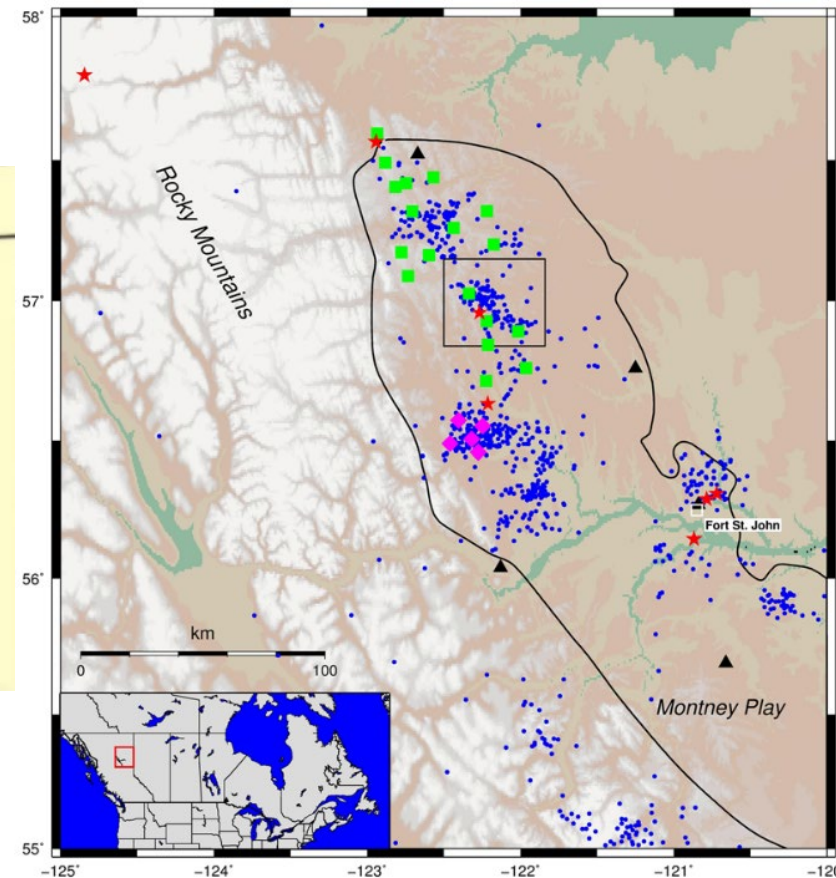[2] *Itasca Consulting Group, Inc.*

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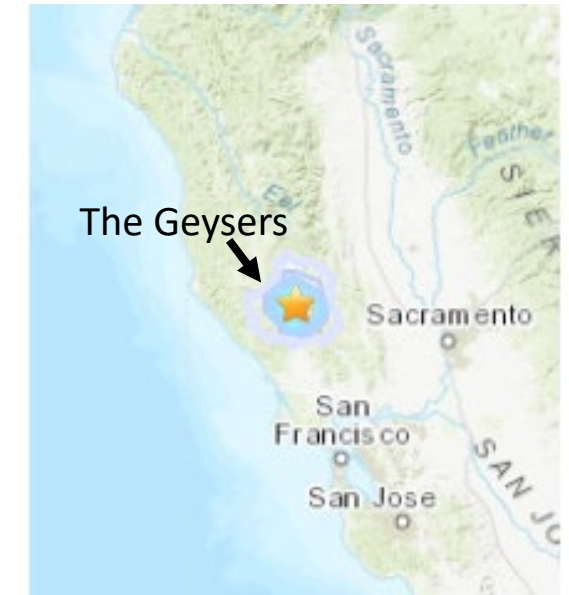# Motivation

- Injection Induced Seismicity

Geothermal reinjection/Hydraulic stimulation Mw 4.5

Hydraulic Fracturing Mw 4.6

Wastewater Disposal Mw 5.8

The Geysers

Mw 4+

Mahani, et al. 2017

XSite™ validation against hydraulic fracturing lab experiments

3D Ultrasonic Surveying

Hydraulic Fracturing test

XSite™

Numerical Modeling Mechanistic Studies

1

2

4
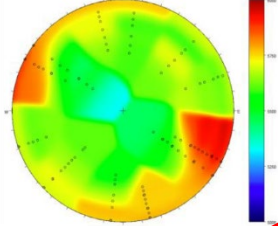
16-bit continuous data acquisition
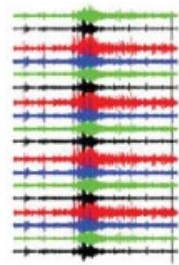
Amplified Acoustic Data

InSite-Lab™

3

processing software
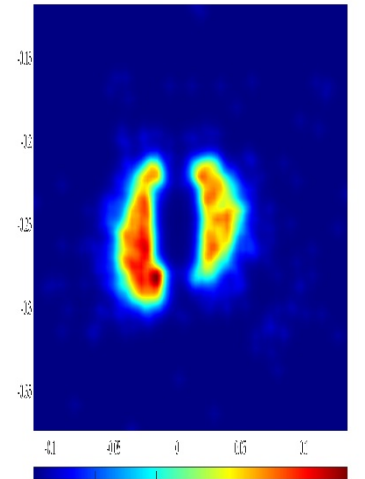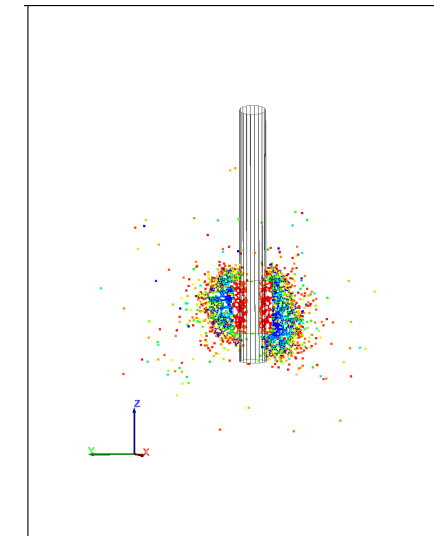
Model Verification

5
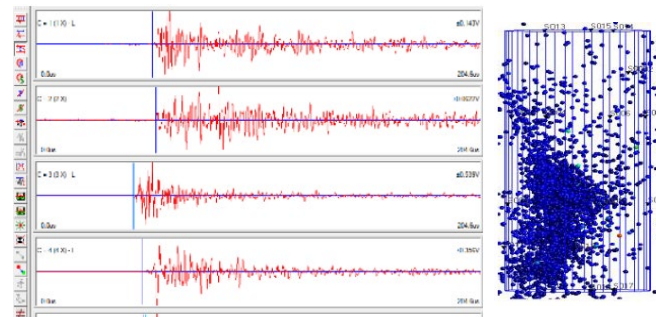
Laboratory Experiment

- Why this published test?
  - Intact **homogeneous** rock
  - **Hydraulic Fracturing** in a cubic sample shape
  - **Bottomhole pressure** data
  - **Displacement** data
  - **Acoustic Emission** count and reasonable precise hypocenter data

Rock Mechanics and Rock Engineering
September 2014, Volume 47, Issue 5, pp 1521–1532 | Cite as

Onset of Hydraulic Fracture Initiation Monitored by Acoustic Emission and Volumetric Deformation Measurements

Authors   Authors and affiliations

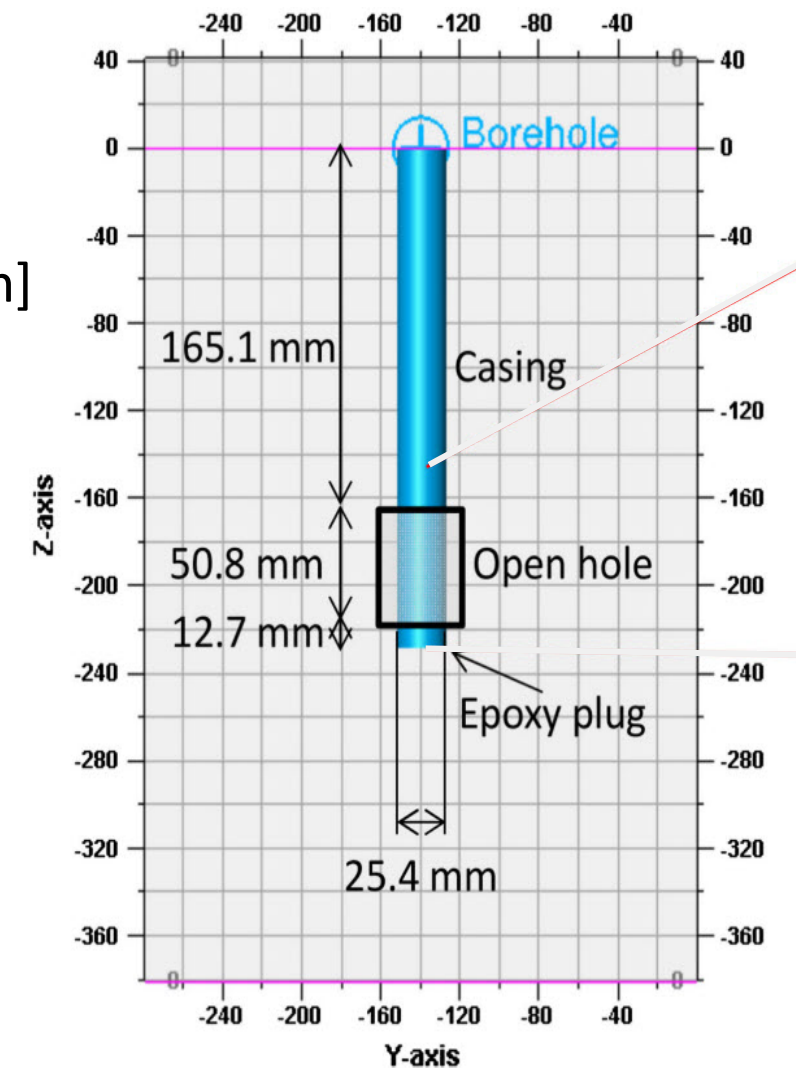Sergey Stanchits ✉, Aniket Surdi, Patrick Gathogo, Eric Edelman, Roberto Suarez-Rivera

Stanchits et al. 2014

Laboratory Experiment

- Experimental setup
  - Sample size in X×Y×Z: 279×279×381 mm^3
  - Hole dimension: D (25.4)/h (241.3)/open hole length (50.8) [mm]
  - Two longitudinal notches

Stanchits et al. 2014, I. Vera Rodriguez et al. 2017

Laboratory Experiment

- Experimental setup
  - Sample size in X×Y×Z: 279×279×381 mm^3
  - Hole dimension: D (25.4)/h (241.3)/open hole length (50.8) [mm]
  - Two longitudinal notches
  - Loaded hydraulically by flat jacks
  - Acoustic Emission by 24 receivers (continuous)
  - Ultrasonic velocity by 1 transmitter and 5 receivers (1Hz)
  - Injection fluid: silicone oil (μ=2.5 McP) at 5 mL/min

σ_V = 27.6 MPa
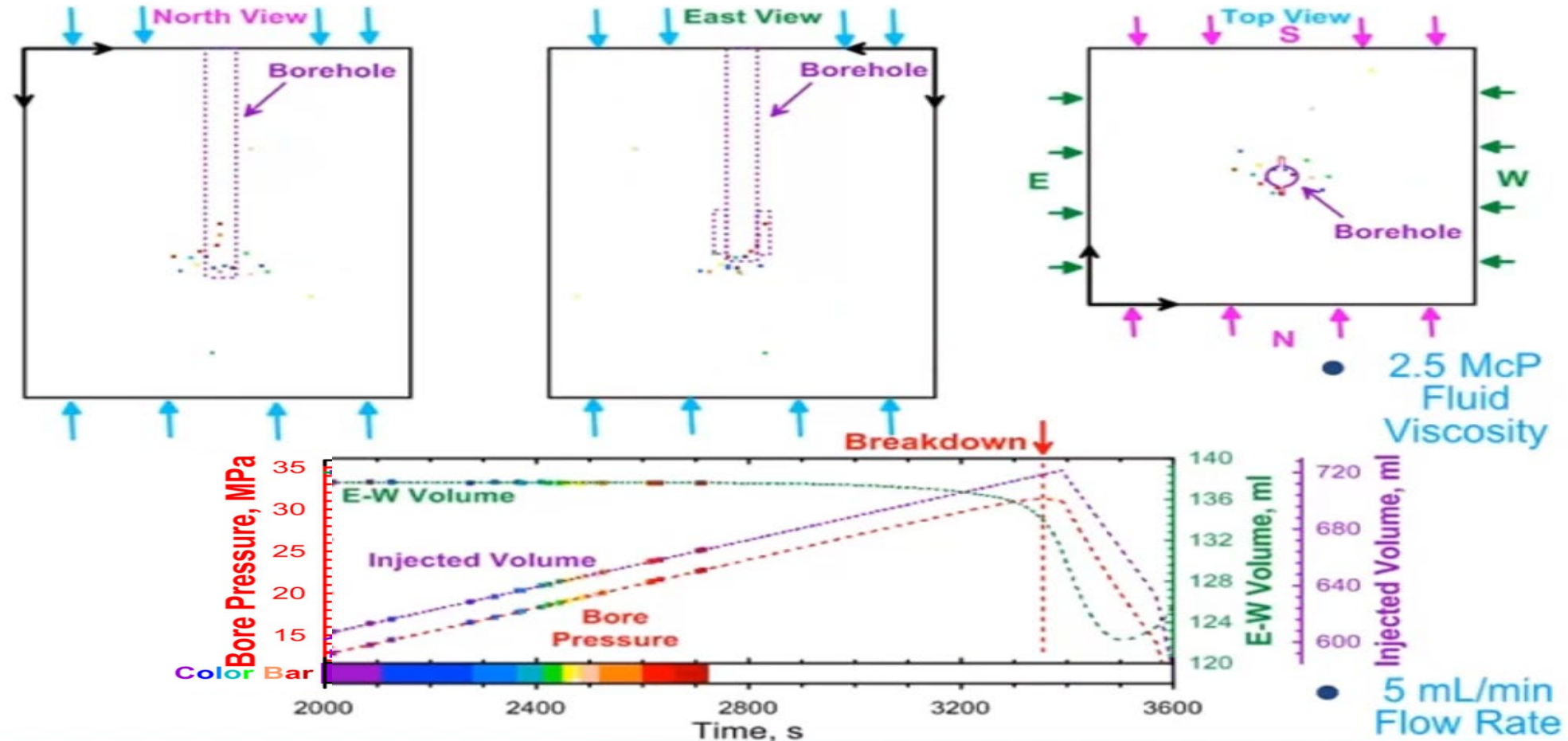
σ_H = 13.8 MPa

σ_h = 6.9 MPa

Stanchits et al. 2014

The Hydraulic Fracturing Experiment on homogenous Colton sandstone- Test results
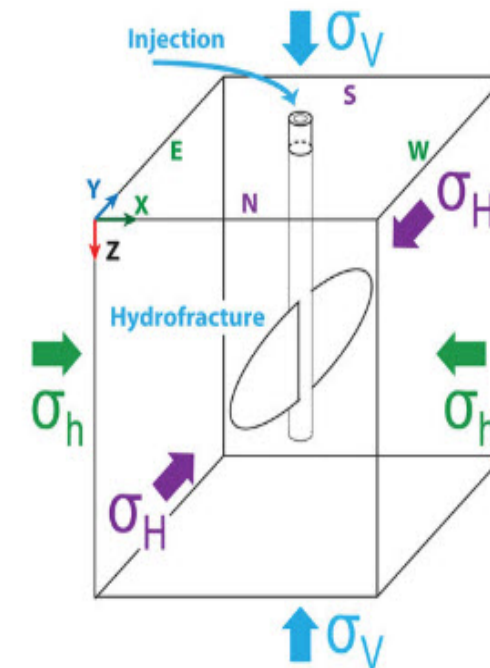
$\sigma_V = 27.6$ MPa

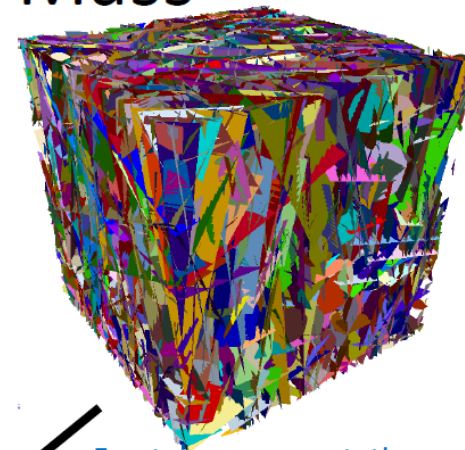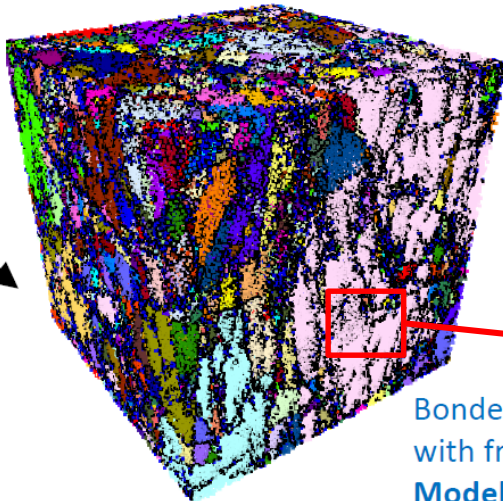$\sigma_H = 13.8$ MPa

$\sigma_h = 6.9$ MPa

Stanchits's lecture at The University of Utah, 2013

Itasca XSite™

Synthetic Rock Mass

Intact rock representation by DEM (including brittle fracture)
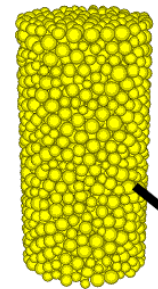
Fracture representation – 3D DFN (Discrete Fracture Network)

Bonded-particle assembly intersected with fractures (using the **Smooth Joint Model – SJM**)

XSite
©2018 Itasca Consulting Group, Inc.

Sketch Model
Elements
- Wellbore-Stage_5-2-1
- Wellbore-Stage_4-2-2
- Wellbore-Stage_3-2-3
- Wellbore-Stage_2-2-4
- Wellbore-Stage_1-2-5

Sketch Model
Elements
- Boreholes

Pipes
Cylinders (1,712,776)
- 2.9357E-02
- 2.7500E-02
- 2.5000E-02
- 2.2500E-02
- 2.0000E-02
- 1.7500E-02
- 1.5000E-02
- 1.2500E-02
- 1.0000E-02
- 7.5000E-03
- 5.0000E-03
- 2.5000E-03
- 1.0000E-06

Scale: 235
Aperture (m)

joint plane

Damjanac et al., 2016
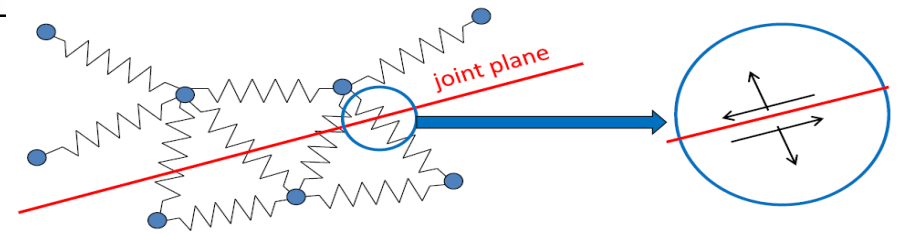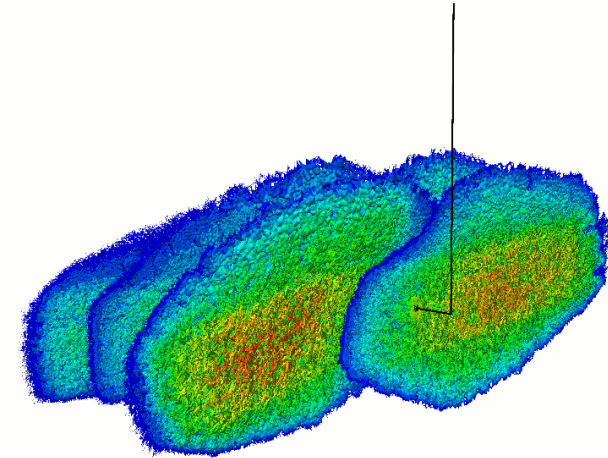
Numerical simulation and model setup

- Rock Properties Input of Colton Sandstone:

Rock Properties	Value
Density	$2380[kg/m^3]$
E	$20.4[GPa]$
v	$0.2[-]$
UCS	$69[MPa]$
Tensile Strength	$7.4[MPa]$
Fracture Toughness	$0.47[MPa.m^{0.5}]$
Porosity	10.9%
Permeability	$4 \times 10^{-17}[m^2]$
Notch Aperture	$3.175[mm]$

Casas et al. 2006; Chuprakov et al. 2014; Stanchits et al. 2014

Numerical simulation and model setup

- Model setup
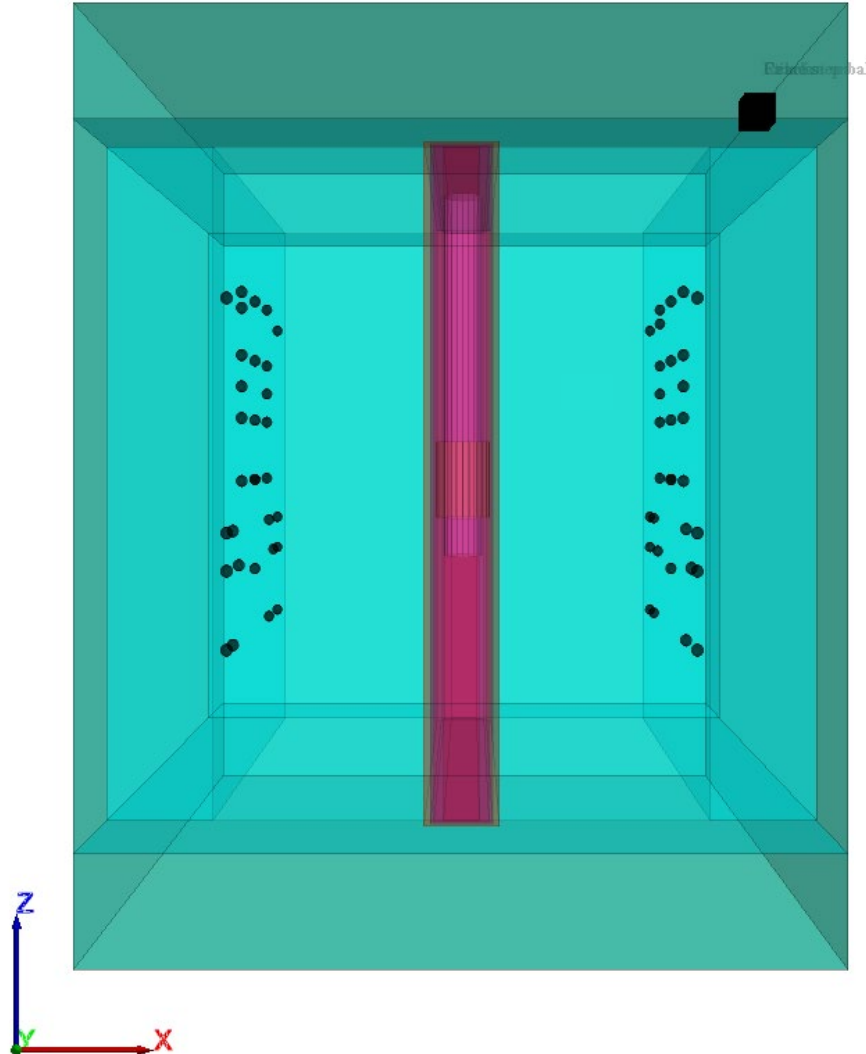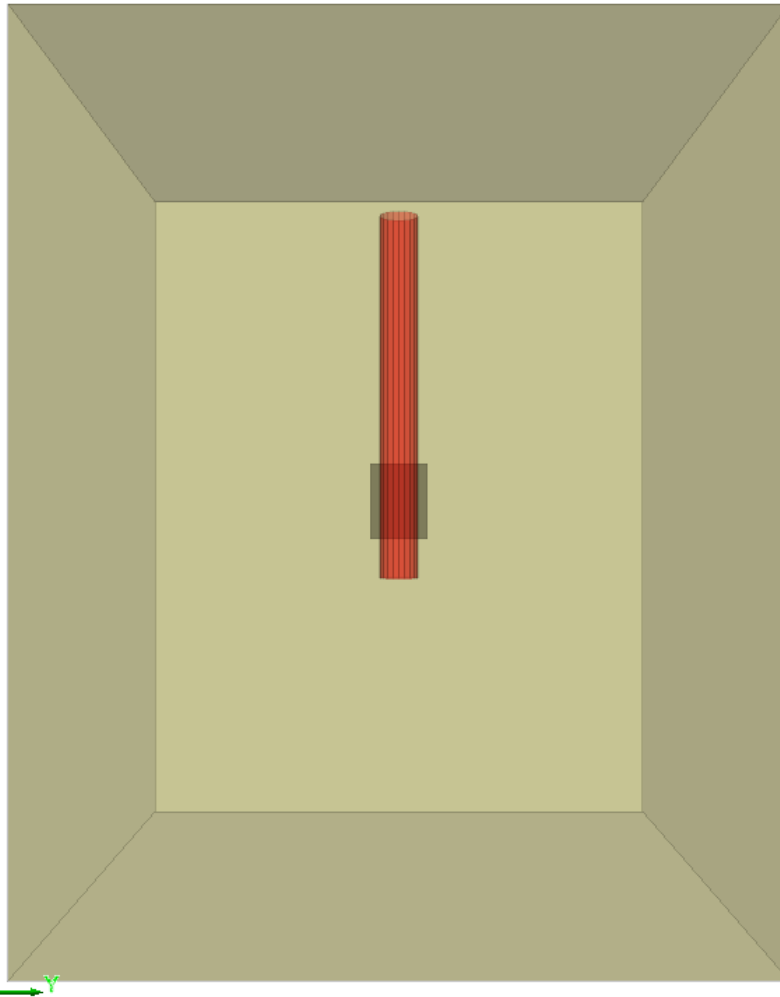
Experiment
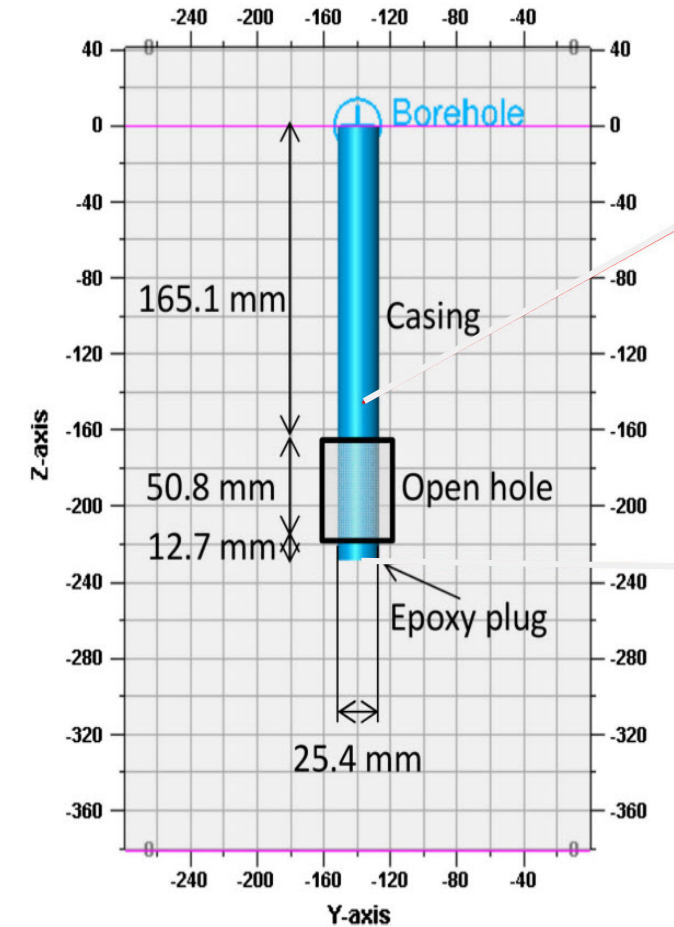
I. Vera Rodriguez et al. 2017

Simulation Results vs. Experimental Results

Spatio-temporal distribution of AE at breakdown pressure

Experimental results

Simulation results
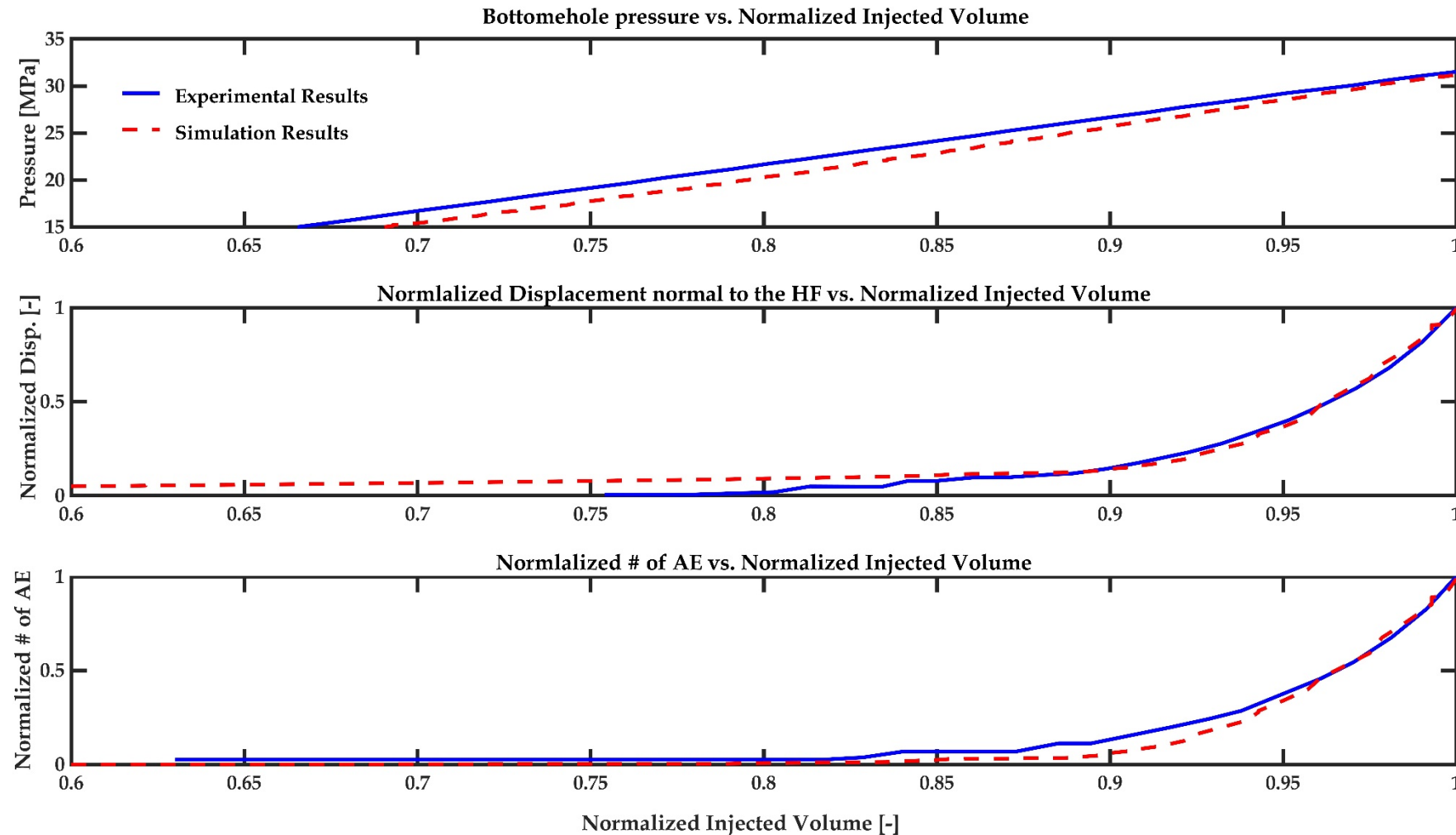
Normalized Injected volume
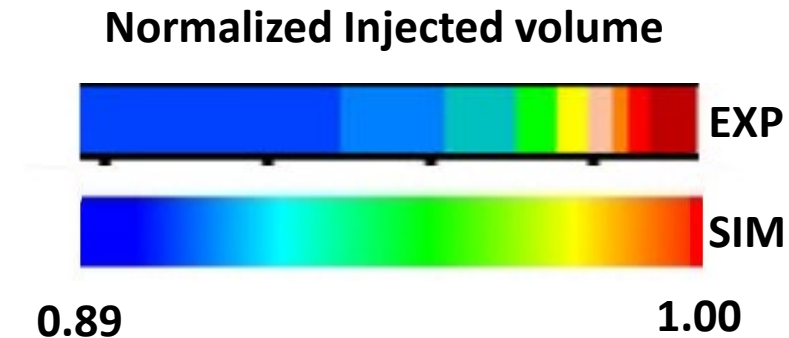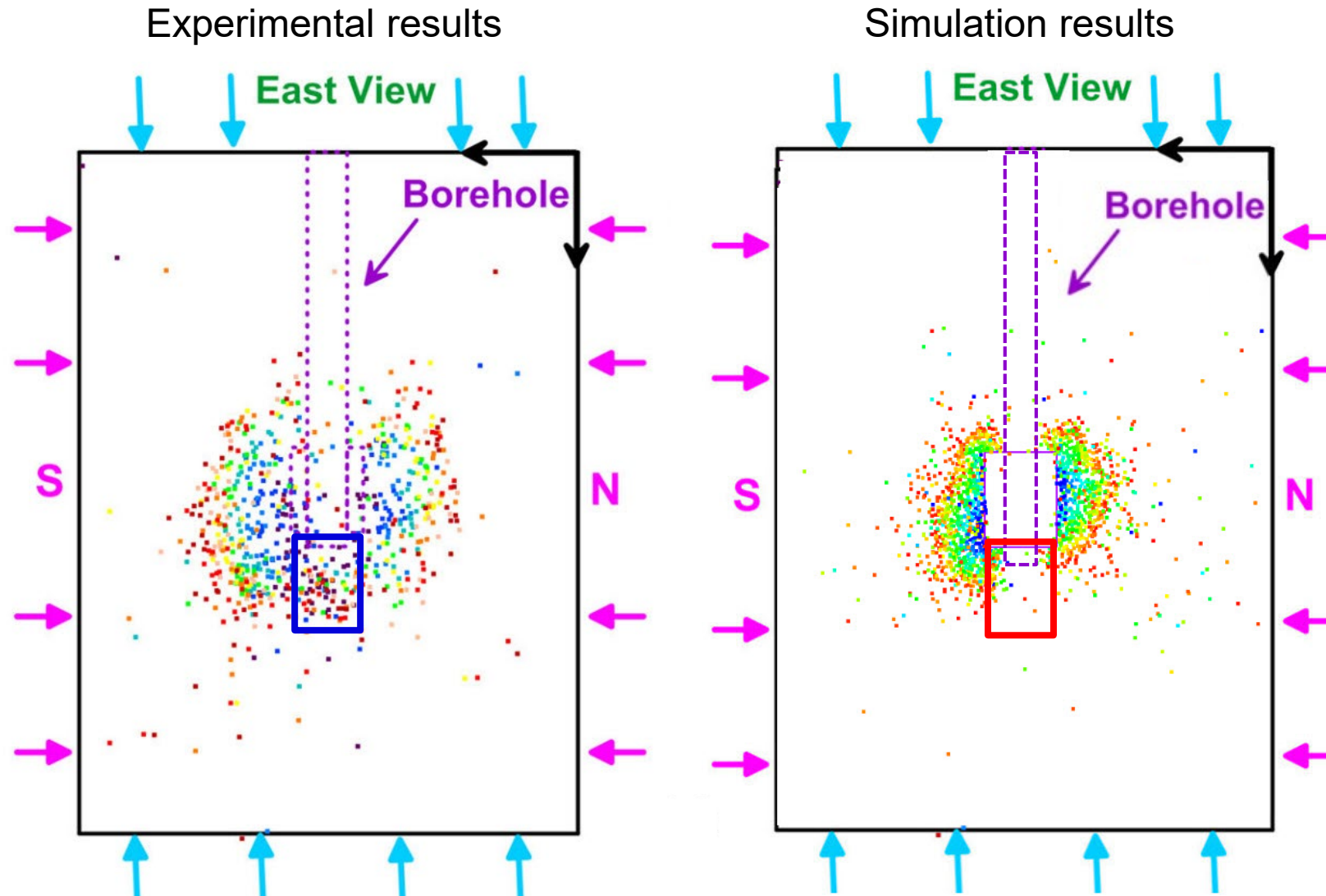
EXP: 1. damage due to drilling the hole, 2. ±6 mm hypocenters

SIM: 1. No damage due to drilling the hole, 2. ±0 mm hypocenters

Spatio-temporal distribution of AE at breakdown pressure

Experimental results

Simulation results
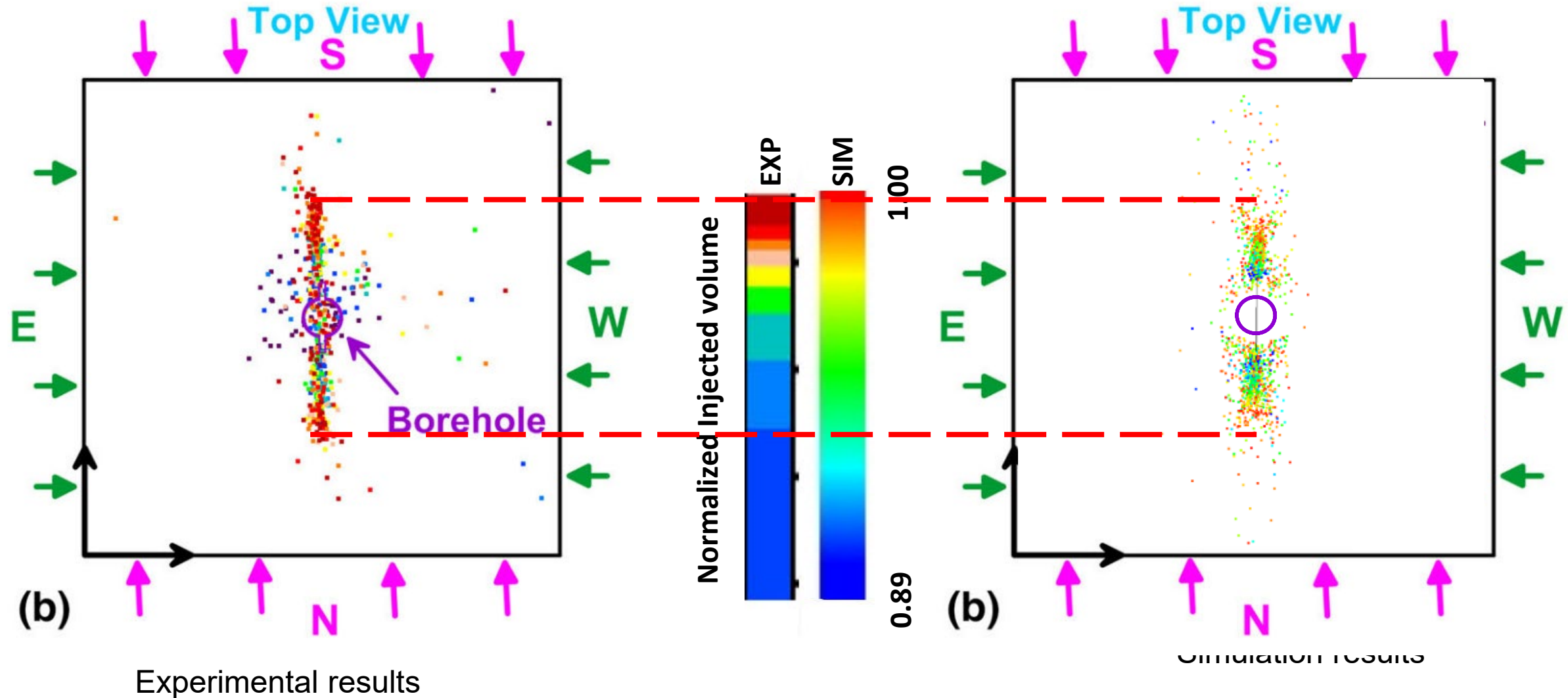
Spatial distribution of AE cloud density at breakdown pressure

Stress redistribution is similar
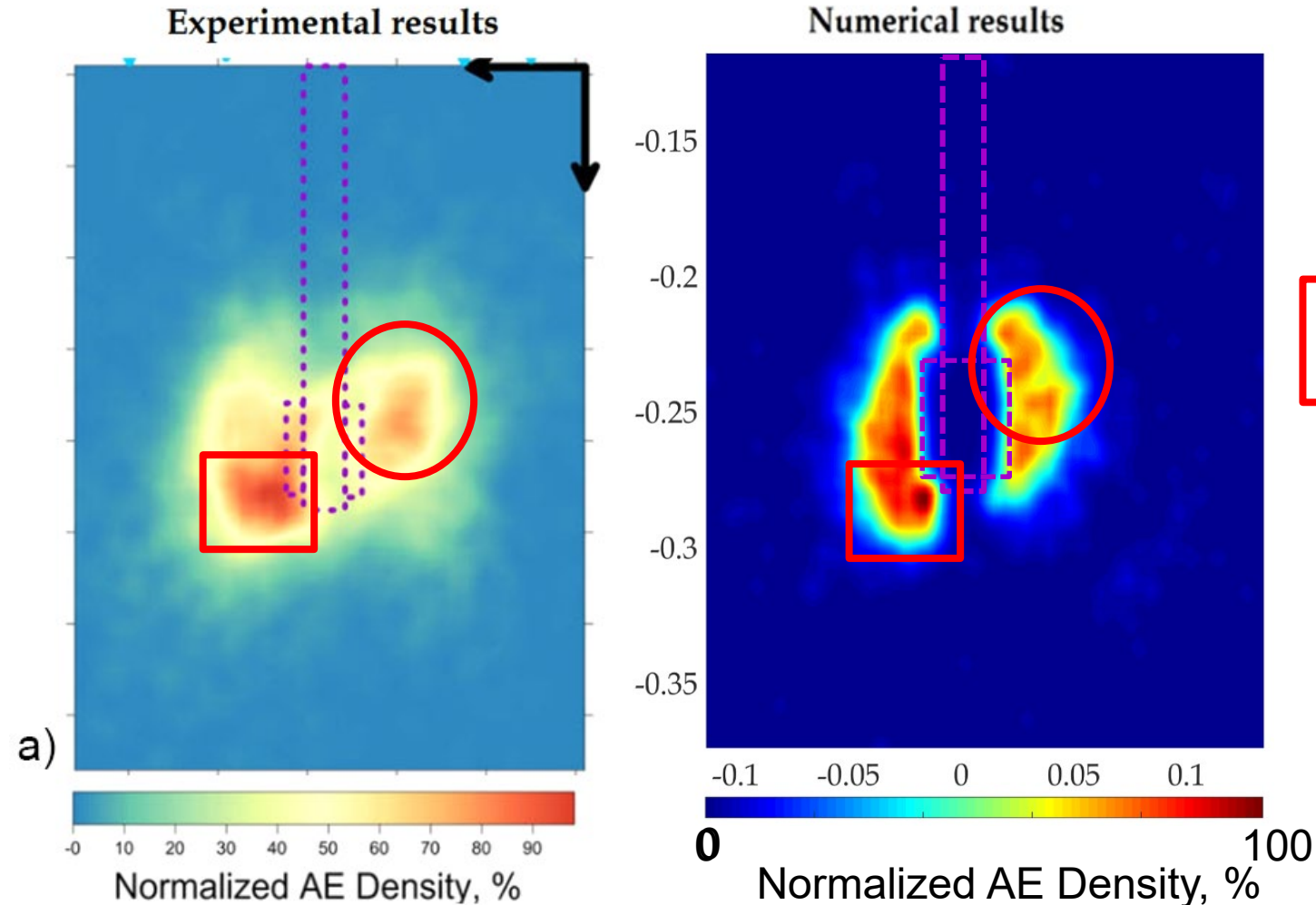
Conclusion and summary

- We **validated XSite™** for producing the **hydraulic fracturing behavior** at the breakdown pressure in homogenous rock sample.

- **Toughness dominated regime (uniform pressure inside the fracture)** is a **reasonable estimation** of **hydraulic fracture propagation** in this laboratory test.

- **A good agreement** b/w the results of the **experiment** and the **simulation**:
  - **same breakdown pressure of 31 MPa**
  - **normalized-displacements and cumulative AE event counts**
  - **spatio-temporal distribution of AE cloud as well as the shape of the fracture**

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Danke sehr

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