Wister Exploration and Drilling Project

CONDUCTING A 3D CONVERTED SHEAR WAVE PROJECT TO REDUCE EXPLORATION RISK AT WISTER, CA

Final Exploration Studies Report
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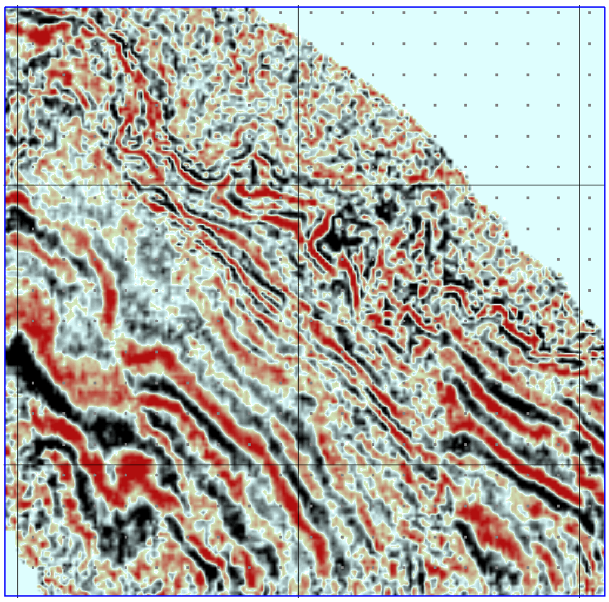

United States Department of Energy – Geothermal Technologies Program

Ormat Nevada, Inc.

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1. Executive Summary

Ormat sited 2 full-size exploration wells based on 3D seismic interpretation of fractures, prior drilling results, and temperature anomaly. The wells indicated commercial temperatures (>300 F), but almost no permeability, despite one of the wells being drilled within 820 ft of an older exploration well with reported indications of permeability. Following completion of the second well in 2012, Ormat undertook a lengthy program to 1) evaluate the lack of observed permeability, 2) estimate the likelihood of finding permeability with additional drilling, and 3) estimate resource size based on an anticipated extent of permeability.

The resource re-evaluation work included reprocessing the 3D seismic survey and interpreting the results and incorporating available well data. Results indicated that previously identified permeability was likely to have been locally present along a specific fracture or fracture intersection and that future wells would have high risk of failure due to low permeability. Even if the fracture were continuous, the anticipated size of the project would be <1/5 of the originally planned project with wells >4000 ft needed to develop the project. Reservoir connectivity was also a major concern, possibly leading to rapid pressure drawdown.

Ormat drilled the Wister 12-27 well, which was the first geothermal exploration well located by using 3D seismic data in the Imperial Valley. The innovation of using 3D seismic data was new to the geothermal industry in this region and may lead to expanded utilization of reflection seismic to reduce geothermal exploration drilling risks in sedimentary environments. Wister 12-27 is in the southeastern part of the 3D survey. The location was selected to drill into an east-dipping fault zone. The vertical well had a total depth of 6375 ft with commercial temperature but low permeability.

Ormat drilled well 85-20 ~820 ft from a Unocal well, 88-1, which was reported to have lost circulation indicating permeability before wellbore issues caused it to be abandoned. 85-20 was a full size vertical well drilled to 4994', again with commercial temperature but no permeability. Resistivity image logs (Schlumberger FMI) in 85-20 indicate that maximum horizontal stress (S_{hmax}) is oriented NNE but that open fractures are oriented sub-optimally.

2. Introduction

The Wister Prospect is on the northeast margin of the Salton Trough immediately adjacent to the San Andreas Fault (Figure 1). The Salton Trough includes several producing geothermal areas, including the Salton Sea (SS), Brawley (BR), Heber (HB), etc. The geologic setting for the Salton Trough is crustal thinning in a transtensional structural zone where right-stepping, right lateral faults produce extensional basins (e.g. Elders et al., 1972, Hulen et al., 2002). These basins are filled with up to 6,100 m (20,000 ft) of low density, high permeability sediments from the Colorado River. Bi-modal magmatic intrusions into these basins have produced extraordinary temperature anomalies, with measured temperatures as high as 389° C measured at 2 km depth (Hulen et al., 2002). Sedimentary fill permeability is enhanced by continued motion along fractures resulting in commercial flow rates of high temperature fluid. Minimal pressure drawdown in producing areas indicates rapid, extensive recharge and long-lived power generation potential.

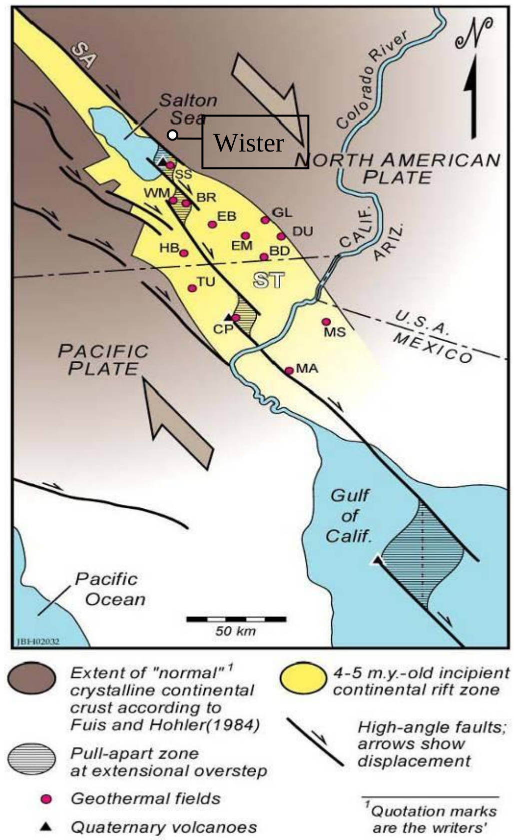


Figure 1: Map of Salton Trough with producing and non-producing known geothermal areas. Modified from Hulen et al. 2002.

In July 2010, Ormat Nevada, Inc. conducted a three-dimensional (3D) multicomponent (3C) seismic reflection survey on the Wister Geothermal prospect area in the northern portion of the Imperial Valley, California (Figure 2). Matching funding for this seismic survey is provided through the U. S. Department of Energy Geothermal Technologies Program as part of the American Recovery and Reinvestment Act Of 2009. The Wister seismic survey was 13.2 square miles and was in an agricultural area that required significant survey planning, permitting and operational flexibility. The prospect is situated in farm fields that occur in a broad, flat valley.

This farming activity has destroyed any surface geological features. Surface thermal features such as hot springs do not exist. Figure 3 shows a Google Earth image of the survey area outline.

The 3D 3C reflection survey data were acquired by Dawson Geophysical Company of Midland, Texas under the supervision of ExplorTech LLC (Centennial, Colorado) personnel. Sage Geodetic, LLC provided RTK GPS surveying of the source/receiver positioning. Seismic data processing was performed by FairfieldNodal in their Denver, Colorado offices. FairfieldNodal has extensive experience in P-wave and converted S-wave data processing. The interpretation was completed by ExplorTech.

The objective of the Wister seismic survey was to reduce exploration risk by mapping structure, faults, fracture systems and geology as they relate to a potential blind geothermal resource. To meet the objective, Ormat proposed a converted wave or 3D 3C reflection seismic survey centered on a known heat flow anomaly. The shape of the temperature anomaly suggested that faults and fractures may control the upwelling of thermal fluids. UNOCAL discovered this potential resource in 1988 using widely spaced temperature gradient holes and an exploration well. The UNOCAL exploration well collapsed during drilling preventing testing and reservoir characterization.

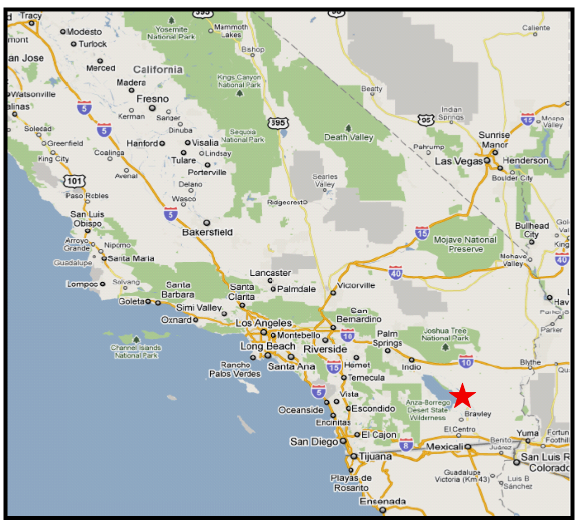


Figure 2: Wister 3D 3C general location map.

Figure 3: Google Earth image of Wister 3D 3C survey area (red outline).

Ormat initiated an exploration program at Wister that has identified several faults that may control the geothermal reservoir. None of these faults are exposed at the surface. In order to define the fractures controlling the Wister geothermal resource, Ormat proposed collecting, processing, and interpreting a 3D 3C seismic survey. Other geophysical data and temperature gradient drilling have limited the area of the potential reservoir at Wister, but better fracture definition reduces exploration risk associated with drilling a blind geothermal resource. This new acquired information was merged with previously obtained data to predict the most likely locations for high fracture density and hot fluids. The intent of this program was to use a 3D seismic survey with shear wave conversion combined with available data to site and drill a production well at Wister.

3. Data Acquisition

Dawson Geophysical Company conducted the field data acquisition in the first half of July. Most of the land in the survey area (13.2 square miles) is private or fee leases. A little more than 2 square miles are BLM lands. The survey was planned for the early spring, but the BLM permits delayed the field work until July.

The pre-survey field layout plan is shown in Figure 4. The Wister 3D grid consisted of 1929 receiver positions, and a total of 1368 source points. The source points were located along ¼ mile spaced north-south access roads. The receiver lines were oriented in northeast-southwest direction (45° azimuth). The source intervals were 220 feet with source line interval of 1320 feet. The receiver line interval was 622 feet with a receiver station interval of 311 feet. The receiver design is based on an ideal receiver line interval of 880 feet with an ideal receiver interval of 220 feet. This design yields a relatively smooth fold distribution and a subsurface bin size of 110 feet by 110 feet. The fold refers to the number of redundant recording receivers for a specific data point. The recording patch was 20,000 feet by 20,000 feet with a maximum full fold of 92. The fold at 4000 feet is 8 to 12 (Figure 5). Fold at 8,000 feet is over 40 (Figure 6).

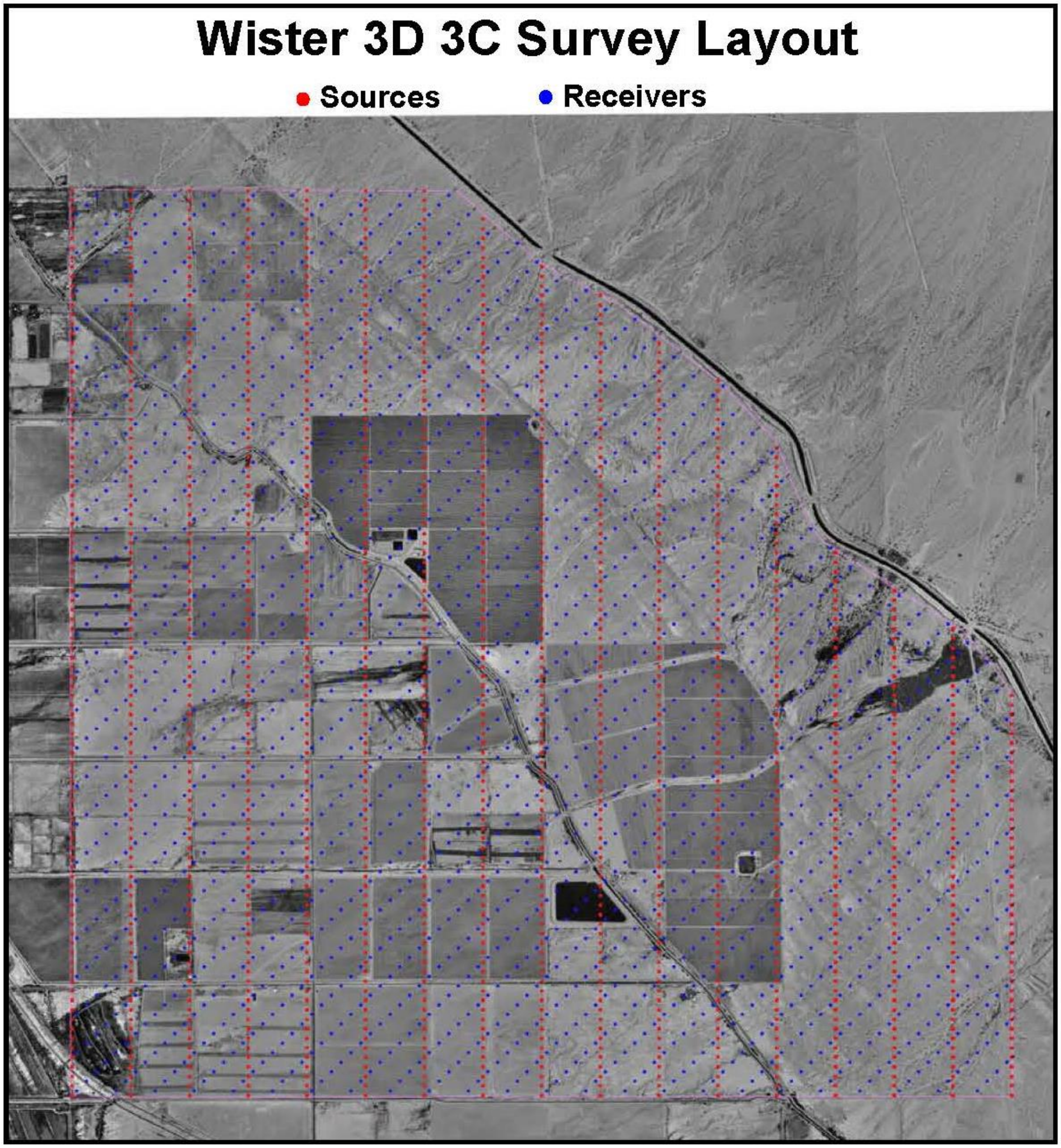


Figure 4. Wister 3D 3C survey field layout.

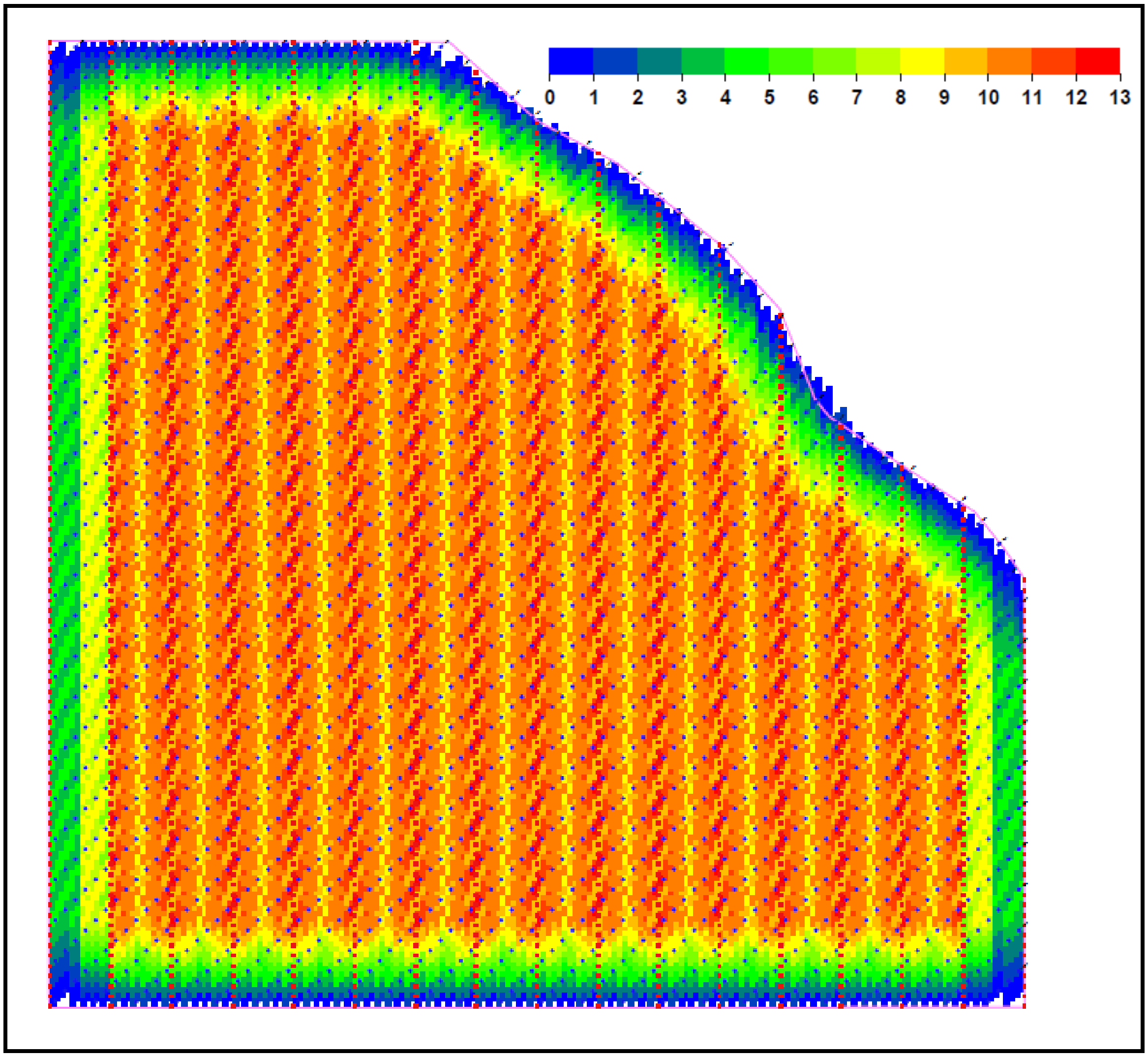


Figure 5. Fold at 4,000 foot offset limit. Color bar indicates fold density.

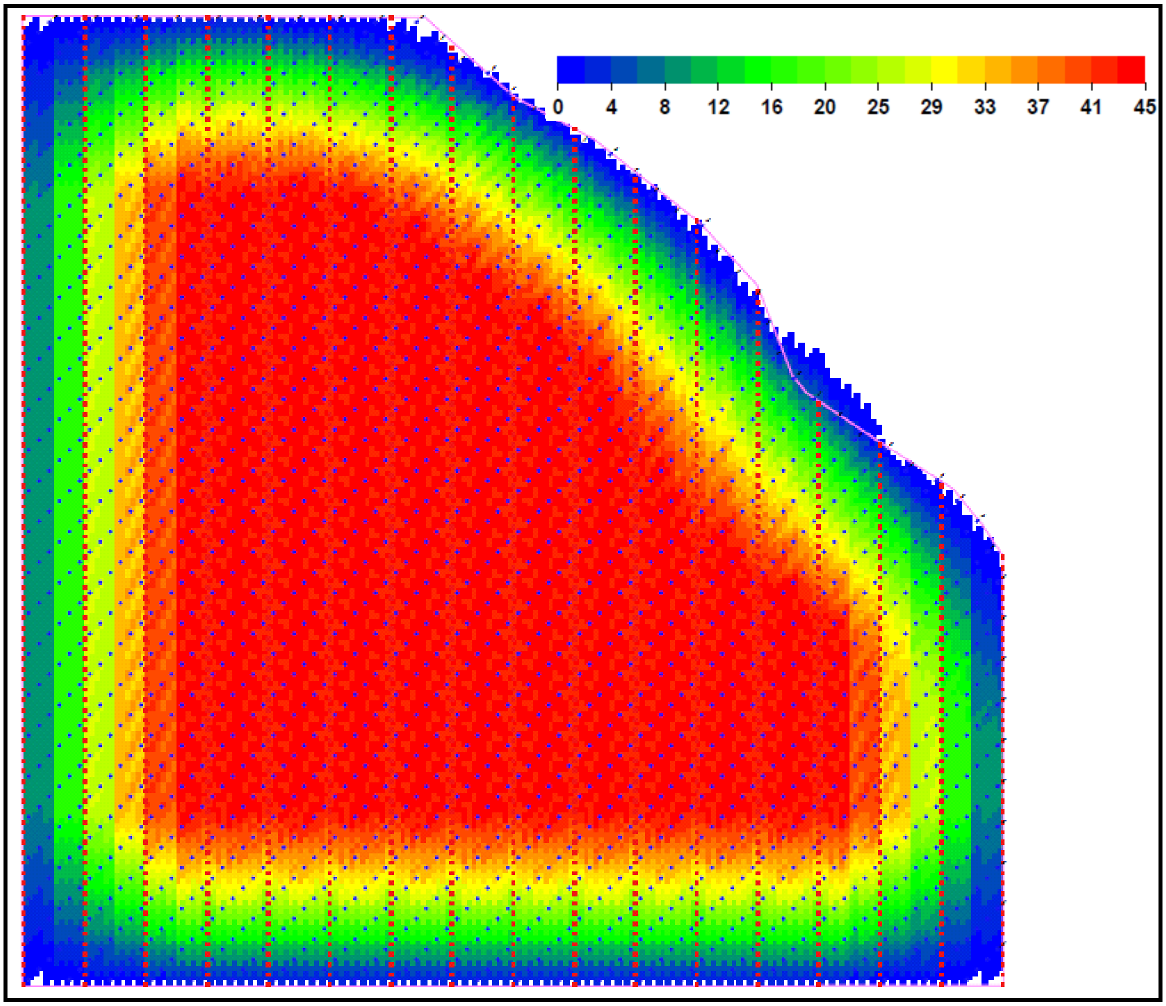


Figure 6. Fold at 8,000 foot offset limit. Color bar indicates fold density.

The survey was recorded using Vibroseis sources and a Geospace Seismic Recorder (GSR) cable-less recording system with a single 3 component geophone at each recording station. Two (2) I/O AHV IV 60,000 pound vibrators were used at each source position. Figure 7 shows an example of the Vibroseis buggies. The source sweep was a 4 to 96 Hz linear sweep. Four (4) sweeps of 8 seconds in length without a move up of the vibrators were used at each source position. The recording listen time or correlated record length was 6 seconds. The GSR recording system had a small four-channel recording box, a battery and a geophone at each receiver station (Figure 8). The GSR system records continuously with a battery life of over a week. After data are acquired the data are downloaded to a collection system and then are correlated, sorted, and output as standard shot records. Since Wister is a multicomponent 3D survey, 3 component geophones were used at each station (Figure 9). Each geophone was accurately oriented at each station location with the primary H1 component pointed at an azimuth of 45° (N45°E) as seen in the project layout diagram in Figure 10. Each component of the field data were delivered to the processor (vertical or P-wave, H1 and H2) in industry standard SEG-Y format.

Figure 7. I/O AHV IV Vibroseis buggy.

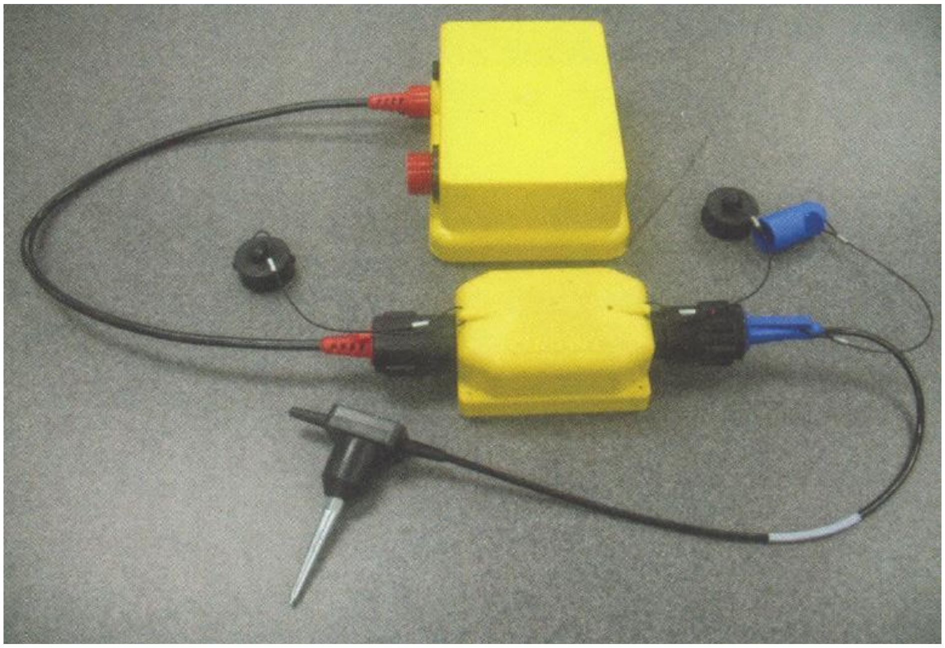


Figure 8. GSR recording unit.

Figure 9. Geospace 3 component geophone with Wister survey orientation.

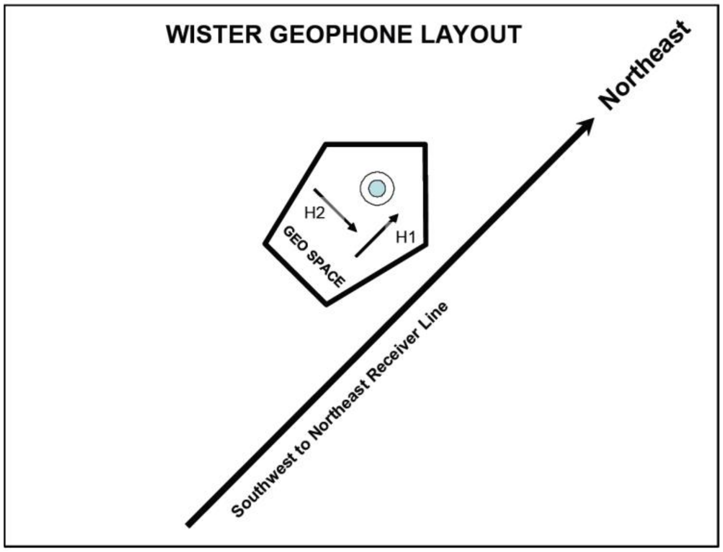


Figure 10. Wister 3D 3C geophone layout diagram.

Survey control for source points, receiver positions, and key monuments were acquired using a GPS base and rover RTK GPS survey system run by Sage Geodetic personnel. Survey data were acquired for points in Latitude and Longitude and converted to California State Plane Zone VI NAD83 coordinates in feet.

4. P-Wave Data Processing

After the data were acquired, the data were processed at FairfieldNodal in Denver. The field data were delivered to the processing center as correlated records in SEGY format with a 6.0-second record length and 2-millisecond sample rate. The data acquired show only weak reflected energy on the P-wave data. This is demonstrated on filter panels of a shot record in Figure 11. The field data were processed to 3D binned common-depth-point migrated stacks (CDP) with 110x110 feet bins. Solutions to reduce the effects of refraction statics, the near-surface perturbations of the propagating wavefield, were utilized in the processing. An elevation map of the receiver locations is shown in Figure 12. This map shows the gentle surface topography that slopes towards the center of the valley (southwest). The elevations are above sea level in the northeast and below sea level in the southwest. The gaps in this map reflect areas of no surface occupancy for the survey.

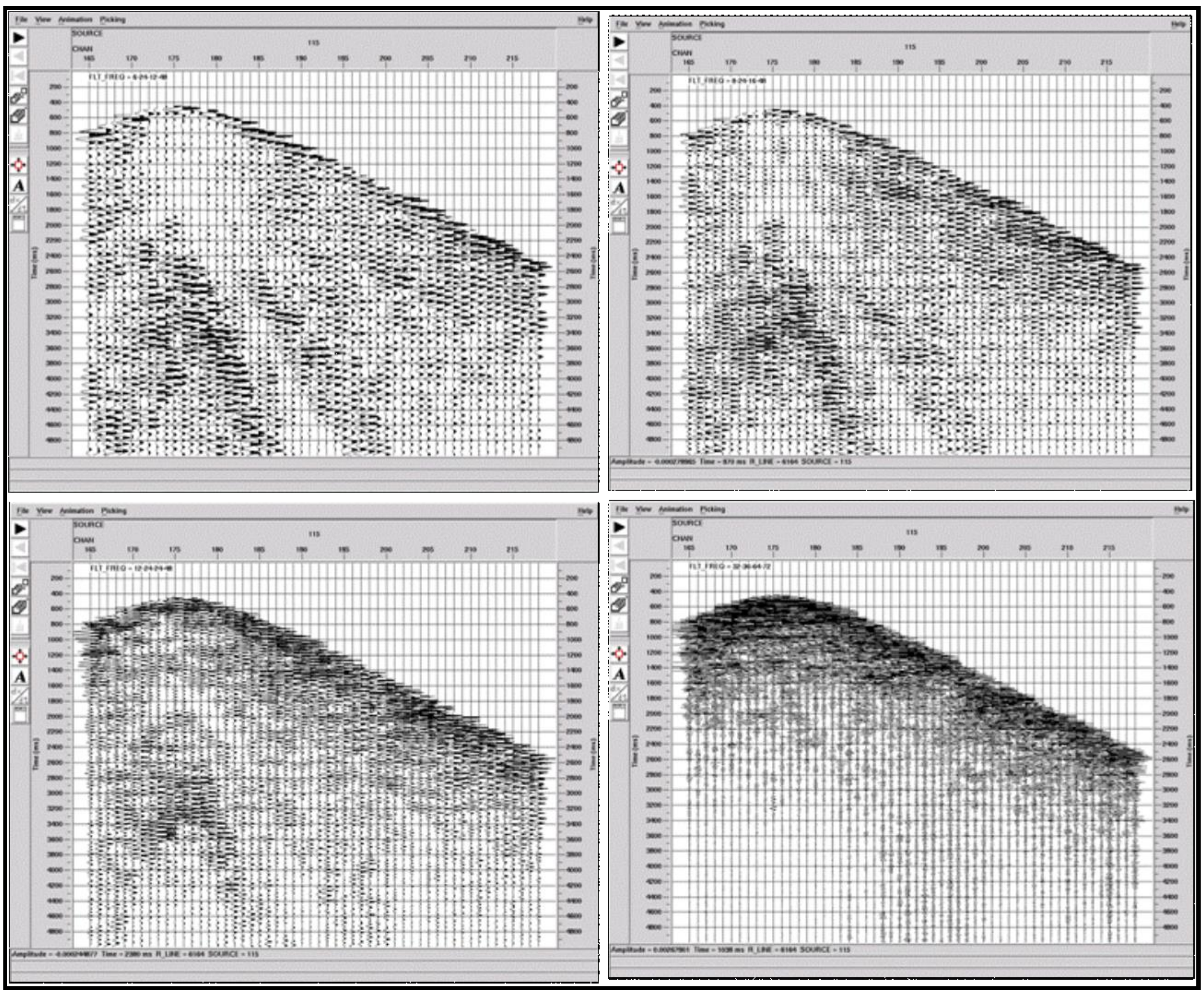


Figure 11. Filter panels of P-wave shot record.

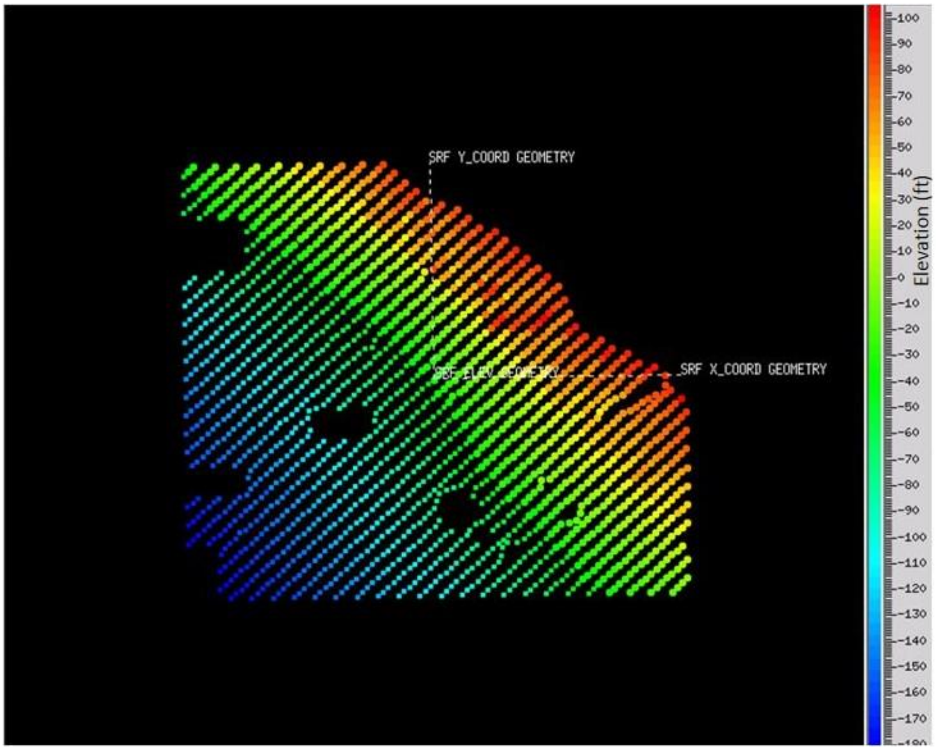


Figure 12. Receiver elevation map.

After the refraction static analysis solutions were applied, signal processing and deconvolution testing were conducted. Most seismic surveys exhibit surface waves or ground roll on field records. Normally, the ground noise is lower frequency than the reflected signal and can be removed by stacking, filtering, and sometimes muting. However, the ground noise at Wister is non-coherent and has a spectrum that is very similar as the reflected signal. Figure 13 is a shot record with spectrum of both signal and ground noise. The spectrum of the non-coherent ground noise has a dominant frequency of around 10 Hz (Figure 14). The spectrum of the same field record with the non-coherent ground noise removed is shown in Figure 15. It has a higher dominant frequency, but is similar to the noise. This analysis showed this noise should be attenuated before stacking. Figure 16 shows the same record with attenuation of the non-coherent ground noise. This attenuation process was applied prior to deconvolution.

Ensemble deconvolution was tested on the same shot record with the non-coherent ground noise muted out and is shown in Figure 17. The deconvolution test on the same shot record with the non-coherent ground noise attenuated shows a similar spectrum (Figure 18). These tests show that the spectrums of both are very similar. In order to not remove any reflected signal that is present under the ground noise area, deconvolution was applied to the data with the non-coherent ground noise attenuated.

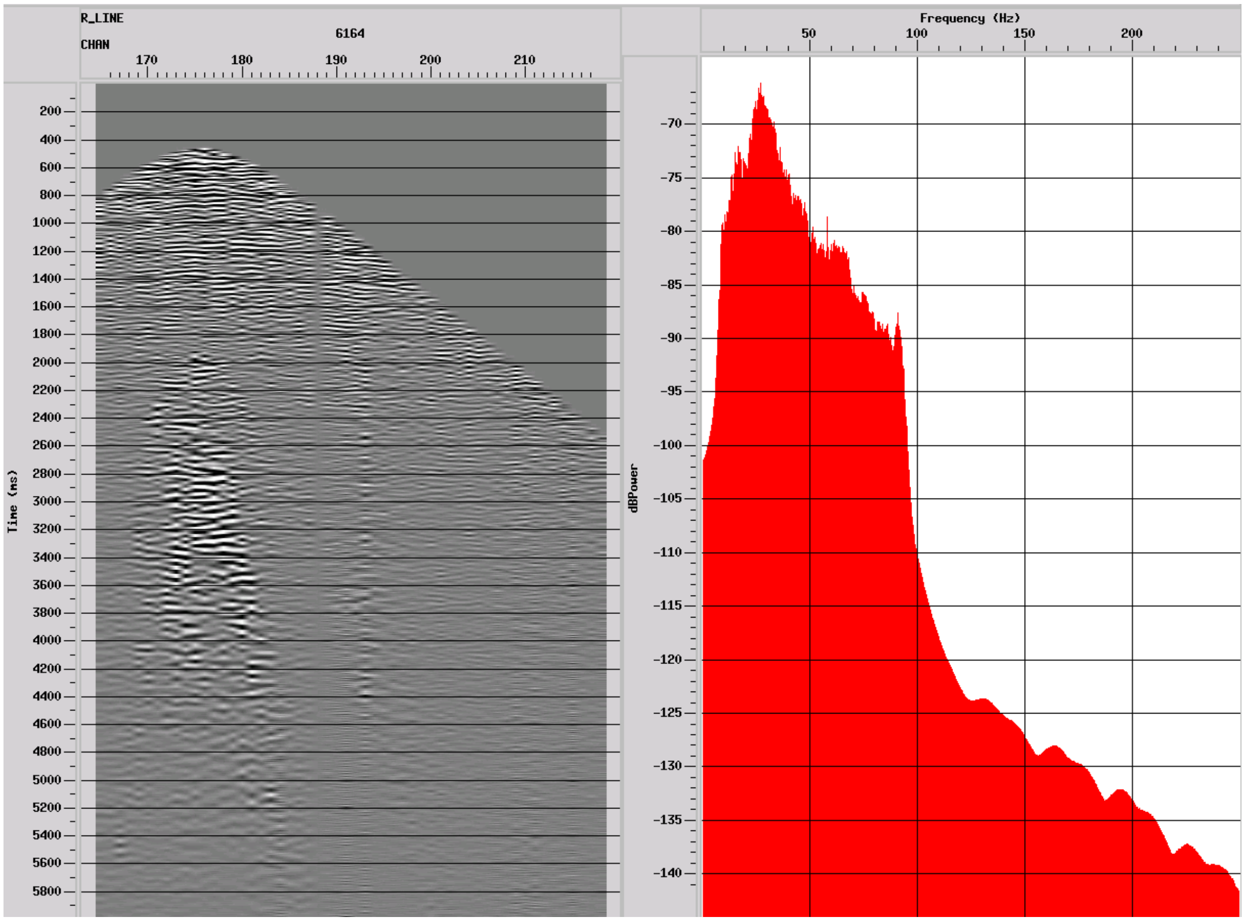


Figure 13. Shot record with spectrum.

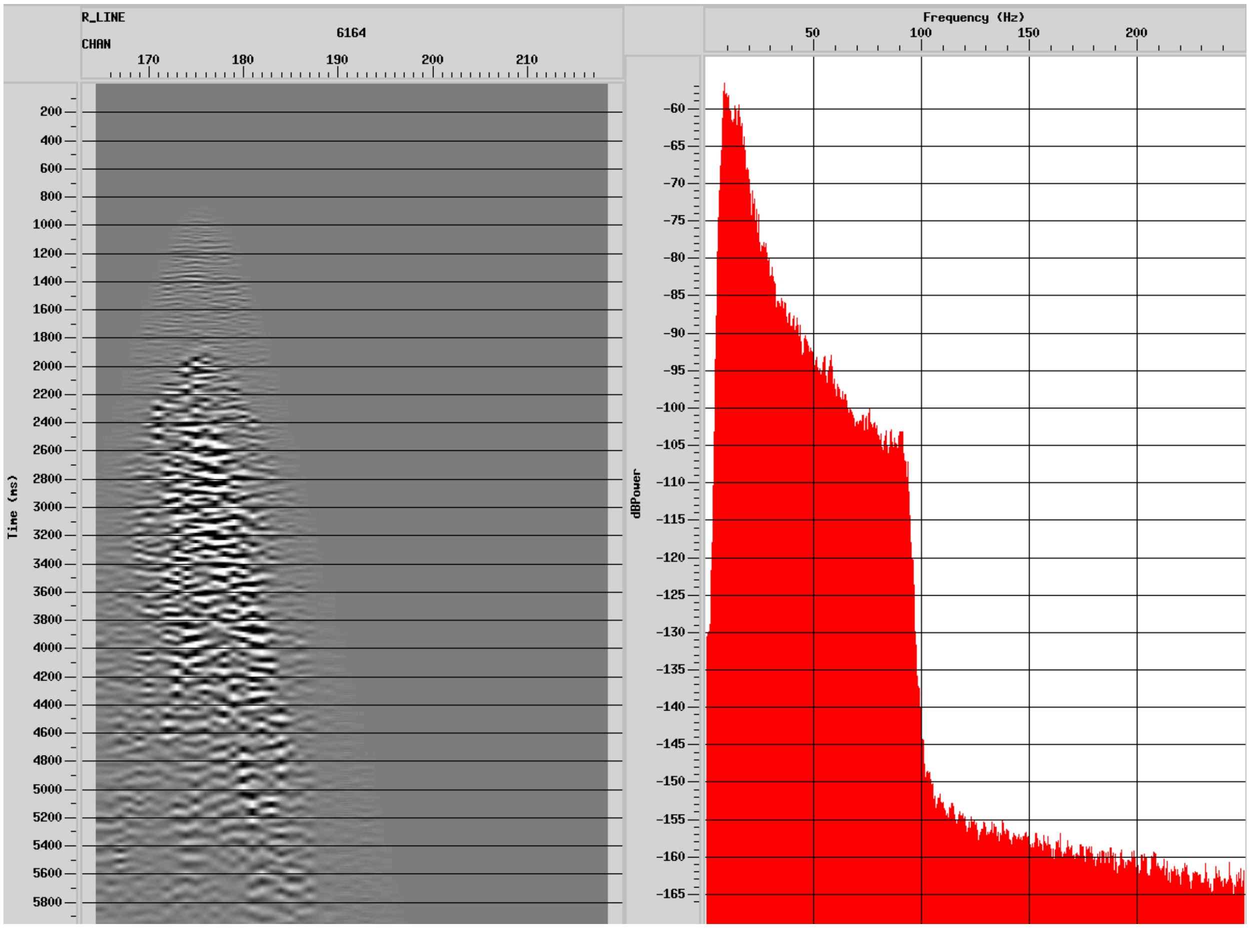


Figure 14. Spectrum of non-coherent ground noise.

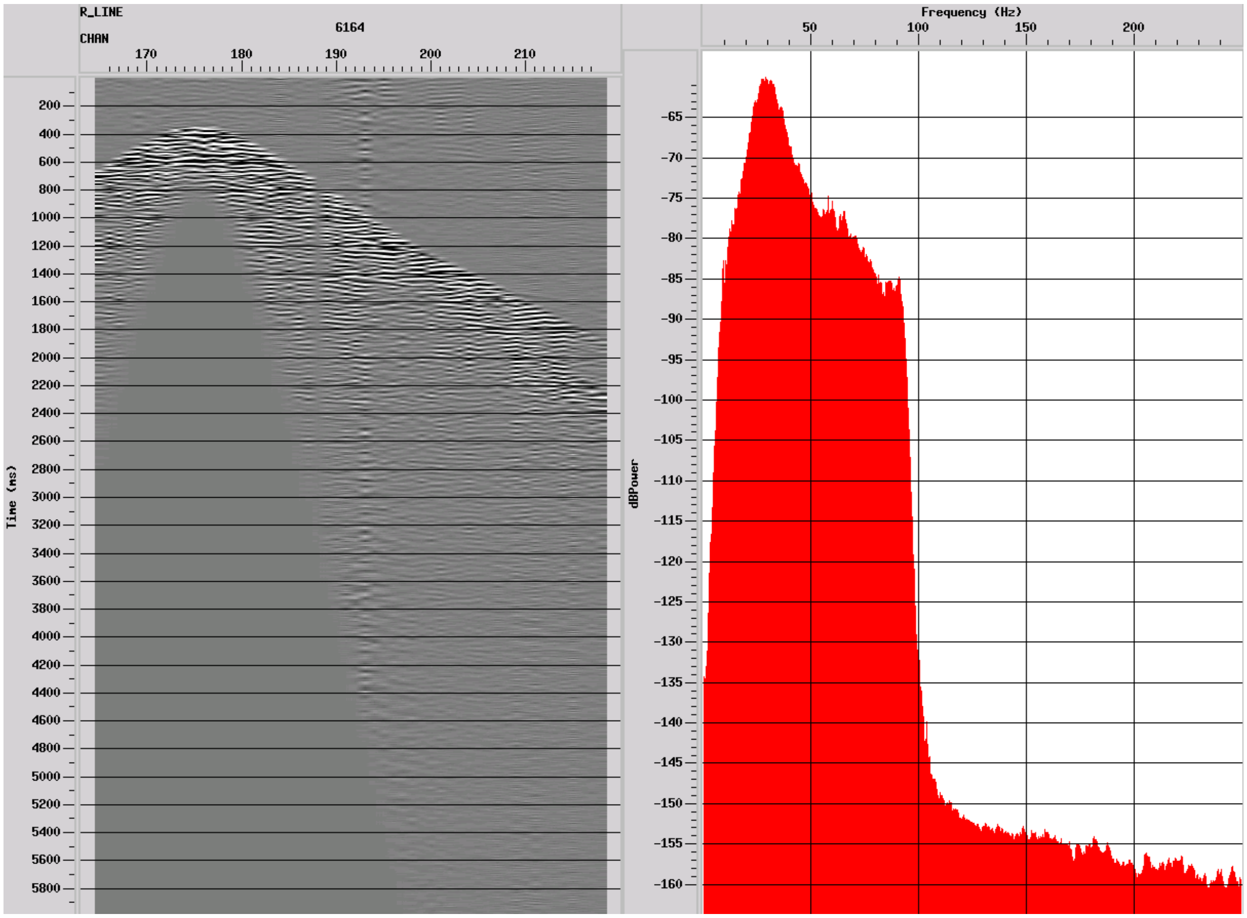


Figure 15. Spectrum of field record with non-coherent ground noise muted out.

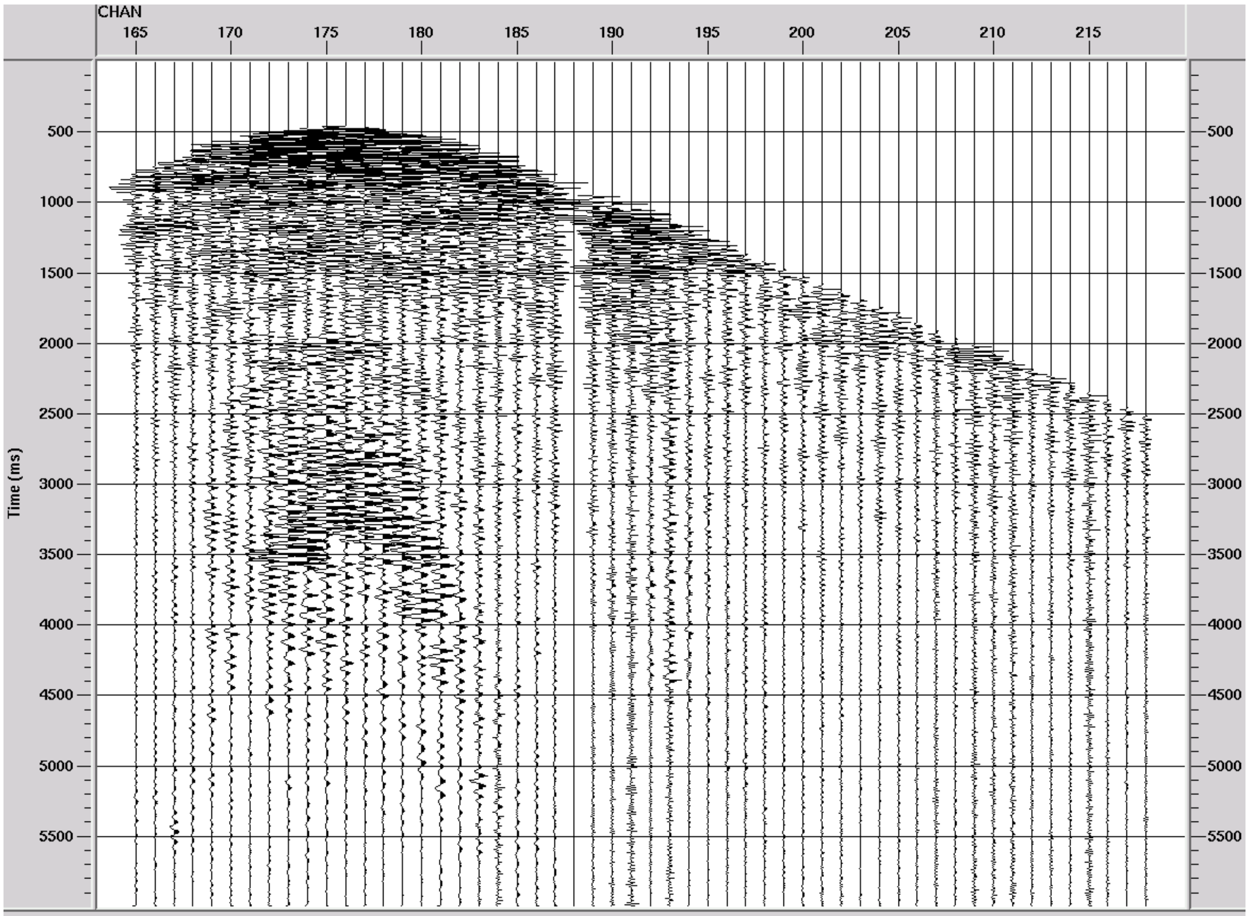


Figure 16. Field record with non-coherent ground noise attenuated.

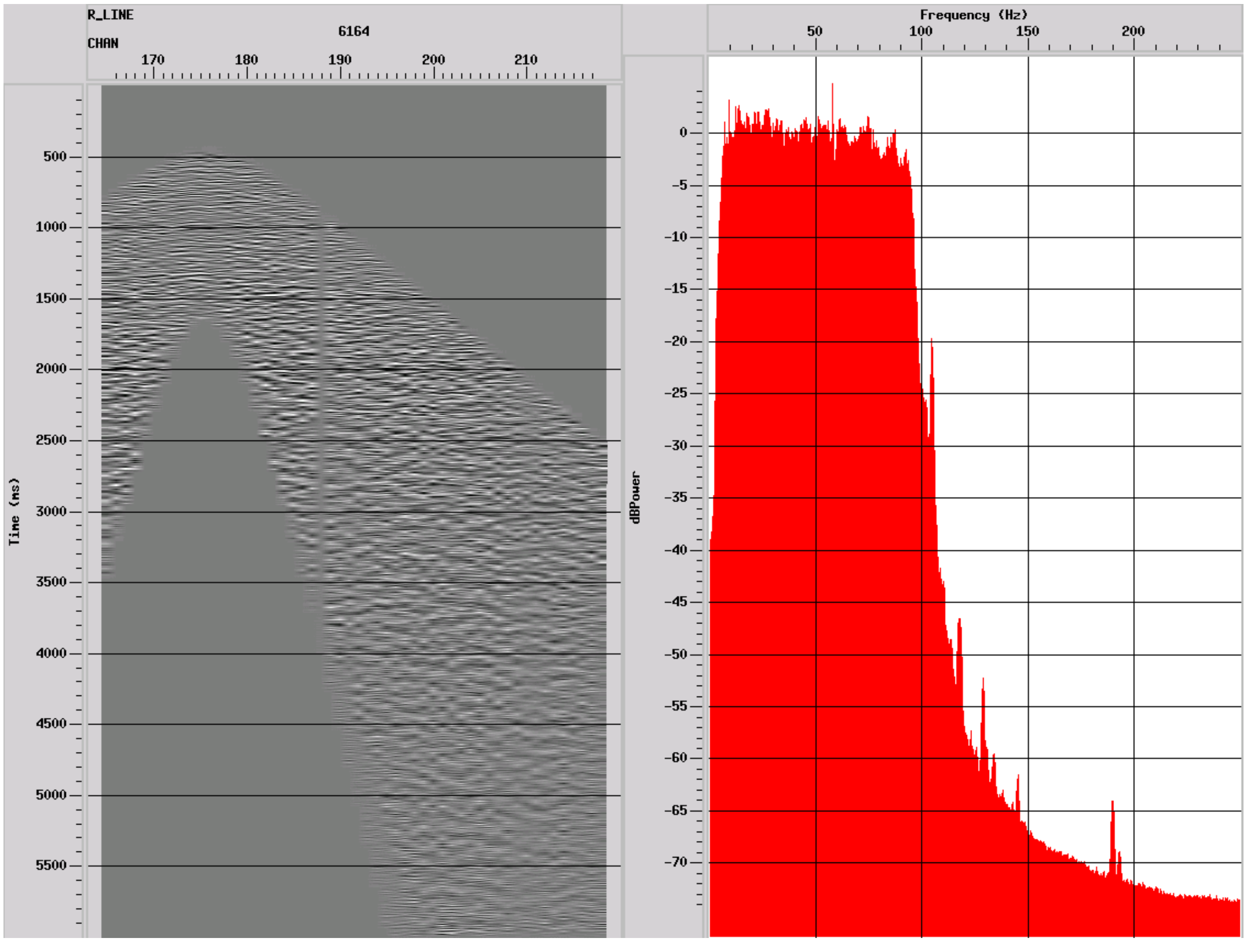


Figure 17. Field record with non-coherent ground noise muted out with ensemble deconvolution applied.

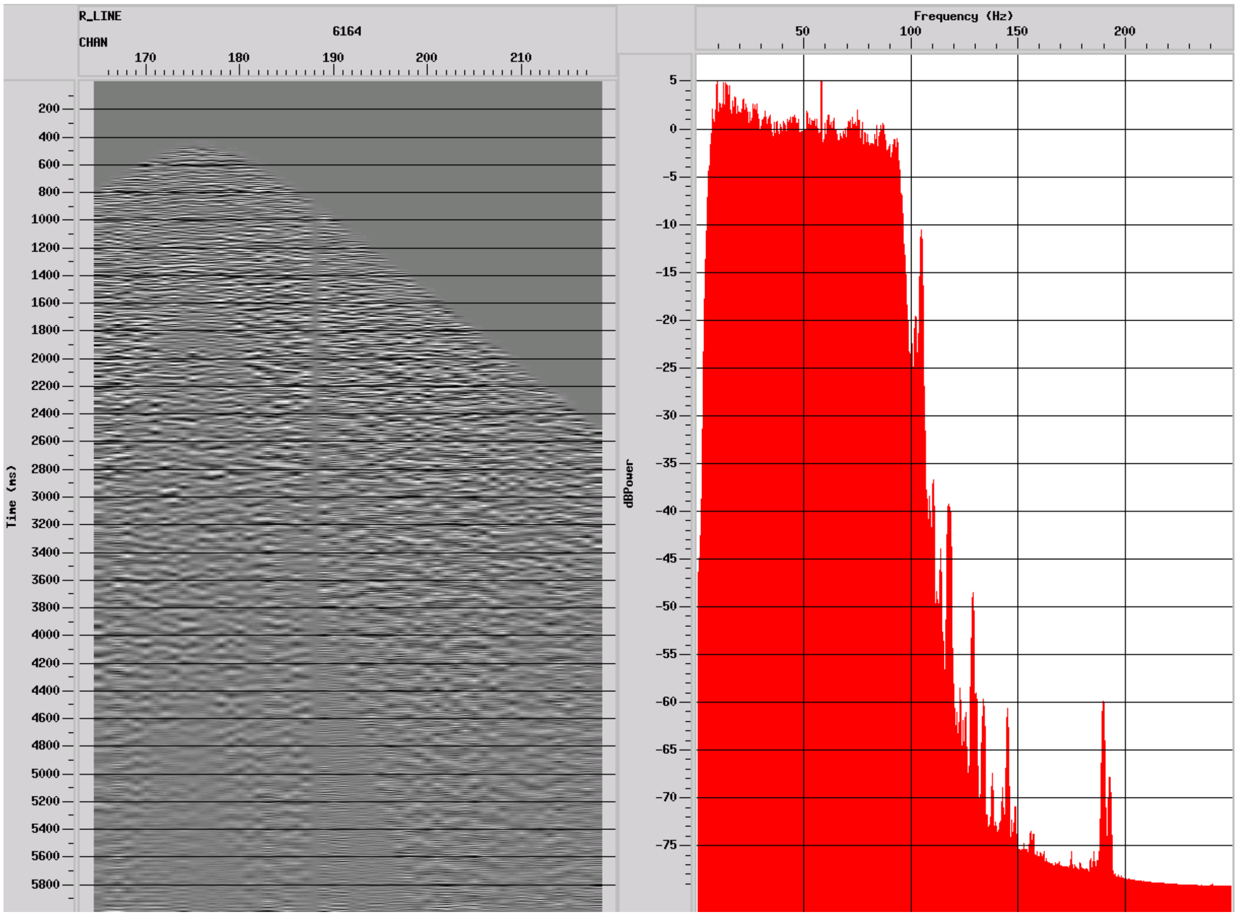


Figure 18. Field record with non-coherent ground noise attenuated with ensemble deconvolution applied.

Figure 19 is a west to east brute stack display in the center of the survey along Inline 90. Figure 20 is shows the final post-stack migrated data. Enhancements were applied to these displays for noise reduction. The post-stack migrated data were adequate to start fault interpretations, which were updated after the pre-stack time migrated data were received.

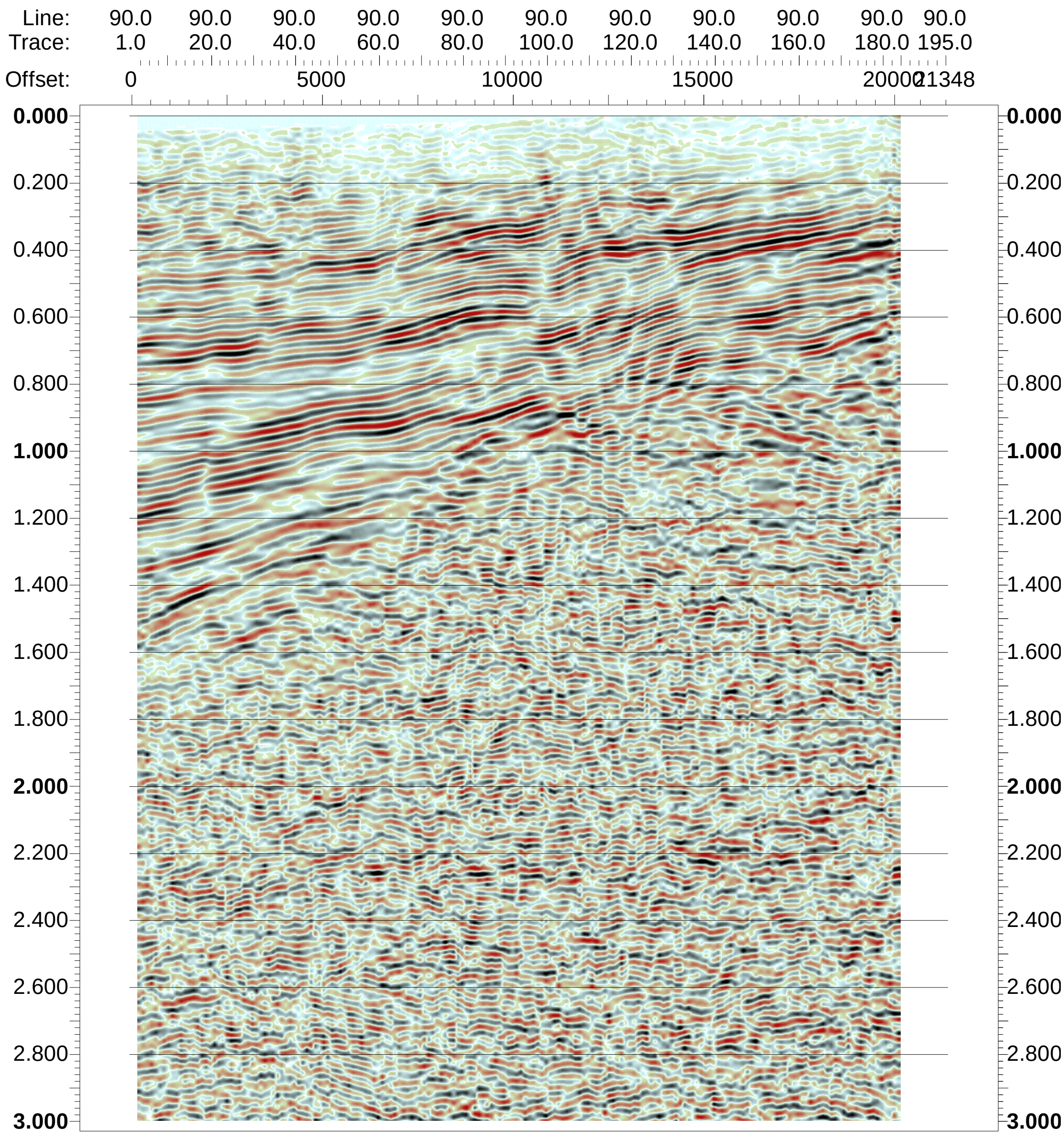


Figure 19. Brute stack of Inline 90 without deconvolution and with post-stack Fxy deconvolution and Fk filtering applied.

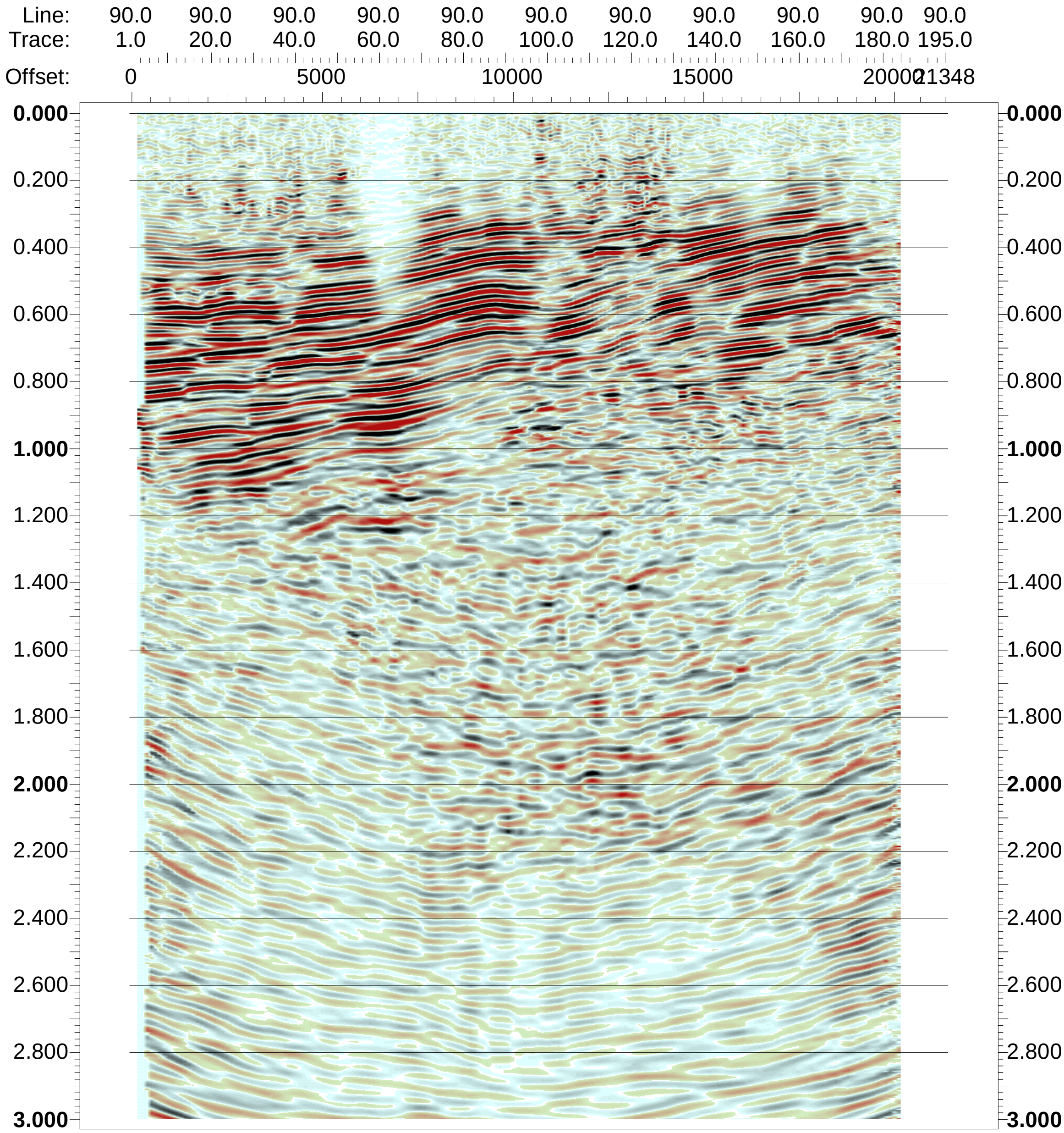


Figure 20. Post-stack migration of Inline 90 with post-stack enhancements applied.

5.1 WISTER 3D P-WAVE POST-STACK MIGRATION PROCESSING FLOW

1. *Reformat and process at 2 milliseconds*
2. *QC plot all records for trace edits*
3. *Merge survey data with seismic data*
4. *Spherical divergence and inelastic attenuation compensation*
5. *Refraction static analysis and application*
6. *Relative amplitude preservation*
7. *Initial parameter analysis (trace, shot and surface consistent deconvolution tests plus bandwidth analysis)*
8. *Deconvolution (Ensemble Deconvolution, 11 trace average, 120 ms operator, .01 window design gate)*
9. *Spectral balance (frequency compensation)*
10. *3D CDP bin assignment and sort (plot source/receiver XY locations)*
11. *3D velocity analysis (one mile grid)*
12. *QC brute stack entire data volume*
13. *QC time slices of brute stack data volume*
14. *Surface consistent 3D residual statics*
15. *QC stack control lines with residual statics applied*
16. *Intermediate parameter analysis (Post NMO-mute, pre-stack scaling and bandwidth)*
17. *Second pass of 3D velocity analysis (half mile grid)*
18. *Stack all lines for QC over static analysis window*
19. *Second pass of 3D surface consistent residual statics*
20. *QC stack selected lines*
21. *Final 3D bin stack*
22. *3D noise suppression*
23. *QC plots of stack volume*
24. *QC time slices*
25. *Final parameter analysis (filtering, scaling, spectral balance)*
26. *3D migration velocity analysis*
27. *3D migration*
28. *3D noise suppression (2 Pass - FX Decon)*
29. *Filtering and Balance*

After the post-stack migration was completed, pre-stack time migration (PSTM) was undertaken. PSTM produced better imaging of faulting and steeply dipping events. The PSTM data showed moderately noisy images of faulting and the base of reflective sediments. Figure 21 shows the

PSTM data along west to east Inline 90 without noise reduction. This figure showed that post-stack noise reduction was needed. A mild Fxy deconvolution was applied to the data to test the effectiveness of removing random noise in Figure 22. The Fxy deconvolution did not reduce noise sufficiently, so a two-pass Fx deconvolution was applied. Fx deconvolution is a 2D process that was run first in an inline direction and then in a crossline direction. This significantly reduced the noise as can be seen in Figure 23. A final application of an outside mute with the two-pass Fx deconvolution shows the surface gaps in Figure 24. Both of these two-pass Fx deconvolution data volumes were used for the P-wave interpretations of faults and seismic horizons. Figure 25 is a time slice of these data showing obvious faulting.

5.2 WISTER 3D P-WAVE PRE-STACK TIME MIGRATION PROCESSING FLOW

1. *Input deconvolved gathers with all statics applied*
2. *3D Kirchhoff pre-stack time migration of velocity target lines at 1320 feet*
3. *Velocity analysis (1/2 mile grid)*
4. *3D Kirchhoff pre-stack time migration of full volume processed at 2 milliseconds*
   - *Aperture 8,000 feet (one side), Output 35 fold CDP gathers, Output binning 110' x 110'*
5. *Velocity analysis (1/2 mile grid)*
6. *Stack pre-stack migrated data to produce full offset volume*
7. *Filtering and balance*
8. *Two-pass Fx deconvolution*

The final processing datum or seismic reference datum for the Wister 3D is sea level. The quality of the final processed data is good and clearly shows the structures at Wister.

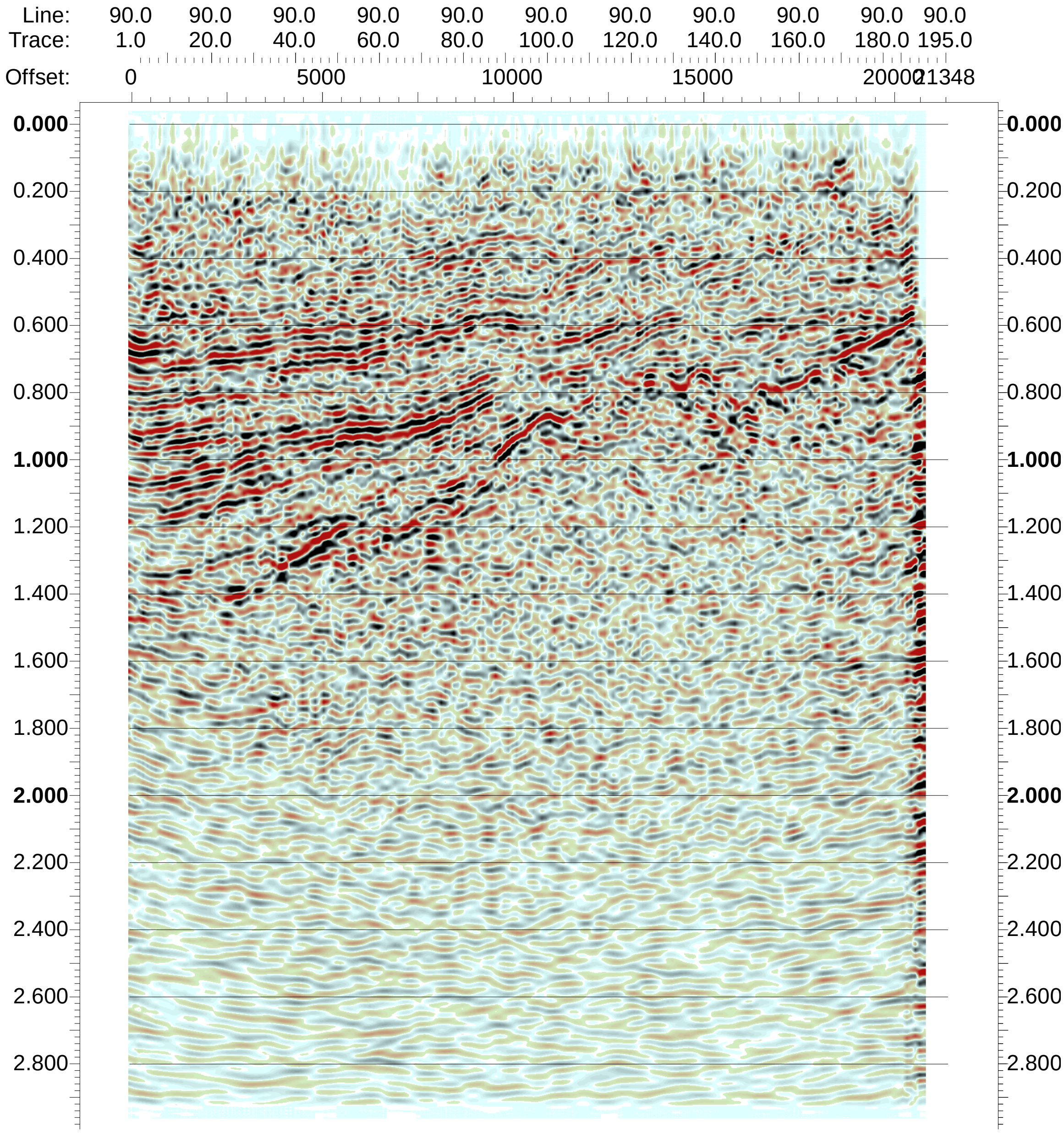


Figure 21. Pre-stack time migration of Inline 90 without noise reduction.

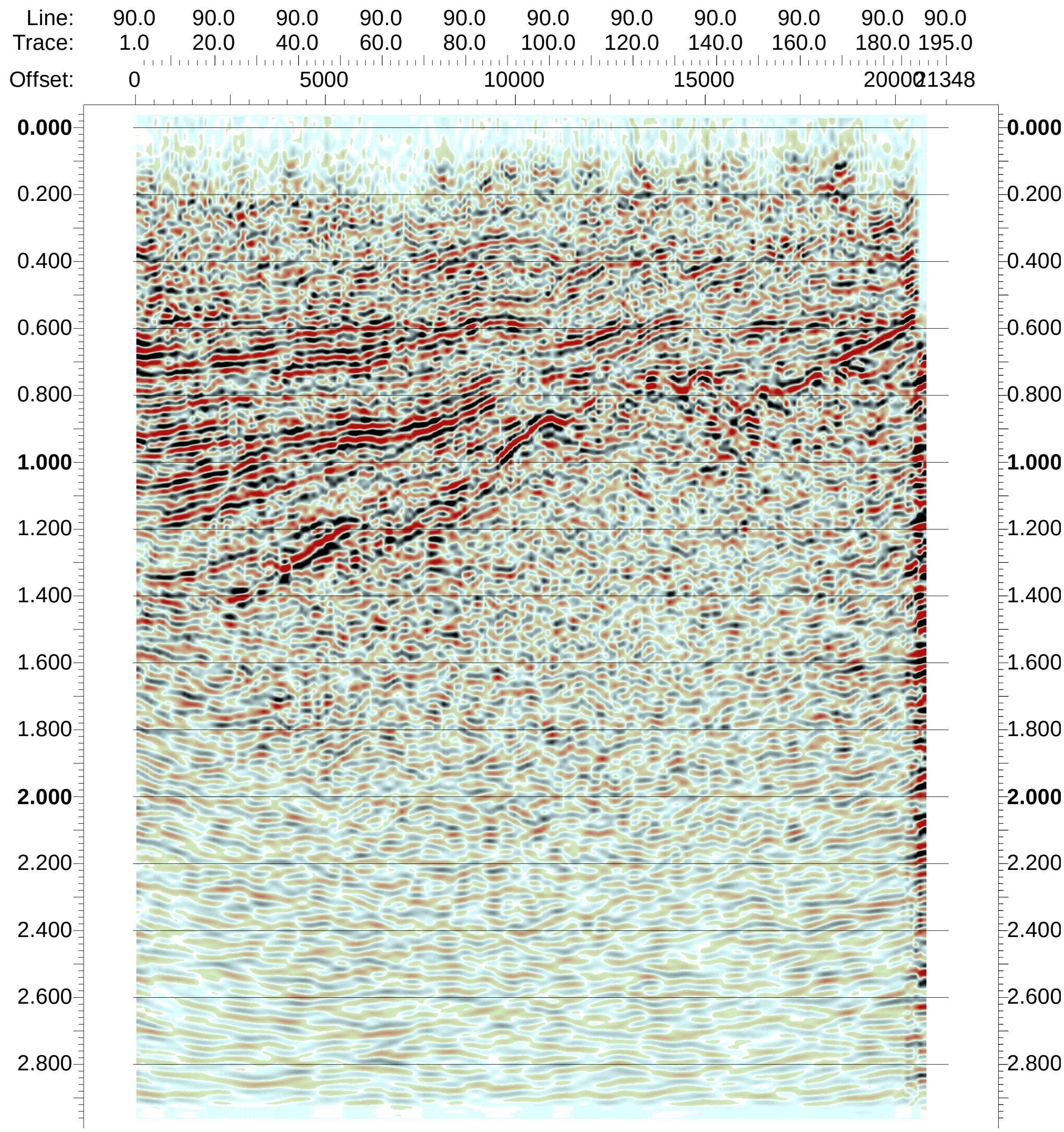


Figure 22. Pre-stack time migration of Inline 90 with post-stack Fxy deconvolution applied.

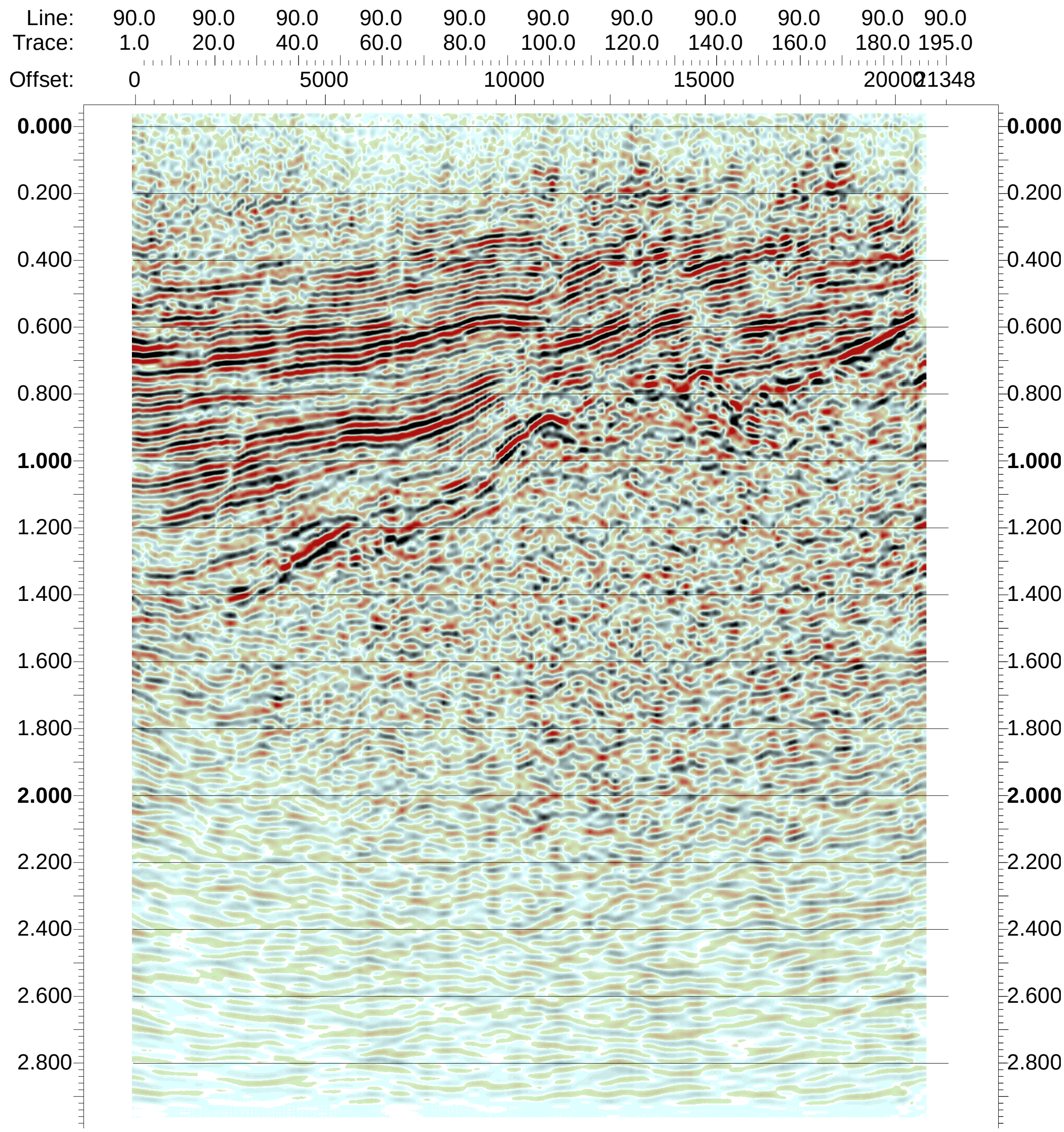


Figure 23. Pre-stack time migration of Inline 90 with 2 pass Fx deconvolution applied.

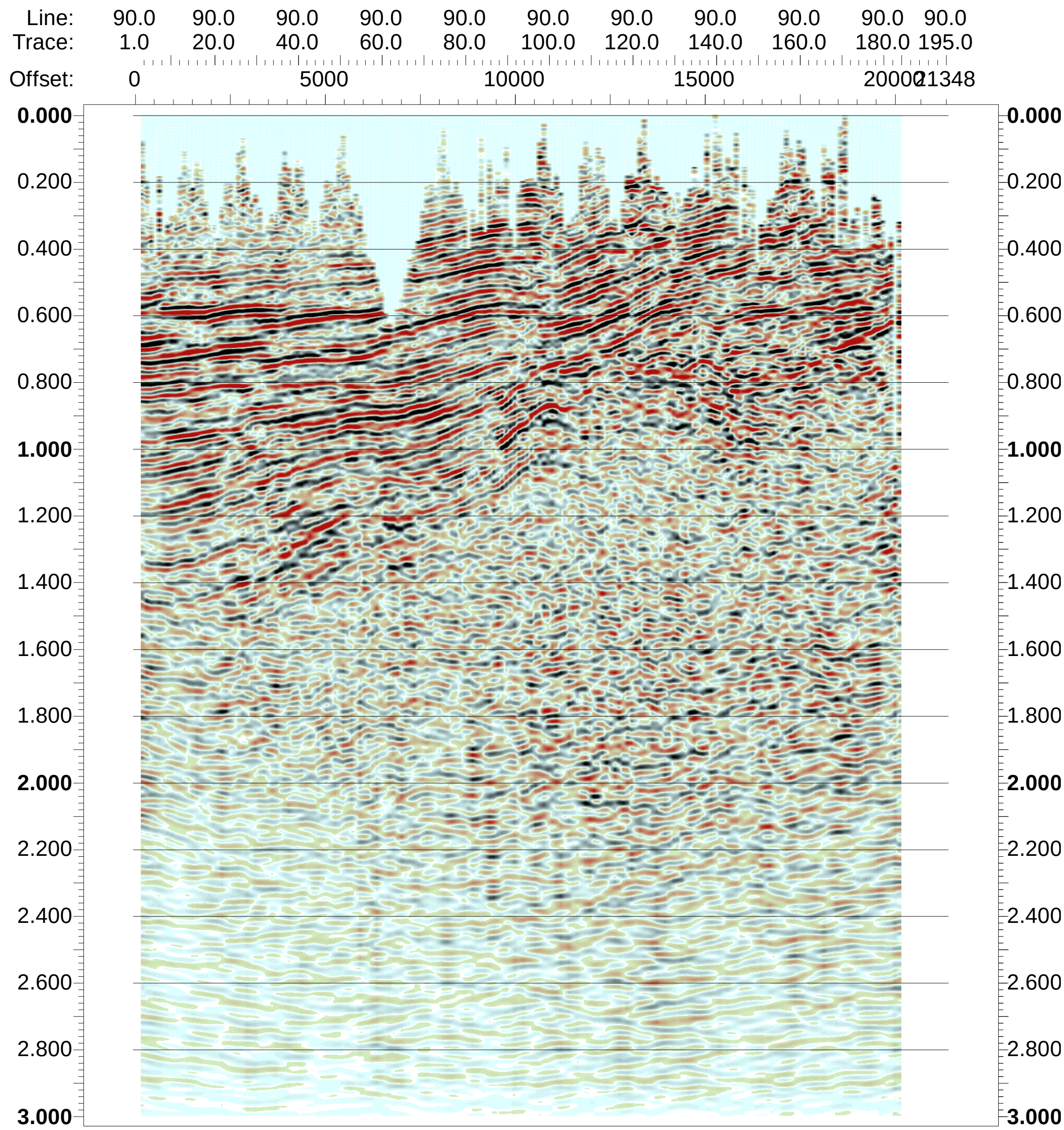


Figure 24. Pre-stack time migration of Inline 90 with 2 pass Fx deconvolution and mute applied.

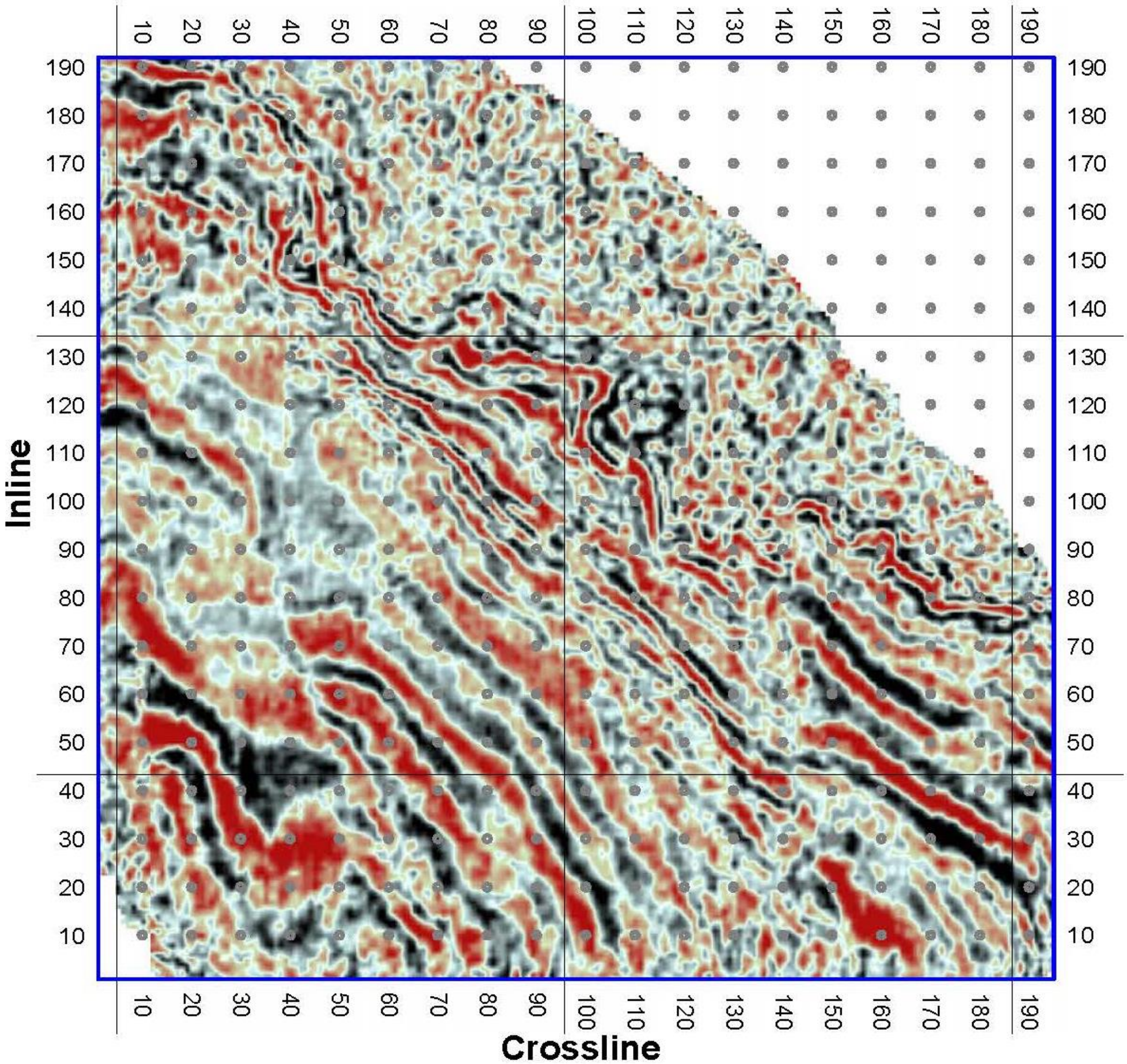


Figure 25. Pre-stack time migration with 2 pass Fx deconvolution horizontal time slice at 0.770 seconds. Continuous red to black to white reflectors represent strata dipping to the southwest toward the Imperial Valley. Reflector discontinuities likely indicate fault truncations.

5. Converted Shear Wave Data Processing

After the P-wave data were processed, the converted wave processing was started. The normal sequence with multicomponent seismic data to first process the P-wave data and, then use information from that to help with processing of the converted shear wave data. Fairfield has worked hard to find good imaging velocities with ambiguous results. This is due to two factors, weak reflectivity and shear wave velocity uncertainty.

First, the relatively unconsolidated sediments in the Imperial Valley exhibit small P-wave velocity and density contrasts between sands, silts and shales. This produces minimal reflectivity between the various rock sequences. This was observed in the relatively weak P-wave reflectivity in the 3D data. If the P-wave response is weak, it should then be expected that a weaker converted shear wave response will be produced due to energy partitioning.

Secondly, shear wave (S-wave) velocities are much slower than P-wave velocities. P-wave to S-wave ratios (Vp/Vs) in rocks can range from 1.6 to over 6. The highest ratios are found in unconsolidated sediments such as in the shallow sedimentary section in the Imperial Valley. This implies that in the near surface where the P-wave velocities are less than 6,000 feet per second, the S-wave velocities might be in the range of 1,500 feet per second. This is a huge range of velocities to examine for proper converted wave imaging. With the small converted shear wave reflectivity, it is very hard to find the correct imaging velocities. Semblance analyses and constant velocity stacks were ambiguous.

6. Analyses and Interpretation Methodology

After the 3D P-wave seismic data volumes were processed, they were loaded into an SMT/Kingdom seismic interpretation workstation for analysis and interpretation. The interpretation began with the picking of faults across the survey. The pre-stack time migration with 2 pass Fx deconvolution data volume was used for the P-wave interpretation. Faults were picked by using both vertical seismic sections and horizontal time slices. The faulting seen on the P-wave data are normal faults as can be seen on the vertical seismic sections shown in Figure 26, Figure 27, Figure 28 and Figure 29. Faults can also be followed on time slices such as those observed in Figure 30. In order to verify the validity of the interpreted faults, fault plane maps were constructed for each fault. Figure 31 is a time structure fault plane map of one of the key faults seen in this 3D survey.

In order to understand the subsurface structure beyond just the fault systems, a couple of seismic reflectors or horizons were selected for interpretation. The seismic horizons represent laterally continuous velocity/density contrasts across lithology interfaces such as sand over shale or vice versa. Several horizons were interpreted. Two key horizons that are seen on Figure 26 as yellow and green events were mapped across the 3D survey. They were picked on every 5th inline and crossline. Figure 32 shows the Horizon 2 time structure map with fault polygons with fault dip symbols. These horizon picks were then mapped across the survey area and contoured to produce a time structure map such as was done for the yellow Horizon 2 (Figure 33) and the green Horizon 3 (Figure 34).

Since seismic data are measured, processed, displayed and interpreted in time (seconds), additional data are needed to quantify the depths that are being mapped. Borehole data are the best way of converting time to depth. Vertical seismic profiles, well check shot surveys or sonic log data from wells are the best time to depth information. Without this information, an estimate of rock velocities can be made using information derived during data processing (seismic stacking velocities). The use of stacking velocities is better than an educated guess, but often produces significant errors. Since there are no well velocity data within the survey area, the time depth curve developed from the Emanuelli-2 well sonic log was used to depth convert the Horizon 3 time structure map (Figure 34) to a depth structure map. The computed structure map of Horizon 3 is shown in Figure 35. The absolute vertical accuracy of this map may be somewhat in error due to using a single velocity function from a well 18 miles away from the survey.

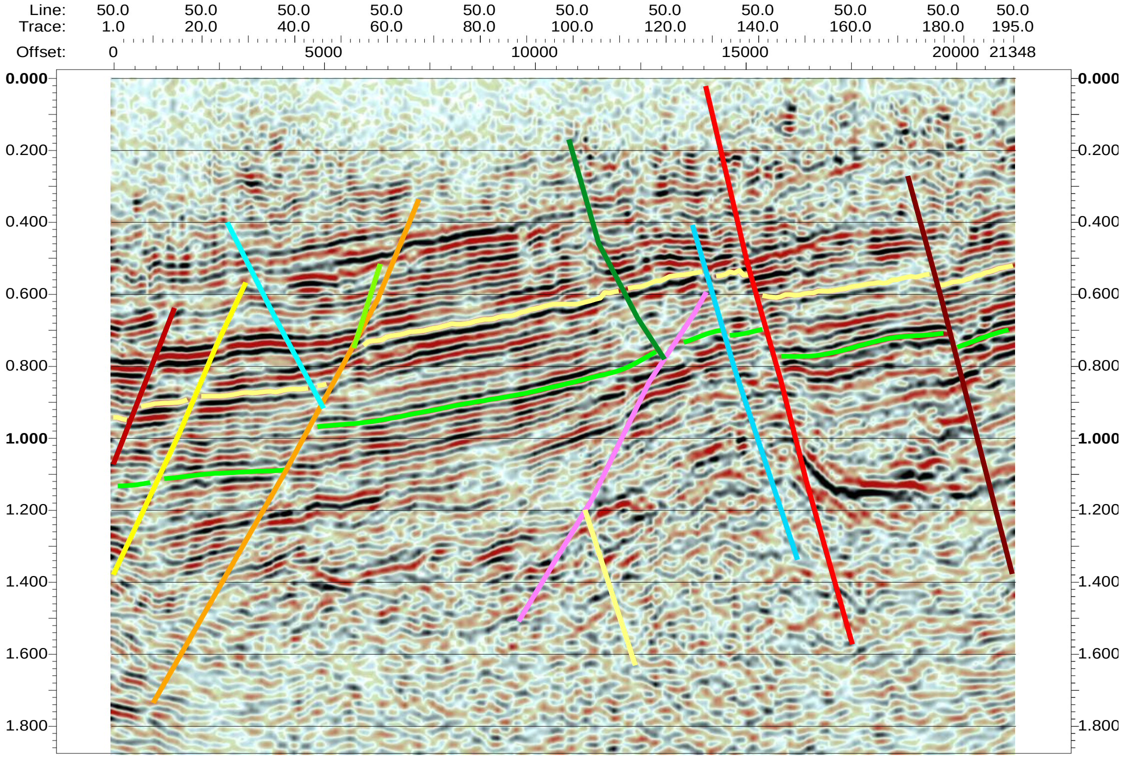


Figure 26. Inline 50 interpreted PSTM data in time (seconds) with interpreted faults and horizons.

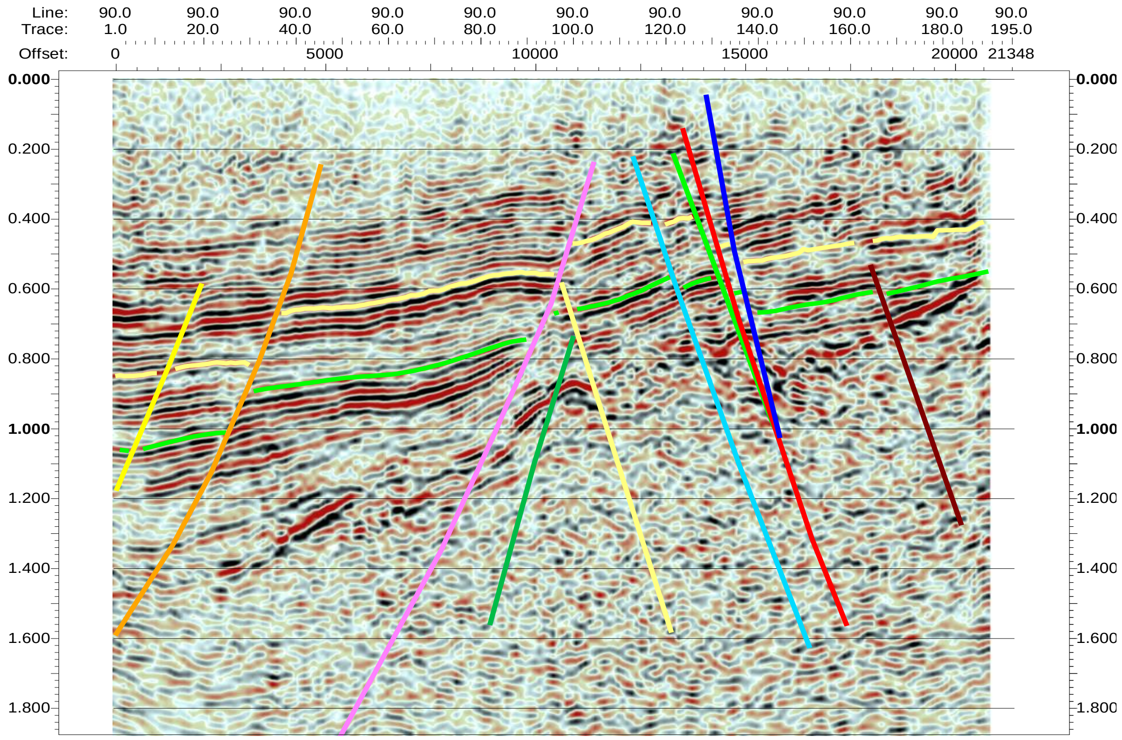


Figure 27. Inline 90 interpreted PSTM data in time (seconds).

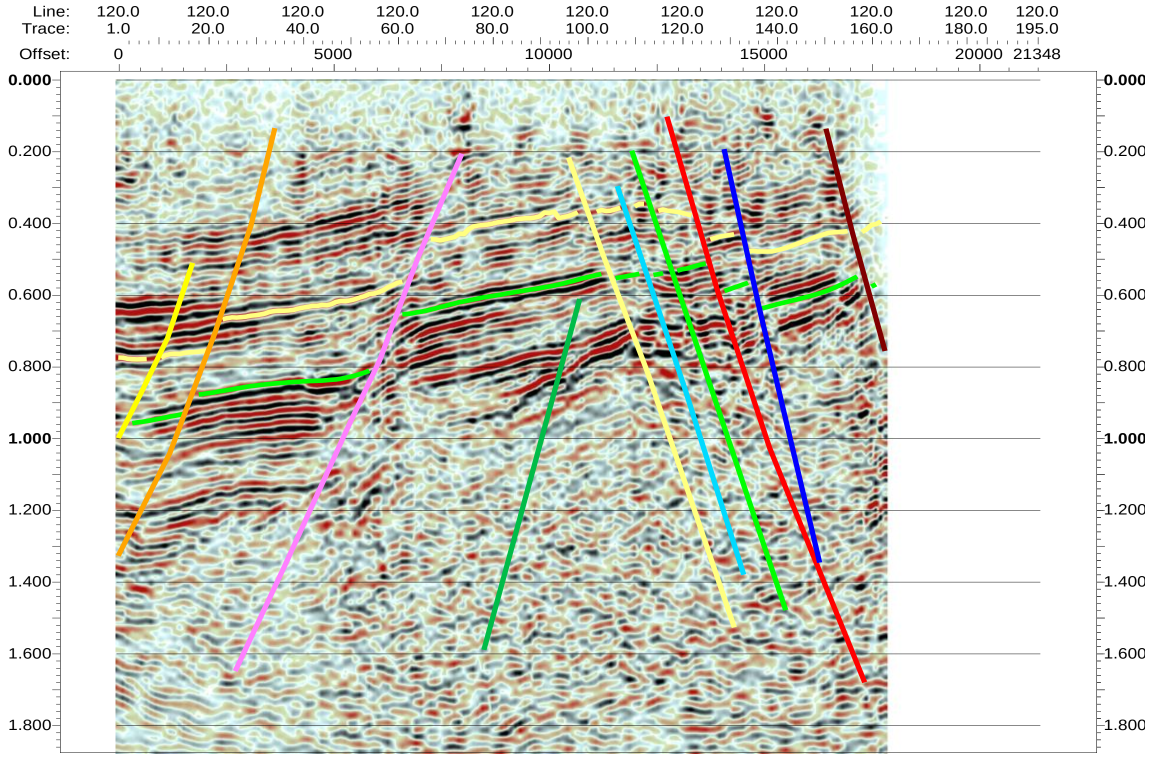


Figure 28. Inline 120 interpreted PSTM data in time (seconds).

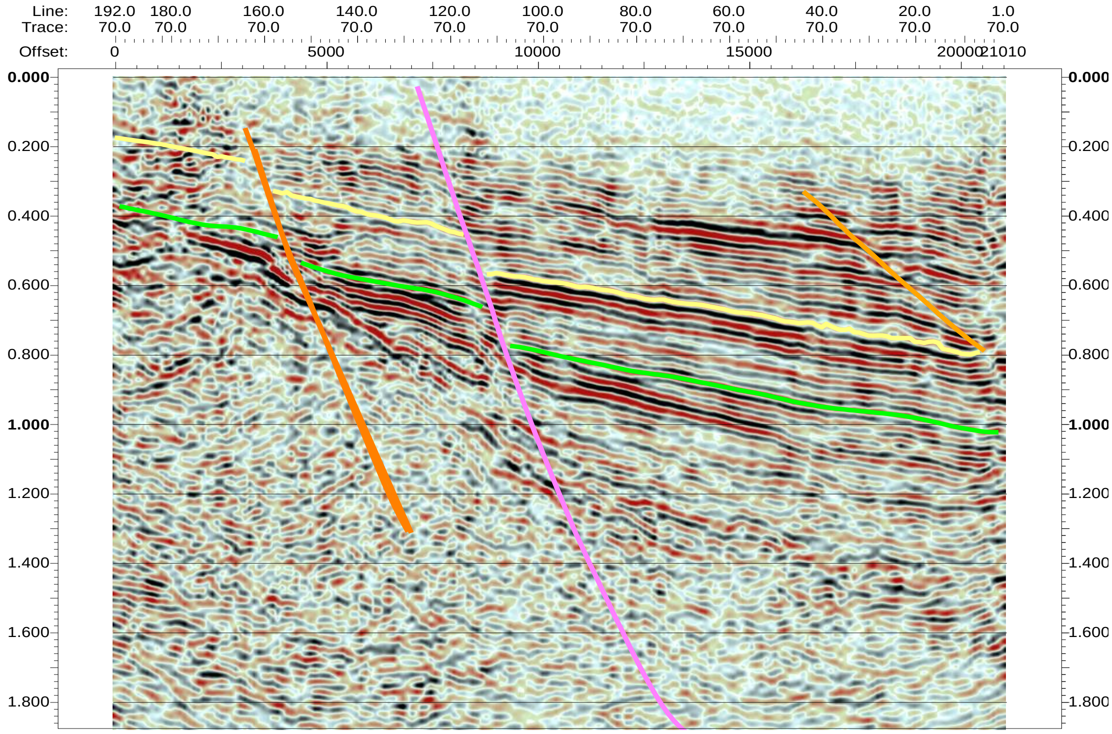


Figure 29. Crossline 70 interpreted PSTM data in time (seconds).

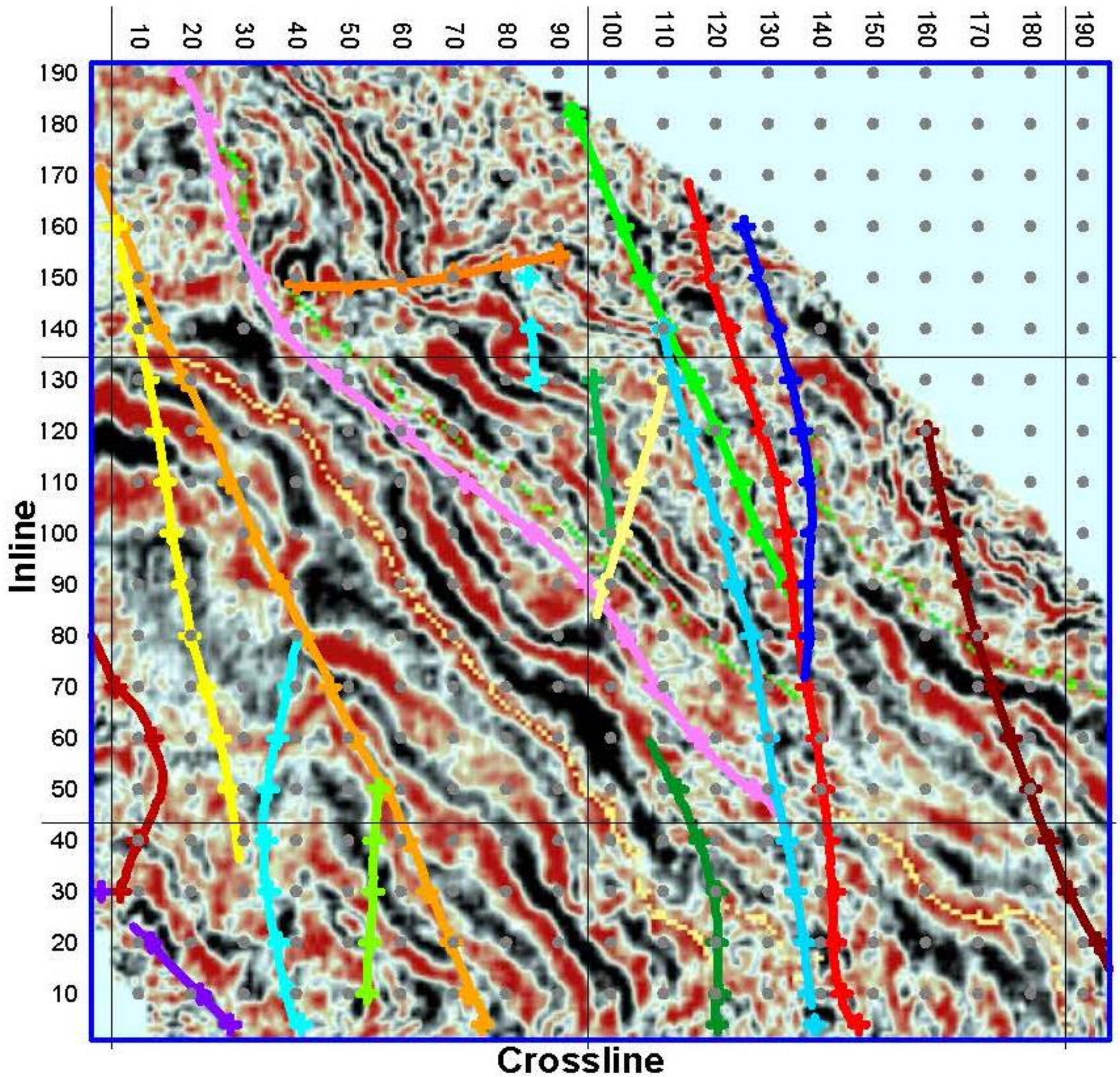


Figure 30. Interpreted PSTM horizontal time slice data (0.635 seconds). Thick colored lines are interpreted faults; fine colored lines are interpreted stratigraphic horizons.

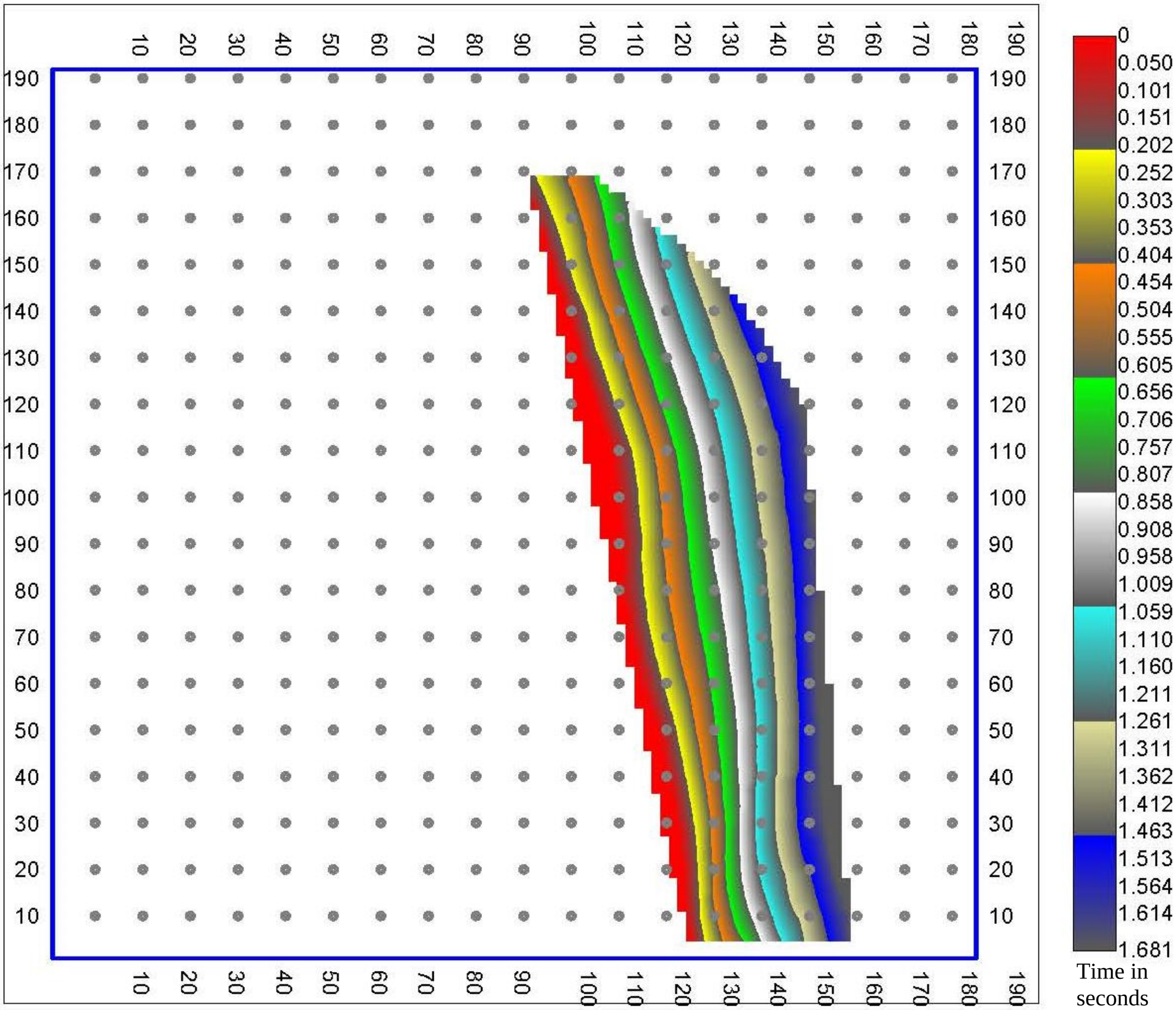


Figure 31. Fault plane time structure map. Map view of interpreted east-dipping fault plane. Color contours indicate time from surface to fault at depth.

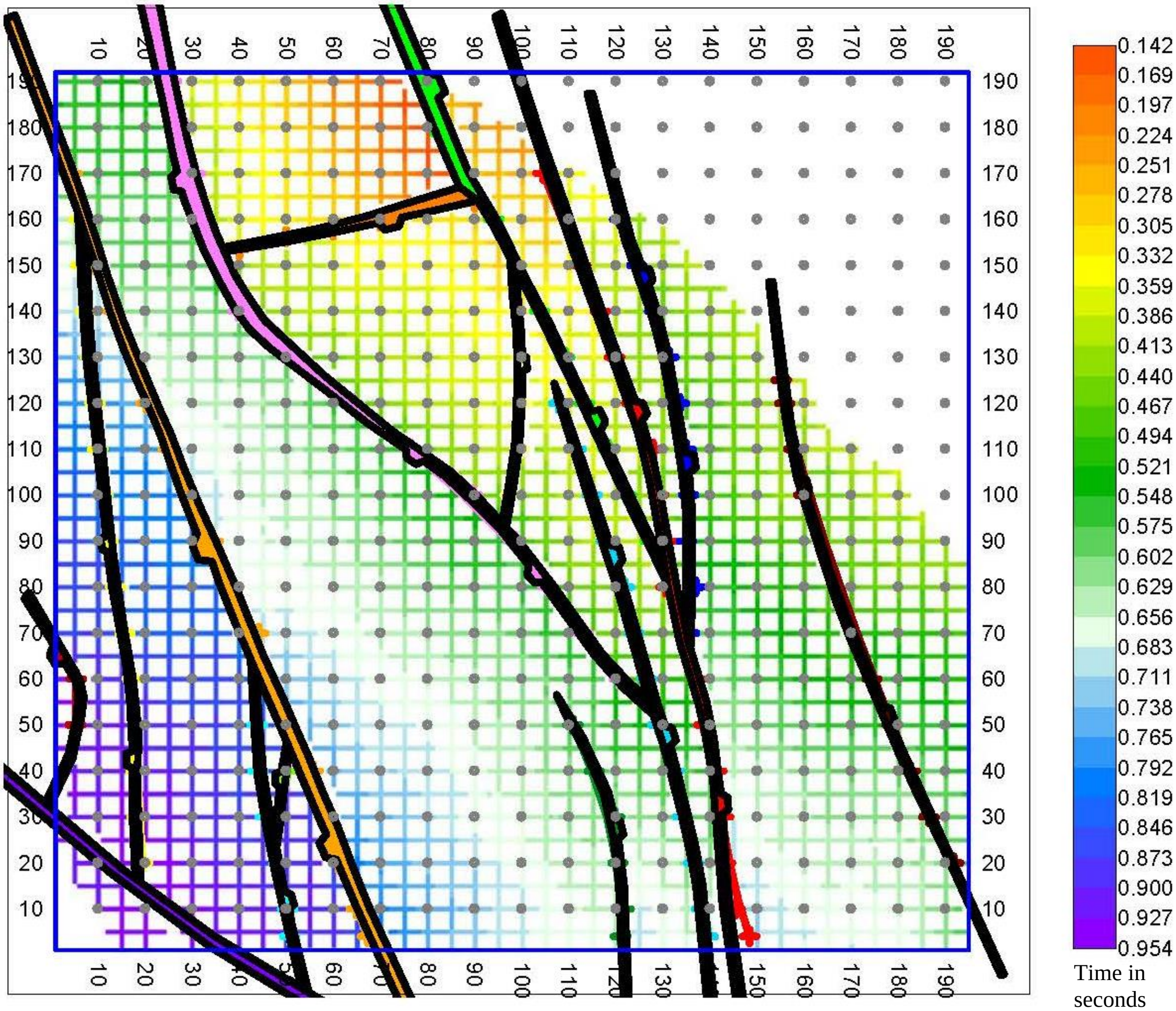


Figure 32. Horizon 2 (5x5) time structure map. Colored grid represents time to the semi-continuous interpreted prominent reflector here referred to as Horizon 2. Variable thickness colored lines represent interpreted faults with the normal sense of motion indicated in the tab direction. Thicker lines indicate a shallower dip.

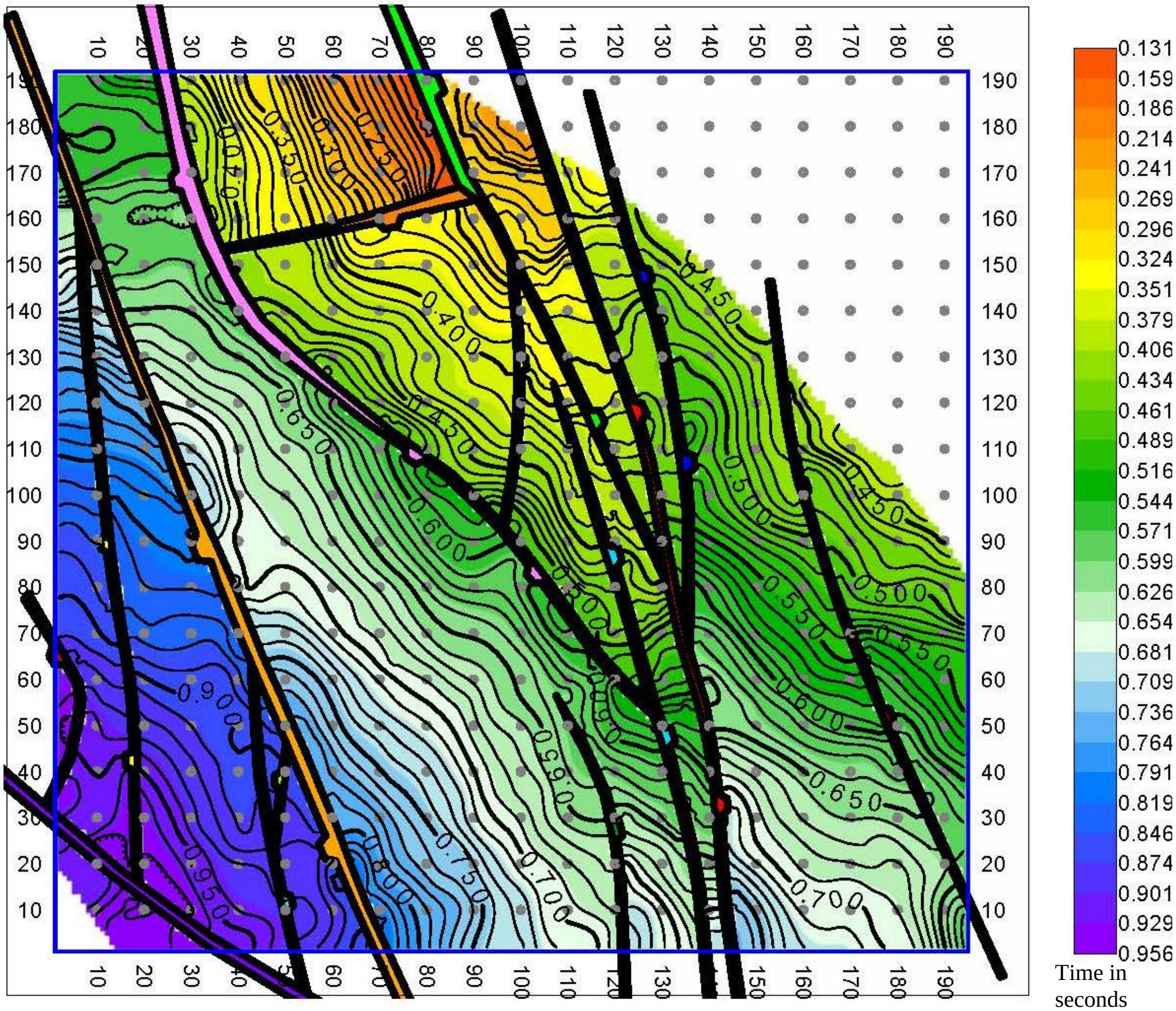


Figure 33. Horizon 2 time structure map. Colored contoured surface represents time to the semi-continuous interpreted prominent reflector here referred to as Horizon 2. Variable thickness colored lines represent interpreted faults with the normal sense of motion indicated in the tab direction. Thicker lines indicate a shallower dip.

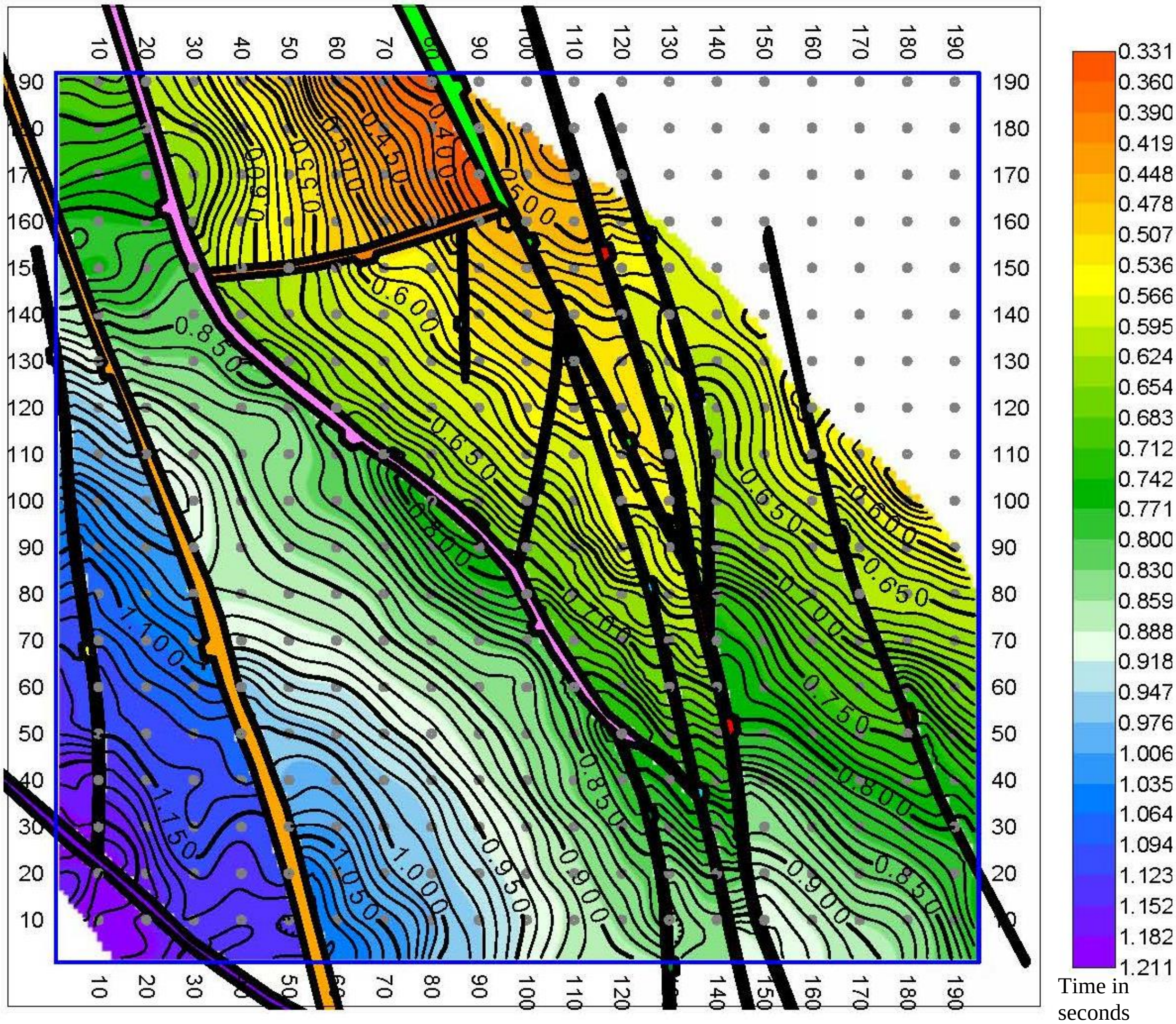


Figure 34. Horizon 3 time structure map. Colored contoured surface represents time to the semi-continuous interpreted prominent reflector here referred to as Horizon 3. Variable thickness colored lines represent interpreted faults with the normal sense of motion indicated in the tab direction. Thicker lines indicate a shallower dip.

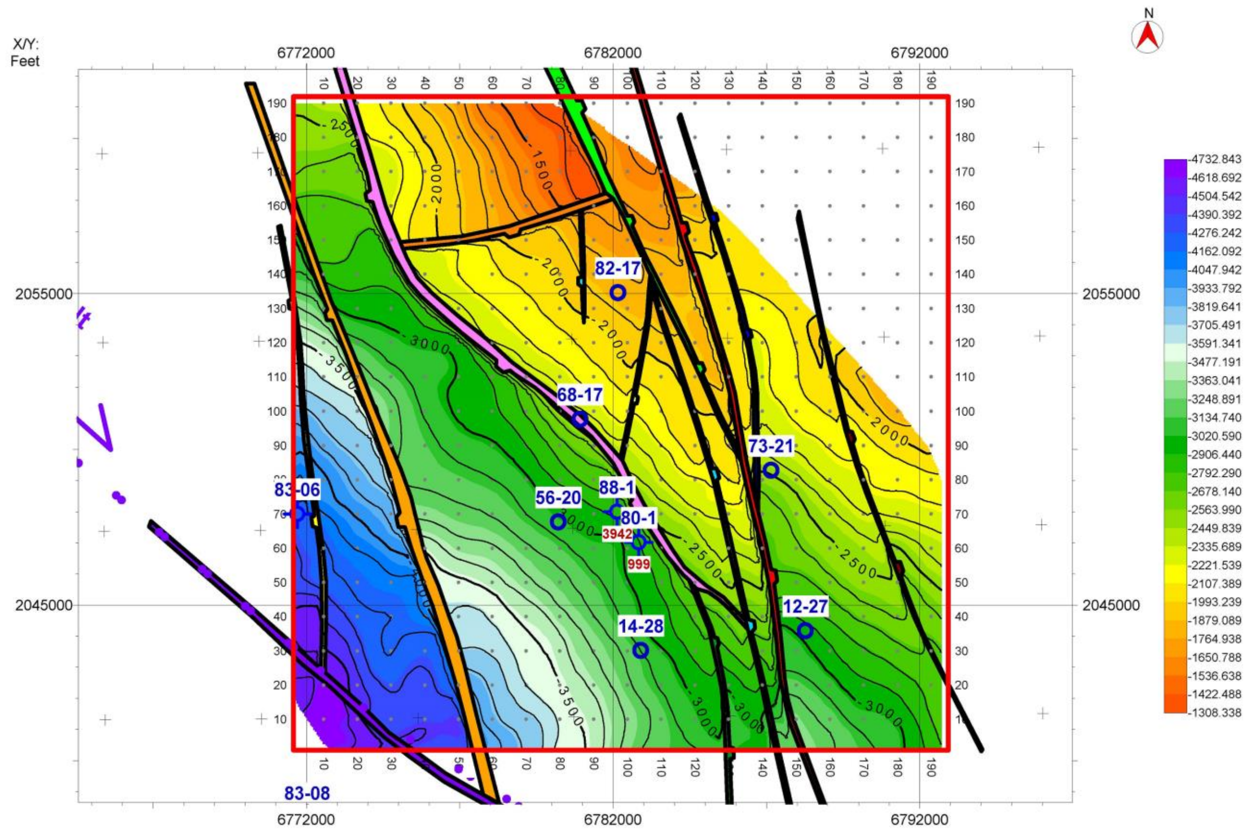


Figure 35. Horizon 3 structure map (feet subsea). Colored contoured surface represents depth to the semi-continuous interpreted prominent reflector here referred to as Horizon 3. Variable thickness colored lines represent interpreted faults with the normal sense of motion indicated in the tab direction. Thicker lines indicate a shallower dip.

7. <u>Data Integration and Proposed Exploration Well</u>

Wister is a blind geothermal prospect that does not exhibit surface thermal features such as hot springs. In 1988, based on temperature gradient data, UNOCAL drilled exploration well 88-1. The well was drilled to 3942 feet when the well bore collapsed after intersecting a large fracture. During cleanout attempts, the well flowed strongly, but these attempts to clear the blockage failed and UNOCAL converted the well into a temperature observation hole. The P-wave seismic data clearly show the fault or fracture system that the 88-1 well intersected. Inline 70 (Figure 36) shows how clearly the P-wave seismic data identifies the fault systems at Wister. These faults likely control the upward movement of thermal fluids.

The Wister area temperature gradient anomaly suggests that faulting controls its shape. The inner 8°F/100 feet contour is narrow and somewhat linear in shape (Figure 37). Ormat conducted a detailed gravity survey to identify fault structures. The horizontal gravity gradient map shows changes that are interpreted to be faults (Figure 39). The temperature gradient data overlaid on this map support the concept of fault influence on thermal fluid movement.

The capability of mapping the details of faults and fault (fracture) zones with the 3D seismic data can greatly improve identification of drilling targets. The depth converted structure map of Horizon 3 and the orientation of interpreted faults suggest that these faults may be conduits for geothermal fluids (Figure 35). With this evidence in mind and the obvious fault intersection of the 88-1 well as seen in the seismic data, the 3D P-wave seismic data can be effectively used to reduce exploration risk by identifying potential fault and fractured drilling targets.

Ormat proposed to drill an exploration well based on the Wister 3D seismic survey. The proposed Wister 12-27 well was in the southeastern part of the 3D survey (Figure 40). The location was selected to drill into an east-dipping fault zone. Figure 40 shows the 12-27 well location with the target fault zone, temperature anomaly and the location of Inline 36. Inline 36 seismic section details the fault zone target of this exploration well (Figure 41). This well was planned to provide a test of targeting seismically defined fault and fracture zones for geothermal in a sedimentary rock sequence.

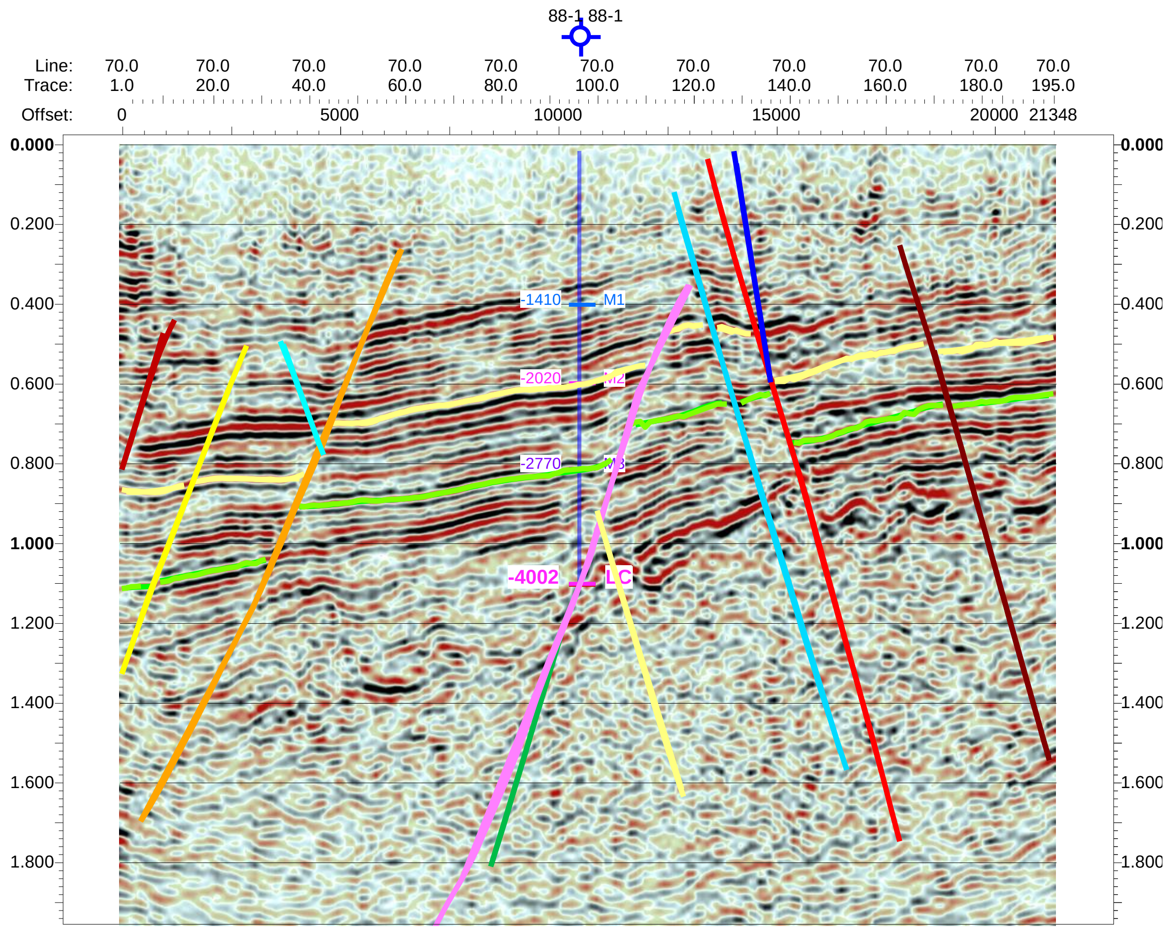


Figure 36. Inline 70 PSTM data with UNOCAL 88-1 well. Lost circulation zone shown as LC at -4002 feet subsea. Colored horizons were selected based on signature uniqueness and consistency and traced throughout the volume.

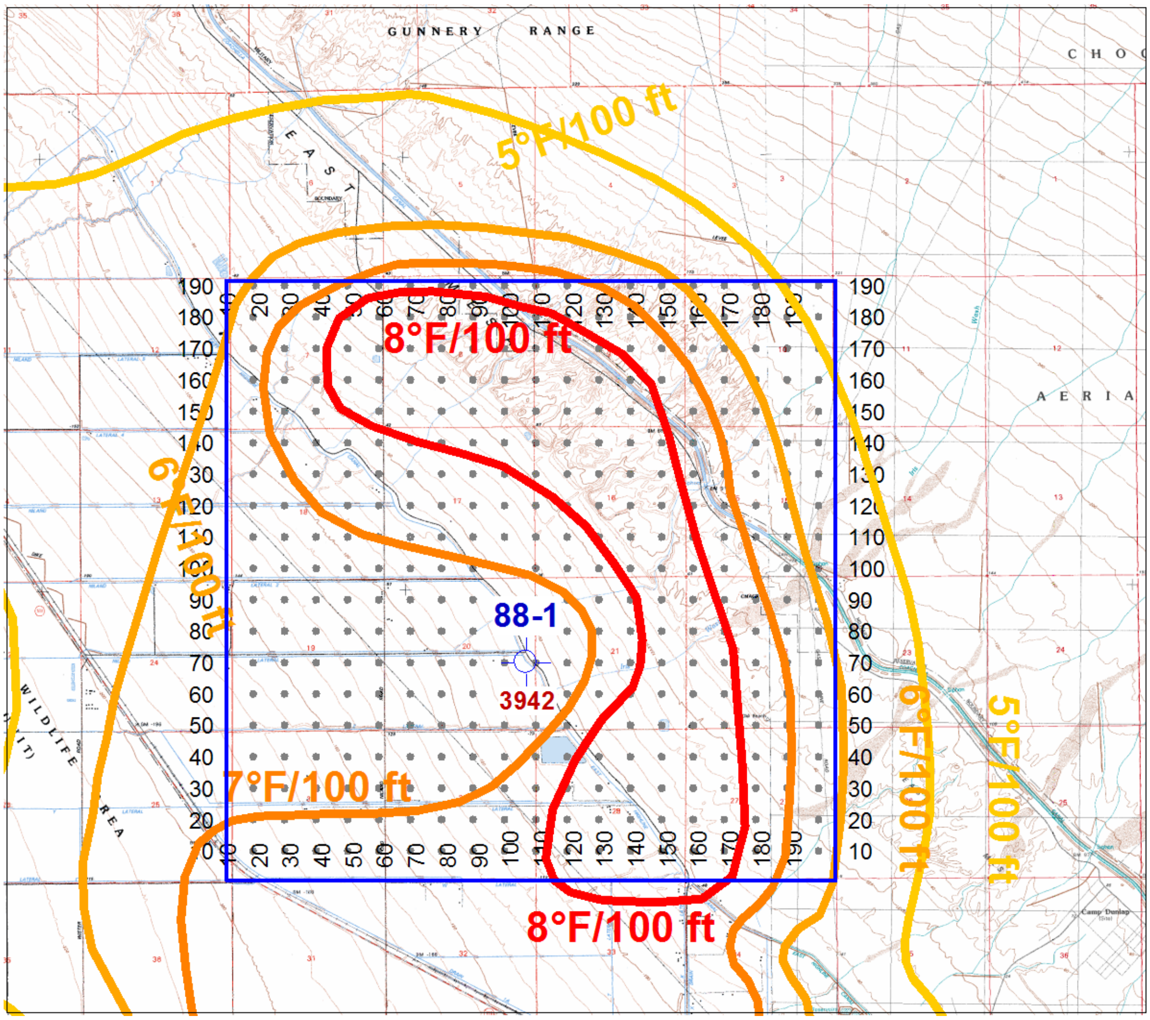


Figure 37. Wister seismic survey layout and shallow temperature gradient map based on historic gradient wells.

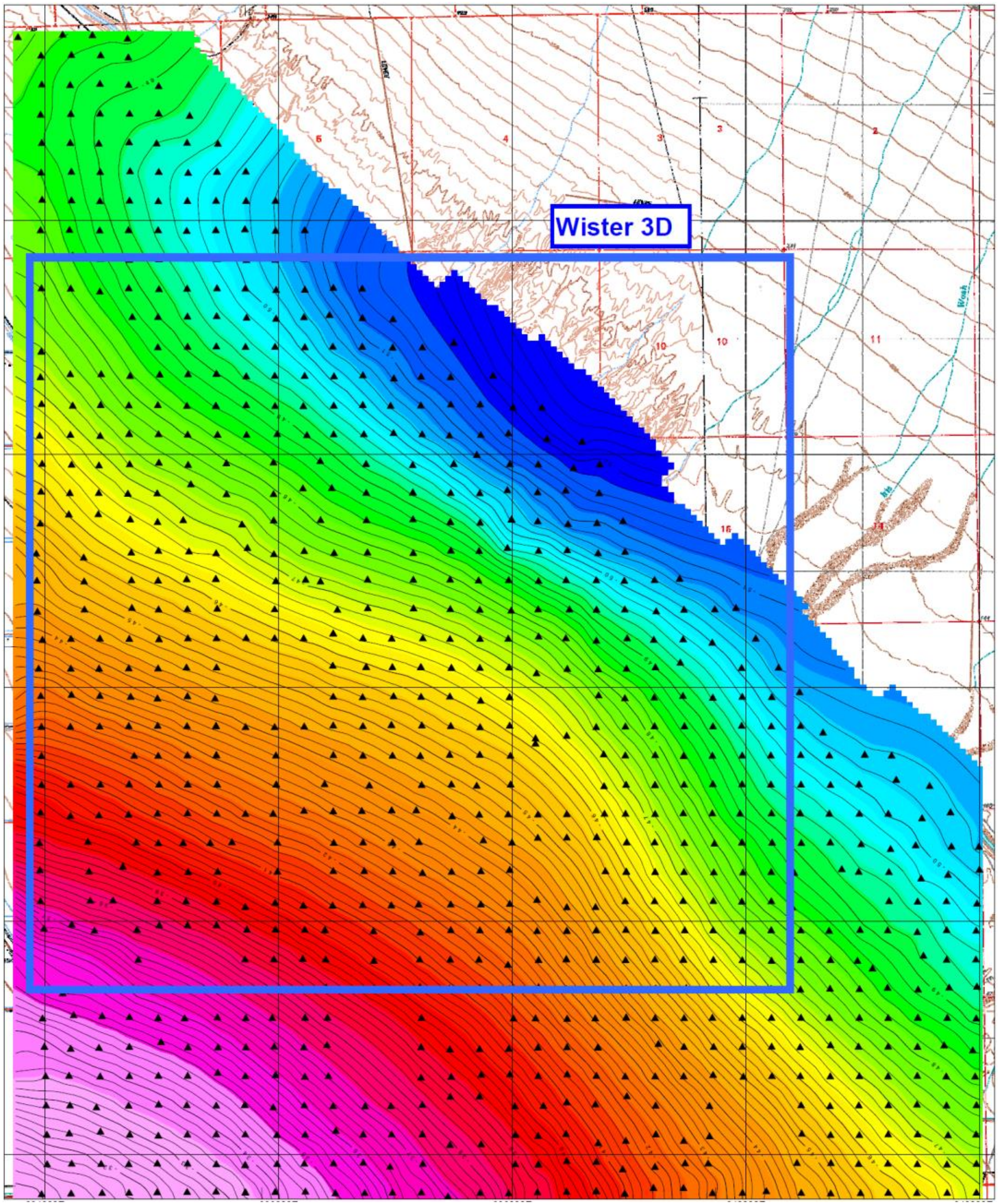


Figure 38. Wister Bouguer Gravity map with gravity stations shown as black triangles.

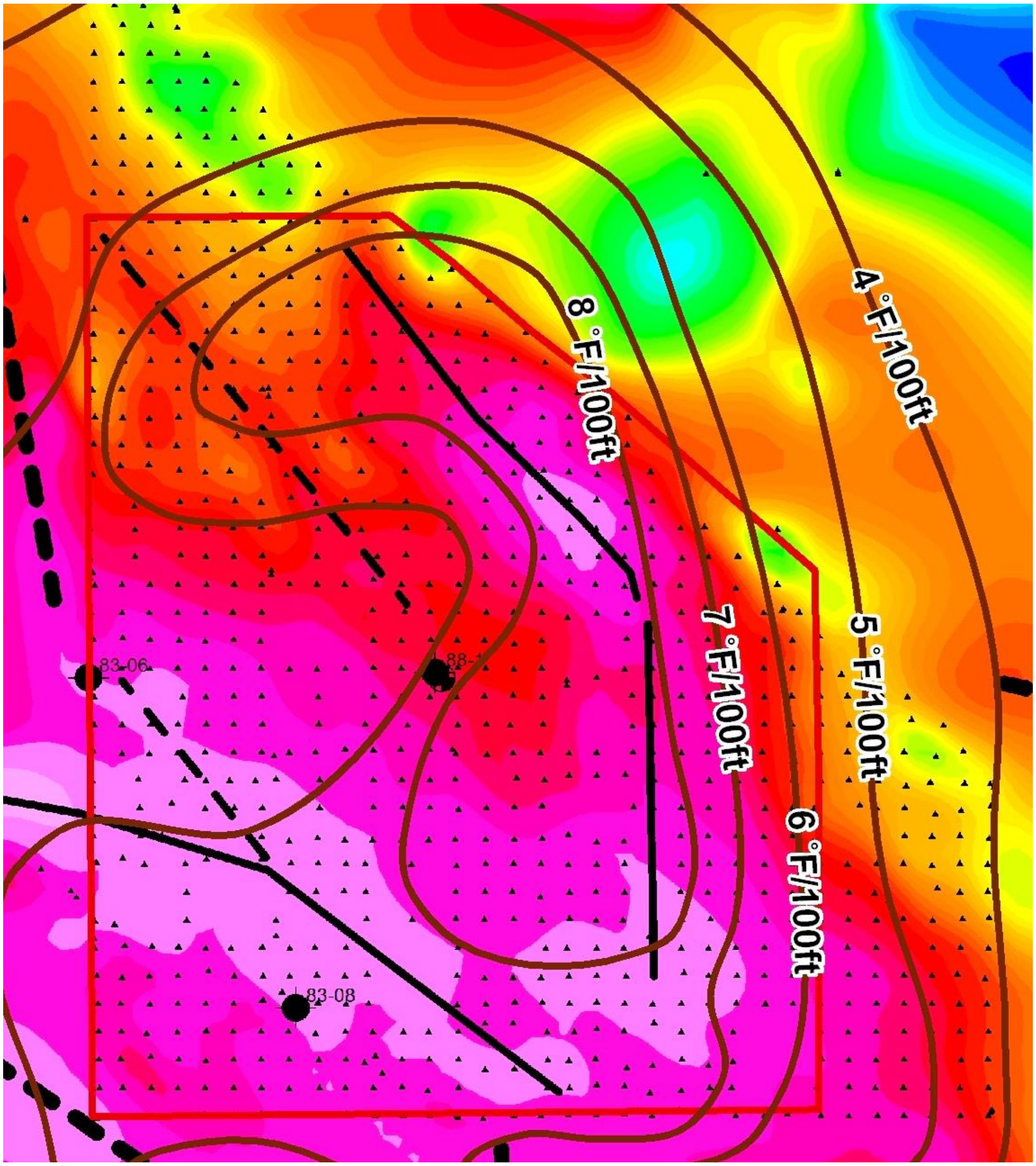


Figure 39. Wister horizontal gradient map with fault interpretation and temperature gradient contours.

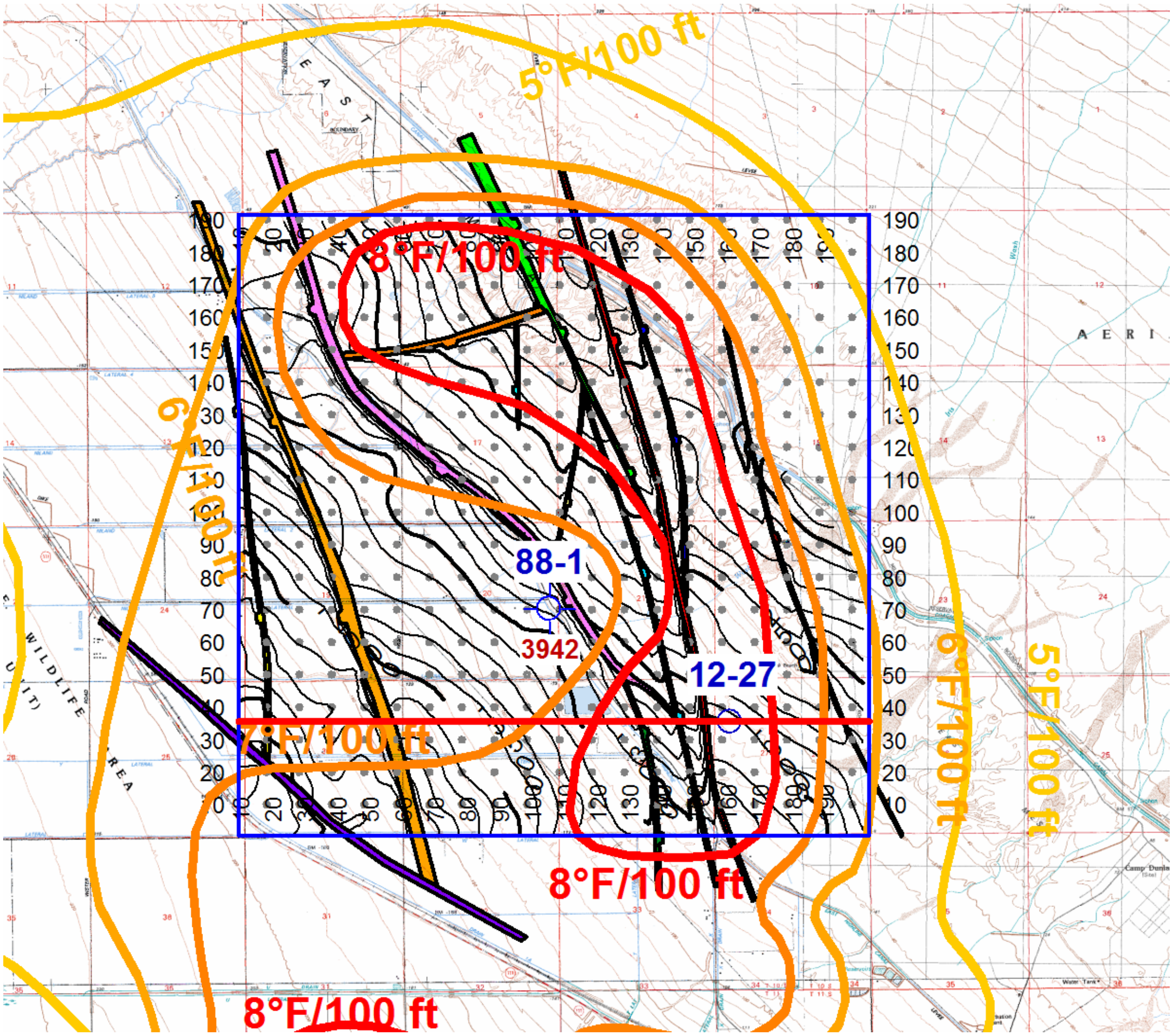


Figure 40. Seismic Horizon 3 structure map with temperature gradient overlay and position of Inline 36 seismic section (red line) through proposed Wister 12-27 well location.

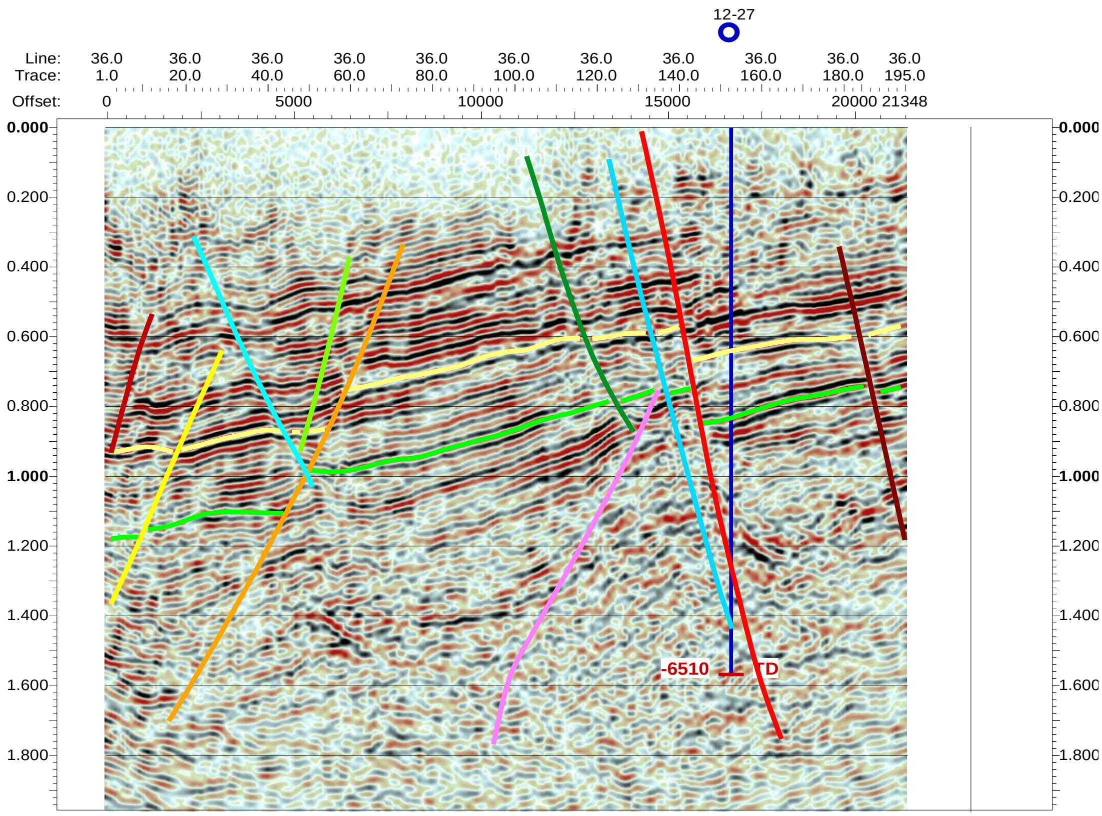


Figure 41. Inline 36 PSTM data showing Wister 12-27 well location.

8. <u>Drilling results</u>

Ormat drilled two wells at Wister, 12-27 and 85-20 (Appendices). The intervals with commercial temperatures in both wells were primarily siltstone and clay, and both TD in granodiorite (Figure 42). Neither well lost circulation during drilling nor encountered sufficient sand or fracture permeability to be commercial. 85-20 had been targeted ~820 ft from a Unocal well, 88-1, which was reported to have lost circulation indicating permeability before wellbore issues caused it to be abandoned. An explanation of this result is in Section 9. Seismic reprocessing and interpretation.

12-27 was a full size well drilled to 6375’ with no permeability, reaching 243°F at 3105’ (tool could not continue); granodiorite at 3860’. 85-20: Full size well drilled to 4994’, with no permeability, reaching 337°F at 4236’ (tool could not continue); granodiorite at 4470’.

Resistivity image logs (Schlumberger FMI) in 85-20 indicate that maximum horizontal stress (S_{hmax}) is oriented NNE but that open fractures are oriented suboptimally (Figure 43, Figure 44).

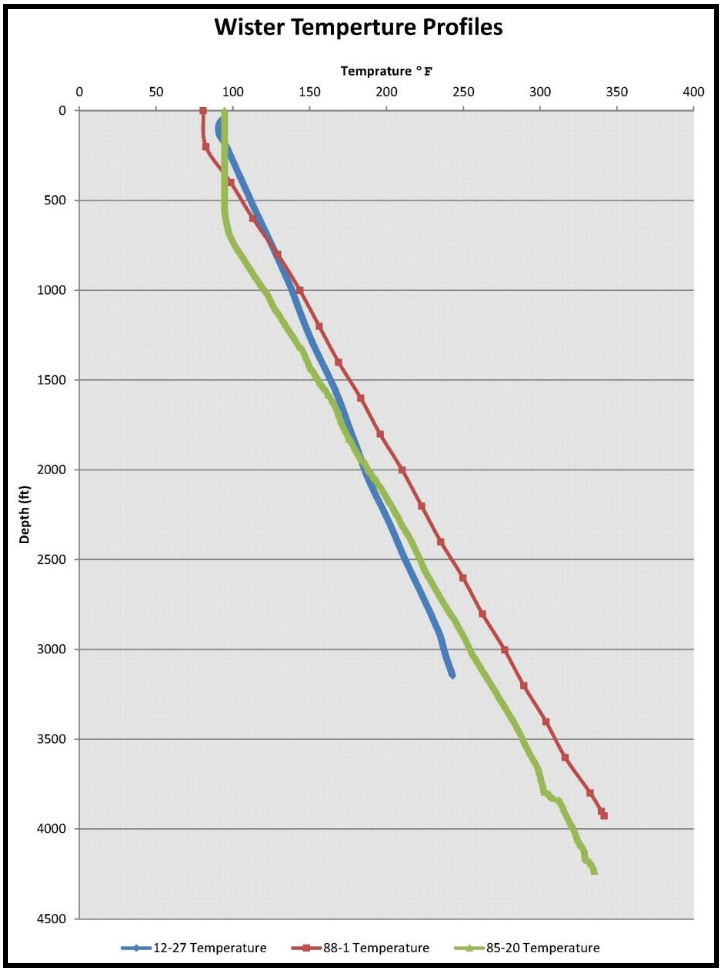


Figure 42. Temperature logs from Ormat wells 12-27 and 85-20 and Unocal well 88-1.

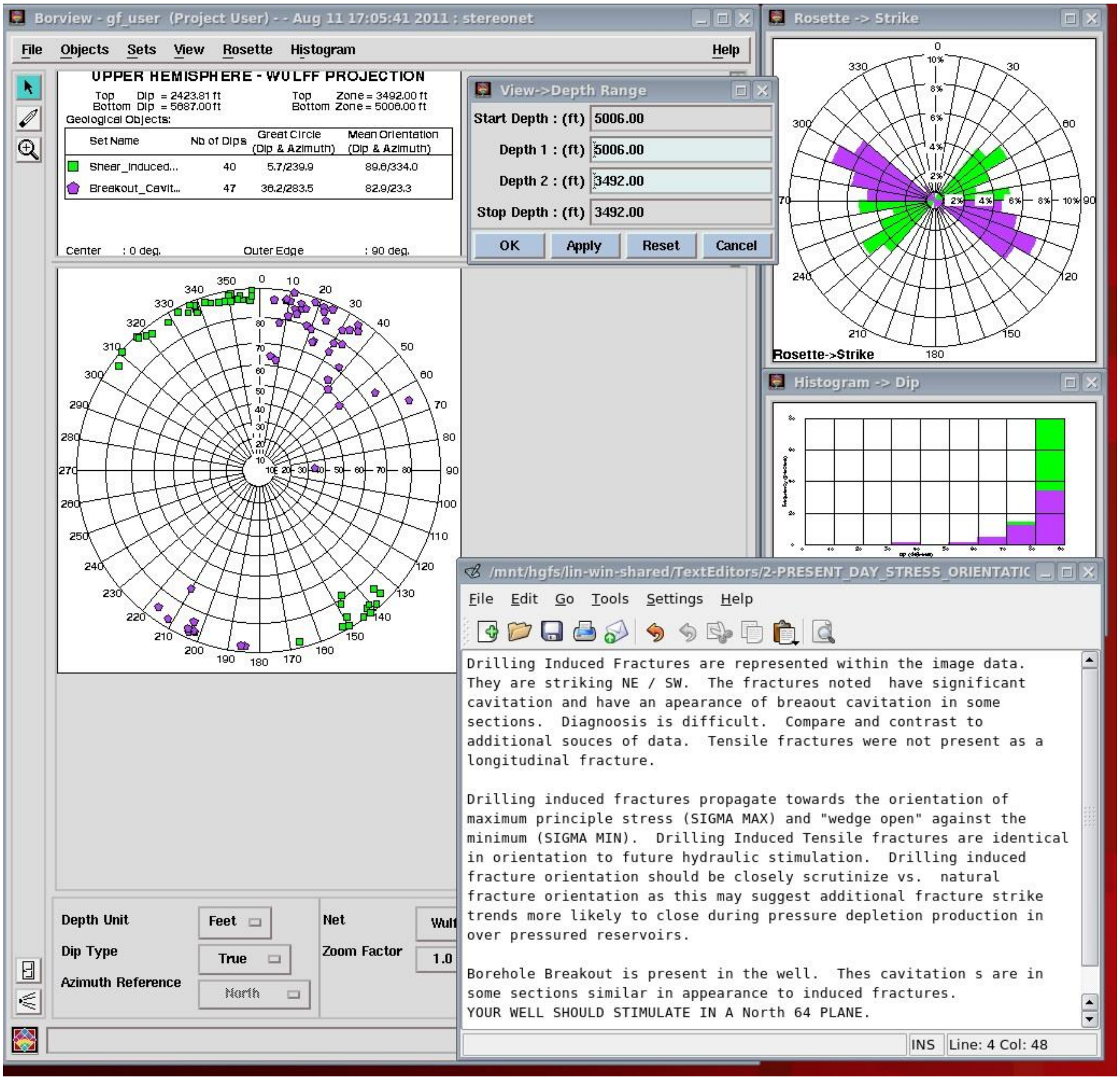


Figure 43. Orientations of induced fractures and borehole breakouts indicating S_{hmax}..oriented NNE.

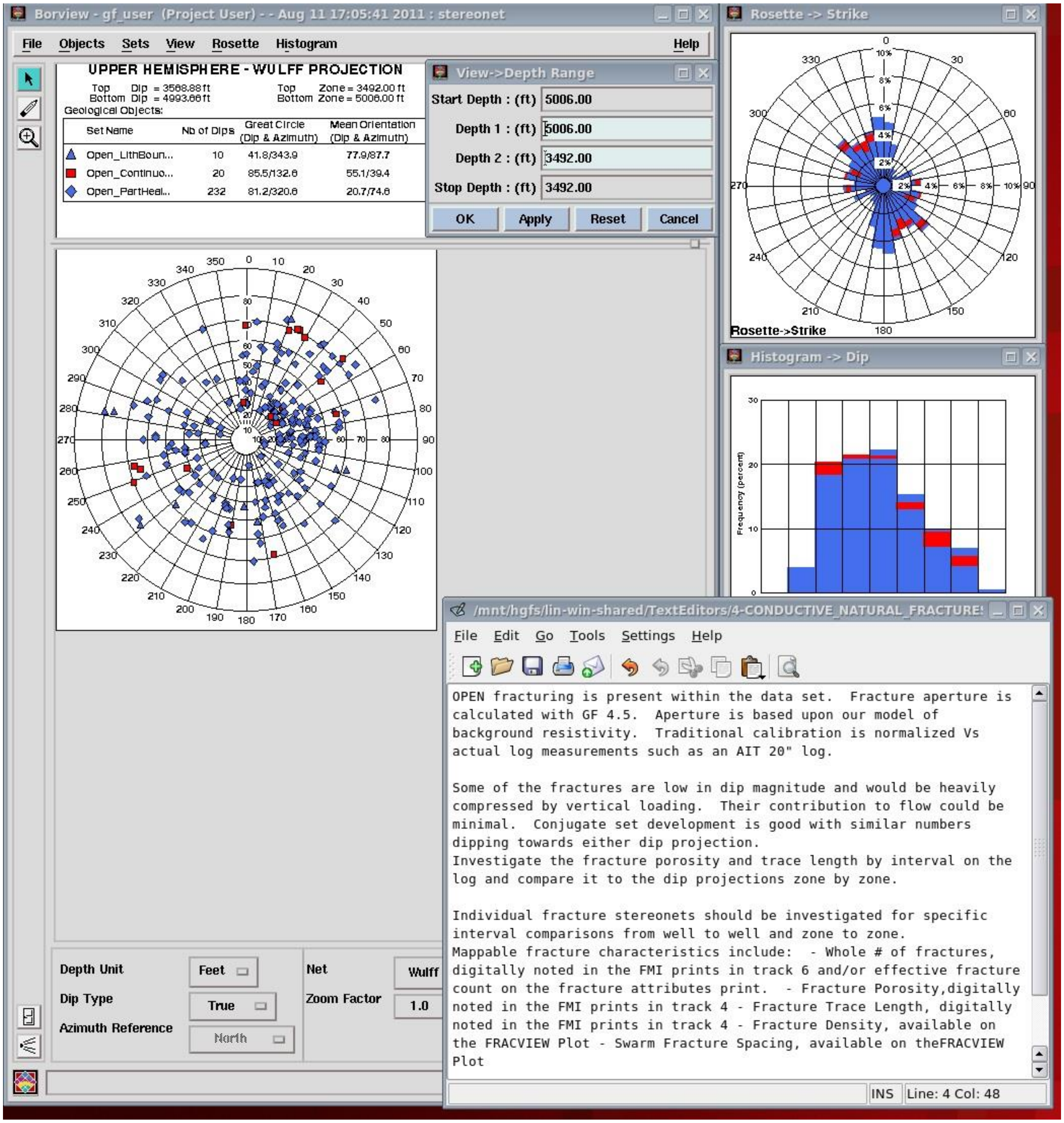


Figure 44. Open and partially open fractures indicate suboptimal orientations and frequent low dip angles that are less likely to provide high permeability.

9. Seismic reprocessing and interpretation

In 2014 Ormat contracted with CGG to reprocess the data originally processed by Fairfield. The improvements in image quality, reflection focusing, and resolution were dramatic. The dominant frequency of the 2011 vintage is 24 Hz, and has a narrow band. The central frequency of the

2014 vintage is approximately 40-45 Hz, with the high end at about 85 Hz. The 2014 data has broader bandwidth than the 2011 vintage. All processes contribute to the enhancement or destruction of signal bandwidth, but the two most notable ones are the pre-deconvolution noise attenuation, and the deconvolution routines that CGG employed. Full processing steps are listed below:

P-Wave Pre Stack Sequence:

1. Geometry Description
    - Read in field geometry from tape headers. Made adjustments were noted by observer. All field recorded were plotted to confirm source location.

2. True Amplitude Recovery
    - 1.8 Time Power Constant applied to 2.5 sec.

3. Minimum Phase Filter correction operator for Zero Phase Source

4. Refraction Statics
    - Datum: 0 Ft.
    - Replacement Velocity: 5500 Ft. /sec.
    - 500 – 4000 Ft. offset ranges were used in model
    - Refraction static stack showed improvement over a conventional elevation statics solution.

5. Surface Consistent Amplitude Analysis and Application
    - Source and Receiver
    - Gate below first breaks to 3.0 sec.

6. Ensemble Deconvolution (Receiver Line ensembles)
    - Spiking
    - 11 trace average
    - 210 ms Operator
    - .01% white noise
    - Single gate design from below first breaks to 3.5 sec.

7. Frequency Dependent Diversity Scaling.
    - Receiver Line Ensemble
    - 200 ms time gate
    - 5 freq panels,

8. Two passes velocity analysis, 2 passes surface consistent residual statics
    - First pass 1 Mile Grid / Second Pass ½ Mile Grid

Conventional CDP Stack Post Stack Sequence:

1. CDP Stack

2. Post Stack Enhancement
   - 2x2 FX Deconvolution, T-X dip filter
   - +/- 10 msec. Per trace in both directions

Pre-stack Time Migration Processing Sequence
Input to PSTM sequence Conventional CDP gathers prior to CDP Stack

1. Defining Arbitrary PSTM Binning
   a. Compute Equal Area Binning
   b. Compute Bin Sharing Parameters
   c. Compute Pre-stack Scaling

2. Kirchhoff PSM Velocity Analysis
   a. Pre-stack Kirchhoff curved ray time migration
   b. 20 iline x 20 xline velocity grid

3. Picked new velocity field on migrated gathers

4. Kirchhoff Pre Stack Migration full Volume
   a. Mute Pre Stack Volume

5. PSTM Residual Velocity Analysis
   a. Conventional Stacking Velocity Analysis

6. CRP Stack

7. Post Stack Enhancement
   a. 2x2 FX Deconvolution
   b. T-X dip filter
      i. +/- 10 msec. per trace in both directions

8. SEGY output Final Enhanced Pre-stack Time Migration

File: final-p-wave-pstm.segy

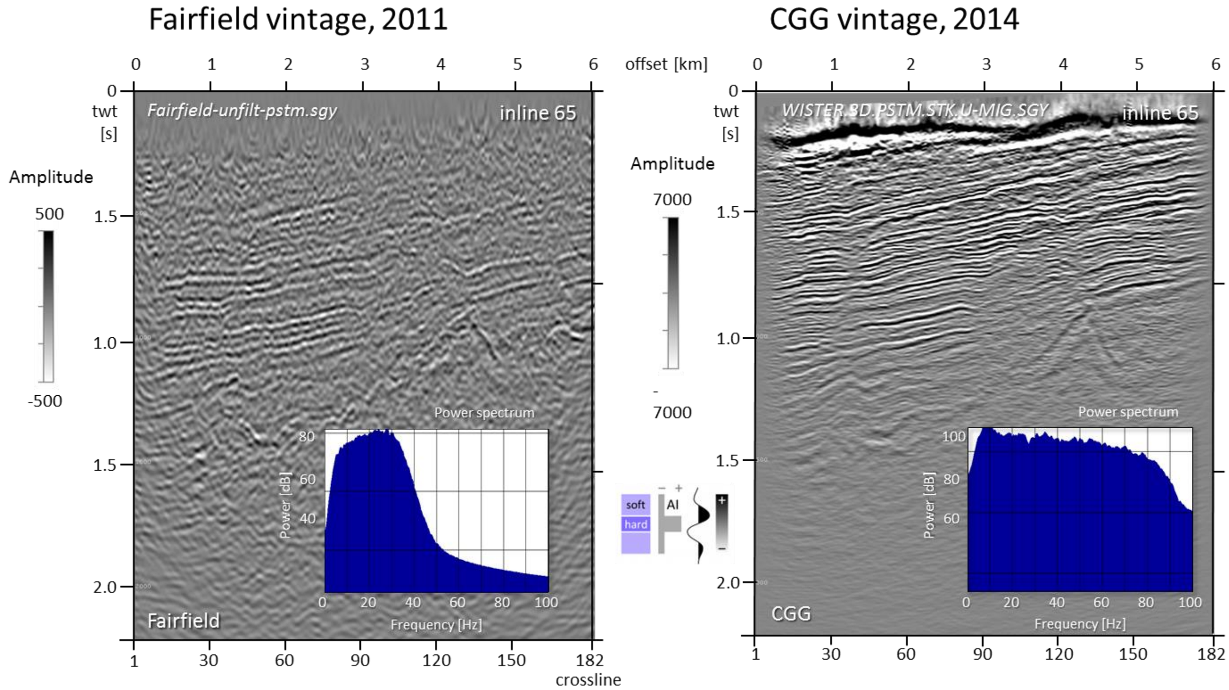


Figure 45. Comparison of seismic images and power spectrum between both processed volumes.

Interpretation of reprocessed results

Improved seismic imaging resulted in higher definition of controlling structures and dramatically improved frequency spectrum due to pre-deconvolution noise attenuation and deconvolution routines (Figure 45). The power spectrum is a measure of the signal strength for the frequency range. These interpretations led to the explanation that Unocal 88-1 found an intersection of 2 faults that may have locally provided enhanced permeability that resulted in lost circulation. However, the 85-20 only intersected a single fracture (Figure 46).

The low permeability of the 2 wells and structural analyis from reprocessed seismic data indicate that 1) sand is unlikely to provide permeability anywhere within the temperature anomaly, 2) if permeable faults are present their extent would be ~2 linear miles with limited storativity and unknown connectivity. In addition, little or no lateral variation in stratigraphic thickness indicates that recent extensional fault activity is unlikely, which may preclude extensive open-mode fratures.

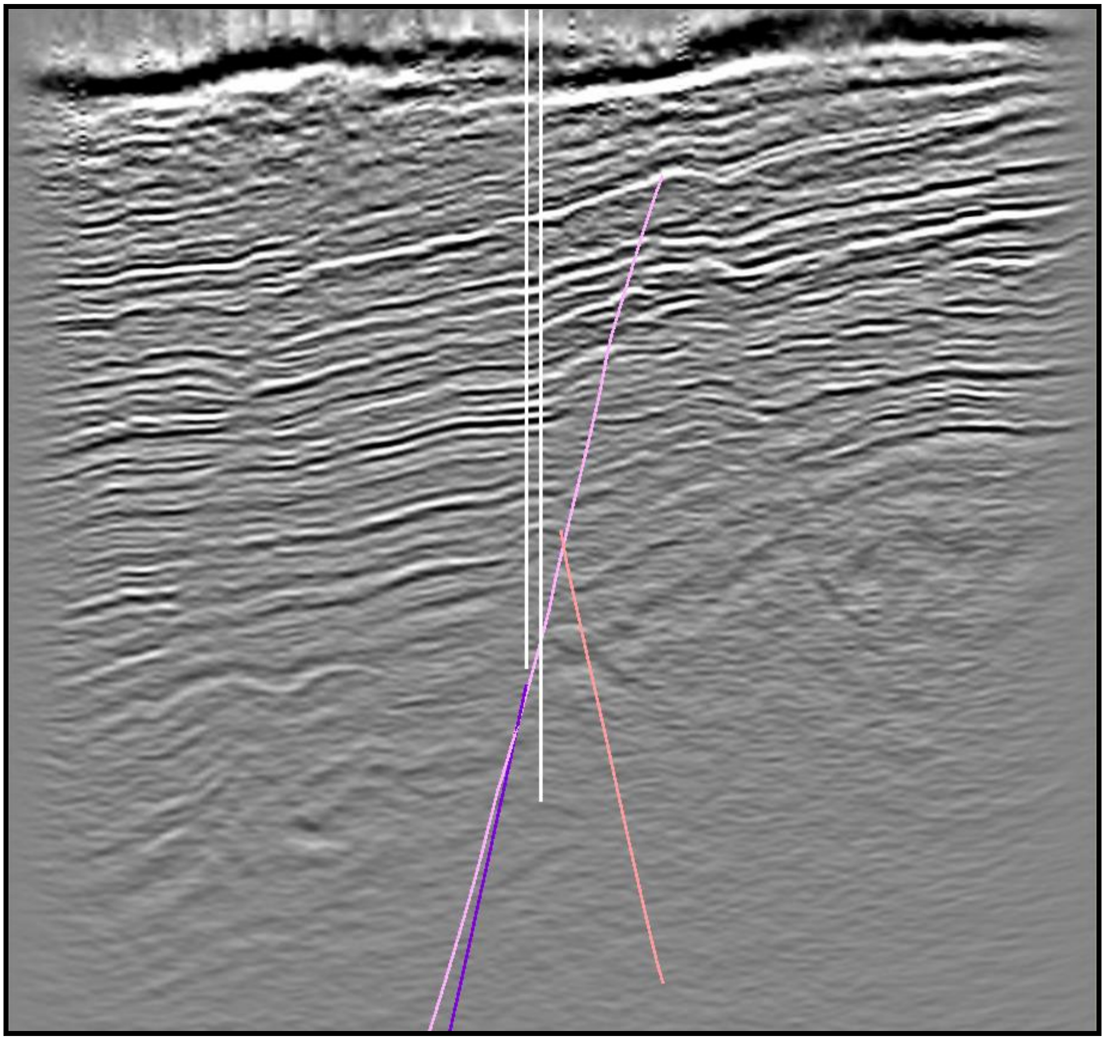


Figure 46. Seismic image with 3 interpreted faults (purple, pink and peach) and wells in white. 88-1 is the shallower and left of the 2. 85-20 is the deeper well to the right. 88-1 is interpreted to have intersected both pink and purple faults while 85-20 only interpreted the pink fault. The faults diverge away from this section with the purple fault increasingly prominent to the north.

10. Lessons learned & Conclusions

Properly designed and processed P-wave 3D seismic surveys can be used to find and map faults and fracture zones in this area. Seismic imaging of the subsurface structure has provided good targets for exploration drilling. The positions of the major seismically mapped fault zones are supported by the gravity data interpretations. The mapped temperature gradient anomaly appears to be related to fluid movement along seismically mapped fault/fracture systems. These fault zones are likely regions of fracture permeability that will produce hot geothermal fluids.

The likelihood of finding economic temperatures, fluids and permeability was high. The temperature gradient map and UNOCAL 88-1 show that high temperatures can be found and P-wave 3D seismic data shows fault zones that are good exploration targets.

The Wister 12-27 well was the first geothermal exploration well located by using 3D seismic data in the Imperial Valley. The innovation of using 3D seismic data is new to the geothermal industry in this region and may lead to expanded utilization of reflection seismic to reduce geothermal exploration drilling risks in sedimentary environments. Similarly, 85-20 targeted a seismically-defined west-dipping fracture close to the Unocal 88-1 well. Both wells encountered commercial temperatures but sub-commercial permeability.

An integral part of the Wister 3D 3C seismic survey is the converted shear wave data. The sensitivity of shear waves to open fractures had been anticipated to allow for mapping of fracture systems. The processing of the converted shear wave 3D seismic data yielded velocity ambiguities that were not able to be resolved despite S-wave velocity information from 12-27. The converted shear wave data processing was abandoned. This issue may be addressed in the future as additional multi-component surveys are collected and processed throughout the Imperial Valley.

Independent S-wave velocity data is needed for data processing of converted shear wave (or shear wave) data here. In-situ velocity data obtained from vertical seismic profiles, check-shot surveys or dipole sonic logs are essential for processing converted shear wave data. These well data are also invaluable for evaluating seismic results and refining the interpretations and depth calculations.

Investigations of the Wister Prospect indicate that despite containing some characteristics of the existing producing fields, a geothermal system is likely to be limited in permeability, extent, and connectivity. It is possible that with additional drilling a basement-controlled fracture system could be productive.

11. References

Elders, W.A., Rex, R.W., Meidav, T., Robinson, P.T., and Biehler, S., 1972, Crustal spreading in southern California – The Imperial Valley and the Gulf of California formed by rifting apart of a continental plate: Science, v. 178, p. 15-24.

Hulen, Jeffrey, Kaspereit, Dennis, Norton, Denis L., Osborn, William and Pulka, Fred, 2002, Refined Conceptual Modeling and a New Resource Estimate For the Salton Sea Geothermal Field, Imperial Valley, California; GRC Transactions Vol. 26.

12. Appendices

DRILLING HISTORY

Geothermal Well 12-27

LOCATION: 1460 ft S and 313.8 ft E of the NW corner of Section 27 T10S, R14E SBB&M

Latitude: 33°16’26.812”N **Longitude:** 115°30’33.701”W

ELEVATION: -15 ft MSL
KB: 27 FT above ground

MIDNIGHT TO MIDNIGHT REPORT
(ALL DEPTHS REFERENCE KB 30 Ft AGL UNLESS SPECIFIED)

DATE	**ACTIVITY**
4/14/10	Started construction of a drilling pad measuring 500 ft by 500 ft in accordance with regulatory requirements. The area adjacent to the well pad will include a containment basin measuring 100 ft by 200 ft by 7 ft deep. The pad is constructed to meet standard industry specification that includes soil compaction to support rig weight. The pad is contoured to drain into the cellar from the area around rig.
4/29/10	Finished the construction of the Pad and containment basin.
10/09/10	Lined basin with 40 mil PVC liner. Sealed seams with 4 ft over-lap with PVC glue. (Approximate Date).
10/10/10	Rigged up (RU) Howell Drilling. Dug 36-in hole from surface to 80 ft below ground. **Ran 80 ft of 30-in. 3/8-in. Wall Grade B PEBFW into hole with 2-inch pipe on outside. Final conductor depth was 73.5 ft below ground (101 ft KB).** Rigged down (RD) Howell. Pumped 9 cu yd of Ready-mix neat cement through 2-in. pipe. Cement returns.

10/11/10 Installed an 8 ft round cellar according to the rig specifications with a 6 ft depth.

10/12/10 Moved out two frac tanks for Dead Horse and one to lower location. Drained fuel tank of 6485 gallons and transported to the Battle Mountain Western Energetix bulk plant for the use of other rigs in the area. RD and prepared rig for load out. RD 90% complete.

10/13/10 Moved in cranes and set out rig in preparation for load out tomorrow. Rig down 98% complete.

10/14/10 Rigged down (100%). Loaded and moved out 11 loads to Wister.

10/15/10 Total loads moved to Wister to date = 16 loads.

10/16/10 Total loads moved to Wister to date = 18 loads. One truck is loaded waiting for the road to be cleared of the broken down permit load. The SCR house tipped while Eagle Trucking truck #115 with trailer #511 (tractor California license plate #9016684 and trailer California license plate # 4-KK6408) was attempting to leave the site contrary to orders and with no notification of his intent to the trucking company pusher or other personnel on location. The rear wheels of the trailer went into a shallow bar ditch while making a left hand turn from the north plant access road to Bucher canyon road causing the trailer, load and tractor to tip over on the left side. All trucks were to remain on location or pull off the access road at a wide spot and wait until the broken down truck had been cleared from the southern plant access road to Bucher Canyon road. Cranes were sent to right the tipped truck and SCR house. The truck pulled the damaged trailer and load off of the road near the gravel pit. The Chicken Hawk winch truck arrived on site at 8 PM and is ready to clear the south access road in the morning.

10/17/10 Total loads moved to Wister to date = 25. The day tank is loaded and will be on the road tomorrow. Approximately 6 miscellaneous loads remain to be loaded out. Cleared the disabled truck from the south access road, hooked up a new tractor and hauled the mud pump towards Wister.

10/18/10 Waited for loads from Nevada.

10/19/10 Received drillers side sub, shaker tanks, junk basket.

10/20/10 Received off drillers side sub, draw works, and eight 8-in. drill collars (DC). Rigged up sub, driller's floor, draw works, and derrick.

10/21/10 Received water tank. Raised derrick.

10/22/10 Spotted No. 2 mud pump, SCR house and generator skids. Electricians performed a series of test on SCR house and found it to be OK. Lugged up generators to SCR house. Completed inspection of 8-in. drill collars and misc subs. Heavy drill pipe as of now have not been delivered to Tubular Inspection in Bakersfield for inspection and hard banding. No. 1 mud pump and 1 shaker still not on location.

10/23/10 Spotted #1 mud pump, #2 shaker, and trip tank. Rigged up. Started filling water tank and mud pits with water.

10/24/10 Continued to inspect all electrical functions of the rig. Found and repaired some minor problems inside SCR house and inside upper dog house at drillers console. Installed 30-in. riser and flow line. Filled tanks with water.

10/25/10 Continued to rig up. Finished with electrical repairs. Mixed mud. Spotted one Baker tank. Drilled rat hole and mouse hole. Commenced operations at 1900 hrs. Picked up bit and bottom hole assembly and ran in hole. Tagged at 105 ft.

10/26/10 IADC rig inspection. Drilled 26-in. hole from 105 ft to 138 ft. Deviation survey at 125 ft = 0.25 degrees. Drilled from 138 ft to 164 ft. Deviation survey at 151 ft = 0.5 degrees. Drilled to 196 ft. Deviation survey at 184 ft = 0.0 degrees. Drilled to 230 ft. Deviation survey at 225 ft = 0.0 degrees. Drilled to 321 ft. Deviation survey at 279 ft = 0.25 degrees. Drilled to 352 ft. Deviation survey at 340 ft = 0.25 degrees. Drilled to 413 ft. Deviation survey at 371 ft = 0.5 degrees. Drilled to 444 ft. Deviation survey at 433 ft = 0.25 ft. Drilled to 475 ft.

10/27/10 Drilled 26-in. hole from 433 ft to 512 ft. Circulated hole clean. Surveyed at 505 ft = 0.5 degree. Wiped hole to shoe (105 ft). Pumped hi-vis sweep around to surface. Pulled out of hole for casing. Well started to flow while picking up drill pipe for stab-in. Ran in hole to 490 ft with opened ended drill pipe. Circulated and wait on weighted up material. Gained approximately 63 bbls while running pipe in hole. Gained another 20 bbls while circulating before well stabilized. Pumped 240 bbls 9.5 lb per gal mud down drill pipe. Checked for flow, OK. Pulled out of hole with drill pipe. Ran in hole with 26-inch bottom hole assembly. Tagged at 501 ft. Washed to bottom, 512 ft. Circulated and raised mud weight to 9.5 lb per gal throughout total system. Checked for flow, OK. Wiped hole to shoe. Circulated 1 hr. Checked for flow, OK. Pulled out of hole. Rigged up casing crew. Held safety meeting on running casing and well control. Ran 20-in., 94 lb, K-55, BT&C casing. Tack welded bottom 3 joints.

10/28/10 Ran 12 joints of 20-in, 94 lb, K-55, BT&C casing. Tack welded bottom 3 joints. Centralizers on shoe joint and every 3rd joint, 4 total. Shoe set at 504.53 ft, float collar at 470.41 ft. Ran in the hole with the stab-in tool, stabbed in and circulated for cement. HSM, rigged up Halliburton. Tested lines to 2500 psi, pumped 20 bbls H2O, 30 bbls mud flush, 20 bbls H2O, 10 bbls FLOCHECK, 10 bbls H2O, 305 bbls Lead cement (SWIFTCEM, 700 sks, 13 ppg, yield 2.49, mix water 11.16 gal/sk), 41 bbls Latex Tail cement (ELASTICEM, 130 sks, 15 ppg, yield 2.01, mix water 9.75 gal/sk), shut down and washed pumps, displaced with 9 bbls H2O, check floats, good. Had 55 bbls of cement back to surface. CIP at 05:10 hrs. Waited on cement 6 hrs, cement at ground level. Rough cut 30-in and 20-in casing.

10/29/10 Finish cut 20-in. casing and welded on a 20-in. x 600 flange. Built spacer spool and adjusted choke line. Nippled up mud cross, single gate with blind rams, Hydril, riser and rotating head. Hooked up flow and kill lines. Function and pressure tested BOPE and choke to 500 psi. Made up 17-1/2-in. bit with float, ran in the hole, tagged float collar at 473 ft. Circulated bottoms up, tested Hydril and choke valves to 500 psi. Drilled out float collar, cement and the float shoe at 504 ft (solid cement at the shoe). Surveyed at 495 ft, 1/2°. Drilled 17-1/2-in. hole from 511 ft to 538 ft.

10/30/10 Drilled and surveyed 17-1/2-in. hole from 538 ft to 757 ft. Circulated hole clean and tripped out for stabilizers. Made up stabilizers at 30 and 60 ft from bit and tripped in the hole. Safety ream 50 ft back to bottom. Appeared 1 jet was plugged and the bit was balled up. Worked the ball off of the bit and the jet cleaned up also. Drilled and surveyed 17-1/2-in. hole from 757 ft to 988 ft. Surveys 1/4 to 1/2 degree.

10/31/10 Drilled and surveyed 17-1/2-in. hole from 988 ft to 1239 ft. Circulated hole clean, surveyed and wiped the hole, stabilizers to the 20-in. casing shoe. Drilled and surveyed 17-1/2-in. hole from 1239 ft to 1474 ft. Surveys were 1/4 to 3/4 degree.

11/1/10 Drilled and surveyed 17-1/2-in. hole from 1474 ft to 1648 ft. Circulated hole clean, surveyed and wiped the hole, with stabilizers to the 20-in. casing shoe. Drilled and surveyed 17-1/2-in. hole from 1648 ft to 1870 ft. Surveys: 1511 ft - 3/4°, 1637 ft - 1/2°, 1733 ft - 1/2°, 1858 ft - 1/2°.

11/2/10 Drilled and surveyed 17-1/2-in. hole from 1870 ft to 2055 ft. Circulated hole clean and wiped the hole, with stabilizers to the 20-in. casing shoe. Drilled and surveyed 17-1/2-in. hole from 2055 ft to 2151 ft. Surveys: 1983 ft - 1-1/4°, 2108 ft - 1/2°.

11/3/10 Drilled 17-1/2-in. hole from 2151 ft to 2244 ft, circulated bottoms up and surveyed at 2233 ft. The survey was split between 1/4 and 1-3/4 degrees and not accurate. POH for wiper trip and to inspect the bit and remove balled up clay from the stabilizers and bit. Pulled 45,000 pounds overweight off bottom. PU new bit and shock tool and RIH to 2244 ft reaming at 1440 ft and from 2158 ft to 2244 ft and circulating out thick (gumbo like) mud. Drilled 17-1/2-in. hole from 2244 ft to 2257 ft, circulated bottoms up and surveyed. The well bore inclination survey was 1/2 degree from vertical at 2246 ft.

11/4/10 Drilled 17-1/2-in. hole from 2257 ft to 2383 ft, circulated bottoms up with sap bomb and walnut hull (SBWH) sweep to clean the bit and stabilizers of balled up clay (this sweep generally increases the penetration rate from 8 FPH to 12 FPH). Pulled 65,000 pounds overweight from 2325 ft to 2330 ft. Surveyed at 2373 ft. The wellbore inclination survey at 2373 ft was 1/2 degree from vertical. Had 4 ft of fill on bottom after the survey. Drilled 17-1/2-in. hole from 2383 ft to 2431 ft. Pumped SBWH sweep as above and POH for wiper trip to shoe. Pulled 25,000 pounds overweight 2165 ft to 2155 ft and 2125 ft to 2115 ft.

11/5/10 POH to shoe and RIH to 1429 ft. Filled DP and cooled well with thick mud returns to surface. Encountered tight spot at 1524 ft and reamed. RIH from 1524 ft to 1597 ft and reamed tight spot. RIH from 1597 ft to 1902 ft and found more tight hole. Reamed from 1902 ft to 1975 ft and circulated the hole clean. RIH from 1975 ft to 2014 ft and hit more tight hole. Reamed from 2014 ft to TD at 2431 ft. Drilled 17-1/2-in. hole from 2431 ft to 2509 ft, pumped SBWH sweep and surveyed. The wellbore inclination survey at 2498 ft was 1/4 degree from vertical. Drilled 17-1/2-in. hole from 2509 ft to 2540 ft, pumped SBWH sweep and circulated until the shaker screens were clean for wiper trip to shoe. In order to control swelling clays the wiper trip frequency was increased from every 24 hr to 12 hr, the fluid loss was dropped from 8.5 ml/30 min. to 6.5 ml/30 min. by the addition of 0.065 PPB Geopac and 3 gal/BBL DMS was added for lubricity (this worked – the subsequent wiper trip was accomplished in 3 hr. rather than 12 hr. with no drag and no fill and no reaming).

11/6/10 Circulated the hole clean and POH to the shoe at 500 ft (no drag) and serviced the rig. RIH to TD at 2540 ft with no drag and no fill. Drilled 17-1/2-in. hole from 2540 ft to 2633 ft, circulated the hole clean and surveyed. The wellbore inclination survey at 2623 ft was 1/4 degree from vertical. Drilled 17-1/2-in. hole from 2633 ft to 2659 ft. Circulated the hole clean, POH for wiper trip and to check the bit due to low penetration rate in sticky clay (no drag). Bit good. Cleaned clay from the stabilizers and bit, RIH to 457 ft and changed the valves and seats in the mud pumps.

11/7/10 Worked on mud pumps and circulated at shoe. RIH from 457 ft to 2659 ft (no drag or fill). Drilled 17-1/2-inch hole from 2659 ft to 2759 ft, circulated the hole clean and surveyed. The wellbore inclination survey at 2748 ft was 1/2 degree from vertical. Drilled 17-1/2-inch hole from 2759 ft to 2813 ft, circulated the hole clean and checked for flow (always). POH for wiper trip and to clean balled up clay from the stabilizers and the bit. POH to stabilizers and cleaned same.

11/8/10 POH, cleaned balled up clay from stabilizer and bit. Bit in gage and OK. RIH to shoe, slipped and cut the drilling line, and serviced the rig. RIH to 2809 ft, tagged 4 ft of fill and CO fill to 2813 ft. Drilled 17-1/2-inch hole from 2813 ft to 2883 ft, circulated the hole clean and surveyed. The wellbore inclination survey at 2873 ft was 1 degree from vertical. Dropped the WOB from 20,000 pounds to 15,000 pounds to maintain the hole angle and drilled 17-1/2-inch hole from 2883 ft to 2964 ft. Circulated the hole clean for 18 hour wiper trip and to inspect and clean the bit and stabilizers.

11/9/10 Circulated the hole clean, checked for flow and POH from 2964 ft to surface to inspect and clean bit and stabilizers and check float (no drag). Serviced rig. PU new long, scoop tooth insert bit due to firming claystones and sandstones and chips and cracks in the old bit. RIH to 2958 ft. Found six ft of fill, cleaned out same and drilled 17-1/2 inch hole from 2964 ft to 3008 ft. Circulated the hole clean and surveyed. The wellbore inclination survey at 2997 ft was 1.5 degree from vertical. Drilled 17-1/2 inch hole from 3007 ft to 3020 ft. The penetration rate slowed in sticky clay to 2 fph. Tested the bit and formation response to weight and increased the penetration rate from 2 fph to 8 fph by increasing the bit weight from 15,000 pounds to 25,000 pounds. Circulated the hole clean, checked for flow and made wiper trip to change the BHA from pendulum to stiff in order to increase the bit weight to increase the penetration rate and not kick the well further off vertical.

11/10/10 Tripped out of hole from 2244 ft. Moved top stabilizer down to top of bit and inspected the bit, GOOD. Ran in the hole to 3020 ft, no fill. Drilled from 3020 ft to 3132 ft. Circulate and survey at 3121 ft - 0°.

11/11/10 Drilled 17-1/2-in. hole from 3132 ft to 3165 ft - 13-3/8-in. casing point. Circulate hole clean. Wipe the hole to the 20 in. casing shoe service rig. Tripped in the hole to 3165 ft, no fill. Circulate hole clean. Tripped out of the hole. HSM, rig up Schlumberger, Ran E-Logs, induction, gamma, porosity, di-pole sonic, and SP logs from 3165 ft to 500 ft.

11/12/10 Finished running E-Logs, induction, gamma, porosity, di-pole sonic, and SP logs from 3165 ft to 500 ft. Rigged down Schlumberger. Made up BHA, stabs at 0 and 30 ft. Tripped in hole, filled pipe at 1500 ft, Tripped on in to 3165 ft, no fill. Circulated and pumped sweeps to clean the hole to run 13-3/8-in. casing. Tripped out of the hole. Rigged up to run 13-3/8-in casing. Tack weld first 4 joints and run centralizers on bottom 2 joints and every third joint. **Ran 75 joints of 78 total. Casing - float shoe, 1 joint, float collar, 77 joints (bottom 4 joints tack welded and centralizers on bottom 2 joints then every 3rd joint to 161 feet, 26 total) of 13-3/8-in. 68#, K-55 casing, shoe set at 3153 ft, float collar at 3114 ft.**

11/13/10 Finished running 13-3/8-in. casing. Casing - float shoe, 1 joint, float collar, 77 joints (bottom 4 joints tack welded and centralizers on bottom 2 joints then every 3rd joint to 161 feet, 26 total) of **13-3/8-in. 68#, K-55 casing, shoe set at 3153 ft, float collar at 3114 ft.** Circulate down casing while rigging down the casing crew. Run in the hole with the stab-in tool and stab into the float collar at 3114 ft. Circulate to cool the well for cement. HSM, rig up Halliburton, test lines to 3000 psi, pump 40 bbls H_2O at 6 bpm, pump 20 bbls Mud Flush III at 6 bpm, pump 30 bbls Sepiolite 10.5 ppg at 6 bpm, pump 10 bbls H_2O at 6 bpm, pump 13 bbls Flochek 14 ppg, at 3 bpm, pump 15 bbls H_2O at 6 bpm. Start Latex lead cement at 09:35, 1820 sks (682 bbls) of 13.5 ppg at 6 bpm, lost return at 10:58, 508 bbls pumped, returns back at 11:16, 609 bbls pumped, lost return at 11:33, 707 bbls pumped, pump 130 sks (40 bbls) of 15 ppg Latex tail at 2.6 bpm, wash pump lines, pump displacement, 2 bbls water, 55 bbls mud, 2 bbls water (over displace by 2 bbls), regained returns, est 5 bbls of 13.7 ppg cement to surface, pumping pressure up to 791 psi, bleed off, check floats - good, CIP at 12:37 hrs. Sting out of the float collar and Tripped out with the stab-in string. Wait on cement, 4 bolt BOPE, tag cement, down about 40 ft, will do a top job.

11/14/10 Waited on cement, build BOPE riser spool, 4 bolt BOPE, rough cut 13-3/8-in. casing, nipple down the 20-in. BOPE, dig out cellar bottom and cut off the 20-in. and 30-in. casing lower to finish cut the 13-3/8-in. casing low enough to install the well head 35-in. below ground level. Run 1-in. pipe down the 13-3/8-in. casing annulus to 50 ft. below GL. Pump top job, 35 sks, 15.8 ppg, 1.56 yield, 54 cu/ft (10 bbls), 35% SF, 2% CC. Weld on the 12-in X 400 X 13-3/8-in. SOW well head 35-in. below GL. Test weld to with N2 to 1000 psi for 15 min. - good. Called for cement for 2nd top job. Nipple up Class III, 13-3/8-in. 2M BOPE, function and pressure test blind rams to 500 psi. Pump 2nd top job, 15 sks, 15.8 ppg, 1.56 yield, 22.5 cu/ft (4 bbls), 35% SF, 2% CC. Make up and run BHA in the hole. Test BOPE and choke valves to 1000 psi, test witnessed and approved by the CDOGGR (Cliff Parli). Run in hole to 571 ft.

11/15/10 Tripped in the hole from 571 ft tag at 3119 ft. Drilled out float collar at 3119 ft, cement and shoe at 3158 ft and to 3159 ft. Shoe test, .65/ft gradient, 475 psi - 15 min - good. Drilled out cement to 3165 ft. Drilled 12-1/4-in. hole from 3165 ft to 3183 ft. Circulate and survey at 3173 ft- 1/4°. Drilled 12-1/4-in. hole from 3183 ft to 3246 ft. Rig had motor problems. Tripped out for stabs, 1 above bit and 2nd 30 ft up. Service rig. Run in the hole to 3181 ft, ream to 3246 ft. Drilled 12-1/4-in. hole from 3246 ft to 3285 ft. Circulate and survey at 3274 ft - 1/2°.

11/16/10 Drilled 12-1/4-in. hole from 3274 ft to 3410 ft. Circulate and survey at 3400 ft - 3/4°. Drilled 12-

1/4-in. hole from 3410 ft to 3442 ft. Pull to the shoe. Rig repair, main motor problems.

11/17/10 Waiting on the Electrician, Technician and Mechanic, Motor repaired, RIH 3148 ft to 3234 ft Circulate hole clean, RIH and tag fill at 3260 ft, Lay down joints, RIH to 3243 ft and reamed from 3243 ft to 3285 ft.

11/18/10 Reamed from 3285 ft to 3442 ft, Drilled from 3442 ft to 3536 ft. Surveyed at 3525 ft (1 1/2 degrees), POOH to change BHA, RIH to 13-3/8-in. shoe, Work on mud pumps, RIH, Pull back up to the 13-3/8-in. shoe and repair rotary right angle drive, RIH, Drilled from 3536 ft to 3549 ft.

11/19/10 Drilled from 3549 ft to 3603 ft. Pulled to the 13-3/8-in. shoe and circulated while they changed oil in #3 motor. RIH, and drilled from 3603 ft to 3660 ft. Surveyed at 3649 ft (1.5 degrees). Drilled from 3660 ft to 3732 ft. Made wiper trip, slipped and cut drilling line. Drilled from 3732 ft to 3744 ft.

11/20/10 Drilled from 3744 ft to 3780 ft and surveyed at 3774 ft (1.5 degree). Drilled from 3774 ft to 3815 ft. Pumped high Vis sweep. Circulated bottoms up. Pulled up to 13-3/8-in. shoe to replace motor.

11/21/10 Continued working on motor. Circulate and conditioned hole at 3148 ft. RIH, and tagged at 3519 ft. Reamed from 3520 ft to 3535 ft. Pumped sweep and circulated at 3535 ft. Increased mud weight to 9.7 ppg to help hold back the formation. Reamed from 3500 ft to 3629 ft. Circulated clean. Laid down drill pipe and RIH to 3639 ft. Reamed from 3639 ft to 3815 ft. Drilled from 3815 ft to 3850 ft.

11/22/10 Drilled from 3850 ft to 3910 ft. Surveyed at 3899 ft (1.5 degrees). Drilled from 3910 ft to 4000 ft.

11/23/10 Drilled to 4025 ft. Surveyed at 4019 ft (1.5 degrees). Ran wiper trip to 13-3/8-in. shoe, and pulled 10 stands. Serviced Rig (changed oil in motors). RIH, and drilled from 4035 ft to 4072 ft. After talking the Bit representative and some experts the decision was made to POH to change bit. Laid down jars and three collars and one stabilizer with bad face. Made up new BHA and RIH. Drilled from 4072 ft to 4075 ft.

11/24/10 Drilled from 4075 ft to 4160 ft. Circulated and surveyed at 4150 ft, 1-3/4°. Drilled from 4160 ft to 4224 ft. Circulated and wiped the hole to 3848 ft. Tripped in to 4224 ft, no fill. Drilled from 4224 ft to 4267 ft. Developed a hole in kelly hose, pulled to the shoe, changed out kelly hose, and tripped back in to 4267 ft. Drilled from 4267 ft to 4287 ft. Circulated and surveyed at 4276 ft, 1-1/2°. Drilled from 4287 ft to 4303 ft.

11/25/10 Drilled from 4303 ft to 4381 ft. Circulated and surveyed at 4370 ft, 2°. Wiped the hole to 3994 ft, and tripped in to 4381 ft, no fill. Drilled from 4381 ft to 4497 ft.

11/26/10 Drilled from 4497 ft to 4508 ft. Circulated and surveyed at 4495 ft, 1-1/2°. Wiped new hole to 4118 ft, and tripped in to 4508 ft, no fill. Drilled from 4508 ft. to 4631 ft. Circulated and surveyed at 4621 ft, 2°. Spotted mud thinner on bottom. Tripped out for a BHA change. Stabilizers were 1/4-in. under gauge. Change out stabilizers, put in stabs at the bit, 45 ft up and 75 ft. above the bit. Change out the drill bit and picked up 3 more 8-in. drill collars below the drilling jars.

11/27/10 Tripped in to 2903 ft, filled drill pipe, and serviced rig. Tripped in to 4631 ft - no fill. Drilled from 4631 ft to 4760 ft with 25 to 35K weight on bit. Circulated and surveyed at 4749 ft, 2-1/2°. Wiped new hole to 4465 ft, and tripped in to 4760 ft, no fill. Drilled from 4760 ft to 4824 ft. Back weight off on bit to 20K.

11/28/10 Drilled from 4824 ft to 4884 ft. With weight on bit at 20K. Circulated and surveyed at 4873 ft, 3°. Pump omnipol pill. Tripped out, and laid down bottom stabilizer and shock tool. Tripped in to the shoe and serviced rig. Tripped on in the hole to 4669 ft and reamed to bottom (attempted to drop the inclination back from 3°). Drilled from 4886 ft to 4899 ft with 10 to 15K weight on bit.

11/29/10 Drilled from 4899 ft to 4919 ft with weight on bit at 20K. Serviced rig and equipment. Pulled to the shoe for rig repairs - worked on rotary table rotary seal. Decided to trip out and changed BHA, tripped out, changed bit, picked up new shock tool, and stabilizer above the bit. Tripped in the hole, and tagged at 4888 ft. Washed and reamed to 4917 ft. Rotary table rotary seal went out again, pulled to the shoe, made repairs, and tripped back in the hole to 4919 ft. Drilled from 4919 ft to 4947 ft with 10 to 30K weight on bit.

11/30/10 Drilled from 4947 ft to 5011 ft. Circulated and surveyed at 5001 ft, 2-1/4°. Wiped new hole. Drilled from 5011 ft to 5143 ft.

12/1/10 Drilled from 5143 ft to 5286 ft. Circulated and surveyed at 5252 ft, 3.75°. Pulled up in to 13-3/8-in. shoe so GeoDrill can repair EDDY electric brake(hydromatic) it has to be sent to Bakersfield for repair.

12/2/10 EDDY electric brake has to be sent to Bakersfield for repair. Circulated one pump at 40 spm. Waited on brake to be repaired and returned.

12/3/10 Circulated one pump at 40 spm. Waited on brake to be repaired and returned. Brake on location at 1700 Hrs. Installed brake and tested brake. Brake good. Slipped and cut drilling line. Did 500 hour service on motors.

12/4/10 RIH. Stopped every 500 ft and circulated. Drilled from 5286 ft to 5369 ft with weight on bit at 20K. Pump pressure kept falling off, checked pumps, pumps good. Pulled to the shoe and checked drill pipe for wash out. Found wash out at 463 ft. Laid down 2 joints. Kellied up and tested drill string. Pump pressure good, picked up 2 new joints. RIH and drilled from 5369 ft to 5409 ft.

12/5/10 Drilled from 5409 ft to 5419 ft. Surveyed at 5408 ft 3-1/2 degrees. Drilled from 5419 ft to 5543 ft. Surveyed at 5533 ft 4-1/2 degrees. Wiper new hole, no fill. Drilled 50 ft more and surveyed again. Drilled from 5543 ft to 5553 ft.

12/6/10 Drilled from 5553 ft to 5599 ft. Surveyed at 5593 ft (4 degrees). POH looking for a wash out and checked bit. Wash out at 4831 ft and laid down 2 joints of drill pipe. Picked up 2 new joints. Found 1 collar with a dad face and 1 with pulled threads. Laid down and checked all collars all 10 collars have bad threads, 1 stabilizer had a face, laid BHA down. Geodrill doesn't have any more 8-in. collars, called Weatherford for eight 8-in. collars. Made up BHA.

12/7/10 Made up BHA. RIH, and drill from 5599 ft to 5658 ft. POH looking for a wash out. Wash out at 626 ft. Laid down bad joint and replaced. Drilled for 5658 ft to 5715 ft. Surveyed at 5704 ft (4 degrees). Drilled from 5715 ft to 5739 ft, lost pump pressure do to wash out. POH and laid down drill pipe.

12/8/10 Held safety meeting, laid down est. 119 joints of drill pipe and 8-in drill collars. Changed out near bit stabilizer, string stabilizer, and shock tool. Picked up drill pipe to 2964 ft, and circulated to cool the well. Picked up drill pipe to 4407 ft. Circulated, 118 strokes = 1330 psi. Tripped in to 4850 ft, pump pressure 1380 psi. Tripped in to 5316 ft, pump pressure 1440 psi. Tripped in to 5722 ft, pump pressure 1490 psi. Reamed from 5722 ft to 5739 ft. Drilled from 5739 ft to 5744 ft.

12/9/10 Drilled from 5744 ft to 5827 ft. Circulated and run survey, parted survey line while going in hole with survey tool. Tripped out of the hole to the heavy weight drill pipe and retrieve survey tool - no survey. Trip in the hole to the shoe and changed out the survey line. Circulated to cool the well. Tripped in the hole to 5827 ft, circulated to cool the well and run survey. Surveyed at 5817 ft, 4.1°, and 347.65 azimuth. Drilled from 5827 ft to 5846 ft.

12/10/10 Drilled from 5846 ft to 5953 ft. Circulated and ran survey at 5942 ft, 4.2°, and 11.55 azimuth. Wiped new hole. Drilled from 5942 ft to 5993 ft.

12/11/10 Drilled from 5993 ft to 6102 ft. Lost 500 psi pump pressure and 40K weight. Trip out, recovered 2-in. of the top of the fifth 6-in. drill collar. There is 298 ft of the BHA left in the hole. Top of the fish is at 5813 ft. Fishing tools coming from Baker Oil Tools. Picked up twelve 8-in. drill collars for the fishing string.

12/12/10 Picked up twelve 8-in. drill collars for the fishing string. Slipped and cut drilling line. Made up fishing tools, check connections on the 6-in. drill collars and tripped in the hole to 5788 ft. Circulated to cool the well. Worked the over shot down over the fish, picked up, gained 40K string weight. Tripped out with the fish, laid down the fishing tools, damaged 6-in drill collar, six damaged 8-in. drill collars and shock tool. Made up new BHA with a new bit and stabs. Service rig, ran in the hole, filled the pipe at 1633 ft and trip in the hole to the shoe.

12/13/10 Tripped in the hole to 5810 ft. Safety reamed to 6102 ft. Drill from 6102 ft to 6104 ft, circulated and surveyed at 6092 ft, 4.8°, 11.25 AZ. Drilled from 6104 ft to 6118 ft. Lost 250 psi pump pressure, pumped some soft rope and tripped out looking for wash out. Did not find a wash out, go through the mud pumps, changed out 2 valves and seats and serviced rig. Checked rotary tong torque indicator against a Weatherford torque indicator, considerable difference, 25K foot pounds. Installed new torque indicator that GeoDrill had on hand. Serviced all BHA connections and tripped in to the shoe, filled pipe, tripped in to 4557 ft, filled pipe, tripped on in to 6118 ft. Drilled from 6118 ft to 6130 ft.

12/14/10 Drilled from 6133 ft to 6156 ft. Changed out swivel wash pipe. Drilled from 6156 ft to 6309ft.

12/15/10 Drilled from 6309 ft to **TD 6375 ft.** Circulated and conditioned mud for logs. Tripped out of the hole, and laid down stabs and monel drill collar. Rig up Schlumberger and run Platform Express, Array Induction, Gamma Ray - SP - Caliper and Sonic Scanner, Gamma Ray - Caliper logs.

12/15/10 Drilled from 6309 ft to **TD 6375 ft.** Circulated and conditioned mud for logs. Tripped out of the hole, and laid down stabs and monel drill collar. Rig up

Schlumberger and run Platform Express, Array Induction, Gamma Ray - SP - Caliper and Sonic Scanner, Gamma Ray - Caliper logs.

12/16/10 Finished running Platform Express, Array Induction, Gamma Ray - SP - Caliper and Sonic Scanner, Gamma Ray - Caliper logs. Made up a reduced BHA and tripped in the hole to the shoe. Performed open hole injection test, 1.5 bpm at 600 psi. Cleaned mud tanks and mixed 3% KCL change over fluid. Tripped in the hole to TD. Pumped 100 bbls fresh water and 560 bbls 3% KCL. Pulled to the shoe and pumped another 440 bbls 3% KCL. Rigged up Weatherford lay down machine. Laid down an estimated 2000 ft of the drill string.

12/17/10 Laid down drill string and rigged down the lay down machine. **Nipple down the BOPE** and nipple up a 12-in. X 400 master valve. Cleaned mud tanks.

12/18/10 Rigged Down.

DHISERVICES
Formation Evaluation Specialists

dhiservices.com

SCALE: 1:600

LOG INTERVAL

DEPTHS:	380'	TO	6375'
DATES:	10/25/10	TO	12/15/2010

MUD TYPES

Gel/Water	TO	6375'
	TO	
	TO	
	TO	
	TO	

CASING DATA

30"	TO	95'
20"	TO	505'
13.375"	TO	3154'
	TO	
	TO	

HOLE DATA

36"	TO	100'
26"	TO	512'
17.5"	TO	3165'
12.25"	TO	6375'
	TO	

ABBREVIATIONS

NB	New Bit	LAT	Lagged After Trip
RRB	Re Run Bit	LAS	Lagged After Survey
CB	Core Bit	NR	No Returns
Cnxn	Connection	PR	Poor Returns
CG	Cnxn Gas	LC	Lost Circulation
TG	Trip Gas	CO	Circulate Out
SG	Survey Gas	SVY	Survey
SWG	Swab Gas	AZI	Azimuth
WOB	Weight On Bit	Inc	Inclination
RPM	Rotary RPM	CSG	Casing
PP	Pump Pressure		
SPM	Strokes/Min.		
MW	Mud Weight		
VIS	Funnel Viscosity		
PV	Plastic Viscosity		
YP	Yield Point		
FL	Fluid Loss		
Cl	ppm Chloride Ion		
SOL%	Solids %		
SD%	Sand %		
MB	Methylene Blue		
Ca	ppm Calcium		
FC	Filter Cake thick		
Rm	Mud Resistivity		
Rmf	Filtrate Resistivity		

MUDLOG

COMPANY:	ORMAT NAVADA INC.
WELL:	Wister 12-27
FIELD:	Wister
REGION:	Niland, CA
COUNTRY:	USA
COORDINATES:	~700' S and 150' E of NW Section 27-T10S-R14E SBB&M
ELEVATION:	-15' MSL
API Index:	
Spud Date:	10/25/10
Total Depth:	6375
Contractor:	GeoDrill
Rig/Type:	Rotary Triple
Logging Unit:	Unit 6
EDR:	DrillSense
Company Rep:	Bob Mueller
	Tom Turner/Joe Bunce
Engineers:	Tim Jayne
	Terry Crowson
Loggers:	Jonathan Harris/Yosief Segid
	Jack Breland/Simret Zerezghi

SYMBOLS

Casing Shoe
Bit Trip
Wiper Trip
Gas Show Good
Gas Show Fair
Gas Show Poor
Sidewall Core Recovered
Sidewall Core Unrecovered
Wireline
Oil Show Good
Oil Show Fair
Oil Show Poor
Core Rec.
Core Unrec.
DEV Survey
Connection Gas

Shows
None
Weak
Moderate
Strong

LITHOLOGY

No Sample
Cement
Aluvium / Conglomerate
Sand
Siltstone
Claystone
Shale
Limestone
Dolomite
Coal
Quartzite
Chert
Anhydrite
Mudstone
Volcanics
Basalt
Igneous (Extrusive)
Igneous (Intrusive)
Tuff
Metamorphics

MODIFIERS

Calcareous
Dolomitic
Limestone Stringer
Dolomite Stringer
Sandy
Argillaceous
Coal
Pyritic
Silicic
Fossils
Porphyritic
Euhedral Crystals
Fractures
Epidote
Mica
Chlorite
Anhydrite
Fe-Ti Oxides

Penetration	M. Depth	Hole Size	Sec Mnrls	Gamma Ray	Percent Lithology	Resistivity	Porosity	Gas	Lithology Remarks
ROP 150 FT/HR 0; WOB 0 KLBS 30		HCAL 10 IN 25; BIT SIZE 10 25		Gamma-Ray 30 GAPI 140; SP -50 MV 20		AT10 0.1 OHMM 10; AT30 0.1 OHMM 10; AT90 0.1 OHMM 10; True Resistivity 0.1 OHMM 10	DPHZ 0.7 CFCF 0; Neutron Porosity 0.7 CFCF 0	CO2 0 % 2; TOTALGAS 0 UNITS 2; H2S 0 PPM 2	

10/26/2010

NB #1; 26 in., 3x18 ; Serial:B884444

300

QUARTZ CALCITE PYRITE EPIDOTE CHLORITE

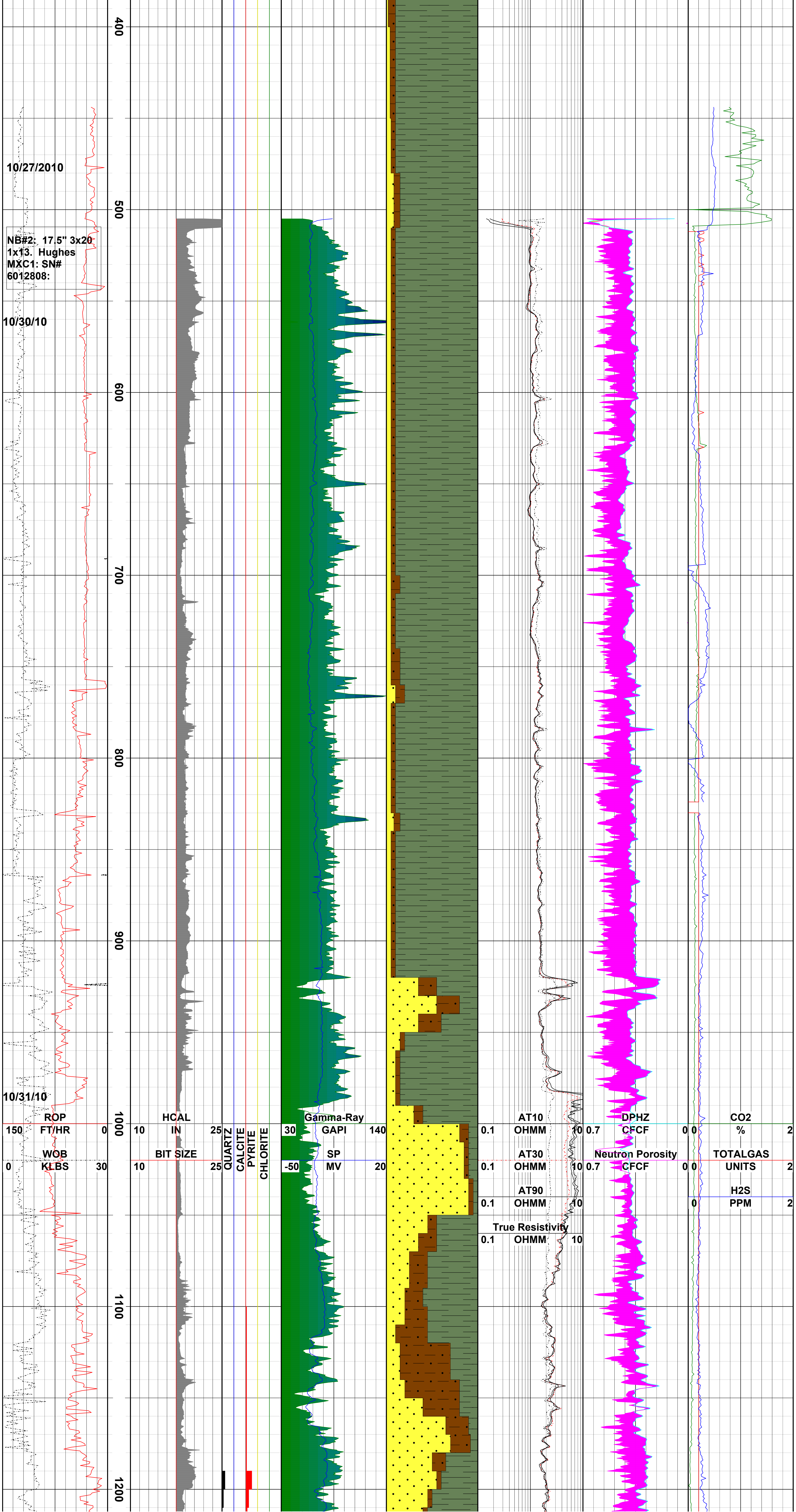
All depths driller's depths measured from kelly bushing.

All lithology descriptions from wet cuttings unless noted.

All gas calibrated to SPWLA standards.

Started collecting 10 foot samples at the depth of 380 ft.

Claystone: yellowish brown, large



chunky to blocky cuttings, soft, gummy texture, sticking to shale screens, highy calcareous, traces of yellowish brown silty sand imbedded in clay cuttings.

Claystone: yellowish brown, light olive grey, chunky to blocky, gummy texture, sticking to shale screens, highy calcareous, tr of yellowish brown silty sand imbedded in clay cuttings.

Set 20 inch diameter Surface Casing @ approx 505 ft. N/U BOP, Pressure Test, RIH drill out shoe.

Claystone: light olive grey, tr yellowish brown, chunky to blocky, gummy texture, sticking to shale screens, highy calcareous, tr of yellowish brown silty sand imbedded in clay cuttings.

Claystone: yellowish brown, chunky to blocky, gummy texture, sticking to shale screens, highy calcareous, tr of yellowish brown silty sand imbedded in clay cuttings.

Clay: reddish brn to tan gy. Lrg blcky ctgs, mod firm but pliable. sticky to earthy tex, calc. abundant anhydrite nodules. sli sandy in places. backing up on shakers

Note: Drill t/757'. Circ and survey. POOH for new BHA (RRB#2)

Clay: tan/brn to olive gy. firm plas ctgs, sticky text. anhydrite nodules, calc.

Clay: reddish brn to tan gy. Lrg blcky ctgs, mod firm but pliable. sticky to earthy tex, calc. sli sandy in places. backing up on shakers

Sandstone, dk grey, brown, fine grained, very hard, ferriferous, well cemented, interbedded off white soft silt layers, minor soft cohesive clay.

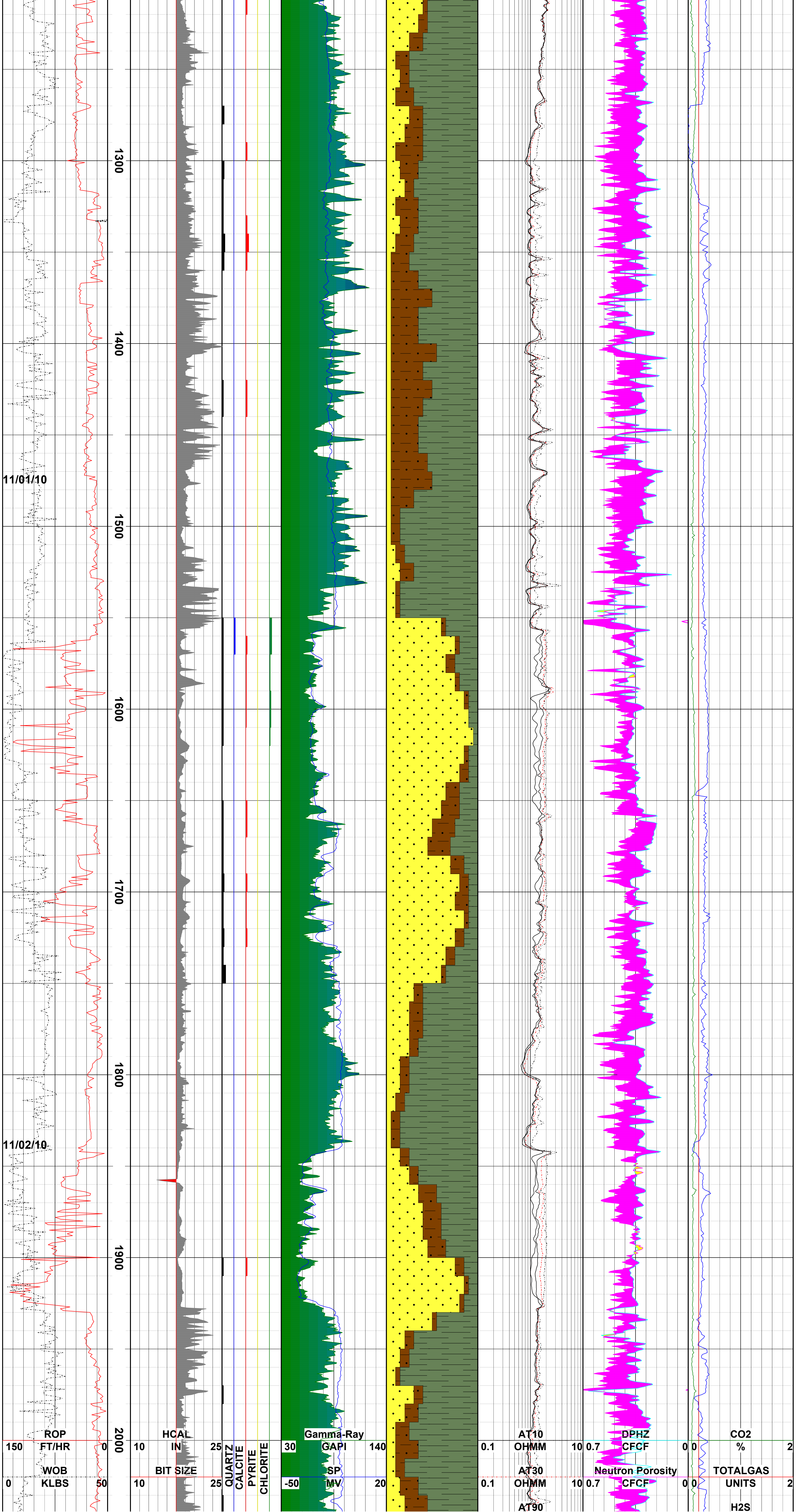
Clay: tan/brn to olive gy. firm plas ctgs, sticky text. anhydrite nodules, calc.

Sand: light grey to med grey, fine to coarse grained, sb ang to sb round, unconsolidated, poorly to moderately sorted,

Clay: light olive grey, tr yellowish brown, chunky to blocky, gummy texture, sticking to shale screens, highy calcareous, tr of yellowish brown silty sand imbedded in clay cuttings.

Silt: off white to very light grey, soft, slightly cons, sucrosic tex., calcareous, interbedded in clay and sand layers as above.

Sandstone: pl brn to predom lt-med gray, mod hard to hard, calcitic, fine to crs grn, overall well sorted, low sphericity, sli subrnd to



most subang.

Note: Drill to 1239'. Circ, Wipe hole to shoe.

Clay: predom lt olive gry to lt gry, punky to mushy to clumpy, occ gelat, loc malleable, erthy fract, nod ctgs habit, dull erthy luster, sli gritty clayey text, occ banded to predom soft sed struct.

CLT: tan gy to reddish brn. blocky to flaky ctgs hbt, mod firm to firm, earthy lust, easily scored. calc. occ. anhydrite w/ loc. dolostone stringers. scat. qtz and pyrite xtls.

Silt: off white to very light grey, soft, slightly cons to lsly cons, sucrosic tex., calcareous, interbedded in clay and sand layers as above.

Clay: light olive grey, reddish brown, tr yellowish brown, flaky, platy to blocky, gummy texture, sticking to shale screens, highy calcareous, tr of yellowish brown silty sand, layered and imbedded in clay cuttings.

Sand: overall gy. unconsol. w/ weak clay matrix suprt. f grn, sub rnd to rnd. well srt. predom frosted qtz. access. calcite, fldsp, micas. loc chlorite, pyrite.

Sand: overall lt gy to gy. unconsol w/ occ. clay matrix suprt. vf grn, well srt. predom qtz w/ plag fldsp, mica. com carbonaceous frags.

Note: Drill t/1648'. Circ and survey, Wipe hole to shoe.

Claystone: lt gry to med drk gry to loc redish hues, sli mshy to clmpy to loc mod stiff consis, eas crmbl to occ sli crnchy, planar to irreg frac, globular to massive to loc plty ctgs, dull erthy to sli grsy lstr, smooth clayey to vry sli gritty text, scat thin lam to massive struct.

Sand: gy. predom. uncosol (weak clay suprt) w/ occ SST pieces. vf to f grn, subrnd to rnd, mod well to well srt. dom frosted qtz w/ fldsp, mica. sme scndry minrlztn (qtz, pyr). occ dolostone stringers.

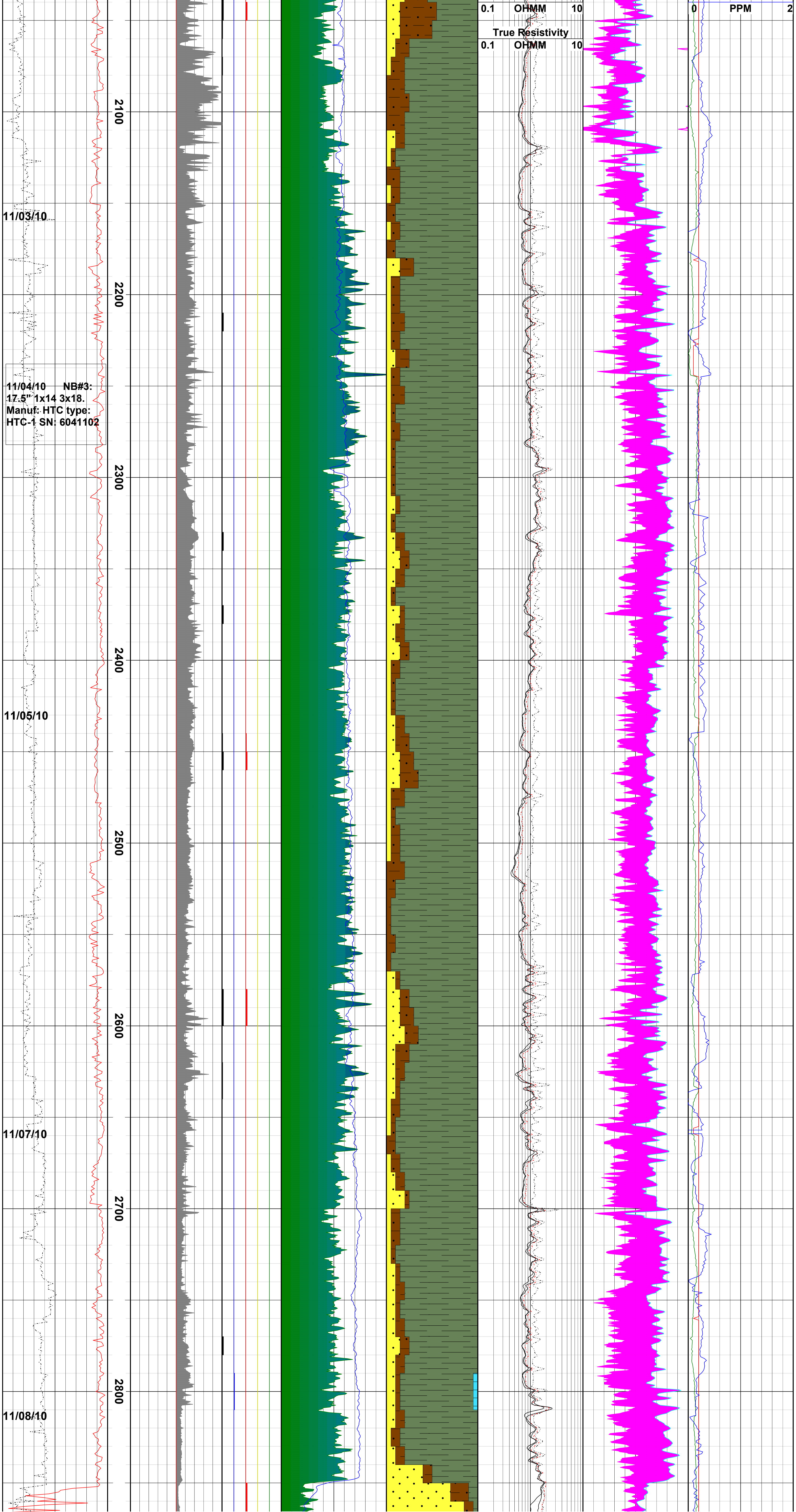
Clay: light olive grey, flaky, platy to blocky, gummy texture, sticking to shale screens, highy calcareous, tr of yellowish brown silty sand, layered and imbedded in clay cuttings.

Sand: gy. predom. uncosol occ SST pieces. vf to f grn, subrnd to rnd, mod well to well srt. dom frosted qtz w/ fldsp, mica. sme scndry minrlztn (qtz, pyr).

Clay: lt gray to med gray. occ platy, soft, slightly crumbly. smooth sli gritty texture. mostly massive/globular ctgs, good cohesion, weak-mod adhesion. dull earthy luster. soluble.

Note: Drill t/2056'. Wipe hole to shoe.

Siltstone: med gray. faint dark



flecks. easily friable to firm/friable. equant to wedgelike ctgs habit. sli vitreous luster. silty/gritty text, occ laminae to massive struct. mod calc.

Clay: lt gray to med gray. occ platy, soft, slightly crumbly. smooth sli gritty texture. mostly massive/globular ctgs, good cohesion, weak-mod adhesion. dull earthy luster. soluble.

Clay: light olive grey, mod sft to firm, flaky, platy to blocky, gummy texture, highy calcareous, tr of yellowish brown, hd, sandstone, layered and imbedded in clay cuttings.

Claystone: med/dk gy to red/brn. firm to mod hd. massive to platy ctgs. smooth to sli waxy text, easily scored. occ laminae vis. calc.

Note: Drill t/2244'. POOH. Change bit (NB#3).

Claystone: med/dk gy to red/brn. firm to mod hd. massive to platy ctgs. smooth to sli waxy text, easily scored. occ laminae vis. calc.

Siltstone: med lt gry to drk gry to loc dsky red to mod redsh brn, scat fnt blk inclusions, fria to frm friable. nodular to wedgelike ctgs habit. sli sprklg earthy luster. silty/gritty text, ovrall massive struct. sli to mod calc.

Sandstone: vry lt gry to med gry to occ lt red, vry fn to fn to trace med grn, ovrall well srtd, sli subang to subrnd'd angulrty, mod sphrticty, occ sli frsted, friable to mod hard, vry sli calcitic cement matrix.

Note: Drill t/2431', wipe hole to shoe.

Clay: lt gry to med gry to dsky red, mushy to pasty/tacky to loc sctile, soft to occ slightly crmbly, smooth sli grtty text, massive to globular ctgs, ovrall gd cohsn/adhsn, dull erthy lster, massive to scat vry thin lam strct, mod calc.

Claystone: med gry to occ. gry/brn. firm, mod well indurated. blocky to platy ctgs. smooth to sli gritty text, easily scored. overall massive struct. w/ loc laminae vis. mod calc.

Clay: lt gry w/ greenish hues.mushy to tacky. massive ctgs habit. dull earthy luster.smooth text, good choesion mod/good adhesion, weak to mod calc.

Note: Drill to 2659'. Circ. POOH to inspect bit. (RRB#3)

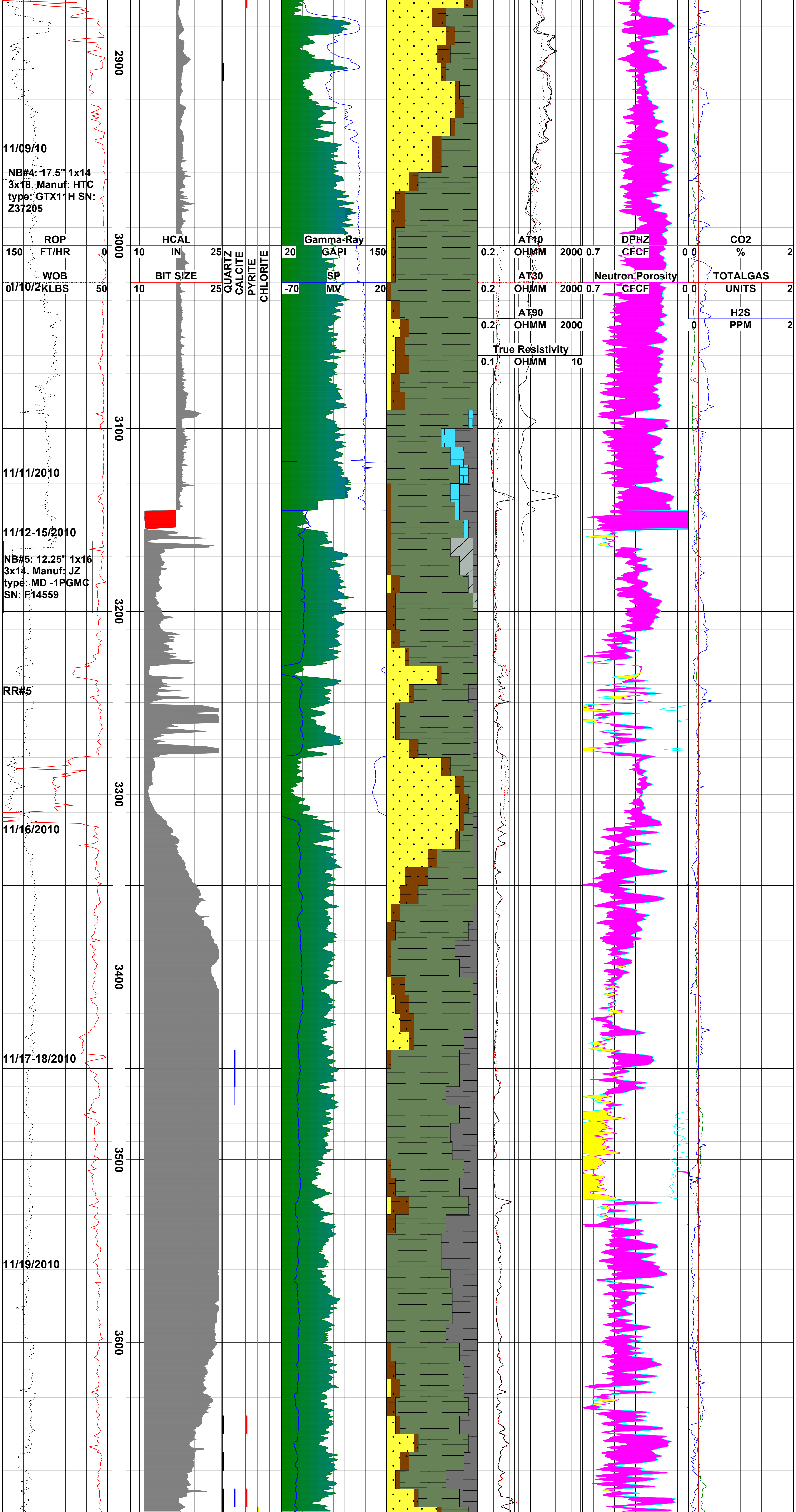
Claystone: med/dk gy to red/brn. firm to mod hd. tabular to platy ctgs. smooth to loc. gritty text,. overall massive structure with occ. laminae vis. mod calc.

Sandstone: lt to med gy w/scat greenish hues. vf to f grn, v well sorted, rounded grs. irregular nodular ctgs, friable to firm/friable. earthy/sli sprklng luster, gritty text predom qtz. weak to loc. mod calc.

Note: Drill to 2813'. Circ. POOH to inspect bit. (RRB#3)

Sand: wht to vry lt gry, indiv grains are clear to transl to mlky wht, vry fn to fn to loc crs, well to vry well srtd, subang to subrnd ang, low sheric, frosted to sli polished, predom grn support, unsol at surf, tr pyrite, sli to loc mod calc.

Sandstone: lt gry to med gy to pale



Sandstone: lt gry to med gy to pale rddish brn. fri to mod hd. med to crse grn. mod to well srt, rnd to sbang, low spher. crumbly to brittle. tabular to nodular ctgs habit. frsted to mod sparkling luster. gritty to sucrosic text. massive structure. fair to loc mod calc. cmnt. com mafic lithic frags.

Note: Drill to 2964'. Circ. POOH to change bit. (NB#4)

Claystone/ Marl: lt gry to med gray, occ red brn; dom v well hydrated, over all clumpy to sticky; occ firm to mod hard tabular to platy ctgs; smooth w/minor gritty text; weak to faint laminated; increased amount of calcareous to marly layers F/ 3010 to 3020'

POOH @ 3020' for stab. RRB#4

Claystone/Shale: gry to med gry; fine smooth tex; occ laminated; over all mod hydrated, occ firm ctgs; similar to above units; highly calcareous to marly.

Wipe hole 5 Stands @ 3132'

Claystone/shale: f/ 3140' to 3165', dom brn reddish w/ minor med gry; fine smooth tex; big ctgs firm to hard; dom hydrated to soft clay; mod calc

Drill to 3165'; Wipe hole to shoe; RIH and circ b/u, POOH for E-Log. Set 13 3/8" casing @ 3154'. Cement. N/U BOP. Pressure test. Drill out shoe, drill ahead.

Claystone: med gry to occ. gry/brn, mod well indurated. blocky to platy ctgs. smooth to sli gritty text, easily scored. overall massive struct. w/ occ. loc. fissility. mod calc.

Note: Drill t/3246'. POOH, change BHA (RRB#5)

Sandstone: med gry to white; upper med to fine grained; mod well sorted and rounded; dom consolidated, easily friable w/occ firm carbonate cemented ctgs; over all massive w/no visible bedding structure becomes thinly bedded f/3310' to 3340'; mainly comp of qtz , occ surfaces of conc black mica minerals; mixed with minor brn and drk gry claystone, similar to above units; slightly calc.

Claystone/shale: med to drk gry, minor reddish brn; vfn smooth tex; appears thickly bedded with occ visible pronounced fissilty; slightly to mod calc.

Note: Drill t/3442'. pulled to shoe for rig power repair.

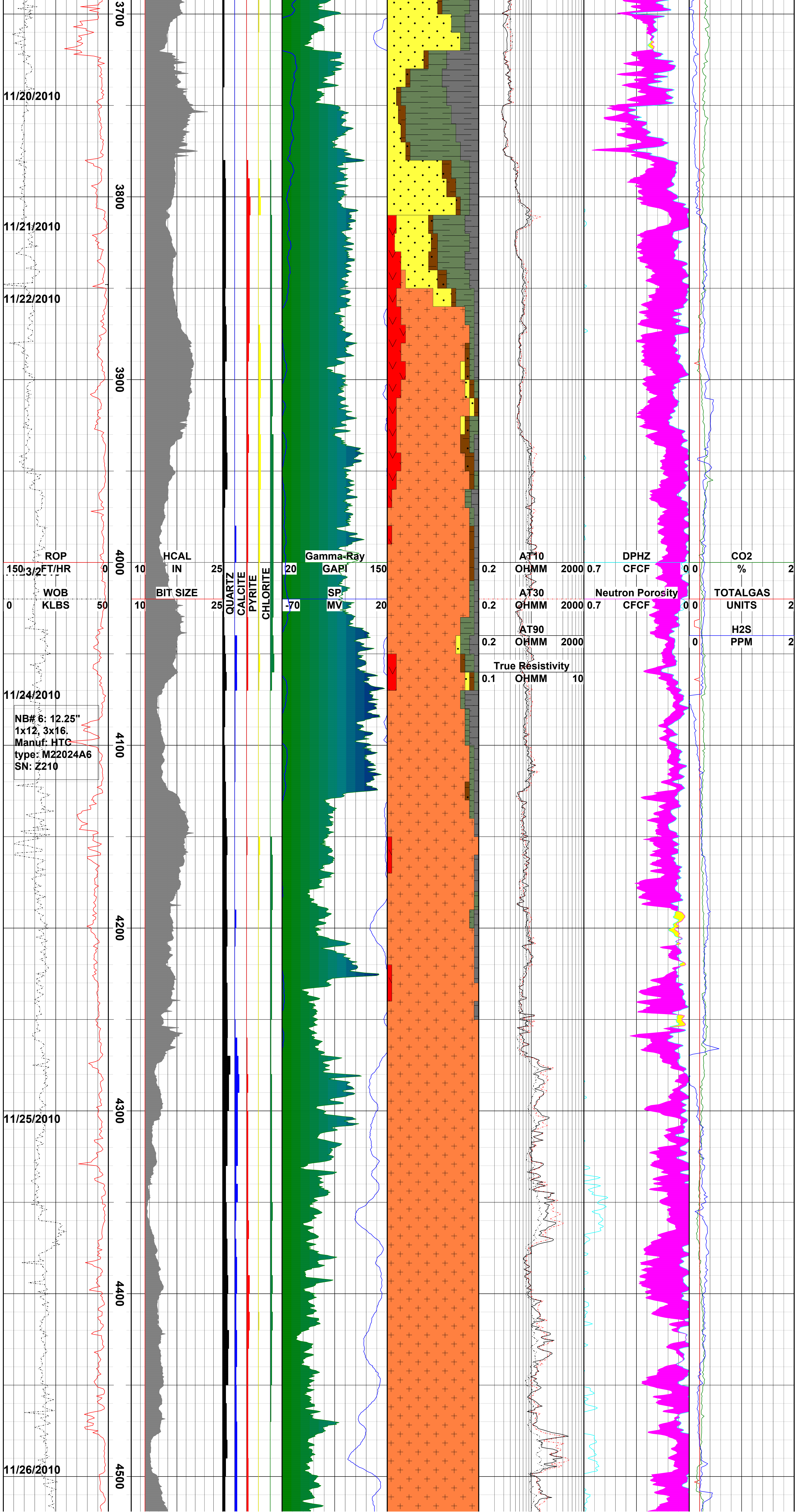
Claystone/Shale: med to drk gry, minor reddish to brwn ctgs; vfn smooth tex; firm to mod hard; occ show grading in color and tex; appears dom thinly to thickly bedded, w/com fissile thin platy ctgs; minor calcite crystal @ 3460'; overall slightly calc.

Note: Drill t/3536'. Circ and survey. POOH to change BHA (RRB#5).

Claystone/Shale: med to drk gry, similar to above units; vfn smooth tex; firm to mod hard; dom platy ctgs; thickly to thinly bedded with/com in bed lamination defined by color/ composition variation; no vis mineralization/alteration; over all slightly calc.

Note: wipe hole to shoe@ 3603'.

Sandstone: lt gy to grysh ornge pink to loc. pale red, rare greenish hues. mod hd to occ friable. vf to low f grn, sbrnd to rnd, mod well srt. predom qtz w/ access calcite, fldsp, lithic frags. mod calc cmnt. overall massive structure. loc



overall massive structure. loc. xtalline qtz/pyr aggs.

Note: wipe hole to shoe @ 3722'

Claystone/Shale: med to drk gry; occ lt gry, similar to above units; vfn smooth tex; firm to mod hard; dom pebble size platy ctgs; over all thinly bedded with/com in bed lamin.

Sandstone: med gy to gryish orng pink. bleached apprnce when dry. overall mottled apprnce. mod hd to v hd. signific. appar. alteration. grain structure occ. not obvious. com qtz, pyrite xtals, some epidote. low to non calc.

Note; Pulled to shoe @ 3815' to replace Motor.

Granitoid: slightly Altered, variegated colored; white, pink, lt greenish to slightly lt reddish; over all crystalline; intermidate grained, appears intrusive; mainly compo of feldspars; mixed w/minor porphyry dacitic ctgs, w/com elongated to rectangular plagioclase incrusted in fine ground mass; very hard to hard; occ slightly chloritized, with abundant microcrystalline pyrite.

Volcanics: porphyritic dacite/rhyolite. varieg color f/ dk brnsh rd t/ gy to grn. hd to vhd ctgs. porphyritic text, lath shaped feldsp. phenocrysts in aphanitic to vf xtalline groundmass. loc chloritization, scat pyrite xtals.

Granitoid: lt greenish to lt pink; com white patches; med grained; predom crystalline w/occ porphyritic tex; comp of feldspars, qtz and minor mafic minerals; disseminated pyrite minerals throughtout, minor reddish oxidized spots; over chloritized; minor thin calcite veins; weak to non calc.

Note: Wipe hole to shoe @ 4035'

Granitoid:as above, with loc. mineralized striations, com calcite xtals. apparent alteration to clay in places

Note: Drill t/ 4072. circ. POOH for bit (NB#6)

Granitoid: predom white to lt mint green, com pink shades; med to fine crystalline tex; comp of feldspars and qtz; increased amount of pinkish feldspars from above unit; over all appears fractured filled with oxidized reddish mineral precipitates, @ 4140' fractures filled w/quartz , trc to non pyritic; show slight variation in comp/color with depth; weak to non calc

Granitoid: similar to above units. lt grn to whitish, com pinkinsh. loc grysh red. fine to med xtalline, phaneritic text loc. discernable. dom small ctgs. predom qtz, feldsp, minor mafics, occ mica. scat pyr. com chloritized. some fractures/ minrlzd (qtz) veining vis.

Note: drill t/4224'. WIpe hole (pull 2 stands).

Granitoid: predom. wh to v pa grn. loc dk grn. v small pulvrzd ctgs. larger ctgs show f to med phaneritic text, composed qtz, fldps, minor mafics.

Note: Drill t/ 4268'. Pull to shoe to replace kelly hose

Granitoid: over all pale green to white, com peppered white and deep green; med to fine crystalline tex; comp of qtz, feldspars and mafic minerals; F/4290' to 4350' increased amnt of deep green mafic minerals; abnd qtz and calcite crystals/veins; minor microcrystaline pyrite, slightly chloritized; occ appears sheared with reduced grain size; show slight variation in comp/color with depth; weak to non calc

Note: Drill t/ 4381'. Wipe hole (pull 3 stands).

Granodiorite: darker than above units, dusky grn to gryish olive grn, loc light gry. hd to v hd. microxtalline to med xtalline. phaneritic text. dom feldsp, qtz, signif mafics inc. hornblnd. scat mica. com. fracs. and minrlzd vng (qtz, calcite fill). pervasive microxtalline pyr. loc red/brn oxidizd precipitates. mod to loc. significant chloritization.

Diorite: similar to above units; coarse to med grained; drk green, black peppered by dusky white; vhard to hard; mafic rich; comp of pyroxenes, amphiboles, plagioclase; minor qtz; com euhedral to microxlline pyrite, calcite crystals; gradually with depth becoming mafic rich in composition (f/4480'-4520'); thin fractures filled by calcite, qtz veins; over all mod to weak calc

Note: wipe hole @ 4506'; 4 stands.

Granodiorite: gryish olive grn to lt grnsh gry, loc v pa gry. hd to v hd. blocky irregular ctgs. med xtalline, phaneritic text. dom feldsp, qtz, com mafics (pyrx, amphiboles). com minrlzd striations and minrlzd veining (qtz, calcite), com microxtalline pyr dissem. through ctgs. rare red/brn precipitates on fracture surfaces.

Note: Drill t/ 4631'. Circ and survey. POOH to inspect bit and change BHA. Change bit (NB#7)

Granitoid: over all light colored, white to lt pink peppered with minor lt greenish; med to coarse grained; crystalline tex; mainly compo of qtz, feldspars, minor mafic minerals; becoming more felsic than above ctgs; very hard to hard; minor microcrystalline pyrite, calcite crystals; fractures filled with reddish brn precipitates; mod calc.

Granitoid: lt grnsh gry to v pa gy. hd. f to med xtalline. overall irregular ctgs, w/ an increase of v small pulverized ctgs f/4730', resembling coarse sand. predom qtz, fdlsp, mod mafic component, scat micas., rare loc pyr. com fractures and veining. rare loc. alteration to v. pa grn clay.

Note: Drill t/ 4760'. Wipe hole (pull 2 stands).

Granitoid : f/ 4800' to 4870' mix of drk, lt greenish and white ctgs; vhard; fn to med grained; becoming darker w/depth, abundant amphiboles w/ cleavage surfaces vis., qtz, epidote, minor feldspars, and trc micas; minor ctgs slightly altered/ sheared w/aligned minerals under microscope, disseminated pyrite xtals throughout, com calcite crystals; slightly chloritized; pulverized ctgs w/slickenside; slightly calc.

Note: Drill t/4884'. Circ and survey. POOH to change BHA. RRB#7.

Note: Drill t/4919'. POOH for new bit and BHA. (NB#8)

Granitoid: similar to above unit w/com chloritized ctgs; mix of drk, lt greenish and white ctgs; v hard; fn to med grained; abundant amphiboles, qtz, slight incr in plagioclase, epidote, minor localized biotites; disseminated euhedral pyrite throughout, minor calcite crystals; minor pulverized ctgs w/slickenside, thin fractures filled with reddish and white precipitates; slightly to mod calc.

Granitoid: overall olive gry to dusky grn, loc med gy. v hd. small, occ pulverized ctgs. med xtalline, phaneritic text. composed fldsp, some qtz, mafics include pyrxn, amphib. occ micas. mineral comp occ grading to more dioritic, w/ more abundant mafic component. com epidote and chloritization. scat minrlzd fracs and veining w/ qtz and occ. calcite fill. com dissem pyr cubes.

Silicified Rhyolite: f/ 5090' to 5120'; dusky white; felsic, aphanitic xtalline rock; smooth, v hard, irrg angular ctgs; com of dom microcrystalline qtz, plagioclase; appears silicified; with no visible mafic minerals; minor euhedral pyrite crystals, calcite crystals; fractured filled with calcite precipitate; probably a rhyolite dike/silicified tonalite; weak to non calc

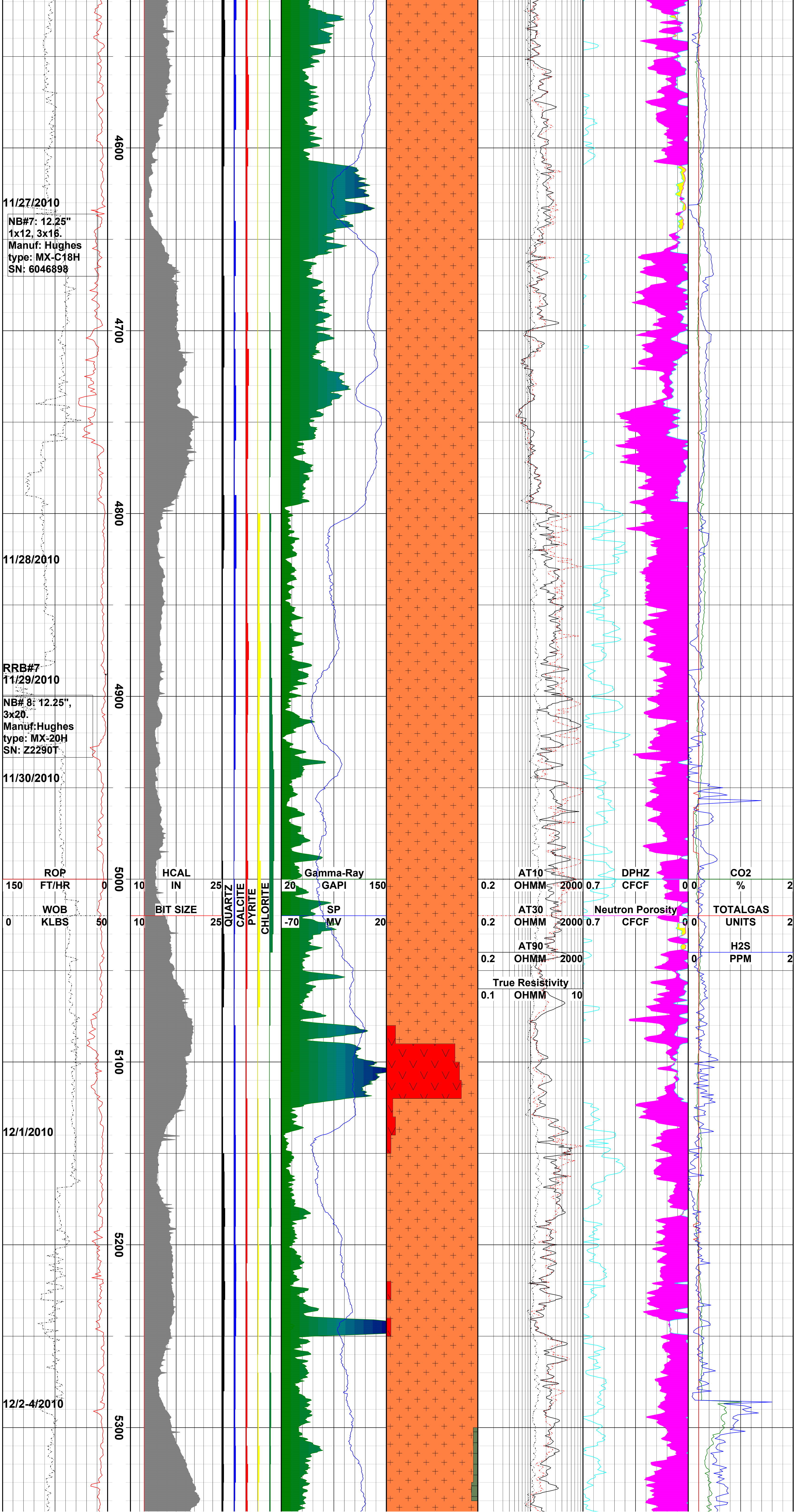
Note: Wipe hole @ 5168' to 5001'.

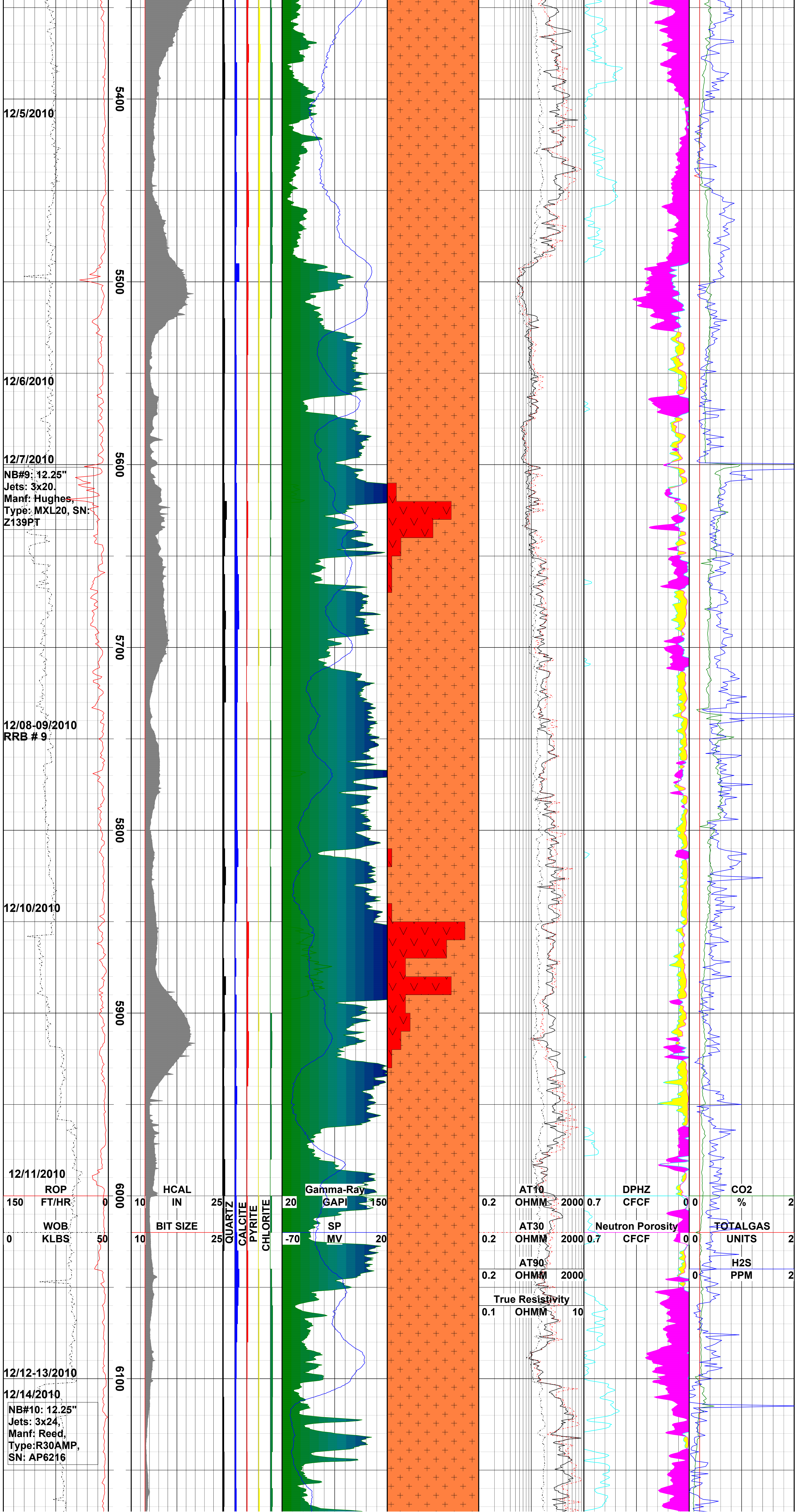
Granitoid: over med gy to olive gy colored, com dusky white peppered by drk greenish; med to fn grained xtalline rock; v hard to hard; dom comp of qtz, feldspars and mafic minerals; occ appears silicified; occ epidotized and chloritized ctgs; com calcite, pyrite and qtz crystals; mod calc. com. minrlzd slickensides/fracs.

Granitoid: predom med gy to lt mint green, loc grdng to dusky grn. v hard. med to fine crystalline tex, comp of feldspars and qtz; minor mafic component (mafic component inc. pyx, amphbole, scat mica). minor fractures filled w/quartz ,dissem pyr. loc chloritization.

Note:Pulled to shoe @ 5286' for Rig repair.

Granitoid: med gy to olive gy, loc grdng to drk green. hd. med xtalline. predom. feldsp, qtz with minor mafics. com to abundant micas and dissem pyr. occ. minrlzd fracs (milky qtz, some calcite). scat claystone ctgs (mod brn





scat claystone ctgs (mod brn, indurated, waxy text. loc grdg to siltstone).

Note: Drill t/5370'. Pull to 4906'. L/D washed out drillpipe.

Granitoid: It to med dark greenish peppered w/white; med to occ coarse grained; hard; comp of qtz, feldspars, amphiboles, brn biotite; occ chloritized and epidotized ctgs; @ 5400' minor sheared ctgs w/faint foliation surfaces; euhedral pyrite, calcite; minor pulverized with slickenside ctgs; shows minor change in comp and color with depth.

Granitoid (Granodiorite): overall olive gry to dusky grn. v hd. small, occ pulverized ctgs. med xtalline, phaneritic text. composed fldsp, some qtz, mafics inc amphib. biotite. mineral comp occ grading to more dioritic occ. gabbroic, w/ more abundant mafic component. more felsic f/4490', w/com calcite minrlztn.

Note: Wipe hole @ 5543', 2 stand.

Granitoid: F/ 5510' to 5600'; over all white w/minor lt greenish ctgs; upp med to med grained xtalline rock; dom comp of qtz, plagioclase, w/decreased biotite/mica from above units; becomes more felsic/tonalitic in comp with depth; minor pulverized w/slickenside ctgs; euhedral pyrite, calcite; greenish ctgs dom chloritzed, and epidotized; mod to weak calc

Note: Drill t/ 5599'. Circ and survey, POOH (L/D washed out DP @ 897'). Change BHA and bit (NB#9).

Silicified volcanics: lt grnsh gy to pa grnsh yel to loc light olive grn. v hd sml irreg ctgs. aphanitic to cyptocrystalline. silicified, occ intergrowth of pyr xtals on ctgs.

Note: Drill t/5658'. Pull t/ 4984'. L/D washed out drillpipe.

Altered Granitoid: f/ 5670-90'. v lt to lt gy. v hd. small irreg. ctgs. apparent silicification, along w/ abundant calcite minrlzation. difficult to make out any fabric or texture. possible vein fill. no epidote, minor chlorite specks, rare pyr.

Note: Drill t/5739', Lost pressure ~ 300 psi; POOH look for washed out DP and L/D 118 joints of DP. M/U new BHA and P/U new DP. RRB#9.

Granitoid: f/ 5700 to 5780'; dom white w/minor lt greenish shades; felsic crystalline rock; dom comp of plagioclase, qtz, v minor biotite; v few ctgs chloritized, no visible epidotization; minor yellowish to reddish iron oxidation @ 5760', prob limonite; minor pyrite crystals;com calcite crystals; minor qtz veins; weak to mod calc

Note: Drill t/5826'. attempt to run survey. cable snapped, POOH to retrieve survey tool. RIH. re-run survey

Silicified volcanics/Quartzite?: dom yellowish gry w/minor white and pale greenish varieties; dom irregular/angular ctgs. crypto to microcrystalline , smooth tex; v hard; appears silicified, micro crystals of pyrite throughout ctgs; minor calcite.

Granitoid: predom lt gy to lt grnish gry, loc grdng to dusky grn. v hard. f to med crystalline tex, comp of feldspars and qtz; minor mafic component (scat mica). minor fractures filled w/quartz, dissem pyr. loc to com. chloritization. loc minrlzd fracs and striations (calcite fill).

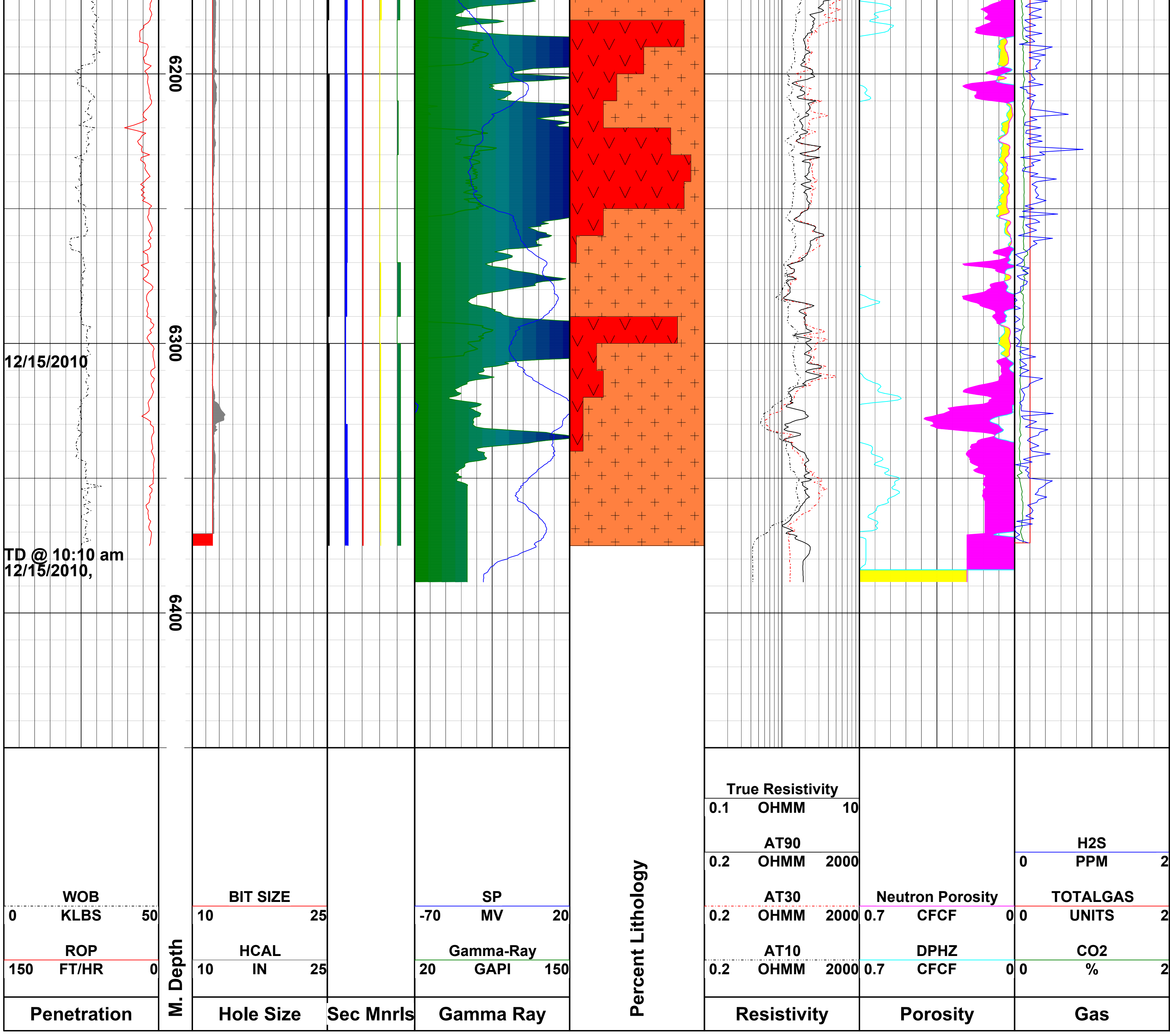
Granitoid: f/5950'-5980' intermediate intrusive rock (meta granitoid); dom comp of qtz, biotite and plagioclase; some chloritized; shows parallel alignments of mica minerals, and clear striations; weak to mod calc.

Granitoid: F/5980 to 6000' lt gry to dusky white; med grained felsic crystalline rock; hard; dom comp of plagioclase, qtz, and minor biotites; becomes intermediate to mafic intrusive F/6000' to 6020' w/ predom comp of biotite, amphibole, plagioclase and minor qtz; slightly chloritized, minor epidotized ctgs; occ shows faint foliation/ alignment of minerals; grades back to light felsic rock F/6020' to 6040', similar to above units. F/6040 to 6090', becomes more mafic rich w/increased chloritized ctgs; abandant calcite crystals throughout.

Note: Lost ~ 500 psi and 40k pounds Hook load @ 6100'; twisted off @ 5804', POOH.

Note:lost 250 psi @ 6118' POOH.

Granitoid: F/ 6100' to 6180' drk greenish to black, mixed with white ctgs; hard, intermediate intrusive, comp of biotite, amphibole, plagioclase, & qtz; moderately



Lithology Remarks

chloritized, occ faint to well developed folation surfaces; calcite crystals, minor epidote and pyrite.

Silicified Volcanics: dom yellowish gry w/minor white and pale greenish varieties; felsic, crypto to microcrystalline, smooth tex; mod hard; appears silicified w/minor porphyry muscovite, micro crystals of pyrite and calcite crystals; pulverized ctgs with slickenside; similar to upper volcanic units.

Granitoid: F/ 6260' to 6290'; lt to dark greenish to occ black, mixed with white ctgs; mod hard, intermediate crystalline rock, comp of biotite, amphibole, plagioclase, & qtz; slightly chloritized, occ faint foliation/ alignment of minerals; calcite crystals, minor epidote and pyrite.

Granitoid; pale grnish to dark intermediate intrusive; moderately to highly chloritized; comp of amphibole, feldspare, biotite and qtz; sec minls pyrite, calcite and epidote; occ fracture surfaces.

Granitoid: F/ 6350 to 6375'; similar to above units, drk greenish peppered w/white , intermediate intrusive rock with increased mafic minerals; com chloritized ctg, com calcite crystals, minor epidot, and tr of pyrite.

POOH @ 6375' for E-Log. Run E-log, conduct injection test on open hole @ 1.52 strokes/min, 600 psi; Change over, L/D DP.

DRILLING HISTORY

Geothermal Well 85-20

LOCATION: 1615 ft North and 354 ft W of the South east corner of Section 20 T10S, R14E SBB&M

Latitude: 33.2825955° **Longitude:** 115.5288291°

ELEVATION: -63.30 ft MSL

KB: 27 FT above ground

MIDNIGHT TO MIDNIGHT REPORT
(ALL DEPTHS REFERENCE KB 27 Ft AGL UNLESS SPECIFIED)

DATE	ACTIVITY
5/4/11 to 5/12/11	Built drilling pad measuring 300 by 300 ft. Adjacent to the pad a containment basin measuring 120 by 300 by 7 ft deep.
5/13/11	Moved in and rigged up (MIRU) Howell Drilling. Drilled 36-in. hole to 80 ft. **Ran 80 ft of 30-in., 3/8-in. wall, Grade B, PEBFW line pipe.** Cemented it with **7 cu yd of cement.** Cement to surface.
5/14/11	Set in 8 ft X 6 ft cellar.
5/15/11	Install sump liner
6/27/11	Moved equipment onto location with Eagle Trucking.
6/28/11	Rigged up (RU), sub base and mud tanks set. Repair work in progress on the derrick.
6/29/11	Hooked up equipment. Continued repairing derrick.
6/30/11	Repaired derrick and inspected welds - GOOD. Set in derrick and derrick board. Strung up blocks and set in cement silos.
7/1/11	Raised the derrick. Rig up the rig floor. Extended the slides on the solids control equipment to reach

the sump. Welded on the 30-in. riser. Set in the V-door and cat walk. Had some electrical issues with electrical plugs.

7/2/11 Rigged up flow line. Drilled and set rat and mouse holes. Mixed spud mud. **Spudded well.** Made up (MU) 26-in bit on 8-in. drill collars (DC), tagged bottom at 107 ft, and drilled from 107 ft to 198 ft.

7/3/11 Drilled and surveyed 26-in. hole from 198 ft to 517 ft. Circulated hole clean. Surveys, 183 ft-3/8°, 273 ft-1/4°, 367 ft-1/2°, and 490 ft-1/2°. Wiped the hole to 100 ft, tripped in to 511 ft, 6 ft of fill. Circulated hole clean and pumped a sweep. Tripped out with the bit. Pick up (PU) drill pipe (DP) for the stab-in string with the 26-in. bit, no fill.

7/4/11 Tripped out from 517 ft. Laid down the bit and bit sub. Held safety meeting with Weatherford. **Ran 12 joints of 20-in., 94#, J-55, BT&C threaded casing**, length 514.41 ft. Ran shoe, 1 joint, float collar, 11 joints, and tack weld bottom 5 joints. **Shoe set at 512.41 ft**, float collar set at 470.52-ft. Tripped in with the stab-in tool, stab-in the float collar at 470 ft. Circulated to cool the hole for cement and rigged up ThermaSource Cementing, held safety meeting. Tested lines to 1800 psi, pumped 30 barrels (bbls) H_2O, pumped 30 bbls Sepolite flush, pumped 10 bbls H_2O spacer, pumped 13 bbls Sodium Silicate, pumped 5 bbls H_2O spacer, started cement at 12:30 hrs, **pumped 230 bbls lead cement at 13 lb/gal (1291.4 cu/ft / 519 sacks (sks)) Cal-premium cement** / 30% SF-200 /10% MS-500 / Slurry-lite 10 lb/sk / 0.5% TSFL-180 / HW Gypsum 5 lb/sk / 2% $CACL_2$. Cement to surface 200 bbls into lead at 1:02 hrs, cut lead by 100 bbls and went to tail cement. **Pumped 41 bbls tail latex at 15 lb/gal (231.4 cu/ft / 130 sks) Cal-premium cement** / 30% SF-200 /10% MS-500 / 0.5% TSFL-180 / 0.2% FWCA / Latex 1.5 gal/sk / TCD- 1L 0.8 gal/sk / DFA-22L 0.15 gal/sk. Displaced with 7.5 bbls H_2O. Cement in place (CIP) at 1:17 hrs. Tripped out with the stab-in string. Drained cement from stack after 1/2 hr. Waited on cement (WOC). Rough cut the 30-in. and 20-in. casing.

7/5/11	Welded on a 20-in X 600 flange and **nippled up the 20-in BOPE.** Function and pressure tested blind rams and choke valves to 500 psi for 10 minutes. Made up bottom hole assembly (BHA) with a 17-1/2-in. bit. Ran BHA and installed rotating head. Tested BOPE, test witnessed and approved by CDOGGR (Ben Minx). Drilled out the float collar at 470 ft, and the cement and shoe at 512 ft. Circulated clean, perform formation leak off test to 0.65 psi gradient, less than a 1/10 of a bbl/min. Drilled out cement from 512 ft to 517 ft. Drilled 17-1/2-in. hole from 517 ft to 593 ft.
7/6/11	Circulated clean, tripped out, and picked up stabilizers (stabs) at 30 and 60 ft and 3 more 8-in. drill collars. Tripped in hole and drilled 17-1/2-in. hole from 593 ft to 602 ft. Surveyed at 592 ft, 0 degrees. Drilled 17-1/2-in. hole from 602 ft to 788 ft, with 5-10k and 60-80 rpm. Surveyed at 777 ft, 0.5 degrees. Drilled 17-1/2-in. hole from 788 ft to 881 ft, with 5-10k and 60-80 rpm. Surveyed at 871 ft, 0 degrees. Drilled 17-1/2-in. hole from 881 ft to 913 ft, with 5-10k and 60-80 rpm. Wiped hole to the Shoe and drilled 17-1/2-in. hole from 913 ft to 936 ft, with 5-10k and 60-80 rpm.
7/7/11	Drilled 17-1/2-in. hole with 10k and 100 rpm from 936 ft to 976 ft. Surveyed at 956 ft, 0.25 degrees. Wiped hole to the 20-in. shoe and drilled 17-1/2-in. hole with 10k and 100 rpm from 976 ft to 1069 ft. Wiped hole to the 20-in. shoe and drilled 17-1/2-in. hole with 10k and 100 rpm from 1069 ft to 1164 ft. Surveyed at 1154 ft, 0.25 degrees. Drilled 17-1/2-in. hole with 10-15k and 100 rpm from 1164 ft to 1258 ft. Wiped hole to the 20-in. shoe and drilled 17-1/2-in. hole with 10-15k and 100 rpm from 1258-ft to 1353 ft. Surveyed at 1343 ft, 1/2 degree.
7/8/11	Drilled 17-1/2-in. hole with 10k and 100 rpm from 1353 ft to 1447 ft. Surveyed at 1437 ft, 1/2 degree. Wiped hole to the 20-in. Shoe and drilled 17-1/2-in. hole with 10k and 100 rpm from 1447 ft. to 1541 ft. Circulated and surveyed at 1531 ft, 1 degree. POH, picked up shock sub and moved stabs up 30 ft. RIH and drilled 17-1/2-in. hole with 5-10k and 100 rpm from 1541 ft to 1584 ft.

7/9/11	Drilled 17-1/2-in. hole with 10k and 100 rpm from 1584 ft to 1617 ft. Surveyed at 1606 ft, 1/8 degree. Wiped hole to the 20-in. shoe and drilled 17-1/2-in. hole with 10-15k and 100 rpm from 1617 ft to 1711 ft. Surveyed at 1700 ft, 1/2 degree. Wiped hole to the 20-in. shoe and tagged up at 1621 ft, possible ledge. Reamed from 1620 ft to 1711 ft (easy reaming). Drilled 17-1/2-in. hole from 1711 ft to 1805 ft with 10-15k and 100 rpm and survey at 1795 ft, 0 degrees. Wiped hole to the 20-in. shoe. Hole clean no fill, no tight spots. Drilled 17-1/2-in. hole with 10-15k and 100 rpm from 1805 ft to 1836 ft.
7/10/11	Drilled 17-1/2-in. hole with 10-15k and 100 rpm from 1836 ft to 1899 ft. Surveyed at 1889 ft, 0 degrees. Wiped hole to the 20-in. shoe. Hole clean no fill, no tight spots. Drilled 17-1/2-in. hole with 10-15k and 100 rpm from 1899 ft to 2057 ft. Wiped hole to the 20-in. shoe, 10 ft of fill, and no tight spots. Drilled 17-1/2-in. hole with 10-15k and 100 rpm from 2057 ft to 2088 ft. Surveyed at 2078 ft 0.25 degrees. Drilled 17-1/2-in. hole with 10-15k and 100 rpm from 2088 ft to 2138 ft.
7/11/11	Drilled 17-1/2-in. hole with 10-15k and 100 rpm from 2136 ft. to 2182 ft. Wipe hole to the 20" Shoe. Hole clean no fill, no tight spots. Drilled 17-1/2-in. hole with 15-20k and 100 rpm from 2182 ft. to 2340 ft. Survey at 2330 ft. 1/4 degree. Wipe hole to the 20" Shoe. Hole clean no fill, no tight spots. Drilled 17-1/2-in. hole with 10-15k and 100 rpm from 2182 ft. to 2432 ft.
7/12/11	Drilled 17-1/2-in. hole with 10-15k and 100 rpm from 2432 ft. to 2435 ft. Wiped hole to the 20-in. shoe, 10 ft. fill, no tight spots. Reamed from 2393 ft. to 2435 ft. Drilled 17-1/2-in. hole with 10-15k and 100 rpm from 2435 ft. to 2529 ft. Circulated and surveyed at 2519 ft., 0 degrees. Wiped hole and checked bit (bit OK). Serviced rig. RIH to 2529 ft. Drilled 17-1/2-in. hole with 25-30k and 100 rpm from 2529 ft. to 2608 ft.
7/13/11	Drilled 17-1/2-in. hole with 25-30k and 100 rpm from 2608 ft. to 2655 ft. Circulated and surveyed at 2644

ft., 1/8 degree. Wiped hole to shoe and changed out Kelly bushings. Hole clean no fill, no tight spots. Performed precautionary ream from 2456 ft. to 2655 ft. Drilled 17-1/2-in. hole with 25-30k and 100 rpm from 2655 ft. to 2812 ft. Circulated hole clean. Wiped hole to shoe. Serviced rig. RIH to 2782 ft. Hole clean no fill, no tight spots. Performed precautionary ream from 2782 ft. to 2812 ft. Drilled 17-1/2-in. hole with 25-30k and 100 rpm from 2812 ft. to 2843 ft.

7/14/11 Drilled 17-1/2-in. hole with 25-30k and 100 rpm from 2843 ft. to 2875 ft. Circulated and surveyed at 2833 ft., 1/2 degree. Drilled 17-1/2-in. hole with 20-25k and 100 rpm from 2875 ft. to 2937 ft. Wiped hole to 2050 ft. Hole clean no fill, no tight spots. Drilled 17-1/2-in. hole with 20-25k and 100 rpm from 2937 ft. to 3014 ft. POH and checked bit. Jet and threads washed out. Changed bits and RIH.

7/15/11 Drilled 17-1/2-in. hole with 20-25k and 100 rpm from 3014 ft. to 3065 ft. Circulated and surveyed at 3054 ft., 1-1/2 degrees. Drilled 17-1/2-in. hole with 10-15k and 120 rpm from 3065 ft. to 3160. Wiped hole to 2000 ft., no tight spots, no fill. Drilled 17-1/2-in. hole with 10-15k and 120 rpm from 3160 ft. to 3240 ft.

7/16/11 Drilled 17-1/2-in. hole with 10-15k and 120 rpm from 3240 ft. to 3254 ft. Circulated and surveyed at 3244 ft., 3/4 degrees. Wiped hole to 20-in. shoe, no tight spots, 24 ft. fill. Reamed from 3230 ft. to 3254 ft. Drilled 17-1/2-in. hole with 15-20k and 120 rpm from 3160 ft. to 3380 ft. Circulated and wiped hole to 20-in. shoe. Serviced rig. RIH to 3327 ft. Tight spot at 3327 ft. Reamed from 3306 ft. to 3380 ft. Drilled 17-1/2-in. hole with 15-20k and 120 rpm from 3380 ft. to 3411 ft.

7/17/11 Drilled 17-1/2-in. hole with 15-20k and 120 rpm from 3411 ft. to 3474 ft. Circulated and surveyed at 3460 ft., 0 degrees. Drilled 17-1/2-in. hole with 20-25k and 120 rpm from 3474 ft. to 3505. POH to bit and checked for wash out, packing washing out of jars. Changed Jars and Shock Sub. Bearings failed on one cone of the bit. Picked up and re-ran bit #2. RIH to shoe. Repaired accumulator. RIH to 2611 ft. well started flowing 80 bbls/hr. Stripped into hole to 3400 ft. Circulated out CO_2 through choke. Circulated and conditioned mud. Bring mud weight up to 9.4 from 9.2.

7/18/11 Reamed from 3399 ft. to 3505 ft. 70 ft. fill. Circulated and conditioned mud. Bring mud weight up to 9.4. Wiped hole to 20-in. shoe. Slip and cut drilling line. RIH to 3502 ft. No fill. Circulated hole clean and conditioned mud for logs. Rigged up Schlumberger and ran electric wire line open hole logs from 3480 ft. up to 470 ft. (25 ft. fill on bottom). RIH to 3480 ft clean out fill to 3505 ft.

7/19/11 Circulated hole clean. Wiped hole to shoe. Cleaned out fill 3280 ft. to 3505 ft. Circulated and conditioned mud for casing and circulated hole clean. POH and laid down 17-1/2-in. tools, to run 13-3/8-in. casing. Rigged up and ran 13-3/8-in. casing. **Ran 86 joints (3491.85 feet) of 68# K-55 BT&C casing. Set shoe at 3487 ft. and float collar at 3412 ft.**

7/20/11 Finished running 13-3/8-in. casing from 3164-ft to 3487-ft and rigged down the casing crew. Ran in the hole with the stab-in string and stabbed into the float collar at 3420-ft. Circulated for cement while mixing up latex fluid. Held safety meeting. Pressure tested lines to 2000 psi. Pumped 30 bbls H_2O, 20 bbls Mud Clean, 20 bbls H_2O, 30 bbls sepiolite flush, 7 bbls of H_2O, 13 bbls of Sodium Silicate, 5 bbls H_2O. **Pump 790 bbls (4435 cu/ft., 2036 sks) 13.5# Calprem Latex Cement** with 30% SF-200, 10% MS-500, Slurrylite 10 lb/sk, 0.5% TSFL-180, 0.2% FWCA. **Pump 41 bbls (230 cu/ft., 130 sks) 15# Calprem Latex Cement,** with 30% SF-200, 10% MS-500, 0.5% TSFL-180. Latex Blend 1.5 gal/sk, Defoam 0.15 gal/sk, Dispersant 0.08 gal/sk. Displaced with 61 bbls water. CIP at 12:00 hrs. WOC and tripped out with the stab-in string. Tagged cement at 100-ft with 1-in pipe after 6 hrs. **Pumped top job, 22 bbls (123 cu/ft., 70 sks) 15.5# cement** with 30% SF-200, 10% MS-500, 0.5% TSFL-180, 2% $CACL_2$. CIP at 22:04 hrs. WOC.

7/21/11 Lifted BOPE and rough cut casing. Finished cutting and welded on 12-in. ANSI 400 X 13-3/8-in. SOW well head 35-in below GL, tested to 1000 psi. **Nippled up**

BOPE, flow line, choke line, and kill lines. Function and pressure tested blind rams to 500 psi. Made up BHA and ran in the hole. Tested BOPE to 1000 psi, test witnessed and approved by CDOGGR (Ben Minx).

7/22/11 Finished the BOPE test to 1000 psi, test witnessed and approved by CDOGGR (Ben Minx). Tripped in the hole to 3412-ft. Drilled out the float collar, cement, and shoe to 3487-ft. Circulated bottoms up and performed formation leak off test to 0.65 frac gradient (563 psi for 15 min.) good. Drilled 12-1/4-in. hole from 3487-ft to 3551-ft. Pulled tight at 3511-ft while making a connection. Reamed area 3487-ft to 3551-ft. Drilled 12-1/4-in. hole from 3551-ft to 3583-ft. Circulated and surveyed at 3541-ft, 3/4 degree. Tripped out, picked up near bit stabilizer and string stabs at 30-ft and 60-ft, and run in the hole. Drilled 12-1/4-in. hole from 3583-ft to 3613-ft. Pulled tight while making a connection. Reamed from 3540-ft to 3592-ft.

7/23/11 Reamed from 3552-ft to 3613-ft. Drilled 12-1/4-in. hole from 3613-ft to 3706-ft. Pulled tight, reamed from 3645-ft to 3706-ft. Circulated and surveyed at 3696-ft, 1/4 degree. Wiped the hole to the shoe, no fill and no drag. Drilled 12-1/4-in. hole from 3706-ft to 3800-ft. Circulated and surveyed at 3789-ft, 1/4 degree. Wiped the hole to the shoe. Drilled 12-1/4-in. hole from 3800-ft to 3927-ft. Circulated and surveyed at 3916-ft, 1/4 degree.

7/24/11 Surveyed at 3916-ft, 1/4 degree. Tripped out of the hole, 30-40K drag, laid down the stabilizers and tripped back in the hole to 3434-ft. Serviced the rig. Tripped in the hole to 3927-ft (no fill). Drilled 12-1/4-in. hole from 3927-ft to 4041-ft. Circulated and surveyed at 4030-ft, 1/4 degree. Drilled 12-1/4-in. hole from 4041-ft to 4196-ft. Circulated and surveyed at 4186-ft, 1/4 degree. Wiped the hole to the shoe, reamed tight areas 3740-ft to 3770-ft and 3850-ft to 4180-ft.

7/25/11 Drilled 12-1/4-in. hole from 4196-ft to 4322-ft. Circulated and surveyed at 4312-ft, 2 degrees. Wiped hole to 4029-ft, tripped in to 4322-ft. Drilled 12-1/4-in. hole from 4322-ft to 4441-ft.

7/26/11 Drilled 12-1/4-in. hole from 4441-ft to 4448-ft. Circulated and surveyed at 4437-ft, 2-1/2 degrees. Wiped hole to 4217-ft, tripped in to 4448-ft. Drilled 12-1/4-in. hole from 4322-ft to 4503-ft. Circulated 1/2 hour and tripped out, changed out bit and tripped in to the shoe. Serviced rig and equipment. Tripped in to 4503-ft. Drilled 12-1/4-in. hole from 4503-ft to 4605-ft.

7/27/11 Circulated and surveyed at 4595-ft, 2-3/4 degrees. Drilled 12-1/4-in. hole from 4605-ft to 4762-ft. Circulated and attempted survey at 4751-ft, pulling tight, aborted survey, worked pipe free and reamed tight area. Surveyed at 4720-ft, 2-1/4 degrees. Drilled 12-1/4-in. hole from 4762-ft to 4764-ft. Tripped out to check bit and for wash out. No wash out found.

7/28/11 Changed out bit and jars, and picked up shock tool. Tripped in to the shoe and serviced rig. Tripped in to 4754-ft, 10-ft of fill, cleaned out to 4764-ft. Drilled 12-1/4-in. hole from 4764-ft to 4899-ft. Pumped sweep, circulated and surveyed at 4889-ft, 3 degrees. Pulled tight, pulled 1 joint and reamed out to 4899-ft. Drilled 12-1/4-in. hole from 4899-ft to 4931-ft.

7/29/11 Drilled 12-1/4-in. hole from 4931-ft to 4994-ft. Circulated hole clean. Wiped hole to the shoe and tripped in to 4994-ft. Circulated hole clean. Surveyed at 4964-ft, 3 degrees. Wiped hole to 4512-ft and tripped in to 4994-ft. Circulated to cool the well for E-logs. Tripped out of the hole for logs. Schlumberger arrived at 21:25 hrs, held safety meeting and rigged up loggers.

7/30/11 Schlumberger ran E-logs (Platform Express Array Induction, Gamma Ray, SP, Caliper, Density, Neutron, FMI). Performed injection test, 4 bpm at 360 psi. Laid down 8-in. BHA and picked up drill pipe to replace 8-in. tools. Tripped in the hole to 3468-ft. Circulated at the shoe, tripped in to 4994-ft and circulated to cool the well. Pulled to the shoe. Cleaned mud tanks, filled with water and mixed change over fluid (70% salt, 30% KCL) to 9.1 ppg. Conducted injection test at 4 BPM at 360 psig.

7/31/11 Tripped in to 4994-ft, pumped change over fluid, pulled to the shoe, and rigged up laydown machine. Laid down drill string. Rigged down the lay down machine. Flushed mud pumps and mud tanks. **Nippled down the BOPE.** Released rig. Preparing to rig down.

8/1/11 Loaded out used stabilizers, shock tools, and jars. Set sub base down, re-pinned rams and laid down the derrick. Loaded BHA, drill collars, heavy weight drill pipe, and drill pipe. Send to Tubular Inspection for inspection. Rigged down auxiliary equipment.

8/2/11 Rigging down. Cleaned baker tanks. Cranes arrived on location, rigged up cranes. Trucks and trailers arrived on location.

8/3/11 Loaded out rig.

8/4/11 Loaded out rig.

TECTON GEOLOGIC

COMPANY Ormat
WELL ORMAT Wister 85-20
FIELD Brawley
COUNTY/STATE Imperial, California
WELL HEAD COORDINATES
2200'N &400'W of SE corner of Sec20,T10S,R14E
ELEVATION -200' MSL
SPUD DATE 7/02/2011
TD DATE 7/29/2011
TOTAL DEPTH 4994'
TRUE VERTICAL DEPTH n/a
TD LOCATION n/a
CONTRACTOR/RIG Geodrill Rig #1
COMPANY REPRESENTATIVE B. Mueller, R. Lemon

LOG INTERVAL

DATE LOGGED	7/02/2011	TO	7/31/2011
DEPTH LOGGED	107'	TO	4994'
MUD DRILLING	107'	TO	4994'
AIR DRILLING	n/a	TO	n/a
LOG SCALE	1:600	UNIT NO.	C22

LOGGING GEOLOGISTS
J. Everts, K. Richardson, E. ter Weele
M. McLaughlin, S. Sauvageau

HOLE

26"	TO	517'
17.5"	TO	3505'
12.25"	TO	4994'
	TO	
	TO	
	TO	

CASING

20"	FROM	0'	TO	514'
13.375"	FROM	0'	TO	3495'
	FROM		TO	
	FROM		TO	
	FROM		TO	

ABBREVIATIONS

NB New Bit
RRB Re-run Bit
CB Core Bit
WOB Weight On Bit
SPM Strokes per Minute
PP Pump Pressure
RPM Revolutions per Min
BHT Bottom Hole Temp
C Carbide Test
NR No Returns
LAT Logged After Trip
CFM Cubic Feet per Min
BUT Bottoms Up Temp

SYMBOLS

Wireline Log
Steam/Water Entry
Deviation Survey
Casing Shoe
Flow Test
Cored Interval
No Recovery

LITHOLOGY

Clay
Claystone
Siltstone
Sand
Sandstone
Gravel/Conglomerate
Granodiorite/ Diorite
Quartz

REMARKS

All depths from 27' Kelly Bushing

Survey temperatures from MRT

je = Justin Everts
kl = Kelly Richardson
et = Eric ter Weele
mm = Mike McLaughlin
ss = Sarah Sauvageau

Injection Test: 4bbls/min at 360psi.

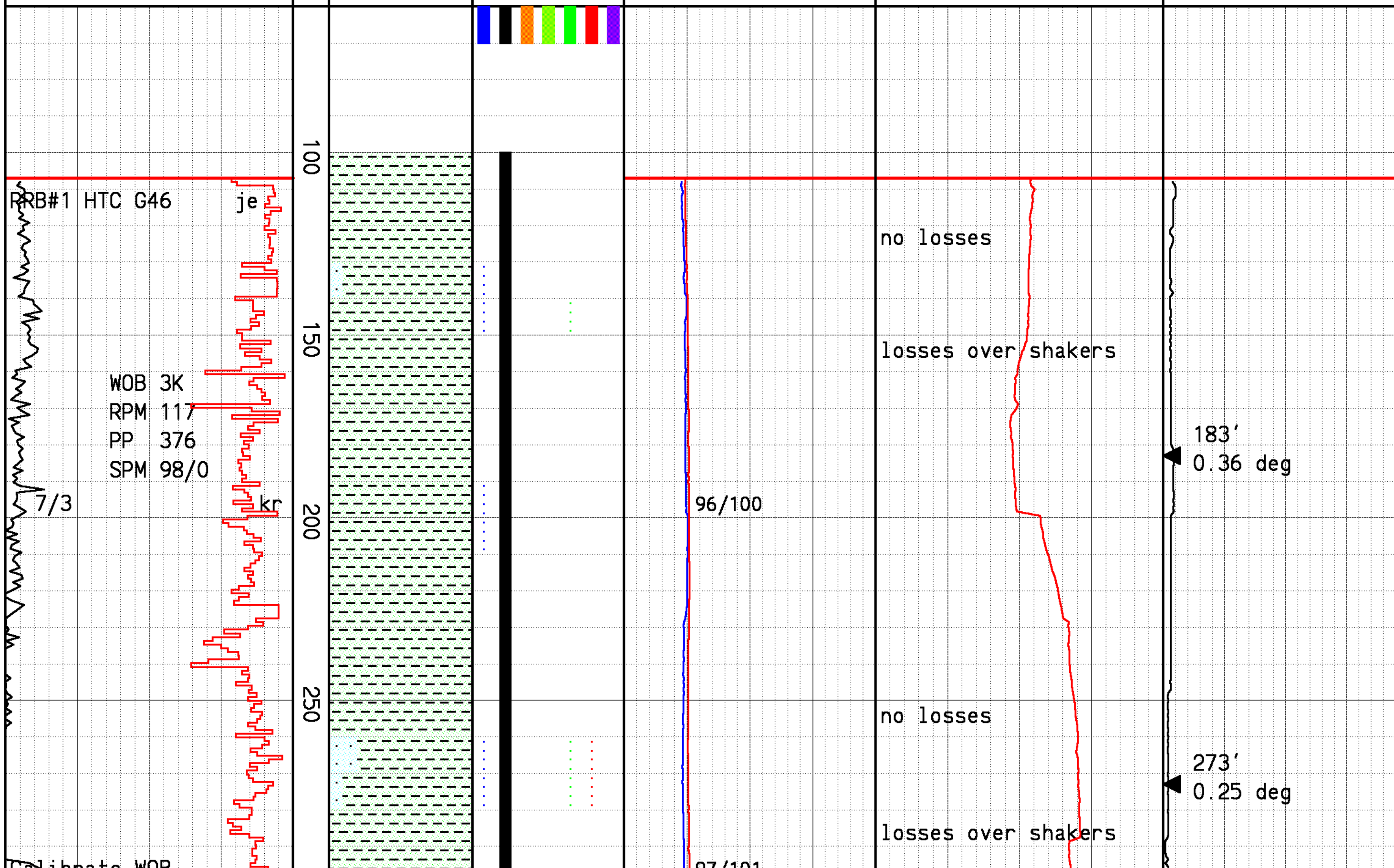
SECONDARY MINERALS

Q = Quartz
C = Calcite
P = Pyrite
E = Epidote
Ch = Chlorite
H = Hematite
An = Anhydrite

Rare	<< 1%
Trace	< 1%
Minor	1% to 4%
Common	4% to 7%
Abundant	7% to 10%
	> 10%

Tecton Geologic | W85-20 | Scale 1: 600

Drilling Data	Depth	Lithology	Minerals	Temperatures	Circulation	Gas Analysis	Descriptions
ROP: 200 ft/hr 0 Weight on Bit: 0 k lbs 80			Quartz, Calcite, Pyrite, Epidote, Chlorite, Hematite, Anhydrite	Temperature In Temperature Out: 50 deg F 250	Pit Total: 0 bbls 1000	Carbon Dioxide: 0 ppm 10000	

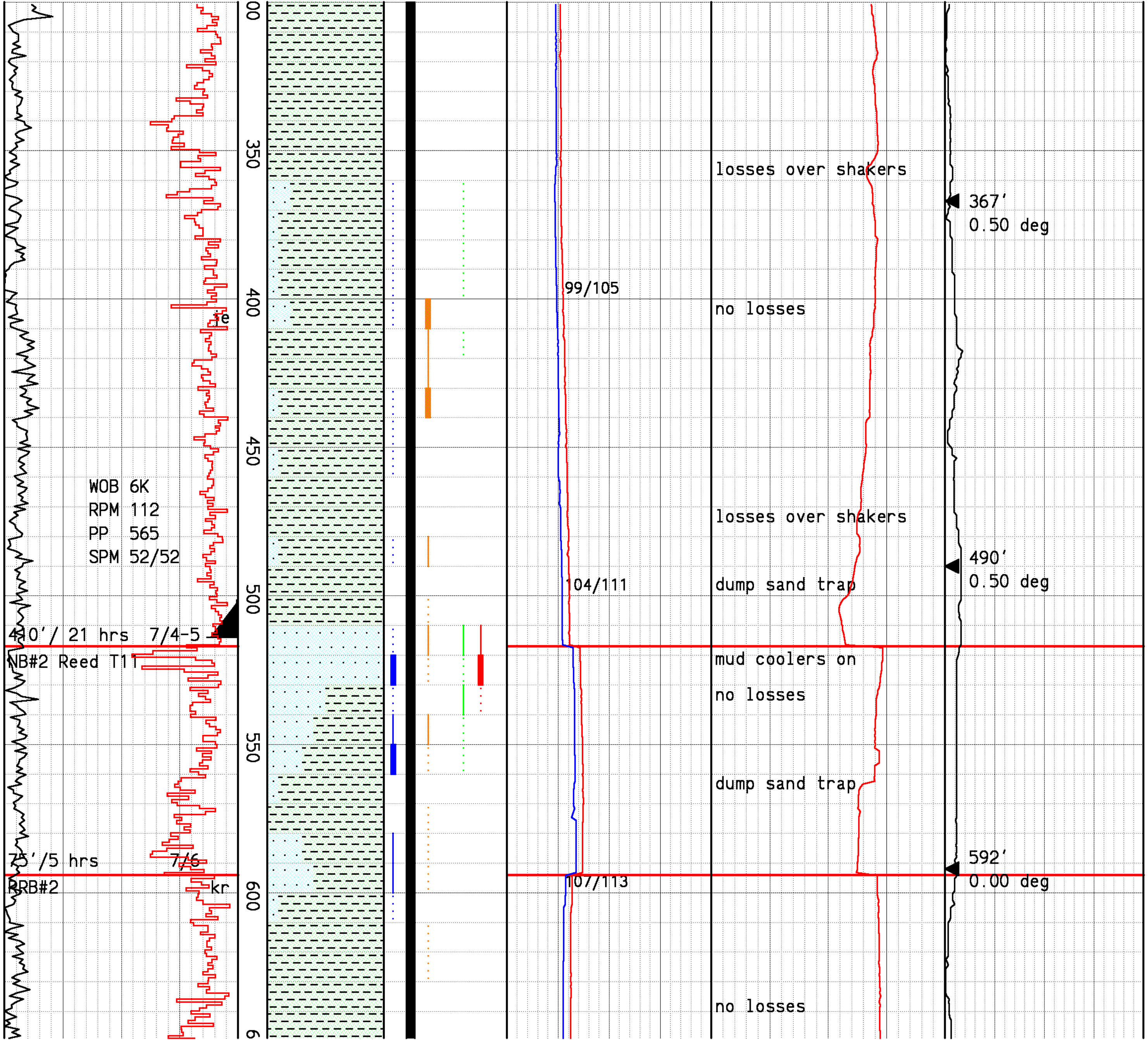


Spud well Wister 85-20 on 7/02/2011. 30" conductor set at 107'. Drill ahead with 26" bit.

Clay:lt brn,lt gry,v sft-sft, sticky,low-mod water sol, smooth txt,str calc matrix,r loc qtz & chloritized frags.

Drilling breaks at 161' & 170'.ROP= 61-70'/hr, WOB= 0-3K.No losses associated.

Clay:lt gry,gry-grn,loc rd-brn.Soft,v stcky,loc silty-sandy,Rd brn Clay slightly lithified,com calc matric,r loc qtz,loc intrbdd w/Sand: multi color,sub ang-sub rnd, mod-prly srtd,r qtz,r hem stng,r chlor.



Clay:lt gry,gry-brn,loc rd-brn,sft,v stcky,loc silty-sandy,com calc matrix,loc intrbdd w/Sand:clr,wht,blck,grn,sub rnd,mod srtd,r qtz,r chlor.

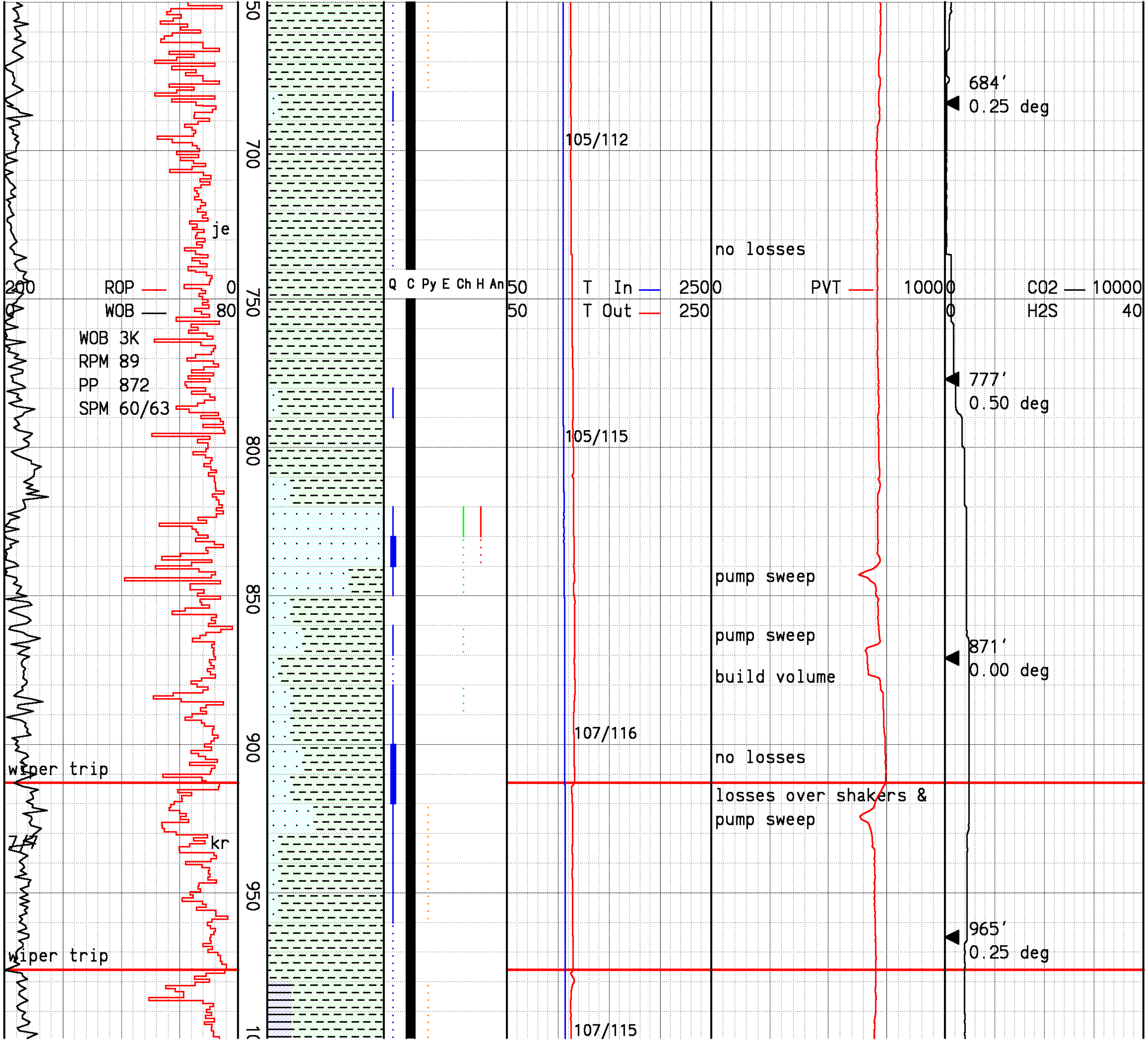
Clay:lt brn,loc lt gry,loc rd-brn,v sft-sft,v sticky,low-mod water sol,smooth txt,loc silty,str calc mtx;loc intrbdd w/Sand:clr,wht,blk,fn-med gr,subang-subrnd,mod srtd,r qtz,abnst-mnr pyr agg(up to 1cm thick cluster)

Drill 26" hole to 517'.Run 12 joints of 20", 94#, J-55 BTC casing to 514'. Cement to surface. Drill ahead with 17 1/2" bit.

Sand:clr,frosted,orng,yel,lt grn,red,unconsol grs,dom qtz grs,tr-mnr ign/volc/sed grs,med-crs gr,subang-rndd,mod srtd,tr silic altn,r-tr pyr,r-tr chlor,r-mnr hem.

Drill t/592'.POH to M/U stabilized drilling assembly w/float.

Clay:rd-brn,lt gry,v sft-



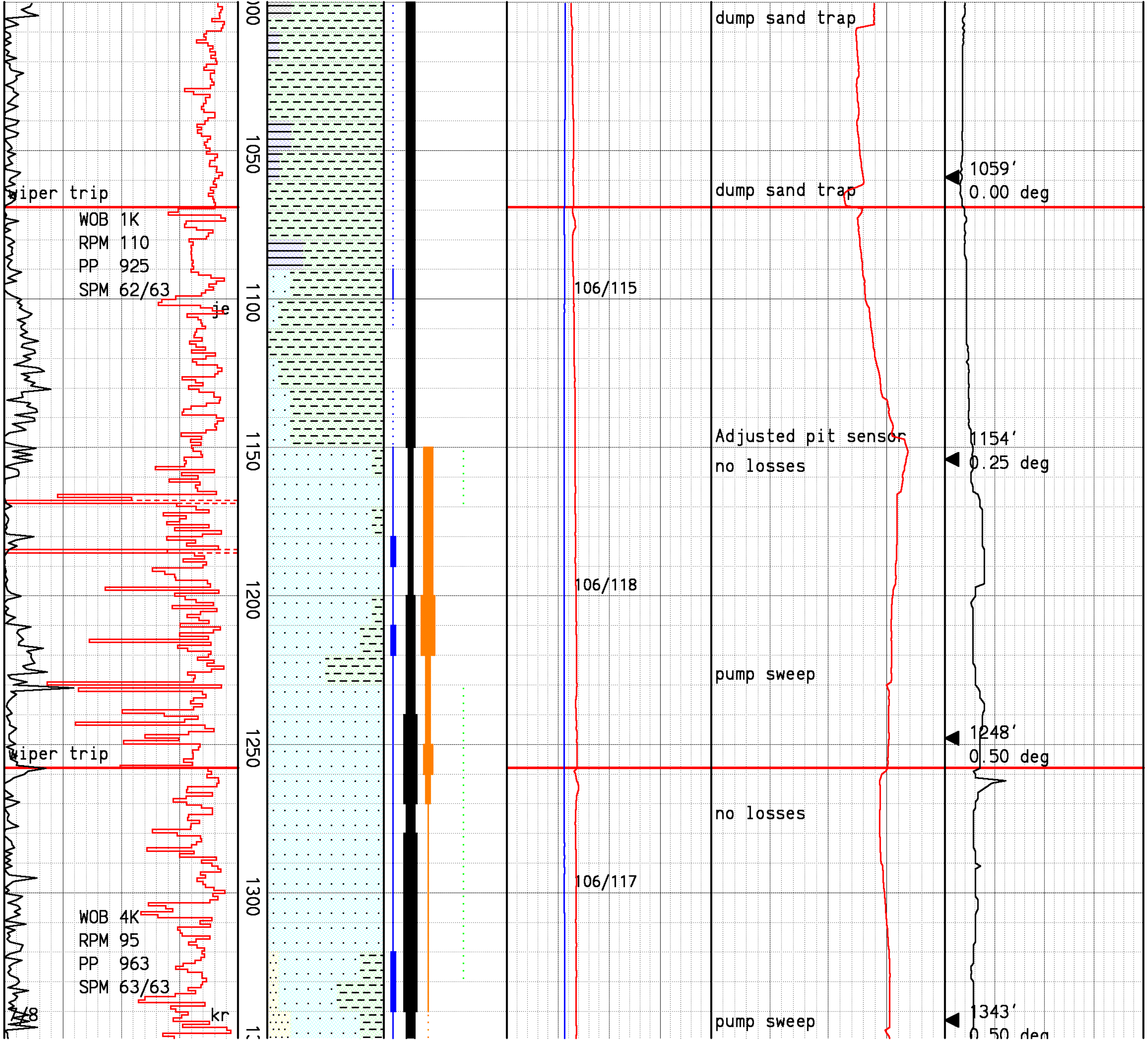
firm,v sticky,brn clay firm,
fine lam,low-mod water sol,
smooth txt,loc silty,str
calc mtx;loc intrbdd w/Sand:
clr,wht,blk,fn-med gr,subang-
subrnd,mod srtd,r qtz,abnst-
r pyr agg.

Clay:lt brn,lt gry,oran,v
sft-firm,v sticky,low-mod
water sol,smooth txt,loc
silty,str calc mtx,tr-mnr fn
mafic lithics,absnt-com Sand.

Series of drilling breaks
within Sand from 826-845',
ROP= 66-97'/hr, WOB= 0-2K.
No losses associated.

Sand:dom clr,frosted,orng,yel
lt grn,unconsol grs,dom qtz
grs,r ign/volc/sed grs,fn-crs
gr,ang-subrndd,prly srtd,tr-
mnr silic altn,r-tr chlor,r-
tr hem,r-mnr mica.

Clay:rd-brn,sft-firm,firming
with depth,v sticky,loc fine
lam,low-mod water sol,smooth
txt,str calc mtx;loc intrbdd
w/Sand:clr,wht,blk,med gr,
subang-subrnd,mod-well srtd,
loc loosely consol,r qtz,abs-
r pyr agg.

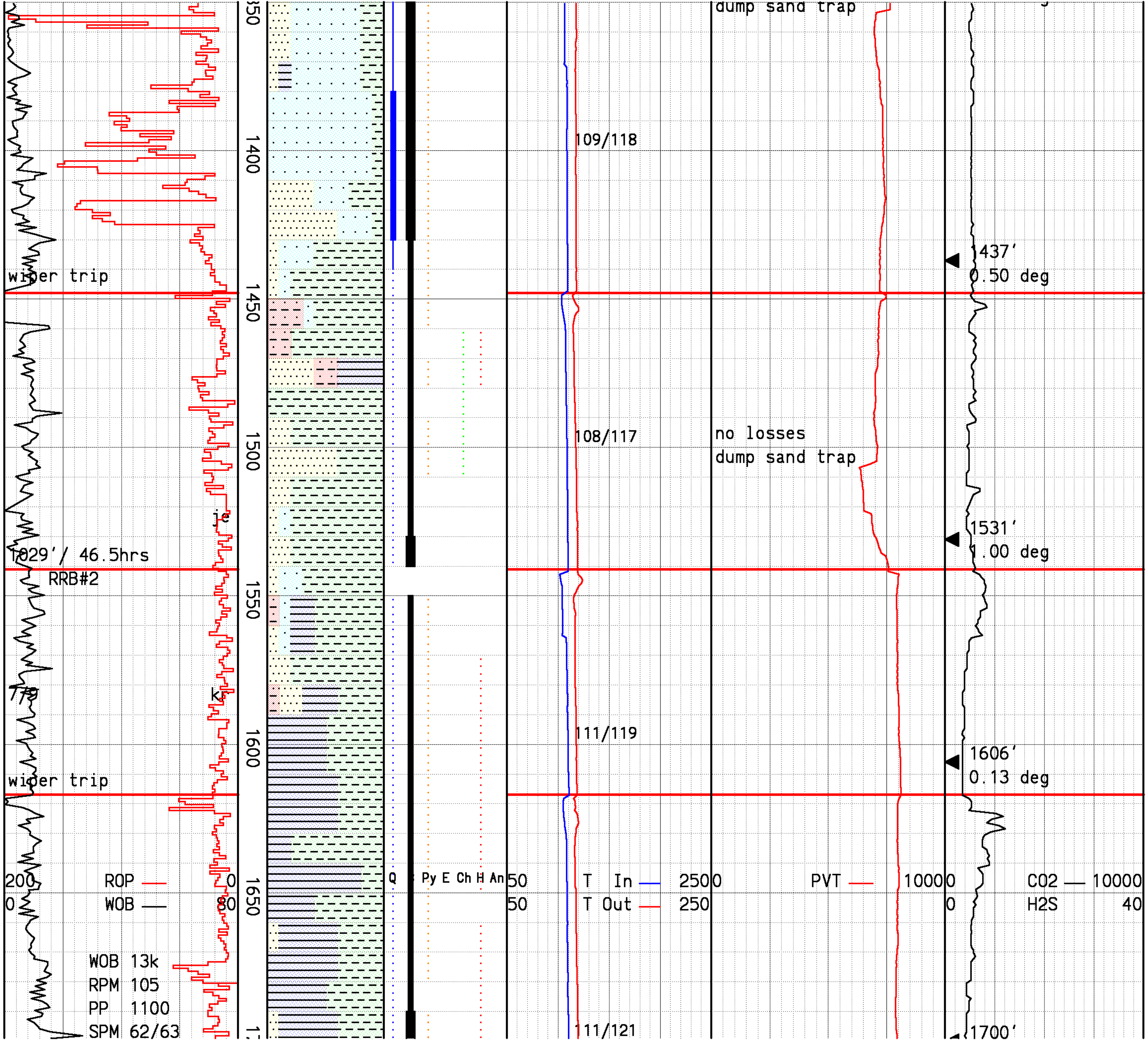


Clay:rd-brn,sft-firm,firming with depth,v sticky,loc fine lam,low-mod water sol,smooth txt,str calc mtx;grading into Claystone:brn,rd-brn,sft-frm, v fin lam,smooth,loc,silty,r qtz,com calc,abs-r pyr.

Series of drilling breaks within Sand starting at 1157',ROP= 59-261'/hr,WOB= 0-1K.No losses associated.

Sand:clr,frosted wht,dk gry, unconsol grs,dom qtz grs,mnr-abun ign/volc/sed grs,fn-med gr,subang-rndd,mod-well srtd, tr-mnr silic altn,com-abun pyr agg,tr-com blk organic material,mnr-abun Sandstone frags,r-tr Siltstone frags.

Sand:clr,frosted wht,dk gry, unconsol grs,dom qtz grs,mnr ign/volc/sed grs,dom fn gr, dom ang,well srtd,tr silic altn,com-abun calc coating, mnr pyr agg,r loc chlor stn, mnr blk organic material.

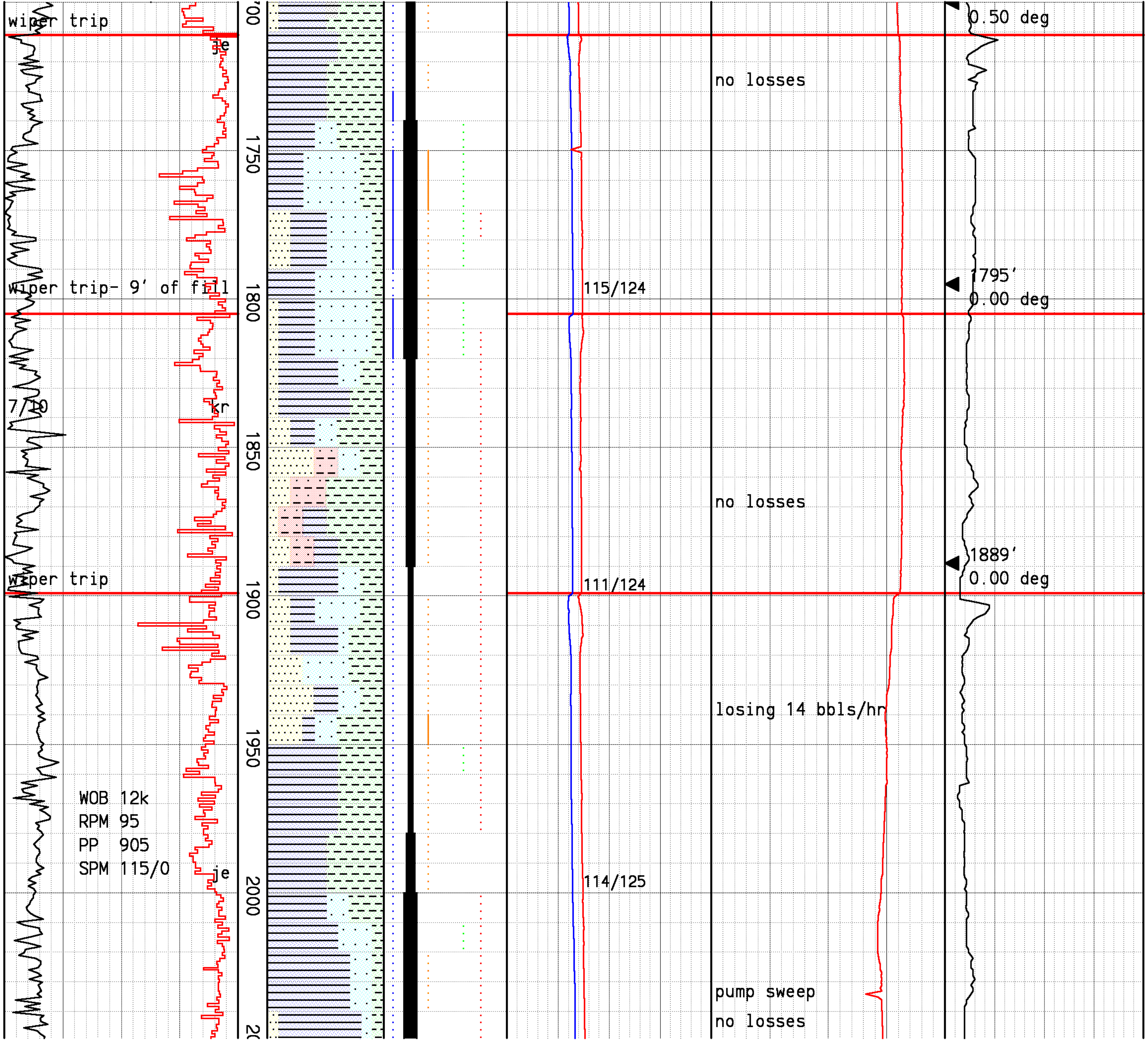


Sandstone:gry,rd/brn-lt brn, sub-and-sub rnd grns,pred qtz,mod srtd,calc cement,tr-mnr qtz,com-abund calc,abs-tr pyr,loc r chlor,w/Sand: clr,frosted wht,dk gry,dom qtz grs,mnr-abun ign/volc/ sed grs,medgr,subang-rndd, mod-well srtd,r pyr agg,w/ Clay:gry,sft,sticky,smooth,r qtz,com calc,r pyr.

Siltstone:dk gry,brn,frm,loc sandy,loc fine qtz vn,calc cement,r qtz,mnr calc,abst-r pyr,loc r chlor wash;intrbdd w/Clay:gry,grn-gry,sft-firm, firming with depth,v sticky, loc fine lam,low-mod water sol,smooth txt,str calc mtx, r pyr,loc r chlor.

Claystone:lt-dk gry,rd brn, sft-frm,friable,micro lams, alternating gry/rd layers,r qyz,mnr calc,r pyr, loc r hem,intrbdd w/Clay:gry,brn, sft,sticky,smooth,r qtz,com calc,r pyr.

Claystone:lt-dk gry,rd brn, sft-frm,friable,micro lams, alternating gry/rd layers,



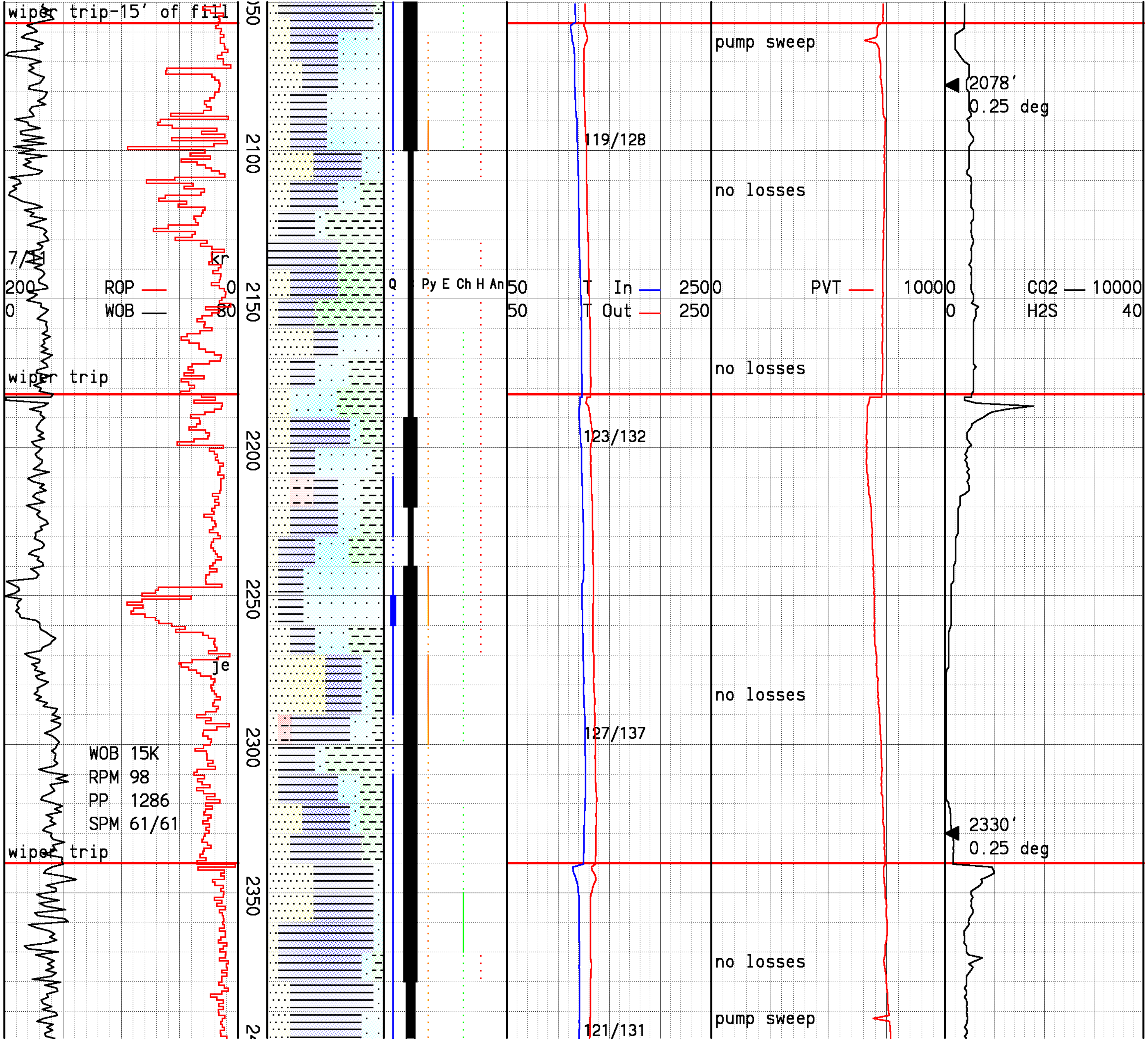
loc sandy,com-abun Sandstone frags,r qtz,mnr calc,r pyr,r loc hem;intrbdd w/Clay:gry, brn,v sft-sft,sticky,smooth, r qtz,str calc mtx.

Tight spot at 1621' during wiper trip.

Sand:clr,frsted wht,unconsol grs,dom qtz grs,r ign/volc/ sed grs,fn-med gr,subrndd- ang,mod-well srtd,tr silic altn,abun calc coating,r pyr agg,r loc chlor/hem stn,mnr blk organic material;intrbdd w/Claystone:lt-dk gry,brn,rd brn,dom frm,friable,loc lams, loc silty,abun v sft clay.

Sandstone:lt gry,red-brn,fr- hd,speckled with blck,loc friable,loc r fn qtz vns,mod- mod well srtd,subang-subrndd grns,r qtz,mnr calc,abs-r pyr,loc r hm, w/Claystone:lt- med gry,brn,rdbrn,dom frm, friable,lams,loc silty-sandy, r qtz,mnr calc,r pyr,abun v sft clay.

Claystone:lt-med gry,brn,rd- brn,frm-mod hd,friable,lams, loc silty-sandy,r qtz,str

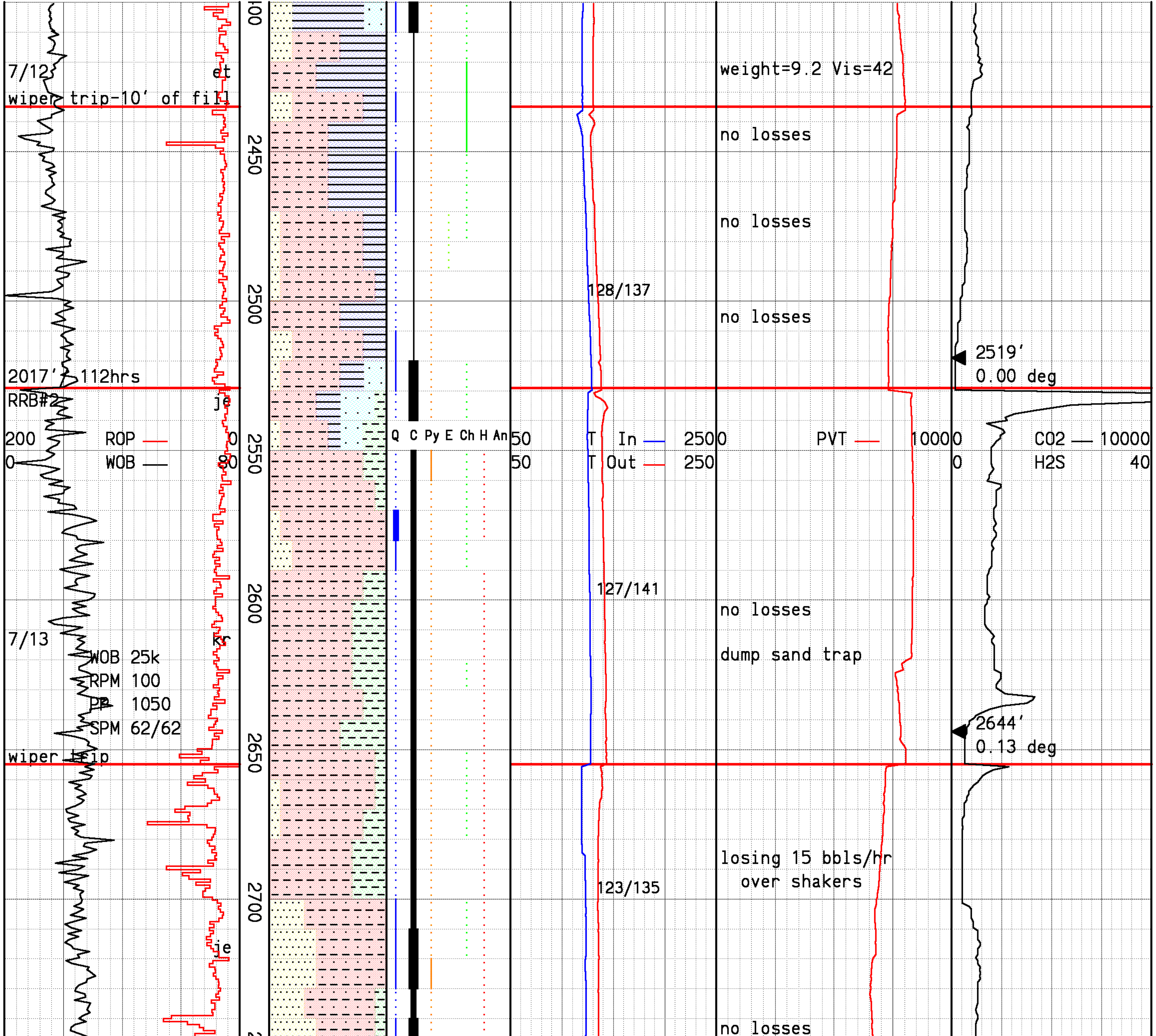


calc mtx;intrbdd w/Sand:clr, frsted,unconsol grs,dom qtz grs,r ign/volc/sed grs,fn-med gr,subrndd-ang,mod-well srtd, tr silic altn,com-abun calc coating/agg,r pyr agg,r loc chlor/hem stn,r loc mica.

Sandstone:med gry,rd brn,loc sft-pred hd,loc loosely lith, loc lams,salt & pepper apprnce,loc hem stn,r qtz, com calc,tr-r pyr,r hem; intrbdd w/Claystone:lt-dk gry,dom frm,friable,loc lams, loc silty;intrbdd w/Clay:gry, grn-gry,sft-firm,v sticky,r loc fn lam,low-mod water sol, smooth txt,str calc mtx,r pyr,r loc chlor.

Series of drilling breaks w/in Sand from 2248'-2257', ROP= 40-95'/hr, WOB= 0-5K. No losses associated.

Sandstone:wht,pale gry,mod hd-v hd,dom clr-wht qtz grs, com prly indurated,r-tr ign/ volc grs,v fn gr,subrndd-ang, mod sorted,r-tr qtz agg,abun calc cement,r pyr agg,r chlor stng,tr blk organic material; intrbdd w/Claystone:dom lt-dk gry,brn,rd-brn,frm-mod hd, friable,loc lams,platy,com



silty,tr-abun sticky Clay.

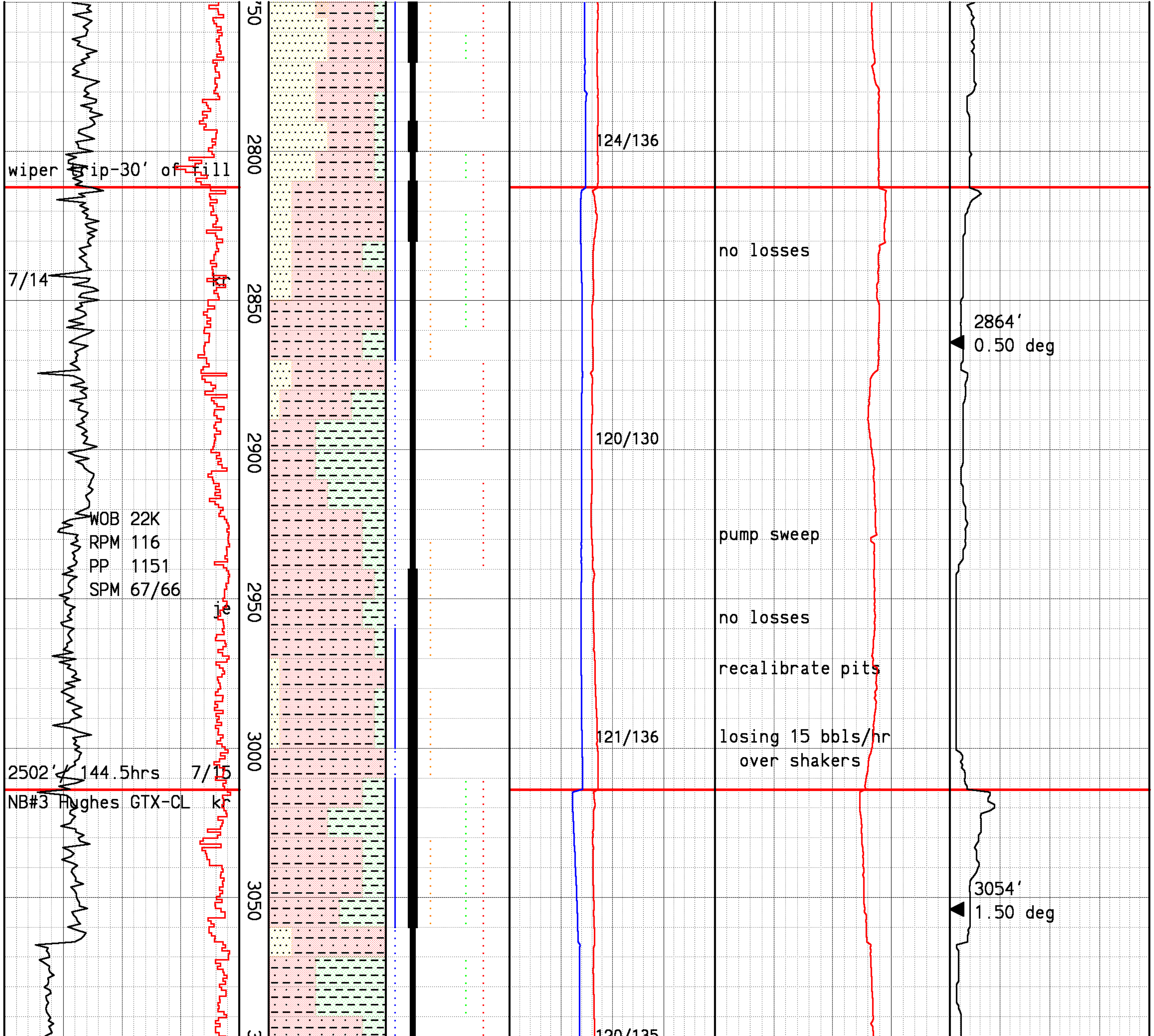
Drilling break at 2447'.
ROP= 63'/hr, WOB= 5K.
No losses associated.

Siltstone:lt gry-med gry,occ rd-brwn,vry sft-mod hrd,loc britt pred smooth text,com clay laminations,r-tr dissem pyr,r loc chalcopyr,r epd, r-tr chlor.

CO2 spike after getting circulation from the trip.

Siltstone:lt-med gry,occ brn, frm-hd,com britt,pred smooth text,com clay lams,mod calc mtx,r-tr dissem pyr,r loc chlor,r loc hem,r-mnr blk organic material, w/Clay:med gry,silty-sandy,sticky,r qtz, mnr calc,loc r pyr,loc r hem.

Siltstone:lt-med gry,loc rd-brn,frm-hd,loc britt,pred smooth text,com clay lams,loc sandy,mod calc mtx,r dissem pyr,r loc chlor,r hem,intrbdd w/Clay:med gry,loc rd-brn, silty-sandy,sticky,r qtz,mnr calc,loc r pyr,loc r hem stn.

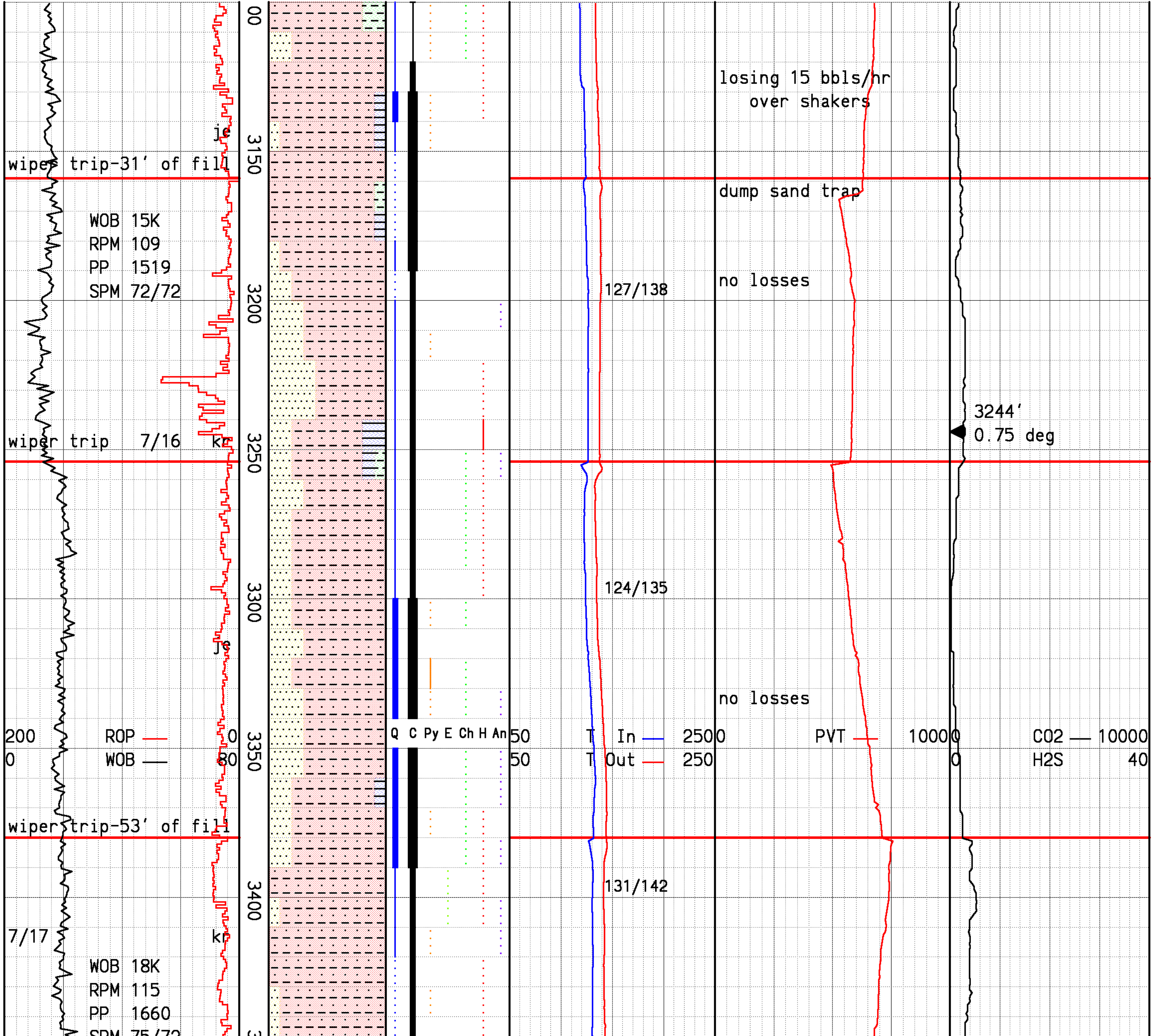


Siltstone:lt-dk gry,loc rd-brn,frm-mod hd,friable,pred smooth text,mnr clay lams, com platy,r loc qtz vn,mod calc mtx,r dissem pyr,r hem, w/abun-10% Clay:lt gry,v sft, v water sol,sticky;intrbdd w/Sandstone:wht,lt-med gry, speckld w/blk mafics,hd,dom clr-wht qtz grs,com prly indurated,fn gr,loc bedding, r-tr qtz agg,com calc cmt,r pyr agg,r loc chlor stng.

Siltstone:lt-dk gry,loc rd-brn,frm-mod hd,loc friable, pred smooth text,mnr clay lams,com platy,r qtz vn,mod calc mtx,r dissem pyr,loc r hem,intrbdd w/Clay:lt gry,loc rd-brn,sticky,v sft,r qtz,mnr calc,r pyr,loc r hem.

21' of fill after trip.

Siltstone:lt-med gry,loc rd-brn,frm-mod hd,pred smooth text,loc mnr clay lams,com platy,abund Sandstone,r qtz vn,mod calc mtx,r dissem pyr, r chlor,loc r hem,intrbdd w/



Clay:lt gry,loc rd-brn,sticky v sft,r qtz,mnr calc,r pyr,r chlor,loc r hem.

Tight spot at 3080' and 3123' after trip.

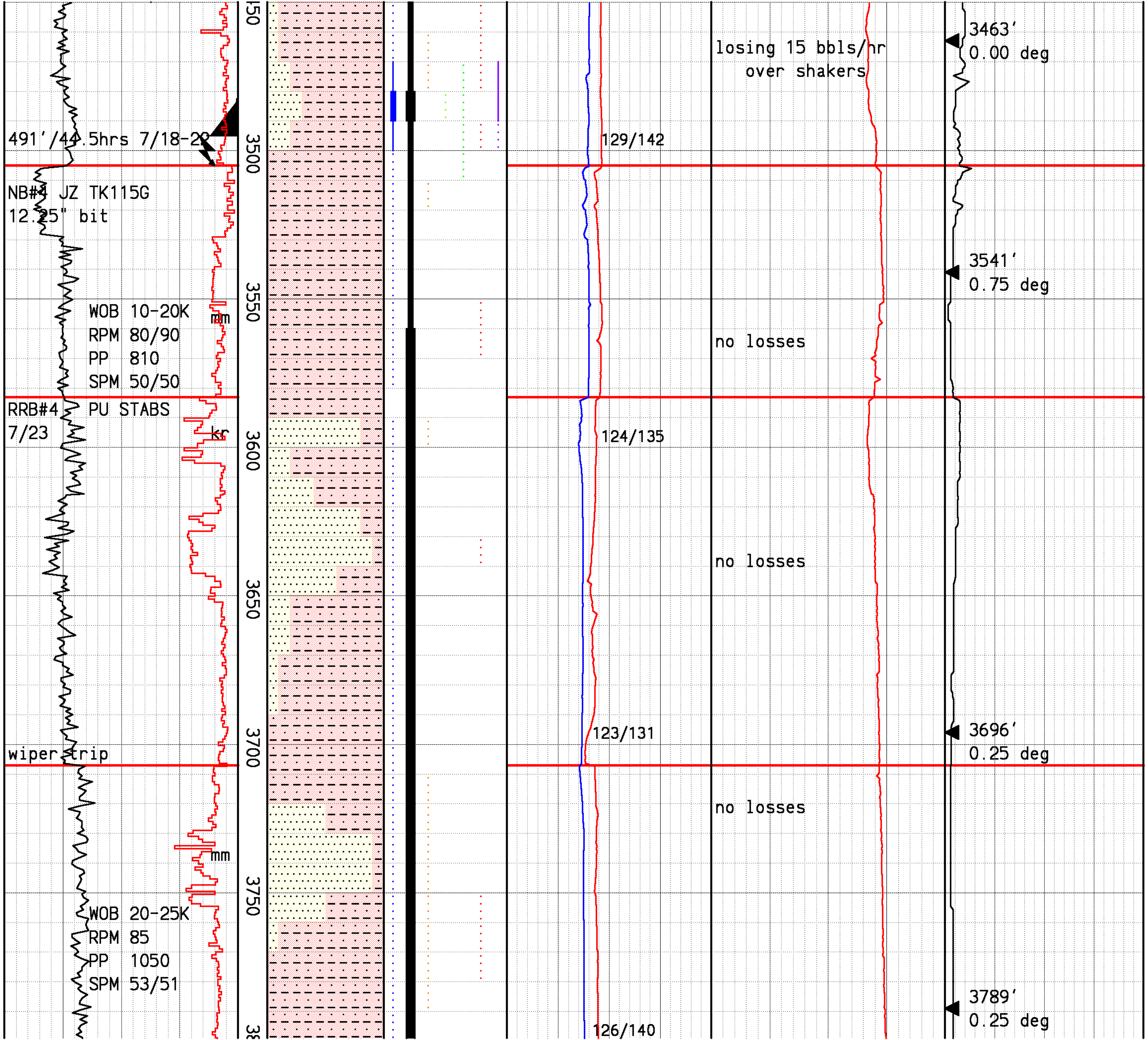
Siltstone:lt-med gry,brn,rd-brn,mod hd-v hd,dom britt, smooth text,tr lt/dk banding, com platy,r qtz vn,str calc mtx;intrbdd w/Sandstone:wht, loc lt gry,com speckld w/blk mafics,com sugary appr,v hd, occ friable,well indurated, fn gr,r-tr qtz agg,mnr calc cmt,r loc pyr,r loc anhyd.

Drilling break at 3226'. ROP= 66'/hr, WOB= 4-7K. No losses associated.

Siltstone:lt-med gry,brn,rd-brn,mod hd-v hd,com britt, smooth text,r lt/dk banding, mnr platy,r qtz vn,str calc mtx,tr-abun Claystone frags; intrbdd w/Sandstone:wht,loc lt gry,com speckld w/blk mafics,com sugary appr,v hd, occ friable,well indurated, fn gr,mnr qtz agg,mnr calc cmt,r loc pyr,r chlor stng,r anhyd,r Conglomerate frag,r-mnr blk organic material.

Tight spot at 3327' after trip.

Siltstone:lt-med gry,brn,rd-brn,mod hd-v hd,red-brn,tr lt/dk bndg,r qtz vn,str calc mtx,r pyr,loc r hem,loc r



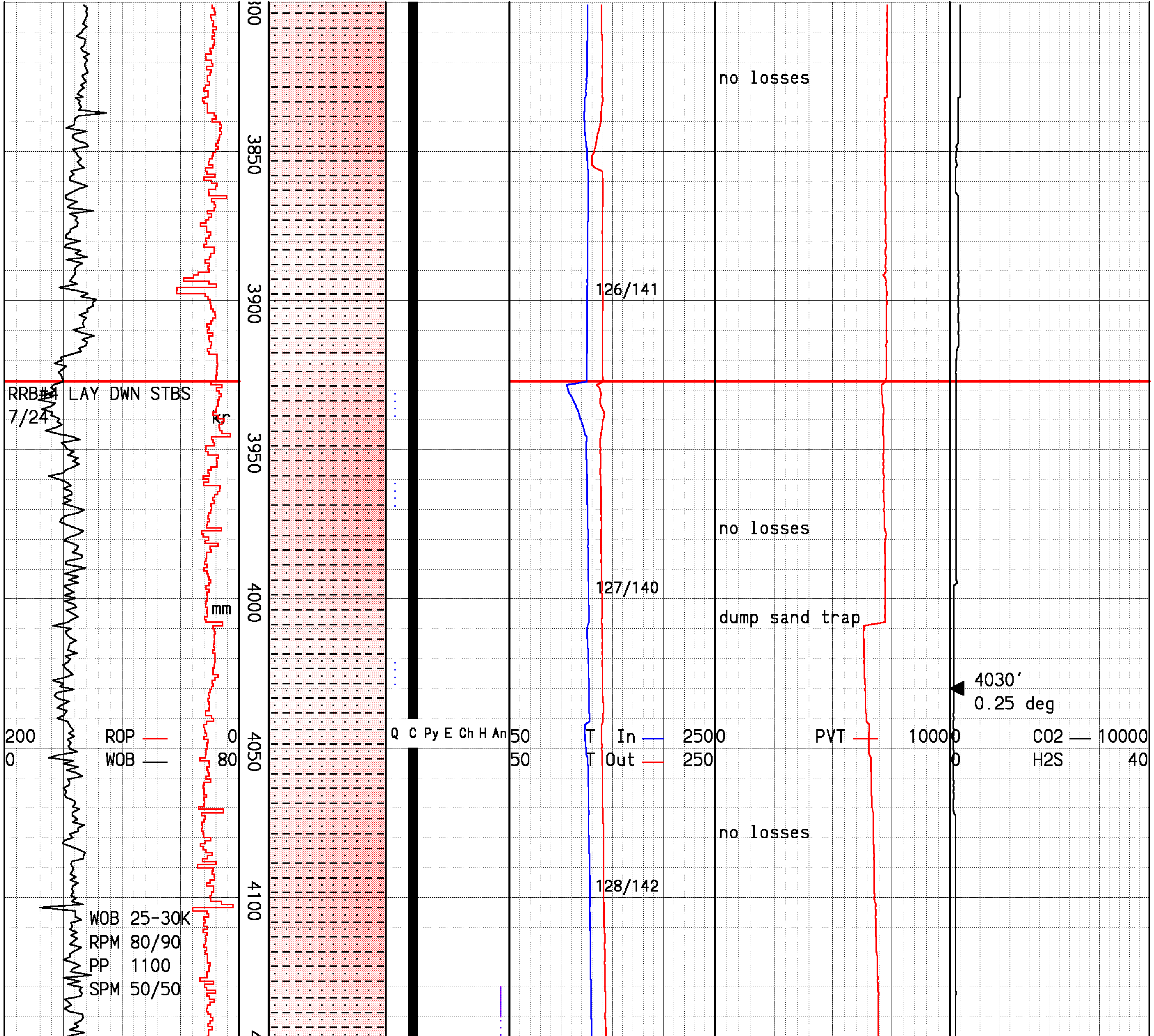
epid;intrbdd w/Sandstone:wht, loc lt gry,com speckld w/blk mafics,v hd,occ fri,fn gr,r qtz agg,mnr calc cmt,r loc pyr,loc r chlor wash,r loc anhyd.

Drill 17.5" hole to 3505'. Well began flowing 80 bph with high CO2. Run E-logs. Run 86 joints of 13.375", 68#, K-55 BTC casing to 3495'. One top job brings cement to the surface. Drill ahead with 12.25" bit.

Sandstone:wht,lt gry,friable, hd,mod well srtd,subang-sub rndd,fn gr,r qtz agg,mnr-com calc cmt,loc r chlor wash,r loc anhyd,intrbdd w/ Siltstone:med gry,mod hd-v hd,loc lt/dk bndg,r fine qtz vn,str calc mtx.

Siltstone:med-dk gry,loc sandy,frm-hd,platy,loc fine lams,qtz agg,abun sandstone, r qtz,com calc mtx.

Sandstone:pred wht,v lt gry, frm,v fri,com disagg grs,pred qtz & felds grs,v fn-fn gr, abun grdg to crs silt,subang-rndd,mod srtd,r qtz agg,mnr-com calc cmt,r disem/cube pyr,loc hem stng,mnr v fn blk



org mat.

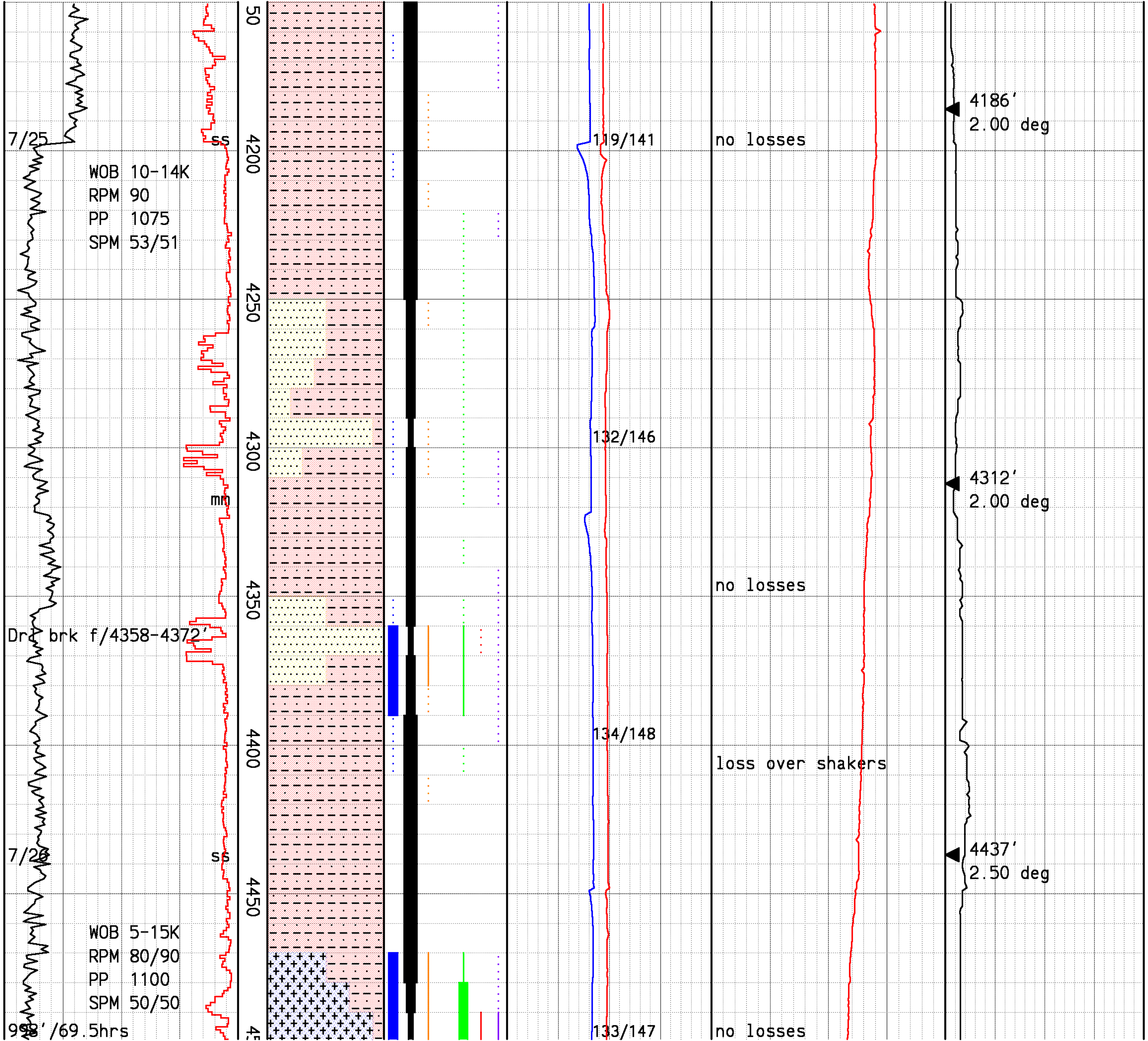
Siltstone:med-dk gry,occ red brn,frm-mod hd,mass,mod-str calc clay mtx,sl fiss,occ lams,pred platey ctgs,r disem & agg pyr,mnr v fn blk org mat.

Siltstone:med-dk gry,frm-mod hd,mass,mod-str calc clay mtx,loc crs silt grs,sl fiss,occ fine lams,pred platey ctgs,absnt-r qtz.

Siltstone:med-dk gry,frm-mod hd,mass,mod-str calc clay mtx,loc fn sndy beds,sl fiss,occ fine lams,pred platey ctgs.

Siltstone:med-dk gry,pred mod hd,abun brittle,mass, mod-str calc clay mtx,loc crs silt grs,sl fiss,occ fine lams,pred platey ctgs, loc r qtz agg.

Siltstone:med-dk gry,frm-mod hd,mass,mod-str calc clay mtx,loc crs silt grs,sl fiss,occ fine lams,pred platey ctgs,loc r silic qtz agg, com-abun wht calc vng



w/poss brn sphal,r-tr fib
anhyd.

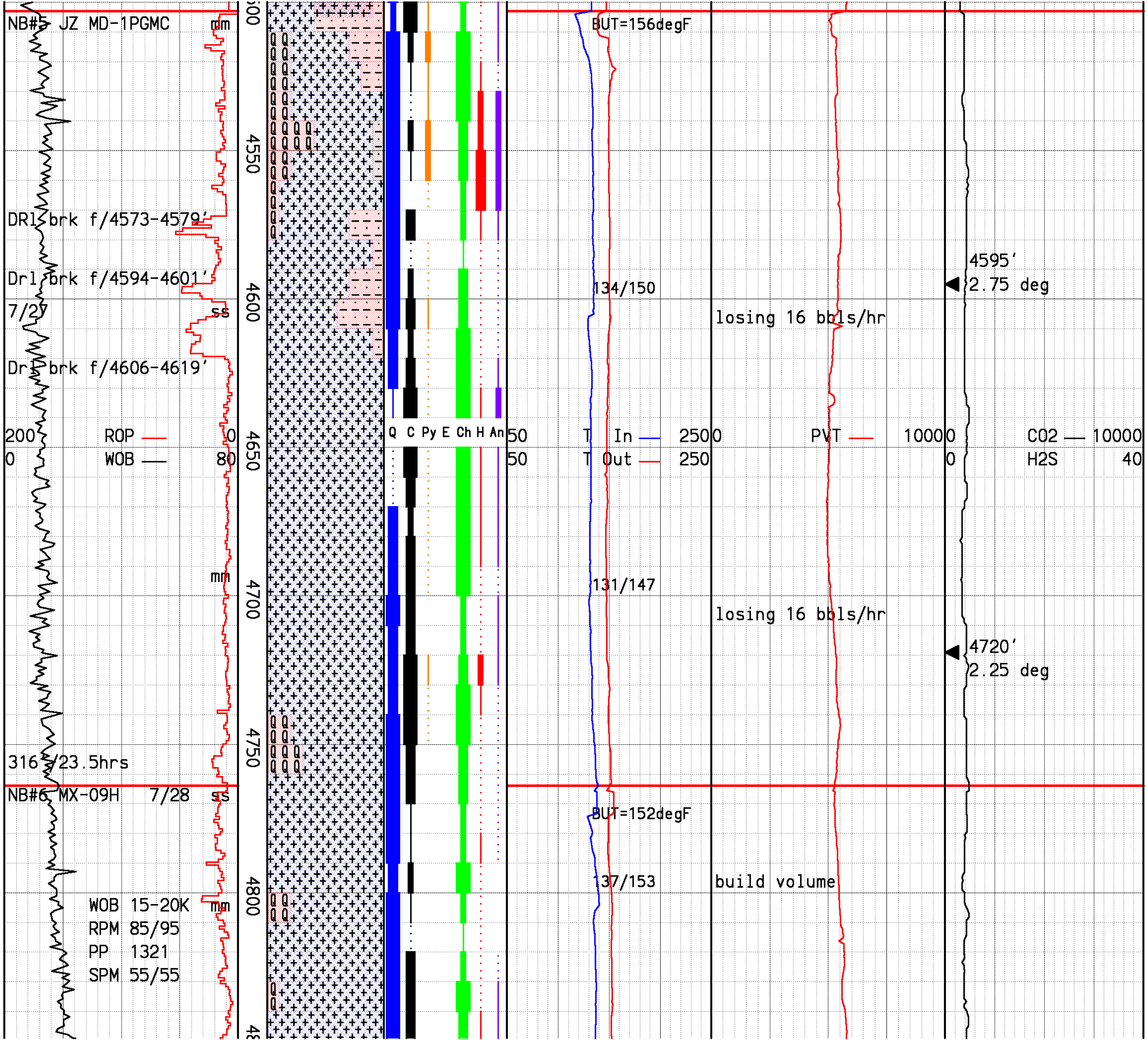
Tight spots during wiper trip from 3740-3770' and 3850-4180'.

Siltstone:med-dk gry,becoming lighter gry w/depth,r sl mint grn,frm-mod hd,mass,str calc clay mtx,loc crs silt grs,sl fiss,loc fine lams,pred plty ctgs,loc qtz microvng,loc chlor wash.

Sandstone: pred wht,frm,fri, abun-pred disagg clr qtz grs, com wht felds grs,v fn-fn gr, subang-rndd,mod-well srtd,loc r qtz overgrowths,wk calc cly cmt,tr disem/cube pyr,r-tr chlor wash,loc r hem,r anyhd.

Siltstone:lt gry-lt grn,mod hd-hd,mod altrd,sl-mod silic, r clr/wht qtz vng,r-tr disem/ cube pyr,tr chlor wash,r wht anhyd.

Siltstone:dk gry,frm-mod hd, mass,mod-str calc clay mtx, loc crs silt grs,loc fn lam, pred plty ctgs,abs-loc disem pyr.

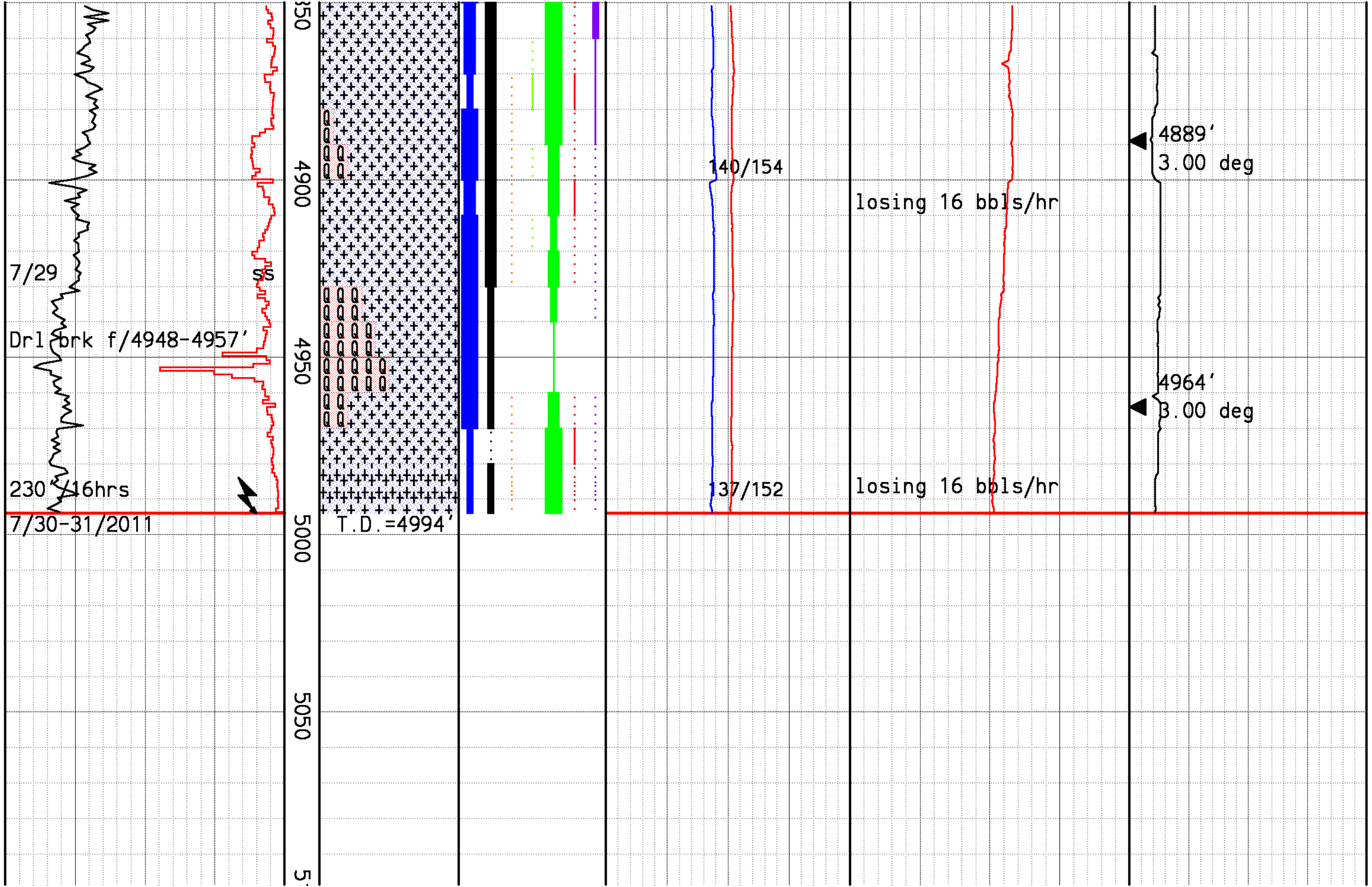


Granodiorite:wht,lt grn,lt orng brn,mod hd-hd-v hd,str-v str altrn,mod-v str silic, mod-str chlortzn,mod str-perv blchd appr,pr-indist-absnt gr bndrs,abun-40% qtz vng,r-tr euhed/drusy qtz xtls up to 4mm,tr-mnr disem/vn/cube pyr, mnr-abun chlortzd grs/wash,r-com hem/stng,tr-mnr anhyd,tr-abun clay altrn.

Granodiorite:wht,v lt-lt grn, mod hd-hd,loc fri,com v hd, mod-v str altrn,mod-str silic,mod-str chlortzn,mod-str blchd appr,pr-absnt gr bndrs,abun mass wht qtz,r-tr euhed/drusy qtz,com-abun intrstit calc,r-tr disem/cube pyr,com-abun chlortzd grs/ wash,r-com hem altrn/stng,tr-mnr anhyd.

Granodiorite:wht,v lt grn,hd-v hd,str altrd,v str silic, mod-str chlortzd,v str blchd appr,pred absnt gr brndrs, abun-25% mass wht qtz,r-tr euhed qtz xtls,com-abun intr-stit calc,r-tr disem/cube pyr,com-abun chlortzd grs/ wash,r-tr hem stng,r anhyd, com-abun clay altrd felds.

Granodiorite:med-dk gry grn, med-dk gry,wht,mod hd-hd,abun v hd,sl-pred mod altrd,v str silic in part,pred mod chlor-tzd,aphan,pred fn gr dk mafic mnrls w/v fn gr felds & qtz



xtls,mnr-20% mass wht qtz,tr-com intrstit calc,r-tr disem/vn yel epid f/4870',mnr-abun chlortzd mafics,r-tr spec hem w/vng/stng,absnt-tr anhyd,tr-abun wht clay altrd felds grs w/speckled appr,r fn disem magn.

Granodiorite:med-dk grn gry, wht,lt gry,mod hd-hd,abun v hd,pred str altrd,v str silic,mod-str chlortzd,aphan in part,abun fn gr dk mafic mnrls w/fn gr qtz & felds xtls,pred absnt gr brndrs, abun-50% mass wht qtz,r euhed qtz xtls, mnr-com intrstit calc,r disem/cube pyr,com-abun chlortzd grs/wash,r-tr hem vng/stng,r anhyd,com-abun clay altrd felds.

Drill 12.25" hole to 4994' losing 16 BPH. Run wireline logs. Run injection test: 4bbls/min @360psi. Change well bore over to brine.

Processing Report for

Ormat Technologies

Imperial Valley, CA

3D 3C Wister Survey

Processed By

FairfieldNodal

1776 Lincoln St., Suite 1200

Denver, CO 80203

January, 2012

RECORDING PARAMETERS

A. <u>Contractor</u>

Company	: Dawson Geophysical Company
Date Acquired	: July 2010

B. <u>Recording Parameters</u>

Instruments	: GSR
Max. No. of Recvs	: 924
Sample Rate	: 2 msec.
Listening Time	: 6 Sec.
Data Format	: SEGY

C. <u>Field Filters</u>

Low Cut	: out(3) Hz. 40 Db. /sec.
High Cut	: 207 Hz. 298 Db./sec.
Pre Amp Gain	: 36 Db.

D. <u>Source Parameters</u>

Energy Source	: Vibroseis
Source Interval	: 220 Ft.
Vibrator Model	: AHV-IV
Sub-array length	: Inline Stack over 82.5 ft.
Sweeps/VP	: 4
Sweep control	: Fund. Force Control
Phase Lock	: Ground Force
Number of vibrators	: 2 set of 2
Sweep duration	: 8 sec
Tapers	: .3 ms / .3 ms.
Sweep Frequencies	: 4 – 96 HZ

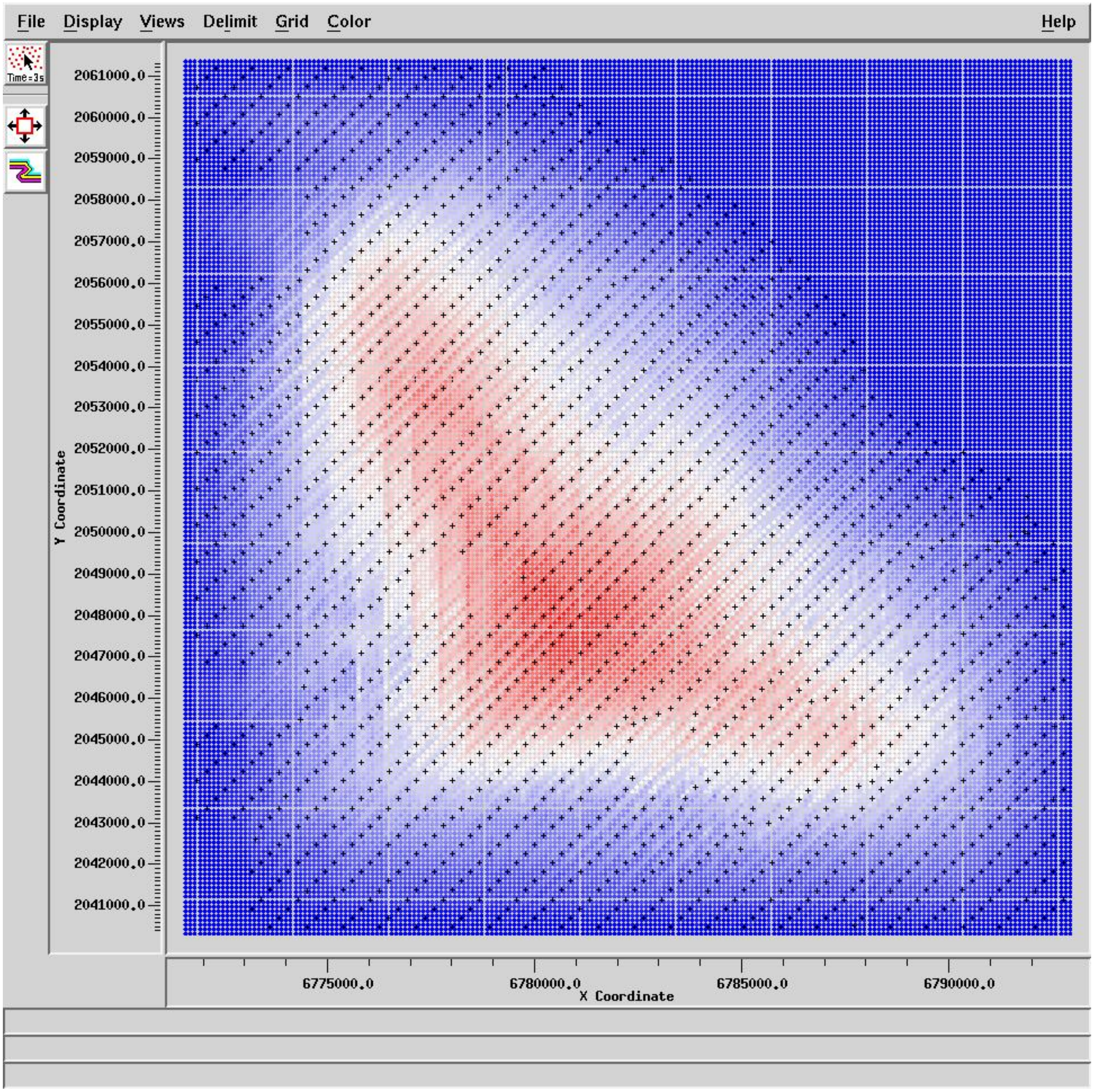
E. <u>Receiver Parameters</u>

Geophone Type	: 3C / 10 HZ
Station Interval	: 311 Ft.
Resonant Frequency	: 10 Hz
Geophone Array	: Single 3C phone
Array Length	: 1
Geophones/Station	: 1

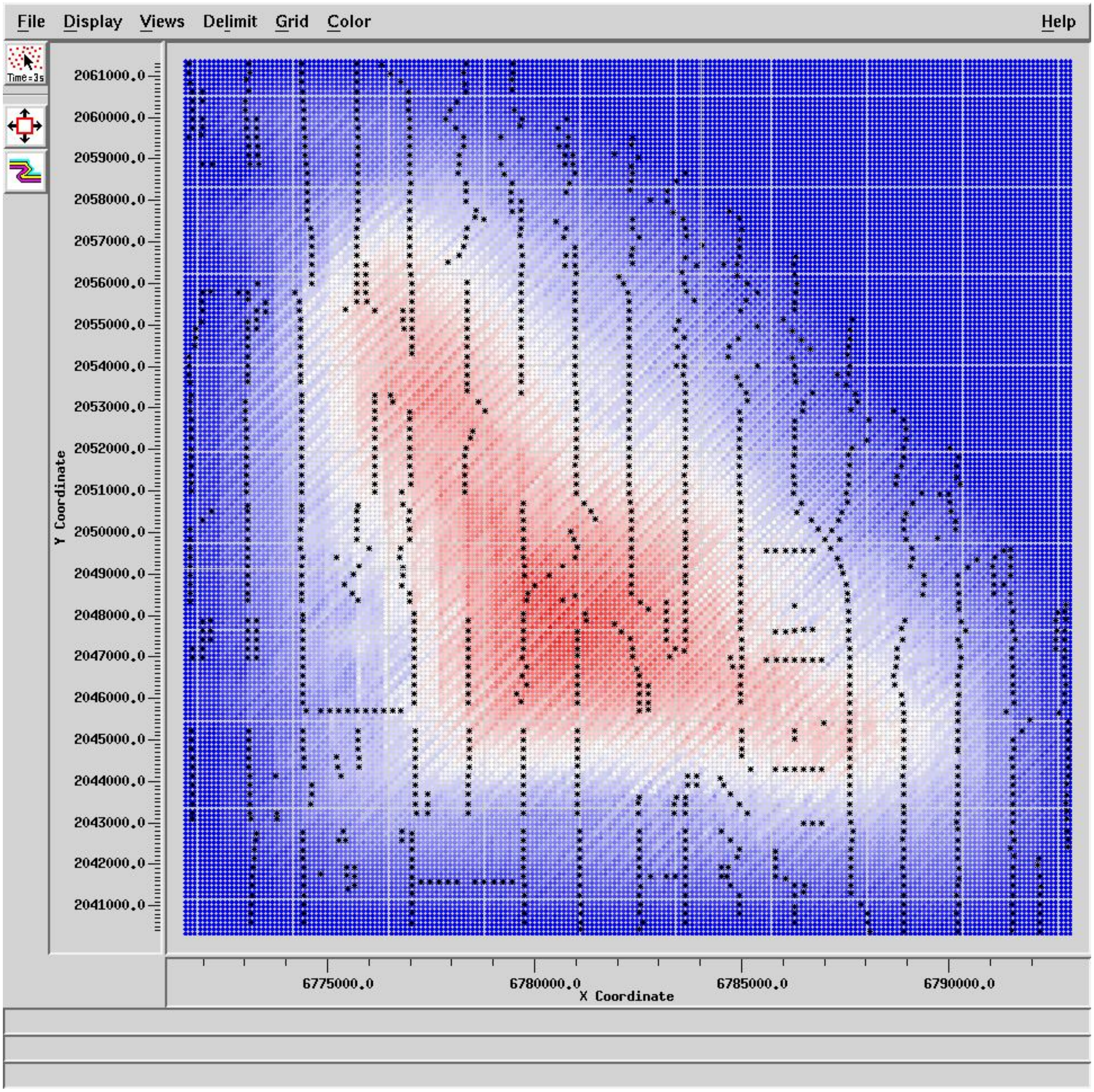
F. <u>Geometry</u>

Channels per Source	: max 924 x 3

Survey:

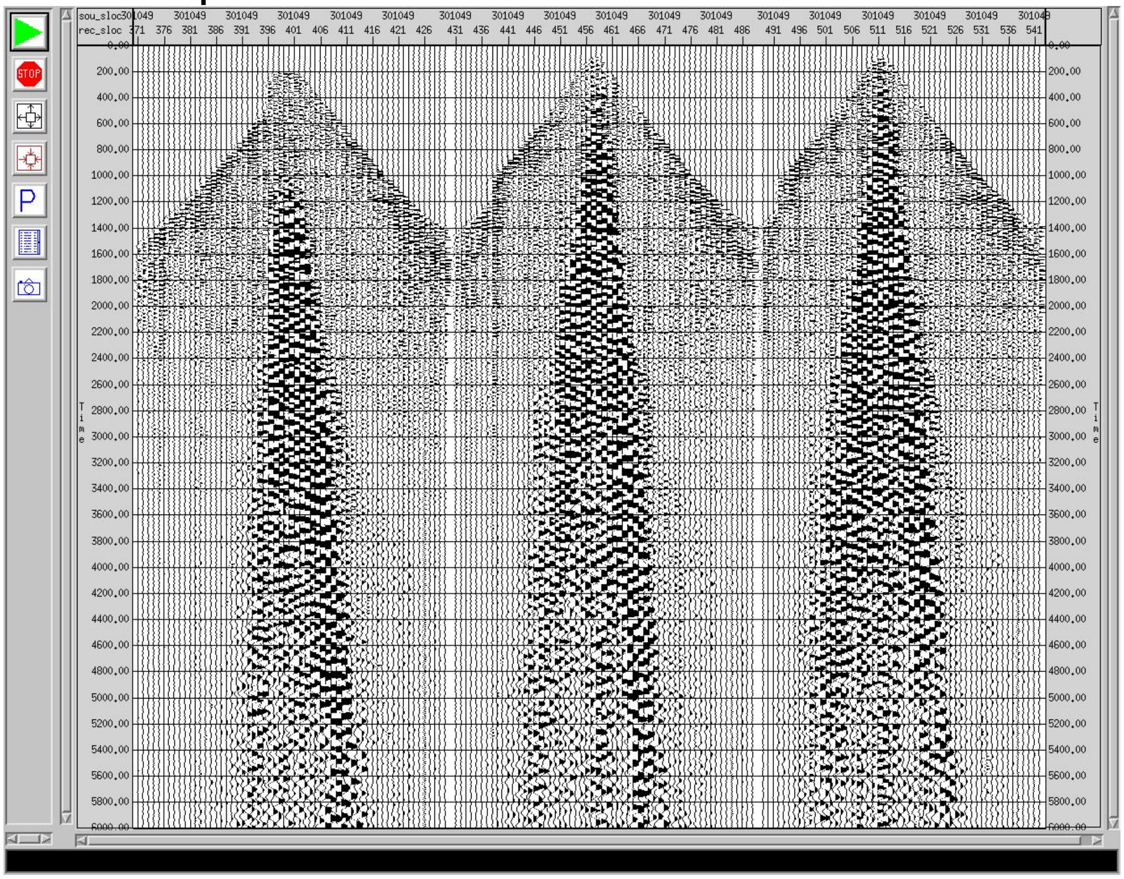


Receiver locations and CDP Fold (Max Fold 75)



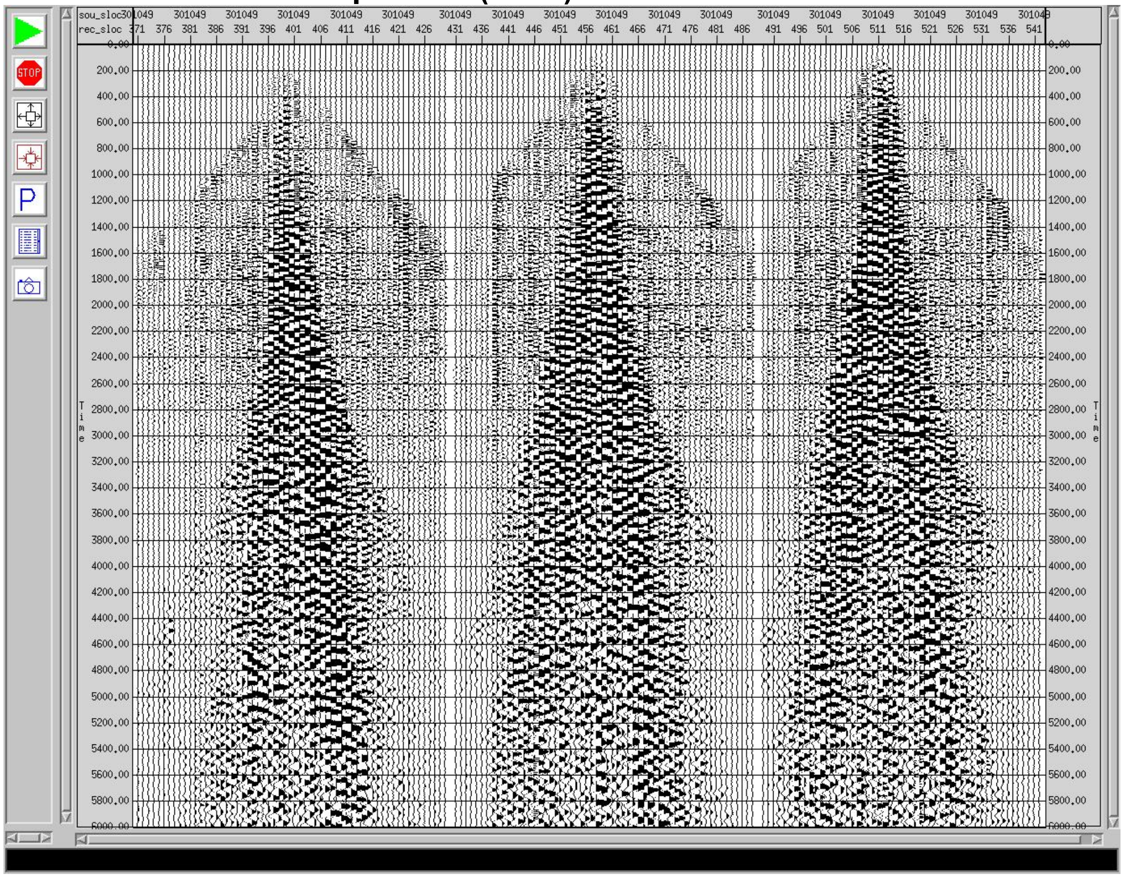
Source Location

Data Quality:
Vertical Component:



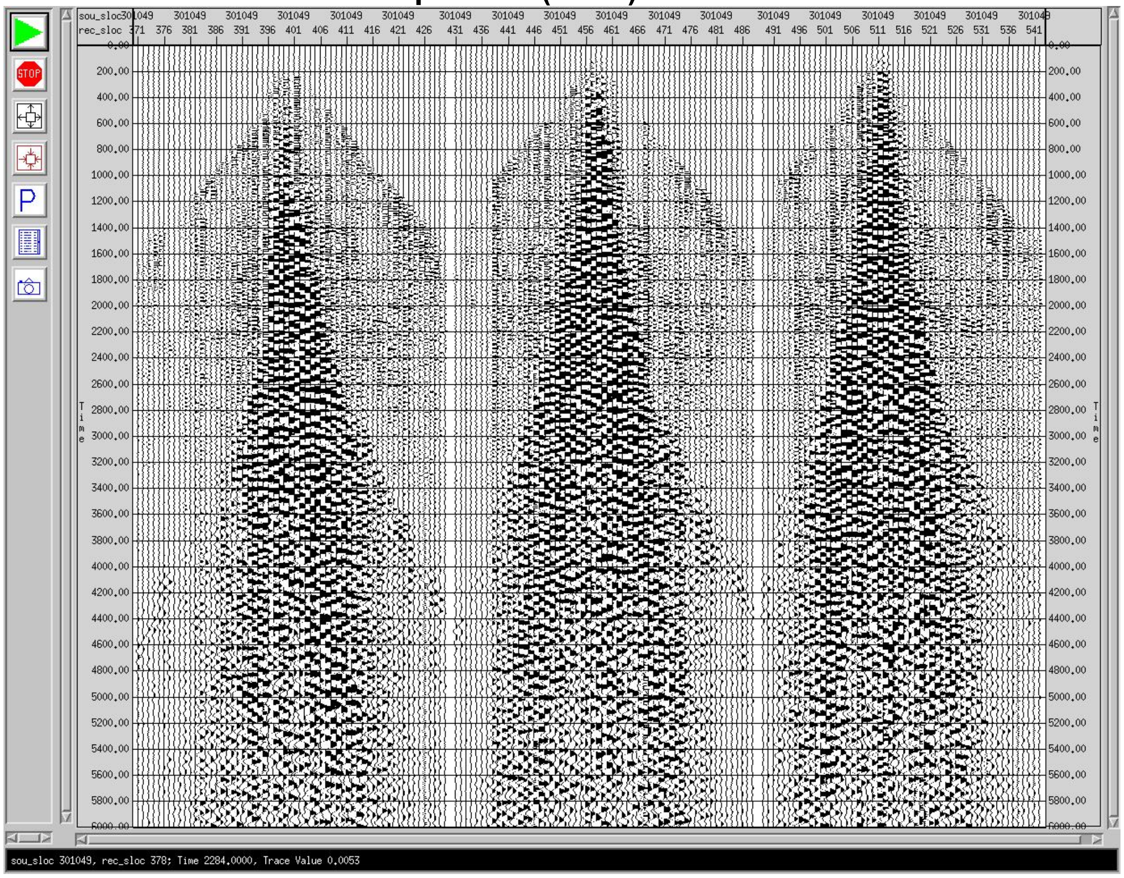
True Amplitude Display. High Amplitude, low velocity noise.

Horizontal In Line Component: (P-SV)



P wave contaminated. Weak coherent Converted wave reflected energy.

Horizontal Cross Line Component: (P-SH)



The converted wave energy appears stronger on the cross line phones then the in line phones suggesting a subsurface median highly anisotropic. In an isotropic median, converted wave energy would be nearly absent on the cross line phones when the phones are in the Transverse direction. Here they are since I have chosen the receiver lines closest to the source.

The processing approach taken when processing 3C 3D projects, is to first process the P-Wave data, resolve the P Wave velocity and statics required to image the Vertical component and then begin the processing of the converted wave energy, using the P Wave velocity function and the P Wave Statics derived during processing.

The first section of this report will be the P Wave Processing Sequence, with diagnostic displays, followed by the C Wave Processing Sequence.

P Wave Processing Sequence, and Diagnostic Displays.

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Geometry Description and Application

Geometry was described in the trace headers as well as supporting SEGP1 files. The technician loads this information, and then verifies the provided information by QC'ing the field records. Verification includes visual inspection of the field records with a linear moveout applied, QCing the moved out data with errant arrival times of the direct arrivals. During inspection traces noisy traces are removed and shots incorrectly recorded are edited.

Datum Static Parameters

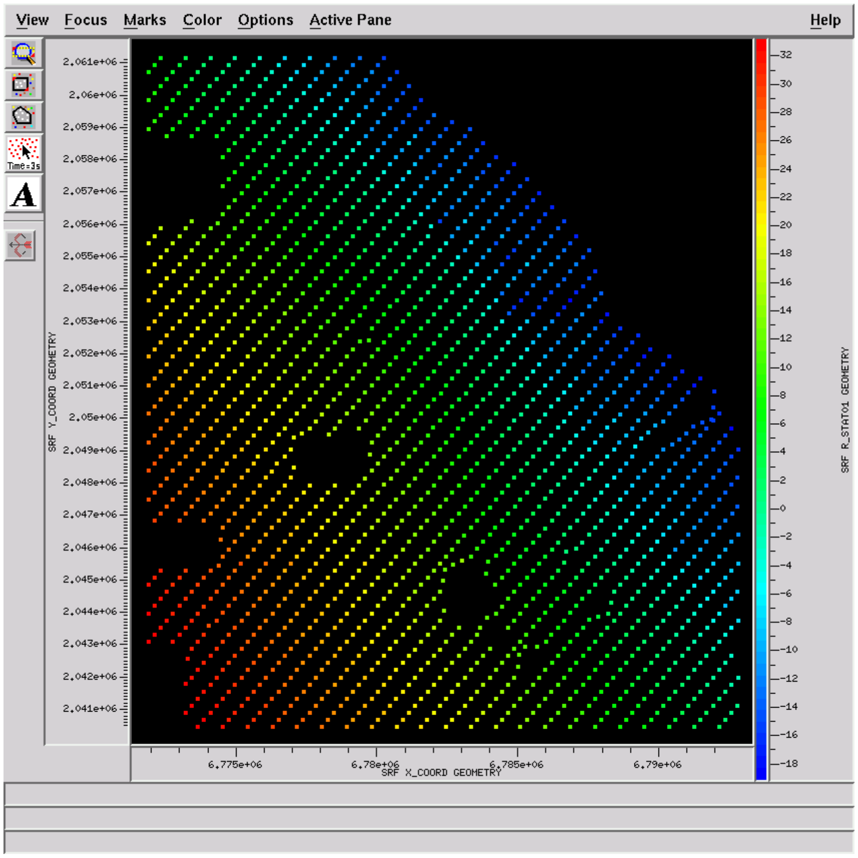
Datum Elevation 0 (Sea Level)
Replacement Velocity 5500 ft/sec.

A pre stack datum is used to correct the gathers with NMO. The Final Datum Static is subtracted from the average Datum static at each CDP.

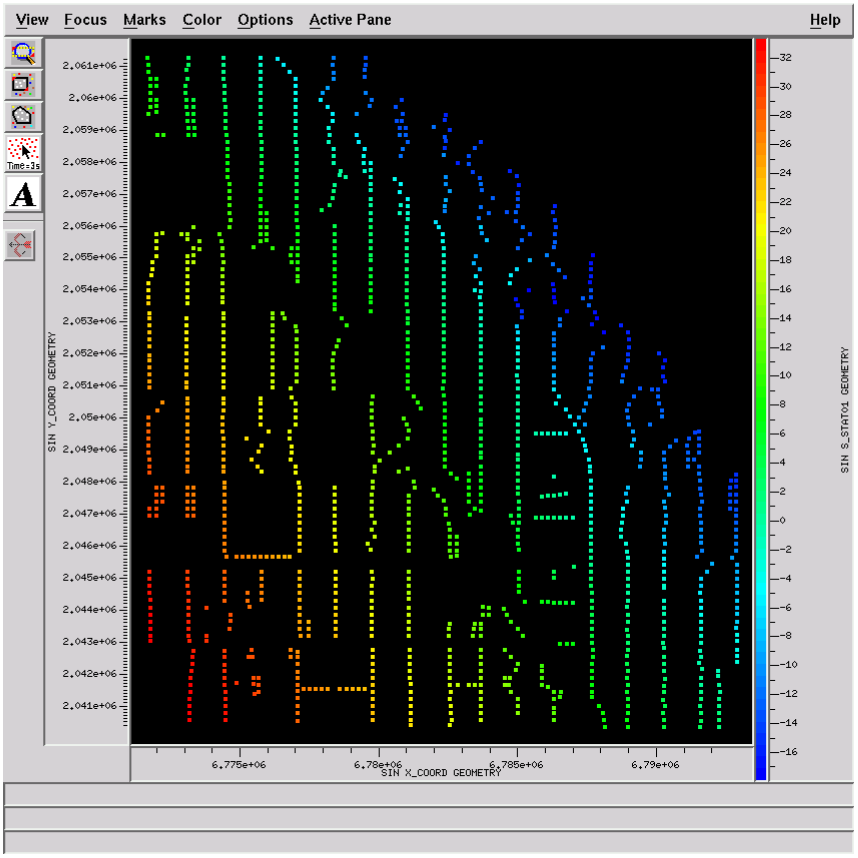
Pre Stack Datum Static = Final Datum Static – Average datum static at CDP

Post Stack Datum Static = Average datum statics at CDP
Receiver Static

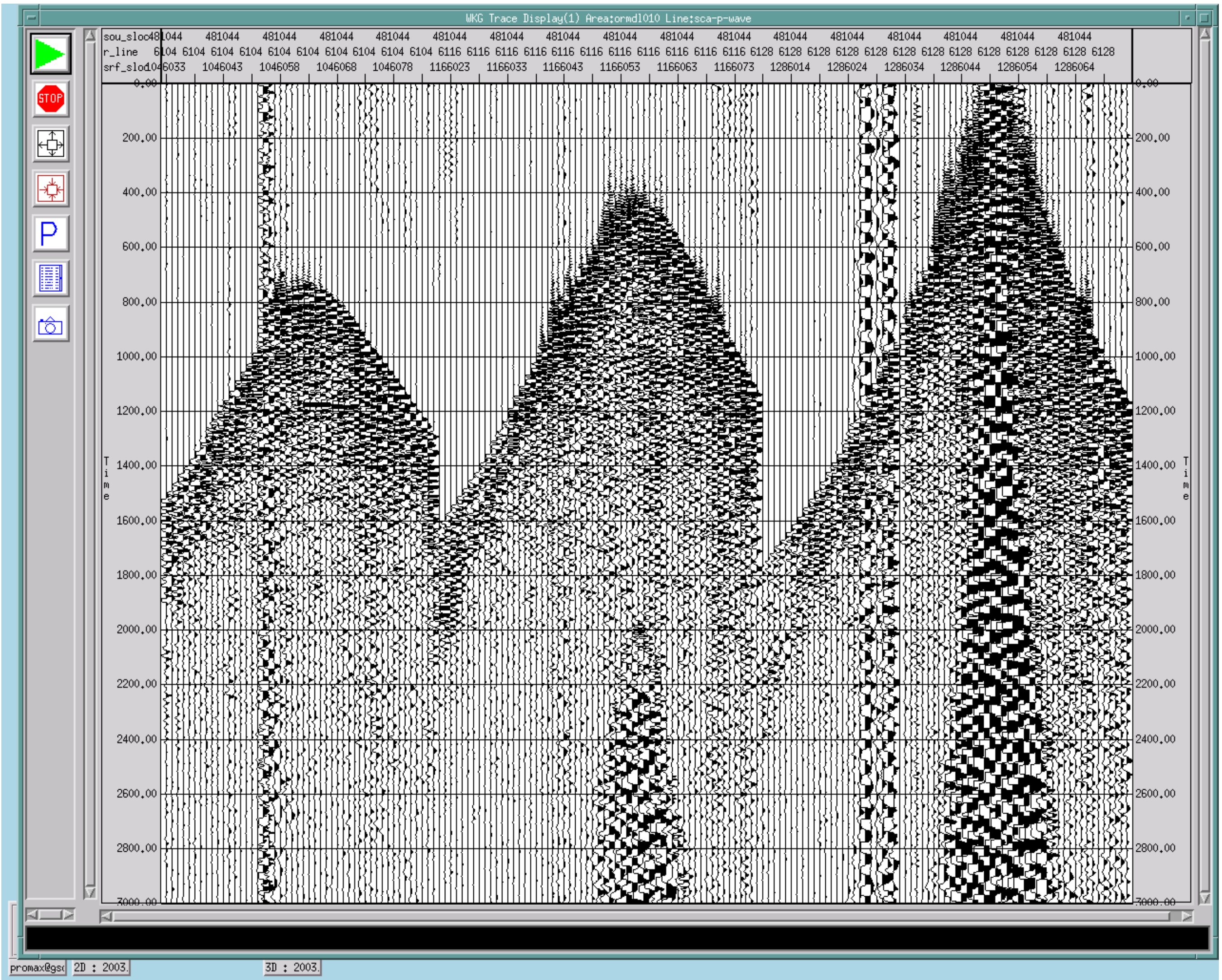
RECEIVER STATICS



SOURCE STATICS

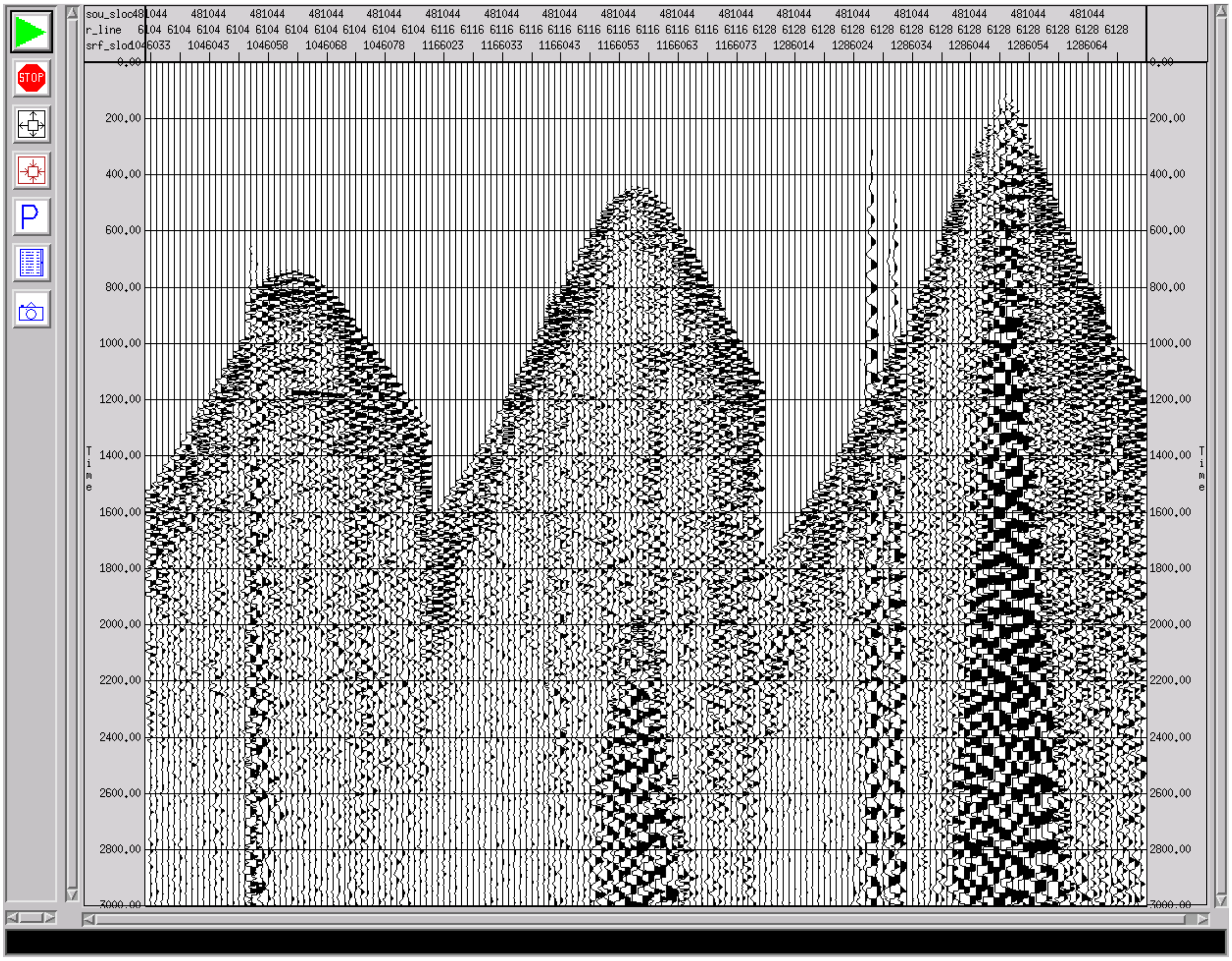


FIELD DATA



A Source Record with 3 of the 14 receiver lines illustrates the
Following applications applied. Near, middle and far receiver line are selected for this illustration.

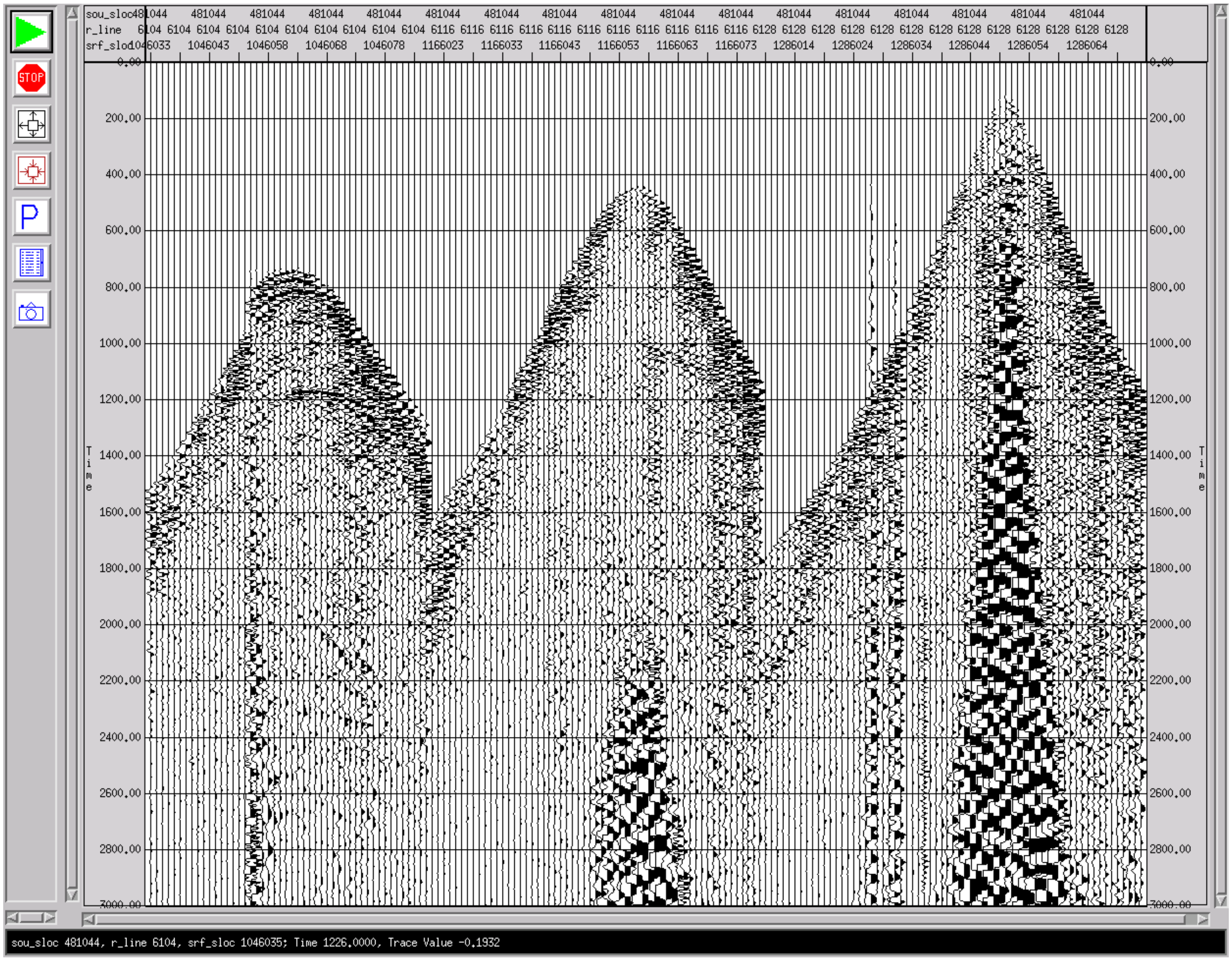
TRUE AMPLITUDE RECOVERY



A Time raised to a power correction Time $^{XX1.8}$.to 2.5 sec.

MINIMUM PHASE FILTER APLICATION

ENSEMBLE DECONVOLUTION



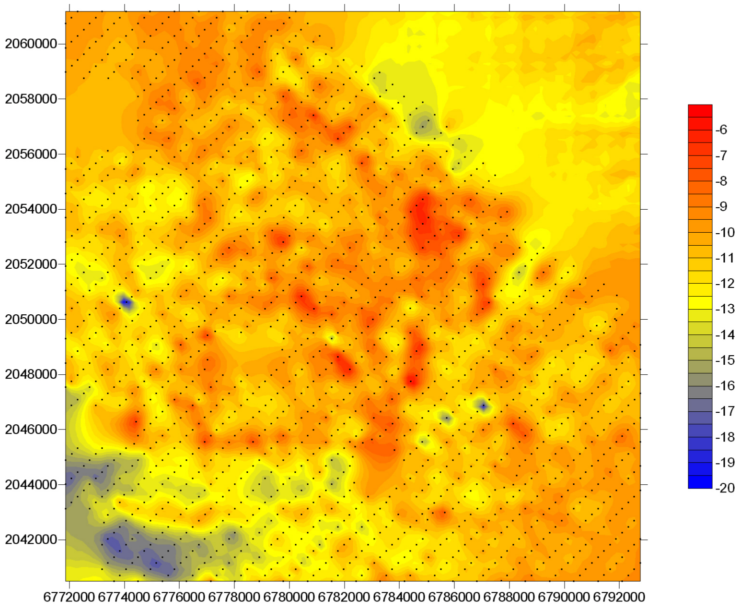
The Minimum phase filter is applied to correct the data to minimum phase. During the sweep and correlation process performed in the field, the data is a mixed phase. The combination af the minimum phase filter application and the Spiking Deconvolution application the resultant phase of the data is zero.

Deconvolution Parameters:

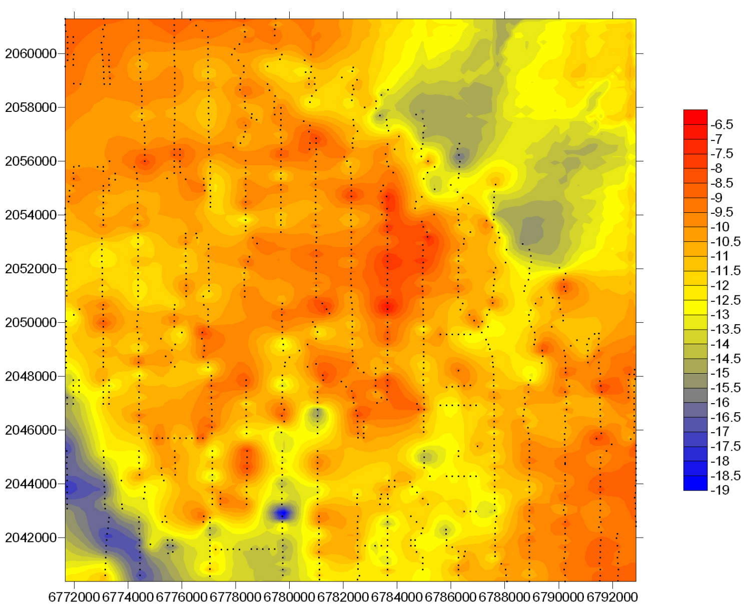
Ensemble Source/Receiver Line

No. Tr. Average:	11
Operator Length:	120 ms.
% WN:	.01
Gate:	200 – 3500 ms, below first breaks

SURFACE CONSISTENT AMPLITUDE CORRECTIONS



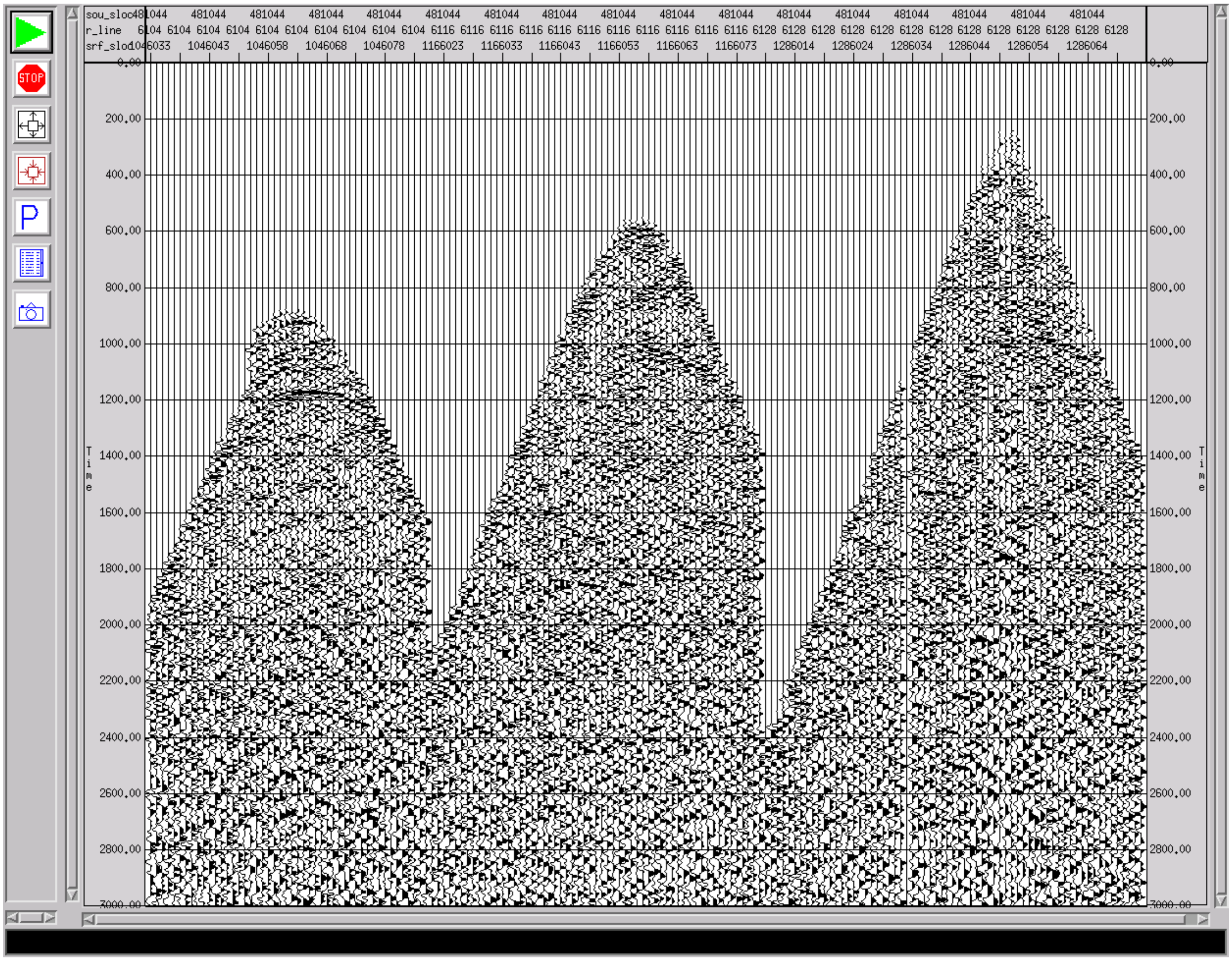
Receiver Corrections in Db



Source Corrections in Db

An rms amplitude level of the traces are measured, and Surface Consistent measurements are removed from the data.

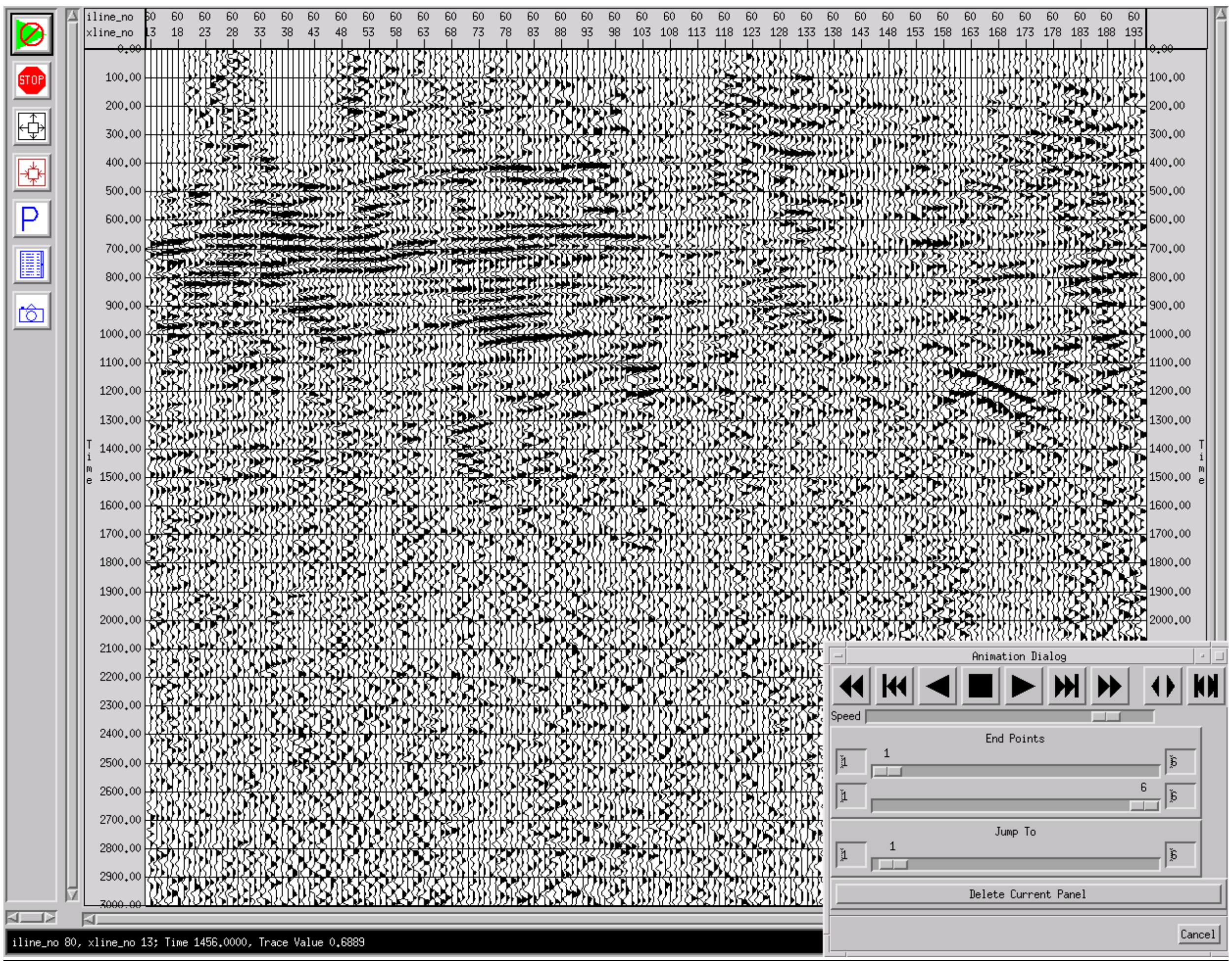
Frequency Dependent Diversity Scaling



Frequency dependent Diversity scaling has also been applied. Comparing this to the previous illustration shows the results. The high amplitude undesireable ground roll energy has been basically eliminated. The remaining energy appears to be downgoing p wave energy and ambient non-coherent noise, the non coherent ambient noise will be attenuated with CDP stack.

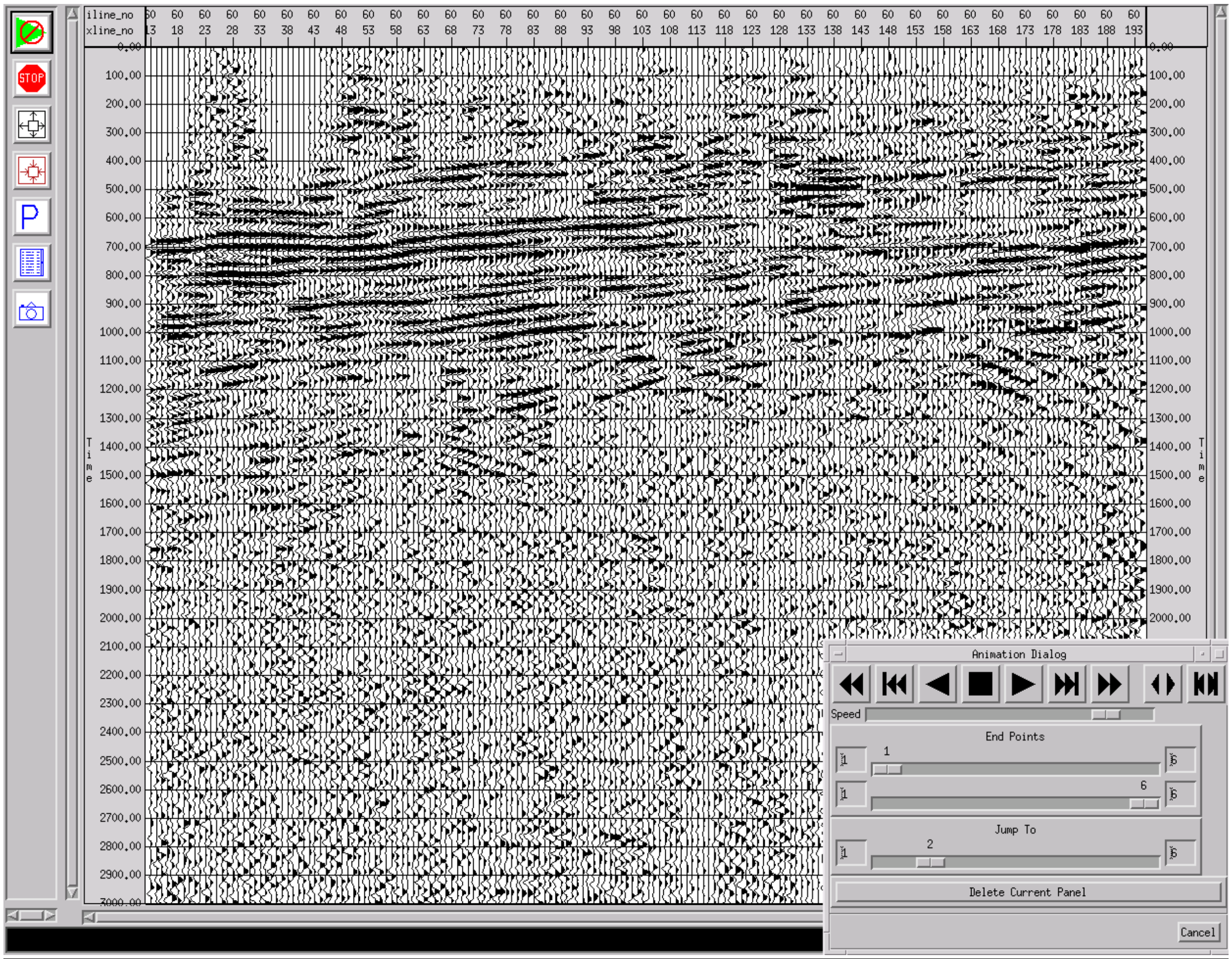
The following illustrations are representative stacks after various stages of the iterations resolving the residual statics and stacking velocities. A final mute, and post stack enhancements are also determined during this stage of the processing sequence. Once a satisfactory solution is obtained the pre stack gathers with the results from the residual statics iterations are input to the Kirchhoff Pre Stack Migration.

<u>Elevation Statics Stack</u>



To verify the refraction statics solution comparisons are made of the stacks. Elevation Statics vs. Refraction Statics. This illustration, and the following one illustrate the improvement in the stack response after the application of refraction statics.

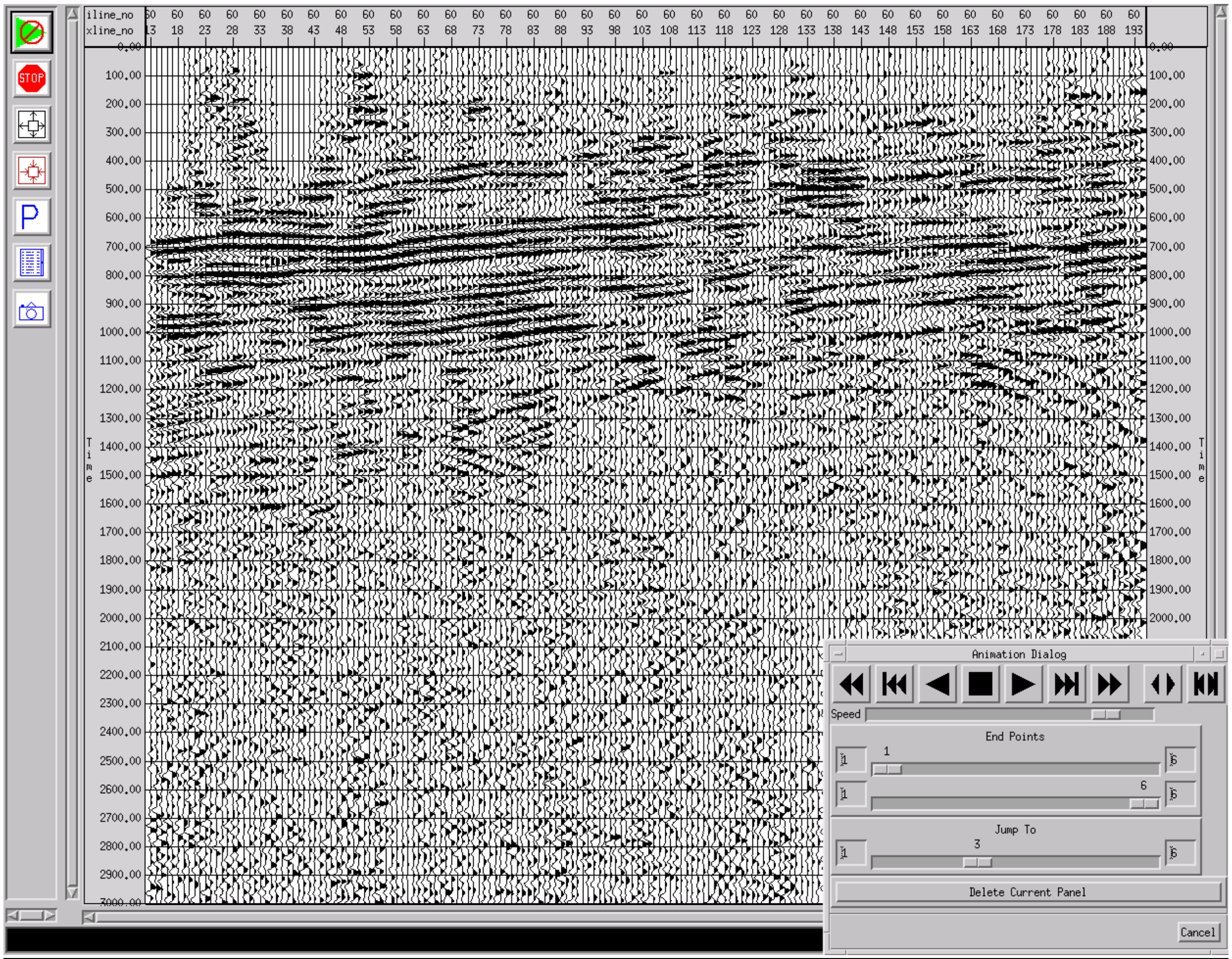
Refraction Statics Stack



A limited offset range of first break picks were used to model the first refractor, The delay times, and the refractor velocity are used to compute a near surface model which is used to recomputed a datum static.

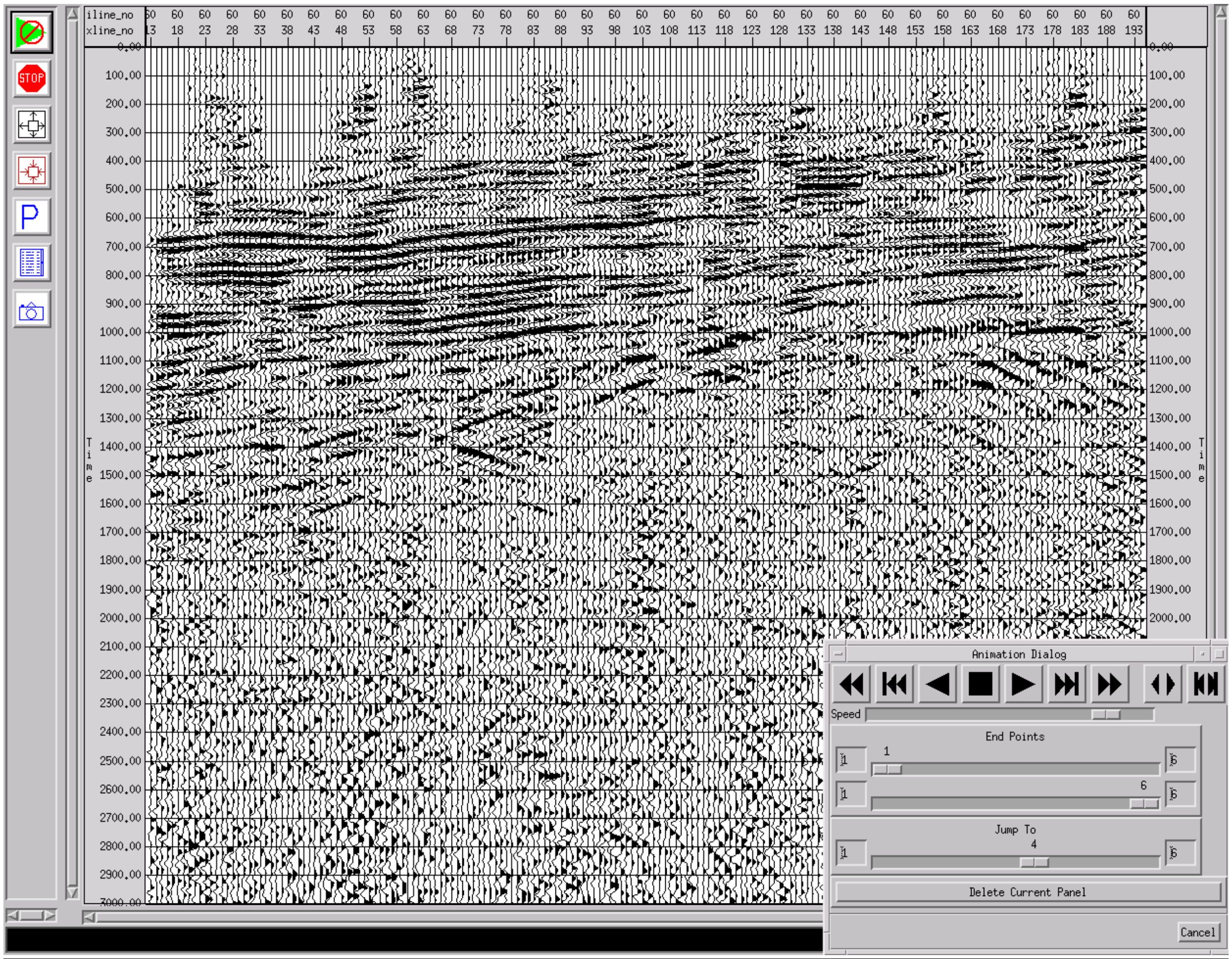
1st Pass Stacking Velocity Analysis by Constant Velocity Stack

1st Pass Surface Consistent Residual Statics



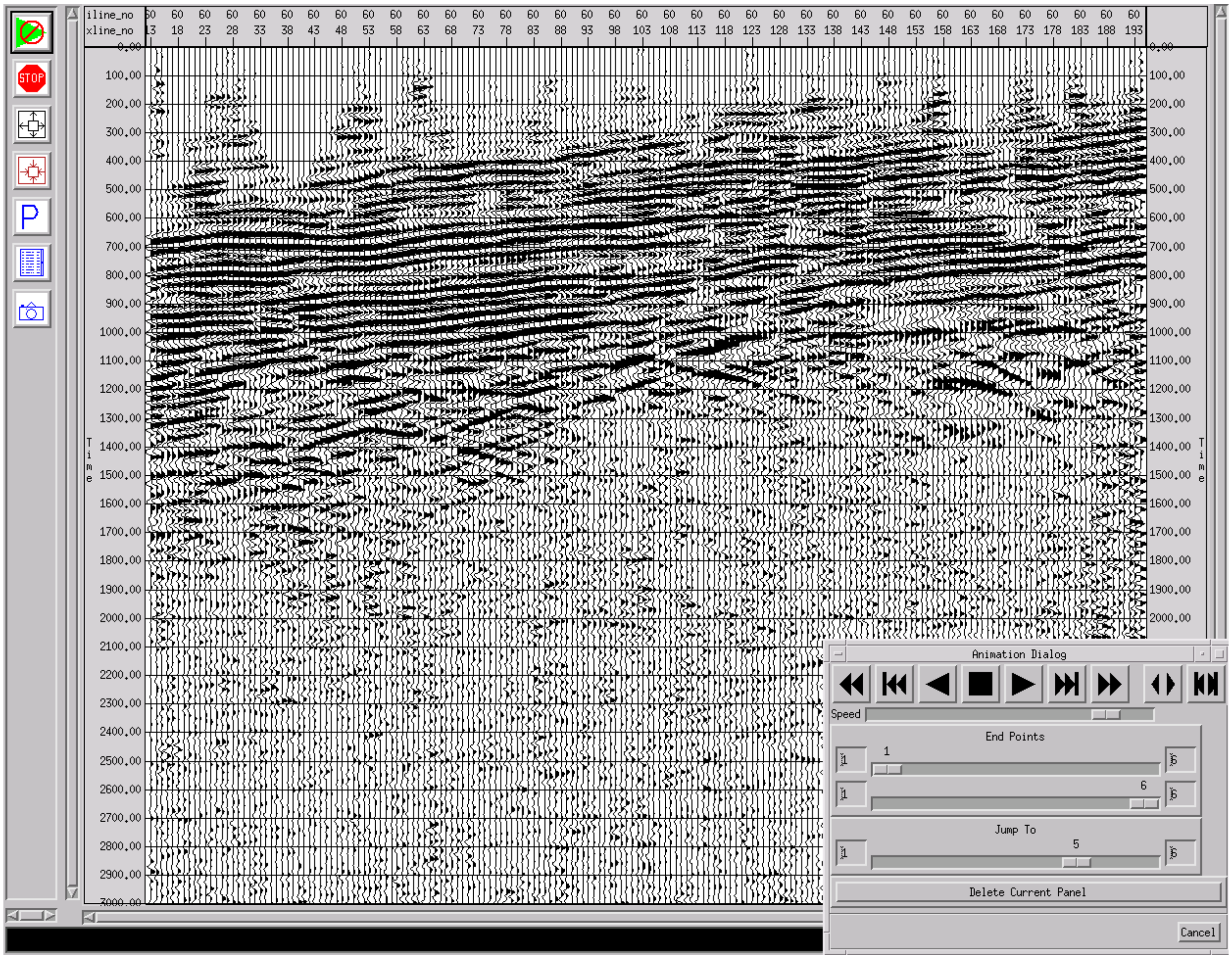
Stacking velocities were picked on a ½ mile grid. A maximum power surface consistent residual statics application was used to compute the statics. A gate designed over the coherent signal was used to derive the statics.

Final Mute selection



Final pre stack parameters have been selected.

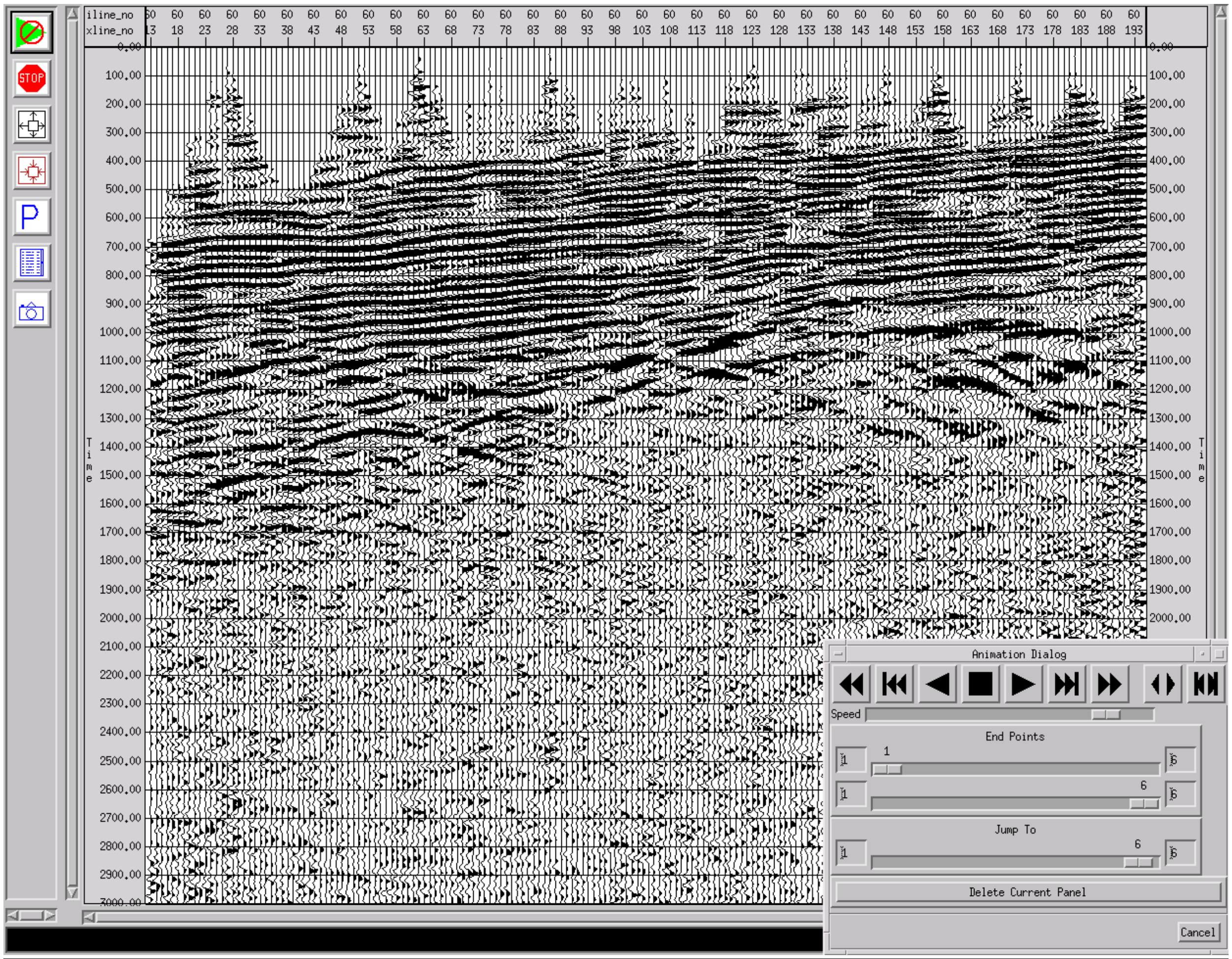
Post Stack Signal Enhancements



Post Stack Enhancements have been selected. An inline fx filter followed by an fk filter, and then the same has been applied in the cross line direction.

2nd Pass Stacking Velocity Analysis by Constant Velocity Stack

2nd Pass Surface Consistent Residual Statics



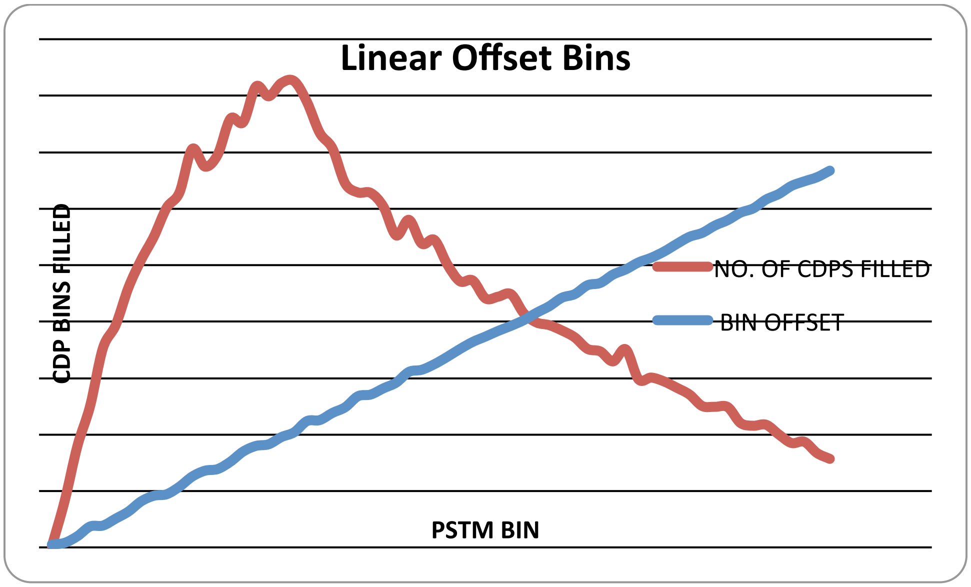
Final Iterations of surface consistent statics and stacking velocities are applied. As well as the final post stack enhancements.

Kirchhoff Pre Stack Time Migration

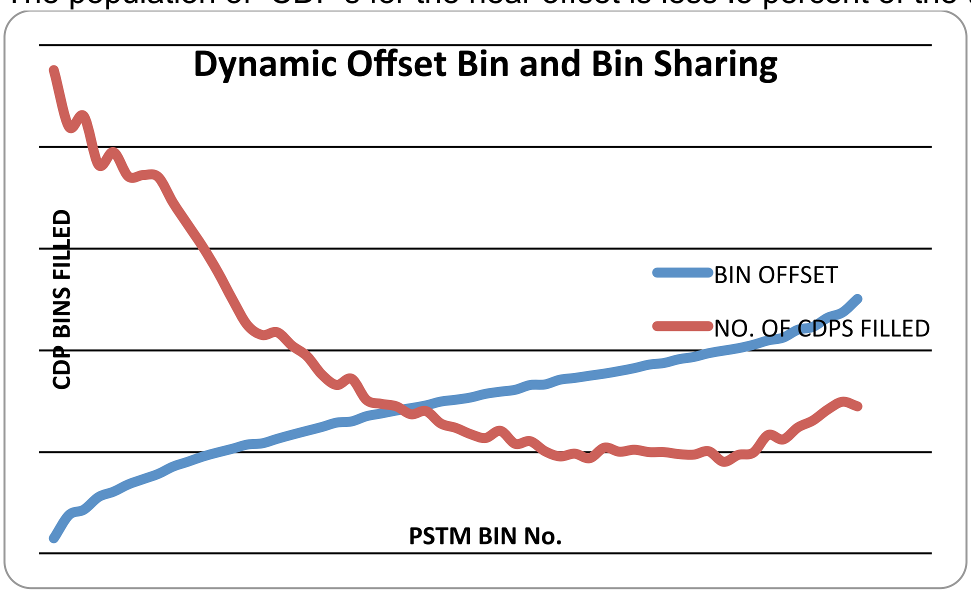
The offset bin definition for Kirchhoff Pre Stack Time Migration is arbitrary. The most important consideration for the prestack migration is defining an offset bin such that all CDP's are populated with live traces. Two approaches offered by FairfieldNodal are OVT binning, and Dynamically offset binning with bin sharing. Recently OVT binning has been added to our toolkit to preserve offset and azimuth for pre stack analysis. The reason for OVT binning is to interpret the velocity effects on offset and azimuth. This is very useful for projects like this to observe the anisotropy with pre stack time migrated gathers. Dynamic offset binning is useful for improving the quality of each offset bin for AVO analysis. At the time of this project OVT binning was not available. The Kirchhoff Pre Stack Migration product for this project was dynamically offset binned.

Before illustrating the results of this stage of the processing I will present some diagnostic displays for using Dynamic Offset Binning with bin sharing.
Dynamic Offset binning with bin sharing designs bins based on equal area. The acquisition design for this survey was not orthogonal. The receiver lines were at a 45 degree angle from the direction of the source lines. The maximum offset used to compute the bins for the source line direction was 7260', and for the receiver line direction was 5720' yielding 55 offset bins.

TOTAL NUMBER OF CDP's FOR THIS SURVEY : 29964.

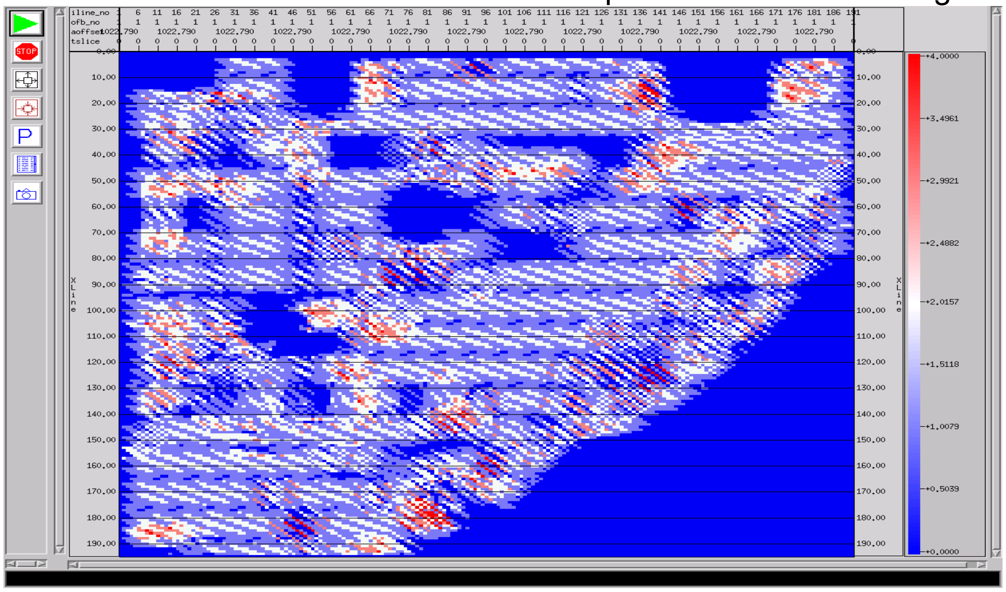


The population of CDP's for the near offset is less .5 percent of the total number of cdps.

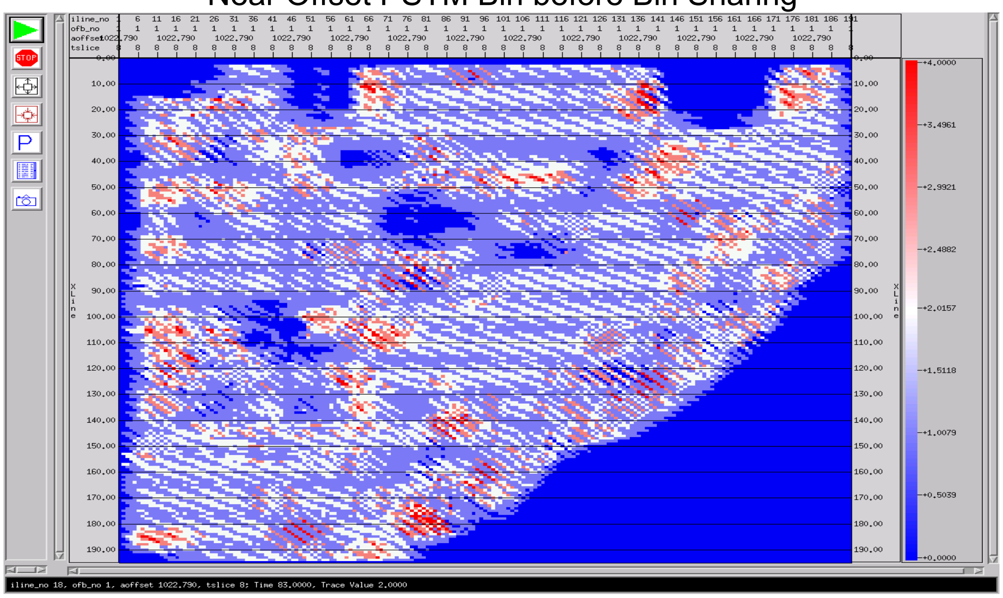


The population of CDP's for the near offset is more than 45 percent of the total number of cdps.

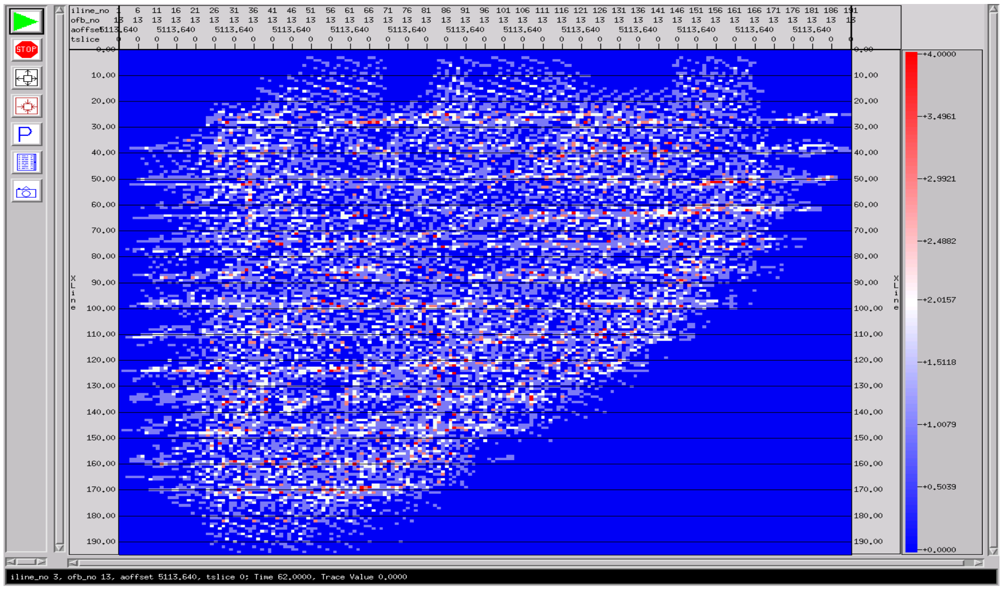
Bin Sharing borrows traces from adjacent PSTM bins to populate additional cdps. The following illustrations show the increased number of cdps filled after bin sharing.



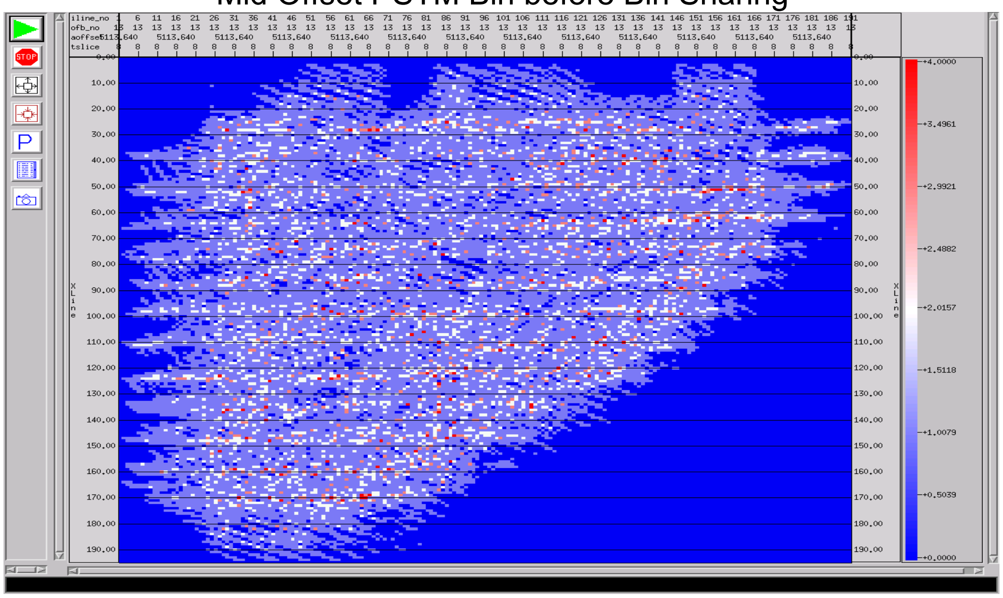
Near Offset PSTM Bin before Bin Sharing



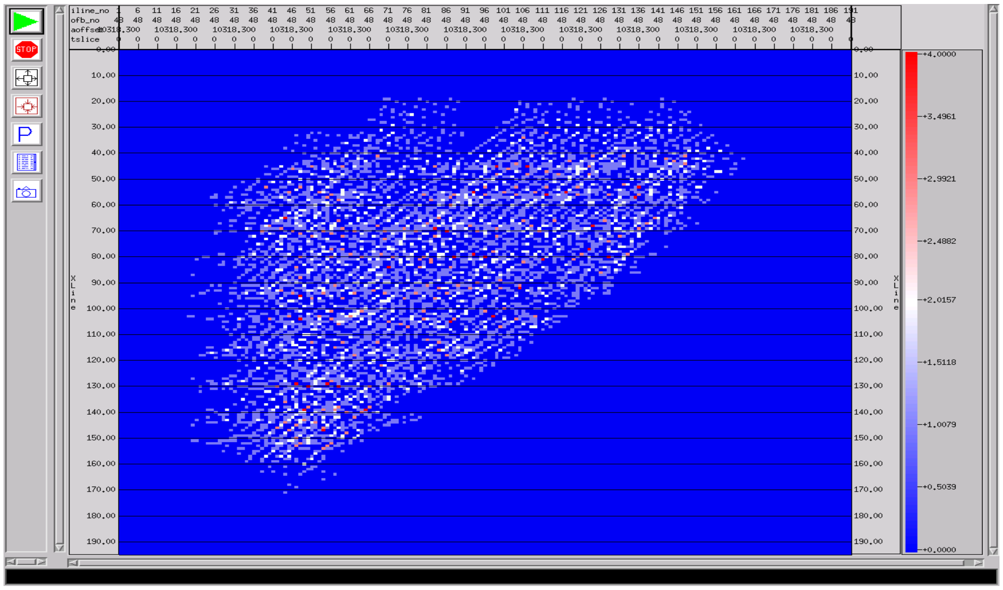
Near Offset PSTM Bin after Bin Sharing



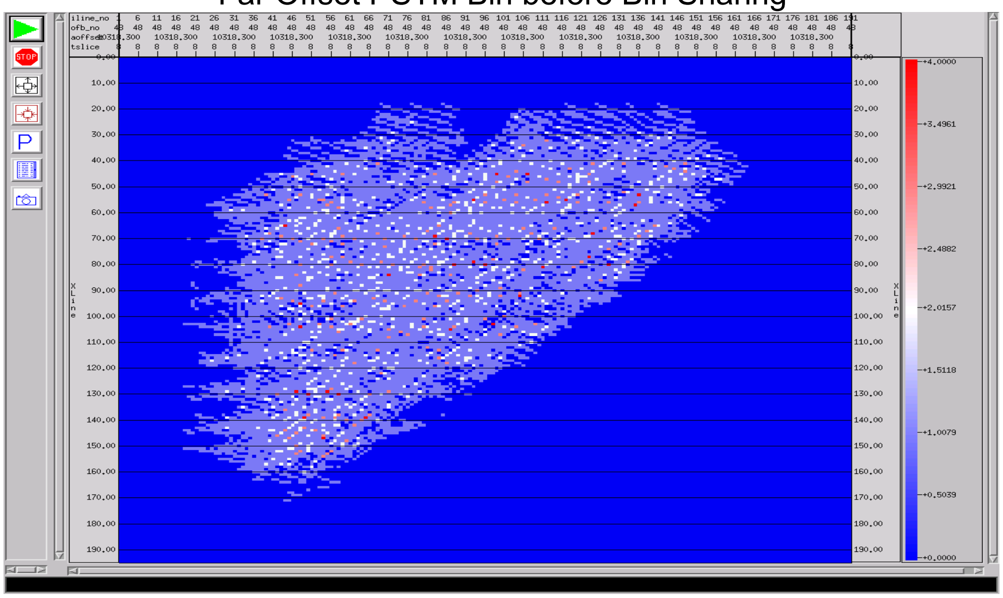
Mid Offset PSTM Bin before Bin Sharing



Mid Offset PSTM Bin after Bin Sharing

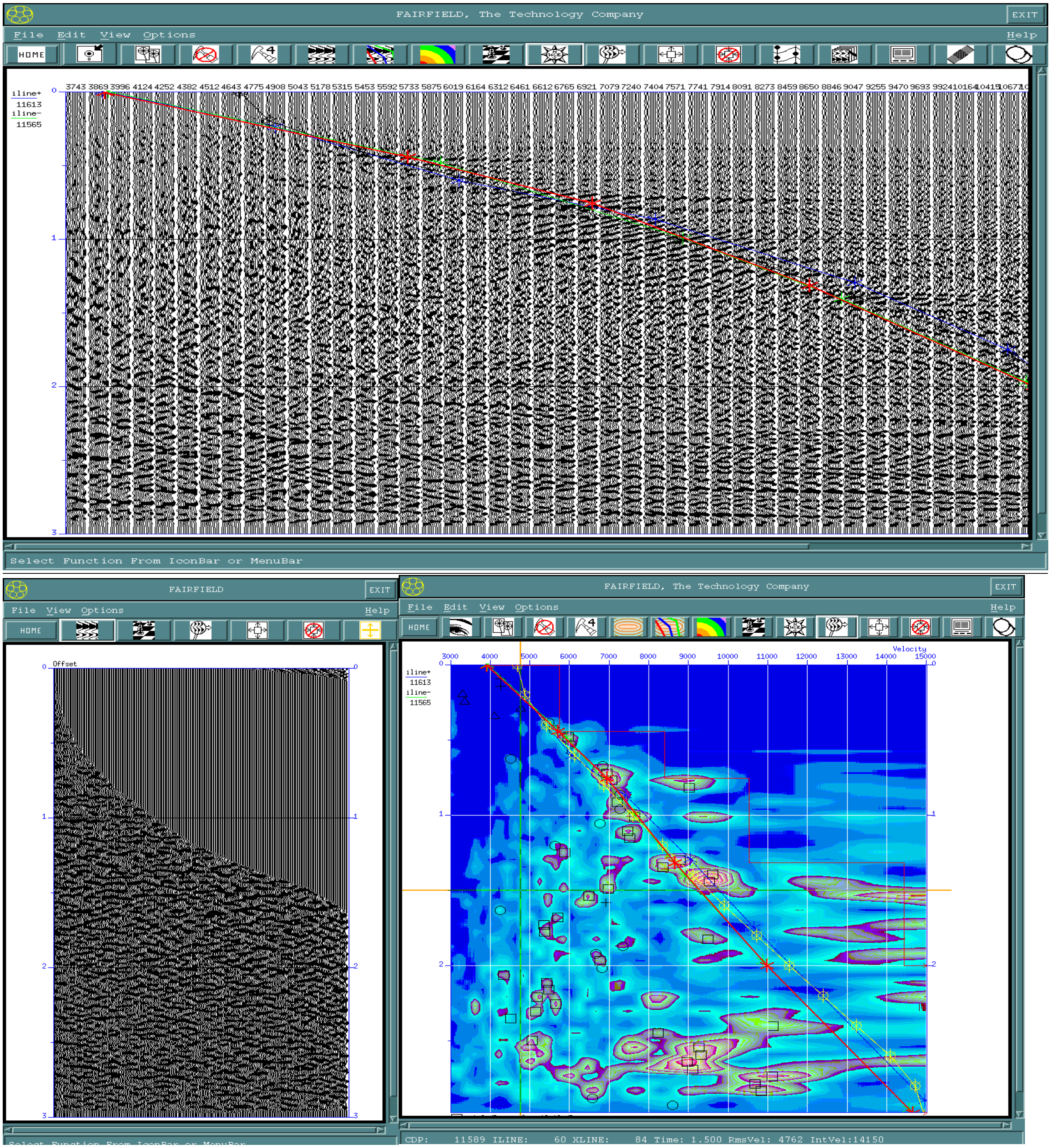


Far Offset PSTM Bin before Bin Sharing



Far Offset PSTM Bin after Bin Sharing

Kirchhoff Pre Stack Time Migration Velocity Analysis

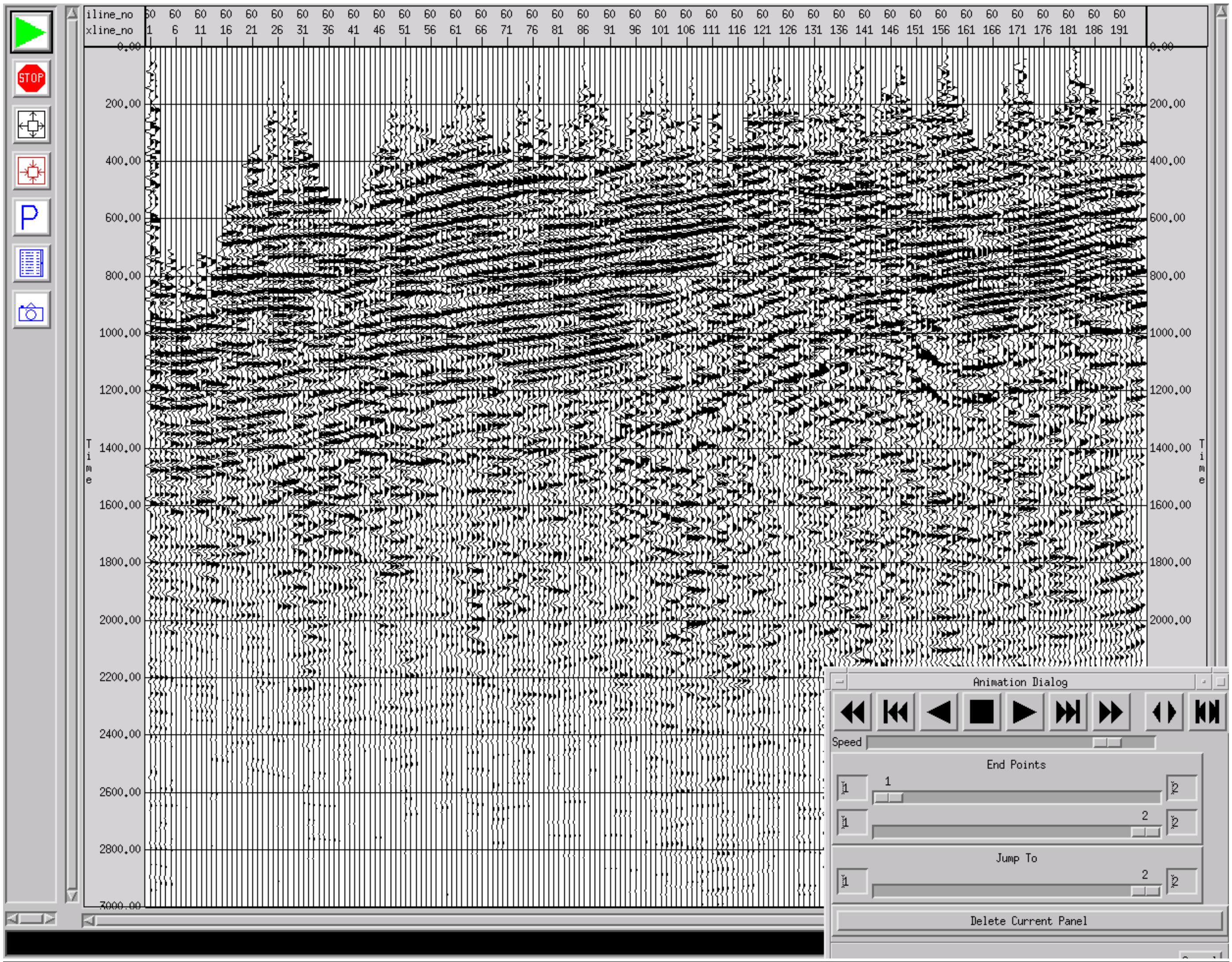


The illustrations above are the displays of a velocity analysis. The approach used to resolve the PSTM velocities consisted of a velocity analysis like this on migrated gathers. A Migration is applied to the data with a smooth stacking velocity from the conventional stack. A velocity analysis is run on ½ x ½ mile grid. The velocity function is smoothed and Kirchhoff Pre Stack

Migration is applied to the whole volume. A residual velocity analysis is run to flatten the gathers.

Kirchhoff Pre Stack Time Migrations

Post Stack Signal Enhancement



Final signal enhancements included:

Spectral Whitening:	6-84 Hz. 10 hz panels, 256 ms gate length.
2x2 FX Deconvolution:	6-84 Hz.
2x2 Frequency Wavenumber Filter:	Reject Operator: 15 tr x 34 ms., 13 to 79 ms/tr

CONCLUSION

P-Wave Pre Stack Sequence:

1. Geometry Description
   - Read in field geometry from tape headers. Made adjustments were noted by observer. All field recorded were plotted to confirm source location.

2. True Amplitude Recovery
   - 1.8 Time Power Constant applied to 2.5 sec.

3. Minimum Phase Filter correction operator for Zero Phase Source

4. Refraction Statics
   - Datum: 0 Ft.
   - Replacement Velocity: 5500 Ft. /sec.
   - 500 – 4000 Ft. offset ranges were used in model
   - Refraction static stack showed improvement over a conventional elevation statics solution.

5. Surface Consistent Amplitude Analysis and Application
   - Source and Receiver
   - Gate below first breaks to 3.0 sec.

6. Ensemble Deconvolution (Receiver Line ensembles)
   - Spiking
   - 11 trace average
   - 210 ms Operator
   - .01% white noise
   - Single gate design from below first breaks to 3.5 sec.

7. Frequency Dependent Diversity Scaling.
   - Receiver Line Ensemble
   - 200 ms time gate
   - 5 freq panels,

8. Two passes velocity analysis, 2 passes surface consistent residual statics
   - First pass 1 Mile Grid / Second Pass ½ Mile Grid

Conventional CDP Stack Post Stack Sequence:

1. CDP Stack

2. Post Stack Enhancement
    - 2x2 FX Deconvolution, T-X dip filter
    - +/- 10 msec. Per trace in both directions

Pre-stack Time Migration Processing Sequence

Input to PSTM sequence Conventional CDP gathers prior to CDP Stack

1. Defining Arbitrary PSTM Binning
    a. Compute Equal Area Binning
    b. Compute Bin Sharing Parameters
    c. Compute Pre-stack Scaling

2. Kirchhoff PSM Velocity Analysis
    a. Pre-stack Kirchhoff curved ray time migration
    b. 20 iline x 20 xline velocity grid

3. Picked new velocity field on migrated gathers

4. Kirchhoff Pre Stack Migration full Volume
    a. Mute Pre Stack Volume

5. PSTM Residual Velocity Analysis
    a. Conventional Stacking Velocity Analysis

6. CRP Stack

7. Post Stack Enhancement
    a. 2x2 FX Deconvolution
    b. T-X dip filter
        i. +/- 10 msec. per trace in both directions

8. SEGY output Final Enhanced Pre-stack Time Migration
    a. File: final-p-wave-pstm.segy

CGG Seismic Processing Report

Wister 2013 3D
Seismic Processing Report

Prepared for Ormat Technologies
by CGG Subsurface Imaging

September 2014

Passion for Geoscience
cgg.com

Proprietary Notice

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Table of Contents

TABLE OF FIGURES

1. Introduction

This report describes the analysis, testing and processing applied to the Wister 2013 3D data set. The work was performed by CGG subsurface imaging for Ormat Technologies, in CGG processing centre in Calgary, Canada 2013.

The final processing sequence was developed based on a complete set of CGG standard tests, auxiliary tests as deemed relevant to this data set, and client requested displays and analysis.

Where appropriate, a small-scale figure is included directly within the text. Please note all images included in the report and additional images are also assembled as PowerPoint® slides on the accompanying CD. The reader may wish to toggle the PowerPoint slides on the screen as a convenient method to visually compare the images.

1.1 Ormat 2013 3D Acquisition Parameters

AREA:	Wister 3D		
LOCATION:	Imperial, California		
BIN SIZE:	110 x 110 FT	ACQUIRED:	2010

SOURCE INFORMATION

SHOT BY:	Dawson Geophysical Company
LINE ORIENTATION:	N-S
NUMBER OF SHOTS:	1275
SOURCE TYPE:	Vibroseis
SWEEP SPECTRUM:	4 TO 96 HZ
SOURCE ARRAY:	SINGLE VIBES
SWEEP LENGTH:	24SEC
SOURCE INTERVA:	220 M
SOURCE LINE INTERVAL:	229 M

RECEIVER INFORMATION

LINE ORIENTATION:	NE-SW
RECEIVER TYPE:	3C Geophone
NUMBER OF STATIONS:	1826
RECEIVER ARRAY:	SINGLE
RECEIVER INTERVAL:	311 M
RECEIVER LINE INTERVAL:	95 M

RECORDING PARAMETERS

INSTRUMENT:	GSR
FILTER:	LOWCUT 3 HZ HIGHCUT 207 HZ
NOTCH FILTERS:	OUT
SAMPLE RATE:	1MS
RECORD LENGTH:	6000MS

2. Processing Flow and Parameters

1. Demultiplex / Re-format

2. 3D Geometry
   Bin size: 110 x 110 FT

3. Rephrase: zero phase to minimum phase
   Spherical Divergence
   Type: T^1.4

4. Surface Consistent Scaling
   Line, shot, receiver components
   Design window: as per Decon design window
   Design window:

Offset [ft]	Time[ms]
139	250-1600
4300	1000-1800

5. Structure Statics

Analysis method:	FirstBreak Tomography
Datum elevation:	0 ft
Weathering velocity:	3000 ft/s
Replacement Velocity:	5000 ft/s
Application:	Surface consistent short wavelength component only

6. Low Frequency Coherent Noise Attenuation C.N.A. on shots

7. BLAST and FLASH De-burst

8. Preliminary Velocity Analysis: Double square root NMO

Type:	Constant Velocity Stacks – 20 row interval
Reference:	Datum

9. Stack for QC – Noise attenuation and structure

10. Residual long wavelength static correction. Calculated from shot and station stacks.

11. Surface Consistent Scaling
    Line, shot, receiver components
    Design window: as per Decon design window
    Design window:

Offset [ft]	Time[ms]
139	250-1600
4300	1000-1800

12. Surface Consistent Deconvolution
    Line, shot, and receiver components were applied.

Operator Length:	120 ms
Pre-whitening:	.01%
Operator design gate:	
Offset [ft]	time [ms]
139	250-1600
4300	1000-1800

13. Automatic Surface Consistent Statics 1

Design window:	300 - 1500 ms
Design filter:	10/15 – 40/50 Hz
Max. Static:	+/- 10 ms

14. Velocity Analysis: Double square root NMO

Type:	Interactive Semblance – 800 ft interval
Zone:	3x3
Reference:	Datum

15. BLAST and FLASH De-burst

16. Final Velocity Analysis
    Referenced from floating datum
    Analysis interval: 250 x 250 m grid

17. Second pass residual long wavelength static correction.

18. Automatic Surface Consistent Statics 2

Design window:	300 - 1500 ms
Design filter:	10/15 – 70/80 Hz
Max. Static:	+/- 30ms

19. Surface Consistent Scaling
    Design window:

Offset [ft]	time [ms]
139	250-1600
4300	1000-1800

20. 5D Interpolation – Regularization of data.

Pre-Stack Migration Sub-Flow

**** Input Gathers from STEP #19 ****

21. Accordion binning migration prep

22. PSTM Velocity Analysis – Migrated Constant Velocity Stacks

23. 3D Kirchhoff Pre-Stack Time Migration

Half aperture:	8800 ft
Anti-aliasing:	75%
Max angle:	80 degrees

24. Residual velocity Analysis

25. Stacking mute, Stack

26. Structure Statics

Analysis method:	Refraction Tomography
Application:	Long wavelength component

3. Geometry

3.1 Overview

The accuracy of the geometry information is crucial not only for proper positioning of structural features, but also to obtain the best overall signal to noise ratio. Incorrect positioning of shots and/or receivers will result in improper distribution of traces into CDP bins and degraded signal-to-noise ratio.

The geometry was generated using various pieces of information. These included:

- Source and receiver locations and elevations from SEGP1
- Source/field file number relationships
- Receiver pattern information for individual shots
- Driller's reports for specific hole depth information
- Observer logs

3.2 Geometry Information from Trace Headers

The primary source of the relationship between Field Record Number (FFID) and Source Location was the tape headers of the seismic. These headers also contain detailed shot pattern information (cable), relating source and receiver number to physical location for each recorded trace on all individual shots.

3.3 Survey Information QC

Survey information was received in the form of SEGP1 files. This information is first checked for any gross errors before being incorporated into the geometry. Small-scale errors are later determined by combining the geometry with the recorded seismic data.

The methodology used to determine gross errors is to graphically display the source and receiver coordinate information to ensure overall compliance with the acquisition map. Relative distances between consecutive source/receiver locations were displayed to confirm that the interval fell within an anticipated range.

Survey information is used to ensure overall compliance with the acquisition map. Relative distances between consecutive source/receiver locations were displayed to confirm that the interval fell within an anticipated range.

Elevation Maps

In addition to checking the elevations of the individual source and receiver lines during the reading of the SEGP1 files, the elevations of the total survey were also verified by creating and inspecting a color map of the surface elevations.

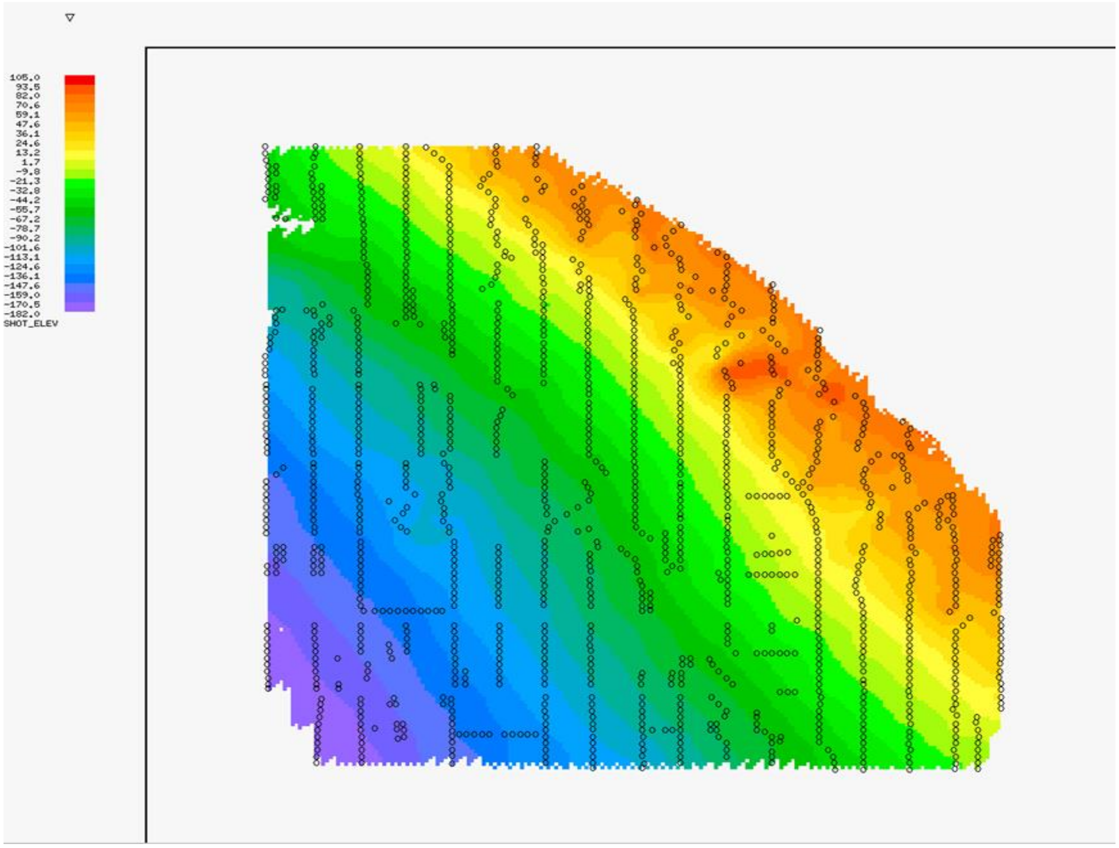


Figure 3-1: Surface elevation map of geometry with shots shown.

3.4 Geometry QC

A number of different approaches to ensure proper shot and receiver positioning may be used. Shot and receiver positions identified as having potential coordinate errors were interactively reviewed and adjusted if necessary. A description of the various geometry QC methods is given below.

Linear Velocity Overlay

In the first pass through the linear velocity QC procedure, the first break pick times are used independent of the refraction solution. This locates any large skid or positioning errors in the relational data, provided that the first break picks are reasonable.

A utility called GLIMDL_STK was run on the data set to estimate shot / station skid errors and store them in the geometry database. This estimate is based upon the actual first break time of the data compared to the offset as stored in the geometry. The value assigned represents the difference, in ms, between the geometry profile and the actual pick time. The validity of this method is dependent on the quality of the first break picks, so visual analysis of the shot with respect to the geometry profile is a necessity.

This error information can be displayed in two ways. The first method is a simple SHOT vs. ERROR graph done over the entire shot range. A second method is to display the error value attributes in the geometry database in plain view.

Either QC method will indicate any shot records that require further checking. At this point, any problematic shot is reviewed interactively with first break pick times and time/distance profile displayed.

A line that represents a simple linear velocity (time/distance profile) is overlain above the first arrival on data display. A shot that has incorrect geometry assigned to it will show a discrepancy between the first arrival data and the linear velocity overlay. A misalignment represents either a shot that is mis-positioned or incorrect cable configuration. The cable can be easily checked with other surrounding shots. As long as the surrounding shots' first breaks match their profiles, it may be assumed that they are correctly positioned. To verify the cable, distinctive receiver stations (such as dead or noisy stations) can be compared to the surrounding shots. In this way, it can be determined whether an error is due to incorrect source x-y position or is cable related.

Once we have determined that the error is a positioning issue, the shot is skidded into its correct position. This can either be done manually or with the interactive auto-skid utility. Note that at this stage the auto-skid utility is entirely based upon the first break picks. For finer detail, the difference between the refraction model and first break pick times may be displayed after running refraction analysis.

If a shot requires a positioning correction, the new x-y co-ordinate is saved and updated into the geometry database (geometry database). As mentioned previously, this method is dependent on the quality of the first break picks. The resolution of this method with exceptional first breaks is approximately ½ station interval. Generally speaking, errors of greater than 1 station intervals are found through the first pass QC checking.

REFRACTION Based Geometry QC

After correcting any large-scale errors via the SKID utility and updating the geometry database, the data are subjected to a second pass of geometry verification. This method combines the refraction solution and common source and receiver stacks.

In this geometry verification pass, the statics calculated through the refraction analysis are used instead of the first break pick times to further detect any possible shot/station errors. Rather than using the error graph display or the color map display to show problematic shots, common shot and receiver stacks are generated. Common shot stacks that have been flattened to the TOMO_MODEL are output. The TOMO_MODEL is the theoretical pick time derived from the model generated through the refraction analysis package as described in the next section. If the model is reasonable, and the theoretical picks flatten the data well, the resulting stacked trace compares well with surrounding traces. If the shot or station is positioned incorrectly, the resultant stacked trace is quite different from its neighbors and that shot needs to be examined further.

Quadrant QC (azimuth-restricted) stacks

In this QC, prior to stacking, each shot is split into four azimuthally-restricted quadrants based on shot-receiver azimuth. Five shot stacks are then generated: data from all azimuths, data from the first quadrant, second quadrant, third quadrant, and fourth quadrant. Windowed data (the first 500ms, typically) of the quadrant stacks are arranged in a tiered display. Even slight positional errors will stand out, as the opposite effects can be seen in opposite quadrants. As well, quadrant stacks were used to identify reverse polarity receivers.

Predicted first breaks applied as a static shift

This method applies the predicted first break pick times (calculated from the refraction model) as static shifts to the data. Shot and receiver stacks are then generated from the shifted data. The resulting stacks are analyzed for changes in the stack response that can indicate:

- Geometry errors (incorrect shot or receiver coordinates, incorrect cable definition)
- Poor quality first break picks
- Reversed/noisy/dead receivers
- Changes in the S/N for specific shots or receivers

All shots and receivers are reviewed and any apparent problems are investigated and corrected.

CMP Stack QC

Stack QCs are done throughout the processing flow as an efficient way to identify various problems.

3.5 Binning Strategy

The data were gathered into 110 x 110 ft bins. After the initial binning had been assigned, midpoint scatter maps were generated interactively to examine the distribution of midpoints within the binning space. At this point the grid could be shifted or rotated interactively to achieve the best possible fit between midpoint scatter and bin centers.

Corner Coordinates of Grid:

XY coordinates (Inline 1, Xline 1)	(2040355.1, 6771661.0)
XY coordinates (Inline 192, Xline 1)	(2061365.1, 6771661.0)
XY coordinates (Inline 1 Xline 196)	(2040355.1, 6793111.0)
XY coordinates (Inline 192, Xline 196)	(2061365.1, 6793111.0)

GEODETIC DATUM: NAD 83

3D Azimuth angle from north: 0 Degrees

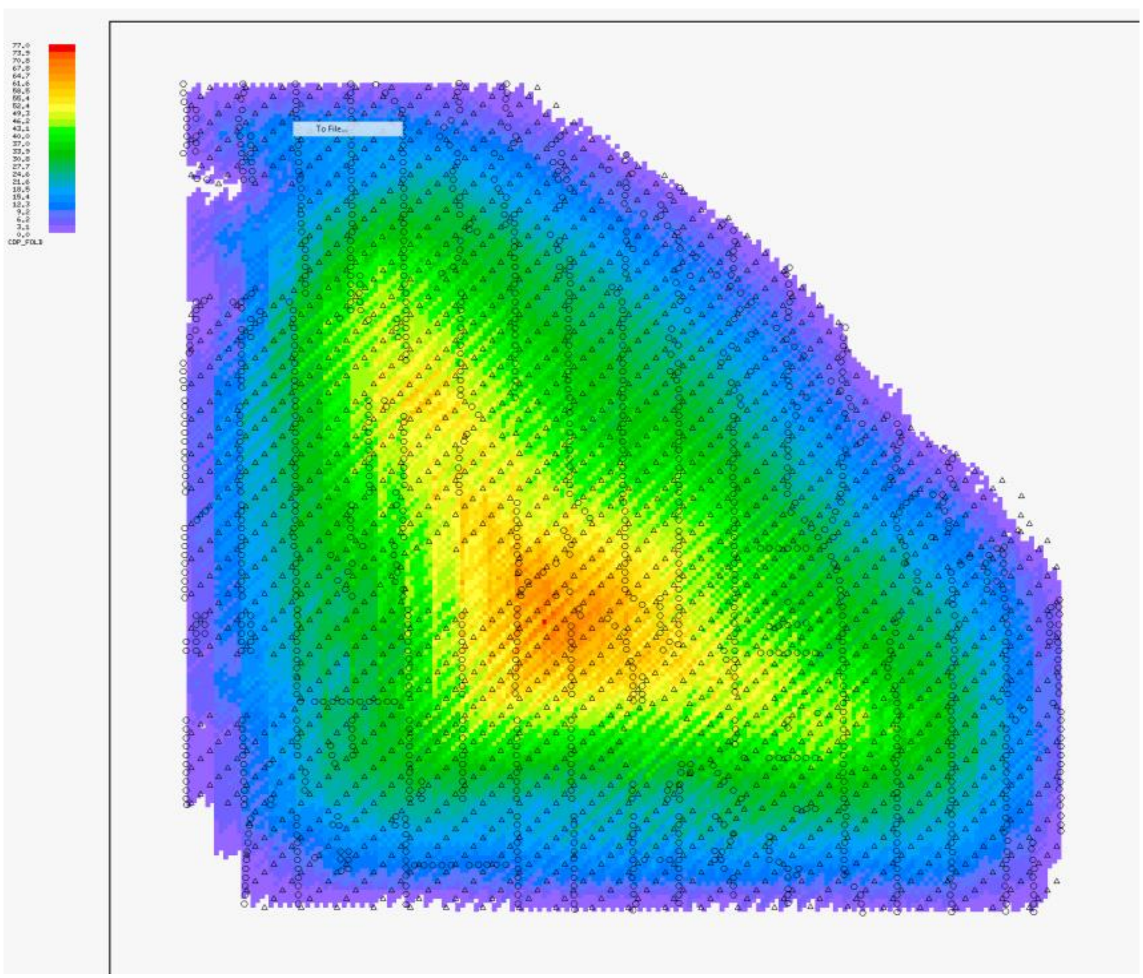


Figure 3-2: Full offset CMP fold associated with the final binning

4. Near-Surface Statics

4.1 Overview

Near-surface statics are always a significant concern, primarily due to the fact that the existing surface conditions during acquisition influence the accuracy of the resulting time structure. In this case, the first arrivals produced from the vibroseis source were of reasonable quality and provided reliable first arrival pick times. Errors associated with the refraction analysis are thus significantly reduced.

First breaks were picked and then used to generate both GLI and TOMO refraction static solutions, upon review, the TOMO solution was selected for production.

4.2 First Break Picking

Field data proved to have reasonable signal to noise ratio to allow for a guided automatic picking of the first breaks in batch mode. Upon subsequent interactive checks of first break pick quality, some areas required the additional manual re-picking process.

4.3 GLI Generalized Linear Inversion Method

GLI (Generalized Linear Inversion) mathematically ray-traces an initial earth model (defined by the processor) and compares the differences between the modeled and the actual first break pick times. The program then uses a linear inversion method to determine a corrected near surface earth model. The corrected model is iterated back through the program generating another set of solutions, continuing for a specified number of iterations to achieve a final model. The initial near surface earth model for the GLI refraction statics may be built using the velocity and time intercept information extracted from the first break picks of the seismic data.

GLI is appropriate for a layered near surface with mild lateral variations, and computes a natural base of drift. **Turning-Ray Tomography** represents the near surface as a grid model and is better equipped to handle vertical gradients, inversions and more complex velocity variations than traditional layer-based methods.

4.4 Turning-Ray Tomography Method

Tomography is a method of determining the internal structure of a solid body by observation and analysis of waves that have travelled through the body along different paths. For seismic tomography, this usually translates into analyzing the difference between observed travel-times and travel-times calculated by ray tracing through a gridded velocity model. The model is globally updated to minimize these travel-time differences.

The near surface velocity structure is represented by a grid model. Each node of the grid is assigned a node velocity and velocity within a grid cell is linearly interpolated from its node velocities. As the grid spacing is small and the node velocities can vary in an arbitrary fashion, the method can model strong velocity variations in both vertical and horizontal directions. First arrivals are treated as direct body waves propagating along turning rays, enabling the method to determine the first layer velocity as well.

The node velocities are determined by solving a nonlinear least-squares problem which minimizes the differences between the observed travel times of first arrivals and those predicted from the grid model. As the inversion requires intensive ray tracing, an accurate and efficient algorithm for travel time and ray path calculation is essential for practical applications. The algorithm must also be robust and devoid of the shadow-zone problem, which can severely reduce the number of observations usable in a tomography calculation and has hindered the tomography methods based on the traditional ray tracing techniques.

Grid Ray-tracing

CGG has developed a grid ray tracing (GRT) technique that combines the advantages of both wave front construction and fast marching methods (Zhu and Cheadle, 1999). This method calculates travel times and wave propagation vectors by tracing rays locally within a grid cell and has been shown to be highly accurate and efficient in modeling turning rays in near-surface environments.

Inversion Scheme

The nonlinear least-squares problem for determining the node velocities of a grid model is solved by successive linearization. The linear least-squares problem resulting from this linearization is, in general, ill-posed due to the limitations of data constraints and the nonlinearity of the inverse problem. Additional constraints on the inverse problem are necessary in order to stabilize the iteration. We regularize our inversion by including in its matrix equation both smoothing and step size constraints; the former reduces the roughness of the velocity model and the latter limits the linear approximation within a trust region. The nonlinear inverse problem is thus reduced to solving iteratively a regularized, linear least-squares problem.

We solve the linear least-squares problem with the LSQR algorithm introduced by Paige and Saunders (1982). The algorithm exploits the scarcity of the matrix equation for time and memory efficiency has been found to have a superior convergence property to other commonly used algorithms for solving sparse matrix equations (Paige and Saunders, 1982). The efficiency of the algorithm is further enhanced in our implementation by a number of modifications made to the original implementation. This, coupled with the grid ray tracing technique, makes our tomography method a highly efficient process for near-surface velocity estimation.

4.5 Near Surface Statics

As mentioned above, the TOMO solution was selected for production for this data set. The replacement velocity used was 2100 m/s and the final datum 750 m above sea level. TOMO was run on the merged data set.

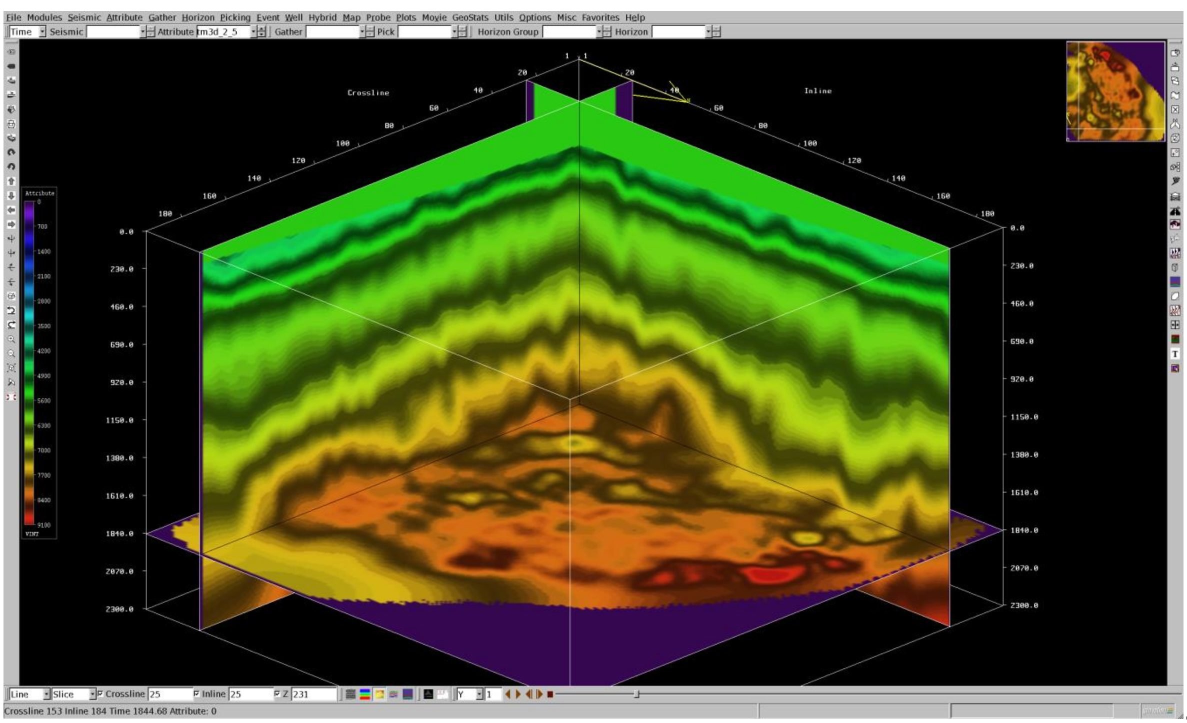


Figure 4-1: TOMO model. Pseudo-datum=400 ft.

5. Amplitude Recovery

Divergence is the spreading out of energy into a greater area as the wave front travels and spreads. Divergence correction was applied via At^N. Various values of N were tested, and simple t^1.4 divergence correction was applied.

6. Re Phase – Zero Phase to Minimum Phase

Vibroseis data is zero phase, our surface consistence decon requires minimum phase data. So we need to adjust the zero phase data to minimum phase by following method: Specify a geophone setting, a recording instrument, a Klauder wavelet (Vibroseis sweep), feeds these responses into a spiking deconvolution algorithm to determine by how much the responses fail to be converted to zero phase, then removes this phase difference from the data.

7. Surface Consistent Scaling

Surface-consistent source and receiver scalars are calculated to account for shot-to-shot and receiver-to-receiver amplitude variations which may arise from physical differences (for example, charge size or receiver-sensitivity differences from station to station) and coupling differences. Further, surface consistent scalars are usually calculated and applied at several stages in the processing sequence to ensure preservation of amplitude integrity after processes which may have affected amplitudes. For this project, it was performed 3 times at these stages: on the raw data after spherical divergence correction, after pre decon noise attenuation and after final post decon noise attenuation.

The surface consistent scalars were calculated over the same window as the deconvolution design window.

8. Pre-Deconvolution Noise Attenuation

8.1 C.N.A. - Pre-stack Adaptive Coherent Noise Attenuation

CNA is an AVO-friendly adaptive process to attenuate coherent noise such as ground-roll, air blasts, or guided waves on wide patch 3D shot or receiver gathers. It is also applicable for 2D shot or receiver gathers.

For each output trace, an offset- and azimuth-limited corridor of traces around the output trace is used to construct 2D "zone" for noise estimation. A modified pie slice filter is applied - in the FX domain - to the corridor of traces to estimate the noise on the output trace. The estimated noise is subtracted from the input to obtain the noise-attenuated output.

While ordinary FK filtering is global in nature and tends to smear large amplitude noise, C.N.A. is adaptive. That is, because a small number of traces are used in the model, and a new corridor model is constructed for each output trace, CNA is localized and therefore can adapt to changing noise conditions at different offsets and azimuths in 3D records. For example, the corridor for the output trace may contain seven traces. These seven traces are used to estimate the coherent noise train over a specified frequency range. The traces are offset ordered to construct a pseudo 2D gather, and a pie-slice velocity model based on the noise characteristics of this corridor of data is found that best fits the data in the FX domain.

The FX domain is used since it honors the true shot-receiver spacing, even if spacing is irregular. Because C.N.A. works in the FX domain, it is able to account for irregular shot-receiver spacing (ordinary FK filtering assumes regular spatial sampling, an assumption which is often not met by 3D shot geometry).

8.2 BLAST De-Burst

BLAST identifies high amplitude noise blasts and scales or mutes the zones. The method locates zones in traces where the amplitude envelope is excessively high (exceeding a user defined threshold). BLAST uses a global estimate of the median amplitude level for thresh holding purposes. The process usually targets a restricted frequency band to specifically target the noise while leaving the bulk of the signal band unaffected. The identified noisy zones are then muted or down scaled and a difference taken to isolate the noise. This is then subtracted from the original broadband input.

BLAST is particularly good for attenuating incoherent shot blast noise and eliminating clipped or spiked signals. BLAST is robust and safe noise removal method and does not alter data anywhere except in zones where amplitudes exceed the threshold and only within the restricted frequency range of the targeted noise problem. If there are no high amplitude zones in the data, BLAST leaves the data unaltered.

8.3 FLASH

Process FLASH was performed to identify and scale down any high amplitude outliers in a zone of traces by comparing the amplitude of each trace with the localized median estimate in the zone. The identified noisy traces are scaled to zero and a difference is taken to isolate the noise in that frequency range. To execute noise attenuation, the noise is then subtracted from the original broadband input.

FLASH is particularly effective for eliminating clipped signals or spikes. FLASH is a robust and safe noise removal method and does not alter data anywhere except in zones where amplitudes exceed the threshold of the targeted noise problem. If there are no high amplitude zones in the data, FLASH leaves the data unaltered.

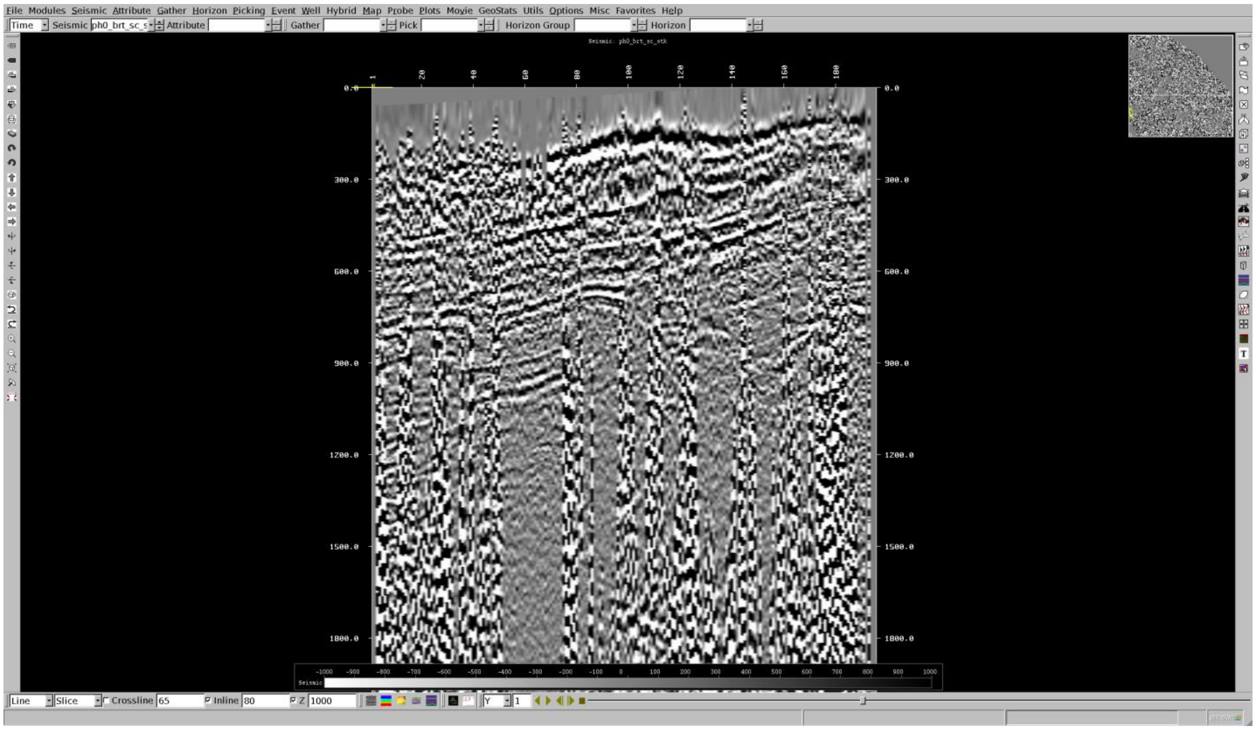


Figure 8-1: Stack before noise attenuation IL 80.

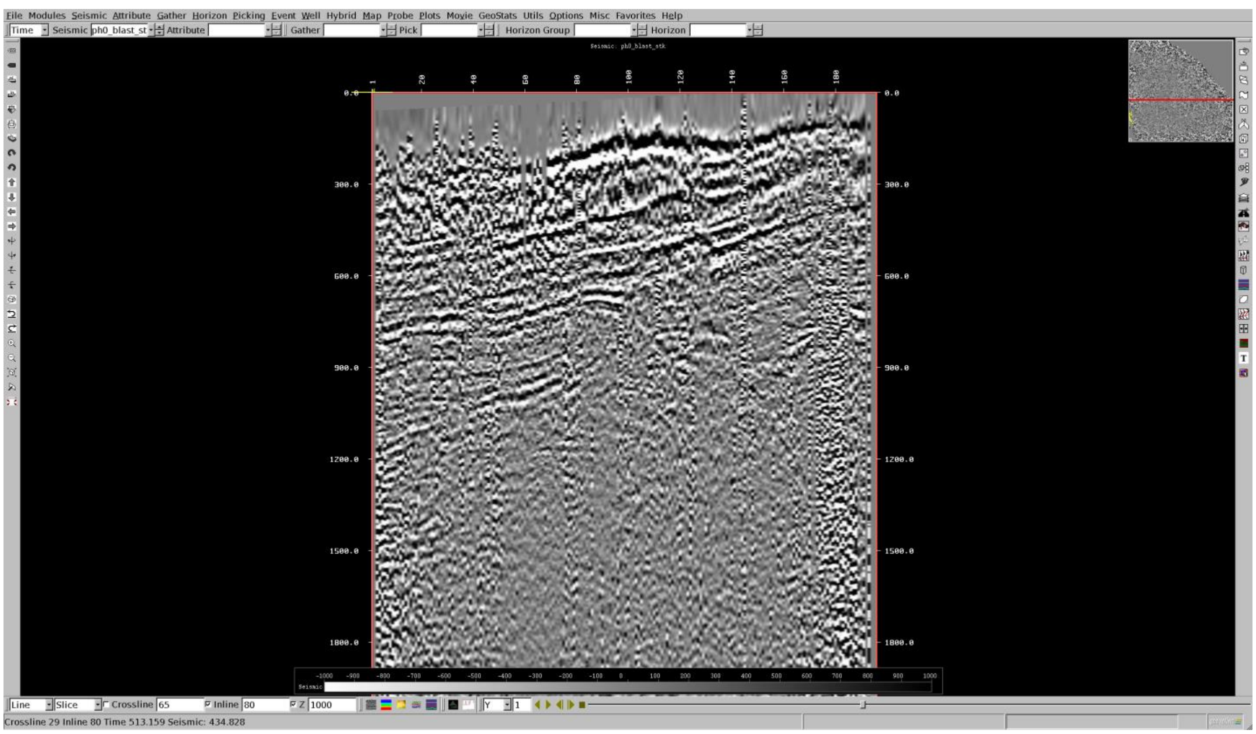


Figure 8-2: Stack after noise attenuation IL 80.

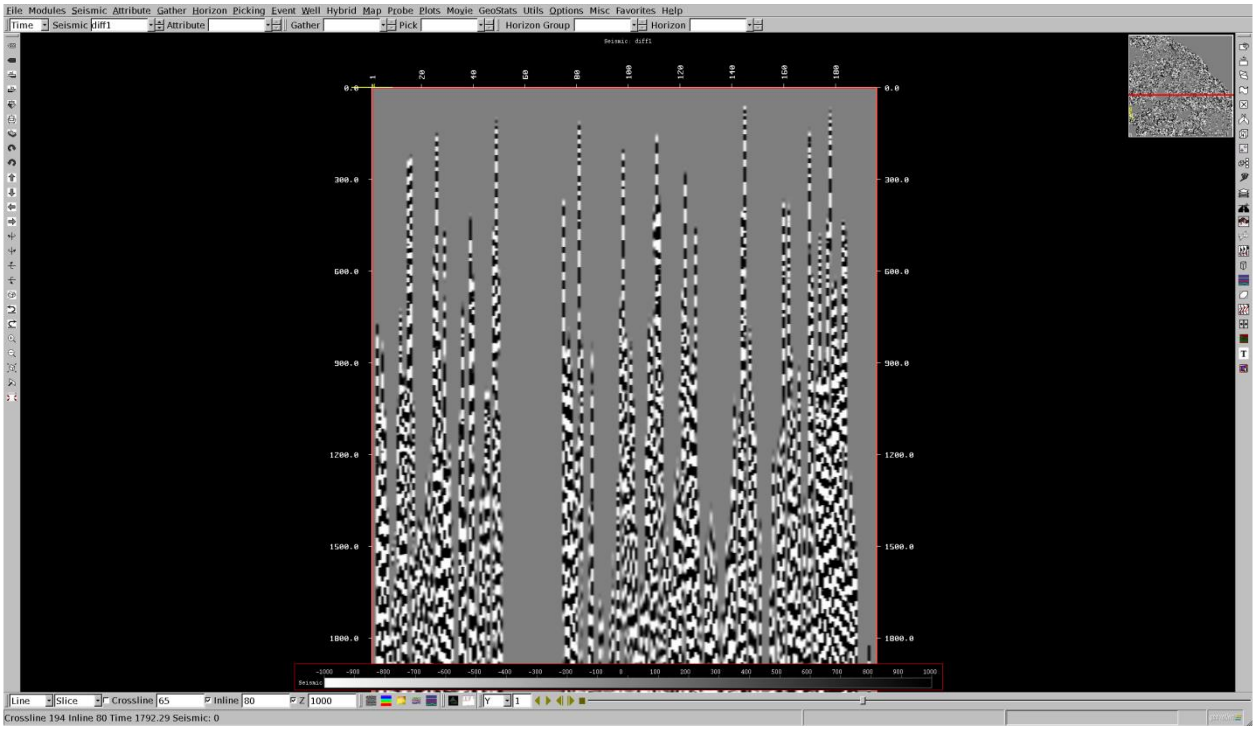


Figure 8-3: Total noise removed by Pre-Decon Noise Attenuation IL 80.

9. Deconvolution

Surface-consistent deconvolution is a multi-channel process. By using the redundancy of multichannel seismic data in deconvolution, we see increased reliability of operator estimates. Since the deconvolution operates surface-consistently, it improves the picking process for residual statics corrections. A key assumption behind statics determination is that the cross-correlation of two reflection events is maximized when the events are aligned. Unless the events are similar wavelets, this will not be the case. Surface-consistent deconvolution acts to balance the spectra of seismic traces, improving the similarity of the wavelets. This is a helpful benefit for surface-consistent statics decomposition, which assumes the trace-to-trace shifts fit a surface-consistent model.

The surface-consistent model compensates for the variations in source and receiver coupling. These are amplitude variations that are due to the seismic method and not indicative of legitimate variations in reflection coefficients. If we are to extract true AVO responses, we must de-convolve the data with care; the surface consistent deconvolution model makes it possible to accurately prepare the data for subsequent AVO and/or AVAZ analysis.

Data are often contaminated by noise which is not consistent to the surface. In such cases, pre-conditioning the data before deconvolution design can be a useful strategy to get better deconvolution operators. For this project, high amplitude noise and some coherent noise was attenuated prior to deconvolution, so that the deconvolution operators are calculated on clean signal rather than on data contaminated by noise.

The window over which the deconvolution operators were designed was based on the zone of interest as well as excluding consistently noisy zones – such as the first arrivals – from the deconvolution design. The deconvolution operators were computed from data within the design window, and applied to the whole trace length and to every offset. Line, shot, and receiver components were applied.

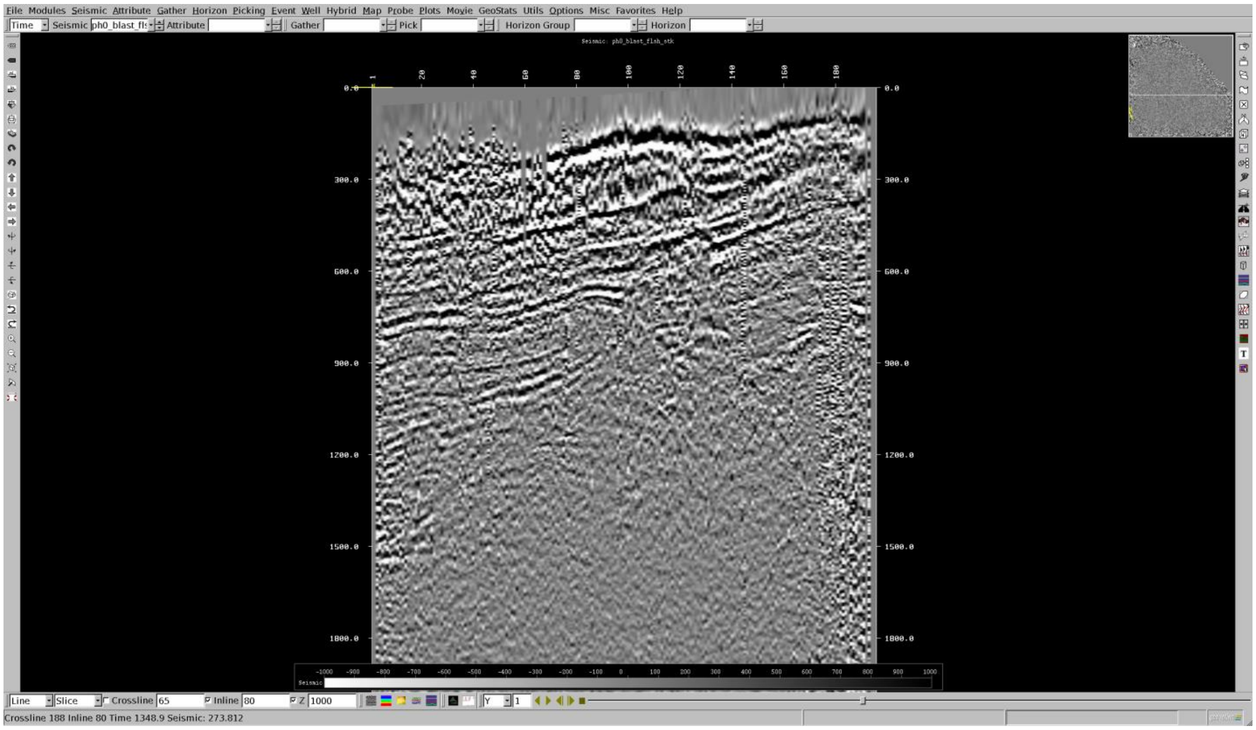


Figure 9-1: Stack after Surface consistent deconvolution IL 80.

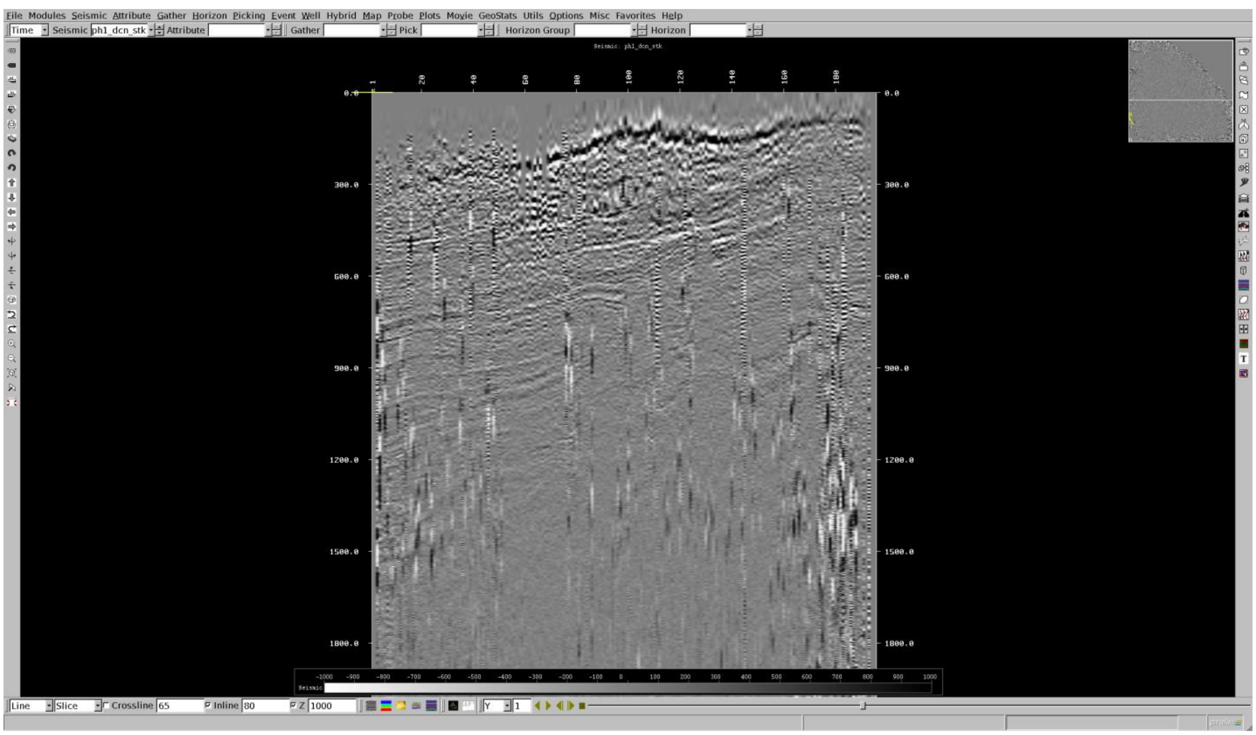


Figure 9-2: Stack after Surface consistent deconvolution IL 80.

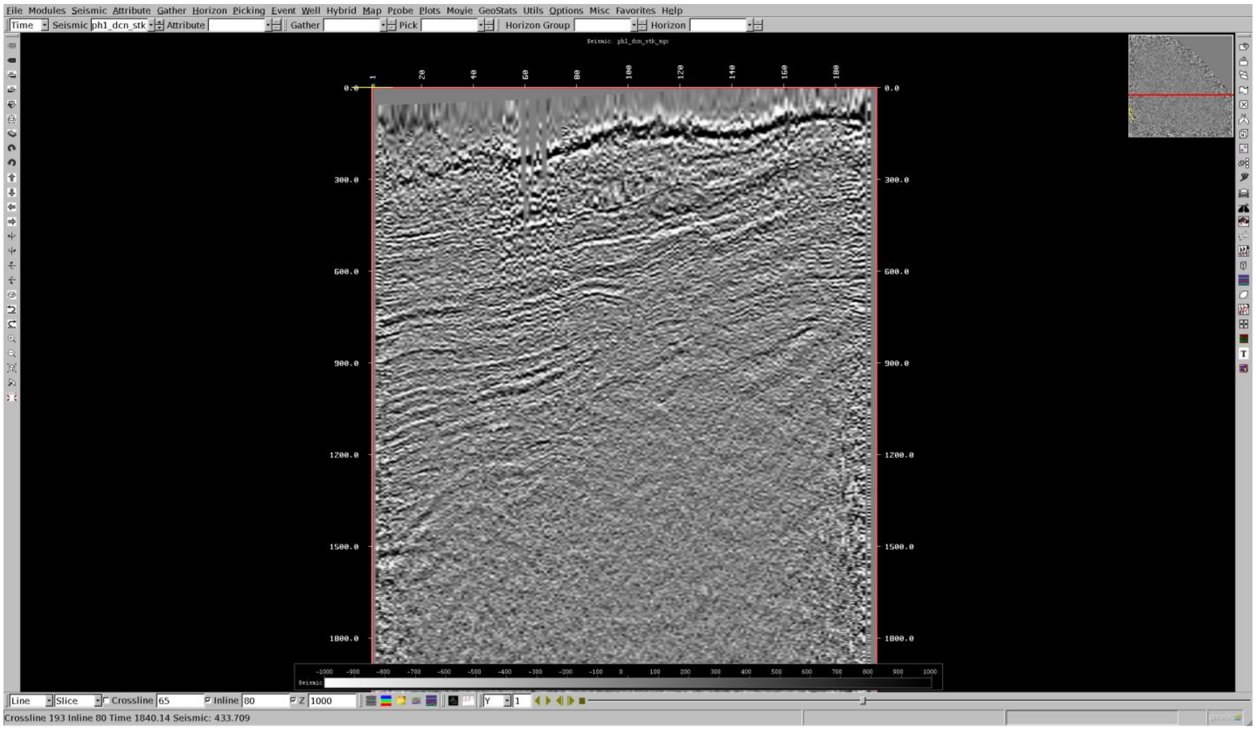


Figure 9-3: Stack after Surface consistent deconvolution IL 80 with 500 ms AGC.

10. Velocity Analysis

10.1 Overview

An initial pass of velocity analysis was performed with TOMO statics applied on constant velocity stacks. The velocities were then used to apply NMO correction prior to calculating the first pass of surface consistent residual statics (MASTT). The final pass of velocities was picked on common offset data.

10.2 Velocity Analysis

Velocities were picked interactively using common offset data and semblance panels. As part of the interactive velocity picking, NMO corrections were applied to Common Offset Stacks in real time, every time a velocity pick was adjusted. This was used as an initial QC of the velocity function.

Specifically, common offset stacks were generated using a 5x5 bin zone at 800 ft interval across the survey. Interactive velocity picking was performed to generate a stacking velocity field. A double square root NMO equation which compensates for any elevation difference between the shots and receivers was used.

The final first break mute function was also picked at this stage.

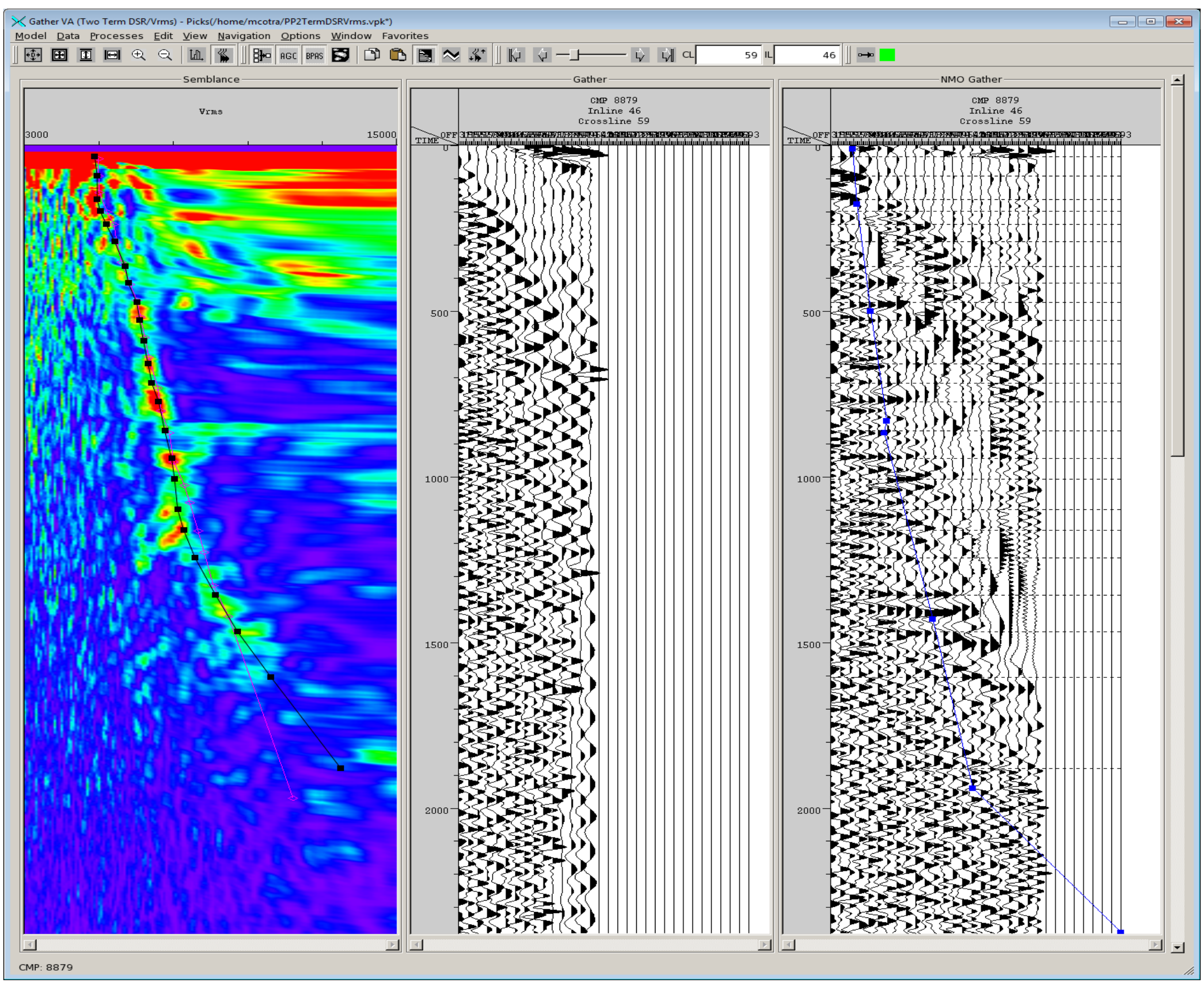


Figure 10-1: Velocity and mute analysis using common offset gathers

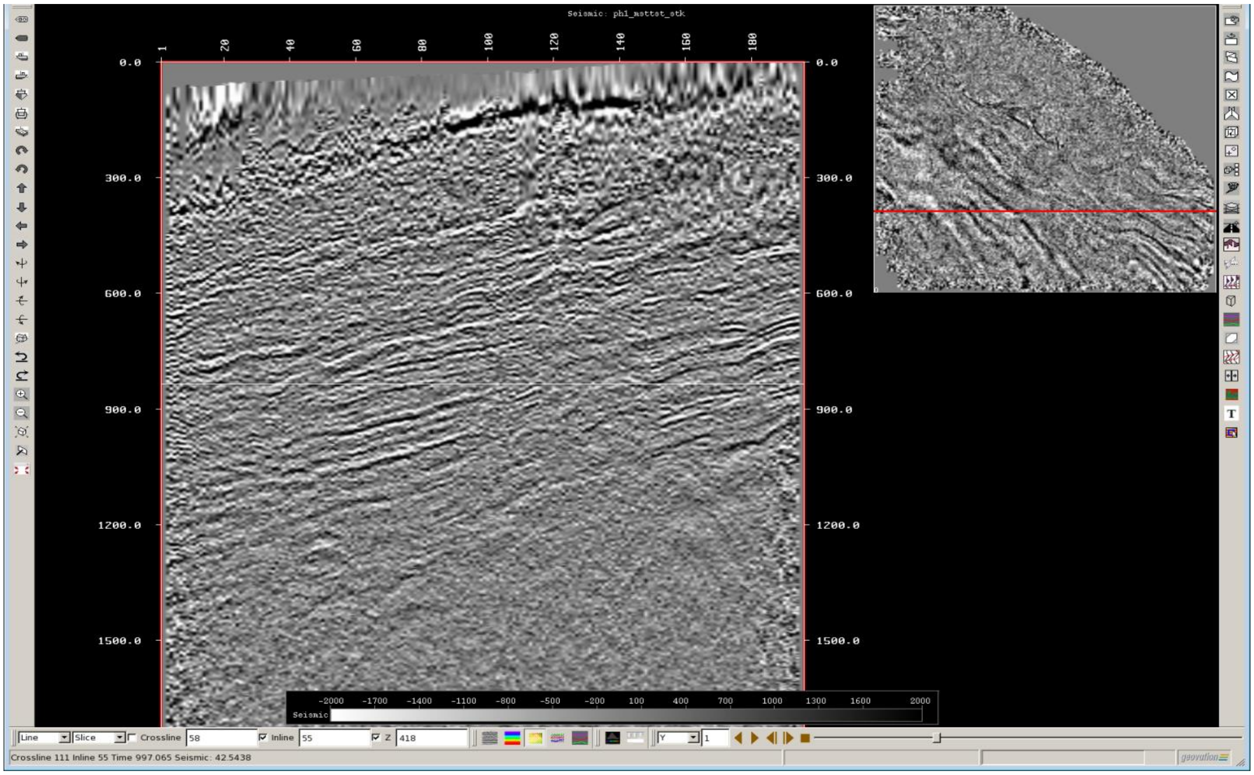


Figure 10-2: Stack after initial pass of velocity and mute analysis – IL 55

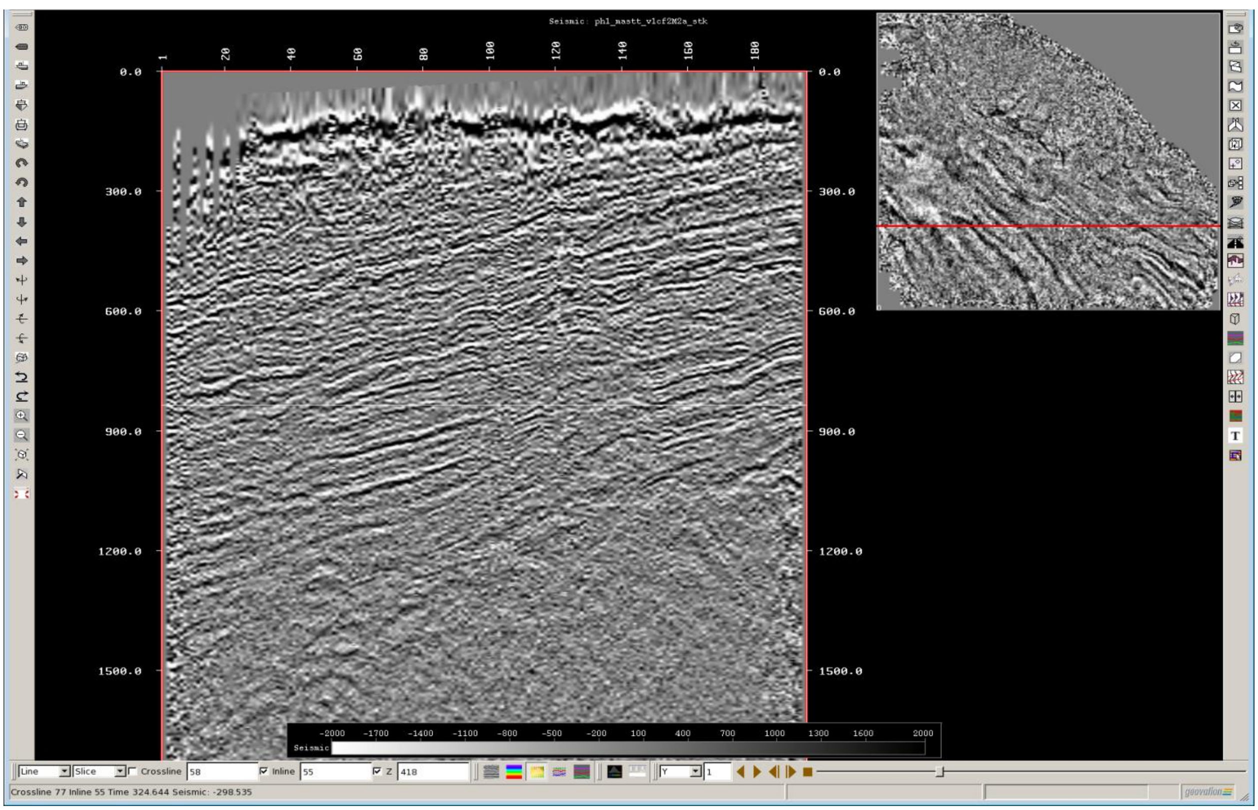


Figure 10-3: Stack after final pass of velocity and mute analysis – IL 55

11. Surface Consistent Residual Statics

Two passes of MASTT surface consistent residual statics were carried out. This method – developed by Techco Geophysical - uses the cross correlation of individual traces against each other, and hence does not rely on a predetermined model. This method is quite robust and generally produces optimum surface consistent statics.

The first pass of surface consistent statics are calculated using the initial pass of velocity, and then applied in a second velocity analysis phase, to be able to better define the velocity field. Then, a second pass of surface consistent statics (typically small residual statics +/-10ms) are then calculated and applied using the newest velocity function on CDP gathers to address any residual high amplitude noise.

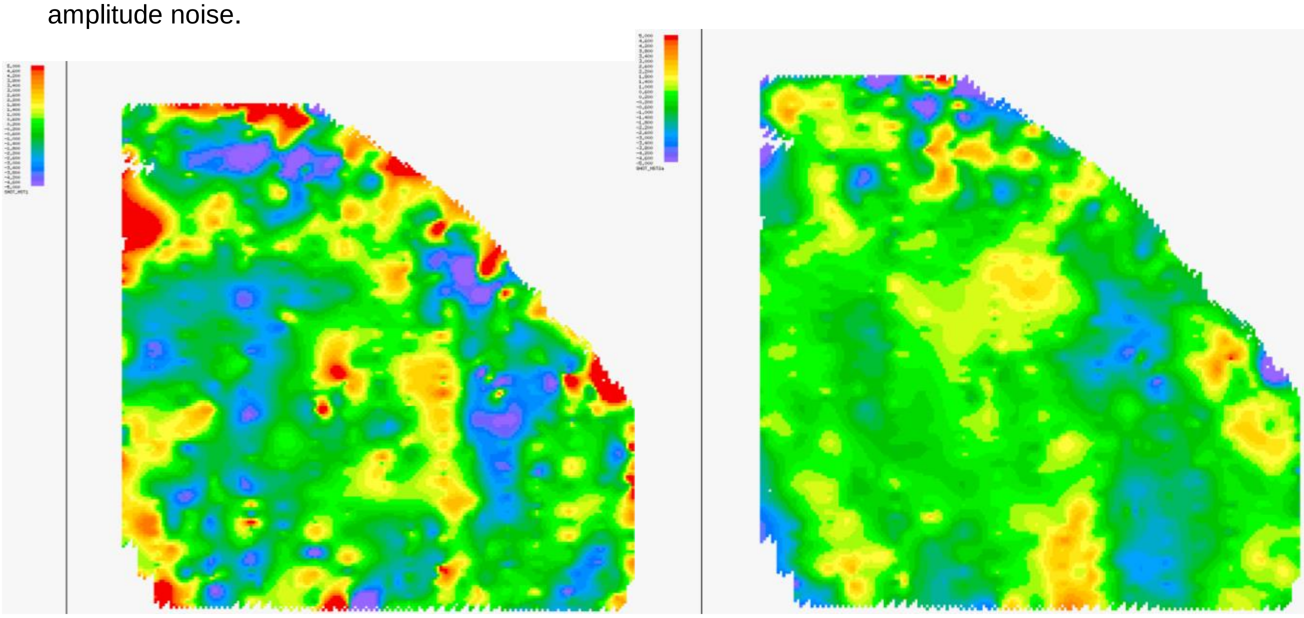


Figure 11-1: Left: shot statics after first pass of reflection statics, ±5ms. Right: shot statics after second pass of reflection statics ±5ms.

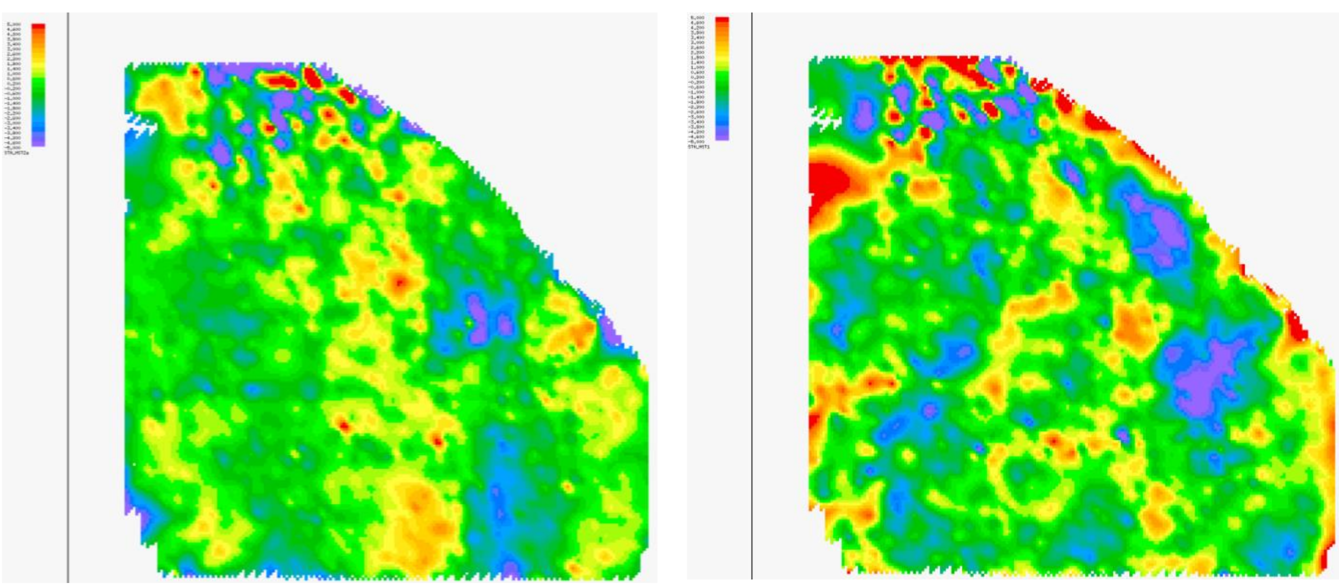


Figure 11-2: Left: receiver statics after first pass of reflection statics, ±5ms. Right: receiver statics after second pass of reflection statics, ±5ms.

12. Post Decon Noise attenuation

12.1 Post Decon Noise Attenuation

Process such as BLAST and FLASH were used for post decon noise attenuation.

BLAST identifies high amplitude noise blasts and scales or mutes the zones. The method locates zones in traces where the amplitude envelope is excessively high (exceeding a user defined threshold). BLAST uses a global estimate of the median amplitude level for thresh holding purposes.

Process FLASH was performed to identify and scale down any high amplitude outliers in a zone of traces by comparing the amplitude of each trace with the localized median estimate in the zone. The identified noisy traces are scaled to zero and a difference is taken to isolate the noise in that frequency range. To execute noise attenuation, the noise is then subtracted from the original broadband input. See above, page 17 and 18 for detailed descriptions on the three processes.

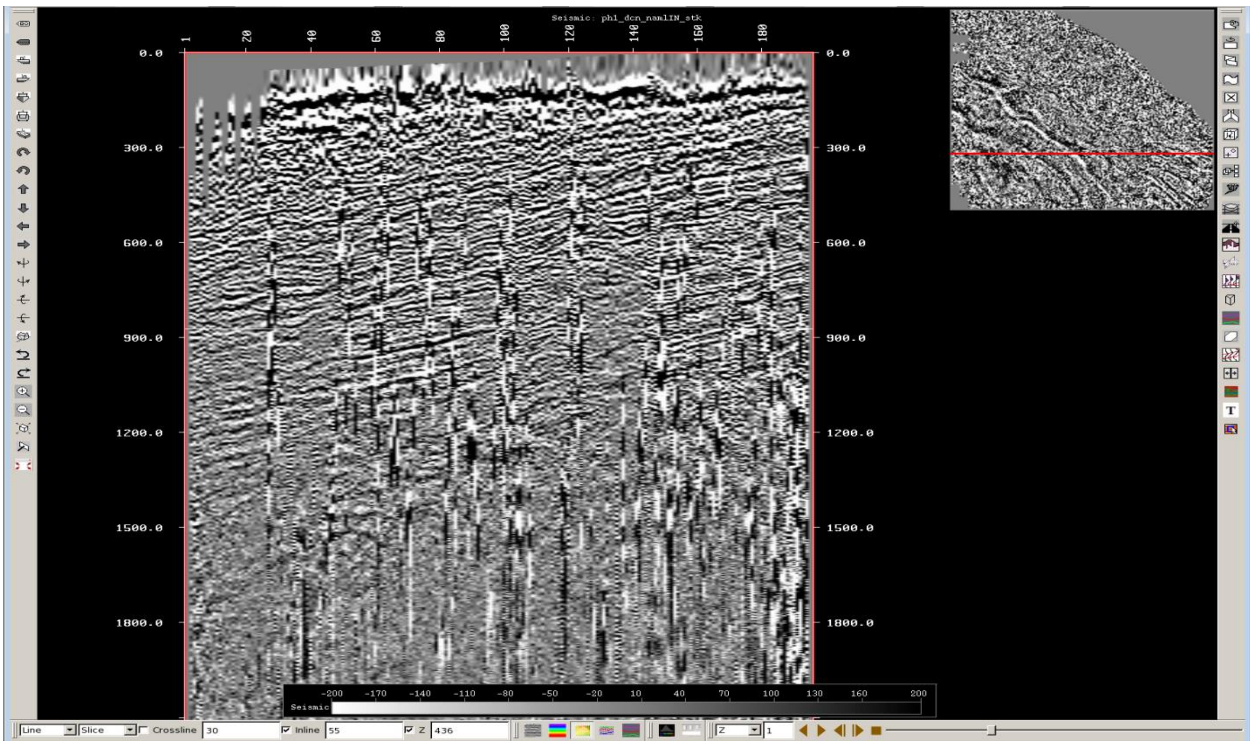


Figure 12-1: Post Decon Stack without post decon noise attenuation – IL 55

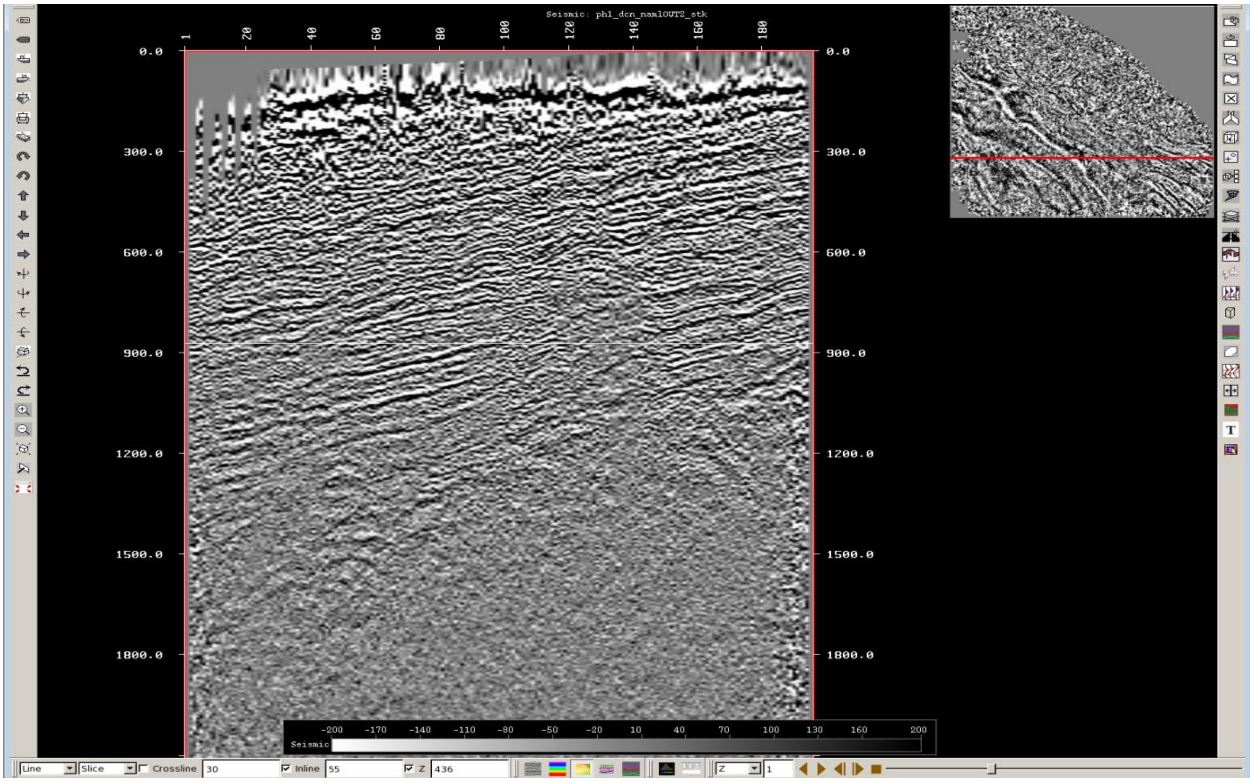


Figure 12-2: Post Decon Stack with post decon noise attenuation – IL 55

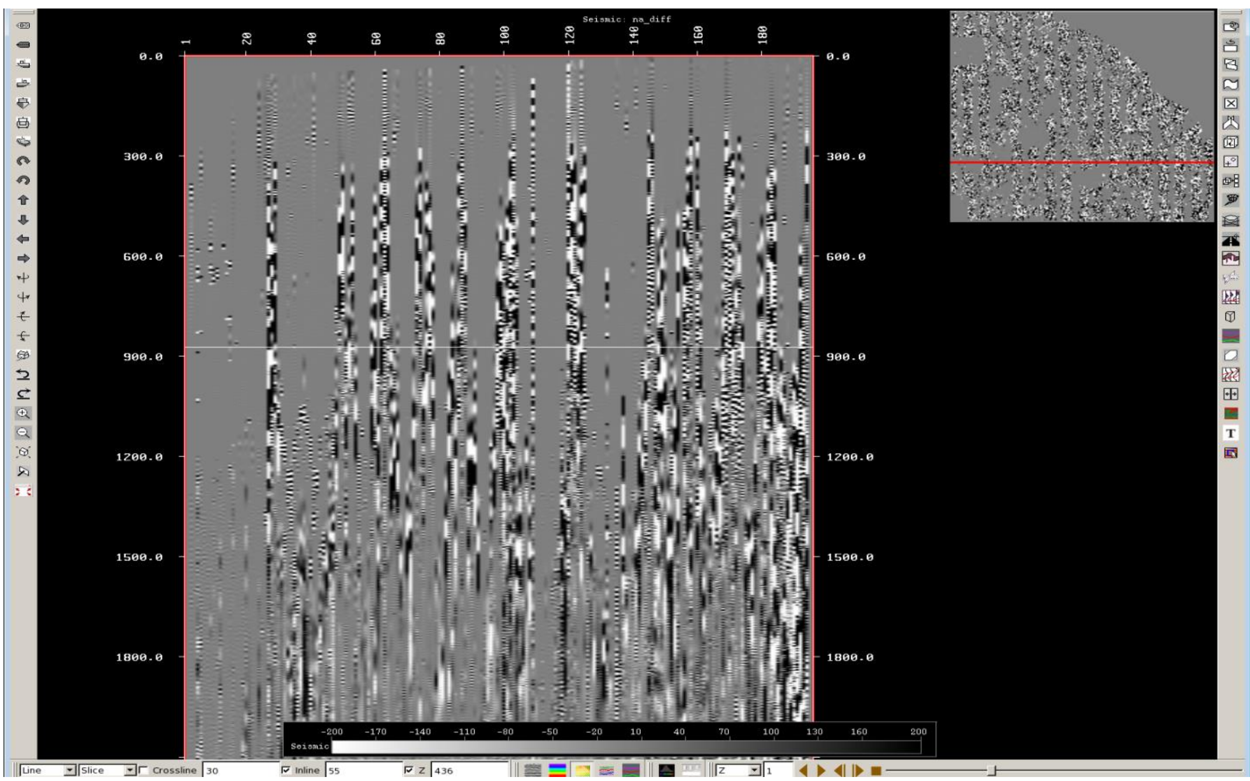


Figure 12-3: Total noise removed by post decon noise attenuation – IL 55

13. 5D Interpolation

13.1 Overview

Sparse or irregularly sampled seismic acquisitions can leave interpreters with uncertain images of the subsurface. To overcome this problem and enable interpreters to have more reliable information from existing surveys, CGG has developed 5D Interpolation, a global multidimensional interpolator to infill sampling gaps and increase spatial sampling while preserving original recorded data.

5D Interpolation performs simultaneous pre-stack interpolation in five dimensions - offset, azimuth, inline, cross-line and frequency – to predict new shots and receivers at desired locations. 5D Interpolation alleviates many of the problems affecting pre-stack processing, and offers a very useful tool to pre-condition the data for pre-stack migration, AVO and AVAZ.

13.2 Data Preparation and Testing

The data were prepared by applying all the statics and the final velocities. Also an open mute was applied to remove some of the NMO stretch. It was decided to only interpolate the shots as these were sparse compared to receivers. The receivers were also already fairly regular.

The data were interpolated using 0 – 15000 ft offsets as this was determined to be the usable range in the dataset.

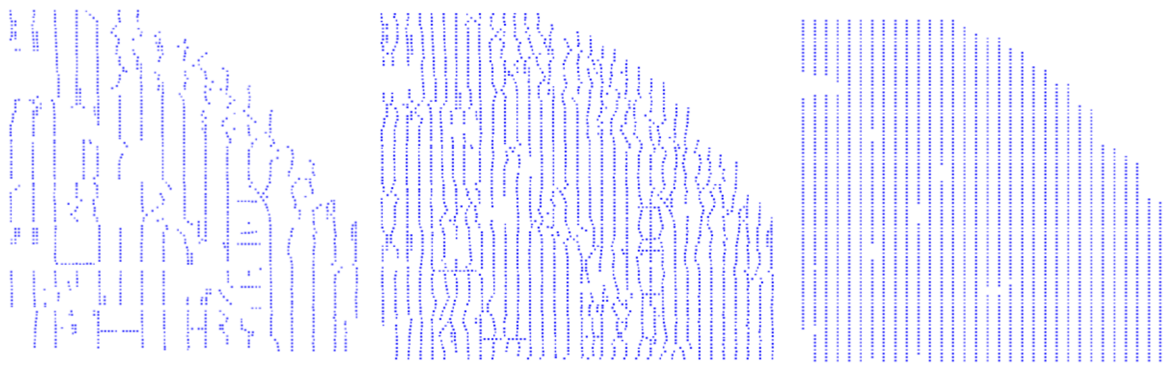


Figure 13-1: Left shows shots before interpolation. Middle shows interpolated shots and original shots. Right shows regularized shots.

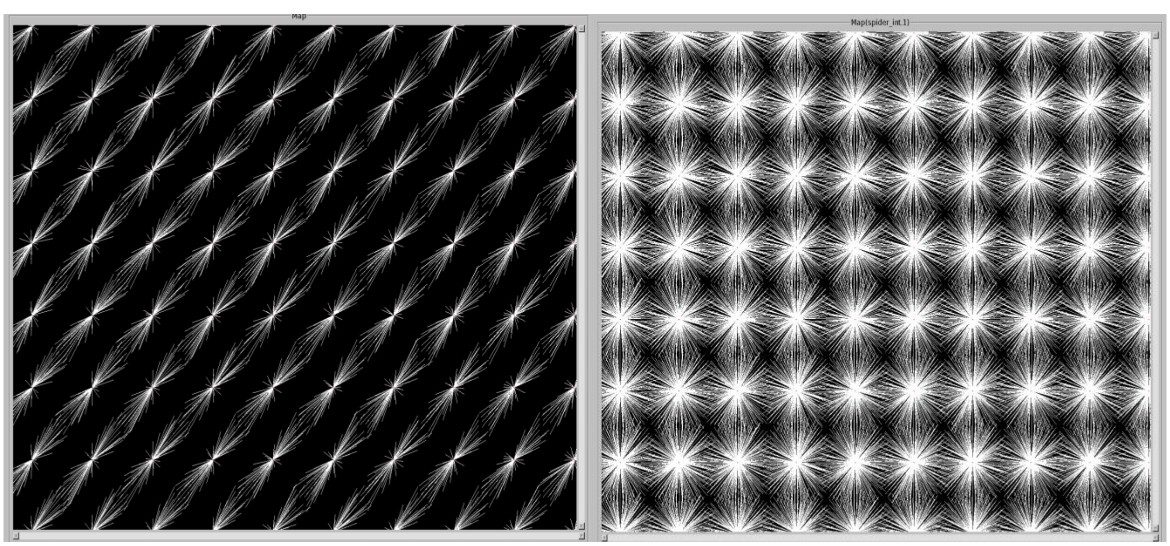


Figure 13-2: Left: spider plot before Interpolation. Right: Spider plot after Interpolation/Regularization.

13.3 5D Interpolation Results

The new total shot count is 2976 (old total shot count 1275). All of the QC's after interpolation were checked thoroughly to see if data integrity was maintained. RMS amplitude maps were checked to see if the amplitude variations were preserved through the Interpolation process. It was decided to proceed with the interpolated data to migration as the original data is still preserved in interpolation but not regularization. The results were also very similar as seen in the stacks below.

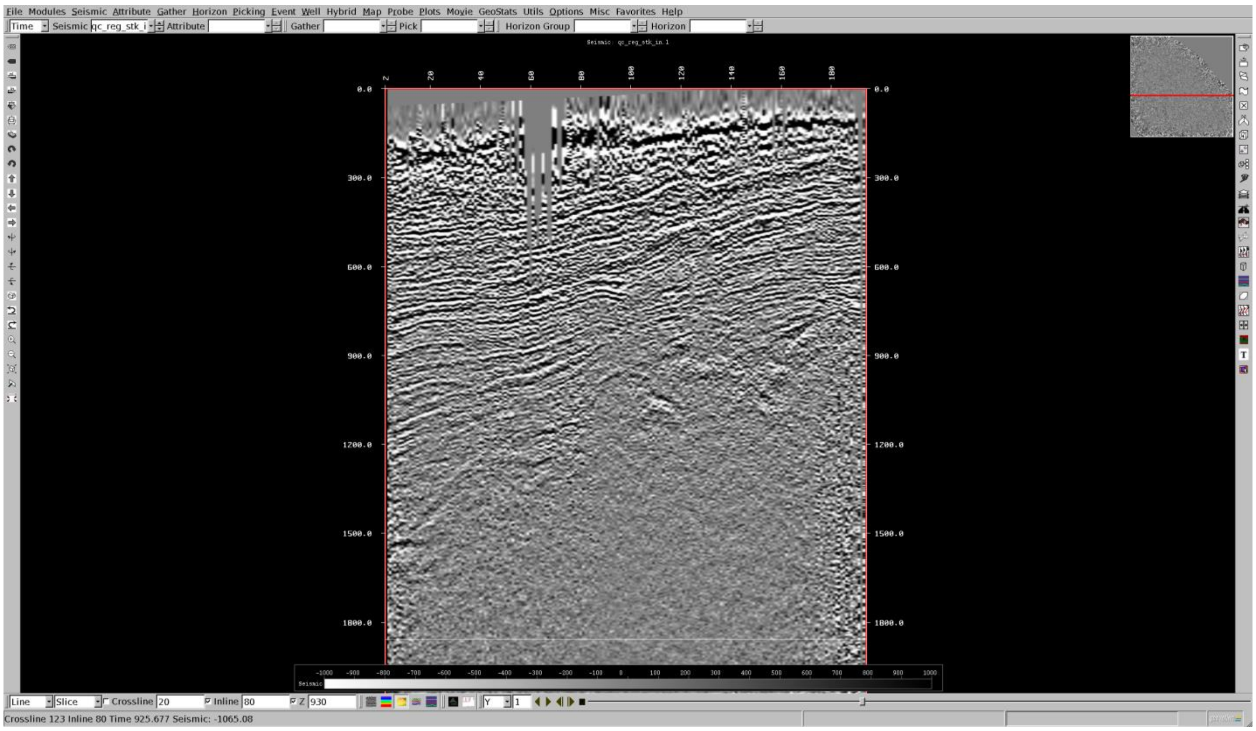


Figure 13-3: Stack before interpolation – IL 80.

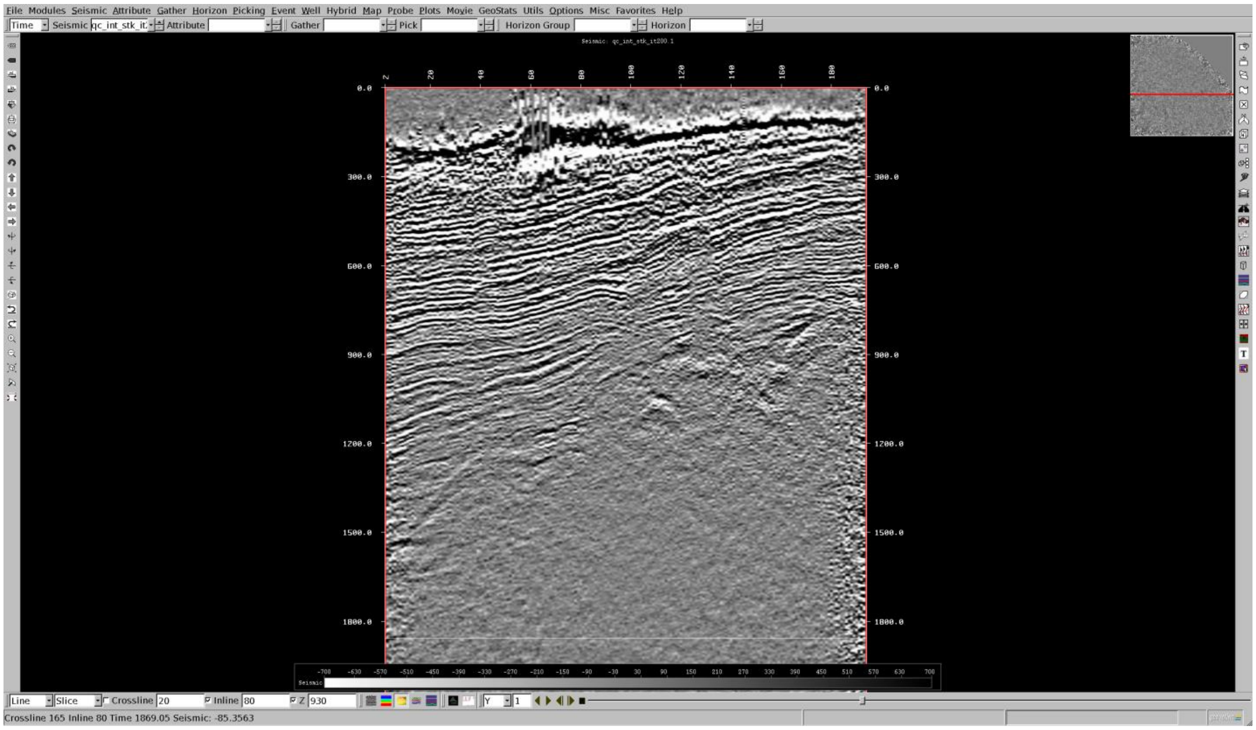


Figure 13-4: Stack after interpolation – IL 80.

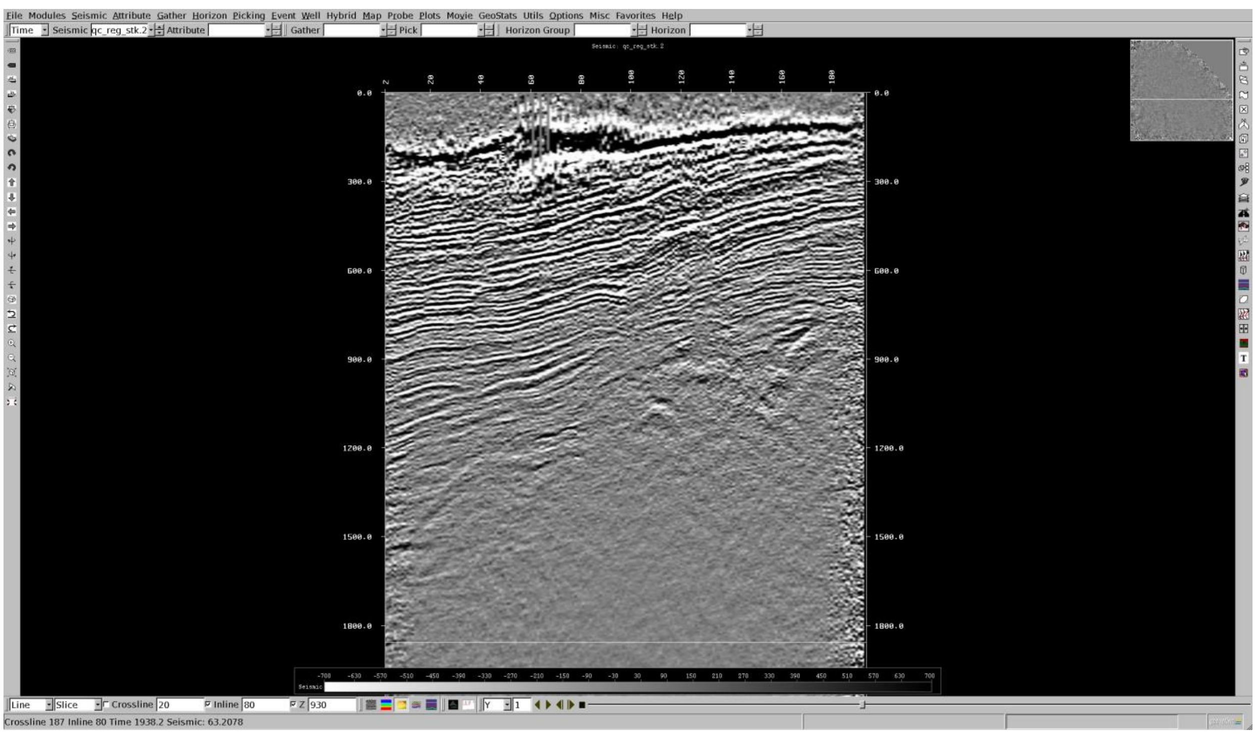


Figure 13-5: Stack after regularization – IL 80.

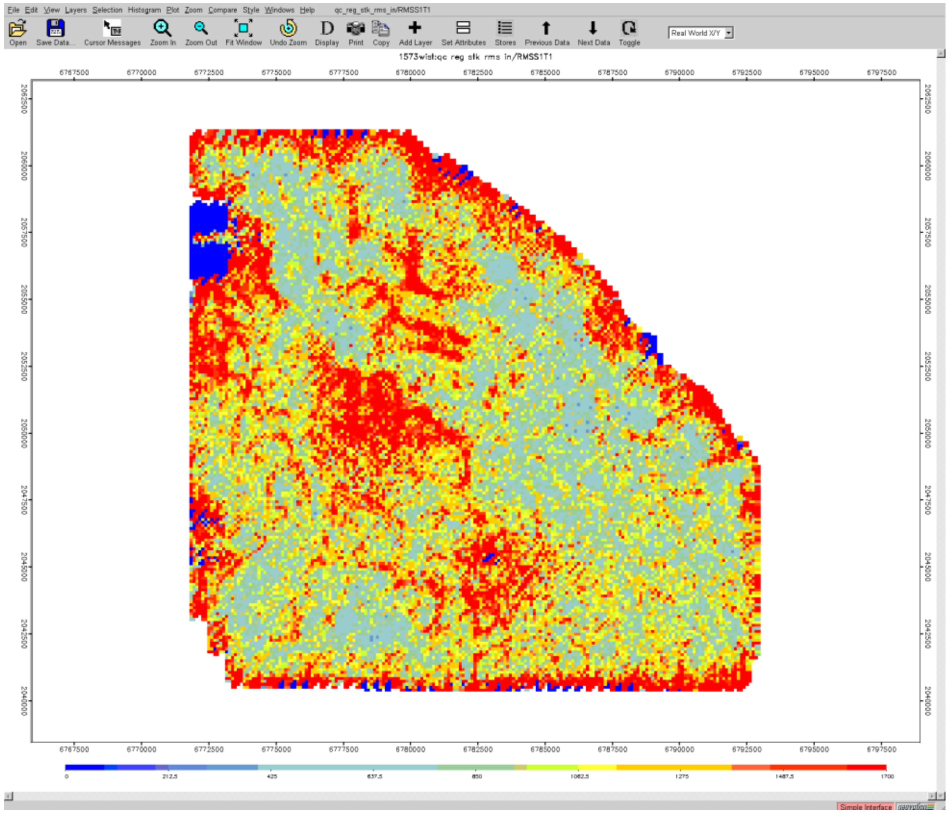


Figure 13-6: Full offset RMS Map before interpolation.

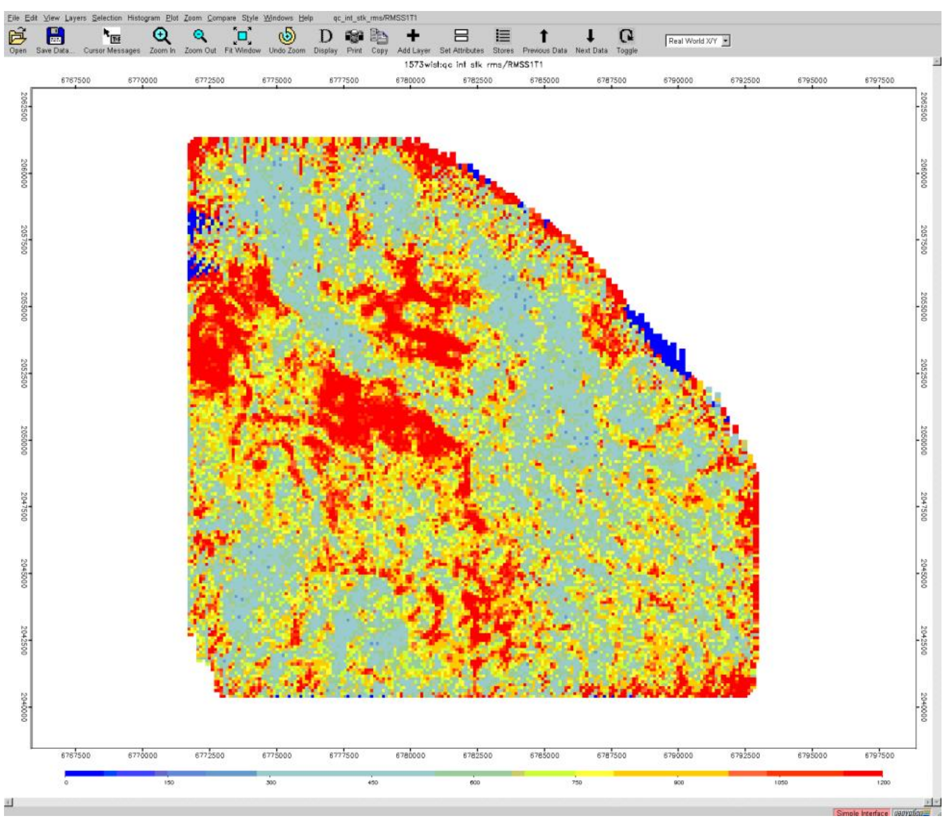


Figure 13-7: Full offset RMS Map after interpolation.

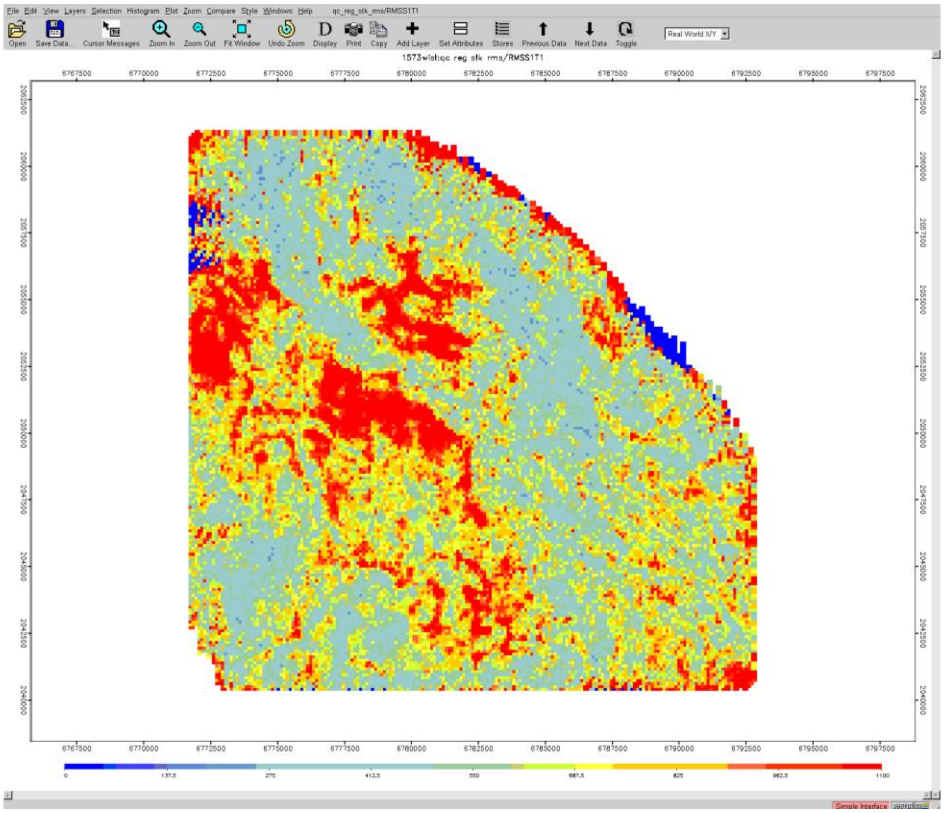


Figure 13-8: Full offset RMS Map after regularization.

14. Pre-stack Time Migration

14.1 Pre-stack Time Migration

The pre-stack time migration was performed using the Kirchhoff algorithm. The practical difference between the pre-stack and post-stack migration is that the former both permits and demands higher velocity resolution than the latter. The result of post stack migration is strictly limited by the quality of the stack that can be realized with conventional NMO and DMO techniques. The results usually show more accurate positioning, better definition of faults and other subsurface features.

Two different binning techniques were tested; accordion binning and common offset vector (COV) binning. After review the tests with the clients, it was decided to proceed with accordion binning.

Area Weighting

This process is used to mitigate any residual sampling gaps within each offset class prior to prestack migration. This computes an equalization weight based on the ratio of populated bins within a Fresnel radius of every CDP bin within each offset class. Traces are thus upweighted in the vicinity of holes or gaps to compensate for the energy missing samples would have contributed to the summation process.

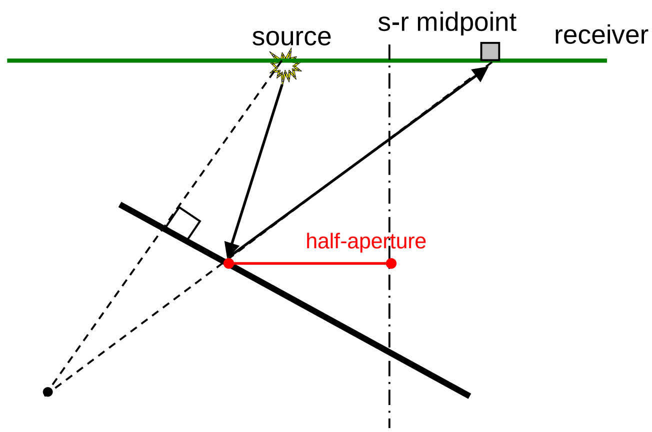
PSTM Velocity Analysis

Pre-stack migration velocity analysis is performed using principle tools similar to conventional stacking velocity analysis. Target lines are migrated with all the data required to form the common offset gathers. An interpolated velocity field is then used to drive the full volume migration. For this data Migrated Constant Velocity Stacks (MCVS's) were used.

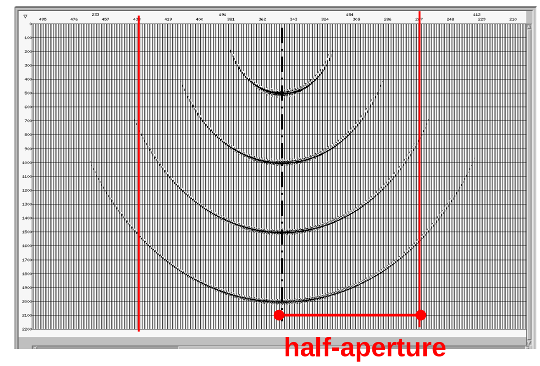
Aperture

Aperture refers to the ideal of having samples from an infinite spatial range (the Kirchhoff integral extends from minus infinity to plus infinity), or physically a full angular recording range at all reflection points. In practice, of course, our acquisition perimeters - the coverage of each shot record and the overall survey edges - limit the aperture. The spatial extent of Kirchhoff summation along the diffraction hyperbolae is usually further limited by the user to be carried out over a defined spatial area; this parameter is known as the migration aperture. The advantages of limiting the aperture include decreasing the computational expense and suppressing noise. One consequence of limited apertures, however, is that the migration operators are dip-restricted, meaning that steeper dips are progressively attenuated.

Too narrow a migration aperture will truncate the operators and reduce the 'swing' especially of the deeper events - which may mean steeply dipping events are suppressed. Too wide an aperture may introduce a significant cost in run time with no improvement in quality; in fact a large aperture may degrade the migration of low signal-to-noise ratio data. As well, too wide an aperture leaves velocity artifacts at the edges of the deeper events. The aperture can be viewed as a tradeoff between dip reconstruction and control of operator swing noise.



Aperture controls the lateral distance an operator will swing from the midpoint. This corresponds to the lateral displacement between the midpoint and the reflection point from a dipping reflector.



Aperture parameter shown on migrated spike series.

Pre-stack Time Migration Parameters

The parameters that were tested include migration aperture, dip limit, and offset class discrimination

- Accordion binning was used.
- The selected optimal migration parameters were
    - aperture: 8800 ft (80 traces)
    - maximum angle: 80 degrees
    - alias: 75%

Residual Migration Velocity Analysis

Post-PSTM velocity review for Residual NMO was conducted.

Figure 14-1: Input to migration stack – IL 80.

Figure 14-2: PSTM stack migration – IL 80.

15. Final Deliverables – SEG-Y Format

1) Unfiltered PoSTM Stack Migration
2) Fold Cube
3) Interpolated Gathers
4) Interpolated Stack
5) Unfiltered PSTM Stack Migration
6) PSTM Gathers
7) TOMO Velocity Model
8) Final Migration Velocities – Interval
9) Final Migration Velocities – RMS
10) Final Stacking Velocities – Interval
11) Final Stacking Velocities - RMS

16. Contact Information

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17. Appendix – Hotlinks to PowerPoint® presentations

1. 01_WISTER3D_GEOMETRY.ppt
2. 02_WISTER3D_PREDCN_NA.ppt
3. 03_WISTER3D_DCN_MASTT.ppt
4. 04_WISTER3D_VELS_MUTE.pptx
5. 05_WISTER3D_POSTDCN_NA.pptx
6. 06_WISTER3D_INTERP.ppt