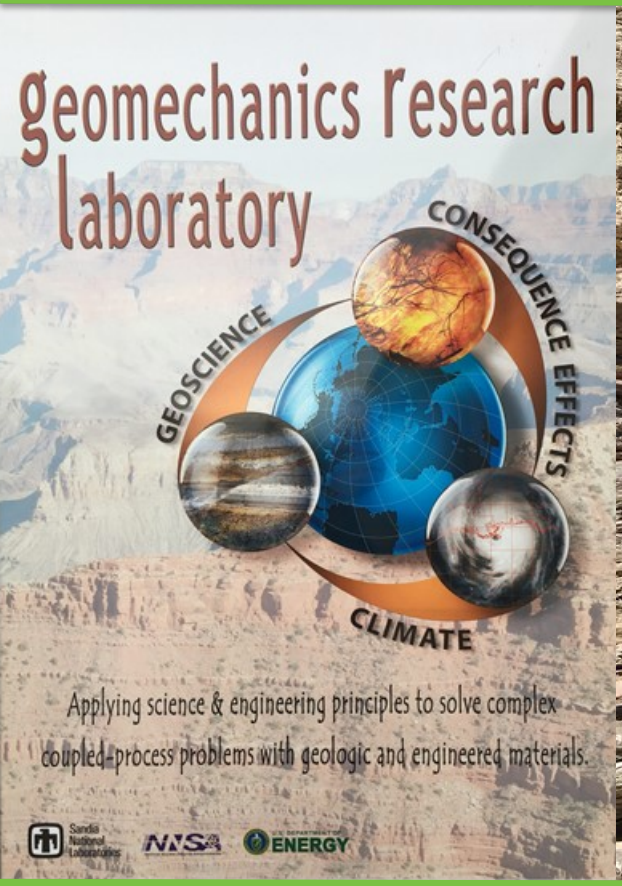


Laboratory Evaluation of EGS Shear Stimulation

Project Officer: Lauren Boyd
Total Project Funding: $941K
Duration: 2014-2017

November 14, 2017

Principal Investigator SJ Bauer
SJ Bauer[1], Ahmad Ghassemi[2]
[1]Sandia National Laboratories
[2]University of Oklahoma
EGS Geosciences

This presentation does not contain any proprietary confidential, or otherwise restricted information.

[1]Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. SAND2017-10998 C

Relevance to Industry Needs and GTO Objectives

Objectives and purpose

1-Develop a lab based physical model of an EGS system:

Hot Wet Stressed Fractured Rock at Pressure and Stress

Flow water through the fracture

Attempt to Demonstrate/Observe/Quantify the Hydroshear Phenomena

2-Develop/deploy analysis methods to numerically model (1)

3-Provide insight into operative mechanisms of hydroshear

4-Stretch goal for GTO to look further at lab & model studies as a means to provide insight of complex geothermal systems

Objectives and purpose (2)

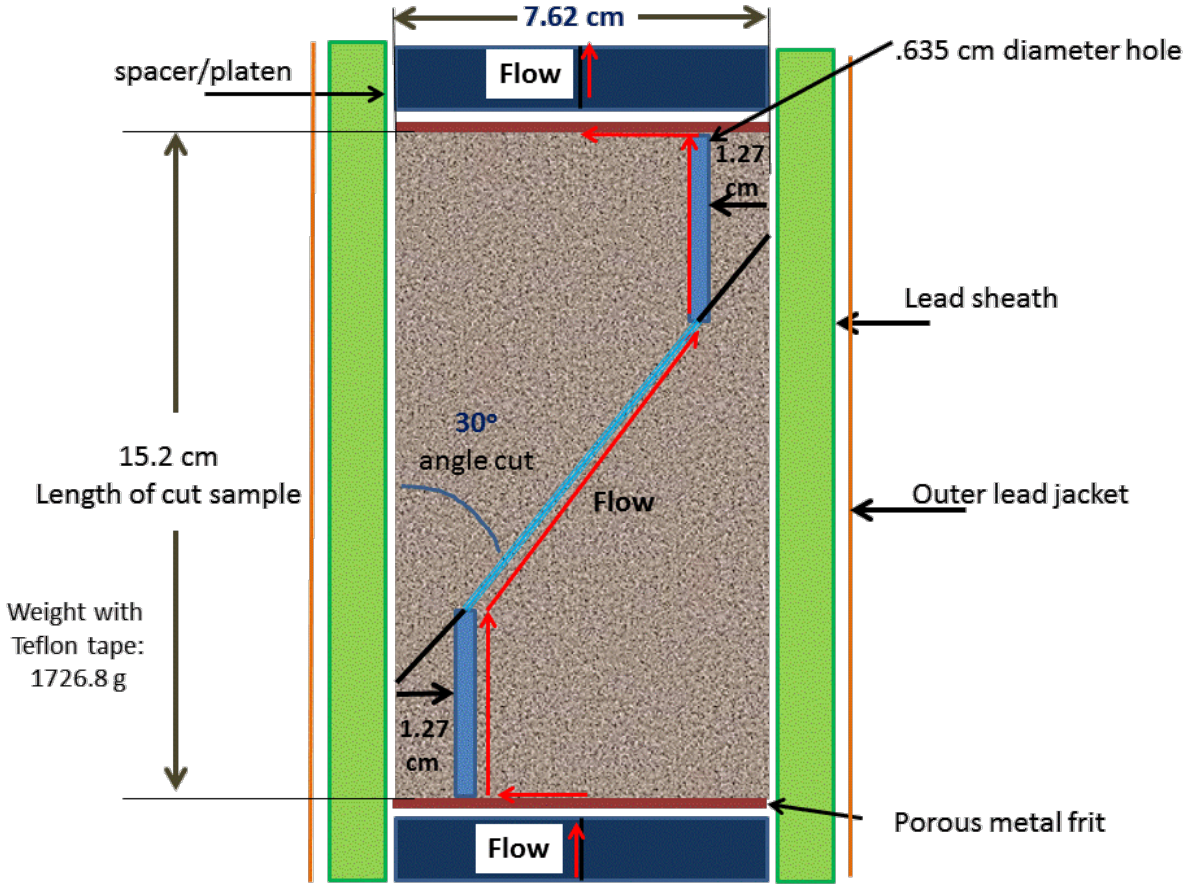
Describe the challenges, barriers, knowledge gaps, or problems being address by this project.

This work may have provided insight into better understanding the physics of an important geothermal stimulation means.

Segments of the experimental program provide data sets for model input parameters, i.e., material properties, and other segments of the experimental program will represent small scale physical models of an EGS system, which may be modeled.

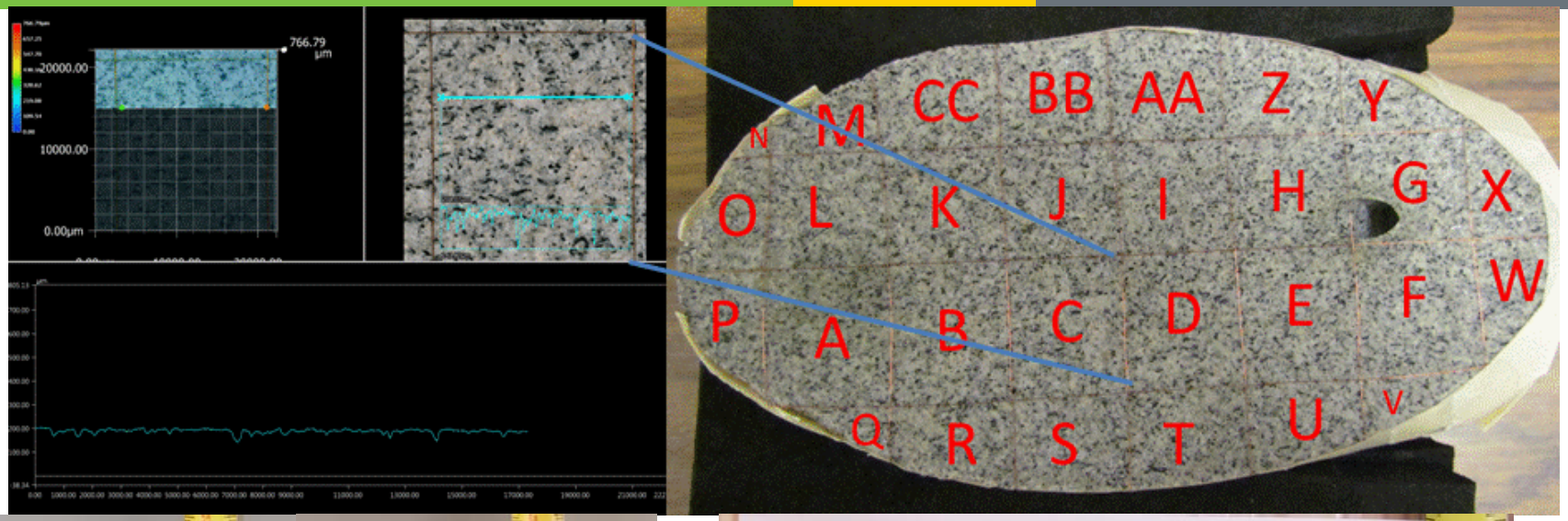
The work provides valuable input data to evaluate stimulation models, thus helping design effective EGS.

Sample schematic: dimensions, jacketing system, and flow path



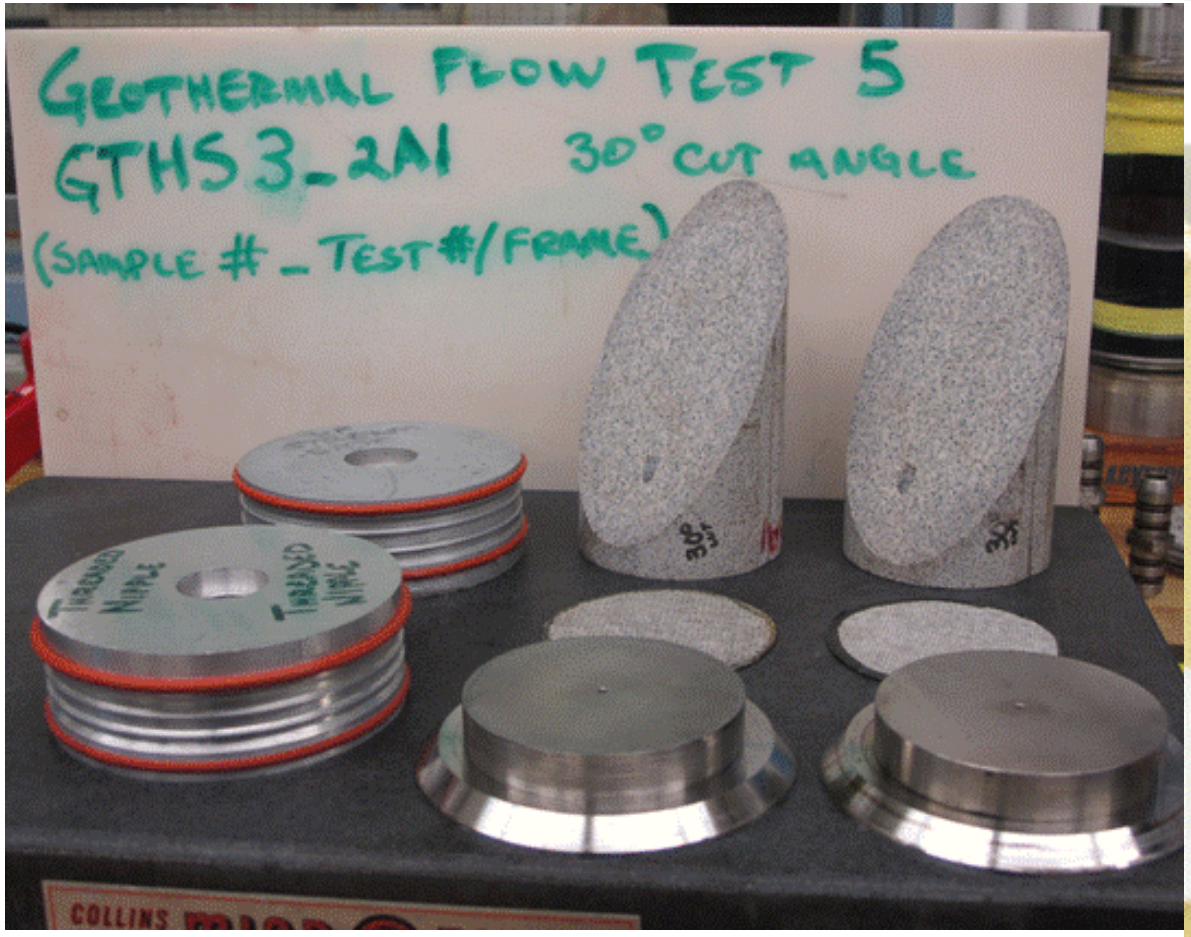
T= 175°C

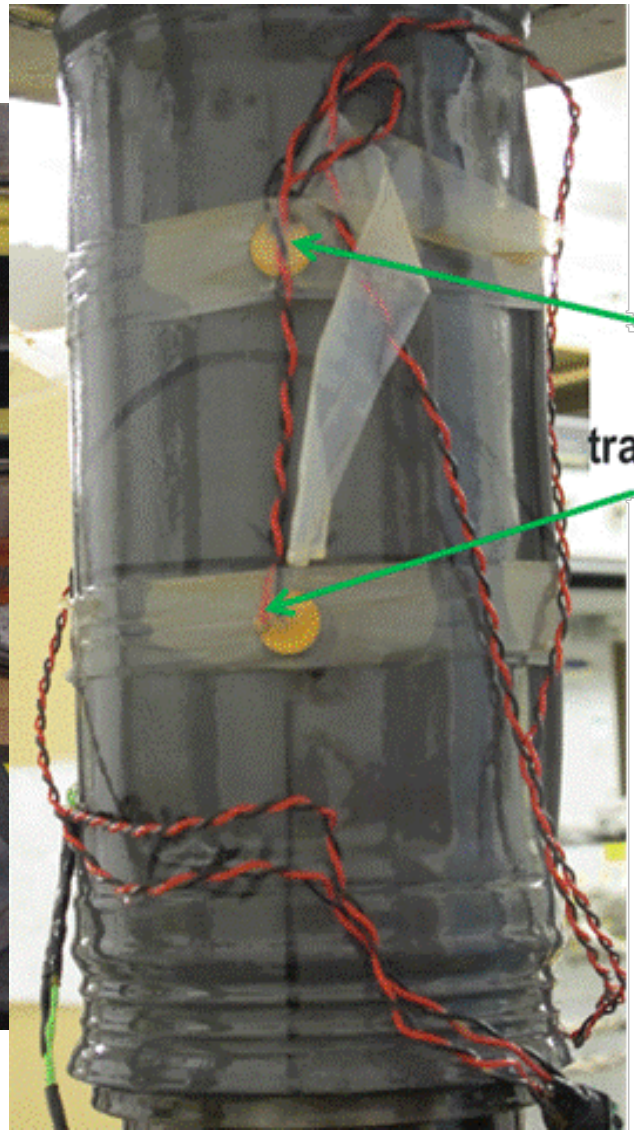
Characterization of Surface Roughness



Special thanks to Brian Asbury at Col. School of Mines

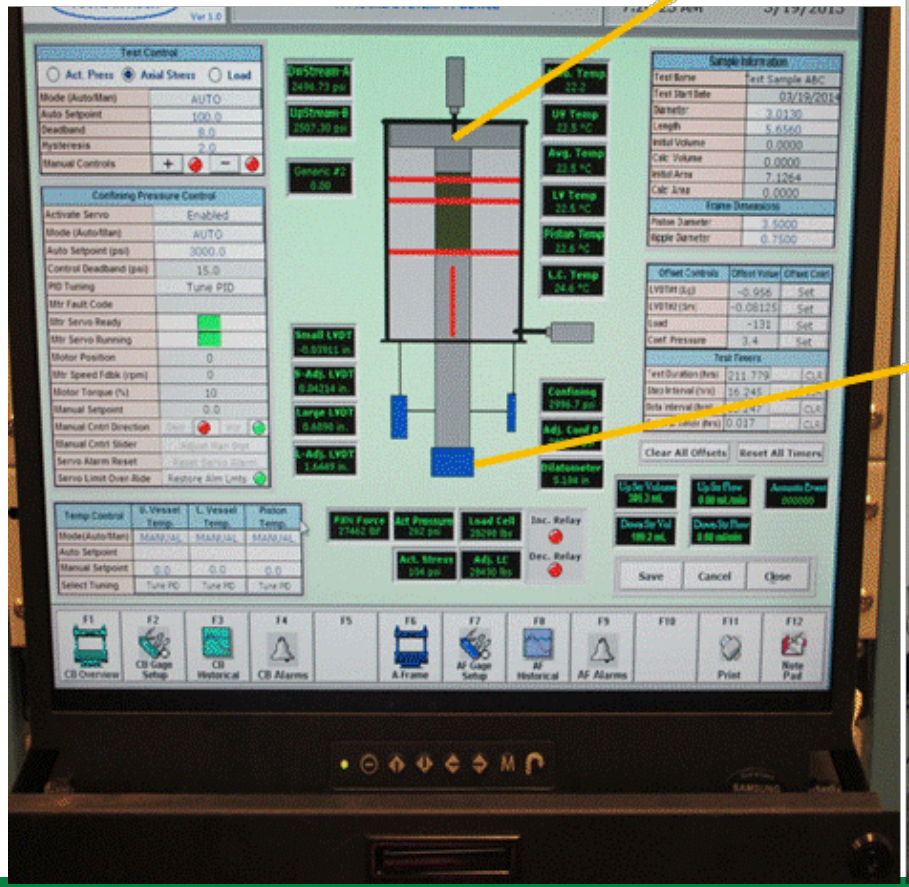
Sample assembly parts and assembly.

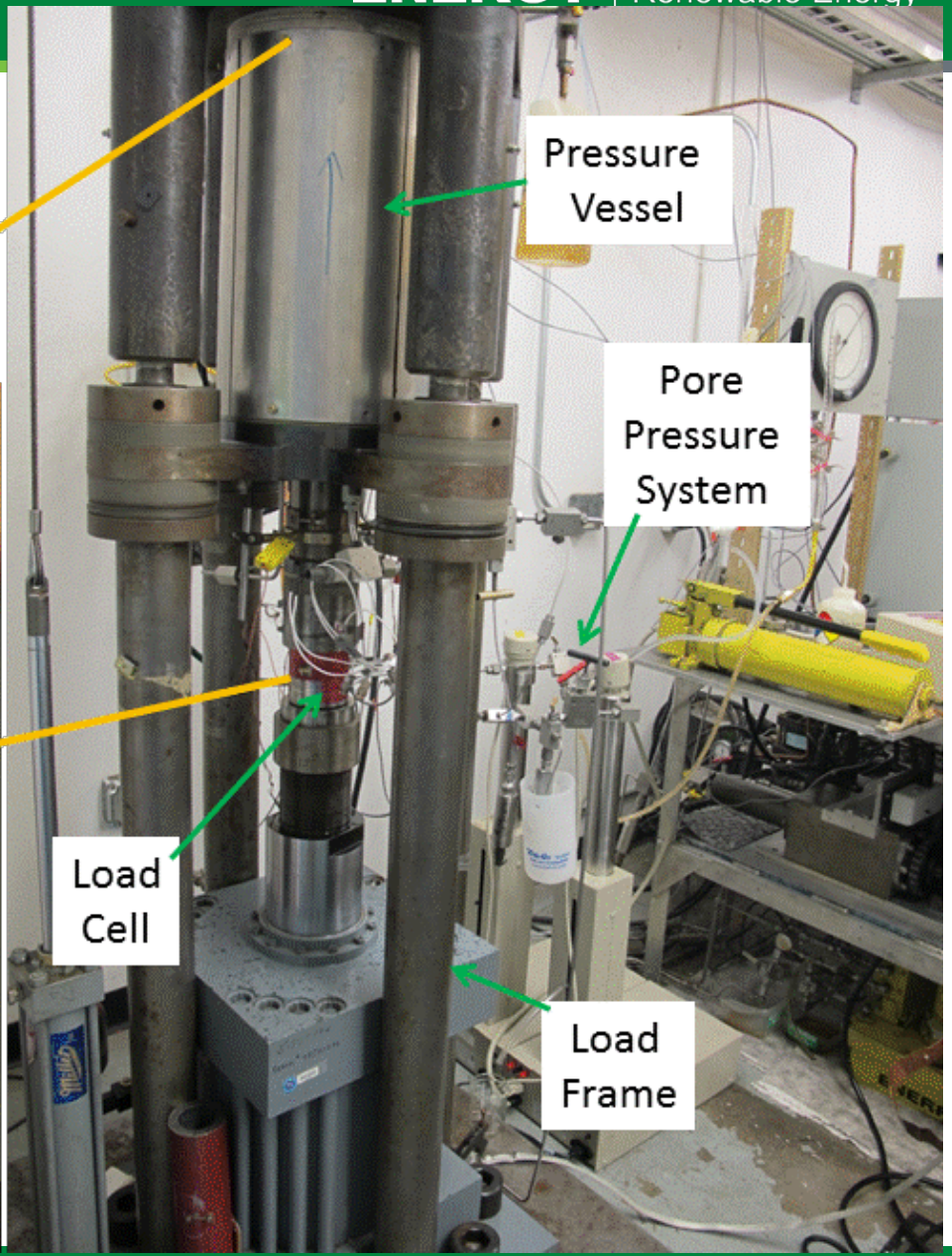


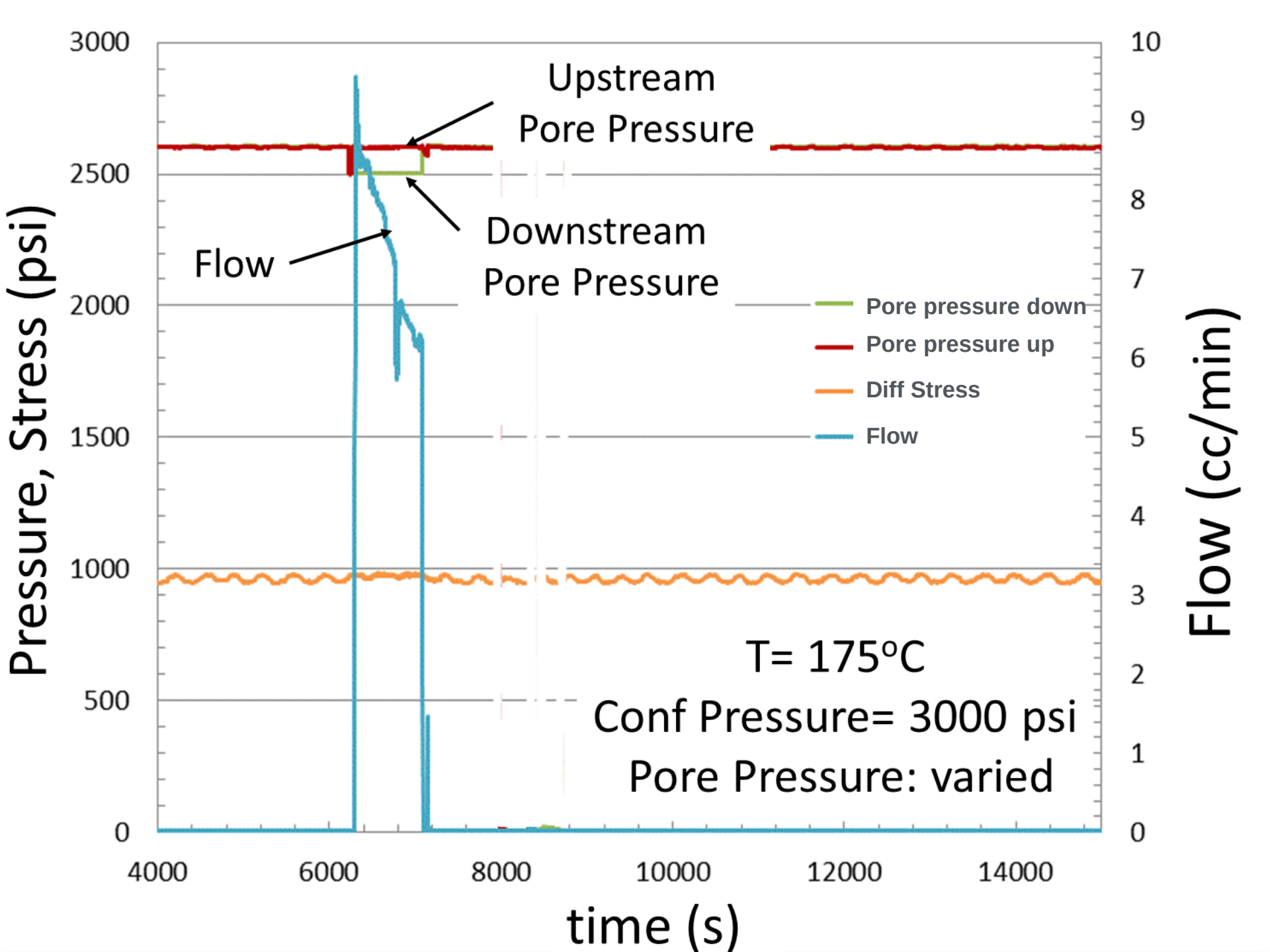


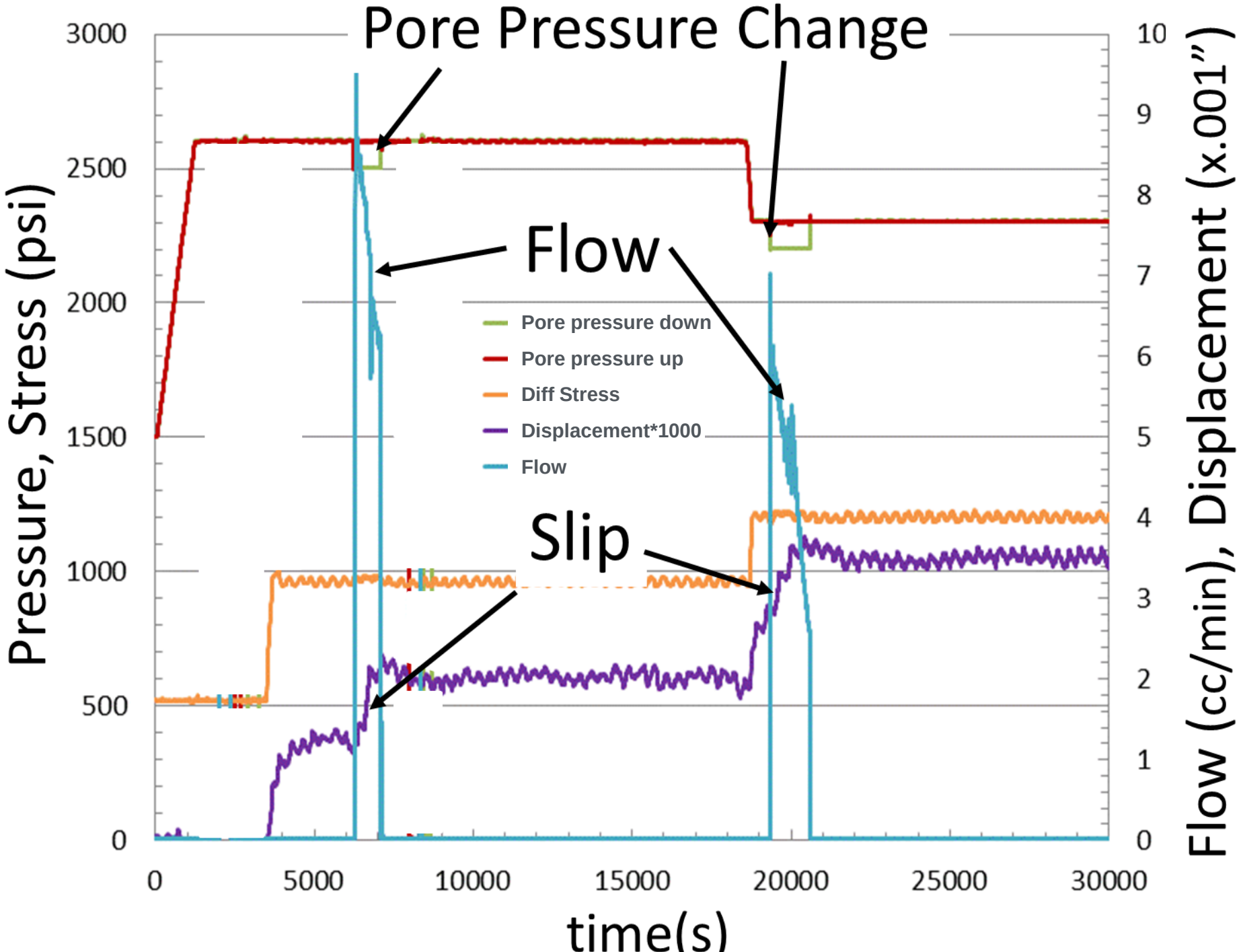
Test system

DAS/GUI

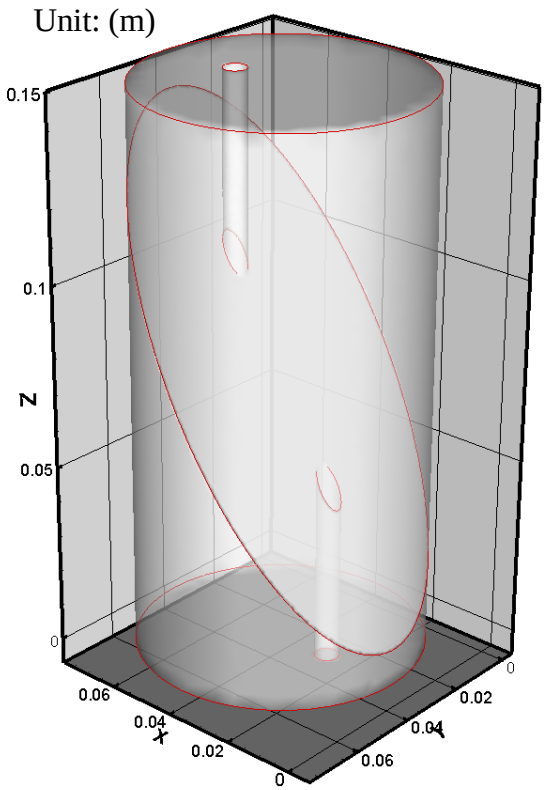




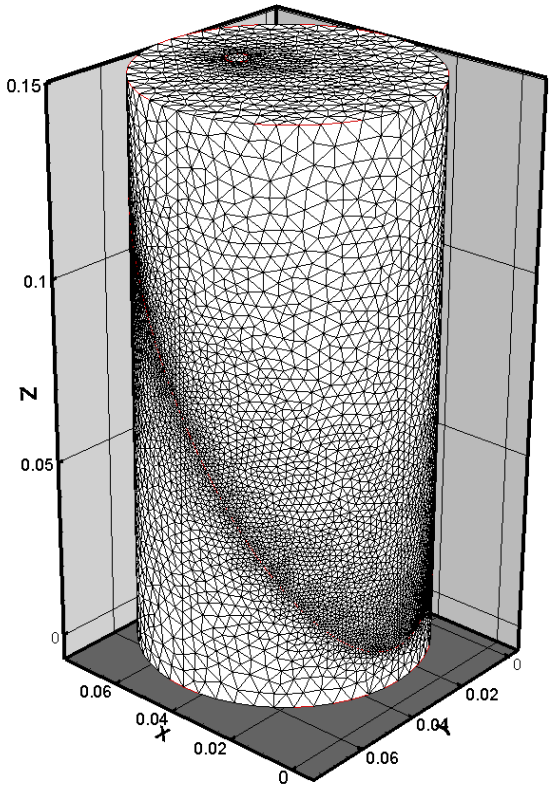

Upstream
Pore Pressure
Downstream
Pore Pressure
Flow
Pore pressure down
Pore pressure up
Diff Stress
Flow
T= 175°C
Conf Pressure= 3000 psi
Pore Pressure: varied
Pressure, Stress (psi)
Flow (cc/min)
time (s)
3000
2500
2000
1500
1000
500
0
10
9
8
7
6
5
4
3
2
1
0
4000
6000
8000
10000
12000
14000


Pore Pressure Change
Flow
Slip
Pore pressure down
Pore pressure up
Diff Stress
Displacement*1000
Flow
Pressure, Stress (psi)
Flow (cc/min), Displacement (x.001")
time(s)
3000
2500
2000
1500
1000
500
0
10
9
8
7
6
5
4
3
2
1
0
0
5000
10000
15000
20000
25000
30000

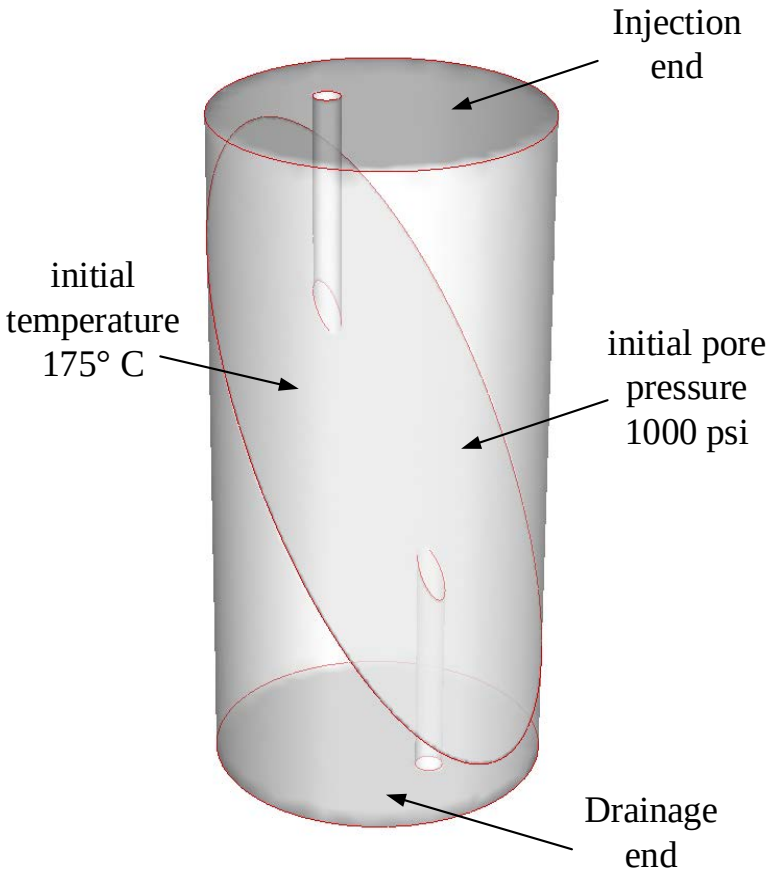
(a) Problem geometry; (b) Mesh scheme; (c) Experimental sets



(a)

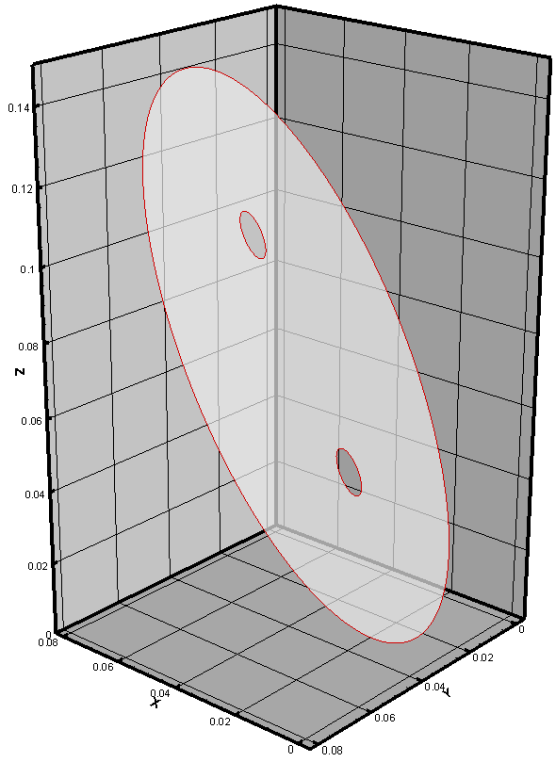


(b)

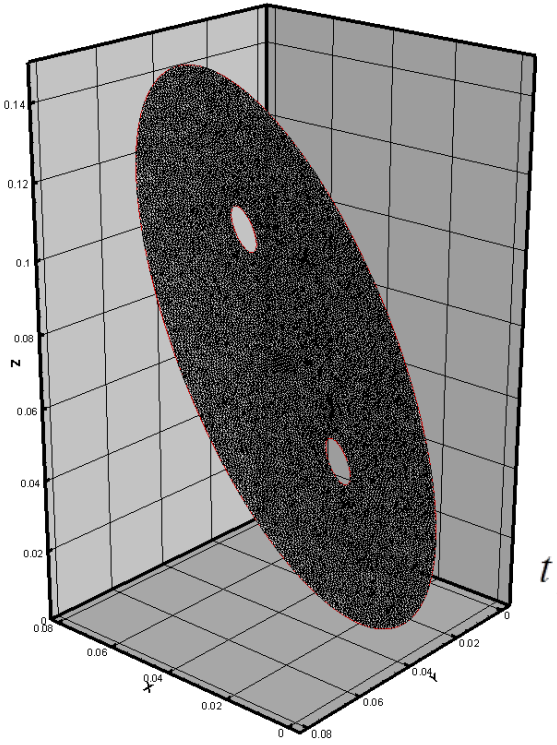


(c)

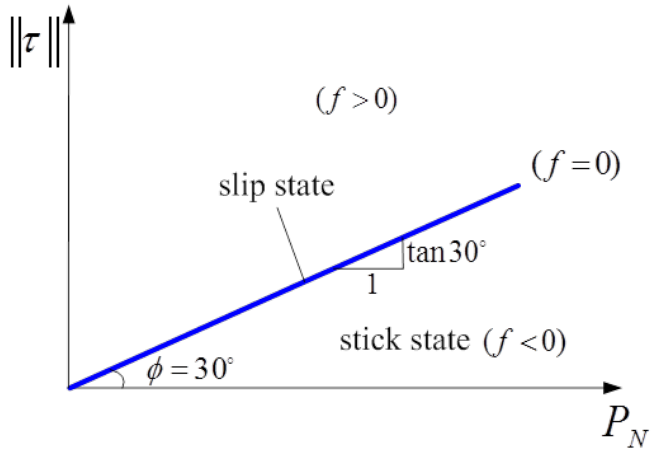
(a) Fracture interface geometry (b) mesh scheme. (c) mechanical response of interface elements

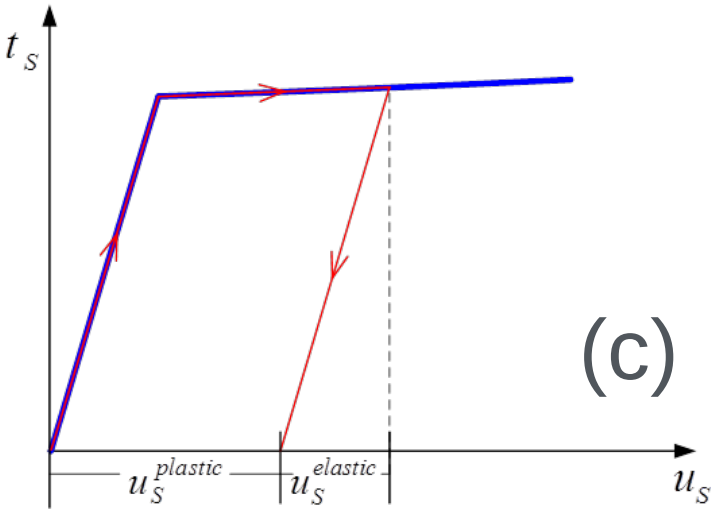


(a)



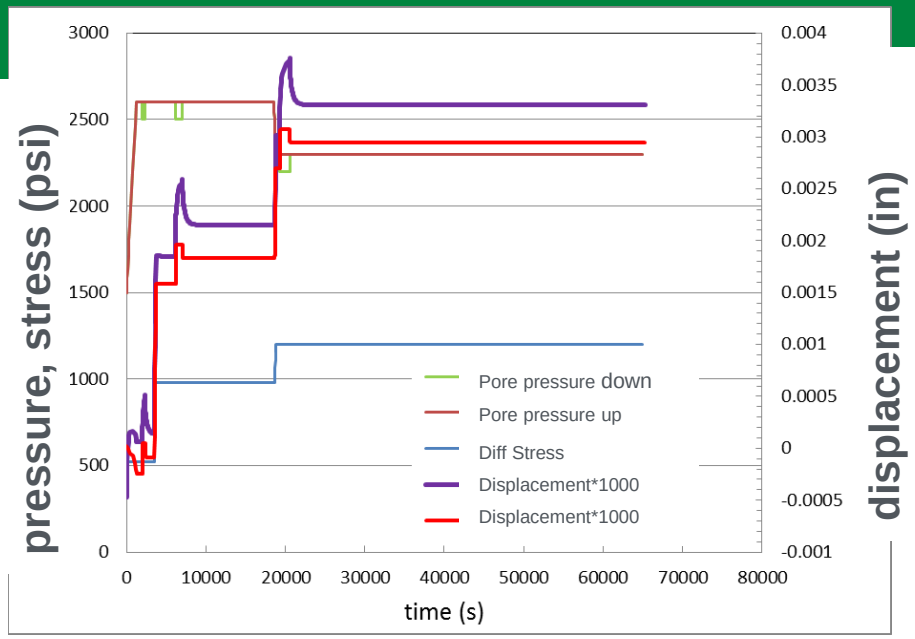
(b)

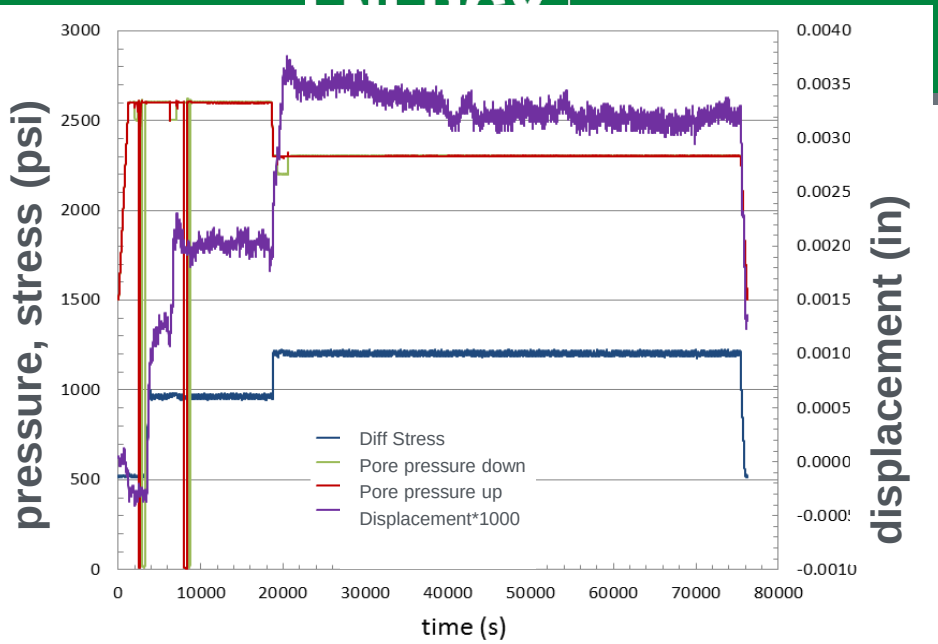


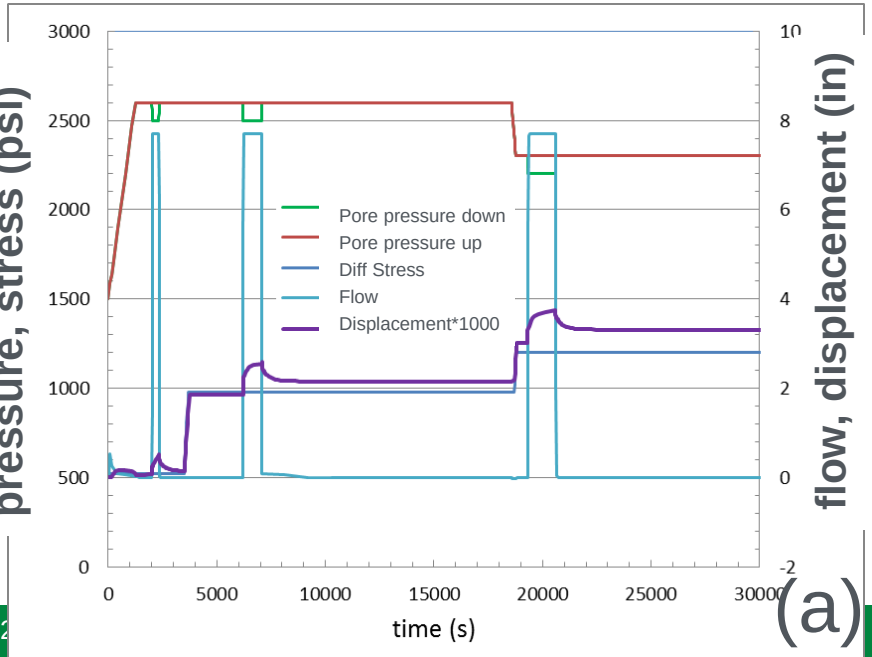


(c)

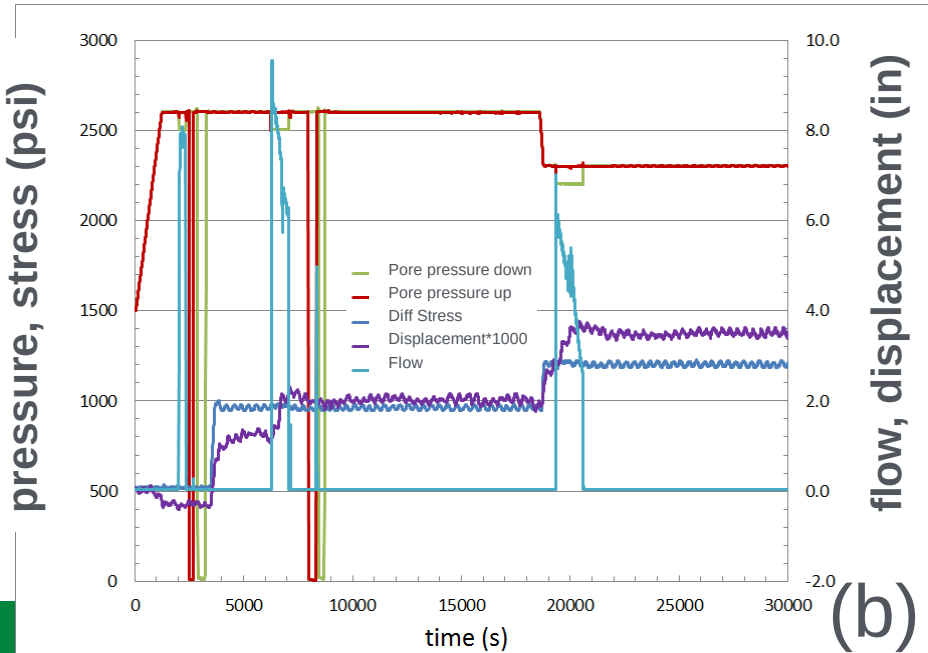
(a) numerical simulation, (b) experiment





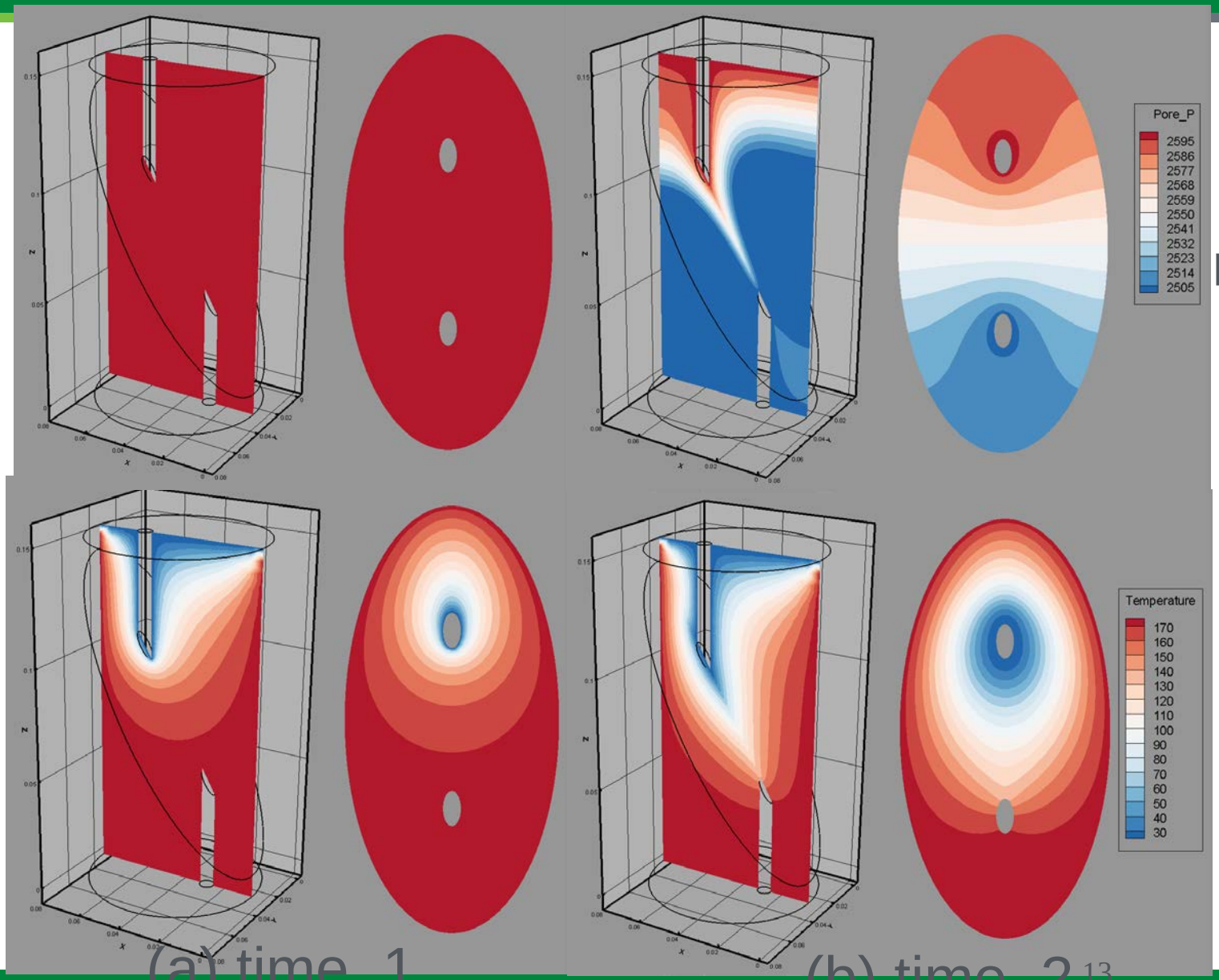


(a)



(b)

Temperature, pore pressure contour on middle slice and fracture surface at (a) time 1 and (b) time 2

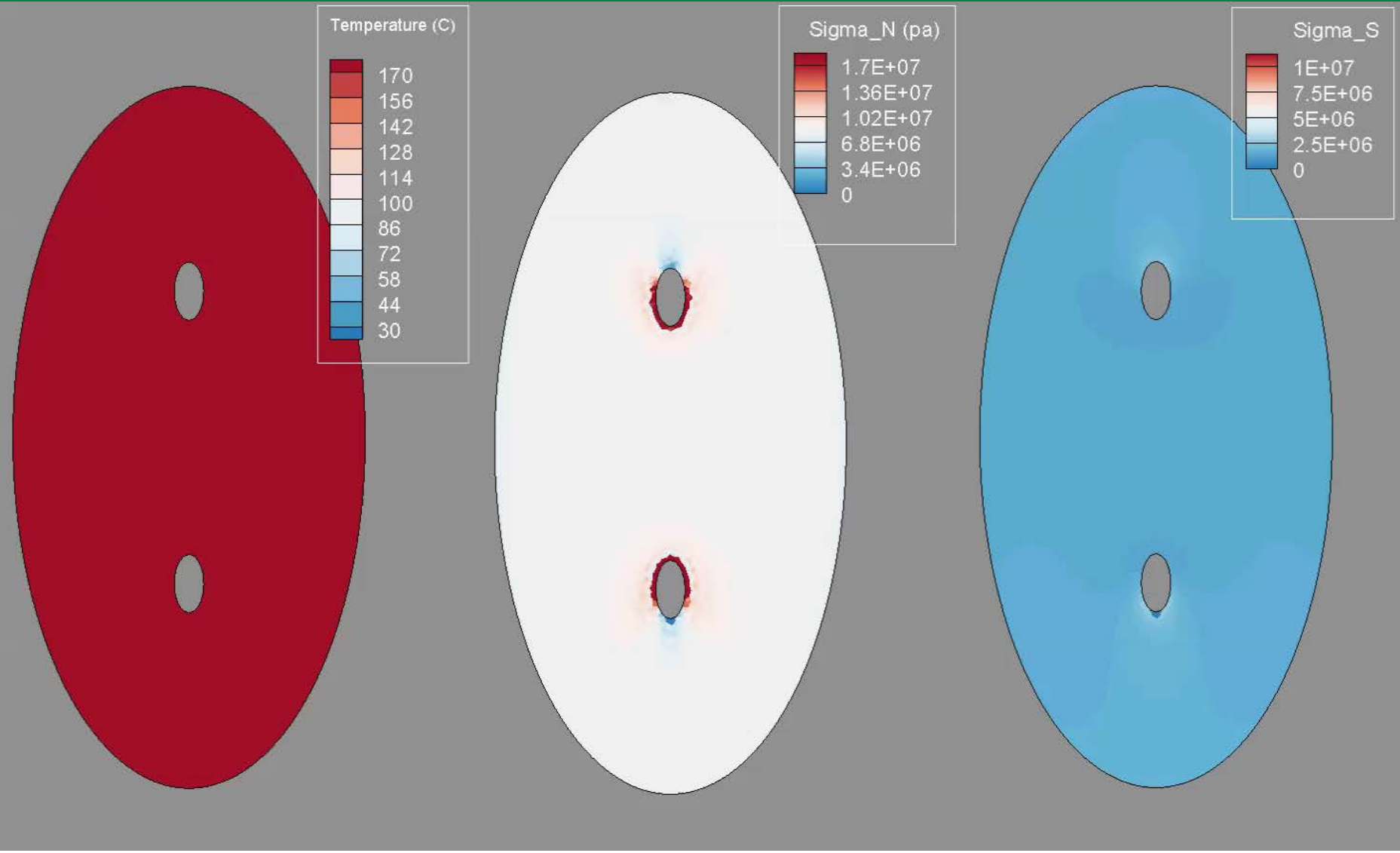


Pore pressure

Temperature

(a) time 1

(b) time 2


Temperature (C)
170
156
142
128
114
100
86
72
58
44
30
Sigma_N (pa)
1.7E+07
1.36E+07
1.02E+07
6.8E+06
3.4E+06
0
Sigma_S
1E+07
7.5E+06
5E+06
2.5E+06
0

Technical Accomplishments and Progress

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Describe Accomplishments/Progress to date.

1-Developed a lab based physical model of an EGS system:

– Hot Wet Stressed Fractured Rock at Pressure and Stress

– Flow water through the fracture

– Demonstrate/Observe/Quantify the Hydroshear Phenomena

2-Developed/deployed analysis methods to numerically model

3-Provided insight into operative mechanisms of hydroshear

Discuss how your actual technical accomplishments compare to the current state of the art.

Our work may represent one of the 1st of its kind in terms of simulating hydroshear by experiment & modeling

Include a summary table of your original planned milestones/technical accomplishments to date and then compare those to the actual milestones or technical accomplishments that were achieved.

Please see write up

Cost variances should be briefly summarized here. N/A

Original Planned Milestone/ Technical Accomplishment	Actual Milestone/Technical Accomplishment	Date Completed
See write up and QALMS	See write up and QALMS	

Strong collaboration between Sandia and U. of Oklahoma: 2-3 PhD students matriculated, K. Huang, Q. Chen

Publications:

Bauer, S. J., K. Huang, Q. Chen, A. Ghassemi, P. Barrow, *Laboratory and Numerical Evaluation of EGS Shear Stimulation*, PROCEEDINGS, 41st Workshop on Geothermal Reservoir Engineering, Stanford Univ., February 22-24, 2016, SGP-TR-209

Bauer, S. J., K. Huang, Q. Chen, A. Ghassemi, P. Barrow, *Experimental and Numerical Investigation of Hydro-Thermally Induced Shear Stimulation*, 50th US Rock Mechanics / Geomechanics Symposium, 26-29 June 2016.

Ye, Z., M. Janis, A. Ghassemi, S. Bauer, *Experimental Investigation of Injection-driven Shear Slip and Permeability Evolution in Granite for EGS Stimulation*, PROCEEDINGS, 42nd Workshop on Geothermal Reservoir Eng., Stanford Univ. Stanford, CA, Feb. 13-15, 2017

Huang, K., Q. Cheng, A. Ghassemi, S. Bauer, *Evaluation of Stimulation by Shear Slip in Fractured Rock Using a 3D Coupled Thermo–Poro-Mechanical FEM*, sub. to refereed journal

- Software available to public
- Communicating with students at Univ of Utah who are setting up test system

Future Directions

- Lab and analysis methods developed and ready to be applied in the event of appropriate interest.
- Communicating with students at Univ. of Utah who are setting up similar test system

Mandatory Summary Slide

- Experimental and numerical techniques developed to evaluate thermal, mechanical, hydrologic aspects of hydroshearing
- Favorable comparisons between experimental and numerical results
- A combination of water heating and rock cooling modifies normal stress condition on fracture surface to promote slip