Final Report
Lodwick 3D Survey 2022
Seismic Processing
For
Red Sky Energy

Contents

1. Introduction 2
2. Acquisition Parameters 3
    2.1 Lodwick 3D Acquisition Parameters 3
3. Processing Flow Summary 4
    3.1 Lodwick 3D Processing Flow Summary 4
4. Geometry 5
    4.1 Lodwick 3D Processing Geometry 5
5. Processing Flow Detail – PSTM 8
6. 3D Processing Flow Technical Discussion and Testing 9
    6.1 3D Refraction Statics 9
    6.2 3D Amplitude Recovery 13
    6.3 3D Squelch 13
    6.4 3D Quash Adaptive Noise Attenuation 17
    6.5 3D Surface Consistent Deconvolution Tests 20
    6.6 Velocity Analysis 21
    6.7 Residual Statics 22
    6.8 Pre-Stack Time Migration Parameters 25
    6.9 Post PSTM Velocities and Mute 25
    6.10 Post Stack Enhancement Tests 25
7. Conclusions and Recommendations 29

Appendix A – 3D Data Disposition 30
    PSTM Stacks 30
    Gathers 30
    Statics 30
    Velocities 30
Appendix C – Example EBCDIC headers 31
Appendix D - Contact Information 31
    Client 31
    Processing Contractor 31

1. Introduction

In March 2022, "Red Sky Energy Limited" , engaged Dayboro to process the newly acquired Lodwick 3D Seismic Survey from PRL 13, in the Otway Basin, South Australia. The data were acquired in February 2022 by Velseis.

The Lodwick 3D consisted of approximately 15 square kilometres of seismic acquisition. The area covered by the survey consists of simple topography, and relatively straight forward surface conditions. The seismic data is of high quality. The objective of the survey was to better delineate the Sawpit Sandstone reservoir, within which oil was intercepted at a depth of 850m in the Killanoola-1 well. In this region of the Penola Trough, the seismic basement sits at between 1000 and 2000ms. Accumulations of natural gas are not considered important, and true amplitude processing was not required.

This report outlines the processing parameters and processes used in the processing.

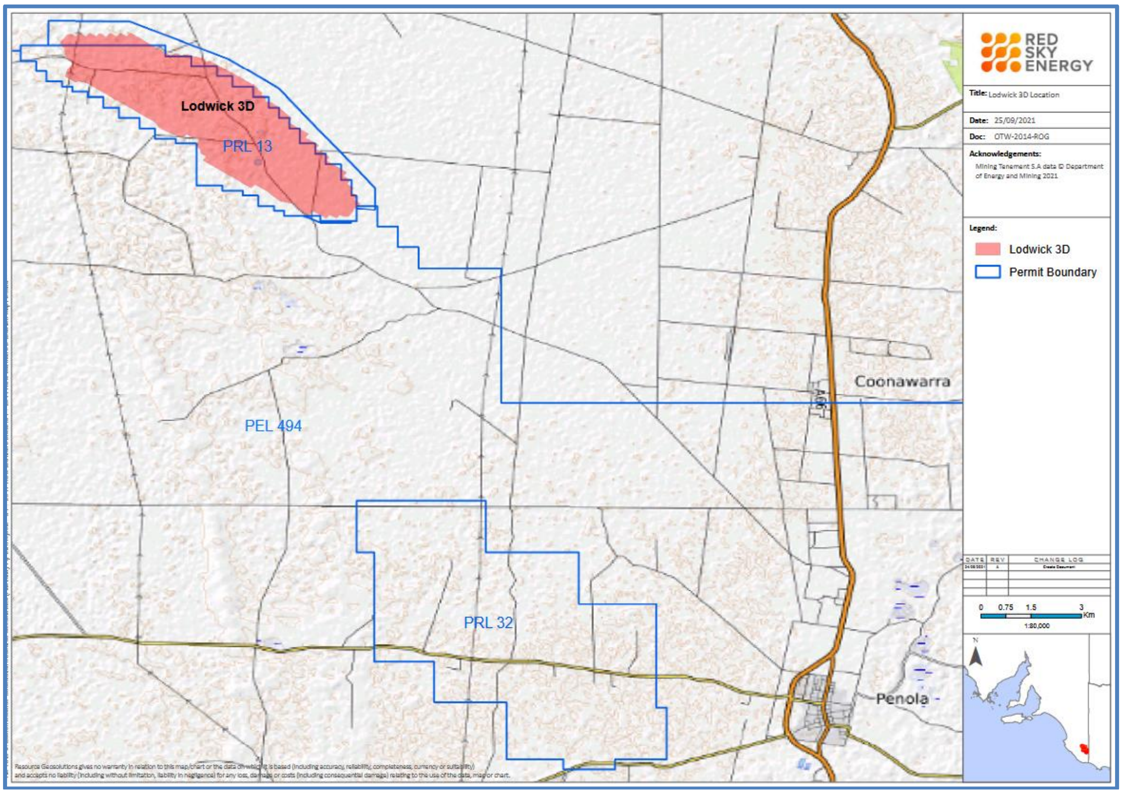

Figure 1.1 – Basemap showing the Lodwick 3D

2. Acquisition Parameters

2.1 Lodwick 3D Acquisition Parameters

Parameter	Value
Receiver Line Spacing	200m
Receiver Interval	20m
Maximum Receivers	3893
Number of Shots	5898
Record Length	4000ms
Sample Rate	1ms
Shot Line Spacing	140m
Shot Interval	20m
Sweep Band	3Hz-100Hz
Sweep Length	10000ms
Number of Vibes	3
Type of Sweep	Linear: 200ms Taper Front : 300ms Taper End
Vibrator Force	70%
Vibrator Type	UniVibs 22000lbs H/D
Survey Area	15.2sqkm
Maximum Fold	313
Patch Size	40 Lines
Receiver Type	SMARTSOLO 10Hz

Table 2.1 - Lodwick 3D Acquisition Parameter Summary

3. Processing Flow Summary

3.1 Lodwick 3D Processing Flow Summary

- Reformat
- ShotEdit/Trace Edit/Polarity Reversal
- Geometry Application and Survey Merge
- First Break Picking
- Refraction Statics Calculation and Application
- Spherical Divergence Correction
- Squelch – Adaptive Noise Attenuation
- Quash - Linear Adaptive Noise Attenuation
- Surface Consistent Deconvolution 2ms Gap
- AGC
- First Pass Velocity Analysis 400m x 400m
- First Pass Residual Statics
- Second Pass Velocity Analysis 200m x 200m
- Second Pass Residual Statics
- PSTM Velocity Analysis 200m x 200m
- Kirchhoff PSTM
- NMO Inverse PSTM Velocity
- Final Velocity Analysis 200m x 200m
- NMO-Final Velocity
- Mute
- Stack
- AGC 500ms
- Cascaded FXY Deconvolution
- FXYRunning Mix
- Spectral Whitening
- Shift to Final Datum 58m (Vrep 2500m/s)
- Output

4. Geometry

4.1 Lodwick 3D Processing Geometry

The geometry for the Lodwick 3D was generated from SPS files provided by the Client. Figure 4.1a shows the location of shots in red and receivers in blue. Figure 4.1c shows the elevation displayed as colour over the source and receiver positions. The elevation ranges from around 49m above sea level to approximately 57m above sea level. Figure 4.1d illustrates the fold of coverage for all offsets over the survey.

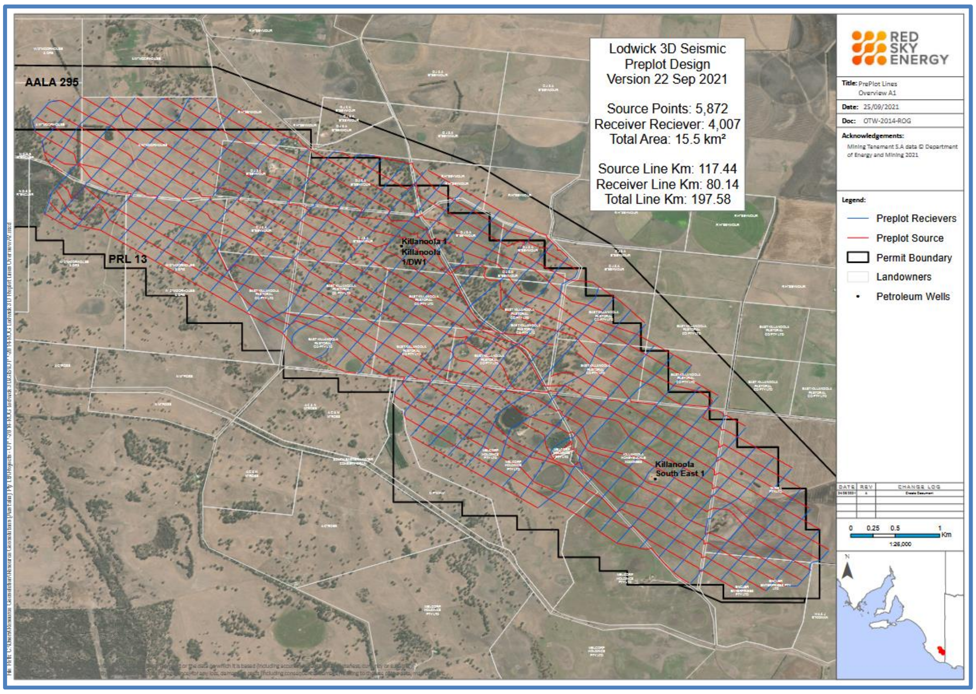

Figure 4.1a 3D Source and Receiver Locations.
(Blue Points – Receiver Locations, Red Points – Source Locations)

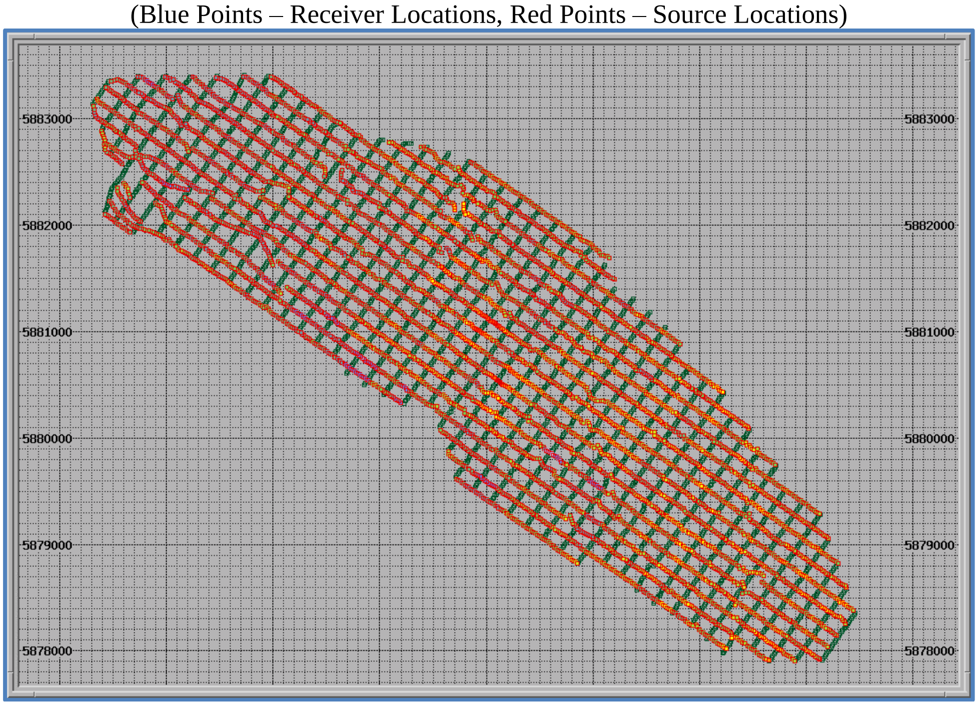

Figure 4.1b 3D Source and Receiver Locations.
(Green Points – Receiver Locations, Red Points – Source Locations)

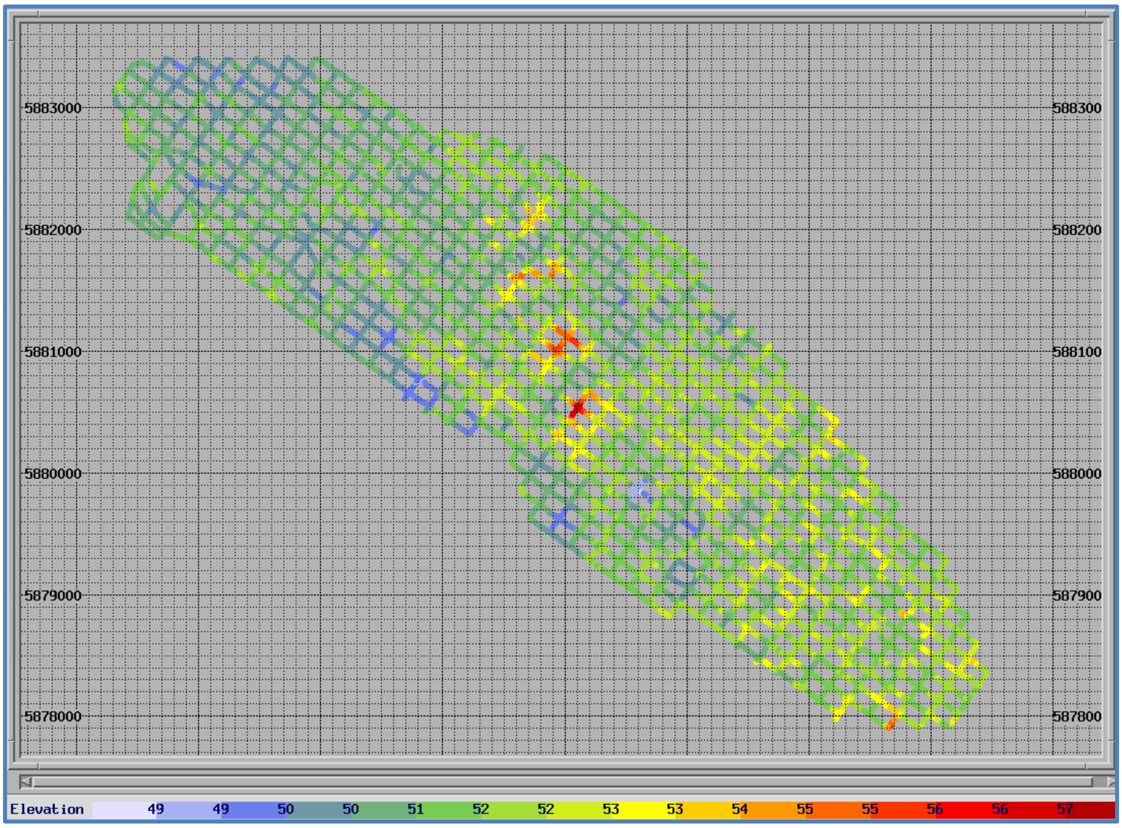

Figure 4.1c – Lodwick 3D Elevation Map.

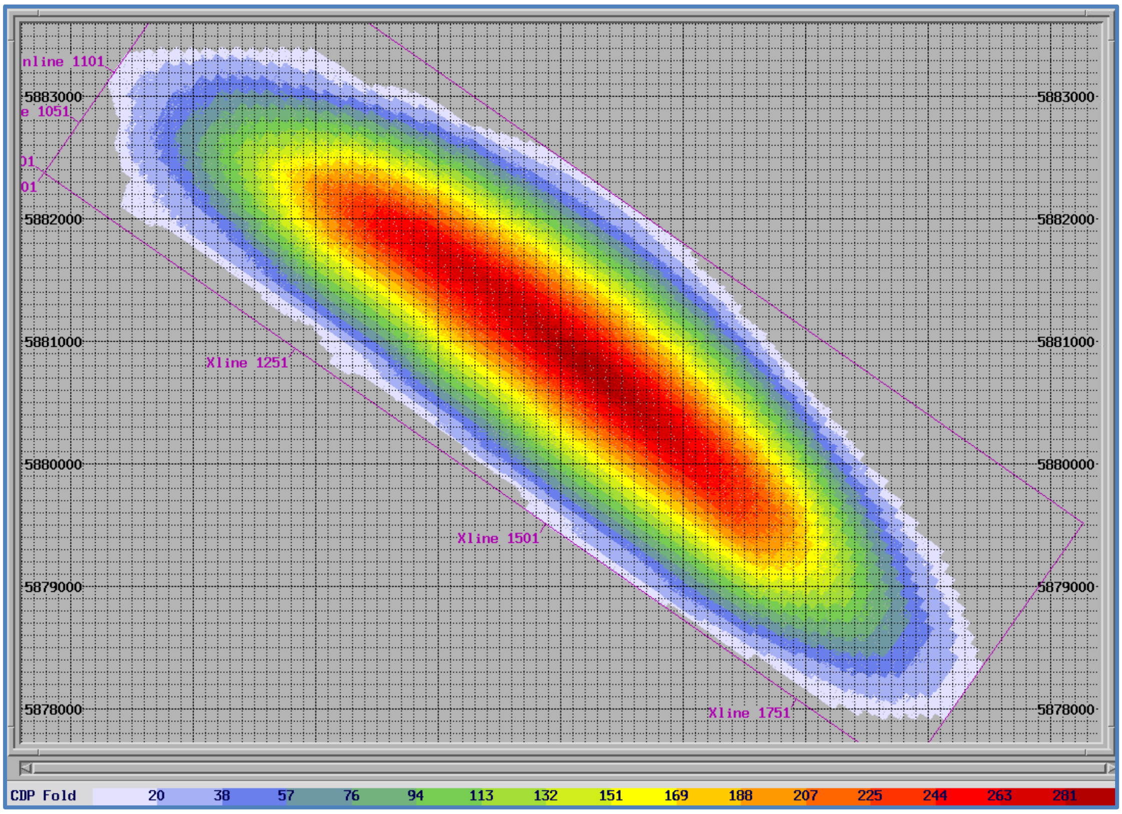

Figure 4.1d – Lodwick 3D: Fold Map (Smaller Insert from Acquisition Report)

Inline	Crossline	Easting	Northing
1001	1001	466784.53	5882379.00
1001	1860	473821.03	5877452.00
1253	1860	475266.44	5879516.50
1253	1001	468229.94	5884443.50

Table 4.1 Lodwick 3D Processing Grid

The processing grid, enumerated in Table 4.1 was designed to situate the highest midpoint density in the centre of the bins for the majority of the survey. The bin dimensions are 10m x 10m. The following PowerPoint presentations detail the geometry and bin definition in detail:

PPTX\0010_GeometryInitialization.pptx
PPTX\0011_GeometryInitialization.pptx
PPTX\0012_GeometryInitialization.pptx

5. Processing Flow Detail – PSTM

Table 5.1 PSTM Processing Flow	Lodwick 3D	
Process	Parameters	
Reformat		
Trace Edit/Polarity Reversal		
Geometry Application		
First Break Picking		
Refraction Statics Calculation		
Refraction Statics Application		
Spherical Divergence Correction	$V^2T^{1.6}$	
Squelch	Frequency Band	3-6-15-20Hz
	Airwave Attenuation	Vel 320m/s Zwidth 250ms Twidth 300
Quash	Model	FKKF: +/-20ms/tr
	Adaptive Subtraction	Monk: 1000ms Gate
	Expansion Factor	1.3
Spiking	Type	Surface Consistent
	Window	X(m, pos. and neg. offsets) T(ms)
		0m 80-2000 (applied 0-4000ms)
		1700m 960-2400 (applied 0-4000ms)
		2900m 1612-2800 (applied 0-4000ms)
		4200m 1850-2800 (applied 0-4000ms)
	Gap Length/Operator Length	2ms/120ms
AGC	1000ms Gate	
First Pass Velocity Analysis	400m x 400m Interval	
First Pass Residual Statics		
Second Pass Velocity Analysis	200m x200m Interval	
Second Pass Residual Statics		
PSTM Velocity Analysis	200m x 200m Interval	
Kirchhoff Pre-Stack Time Migration	Half Aperture	Time Half Aperture
		0ms 0m
		1000ms 2000m
		2000ms 3000m
		3000ms 3500m
	Maximum Angle	60Deg
	Offsets	50-3000@50m :3100-4000@100m
NMO Inverse	Remove Final Migration Velocity	
Final Velocity Analysis	200m x 200m Interval	
NMO	Apply Final Velocity	
Mute	Stretch	80%
Stack		
FXY Deconvolution	Type	Cascaded (Three)
	Params	FiltLength 19 Tr : Ntraces 50/10 Overlap : Wlenght 100ms/10ms Overlap
FXY Running Mix	Ntraces	3x3
	Max Dip	30ms/tr
Spectral Whitening	Band	3-6-80-100Hz
AGC	500ms	
Move to Final Datum	Datum	58m a.s.l
	Replacement Velocity	2500 m/s
Output SEGY		

Table 5.1 Lodwick 3D PSTM Processing Parameters

6. 3D Processing Flow Technical Discussion and Testing

6.1 3D Refraction Statics

Refraction statics were derived from a near-surface model created using Claritas' Refraction Inversion (Woodward et al, 1991) after picking the first-arrivals. First-arrivals were picked on traces with offsets ranging from 0 to 2500 meters, but restricted to a maximum offset of 1400m in the refraction inversion itself.

Figure 6.1a provides an example of the first-arrival picking and Figure 6.1b illustrates the source and receiver statics calculated using the refraction inversion model.

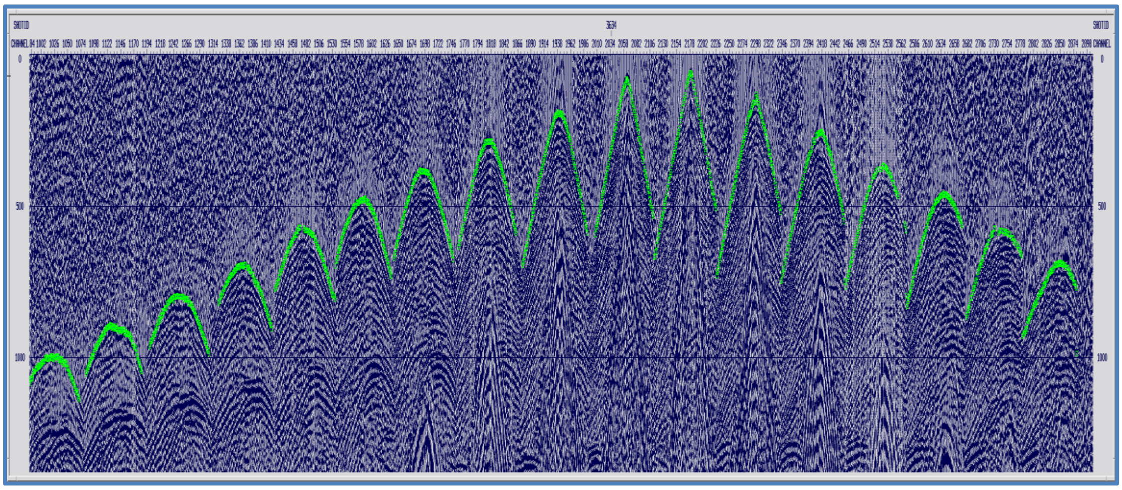

Figure 6.1a Example First-Arrival Picking

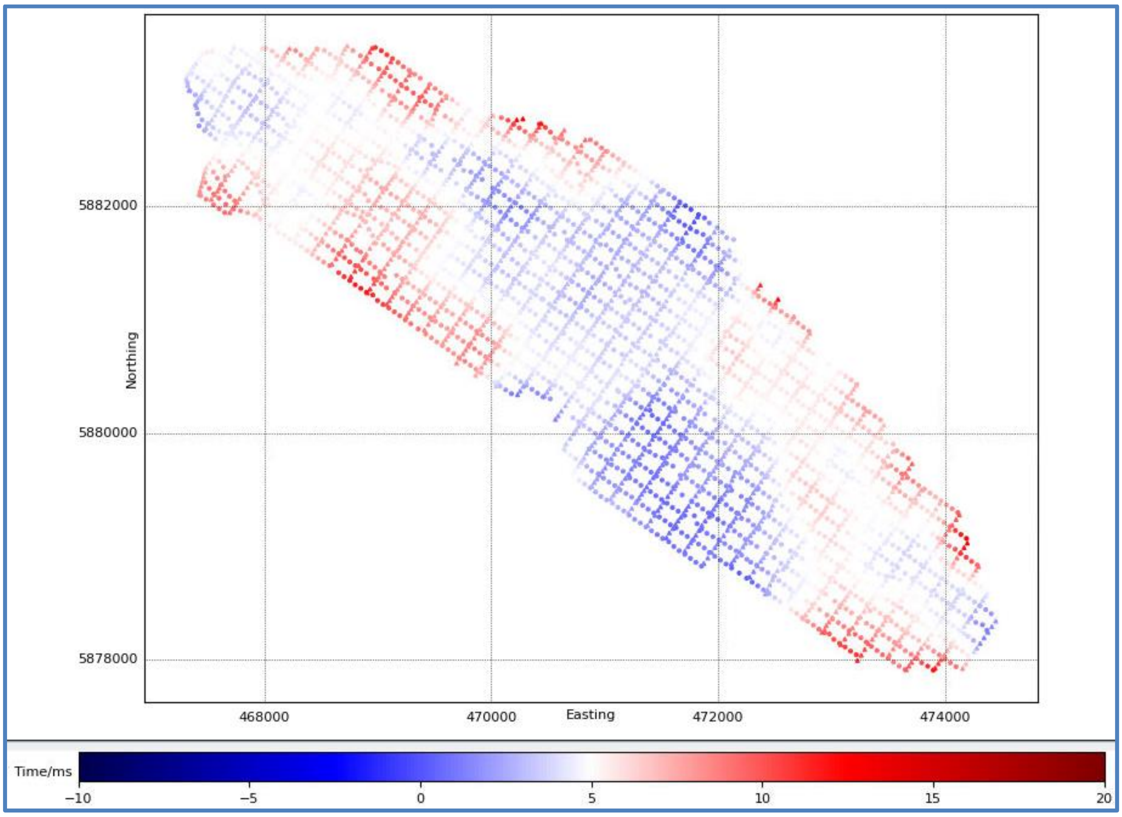

Figure 6.1b Claritas Refraction Inversion Statics

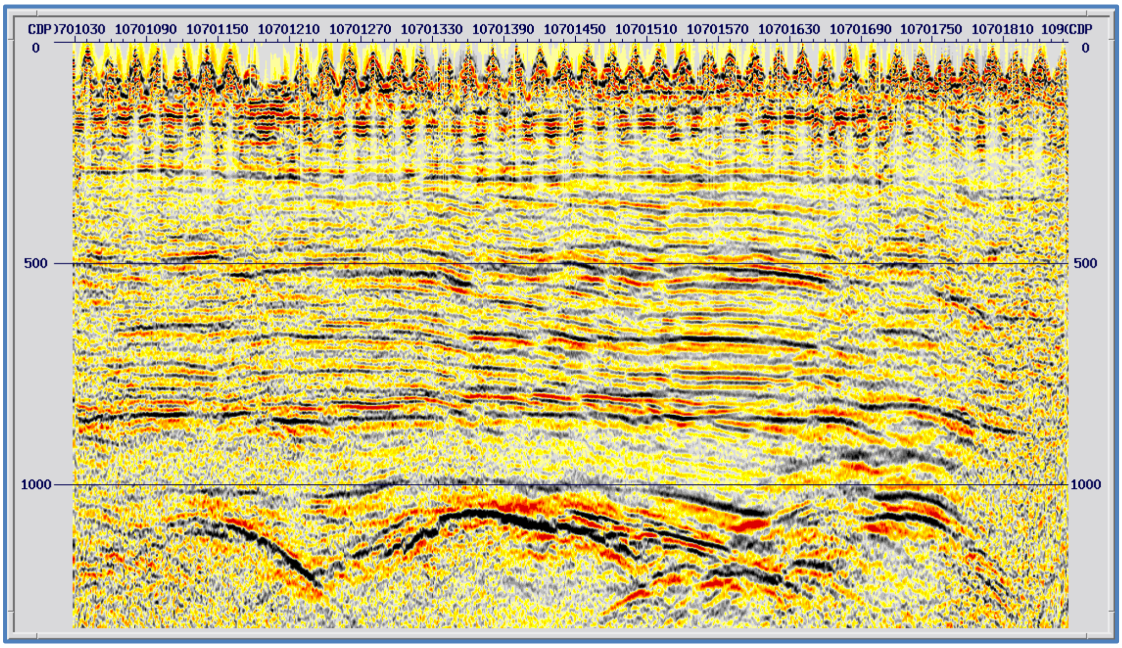

Figure 6.1c. Inline 1070 – Without Refraction Statics

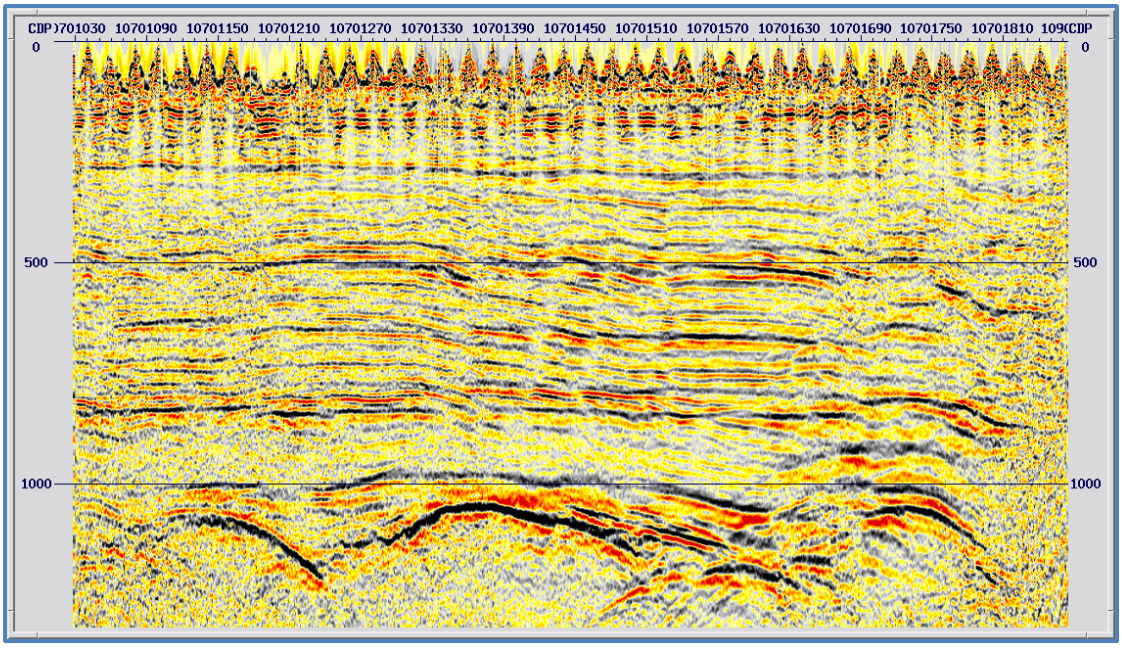

Figure 6.1d Inline 1070 – With Refraction Statics

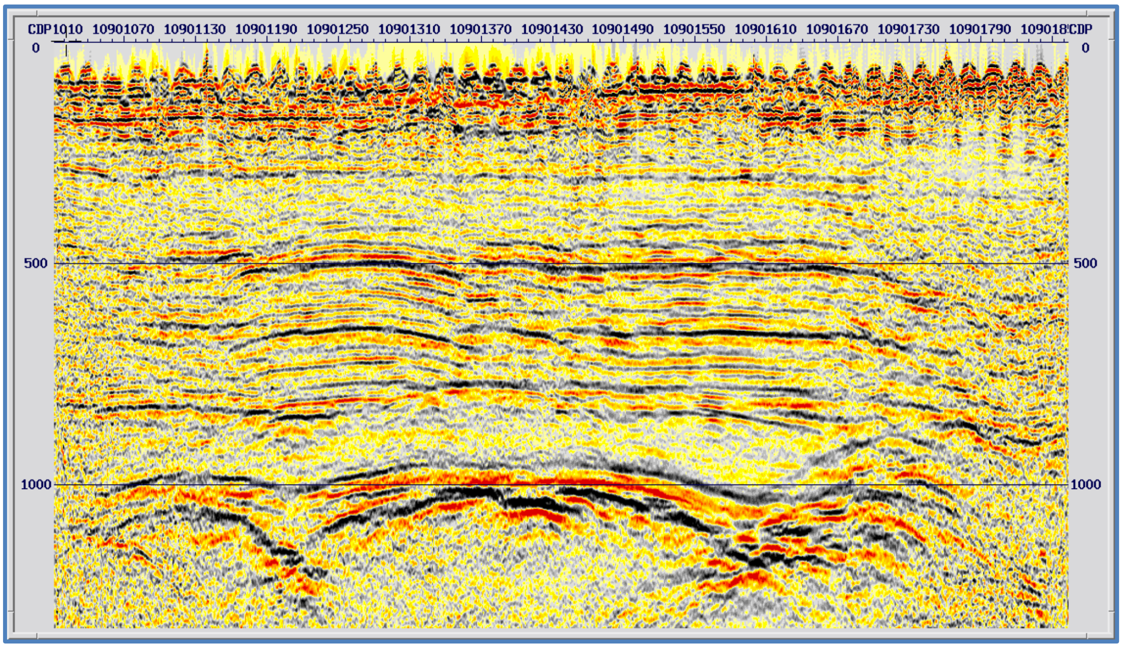

Figure 6.1d. Inline 1090 – Without Refraction Statics

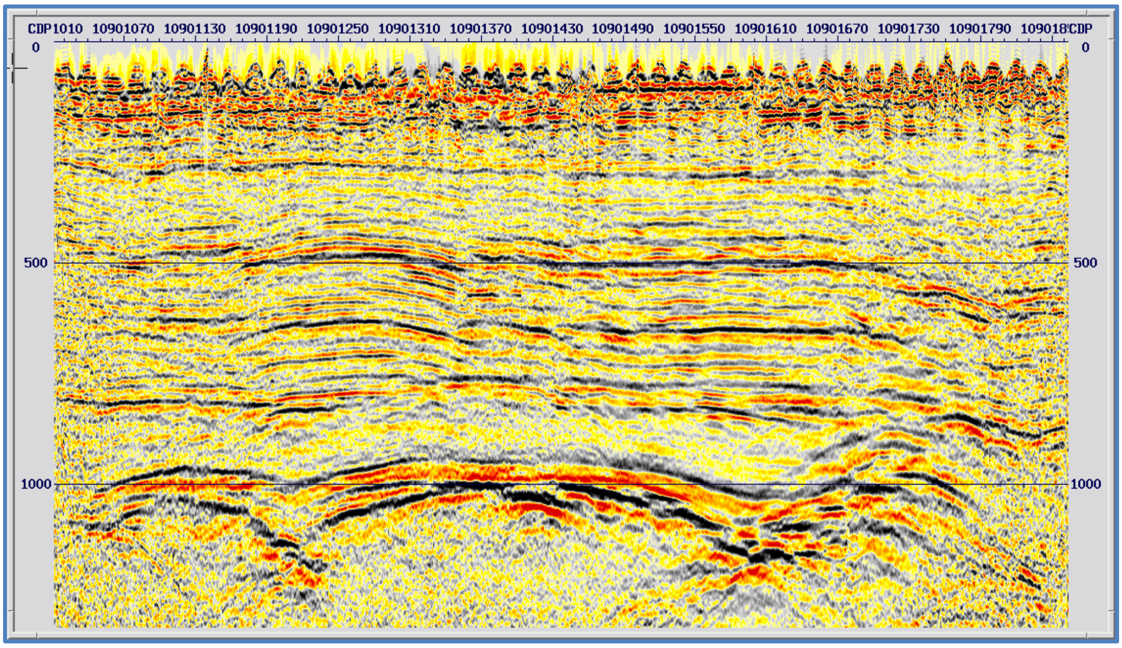

Figure 6.1e Inline 1070 – With Refraction Statics

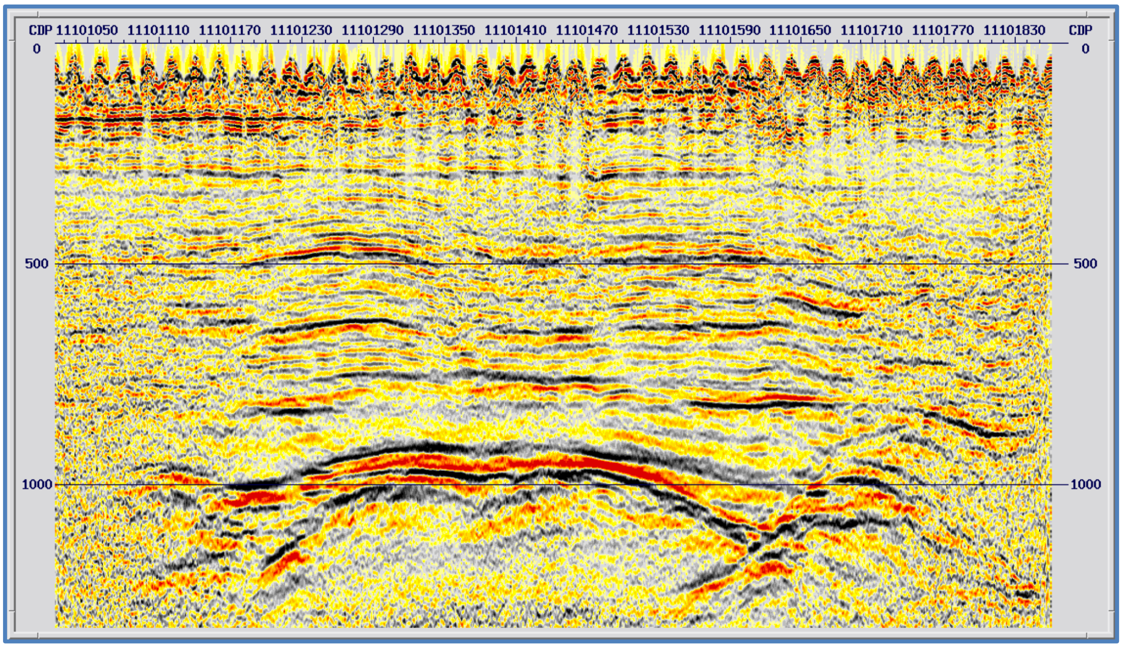

Figure 6.1f. Inline 1110 – Without Refraction Statics

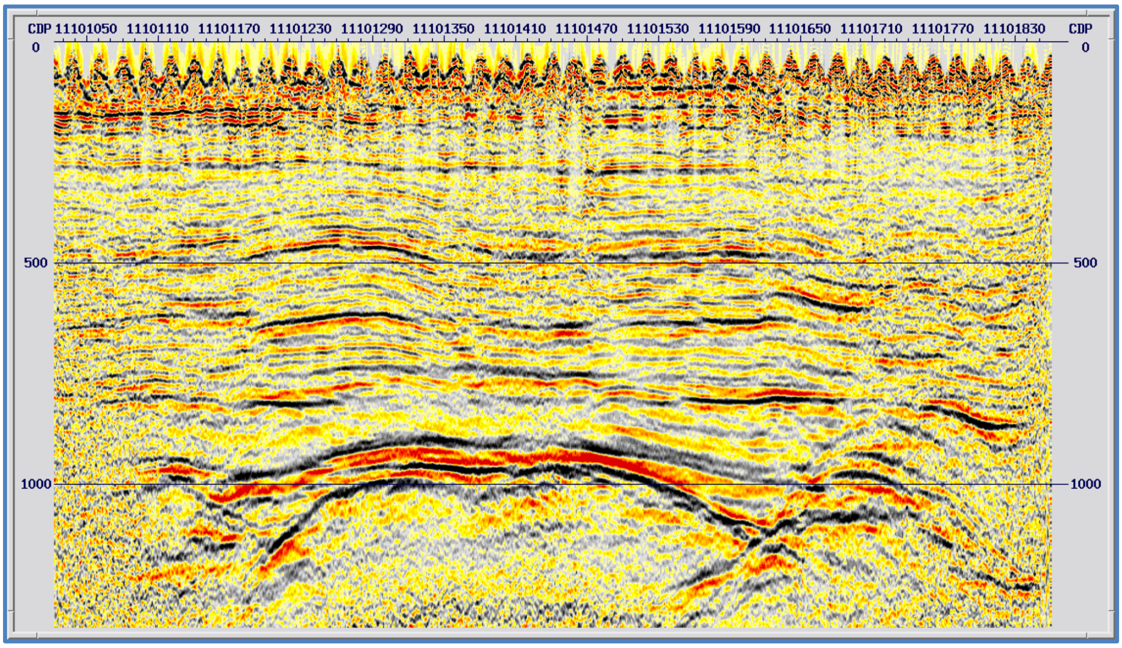

Figure 6.1g Inline 1110 – With Refraction Statics

Figures 6.1c through g display an inline prior to and following application of the refraction inversion statics. A complete explanation and review of the refraction statics testing and verification can be found in the following PowerPoint presentation along with further examples of first break picking:

PPTX\0015_FBPickingExamples.pptx
PPTX\0016_PreliminaryStatics.pptx

6.2 3D Amplitude Recovery

Stacks were created after noise attenuation, refractions statics, initial velocity analysis using a range of pre-stack spherical divergence corrections to compensate for natural amplitude decay due to increasing receiver offset and depth of reflection events.

The spherical divergence corrections tested were:

V^0T^1
V^1T^1
$V^{1.5}T^1$
V^2T^1
$V^2T^{1.2}$
$V^2T^{1.4}$
$V^2T^{1.6}$
$V^2T^{1.8}$
V^2T^2

$V^2T^{1.6}$ was chosen as the optimum Spherical Divergence.

6.3 3D Squelch

Very strong amplitude ground roll is present on the data. The amplitude of this noise is an order magnitude stronger than the signal. This ground roll is quite limited in bandwidth. The process used to remove this noise is known as Squelch. In Squelch, spurious noise segments are removed using an algorithm that compares RMS amplitude level in a moving window against neighbouring seismic traces. When properly parameterised, it removes high amplitude additive noise from sources like wind, tree branch movement, personnel and vehicles that were on the seismic patch during data recording.

Squelch is a proprietary method for removing high amplitude noise. The noises are separated from the signal by frequency bands and their amplitudes are reduced. Then the frequency bands are combined back together to create the noise-attenuated dataset.

The effects of Squelch noise attenuation are much more pronounced on the pre-stack data than on the stack data, as the stack is also a very-good noise filter.

Squelch will enhance the reliability of pre-stack data analysis and the effects can be clearly seen on the stack data also.

Shot records and stacks were compared before and after Squelch application. Figure 6.3a, and b display shot records before and after Squelch, Figure 6.3c shows the difference plot. Figure 6.3d and e illustrate a selected inline and crossline prior to and following the application of Squelch.

The full test analysis can be found in the following PowerPoint presentation:

PPTX\0020_SquelchTests.pptx

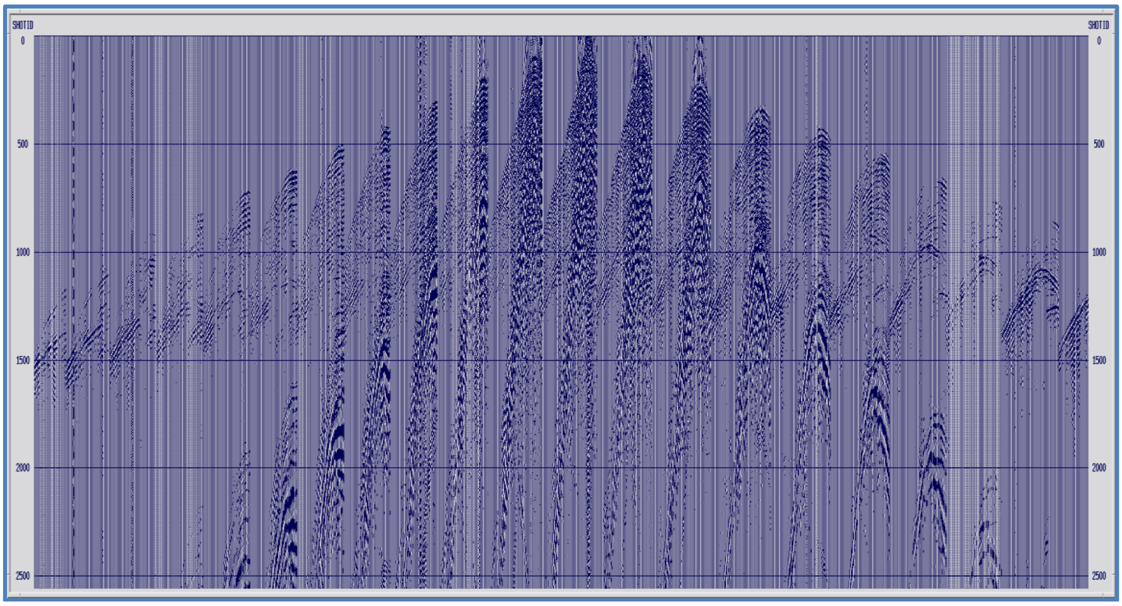

Figure 6.3a Raw Shot Record

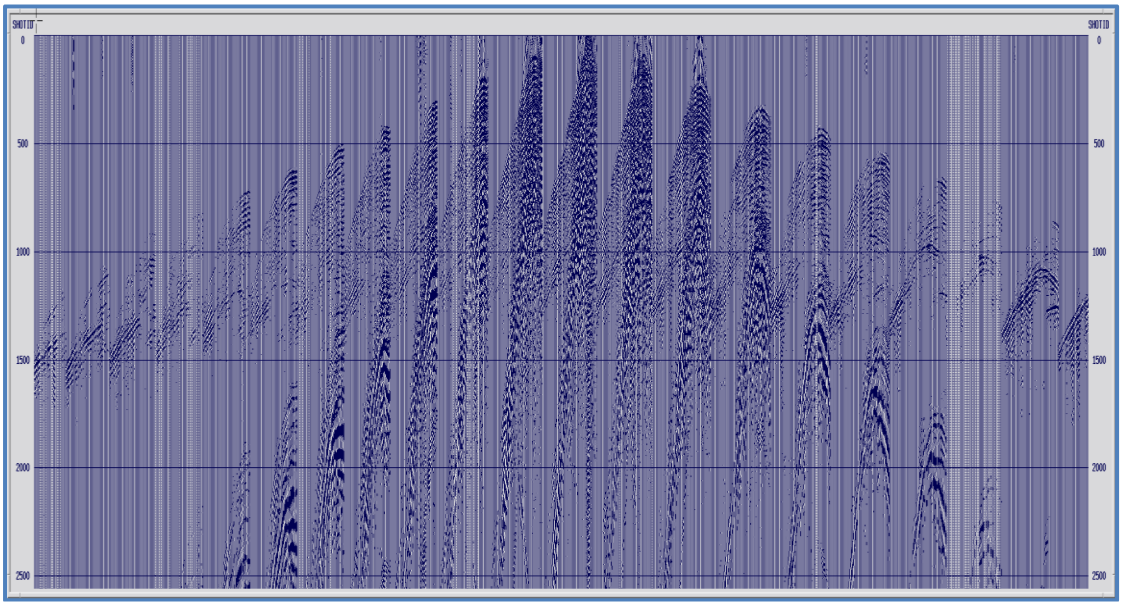

Figure 6.3b Squelch Shot Record

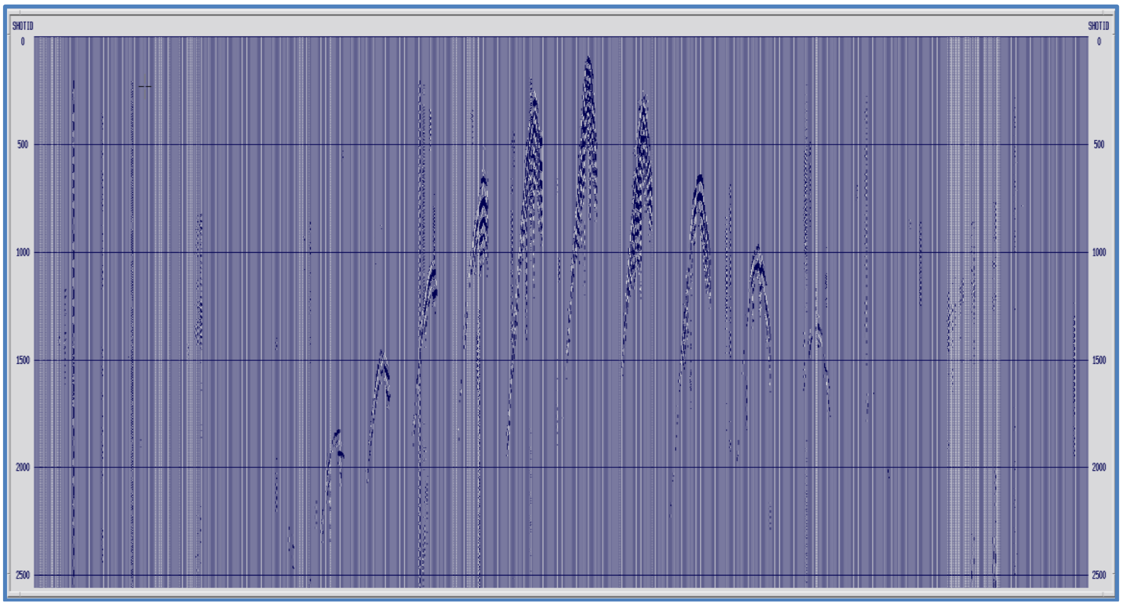

Figure 6.3c Raw – Squelch Difference Plot

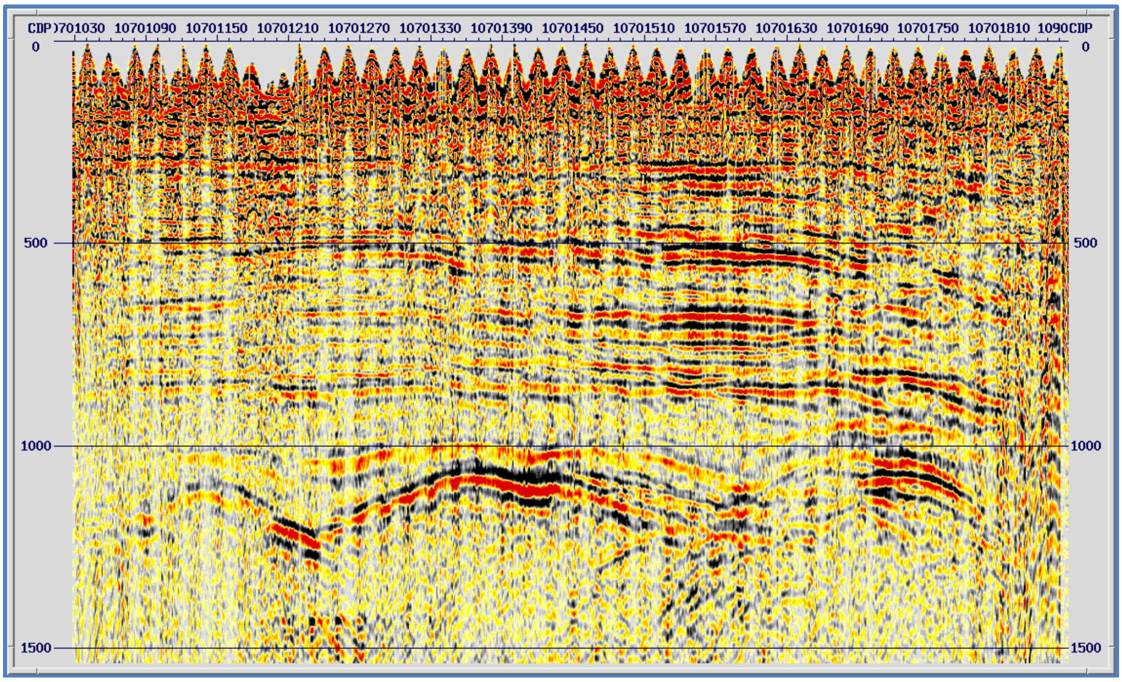

Figure 6.3d Inline 1070 Prior to Squelch

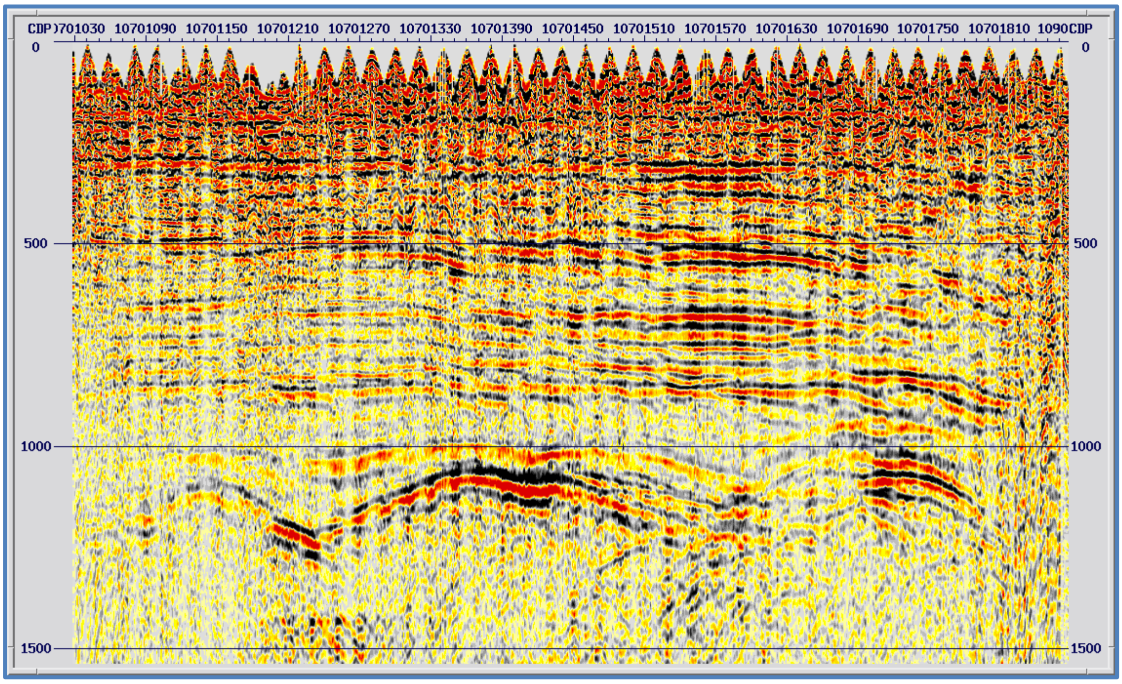

Figure 6.3e Inline 1070 After Squelch

6.4 3D Quash Adaptive Noise Attenuation

The second process in the noise attenuation flow is called Quash. Also, a proprietary Dayboro process, Quash works by estimating the linear noise, within a velocity (dip) defined 3D cone centred on the middle of the Cross-Spread, and then adaptively subtracting the data across 3D windows. The noise is modelled using a 3DFK filter, the noise model is then adaptively subtracted from the original gather in a similar way to the adaptive subtraction methodology used in marine SRME. The end result is that only noise within the defined 3D cone, and only the specified linear noise energy is affected. Outside the cone, the gather is un-modified. The impact on the stacked data is less than observed on the gathers as expected, however the process will be significant when the data is interpolated and migrated pre-stack.

Figures 6.4a and b, illustrate a shot record prior to and following Shot Domain Quash, 6.4c shows the difference between the two. Figures 6.4d and e display an inline before and after the Quash process. The following two presentations demonstrate a more complete examination of the testing for the Quash processes:

PPTX\0030_QuashTests.pptx

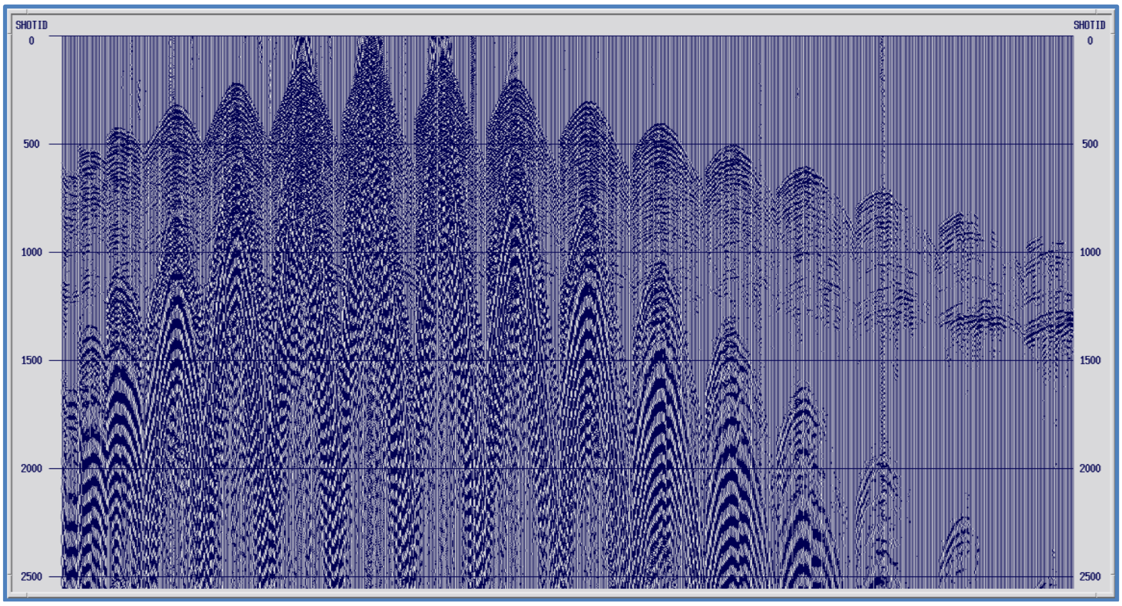

Figure 6.4a Shot Record Prior to Crosspread Domain Quash

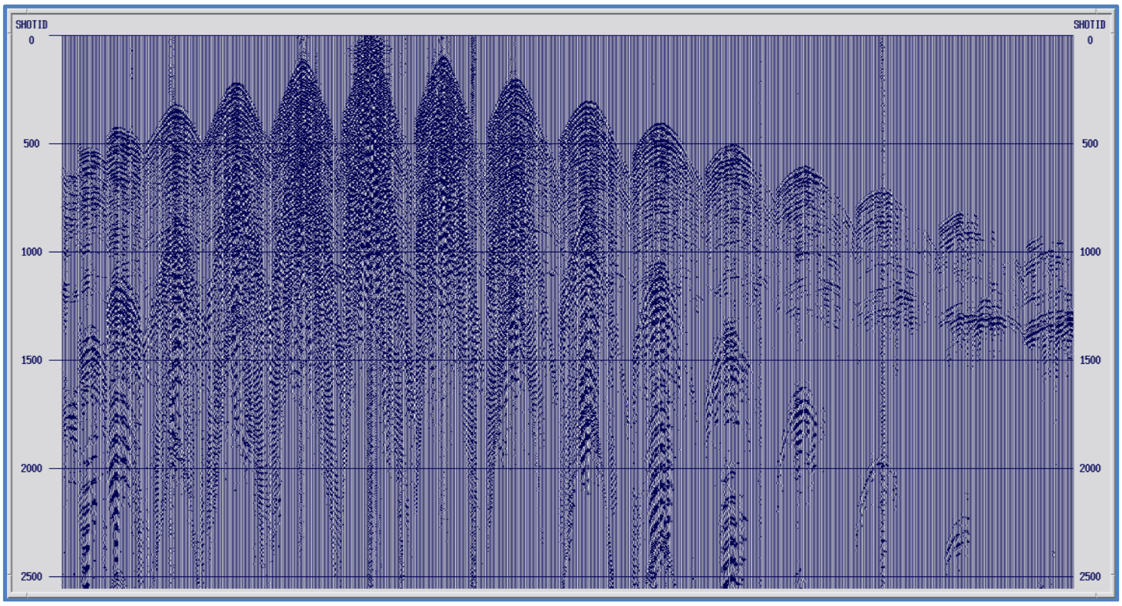

Figure 6.4b Shot Record Following Shot Domain Quash

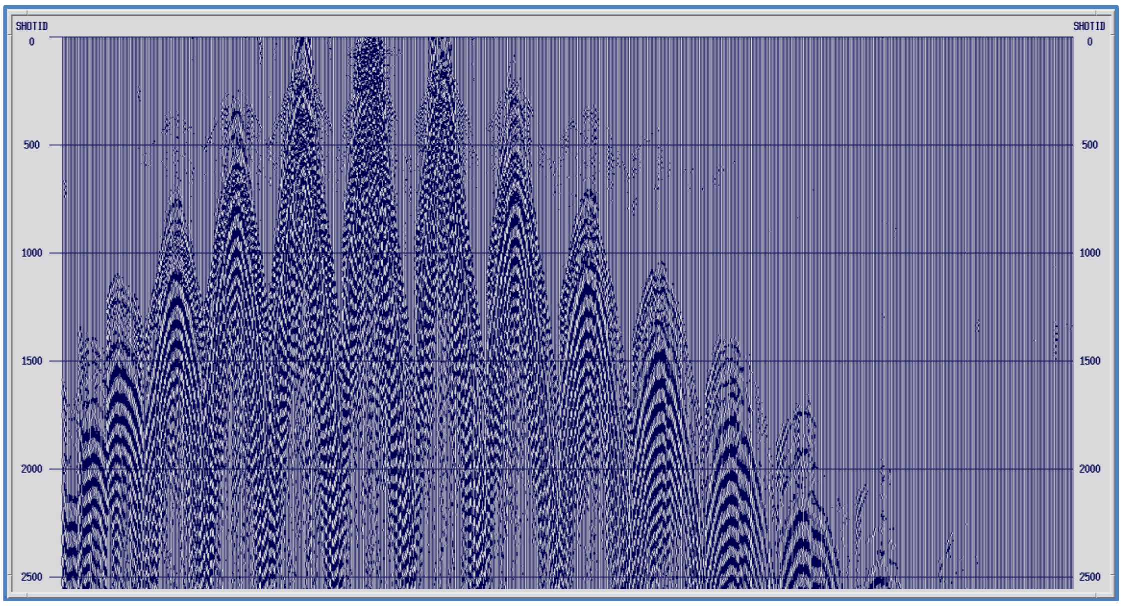

Figure6.4c Shot Record Difference Raw - Shot Domain Quash

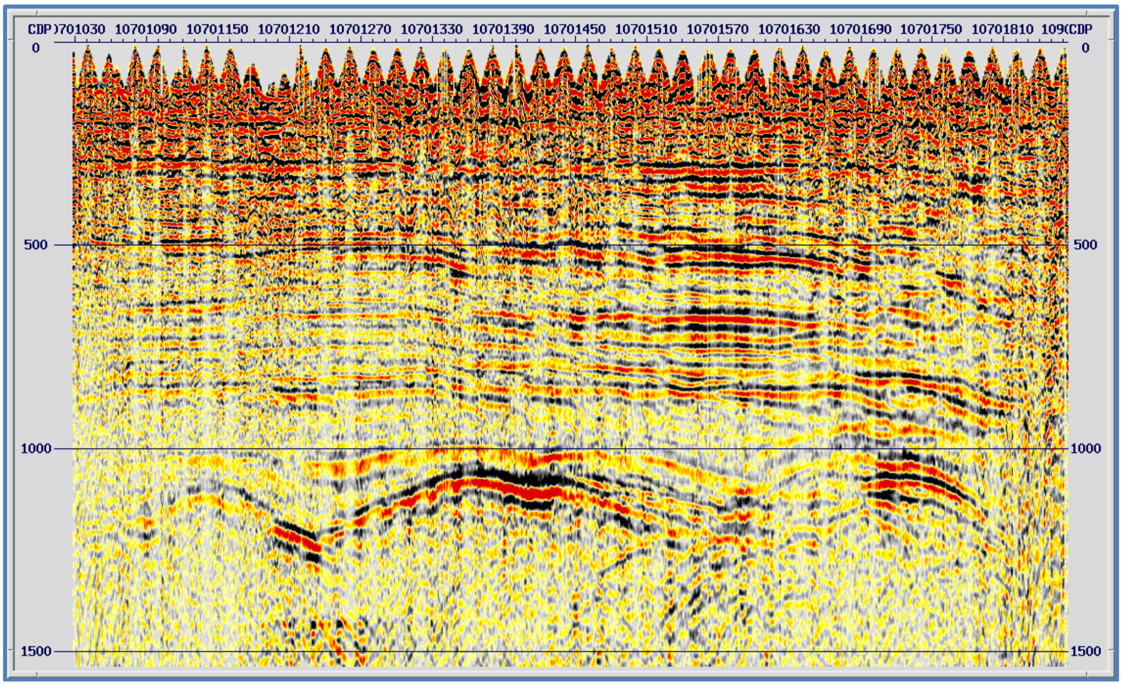

Figure 6.4d Inline 1300 Before Quash

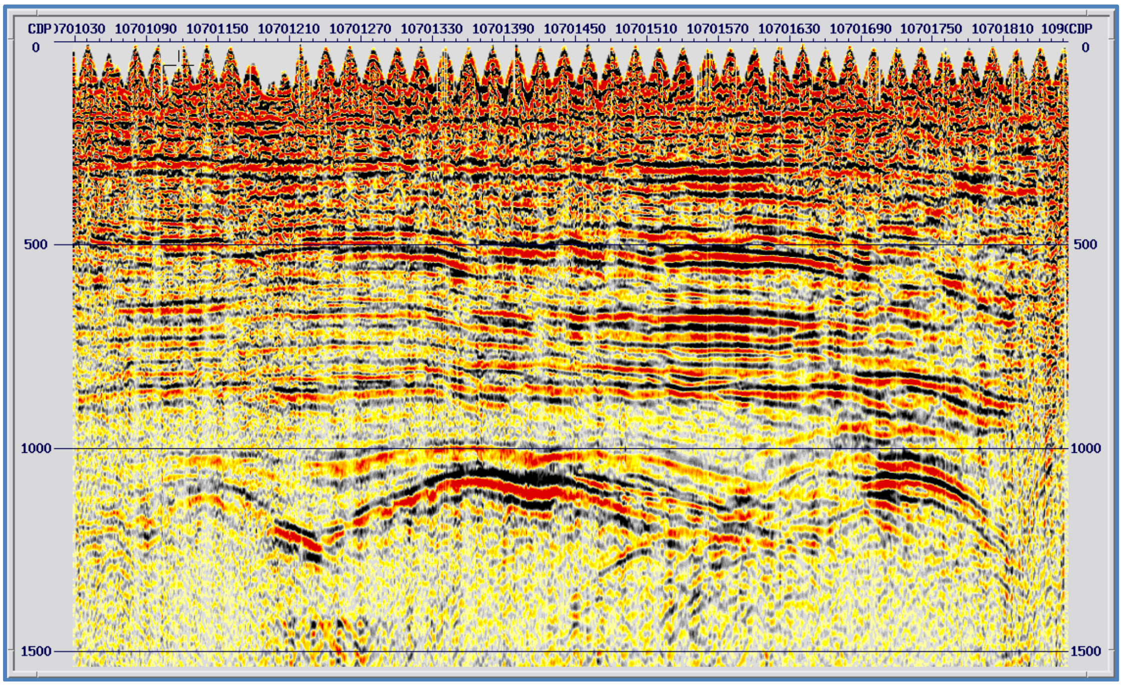

Figure 6.4e Inline 1300 After Shot Domain Quash

6.5 3D Surface Consistent Deconvolution Tests

Surface Consistent Weiner Deconvolution was applied using the following window parameters:

Window X(m, pos. and neg. offsets)	T(ms)
0	80-2000 applied 0-4000
1700	960-2400 applied 0-4000
2900	1612-2800 applied 0-4000
4200	1850-2800 applied 0-4000

A 120 msec Operator Length was initially employed for tests in order to preserve primary reflections. Gaps of 2ms (Spiking), 4ms, 8ms, 16ms, 16ms, 24ms and 32ms were tested. Additional tests with 24ms Gap and longer Operator Lengths (180ms and 240ms) were performed.

Inline and crossline stacks were compared with no SC Deconvolution, Spiking SC Deconvolution and various gapped SC Deconvolutions. The deconvolution parameters were evaluated based on visual examination of the stack volumes, as well as comparisons of autocorrelations and spectra before and after the deconvolution. The link below opens the PowerPoint file showing the full suite of deconvolution tests:

PPTX\0040_DeconTests.pptx

The 2ms spiking deconvolution with an operator length of 120ms was chosen and applied to the dataset.

6.6 Velocity Analysis

Two rounds of Velocity Analysis were conducted on the data prior to the migration, following each of these Residual Statics was calculated and applied to the data. A third Velocity Analysis was carried out after a preliminary PSTM. The first Velocity Analysis was carried out on a 400m x 400m grid, the second with a 200m x 200m grid. The Velocity Analysis utilized Semblance Displays, NMO Corrected Gathers and Variable Velocity Mini-Stacks. The Semblance display was calculated using a 3 x 3 super bin surrounding each analysis location. Figure 6.6a illustrates a typical velocity analysis from a particular location.

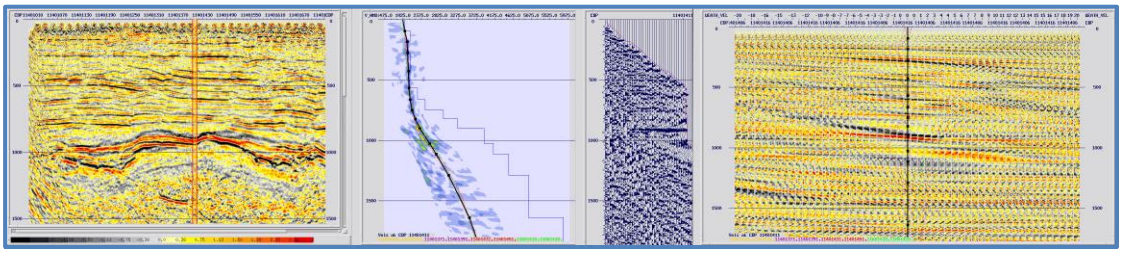

Figure 6.6a Typical Velocity Analysis

6.7 Residual Statics

Following the First Pass Velocity Analysis, and the Second Pass Velocity Analysis, a Stack Power Residual Statics routine was implemented to determine the short period shot and receiver statics. The program, known as SPSTAT works as follows: On the first call, the program reads the input model stack volume into memory, A shot is then read in and cross-correlated with that part of the volume to which it corresponds. The shot is then subtracted from the volume and added again at the new position (with the static shift for the shot applied). This is repeated for each shot in turn. The model volume being updated with each non-zero shot static. Next the receiver ordered data is similarly cross-correlated receiver by receiver and the model volume updated with each non-zero receiver static. The stack power of the volume is measured prior to and following this process. The process is applied iteratively and the stack power values are reported for each iteration, in order to determine the best iteration to apply to the data.

The relevant parameters used in both rounds of residual statics are shown below:

Analysis Window: 100ms – 1500ms
Maximum Shift: 28ms

The iterative sequence of velocity analysis and residual statics is illustrated for a selection of inlines in Figures 6.7a through e. A more complete examination is presented in the following PowerPoint presentation:

PPTX\0050_V1_R1_V2_R2.pptx

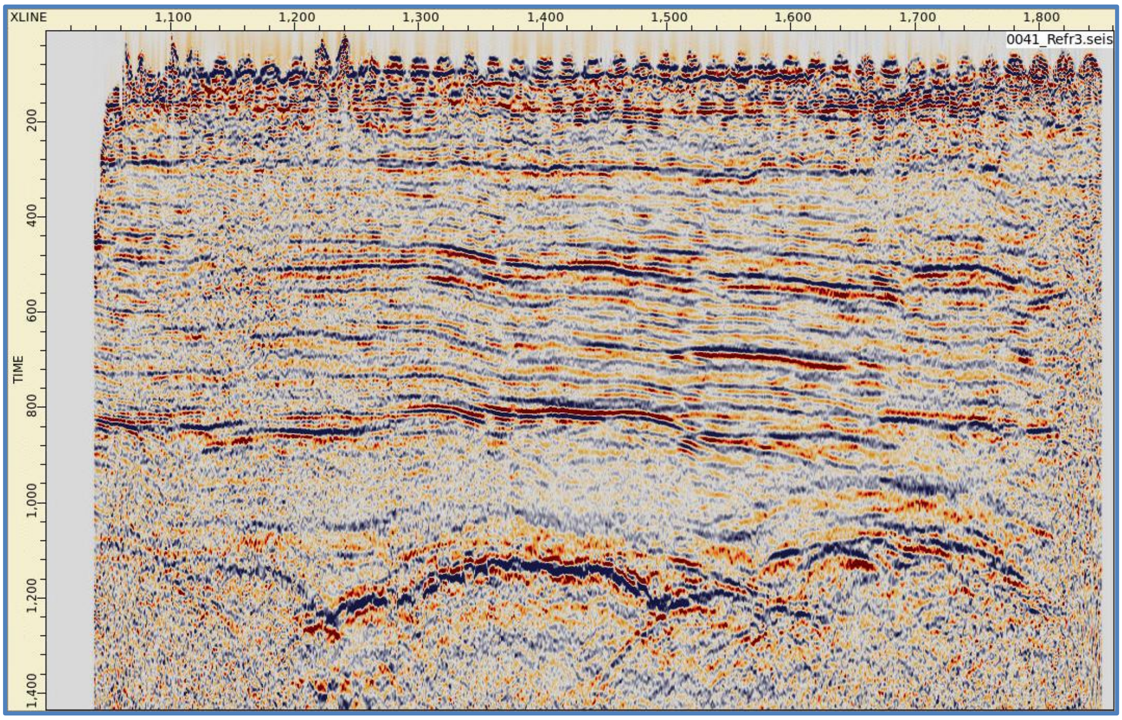

Figure 6.7a Inline 1050 Prior to First Pass Velocity Analysis

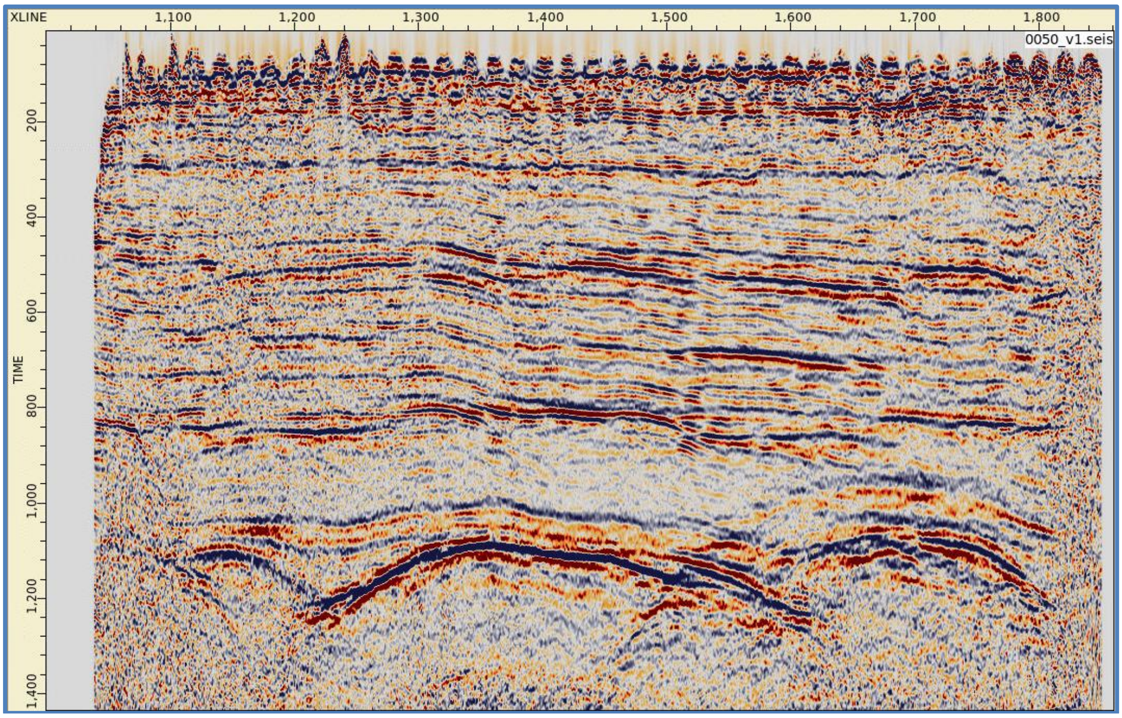

Figure 6.7b Inline 1050 Following First Pass Velocity Analysis

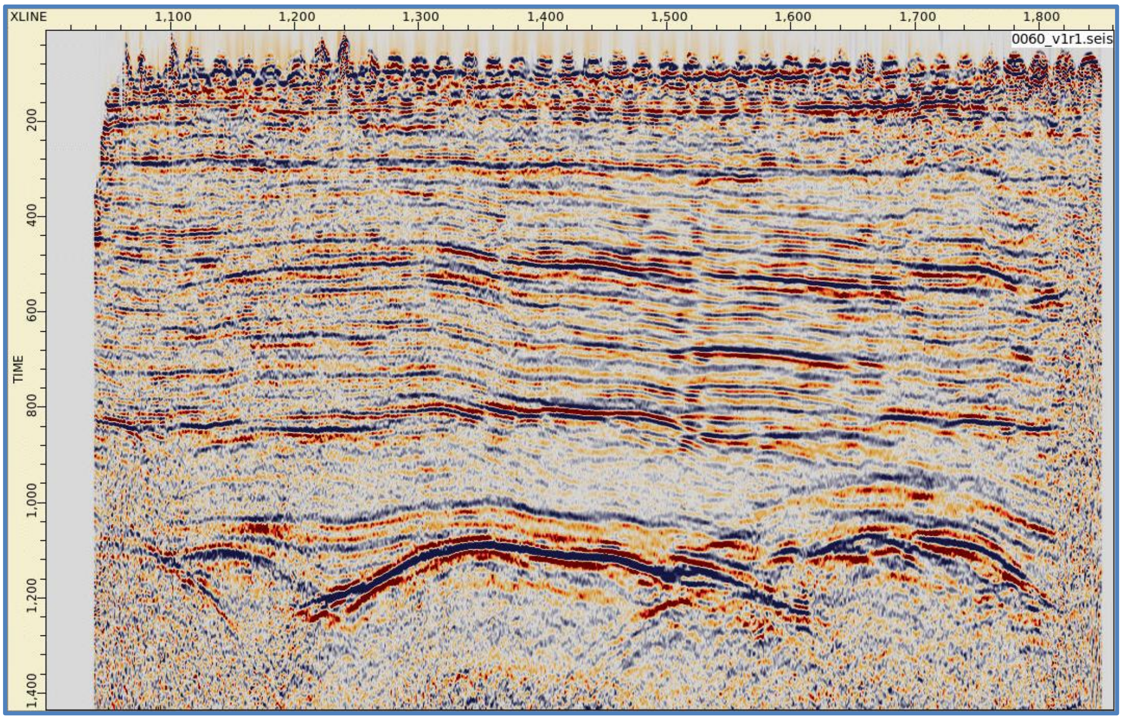

Figure 6.7c Inline 1050 Following First Pass Residual Statics Analysis and Application

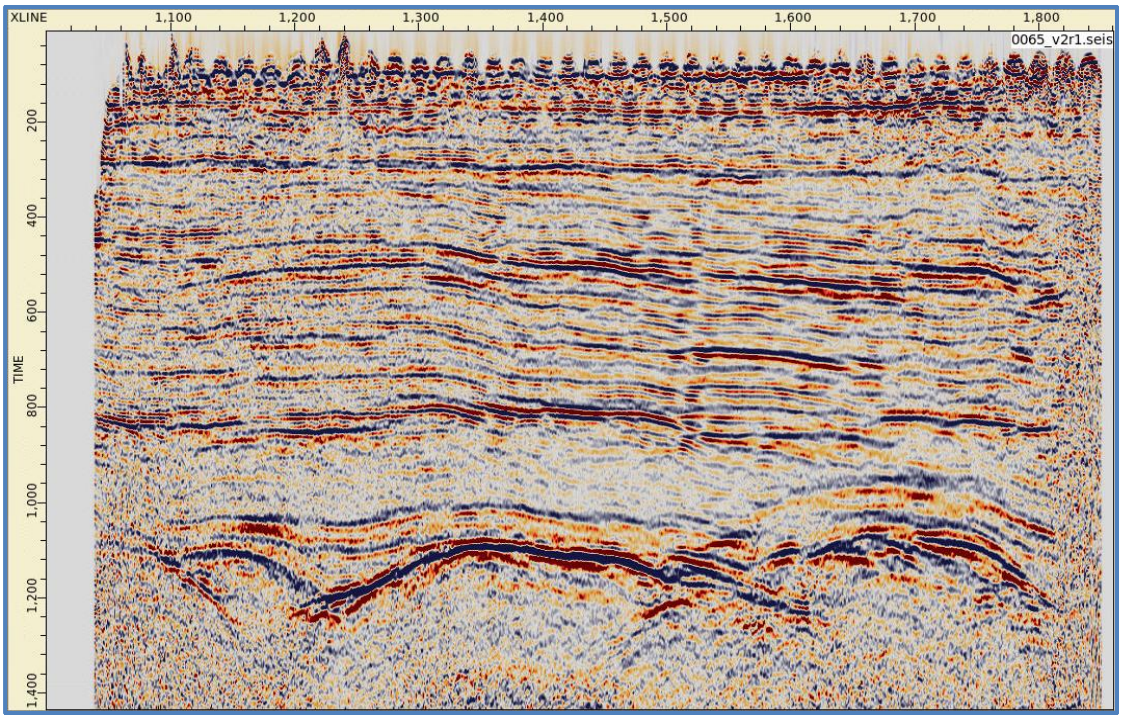

Figure 6.7d Inline 1050 Following Second Pass Velocity Analysis

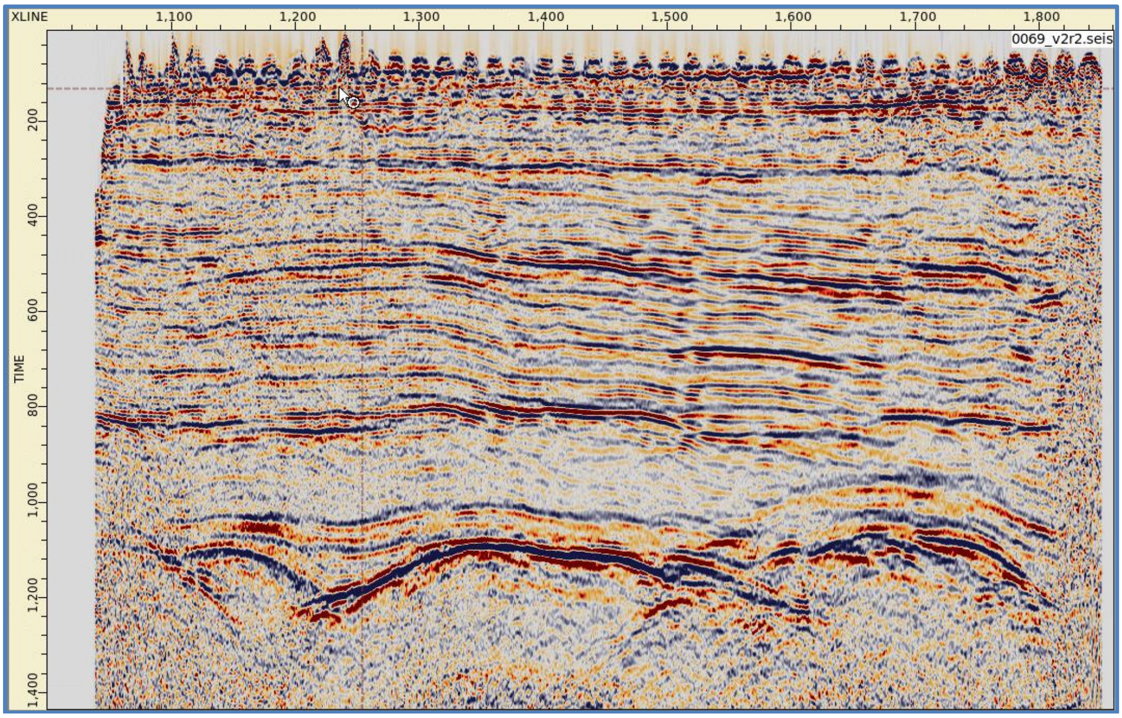

Figure 6.7e Inline 1050 Following Second Pass Residual Statics Analysis and Application

6.8 Pre-Stack Time Migration Parameters

The parameters used in the migration are as follows:

Migration Type:	Isotropic Kirchhoff Pre-Stack Migration
Aperture Time(ms)/Radius Pairs(m):	0-0:1000-2000:2000-3000:3000–3500
Aperture Ratio:	1.0
Trace Interpolation Factor:	8
Xline Patch:	3
Inline Patch:	3
Number of Anti-Alias Filters:	30
Filter Roll-Off:	20 dB/Oct
Offsets:	50-3000m @ 50m : 3100-4000m @ 100m

6.9 Post PSTM Velocities and Mute

After the final PSTM, the NMO was removed using the migration velocity field and a final velocity analysis was conducted on a 200m x 200m grid.

The following presentation illustrates a selection of inlines and crosslines prior to and following the final velocity analysis and application of the final outside mute.

PPTX\0080_PrelimPSTM.pptx

6.10 Post Stack Enhancement Tests

Post stack enhancements such as Spectral Shaping and Balancing, Gain and Coherency Filtering were trialled on the final migrated stack, the following presentation displays the results of this testing:

PPTX\0090_PostPSTMTests.pptx
PPTX\0091_PostPSTMSpectralBalance.pptx

Figures 6.10a through d illustrate an inline from the volume displayed at the various stages in the post stack processing. The final post-stack enhancement processes that were applied along with the relevant parameters are as follows:

FXY Deconvolution:	Two Cascades
	Filter Length 19x19 Tr
	Ntraces 50x50/10 Overlap
	Wlenght 100ms/10ms Overlap
FXYRunning Mix	3x3Traces
	Max Dip 30ms/tr
Spectral Whitening:	3-6-80-100Hz
AGC:	500ms

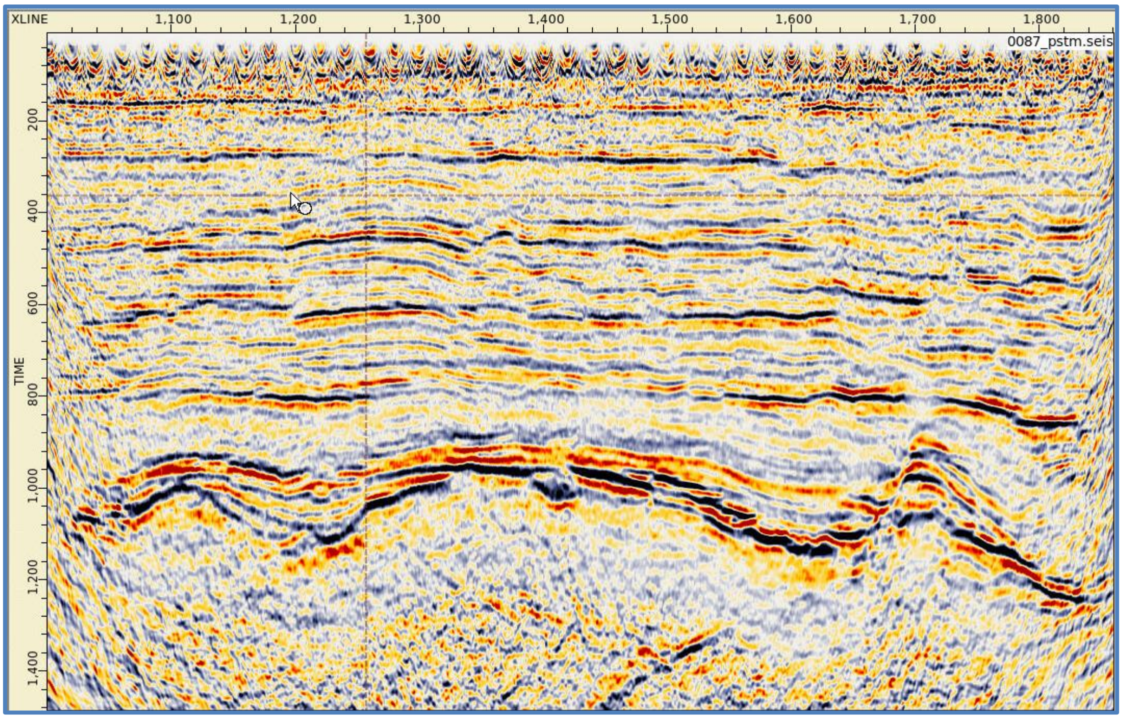

Figure 6.10a Raw PSTM Inline

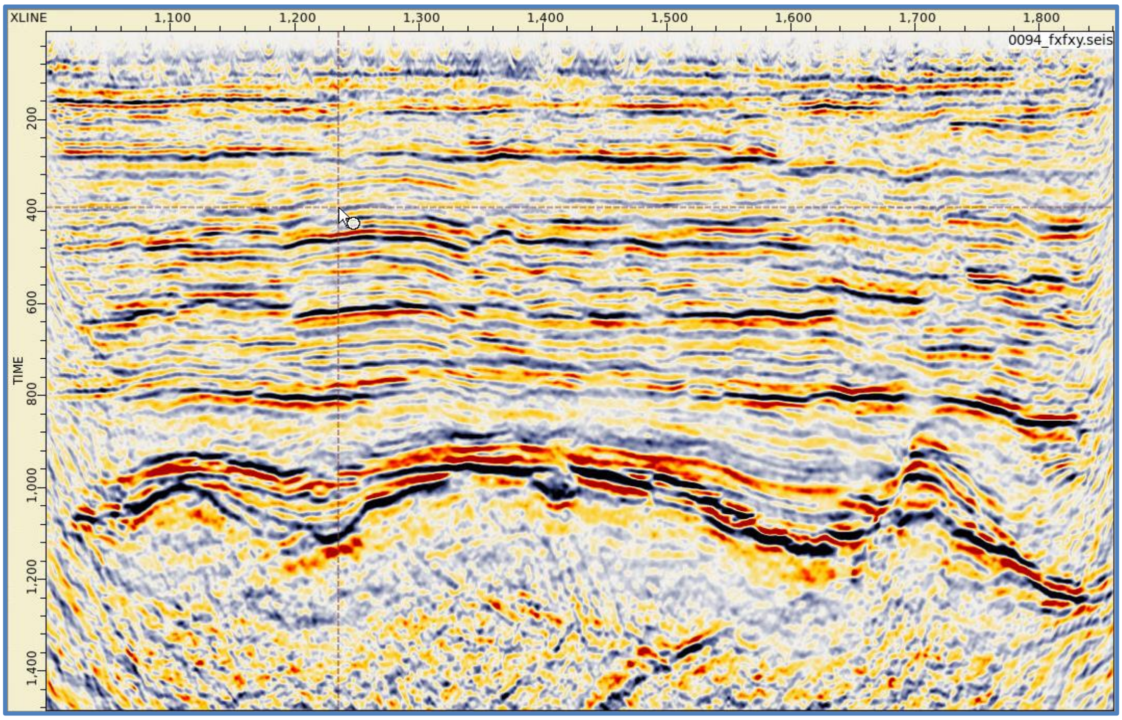

Figure 6.10b Cascaded FXY Decon PSTM Inline

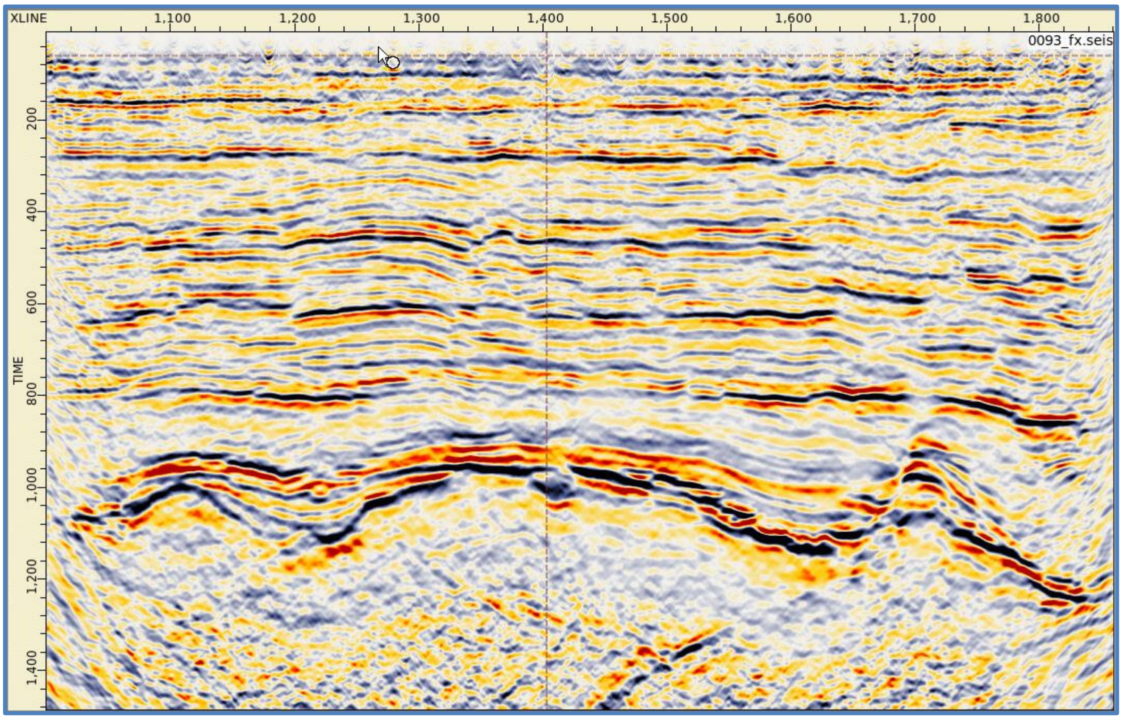

Figure 6.10c Cascaded FXY Decon + FXYRunningMix - PSTM Inline

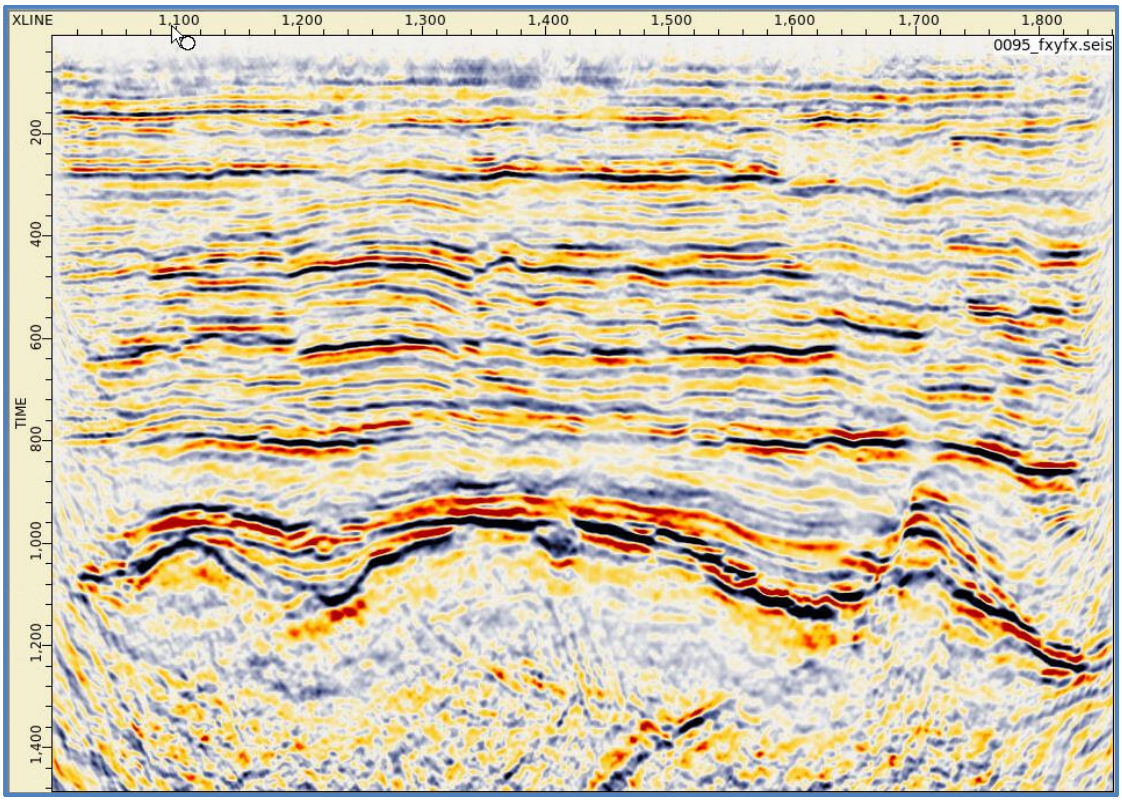

Figure 6.10d Cascaded FXY Decon + FXY RunningMix - PSTM Inline

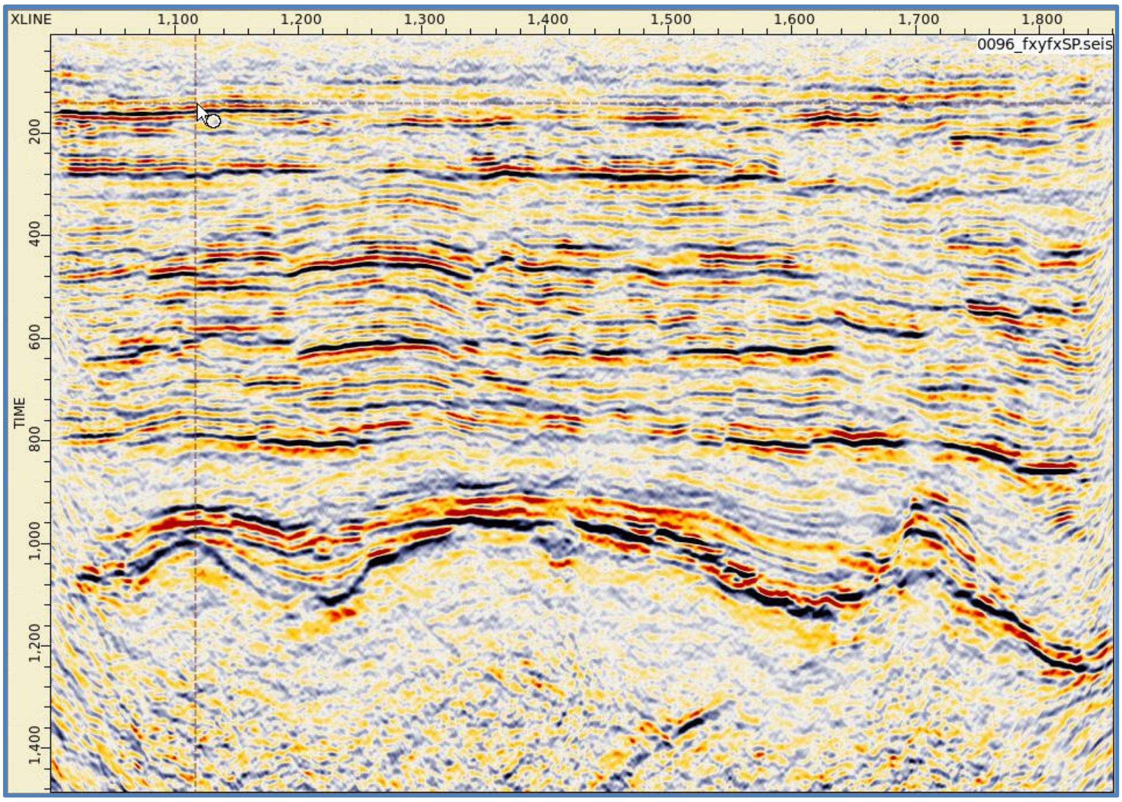

Figure 6.10d Cascaded FXY Decon + FXY RunningMix + Spectral Shaping - PSTM Inline

7. Conclusions and Recommendations

The high fold, and high quality seismic data in combination with the relatively simple processing flow focussing on accurate velocities and statics, has produced a final processed 3D pre-stack time migration product that is highly continuous and relatively noise free. The processing flow has made the most out of the available bandwidth. The expression of the faulting is clear and relatively sharp and the target zone is well imaged.

In general, the distribution of offsets and azimuths was adequate, however we consider that 5D interpolation would have provided a significant uplift to this dataset. Furthermore, there are significant velocity contrasts present at the base of the sedimentary sequence that present some challenges to the imaging, it is likely that Pre-Stack Depth Imaging will provide a sharper image in these areas.

Appendix A – 3D Data Disposition

Data were delivered initially to Red Sky Energy via FTP, and then final data was archived to HDD. The data on the hard disc is listed below:

PSTM Stacks

010_Final_FilteredPSTM.segy
020_Final_RawPSTM.segy
030_Final_RawPSTM_TightMute.segy

Gathers

040_Final_RawPSTMGathers.segy

Statics

050_RefractionStatics.shf
060_ResidualStatics.shf
070_FloatingDatum.shf

Velocities

080_FinalPSTMVelocities.nmo

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Appendix C – Example EBCDIC headers

```
Line  1 : Client: Red Sky Energy
Line  2 : Survey: Lodwick 3D
Line  3 :
Line  4 : Dataset - Final Filtered PSTM
Line  5 :
Line  6 : Processing Flow
Line  7 : Reformat
Line  8 : Geometry Application
Line  9 : First Break Picking
Line 10 : Refraction Inversion Statics
Line 11 : Squelch - Adaptive Random and Spurious Noise Attenuation
Line 12 : Quash - Adaptive Linear Noise Attenuation
Line 13 : Surface Consistent Deconvolution 24ms Gap
Line 14 : Trace Balance
Line 15 : First Pass Velocity Analysis 400m x 400m
Line 16 : First Pass Residual Statics
Line 17 : Second Pass Velocity Analysis 200m x 200m
Line 18 : Migration Velocity Analysis 200m x 200m
Line 19 : Kirchhoff Pre-Stack Time Migration
Line 20 : Final Velocity Analysis 200m x 200m
Line 21 : NMO - Mute - Stack - 500ms AGC
Line 22 : Cascaded FXY Deconvolution (Two Cascades)
Line 23 : FXYRunning Mix
Line 24 : Spectral Shaping
Line 25 : Shift to Final Datum
Line 26 : Output
Line 27 : Header     Byte      Format
Line 28 : CDP        17        I4
Line 29 : CDP_X      73        I4
Line 30 : CDP_Y      77        I4
Line 31 : INLINE     189       I4
Line 32 : CROSSLINE  193       I4
Line 33 :
Line 34 : Grid - Inlines 1001-1253 Crosslines 1001-1860 10x10m Bins
Line 35 : Inline     Crossline    Easting     Northing
Line 36 : 1001       1001         466784.53   5882379.00
Line 37 : 1001       1860         473821.03   5877452.00
Line 38 : 1253       1860         475266.44   5879516.50
Line 39 : 1253       1001         468229.94   5884443.50
Line 40 : Datum: 58m a.s.l Replacement Velocity: 2500m/s
```

Figure C.1 Final 3D PSTM EBCDIC Header

Appendix D - Contact Information

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