2009 Galilee Energy Seismic Survey

ATP799P

Final Processing Report

Prepared By
Daryn Voss
Quantum Geoservices (Asia Pacific) Pte Ltd

December 2009

Report number: 09001

Quantum Geoservices (Asia Pacific) Pte. Ltd.

http://www.quantumgeos.com/

Q U A L I T Y

I N N O V A T I O N

T E C H N O L O G Y

Table of Contents

1.0 Introduction

In October and November 2009, Quantum Geoservices processed approximately 145 km of 2D land seismic data for Galilee Energy Limited. The data had been acquired by Terrex Pty Ltd in permit area ATP799P in Queensland, Australia.

The main target of investigation was the Permian coals at approximately 1000 ms two-way-time below surface. Little well-log or seismic data was available in the immediate area of the survey.

The field data tapes were sent to Dayboro Geophysical at Dayboro in Queensland, and the data sent to Quantum's office in Singapore via FTP.

The original agreed turnaround time for this project was 4 weeks. A change was made to the acquisition plan, such that the source interval was reduced from 30 m to 15 m, thus doubling the volume of data. The turnaround time was renegotiated to 6 weeks. Ultimately, the time between the receipt of the first field data tapes and the presentation of filtered migrated stacks for all lines was four weeks and five days.

The data consisted of five crooked, non-intersecting Vibroseis lines. The data was shot using a two-vibrator array and a single sweep. For most of the lines, first breaks were reasonably stable. For lines 2009-GEL-04 and 2009-GEL-05, there was greater difficulty in following consistent refractors. Reports from the field suggested that this may have been due to varying surface conditions. Ultimately, 2009-GEL-04 was processed using an elevation static model. The remaining four lines were processed starting with a refraction-based static model.

At the sharp corners of crooked 2D lines, there can be a great distance between the trace midpoints and the trace CDP bin location. This is an inherent feature of applying 2D processing to traces with midpoints are distributed in broad patterns rather than linearly. At such corners, strength of stack can be diminished. This may be the case near sharp corners of the lines in this project.

The data were processed through a processing sequence which included linear noise reduction, predictive deconvolution, parabolic radon de-multiple and Kirchhoff pre-stack time migration. The following report details the processes and parameters utilised.

2.0 Acquisition Parameters

2009 Data Acquisition

Data Acquisition Crew	Terrex Seismic Crew 401
Field Instrument	Sercel 428
Sample Rate	1 ms
Record Length	3000 msec
Field Filter	0.8 Nyquist linear phase (400 Hz)
Source interval:	15 m
Vibrator:	IVI Hemi 50 (80% force)
Vibrator array:	2 Vibrators centred on half-station
Sweep:	Single sweep, 10 – 110 Hz, 6 second duration
Receiver interval:	15 m
Geophone array:	6 phones over 12.5 m, centred on peg
Far offset:	1792.5 m
Near offset:	7.5 m
Number of channels:	240
Nominal CDP fold:	120

3.0 Processing Sequence Summary

Reformat

- SEGY to Internal Format
- re-sample to 2 msec

Geometry application

- Source, receiver and midpoint locations added
- 2D crooked line CDP binning applied (7.5 m rectangular bins)

Shot and channel edits

- Removal of bad traces and shots

Shot averaged amplitude scaling

- one scalar applied per shot record

Phase change

- Minimum-phase mimicking filter

Spherical divergence correction

- $V^2T^{1.4}$

Noise removal

- shot domain F-K filtering
- Adaptive noise attenuation algorithm
- Air blast attenuation

Deconvolution

- surface consistent spiking deconvolution
- 80 ms operator length
- 0.1% white noise

Spectral whitening

- Corner frequencies 5-10-90-110 Hz

Refraction statics calculation and application

- 2650 m/s replacement velocity, 400 m ASL datum
- NB: Elevation statics were used in the case of 2009-GEL-04

First pass velocity analysis

- 750 m interval

First pass residual statics calculation and application

- NB: Elevation statics were used in the case of 2009-GEL-04

Second pass velocity analysis

- 750 m interval

Pre-Stack Time Migration

- type – Kirchhoff time migration to gathers
- migration aperture radius 3000m
- Maximum angle 60 degrees

- Smoothed second pass velocities used

Final Velocity Analysis

- 375 m interval

Apply final velocities

- Inverse NMO previous velocities
- Apply final velocities
- 20% stretch mute

Pre-stack Radon de-multiple

- 200 ms maximum differential moveout at far offset

Pre-stack F-K filtering

- Velocity cut 9375 m/s

CDP trim statics

- Maximum shift, 8 ms

Pre-stack gain

- AGC, 500 ms operator

Mute

- Hand-picked inner trace mute

Stack

- CDP stack, unity balancing

Spectral whitening

- Corner frequencies 10-15-85-95 Hz

Bandpass filter

- Time varying bandpass filter

Coherency filter

- 7 trace F-X domain filter

Balance

- Trace balance

Shallow noise mute

- Mute noise above reflection data

Shift to final datum

- Apply datum correction to 400 m ASL

4.0 Processing Sequence Detail

4.1 Reformat

The data were reformatted from SEGY records to the Claritas internal format and resampled from 1 ms to 2 ms using a 90% Nyquist anti-alias filter.

4.2 Geometry application

Source, receiver and midpoint locations were added to trace headers. CDP bin numbers were assigned on the basis of 7.5 metre rectangular bins using 2D crooked line geometry. The coordinates provided by the client were in GDA94 UTM Zone 55 using AHD.

4.3 Shot and channel edit

Noisy or otherwise bad shots and channels were removed from the processing flow.

4.4 Shot averaged amplitude scaling

A single scalar was applied to each shot to balance amplitudes between shots, in order to compensate for varying surface conditions.

4.5 Phase-shifting filter

Based on the sweep autocorrelation found in the auxiliary traces, a filter was designed for converting the zero-phase wavelet into a minimum-phase wavelet, and this filter was applied to all traces.

4.6 Spherical Divergence Correction

A Spherical Divergence Correction of $V^2T^{1.4}$ was applied to the data using first pass velocities.

4.7 Shot-domain F-K filter

An F-K filter was applied in the shot-domain in order to attenuate linear noise of various kinds. A 1600 m/s velocity cut was used.
A 500 ms AGC was applied before application of this filter, and removed afterwards.

4.8 Adaptive noise attenuation algorithm (Squelch)

An adaptive noise attenuation algorithm (Squelch) was applied to deal with various kinds of noise. Squelch works by separating the signal into frequency bands and applying amplitude limits in various regions in T-X space.

4.9 Air blast attenuation

An algorithm was applied to attenuate moderate to high frequency air blast noise.

4.10 Deconvolution

A surface consistent spiking deconvolution was applied, using the following parameters:
Operator length: 80 ms
Noise addition: 0.1%

Design gate:

offset	time range
130 m	360-1500 ms
830 m	742-1500 ms
1800 m	1300-1500 ms

4.11 Spectral whitening

Spectral whitening was applied, using the following parameters:
Corner frequencies: 5-10-90-100 Hz
Spectral balancing gate: 25 Hz

4.12 Refraction statics calculation and application

Using picked first-breaks, refraction statics models were calculated and applied. A constant 800 m/s V0 was used, with refractor depth and 2nd layer velocity being modelled. A 2650 m/s replacement velocity and 400 m ASL datum were used.

NB, in the case of 2009-GEL-04, an elevation-only statics model was applied at this point, due to the unreliability of first breaks on that line.

4.13 First pass velocity analysis

First pass velocity analysis was carried out using a 750 m picking interval.

4.14 Surface consistent Residual statics calculation

Residual statics were calculated using a 5 trace smoothing function. The analysis window was a constant time gate from 300 ms to 1200 ms. The maximum allowed shift per iteration was 16 ms, and four iterations were used.

4.15 Second pass velocity analysis

Second pass velocity analysis was carried out using a 750 m picking interval.

4.16 Pre-Stack Time Migration

Kirchhoff pre-stack time Migration was applied to the data using the following parameters:

- Type – migration to gathers
- Migration full aperture radius 3000m
- Maximum angle 60 Deg
- Output offset increment 30m
- Smoothed second pass velocities used as migration velocities
- Note that non-migrated stacks were also provided.

4.19 Final Velocity Analysis

A final pass of stacking velocity analysis was performed on the PSTM gathers at a 375 m interval.

4.20 Radon De-multiple

- Remove second pass velocities NMO
- Apply final velocities NMO with a 20% stretch mute
- Apply radon de-multiple algorithm (200 ms maximum differential moveout at far offset)
- Note that migrated stack versions without radon de-multiple were also provided.

4.21 F-K filter

Apply F-K filter with 9375 m/s velocity cut.

4.22 CDP trim statics

CDP trim statics were calculated using a maximum shift of 8 ms, and applied.

4.23 Pre-stack gain

AGC was applied using a 500 ms operator.

4.24 Final stack

CDP stack was performed using unity normalisation.

4.25 Spectral whitening

Post-stack spectral whitening was applied using the following parameters;
Corner frequencies: 10-15-85-95 Hz
Spectral balancing gate: 30Hz

4.26 Bandpass filter

A time-varying bandpass filter with the following parameters was applied:

0-1200 ms	10-15-70-80 Hz
1500-3000 ms	15-20-60-70 Hz

4.27 Coherency filter

An F-X domain coherency filter was applied using the following parameters:
Horizontal window width: 7 traces
Maximum dip: 1 ms per trace

4.28 Trace Balance

A whole-trace amplitude balance was applied, based on an amplitude window from 0-1300 msec.

4.29 Shift to final datum

A correction was applied to each trace to shift to a 400 m ASL datum.

4.30 Output to SEG-Y format

The stacked data and were output in SEG-Y format on DVD and delivered the client representative of Galilee Energy along with the other deliverables.

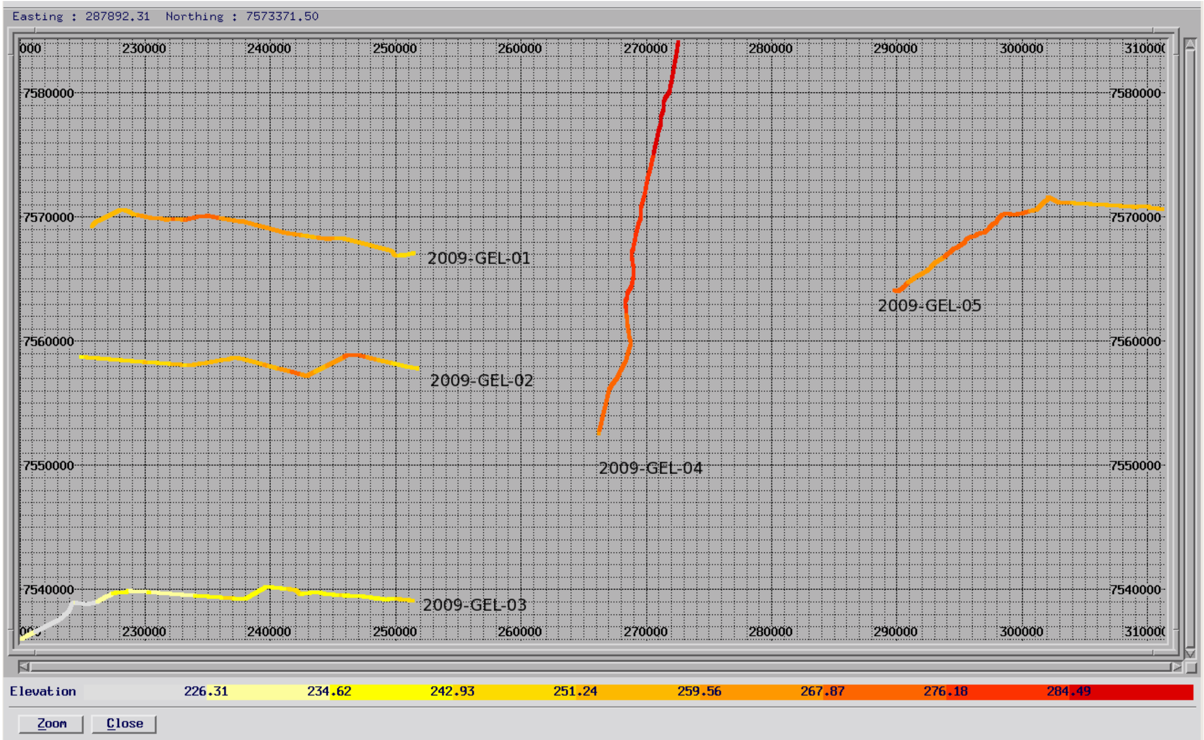
5. Conclusion

The energy of the reflections from the primary reflectors of interest was sufficiently strong to produce high signal to noise ratios. To ensure good imaging of weaker, shallower reflectors, a two-pronged noise attenuation approach was applied prior to deconvolution, involving F-K filtering and an adaptive noise attenuation using an amplitude limiting approach (“Squelch”).

For four of the lines, first breaks were continuous enough to permit meaningful refraction models to be built. First breaks on line 2009-GEL-04 were less continuous, and after testing and consultation with the client representative, the decision was made to use elevation-only correction as an initial statics model for that line.

Appendix A - General Survey Information

Line Map



Line List

Name	FFID Range		Station Range		Length (km)
2009-GEL-01	20	1807	1000	2788	26.835
2009-GEL-02	1808	3640	1000	2848	27.735
2009-GEL-03	3641	5842	1000	3204	33.075
2009-GEL-04	5843	8023	944	3126	32.745
2009-GEL-05	8024	9652	1000	2626	24.405
TOTAL					144.795

Appendix B – Testing

A subset of the images and results from our testing sequence is presented below. This is part of the testing information provided to the client representative during the course of the project. Some velocity spectra examples were also provided. Additionally, various static models were tested for line 2009-GEL-04, and related images were provided.

Test 1: Refraction statics check

Test Line 2009-GEL-01

Objective:
To check that our refraction statics model is reasonable.

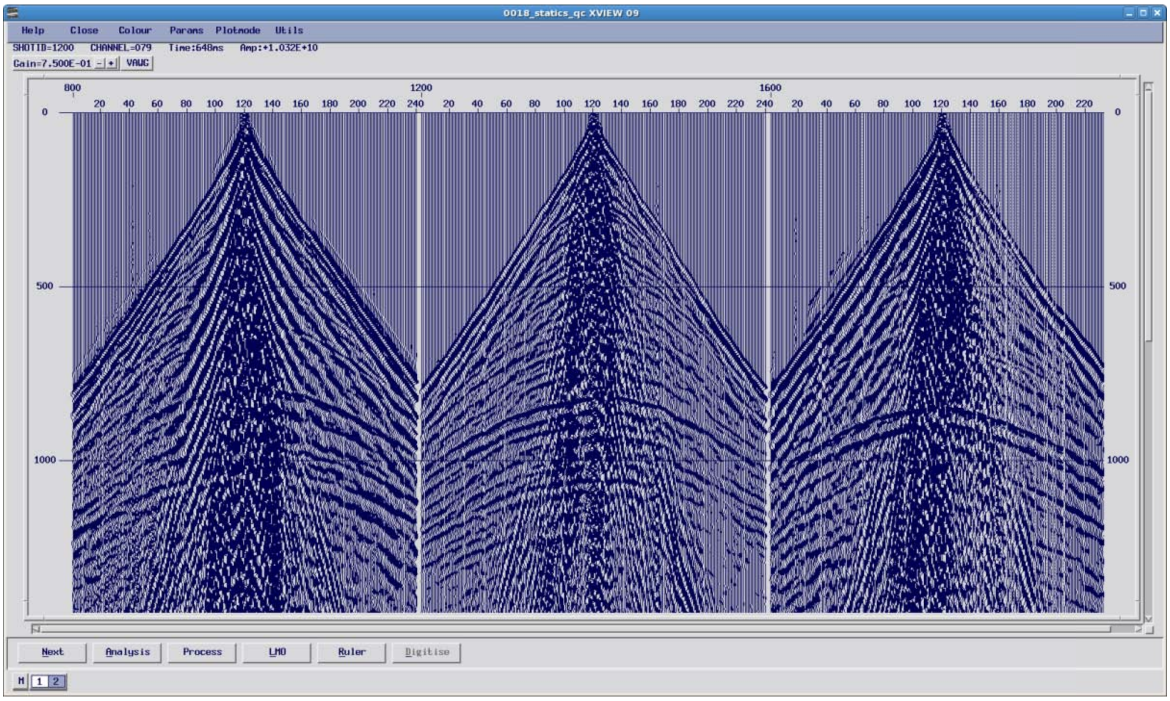
Procedure:
The effect of refraction statics application on the refraction events in shot records was examined, and a comparison was made between elevation and refraction statics on the basis of brute stacks.

Display:
The first two images show a small sample of raw shot records with and without refraction statics application.
The final two images show filtered brute stacks (no deconvolution) based on a) elevation statics and b) refraction statics.

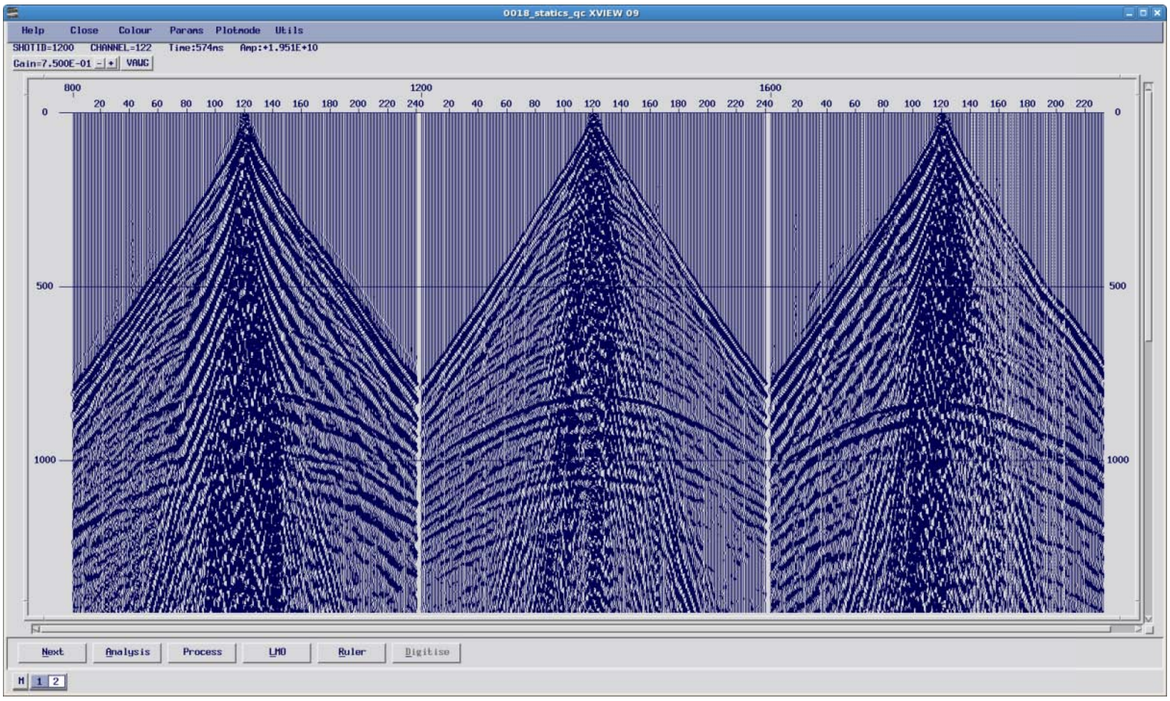
Comment:
The improvement in structural integrity and continuity of reflection events was improved when our refraction static corrections were applied, both in raw records and in brute stacks. This suggests that our model is reasonable.

Processing flow for shot records in Test 1

- Reformat SEG-Y data to Claritas internal format.
- Resample to 2 ms
- Spherical divergence correction ($G(T) = V^2T^1$, rough velocities)
- **Refraction statics correction (or null)**
- Bandpass filter, 10-80 Hz



No refraction static application (**<u>2009-GEL-01)</u>**



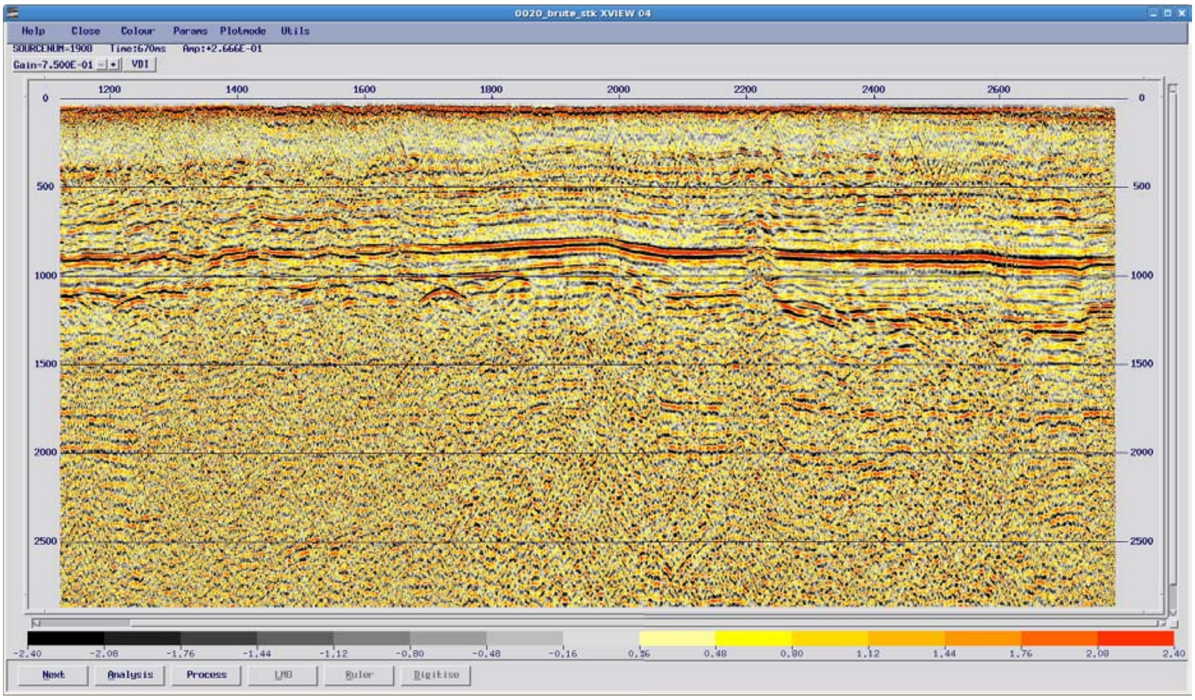
After refraction static application (**<u>2009-GEL-01)</u>**

Processing flow for stacks in Test 1

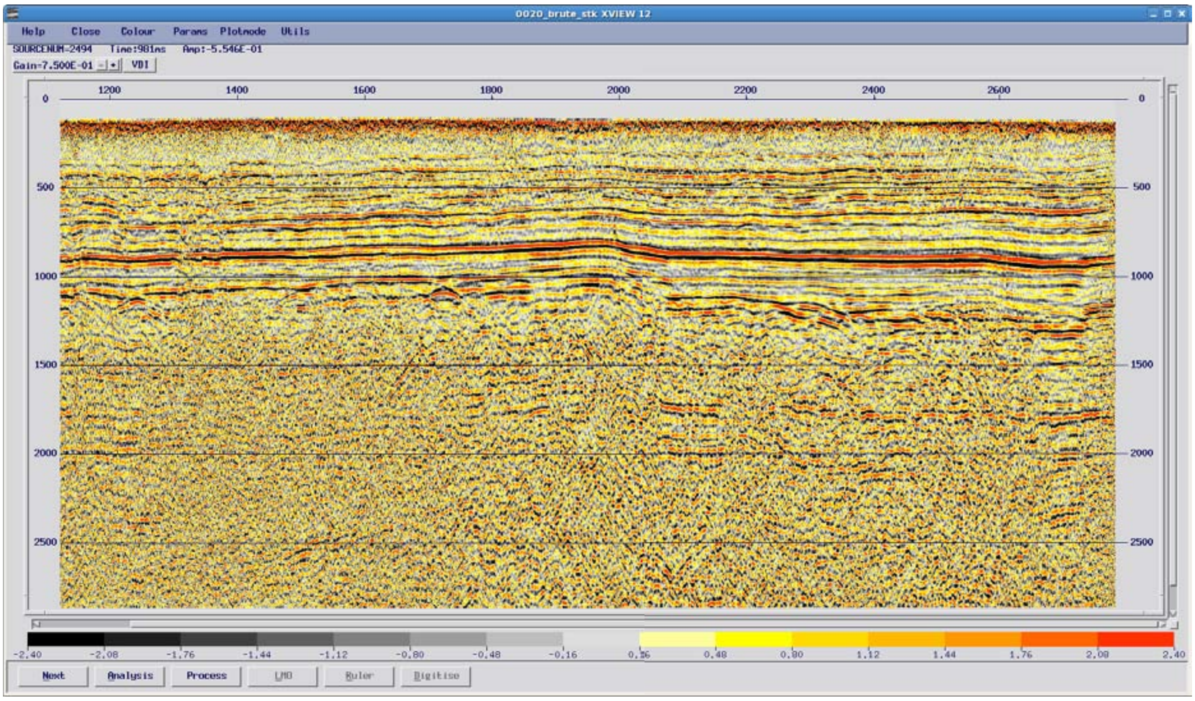
- Reformat SEG-Y data to Claritas internal format.

- Resample to 2 ms
- Spherical divergence correction ($G(T) = V^2T^1$, rough velocities)
- **Statics correction (elevations statics or refraction statics)**
- NMO (rough velocities), 40% stretch mute
- AGC, 500 ms operator
- Stack, shift to final datum (400 m)
- Bandpass filter, 10-80 Hz
- AGC, 500 ms operator

A bulk shift has been applied to the elevation statics stack in order to aid comparison.



Brute stack, elevation statics (**2009-GEL-01)**



Brute stack, refraction statics (**2009-GEL-01)**

Test 2: Klauder wavelet mininum-phasing

Test Line 2009-GEL-01

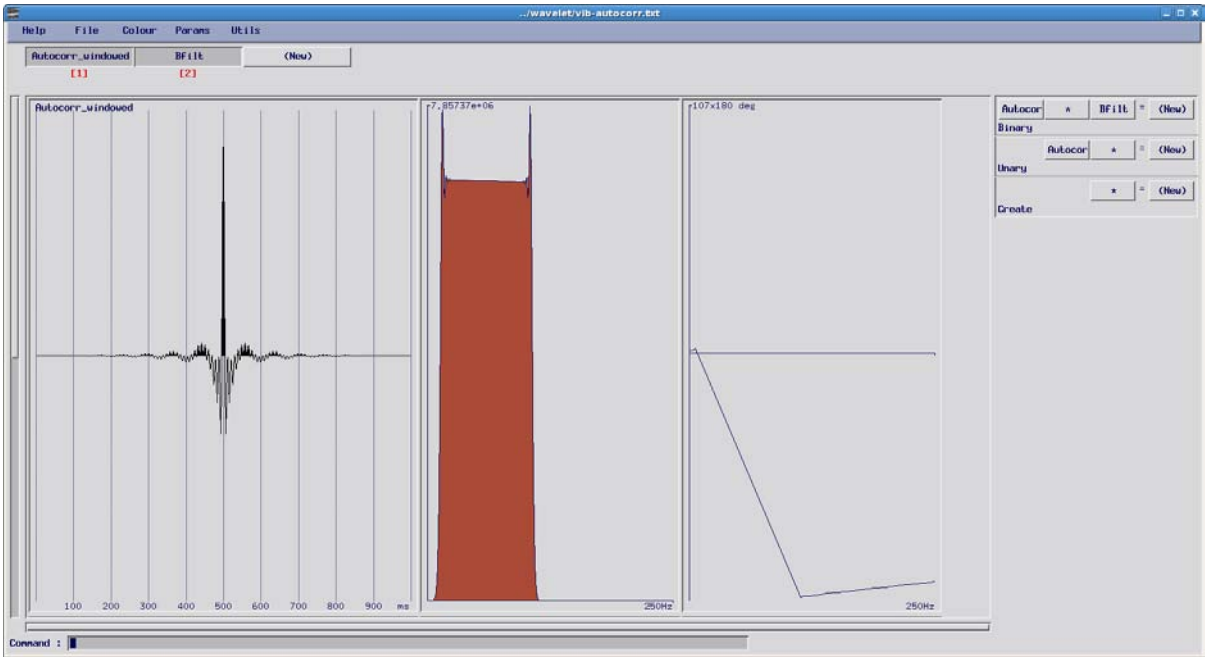
Objective:
To check that our minimum-phasing filter is having the desired effect without introducing spurious noise.

Discussion:
Autocorrelated Vibroseis data has an intrinsic wavelet (the Klauder wavelet) that is roughly zero-phase. Early in the processing sequence, we apply a filter whose effect should be to convert this to a minimum-phase wavelet.

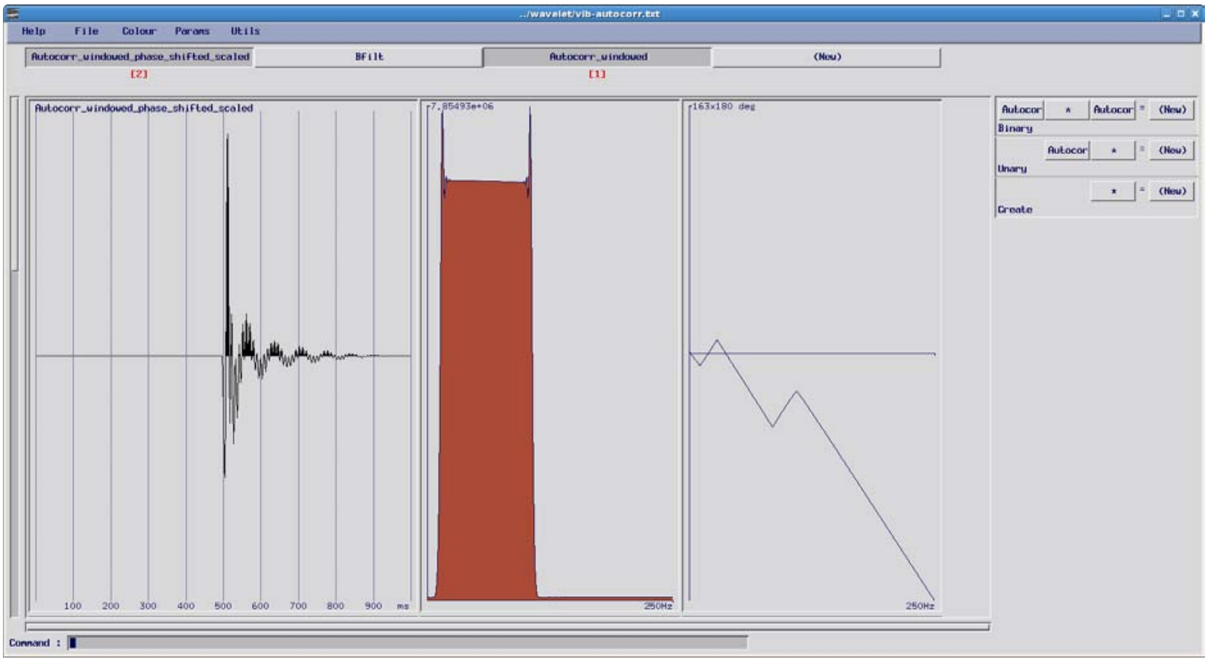
In this case, we have used the sweep autocorrelation recorded in auxiliary channels as the Klauder wavelet. The convolution of the Klauder wavelet with our minimum-phasing filter should produce a wavelet similar to the theoretically calculated minimum-phase wavelet.

These slides show the effect of our calculated minimum-phasing filter on the Klauder wavelet for this dataset. Additionally, brute stacks created with and without the minimum-phasing operation are shown.

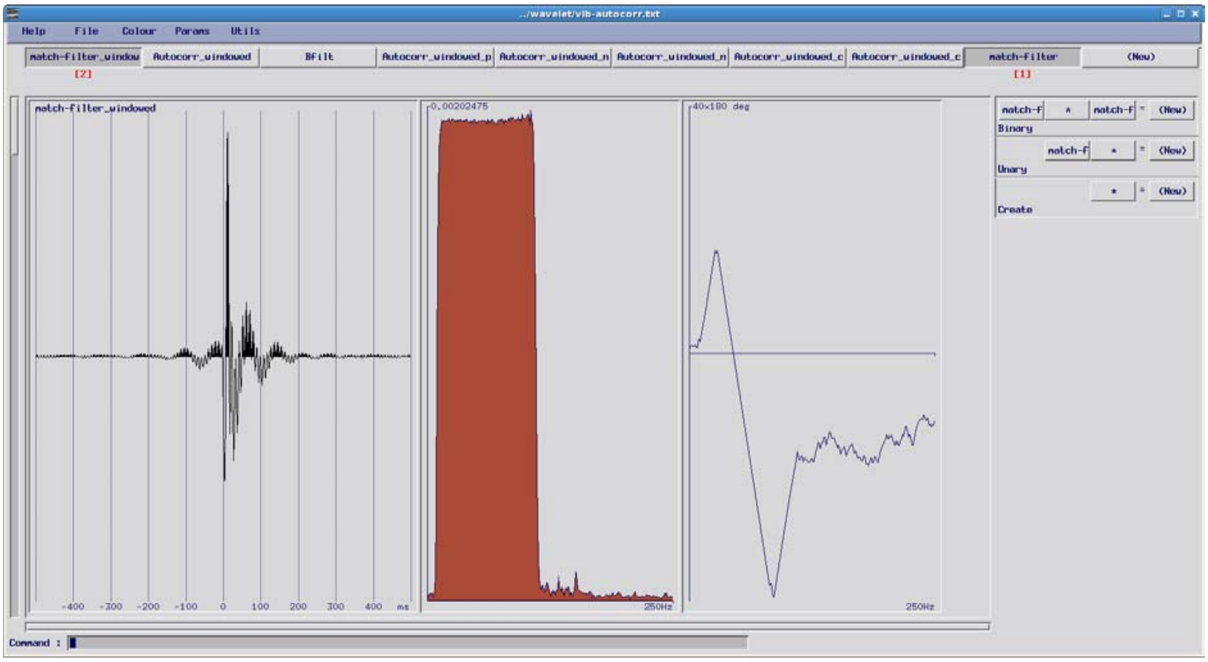
Comment:
Our minimum-phasing filter appears to have the appropriate effect when applied to the Klauder wavelet for this dataset, and also has the expected effect on the brute stacks.



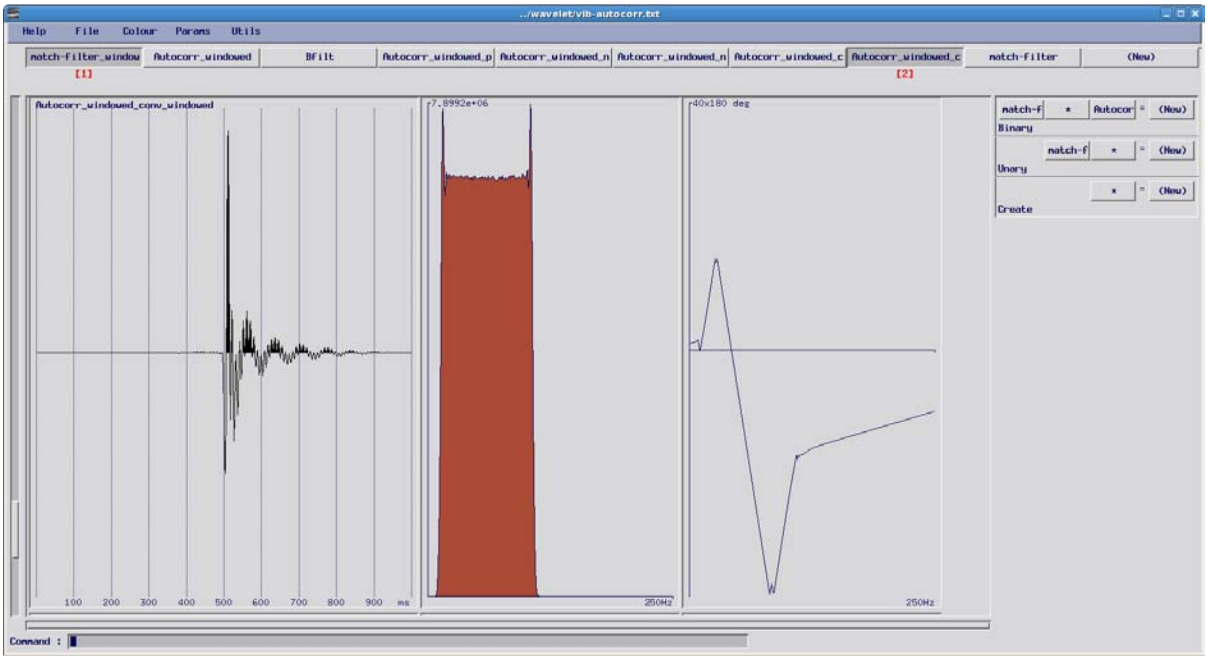
Klauder wavelet (extracted from aux channels)



Theoretical minimum-phase equivalent (calculated from Klauder wavelet)



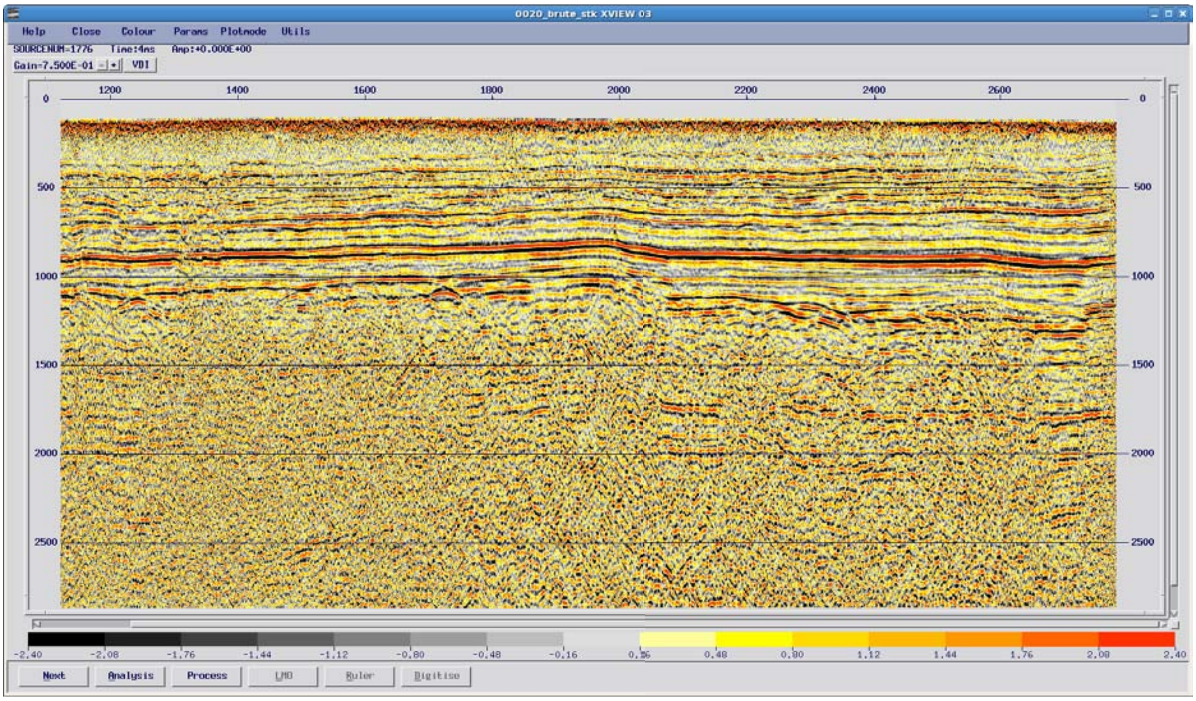
Minimum-phasing filter



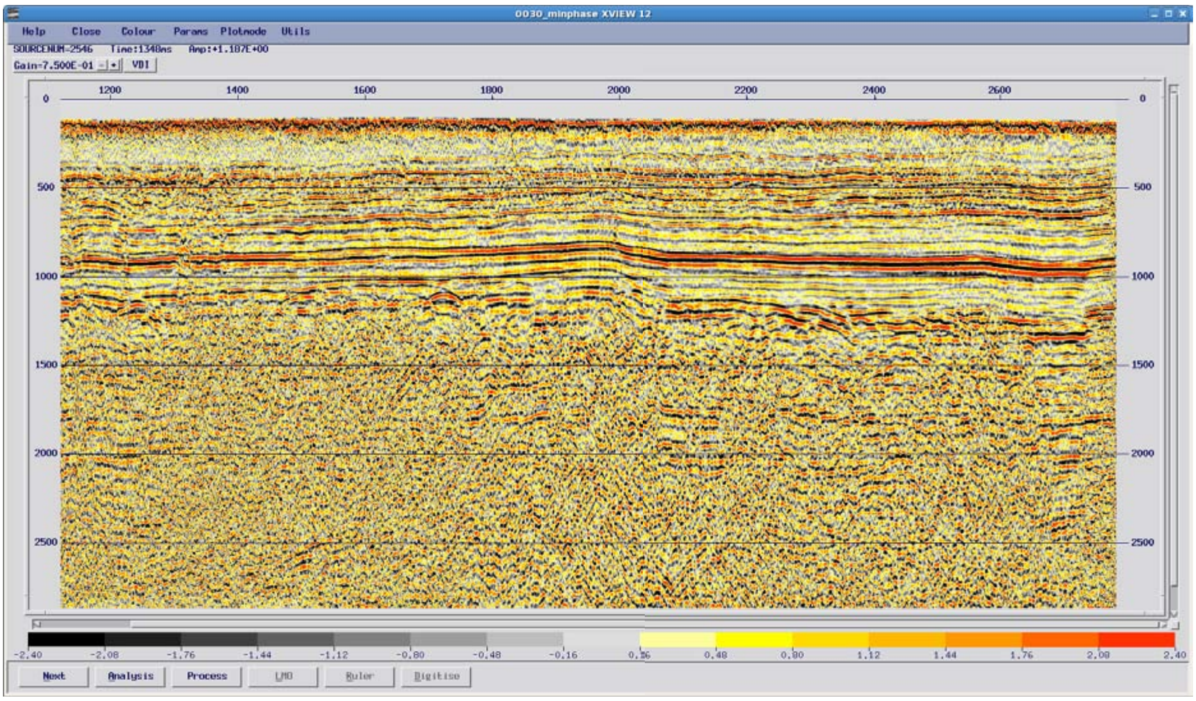
Klauder wavelet convolved with minimum-phasing filter

Processing flow for stacks in Test 2

Reformat SEG-Y data to Claritas internal format
Resample to 2 ms
Minimum-phasing filter (or null)
Spherical divergence correction
Refraction statics correction as shown
NMO(rough velocities), 40% stretch mute
AGC, 500 ms operator
Stack, shift to final datum (400 m)
Bandpass filter, 10 – 80 Hz
AGC, 500 ms operator



Brute stack (no minimum-phasing) (**2009-GEL-01)**



Brute stack (with minimum-phasing filter applied in flow) (**2009-GEL-01)**

Test 3: Frequency

Test Line 2009-GEL-01

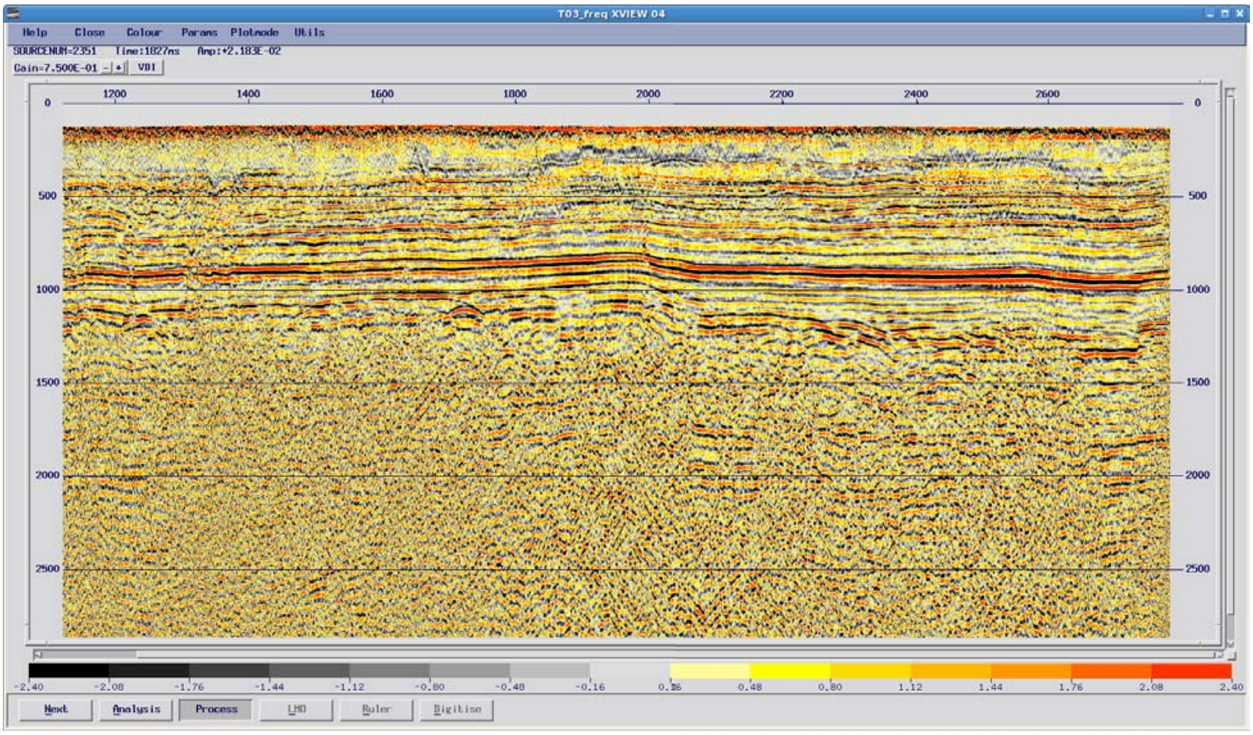
Objective:
To examine the frequency content of various kinds of events and noise within the data, as viewed in source records and in brute stacks.

Discussion:
The frequency-related properties of the dataset were examined within source records and brute stacks in two ways: by viewing the spectra of selected windows, and by applying rolling narrow bandpass filters, from 10 – 20 Hz up to 100 – 110 Hz.

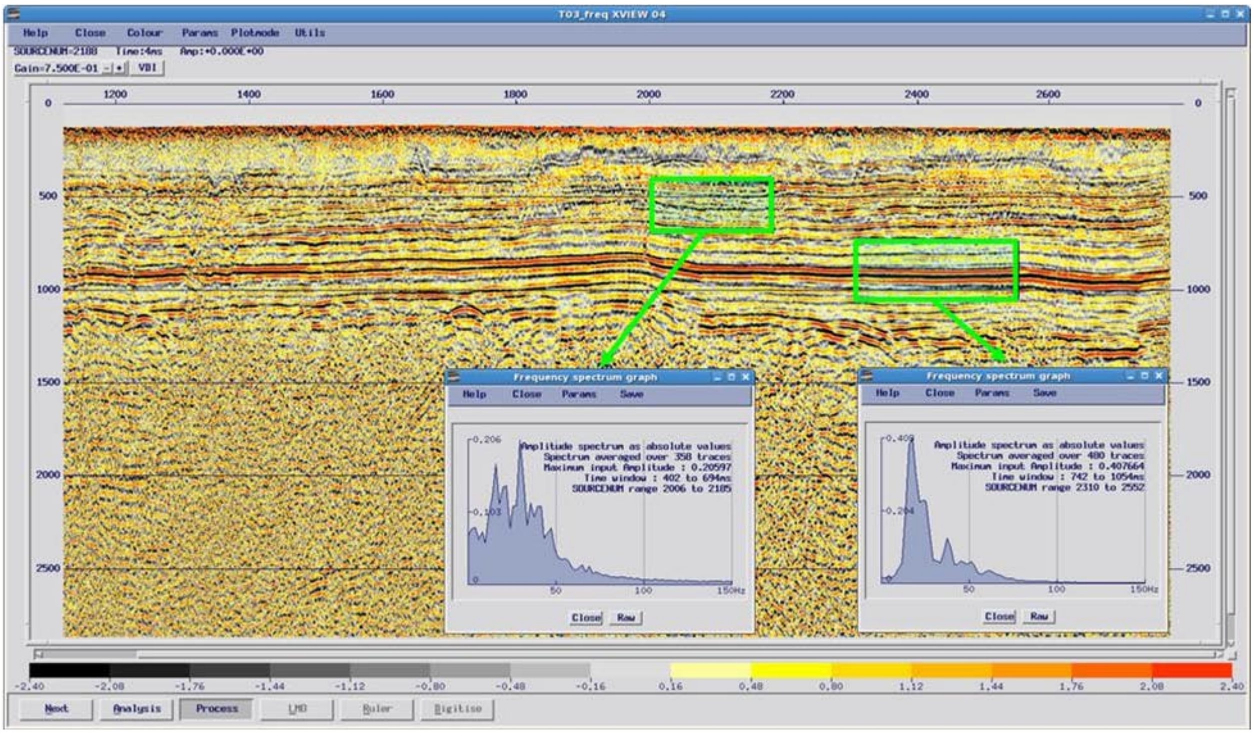
Comment:
The reflection energy in the target zone appears to be significant from the bottom of the sweep (10 Hz) up to around 80 to 90 Hz. The groundroll is mainly under 30 Hz, while the air blast is only significant above 70 Hz.

Processing flow for stacks in Test 3

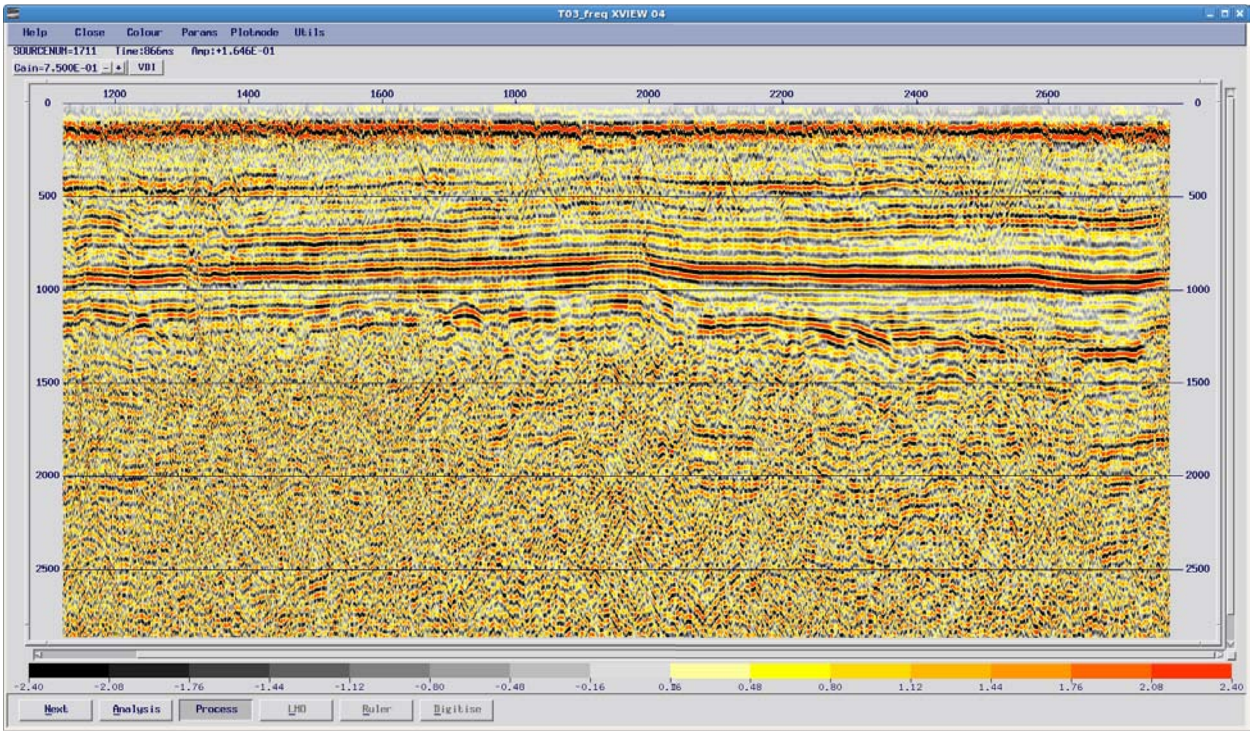
- Reformat SEG-Y data to Claritas internal format
- Resample to 2 ms
- Minimum-phasing filter
- Spherical divergence correction
- Refraction statics correction
- NMO (rough velocities), 40% stretch mute
- AGC, 500 ms operator
- Stack, shift to final datum (400 m)
- **Bandpass filter, as shown**
- AGC, 500 ms operator



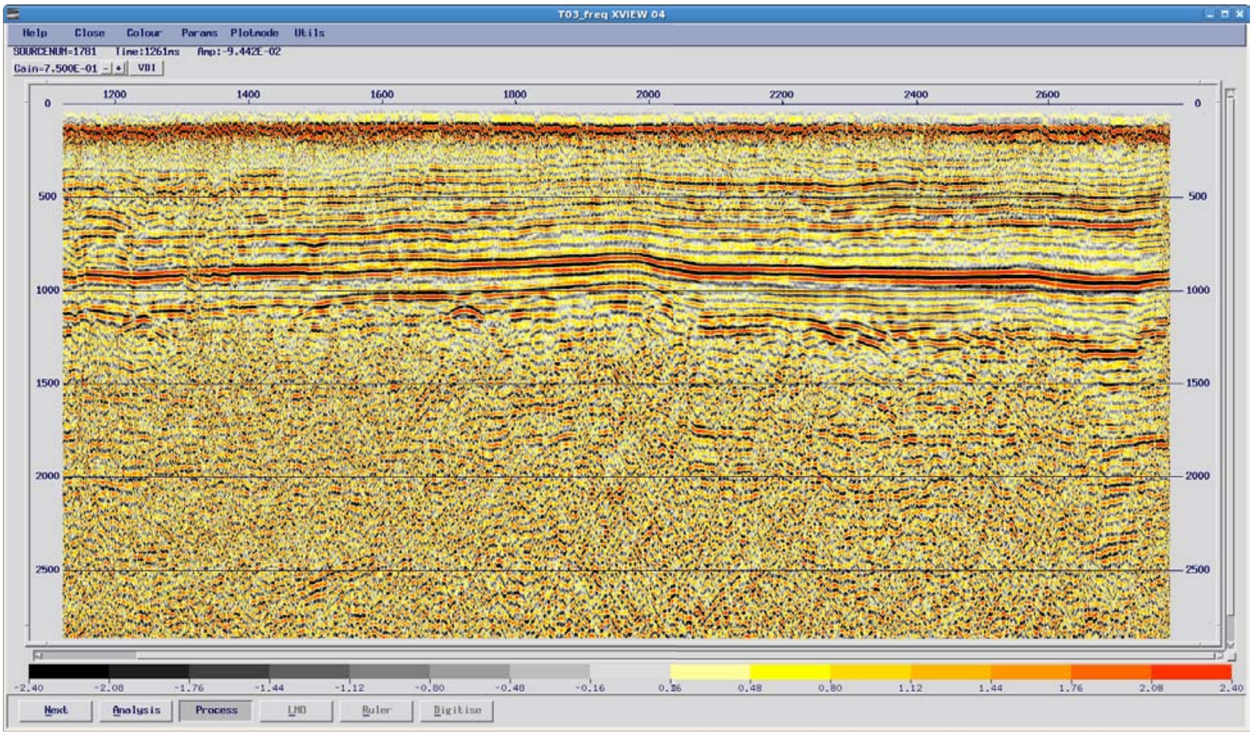
Brute stack, no bandpass filter (**2009-GEL-01)**



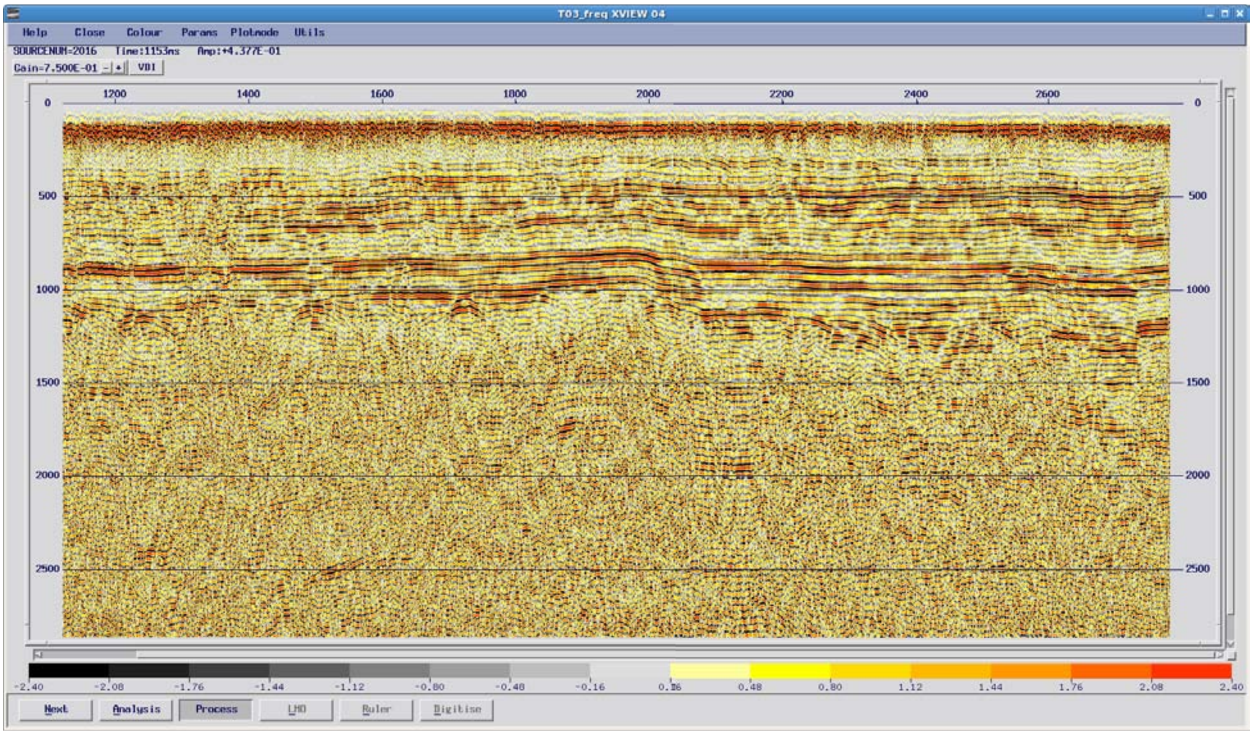
Brute stack, no bandpass filter (windowed spectra) (**2009-GEL-01)**



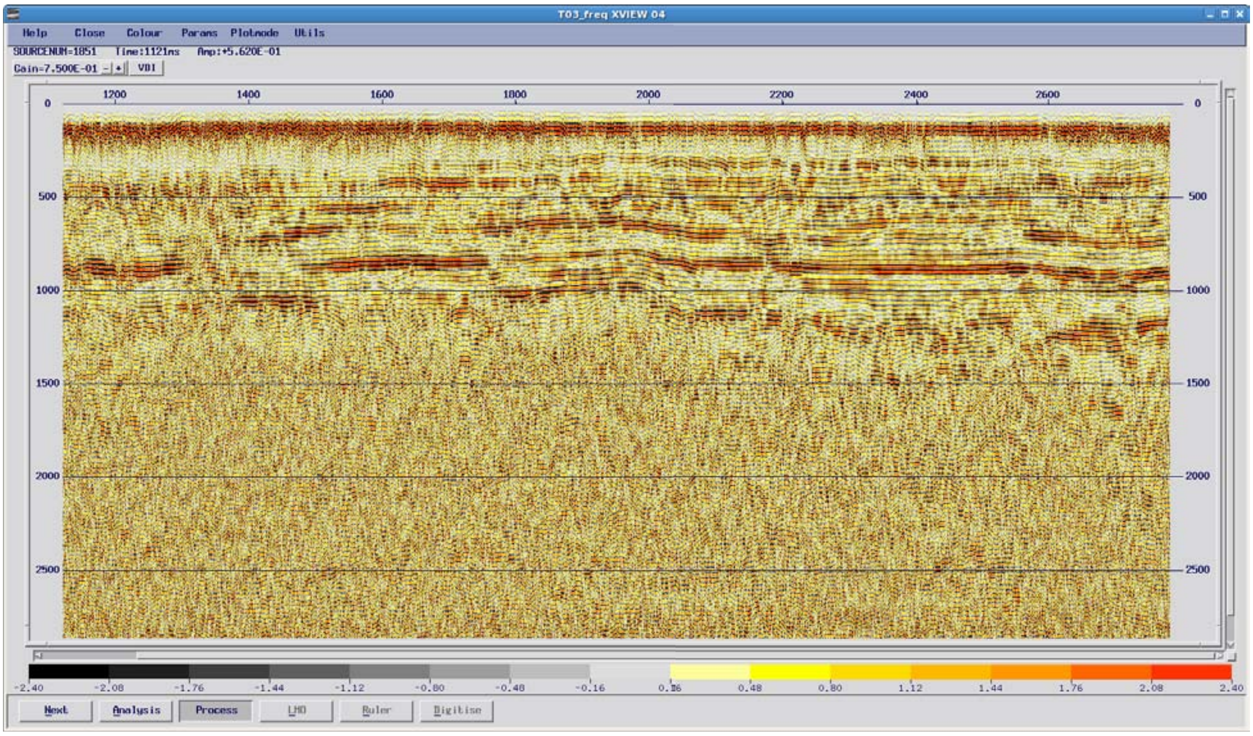
Brute stack, bandpass filter (10 – 20 Hz) (**2009-GEL-01)**



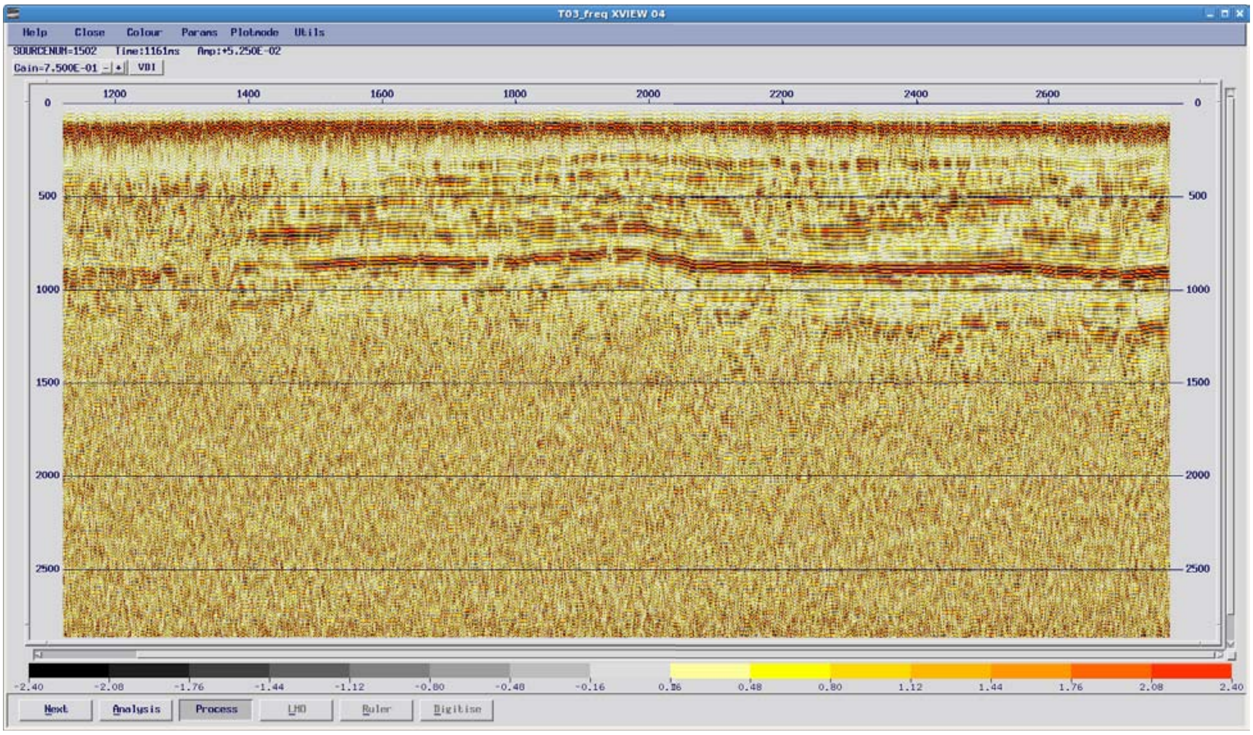
Brute stack, bandpass filter (20 – 30 Hz) (**2009-GEL-01)**



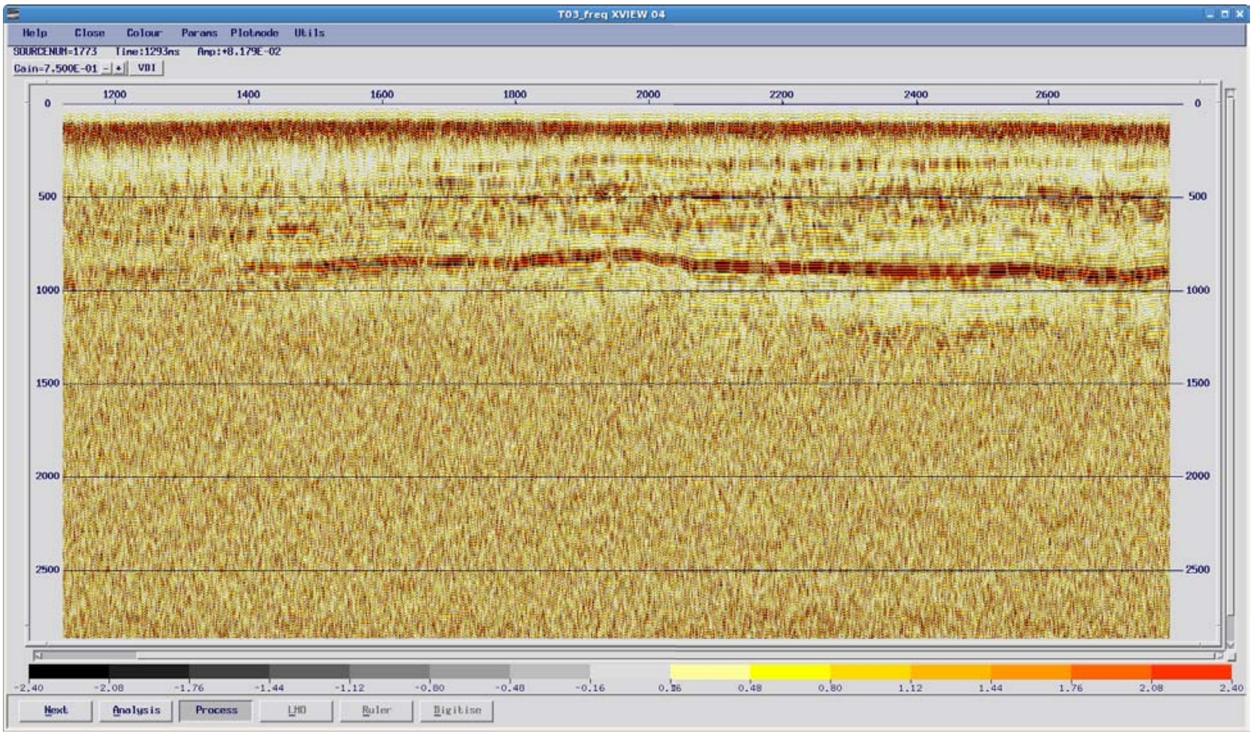
Brute stack, bandpass filter (30 - 40 Hz) (**2009-GEL-01)**



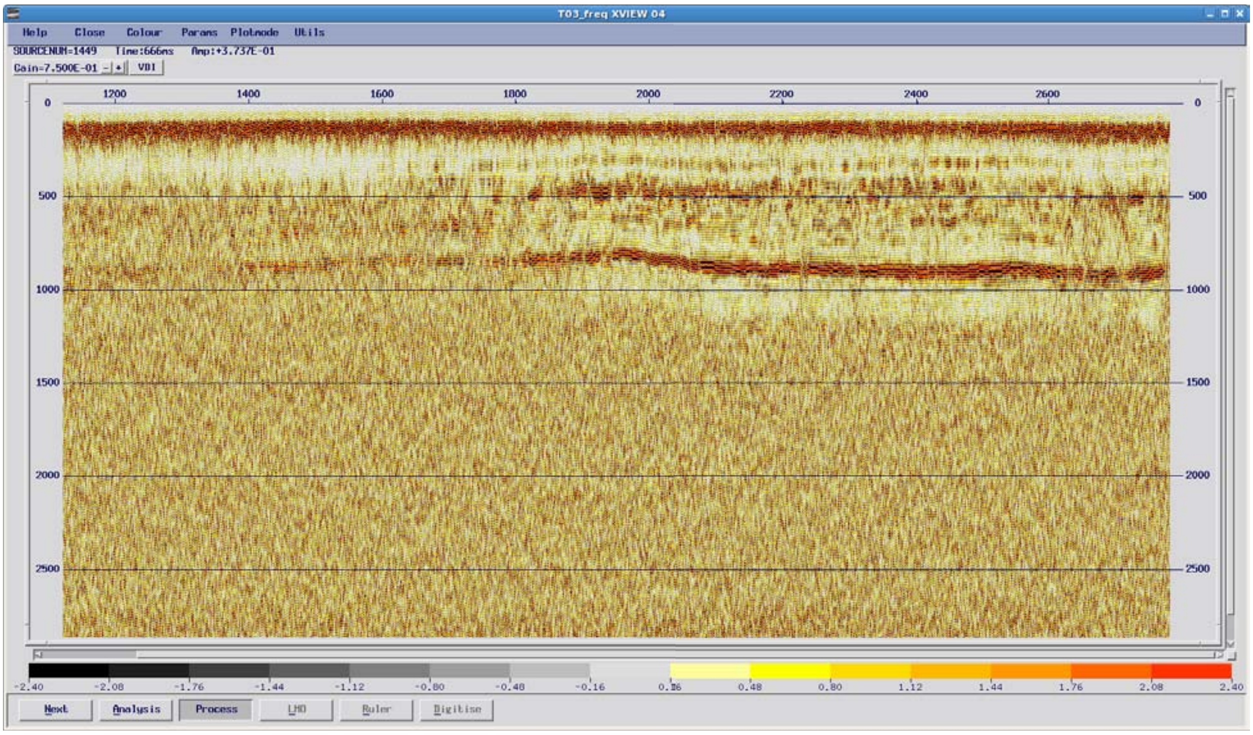
Brute stack, bandpass filter (40 - 50 Hz) (**2009-GEL-01)**



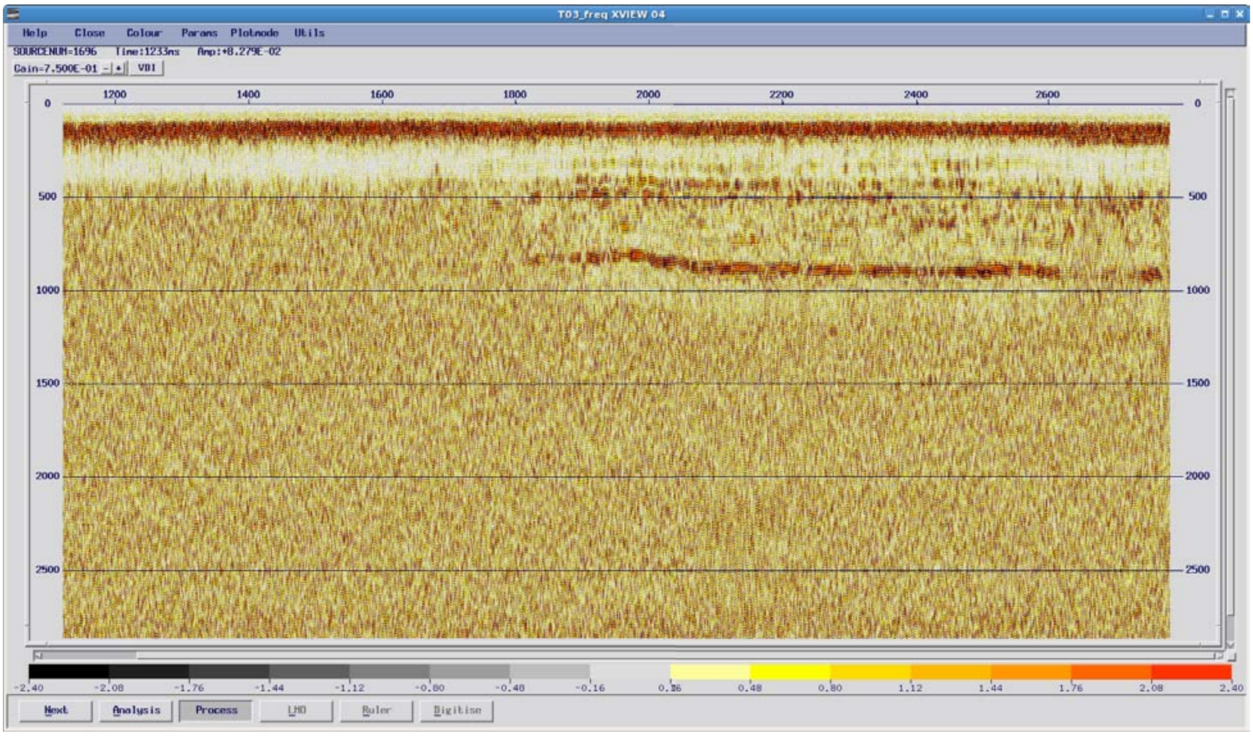
Brute stack, bandpass filter (50 - 60 Hz) (**<u>2009-GEL-01)</u>**



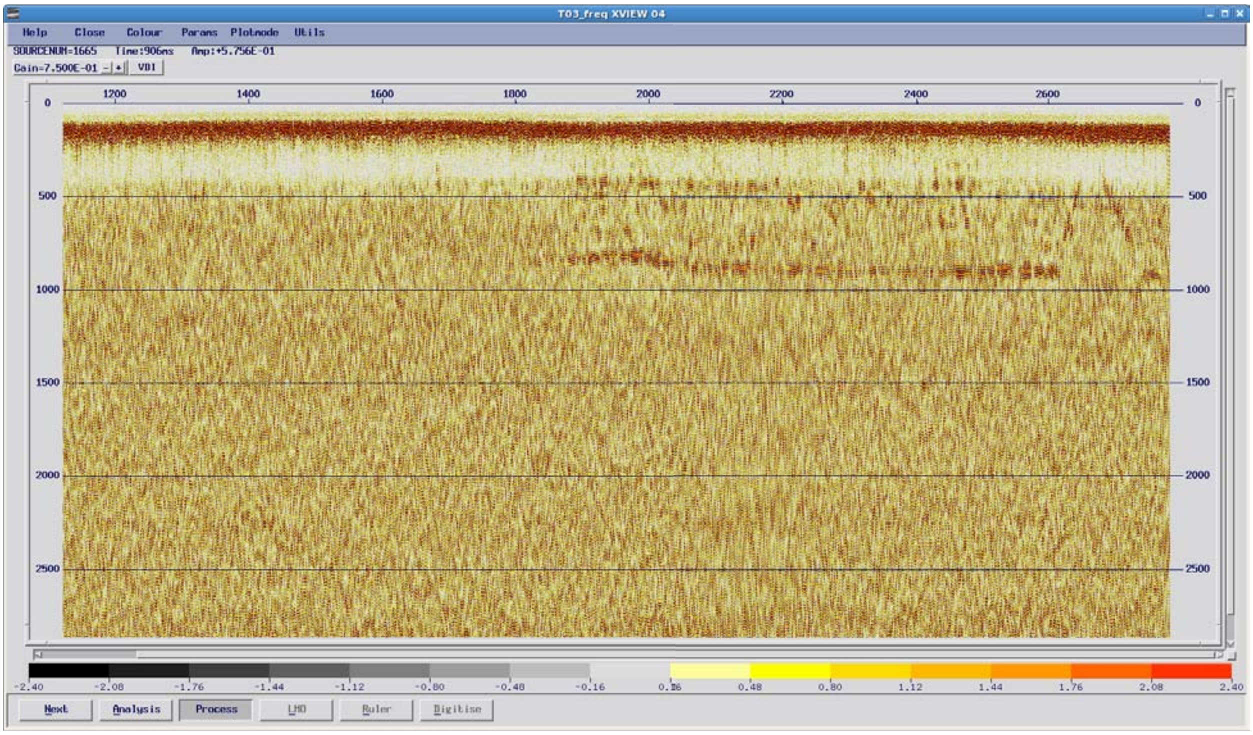
Brute stack, bandpass filter (60 - 70 Hz) (**<u>2009-GEL-01)</u>**



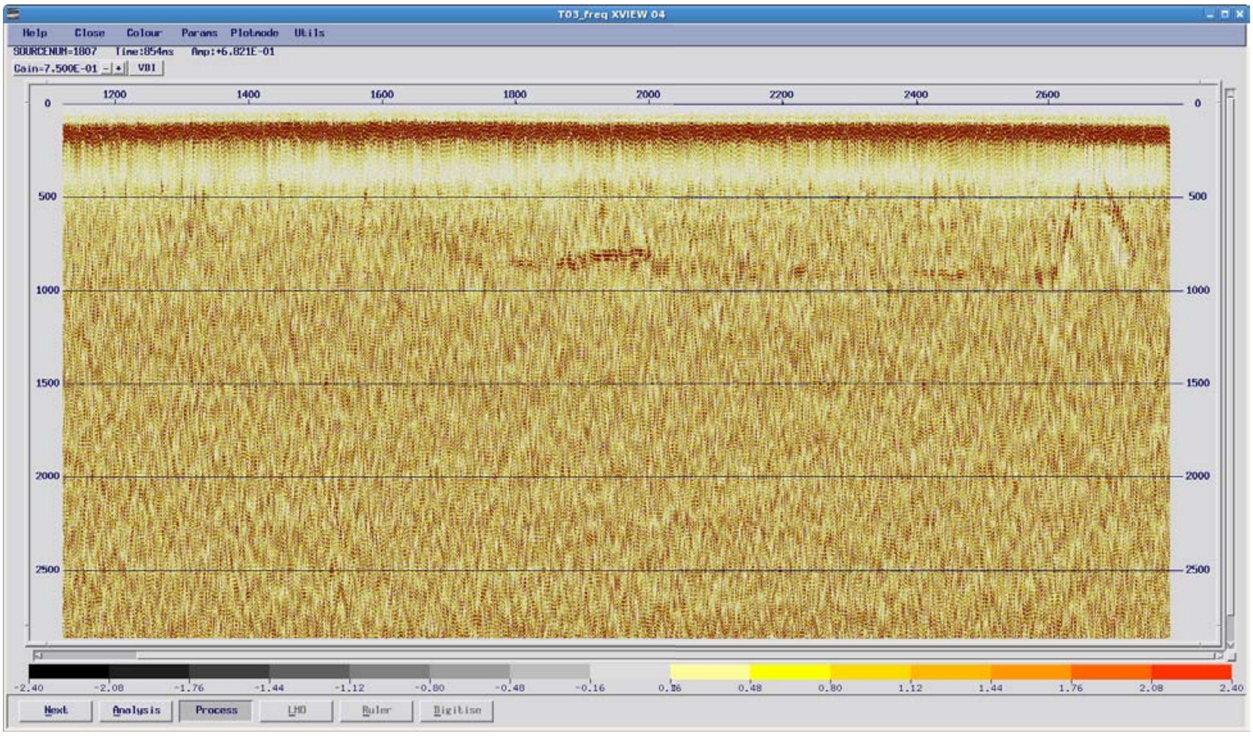
Brute stack, bandpass filter (70 - 80 Hz) (**2009-GEL-01)**



Brute stack, bandpass filter (80 - 90 Hz) (**2009-GEL-01)**



Brute stack, bandpass filter (90 - 100 Hz) (**2009-GEL-01)**



Brute stack, bandpass filter (100 – 110 Hz) (**2009-GEL-01)**

Test 4: Spherical divergence correction

Test Line 2009-GEL-01

Objective:
To select appropriate spherical divergence correction parameters.

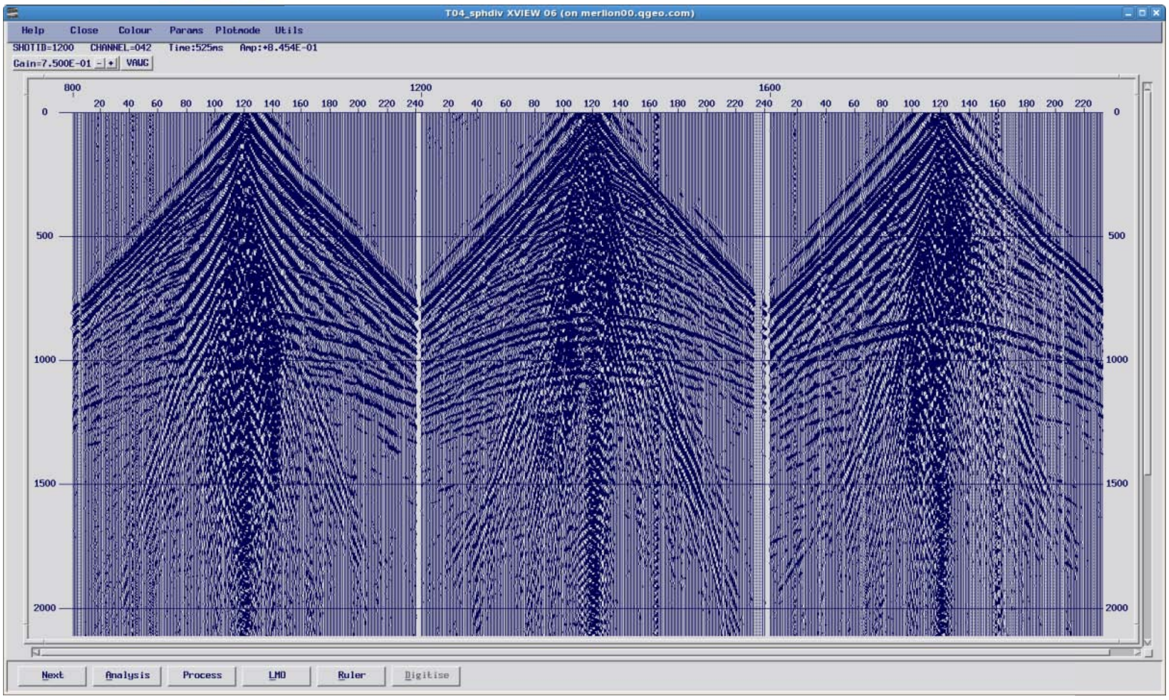
Procedure:
Spherical divergence correction, using various time exponents, was applied to a subset of source records within the test line, in order to determine which option provides the best amplitude balance between like reflectors at different times.

Discussion:
The major reflectors in the target zone (the Permian coals) have a much higher intrinsic reflectivity than the other strata in this area, and allowances have been made for this when making decisions on the spherical divergence correction.

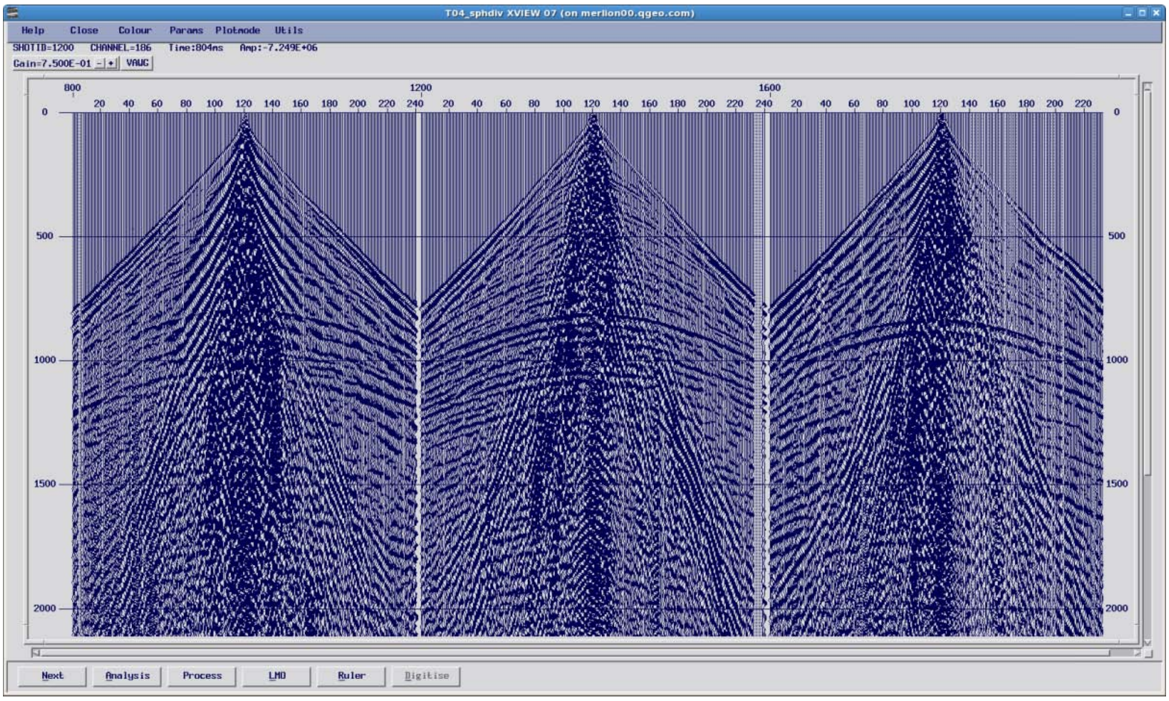
Comment:
A time exponent of 1.4 appears to give a reasonable balance between like reflectors.

Processing flow for source records in Test 4

- Reformat SEG-Y data to Claritas internal format
- Resample to 2 ms
- **Spherical divergence correction (rough velocities), as shown**
- Refraction statics correction
- Bandpass filter, 10 – 80 Hz



Source records, no spherical divergence correction



Source records, spherical divergence correction $G(T) = V^2T^2$