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NYSE CPN

A GENERATION AHEAD, *today*

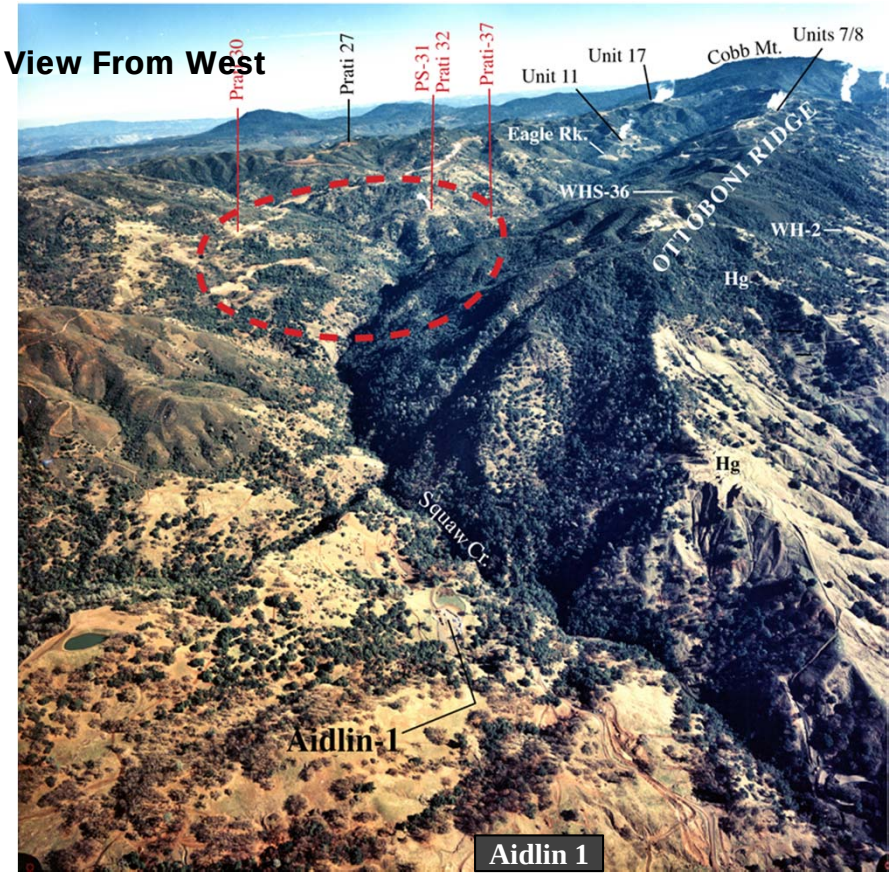
Northwest Geysers Enhanced Geothermal System Demonstration Project

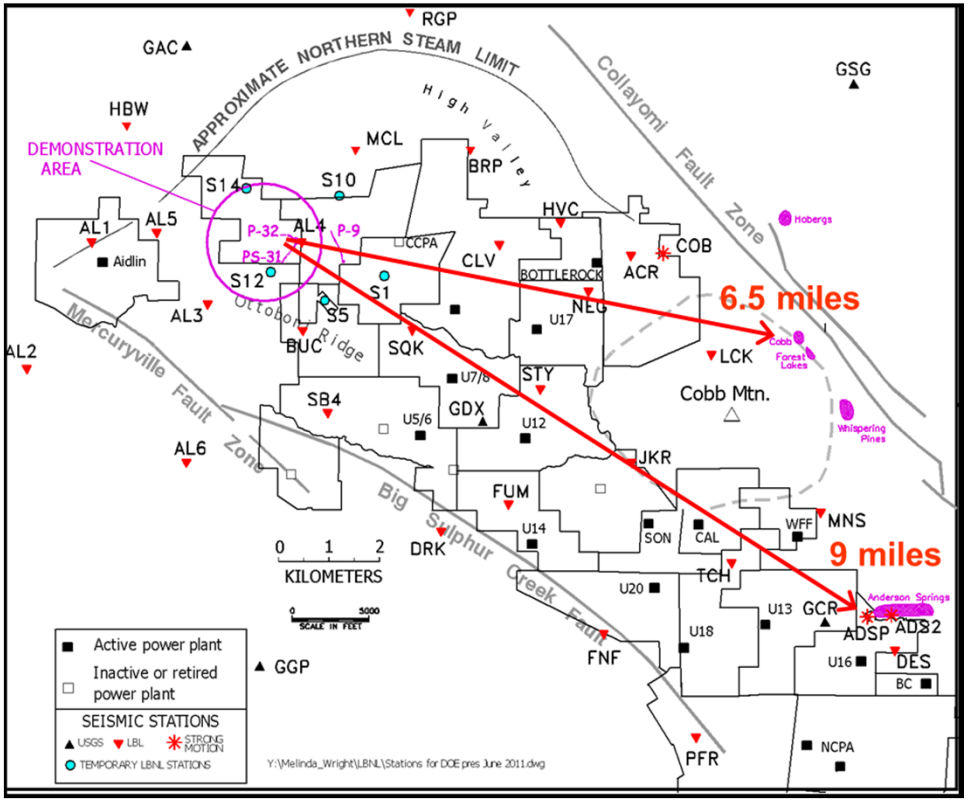
November 4, 2011

Calpine Corporation's Second Public Informational Meeting Reporting Progress on the U.S. Department of Energy's and Calpine's Enhanced Geothermal System (EGS) Demonstration Project Underway at The Geysers

Mark Walters, Senior Geologist
Craig Hartline, Senior Geophysicist

Northwest Geysers EGS Demonstration
Location





Selected Wells:

Prati State 31

656 °F 1983

Prati 32

600 °F 1985

750 °F 2010 - Deepened

NW Geysers explored in 1980's

CCPA Power Plant Operated from 1988 - 1996

High concentrations non-condensible gas

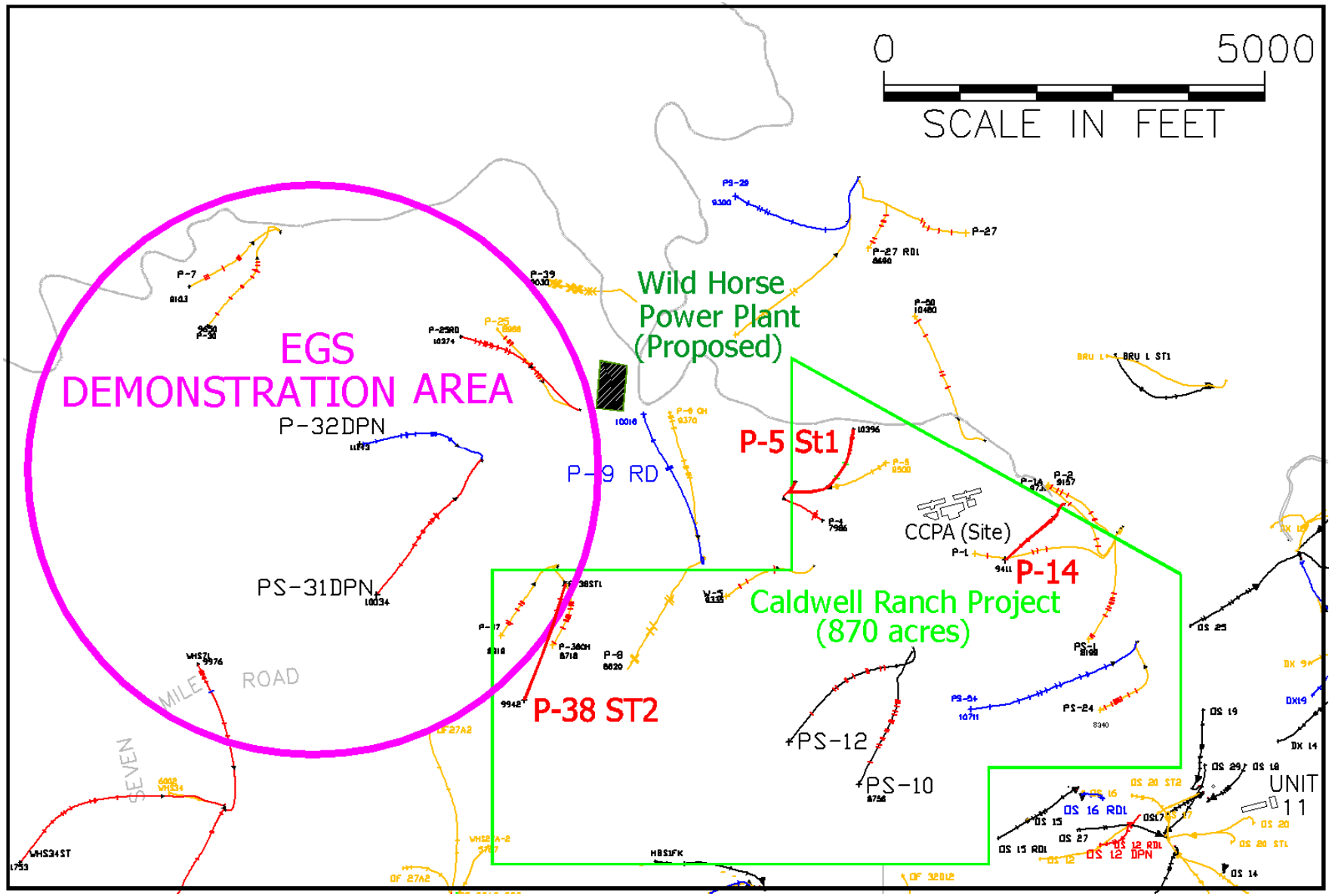
Corrosive chloride gas

Technology and process improvements …

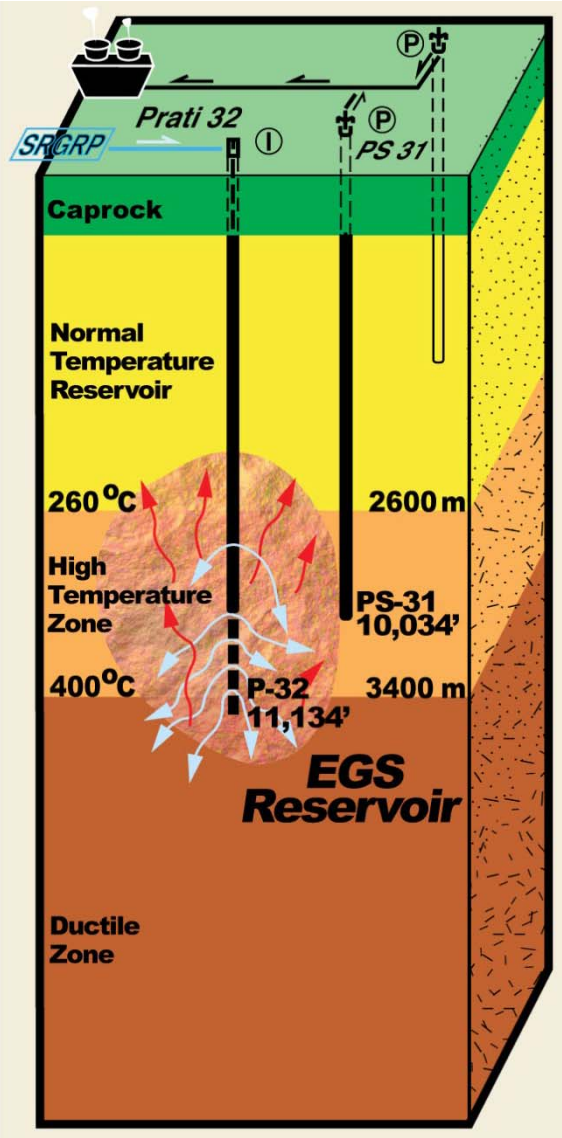
EGS demonstration is relatively remote from sensitive communities

Northwest Geysers EGS Demonstration

Location of adjacent DOE Caldwell Ranch Project



Northwest Geysers EGS Demonstration
Project Concept



Treated wastewater from the City of Santa Rosa is injected into the high temperature zone in Prati 32 to stimulate the production of quality steam in PS-31.

Motivations

- **Increase steam production.**
  Use under-produced NW Geysers area.
- **Mitigate very high NCG concentrations in high temperature reservoir.**
- **Stimulate wells to enhance permeability.**
- **Achieve 100% mass replacement.**
  Support sustained electrical production for future development.
- **Address public concerns on injection-induced seismicity.**

Northwest Geysers EGS Demonstration

Concept for Creating a Cloud of Fractures by Shear Reactivation

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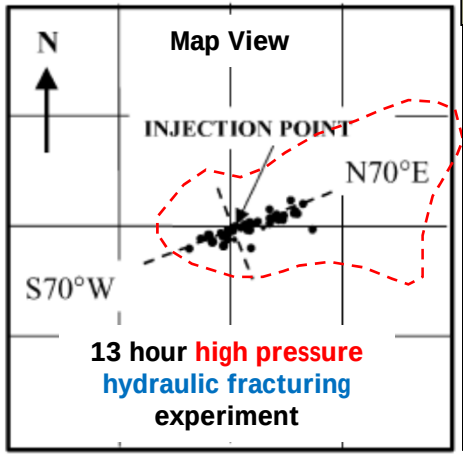
Modified From Rutqvist and Stephansson, 2003

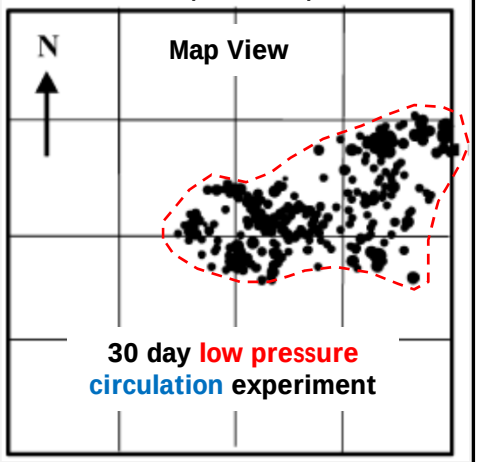


13 hour high pressure hydraulic fracturing experiment

Hijiori Hot Dry Rock Experiments

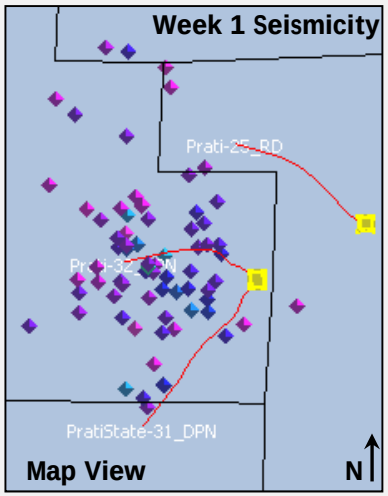
1988 Hydraulic Fracturing		1989 Circulation
250.0	Temperature (^{O}C)	250.0
33.0	Minimum Principle Stress (MPa)	33.0
0.5	Test Duration (days)	30.0
6.2	Maximum Flow Rate (m^3/min)	2.1
16.0	Maximum Wellhead Pressure (MPa)	7.4
1802.0	Well Depth (m)	1802.0
1802.0	Water Column Height (m)	1802.0
33.1	Maximum Reservoir Pressure (MPa)	24.5

Modified From Rutqvist and Stephansson, 2003



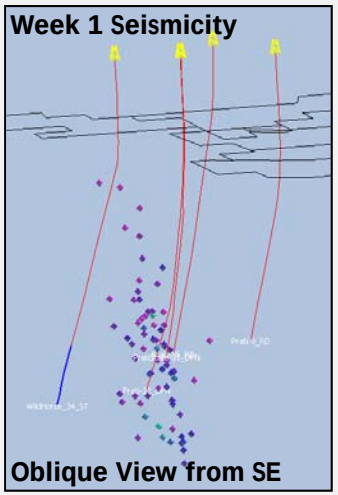
30 day low pressure circulation experiment

Maximum reservoir pressure slightly above the minimum principle stress



The Geysers Enhanced Geothermal System Demonstration

10/6/2011 24-Hour Start		2011-2012 Reservoir Stimulation
280.0	Temperature (^{O}C)	280.0
24.0	Minimum Principle Stress (MPa)	24.0
1.0	Test Duration (days)	360.0
4.2	Maximum Flow Rate (m^3/min)	3.0
0.0	Maximum Wellhead Pressure (MPa)	0.0
3396.0	Well Depth (m)	3396.0
1019.0	Estimated Water Column Height (m)	836.0
9.7	Maximum Reservoir Pressure (MPa)	7.9



Maximum reservoir pressure at Prati 32 will be much less than minimum principle stress (similar to Hijiori circulation experiment)

Low pressure injection avoids potentially damaging hydraulic fracturing and promotes gradual reactivation of existing fractures

Northwest Geysers EGS Demonstration
Induced Seismicity in nearby Prati 9 injection well

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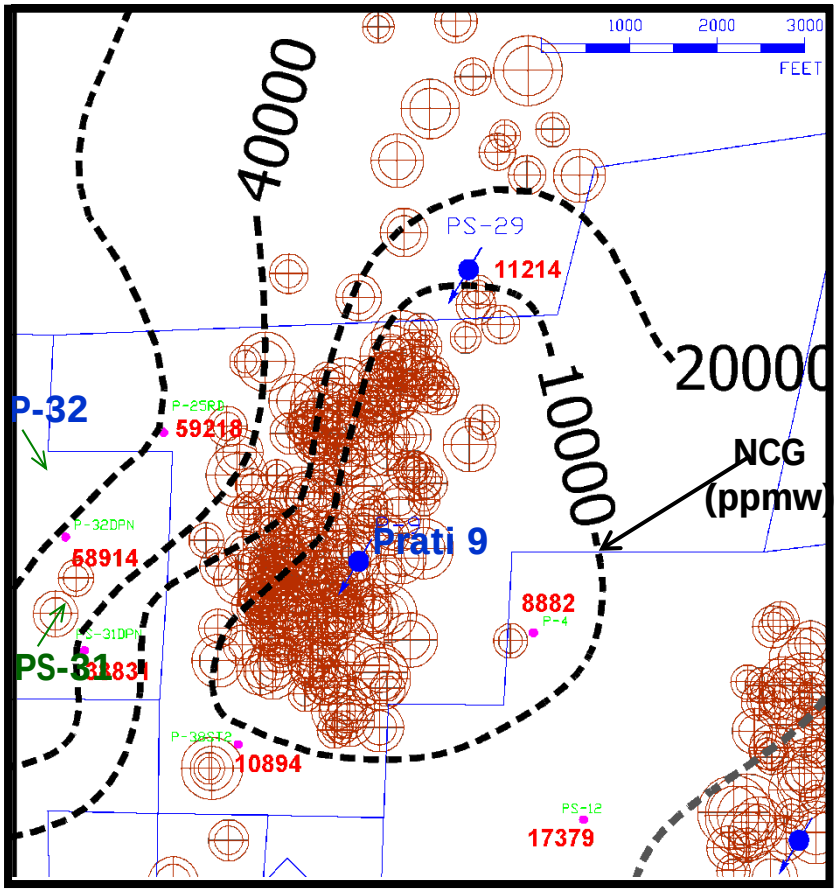
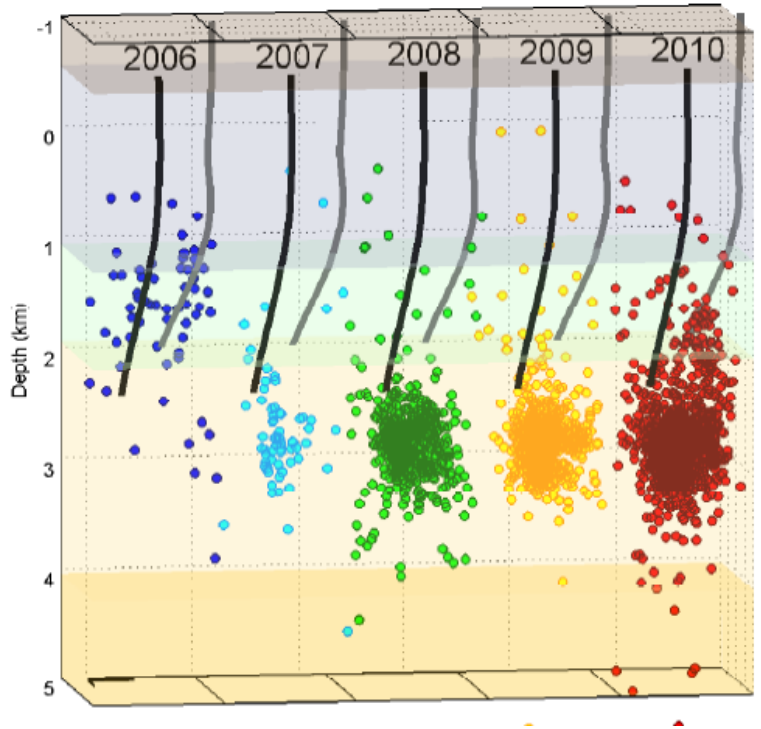
Current MEQ Monitoring of Nearby Injection

MEQ Events (M≥1.0) 10/1/2010 to 3/31/2011



Total year injection (million gallons)

Well	2006	2007	2008	2009	2010
Prati 9	0	32.6	325.1	332.8	337.2
Prati State 29	0	0	0	0	208.7



Characterization of induced seismicity near Prati 9 injection well (To be published at GRC Proceedings 2011, Gisela Viegas Fernandes and Lawrence Hutchings, LBNL.)

Northwest Geysers EGS Demonstration

Production-Injection Well Pair: P-PS-31 and P-32

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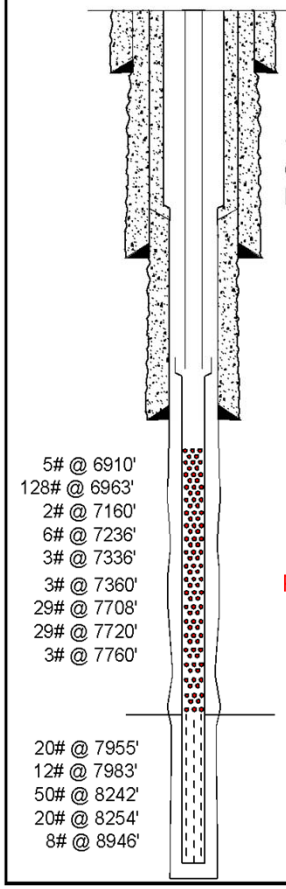
Prati State 31



All depths relative to KB (GL+30').

(30" Cemented Conductor to 58' in 36" hole Not Shown)

-290', 20" 94# K-55. 26" hole. Cemented.

-10-3/4" Tieback. 60 jts 45.5# K-55 10-5/8" with 9-5/8"x10-5/8" crossover and bottom 2 jts 9-5/8" 40# K-55 stabbed in at 2503'. Bottom of 10-3/4" at 2425'. Good cement job.

-2705', 13-3/8" buttress casing, 6 jts 68# K-55, 64 jts 61# K-55. 17-1/2" hole. CBL showed cement up to 1215', perfed at 1212' and squeezed cement.

-5523', 7" 26# L80 BTC hangdown liner.

-5482', Top of 8-1/8" stab-in receptacle (36# N80, 5545-5482').

-5545', Top of 7" liner.

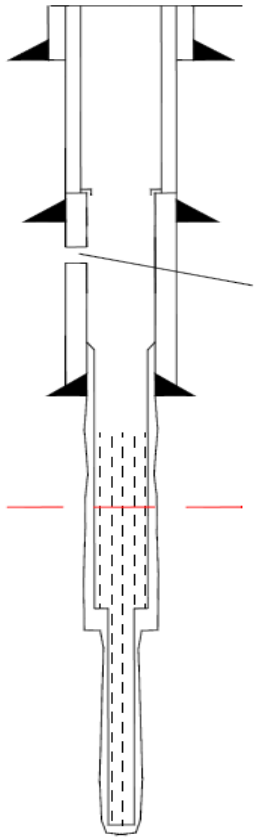
-5720', 9-5/8" buttress casing, 12 jts 40# SS95, 24 jts 40# N80, 22 jts 40# K-55, 21 jts 36# K-55. 12-1/4" hole. Hung on 13-3/8" at 2503'. Good cement job.

Perforate blank 7" liner from 6776' to 7696' (GL).

±7900': Top of High Temperature Zone (500°F.)
Slots from 7,879'-10,000'

-10,000', Bottom of 7" liner.
-10,034', M.D., 8-1/2" open hole.

Prati 32



DESCRIPTION

(30" Cemented Conductor Not Shown)

-322', 26" Hole, 22" 86.6# Line Pipe. Cemented.

-2805', Tieback, 13-3/8" 61# K-55 (73 jts) at 2713', with 11-3/4"x 13-3/8" crossover & 2- 11-3/4" stab in joints. Good cement job.

-2993', 20-1/2" Hole, 16-1/8" 95.6# N-80 (13 jts), 16" 84# K-55 (17 jts), 16" 75# K55 (41 jts) Casing.
No cement returns to surface, top job to 327'.

Swedged and milled collapsed liner at 3047' resulting in hole. Unintended sidetrack (481') through hole. Cement back hole.

-5904', Top of Liner.

-6113', 14-3/4" Hole, 11-3/4" 54# K-55 (17 jts), 60# K-55 (26jts), 60# N-80 (21 jts), 60# SS-95 (14jts) Casing. Little to no cement returns. Hung on Midway 16x11-3/4" double slip hanger at 2805'. **(SEE ORIGINAL WELL COMPLETION)

- ±8400' Top Of High Temperature Zone (500°F.)

7", 29# L80 slotted liner 10,004'-11,115'
8-5/8" 40# L80 slotted liner 6801'-10,004'
8-5/8" 40# L80 blank liner 5904'-6801'

-10,004 M.D., 10-5/8" Open Hole.
11,143 M.D., 8-1/2" Open Hole.

Flow Testing		Geochemistry			
KPH (klbs/hr)	WHP (psig)	SIWHP (psig)	NCG (wt.%)	H_2S (ppmw)	Cl (ppmw)
55	100	323	4.7	1299	135

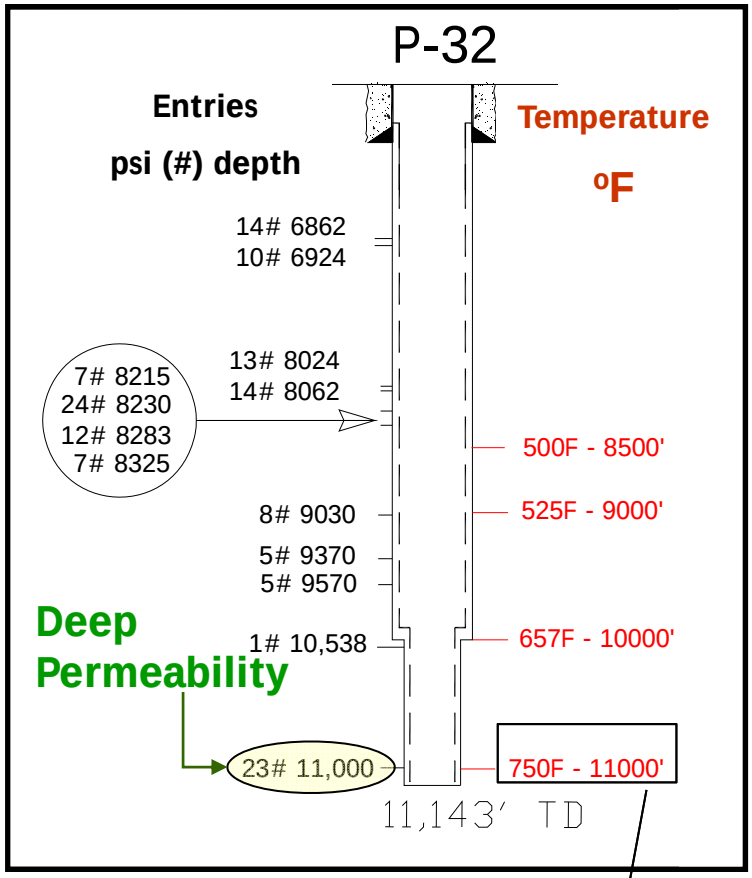
	Flow Testing			Geochemistry		
	KPH (klbs/hr)	WHP (psig)	SIWHP (psig)	NCG (wt.%)	H_2S (ppmw)	Cl (ppmw)
	84	100	340	5.9	1380	72

Northwest Geysers EGS Demonstration
Deepening of Prati 32

Average bit condition after 300’ of air drilling for about 30 hours at the Geysers.

Prati 32 final bit condition after 105’ of air drilling for 17 hours to TD (11,134’).

Northwest Geysers EGS Demonstration
Recompletion of Prati 32 as an Injector

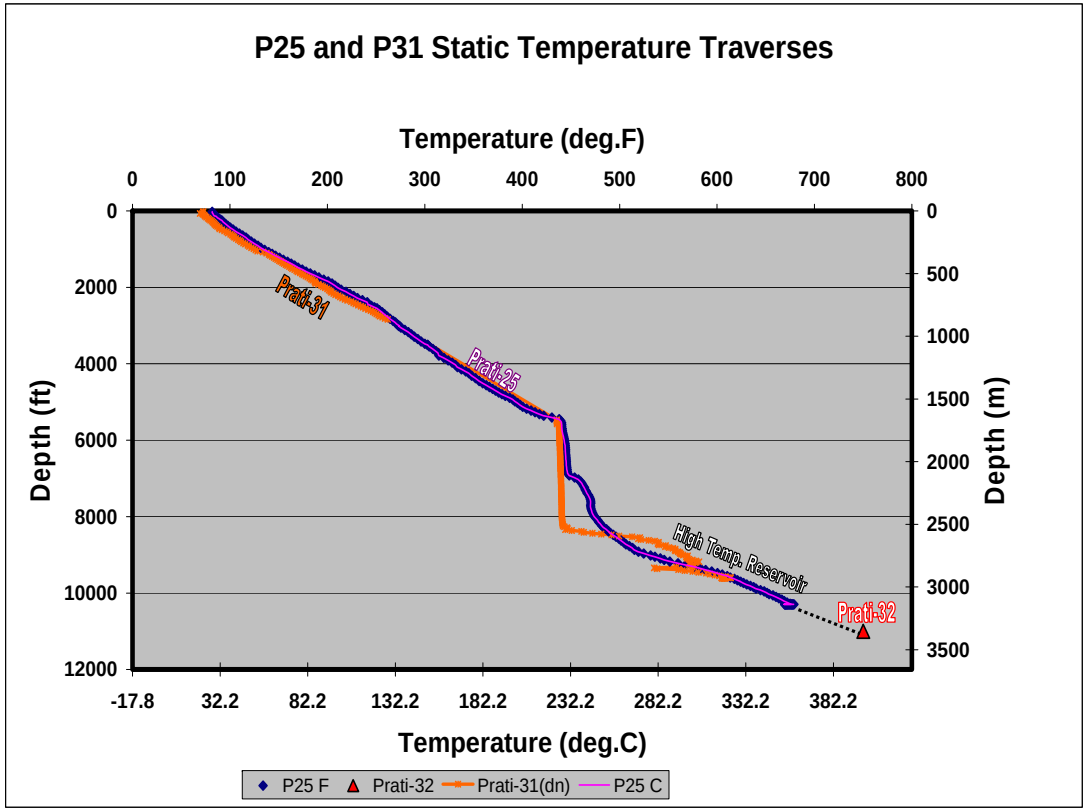


Maximum temperature recorded with a Kuster mechanical tool

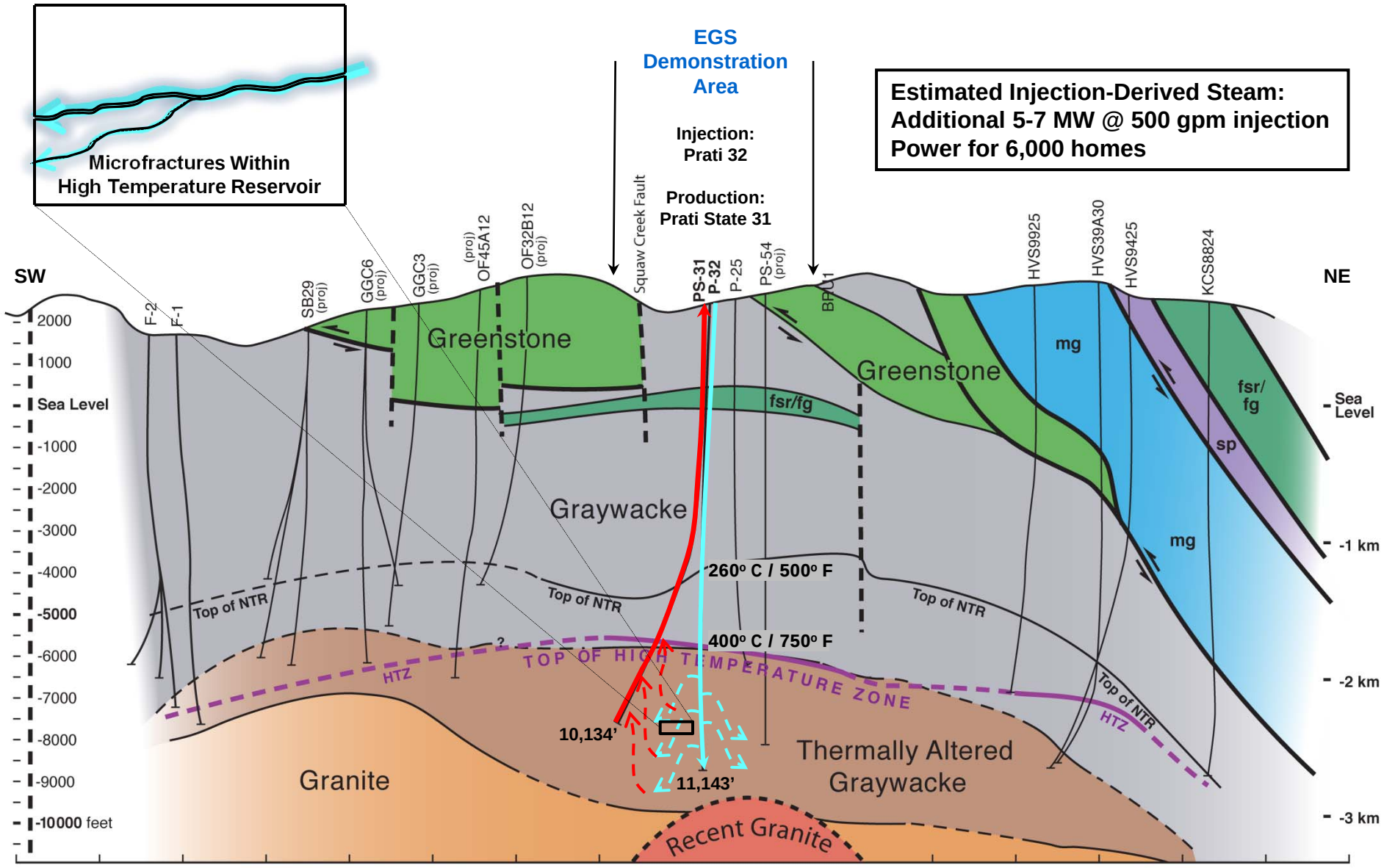
Based on Well Logging Results

P-32 was re-completed as an injector

PS-31 was re-completed as a producer



Northwest Geysers EGS Demonstration
Geologic Section and EGS Approach



Northwest Geysers EGS Demonstration
Injection Pipeline completed December 2010

Injection Water Pipeline for EGS Demonstration Injection Well

- Approximately 4800 feet of 10 in. and 12 in. diameter pipeline to P-32 pad were constructed. Cost: $1.97M.
- Pipeline successfully hydro-tested to 1125 psi.
- Prati 32 will use about 200 to 800 gpm for the stimulation experiment. Injection pipeline capacity = 1200 gpm.
- Instrumentation of PS-31 and P-32 completed.
- Injection Flow rate data are updated within Calpine internal system – PI Data Capture – on about 15 second intervals.
- Injection flow rates and seismic events are being continuously monitored since the stimulation began on October 6, 2011.

Northwest Geysers EGS Demonstration
Seismic Monitoring Networks

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Permanent Monitoring / Real-Time Processing

▼ **Lawrence Berkeley National Laboratory**
Installed in 2003; continued upgrades
31 stations; M 1.0 threshold
Primary Contact: Dr. Ernie Major (LBNL)

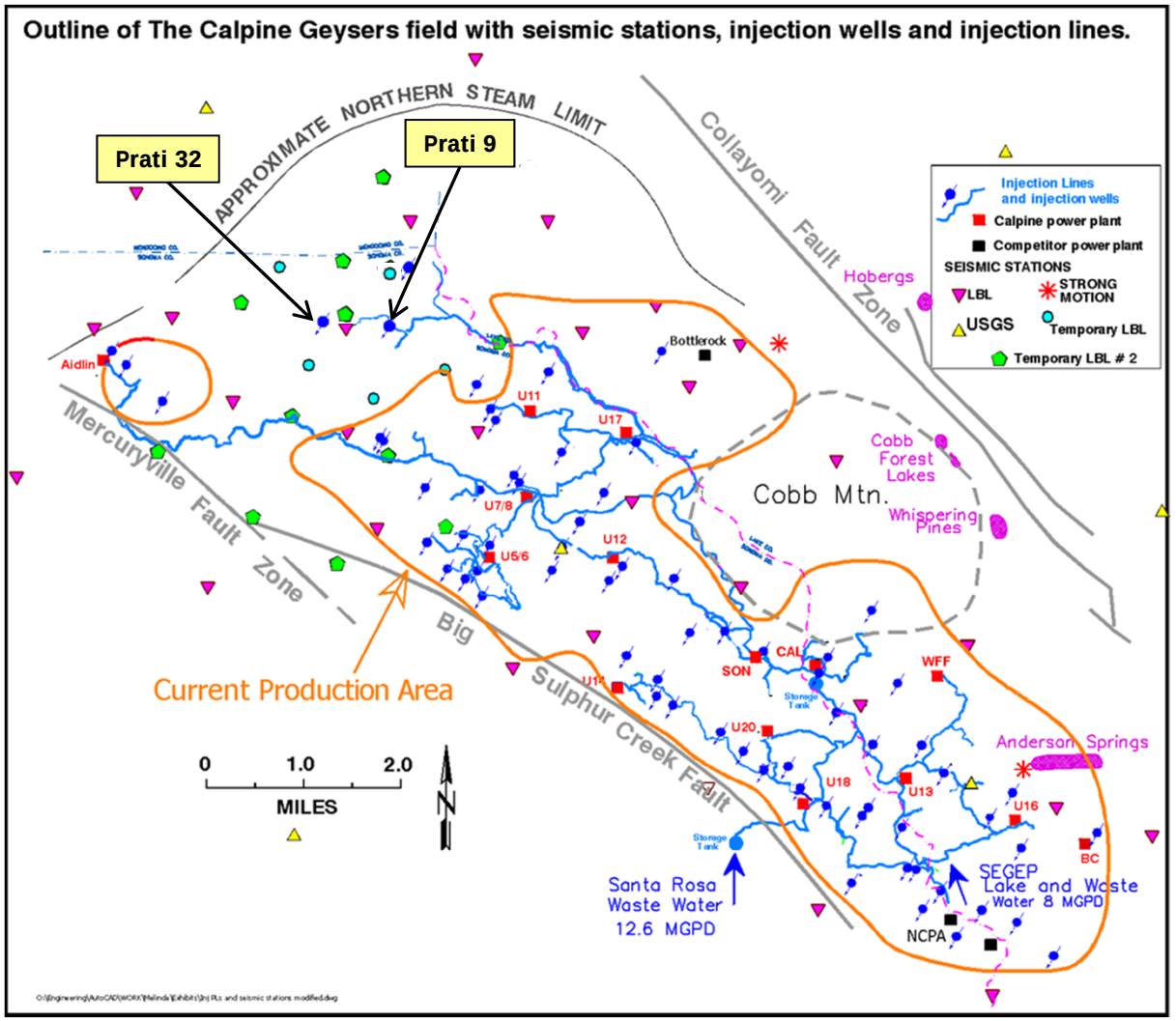
△ **US Geological Survey**
Installed in 1970's; some upgrades
5 stations; M 1.5 threshold
Primary Contact: David Oppenheimer (USGS)

✳ **Strong motion instruments: 3**
Installed in 2003; perceived shaking
3 stations; ~0.1% g threshold
Primary Contact: Jim Cullen (USGS contracted)

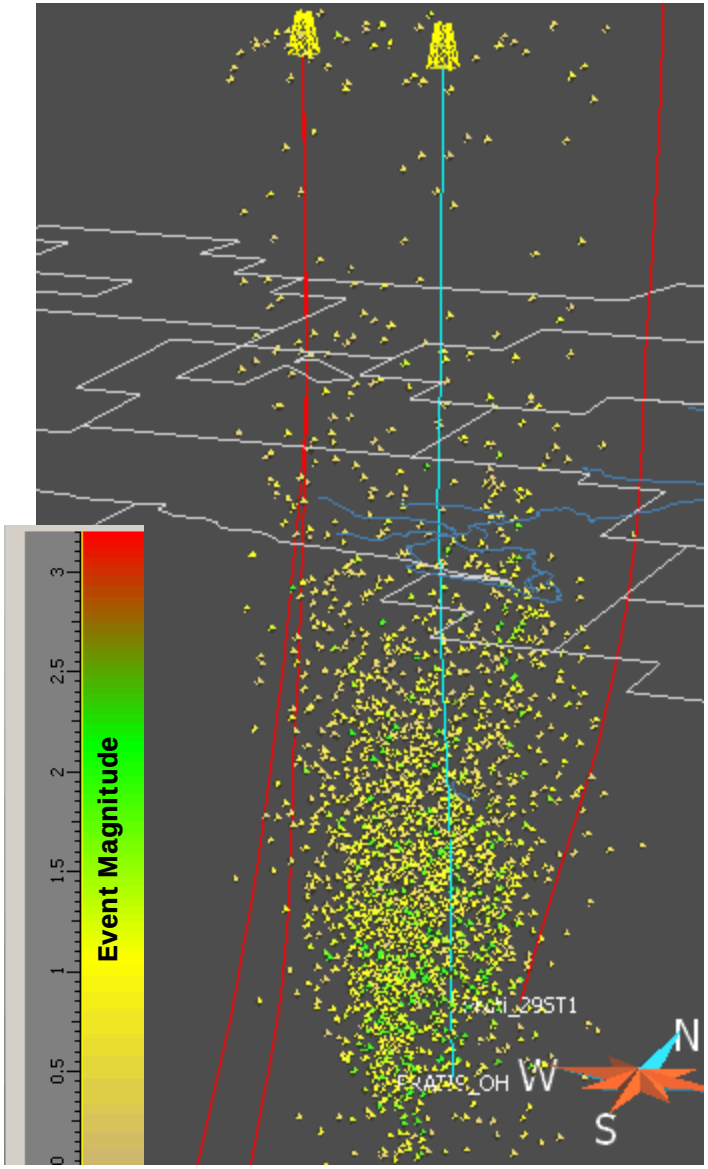
Project Dedicated Temporary Monitoring

○ **Lawrence Berkeley National Laboratory**
Installed in 2010, ~ M1.0 threshold
5 stations; 4-6 months storage
Primary Contact: Dr. Ernie Major (LBNL)

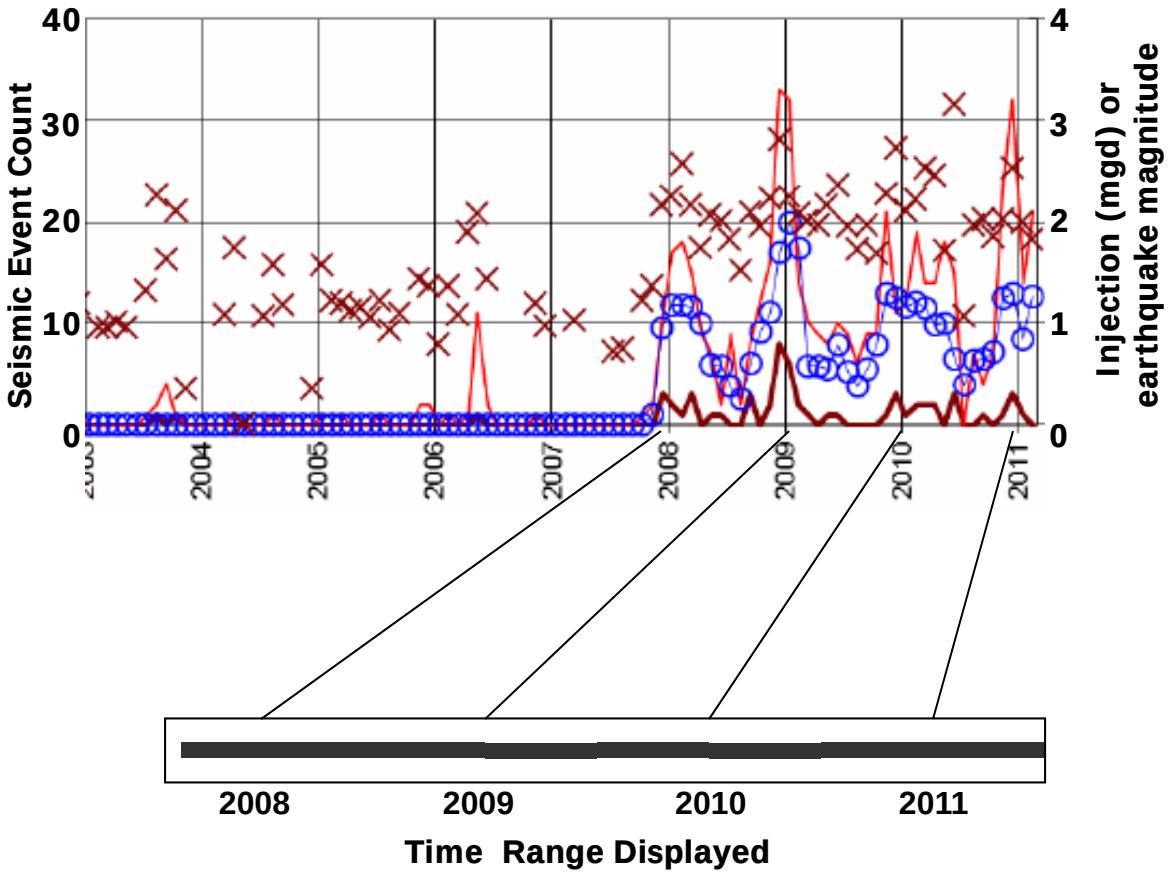
⬟ **Lawrence Berkeley National Laboratory**
Installed in 2011, ~ M1.0 threshold
9 stations; 3-4 weeks storage
Primary Contact: Dr. Lawrence Hutchings (LBNL)



Northwest Geysers EGS Demonstration
Prati 9 Injection Response

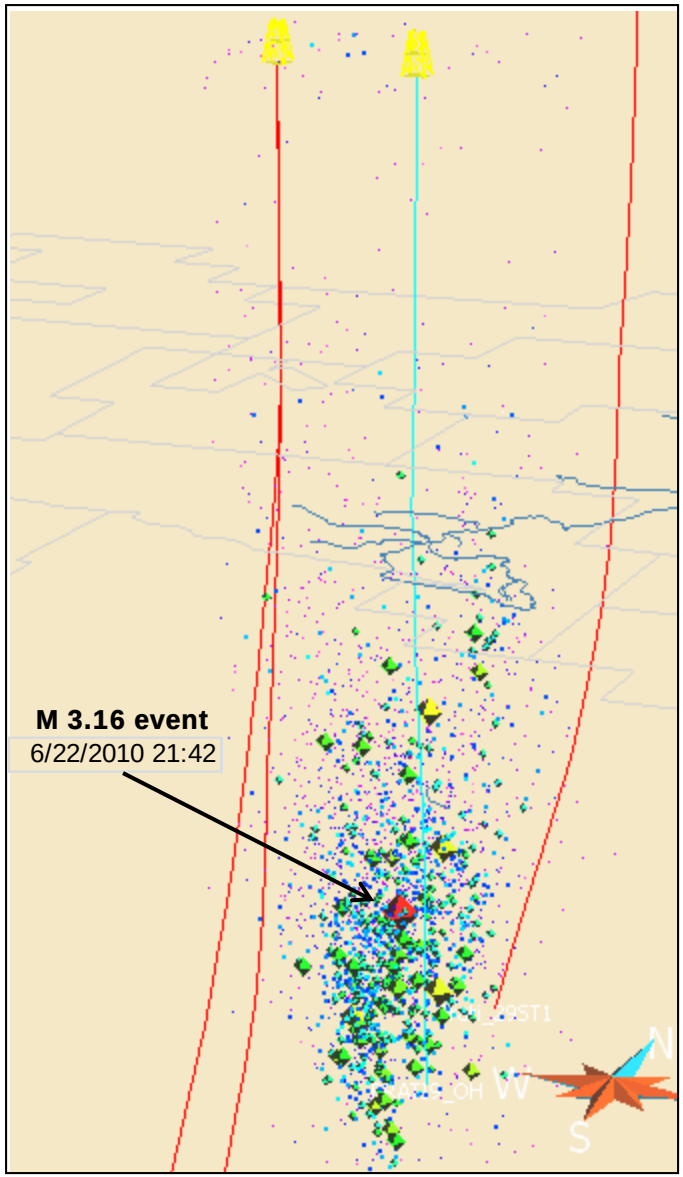


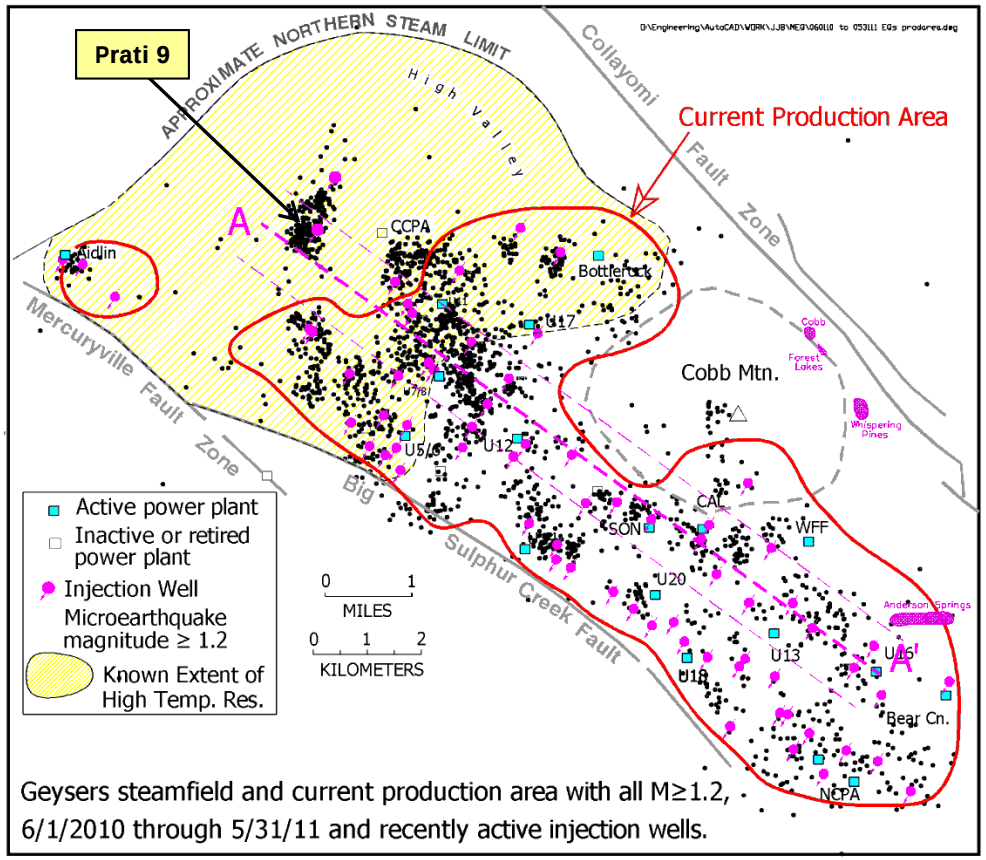
Blue circles: monthly water injection
Red line: monthly count of earthquakes of M>=1.2
Brown line: monthly count of earthquakes of M>=2.0
Brown X's: maximum magnitude each month



Northwest Geysers EGS Demonstration

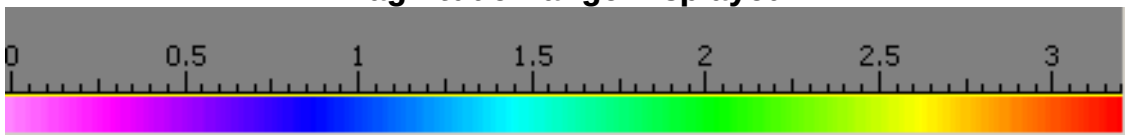
Prati 9 Injection Response





Geysers steamfield and current production area with all M≥1.2, 6/1/2010 through 5/31/11 and recently active injection wells.

Magnitude Range Displayed



Northwest Geysers EGS Demonstration
Prati 9 Injection Response

Prati 9 M 3.16 event

Cobb Strong Motion Station

Peak Ground Acceleration

26 cm/sec² (2.6% g) MMI IV

Peak Ground Velocity

0.51 cm/sec MMI II-III

One felt report

Anderson Springs Strong Motion Station

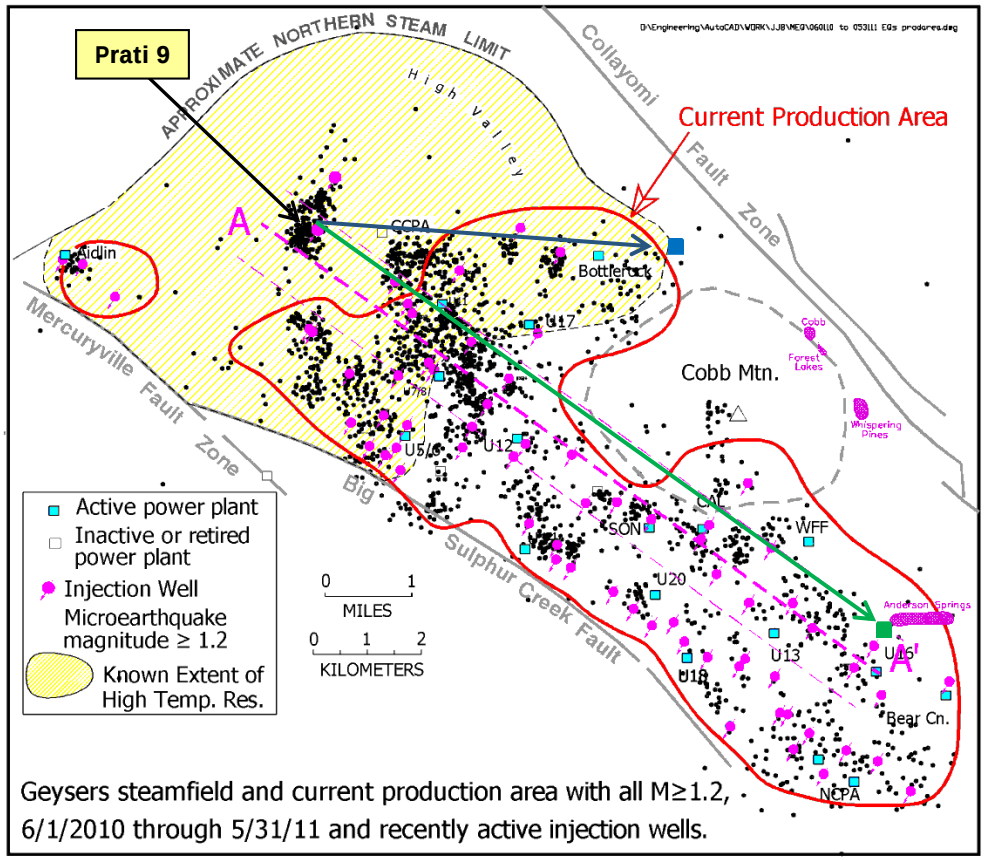
Peak Ground Acceleration

6.7 cm/sec2 (0.7% g) MMI II

Peak Ground Velocity

0.12 cm/sec MMI II

No report



Geysers steamfield and current production area with all M≥1.2, 6/1/2010 through 5/31/11 and recently active injection wells.

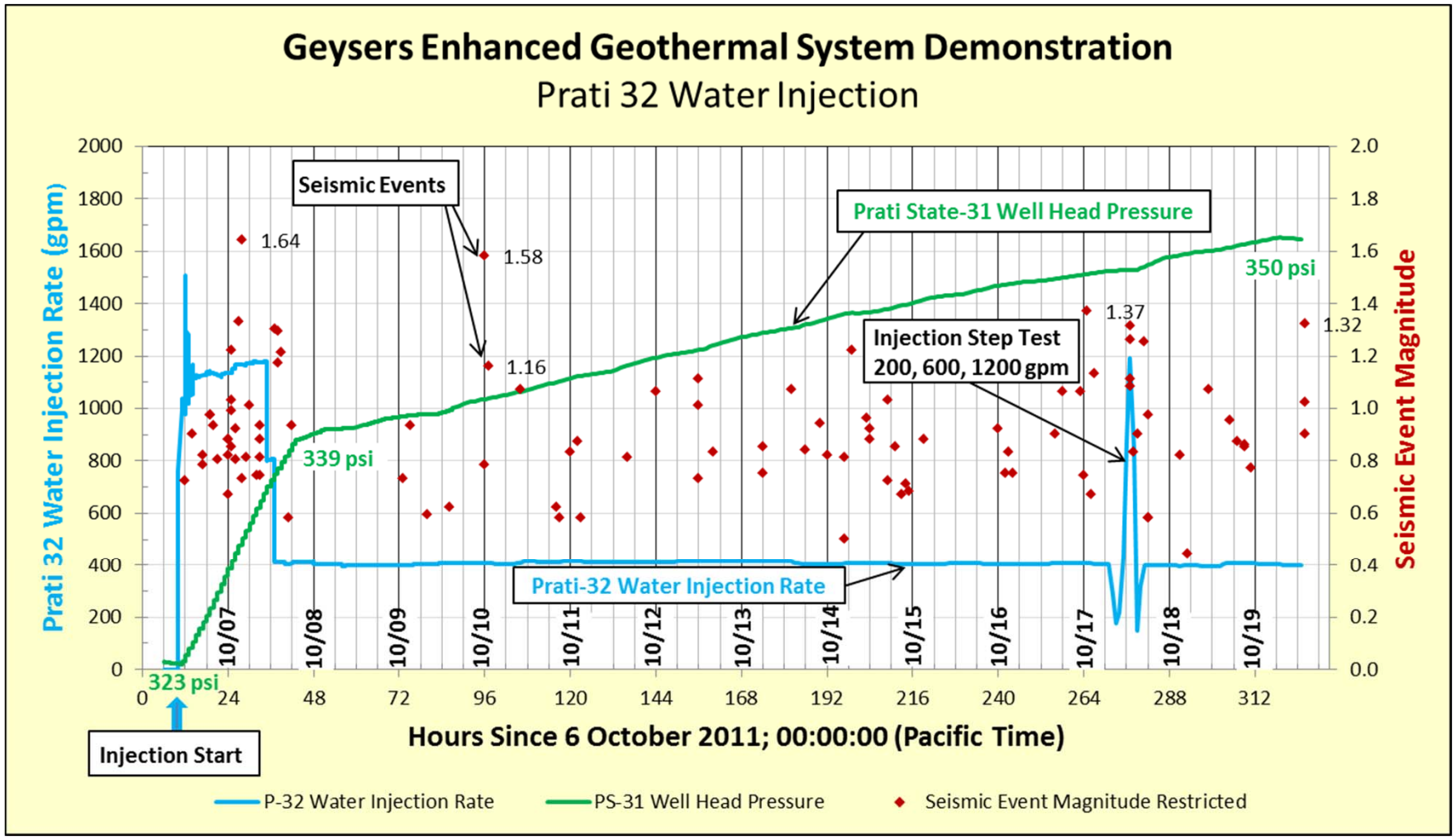
Perceived Shaking	Not Felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
Potential Damage	None	None	None	Very Light	Light	Moderate	Mod/Heavy	Heavy	Very Heavy
Peak Acceleration (% of g)	< 0.17	0.17 - 1.4	1.4 - 3.9	3.9 - 9.2	9.2 - 18.0	18.0 - 34.0	34.0 - 65.0	65.0 - 124.0	> 124.0
Peak Velocity (cm/sec)	< 0.10	0.1 - 1.1	1.1 - 3.4	3.4 - 8.1	8.1 - 16.0	16.0 - 31.0	31.0 - 60.0	60.0 - 116.0	> 116.0
Modified Mercalli Intensity	I	II-III	IV	V	VI	VII	VIII	IX	X

NW Geysers EGS Demonstration

Seismicity Analysis: 1 October 2011 to 19 October 2011

Prati 32 Injection Area

LBNL database events with Erh (horizontal error) and ErZ (vertical error) less than 1 km

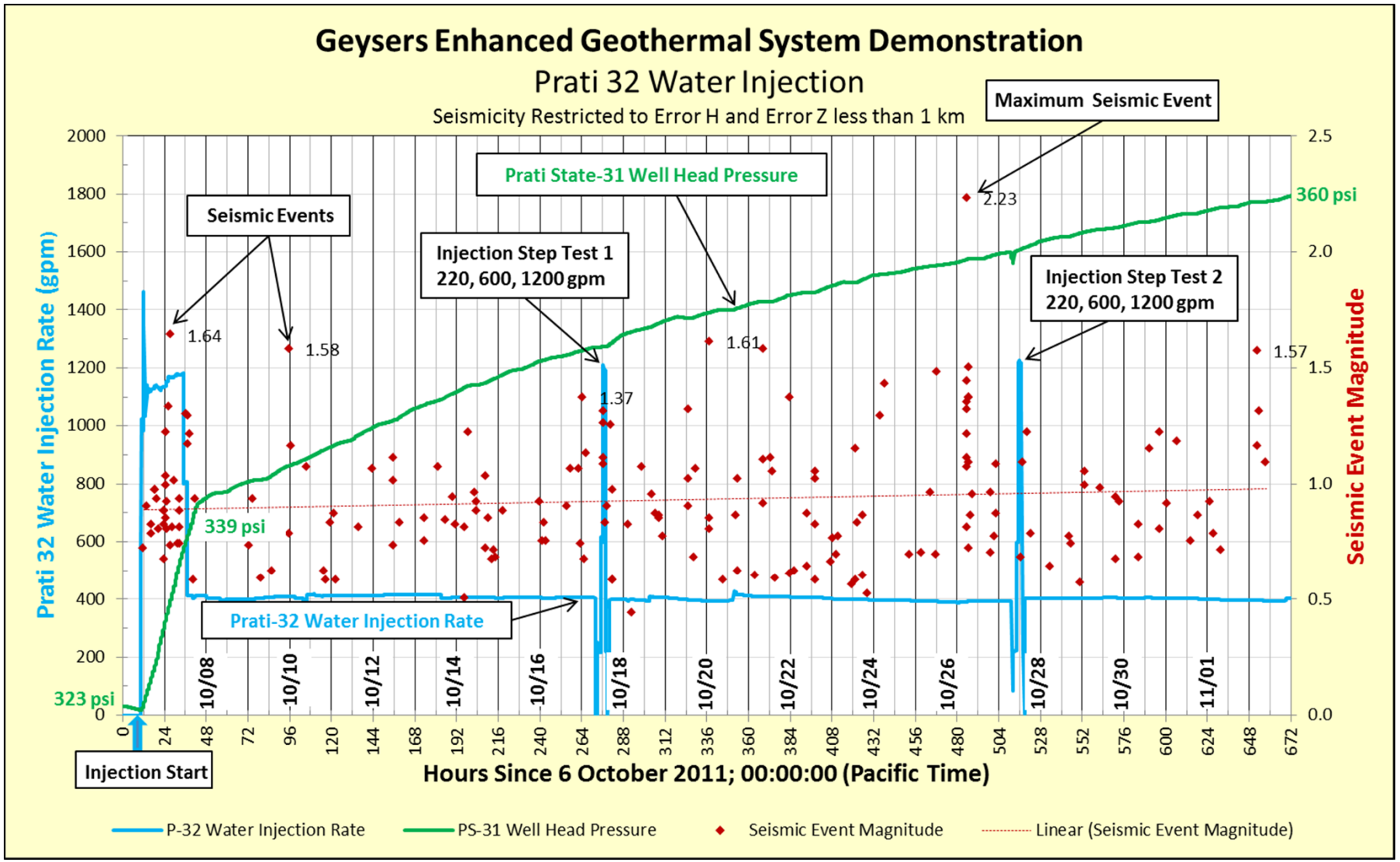


NW Geysers EGS Demonstration

Seismicity Analysis: 6 October 2011 to 02 November 2011

Prati 32 Injection Area

LBNL database events with Erh (horizontal error) and ErZ (vertical error) less than 1 km



NW Geysers EGS Demonstration

Seismicity Analysis: 5 October 2011 to 19 October 2011

LBNL database events with Erh (horizontal error) and ErZ (vertical error) less than 1 km

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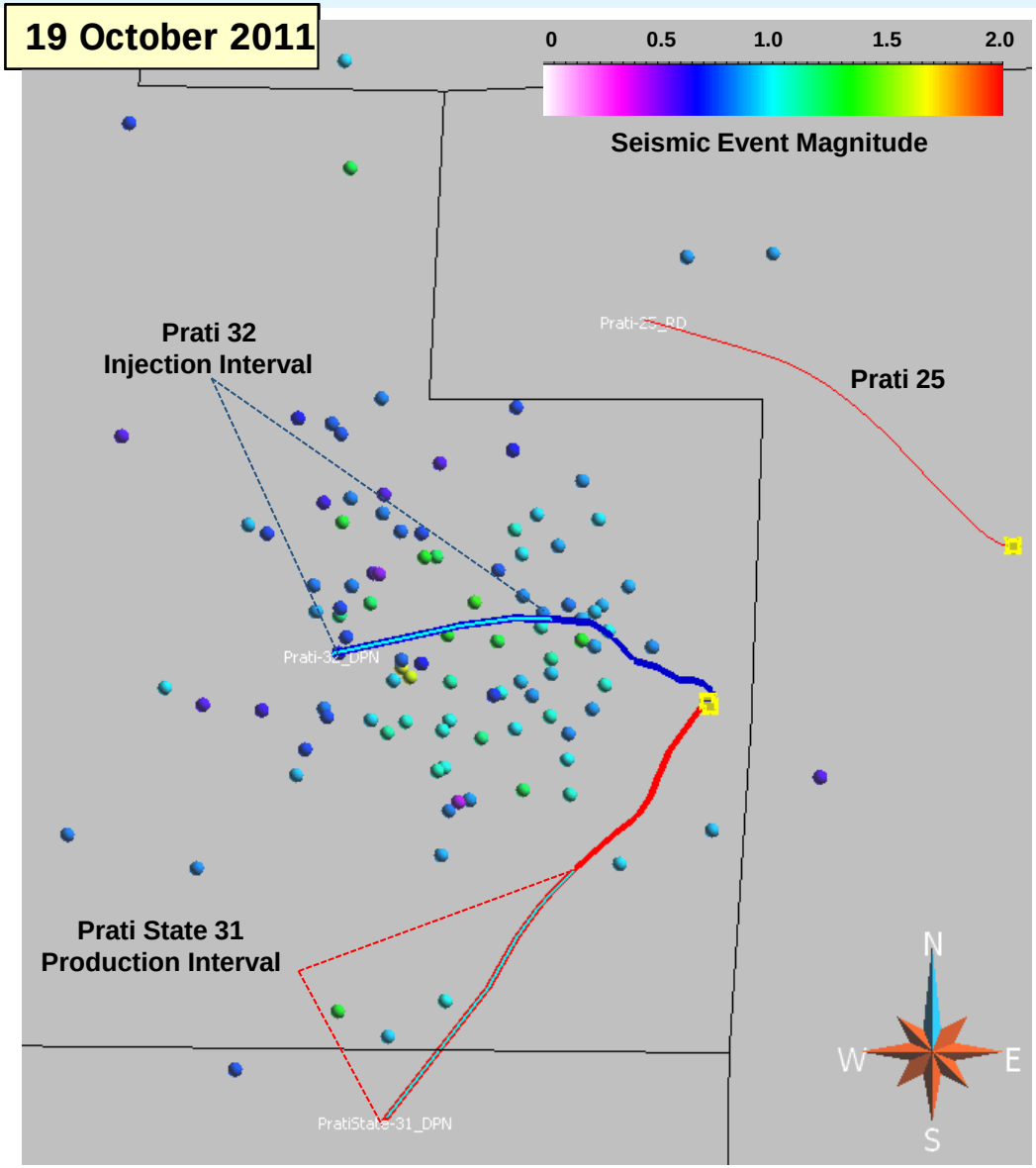
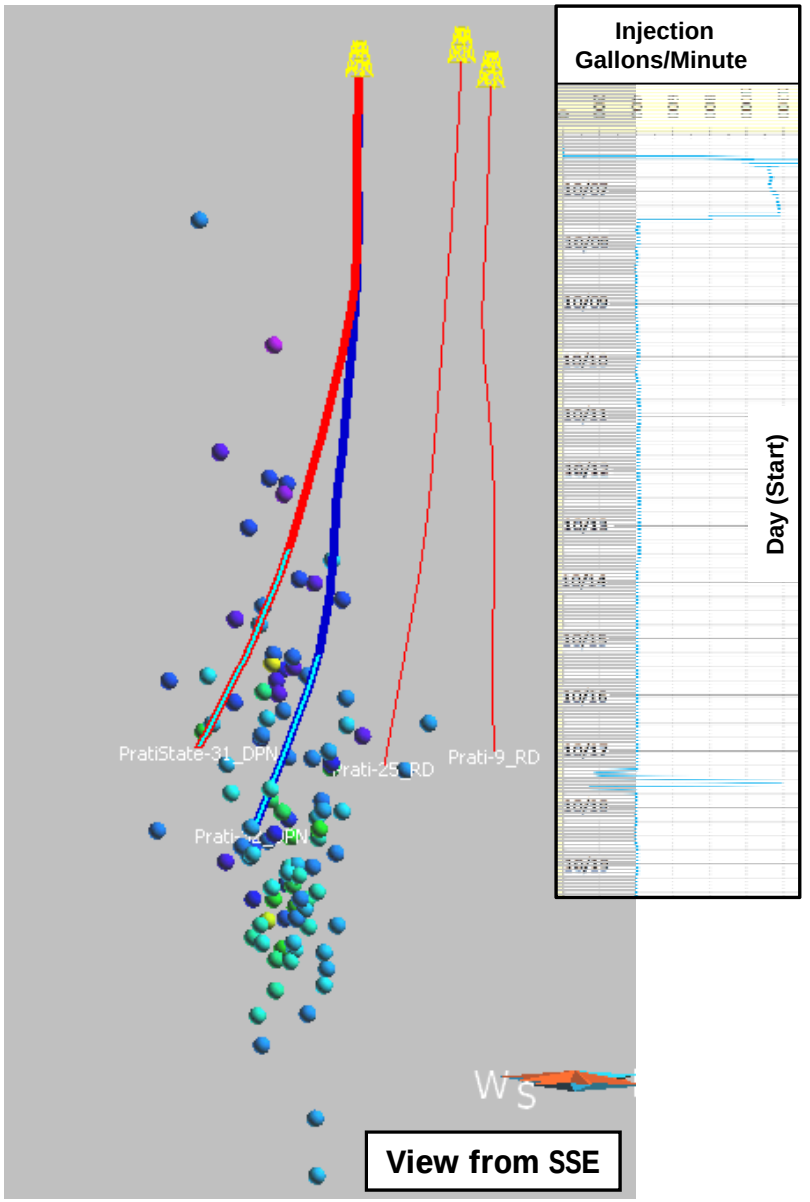
19 October 2011



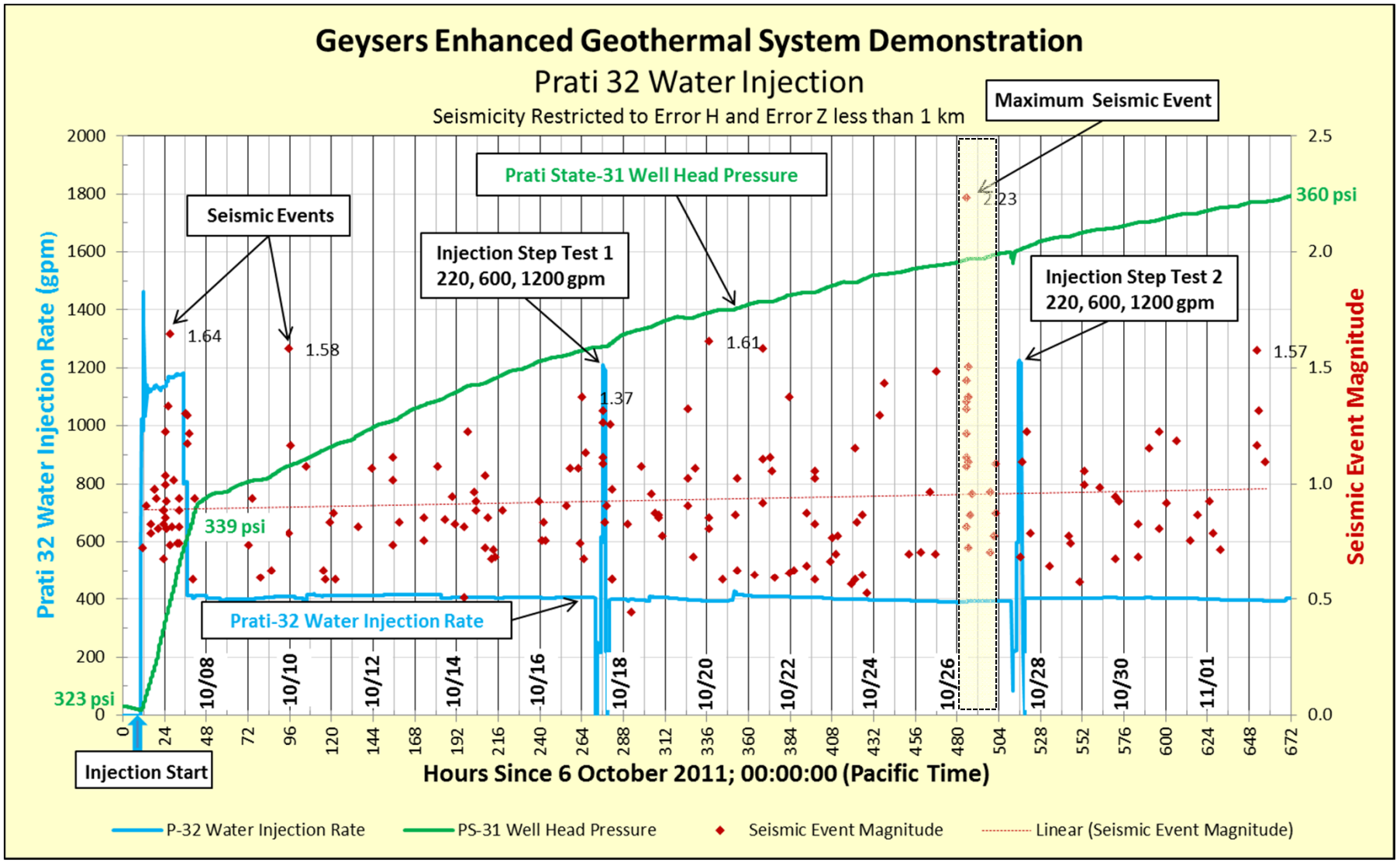


NW Geysers EGS Demonstration

Seismicity Analysis: 6 October 2011 to 02 November 2011

Prati 32 Injection Area

LBNL database events with Erh (horizontal error) and ErZ (vertical error) less than 1 km

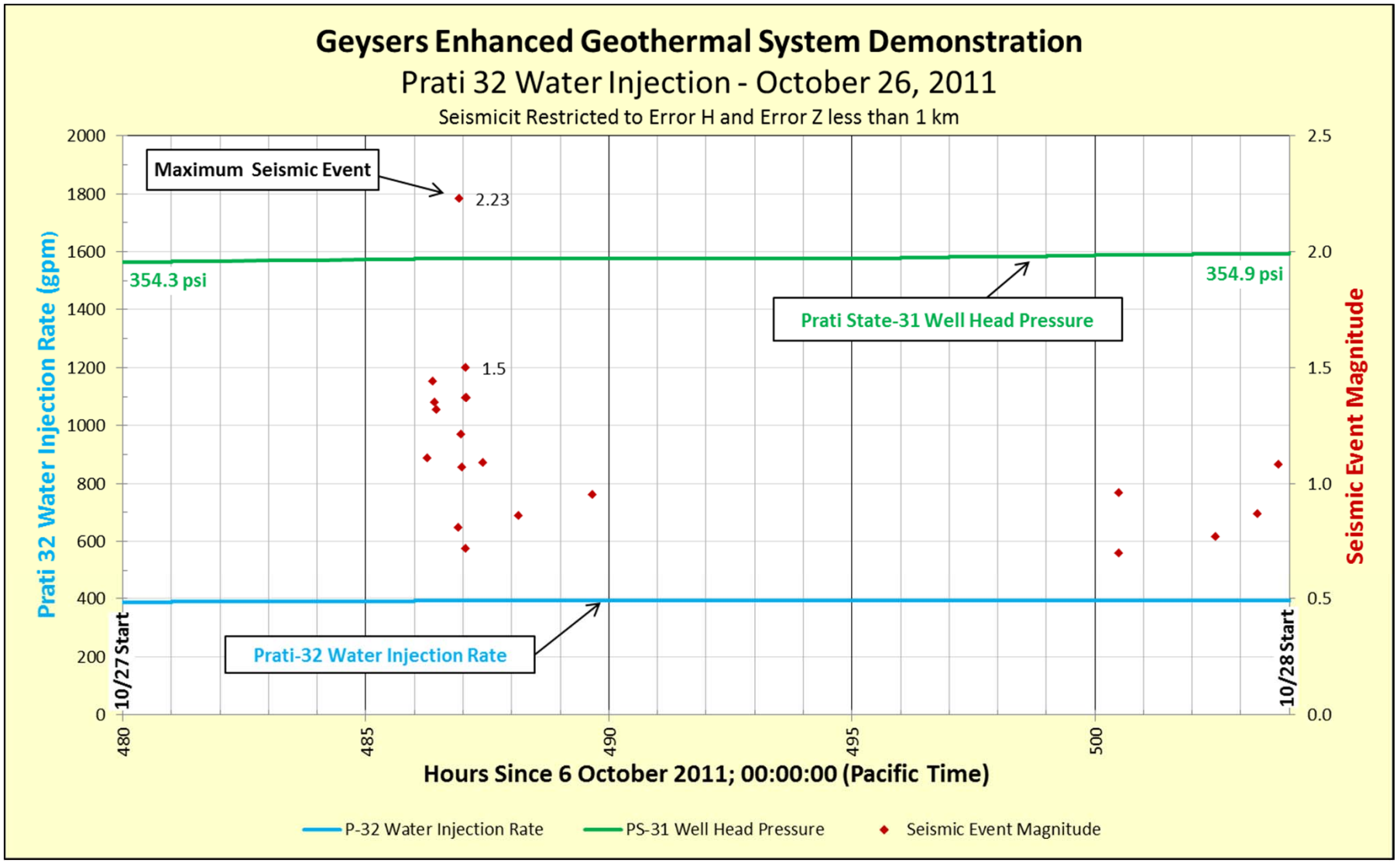


NW Geysers EGS Demonstration

Seismicity Analysis: 26 October 2011

Prati 32 Injection Area

LBNL database events with Erh (horizontal error) and ErZ (vertical error) less than 1 km



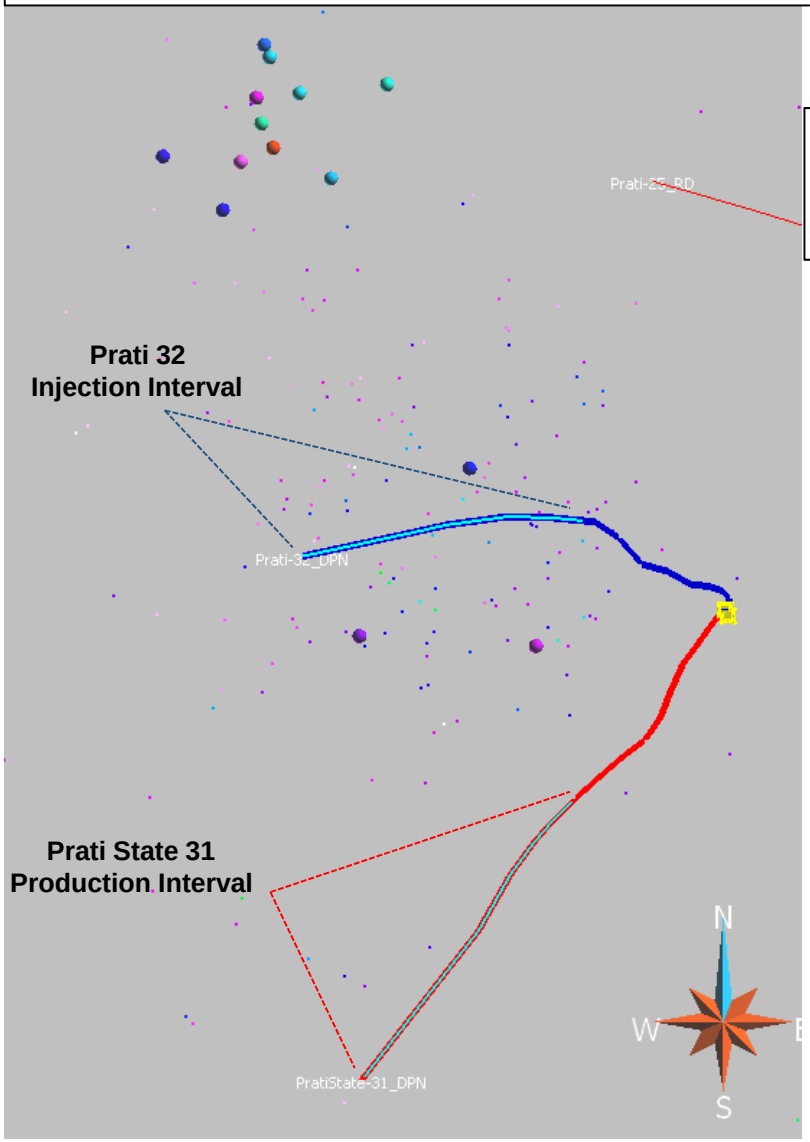
NW Geysers EGS Demonstration

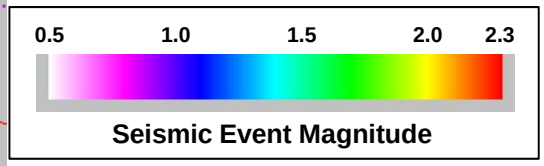
Seismicity Analysis: 26 October 2011

Prati 32 Injection Area

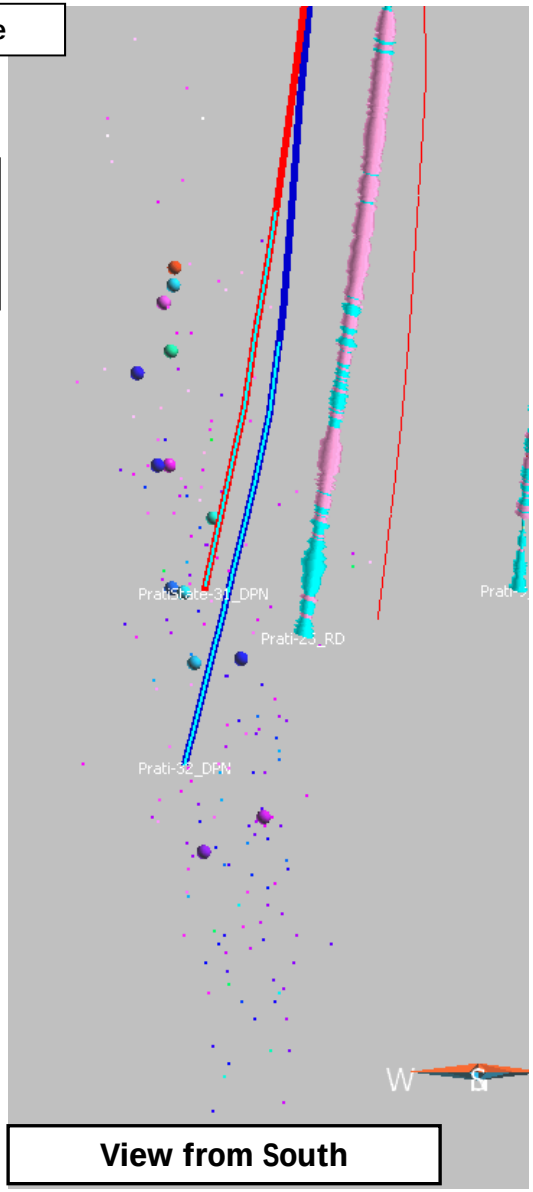
LBNL database events with Erh (horizontal error) and ErZ (vertical error) less than 1 km

26 October 2011 Seismic Event Hypocenters Occurrence Limited in Time, Map Area and Depth Range





Hour	Minute	Second	Magnitude
6	16	39	1.11
6	23	26	1.44
6	25	15	1.35
6	27	36	1.32
6	54	53	0.81
6	55	34	2.23
6	57	32	1.21
6	59	15	1.07
7	3	17	0.72
7	3	36	1.50
7	3	46	1.37
7	4	12	1.37
7	25	7	1.09
8	8	18	0.86
9	39	43	0.95
20	29	20	0.96
20	29	27	0.70
22	29	6	0.77
23	20	38	0.87
23	46	58	1.08



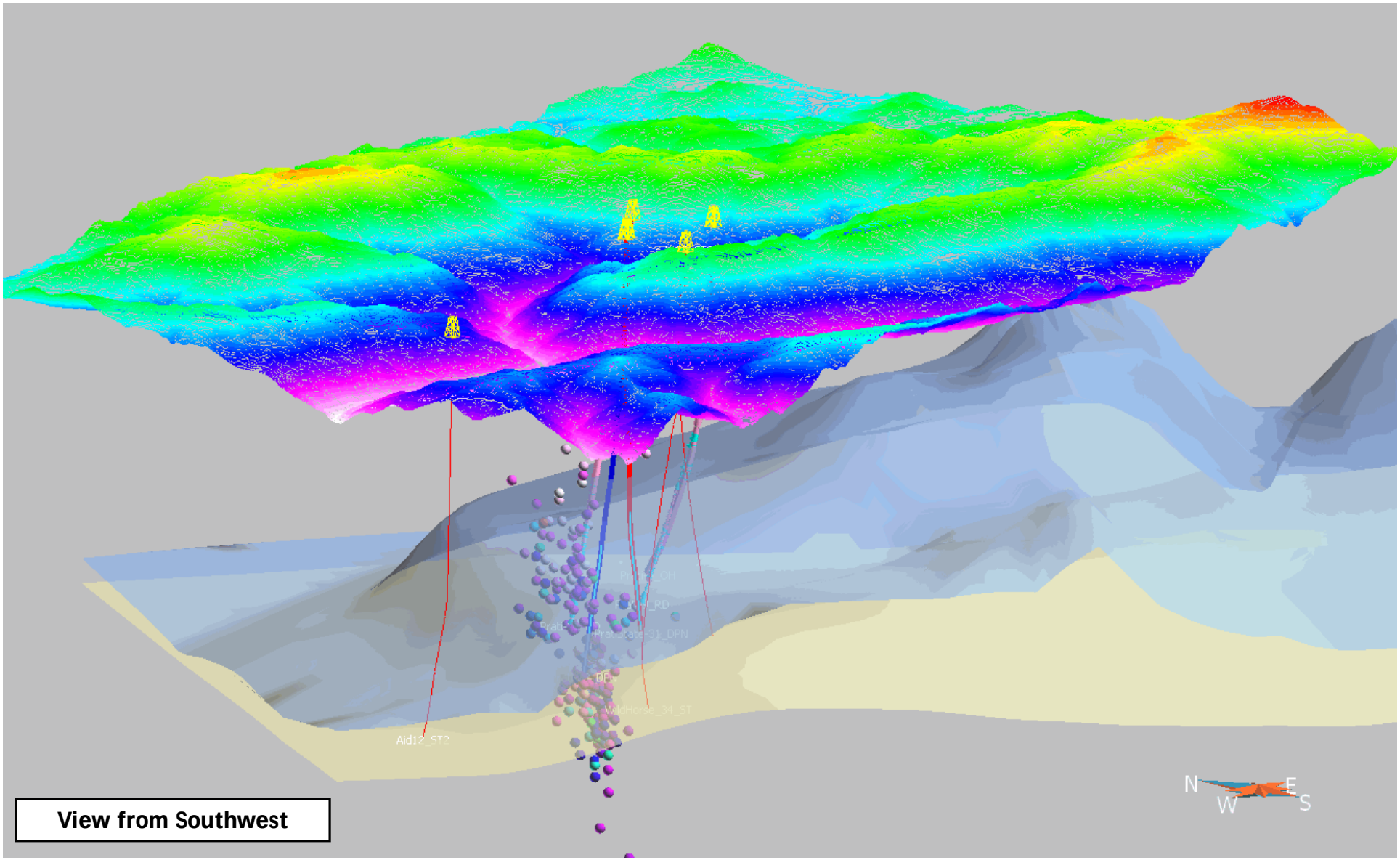
View from South

NW Geysers EGS Demonstration

Seismicity Analysis: 6 October 2011 to 02 November 2011

Prati 32 Injection Area

LBNL database events with Erh (horizontal error) and ErZ (vertical error) less than 1 km



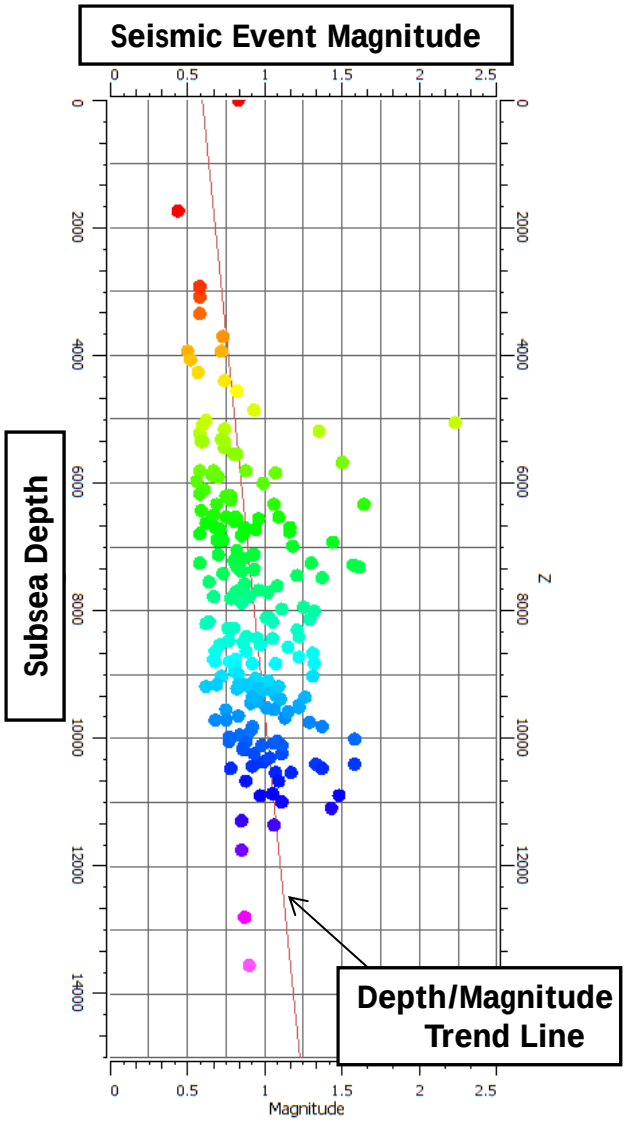
View from Southwest

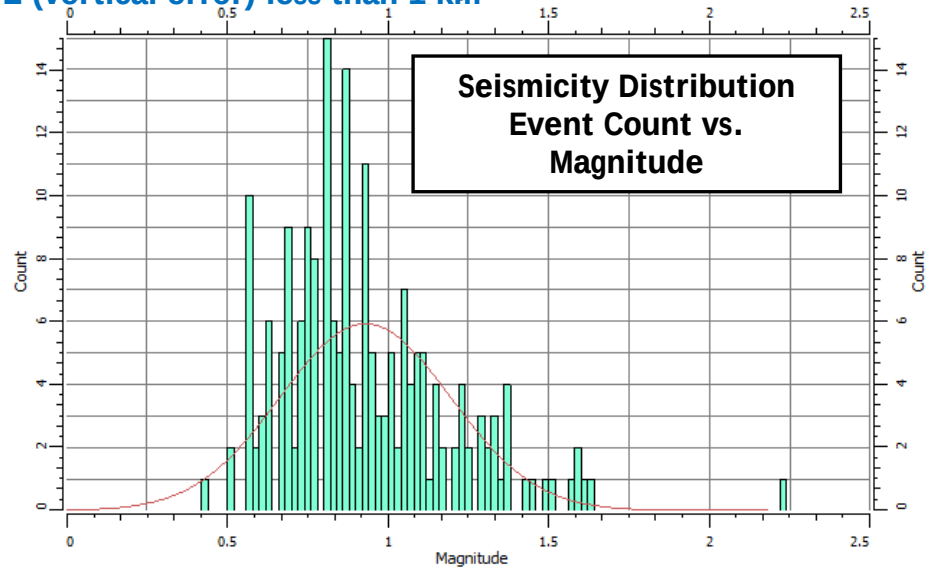
NW Geysers EGS Demonstration

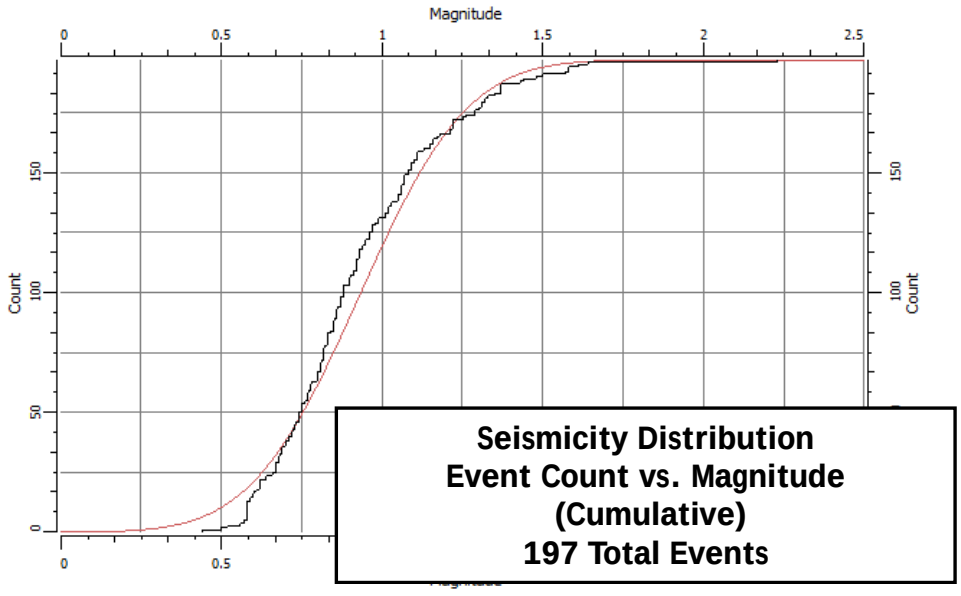
Seismicity Analysis: 6 October 2011 to 02 November 2011

Prati 32 Injection Area

LBNL database events with Erh (horizontal error) and ErZ (vertical error) less than 1 km







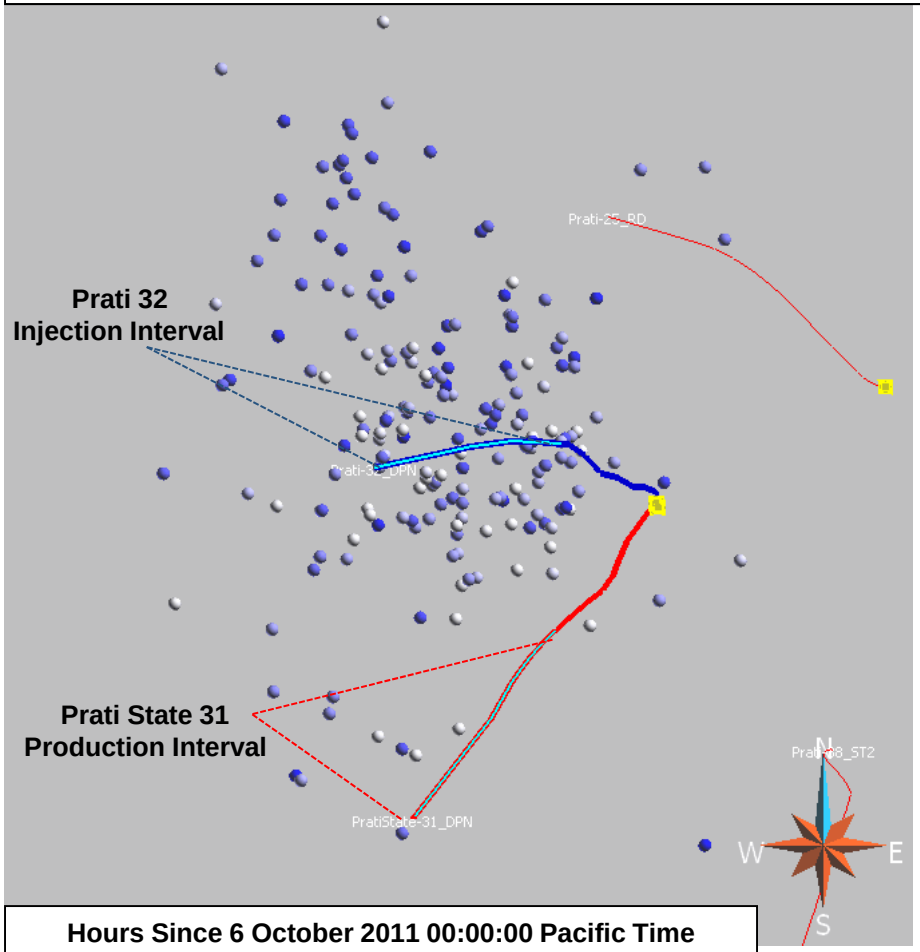
NW Geysers EGS Demonstration

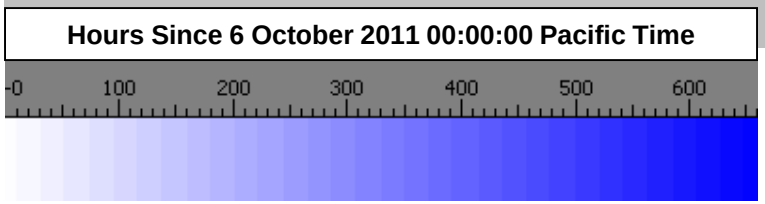
Seismicity Analysis: 6 October 2011 to 02 November 2011

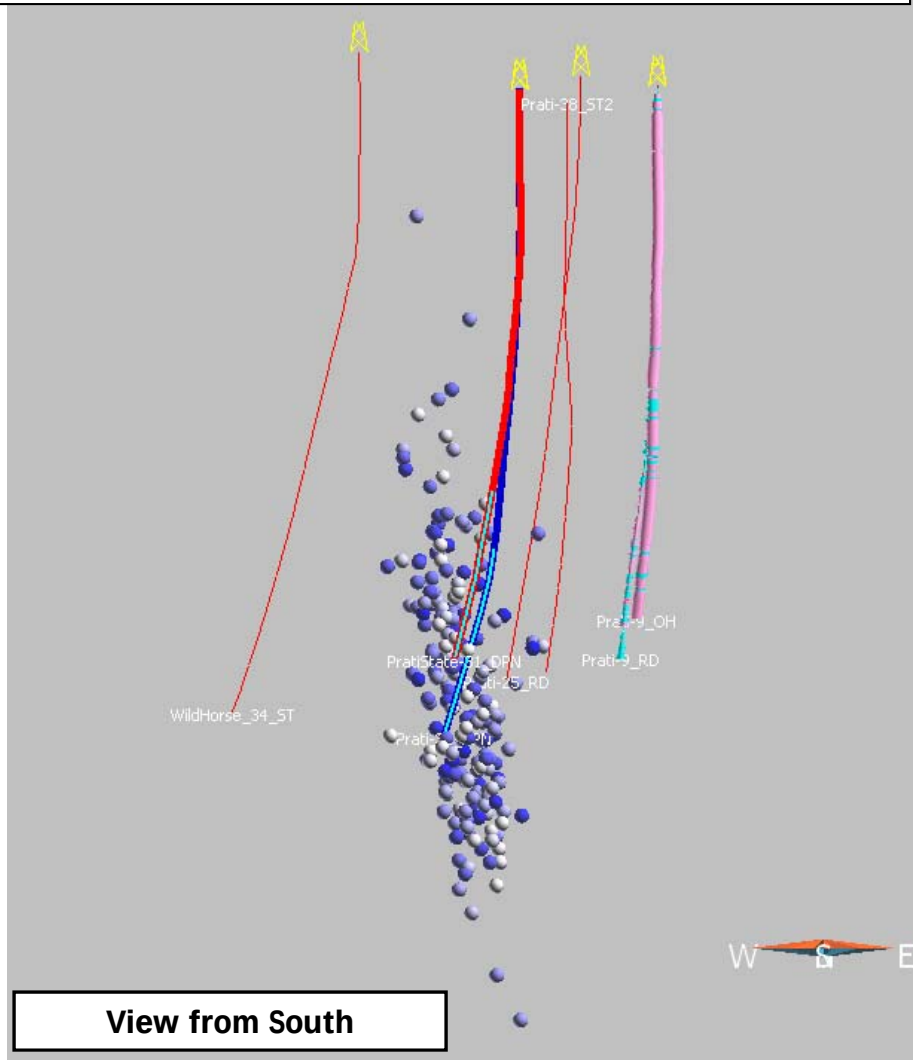
Prati 32 Injection Area

LBNL database events with Erh (horizontal error) and ErZ (vertical error) less than 1 km

Majority of Early Events Relatively Near Injection Center
Significantly More Events to N / NW with Increasing Time







View from South

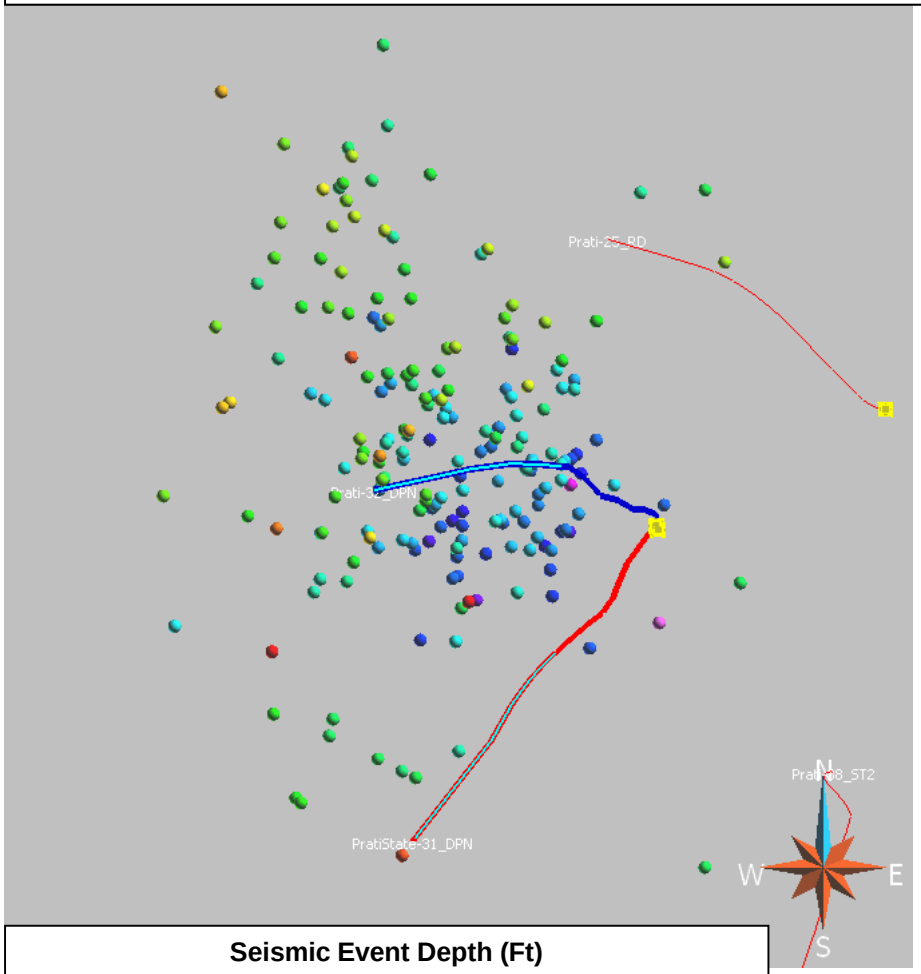
NW Geysers EGS Demonstration

Seismicity Analysis: 6 October 2011 to 02 November 2011

Prati 32 Injection Area

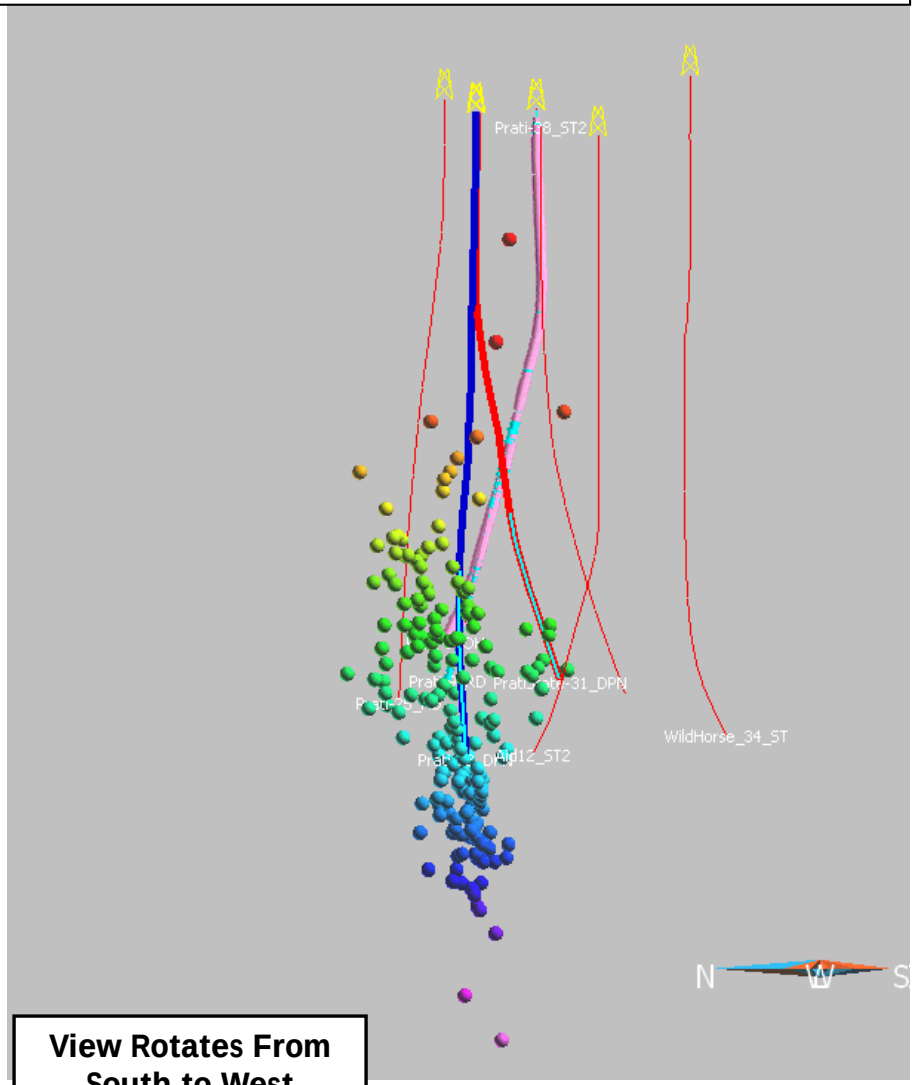
LBNL database events with Erh (horizontal error) and ErZ (vertical error) less than 1 km

Seismic Event Hypocenters Suggest Preferential Water Movement NNW / SSE Along a Tilted Zone of Higher Permeability



Seismic Event Depth (Ft)

4000 6000 8000 10000 12000 14000



View Rotates From South to West

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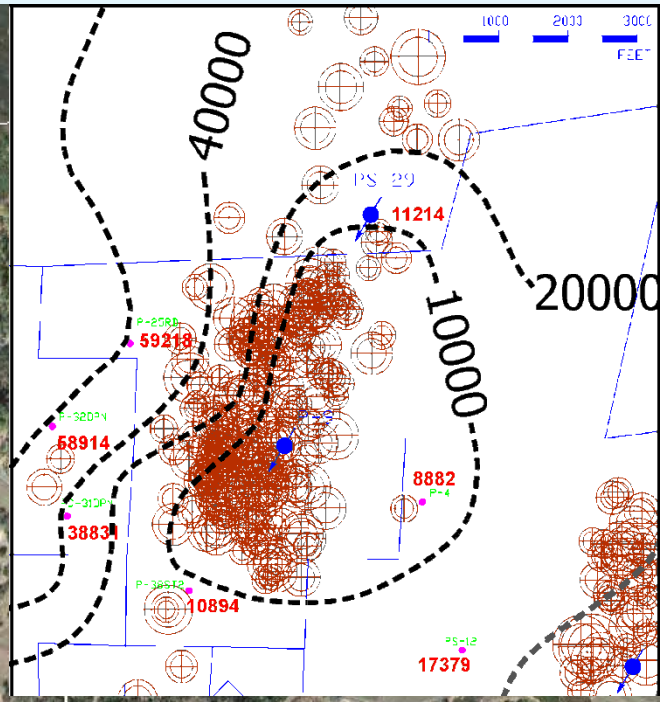
NYSE CPN

Prati 25	1993	2010
NCG (ppmw)	56400	59217
Reservoir Entry Pressure [psia]	423 (1998)	435

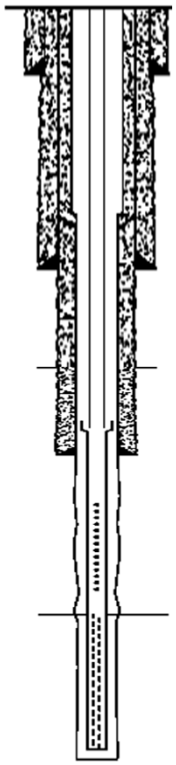
Prati 32	1985	2010
NCG (ppmw)	65223	59386
Reservoir Entry Pressure [psia]		412

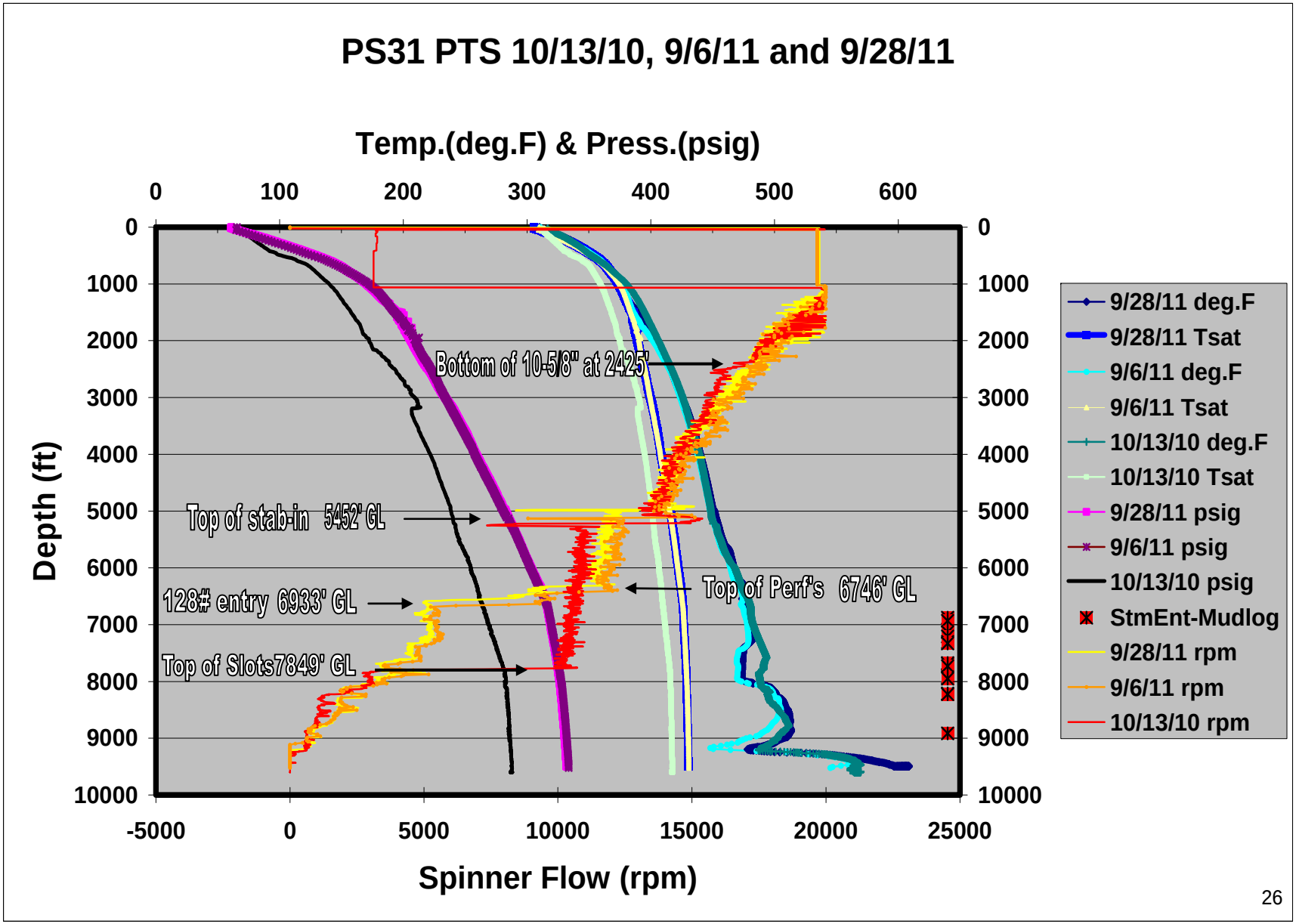
Prati State 31	1984	2010
NCG (ppmw)	56600	38724
Reservoir Entry Pressure [psia]	373 (1995)	376

Prati 38	1989	2011
NCG (ppmw)	10,100	6,696
Reservoir Entry Pressure [psia]		334

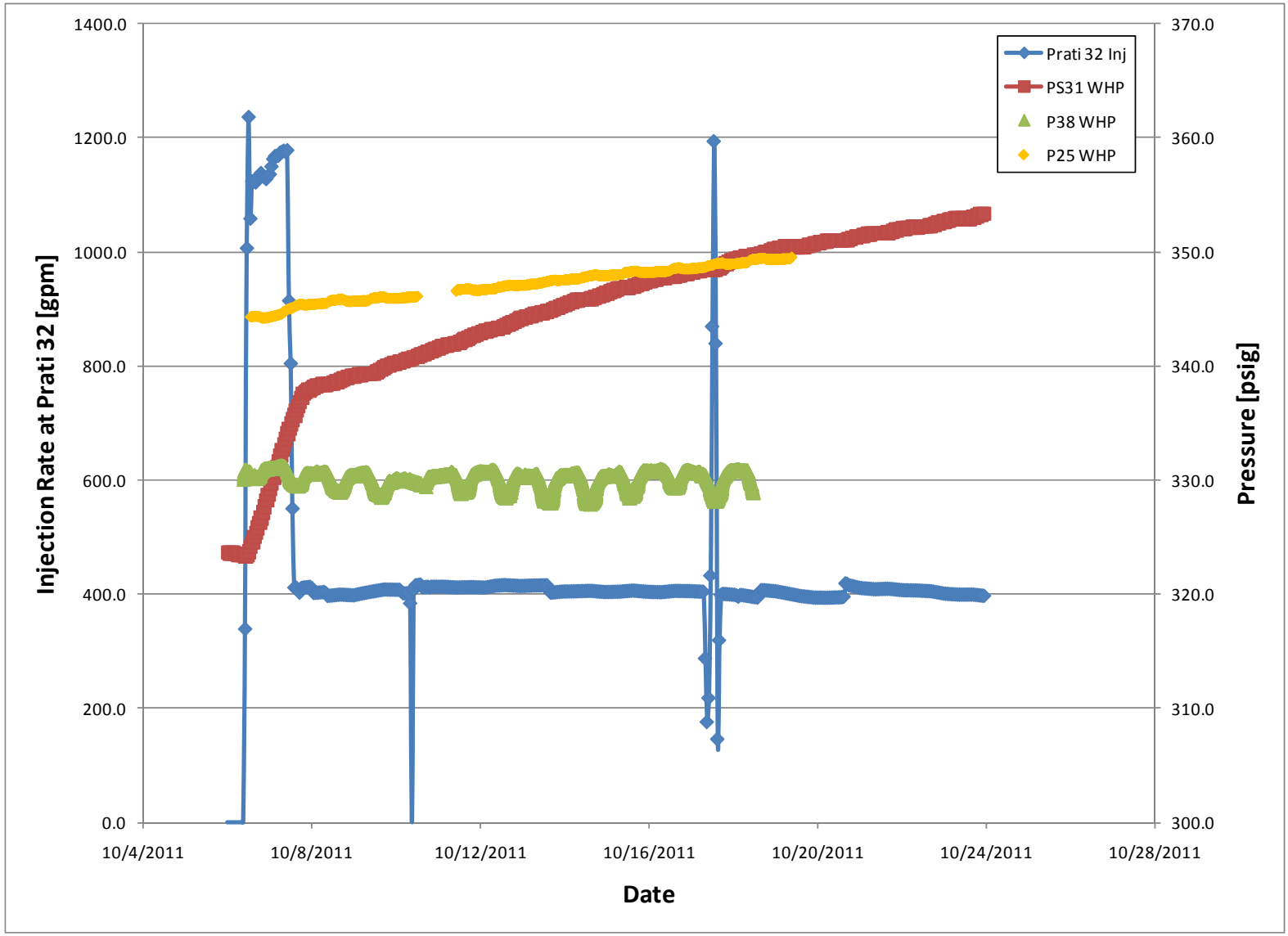


Prati State 31
Pressure-Temperature-Spinner (PTS) Logs



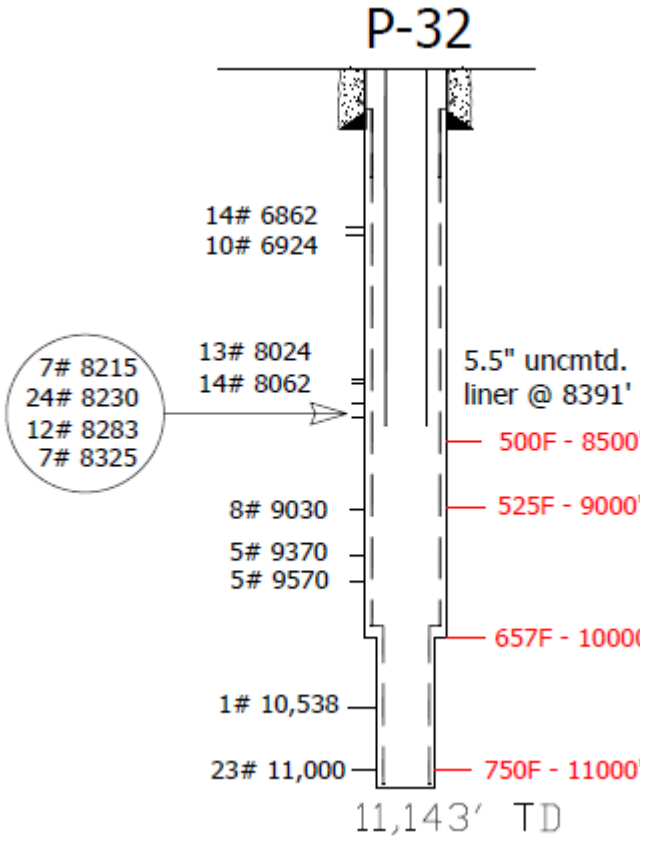


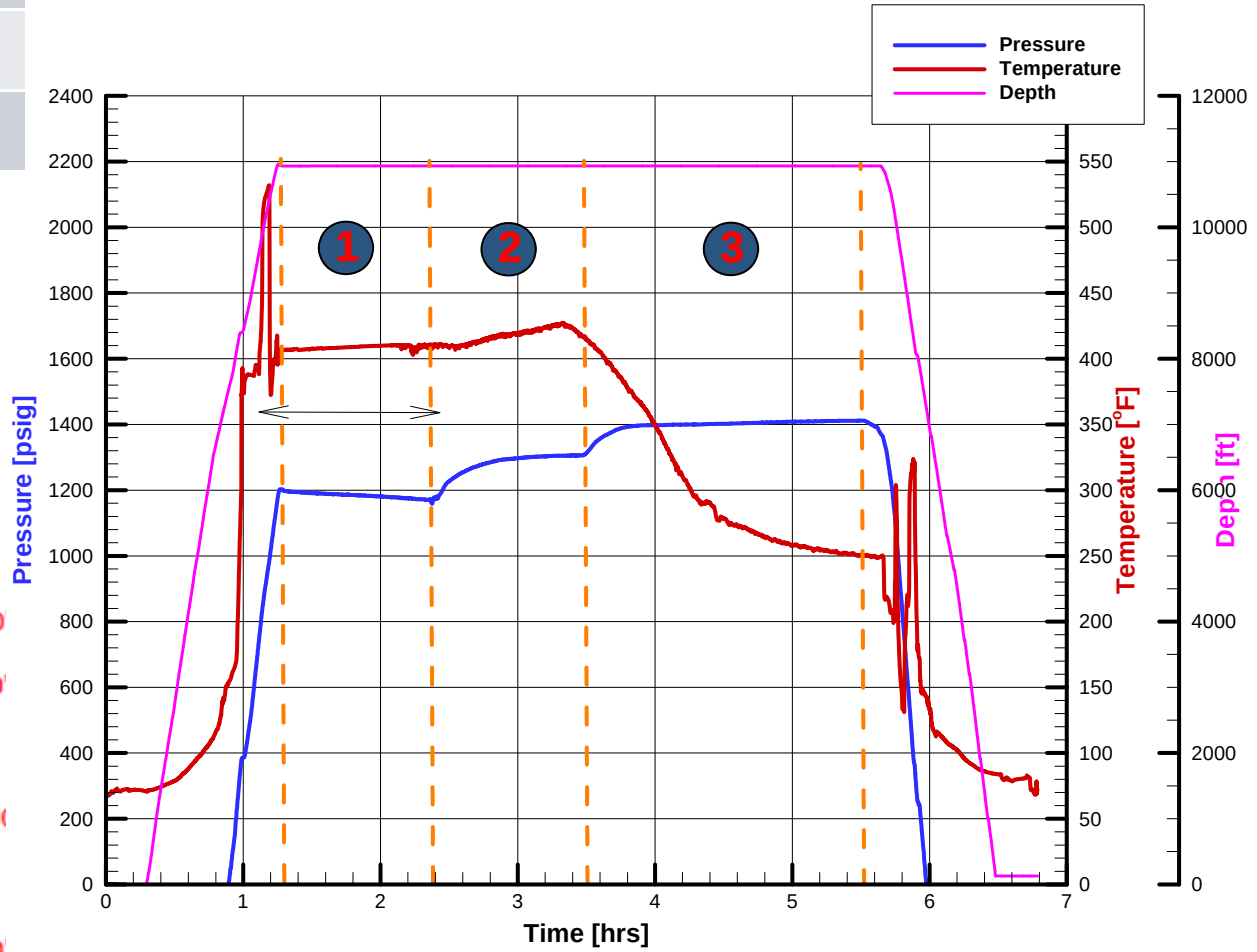
Initial Effects of Prati 32 injection on Prati State -31



Prati 32
Pressure-Temperature Injectivity Test

	Injection Rate [gpm]	Water Level [ft]
1	280	7690
2	620	7300
3	1200	7440





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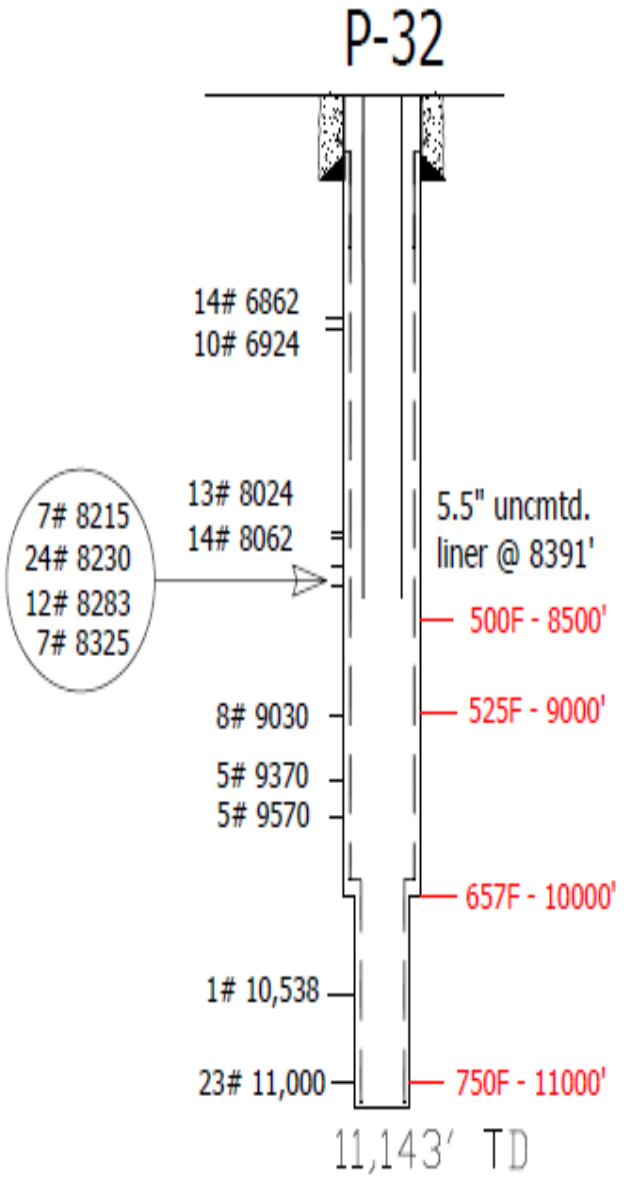
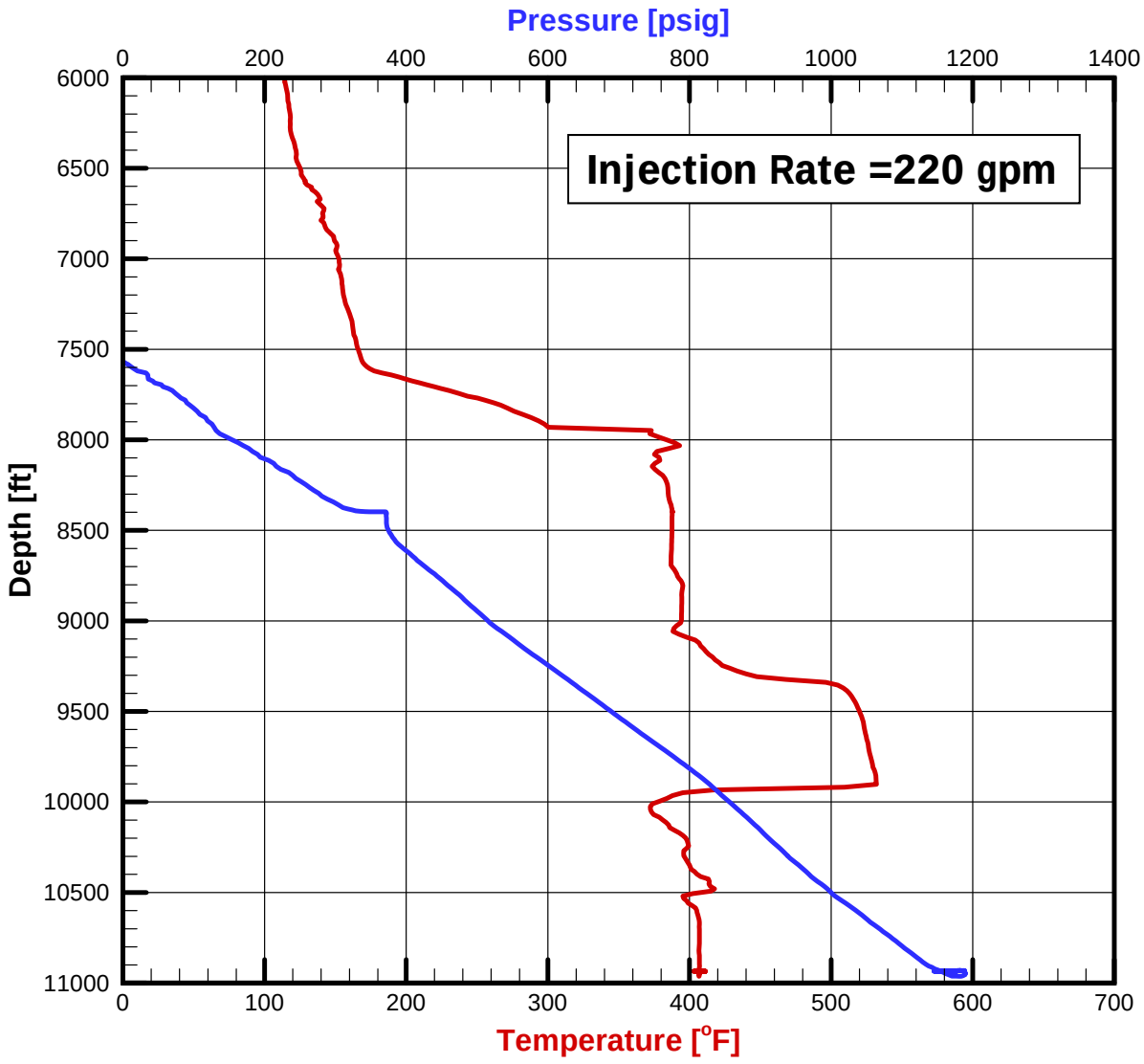
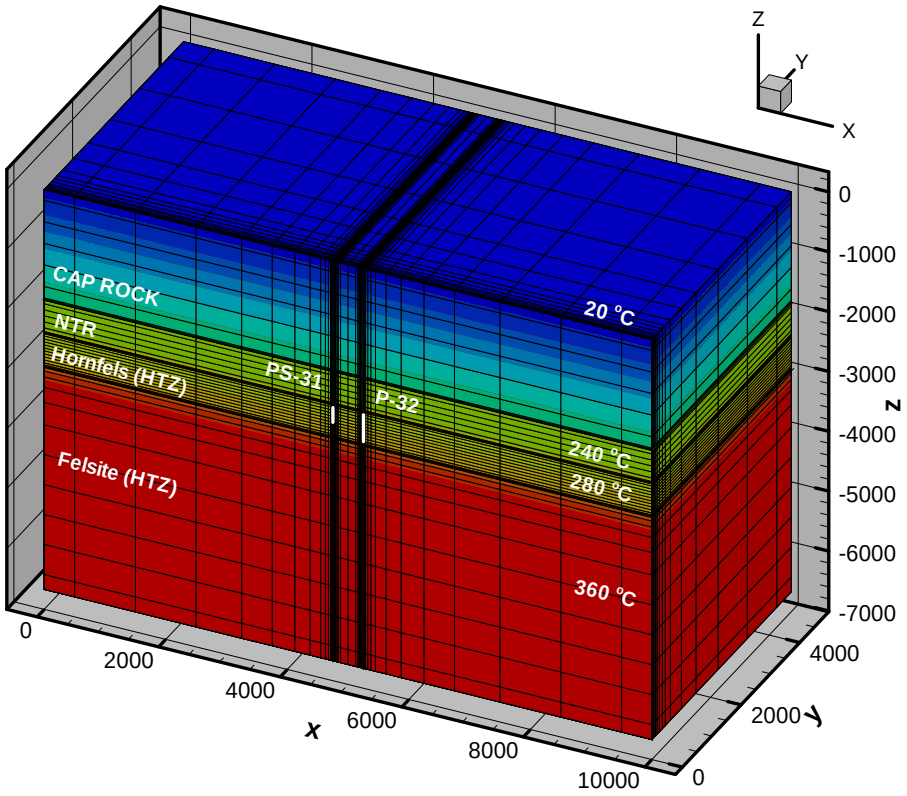
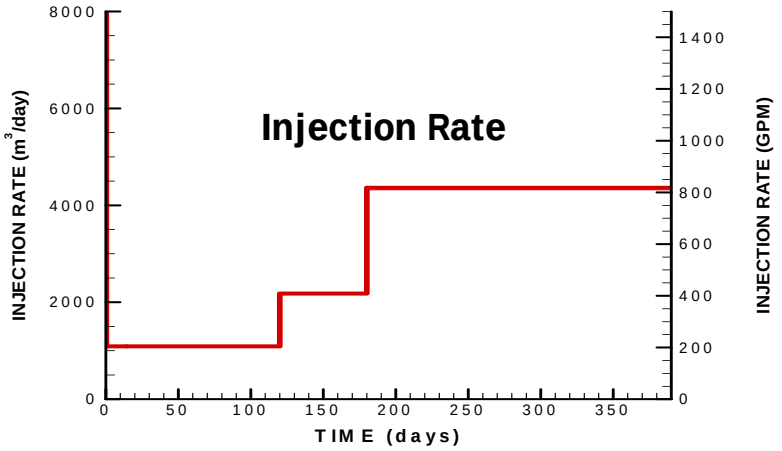
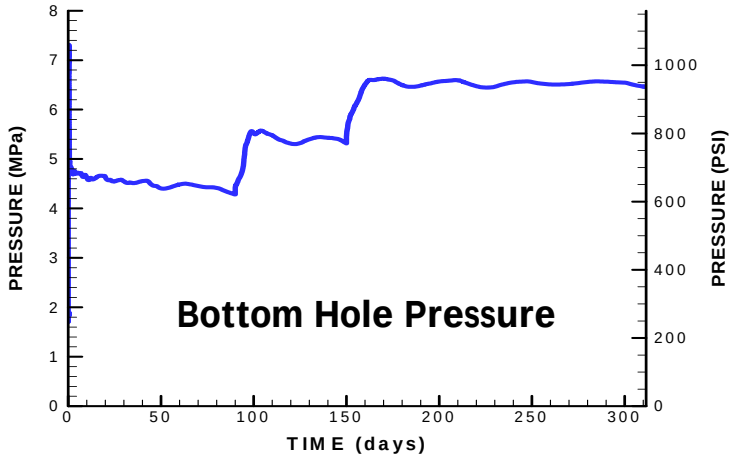




Northwest Geysers EGS Demonstration
Reservoir Modeling







Staged injection rates over 12 months

“Gentle” progressive stimulation of the High Temperature Zone

CALPINE®

NYSE CPN

NW Geysers EGS Demonstration
Seismicity Analysis – Depth Accuracy/Precision

Ernie Majer:

LBNL about +/- 500 meters (accuracy); precision much better. Our velocity models are not that good, after Katie et al derives a better model it may improve. Dave says less than 50 meters precision on theirs (DD), Dave? We have never done multiple calibration shots to check it out. You saw the email from Mitch, he estimated +/- 1000 meters.

David Oppenheimer:

For DD, I think relative accuracy of meters (correct, Felix?). For regular, one-off hypoinverse locations, I'd say a few hundred meters, but as you note, we have no ground-truth. In the 1985 Eberhart-Phillips paper we relocated several explosions. See last paragraph of attached. GSM, referenced in the above, is "Socrates Mine" located at (38.769165; -122.781166) .The station was discontinued in 1986.
Attachment: The typical horizontal and vertical standards errors of these locations are about 0.4 to 0.7 km, respectively (and increase with distance).

Felix Waldhauser:

Precision is probably in the meter to few tens of meters range in the optimal cases, that is relative depths based on highly correlated seismograms. Note that when locations are mainly controlled by correlation measurements, then we are talking about the location of maximum moment release during rupture. That location might be different from the one derived from the onset of seismic phases, which images the nucleation point. This is especially relevant for larger events, when you mix onset and correlation data.
Our NCA relocation paper (attached) has some statistics included that try to address the accuracy vs. precision issue.
The absolute locations of the DD solutions in the NCAeqDD catalog are essentially referenced to a local average of NCSN depths.
Waldhauser and Schaff, 2007: For the NCSN catalog, inaccuracies in the phase picks and errors in the model cause hypoecenter location uncertainties in the range of several hundred meters to a few kilometers, with depth more poorly constrained than the epicenter.

Katie Boyle:

What date range are you considering for your catalogs? I have relocated the 2004 and 2005 LBNL-Geysers datasets in tomoDD and can pass those locations along if you are interested. I imagine they will have better depth constraint than the standard LBNL catalog because they incorporate double-difference relative relocation, which carries the benefits that Felix mentioned. I have not looked at aggregate depth error for these locations, but can do so tomorrow if you're interested.
The locations are subject to small changes as I continue to play around with tomoDD parameters, but I think the perturbations will be pretty small from this point forward. I'm almost certain that these events predate the Prati 9 injection, so they may not be in your study area, but I'd be happy to send them along.

Mitch Stark:
The 1 km for our in-house data sounds vaguely correct, but I don't remember much of the basis for that. Craig, in the files you might find some old memos by Bob Daniel, and maybe even by me, circa early 1990's, in which we tried to estimate the hypocentral accuracy. There was a calibration shot, among other techniques tried.

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