Phase 2.2 Report Appendices

DOE Award: DE-EE0002777

AltaRock Energy, Inc.

July 2, 2015

Contributing Authors

AltaRock Energy

Trenton T. Cladouhos, Susan Petty, Yini Nordin, Geoff Garrison,

Matt Uddenberg, Michael Swyer, Kyla Grasso

Consultants and Sub-recipients

Paul Stern (PLS Environmental)

Eric Sonnenthal (LBNL)

Pete Rose (EGI)

Gillian Foulger and Bruce Julian (Foulger Consulting)

Acknowledgment: This material is based upon work supported by the Department of Energy under Award Number DE-EE0002777.

APPENDICES

Appendix A
Amendments for 2012 Induced Seismicity Mitigation Plan

Department of Energy
Golden Field Office
15013 Denver West Parkway
Golden, Colorado 80401

July 1, 2014

Carol Benkosky
Prineville District Manager
Prineville District – Bureau of Land Management
3050 NE Third Street
Prineville, OR 97754

SUBJECT: Approval of Induced Seismicity Mitigation Plan (ISMP) edits associated with Department of Energy (DOE) Award Number DE-EE0002777, *Recovery Act: Newberry Volcano EGS Demonstration*

Dear Ms. Benkosky,

This letter is meant to inform the Prineville District that DOE has approved the attached ISMP appendix (Appendix "J") associated with the Newberry EGS demonstration project.

On April 14, 2014 DOE held the second of four "Stage Gate" reviews associated with the Newberry project. During this review meeting and in the weeks following, throughout which the discussion continued, three potential amendments to the original ISMP were discussed amongst AltaRock, DOE, the DOE appointed Stage Gate Review Team, and the DOE Technical Monitoring Team.

Based on the fact that NWG 55-29 did not develop a positive well head pressure, AltaRock proposed a reduction in the amount of empty sump capacity required in the original ISMP. The DOE Stage Gate Review Team and Technical Monitoring Team suggested that additional field calibrated modeling would be necessary to determine a theoretical potential for flowback from the well under several possible conditions, because the lack of wellhead pressure and inability of NWG 55-29 to flow was likely attributable to the casing leak rather than the reservoir character. AltaRock and Lawrence Berkeley National Laboratory developed and ran a range of modeled scenarios to determine the necessary flowback storage capacity required during the stimulation. The modeling results indicate that a flowback storage capacity of 5% should be sufficient, and that "constructing a pipeline for restimulating well NWG 55-29 in 2014 is neither necessary nor cost effective."

The second amendment to the ISMP will require that additional information is shared in the daily seismicity reports that DOE, BLM, FS and other involved parties receive from AltaRock during the stimulation. Since 2011 when the ISMP was developed and signed, seismologists have identified additional parameters that are considered indicators of seismic risk or seismogenic potential. One such indicator is based on the relationship between the cumulative injected volume of fluid and the cumulative seismic moment, which correlates with the largest induced event that may occur at a given site. Going forward, AltaRock's seismicity report will track injected volume and seismic moment data on a daily basis. Based on the recommendation from renowned seismologist Dr. Ernest Majer, the daily seismicity report will also include another new chart that plots b-value vs. time. A reduction in the b-value indicates that higher magnitude events are occurring with greater frequency or at a higher rate, and can serve as an indicator of seismic risk.

The final amendment to the ISMP consists of edits to the contact information listed in the original document. Details can be found in the attached appendix.

This letter constitutes written acknowledgement that the proposed amendments to AltaRock Energy Inc.'s Newberry Induced Seismicity Mitigation Plan (ISMP), detailed in Appendix J, have been deemed technically acceptable by DOE, the DOE Stage Gate Review Team and Technical Monitoring Team.

Please feel free to contact the DOE Project Officer, Lauren Boyd, at (202) 287-1854 to discuss these modifications or any other matters relevant to the Newberry EGS demonstration, at your convenience.

Best Regards,

Michael A. Buck

Michael A. Buck
DOE Contracting Officer

Appendix J: Proposed Amendments to Induced Seismicity Mitigation Plan

Background

In Phase 1 of the Newberry EGS Demonstration an Induced Seismicity Mitigation Plan (ISMP) was developed and incorporated into the BLM's Environmental Assessment (BLM, 2012) and the DOE award documents. The full ISMP is also available on AltaRock's website (AltaRock, 2011a, 2011b). Based on the results of the 2012 stimulation, three amendments to the ISMP are proposed here:

1. A change in the amount of empty sump capacity required and new pressure bleed off guidelines.
2. The addition of two new graphs to the seismicity reports.
3. Updates of the contact information for induced seismicity communications.

Sump Capacity Change

The controls and guidelines developed for the ISMP were based on the analysis of the Newberry site-specific geologic and environmental conditions, and lessons learned from other EGS sites. A lesson learned from the Deep Heat Mining (DHM) project in Basel, Switzerland was related to flow-back to relieve reservoir pressure after a potentially damaging microseismic event. At Basel, injection resulted in a positive well head pressure after the pumps were turned off and relieving that pressure by allowing flow-back resulted in an immediate stop to microseismic events. Based on the Basel experience, a 2.5 mile long, temporary pipeline was constructed to connect the 55-29 pad to the 46-16 sump and provide a total of 2.8 million gallons of sump capacity, or more than 10% of the planned injection volume of 24 million gallons. Renting the pipeline and pumps as well as the labor to install and remove the pipeline was a significant cost and effort (Section 2.8).

Flow Back Simulations

One result of the 2012 stimulation at Newberry was that a positive well head pressure did not develop. Rather, well head pressure quickly dropped to zero once the injection pumps were shut off, and well head pressure remained negative for several weeks thereafter. The field-data-calibrated THM model described in Section 4.2 of the main report was used to test the theoretical potential for flowback from well NWG 55-29 under several different possible post-stimulation conditions.

Figures J-1, J-2, and J-3 illustrate the range of modeled stimulation scenario results. In the first, pore compressibility increased ten-fold with no change in reservoir permeability by injecting 2.9 x 10^6 gallons of water at 96 gpm over 21 days. The well then flowed back 135,000 gallons, or 4.7%, over nine days. Such an increase in compressibility without a corresponding increase in permeability is not a realistic scenario and thus considered a worst case. In the second scenario, permeability was increased seven-fold (k_x=3.5e^{-17} m^2, k_y=k_z=7.e^{-17} m^2) by injecting 4.85 x 10^6 gallons of water at a rate of 170 gpm over 21 days. The well then flowed back only about 56,000 gallons, or 1% of the total injection volume, over six days. In the third case, the simulation continued much longer, for 56 days in order to reach a volume nearer the injection goal of 20 million gallons. In this case, the cooling of the rock mass caused even less flow back than the 21 day scenarios. Therefore, the modeling results indicate that a revised a well pad flowback storage capacity of 5% will be sufficient, and that constructing a pipeline for restimulating well NWG 55-29 in 2014 is neither necessary nor cost effective.

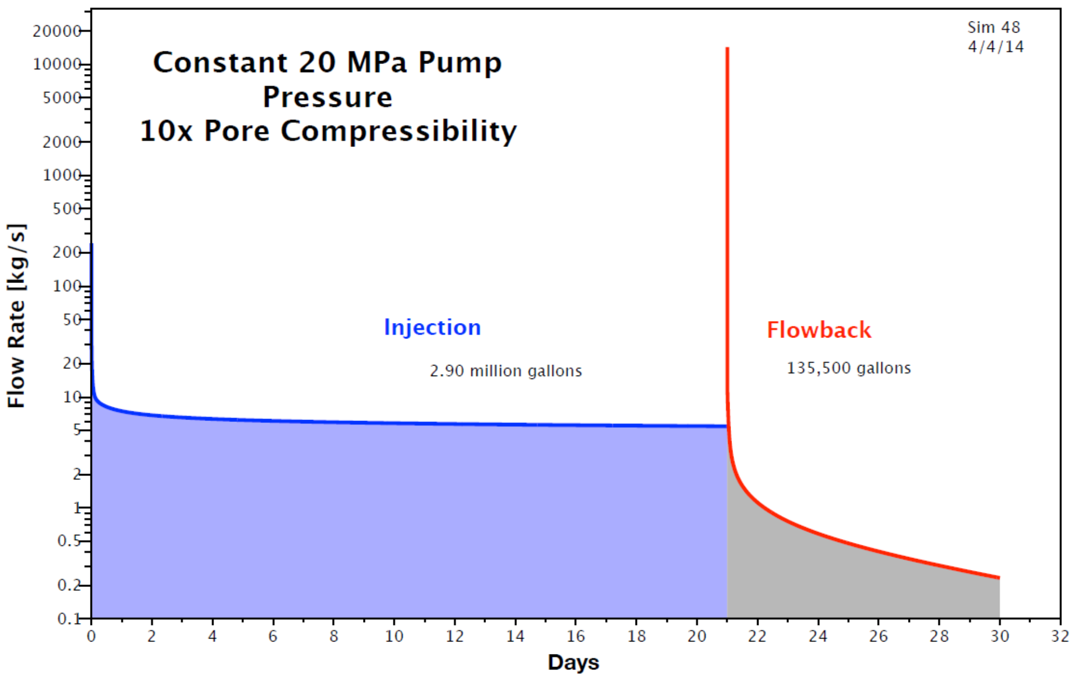


Figure J-1. Worst case modeled stimulation and flowback of well NWG 55-29, 10-fold increase in pore compressibility. Blue = injection period, red = flowback period.

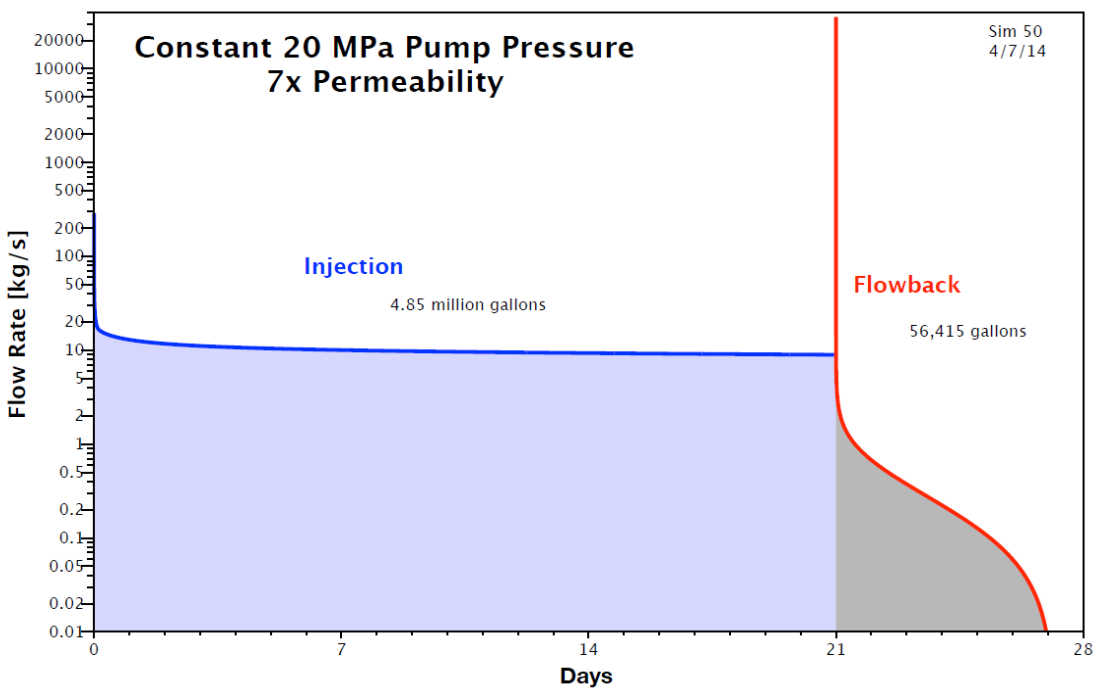


Figure J-2. Best case modeled stimulation and flowback of well NWG 55-29, 7-fold permeability increase. Blue = injection period, red = flowback period.

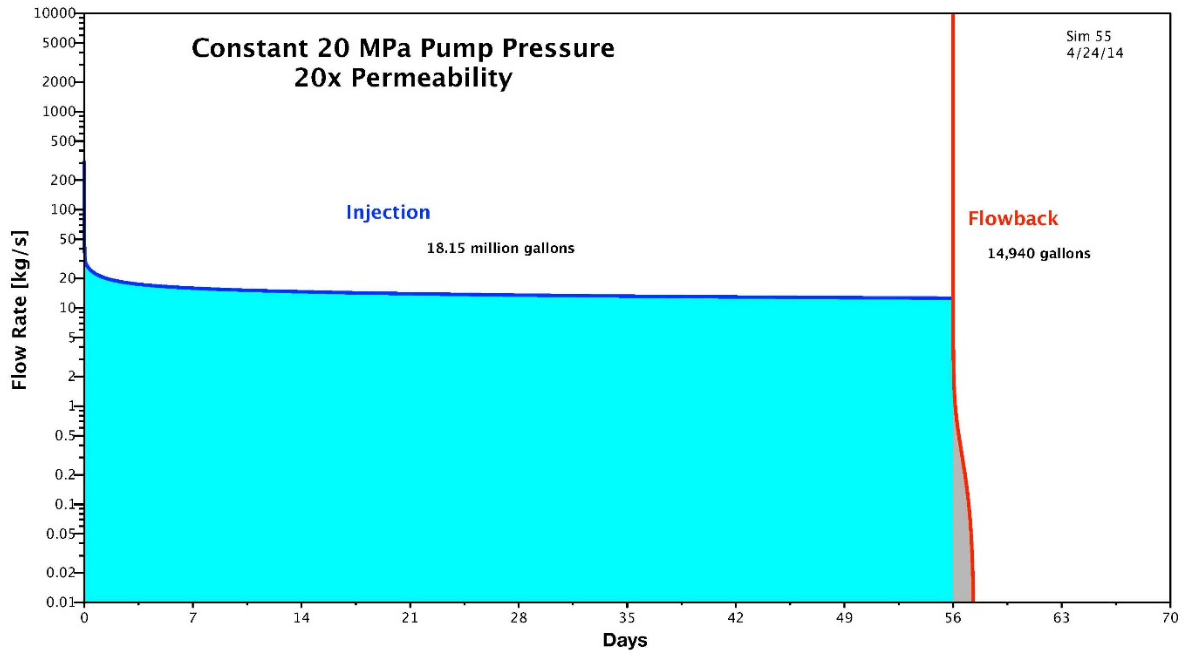


Figure J-3. Modeled stimulation to inject ~20 million gallons and flowback of well NWG 55-29, 20-fold permeability increase. Blue = injection period, red = flowback period.

Pressure bleed-off during shut-in

After shut-in in 2012, the well head pressure dropped to 50% of the shut-in pressure in 19 minutes and 75% in 66 minutes. The well head pressure was 0 in just 16 hours. The pressure fall-off is expected to be more gradual after re-stimulation in 2014; however, if pressure remains high after shut-in, this could result in increased seismicity and increased chance of larger (M >2.0) seismic events. Therefore, as an extra precaution, we will bleed-off the fluid pressure to 50% of the initial shut-in pressure if it does not reach that value on its own within 12 hours. Furthermore, if, during the shut-in period, an M>2.7 event occurs, and well head pressure has not dropped to 10% of the initial shut-in pressure, it will be bled-off to 10%. After the cold injected water has time to heat up, the well head pressure should begin to rise again as a gas cap forms. Once the well head pressure builds back up to 1000 psi due to heat up, the well will be ready to flow

Additions to Seismicity Report

During the 2012 stimulation, the microseismic array (MSA) was used to constantly monitor the characteristics of induced microseismicity and growth of the EGS reservoir during hydroshearing operations. At the operational office located at the well site, project geoscientists monitored and compared the injection rate, wellhead pressure, event locations, maximum event size, the size distribution of microseismicity (the b-value), and other parameters.

When microseismicity was being induced by the stimulation, a seismicity report was prepared and emailed to representatives of the DOE, BLM, FS, PNSN and LBNL. All of these seismicity reports are provided in Appendix D. Each report contained graphs showing the well head pressure and flow rate versus time, compared to microseismic event times. Map view and cross-sectional views of the events were also provided.

Since the original ISMP was written, additional tracking parameters has been developed to monitor for changes in seismic risk. For example, McGarr (2014), showed the relationship between seismic moment of the largest induced event (or cumulative seismic moment) and cumulative injected volume (Figure J-

4). The M_0=GΔV line in Figure J-4 is an upper bound to the relationship between injected volume and seismic response. This analysis shows that, compared to other injection projects, the seismicity induced during the Newberry EGS demonstration in 2012 is far from the M_0=GΔV boundary, indicating a low seismogenic potential. This graph provides an empirical and theoretical basis for judging the potential for induced seismic events which might be felt. Therefore, a version of this graph, updated with the cumulative volume and both cumulative and maximum moment will be included in the regular seismicity reports.

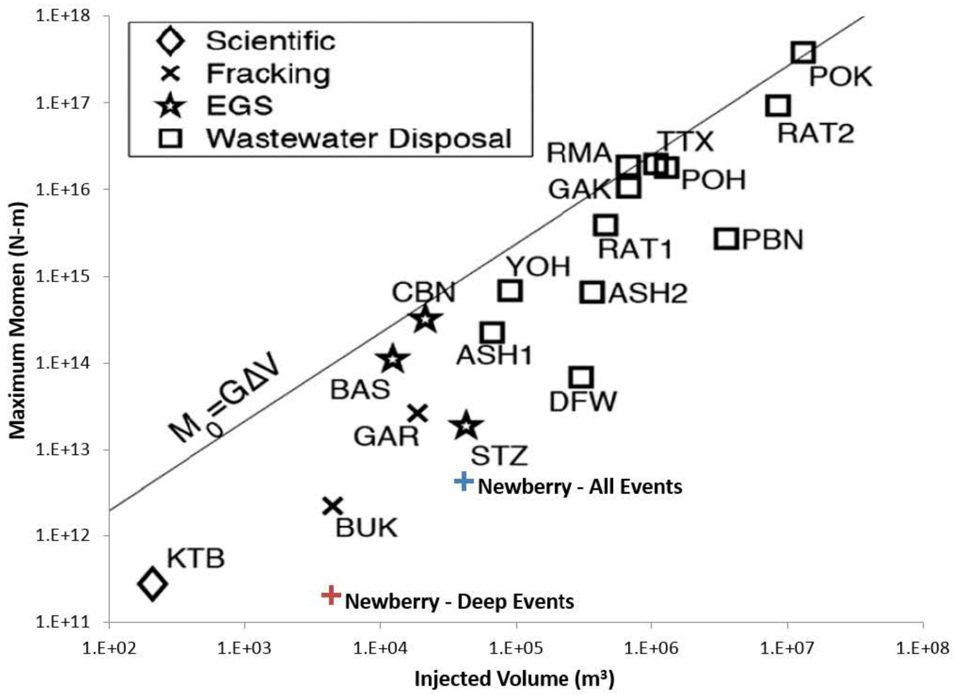


Figure J-4. Comparison of Injected Volume to Maximum Moment for various injection projects (McGarr, 2014) with Newberry EGS seismicity data overlain. This figure is also shown and discussed as Figure 5-22 in main text.

Another technique developed since the original ISMP was written is tracking of the temporal evolution of the b-value of the Gutenberg-Richter relationship. A reduction in the b-value will indicate that seismic events with relatively larger magnitudes are occurring at a higher rate. The best way to track evolution of the b-value is to use a sliding window of at least 100 of the most recent seismic event magnitudes. A b-value vs. time chart will also be included in the seismicity reports as soon as a catalog of about 100 events with acceptable quality magnitudes is developed.

Neither of the proposed new seismic risk tracking parameters have been used during an EGS stimulation to inform operational parameters. Providing this information to the seismic reviewers (seismologists at PNSN, LBL, and DOE) on a regular basis will allow further evaluation on the use of these parameters to quantify evolving seismic risk. If an increasing seismic risk is suggested by analysis of either data set, a discussion with the seismic reviewers will be initiated. Factors such as the quality of the data set, the rate of change of the seismic risk and what proactive measures might be taken to lower the seismic risk will be taken into consideration. If the seismic team concludes that an unacceptable seismic risk has developed and that the risk can be lowered by mitigative actions such as lowering the well head pressure and flow rate, AltaRock, with concurrence from the DOE, will undertake these actions.

ISMP Amendments

The following highlighted edits are proposed for the ISMP, including an update of contact information:

Proposed edits to Page 12 to update Toll Free Number (original number was lost):

Two web sites, several social media outlets, and a toll-free telephone line (1-844-EGS4USA) have been established to promote Demonstration communication.

Proposed edits to Page 35:

As shown at the top panel in Figure 3-8 the flow-back at Basel was initially as high as 1000 L/m (~250 gpm), about 25% of the injection rate, which caused an immediate stop to the microseismic events M > 2.0. In the first day of flow-back about 10% of the injected fluid returned. Eventually, over the next 14 months, a total of about 30% (900,000 gallons) of the injected fluid flowed back (Häring et al., 2008). **DELETE:** ~~After hydroshearing is completed at the Newberry EGS Demonstration, we plan to immediately flow back the injected water to relieve reservoir pressure and mitigate continued fracture growth and induced seismicity. Based on the Basel experience, we plan to keep sufficient room in sumps to hold at least 10% of the volume injected in any stage. Accordingly, two sumps with a combined capacity of about 3,000,000 gallons will be available, sufficient to contain 12% of the maximum water use estimated for single-well stimulation over a 21-day period.~~ **REPLACE WITH:** During the Newberry EGS Demonstration stimulation in 2012, AltaRock kept sufficient room in the well pad sumps to hold at least 10% of the injected volume for potential flow back. This volume was selected based on experiences at the Basel project. Having this storage volume required a 2.5 mile long temporary pipeline be constructed to connect the 55-29 pad to the 46-16 sump and provide a total of 2.8 million gallons of sump capacity, or more than 10% of the planned injection volume of 24 million gallons. One result of the 2012 stimulation at Newberry was that positive well head pressure did not develop. Instead, well head pressure rapidly dropped to zero once the injection pumps were shut off, and well head pressure remained negative for several weeks thereafter. A thermal-hydrological-mechanical (THM) model was developed and calibrated using the results of the 2012 stimulation. The model was used to simulate the theoretical potential for flowback from well NWG 55-29 under a range of possible post-stimulation conditions. A conservative estimate of the usable dimensions of the S-29 pad sump is 133x16x2.5m, for an estimated volume of 5300m^3 or 1.4 million gallons. The northern half of the sump, which will be used for water supply, is about 30% of the total volume, or roughly 400,000 gallons. This leaves a capacity of at least 1 million gallons in the southern part of the sump for emergency flow back water. Therefore, even under unrealistically conservative conditions, the modeling results indicate that a revised well pad flowback storage capacity of 5% will be sufficient, and that constructing a pipeline for restimulating well NWG 55-29 in 2014 is neither necessary nor cost effective.

Proposed edits to Page 43:

The MSA will be used to constantly monitor the growth of the EGS reservoir during hydroshearing operations. At the operational center located near the well site, seismologists and engineers will be monitoring and comparing the injection rate, wellhead and downhole pressure, event locations, maximum event size, the size distribution of microseismicity (the b-value), cumulative injected volume, cumulative seismic moment, and other parameters 24 hours a day.

The Project Manager will ensure that a daily activity report is transmitted to the DOE, BLM, FS, PNSN and LBNL. The daily report will be accompanied by several graphs including surface pressure, bottom hole pressure and flow rate versus time, and temperature versus depth. The daily seismicity graphic will show events versus depth and distance from the well. The events will be color-coded to differentiate recent and older events, and size-coded to delineate event magnitude. The report will include a graph which shows the b-value calculated from the last 100 events so that a systematic change in B-value can be visualized. The report will also include graph of total injected volume vs cumulative seismic moment and maximum seismic moment (i.e. the McGarr graph). These reports will be transmitted to designated third parties (e.g., DOE and BLM) by 11:00 am each day. If an increasing seismic risk is suggested by analysis of b-value or McGarr graphs, a discussion with the seismic reviewers will be initiated. Mitigative action will be taken if responsible parties agree it is warranted.

Proposed edits to Page 49:

7. Stop Injection and Flow Well – Any ground motion recorded on the Paulina Lake SMS with a PGA greater than 0.028 g that can be correlated in time to a seismic event within the 3 km (1.9 mi) aperture of the MSA will result in injection being halted. In addition, any seismic event detected within the 3 km (1.9 mi) aperture of the MSA with M greater than 3.5 as determined by PNSN or the AltaRock MSA, will also result in injection being halted. After injection is stopped, the well will be immediately flowed to surface test equipment to relieve reservoir pressure (see Section 4.6). Sufficient sump capacity will be available to store at least ~~10%~~ 5% of the injected fluid. Resumption of stimulation will be made only after consultation and agreement between AltaRock, DOE, BLM and FS.

8. Bleed-off during shut-in – After the well is shut-in, it is expected that the well head pressure will drop rapidly on its own. To reduce the probability of post-stimulation induced seismicity caused by fluid overpressure, the well will be bled-off to 50% of the initial shut-in pressure if it does not reach that value on its own within 12 hours. Furthermore, if, during the shut-in period, an M>2.7 event occurs, and well head pressure has not dropped to 25% of the initial shut-in pressure, it will be bled-off to 25%. After the cold injected water has time to heat up, the well head pressure should begin to rise again as a gas cap forms. If the well head pressure builds back up to 50% of the shut-in pressure due to heat up and development of a gas cap, the well will be opened up and the flow test begun. If well head pressure does not build back up to this value, other criteria will be used to determine when to start the flow test.

Proposed edits to Page 43 to update Contacts:

Table 4-3. Updated Contacts for Induced Seismicity Communications

Organization	Contact Name	Email Address	Phone
Technical Notification and Review: Outlier, Trigger, and Mitigation Reports			
Pacific Northwest Seismic Network (PNSN)	John Vidale	john_vidale@mac.com	(206) 543-6790
U.S. Department of Energy (DOE)	Lauren Boyd	Lauren.Boyd@go.doe.gov	(202) 297-8798
Lawrence Berkeley National Lab (LBNL)	Ernest Majer	elmajer@lbl.gov	(510) 486-6709
U.S. Bureau of Land Management (BLM)	Steve Storo	steve_storo@blm.gov	(541) 295-0871
U.S. Forest Service (FS)	Barton Wills	bwills@fs.fed.us	(541) 480-6194
Emergency Notification: Seismic Event Reports			
Deschutes County Sheriff	Dispatch	NA	**(541) 693-6911**

Proposed edits to Page 52 to update Toll Free Number (original number was lost):

- Signs will be posted at the beginning of Road 500 for uphill traffic, and on Paulina Peak for downhill traffic, stating “Rock fall hazard ahead. Please contact 844-USA-4-EGS toll-free (844-347-4872) to report rocks on the road,” or alternative text approved by the FS. ….
- Signs will be posted at snow parks and other entrance points that provide winter access to NNVM. The signs will read “Warning: snow avalanche hazards exist on any slope steeper than 25°, including the slopes leading to Paulina Lake and East Lake from the Crater Rim. Skiers and snowmobilers, and geothermal demonstration activities occurring this winter can trigger avalanches on hazardous slopes. Call 844-USA-4-EGS toll-free (844-347-4872) for more information”, or alternative text approved by the FS……

References

AltaRock (2011a), Induced Seismicity Mitigation Plan, Newberry EGS Demonstration. Posted August 2011, 3 MB, http://altarockenergy.com/projectupdates/Newberry_ISMPlan.pdf

AltaRock (2011a), Induced Seismicity Mitigation Plan, Newberry EGS Demonstration. Posted August 2011, full version with appendices 60 MB, http://altarockenergy.com/projectupdates/Newberry%20EGS%20Demonstration%20ISMP%203Aug11.pdf

BLM, 2012, Environmental Assessment for Newberry Volcano Enhanced Geothermal System (EGS) Demonstration Project, Decision Record April 5, 2012, http://www.blm.gov/or/districts/prineville/plans/newberryegs/index.php

McGarr, A. 2014. Maximum magnitude earthquakes induced by fluid injection. Journal of Geophysical Research: Solid Earth, 119.

Appendix B
Stimulation Daily Field Progress Reports

ALTAROCK ENERGY INC

Daily Report

AltaRock Energy

Well ID: NWG 55-29 **Job ID: Stim 2014** **Well Name: Northwest Geothermal 55-29**

Field: Newberry Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 1 **Report For 22-Sep-14**

Operator:	AltaRock Energy	**Rig:**		**Spud Date:**	13-Apr-08	**Daily Cost / Mud ($):**			---
Measured Depth (ft):		**Drilling Days (act.):**	0	**Well Bore:**	Original Well Bore	**AFE No.**		**AFE ($)**	**Actual ($)**
Vertical Depth (ft):	10060	**Drilling Days (plan):**	68	**RKB Elevation (ft):**	0.00	---		---	---
Proposed TD (ft):	10000	**Days On Location:**	1	**Last BOP Test:**		---		---	---
Hole Made (ft) / Hrs:	10,060 / 0.0	**Last Casing:**	7.000 at 9,990			**Totals**		---	---
Average ROP (ft/hr):		**Next Casing:**		**Working Interest:**		**Job/Well Cost ($):**			---

Personnel: **Operator:**	**Contractor:**	**Service:**	**Other:**	**Total:**	0

Current Operations: Rigged up and begin inject to cool operations around 19:15. Set-up DTS onsite and prepare to run in hole tomorrow.

Planned Operations: Continue to run stim pump 1 to cool wellbore overnight. Install DTS and continue injection test at 1200 psi, 1600psi, 1800 psi and 2000 psi.

Wellsite Supervisors: Michael Moore, Ted De Rocher **Tel No.:**

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
8:00	19:15	11.25		TEST	Pick-up DTS from storage yard this morning. WAC onsite, rigging up lubricator to RIH with DTS tomorrow. Coastcom onsite for fiber optic splicing. Configuring instrumentation and testing pump	
19:15	0:00	4.75		INJ	Started pump 1: Stim rpm = 46.8 hz, Bypass open full WHP = 855 psi, Downhole flow = 30 gpm (ultrasonic) to 40 gpm (Weir box subtraction). Inlet flow = 550 gpm; Current outside Temp = 54 F	

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Safety Information

First Aid:	**Medical:**	**Lost Time Accidents:**	**Days Since LTA:** 0
☐ **BOP Test**	☐ **Crownamatic Check**		

Weather Information

Sky Condition:	Clear	**Visibility:**	
Air Temperature:	54.0 degF	**Bar. Pressure:**	
Wind Speed/Dir:	/	**Wind Gusts:**	

ALTAROCK ENERGY INC

Daily Report

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 2 | **Report For 23-Sep-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):	---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No. / AFE ($) / Actual ($)	
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	--- / ---	---
Proposed TD (ft):	10000	Days On Location:	2	Last BOP Test:		--- / ---	---
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals / ---	---
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):	---

Personnel: Operator: | Contractor: | Service: | Other: | Total: 0

Current Operations: RIH with DTS. 30 degrees of cooling achieve at the bottom of the DTS (~8500 ft) as of this AM.

Planned Operations: Conduct injectivity test over night at 1200 psi, 1400 psi, 1600 psi and 1800 psi. Then begin stimulation.

Wellsite Supervisors: Trenton Cladouhos, Ted De Rocher | Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	12:00	12.00		INJ	Injecting overnight to cool the wellbore in preparation for the DTS install. Stim pump 1 running, approximately 850-860psi WHP and 20-25gpm. Coastcom onsite at 9AM to prep the DTS connectors.	
12:00	18:00	6.00		RIH	12:30 DTS started to run in hole. Weight tested every 1000ft. Tested fiber at 7000' with power meter to ensure good signal return with the dual ended configuration. 16:00 DTS reached 9556'. Testing with power meter showed no signal returns. Connected the DTS to the signal box and shot both multi-mode fibers. Signal loss showed fiber break at approximately 7800-7850 ft downhole in both channels. (~9300 ft from the surface. Total fiber length was approximately 10,760 ft). Lowered the cable another 59ft to a final setting depth of 9615ft. 18:00 release WAC. Spooling truck left on site.	
18:00	18:30	0.50		INJ	Stim pump 1 started at 18:05, 612 WHP. Stim pump 2 started at 18:20, 1104 WHP. Water leak in lubricator detected, shut pumps down at 18:30 to tighten.	
18:30	22:10	3.67		SERV	Leak in lubricator. Welder onsite repairing leaks.	
22:10	0:00	1.83		INJ	22:10 Stim pump 1 started, 598 psi WHP. 22:45 stim pump 2 started, 900 WHP. 23:07 WHP reached 1200 psi, flow rate approximately 23 gpm from ultrasonic meter read. Begin step-rate injection test overnight.	

Comments

Seismic System operational. 16 stations.
No microseismic events detected. Results can be viewed at
http://esd.lbl.gov/research/projects/induced_seismicity/egs/newberry.html and http://pnsn.org/volcanoes/newberry

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

ALTAROCK ENERGY INC	Daily Report		AltaRock Energy
	Well ID: NWG 55-29	Job ID: Stim 2014	Well Name: Northwest Geothermal 55-29
	Field: Newberry		Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 3 — **Report For 24-Sep-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):	---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No. / AFE ($) / Actual ($)	
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	--- / --- / ---	
Proposed TD (ft):	10000	Days On Location:	3	Last BOP Test:		--- / --- / ---	
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals / --- / ---	
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):	---

Personnel:	Operator:	Contractor:	Service:	Other:	Total: 0

Current Operations: Step rate injection test started last on previous day was completed by 11:00. Flow rates into well were very low, indicating an injectivity index of 0.012 gpm/psi. This is lower than 2012 baseline injectivity of 0.035 gpm/psi, likely due to smaller casing diameter, perforated liner in open hole, and isolation of PAS line on 9 5/8" casing.

Varying pumping pressures today as repairs continued to seal leaks around the wellhead when operating at high pressures. Maximum pressure reached: 2252 psi with approximately 36-42 gpm going downhole.

Planned Operations: Hold steady at 2200 psi WHP overnight. In daytime, ramp up WHP further until permeability increase occur. Maximum allowable WHP is 3000 psi; however, practical maximum is close to 2600 psi.

Wellsite Supervisors: Susan Petty, Ted De Rocher — Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	0:20	0.33		INJ	Step 1 of injection test ongoing, WHP at 1200 psi, flow stabilizes at average of 17 gpm	
0:20	2:20	2.00		INJ	Step 2: Increase to WHP of 1400 psi, flow stabilizes at average of 19 gpm	
2:20	4:42	2.37		INJ	Step 3: Increase to WHP of 1600 psi, flow stabilizes at average of 19 gpm	
4:42	5:04	0.37		INJ	Step 3.5: Increase to WHP of 1700 psi, hold for 15 minutes before continuing to next step	
5:04	8:48	3.73		INJ	Step 4: Increased to WHP of 1800 psi, flow stabilizes at average of 24 gpm	
8:48	10:12	1.40		INJ	Step 5: Increased to WHP of 2000 psi, flow stabilizes at average of 23 gpm	
10:12	12:09	1.95		INJ	WHP increases 18 psi in 5 minutes with no change in pump parameters (unknown cause). 11:12 starting to use bypass throttle valve to increase WHP. 12:09 at 2158 psi WHP, new leaks are detected. Lowered stimulation pressures down to approximately 1000 psi to fix leaks.	
12:09	18:38	6.48		REPR	12:09 WHP reached 2158, new leaks are detected. Lowered pressure to fix leaks. Stim pump 2 trip at 14:06, reset and troubleshoot pump 2 fail to start. Bypass valve not fully opened caused failed to start. Injection mostly continued downhole during this period with stim pump 1 running. Both pumps down during 18:00 to 18:38	
18:38	0:00	5.37		INJ	Restarted pumps and ramp up pressure. 19:50 WHP reached 2252, new leaks are detected, pressure lowered to 735 to fix leaks. 22:05 WHP at 2012 psi, downhole flow at 23 gpm. 22:50 increased WHP to 2200 psi, small leak on lubricator but not of concern. Downhole flow at 34gpm. Bypass throttle valve at 40%. Staying steady overnight.	

Comments

Flow rates are measured using an Ultra-sonic flow meter on the high pressure inlet. At each step the rate would fluctuate by +/- 2gpm around the average reported above. We were skeptical of the low flows being reported, so compared this flow to weir box calculations, draw down rate of sump, and (after it was installed at 11:00) a mag meter on the bypass return flow line. By these comparisons (none very precise), we concluded that average flows into the well were less than 30 gpm.

No induced microseismicity has been detected.

Transfer pump installed to move water from south sump to north sump; working well.

Began installing heat tape on instrumentation in preparation for freezing weather ahead.

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Rainy	Visibility:	
Air Temperature:	60.0 degF	Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	

ALTAROCK ENERGY INC

Daily Report

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 4 | **Report For 25-Sep-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):		---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No.	AFE ($)	Actual ($)
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	---	---	---
Proposed TD (ft):	10000	Days On Location:	4	Last BOP Test:		---	---	---
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals	---	---
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):		---

Personnel: Operator: | Contractor: | Service: | Other: | Total: 0

Current Operations: Increasing WHP and stimulate well

Planned Operations: Continue to inject and stimulate well. We intend to drop the pressures down to 1500 psi or less for a period of time to test the apparatus that we have built to inject diverter. It is a secondary line and has ports for adding diverter. No diverter will be injected, just water.

Wellsite Supervisors: Susan Petty, Ted De Rocher | Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	10:30	10.50		INJ	WHP held steady near 2200 psi overnight, approximately 31-34 gpm going downhole	
10:30	12:30	2.00		INJ	WHP increased to 2400 psi, approximately 50 gpm going downhole	
12:30	15:50	3.33		INJ	WHP increased to 2550 psi, approximately 55 gpm going downhole	
15:50	0:00	8.17		INJ	WHP increased to 2580 psi, approximately 65 gpm going downhole. 20:30 Average flow rate increased to 70 gpm at steady WHP OF 2580 psi. WHP held steady near 2580 psi overnight, ~68-72 gpm going downhole	

Comments

All instruments have been heat taped to prepare for freezing temperatures.
2580 psi is close to the maximum pressure that pumps can achieve in current configuration. We will try other measures such as throttling the bypass valve to reach higher pressures.
The bottom of the DTS at 8000ft has been cooled from 520 deg. F down to 340 deg. F. Thermal stimulation (cracking due to thermal contraction) may be occurring, which we hope will lead to mechanical stimulation as well.
See attached graphs of pressure and flow histories and temperature profiles.

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Rainy	Visibility:	
Air Temperature:	60.0 degF	Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	

Daily Report

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 5 | **Report For 26-Sep-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):	---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No. / AFE ($) / Actual ($)	
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	--- / --- / ---	
Proposed TD (ft):	10000	Days On Location:	5	Last BOP Test:		--- / --- / ---	
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals / --- / ---	
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):	---

Personnel: Operator: | Contractor: | Service: | Other: | Total: 0

Current Operations: Ramp down pumps and fix leaks. Test diverter injection spool. Re-start pumps and increase pressure in step-wise fashion to see if permeability improvement is permanent. Continue stimulation.

Planned Operations: Reach previous high pressure of 2580 psi. During the shutdown, adjustments were made to the pump drives that should allow higher pressures to be achieved.

Wellsite Supervisors: Michael Moore, Trenton Cladouhos | Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	10:40	10.67		INJ	WHP and flow held steady overnight at 2580 psi and approximately 70 gpm.	
10:40	12:20	1.67		INJ	Slowly ramping down pumps.	
12:20	16:50	4.50		REPR	Welder on site repairing lubricator leak. Pressure tested lubricator.	
16:50	19:15	2.42		TEST	Diverter injection spool tested. Inlet valve was found to be faulty. Replaced inlet valve.	
19:15	20:00	0.75		INJ	Injection resumed. Pressure will be increased in steps to measure injectivity changes.	
20:00	20:45	0.75		INJ	1600 psi WHP and held for 45 minutes.	
20:45	22:56	2.18		INJ	1800 psi WHP and flowrate stablized around 42 gpm.	
22:56	0:00	1.07		INJ	2000 psi WHP and flowrate stablized around 50 gpm.	

Comments

Seismicity: Attached see the preliminary email report for the first seismic event on Sept 25 at 23:18 and a map of the location after reivew by a seismologist.

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Safety Information

First Aid: | Medical: | Lost Time Accidents: | Days Since LTA: 1

☐ BOP Test ☐ Crownamatic Check

Weather Information

Sky Condition:	Partly Cloudy	Visibility:	
Air Temperature:	60.0 degF	Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	

ALTAROCK ENERGY INC

Daily Report

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 6 | **Report For 27-Sep-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):	---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No. / AFE ($) / Actual ($)	
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	--- / --- / ---	
Proposed TD (ft):	10000	Days On Location:	6	Last BOP Test:		--- / --- / ---	
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals / --- / ---	
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):	---

Personnel: Operator: | Contractor: | Service: | Other: | Total: 0

Current Operations: GRC field tour on site 10:30 am - noon.
2765 psi is close to maximum pump pressure.
Well bore continues to cool. Bottom of DTS 265F

Planned Operations: Continue to stimulate

Wellsite Supervisors: Michael Moore, Trenton Cladouhos | Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	1:08	1.13		INJ	Held third step at 2000 psi for two hours. Flowrate stabilized around 50 gpm.	
1:08	3:05	1.95		INJ	Fourth step at 2200 psi. Held for two hours. Flowrate stabilized around 60 gpm.	
3:05	5:15	2.17		INJ	Fifth step at 2400 psi. Held for two hours. Flowrate stabilized around 70 gpm.	
5:15	14:05	8.83		INJ	Increased WHP to 2690 psi at 05:15. Then gradually increasing pumping pressures. 13:11-14:05 WHP up to 2752 psi.	
14:05	23:59	9.90		INJ	WHP up to 2765 psi and hold overnight. Flowrates approximately 90 gpm at midnight.	

Comments

Cumulative injected Volume = 331,241 gallons

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Rainy/Partly cloudy	Visibility:	
Air Temperature:	47.0 degF	Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	

Daily Report

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 7 | **Report For 28-Sep-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):		---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No.	AFE ($)	Actual ($)
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	---	---	---
Proposed TD (ft):	10000	Days On Location:	7	Last BOP Test:		---	---	---
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals	---	---
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):		---

Personnel: Operator:	Contractor:	Service:	Other:	Total:	0

Current Operations: Continue stimulation

Planned Operations: Continue pumping at current rate. Monitor seismicity and injectivity improvement.

Wellsite Supervisors: Michael Moore, Trenton Cladouhos | Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	11:30	11.50		INJ	Pumps held steady, WHP slowly decreased from 2765 to 2757, injecting 80-96 gpm	
11:30	18:57	7.45		INJ	Pressure increased and held at 2777 psi by throttling bypass valve,injecting 105 gpm	
18:57	19:04	0.12		INJ	Pressure increase and held at 2820 psi by throttling bypass valve, injecting 110 gpm	
19:04	23:59	4.92		INJ	Hold pressure at 2820 psi and inject overnight.	

Comments

Bottom of DTS: 204 deg. F
Seismicity: 6 mciroseismic events. Seismologist will review and provide locations on Monday.

Cumulative injected Volume 477,540 gallons.

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Partly cloudy	Visibility:	
Air Temperature:	47.0 degF	Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	

Daily Report

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 8 | **Report For 29-Sep-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):			---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No.		AFE ($)	Actual ($)
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	---		---	---
Proposed TD (ft):	10000	Days On Location:	8	Last BOP Test:		---		---	---
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals		---	---
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):			---

Personnel: Operator:	Contractor:	Service:	Other:	Total:	0

Current Operations: Stimulation. Bottom (8056ft) of DTS 204 deg. F. Well temperature equilibrated at current injection rates.

Planned Operations: Continue stimulation. Inject at current rate. Monitoring seismicity and injectivity improvements.

Wellsite Supervisors: Michael Moore, Trenton Cladouhos | Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	11:35	11.58		INJ	Pumps held stead, WHP gradually increased from 2819 to 2827 psi. Flowrate between 120-100 gpm.	
11:35	14:08	2.55		INJ	Bypass valve opened slightly, resulting in WHP dropping back to 2819 psi. Flowrate approximately 100 gpm.	
14:08	23:59	9.85		INJ	Slight WHP pressure drop at 14:08 to 2809 psi with no operational change. Injecting approximately 100-110 gpm.	

Comments

Seismicity: Four more microseismic events. Seven microseismic events on 9/28/2014, for total of 11. Events have magnitudes between 0.6 and 1.3 and preliminary depths of 2.33 – 2.73 km below sea level. The bottom of the hole is at about 1 km below sea level, so these events are below the bottom of the well. See attached map for PRELIMINARY locations.

Cumulative injected Volume 635,030 gallons

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Clear to overcast to drizzly	Visibility:	
Air Temperature:	41.0 degF	Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	
Comments:	Hi 60, low 41. Some wind.		

ALTAROCK ENERGY INC

Daily Report

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 9 | **Report For 30-Sep-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):	---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No. / AFE ($) / Actual ($)	
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	--- / --- / ---	
Proposed TD (ft):	10000	Days On Location:	9	Last BOP Test:		--- / --- / ---	
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals / --- / ---	
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):	---

Personnel: Operator: | Contractor: | Service: | Other: | Total: 0

Current Operations: Continue to stimulate. Bottom (8056ft) of DTS 194 deg. F. Well temperature has equilibrated.

Planned Operations: Continue injecting at current rate, and monitoring seismicity and injectivity improvement.

Wellsite Supervisors: Michael Moore, Trenton Cladouhos | Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	10:20	10.33		INJ	Pumps held steady, WHP at 2806. Injection rate between 100-110 gpm.	
10:20	11:00	0.67		INJ	Bypass shut 2% resulting in 20 psi WHP increase to 2826 psi.	
11:00	14:00	3.00		INJ	Globe valve close 1/2 resulting in 12 psi WHP increase to 2838 psi. Water well turned on. resulting in 12 deg. F reduction in injection temp to 76 deg. F.	
14:00	23:59	9.98		INJ	Gradual increase in WHP to 2847 psi. Injection rate about 123 gpm. Hold flowrate and pressure overnight.	

Comments

Seismicity: Thirty-one more microseismic events, for total of 45 events. Events have PRELIMINARY magnitudes between 0.6 and 1.7 and PRELIMINARY depths of -0.15 – 3.0 km below sea level. The bottom of the hole is at about 1 km below sea level, so most of these events are below the bottom of the well. New hand processed locations should be available tomorrow. Foulger Consulting has started processing seismic data for moment tensor solutions.

Cumulative injected volume: 800,200 gallons

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Overcast to partly cloudy	Visibility:	
Air Temperature:	35.0 degF	Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	
Comments:	Some wind, Hi 50, low 35		

Daily Report

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 10 | **Report For 01-Oct-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):	---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No. / AFE ($) / Actual ($)	
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	--- / --- / ---	
Proposed TD (ft):	10000	Days On Location:	10	Last BOP Test:		--- / --- / ---	
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals / --- / ---	
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):	---

Personnel: Operator: | Contractor: | Service: | Other: | Total: 0

Current Operations: Stimulation and testing diverter (TZIM) injection methods

Planned Operations: Continue injecting at current rate, and monitoring seismicity and injectivity improvement.

Wellsite Supervisors: Michael Moore, Trenton Cladouhos | Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	7:25	7.42		INJ	Pumps running stead overnight, WHP at 2795 psi with injection rates averaging 120 gpm. (The inlet flow dropped to 627 gpm at 02:45, but injection downhole remained unchanged)	
7:25	14:15	6.83		INJ	Opened globe valve 2/3 turn, now at 7-5/6 turns. WHP reached 2841 psi. Injection down the well between 100-110 gpm.	
14:15	15:20	1.08		INJ	Stepped pressure down to test Diverter Injection Vessel Assembly (D.I.V.A.). WHP reached 2443 psi. Reduction in WHP resulted in no flow going into the well.	
15:20	17:30	2.17		INJ	Flow resumed to well at 2461 psi. WHP increased to 2529 psi at 16:00 and held.	
17:30	21:39	4.15		INJ	17:30 - 18:45 WHP increased to 2550 psi and held 18:45 - 19:45 WHP increased to 2600 psi and held 19:45 - 20:30 WHP increased to 2650 psi and held	
21:39	23:59	2.33		INJ	WHP increased to 2800 psi, increased to 2856 psi over next hour. Hold pressure and inject overnight	

Comments

Seismicity: 43 additional microseismic events, for a total of 88. Depths for the 32 handpicked events range from 1.97 to 2.73 km bgs and magnitudes for handpicked events range from 0.6 - 1.7. Depths of the 78 auto-picked events with vertical errors less than 1 km range from 0.26 to 4.55 km bgs.

In the one hour period, when well head pressure lowered from 2841 to 2443, there were three microseismic events.

Cumulative injected Volume 950,080 gallons

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Clear	Visibility:	
Air Temperature:	24.0 degF	Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	
Comments:	Some wind, Hi 53, low 24		

Daily Report

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 11 | **Report For 02-Oct-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):	---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No. / AFE ($) / Actual ($)	
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	--- / --- / ---	
Proposed TD (ft):	10000	Days On Location:	11	Last BOP Test:		--- / --- / ---	
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals / --- / ---	
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):	---

Personnel: Operator: | Contractor: | Service: | Other: | Total: 0

Current Operations: Continue stimulation. Lauren Boyd, Ben Phillips, and Elisabeth Metcalfe of DOE visited site in morning.

Planned Operations: Continue injecting at current rate, and monitoring seismicity and injectivity improvement

Wellsite Supervisors: Michael Moore, Trenton Cladouhos | Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	11:30	11.50		INJ	Pumps running steady overnight. WHP between 2871-2860 psi.	
11:30	14:16	2.77		REPR	Shut down pumps to replace bypass ball valve and service generator. WHP falling off at ~100 psi/hr. 13:30 restarted stim pumps and began ramping up speed.	
14:16	17:05	2.82		INJ	Ramping up pumps. 16:00-17:00 stim pump 2 tripped because the Hz setting was higher than the actual Hz reading during ramp up from last shut down. Slowed stim pump 1 down to 42 Hz.	
17:05	22:50	5.75		INJ	17:05 stim pump 2 start-up initiated. Followed ramp up procedures not allowing Hz-setting and Hz-actual deviate by more than 0.5 Hz and allowing Hz-actual to catch up before increasing speed.	
22:50	23:59	1.15		INJ	Opened bypass to 46% . Ramped up stim pumps to full speed. Hold flow and pressure for 1 hour then throttle bypass and globe valve. WHP at approximately 2800psi	

Comments

Seismicity: 39 additional seismic events for a total of 128. Error in station elevations had been made in the seismic software inputs - all stations had been put near sea level. With correct station elevations (4700 to 6400 feet) the seismic depths are now adjacent to the open hole. Event magnitudes are being re-calculated. See attached maps of hand-picked event locations.

Cumulative injected volume 1,076,00 gallons

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Clear	Visibility:	
Air Temperature:	27.0 degF	Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	
Comments:	Light breeze, Hi 64		

Daily Report

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 12 | **Report For 03-Oct-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):	---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No. / AFE ($) / Actual ($)	
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	--- / --- / ---	
Proposed TD (ft):	10000	Days On Location:	12	Last BOP Test:		--- / --- / ---	
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals / --- / ---	
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):	---

Personnel: Operator: | Contractor: | Service: | Other: | Total: 0

Current Operations: Continue Stimulation

Planned Operations: Continue injecting at current rate, and monitoring seismicity and injectivity improvement.

Wellsite Supervisors: Michael Moore, Marc Steffen | Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	0:50	0.83		INJ	Throttled bypass to 35%. WHP reached 2835psi.	
0:50	2:17	1.45		INJ	Pump 2 tripped. Ramped down pump 1 and re-started pump 2. Ramped back up to full pump speed and closed bypass to 39%.	
2:17	9:45	7.47		INJ	Ramp up pumps to reach 2840 WHP. Closed bypass valve to 45%.	
9:45	11:40	1.92		INJ	Pump 2 tripped. Reset drive breaker and manually turn the drive shaft to re-start pump.	
11:40	23:59	12.32		INJ	Increase Hz to 62.9 on Stim pump 1 and 60.1 on Stim pump 2; WHP between 2550-2700 psi. Injection rate approximately 100gpm.	

Management Summary

Checked globe valve to see if working. With the auto valve set at 40% we made 7.5 turns on the globe valve and the pressure went up, meaning the globe valve is operational.

Comments

Seismicity: 42 additional seismic events for a total of 150. See attached visual for event locations.

Cumulative injected volume 1,186,000 gallons

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Clear	Visibility:	
Air Temperature:	33.0 degF	Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	
Comments:	Light breeze, Hi 65		

ALTAROCK ENERGY INC	Daily Report		AltaRock Energy
	Well ID: NWG 55-29	Job ID: Stim 2014	Well Name: Northwest Geothermal 55-29
	Field: Newberry		Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 13 — **Report For 04-Oct-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):			---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No.		AFE ($)	Actual ($)
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	---		---	---
Proposed TD (ft):	10000	Days On Location:	13	Last BOP Test:		---		---	---
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals		---	---
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):			---

Personnel: Operator:	Contractor:	Service:	Other:	Total: 0

Current Operations:	Continue stimulation
Planned Operations:	Continue injecting at current rate, and monitoring seismicity and injectivity improvement.
Wellsite Supervisors:	Michael Moore, Marc Steffen
Tel No.:	

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	23:59	23.98		INJ	Stim pump 1 at 63 Hz, Stim pump 2 at 60 Hz, wellhead pressure at approximately 2800 psi with injection rates between 80-90 gpm. 18:30: Water well turned on to reduce inlet flow temperature (still running at the same Hz)	

Comments

Seismicity: 30 additional seismic events for a total of 180. See attachments for additional seismic event analysis.

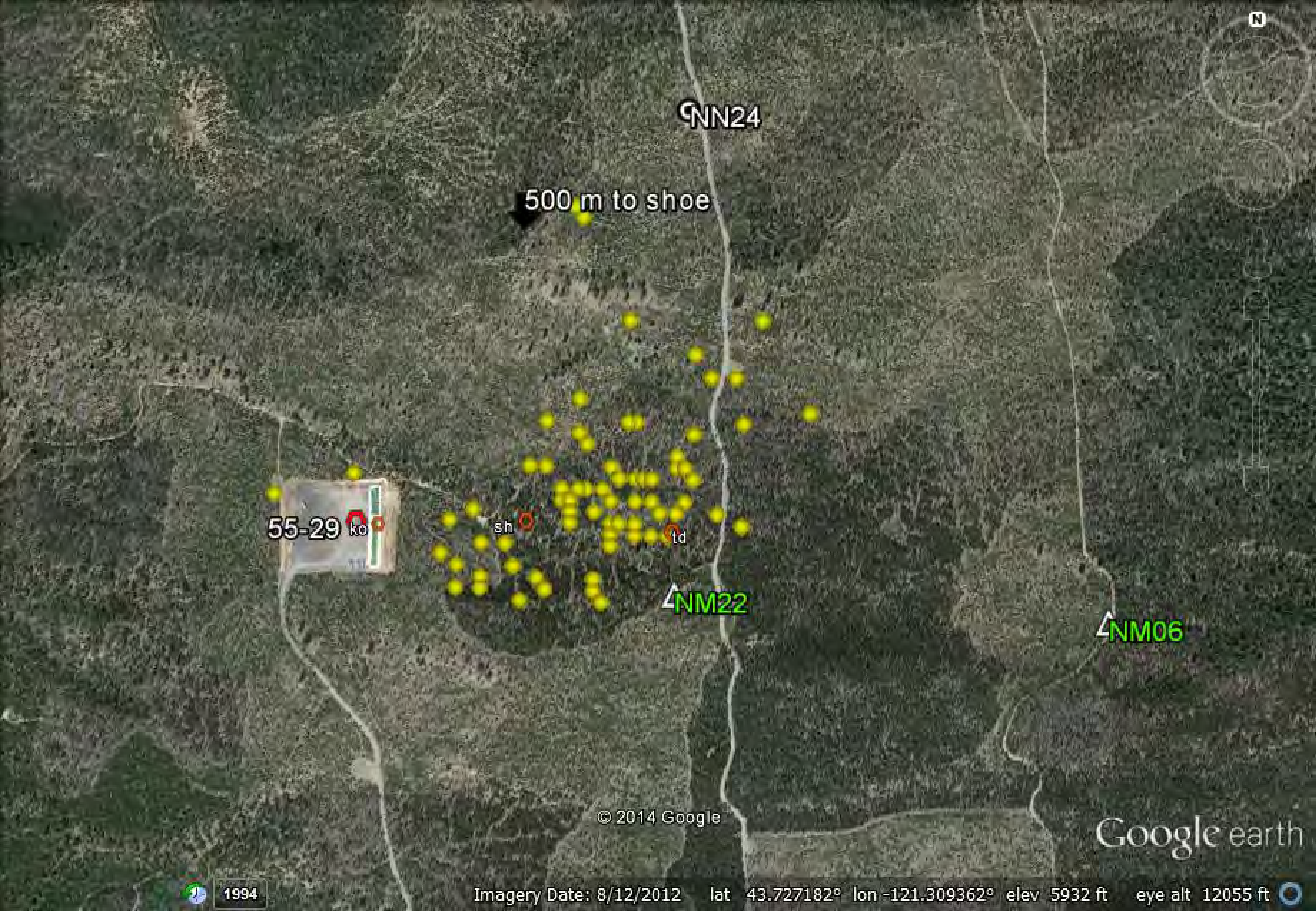
Cumulative injected volume 1,306,700 gallons

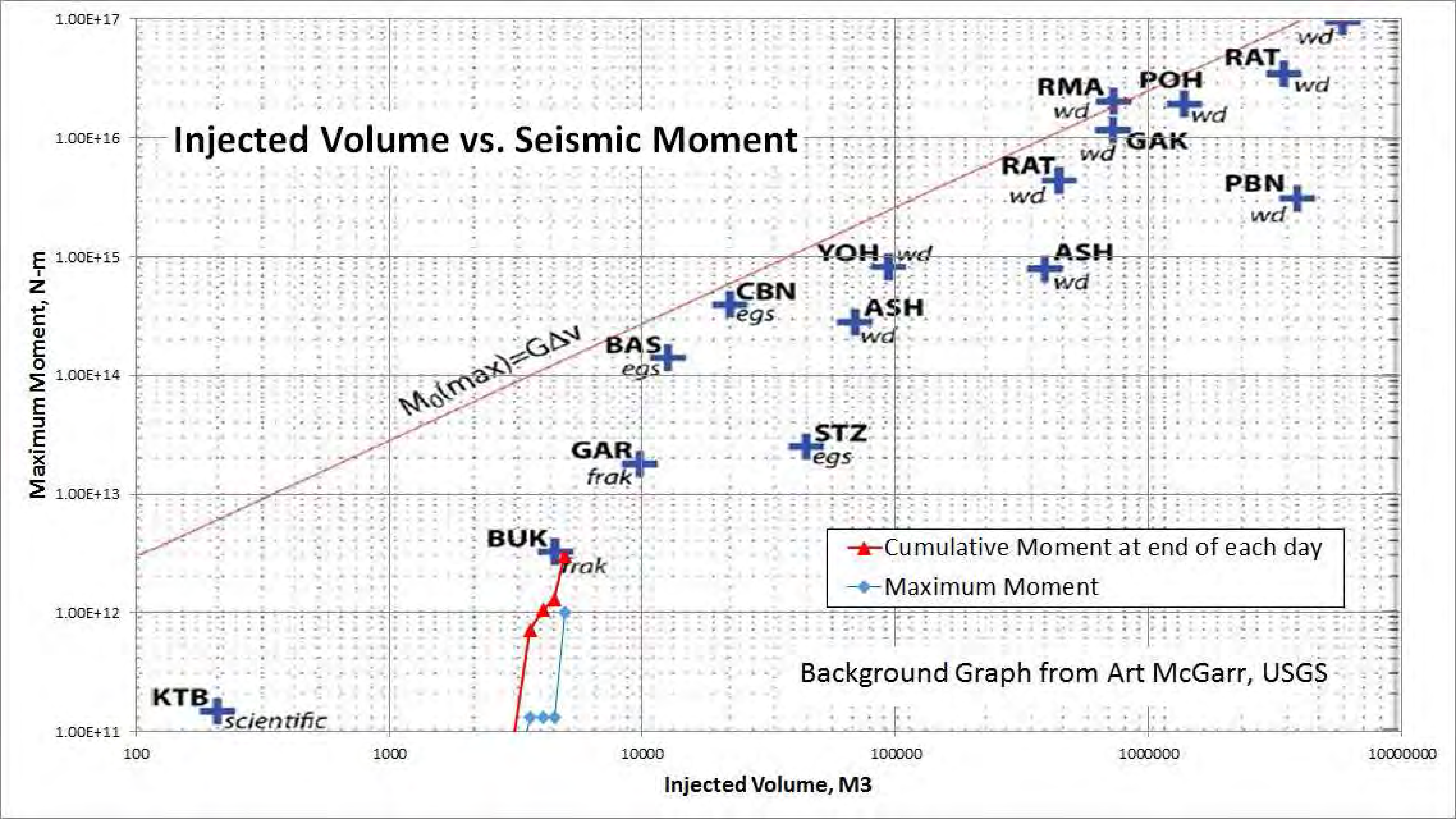
Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

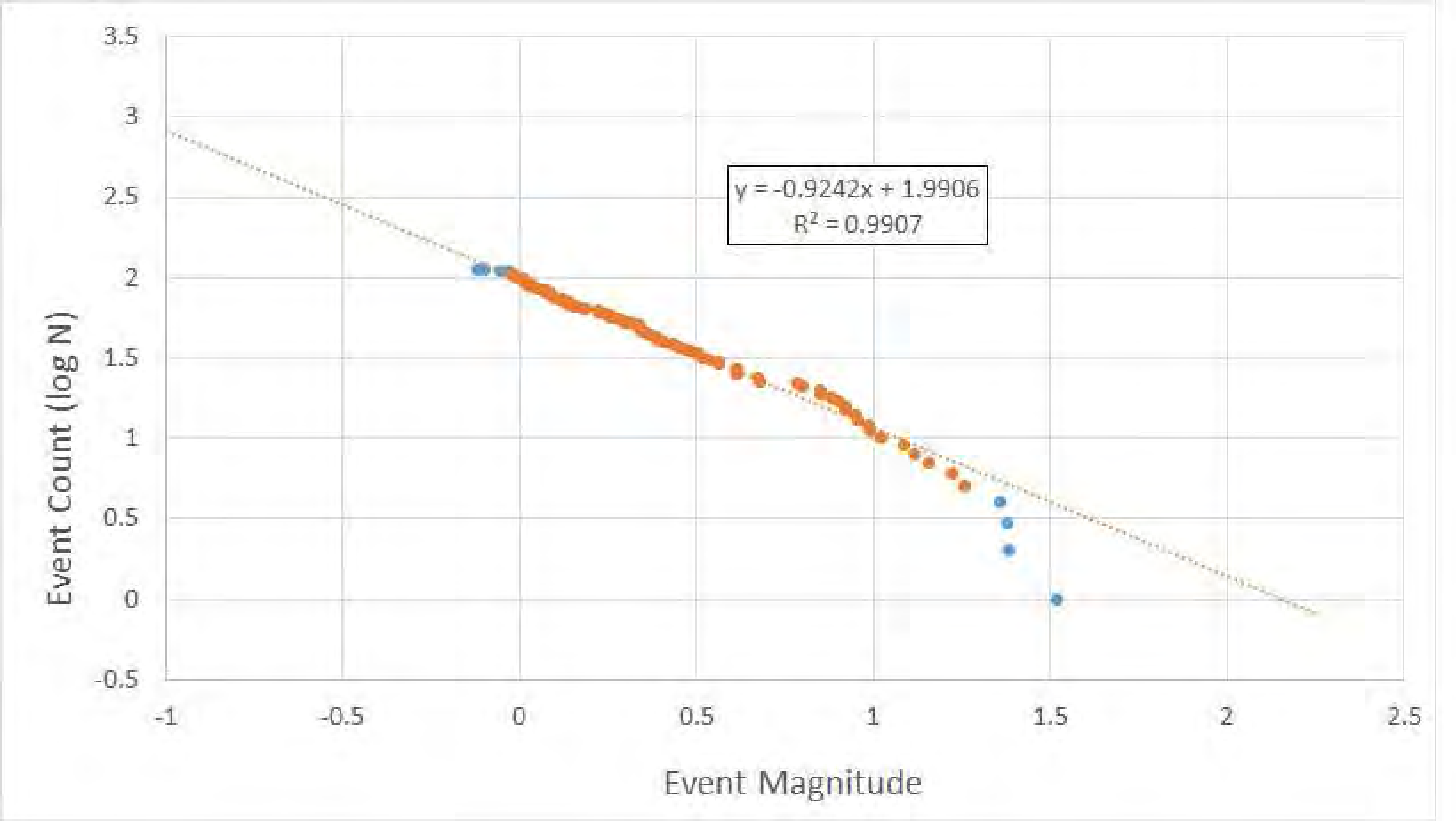
Weather Information

Sky Condition:	Clear	Visibility:	
Air Temperature:	36.0 degF	Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	
Comments:	Light breeze, Hi 69		

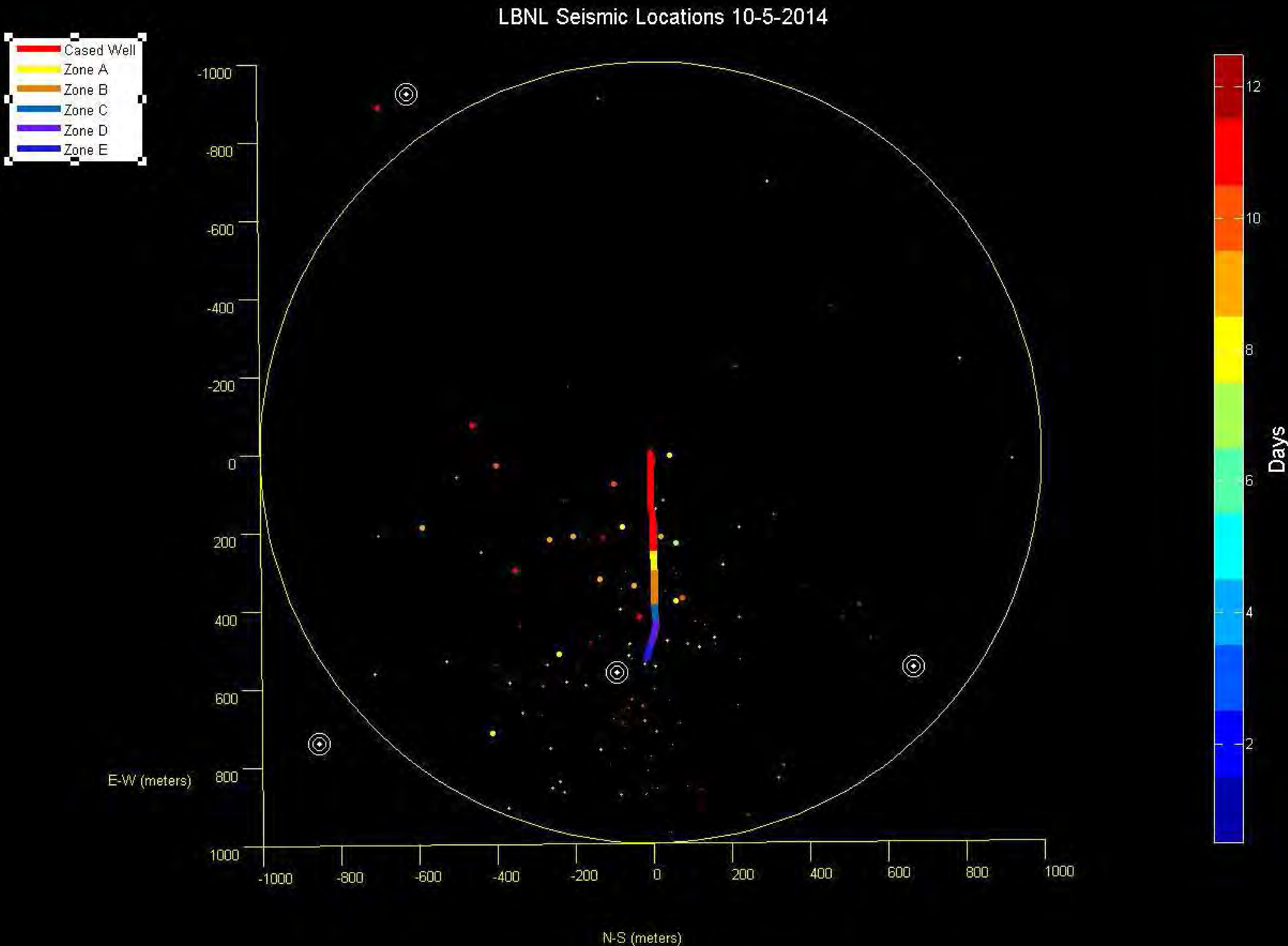

NN24
500 m to shoe
55-29
ko
sh
td
NM22
NM06
© 2014 Google
Google earth
1994
Imagery Date: 8/12/2012 lat 43.727182° lon -121.309362° elev 5932 ft eye alt 12055 ft



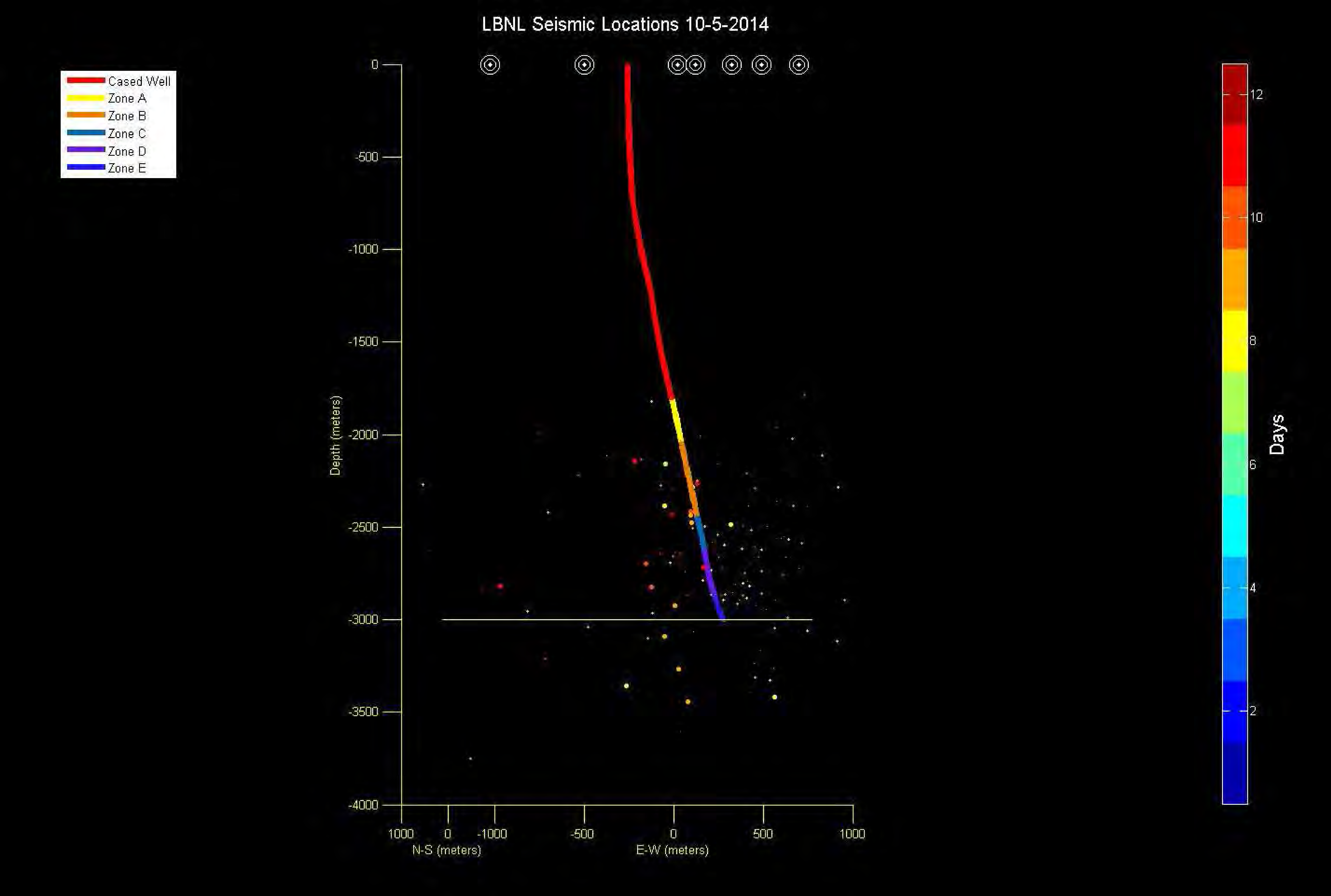
Injected Volume vs. Seismic Moment
Maximum Moment, N-m
Injected Volume, M3
1.00E+17
1.00E+16
1.00E+15
1.00E+14
1.00E+13
1.00E+12
1.00E+11
100
1000
10000
100000
1000000
10000000
$M_0(max)=G\Delta v$
KTB scientific
BUK frak
GAR frak
BAS egs
CBN egs
STZ egs
ASH wd
YOH wd
ASH wd
RAT wd
RMA wd
GAK wd
POH wd
RAT wd
PBN wd
wd
Cumulative Moment at end of each day
Maximum Moment
Background Graph from Art McGarr, USGS



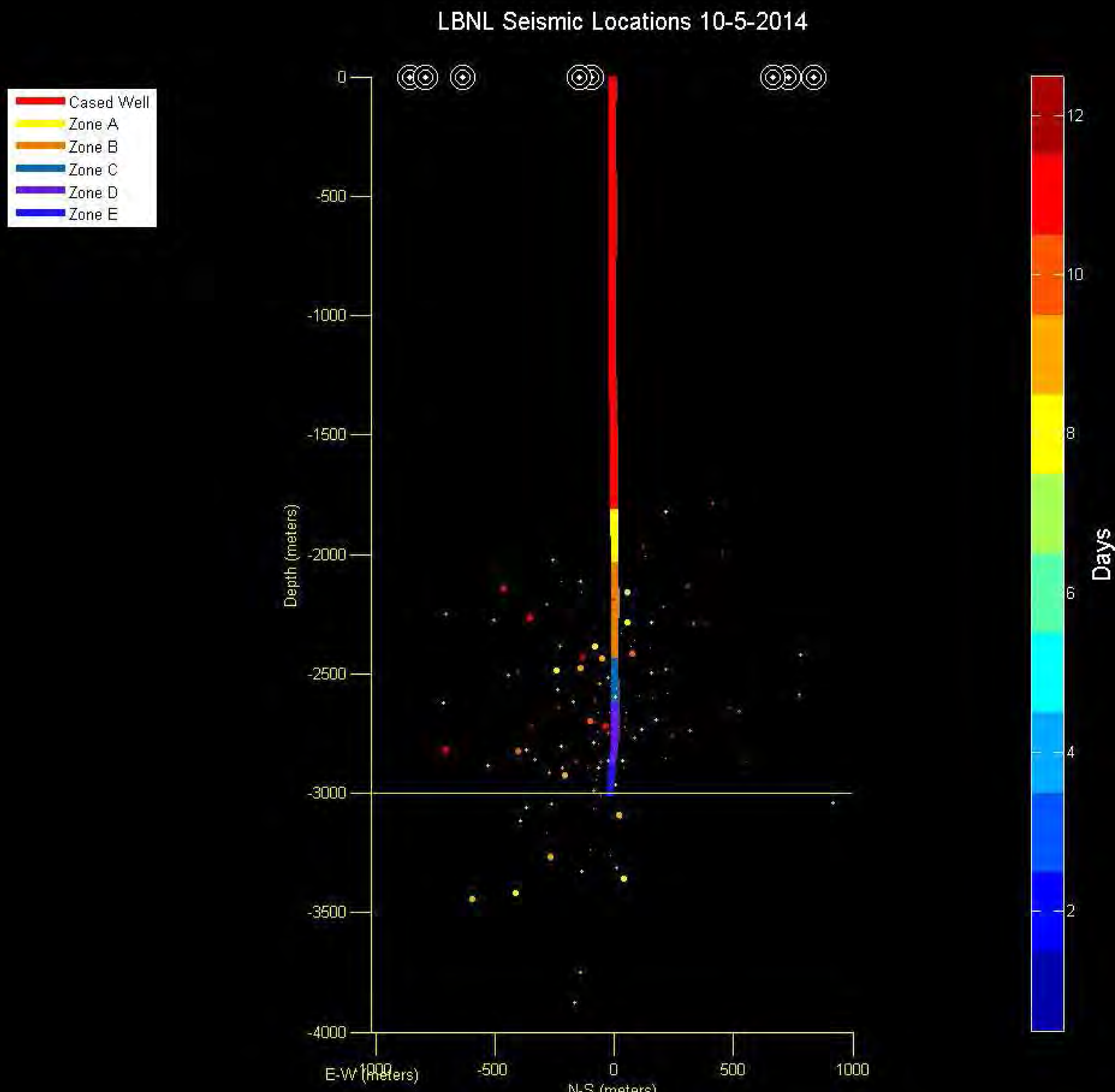
y = -0.9242x + 1.9906
R² = 0.9907
Event Count (log N)
Event Magnitude
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-0.5
0
0.5
1
1.5
2
2.5



LBNL Seismic Locations 10-5-2014
Cased Well
Zone A
Zone B
Zone C
Zone D
Zone E
-1000
-800
-600
-400
-200
0
200
400
600
800
1000
E-W (meters)
-1000
-800
-600
-400
-200
0
200
400
600
800
1000
N-S (meters)
12
10
8
6
4
2
Days



LBNL Seismic Locations 10-5-2014
Cased Well
Zone A
Zone B
Zone C
Zone D
Zone E
Depth (meters)
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
1000
0
-1000
-500
0
500
1000
N-S (meters)
E-W (meters)
Days
12
10
8
6
4
2



LBNL Seismic Locations 10-5-2014
Cased Well
Zone A
Zone B
Zone C
Zone D
Zone E
Depth (meters)
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
E-W (meters)
-1000
-500
0
500
1000
N-S (meters)
12
10
8
6
4
2
Days

ALTAROCK ENERGY INC

Daily Report

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 14 — **Report For 05-Oct-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):				---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No.		AFE ($)		Actual ($)
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	---		---		---
Proposed TD (ft):	10000	Days On Location:	14	Last BOP Test:		---		---		---
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals		---		---
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):				---

Personnel: Operator:	Contractor:	Service:	Other:	Total: 0

Current Operations: Continue stimulation

Planned Operations: Continue injecting at current rate, and monitoring seismicity and injectivity improvement.

Wellsite Supervisors: Michael Moore, Marc Steffen | Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	16:20	16.33		INJ	Injecting at WHP ranging 2750-2805psi. 13:00: add oil to stim pump 2 thrust box.	
16:20	19:15	2.92		REPR	Shutdown system to change out pump 2 leaking auto bypass valve; isolated inlet to pump 1.	X
19:15	23:59	4.73		INJ	Restarted pump 1 on 19:15. Started pump 2 on 20:40 after 4 attempts. Closed pump 2 manual bypass to 7 turns on final attempt. Increasing pump speeded. Reached 2600psi WHP and maintain current settings overnight.	

Comments

Seismicity: 19 additional seismic events for a total of 199. See attachments for additional seismic event analysis.

Cumulative injected volume 1,400,000 gallons

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Clear	Visibility:	
Air Temperature:	30.0 degF	Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	
Comments:	Hi 82		

Daily Report

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 15 | **Report For 06-Oct-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):		---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No.	AFE ($)	Actual ($)
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	---	---	---
Proposed TD (ft):	10000	Days On Location:	15	Last BOP Test:		---	---	---
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals	---	---
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):		---

Personnel:	Operator:	Contractor:	Service:	Other:	Total: 0

Current Operations: Continue stimulation

Planned Operations: Continue injecting at current rate, and monitoring seismicity and injectivity improvement.

Wellsite Supervisors: Michael Moore, Marc Steffen | Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	10:05	10.08		INJ	WHP approximately 2600 psi and injection rate 60-70gpm.	
10:05	11:10	1.08		INJ	Pump 2 trip when bypass throttled to 30%. Opened bypass, ramped down pump 1, re-started pump 2 and ramped up both pumps.	
11:10	17:45	6.58		INJ	Throttled bypass to 40% and hold until WHP stabilized at 2400 psi.	
17:45	19:45	2.00		INJ	Stepped up WHP to 2600 psi.	
19:45	20:45	1.00		INJ	Stepped up WHP to 2700 psi.	
20:45	23:59	3.23		INJ	Stepped up WHP to 2800 psi. Hold pressure and inject overnight.	

Comments

Seismicity: 3 additional seismic events for a total of 201.

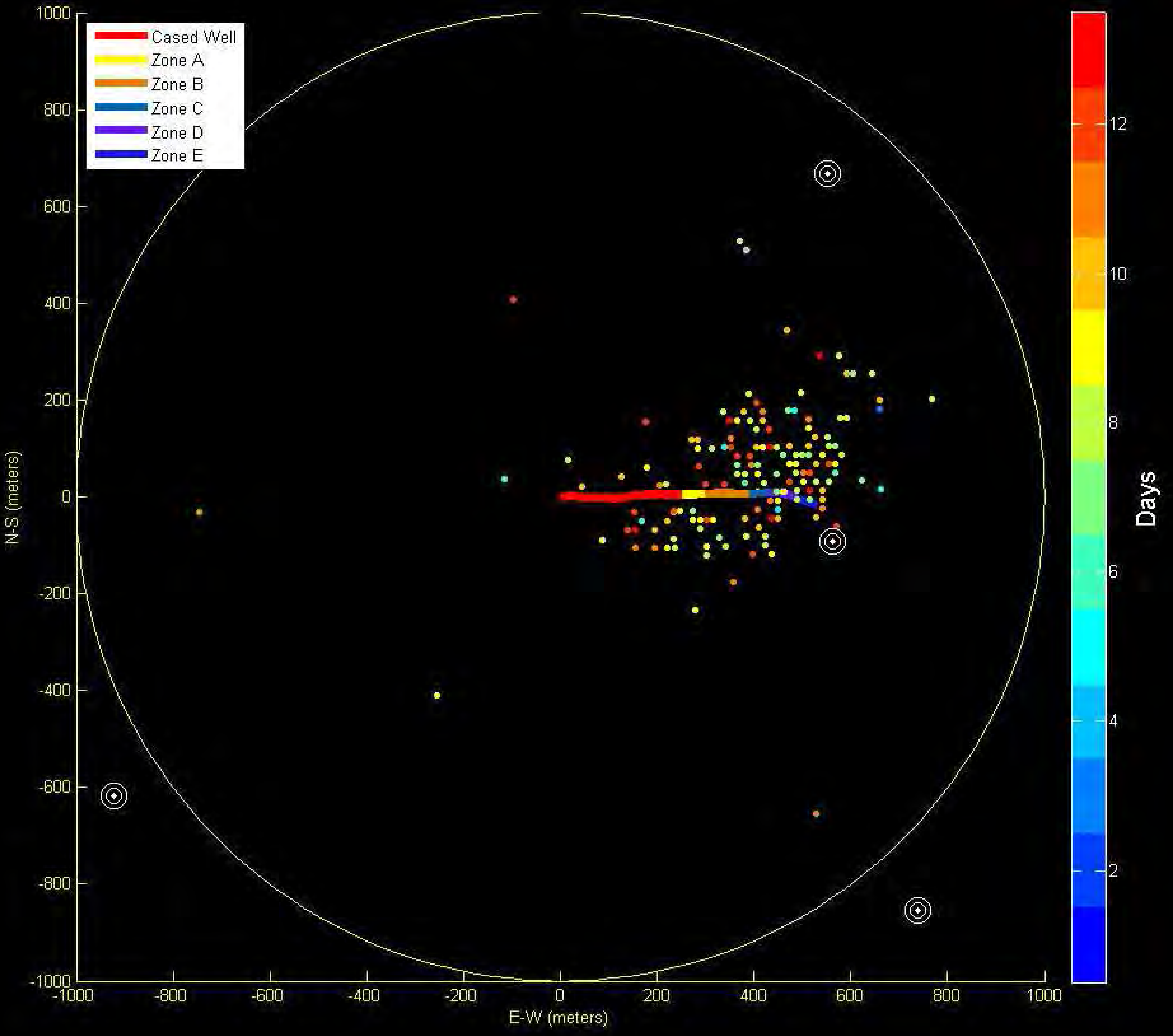
Cumulative injected volume 1,500,440 gallons

Casing/Tubular Information

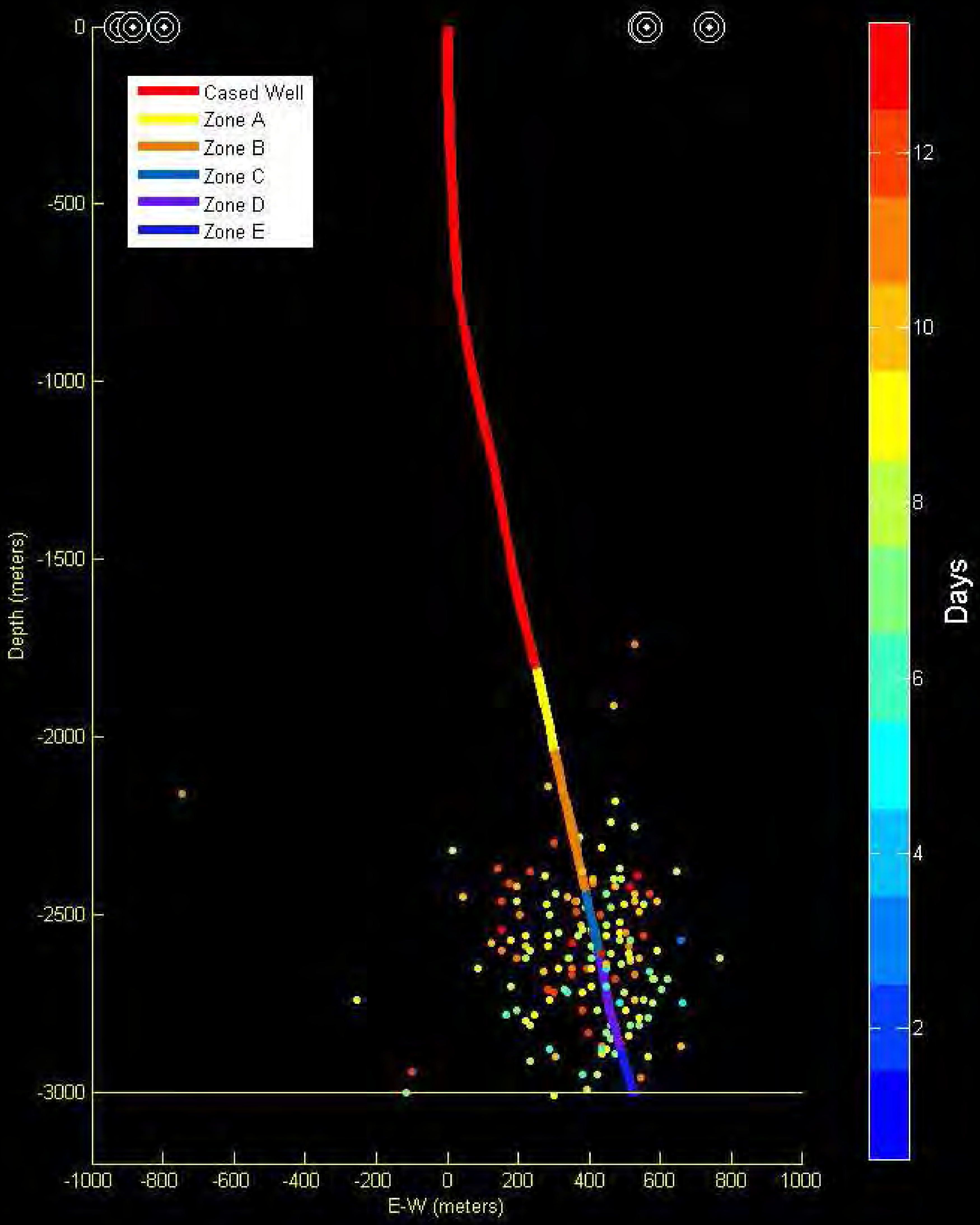
Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

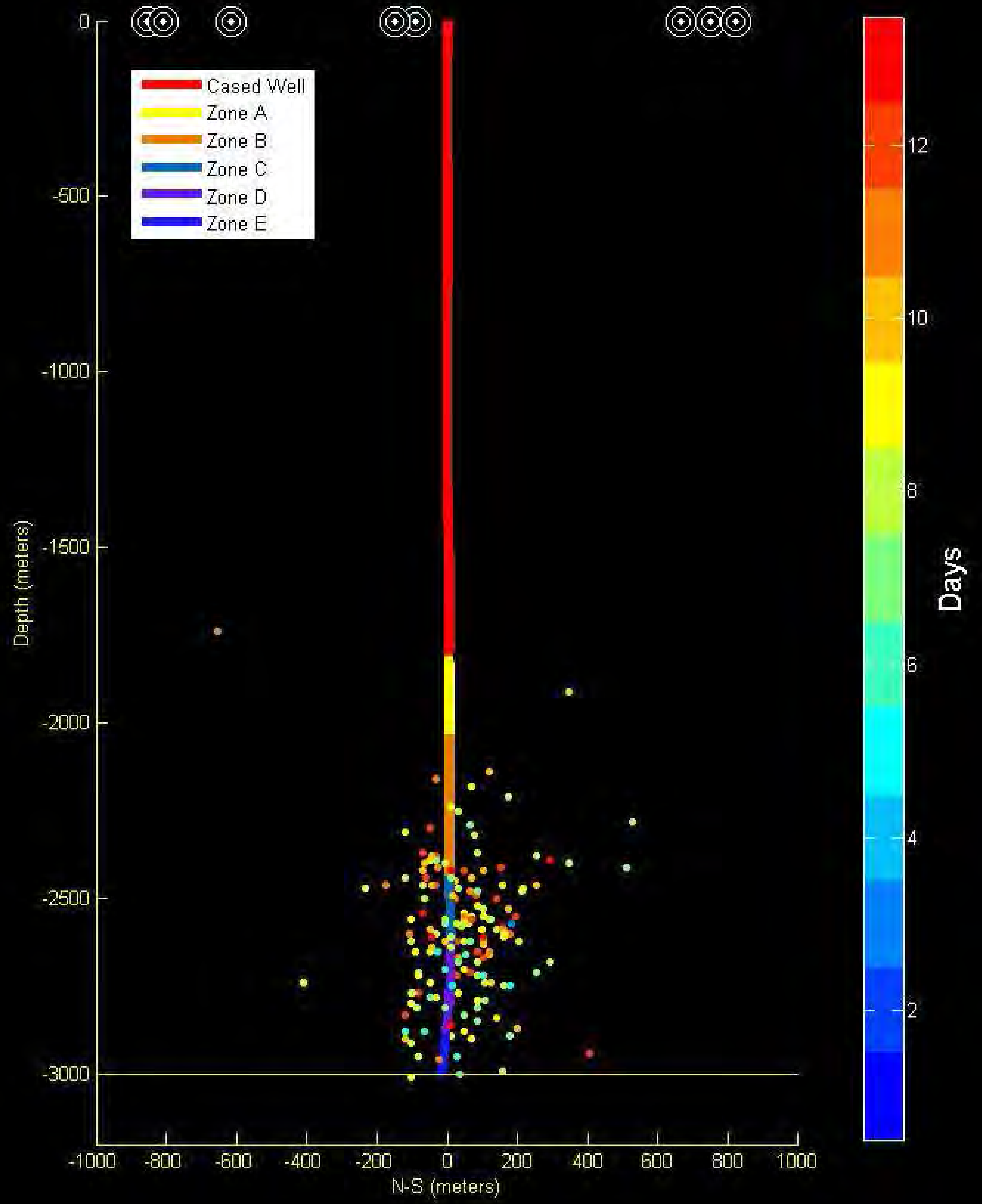
Sky Condition:	Clear	Visibility:	
Air Temperature:	41.0 degF	Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	
Comments:	Light breeze, Hi 77		



Cased Well
Zone A
Zone B
Zone C
Zone D
Zone E
N-S (meters)
E-W (meters)
Days
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
12
10
8
6
4
2



Cased Well
Zone A
Zone B
Zone C
Zone D
Zone E
0
-500
-1000
-1500
-2000
-2500
-3000
Depth (meters)
-1000
-800
-600
-400
-200
0
200
400
600
800
1000
E-W (meters)
12
10
8
6
4
2
Days



Cased Well
Zone A
Zone B
Zone C
Zone D
Zone E
Depth (meters)
0
-500
-1000
-1500
-2000
-2500
-3000
-1000
-800
-600
-400
-200
0
200
400
600
800
1000
N-S (meters)
Days
12
10
8
6
4
2

ALTAROCK ENERGY INC

Daily Report

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 16 | **Report For 07-Oct-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):	---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No. / AFE ($) / Actual ($)	
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	--- / --- / ---	
Proposed TD (ft):	10000	Days On Location:	16	Last BOP Test:		--- / --- / ---	
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals / --- / ---	
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):	---

Personnel: Operator: | Contractor: | Service: | Other: | Total: 0

Current Operations: Continue stimulation

Planned Operations: Step up to 2800 psi and monitor seismicity and injectivity improvement.

Wellsite Supervisors: Michael Moore, Susan Petty | Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	14:05	14.08		INJ	WHP~2800psi and downhole flow 80-90gpm.	
14:05	18:15	4.17		INJ	Ramp down stim pumps and sump pump turned off to relieve WHP for diverter injection.	
18:15	21:14	2.98		INJ	Sump pump turned on. Diverter added to well.	
21:14	23:59	2.75		INJ	Start up stim pumps and ramp up to 1st pressure step at 2500psi.	

Comments

Seismicity: 10 additional seismic events for a total of 211.

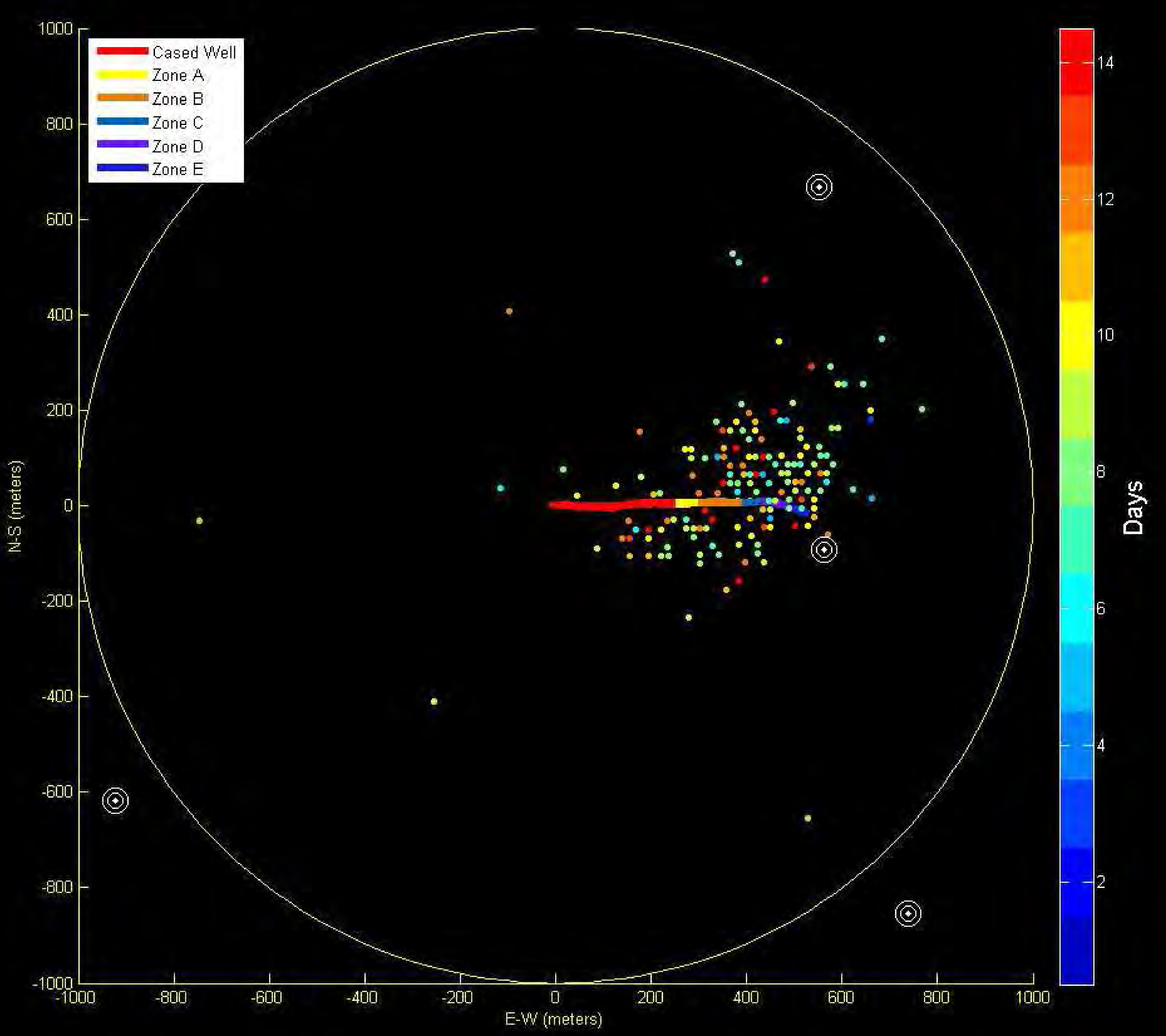
Cumulative injected volume 1,586,770 gallons

Casing/Tubular Information

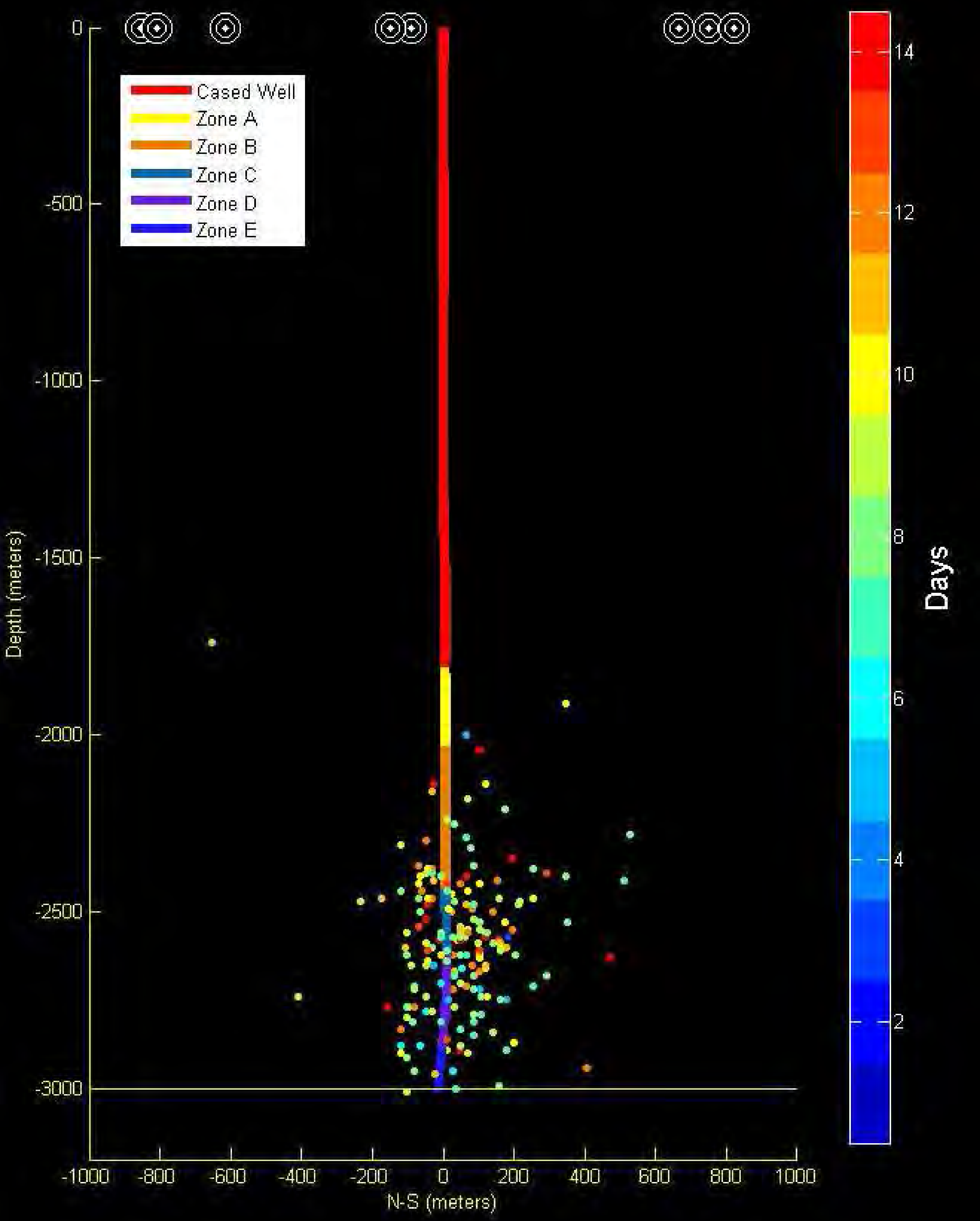
Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

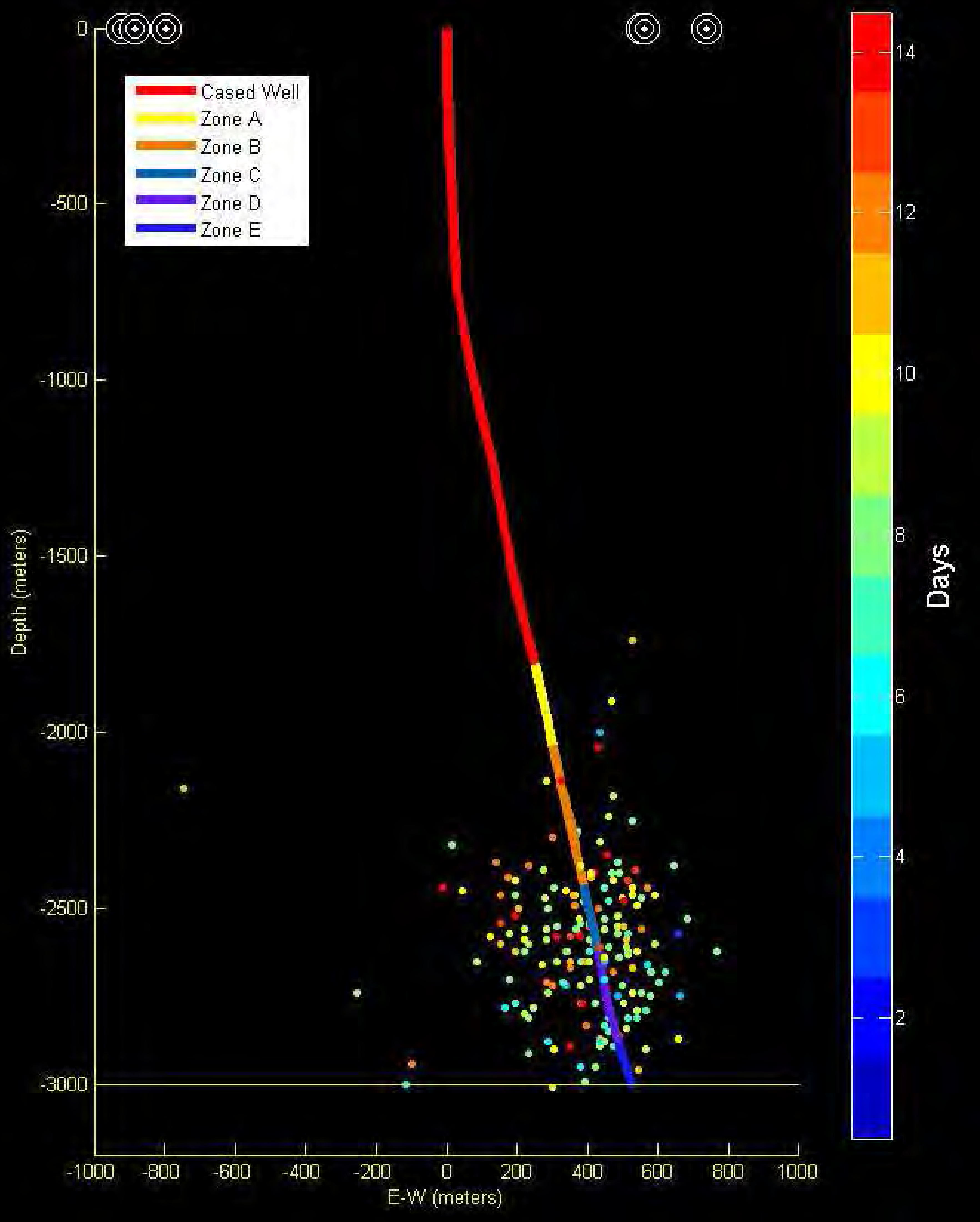
Sky Condition:	Clear	Visibility:	
Air Temperature:	42.0 degF	Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	
Comments:	Light breeze, Hi 68		



Cased Well
Zone A
Zone B
Zone C
Zone D
Zone E
N-S (meters)
E-W (meters)
Days
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
1000
14
12
10
8
6
4
2



Cased Well
Zone A
Zone B
Zone C
Zone D
Zone E
0
-500
-1000
-1500
-2000
-2500
-3000
Depth (meters)
-1000
-800
-600
-400
-200
0
200
400
600
800
1000
N-S (meters)
14
12
10
8
6
4
2
Days



Cased Well
Zone A
Zone B
Zone C
Zone D
Zone E
0
-500
-1000
-1500
-2000
-2500
-3000
Depth (meters)
-1000
-800
-600
-400
-200
0
200
400
600
800
1000
E-W (meters)
14
12
10
8
6
4
2
Days

Daily Report

AltaRock Energy

Well ID: NWG 55-29	Job ID: Stim 2014	Well Name: Northwest Geothermal 55-29
Field: Newberry		Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 17 — **Report For 08-Oct-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):			---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No.		AFE ($)	Actual ($)
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	---		---	---
Proposed TD (ft):	10000	Days On Location:	17	Last BOP Test:		---		---	---
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals		---	---
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):			---

Personnel: Operator:	Contractor:	Service:	Other:	Total: 0

Current Operations:	Continue stimulation		
Planned Operations:	Continue to monitor seismicity and injectivity improvement. Prepare to inject high temperature diverter on Friday or Monday.		
Wellsite Supervisors:	Michael Moore, Trenton Claduhos	Tel No.:	

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	2:02	2.03		INJ	First pressure step at 2550 psi WHP	
2:02	4:24	2.37		INJ	Second pressure step at 2760 psi WHP	
4:24	15:15	10.85		INJ	Third pressure step at 2820 psi WHP	
15:15	16:15	1.00		INJ	Ramped down stim pumps to injection 150lbs of low-temperature diverter.	
16:15	23:59	7.73		INJ	Slowly ramped up stim pumps to 2500 psi.	

Management Summary

After 16:00, the ultra sonic meter began reporting higher flows but is inconsistent compared to other system flow measurements. Will diagnose in the morning.

Comments

Seismicity: 13 additional seismic events for a total of 225.

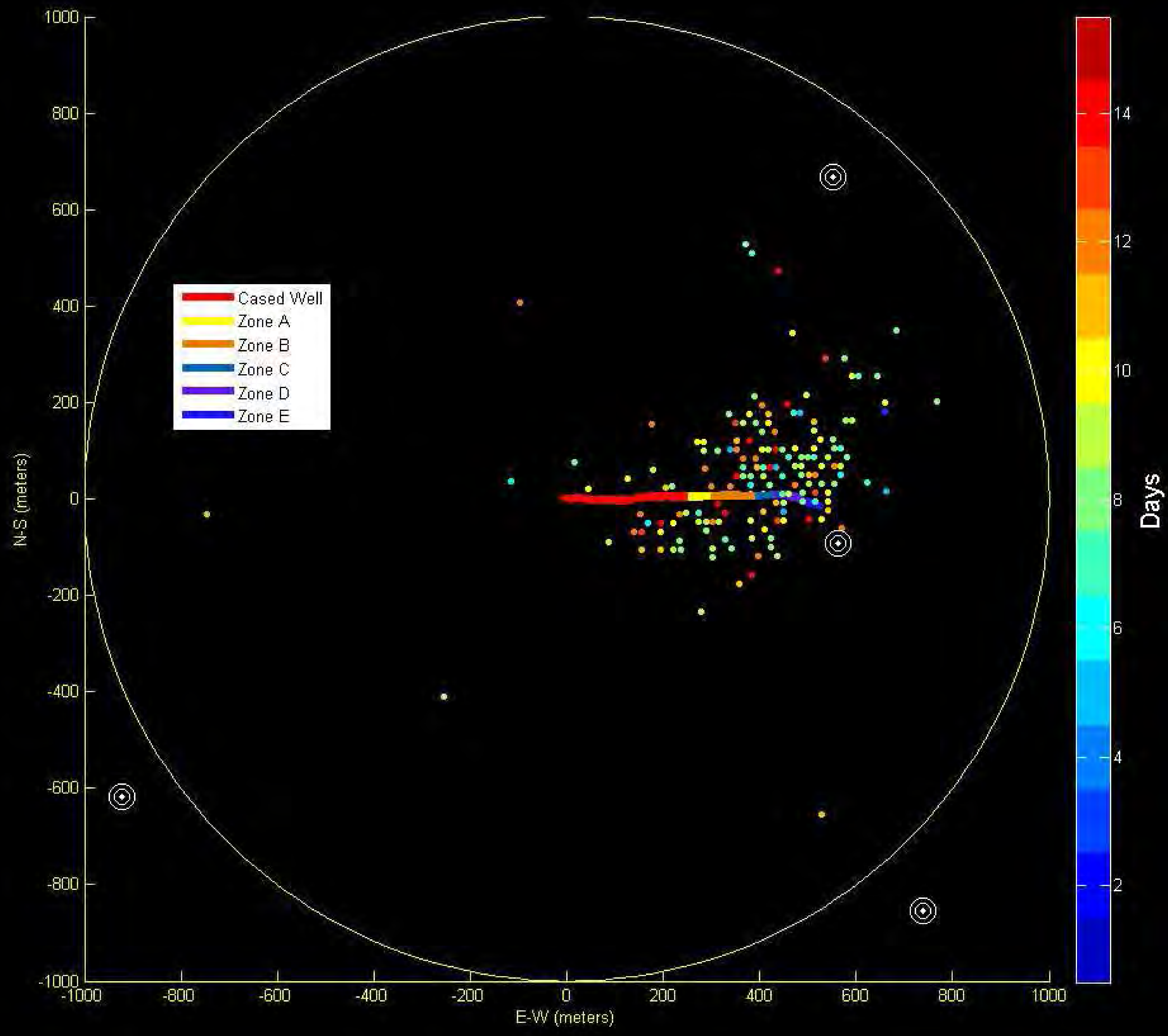
Cumulative injected volume 1,814,300 gallons*

Casing/Tubular Information

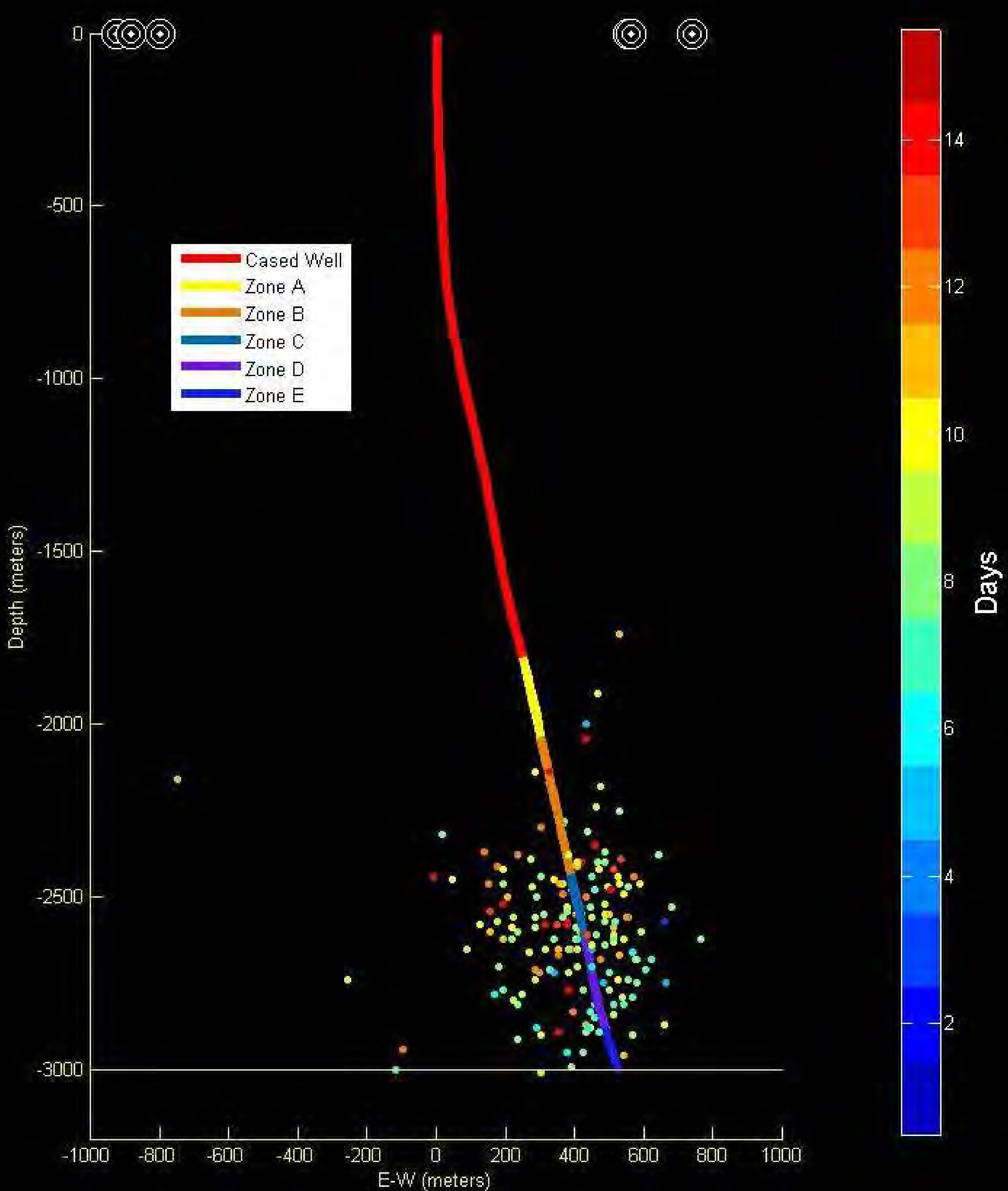
Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

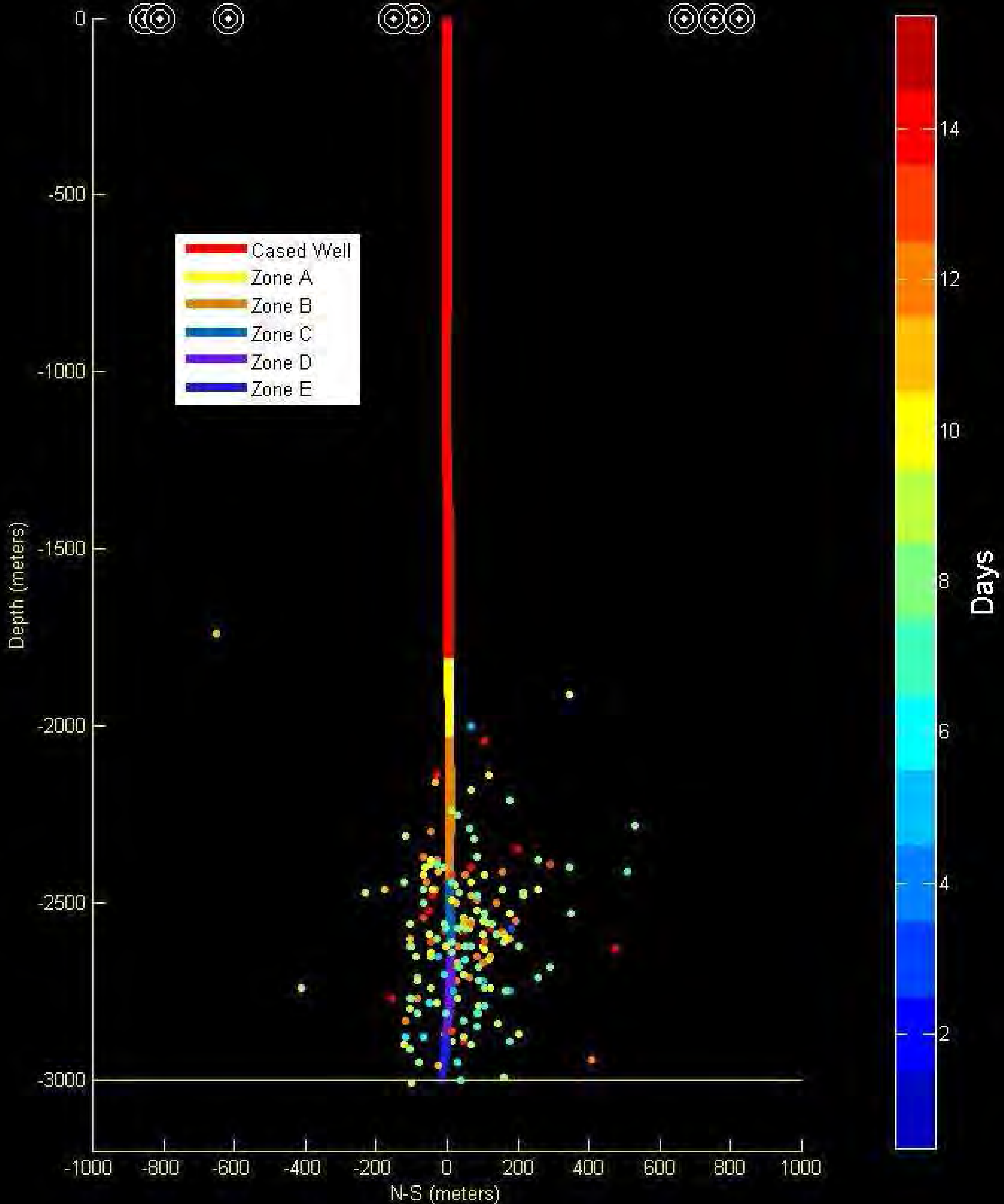
Sky Condition:	Clear	Visibility:	
Air Temperature:	35.0 degF	Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	
Comments:	Light breeze, Hi 64		



Cased Well
Zone A
Zone B
Zone C
Zone D
Zone E
N-S (meters)
E-W (meters)
Days
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
2
4
6
8
10
12
14



Cased Well
Zone A
Zone B
Zone C
Zone D
Zone E
Depth (meters)
0
-500
-1000
-1500
-2000
-2500
-3000
-1000
-800
-600
-400
-200
0
200
400
600
800
1000
E-W (meters)
Days
2
4
6
8
10
12
14



Cased Well
Zone A
Zone B
Zone C
Zone D
Zone E
Depth (meters)
N-S (meters)
Days
0
-500
-1000
-1500
-2000
-2500
-3000
-1000
-800
-600
-400
-200
0
200
400
600
800
1000
2
4
6
8
10
12
14

ALTAROCK ENERGY INC

Daily Report

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 18 — **Report For 09-Oct-14**

Operator: AltaRock Energy	Rig:	Spud Date: 13-Apr-08	Daily Cost / Mud ($):		---		
Measured Depth (ft):	Drilling Days (act.): 0	Well Bore: Original Well Bore	AFE No.	AFE ($)	Actual ($)		
Vertical Depth (ft): 10060	Drilling Days (plan): 68	RKB Elevation (ft): 0.00	---	---	---		
Proposed TD (ft): 10000	Days On Location: 18	Last BOP Test:	---	---	---		
Hole Made (ft) / Hrs: 0 / 0.0	Last Casing: 7.000 at 9,990		Totals	---	---		
Average ROP (ft/hr):	Next Casing:	Working Interest:	Job/Well Cost ($):		---		

Personnel: Operator:	Contractor:	Service:	Other:	Total: 0

Current Operations: Continue stimulation.

Planned Operations: Continue to monitor seismicity and injectivity improvement. Prepare to inject high temperature diverter on Friday or Monday. Repair electrical issue with PLC in the AM.

Wellsite Supervisors: Michael Moore, Trenton Claduhos | Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	4:23	4.38		INJ	Pressure held at 2550psi, bypass valve closed to 22%.	
4:23	5:35	1.20		INJ	Pressure increased to 2600 psi by increasing pump speed.	
5:35	9:53	4.30		INJ	Pressure increased to 2650 psi by increasing pump speed.	
9:53	13:39	3.77		INJ	09:53 Opened bypass to 42% to increase flow through pumps and diagnose ultrasonic flow meter. Pressure dropped to 2600psi. 10:19 Ramped pumps up to full speed and closed bypass to 25%. WHP 2775 psi. 11:00 Opend bypass to 34% to decrease pump 2 suction pressure and prevent pump trip.	
13:39	23:00	9.35		INJ	Pressure held at 2840 psi.	
23:00	0:00	1.00		REPR	Generator 1 trip. Started generator 2 in attempt to restart system, but outside PLC would not stay on. Generator 2 left on, and started submersible pump 1 manually to keep water moving through the system at 125 gpm to prevent freezing.	X

Management Summary

*Ultrasonic flow meter seems to be measuring ~200 gpm too high compared to other methods (water consumption and weir box measurements). We will continue to diagnose the next time that flow to the well is stopped.

Comments

Seismicity: 13 additional seismic events for a total of 238. (Based on Event ID 281 at 6:38 pm)

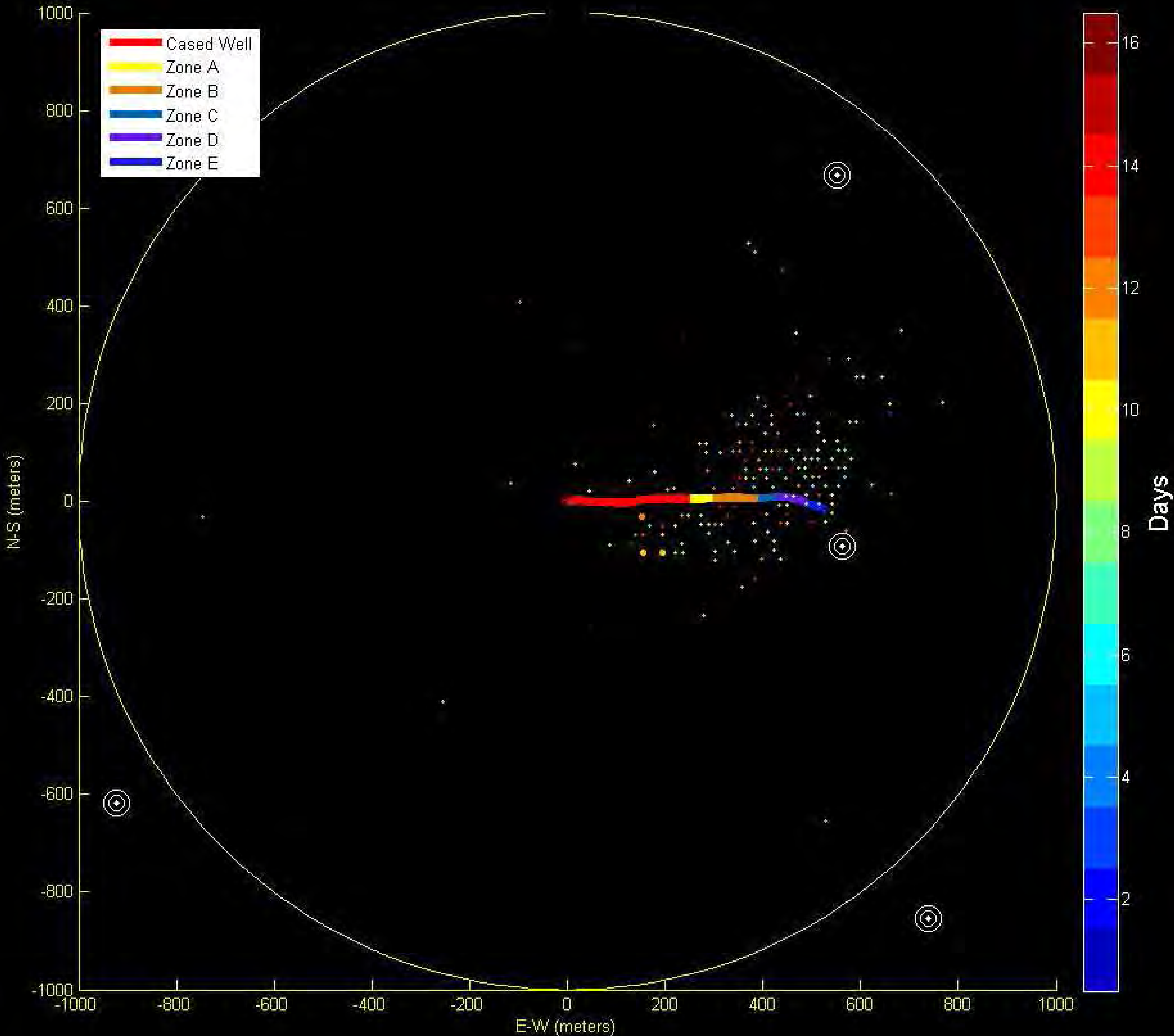
Cumulative injected volume 2,011,966 gallons* (Added 2,011,822 gallons to Ultrasonic cumulative reading because this was the value when it zeroed out)

Casing/Tubular Information

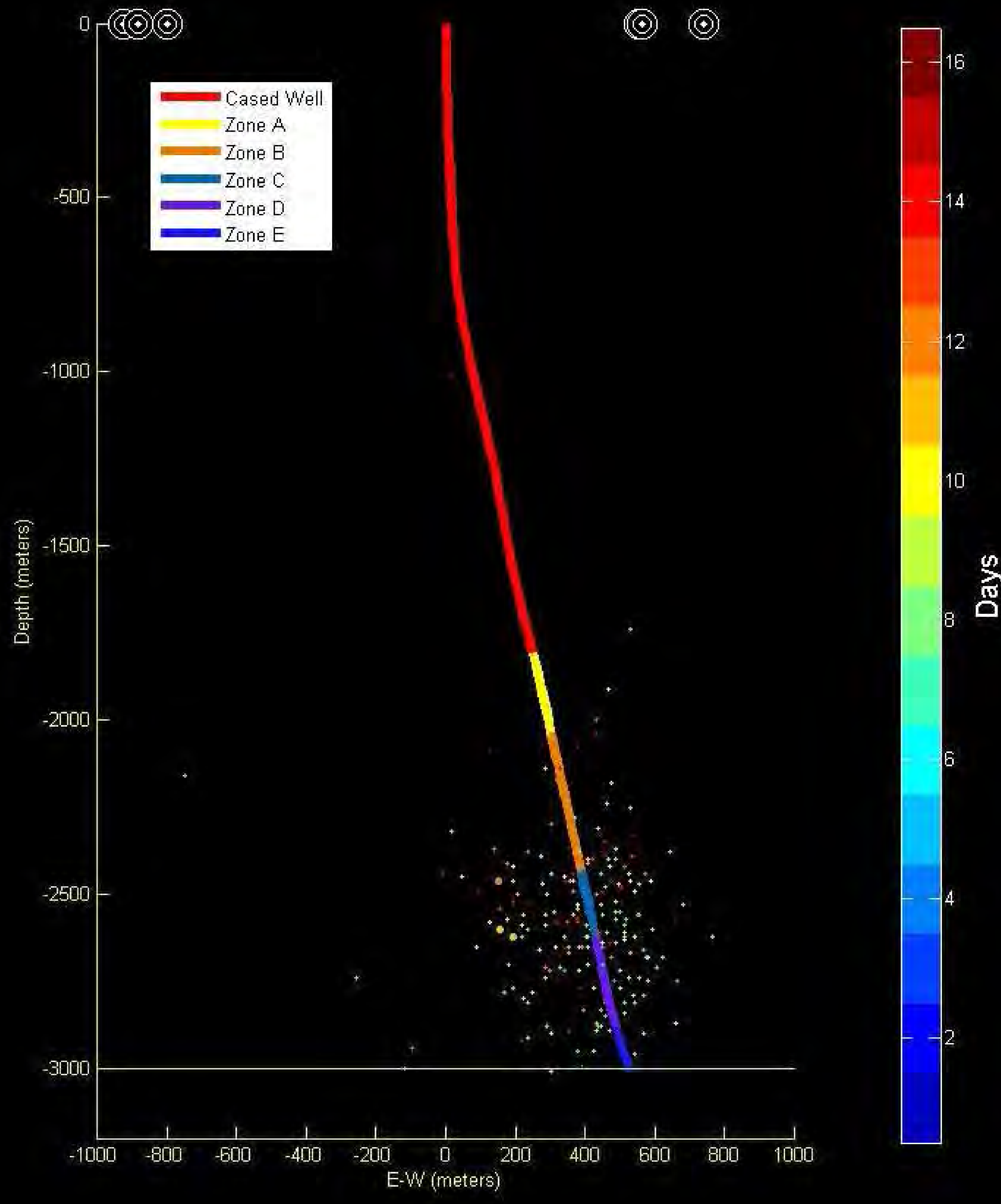
Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

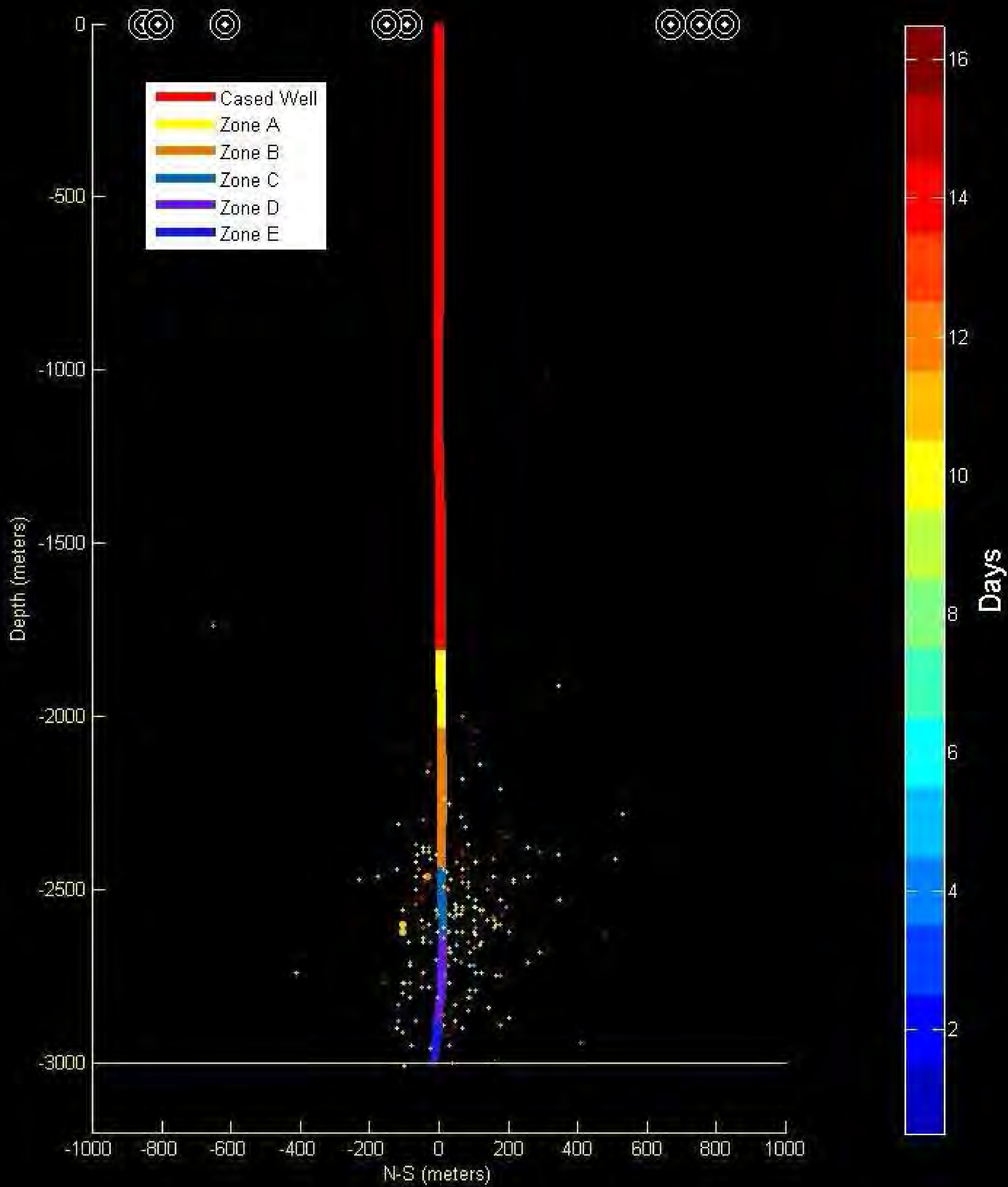
Sky Condition: Clear	Visibility:
Air Temperature: 32.0 degF	Bar. Pressure:
Wind Speed/Dir: /	Wind Gusts:
Comments: Light breeze, Hi 64	



Cased Well
Zone A
Zone B
Zone C
Zone D
Zone E
N-S (meters)
E-W (meters)
Days
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
-1000
-800
-600
-400
-200
0
200
400
600
800
1000
16
14
12
10
8
6
4
2



Cased Well
Zone A
Zone B
Zone C
Zone D
Zone E
Depth (meters)
E-W (meters)
Days
0
-500
-1000
-1500
-2000
-2500
-3000
-1000
-800
-600
-400
-200
0
200
400
600
800
1000
16
14
12
10
8
6
4
2


Cased Well
Zone A
Zone B
Zone C
Zone D
Zone E
Depth (meters)
0
-500
-1000
-1500
-2000
-2500
-3000
-1000
-800
-600
-400
-200
0
200
400
600
800
1000
N-S (meters)
Days
16
14
12
10
8
6
4
2

Daily Report

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 19 | **Report For 10-Oct-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):	---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No. / AFE ($) / Actual ($)	
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	--- / --- / ---	
Proposed TD (ft):	10000	Days On Location:	19	Last BOP Test:		--- / --- / ---	
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals / --- / ---	
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):	---

Personnel:	Operator:	Contractor:	Service:	Other:	Total: 0

Current Operations: Continue Stimulation.

Planned Operations: Continue to monitor seismicity and injectivity improvement. Prepare to inject high temperature diverter on Monday.

Wellsite Supervisors: Michael Moore, Trenton Claduhos | Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	2:30	2.50		INJ	Submersible pump 1 running to keep water moving through the system at 125gpm to prevent freezing. Closed 8" valve at 1AM between pump 2and wellhead to shut in well. Measured flow through weir box and compared to inlet flow*.	
2:30	7:16	4.77		INJ	Started stim pump 1.	
7:16	8:16	1.00		INJ	Started stim pump 2.	
8:16	13:11	4.92		INJ	Ramped pumps up to full speed. Bypass throttled to 30%.	
13:11	19:17	6.10		INJ	Opened bypass to 35% and lowered pump 2 suction pressure.	
19:17	0:00	4.72		INJ	Held steady at WHP of 2790 psi.	

Management Summary

*Inlet flow meter was 100gpm less than weir box.

Comments

Seismicity: 8 additional seismic events for a total of 246. (Based on Event ID 289 at 10:47 pm)

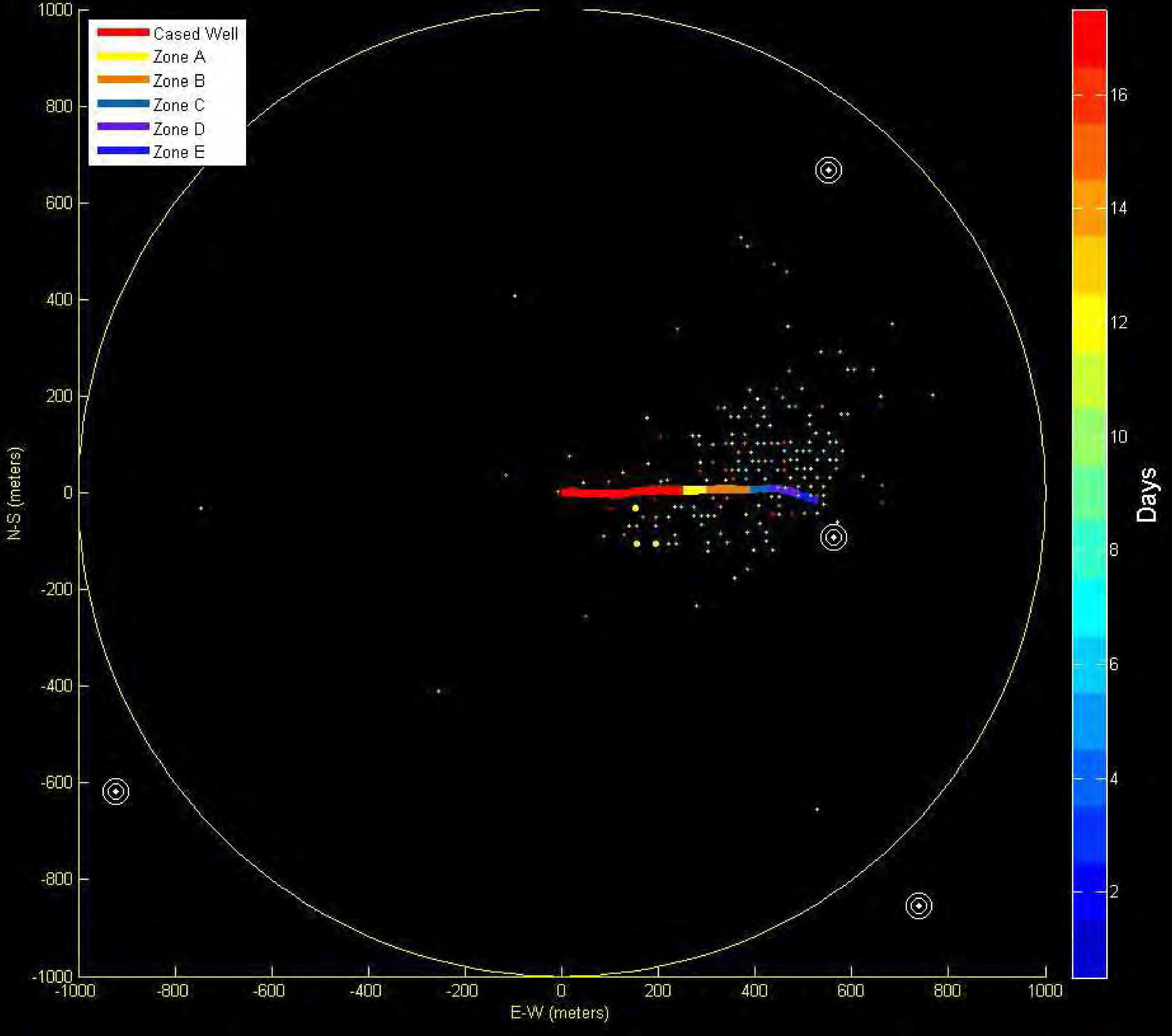
Cumulative injected volume 2,447,832 gallons* (Added 2,011,822 gallons to Ultrasonic cumulative reading because this was the value when it zeroed out)

Casing/Tubular Information

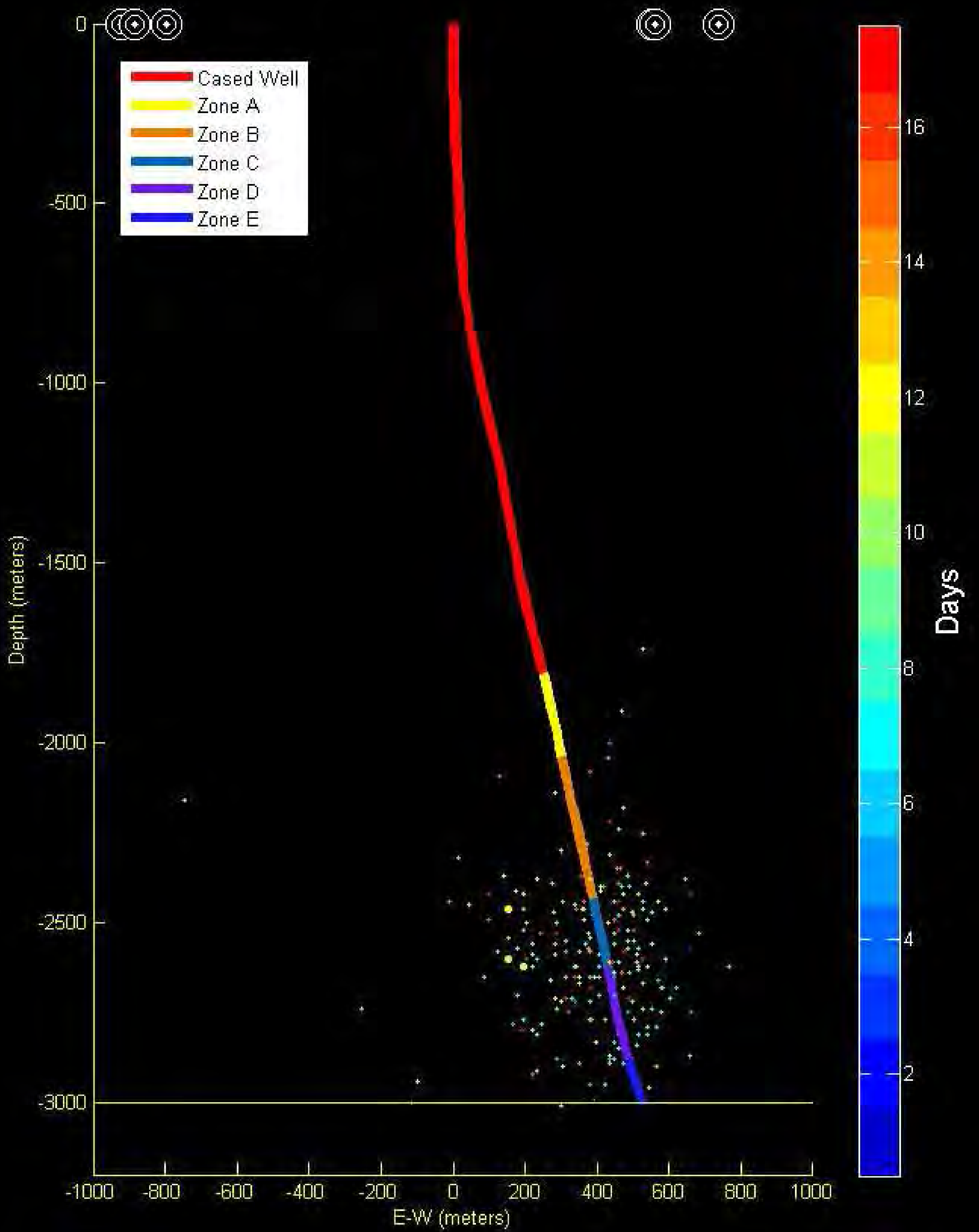
Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

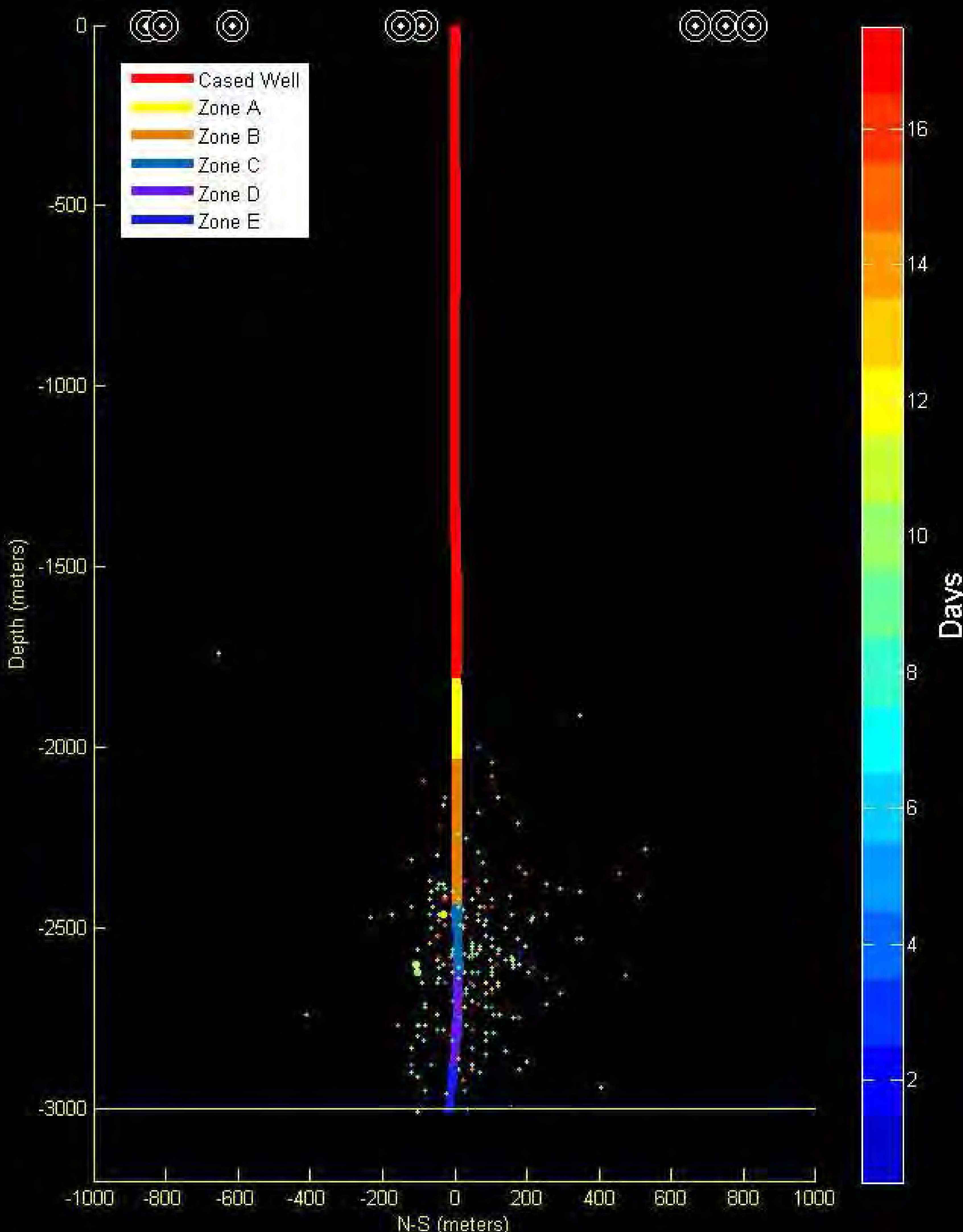
Sky Condition:	Clear	Visibility:	
Air Temperature:	33.0 degF	Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	
Comments:	Light breeze, Hi 64.		



Cased Well
Zone A
Zone B
Zone C
Zone D
Zone E
N-S (meters)
E-W (meters)
Days
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
2
4
6
8
10
12
14
16



Cased Well
Zone A
Zone B
Zone C
Zone D
Zone E
Depth (meters)
0
-500
-1000
-1500
-2000
-2500
-3000
-1000
-800
-600
-400
-200
0
200
400
600
800
1000
E-W (meters)
Days
16
14
12
10
8
6
4
2



Cased Well
Zone A
Zone B
Zone C
Zone D
Zone E
Depth (meters)
N-S (meters)
Days
0
-500
-1000
-1500
-2000
-2500
-3000
-1000
-800
-600
-400
-200
0
200
400
600
800
1000
2
4
6
8
10
12
14
16

ALTAROCK ENERGY INC

Daily Report

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 20 | **Report For 11-Oct-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):	---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No. / AFE ($) / Actual ($)	
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	--- / --- / ---	
Proposed TD (ft):	10000	Days On Location:	20	Last BOP Test:		--- / --- / ---	
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals / --- / ---	
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):	---

Personnel: Operator: | Contractor: | Service: | Other: | Total: 0

Current Operations: Continue stimulation.

Planned Operations: Continue to monitor seismicity and injectivity improvement. Prepare to inject high temperature diverter on Monday.

Wellsite Supervisors: Michael Moore, Trenton Claduhos | Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	12:04	12.07		INJ	Pumps and bypass held stead with WHP approximately 2840psi.	
12:04	17:45	5.68		INJ	Ramp down pump to WHP of 2000 psi and test DIVA.	
17:45	23:59	6.23		INJ	Ramp up pumps to 2520 psi WHP and maintain injection at this pressure overnight.	

Comments

Seismicity: 6 additional seismic events for a total of 252.

Cumulative injected volume 2,781,000 gallons
Note 1: Previous counts were based on Auto-picked seismic events. Manual review has determined 20 were either regional events or non-seismic.
Note 2: Yesterday (October 10), during the work day a road grader and compactor were working 5 miles of the gravel access road from the pad down to the gate. The road goes past seismic stations NN19, NN24, and NM22. This surface noise prevented any microseismic detections during that time period

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Clear	Visibility:	
Air Temperature:	38.0 degF	Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	
Comments:	Hi 48		

Daily Report

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 21 — **Report For 12-Oct-14**

Operator: AltaRock Energy	Rig:	Spud Date: 13-Apr-08	Daily Cost / Mud ($): ---
Measured Depth (ft):	Drilling Days (act.): 0	Well Bore: Original Well Bore	AFE No. / AFE ($) / Actual ($)
Vertical Depth (ft): 10060	Drilling Days (plan): 68	RKB Elevation (ft): 0.00	--- / --- / ---
Proposed TD (ft): 10000	Days On Location: 21	Last BOP Test:	--- / --- / ---
Hole Made (ft) / Hrs: 0 / 0.0	Last Casing: 7.000 at 9,990		Totals / --- / ---
Average ROP (ft/hr):	Next Casing:	Working Interest:	Job/Well Cost ($): ---

Personnel: Operator:	Contractor:	Service:	Other:	Total: 0

Current Operations: Continue Stimulation

Planned Operations: Inject high temperature diverter on Monday. Seismic goal has been reached. Current plan is to temporarily shut down for about 10 days to analyze data and wait for arrival of the replacement DTS (distributed temperature sensing system) that can be deployed to the bottom the well where the fluid is exiting the well. We will then restart for as long as funds and weather holds.

Wellsite Supervisors: Michael Moore, Trenton Claduhos | Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	9:45	9.75		INJ	Pumps and bypass valve held stead with WHP near 2525 psi.	
9:45	15:25	5.67		INJ	Increase pump speed to reach 2610 psi WHP.	
15:25	16:19	0.90		INJ	Increase pump speed to reach 2714 psi WHP.	
16:19	18:40	2.35		INJ	Closing bypass valve to reach 2777 psi. WHP increased to 2829 prsi, re-open bypass valve to prevent high pressure condition between pumps.	
18:40	21:00	2.33		INJ	Injecting with WHP around 2842 psi.	
21:00	23:59	2.98		INJ	New leak found in bypass line, pressure reduced to 2766 psi.	

Management Summary

Over the past two days we have compared the flow between the ultrasonic meter on the high pressure line to the WH, the magnetic meter on the inlet flow, the pump curves of the submersible pumps, the magnetic meter on the bypass recirculation line, the magnetic meter on the water well, flow measured in the weir box, and water level in the sumps. All flow measurements are imprecise! We have concluded that the inlet magmeter reports about 100 gpm low and the ultrasonic flow meter reports about 100 gpm too high. This discrepancy seems to have begun on Oct 8 18:00. Over the past 5 days the ultra sonic meter has reported flow rates of 250-350 gpm down the well. Actual flow rates are likely in the range of 150-250 gpm. A correction will be developed soon.

Comments

Seismicity: 19 new events. Total of 248 (accounts for some removals from catalog). Today's events included a M1.7 and M 0.9 picked up by the USGS network. The USGS uses only four of our stations, so has a higher detection threshold. The USGS has detected 91 events during this year's stimulation.

Cumulative injected volume 3,115,600 gallons (expect revision downward).

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Clear	Visibility:	
Air Temperature:	27.0 degF	Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	
Comments:	Hi 55		

Daily Report		AltaRock Energy
Well ID: NWG 55-29	Job ID: Stim 2014	Well Name: Northwest Geothermal 55-29
Field: Newberry		Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 22 — **Report For 13-Oct-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):		---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No.	AFE ($)	Actual ($)
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	---	---	---
Proposed TD (ft):	10000	Days On Location:	22	Last BOP Test:		---	---	---
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals	---	---
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):		---

Personnel:	Operator:	Contractor:	Service:	Other:	Total: 0

Current Operations:	Inject diverter, continue stimulation.
Planned Operations:	Continue to monitor seismicity and injectivity improvement.
Wellsite Supervisors:	Michael Moore, Trenton Cladhuos
Tel No.:	

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	7:06	7.10		INJ	Maintain injection overnight, WHP held at 2765 psi.	
7:06	7:48	0.70		INJ	Ramp down pumps to try pressure cycling. Cycling wellhead pressure between 2467 psi and 2692 psi.	
7:48	10:30	2.70		REPR	Ramp down and turn off pumps for DIVA loading. Repair leaking on bypass valve #2.	X
10:30	16:21	5.85		INJ	Pump 1 back on at 10:31. Pump 2 back on at 10:42. WHP reached 2650 psi. Slow pumps down to 2200 psi at 13:50 to bleed off pressure for diverter injection.	
16:21	16:55	0.57		INJ	Load and pressurize DIVA. Inject pill #1, 150 lbs of AltaVert 251 at 16:21. Reload DIVA and inject pill #2, 150 lbs of AltaVert 251 at 16:55.	
16:55	21:10	4.25		INJ	Maintain 2404 psi WHP, 80 gpm injection.	
21:10	23:05	1.92		INJ	Step-up to and maintain WHP at 2500 psi.	
23:05	23:59	0.90		INJ	Step-up to and maintain WHP at 2600 psi.	

Management Summary

The outlet flow valve was discovered to be not fully closed, which was allowing approximately 95gpm to exit. After shutting in the valve completely, ultrasonic flow measurements reduced.

Comments

Successfully injected two, 150 lb pills of AltaVert 251 using DIVA system today. Pressure and flow response indicate successful diverter application.

Seismicity: 7 new events today.6 before diversion.

Cumulative injected volume 3,328,000 gallons

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Clear	Visibility:	
Air Temperature:	45.0 degF	Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	
Comments:	Hi 59		

Daily Report

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 23 | **Report For 14-Oct-14**

Operator: AltaRock Energy	Rig:	Spud Date: 13-Apr-08	Daily Cost / Mud ($):		---		
Measured Depth (ft):	Drilling Days (act.): 0	Well Bore: Original Well Bore	AFE No.	AFE ($)	Actual ($)		
Vertical Depth (ft): 10060	Drilling Days (plan): 68	RKB Elevation (ft): 0.00	---	---	---		
Proposed TD (ft): 10000	Days On Location: 23	Last BOP Test:	---	---	---		
Hole Made (ft) / Hrs: 0 / 0.0	Last Casing: 7.000 at 9,990		Totals	---	---		
Average ROP (ft/hr):	Next Casing:	Working Interest:	Job/Well Cost ($):		---		

Personnel: Operator:	Contractor:	Service:	Other:	Total: 0

Current Operations: Test AltaVert fiber. Continue stimulation.

Planned Operations: We will pull out the DTS cable and log the well with a pressure-temperature tool. Both injecting and flowing profiles will be collected. We learned this morning that the replacement DTS was damaged during final manufacture. The results of tomorrow's logging will determine the next steps.

Wellsite Supervisors: Michael Moore, Trenton Claduhos | Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	1:15	1.25		INJ	Maintain 2635 psi WHP.	
1:15	8:28	7.22		INJ	Ramp up to 2829 psi WHP.	
8:28	11:30	3.03		REPR	Generator trip. Troubleshoot generator.	X
11:30	16:10	4.67		INJ	Re-start pumps and ramp-up injection. 15:00 generator trip while receiving maintenance from Peterson mechanic. Restart generator and pumps.	
16:10	17:50	1.67		INJ	Fill DIVA and pump diverter- one 15 lb pill of AltaVert fiber injected	
17:50	23:59	6.15		INJ	Ramp up to 2808 psi WHP; 90 gpm injection.	

Comments

Successfully injected one 15 lb pill of AltaVert Fiber using DIVA system today. Pressure and flow response is uncertain at this time – will require further analysis.

Two generator trips required Peterson CAT mechanical support on-site. Road repair work continued throughout the day.

A reporter and photographer from the Bend Bulletin visited in the morning. Members of the Sunriver and La Pine chambers of commerce and city council visited in the afternoon.

Seismicity: 4 new events.

Cumulative injected volume 3,423,000 gallons

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Clear skies, turned to light rain in evening	Visibility:	
Air Temperature:	39.0 degF	Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	
Comments:	Hi 56		

ALTAROCK ENERGY INC

Daily Report

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 24 | **Report For 15-Oct-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):	---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No. / AFE ($) / Actual ($)	
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	--- / --- / ---	
Proposed TD (ft):	10000	Days On Location:	24	Last BOP Test:		--- / --- / ---	
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals / --- / ---	
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):	---

Personnel: Operator: | Contractor: | Service: | Other: | Total: 0

Current Operations: Remove DTS. Run PT survey of entire wellbore, conduct step-rate injectivity test and pressure fall-off test.

Planned Operations: Go into hibernation mode, while data is analyzed, budget checked.

Wellsite Supervisors: Michael Moore, Trenton Claduhos | Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	8:53	8.88		INJ	WHP dropped to 2567 psi (minor cycling test). Increases WHP to 2770 psi and held over night.	
8:53	11:36	2.72		POH	Wellaco on site. Shut down pumps at 8:53and prepare for DTS removal. Well bled off from 2612-1533 psi through DIVA. DTS out of hole by 11:36. Partial tubing break observed at 847ft BGS. Multi-mode fibers still functional.	
11:36	14:22	2.77		WOE	Well-shut in while preparing to run PT survey. WHP builds from 1516 to 1920 psi. 13:45: put well on 200-300 gpm flowback to reduce WHP to 595 psi in order to run survey.	
14:22	15:23	1.02		RIH	Ran in hole with PT tool while well flowing back at ~100 gpm and pressure declined from 712 to 487 psi. Ran tool to 9800 ft.	
15:23	17:45	2.37		INJ	Started pumps and held PT tool at 9800ft. 16:30: POOH logging 9800ft to 4000ft interval with well under injection at 2200 psi WHP and 200 gpm.	
17:45	18:15	0.50		INJ	PT tool parked at 4000 ft (static temperature of 300F). Step-rate test with tool in hole. Finish 2200 psi step. Flow stablized at 83 gpm.	
18:15	20:45	2.50		INJ	2500 psi step. Flow quasi-stable at 105 gpm.	
20:45	22:30	1.75		INJ	2800 psi step. Flow quasi-stable at 130 gpm	
22:30	23:49	1.32		TEST	Pumps and generators shut down. Begin 11 hour pressure fall-off test with PTS tool set at 4000ft.	

Comments

Seismicity: 3 events.

Cumulative injected volume ~3,500,000 gallons (expect revision)

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Snow flurries and gusty wind at times	Visibility:	
Air Temperature:	34.0 degF	Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	
Comments:	Hi 51		

Daily Report

AltaRock Energy

Well ID: NWG 55-29	Job ID: Stim 2014	Well Name: Northwest Geothermal 55-29
Field: Newberry		Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 25 — **Report For 11-Nov-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):	---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No. / AFE ($) / Actual ($)	
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	--- / --- / ---	
Proposed TD (ft):	10000	Days On Location:	25	Last BOP Test:		--- / --- / ---	
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals / --- / ---	
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):	---

Personnel: Operator:	Contractor:	Service:	Other:	Total: 0

Current Operations: Restart generator and pumps. Conduct injectivity test

Planned Operations: Continue step rate test to 2200 psi. Re-calibrate WHP gauge tomorrow. Inject to cool wellbore in preparation for perf shots

Wellsite Supervisors: Michael Moore, Ted De Rocher — Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	10:30	10.50		IDLE		
10:30	14:51	4.35		WOE	10:30 Started generator, turned on heaters, removed ice from pumps/pipes etc. Circulated oil through stim pumps to prep for startup in cold weather. 14:40 Re calibrated stim pump 1 inlet pressure gauge.	X
14:51	16:15	1.40		INJ	Stim pump 1 start, closed bypass valve 1 and ramped up to 41 Hz. 8" crown valve started leaking, cycled valve open/closed to remove potential debris. Closed valve but still has small leak.	
16:15	17:17	1.03		INJ	Starting stim pump 2. Stim pump 2 trip. Opened bypass valve 1 by 50% and ramp down pump 1 to 38 Hz. 16:48: restarted stim pump. Ramping up pumps and injecting into well. Begin step-wise injectivity test.	
17:17	19:39	2.37		INJ	1st pressure step at 1250 psi WHP.	
19:39	21:38	1.98		INJ	2nd pressure step at 1450 psi WHP.	
21:38	23:35	1.95		INJ	3rd pressure step at 1650 psi WHP.	
23:35	23:59	0.40		INJ	4th pressure step at 1850 psi WHP.	

Comments

Comments: WHP not recording, use pump 2 discharge pressure until WHP gauge re-calibrated.

Seismicity: no new seismicity

Cumulative injected volume: 29,594 gallons

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

ALTAROCK ENERGY INC	**Daily Report** Well ID: NWG 55-29 Field: Newberry	AltaRock Energy Job ID: Stim 2014 Well Name: Northwest Geothermal 55-29 Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 26 — **Report For 12-Nov-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):		---			
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No.	AFE ($)	Actual ($)			
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	---	---	---			
Proposed TD (ft):	10000	Days On Location:	26	Last BOP Test:		---	---	---			
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals	---	---			
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):		---			

Personnel: Operator:	Contractor:	Service:	Other:	Total: 0

Current Operations:	Inject to cool
Planned Operations:	Continue to hold 2200 psi. Run perforation shots in the morning. Re-calibrate flow meter while flow stopped for lubricator install.
Wellsite Supervisors:	Michael Moore, Ted De Rocher — Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	2:31	2.52		INJ	4th pressure step at 1850 psi.	
2:31	2:59	0.47		WOE	Both pumps tripped during 5th step up. Restart pumps.	X
2:59	4:30	1.52		INJ	Ramping up to resume step-rate test.	
4:30	6:46	2.27		INJ	5th pressure step at 1950 psi.	
6:46	10:30	3.73		INJ	6th pressure step at 2200 psi.	
10:30	23:59	13.48		INJ	Continue injecting at 2200 psi to cool well overnight. 10:30 LBNL onsite to install geophone and digitizer. 14:46 COGCO onsite to drop off lubricator/rig and perforation guns.	

Comments

WHP not recording, use pump 2 discharge pressure. WHP sensor malfunctioning – not sending signal to PLC. Continue to use pump 2 discharge pressure and read gauge at wellhead. Flow meter may be reading 15-20 gpm too high due to non-zero flow during pump trip.
The step-rate test shows that injectivity improvement (about 4x) achieved 9/23-10/15 has been maintained. Injectivity at WH pressures below 2200 psi is now 0.04 gpm/psi.

Seismicity: no new seismicity.
Alex Morales of LBNL installed a Geophone on the exposed casing and connected a RefTek digitizer, in order to precisely record the timing of the perforation shots.

Cumulative injected volume: 122,762 gallons.

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Snow	Visibility:	
Air Temperature:	15.0 degF	Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	
Comments:	Hi 25. Snow through the night with 2” accumulation on site; expected to continue through tomorrow.		

ALTAROCK ENERGY INC	Daily Report		AltaRock Energy
	Well ID: NWG 55-29	Job ID: Stim 2014	Well Name: Northwest Geothermal 55-29
	Field: Newberry		Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 27 — **Report For 13-Nov-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):			---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No.		AFE ($)	Actual ($)
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	---		---	---
Proposed TD (ft):	10000	Days On Location:	27	Last BOP Test:		---		---	---
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals		---	---
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):			---

Personnel: Operator:	Contractor:	Service:	Other:	Total: 0

Current Operations:	COGCO onsite conducting perf shots		
Planned Operations:	Prepare wellhead for high pressure injection. Run booster pump overnight to prevent freezing.		
Wellsite Supervisors:	Michael Moore, Ted De Rocher	Tel No.:	

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	8:00	8.00		INJ	Injecting at 2200 psi.	
8:00	10:17	2.28		INJ	COGCO onsite, installing lubricator for temperature survey.	
10:17	14:21	4.07		INJ	Ramp down pumps slowly to lower pressure while maintaining injection. Ran in hole 4 times unsuccessfully.	
14:21	15:25	1.07		SURV	Open flowback valve to lower WHP. Run temperature survey.	
15:25	17:58	2.55		PERF	Ramp up pumps to intiate flow into well. Run in hole 1st perforation shot. Top of gun: 8402'. Bottom of gun: 8412'. Shot fired @ 17:09:15.	
17:58	19:01	1.05		REPR	Ramping down pumps to stop flow due to crown valve leak. Pumps shut down at 8:39. Open flowback valve to lower WHP.	X
19:01	20:26	1.42		PERF	Run in hole 2nd perforation shot. Top of gun: 8229'. Bottom of gun: 8239'. Shot fired @ 19:33:30.	
20:26	23:59	3.55		INJ	Master valve would not close all the way. 3rd shot cancelled. Rig down Cogco. Run booster pump overnight for freeze prevention.	

Comments

WHP not recording, use pump 2 discharge pressure. WHP sensor malfunctioning – not sending signal to PLC. Continue to use pump 2 discharge pressure and read gauge at wellhead. Flow meter may be reading 15-20 gpm too high due to non-zero flow during pump trip.

Seismicity: no new seismicity

Cumulative injected volume: 209,451 gallons

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Snow/rain	Visibility:	
Air Temperature:	15.0 degF	Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	
Comments:	high 25, low 15 F. Snow stopped. Rain in the evening.		

Daily Report

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 28 — **Report For 14-Nov-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):			---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No.		AFE ($)	Actual ($)
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	---		---	---
Proposed TD (ft):	10000	Days On Location:	28	Last BOP Test:		---		---	---
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals		---	---
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):			---

Personnel: Operator:		Contractor:		Service:		Other:		Total:	0

Current Operations: Reconfigure wellhead for high pressure injection. Re-start pumps.

Planned Operations: Ramp up to 2800 psi and hold until Diverter is injected on Tuesday.

Wellsite Supervisors: Michael Moore, Ted De Rocher | Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	8:30	8.50		INJ	Run booster pump overnight for freeze prevention.	
8:30	13:57	5.45		WOE	COGCO onsite to de-mob equipment. Removing 8" crown valve. PNSN onsite to collect GPS/Digitizer, Geophone left on wellhead during crown valve removal to be collected later. Re-install 3" valve	X
13:57	16:11	2.23		FLOW	Flowback initiated at 1009 psi. Well flowing at 130 gpm initially. Reduced to 72 gpm around 14:19.	
16:11	17:00	0.82		WOE	Stopped flowback. Setting up for injection.	X
17:00	18:54	1.90		INJ	Stim pumps started up. Ramp up to 1200 psi. Repair 3" valve leak.	
18:54	20:19	1.42		INJ	Ramp up pumps to 1400 psi.	
20:19	21:30	1.18		INJ	Ramp up pumps to 1600 psi.	
21:30	22:50	1.33		INJ	Ramp up pumps to 1800 psi.	
22:50	23:59	1.15		INJ	Ramp up pumps to 2000 psi. Step up pressure to 2200 psi at 23:50.	

Comments

WHP not recording, use pump 2 discharge pressure. WHP sensor malfunctioning – not sending signal to PLC. Continue to use pump 2 discharge pressure and read gauge at wellhead. Flow meter calibrated today at 11:05.

The 800 g total perforation shots fired on 11/13/2014 were detected on at least 3 BH geophones and 2 surface geophones. Arrival times will be used to improve the velocity model, resulting in better seismic locations.

Seismicity: No events located with

Cumulative injected volume: 259,782 gallons

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Snow	Visibility:	
Air Temperature:		Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	

Comments: high 35, low 0 F. Snow stopped. Heavy snow in the morning and during the day. Clear and cold overnight.

Daily Report

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 29 | **Report For 15-Nov-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):	---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No. / AFE ($) / Actual ($)	
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	--- / --- / ---	
Proposed TD (ft):	10000	Days On Location:	29	Last BOP Test:		--- / --- / ---	
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals / --- / ---	
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):	---

Personnel: Operator: | Contractor: | Service: | Other: | Total: 0

Current Operations: Inject at high pressure. Continue to monitor seismicity and injectivity improvement.

Planned Operations: Inject at high pressure. Continue to monitor seismicity and injectivity improvement.

Wellsite Supervisors: Michael Moore, Ted De Rocher | Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	11:30	11.50		INJ	Injecting at 2300 psi.	
11:30	16:52	5.37		INJ	Ramp pumps to full speed. Throttled bypass to 28% open and globe valve to 32% open.	
16:52	18:09	1.28		INJ	Ramped down pumps to prevent trip.	
18:09	23:59	5.83		INJ	Hold pump speed. WHP at 2700 psi.	

Comments

WHP not recording, use pump 2 discharge pressure. WHP sensor malfunctioning – not sending signal to PLC. Continue to use pump 2 discharge pressure and read gauge at wellhead. Geophone removed from wellhead, indent pointing ESE. Flow data log now recording pump 2 discharge pressure starting at 12:12.

Seismicity: 8 seismic event

Cumulative injected volume: 439,215 gallons

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Partly cloudy	Visibility:	
Air Temperature:		Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	

Comments: high 36, low 0° F. Cloudy in the morning, clear in the afternoon and evening.

ALTAROCK ENERGY INC	Daily Report		AltaRock Energy
	Well ID: NWG 55-29	Job ID: Stim 2014	Well Name: Northwest Geothermal 55-29
	Field: Newberry		Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 30 — **Report For 16-Nov-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):	---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No. / AFE ($) / Actual ($)	
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	--- / --- / ---	
Proposed TD (ft):	10000	Days On Location:	30	Last BOP Test:		--- / --- / ---	
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals / --- / ---	
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):	---

Personnel:	Operator:	Contractor:	Service:	Other:	Total: 0

Current Operations: Inject at high pressure. Continue to monitor seismicity and injectivity improvement.

Planned Operations: PTS log with surface read-out to bottom while injecting at 2700 psi WHP. A flowing profile may also be performed depending on result of injecting profile. Diverter injection currently schedule for 11/18/14.

Wellsite Supervisors: Michael Moore, Ted De Rocher — **Tel No.:**

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	13:00	13.00		INJ	Injecting at 2700 psi WHP	
13:00	23:59	10.98		INJ	WAC onsite from 13:00-16:30 to prep PTS tool and lubricator. Continue injection at 2700 psi WHP.	

Comments

Seismicity: 29 microseismic events since 11/15/2014. On 11/16/2014 at 8:41 PM (local time), a Moment Magnitude 2.2 event (magnitude reported by LBNL) occurred. The ISMP requires notification and no flow increase for events with M>2.0. Since the WHP is already at a maximum, no further pressure increases are planned. In addition, some events were initially located as shallow (depth =1.5 km above sea level). AltaRock requested that these outliers be confirmed. After checking, LBNL seismologists determined that the events were below sea level

Cumulative injected volume: 577,678 gallons

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Partly cloudy	Visibility:	
Air Temperature:		Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	
Comments:	Weather: high 40, low 0° F. Cloudy in the morning, clear in the afternoon and evening.		

ALTAROCK ENERGY INC

Daily Report

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 31 | **Report For 17-Nov-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):	---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No. / AFE ($) / Actual ($)	
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	--- / --- / ---	
Proposed TD (ft):	10000	Days On Location:	31	Last BOP Test:		--- / --- / ---	
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals / --- / ---	
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):	---

Personnel: Operator: | Contractor: | Service: | Other: | Total: 0

Current Operations: Continue to inject at high pressure while monitoring seismicity and injectivity improvements. Conduct PTS log under injecting and flowing conditions.

Planned Operations: Continue injection. Inject TZIM while monitoring temperature/pressure with PTS tool downhole.

Wellsite Supervisors: Michael Moore, Trenton Cladouhos | Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	9:10	9.17		INJ	Injecting at 2646 psi WHP.	
9:10	13:40	4.50		INJ	Injecting at 2700 psi WHP. 11:22-13:10, WAC ran PTS log to TD while injecting (some extra logging at flow zones).	
13:40	15:51	2.18		FLOW	Shut off pumps. 14:30-15:51, flow back started. Inital estimated flow rate ~400 gpm at 2800 psi. Final estimated flow rate 180 gpm at 965 psi. WAC ran PTS log to shoe while flowing.	
15:51	16:40	0.82		WOE	Restarted north generator (was previously running on south generator). Start stim pumps.	X
16:40	17:42	1.03		INJ	Flow re-established down hole at 1800 psi WHP.	
17:42	19:25	1.72		INJ	Injecting at 2130-2159 psi WHP.	
19:25	20:22	0.95		INJ	Ramp up pumps. Injecting at 2340-2260 psi WHP.	
20:22	22:49	2.45		INJ	Ramping up pumps to 2500 psi.	
22:49	23:59	1.17		INJ	Ramping up pumps to 2700 psi.	

Comments

Seismicity: 12 new seismic events for total of 39 since restart
Cumulative injected volume: 692,274 gallons

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Clear	Visibility:	
Air Temperature:	20.0 degF	Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	
Comments:	high 42, low 20° F. Clear.		

Daily Report

ALTAROCK ENERGY INC

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 32 | **Report For 18-Nov-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):	---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No. / AFE ($) / Actual ($)	
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	--- / --- / ---	
Proposed TD (ft):	10000	Days On Location:	32	Last BOP Test:		--- / --- / ---	
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals / --- / ---	
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):	---

Personnel: Operator:	Contractor:	Service:	Other:	Total:	0

Current Operations: Inject tracer and TZIM. Run PTS survey to TD to document diversion.

Planned Operations: Maintain small amount of flow over night to prevent freezing. Inject fiberous TZIM.

Wellsite Supervisors: Michael Moore, Trenton Cladouhos | Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	4:44	4.73		INJ	Injecting at 2629 psi WHP.	
4:44	9:48	5.07		INJ	Ramped down to 2400 psi to prepare for TZIM injection.	
9:48	10:54	1.10		INJ	Well bled off to 1743 psi WHP.	
10:54	12:38	1.73		INJ	11:06: Tracer (NDS 1,3,6) injected. 11:15: 450lbs of AltaVert 251 mixed in 10 bbl water (250 lbs A, 150 lbs AB, 50 lb B). 11:24 Pill 1 injected at WHP 1923 psi. 11:45 Pill 2 injected at WHP ~2000 psi. 12:02 Pill 3 injected at WHP 2118 psi. 12:20 Pill 4 injected at WHP 2198 psi. 12:38 Pill 5 injected at WHP 2212 psi.	
12:38	19:34	6.93		INJ	Inject starting at 2360 psi ending at 2545 psi to maintain constant flow of 100 gpm while diverter chased down hole. 17:15-18:19: WAC run PTS to TD while injecting to document diversion. 18:20-19:20 WAC POOH PTS logging while injecting to document diversion.	
19:34	23:59	4.42		INJ	Ramped down to WHP 2194 psi to prepare for TZIM.	

Comments

Total injected volume: 781,984 gallons

Seismicity: 3 new seismic events.

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Partly Cloudy	Visibility:	
Air Temperature:		Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	
Comments:	high 45, low 18° F. Partly cloudy		

ALTAROCK ENERGY INC

Daily Report

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 33 | **Report For 19-Nov-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):	---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No. / AFE ($) / Actual ($)	
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	--- / --- / ---	
Proposed TD (ft):	10000	Days On Location:	33	Last BOP Test:		--- / --- / ---	
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals / --- / ---	
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):	---

Personnel: Operator: | Contractor: | Service: | Other: | Total: 0

Current Operations: Injecting tracers and fibrous diverter using ThermaSource mixing truck.

Planned Operations: Continue stimulation and monitor seismicity.

Wellsite Supervisors: Michael Moore, Trenton Cladouhos | Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	6:30	6.50		INJ	Ramping down from 2200 to 1962 to prepare for TZIM injection.	
6:30	10:00	3.50		INJ	WHP head at 1962 psi.	
10:00	12:16	2.27		INJ	10:25: Tracer (NTS 2,7) injected. 11:07: Pill 1 of AltaVert 251 Fiber injected (10 lbs in 150 gallons) at WHP 2019 psi 12:07: Pill 2 injected at WHP 2150 psi 12:25: Pill 3 injected at WHP 2150 psi 12:55: Pill 4 injected at WHP 2216 psi 13:15: Pill 5 injected at WHP 2257 psi	
12:16	20:00	7.73		SURV	Inject starting at 2317 psi ending at 2539 psi WHP to maintain constant flow of 100 gpm while diverter chased down hole. 17:15-20:00 WAC ran PTS to TD and back while injecting to document diversion	
20:00	20:40	0.67		INJ	WHP increased to 2660 psi.	
20:40	21:45	1.08		INJ	WHP increased to 2772 psi.	
21:45	23:59	2.23		INJ	WHP increased to 2795 psi. Maintain 100 gpm downhole flow.	

Comments

Seismicity: 10 new seismic events.

Injected volume: 855,384 gallons

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Overcast	Visibility:	
Air Temperature:		Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	

Comments: high 41, low 31° F. Overcast. Small snow showers throughout the night.

ALTAROCK ENERGY INC

Daily Report

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 34 | **Report For 20-Nov-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):		---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No.	AFE ($)	Actual ($)
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	---	---	---
Proposed TD (ft):	10000	Days On Location:	34	Last BOP Test:		---	---	---
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals	---	---
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):		---

Personnel: Operator:	Contractor:	Service:	Other:	Total:	0

Current Operations:	Run final PTS survey while injecting. Shut down pumps and monitoring WHP falloff
Planned Operations:	Disassemble pumps and plumbing. Prepare for flow back test on Monday- Tuesday. Complete demobilization after Thanksgiving.
Wellsite Supervisors:	Michael Moore, Trenton Cladouhos
Tel No.:	

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	15:30	15.50		INJ	WHP held at around 2725 psi. 10:00-12:00 WAC ran final PTS log to TD and back. New flow zones observed at depth.	
15:30	18:30	3.00		INJ	Pumps shutdown and restarted on Generator 2 to lower diesel tank to <20%. 18:30: pumps shut down and master valve shut	
18:30	23:59	5.48		RIGD	Lines drained. Recording WHP decline.	

Comments

Seismicity: 22 new seismic events.

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Overcast	Visibility:	
Air Temperature:		Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	
Comments:	high 40, low 31° F. Overcast. Some snow showers throughout the day.		

ALTAROCK ENERGY INC

Daily Report

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 35 — **Report For 24-Nov-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):	---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No. / AFE ($) / Actual ($)	
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	--- / --- / ---	
Proposed TD (ft):	10000	Days On Location:	34	Last BOP Test:		--- / --- / ---	
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals / --- / ---	
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):	---

Personnel: Operator: | Contractor: | Service: | Other: | Total: 0

Current Operations: Flow test well and collect water samples.

Planned Operations: Flow until ~10:00 am 11/26, To a cumulative flow of >225,000 gallons. Then complete demobilization.

Wellsite Supervisors: Michael Moore, Trenton Cladouhos | Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	10:10	10.17		WOO	Well shut-in since 11/21	X
10:10	13:00	2.83		TEST	Flow test started. Initial WHP 1300 psi. Initial flow 200 gpm. Flow gradually declined to 100 gpm by 13:00. Flow temp: 162 deg. F	
13:00	17:30	4.50		TEST	Temperature reaches ~200 deg. F at wellhead. Geysering begins. 200 gpm surges, every 90 seconds.	
17:30	23:59	6.48		TEST	Spacing between surges reach 6 minutes. Average flow ~40 gpm. Cumulative flow of 124,000 gallons.	

Comments

Water samples for tracer, geochemistry and isotopes taken every 2 hours.

Seismicity: No seismic events.

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Overcast	Visibility:	
Air Temperature:		Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	
Comments:	high 50, low 29° F. Overcast. Clear in morning, cloudy in afternoon, drizzly in evening		

ALTAROCK ENERGY INC

Daily Report

AltaRock Energy

Well ID: NWG 55-29 | Job ID: Stim 2014 | Well Name: Northwest Geothermal 55-29

Field: Newberry | Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 36 | **Report For 25-Nov-14**

Operator:	AltaRock Energy	Rig:		Spud Date:	13-Apr-08	Daily Cost / Mud ($):		---
Measured Depth (ft):		Drilling Days (act.):	0	Well Bore:	Original Well Bore	AFE No.	AFE ($)	Actual ($)
Vertical Depth (ft):	10060	Drilling Days (plan):	68	RKB Elevation (ft):	0.00	---	---	---
Proposed TD (ft):	10000	Days On Location:	35	Last BOP Test:		---	---	---
Hole Made (ft) / Hrs:	0 / 0.0	Last Casing:	7.000 at 9,990			Totals	---	---
Average ROP (ft/hr):		Next Casing:		Working Interest:		Job/Well Cost ($):		---

Personnel: Operator: | Contractor: | Service: | Other: | Total: 0

Current Operations: Flow test well and collect water samples.

Planned Operations: Flow until ~10 am 11/26. Then complete demobilization.

Wellsite Supervisors: Michael Moore, Trenton Cladouhos | Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	12:00	12.00		TEST	Flow test continued. Steam lifted surges of 400-500 gpm every 10-20 minutes. Average flow of 36 gpm in first half of day.	
12:00	23:59	11.98		TEST	Average flow of 30 gpm in second half of day.	

Comments

Water samples for tracer, geochemistry and isotopes taken every 2-3 hours. Total of 14 samples starting at 11/24 13:00. Infra-red thermometer shows 190 F on casing. Cumulative volume flowed 116,500 gallons (note: an error was made in reporting yesterday's total).

Seismicity: 1 seismic event.

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Overcast	Visibility:	
Air Temperature:	30.0 degF	Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	
Comments:	Hi 40. Low 30.		

ALTAROCK ENERGY INC	Daily Report		AltaRock Energy
	Well ID: NWG 55-29	Job ID: Stim 2014	Well Name: Northwest Geothermal 55-29
	Field: Newberry		Sect: 29 Town: 21S Rng: 12E County: Deschutes State: OR

Report No: 37			Report For 26-Nov-14
Operator: AltaRock Energy	Rig:	Spud Date: 13-Apr-08	Daily Cost / Mud ($): ---
Measured Depth (ft):	Drilling Days (act.): 0	Well Bore: Original Well Bore	AFE No. / AFE ($) / Actual ($)
Vertical Depth (ft): 10060	Drilling Days (plan): 68	RKB Elevation (ft): 0.00	--- / --- / ---
Proposed TD (ft): 10000	Days On Location: 36	Last BOP Test:	--- / --- / ---
Hole Made (ft) / Hrs: 0 / 0.0	Last Casing: 7.000 at 9,990		Totals / --- / ---
Average ROP (ft/hr):	Next Casing:	Working Interest:	Job/Well Cost ($): ---

Personnel: Operator:	Contractor:	Service:	Other:	Total: 0

Current Operations:	Complete flow testing. Demob equipment.
Planned Operations:	Have a Happy Thanksgiving!
Wellsite Supervisors:	Michael Moore, Trenton Cladouhos — Tel No.:

Operations Summary

From	To	Elapsed	End MD(ft)	Code	Operations Description	Non-Prod
0:00	10:00	10.00		TEST	Flow test continued. Steam lifted surges of 300-400 gpm every 10-20 minutes. Average flow 26 gpm.	
10:00	12:00	2.00		RIGD	Well shut in at 10:00 am. WHP 320 psi at 11:30 am. Demob site.	

Comments

Water samples for tracer, geochemistry and isotopes taken every 2-3 hours. Total of 19 samples collected. Infra-red thermometer shows 190 F on casing. Cumulative volume flowed 130,000 gallons

Seismicity: one seismic event.

Casing/Tubular Information

Type	Size	Top MD	Top TVD	Bottom MD	Bottom TVD	Hole Section	Avg OH Diam	LOT
FULL	30.000	30		134		COND		
FULL	20.000	0	0	1109	1109	SURF	26.000	
FULL	13.375	-4		4391	4349	INT1	17.500	11.50
TIEBCK	9.625	0		4212				
LINER	9.625	4199		6462		INT2		13.40
LINER	7.000	6222		9990		PROD	8.500	

Weather Information

Sky Condition:	Clear	Visibility:	
Air Temperature:	40.0 degF	Bar. Pressure:	
Wind Speed/Dir:	/	Wind Gusts:	

Appendix C
Memo of November 10: Plans for completing 2014 stimulation at Newberry Volcano EGS Demonstration

DATE:	November 10, 2014
MEMO TO:	DOE Technical Monitoring Team
FROM:	AltaRock Energy, Inc.
SUBJECT:	Plans for completing 2014 stimulation at Newberry Volcano EGS Demonstration1

Background

Three weeks of hydraulic stimulation at well head pressures (WHP) up to 2850 psi, has produced an EGS reservoir with dimension defined by microseismicity (Figure 1) of close to a cubic kilometer, reaching an important goal of the Newberry Volcano EGS demonstration. The injectivity of NWG 55-29 appears to have increased by ~3-4x (Figure 2); however, the well's permeability is still much too low to become an economic injector in an EGS well pair. Thus, AltaRock Energy has proposed additional stimulation procedures to further increase the injectivity of the EGS target well.

Fluid Exits in well bore

Unfortunately, the fiber option DTS in the hole during stimulation failed at 8100ft during installation, thus PTS logging at the end of the stimulation period provides the only data on the well's permeability profile below 8100 ft. The flowing temperature profile (Figure 3) indicates that up to 6 zones flowed when the pressure in the well was bled off. On injection (Figure 4), the fracture zone at a depth of 9500ft dominates the permeability of the well bore as indicated by the injecting temperature profile.

We hypothesize that the best depths to further enhance permeability will be those that already take some fluid as indicated by the gradient changes on flowing and injecting temperature profiles. Two methods to augment hydraulic stimulation were initially proposed; first perforation shots and chemical leaching of silicate minerals using a strongly basic NaOH solution. After further research and modeling, the chemical stimulation was dropped from the program.

Perforation Shots

Perforation shots will be used to initiate new, or enhance existing, fracture permeability at the well bore face. The shots will be shaped charges designed to penetrate 72" into the rock mass. Each shaped charge will be 39 grams with 20 charges per 10ft gun. Three separate perforation gun runs will be made. We do not expect that shots alone will be able to increase the well permeability. Rather, post-shot hydraulic stimulation and thermal cooling will be able to exploit the new weaknesses in the well bore face, allowing new connections to be made away from the well bore, thus increasing the overall well permeability.

Three depths have been chosen for perforation shots. The criteria for choosing the depths for perforations are 1) a relatively brittle rock type, 2) in a portion of the hole that already has fractures and breakouts, and 3) in a portion of the hole that already shows evidence of fluid exit.

In addition, due to the operational constraints of the perforation gun to be less than 400 F, it must be possible to cool the selected depths to 400 F by injection. With the logging valve and lubricator suitable for the perforation gun the maximum well head pressure will be limited to 2200 psi and a worst case injection rate of about 40 gpm (if the injectivity index on 9/25 holds). Based on the experience from early in the stimulation (September 24 and 25), 12 hours stepping up from 1000 to 2200 psi followed by

36 hours of steady injection at 2200 psi, will cool the well at ~8000ft to 390 F (Figure 5). Cogco, the service company contracted to run the perforation shots, will run a temperature log prior to deploying the perforation gun, in order to confirm that the cooling is sufficient.

Calibration Shot

Down-hole explosions can be used to improve the seismic velocity models for microseismic arrays surrounding wells. Although the perforation shots planned here may be too small to detect on the Newberry MSA stations, the team believes that determining the exact (i.e. millisecond precision) timing of the perforation shots may be useful. Therefore, LBNL will be sending to the site a digitizer (REFTEK 130) capable of recording at 1000 samples/second, and a geophone. A LBNL technician will install the geophone to the casing exposed in the well head cellar and record data during the perforation shot program.

Targets

The three depths that will be targeted for perforation shots are described below. All depths are listed from ground surface (GS). The mud log and the borehole schematic are referenced to the KB at 32 feet above GS, thus 32ft are subtracted from those depths when compared to the other temperature and BHTV logs which are referenced to GS.

7685-7695ft BGS: Figure 6 — The first selected perforation zone is behind blank liner, thus the signal on the flowing temperature profile may be obscured (top third of Figure 6). Thus we relied more on the mud log and BHTV image to choose this perforation depth. The mud log shows dacite and basaltic andesite between 7530 and 7700ft, which is likely to be a stronger and more brittle rock type that the altered tuff that dominates the BH lithology down to measured depths of 8000ft. The BHTV image shows borehole breakouts and three minor fractures at 7685ft.

8230-8240ft BGS: Figure 7— The second selected perforation zone is in the lower perforated liner section. At the depth is one of the most prominent features on the flow back temperature profile, although it does not show prominently on the injecting temperature profile. The mud log shows a felsic dike at about 8200ft and the BHTV image shows a distinctively brighter unit between 8220ft and 8240ft and significant fractures

8400ft BGS: Figure 8 — The third selected perforation zone has many of the same features as the second zone; a prominent temperature feature on flow-back, a felsic dike on the mud log and significant fractures in the BHTV.

Other important flow zones in 55-29

The most prominent fracture zones evident on the injecting and flow back temperature profiles are deeper in the hole and likely related to the margins of granodiorite dikes. These zones were not considered for perforation shots due to the high temperatures; however, the mineralogy of these zones were analyzed to evaluate the potential efficacy of caustic treatment. Through TOUGH-REACT modeling, it was determined that the alteration mineralogy of these zones would not be conducive to dissolution by a strongly basic solution, thus the chemical treatment was dropped from the program. Also see references provided below.

8800ft BGS: Figure 10 — The top of the first of five granodiorite dikes in NWG 55-29 is reached at a measured depth of 8600ft (GS). The bottom of the first dike appears to be a flow zone based on the flow-back temperature profile. The alteration mineralogy at this depth is dominated by K-spar metasomatism and chloritization.

9500ft BGS: Figure 11 – The major flow zone in the well appears to be near the contact between the deepest granodiorite dike and subvolcanic basalt. Alteration mineralogy at this depth includes K-spar metasomatism and epidote.

Schedule to Complete

The proposed schedule to complete the stimulation of NWG 55-29 is shown below in Table 1. This program includes 2 days of cooling the well, 2 separate step-rate tests, three perforation shots, two tracer and diverter injections, and a total of 11 days of well stimulation.

Table 1: Schedule to complete 2014 stimulation

Day/Date	**Planned Field Activities**
Mon 10	Install 8" logging valve. Test pumps to 2000 psi look for leaks. Shutdown for night.
Tue 11	Restart. Step rate test 1200 to 2200. psi 200 psi steps, 1-2 hours at each step
Wed 12	Hold at 2200 psi (max WHP with 8" valve) to cool for perforation shot
Thu 13	Perforation shots by Cogco. Start with Cogco Temp log, then 3 gun runs. After complete allow flow back overnight to clean out dust
Fri 14	Replace 3" logging valve. Restart pumps with Step rate test 1200 to 2800 psi.1 hour at each step below 2200, 2 hours at steps above.
Sat 15	Run at 2800 psi. Possible pressure cycling.
Sun 16	Run at 2800 psi. Possible pressure cycling.
Mon 17	Inject 1 DIVA of tracer, RIH with PTS (Wellaco) to TD. 2-4 DIVAs full of powder diverter (Thermasource to mix) Pull PTS out to confirm blocking of most permeable zones (9500ft)
Tue 18	Depending on well behavior, WHP may be keep Wellaco on standby while pumping water, possible PTS log to confirm diverter is holding.
Wed 19	Pump 1 DIVA of tracer, RIH PTS to TD. 3-4 DIVAs full of powder or fiber diverter (depending on prior result). POOH DTS. Release Wellaco and Thermasource
Thu 20	Run at 2800 psi.
Fri 21	Run at 2800 psi. Depending on results to-date, diesel on hand, budget, etc. pump third stage of diverter or shutdown and shut-in well
Sat 22	If shutdown, release generators, start pump demobilization
Sun 23	Allow for heat-up
Mon 24	Start 36 hour flow test (?) from initial WHP of ~1500 psi

Selected References

Chabora et al., 2012. Hydraulic stimulation of well 27-15, Desert Peak Geothermal Field, Nevada, USA. Thirty-Seventh Workshop on Geothermal Reservoir Engineering Stanford University, Stanford, California, January 30 - February 1, 2012

Choquette, M., Berudbe, M-A., Locat, J., 1991, Behavior of common rock-forming minerals in a strongly basic NaOH solution, Canadian Mineralogist, V 29, pp. 163-173.

Xu et al., 2009. On modeling of chemical stimulation of an enhanced geothermal system using a high pH solution with chelating agent. Geofluids **9**, 167-177.

FIGURES

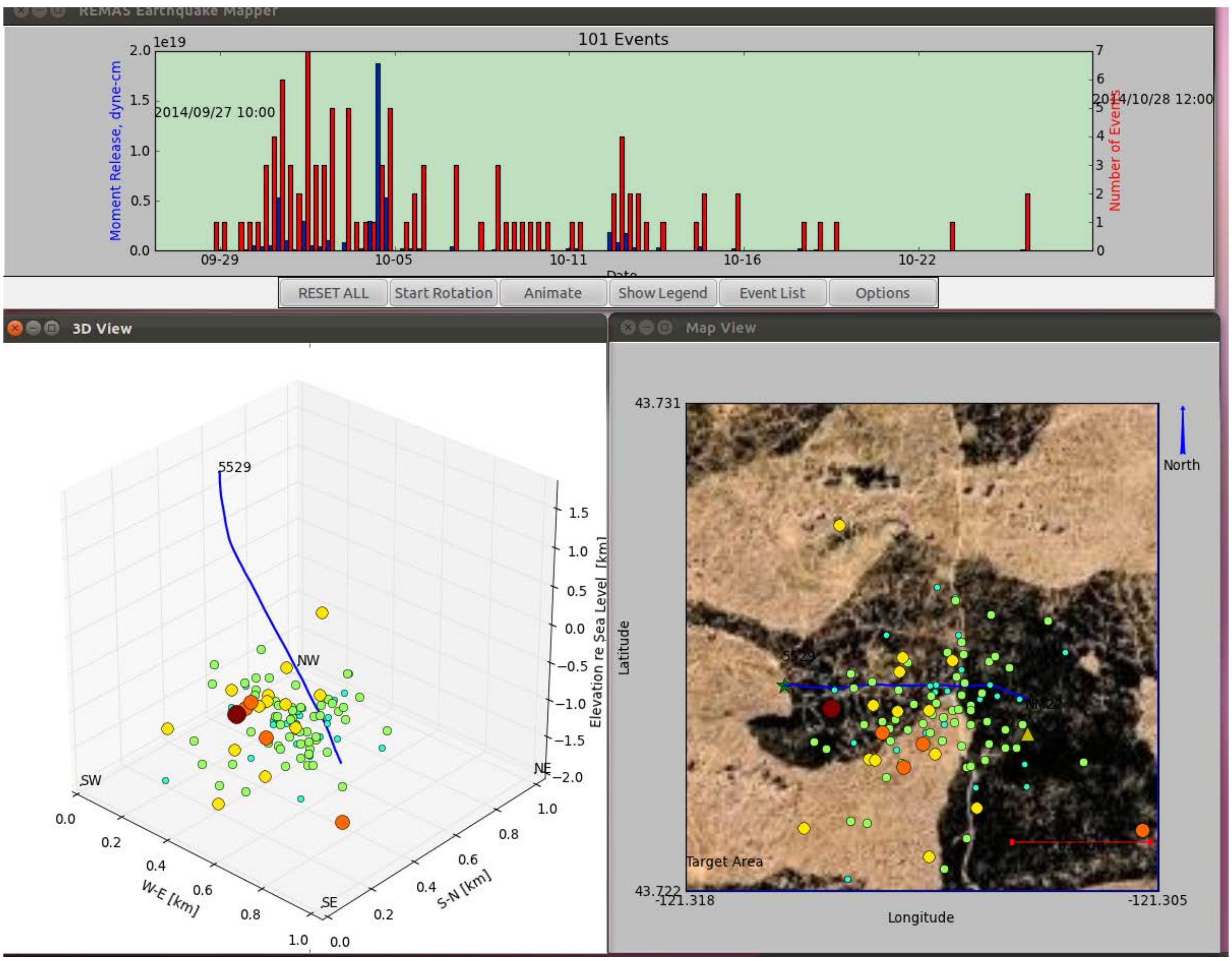


Figure 1 Microseismic event locations determined by LBL. Other location data sets also show about 1 km of stimulated volume. Additional analysis and relocations will likely tighten the pattern.

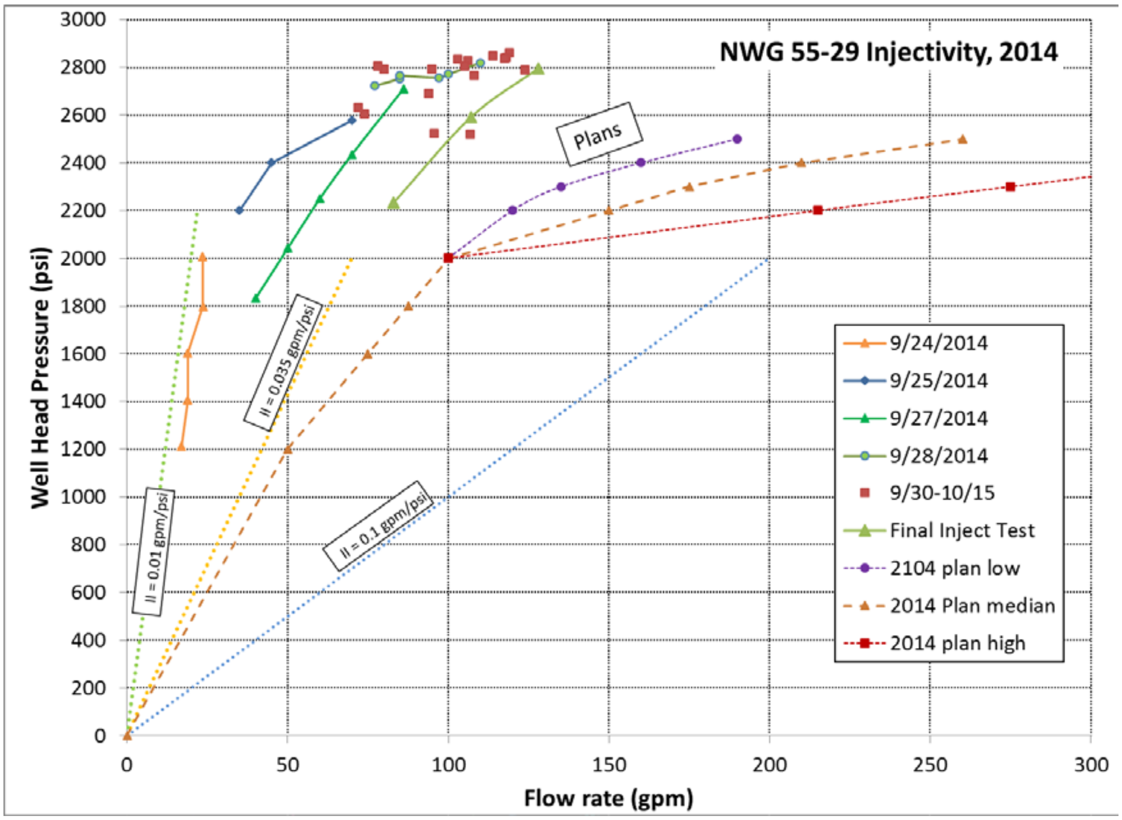


Figure 2: Stimulation results through October 15. Initial step-rate test on Nov 11 will provide confirmation of injectivity improvement from 1200 to 2200 psi WHP.

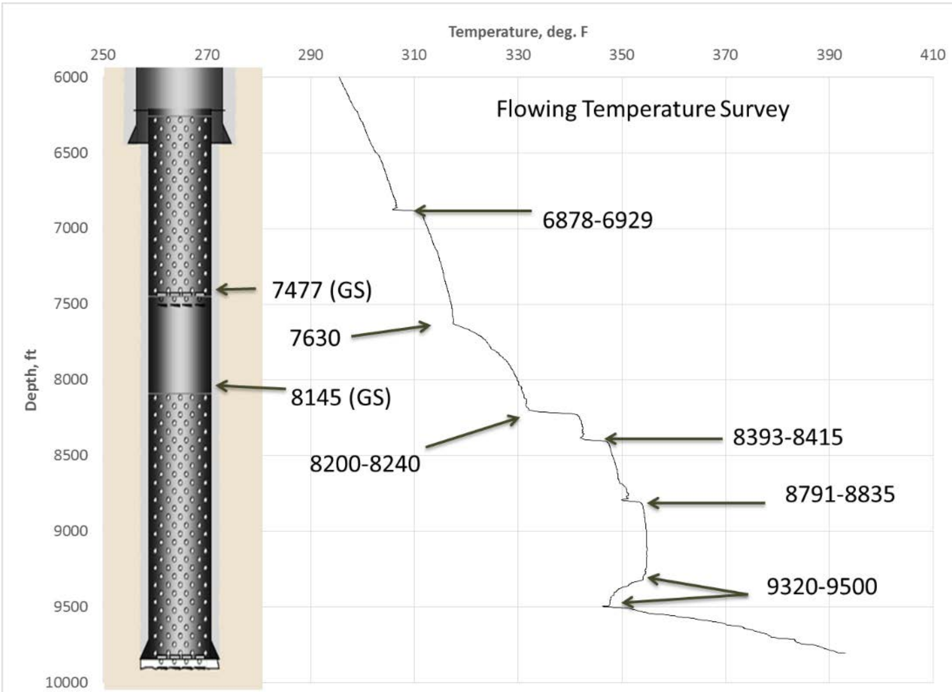


Figure 3: Temperature profile during flow-back (~200 gpm)

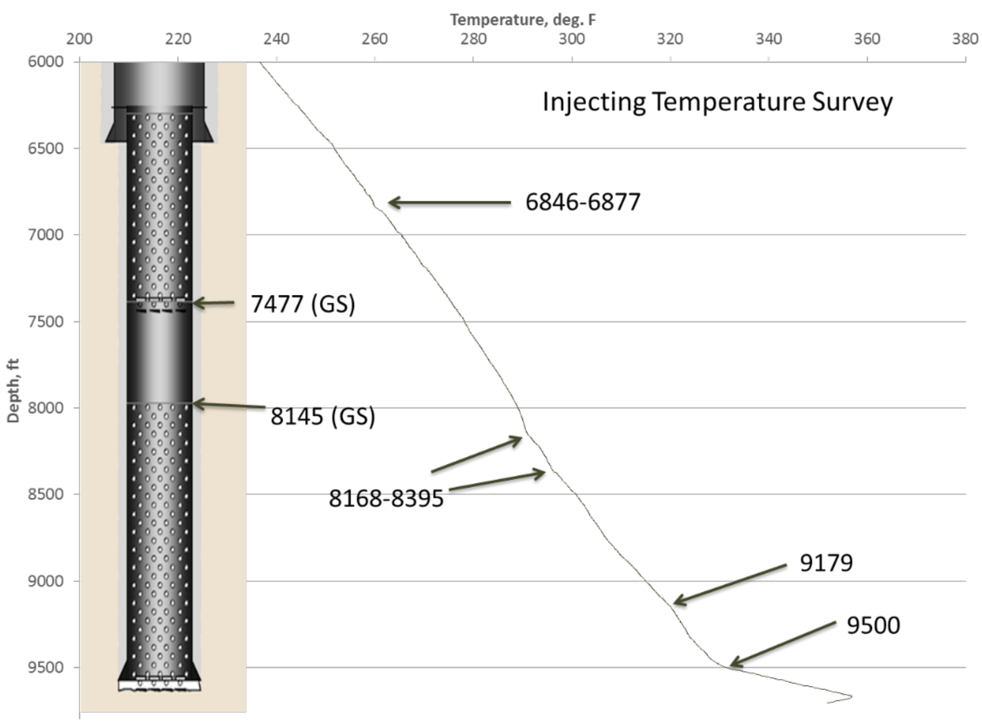


Figure 4: Temperature profile during injection

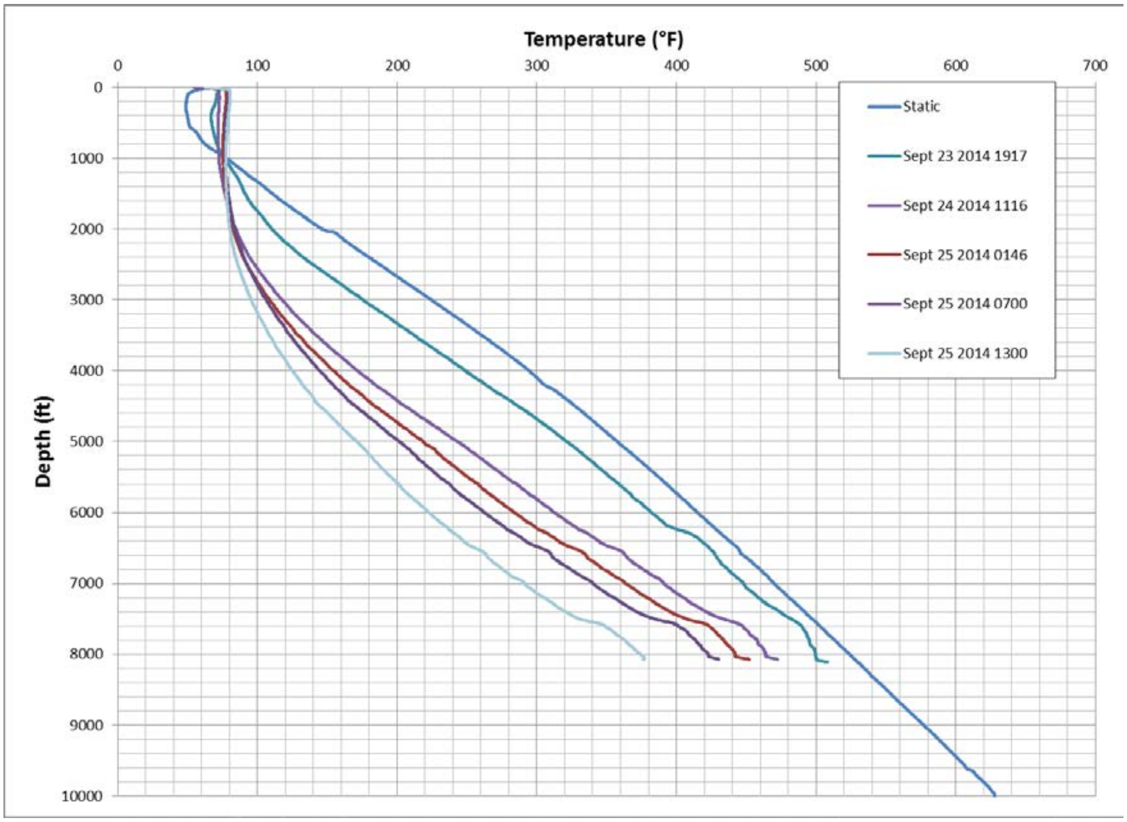
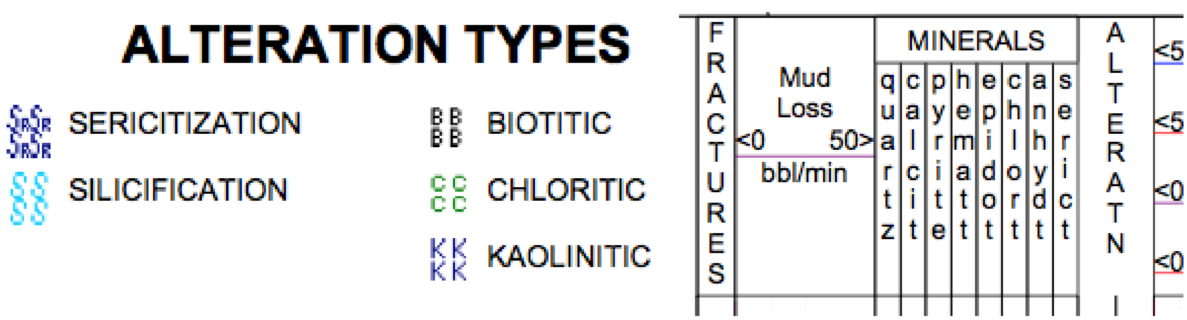


Figure 5: Cooling of well bore at beginning of first stimulation.



NOTE At 8690ft: SILIFICATION SYMBOL IN ALTERATION TYPE COLUMN REFERS MORE TO K-SPAR METASOMATISM FROM 8690' ON THAN TO SILIFICATION.

Figure 6 Legend and explanation for alteration symbols in mud log snippets shown below.

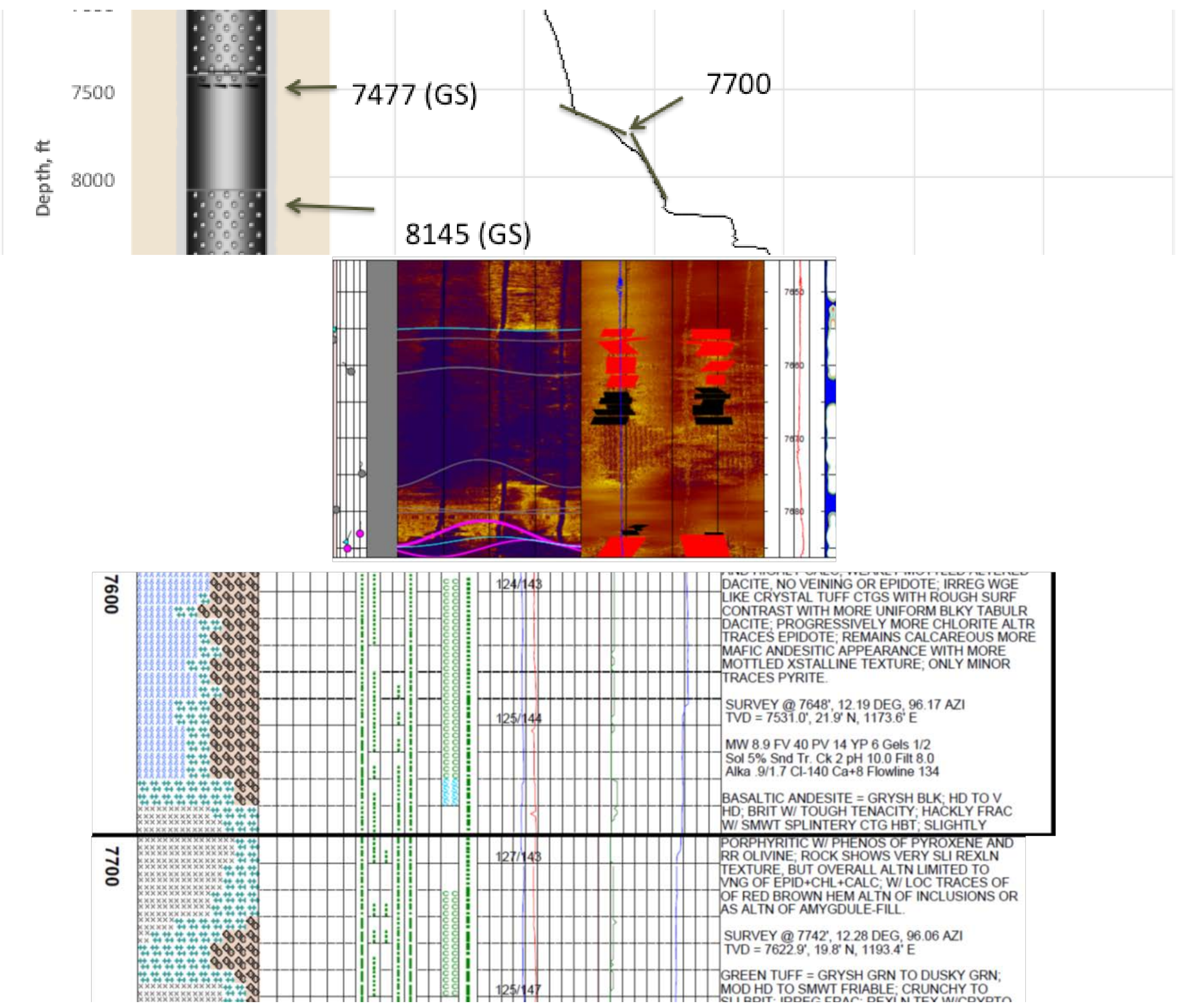


Figure 7: Perforation target #1, 7680

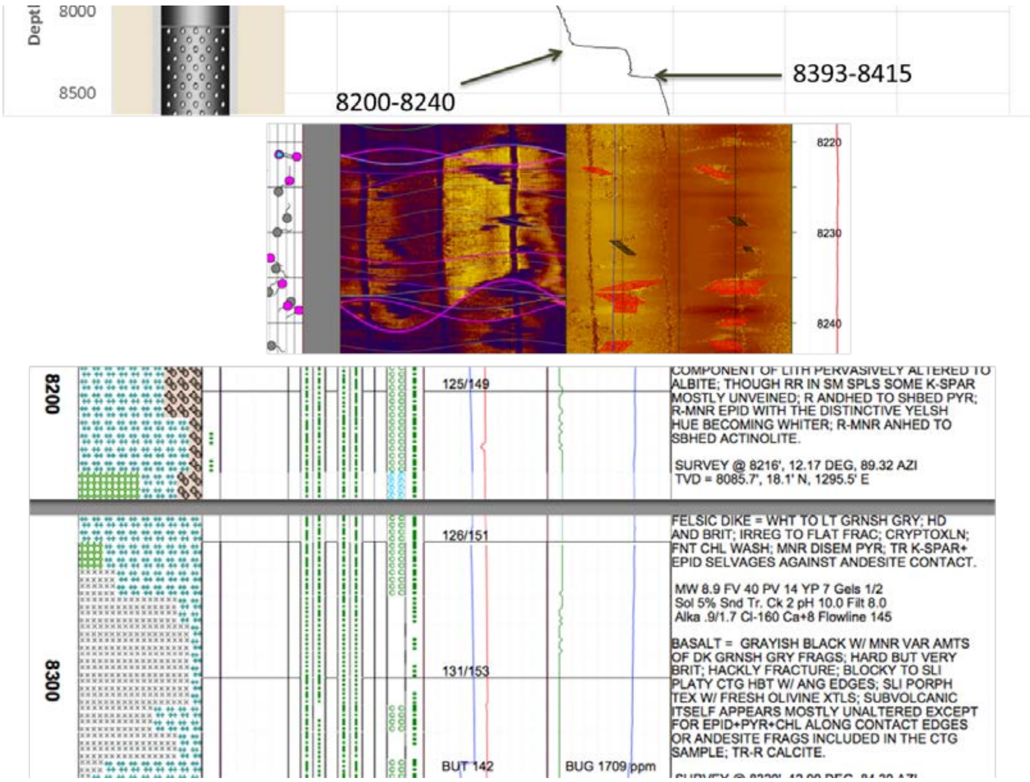


Figure 8: Perforation target #2 at ~8200ft. Chemical stimulation will also enhance the contact between the felsic dike and basalt which is already taking some fluid as evidenced by flow back of hot

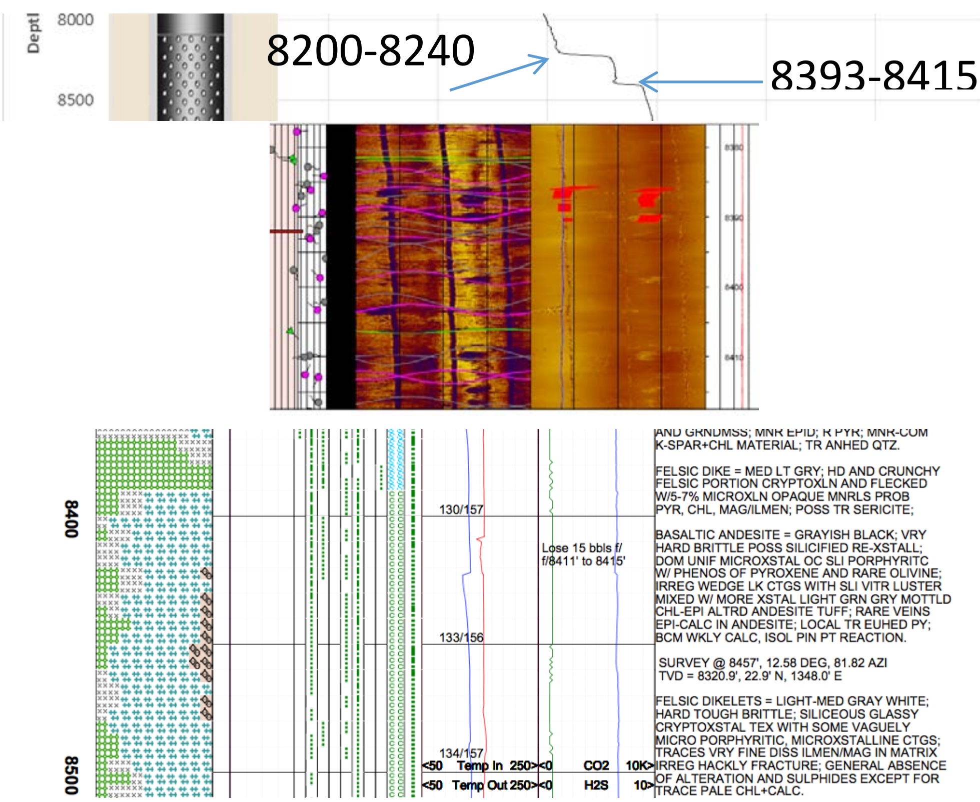


Figure 9: Perforation target #3 at ~8400ft.

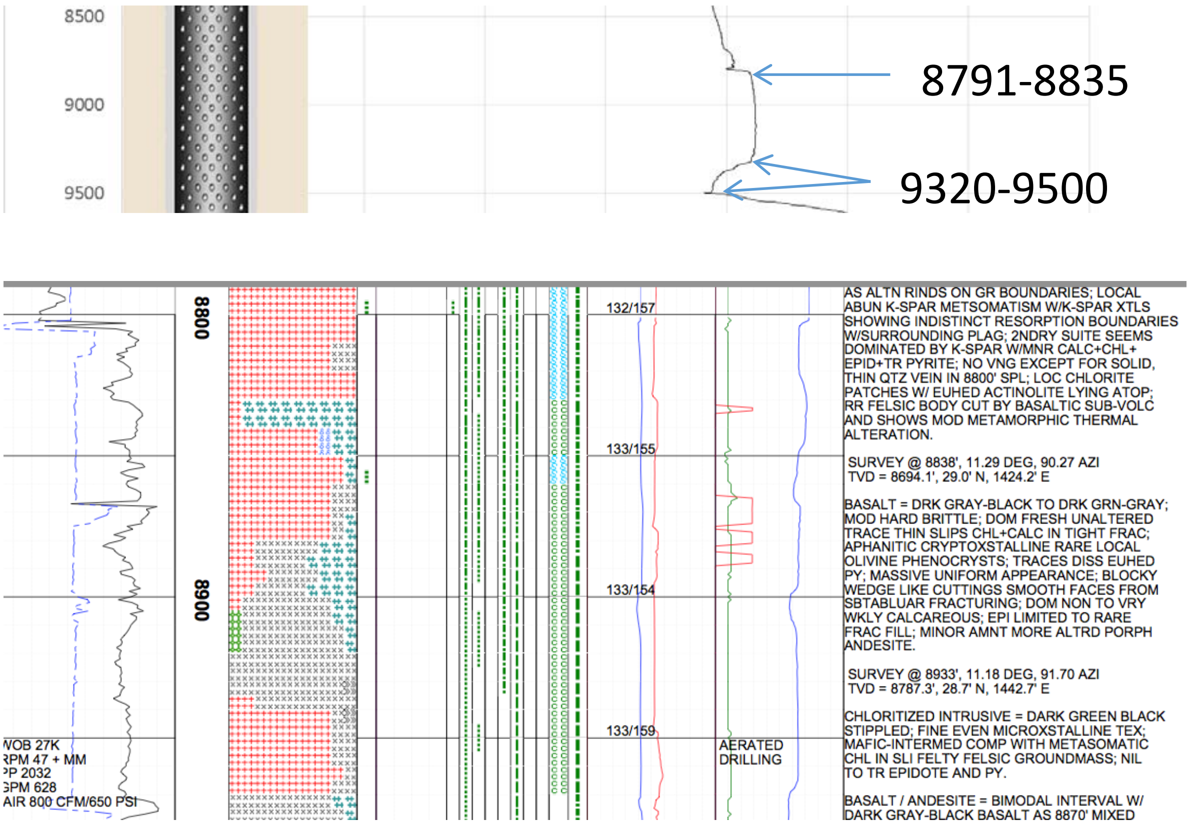


Figure 10: Flow zone at 8800ft. Alteration mineralogy examined for chemical treatment planning.

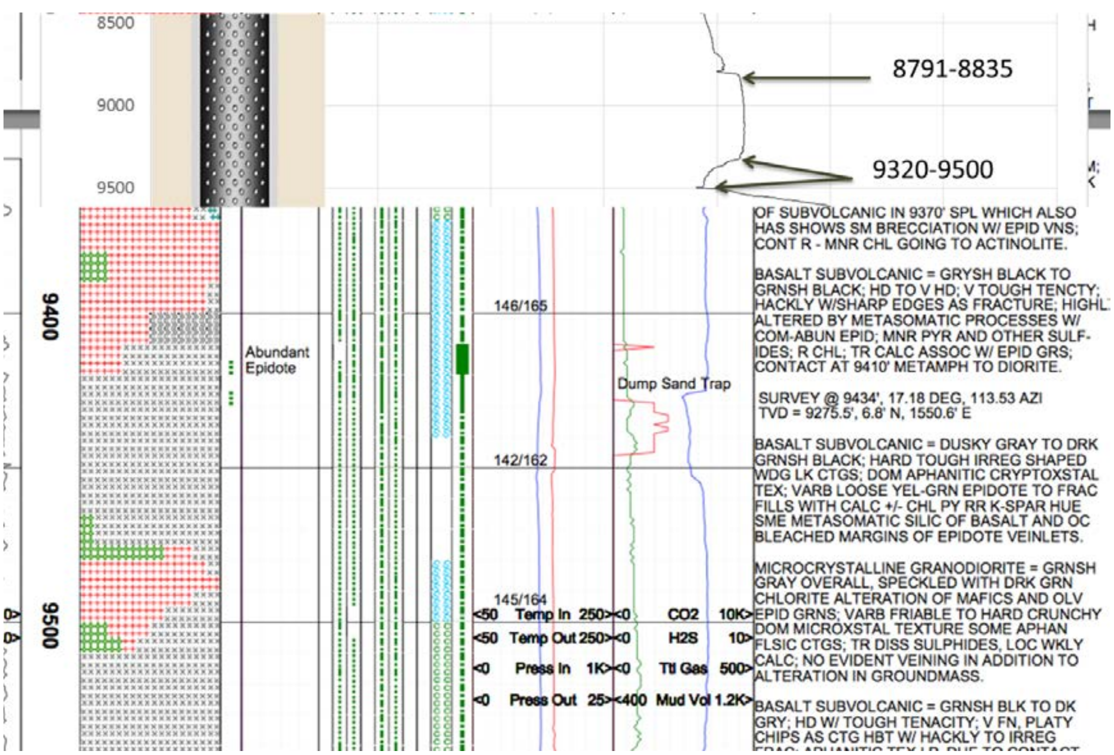


Figure 11: Flow zone at 9500ft. Alteration mineralogy examined for chemical treatment planning

Appendix D
Groundwater Quality Analytical Results

Surface Water and Groundwater Quality Data, Newberry EGS Demonstration Project

			Field Parameters					Laboratory Analytical Results												
Monitoring Location	Sample Type	Date	Temp, (°C)	pH (SU)	Cond. (mS/m)	ORP (mV)	Turbidity (NTU)	Alkalinity, Total (mg/L CaCO3)	Alkalinity/HCO_3^- (mg/L $CaCO_3$)	Alkalinity/CO_3^{2-} (mg/L $CaCO_3$)	Alkalinity/OH^- (mg/L $CaCO_3$)	Aluminum (mg/L)	Ammonia (mg/L N)	Arsenic (mg/L)	Barium (mg/L)	Boron (mg/L)	Calcium (mg/L)	Cesium (mg/L)	Chloride (mg/L)	Chromium (mg/L)
PLHS	B	10/7/2011	49.9	6.09	0.99	81	–	540	540	<2	<2	<0.05	<0.1	0.015	0.28	0.76	48	0.004	7	<0.002
PLHS	B	7/26/2012	50.4	6.64-6.72	0.672-0.691	174	–	520	520	<2	<2	<0.05	<0.1	0.013	0.12	0.77	43	0.004	5	<0.002
PLHS	D	11/27/2012	46.8	6.33	0.917	145	0.08	660	660	<2	<2	<0.05	<0.1	0.014	0.24	0.9	56	0.004	7.5	<0.002
PLHS	P	1/6/2013	42.1	6.7	0.815	152	0.75	390	390	<2	<2	<0.05	<0.1	0.018	0.02	0.88	32	<0.002	3.8	<0.002
PLHS	P	2/9/2013	46.1	7.05	0.584	232	0.64	450	450	<2	<2	<0.05	<0.1	0.012	0.054	0.88	37	0.002	5.0	<0.002
PLHS	P	3/12/2013	39	6.35	0.764	176	0.08	550	550	<2	<2	<0.05	<0.1	0.022	0.011	0.72	50	0.004	7	<0.002
PLHS	P	4/10/2013	37.2	6.67	177	0.501	0.83	550	550	<2	<2	<0.05	<0.1	0.024	0.011	0.74	52	0.004	7.7	<0.002
PLHS	P	5/15/2013	39.8	6.53	174	0.793	-0.14	550	550	<2	<2	<0.05	<0.1	0.024	0.012	0.73	52	0.005	7.7	<0.002
PLHS	P	7/19/2013	52.4	6.2	–	–	0.07	580	580	<2	<2	<0.05	<0.1	0.011	0.2	0.76	50	0.004	6.8	<0.002
ELHS	B	10/6/2011	54.5	6.26	1.29	-37	28.1	740	740	<2	<2	<0.05	0.1	0.003	0.005	0.61	130	<0.002	4.5	<0.002
ELHS	B	7/26/2012	38.8	6.46	0.83	33	-	500	500	<2	<2	<0.05	0.2	<0.002	0.014	0.8	86	<0.002	1.7	<0.002
ELHS	D	11/29/2012	46.8	6.33	0.91	145	0.08	160	160	<2	<2	<0.05	<0.1	0.006	0.019	1	35	<0.002	1.4	<0.002
ELHS	P	1/6/2013	16	8.66	0.225	127	0.06	130	130	<2	<2	<0.05	<0.1	<0.002	0.019	0.98	29	<0.002	0.7	<0.002
ELHS	P	2/9/2013	28.4	6.58	0.684	134	0.1	510	510	<2	<2	<0.05	<0.1	<0.002	0.011	0.91	77	<0.002	3.8	<0.002
ELHS	P	3/12/2013	48.8	6.49	0.425	146	1.20	250	250	<2	<2	<0.05	0.2	<0.002	0.015	0.96	43	<0.002	2	<0.002
ELHS	P	4/10/2013	42	6.75	85	0.345	3.99	260	260	<2	<2	<0.05	<0.1	<0.002	0.013	0.95	46	<0.002	2.3	<0.002
ELHS	P	5/15/2013	22.9	6.77	132	0.289	0.47	150	150	<2	<2	<0.05	<0.1	<0.002	0.018	0.95	32	<0.002	0.8	<0.002
ELHS	P	7/19/2013	32.9	6.8	–	–	0.6	130	130	<2	<2	<0.05	<0.1	<0.002	0.017	1	30	<0.002	0.8	<0.002
PCG	B	7/26/2012	11.5	7.37	0.06	124	-	48	48	<2	<2	<0.05	<0.1	<0.002	0.003	<0.05	4.3	<0.002	1.7	<0.002
PCG	P	6/22/2013	9.7	7.98	108	0.48	0.12	44	44	<2	<2	<0.05	<0.1	<0.002	0.003	<0.05	4.4	<0.002	1.4	<0.002
PCG	P	7/23/2013	11.9	7.35	–	0.248	–	44	44	<2	<2	<0.05	<0.1	<0.002	<0.004	<0.05	4	<0.002	1.1	<0.002
VC	B	7/26/2012	7.9	6.43	0.051	142	err	44	44	<2	<2	<0.05	0.2	<0.002	0.005	<0.05	3.9	<0.002	1.4	<0.002
VC	P	6/22/2013	5.7	7.21	165	0.027	-0.12	41	41	<2	<2	<0.05	<0.1	0.002	0.004	<0.05	3.9	<0.002	1.2	<0.002
VC	P	7/23/2013	14.1	6.5	–	0.248	0.01	41	41	<2	<2	<0.05	<0.1	<0.002	<0.004	<0.05	4.2	<0.002	1	<0.002
NEWW	B	10/7/2011	8.6	7.27	0.064	124	0.55	50	50	<2	<2	<0.05	<0.1	<0.002	0.002	<0.05	5.5	<0.002	1.7	<0.002
NEWW	B	10/6/2011	9.1	7.38	0.093	120	Error	57	57	<2	<2	<0.05	<0.1	<0.002	0.002	<0.05	8.2	<0.002	2.4	<0.002
NEWW	B	7/26/2012	10.3	7.53	0.067	184	–	57	57	<2	<2	<0.05	<0.1	<0.002	0.004	<0.05	7.8	<0.002	2.3	<0.002
NEWW	P	1/18/2013	7.9	7.38	0.086	93	0.17	60	60	<2	<2	<0.05	<0.1	<0.002	0.003	<0.05	7.8	<0.002	2.3	<0.002
NEWW	P	2/28/2013	8.5	7.32	0.80	136	0.03	–	–	–	–	<0.05	–	<0.002	0.005	<0.05	7.9	<0.002	–	<0.002
NEWW	P	3/22/2013	8.7	7.20	0.077	137	-0.05	58	58	<2	<2	<0.05	<0.1	<0.002	0.004	<0.05	8	<0.002	2.4	<0.002
Pad 16 Water Well	B	8/16/2012	6	7.7	0.013	169	NA	42	42	<2	<2	<0.05	0.1	<0.002	0.002	<0.05	5	<0.002	0.7	<0.002
Pad 16 Water Well	D	11/26/2012	7.7	7.79	0.033	122	0.15	39	39	<2	<2	<0.05	<0.1	<0.004	<0.002	<0.05	5.1	<0.002	0.9	<0.002
Pad 16 Water Well	P	9/12/2013	6.88	8.2	-65	–	0.84	40	40	<2	<2	<0.05	<0.1	<0.002	0.003	<0.05	5.1	<0.001	0.8	<0.002
Pad 29 Water Well	P	8/10/2011	NA	NA	NA	NA	NA	240	240	<2	<2	<0.05	0.3	0.032	0.009	0.55	19	<0.002	4	<0.002
Pad 29 Water Well	B	8/12/2011	NA	NA	NA	NA	NA	240	240	<2	<2	<0.05	<0.1	0.032	0.007	0.57	19	<0.002	3.8	<0.002
Pad 29 Water Well	B	9/23/2011	NA	NA	NA	NA	NA	230	230	<2	<2	<0.05	<0.1	0.026	0.008	0.55	19	<0.002	3	<0.002
Pad 29 Water Well	D	10/18/2012	15.9	7.56	0.385	101	0.12	250	250	<2	<2	<0.05	0.1	0.033	0.008	0.59	19	<0.002	3.5	<0.002
Pad 29 Water Well	D	11/26/2012	16.7	7.69	0.368	170	0.02	250	250	<2	<2	<0.05	<0.1	0.034	0.007	0.58	20	<0.002	3.5	<0.002
Pad 29 Water Well	P	12/10/2012	14.5	7.54	0.345	71	0	250	250	<2	<2	<0.05	<0.1	0.033	0.008	0.56	19	<0.002	3.5	<0.002
Pad 29 Water Well	P	7/18/2013	16.7	7.15	–	0.305	0	250	250	<2	<2	<0.05	<0.1	0.028	0.007	0.57	19	<0.002	3.6	<0.002
Pad 29 Water Well	P	7/18/2013	16.3	7.23	–	0.333	0	250	250	<2	<2	<0.05	<0.1	0.028	0.01	0.56	19	<0.002	3.5	<0.002
Pad 29 Water Well	P	9/11/2013	7.25	24.3	-83	**	0.1	250	250	<2	<2	<0.05	0.1	0.029	0.007	0.57	19	<0.001	3.6	<0.002
NN-17	B	10/5/2012	13.1	6.92	0.53	NA	119	241	233	8	<2	<0.05	0.1	0.01	0.004	0.56	18	<0.002	3.1	<0.002
NN-17	D	10/18/2012	8.1	7.82	0.343	NA	17.2	240	240	<2	<2	<0.05	0.3	0.011	0.006	0.55	18	<0.002	3	<0.002
NN-17	P	1/7/2013	5.6	8.66	0.225	-75	4.57	240	240	<2	<2	<0.05	<0.1	0.011	0.006	0.55	16	<0.002	3.6	<0.002
NN-17	P	2/10/2013	6	8.26	0.145	-72	5.16	210	210	<2	<2	<0.05	<0.1	0.009	0.006	0.46	18	<0.002	2.8	<0.002
NN-17	P	3/14/2013	7.9	8.27	0.220	-61	4.65	210	210	<2	<2	<0.05	<0.1	0.009	0.009	0.42	18	<0.002	2.6	<0.002
NN-17	P	4/11/2013	4.6	8.2	129	0.214	0.83	242	233	9	<2	<0.05	0.2	0.013	0.006	0.56	18	<0.002	3.7	<0.002
NN-17	P	5/15/2013	8.6	7.78	-63	0.308	3.12	240	230	10	<2	<0.05	<0.1	0.014	0.005	0.55	18	<0.002	3.6	<0.002
NN-17	P	7/19/2013	9	7.3	–	–	3.26	250	250	<2	<2	<0.05	<0.1	0.014	0.005	0.56	18	<0.002	3.4	<0.002
NN-17	P	9/3/2013	7.74	9.9	-108	–	7.97	240	240	<2	<2	<0.05	<0.1	0.013	0.007	0.56	18	<0.002	3.4	<0.002
NN-18	B	10/9/2012	12.8	9.02	0.249	NA	16.8	171	80	91	<2	<0.05	<0.1	0.028	0.005	0.86	9.4	<0.002	6.5	<0.002
NN-18	D	10/18/2012	7.51	5.3	0.264	NA	2.86	190	190	<2	<2	<0.05	0.1	0.028	0.014	0.96	12	<0.002	6.6	<0.002
NN-18	P	1/7/2013	4.8	8.36	0.247	247	5.18	190	190	<2	<2	<0.05	<0.1	0.026	0.013	0.88	9.7	<0.002	6.3	<0.002
NN-18	P	2/10/2013	2.9	8.18	0.206	110	6.53	180	180	<2	<2	<0.05	<0.1	0.023	0.018	0.87	10	<0.002	6.3	<0.002
NN-18	P	3/14/2013	4.9	7.82	0.288	168	1.84	180	180	<2	<2	<0.05	<0.1	0.018	0.011	0.86	10	<0.002	6.3	<0.002
NN-18	P	4/11/2013	8	7.8	34	0.194	8.52	180	174	6	<2	<0.05	0.1	0.025	0.012	0.85	10	<0.002	6.1	<0.002
NN-18	P	5/17/2013	7.8	8.16	132	0.253	0.14	178	170	8	<2	<0.05	<0.1	0.025	0.012	0.82	9.6	<0.002	5.9	<0.002
NN-18	P	7/19/2013	14	7.93	–	–	–	180	180	<2	<2	<0.05	<0.1	0.026	0.012	0.85	9.7	<0.002	5.6	<0.002
NN-18	P	9/3/2013	7.69	13.9	-106	0.25	0.34	180	180	<2	<2	<0.05	<0.1	0.027	0.011	0.82	9.6	<0.002	5.7	<0.002

Surface Water and Groundwater Quality Data, Newberry EGS Demonstration Project (continued)

Monitoring Location	Sample Type	Date	Laboratory Analytical Results																
			F (mg/L)	Fe (mg/L)	Li (mg/L)	Mg (mg/L)	Mn (mg/L)	Hg (mg/L)	NO_3 (mg/L N)	P (mg/L)	K (mg/L)	Rb (mg/L)	SiO_2 (mg/L)	Na (mg/L)	Sr (mg/L)	SO_4 (mg/L)	TDS (mg/L)	δ^2H	$\delta^{18}O$
PLHS	B	10/7/2011	0.9	0.13	0.2	42	2.7	<0.0002	<0.5	0.2	13	0.032	160	110	0.2	3.5	720	-108.3	-14.44
PLHS	B	7/26/2012	0.6	<0.05	0.15	41	1.3	<0.0002	<0.5	0.14	11	0.032	150	96	0.18	3.2	630	-104.05	-13.75
PLHS(dup)	B	7/26/2012	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	-104.05	-13.78
PLHS	D	11/27/2012	0.9	<0.05	0.2	48	1.2	<0.0001	<0.5	0.13	16	0.04	220	140	0.2	3.5	820	–	–
PLHS	P	1/6/2013	0.8	<0.05	<0.1	41	0.031	<0.0001	1.3	0.04	6.6	0.016	58	58	0.11	4.9	380	–	–
PLHS	P	2/9/2013	0.8	<0.05	0.1	44	0.45	<0.0002	<0.5	0.06	8.8	0.022	100	78	0.15	3.4	500	–	–
PLHS	P	3/12/2013	0.8	<0.05	0.18	42	0.32	<0.0002	<0.5	0.18	13	0.039	180	110	0.15	12	690	–	–
PLHS	P	4/10/2013	0.9	<0.05	0.17	43	0.46	<0.0001	<0.5	0.17	13	0.038	170	110	0.2	12	690	-105.93	-14.19
PLHS	P	5/15/2013	0.9	<0.05	0.2	43	1	<0.0001	<0.5	0.18	13	0.04	170	110	0.21	12	710	-107.96	-14.35
PLHS	P	7/19/2013	0.5	<0.1	0.2	44	1.7	<0.0001	<0.5	0.12	14	0.034	210	120	0.2	3.4	740	-109.13	-14.41
ELHS	B	10/6/2011	0.5	0.15	<0.1	54	0.58	<0.0002	<0.5	0.15	13	0.012	180	90	0.36	<0.2	900	-113.6	-15.16
ELHS	B	7/26/2012	<0.1	0.56	<0.1	37	0.41	<0.0002	<0.5	0.12	9	0.015	110	63	0.27	26	590	-98.5	-12.4
ELHS(dup)	B	7/26/2012	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	-97.4	-12.2
ELHS	D	11/29/2012	0.2	0.17	<0.1	17	0.15	<0.0001	<0.5	0.08	4.8	0.013	37	32	0.11	54	270	–	–
ELHS	P	1/6/2013	0.2	0.06	<0.1	14	0.042	<0.0001	<0.5	0.03	4.2	0.011	19	27	0.12	61	230	–	–
ELHS	P	2/9/2013	0.3	<0.05	<0.1	39	0.45	<0.0002	<0.5	0.34	9.2	0.03	190	64	0.22	5.8	640	–	–
ELHS	P	3/12/2013	0.3	0.06	<0.1	21	0.23	<0.0002	<0.5	0.1	5.7	0.018	71	37	0.15	46	350	–	–
ELHS	P	4/10/2013	0.2	0.09	<0.1	22	0.33	<0.0001	<0.5	0.13	5.9	0.018	76	39	0.15	42	380	-92.5	-10.7
ELHS	P	5/15/2013	0.1	0.08	<0.1	14	0.098	<0.0001	<0.5	0.02	4.5	0.012	26	28	0.12	58	250	-82.9	-8.9
ELHS	P	7/19/2013	0.1	<0.1	<0.1	14	0.067	<0.0001	<0.5	<0.02	4.3	0.011	22	29	0.12	59	240	-79.87	-8.60
PCG	B	7/26/2012	0.2	<0.05	<0.1	3.5	<0.002	<0.0002	0.5	0.09	1.4	0.004	35	7.9	<0.05	1.5	70	-120.46	-16.2
PCG(dup)	B	7/26/2012	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	-120.22	-16.26
PCG	P	6/22/2013	0.1	<0.05	<0.1	3.7	0.003	<0.0001	<0.5	0.07	1.8	0.003	36	8.4	<0.05	0.6	76	-120.56	-16.14
PCG	P	7/23/2013	<0.1	<0.1	<0.1	3.4	<0.004	<0.0001	<0.5	0.07	1.5	0.003	37	7.8	<0.05	0.4	70	-120.09	-16.21
VC	B	7/26/2012	0.8	<0.05	<0.1	3	0.003	<0.0002	0.9	0.1	1.8	0.004	44	7.3	<0.05	0.4	76	-111.54	-15.4
VC(dup)	B	7/26/2012	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	-111.38	-15.37
VC	P	6/22/2013	0.7	0.07	<0.1	3.1	<0.002	<0.0001	<0.5	0.09	1.9	0.004	45	7.3	<0.05	0.4	86	-112.28	-15.3
VC	P	7/23/2013	0.6	<0.1	<0.1	3.1	<0.004	<0.0001	<0.5	0.08	1.9	0.004	47	7.1	<0.05	0.4	70	-112.16	-15.28
NEWW	B	10/7/2011	0.2	<0.05	<0.1	4.3	<0.002	<0.0002	<0.5	0.31	1.5	0.002	43	9.1	<0.05	0.5	92	-120.5	-16.14
NEWW	B	10/6/2011	0.2	0.1	<0.1	4.7	0.002	<0.0002	0.9	0.22	1.4	<0.002	42	10	<0.05	1.7	110	-119.8	-15.72
NEWW	B	7/26/2012	0.2	<0.05	<0.1	4.4	<0.002	<0.0002	1.9	0.18	1.4	<0.004	45	9.9	<0.05	2	100	-118.3	-15.8
NEWW	P	1/18/2013	0.2	<0.05	<0.1	4.5	0.002	<0.0002	1.3	0.17	1.4	<0.002	44	10	<0.05	1.5	96	–	–
NEWW	P	2/28/2013		<0.05	<0.1	4.6	0.002	<0.0002	–	–	1.4	<0.002	46	10	<0.05			–	–
NEWW	P	3/22/2013	0.1	<0.05	<0.1	4.5	0.002	<0.0002	1.1	0.18	1.4	<0.002	49	10	<0.05	1.5	100	-120.98	-15.68
Pad 16 Water Well	B	8/16/2012	0.2	0.08	<0.1	2.6	0.002	<0.0002	<0.5	0.12	1.1	0.003	41	6.8	<0.05	0.3	70	–	–
Pad 16 Water Well	D	11/26/2012	0.2	0.06	<0.1	2.5	0.002	<0.0001	<0.5	0.12	0.98	0.003	39	6.3	<0.05	0.3	76	–	–
Pad 16 Water Well	P	9/12/2013	0.2	<0.05	<0.1	2.6	0.003	<0.0001	<0.5	0.1	1.6	0.002	39	6.2	<0.05	0.3	74	-113.96	-15.58
Pad 29 Water Well	B	8/10/2011	0.8	0.1	<0.1	24	0.002	NA	0.29	0.15	4.7	0.014	59	44	0.08	2.5	280	–	–
Pad 29 Water Well	B	8/12/2011	0.8	0.07	<0.1	25	<0.002	NA	0.13	0.16	4.8	0.014	62	45	0.08	2.5	280	–	–
Pad 29 Water Well	B	9/23/2011	0.5	<0.1	<0.1	24	<0.002	NA	<0.5	0.2	5	0.012	60	42	0.08	2.5	270	–	–
Pad 29 Water Well	D	10/18/2012	0.7	<0.05	<0.1	25	0.003	<0.0002	<0.5	0.19	4.7	0.013	57	44	0.08	2.4	280	-110.8	-14.7
Pad 29 Water Well	D	11/26/2012	0.7	<0.05	<0.1	26	<0.002	<0.0001	<0.5	0.18	4.7	0.013	60	46	0.06	2.4	280	–	–
Pad 29 Water Well	P	12/10/2012	0.7	<0.05	<0.1	25	0.003	<0.0001	<0.5	0.18	4.7	0.012	55	46	0.05	2.5	280	-110.6	-14.72
Pad 29 Water Well	P	7/18/2013	0.5	<0.05	<0.1	25	<0.002	<0.0001	<0.5	0.15	5.2	0.012	58	44	0.08	2.5	280	–	–
Pad 29 Water Well(dup)	P	7/18/2013	0.6	<0.05	<0.1	25	<0.002	<0.0001	<0.5	0.15	5	0.012	58	43	0.07	2.6	280	–	–
Pad 29 Water Well	P	9/11/2013	0.6	<0.05	<0.1	25	<0.002	<0.0001	<0.5	0.2	5.1	0.012	60	44	0.08	2.5	280	-110.16	-14.71
NN-17	B	10/5/2012	0.7	<0.05	<0.1	24	0.092	<0.0002	<0.5	0.08	4.2	0.013	52	40	0.07	2.1	270	-111.4	-14.88
NN-17(dup)	B	10/5/2012	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	-112.3	-14.96
NN-17	D	10/18/2012	0.7	<0.05	<0.1	24	0.09	<0.0002	<0.5	0.09	4	0.013	51	39	0.07	1.9	260	-111.8	-14.77
NN-17(dup)	D	10/18/2012	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	-112.3	-14.96
NN-17	P	1/7/2013	0.8	0.27	<0.1	24	0.066	<0.0001	<0.5	0.1	4.2	0.014	55	40	0.07	1.9	240	–	–
NN-17	P	2/10/2013	0.6	0.13	<0.1	22	0.032	<0.0002	<0.5	0.12	3.6	0.009	50	34	0.08	2.1	230	–	–
NN-17	P	3/14/2013	0.6	0.13	<0.1	21	0.015	<0.0002	<0.5	0.14	3.4	0.009	50	31	0.06	2.2	230	–	–
NN-17	P	4/11/2013	0.7	0.08	<0.1	24	0.025	<0.0001	<0.5	0.1	4.5	0.014	53	41	0.07	1.8	260	-110.15	-14.87
NN-17	P	5/15/2013	0.7	0.16	<0.1	25	0.021	<0.0001	<0.5	0.1	4.4	0.014	54	42	0.12	1.8	270	-111.97	-14.99
NN-17	P	7/19/2013	0.6	0.2	<0.1	25	0.018	<0.0001	<0.5	0.09	4.4	0.014	55	41	0.1	1.9	270	-112.42	-14.92
NN-17	P	9/3/2013	0.6	0.24	<0.1	24	0.04	<0.0001	<0.5	0.1	4.7	0.013	55	41	0.1	1.8	260	-112.23	-15.08
NN-18	B	10/9/2012	0.4	0.09	<0.1	6.4	0.008	<0.0002	2.2	0.03	7.6	0.016	39	46	<0.05	13	190	-113.77	-15.13
NN-18(dup)	B	10/9/2012	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	-112.7	-15.13
NN-18	D	10/18/2012	0.5	<0.05	<0.1	14	0.015	<0.0002	<0.5	0.12	6.3	0.013	72	48	<0.05	4.9	240	-113.77	-15.14
NN-18	P	1/7/2013	0.5	<0.05	<0.1	13	0.012	<0.0001	<0.5	0.13	6.1	0.012	69	46	<0.05	4.7	230	–	–
NN-18	P	2/10/2013	0.5	0.26	<0.1	13	0.016	<0.0002	<0.5	0.12	6.1	0.013	67	47	<0.05	5	240	–	–
NN-18	P	3/14/2013	0.4	0.18	<0.1	13	0.009	<0.0002	<0.5	0.09	6.3	0.013	71	45	<0.05	4.7	240	–	–
NN-18	P	4/11/2013	0.4	0.2	<0.1	13	0.007	<0.0001	<0.5	0.1	6.3	0.012	68	46	<0.05	4.6	250	-113.47	-15.22
NN-18	P	5/17/2013	0.4	0.12	<0.1	13	0.006	<0.0001	<0.5	0.1	6.1	0.012	69	45	<0.05	4.4	250	-113.27	-15.25
NN-18	P	7/19/2013	0.3	0.2	<0.1	13	0.008	<0.0001	<0.5	0.1	6.3	0.012	70	46	<0.05	4.6	240	-111.32	-15.19
NN-18	P	9/3/2013	0.4	0.11	<0.1	13	0.004	<0.0001	<0.5	0.1	6.1	0.011	68	45	<0.05	4.6	250	-111.39	-15.16

B- background; D-during stimulation; P-post stimulation; (dup) – duplicate analysis; ELHS – East Lake Hot Springs; NEWW – Newberry Estates water well; PLHS – Paulina Lake Hot Springs; Cond. – Conductivity; TA – Total Alkalinity; Temp. – temperature; < – constituent was not detected above the laboratory reporting limit; "– " – data not collected

Appendix E
Foulger Consulting Microseismicity Reports
(Six Weekly and Final)

Foulger Consulting

1025 Paradise Way
Palo Alto, CA 94306-2637, USA
Tel: 650/493-2553
Cell: 650/996-8886
FAX: 866/532-6907
gillian@foulgerconsulting.com
http://www.foulgerconsulting.com/

October 8, 2014

WEEKLY REPORT #1 TO ALTAROCK ENERGY INC.

PROCESSING OF INDUCED EARTHQUAKES ASSOCIATED WITH THE NEWBERRY EGS INJECTION STARTING SEPTEMBER 2014

GILLIAN R. FOULGER & BRUCE R. JULIAN

Brief summary

Ten earthquakes with M $\geq$ 1.0 that occurred up to 4 October were carefully re-processed, located, and moment tensors derived. Despite some difficulties with the data, that are currently being resolved, interim results were obtainable and these are mostly of excellent quality.

To date, we have only briefly assessed the results. The moment tensors mostly fall in the +Dipole to -Dipole range. Such a distribution is commonly seen in sets of earthquakes associated with hydrofracturing. There may be some indication that crack opening was more extreme toward the beginning of the 4-day period studied. Individual source types are most easily appreciated from the source-type plots in the upper right-hand panel of the graphical results shown in Appendix 3*.*

The T-axes, which are displayed, for example, in the P polarity plots in the graphical summaries in Appendix 3*, mostly plunge at ~ 45˚ and trend in the range south through southwest.*

1 Task 1 – Planning, conference calls, discussion of work, correspondence, follow-up

In addition to conference calls and planning correspondence earlier in the year, we participated in conference calls August 20, September 3 and 24 and October 1. From August onward, ~ 200 emails were exchanged and we maintained close communication with AltaRock, LBNL (Ernie Majer) and ISTI (Paul Friberg and others).

2 Task 2 – System Setup

The first waveforms were made available to us by AltaRock via Dropbox 30 September 2014, and by direct transfer from AltaRock's server via VPN 4th October, 2014. A few days were required to integrate the data provided into the Foulger Consulting workflow. Details of this work will be provided in a future report.

As the moment-tensor derivation work got into full swing, some residual glitches surfaced. Significant issues that had to be dealt with include:

1. For the waveforms for most earthquakes, a few channels had a timing error of a few seconds, and
2. Some channels were missing.

An example is the earthquake of 20141004_1851:

1. Only 39 out of 48 channels were available;
2. Channels NM08_Z and NM42_Z had ~ 2-s timing errors;
3. Channel NM08_Z was not working properly, and the two horizontals are also suspect
4. Channel NN09_N recorded monochromatic noise.

We are working with ISTI to overcome the problems of missing data and faulty timing. In the meantime, we are obtaining preliminary results using work-arounds and the partial dataset.

3 Task 3 – Quality control of pre-picked MEQs and preparation for relocation and moment tensor calculation

At AltaRock’s request, during the reporting period we focused on obtaining high-quality locations and moment tensors for the largest earthquakes. We quality controlled and re-measured arrival times for individual earthquakes as follows. This process provides data for accurate individual locations, and moment tensors.

1. The waveforms were imported into the Foulger Consulting interactive seismogram processing program *epick*;
2. In a first sweep through the data, *P*- and *S*-wave arrival times were measured and an initial location calculated;
3. In a second sweep through the data, each channel was re-processed, rotating the Z, E, and N channels to the earthquake epicenter, and displaying U, R (radial) and T (transverse) seismograms;
4. The seismograms were filtered with a 5-Hz high-frequency cut-off, *P*- and *S*-wave polarities and amplitudes were measured, and additional *S*-wave measurements were added where enhancement by the rotation process made this possible;
5. The earthquake was relocated, the residuals examined, and arrival-time measurements with large residuals are checked and corrected where appropriate.

The earthquakes processed to date are listed in Table 1. Foulger Consulting relocations are given in Appendix 1.

Table 1: The 10 earthquakes with M $\geq$ 1.0, for which moment tensors were obtained. Locations given below are from the ISTI catalog.

yr	jday	month	day	hour	minute	sec	lat	lon	depth	magnitude
2014	274	10	1	12	3	16.881	43.72658	-121.3158	1.587	1.086
2014	274	10	1	14	53	5.102	43.72545	-121.31355	0.613	1.381
2014	275	10	2	6	47	52.916	43.72632	-121.31322	1.323	1.117
2014	275	10	2	7	7	11.646	43.72488	-121.31192	0.708	1.378
2014	275	10	2	11	1	48.042	43.72567	-121.31168	0.666	1.22
2014	276	10	3	6	6	22.727	43.72528	-121.31493	0.928	1.157
2014	276	10	3	18	54	54.199	43.72678	-121.31125	0.647	1.021
2014	277	10	4	1	19	33.657	43.72008	-121.32708	1.048	1.357
2014	277	10	4	17	32	52.716	43.72207	-121.31693	0.376	1.521
2014	277	10	4	18	51	11.991	43.72295	-121.31227	0.496	1.97

4 Task 4 –Relative locations

Relative location of all the earthquakes in the ISTI catalog is currently in hand and we expect to have preliminary results within a few days.

5 Task 5 - Moment tensor calculations

Moment tensors were derived for the 10 earthquakes with M $\geq$ 1.0 that occurred up to 4 October. We used our in-house program *eqmec*. The numerical results are given in

Table 2. Graphical results are shown in Appendix 3.

In addition to the problems with the data, some additional complexities presented challenges. For example, the event of 20141002 1101 was preceded by a small foreshock that corrupted the first *P*-wave arrival. Nevertheless, excellent moment tensors were obtained for most of the events (

Table 2).

Table 2: Numerical moment tensor results for the 10 earthquakes with M $\geq$ 1.0 that occurred up to 10 Oct.

2.00E-01	-1.41E-01	-1.46E-01	1.40E-01	-8.71E-03	7.41E-02	2014	10	1	12	3	16.94	good
1.58E-01	3.47E-02	6.67E-02	2.48E-01	6.32E-02	8.34E-02	2014	10	1	14	53	5.23	excellent
2.17E-01	-3.67E-02	-6.42E-02	2.35E-01	7.20E-02	3.18E-02	2014	10	1	19	5	16.54	excellent
-1.46E-02	9.64E-02	-3.98E-01	2.60E-02	1.69E-01	-4.69E-03	2014	10	2	6	47	52.94	excellent
-1.17E-01	1.71E-01	-1.99E-01	1.39E-01	-2.43E-02	1.64E-02	2014	10	2	7	7	4.16	excellent
2.41E-01	-7.30E-02	-9.79E-02	1.73E-01	4.30E-02	8.35E-02	2014	10	2	11	1	42.38	excellent
6.07E-03	-2.23E-01	-9.16E-02	1.94E-01	3.37E-02	-6.18E-04	2014	10	3	6	6	22.76	excellent
-5.77E-02	-1.66E-01	-1.43E-01	1.46E-01	7.81E-02	-1.95E-02	2014	10	3	18	54	53.93	fair
-1.03E-01	1.33E-01	-1.19E-01	1.48E-01	5.51E-02	1.07E-01	2014	10	4	17	32	52.76	excellent
8.71E-02	1.26E-01	-4.19E-02	1.81E-01	8.43E-02	8.72E-02	2014	10	4	18	51	12	excellent

6 Brief summary statement

The moment tensors obtained to date mostly fall in the +Dipole to -Dipole range. Such a distribution is commonly seen in sets of earthquakes associated with hydrofracturing. There may be some indication that crack opening was more extreme toward the beginning of the 4-day period studied. Individual source types are most easily appreciated from the source-type plots in the upper right-hand panel of the graphical results shown in Appendix 3.

The T-axes, which are displayed, for example, in the P polarity plots in the graphical summaries in Appendix 3, mostly plunge at ~ 45˚ and trend in the range south through southwest.

Appendix 1: Locations of the 10 largest earthquakes up to 4 October.

2014 Oct 1   14:53:20.145 UTC

Lat: 43.72651   Lon: -121.30910   Depth: 0.824 km
       43:43.590 N   121:18.546 W

STA	CHN	DELTA	j0	i0	j1	i1	PHASE	TIME	RES	SIGMA	WT	IMP	P	AMPLITUDE	FREQ
di0/dN	di0/dE	dj0/dN	dj0/dE												
NM03	EHU	2.92	11	118	11	158	P	1.138	0.005	0.038	0.98	0.00	-1	-6.172e+01	1.726e+01
NM03	EHR	2.92	11	118	11	157	S	1.807	-0.063	0.117	0.98	0.00	1	7.757e+02	1.358e+01
NM06	EHU	0.75	107	160	107	171	P	0.817	0.016	0.020	0.98	0.00	1	7.309e+02	1.242e+01
NM06	EHR	0.75	107	160	107	171	S	1.391	0.069	0.109	0.98	0.00	-1	-2.305e+03	2.169e+01
NM06	EHT	0.75	107	160	107	171	S	1.405	0.083	0.109	0.98	0.00	-1	-1.024e+03	1.205e+01
NM08	EHR	2.90	170	118	170	157	S	1.931	0.089	0.117	0.98	0.00	0	0.000e+00	0.000e+00
NM22	EHU	0.14	175	176	175	178	P	0.753	-0.010	0.019	0.97	0.00	1	1.161e+03	1.517e+01
NM22	EHR	0.14	175	176	175	178	S	1.295	0.035	0.108	0.98	0.00	-1	-4.579e+03	8.849e+00
NM22	EHT	0.14	175	176	175	178	S	1.257	-0.003	0.108	0.98	0.00	-1	-3.184e+03	1.540e+01
NM40	EHU	2.54	111	124	111	159	P	1.151	0.040	0.103	0.98	0.00	1	0.000e+00	0.000e+00
NM40	EHN	2.54	111	124	111	159	S	1.797	-0.036	0.115	0.98	0.00	-1	-2.664e+02	2.138e+01
NM40	EHT	2.54	111	124	111	159	S	1.806	-0.027	0.115	0.98	0.00	-1	-1.971e+02	1.210e+01
NM42	EHU	3.60	42	111	42	156	P	1.333	0.001	0.030	0.98	0.00	-1	-2.990e+02	1.107e+01
NM42	EHR	3.60	42	111	42	156	S	2.295	0.096	0.122	0.97	0.00	1	1.575e+03	1.711e+01
NM42	EHT	3.60	42	111	42	156	S	2.177	-0.022	0.122	0.98	0.00	-1	-6.571e+02	8.230e+00
NN07	EHU	3.06	335	114	335	157	P	0.972	0.009	0.028	0.98	0.00	-1	-1.963e+02	1.424e+01
NN07	EHR	3.06	335	114	335	157	S	1.561	-0.030	0.120	0.98	0.00	-1	-2.727e+02	2.582e+01
NN07	EHT	3.06	335	114	335	157	S	1.612	0.020	0.120	0.98	0.00	1	3.397e+02	1.471e+01
NN09	EHU	2.03	291	129	291	160	P	0.785	0.020	0.024	0.98	0.00	-1	-1.509e+01	2.286e+01
NN09	EHR	2.03	291	129	291	160	S	1.254	-0.010	0.063	0.98	0.00	-1	-1.474e+03	2.406e+01
NN09	EHT	2.03	291	129	291	160	S	1.301	0.037	0.114	0.98	0.00	-1	-9.974e+02	2.743e+01
NN17	EHZ	1.62	247	137	247	163	P	0.727	-0.008	0.022	0.98	0.00	1	1.094e+02	1.985e+01
NN17	EHR	1.62	247	137	247	163	S	1.233	0.018	0.112	0.98	0.00	-1	-1.619e+03	2.047e+01
NN17	EHT	1.62	247	137	247	163	S	1.224	0.010	0.112	0.98	0.00	1	1.358e+03	1.572e+01
NN18	EHZ	1.35	25	144	25	165	P	0.749	-0.001	0.021	0.98	0.00	-1	-2.989e+02	1.647e+01
NN18	EHR	1.35	25	144	25	165	S	1.258	0.018	0.110	0.98	0.00	1	2.406e+03	1.462e+01
NN18	EHT	1.35	25	144	25	165	S	1.285	0.045	0.110	0.98	0.00	-1	-7.653e+01	3.256e+01
NN19	EHU	0.93	169	154	169	169	P	0.689	0.003	0.020	0.98	0.00	1	7.179e+02	1.713e+01
NN19	EHR	0.93	169	154	169	169	S	1.171	0.038	0.109	0.98	0.00	-1	-1.335e+03	1.708e+01
NN19	EHT	0.93	169	154	169	169	S	1.158	0.025	0.109	0.98	0.00	-1	-6.589e+02	3.136e+01
NN21	EHZ	1.72	64	137	64	163	P	0.841	-0.008	0.022	0.98	0.00	-1	-6.455e+01	1.485e+01
NN21	EHR	1.72	64	137	64	163	S	1.329	-0.072	0.111	0.97	0.00	1	4.239e+02	1.542e+01
NN21	EHT	1.72	64	137	64	163	S	1.432	0.030	0.111	0.98	0.00	-1	-3.783e+02	2.844e+01
NN24	EHU	0.62	2	162	2	172	P	0.665	-0.016	0.019	0.97	0.00	-1	-2.176e+02	1.867e+01
NN24	EHR	0.62	2	162	2	172	S	1.087	-0.039	0.108	0.98	0.00	-1	-3.159e+03	1.757e+01
NN24	EHT	0.62	2	162	2	172	S	1.093	-0.033	0.108	0.98	0.00	1	6.795e+02	2.426e+01
NN32	EHU	2.92	210	116	210	157	P	0.912	-0.010	0.028	0.98	0.00	-1	-8.134e+00	1.169e+01
NN32	EHR	2.92	210	116	210	157	S	1.469	-0.054	0.119	0.98	0.00	-1	-5.128e+02	3.119e+01
NN32	EHT	2.92	210	116	210	157	S	1.529	0.006	0.119	0.98	0.00	1	6.086e+02	1.366e+01

2014 Oct 1   19:05:32.707 UTC

Lat: 43.72725   Lon: -121.30803   Depth: 0.900 km
       43:43.635 N   121:18.482 W

STA	CHN	DELTA	j0	i0	j1	i1	PHASE	TIME	RES	SIGMA	WT	IMP	P	AMPLITUDE	FREQ
di0/dN	di0/dE	dj0/dN	dj0/dE												
NM03	EHU	2.83	9	121	9	158	P	1.153	0.031	0.026	0.96	0.00	-1	-4.743e+01	1.728e+01
NM03	EHR	2.83	9	121	9	158	S	1.797	-0.057	0.117	0.98	0.00	1	6.583e+02	1.412e+01
NM03	EHT	2.83	9	121	9	158	S	1.802	-0.052	0.117	0.98	0.00	1	2.721e+02	2.117e+01
NM06	EHN	0.70	115	162	115	172	S	1.486	0.145	0.109	0.95	0.00	0	0.000e+00	0.000e+00
NM06	EHE	0.70	115	162	115	172	S	1.442	0.101	0.109	0.97	0.00	0	0.000e+00	0.000e+00
NM42	EHN	3.48	42	114	42	157	S	2.257	0.086	0.122	0.97	0.00	0	0.000e+00	0.000e+00
NM42	EHE	3.48	42	114	42	157	S	2.275	0.104	0.122	0.97	0.00	0	0.000e+00	0.000e+00
NN07	EHN	3.02	333	116	333	157	S	1.592	0.001	0.120	0.98	0.00	0	0.000e+00	0.000e+00
NN07	EHE	3.02	333	116	333	157	S	1.631	0.040	0.120	0.98	0.00	0	0.000e+00	0.000e+00
NN09	EHU	2.08	288	130	288	160	P	0.795	0.011	0.024	0.98	0.00	-1	-2.800e+00	9.547e+00
NN09	EHR	2.08	288	130	288	160	S	1.266	-0.030	0.115	0.98	0.00	-1	-1.013e+03	1.899e+01
NN09	EHT	2.08	288	130	288	160	S	1.312	0.016	0.115	0.98	0.00	-1	-9.672e+02	2.598e+01
NN17	EHU	1.73	245	136	245	163	P	0.741	-0.022	0.023	0.98	0.00	1	7.857e+01	2.055e+01

```
NN17 EHR   1.73 245 136 245 163 S      1.246  -0.015  0.112 0.98 0.00 -1 -1.158e+03  2.363e+01
NN17 EHT   1.73 245 136 245 163 S      1.234  -0.028  0.112 0.98 0.00 -1 -2.241e-05  1.600e+01
NN18 EHU   1.24  23 147  23 167 P      0.762   0.011  0.021 0.98 0.00 -1 -2.046e+02  1.561e+01
NN18 EHR   1.24  23 147  23 166 S      1.201  -0.039  0.110 0.98 0.00 -1 -2.856e+02  2.470e+01
NN18 EHT   1.24  23 147  23 166 S      1.313   0.073  0.110 0.97 0.00  1  9.706e+02  1.812e+01
NN19 EHU   1.00 175 153 175 169 P      0.701  -0.005  0.020 0.98 0.00  1  4.539e+02  1.708e+01
NN19 EHR   1.00 175 153 175 169 S      1.133  -0.035  0.110 0.98 0.00  1  2.710e+02  2.470e+01
NN19 EHT   1.00 175 153 175 169 S      1.170   0.002  0.110 0.98 0.00 -1 -4.846e+02  3.397e+01
NN21 EHE   1.61  66 140  66 164 S      1.297  -0.098  0.111 0.97 0.00  0  0.000e+00  0.000e+00
NN24 EHU   0.54 353 165 353 174 P      0.678  -0.015  0.020 0.98 0.00 -1 -1.542e+02  1.837e+01
NN24 EHR   0.54 353 165 353 174 S      1.103  -0.041  0.109 0.98 0.00 -1 -1.866e+03  1.910e+01
NN24 EHT   0.54 353 165 353 174 S      1.066  -0.078  0.109 0.98 0.00  1  4.470e+02  1.815e+01
NN32 EHU   3.04 211 116 211 157 P     -2.171  -3.121    inf 0.98 0.00  1  7.262e+01  1.822e+01
NN32 EHR   3.04 211 116 211 157 S     -1.974  -3.545    inf 0.98 0.00 -1 -7.399e+02  2.900e+01
NN32 EHT   3.04 211 116 211 157 S     -1.932  -3.503    inf 0.98 0.00  1  4.947e+02  2.459e+01

2014 Oct 4   17:33:07.355 UTC
Lat:   43.72660      Lon:  -121.30958      Depth:  0.792 km
       43:43.596 N          121:18.575 W

STA  CHN  DELTA  j0  i0  j1  i1 PHASE  TIME     RES   SIGMA  WT  IMP   P  AMPLITUDE    FREQ
di0/dN    di0/dE    dj0/dN    dj0/dE

NM03 EHU   2.92  12 117  12 157 P      1.130   0.001  0.026 0.98 0.00 -1 -1.171e+02  1.573e+01
NM03 EHR   2.92  12 117  12 157 S      1.800  -0.064  0.117 0.98 0.00  1  2.296e+03  1.365e+01
NM03 EHE   2.92  12 117  12 157 S      1.873   0.009  0.117 0.98 0.00  0  0.000e+00  0.000e+00
NM08 EHN   2.91 169 117 169 157 S      1.880   0.039  0.117 0.98 0.00  1  1.639e+02  1.668e+01
NM22 EHU   0.16 161 175 161 178 P      0.744  -0.013  0.019 0.97 0.00  1  3.020e+03  1.368e+01
NM22 EHR   0.16 161 175 161 178 S      1.316   0.067  0.108 0.98 0.00 -1 -1.434e+04  1.288e+01
NM22 EHT   0.16 161 175 161 178 S      1.264   0.015  0.108 0.98 0.00  1  4.666e+03  2.083e+01
NM42 EHU   3.62  43 111  43 156 P      1.334   0.001  0.030 0.98 0.00 -1 -8.149e+02  1.070e+01
NM42 EHR   3.62  43 111  43 156 S      2.263   0.062  0.122 0.98 0.00  1  4.240e+03  1.209e+01
NM42 EHT   3.62  43 111  43 156 S      2.182  -0.019  0.122 0.98 0.00 -1 -1.455e+03  9.471e+00
NN07 EHU   3.03 336 114 336 157 P      0.961   0.006  0.028 0.98 0.00 -1 -5.471e+02  1.370e+01
NN09 EHU   1.99 292 129 292 160 P      0.764   0.010  0.024 0.98 0.00 -1 -1.125e+02  2.025e+01
NN09 EHR   1.99 292 129 292 160 S      1.241  -0.006  0.114 0.98 0.00 -1 -4.595e+03  1.013e+01
NN17 EHU   1.58 246 137 246 163 P      0.717  -0.008  0.022 0.98 0.00  1  4.758e+02  1.840e+01
NN17 EHR   1.58 246 137 246 163 S      1.214   0.015  0.111 0.98 0.00 -1 -3.737e+03  1.630e+01
NN17 EHT   1.58 246 137 246 163 S      1.209   0.011  0.111 0.98 0.00  1  3.781e+03  1.708e+01
NN18 EHU   1.36  26 143  26 165 P      0.749   0.003  0.021 0.98 0.00 -1 -6.821e+02  1.582e+01
NN18 EHR   1.36  26 143  26 165 S      1.265   0.032  0.110 0.98 0.00  1  5.113e+03  1.515e+01
NN18 EHT   1.36  26 143  26 165 S      1.301   0.068  0.110 0.98 0.00  1  3.982e+03  1.973e+01
NN19 EHU   0.94 167 153 167 169 P      0.689   0.008  0.020 0.98 0.00  1  1.717e+03  1.749e+01
NN19 EHR   0.94 167 153 167 169 S      1.193   0.067  0.109 0.98 0.00 -1 -1.457e+03  1.964e+01
NN19 EHT   0.94 167 153 167 169 S      1.152   0.026  0.109 0.98 0.00 -1 -1.126e+03  2.097e+01
NN21 EHU   1.75  65 135  65 162 P      0.845  -0.003  0.022 0.98 0.00 -1 -1.804e+02  1.423e+01
NN21 EHT   1.75  65 135  65 162 S      1.408   0.007  0.111 0.98 0.00 -1 -1.286e+03  2.413e+01
NN24 EHU   0.61   5 162   5 172 P      0.668  -0.007  0.019 0.98 0.00 -1 -4.371e+02  2.169e+01
NN24 EHR   0.61   5 162   5 172 S      1.098  -0.017  0.108 0.98 0.00 -1 -8.308e+03  2.140e+01
NN24 EHT   0.61   5 162   5 172 S      1.092  -0.022  0.108 0.98 0.00  1  1.793e+03  2.207e+01
NN32 EHU   2.91 210 115 210 157 P     -5.115  -6.032    inf 0.98 0.00 -1 -8.797e+01  1.532e+01

2014 Oct 4   18:51:27.825 UTC
Lat:   43.72602      Lon:  -121.30946      Depth:  0.836 km
       43:43.561 N          121:18.568 W

STA  CHN  DELTA  j0  i0  j1  i1 PHASE  TIME     RES   SIGMA  WT  IMP   P  AMPLITUDE    FREQ
di0/dN    di0/dE    dj0/dN    dj0/dE

NM03 EHU   2.98  11 118  11 157 P      1.148   0.003  0.026 0.98 0.00 -1 -6.094e+02  1.656e+01
NM03 EHR   2.98  11 118  11 157 S      1.795  -0.095  0.117 0.97 0.00  1  1.075e+04  1.330e+01
NM22 EHU   0.10 155 177 155 179 P      0.759  -0.006  0.019 0.98 0.00  1  1.385e+04  1.326e+01
NM22 EHR   0.10 155 177 155 179 S      1.244  -0.020  0.108 0.98 0.00  1  2.015e+04  1.140e+01
NM22 EHT   0.10 155 177 155 179 S      1.279   0.016  0.108 0.98 0.00 -1 -3.239e+04  2.507e+01
NM41 EHU   2.26 139 128 139 160 P      1.016  -0.005  0.037 0.98 0.00  1  1.202e+03  1.273e+01
NM41 EHR   2.26 139 128 139 160 S      1.604  -0.081  0.114 0.98 0.00 -1 -1.021e+04  1.486e+01
NM41 EHT   2.26 139 128 139 160 S      1.659  -0.026  0.062 0.98 0.00 -1 -1.358e+04  1.757e+01
NM42 EHZ   3.66  42 111  42 156 P     -0.649  -1.994    inf 0.98 0.00 -1  0.000e+00  0.000e+00
NM42 EHE   3.66  42 111  42 156 S      2.346   0.126  0.123 0.97 0.00  0  0.000e+00  0.000e+00
NN07 EHZ   3.10 336 114 336 157 P      0.971   0.001  0.028 0.98 0.00  0  0.000e+00  0.000e+00
NN07 EHN   3.10 336 114 336 157 S      1.590  -0.014  0.120 0.98 0.00  0  0.000e+00  0.000e+00
```

NN09	EHU	2.02	293	129	293	160	P	0.773	0.008	0.024	0.98	0.00	-1	-3.764e+02	1.765e+01
NN09	EHR	2.02	293	129	293	160	S	1.255	-0.010	0.114	0.98	0.00	-1	-1.997e+04	1.255e+01
NN09	EHT	2.02	293	129	293	160	S	1.272	0.007	0.114	0.98	0.00	1	5.707e+03	2.665e+01
NN17	EHU	1.57	248	139	248	163	P	0.727	-0.004	0.022	0.98	0.00	1	4.084e+03	1.514e+01
NN17	EHR	1.57	248	139	248	163	S	1.224	0.018	0.112	0.98	0.00	-1	-1.603e+04	1.540e+01
NN17	EHT	1.57	248	139	248	163	S	1.219	0.013	0.058	0.98	0.00	1	1.663e+04	1.621e+01
NN18	EHU	1.41	25	143	25	165	P	0.760	-0.001	0.021	0.98	0.00	-1	-3.027e+03	1.542e+01
NN18	EHR	1.41	25	143	25	165	S	1.200	-0.057	0.110	0.98	0.00	-1	-3.240e+03	1.996e+01
NN18	EHT	1.41	25	143	25	165	S	1.300	0.044	0.110	0.98	0.00	-1	-2.704e+03	2.998e+01
NN19	EHU	0.88	167	155	167	170	P	0.700	0.016	0.020	0.97	0.00	1	7.953e+03	1.591e+01
NN19	EHR	0.88	167	155	167	170	S	1.179	0.049	0.109	0.98	0.00	-1	-9.036e+03	4.231e+01
NN19	EHT	0.88	167	155	167	170	S	1.163	0.033	0.109	0.98	0.00	-1	-5.832e+03	2.413e+01
NN21	EHU	1.77	63	136	63	162	P	0.863	0.005	0.022	0.98	0.00	-1	-7.856e+02	1.451e+01
NN21	EHR	1.77	63	136	63	162	S	1.396	-0.021	0.111	0.98	0.00	-1	-5.525e+03	9.318e+00
NN21	EHT	1.77	63	136	63	162	S	1.455	0.039	0.111	0.98	0.00	-1	-6.254e+03	2.733e+01
NN24	EHU	0.67	4	161	4	172	P	0.679	-0.008	0.019	0.98	0.00	-1	-2.073e+03	2.068e+01
NN24	EHR	0.67	4	161	4	172	S	1.115	-0.021	0.109	0.98	0.00	-1	-3.766e+04	1.996e+01
NN24	EHT	0.67	4	161	4	172	S	1.107	-0.029	0.109	0.98	0.00	1	8.479e+03	3.556e+01
NN32	EHU	2.86	211	117	211	157	P	0.895	-0.016	0.027	0.98	0.00	-1	-3.243e+02	1.513e+01
NN32	EHR	2.86	211	117	211	157	S	1.559	0.053	0.119	0.98	0.00	1	2.281e+04	1.093e+01
NN32	EHT	2.86	211	117	211	157	S	1.567	0.061	0.119	0.98	0.00	1	7.876e+03	1.652e+01

2014 Oct 1 12:03:31.644 UTC

Lat: 43.72540 Lon: -121.30867 Depth: 1.207 km
43:43.524 N 121:18.520 W

di0/dN di0/dE dj0/dN dj0/dE

STA	CHN	DELTA	j0	i0	j1	i1	PHASE	TIME	RES	SIGMA	WT	IMP	P	AMPLITUDE	FREQ
NM03	EHU	3.04	10	124	10	159	P	1.196	0.001	0.028	0.98	0.00	-1	-3.100e+01	2.007e+01
NM03	EHR	3.04	10	124	10	159	S	1.989	0.014	0.120	0.98	0.00	1	7.964e+02	2.881e+01
NM06	EHZ	0.69	98	164	98	173	P	0.929	0.054	0.021	0.52	0.00	1	0.000e+00	0.000e+00
NM22	EHN	0.03	230	179	230	180	S	1.368	-0.026	0.110	0.98	0.00	-1	0.000e+00	0.000e+00
NM40	EHN	2.47	109	132	109	161	S	1.898	0.002	0.117	0.98	0.00	-1	0.000e+00	0.000e+00
NM42	EHU	3.67	40	118	40	158	P	1.380	-0.000	0.032	0.98	0.00	1	-2.451e+02	1.313e+01
NM42	EHR	3.67	40	118	40	158	S	2.381	0.102	0.125	0.97	0.00	-1	-1.137e+03	1.440e+01
NM42	EHT	3.67	40	118	40	158	S	2.368	0.090	0.125	0.97	0.00	1	1.098e+03	1.132e+01
NN07	EHU	3.19	335	121	335	158	P	1.028	0.004	0.030	0.98	0.00	-1	-6.976e+01	1.670e+01
NN07	EHR	3.19	335	121	335	158	S	1.728	0.034	0.123	0.98	0.00	-1	-4.112e+02	1.480e+01
NN09	EHU	2.11	294	135	294	162	P	0.848	0.016	0.026	0.97	0.00	-1	-4.984e+01	1.934e+01
NN09	EHR	2.11	294	135	294	162	S	1.364	-0.011	0.117	0.98	0.00	-1	-4.659e+02	2.544e+01
NN09	EHT	2.11	294	135	294	162	S	1.400	0.025	0.117	0.98	0.00	-1	-8.397e+02	1.551e+01
NN17	EHU	1.60	251	144	251	165	P	0.800	0.003	0.024	0.98	0.00	1	1.402e+01	2.620e+01
NN17	EHR	1.60	251	144	251	165	S	1.293	-0.024	0.114	0.98	0.00	1	1.879e+02	2.925e+01
NN17	EHT	1.60	251	144	251	165	S	1.293	-0.023	0.114	0.98	0.00	1	4.852e+02	1.185e+01
NN18	EHU	1.45	21	147	21	166	P	0.820	-0.010	0.023	0.98	0.00	-1	-1.371e+02	1.876e+01
NN18	EHR	1.45	21	147	21	166	S	1.368	-0.003	0.112	0.98	0.00	1	4.544e+02	1.869e+01
NN19	EHU	0.80	170	161	170	172	P	0.764	0.013	0.021	0.97	0.00	1	1.866e+02	1.808e+01
NN19	EHR	0.80	170	161	170	172	S	1.232	-0.008	0.111	0.98	0.00	1	7.447e+02	1.798e+01
NN21	EHZ	1.74	60	142	60	165	P	0.892	-0.022	0.023	0.97	0.00	-1	-5.902e+01	1.513e+01
NN24	EHU	0.74	359	162	359	172	P	0.748	-0.019	0.021	0.98	0.00	-1	-1.402e+02	1.831e+01
NN24	EHR	0.74	359	162	359	172	S	1.221	-0.047	0.111	0.98	0.00	-1	-7.148e+02	1.890e+01
NN24	EHT	0.74	359	162	359	172	S	1.216	-0.052	0.111	0.98	0.00	1	4.442e+02	2.181e+01
NN32	EHU	2.84	212	125	212	159	P	0.925	-0.022	0.029	0.98	0.00	1	5.945e+01	1.130e+01
NN32	EHR	2.84	212	125	212	159	S	1.541	-0.025	0.121	0.98	0.00	-1	-1.743e+02	1.837e+01
NN32	EHT	2.84	212	125	212	159	S	1.556	-0.009	0.121	0.98	0.00	1	1.398e+02	1.722e+01

2014 Oct 2 06:48:07.652 UTC

Lat: 43.72574 Lon: -121.30813 Depth: 1.175 km
43:43.544 N 121:18.488 W

di0/dN di0/dE dj0/dN dj0/dE

STA	CHN	DELTA	j0	i0	j1	i1	PHASE	TIME	RES	SIGMA	WT	IMP	P	AMPLITUDE	FREQ
NM03	EHU	2.99	9	124	9	159	P	1.188	0.004	0.028	0.98	0.00	-1	-3.579e+01	1.906e+01
NM03	EHR	2.99	9	124	9	159	S	1.984	0.028	0.119	0.98	0.00	1	7.658e+02	1.035e+01
NM06	EHZ	0.66	101	165	101	173	P	0.888	0.022	0.021	0.97	0.00	-1	-5.268e+01	1.729e+01
NM06	EHN	0.66	101	165	101	173	S	1.499	0.070	0.110	0.98	0.00	-1	-7.360e+02	1.247e+01
NM22	EHZ	0.09	229	178	229	179	P	0.835	-0.003	0.020	0.98	0.00	1	1.257e+02	1.419e+01
NM22	EHN	0.09	229	178	229	179	S	1.368	-0.014	0.110	0.98	0.00	-1	-5.255e+02	1.350e+01
NM41	EHE	2.16	141	136	141	162	S	1.730	-0.010	0.115	0.98	0.00	-1	0.000e+00	0.000e+00

NM42	EHU	3.62	40	118	40	158	P	1.364	-0.002	0.031	0.98	0.00	-1	-3.035e+02	1.111e+01
NM42	EHR	3.62	40	118	40	157	S	2.362	0.107	0.125	0.97	0.00	-1	-1.597e+03	1.544e+01
NM42	EHT	3.62	40	118	40	157	S	2.360	0.105	0.125	0.97	0.00	1	1.464e+03	1.247e+01
NN07	EHU	3.17	334	120	334	158	P	1.022	0.004	0.030	0.98	0.00	-1	-9.658e+01	1.680e+01
NN07	EHR	3.17	334	120	334	158	S	1.722	0.039	0.123	0.98	0.00	-1	-4.929e+02	1.484e+01
NN09	EHU	2.13	293	134	293	162	P	0.848	0.017	0.026	0.98	0.00	-1	-5.880e+01	2.072e+01
NN09	EHR	2.13	293	134	293	162	S	1.356	-0.017	0.116	0.98	0.00	-1	-6.693e+02	2.666e+01
NN09	EHT	2.13	293	134	293	162	S	1.399	0.025	0.116	0.98	0.00	-1	-1.119e+03	1.975e+01
NN17	EHU	1.66	251	142	250	165	P	0.795	-0.003	0.024	0.98	0.00	1	1.753e+01	2.555e+01
NN17	EHR	1.66	251	142	250	165	S	1.329	0.010	0.114	0.98	0.00	-1	-6.313e+02	2.666e+01
NN17	EHT	1.66	251	142	250	165	S	1.301	-0.017	0.114	0.98	0.00	1	6.554e+02	1.760e+01
NN18	EHU	1.40	20	148	20	167	P	0.808	-0.010	0.022	0.98	0.00	-1	-1.796e+02	1.579e+01
NN18	EHR	1.40	20	148	20	167	S	1.364	0.013	0.112	0.98	0.00	1	6.117e+02	1.573e+01
NN19	EHU	0.83	173	160	173	171	P	0.757	0.010	0.021	0.98	0.00	1	2.424e+02	1.638e+01
NN19	EHR	0.83	173	160	173	171	S	1.223	-0.010	0.111	0.98	0.00	1	7.866e+02	2.710e+01
NN21	EHZ	1.69	61	143	61	165	P	0.887	-0.015	0.023	0.98	0.00	-1	-5.488e+01	1.539e+01
NN24	EHU	0.71	355	163	355	173	P	0.744	-0.014	0.021	0.97	0.00	-1	-1.750e+02	1.799e+01
NN24	EHR	0.71	355	163	355	173	S	1.201	-0.052	0.110	0.98	0.00	-1	-9.444e+02	2.226e+01
NN24	EHT	0.71	355	163	355	173	S	1.212	-0.041	0.110	0.98	0.00	1	5.084e+02	2.011e+01
NN32	EHU	2.89	213	123	213	159	P	0.931	-0.021	0.029	0.97	0.00	1	7.103e+01	1.293e+01
NN32	EHR	2.89	213	123	213	159	S	1.537	-0.038	0.121	0.98	0.00	-1	-2.267e+02	2.150e+01
NN32	EHT	2.89	213	123	213	159	S	1.557	-0.018	0.121	0.98	0.00	1	2.025e+02	1.354e+01

2014 Oct 2   07:07:19.637 UTC

Lat: 43.72629   Lon: -121.30910   Depth: 0.885 km
       43:43.578 N   121:18.546 W

STA	CHN	DELTA	j0	i0	j1	i1	PHASE	TIME	RES	SIGMA	WT	IMP	P	AMPLITUDE	FREQ
di0/dN		di0/dE		dj0/dN		dj0/dE									
NM03	EHU	2.95	11	119	11	158	P	1.154	0.011	0.040	0.98	0.00	-1	-5.387e+01	1.751e+01
NM03	EHR	2.95	11	119	11	158	S	1.936	0.048	0.117	0.98	0.00	1	1.427e+03	9.593e+00
NM06	EHU	0.75	105	160	105	172	P	0.843	0.031	0.029	0.97	0.00	1	6.534e+02	1.550e+01
NM06	EHR	0.75	105	160	105	172	S	1.439	0.097	0.109	0.97	0.00	-1	-2.334e+03	2.112e+01
NM06	EHT	0.75	105	160	105	172	S	1.483	0.142	0.052	0.55	0.00	1	6.989e+03	1.221e+01
NM22	EHU	0.12	174	177	174	179	P	0.763	-0.013	0.026	0.98	0.00	1	1.020e+03	1.532e+01
NM22	EHT	0.12	174	177	174	179	S	1.267	-0.015	0.108	0.98	0.00	-1	-2.707e+03	1.901e+01
NM41	EHT	2.26	140	129	140	160	S	1.645	-0.052	0.114	0.98	0.00	-1	-1.348e+03	1.377e+01
NM42	EHU	3.62	42	113	42	156	P	1.351	0.011	0.046	0.98	0.00	-1	-3.058e+02	1.144e+01
NM42	EHR	3.62	42	113	42	156	S	2.290	0.077	0.123	0.98	0.00	1	1.402e+03	1.811e+01
NM42	EHT	3.62	42	113	42	156	S	2.193	-0.020	0.123	0.98	0.00	-1	-6.947e+02	1.118e+01
NN07	EHU	3.08	335	116	335	157	P	0.983	0.011	0.029	0.98	0.00	-1	-1.919e+02	1.340e+01
NN07	EHR	3.08	335	116	335	157	S	1.571	-0.036	0.120	0.98	0.00	-1	-2.787e+02	2.112e+01
NN09	EHU	2.04	292	130	292	161	P	0.787	0.013	0.025	0.98	0.00	-1	-2.743e+01	1.983e+01
NN09	EHR	2.04	292	130	292	161	S	1.272	-0.008	0.114	0.98	0.00	-1	-1.448e+03	2.377e+01
NN09	EHT	2.04	292	130	292	161	S	1.311	0.031	0.114	0.98	0.00	-1	-1.108e+03	1.483e+01
NN17	EHU	1.61	247	139	247	163	P	0.743	-0.000	0.023	0.98	0.00	1	1.734e+02	2.042e+01
NN17	EHR	1.61	247	139	247	163	S	1.234	0.006	0.112	0.98	0.00	-1	-1.843e+03	2.238e+01
NN17	EHT	1.61	247	139	247	163	S	1.235	0.006	0.112	0.98	0.00	1	1.542e+03	1.407e+01
NN18	EHU	1.38	24	144	24	165	P	0.759	-0.005	0.024	0.98	0.00	-1	-3.199e+02	1.565e+01
NN18	EHR	1.38	24	144	24	165	S	1.200	-0.062	0.110	0.98	0.00	-1	-5.999e+02	2.080e+01
NN18	EHT	1.38	24	144	24	165	S	1.311	0.049	0.110	0.98	0.00	1	1.579e+03	1.380e+01
NN19	EHU	0.90	169	155	169	170	P	0.695	-0.000	0.021	0.98	0.00	1	7.141e+02	1.628e+01
NN19	EHR	0.90	169	155	169	170	S	1.148	-0.001	0.109	0.98	0.00	1	4.578e+02	2.516e+01
NN19	EHT	0.90	169	155	169	170	S	1.167	0.018	0.109	0.98	0.00	-1	-7.297e+02	2.240e+01
NN21	EHU	1.73	64	137	64	163	P	0.851	-0.008	0.025	0.98	0.00	-1	-9.752e+01	1.372e+01
NN21	EHR	1.73	64	138	64	163	S	1.296	-0.124	0.111	0.96	0.00	1	5.541e+02	1.356e+01
NN24	EHU	0.64	2	162	2	172	P	0.675	-0.020	0.021	0.97	0.00	-1	-2.630e+02	1.823e+01
NN24	EHR	0.64	2	162	2	172	S	1.095	-0.055	0.109	0.98	0.00	-1	-2.942e+03	1.606e+01
NN24	EHT	0.64	2	162	2	172	S	1.063	-0.087	0.109	0.97	0.00	1	6.421e+02	0.000e+00
NN32	EHU	2.90	211	117	211	157	P	0.911	-0.012	0.035	0.98	0.00	-1	-1.222e+01	2.118e+01
NN32	EHT	2.90	211	117	211	157	S	1.539	0.012	0.120	0.98	0.00	1	5.951e+02	1.119e+01

2014 Oct 2   11:01:58.257 UTC

Lat: 43.72671   Lon: -121.31007   Depth: 0.794 km
       43:43.603 N   121:18.604 W

STA	CHN	DELTA	j0	i0	j1	i1	PHASE	TIME	RES	SIGMA	WT	IMP	P	AMPLITUDE	FREQ
di0/dN		di0/dE		dj0/dN		dj0/dE									
NM03	EHU	2.92	13	117	13	157	P	1.151	0.022	0.026	0.97	0.00	-1	-4.089e+01	3.112e+01

NM06	EHU	0.84	107	157	107	170	P	0.822	0.020	0.020	0.97	0.00	1	7.520e+02	1.473e+01
NM06	EHR	0.84	107	157	107	170	S	1.396	0.073	0.109	0.98	0.00	-1	-1.609e+03	1.206e+01
NM06	EHT	0.84	107	157	107	170	S	1.466	0.143	0.109	0.96	0.00	1	3.586e+03	1.242e+01
NM08	EHN	2.93	169	117	169	157	S	1.957	0.109	0.117	0.97	0.00	-1	0.000e+00	0.000e+00
NM22	EHU	0.19	151	175	151	178	P	0.738	-0.020	0.019	0.97	0.00	1	9.007e+02	1.440e+01
NM42	EHZ	3.64	43	110	43	156	P	-0.667	-2.004	inf	0.98	0.00	0	0.000e+00	0.000e+00
NM42	EHR	3.64	43	110	43	156	S	2.241	0.034	0.123	0.98	0.00	1	1.513e+03	1.269e+01
NM42	EHT	3.64	43	110	43	156	S	2.243	0.036	0.123	0.98	0.00	1	1.662e+03	5.736e+00
NN07	EHU	3.01	336	114	336	157	P	0.955	0.005	0.028	0.98	0.00	-1	-1.242e+02	1.610e+01
NN07	EHT	3.01	336	114	336	157	S	1.508	-0.062	0.119	0.98	0.00	1	4.503e+02	6.950e+00
NN09	EHU	1.95	292	130	292	161	P	0.761	0.013	0.024	0.98	0.00	1	6.596e+01	1.857e+01
NN09	EHR	1.95	292	130	292	160	S	1.222	-0.014	0.114	0.98	0.00	-1	-1.183e+03	1.095e+01
NN09	EHT	1.95	292	130	292	160	S	1.262	0.027	0.114	0.98	0.00	-1	-5.299e+02	1.617e+01
NN17	EHU	1.55	245	138	245	163	P	0.719	-0.002	0.022	0.98	0.00	1	4.322e+01	2.780e+01
NN17	EHR	1.55	245	138	245	163	S	1.215	0.022	0.111	0.98	0.00	-1	-7.004e+02	2.187e+01
NN17	EHT	1.55	245	138	245	163	S	1.203	0.011	0.111	0.98	0.00	1	1.605e+03	1.927e+01
NN18	EHU	1.37	28	143	28	165	P	0.738	-0.009	0.021	0.98	0.00	-1	-1.542e+02	1.837e+01
NN18	EHR	1.37	28	143	28	165	S	1.241	0.006	0.110	0.98	0.00	1	1.887e+03	1.302e+01
NN19	EHU	0.97	165	153	165	168	P	0.687	0.003	0.020	0.98	0.00	1	4.202e+02	2.131e+01
NN19	EHR	0.97	165	153	165	168	S	1.136	0.006	0.109	0.98	0.00	-1	-3.790e+02	3.788e+01
NN19	EHT	0.97	165	153	165	168	S	1.169	0.039	0.109	0.98	0.00	-1	-1.876e+02	4.374e+01
NN21	EHU	1.78	66	135	66	162	P	0.837	-0.016	0.022	0.97	0.00	-1	-5.218e+01	1.436e+01
NN21	EHR	1.78	66	135	66	162	S	1.392	-0.017	0.111	0.98	0.00	-1	-4.966e+02	1.927e+01
NN21	EHT	1.78	66	135	66	162	S	1.396	-0.013	0.111	0.98	0.00	-1	-2.787e+02	1.624e+01
NN24	EHU	0.60	9	163	9	173	P	0.667	-0.008	0.019	0.98	0.00	-1	-1.230e+01	4.208e+01
NN24	EHR	0.60	9	163	9	173	S	1.086	-0.028	0.108	0.98	0.00	-1	-2.422e+03	2.430e+01
NN24	EHT	0.60	9	163	9	173	S	1.094	-0.020	0.108	0.98	0.00	-1	-7.408e+02	1.747e+01
NN32	EHU	2.90	209	115	209	157	P	0.894	-0.022	0.039	0.98	0.00	-1	-4.346e+01	1.787e+01
NN32	EHT	2.90	209	115	209	157	S	1.503	-0.010	0.119	0.98	0.00	1	3.635e+02	1.482e+01

<u>2014 Oct 3   06:06:37.324 UTC</u>

Lat: 43.72613   Lon: -121.31028   Depth: 0.944 km
43:43.568 N   121:18.617 W

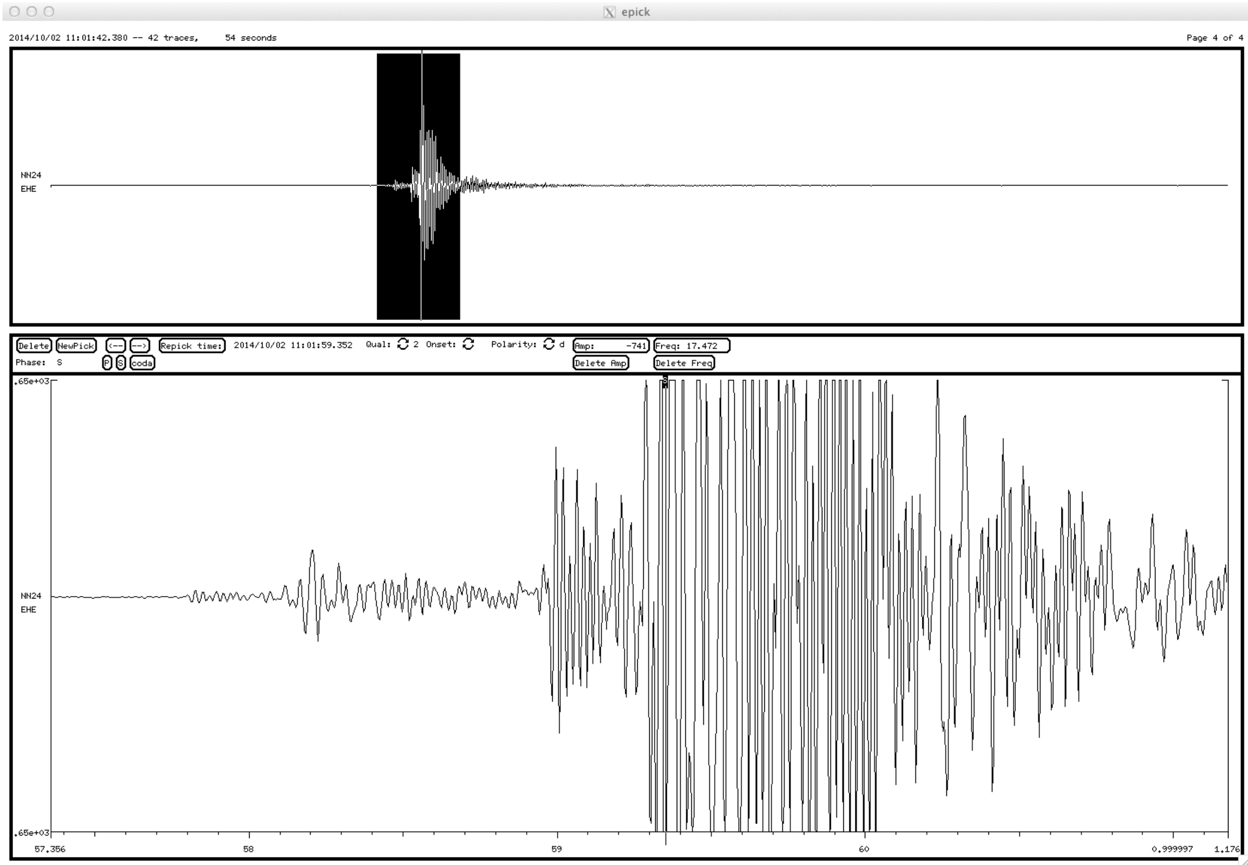
STA	CHN	DELTA	j0	i0	j1	i1	PHASE	TIME	RES	SIGMA	WT	IMP	P	AMPLITUDE	FREQ
di0/dN	di0/dE	dj0/dN	dj0/dE												
NM03	EHU	2.98	13	120	13	158	P	1.164	0.008	0.027	0.98	0.00	-1	-3.058e+01	1.865e+01
NM03	EHT	2.98	13	120	13	158	S	1.891	-0.018	0.118	0.98	0.00	1	7.108e+02	1.195e+01
NM06	EHU	0.84	102	159	102	171	P	0.847	0.017	0.020	0.98	0.00	1	4.173e+02	1.323e+01
NM06	EHR	0.84	102	159	102	171	S	1.506	0.134	0.109	0.96	0.00	1	2.825e+03	9.570e+00
NM06	EHT	0.84	102	159	102	171	S	1.499	0.128	0.109	0.96	0.00	1	3.058e+03	1.123e+01
NM22	EHU	0.15	133	176	133	178	P	0.752	-0.037	0.019	0.91	0.00	1	6.829e+02	1.136e+01
NM22	EHT	0.15	133	176	133	178	S	1.447	0.145	0.109	0.96	0.00	-1	-3.942e+03	1.001e+01
NM42	EHU	3.70	43	113	43	157	P	1.370	0.010	0.031	0.98	0.00	-1	-1.913e+02	1.291e+01
NM42	EHR	3.70	43	113	43	156	S	2.316	0.070	0.124	0.98	0.00	1	9.174e+02	1.266e+01
NM42	EHT	3.70	43	113	43	156	S	2.370	0.124	0.124	0.97	0.00	1	8.188e+02	1.264e+01
NN07	EHZ	3.06	337	117	337	157	P	0.978	0.005	0.028	0.98	0.00	-1	-8.978e+01	1.382e+01
NN09	EHU	1.96	294	133	294	161	P	0.787	0.017	0.024	0.98	0.00	1	1.356e+01	1.658e+01
NN09	EHR	1.96	294	133	294	161	S	1.259	-0.013	0.114	0.98	0.00	-1	-5.092e+02	2.642e+01
NN09	EHT	1.96	294	133	294	161	S	1.287	0.015	0.114	0.98	0.00	-1	-4.948e+02	2.613e+01
NN17	EHU	1.51	247	142	247	164	P	0.743	0.003	0.022	0.98	0.00	1	3.209e+01	2.571e+01
NN17	EHR	1.51	247	142	247	164	S	1.239	0.016	0.112	0.98	0.00	-1	-6.754e+02	1.262e+01
NN17	EHT	1.51	247	142	247	164	S	1.231	0.008	0.112	0.98	0.00	1	8.922e+02	1.556e+01
NN18	EHU	1.43	27	144	27	165	P	0.776	-0.005	0.021	0.98	0.00	-1	-8.830e+01	1.826e+01
NN18	EHR	1.43	27	144	27	165	S	1.259	-0.031	0.111	0.98	0.00	1	1.191e+03	1.170e+01
NN19	EHU	0.91	163	156	163	170	P	0.715	0.008	0.020	0.98	0.00	1	3.789e+02	1.732e+01
NN19	EHR	0.91	163	156	163	170	S	1.274	0.106	0.110	0.97	0.00	1	5.767e+02	1.913e+01
NN19	EHT	0.91	163	156	163	170	S	1.123	-0.045	0.110	0.98	0.00	-1	-2.248e+02	9.095e+00
NN21	EHZ	1.82	65	137	65	163	P	0.872	-0.011	0.022	0.97	0.00	-1	-3.862e+01	1.564e+01
NN21	EHN	1.82	65	137	65	163	S	1.432	-0.025	0.112	0.98	0.00	-1	-2.572e+02	1.913e+01
NN24	EHU	0.67	10	162	10	172	P	0.695	-0.014	0.020	0.97	0.00	-1	-3.319e+01	3.106e+01
NN24	EHR	0.67	10	162	10	172	S	1.119	-0.052	0.109	0.98	0.00	-1	-1.682e+03	2.010e+01
NN32	EHZ	2.84	209	119	209	158	P	0.908	-0.010	0.028	0.98	0.00	-1	-2.207e+01	1.345e+01
NN32	EHE	2.84	209	119	209	158	S	1.601	0.084	0.119	0.98	0.00	-1	0.000e+00	0.000e+00

<u>2014 Oct 3   18:55:09.929 UTC</u>

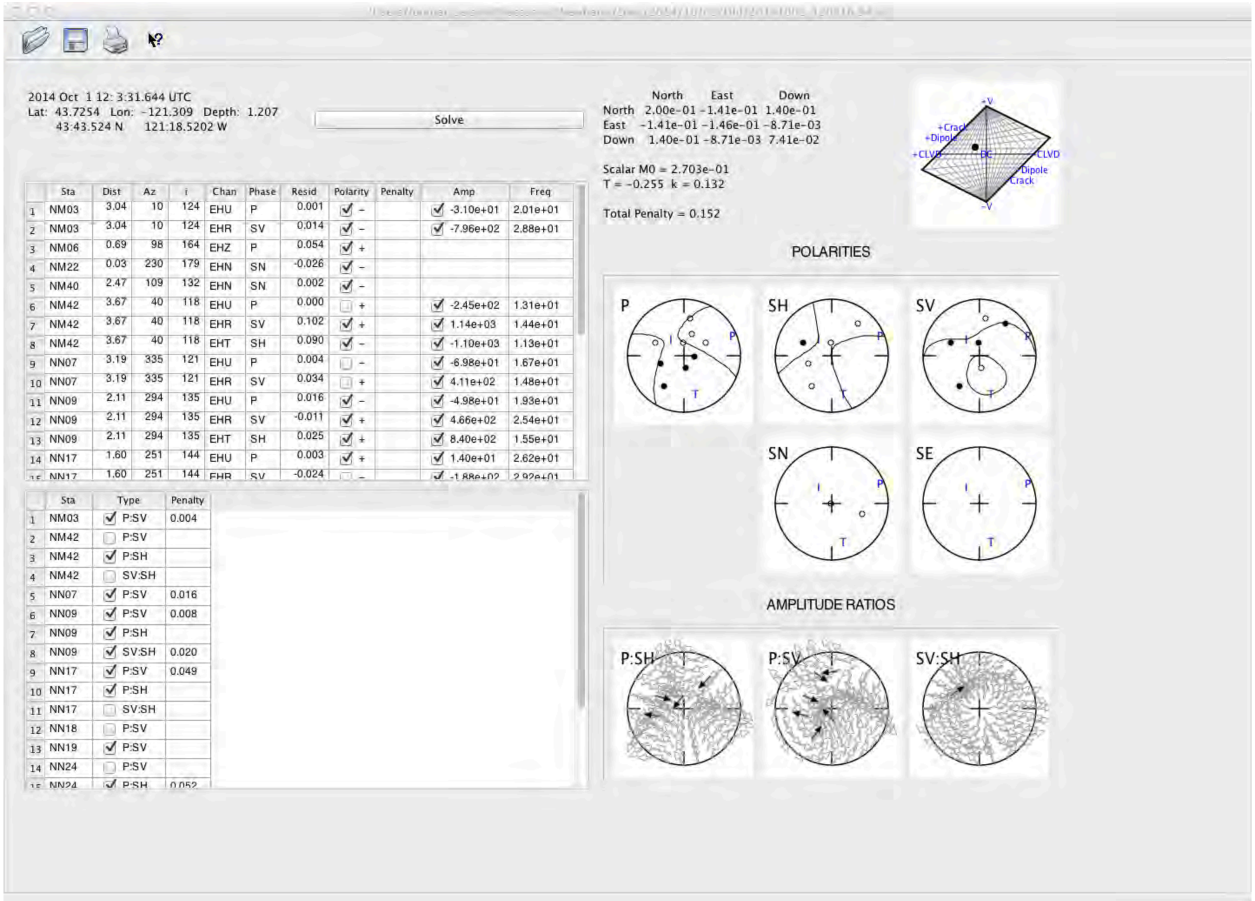
Lat: 43.72644   Lon: -121.31005   Depth: 0.943 km
43:43.586 N   121:18.603 W

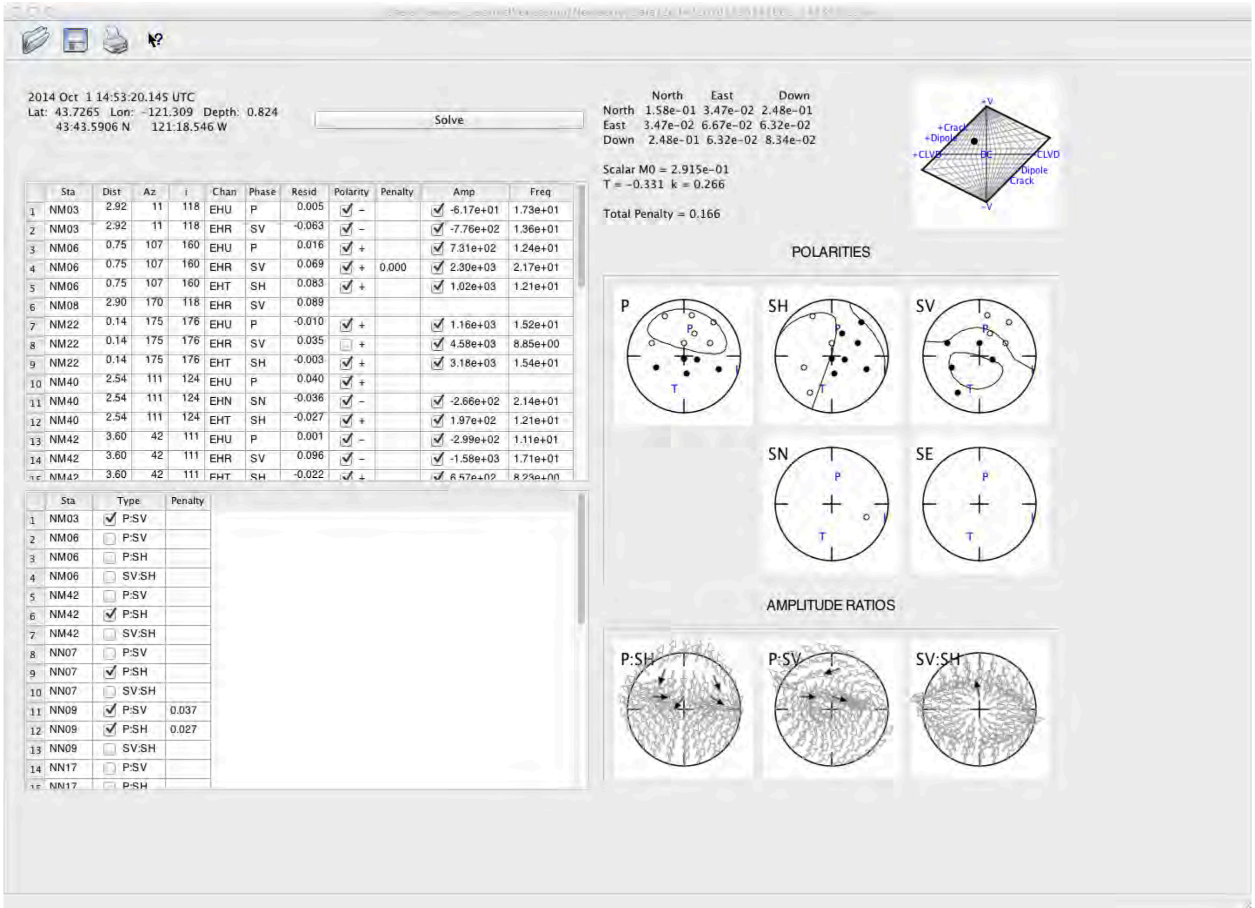
STA	CHN	DELTA	j0	i0	j1	i1	PHASE	TIME	RES	SIGMA	WT	IMP	P	AMPLITUDE	FREQ
di0/dN		di0/dE		dj0/dN		dj0/dE									
NM03	EHZ	2.95	12	120	12	158	P	-0.806	-1.955	inf	0.98	0.00	0	0.000e+00	0.000e+00
NM42	EHZ	3.66	43	114	43	157	P	1.383	0.030	0.104	0.98	0.00	0	0.000e+00	0.000e+00
NN07	EHU	3.04	336	117	336	157	P	-1.007	-1.976	inf	0.98	0.00	-1	-5.663e+01	1.675e+01
NN07	EHT	3.04	336	117	336	157	S	1.621	0.019	0.120	0.98	0.00	1	1.100e+02	2.314e+01
NN09	EHU	1.96	292	132	292	161	P	0.779	0.008	0.024	0.98	0.00	1	1.033e+01	1.266e+01
NN09	EHR	1.96	292	132	292	161	S	1.257	-0.016	0.114	0.98	0.00	-1	-5.076e+02	1.198e+01
NN09	EHT	1.96	292	132	292	161	S	1.295	0.022	0.114	0.98	0.00	-1	-4.008e+02	4.320e+01
NN17	EHU	1.54	246	141	246	164	P	0.744	0.000	0.022	0.98	0.00	1	1.747e+01	2.457e+01
NN17	EHR	1.54	246	141	246	164	S	1.244	0.015	0.112	0.98	0.00	-1	-4.403e+02	1.369e+01
NN17	EHT	1.54	246	141	246	164	S	1.237	0.007	0.112	0.98	0.00	1	4.919e+02	1.767e+01
NN18	EHU	1.39	27	145	27	166	P	0.773	-0.003	0.021	0.98	0.00	-1	-7.628e+01	1.733e+01
NN18	EHR	1.39	27	145	27	165	S	1.210	-0.072	0.111	0.98	0.00	-1	-2.079e+02	1.721e+01
NN19	EHU	0.94	165	155	165	170	P	0.720	0.010	0.020	0.98	0.00	1	2.188e+02	1.907e+01
NN19	EHT	0.94	165	155	165	169	S	1.192	0.020	0.110	0.98	0.00	-1	-9.710e+01	4.981e+01
NN21	EHZ	1.79	65	137	65	163	P	0.881	0.003	0.022	0.98	0.00	0	0.000e+00	0.000e+00
NN24	EHZ	0.63	9	163	9	173	P	0.701	-0.006	0.020	0.98	0.00	0	0.000e+00	0.000e+00
NN24	EHN	0.63	9	163	9	173	S	1.125	-0.043	0.109	0.98	0.00	0	0.000e+00	0.000e+00
NN32	EHZ	2.88	209	119	209	158	P	0.907	-0.018	0.028	0.98	0.00	0	0.000e+00	0.000e+00

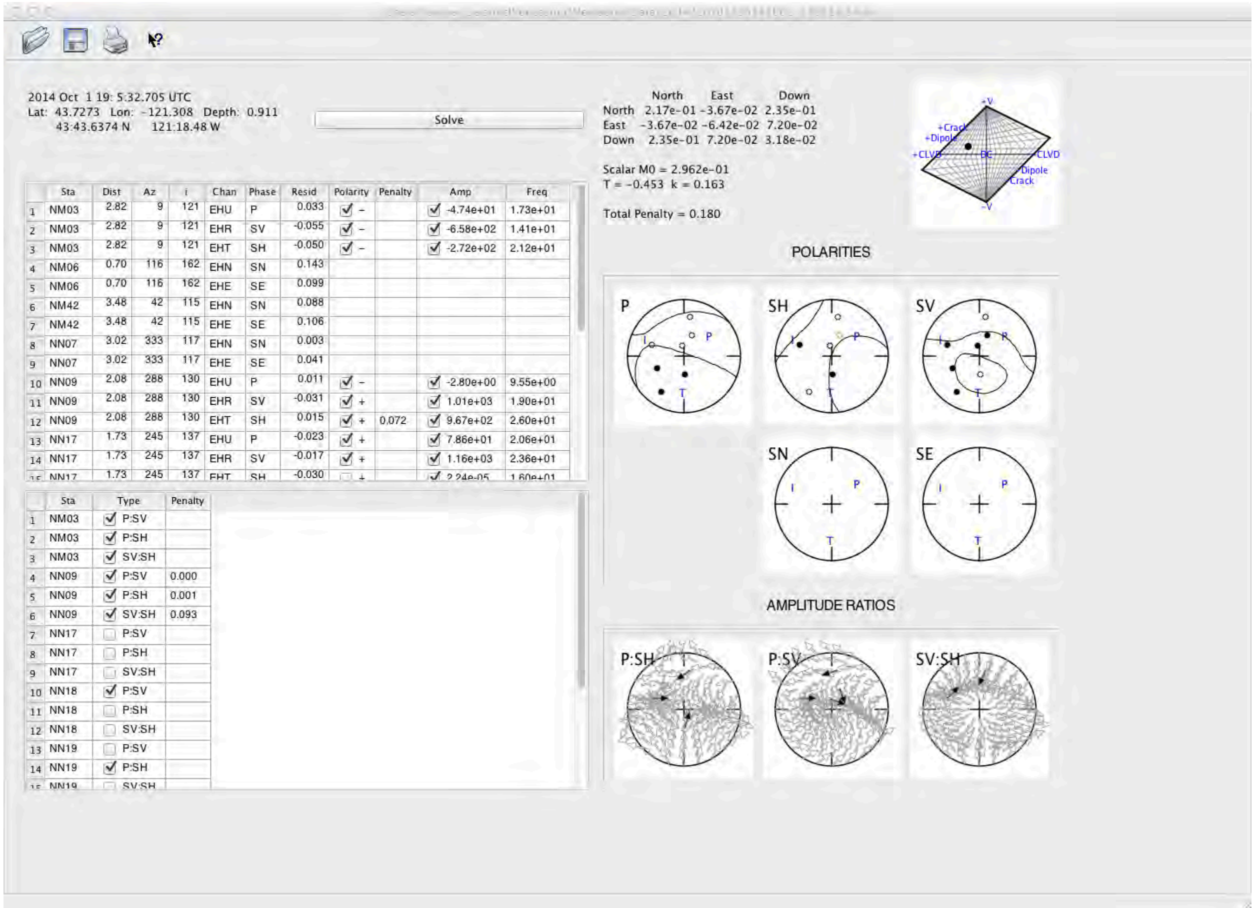
Appendix 2: Event 20141002_110148 – preceded by a small foreshock.

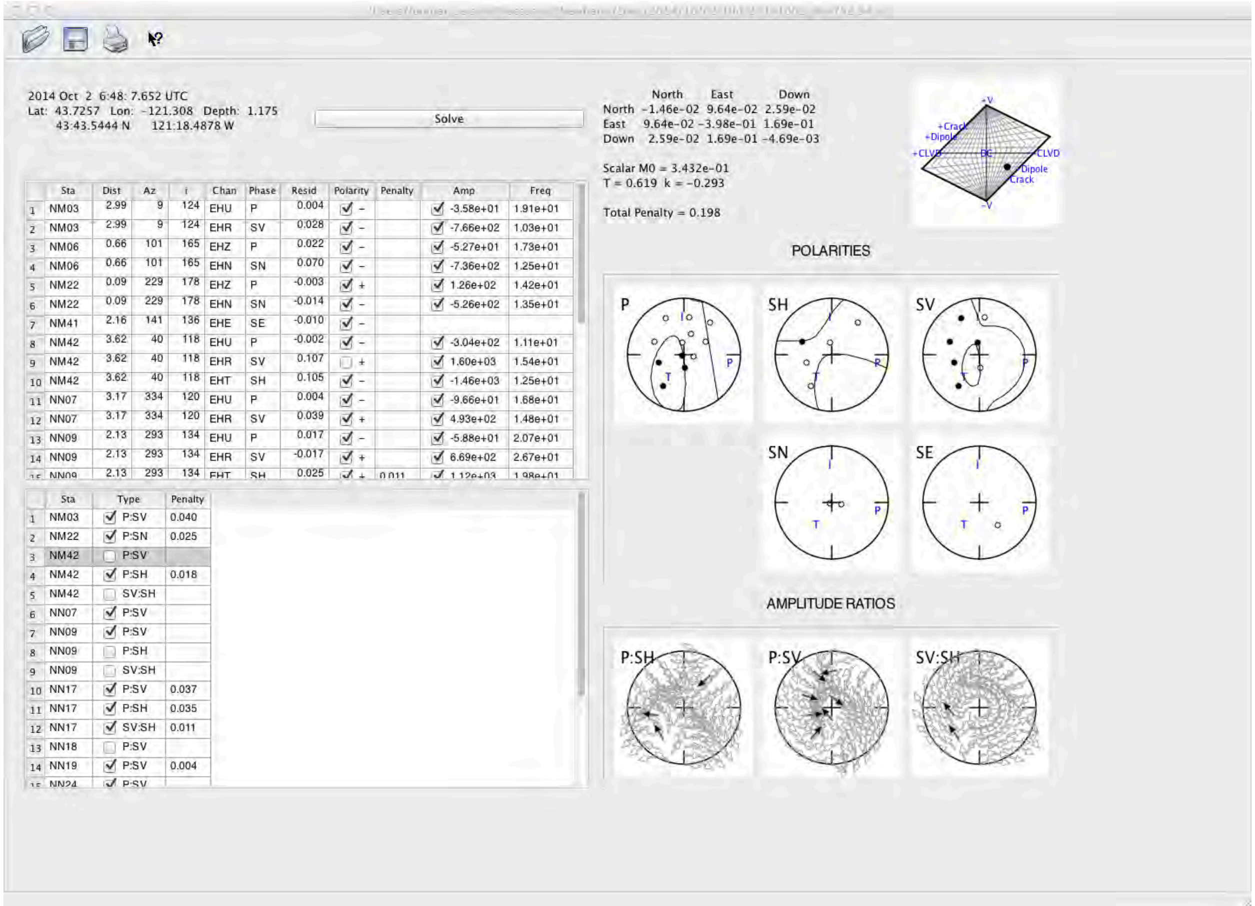


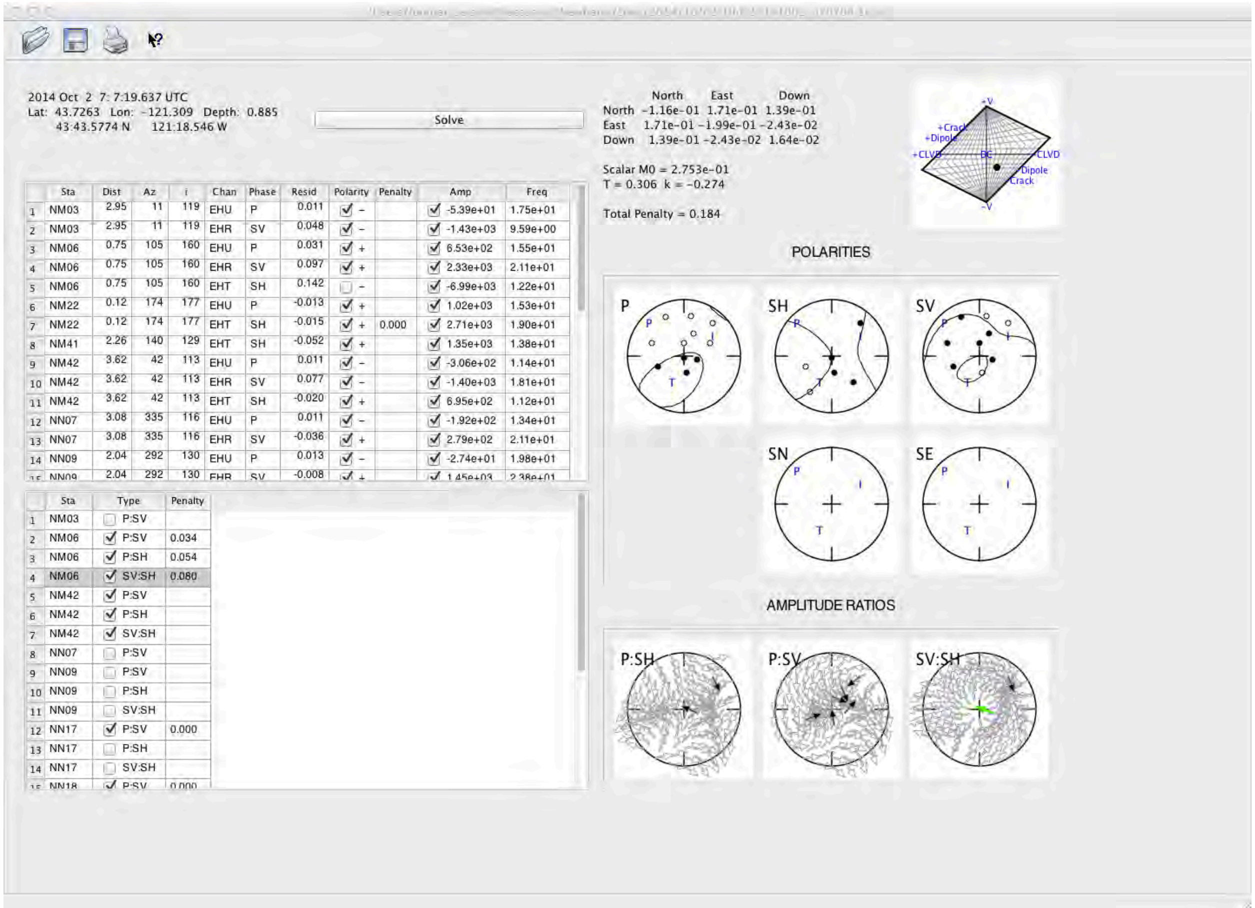
Appendix 3: Moment tensors of the 10 largest earthquakes up to 4 October.

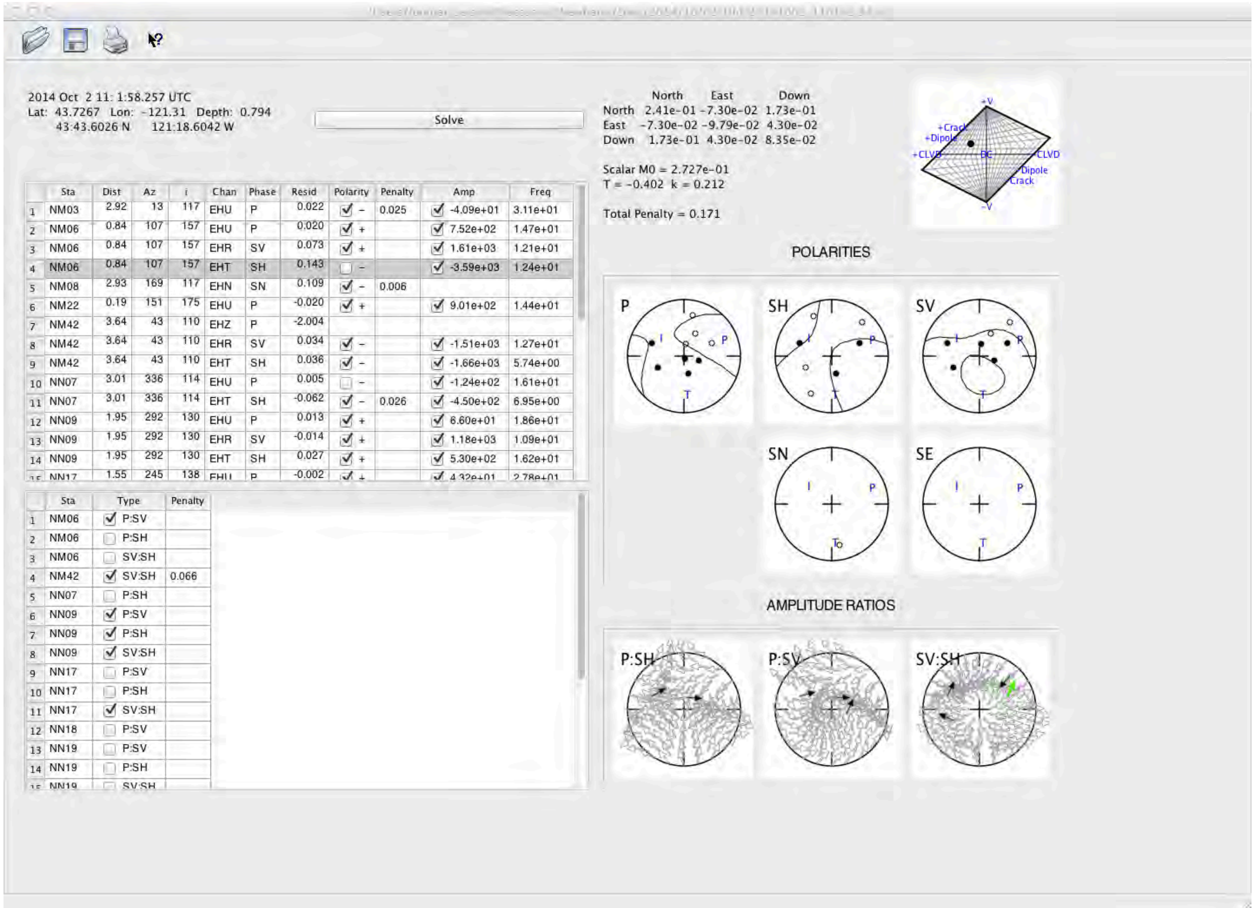


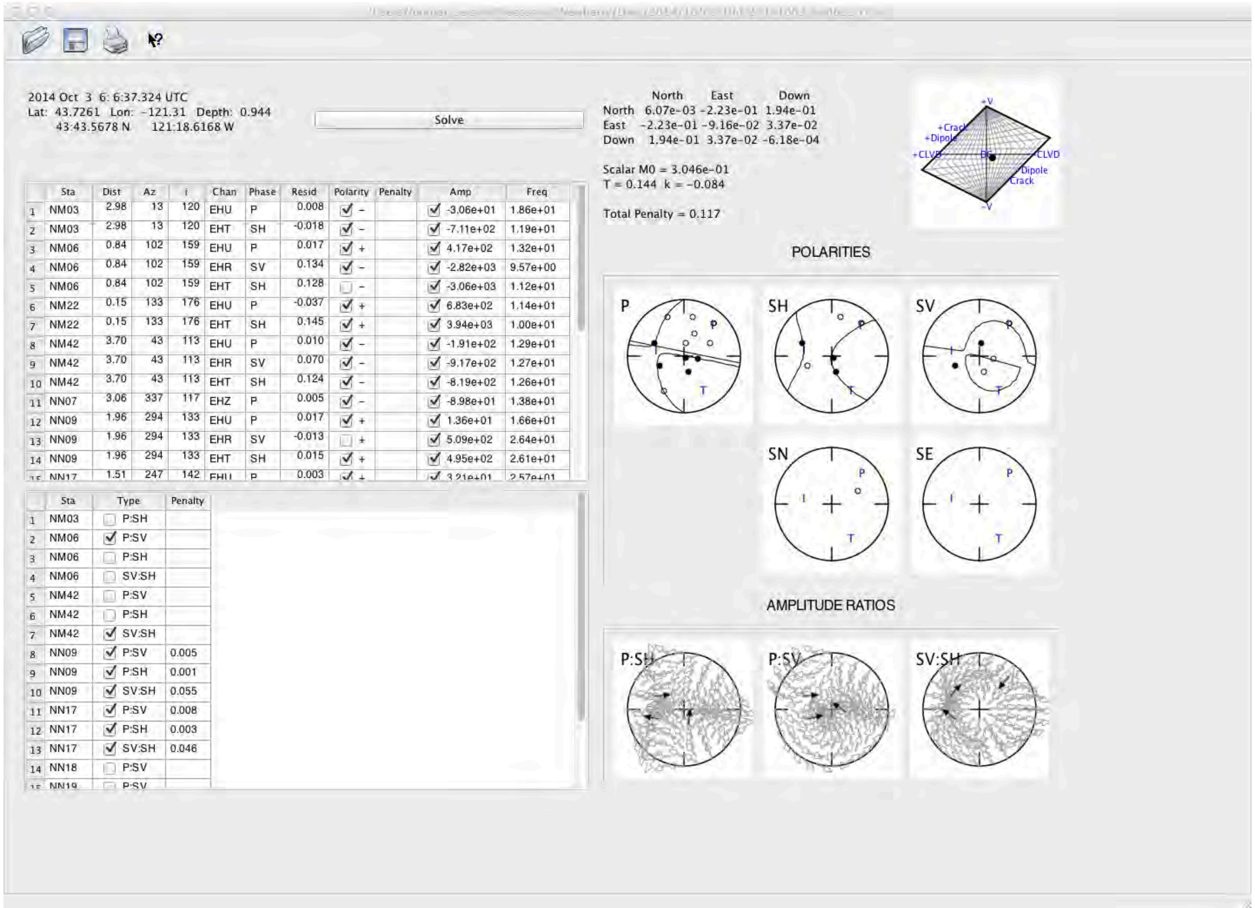

2014 Oct 1 14:53:20.145 UTC
Lat: 43.7265 Lon: -121.309 Depth: 0.824
43:43.5906 N 121:18.546 W
Solve
North East Down
North 1.58e-01 3.47e-02 2.48e-01
East 3.47e-02 6.67e-02 6.32e-02
Down 2.48e-01 6.32e-02 8.34e-02
Scalar M0 = 2.915e-01
T = -0.331 k = 0.266
Total Penalty = 0.166
+V
+Crack
+Dipole
+CLVD
DC
CLVD
Dipole
Crack
-V
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM03 2.92 11 118 EHU P 0.005 – -6.17e+01 1.73e+01
2 NM03 2.92 11 118 EHR SV -0.063 – -7.76e+02 1.36e+01
3 NM06 0.75 107 160 EHU P 0.016 + 7.31e+02 1.24e+01
4 NM06 0.75 107 160 EHR SV 0.069 + 0.000 2.30e+03 2.17e+01
5 NM06 0.75 107 160 EHT SH 0.083 + 1.02e+03 1.21e+01
6 NM08 2.90 170 118 EHR SV 0.089
7 NM22 0.14 175 176 EHU P -0.010 + 1.16e+03 1.52e+01
8 NM22 0.14 175 176 EHR SV 0.035 + 4.58e+03 8.85e+00
9 NM22 0.14 175 176 EHT SH -0.003 + 3.18e+03 1.54e+01
10 NM40 2.54 111 124 EHU P 0.040 +
11 NM40 2.54 111 124 EHN SN -0.036 – -2.66e+02 2.14e+01
12 NM40 2.54 111 124 EHT SH -0.027 + 1.97e+02 1.21e+01
13 NM42 3.60 42 111 EHU P 0.001 – -2.99e+02 1.11e+01
14 NM42 3.60 42 111 EHR SV 0.096 – -1.58e+03 1.71e+01
Sta Type Penalty
1 NM03 P:SV
2 NM06 P:SV
3 NM06 P:SH
4 NM06 SV:SH
5 NM42 P:SV
6 NM42 P:SH
7 NM42 SV:SH
8 NN07 P:SV
9 NN07 P:SH
10 NN07 SV:SH
11 NN09 P:SV 0.037
12 NN09 P:SH 0.027
13 NN09 SV:SH
14 NN17 P:SV
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH

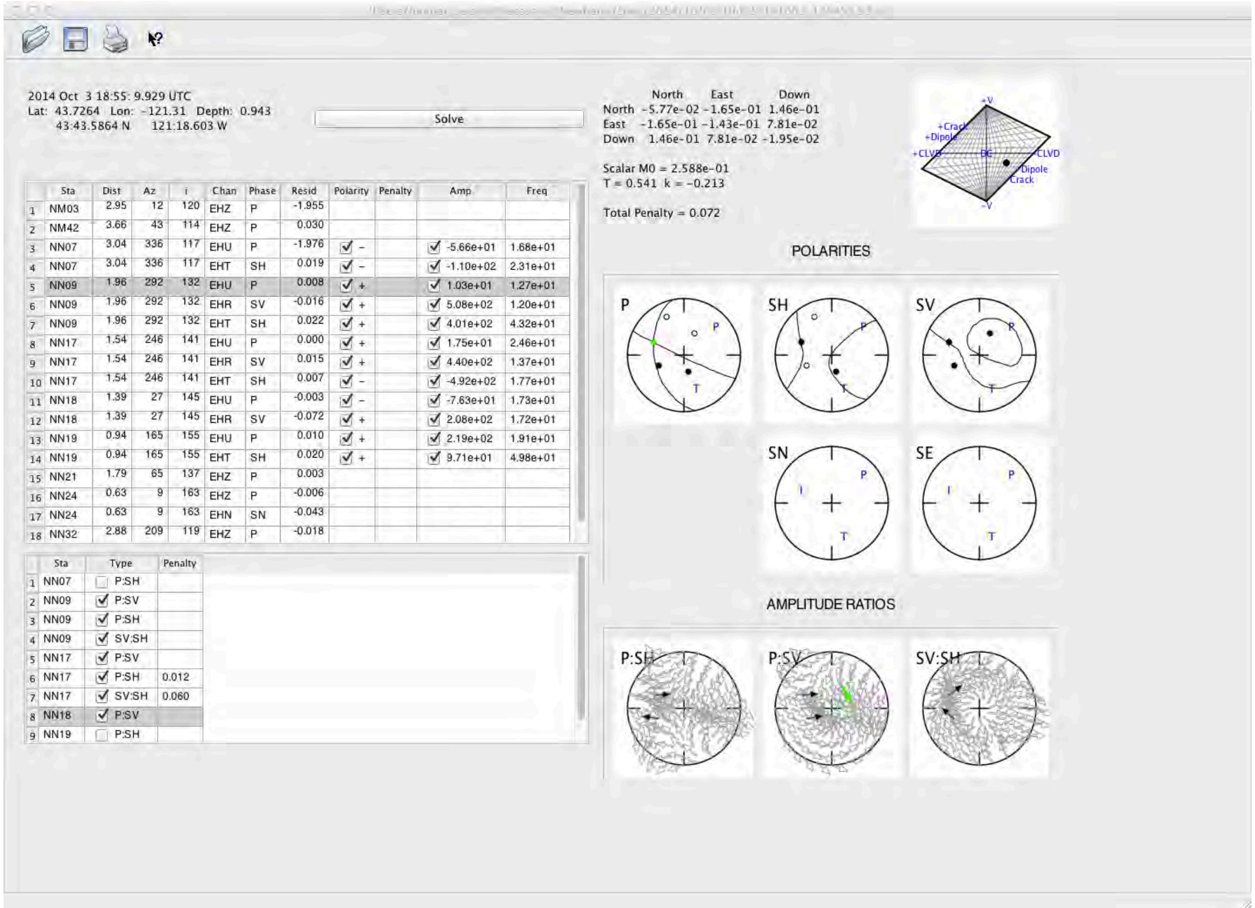

2014 Oct 1 19: 5:32.705 UTC
Lat: 43.7273 Lon: -121.308 Depth: 0.911
43:43.6374 N 121:18.48 W
Solve
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM03 2.82 9 121 EHU P 0.033 – -4.74e+01 1.73e+01
2 NM03 2.82 9 121 EHR SV -0.055 – -6.58e+02 1.41e+01
3 NM03 2.82 9 121 EHT SH -0.050 – -2.72e+02 2.12e+01
4 NM06 0.70 116 162 EHN SN 0.143
5 NM06 0.70 116 162 EHE SE 0.099
6 NM42 3.48 42 115 EHN SN 0.088
7 NM42 3.48 42 115 EHE SE 0.106
8 NN07 3.02 333 117 EHN SN 0.003
9 NN07 3.02 333 117 EHE SE 0.041
10 NN09 2.08 288 130 EHU P 0.011 – -2.80e+00 9.55e+00
11 NN09 2.08 288 130 EHR SV -0.031 + 1.01e+03 1.90e+01
12 NN09 2.08 288 130 EHT SH 0.015 + 0.072 9.67e+02 2.60e+01
13 NN17 1.73 245 137 EHU P -0.023 + 7.86e+01 2.06e+01
14 NN17 1.73 245 137 EHR SV -0.017 + 1.16e+03 2.36e+01
Sta Type Penalty
1 NM03 P:SV
2 NM03 P:SH
3 NM03 SV:SH
4 NN09 P:SV 0.000
5 NN09 P:SH 0.001
6 NN09 SV:SH 0.093
7 NN17 P:SV
8 NN17 P:SH
9 NN17 SV:SH
10 NN18 P:SV
11 NN18 P:SH
12 NN18 SV:SH
13 NN19 P:SV
14 NN19 P:SH
North East Down
North 2.17e-01 -3.67e-02 2.35e-01
East -3.67e-02 -6.42e-02 7.20e-02
Down 2.35e-01 7.20e-02 3.18e-02
Scalar M0 = 2.962e-01
T = -0.453 k = 0.163
Total Penalty = 0.180
+V
+Crack
+Dipole
+CLVD
DC
-CLVD
-Dipole
-Crack
-V
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH

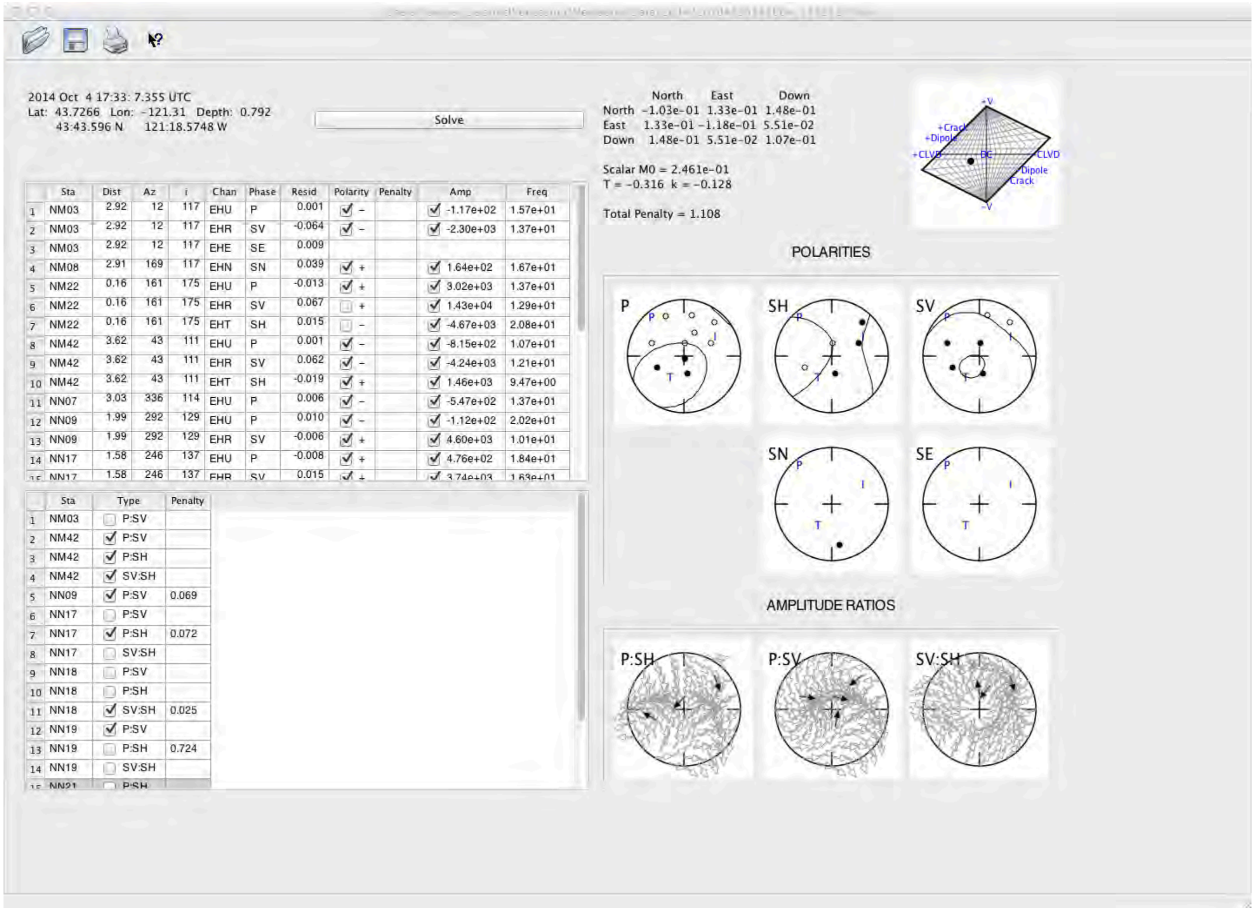

2014 Oct 2 6:48: 7.652 UTC
Lat: 43.7257 Lon: -121.308 Depth: 1.175
43:43.5444 N 121:18.4878 W
Solve
North East Down
North -1.46e-02 9.64e-02 2.59e-02
East 9.64e-02 -3.98e-01 1.69e-01
Down 2.59e-02 1.69e-01 -4.69e-03
Scalar M0 = 3.432e-01
T = 0.619 k = -0.293
Total Penalty = 0.198
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH

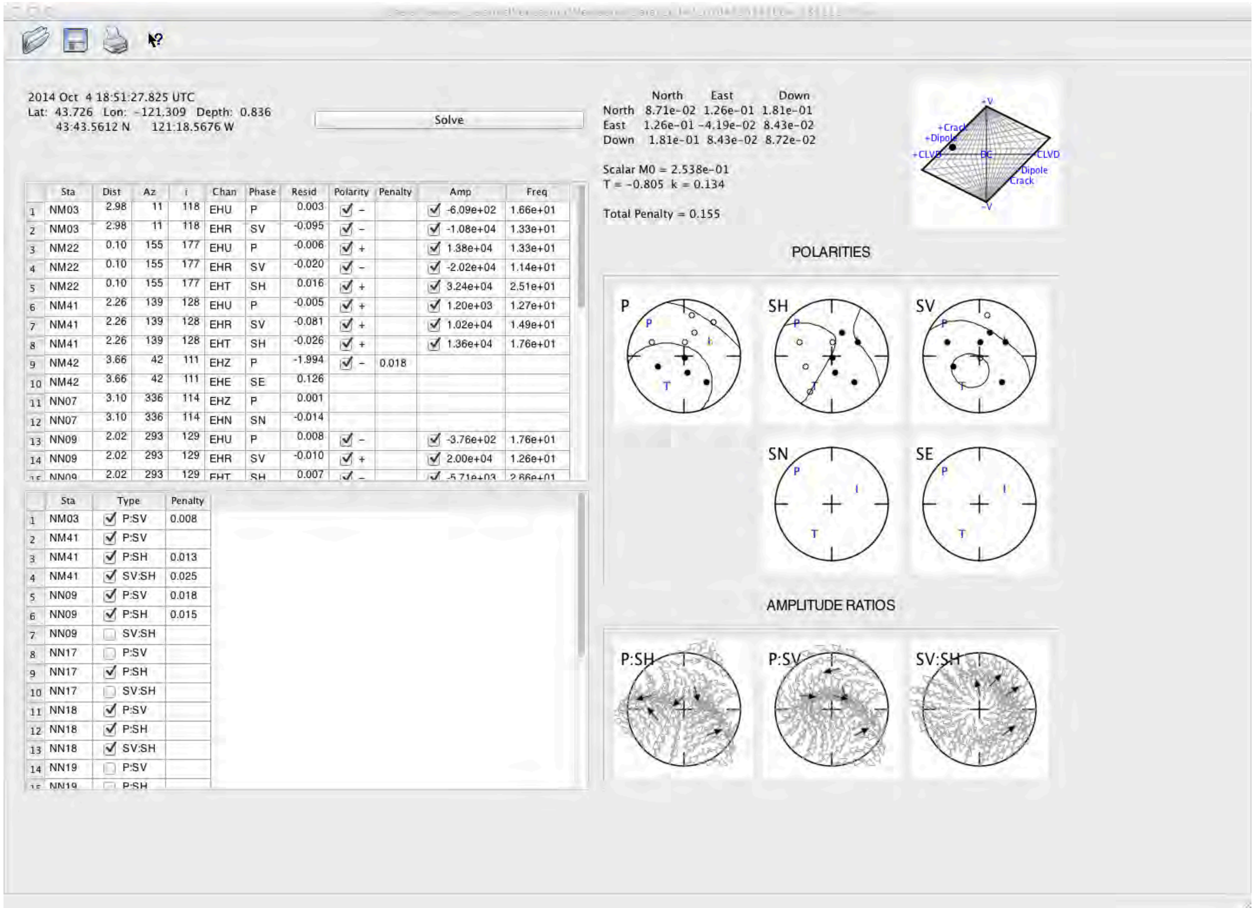

2014 Oct 2 7: 7:19.637 UTC
Lat: 43.7263 Lon: -121.309 Depth: 0.885
43:43.5774 N 121:18.546 W
Solve
North East Down
North -1.16e-01 1.71e-01 1.39e-01
East 1.71e-01 -1.99e-01 -2.43e-02
Down 1.39e-01 -2.43e-02 1.64e-02
Scalar M0 = 2.753e-01
T = 0.306 k = -0.274
Total Penalty = 0.184
+V
+Crack
+Dipole
+CLVD
DC
CLVD
Dipole
Crack
-V
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM03 2.95 11 119 EHU P 0.011 - -5.39e+01 1.75e+01
2 NM03 2.95 11 119 EHR SV 0.048 - -1.43e+03 9.59e+00
3 NM06 0.75 105 160 EHU P 0.031 + 6.53e+02 1.55e+01
4 NM06 0.75 105 160 EHR SV 0.097 + 2.33e+03 2.11e+01
5 NM06 0.75 105 160 EHT SH 0.142 - -6.99e+03 1.22e+01
6 NM22 0.12 174 177 EHU P -0.013 + 1.02e+03 1.53e+01
7 NM22 0.12 174 177 EHT SH -0.015 + 0.000 2.71e+03 1.90e+01
8 NM41 2.26 140 129 EHT SH -0.052 + 1.35e+03 1.38e+01
9 NM42 3.62 42 113 EHU P 0.011 - -3.06e+02 1.14e+01
10 NM42 3.62 42 113 EHR SV 0.077 - -1.40e+03 1.81e+01
11 NM42 3.62 42 113 EHT SH -0.020 + 6.95e+02 1.12e+01
12 NN07 3.08 335 116 EHU P 0.011 - -1.92e+02 1.34e+01
13 NN07 3.08 335 116 EHR SV -0.036 + 2.79e+02 2.11e+01
14 NN09 2.04 292 130 EHU P 0.013 - -2.74e+01 1.98e+01
Sta Type Penalty
1 NM03 P:SV
2 NM06 P:SV 0.034
3 NM06 P:SH 0.054
4 NM06 SV:SH 0.080
5 NM42 P:SV
6 NM42 P:SH
7 NM42 SV:SH
8 NN07 P:SV
9 NN09 P:SV
10 NN09 P:SH
11 NN09 SV:SH
12 NN17 P:SV 0.000
13 NN17 P:SH
14 NN17 SV:SH
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH


2014 Oct 2 11: 1:58.257 UTC
Lat: 43.7267 Lon: -121.31 Depth: 0.794
43:43.6026 N 121:18.6042 W
Solve
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM03 2.92 13 117 EHU P 0.022 – 0.025 -4.09e+01 3.11e+01
2 NM06 0.84 107 157 EHU P 0.020 + 7.52e+02 1.47e+01
3 NM06 0.84 107 157 EHR SV 0.073 + 1.61e+03 1.21e+01
4 NM06 0.84 107 157 EHT SH 0.143 – -3.59e+03 1.24e+01
5 NM08 2.93 169 117 EHN SN 0.109 – 0.006
6 NM22 0.19 151 175 EHU P -0.020 + 9.01e+02 1.44e+01
7 NM42 3.64 43 110 EHZ P -2.004
8 NM42 3.64 43 110 EHR SV 0.034 – -1.51e+03 1.27e+01
9 NM42 3.64 43 110 EHT SH 0.036 – -1.66e+03 5.74e+00
10 NN07 3.01 336 114 EHU P 0.005 – -1.24e+02 1.61e+01
11 NN07 3.01 336 114 EHT SH -0.062 – 0.026 -4.50e+02 6.95e+00
12 NN09 1.95 292 130 EHU P 0.013 + 6.60e+01 1.86e+01
13 NN09 1.95 292 130 EHR SV -0.014 + 1.18e+03 1.09e+01
14 NN09 1.95 292 130 EHT SH 0.027 + 5.30e+02 1.62e+01
Sta Type Penalty
1 NM06 P:SV
2 NM06 P:SH
3 NM06 SV:SH
4 NM42 SV:SH 0.066
5 NN07 P:SH
6 NN09 P:SV
7 NN09 P:SH
8 NN09 SV:SH
9 NN17 P:SV
10 NN17 P:SH
11 NN17 SV:SH
12 NN18 P:SV
13 NN19 P:SV
14 NN19 P:SH
North East Down
North 2.41e-01 -7.30e-02 1.73e-01
East -7.30e-02 -9.79e-02 4.30e-02
Down 1.73e-01 4.30e-02 8.35e-02
Scalar M0 = 2.727e-01
T = -0.402 k = 0.212
Total Penalty = 0.171
+V
+Crack
+Dipole
+CLVD
DC
-CLVD
-Dipole
-Crack
-V
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH


2014 Oct 3 6: 6:37.324 UTC
Lat: 43.7261 Lon: -121.31 Depth: 0.944
43:43.5678 N 121:18.6168 W
Solve
North East Down
North 6.07e-03 -2.23e-01 1.94e-01
East -2.23e-01 -9.16e-02 3.37e-02
Down 1.94e-01 3.37e-02 -6.18e-04
Scalar M0 = 3.046e-01
T = 0.144 k = -0.084
Total Penalty = 0.117
+V
+Crack
+Dipole
+CLVD
DC
-CLVD
-Dipole
-Crack
-V
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM03 2.98 13 120 EHU P 0.008 - -3.06e+01 1.86e+01
2 NM03 2.98 13 120 EHT SH -0.018 - -7.11e+02 1.19e+01
3 NM06 0.84 102 159 EHU P 0.017 + 4.17e+02 1.32e+01
4 NM06 0.84 102 159 EHR SV 0.134 - -2.82e+03 9.57e+00
5 NM06 0.84 102 159 EHT SH 0.128 - -3.06e+03 1.12e+01
6 NM22 0.15 133 176 EHU P -0.037 + 6.83e+02 1.14e+01
7 NM22 0.15 133 176 EHT SH 0.145 + 3.94e+03 1.00e+01
8 NM42 3.70 43 113 EHU P 0.010 - -1.91e+02 1.29e+01
9 NM42 3.70 43 113 EHR SV 0.070 - -9.17e+02 1.27e+01
10 NM42 3.70 43 113 EHT SH 0.124 - -8.19e+02 1.26e+01
11 NN07 3.06 337 117 EHZ P 0.005 - -8.98e+01 1.38e+01
12 NN09 1.96 294 133 EHU P 0.017 + 1.36e+01 1.66e+01
13 NN09 1.96 294 133 EHR SV -0.013 + 5.09e+02 2.64e+01
14 NN09 1.96 294 133 EHT SH 0.015 + 4.95e+02 2.61e+01
Sta Type Penalty
1 NM03 P:SH
2 NM06 P:SV
3 NM06 P:SH
4 NM06 SV:SH
5 NM42 P:SV
6 NM42 P:SH
7 NM42 SV:SH
8 NN09 P:SV 0.005
9 NN09 P:SH 0.001
10 NN09 SV:SH 0.055
11 NN17 P:SV 0.008
12 NN17 P:SH 0.003
13 NN17 SV:SH 0.046
14 NN18 P:SV
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH


Solve
2014 Oct 3 18:55: 9.929 UTC
Lat: 43.7264 Lon: -121.31 Depth: 0.943
43:43.5864 N 121:18.603 W
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM03 2.95 12 120 EHZ P -1.955
2 NM42 3.66 43 114 EHZ P 0.030
3 NN07 3.04 336 117 EHU P -1.976 – -5.66e+01 1.68e+01
4 NN07 3.04 336 117 EHT SH 0.019 – -1.10e+02 2.31e+01
5 NN09 1.96 292 132 EHU P 0.008 + 1.03e+01 1.27e+01
6 NN09 1.96 292 132 EHR SV -0.016 + 5.08e+02 1.20e+01
7 NN09 1.96 292 132 EHT SH 0.022 + 4.01e+02 4.32e+01
8 NN17 1.54 246 141 EHU P 0.000 + 1.75e+01 2.46e+01
9 NN17 1.54 246 141 EHR SV 0.015 + 4.40e+02 1.37e+01
10 NN17 1.54 246 141 EHT SH 0.007 – -4.92e+02 1.77e+01
11 NN18 1.39 27 145 EHU P -0.003 – -7.63e+01 1.73e+01
12 NN18 1.39 27 145 EHR SV -0.072 + 2.08e+02 1.72e+01
13 NN19 0.94 165 155 EHU P 0.010 + 2.19e+02 1.91e+01
14 NN19 0.94 165 155 EHT SH 0.020 + 9.71e+01 4.98e+01
15 NN21 1.79 65 137 EHZ P 0.003
16 NN24 0.63 9 163 EHZ P -0.006
17 NN24 0.63 9 163 EHN SN -0.043
18 NN32 2.88 209 119 EHZ P -0.018
Sta Type Penalty
1 NN07 P:SH
2 NN09 P:SV
3 NN09 P:SH
4 NN09 SV:SH
5 NN17 P:SV
6 NN17 P:SH 0.012
7 NN17 SV:SH 0.060
8 NN18 P:SV
9 NN19 P:SH
North East Down
North -5.77e-02 -1.65e-01 1.46e-01
East -1.65e-01 -1.43e-01 7.81e-02
Down 1.46e-01 7.81e-02 -1.95e-02
Scalar M0 = 2.588e-01
T = 0.541 k = -0.213
Total Penalty = 0.072
+V
+Crack
+Dipole
+CLVD
DC
-CLVD
-Dipole
-Crack
-V
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH


2014 Oct 4 17:33: 7.355 UTC
Lat: 43.7266 Lon: -121.31 Depth: 0.792
43:43.596 N 121:18.5748 W
Solve
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM03 2.92 12 117 EHU P 0.001 – -1.17e+02 1.57e+01
2 NM03 2.92 12 117 EHR SV -0.064 – -2.30e+03 1.37e+01
3 NM03 2.92 12 117 EHE SE 0.009
4 NM08 2.91 169 117 EHN SN 0.039 + 1.64e+02 1.67e+01
5 NM22 0.16 161 175 EHU P -0.013 + 3.02e+03 1.37e+01
6 NM22 0.16 161 175 EHR SV 0.067 + 1.43e+04 1.29e+01
7 NM22 0.16 161 175 EHT SH 0.015 – -4.67e+03 2.08e+01
8 NM42 3.62 43 111 EHU P 0.001 – -8.15e+02 1.07e+01
9 NM42 3.62 43 111 EHR SV 0.062 – -4.24e+03 1.21e+01
10 NM42 3.62 43 111 EHT SH -0.019 + 1.46e+03 9.47e+00
11 NN07 3.03 336 114 EHU P 0.006 – -5.47e+02 1.37e+01
12 NN09 1.99 292 129 EHU P 0.010 – -1.12e+02 2.02e+01
13 NN09 1.99 292 129 EHR SV -0.006 + 4.60e+03 1.01e+01
14 NN17 1.58 246 137 EHU P -0.008 + 4.76e+02 1.84e+01
Sta Type Penalty
1 NM03 P:SV
2 NM42 P:SV
3 NM42 P:SH
4 NM42 SV:SH
5 NN09 P:SV 0.069
6 NN17 P:SV
7 NN17 P:SH 0.072
8 NN17 SV:SH
9 NN18 P:SV
10 NN18 P:SH
11 NN18 SV:SH 0.025
12 NN19 P:SV
13 NN19 P:SH 0.724
14 NN19 SV:SH
North East Down
North -1.03e-01 1.33e-01 1.48e-01
East 1.33e-01 -1.18e-01 5.51e-02
Down 1.48e-01 5.51e-02 1.07e-01
Scalar M0 = 2.461e-01
T = -0.316 k = -0.128
Total Penalty = 1.108
+V
+Crack
+Dipole
+CLVD
DC
-CLVD
-Dipole
-Crack
-V
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH


2014 Oct 4 18:51:27.825 UTC
Lat: 43.726 Lon: -121.309 Depth: 0.836
43:43.5612 N 121:18.5676 W
Solve
North East Down
North 8.71e-02 1.26e-01 1.81e-01
East 1.26e-01 -4.19e-02 8.43e-02
Down 1.81e-01 8.43e-02 8.72e-02
Scalar M0 = 2.538e-01
T = -0.805 k = 0.134
Total Penalty = 0.155
+V
+Crack
+Dipole
+CLVD
DC
-CLVD
-Dipole
-Crack
-V
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM03 2.98 11 118 EHU P 0.003 - -6.09e+02 1.66e+01
2 NM03 2.98 11 118 EHR SV -0.095 - -1.08e+04 1.33e+01
3 NM22 0.10 155 177 EHU P -0.006 + 1.38e+04 1.33e+01
4 NM22 0.10 155 177 EHR SV -0.020 - -2.02e+04 1.14e+01
5 NM22 0.10 155 177 EHT SH 0.016 + 3.24e+04 2.51e+01
6 NM41 2.26 139 128 EHU P -0.005 + 1.20e+03 1.27e+01
7 NM41 2.26 139 128 EHR SV -0.081 + 1.02e+04 1.49e+01
8 NM41 2.26 139 128 EHT SH -0.026 + 1.36e+04 1.76e+01
9 NM42 3.66 42 111 EHZ P -1.994 - 0.018
10 NM42 3.66 42 111 EHE SE 0.126
11 NN07 3.10 336 114 EHZ P 0.001
12 NN07 3.10 336 114 EHN SN -0.014
13 NN09 2.02 293 129 EHU P 0.008 - -3.76e+02 1.76e+01
14 NN09 2.02 293 129 EHR SV -0.010 + 2.00e+04 1.26e+01
Sta Type Penalty
1 NM03 P:SV 0.008
2 NM41 P:SV
3 NM41 P:SH 0.013
4 NM41 SV:SH 0.025
5 NN09 P:SV 0.018
6 NN09 P:SH 0.015
7 NN09 SV:SH
8 NN17 P:SV
9 NN17 P:SH
10 NN17 SV:SH
11 NN18 P:SV
12 NN18 P:SH
13 NN18 SV:SH
14 NN19 P:SV
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH

Foulger Consulting

1025 Paradise Way
Palo Alto, CA 943062637, USA
Tel: 650/4932553
Cell: 650/9968886
FAX: 866/5326907
gillian@foulgerconsulting.com
http://www.foulgerconsulting.com/

November 12, 2014

WEEKLY REPORT #6 TO ALTAROCK ENERGY INC.

PROCESSING OF INDUCED EARTHQUAKES ASSOCIATED WITH THE NEWBERRY EGS INJECTION STARTING SEPTEMBER 2014

GILLIAN R. FOULGER & BRUCE R. JULIAN

Brief summary

During the last week, additional results were obtained for 10 more moment tensors. We are progressively deriving mechanisms for smaller events, but the quality of the results remains excellent in most cases. We added these additional events to our set of the highest-quality events for relative locations.

New results this week may be summarised:

1. *The addition of more, highly accurately measured and located earthquakes to the relative location set has revealed yet more fine detail. The pair of clusters identified earlier remains a stable feature, as does their clear separation by an essentially aseismic layer. The deeper cluster shows extraordinarily sharp focusing and appears to delineate an EW-trending plane and not a NW-trending plane as thought earlier. It appears to form part of the NW-trending zone observable in map view simply because it lies somewhat to the SE of the shallower cluster. The sharpness of the planar surface apparently delineated suggests that the relative locations may be accurate to a few meters, an unusually high-quality result. This interpretation also has support in the absolute locations which are suggestive of an EW orientation in the earthquakes of the deeper, more southerly cluster.*
2. *It is emphasised that relative location results will change with variation of run-time parameters and with the addition of more earthquakes to the set. The results described here appear to be stable as the run-time parameters are varied, but some changes may occur as the work progresses and the size of the dataset increases. The geometry of structures described here should thus be viewed as interim results.*
3. *The source types of the earthquakes for which moment tensors were derived continue to range from +Dipole to -Dipole.*
4. *A systematic variation in source type with time, during the three weeks of injection studied, is now visible in the growing data set. The proportion of crack-opening source types progressively reduces with time. During Week 1 about equal numbers of earthquakes were crack-opening and crack-closing types. The proportion of crack-opening events reduced to about 20% in Week 2 and in Week 3 none of the 9 moment tensors derived have a significant crack-opening component.*
5. *Variation in source-type with depth is also observed, with crack-opening source types more abundant and more extreme in the shallower cluster compared with the deeper cluster.*

The patterns of orientation of the P-, T- and I-axes reported earlier continue to strengthen in confidence with the addition of more data. Possible variations in orientations between the shallower and the deeper cluster were sought, but no evidence could be found. This suggests that the orientation of stress axes is similar in both hypocentral volumes.

1 Task 1 – Planning, conference calls, discussion of work, correspondence, followup

We continued to maintain contact with team members as before. The work continued to run on a routine basis.

2 Task 2 – System Setup

No additional system setup was done during the last week.

3 Task 3 – Quality control of prepicked MEQs and preparation for relocation and moment tensor calculation

We continued to derive moment tensors using the procedure described in our Weekly Report #1. We report here an additional 10 moment tensors, bringing the total number derived up to 54 (

Table 1). We have provided the locations and moment-tensor decomposition data of these new moment tensors to Trenton Cladouhos of AltaRock electronically, by email attachment.

Table 1: The 54 earthquakes for which moment tensors have been obtained to date. Locations given below are from the webpage http://fracture.lbl.gov/Newberry/locations.txt.

jday	month	day	hour	minute	sec	lat	lon	depth	magnitude
272	9	29	9	57	54.34	43.7245	-121.30857	0.845	0.721
272	9	29	18	3	37.724	43.72365	-121.30658	1.274	0.669
273	9	30	9	23	48.799	43.71965	-121.30908	0.854	0.853
273	9	30	21	30	43.689	43.72667	-121.313	0.387	0.972
274	10	1	1	3	14.64	43.7239	-121.30957	0.714	0.987
274	10	1	8	8	58.215	43.72623	-121.31412	1.196	0.848
274	10	1	10	50	55.229	43.72275	-121.30868	1.051	0.787
274	10	1	12	3	16.881	43.72658	-121.3158	1.587	1.086
274	10	1	15	1	55.056	43.72775	-121.31227	0.923	0.682
274	10	1	16	56	11.256	43.72232	-121.30712	1.65	0.901
275	10	2	6	38	47.428	43.7243	-121.31328	1.153	0.951
275	10	2	6	47	52.916	43.72632	-121.31322	1.323	1.117
275	10	2	12	39	9.082	43.7264	-121.31438	1.332	0.852
275	10	2	18	53	48.447	43.72082	-121.31372	1.671	0.957
275	10	2	20	36	50.997	43.72377	-121.31323	1.499	0.991

276	10	3	15	27	57.912	43.72257	-121.31562	1.054	0.919
276	10	3	18	54	54.199	43.72678	-121.31125	0.647	1.021
277	10	4	5	29	8.347	43.72578	-121.31068	0.946	0.922
278	10	5	2	6	17.079	43.7266	-121.31217	0.925	0.86
278	10	5	2	14	37.358	43.72433	-121.30915	0.459	0.665
278	10	5	15	55	21.373	43.73483	-121.30918	0.702	0.695
278	10	5	16	7	32.904	43.7253	-121.30967	1.205	0.819
278	10	5	23	22	16.638	43.72368	-121.3116	1.055	0.931
279	10	6	4	2	55.851	43.72307	-121.30835	0.835	0.637
279	10	6	6	13	48.787	43.72425	-121.3097	0.638	0.604
280	10	7	6	12	8.757	43.72372	-121.31015	0.564	0.791
280	10	7	10	47	21.079	43.72403	-121.3095	1.136	0.822
282	10	9	6	24	33.517	43.72232	-121.31203	0.735	0.769
282	10	9	10	16	9.958	43.7172	-121.31332	1.378	0.722
284	10	11	3	29	5.813	43.72417	-121.31338	0.409	0.852
284	10	11	10	53	26.568	43.72493	-121.30897	1.292	0.824
285	10	12	10	12	29.727	43.7257	-121.3135	0.783	0.863
285	10	12	16	47	1.174	43.7297	-121.3126	1.07	0.681
285	10	12	18	33	4.878	43.72363	-121.30787	0.359	0.743
285	10	12	21	10	18.995	43.72783	-121.31002	0.653	0.792
286	10	13	10	22	29.146	43.7302	-121.3153	0.831	0.907
287	10	14	5	46	14.161	43.71765	-121.31087	0.161	0.904
288	10	15	15	3	44.691	43.72658	-121.30768	0.897	0.781
288	10	15	15	37	26.034	43.72713	-121.30915	0.934	0.883
289	10	16	16	53	27.596	43.72378	-121.31295	-0.186	0.736
291	10	18	23	57	3.867	43.72965	-121.31732	0.116	0.781
292	10	19	9	7	50.375	43.73525	-121.3113	0.837	0.776
272	9	29	9	57	54.34	43.7245	-121.30857	0.845	0.721
272	9	29	18	3	37.724	43.72365	-121.30658	1.274	0.669
273	9	30	9	23	48.799	43.71965	-121.30908	0.854	0.853
273	9	30	21	30	43.689	43.72667	-121.313	0.387	0.972
274	10	1	1	3	14.64	43.7239	-121.30957	0.714	0.987
274	10	1	8	8	58.215	43.72623	-121.31412	1.196	0.848
274	10	1	10	50	55.229	43.72275	-121.30868	1.051	0.787
274	10	1	12	3	16.881	43.72658	-121.3158	1.587	1.086
274	10	1	15	1	55.056	43.72775	-121.31227	0.923	0.682
274	10	1	16	56	11.256	43.72232	-121.30712	1.65	0.901
275	10	2	6	38	47.428	43.7243	-121.31328	1.153	0.951
275	10	2	6	47	52.916	43.72632	-121.31322	1.323	1.117

4 Task 4 –Improved locations and relative locations

4.1 Absolute locations

We have updated our map of events for which moment tensors were derived and the full 54-event dataset is shown in Figure 1 and Figure 2.

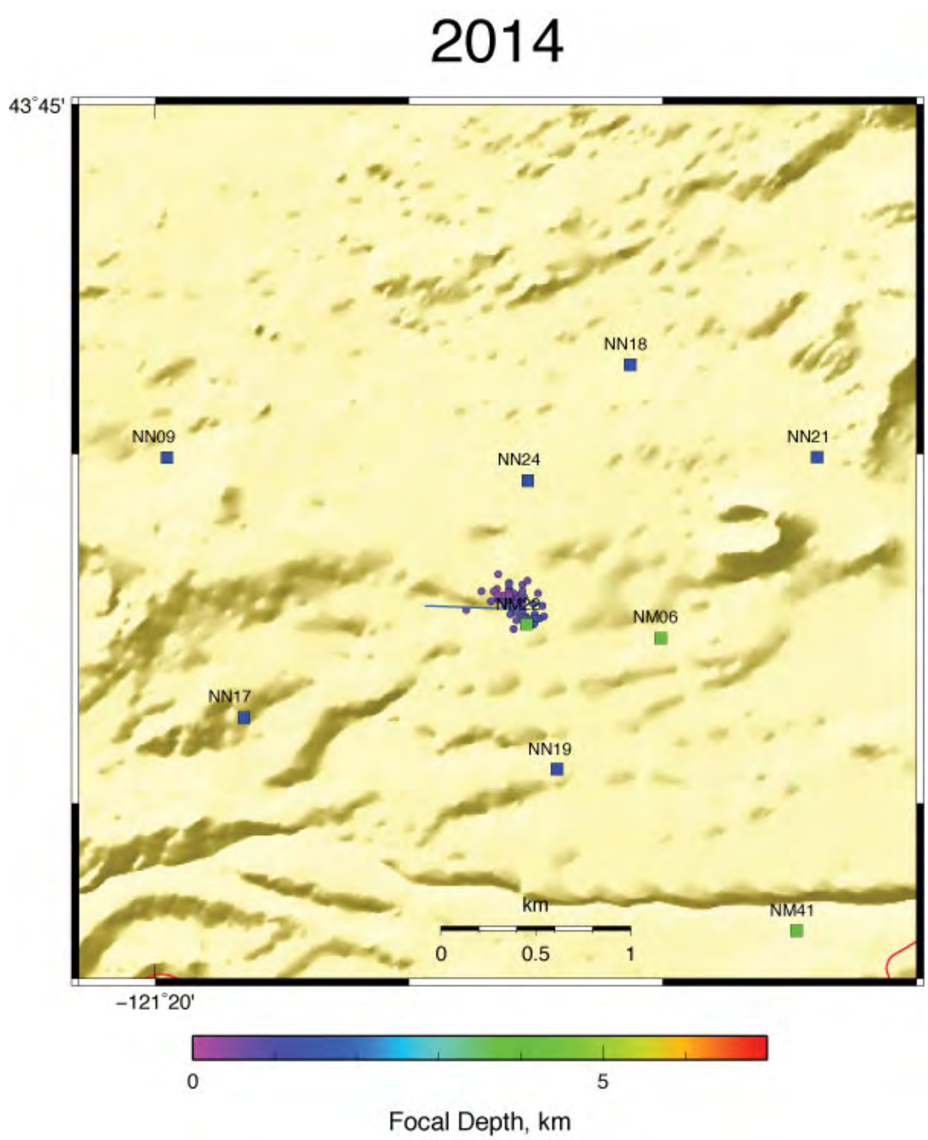


Figure 1: High quality estimated hypocenters of 54 microearthquakes that occurred between Sept. 29 and Oct. 19, 2014, and for which moment tensors were derived. These locations are computed using

arrival times measured carefully in connection with the moment-tensor analysis. Well NWD 55-29 is shown in blue.

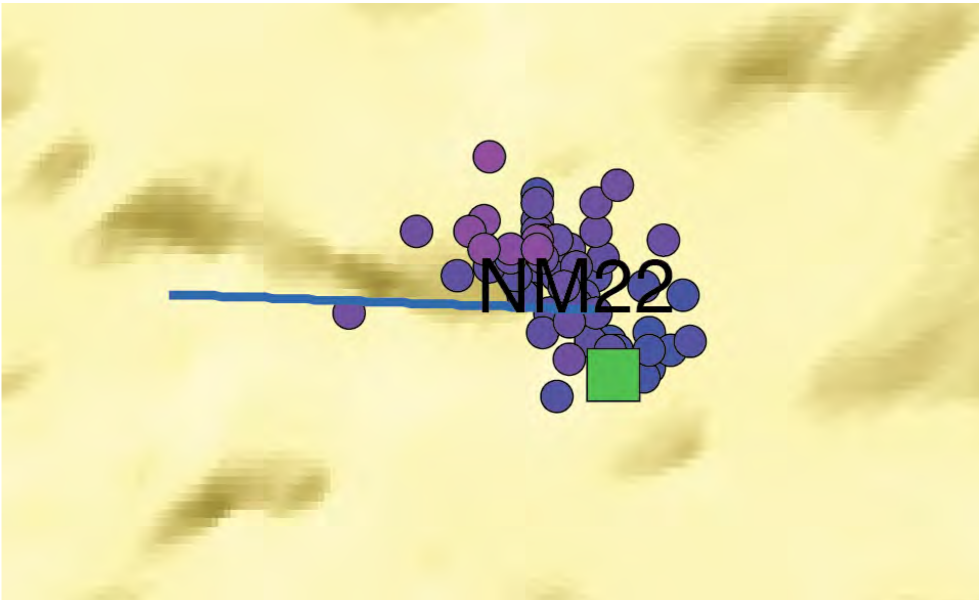


Figure 2: Expanded view of the locations of the earthquakes for which moment tensors were derived.

4.2 Relative locations

We continued with the relative location work, applying the method to the 54 earthquakes for which moment tensors have now been derived. These events are the best-located set currently available. We used the same procedure as described in earlier reports.

We explored further different run-time parameters. Different parameters are optimal for different data sets so this must be done each time a new dataset is subject to relative location. We performed about 12 trial inversions and found the following to give the best result. This is the result that shows in the most focus, patterns in the results which appear to be stable across several sets of results obtained using different run-time parameter choices.

- *minclust*–the minimum number of earthquakes to define a cluster (a value of 8 was used);
- *maxit*–the maximum allowed number of relocation iterations (optimal value identified = 7);
- *maxsep*–the maximum separation allowed between linked pairs of earthquakes (optimal value identified = 0.15 km);
- *minlinks*–the minimum number of "links" (i.e., measured station/phases in common between pairs of earthquakes) needed for an earthquake to be passed to the final relocated set (optimal values identified = 21);

This inversion read in the 54 original earthquakes. 25 failed the *minlinks* cut-off criterion, and a further 5 failed the *maxsep* criterion. This left the 24 highest-quality earthquakes, which fell into two clusters, one containing 16 earthquakes (the shallower cluster) and the other 8 earthquakes (the deeper cluster).

The two clusters were fixed by pinnning them to one excellently located earthquake in each cluster (i.e., a total of two earthquakes). The following were used:

- `2014 10 01 14 53 20.145 43.726509 -121.309105 0.82 0.0 0.00 0.00 0.0 11`
- `2014 10 01 08 08 57.998 43.725528 -121.308941 1.21 0.0 0.00 0.00 0.0 6`

The results are shown in Figure 3 to Figure 6.

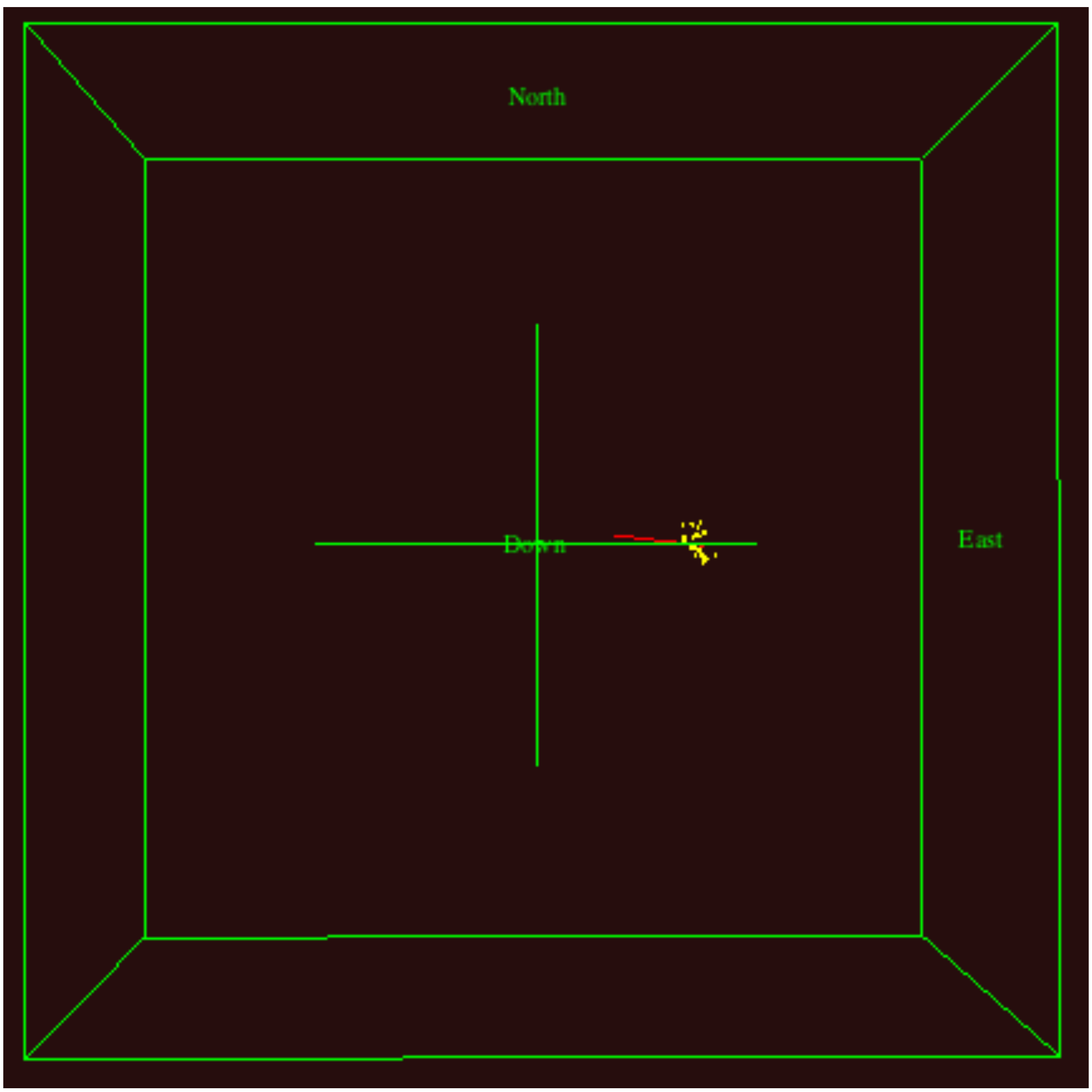


Figure 3: Map of relative locations of 24 moment-tensor earthquakes that occurred in the time period 29 September - 19 October, 2014. Runtime parameters used were *minclust* = 8, *maxit* = 7, *maxsep* = 0.15 km, *minlinks* = 21.

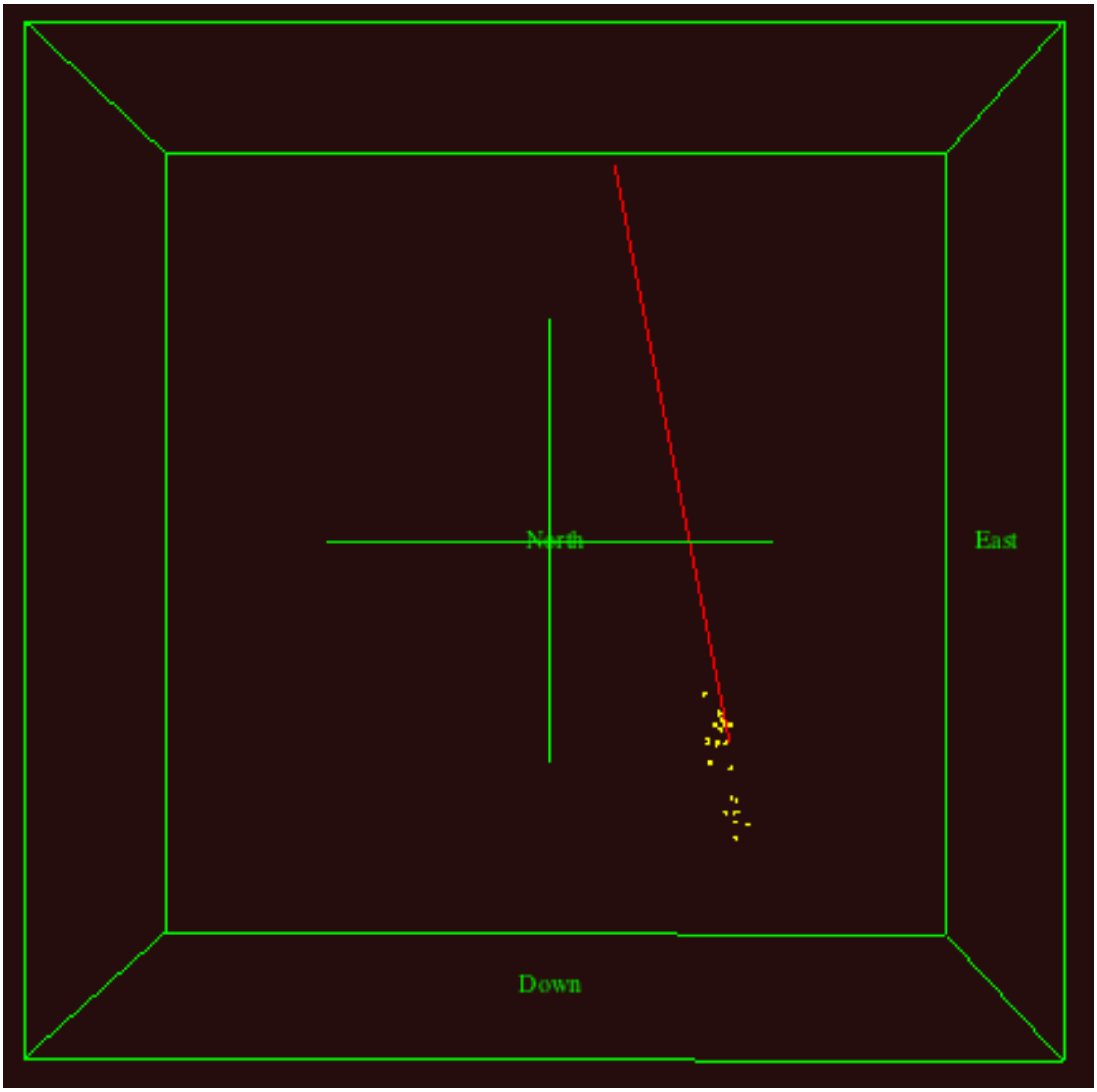


Figure 4: Same as Figure 3 except in cross section looking north.

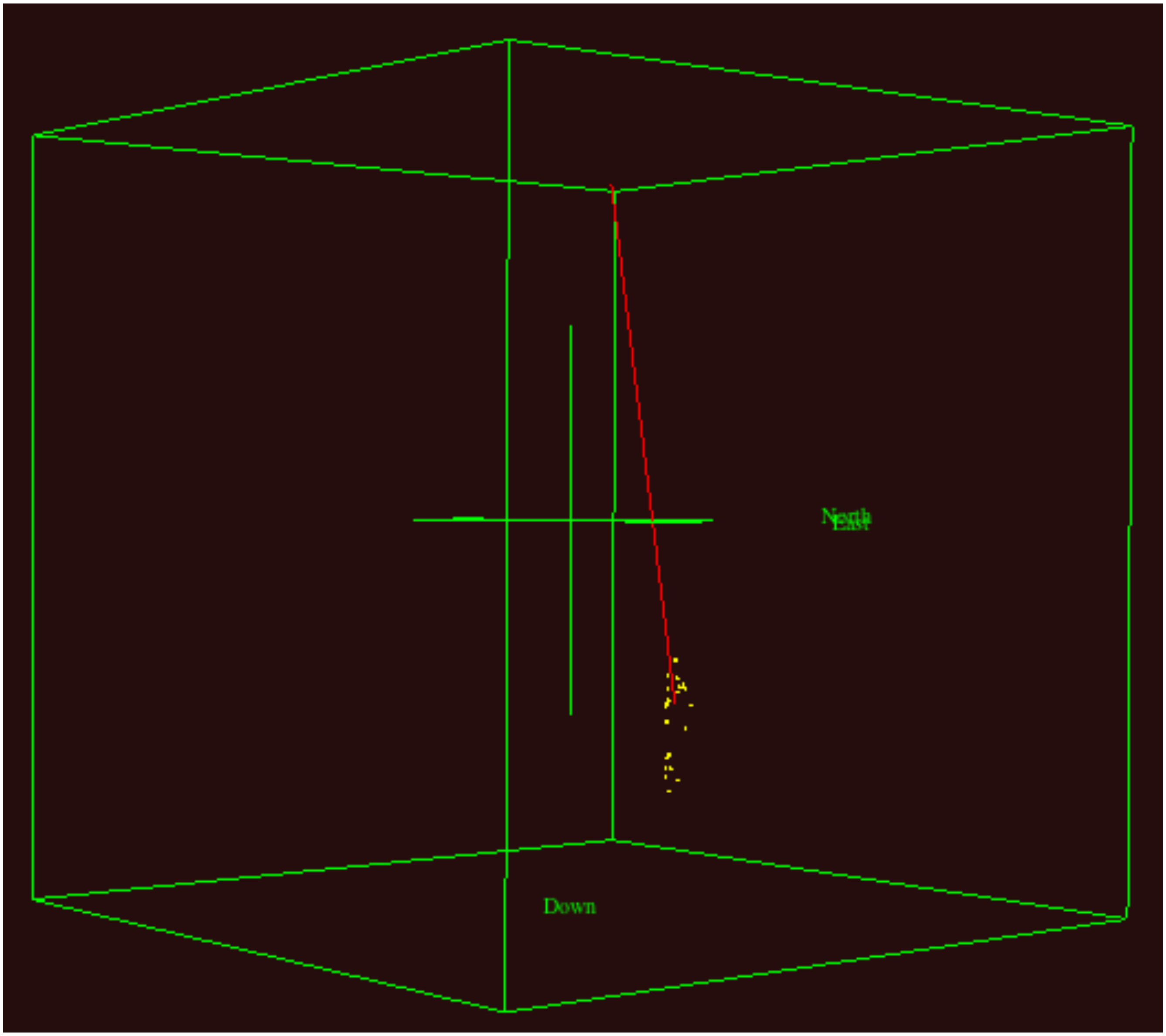


Figure 5: Same as Figure 3 except in cross section looking northwesterly, along the strike of the planar structure visible in map view.

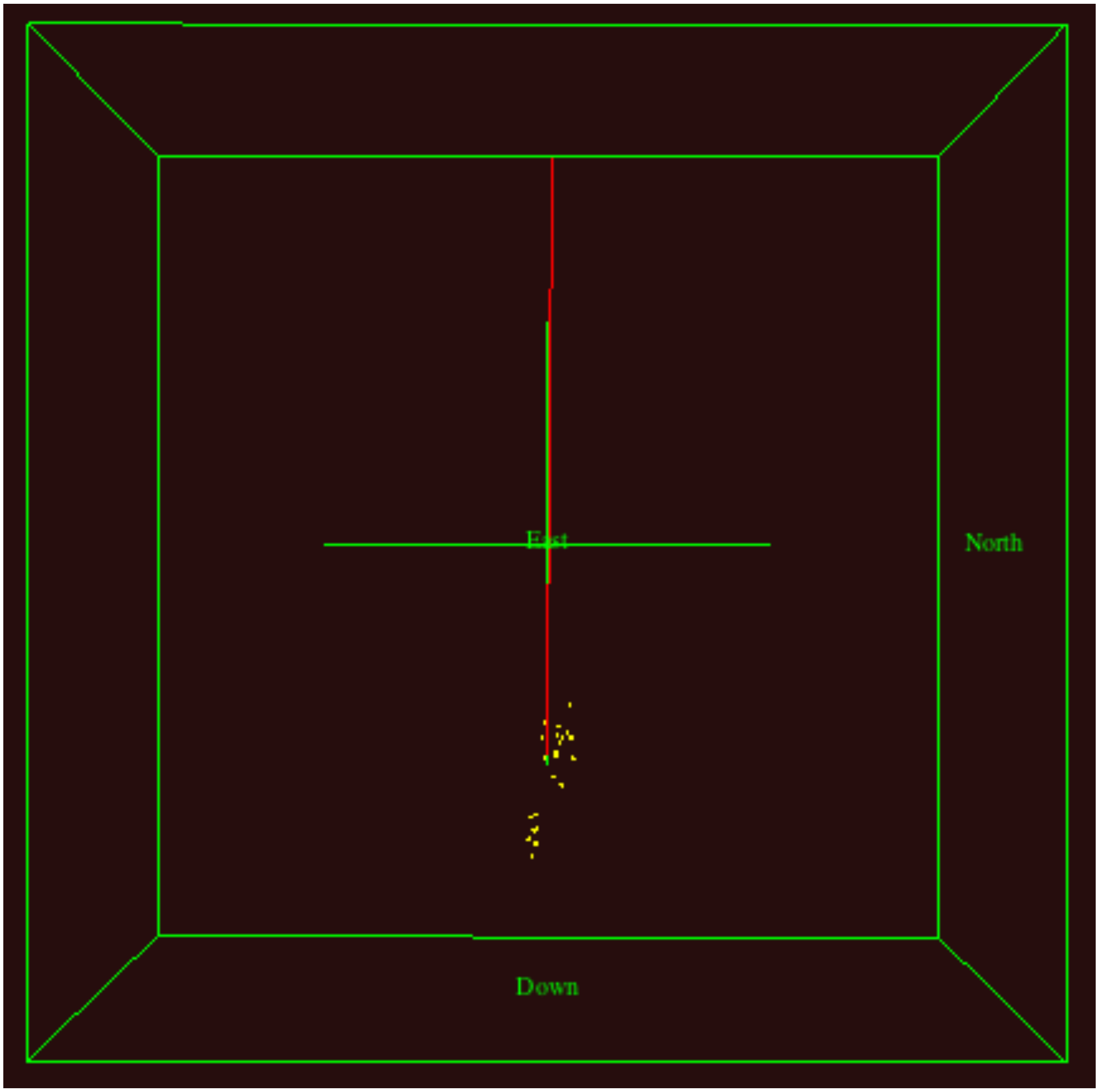


Figure 6: Same as Figure 3 except in cross section looking easterly.

The relative location results continue to reveal intriguing new patterns. The results described in earlier reports are confirmed, but with increasing detail suggested. In map view (Figure 3) the epicenters delineate clear linear zone striking at ~ N 45˚W. In cross section, two separate clusters are visible, separated by a depth interval ~ 200 m thick with very few earthquakes.

A cross section looking northwesterly along the strike of the surface trend (Figure 5) shows a more focused picture, with the earthquakes presenting a much narrower aspect. However, in a cross section looking due west, the lower cluster appears to be even more focused. It shows extremely sharp edges suggesting that relative locations may be accurate even to a few meters. Further investigation of this is warrented, along with a concentrated effort to process as many of the larger earthquakes as possible in order to increase the size of this excellent subset of locations.

The relocated hypocenters were studied at some length, rotating the plot in three dimensions using the *Mathematica* software There is a suggestion that the lower cluster may occur on an EW orientated planar structure, and not on a NW-orientated one. It may be that it forms just the southeasternmost part of the NW-elongated epicentral trend observed in map view (Figure 1, Figure 2 and Figure 3) but does not itself lie on a structure with this trend. In fact, the distribution of epicenters shown in Figure 2 also suggests this, with a remarkably sharp linear array of earthquakes visible south of Well NWD 55-29.

Numerical data for these interim results have been provided to AltaRock by email attachment to Trenton Cladouhos.

5 Task 5 Moment tensor calculations

The numerical results of the entire moment-tensor catalog, including the 10 new results obtained during the last week, are given in Appendix 1. Graphical results for the additional 10 events are given in Appendix 2.

The source types for the entire 54-event set are shown in source-type space in Figure 7. The distribution remains similar to that reported earlier, i.e., source types ranging from +Dipole to -Dipole.

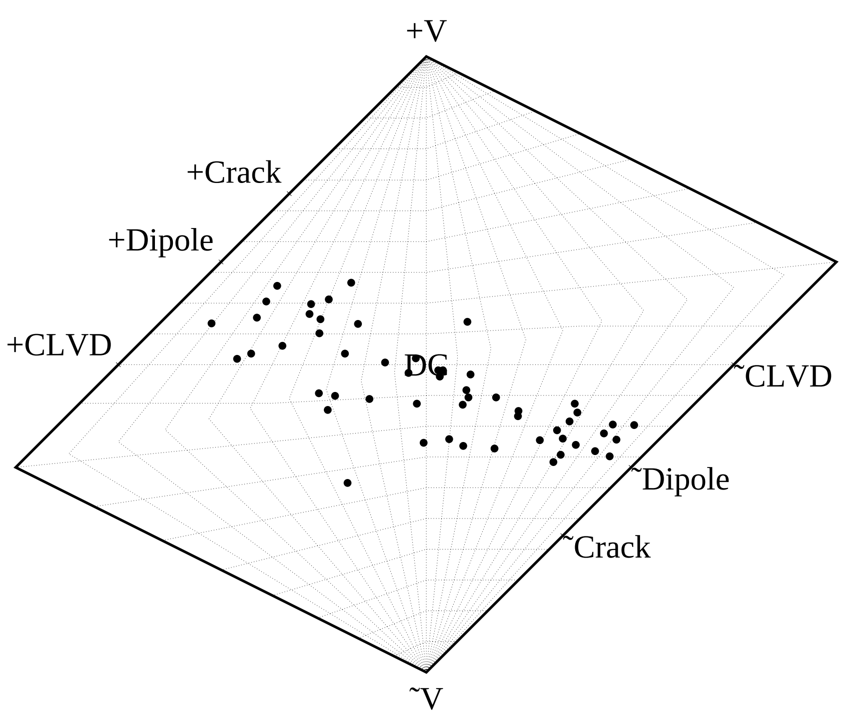
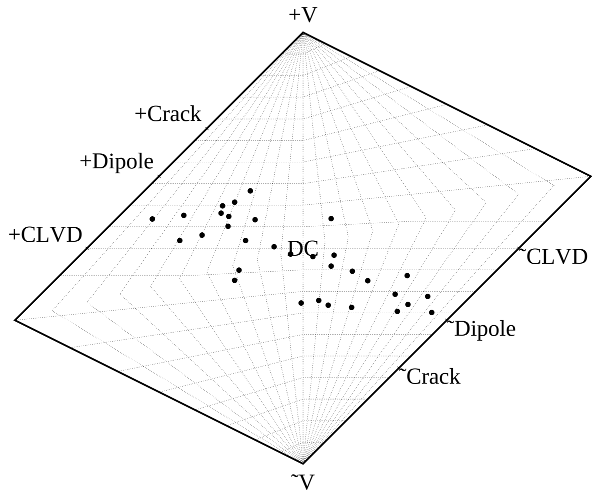
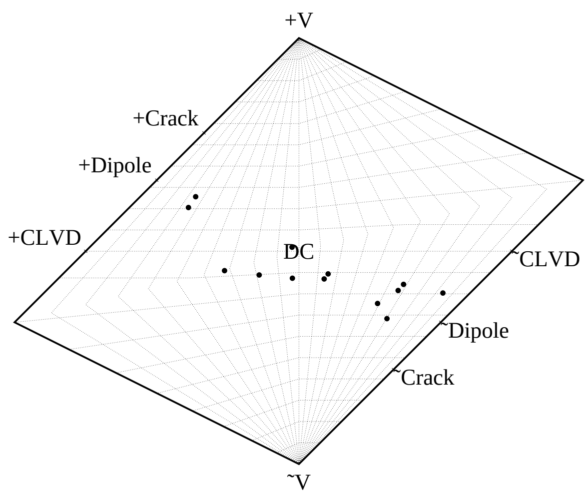


Figure 7: Source-type plot showing the 54 earthquakes for which moment tensors have been derived to date.

The data set is now large enough that temporal variations in source type can be studied. Figure 8 shows source-type plots for Week 1 of the stimulation (29 September -5 October), Week 2 (6-13 October), and Week 3 (14-20 October). A systematic variation in source type is evident, with the proportion of crack-opening source types progressively reducing. During Week 1 about equal numbers were crack-opening and crack-closing types. The proportion of crack-opening events reduced to about 20% in Week 2 and in Week 3 none of the 9 moment tensors derived have a significant crack-opening component.


+V
+Crack
+Dipole
+CLVD
DC
˜CLVD
˜Dipole
˜Crack
˜V


+V
+Crack
+Dipole
+CLVD
DC
˜CLVD
˜Dipole
˜Crack
˜V

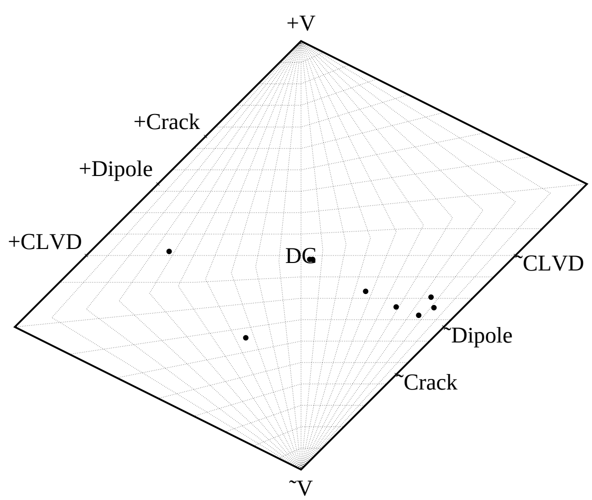

+V
+Crack
+Dipole
+CLVD
DC
˜CLVD
˜Dipole
˜Crack
˜V

Figure 8: Top: Moment tensors for Week 1 of the stimulation (29 September -5 October), Middle: Moment tensors for Week 2 of the stimulation (6-13 October), Bottom: Moment tensors for Week 3 of the stimulation (14-20 October).

Figure 9 shows the source types divided up by depth. The upper panel shows source types in the shallower group of earthquakes observed in the relative locations (e.g., Figure 6), and the lower panel shows events in the deeper group. Both sets of earthquakes have source types that extend almost to the -Dipole point (crack closing) but the shallower group has more sources close to the +Dipole point, indicating crack opening. These extreme crack-opening source types are both more numerous and more extreme in the shallower event group.

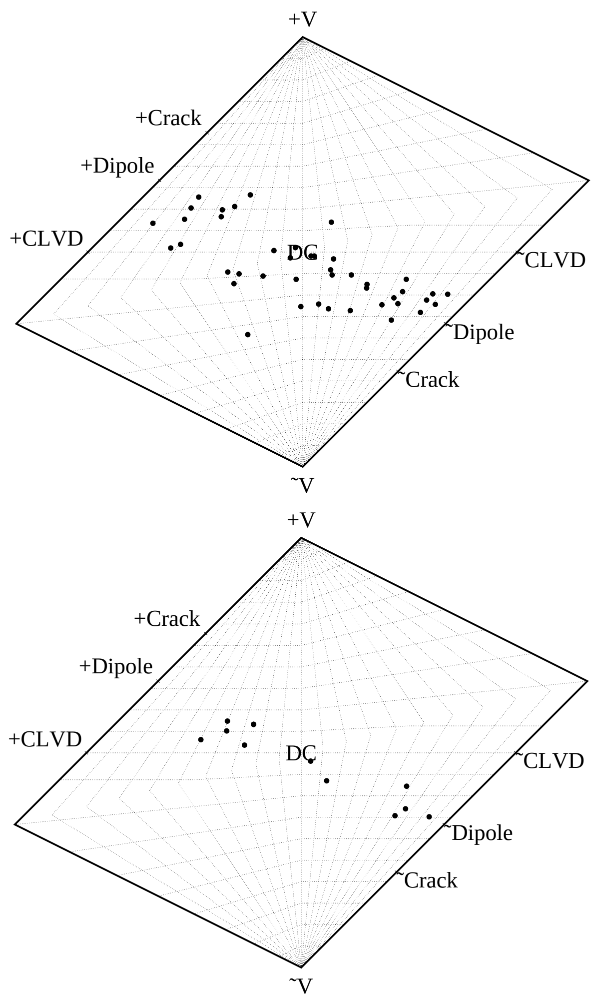


Figure 9: Top: Source types of earthquakes shallower than 1 km b.s.l., Bottom: Source types of earthquakes deeper than 1 km b.s.l.

Figure 10 shows a plot of the P-, T- and I-axes, approximately corresponding to the directions of σ_1, σ_3 and σ_2. The addition of more earthquakes has strengthened the distribution seen earlier. Most T axes cluster systematically subhorizontally and to the S ± 20˚ or so. The orientations of the P-axes show some clustering in a sub-horizontal orientation to the NNE-ENE directions.

Figure 11 shows P-, T-, and I-axes for the earthquakes that located deeper than 1 km only, i.e. events in the lower group identified in the relative locations. The distribution is similar, overall, to the events as a whole. This suggests that there is no evidence in the moment-tensor dataset obtained to date for a rotation of the stress axes with depth in the stimulated volume.

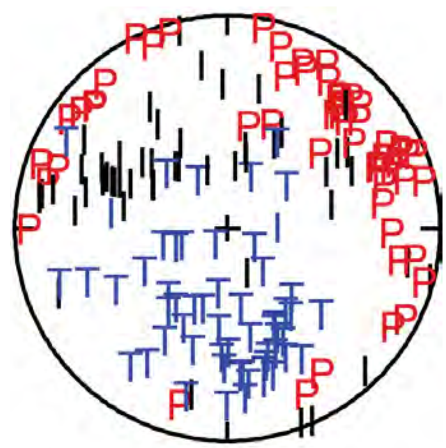


Figure 10: Plot of pressure (P ~ σ_1) and tension (T ~ σ_3) and intermediate (I ~ σ_2) axes for the 44 earthquakes for which moment tensors have been derived to date.

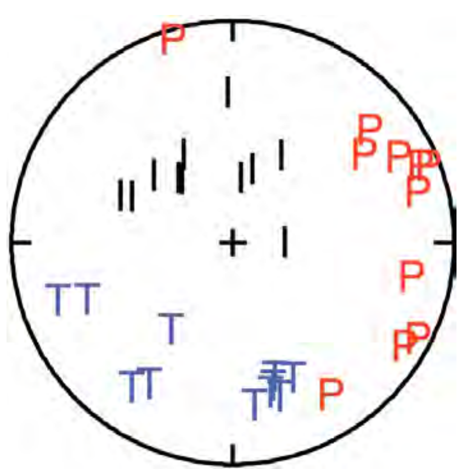


Figure 11: Plot of pressure (P ~ σ_1) and tension (T ~ σ_3) and intermediate (I ~ σ_2) axes for the 11 earthquakes for which moment tensors have been derived that were located deeper than 1 km depth.

6 Brief summary statement

During the last week, additional results were obtained for 10 more moment tensors. We are progressively deriving mechanisms for smaller events, but the quality of the results remains excellent in most cases. We added these additional events to our set of the highest-quality events for relative locations.

New results this week may be summarised:

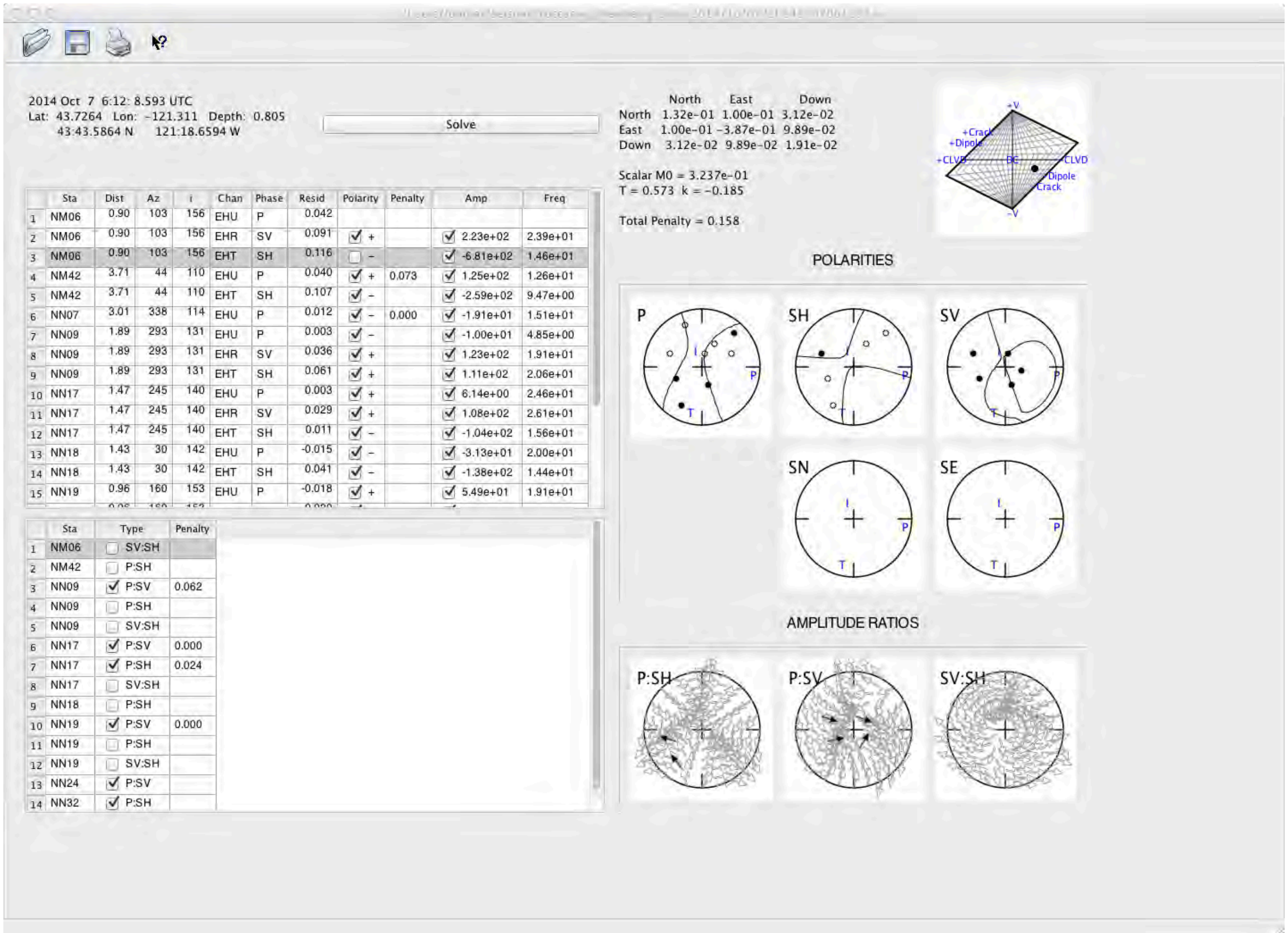
6. The addition of more, highly accurately measured and located earthquakes to the relative location set has revealed yet more fine detail. The pair of clusters identified earlier remains a stable feature, as does their clear separation by an essentially aseismic layer. The deeper cluster shows extraordinarily sharp focusing and appears to delineate an EW-trending plane and not a NW-trending plane as thought earlier. It appears to form part of the NW-trending zone observable in map view simply because it lies somewhat to the SE of the shallower cluster. The sharpness of the planar surface apparently delineated suggests that the relative locations may be accurate to a few meters, an unusually high-quality result. This interpretation also has support in the absolute locations which are suggestive of an EW orientation in the earthquakes of the deeper, more southerly cluster.
7. It is emphasised that relative location results will change with variation of run-time parameters and with the addition of more earthquakes to the set. The results described here appear to be stable as the run-time parameters are varied, but some changes may occur as the work progresses and the size of the dataset increases. The geometry of structures described here should thus be viewed as interim results.
8. The source types of the earthquakes for which moment tensors were derived continue to range from +Dipole to -Dipole.
9. A systematic variation in source type with time, during the three weeks of injection studied, is now visible in the growing data set. The proportion of crack-opening source types progressively reduces with time. During Week 1 about equal numbers of earthquakes were crack-opening and crack-closing types. The proportion of crack-opening events reduced to about 20% in Week 2 and in Week 3 none of the 9 moment tensors derived have a significant crack-opening component.
10. Variation in source-type with depth is also observed, with crack-opening source types more abundant and more extreme in the shallower cluster compared with the deeper cluster.
11. The patterns of orientation of the P-, T- and I-axes reported earlier continue to strengthen in confidence with the addition of more data. Possible variations in orientations between the shallower and the deeper cluster were sought, but no evidence could be found. This suggests that the orientation of stress axes is similar in both hypocentral volumes.

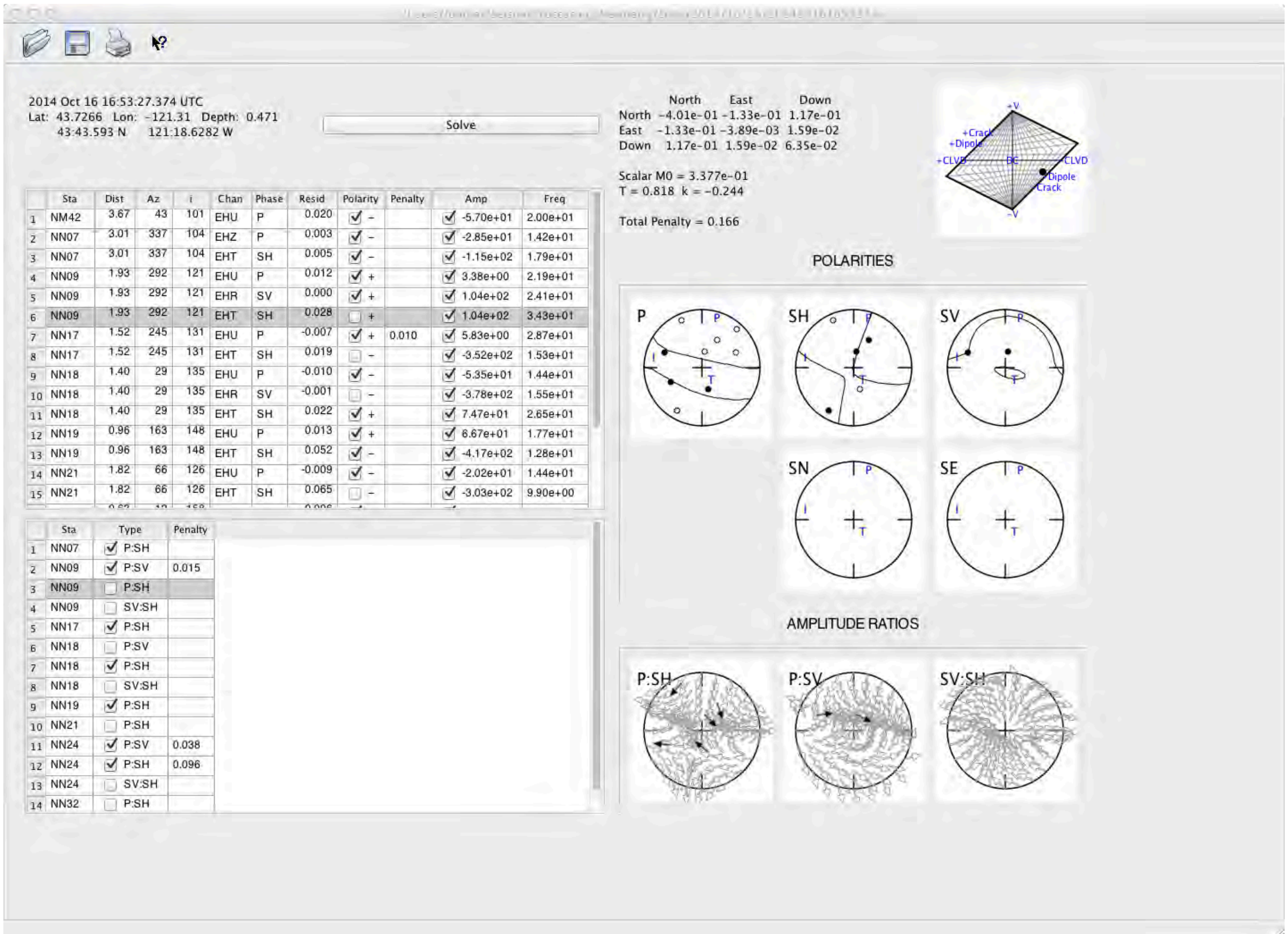
Appendix 1: Numerical moment tensor results for the 54 MEQs studied to date. N=North, E=East, D=Down.

NN	NE	EE	ND	ED	DD	Year	Mo	Day	Hr	min	Sec	Quality
1.578e-01	3.466e-02	6.671e-02	2.482e-01	6.317e-02	8.338e-02	2014	10	01	14	53	05.23	excellent
2.172e-01	-3.673e-02	-6.417e-02	2.346e-01	7.204e-02	3.184e-02	2014	10	01	19	05	16.54	excellent
8.713e-02	1.262e-01	-4.193e-02	1.814e-01	8.429e-02	8.722e-02	2014	10	04	18	51	12.00	excellent
-1.029e-01	1.325e-01	-1.185e-01	1.480e-01	5.508e-02	1.074e-01	2014	10	04	17	32	52.76	excellent
-1.165e-01	1.705e-01	-1.989e-01	1.394e-01	-2.430e-02	1.639e-02	2014	10	02	07	07	04.16	excellent
2.406e-01	-7.298e-02	-9.789e-02	1.731e-01	4.297e-02	8.349e-02	2014	10	02	11	01	42.38	excellent
-1.461e-02	9.643e-02	-3.978e-01	2.595e-02	1.691e-01	-4.693e-03	2014	10	02	06	47	52.94	excellent
6.066e-03	-2.231e-01	-9.157e-02	1.941e-01	3.367e-02	-6.184e-04	2014	10	03	06	06	22.76	excellent
-5.772e-02	-1.655e-01	-1.427e-01	1.464e-01	7.811e-02	-1.952e-02	2014	10	03	18	54	53.93	fair
2.004e-01	-1.410e-01	-1.461e-01	1.400e-01	-8.713e-03	7.412e-02	2014	10	01	12	03	16.94	good
5.304e-02	6.783e-02	-1.175e-01	1.615e-01	7.508e-02	2.206e-01	2014	10	05	04	07	20	excellent
-1.777e-01	-1.053e-01	-1.512e-01	7.111e-02	1.063e-01	1.057e-01	2014	10	01	01	03	14.49	excellent
-2.667e-01	1.320e-01	-6.399e-02	6.063e-02	1.031e-01	7.787e-02	2014	09	30	21	30	43.503	excellent
-1.871e-01	8.995e-02	-9.473e-02	-1.446e-01	-2.491e-02	1.992e-01	2014	10	05	23	22	16.499	good
1.684e-01	-3.350e-02	-9.826e-03	2.952e-01	3.542e-02	9.350e-02	2014	10	04	05	29	08.258	fair
2.449e-01	-8.111e-02	-1.972e-01	1.741e-01	1.624e-02	1.507e-02	2014	10	03	15	27	57.661	good
-2.209e-01	-8.132e-02	-2.190e-02	-1.520e-01	3.521e-02	2.201e-01	2014	10	01	16	56	11.343	good
1.477e-01	-1.175e-01	-1.492e-01	1.577e-01	-3.130e-02	9.546e-02	2014	10	01	08	08	57.998	excellent
-3.263e-02	2.220e-01	-3.373e-01	1.644e-02	7.162e-02	9.879e-03	2014	10	01	10	50	55.107	excellent
-1.038e-01	1.463e-01	-2.541e-01	1.246e-01	-1.332e-02	7.335e-02	2014	10	01	15	01	54.950	excellent
2.306e-03	-1.802e-01	-9.214e-02	2.203e-01	-4.354e-03	9.593e-02	2014	10	02	18	54	03.152	good
1.619e-01	4.200e-02	-2.041e-01	2.158e-01	-2.044e-02	7.759e-02	2014	10	02	06	39	02.998	excellent
-6.570e-02	-1.851e-01	-1.140e-01	1.691e-01	4.183e-02	2.826e-02	2014	10	02	12	39	24.317	good
1.420e-01	-1.373e-01	-1.638e-01	1.721e-01	1.076e-02	5.384e-02	2014	10	02	20	37	06.043	good
-1.365e-01	-1.837e-01	-5.911e-02	1.611e-01	-1.124e-02	9.224e-02	2014	10	05	02	06	16.967	excellent
2.866e-01	-3.707e-02	-1.787e-01	9.263e-02	1.263e-01	2.268e-02	2014	10	05	16	07	32.777	excellent
-2.286e-01	1.607e-01	-7.209e-02	-9.281e-02	8.007e-02	-3.216e-02	2014	10	05	15	55	21.007	good
-1.352e-01	-1.174e-01	-4.098e-02	1.996e-01	-5.345e-02	8.302e-02	2014	10	12	10	12	29	good
-2.211e-01	1.542e-01	4.959e-02	9.042e-02	8.191e-02	7.603e-02	2014	10	12	21	10	23.311	good
-4.882e-01	-1.017e-01	5.620e-02	5.965e-02	-1.844e-03	1.292e-01	2014	10	12	16	37	43.287	excellent

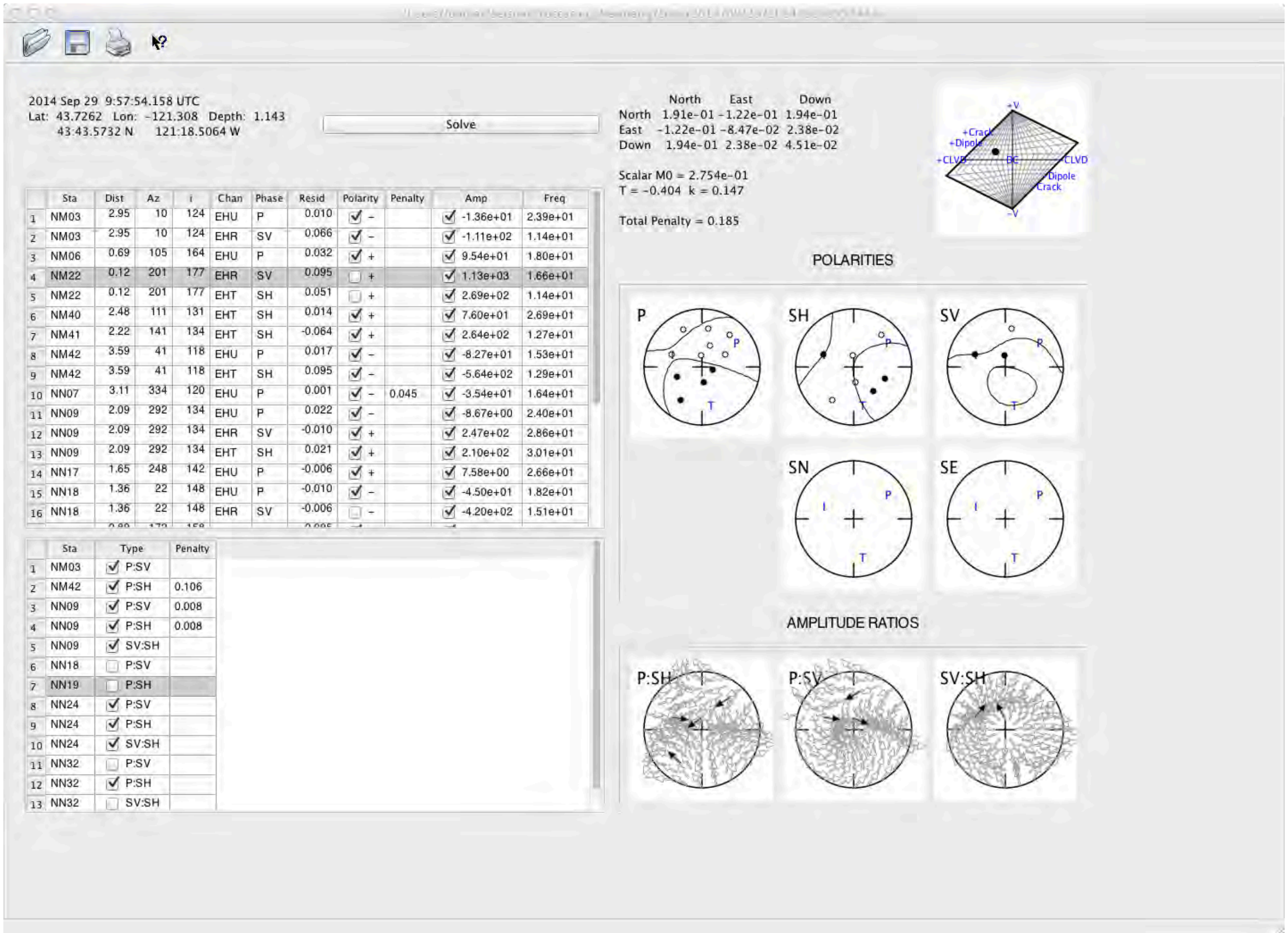
-5.873e-02	-1.252e-01	-2.804e-01	6.116e-02	1.409e-01	6.331e-03	2014	10	13	00	57	06.717	good
2.607e-02	-1.181e-01	-2.888e-01	8.025e-02	1.234e-01	4.154e-02	2014	10	13	04	12	29.126	excellent
-1.162e-01	-1.387e-01	-1.174e-01	1.514e-01	5.536e-02	7.558e-02	2014	10	13	10	22	29.084	excellent
-1.128e-01	-2.729e-02	-2.406e-01	5.661e-02	5.175e-02	3.753e-01	2014	10	14	05	46	13.914	exellent
-5.101e-02	-1.756e-01	-8.505e-02	1.953e-01	1.276e-03	1.195e-01	2014	10	15	15	37	25.945	excellent
-1.267e-01	-1.699e-01	3.343e-02	1.566e-01	-5.422e-02	7.857e-02	2014	10	15	15	03	44.602	excellent
6.492e-02	-9.495e-02	-2.842e-01	6.736e-02	1.452e-01	-3.577e-02	2014	09	30	09	23	48.626	good
-1.426e-01	-1.356e-01	3.347e-03	1.557e-01	-5.829e-02	1.550e-01	2014	10	11	03	29	05.667	good
3.707e-03	3.866e-02	-3.573e-01	5.614e-02	2.090e-01	2.164e-02	2014	10	11	10	53	26.502	good
4.380e-02	2.443e-01	-1.804e-01	4.365e-02	9.993e-02	-2.176e-05	2014	10	07	10	47	20.916	good
2.443e-02	7.095e-02	-2.428e-02	-8.639e-02	-1.620e-01	3.127e-01	2014	10	09	06	24	33.418	excellent
-4.203e-02	-1.463e-01	-3.196e-01	-5.380e-04	1.433e-01	5.826e-02	2014	10	18	23	57	03.695	good
-1.860e-01	8.584e-02	-2.758e-01	1.397e-01	-1.349e-02	6.014e-02	2014	10	19	09	07	50.325	good
2.027e-01	-2.424e-02	-3.047e-01	1.709e-01	-4.330e-02	1.575e-02	2014	10	12	18	33	04.693	moderate
1.319e-01	1.004e-01	-3.874e-01	3.120e-02	9.894e-02	1.908e-02	2014	10	07	06	12	08.593	good
-4.011e-01	-1.326e-01	-3.893e-03	1.173e-01	1.595e-02	6.345e-02	2014	10	16	16	53	27.374	good
7.443e-02	8.687e-02	-6.603e-02	-1.453e-01	-9.859e-02	1.981e-01	2014	10	09	10	16	09.945	moderate
1.913e-01	-1.220e-01	-8.473e-02	1.936e-01	2.385e-02	4.506e-02	2014	09	29	09	57	54.158	excellent
4.999e-02	-1.926e-01	-1.244e-01	1.754e-01	2.482e-02	3.990e-02	2014	09	29	18	03	37.660	excellent
4.020e-02	-1.230e-01	-2.565e-01	1.610e-01	1.968e-02	9.601e-02	2014	10	12	16	47	01.137	excellent
-2.448e-02	-1.879e-01	-1.233e-01	1.689e-01	9.679e-03	1.193e-01	2014	10	05	02	14	37.168	excellent
-8.061e-02	-9.300e-02	-2.670e-01	6.013e-02	1.629e-01	-2.038e-02	2014	10	06	04	02	55.789	good
-2.166e-01	-2.314e-01	4.005e-02	5.036e-02	7.205e-02	3.578e-02	2014	10	02	16	12	35.315	weak
-3.561e-01	1.589e-01	1.186e-01	5.145e-02	2.877e-02	4.702e-02	2014	10	06	06	13	48.626	excellent

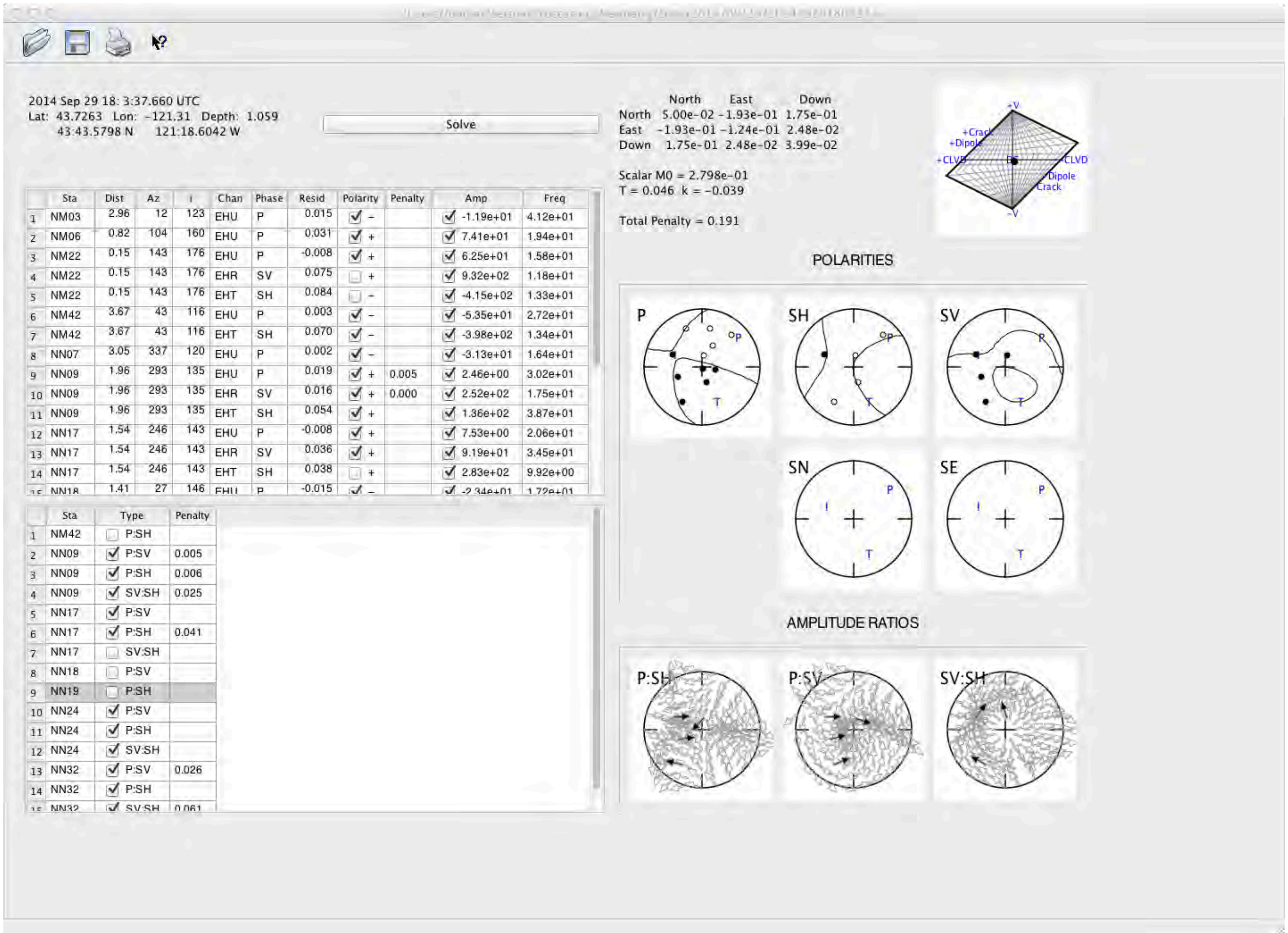
Appendix 2: The additional nine moment tensors derived over the reporting week.

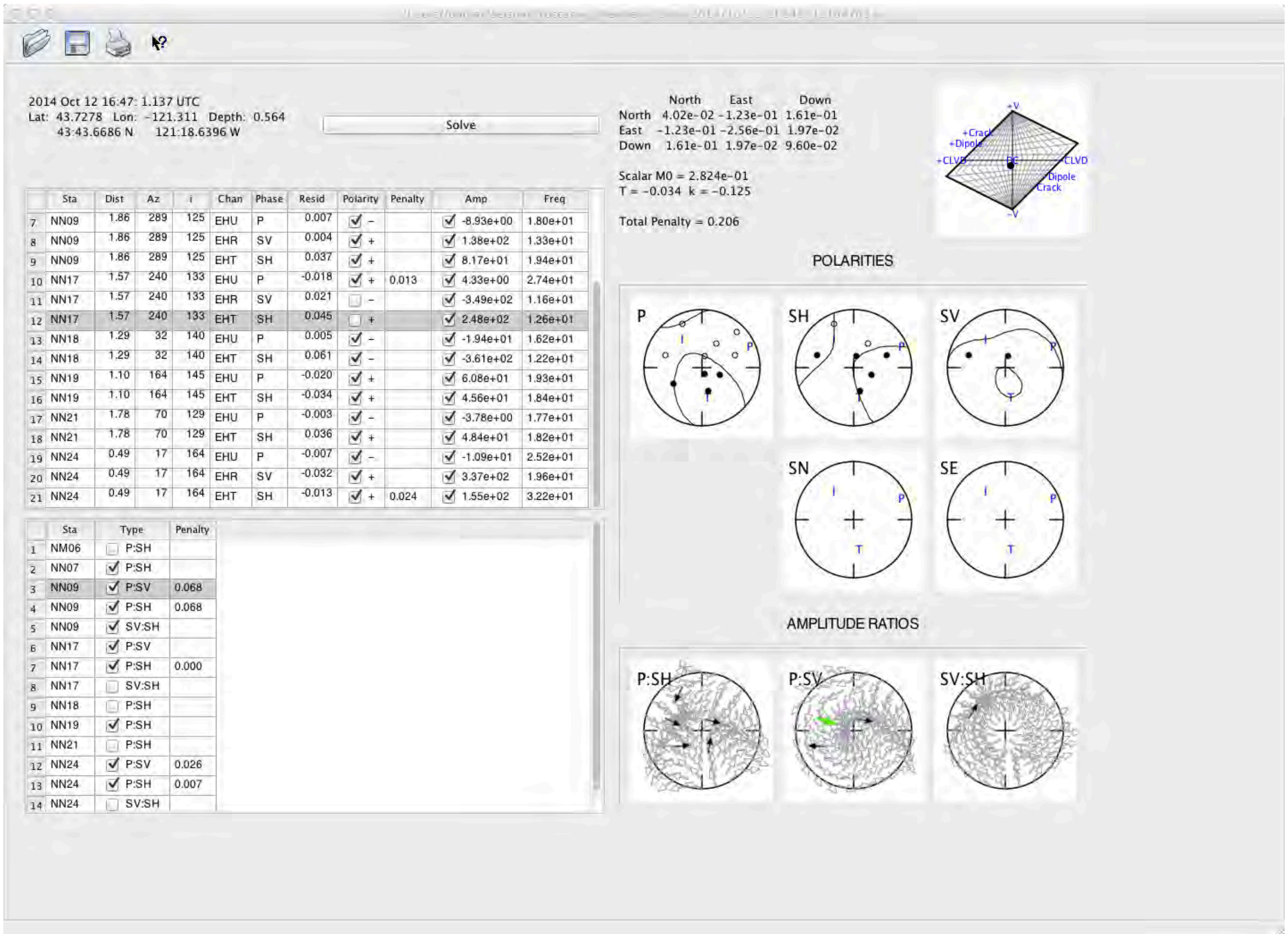

Solve
2014 Oct 7 6:12: 8.593 UTC
Lat: 43.7264 Lon: -121.311 Depth: 0.805
43:43.5864 N 121:18.6594 W
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM06 0.90 103 156 EHU P 0.042
2 NM06 0.90 103 156 EHR SV 0.091 + 2.23e+02 2.39e+01
3 NM06 0.90 103 156 EHT SH 0.116 - -6.81e+02 1.46e+01
4 NM42 3.71 44 110 EHU P 0.040 + 0.073 1.25e+02 1.26e+01
5 NM42 3.71 44 110 EHT SH 0.107 - -2.59e+02 9.47e+00
6 NN07 3.01 338 114 EHU P 0.012 - 0.000 -1.91e+01 1.51e+01
7 NN09 1.89 293 131 EHU P 0.003 - -1.00e+01 4.85e+00
8 NN09 1.89 293 131 EHR SV 0.036 + 1.23e+02 1.91e+01
9 NN09 1.89 293 131 EHT SH 0.061 + 1.11e+02 2.06e+01
10 NN17 1.47 245 140 EHU P 0.003 + 6.14e+00 2.46e+01
11 NN17 1.47 245 140 EHR SV 0.029 + 1.08e+02 2.61e+01
12 NN17 1.47 245 140 EHT SH 0.011 - -1.04e+02 1.56e+01
13 NN18 1.43 30 142 EHU P -0.015 - -3.13e+01 2.00e+01
14 NN18 1.43 30 142 EHT SH 0.041 - -1.38e+02 1.44e+01
15 NN19 0.96 160 153 EHU P -0.018 + 5.49e+01 1.91e+01
Sta Type Penalty
1 NM06 SV:SH
2 NM42 P:SH
3 NN09 P:SV 0.062
4 NN09 P:SH
5 NN09 SV:SH
6 NN17 P:SV 0.000
7 NN17 P:SH 0.024
8 NN17 SV:SH
9 NN18 P:SH
10 NN19 P:SV 0.000
11 NN19 P:SH
12 NN19 SV:SH
13 NN24 P:SV
14 NN32 P:SH
North East Down
North 1.32e-01 1.00e-01 3.12e-02
East 1.00e-01 -3.87e-01 9.89e-02
Down 3.12e-02 9.89e-02 1.91e-02
Scalar M0 = 3.237e-01
T = 0.573 k = -0.185
Total Penalty = 0.158
+V
+Crack
+Dipole
+CLVD
DC
-CLVD
-Dipole
-Crack
-V
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH

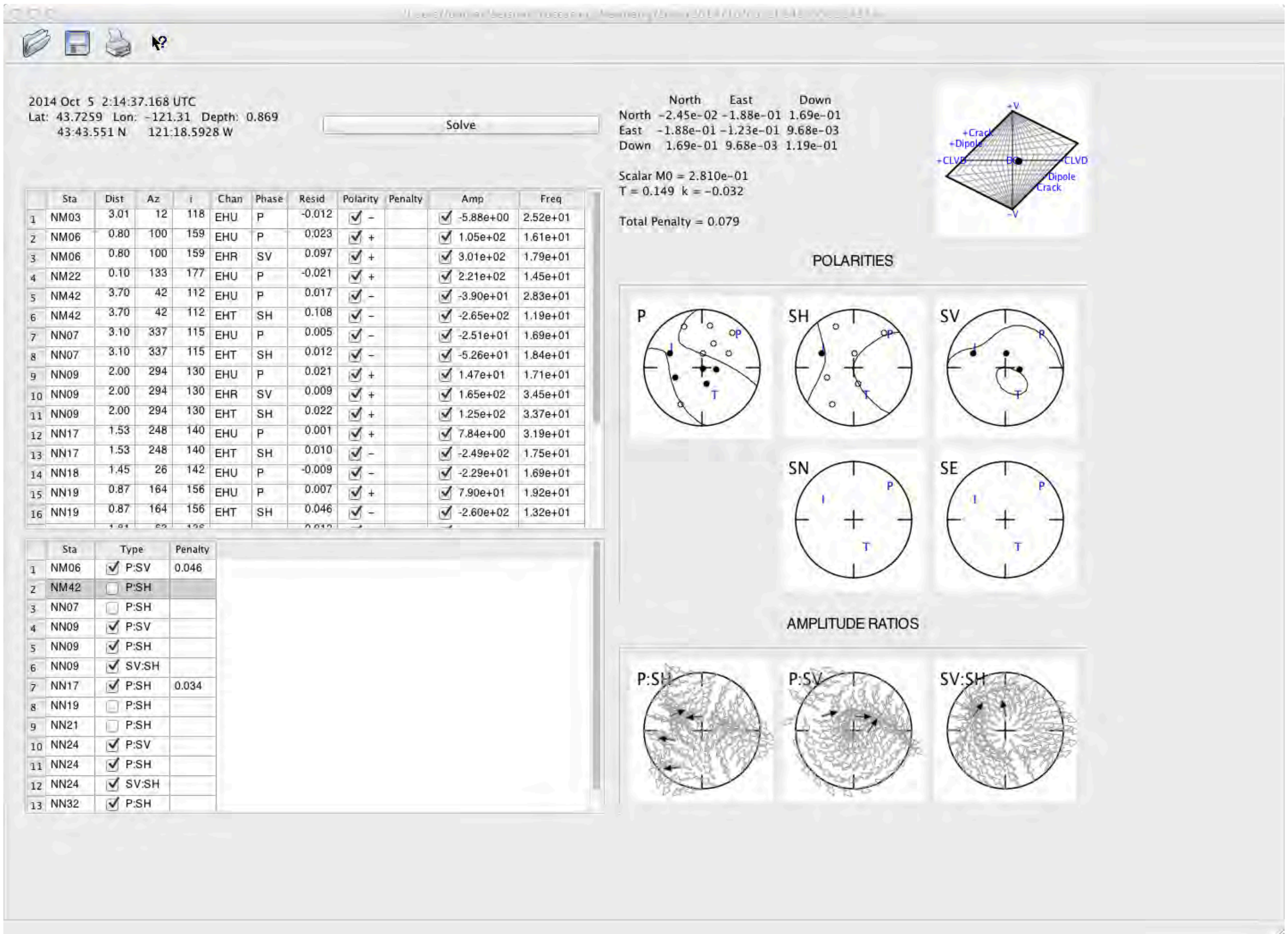

Solve
2014 Oct 16 16:53:27.374 UTC
Lat: 43.7266 Lon: -121.31 Depth: 0.471
43:43.593 N 121:18.6282 W
North East Down
North -4.01e-01 -1.33e-01 1.17e-01
East -1.33e-01 -3.89e-03 1.59e-02
Down 1.17e-01 1.59e-02 6.35e-02
Scalar M0 = 3.377e-01
T = 0.818 k = -0.244
Total Penalty = 0.166
+V
+Crack
+Dipole
+CLVD
DC
-CLVD
-Dipole
-Crack
-V
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM42 3.67 43 101 EHU P 0.020 - -5.70e+01 2.00e+01
2 NN07 3.01 337 104 EHZ P 0.003 - -2.85e+01 1.42e+01
3 NN07 3.01 337 104 EHT SH 0.005 - -1.15e+02 1.79e+01
4 NN09 1.93 292 121 EHU P 0.012 + 3.38e+00 2.19e+01
5 NN09 1.93 292 121 EHR SV 0.000 + 1.04e+02 2.41e+01
6 NN09 1.93 292 121 EHT SH 0.028 + 1.04e+02 3.43e+01
7 NN17 1.52 245 131 EHU P -0.007 + 0.010 5.83e+00 2.87e+01
8 NN17 1.52 245 131 EHT SH 0.019 - -3.52e+02 1.53e+01
9 NN18 1.40 29 135 EHU P -0.010 - -5.35e+01 1.44e+01
10 NN18 1.40 29 135 EHR SV -0.001 - -3.78e+02 1.55e+01
11 NN18 1.40 29 135 EHT SH 0.022 + 7.47e+01 2.65e+01
12 NN19 0.96 163 148 EHU P 0.013 + 6.67e+01 1.77e+01
13 NN19 0.96 163 148 EHT SH 0.052 - -4.17e+02 1.28e+01
14 NN21 1.82 66 126 EHU P -0.009 - -2.02e+01 1.44e+01
15 NN21 1.82 66 126 EHT SH 0.065 - -3.03e+02 9.90e+00
Sta Type Penalty
1 NN07 P:SH
2 NN09 P:SV 0.015
3 NN09 P:SH
4 NN09 SV:SH
5 NN17 P:SH
6 NN18 P:SV
7 NN18 P:SH
8 NN18 SV:SH
9 NN19 P:SH
10 NN21 P:SH
11 NN24 P:SV 0.038
12 NN24 P:SH 0.096
13 NN24 SV:SH
14 NN32 P:SH
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH

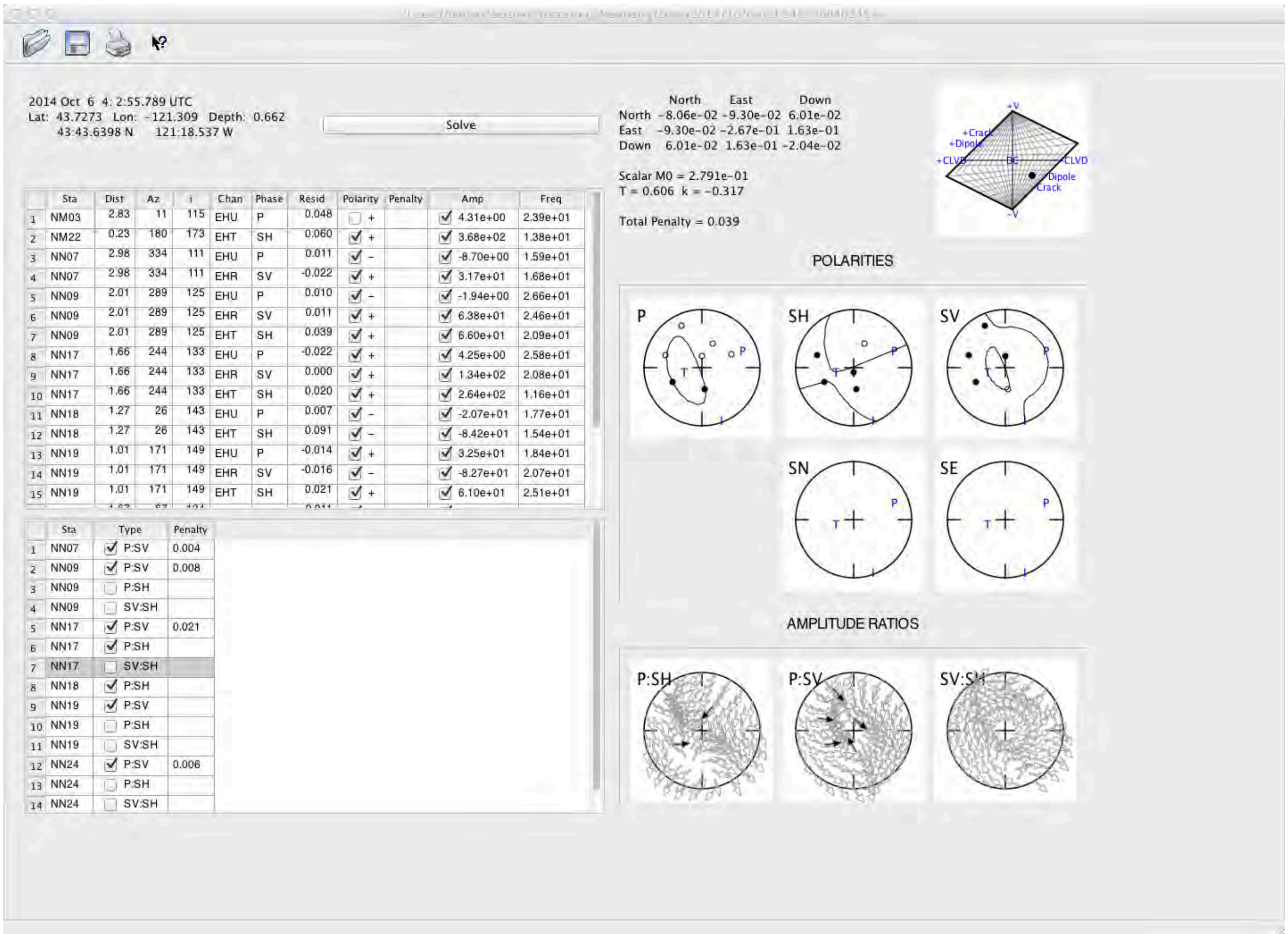

2014 Oct 9 10:16: 9.945 UTC
Lat: 43.7262 Lon: -121.311 Depth: 0.847
43:43.5744 N 121:18.6756 W
Solve
North East Down
North 7.44e-02 8.69e-02 -1.45e-01
East 8.69e-02 -6.60e-02 -9.86e-02
Down -1.45e-01 -9.86e-02 1.98e-01
Scalar M0 = 2.509e-01
T = -0.652 k = 0.205
Total Penalty = 0.068
+V
+Crack
+Dipole
+CLVD
DC
-CLVD
-Dipole
-Crack
-V
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM03 2.99 14 118 EHU P 0.019 + 1.17e+01 2.20e+01
2 NM06 0.92 102 156 EHU P 0.013 + 1.38e+02 1.40e+01
3 NM06 0.92 102 156 EHT SH 0.120 – -5.78e+02 1.84e+01
4 NM42 3.74 44 111 EHU P 0.049 + 1.35e+02 1.47e+01
5 NM42 3.74 44 111 EHT SH 0.030 – -2.54e+02 5.90e+00
6 NN07 3.02 338 115 EHU P 0.002 – -1.90e+01 1.80e+01
7 NN07 3.02 338 115 EHT SH -0.002 – -5.16e+01 2.29e+01
8 NN17 1.44 245 141 EHU P -0.004 + 0.018 6.21e+00 3.06e+01
9 NN17 1.44 245 141 EHR SV 0.034 + 2.41e+01 3.18e+01
10 NN17 1.44 245 141 EHT SH 0.014 – 0.001 -1.97e+02 1.55e+01
11 NN18 1.46 30 142 EHU P -0.029 – -2.73e+01 1.78e+01
12 NN18 1.46 30 142 EHR SV -0.051 – -2.90e+02 1.30e+01
13 NN18 1.46 30 142 EHT SH 0.022 – -1.06e+02 1.39e+01
14 NN19 0.95 158 154 EHU P -0.001 + 4.99e+01 1.93e+01
15 NN19 0.95 158 154 EHT SH 0.043 – -2.49e+02 1.23e+01
Sta Type Penalty
1 NM06 P:SH 0.031
2 NM42 P:SH
3 NN07 P:SH
4 NN17 P:SV
5 NN17 P:SH 0.018
6 NN17 SV:SH
7 NN18 P:SV
8 NN18 P:SH
9 NN18 SV:SH
10 NN19 P:SH
11 NN21 P:SH
12 NN32 P:SV
13 NN32 P:SH
14 NN32 SV:SH
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH

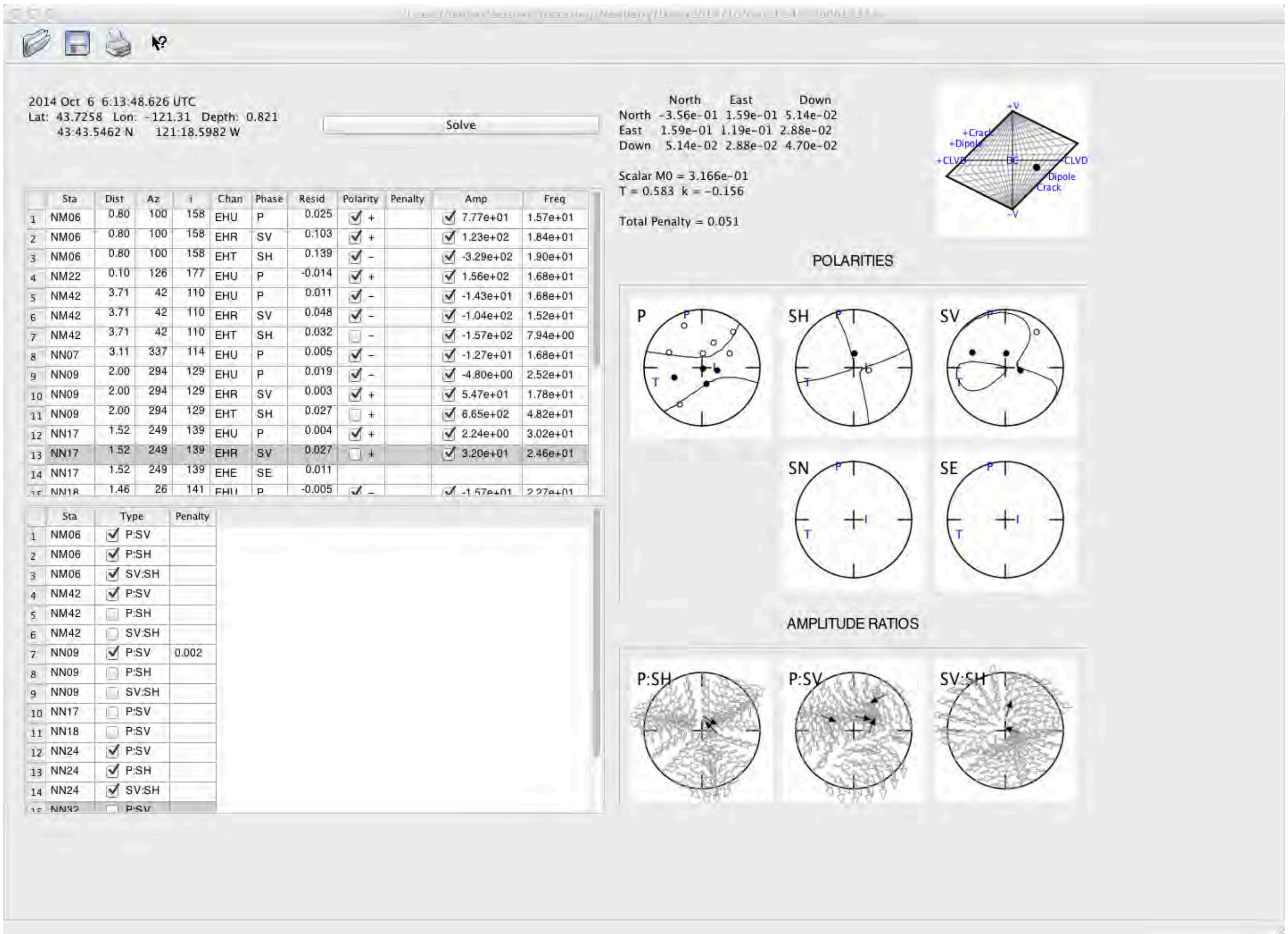

2014 Sep 29 9:57:54.158 UTC
Lat: 43.7262 Lon: -121.308 Depth: 1.143
43:43.5732 N 121:18.5064 W
Solve
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM03 2.95 10 124 EHU P 0.010 - -1.36e+01 2.39e+01
2 NM03 2.95 10 124 EHR SV 0.066 - -1.11e+02 1.14e+01
3 NM06 0.69 105 164 EHU P 0.032 + 9.54e+01 1.80e+01
4 NM22 0.12 201 177 EHR SV 0.095 + 1.13e+03 1.66e+01
5 NM22 0.12 201 177 EHT SH 0.051 + 2.69e+02 1.14e+01
6 NM40 2.48 111 131 EHT SH 0.014 + 7.60e+01 2.69e+01
7 NM41 2.22 141 134 EHT SH -0.064 + 2.64e+02 1.27e+01
8 NM42 3.59 41 118 EHU P 0.017 - -8.27e+01 1.53e+01
9 NM42 3.59 41 118 EHT SH 0.095 - -5.64e+02 1.29e+01
10 NN07 3.11 334 120 EHU P 0.001 - 0.045 -3.54e+01 1.64e+01
11 NN09 2.09 292 134 EHU P 0.022 - -8.67e+00 2.40e+01
12 NN09 2.09 292 134 EHR SV -0.010 + 2.47e+02 2.86e+01
13 NN09 2.09 292 134 EHT SH 0.021 + 2.10e+02 3.01e+01
14 NN17 1.65 248 142 EHU P -0.006 + 7.58e+00 2.66e+01
15 NN18 1.36 22 148 EHU P -0.010 - -4.50e+01 1.82e+01
16 NN18 1.36 22 148 EHR SV -0.006 - -4.20e+02 1.51e+01
Sta Type Penalty
1 NM03 P:SV
2 NM42 P:SH 0.106
3 NN09 P:SV 0.008
4 NN09 P:SH 0.008
5 NN09 SV:SH
6 NN18 P:SV
7 NN19 P:SH
8 NN24 P:SV
9 NN24 P:SH
10 NN24 SV:SH
11 NN32 P:SV
12 NN32 P:SH
13 NN32 SV:SH
North East Down
North 1.91e-01 -1.22e-01 1.94e-01
East -1.22e-01 -8.47e-02 2.38e-02
Down 1.94e-01 2.38e-02 4.51e-02
Scalar M0 = 2.754e-01
T = -0.404 k = 0.147
Total Penalty = 0.185
+V
+Crack
+Dipole
+CLVD
DC
-CLVD
-Dipole
-Crack
-V
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH

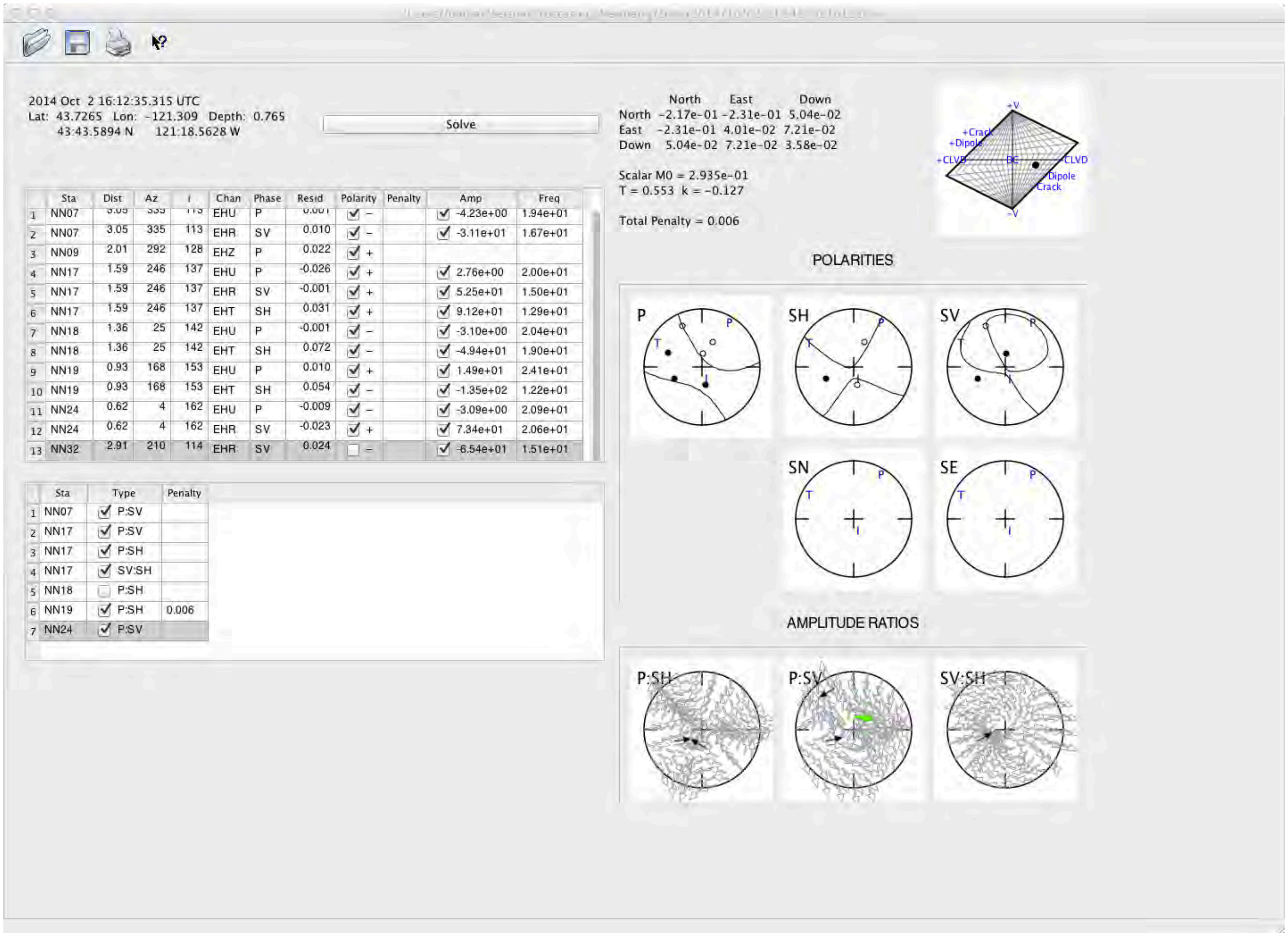

2014 Sep 29 18: 3:37.660 UTC
Lat: 43.7263 Lon: -121.31 Depth: 1.059
43:43.5798 N 121:18.6042 W
Solve
North East Down
North 5.00e-02 -1.93e-01 1.75e-01
East -1.93e-01 -1.24e-01 2.48e-02
Down 1.75e-01 2.48e-02 3.99e-02
Scalar M0 = 2.798e-01
T = 0.046 k = -0.039
Total Penalty = 0.191
+V
+Crack
+Dipole
+CLVD
CLVD
Dipole
Crack
-V
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM03 2.96 12 123 EHU P 0.015 - -1.19e+01 4.12e+01
2 NM06 0.82 104 160 EHU P 0.031 + 7.41e+01 1.94e+01
3 NM22 0.15 143 176 EHU P -0.008 + 6.25e+01 1.58e+01
4 NM22 0.15 143 176 EHR SV 0.075 + 9.32e+02 1.18e+01
5 NM22 0.15 143 176 EHT SH 0.084 - -4.15e+02 1.33e+01
6 NM42 3.67 43 116 EHU P 0.003 - -5.35e+01 2.72e+01
7 NM42 3.67 43 116 EHT SH 0.070 - -3.98e+02 1.34e+01
8 NN07 3.05 337 120 EHU P 0.002 - -3.13e+01 1.64e+01
9 NN09 1.96 293 135 EHU P 0.019 + 0.005 2.46e+00 3.02e+01
10 NN09 1.96 293 135 EHR SV 0.016 + 0.000 2.52e+02 1.75e+01
11 NN09 1.96 293 135 EHT SH 0.054 + 1.36e+02 3.87e+01
12 NN17 1.54 246 143 EHU P -0.008 + 7.53e+00 2.06e+01
13 NN17 1.54 246 143 EHR SV 0.036 + 9.19e+01 3.45e+01
14 NN17 1.54 246 143 EHT SH 0.038 + 2.83e+02 9.92e+00
Sta Type Penalty
1 NM42 P:SH
2 NN09 P:SV 0.005
3 NN09 P:SH 0.006
4 NN09 SV:SH 0.025
5 NN17 P:SV
6 NN17 P:SH 0.041
7 NN17 SV:SH
8 NN18 P:SV
9 NN19 P:SH
10 NN24 P:SV
11 NN24 P:SH
12 NN24 SV:SH
13 NN32 P:SV 0.026
14 NN32 P:SH
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH


2014 Oct 12 16:47: 1.137 UTC
Lat: 43.7278 Lon: -121.311 Depth: 0.564
43:43.6686 N 121:18.6396 W
Solve
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
7 NN09 1.86 289 125 EHU P 0.007 - -8.93e+00 1.80e+01
8 NN09 1.86 289 125 EHR SV 0.004 + 1.38e+02 1.33e+01
9 NN09 1.86 289 125 EHT SH 0.037 + 8.17e+01 1.94e+01
10 NN17 1.57 240 133 EHU P -0.018 + 0.013 4.33e+00 2.74e+01
11 NN17 1.57 240 133 EHR SV 0.021 - -3.49e+02 1.16e+01
12 NN17 1.57 240 133 EHT SH 0.045 + 2.48e+02 1.26e+01
13 NN18 1.29 32 140 EHU P 0.005 - -1.94e+01 1.62e+01
14 NN18 1.29 32 140 EHT SH 0.061 - -3.61e+02 1.22e+01
15 NN19 1.10 164 145 EHU P -0.020 + 6.08e+01 1.93e+01
16 NN19 1.10 164 145 EHT SH -0.034 + 4.56e+01 1.84e+01
17 NN21 1.78 70 129 EHU P -0.003 - -3.78e+00 1.77e+01
18 NN21 1.78 70 129 EHT SH 0.036 + 4.84e+01 1.82e+01
19 NN24 0.49 17 164 EHU P -0.007 - -1.09e+01 2.52e+01
20 NN24 0.49 17 164 EHR SV -0.032 + 3.37e+02 1.96e+01
21 NN24 0.49 17 164 EHT SH -0.013 + 0.024 1.55e+02 3.22e+01
Sta Type Penalty
1 NM06 P:SH
2 NN07 P:SH
3 NN09 P:SV 0.068
4 NN09 P:SH 0.068
5 NN09 SV:SH
6 NN17 P:SV
7 NN17 P:SH 0.000
8 NN17 SV:SH
9 NN18 P:SH
10 NN19 P:SH
11 NN21 P:SH
12 NN24 P:SV 0.026
13 NN24 P:SH 0.007
14 NN24 SV:SH
North East Down
North 4.02e-02 -1.23e-01 1.61e-01
East -1.23e-01 -2.56e-01 1.97e-02
Down 1.61e-01 1.97e-02 9.60e-02
Scalar M0 = 2.824e-01
T = -0.034 k = -0.125
Total Penalty = 0.206
+V
+Crack
+Dipole
+CLVD
DC
-CLVD
-Dipole
-Crack
-V
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH


2014 Oct 5 2:14:37.168 UTC
Lat: 43.7259 Lon: -121.31 Depth: 0.869
43:43.551 N 121:18.5928 W
Solve
North East Down
North -2.45e-02 -1.88e-01 1.69e-01
East -1.88e-01 -1.23e-01 9.68e-03
Down 1.69e-01 9.68e-03 1.19e-01
Scalar M0 = 2.810e-01
T = 0.149 k = -0.032
Total Penalty = 0.079
+V
+Crack
+Dipole
+CLVD
-CLVD
-Dipole
-Crack
-V
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM03 3.01 12 118 EHU P -0.012 - -5.88e+00 2.52e+01
2 NM06 0.80 100 159 EHU P 0.023 + 1.05e+02 1.61e+01
3 NM06 0.80 100 159 EHR SV 0.097 + 3.01e+02 1.79e+01
4 NM22 0.10 133 177 EHU P -0.021 + 2.21e+02 1.45e+01
5 NM42 3.70 42 112 EHU P 0.017 - -3.90e+01 2.83e+01
6 NM42 3.70 42 112 EHT SH 0.108 - -2.65e+02 1.19e+01
7 NN07 3.10 337 115 EHU P 0.005 - -2.51e+01 1.69e+01
8 NN07 3.10 337 115 EHT SH 0.012 - -5.26e+01 1.84e+01
9 NN09 2.00 294 130 EHU P 0.021 + 1.47e+01 1.71e+01
10 NN09 2.00 294 130 EHR SV 0.009 + 1.65e+02 3.45e+01
11 NN09 2.00 294 130 EHT SH 0.022 + 1.25e+02 3.37e+01
12 NN17 1.53 248 140 EHU P 0.001 + 7.84e+00 3.19e+01
13 NN17 1.53 248 140 EHT SH 0.010 - -2.49e+02 1.75e+01
14 NN18 1.45 26 142 EHU P -0.009 - -2.29e+01 1.69e+01
15 NN19 0.87 164 156 EHU P 0.007 + 7.90e+01 1.92e+01
16 NN19 0.87 164 156 EHT SH 0.046 - -2.60e+02 1.32e+01
Sta Type Penalty
1 NM06 P:SV 0.046
2 NM42 P:SH
3 NN07 P:SH
4 NN09 P:SV
5 NN09 P:SH
6 NN09 SV:SH
7 NN17 P:SH 0.034
8 NN19 P:SH
9 NN21 P:SH
10 NN24 P:SV
11 NN24 P:SH
12 NN24 SV:SH
13 NN32 P:SH
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH


2014 Oct 6 4: 2:55.789 UTC
Lat: 43.7273 Lon: -121.309 Depth: 0.662
43:43.6398 N 121:18.537 W
Solve
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM03 2.83 11 115 EHU P 0.048 + 4.31e+00 2.39e+01
2 NM22 0.23 180 173 EHT SH 0.060 + 3.68e+02 1.38e+01
3 NN07 2.98 334 111 EHU P 0.011 – -8.70e+00 1.59e+01
4 NN07 2.98 334 111 EHR SV -0.022 + 3.17e+01 1.68e+01
5 NN09 2.01 289 125 EHU P 0.010 – -1.94e+00 2.66e+01
6 NN09 2.01 289 125 EHR SV 0.011 + 6.38e+01 2.46e+01
7 NN09 2.01 289 125 EHT SH 0.039 + 6.60e+01 2.09e+01
8 NN17 1.66 244 133 EHU P -0.022 + 4.25e+00 2.58e+01
9 NN17 1.66 244 133 EHR SV 0.000 + 1.34e+02 2.08e+01
10 NN17 1.66 244 133 EHT SH 0.020 + 2.64e+02 1.16e+01
11 NN18 1.27 26 143 EHU P 0.007 – -2.07e+01 1.77e+01
12 NN18 1.27 26 143 EHT SH 0.091 – -8.42e+01 1.54e+01
13 NN19 1.01 171 149 EHU P -0.014 + 3.25e+01 1.84e+01
14 NN19 1.01 171 149 EHR SV -0.016 – -8.27e+01 2.07e+01
15 NN19 1.01 171 149 EHT SH 0.021 + 6.10e+01 2.51e+01
Sta Type Penalty
1 NN07 P:SV 0.004
2 NN09 P:SV 0.008
3 NN09 P:SH
4 NN09 SV:SH
5 NN17 P:SV 0.021
6 NN17 P:SH
7 NN17 SV:SH
8 NN18 P:SH
9 NN19 P:SV
10 NN19 P:SH
11 NN19 SV:SH
12 NN24 P:SV 0.006
13 NN24 P:SH
14 NN24 SV:SH
North East Down
North -8.06e-02 -9.30e-02 6.01e-02
East -9.30e-02 -2.67e-01 1.63e-01
Down 6.01e-02 1.63e-01 -2.04e-02
Scalar M0 = 2.791e-01
T = 0.606 k = -0.317
Total Penalty = 0.039
+V
+Crack
+Dipole
+CLVD
DC
-CLVD
-Dipole
-Crack
-V
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH


2014 Oct 6 6:13:48.626 UTC
Lat: 43.7258 Lon: -121.31 Depth: 0.821
43:43.5462 N 121:18.5982 W
Solve
North East Down
North -3.56e-01 1.59e-01 5.14e-02
East 1.59e-01 1.19e-01 2.88e-02
Down 5.14e-02 2.88e-02 4.70e-02
Scalar M0 = 3.166e-01
T = 0.583 k = -0.156
Total Penalty = 0.051
+V
+Crack
+Dipole
+CLVD
DC
-CLVD
-Dipole
-Crack
-V
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM06 0.80 100 158 EHU P 0.025 + 7.77e+01 1.57e+01
2 NM06 0.80 100 158 EHR SV 0.103 + 1.23e+02 1.84e+01
3 NM06 0.80 100 158 EHT SH 0.139 – -3.29e+02 1.90e+01
4 NM22 0.10 126 177 EHU P -0.014 + 1.56e+02 1.68e+01
5 NM42 3.71 42 110 EHU P 0.011 – -1.43e+01 1.68e+01
6 NM42 3.71 42 110 EHR SV 0.048 – -1.04e+02 1.52e+01
7 NM42 3.71 42 110 EHT SH 0.032 – -1.57e+02 7.94e+00
8 NN07 3.11 337 114 EHU P 0.005 – -1.27e+01 1.68e+01
9 NN09 2.00 294 129 EHU P 0.019 – -4.80e+00 2.52e+01
10 NN09 2.00 294 129 EHR SV 0.003 + 5.47e+01 1.78e+01
11 NN09 2.00 294 129 EHT SH 0.027 + 6.65e+02 4.82e+01
12 NN17 1.52 249 139 EHU P 0.004 + 2.24e+00 3.02e+01
13 NN17 1.52 249 139 EHR SV 0.027 + 3.20e+01 2.46e+01
14 NN17 1.52 249 139 EHE SE 0.011
15 NN18 1.46 26 141 EHU P -0.005 – -1.57e+01 2.27e+01
Sta Type Penalty
1 NM06 P:SV
2 NM06 P:SH
3 NM06 SV:SH
4 NM42 P:SV
5 NM42 P:SH
6 NM42 SV:SH
7 NN09 P:SV 0.002
8 NN09 P:SH
9 NN09 SV:SH
10 NN17 P:SV
11 NN18 P:SV
12 NN24 P:SV
13 NN24 P:SH
14 NN24 SV:SH
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH


2014 Oct 2 16:12:35.315 UTC
Lat: 43.7265 Lon: -121.309 Depth: 0.765
43:43.5894 N 121:18.5628 W
Solve
North East Down
North -2.17e-01 -2.31e-01 5.04e-02
East -2.31e-01 4.01e-02 7.21e-02
Down 5.04e-02 7.21e-02 3.58e-02
Scalar M0 = 2.935e-01
T = 0.553 k = -0.127
Total Penalty = 0.006
+V
+Crack
+Dipole
+CLVD
DC
-CLVD
-Dipole
-Crack
-V
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NN07 3.05 335 113 EHU P 0.001 − -4.23e+00 1.94e+01
2 NN07 3.05 335 113 EHR SV 0.010 − -3.11e+01 1.67e+01
3 NN09 2.01 292 128 EHZ P 0.022 +
4 NN17 1.59 246 137 EHU P -0.026 + 2.76e+00 2.00e+01
5 NN17 1.59 246 137 EHR SV -0.001 + 5.25e+01 1.50e+01
6 NN17 1.59 246 137 EHT SH 0.031 + 9.12e+01 1.29e+01
7 NN18 1.36 25 142 EHU P -0.001 − -3.10e+00 2.04e+01
8 NN18 1.36 25 142 EHT SH 0.072 − -4.94e+01 1.90e+01
9 NN19 0.93 168 153 EHU P 0.010 + 1.49e+01 2.41e+01
10 NN19 0.93 168 153 EHT SH 0.054 − -1.35e+02 1.22e+01
11 NN24 0.62 4 162 EHU P -0.009 − -3.09e+00 2.09e+01
12 NN24 0.62 4 162 EHR SV -0.023 + 7.34e+01 2.06e+01
13 NN32 2.91 210 114 EHR SV 0.024 − -6.54e+01 1.51e+01
Sta Type Penalty
1 NN07 P:SV
2 NN17 P:SV
3 NN17 P:SH
4 NN17 SV:SH
5 NN18 P:SH
6 NN19 P:SH 0.006
7 NN24 P:SV
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH

Foulger Consulting

1025 Paradise Way
Palo Alto, CA 943062637, USA
Tel: 650/4932553
Cell: 650/9968886
FAX: 866/5326907
gillian@foulgerconsulting.com
http://www.foulgerconsulting.com/

October 15, 2014

WEEKLY REPORT #2 TO ALTAROCK ENERGY INC.

PROCESSING OF INDUCED EARTHQUAKES ASSOCIATED WITH THE NEWBERRY EGS INJECTION STARTING SEPTEMBER 2014

GILLIAN R. FOULGER & BRUCE R. JULIAN

Brief summary

There are still some problems transferring data and working on these occupied considerable time during the last week. We derived an additional five moment tensors, most of which showed small to moderate volumetric components, approximately equally divided between crack-opening and crack-closing.

Plots of the different sets of locations available to date show systematic differences between the locations produced by different computer programs. Most events lie within a circle about 500 m in diameter and centered 100 to 200 m north of the bottom of well NWD 55-29. The most accurate absolute locations available to date are from the 15 events for which moment tensors have been derived. These events cluster tightly around the bottom of the well in the depth range 700 - 1200 m b.s.l.

There may be a tendency for the earthquakes to shallow slightly with time. This is apparent depth plots of both the entire catalog, and the moment-tensor events.

1 Task 1 – Planning, conference calls, discussion of work, correspondence, followup

We continued to maintain close communication with other team members, primarily ISTI (Paul Friberg and others) as we worked to smooth the initial glitches in data formats and completeness. Moment tensor work was suspended for a few days as we awaited resolution of the remaining issues. Some problems still remain, on which we continue to work. Moment tensor analysis was resumed when it became clear that the problems would take more than two or three days to sort out.

2 Task 2 – System Setup

Significant progress was made in setting up a relative relocation workflow, including focus on relative relocation work, planned for the forthcoming week.

3 Task 3 – Quality control of prepicked MEQs and preparation for relocation and moment tensor calculation

We continued to derive moment tensors for the largest earthquakes, adding events to our working list as events were recorded day by day. We used the same procedure as described in our Weekly Report #1. We report here an additional five moment tensors. The entire list of earthquakes processed to date is given in Table 1. Full location files, in the format given in Weekly Report #1, Appendix 1, will be provided on request.

Table 1: The 15 earthquakes for which moment tensors have obtained. Locations given below are from the webpage http://fracture.lbl.gov/Newberry/locations.txt.

yr	jday	month	day	hour	minute	sec	lat	lon	depth	magnitude
2014	273	9	30	21	30	43.689	43.72667	121.313	0.387	**0.972**
2014	274	10	1	1	3	14.64	43.7239	121.30957	0.714	**0.987**
2014	274	10	1	12	3	16.881	43.72658	121.3158	1.587	**1.086**
2014	274	10	1	14	53	5.102	43.72545	121.31355	0.613	**1.381**
2014	274	10	1	19	5	16.377	43.72662	121.31117	0.517	**1.259**
2014	275	10	2	6	47	52.916	43.72632	121.31322	1.323	**1.117**
2014	275	10	2	7	7	11.646	43.72488	121.31192	0.708	**1.378**
2014	275	10	2	11	1	48.042	43.72567	121.31168	0.666	**1.22**
2014	276	10	3	6	6	22.727	43.72528	121.31493	0.928	**1.157**
2014	276	10	3	18	54	54.199	43.72678	121.31125	0.647	**1.021**
2014	277	10	4	5	29	8.347	43.72578	121.31068	0.946	**0.922**
2014	277	10	4	17	32	52.716	43.72207	121.31693	0.376	**1.521**
2014	277	10	4	18	51	11.991	43.72295	121.31227	0.496	**1.97**
2014	278	10	5	4	7	30.446	43.725	121.31322	0.659	**1.696**
2014	278	10	5	23	22	16.638	43.72368	121.3116	1.055	**0.931**

Of the five new moment tensors, two are significantly implosive, two significantly explosive, and one (the event of Oct 5 23:22) has no significant volumetric component.

4 Task 4 –Improved locations and relative locations

Relative locations of all the earthquakes in the ISTI catalog is currently in hand and we expect to have preliminary results within a few days. In preparation for this, we developed a plotting script and have examined the absolute locations available within the team so far.

Figure 1 shows LBNL locations. There is great scatter in these locations.

Figure 2 shows ISTI arrival-time measurements used to locate the earthquakes using **qloc**, the location program used by *Foulger Consulting*. Most events lie within a circle about 500 m in diameter and centered 100 to 200 m north of the bottom of well NWD 55-29.

Figure 3 shows ISTI locations derived using one of the **hypo** generation of location programs.

Significant differences can be seen between these last two sets of locations, simply when different programs are used.

Figure 4 shows the locations of the MEQs for which moment tensors were derived. These earthquakes are the largest and best-located, have been subject to the most careful processing and outlier-rejection, and are the most accurately located earthquakes available to date.

Figure 5 shows the depth as a function of time. The average depth appears to be decreasing slightly, and deeper events are reducing in number with time.

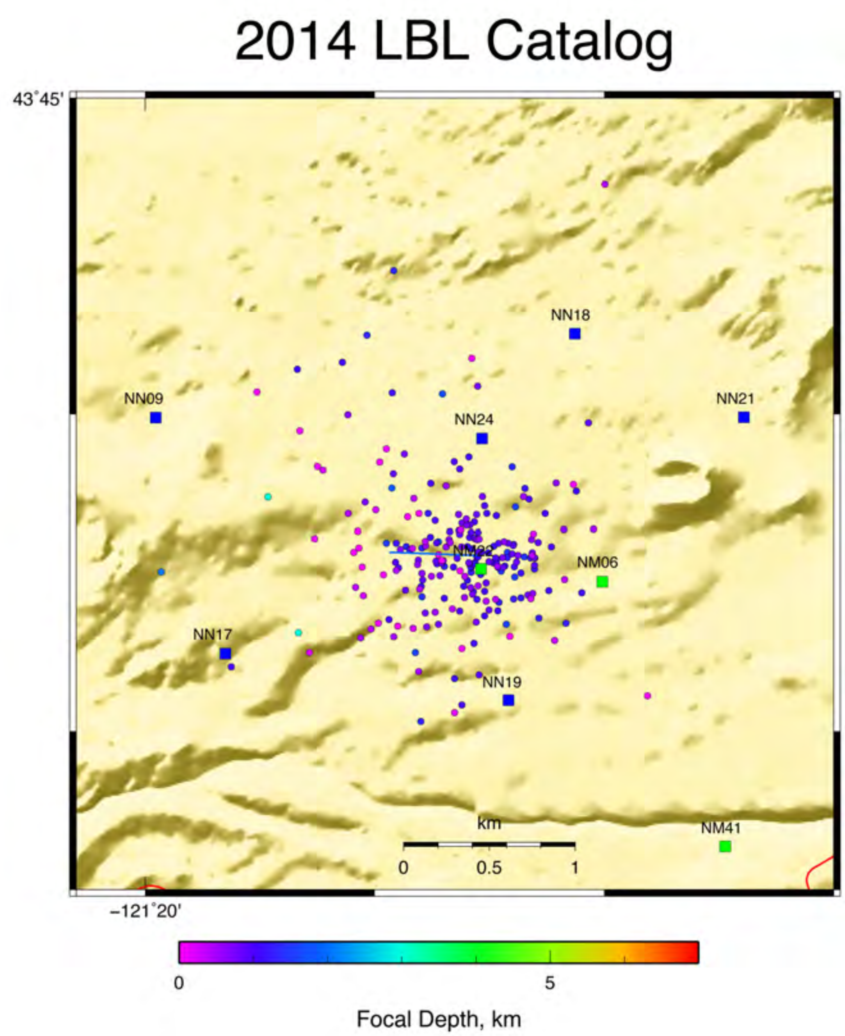


Figure 1: Estimated hypocenters of 228 MEQs between Sept. 28 and Oct. 15, 2014 within the NMSA network, as given in the earthquake catalog of the Lawrence Berkeley Laboratory. These locations are significantly more scattered than those shown in Figure 2 and Figure 3, probably because of differences in either the method of measuring seismic-wave arrival times or of

inverting them to determine hypocenter locations. Blue line: well NWD 55-29; green squares: surface seismometers; blue squares: borehole seismometers.

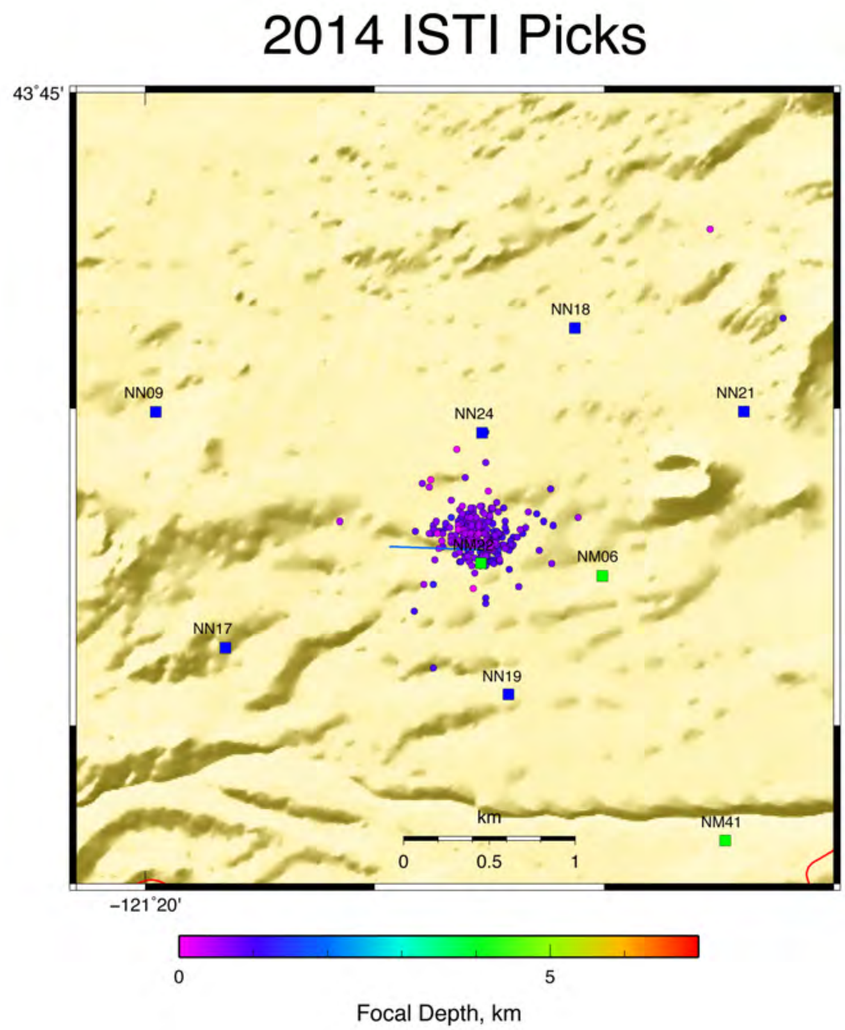


Figure 2: Estimated hypocenters of 257 MEQs between Sept. 26 and Oct. 13, 2014 within the NMSA network. Most events lie within a circle about 500 m in diameter and centered 100 to 200 m north of the bottom of well NWD 55-29, which is shown in blue. These locations were obtained by using the **qloc** program to invert *P*- and *S*-phase arrival times measured by ISTI on digital seismograms from the NMSA network. Figure 5 shows the focal depths of these events as a function of time.

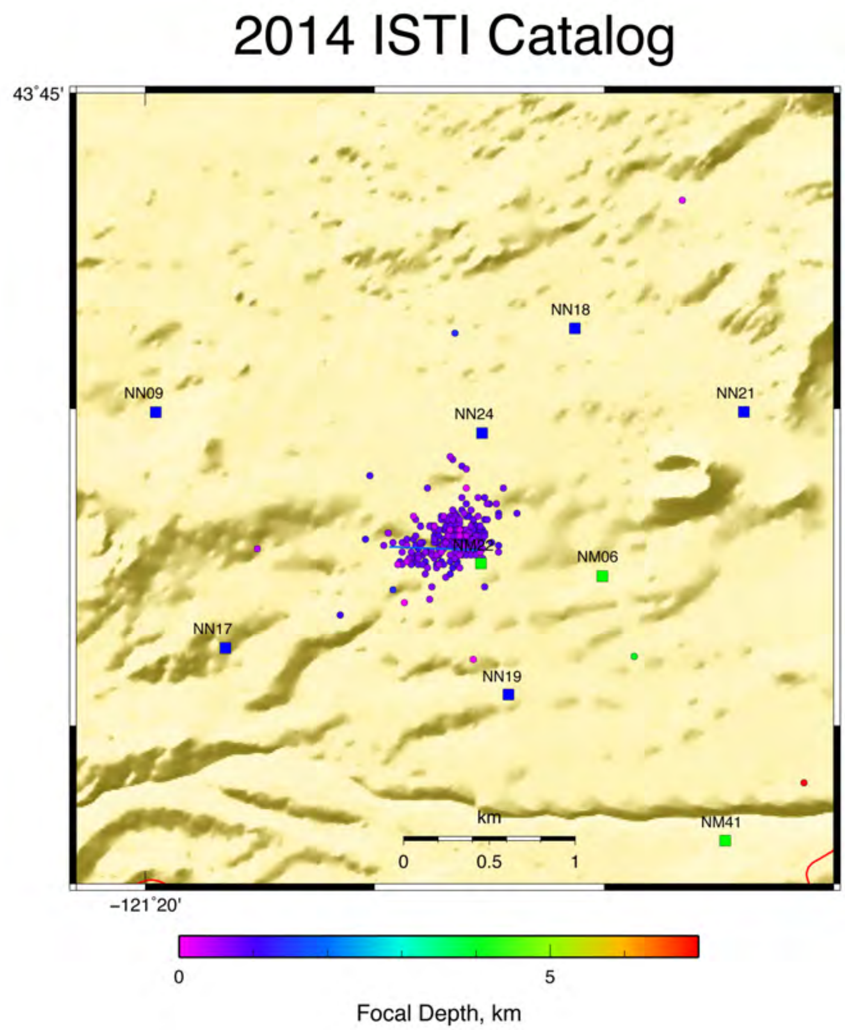


Figure 3: Estimated hypocenters of 263 MEQs between Sept. 26 and Oct. 14, 2014 within the NMSA network, as given in the earthquake catalog of the ISTI Corporation. These locations are slightly but significantly west of those shown in Figure 2, which were derived from substantially the same seismic data but using a different computer program. Well NWD 55-29 is shown in blue.

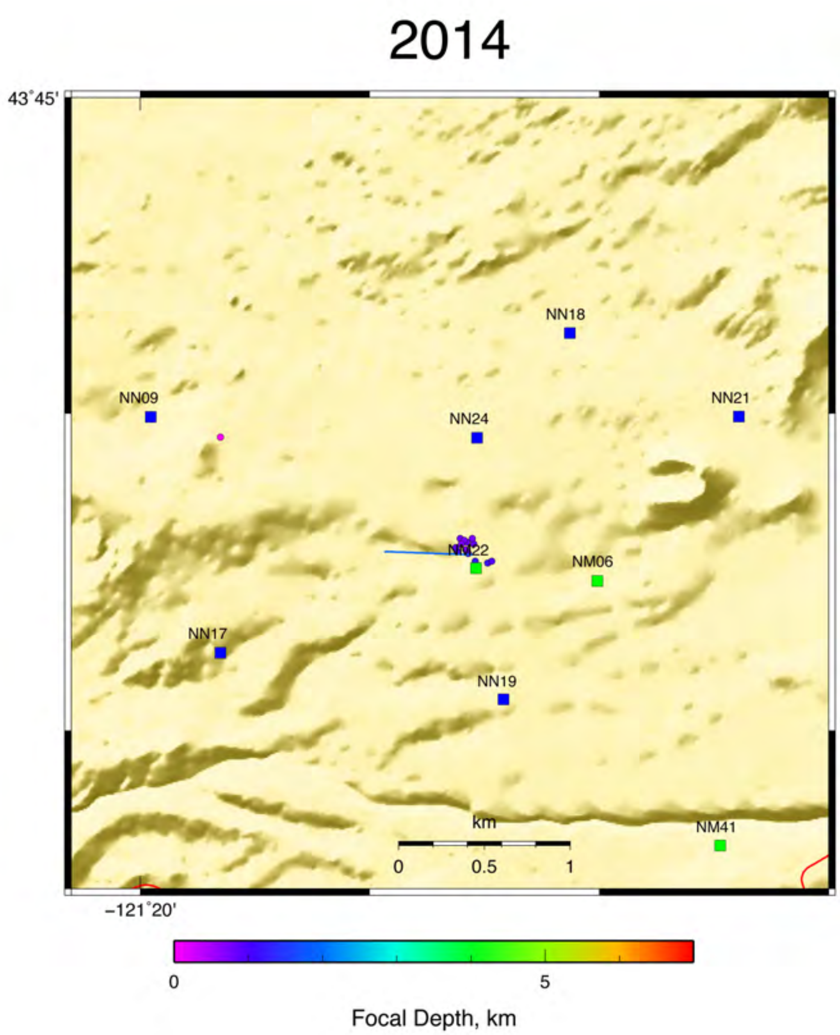


Figure 4: Map showing the locations of the fifteen earthquakes for which moment tensors have been derived. These events have been very carefully processed, including identifying the correct *S*-wave arrivals by filtering, measuring their arrival times on both horizontal components rotated toward the source, and rejecting outliers.

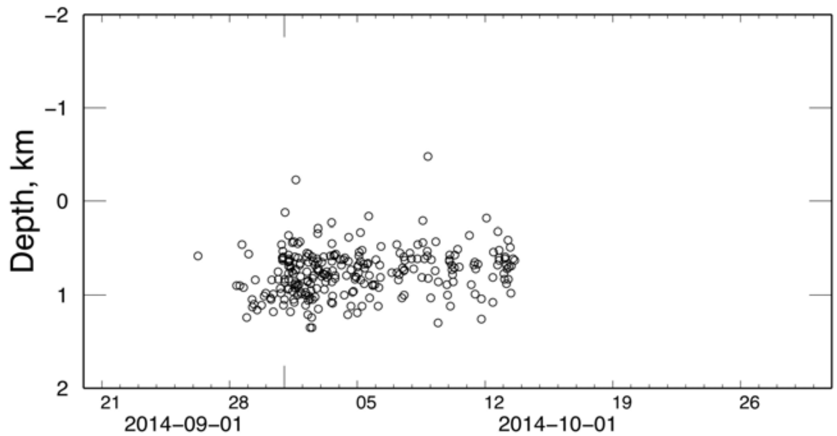


Figure 5: Estimated depths, with respect to sea level, of 257 MEQs within the NMSA network as a function of time. The average depth appears to be decreasing slightly with time because of a decrease in the number of deeper events. These depths were obtained by using the **qloc** program to invert *P*- and *S*-phase arrival times measured by ISTI on digital seismograms from the NMSA network.

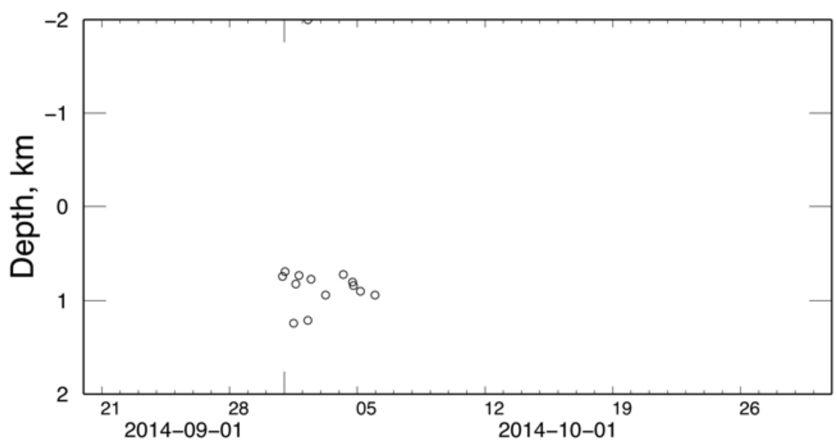


Figure 6: Same as Figure 5 except for the 15 MEQs for which moment tensors were derived.

5 Task 5 Moment tensor calculations

Moment tensors were derived for an additional five earthquakes using the same procedure as described in Weekly Report #1. There is no shortage of events that yield good or excellent results. The numerical results of the catalog to date are given in

Table 2. Graphical results are shown in

Appendix 1.

We continue to work on checking the calibration of the sensors, and the results given here should be considered preliminary.

Table 2: Numerical moment tensor results for the 15 MEQs studied to date.

1.578e-01	3.466e-02	6.671e-02	2.482e-01	6.317e-02	8.338e-02	2014	10	01	14	53	05.23	excellent
2.172e-01	-3.673e-02	-6.417e-02	2.346e-01	7.204e-02	3.184e-02	2014	10	01	19	05	16.54	excellent
8.713e-02	1.262e-01	-4.193e-02	1.814e-01	8.429e-02	8.722e-02	2014	10	04	18	51	12.00	excellent
-1.029e-01	1.325e-01	-1.185e-01	1.480e-01	5.508e-02	1.074e-01	2014	10	04	17	32	52.76	excellent
-1.165e-01	1.705e-01	-1.989e-01	1.394e-01	-2.430e-02	1.639e-02	2014	10	02	07	07	04.16	excellent
2.406e-01	-7.298e-02	-9.789e-02	1.731e-01	4.297e-02	8.349e-02	2014	10	02	11	01	42.38	excellent
-1.461e-02	9.643e-02	-3.978e-01	2.595e-02	1.691e-01	-4.693e-03	2014	10	02	06	47	52.94	excellent
6.066e-03	-2.231e-01	-9.157e-02	1.941e-01	3.367e-02	-6.184e-04	2014	10	03	06	06	22.76	excellent
-5.772e-02	-1.655e-01	-1.427e-01	1.464e-01	7.811e-02	-1.952e-02	2014	10	03	18	54	53.93	fair
2.004e-01	-1.410e-01	-1.461e-01	1.400e-01	-8.713e-03	7.412e-02	2014	10	01	12	03	16.94	good
5.304e-02	6.783e-02	-1.175e-01	1.615e-01	7.508e-02	2.206e-01	2014	10	05	04	07	20	excellent
-1.777e-01	-1.053e-01	-1.512e-01	7.111e-02	1.063e-01	1.057e-01	2014	10	01	01	03	14.49	excellent
-2.667e-	1.320e-01	-6.399e-	6.063e-02	1.031e-01	7.787e-02	2014	09	30	21	30	43.503	excellent

01		02										
-1.871e-01	8.995e-02	-9.473e-02	-1.446e-01	-2.491e-02	1.992e-01	2014	10	05	23	22	16.499	good
1.684e-01	-3.350e-02	-9.826e-03	2.952e-01	3.542e-02	9.350e-02	2014	10	04	05	29	08.258	fair

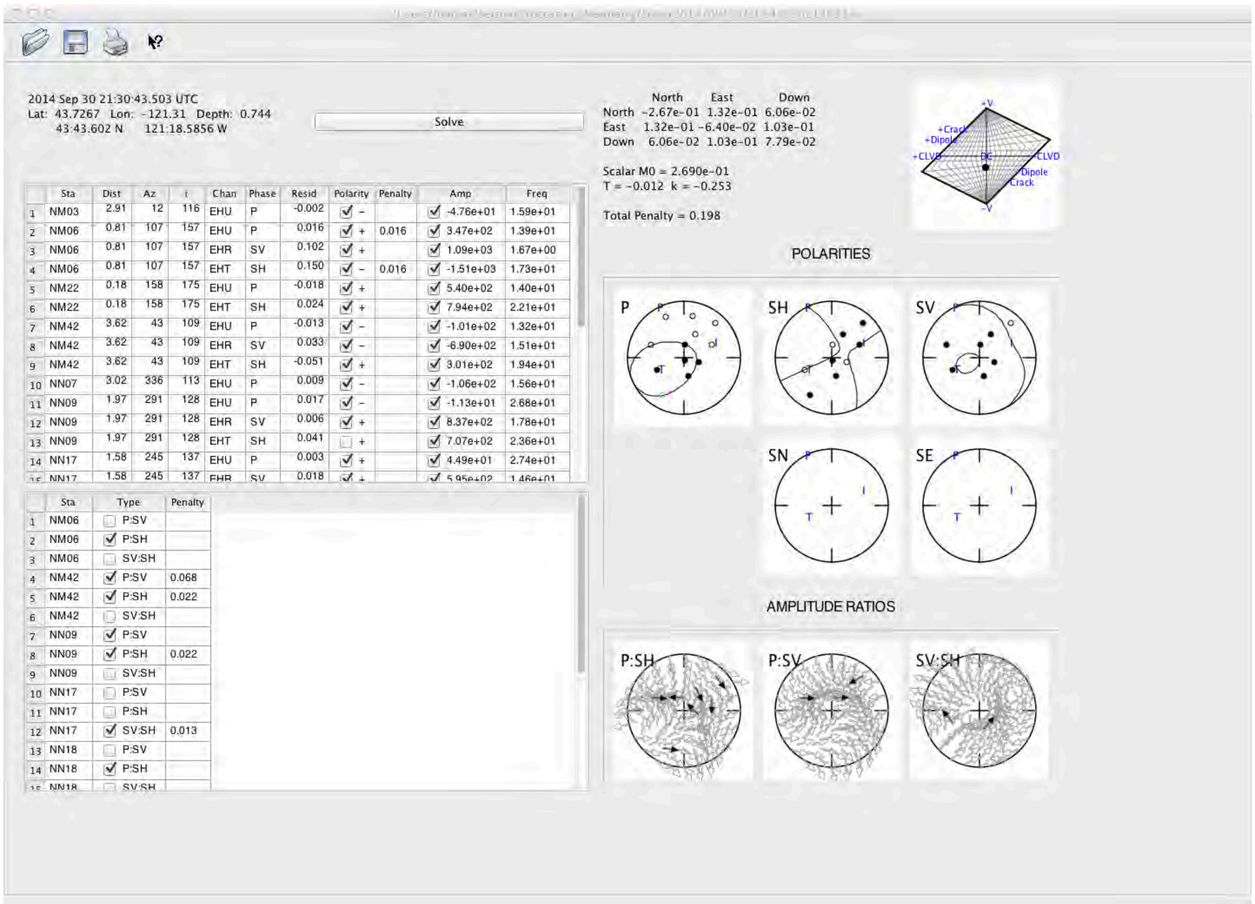
6 Brief summary statement

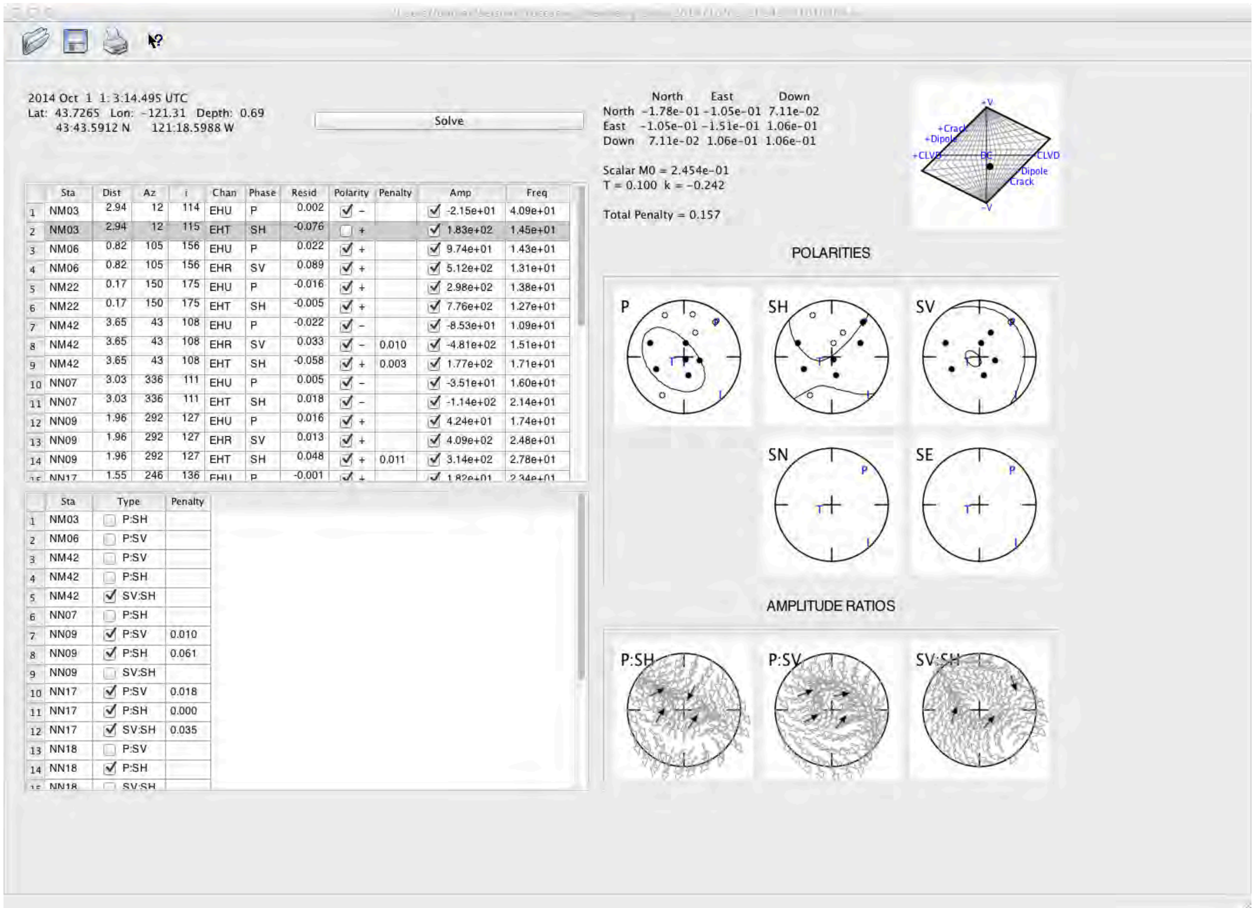
There are still some problems transferring data and working on these occupied considerable time during the last week. We derived an additional five moment tensors, most of which showed small to moderate volumetric components, approximately equally divided between crack-opening and crack-closing.

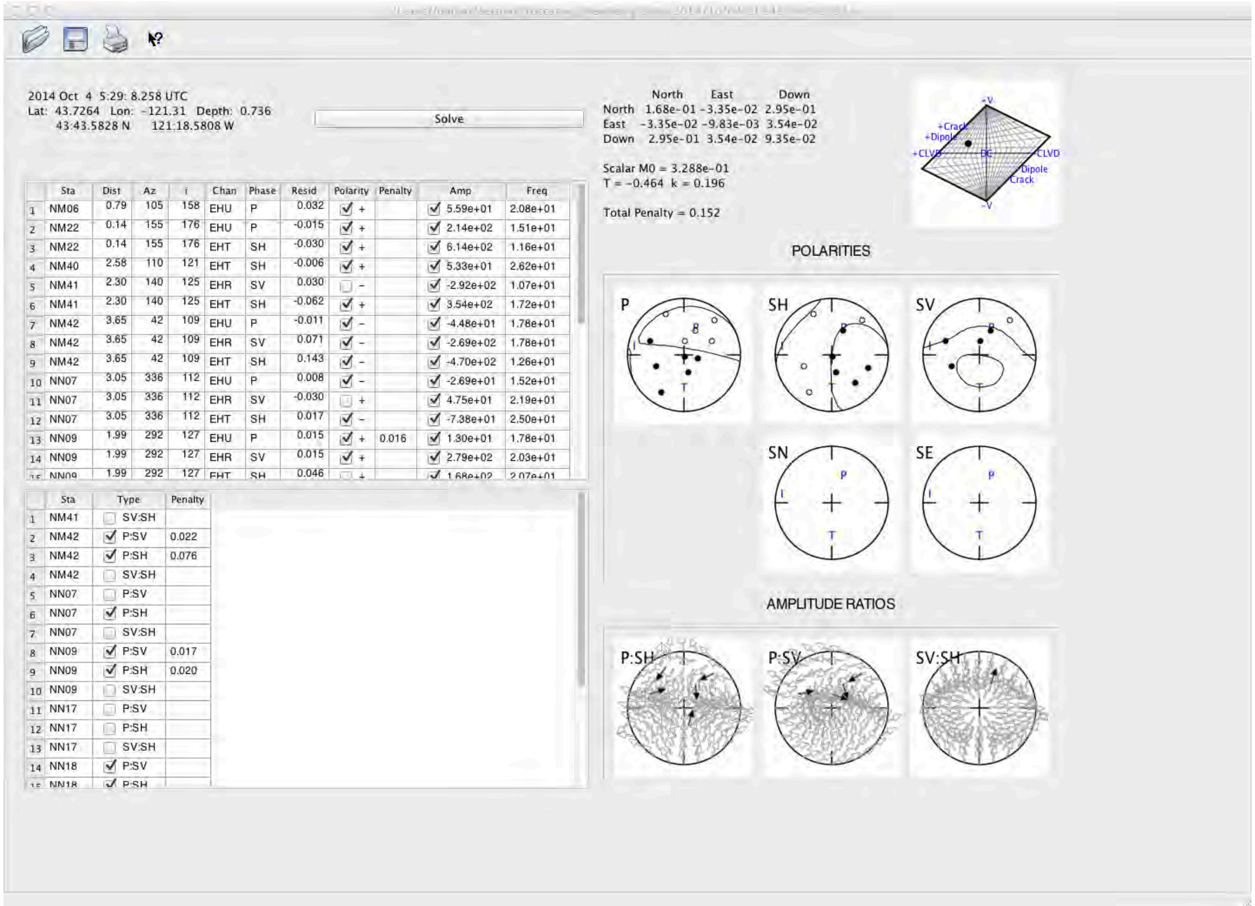
Plots of the different sets of locations available to date show systematic differences between the locations produced by different computer programs. Most events lie within a circle about 500 m in diameter and centered 100 to 200 m north of the bottom of well NWD 55-29. The most accurate absolute locations available to date are from the 15 events for which moment tensors have been derived. These events cluster tightly around the bottom of the well in the depth range 700 - 1200 m b.s.l.

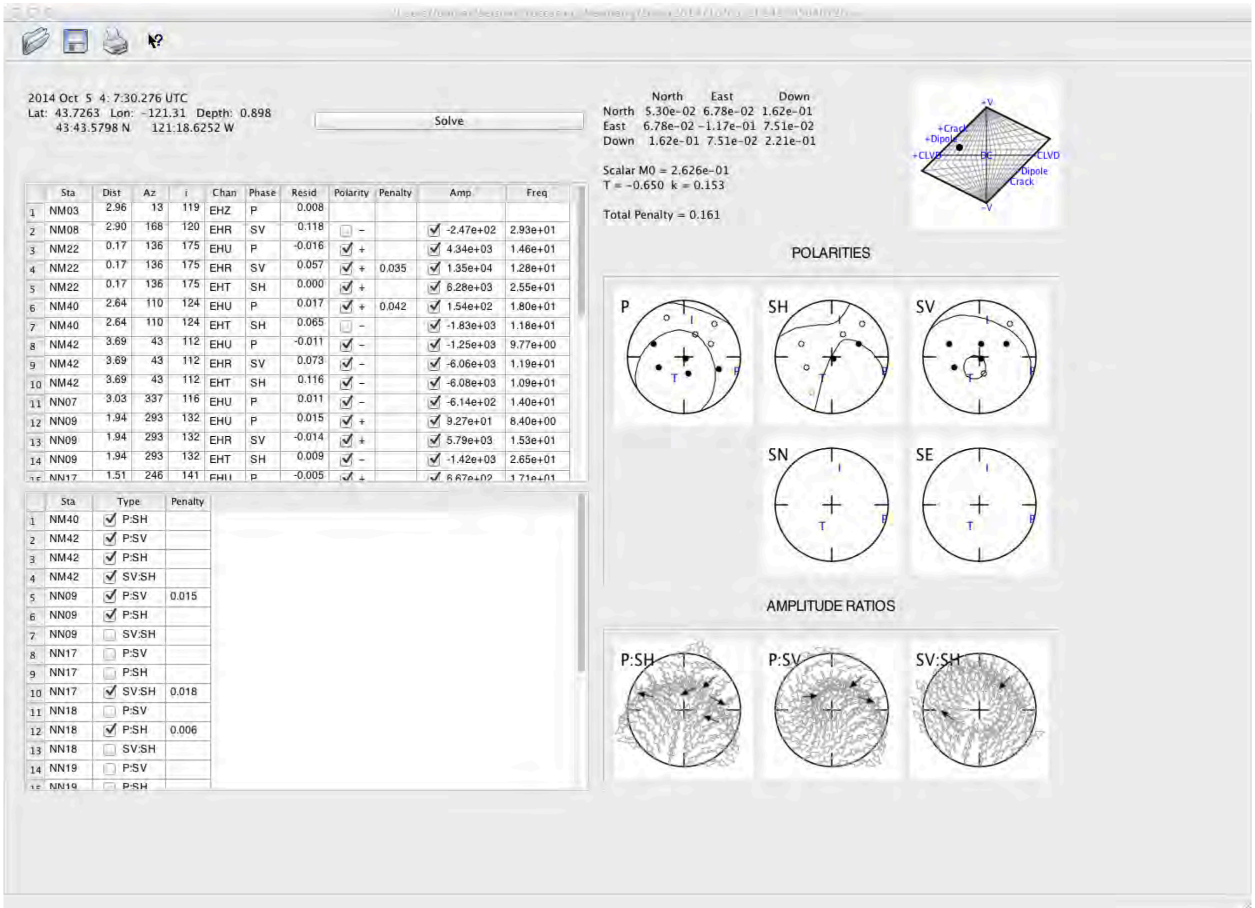
There may be a tendency for the earthquakes to shallow slightly with time. This is apparent depth plots of both the entire catalog, and the moment-tensor events.

Appendix 1: The addition five moment tensors derived over the previous week.

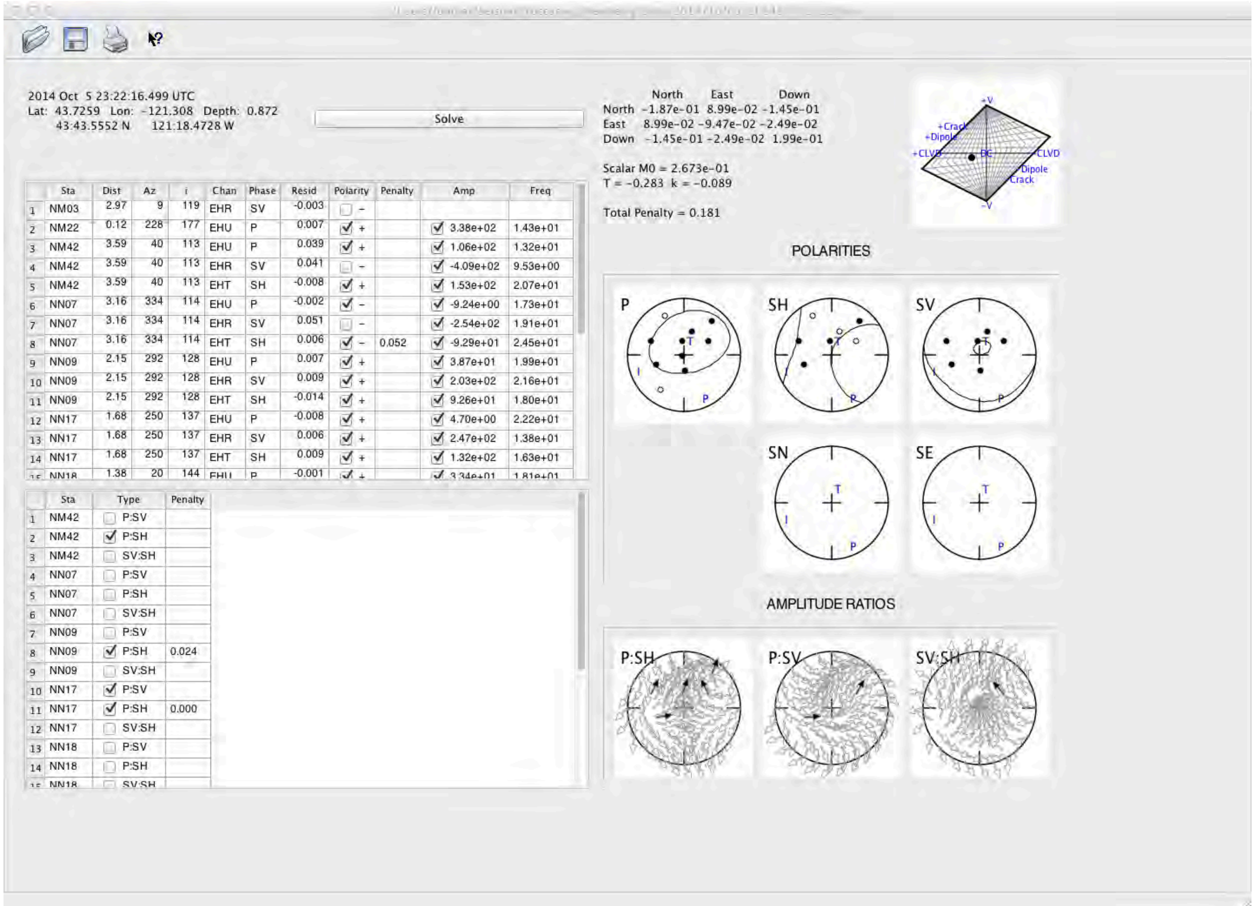



Solve
2014 Oct 1 1:3:14.495 UTC
Lat: 43.7265 Lon: -121.31 Depth: 0.69
43:43.5912 N 121:18.5988 W
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM03 2.94 12 114 EHU P 0.002 - -2.15e+01 4.09e+01
2 NM03 2.94 12 115 EHT SH -0.076 + 1.83e+02 1.45e+01
3 NM06 0.82 105 156 EHU P 0.022 + 9.74e+01 1.43e+01
4 NM06 0.82 105 156 EHR SV 0.089 + 5.12e+02 1.31e+01
5 NM22 0.17 150 175 EHU P -0.016 + 2.98e+02 1.38e+01
6 NM22 0.17 150 175 EHT SH -0.005 + 7.76e+02 1.27e+01
7 NM42 3.65 43 108 EHU P -0.022 - -8.53e+01 1.09e+01
8 NM42 3.65 43 108 EHR SV 0.033 - 0.010 -4.81e+02 1.51e+01
9 NM42 3.65 43 108 EHT SH -0.058 + 0.003 1.77e+02 1.71e+01
10 NN07 3.03 336 111 EHU P 0.005 - -3.51e+01 1.60e+01
11 NN07 3.03 336 111 EHT SH 0.018 - -1.14e+02 2.14e+01
12 NN09 1.96 292 127 EHU P 0.016 + 4.24e+01 1.74e+01
13 NN09 1.96 292 127 EHR SV 0.013 + 4.09e+02 2.48e+01
14 NN09 1.96 292 127 EHT SH 0.048 + 0.011 3.14e+02 2.78e+01
Sta Type Penalty
1 NM03 P:SH
2 NM06 P:SV
3 NM42 P:SV
4 NM42 P:SH
5 NM42 SV:SH
6 NN07 P:SH
7 NN09 P:SV 0.010
8 NN09 P:SH 0.061
9 NN09 SV:SH
10 NN17 P:SV 0.018
11 NN17 P:SH 0.000
12 NN17 SV:SH 0.035
13 NN18 P:SV
14 NN18 P:SH
North East Down
North -1.78e-01 -1.05e-01 7.11e-02
East -1.05e-01 -1.51e-01 1.06e-01
Down 7.11e-02 1.06e-01 1.06e-01
Scalar M0 = 2.454e-01
T = 0.100 k = -0.242
Total Penalty = 0.157
+V
+Crack
+Dipole
+CLVD
DC
-CLVD
-Dipole
-Crack
-V
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH


2014 Oct 4 5:29: 8.258 UTC
Lat: 43.7264 Lon: -121.31 Depth: 0.736
43:43.5828 N 121:18.5808 W
Solve
North East Down
North 1.68e-01 -3.35e-02 2.95e-01
East -3.35e-02 -9.83e-03 3.54e-02
Down 2.95e-01 3.54e-02 9.35e-02
Scalar M0 = 3.288e-01
T = -0.464 k = 0.196
Total Penalty = 0.152
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH



2014 Oct 5 4: 7:30.276 UTC
Lat: 43.7263 Lon: -121.31 Depth: 0.898
43:43.5798 N 121:18.6252 W
Solve
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM03 2.96 13 119 EHZ P 0.008
2 NM08 2.90 168 120 EHR SV 0.118 − -2.47e+02 2.93e+01
3 NM22 0.17 136 175 EHU P -0.016 + 4.34e+03 1.46e+01
4 NM22 0.17 136 175 EHR SV 0.057 + 0.035 1.35e+04 1.28e+01
5 NM22 0.17 136 175 EHT SH 0.000 + 6.28e+03 2.55e+01
6 NM40 2.64 110 124 EHU P 0.017 + 0.042 1.54e+02 1.80e+01
7 NM40 2.64 110 124 EHT SH 0.065 − -1.83e+03 1.18e+01
8 NM42 3.69 43 112 EHU P -0.011 − -1.25e+03 9.77e+00
9 NM42 3.69 43 112 EHR SV 0.073 − -6.06e+03 1.19e+01
10 NM42 3.69 43 112 EHT SH 0.116 − -6.08e+03 1.09e+01
11 NN07 3.03 337 116 EHU P 0.011 − -6.14e+02 1.40e+01
12 NN09 1.94 293 132 EHU P 0.015 + 9.27e+01 8.40e+00
13 NN09 1.94 293 132 EHR SV -0.014 + 5.79e+03 1.53e+01
14 NN09 1.94 293 132 EHT SH 0.009 − -1.42e+03 2.65e+01
Sta Type Penalty
1 NM40 P:SH
2 NM42 P:SV
3 NM42 P:SH
4 NM42 SV:SH
5 NN09 P:SV 0.015
6 NN09 P:SH
7 NN09 SV:SH
8 NN17 P:SV
9 NN17 P:SH
10 NN17 SV:SH 0.018
11 NN18 P:SV
12 NN18 P:SH 0.006
13 NN18 SV:SH
14 NN19 P:SV
North East Down
North 5.30e-02 6.78e-02 1.62e-01
East 6.78e-02 -1.17e-01 7.51e-02
Down 1.62e-01 7.51e-02 2.21e-01
Scalar M0 = 2.626e-01
T = -0.650 k = 0.153
Total Penalty = 0.161
+V
+Crack
+Dipole
+CLVD
DC
-CLVD
-Dipole
-Crack
-V
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH


2014 Oct 5 23:22:16.499 UTC
Lat: 43.7259 Lon: -121.308 Depth: 0.872
43:43.5552 N 121:18.4728 W
Solve
North East Down
North -1.87e-01 8.99e-02 -1.45e-01
East 8.99e-02 -9.47e-02 -2.49e-02
Down -1.45e-01 -2.49e-02 1.99e-01
Scalar M0 = 2.673e-01
T = -0.283 k = -0.089
Total Penalty = 0.181
+V
+Crack
+Dipole
+CLVD
DC
-CLVD
-Dipole
-Crack
-V
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM03 2.97 9 119 EHR SV -0.003 –
2 NM22 0.12 228 177 EHU P 0.007 + 3.38e+02 1.43e+01
3 NM42 3.59 40 113 EHU P 0.039 + 1.06e+02 1.32e+01
4 NM42 3.59 40 113 EHR SV 0.041 – -4.09e+02 9.53e+00
5 NM42 3.59 40 113 EHT SH -0.008 + 1.53e+02 2.07e+01
6 NN07 3.16 334 114 EHU P -0.002 – -9.24e+00 1.73e+01
7 NN07 3.16 334 114 EHR SV 0.051 – -2.54e+02 1.91e+01
8 NN07 3.16 334 114 EHT SH 0.006 – 0.052 -9.29e+01 2.45e+01
9 NN09 2.15 292 128 EHU P 0.007 + 3.87e+01 1.99e+01
10 NN09 2.15 292 128 EHR SV 0.009 + 2.03e+02 2.16e+01
11 NN09 2.15 292 128 EHT SH -0.014 + 9.26e+01 1.80e+01
12 NN17 1.68 250 137 EHU P -0.008 + 4.70e+00 2.22e+01
13 NN17 1.68 250 137 EHR SV 0.006 + 2.47e+02 1.38e+01
14 NN17 1.68 250 137 EHT SH 0.009 + 1.32e+02 1.63e+01
Sta Type Penalty
1 NM42 P:SV
2 NM42 P:SH
3 NM42 SV:SH
4 NN07 P:SV
5 NN07 P:SH
6 NN07 SV:SH
7 NN09 P:SV
8 NN09 P:SH 0.024
9 NN09 SV:SH
10 NN17 P:SV
11 NN17 P:SH 0.000
12 NN17 SV:SH
13 NN18 P:SV
14 NN18 P:SH
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH

Foulger Consulting

1025 Paradise Way
Palo Alto, CA 943062637, USA
Tel: 650/4932553
Cell: 650/9968886
FAX: 866/5326907
gillian@foulgerconsulting.com
http://www.foulgerconsulting.com/

November 19, 2014

WEEKLY REPORT #7 TO ALTAROCK ENERGY INC.

PROCESSING OF INDUCED EARTHQUAKES ASSOCIATED WITH THE NEWBERRY EGS INJECTION STARTING SEPTEMBER 2014

GILLIAN R. FOULGER & BRUCE R. JULIAN

Brief summary

During the last week, vigorous earthquake activity has occurred in response to renewed injection. These earthquakes appear to be located slightly further to the NW than earlier earthquakes. They are restricted in time and the largest of them had a larger magnitude than any previous earthquake in the 8-week-long sequence.

Preliminary relative locations suggest that these later earthquakes may have partly filled the gap between the two earlier, separate seismogenic volumes. This result is preliminary and needs to be looked at more carefully in future, perhaps relative locating these later earthquakes separately from the earlier ones.

An additional 11 moment tensor results were obtained, including a result for the largest, M2.2 event. This event was complex and it proved difficult to either locate it or derive a moment tensor. Subsequent to our initial result, which showed a thrust mechanism, we obtained additional information on the calibration of the instruments. This moment tensor will be re-studied in the light of that new information. The general pattern of P- T- and I-axis orientations remains similar to what was observed earlier.

1 Task 1 – Planning, conference calls, discussion of work, correspondence, followup

We continued to maintain contact with team members as before. The work continued to run smoothly.

2 Task 2 – System Setup

No additional system setup was done during the last week.

3 Task 3 – Quality control of prepicked MEQs and preparation for relocation and moment tensor calculation

We continued to derive moment tensors using the procedure described in our Weekly Report #1. We report here an additional 11 moment tensors, bringing the total number derived up to 65 (Appendix 1). We have provided the locations and moment-tensor decomposition data of these new moment tensors to Trenton Cladouhos of AltaRock electronically, by email attachment.

4 Task 4 –Improved locations and relative locations

4.1 Absolute locations–ISTI picks

We located all the earthquakes hand-picked by ISTI to date, using our in-house location program *qloc*. A map showing the entire set is given in Figure 1.

Figure 2 and Figure 3 show the locations on a week-by-week basis. Of particular interest is the map of the week 11/14 - 11/18, which shows the locations of the most recent earthquakes that occurred after injection was resumed. The earthquakes appear to locate further to the NW. A map showing the depth distribution of all the earthquakes as a function of time is given in Figure 4. The earthquakes are restricted in time, and span the entire depth range activated in previous weeks.

4.2 Absolute locations–Foulger Consulting picks for moment-tensor derivation

We picked an additional 11 earthquakes for the purpose of moment-tensor derivation, bringing the total in hand to 65. We have updated our map of these and the results are shown in Figure 5 and Figure 6.

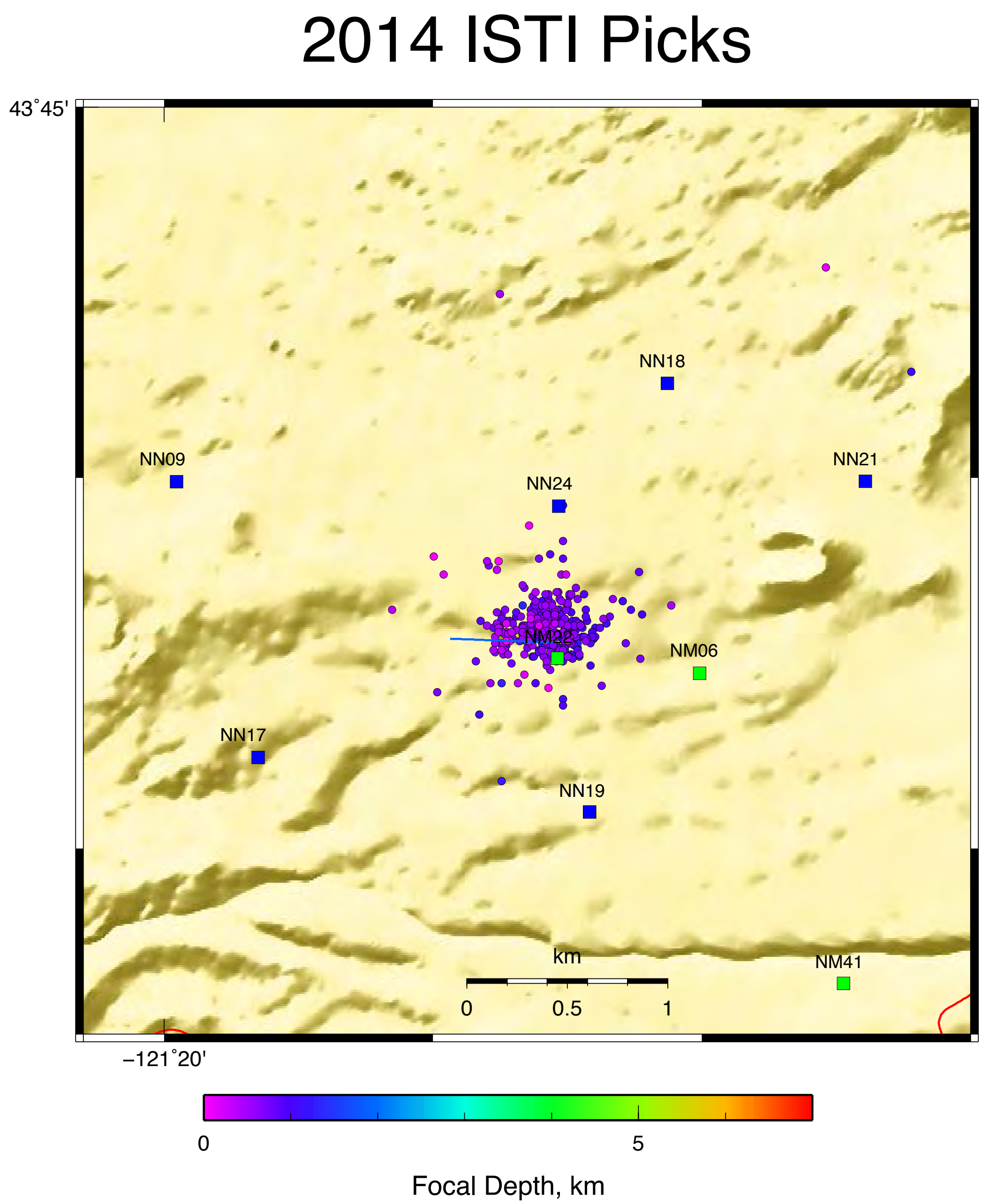


Figure 1: All earthquakes located using ISTI picks, and the *eloc* location program.

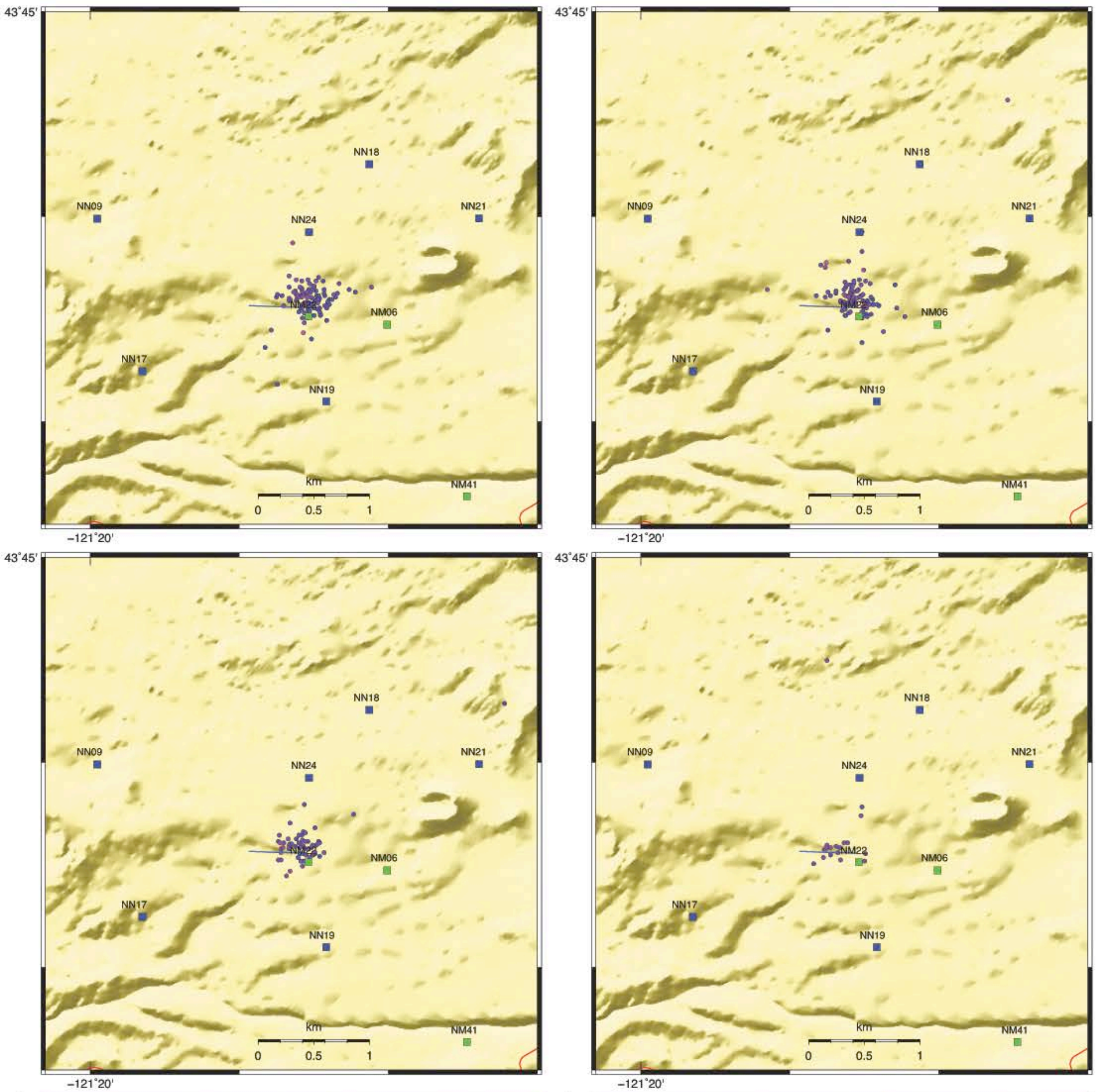


Figure 2: Top left, top right, lower left, lower right, plots of *eloc* Locations, using ISTI picks, for the weeks 09/26-10/02, 10/03-10/09, 10/10-10/16 and 10/17-10/23.

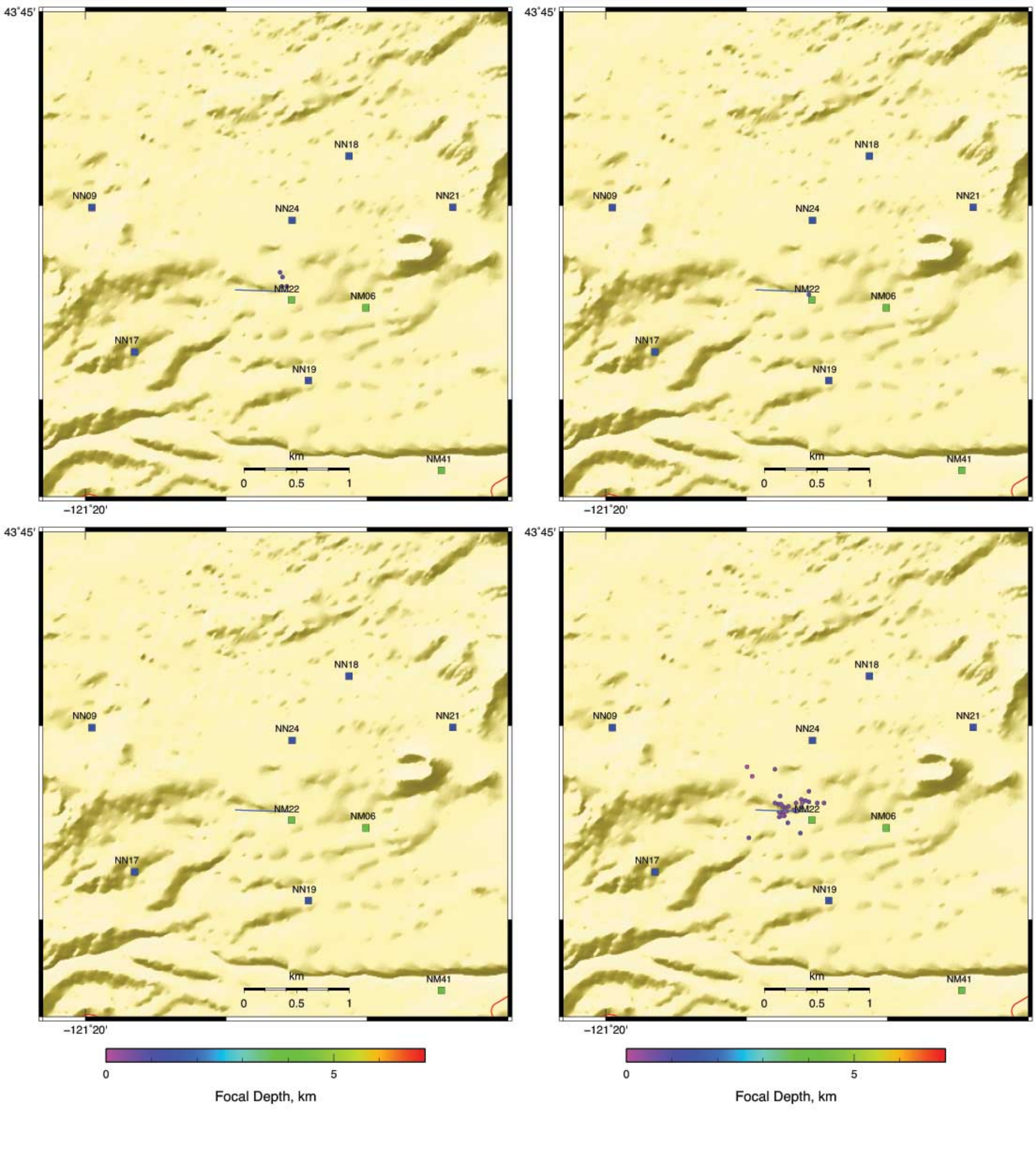


Figure 3: As Figure 2 except for the weeks 10/24-10/30, 10/31-11/06, 11/07-11/13 and 11/14-11/18 (incomplete week).

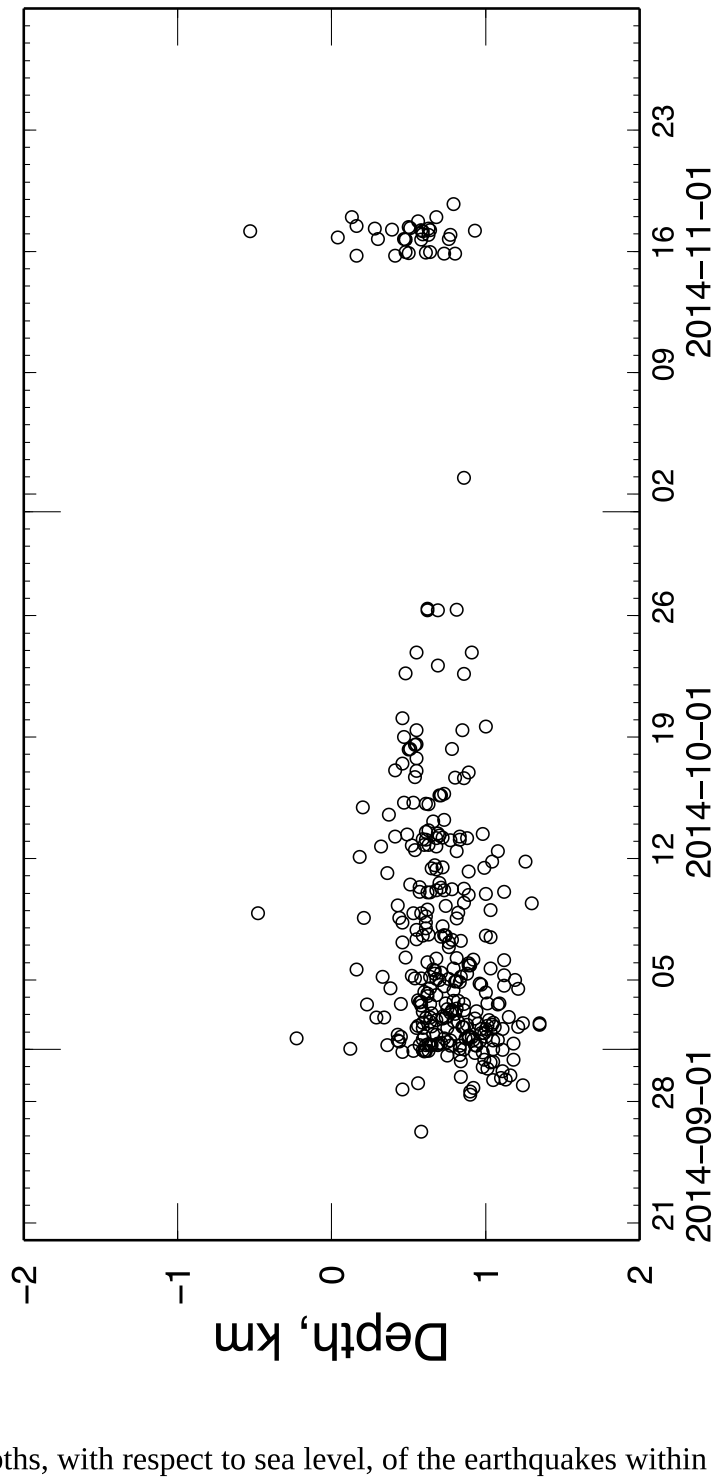


Figure 4: Estimated depths, with respect to sea level, of the earthquakes within the NMSA network as a function of time. These depths were obtained by using *qloc* to invert *P*- and *S*-phase arrival times measured by personnel of the ISTI Corporation on digital seismograms from the NMSA network.

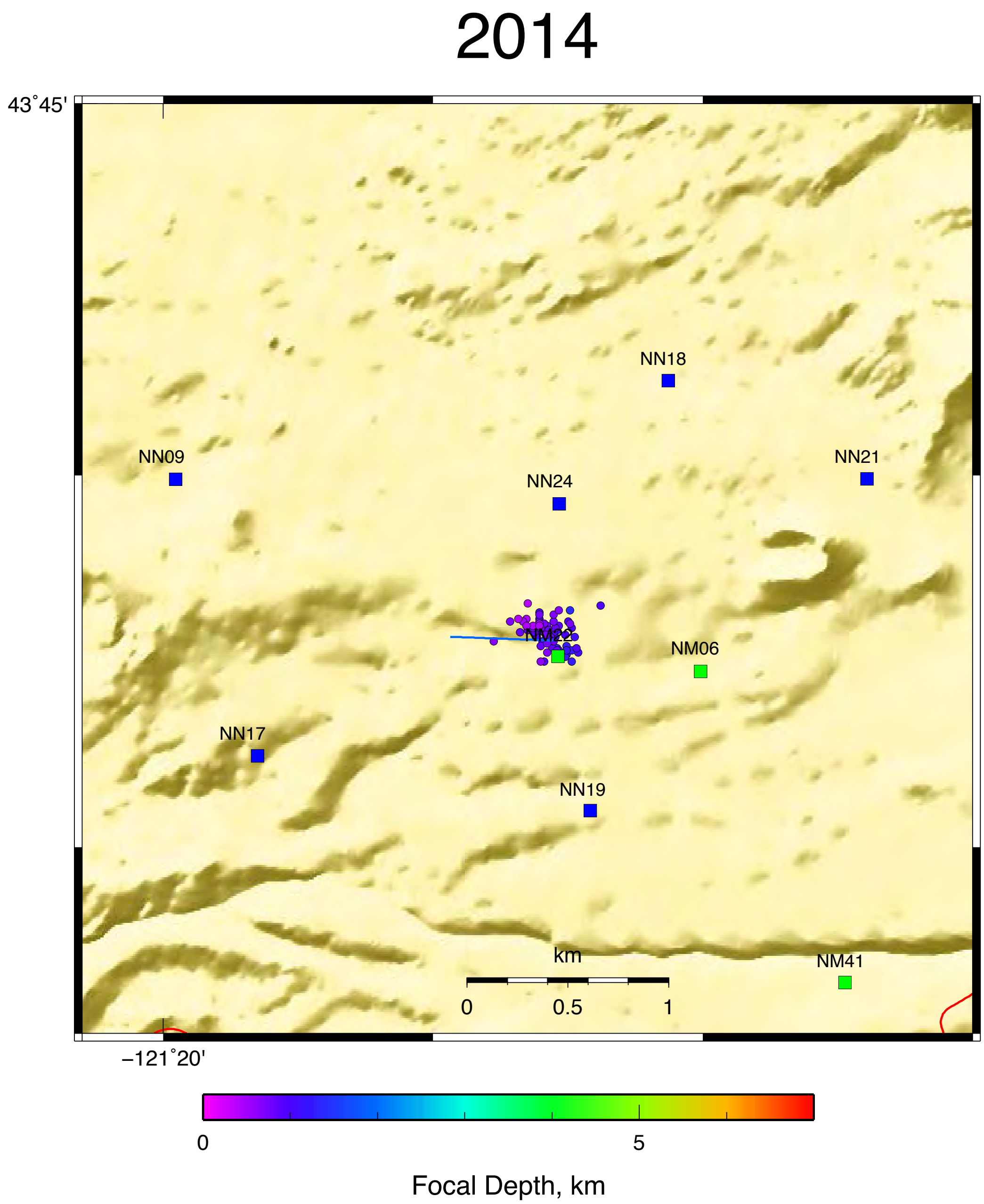


Figure 5: High quality estimated hypocenters of 65 microearthquakes that occurred between Sept. 29 and Oct. 23, 2014, plus one event from Nov. 17. Moment tensors were derived for these events. The locations are computed using arrival times measured carefully in connection with the moment-tensor analysis. Well NWD 55-29 is shown in blue.

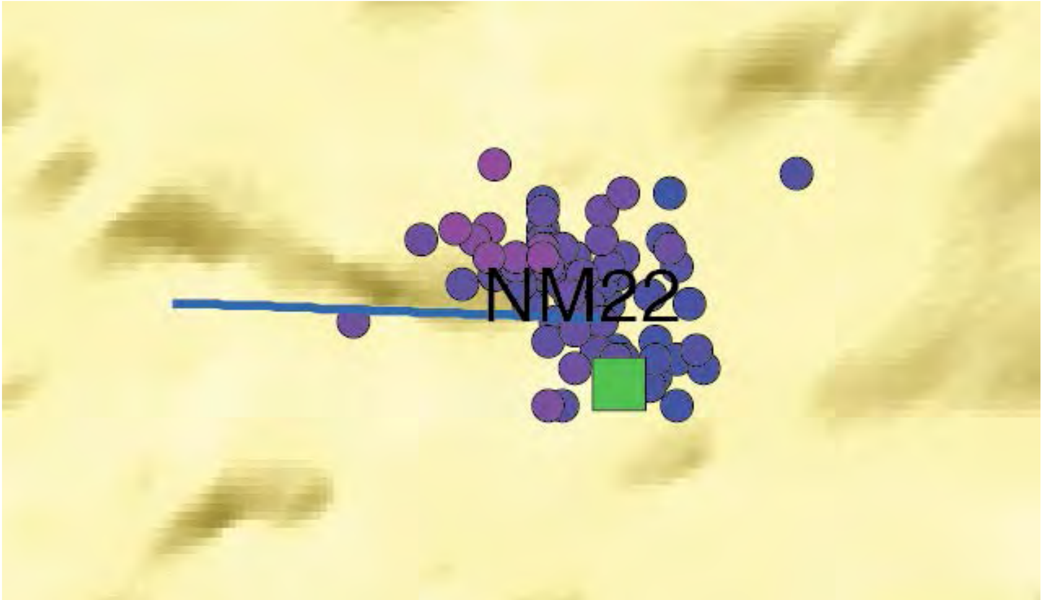


Figure 6: Expanded view of the locations of the earthquakes for which moment tensors were derived.

4.3 Relative locations

We continued with the relative location work, applying the method to the full catalog of ISTI-picked events up to 19 November. This contained 332 earthquakes. We relative located this catalog using the same input parameters as used and reported in our Weekly Report #4 of 29 October. These parameters were:

- *minclust*–the minimum number of earthquakes to define a cluster (a value of 10 was used);
- *maxit*–the maximum allowed number of relocation iterations (optimal value identified = 25);
- *maxsep*–the maximum separation allowed between linked pairs of earthquakes (optimal value identified = 0.15 km);
- *minlinks*–the minimum number of "links" (i.e., measured station/phases in common between pairs of earthquakes) needed for an earthquake to be passed to the final relocated set (optimal values identified = 14).

Of the original 332 earthquakes, the *maxsep* cut-off reduced the number to 100 and the *minlinks* threshold reduced it further to 73. This may be compared with the result we reported 29 October had 66 events remaining after these filters.

The results are shown in Figure 7 - Figure 9.

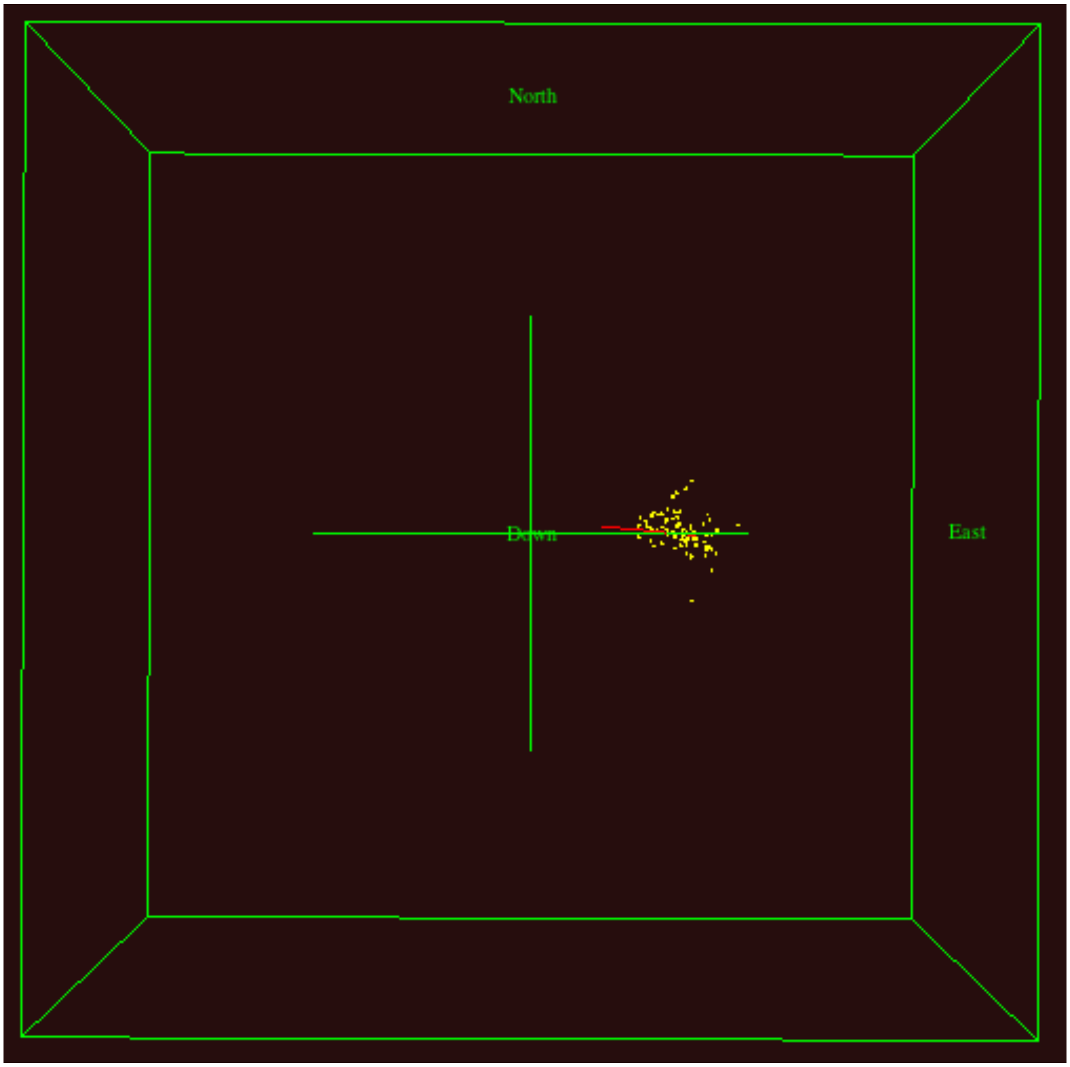


Figure 7: Map of relative locations of 73 earthquakes that occurred in the time period 26 September - 19 October, 2014. Runtime parameters used were *minclust* = 10, *maxit* = 25, *maxsep* = 0.15 km, *minlinks* = 14.

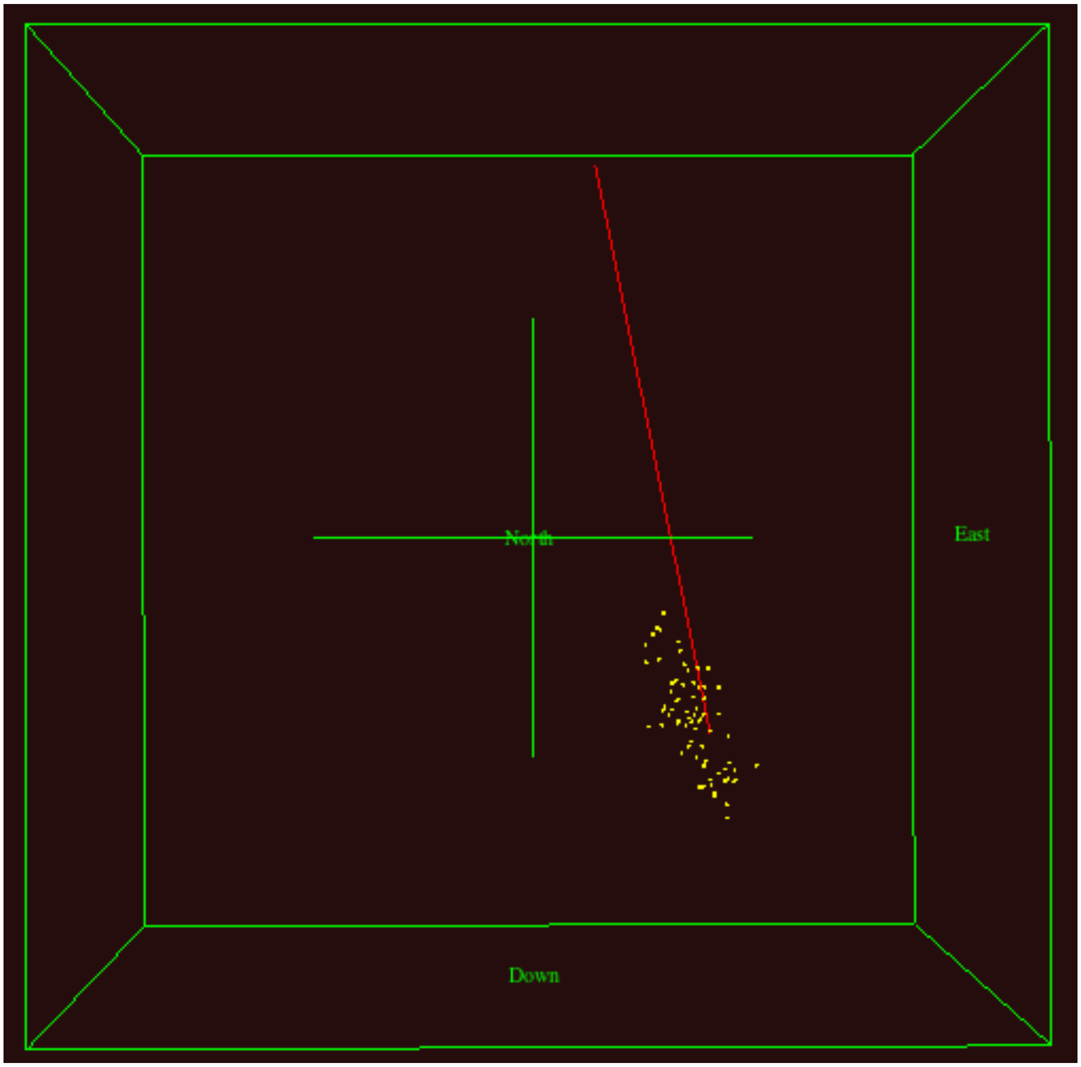


Figure 8: Same as Figure 7 except looking N.

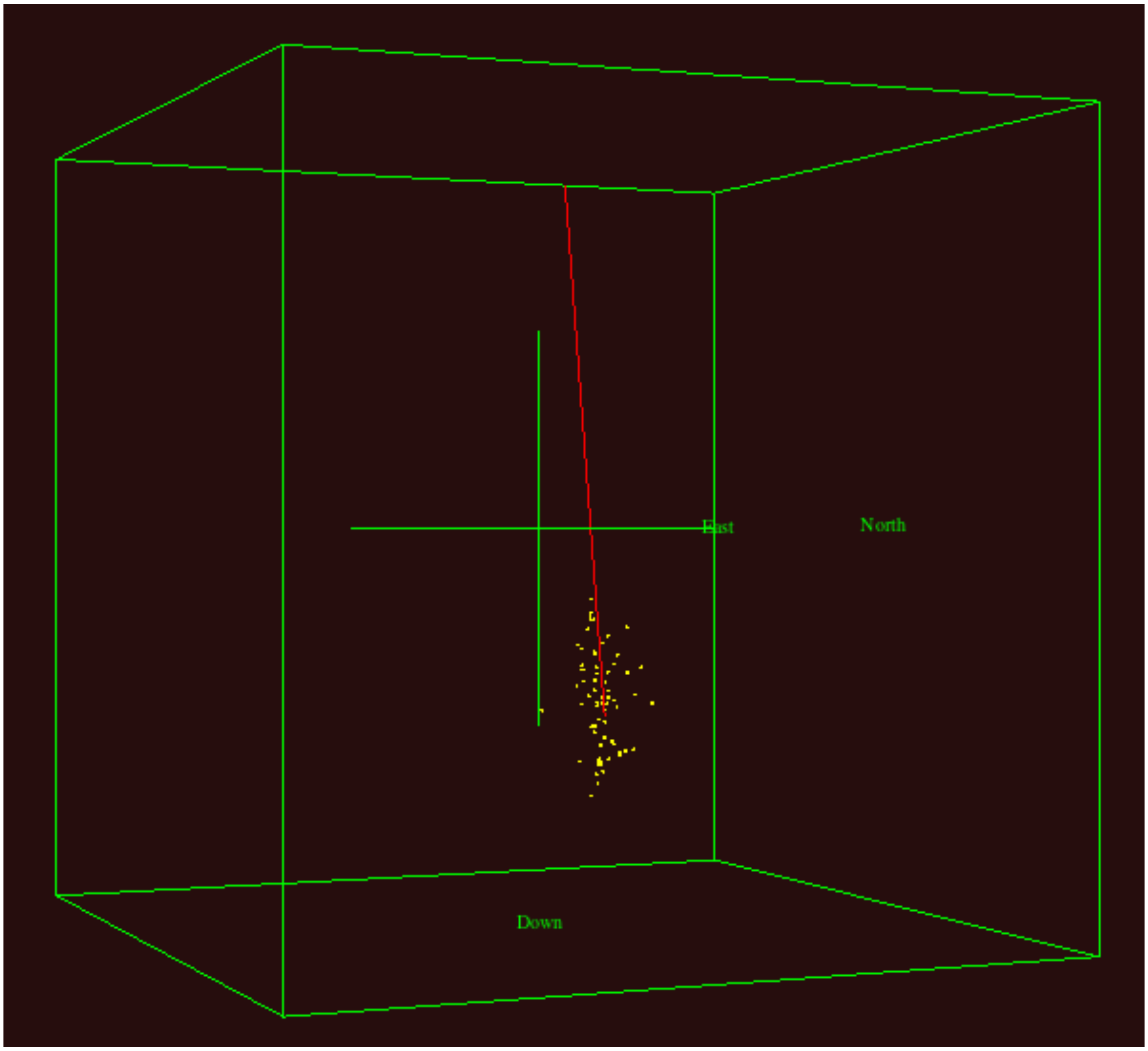


Figure 9: Same as

Figure 8 except looking along the strike of the epicentral trend, to the NW.

The northwesterly trending epicentral zone continues to be apparent. Perhaps the most striking difference between the earlier results and these, which contain earthquakes that occurred later in the sequence, is that the sharp separation between the two clusters is less obvious. It may be that the earthquakes that occurred after 29 October have partly filled in the gap between the two clusters.

Numerical data for these interim results have been provided to AltaRock by email attachment to Trenton Cladouhos.

5 Task 5 Moment tensor calculations

5.1 Instrument polarities and orientations

A quarry blast about 12 km southwest of the Newberry seismic network at about 21:10:20 UTC on Nov. 10, 2014 enabled us to check the polarities and orientations of the seismometers, information that is needed in order to use polarities and amplitude ratios to study source mechanisms. The quarry location is 43.652318° N, 121.423070° W (information provided by Trenton Cladouhos), which is 11.9 km southwest (azimuth 227°) of the 55-29 well head.

Vertical-component polarities: The vertical-component seismograms of the blast (Figure 10 to Figure 12) show clear upward first motions, as expected for an explosion, at all stations except NN17, NN08, and NN03, which appear to be dead. Waveforms from the functioning stations are similar to one another, except for NN21 and NN40, which are deficient in high frequencies, possibly indicating defects in the electronics or in the mechanical installation of the sensors.

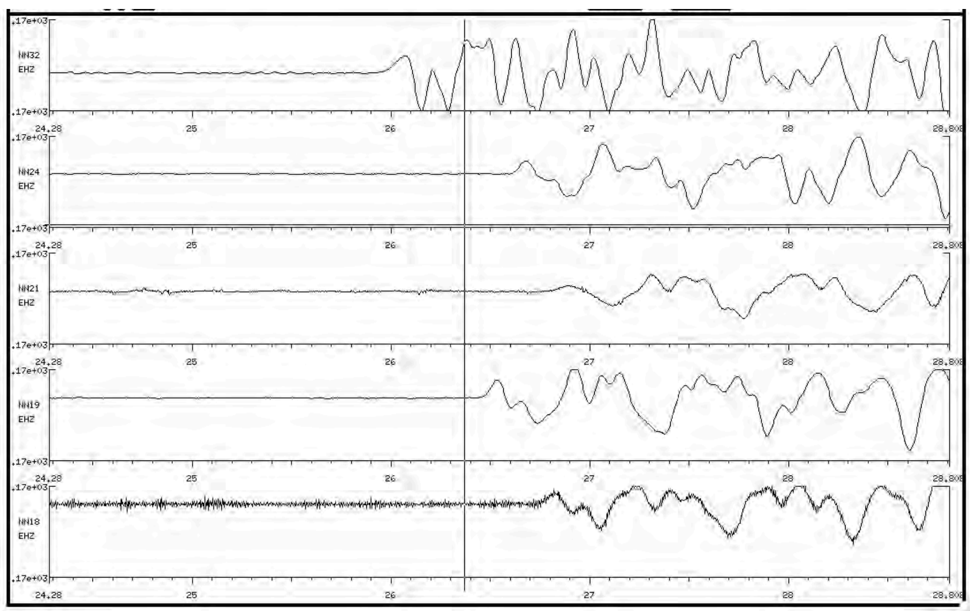


Figure 10: Vertical-component seismograms of the Nov. 10 quarry blast from stations NN32, NN24, NN21, NN19, and NN18. All first motions are upward, as expected.

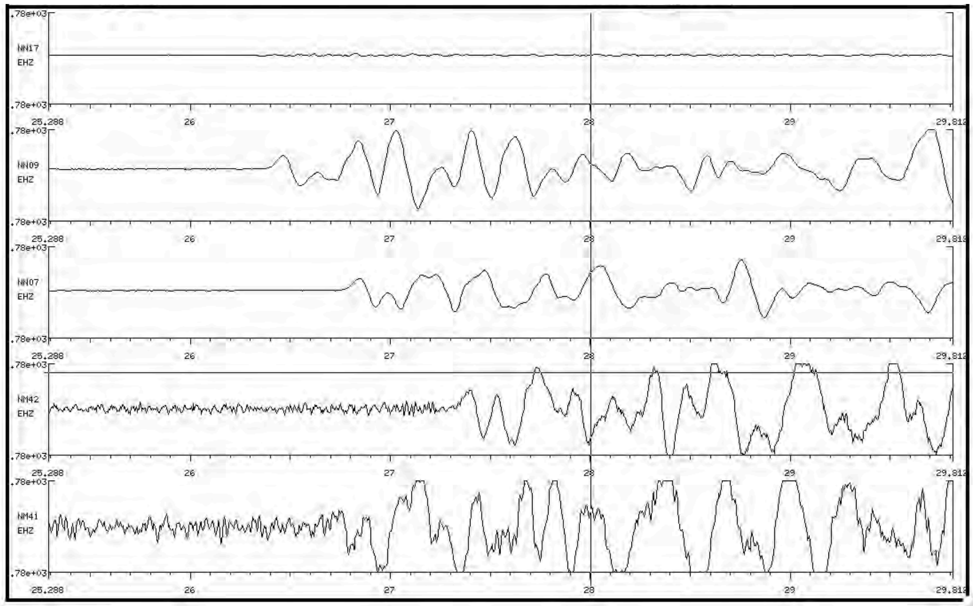


Figure 11: Vertical-component seismograms from stations NN17, NN09, NN07, NM42, and NM41. All except NN17 have upward first motions, as expected.

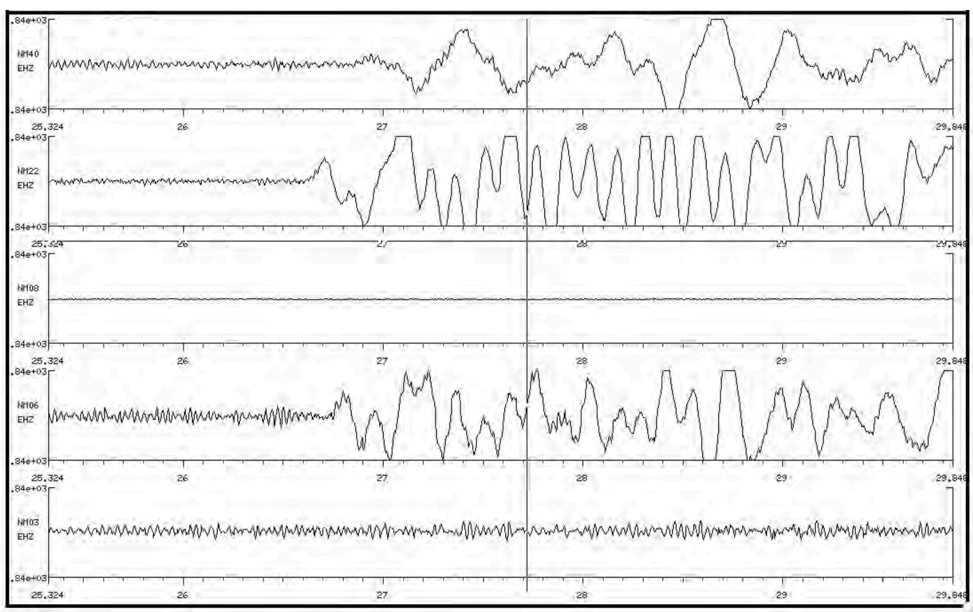


Figure 12: Vertical-component seismograms from stations NM40, NM22, NM08, NM06, and NM03. NM40, NM22, and NM06 have upward first motions, as expected.

Horizontal-component orientations and polarities: Regional signals such as those from quarry blasts are poorly suited for determining the polarities and orientations of horizontal-component sensors, because

P-phase signals involve weak horizontal motion. Nevertheless, we have been able to obtain useful information for most stations of the Newbery network.

P-phase first motions are expected to be away from an explosion, so for an event to the southwest first motions should be to the north and east. The north-component signals for 12 stations are in accord with this expectation; those for NM40,NM08, and NM06 cannot be determined reliably because of noise (Figure 13 to Figure 15).

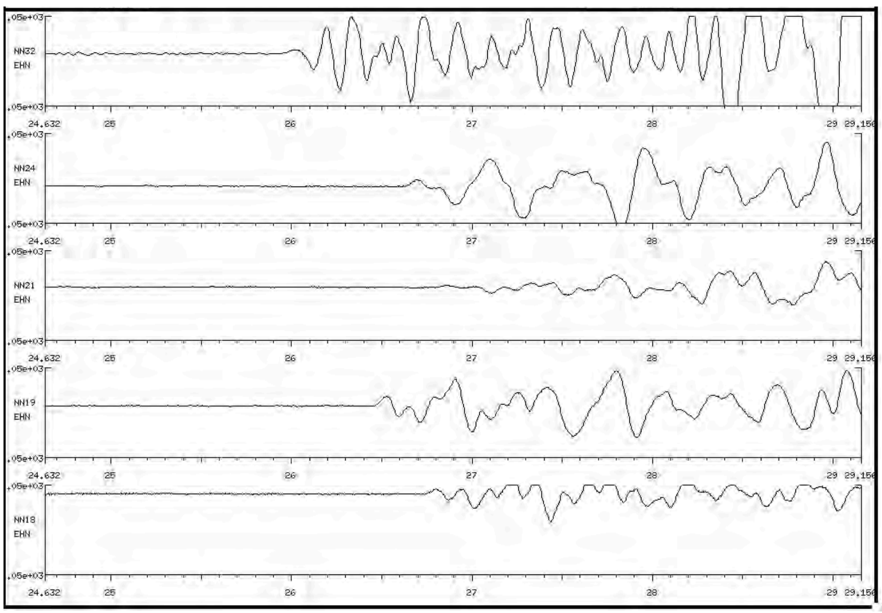


Figure 13: North-component seismograms of the Nov. 10 quarry blast from stations NN32, NN24, NN21, NN19, and NN18. All first motions are to the north, as expected.

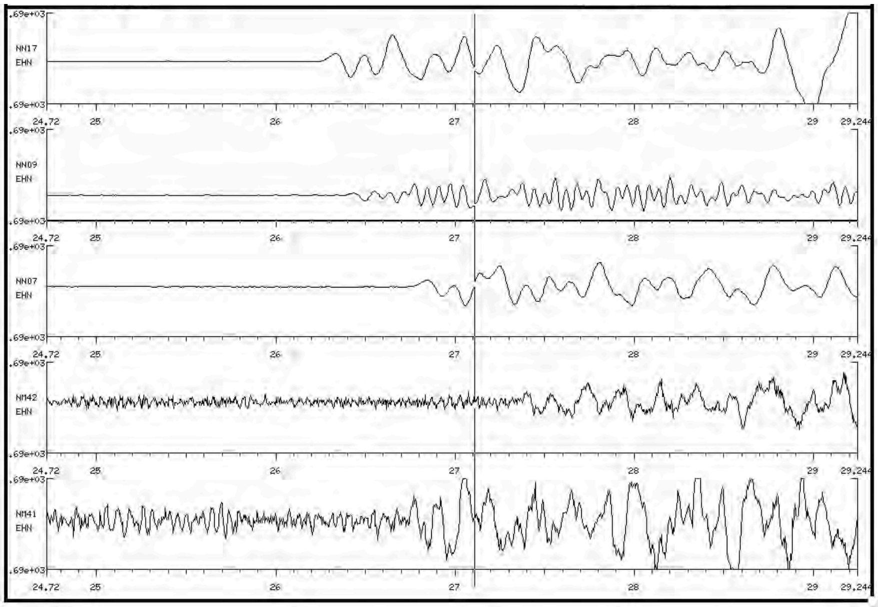


Figure 14: North-component seismograms of the Nov. 10 quarry blast from stations NN17, NN09, NN07, NM42, and NM41. All first motions are to the north, as expected.

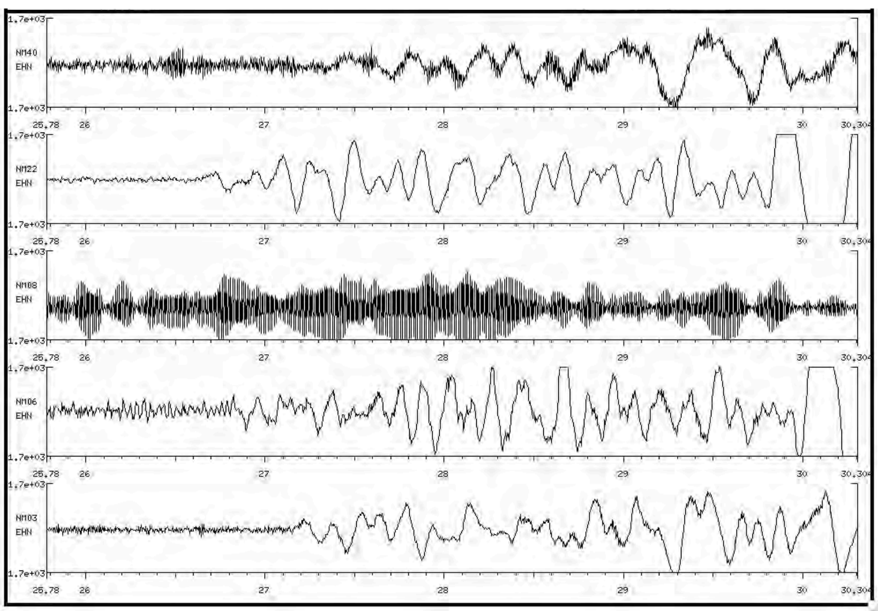


Figure 15: North-component seismograms of the Nov. 10 quarry blast from stations NM40, NM22, NM08, NM06, and NM03. First motions for NM22 and NM03 are to the north, as expected; signals from NM40, NM08, and NM06 are too noisy to be useful.

The east-component seismograms indicate that one station, NN09, has incorrect polarity. All the others appear to have correct polarity, although the signals are weak at NM42, NM41, NM40, NM06, and NM03 (Figure 16 to Figure 18).

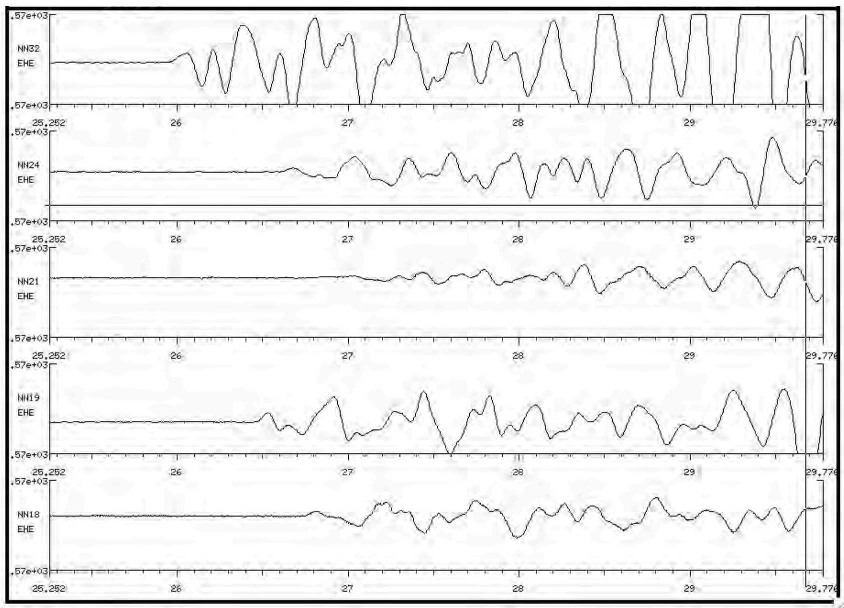


Figure 16: East-component seismograms of the Nov. 10 quarry blast from stations NN32, NN24, NN21, NN19, and NN18. All first motions are to the east, as expected.

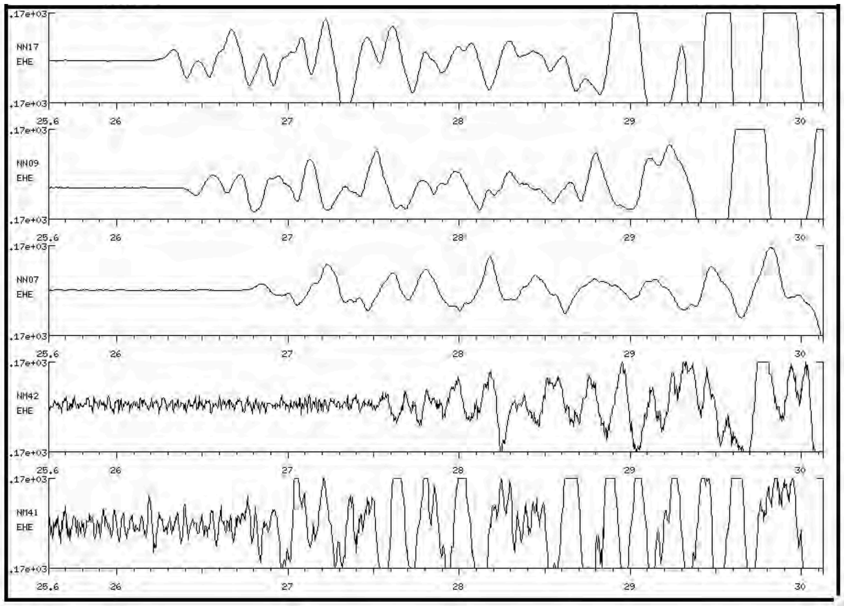


Figure 17: East-component seismograms of the Nov. 10 quarry blast from stations NN17, NN09, NN07, NM42, and NM41. First motions for NN17 and NN07 are to the east, as expected. Those for NM42 and NM41 are noisy, but probably to the east. The first motion for NN09 is to the west, indicating that the instrument is either wired incorrectly or installed incorrectly.

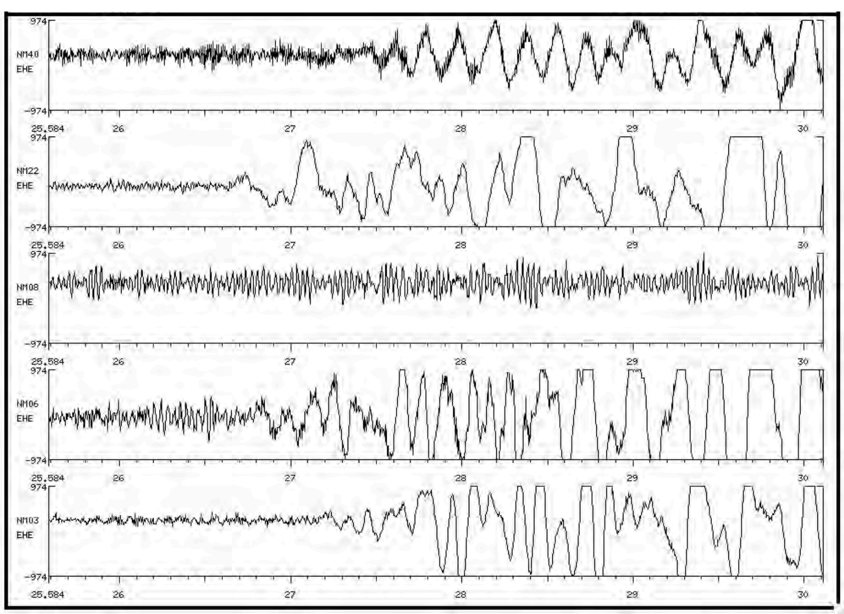


Figure 18: East-component seismograms of the Nov. 10 quarry blast from stations NM40, NM22, NM08, NM06, and NM03. The first motions for NM22 is to the east, as expected; those from NM40, NM06, and NM03 are noisy, but probably to the east. Station NM08 appears to be malfunctioning.

Table 1 summarizes the results of the polarity measurements made for this blast.

Table 1: Observed *P*-phase Polarities for Blast of 2014 Nov. 10, 21:10:20 UTC.

Station	V	N	E
NN32	+	+	+
NN24	+	+	+
NN21	+	+	+
NN19	+	+	+
NN18	+	+	+
NN17	BAD	+	+
NN09	+	+	-
NN07	+	+	+
NM42	+	+	+?
NM41	+	+	+?
NM40	+	?	+?
NM22	+	+	+
NM08	BAD	BAD	BAD
NM06	+	+?	+?
NM03	BAD	+	+?

5.2 Moment tensors

We continued to derive moment tensors using the procedure described in our Weekly Report #1. We report here an additional 11 moment tensors. The entire list of earthquakes processed to date is given in Appendix 1. The numerical results of the entire moment-tensor catalog, including the 10 new results obtained during the last week, are given in Appendix 2. Graphical results for the additional 10 events are given in Appendix 3. We have provided the locations and moment tensor decomposition data of these new moment tensors to Trenton Cladouhos of AltaRock electronically, by email attachment.

The source types for the entire 65-event set are shown in source-type space in Figure 19. The distribution remains similar to that reported earlier, i.e., source types ranging from +Dipole to -Dipole.

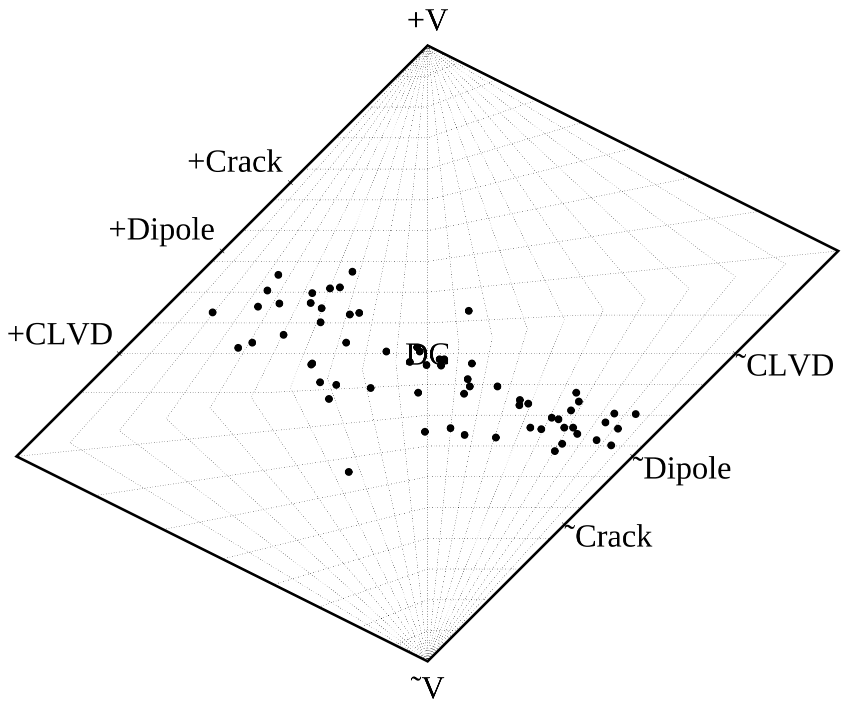


Figure 19: Source-type plot showing the 65 earthquakes for which moment tensors have been derived to date.

Figure 20 shows a plot of the P-, T- and I-axes, approximately corresponding to the directions of σ_1, σ_3 and σ_2. The addition of more earthquakes has strengthened the distribution seen earlier. Most T axes cluster systematically subhorizontally and to the S ± 20˚ or so. The orientations of the P-axes show some clustering in a sub-horizontal orientation to the NNE-ENE directions.

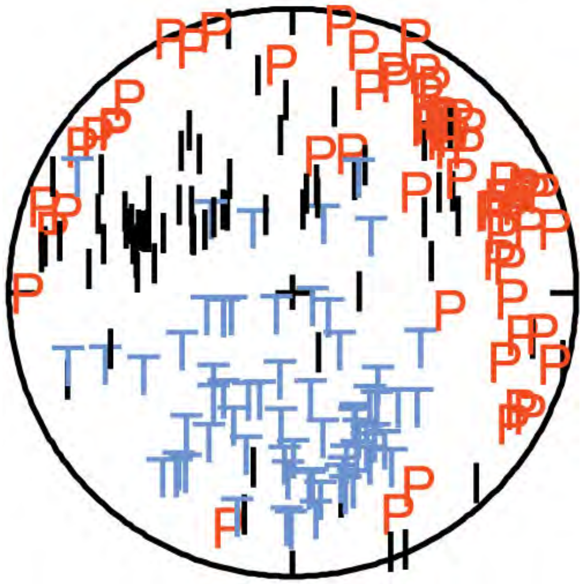


Figure 20: Plot of pressure (P ~ σ_1) and tension (T ~ σ_3) and intermediate (I ~ σ_2) axes for the 65 earthquakes for which moment tensors have been derived to date.

6 Brief summary statement

During the last week, vigorous earthquake activity has occurred in response to renewed injection. These earthquakes appear to be located slightly further to the NW than earlier earthquakes. They are restricted in time and the largest of them had a larger magnitude than any previous earthquake in the 8-week-long sequence.

Preliminary relative locations suggest that these later earthquakes may have partly filled the gap between the two earlier, separate seismogenic volumes. This result is preliminary and needs to be looked at more carefully in future, perhaps relative locating these later earthquakes separately from the earlier ones.

An additional 11 moment tensor results were obtained, including a result for the largest, M2.2 event. This event was complex and it proved difficult to either locate it or derive a moment tensor. Subsequent to our initial result, which showed a thrust mechanism, we obtained additional information on the calibration of the instruments. This moment tensor will be re-studied in the light of that new information. The general pattern of P- T- and I-axis orientations remains similar to what was observed earlier.

Appendix 1: The 65 earthquakes for which moment tensors have been obtained to date. Locations given below are from the webpage http://fracture.lbl.gov/Newberry/locations.txt.

jday	month	day	hour	minute	sec	lat	lon	depth	magnitude
272	9	29	9	57	54.34	43.7245	-121.30857	0.845	0.721
272	9	29	18	3	37.724	43.72365	-121.30658	1.274	0.669
273	9	30	9	23	48.799	43.71965	-121.30908	0.854	0.853
273	9	30	21	30	43.689	43.72667	-121.313	0.387	0.972
274	10	1	1	3	14.64	43.7239	-121.30957	0.714	0.987
274	10	1	8	8	58.215	43.72623	-121.31412	1.196	0.848
274	10	1	10	50	55.229	43.72275	-121.30868	1.051	0.787
274	10	1	12	3	16.881	43.72658	-121.3158	1.587	1.086
274	10	1	14	53	5.102	43.72545	-121.31355	0.613	1.381
274	10	1	15	1	55.056	43.72775	-121.31227	0.923	0.682
274	10	1	16	56	11.256	43.72232	-121.30712	1.65	0.901
274	10	1	19	5	16.377	43.72662	-121.31117	0.517	1.259
274	10	1	20	47	39.649	43.72612	-121.30912	0.826	0.505
274	10	1	22	13	54.154	43.72238	-121.30277	1.344	0.566
275	10	2	6	38	47.428	43.7243	-121.31328	1.153	0.951
275	10	2	6	47	52.916	43.72632	-121.31322	1.323	1.117
275	10	2	7	7	11.646	43.72488	-121.31192	0.708	1.378
275	10	2	7	21	48.731	43.72303	-121.30773	1.09	0.538
275	10	2	9	3	53.33	43.72217	-121.31288	0.736	0.519
275	10	2	11	1	48.042	43.72567	-121.31168	0.666	1.22
275	10	2	12	39	9.082	43.7264	-121.31438	1.332	0.852
275	10	2	16	12	20.481	43.72583	-121.30738	0.746	0.566
275	10	2	18	53	48.447	43.72082	-121.31372	1.671	0.957
275	10	2	20	36	50.997	43.72377	-121.31323	1.499	0.991
276	10	3	6	6	22.727	43.72528	-121.31493	0.928	1.157
276	10	3	15	27	57.912	43.72257	-121.31562	1.054	0.919
276	10	3	18	54	54.199	43.72678	-121.31125	0.647	1.021
277	10	4	5	29	8.347	43.72578	-121.31068	0.946	0.922
277	10	4	17	32	52.716	43.72207	-121.31693	0.376	1.521
277	10	4	18	51	11.991	43.72295	-121.31227	0.496	1.97
277	10	4	21	29	47.632	43.72813	-121.30428	0.988	0.586
278	10	5	2	6	17.079	43.7266	-121.31217	0.925	0.86
278	10	5	2	14	37.358	43.72433	-121.30915	0.459	0.665

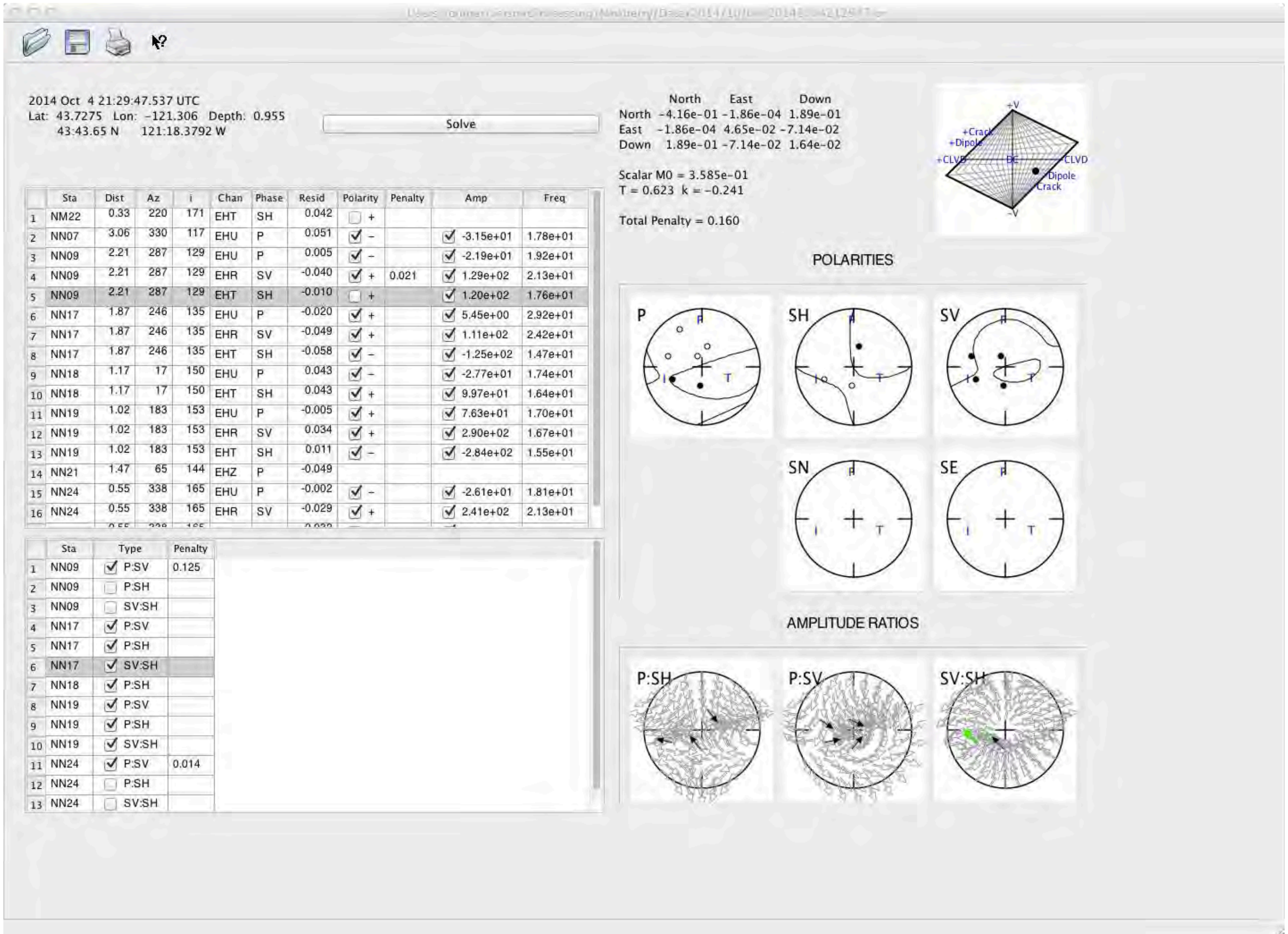
278	10	5	4	7	30.446	43.725	-121.31322	0.659	1.696
278	10	5	15	55	21.373	43.73483	-121.30918	0.702	0.695
278	10	5	16	7	32.904	43.7253	-121.30967	1.205	0.819
278	10	5	23	22	16.638	43.72368	-121.3116	1.055	0.931
279	10	6	4	2	55.851	43.72307	-121.30835	0.835	0.637
279	10	6	6	13	48.787	43.72425	-121.3097	0.638	0.604
280	10	7	6	12	8.757	43.72372	-121.31015	0.564	0.791
280	10	7	7	26	23.29	43.71807	-121.31032	0.962	0.574
280	10	7	10	47	21.079	43.72403	-121.3095	1.136	0.822
281	10	8	7	5	6.107	43.72662	-121.3048	0.864	0.541
281	10	8	19	8	20.701	43.71945	-121.31087	1.267	0.523
281	10	8	21	16	58.206	43.73442	-121.31173	1.703	0.522
282	10	9	6	24	33.517	43.72232	-121.31203	0.735	0.769
282	10	9	10	16	9.958	43.7172	-121.31332	1.378	0.722
284	10	11	3	29	5.813	43.72417	-121.31338	0.409	0.852
284	10	11	10	53	26.568	43.72493	-121.30897	1.292	0.824
285	10	12	10	12	29.727	43.7257	-121.3135	0.783	0.863
285	10	12	16	37	43.42	43.72515	-121.3151	0.49	1.482
285	10	12	16	47	1.174	43.7297	-121.3126	1.07	0.681
285	10	12	18	33	4.878	43.72363	-121.30787	0.359	0.743
285	10	12	21	10	18.995	43.72783	-121.31002	0.653	0.792
286	10	13	0	57	6.873	43.72382	-121.3175	0.242	1.197
286	10	13	4	12	29.232	43.72657	-121.30698	0.882	1.179
286	10	13	10	22	29.146	43.7302	-121.3153	0.831	0.907
287	10	14	5	46	14.161	43.71765	-121.31087	0.161	0.904
288	10	15	15	3	44.691	43.72658	-121.30768	0.897	0.781
288	10	15	15	37	26.034	43.72713	-121.30915	0.934	0.883
289	10	16	16	53	27.596	43.72378	-121.31295	-0.186	0.736
291	10	18	23	57	3.867	43.72965	-121.31732	0.116	0.781
292	10	19	9	7	50.375	43.73525	-121.3113	0.837	0.776
296	10	23	21	2	22.32	43.7257	-121.30855	0.819	0.6
321	11	17	4	41	53.061	43.7249	-121.31087	0.708	2.2

Appendix 2: Numerical moment tensor results for the 65 MEQs studied to date. N=North, E=East, D=Down.

NN	NE	EE	ND	ED	DD	Year	Mo	Day	Hr	min	Sec	Quality
1.91E-01	-1.22E-01	-8.47E-02	1.94E-01	2.39E-02	4.51E-02	2014	9	29	9	57	54.158	excellent
5.00E-02	-1.93E-01	-1.24E-01	1.75E-01	2.48E-02	3.99E-02	2014	9	29	18	3	37.66	excellent
6.49E-02	-9.50E-02	-2.84E-01	6.74E-02	1.45E-01	-3.58E-02	2014	9	30	9	23	48.626	good
-2.67E-01	1.32E-01	-6.40E-02	6.06E-02	1.03E-01	7.79E-02	2014	9	30	21	30	43.503	excellent
-1.78E-01	-1.05E-01	-1.51E-01	7.11E-02	1.06E-01	1.06E-01	2014	10	1	1	3	14.49	excellent
1.48E-01	-1.18E-01	-1.49E-01	1.58E-01	-3.13E-02	9.55E-02	2014	10	1	8	8	57.998	excellent
-3.26E-02	2.22E-01	-3.37E-01	1.64E-02	7.16E-02	9.88E-03	2014	10	1	10	50	55.107	excellent
2.00E-01	-1.41E-01	-1.46E-01	1.40E-01	-8.71E-03	7.41E-02	2014	10	1	12	3	16.94	good
1.58E-01	3.47E-02	6.67E-02	2.48E-01	6.32E-02	8.34E-02	2014	10	1	14	53	5.23	excellent
-1.04E-01	1.46E-01	-2.54E-01	1.25E-01	-1.33E-02	7.34E-02	2014	10	1	15	1	54.95	excellent
-2.21E-01	-8.13E-02	-2.19E-02	-1.52E-01	3.52E-02	2.20E-01	2014	10	1	16	56	11.343	good
2.17E-01	-3.67E-02	-6.42E-02	2.35E-01	7.20E-02	3.18E-02	2014	10	1	19	5	16.54	excellent
3.03E-02	-1.92E-01	-9.50E-02	1.99E-01	1.07E-02	7.11E-02	2014	10	1	20	47	39.521	excellent
1.28E-01	1.27E-01	-6.92E-02	8.79E-02	1.45E-01	-8.42E-02	2014	10	1	22	13	54.151	good
1.62E-01	4.20E-02	-2.04E-01	2.16E-01	-2.04E-02	7.76E-02	2014	10	2	6	39	2.998	excellent
-1.46E-02	9.64E-02	-3.98E-01	2.60E-02	1.69E-01	-4.69E-03	2014	10	2	6	47	52.94	excellent
-1.17E-01	1.71E-01	-1.99E-01	1.39E-01	-2.43E-02	1.64E-02	2014	10	2	7	7	4.16	excellent
3.77E-01	-1.27E-02	-1.42E-01	1.29E-01	8.11E-02	3.59E-02	2014	10	2	7	22	3.575	good
5.18E-02	-1.72E-01	-2.48E-02	2.09E-01	-2.97E-02	1.02E-01	2014	10	2	9	4	8.647	good
2.41E-01	-7.30E-02	-9.79E-02	1.73E-01	4.30E-02	8.35E-02	2014	10	2	11	1	42.38	excellent
-6.57E-02	-1.85E-01	-1.14E-01	1.69E-01	4.18E-02	2.83E-02	2014	10	2	12	39	24.317	good
-2.17E-01	-2.31E-01	4.01E-02	5.04E-02	7.21E-02	3.58E-02	2014	10	2	16	12	35.315	weak
2.31E-03	-1.80E-01	-9.21E-02	2.20E-01	-4.35E-03	9.59E-02	2014	10	2	18	54	3.152	good
1.42E-01	-1.37E-01	-1.64E-01	1.72E-01	1.08E-02	5.38E-02	2014	10	2	20	37	6.043	good
6.07E-03	-2.23E-01	-9.16E-02	1.94E-01	3.37E-02	-6.18E-04	2014	10	3	6	6	22.76	excellent
2.45E-01	-8.11E-02	-1.97E-01	1.74E-01	1.62E-02	1.51E-02	2014	10	3	15	27	57.661	good
-5.77E-02	-1.66E-01	-1.43E-01	1.46E-01	7.81E-02	-1.95E-02	2014	10	3	18	54	53.93	fair
1.68E-01	-3.35E-02	-9.83E-03	2.95E-01	3.54E-02	9.35E-02	2014	10	4	5	29	8.258	fair
-1.03E-01	1.33E-01	-1.19E-01	1.48E-01	5.51E-02	1.07E-01	2014	10	4	17	32	52.76	excellent
8.71E-02	1.26E-01	-4.19E-02	1.81E-01	8.43E-02	8.72E-02	2014	10	4	18	51	12	excellent
-4.16E-01	-1.86E-04	4.65E-02	1.89E-01	-7.14E-02	1.64E-02	2014	10	4	21	29	47.537	moderate
-1.37E-01	-1.84E-01	-5.91E-02	1.61E-01	-1.12E-02	9.22E-02	2014	10	5	2	6	16.967	excellent
-2.45E-02	-1.88E-01	-1.23E-01	1.69E-01	9.68E-03	1.19E-01	2014	10	5	2	14	37.168	excellent
5.30E-02	6.78E-02	-1.18E-01	1.62E-01	7.51E-02	2.21E-01	2014	10	5	4	7	20	excellent
-2.29E-01	1.61E-01	-7.21E-02	-9.28E-02	8.01E-02	-3.22E-02	2014	10	5	15	55	21.007	good
2.87E-01	-3.71E-02	-1.79E-01	9.26E-02	1.26E-01	2.27E-02	2014	10	5	16	7	32.777	excellent
-1.87E-01	9.00E-02	-9.47E-02	-1.45E-01	-2.49E-02	1.99E-01	2014	10	5	23	22	16.499	good

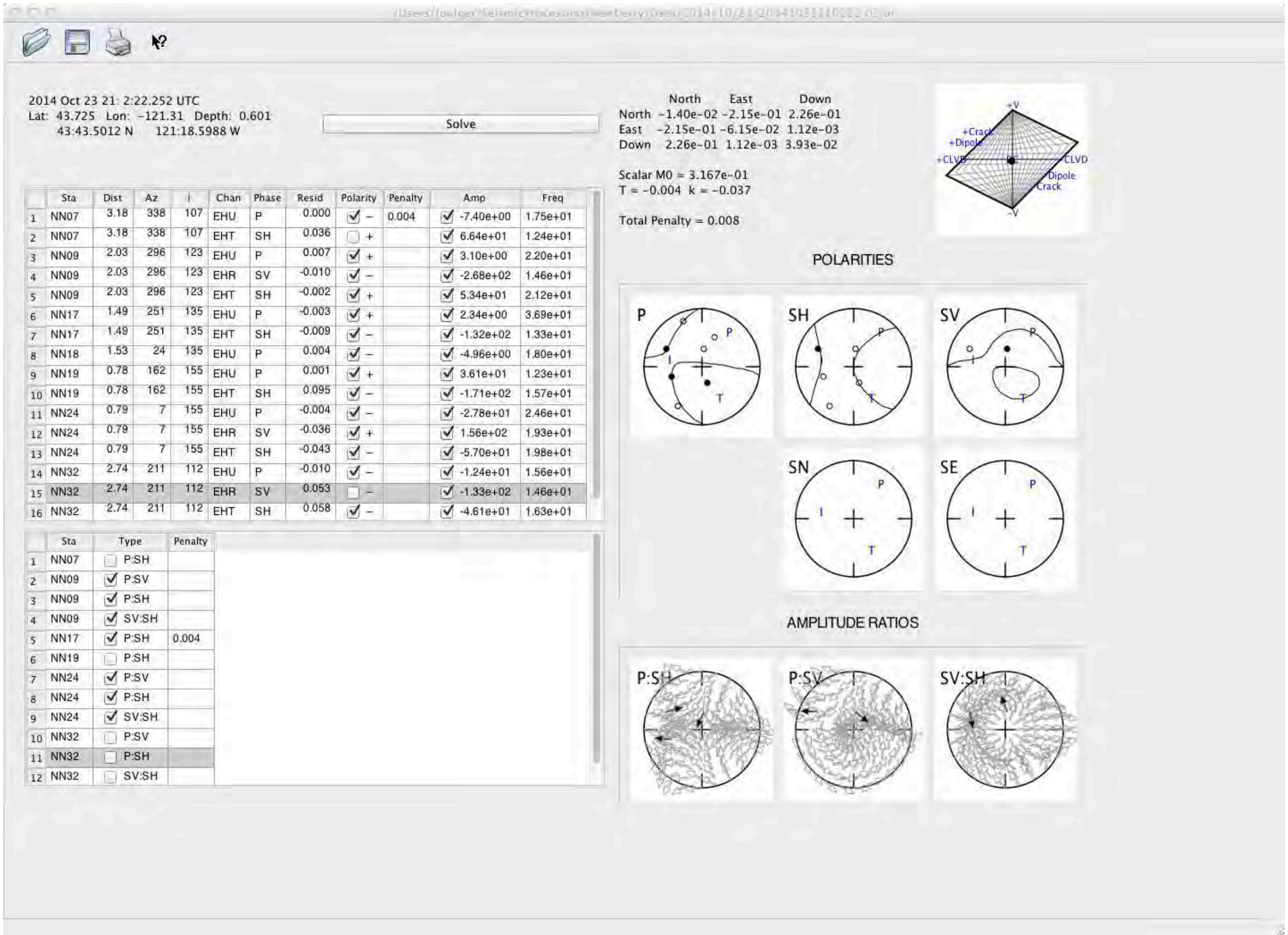
-8.06E-02	-9.30E-02	-2.67E-01	6.01E-02	1.63E-01	-2.04E-02	2014	10	6	4	2	55.789	good
-3.56E-01	1.59E-01	1.19E-01	5.15E-02	2.88E-02	4.70E-02	2014	10	6	6	13	48.626	excellent
1.32E-01	1.00E-01	-3.87E-01	3.12E-02	9.89E-02	1.91E-02	2014	10	7	6	12	8.593	good
2.45E-01	-1.19E-01	-1.14E-01	1.67E-01	-1.16E-02	4.69E-02	2014	10	7	7	26	23.18	good
4.38E-02	2.44E-01	-1.80E-01	4.37E-02	9.99E-02	-2.18E-05	2014	10	7	10	47	20.916	good
2.55E-02	1.51E-01	-2.81E-01	1.69E-02	1.79E-01	-4.14E-04	2014	10	8	7	5	5.941	weak
-7.82E-03	2.19E-01	-2.87E-01	2.80E-02	1.01E-01	-8.51E-03	2014	10	8	19	8	20.619	excellent
-1.75E-01	-2.00E-01	-6.44E-02	1.28E-01	-1.70E-02	6.96E-02	2014	10	8	21	16	58.2	good
2.44E-02	7.10E-02	-2.43E-02	-8.64E-02	-1.62E-01	3.13E-01	2014	10	9	6	24	33.418	excellent
7.44E-02	8.69E-02	-6.60E-02	-1.45E-01	-9.86E-02	1.98E-01	2014	10	9	10	16	9.945	moderate
-1.43E-01	-1.36E-01	3.35E-03	1.56E-01	-5.83E-02	1.55E-01	2014	10	11	3	29	5.667	good
3.71E-03	3.87E-02	-3.57E-01	5.61E-02	2.09E-01	2.16E-02	2014	10	11	10	53	26.502	good
-1.35E-01	-1.17E-01	-4.10E-02	2.00E-01	-5.35E-02	8.30E-02	2014	10	12	10	12	29	good
-4.88E-01	-1.02E-01	5.62E-02	5.97E-02	-1.84E-03	1.29E-01	2014	10	12	16	37	43.287	excellent
4.02E-02	-1.23E-01	-2.57E-01	1.61E-01	1.97E-02	9.60E-02	2014	10	12	16	47	1.137	excellent
2.03E-01	-2.42E-02	-3.05E-01	1.71E-01	-4.33E-02	1.58E-02	2014	10	12	18	33	4.693	moderate
-2.21E-01	1.54E-01	4.96E-02	9.04E-02	8.19E-02	7.60E-02	2014	10	12	21	10	23.311	good
-5.87E-02	-1.25E-01	-2.80E-01	6.12E-02	1.41E-01	6.33E-03	2014	10	13	0	57	6.717	good
2.61E-02	-1.18E-01	-2.89E-01	8.03E-02	1.23E-01	4.15E-02	2014	10	13	4	12	29.126	excellent
-1.16E-01	-1.39E-01	-1.17E-01	1.51E-01	5.54E-02	7.56E-02	2014	10	13	10	22	29.084	excellent
-1.13E-01	-2.73E-02	-2.41E-01	5.66E-02	5.18E-02	3.75E-01	2014	10	14	5	46	13.914	exellent
-1.27E-01	-1.70E-01	3.34E-02	1.57E-01	-5.42E-02	7.86E-02	2014	10	15	15	3	44.602	excellent
-5.10E-02	-1.76E-01	-8.51E-02	1.95E-01	1.28E-03	1.20E-01	2014	10	15	15	37	25.945	excellent
-4.01E-01	-1.33E-01	-3.89E-03	1.17E-01	1.60E-02	6.35E-02	2014	10	16	16	53	27.374	good
-4.20E-02	-1.46E-01	-3.20E-01	-5.38E-04	1.43E-01	5.83E-02	2014	10	18	23	57	3.695	good
-1.86E-01	8.58E-02	-2.76E-01	1.40E-01	-1.35E-02	6.01E-02	2014	10	19	9	7	50.325	good
-1.40E-02	-2.15E-01	-6.15E-02	2.27E-01	1.12E-03	3.93E-02	2014	10	23	21	2	22.252	good
-2.49E-01	-8.81E-02	-1.12E-01	3.18E-02	-3.71E-02	3.26E-01	2014	11	17	4	41	52.962	excellent

Appendix 3: The additional 11 moment tensors derived over the reporting week.



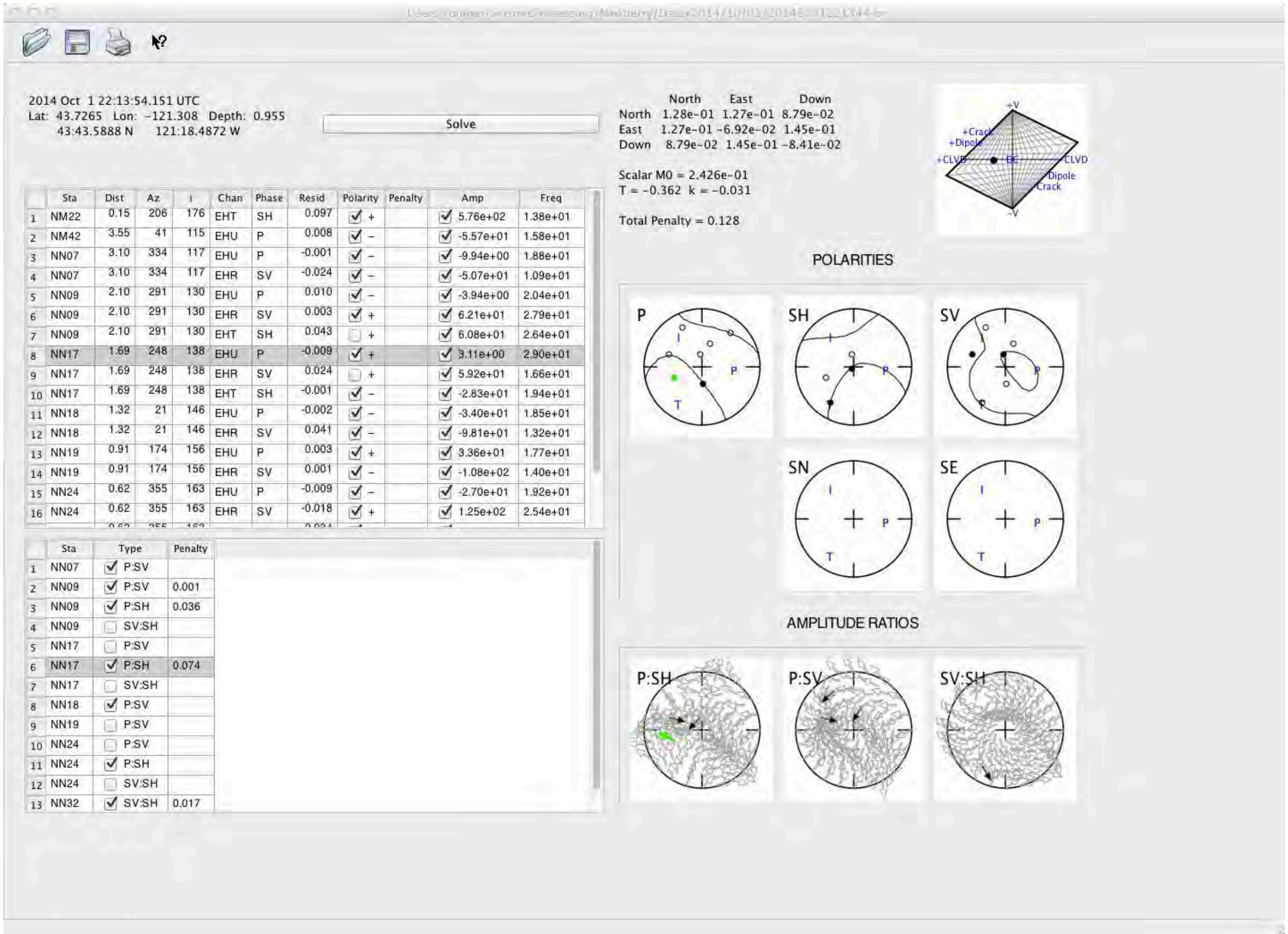
	Sta	Dist	Az	i	Chan	Phase	Resid	Polarity	Penalty	Amp	Freq
1	NM22	0.33	220	171	EHT	SH	0.042	☐ +			
2	NN07	3.06	330	117	EHU	P	0.051	✓ –		✓ -3.15e+01	1.78e+01
3	NN09	2.21	287	129	EHU	P	0.005	✓ –		✓ -2.19e+01	1.92e+01
4	NN09	2.21	287	129	EHR	SV	-0.040	✓ +	0.021	✓ 1.29e+02	2.13e+01
5	NN09	2.21	287	129	EHT	SH	-0.010	☐ +		✓ 1.20e+02	1.76e+01
6	NN17	1.87	246	135	EHU	P	-0.020	✓ +		✓ 5.45e+00	2.92e+01
7	NN17	1.87	246	135	EHR	SV	-0.049	✓ +		✓ 1.11e+02	2.42e+01
8	NN17	1.87	246	135	EHT	SH	-0.058	✓ –		✓ -1.25e+02	1.47e+01
9	NN18	1.17	17	150	EHU	P	0.043	✓ –		✓ -2.77e+01	1.74e+01
10	NN18	1.17	17	150	EHT	SH	0.043	✓ +		✓ 9.97e+01	1.64e+01
11	NN19	1.02	183	153	EHU	P	-0.005	✓ +		✓ 7.63e+01	1.70e+01
12	NN19	1.02	183	153	EHR	SV	0.034	✓ +		✓ 2.90e+02	1.67e+01
13	NN19	1.02	183	153	EHT	SH	0.011	✓ –		✓ -2.84e+02	1.55e+01
14	NN21	1.47	65	144	EHZ	P	-0.049				
15	NN24	0.55	338	165	EHU	P	-0.002	✓ –		✓ -2.61e+01	1.81e+01
16	NN24	0.55	338	165	EHR	SV	-0.029	✓ +		✓ 2.41e+02	2.13e+01

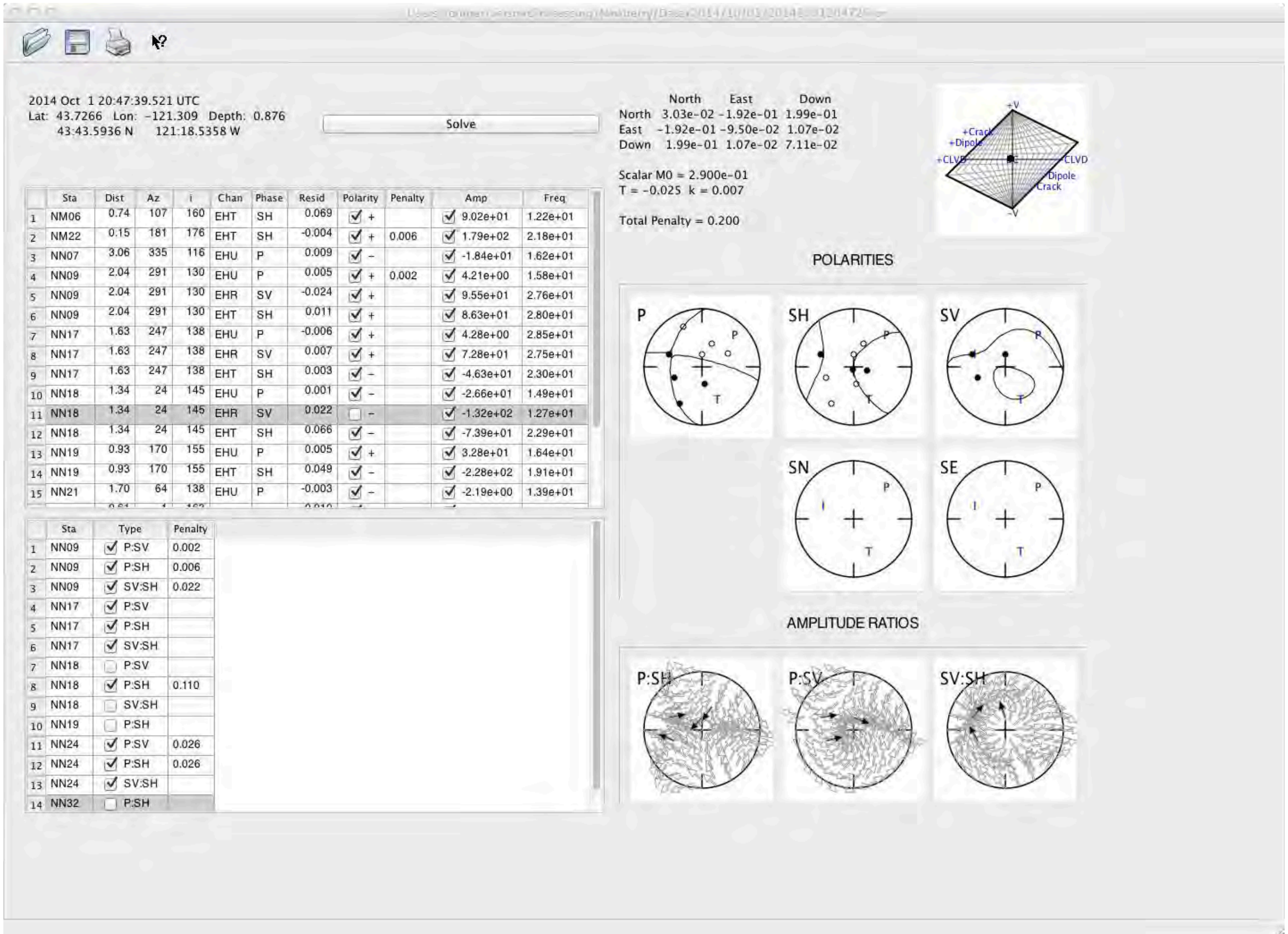
	Sta	Type	Penalty
1	NN09	✓ P:SV	0.125
2	NN09	☐ P:SH	
3	NN09	☐ SV:SH	
4	NN17	✓ P:SV	
5	NN17	✓ P:SH	
6	NN17	✓ SV:SH	
7	NN18	✓ P:SH	
8	NN19	✓ P:SV	
9	NN19	✓ P:SH	
10	NN19	✓ SV:SH	
11	NN24	✓ P:SV	0.014
12	NN24	☐ P:SH	
13	NN24	☐ SV:SH	

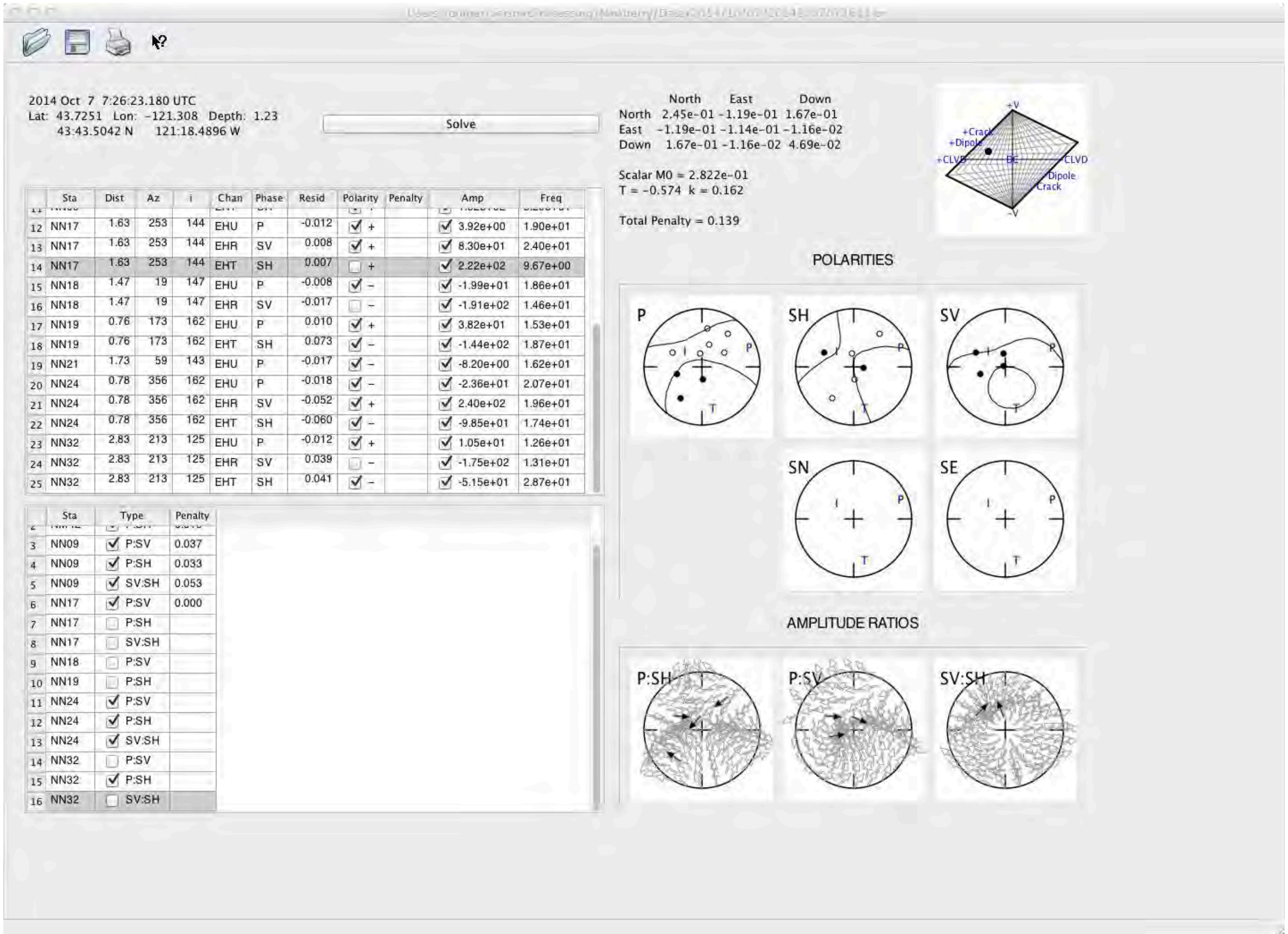


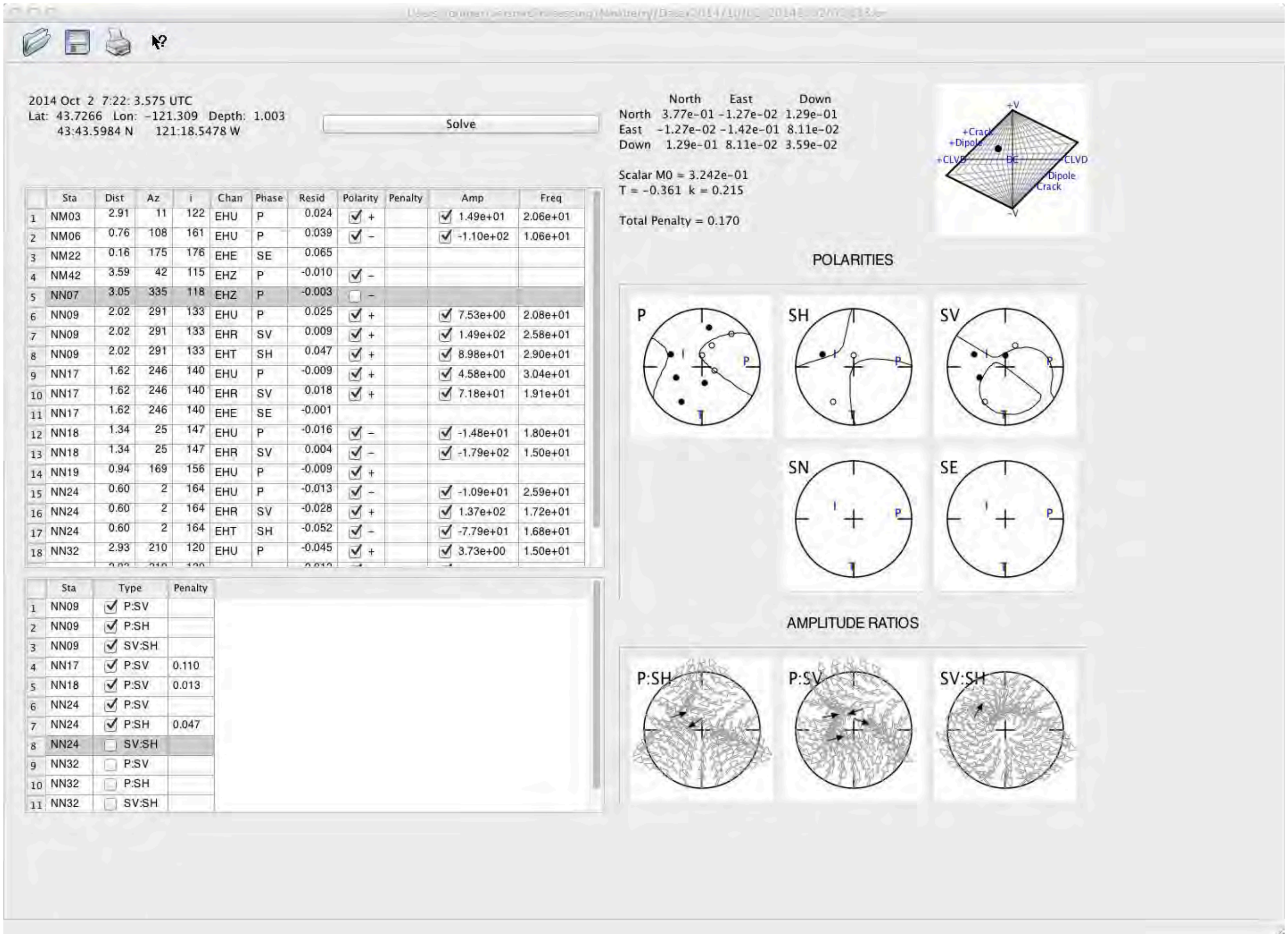
	Sta	Dist	Az	i	Chan	Phase	Resid	Polarity	Penalty	Amp	Freq
1	NN07	3.18	338	107	EHU	P	0.000	✓ −	0.004	✓ -7.40e+00	1.75e+01
2	NN07	3.18	338	107	EHT	SH	0.036	☐ +		✓ 6.64e+01	1.24e+01
3	NN09	2.03	296	123	EHU	P	0.007	✓ +		✓ 3.10e+00	2.20e+01
4	NN09	2.03	296	123	EHR	SV	-0.010	✓ −		✓ -2.68e+02	1.46e+01
5	NN09	2.03	296	123	EHT	SH	-0.002	✓ +		✓ 5.34e+01	2.12e+01
6	NN17	1.49	251	135	EHU	P	-0.003	✓ +		✓ 2.34e+00	3.69e+01
7	NN17	1.49	251	135	EHT	SH	-0.009	✓ −		✓ -1.32e+02	1.33e+01
8	NN18	1.53	24	135	EHU	P	0.004	✓ −		✓ -4.96e+00	1.80e+01
9	NN19	0.78	162	155	EHU	P	0.001	✓ +		✓ 3.61e+01	1.23e+01
10	NN19	0.78	162	155	EHT	SH	0.095	✓ −		✓ -1.71e+02	1.57e+01
11	NN24	0.79	7	155	EHU	P	-0.004	✓ −		✓ -2.78e+01	2.46e+01
12	NN24	0.79	7	155	EHR	SV	-0.036	✓ +		✓ 1.56e+02	1.93e+01
13	NN24	0.79	7	155	EHT	SH	-0.043	✓ −		✓ -5.70e+01	1.98e+01
14	NN32	2.74	211	112	EHU	P	-0.010	✓ −		✓ -1.24e+01	1.56e+01
15	NN32	2.74	211	112	EHR	SV	0.053	☐ −		✓ -1.33e+02	1.46e+01
16	NN32	2.74	211	112	EHT	SH	0.058	✓ −		✓ -4.61e+01	1.63e+01

	Sta	Type	Penalty
1	NN07	☐ P:SH	
2	NN09	✓ P:SV	
3	NN09	✓ P:SH	
4	NN09	✓ SV:SH	
5	NN17	✓ P:SH	0.004
6	NN19	☐ P:SH	
7	NN24	✓ P:SV	
8	NN24	✓ P:SH	
9	NN24	✓ SV:SH	
10	NN32	☐ P:SV	
11	NN32	☐ P:SH	
12	NN32	☐ SV:SH	


2014 Oct 1 22:13:54.151 UTC
Lat: 43.7265 Lon: -121.308 Depth: 0.955
43:43.5888 N 121:18.4872 W
Solve
North East Down
North 1.28e-01 1.27e-01 8.79e-02
East 1.27e-01 -6.92e-02 1.45e-01
Down 8.79e-02 1.45e-01 -8.41e-02
Scalar M0 = 2.426e-01
T = -0.362 k = -0.031
Total Penalty = 0.128
+V
+Crack
+Dipole
+CLVD
DC
CLVD
Dipole
Crack
-V
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM22 0.15 206 176 EHT SH 0.097 + 5.76e+02 1.38e+01
2 NM42 3.55 41 115 EHU P 0.008 – -5.57e+01 1.58e+01
3 NN07 3.10 334 117 EHU P -0.001 – -9.94e+00 1.88e+01
4 NN07 3.10 334 117 EHR SV -0.024 – -5.07e+01 1.09e+01
5 NN09 2.10 291 130 EHU P 0.010 – -3.94e+00 2.04e+01
6 NN09 2.10 291 130 EHR SV 0.003 + 6.21e+01 2.79e+01
7 NN09 2.10 291 130 EHT SH 0.043 + 6.08e+01 2.64e+01
8 NN17 1.69 248 138 EHU P -0.009 + 3.11e+00 2.90e+01
9 NN17 1.69 248 138 EHR SV 0.024 + 5.92e+01 1.66e+01
10 NN17 1.69 248 138 EHT SH -0.001 – -2.83e+01 1.94e+01
11 NN18 1.32 21 146 EHU P -0.002 – -3.40e+01 1.85e+01
12 NN18 1.32 21 146 EHR SV 0.041 – -9.81e+01 1.32e+01
13 NN19 0.91 174 156 EHU P 0.003 + 3.36e+01 1.77e+01
14 NN19 0.91 174 156 EHR SV 0.001 – -1.08e+02 1.40e+01
15 NN24 0.62 355 163 EHU P -0.009 – -2.70e+01 1.92e+01
16 NN24 0.62 355 163 EHR SV -0.018 + 1.25e+02 2.54e+01
Sta Type Penalty
1 NN07 P:SV
2 NN09 P:SV 0.001
3 NN09 P:SH 0.036
4 NN09 SV:SH
5 NN17 P:SV
6 NN17 P:SH 0.074
7 NN17 SV:SH
8 NN18 P:SV
9 NN19 P:SV
10 NN24 P:SV
11 NN24 P:SH
12 NN24 SV:SH
13 NN32 SV:SH 0.017
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH

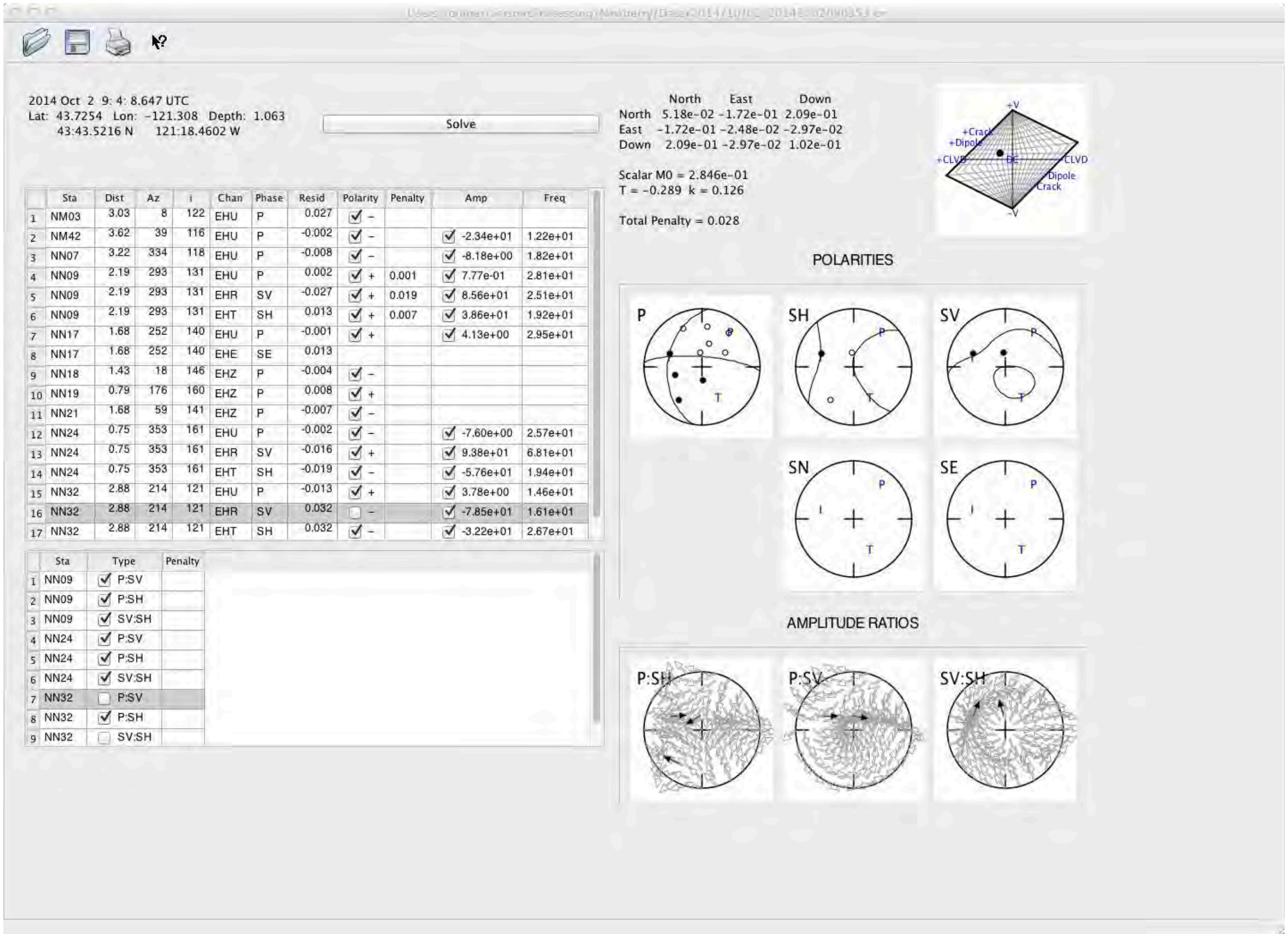

2014 Oct 1 20:47:39.521 UTC
Lat: 43.7266 Lon: -121.309 Depth: 0.876
43:43.5936 N 121:18.5358 W
Solve
North East Down
North 3.03e-02 -1.92e-01 1.99e-01
East -1.92e-01 -9.50e-02 1.07e-02
Down 1.99e-01 1.07e-02 7.11e-02
Scalar M0 = 2.900e-01
T = -0.025 k = 0.007
Total Penalty = 0.200
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM06 0.74 107 160 EHT SH 0.069 + 9.02e+01 1.22e+01
2 NM22 0.15 181 176 EHT SH -0.004 + 0.006 1.79e+02 2.18e+01
3 NN07 3.06 335 116 EHU P 0.009 – -1.84e+01 1.62e+01
4 NN09 2.04 291 130 EHU P 0.005 + 0.002 4.21e+00 1.58e+01
5 NN09 2.04 291 130 EHR SV -0.024 + 9.55e+01 2.76e+01
6 NN09 2.04 291 130 EHT SH 0.011 + 8.63e+01 2.80e+01
7 NN17 1.63 247 138 EHU P -0.006 + 4.28e+00 2.85e+01
8 NN17 1.63 247 138 EHR SV 0.007 + 7.28e+01 2.75e+01
9 NN17 1.63 247 138 EHT SH 0.003 – -4.63e+01 2.30e+01
10 NN18 1.34 24 145 EHU P 0.001 – -2.66e+01 1.49e+01
11 NN18 1.34 24 145 EHR SV 0.022 – -1.32e+02 1.27e+01
12 NN18 1.34 24 145 EHT SH 0.066 – -7.39e+01 2.29e+01
13 NN19 0.93 170 155 EHU P 0.005 + 3.28e+01 1.64e+01
14 NN19 0.93 170 155 EHT SH 0.049 – -2.28e+02 1.91e+01
15 NN21 1.70 64 138 EHU P -0.003 – -2.19e+00 1.39e+01
Sta Type Penalty
1 NN09 P:SV 0.002
2 NN09 P:SH 0.006
3 NN09 SV:SH 0.022
4 NN17 P:SV
5 NN17 P:SH
6 NN17 SV:SH
7 NN18 P:SV
8 NN18 P:SH 0.110
9 NN18 SV:SH
10 NN19 P:SH
11 NN24 P:SV 0.026
12 NN24 P:SH 0.026
13 NN24 SV:SH
14 NN32 P:SH
+V
+Crack
+Dipole
+CLVD
-CLVD
-Dipole
-Crack
-V
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH


Solve
2014 Oct 7 7:26:23.180 UTC
Lat: 43.7251 Lon: -121.308 Depth: 1.23
43:43.5042 N 121:18.4896 W
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
12 NN17 1.63 253 144 EHU P -0.012 + 3.92e+00 1.90e+01
13 NN17 1.63 253 144 EHR SV 0.008 + 8.30e+01 2.40e+01
14 NN17 1.63 253 144 EHT SH 0.007 + 2.22e+02 9.67e+00
15 NN18 1.47 19 147 EHU P -0.008 – -1.99e+01 1.86e+01
16 NN18 1.47 19 147 EHR SV -0.017 – -1.91e+02 1.46e+01
17 NN19 0.76 173 162 EHU P 0.010 + 3.82e+01 1.53e+01
18 NN19 0.76 173 162 EHT SH 0.073 – -1.44e+02 1.87e+01
19 NN21 1.73 59 143 EHU P -0.017 – -8.20e+00 1.62e+01
20 NN24 0.78 356 162 EHU P -0.018 – -2.36e+01 2.07e+01
21 NN24 0.78 356 162 EHR SV -0.052 + 2.40e+02 1.96e+01
22 NN24 0.78 356 162 EHT SH -0.060 – -9.85e+01 1.74e+01
23 NN32 2.83 213 125 EHU P -0.012 + 1.05e+01 1.26e+01
24 NN32 2.83 213 125 EHR SV 0.039 – -1.75e+02 1.31e+01
25 NN32 2.83 213 125 EHT SH 0.041 – -5.15e+01 2.87e+01
Sta Type Penalty
3 NN09 P:SV 0.037
4 NN09 P:SH 0.033
5 NN09 SV:SH 0.053
6 NN17 P:SV 0.000
7 NN17 P:SH
8 NN17 SV:SH
9 NN18 P:SV
10 NN19 P:SH
11 NN24 P:SV
12 NN24 P:SH
13 NN24 SV:SH
14 NN32 P:SV
15 NN32 P:SH
16 NN32 SV:SH
North East Down
North 2.45e-01 -1.19e-01 1.67e-01
East -1.19e-01 -1.14e-01 -1.16e-02
Down 1.67e-01 -1.16e-02 4.69e-02
Scalar M0 = 2.822e-01
T = -0.574 k = 0.162
Total Penalty = 0.139
+V
+Crack
+Dipole
+CLVD
DC
CLVD
Dipole
Crack
-V
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH



	Sta	Dist	Az	i	Chan	Phase	Resid	Polarity	Penalty	Amp	Freq
1	NM03	2.91	11	122	EHU	P	0.024	✓ +		✓ 1.49e+01	2.06e+01
2	NM06	0.76	108	161	EHU	P	0.039	✓ –		✓ -1.10e+02	1.06e+01
3	NM22	0.16	175	176	EHE	SE	0.065				
4	NM42	3.59	42	115	EHZ	P	-0.010	✓ –			
5	NN07	3.05	335	118	EHZ	P	-0.003	☐ –			
6	NN09	2.02	291	133	EHU	P	0.025	✓ +		✓ 7.53e+00	2.08e+01
7	NN09	2.02	291	133	EHR	SV	0.009	✓ +		✓ 1.49e+02	2.58e+01
8	NN09	2.02	291	133	EHT	SH	0.047	✓ +		✓ 8.98e+01	2.90e+01
9	NN17	1.62	246	140	EHU	P	-0.009	✓ +		✓ 4.58e+00	3.04e+01
10	NN17	1.62	246	140	EHR	SV	0.018	✓ +		✓ 7.18e+01	1.91e+01
11	NN17	1.62	246	140	EHE	SE	-0.001				
12	NN18	1.34	25	147	EHU	P	-0.016	✓ –		✓ -1.48e+01	1.80e+01
13	NN18	1.34	25	147	EHR	SV	0.004	✓ –		✓ -1.79e+02	1.50e+01
14	NN19	0.94	169	156	EHU	P	-0.009	✓ +			
15	NN24	0.60	2	164	EHU	P	-0.013	✓ –		✓ -1.09e+01	2.59e+01
16	NN24	0.60	2	164	EHR	SV	-0.028	✓ +		✓ 1.37e+02	1.72e+01
17	NN24	0.60	2	164	EHT	SH	-0.052	✓ –		✓ -7.79e+01	1.68e+01
18	NN32	2.93	210	120	EHU	P	-0.045	✓ +		✓ 3.73e+00	1.50e+01

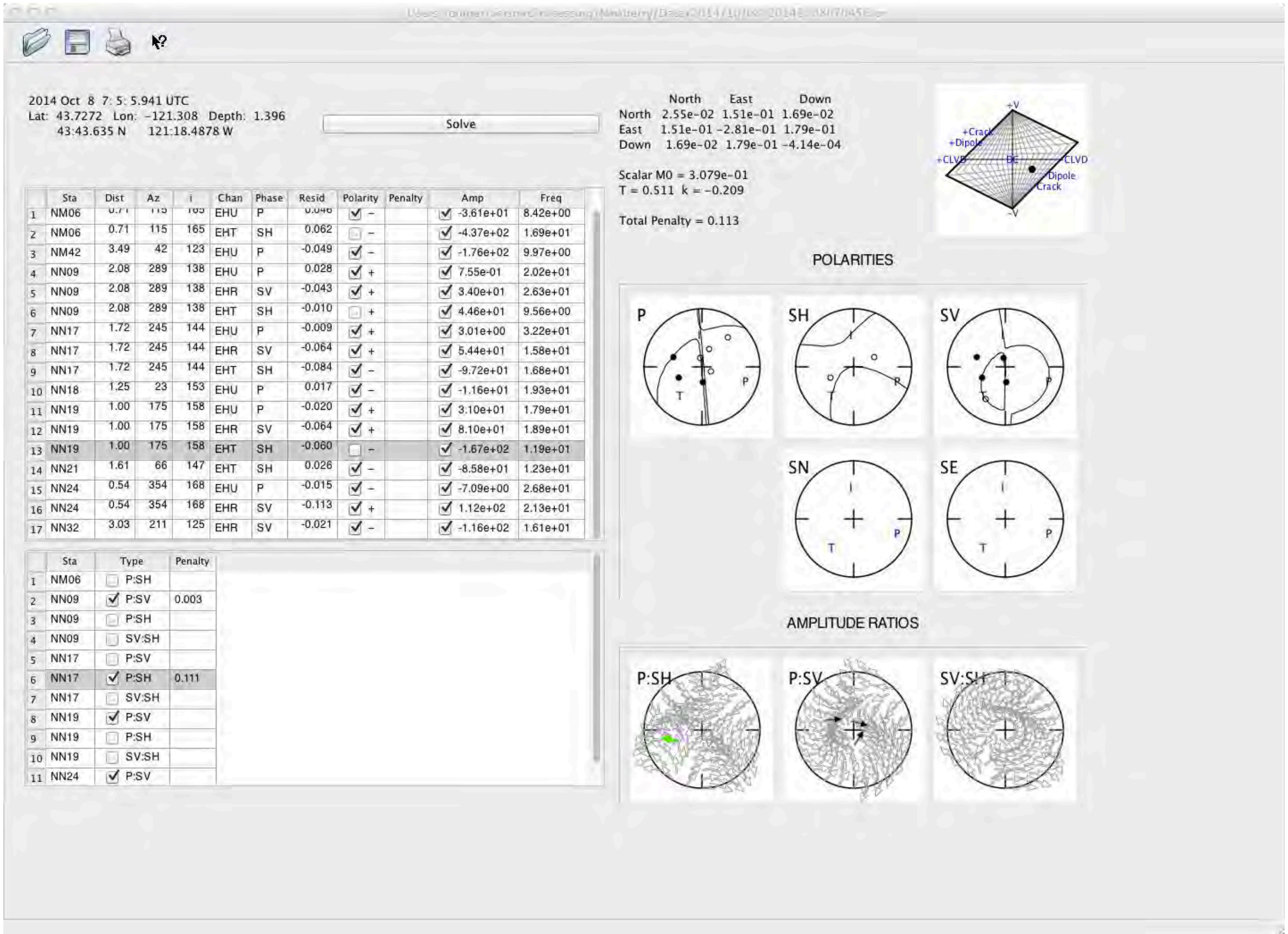
	Sta	Type	Penalty
1	NN09	✓ P:SV	
2	NN09	✓ P:SH	
3	NN09	✓ SV:SH	
4	NN17	✓ P:SV	0.110
5	NN18	✓ P:SV	0.013
6	NN24	✓ P:SV	
7	NN24	✓ P:SH	0.047
8	NN24	☐ SV:SH	
9	NN32	☐ P:SV	
10	NN32	☐ P:SH	
11	NN32	☐ SV:SH	


2014 Oct 2 9: 4: 8.647 UTC
Lat: 43.7254 Lon: -121.308 Depth: 1.063
43:43.5216 N 121:18.4602 W
Solve

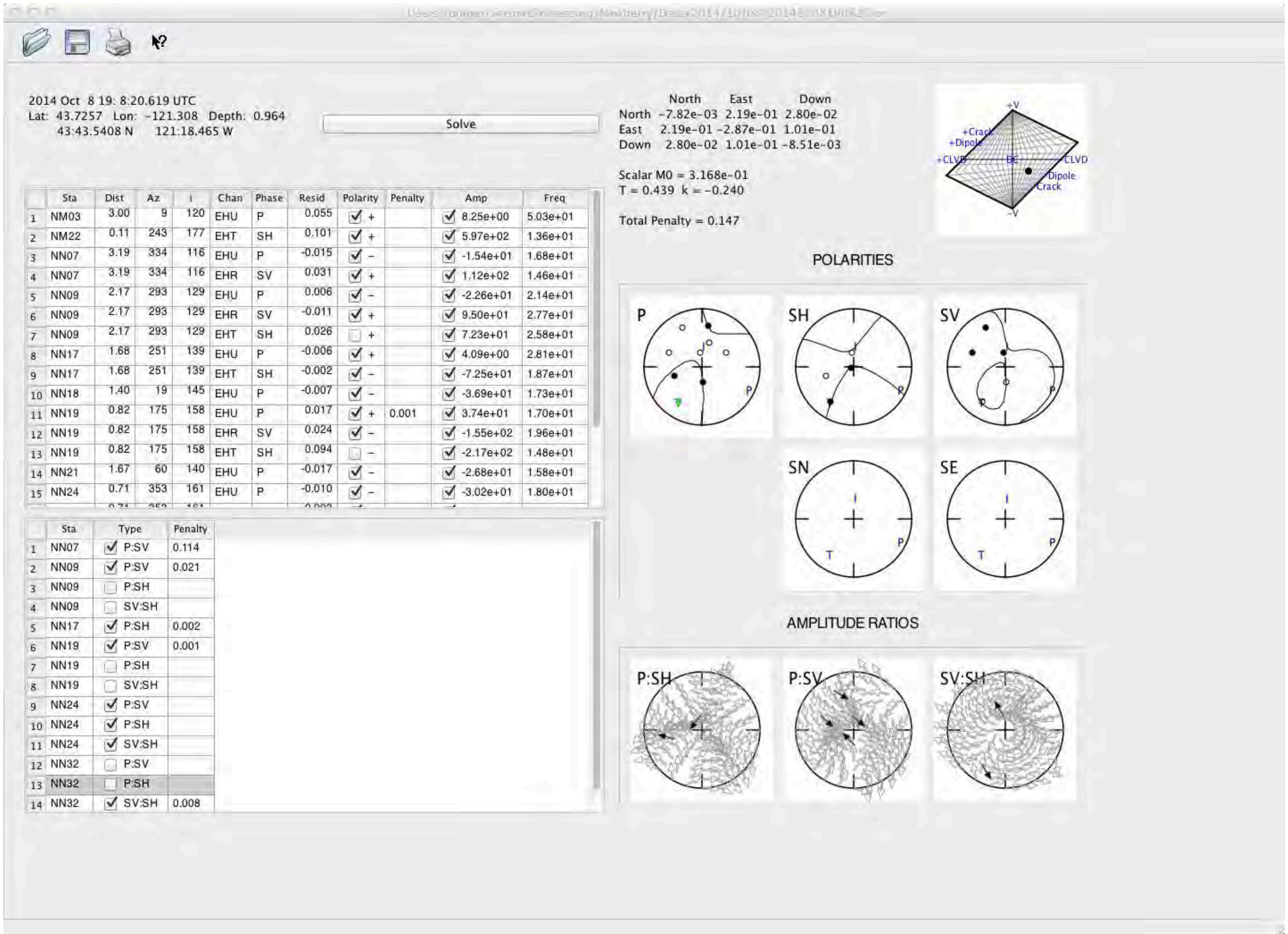
	Sta	Dist	Az	i	Chan	Phase	Resid	Polarity	Penalty	Amp	Freq
1	NM03	3.03	8	122	EHU	P	0.027	✓ –			
2	NM42	3.62	39	116	EHU	P	-0.002	✓ –		✓ -2.34e+01	1.22e+01
3	NN07	3.22	334	118	EHU	P	-0.008	✓ –		✓ -8.18e+00	1.82e+01
4	NN09	2.19	293	131	EHU	P	0.002	✓ +	0.001	✓ 7.77e-01	2.81e+01
5	NN09	2.19	293	131	EHR	SV	-0.027	✓ +	0.019	✓ 8.56e+01	2.51e+01
6	NN09	2.19	293	131	EHT	SH	0.013	✓ +	0.007	✓ 3.86e+01	1.92e+01
7	NN17	1.68	252	140	EHU	P	-0.001	✓ +		✓ 4.13e+00	2.95e+01
8	NN17	1.68	252	140	EHE	SE	0.013				
9	NN18	1.43	18	146	EHZ	P	-0.004	✓ –			
10	NN19	0.79	176	160	EHZ	P	0.008	✓ +			
11	NN21	1.68	59	141	EHZ	P	-0.007	✓ –			
12	NN24	0.75	353	161	EHU	P	-0.002	✓ –		✓ -7.60e+00	2.57e+01
13	NN24	0.75	353	161	EHR	SV	-0.016	✓ +		✓ 9.38e+01	6.81e+01
14	NN24	0.75	353	161	EHT	SH	-0.019	✓ –		✓ -5.76e+01	1.94e+01
15	NN32	2.88	214	121	EHU	P	-0.013	✓ +		✓ 3.78e+00	1.46e+01
16	NN32	2.88	214	121	EHR	SV	0.032	–		✓ -7.85e+01	1.61e+01
17	NN32	2.88	214	121	EHT	SH	0.032	✓ –		✓ -3.22e+01	2.67e+01

	Sta	Type	Penalty
1	NN09	✓ P:SV	
2	NN09	✓ P:SH	
3	NN09	✓ SV:SH	
4	NN24	✓ P:SV	
5	NN24	✓ P:SH	
6	NN24	✓ SV:SH	
7	NN32	P:SV	
8	NN32	✓ P:SH	
9	NN32	SV:SH	

North East Down
North 5.18e-02 -1.72e-01 2.09e-01
East -1.72e-01 -2.48e-02 -2.97e-02
Down 2.09e-01 -2.97e-02 1.02e-01
Scalar M0 = 2.846e-01
T = -0.289 k = 0.126
Total Penalty = 0.028
+V
+Crack
+Dipole
+CLVD
DC
-CLVD
-Dipole
-Crack
-V
POLARITIES
P
SH
SV
SN
SE
P
T
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH



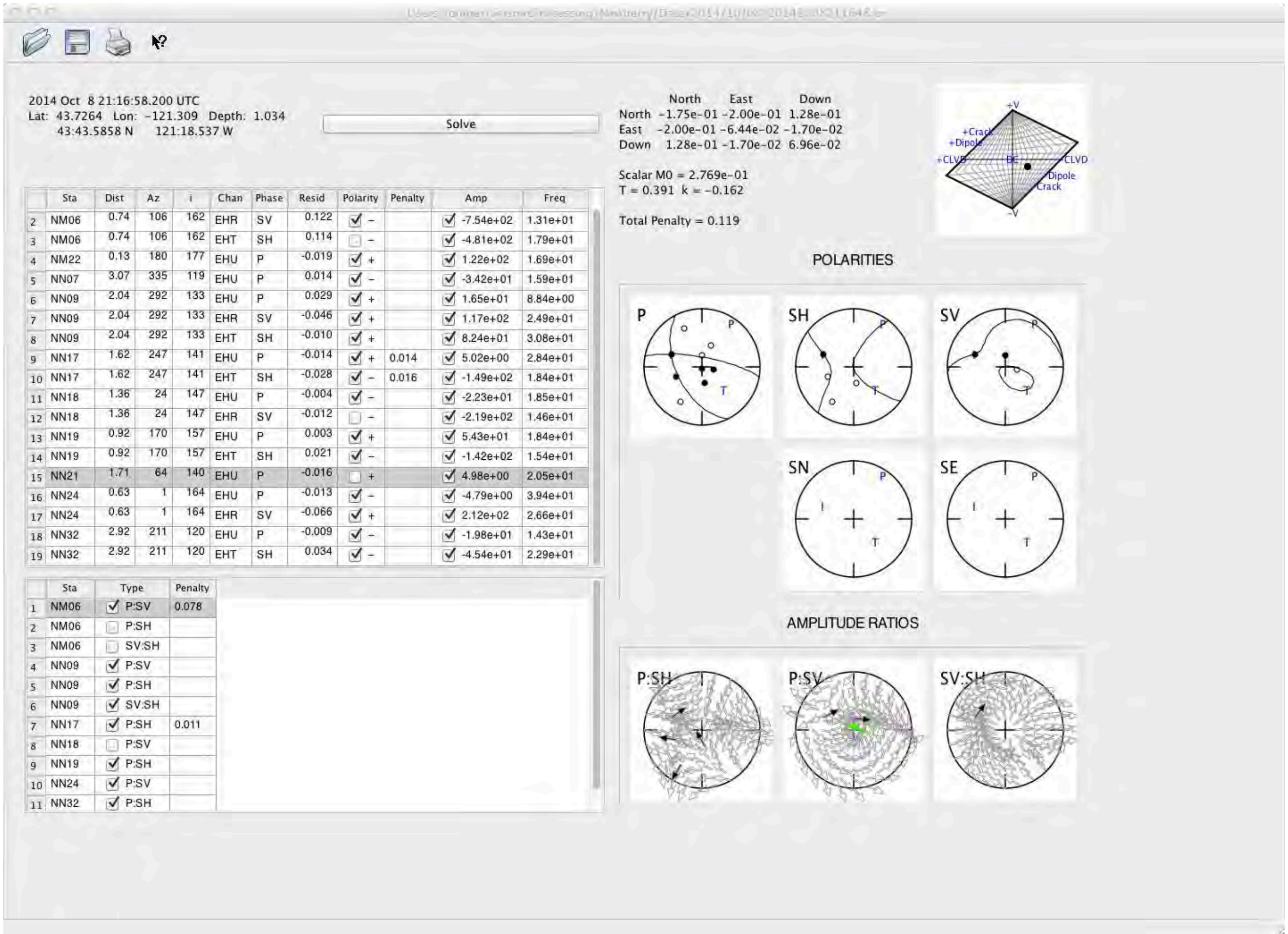
Solve
2014 Oct 8 7: 5: 5.941 UTC
Lat: 43.7272 Lon: -121.308 Depth: 1.396
43:43.635 N 121:18.4878 W
North East Down
North 2.55e-02 1.51e-01 1.69e-02
East 1.51e-01 -2.81e-01 1.79e-01
Down 1.69e-02 1.79e-01 -4.14e-04
Scalar M0 = 3.079e-01
T = 0.511 k = -0.209
Total Penalty = 0.113
+V
+Crack
+Dipole
+CLVD
DC
-CLVD
-Dipole
-Crack
-V
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM06 0.71 115 165 EHU P 0.046 – -3.61e+01 8.42e+00
2 NM06 0.71 115 165 EHT SH 0.062 – -4.37e+02 1.69e+01
3 NM42 3.49 42 123 EHU P -0.049 – -1.76e+02 9.97e+00
4 NN09 2.08 289 138 EHU P 0.028 + 7.55e-01 2.02e+01
5 NN09 2.08 289 138 EHR SV -0.043 + 3.40e+01 2.63e+01
6 NN09 2.08 289 138 EHT SH -0.010 + 4.46e+01 9.56e+00
7 NN17 1.72 245 144 EHU P -0.009 + 3.01e+00 3.22e+01
8 NN17 1.72 245 144 EHR SV -0.064 + 5.44e+01 1.58e+01
9 NN17 1.72 245 144 EHT SH -0.084 – -9.72e+01 1.68e+01
10 NN18 1.25 23 153 EHU P 0.017 – -1.16e+01 1.93e+01
11 NN19 1.00 175 158 EHU P -0.020 + 3.10e+01 1.79e+01
12 NN19 1.00 175 158 EHR SV -0.064 + 8.10e+01 1.89e+01
13 NN19 1.00 175 158 EHT SH -0.060 – -1.67e+02 1.19e+01
14 NN21 1.61 66 147 EHT SH 0.026 – -8.58e+01 1.23e+01
15 NN24 0.54 354 168 EHU P -0.015 – -7.09e+00 2.68e+01
16 NN24 0.54 354 168 EHR SV -0.113 + 1.12e+02 2.13e+01
17 NN32 3.03 211 125 EHR SV -0.021 – -1.16e+02 1.61e+01
Sta Type Penalty
1 NM06 P:SH
2 NN09 P:SV 0.003
3 NN09 P:SH
4 NN09 SV:SH
5 NN17 P:SV
6 NN17 P:SH 0.111
7 NN17 SV:SH
8 NN19 P:SV
9 NN19 P:SH
10 NN19 SV:SH
11 NN24 P:SV
POLARITIES
P
T
P
SH
P
SV
P
SN
T
P
SE
T
P
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH

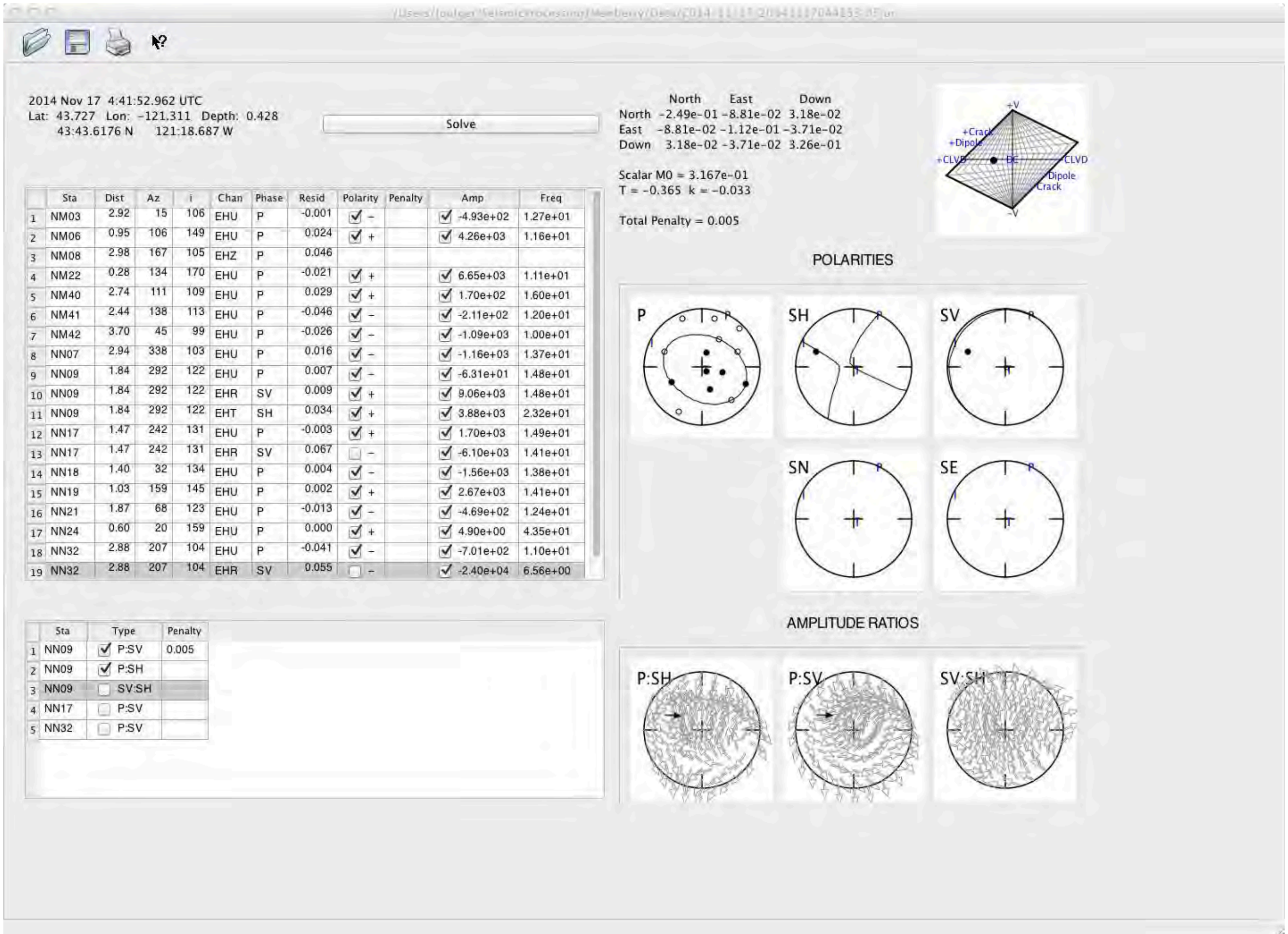


2014 Oct 8 19: 8:20.619 UTC
Lat: 43.7257 Lon: -121.308 Depth: 0.964
43:43.5408 N 121:18.465 W

	Sta	Dist	Az	i	Chan	Phase	Resid	Polarity	Penalty	Amp	Freq
1	NM03	3.00	9	120	EHU	P	0.055	✓ +		✓ 8.25e+00	5.03e+01
2	NM22	0.11	243	177	EHT	SH	0.101	✓ +		✓ 5.97e+02	1.36e+01
3	NN07	3.19	334	116	EHU	P	-0.015	✓ –		✓ -1.54e+01	1.68e+01
4	NN07	3.19	334	116	EHR	SV	0.031	✓ +		✓ 1.12e+02	1.46e+01
5	NN09	2.17	293	129	EHU	P	0.006	✓ –		✓ -2.26e+01	2.14e+01
6	NN09	2.17	293	129	EHR	SV	-0.011	✓ +		✓ 9.50e+01	2.77e+01
7	NN09	2.17	293	129	EHT	SH	0.026	☐ +		✓ 7.23e+01	2.58e+01
8	NN17	1.68	251	139	EHU	P	-0.006	✓ +		✓ 4.09e+00	2.81e+01
9	NN17	1.68	251	139	EHT	SH	-0.002	✓ –		✓ -7.25e+01	1.87e+01
10	NN18	1.40	19	145	EHU	P	-0.007	✓ –		✓ -3.69e+01	1.73e+01
11	NN19	0.82	175	158	EHU	P	0.017	✓ +	0.001	✓ 3.74e+01	1.70e+01
12	NN19	0.82	175	158	EHR	SV	0.024	✓ –		✓ -1.55e+02	1.96e+01
13	NN19	0.82	175	158	EHT	SH	0.094	☐ –		✓ -2.17e+02	1.48e+01
14	NN21	1.67	60	140	EHU	P	-0.017	✓ –		✓ -2.68e+01	1.58e+01
15	NN24	0.71	353	161	EHU	P	-0.010	✓ –		✓ -3.02e+01	1.80e+01

	Sta	Type	Penalty
1	NN07	✓ P:SV	0.114
2	NN09	✓ P:SV	0.021
3	NN09	☐ P:SH	
4	NN09	☐ SV:SH	
5	NN17	✓ P:SH	0.002
6	NN19	✓ P:SV	0.001
7	NN19	☐ P:SH	
8	NN19	☐ SV:SH	
9	NN24	✓ P:SV	
10	NN24	✓ P:SH	
11	NN24	✓ SV:SH	
12	NN32	☐ P:SV	
13	NN32	☐ P:SH	
14	NN32	✓ SV:SH	0.008


2014 Oct 8 21:16:58.200 UTC
Lat: 43.7264 Lon: -121.309 Depth: 1.034
43:43.5858 N 121:18.537 W
Solve
North East Down
North -1.75e-01 -2.00e-01 1.28e-01
East -2.00e-01 -6.44e-02 -1.70e-02
Down 1.28e-01 -1.70e-02 6.96e-02
Scalar M0 = 2.769e-01
T = 0.391 k = -0.162
Total Penalty = 0.119
+V
+Crack
+Dipole
+CLVD
DC
CLVD
Dipole
Crack
-V
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
2 NM06 0.74 106 162 EHR SV 0.122 – -7.54e+02 1.31e+01
3 NM06 0.74 106 162 EHT SH 0.114 – -4.81e+02 1.79e+01
4 NM22 0.13 180 177 EHU P -0.019 + 1.22e+02 1.69e+01
5 NN07 3.07 335 119 EHU P 0.014 – -3.42e+01 1.59e+01
6 NN09 2.04 292 133 EHU P 0.029 + 1.65e+01 8.84e+00
7 NN09 2.04 292 133 EHR SV -0.046 + 1.17e+02 2.49e+01
8 NN09 2.04 292 133 EHT SH -0.010 + 8.24e+01 3.08e+01
9 NN17 1.62 247 141 EHU P -0.014 + 0.014 5.02e+00 2.84e+01
10 NN17 1.62 247 141 EHT SH -0.028 – 0.016 -1.49e+02 1.84e+01
11 NN18 1.36 24 147 EHU P -0.004 – -2.23e+01 1.85e+01
12 NN18 1.36 24 147 EHR SV -0.012 – -2.19e+02 1.46e+01
13 NN19 0.92 170 157 EHU P 0.003 + 5.43e+01 1.84e+01
14 NN19 0.92 170 157 EHT SH 0.021 – -1.42e+02 1.54e+01
15 NN21 1.71 64 140 EHU P -0.016 + 4.98e+00 2.05e+01
16 NN24 0.63 1 164 EHU P -0.013 – -4.79e+00 3.94e+01
17 NN24 0.63 1 164 EHR SV -0.066 + 2.12e+02 2.66e+01
18 NN32 2.92 211 120 EHU P -0.009 – -1.98e+01 1.43e+01
19 NN32 2.92 211 120 EHT SH 0.034 – -4.54e+01 2.29e+01
Sta Type Penalty
1 NM06 P:SV 0.078
2 NM06 P:SH
3 NM06 SV:SH
4 NN09 P:SV
5 NN09 P:SH
6 NN09 SV:SH
7 NN17 P:SH 0.011
8 NN18 P:SV
9 NN19 P:SH
10 NN24 P:SV
11 NN32 P:SH
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH



	Sta	Dist	Az	i	Chan	Phase	Resid	Polarity	Penalty	Amp	Freq
1	NM03	2.92	15	106	EHU	P	-0.001	✓ –		✓ -4.93e+02	1.27e+01
2	NM06	0.95	106	149	EHU	P	0.024	✓ +		✓ 4.26e+03	1.16e+01
3	NM08	2.98	167	105	EHZ	P	0.046				
4	NM22	0.28	134	170	EHU	P	-0.021	✓ +		✓ 6.65e+03	1.11e+01
5	NM40	2.74	111	109	EHU	P	0.029	✓ +		✓ 1.70e+02	1.60e+01
6	NM41	2.44	138	113	EHU	P	-0.046	✓ –		✓ -2.11e+02	1.20e+01
7	NM42	3.70	45	99	EHU	P	-0.026	✓ –		✓ -1.09e+03	1.00e+01
8	NN07	2.94	338	103	EHU	P	0.016	✓ –		✓ -1.16e+03	1.37e+01
9	NN09	1.84	292	122	EHU	P	0.007	✓ –		✓ -6.31e+01	1.48e+01
10	NN09	1.84	292	122	EHR	SV	0.009	✓ +		✓ 9.06e+03	1.48e+01
11	NN09	1.84	292	122	EHT	SH	0.034	✓ +		✓ 3.88e+03	2.32e+01
12	NN17	1.47	242	131	EHU	P	-0.003	✓ +		✓ 1.70e+03	1.49e+01
13	NN17	1.47	242	131	EHR	SV	0.067	–		✓ -6.10e+03	1.41e+01
14	NN18	1.40	32	134	EHU	P	0.004	✓ –		✓ -1.56e+03	1.38e+01
15	NN19	1.03	159	145	EHU	P	0.002	✓ +		✓ 2.67e+03	1.41e+01
16	NN21	1.87	68	123	EHU	P	-0.013	✓ –		✓ -4.69e+02	1.24e+01
17	NN24	0.60	20	159	EHU	P	0.000	✓ +		✓ 4.90e+00	4.35e+01
18	NN32	2.88	207	104	EHU	P	-0.041	✓ –		✓ -7.01e+02	1.10e+01
19	NN32	2.88	207	104	EHR	SV	0.055	–		✓ -2.40e+04	6.56e+00

	Sta	Type	Penalty
1	NN09	✓ P:SV	0.005
2	NN09	✓ P:SH	
3	NN09	SV:SH	
4	NN17	P:SV	
5	NN32	P:SV	

Foulger Consulting

1025 Paradise Way
Palo Alto, CA 943062637, USA
Tel: 650/4932553
Cell: 650/9968886
FAX: 866/5326907
gillian@foulgerconsulting.com
http://www.foulgerconsulting.com/

November 26, 2014

WEEKLY REPORT #8 TO ALTAROCK ENERGY INC.

PROCESSING OF INDUCED EARTHQUAKES ASSOCIATED WITH THE NEWBERRY EGS INJECTION STARTING SEPTEMBER 2014

GILLIAN R. FOULGER & BRUCE R. JULIAN

Brief summary

During the last week we concentrated on studying the November swarm with a view to examining whether it had different characteristics from the September/October earthquake activity. This seems indeed to be the case:

- *The swarm comprises two bursts, the first peaking in intensity about 16 November and the second peaking in intensity about 21 November.*
- *The earthquakes of the second burst are ~ 300 m deeper than those of the first burst.*
- *Both the absolute locations of the 6 moment-tensor events studied from the November swarm and the relative locations of the November-only earthquakes suggest that a more northerly striking planar feature was activated (~ N15˚W, compared with N60˚W for the September/October planar feature).*
- *The depth range of the earthquakes spanned the zone that was aseismic during September/October, closing the "aseismic gap".*
- *Moment tensor calculations suggest that the P- and T-axes are orientated systematically differently, namely the T-axes plunge more steeply and trend more westerly, and the P-axes trend more northerly. This consistent with a different stress field and a rotated plane of failure.*

During the forthcoming week we will work to increase the size of our relative-location and moment-tensor data set for the November earthquakes in order to test these preliminary results.

1 Task 1 – Planning, conference calls, discussion of work, correspondence, followup

We continued to maintain contact with team members as before. The work continued to run smoothly.

2 Task 2 – System Setup

No additional system setup was done during the last week.

3 Task 3 – Quality control of prepicked MEQs for relocation and moment tensor calculation

We continued to derive moment tensors using the procedure described in our Weekly Report #1. We report here an additional 5 moment tensors from 16, 17 and 21 November. This brings the total number derived up to 70 (Appendix 1). We have provided the locations of these new moment tensors to Trenton Cladouhos of AltaRock electronically, by email attachment.

4 Task 4 –Improved locations and relative locations

4.1 Absolute locations–ISTI picks

We locate all the earthquakes hand-picked by ISTI as a routine matter, using our in-house location program *qloc*. In our report #7 of 19 November, we presented week-by-week maps of the earthquake locations which showed the development with time of the activity. Here we update the incomplete week shown in that report and add an additional week. Figure 1 shows maps of the earthquakes for November 14-20 and November 21-24 (incomplete week).

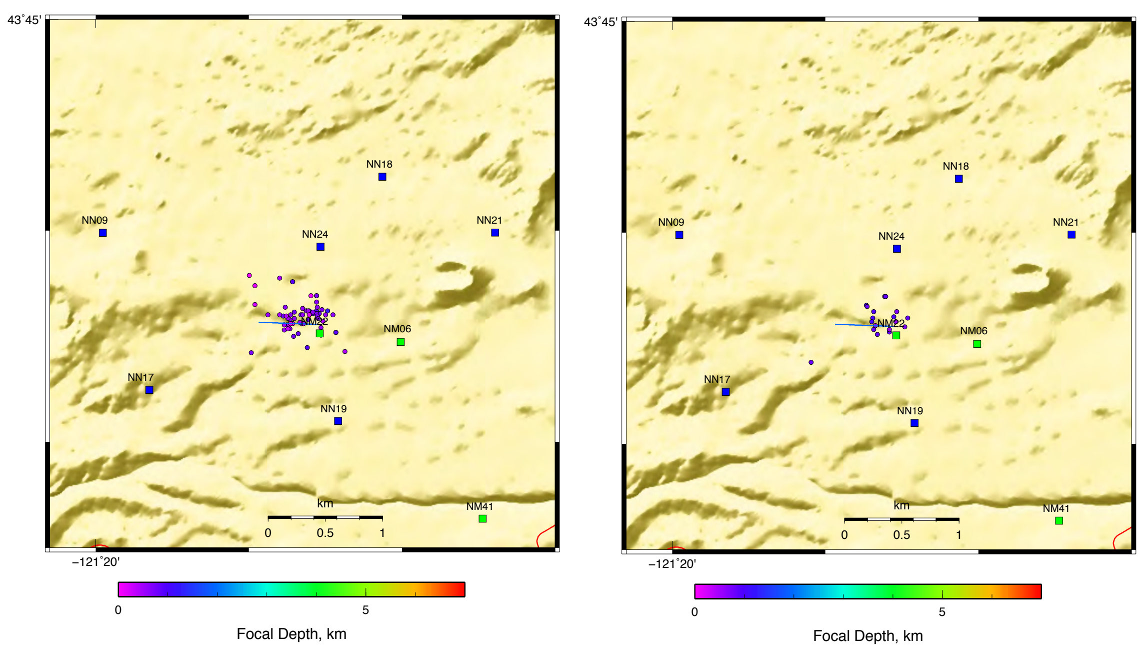


Figure 1: Earthquakes located using ISTI picks, and our in-house *qloc* location program for the weeks (left) November 14-20 and (right) November 21-24 (incomplete week).

Figure 2 shows the depths of all the earthquakes as a function of time (*qloc* locations, using ISTI picks). The November swarm comprises two bursts, the first peaking in intensity about 16 November and the second peaking in intensity about 21 November. The earthquakes of the second burst are significantly (~ 300 m) deeper than those of the first burst.

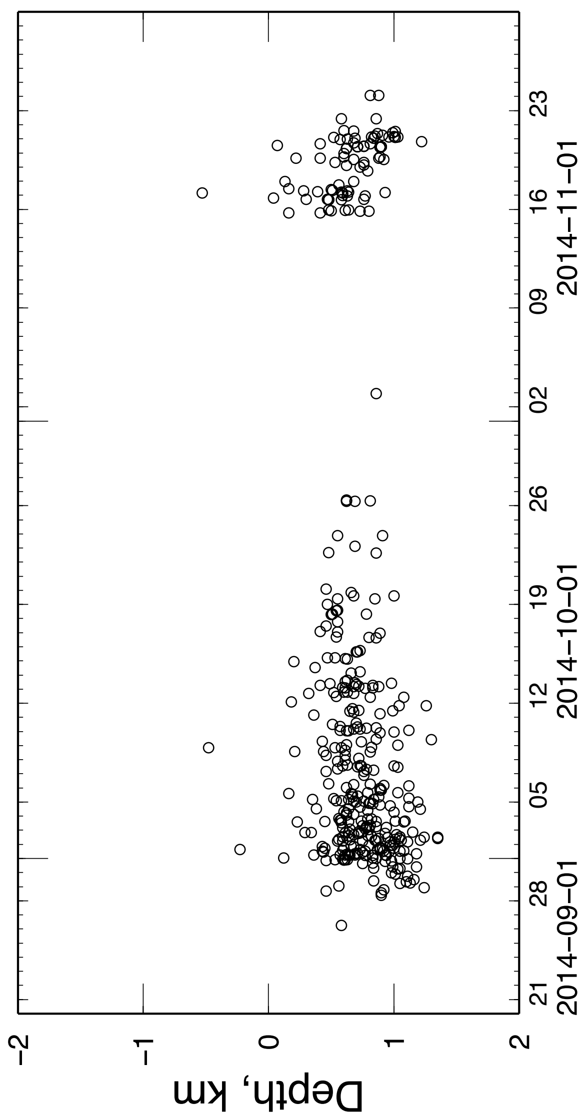


Figure 2: Estimated depths, with respect to sea level, of the earthquakes within the NMSA network as a function of time. These depths were obtained by using *qloc* to invert *P*- and *S*-phase arrival times measured by personnel of the ISTI Corporation on digital seismograms from the NMSA network.

4.2 Absolute locations–Foulger Consulting picks for moment-tensor derivation

We picked an additional 5 earthquakes for the purpose of moment-tensor derivation, bringing the total in hand to 70. Figure 3 shows a map of the 6 earthquakes that occurred in November, for which moment tensors have been derived. These locations are exceptionally accurate, being a by-product of the moment tensor deriviation process. The epicenters lie in a linear zone that trends more northerly than the entire earthquake set (see previous reports). This result agrees well with the results of relative locations of the November swarm as a whole (Section 4.4).

A map of all 70 moment-tensor-earthquake locations is shown in Figure 4.

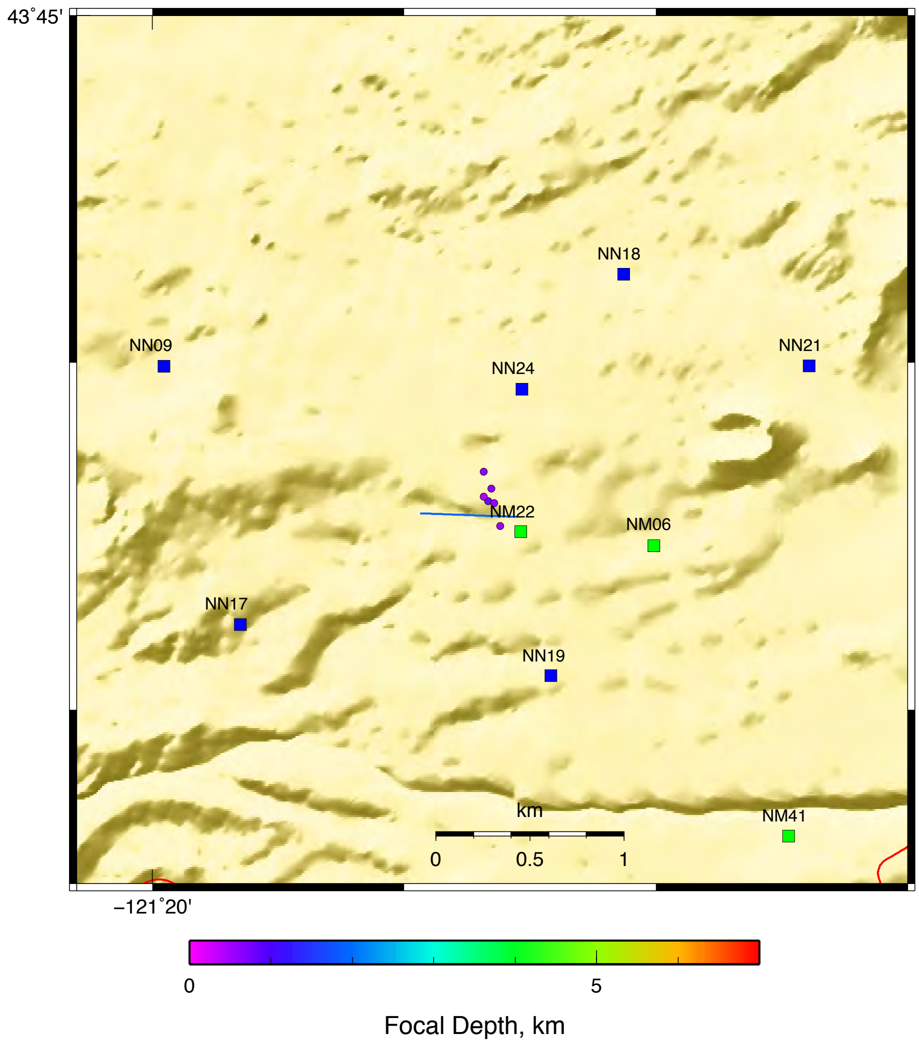


Figure 3: High-quality estimated hypocenters of 6 microearthquakes that occurred in November. Moment tensors were derived for these events. The locations are computed using arrival times measured using advanced (and more time-consuming) methods in connection with the moment-tensor analysis. Well NWD 55-29 is shown in blue.

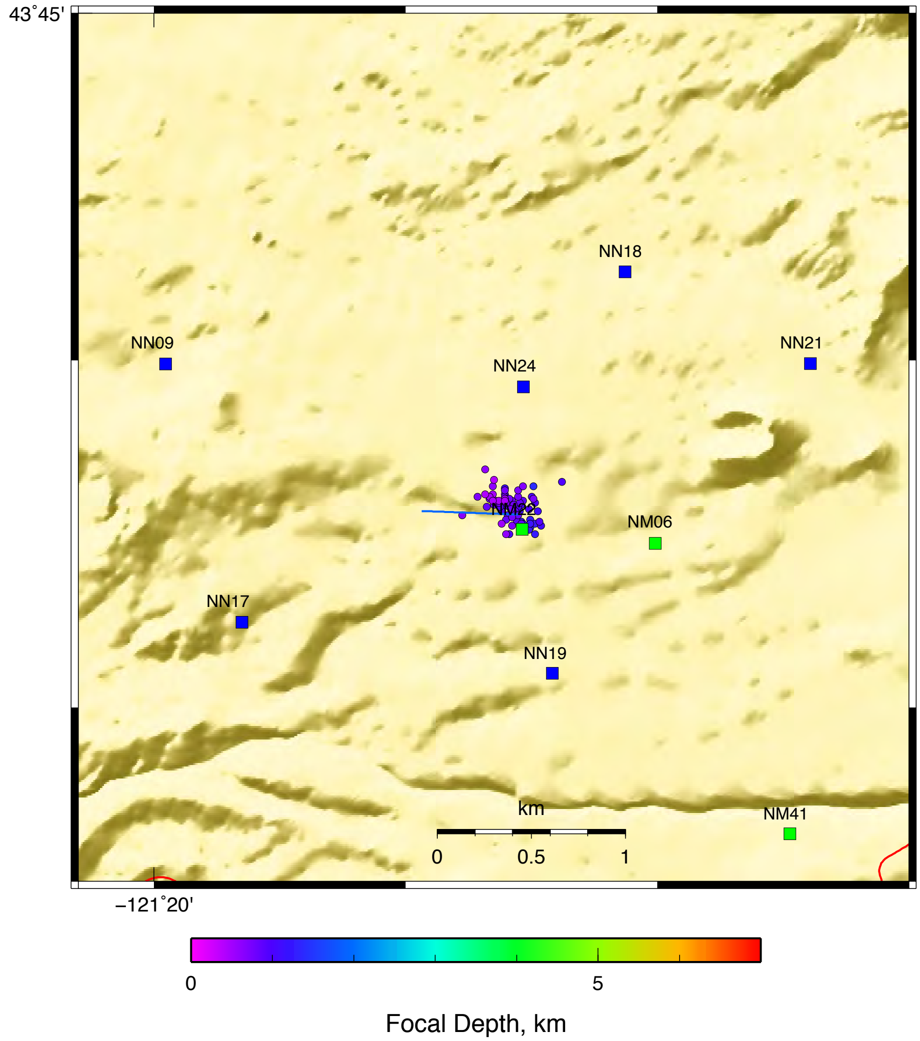


Figure 4: High quality estimated hypocenters of the entire 70-earthquake set for which moment tensors have been derived. Well NWD 55-29 is shown in blue.

4.3 Relative locations: the entire catalog

We continued with the relative location work, applying the method to the catalog of ISTI-picked events up to and including 21 November. This set contained 376 earthquakes. We relative located this catalog using the following input parameters:

- *minclust* = 10;
- *maxit* = 25;
- *maxsep* = 0.20 km;
- *minlinks* = 18.

A higher threshold of *minlilnks* = 18 could be used because of the larger size of the catalog. 25 earthquakes passed the thresholds and were located.

The results are shown in Figure 5 and Figure 6.

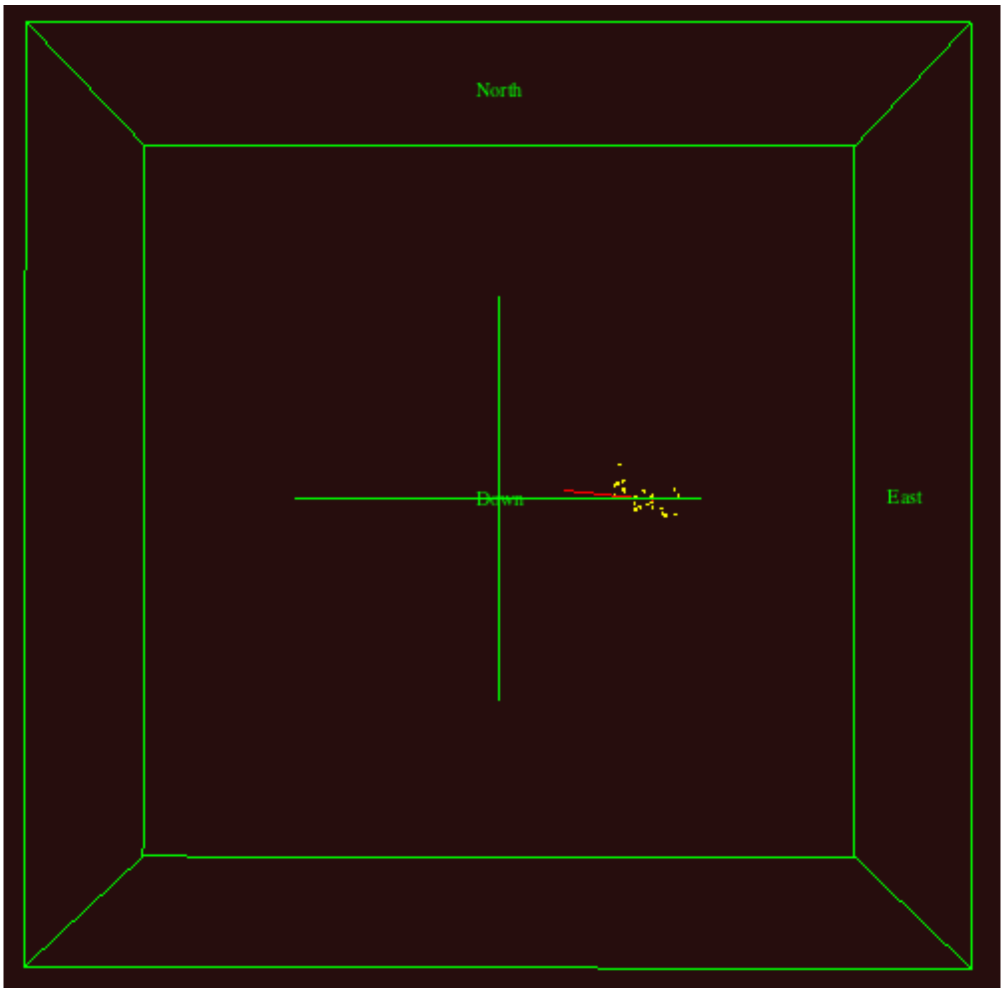


Figure 5: Map of relative locations of 25 earthquakes that occurred in the time period 26 September - 21 November, 2014. Runtime parameters used were *minclust* = 10, *maxit* = 25, *maxsep* = 0.20 km, *minlinks* = 18.

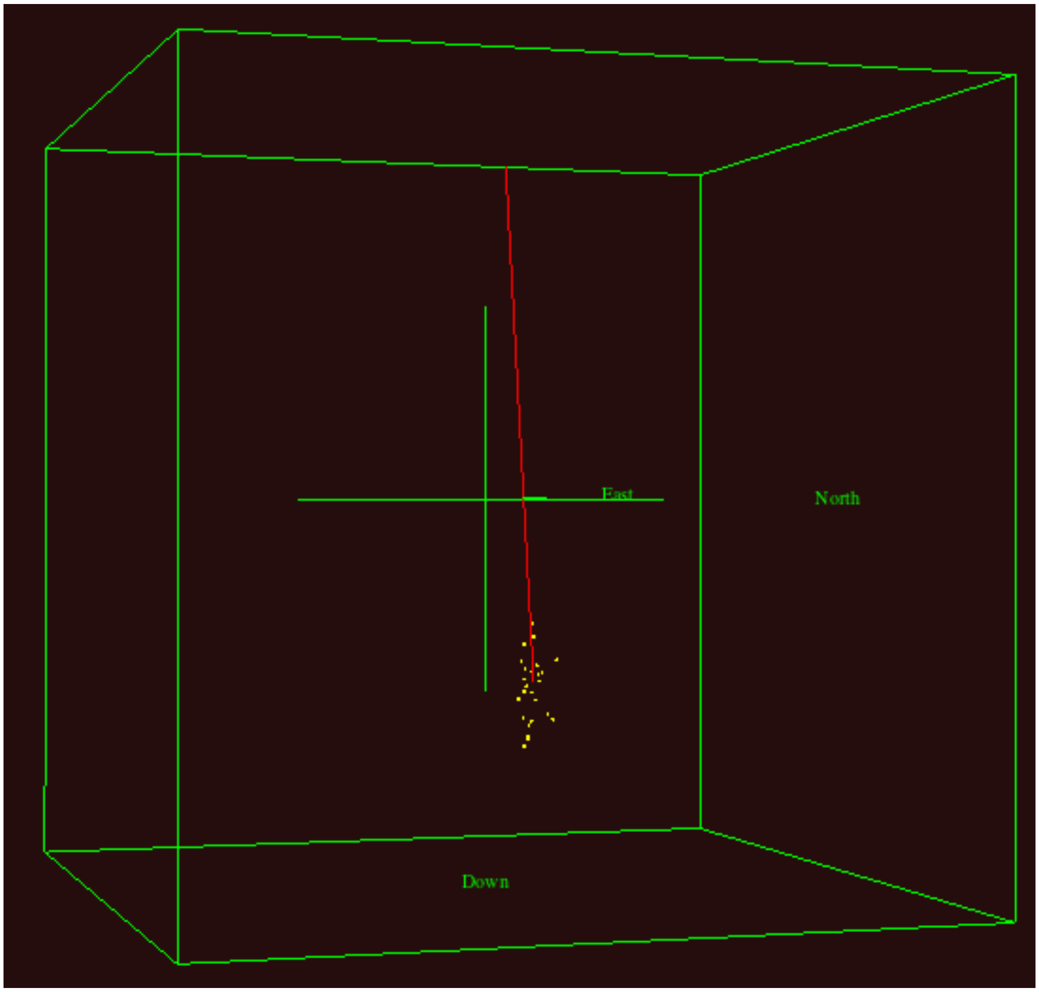


Figure 6: Same as Figure 5 except looking along the strike of the epicentral trend, to the NW.

The northwesterly trending epicentral zone continues to be apparent.

4.4 Relative locations: The November swarm

Relative locations were calculated for the November swarm only, using earthquakes that occurred in the period 15 - 21 November. This subset of the data comprised 78 earthquakes. The following input parameters were used. These yielded the best balance between selecting out the highest-quality locations, whilst not reducing the number of earthquakes to a very small number:

- *minclust* = 10;
- *maxit* = 25;
- *maxsep* = 0.20 km;
- *minlinks* = 14.

Of the original 78 earthquakes, 17 were located. The results are shown in Figure 7 and Figure 8.

Interestingly, these earthquakes delineate a sub-vertical, planar feature, but in contrast to the September/October earthquakes, the strike of the November feature is more northerly. It strikes just slightly west of north (Figure 7). This seems to be consistent with an apparent change in the orientation of the P-, and T-axes detected in new moment tensors derived (see Section 5).

The depth range of the November earthquakes includes the layer that was aseismic in September/October, separating those earthquakes into two clusters. This is consistent with the depth distribution of the entire catalog no longer showing a division into two clusters (Figure 6).

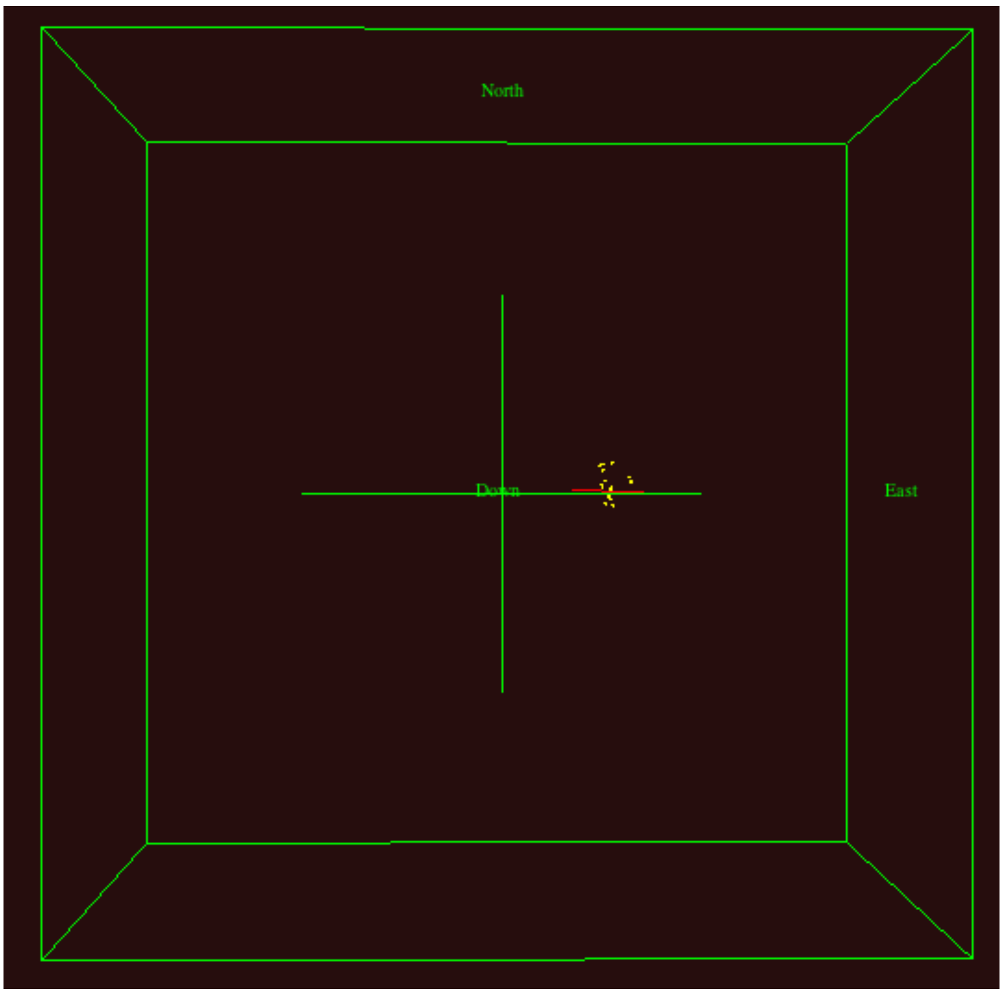


Figure 7: Map of relative locations of 17 earthquakes that occurred in the time period 15 - 21 November, 2014. Runtime parameters used were *minclust* = 10, *maxit* = 25, *maxsep* = 0.20 km, *minlinks* = 14.

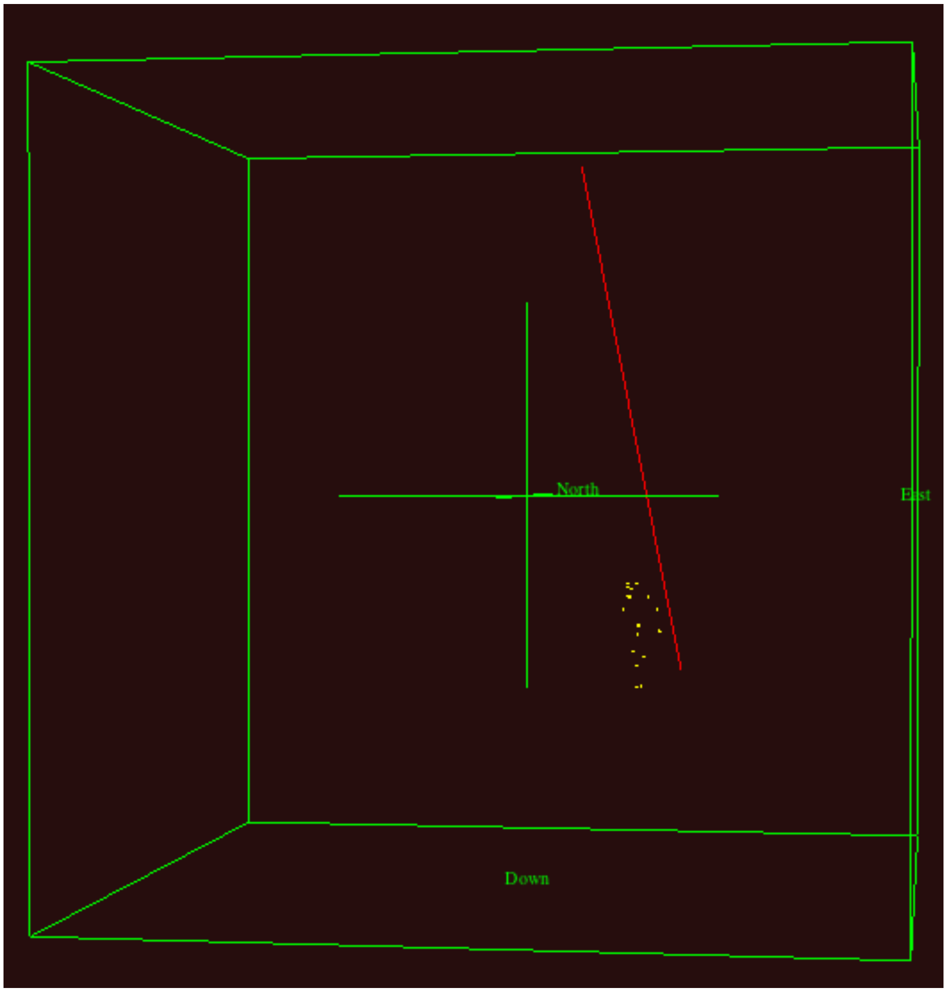


Figure 8: Same as Figure 7 except looking along the strike of the epicentral trend, to the NNW.

5 Task 5 Moment tensors

We continued to derive moment tensors and report here an additional 5. We focused on the earthquake sequence that occurred in mid-November, and report mechanisms for events from 16, 17 and 21 November.

The entire list of earthquakes processed to date is given in Appendix 1. The numerical results of the entire moment-tensor catalog, including the 5 new results are given in Appendix 2. Graphical results for the additional 5 events are given in Appendix 3. We have provided the decomposition data of these new moment tensors to Trenton Cladouhos of AltaRock electronically, by email attachment.

The source types for the 6 moment tensors we have now derived for the November sequence are shown in Figure 9. The distribution lies along the +Dipole to -Dipole range, but does not occupy the full range. Mechanisms range from strongly implosive (-Dipole) to mildly explosive. This suggests that these earthquakes were dominantly volume-decreasing. The dataset is small, and it will be interesting to see if this is confirmed when more mechansims from this sequence are derived.

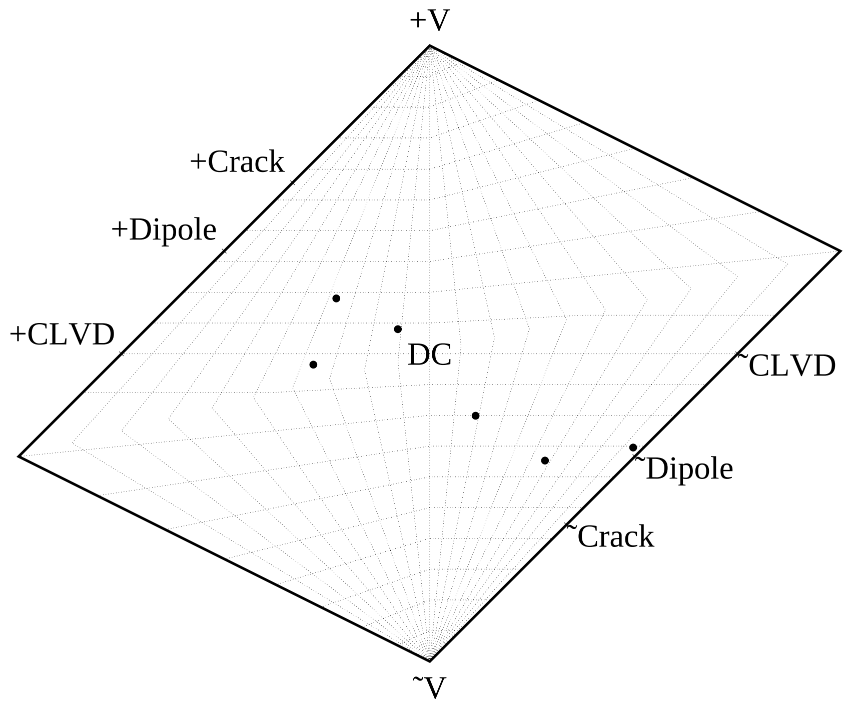


Figure 9: Source-type plot showing the 6 earthquakes from November for which moment tensors have been derived to date.

Figure 10 shows plots of the P-, T- and I-axes, approximately corresponding to the directions of σ_1, σ_3 and σ_2. The plot on the left is of the 65 events from September and October, reported in our Weekly Report #7 of 19 November. The plot on the right is of the 6 events from the November swarm.

The number of events is small, but there appears to be a significant difference in the orientation of the P-, T- and I-axes compared with the events of September and October. The T-axes dip more steeply and are somewhat more westerly oriented. The P-axes are distributed around the north direction, and do not preferentially trend NE as was the tendency in the earlier earthquakes.

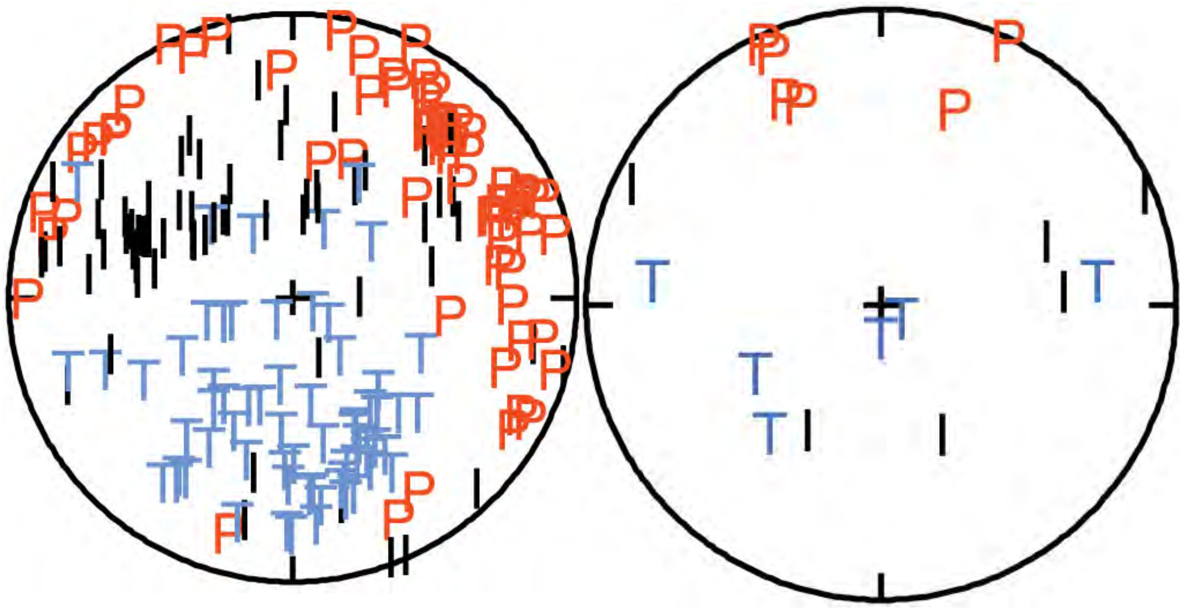


Figure 10: Plots of pressure (P ~ σ_1) and tension (T ~ σ_3) and intermediate (I ~ σ_2) axes. Left: the 65 earthquakes that occurred in September and October; Right: the 6 earthquakes that occurred 16, 17 and 21 November.

6 Brief summary statement

During the last week we concentrated on studying the November swarm with a view to examining whether it had different characteristics from the September/October earthquake activity. This seems indeed to be the case:

- The swarm comprises two bursts, the first peaking in intensity about 16 November and the second peaking in intensity about 21 November.
- The earthquakes of the second burst are ~ 300 m deeper than those of the first burst.
- Both the absolute locations of the 6 moment-tensor events studied from the November swarm and the relative locations of the November-only earthquakes suggest that a more northerly striking planar feature was activated (~ N15˚W, compared with N60˚W for the September/October planar feature).
- The depth range of the earthquakes spanned the zone that was aseismic during September/October, closing the “aseismic gap”.
- Moment tensor calculations suggest that the P- and T-axes are orientated systematically differently, namely the T-axes plunge more steeply and trend more westerly, and the P-axes trend more northerly. This consistent with a different stress field and a rotated plane of failure.

During the forthcoming week we will work to increase the size of our relative-location and moment-tensor data set for the November earthquakes in order to test these preliminary results.

Appendix 1: The 70 earthquakes for which moment tensors have been obtained to date. Locations given below are from the webpage http://fracture.lbl.gov/Newberry/locations.txt.

jday	month	day	hour	minute	sec	lat	lon	depth	magnitude
272	9	29	9	57	54.34	43.7245	-121.30857	0.845	0.721
272	9	29	18	3	37.724	43.72365	-121.30658	1.274	0.669
273	9	30	9	23	48.799	43.71965	-121.30908	0.854	0.853
273	9	30	21	30	43.689	43.72667	-121.313	0.387	0.972
274	10	1	1	3	14.64	43.7239	-121.30957	0.714	0.987
274	10	1	8	8	58.215	43.72623	-121.31412	1.196	0.848
274	10	1	10	50	55.229	43.72275	-121.30868	1.051	0.787
274	10	1	12	3	16.881	43.72658	-121.3158	1.587	1.086
274	10	1	14	53	5.102	43.72545	-121.31355	0.613	1.381
274	10	1	15	1	55.056	43.72775	-121.31227	0.923	0.682
274	10	1	16	56	11.256	43.72232	-121.30712	1.65	0.901
274	10	1	19	5	16.377	43.72662	-121.31117	0.517	1.259
274	10	1	20	47	39.649	43.72612	-121.30912	0.826	0.505
274	10	1	22	13	54.154	43.72238	-121.30277	1.344	0.566
275	10	2	6	38	47.428	43.7243	-121.31328	1.153	0.951
275	10	2	6	47	52.916	43.72632	-121.31322	1.323	1.117
275	10	2	7	7	11.646	43.72488	-121.31192	0.708	1.378
275	10	2	7	21	48.731	43.72303	-121.30773	1.09	0.538
275	10	2	9	3	53.33	43.72217	-121.31288	0.736	0.519
275	10	2	11	1	48.042	43.72567	-121.31168	0.666	1.22
275	10	2	12	39	9.082	43.7264	-121.31438	1.332	0.852
275	10	2	16	12	20.481	43.72583	-121.30738	0.746	0.566
275	10	2	18	53	48.447	43.72082	-121.31372	1.671	0.957
275	10	2	20	36	50.997	43.72377	-121.31323	1.499	0.991
276	10	3	6	6	22.727	43.72528	-121.31493	0.928	1.157
276	10	3	15	27	57.912	43.72257	-121.31562	1.054	0.919
276	10	3	18	54	54.199	43.72678	-121.31125	0.647	1.021
277	10	4	5	29	8.347	43.72578	-121.31068	0.946	0.922
277	10	4	17	32	52.716	43.72207	-121.31693	0.376	1.521
277	10	4	18	51	11.991	43.72295	-121.31227	0.496	1.97
277	10	4	21	29	47.632	43.72813	-121.30428	0.988	0.586
278	10	5	2	6	17.079	43.7266	-121.31217	0.925	0.86
278	10	5	2	14	37.358	43.72433	-121.30915	0.459	0.665

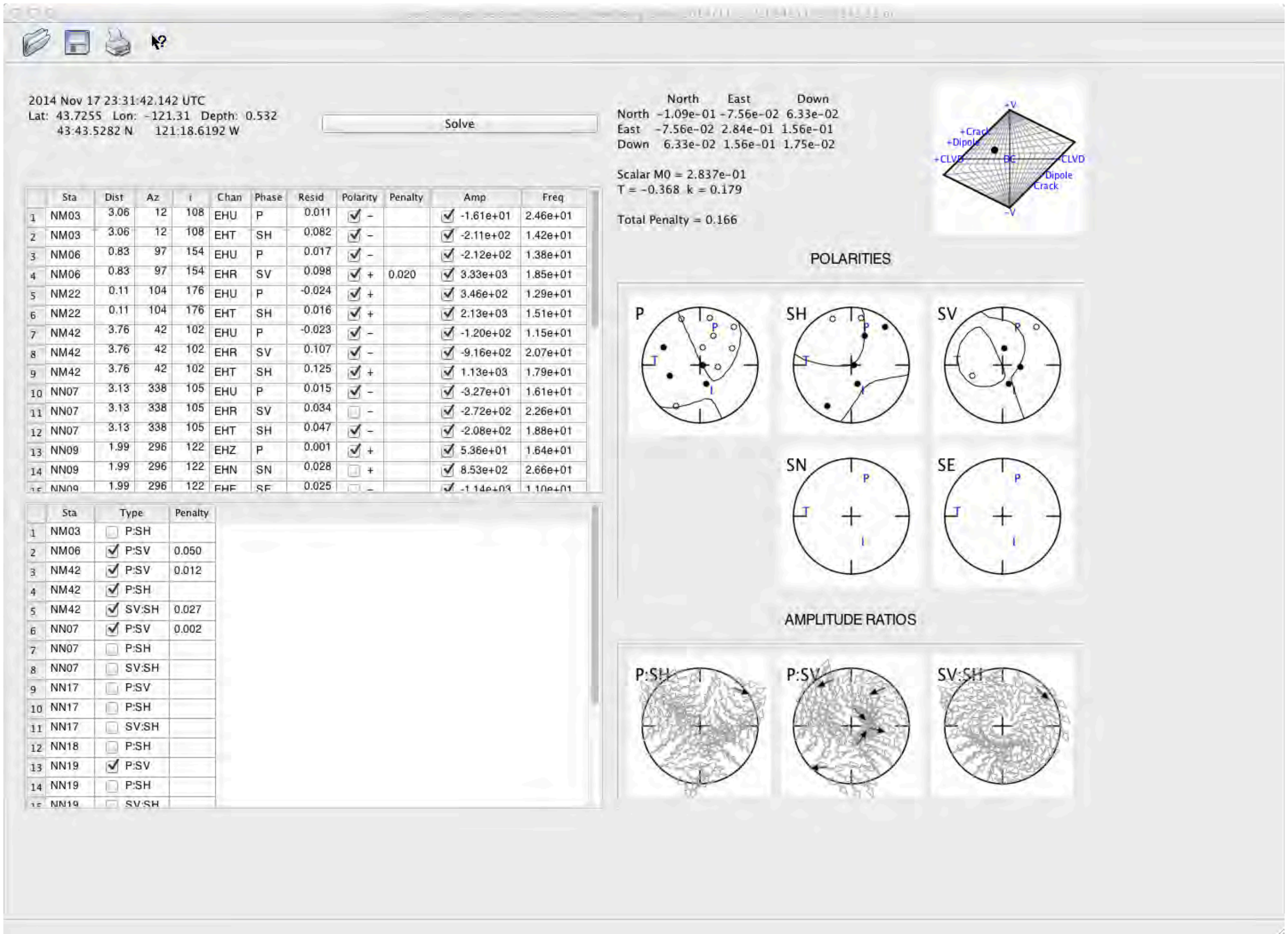
278	10	5	4	7	30.446	43.725	-121.31322	0.659	1.696
278	10	5	15	55	21.373	43.73483	-121.30918	0.702	0.695
278	10	5	16	7	32.904	43.7253	-121.30967	1.205	0.819
278	10	5	23	22	16.638	43.72368	-121.3116	1.055	0.931
279	10	6	4	2	55.851	43.72307	-121.30835	0.835	0.637
279	10	6	6	13	48.787	43.72425	-121.3097	0.638	0.604
280	10	7	6	12	8.757	43.72372	-121.31015	0.564	0.791
280	10	7	7	26	23.29	43.71807	-121.31032	0.962	0.574
280	10	7	10	47	21.079	43.72403	-121.3095	1.136	0.822
281	10	8	7	5	6.107	43.72662	-121.3048	0.864	0.541
281	10	8	19	8	20.701	43.71945	-121.31087	1.267	0.523
281	10	8	21	16	58.206	43.73442	-121.31173	1.703	0.522
282	10	9	6	24	33.517	43.72232	-121.31203	0.735	0.769
282	10	9	10	16	9.958	43.7172	-121.31332	1.378	0.722
284	10	11	3	29	5.813	43.72417	-121.31338	0.409	0.852
284	10	11	10	53	26.568	43.72493	-121.30897	1.292	0.824
285	10	12	10	12	29.727	43.7257	-121.3135	0.783	0.863
285	10	12	16	37	43.42	43.72515	-121.3151	0.49	1.482
285	10	12	16	47	1.174	43.7297	-121.3126	1.07	0.681
285	10	12	18	33	4.878	43.72363	-121.30787	0.359	0.743
285	10	12	21	10	18.995	43.72783	-121.31002	0.653	0.792
286	10	13	0	57	6.873	43.72382	-121.3175	0.242	1.197
286	10	13	4	12	29.232	43.72657	-121.30698	0.882	1.179
286	10	13	10	22	29.146	43.7302	-121.3153	0.831	0.907
287	10	14	5	46	14.161	43.71765	-121.31087	0.161	0.904
288	10	15	15	3	44.691	43.72658	-121.30768	0.897	0.781
288	10	15	15	37	26.034	43.72713	-121.30915	0.934	0.883
289	10	16	16	53	27.596	43.72378	-121.31295	-0.186	0.736
291	10	18	23	57	3.867	43.72965	-121.31732	0.116	0.781
292	10	19	9	7	50.375	43.73525	-121.3113	0.837	0.776
296	10	23	21	2	22.32	43.7257	-121.30855	0.819	0.6
320	11	16	16	44	39.436	43.72772	-121.31492	1	1.099
320	11	16	18	52	9.671	43.72657	-121.31147	0.868	0.864
321	11	17	3	34	37.593	43.7274	-121.31807	0.203	1.088
321	11	17	4	41	53.061	43.7249	-121.31087	0.708	2.229
321	11	17	23	31	42.368	43.72523	-121.3094	-0.399	1.12
325	11	21	9	57	35.294	43.72682	-121.31657	0.475	1.219

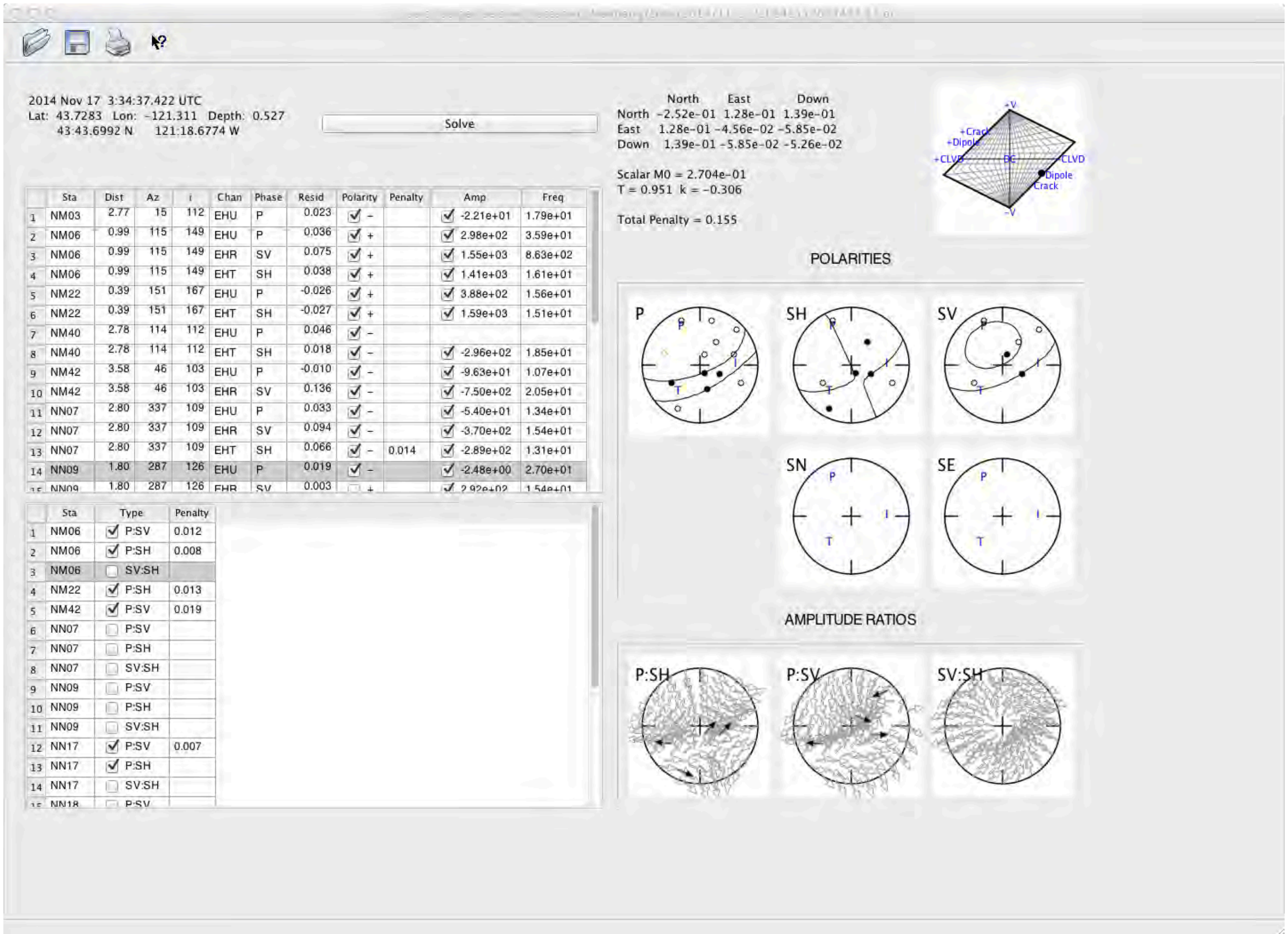
Appendix 2: Numerical moment tensor results for the 70 MEQs studied to date. N=North, E=East, D=Down.

NN	NE	EE	ND	ED	DD	Year	Mo	Day	Hr	min	Sec	Quality
1.578e-01	3.466e-02	6.671e-02	2.482e-01	6.317e-02	8.338e-02	2014	10	01	14	53	05.23	excellent
2.172e-01	-3.673e-02	-6.417e-02	2.346e-01	7.204e-02	3.184e-02	2014	10	01	19	05	16.54	excellent
8.713e-02	1.262e-01	-4.193e-02	1.814e-01	8.429e-02	8.722e-02	2014	10	04	18	51	12.00	excellent
-1.029e-01	1.325e-01	-1.185e-01	1.480e-01	5.508e-02	1.074e-01	2014	10	04	17	32	52.76	excellent
-1.165e-01	1.705e-01	-1.989e-01	1.394e-01	-2.430e-02	1.639e-02	2014	10	02	07	07	04.16	excellent
2.406e-01	-7.298e-02	-9.789e-02	1.731e-01	4.297e-02	8.349e-02	2014	10	02	11	01	42.38	excellent
-1.461e-02	9.643e-02	-3.978e-01	2.595e-02	1.691e-01	-4.693e-03	2014	10	02	06	47	52.94	excellent
6.066e-03	-2.231e-01	-9.157e-02	1.941e-01	3.367e-02	-6.184e-04	2014	10	03	06	06	22.76	excellent
-5.772e-02	-1.655e-01	-1.427e-01	1.464e-01	7.811e-02	-1.952e-02	2014	10	03	18	54	53.93	fair
2.004e-01	-1.410e-01	-1.461e-01	1.400e-01	-8.713e-03	7.412e-02	2014	10	01	12	03	16.94	good
5.304e-02	6.783e-02	-1.175e-01	1.615e-01	7.508e-02	2.206e-01	2014	10	05	04	07	20	excellent
-1.777e-01	-1.053e-01	-1.512e-01	7.111e-02	1.063e-01	1.057e-01	2014	10	01	01	03	14.49	excellent
-2.667e-01	1.320e-01	-6.399e-02	6.063e-02	1.031e-01	7.787e-02	2014	09	30	21	30	43.503	excellent
-1.871e-01	8.995e-02	-9.473e-02	-1.446e-01	-2.491e-02	1.992e-01	2014	10	05	23	22	16.499	good
1.684e-01	-3.350e-02	-9.826e-03	2.952e-01	3.542e-02	9.350e-02	2014	10	04	05	29	08.258	fair
2.449e-01	-8.111e-02	-1.972e-01	1.741e-01	1.624e-02	1.507e-02	2014	10	03	15	27	57.661	good
-2.209e-01	-8.132e-02	-2.190e-02	-1.520e-01	3.521e-02	2.201e-01	2014	10	01	16	56	11.343	good
1.477e-01	-1.175e-01	-1.492e-01	1.577e-01	-3.130e-02	9.546e-02	2014	10	01	08	08	57.998	excellent
-3.263e-02	2.220e-01	-3.373e-01	1.644e-02	7.162e-02	9.879e-03	2014	10	01	10	50	55.107	excellent
-1.038e-01	1.463e-01	-2.541e-01	1.246e-01	-1.332e-02	7.335e-02	2014	10	01	15	01	54.950	excellent
2.306e-03	-1.802e-01	-9.214e-02	2.203e-01	-4.354e-03	9.593e-02	2014	10	02	18	54	03.152	good
1.619e-01	4.200e-02	-2.041e-01	2.158e-01	-2.044e-02	7.759e-02	2014	10	02	06	39	02.998	excellent
-6.570e-02	-1.851e-01	-1.140e-01	1.691e-01	4.183e-02	2.826e-02	2014	10	02	12	39	24.317	good
1.420e-01	-1.373e-01	-1.638e-01	1.721e-01	1.076e-02	5.384e-02	2014	10	02	20	37	06.043	good
-1.365e-01	-1.837e-01	-5.911e-02	1.611e-01	-1.124e-02	9.224e-02	2014	10	05	02	06	16.967	excellent
2.866e-01	-3.707e-02	-1.787e-01	9.263e-02	1.263e-01	2.268e-02	2014	10	05	16	07	32.777	excellent
-2.286e-01	1.607e-01	-7.209e-02	-9.281e-02	8.007e-02	-3.216e-02	2014	10	05	15	55	21.007	good
-1.352e-01	-1.174e-01	-4.098e-02	1.996e-01	-5.345e-02	8.302e-02	2014	10	12	10	12	29	good
-2.211e-01	1.542e-01	4.959e-02	9.042e-02	8.191e-02	7.603e-02	2014	10	12	21	10	23.311	good
-4.882e-01	-1.017e-01	5.620e-02	5.965e-02	-1.844e-03	1.292e-01	2014	10	12	16	37	43.287	excellent
-5.873e-02	-1.252e-01	-2.804e-01	6.116e-02	1.409e-01	6.331e-03	2014	10	13	00	57	06.717	good
2.607e-02	-1.181e-01	-2.888e-01	8.025e-02	1.234e-01	4.154e-02	2014	10	13	04	12	29.126	excellent
-1.162e-01	-1.387e-01	-1.174e-01	1.514e-01	5.536e-02	7.558e-02	2014	10	13	10	22	29.084	excellent
-1.128e-01	-2.729e-02	-2.406e-01	5.661e-02	5.175e-02	3.753e-01	2014	10	14	05	46	13.914	excellent
-5.101e-02	-1.756e-01	-8.505e-02	1.953e-01	1.276e-03	1.195e-01	2014	10	15	15	37	25.945	excellent
-1.267e-01	-1.699e-01	3.343e-02	1.566e-01	-5.422e-02	7.857e-02	2014	10	15	15	03	44.602	excellent

6.492e-02	-9.495e-02	-2.842e-01	6.736e-02	1.452e-01	-3.577e-02	2014	09	30	09	23	48.626	good
-1.426e-01	-1.356e-01	3.347e-03	1.557e-01	-5.829e-02	1.550e-01	2014	10	11	03	29	05.667	good
3.707e-03	3.866e-02	-3.573e-01	5.614e-02	2.090e-01	2.164e-02	2014	10	11	10	53	26.502	good
4.380e-02	2.443e-01	-1.804e-01	4.365e-02	9.993e-02	-2.176e-05	2014	10	07	10	47	20.916	good
2.443e-02	7.095e-02	-2.428e-02	-8.639e-02	-1.620e-01	3.127e-01	2014	10	09	06	24	33.418	excellent
-4.203e-02	-1.463e-01	-3.196e-01	-5.380e-04	1.433e-01	5.826e-02	2014	10	18	23	57	03.695	good
-1.860e-01	8.584e-02	-2.758e-01	1.397e-01	-1.349e-02	6.014e-02	2014	10	19	09	07	50.325	good
2.027e-01	-2.424e-02	-3.047e-01	1.709e-01	-4.330e-02	1.575e-02	2014	10	12	18	33	04.693	moderate
1.319e-01	1.004e-01	-3.874e-01	3.120e-02	9.894e-02	1.908e-02	2014	10	07	06	12	08.593	good
-4.011e-01	-1.326e-01	-3.893e-03	1.173e-01	1.595e-02	6.345e-02	2014	10	16	16	53	27.374	good
7.443e-02	8.687e-02	-6.603e-02	-1.453e-01	-9.859e-02	1.981e-01	2014	10	09	10	16	09.945	moderate
1.913e-01	-1.220e-01	-8.473e-02	1.936e-01	2.385e-02	4.506e-02	2014	09	29	09	57	54.158	excellent
4.999e-02	-1.926e-01	-1.244e-01	1.754e-01	2.482e-02	3.990e-02	2014	09	29	18	03	37.660	excellent
4.020e-02	-1.230e-01	-2.565e-01	1.610e-01	1.968e-02	9.601e-02	2014	10	12	16	47	01.137	excellent
-2.448e-02	-1.879e-01	-1.233e-01	1.689e-01	9.679e-03	1.193e-01	2014	10	05	02	14	37.168	excellent
-8.061e-02	-9.300e-02	-2.670e-01	6.013e-02	1.629e-01	-2.038e-02	2014	10	06	04	02	55.789	good
-2.166e-01	-2.314e-01	4.005e-02	5.036e-02	7.205e-02	3.578e-02	2014	10	02	16	12	35.315	weak
-3.561e-01	1.589e-01	1.186e-01	5.145e-02	2.877e-02	4.702e-02	2014	10	06	06	13	48.626	excellent
-1.403e-02	-2.150e-01	-6.153e-02	2.265e-01	1.118e-03	3.928e-02	2014	10	23	21	02	22.252	good
-4.159e-01	-1.860e-04	4.651e-02	1.890e-01	-7.142e-02	1.642e-02	2014	10	04	21	29	47.537	moderate
2.446e-01	-1.186e-01	-1.136e-01	1.673e-01	-1.161e-02	4.689e-02	2014	10	07	07	26	23.180	good
1.281e-01	1.267e-01	-6.919e-02	8.793e-02	1.446e-01	-8.415e-02	2014	10	01	22	13	54.151	good
3.027e-02	-1.918e-01	-9.497e-02	1.993e-01	1.073e-02	7.111e-02	2014	10	01	20	47	39.521	excellent
3.771e-01	-1.266e-02	-1.422e-01	1.286e-01	8.113e-02	3.587e-02	2014	10	02	07	22	03.575	good
5.178e-02	-1.721e-01	-2.476e-02	2.088e-01	-2.967e-02	1.023e-01	2014	10	02	09	04	08.647	good
2.550e-02	1.506e-01	-2.807e-01	1.688e-02	1.792e-01	-4.140e-04	2014	10	08	07	05	05.941	weak
-7.821e-03	2.190e-01	-2.873e-01	2.798e-02	1.012e-01	-8.510e-03	2014	10	08	19	08	20.619	excellent
-1.751e-01	-2.003e-01	-6.441e-02	1.282e-01	-1.701e-02	6.958e-02	2014	10	08	21	16	58.200	good
-2.488e-01	-8.809e-02	-1.116e-01	3.179e-02	-3.713e-02	3.255e-01	2014	11	17	04	41	52.962	excellent
-1.087e-01	-7.561e-02	2.844e-01	6.334e-02	1.557e-01	1.754e-02	2014	11	17	23	31	42.142	good
-2.517e-01	1.276e-01	-4.558e-02	1.389e-01	-5.853e-02	-5.262e-02	2014	11	17	03	34	37.422	good
-1.488e-01	8.762e-02	2.022e-01	7.869e-02	-1.506e-01	1.524e-02	2014	11	16	16	44	39.138	excellent
-2.700e-01	1.514e-01	-2.262e-02	7.176e-02	8.808e-02	8.496e-02	2014	11	16	18	52	09.588	moderate
-3.774e-01	1.336e-01	-1.288e-01	7.077e-02	-2.171e-02	4.149e-02	2014	11	21	09	57	35.096	good

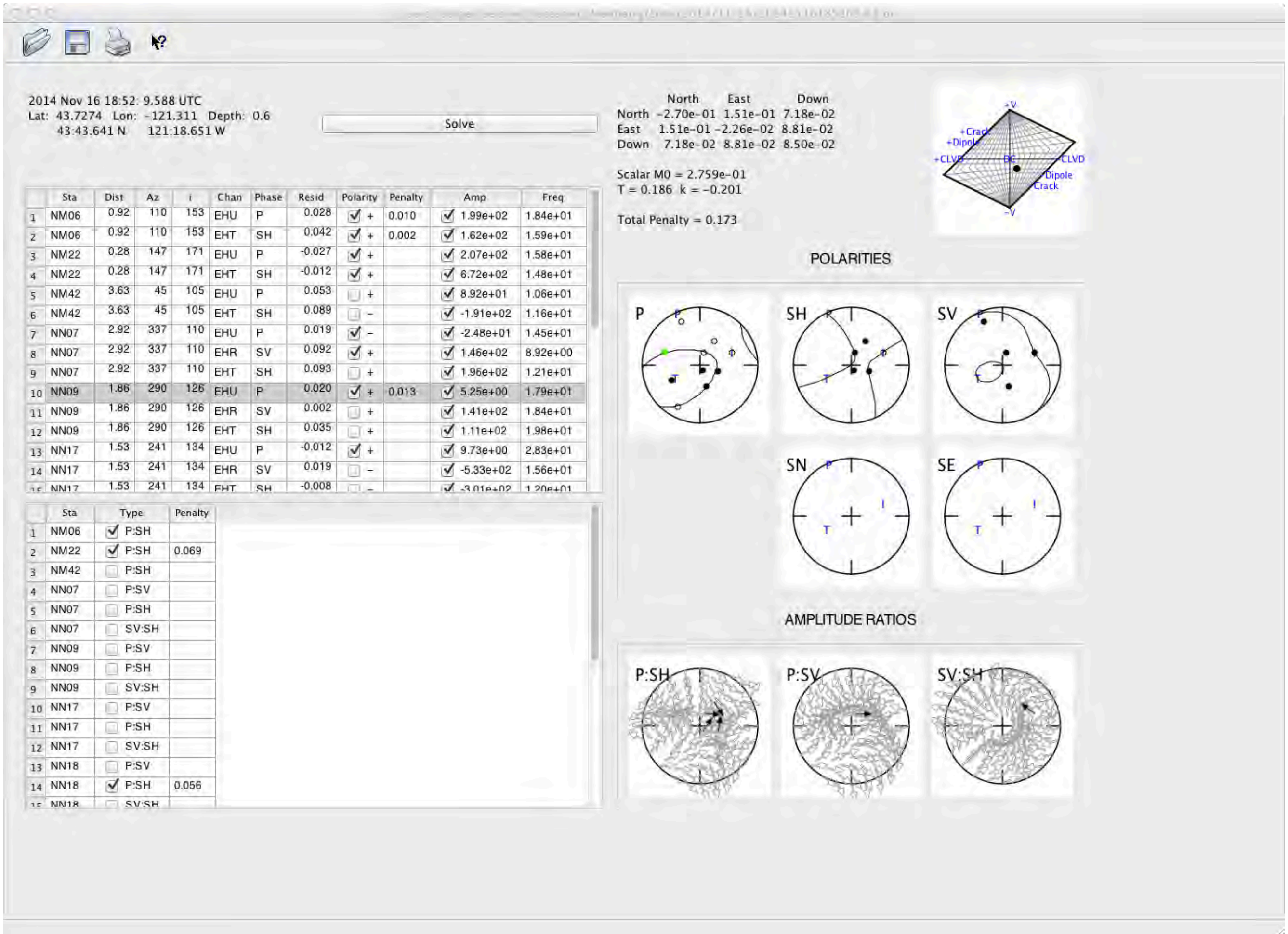
Appendix 3: The additional 5 moment tensors derived over the reporting week.

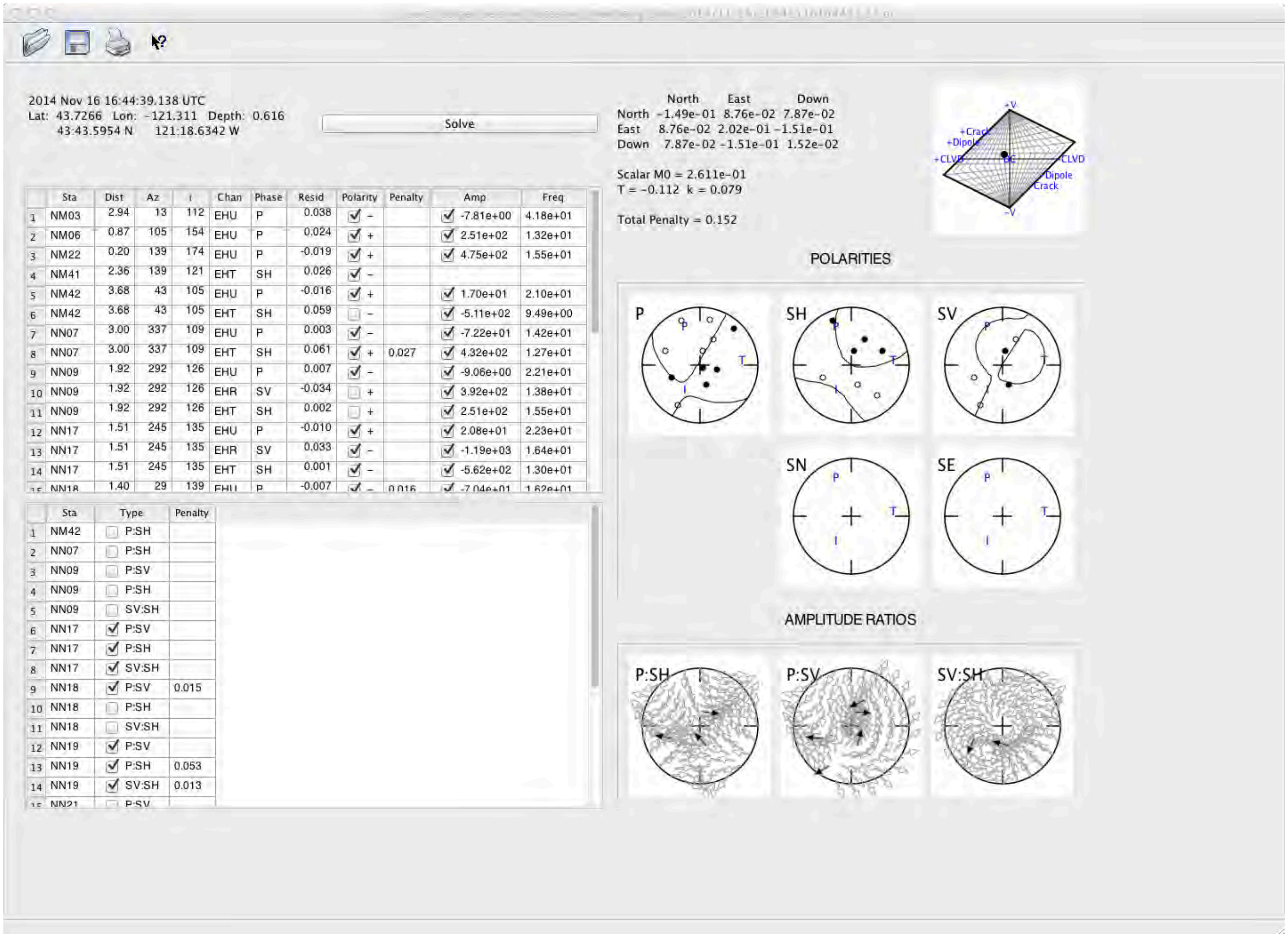

2014 Nov 17 23:31:42.142 UTC
Lat: 43.7255 Lon: -121.31 Depth: 0.532
43:43.5282 N 121:18.6192 W
Solve
North East Down
North -1.09e-01 -7.56e-02 6.33e-02
East -7.56e-02 2.84e-01 1.56e-01
Down 6.33e-02 1.56e-01 1.75e-02
Scalar M0 = 2.837e-01
T = -0.368 k = 0.179
Total Penalty = 0.166
+V
+Crack
+Dipole
+CLVD
DC
-CLVD
-Dipole
-Crack
-V
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM03 3.06 12 108 EHU P 0.011 - -1.61e+01 2.46e+01
2 NM03 3.06 12 108 EHT SH 0.082 - -2.11e+02 1.42e+01
3 NM06 0.83 97 154 EHU P 0.017 - -2.12e+02 1.38e+01
4 NM06 0.83 97 154 EHR SV 0.098 + 0.020 3.33e+03 1.85e+01
5 NM22 0.11 104 176 EHU P -0.024 + 3.46e+02 1.29e+01
6 NM22 0.11 104 176 EHT SH 0.016 + 2.13e+03 1.51e+01
7 NM42 3.76 42 102 EHU P -0.023 - -1.20e+02 1.15e+01
8 NM42 3.76 42 102 EHR SV 0.107 - -9.16e+02 2.07e+01
9 NM42 3.76 42 102 EHT SH 0.125 + 1.13e+03 1.79e+01
10 NN07 3.13 338 105 EHU P 0.015 - -3.27e+01 1.61e+01
11 NN07 3.13 338 105 EHR SV 0.034 - -2.72e+02 2.26e+01
12 NN07 3.13 338 105 EHT SH 0.047 - -2.08e+02 1.88e+01
13 NN09 1.99 296 122 EHZ P 0.001 + 5.36e+01 1.64e+01
14 NN09 1.99 296 122 EHN SN 0.028 + 8.53e+02 2.66e+01
Sta Type Penalty
1 NM03 P:SH
2 NM06 P:SV 0.050
3 NM42 P:SV 0.012
4 NM42 P:SH
5 NM42 SV:SH 0.027
6 NN07 P:SV 0.002
7 NN07 P:SH
8 NN07 SV:SH
9 NN17 P:SV
10 NN17 P:SH
11 NN17 SV:SH
12 NN18 P:SH
13 NN19 P:SV
14 NN19 P:SH
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH

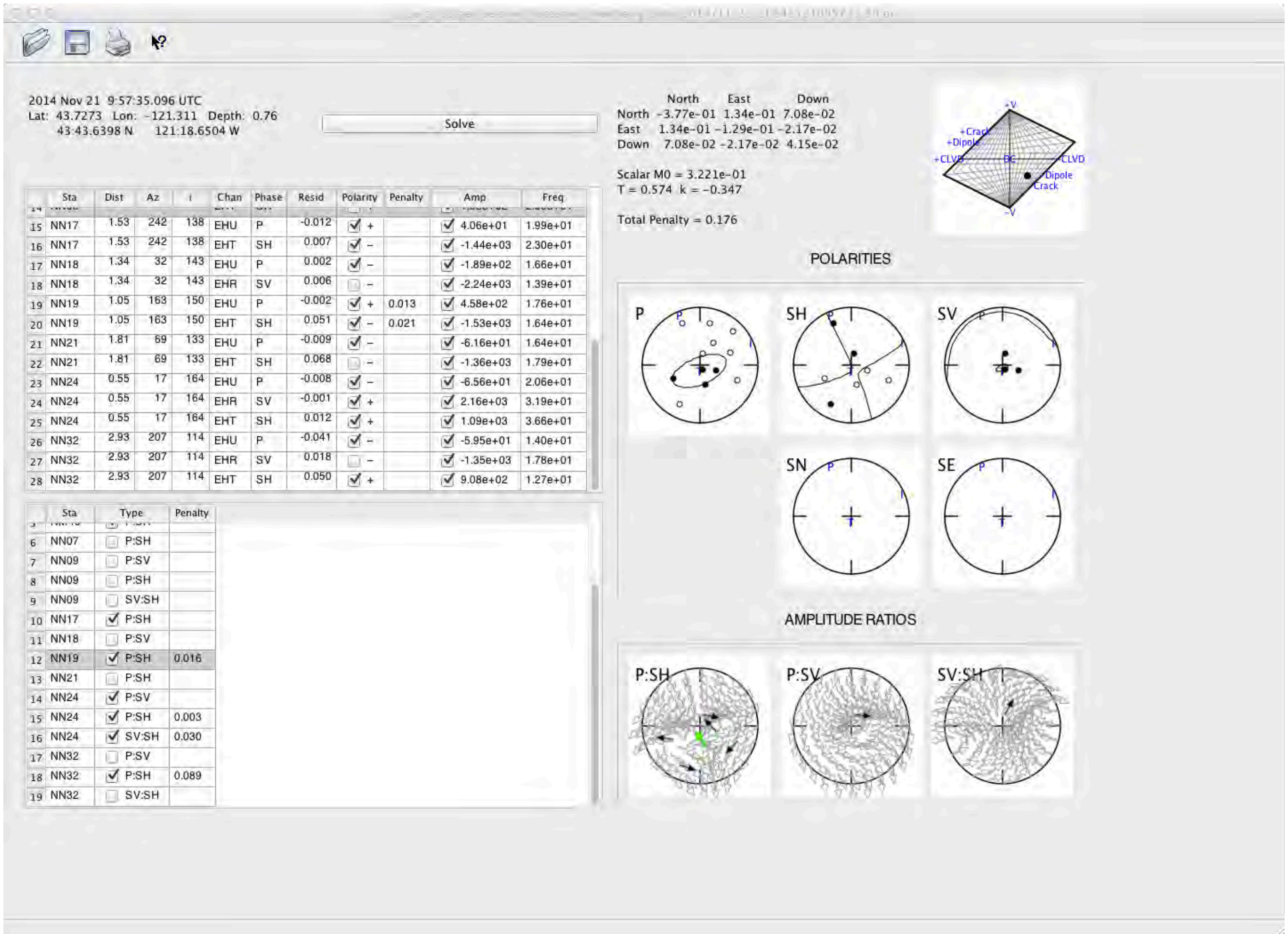


	Sta	Dist	Az	i	Chan	Phase	Resid	Polarity	Penalty	Amp	Freq
1	NM03	2.77	15	112	EHU	P	0.023	✓ –		✓ -2.21e+01	1.79e+01
2	NM06	0.99	115	149	EHU	P	0.036	✓ +		✓ 2.98e+02	3.59e+01
3	NM06	0.99	115	149	EHR	SV	0.075	✓ +		✓ 1.55e+03	8.63e+02
4	NM06	0.99	115	149	EHT	SH	0.038	✓ +		✓ 1.41e+03	1.61e+01
5	NM22	0.39	151	167	EHU	P	-0.026	✓ +		✓ 3.88e+02	1.56e+01
6	NM22	0.39	151	167	EHT	SH	-0.027	✓ +		✓ 1.59e+03	1.51e+01
7	NM40	2.78	114	112	EHU	P	0.046	✓ –			
8	NM40	2.78	114	112	EHT	SH	0.018	✓ –		✓ -2.96e+02	1.85e+01
9	NM42	3.58	46	103	EHU	P	-0.010	✓ –		✓ -9.63e+01	1.07e+01
10	NM42	3.58	46	103	EHR	SV	0.136	✓ –		✓ -7.50e+02	2.05e+01
11	NN07	2.80	337	109	EHU	P	0.033	✓ –		✓ -5.40e+01	1.34e+01
12	NN07	2.80	337	109	EHR	SV	0.094	✓ –		✓ -3.70e+02	1.54e+01
13	NN07	2.80	337	109	EHT	SH	0.066	✓ –	0.014	✓ -2.89e+02	1.31e+01
14	NN09	1.80	287	126	EHU	P	0.019	✓ –		✓ -2.48e+00	2.70e+01
15	NN09	1.80	287	126	EHR	SV	0.003	+		✓ 2.92e+02	1.54e+01

	Sta	Type	Penalty
1	NM06	✓ P:SV	0.012
2	NM06	✓ P:SH	0.008
3	NM06	SV:SH	
4	NM22	✓ P:SH	0.013
5	NM42	✓ P:SV	0.019
6	NN07	P:SV	
7	NN07	P:SH	
8	NN07	SV:SH	
9	NN09	P:SV	
10	NN09	P:SH	
11	NN09	SV:SH	
12	NN17	✓ P:SV	0.007
13	NN17	✓ P:SH	
14	NN17	SV:SH	
15	NN18	P:SV	


2014 Nov 16 18:52: 9.588 UTC
Lat: 43.7274 Lon: -121.311 Depth: 0.6
43:43.641 N 121:18.651 W
Solve
North East Down
North -2.70e-01 1.51e-01 7.18e-02
East 1.51e-01 -2.26e-02 8.81e-02
Down 7.18e-02 8.81e-02 8.50e-02
Scalar M0 = 2.759e-01
T = 0.186 k = -0.201
Total Penalty = 0.173
+V
+Crack
+Dipole
+CLVD
DC
CLVD
Dipole
Crack
-V
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM06 0.92 110 153 EHU P 0.028 + 0.010 1.99e+02 1.84e+01
2 NM06 0.92 110 153 EHT SH 0.042 + 0.002 1.62e+02 1.59e+01
3 NM22 0.28 147 171 EHU P -0.027 + 2.07e+02 1.58e+01
4 NM22 0.28 147 171 EHT SH -0.012 + 6.72e+02 1.48e+01
5 NM42 3.63 45 105 EHU P 0.053 + 8.92e+01 1.06e+01
6 NM42 3.63 45 105 EHT SH 0.089 – -1.91e+02 1.16e+01
7 NN07 2.92 337 110 EHU P 0.019 – -2.48e+01 1.45e+01
8 NN07 2.92 337 110 EHR SV 0.092 + 1.46e+02 8.92e+00
9 NN07 2.92 337 110 EHT SH 0.093 + 1.96e+02 1.21e+01
10 NN09 1.86 290 126 EHU P 0.020 + 0.013 5.25e+00 1.79e+01
11 NN09 1.86 290 126 EHR SV 0.002 + 1.41e+02 1.84e+01
12 NN09 1.86 290 126 EHT SH 0.035 + 1.11e+02 1.98e+01
13 NN17 1.53 241 134 EHU P -0.012 + 9.73e+00 2.83e+01
14 NN17 1.53 241 134 EHR SV 0.019 – -5.33e+02 1.56e+01
Sta Type Penalty
1 NM06 P:SH
2 NM22 P:SH 0.069
3 NM42 P:SH
4 NN07 P:SV
5 NN07 P:SH
6 NN07 SV:SH
7 NN09 P:SV
8 NN09 P:SH
9 NN09 SV:SH
10 NN17 P:SV
11 NN17 P:SH
12 NN17 SV:SH
13 NN18 P:SV
14 NN18 P:SH 0.056
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH


2014 Nov 16 16:44:39.138 UTC
Lat: 43.7266 Lon: -121.311 Depth: 0.616
43:43.5954 N 121:18.6342 W
Solve
North East Down
North -1.49e-01 8.76e-02 7.87e-02
East 8.76e-02 2.02e-01 -1.51e-01
Down 7.87e-02 -1.51e-01 1.52e-02
Scalar M0 = 2.611e-01
T = -0.112 k = 0.079
Total Penalty = 0.152
+V
+Crack
+Dipole
+CLVD
-CLVD
-Dipole
-Crack
-V
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM03 2.94 13 112 EHU P 0.038 - -7.81e+00 4.18e+01
2 NM06 0.87 105 154 EHU P 0.024 + 2.51e+02 1.32e+01
3 NM22 0.20 139 174 EHU P -0.019 + 4.75e+02 1.55e+01
4 NM41 2.36 139 121 EHT SH 0.026 -
5 NM42 3.68 43 105 EHU P -0.016 + 1.70e+01 2.10e+01
6 NM42 3.68 43 105 EHT SH 0.059 - -5.11e+02 9.49e+00
7 NN07 3.00 337 109 EHU P 0.003 - -7.22e+01 1.42e+01
8 NN07 3.00 337 109 EHT SH 0.061 + 0.027 4.32e+02 1.27e+01
9 NN09 1.92 292 126 EHU P 0.007 - -9.06e+00 2.21e+01
10 NN09 1.92 292 126 EHR SV -0.034 + 3.92e+02 1.38e+01
11 NN09 1.92 292 126 EHT SH 0.002 + 2.51e+02 1.55e+01
12 NN17 1.51 245 135 EHU P -0.010 + 2.08e+01 2.23e+01
13 NN17 1.51 245 135 EHR SV 0.033 - -1.19e+03 1.64e+01
14 NN17 1.51 245 135 EHT SH 0.001 - -5.62e+02 1.30e+01
15 NN18 1.40 29 139 EHU P -0.007 - 0.016 -7.04e+01 1.62e+01
Sta Type Penalty
1 NM42 P:SH
2 NN07 P:SH
3 NN09 P:SV
4 NN09 P:SH
5 NN09 SV:SH
6 NN17 P:SV
7 NN17 P:SH
8 NN17 SV:SH
9 NN18 P:SV 0.015
10 NN18 P:SH
11 NN18 SV:SH
12 NN19 P:SV
13 NN19 P:SH 0.053
14 NN19 SV:SH 0.013
15 NN21 P:SV
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH


2014 Nov 21 9:57:35.096 UTC
Lat: 43.7273 Lon: -121.311 Depth: 0.76
43:43.6398 N 121:18.6504 W
Solve
North East Down
North -3.77e-01 1.34e-01 7.08e-02
East 1.34e-01 -1.29e-01 -2.17e-02
Down 7.08e-02 -2.17e-02 4.15e-02
Scalar M0 = 3.221e-01
T = 0.574 k = -0.347
Total Penalty = 0.176
+V
+Crack
+Dipole
+CLVD
DC
CLVD
Dipole
Crack
-V
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
15 NN17 1.53 242 138 EHU P -0.012 + 4.06e+01 1.99e+01
16 NN17 1.53 242 138 EHT SH 0.007 - -1.44e+03 2.30e+01
17 NN18 1.34 32 143 EHU P 0.002 - -1.89e+02 1.66e+01
18 NN18 1.34 32 143 EHR SV 0.006 - -2.24e+03 1.39e+01
19 NN19 1.05 163 150 EHU P -0.002 + 0.013 4.58e+02 1.76e+01
20 NN19 1.05 163 150 EHT SH 0.051 - 0.021 -1.53e+03 1.64e+01
21 NN21 1.81 69 133 EHU P -0.009 - -6.16e+01 1.64e+01
22 NN21 1.81 69 133 EHT SH 0.068 - -1.36e+03 1.79e+01
23 NN24 0.55 17 164 EHU P -0.008 - -6.56e+01 2.06e+01
24 NN24 0.55 17 164 EHR SV -0.001 + 2.16e+03 3.19e+01
25 NN24 0.55 17 164 EHT SH 0.012 + 1.09e+03 3.66e+01
26 NN32 2.93 207 114 EHU P -0.041 - -5.95e+01 1.40e+01
27 NN32 2.93 207 114 EHR SV 0.018 - -1.35e+03 1.78e+01
28 NN32 2.93 207 114 EHT SH 0.050 + 9.08e+02 1.27e+01
Sta Type Penalty
6 NN07 P:SH
7 NN09 P:SV
8 NN09 P:SH
9 NN09 SV:SH
10 NN17 P:SH
11 NN18 P:SV
12 NN19 P:SH 0.016
13 NN21 P:SH
14 NN24 P:SV
15 NN24 P:SH 0.003
16 NN24 SV:SH 0.030
17 NN32 P:SV
18 NN32 P:SH 0.089
19 NN32 SV:SH
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH

Foulger Consulting

1025 Paradise Way
Palo Alto, CA 943062637, USA
Tel: 650/4932553
Cell: 650/9968886
FAX: 866/5326907
gillian@foulgerconsulting.com
http://www.foulgerconsulting.com/

October 29, 2014

WEEKLY REPORT #4 TO ALTAROCK ENERGY INC.

PROCESSING OF INDUCED EARTHQUAKES ASSOCIATED WITH THE NEWBERRY EGS INJECTION STARTING SEPTEMBER 2014

GILLIAN R. FOULGER & BRUCE R. JULIAN

Brief summary

Difficulties with transferring the full data from the ISTI system to our computers have settled down. A few channels are still missing or mis-timed, but these problems are minor and not significantly impacting the quality of the results we are able to produce.

We have completed relative relocations for the earthquakes up to 19 October with good results. The earthquakes clearly define a N 45˚ W striking fault, dipping at ~ 87˚ to the NE and activated in two depth intervals. One depth interval is the lowest ~ 250 m of the borehole and the other is ~ 200 m below the bottom of the borehole. The along-strike length of the activated fault is ~ 250 m.

During the forthcoming week we will update these results with earthquakes that occurred after 19 October, and we will also relatively locate the largest earthquakes using the high-quality arrival time measurements made for moment tensor calculations.

We derived an additional 10 moment tensors, bringing the currently available set to 34. The pattern of source types observed earlier remains constant with the addition of more results. The source types range from +Dipole to -Dipole with approximately equal numbers of earthquakes showing crack-opening and crack-closure. The T-axes, which gives an indication of the direction of σ_3*, cluster sub-horizontally S±20˚ or so. The P- and I-axes are more scattered.*

1 Task 1 – Planning, conference calls, discussion of work, correspondence, followup

We continued to maintain contact with team members. The issues associated with data completeness and formatting have subsided and the number of missing or incorrectly timed traces is now reduced. We have thus not needed to exchange many emails with ISTI, and our work has proceeded smoothly over the reporting week.

2 Task 2 – System Setup

Tailoring our system setup to the data supplied by ISTI, and tuning the relative location software parameters to the 2014 dataset is now essentially complete.

3 Task 3 – Quality control of prepicked MEQs and preparation for relocation and moment tensor calculation

We continued to derive moment tensors, prioritorising the largest earthquakes as in previous weeks. We continue to use the same procedure as described in our Weekly Report #1. We report here an additional 10 moment tensors. The entire list of earthquakes processed to date is given in

Table 1. We have provided the locations and moment tensor decomposition data of these new moment tensors to Trenton Cladouhos of AltaRock electronically, by email attachment.

Table 1: The 34 earthquakes for which moment tensors have been obtained. Locations given below are from the webpage http://fracture.lbl.gov/Newberry/locations.txt.

jday	month	day	hour	minute	sec	lat	lon	depth	magnitude
273	9	30	21	30	43.689	43.72667	-121.313	0.387	0.972
274	10	1	1	3	14.64	43.7239	-121.30957	0.714	0.987
274	10	1	8	8	58.215	43.72623	-121.31412	1.196	0.848
274	10	1	10	50	55.229	43.72275	-121.30868	1.051	0.787
274	10	1	12	3	16.881	43.72658	-121.3158	1.587	1.086
274	10	1	14	53	5.102	43.72545	-121.31355	0.613	1.381
274	10	1	15	1	55.056	43.72775	-121.31227	0.923	0.682
274	10	1	16	56	11.256	43.72232	-121.30712	1.65	0.901
274	10	1	19	5	16.377	43.72662	-121.31117	0.517	1.259
275	10	2	6	38	47.428	43.7243	-121.31328	1.153	0.951
275	10	2	6	47	52.916	43.72632	-121.31322	1.323	1.117
275	10	2	7	7	11.646	43.72488	-121.31192	0.708	1.378
275	10	2	11	1	48.042	43.72567	-121.31168	0.666	1.22
275	10	2	12	39	9.082	43.7264	-121.31438	1.332	0.852
275	10	2	18	53	48.447	43.72082	-121.31372	1.671	0.957
275	10	2	20	36	50.997	43.72377	-121.31323	1.499	0.991
276	10	3	6	6	22.727	43.72528	-121.31493	0.928	1.157
276	10	3	15	27	57.912	43.72257	-121.31562	1.054	0.919
276	10	3	18	54	54.199	43.72678	-121.31125	0.647	1.021
277	10	4	5	29	8.347	43.72578	-121.31068	0.946	0.922
277	10	4	17	32	52.716	43.72207	-121.31693	0.376	1.521
277	10	4	18	51	11.991	43.72295	-121.31227	0.496	1.97
278	10	5	2	6	17.079	43.7266	-121.31217	0.925	0.86
278	10	5	4	7	30.446	43.725	-121.31322	0.659	1.696
278	10	5	15	55	21.373	43.73483	-121.30918	0.702	0.695
278	10	5	16	7	32.904	43.7253	-121.30967	1.205	0.819
278	10	5	23	22	16.638	43.72368	-121.3116	1.055	0.931
285	10	12	10	12	29.727	43.7257	-121.3135	0.783	0.863
285	10	12	16	37	43.42	43.72515	-121.3151	0.49	1.482
285	10	12	21	10	18.995	43.72783	-121.31002	0.653	0.792
286	10	13	0	57	6.873	43.72382	-121.3175	0.242	1.197
286	10	13	4	12	29.232	43.72657	-121.30698	0.882	1.179
286	10	13	10	22	29.146	43.7302	-121.3153	0.831	0.907

287	10	14	5	46	14.161	43.71765	-121.31087	0.161	0.904

4 Task 4 –Improved locations and relative locations

4.1 Absolute locations

We updated our relocation of the earthquakes to date using **qloc**. The epicentral locations up to Oct. 26 are shown in Figure 1, and a depth vs. time plot for the same locations is shown in Figure 2.

Figure 3 shows the week-by-week development of the seismic sequence for the five weeks to date.

Figure 4 shows ISTI epicentral locations for comparison with Figure 1.

The general picture has not changed with an additional week of earthquakes. The cluster is still centered centered 100 to 200 m north of the bottom of well NWD 55-29 and is quasi-circular with a diameter of ~ 500 m.

Figure 5 and Figure 6 show the locations of the MEQs for which moment tensors were derived. These earthquakes are the largest and most accurately located earthquakes available to date. They form two clusters near the bottom of well NWD 55-29, a shallower cluster slightly to the north of the well and a deeper cluster slightly to the south. The pattern of locations of these earthquakes is similar to the relative locations (see below), providing some “ground truth” to the bimodal spatial distribution observed. Interestingly, this pattern, first reported for the moment-tensor-earthquake locations in last week’s report, is now confirmed by the relative location work.

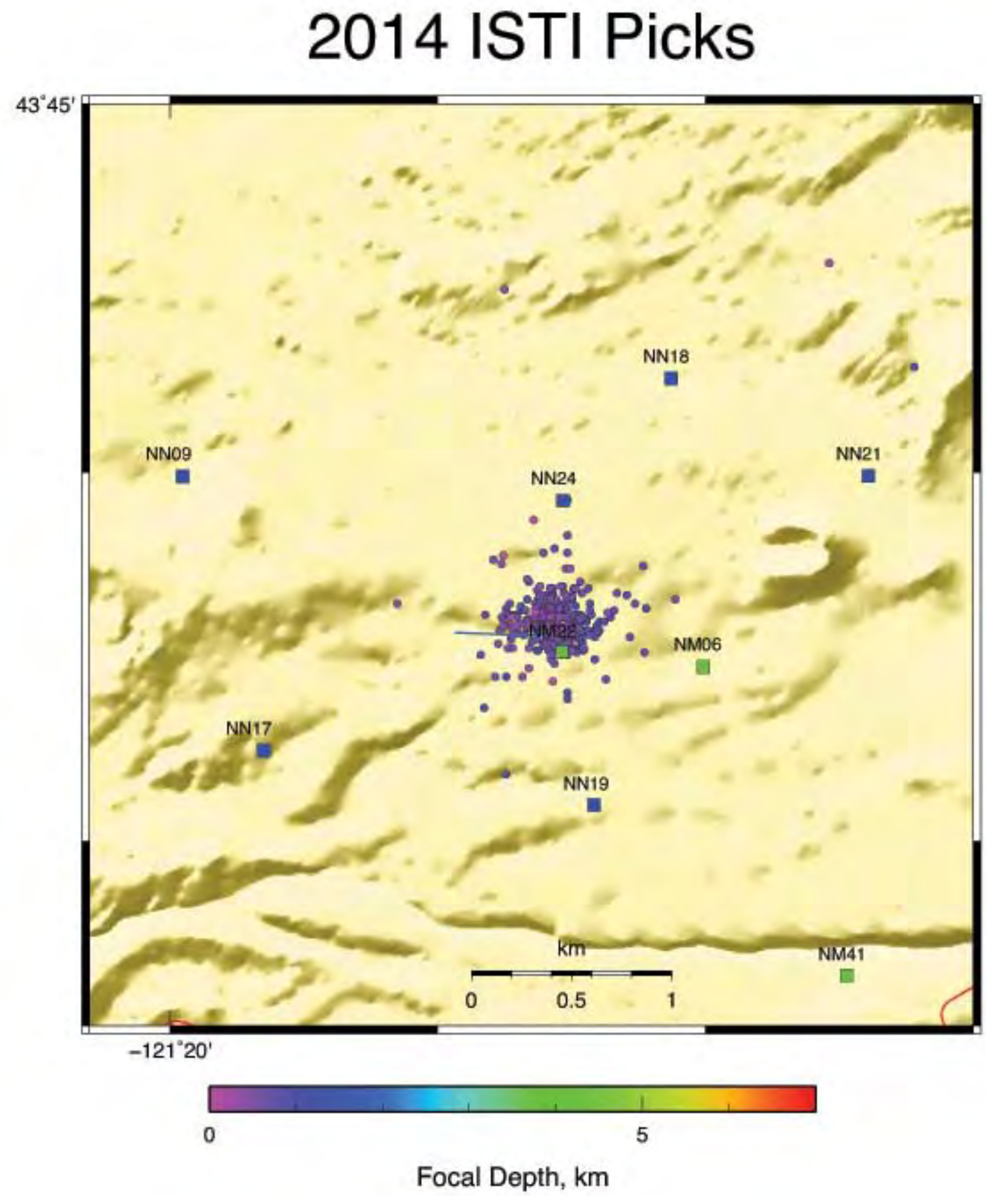


Figure 1: Estimated hypocenters of 297 microearthquakes between Sept. 26 and Oct. 26, 2014 within the NMSA network. Most events lie within a circle about 500 m in diameter and centered 100 to 200 m north of the bottom of well NWD 55-29, which is shown in blue. These locations were obtained by using the **qloc** program to invert *P*- and *S*-phase arrival times measured by personnel of the ISTI Corporation on digital seismograms from the NMSA network.

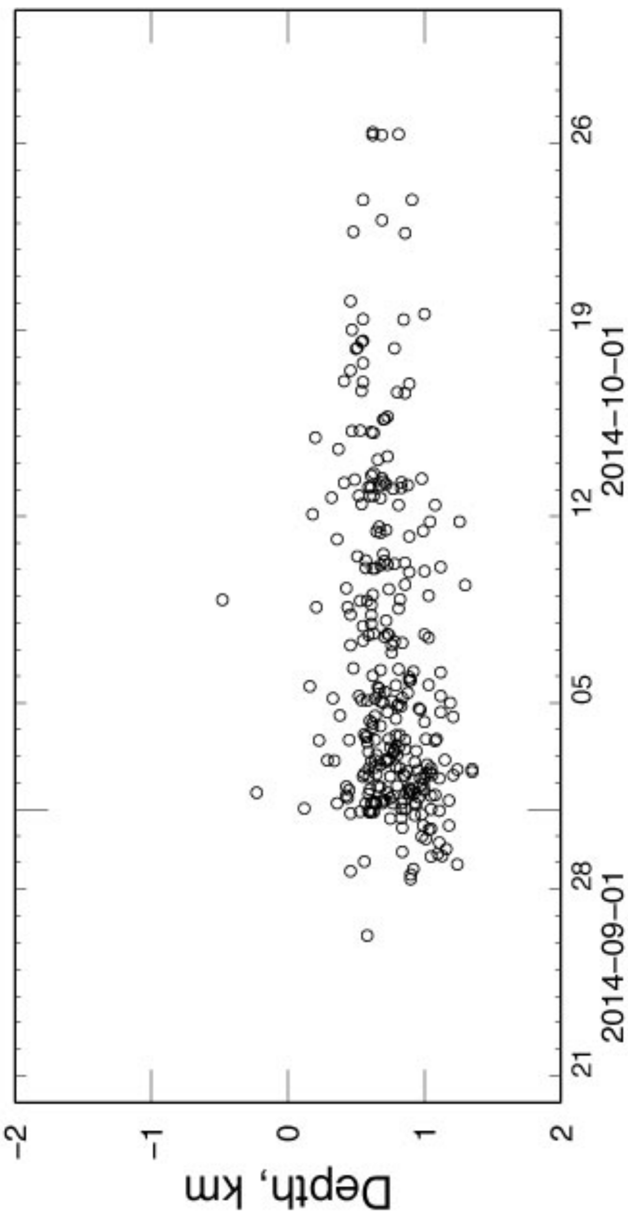


Figure 2: Estimated depths, with respect to sea level, of 297 microearthquakes within the NMSA network as a function of time. The average depth appears to be decreasing slightly with time because of a decrease in the number of deeper events. These depths were obtained by using the **qloc** program to invert *P*- and *S*-phase arrival times measured by personnel of the ISTI Corporation on digital seismograms from the NMSA network.

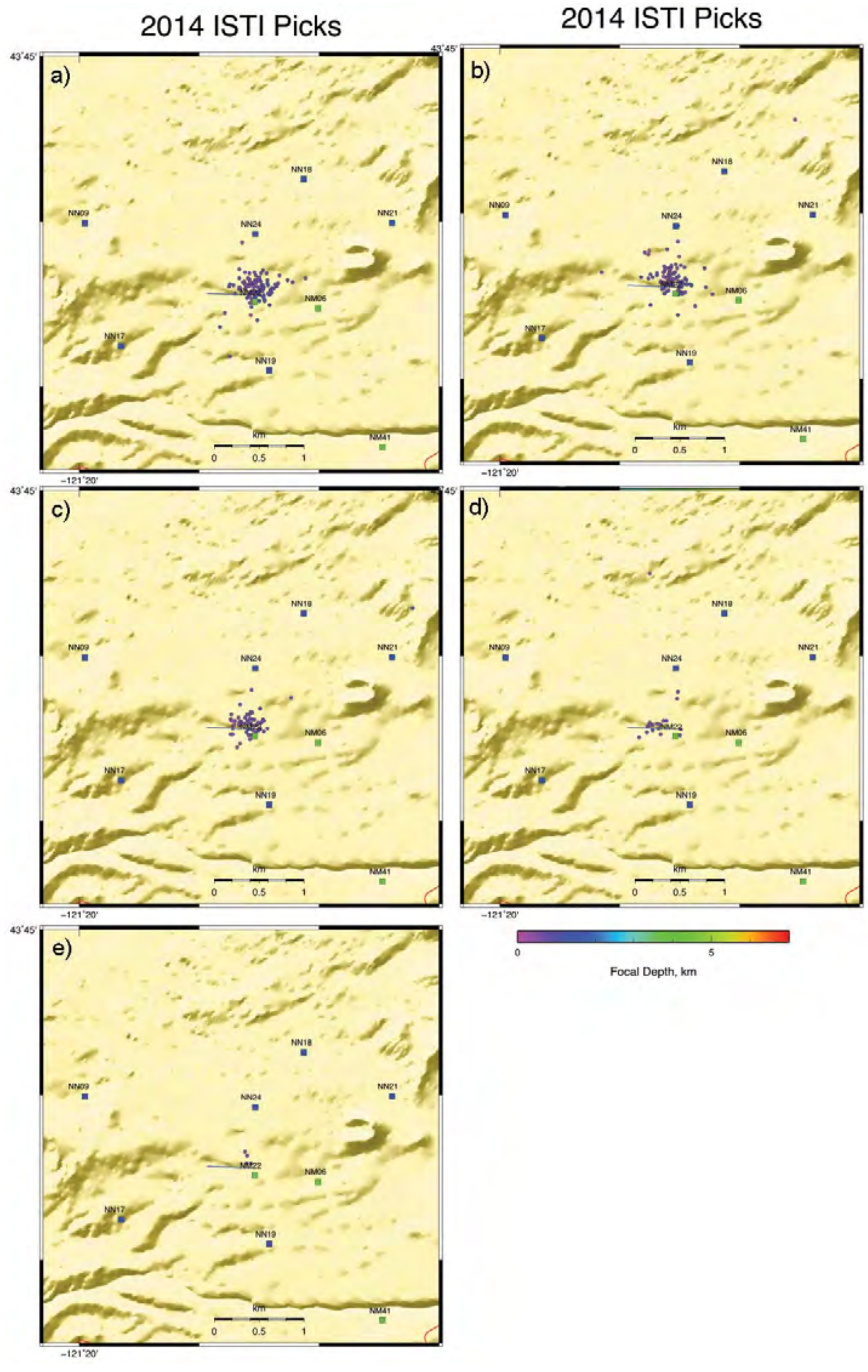


Figure 3: Hypocenters of microearthquakes within the NMSA network as a function of time. (a) 2014 Sept. 26 – Oct. 02; (b) Oct. 03 – Oct. 09; (c) Oct. 10 – Oct. 16; (d) Oct. 17 – Oct. 23; (e) Oct. 24 – Oct. 26 (shorter interval). There is no clear tendency for the events to migrate with time.

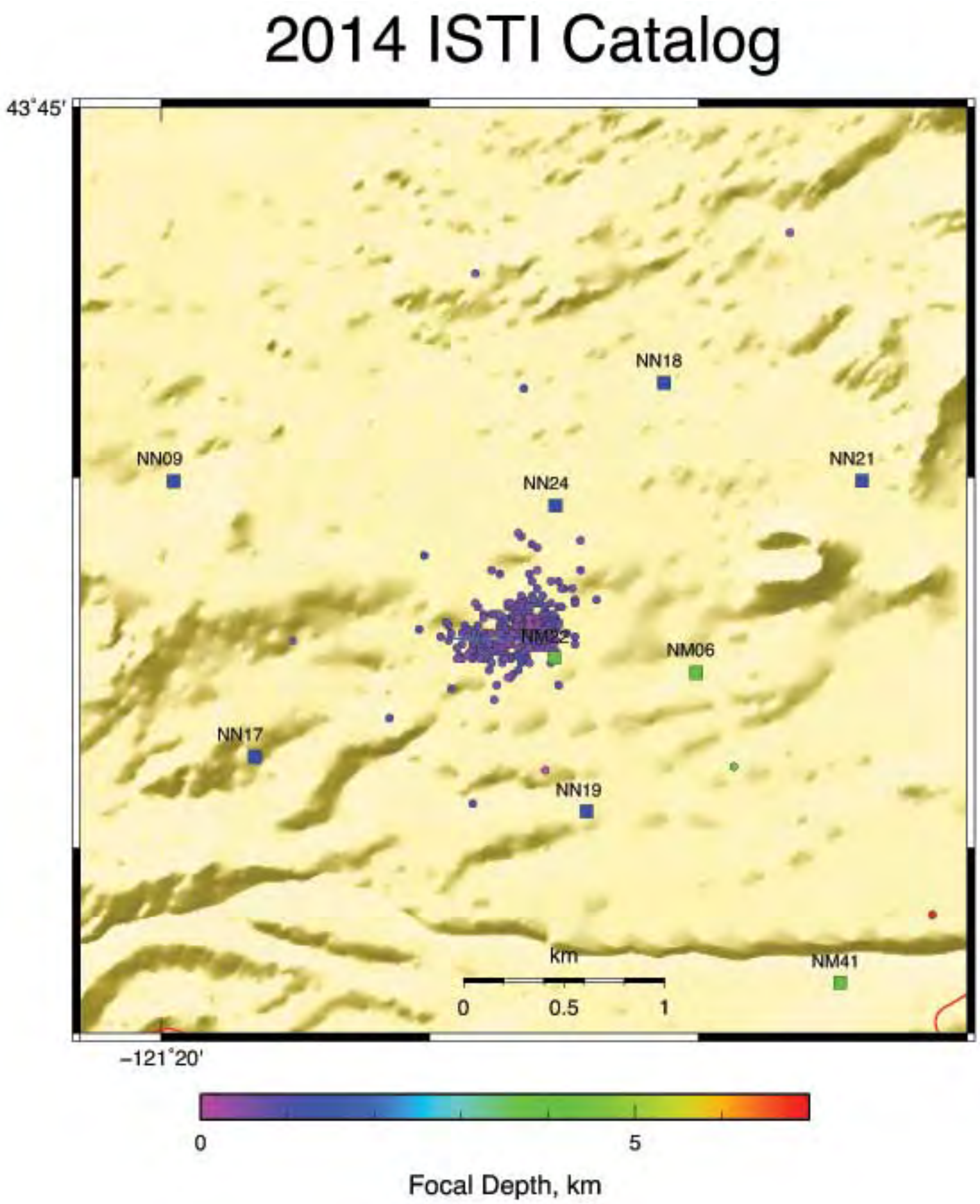


Figure 4: Hypocenters of 297 microearthquakes between Sept. 26 and Oct. 26, 2014 within the NMSA network, as given in the earthquake catalog of the ISTI Corporation. These locations are slightly but significantly west of those shown in Figure 1, which were derived from substantially the same seismic data but using a different computer program. Well NWD 55-29 is shown in blue.

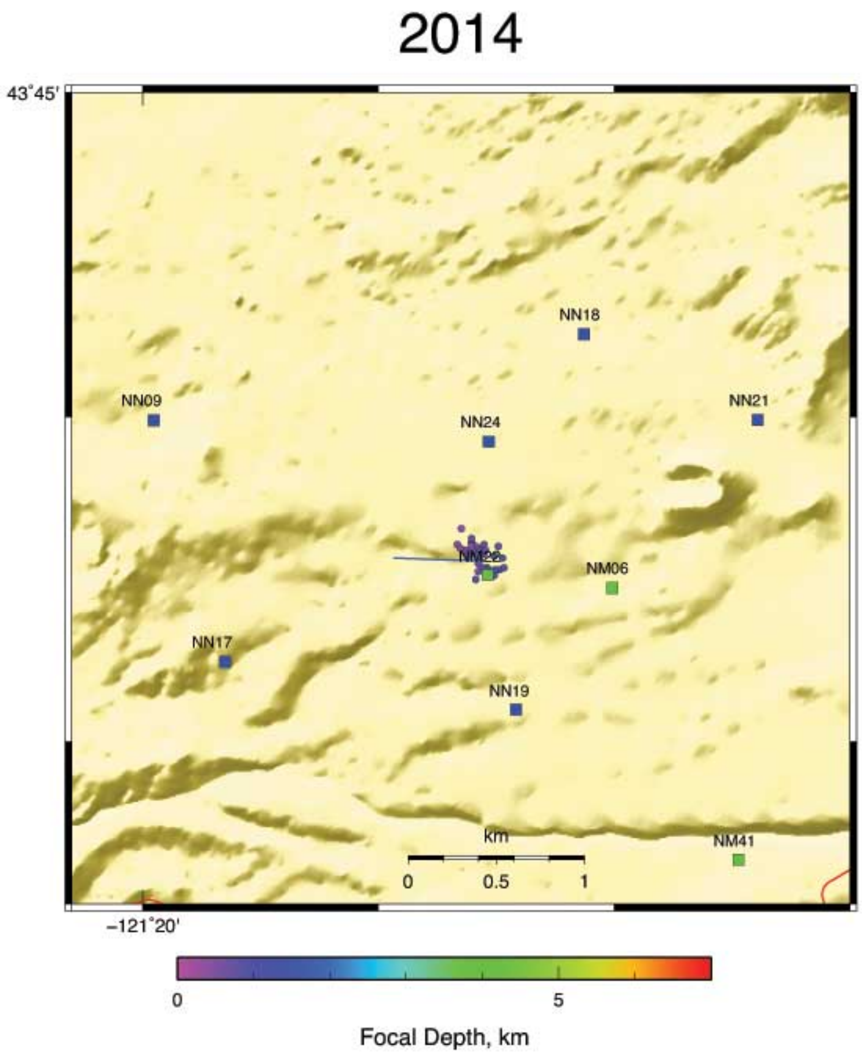


Figure 5: High quality estimated hypocenters of 34 microearthquakes that occurred between Sept. 30 and Oct. 15, 2014, and for which moment tensors were derived. These locations are computed using arrival times measured carefully in connection with the moment-tensor analysis. Well NWD 55-29 is shown in blue.

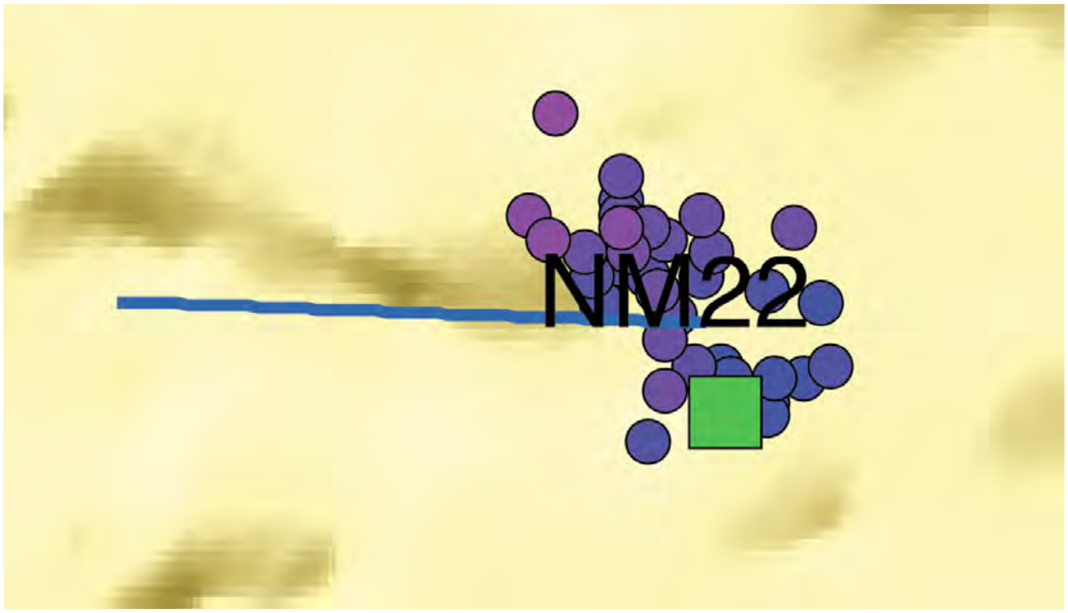


Figure 6: Expanded view of the locations of the earthquakes for which moment tensors were derived.

4.2 Relative locations

We are well advanced with the relative loction work for the earthquakes that occurred from the start of the sequence up to 19 October. We used program **hypocc**, a relative-location program based on the approach of Waldhauser and Ellsworth [2000] but written in the C programming language. This carries with it many advantages, including extreme speed. This enabled us to explored numerous run-time options to obtain the best possible result with the Newberry data.

Absolute hypocenter location methods such as the method ISTI is using, and our **qloc** locations, analyze one earthquake at a time. The results contain systematic errors caused by by errors in the crustal velocity model.

The relative location method works on a different principle, locating many earthquakes simultaneously, using as data the *differences* between the seismic-wave arrival times at common stations for pairs of earthquakes. The program divides the earthquakes into discrete "clusters" of closely grouped earthquakes, and relocates the events in each cluster relative to one another. This method greatly reduces the effect of systematic errors in the crustal model, and provides much higher resolution of the locations of nearby earthquakes *relative to other earthquakes in the same cluster*.

It is important to realize that the *absolute location of the cluster* is not improved by the relative location process. In order to fix the absolute location of the cluster, we pinnned it to a earthquake well located usign **qloc**. This was the M 1.1 earthquake of 2014 10 02 06:47:52.710, located at a latitude of 43.725296, longitude of -121.308326 and depth of 1.21 km b.s.l.

Our work proceeded as follows:

- We used the hand-measured arrival times provided by ISTI;
- We performed over 20 program runs, systematically varying three parameters in particular. These were:
    - *minclust*–the minimum number of earthquakes to define a cluster (a value of 10 was used);
    - *maxit*–the maximum allowed number of relocation iterations (optimal value identified = 25);
    - *maxsep*–the maximum separation allowed between linked pairs of earthquakes (optimal value identified = 0.15 km);
    - *minlinks*–the minimum number of "links" (i.e., measured station/phases in common between pairs of earthquakes) needed for an earthquake to be passed to the final relocated set (optimal values identified = 12 or 14);

We present two sets of results, using *minlinks* of 12 and 14.

The results using *minlinks*=12 are shown in Figure 7, Figure 8 and Figure 9. The original input dataset comprised 288 earthquakes, totalling 3411 arrival times. 129 earthquakes passed the stringent quality control parameters. Of these, 16 earthquakes failed the *maxsep* and *minclust* thresholds and were rejected as singlets. 113 earthquakes remained, comprising one cluster.

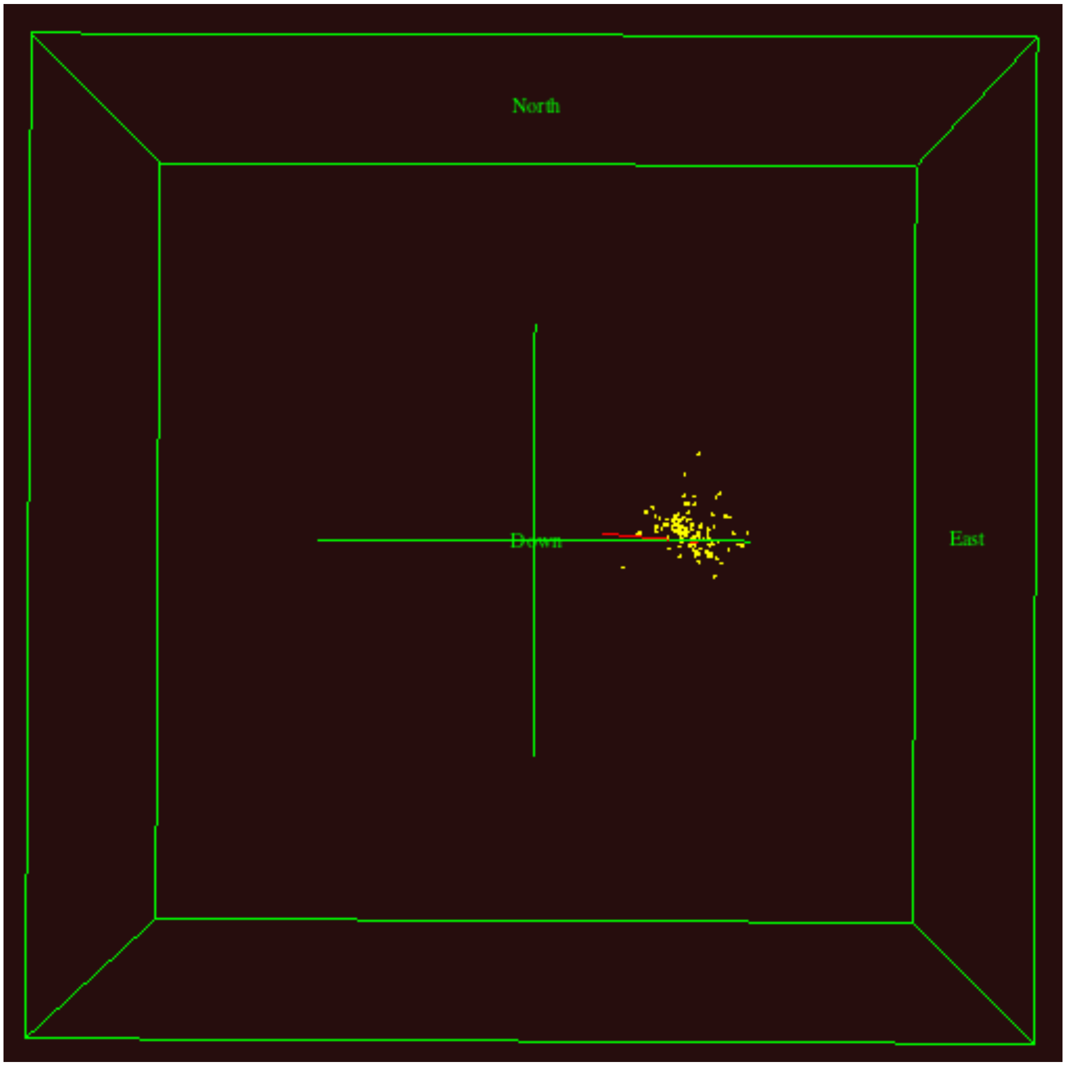


Figure 7: Map of relative locations of 113 earthquakes that occurred in the time period 26 September - 19 October, 2014. Runtime parameters used were *minclust* = 10, *maxit* = 25, *maxsep* = 0.15 km, *minlinks* = 12.

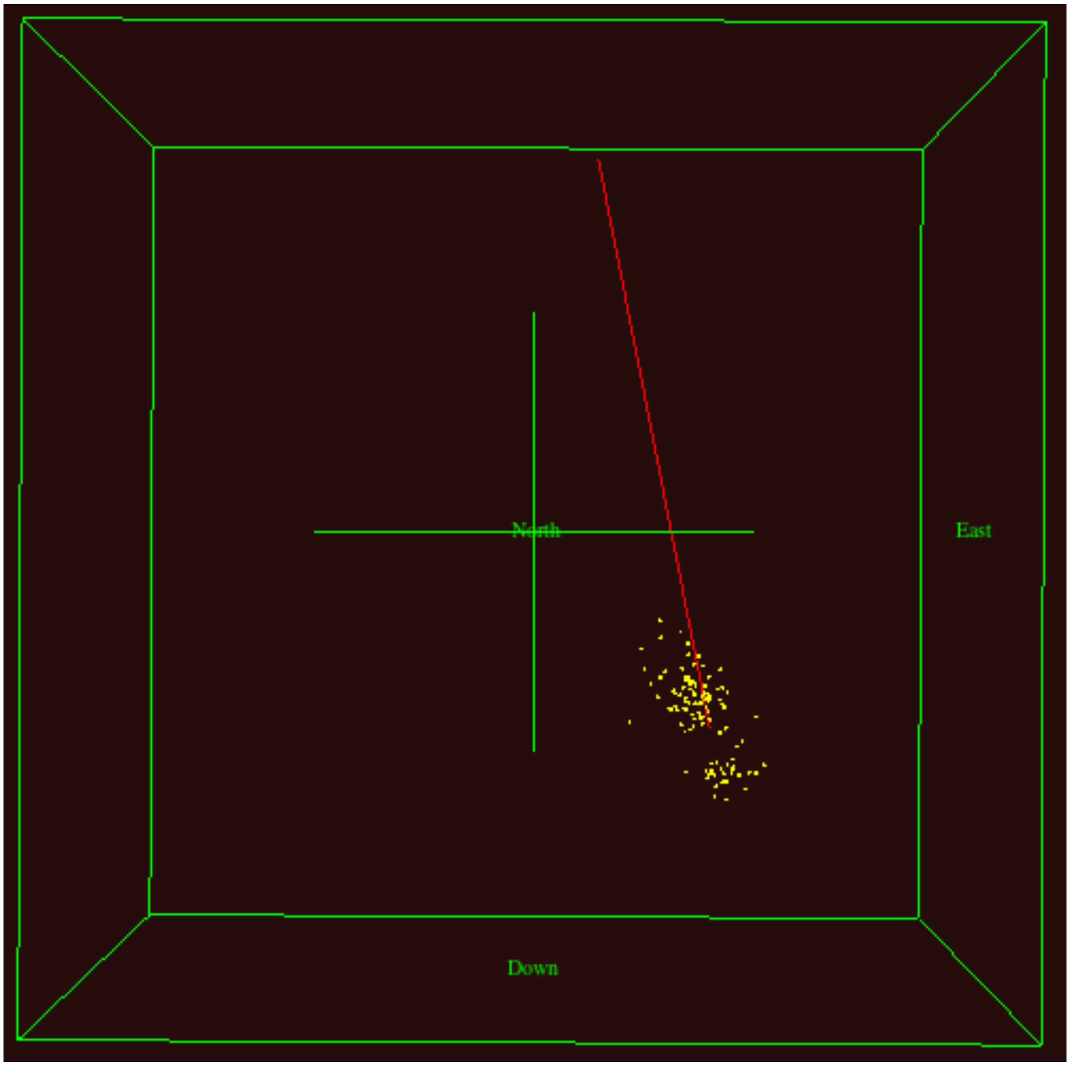


Figure 8: Same as Figure 7 except in cross section looking north.

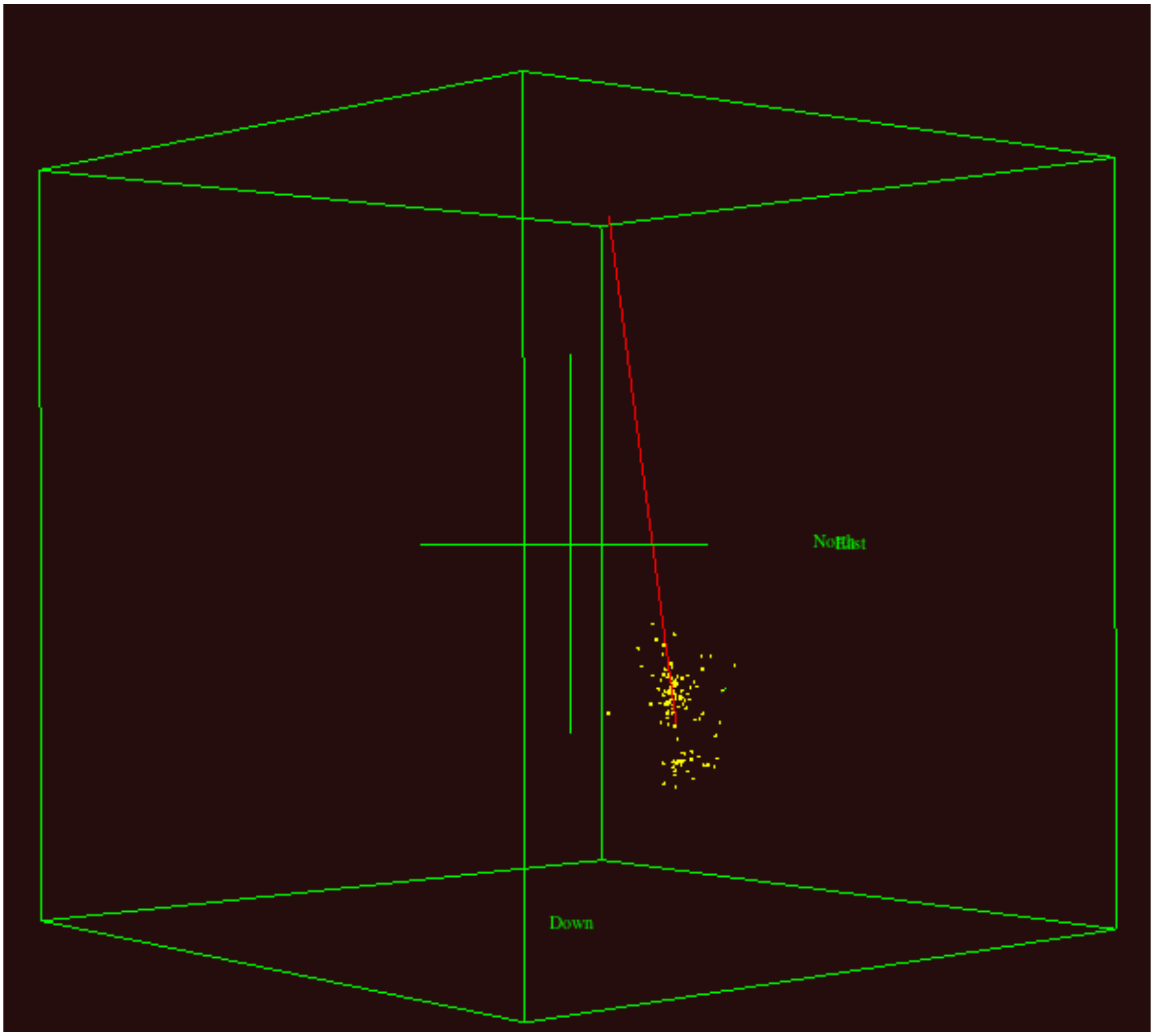


Figure 9: Same as Figure 7 except in cross section looking northwesterly, along the strike of the elongate cluster.

The results using *minlinks*=14 are shown in Figure 10, Figure 11 and Figure 12. 80 earthquakes passed the more-stringent *minlinks* setting. Of these, 14 earthquakes failed the *maxsep* and *minclust* thresholds and were rejected as singlets. 66 earthquakes remained, comprising one cluster.

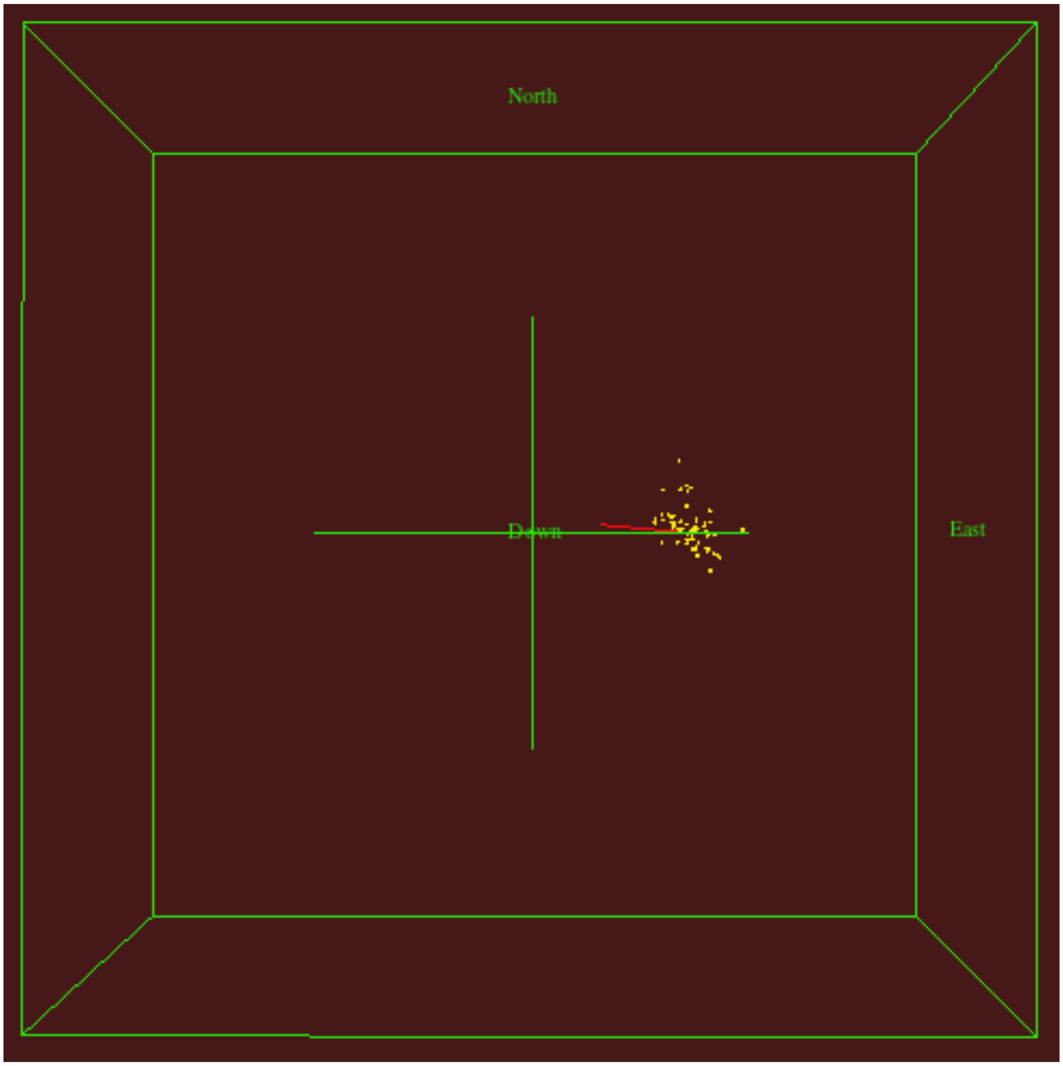


Figure 10: Map of relative locations of 66 earthquakes that occurred in the time period 26 September - 19 October, 2014. Runtime parameters used were *minclust* = 10, *maxit* = 25, *maxsep* = 0.15 km, *minlinks* = 14.

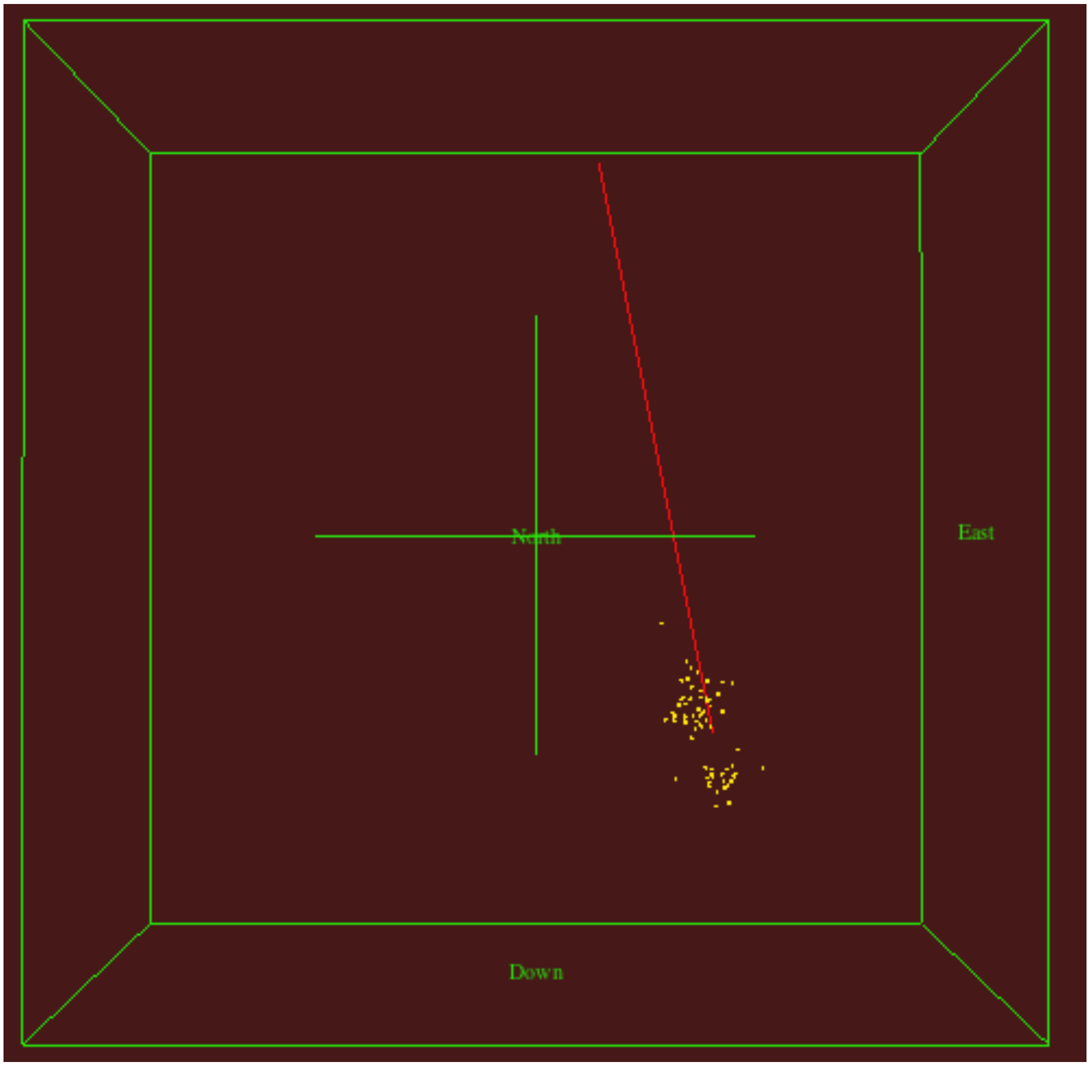


Figure 11: Same as Figure 10except in cross section looking north.

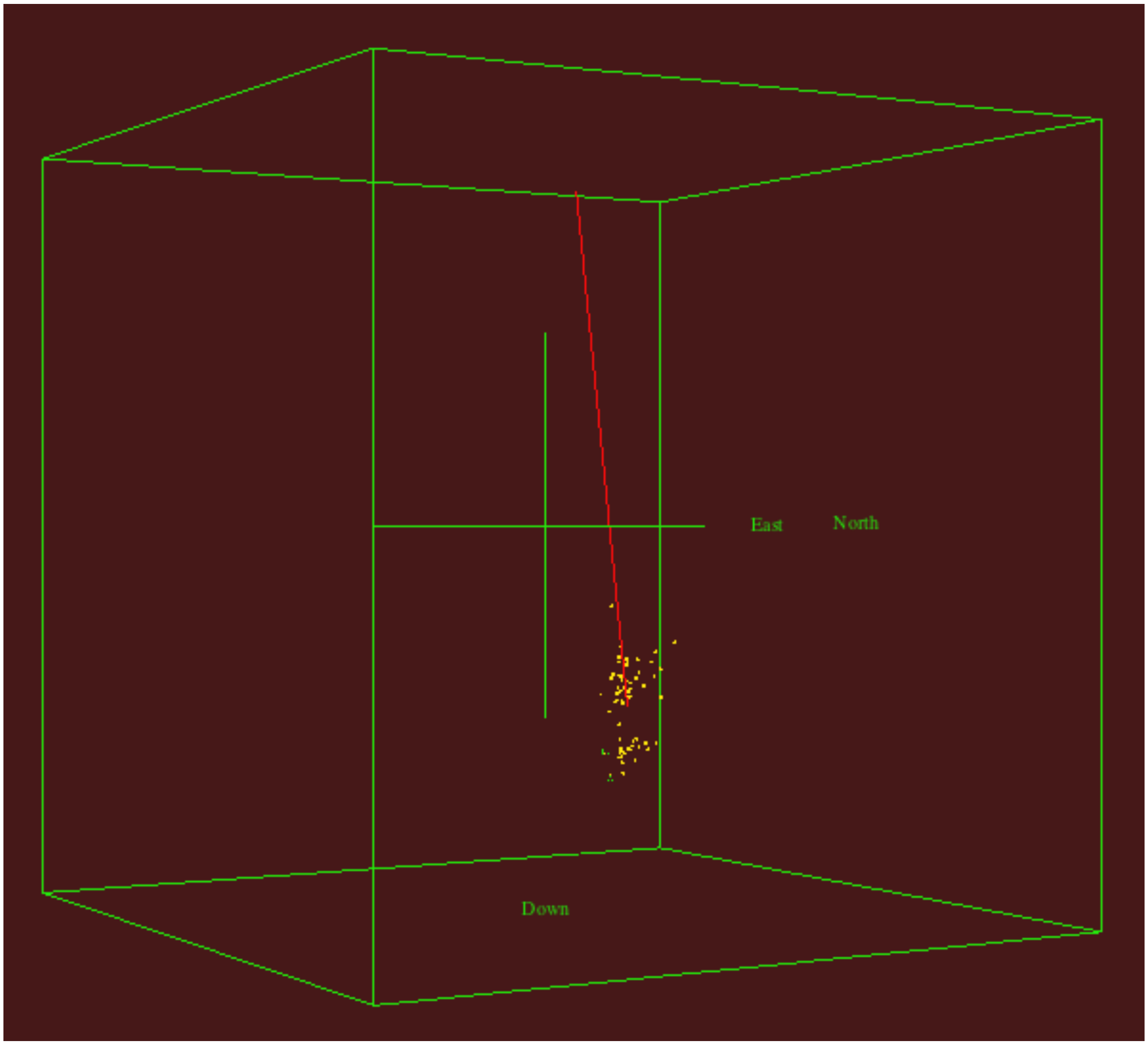


Figure 12: Same as Figure 10 except in cross section looking northwesterly, along the strike of the elongate cluster.

A brief interpretation is as follows. The epicentral region apparent in ISTI locations is quasi-circular, and the earthquake depths show a single diffuse cloud. In the **qloc** locations, more structure is visible and northwesterly orientated structure can marginally be discerned. This structure is greatly enhanced in the relative locations, which show a clear linear zone striking at N 45˚W. In depth section, the cluster clearly forms two subclusters separated by a zone ~ 200 m in depth extent that is almost devoid of earthquakes. When viewed along strike in depth section (Figure 9 and Figure 12), it can be seen that a steeply dipping structure is defined (dip ~ 87˚) that is defined most sharply on its southwesterly side.

These results suggest that the stimulation activated a northwesterly trending fault ~ 250 m in length. Two portions of the fault plane separated in depth were activated. The shallower one extends throughout approximately the lower 250 m of the borehole and the other is approximately 100 m in height, with its top about 200 m below the bottom of the well.

More work needs to be done to fine-tune and study in detail these dimensions and depths and this will comprise our work in the forthcoming week. Numerical data for these interim results have been provided to AltaRock by email attachment to Trenton Cladouhos.

5 Task 5 Moment tensor calculations

Moment tensors were derived for an additional 10 earthquakes using the same procedure as described in Weekly Report #1. The numerical results of the catalog to date are given in

Table 2. Graphical results for the additional events are shown in Appendix 1.

The source types for the entire 34-event set are shown in source-type space in Figure 13. The events form a distribution from the +Dipole to the -Dipole points, indicating a mixture of crack-opening and crack-closing events in approximately equal numbers.

Figure 14 shows a plot of the P-, T- and I-axes, approximately corresponding to the directions of σ_1, σ_3 and σ_2. The addition of more earthquakes has strengthened the distribution seen earlier whereby most T axes cluster systematically subhorizontally and to the S ± 20˚ or so. The orientations of the P- and I-axes are more scattered.

Table 2: Numerical moment tensor results for the 34 MEQs studied to date. N=North, E=East, D=Down.

NN	NE	EE	ND	ED	DD	Year	Mo	Day	Hr	min	Sec	Quality
1.578e-01	3.466e-02	6.671e-02	2.482e-01	6.317e-02	8.338e-02	2014	10	01	14	53	05.23	excellent
2.172e-01	-3.673e-02	-6.417e-02	2.346e-01	7.204e-02	3.184e-02	2014	10	01	19	05	16.54	excellent
8.713e-02	1.262e-01	-4.193e-02	1.814e-01	8.429e-02	8.722e-02	2014	10	04	18	51	12.00	excellent
-1.029e-01	1.325e-01	-1.185e-01	1.480e-01	5.508e-02	1.074e-01	2014	10	04	17	32	52.76	excellent
-1.165e-01	1.705e-01	-1.989e-01	1.394e-01	-2.430e-02	1.639e-02	2014	10	02	07	07	04.16	excellent
2.406e-01	-7.298e-02	-9.789e-02	1.731e-01	4.297e-02	8.349e-02	2014	10	02	11	01	42.38	excellent
-1.461e-02	9.643e-02	-3.978e-01	2.595e-02	1.691e-01	-4.693e-03	2014	10	02	06	47	52.94	excellent
6.066e-03	-2.231e-01	-9.157e-02	1.941e-01	3.367e-02	-6.184e-04	2014	10	03	06	06	22.76	excellent
-5.772e-02	-1.655e-01	-1.427e-01	1.464e-01	7.811e-02	-1.952e-02	2014	10	03	18	54	53.93	fair
2.004e-01	-1.410e-01	-1.461e-01	1.400e-01	-8.713e-03	7.412e-02	2014	10	01	12	03	16.94	good
5.304e-02	6.783e-02	-1.175e-01	1.615e-01	7.508e-02	2.206e-01	2014	10	05	04	07	20	excellent
-1.777e-01	-1.053e-01	-1.512e-01	7.111e-02	1.063e-01	1.057e-01	2014	10	01	01	03	14.49	excellent
-2.667e-01	1.320e-01	-6.399e-02	6.063e-02	1.031e-01	7.787e-02	2014	09	30	21	30	43.503	excellent

-1.871e-01	8.995e-02	-9.473e-02	-1.446e-01	-2.491e-02	1.992e-01	2014	10	05	23	22	16.499	good
1.684e-01	-3.350e-02	-9.826e-03	2.952e-01	3.542e-02	9.350e-02	2014	10	04	05	29	08.258	fair
2.449e-01	-8.111e-02	-1.972e-01	1.741e-01	1.624e-02	1.507e-02	2014	10	03	15	27	57.661	good
-2.209e-01	-8.132e-02	-2.190e-02	-1.520e-01	3.521e-02	2.201e-01	2014	10	01	16	56	11.343	good
1.477e-01	-1.175e-01	-1.492e-01	1.577e-01	-3.130e-02	9.546e-02	2014	10	01	08	08	57.998	excellent
-3.263e-02	2.220e-01	-3.373e-01	1.644e-02	7.162e-02	9.879e-03	2014	10	01	10	50	55.107	excellent
-1.038e-01	1.463e-01	-2.541e-01	1.246e-01	-1.332e-02	7.335e-02	2014	10	01	15	01	54.950	excellent
2.306e-03	-1.802e-01	-9.214e-02	2.203e-01	-4.354e-03	9.593e-02	2014	10	02	18	54	03.152	good
1.619e-01	4.200e-02	-2.041e-01	2.158e-01	-2.044e-02	7.759e-02	2014	10	02	06	39	02.998	excellent
-6.570e-02	-1.851e-01	-1.140e-01	1.691e-01	4.183e-02	2.826e-02	2014	10	02	12	39	24.317	good
1.420e-01	-1.373e-01	-1.638e-01	1.721e-01	1.076e-02	5.384e-02	2014	10	02	20	37	06.043	good
-1.365e-01	-1.837e-01	-5.911e-02	1.611e-01	-1.124e-02	9.224e-02	2014	10	05	02	06	16.967	excellent
2.866e-01	-3.707e-02	-1.787e-01	9.263e-02	1.263e-01	2.268e-02	2014	10	05	16	07	32.777	excellent
-2.286e-01	1.607e-01	-7.209e-02	-9.281e-02	8.007e-02	-3.216e-02	2014	10	05	15	55	21.007	good
-1.352e-01	-1.174e-01	-4.098e-02	1.996e-01	-5.345e-02	8.302e-02	2014	10	12	10	12	29	good
-2.211e-01	1.542e-01	4.959e-02	9.042e-02	8.191e-02	7.603e-02	2014	10	12	21	10	23.311	good
-4.882e-01	-1.017e-01	5.620e-02	5.965e-02	-1.844e-03	1.292e-01	2014	10	12	16	37	43.287	excellent
-5.873e-02	-1.252e-01	-2.804e-01	6.116e-02	1.409e-01	6.331e-03	2014	10	13	00	57	06.717	good
2.607e-02	-1.181e-01	-2.888e-01	8.025e-02	1.234e-01	4.154e-02	2014	10	13	04	12	29.126	excellent
-1.162e-01	-1.387e-01	-1.174e-01	1.514e-01	5.536e-02	7.558e-02	2014	10	13	10	22	29.084	excellent
-1.128e-01	-2.729e-02	-2.406e-01	5.661e-02	5.175e-02	3.753e-01	2014	10	14	05	46	13.914	exellent

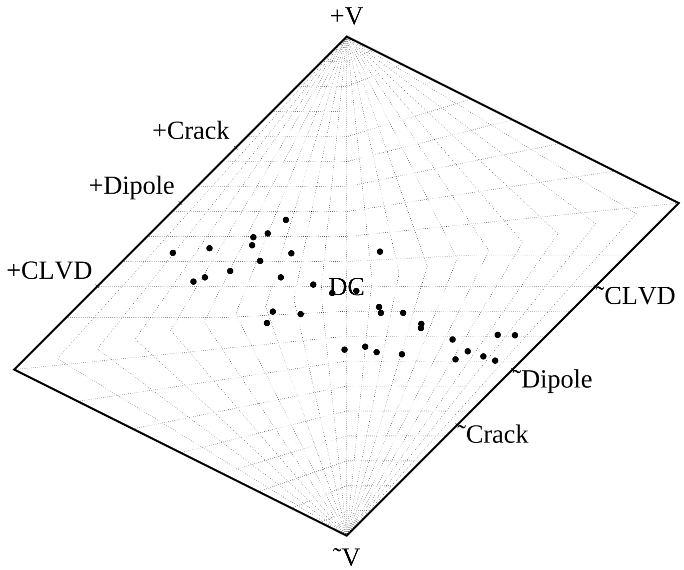


Figure 13: Source-type plot showing the earthquakes for which moment tensors have been derived to date.

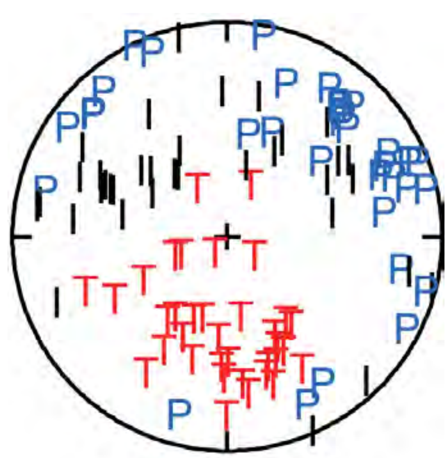


Figure 14: Plot of pressure (P ~ σ_1) and tension (T ~ σ_3) and intermediate (I ~ σ_2) axes for the 34 earthquakes for which moment tensors have been derived to date.

6 Brief summary statement

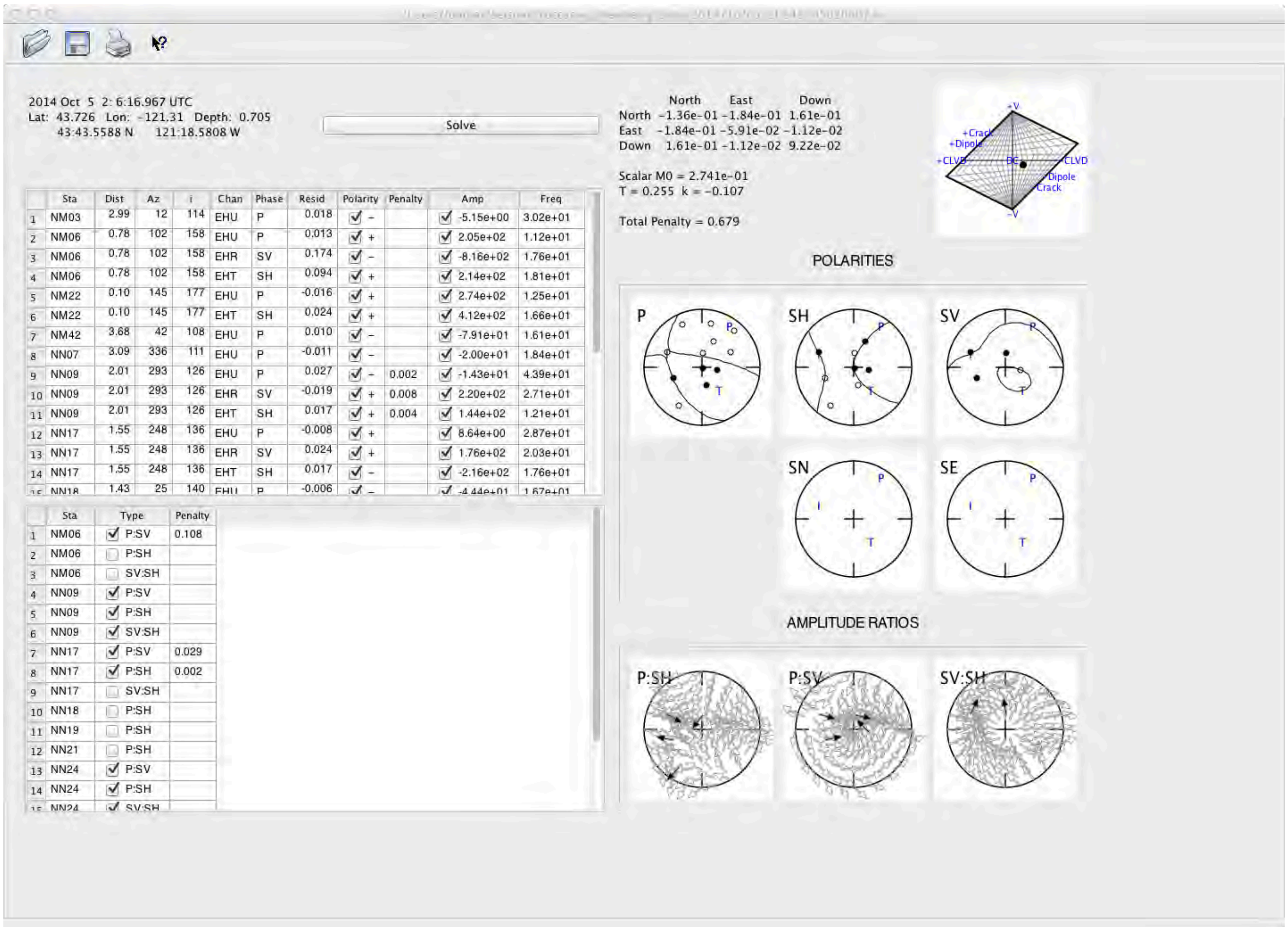
Difficulties with transferring the full data from the ISTI system to our computers have settled down. A few channels are still missing or mis-timed, but these problems are minor and not significantly impacting the quality of the results we are able to produce.

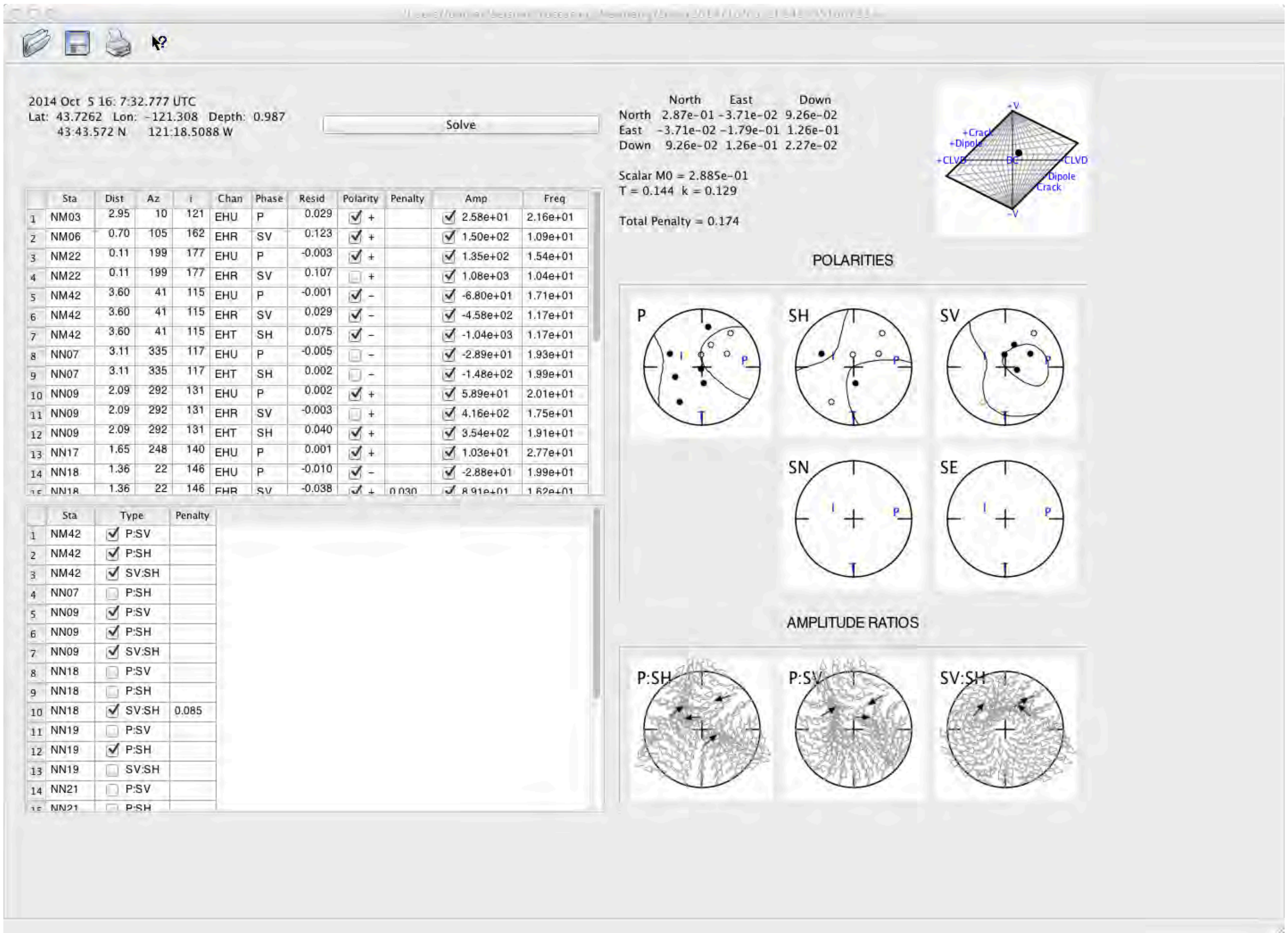
We have completed relative relocations for the earthquakes up to 19 October with good results. The earthquakes clearly define a N 45˚ W striking fault, dipping at ~ 87˚ to the NE and activated in two depth intervals. One depth interval is the lowest ~ 250 m of the borehole and the other is ~ 200 m below the bottom of the borehole. The along-strike length of the activated fault is ~ 250 m.

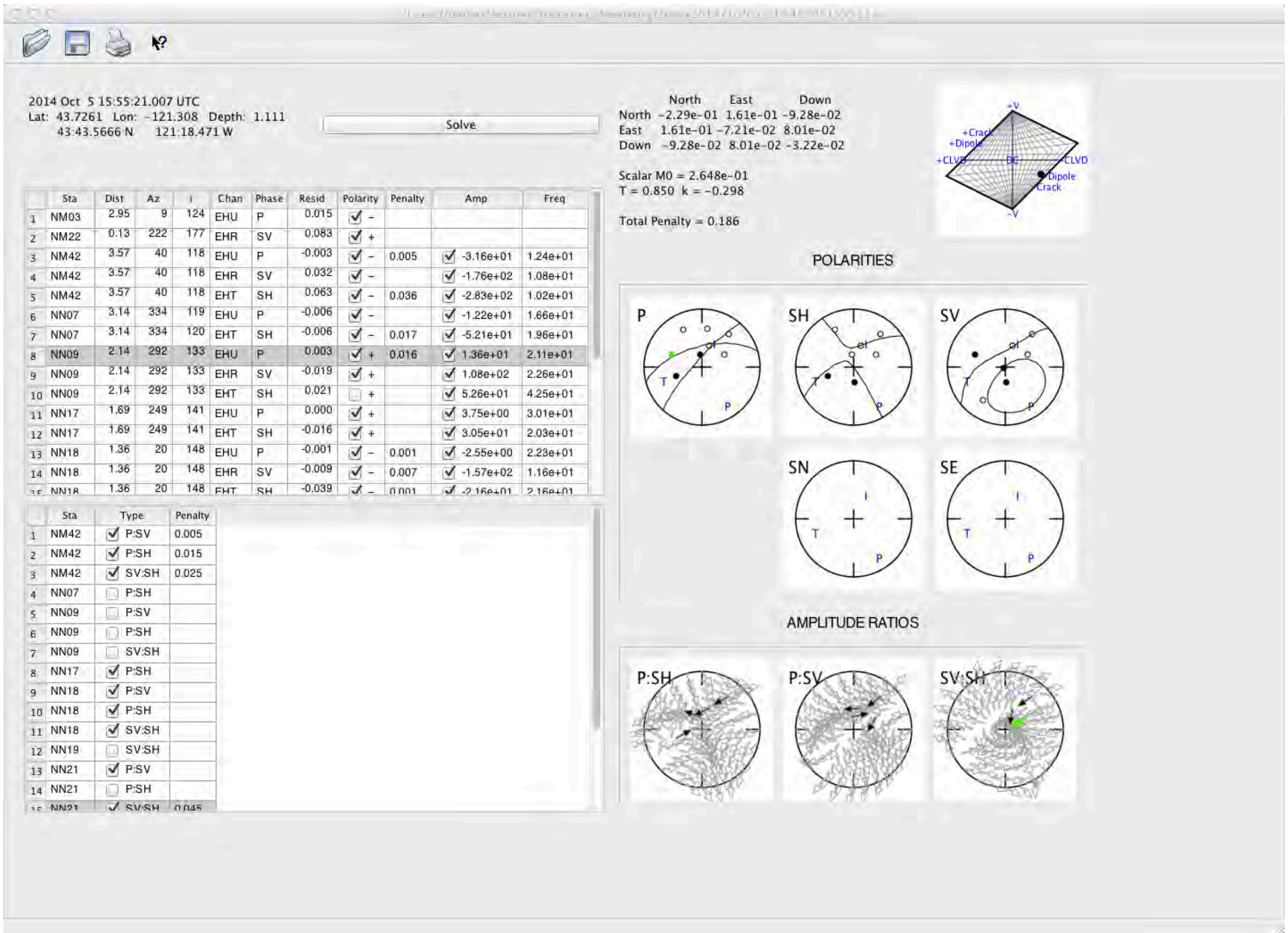
During the forthcoming week we will update these results with earthquakes that occurred after 19 October, and we will also relatively locate the largest earthquakes using the high-quality arrival time measurements made for moment tensor calculations.

We derived an additional 10 moment tensors, bringing the currently available set to 34. The pattern of source types observed earlier remains constant with the addition of more results. The source types range from +Dipole to -Dipole with approximately equal numbers of earthquakes showing crack-opening and crack-closure. The T-axes, which gives an indication of the direction of σ_3, cluster sub-horizontally S±20˚ or so. The P- and I-axes are more scattered.

Appendix 1: The additional nine moment tensors derived over the reporting week.

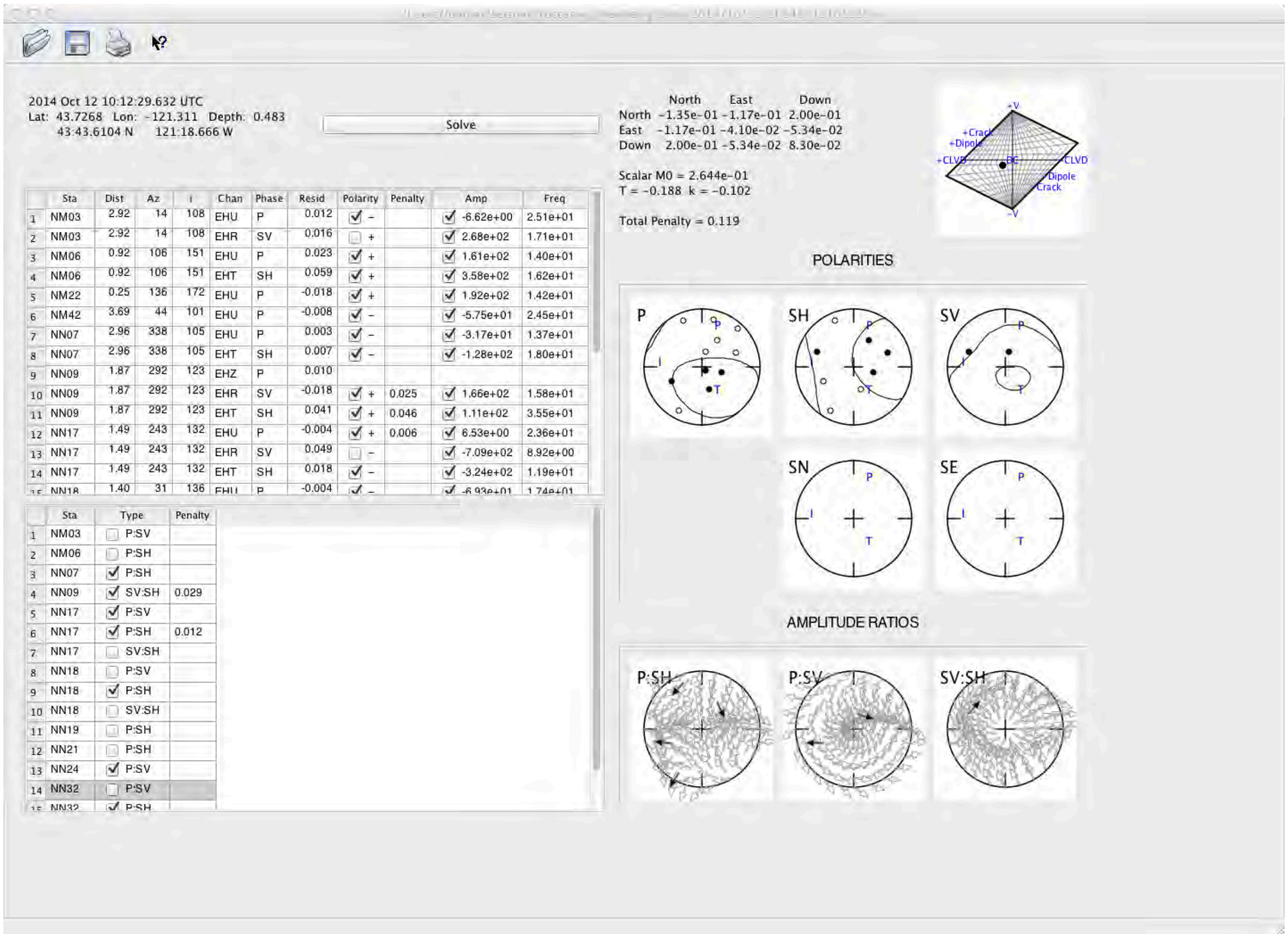


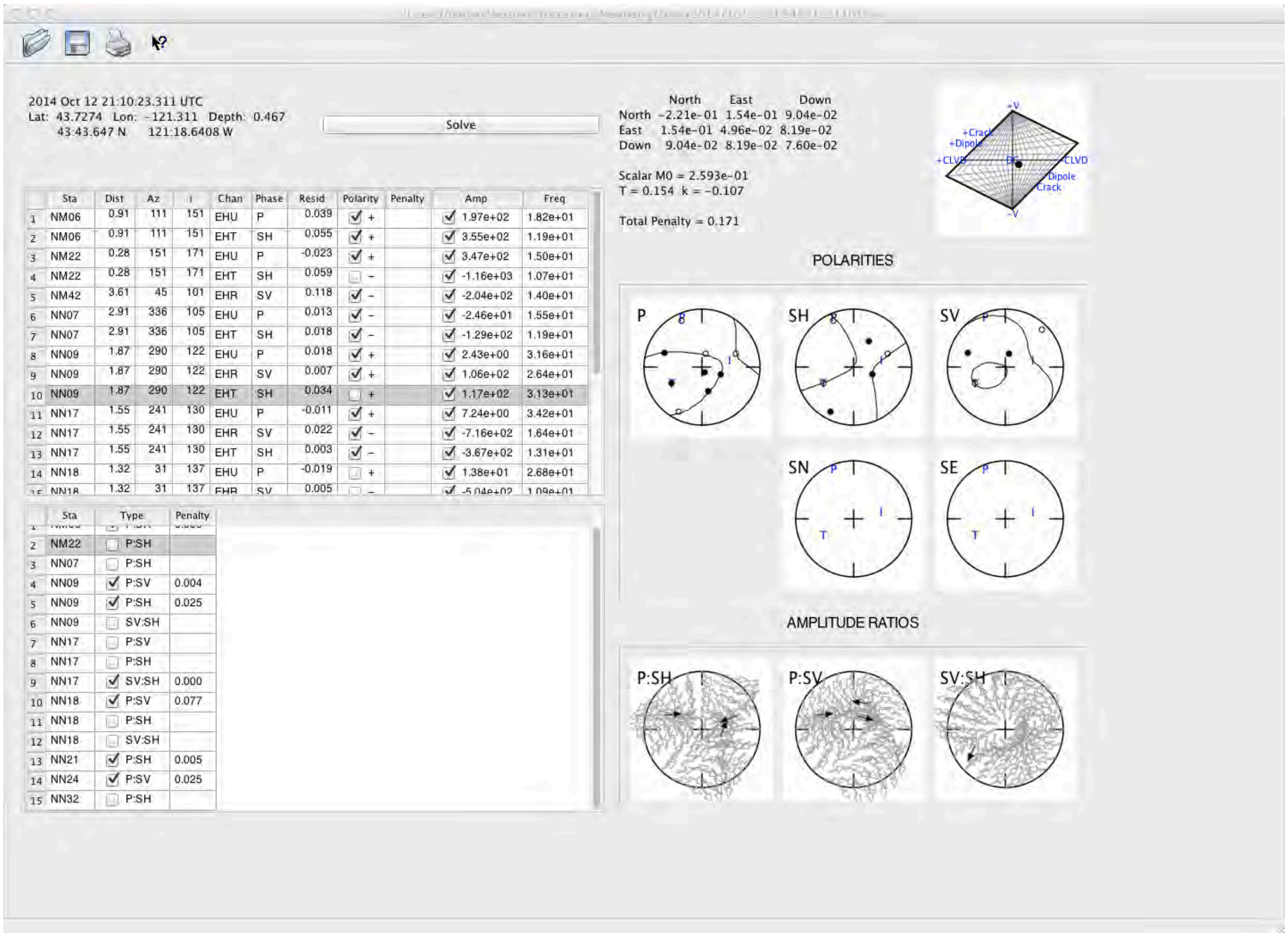

2014 Oct 5 16: 7:32.777 UTC
Lat: 43.7262 Lon: -121.308 Depth: 0.987
43:43.572 N 121:18.5088 W
Solve
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM03 2.95 10 121 EHU P 0.029 + 2.58e+01 2.16e+01
2 NM06 0.70 105 162 EHR SV 0.123 + 1.50e+02 1.09e+01
3 NM22 0.11 199 177 EHU P -0.003 + 1.35e+02 1.54e+01
4 NM22 0.11 199 177 EHR SV 0.107 + 1.08e+03 1.04e+01
5 NM42 3.60 41 115 EHU P -0.001 - -6.80e+01 1.71e+01
6 NM42 3.60 41 115 EHR SV 0.029 - -4.58e+02 1.17e+01
7 NM42 3.60 41 115 EHT SH 0.075 - -1.04e+03 1.17e+01
8 NN07 3.11 335 117 EHU P -0.005 - -2.89e+01 1.93e+01
9 NN07 3.11 335 117 EHT SH 0.002 - -1.48e+02 1.99e+01
10 NN09 2.09 292 131 EHU P 0.002 + 5.89e+01 2.01e+01
11 NN09 2.09 292 131 EHR SV -0.003 + 4.16e+02 1.75e+01
12 NN09 2.09 292 131 EHT SH 0.040 + 3.54e+02 1.91e+01
13 NN17 1.65 248 140 EHU P 0.001 + 1.03e+01 2.77e+01
14 NN18 1.36 22 146 EHU P -0.010 - -2.88e+01 1.99e+01
15 NN18 1.36 22 146 EHR SV -0.038 + 0.030 8.91e+01 1.62e+01
Sta Type Penalty
1 NM42 P:SV
2 NM42 P:SH
3 NM42 SV:SH
4 NN07 P:SH
5 NN09 P:SV
6 NN09 P:SH
7 NN09 SV:SH
8 NN18 P:SV
9 NN18 P:SH
10 NN18 SV:SH 0.085
11 NN19 P:SV
12 NN19 P:SH
13 NN19 SV:SH
14 NN21 P:SV
15 NN21 P:SH
North East Down
North 2.87e-01 -3.71e-02 9.26e-02
East -3.71e-02 -1.79e-01 1.26e-01
Down 9.26e-02 1.26e-01 2.27e-02
Scalar M0 = 2.885e-01
T = 0.144 k = 0.129
Total Penalty = 0.174
+V
+Crack
+Dipole
+CLVD
DC
-CLVD
-Dipole
-Crack
-V
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH

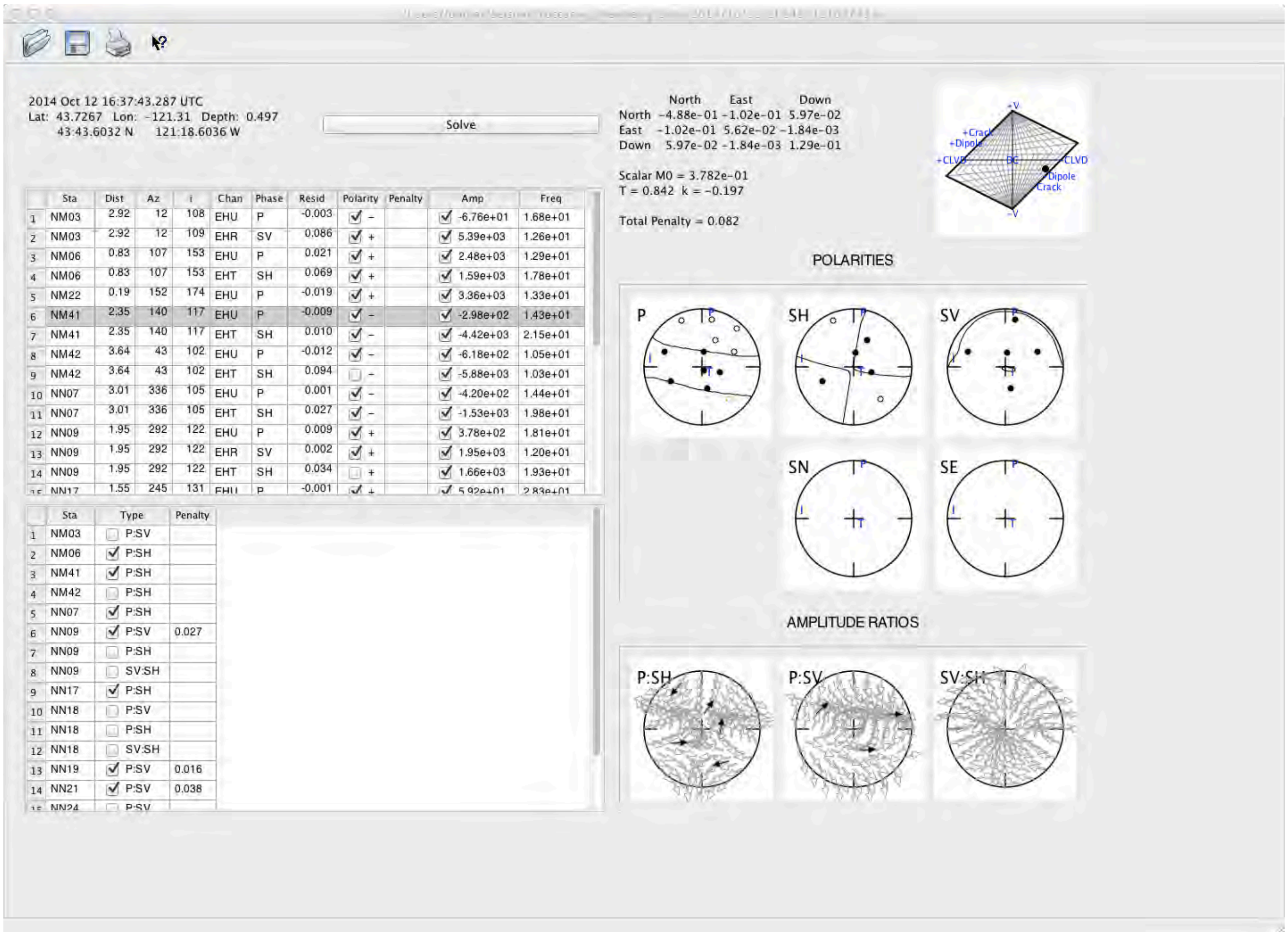

2014 Oct 5 15:55:21.007 UTC
Lat: 43.7261 Lon: -121.308 Depth: 1.111
43:43.5666 N 121:18.471 W
Solve
	Sta	Dist	Az	i	Chan	Phase	Resid	Polarity	Penalty	Amp	Freq
1	NM03	2.95	9	124	EHU	P	0.015	–			
2	NM22	0.13	222	177	EHR	SV	0.083	+			
3	NM42	3.57	40	118	EHU	P	-0.003	–	0.005	-3.16e+01	1.24e+01
4	NM42	3.57	40	118	EHR	SV	0.032	–		-1.76e+02	1.08e+01
5	NM42	3.57	40	118	EHT	SH	0.063	–	0.036	-2.83e+02	1.02e+01
6	NN07	3.14	334	119	EHU	P	-0.006	–		-1.22e+01	1.66e+01
7	NN07	3.14	334	120	EHT	SH	-0.006	–	0.017	-5.21e+01	1.96e+01
8	NN09	2.14	292	133	EHU	P	0.003	+	0.016	1.36e+01	2.11e+01
9	NN09	2.14	292	133	EHR	SV	-0.019	+		1.08e+02	2.26e+01
10	NN09	2.14	292	133	EHT	SH	0.021	+		5.26e+01	4.25e+01
11	NN17	1.69	249	141	EHU	P	0.000	+		3.75e+00	3.01e+01
12	NN17	1.69	249	141	EHT	SH	-0.016	+		3.05e+01	2.03e+01
13	NN18	1.36	20	148	EHU	P	-0.001	–	0.001	-2.55e+00	2.23e+01
14	NN18	1.36	20	148	EHR	SV	-0.009	–	0.007	-1.57e+02	1.16e+01
15	NN18	1.36	20	148	EHT	SH	-0.039	–	0.001	-2.16e+01	2.16e+01

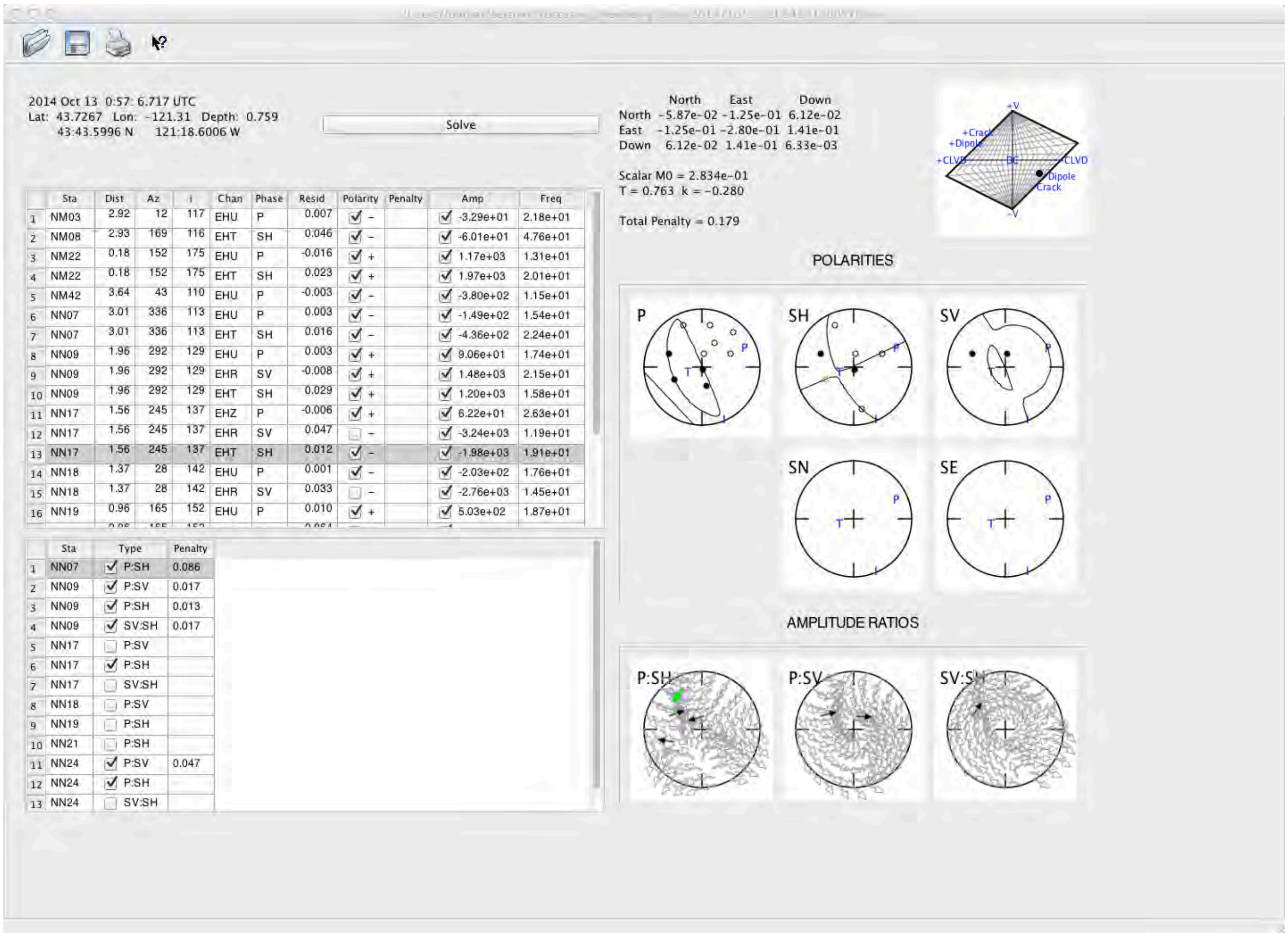
	Sta	Type	Penalty
1	NM42	P:SV	0.005
2	NM42	P:SH	0.015
3	NM42	SV:SH	0.025
4	NN07	P:SH	
5	NN09	P:SV	
6	NN09	P:SH	
7	NN09	SV:SH	
8	NN17	P:SH	
9	NN18	P:SV	
10	NN18	P:SH	
11	NN18	SV:SH	
12	NN19	SV:SH	
13	NN21	P:SV	
14	NN21	P:SH	
15	NN21	SV:SH	0.045

North East Down
North -2.29e-01 1.61e-01 -9.28e-02
East 1.61e-01 -7.21e-02 8.01e-02
Down -9.28e-02 8.01e-02 -3.22e-02
Scalar M0 = 2.648e-01
T = 0.850 k = -0.298
Total Penalty = 0.186
+V
+Crack
+Dipole
+CLVD
DC
-CLVD
-Dipole
-Crack
-V
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH

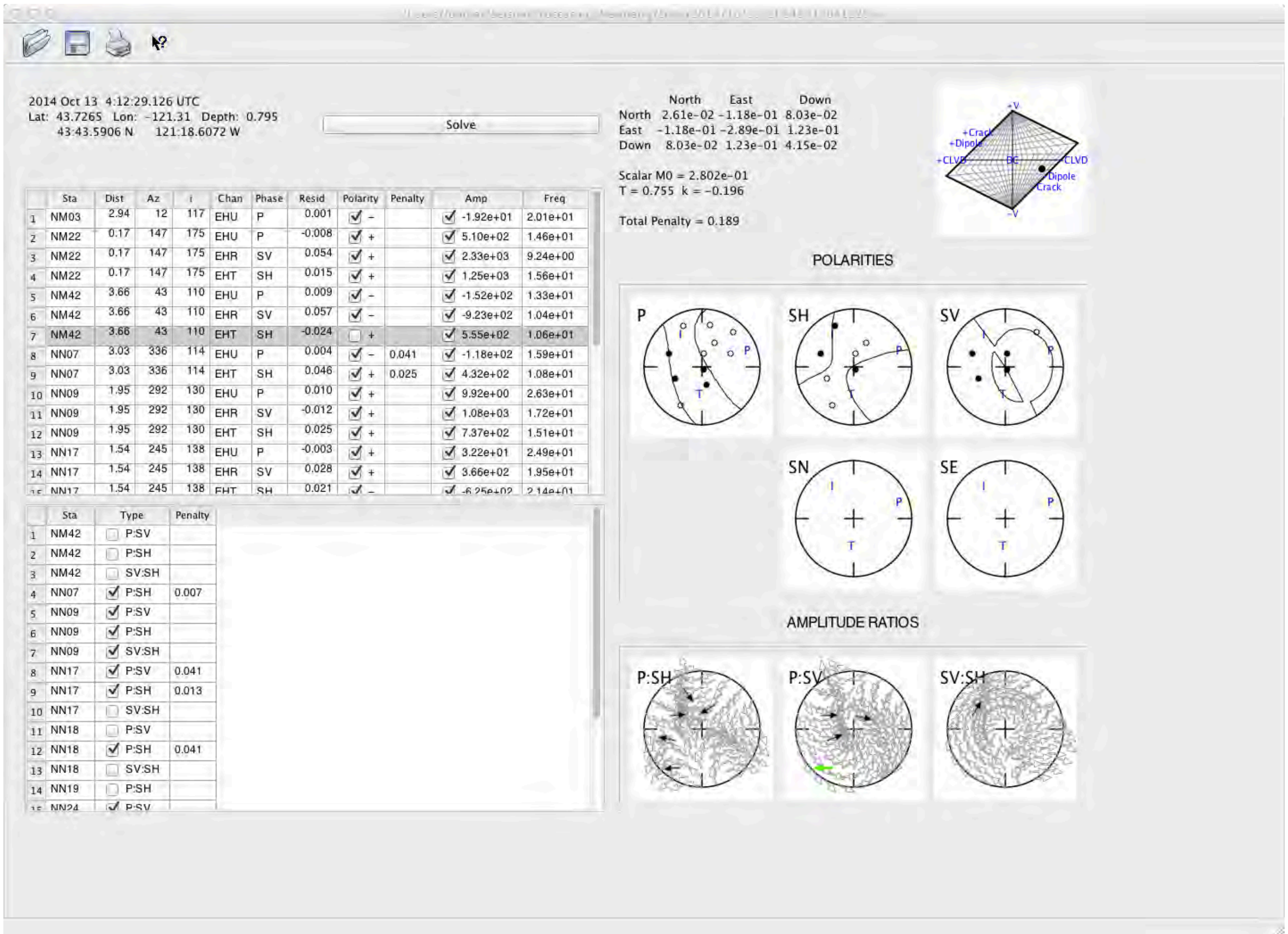

2014 Oct 12 10:12:29.632 UTC
Lat: 43.7268 Lon: -121.311 Depth: 0.483
43:43.6104 N 121:18.666 W
Solve
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM03 2.92 14 108 EHU P 0.012 – -6.62e+00 2.51e+01
2 NM03 2.92 14 108 EHR SV 0.016 + 2.68e+02 1.71e+01
3 NM06 0.92 106 151 EHU P 0.023 + 1.61e+02 1.40e+01
4 NM06 0.92 106 151 EHT SH 0.059 + 3.58e+02 1.62e+01
5 NM22 0.25 136 172 EHU P -0.018 + 1.92e+02 1.42e+01
6 NM42 3.69 44 101 EHU P -0.008 – -5.75e+01 2.45e+01
7 NN07 2.96 338 105 EHU P 0.003 – -3.17e+01 1.37e+01
8 NN07 2.96 338 105 EHT SH 0.007 – -1.28e+02 1.80e+01
9 NN09 1.87 292 123 EHZ P 0.010
10 NN09 1.87 292 123 EHR SV -0.018 + 0.025 1.66e+02 1.58e+01
11 NN09 1.87 292 123 EHT SH 0.041 + 0.046 1.11e+02 3.55e+01
12 NN17 1.49 243 132 EHU P -0.004 + 0.006 6.53e+00 2.36e+01
13 NN17 1.49 243 132 EHR SV 0.049 – -7.09e+02 8.92e+00
14 NN17 1.49 243 132 EHT SH 0.018 – -3.24e+02 1.19e+01
15 NN18 1.40 31 136 EHU P -0.004 – -6.93e+01 1.74e+01
Sta Type Penalty
1 NM03 P:SV
2 NM06 P:SH
3 NN07 P:SH
4 NN09 SV:SH 0.029
5 NN17 P:SV
6 NN17 P:SH 0.012
7 NN17 SV:SH
8 NN18 P:SV
9 NN18 P:SH
10 NN18 SV:SH
11 NN19 P:SH
12 NN21 P:SH
13 NN24 P:SV
14 NN32 P:SV
15 NN32 P:SH
North East Down
North -1.35e-01 -1.17e-01 2.00e-01
East -1.17e-01 -4.10e-02 -5.34e-02
Down 2.00e-01 -5.34e-02 8.30e-02
Scalar M0 = 2.644e-01
T = -0.188 k = -0.102
Total Penalty = 0.119
+V
+Crack
+Dipole
+CLVD
DC
-CLVD
-Dipole
-Crack
-V
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH

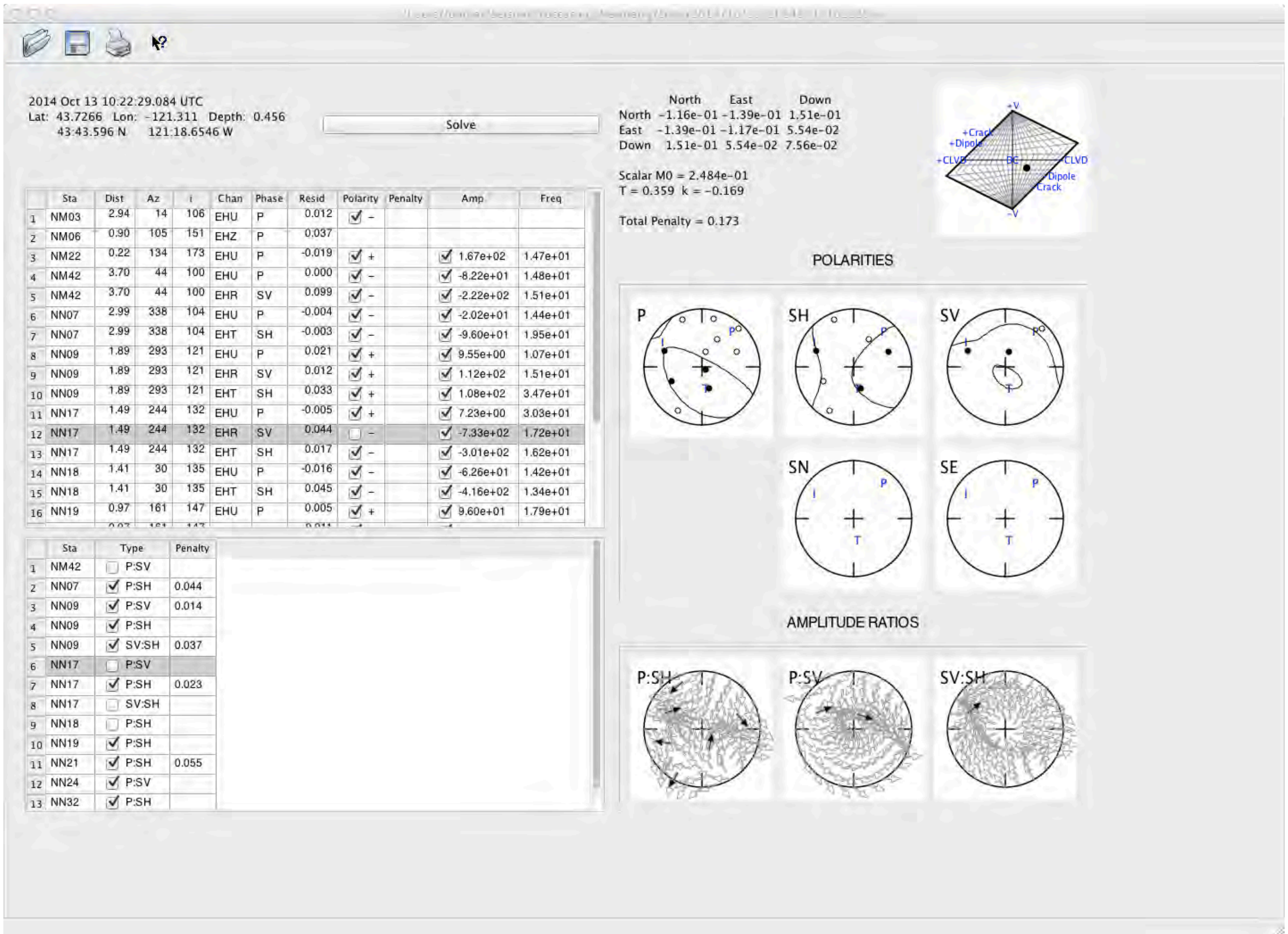

2014 Oct 12 21:10:23.311 UTC
Lat: 43.7274 Lon: -121.311 Depth: 0.467
43:43.647 N 121:18.6408 W
Solve
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM06 0.91 111 151 EHU P 0.039 + 1.97e+02 1.82e+01
2 NM06 0.91 111 151 EHT SH 0.055 + 3.55e+02 1.19e+01
3 NM22 0.28 151 171 EHU P -0.023 + 3.47e+02 1.50e+01
4 NM22 0.28 151 171 EHT SH 0.059 – -1.16e+03 1.07e+01
5 NM42 3.61 45 101 EHR SV 0.118 – -2.04e+02 1.40e+01
6 NN07 2.91 336 105 EHU P 0.013 – -2.46e+01 1.55e+01
7 NN07 2.91 336 105 EHT SH 0.018 – -1.29e+02 1.19e+01
8 NN09 1.87 290 122 EHU P 0.018 + 2.43e+00 3.16e+01
9 NN09 1.87 290 122 EHR SV 0.007 + 1.06e+02 2.64e+01
10 NN09 1.87 290 122 EHT SH 0.034 + 1.17e+02 3.13e+01
11 NN17 1.55 241 130 EHU P -0.011 + 7.24e+00 3.42e+01
12 NN17 1.55 241 130 EHR SV 0.022 – -7.16e+02 1.64e+01
13 NN17 1.55 241 130 EHT SH 0.003 – -3.67e+02 1.31e+01
14 NN18 1.32 31 137 EHU P -0.019 + 1.38e+01 2.68e+01
Sta Type Penalty
2 NM22 P:SH
3 NN07 P:SH
4 NN09 P:SV 0.004
5 NN09 P:SH 0.025
6 NN09 SV:SH
7 NN17 P:SV
8 NN17 P:SH
9 NN17 SV:SH 0.000
10 NN18 P:SV 0.077
11 NN18 P:SH
12 NN18 SV:SH
13 NN21 P:SH 0.005
14 NN24 P:SV 0.025
15 NN32 P:SH
North East Down
North -2.21e-01 1.54e-01 9.04e-02
East 1.54e-01 4.96e-02 8.19e-02
Down 9.04e-02 8.19e-02 7.60e-02
Scalar M0 = 2.593e-01
T = 0.154 k = -0.107
Total Penalty = 0.171
+V
+Crack
+Dipole
+CLVD
-CLVD
-Dipole
-Crack
-V
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH

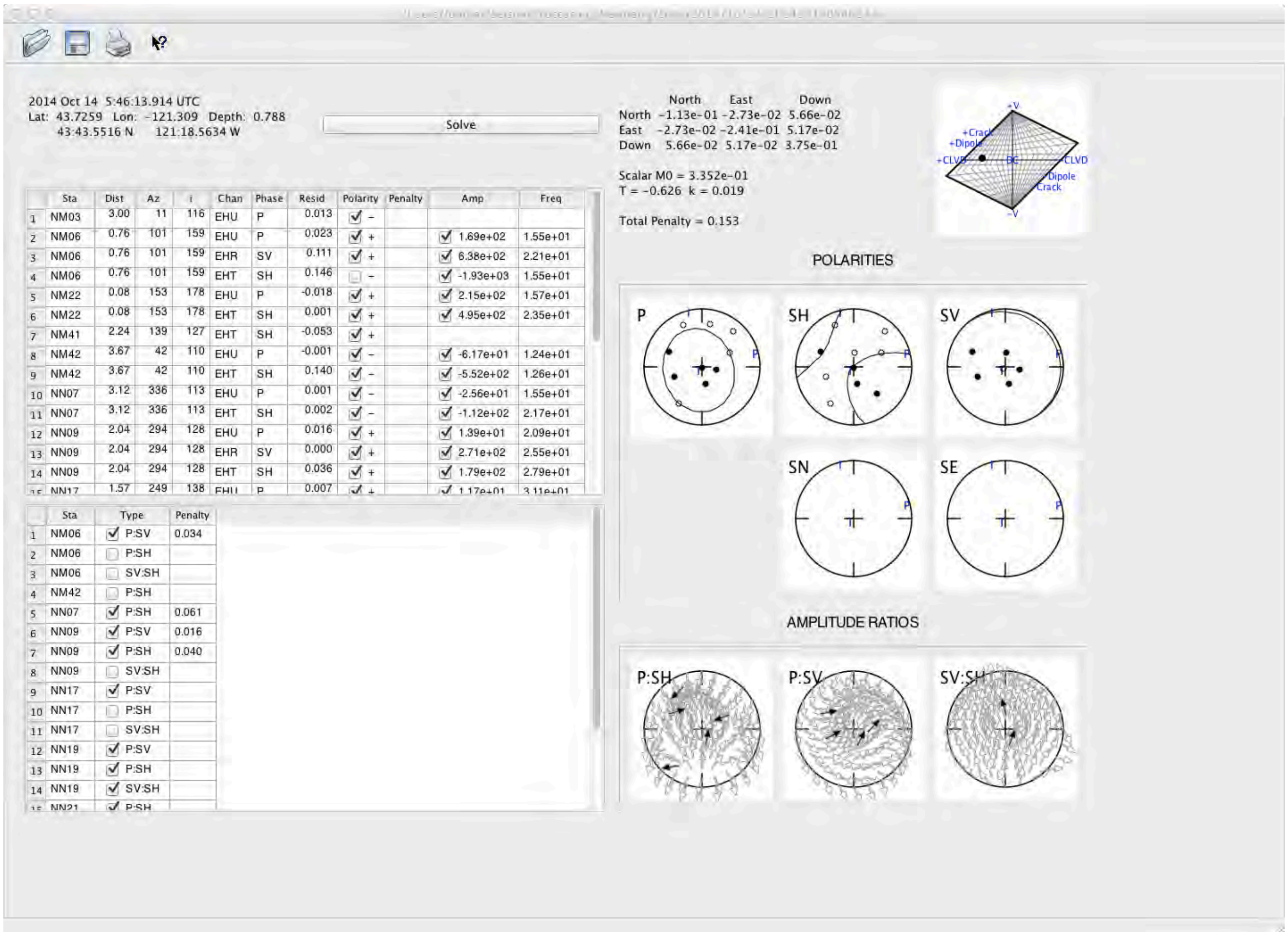

2014 Oct 12 16:37:43.287 UTC
Lat: 43.7267 Lon: -121.31 Depth: 0.497
43:43.6032 N 121:18.6036 W
Solve
North East Down
North -4.88e-01 -1.02e-01 5.97e-02
East -1.02e-01 5.62e-02 -1.84e-03
Down 5.97e-02 -1.84e-03 1.29e-01
Scalar M0 = 3.782e-01
T = 0.842 k = -0.197
Total Penalty = 0.082
+V
+Crack
+Dipole
+CLVD
DC
-CLVD
-Dipole
-Crack
-V
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM03 2.92 12 108 EHU P -0.003 – -6.76e+01 1.68e+01
2 NM03 2.92 12 109 EHR SV 0.086 + 5.39e+03 1.26e+01
3 NM06 0.83 107 153 EHU P 0.021 + 2.48e+03 1.29e+01
4 NM06 0.83 107 153 EHT SH 0.069 + 1.59e+03 1.78e+01
5 NM22 0.19 152 174 EHU P -0.019 + 3.36e+03 1.33e+01
6 NM41 2.35 140 117 EHU P -0.009 – -2.98e+02 1.43e+01
7 NM41 2.35 140 117 EHT SH 0.010 – -4.42e+03 2.15e+01
8 NM42 3.64 43 102 EHU P -0.012 – -6.18e+02 1.05e+01
9 NM42 3.64 43 102 EHT SH 0.094 – -5.88e+03 1.03e+01
10 NN07 3.01 336 105 EHU P 0.001 – -4.20e+02 1.44e+01
11 NN07 3.01 336 105 EHT SH 0.027 – -1.53e+03 1.98e+01
12 NN09 1.95 292 122 EHU P 0.009 + 3.78e+02 1.81e+01
13 NN09 1.95 292 122 EHR SV 0.002 + 1.95e+03 1.20e+01
14 NN09 1.95 292 122 EHT SH 0.034 + 1.66e+03 1.93e+01
Sta Type Penalty
1 NM03 P:SV
2 NM06 P:SH
3 NM41 P:SH
4 NM42 P:SH
5 NN07 P:SH
6 NN09 P:SV 0.027
7 NN09 P:SH
8 NN09 SV:SH
9 NN17 P:SH
10 NN18 P:SV
11 NN18 P:SH
12 NN18 SV:SH
13 NN19 P:SV 0.016
14 NN21 P:SV 0.038
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH



Solve
2014 Oct 13 0:57: 6.717 UTC
Lat: 43.7267 Lon: -121.31 Depth: 0.759
43:43.5996 N 121:18.6006 W
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM03 2.92 12 117 EHU P 0.007 – -3.29e+01 2.18e+01
2 NM08 2.93 169 116 EHT SH 0.046 – -6.01e+01 4.76e+01
3 NM22 0.18 152 175 EHU P -0.016 + 1.17e+03 1.31e+01
4 NM22 0.18 152 175 EHT SH 0.023 + 1.97e+03 2.01e+01
5 NM42 3.64 43 110 EHU P -0.003 – -3.80e+02 1.15e+01
6 NN07 3.01 336 113 EHU P 0.003 – -1.49e+02 1.54e+01
7 NN07 3.01 336 113 EHT SH 0.016 – -4.36e+02 2.24e+01
8 NN09 1.96 292 129 EHU P 0.003 + 9.06e+01 1.74e+01
9 NN09 1.96 292 129 EHR SV -0.008 + 1.48e+03 2.15e+01
10 NN09 1.96 292 129 EHT SH 0.029 + 1.20e+03 1.58e+01
11 NN17 1.56 245 137 EHZ P -0.006 + 6.22e+01 2.63e+01
12 NN17 1.56 245 137 EHR SV 0.047 – -3.24e+03 1.19e+01
13 NN17 1.56 245 137 EHT SH 0.012 – -1.98e+03 1.91e+01
14 NN18 1.37 28 142 EHU P 0.001 – -2.03e+02 1.76e+01
15 NN18 1.37 28 142 EHR SV 0.033 – -2.76e+03 1.45e+01
16 NN19 0.96 165 152 EHU P 0.010 + 5.03e+02 1.87e+01
Sta Type Penalty
1 NN07 P:SH 0.086
2 NN09 P:SV 0.017
3 NN09 P:SH 0.013
4 NN09 SV:SH 0.017
5 NN17 P:SV
6 NN17 P:SH
7 NN17 SV:SH
8 NN18 P:SV
9 NN19 P:SH
10 NN21 P:SH
11 NN24 P:SV 0.047
12 NN24 P:SH
13 NN24 SV:SH
North East Down
North -5.87e-02 -1.25e-01 6.12e-02
East -1.25e-01 -2.80e-01 1.41e-01
Down 6.12e-02 1.41e-01 6.33e-03
Scalar M0 = 2.834e-01
T = 0.763 k = -0.280
Total Penalty = 0.179
+V
+Crack
+Dipole
+CLVD
DC
-CLVD
-Dipole
-Crack
-V
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH


2014 Oct 13 4:12:29.126 UTC
Lat: 43.7265 Lon: -121.31 Depth: 0.795
43:43.5906 N 121:18.6072 W
Solve
North East Down
North 2.61e-02 -1.18e-01 8.03e-02
East -1.18e-01 -2.89e-01 1.23e-01
Down 8.03e-02 1.23e-01 4.15e-02
Scalar M0 = 2.802e-01
T = 0.755 k = -0.196
Total Penalty = 0.189
+V
+Crack
+Dipole
+CLVD
DC
CLVD
Dipole
Crack
-V
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM03 2.94 12 117 EHU P 0.001 – -1.92e+01 2.01e+01
2 NM22 0.17 147 175 EHU P -0.008 + 5.10e+02 1.46e+01
3 NM22 0.17 147 175 EHR SV 0.054 + 2.33e+03 9.24e+00
4 NM22 0.17 147 175 EHT SH 0.015 + 1.25e+03 1.56e+01
5 NM42 3.66 43 110 EHU P 0.009 – -1.52e+02 1.33e+01
6 NM42 3.66 43 110 EHR SV 0.057 – -9.23e+02 1.04e+01
7 NM42 3.66 43 110 EHT SH -0.024 + 5.55e+02 1.06e+01
8 NN07 3.03 336 114 EHU P 0.004 – 0.041 -1.18e+02 1.59e+01
9 NN07 3.03 336 114 EHT SH 0.046 + 0.025 4.32e+02 1.08e+01
10 NN09 1.95 292 130 EHU P 0.010 + 9.92e+00 2.63e+01
11 NN09 1.95 292 130 EHR SV -0.012 + 1.08e+03 1.72e+01
12 NN09 1.95 292 130 EHT SH 0.025 + 7.37e+02 1.51e+01
13 NN17 1.54 245 138 EHU P -0.003 + 3.22e+01 2.49e+01
14 NN17 1.54 245 138 EHR SV 0.028 + 3.66e+02 1.95e+01
15 NN17 1.54 245 138 EHT SH 0.021 – -6.25e+02 2.14e+01
Sta Type Penalty
1 NM42 P:SV
2 NM42 P:SH
3 NM42 SV:SH
4 NN07 P:SH 0.007
5 NN09 P:SV
6 NN09 P:SH
7 NN09 SV:SH
8 NN17 P:SV 0.041
9 NN17 P:SH 0.013
10 NN17 SV:SH
11 NN18 P:SV
12 NN18 P:SH 0.041
13 NN18 SV:SH
14 NN19 P:SH
15 NN24 P:SV
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH


2014 Oct 13 10:22:29.084 UTC
Lat: 43.7266 Lon: -121.311 Depth: 0.456
43:43.596 N 121:18.6546 W
Solve
North East Down
North -1.16e-01 -1.39e-01 1.51e-01
East -1.39e-01 -1.17e-01 5.54e-02
Down 1.51e-01 5.54e-02 7.56e-02
Scalar M0 = 2.484e-01
T = 0.359 k = -0.169
Total Penalty = 0.173
POLARITIES
AMPLITUDE RATIOS
P
SH
SV
SN
SE
P:SH
P:SV
SV:SH



2014 Oct 14 5:46:13.914 UTC
Lat: 43.7259 Lon: -121.309 Depth: 0.788
43:43.5516 N 121:18.5634 W
Solve
North East Down
North -1.13e-01 -2.73e-02 5.66e-02
East -2.73e-02 -2.41e-01 5.17e-02
Down 5.66e-02 5.17e-02 3.75e-01
Scalar M0 = 3.352e-01
T = -0.626 k = 0.019
Total Penalty = 0.153
+V
+Crack
+Dipole
+CLVD
DC
-CLVD
-Dipole
-Crack
-V
Sta Dist Az i Chan Phase Resid Polarity Penalty Amp Freq
1 NM03 3.00 11 116 EHU P 0.013 –
2 NM06 0.76 101 159 EHU P 0.023 + 1.69e+02 1.55e+01
3 NM06 0.76 101 159 EHR SV 0.111 + 6.38e+02 2.21e+01
4 NM06 0.76 101 159 EHT SH 0.146 – -1.93e+03 1.55e+01
5 NM22 0.08 153 178 EHU P -0.018 + 2.15e+02 1.57e+01
6 NM22 0.08 153 178 EHT SH 0.001 + 4.95e+02 2.35e+01
7 NM41 2.24 139 127 EHT SH -0.053 +
8 NM42 3.67 42 110 EHU P -0.001 – -6.17e+01 1.24e+01
9 NM42 3.67 42 110 EHT SH 0.140 – -5.52e+02 1.26e+01
10 NN07 3.12 336 113 EHU P 0.001 – -2.56e+01 1.55e+01
11 NN07 3.12 336 113 EHT SH 0.002 – -1.12e+02 2.17e+01
12 NN09 2.04 294 128 EHU P 0.016 + 1.39e+01 2.09e+01
13 NN09 2.04 294 128 EHR SV 0.000 + 2.71e+02 2.55e+01
14 NN09 2.04 294 128 EHT SH 0.036 + 1.79e+02 2.79e+01
15 NN17 1.57 249 138 EHU P 0.007 + 1.17e+01 3.11e+01
Sta Type Penalty
1 NM06 P:SV 0.034
2 NM06 P:SH
3 NM06 SV:SH
4 NM42 P:SH
5 NN07 P:SH 0.061
6 NN09 P:SV 0.016
7 NN09 P:SH 0.040
8 NN09 SV:SH
9 NN17 P:SV
10 NN17 P:SH
11 NN17 SV:SH
12 NN19 P:SV
13 NN19 P:SH
14 NN19 SV:SH
15 NN21 P:SH
POLARITIES
P
SH
SV
SN
SE
AMPLITUDE RATIOS
P:SH
P:SV
SV:SH

Appendix F
Stress Modeling by Earth Analysis

Preliminary analysis of moment tensor and stress data generated by the Newberry EGS Stimulation, Fall 2014

Consideration of Stress Sources

Richard Styron, Ph.D.

Earth Analysis, Seattle, WA

richard@earth-analysis.com

April 1, 2015

Executive Summary

The earthquakes generated by the fall 2014 stimulations at the Newberry EGS site display moment tensors consistent with horizontal compression over a wide azimuthal range, and relatively weaker vertical stress. Though this strain and apparent stress configuration is internally quite consistent, it is inconsistent with the local and regional strain field suggestive of a vertical σ_1. We (*Earth Analysis*) were asked by *AltaRock Energy Inc.* to investigate the stress field at the Newberry EGS site.

We chose to make first-order, quantitative models of four likely source of stress in the region, to evaluate their contributions to the total stress field and to test whether they can explain the observations from the stimulation seismicity; *1)* Tectonic stress, through a regional stress inversion; *2)* Local topographic stress; *3)* Magmatic stress; and *4)* Subduction zone stress. We find that *1)* Regional tectonic stress has a maximum compressive stress trending at 15° and increases with depth at about 0.15 * $\rho g z$ (i.e. about 3 MPa km^{-1}). The minimum horizontal compressive stress is tensile and has a most likely value near zero, but may be more strongly tensile. *2)* Topographic stresses at the bottom of the injection well have a steeply west-plunging σ_1 of about 12 MPa, and are consistent with normal faulting on steep, north-striking faults. *3)* Magmatic stress, calculated using locations from previous studies and estimated magma production rates since the last eruption (1300 years ago), can feasibly contribute up to 30 MPa of EW compression at the bottom of the well, and other stress components (which may be tensile) in the 10s of MPa. The location and size (or, equivalently, pressure) of any magma chambers are poorly resolved at this point, so changes to these parameters can surely reproduce the stress state inferred from the induced seismicity, though this would not necessarily be independently

validated. *4)* Stresses from the Cascadia subduction zone, modeled as 15 m of slip accumulating below the locked zone of the megathrust, are insignificant at Newberry.

The combined stresses as modeled from comparisions with external data are on the whole inconsistent with the local stress field inferred from the induced seismicity, though it is possible that particular configurations of a magma pressurized magma chamber could increase consistency.

We also analyzed the moment tensors and locations of the induced earthquakes, in order to discern any patterns or correlations that may yield insight into the stress discrepancy. The net moment release from the induced seismicity indicates contraction (volume loss) of the stimulated volume of the crust. There are few apparent correlations with moment tensor properties and time or location. The most elucidating relationship is that near the center of the cloud (the assumed bottom of the well), the P-axes of the events point towards the center, while farther away they do not. This suggests that the fluid injection, with a wellhead pressure of about 20 MPa, is significantly modifying the stress field in addition to simply raising pore fluid pressures. Without additional, careful modeling of this phenomenon, it is not clear whether this could cause the stress field inferred from the seismicity.

Contents

1 Introduction

In contrast to the regional signal of east-west extension via roughly north-striking normal faults and northwest-striking strike-slip faults, focal mechanisms of earthquakes induced by the stimulations at the Newberry EGS site display P, T and N axes indicating broadly northeast-southwest contraction and vertical extension (i.e consistent with reverse faulting along roughly northeast- to northwest-striking faults).

The discrepancy between local and regional deformation could be the result of several factors. First, the induced earthquakes are in a relatively compact cluster (essentially a 1 km^3 volume) in the shallow crust; therefore, they may respond to local stresses due to topography or magmatic sources that are not characteristic of the central Oregon Cascades as a whole. Second, it is possible that in the 'late interseismic' portion of the Cascadia subduction zone earthquake cycle, stresses from elastic strain accumulation are strong enough to temporarily reorient the longer-term regional stress field into one resembling the observations made at Newberry. Finally, it is possible that the stresses produced by the stimulation itself are capable of perturbing the ambient stress field sufficiently to produce the observations. It is also important to note that none of these potential factors are mutually exclusive, and all of them are likely to contribute to the total stress field to some extent.

1.1 Proposed work

In order to understand this discrepancy, we (Richard Styron, *Earth Analysis*) have proposed to calculate the stresses resulting from the potential stress sources above in order to quantitatively address the influence of each, and to test whether any of them is likely to produce the observed deformation. Because of the variety of stress sources and the time constraints of both *AltaRock* and *Earth Analysis*, at this time we have proposed to do fairly preliminary calculations, essentially to test whether any of the stress sources are grossly capable of producing the observations, rather than replicating them exactly by fine-tuning parameters.

In particular, we have proposed to do several sets of calculations:

1. Regional background stress inversion, using topography, faults and earthquake data
2. Calculations of local stress from higher-resolution topography
3. Calculations of stress from locking on the Cascadia subduction zone
4. Calculations of stress from possible magmatic activity under Newberry caldera
5. Analysis of Newberry stimulation seismic data

Additionally, we were to make a small informational packet on magmatic stress calculations. We delivered a packet containing some literature (*Dzurisin, 1999*), an IPython Notebook (an executable document containing pictures, text and functional Python code) covering the theory, mathematics and computation of magmatic stresses, and a .pdf file of the notebook, to Michael Swyer via email.

2 Stress Calculations

2.1 Regional background stress inversion

The regional background stress inversion is based on the premise that the total stress field in the crust determines brittle faulting patterns, and is represented by topographic, tectonic and lithostatic components; other stresses are either too small, localized, or ephemeral to make a considerable difference. The goal is to estimate topographic stresses as they are resolved on faults and then find tectonic stresses that combine with the topographic stresses to produce net shear stress that is, on average, in the direction of fault slip. If there is a variety of fault types, at different orientations, then it is often possible to get good constraints on the tectonic stress field, both in terms of orientation and magnitude.

2.1.1 Methods

There are several steps to this inversion. The first was to calculate regional topographic stresses. Then, a fault and focal mechanism dataset was constructed, and topographic stresses were resolved on the points in that dataset. Finally, the tectonic stresses consistent with observed (or inferred) slip directions on the faults (or at the focal mechanisms locations) is calculated through Bayesian Monte Carlo methods.

These methods have been developed by Richard Styron and Eric Hetland, and details of the theory and implementation are described in *Styron and Hetland (2015)*. Here, we will give a brief overview of the methods as they pertain to this study.

Topographic stress calculation The initial step in the regional stress inversion is to calculate the stresses in the upper and middle crust resulting from regional topography. We follow *Liu and Zoback (1992)* in a method based on convolving topography (in DEM form) with Green's functions representing the stresses in an elastic halfspace produced by point loads on the surface (Figure 1). The convolution has two parts; the first is treating the topography as vertical loads on the surface, and the second is a correction for horizontal loads induced by the topographic slopes. Each of the six independent components of the stress tensor is calculated with this method.

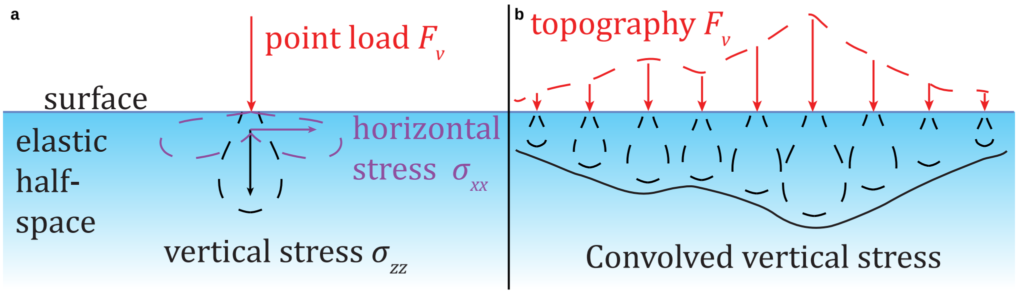


Figure 1: **a**) Schematic of σ_{xx} and σ_{zz} emanating in a halfspace from a single vertical point load at the surface. **b**) Schematic of σ_{zz} throughout the halfspace due to the convolution of topography with the Green's functions illustrated in **a**.

This method enables topographic stresses to be calculated accurately and at high resolution for relatively little computational cost; setting up the computations is also fairly painless, as it mostly involves preparing a DEM and gathering its metadata into a usable form. However, the method does suffer some drawbacks. The biggest, which is worth mentioning, is that it can only calculate topographic stresses within the halfspace itself, not 'within' the topography overlying the halfspace (in actuality, stresses can only be computed within some finite distance below the surface of the halfspace, due to singularities in the Green's functions at $z = 0$; based on testing, we typically start calculations at 1 DEM resolution unit below sea level, e.g. 90 m below sea level for SRTM data). For a regional study, using a fairly coarse DEM, our calculations begin at 700 m below sea level.

For this computation, we calculate the stresses over a wide area, covering much of the Pacific Northwest and adjacent regions (Figure 2). The DEM contains SRTM terrestrial elevation data and bathymetric data from a variety of sources, combined by the Global Multi-Resolution Topography (GMRT) synthesis. The DEM was projected from WGS84 geographic coordinates to a custom Albers projection to minimize distortion in central Oregon.

Stresses were calculated at 700 m horizontal and vertical intervals, from -700 m to -157000 m depth.

Fault and earthquake data processing In order to resolve stresses onto faults and compare the resolved shear stress orientations to the slip rake, we have taken a sample of fault from the USGS Quaternary Fault and Fold (QFault) database, simplified the traces, and projected the traces down dip. Each fault was then discretized into a set of x, y, z points. A total of 44 faults were chosen. The faults were chosen based on size (favoring larger faults), distribution (favoring faults that occur in areas without a lot of similar faults) and epistemic quality (favoring faults that are well known). The faults chosen are shown in Figure 2). Fault dips were either taken from

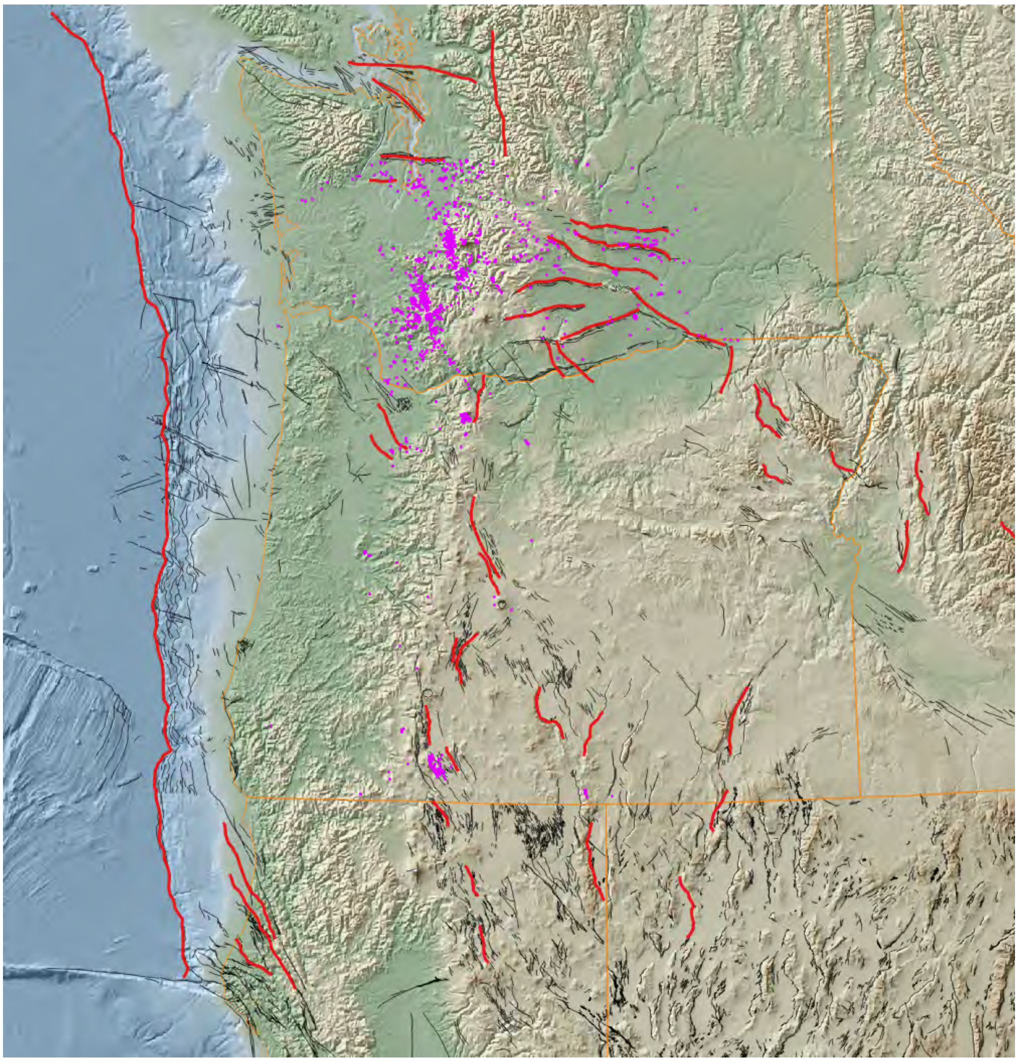


Figure 2: DEM used in the regional topographic inversion, with fault and seismicity data shown as well. Traces for faults used in the regional stress inversion are shown in red. The purple points show locations of earthquakes with focal mechanisms from the PNSN catalog that were used as well. Thin black lines show the USGS Quaternary Fault and Fold database, which was used to select and map important fault in this study.

the QFault database, or assumed based on 'Andersonian' characteristics (i.e. normal faults were given dips of 60°, thrust faults 20°, and strike-slip faults 90°). The faults were also given rakes consistent with 'pure' dip or strike slip rather than oblique slip, even in areas with probable mixed-mode faulting. Though some truly oblique faults exist in the study area, if this was considered likely in the QFaults database for the structures in question, they were not used.

We also wanted to include active seismicity in our inversion, in case the long- term stress field, as indicated by active structures, differs somewhat from the contemporary stress field due to, for example, Cascadian seismic cycle effects. The most comprehensive focal mechanism catalog available was the PNSN catalog, though it does seem relatively sparse in Oregon versus Washington. The catalog with focal mechanisms, does not seem to be publicly available as a compilation, so a shell script was written to download the html pages for each earthquake, parse the file to get the relevant information (strike, dip, rake) and then join that data with the locations and event IDs, which were available. This compilation is available to AltaRock if they would like it.

Bayesian tectonic stress inversion We assume that tectonic stresses are purely horizontal and, for this preliminary regional study, horizontally invariant. We further assume that tectonic stresses increase linearly with depth in the crust, maintaining a critical stress state with depth. This allows us to describe the tectonic stress state with three variables: the magnitudes of the maximum and minimum principal tectonic stresses ($T_{\max}$ and $T_{\min}$) and θ, the azimuth of $T_{\max}$ Unlike the topographic stress calculations, tectonic stresses are 'inverted' for using a Bayesian Monte Carlo scheme (it is a nonlinear, nonunique problem so the result is not a true inversion).

First, priors for $T_{\max}$, $T_{\min}$ and θ were chosen. $p(T_{\max})$ was picked as a uniform distribution from 0–2 $\rho g z$, $p(T_{\min})$ was picked as a uniform distribution from -1–1 $T_{\max}$ ($T_{\min}$ is by definition smaller than $T_{\max}$, so it cannot be independently defined), and $p(\theta)$ was picked as a uniform distribution from 0°–360°. Next, 100,000 samples were drawn from these prior distributions, and transformed into T_{xx}, T_{yy} and T_{xy}. These stresses, still relative to $\rho g z$, are then turned into dimensional stresses in MPa for each point in the fault and earthquake dataset. The complete stress tensor at each point is then calculated by summing the tectonic, topographic and lithostatic contributions to each component of the stress tensor.

Once the total stress tensor has been calculated for each point, the maximum shear stress magnitude and rake is calculated, using the strike and dip of the fault at that point. (For the earthquake dataset, one plane is chosen at random from the two possible points in the focal mechanism.) Then, a misfit between the rake of maximum shear stress and the slip rake is calculated, considering the rake uncertainty, if given (if not, a rake of 20° is used as the standard error). Finally, the average error for each of the 100,000 iterations is calculated, and the posterior probability distributions for $T_{\max}$, $T_{\min}$, and θ is estimated by retaining the prior samples proportionally to their goodness of fit.

2.1.2 Results

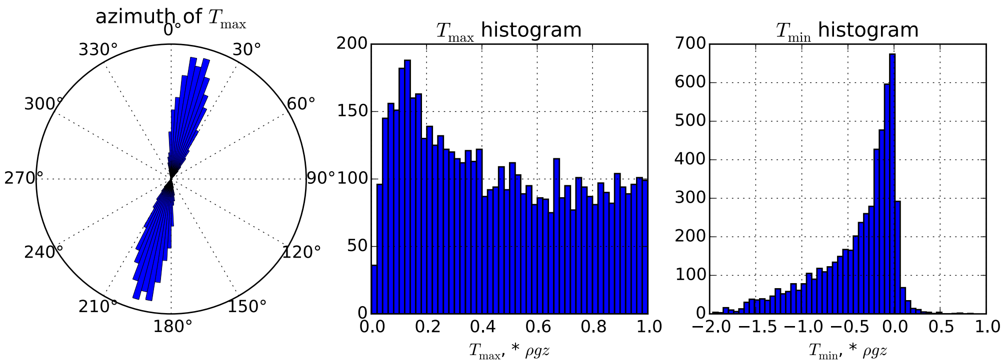


Figure 3: Results of the stress inversion. The counts in the histograms are proportional to the likelihood of those values, i.e. higher counts are more likely values.

T_{max} is very tightly constrained to trend at 15°. The magnitude of T_{max} may be anything from about 0.05-1 $\rho g z$, though the highest likelihood values are in a sharp peak on the histograms from about 0.05–0.2 $\rho g z$. For comparison, these are much lower stresses than we have inferred from other orogens; for example, we have found well-constrained most likely values for T_{max} from 0.5–2 $\rho g z$ in various parts of the Himalayan-Tibetan orogen. Values for T_{min} are also low, with a strong peak in the probabilities at around 0; however, a noticeable tail extending to about -2 $\rho g z$ exists; these negative values indicate that there is a reasonable chance of significant tectonic tension, trending WNW-ESE.

The relative weakness of the tectonic stress in the area indicates that stresses from topography may be responsible for driving much of the deformation.This seems consistent with the low strain rates in the region as well, although one must be careful mapping stress magnitudes to strain rates.

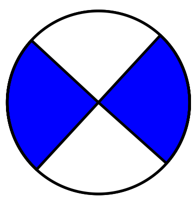


Figure 4: Beachball (lower hemisphere) resulting from deformation on optimal fault plane (strike=43°, dip=90°), considering only tectonic stress sources.

Deformation from the tectonic-only stresses on an optimal fault plane would produce left-lateral slip on a NE-striking vertical fault, or right-lateral slip on a NW-striking vertical fault.

At the bottom of the Newberry well, these stresses are on the order of -1 to 5 MPa; they are therefore quite below lithostatic stress, and may not be sufficient to cause deformation without very high fluid pressures or low friction on pre-existing faults.

2.2 Local topographic stress calculations

To get more accurate calculations of the topographic stresses at the Newberry EGS site, we have performed a more local topographic stress calculation using much higher resolution topographic data (80 m data vs. 700 m for the regional stress calculation). In addition to increasing the accuracy of the calculations, this allows us to calculate stresses at shallower crustal depths: As described above, we cannot calculate stresses shallower than one 'map resolution unit' below the surface of the halfspace, which is typically zero. By using a local, higher-resolution DEM and setting the surface of the halfspace higher, we can calculate stresses at much shallower levels.

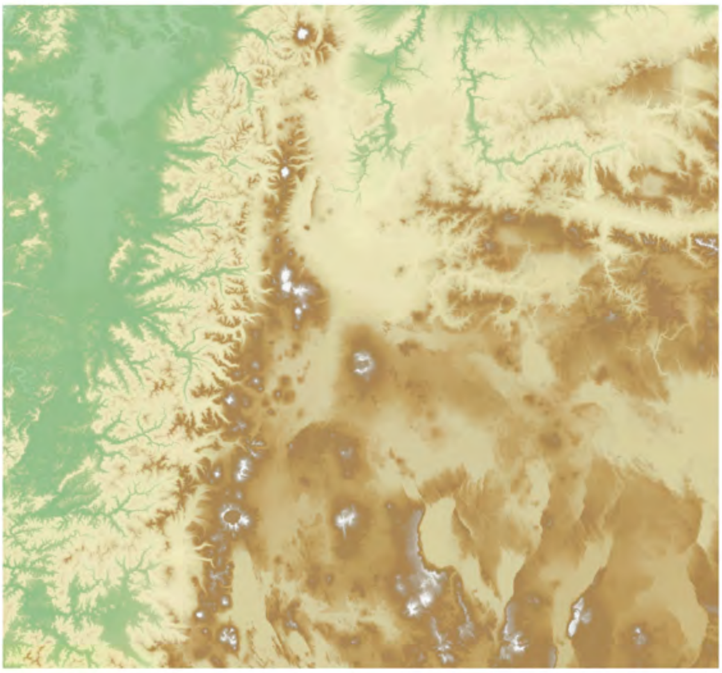


Figure 5: SRTM 90 m DEM used in the high-resolution topographic stress calculation. Newberry Caldera is in the center of the DEM.

2.2.1 Methods

The methods used in this topographic stress calculation are the same as described above. We used a DEM approximately 400 x 400 km, at 80 m resolution (the data is SRTM 90 m, but when projected into a custom Albers projection suitable for midlatitudes, the data is at 80 m). The elevations in the DEM were normalized to La Pine, OR, elevation 1290 m. This lets us calculate the stresses at up to 1200 m above sea level.

2.2.2 Results

Horizontal topographic stresses at the Newberry EGS well are around 6 MPa for both σ_{EW} and σ_{NS} (Figure 6). σ_{zz} is twice as strong. The shear stresses are insignificant except for σ_{Ez}, which is -3 MPa; this stress component causes a rotation of the stress field around a north-trending horizontal axis, with a top-west sense of shear.

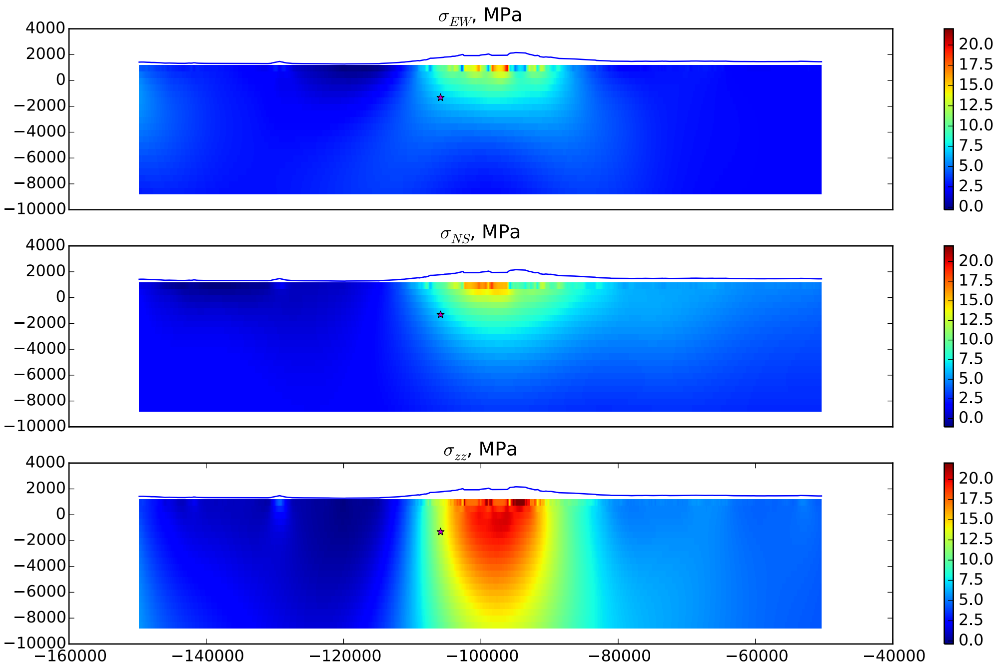


Figure 6: E-W section (north-looking view) across the Newberry region showing cardinal topographic stress components (in MPa) from the local topographic stress calculation. Topography is shown as the blue line. Shear stresses are calculated but not shown. Some vertical exaggeration. Star is location of bottom of Newberry EGS well.

The stress field at the bottom of the Newberry EGS well from topography yields an optimal fault orientation with a strike=187°, dip=84°, and rake=-93°(Figure 7a).

This is consistent with a σ_1 trending E-W and plunging to the W; essentially, stress radiating outwards from the volcanic edifice.

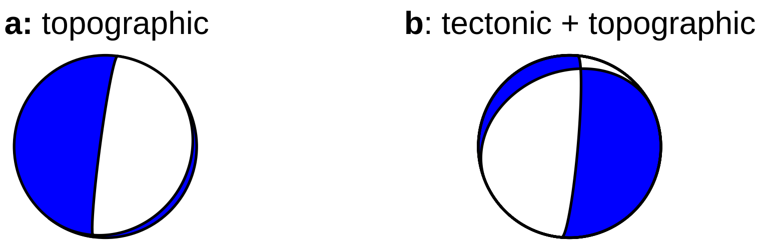


Figure 7: **a**: Beachball (lower hemisphere) resulting from slip on optimal fault plane considering only topographic stress at the bottom of the Newberry EGS well. **b**: Beachball from slip on optimal plane considering both tectonic and topographic stress.

Though the topographic stresses are equal to or larger than the tectonic stresses, the addition of both of them reorients the stress field enough to change the dip direction of the optimal fault, though the general fault pattern (normal faulting on a near-vertical, N-striking fault) is similar (Figure 7b).

2.3 Stresses from Newberry magma chamber

Because Newberry volcano is active, some amount of stress is presumed to be generated from magmatic activity, predominantly the inflation of a magma chamber at some depth. Several studies suggest that a magma chamber exists in the upper crust; for example, *Heath (2014)* images the chamber at approximately 2500 m below sea level using seismic tomography and receiver functions. *Dzurisin (1999)* finds geodetic evidence for an inflating magma chamber at about 8000 m below sea level. It is important to note that these results are complementary, and provide evidence for a vertically-layered magmatic plumbing system; they are in no sense mutually exclusive.

2.3.1 Methods

To evaluate the possible effects of a magma chamber on stresses at the bottom of the Newberry EGS well, we use a modification of the Mogi model of a pressure source embedded in an elastic halfspace; because we do not have information on magmatic overpressure, we instead use a spherical volume source at ambient pressure. We use the formulation of *McTigue (1987)*, though we do not use the higher-order surface corrections discussed in that work, because they are both minor at appreciable distance from the source, and rather tedious.

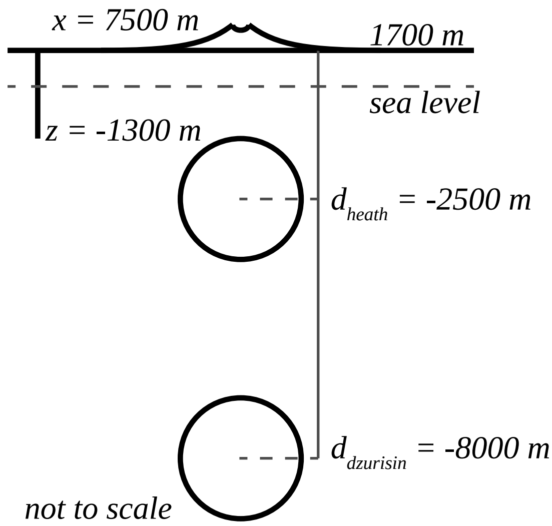


Figure 8: Schematic of the magmatic stress calculations at Newberry.

We analyze two models that differ only in their depth, based on the work by *Heath (2014)* and *Dzurisin (1999)* discussed above. *Heath (2014)* provides evidence for an active, hot chamber, while *Dzurisin (1999)* provides evidence for a growing chamber, and derives a magmatic inflation rate of $\sim$0.001 km^3 yr^{-1} using leveling data and an inversion similar to this (with only the vertical component of deformation). The last eruption at Newberry caldera was 1300 years ago. We use this rate and duration to estimate a source volume of 1.3 km^3.

2.3.2 Results

The possible stresses from magma at the Newberry EGS site are substantial (Figure 9). The horizontal, E-W compression is the strongest stress, and could be up to 30 MPa. The other stress components are just as large (N-S compression is everywhere 1/2 of the E-W compression, and the vertical and shear stresses are still up to 10-15 MPa, depending on location.

These stresses by themselves result yield optimal fault planes consistent with either strike-slip or oblique normal deformation (Figure 10). It is worth noting that the magnitude of the stresses scales linearly with the volume or overpressure of injected magma; however, the kinematics of the resulting deformation (shown by the beach-balls) is independent of the source magnitude, as long as no other stresses are taken into account. As we will see later, we can modify the source volume when considering deformation from all stress sources, which changes the net deformational kinematics.

It needs to be stated that it is not known how large the magma chamber may be at

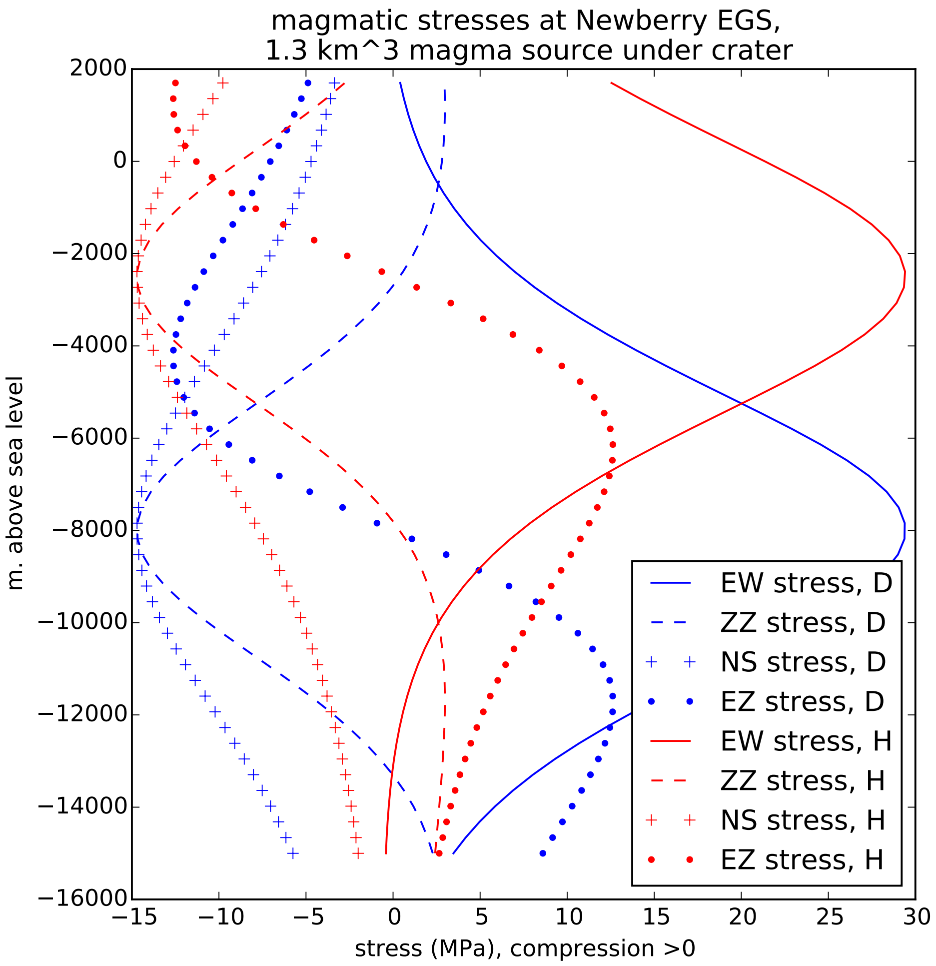


Figure 9: Calculations of stress components at a vertical profile at the Newberry EGS site. 'H' indicates a magma source at -2500 m (*Heath, 2014*) and 'D' indicates a magma source at -8000 m (*Dzurisin, 1999*).

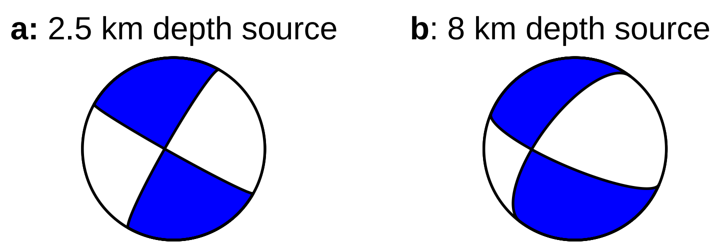


Figure 10: Beachballs resulting from slip on optimal fault planes from magmatic stresses. **a**: Source at 2.5 km depth (*Heath, 2014*). **b**: Source at 8 km depth (*Dzurisin, 1999*).

Newberry; though work has done to estimate the chamber inflation rate over the past several decades (*Dzurisin, 1999*). However, it is not known for how long this magma chamber has been inflating, whether there is only one chamber, what its shape is, and whether permanent deformation of the crust around the chamber (for example via faulting) has led to reduction in magmatic stresses during the time of chamber inflation. Nonetheless, these calculations show that it is quite possible that magmatism significantly affects the local stress field; therefore, its effects need to be considered. Additional analysis of existing geodetic and seismic data from Newberry may be able to provide more precise estimates on this stress perturbation, but for now it has gone from being an 'unknown unknown' to a 'known unknown'.

2.4 Stresses from locking on the Cascadia subduction zone

One possible explanation for the discrepancy between the stress state inferred from regional faulting in the Oregon Cascades and the modern stress state inferred from induced seismicity at Newberry is that the regional faults are active following great Cascadia subduction earthquakes, when E-W stresses due to elastic strain accumulation on the locked megathrust are low. To investigate this, we have made a model of the Cascadia subduction zone, with a dislocation representing slip on the megathrust below a locked zone. This allows us to quantify the stresses at Newberry from the Cascadian seismic cycle and evaluate the contribution to the total local stress field.

2.4.1 Methods

We have simulated elastic strain accumulation on the Cascadian megathrust by assembling a dislocation representing the creeping portion of the megathrust. The fault patch is roughly 1100 km N-S and 250 km E-W, with its upper boundary at 20 km depth and its lower boundary at 100 km depth, dipping at 17°. (Figure 11). The convergence (slip) direction trends at 66°, so it is somewhat oblique. We have put 15 m of slip on the fault, simulating creep of 50 mm yr^{-1} for 300 years, which corresponds to the modern convergence rate and time since the last great subduction earthquake. The fault itself was discretized into six triangular coplanar elements, in order to use existing code (*Meade, 2007*).

2.4.2 Results

Stresses from Cascadian strain accumulation are low at the Newberry EGS site. $\sigma_{H\max}$ is ~800 kPa and trends 48°. The other stress components are comparable in magnitude or smaller. Clearly, this is a much weaker stress than the other stress

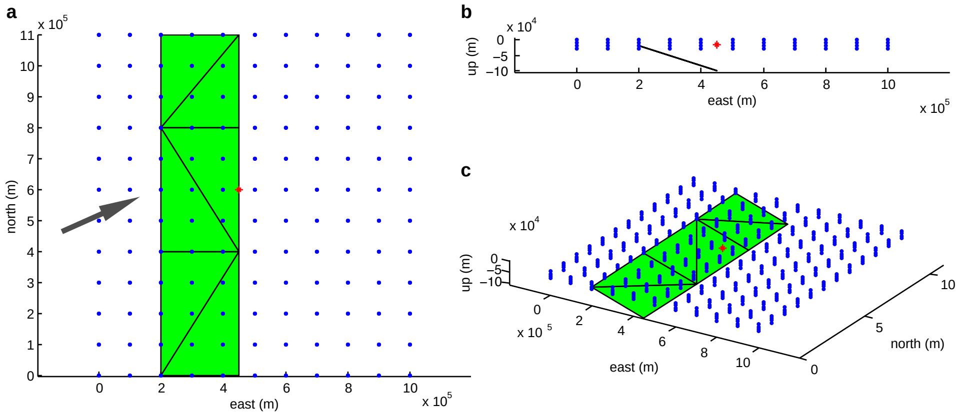


Figure 11: Illustration of Cascadia locking model. Green triangles indicate slipping patches; red asterisk is the bottom of the Newberry EGS well; grey arrow is the subduction direction; blue points are grid points for calculating the solution outside of the Newberry site. **a**: Map view. **b**: Cross-section, looking north. **c**: Oblique view.

components, so the influence of the subduction zone at the Newberry site is likely minimal.

2.5 Consideration of combined stress sources

By combining the local topographic stresses at the bottom of the Newberry EGS injection well, the most likely tectonic stress tensor (e.g., the peaks of the histograms shown in Figure 3), and the magmatic stresses, we can get find the kinematics of deformation on the optimally-oriented fault given these stresses. The biggest source of uncertainty in this calculation is the magmatic stress; the local topographic stress calculations have very little uncertainty and the peaks of the probability distributions for the tectonic stress variables are relatively well defined.

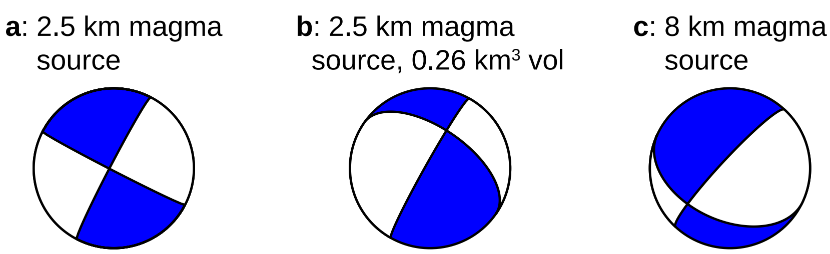


Figure 12: Beachballs (lower hemisphere) resulting from combined stresses from topographic, tectonic and magmatic sources. The only differences are in the size and location of the magma chamber.

In Figure 12 we show the beachballs that would result from optimal slip given the total stresses with several choices for the size and depth of the magma chamber. The combined stresses generally have horizontal, or near-horizontal, and E- to NE-trending σ_1, horizontal or shallowly-plunging N-trending σ_3 and vertical or near-vertical σ_2 (Figure 12). The orientation of σ_1 in these stress fields is reasonably consistent with the majority of P axes from the Newberry stimulation earthquakes, but the other axes are not as well aligned.

Based on the general style of the stress field including magmatic effects, and the sensitivity of the results to the magmatic source location and geometry, it seems likely that the stresses evinced by the stimulation earthquakes would be reproducible with small changes in the location and geometry of the magma chamber.

2.6 Analysis of Newberry seismic data

The final step in our work was to actually examine the seismicty data in detail. There are a lot of different avenues to explore here: correlations between different variables, time series, physically-based modeling, and more. This work could have certainly eaten up the entirety of the month allotted for our entire analysis, so we left it until the end, and chose to investigate a smattering of things (mostly correlations).

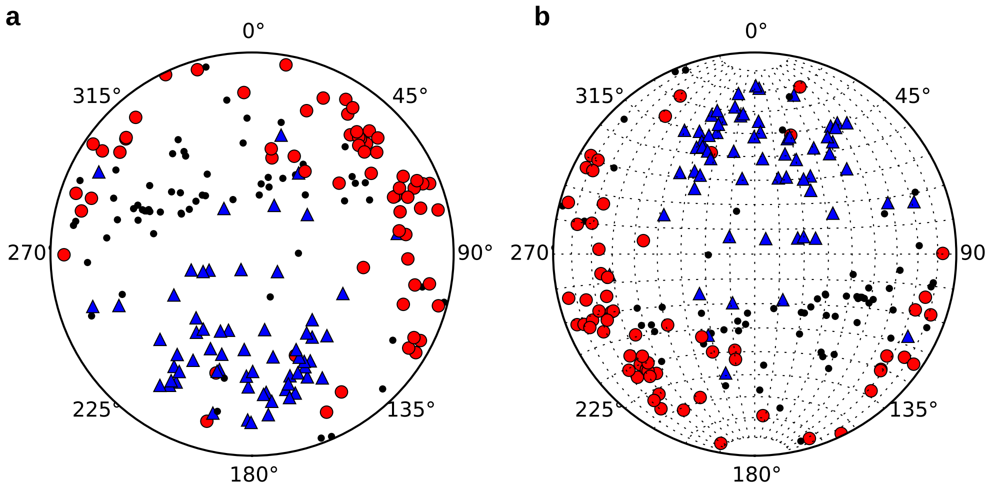


Figure 13: Stereonets of the principal axes of the stimulation data. Red circles indicate P axes. Blue triangles indicate T axes. Black dots indicate N axes. **a**: upper hemisphere. **b**: lower hemisphere.

2.6.1 Initial inspection of data

The first thing we did was to take the moment tensor data (EE, NN, etc.) and replicate the principal axis plots, to make sure we had a handle on everything (Figure 13a). Then, we redid some of the plots in a lower-hemisphere projection, to be consistent with the beachballs and other plots from the rest of this work (Figure 13b).

The total moment release (created by summing the moment tensors for all events) is consistent with the pattern shown in the stereonets of the principal axes. A beachball of this is shown in Figure 14. It is clear that on the whole, moment release (and therefore strain) doesn't really have a double-couple pattern. The beachball and stereonets seem to indicate a more constrictive stress regime, with a somewhat restricted area of relatively lower area of compression steeply plunging NNE and higher compression all around.

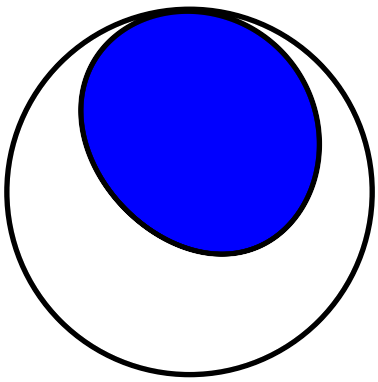


Figure 14: Beachball (lower hemisphere) of the total moment release of all of the stimulated earthquakes.

Additionally, and somewhat importantly, the total moment release has a negative trace, or first tensor invariant (-6.32 of whatever units these moment tensors are in), *indicating net contraction of the crust around the well!* We find this to be hard to explain. The only hypothesis comes to mind is that the rocks here had some component of pore (void) space such as vesicles that were underpressured after burial to the modern depths, but the rock was strong enough to resist deformation until fluid injection pushed it across the failure envelope. Then, the rock essentially collapsed on itself.

Next, we began looking at the data for basic correlations: Are there relationships between *Mw* and depth, for example, or *Mw* and stress orientation?

The answer to both of these is 'no'; based on visual inspection there seems to be no relationship (Figure 15), so it doesn't look worth quantifying. Several other sets of variables were explored, such as depth vs. stress orientation, and time series of location, magnitude, stress orientations, and so forth did not yield any insight into the general problem of understanding the stresses at the well. The perennial academic statement 'more work should be done' can be made, although it's not obvious to us that digging deeper into simple correlations will have a better return on investment than other analysis such as physical modeling.

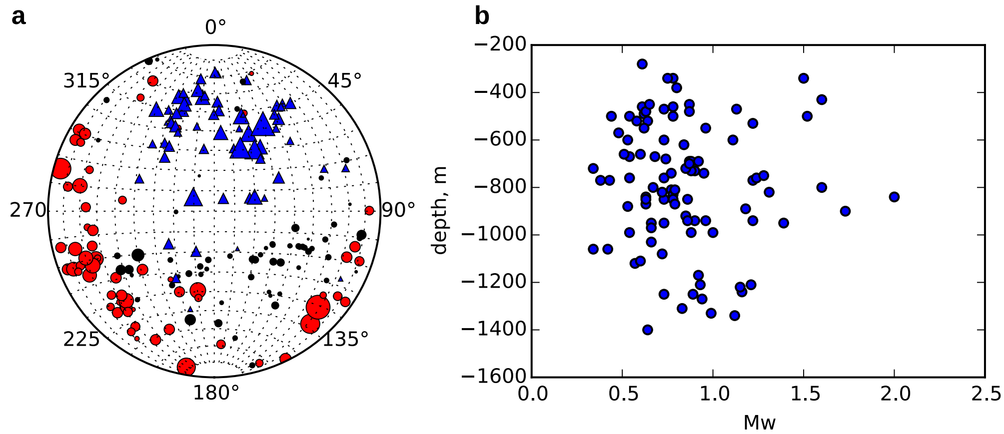


Figure 15: **a**: Stereonet of principal axes of the stimulation data. Symbology same as in 13, except sizes are scaled by *Mw*. **b**: Scatter plot of depth vs. magnitude, illustrating no apparent correlation.

2.6.2 Further analysis: Effects of pumping pressure

The wellhead pressure of about 3000 psi (~20 MPa) is substantial, and assuming it is the same at the bottom of the well, comparable with other *in situ* stresses from lithostatic pressure, topography and tectonic stress. Although this is nominally a pore fluid pressure increase, given the fact that it is so overpressured (enough to cause faulting) suggests that it might be a net pressure source in the same way that a magma chamber is, and place differential stresses in the crust in addition to elevation of pore fluid pressure.

There are a couple ways of determining whether the pressures at the bottom of the well had any effect on the stress orientations at the earthquakes. One of them would be to do full calculations using a Mogi source, as in the section on magmatic stresses above. This is a time-consuming activity, especially because there are many 'receiver' locations for the stresses emanating from the pressure source, so the problem can't be reduced to a two-dimensional approach as used in the magmatic analysis. Therefore, some more work involving three-dimensional tensor rotations would have to be done, which can be time sinks to code and thorougly test, as bugs here can be subtle. Additionally, an even more physical model involving pressurized fluid diffusion with time could be implemented. This could be cool to do but would involve a lot of time dependence, both estimating the migration of the fluid front, and any rheologic changes (especially to the Poisson ratio) imposed by fluid overpressure.

Instead, we have opted for a relatively quick analysis, simply to see whether the principal stress axes for each event are collinear with a line from the bottom of the well to the earthquake. The idea behind this is that if injection pressures are a large component of the total stress field, then σ_1, or the P axis, of the seismicity should point at the pressure source.

To test this, we have made Cartesian unit vectors from the principal axes of each earthquake ($\vec{P}$, $\vec{N}$, and $\vec{T}$). Then, we have calculated the vector $\vec{r}$ from the well to each earthquake. (Based on the Foulger consulting report, we have calculated the centroid of the earthquake cloud as the well/pressure source location, since we do not have this information with the necessary precision). Then, we calculate the collinearity of the axis vectors (for example $\vec{P}$) with $\vec{r}$ for each earthquake as

$$\left|\vec{P} \cdot ||\vec{r}||\right|$$

where $\cdot$ is the dot (inner) product, and $||\vec{r}||$ is $\vec{r}$ normalized to length 1. The absolute values are used because the principal axes are bidirectional, so the sign of the dot product is irrelevant (it's only affected by whether the earthquakes are above or below the centroid).

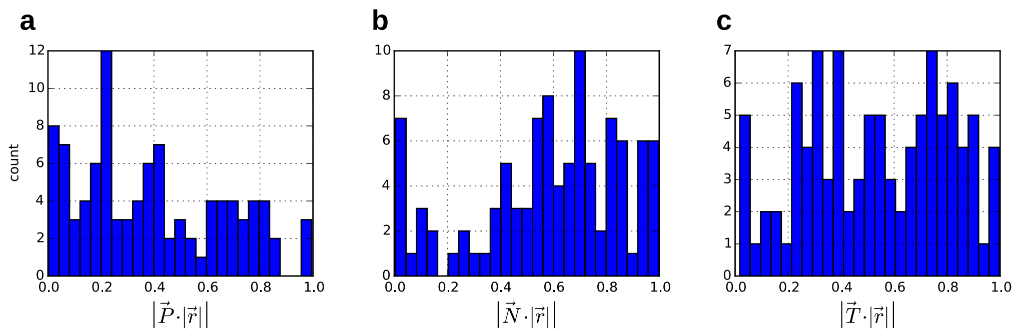


Figure 16: Histogram of collinearity between the orientation of the principal stress axes and the orientation of the earthquakes with respect to the center of the seismic cloud. '1' indicates collinearity, while '0' indicates orthogonality. **a**: P axes. **b**: N axes. **c**: T axes.

Histograms of these calculations are shown in Figure 16. The histograms look like the distribution of the collinearity measurements are dominantly random, as would be expected if fluid injection was not significantly perturbing the stress field.

However, further consideration of this idea suggests that the pressure, and therefore stress perturbation, should decrease with the square of distance (this is true of all spherically-radiating energy sources). The hypothesis in this case is that the closer to the source, the more aligned $\vec{r}$ and $\vec{P}$ should be, while $\vec{N}$ and $\vec{T}$ should be more aligned with increasing distance. To test this hypothesis, we plotted the collinearity versus $\vec{r}^2$ (Figure 17). The plots show that the hypothesized trends are apparent for

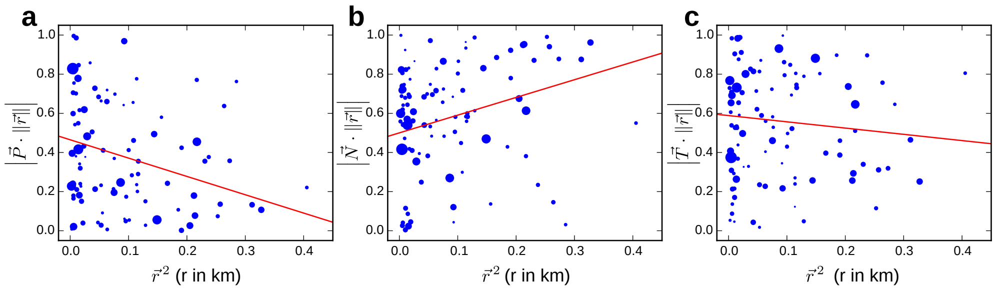


Figure 17: Scatterplots of earthquake distance from the pressure source vs. collinearity between principal axis orientation and earthquake location with respect to the pressure source. Markers are scaled by magnitude. Red lines indicate least-squares regressions, weighted by magnitude. **a**: P axes. **b**: N axes. **c**: T axes.

the P and N axes. We fit least-squares regression lines, weighted by Mw^2 (since Mw is not linear). These clearly demonstrate the observed trends.

We interpret this to strongly suggest that the hydraulic pressure at the bottom of the well has sufficiently perturbed the stress field to reorient at least the P axes.

3 Summary and conclusions

- Regional tectonic stresses are low, T_{max} trending at 15°and ~0.1–0.2 $\rho g z$. T_{min} has a most-likely value near zero, but may be more strongly negative (tensile) than T_{max} is compressive.

- Local stresses from topography yield most compressive σ_{zz} at the Newberry well (~12 MPa); E-W and N-S compression are smaller by half. This is consistent with normal slip on steeply-dipping, north-striking faults. These deformation patterns are similar when topographic and tectonic stresses are combined.

- Magmatic stresses are potentially very substantial (tens of MPa), and are much less well known than the topographic and tectonic components. We obtain moderately different results using different depths for an inflating magma chamber based on previous studies; however, these potential chamber locations are not necessarily mutually exclusive, and other locations could exist as well. The volume (or equivalently, the overpressure) of the magmatic source is also not known.

- Stresses from 300 years of locking and strain accumulation on the Cascadia subduction zone are less than 1 MPa at Newberry. This is well below the levels of stress from the other stress sources, so subduction stresses are negligible here.

- The sum of these stresses at Newberry is not overly consistent with the stresses at the bottom of the EGS well, as inferred from the induced seismicity. It is possible that a different (yet still plausible) location for the magma chamber could better fit the seismic data, but there would be little independent verification of such a magma chamber.

- The induced seismicity is enigmatic, in particular the steeply to moderately plunging T axes and the wide range in azimuths of the shallowly plunging P axes; this is essentially the opposite of the tectonic and topographic stress fields. The net moment release from these earthquakes indicates contraction (volume reduction) of the crust due to these earthquakes.

- P axes from the induced seismicity point towards the bottom of the well near the well, but not as much with increasing distance. This suggests that pressures at the injection site are strong enough to locally reorient the stress field, in addition to simply increasing fluid pressure.

- This would all make a lot more sense if the polarity of the seismometers was reversed.

3.1 Future work

Though the work done here was first billed as preliminary, much of it (in particular, the topographic, tectonic and subduction zone stress work) is complete. However, additional work could be done to shed more light on the local stresses.

- Do a more comprehensive evaluation of magma chamber inflation at Newberry Volcano. The previous geodetic inversion was done through leveling data, and since then, the volcano has been instrumented with GPS and seismomemters. A real inversion using modern, high-quality data could be very insightful.

- Calculations of all of these stresses at each earthquake location, instead of only at the estimated location of the bottom of the well. Topographic and magmatic stresses vary over short distances in the vicinity of the well. This could be coupled with estimates of injection-induced stress changes at each earthquake location.

- Then, analyze the difference between the total estimated stress and the moment release. See if there are systematic residuals, or of they are spatially incoherent. If there is a pattern, think about it and analyze what could be causing it.

- Use the quantified stress field to estimate rock strength parameters (static friction and cohesion), to better estimate the required wellhead pressures for optimal stimulation.

4 References

Dzurisin, D. (1999). Results of repeated leveling surveys at Newberry Volcano, Oregon, and near Lassen Peak Volcano, California. *Bulletin of Volcanology*, 61(1-2), 83-91.

Heath, B. (2014). New Constraints on the Magmatic System beneath Newberry Volcano from the Analysis of Active and Passive Source Seismic Data and Ambient Noise. Unpublished M.S. Thesis, University of Oregon.

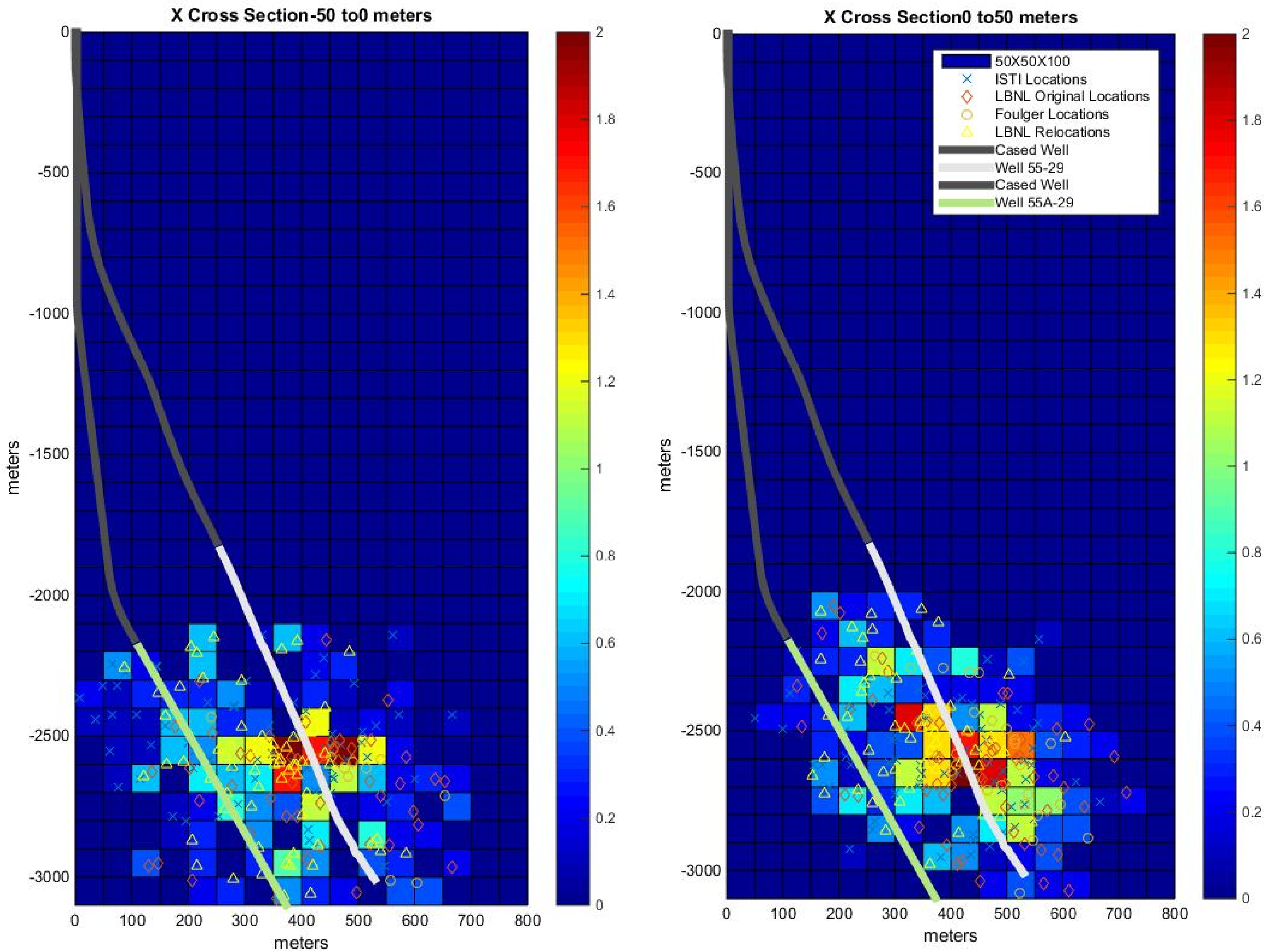
Liu, L., & Zoback, M. D. (1992). The effect of topography on the state of stress in the crust: application to the site of the Cajon Pass Scientific Drilling Project. *Journal of Geophysical Research: Solid Earth*, 97(B4), 5095-5108.

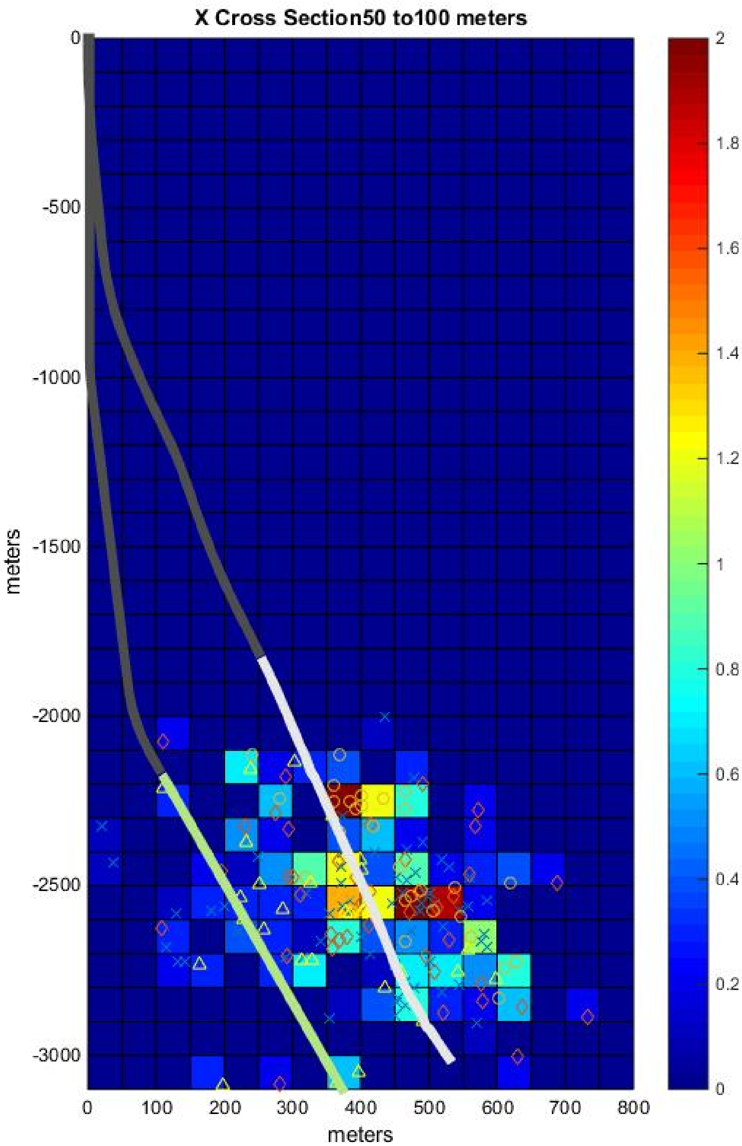
McTigue, D. F. (1987). Elastic stress and deformation near a finite spherical magma body: resolution of the point source paradox. *Journal of Geophysical Research: Solid Earth*, 92(B12), 12931-12940.

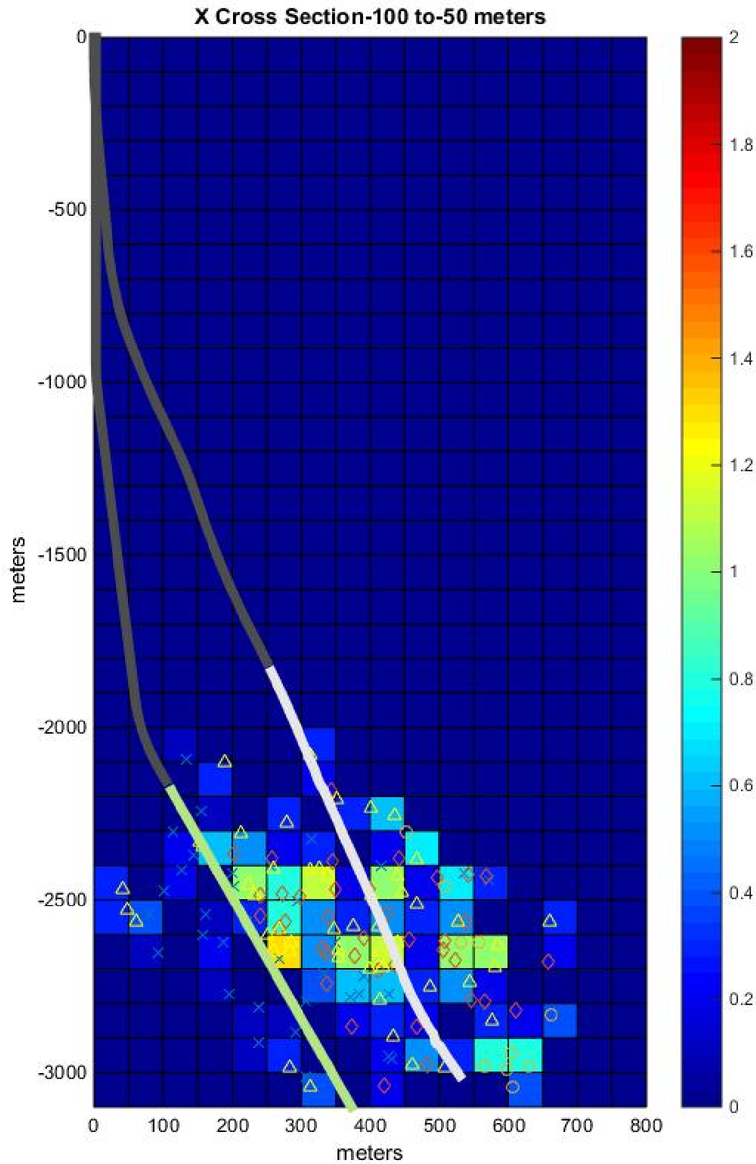
Meade, B. J. (2007). Algorithms for the calculation of exact displacements, strains, and stresses for triangular dislocation elements in a uniform elastic half space. *Computers & Geosciences*, 33(8), 1064-1075.

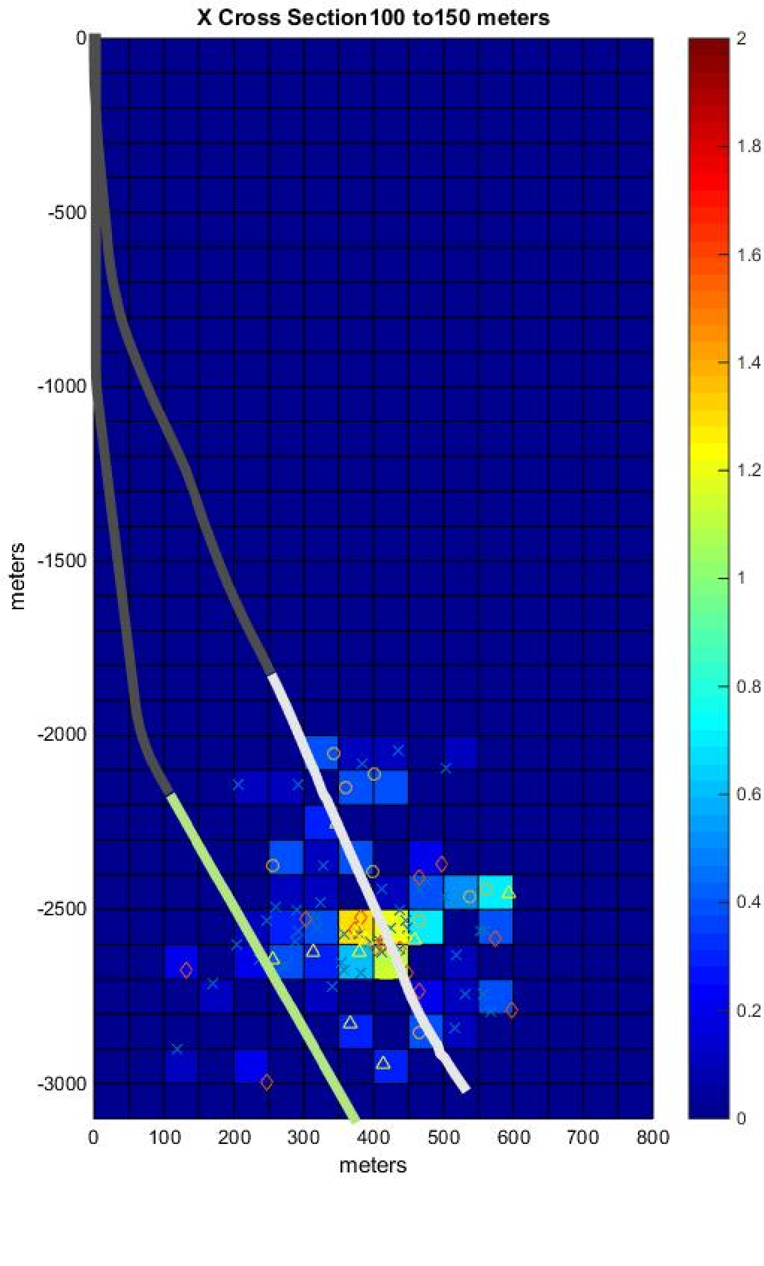
Styron, R. H., & Hetland, E. A. (2015). The weight of the mountains: Constraints on tectonic stress, friction, and fluid pressure in the 2008 Wenchuan earthquake from estimates of topographic loading. *Journal of Geophysical Research: Solid Earth*, in press.

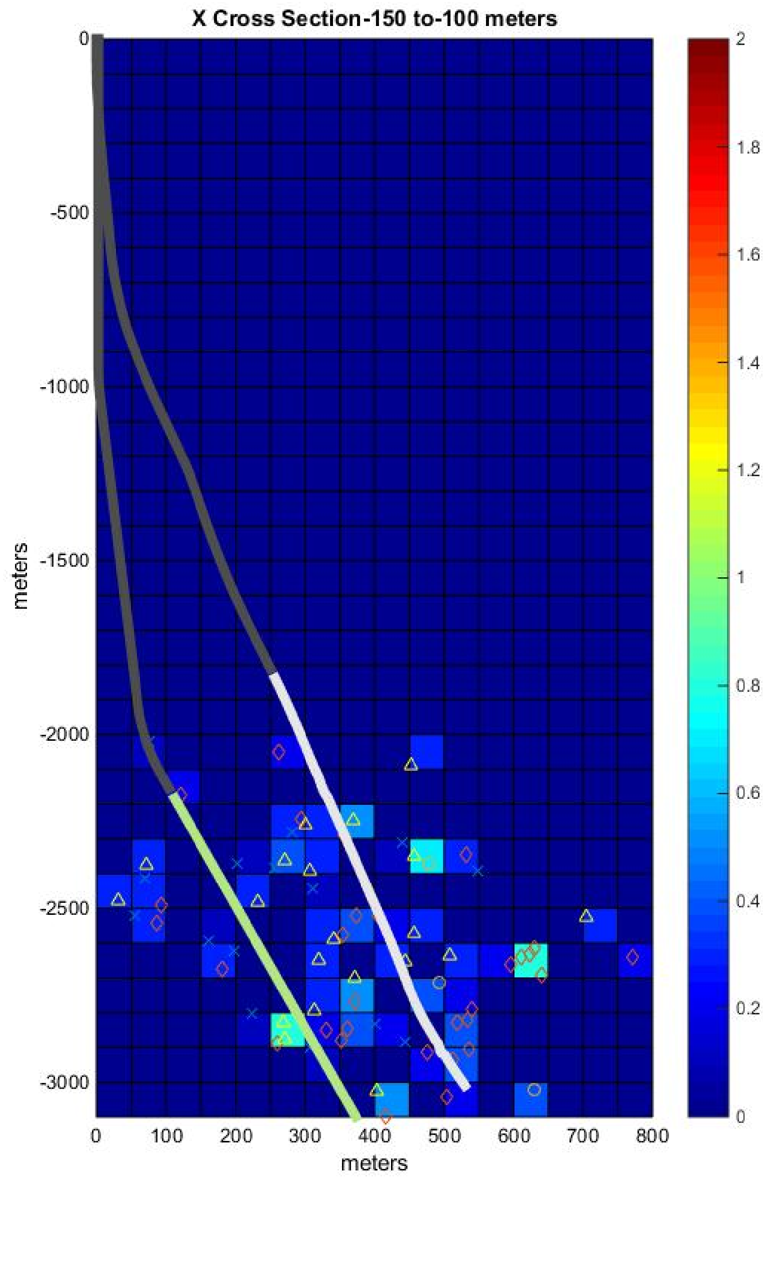
Appendix G
Seismic Plots: LBNL maps and combined catalog density (CCD) maps

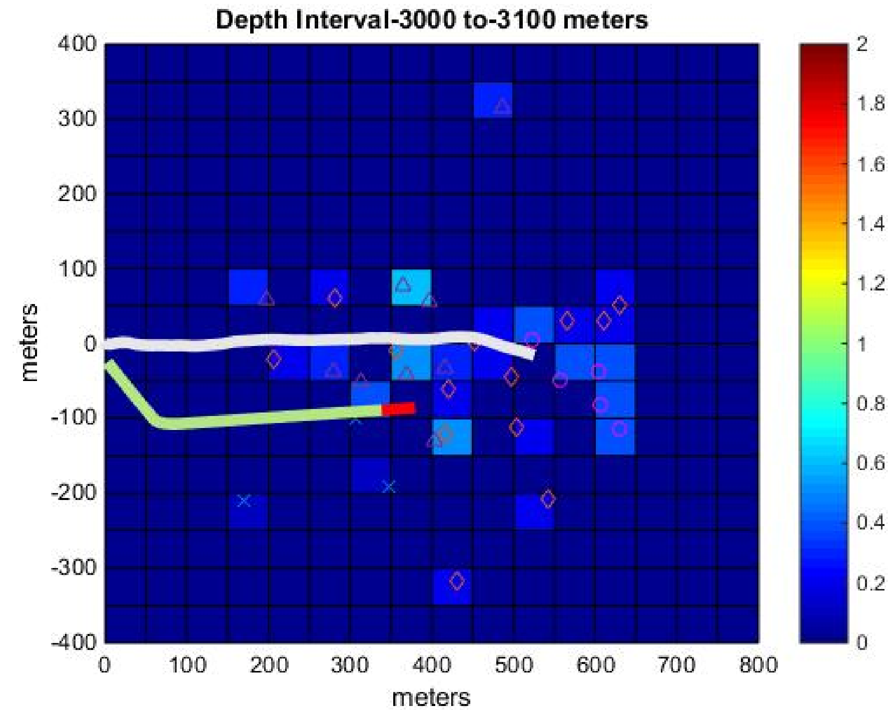

X Cross Section-50 to0 meters
X Cross Section0 to50 meters
50X50X100
ISTI Locations
LBNL Original Locations
Foulger Locations
LBNL Relocations
Cased Well
Well 55-29
Cased Well
Well 55A-29
meters
meters


X Cross Section50 to100 meters
meters
meters
0
-500
-1000
-1500
-2000
-2500
-3000
0 100 200 300 400 500 600 700 800
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2

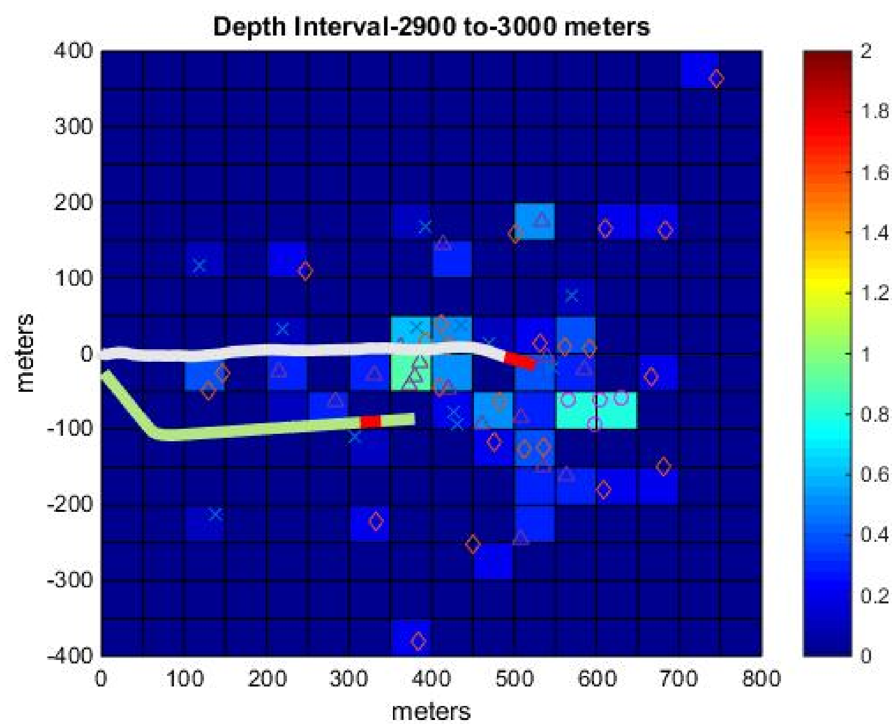

X Cross Section-100 to-50 meters
meters
meters
0
-500
-1000
-1500
-2000
-2500
-3000
0 100 200 300 400 500 600 700 800
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2


X Cross Section100 to150 meters
meters
meters
0
-500
-1000
-1500
-2000
-2500
-3000
0
100
200
300
400
500
600
700
800
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0

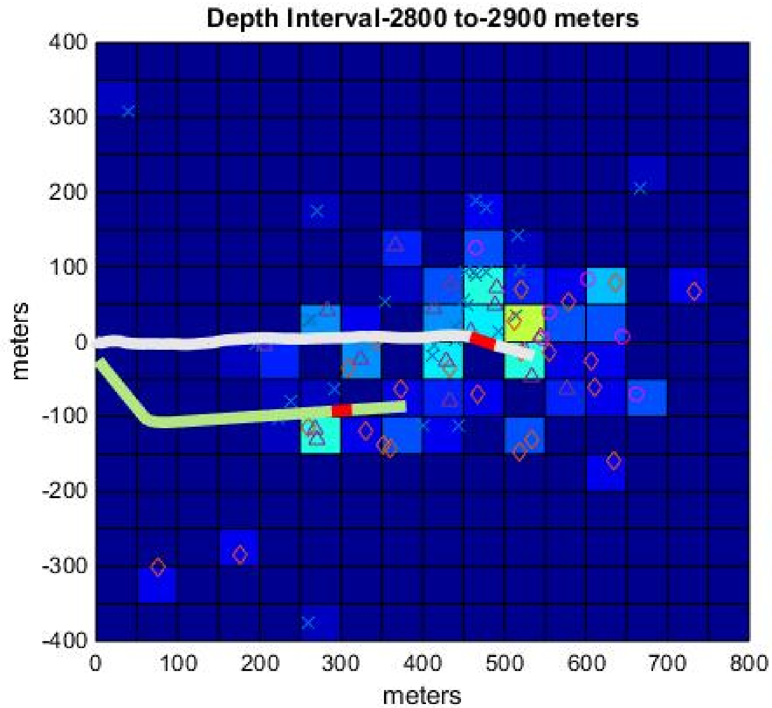

X Cross Section-150 to-100 meters
meters
meters
0
-500
-1000
-1500
-2000
-2500
-3000
0
100
200
300
400
500
600
700
800
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0

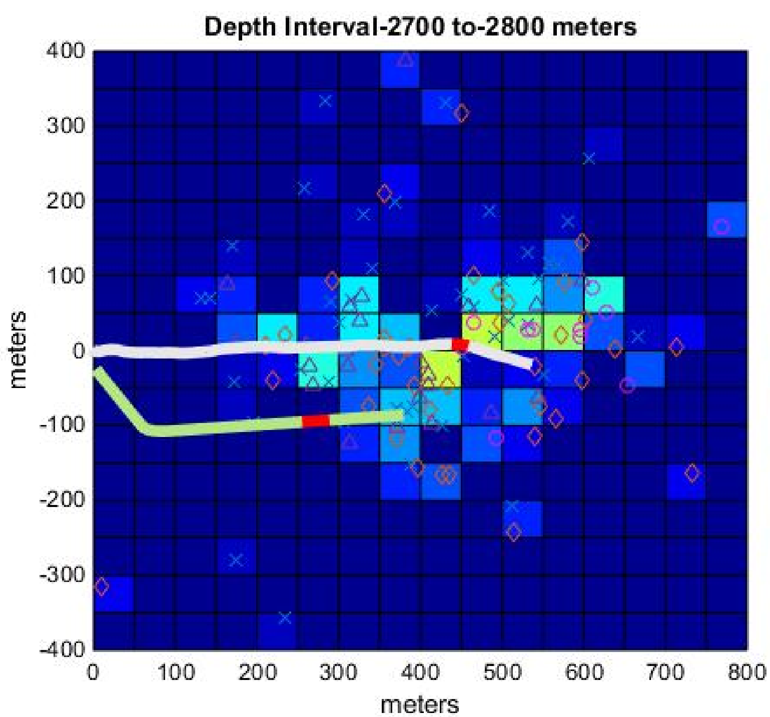


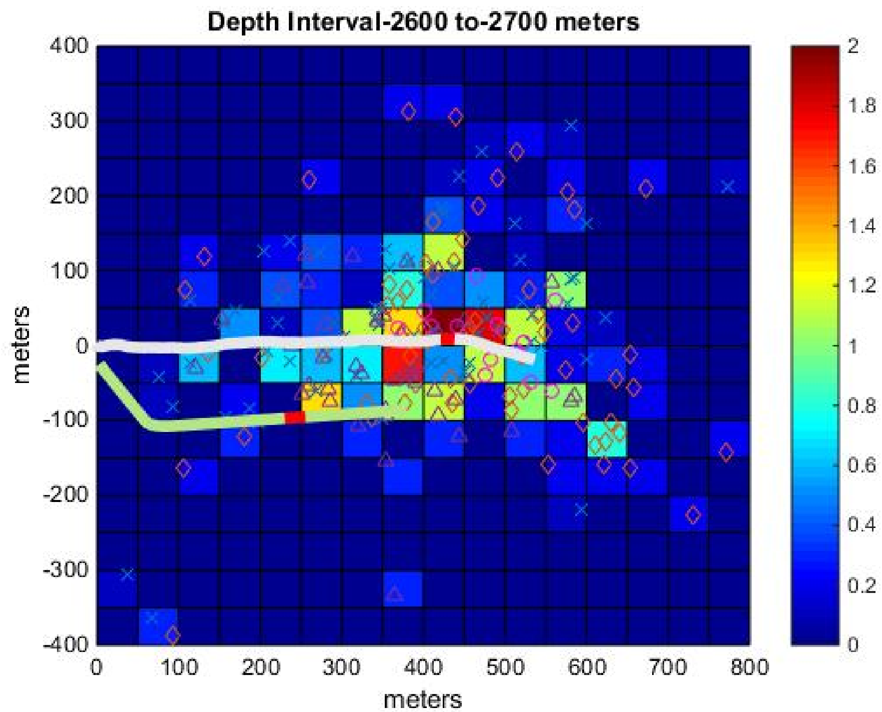
Depth Interval-3000 to-3100 meters
meters
meters
400
300
200
100
0
-100
-200
-300
-400
0
100
200
300
400
500
600
700
800
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0



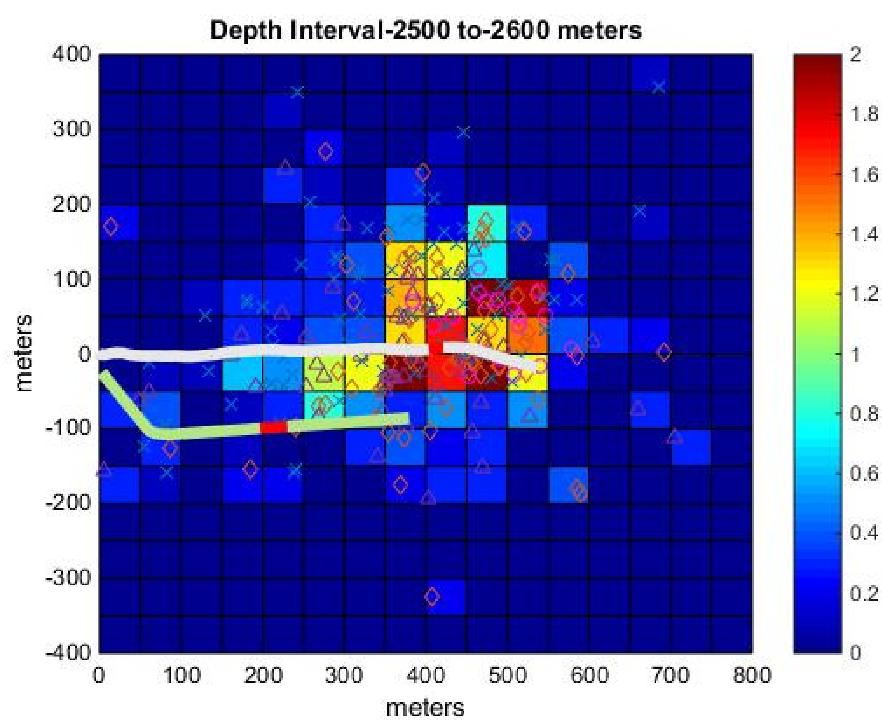
Depth Interval-2900 to-3000 meters
meters
meters
400
300
200
100
0
-100
-200
-300
-400
0
100
200
300
400
500
600
700
800
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0


Depth Interval-2800 to-2900 meters
meters
meters
400
300
200
100
0
-100
-200
-300
-400
0
100
200
300
400
500
600
700
800
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0

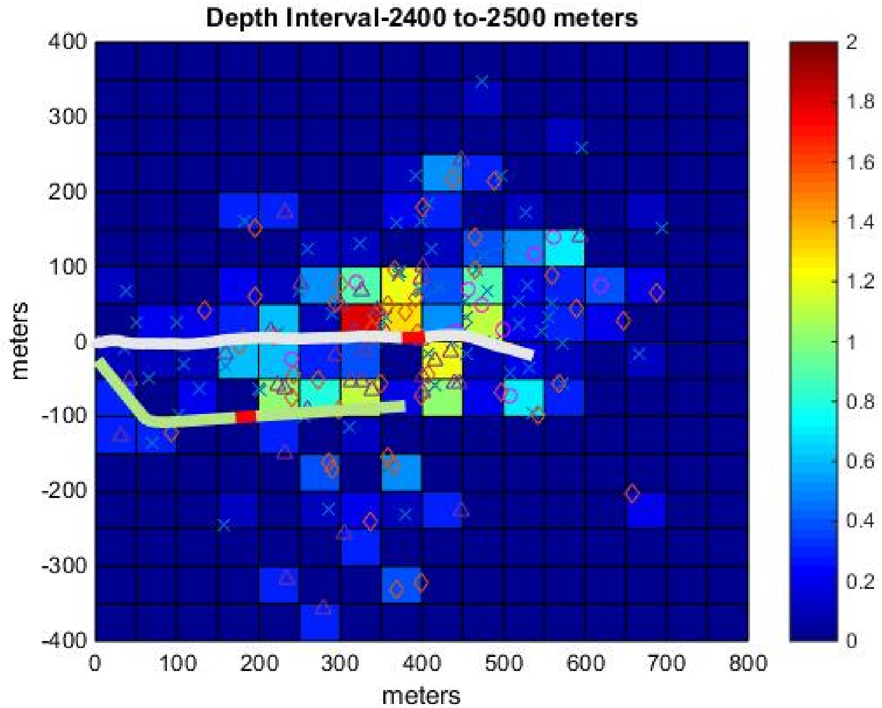

Depth Interval-2700 to-2800 meters
meters
meters
400
300
200
100
0
-100
-200
-300
-400
0
100
200
300
400
500
600
700
800
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0

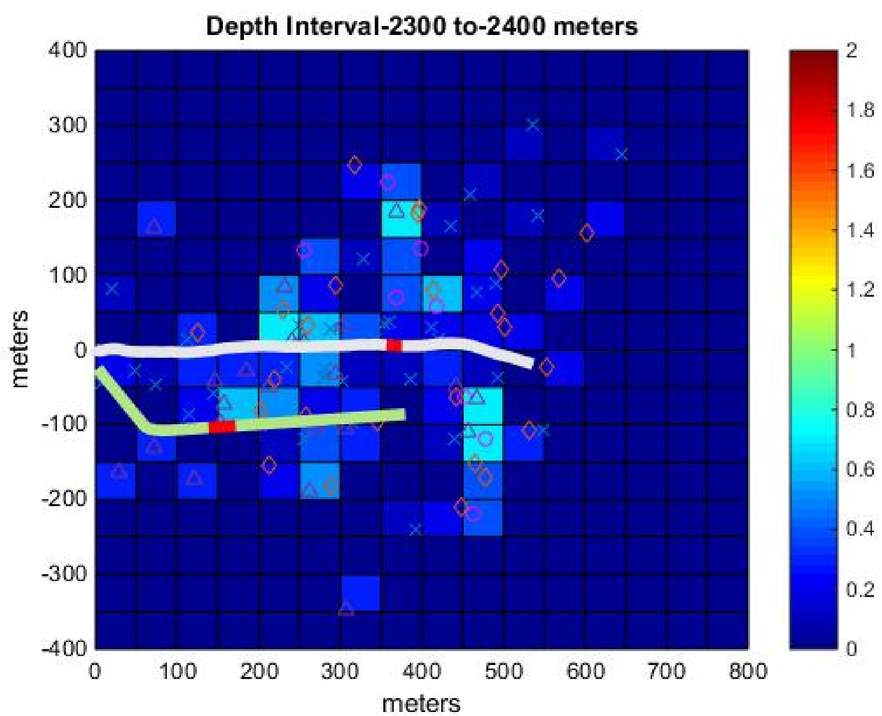


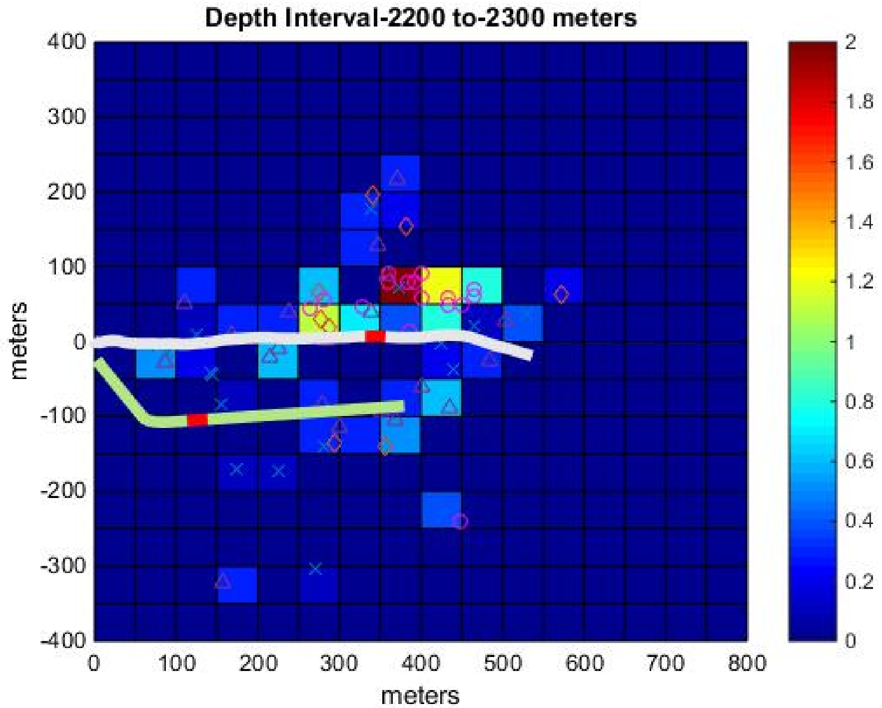
Depth Interval-2600 to-2700 meters
meters
meters
400
300
200
100
0
-100
-200
-300
-400
0
100
200
300
400
500
600
700
800
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0



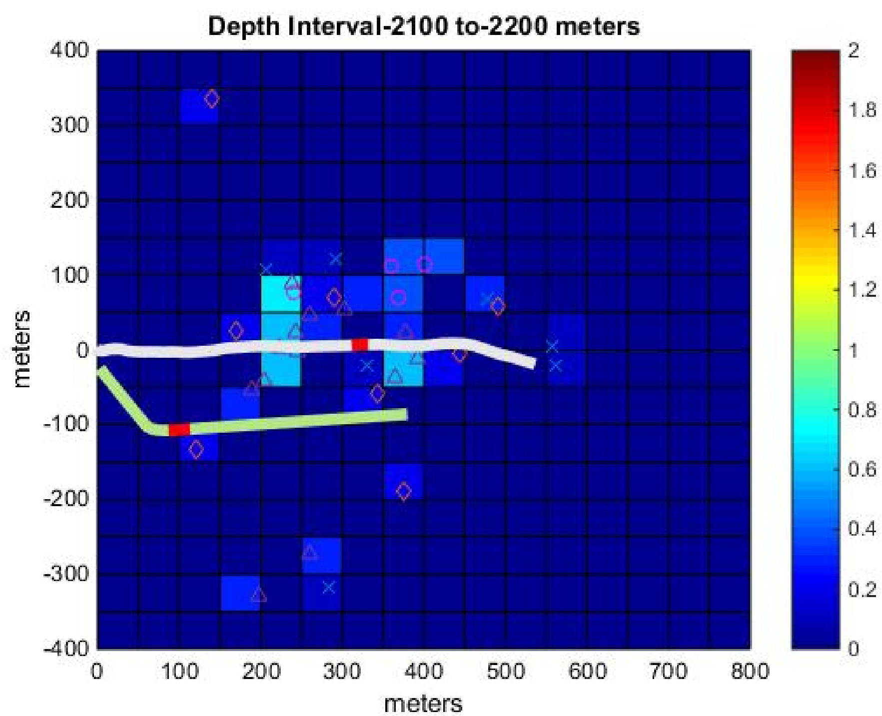
Depth Interval-2500 to-2600 meters
meters
meters
400
300
200
100
0
-100
-200
-300
-400
0
100
200
300
400
500
600
700
800
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0


Depth Interval-2400 to-2500 meters
meters
meters
400
300
200
100
0
-100
-200
-300
-400
0
100
200
300
400
500
600
700
800
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0


Depth Interval-2300 to-2400 meters
meters
meters
400
300
200
100
0
-100
-200
-300
-400
0
100
200
300
400
500
600
700
800
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0



Depth Interval-2200 to-2300 meters
meters
meters
400
300
200
100
0
-100
-200
-300
-400
0
100
200
300
400
500
600
700
800
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0



Depth Interval-2100 to-2200 meters
meters
meters
400
300
200
100
0
-100
-200
-300
-400
0
100
200
300
400
500
600
700
800
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0

Appendix H
Detailed Drilling Plan

Newberry 55A-29 Drilling Program

5/06/2015

Section 29, T 21S, R12E, Deschutes County
Newberry Field, Oregon

1. **Site preparation**
   - 1.1 Install 30" conductor pipe to 100'+/- as directed.
   - 1.2 Construct cellar around conductor pipe with drain line to sump.
   - 1.3 Coordinate site visit with rig contractor and review location conditions.
   - 1.4 Drill "rathole" per rig layout.
   - 1.5 Install water, electrical and other utility systems as necessary.
   - 1.6 Pre-fabricate or prepare as much support equipment as necessary in advance of the rig.
   - 1.7 Coordinate site visit with ARE and rig contractor personnel to review rig footprint and rig-up plan.
2. **Move in selected drilling rig and associated equipment.**
   - 2.1 Conduct safety orientation and training with all rig and truck personnel prior to mobilization activities.
   - 2.2 Move in cranes, unload trucks, and set in rig equipment on the 55-29 pad per rig-up plan.
   - 2.3 Set in work/living trailers and hook up utilities.
   - 2.4 Install direct communications between rig floor, tool pusher and company man.
   - 2.5 Rig up mud logging equipment, H2S monitors, and all safety equipment.
   - 2.6 Fill all fuel and water tanks as necessary.
   - 2.7 Hook up circulating system. Fill mud pits as necessary and test all lines. Mix spud mud.
   - 2.8 Review all regulatory permits and compliance requirements.
   - 2.9 Hold pre-spud meeting. Discuss the proposed drilling program, geologic prognosis, directional program, chain of command, and any other relevant start-up operations.
3. **Drill 26" hole to 1100' +/-**
   - 3.1 Use 26" bit and mud motor assembly as directed. Use drilling jars on all assemblies.
   - 3.2 Keep hole as vertical as possible.
   - 3.3 Maintain mud properties and rheology per fluids program.
   - 3.4 Use LCM as directed for circulation control. Note: if high percentage of LCM is needed, use of drilling motor may be curtailed and shakers may need to be bypassed.
   - 3.5 Ensure that all mud cleaning equipment is working efficiently.
   - 3.6 Regulate ROP as necessary for efficient cleaning and solids processing.
   - 3.7 Take surveys every 250' +/-(30' off bottom).
   - 3.8 Mud logging(lithology analysis) will be conducted as directed.
   - 3.9 At T.D., circulate hole clean and make wiping trip.
4. **Install and cement 20" casing**
   - 4.1 Verify that the hole is staying full.
   - 4.2 Rig up casing handling and make-up equipment.
   - 4.3 Make up and run 20", 106.5#, K-55, Buttress casing to 1100' +/-(3' to 5' off bottom).
   - 4.4 Run casing guide shoe only.
   - 4.5 Place centralizer at shoe joint and every 3 casing collars to surface. Fill casing when RIH.
   - 4.6 Run casing slow to prevent surging.
   - 4.7 Condition mud for cement job.

4010 Stone Way N, Suite 400 • Seattle, WA 98103 • Telephone (206) 729-2400

4.8 Rig up cementing equipment. Prepare for reverse job with 30" conductor pipe. Connect to casing for returns and rig up manifold, including flow meter. Test all lines.

4.9 Establish circulation initially down the casing for bottoms up. Circulate down the 30"/20" annulus to check all flow systems and cool wellbore. Calibrate the flow meter.

4.10 Mix and displace cement slurry per program. Monitor and document returns. **(Note: 30% excess is being used with an objective of 300' of fill inside the casing.)**

4.11 Immediately shut in manifold flow valve. Wait on cement at least 15-18 hours. Perform top job(s) as necessary with tail slurry.

5. **Install casing head flange and BOPE. Test casing and BOPE.**

5.1 Cut off 30" conductor pipe and make an initial cut on the 20" casing.

5.2 Install 20" casing head. Space out casing head to height of BOP stack.

5.3 Nipple up 21-1/4" X 2000 psi double gate with CSO and pipe rams, annular preventer, and pitcher nipple.

5.4 Hook up flow line, kill and choke lines.

5.5 Make up 17-1/2" BHA. Tag top of cement and clean out inside 20" to 10' above shoe.

5.6 Notify BLM and DOGAMI as necessary.

5.7 Pressure test rams and casing to 1000 psi and annular preventers to 750 psi. Log test on tour sheet.

5.8 Drill to casing shoe and condition mud.

6. **Drill 17-1/2" hole to 3000' +/-.**

6.1 Use mud motor or steerable mud motor assemblies as directed. Use shock tools and drilling jars in all assemblies.

6.2 Keep hole as vertical as possible. Refer to directional program.

6.3 Drill 5 feet of new hole, circulate, spot a thick LCM pill and pull into the shoe.

6.4 Conduct leak off test using LOT procedure. Record result on tour sheet.

6.5 Drill 17-1/2" hole to 3000' +/-. Casing point will be determined by geology analysis.

6.6 Continued lithology analysis by mud loggers.

6.7 Maintain mud rheology properties per fluids program and solids control equipment.

6.8 At casing point, pump mud sweeps and circulate hole. Make wiping trip and condition mud as necessary. Strap pipe while POOH.

7. **Install and cement 13-3/8" casing**

7.1 Rig up casing handling and make-up equipment.

7.2 Make up and run 13-3/8", 68#, K-55, Buttress casing to 3000'+/-. Keep casing off bottom and in tension.

7.3 Run casing guide shoe only.

7.4 Place centralizer at shoe joint and every 3 casing collars to surface.

7.5 Run casing slow to prevent surging and fill while RIH.

7.6 Rig up cementing equipment. Prepare for reverse job and connect pumping lines to 13-3/8" annulus. Connect to casing for returns and rig up manifold, including flow meter. Test all lines.

7.7 Establish circulation initially down the casing for bottoms up. Circulate down the 20"/13-3/8" annulus to check all flow systems and cool wellbore. Calibrate the flow meter.

7.8 Mix and displace cement slurry per program. Monitor and document returns. **(Note: 30% excess is being used with an objective of 500' of fill inside the casing.)**

7.9 Immediately shut in manifold flow valve. Wait on cement at least 15-18 hours. Perform top job(s) as necessary with tail slurry.

8. **Install 13-3/8" casing head and BOP stack.**

8.1 Lift BOP and make an initial cut on the 13-3/8" casing. Lay down cut-off casing and nipple down BOPE.
8.2 Install SOW 13-3/8" 2M casing head with 3-1/8" side outlets casing head.
8.2.1 Use a certified welder and proper pre and post weld heat treatment.
8.2.2 Test casing head to 1000 psi.
8.3 Install 12" 1500 master valve(12-3/8" bore).
8.4 Nipple up 13-5/8" BOP stack with CSO and pipe rams, annular preventer, and rotating head.
8.5 Install flow line, kill and choke lines.
8.6 Pressure test casing and blind rams to 1000 psi. Log on tour sheet. Notify BLM and DOGAMI as required per permit conditions.
8.7 Make up 12-1/4" BHA. Tag top of cement and clean out inside 13-3/8" to 5' above shoe.
8.8 Pressure test pipe rams and casing to 1000 psi. Log test on tour sheet. Notify BLM and DOGAMI as needed.
8.9 Drill out to casing shoe and condition mud.

9. **<u>Drill 12-1/4" hole to 7100' +/- or as determined by geologist.</u>**

9.1 Rig up pumping and filtration equipment as necessary for water hammer drilling operations.
9.2 Drill out of casing shoe 5' of new hole. Conduct leak off test using LOT program.
9.3 Drill 12-1/4" hole to 7100' +/- using water hammer or steerable mud motor assemblies as needed for directional drilling and/or correction runs. Refer to directional well plan: at 3100', build angle to 6 deg and establish directional heading of S36E. Hold these parameters to 6300', then build angle to 16 deg and turn back to N86E heading. Hold to casing point.
9.4 Run non-magnetic drill collar with hammer BHA and take single shot surveys every 90'-120'. Run shock tool and jars for all runs.
9.5 Continue lithology analysis by mud loggers.
9.6 Install mud cooler as necessary if/when flowline temperature reaches 150 deg F.
9.7 Maintain mud rheology properties per fluids program and solids control equipment. Use filtration equipment as needed for water hammer drilling and hole cleaning.
9.8 Run open hole E-logs as directed.
9.9 At casing point, pump mud sweeps and circulate hole . Make wiping trip and condition mud as necessary. Strap pipe while POOH.

10. **<u>Install and cement 9-5/8" casing</u>**

10.1 Rig up casing handling and make-up equipment.
10.2 Make up and run 9-5/8"", 53.5#, L-80, VAM casing to 7100'+/-. Keep casing off bottom and in tension.
10.3 Run casing guide shoe only.
10.4 Place centralizer at shoe joint and every 3 casing collars to surface
10.5 Run casing slow to prevent surging and fill while RIH.
10.6 Rig up cementing equipment. Prepare for reverse job and connect pumping lines to 9-5/8" annulus. Connect to casing for returns and rig up manifold, including flow meter. Test all lines.
10.7 Establish circulation initially down the casing for bottoms up. Circulate down the 13-3/8"/9-5/8" annulus to check all flow systems and cool wellbore. Calibrate the flow meter.
10.8 Mix and displace cement slurry per program. Monitor and document returns. **(Note: 30% excess is being used with an objective of 500' of fill inside the casing.)**

10.9 Immediately shut in manifold flow valve. Wait on cement at least 15-18 hours. Perform top job(s) as necessary with tail slurry.

11. **Install 9-5/8' casing head and BOP stack**
    - 11.1 Lift BOP and make an initial cut on the 9-5/8" casing. Lay down cut-off casing and nipple down BOPE.
    - 11.2 Install SOW 9-5/8"(10" nominal) 5M casing head with 3-1/8" side outlets casing head.
        - 11.2.1 Use a certified welder and proper pre and post weld heat treatment.
        - 11.2.2 Test casing head to 4000 psi.
    - 11.3 Install 10" 1500 master valve(8-3/4" bore). Install 10" X 12" DSA to accommodate BOPE.
    - 11.4 Nipple up 13-5/8" BOP stack with CSO and pipe rams, annular preventer, and rotating head.
    - 11.5 Install flow line, kill and choke lines.
    - 11.6 Pressure test casing and blind rams to 4000 psi. Use pump truck. Log on tour sheet. Notify BLM and DOGAMI as required per permit conditions.
    - 11.7 Make up 8-1/2" BHA. Tag top of cement and clean out inside 9-5/8" to 5' above shoe.
    - 11.8 Pressure test pipe rams and casing to 4000 psi. Log test on tour sheet. Notify BLM and DOGAMI as needed.
    - 11.9 Drill out to casing shoe and condition fluid system for cement contamination.
12. **Drill 8-1/2" hole to 10,323' T.D +/- or as determined by geologist**
    - 12.1 Drill out of casing shoe 50' of new hole. Conduct in situ stress test per attached procedure(Appendix I-3).
    - 12.2 Drill 8-1/2" hole to 10,325' or as directed. Refer to directional plan. Hold 16 deg hole angle and N86E azimuth to projected T.D. at 10,323' M.D.(10,168' T.V.D.).
    - 12.3 Drill this entire interval with 8-1/2" water hammer if possible. Run Non-magnetic DC in the BHA and take single shot surveys every 90'-120'. Run shock tool and jars on all runs.
    - 12.4 Run steerable mud motor for any directional correctional runs as necessary.
    - 12.5 Continue lithology analysis by mud loggers.
    - 12.6 Install or continue using mud cooler as necessary.
    - 12.7 Maintain mud rheology properties per fluids program and solids control equipment. Use filtration equipment as needed for water hammer drilling and hole cleaning.
    - 12.8 Run open hole E-logs and P/T survey as directed. Run BHTV as directed to capture results of in situ stress test below 9-5/8" shoe.
    - 12.9 Circulate and clean hole . Make wiping trip and check for fill. Clean hole as necessary.
13. **7" Liner installation.**
    - 13.1 Rig up casing handling equipment.
    - **13.2 Make up 7" blank joint in the mouse hole with circulating head and inside BOP gate on top for well control contingency when making up the perforated pipe.**
    - 13.3 Make up 7", 26#, K-55, Buttress blank/perforated liner and 7" X 9-5/8" double-slip hanger. Run on drill pipe and hang from 6900' to 10,300'. Release from liner with setting tool. **Note: the top 300' of liner will be blank and the remainder will be perforated((3/4" holes, 10 rows X 6" centers, 20 holes/ft.).**
14. **Stimulation and Wellbore analysis.**
    - 14.1 Inject and stimulate well as directed.
    - 14.2 Run any logging and diagnostic tools as directed.
15. **Rig down**

15.1 Lay down drill pipe and tools.
15.2 Remove and dismantle BOP stack. Rig down flow line equipment and muffler.
15.3 Rig down all Hanjin equipment and prepare for shipping.
15.4 Release rig and prepare to load out for de-mobilization.

4010 Stone Way N, Suite 400 • Seattle, WA 98103 • Telephone (206) 729-2400

APPENDIX I-3

IN SITU STRESS TEST PROCEDURE

1. Drill a 50 ft rat hole below the 9-5/8" casing shoe.

2. Rig up pump truck and test equipment as shown in Figure 1.

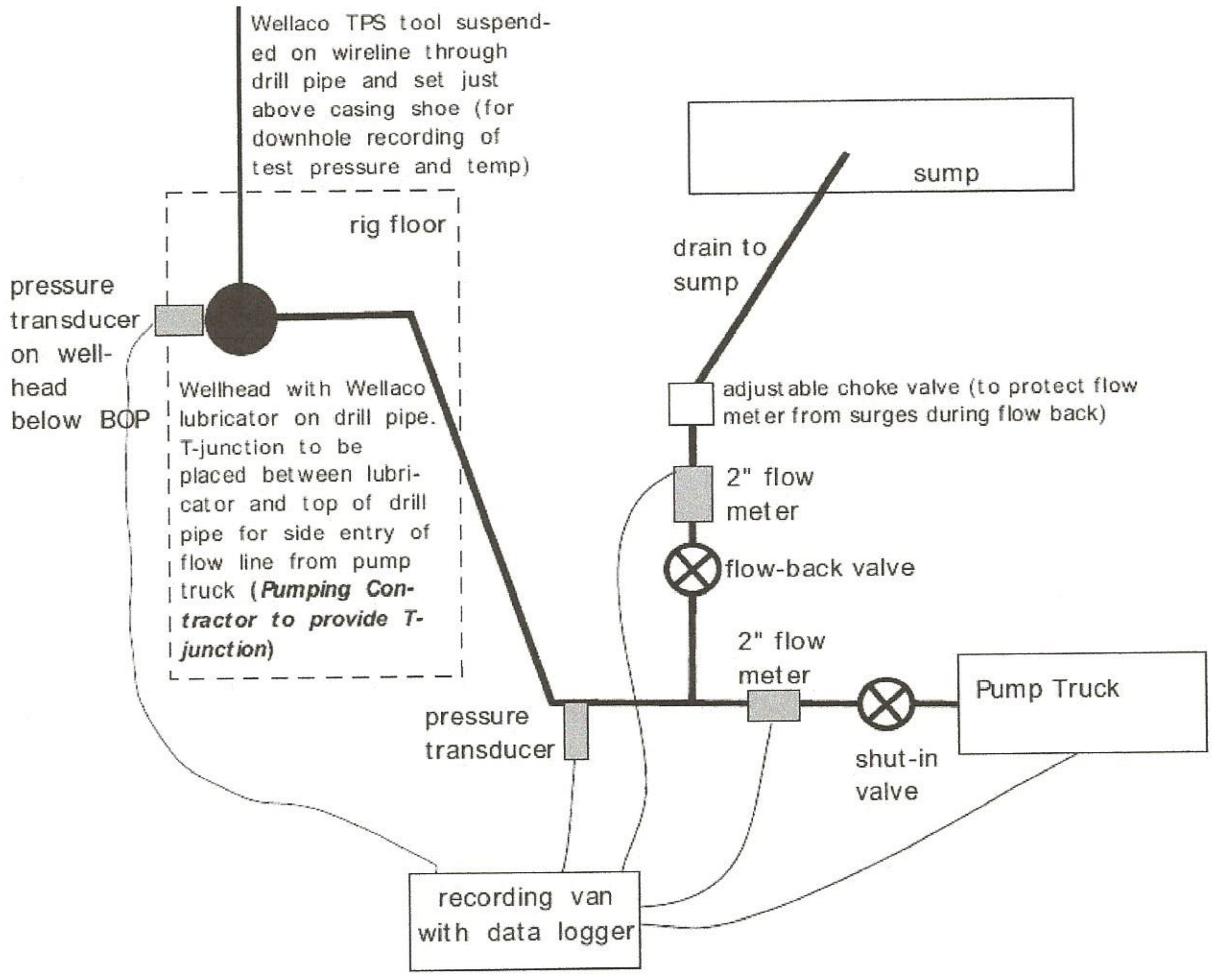
3. Run casing squeeze packer in hole on drill pipe and set inside 13-3/8" casing as deep as possible per temperature constraints. Rig up T-junction and lubricator at wellhead.

4. Run PTS tool into hole through lubricator to just above the casing shoe, stopping every 500 ft to record pressure and temperature.

5. Top off drill pipe with water, bleed air out of pumps and tubing, and close off lubricator. Connect pressure transducers and flow meters to flow lines and test them.

6. Close annular BOP and pressurize back side of RTTS tool to 200 psi and hold for duration of test. Record back side pressure (along with other test parameters) in recording van to check for packer bypass.

7. **PRE-INJECTION PULSE-DECAY PERMEABILITY TEST (takes 30 minutes)**
    a. Pump at 1 bpm to wellhead pressure of 150 psi, which is below the expected roll over pressure, and close shut-in valve.
    b. Monitor pressure until it decays to about 50% of its initial value, and then open flow-back valve to bleed off excess wellhead pressure.
    c. Allow pressure to equalize for 3 times duration of pulse before closing flow-back valve and starting injection test.



Notes:
1) Shut-in and flow-back valves must be quick-acting ball valves, for rapid closure.
2) Flow rates needed during test are 0.5-8 bbl/min, with anticipated wellhead pressure less than 5000 psi.
3) Recording van must have real-time visual display of surface flow rates, wellhead pressure and backside pressure.
4) Recording van must also record pump truck flow rate output derived from stroke counter (or similar means) so we have independent record of pump rate in case 2" flow meter fails.
5) 200 bbl of fresh water or produced reservoir fluid needed for pumping during test.
6) Pressure transducer on BOP stack is to monitor pressure on back side of RTTS during test.

Figure 9.2-1 Surface equipment layout for formation injection test. ***Unless otherwise noted, all equipment shown is to be provided by pumping vendor.***

8. <u>**FORMATION INECTION TEST (takes about 1 hour)**</u>
   a. Conduct cycle #1 of test, pumping at 1 bpm until pressure rolls over, indicating breakdown.
   b. If breakdown rollover occurs, immediately stop pumping, close shut-in valve, and monitor shut-in pressure decay. If breakdown does not occur, stop pumping, open flow-back valve, bleed off wellhead pressure for 3 times duration of pumping, and repeat step 10 at 2 bbl/min.

c. After monitoring shut-in decay for 5 minutes, open flow-back valve and bleed off excess wellhead pressure.
d. Close flow-back valve and repeat steps 9a – 9c for three or four additional cycles at the same flow rate, but for progressively longer and longer durations, until stable pumping and instantaneous shut-in pressures are obtained.
e. Conduct variable flowrate (step-rate) injection test as an additional check on the least principal stress. Start at lowest possible flow rate (0.25 - 0.5 bbl/min) and increase in stepwise manner to 5-8 bbl/min, waiting until pressure is approximately stabilized at each flow rate.
f. Close shut-in valve and monitor pressure decay for 10 minutes.
g. Open flow-back valve and bleed off excess wellhead pressure.

9. **POST-INJECTION PULSE-DECAY PERMEABILITY TEST (takes 30 minutes)**
   a. Close flow-back valve and wait until wellhead pressure stabilizes (this provides a stable background pressure on which to superimpose pulse-decay permeability test).
   b. Pump at 1 bpm to wellhead pressure of 150 psi, which is well below the expected roll over pressure, and close shut-in valve.
   c. Monitor pressure until it decays to about 50% of its initial value, and then open flow-back valve to bleed off excess wellhead pressure.

10. Release lubricator and pull PTS tool from well, stopping every 500 ft to record pressure and temperature. Unset RTTS tool and pull out of hole. LD RTTS. *DATA REVIEW

ALTAROCK ENERGY INC

Bore Hole Schematic

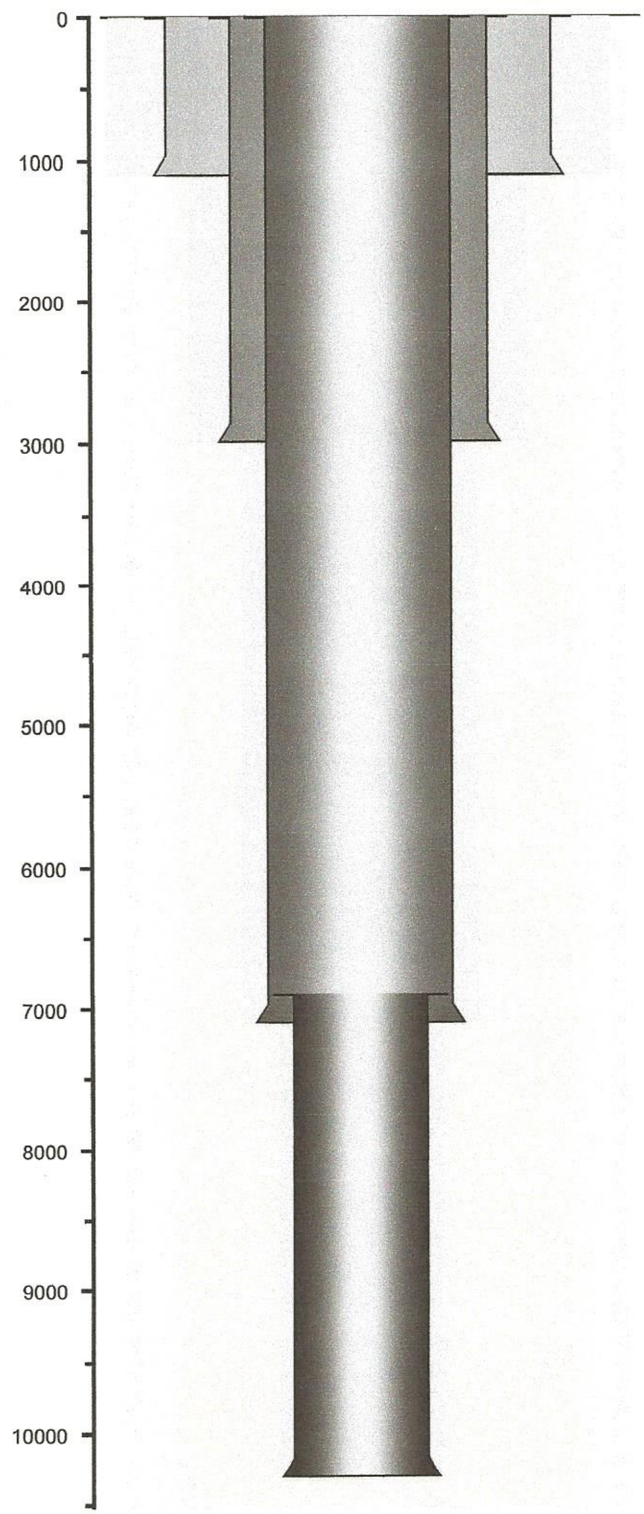
Well ID: 55A-29

Report Date: 28-Mar-06

AltaRock Energy

Well Name: 55A-29

Plan Data



Ground Level
All Depths are relative to the Original RKB Elevation
Original RKB Elevation at 0.00ft above Ground Level

Section - SURF - 26ins Hole to 1100ft
20ins Casing to 1100ft (to ft TVD)
Casing Grade: K55, Weight: 106.5, Connection: BUTT

Section - INT1 - 17.5ins Hole to 3000ft
13.375ins Casing to 3000ft (to ft TVD)
Casing Grade: K-55, Weight: 68, Connection: BUTT

Section - PRD1 - 12.25ins Hole to 7100ft
9.625ins Casing to 7100ft (to ft TVD)
Casing Grade: L-80, Weight: 53.5, Connection: VAM

7" Liner will be a combination of blanks and perfs.
Perfs from 7500' to 10,300' with 3/4 round holes, 20 hpf.

Section - PROD - 8.5ins Hole to 10300ft (10100ft TVD)
7ins Casing from 6900ft to 10300ft (to ft TVD)
Casing Grade: K-55, Weight: 26, Connection: BUTT

ALTAROCK ENERGY

Location:	OREGON	Slot:	NWG 55A-29
Field:	Newberry_	Well:	NWG 55A-29
Facility:	SECTION 29 T21S R12E	Wellbore:	NWG 55A-29

Well Profile Data

Design Comment	MD (ft)	Inc (°)	Az (°)	TVD (ft)	Local N (ft)	Local E (ft)	DLS (°/100ft)	VS (ft)
Tie On	0.00	0.000	143.267	0.00	0.00	0.00	0.00	0.00
End of Tangent	3100.00	0.000	143.267	3100.00	0.00	0.00	0.00	0.00
End of Build (XS)	3392.02	5.840	143.267	3391.51	-11.92	8.89	2.00	10.73
End of Tangent (XS)	6299.48	5.840	143.267	6283.88	-249.02	185.84	0.00	224.19
End of 3D Arc (XS)	6983.11	15.914	85.740	6955.83	-270.04	300.66	2.00	340.90
End of Tangent (XS)	7083.11	15.914	85.740	7052.00	-268.00	328.00	0.00	367.54
End of Tangent	10323.30	15.914	85.740	10168.00	-202.00	1214.00	0.00	1230.69

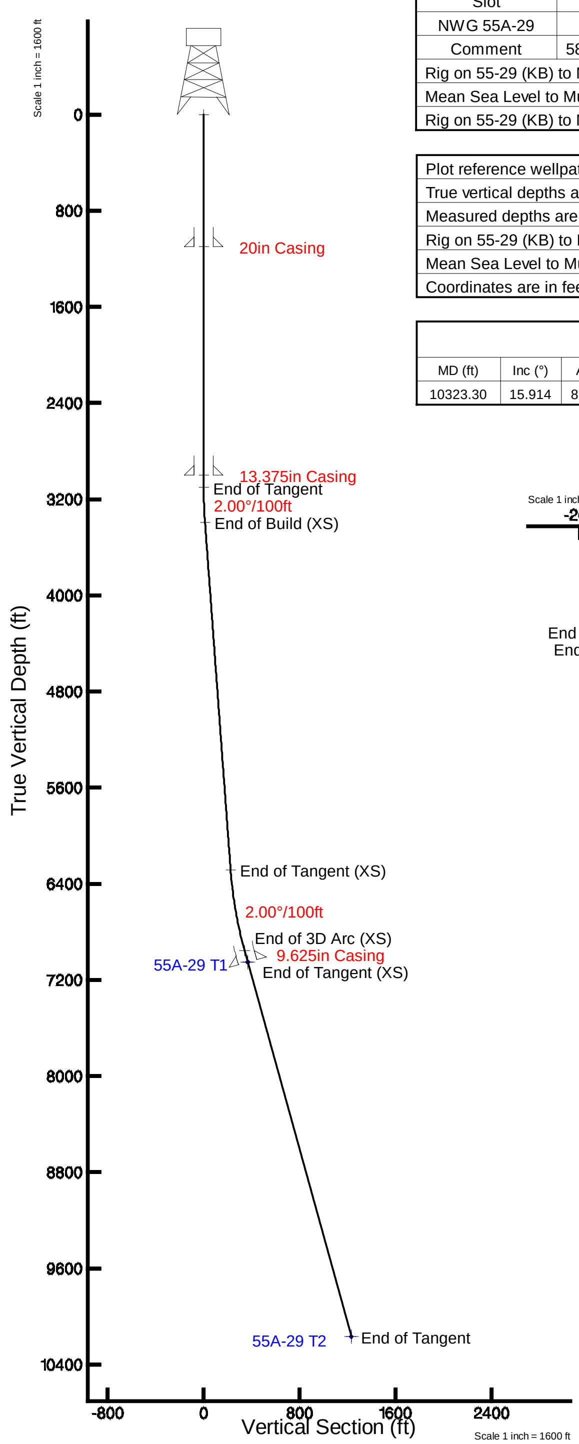
Location Information

Facility Name			Grid East (m)	Grid North (m)	Latitude	Longitude
SECTION 29 T21S R12E			636190.000	4841960.000	43°43'05.403"N	121°18'33.537"W
Slot	Local N (ft)	Local E (ft)	Grid East (m)	Grid North (m)	Latitude	Longitude
NWG 55A-29	2779.35	-1709.61	635669.000	4842807.000	43°43'33.190"N	121°18'56.042"W
Comment	5846' INCLUDES 31' RIG KB					
Rig on 55-29 (KB) to Mud line (At Slot: NWG 55A-29)					5846ft	
Mean Sea Level to Mud line (At Slot: NWG 55A-29)					0ft	
Rig on 55-29 (KB) to Mean Sea Level					5846ft	

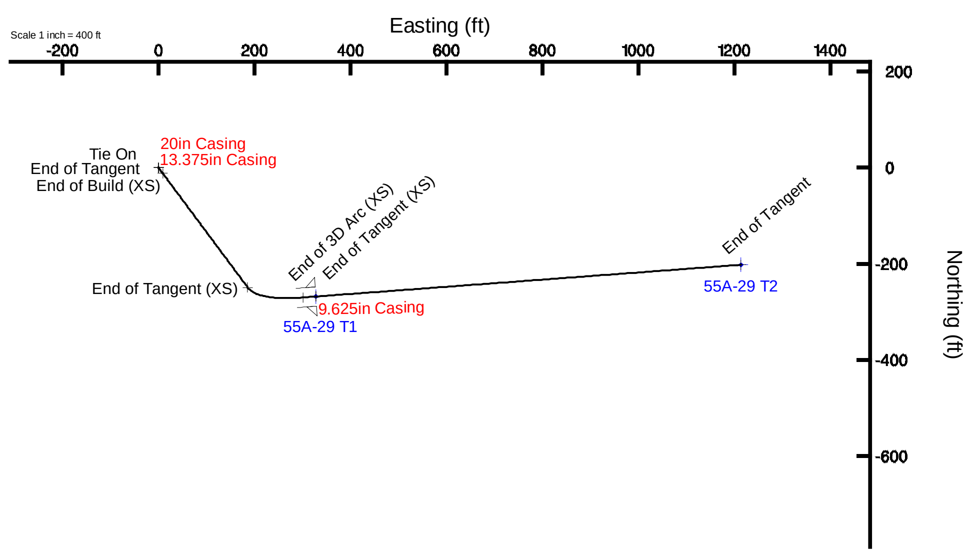
Plot reference wellpath is NWG 55A-29 Rev-A.0	
True vertical depths are referenced to Rig on 55-29 (KB)	Grid System: NAD83 / UTM Zone 10 North
Measured depths are referenced to Rig on 55-29 (KB)	North Reference: Grid north
Rig on 55-29 (KB) to Mean Sea Level: 5846 feet	Scale: True distance
Mean Sea Level to Mud line (At Slot: NWG 55A-29): 0 feet	Depths are in feet
Coordinates are in feet referenced to Slot	Created by: vazqjosl on 3/18/2015

Bottom Hole Location

MD (ft)	Inc (°)	Az (°)	TVD (ft)	Local N (ft)	Local E (ft)	Grid East (m)	Grid North (m)	Latitude	Longitude
10323.30	15.914	85.740	10168.00	-202.00	1214.00	636038.96	4842745.44	43°43'30.951"N	121°18'39.569"W



Azimuth 99.45° with reference 0.00 N, 0.00 E



ALTAROCK

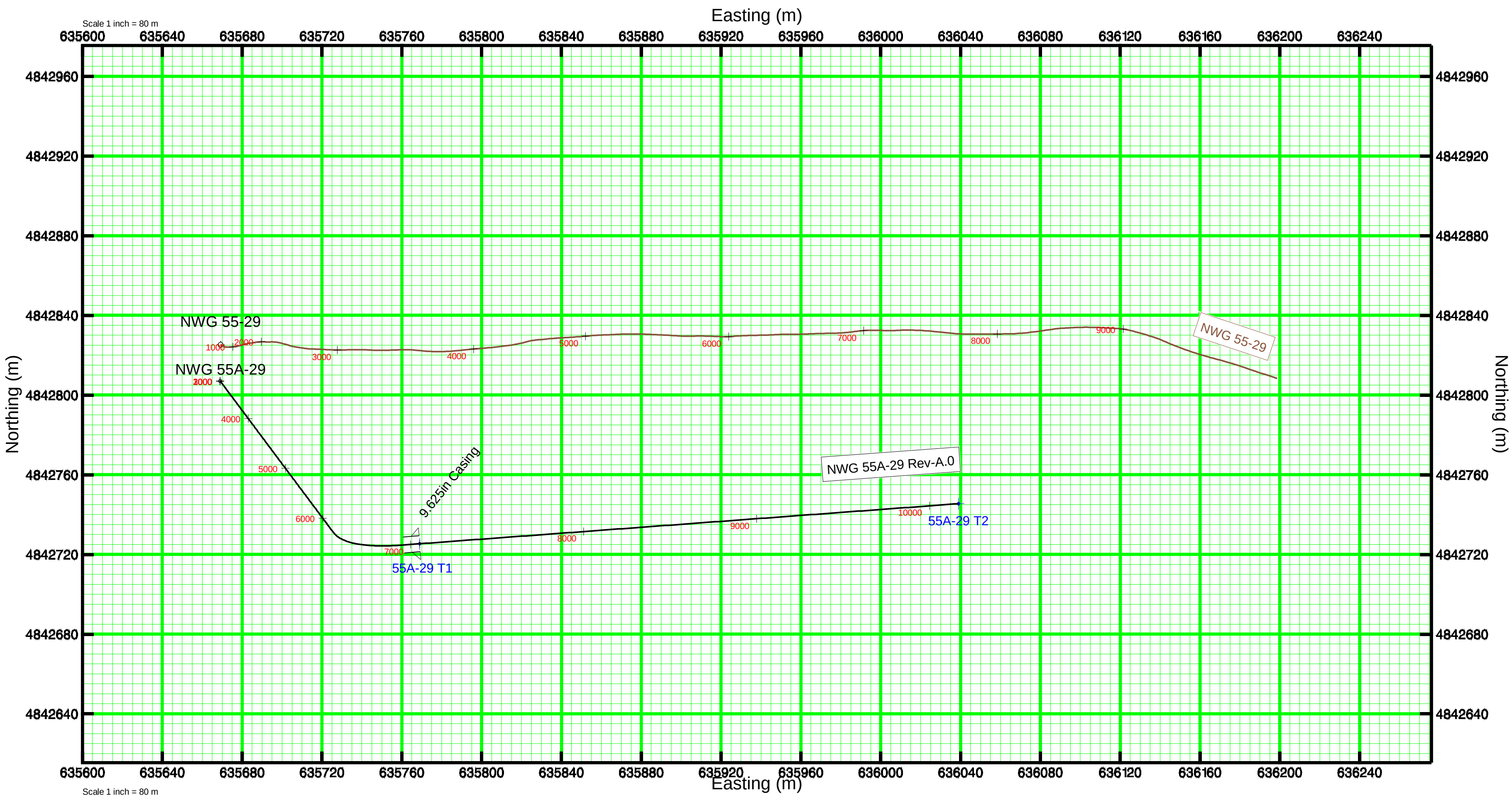
ALTAROCK ENERGY

Location: OREGON
Field: Newberry_
Facility: SECTION 29 T21S R12E

Slot: NWG 55A-29
Well: NWG 55A-29
Wellbore: NWG 55A-29

BAKER HUGHES

Plot reference wellpath is NWG 55A-29 Rev-A.0	
True vertical depths are referenced to Rig on 55-29 (KB)	Grid System: NAD83 / UTM Zone 10 North
Measured depths are referenced to Rig on 55-29 (KB)	North Reference: Grid north
Rig on 55-29 (KB) to Mean Sea Level: 5846 feet	Scale: True distance
Mean Sea Level to Mud line (At Slot: NWG 55A-29): 0 feet	Depths are in feet
Coordinates are in feet referenced to Slot	Created by: vazqjosl on 3/18/2015



Planned Wellpath Report

NWG 55A-29 Rev-A.0

REFERENCE WELLPATH IDENTIFICATION			
Operator	**ALTAROCK ENERGY**	Slot	**NWG 55A-29**
Area	**OREGON**	Well	**NWG 55A-29**
Field	**Newberry_**	Wellbore	**NWG 55A-29**
Facility	**SECTION 29 T21S R12E**		

REPORT SETUP INFORMATION			
Projection System	**NAD83 / UTM Zone 10 North**	Software System	**WellArchitect® 4.0.0**
North Reference	**Grid**	User	**Vazqjosl**
Scale	**0.999826**	Report Generated	**3/18/2015** at **10:45:22 AM**
Convergence at slot	**1.16° East**	Database/Source file	**BHI_Shafter/NWG_55A-29.xml**

WELLPATH LOCATION						
	Local coordinates		**Grid coordinates**		**Geographic coordinates**	
	North[ft]	**East[ft]**	**Easting[m]**	**Northing[m]**	**Latitude**	**Longitude**
Slot Location	2779.35	-1709.61	**635669.00**	**4842807.00**	43°43'33.190"N	121°18'56.042"W
Facility Reference Pt			**636190.00**	**4841960.00**	43°43'05.403"N	121°18'33.537"W
Field Reference Pt			636450.44	4802503.65	**43°21'46.800"N**	**121°18'57.600"W**

WELLPATH DATUM			
Calculation method	**Minimum curvature**	Rig on 55-29 (KB) to Facility Vertical Datum	**5846.00ft**
Horizontal Reference Pt	**Slot**	Rig on 55-29 (KB) to Mean Sea Level	**5846.00ft**
Vertical Reference Pt	**Rig on 55-29 (KB)**	Rig on 55-29 (KB) to Mud Line at Slot (NWG 55A-29)	**5846.00ft**
MD Reference Pt	**Rig on 55-29 (KB)**	Section Origin	**N 0.00, E 0.00 ft**
Field Vertical Reference	**Mean Sea Level**	Section Azimuth	**99.45°**

REFERENCE WELLPATH IDENTIFICATION			
Operator	**ALTAROCK ENERGY**	Slot	**NWG 55A-29**
Area	**OREGON**	Well	**NWG 55A-29**
Field	**Newberry_**	Wellbore	**NWG 55A-29**
Facility	**SECTION 29 T21S R12E**		

WELLPATH DATA (109 stations) † = interpolated/extrapolated station

MD [ft]	Inclination [°]	Azimuth [°]	TVD [ft]	TVD from Fld Vert Ref [ft]	Vert Sect [ft]	North [ft]	East [ft]	Grid East [m]	Grid North [m]	DLS [°/100ft]	Toolface [°]	Build Rate [°/100ft]	Turn Rate [°/100ft]	Comments
0.00	0.000	143.267	0.00	-5846.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	Tie On
100.00†	0.000	143.267	100.00	-5746.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
200.00†	0.000	143.267	200.00	-5646.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
300.00†	0.000	143.267	300.00	-5546.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
400.00†	0.000	143.267	400.00	-5446.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
500.00†	0.000	143.267	500.00	-5346.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
600.00†	0.000	143.267	600.00	-5246.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
700.00†	0.000	143.267	700.00	-5146.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
800.00†	0.000	143.267	800.00	-5046.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
900.00†	0.000	143.267	900.00	-4946.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
1000.00†	0.000	143.267	1000.00	-4846.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
1100.00†	0.000	143.267	1100.00	-4746.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
1200.00†	0.000	143.267	1200.00	-4646.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
1300.00†	0.000	143.267	1300.00	-4546.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
1400.00†	0.000	143.267	1400.00	-4446.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
1500.00†	0.000	143.267	1500.00	-4346.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
1600.00†	0.000	143.267	1600.00	-4246.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
1700.00†	0.000	143.267	1700.00	-4146.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
1800.00†	0.000	143.267	1800.00	-4046.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
1900.00†	0.000	143.267	1900.00	-3946.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
2000.00†	0.000	143.267	2000.00	-3846.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
2100.00†	0.000	143.267	2100.00	-3746.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
2200.00†	0.000	143.267	2200.00	-3646.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
2300.00†	0.000	143.267	2300.00	-3546.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
2400.00†	0.000	143.267	2400.00	-3446.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
2500.00†	0.000	143.267	2500.00	-3346.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
2600.00†	0.000	143.267	2600.00	-3246.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
2700.00†	0.000	143.267	2700.00	-3146.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
2800.00†	0.000	143.267	2800.00	-3046.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
2900.00†	0.000	143.267	2900.00	-2946.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
3000.00†	0.000	143.267	3000.00	-2846.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	0.00	0.00	0.00	
3100.00	0.000	143.267	3100.00	-2746.00	0.00	0.00	0.00	635669.00	4842807.00	0.00	143.27	0.00	0.00	End of Tangent
3200.00†	2.000	143.267	3199.98	-2646.02	1.26	-1.40	1.04	635669.32	4842806.57	2.00	0.00	2.00	0.00	
3300.00†	4.000	143.267	3299.84	-2546.16	5.04	-5.59	4.17	635670.27	4842805.30	2.00	0.00	2.00	0.00	
3392.02	5.840	143.267	3391.51	-2454.49	10.73	-11.92	8.89	635671.71	4842803.37	2.00	0.00	2.00	0.00	End of Build (XS)
3400.00†	5.840	143.267	3399.45	-2446.55	11.32	-12.57	9.38	635671.86	4842803.17	0.00	0.00	0.00	0.00	
3500.00†	5.840	143.267	3498.93	-2347.07	18.66	-20.72	15.47	635673.71	4842800.68	0.00	0.00	0.00	0.00	
3600.00†	5.840	143.267	3598.41	-2247.59	26.00	-28.88	21.55	635675.57	4842798.20	0.00	0.00	0.00	0.00	
3700.00†	5.840	143.267	3697.90	-2148.10	33.34	-37.03	27.64	635677.42	4842795.71	0.00	0.00	0.00	0.00	
3800.00†	5.840	143.267	3797.38	-2048.62	40.68	-45.19	33.72	635679.28	4842793.23	0.00	0.00	0.00	0.00	
3900.00†	5.840	143.267	3896.86	-1949.14	48.03	-53.34	39.81	635681.13	4842790.74	0.00	0.00	0.00	0.00	
4000.00†	5.840	143.267	3996.34	-1849.66	55.37	-61.50	45.90	635682.99	4842788.26	0.00	0.00	0.00	0.00	
4100.00†	5.840	143.267	4095.82	-1750.18	62.71	-69.65	51.98	635684.84	4842785.77	0.00	0.00	0.00	0.00	
4200.00†	5.840	143.267	4195.30	-1650.70	70.05	-77.81	58.07	635686.70	4842783.29	0.00	0.00	0.00	0.00	
4300.00†	5.840	143.267	4294.78	-1551.22	77.39	-85.96	64.15	635688.55	4842780.80	0.00	0.00	0.00	0.00	

Planned Wellpath Report

NWG 55A-29 Rev-A.0

REFERENCE WELLPATH IDENTIFICATION			
Operator	**ALTAROCK ENERGY**	Slot	**NWG 55A-29**
Area	**OREGON**	Well	**NWG 55A-29**
Field	**Newberry_**	Wellbore	**NWG 55A-29**
Facility	**SECTION 29 T21S R12E**		

WELLPATH DATA (109 stations) † = interpolated/extrapolated station

MD [ft]	Inclination [°]	Azimuth [°]	TVD [ft]	TVD from Fld Vert Ref [ft]	Vert Sect [ft]	North [ft]	East [ft]	Grid East [m]	Grid North [m]	DLS [°/100ft]	Toolface [°]	Build Rate [°/100ft]	Turn Rate [°/100ft]	Comments
4400.00†	5.840	143.267	4394.26	-1451.74	84.73	-94.12	70.24	635690.41	4842778.32	0.00	0.00	0.00	0.00	
4500.00†	5.840	143.267	4493.74	-1352.26	92.08	-102.27	76.33	635692.26	4842775.83	0.00	0.00	0.00	0.00	
4600.00†	5.840	143.267	4593.22	-1252.78	99.42	-110.43	82.41	635694.11	4842773.35	0.00	0.00	0.00	0.00	
4700.00†	5.840	143.267	4692.71	-1153.29	106.76	-118.58	88.50	635695.97	4842770.86	0.00	0.00	0.00	0.00	
4800.00†	5.840	143.267	4792.19	-1053.81	114.10	-126.74	94.58	635697.82	4842768.38	0.00	0.00	0.00	0.00	
4900.00†	5.840	143.267	4891.67	-954.33	121.44	-134.90	100.67	635699.68	4842765.89	0.00	0.00	0.00	0.00	
5000.00†	5.840	143.267	4991.15	-854.85	128.79	-143.05	106.75	635701.53	4842763.41	0.00	0.00	0.00	0.00	
5100.00†	5.840	143.267	5090.63	-755.37	136.13	-151.21	112.84	635703.39	4842760.92	0.00	0.00	0.00	0.00	
5200.00†	5.840	143.267	5190.11	-655.89	143.47	-159.36	118.93	635705.24	4842758.44	0.00	0.00	0.00	0.00	
5300.00†	5.840	143.267	5289.59	-556.41	150.81	-167.52	125.01	635707.10	4842755.95	0.00	0.00	0.00	0.00	
5400.00†	5.840	143.267	5389.07	-456.93	158.15	-175.67	131.10	635708.95	4842753.46	0.00	0.00	0.00	0.00	
5500.00†	5.840	143.267	5488.55	-357.45	165.50	-183.83	137.18	635710.81	4842750.98	0.00	0.00	0.00	0.00	
5600.00†	5.840	143.267	5588.03	-257.97	172.84	-191.98	143.27	635712.66	4842748.49	0.00	0.00	0.00	0.00	
5700.00†	5.840	143.267	5687.51	-158.49	180.18	-200.14	149.36	635714.52	4842746.01	0.00	0.00	0.00	0.00	
5800.00†	5.840	143.267	5787.00	-59.00	187.52	-208.29	155.44	635716.37	4842743.52	0.00	0.00	0.00	0.00	
5900.00†	5.840	143.267	5886.48	40.48	194.86	-216.45	161.53	635718.23	4842741.04	0.00	0.00	0.00	0.00	
6000.00†	5.840	143.267	5985.96	139.96	202.21	-224.60	167.61	635720.08	4842738.55	0.00	0.00	0.00	0.00	
6100.00†	5.840	143.267	6085.44	239.44	209.55	-232.76	173.70	635721.93	4842736.07	0.00	0.00	0.00	0.00	
6200.00†	5.840	143.267	6184.92	338.92	216.89	-240.91	179.79	635723.79	4842733.58	0.00	0.00	0.00	0.00	
6299.48	5.840	143.267	6283.88	437.88	224.19	-249.02	185.84	635725.63	4842731.11	0.00	-78.14	0.00	0.00	End of Tangent (XS)
6300.00†	5.843	143.166	6284.40	438.40	224.23	-249.07	185.87	635725.64	4842731.10	2.00	-78.04	0.41	-19.23	
6400.00†	6.555	125.764	6383.82	537.82	233.03	-256.48	193.56	635727.99	4842728.84	2.00	-60.73	0.71	-17.40	
6500.00†	7.731	112.684	6483.05	637.05	244.69	-262.41	204.39	635731.29	4842727.03	2.00	-47.75	1.18	-13.08	
6600.00†	9.195	103.380	6581.97	735.97	259.21	-266.85	218.37	635735.55	4842725.68	2.00	-38.55	1.46	-9.30	
6700.00†	10.831	96.733	6680.44	834.44	276.57	-269.80	235.48	635740.76	4842724.78	2.00	-32.00	1.64	-6.65	
6800.00†	12.571	91.858	6778.36	932.36	296.74	-271.26	255.69	635746.92	4842724.34	2.00	-27.23	1.74	-4.87	
6900.00†	14.378	88.171	6875.61	1029.61	319.71	-271.21	278.98	635754.02	4842724.35	2.00	-23.64	1.81	-3.69	
6983.11	15.914	85.740	6955.83	1109.83	340.90	-270.04	300.66	635760.62	4842724.71	2.00	0.05	1.85	-2.93	End of 3D Arc (XS)
7000.00†	15.914	85.740	6972.07	1126.07	345.40	-269.69	305.27	635762.03	4842724.81	0.00	-179.95	0.00	0.00	
7083.11	15.914	85.740	7052.00[1]	1206.00	367.54	-268.00	328.00	635768.96	4842725.33	0.00	0.00	0.00	0.00	End of Tangent (XS)
7100.00†	15.914	85.740	7068.24	1222.24	372.04	-267.66	332.62	635770.36	4842725.43	0.00	0.00	0.00	0.00	
7200.00†	15.914	85.740	7164.41	1318.41	398.68	-265.62	359.96	635778.70	4842726.05	0.00	0.00	0.00	0.00	
7300.00†	15.914	85.740	7260.57	1414.57	425.32	-263.58	387.31	635787.03	4842726.67	0.00	0.00	0.00	0.00	
7400.00†	15.914	85.740	7356.74	1510.74	451.96	-261.55	414.65	635795.36	4842727.29	0.00	0.00	0.00	0.00	
7500.00†	15.914	85.740	7452.91	1606.91	478.59	-259.51	441.99	635803.70	4842727.92	0.00	0.00	0.00	0.00	
7600.00†	15.914	85.740	7549.08	1703.08	505.23	-257.47	469.34	635812.03	4842728.54	0.00	0.00	0.00	0.00	
7700.00†	15.914	85.740	7645.24	1799.24	531.87	-255.43	496.68	635820.36	4842729.16	0.00	0.00	0.00	0.00	
7800.00†	15.914	85.740	7741.41	1895.41	558.51	-253.40	524.03	635828.70	4842729.78	0.00	0.00	0.00	0.00	
7900.00†	15.914	85.740	7837.58	1991.58	585.15	-251.36	551.37	635837.03	4842730.40	0.00	0.00	0.00	0.00	
8000.00†	15.914	85.740	7933.75	2087.75	611.79	-249.32	578.71	635845.36	4842731.02	0.00	0.00	0.00	0.00	
8100.00†	15.914	85.740	8029.91	2183.91	638.43	-247.29	606.06	635853.69	4842731.64	0.00	0.00	0.00	0.00	
8200.00†	15.914	85.740	8126.08	2280.08	665.07	-245.25	633.40	635862.03	4842732.26	0.00	0.00	0.00	0.00	
8300.00†	15.914	85.740	8222.25	2376.25	691.71	-243.21	660.75	635870.36	4842732.88	0.00	0.00	0.00	0.00	
8400.00†	15.914	85.740	8318.41	2472.41	718.34	-241.18	688.09	635878.69	4842733.50	0.00	0.00	0.00	0.00	
8500.00†	15.914	85.740	8414.58	2568.58	744.98	-239.14	715.44	635887.03	4842734.12	0.00	0.00	0.00	0.00	

Planned Wellpath Report

NWG 55A-29 Rev-A.0

REFERENCE WELLPATH IDENTIFICATION

Operator	**ALTAROCK ENERGY**	Slot	**NWG 55A-29**
Area	**OREGON**	Well	**NWG 55A-29**
Field	**Newberry_**	Wellbore	**NWG 55A-29**
Facility	**SECTION 29 T21S R12E**		

WELLPATH DATA (109 stations) † = interpolated/extrapolated station

MD [ft]	Inclination [°]	Azimuth [°]	TVD [ft]	TVD from Fld Vert Ref [ft]	Vert Sect [ft]	North [ft]	East [ft]	Grid East [m]	Grid North [m]	DLS [°/100ft]	Toolface [°]	Build Rate [°/100ft]	Turn Rate [°/100ft]	Comments
8600.00†	15.914	85.740	8510.75	2664.75	771.62	-237.10	742.78	635895.36	4842734.74	0.00	0.00	0.00	0.00	
8700.00†	15.914	85.740	8606.92	2760.92	798.26	-235.07	770.12	635903.69	4842735.36	0.00	0.00	0.00	0.00	
8800.00†	15.914	85.740	8703.08	2857.08	824.90	-233.03	797.47	635912.03	4842735.99	0.00	0.00	0.00	0.00	
8900.00†	15.914	85.740	8799.25	2953.25	851.54	-230.99	824.81	635920.36	4842736.61	0.00	0.00	0.00	0.00	
9000.00†	15.914	85.740	8895.42	3049.42	878.18	-228.95	852.16	635928.69	4842737.23	0.00	0.00	0.00	0.00	
9100.00†	15.914	85.740	8991.59	3145.59	904.82	-226.92	879.50	635937.02	4842737.85	0.00	0.00	0.00	0.00	
9200.00†	15.914	85.740	9087.75	3241.75	931.46	-224.88	906.84	635945.36	4842738.47	0.00	0.00	0.00	0.00	
9300.00†	15.914	85.740	9183.92	3337.92	958.09	-222.84	934.19	635953.69	4842739.09	0.00	0.00	0.00	0.00	
9400.00†	15.914	85.740	9280.09	3434.09	984.73	-220.81	961.53	635962.02	4842739.71	0.00	0.00	0.00	0.00	
9500.00†	15.914	85.740	9376.25	3530.25	1011.37	-218.77	988.88	635970.36	4842740.33	0.00	0.00	0.00	0.00	
9600.00†	15.914	85.740	9472.42	3626.42	1038.01	-216.73	1016.22	635978.69	4842740.95	0.00	0.00	0.00	0.00	
9700.00†	15.914	85.740	9568.59	3722.59	1064.65	-214.70	1043.56	635987.02	4842741.57	0.00	0.00	0.00	0.00	
9800.00†	15.914	85.740	9664.76	3818.76	1091.29	-212.66	1070.91	635995.36	4842742.19	0.00	0.00	0.00	0.00	
9900.00†	15.914	85.740	9760.92	3914.92	1117.93	-210.62	1098.25	636003.69	4842742.81	0.00	0.00	0.00	0.00	
10000.00†	15.914	85.740	9857.09	4011.09	1144.57	-208.59	1125.60	636012.02	4842743.43	0.00	0.00	0.00	0.00	
10100.00†	15.914	85.740	9953.26	4107.26	1171.21	-206.55	1152.94	636020.36	4842744.05	0.00	0.00	0.00	0.00	
10200.00†	15.914	85.740	10049.43	4203.43	1197.85	-204.51	1180.28	636028.69	4842744.68	0.00	0.00	0.00	0.00	
10300.00†	15.914	85.740	10145.59	4299.59	1224.48	-202.47	1207.63	636037.02	4842745.30	0.00	0.00	0.00	0.00	
10323.30	15.914	85.740	10168.00[2]	4322.00	1230.69	-202.00	1214.00	636038.96	4842745.44	0.00		0.00	0.00	End of Tangent

HOLE & CASING SECTIONS - Ref Wellbore: NWG 55A-29 Ref Wellpath: NWG 55A-29 Rev-A.0

String/Diameter	Start MD [ft]	End MD [ft]	Interval [ft]	Start TVD [ft]	End TVD [ft]	Start N/S [ft]	Start E/W [ft]	End N/S [ft]	End E/W [ft]
26in Open Hole	0.00	1100.00	1100.00	0.00	1100.00	0.00	0.00	0.00	0.00
20in Casing	0.00	1100.00	1100.00	0.00	1100.00	0.00	0.00	0.00	0.00
17.5in Open Hole	0.00	3000.00	3000.00	0.00	3000.00	0.00	0.00	0.00	0.00
13.375in Casing	0.00	3000.00	3000.00	0.00	3000.00	0.00	0.00	0.00	0.00
12.25in Open Hole	0.00	7083.11	7083.11	0.00	7052.00	0.00	0.00	-268.00	328.00
9.625in Casing	0.00	7083.11	7083.11	0.00	7052.00	0.00	0.00	-268.00	328.00
8.5in Open Hole	0.00	10323.30	10323.30	0.00	10168.00	0.00	0.00	-202.00	1214.00

Planned Wellpath Report

NWG 55A-29 Rev-A.0

REFERENCE WELLPATH IDENTIFICATION			
Operator	**ALTAROCK ENERGY**	Slot	**NWG 55A-29**
Area	**OREGON**	Well	**NWG 55A-29**
Field	**Newberry_**	Wellbore	**NWG 55A-29**
Facility	**SECTION 29 T21S R12E**		

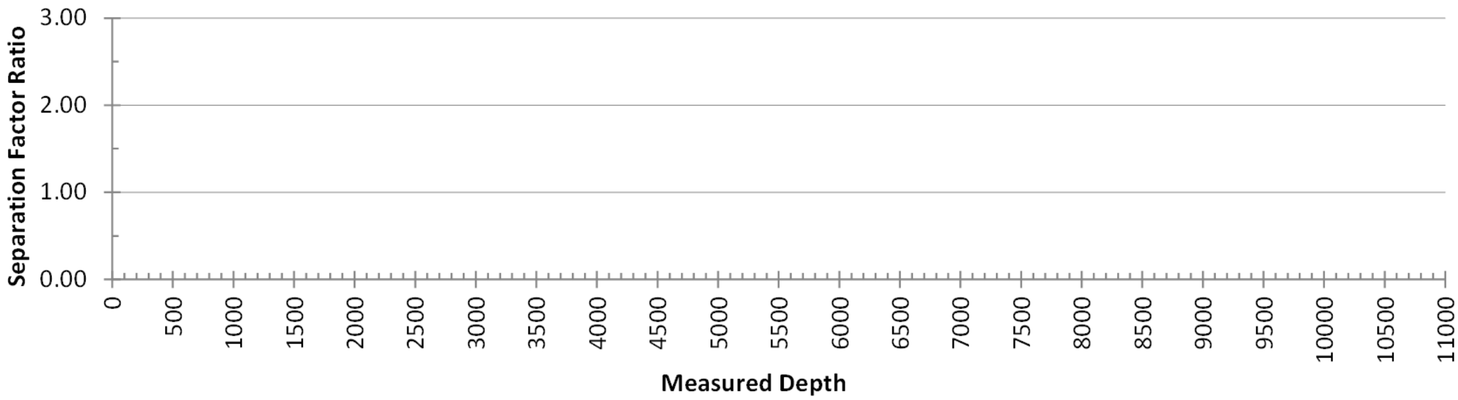
TARGETS									
Name	**MD [ft]**	**TVD [ft]**	**North [ft]**	**East [ft]**	**Grid East [m]**	**Grid North [m]**	**Latitude**	**Longitude**	**Shape**
1) 55A-29 T1	7083.11	7052.00	-268.00	328.00	635768.96	4842725.33	43°43'30.478"N	121°18'51.651"W	point
2) 55A-29 T2	10323.30	10168.00	-202.00	1214.00	636038.96	4842745.44	43°43'30.951"N	121°18'39.569"W	point

SURVEY PROGRAM - Ref Wellbore: NWG 55A-29 Ref Wellpath: NWG 55A-29 Rev-A.0				
Start MD [ft]	**End MD [ft]**	**Positional Uncertainty Model**	**Log Name/Comment**	**Wellbore**
0.00	10325.28	NaviTrak (Standard)		NWG 55A-29

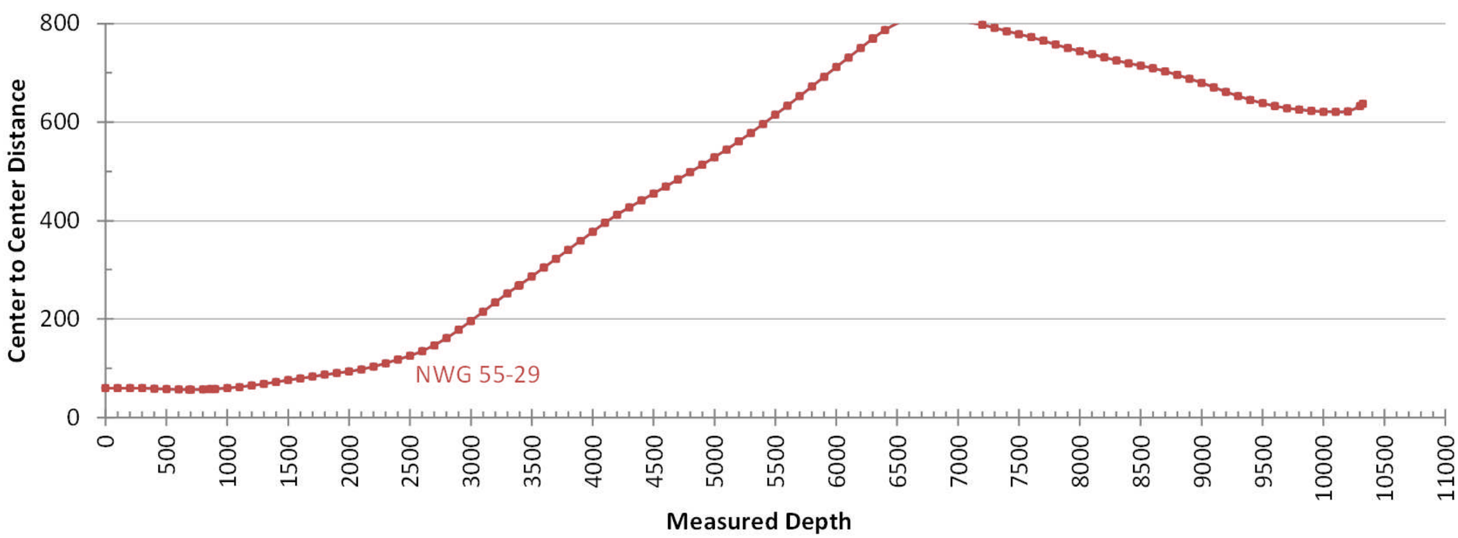
Clearance Plots

NWG 55A-29 Rev-A.0

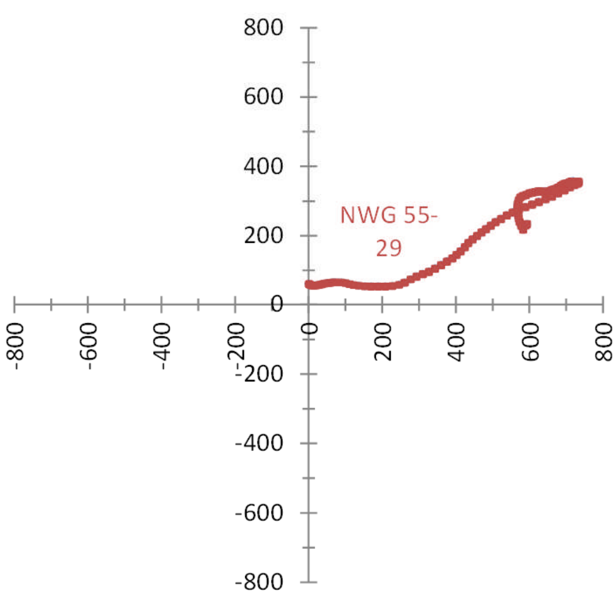
SEPARATION RATIO



CENTER TO CENTER CLEARANCE DISTANCE



TRAVELING CYLINDER (Map North)



Clearance Report

NWG 55A-29 Rev-A.0

Closest Approach

REFERENCE WELLPATH IDENTIFICATION

Operator	**ALTAROCK ENERGY**	Slot	**NWG 55A-29**
Area	**OREGON**	Well	**NWG 55A-29**
Field	**Newberry_**	Wellbore	**NWG 55A-29**
Facility	**SECTION 29 T21S R12E**		

REPORT SETUP INFORMATION

Projection System	**NAD83 / UTM Zone 10 North**	Software System	**WellArchitect® 4.0.0**
North Reference	**Grid**	User	**Vazqjosl**
Scale	**0.999826**	Report Generated	**3/18/2015** at **1:55:03 PM**
Convergence at slot	**1.16° East**	Database/Source file	**BHI_Shafter/NWG_55A-29_CR.xml**

WELLPATH LOCATION

	Local coordinates		Grid coordinates		Geographic coordinates	
	North[ft]	**East[ft]**	**Easting[m]**	**Northing[m]**	**Latitude**	**Longitude**
Slot Location	2779.35	-1709.61	**635669.00**	**4842807.00**	43°43'33.190"N	121°18'56.042"W
Facility Reference Pt			**636190.00**	**4841960.00**	43°43'05.403"N	121°18'33.537"W
Field Reference Pt			636450.44	4802503.65	**43°21'46.800"N**	**121°18'57.600"W**

WELLPATH DATUM

Calculation method	**Minimum Curvature**	Rig on 55-29 (KB) to Facility Vertical Datum	**5846.00ft**
Horizontal Reference Pt	**Slot**	Rig on 55-29 (KB) to Mean Sea Level	**5846.00ft**
Vertical Reference Pt	**Rig on 55-29 (KB)**	Rig on 55-29 (KB) to Mud Line at Slot (NWG 55A-29)	**5846.00ft**
MD Reference Pt	**Rig on 55-29 (KB)**		
Field Vertical Reference	**Mean Sea Level**		

POSITIONAL UNCERTAINTY CALCULATION SETTINGS

Ellipse Confidence Limit	**3.00 Std Dev**	Ellipse Start MD	**0.00ft**	Surface Position Uncertainty	**included**
Declination	**14.93° East of TN**	Dip Angle	**66.36°**	Mag Field Strength	**51992 nT**
Slot Surface Uncertainty @1SD		Horizontal	**2.000ft**	Vertical	**1.000ft**
Facility Surface Uncertainty @1SD		Horizontal	**20.000ft**	Vertical	**3.000ft**

Positional Uncertainty values in the WELLPATH DATA table are the projection of the ellipsoid of uncertainty onto the vertical and horizontal planes

ANTI-COLLISION RULE

Rule Name	**Baker Hughes Stop Drilling**	Rule Based On	**Ratio**
Plane of Rule	**Closest Approach**	Threshold Value	**1.00**
Subtract Casing & Hole Size	**yes**	Apply Cone of Safety	**no**

REFERENCE WELLPATH IDENTIFICATION

Operator	**ALTAROCK ENERGY**	Slot	**NWG 55A-29**
Area	**OREGON**	Well	**NWG 55A-29**
Field	**Newberry_**	Wellbore	**NWG 55A-29**
Facility	**SECTION 29 T21S R12E**		

HOLE & CASING SECTIONS - Ref Wellbore: NWG 55A-29 Ref Wellpath: NWG 55A-29 Rev-A.0

String/Diameter	Start MD [ft]	End MD [ft]	Interval [ft]	Start TVD [ft]	End TVD [ft]	Start N/S [ft]	Start E/W [ft]	End N/S [ft]	End E/W [ft]
26in Open Hole	0.00	1100.00	1100.00	0.00	1100.00	0.00	0.00	0.00	0.00
20in Casing	0.00	1100.00	1100.00	0.00	1100.00	0.00	0.00	0.00	0.00
17.5in Open Hole	0.00	3000.00	3000.00	0.00	3000.00	0.00	0.00	0.00	0.00
13.375in Casing	0.00	3000.00	3000.00	0.00	3000.00	0.00	0.00	0.00	0.00
12.25in Open Hole	0.00	7083.11	7083.11	0.00	7052.00	0.00	0.00	-268.00	328.00
9.625in Casing	0.00	7083.11	7083.11	0.00	7052.00	0.00	0.00	-268.00	328.00
8.5in Open Hole	0.00	10323.30	10323.30	0.00	10168.00	0.00	0.00	-202.00	1214.00

SURVEY PROGRAM - Ref Wellbore: NWG 55A-29 Ref Wellpath: NWG 55A-29 Rev-A.0

Start MD [ft]	End MD [ft]	Positional Uncertainty Model	Log Name/Comment	Wellbore
0.00	10325.28	NaviTrak (Standard)		NWG 55A-29

CALCULATION RANGE & CUTOFF

From: **0.00ft MD**	To: **10323.30ft MD**	C-C Cutoff: **(none)**

OFFSET WELL CLEARANCE SUMMARY (1 Offset Wellpath selected) Ratios are calculated in Closest Approach plane

					C-C Clearance Distance			ACR Separation Ratio			
Offset Facility	Offset Slot	Offset Well	Offset Wellbore	Offset Wellpath	Ref MD [ft]	Min C-C Clear Dist [ft]	Diverging from MD [ft]	Ref MD of Min Ratio [ft]	Min Ratio	Min Ratio Dvrg from [ft]	ACR Status
SECTION 29 T21S R12E	NWG 55-29	NWG 55-29	NWG 55-29	NWG 55-29	687.51	56.91	10100.00	858.27	4.18	10200.00	PASS

Clearance Report

NWG 55A-29 Rev-A.0
Closest Approach

REFERENCE WELLPATH IDENTIFICATION

Operator	**ALTAROCK ENERGY**	Slot	**NWG 55A-29**
Area	**OREGON**	Well	**NWG 55A-29**
Field	**Newberry_**	Wellbore	**NWG 55A-29**
Facility	**SECTION 29 T21S R12E**		

CLEARANCE DATA - Offset Wellbore: NWG 55-29 Offset Wellpath: NWG 55-29

Facility: SECTION 29 T21S R12E Slot: NWG 55-29 Well: NWG 55-29 Threshold Value=1.00 † = interpolated/extrapolated station

Ref MD [ft]	Ref TVD [ft]	Ref North [ft]	Ref East [ft]	Offset MD [ft]	Offset TVD [ft]	Offset North [ft]	Offset East [ft]	Horiz Bearing [°]	C-C Clear Dist [ft]	ACR MASD [ft]	Sep Ratio	ACR Status
0.00	0.00	0.00	0.00	0.00	0.00	59.79	0.69	0.66	59.79	13.92	4.82	PASS
100.00†	100.00	0.00	0.00	99.95	99.95	59.83	0.70	0.67	59.83	13.95	4.81	PASS
200.00†	200.00	0.00	0.00	199.91	199.91	59.94	0.72	0.69	59.95	14.00	4.80	PASS
300.00†	300.00	0.00	0.00	300.26	300.26	59.86	1.01	0.96	59.87	14.10	4.76	PASS
400.00†	400.00	0.00	0.00	400.69	400.68	59.03	2.03	1.97	59.07	14.23	4.64	PASS
500.00†	500.00	0.00	0.00	500.61	500.58	57.77	3.74	3.70	57.89	14.42	4.48	PASS
600.00†	600.00	0.00	0.00	600.35	600.29	56.82	6.04	6.07	57.14	14.65	4.34	PASS
687.51†	687.51	0.00	0.00	687.67	687.57	56.26	8.54	8.64	56.91	14.85	4.25	PASS
700.00†	700.00	0.00	0.00	700.07	699.96	56.20	8.94	9.04	56.91	14.89	4.24	PASS
800.00†	800.00	0.00	0.00	799.75	799.58	55.93	12.42	12.51	57.30	15.15	4.19	PASS
858.27†	858.27	0.00	0.00	857.82	857.60	55.94	14.71	14.74	57.84	15.31	4.18	PASS
900.00†	900.00	0.00	0.00	899.39	899.14	56.01	16.48	16.40	58.39	15.42	4.18	PASS
1000.00†	1000.00	0.00	0.00	999.23	998.88	56.35	20.91	20.36	60.11	15.74	4.21	PASS
1100.00†	1100.00	0.00	0.00	1098.88	1098.43	56.90	25.34	24.01	62.31	15.74	4.28	PASS
1200.00†	1200.00	0.00	0.00	1198.50	1197.94	57.81	29.98	27.41	65.15	15.83	4.39	PASS
1300.00†	1300.00	0.00	0.00	1298.23	1297.55	59.02	34.77	30.50	68.54	16.23	4.50	PASS
1400.00†	1400.00	0.00	0.00	1398.00	1397.19	60.42	39.58	33.23	72.29	16.65	4.62	PASS
1500.00†	1500.00	0.00	0.00	1498.04	1497.10	61.84	44.42	35.69	76.20	17.08	4.74	PASS
1600.00†	1600.00	0.00	0.00	1598.44	1597.38	62.47	49.27	38.26	79.61	17.53	4.82	PASS
1700.00†	1700.00	0.00	0.00	1698.00	1696.82	63.05	54.23	40.70	83.23	17.99	4.90	PASS
1800.00†	1800.00	0.00	0.00	1798.08	1796.77	63.98	59.07	42.72	87.14	18.48	4.99	PASS
1900.00†	1900.00	0.00	0.00	1898.62	1897.21	64.30	63.42	44.61	90.36	18.96	5.04	PASS
2000.00†	2000.00	0.00	0.00	1998.08	1996.59	64.73	67.61	46.25	93.66	19.46	5.08	PASS
2100.00†	2100.00	0.00	0.00	2096.93	2095.27	64.52	73.40	48.68	97.84	19.98	5.17	PASS
2200.00†	2200.00	0.00	0.00	2195.40	2193.48	64.46	80.59	51.35	103.41	20.50	5.31	PASS
2300.00†	2300.00	0.00	0.00	2294.19	2291.88	64.39	89.23	54.18	110.34	21.03	5.52	PASS
2400.00†	2400.00	0.00	0.00	2393.97	2391.11	62.60	99.53	57.83	117.92	21.58	5.75	PASS
2500.00†	2500.00	0.00	0.00	2493.06	2489.60	59.74	110.05	61.51	125.65	22.13	5.97	PASS
2600.00†	2600.00	0.00	0.00	2589.86	2585.66	56.66	121.64	65.02	134.95	22.67	6.25	PASS
2700.00†	2700.00	0.00	0.00	2685.94	2680.78	54.50	135.00	68.02	146.85	23.21	6.64	PASS
2800.00†	2800.00	0.00	0.00	2780.80	2774.39	52.89	150.19	70.60	161.28	23.74	7.13	PASS
2900.00†	2900.00	0.00	0.00	2876.84	2868.87	52.15	167.43	72.70	178.10	24.29	7.69	PASS
3000.00†	3000.00	0.00	0.00	2973.83	2964.10	51.40	185.75	74.53	196.05	24.65	8.27	PASS
3100.00	3100.00	0.00	0.00	3070.46	3058.91	51.31	204.45	75.91	214.76	25.08	8.85	PASS
3200.00†	3199.98	-1.40	1.04	3165.70	3152.21	51.64	223.60	76.60	233.73	25.66	9.41	PASS
3300.00†	3299.84	-5.59	4.17	3264.85	3249.14	51.23	244.48	76.70	252.09	26.33	9.88	PASS
3392.02	3391.51	-11.92	8.89	3354.04	3336.32	50.72	263.22	76.16	267.68	26.93	10.25	PASS
3400.00†	3399.45	-12.57	9.38	3361.75	3343.86	50.73	264.86	76.09	269.01	26.98	10.28	PASS
3500.00†	3498.93	-20.72	15.47	3456.96	3436.80	51.20	285.53	75.09	286.30	27.63	10.68	PASS
3600.00†	3598.41	-28.88	21.55	3554.39	3531.73	51.60	307.43	74.28	304.39	28.34	11.07	PASS
3700.00†	3697.90	-37.03	27.64	3653.99	3628.67	50.04	330.25	73.95	322.41	29.07	11.42	PASS
3800.00†	3797.38	-45.19	33.72	3750.61	3722.70	48.64	352.42	73.59	340.51	29.78	11.76	PASS
3900.00†	3896.86	-53.34	39.81	3846.86	3816.35	48.93	374.61	73.01	359.21	30.50	12.11	PASS
4000.00†	3996.34	-61.50	45.90	3946.94	3913.83	50.78	397.20	72.28	377.93	31.28	12.41	PASS
4100.00†	4095.82	-69.65	51.98	4047.69	4012.12	52.97	419.23	71.54	396.12	32.07	12.69	PASS

Clearance Report

NWG 55A-29 Rev-A.0

Closest Approach

REFERENCE WELLPATH IDENTIFICATION

Operator	**ALTAROCK ENERGY**	Slot	**NWG 55A-29**
Area	**OREGON**	Well	**NWG 55A-29**
Field	**Newberry_**	Wellbore	**NWG 55A-29**
Facility	**SECTION 29 T21S R12E**		

CLEARANCE DATA - Offset Wellbore: NWG 55-29 Offset Wellpath: NWG 55-29

Facility: SECTION 29 T21S R12E Slot: NWG 55-29 Well: NWG 55-29 Threshold Value=1.00 † = interpolated/extrapolated station

Ref MD [ft]	Ref TVD [ft]	Ref North [ft]	Ref East [ft]	Offset MD [ft]	Offset TVD [ft]	Offset North [ft]	Offset East [ft]	Horiz Bearing [°]	C-C Clear Dist [ft]	ACR MASD [ft]	Sep Ratio	ACR Status
4200.00†	4195.30	-77.81	58.07	4158.35	4120.47	54.91	441.58	70.91	412.67	32.96	12.85	PASS
4300.00†	4294.78	-85.96	64.15	4260.50	4220.96	56.88	459.86	70.15	427.13	33.82	12.95	PASS
4400.00†	4394.26	-94.12	70.24	4359.76	4318.64	59.04	477.29	69.38	441.44	34.54	13.10	PASS
4500.00†	4493.74	-102.27	76.33	4459.70	4417.09	62.27	494.21	68.51	455.61	35.34	13.21	PASS
4600.00†	4593.22	-110.43	82.41	4558.85	4514.82	66.31	510.45	67.57	469.68	36.15	13.30	PASS
4700.00†	4692.71	-118.58	88.50	4656.33	4610.81	68.38	527.28	66.92	483.94	37.01	13.38	PASS
4800.00†	4792.19	-126.74	94.58	4753.20	4706.11	70.07	544.59	66.38	498.65	37.74	13.52	PASS
4900.00†	4891.67	-134.90	100.67	4850.00	4801.23	71.20	562.47	65.95	513.73	38.54	13.63	PASS
5000.00†	4991.15	-143.05	106.75	4948.26	4897.74	72.49	580.95	65.56	529.19	39.37	13.74	PASS
5100.00†	5090.63	-151.21	112.84	5043.51	4991.27	73.85	598.90	65.15	544.77	40.17	13.85	PASS
5200.00†	5190.11	-159.36	118.93	5137.63	5083.49	75.29	617.62	64.80	561.35	40.97	13.99	PASS
5300.00†	5289.59	-167.52	125.01	5231.80	5175.60	76.22	637.20	64.55	578.57	41.77	14.14	PASS
5400.00†	5389.07	-175.67	131.10	5325.50	5267.04	77.12	657.62	64.35	596.67	42.59	14.30	PASS
5500.00†	5488.55	-183.83	137.18	5423.17	5362.22	77.53	679.54	64.27	615.15	43.44	14.44	PASS
5600.00†	5588.03	-191.98	143.27	5520.30	5456.75	77.12	701.85	64.28	633.77	44.30	14.59	PASS
5700.00†	5687.51	-200.14	149.36	5612.90	5546.71	76.10	723.79	64.32	652.76	45.11	14.75	PASS
5800.00†	5787.00	-208.29	155.44	5711.17	5641.95	74.75	747.95	64.47	672.47	45.99	14.90	PASS
5900.00†	5886.48	-216.45	161.53	5804.54	5732.48	73.81	770.80	64.53	692.22	46.81	15.06	PASS
6000.00†	5985.96	-224.60	167.61	5910.17	5835.01	74.16	796.17	64.58	712.12	47.77	15.18	PASS
6100.00†	6085.44	-232.76	173.70	6010.74	5932.77	73.32	819.78	64.65	731.03	48.66	15.29	PASS
6200.00†	6184.92	-240.91	179.79	6101.56	6021.06	73.52	841.02	64.57	750.30	49.46	15.44	PASS
6299.48	6283.88	-249.02	185.84	6204.48	6121.17	74.94	864.86	64.49	769.73	50.40	15.54	PASS
6300.00†	6284.40	-249.07	185.87	6205.03	6121.71	74.94	864.98	64.49	769.83	50.40	15.54	PASS
6400.00†	6383.82	-256.48	193.56	6305.71	6219.72	75.55	888.01	64.45	787.04	51.32	15.60	PASS
6500.00†	6483.05	-262.41	204.39	6409.81	6321.19	76.36	911.26	64.39	800.39	52.30	15.56	PASS
6600.00†	6581.97	-266.85	218.37	6518.39	6427.24	77.06	934.52	64.35	809.37	53.30	15.43	PASS
6700.00†	6680.44	-269.80	235.48	6621.81	6528.44	77.23	955.82	64.28	813.90	54.25	15.24	PASS
6800.00†	6778.36	-271.26	255.69	6720.13	6624.67	78.00	975.98	64.13	815.12	55.15	15.01	PASS
6900.00†	6875.61	-271.21	278.98	6822.26	6724.64	78.58	996.88	64.02	812.73	56.09	14.71	PASS
6983.11	6955.83	-270.04	300.66	6900.11	6800.84	78.84	1012.86	63.90	808.07	56.79	14.44	PASS
7000.00†	6972.07	-269.69	305.27	6914.63	6815.03	78.95	1015.92	63.87	806.99	56.92	14.39	PASS
7083.11	7052.00	-268.00	328.00	6981.52	6880.32	79.99	1030.43	63.65	802.49	57.49	14.17	PASS
7100.00†	7068.24	-267.66	332.62	6996.08	6894.49	80.41	1033.73	63.60	801.81	57.45	14.13	PASS
7200.00†	7164.41	-265.62	359.96	7105.17	7000.75	83.20	1058.25	63.46	797.54	58.44	13.81	PASS
7300.00†	7260.57	-263.58	387.31	7217.48	7110.39	83.52	1082.55	63.47	791.45	59.39	13.48	PASS
7400.00†	7356.74	-261.55	414.65	7315.05	7205.75	83.19	1103.23	63.41	784.72	60.25	13.17	PASS
7500.00†	7452.91	-259.51	441.99	7411.75	7300.19	83.87	1124.03	63.28	778.72	61.12	12.88	PASS
7600.00†	7549.08	-257.47	469.34	7516.78	7402.72	83.61	1146.79	63.28	772.46	62.07	12.58	PASS
7700.00†	7645.24	-255.43	496.68	7623.51	7506.98	82.07	1169.53	63.36	765.35	63.03	12.27	PASS
7800.00†	7741.41	-253.40	524.03	7723.86	7605.06	79.82	1190.66	63.44	757.64	63.93	11.97	PASS
7900.00†	7837.58	-251.36	551.37	7816.46	7695.50	78.06	1210.45	63.44	750.40	64.77	11.70	PASS
8000.00†	7933.75	-249.32	578.71	7911.89	7788.63	77.38	1231.26	63.41	744.05	65.64	11.45	PASS
8100.00†	8029.91	-247.29	606.06	8012.25	7886.61	77.55	1252.98	63.34	737.94	66.57	11.19	PASS
8200.00†	8126.08	-245.25	633.40	8112.91	7984.91	77.60	1274.66	63.28	731.69	67.50	10.94	PASS
8300.00†	8222.25	-243.21	660.75	8214.65	8084.31	77.72	1296.33	63.21	725.25	68.45	10.70	PASS

REFERENCE WELLPATH IDENTIFICATION

Operator	**ALTAROCK ENERGY**	Slot	**NWG 55A-29**
Area	**OREGON**	Well	**NWG 55A-29**
Field	**Newberry_**	Wellbore	**NWG 55A-29**
Facility	**SECTION 29 T21S R12E**		

CLEARANCE DATA - Offset Wellbore: NWG 55-29 Offset Wellpath: NWG 55-29

Facility: SECTION 29 T21S R12E Slot: NWG 55-29 Well: NWG 55-29 Threshold Value=1.00 † = interpolated/extrapolated station

Ref MD [ft]	Ref TVD [ft]	Ref North [ft]	Ref East [ft]	Offset MD [ft]	Offset TVD [ft]	Offset North [ft]	Offset East [ft]	Horiz Bearing [°]	C-C Clear Dist [ft]	ACR MASD [ft]	Sep Ratio	ACR Status
8400.00†	8318.41	-241.18	688.09	8303.82	8171.39	78.60	1315.52	62.99	719.40	69.30	10.48	PASS
8500.00†	8414.58	-239.14	715.44	8401.37	8266.51	80.86	1337.02	62.76	714.63	70.25	10.27	PASS
8600.00†	8510.75	-237.10	742.78	8506.44	8369.08	83.99	1359.59	62.50	709.66	71.31	10.04	PASS
8700.00†	8606.92	-235.07	770.12	8617.84	8478.14	86.82	1382.15	62.26	703.40	72.44	9.80	PASS
8800.00†	8703.08	-233.03	797.47	8720.47	8578.77	88.00	1402.25	62.04	695.90	73.47	9.55	PASS
8900.00†	8799.25	-230.99	824.81	8823.36	8679.66	88.61	1422.46	61.86	688.21	74.50	9.32	PASS
9000.00†	8895.42	-228.95	852.16	8926.13	8780.45	88.32	1442.50	61.74	679.99	75.52	9.08	PASS
9100.00†	8991.59	-226.92	879.50	9034.33	8886.69	87.09	1462.97	61.71	670.85	76.57	8.83	PASS
9200.00†	9087.75	-224.88	906.84	9128.67	8979.37	86.14	1480.56	61.54	661.54	77.54	8.60	PASS
9300.00†	9183.92	-222.84	934.19	9222.35	9070.86	82.47	1500.32	61.66	653.07	78.41	8.40	PASS
9400.00†	9280.09	-220.81	961.53	9317.77	9163.41	76.07	1522.64	62.12	645.44	79.19	8.21	PASS
9500.00†	9376.25	-218.77	988.88	9412.53	9254.85	68.16	1546.19	62.76	638.49	79.91	8.05	PASS
9600.00†	9472.42	-216.73	1016.22	9503.01	9341.26	57.88	1570.95	63.66	632.72	80.45	7.93	PASS
9700.00†	9568.59	-214.70	1043.56	9592.66	9426.63	48.41	1596.59	64.56	628.66	80.96	7.82	PASS
9800.00†	9664.76	-212.66	1070.91	9689.62	9519.12	39.90	1624.42	65.47	625.59	81.54	7.73	PASS
9900.00†	9760.92	-210.62	1098.25	9787.28	9612.32	32.11	1652.54	66.35	623.09	82.14	7.64	PASS
10000.00†	9857.09	-208.59	1125.60	9881.72	9701.98	23.46	1680.91	67.32	621.51	82.64	7.58	PASS
10100.00†	9953.26	-206.55	1152.94	9971.68	9786.71	13.73	1709.51	68.41	621.31	83.00	7.54	PASS
10200.00†	10049.43	-204.51	1180.28	10060.00	9869.73	4.21	1738.12	69.49	622.12	83.30	7.52	PASS
10300.00†	10145.59	-202.47	1207.63	10060.00	9869.73	4.21	1738.12	68.71	632.64	82.11	7.76	PASS
10323.30	10168.00	-202.00	1214.00	10060.00	9869.73	4.21	1738.12	68.52	637.33	81.71	7.86	PASS

POSITIONAL UNCERTAINTY - Offset Wellbore: NWG 55-29 Offset Wellpath: NWG 55-29

Slot Surface Uncertainty @1SD	Horizontal	**2.000ft**	Vertical	**1.000ft**
Facility Surface Uncertainty @1SD	Horizontal	**20.000ft**	Vertical	**3.000ft**

WELLPATH COMPOSITION - Offset Wellbore: NWG 55-29 Offset Wellpath: NWG 55-29

Start MD [ft]	End MD [ft]	Positional Uncertainty Model	Log Name/Comment	Wellbore
0.00	10060.00	ISCWSA MWD, Rev. 2 (Standard)	MWD (219'-10060')	NWG 55-29

OFFSET WELLPATH MD REFERENCE - Offset Wellbore: NWG 55-29 Offset Wellpath: NWG 55-29

MD Reference: **Rig on NWG 55-29 (RT)**	*Offset TVD & local coordinates use Reference Wellpath settings (See WELLPATH DATUM on page 1 of this report)*
Ellipse Start MD	**0.00ft**

Planned Wellpath Report

Positional Uncertainty

NWG 55A-29 Rev-A.0

ALTAROCK

BAKER HUGHES

REFERENCE WELLPATH IDENTIFICATION			
Operator	**ALTAROCK ENERGY**	Slot	**NWG 55A-29**
Area	**OREGON**	Well	**NWG 55A-29**
Field	**Newberry_**	Wellbore	**NWG 55A-29**
Facility	**SECTION 29 T21S R12E**		

REPORT SETUP INFORMATION			
Projection System	**NAD83 / UTM Zone 10 North**	Software System	**WellArchitect® 4.0.0**
North Reference	**Grid**	User	**Vigimice**
Scale	**0.999826**	Report Generated	**4/21/2015** at **3:38:41 PM**
Convergence at slot	**1.16° East**	Database/Source file	**Shafter_DB/NWG_55A-29.xml**

WELLPATH LOCATION						
	Local coordinates		**Grid coordinates**		**Geographic coordinates**	
	North[ft]	**East[ft]**	**Easting[m]**	**Northing[m]**	**Latitude**	**Longitude**
Slot Location	2779.35	-1709.61	**635669.00**	**4842807.00**	43°43'33.190"N	121°18'56.042"W
Facility Reference Pt			**636190.00**	**4841960.00**	43°43'05.403"N	121°18'33.537"W
Field Reference Pt			636450.44	4802503.65	**43°21'46.800"N**	**121°18'57.600"W**

WELLPATH DATUM			
Calculation method	**Minimum curvature**	Rig on 55-29 (KB) to Facility Vertical Datum	**5846.00ft**
Horizontal Reference Pt	**Slot**	Rig on 55-29 (KB) to Mean Sea Level	**5846.00ft**
Vertical Reference Pt	**Rig on 55-29 (KB)**	Rig on 55-29 (KB) to Mud Line at Slot (NWG 55A-29)	**5846.00ft**
MD Reference Pt	**Rig on 55-29 (KB)**	Section Origin	**N 0.00, E 0.00 ft**
Field Vertical Reference	**Mean Sea Level**	Section Azimuth	**99.45°**

POSITIONAL UNCERTAINTY CALCULATION SETTINGS					
Ellipse Confidence Limit	**3.00 Std Dev**	Ellipse Start MD	**0.00ft**	Surface Position Uncertainty	**included**
Declination	**14.93° East of TN**	Dip Angle	**66.36°**	Magnetic Field Strength	**51992nT**
Slot Surface Uncertainty @1SD		Horizontal	**2.000ft**	Vertical	**1.000ft**
Facility Surface Uncertainty @1SD		Horizontal	**20.000ft**	Vertical	**3.000ft**
Positional Uncertainty values in the WELLPATH DATA table are the projection of the ellipsoid of uncertainty onto the vertical and horizontal planes					

Planned Wellpath Report

Positional Uncertainty

NWG 55A-29 Rev-A.0

ALTAROCK

BAKER HUGHES

REFERENCE WELLPATH IDENTIFICATION			
Operator	**ALTAROCK ENERGY**	Slot	**NWG 55A-29**
Area	**OREGON**	Well	**NWG 55A-29**
Field	**Newberry_**	Wellbore	**NWG 55A-29**
Facility	**SECTION 29 T21S R12E**		

WELLPATH DATA (109 stations) - with Positional Uncertainty values † = interpolated/extrapolated station

MD [ft]	Inclination [°]	Azimuth [°]	TVD [ft]	Vert Sect [ft]	North [ft]	East [ft]	DLS [°/100ft]	Vertical Semi-Axis [ft]	Horiz Major Semi-Axis [ft]	Horiz Minor Semi-Axis [ft]	Horiz Minor Axis Azim [°]
0.00	0.000	143.267	0.00	0.00	0.00	0.00	0.00	9.49	60.30	60.30	0.000
100.00†	0.000	143.267	100.00	0.00	0.00	0.00	0.00	10.09	60.30	60.30	0.000
200.00†	0.000	143.267	200.00	0.00	0.00	0.00	0.00	10.10	60.30	60.30	0.000
300.00†	0.000	143.267	300.00	0.00	0.00	0.00	0.00	10.11	60.31	60.31	135.000
400.00†	0.000	143.267	400.00	0.00	0.00	0.00	0.00	10.12	60.32	60.32	0.000
500.00†	0.000	143.267	500.00	0.00	0.00	0.00	0.00	10.13	60.33	60.33	0.000
600.00†	0.000	143.267	600.00	0.00	0.00	0.00	0.00	10.14	60.34	60.34	0.000
700.00†	0.000	143.267	700.00	0.00	0.00	0.00	0.00	10.16	60.35	60.35	0.000
800.00†	0.000	143.267	800.00	0.00	0.00	0.00	0.00	10.18	60.37	60.37	0.000
900.00†	0.000	143.267	900.00	0.00	0.00	0.00	0.00	10.21	60.39	60.39	135.000
1000.00†	0.000	143.267	1000.00	0.00	0.00	0.00	0.00	10.23	60.41	60.41	135.000
1100.00†	0.000	143.267	1100.00	0.00	0.00	0.00	0.00	10.26	60.43	60.43	135.000
1200.00†	0.000	143.267	1200.00	0.00	0.00	0.00	0.00	10.30	60.45	60.45	135.000
1300.00†	0.000	143.267	1300.00	0.00	0.00	0.00	0.00	10.33	60.48	60.48	135.000
1400.00†	0.000	143.267	1400.00	0.00	0.00	0.00	0.00	10.37	60.51	60.51	135.000
1500.00†	0.000	143.267	1500.00	0.00	0.00	0.00	0.00	10.42	60.54	60.54	135.000
1600.00†	0.000	143.267	1600.00	0.00	0.00	0.00	0.00	10.46	60.57	60.57	135.000
1700.00†	0.000	143.267	1700.00	0.00	0.00	0.00	0.00	10.51	60.61	60.61	135.000
1800.00†	0.000	143.267	1800.00	0.00	0.00	0.00	0.00	10.56	60.65	60.65	135.000
1900.00†	0.000	143.267	1900.00	0.00	0.00	0.00	0.00	10.62	60.68	60.68	0.000
2000.00†	0.000	143.267	2000.00	0.00	0.00	0.00	0.00	10.68	60.73	60.73	135.000
2100.00†	0.000	143.267	2100.00	0.00	0.00	0.00	0.00	10.74	60.77	60.77	0.000
2200.00†	0.000	143.267	2200.00	0.00	0.00	0.00	0.00	10.81	60.82	60.82	135.000
2300.00†	0.000	143.267	2300.00	0.00	0.00	0.00	0.00	10.87	60.86	60.86	0.000
2400.00†	0.000	143.267	2400.00	0.00	0.00	0.00	0.00	10.95	60.91	60.91	0.000
2500.00†	0.000	143.267	2500.00	0.00	0.00	0.00	0.00	11.02	60.96	60.96	0.000
2600.00†	0.000	143.267	2600.00	0.00	0.00	0.00	0.00	11.11	61.02	61.02	135.000
2700.00†	0.000	143.267	2700.00	0.00	0.00	0.00	0.00	11.19	61.07	61.07	135.000
2800.00†	0.000	143.267	2800.00	0.00	0.00	0.00	0.00	11.28	61.13	61.13	135.000
2900.00†	0.000	143.267	2900.00	0.00	0.00	0.00	0.00	11.37	61.19	61.19	135.000
3000.00†	0.000	143.267	3000.00	0.00	0.00	0.00	0.00	11.47	61.26	61.26	135.000
3100.00	0.000	143.267	3100.00	0.00	0.00	0.00	0.00	11.57	61.32	61.32	135.000
3200.00†	2.000	143.267	3199.98	1.26	-1.40	1.04	2.00	11.67	61.39	61.39	230.878
3300.00†	4.000	143.267	3299.84	5.04	-5.59	4.17	2.00	11.78	61.49	61.46	231.307
3392.02	5.840	143.267	3391.51	10.73	-11.92	8.89	2.00	11.88	61.57	61.52	230.616
3400.00†	5.840	143.267	3399.45	11.32	-12.57	9.38	0.00	11.89	61.58	61.53	230.505
3500.00†	5.840	143.267	3498.93	18.66	-20.72	15.47	0.00	12.01	61.65	61.61	227.911
3600.00†	5.840	143.267	3598.41	26.00	-28.88	21.55	0.00	12.13	61.72	61.69	223.947
3700.00†	5.840	143.267	3697.90	33.34	-37.03	27.64	0.00	12.25	61.80	61.77	217.104
3800.00†	5.840	143.267	3797.38	40.68	-45.19	33.72	0.00	12.38	61.88	61.86	204.395
3900.00†	5.840	143.267	3896.86	48.03	-53.34	39.81	0.00	12.52	61.97	61.95	186.033
4000.00†	5.840	143.267	3996.34	55.37	-61.50	45.90	0.00	12.66	62.07	62.03	171.966
4100.00†	5.840	143.267	4095.82	62.71	-69.65	51.98	0.00	12.80	62.17	62.12	164.371
4200.00†	5.840	143.267	4195.30	70.05	-77.81	58.07	0.00	12.95	62.27	62.21	160.149
4300.00†	5.840	143.267	4294.78	77.39	-85.96	64.15	0.00	13.10	62.38	62.30	157.545

REFERENCE WELLPATH IDENTIFICATION			
Operator	**ALTAROCK ENERGY**	Slot	**NWG 55A-29**
Area	**OREGON**	Well	**NWG 55A-29**
Field	**Newberry_**	Wellbore	**NWG 55A-29**
Facility	**SECTION 29 T21S R12E**		

WELLPATH DATA (109 stations) - with Positional Uncertainty values † = interpolated/extrapolated station

MD [ft]	Inclination [°]	Azimuth [°]	TVD [ft]	Vert Sect [ft]	North [ft]	East [ft]	DLS [°/100ft]	Vertical Semi-Axis [ft]	Horiz Major Semi-Axis [ft]	Horiz Minor Semi-Axis [ft]	Horiz Minor Axis Azim [°]
4400.00†	5.840	143.267	4394.26	84.73	-94.12	70.24	0.00	13.26	62.49	62.39	155.792
4500.00†	5.840	143.267	4493.74	92.08	-102.27	76.33	0.00	13.43	62.61	62.48	154.533
4600.00†	5.840	143.267	4593.22	99.42	-110.43	82.41	0.00	13.59	62.73	62.58	153.584
4700.00†	5.840	143.267	4692.71	106.76	-118.58	88.50	0.00	13.77	62.86	62.68	152.841
4800.00†	5.840	143.267	4792.19	114.10	-126.74	94.58	0.00	13.94	62.98	62.77	152.243
4900.00†	5.840	143.267	4891.67	121.44	-134.90	100.67	0.00	14.13	63.12	62.88	151.750
5000.00†	5.840	143.267	4991.15	128.79	-143.05	106.75	0.00	14.31	63.25	62.98	151.336
5100.00†	5.840	143.267	5090.63	136.13	-151.21	112.84	0.00	14.51	63.39	63.09	150.982
5200.00†	5.840	143.267	5190.11	143.47	-159.36	118.93	0.00	14.70	63.53	63.19	150.677
5300.00†	5.840	143.267	5289.59	150.81	-167.52	125.01	0.00	14.91	63.68	63.30	150.410
5400.00†	5.840	143.267	5389.07	158.15	-175.67	131.10	0.00	15.11	63.83	63.41	150.175
5500.00†	5.840	143.267	5488.55	165.50	-183.83	137.18	0.00	15.32	63.98	63.53	149.966
5600.00†	5.840	143.267	5588.03	172.84	-191.98	143.27	0.00	15.54	64.14	63.64	149.778
5700.00†	5.840	143.267	5687.51	180.18	-200.14	149.36	0.00	15.76	64.30	63.76	149.609
5800.00†	5.840	143.267	5787.00	187.52	-208.29	155.44	0.00	15.99	64.47	63.88	149.456
5900.00†	5.840	143.267	5886.48	194.86	-216.45	161.53	0.00	16.22	64.63	64.00	149.316
6000.00†	5.840	143.267	5985.96	202.21	-224.60	167.61	0.00	16.46	64.80	64.13	149.188
6100.00†	5.840	143.267	6085.44	209.55	-232.76	173.70	0.00	16.70	64.98	64.25	149.070
6200.00†	5.840	143.267	6184.92	216.89	-240.91	179.79	0.00	16.95	65.16	64.38	148.962
6299.48	5.840	143.267	6283.88	224.19	-249.02	185.84	0.00	17.20	65.34	64.51	148.862
6300.00†	5.843	143.166	6284.40	224.23	-249.07	185.87	2.00	17.20	65.34	64.51	148.861
6400.00†	6.555	125.764	6383.82	233.03	-256.48	193.56	2.00	17.46	65.53	64.64	148.475
6500.00†	7.731	112.684	6483.05	244.69	-262.41	204.39	2.00	17.72	65.74	64.77	147.572
6600.00†	9.195	103.380	6581.97	259.21	-266.85	218.37	2.00	17.98	65.96	64.90	146.330
6700.00†	10.831	96.733	6680.44	276.57	-269.80	235.48	2.00	18.25	66.17	65.02	144.811
6800.00†	12.571	91.858	6778.36	296.74	-271.26	255.69	2.00	18.53	66.39	65.15	143.039
6900.00†	14.378	88.171	6875.61	319.71	-271.21	278.98	2.00	18.80	66.62	65.28	141.030
6983.11	15.914	85.740	6955.83	340.90	-270.04	300.66	2.00	19.03	66.82	65.39	139.167
7000.00†	15.914	85.740	6972.07	345.40	-269.69	305.27	0.00	19.08	66.85	65.42	138.765
7083.11	15.914	85.740	7052.00[1]	367.54	-268.00	328.00	0.00	19.32	67.04	65.53	136.722
7100.00†	15.914	85.740	7068.24	372.04	-267.66	332.62	0.00	19.36	67.08	65.55	136.316
7200.00†	15.914	85.740	7164.41	398.68	-265.62	359.96	0.00	19.66	67.32	65.69	133.970
7300.00†	15.914	85.740	7260.57	425.32	-263.58	387.31	0.00	19.95	67.57	65.84	131.732
7400.00†	15.914	85.740	7356.74	451.96	-261.55	414.65	0.00	20.25	67.84	65.98	129.607
7500.00†	15.914	85.740	7452.91	478.59	-259.51	441.99	0.00	20.56	68.11	66.13	127.596
7600.00†	15.914	85.740	7549.08	505.23	-257.47	469.34	0.00	20.87	68.40	66.29	125.700
7700.00†	15.914	85.740	7645.24	531.87	-255.43	496.68	0.00	21.18	68.70	66.44	123.918
7800.00†	15.914	85.740	7741.41	558.51	-253.40	524.03	0.00	21.50	69.02	66.60	122.246
7900.00†	15.914	85.740	7837.58	585.15	-251.36	551.37	0.00	21.83	69.35	66.76	120.680
8000.00†	15.914	85.740	7933.75	611.79	-249.32	578.71	0.00	22.16	69.69	66.92	119.215
8100.00†	15.914	85.740	8029.91	638.43	-247.29	606.06	0.00	22.50	70.04	67.09	117.845
8200.00†	15.914	85.740	8126.08	665.07	-245.25	633.40	0.00	22.84	70.40	67.26	116.566
8300.00†	15.914	85.740	8222.25	691.71	-243.21	660.75	0.00	23.18	70.78	67.43	115.370
8400.00†	15.914	85.740	8318.41	718.34	-241.18	688.09	0.00	23.53	71.16	67.60	114.252
8500.00†	15.914	85.740	8414.58	744.98	-239.14	715.44	0.00	23.89	71.56	67.77	113.207

Planned Wellpath Report

Positional Uncertainty

NWG 55A-29 Rev-A.0

REFERENCE WELLPATH IDENTIFICATION			
Operator	**ALTAROCK ENERGY**	Slot	**NWG 55A-29**
Area	**OREGON**	Well	**NWG 55A-29**
Field	**Newberry_**	Wellbore	**NWG 55A-29**
Facility	**SECTION 29 T21S R12E**		

WELLPATH DATA (109 stations) - with Positional Uncertainty values † = interpolated/extrapolated station

MD [ft]	Inclination [°]	Azimuth [°]	TVD [ft]	Vert Sect [ft]	North [ft]	East [ft]	DLS [°/100ft]	Vertical Semi-Axis [ft]	Horiz Major Semi-Axis [ft]	Horiz Minor Semi-Axis [ft]	Horiz Minor Axis Azim [°]
8600.00†	15.914	85.740	8510.75	771.62	-237.10	742.78	0.00	24.25	71.97	67.95	112.228
8700.00†	15.914	85.740	8606.92	798.26	-235.07	770.12	0.00	24.61	72.39	68.13	111.312
8800.00†	15.914	85.740	8703.08	824.90	-233.03	797.47	0.00	24.98	72.83	68.31	110.453
8900.00†	15.914	85.740	8799.25	851.54	-230.99	824.81	0.00	25.36	73.27	68.50	109.647
9000.00†	15.914	85.740	8895.42	878.18	-228.95	852.16	0.00	25.74	73.72	68.68	108.889
9100.00†	15.914	85.740	8991.59	904.82	-226.92	879.50	0.00	26.12	74.18	68.87	108.177
9200.00†	15.914	85.740	9087.75	931.46	-224.88	906.84	0.00	26.51	74.66	69.06	107.506
9300.00†	15.914	85.740	9183.92	958.09	-222.84	934.19	0.00	26.90	75.14	69.26	106.874
9400.00†	15.914	85.740	9280.09	984.73	-220.81	961.53	0.00	27.30	75.63	69.45	106.277
9500.00†	15.914	85.740	9376.25	1011.37	-218.77	988.88	0.00	27.70	76.13	69.65	105.713
9600.00†	15.914	85.740	9472.42	1038.01	-216.73	1016.22	0.00	28.11	76.64	69.85	105.179
9700.00†	15.914	85.740	9568.59	1064.65	-214.70	1043.56	0.00	28.52	77.16	70.06	104.673
9800.00†	15.914	85.740	9664.76	1091.29	-212.66	1070.91	0.00	28.94	77.69	70.26	104.194
9900.00†	15.914	85.740	9760.92	1117.93	-210.62	1098.25	0.00	29.36	78.23	70.47	103.739
10000.00†	15.914	85.740	9857.09	1144.57	-208.59	1125.60	0.00	29.79	78.78	70.68	103.307
10100.00†	15.914	85.740	9953.26	1171.21	-206.55	1152.94	0.00	30.22	79.33	70.89	102.895
10200.00†	15.914	85.740	10049.43	1197.85	-204.51	1180.28	0.00	30.65	79.89	71.11	102.504
10300.00†	15.914	85.740	10145.59	1224.48	-202.47	1207.63	0.00	31.09	80.46	71.32	102.130
10323.30	15.914	85.740	10168.00[2]	1230.69	-202.00	1214.00	0.00	31.19	80.60	71.37	102.046

HOLE & CASING SECTIONS - Ref Wellbore: NWG 55A-29 Ref Wellpath: NWG 55A-29 Rev-A.0

String/Diameter	Start MD [ft]	End MD [ft]	Interval [ft]	Start TVD [ft]	End TVD [ft]	Start N/S [ft]	Start E/W [ft]	End N/S [ft]	End E/W [ft]
26in Open Hole	0.00	1100.00	1100.00	0.00	1100.00	0.00	0.00	0.00	0.00
20in Casing	0.00	1100.00	1100.00	0.00	1100.00	0.00	0.00	0.00	0.00
17.5in Open Hole	0.00	3000.00	3000.00	0.00	3000.00	0.00	0.00	0.00	0.00
13.375in Casing	0.00	3000.00	3000.00	0.00	3000.00	0.00	0.00	0.00	0.00
12.25in Open Hole	0.00	7083.11	7083.11	0.00	7052.00	0.00	0.00	-268.00	328.00
9.625in Casing	0.00	7083.11	7083.11	0.00	7052.00	0.00	0.00	-268.00	328.00
8.5in Open Hole	0.00	10323.30	10323.30	0.00	10168.00	0.00	0.00	-202.00	1214.00

Planned Wellpath Report

Positional Uncertainty

NWG 55A-29 Rev-A.0

REFERENCE WELLPATH IDENTIFICATION			
Operator	**ALTAROCK ENERGY**	Slot	**NWG 55A-29**
Area	**OREGON**	Well	**NWG 55A-29**
Field	**Newberry_**	Wellbore	**NWG 55A-29**
Facility	**SECTION 29 T21S R12E**		

TARGETS

Name	MD [ft]	TVD [ft]	North [ft]	East [ft]	Grid East [m]	Grid North [m]	Latitude	Longitude	Shape
1) 55A-29 T1	7083.11	7052.00	-268.00	328.00	635768.96	4842725.33	43°43'30.478"N	121°18'51.651"W	point
2) 55A-29 T2	10323.30	10168.00	-202.00	1214.00	636038.96	4842745.44	43°43'30.951"N	121°18'39.569"W	point

SURVEY PROGRAM - Ref Wellbore: NWG 55A-29 Ref Wellpath: NWG 55A-29 Rev-A.0

Start MD [ft]	End MD [ft]	Positional Uncertainty Model	Log Name/Comment	Wellbore
0.00	10325.28	NaviTrak (Standard)		NWG 55A-29

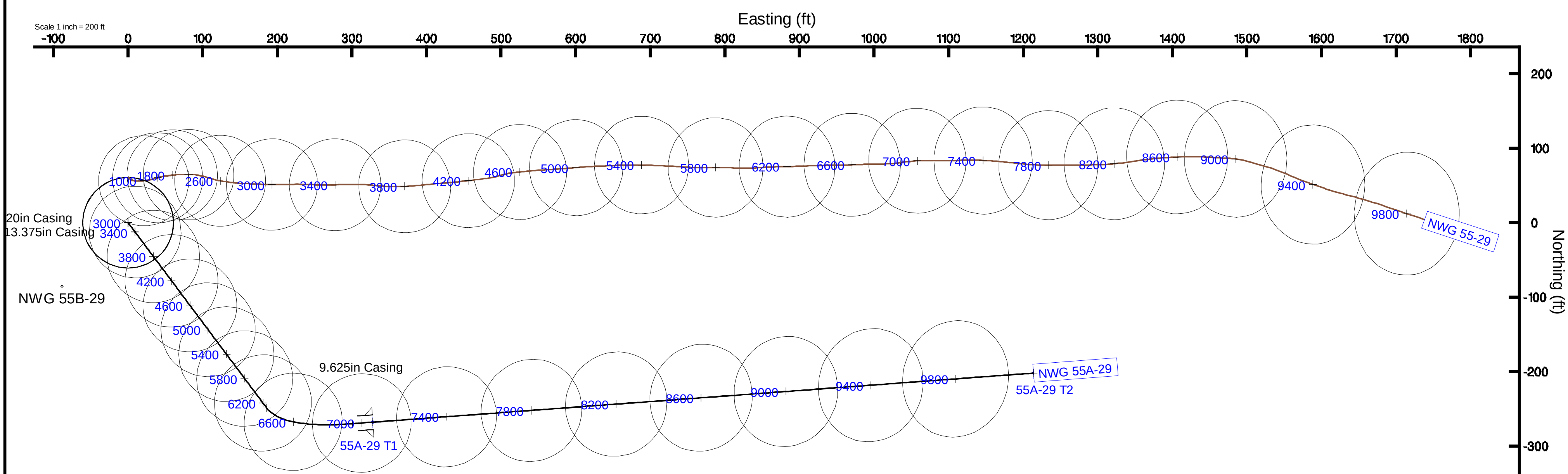
ALTAROCK ENERGY

Location:	OREGON	Slot:	NWG 55A-29
Field:	Newberry_	Well:	NWG 55A-29
Facility:	SECTION 29 T21S R12E	Wellbore:	NWG 55A-29

Well Profile Data

Design Comment	MD (ft)	Inc (°)	Az (°)	TVD (ft)	Local N (ft)	Local E (ft)	DLS (°/100ft)	VS (ft)
Tie On	0.00	0.000	143.267	0.00	0.00	0.00	0.00	0.00
End of Tangent	3100.00	0.000	143.267	3100.00	0.00	0.00	0.00	0.00
End of Build (XS)	3392.02	5.840	143.267	3391.51	-11.92	8.89	2.00	10.73
End of Tangent (XS)	6299.48	5.840	143.267	6283.88	-249.02	185.84	0.00	224.19
End of 3D Arc (XS)	6983.11	15.914	85.740	6955.83	-270.04	300.66	2.00	340.90
End of Tangent (XS)	7083.11	15.914	85.740	7052.00	-268.00	328.00	0.00	367.54
End of Tangent	10323.30	15.914	85.740	10168.00	-202.00	1214.00	0.00	1230.69

Plot reference wellpath is NWG 55A-29 Rev-A.0	
True vertical depths are referenced to Rig on 55-29 (KB)	Grid System: NAD83 / UTM Zone 10 North
Measured depths are referenced to Rig on 55-29 (KB)	North Reference: Grid north
Rig on 55-29 (KB) to Mean Sea Level: 5846 feet	Scale: True distance
Mean Sea Level to Mud line (At Slot: NWG 55A-29): 0 feet	Depths are in feet
Coordinates are in feet referenced to Slot	Created by: vigimice on 4/21/2015



Submitted by:

Marc Brennen

Ridge Cementing, LLC

7085 Eddy Road, Area G
Arbuckle, CA 95912

Davenport Newberry Holdings

NWG 55A-29

Sec. 29, T 21 S R 12 E

API# 36-017-______

Deschutes County, Oregon

20"Surface Casing *Reverse Method*

13-3/8" Intermediate Casing Reverse Method

9-5/8" Production Casing *Reverse Method*

Lost Circulation Plug

Cementing Program & Cost Estimate

Prepared for: **AltaRock Energy, Inc.**

Attn: **Marc Steffen**

Cell No: **707 332-6402**

Email Address: msteffen@altarockenergy.com

Marc

Please find enclosed a preliminary geothermal cementing program and cost estimate for the proposed NWG 55A-29 well at AltaRock Energy's Davenport Newberry Holding's Geothermal project in Deschutes County, near LaPine, Oregon. The information in this proposal includes casing and wellbore information, fluid summaries, cementing material requirements and cost estimates. This proposal is based on schematics and information relayed to our office, earlier discussions and previous successful geothermal cementing services performed in the area.

Ridge Cementing is Davis Bacon compliant and is able to perform prevailing wage work. We require the prevailing wage rates and job classifications from the operator - owner or as instructed by the government documents. We will also need the flow down provisions that will be necessary for employee payroll instructions.
We need to be notified 5 working days in advance to process the documentation and establish the certified payroll.

Cement slurry testing may be conducted prior to preforming actual cementing operations at the project.
Based on field conditions or lab test results the cement slurry additives and concentrations may be adjusted to achieve desired results on the actual job.
We will require potable water or water from an approved source for mixing all cement slurries.

Ridgee Cementing, LLC recognizes the importance of meeting society's need for health, safety and protection of the environment. It is our goal to proactively work with employees, customers, the public, governments and others to work in a sound manner while enforcing protection of health and safety to all personnel. We strive to protect the environment while supplying high quality products and services to our customers.

We wish to thank you for the opportunity to present this cementing proposal and we look forward to working with you in the near future. Our cementing products and services will be dispatched from our facility in Arbuckle, California. If you have any questions or require any additional information, please feel free to contact us at the numbers listed below.

Respectively Submitted by: ______________________________

Marc Brennen
Senior Director, Business Development

SERVICE CENTER: ARBUCKLE, CALIFORNIA

VP CEMENT TECHOLOGY:	MARK SAUTER	970 590-0928
ASSOCIATE TECHNICAL PROFESSIONAL:	MATT RYAN	916 276-8581
SERVICE SUPERVISOR:	BRIAN THORPE	530 514-4421

24 HR CONTACT PHONE NUMBER: **530 476-3333**

RIDGE CEMENTING

Equipment

Heavy-duty, custom designed, double pump cement mixing trailer with cement mixing rates up to 12 bpm, a fluid density range of 8.33 to 21 lb/gal, pump rates from 0-20 bpm, and 11,000 psi working pressure rating.

1710 ft3 Lay Down/Stand Up Silos to minimize space for bulk blended cement storage. Compact 400 cfm air compressor skids that are forklift or crane handy.

Dual centrifugal pump, High energy liquid additive blender suitable for large latex cementing applications.

1600 ft3 Deluxe Portable Bulk Storage Trailers for fast mobilization and rig up/rig down operations

State of the art bulk plant capable of quickly and accurately, blending our cement designs into a homogeneous mix.

620 ft3 Bulk Transport Trailers with 375 cfm compressors

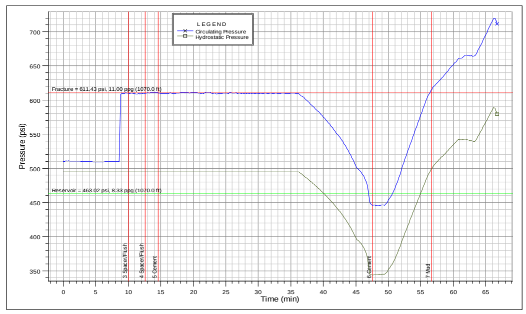
Mobile bulk plants suitable for providing expedited services to remote regions.

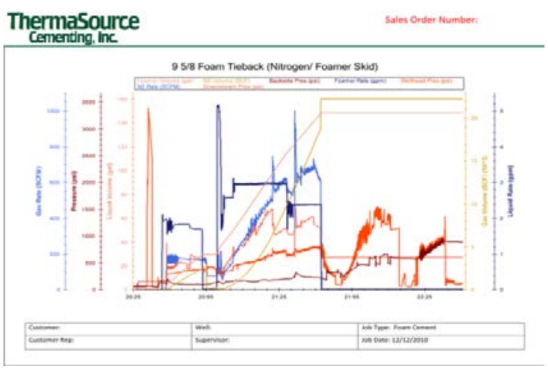
RIDGE CEMENTING

Quality Control

24 hour cementing laboratory provides quality control for slurry thickening-time, compressive strength, viscosity, density, and free fluids.

With Landmark's WellCat and WellPlan software, our engineering staff accurately simulate down-hole circulating temperatures, friction pressure, well-head pressure, centralization, and equivalent circulating density.





With our data acquisition monitoring system, we provide real-time job monitoring with detailed post-job summaries.

Cement samples taken before, during, and after all cement jobs to ensure quality control and post job analysis.

RIDGE CEMENTING

Wellbore and Casing Data

NWG 55A-29

20"Surface Casing Reverse Method

30" Conductor Casing	0 - 130	ft TMD
		ft TVD
Outer Diameter	30.000	in
Inner Diameter	29.250	in
Linear Weight	118.65	lb/ft
26" Open Hole	130 - 1100	ft TMD
		ft TVD
Outer Diameter	26.000	in
Open Hole Excess	30	%
5" Drill Pipe	0 - 1060	ft TMD
		ft TVD
Outer Diameter	5.000	in
Inner Diameter	4.276	in
Linear Weight	19.5	lb/ft
Thread	4-1/2" IF	
20" Surface Casing	0 - 1100	ft TMD
		ft TVD
Outer Diameter	20.000	in
Inner Diameter	19.000	in
Linear Weight	106.5	lb/ft
Thread	BTC	
Casing Grade	K-55	
Shoe Joint	40	ft

Mud Type	Water or Mud
Mud Weight	lb/gal
BHST	deg F
BHCT	deg F

RIDGE CEMENTING

Preliminary Job Procedure

NWG 55A-29
20"Surface Casing   Reverse Method

FLUIDS SCHEDULE

Fluid 1:	40 bbls Fresh Water		**Fluid Density:**	8.33 lb/gal
Preflush / Cool Down			**Fluid Volume:**	40 bbls
Fluid 2:	20 bbls TC Mud Clean		**Fluid Density:**	8.34 lb/gal
Chemical Wash			**Fluid Volume:**	20 bbls
Fluid 3:	50 bbls 10.5# SV SPACER		**Fluid Density:**	10.5 lb/gal
Weighted Viscous Spacer			**Fluid Volume:**	50 bbls
Fluid 4:	13 bbls Sodium Silicate Concentrate		**Fluid Density:**	10.5 lb/gal
Weighted Viscous Spacer	* If Lost Circulation Conditions Warrant		**Fluid Volume:**	13 bbls
Fluid 5:	10 bbls Fresh Water		**Fluid Density:**	8.33 lb/gal
Spacer			**Fluid Volume:**	10 bbls

Fluid 6: 675 sx GEOTAIL + accelerator, if necessary as per well conditions

Tie Back Slurry

Density:	15.0 lb/gal	Yield:	1.75 ft3/sk	Water:	7.74 gal/sk

Slurry Volume:	210.6 bbls
Mix Water Required:	124.4 bbls
Proposed Slurry Volume:	1182.6 ft3
Calculated Top of Tail:	0 feet
Cement Fill inside Casing Shoe:	300 feet

Fluid 7: 685 sx GEOTHIX I + accelerator, if necessary as per well conditions

Tie Back Slurry

Density:	13.0 lb/gal	Yield:	2.44 ft3/sk	Water:	11.16 gal/sk

Slurry Volume:	297.7 bbls
Mix Water Required:	182.0 bbls
Proposed Slurry Volume:	1671.4 ft3
Top of Cement:	0 feet

30" X 20" Annulus	130 feet	X	2.7270 ft3/ft	=						354.5 ft3
26" OH X 20" Annulus	970 feet	X	1.5053 ft3/ft	=	1460.1 ft3	X	30 %	=		1898.2 ft3
20" Shoe Track	300 feet	X	1.9689 ft3/ft	=						590.7 ft3
									TOTAL CALCULATED VOLUME:	2843.4 ft3

RIDGE CEMENTING

Cost Estimate

NWG 55A-29

20"Surface Casing **Reverse Method**

Mtrl Nbr	Description	Qty	UOM	Unit Price	Gross Amt	Disc.	Net Amt
	SERVICES						
6021200	Pump Charge to 1100 ft, first 4 hours	1	EA	4658.00	4658.00	1863.20	2794.80
6021600	Cementing Equipment Additional Hours Day 1	8	HR	1050.00	8400.00	3360.00	5040.00
6021480	Reverse Cementing Process, per job	1	EA	3496.00	3496.00	699.20	2796.80
	process includes design and pre-job engineering services to run						
	OptiCem computer simulation and top connection						
6020050	Remote Jobsite Expenses,	3	DAYS	275.00	4125.00	0.00	4125.00
	Number of personnel	5	MEN				
6021625	Data Acquisition Command Center	1	EA	2835.00	2835.00	850.50	1984.50
6021625	Iron Integrity Inspection, per job	1	EA	83.00	83.00	0.00	83.00
6022150	Cement Engineer, per day	1	EACH	1450.00	1450.00	0.00	1450.00
6020147	Squeeze Manfold Skid	1	JOB	1270.00	1270.00	317.50	952.50
	PREFLUSH OR SPACERS						
6060155	TC Mud Clean	20	BBL	109.50	2,190.00	657.00	1,533.00
6060290	10.5# SV Spacer	50	BBL	111.50	5,575.00	1,672.50	3,902.50
6060485	Sodium Silicate Concentrate, per gallon	550	GAL	18.25	10,037.50	3,513.13	6,524.38
6020288	Chemical Trailer rental	1	EACH	847.00	847.00	254.10	592.90
	REVERSE CEMENT						
6050600	GEOTAIL	675	SK	109.28	73,764.00	29,505.60	44,258.40
6040320	Calcium Chloride, 2% per lb	1270	LB	3.10	3,937.00	1,574.80	2,362.20
6050210	GEOTHIX-I	685	SK	152.71	104,606.35	41,842.54	62,763.81
6040320	Calcium Chloride, 3% per lb	1932	LB	3.10	5,989.20	2,395.68	3,593.52
6040598	DFA-22L	5	GAL	131.95	659.75	263.90	395.85
	TOP OUT CEMENT						
6050140	GEOLITE 140	200	SK	149.08	29,816.00	11,926.40	17,889.60
6040320	Calcium Chloride, 2% per lb	376	LB	3.10	1,165.60	466.24	699.36
	MOBILIZATION & MATERIALS DELIVERY						
6020298	1600 ft3 Cement Field Storage Bin	2	UNITS	1100.00	4400.00	1540.00	2860.00
		2	DAYS				
6020350	Pick Up Truck Mileage r/t	700	MILE	5.95	8330.00	2499.00	5831.00
	Number of Trips or Units	2	UNITS				
6020700	Cement Field Storage Bin Mileage r/t	700	MILE	9.80	13720.00	4802.00	8918.00
	Number of Trips or Units	2					
6020833	State Highway Truck Permits	5	EACH	100.00	500.00	0.00	500.00
6020200	Materials Blending Service	3154	FT3	4.75	14981.50	5992.60	8988.90
6020913	Bulk Materials Delivery	5	TRIPS	4459.00	22295.00	0.00	22295.00
	Minimum Legal load up to 26 tons	98.8	TONS				
		350	MILES				
					Gross	**Discount**	**Net**
					329,130.90	**115,995.89**	**213,135.02**

Estimated Gross	**329,130.90**
Discounted Amount	**115,995.89**
Estimated Net Total	**213,135.02**

Note: This proposal is an estimated cost for a typical job. On an actual job the final cost will reflect actual time, materials and services used.

Cost does not include state and local taxes

* Daily Standby rate will be 12 hours maximum per day unless additl. pumping services are required during the same 24 hr. period.

** Remote location expenses are charged per day, per man for lodging and food expenses

Personnel and Equipment Stand by - Additional Hourly and Daily Rate

6021600	Cementing Equipment Additional Hours *	1	HR	1050.00	1050.00	420.00	630.00
6020050	Subsistence Expenses, **	1	DAYS	275.00	275.00	0.00	275.00
	Number of personnel	1	MEN				

RIDGE CEMENTING

Wellbore and Casing Data

NWG 55A-29
13-3/8" Intermediate Casing Reverse Method

20" Surface Casing	0 - 1100	ft TMD
		ft TVD
Outer Diameter	20.000	in
Inner Diameter	19	in
Linear Weight	106.5	lb/ft
Thread	BTC	
Casing Grade	K-55	
17-1/2" Open Hole	1100 - 3000	ft TMD
		ft TVD
Outer Diameter	17.500	in
Open Hole Excess	30	%
5" Drill Pipe	0 - 2960	ft TMD
		ft TVD
Outer Diameter	5.000	in
Inner Diameter	4.276	in
Linear Weight	19.5	lb/ft
Thread	4-1/2" IF	
13-3/8" Intermediate Casing	0 - 3000	ft TMD
		ft TVD
Outer Diameter	13.375	in
Inner Diameter	12.415	in
Linear Weight	68	lb/ft
Thread	BTC	
Casing Grade	L-80	
Shoe Joint	40	ft
Mud Type	Water or Mud	
Mud Weight	lb/gal	
BHST	deg F	
BHCT	deg F	

RIDGE CEMENTING

Preliminary Job Procedure

NWG 55A-29
13-3/8" Intermediate Casing Reverse Method

FLUIDS SCHEDULE

Fluid 1: 40 bbls Fresh Water
Preflush / Cool Down

Fluid Density: 8.33 lb/gal
Fluid Volume: 40 bbls

Fluid 2: 20 bbls TC Mud Clean
Chemical Wash

Fluid Density: 8.34 lb/gal
Fluid Volume: 20 bbls

Fluid 3: 50 bbls 10.5# SV SPACER
Weighted Viscous Spacer

Fluid Density: 10.5 lb/gal
Fluid Volume: 50 bbls

Fluid 4: 13 bbls Sodium Silicate Concentrate
Weighted Viscous Spacer
* If Lost Circulation Conditions Warrant

Fluid Density: 10.5 lb/gal
Fluid Volume: 13 bbls

Fluid 5: 10 bbls Fresh Water
Spacer

Fluid Density: 8.33 lb/gal
Fluid Volume: 10 bbls

Fluid 6: 1610 sx GEOLITE 140 + retarder, as per lab test results
Tie Back Slurry

Density: 13.5 lb/gal | Yield: 2.14 ft3/sk | Water: 8.90 gal/sk

Slurry Volume: 613.6 bbls
Mix Water Required: 341.2 bbls
Proposed Slurry Volume: 3445.4 ft3
Calculated Top of Tail: 0 feet
Cement Fill inside Casing Shoe: 500 feet

13-3/8" X 20" Annulus	1100 feet	X	1.0190 ft3/ft	=					1120.9 ft3
17.5" OH X Csg. Annulus	2100 feet	X	0.6946 ft3/ft	=	1458.7 ft3	X	30 %	=	1896.3 ft3
13-3/8" Shoe Track	500 feet	X	0.8406 ft3/ft	=					420.3 ft3
								TOTAL CALCULATED VOLUME:	3437.5 ft3

RIDGE CEMENTING

Cost Estimate

NWG 55A-29
13-3/8" Intermediate Casing   Reverse Method

Mtrl Nbr	Description	Qty	UOM	Unit Price	Gross Amt	Disc.	Net Amt
	SERVICES						
6021230	Pump Charge to 3000 ft, first 4 hours	1	EA	4960.00	4960.00	1984.00	2976.00
6021600	Cementing Equipment Additional Hours Day 1	8	HR	1050.00	8400.00	3360.00	5040.00
6021480	Reverse Cementing Process, per job	1	EA	3496.00	3496.00	699.20	2796.80
	process includes design and pre-job engineering services to run						
	OptiCem computer simulation and top connection						
6020050	Remote Jobsite Expenses,	3	DAYS	275.00	4125.00	0.00	4125.00
	Number of personnel	5	MEN				
6021625	Data Acquisition Command Center	1	EA	2835.00	2835.00	850.50	1984.50
6021625	Iron Integrity Inspection, per job	1	EA	83.00	83.00	0.00	83.00
6022150	Cement Engineer, per day	1	EACH	1450.00	1450.00	0.00	1450.00
6020293	Chemical Injection Skid for liquid retarder	1	EACH	2515.00	2515.00	754.50	1760.50
6020147	Squeeze Manfold Skid	1	JOB	1270.00	1270.00	317.50	952.50
	PREFLUSH OR SPACERS						
6060155	TC Mud Clean	20	BBL	109.50	2,190.00	657.00	1,533.00
6060290	10.5# SV Spacer	50	BBL	111.50	5,575.00	1,672.50	3,902.50
6060485	Sodium Silicate Concentrate, per gallon	550	GAL	18.25	10,037.50	3,513.13	6,524.38
6020288	Chemical Trailer rental	1	EACH	847.00	847.00	254.10	592.90
	REVERSE CEMENT						
6050140	GEOLITE 140	1610	SK	149.08	240,018.80	96,007.52	144,011.28
6040320	Calcium Chloride, 2% per lb	940	LB	3.10	2,914.00	1,165.60	1,748.40
6040475	TSCR-30L retarder	20	GAL	235.75	4,715.00	1,886.00	2,829.00
6040598	DFA-22L	5	GAL	131.95	659.75	263.90	395.85
	MOBILIZATION & MATERIALS DELIVERY						
6020298	1600 ft3 Cement Field Storage Bin	3	UNITS	1100.00	6600.00	2310.00	4290.00
		2	DAYS				
6020350	Pick Up Truck Mileage r/t	700	MILE	5.95	8330.00	2499.00	5831.00
	Number of Trips or Units	2	UNITS				
6020700	Cement Field Storage Bin Mileage r/t	700	MILE	9.80	13720.00	4802.00	8918.00
	Number of Trips or Units	2					
6020833	State Highway Truck Permits	6	EACH	100.00	600.00	0.00	600.00
6020200	Materials Blending Service	3851	FT3	4.75	18292.25	7316.90	10975.35
6020913	Bulk Materials Delivery	6	TRIPS	4459.00	26754.00	0.00	26754.00
	Minimum Legal load up to 26 tons	124.5	TONS				
		350	MILES				
					Gross	**Discount**	**Net**
					370,387.30	**130,313.35**	**240,073.96**

Estimated Gross	**370,387.30**
Discounted Amount	**130,313.35**
Estimated Net Total	**240,073.96**

Note: This proposal is an estimated cost for a typical job. On an actual job the final cost will reflect actual time, materials and services used.

Cost does not include state and local taxes

* Daily Standby rate will be 12 hours maximum per day unless additl. pumping services are required during the same 24 hr. period.

** Remote location expenses are charged per day, per man for lodging and food expenses

Personnel and Equipment Stand by - Additional Hourly and Daily Rate

6021600	Cementing Equipment Additional Hours *	1	HR	1050.00	1050.00	420.00	630.00
6020050	Subsistence Expenses, **	1	DAYS	275.00	275.00	0.00	275.00
	Number of personnel	1	MEN				

Wellbore and Casing Data

NWG 55A-29
9-5/8" Production Casing Reverse Method

13-3/8" Intermediate Casing	0 - 3000	ft TMD
		ft TVD
Outer Diameter	13.375	in
Inner Diameter	12.415	in
Linear Weight	68	lb/ft
Thread	BTC	
Casing Grade	L-80	
12-1/4" Open Hole	3000 - 7100	ft TMD
		ft TVD
Outer Diameter	12.250	in
Open Hole Excess	30	%
5" Drill Pipe	0 - 7060	ft TMD
		ft TVD
Outer Diameter	5.000	in
Inner Diameter	4.276	in
Linear Weight	19.5	lb/ft
Thread	4-1/2" IF	
9-5/8" Production Casing	0 - 7100	ft TMD
		ft TVD
Outer Diameter	9.625	in
Inner Diameter	8.535	in
Linear Weight	53.5	lb/ft
Thread	Hydrill or Boss	
Casing Grade	L-80	
Shoe Joint	40	ft
Mud Type		Water or Mud
Mud Weight		lb/gal
BHST		deg F
BHCT		deg F

RIDGE CEMENTING

Preliminary Job Procedure

NWG 55A-29
9-5/8" Production Casing Reverse Method

FLUIDS SCHEDULE

Fluid 1:	**40 bbls Fresh Water**	**Fluid Density:**	**8.33 lb/gal**
Preflush / Cool Down		**Fluid Volume:**	**40 bbls**
Fluid 2:	**20 bbls TC Mud Clean**	**Fluid Density:**	**8.34 lb/gal**
Chemical Wash		**Fluid Volume:**	**20 bbls**
Fluid 3:	**50 bbls 10.5# SV SPACER**	**Fluid Density:**	**10.5 lb/gal**
Weighted Viscous Spacer		**Fluid Volume:**	**50 bbls**
Fluid 4:	**0 bbls Sodium Silicate Concentrate**	**Fluid Density:**	**10.5 lb/gal**
Weighted Viscous Spacer	*** If Lost Circulation Conditions Warrant**	**Fluid Volume:**	**0 bbls**
Fluid 5:	**10 bbls Fresh Water**	**Fluid Density:**	**8.33 lb/gal**
Spacer		**Fluid Volume:**	**10 bbls**

Fluid 6: **1350 sx GEOLITE 180 + retarder, Cmt Bonding additive to be added to first 1/3 of slurry**

Reverse Slurry

Density:	Yield:	Water:
13.5 lb/gal	2.14 ft3/sk	8.90 gal/sk

Slurry Volume:	**514.5 bbls**
Mix Water Required:	**286.1 bbls**
Proposed Slurry Volume:	**2889.0 ft3**
Calculated Top of Tail:	**0 feet**
Cement Fill inside Casing Shoe:	**500 feet**

9-5/8" X 13.375" Annulus	3000 feet	X	0.3354 ft3/ft	=					1006.2 ft3
12.25" OH X Csg. Annulus	4100 feet	X	0.3132 ft3/ft	=	1284.1 ft3	X	30 %	=	1669.4 ft3
9-5/8" Shoe Track	500 feet	X	0.3973 ft3/ft	=					198.7 ft3
								TOTAL CALCULATED VOLUME:	2874.2 ft3

RIDGE CEMENTING

Cost Estimate

NWG 55A-29

9-5/8" Production Casing Reverse Method

Mtrl Nbr	Description	Qty	UOM	Unit Price	Gross Amt	Disc.	Net Amt
	SERVICES						
6021280	Pump Charge to 7100 ft, first 4 hours	1	EA	8560.00	8560.00	3424.00	5136.00
6021600	Cementing Equipment Additional Hours Day 1	8	HR	1050.00	8400.00	3360.00	5040.00
6021480	Reverse Cementing Process, per job	1	EA	3496.00	3496.00	699.20	2796.80
	process includes design and pre-job engineering services to run						
	OptiCem computer simulation and top connection						
6020050	Remote Jobsite Expenses,	3	DAYS	275.00	4125.00	0.00	4125.00
	Number of personnel	5	MEN				
6021625	Data Acquisition Command Center	1	EA	2835.00	2835.00	850.50	1984.50
6021625	Iron Integrity Inspection, per job	1	EA	83.00	83.00	0.00	83.00
6022150	Cement Engineer, per day	1	EACH	1450.00	1450.00	0.00	1450.00
6020293	Chemical Injection Skid for liquid retarder	1	EACH	2515.00	2515.00	754.50	1760.50
6020147	Squeeze Manfold Skid	1	JOB	1270.00	1270.00	317.50	952.50
	PREFLUSH OR SPACERS						
6060155	TC Mud Clean	20	BBL	109.50	2,190.00	657.00	1,533.00
6060290	10.5# SV Spacer	50	BBL	111.50	5,575.00	1,672.50	3,902.50
6060485	Sodium Silicate Concentrate, per gallon	0	GAL	18.25	0.00	0.00	0.00
6020288	Chemical Trailer rental	1	EACH	847.00	847.00	254.10	592.90
	REVERSE CEMENT						
6050180	GEOLITE 180	1350	SK	153.40	207,090.00	82,836.00	124,254.00
6040320	Calcium Chloride, 2% per lb in last 500 sacks	940	LB	3.10	2,914.00	1,165.60	1,748.40
6040475	TSCR-30L retarder, as per lab test results	30	GAL	235.75	7,072.50	2,829.00	4,243.50
6040598	DFA-22L	10	GAL	131.95	1319.50	527.80	791.70
6050010	Rbond-M, Bonding additive in first 1/3 of slurry	2000	LB	4.54	9,080.00	3,632.00	5,448.00
	TOP OUT CEMENT						
6050600	GEOTAIL	200	SK	109.28	21,856.00	8,742.40	13,113.60
	MOBILIZATION & MATERIALS DELIVERY						
6020298	1600 ft3 Cement Field Storage Bin	3	UNITS	1100.00	6600.00	2310.00	4290.00
		2	DAYS				
6020350	Pick Up Truck Mileage r/t	700	MILE	5.95	8330.00	2499.00	5831.00
	Number of Trips or Units	2	UNITS				
6020700	Cement Field Storage Bin Mileage r/t	700	MILE	9.80	13720.00	4802.00	8918.00
	Number of Trips or Units	2					
6020833	State Highway Truck Permits	5	EACH	100.00	500.00	0.00	500.00
6020200	Materials Blending Service	3245.5	FT3	4.75	15416.13	6166.45	9249.68
6020913	Bulk Materials Delivery	5	TRIPS	4459.00	22295.00	0.00	22295.00
	Minimum Legal load up to 26 tons	100.5	TONS				
		350	MILES				

Gross	Discount	Net
357,539.13	127,499.55	230,039.58

Estimated Gross	**357,539.13**
Discounted Amount	**127,499.55**
Estimated Net Total	**230,039.58**

Note: This proposal is an estimated cost for a typical job. On an actual job the final cost will reflect actual time, materials and services used.

Cost does not include state and local taxes

* Daily Standby rate will be 12 hours maximum per day unless additl. pumping services are required during the same 24 hr. period.

** Remote location expenses are charged per day, per man for lodging and food expenses

Personnel and Equipment Stand by - Additional Hourly and Daily Rate

6021600	Cementing Equipment Additional Hours *	1	HR	1050.00	1050.00	420.00	630.00
6020050	Subsistence Expenses, **	1	DAYS	275.00	275.00	0.00	275.00
	Number of personnel	1	MEN				

RIDGE CEMENTING

Wellbhore and Casing Data

NWG 55A-29
Lost Circulation Plug

30" Conductor Casing	0 - 130	ft TMD
		ft TVD
Outer Diameter	30.000	in
Inner Diameter	29.250	in
Linear Weight	118.65	lb/ft
26" Open Hole	130 - 1100	ft TMD
		ft TVD
Outer Diameter	26.000	in
Open Hole Excess	30	%
5" Drill Pipe	0 - 1060	ft TMD
		ft TVD
Outer Diameter	5.000	in
Inner Diameter	4.276	in
Linear Weight	19.5	lb/ft
Thread	4-1/2" IF	

Mud Type	Water or Mud
Mud Weight	lb/gal
BHST	deg F
BHCT	deg F

Preliminary Job Procedure

NWG 55A-29
Lost Circulation Plug

FLUIDS SCHEDULE

Fluid 1:	35 bbls Fresh Water	Fluid Density:	8.33 lb/gal
Spacer Ahead		Fluid Volume:	35 bbls

Fluid 2: 215 sx GEOTAIL + additives as per observed well conditions

LC Plug Slurry

Density:	15.0 lb/gal	Yield:	1.75 ft3/sk	Water:	7.74 gal/sk

Slurry Volume:	67.1 bbls
Mix Water Required:	39.6 bbls
Proposed Slurry Volume:	376.7 ft3
Height of Cement:	100 feet

Fluid 3:	tbd bbls Fresh Water & Mud	Fluid Density:	8.33 lb/gal
Balance & Displace		Fluid Volume:	tbd bbls

Open Hole Volume	100 feet	X	3.687 ft3/ft	X	368.7 ft3	X	0 %	=	368.7 FT3
							TOTAL VOLUME:		368.7 FT3

RIDGE CEMENTING

Cost Estimate

NWG 55A-29
Lost Circulation Plug

Mtrl Nbr	Description	Qty	UOM	Unit Price	Gross Amt	Disc.	Net Amt
	SERVICES						
6021200	Pump Charge to 1100 ft, first 4 hours	1	EA	4658.00	4658.00	1863.20	2794.80
6021600	Cementing Equipment Additional Hours Day 1	8	HR	1050.00	8400.00	3360.00	5040.00
6020050	Remote Jobsite Expenses,	3	DAYS	275.00	2475.00	0.00	2475.00
	Number of personnel	3	MEN				
6021605	Data Acquisition	1	EA	1325.00	1325.00	530.00	795.00
	LOST CIRCULATION PLUG CEMENT #1						
6050600	GEOTAIL	215	SK	109.28	23,495.20	9,398.08	14,097.12
6040320	3% Calcium Chloride, per pound	606	LB	3.10	1,878.60	751.44	1,127.16
	MOBILIZATION & MATERIALS DELIVERY						
6020350	Pick Up Truck Mileage r/t	700	MILE	5.95	4165.00	1249.50	2915.50
	Number of Trips or Units	1	UNITS				
6020700	Cement Field Storage Bin Mileage r/t	700	MILE	9.80	6860.00	2401.00	4459.00
	Number of Trips or Units	1					
6020833	State Highway Truck Permits	2	EACH	100.00	200.00	0.00	200.00
6020200	Materials Blending Service	437.7	FT3	4.75	2079.08	831.63	1247.45
6020913	Bulk Materials Delivery	1	TRIPS	4459.00	4459.00	0.00	4459.00
	Minimum Legal load up to 26 tons	14.5	TONS				
		350	MILES				
					Gross	**Discount**	**Net**
					59,994.88	**20,384.85**	**39,610.03**

Note: This proposal is an estimated cost for a typical job. On an actual job the final cost will reflect actual time, materials and services used.

Cost does not include state and local taxes

Estimated Gross	**59,994.88**
Discounted Amount	**20,384.85**
Estimated Net Total	**39,610.03**

* Daily Standby rate will be 12 hours maximum per day unless additl. pumping services are required during the same 24 hr. period.

** Remote location expenses are charged per day, per man for lodging and food expenses

Personnel and Equipment Stand by - Additional Hourly and Daily Rate

6021600	Cementing Equipment Additional Hours *	1	HR	1050.00	1050.00	420.00	630.00
6020050	Subsistence Expenses, **	1	DAYS	275.00	275.00	0.00	275.00
	Number of personnel	1	MEN				

FORMERLY:

PROPOSAL TERMS AND CONDITIONS

PRICES

The prices of the proposal are based on Ridge Cementing, LLC (RC) being awarded the work on a first call basis. Prices will be reviewed for adjustment if awarded 2nd or 3rd call basis and/or after 30 days of this written analysis. The proposed Services and/or equipment and materials are only estimates based on information presented to RC by the Customer. At the time the Services are performed, conditions, then existing may require an increase or decrease in the equipment, personnel, and/or material actually utilized for the Services. Charges will be based upon prices mutually agreed upon in the applicable Sales Order. Applicable taxes are not included and will be added to the invoice.

PAYMENT

Customer agrees to pay RC during the Term of this Sales Order in accordance with the rates and terms set forth under each Sales Order.

If Customer does not have an open account with RC all sums are due prior to performance of Services, delivery of equipment, products, or materials. Customer may in lieu of paying prior to performance submit an acceptable letter of credit or equal documentation that Customer has the funding to pay for the Services. Opening an account with RC shall include but not limited to completion of a confidential credit application. Credit applications which are deemed satisfactory by the sole discretion of RC shall have the invoice payment terms set forth in Section 8.3. Credit applications that are not satisfactory by the sole discretion of RC may have more stringent invoice payment terms.

Invoices shall be submitted to Customer up to two times per month and shall be paid within twenty (20) days from the invoice date. If the due date of an invoice falls on a weekend or holiday, the due date shall be adjusted to the next following work day.

Any third party expenses incurred by RC on behalf of Customer shall bear a 25% handling charge.

If Customer disputes an invoice or any part thereof, Customer shall, within twenty (20) days after the date of the invoice, notify RC of the item disputed, specifying the reason for the dispute. Payment of the disputed item shall still be paid within the specified time and shall be credited back to Customer if the dispute is resolved in favor of Customer. Any sums not paid within the above specified days shall bear interest at the rate of one and one half percent (1.5%) or the maximum legal rate, whichever is less, per month from the due date until paid. In the event RC employs legal counsel for collection of any account, Customer shall pay all reasonable legal fees, all collection costs and all court costs. Customer agrees that this amount of legal fees, collection cost and court cost set out here is reasonable and necessary.

TERMS AND CONDITIONS

It is mutually agreed upon between the Customer and RC that all Services performed, equipment and materials provided are subject to the Terms and Conditions contained in the RC Sales Order which must be executed by a representative of the Customer prior to commencement of Services or sell of equipment and/or materials. If a Service Agreement exists between the Customer and RC, the Service Agreement shall govern the Services and sale of equipment and/or materials rather than the Sales Order. Customer shall still execute every Sales Order prior to commencement of Services or sale of equipment and/or materials to remind Customer's representative of major Terms and Conditions of the Service Agreement.

7085 Eddy Road, Area G - Arbuckle, California 95912 - (530) 476-3333 - FAX (530) 476-3347

2556 Beasley Drive – Fallon, Nevada 89406 – (775) 867-5927

600 Lone Tree Circle – Nunn, Colorado 80648 – (970) 716-3017

Appendix I
Detailed Stimulation Plan

1 NWG 55A-29 STIMULATION

After well drilling reaches the total planned depth of the production well NWG 55A-29, a series of wireline surveys will be conducted, including BHTV, sonic, gamma ray, induction, neutron porosity, density, and pressure and temperature. After logging operations, NWG 55A-29 will be stimulated in order to improve the connectivity between producer and injector. A horizontal, surface injection pump will be installed on the injection well. Tracers, both conservative (e.g., 2,6-naphthalene disulfonate) and sorbing (e.g., Safranin T), similar to those used during the stimulation of NWG 55-29, will be injected in NWG 55A-29 for sampling at the production well. Breakthrough times will be determined by evaluation of tracer return concentrations. In addition, the concentration of conservative tracers that were injected during the stimulation of the injection well will be measured to determine if the production well is in communication with the discrete fracture networks created during stimulation. Injecting and producing pressure-temperature surveys will be conducted in both wells to identify flow zones, the contribution of each zone to the total flow, and producing and injecting wellbore temperature profiles. This production log data provides essential data for numerical modeling and reservoir characterization. A chemical and/or dual stimulation treatment, may be applied to overcome pressure barriers between the two wells, remove any skin damage, and increase connectivity/transmissivity. And the end of the stimulation, the connection between the injection well and the production well will be evaluated by conducting connectivity tests for up to seven days to determine the system productivity, circulating temperature, reservoir permeability, skin, and fluid loss (Figure 1).

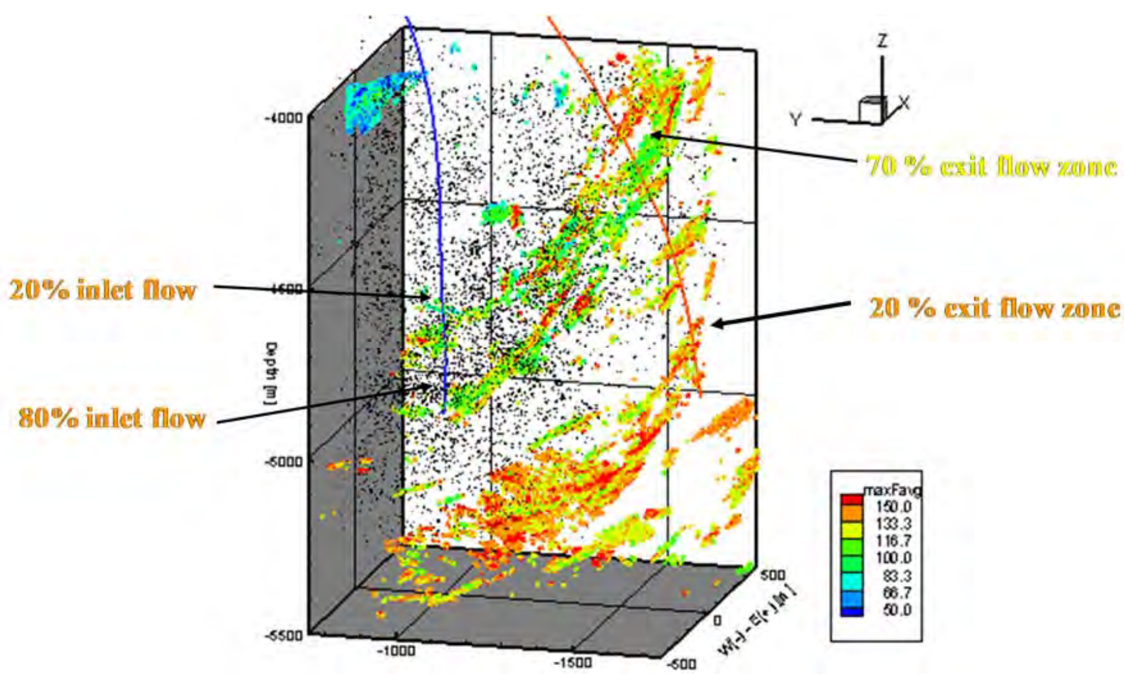


Figure 1. Example of connectivity test data between an injector and a producer and the relative contributions of flow contributed to each zone.

1.1.1 DRAFT STIMULATION PROCEDURE

MAXIMUM WELLHEAD PRESSURE 24.1 MPa (3,500 PSIG)

INDUCED SEISMICITY PROTOCOL MUST BE POSTED IN THE CONTROL ROOM AND FOLLOWED THROUGHOUT THE TREATMENT

The following steps must be followed:

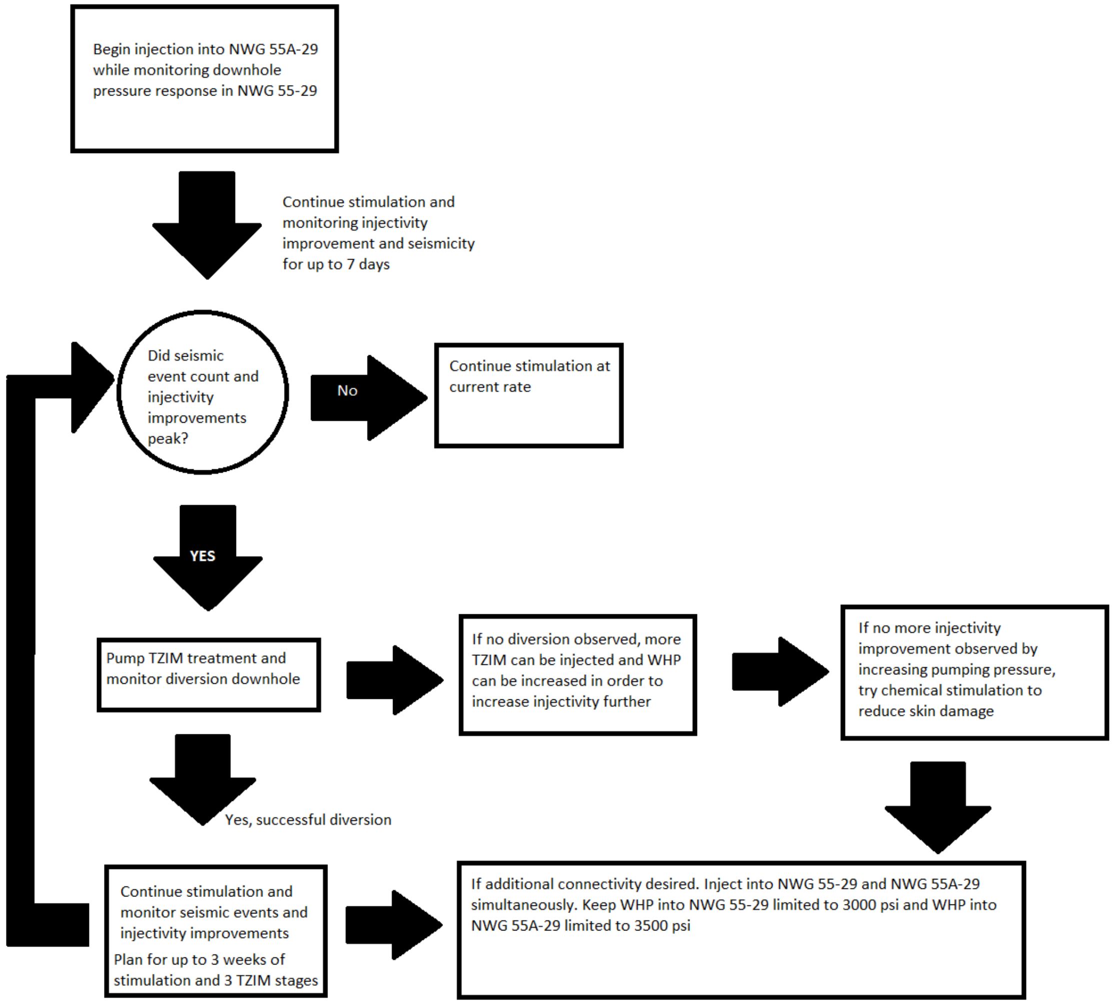
1. Rent and set two-four light plant generators for Pad S-29.
2. Rent two large generator to power the downhole pump in the Pad S-29 water well, sump pumps, stimulation pumps and misc. other site electrical equipment. A Caterpillar XQ2000 or equivalent is required.
3. Set and install flow-back equipment. Install valve, gauges, sampling ports, sampling separator, James tube assembly, muffler and weir box. Bleed off pressure from wellhead through the wing valve through the flow-back equipment and into the sump on pad S-29.
4. Rig up the surface pumping equipment to both NWG 55-29 and NWG 55A-29. The pumps must be manifolded together on the suction and discharge sides. Valves should be positioned to allow each pump to be isolated for maintenance and repair, when necessary. The pumps must be capable of flow rates from 0.6-25 L/s (10-400 gpm) at discharge pressures from 5.2-25 MPa (750-3500 psi) with 50% redundancy.
5. Set and rig up a separate discharge line from the Diverter Injection Vessel Assembly (DIVA) to the wing valve if bypassing the stimulation pump set-up. The water line from the bypass line should have a T and a valve that allows flow through the DIVA when we are mixing diverter. Otherwise, the batch mixer will be bypassed.
6. The discharge lines and manifolding must be rated to at least 25 MPa (3625 psi). Install the hammer union or steel pipe, in-line flow meter, pressure transmitter and RTD on the discharge side of the pumps. All digital instrumentation should also have a non-digital back-up instrument installed (pressure gauge, dial thermometer, etc.).
7. Install downhole pressure monitoring equipment in NWG 55-29 and monitor changes in pressure during stimulation of NWG 55A-29 in order to test connectivity.
8. Flag and tape off the high-pressure equipment and the wellhead.
9. Connect all surface instrumentation to the data logger in the control room and set up all electrical connections to the data trailer.
10. Once all of the equipment is positioned and installed, ensure that the master valve on the wellhead or the stack is closed.
11. Conduct safety meeting. Safety meeting should
    - Identify areas that are off limits to bystanders and AltaRock personnel.
    - Review the maximum operating pressure of 24 MPa (3500 psi).
    - Reiterate that personnel should continuously monitor for line leaks, equipment malfunction, and operating pressure and induced seismicity to ensure a safe operation.
    - Review evacuation procedures, wind sock location and request that all personnel back-in their vehicles, upwind of the equipment, if possible.

- Designate evacuation vehicles.
- Review 911 and nearest hospital information.
- Review PPE requirements.

12. The existing groundwater well on Pad S-29 will flow directly into the south sump and water will be pumped out of the sump utilizing a sump pump for stimulation. Ensure that the magnetic flow meter, downhole pressure transducer, valve and control panel are installed on the Pad 29 water well and functioning properly.
13. Open valve halfway on Pad S-29 water well. Turn on pump and fill sump until water level submerges the sump pump.
14. Fill pumps and lines with water and pressure test to 24 MPa (3500 psi) (3.4 MPa or 500 psi above maximum treatment pressure) for 10 minutes. Check for line leaks and failures. Replace any bad equipment and tighten all connections.
15. Bleed off pressure. Move in and rig up DTS fiber optic monitoring equipment and truck. Deploy cable into well NWG 55A-29. Install surface data acquisition unit. Ensure that the cable is sending viable data.
16. Conduct step-rate injection test to slowly pressure up to 3000 psi.
17. Pump the steps for a minimum of 2 hours each or until the pressures stabilizes, whichever is longer. Step back down at the same rates and time steps. Shut down pumps and monitor pressure fall-off until 80-90% of recovery. Rates to be changed on-the-fly so that pressures do not exceed formation breakdown (keep rates below necessary maximum). Calculate permeability, injectivity and skin effects from data. Repair any surface leaks while WHP is lowered.
18. Begin pumping Stage 1 of the stimulation treatment. The microseismic network will provide real-time data of the seismic events so the duration and rate of the treatment can be adjusted 'on-the-fly' to optimize the fracture network geometry. The fiber optic data will be monitored to identify fluid exit points.
19. Rig up necessary tracer equipment. Tracer Procedure: Within six hours before the end of each stimulation phase, a solution containing a pair of tracers will be injected as a pulse into NWG 55A-29. This procedure will be repeated for each stimulation/diversion event.

    Lower WHP to below 17 MPa (2500 psi), and prepare to pump diverter chemicals. Mix diverters in batch mixer. After diverter mixing is complete, open the appropriate valves on the discharge side of the DIVA and pump the diverter slurry down hole. Displace the diverter with fresh water. Which diverter is used, when it is used, and how much is used are decisions that will be made during the stimulation treatment based on how the well responds, how the fractures grow, at what depth the fractures are formed, etc. If a given fracture set is only partially sealed by one diverter treatment, a second treatment of equal or larger volume will be pumped to seal the remainder of the fracture set.
20. Monitor fiber optic temperature for depth location of new fractures. Observe microseismic data to monitor the growth of new fractures. Repeat steps 17-18 until desired injectivity is achieved.

21. A dual stimulation and/or chemical stimulation may be applied depending on preliminary stimulation results. Following decision flow charts may be used:



22. After the final stimulation stage, shut-down all pumps and monitor pressure decay/leak-off while watching the fiber-optic temperature readings for a minimum of 1 hour.
23. Pull out of hole with fiber optic monitoring system. Rig down, move off fiber optic system.
24. Rig down, move off stimulation pumps, controls and misc equipment. Release all temporary piping and rental equipment.
25. Prepare to flow well NWG 55A-29 and conduct connectivity test. Once the well has heated up and has sufficient energy to flow, open the surface valve to absolute open flow. A compressor may be utilized to push air down the well and further energize the system, if necessary.
26. Conduct safety meeting with all personnel involved at the site. Ensure that all personnel are familiar with the safety supervisor on site, outfitted with appropriate personnel protective equipment, and are aware of safety requirements and escape routes.

27. Begin injecting into NWG 55-29 at approximately 1000 psi WHP. Add tracer to 55-29
28. Initiate H_2S abatement.
29. Open NWG 55A-29 wellhead valve and flow line valve. Inspect wellhead equipment for leaks upstream of flow control valve.
30. Slowly open the throttle valve. Inspect flow line equipment for leaks.
31. Allow NWG 55A-29 well flow to stabilize at a low rate.
32. Record James tube lip pressure and weir box liquid level.
33. Calculate total mass flow and enthalpy. Ensure that total flow does not exceed separator design maximum flow rate.
34. Continue to slowly open throttle valve to maximum well capability or maximum separator design flow rate, whichever is less.
35. Allow well flow to stabilize.
36. On an hourly basis, record all flow test data, including wellhead pressure and temperature, throttle valve position, abatement chemical injection rates, particulate scrub water rate, flow line pressure and temperature, James tube lip pressure, weir box liquid level, frac tank levels, pump discharge pressure, and pump flow rate.
37. Conduct step-rate flow test. Collect data at five separate flow rates at NWG 55A-29 for the same time-step (at least two hours at each rate) to build a productivity curve.
38. Collect fluid samples for tracer testing and geochemical analysis.
39. Shut-in well after flowback period. Rig down flowback equipment.
40. Secure both water wells and EGS wells by placing locked containers over them.

Appendix J Mitchell Plummer Doublet Production Analysis

Flow rate estimate using dipole flow solution for injection extraction well pair

Reference material

Clement, T., M. Truex, & B. Hooker (1997) Two-well test method for determining hydraulic properties of aquifers, Ground Water, V. 35, No. 4.

https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CB4QFjAA&url=http%3A%2F%2Finfo.ngwa.org%2Fgwol%2Fpdf%2F972062753.PDF&ei=zTYLVdD0OMelgwTkhoPABQ&usg=AFQjCNE911Z4Y1vaeucKcPOGw7hFcN6CVg&bvm=bv.88528373,d.eXY

Single-Observation-Well Method

Using the superposition principle and point-source-sink approximation, two-dimensional steady-state head changes due to an injection-extraction well pair in a homogeneous, isotropic, infinite areal extent, horizontal (no regional gradient), confined aquifer can be written as (Bear, 1979),

$$\Delta h(x, y) = \frac{Q_r}{4\pi T} \ln\left[\frac{(x + d)^2 + y^2}{(x - d)^2 + y^2} \right] \tag{1}$$

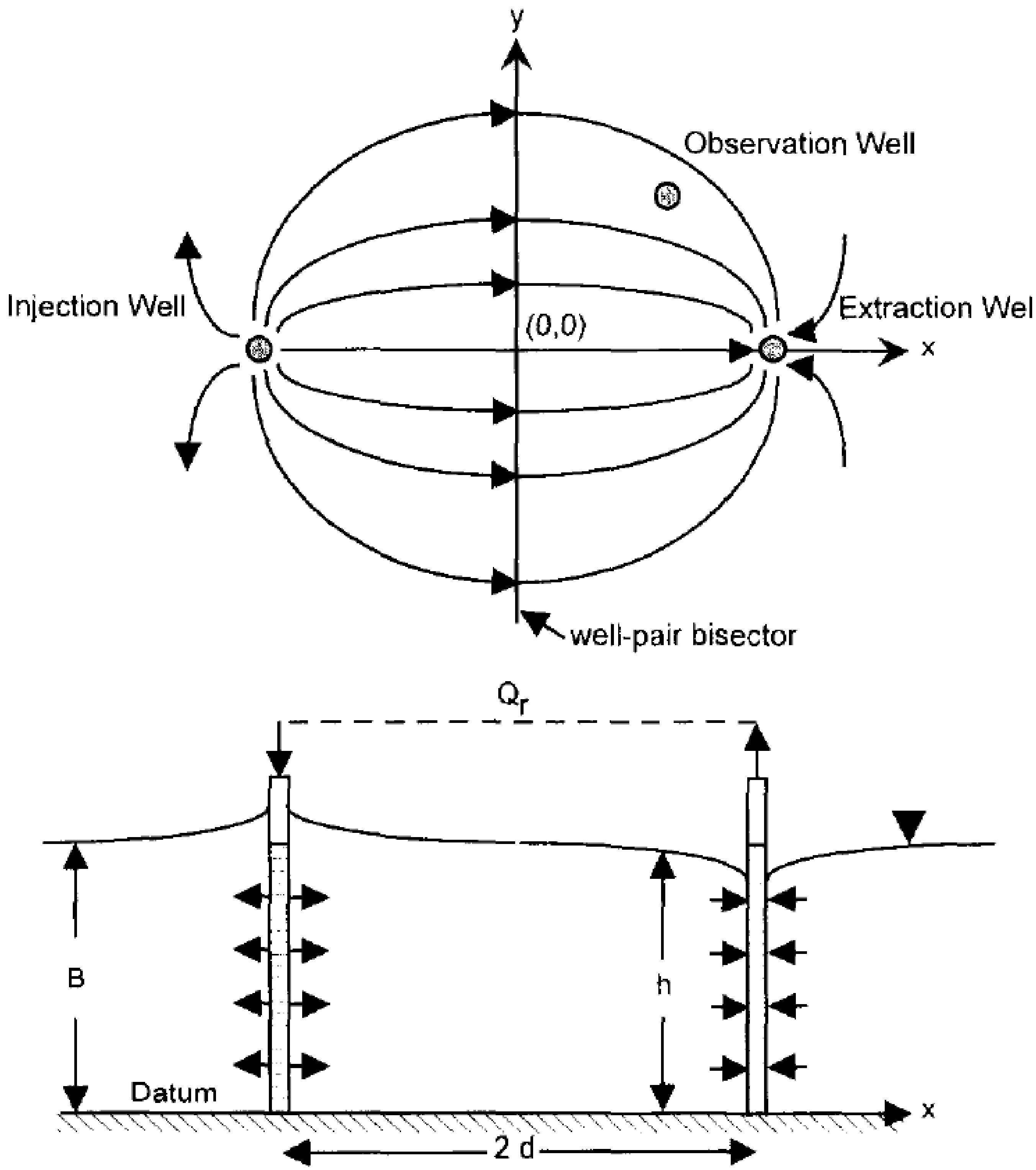


Fig. 1. Well configuration used for two-well aquifer test.

Reference material

Fundamental fluid properties

Viscosity, water $\mu_f := 0.282 \cdot 10^{-3} \cdot Pa \cdot s = 2.82 \times 10^{-3} \cdot poise$

Density, water $\rho_f := 958 \cdot kg \cdot m^{-3}$

\
|
| 100 degC
|
/

Specific heat, water $c_f := 4186 \cdot J \cdot kg^{-1} \cdot K^{-1} = 1 \cdot \frac{cal}{K \cdot gm}$

Heat capacity, water $C_f := \rho_f \cdot c_f = 4.01 \times 10^{6} \cdot J \cdot m^{-3} \cdot K^{-1}$

Hydrogeologic properties

Hydrogeologic Unit	Porosity	k_x (m^2)	k_y (m^2)	k_z (m^2)
Newberry-Deschutes (upper 300 m)	0.20	1.5×10^{-12}	1.5×10^{-12}	1.5×10^{-12}
Newberry-Deschutes	0.04	2.0×10^{-15}	4.0×10^{-15}	4.0×10^{-15}
John Day	0.05	5.0×10^{-18}	1.0×10^{-17}	1.0×10^{-17}
Intruded John Day	0.03	5.0×10^{-18}	1.0×10^{-17}	1.0×10^{-17}
Intruded John Day (lowest 100m)	0.01	1.0×10^{-18}	1.0×10^{-18}	1.0×10^{-18}
Wellbore Cased Interval	0.95	0.0	0.0	1.5×10^{-3}
Wellbore Uncased (Lined) Interval	0.98	1.0×10^{-6}	1.0×10^{-6}	7.9×10^{-4}

Estimated properties for fracture zone connecting wells

Thickness of connecting zone $B := 200m$

Permeability of zone $k := 1 \cdot 10^{-15} m^2$ $k = 1 \times 10^{-11} \cdot cm^2$

Storage coefficient of fracture zone $Ss := 10^{-9} \cdot Pa^{-1}$

Transmissivity $T := k \cdot B = 2 \times 10^{-13} \cdot m^3$

Storativity $S := Ss \cdot B = 2 \times 10^{-7} m \cdot Pa^{-1}$

Hydraulic diffusivity $Diffusivity := \frac{T}{S \cdot \mu_f} = 3.546 \times 10^{-3} \frac{m^2}{s}$

~Aperture that could provide estimated T $b := \left(\frac{T}{12}\right)^{\frac{1}{3}} = 0.026 \cdot mm$

Estimated geometry for injection- extraction dipole

Separation distance between wells $d_{sep} := 200\text{m} = 200\,\text{m}$

Radius of well $r_{well} := 4.5\text{in}$

Pressure drop across dipole $\Delta p := 2500\text{psi}$

Injection well location, x axis $x_{inj} := d_{sep} - r_{well} = 199.886\,\text{m}$

Volumetric flow rate through dipole

$$Q_v(\Delta p) := \frac{\pi \cdot T \cdot \Delta p}{\ln\left[\frac{\left(x_{inj} + \frac{d_{sep}}{2}\right)^2}{\left(x_{inj} - \frac{d_{sep}}{2}\right)^2}\right] \cdot \mu_f} \qquad Q_v(\Delta p) = 276.855\,\text{gpm}$$

Mass flow rate through dipole $Q_m(\Delta p) := Q_v(\Delta p) \cdot \rho_f$ $\qquad Q_m(\Delta p) = 16.733\,\frac{\text{kg}}{\text{s}}$

Energy delivery

Temperature difference, (for enthalpy est.) $\Delta T := 280\,°\text{C} - 20\,°\text{C}$

Energy conversion efficiency $\eta_{th\_e} := 15\%$

Pump efficiency $\eta_{pump} := 75\%$

Thermal power $Q_H(\Delta p) := Q_v(\Delta p) \cdot \Delta T \cdot \rho_f \cdot c_f$ $\qquad Q_H(\Delta p) = 18.212\,\text{MW}$

Estimated pumping loss $\Delta\Phi(\Delta p) := \left(1 - \eta_{pump}\right) \cdot \Delta p \cdot Q_v(\Delta p)$ $\qquad \Delta\Phi(\Delta p) = 0.075\,\text{MW}$

Electricity power $Q_E(\Delta p) := \eta_{th\_e} \cdot Q_H(\Delta p) - \Delta\Phi(\Delta p)$ $\qquad Q_E(\Delta p) = 2.656\,\text{MW}$