



Collab Task 5: Flow Test Characterization and Drillback (Experiment 1)

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Task 5 PI: Tim Johnson

EGS Collab

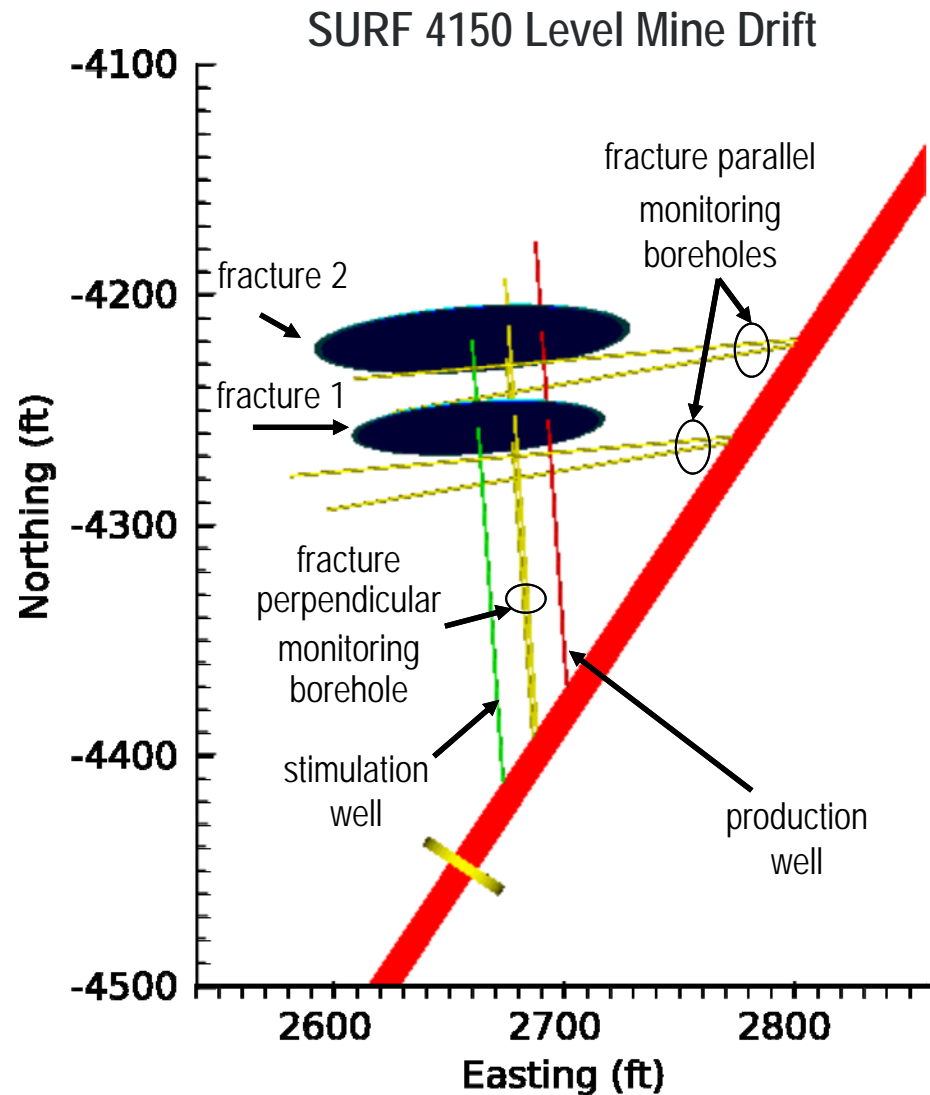
Objective: Provide high resolution THMC-G data sets for EGS model calibration and validation

Goals:

- quantify fracture network spatial heterogeneity
- constrain flow and heat transfer performance
- understand fracture stress-permeability response
- understand geophysical signatures of fracture generation and flow
- provide insight into coupled processes (i.e. cooling induced stress)

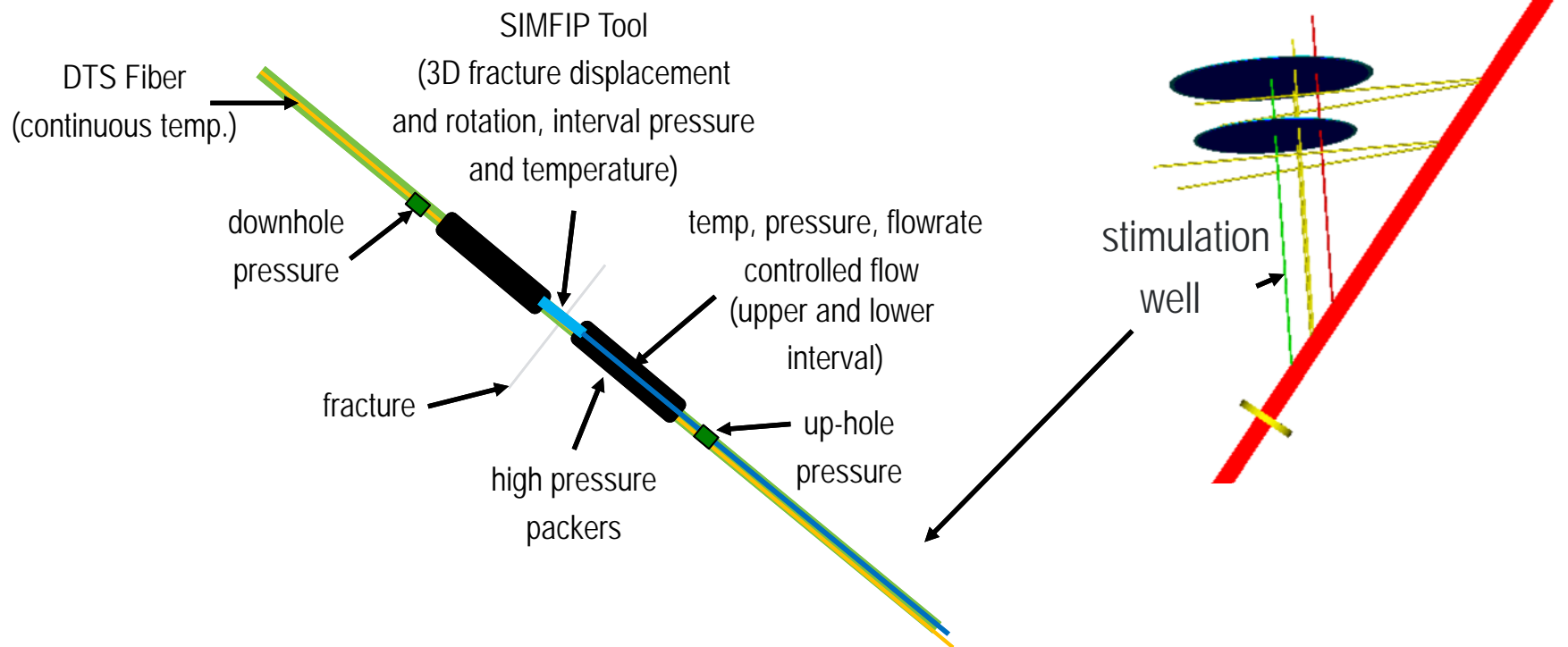
Achieved through a series of precisely controlled and comprehensively monitored flow tests, guided by model predictions, validated by post-test drill-back.

Stimulation and Flow Test Downhole Monitoring System Overview



Downhole Monitoring System: Stimulation and Production Wells

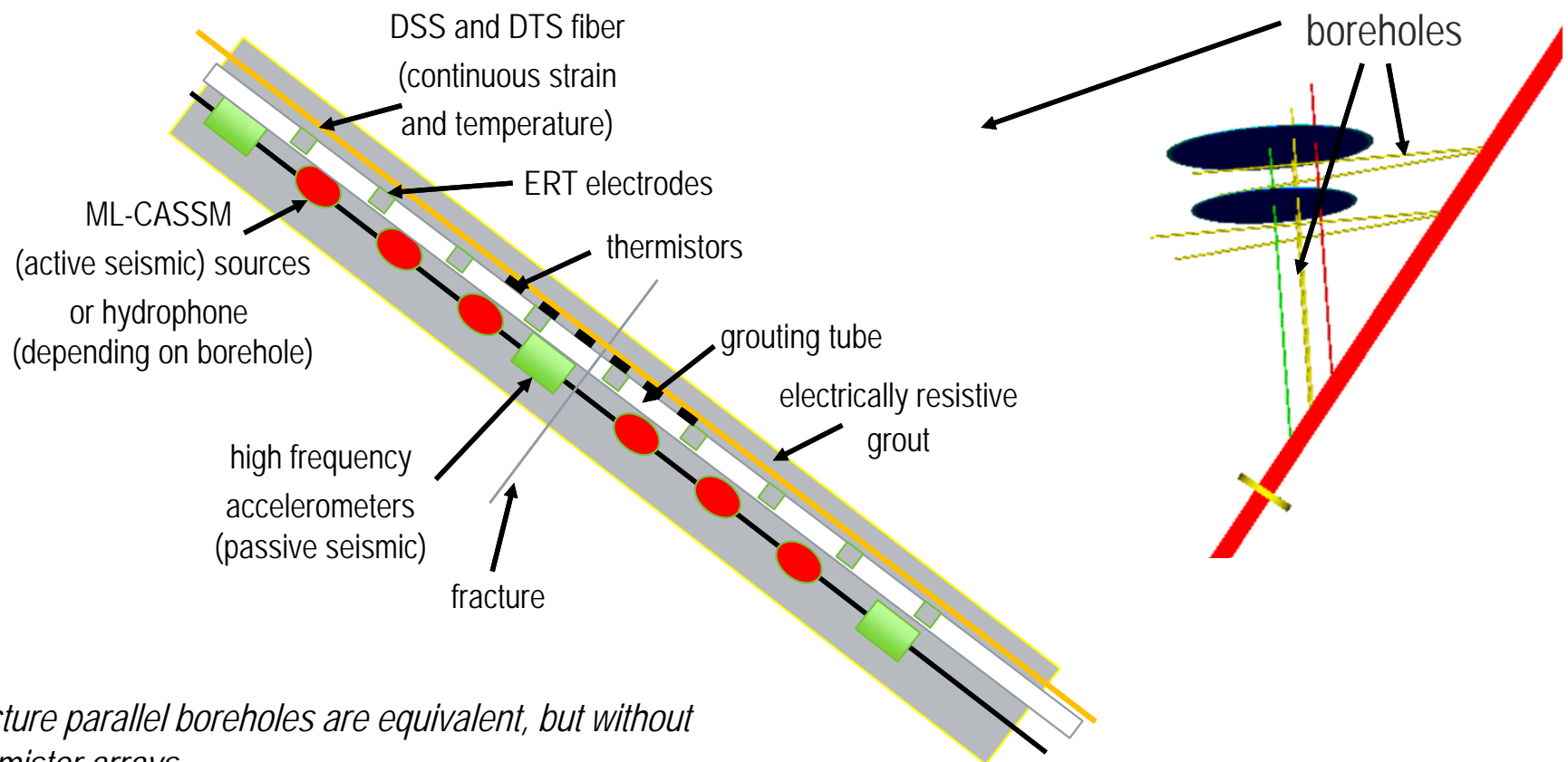
Stimulation/Injection Well Configuration



- *production well is equivalent, with backpressure and backflow control.*

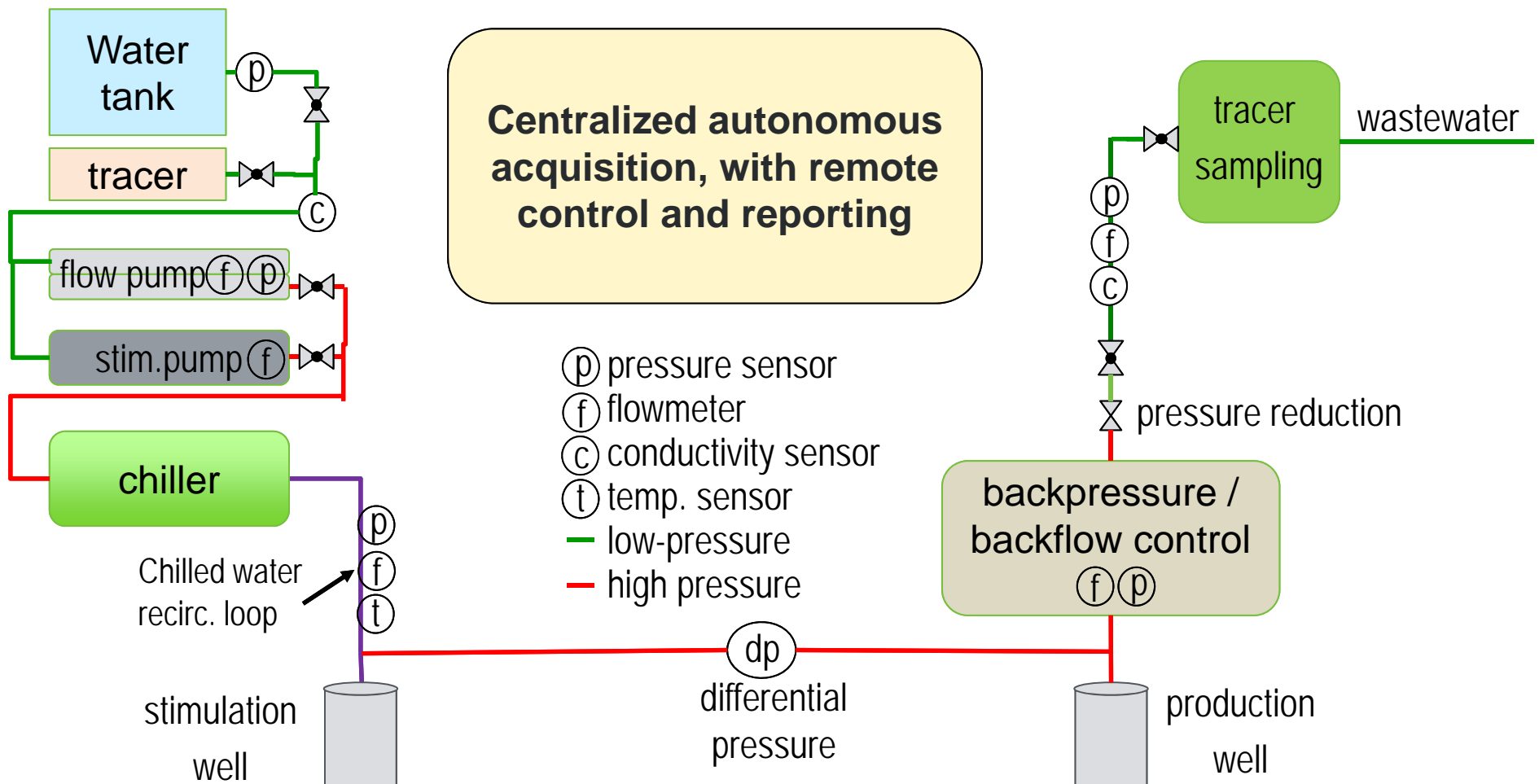
Downhole Monitoring System: Monitoring Boreholes

Fracture Perpendicular Configuration



- *fracture parallel boreholes are equivalent, but without thermistor arrays*

Inter-well Uphole Flow, Pressure, and Temperature Control System



Sequence of well controlled and comprehensively instrumented flow tests: each with a specific objective

- 1) Step rate flow/pressure test (task 5a)
 - 2) Constant rate tracer flow test (task 5a)
 - 3) Long-term heat transfer test (task 5a)
 - 4) Geophysical tracer test (task 5a)
- (Test 1-4 repeated for fracture 2, task 5b)
- 5) Dual fracture, inter-well flow test (tasks 5c and 5d)

Drillback Validation

- 1) Post-testing drillback validation (task 5e)

Test 1: Step Rate Flow/Pressure/Extension Test

Objective

- Investigate the relationship between fracture stress, aperture, and permeability.
- Determine pressure limits for future tests.

Description

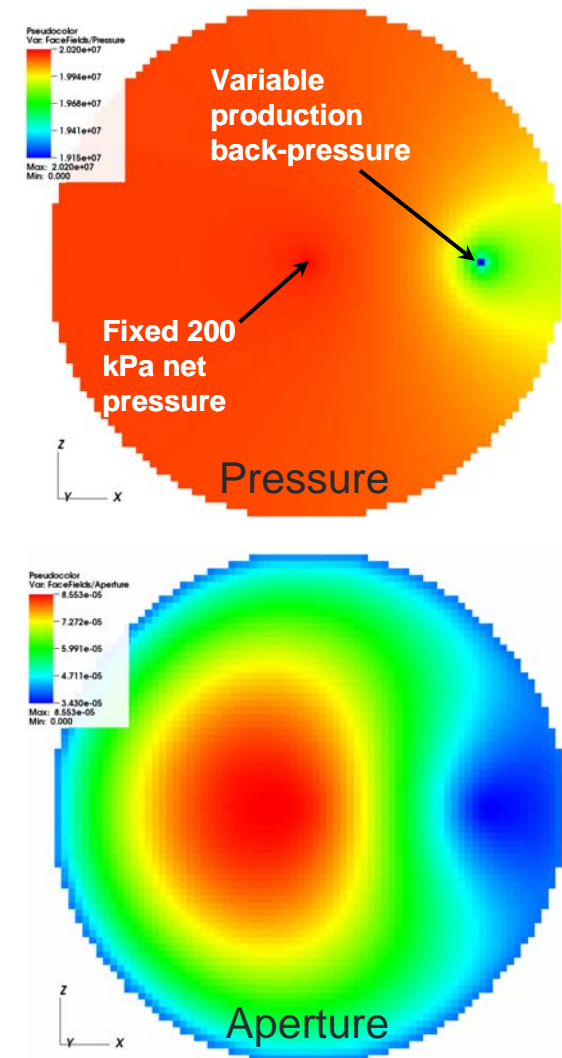
- Precise step modifications in injection well pressure and production well backpressure.

Data sets

- Injection and production well: pressure, flowrate, interval temp, distributed temp., aperture
- Monitoring wells: active & passive seismic, distributed fiber temp. and strain, point temp., ERT

Data Usage

- Validate hydro-mechanical models, constrain monitoring responses to aperture modulation



Courtesy Pencheng Fu, Randy Settgest, Joe Morris

Test 2: Constant flow rate tracer test

Objective

- Investigate relationship between pressure/aperture, residence time and flow path

Description

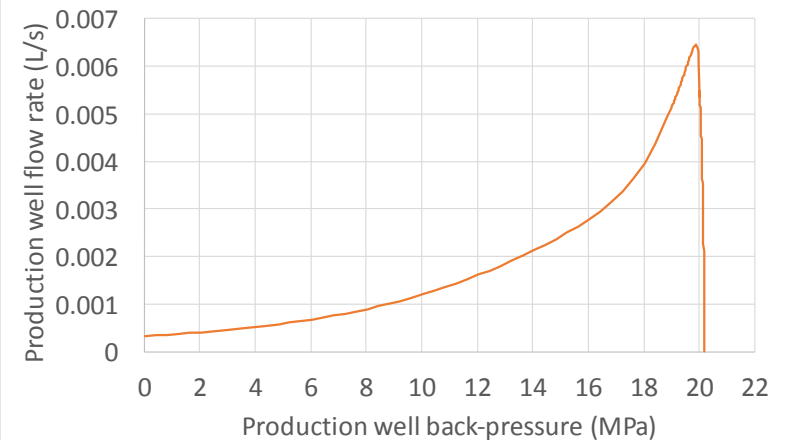
- Constant pressure-flow tests with tracer tests (saline, fluorescent, DNA).

Data sets

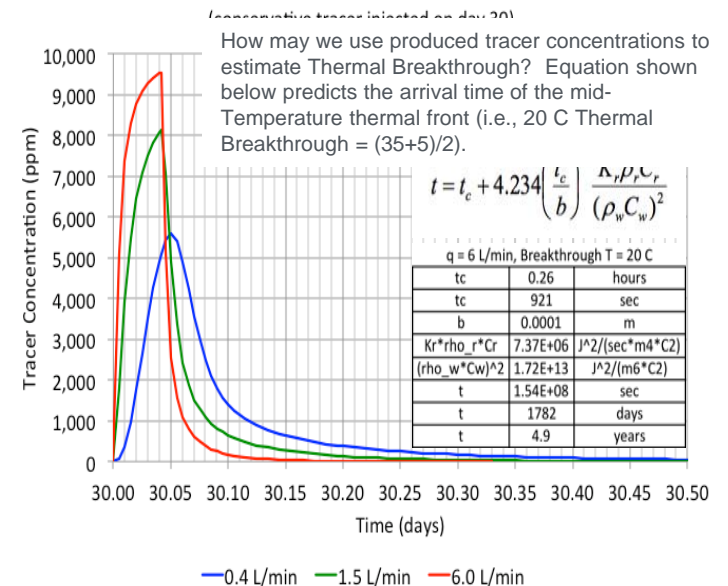
- Inj./Prod. wells: pressure, flowrate, interval temp, distributed temp., aperture, tracer concentration
- Monitoring wells: active & passive seismic, distributed fiber temp. and strain, point temp., ERT

Data Usage

- Validate flow-path predictions, support heat transfer modeling, evaluate monitoring responses



Courtesy Pencheng Fu, Randy Settgast, and Joe Morris



Bud Johnson, Phil Winterfield and Yu-Shu Wu

Test 3: Heat Transfer Flow Test

Objective

- Comprehensive heat transfer performance data: thermo-mechanical response, effects of cooling on stress, aperture and permeability

Description

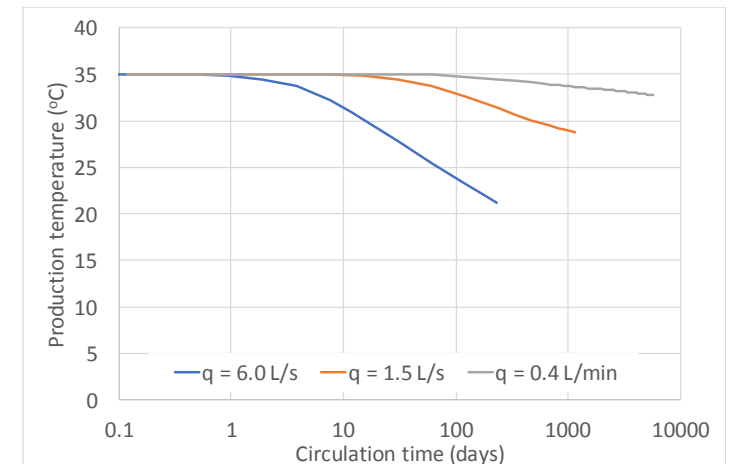
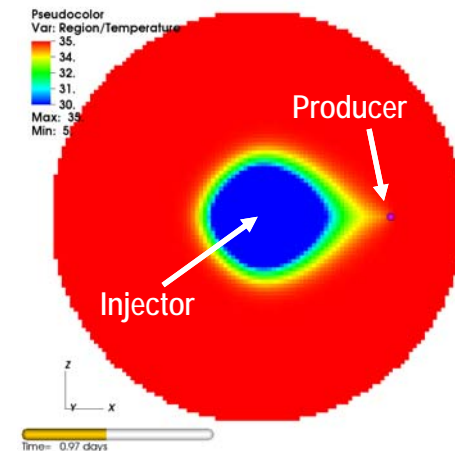
- Long term, constant rate, cold-water circulation test with tracers

Data sets

- Injection and production well: pressure, flowrate, interval temp, distributed temp., aperture, tracer conc. at production
- Monitoring wells: Distributed temp. and strain, point temp., ERT, active seismic

Data Usage

- Validate THM-G model predictions. Validate monitoring capability predictions.



Courtesy Pencheng Fu and Joe Morris

Test 4: Geophysical Tracer Test

Objective

- Image fracture flow paths vs. stress/aperture

Description

- Saline/electrically anomalous fluid circulation + tracers

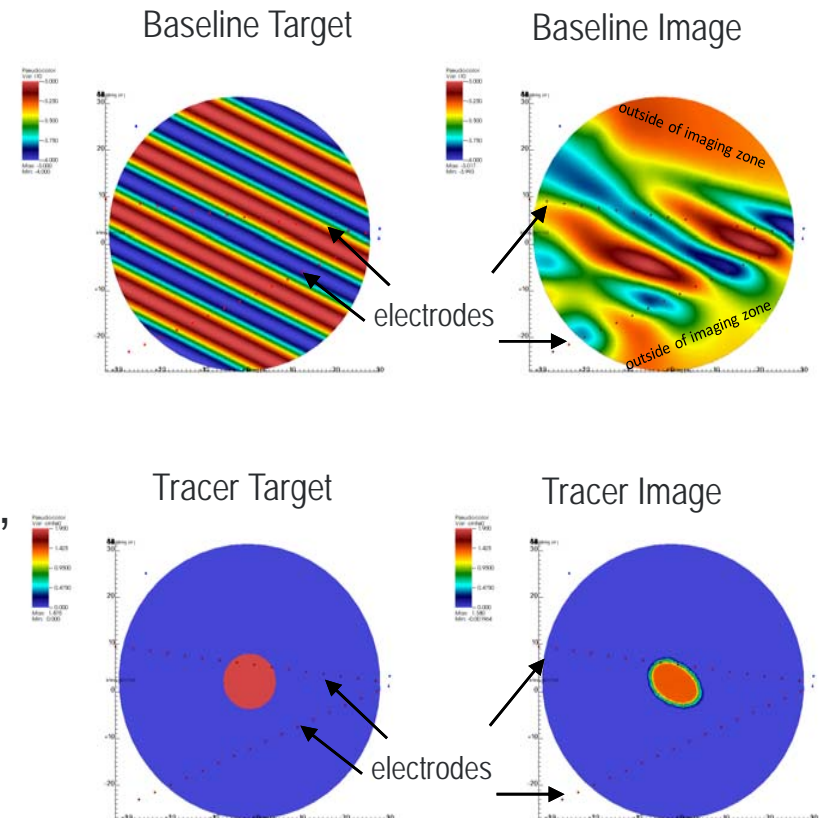
Data sets

- Injection and production wells: pressure, flowrate, interval temp, distributed temp., aperture, tracer conc. at production
- Monitoring wells: Time-lapse ERT, point and distributed temp. and strain.

Data Usage

- Validate residence time, flow path predictions. Validate monitoring capability predictions.

ERT Feasibility Modelling



Test 5: Combined and Zonal Isolation Flow Tests

Objective:

- Predict, demonstrate, and evaluate isolation of fracture zones and simultaneous flow and pressure control.
- Compare isolated and non-isolated behavior.

Description:

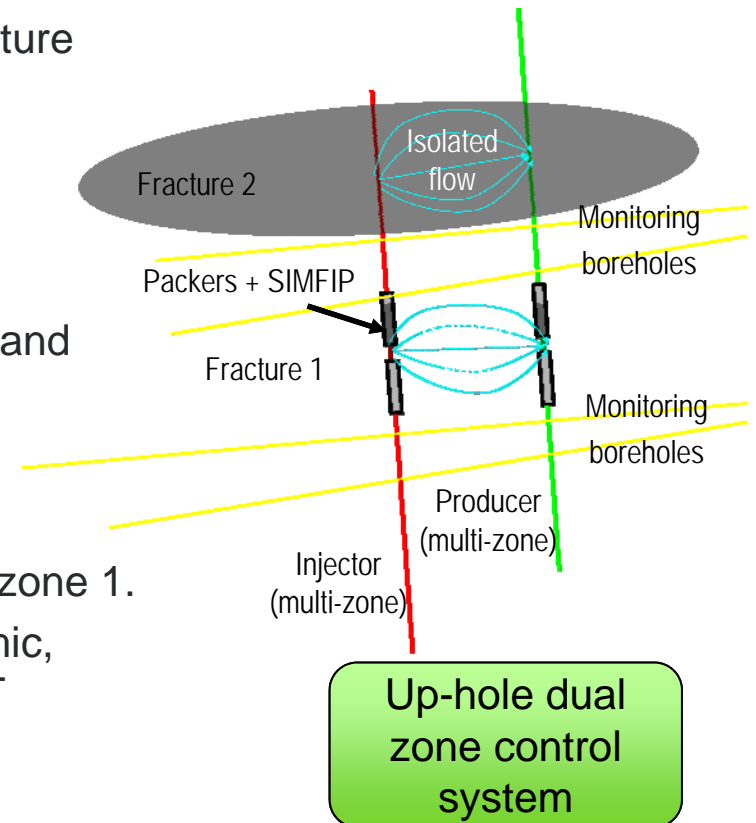
- Model driven combined and independent pressure and flow manipulation of fracture zones

Data sets:

- Pressure, flowrate, temp in each zone, aperture in zone 1.
- Monitoring wells: cross-hole seismic, passive seismic, distributed fiber temp. and strain, point temp., ERT

Data Usage

- Hydro-mechanical model validation of multi-fracture flow and control.
- Monitoring response validation

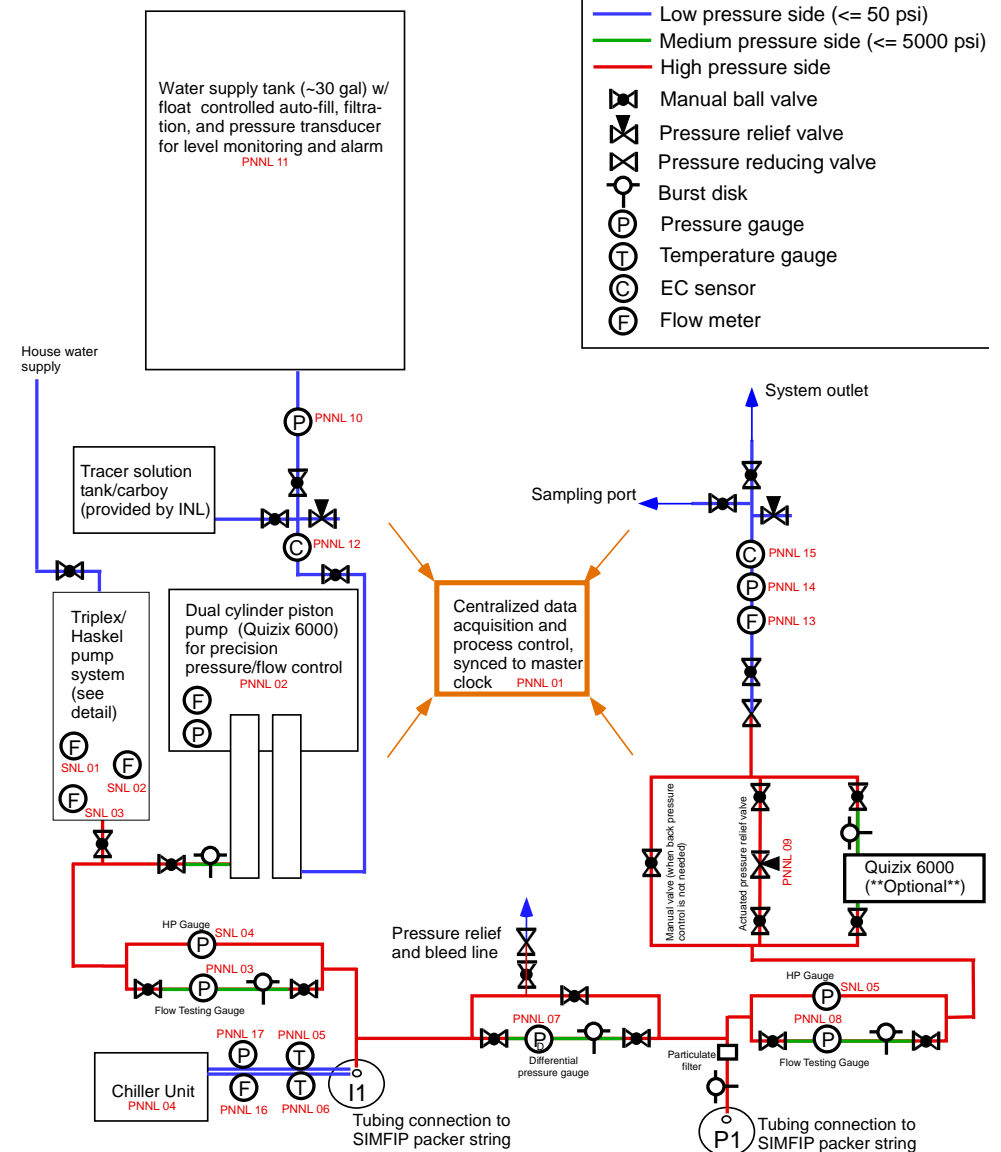


Technical Accomplishments and Progress

Original Planned Milestone/ Technical Accomplishment	Actual Milestone/Technical Accomplishment	Date Completed
Participate in kickoff meeting; task 5 lead presentation & team feedback	Accomplished Original	3/31/17
Task 5 Workplan (full team collaboration) for incorporation into PMP	Accomplished Original	6/30/17
Deliver to LLNL : task 5 infrastructure and equipment requirements, monitoring wellbore & spacing req's for ERT	Accomplished Original	7/31/17

Technical Accomplishments and Progress: Autonomous Precision Flow Test System

- Precise, automated flow and pressure in production and monitoring wells.
- Precision monitoring of pressure, flow and temp.
- Precision temperature control (downhole recirc. loop)
- Dual zone
- Monitoring system timing integrated with flow system.
- Remote control operation and monitoring
- Adaptable to address unexpected contingencies (e.g. larger flow rates, leak off)
- Hardened for mine conditions



Roland Horne (Stanford U.)
DNA Tracers

Bud Johnson (NREL), Phil Winterfied and Yu-Shu Wu (CSM)
Chemical tracer analysis

Tom Doe and Mark McClure
Analysis of fracture flow and leak-off

Future Directions

Milestone or Go/No-Go

Status & Expected Completion Date

Complete flow tests for Experiment 1, fracture set 1 and submit data to the EGS Collab database

September 30, 2018

Title	Oct 2017	Nov 2017	Dec 2017	Jan 2018	Feb 2018	Mar 2018	Apr 2018	May 2018	Jun 2018	Jul 2018	Aug 2018	Sep 2018	Oct 2018	Nov 2018	Dec 2018	Jan 2019
1) Drill & Core Log Orthogonal Top (OT) Monitoring Borehole	● King; Roggenthen															
2) Drill & Core Log Orthogonal Bottom (OB) Monitoring Borehole	● King; Condon															
3) Drill & Core Log Production (P) Borehole	● Condon															
4) Logging of OT, OB, & P	● Ulrich; Roggenthen															
5) General Basic Safety Training	● Horner; Thomle; Johnson; White; Smith; Frash; Foris; Feldman; Knox, J.; Schwering; Robertson															
6) 4850 Visit & Core Logging Training	● Horner; Thomle; Johnson; White; Smith; Frash; Foris; Feldman; Knox, J.; Schwering; Robertson															
7) Drill Stimulation (S) Borehole	● Frash; Rivers															
8) Logging of S & Notch Stimulation Borehole	● Ulrich; Robertson															
9) Drill Parallel Shallow Top (PST) Monitoring Borehole	● Frash															
10) General Basic Safety Training	● Ajo-Franklin; Burghardt; Blankenship; Guglielmi; Herrick															
11) 4850 Visit & Core Logging Training	● Ajo-Franklin; Burghardt; Blankenship; Guglielmi; Herrick															
12) Drill Parallel Shallow Bottom (PSB) Monitoring Borehole	● Horner; Roggenthen															
13) Drill Parallel Deep Top Monitoring Borehole	● Horner; Feldman															
14) Drill Parallel Deep Bottom Monitoring Borehole	● Feldman															
15) Drill Parallel Deep Bottom Monitoring Borehole (Cont. 1)	● Blankenship															
16) Drill Parallel Deep Bottom Monitoring Borehole (Cont. 2) & Demob	● Smith; Blankenship															
17) Complete Geophysical Logging	● Ulrich; Robertson															
18) Seismic Characterization	● Knox, H.; Knox, J.; Schwering															
19) Seismic Characterization	● Knox, H.; Schwering; Roggenthen															
20) Assemble Monitoring Packages	● Strickland; Ajo-Franklin; Johnson; Robertson; Thomle															
21) Grouting	● King; Knox, H.; Foris; Strickland; Robertson; Johnson															
22) Finish Seismic Characterization	● Knox, H.; Schwering; Robertson; Ulrich															
23) Preparation for Stimulation 1	● Cook; Guglielmi; Herrick; Ingraham; King; Strickland; Vermeul															
24) Baseline ERT & Set-up Monitoring (Interference Test)	● Thomle; Johnson; Robertson; Ulrich															
25) Stimulation 1 & Monitoring	● King; Blankenship; Cook; Guglielmi; Herrick; Ingraham; Johnson; Ajo-Franklin; Kneafsey; Knox, H.; Lee; Robertson; Strickland; Vermeul															
26) Find Fracture & Conduct 4.5	● King; Cook; Herrick; Knox, H.; Ulrich; Strickland; Vermeul															
27) Flow Test 1	● Vermeul; Strickland; Knox, H.; Thomle; Johnson															
28) Stimulation 2 & Monitoring	● King; Cook; Guglielmi; Herrick; Ingraham; Johnson; Ajo-Franklin; Knox, H.; Robertson; Strickland; Vermeul															
29) Find Fracture & Conduct 4.5	● King; Cook; Herrick; Knox, H.; Ulrich; Strickland; Vermeul															
30) Flow Test 2	● Vermeul; Strickland; Knox, H.; Johnson; Thomle															
31) Combined System Characterization	● Vermeul; Strickland; Knox, H.; Herrick; Cook; Guglielmi; Ingraham; Ajo-Franklin; Johnson															
32) Combined System Characterization w/ Zonal Isolation	● Vermeul; Strickland; Knox, H.; Herrick; Cook; Guglielmi; Ingraham; Ajo-Franklin; Johnson															
33) Drillback																

Task 5 will provide:

Precisely controlled and comprehensively monitored flow tests, guided by model predictions, validated by post-test drill-back.

- *Enables assessment of THMC-G predictive capability: Critical for validation of EGS computational tools*
- Fractures will be characterized by:
 - dimension, geomechanical properties, hydrogeologic properties, heat transfer properties, and geophysical properties
- Enables assessment of field tools for characterization
- Comprehensive THMC-G community data set to facilitate advancement of EGS systems will be made generally available