Geothermal Technologies Office 2013 Peer Review

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

Concept Testing and Development at the Raft River Geothermal Field, Idaho

Project Officer: W. Vandermeer

Total Project Funding: $10,214,987

April 22, 2013

Principal Investigators:

J. Moore and J. McLennan

Organization: University of Utah

Track Name: EGS Demonstration Projects

Relevance/Impact of Research

1. Develop and demonstrate techniques required to form and sustain EGS reservoirs by combining thermal and hydraulic stimulations.

2. Improve performance and output of Raft River geothermal field by increasing production or injectivity.

3. Objectives directly address the following barriers and DOE goals:

- Demonstrate 5 MW reservoir creation by 2020
- Lower LCOE to 6 cents by 2030
- Improve methods reservoir characterization
- Demonstrate flow rates of at least 20 kg/s
- Demonstrate interwell connectivity
- Develop long-term reservoir sustainability
- Predict seismic activity

- Operational in January 2008
- Maximum resource T ~150 C
- Produces ~10.5-11.5
- 4 Production Wells; 3 Injection Wells
- Production: ~ 5,000 gpm (individual wells produce 850-2,200 gpm
- 433 gpm per MWe

Accomplishments, Results and Progress

- Completed all Phase 1 activities
  - Successfully completed well RRG-9 ST1 for stimulation
  - Developed a geologic model
  - Prepared a stimulation plan based on the results of step-rate testing and the geologic model
- Stimulation program (Phase 2) approved
- Drilling of 4 seismic monitoring wells to commence shortly

Planned milestones were accomplished. There were no variances from proposed program since last review.

Original Planned Milestone/ Technical Accomplishment	Actual Milestone/Technical Accomplishment	Date Completed
Complete pre-stimulation activities	Phase 1 activities completed	10/2013
Prepare Phase 1 report for Go/No-Go approval	Phase 2 and stimulation plan Approved	1/24/2013

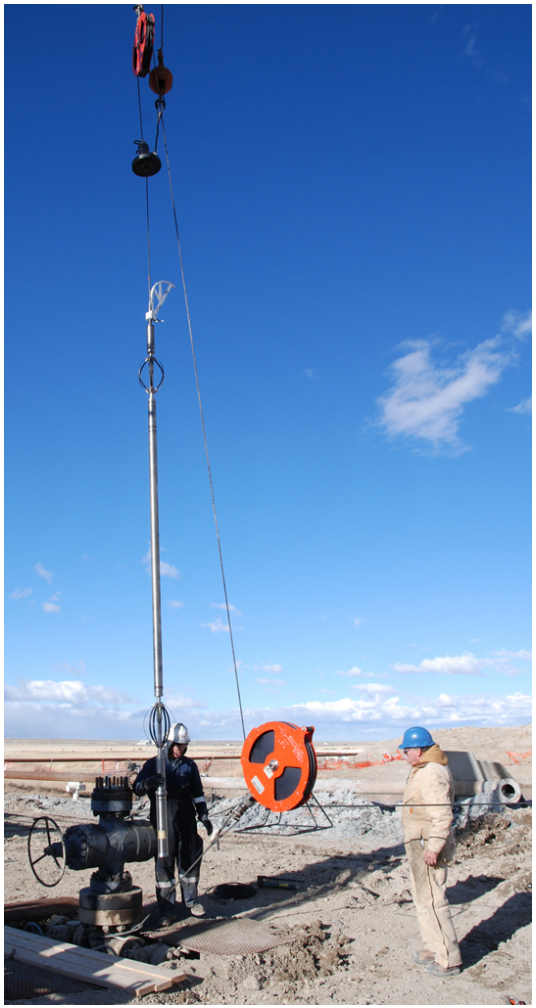
Scientific/Technical Approach

Developing an EGS Reservoir

Success requires adequate flow rates and thermal stability

1) Understanding resource's geologic setting:
   - ✓ Petrologic analyses of well cuttings and cores
   - ✓ Water geochemistry
   - ✓ Geophysical log analysis
   - ✓ Field data (MT, gravity, seismic, geochemistry)
   - ✓ Rock mechanics testing
2) Understanding reservoir properties
   - ✓ Borehole televiewer imaging and logging
   - ✓ Injection testing
   - ✓ Seismic monitoring
   - ✓ Hydraulic fracture modeling
   - ✓ Infer production potential
3) Phase 2: Go/No Go Review
   - ✓ Develop stimulation program
   - **Stimulate well**
4) Monitor stimulation metrics – pressure, temperature, microseismicity, and well interference.

All checked activities have been completed



Televiewer survey provided by SNL

The Geologic Setting

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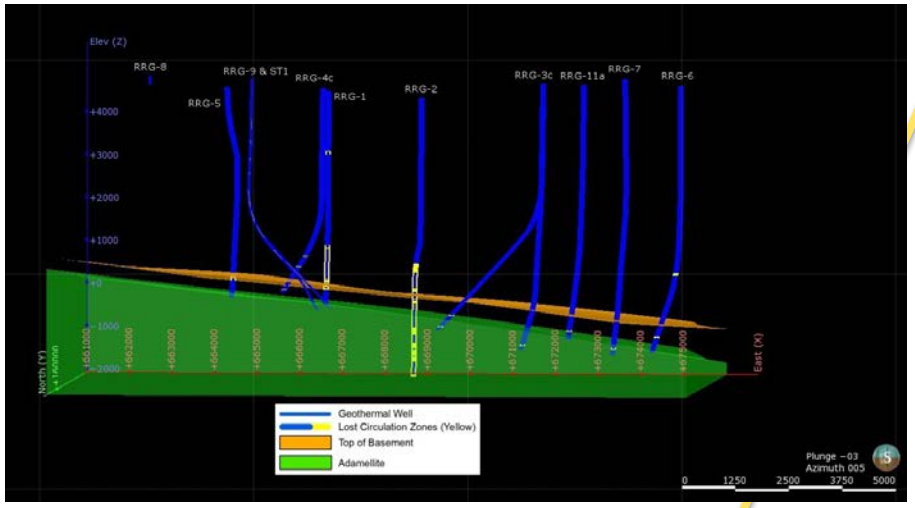
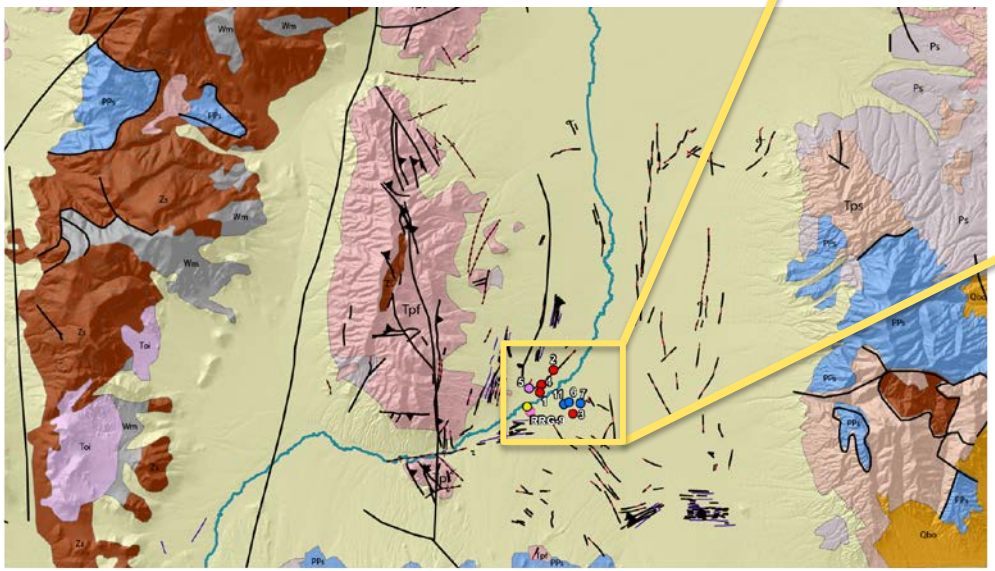
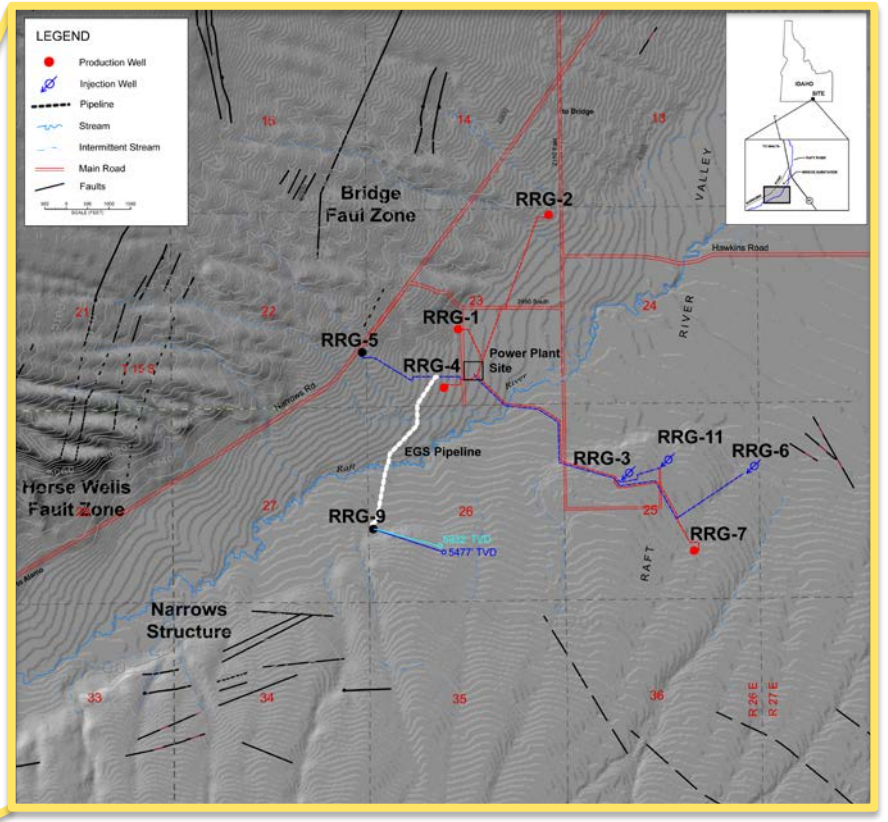
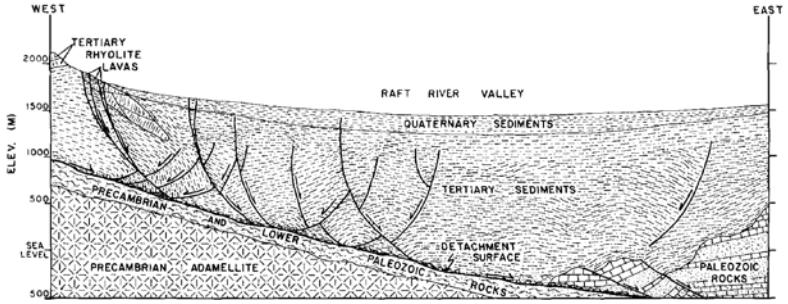
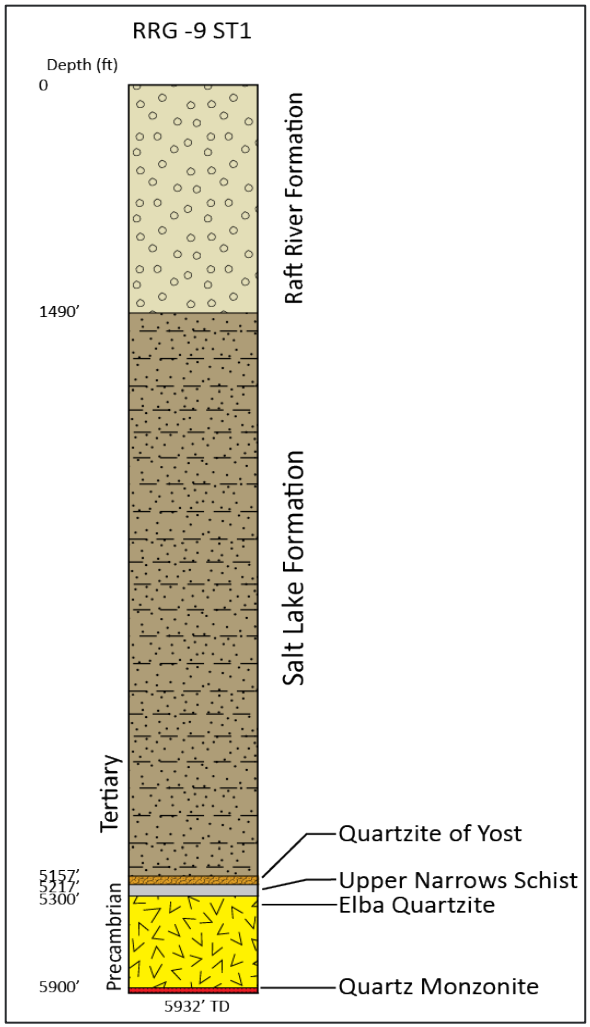


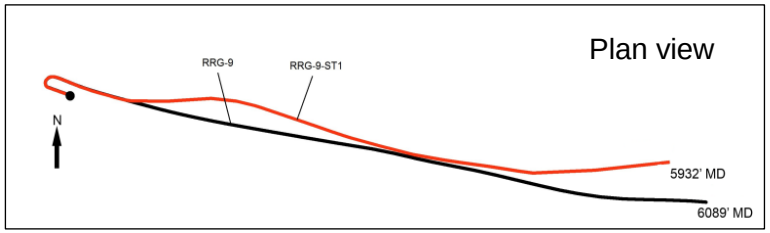


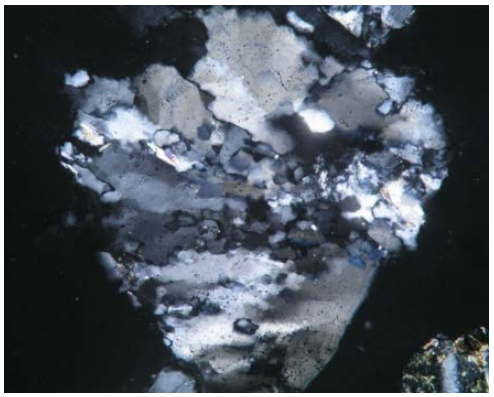




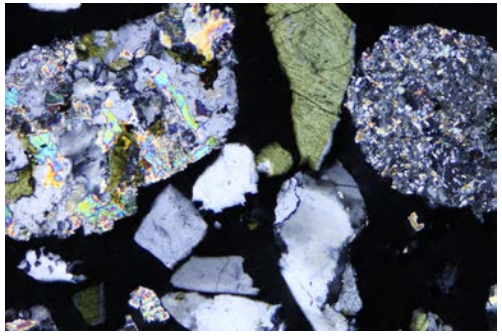
Geologic Stetting: Petrologic Studies



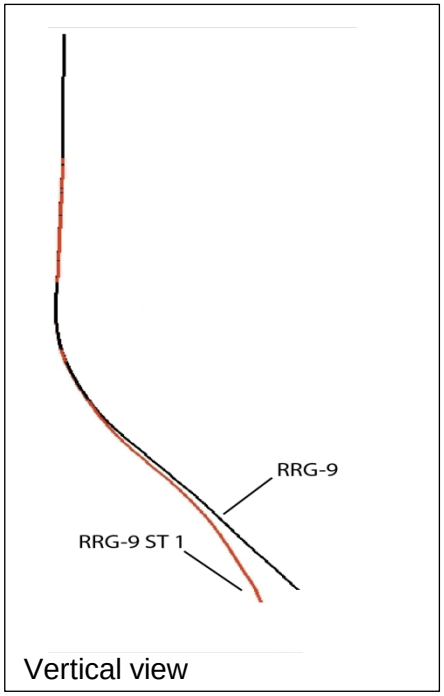




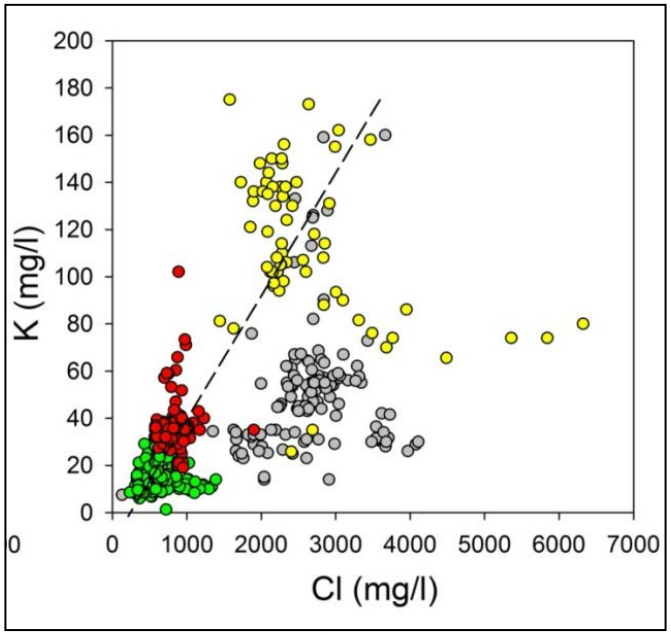
Elba Quartzite

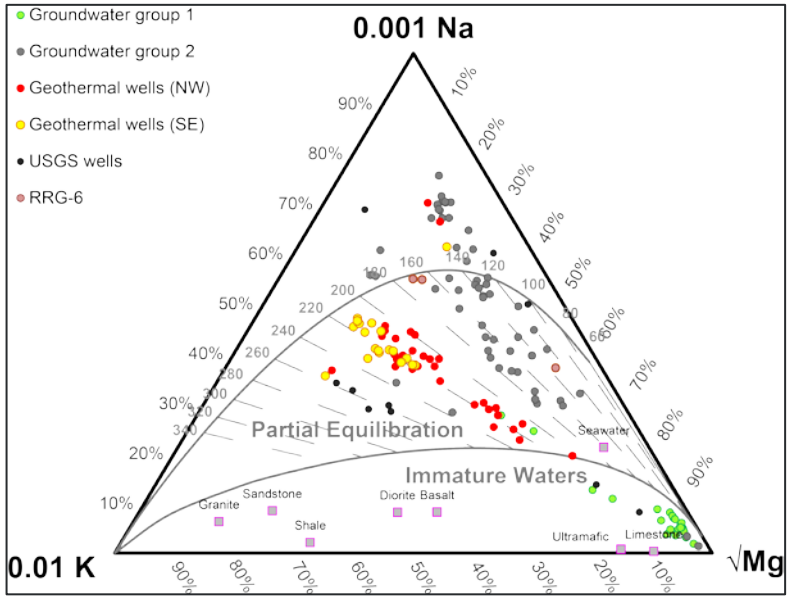


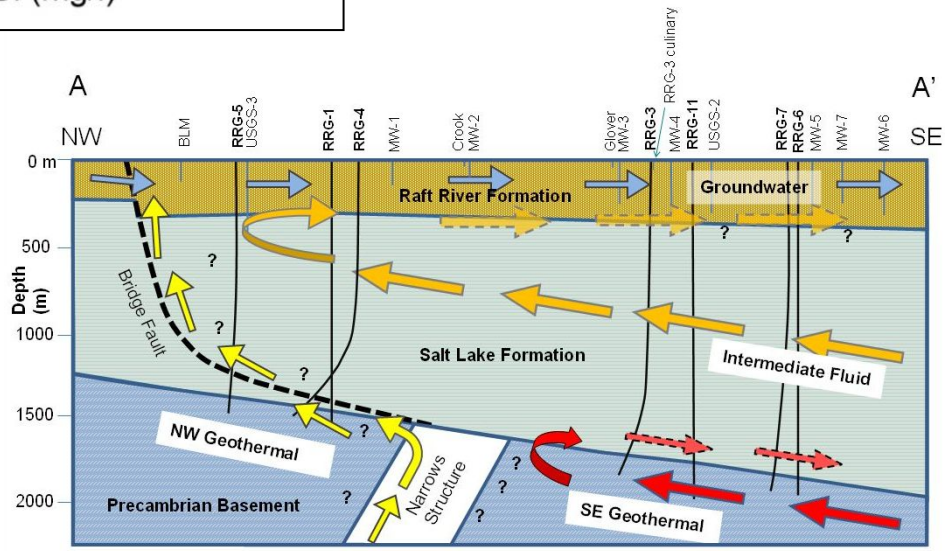
Quartz Monzonite



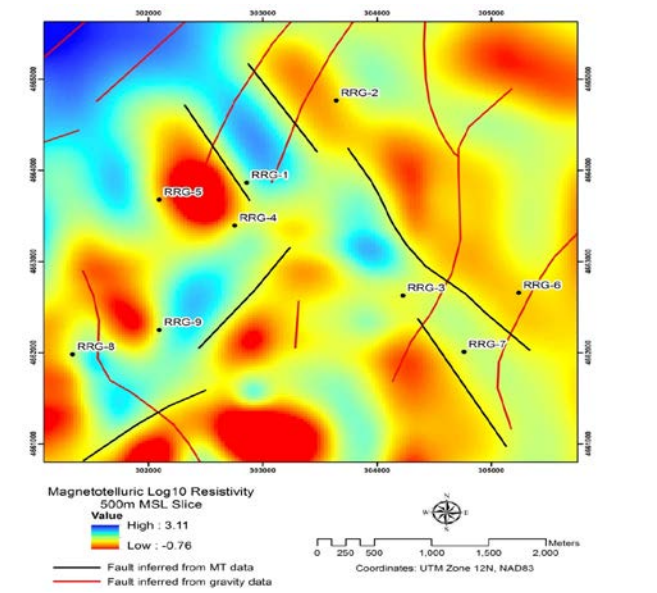
Geologic Setting: Water Geochemistry

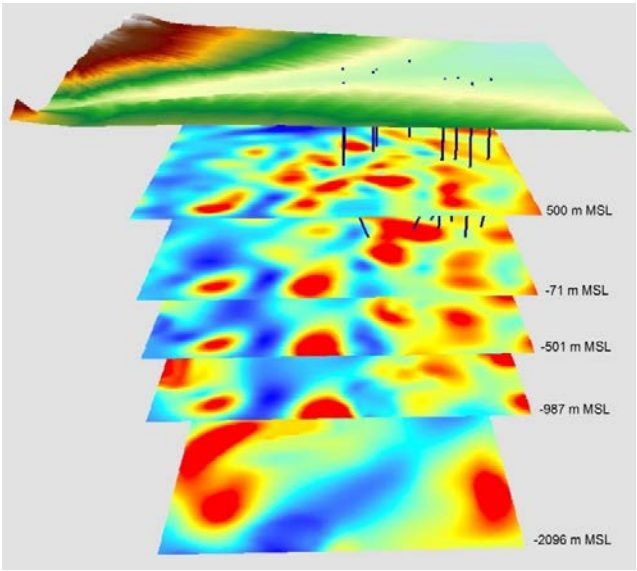


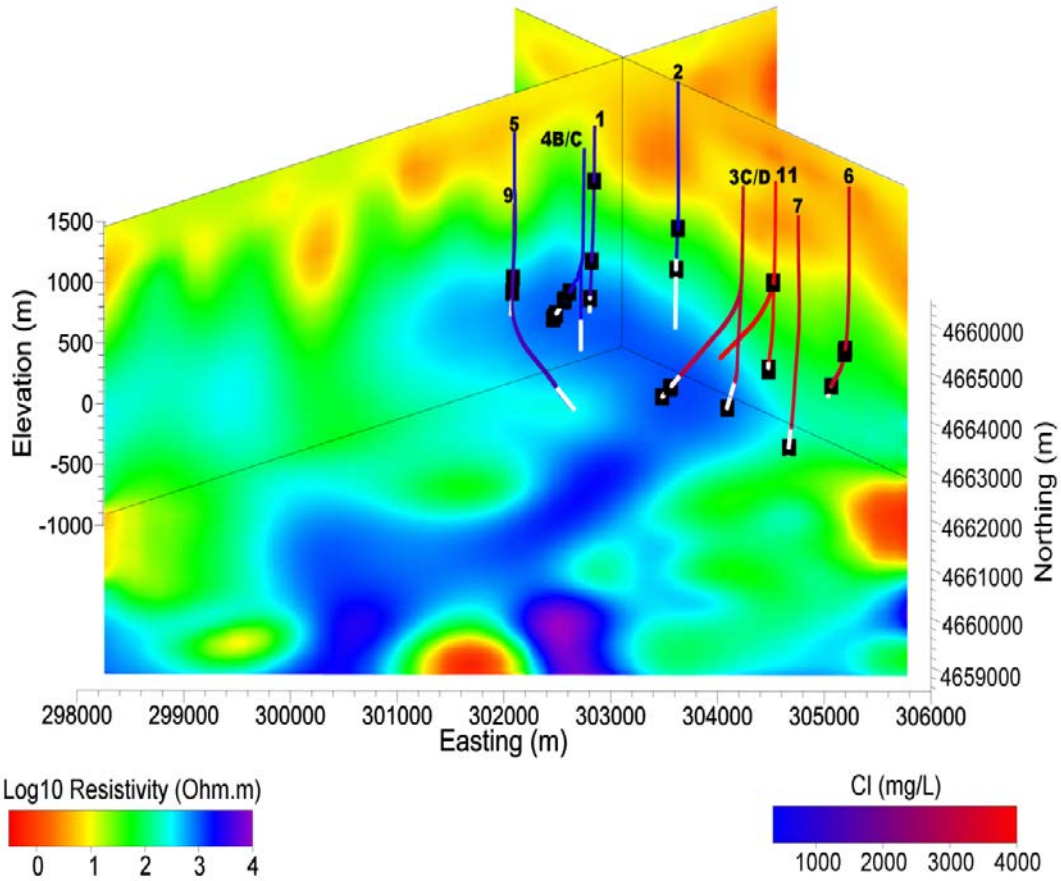




Geophysical Studies







Reservoir Properties: Borehole Televiewer Imaging

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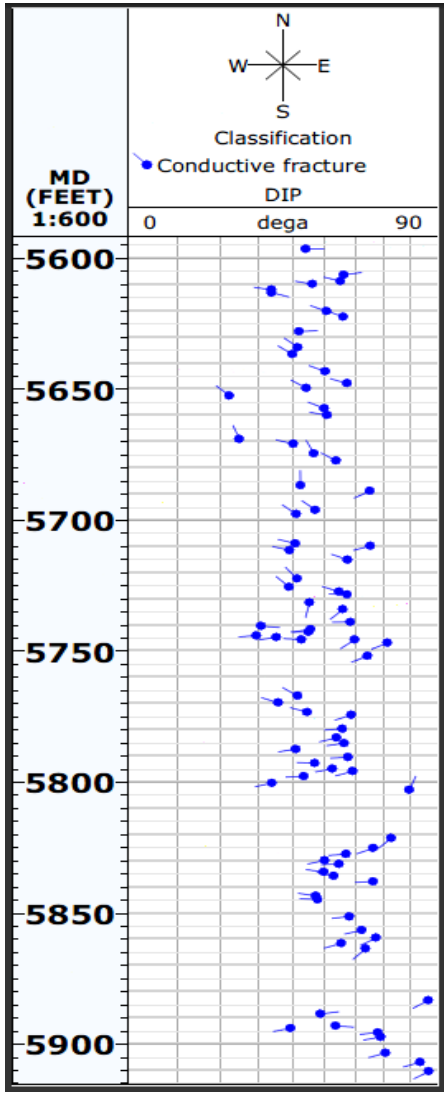
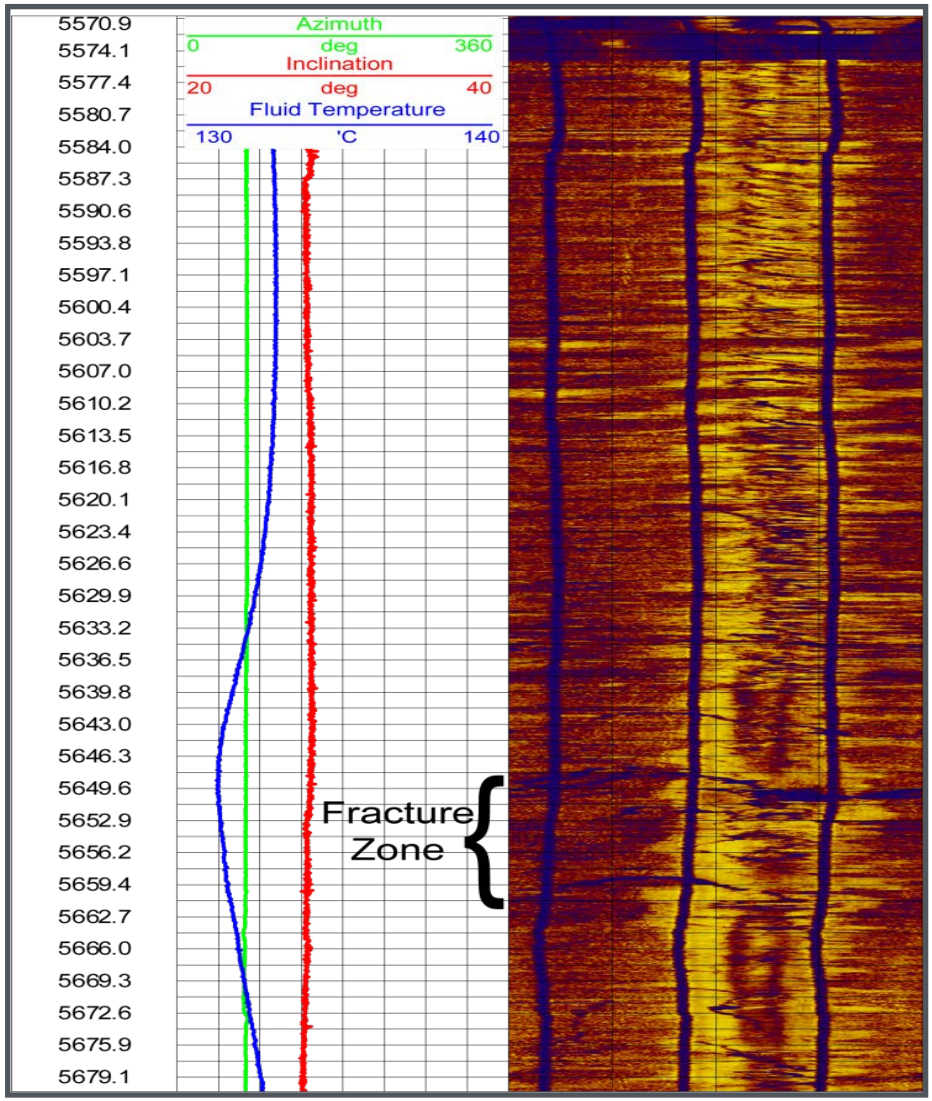
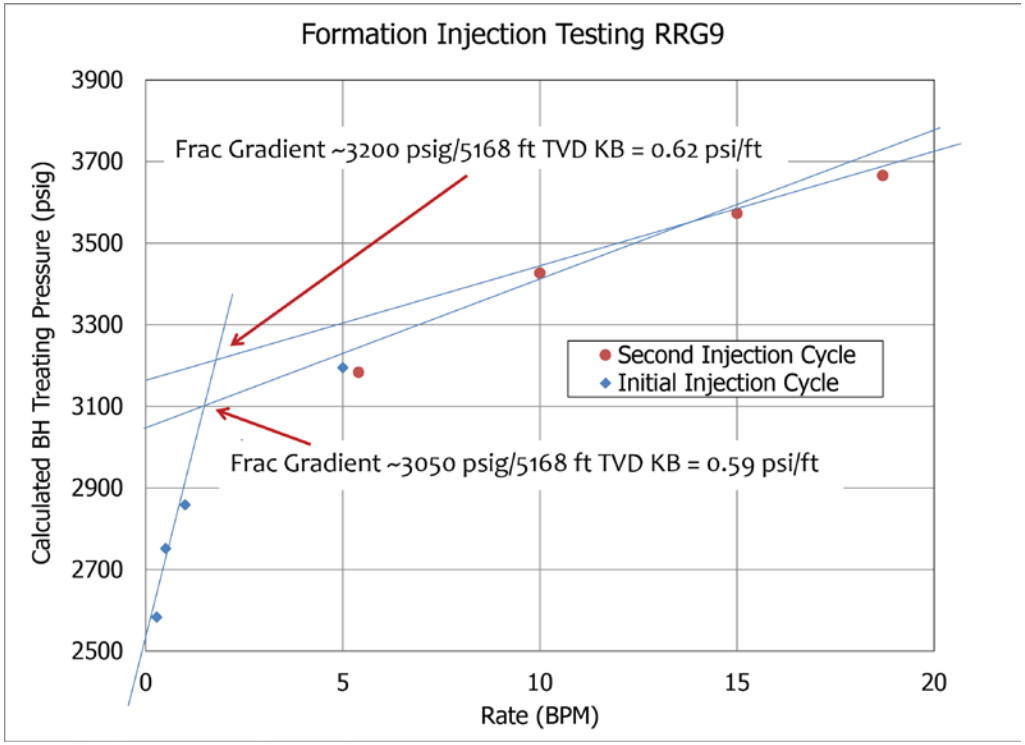
- 86 fractures between 5,525 to 5,920 ft
- 75% of fractures trend from N30W to N30E
- Major fracture zone at 5645-5660 ft. Fractures dip NW (22-57 degrees) and strike N11 - 42E)

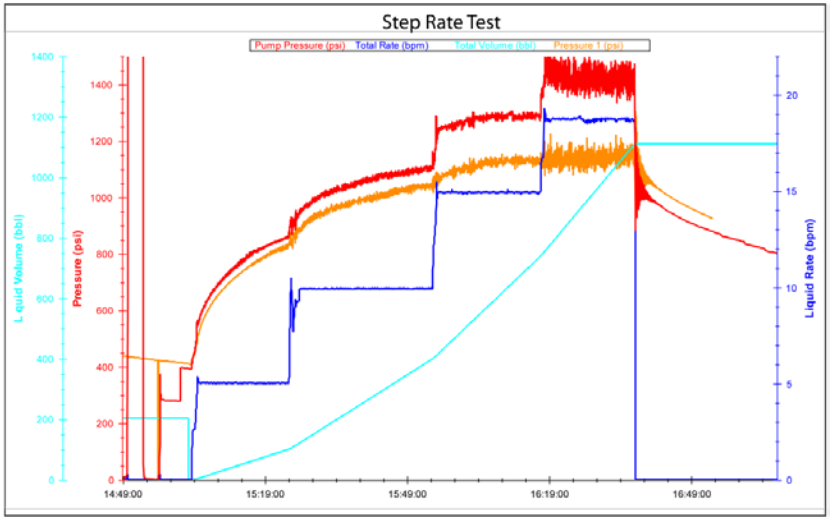




Reservoir Properties: Injection Testing

Properties	Value
True Vertical Depth	5168 ft TVD
Fracture Gradient	0.59-0.62 psi/ft
Minimum in-situ principal stress	3050-3200 psi
Reservoir Pressure	2938 psi
Permeability	0.03 md

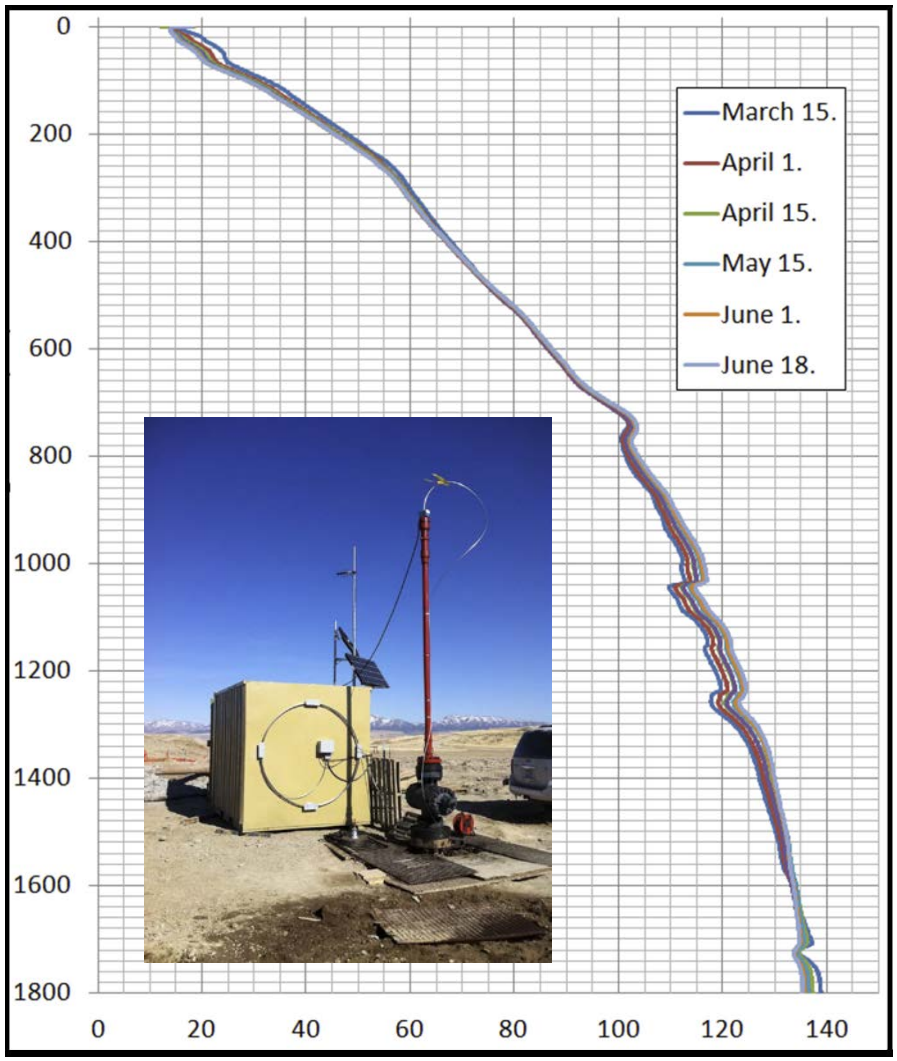


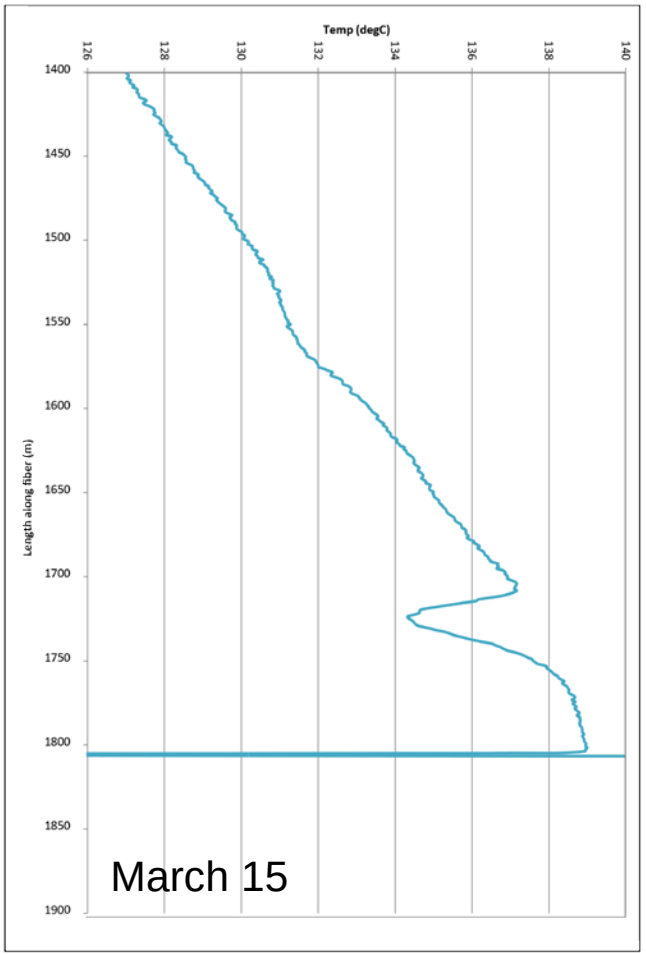


Injection parameters:

- rates of 11 to 756 gpm,
- maximum wellhead pressure ~1,150 psi,
- total injected volume 81,648 gal

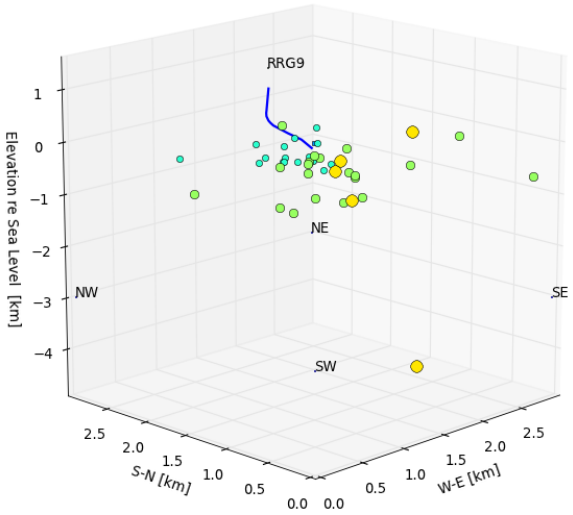
Reservoir Properties: Distributed Temperature Sensor Survey



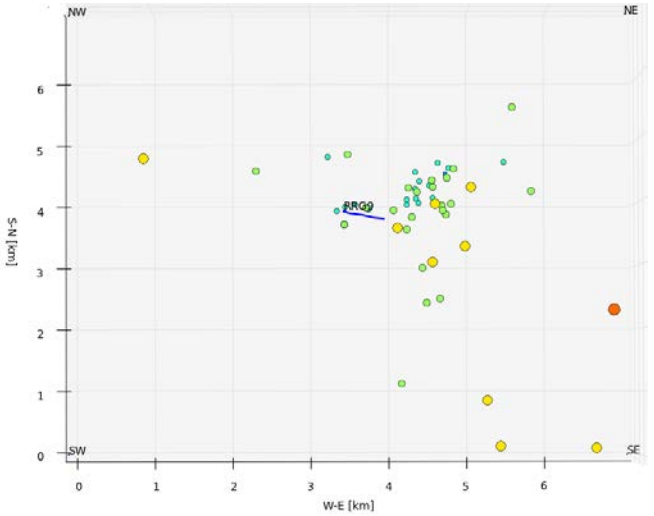


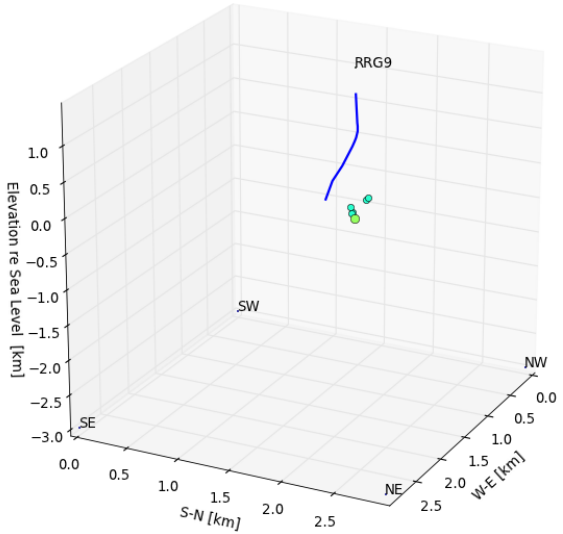
Courtesy B. Freifeld, LBL

Reservoir Properties: Seismic Monitoring

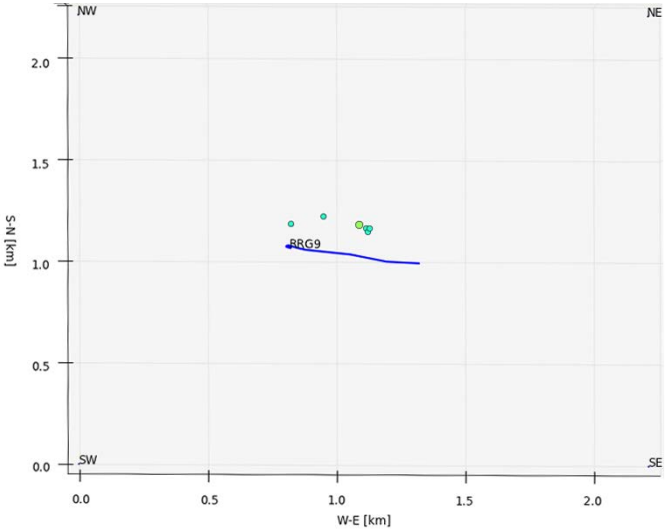


- All local events 8/10 to 3/13
- 57 events
- Moment Mag 0.0 to 1.5





- Events during Injection 2/24 – 25/12
- Moment Mag 0.2 to 0.5



Courtesy E. Majer, LBL

Future Directions

Phase 2 Milestones

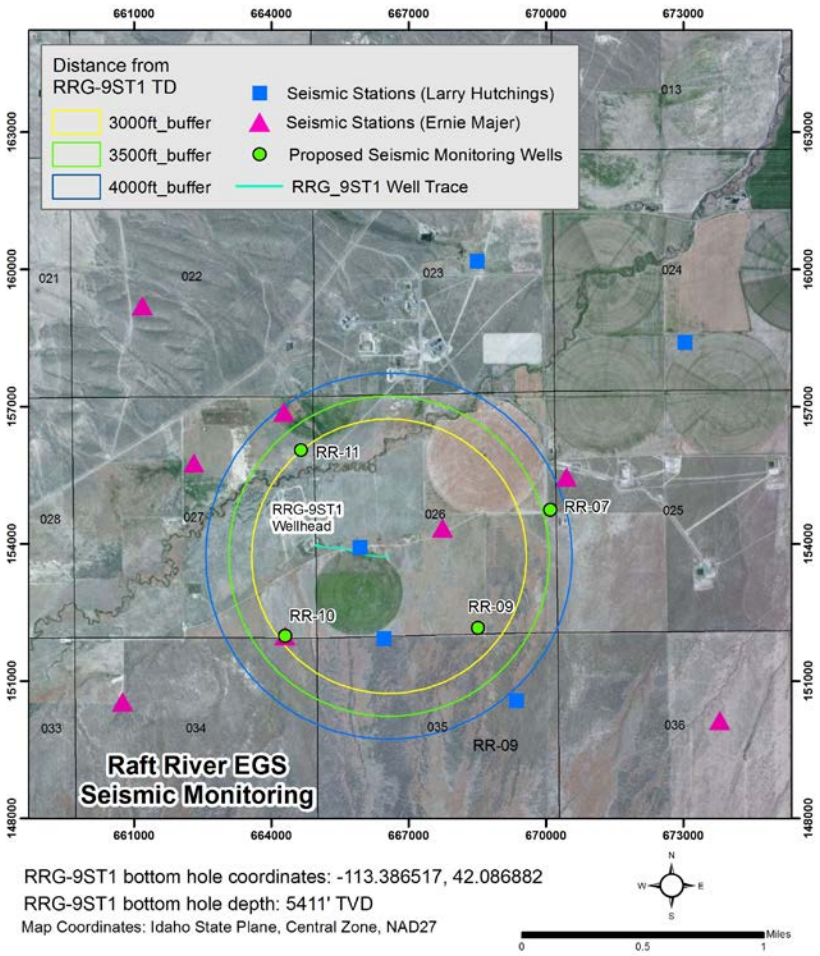
- Drill seismic monitoring wells (4/2013)
- Conduct thermal and hydraulic stimulation (4-9/2013)

Phase 2 Activities

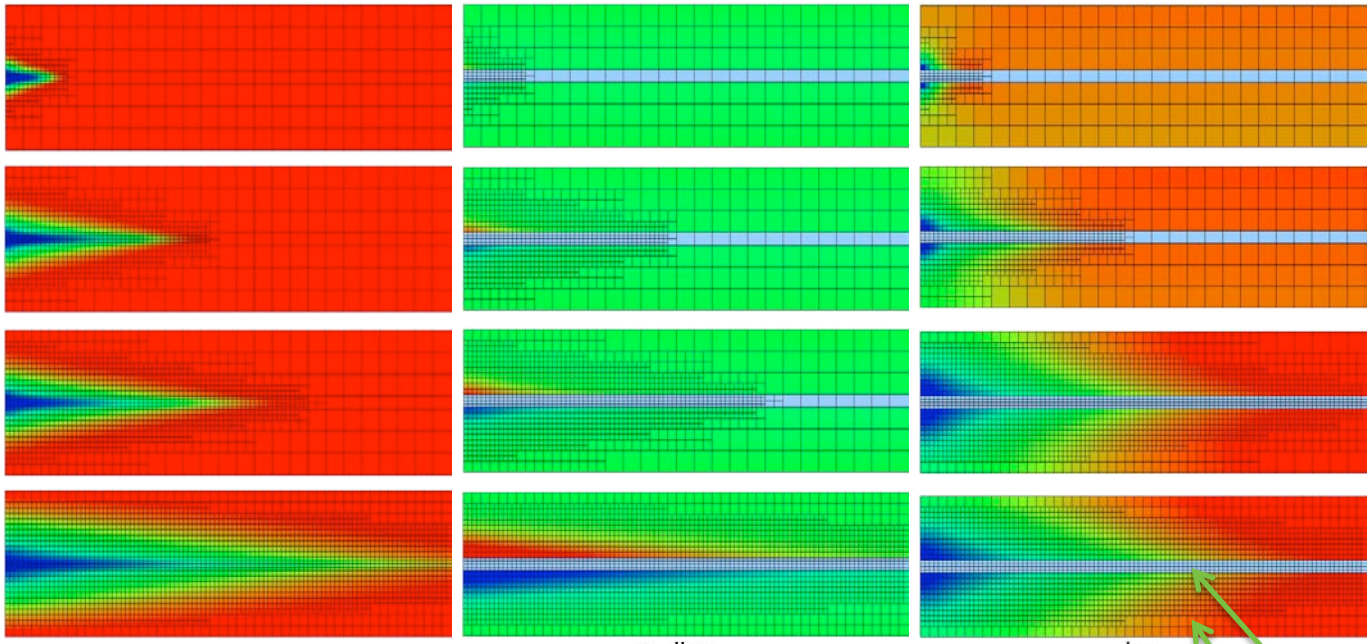
- Numerical modeling – reservoir volume, area, temperatures, fracture characteristics, stresses (M. Plummer, H. Huang, R. Podgorney, INL)
- Monitor seismicity (E. Majer, LBL)
- Monitor temperatures – Stages 1, 2 (B. Freifeld, LBL)
- Noble gas concentrations (B.M. Kennedy, LBL)
- Televiewer surveys – pre/post Stage 3 (D. King, SNL)
- Tracer studies – Stage 3 (P. Rose, EGI)
- Monitor electrical resistivities – Stage 3 (G. Newman, LBL)
- Prepare Phase 2 report

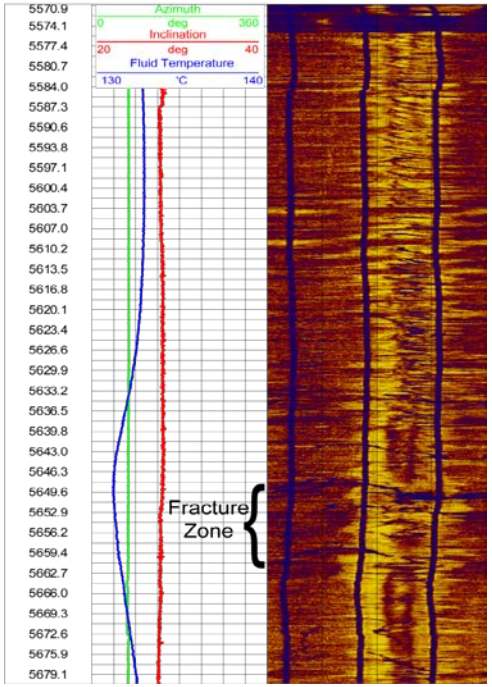
Phase 3: Long-term monitoring (9/2013)

- Tracer concentrations, temperatures (RRG-9 ST1); pressures (RRG-9 ST1 and production wells), seismicity, production rates



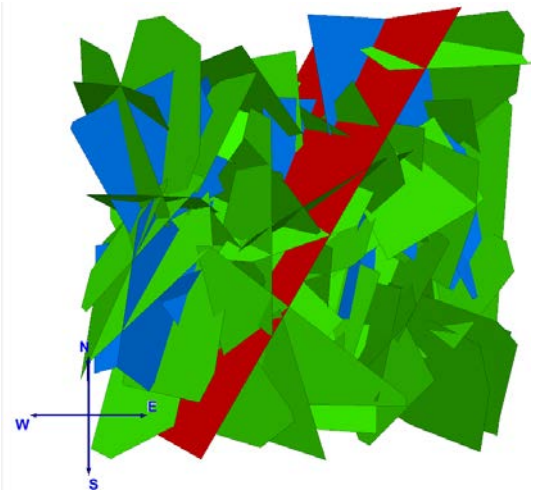
Thermal Stimulation Modeling of a Single Fault Zone



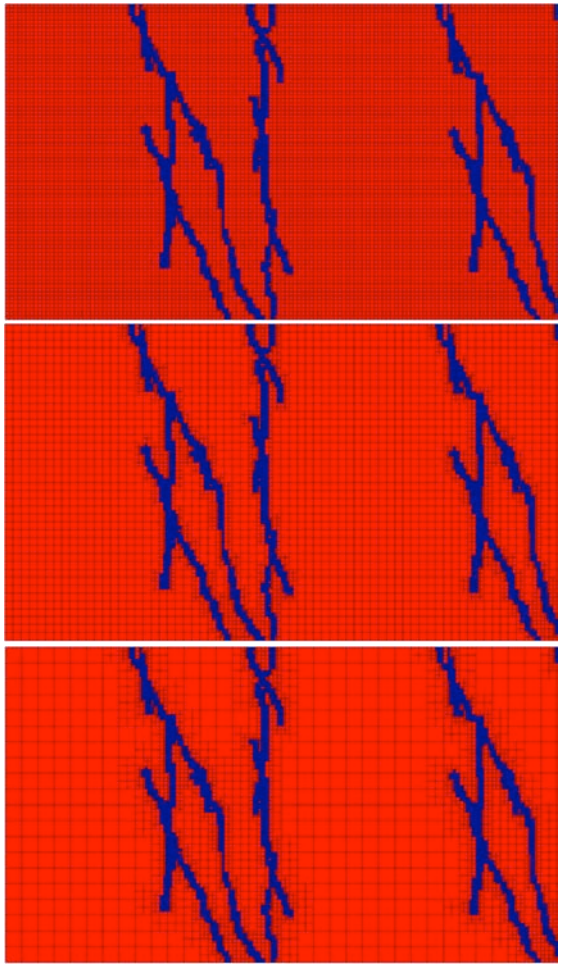


- Evaluation of thermal stimulation stage 1 in RRG-09
- Preliminary model results, 90 day injection
- Suggest thermal stimulation may significantly increase permeability

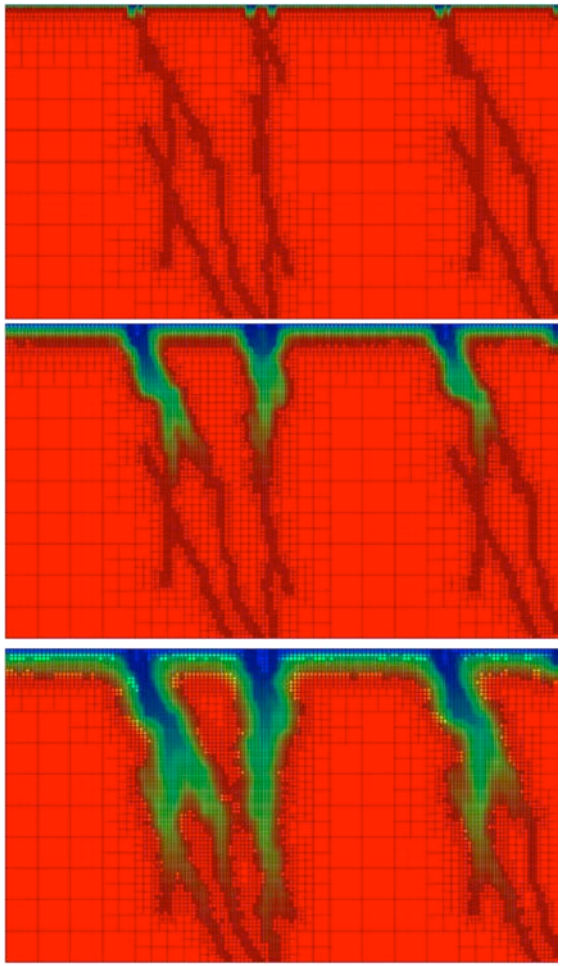
THM Stimulation of Multiple Fault/Fracture Zones



- Use FracMan fracture distributions
- Map into FALCON via automatic mesh refinement
- Simulate pressure and thermal stimulation at the reservoir scale



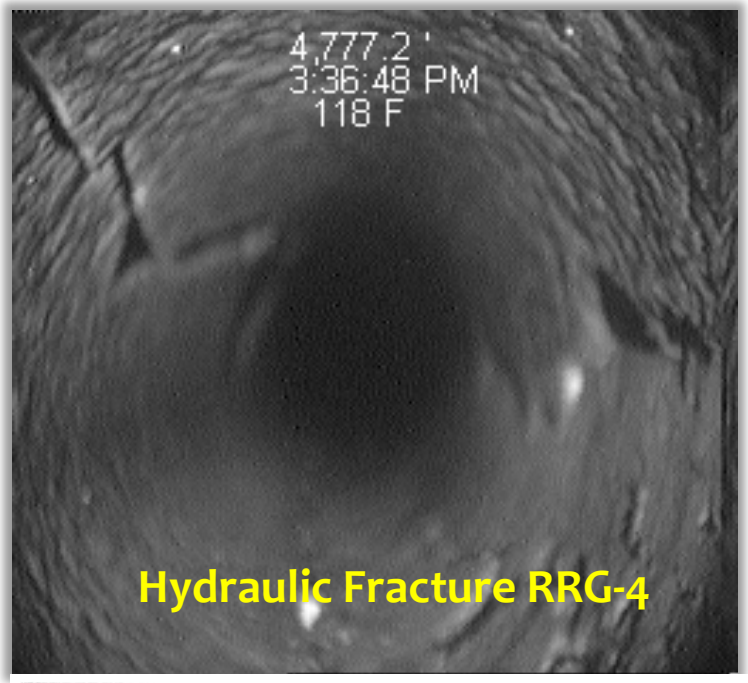
Automatic mesh refinement-FracMan fractures in FALCON code

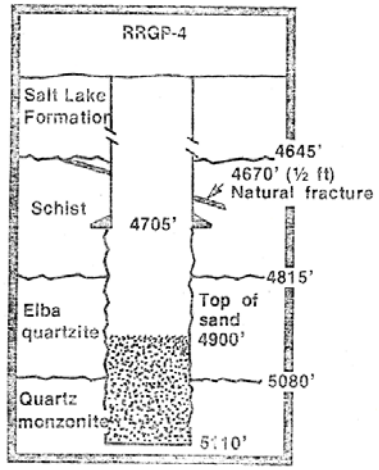


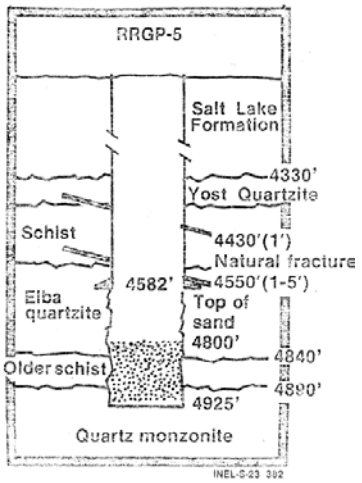
Temperature profiles over time in fracture network

Previous Stimulations

RRGP-4		RRGP-5
4-Stage Kiel Frac 8/20/1979		Conventional (Planar) Frac 11/12/1979
Frac Fluid	7,900 bbl (331,800 gal)	7,600 bbl (319,200 gal)
	10 lb H.P. Guar/1,000 gal	30 lb H.P. Guar/1,000 gal
	2 lb XC Polymer/1,000 gal	
Sand	50,400 lb 100 mesh	84,000 lb 100 mesh
	58,000 lb 20/40 mesh	347,000 lb 20/40 mesh
Rate	50 bpm (1862 gpm)	50 bpm (1862 gpm)
Interval	4,705-4,900 ft (195 ft)	4,587-4,803 ft (216 ft)
Frac Height	195 ft	135 ft
Orientation	N72^{o}E	N29^{o}E







The Stimulation Plan

Microseismic Network
Drill monitoring wells to 300 ft
Install geophones
Install ground motion sensors

Run Acoustic Televiewer

Connect Pipeline to Plant Injection Pump
5000 gpm of injectate at 140 F available

Initiate Phase 1 Stimulation
Inject 140 F injectate at 210 gpm and 300 psi
Inject for min. 30 and max. 60 days
*(300 psi = max pipeline pressure,
210 gpm based on step rate test done in Phase 1)

Continue until:
Well is on vacuum - increase rate if capacity is available
Pressure increases to more than ~300 psig - decrease injection rate to pressure <300 psig
The Injectivity Index stable for 7 days and no change in Hall plot

Seismic Activity
Seismic activity or ground motion > 1/2 allowable limit
evaluate seismic risk

Seismic risk exceeds allowable limits

STOP

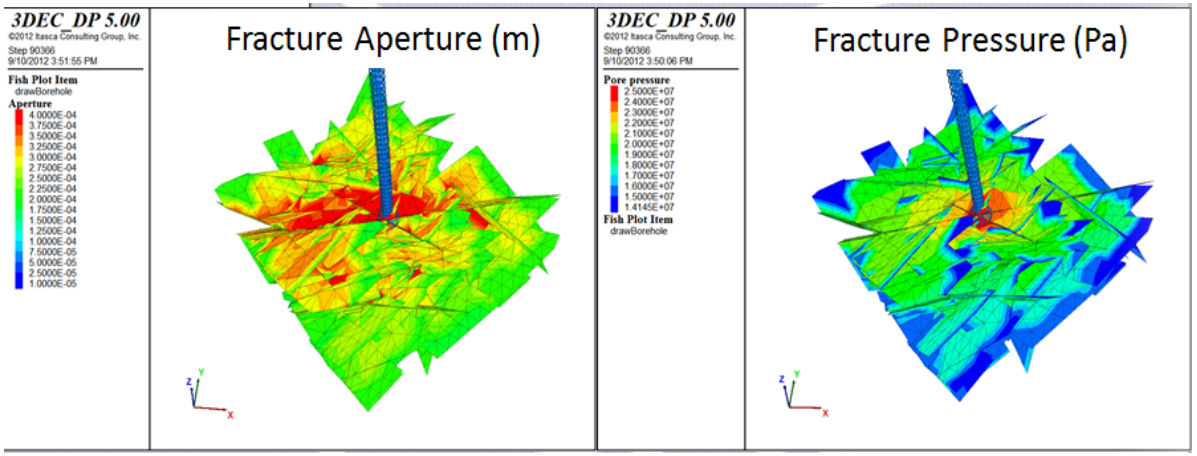
Run Acoustic Televiewer

Connect Pipeline to Cooling Tower

Initiate Phase 2 Stimulation
Inject 50F blow down at 210 gpm and 300 psi
Inject for min 30 and max 60 days
*(300 psi = max pipeline pressure,
210 gpm based on step rate test done in Phase 1)

Conduct Falloff Test
Pump for 1 day
Monitor pressure decay

The Stimulation Plan



Garcia and Nagel, Itasca

Initiate Phase 3

Conduct High Rate Large Volume Hydraulic Fracturing

Inject 1,000,000 gal injectate at 2100 gpm

Wellhead pressure = 2/3 allowable limit - reduce rate to <80%

Ground and microseismic activity = allowable limit
→ stop pumping, reinititate injection at 75%

Ground and microseismic activity exceeds allowable limit

Long term Monitoring

STOP

Summary Slide

- RRG-9 ST-1 was successfully completed to a total depth of 5,932 ft
- Step Rate testing yielded a fracture gradient of 0.59 to 0.62 psi/ft
- 86 natural fractures trending N20W to N20E were identified in the open hole section; fractures at ~5660 ft are permeable

- A three stage stimulation plan will be implemented at RRG-9 ST-1
  - Phase I: 140º F Water
  - Phase II: 55º F Water
  - Phase III: Hydraulic

Project Management

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Timeline

Planned Start Date	Planned End Date	Actual Start Date	Current End Date
9/2008	6/2014	6/2009	6/2014

Budget

Federal Share	Cost Share	Planned Expenses to Date	Actual Expenses to Date	Value of Work Completed to Date	DOE Funding Needed to Complete Work
$8,591,766	$746,411	$6,714,336	$6,714,336	$6,714,336	$1,811,430

- **Principal Investigator: Dr. Joseph Moore (EGI)**
  - Oversees work and coordinates communication and reporting activities among team members, DOE Project Managers and Technical Monitoring Team; assumes overall responsibility for budget; Managers and their
- **Leveraging of funds**
  - U. of Utah (cost share for students);U.S. Geothermal (access to field and cost share); Geothermal Resources Group; APEX-HiPoint
  - DOE provides support for field activities by LBL and Sandia National Laboratories
- **Coordination and integration with other projects**
  - Several of the team members are also part of other demonstration teams and DOE projects
  - The DOE Technical Monitoring Team provides contact information and links to reports