

# **EGS Collab Rock Mechanics and Fracturing Studies at SURF**

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*Conference on Science at the Sanford Underground Research  
Facility*

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# EGS Collab Project

A collaborative experiment and model comparison project:

- Compare and **validate** reservoir model predictions with ~10 m-scale field experiment data
  - At-depth fracture characterization
  - Well-performed well-monitored experiments collecting high-quality data using comprehensive instrumentation
- Advance the understanding of relationships between permeability enhancement and stress, seismicity, other other parameters.
- Improve tools for FORGE (Frontier Observatory for Research in Geothermal Energy) and EGS (Enhanced Geothermal Systems).

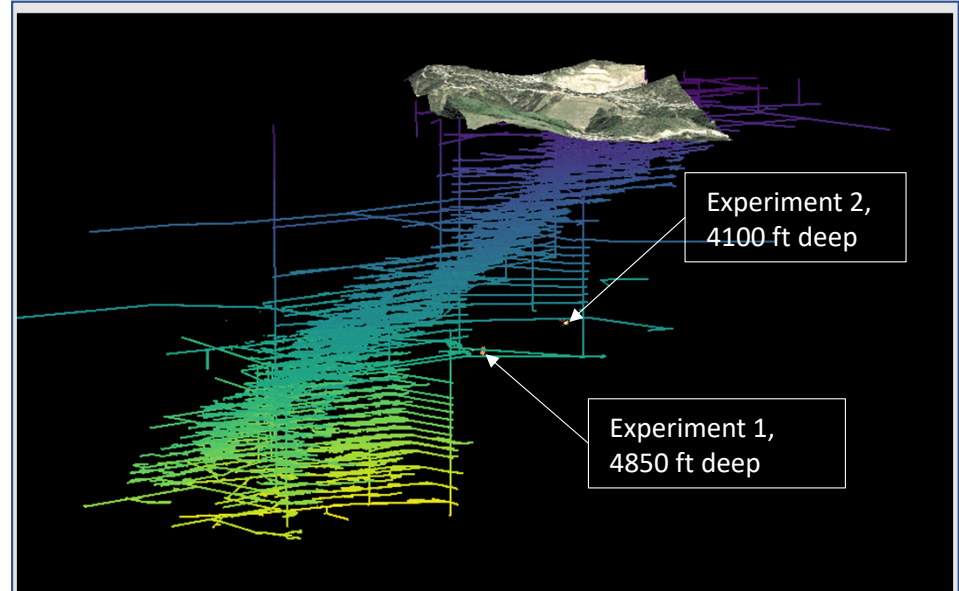


# Participating Organizations



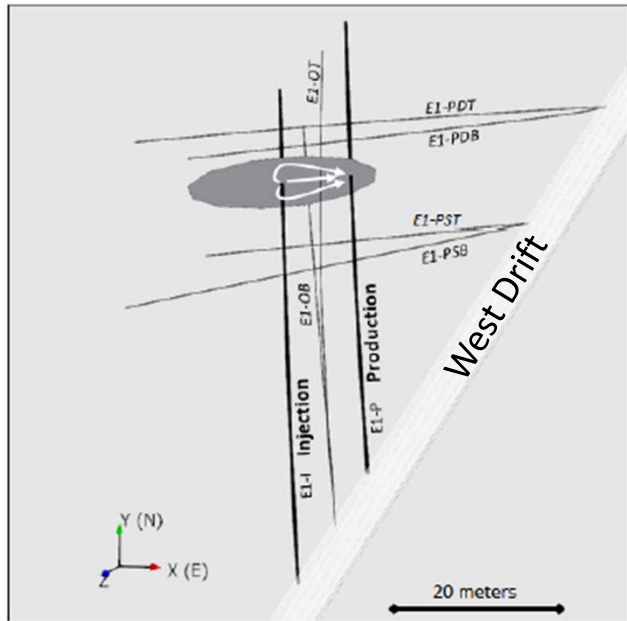
# EGS Collab Experiments

- **Experiment 1** - intended to investigate **hydraulic fracturing\***, at the Sanford Underground Research Facility (SURF) at 4,850 ft. depth (fieldwork complete)
- **Experiment 2** - designed to investigate **shear stimulation\*** at SURF at 4,100 ft. depth (under way)
- **Experiment 3** - will investigate changes in fracturing strategies and will be further specified as the project proceeds.

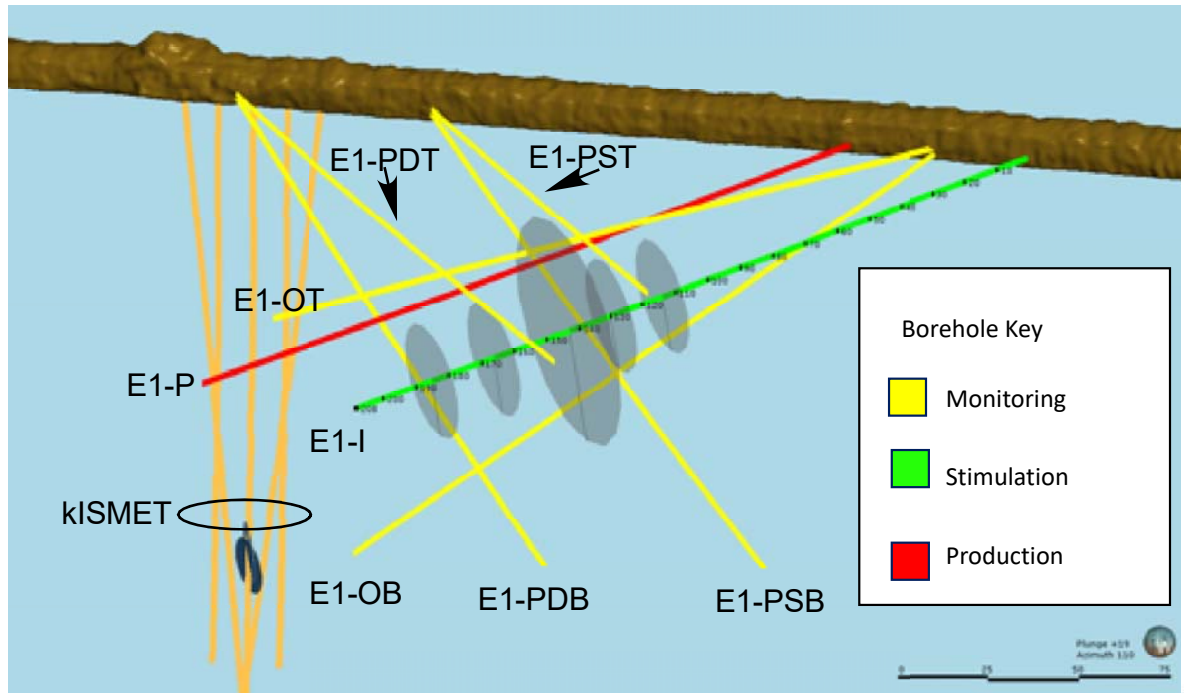


Each experiment consists of multiple stimulations; and characterizations of flow, tracer, and heat transfer behavior. Pre- and post-test simulations are performed for each.

# Test Bed 1 4850 Level: Stimulations and Flow Tests

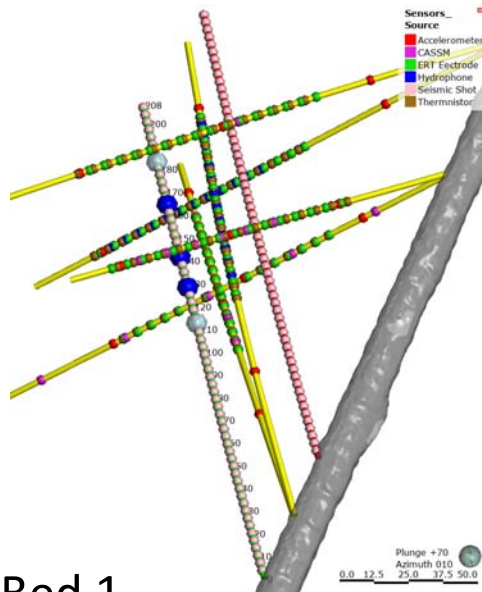


To Yates Shaft



# Experiment Layout and Instrumentation

Well characterized/instrumented\*



Test Bed 1

## Local stress measurements

### Borehole

- Optical and acoustic televiewer
- Full waveform seismic
- Electromagnetic
- Gamma
- Temperature
- Fluid conductivity

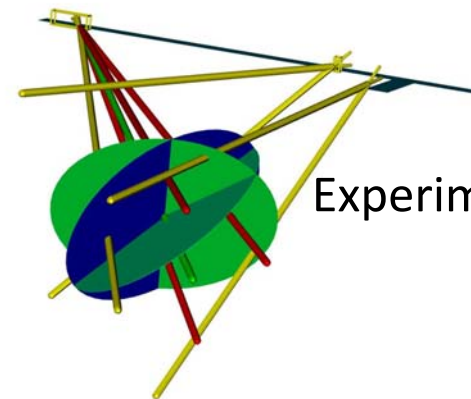
### Test “block”

- P- and S-wave characterization using mobile and grouted borehole sensors, grouted and mobile sources
- Extended hydrologic characterizations
- Electrical Resistance Tomography (ERT), baseline and flow

### Core

- Lithologies, fractures, and veins
- X-ray CT, magnetic susceptibility, gamma density, p-wave velocity, Ca/Si, Ca/Al, Si/Al, and Fe/S ratios, light elements, Ca, and Si abundance

- Acoustic emissions (AE)
- Continuous Active-Source Seismic Monitoring (CASSM)
- MicroEarthquake (MEQ)
- Electrical Resistivity Tomography (ERT)
- Temperature by distributed temperature sensing (DTS), thermistors
- Strain by distributed strain sensing (DSS)
- Direct 3-D fracture displacement using SIMFIP at injection and production boreholes



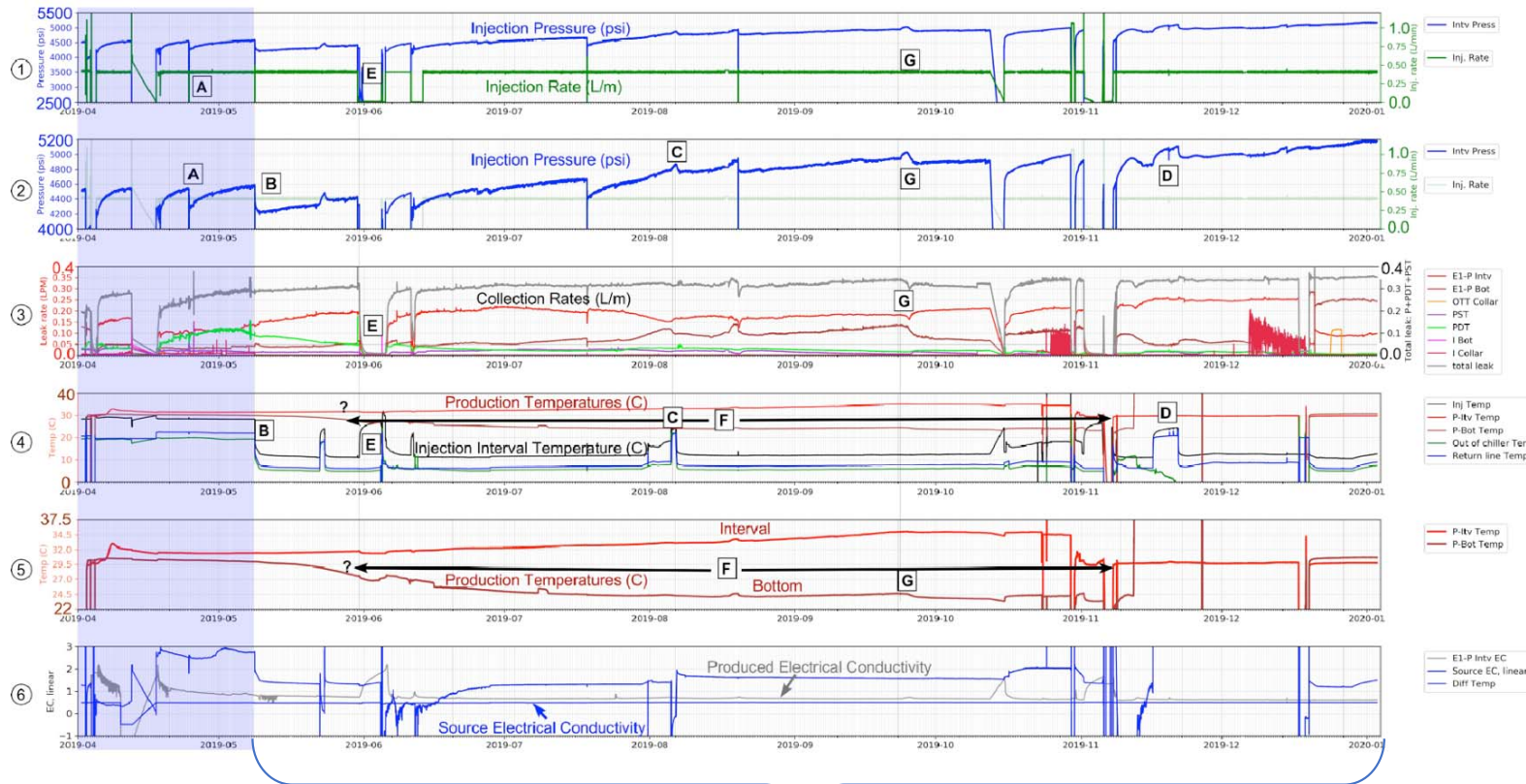
Experiment 2



## Packers:

- used to isolate zones
- induce pressure for fracturing
- measure fluid outflow

# Flow Test Data

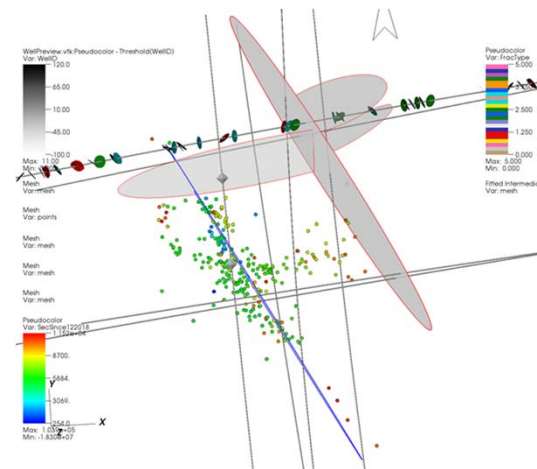


Chilled Water Injection



# Test Bed 1 Major experiments/tests

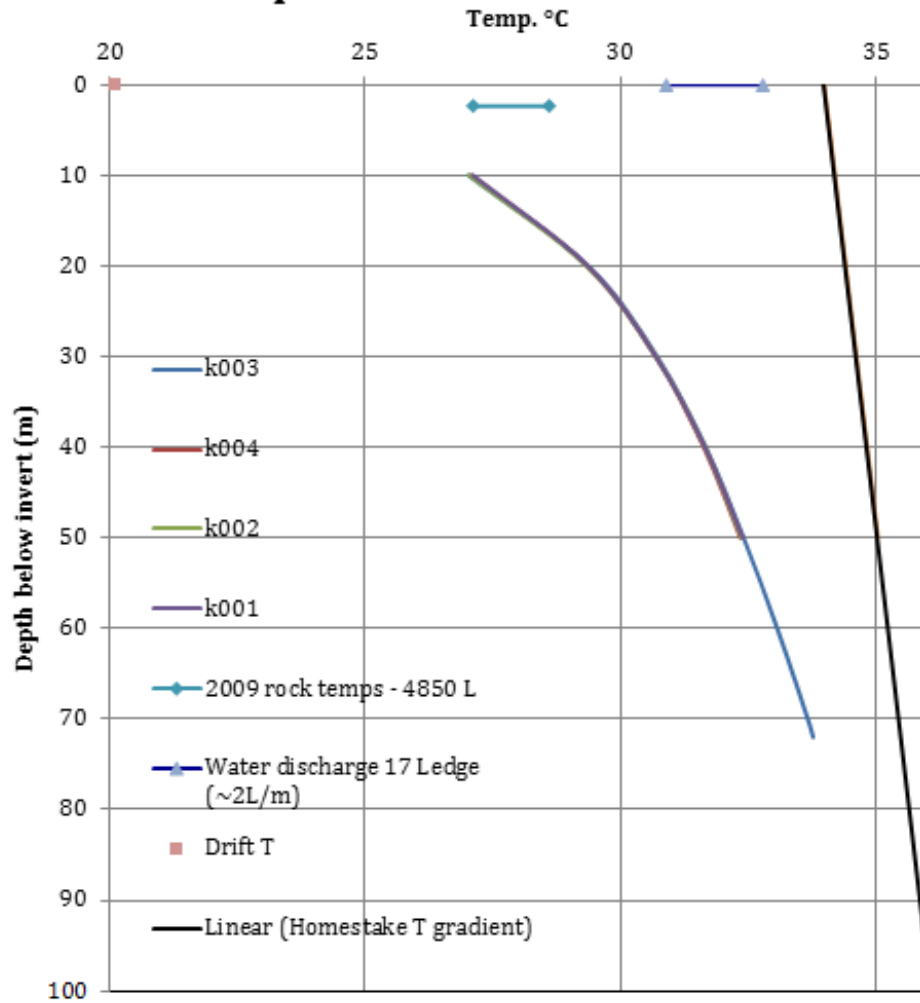
- Multiple stimulations of three intervals; established hydraulic connection between wells
- Stimulated a large natural fracture system and new hydraulic fractures
- Tracer tests
- ~Year-long cold water injection test, 90+% water recovery



All subjected to continuous geophysical monitoring and extensive analysis aided by near-real time numerical modeling. Tests are performed with Zoom calls to allow observation and adaptive control.



## Temperature data - 4850 level



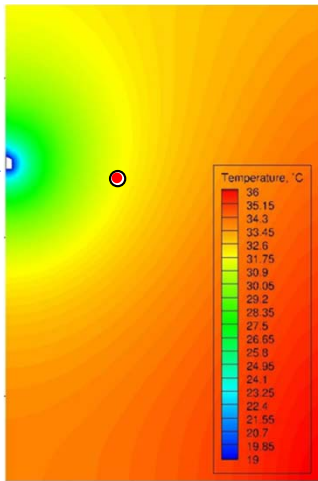
Temperatures measured in KISMET vertical holes near Test Bed 1

Plotted by Dobson, 2017

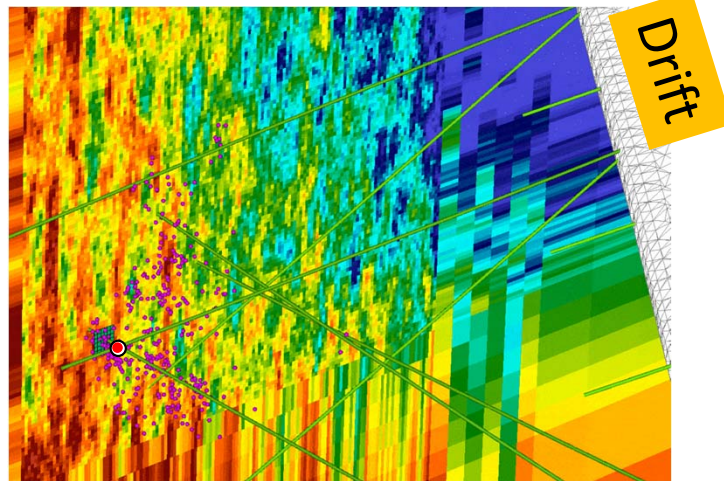
# Temperature profile, induced stress profile and anticipated fracture shape and arrival time

Thermoelastic effect

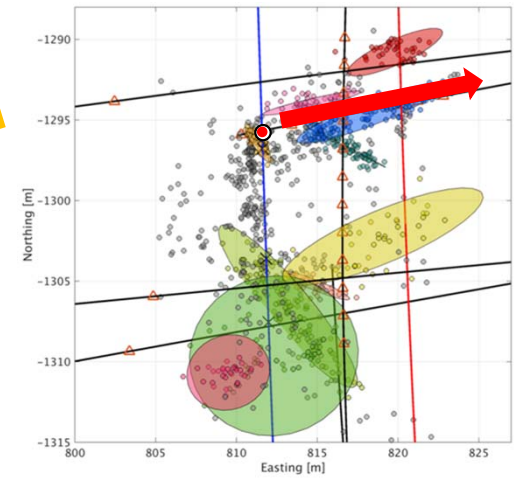
Drift



Mark White (PNNL)



Pengcheng Fu (LLNL)



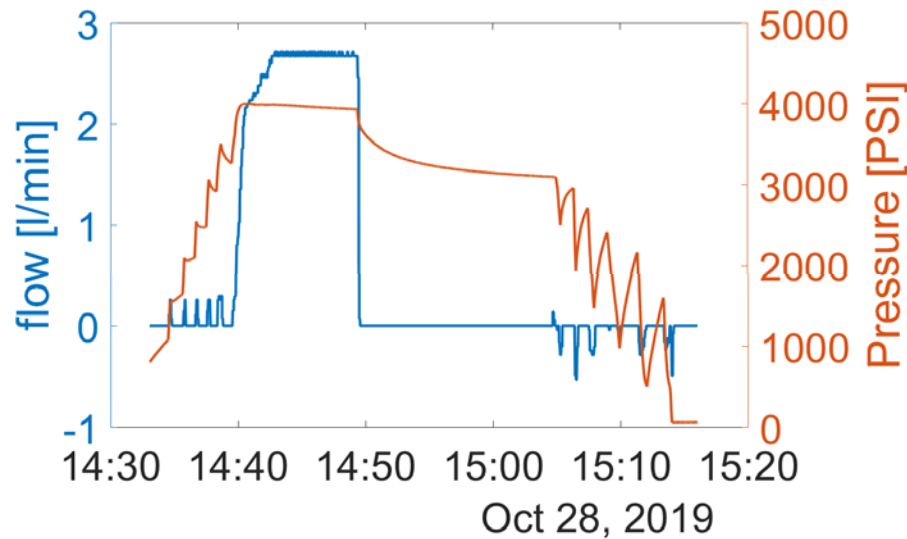
Drift

Martin Schoenball (LBNL)

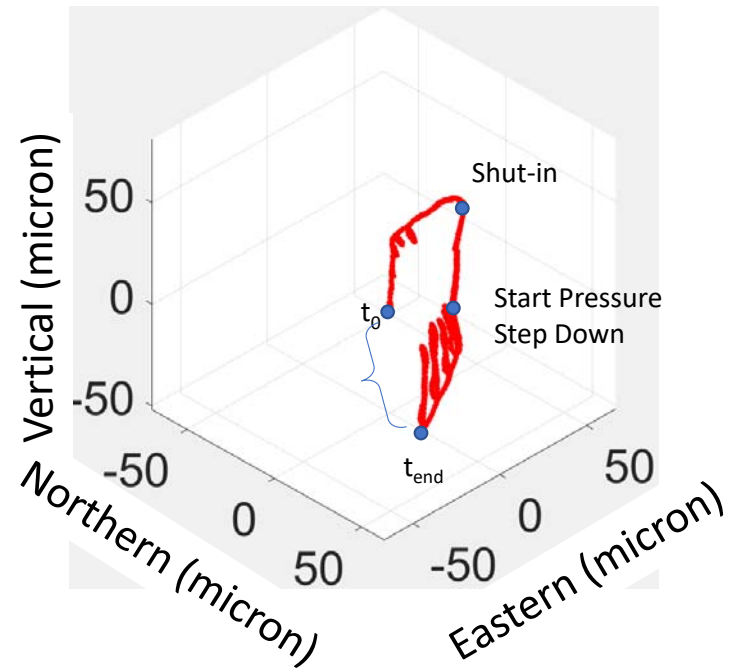
# Test Bed 1: Stress and Displacement

SIMFIP measurements (displacement across a fracture - example)

Injection pressure and flow

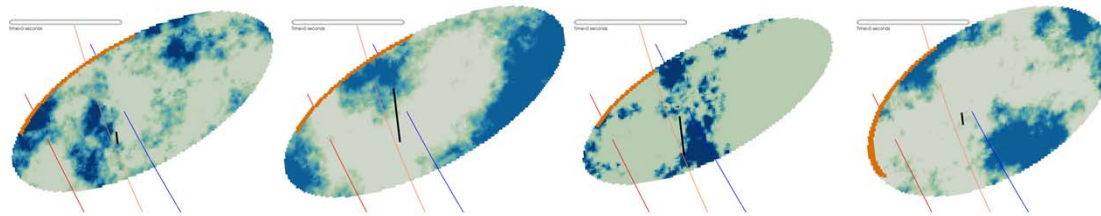
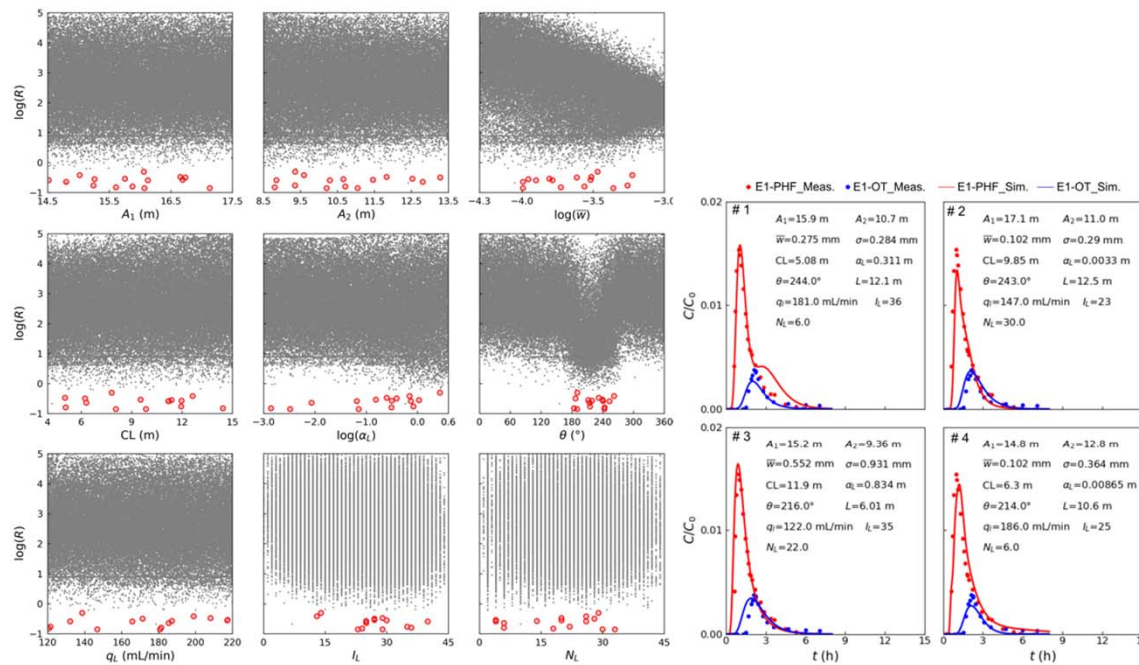


Displacement



Yves Guglielmi (LBNL)

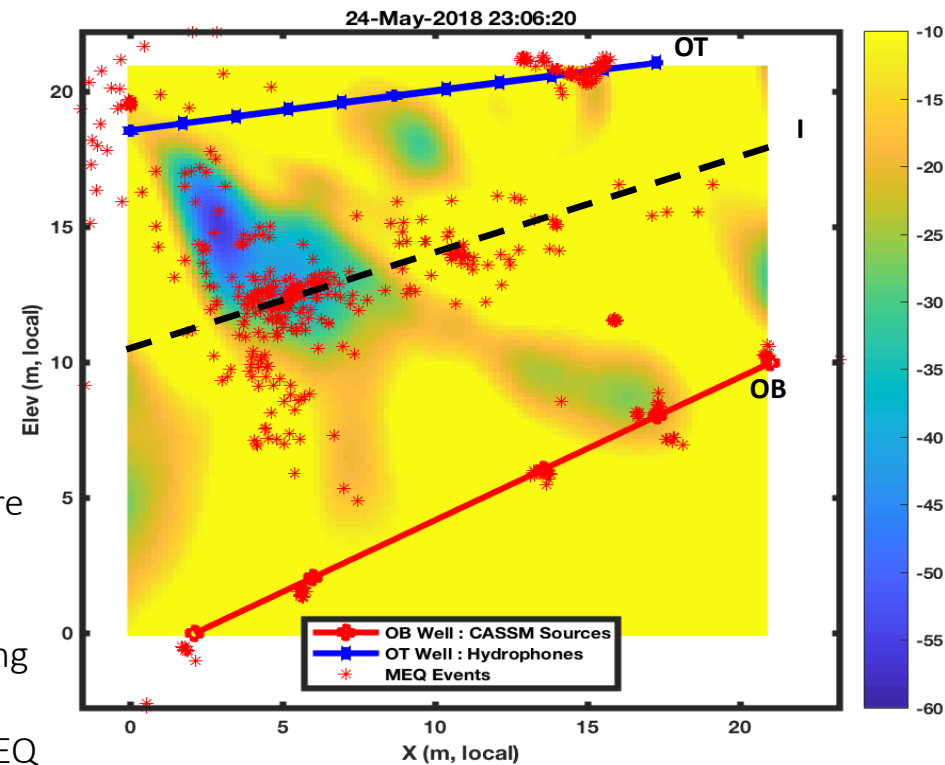
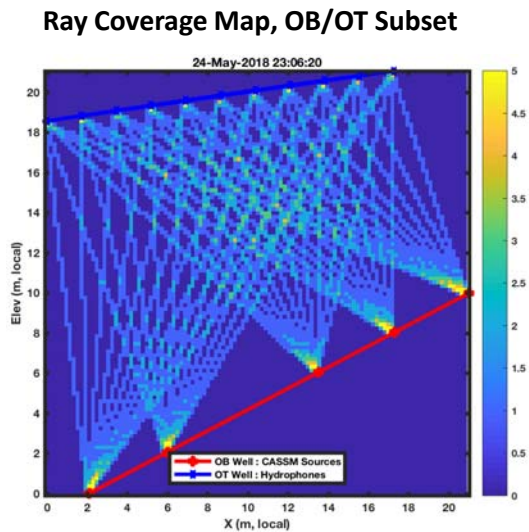
# Extensive modeling to support result interpretation and decision making.

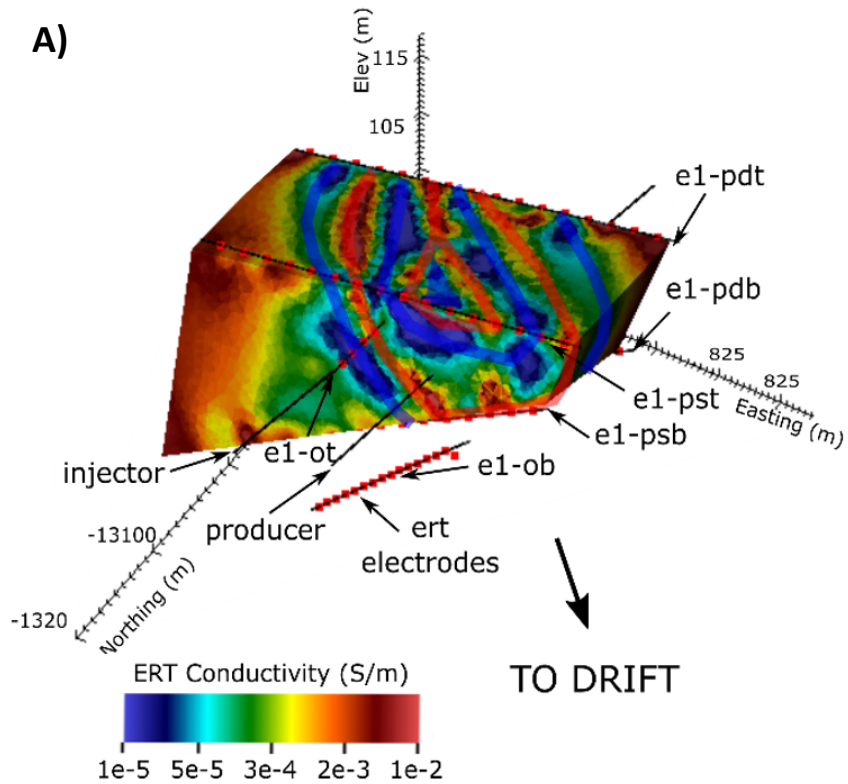


Millions of stochastic realizations of tracer transport model by Wu et al. (LLNL)

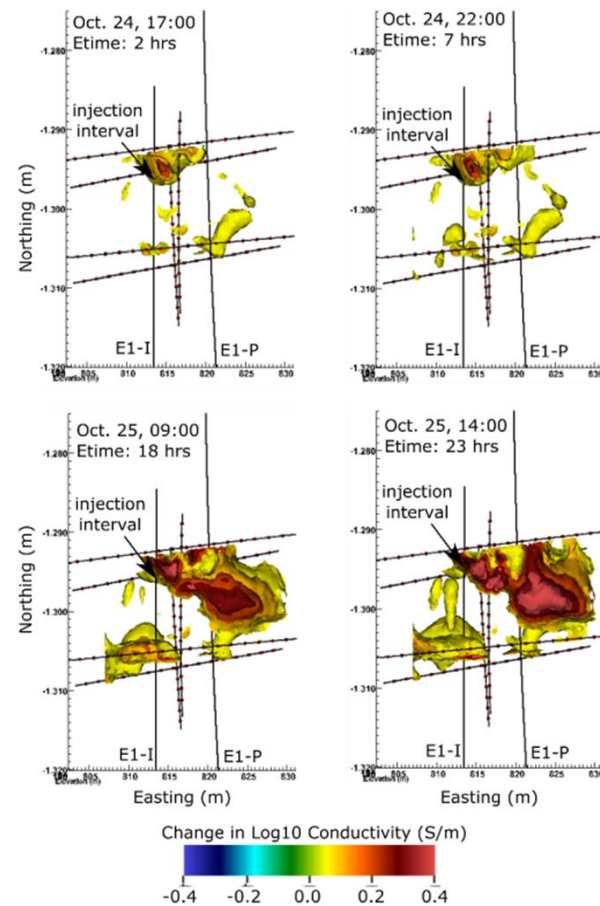
# Continuous Active Seismic Source Monitoring

- Excellent correlation between CASSM and MEQ dataset
- Velocity reduction shows both a damage and pore-pressure dependent component.
  - Strong (-60 m/s) fracture response, recovers during shut-in as effective stress increases
  - Permanent  $V_p$  reduction (damage effect)
- Poor resolution of lower fracture half (some hints) due to asymmetric ray coverage
- Provides a path to understanding fracture dynamics and stress dependence *independent* of MEQ activity





Electrical resistivity model prior to stimulation



Selections from time-lapse ERT imaging sequence during post-stimulation constant rate flow testing at the 164 ft depth

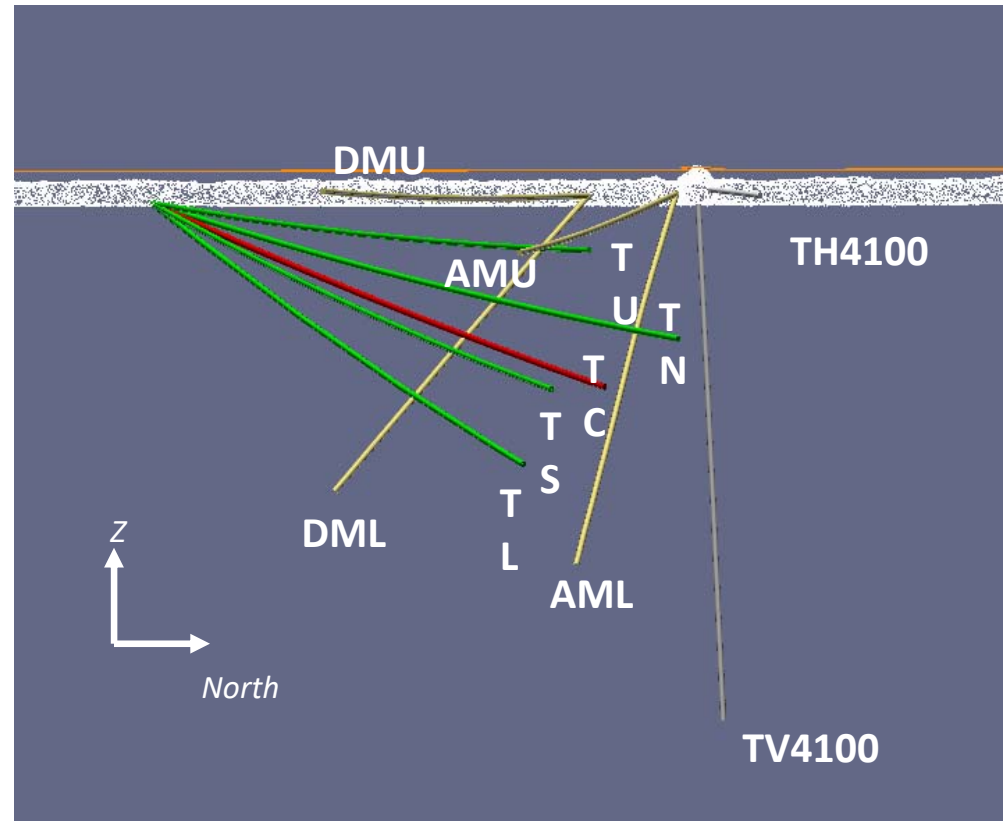
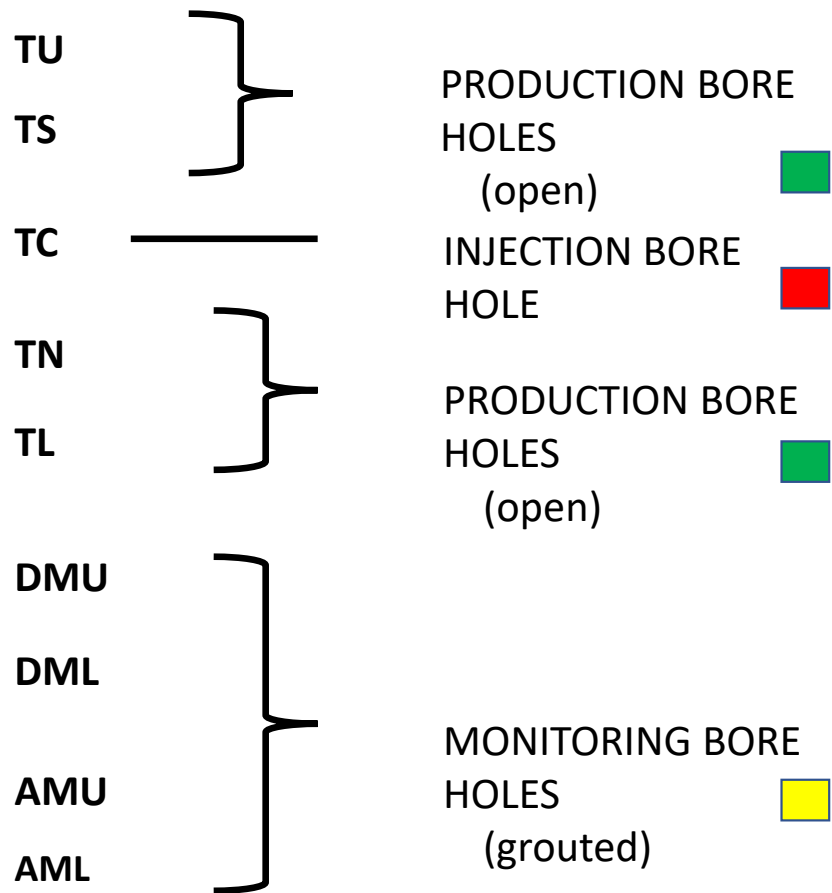
# Test Bed 1 and 2 Rock Characteristics

Exp 1  
Carbonate  
-mica  
phyllite

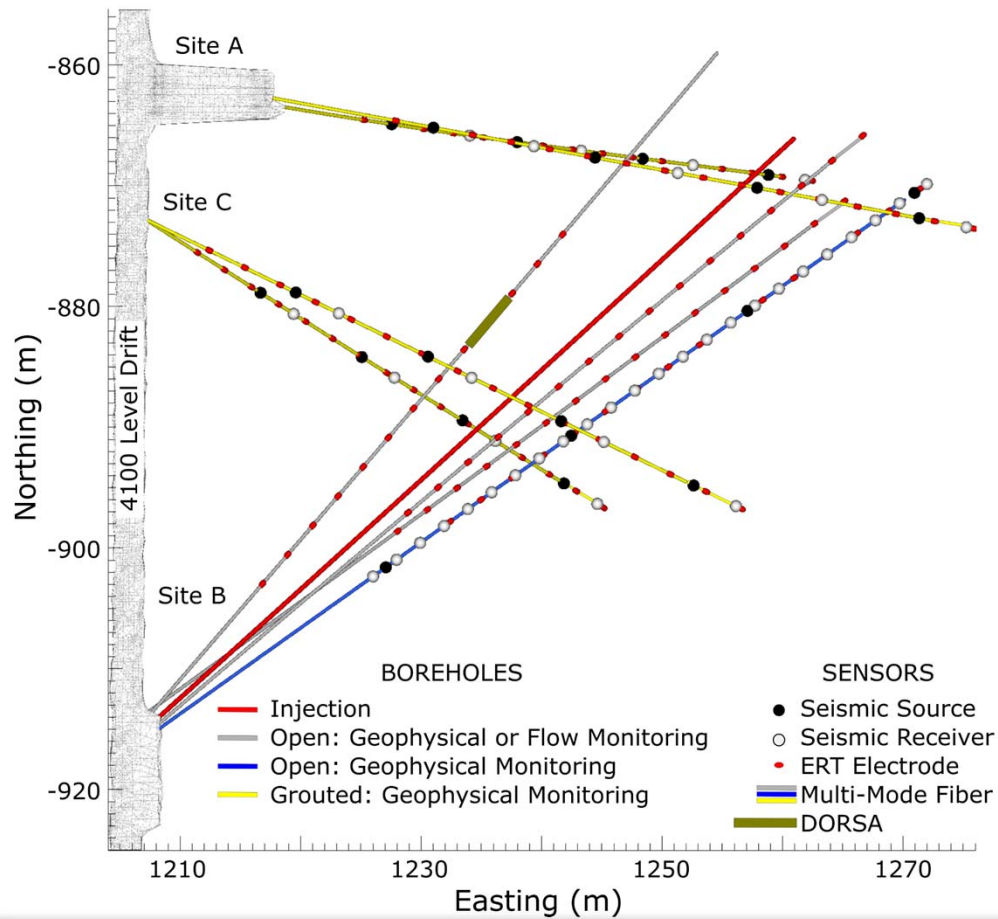


Exp 2  
Amphibolite  
-massive with  
healed fractures



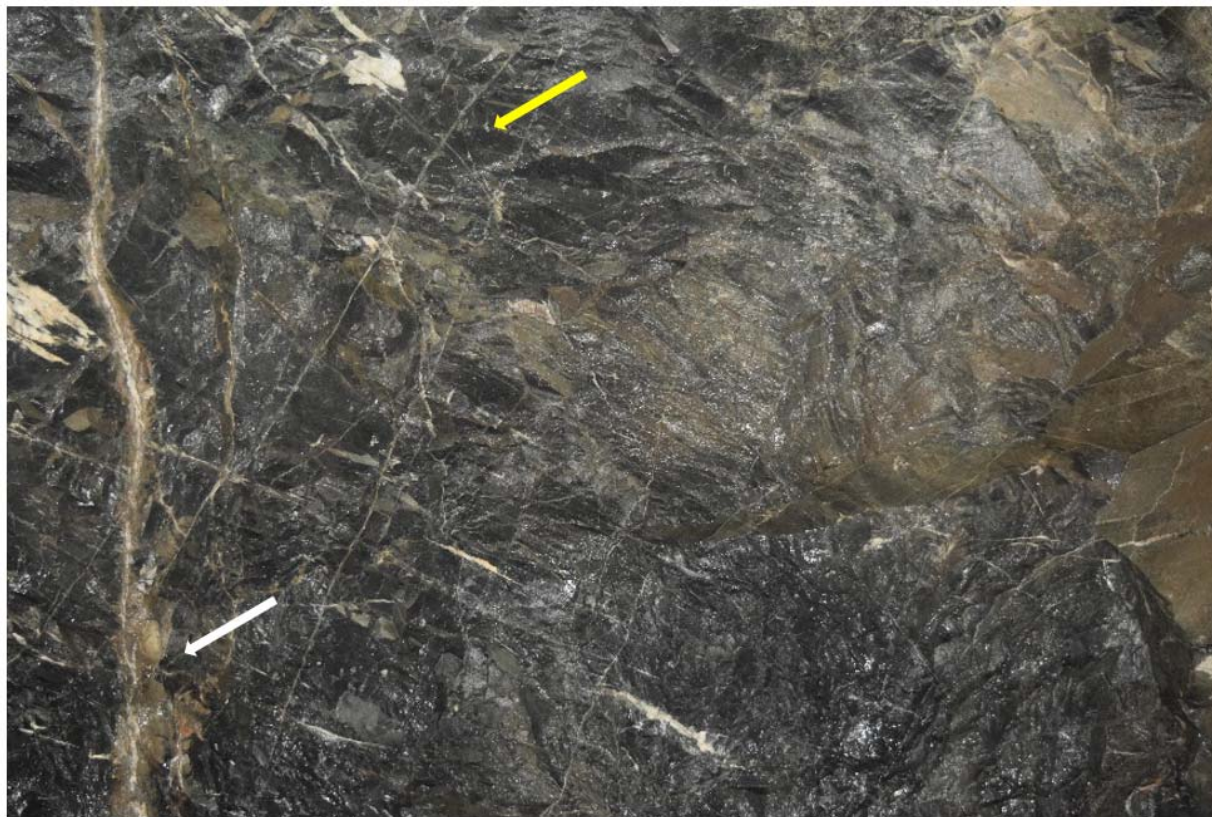


# Geophysical Monitoring Sensor Locations



- Also:
  - Distributed
    - Temperature
    - Strain
    - Acoustics
- SIMFIP in injection during stimulation
- DORSA for remote strain monitoring

# Observed Test Bed 2 Fractures

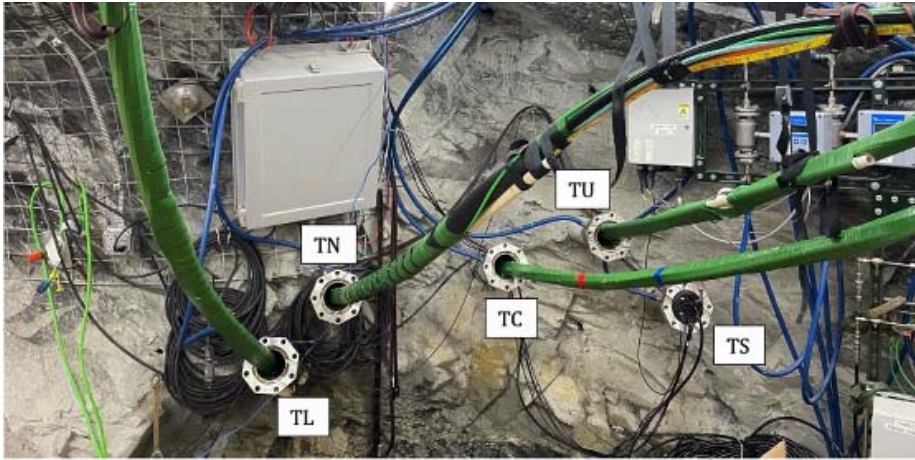


# Highly Fractured Interval



# Experiment 2 Testbed





*All I/P packers installed.*



# Project Information Sources

- EGS Collab wiki

[https://openei.org/wiki/EGS\\_Collab\\_Project\\_Overview](https://openei.org/wiki/EGS_Collab_Project_Overview)

- Data migrating to GDR
- Data indexed in Google datasets
- Journal and conference papers indexed in Google Scholar



## GDR

### GDR Data Impact Report for EGS Collab February

#### Impact Snapshot:



**145**

Downloads  
in February



**733**

Downloads  
FYTD



**1.75 TB**

Submitted  
Data



**304**

Available  
Resources

