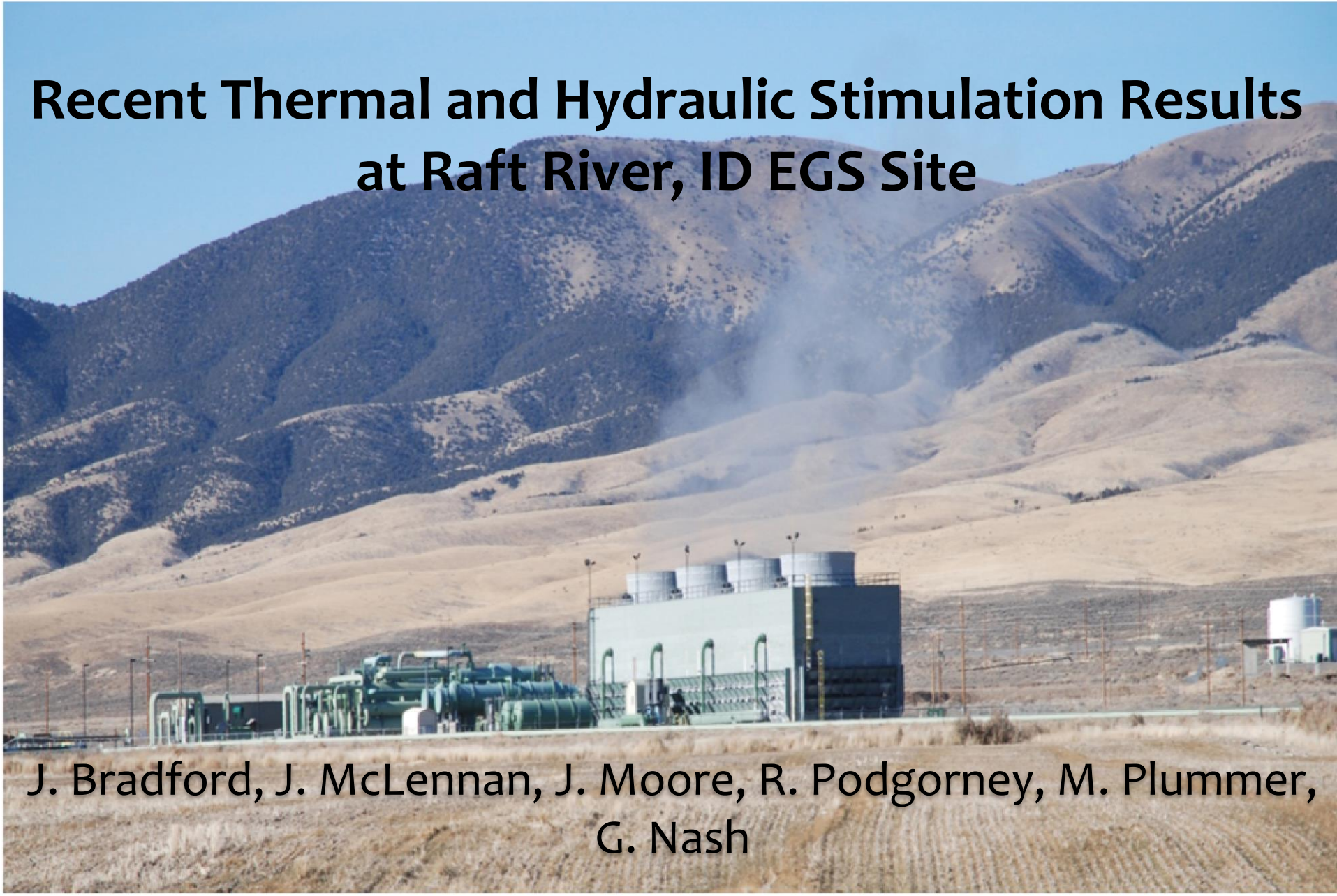
Recent Thermal and Hydraulic Stimulation Results at Raft River, ID EGS Site



J. Bradford, J. McLennan, J. Moore, R. Podgorney, M. Plummer, G. Nash

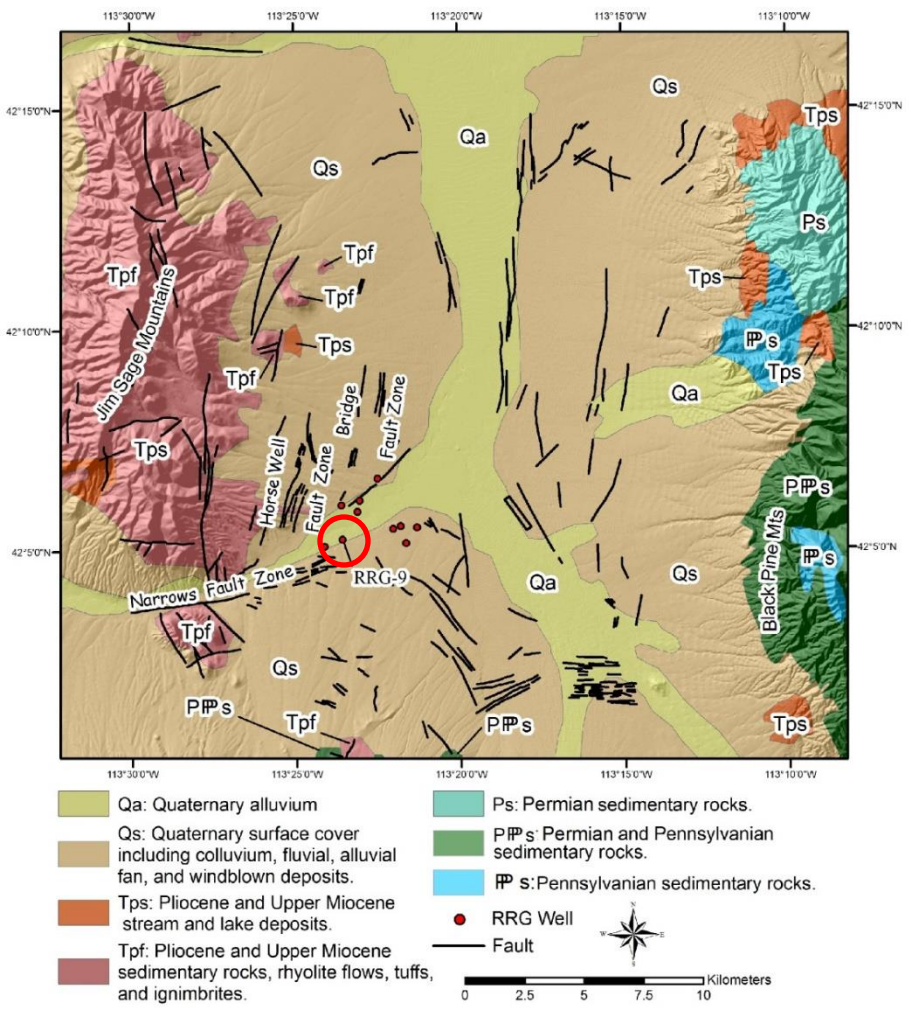
Introduction

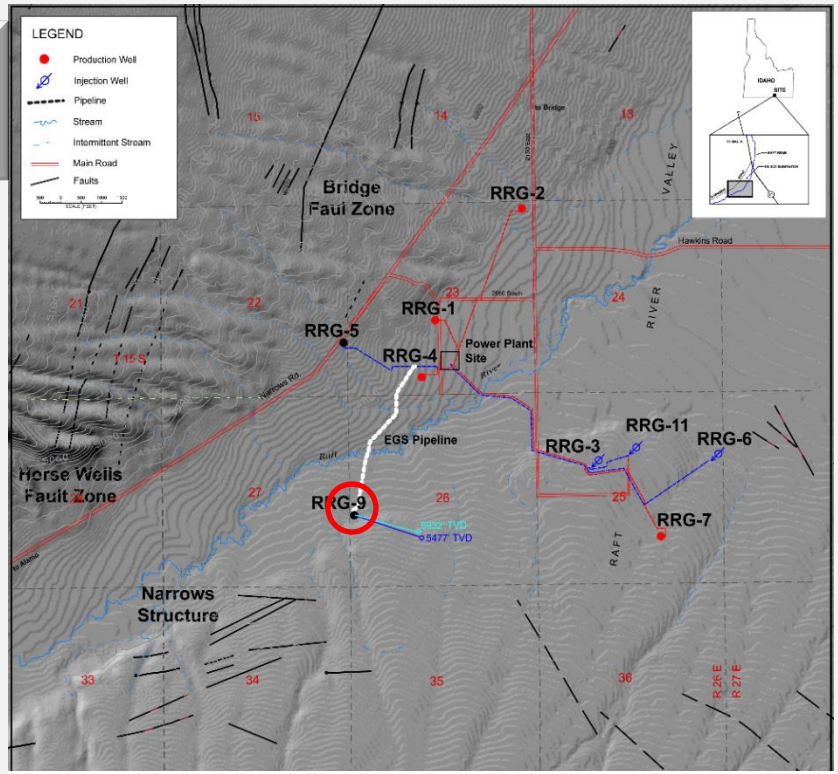
- U.S. Geothermal Inc.
- Operational in January 2008
- Ormat Nevada Inc. binary unit
- Maximum resource temperature ~150°C
- 15.8 MW_e capacity, produces ~10.5-11.5 MW_e

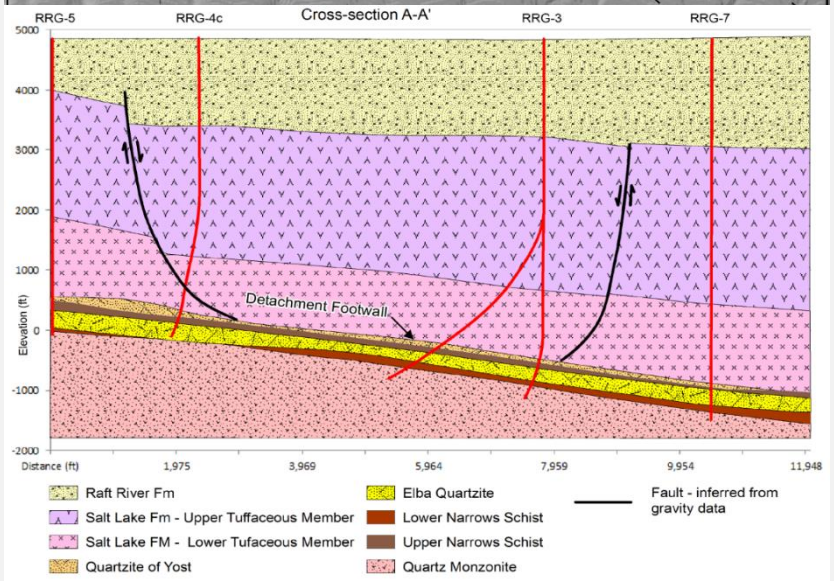
Drilling of RRG-9 ST1

- 4 Production Wells
- 3 Injection Wells
- Total Production: ~ 5,000 gpm
- Production Wells: 850-2,200 gpm
- 433 gpm per MW_e

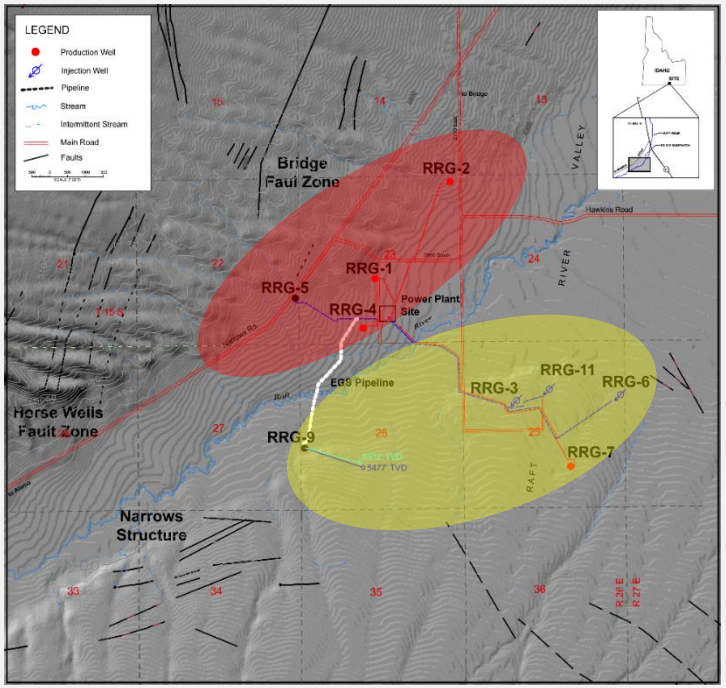
The Geologic Setting

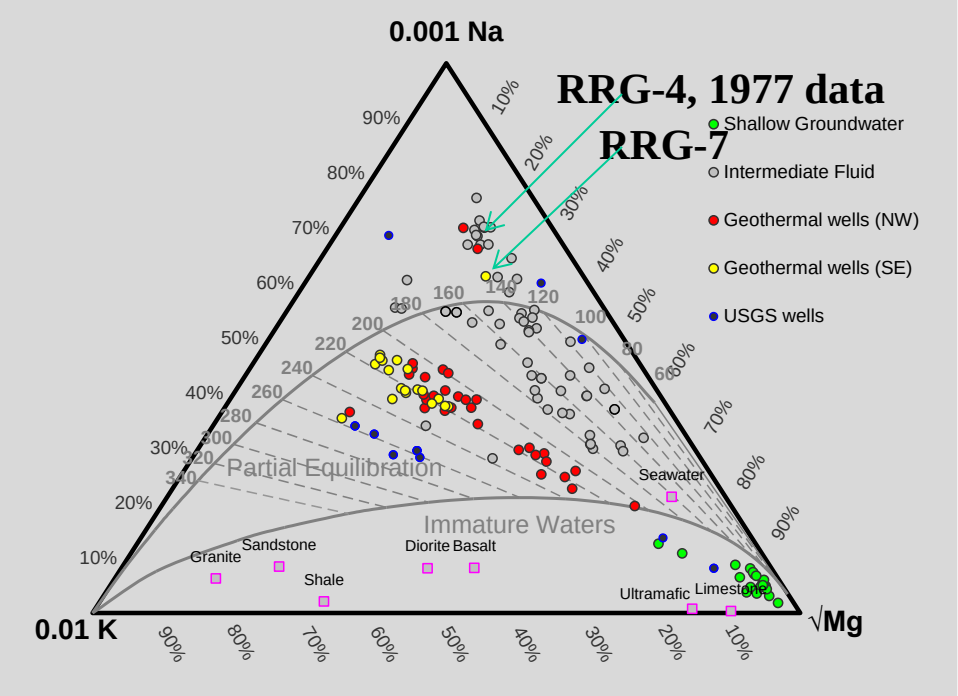


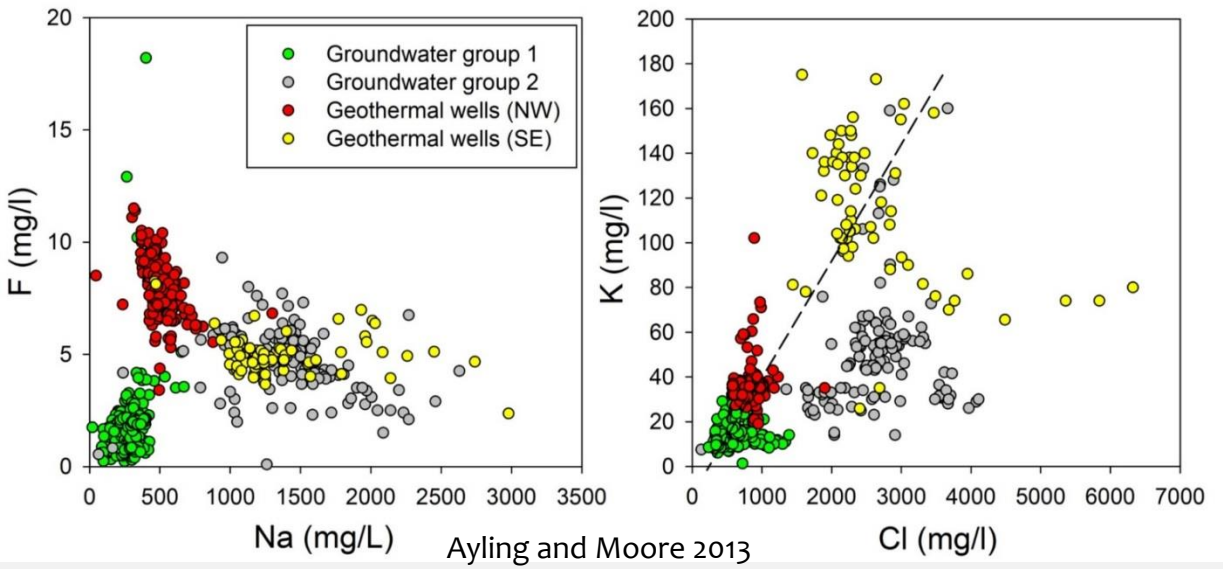




Fluid Compositions

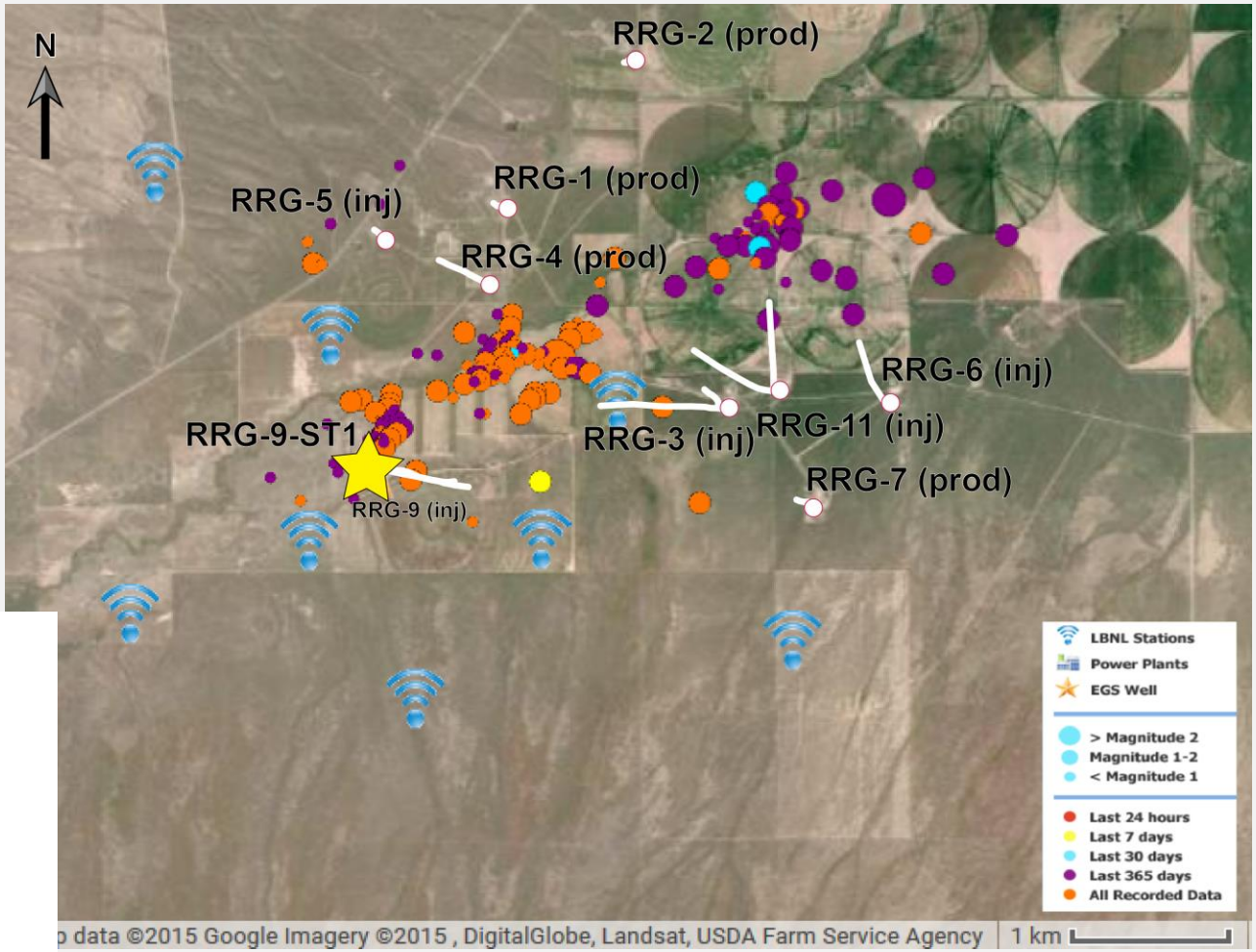


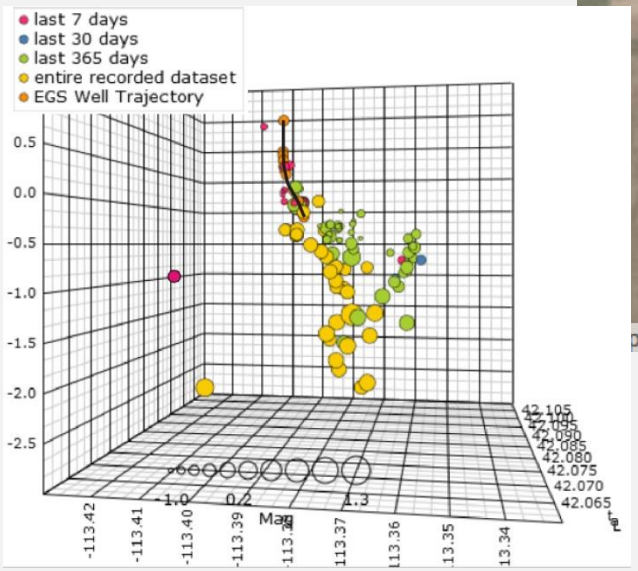




Ayling and Moore 2013

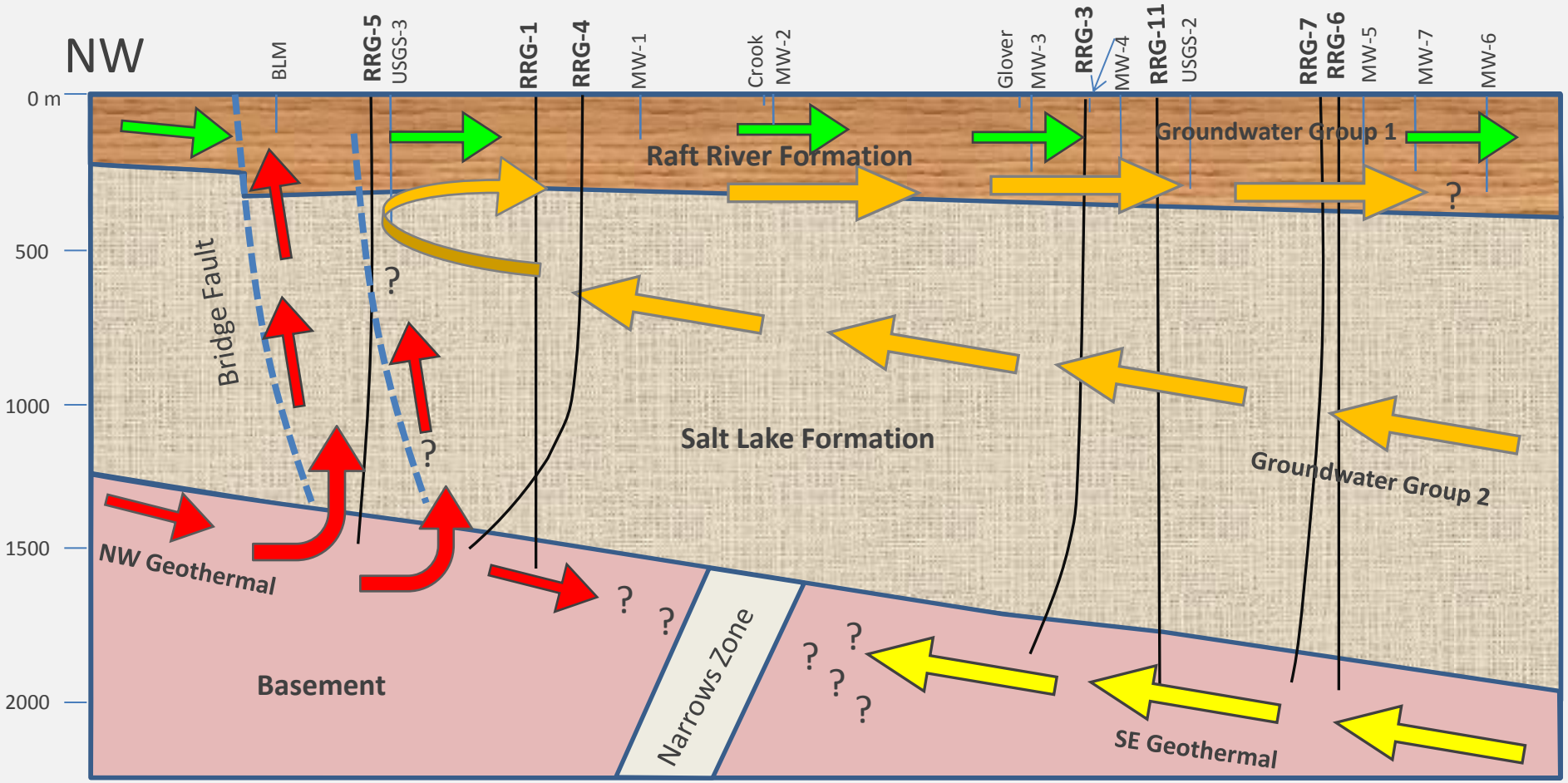
Seismic Activity





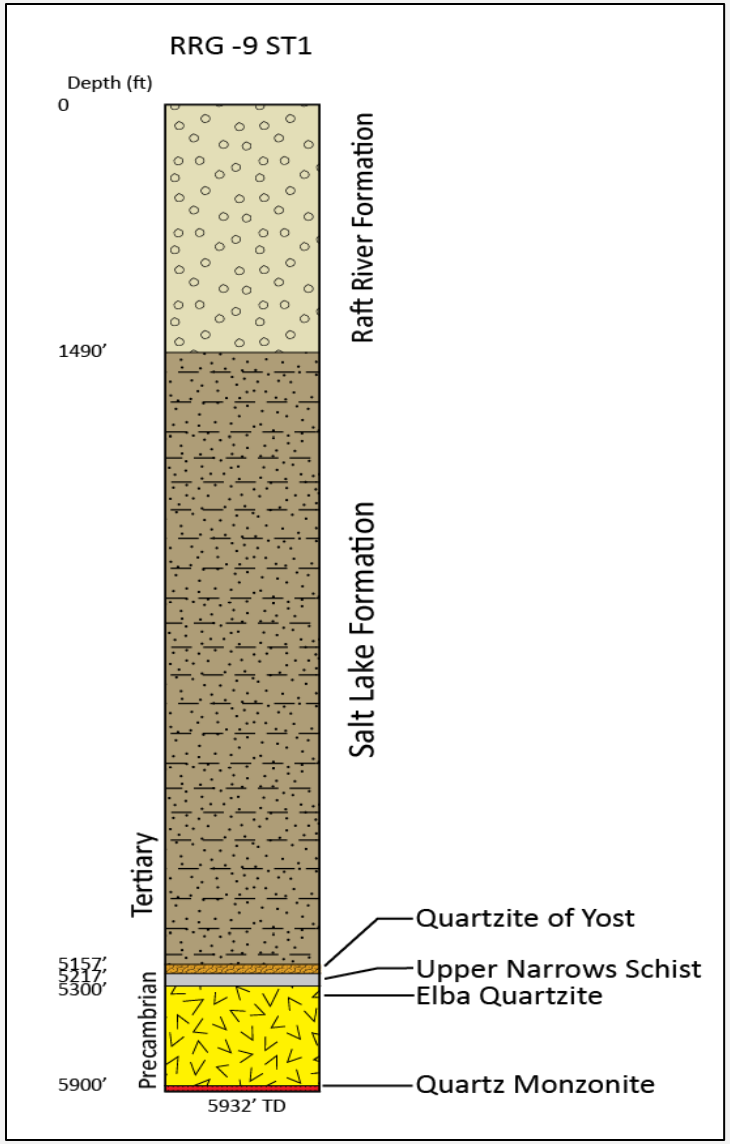
Lawrence Berkeley National Laboratory Induced Seismicity

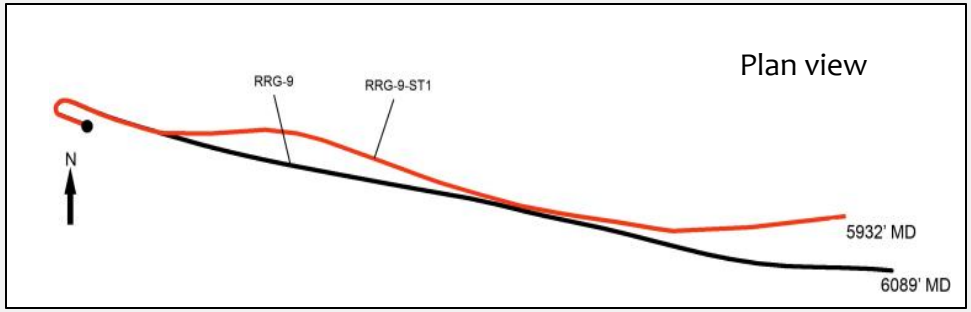
Possible Fluid Pathways

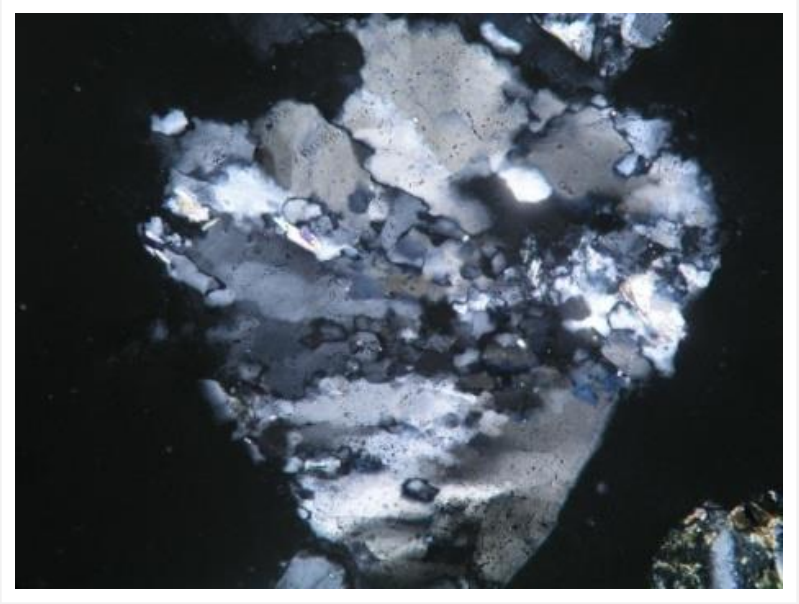


Ayling and Moore 2013

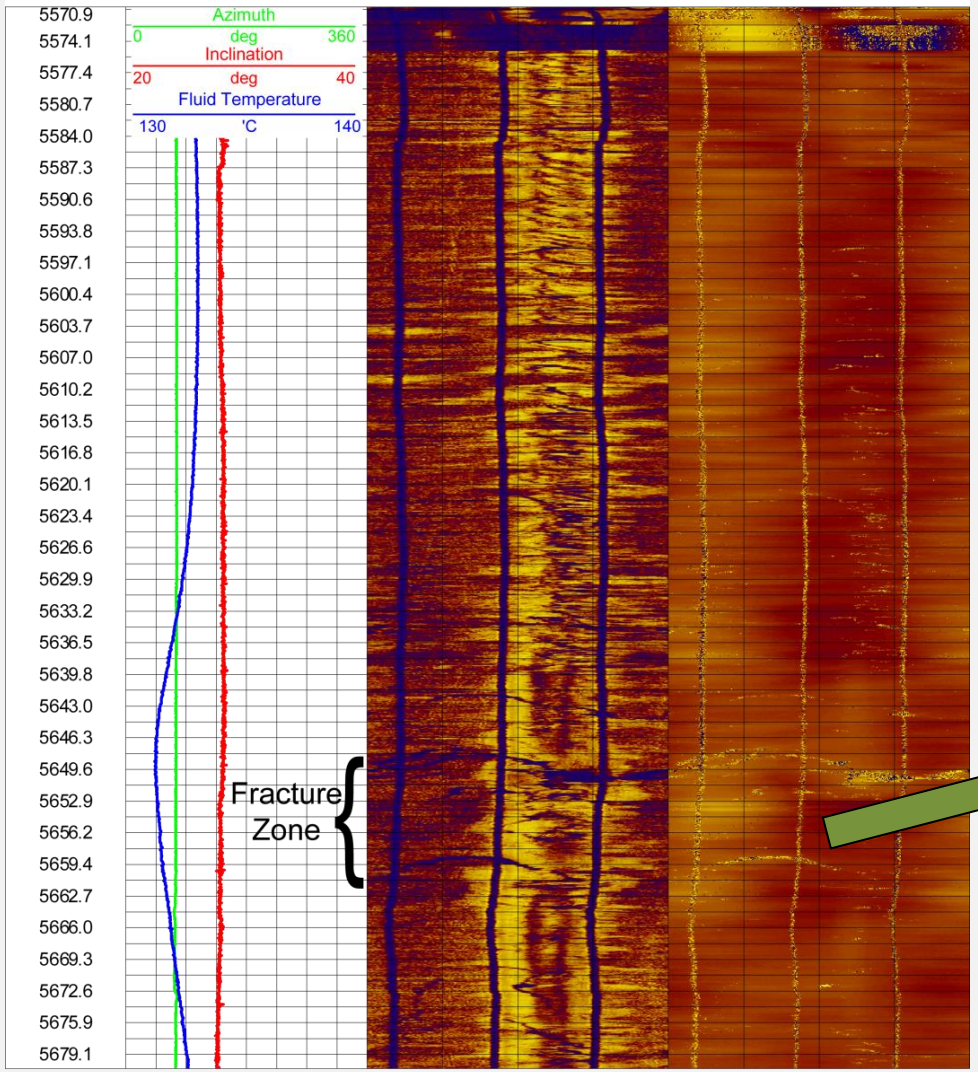
RRG-9 ST-1

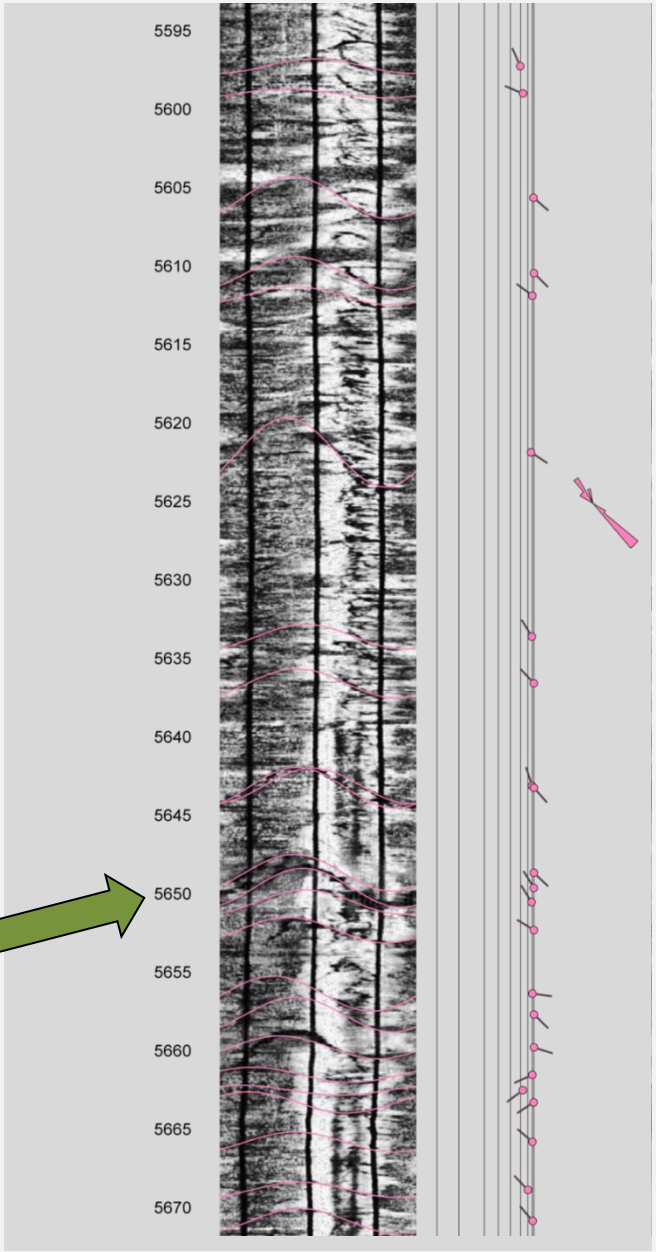

RRG -9 ST1
Depth (ft)
0
1490'
5157'
5217'
5300'
5900'
5932' TD
Tertiary
Precambrian
Raft River Formation
Salt Lake Formation
Quartzite of Yost
Upper Narrows Schist
Elba Quartzite
Quartz Monzonite


Plan view
RRG-9
RRG-9-ST1
N
5932' MD
6089' MD



Major Fracture Zone at 5,650 ft.





Waters Petroleum, LLC

Waters Petroleum, LLC

Fracture Statistics

Well Name: RAFT RIVER 9

Stereonet interval: 5524.59 to 5920.08 ft Wulff (Upper) Data source: Pick Set A - coded by category

Rose bin size: 10.0

Rose rim value: Auto

Strike Plot

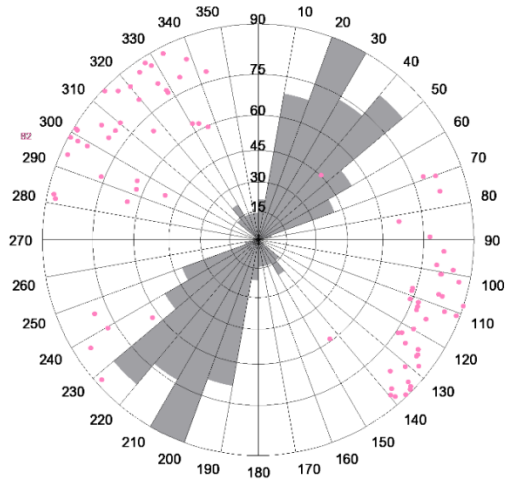
N = 82

Dip minimum: 0.00

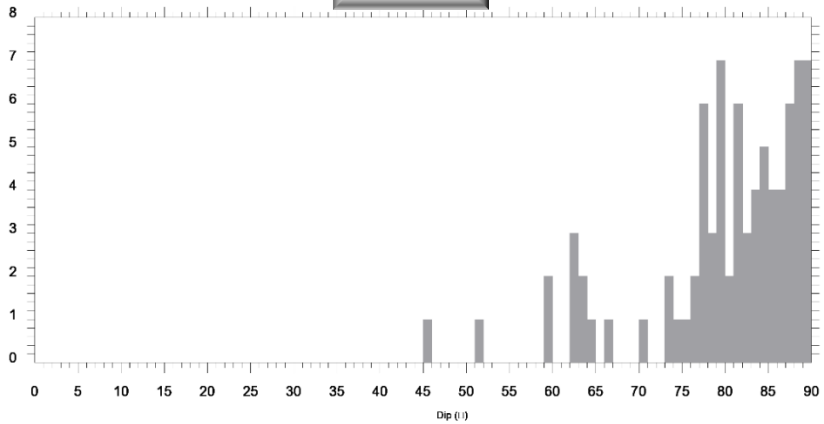
Dip maximum: 180.00

Dip quality cutoff: 0.00

Dip fill cutoff: 0.00



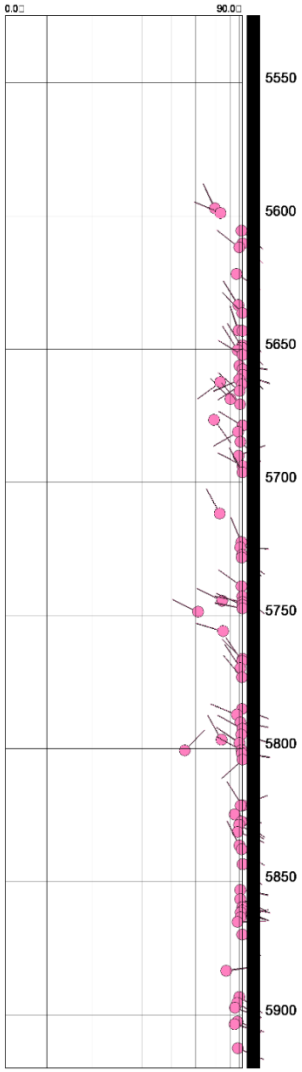
Strike



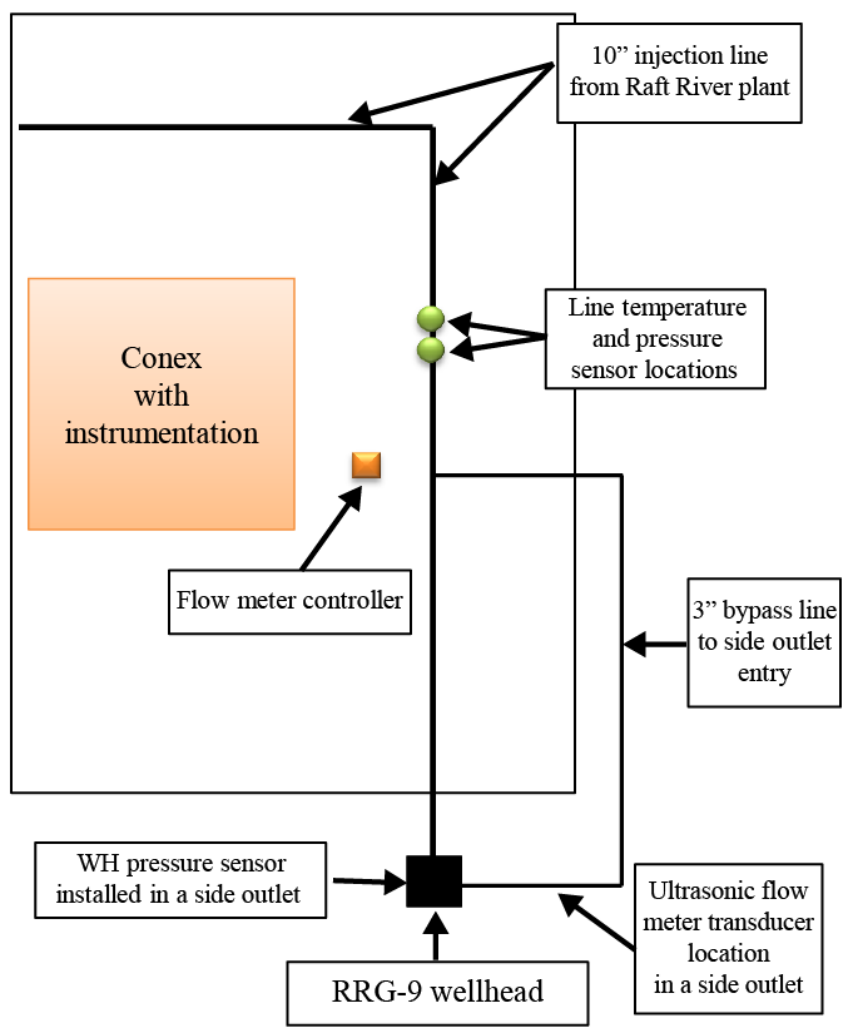
Dip Angle

Tadpole plot - coded by pick type

Unrotated data



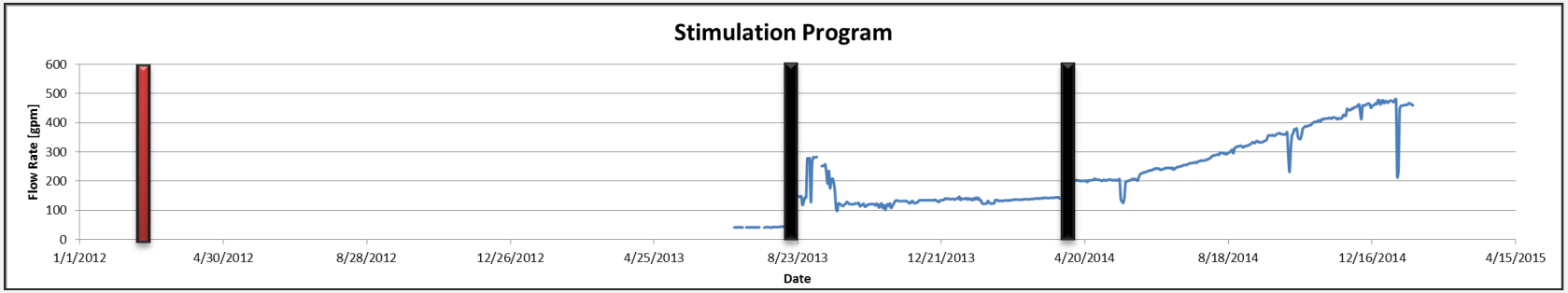
RRG-9 ST1 Layout



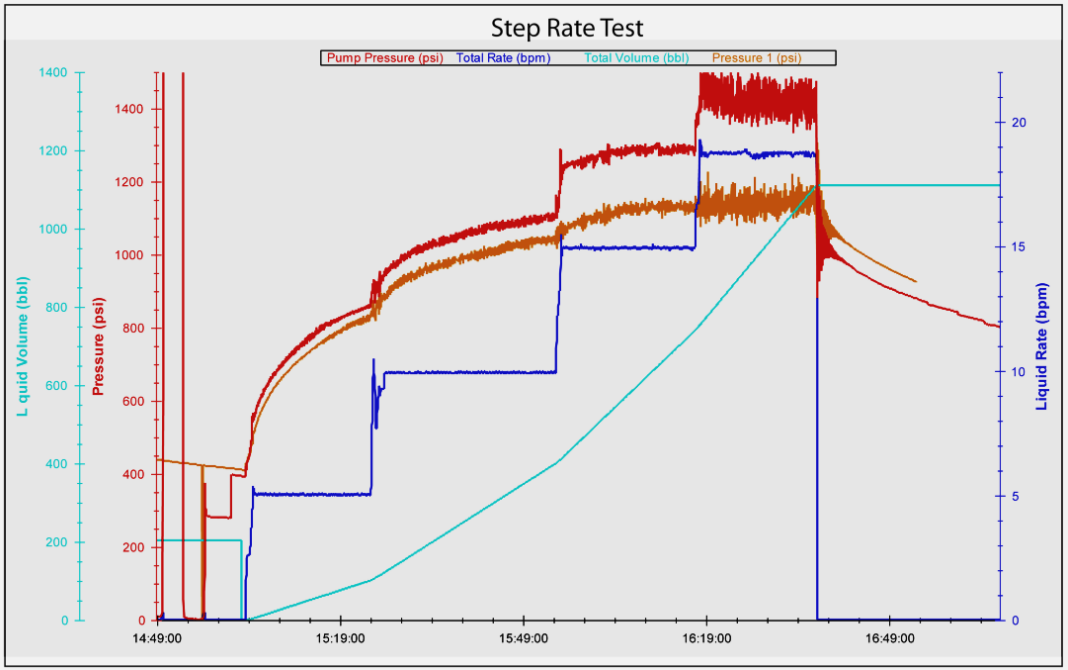
Stimulation 1

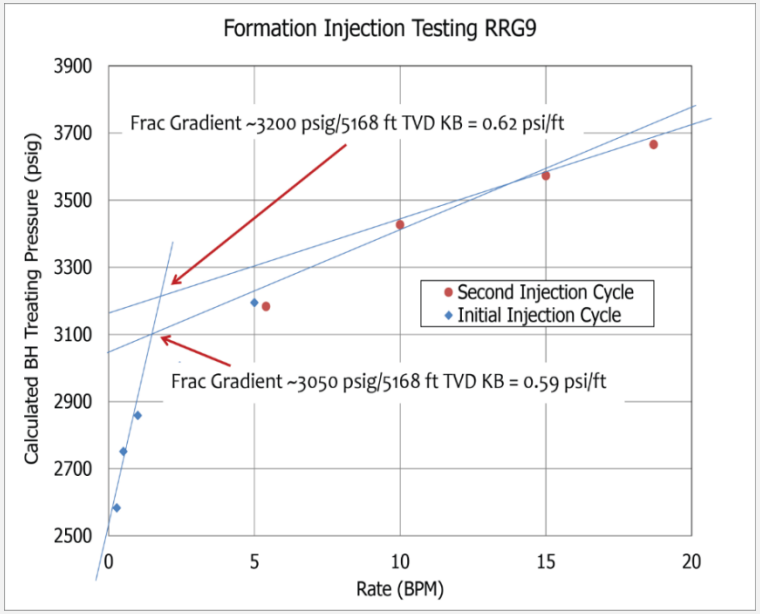
Injection parameters:

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



Stimulation 1

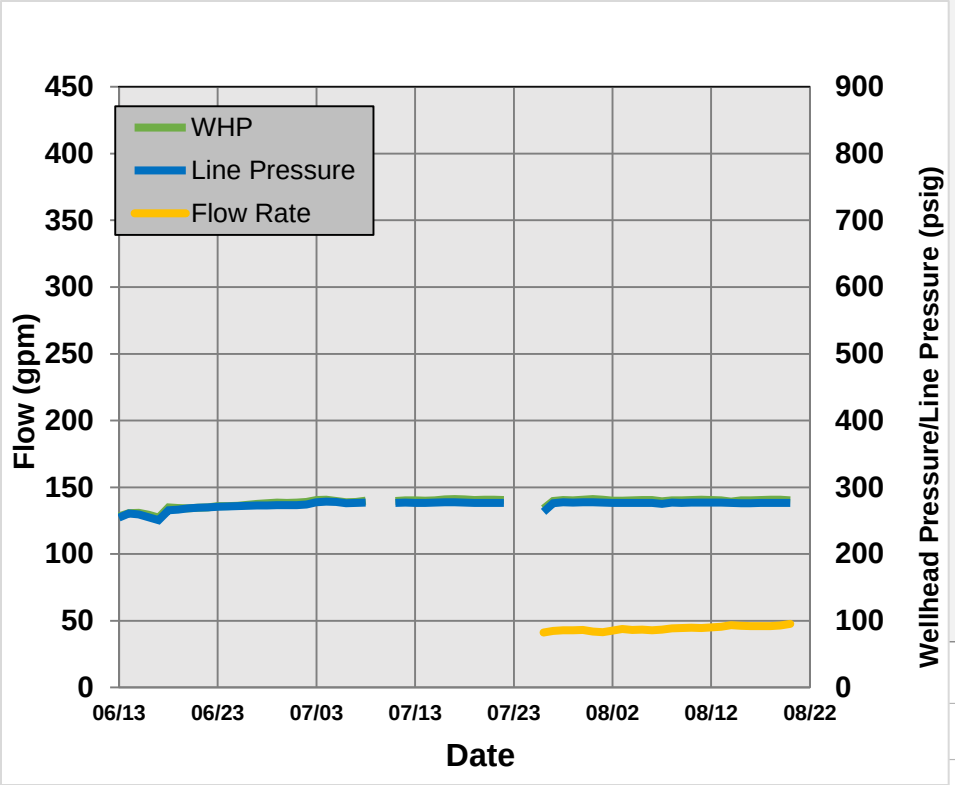


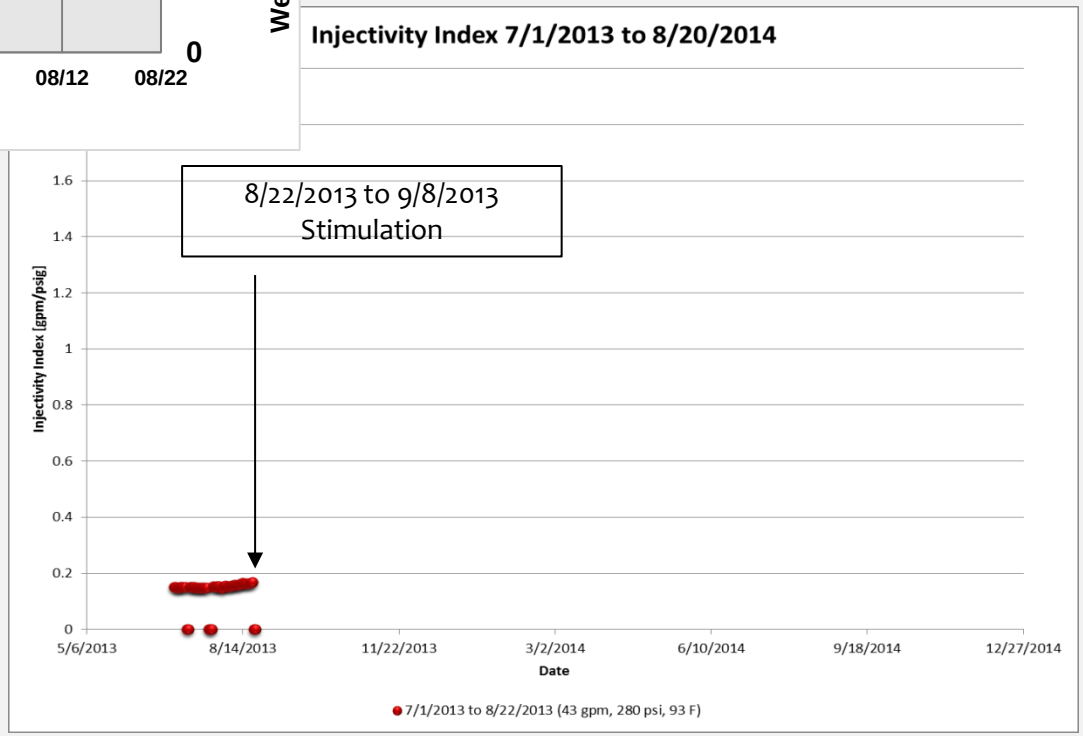


Properties	Value
True Vertical Depth	5168 ft TVD
Fracture Gradient	0.59-0.62 psi/ft
Minimum in-situ principal stress	3050-3200 psi
Maximum wellhead pressure	1150 psi
Reservoir Pressure	2938 psi
Permeability	0.03 md

Injectivity Prior to Stimulation 2

(after 1.5 years of no activity)

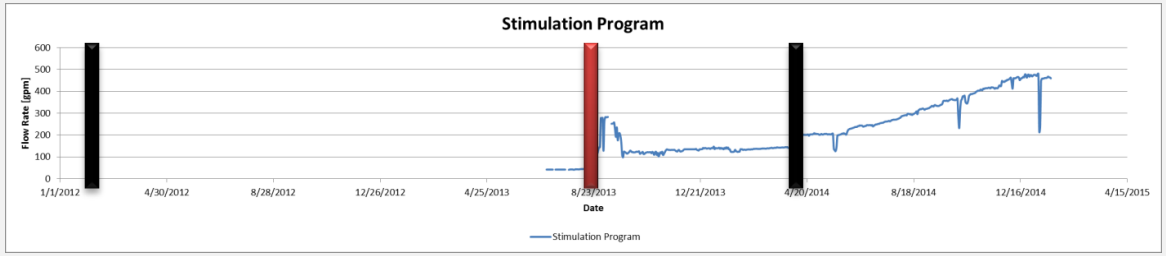




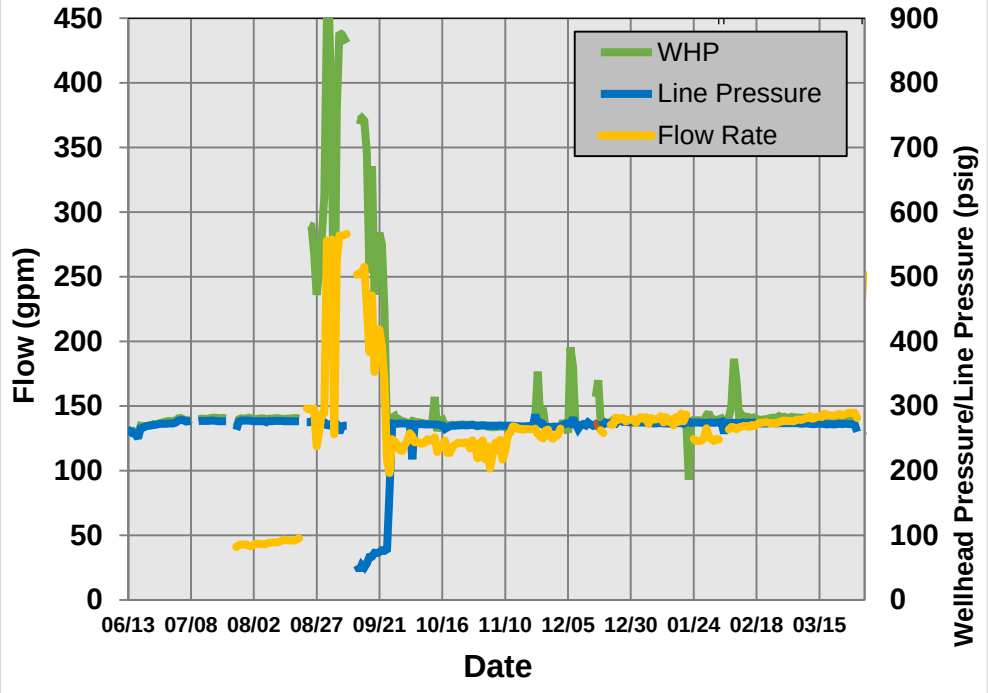
Stimulation 2

Injection parameters:

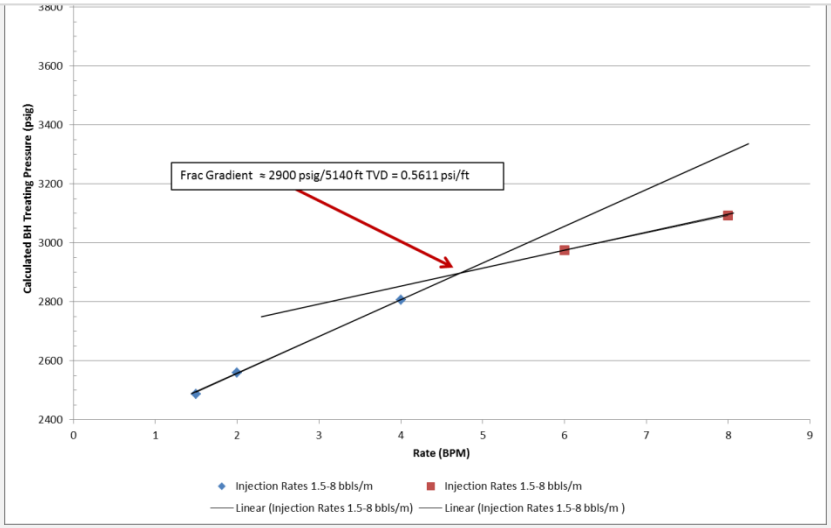
- max flow 333 gpm
- max well head pressure 908 psig
- temperature 40-46 °C

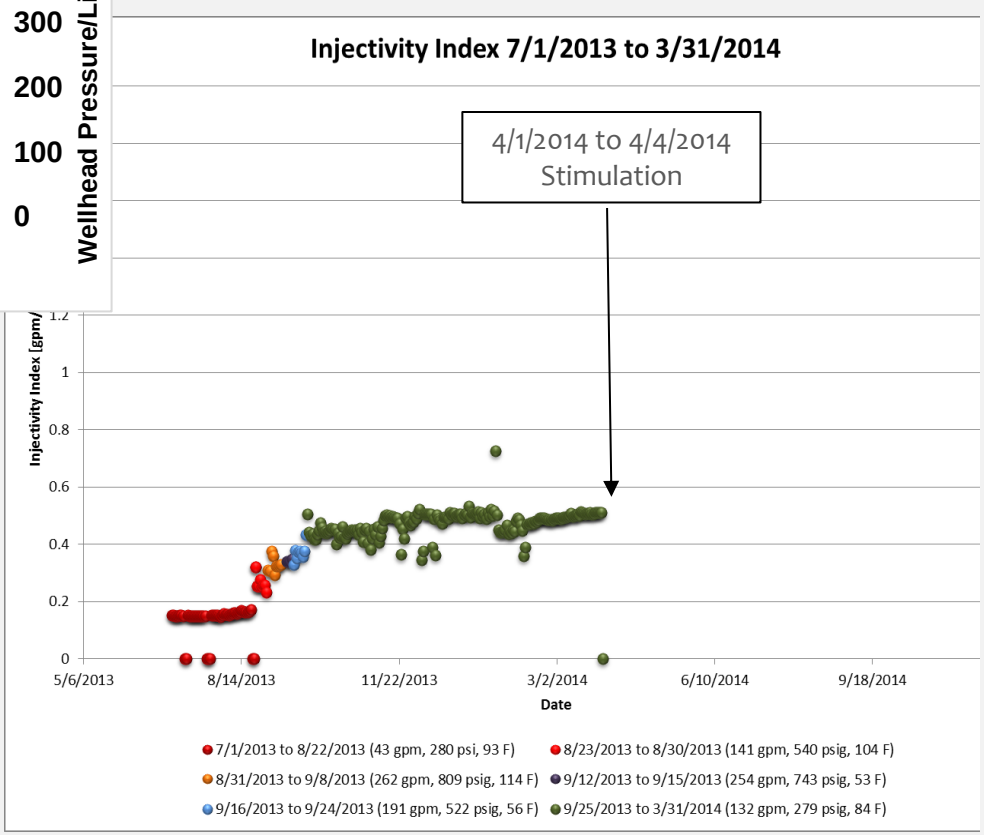


Post Stimulation 2

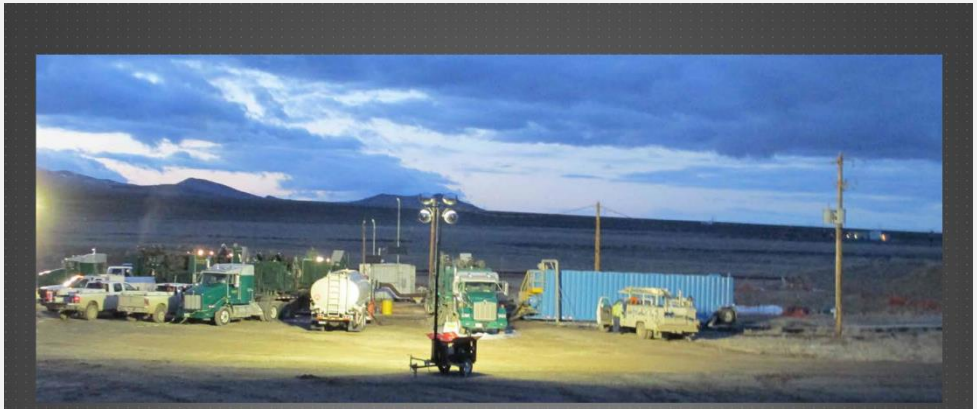


(6/2013 to 4/2014)

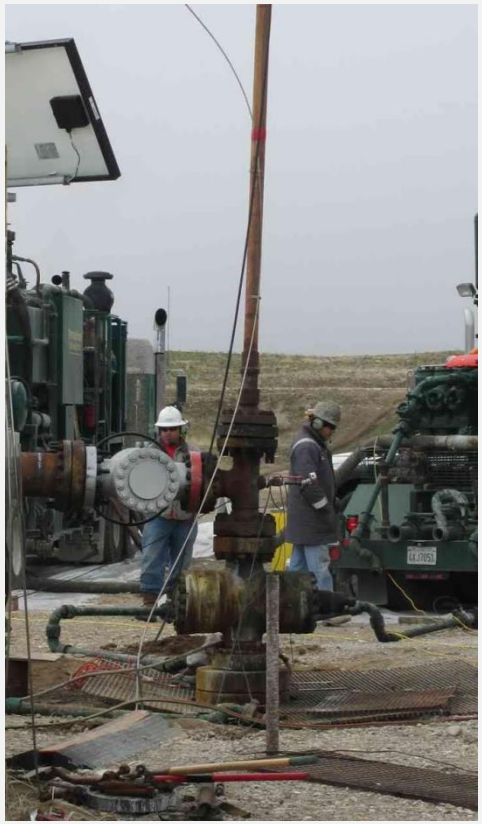




Stimulation 3

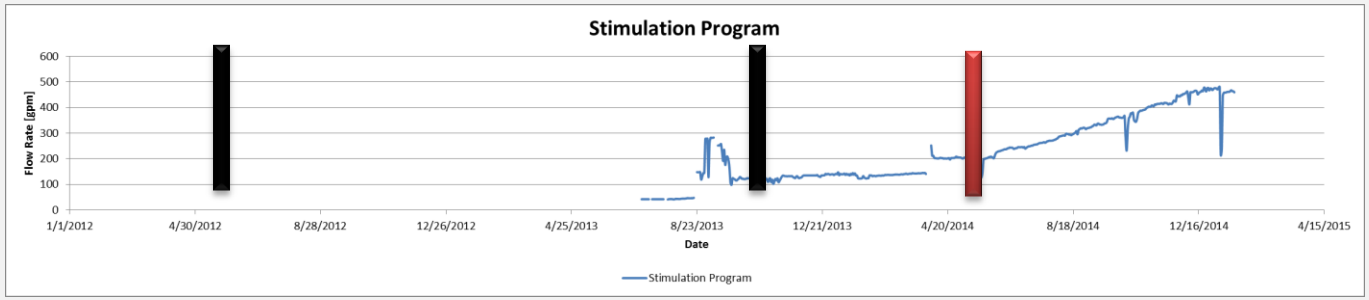


Day 2 pumping set-up



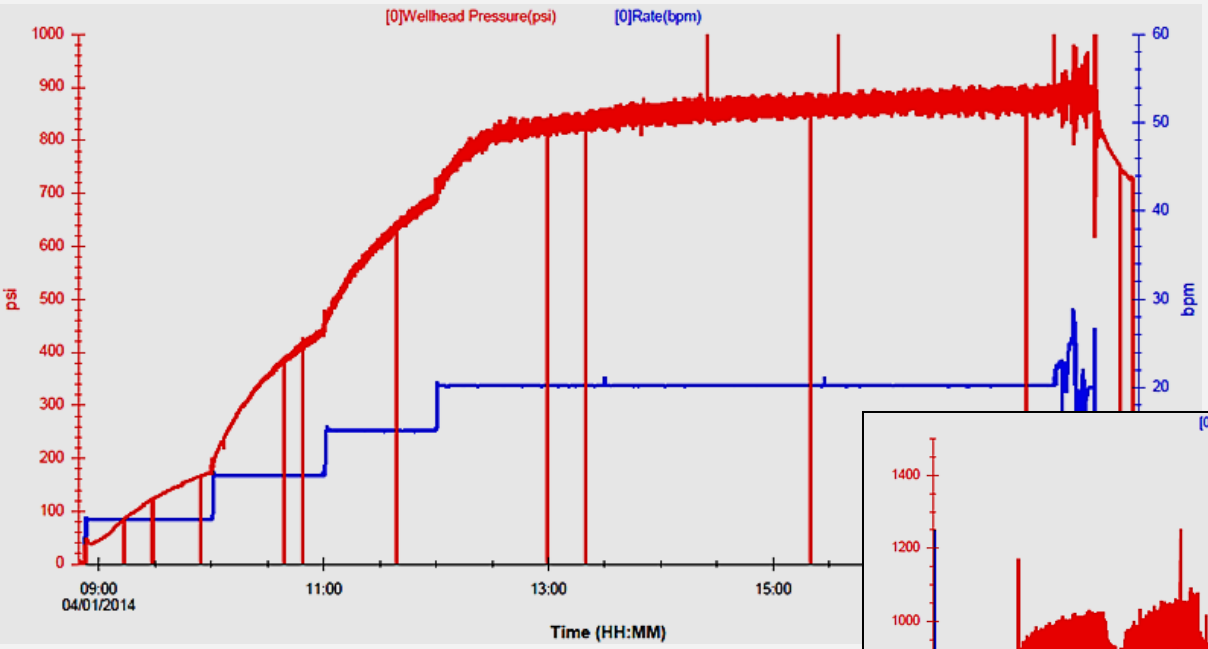
Injection parameters:

- 840-1260 gpm
- wellhead pressure 850-980 psig
- temperature 10-15 °C

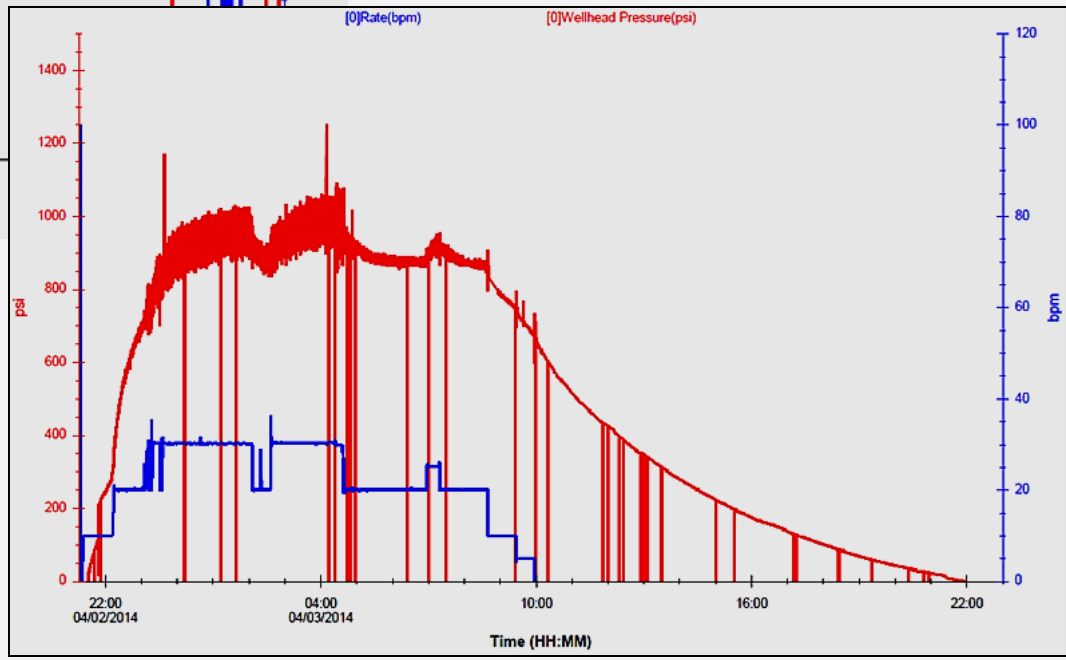


Stimulation 3 Day 1-3

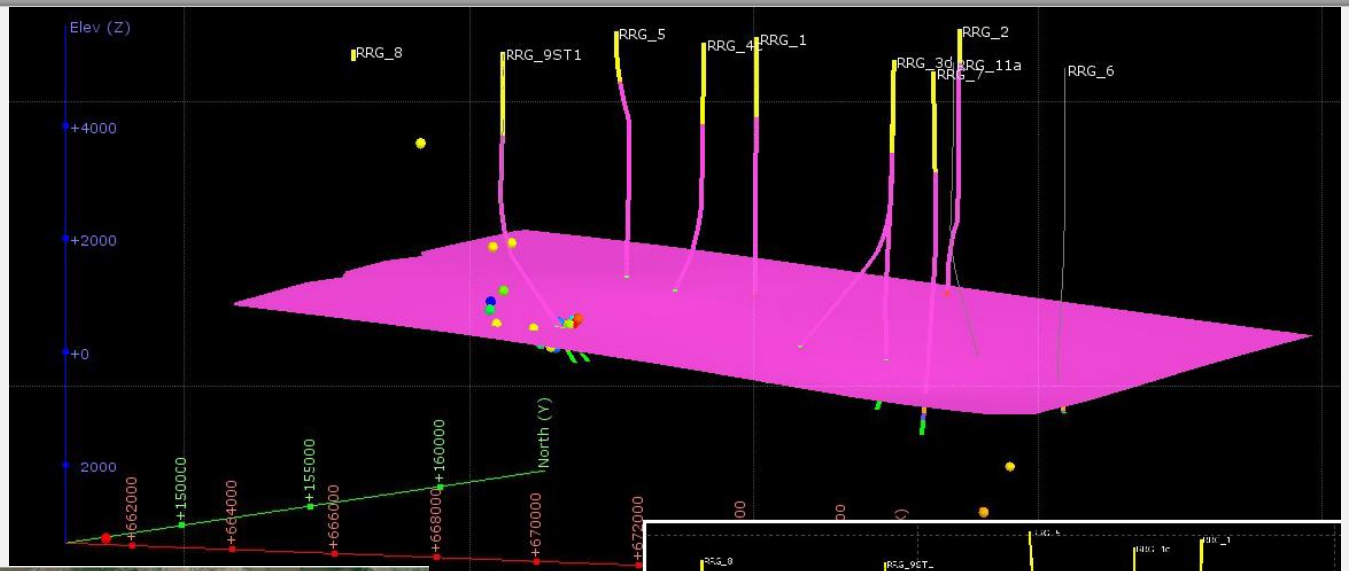
Day 1

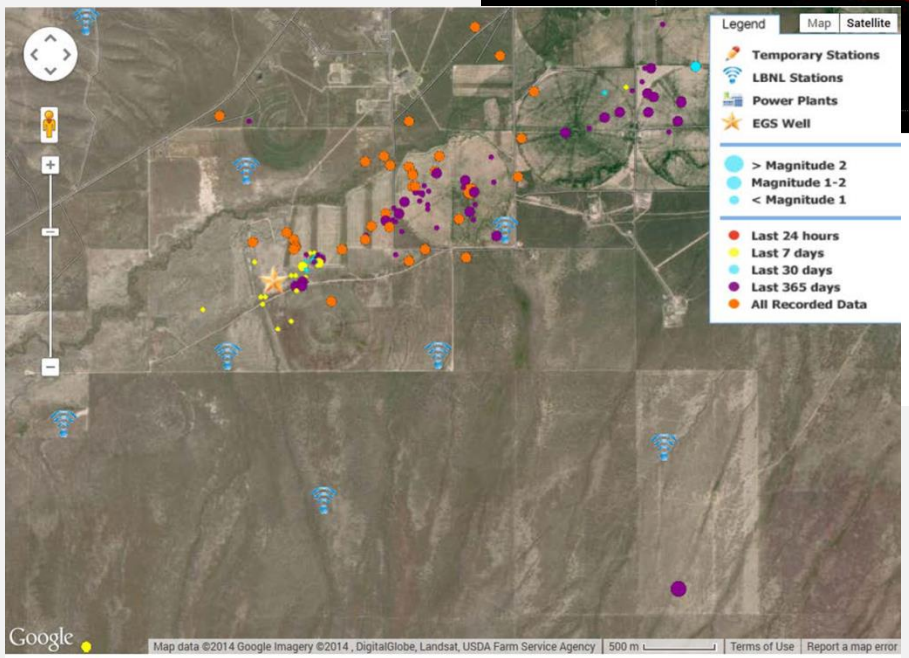


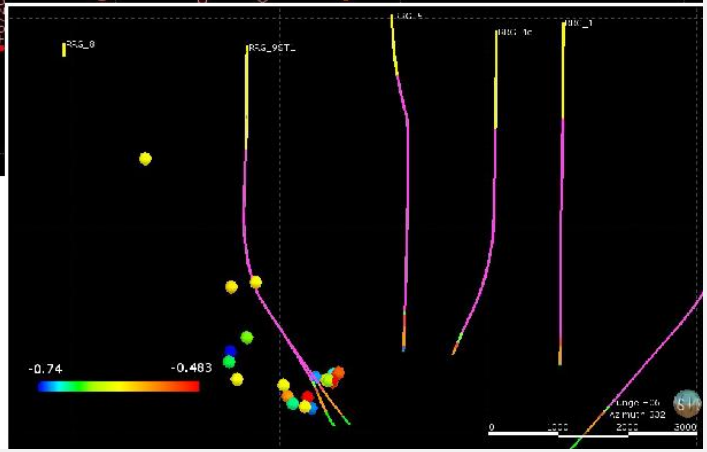
Day 2 and 3



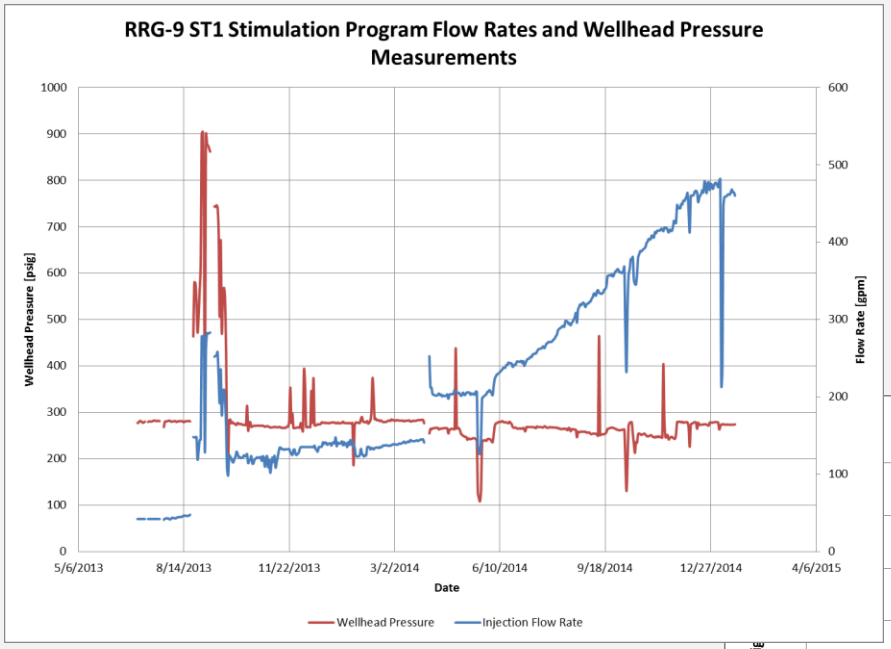
Seismic Activity During the Stimulation

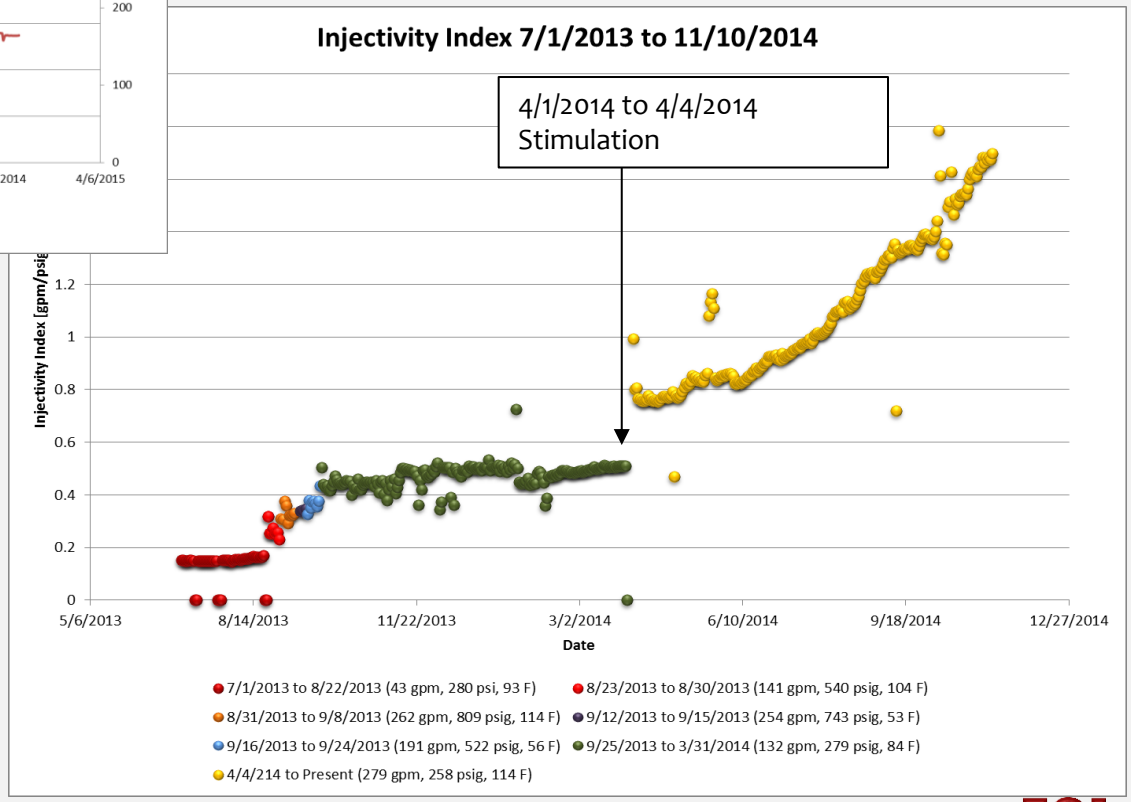




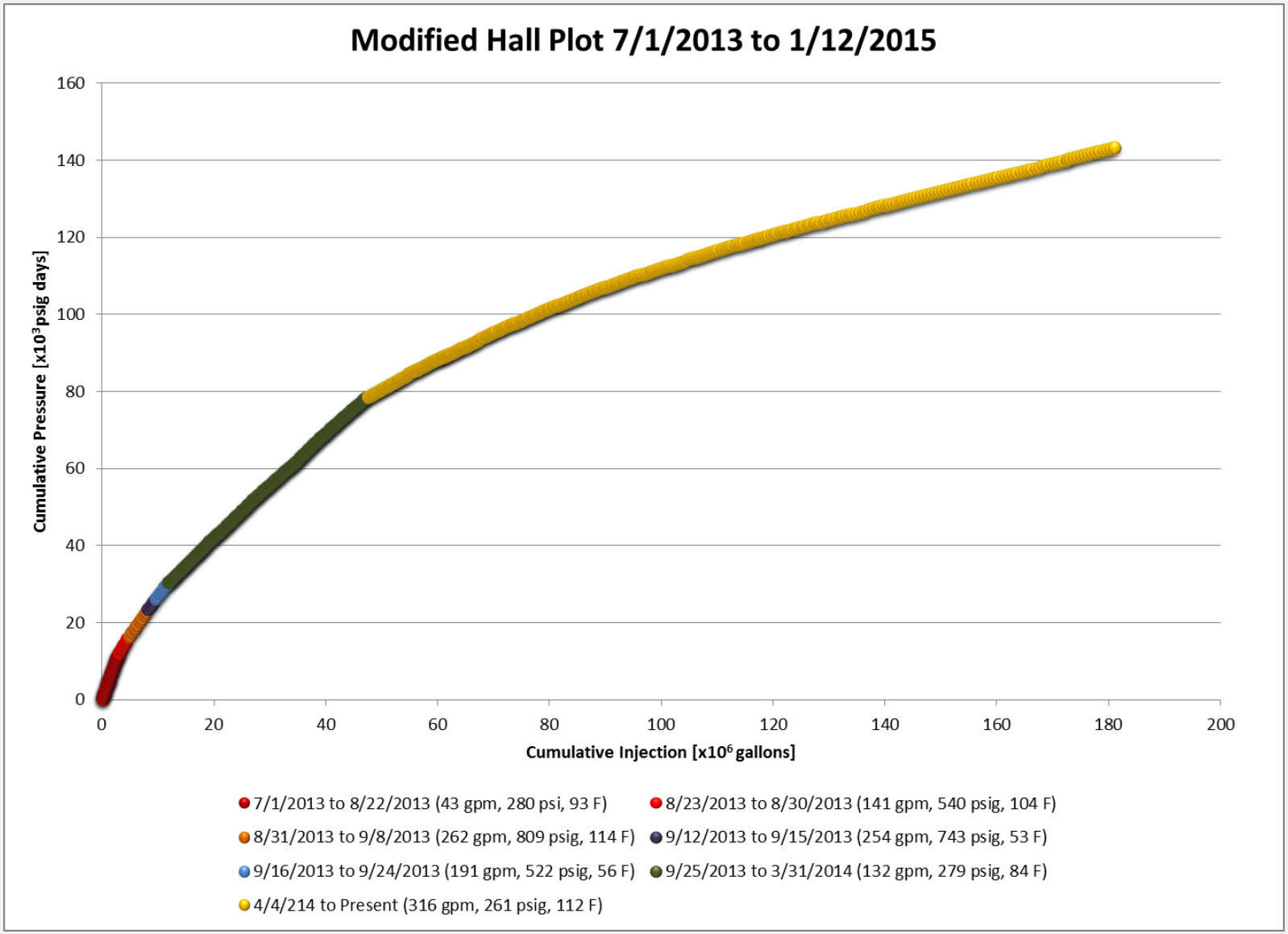


Post Stimulation 3 (4/1/2014 to 4/4/2014)

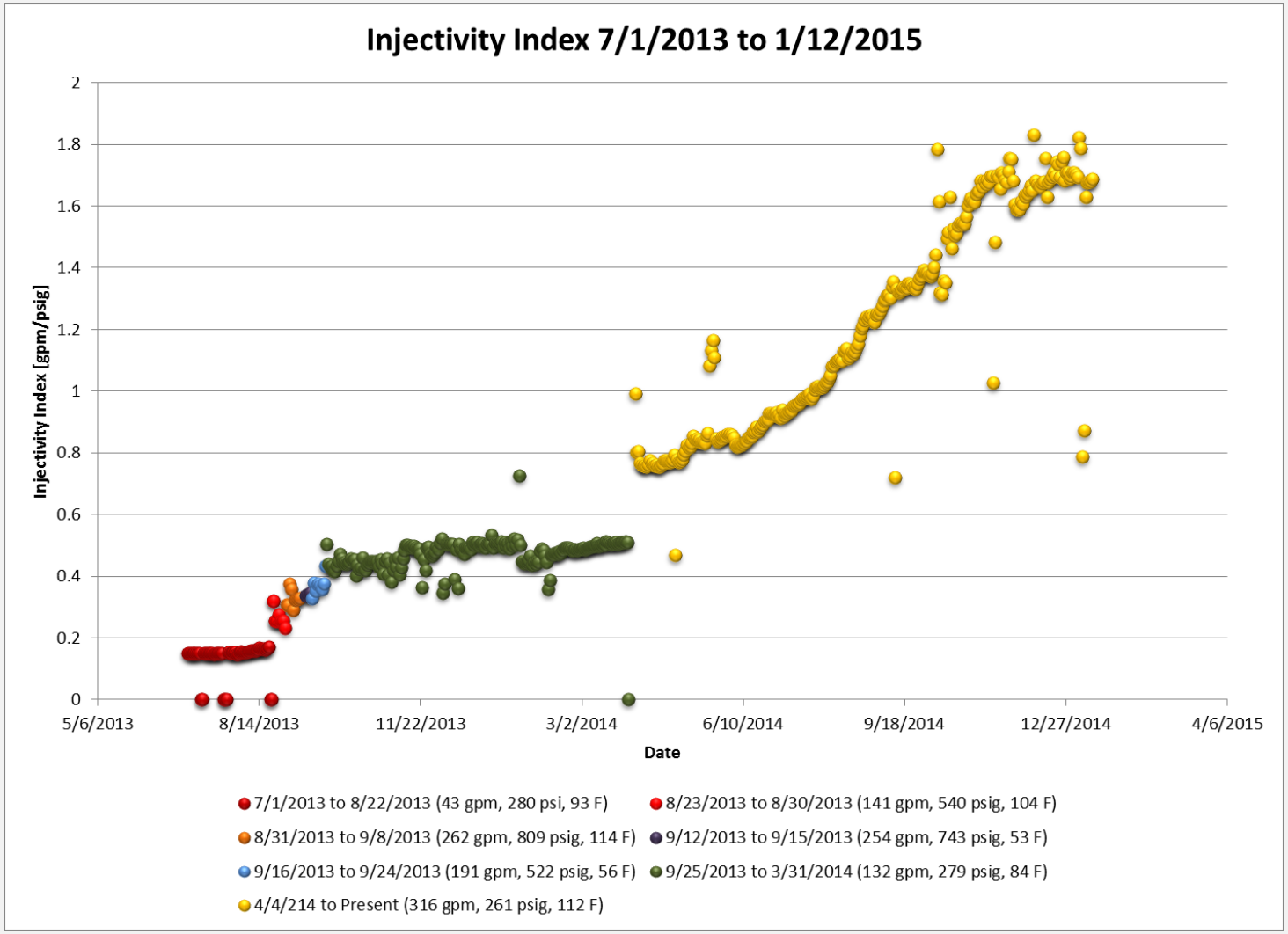




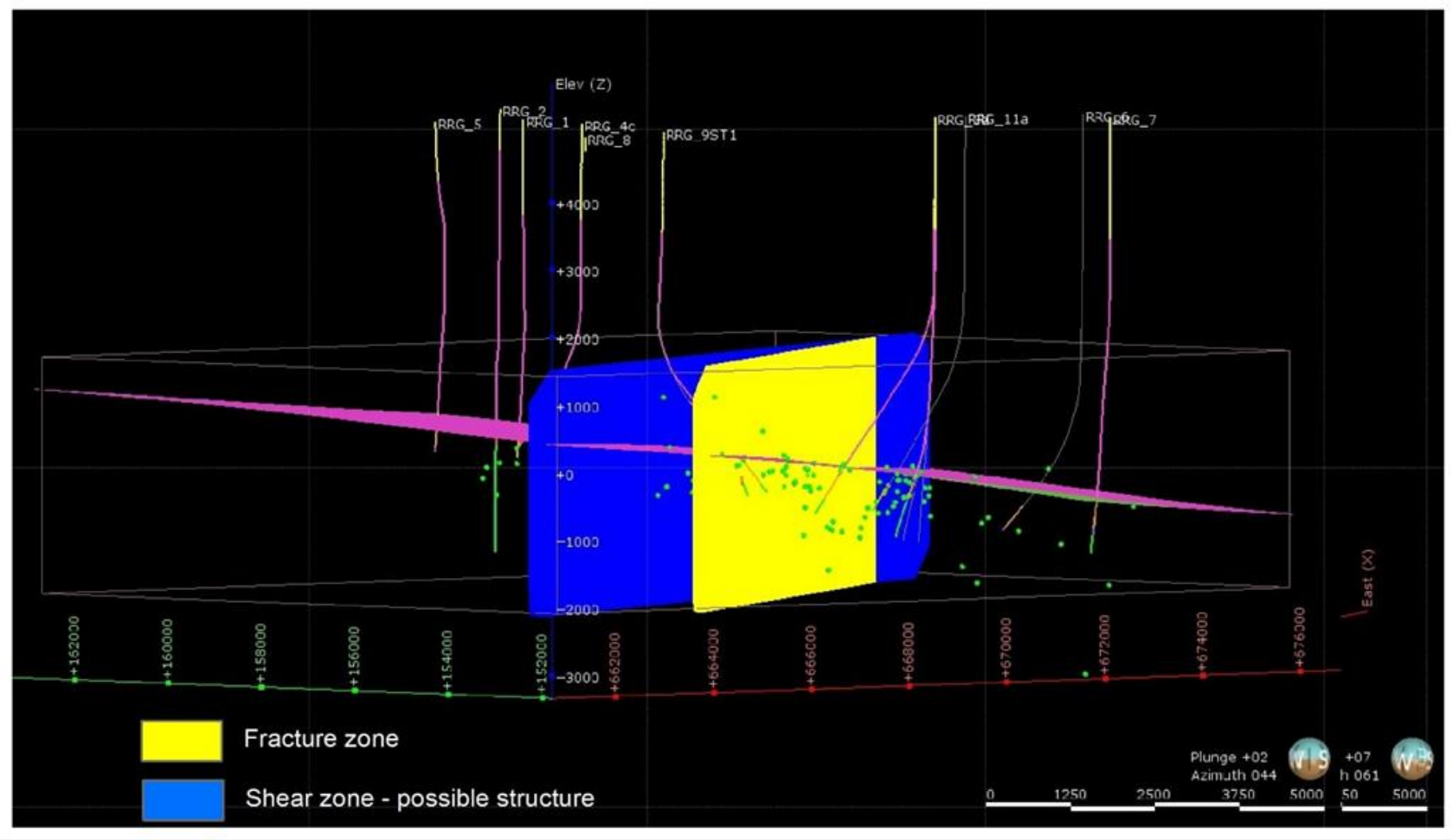
RRG-9 ST1 Stimulation Hall Plot



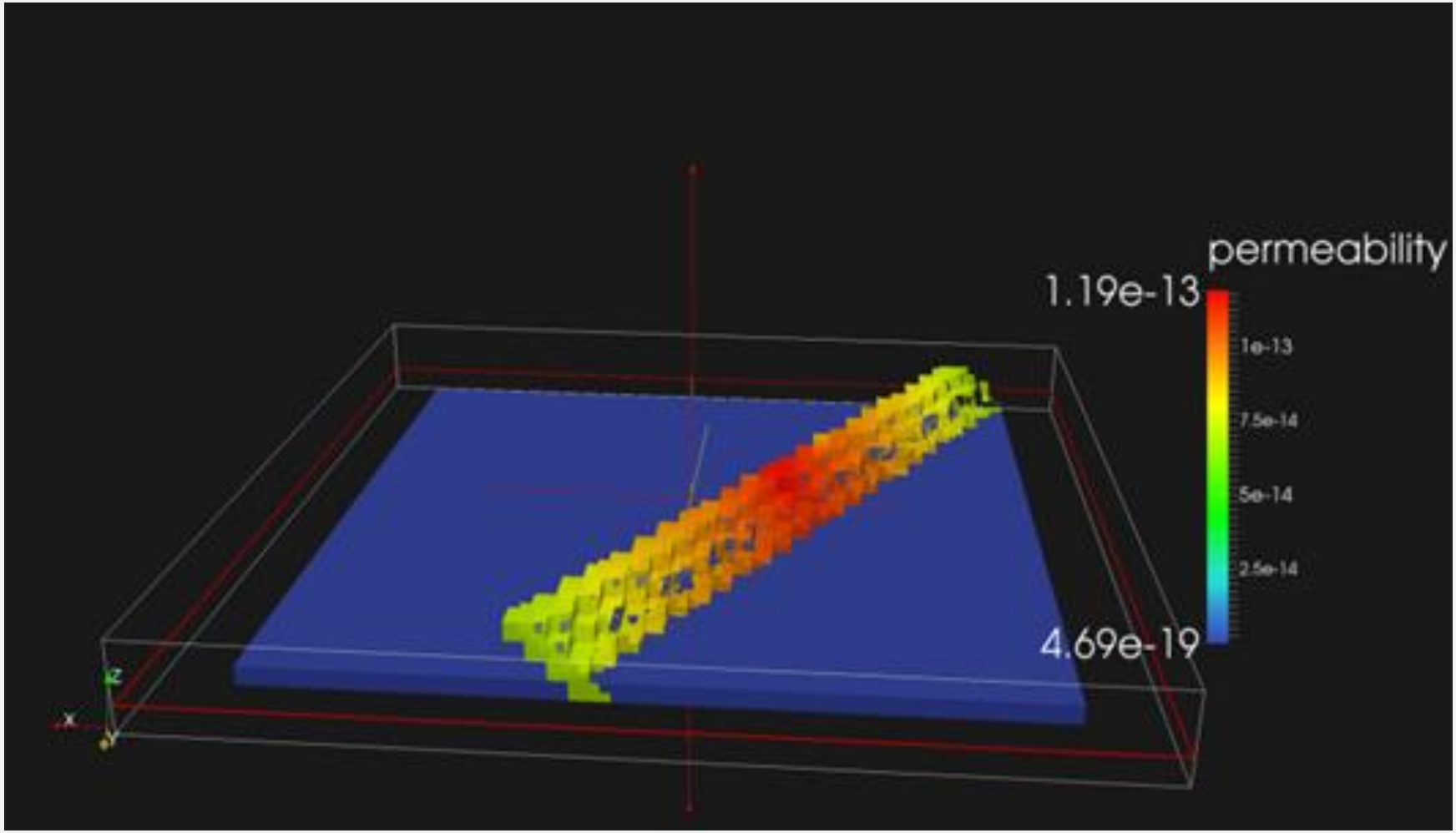
RRG-9 Stimulation Injectivity Plot



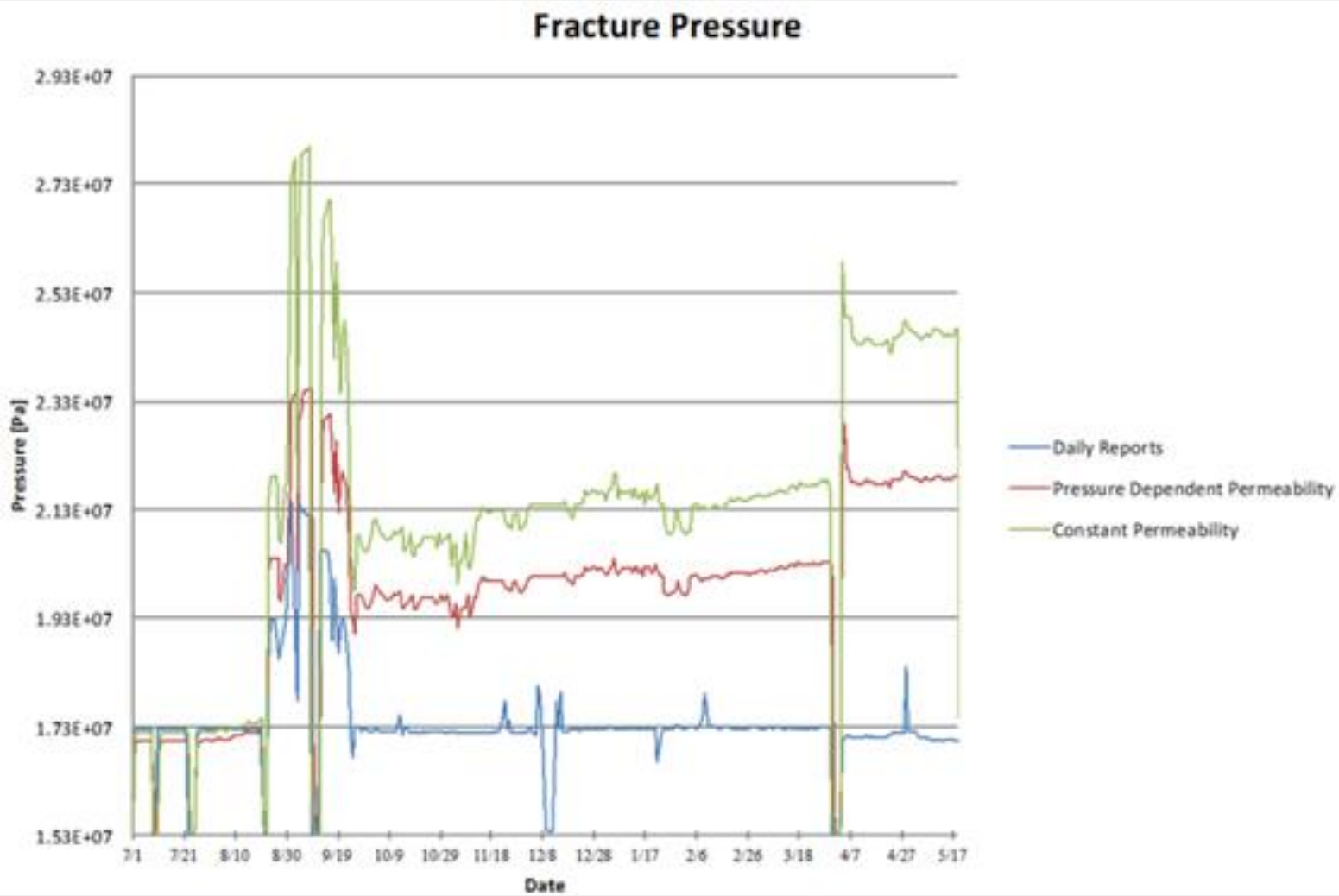
Conceptual Model



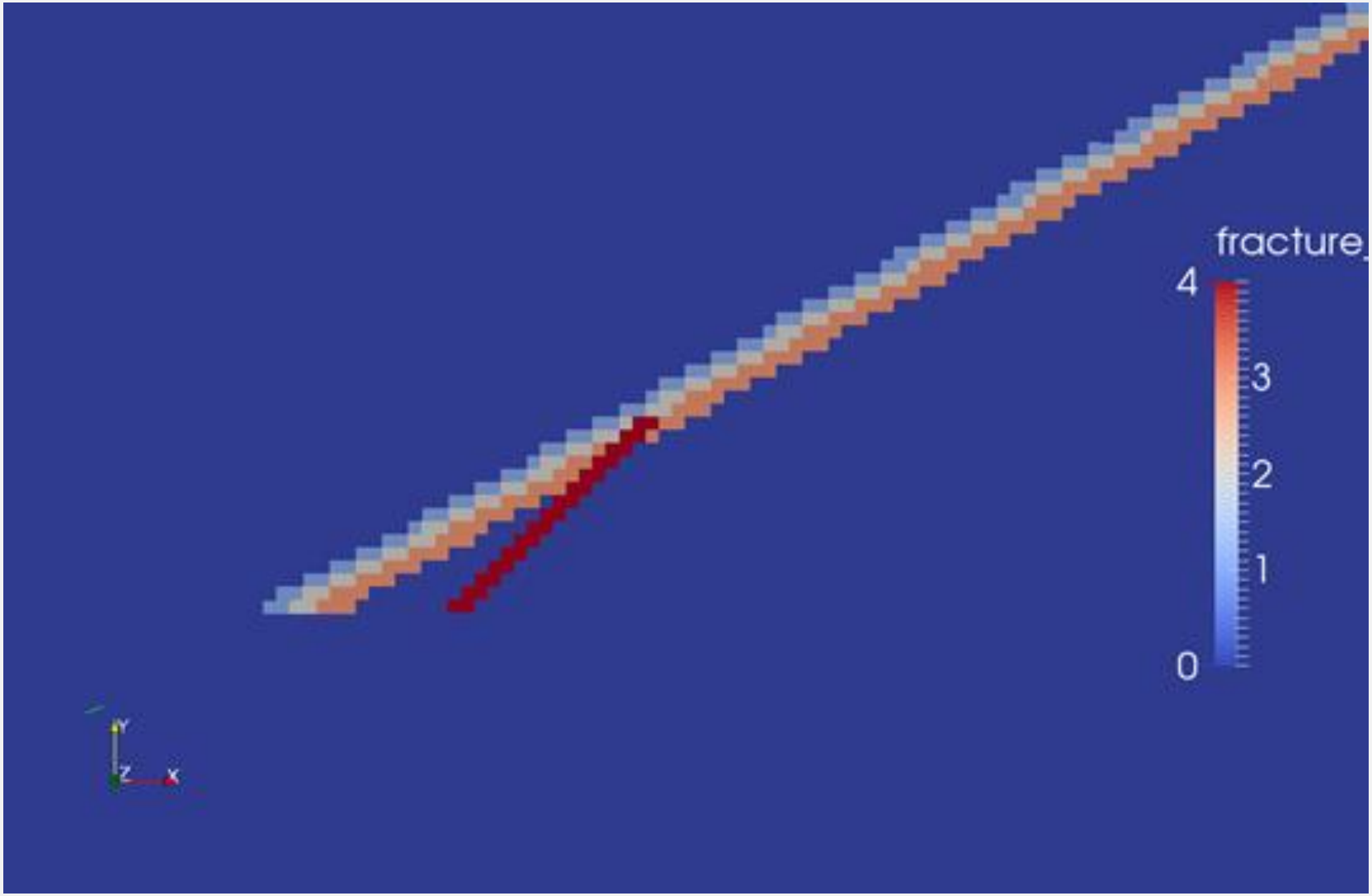
Idaho National Laboratory's FALCON Code



Single Fracture Model

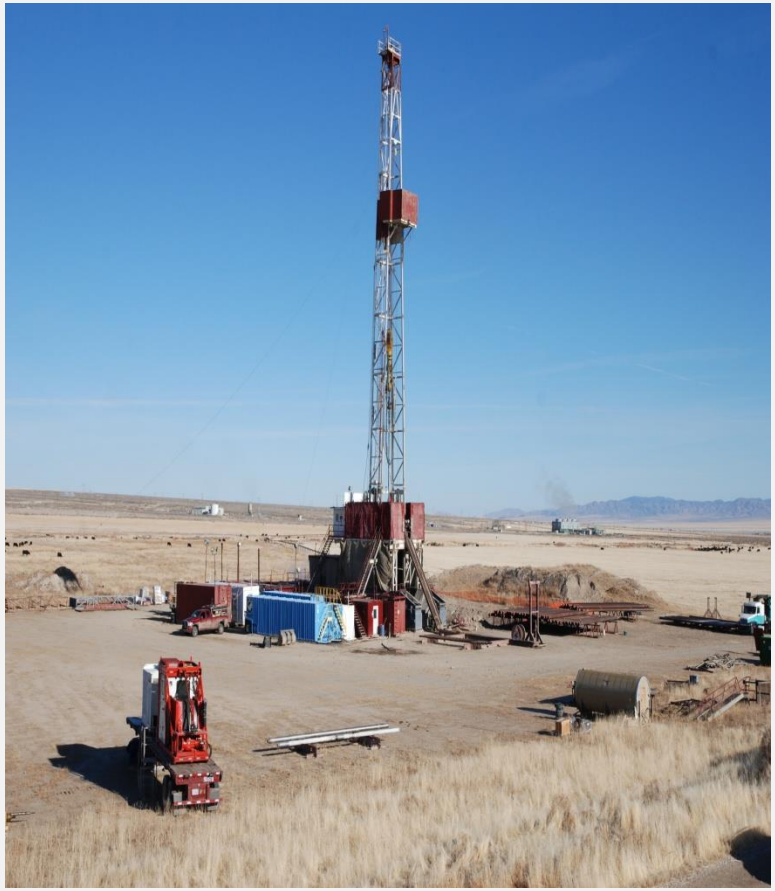


Revised RRG-9 ST1 Model

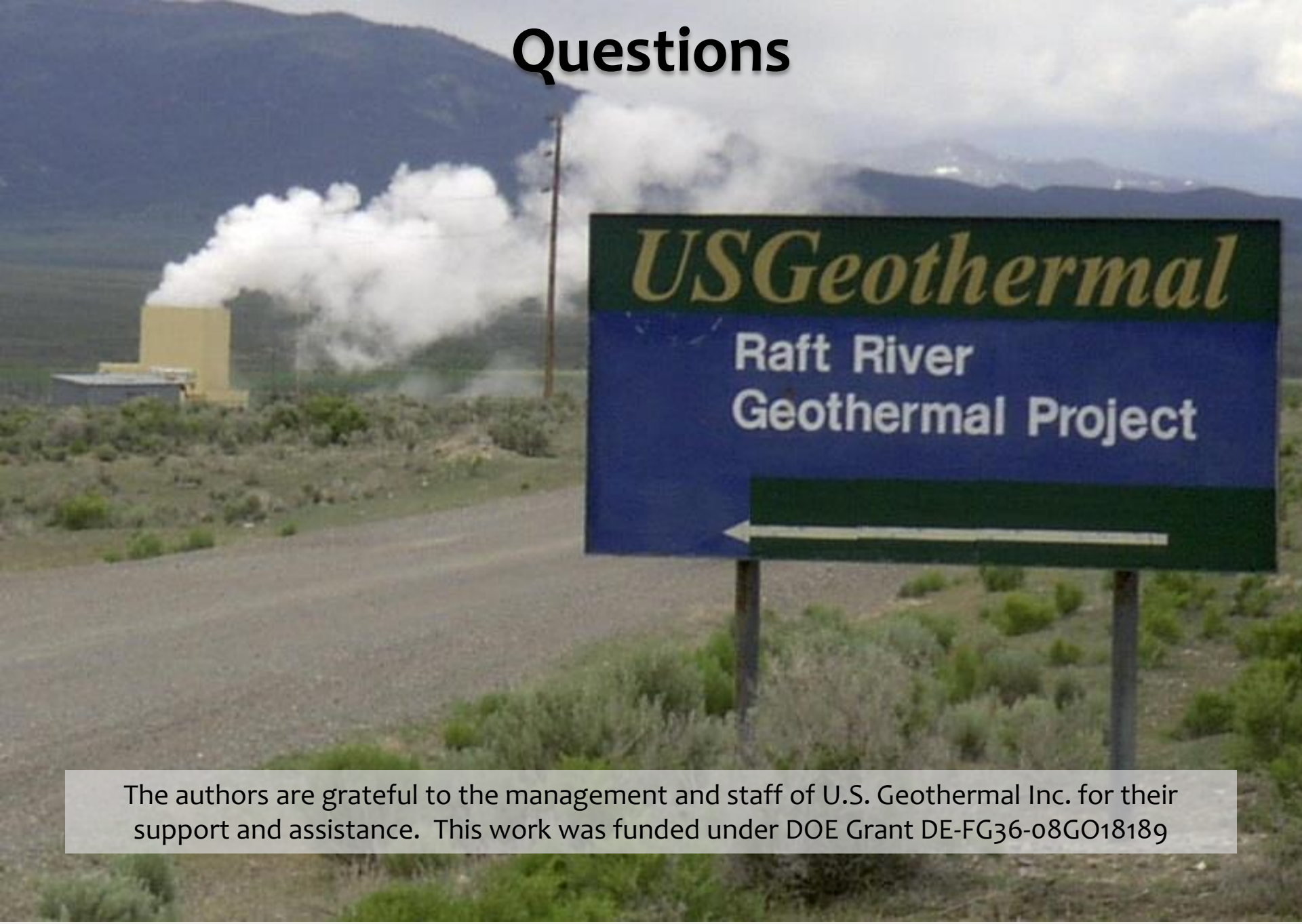


Conclusions

- Conducted a three stage stimulation program
  - Stage 1 high temperature injection
  - Stage 2 low temperature injection
  - Stage 3 high pressure injection
  - Injection flow rates have increased from 20-460 gpm (0.16 to 1.7 gpm/psi)
  - Permeability increases due dominantly to thermal cracking
- Developed a conceptual model
  - Model consists of 2 fracture zones based on earthquake, chemical and televiewer data.
- Hall plot and injectivity analysis
  - Indicates opening of new and/or existing fracture pathways around RRG-9 ST1.
- Numerical simulations being conducted using FALCON
- Future options
  - Cycling flow rates
  - High pressure injection



Questions



The authors are grateful to the management and staff of U.S. Geothermal Inc. for their support and assistance. This work was funded under DOE Grant DE-FG36-08GO18189