Geothermal Technologies Program 2010 Peer Review

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

Desert Peak EGS Project

DOE: DE-FC6-02ID14406

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Innovative Exploration Technologies

Overview

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- Timeline
  - Project start date: September 2002
  - Project end date: July 2010
  - Percent complete: ~65%
- Budget
  - Total project funding: $5,803,532
  - DOE share: $4,318,003
  - Awardee share:$1,485,529

  Reported funds are associated with the EGS development in well 23-1 (2003-2006) and well 27-15 (2007-current)

  - funding received in FY07- FY09: $1,575,944
  - funding for FY10: $552,336
- Challenge: Synchronizing LBNL, USGS, UNR, EGI, Temple GX and Ormat work during the stimulation period
- Partners: GeothermEx

Objectives

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Project Goals:

- Stimulate Permeability in Tight Well 27-15 and Improve Connection to Rest of the Field
- Improve overall Productivity or Injectivity
- Common EGS/Geothermal development goal
- Successful stimulation yields more production and enables more power generation
- Desert Peak methodologies can apply to other EGS projects – "Toolbox"

Well Selection:

- Located in develop geothermal field – "In Field" EGS
- High Temperature
- Favorable rock formations amenable to hydraulic stimulation

Project Accomplishments

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- Borehole Logging (wellbore image and other logs)
- Petrologic Analysis of Cuttings
- Geomechanical Analysis of Core
- Review of Existing Geophysical Data (CSAMT/MT)
- Seismic Reflection Survey
- Production/Injection Baseline Data Compilation
- Pressure Transient Testing
- Tracer Testing
- Geochemical Baseline Sampling
- Conceptual Structural Model
- Seismic Network Improvement, Calibration and Monitoring
- Well Recompletion
- Mini-Frac/Baseline Injection Test
- Stimulation Plan

Desert Peak, Nevada

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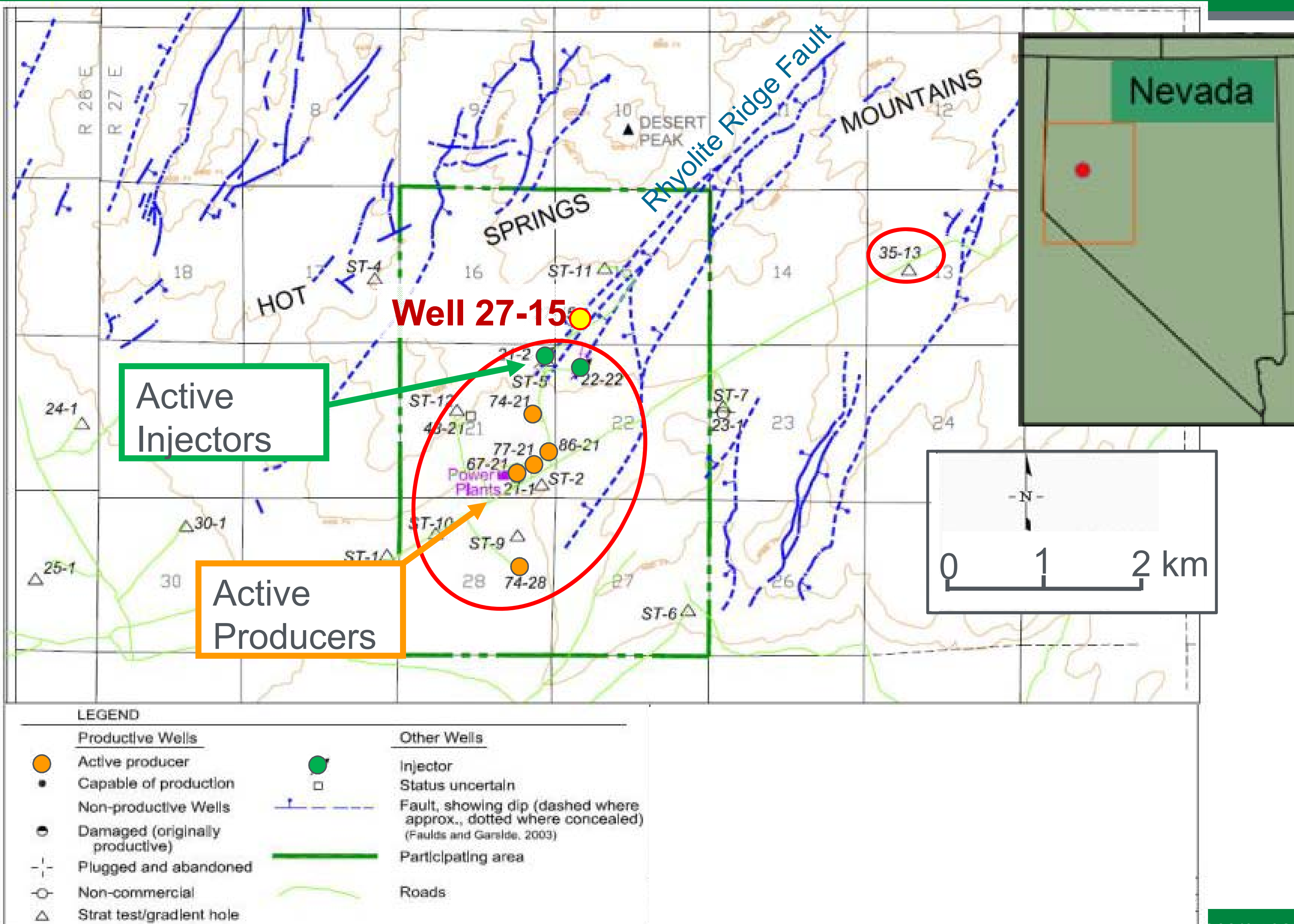


Borehole Logging Methods and Analysis: DP 27-15

- Image logs – joint analysis of FMS and Borehole Televiewer*:
  - Natural Fractures (distribution, attitude and characteristics)
  - Bed Dips
  - Lithologic Boundaries
  - Stress Directions & Magnitudes
  - Borehole Condition/Bond Logs
- Temperature-Pressure-Spinner Flowmeter logs:
  - Fluid inflow and outflow zones
- Density logs:
  - Vertical Stress Magnitude, Rock Mechanics, Porosity
- Velocity logs:
  - Rock Mechanics
- Mud logs and cuttings analysis (*Lutz et al., 2009*):
  - Cuttings Lithology, Alteration, Texture
  - Mud Losses
  - ROP

Evaluation of Potential Stimulation Zones in 27-15

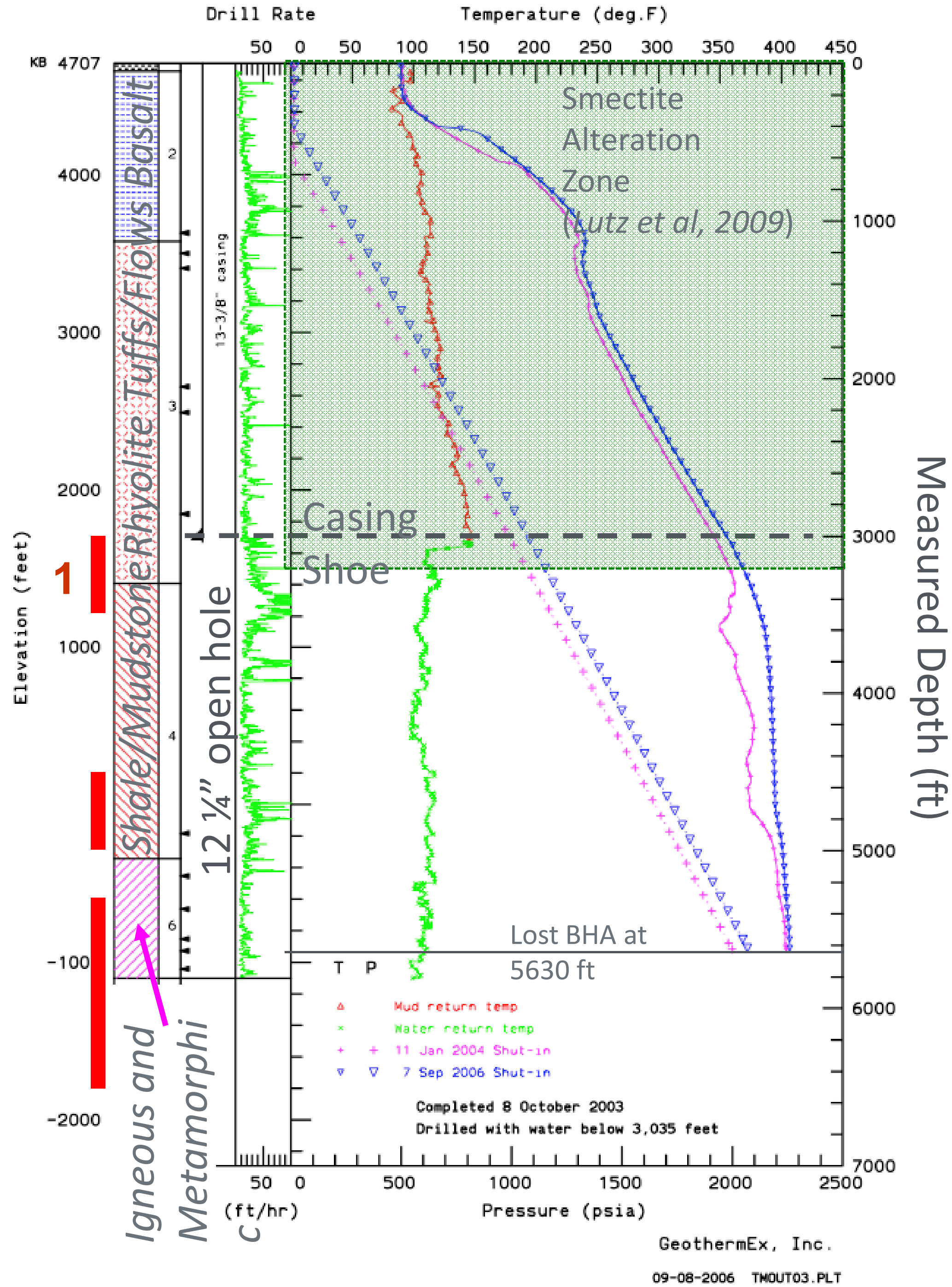
- 13-3/8 inch casing to 3,000 ft
- Max temp 409°F (209°C)
- Fluid leaving well at two depths
  1) ~3,400 feet Near base of Rhyolite Unit
  2) ~4,700 feet In shale near base of pT1

Geologic Criteria:

- Below smectite alteration zone.
- High temperatures, below conductive low-temperature cap.
- Highly stressed, slightly permeable fractures well oriented for frictional (shear) failure.
- Hard rock; i.e., fractures prone to "self-propping" dilatation and permeability increase during shear.

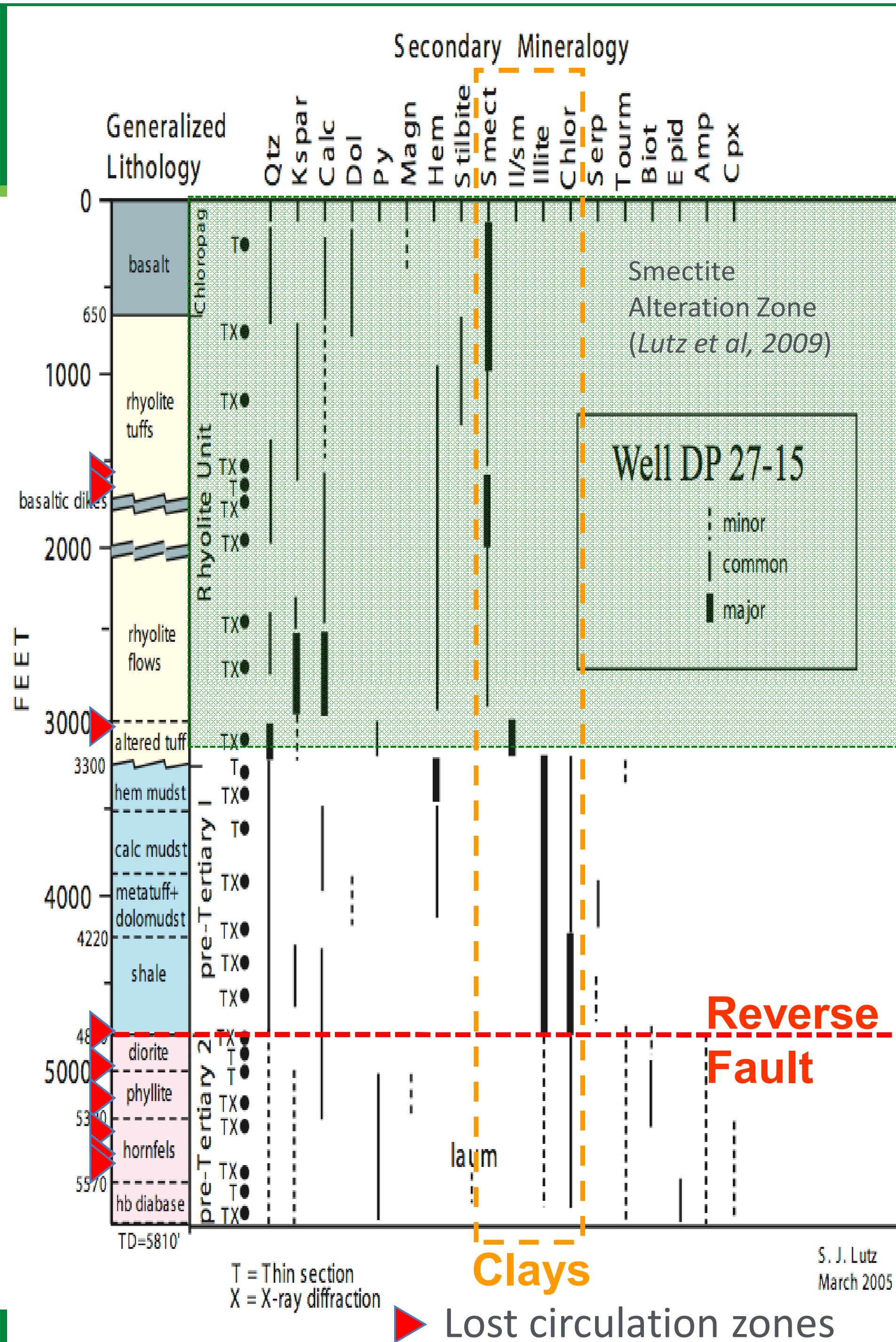
Goal:

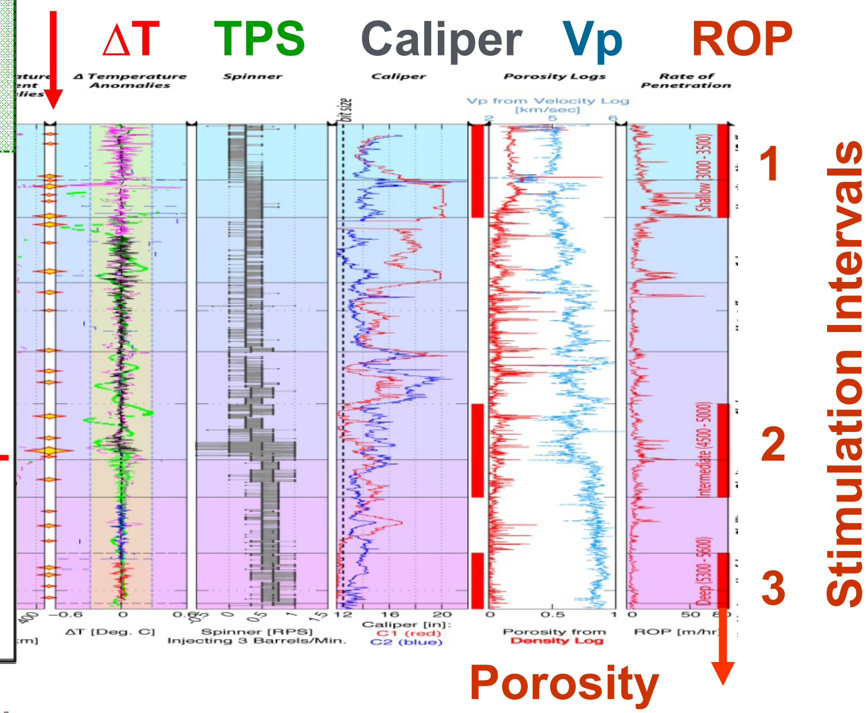
- Stimulate just below current casing shoe: 3000 to 3500 ft MD

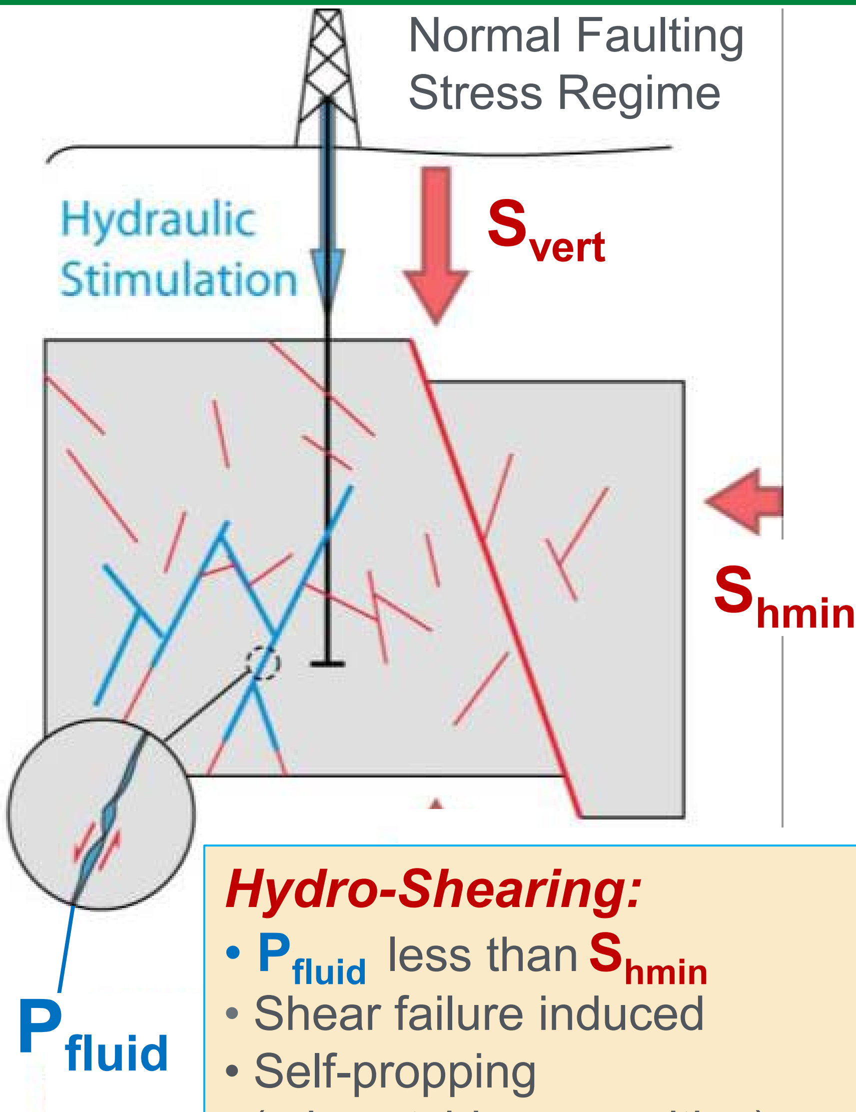


Controls on Dilatancy During Shearing

Comparisons of lab and in-situ permeability shows that "hard" rocks with low clay content and low porosity will undergo greatest permeability increases upon shearing (*Brace 1980, 1984; Wong and Zhu, 1999; Crawford 2002*)







Hydro-Shearing:
- P_{fluid} less than S_{hmin}
- Shear failure induced
- Self-propping (mismatching asperities)

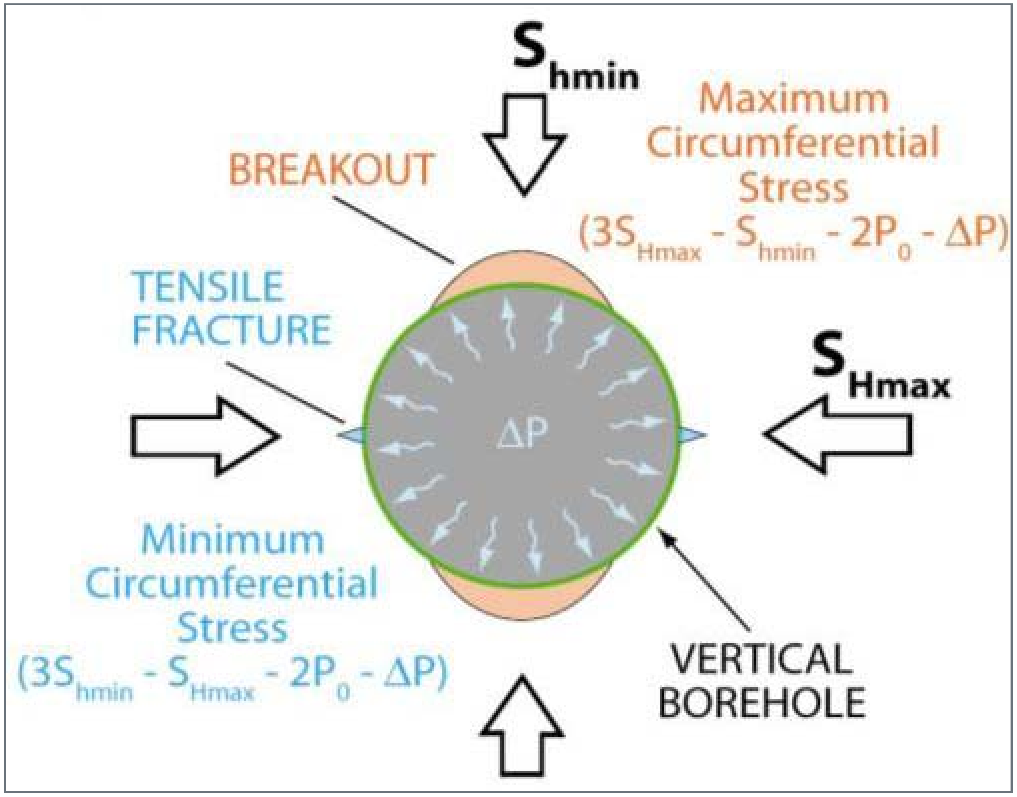
Geomechanical Data Needed for Stimulation Design in Desert Peak EGS Well 27-15:

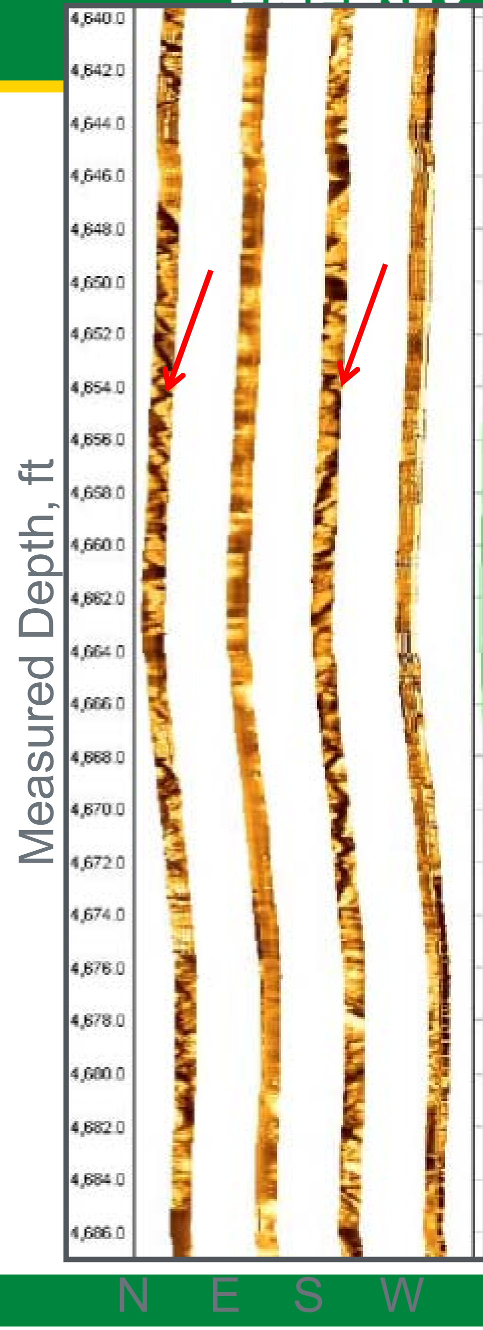
- In-situ stress orientations and magnitudes
- Fracture distribution and orientations
- Identification of fluid loss zones
- Lab testing of rock frictional properties

Use to predict fluid injection pressures needed for re-activation of shear fractures

Drilling-Induced Tensile Fractures in Well 27-15

Formation MicroScanner Log





Drilling-induced tensile fractures (180º apart)

3 m

S_{hmin} Orientation Also Consistent with Normal Faulting on Fractures Seen in DP 27-15 Image Logs

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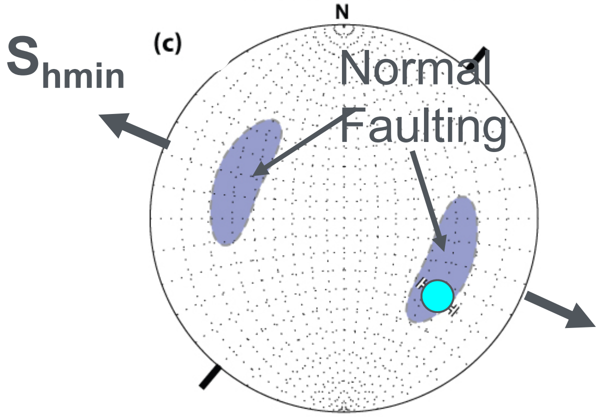
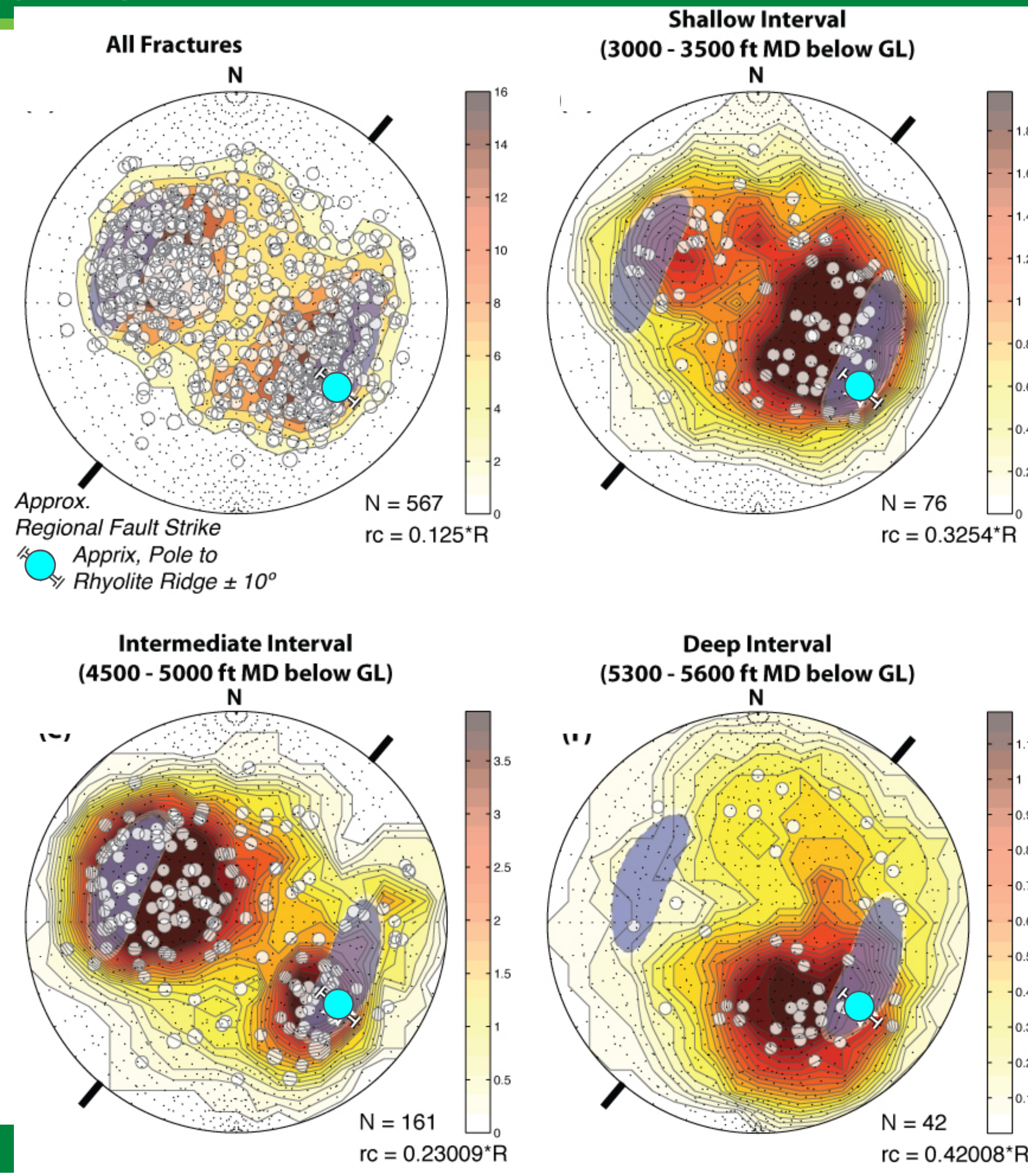
Borehole televiewer log shows tensile failures S_{hmin} azimuth from drilling-induced tensile fractures: 115 ± 19º

Estimated Optimal Normal Fault Orientations

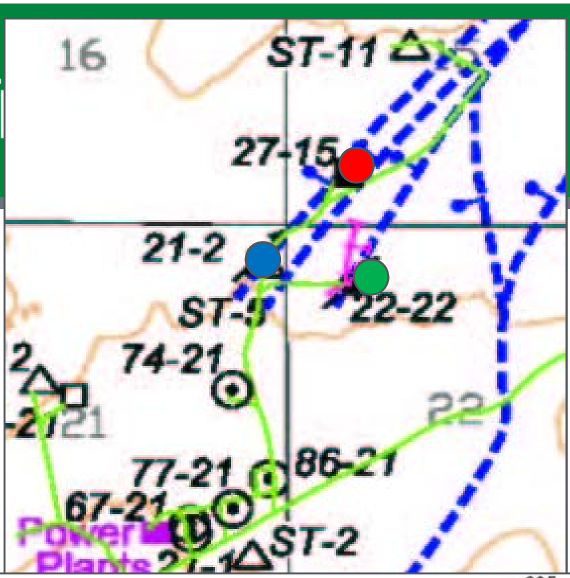


Based on Horizontal Stress Direction
Assume optimally oriented normal faults dip 50-70˚

Fractures that are well oriented for normal faulting in ambient stress field found in all three potential stimulation intervals.



Pressure Transient Testing



Objective

- Evaluate the hydraulic connection between 27-15 and the wellfield.
- 27-15 Pre-Test; Reservoir has approx. permeability-thickness of 5,600 md-ft
- Injectivity Index of 100 (lbs/hr)/psi

Approach

- Alter the relative injection rates in the two injectors (21-2 & 22-22)
- Observe pressure response at 27-15

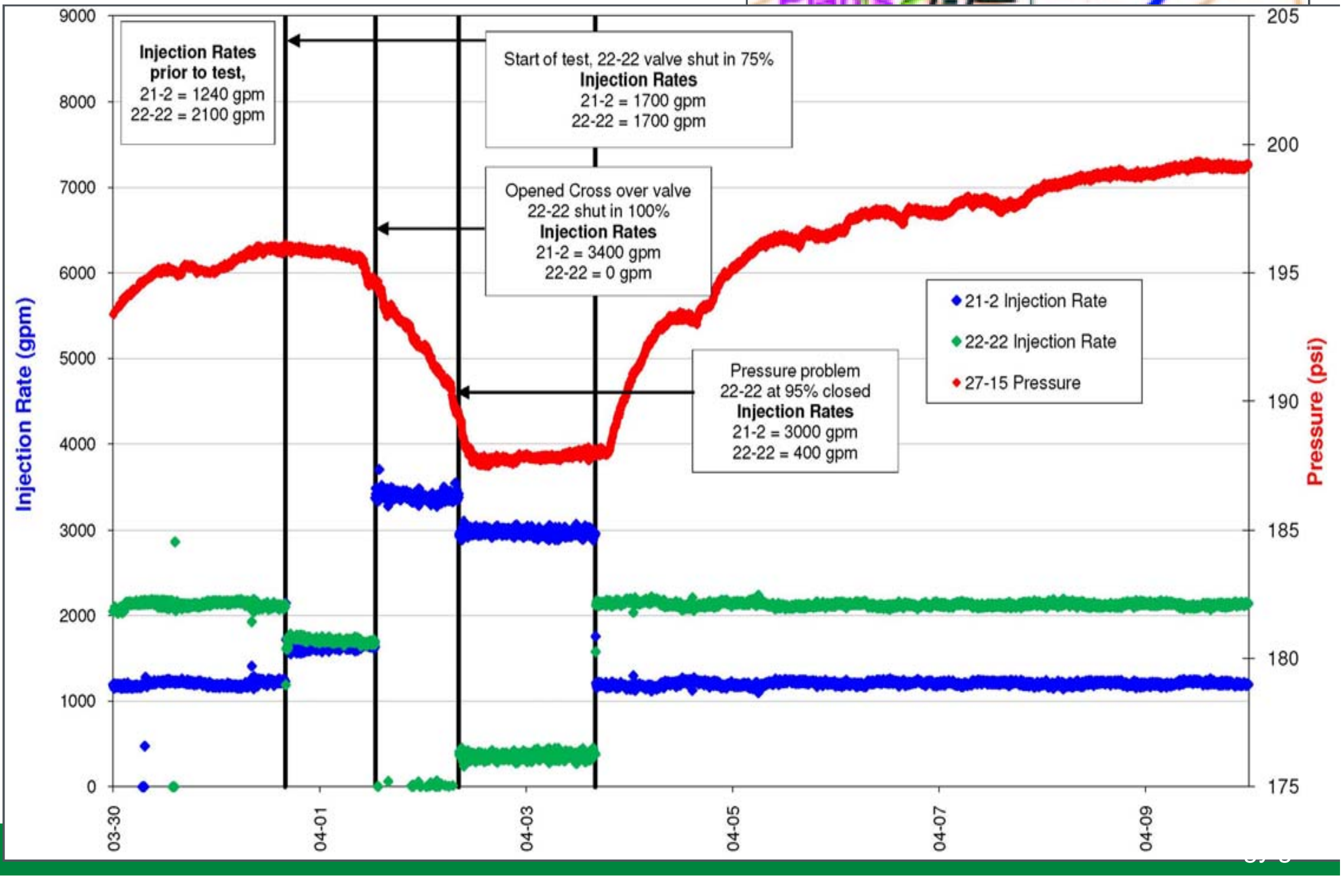
Results

- Much greater connectivity between 22-22 and 27-15

22-22 permeability in two zones:

1) Rhyolite Unit - ~40% of flow
2) Basement (pT1) - ~60% of flow

In same structural block as 27-15



Tracer Test

Objective

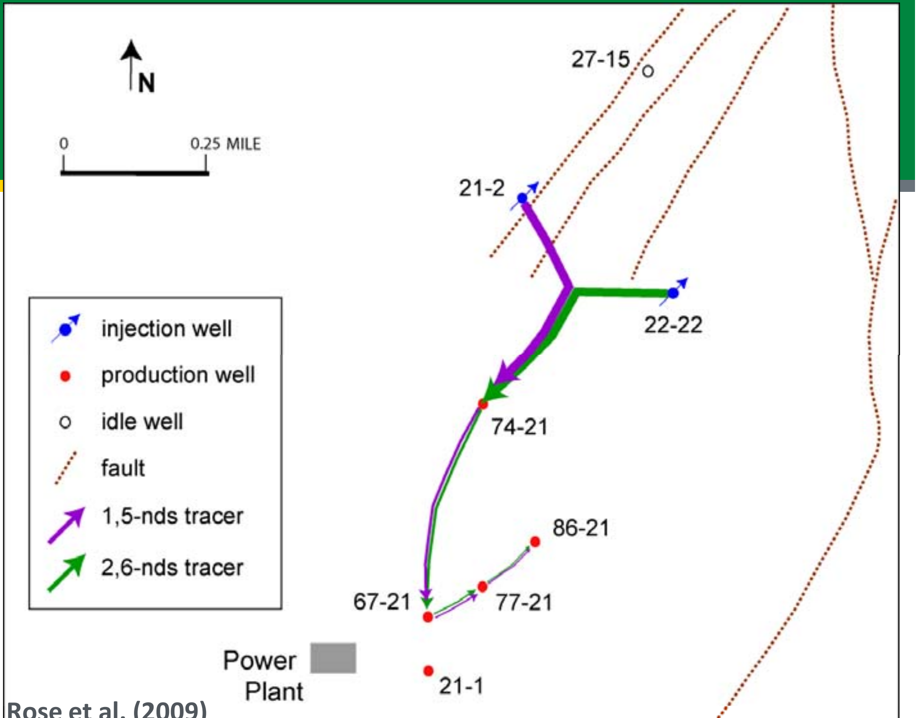
- To determine flow patterns between injectors and the production wells
- Baseline calibration for the numerical model

Approach

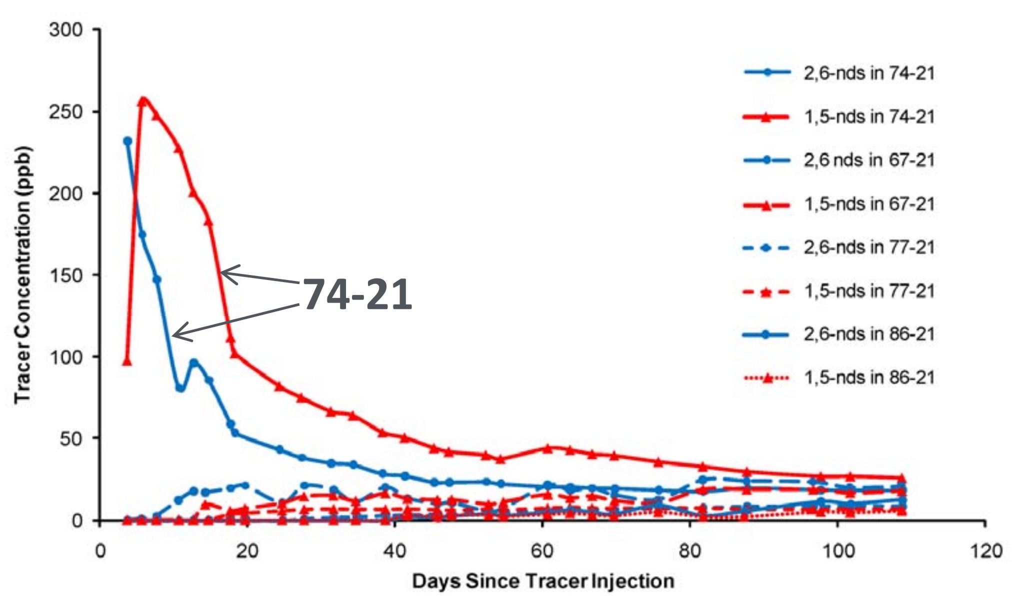
- 85 kg of 2,6-nds and 100 kg of 1,5-nds injected into 22-22 and 21-2, respectively
- Production wells subsequently sampled and analyzed for produced tracers

Results

- Strong returns to nearest producer (74-21)
- Slower, weaker returns to other wells
- 22-22's connection to reservoir is direct – through base of Rhyolite Unit (stimulated zone) and also through pT2 basement
- 21-2's permeability is near Rhyolite-pT2 contact



Rose et al. (2009)



Rose et al. (2009)

Desert Peak Structural Model: Fault Bounded Domains

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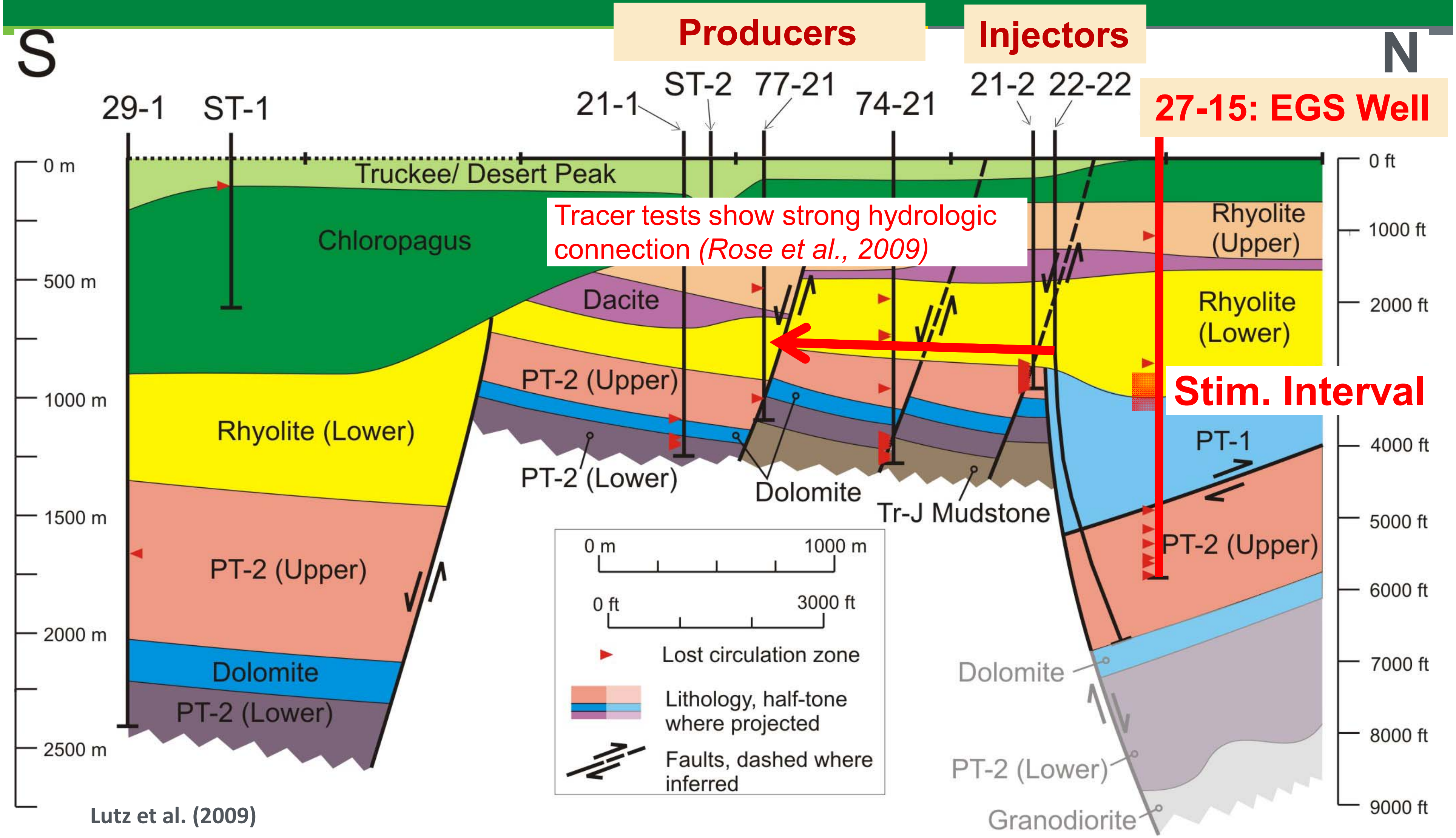
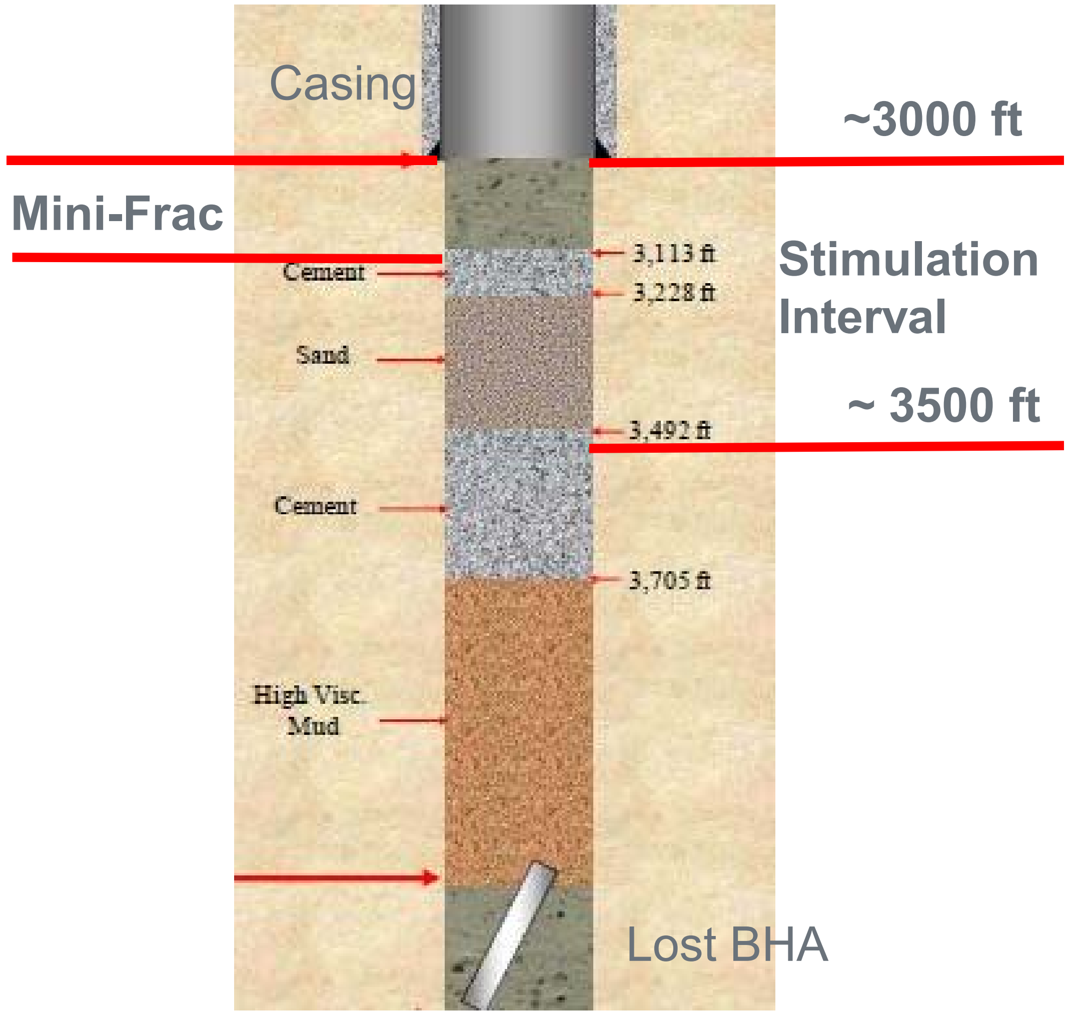


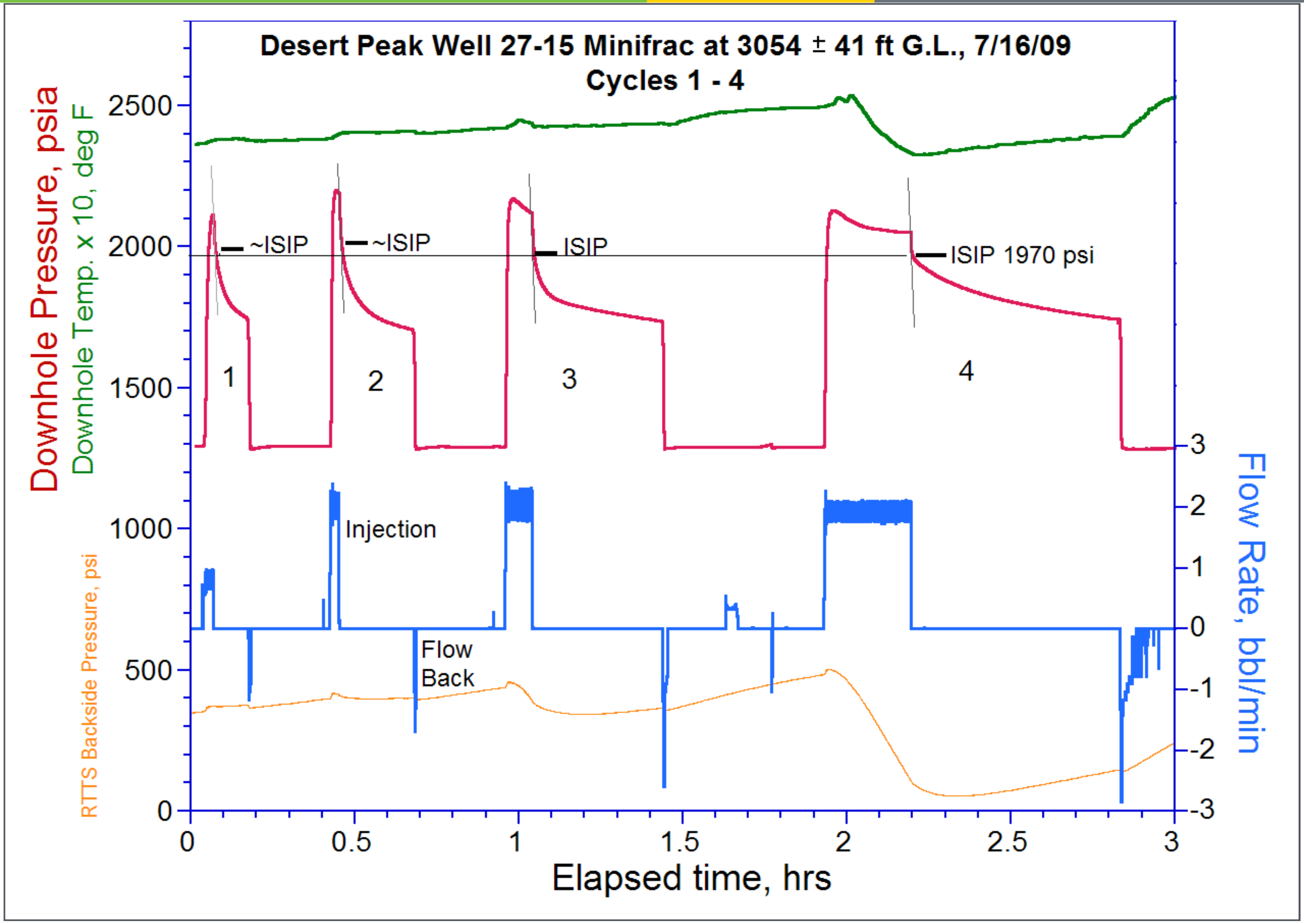
Lutz et al. (2009)

Recompletion/Stimulation Plan

- S_{hmin} can be readily determined from mini-frac
- Good probability of connection to field through rhyolite (producing horizon)
- Rock strength can be determined (existing core from well 35-13)
- Applicability for EGS in volcanic rock
- Re-completion, mini-frac and initial injection testing July 2009

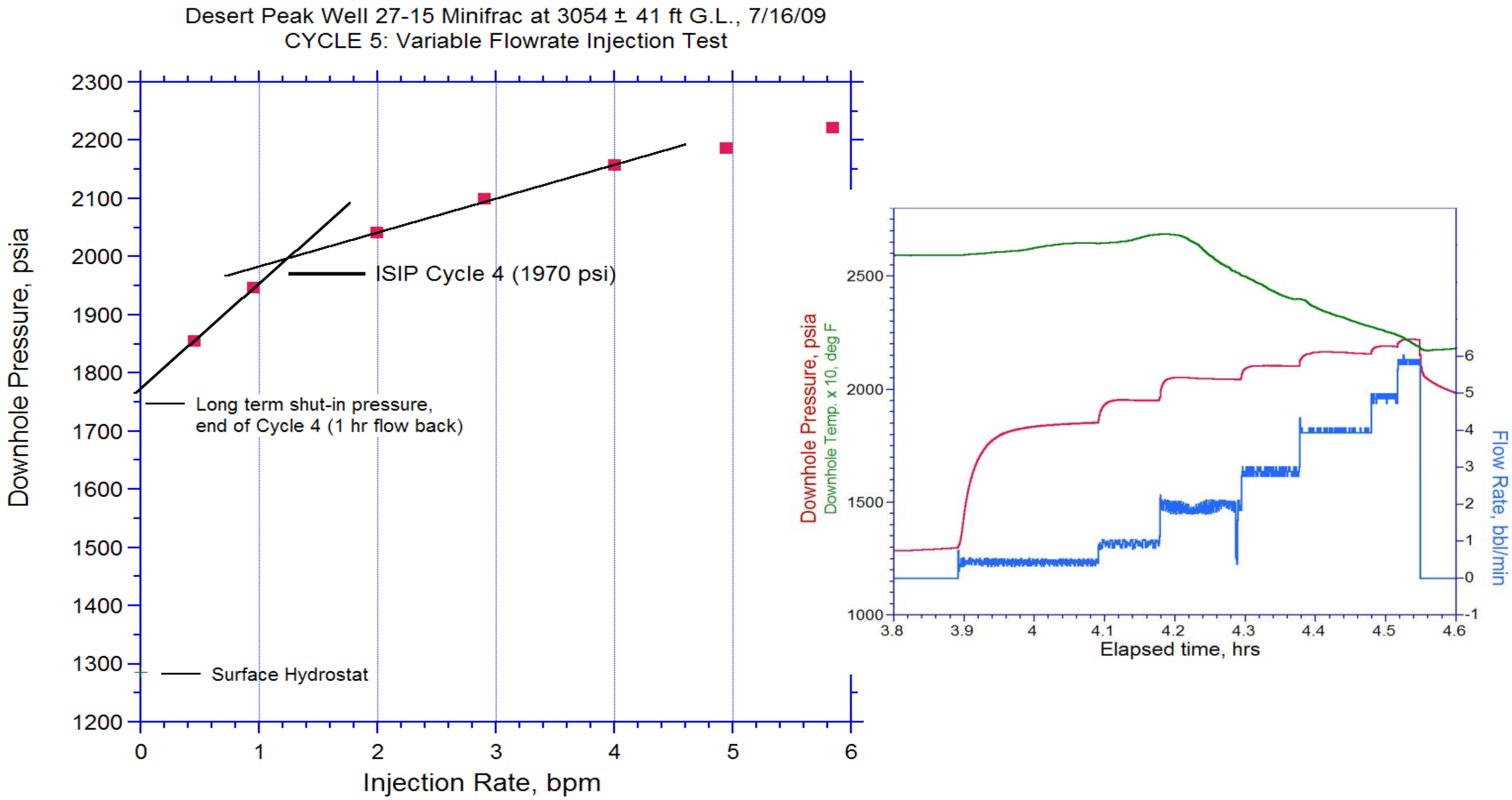


Mini-Frac



Desert Peak Well 27-15 Minifrac at 3054 ± 41 ft G.L., 7/16/09
Cycles 1 - 4
Downhole Pressure, psia
Downhole Temp. x 10, deg F
RTTS Backside Pressure, psi
Flow Rate, bbl/min
Elapsed time, hrs
~ISIP
~ISIP
ISIP
ISIP 1970 psi
1
2
3
4
Injection
Flow Back
2500
2000
1500
1000
500
0
0.5
1
1.5
2
2.5
3
-1
-2
-3

Mini-Frac Analysis



At 3054 ± 41 ft GL (test interval center):

S_{hmin} **= 1970 + 25 psi = 1995 psi (13.76 MPa)**

S_V **= 3277 psi,** S_{hmin}/S_V **= 0.609**

Baseline Injection Test

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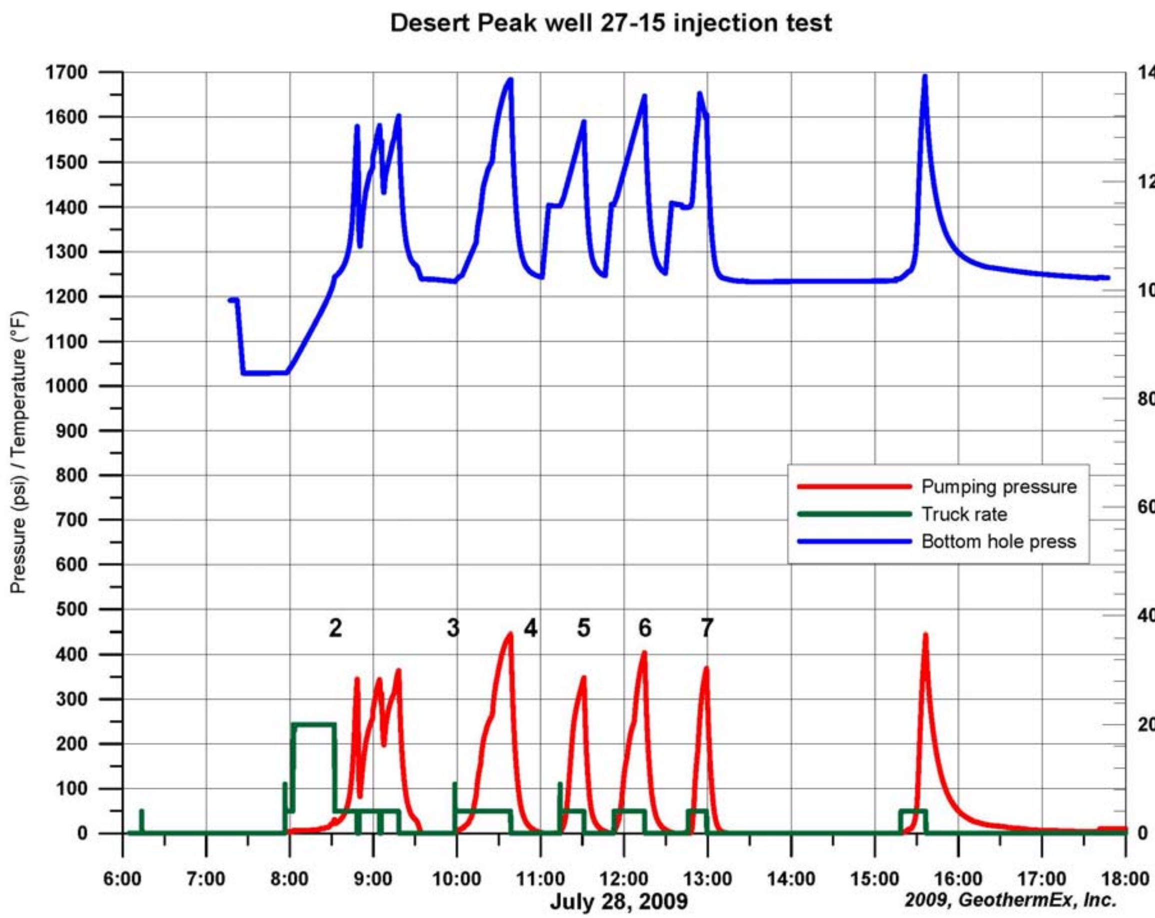
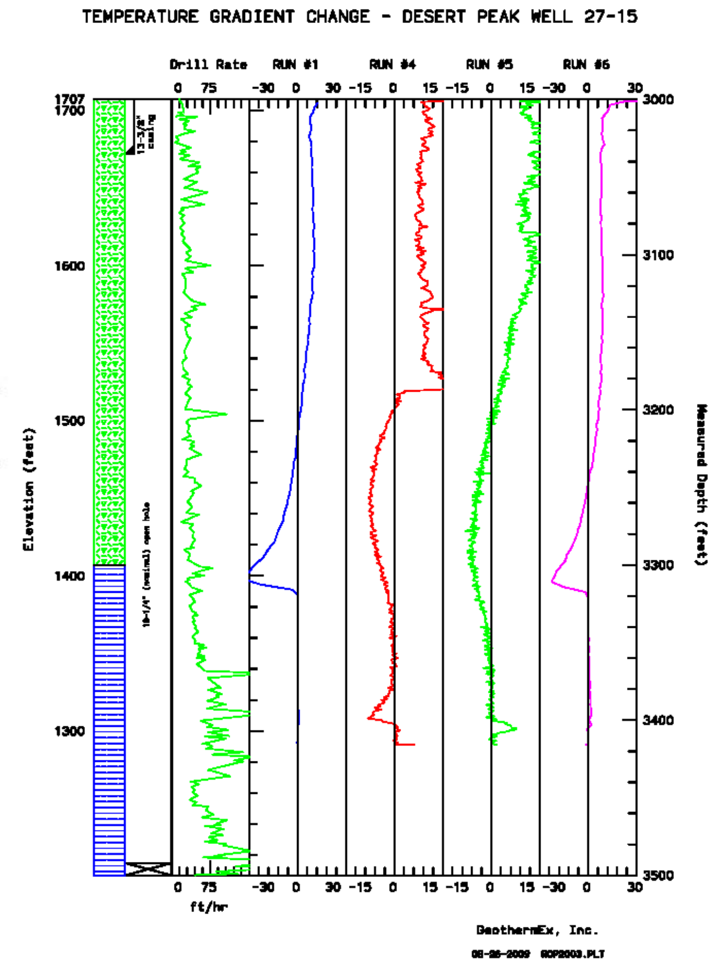
Upper limit of 450psi WHP – Max flow rate achieved: 16.4gpm

Confirms Low Injectivity of Stimulation Interval (0.04 gpm/psi; kh ~60 md-ft)





Seismic monitoring array (LBNL / USGS)

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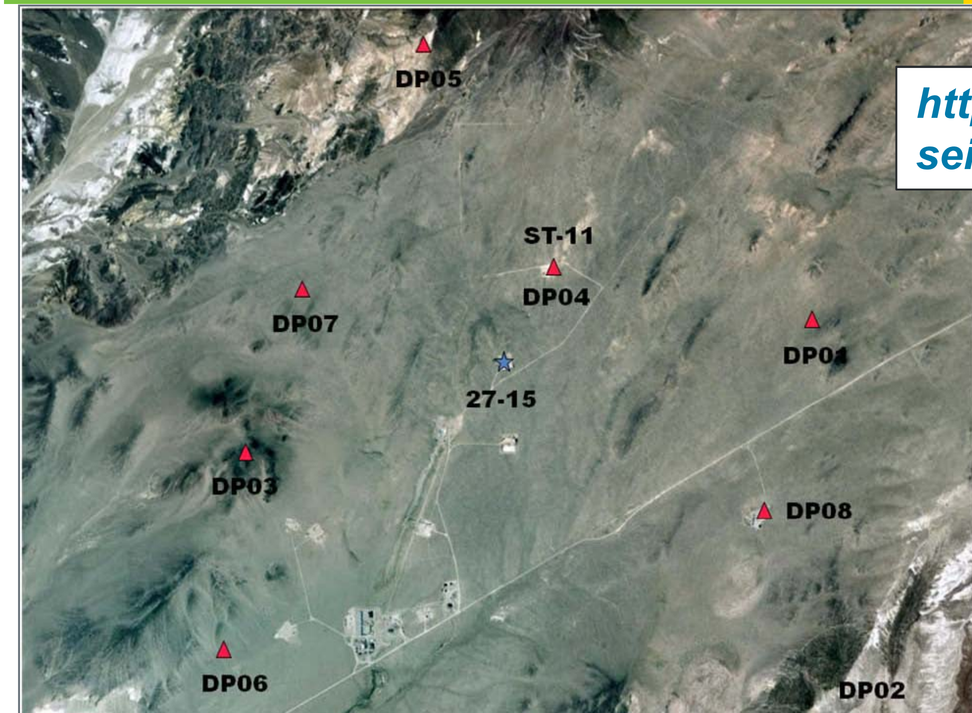
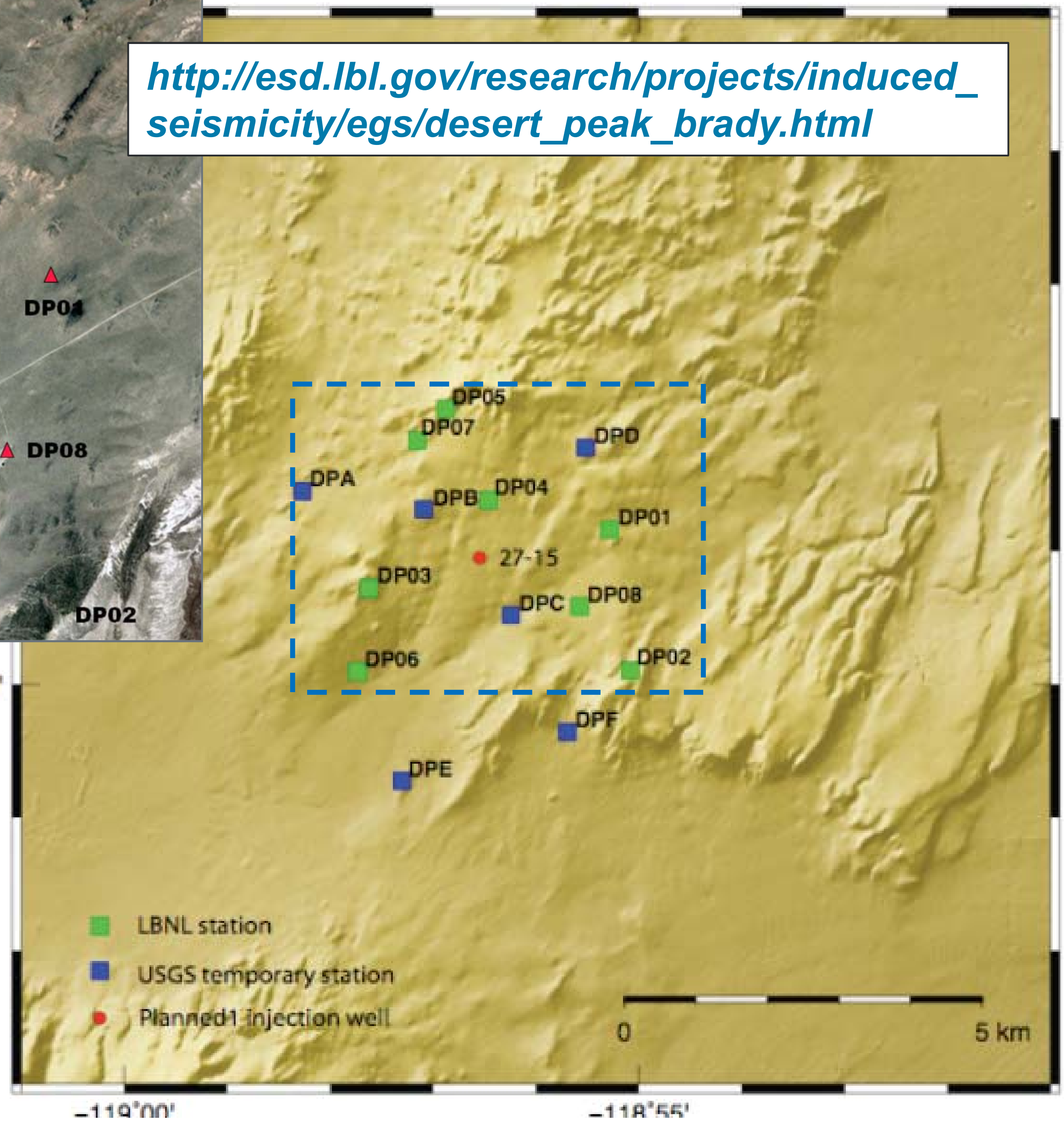


http://esd.lbl.gov/research/projects/induced_seismicity/egs/desert_peak_brady.html



LBNL

- Real Time Multi Station Array
- 6 Surface – 3 component 4.5 Hz
- 2 Downhole (960' & 296')
- MEQ Events to M0

USGS

- 6 Surface-3 component 2 Hz

Future Directions-Outline of Stimulation Plan (1)

1. 2-week baseline pressure monitoring in 27-15 and other existing monitoring wells
2. 1-week constant rate injection test with wellhead pressure < 200 psi
   - Determine injectivity and radius of investigation. Evaluate as dual porosity to get relative characteristics of fractures vs matrix; identify permeable fractures by TPS logging after fall-off while injecting at same low rate.
3. Initial hydraulic stimulation. Increase rates in a series of steps with wellhead pressures up to 600 psi. Inject tracer (fluorescein) continuously during stimulation and sample at flow line of nearest producer (74-21).
4. Run wellbore image log after completing stimulation.
5. Post stimulation step-rate injection test and fall-off
   - reactive and nonreactive tracer injected
   - TPS logging after pulling cap tubing at 3 injection rates
   - flow back well using nitrogen assist on coiled tubing
   - analyze fluids for tracers and fluid/isotope geochemistry.

Future Directions-Outline of Stimulation Plan (2)

- Decision about next steps
  - Is skin still an issue, are we where we wanted to be with the hydraulic stimulation?
  - Chemical stimulation (chelating agent - - either NTA or EDTA) followed by air lift to analyze flow back fluid.
  - Post chemical stimulation injection test
  - Review to determine if additional hydraulic stimulation is needed
  - Test well by injection and/or production (if well will flow)

Project Management/Coordination

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- Summarized management activities :
  - Maintaining project timetable and resources allocation
  - Monitoring funds/budget/spend plan
  - Executing on-site activities
  - Information flow: conducting quarterly meeting and workshops

    Evaluate relevant technologies , i.e. Tilt Metering survey, Shot calibration …
  - Progress Reporting
  - Synchronizing project targets with industry standards (i.e. IS)
  - Coordinating UNR & BLM stimulation monitoring and activities

Summary Slide

- The Desert Peak EGS Project Emphasizes the Importance of:
  - Strong research team plus dedicated field operations partner
  - Integration of tectonics, geology, petrology, rock mechanics and stress
  - Well designed MEQ system that has been deployed early in the project
  - Protocol for monitoring and managing Induced Seismicity

- Our Goal: Enhance permeability in 27-15 to increase generation at the Desert Peak Power plant by 1-2 MW

Desert Peak EGS Research Team

- **Ormat** (field owner / operator) – oversight, organization, drive, interface with DOE, drilling, field operations
- **GeothermEx** – technical management, hydraulic testing, modeling, evaluation
- **USGS:** 1) *Steve Hickman, Nick Davatzes* (now Temple University) - stress field analysis, rock mechanics, mini-frac, structural modeling; 2) Bruce Julian, Gillian Foulger – seismic monitoring and analysis
- **EGI :** Peter Rose, Joe Moore – tracer testing, geologic modeling
- **LBNL :** Ernie Majer (seismic monitoring and analysis); Mack Kennedy (fluid and isotope geochemistry)
- **Schlumberger TerraTek** (Susan Lutz) – petrology, stratigraphy, geological model, core testing
- Roy Baria (**Miltech**) and Dimitra Teza (**Bestec**) - project peer review and stimulation planning
- **StrataGen Engineering** (Bill Minner) – stimulation planning