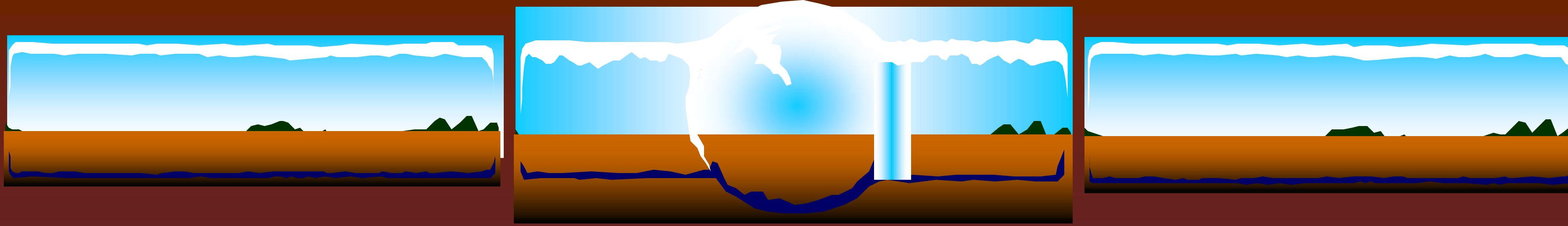

DOE’s EGS Program Review

Fracture Evolution Following a Hydraulic Stimulation within an EGS Reservoir

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Project Objective

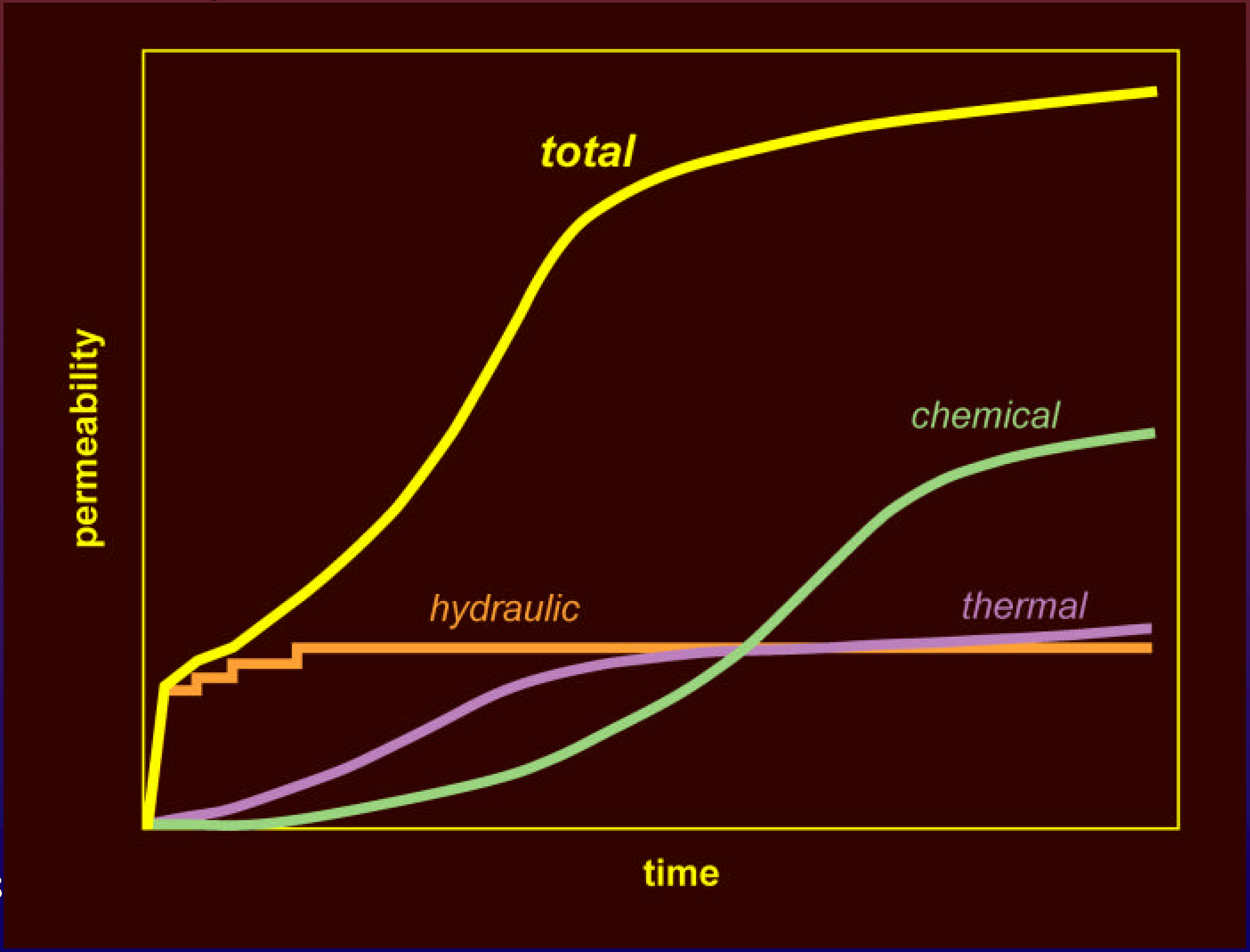
- To characterize the evolution of fluid-flow patterns within an EGS reservoir as the result of long-term injection into a well following a hydraulic stimulation.

EGS Problem

- Why is project important to EGS program?
  - Hydraulic and chemical stimulation are the major processes being studied for creation of permeability within engineered geothermal systems. However, very little is known about the long-term effectiveness of these stimulation approaches. This project is important to EGS, since it attempts to understand and quantify those long-term effects in a well-characterized EGS setting.
- What technical issue does the project address?
  - This project addresses the long-term effects of hydraulic and chemical stimulation on permeability.
- How will project help to achieve overall program goals?
  - Accomplishment of the objectives of this project will assist DOE in meeting its interim objective of demonstrating the feasibility of creating EGS circulation systems at commercial production rates by 2010.
    - Increase EGS net output power of one production well from 1.4 MWe to 2.5-9.8 MWe by 2010
    - Double the mass flow rate of one well from 15 kg/sec to 30 kg/sec
    - Increase the effective fracture contact area from 0.56 to 0.6 km^2
    - Increase the short-circuiting index from 0.000011 to 0.0033

Background/Approach

Reservoir Stimulation Is Achieved through a Combination of Hydraulic, Chemical and Thermal Effects



Measuring Changes in Effective Temperature along Injection/Production Pathways Using Reactive Tracers

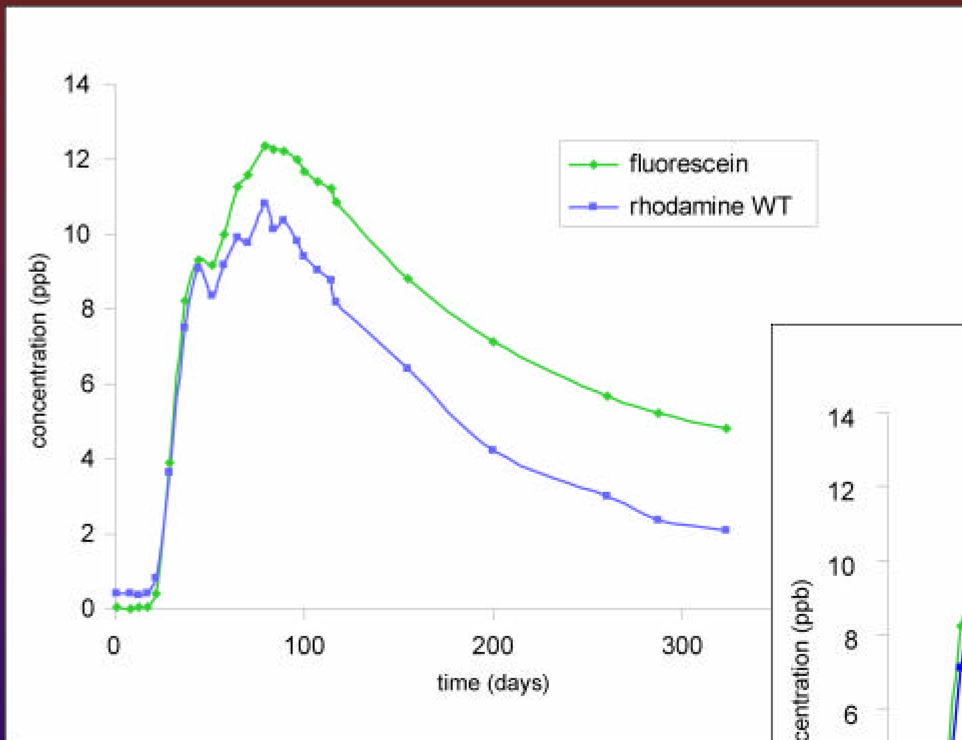
Ratio of Decay-Rate Expressions:

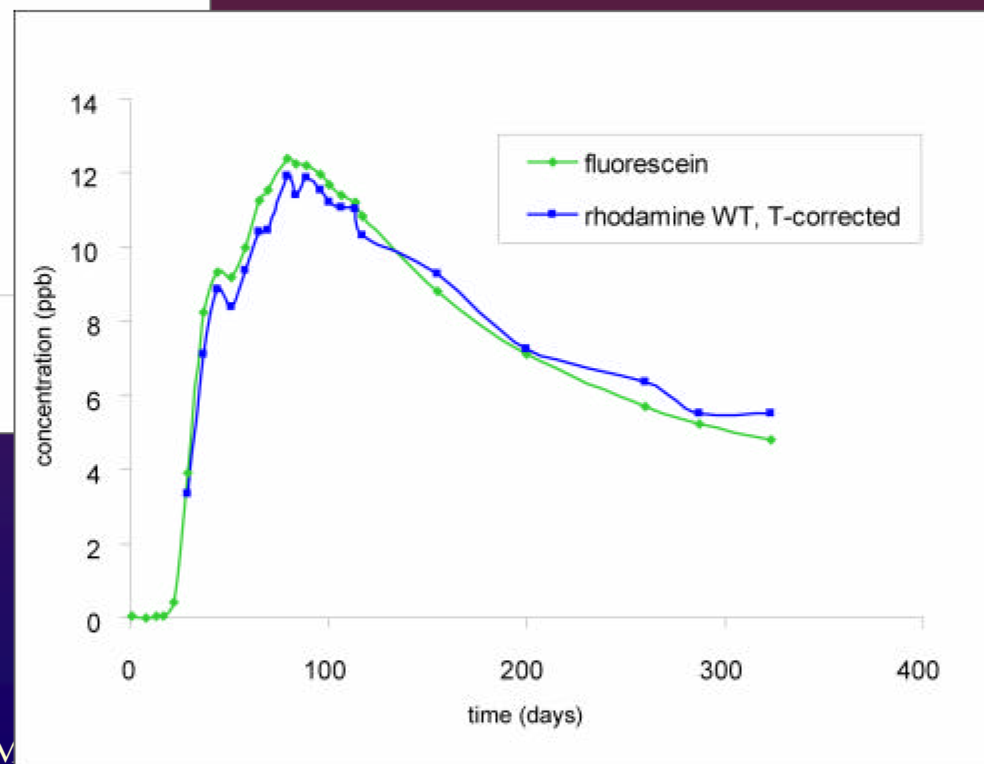
$$\frac{C_1}{C_2} = \frac{C_1^o}{C_2^o} \; e^{(k_2 - k_1)t}$$

Temperature Dependence of Decay Rate Constant:

$$k = Ae^{(-E_a/RT)}$$

Reactive Tracing at the Steamboat Hills Geothermal Reservoir





$$\frac{C_R}{C_F} = 1.2 \ e^{-.00358\,t}$$

$T_{eff} = 163^oC$

Quantifying Changes in Reservoir Mean Residence Time and Tracer-Swept Pore Volume

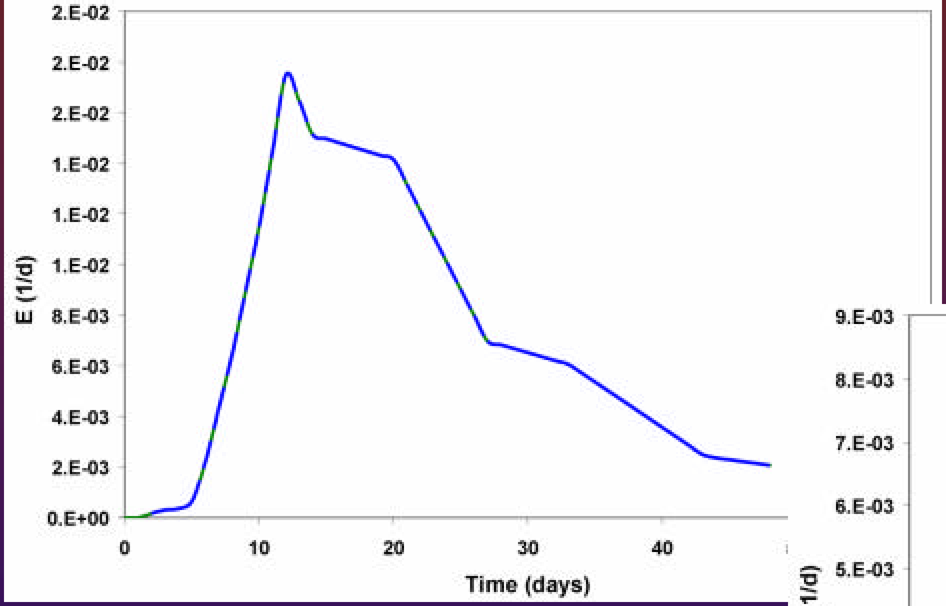
Age Distribution Function:

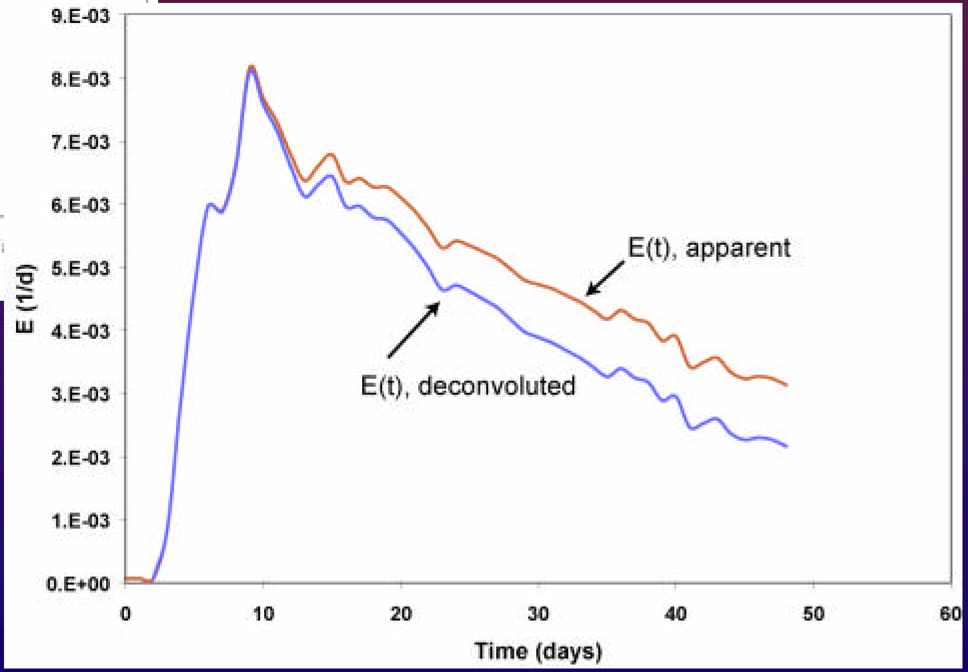
$$E(t) = \frac{C(t) \;\; q_{inj}}{M_{inj}}$$

Tracer-Swept Pore Volume:

$$V_p = \frac{m}{M} \;\; Q \;\; t^*$$

Quantifying Changes in Reservoir Mean Residence Time and Tracer-Swept Pore Volume



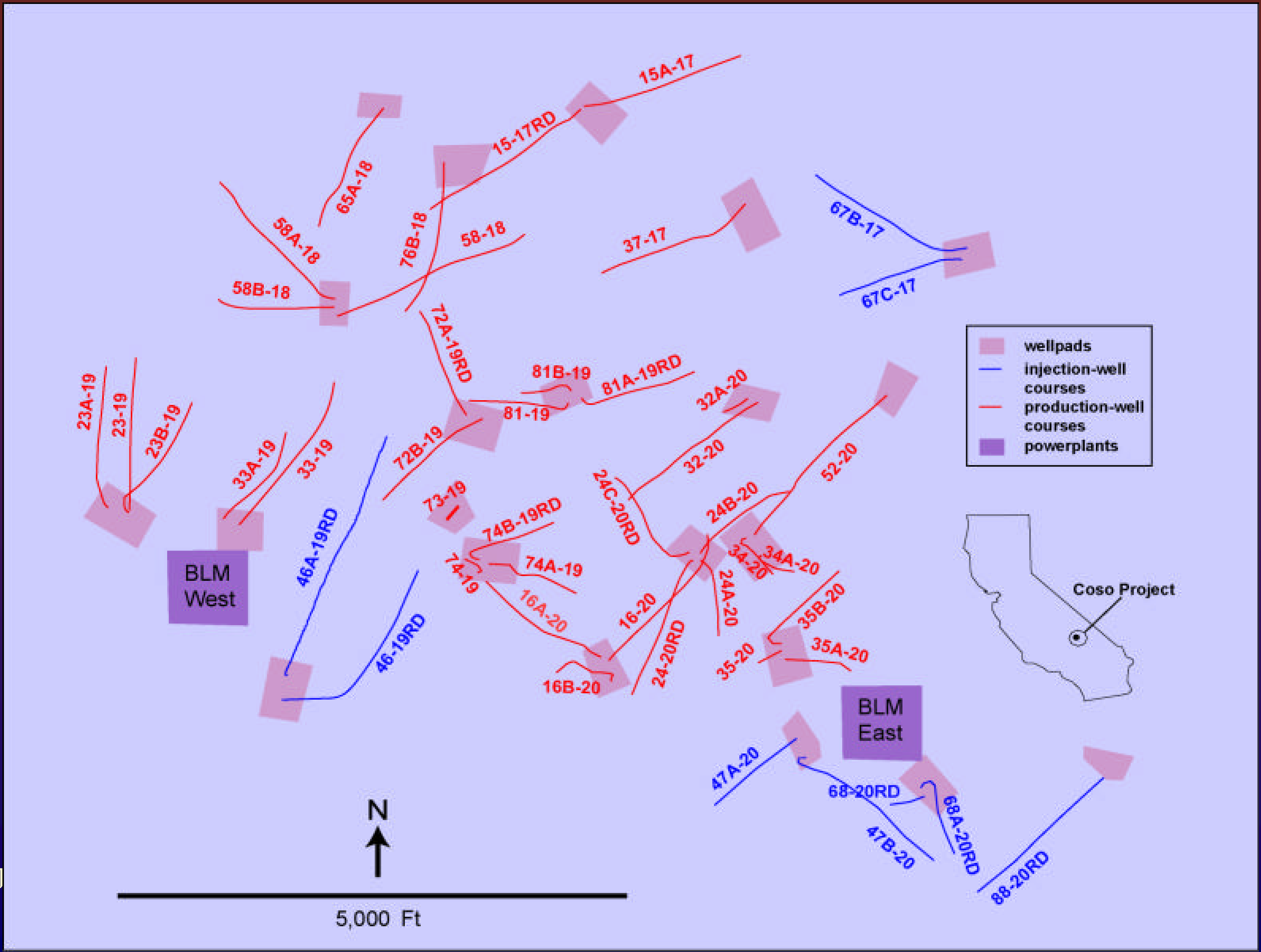


Well Name	Max. Flow Rate (l/s)	Wellhead Pressure (MPa)	Tracer-Swept Pore Volume (m^3)	Tracer Recov-ery (%)
Soultz GPK-1	23	2	16,000	20
Coso 34A-9	126	0.4	41,000	35

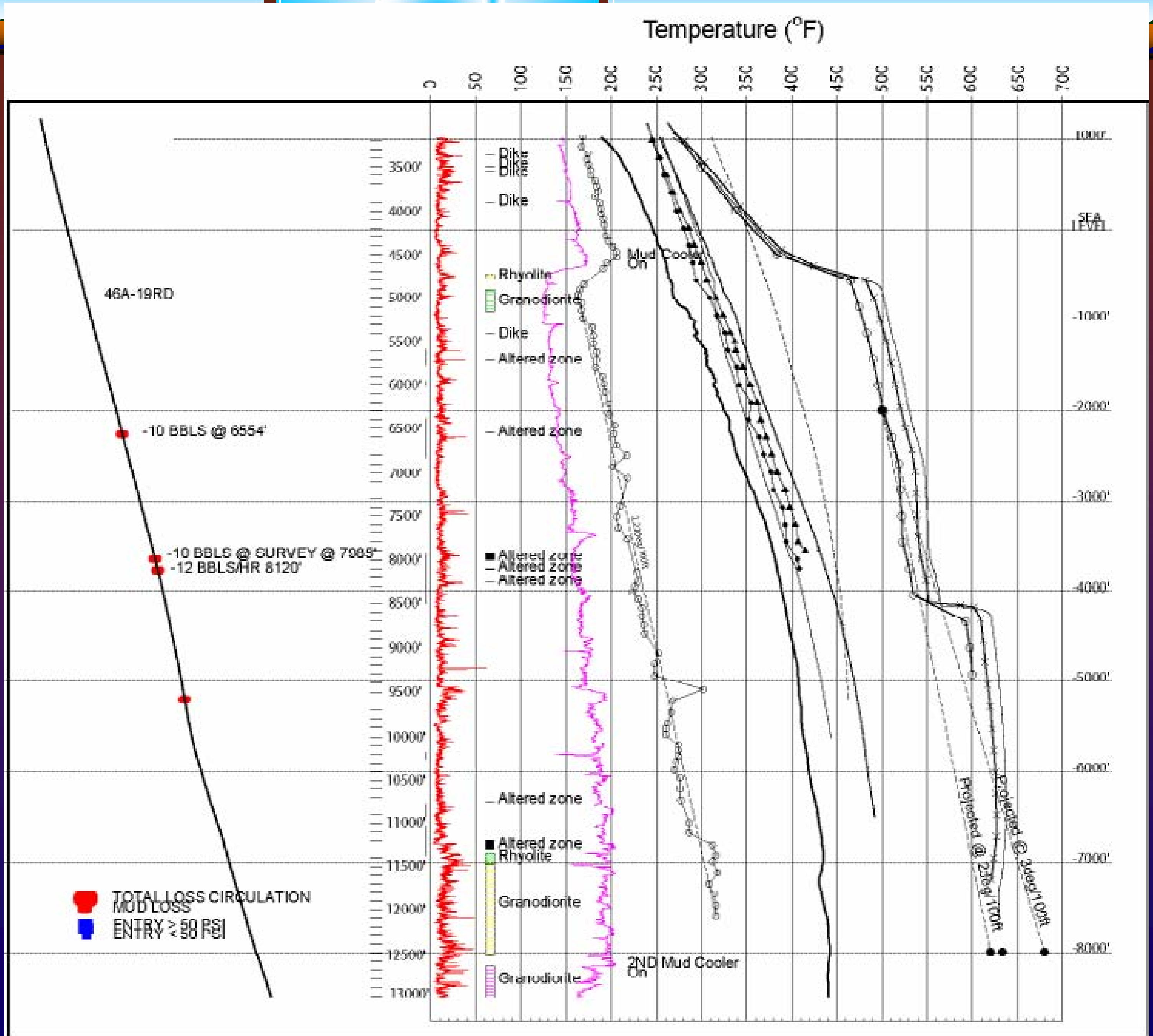
EGS Target Stimulation Well 46A-19RD

- Drilled in 1994 to a TVD of 12,678 ft
- Bottomhole temperatures estimated to exceed 350^{o}C
- Very low injectivity observed below ~10,000 ft

Location of 46A-19RD within the Southwest Corner of the Coso Field



46A-19RD



July 18, 2006

46A-19RD Preparation and Workover

- Install Navy's temporary seismic array, debug, test equipment, and collect background data in anticipation of workover and stimulation
- Move rig to 46-19 pad
- Remove liner from 2065' to TD
- Conduct borehole image log using the HT borehole televiewer
- Conduct suite of logs including PTS, natural gamma, velocity, and density
- Cement new 7" liner from surface to ~10,000 ft
- Conduct mini-hydrofrac in bottom, open-hole section
- Conduct rig-injection test in order to determine baseline injectivity and to help design the stimulation experiment

46A-19RD Post-Stimulation Analysis

- Conduct circulation test including tracer testing to confirm newly created fracture-flow pathways.
  - A liquid-phase-tracer test will use a combination of a thermally reactive tracer with a thermally conservative tracer.
  - A vapor-phase-tracer test will accompany the liquid-phase test.
- Continue to acquire and analyze microseismic data
- Evaluate and calibrate as necessary the fluid-flow models predicting effects of shear failure, temperature and chemical dissolution on reservoir permeability.

Experimental Approach

- ***Rose and Mella:*** Conduct two tracer tests during the year following the hydraulic stimulation of 46A-19 using a reactive tracer in conjunction with a conservative tracer in each test.
- ***Rose and Mella:*** Analyze the data in order to determine changes in the effective temperature and the tracer swept pore volume.
- ***Kovac, Xu, and Pruess:*** Develop a fluid-flow reactive-transport model to predict changes due to mineral dissolution/precipitation processes. Update and calibrate the model using tracer data.
- ***Foulger, Julian, Monastero and Richards-Dinger:*** Use microseismic data to constrain the fluid-flow reactive-transport model and to help develop a conceptual model of fracture evolution.

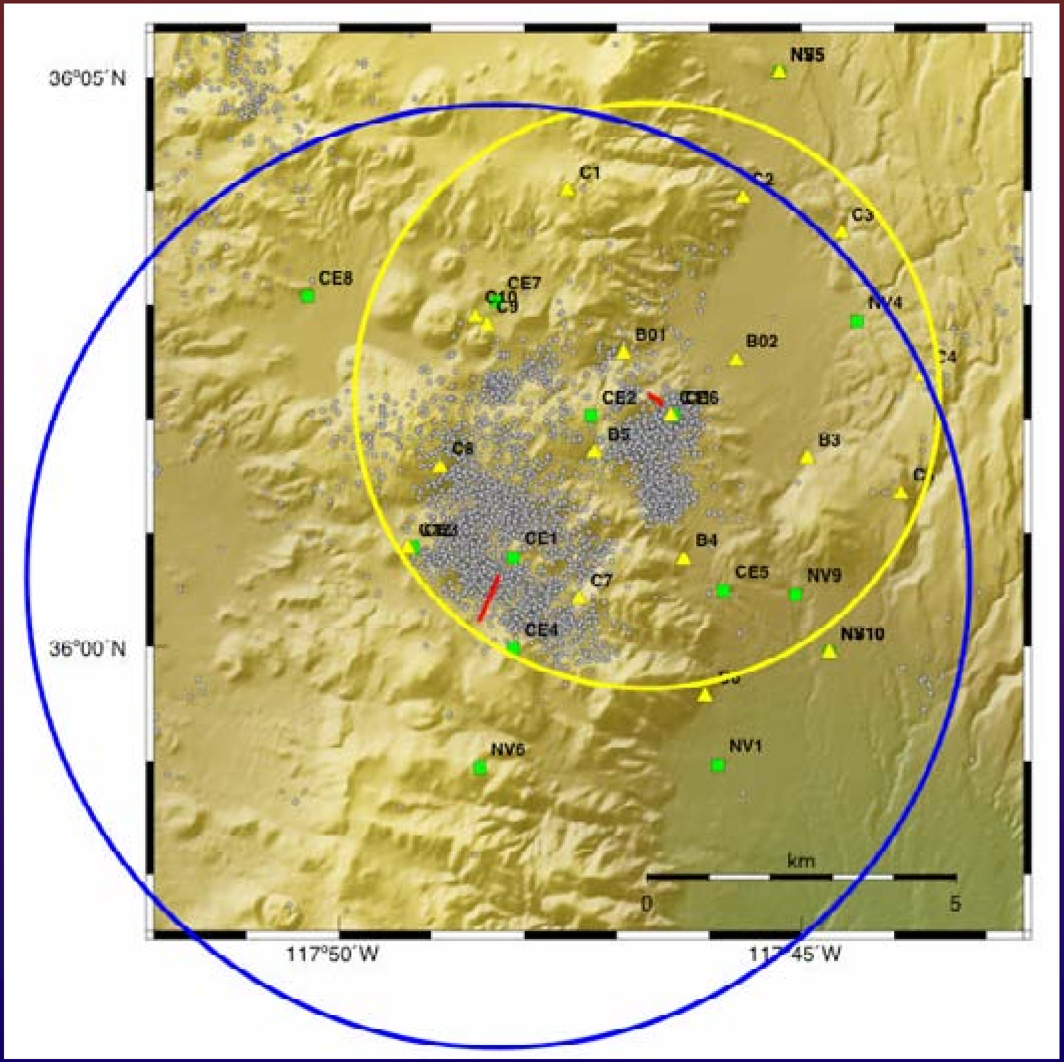
Microseismic Analysis of Injection-Induced Earthquakes

Gillian Foulger, Foulger Consulting; Bruce Julian, USGS; Frank Monastero and Keith Richards-Dinger, GPO

Objectives:

- ❖To measure the locations of earthquakes associated with injection into 46A-19RD.
- ❖To calculate moment tensors associated with those earthquakes in order to determine failure mechanisms.
- ❖To use the results in the modeling of the evolution of fracture pathways.

Microseismicity



Results/Accomplishments

- This project will start upon the completion of the Coso/EGS project.

Conclusion

- Will the project objective (slide 2) be achieved by the project completion date? *Yes*.