SCRIPPS / UNR

Survey: SONGS
Area: Offshore Southern California

Offshore & Onshore 3D High Resolution Processing Final Report

Geotrace Project No.: 5800411

Date:	April 2014
Geotrace Contact:	Frank Landers
Addressee:	Dr. Graham Kent

Geotrace Technologies
12141 Wickchester Lane, Suite 200
Houston, Texas 77079
Tel: (281) 497 8440 Fax: (281) 497 4619

Seismic Data Processing Report

Area : San Onofre Nuclear Generating Station (SONGS)
Offshore southern California, USA

Date acquired: October 2013 – April 2014

Prepared by:

Geotrace Technologies
12141 Wickchester Lane, Suite 200
Houston, Texas 77079
USA

For:

Scripps University California San Diego
University Nevada Reno

Contents

1 Introduction

This report describes the onboard and onshore high resolution data processing carried out on behalf of Scripps Institute of Oceanography UCSD and UNR during the period October 2013 to April 2014, by Geotrace Technologies, onboard the academic research vessel New Horizon operated by Scripps Institute of Oceanography.

The survey was acquired over the SONGS area, offshore southern California, USA. The area covered by the 3D seismic survey totals approximately 100 km^2.

The survey was acquired using the P-Cable acquisition configuration. This comprised a single source and 14 streamers attached to a cross cable. The survey was acquired at both a 0.25ms and 0.5ms sample rate. The native bin size was 3.125m inline and 3.125m crossline separation for acquisition. The final data was processed using a 3.125m inline and 3.125m crossline separation. Full details of the acquisition parameters can be found in Section 2 of this report and a full inventory of the lines processed is provided in the Appendix A.

This report covers the development and application of an appropriate data processing scheme, including the tests performed and a summary of the processing sequence adopted. The report also details the quality control products generated both as part of the acquisition QC and the processing QC.

The main objectives of the processing were to provide Scripps and UNR with a raw 3D stack that could be produced onboard and maintained alongside acquisition. Further processing would then be carried out onshore to produce a final migrated volume.

Testing was conducted prior to the start of the acquisition phase using supplied 2D data acquired August 2013 prior to the start of acquisition of the 3D surveys in October 2013. The testing then continued during the acquisition of the 3D surveys. Part of the testing was performed on the vessel and was followed by the onshore stage involving Scripps and UNR in all important stages of processing to provide confirmation of any major parameter decisions.

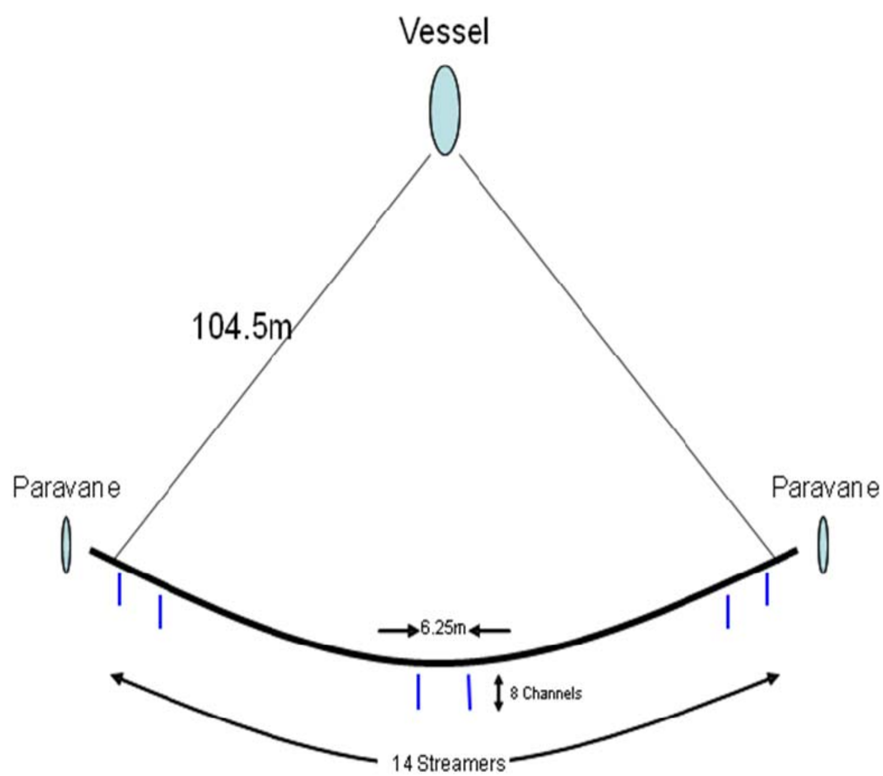
The report concludes with a qualitative assessment of the project, together with a list of the personnel involved. Data and test examples are also included in the report.

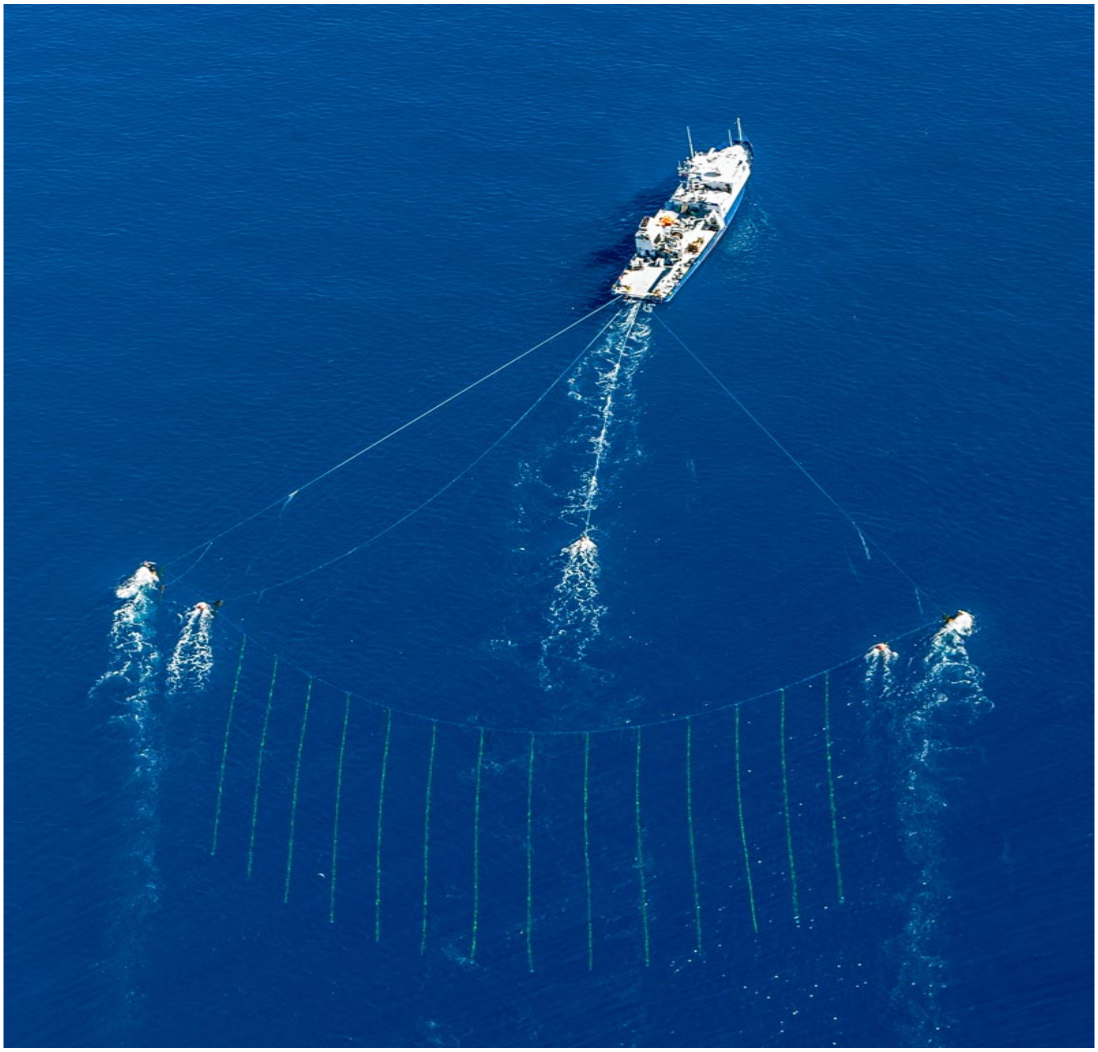
2 Acquisition & Survey Area

2.1 Specifications

The survey was acquired by R/V New Horizon (Scripps Institute of Oceanography) from October 2013 to November 2014. The acquisition geometry comprised a single source and a cross cable with 14 small streamers attached, each with 8 channels. This is the P-Cable acquisition system details of which are summarised below.

2.1.1 P-Cable 14 Streamer Configuration:





2.1.2 Energy source:

Types	Boomer (using 3 plates) Sparker (using 3 tips)
Shot interval	3.125m (B) 6.25m (S)
Direction of shooting	132 or 312 degrees (B) and 135 or 315 degrees (S)
Source depth	0.5m (B) and 2m (S)

2.1.3 Receiving arrangements:

No. of groups	8 *14
Group interval	6.25m
Cable depth	2m

2.1.4 Instrumentation:

Format	SEGY

Recording length	800ms (B) and 2000ms (S)
Sample rate	0.25ms (B) and 0.5ms (S)
Recording polarity	Normal (SEG convention)
Recording delay	0ms

2.2 Survey Area

Offshore southern California, USA with survey areas highlighted (from Google Earth)

3 Navigation & 3D Geometry Definition

3.1 Coordinate System

Processed navigation data in UKOOA P1/90 format was created onboard for the paravane and source positions. The following projection and datum were used:-

Geodetic Datum:	WGS84
Spheroid:	WGS84
Longitude of Central Meridian:	129° West
Projection Type:	001 TM North Orientated
UTM Projection Zone:	11 N

3.2 3D Bin Grid Definition Boomer

Grid Origin : Inline 1000 Crossline 1000
(“local” coordinate x,y = 0,0m)

Defined at Co-ordinate Point : **Easting** : 438370.4 E
Northing : 3686647.4 N
(centre of bin)

Grid Bearings : inline direction 132°

Local Rotation Angle : -42° (anti clockwise rotation)

3D Processing Geometry:

Bin Size : Inline spacing : 3.125m
Crossline spacing : 3.125m

Numerical Bin Increment: Inline separation : 1
Crossline separation : 1

Total Number of Bins : Inlines : 2100
(1001,1002,1003, …….3100)
Crosslines : 5400
(1001,1002,1003…….6400)

Local Rotation Angle: -42°

Geometry Corner Coordinates:

Cross line	Inline	Easting	Northing
1001	1001	438370.40	3686647.40
1001	3100	442759.48	3691521.97
6400	3100	455927.73	3680232.48
6400	1001	450908.65	3675357.91

3.3 3D Bin Grid Definition Sparker

Grid Origin :	Inline 1000 Crossline 1000 ("local" coordinate x,y = 0,0m)
Defined at Co-ordinate Point :	**Easting** : 435186.3 E **Northing** : 3681633.1 N (centre of bin)
Grid Bearings :	inline direction 135.52°
Local Rotation Angle :	-45.52° (anti clockwise rotation)

3D Processing Geometry:

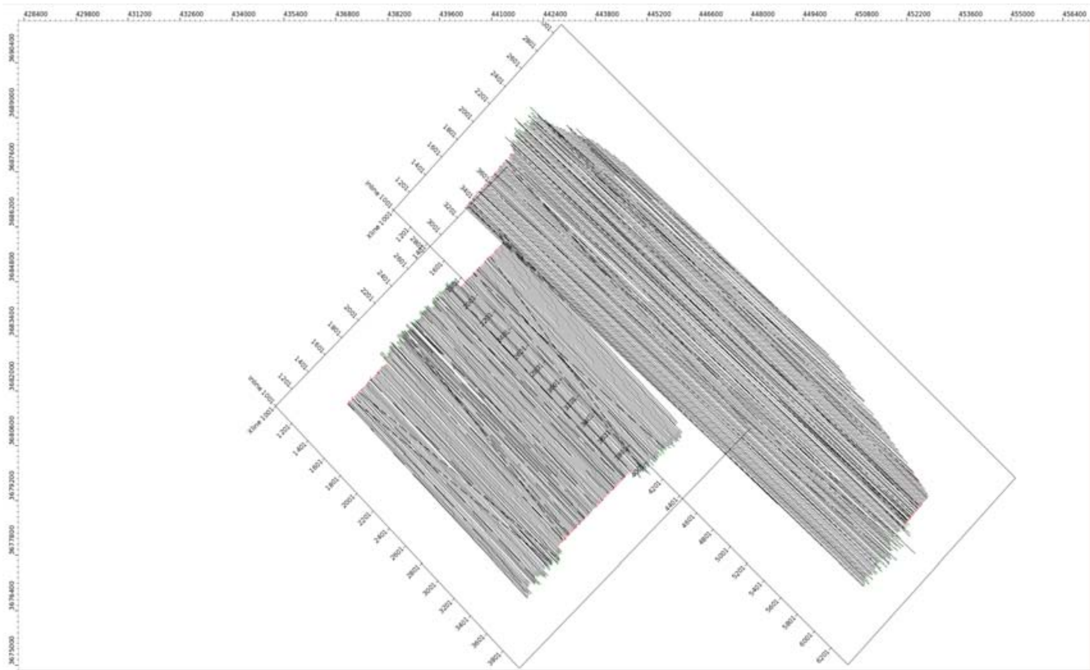
Bin Size :	Inline spacing		: 3.125m
	Crossline spacing		: 3.125m
Numerical Bin Increment:	Inline separation		: 1
	Crossline separation		: 1
Total Number of Bins :	Inlines	: 2800 (1001,1002,1003, …….3800)	
	Crosslines	: 3000 (1001,1002,1003……4000)	
Local Rotation Angle:	-45.52°		

Geometry Corner Coordinates:

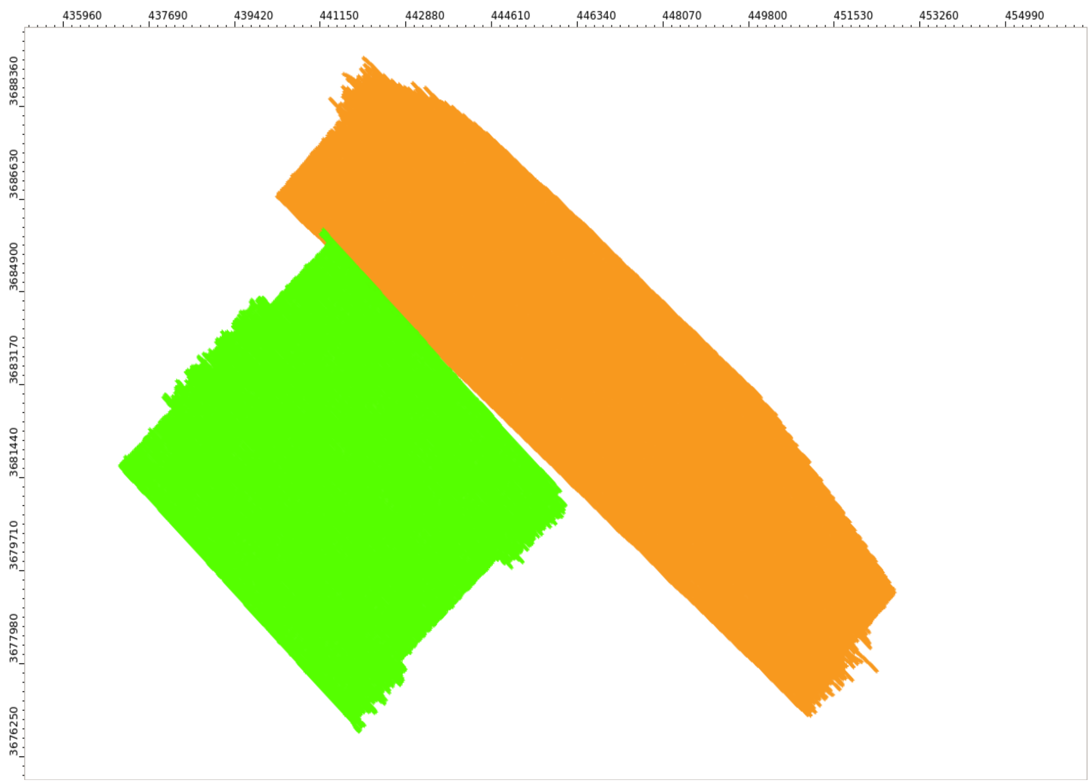
Cross line	Inline	Easting	Northing
1001	1001	435186.30	3681633.10
1001	3800	441314.89	3675392.25
4000	3800	448001.67	3681958.75
4000	1001	441873.09	3688199.60

3.4 Unrotated Survey Area (Boomer and Sparker)

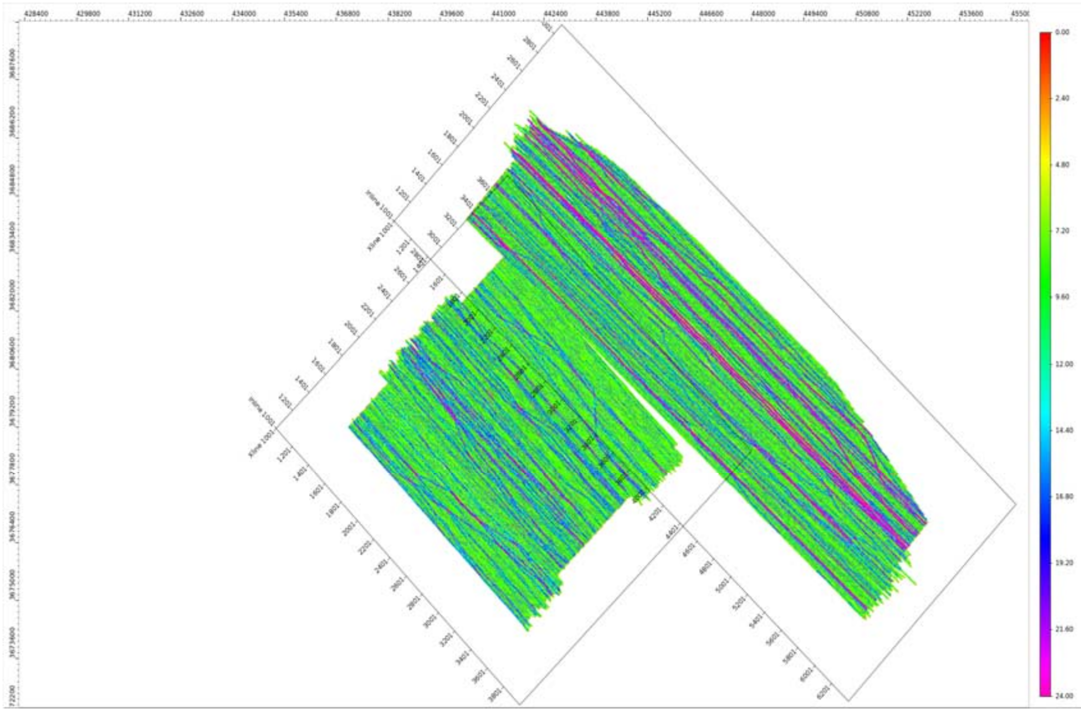
As acquired sail lines (all lines)



As acquired source positions (all lines, all shots)

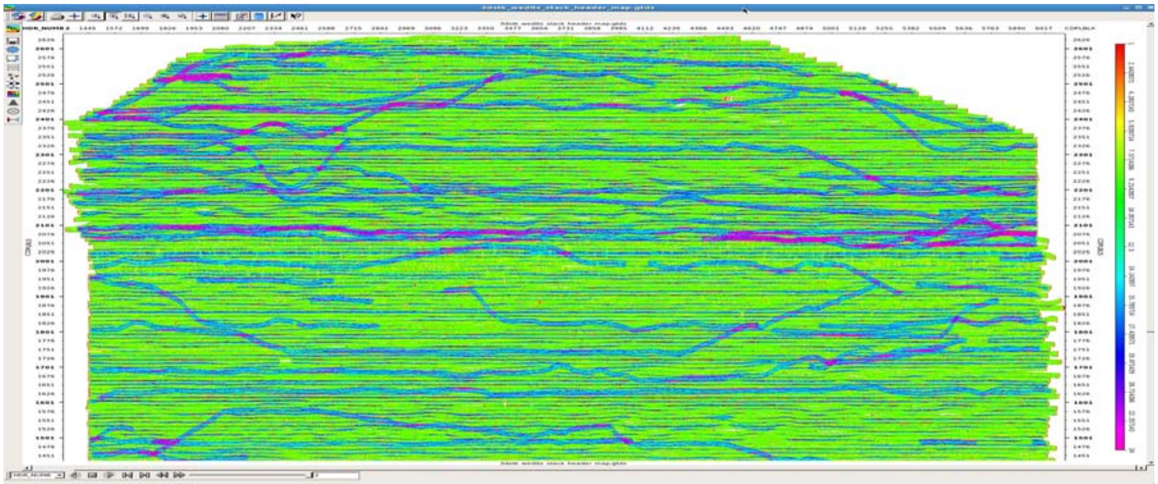


As acquired fold of coverage (all offsets)

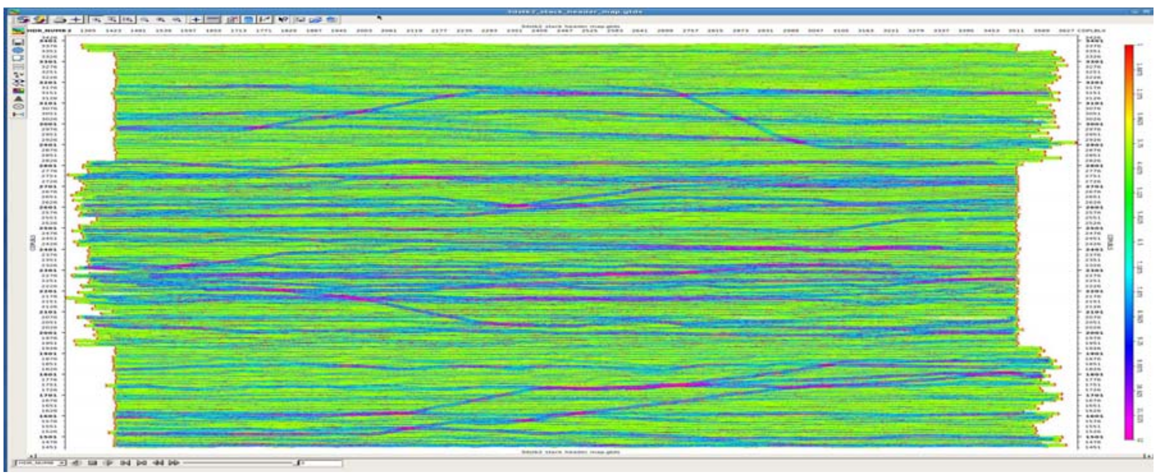


3.5 Rotated Survey Area

As acquired Boomer fold of coverage (nominal=8, all offsets)



As acquired Sparker fold of coverage (nominal=4, all offsets)



4 Acquisition QC and Onboard Processing

Geotrace Technologies performed full data acquisition QC. Products and examples are described in this section. QC products were created after the acquisition of each line when the SEG-Y data with the modelled receiver co-ordinates were available.

The parameterisation and production of the QC displays take into account the specifications for the acquisition and the local geology and conditions.

4.1 Amplitude and Frequency Maps

Amplitude and frequency analyses were conducted as part for the standard qc for every line acquired. The following design windows were used:

Ambient Window: Measured above direct arrival – Amplitude measured in microbars

Boomer	Near chan: 2 to 60ms	Far chan: 2 to 60ms
Sparker	Near chan: 2 to 60ms	Far chan: 2 to 60ms

Data Window: Measured over area of best S/N or target. Amplitude and dominant frequency measured-RMS and Hz.

Boomer	Near chan: 300 to 400ms	Far chan: 300 to 400ms
Sparker	Near chan: 1250 to 1500ms	Far chan: 1250 to 1500ms

Deep Window: Measured over last 500ms of trace. Amplitude and dominant frequency measured-microbars and Hz.

Boomer	Near chan: 700 to 800ms	Far chan: 700 to 800ms
Sparker	Near chan: 1900 to 2000ms	Far chan: 1900 to 2000ms

Whole Trace: Measured over full trace length, RMS and Hz.

Boomer	Near chan: 2 to 800ms	Far chan: 2 to 800ms
Sparker	Near chan: 2 to 2000ms	Far chan: 2 to 2000ms

4.2 Near Trace Gathers

Four near trace gathers (streamers 1, 5, 10 and 14), were generated for each sail line. These displays were useful in quickly determining any possible errors with acquisition. They reveal source changes, bad records, time break problems and mis-fires not reported by the recording system. They also provided a good indication of the geological conditions including the strength of water bottom multiples and swell noise contamination.

4.3 Shot Gathers

The raw 0.25ms and the resampled, filtered 1.0ms shot volumes stored for further processing could be viewed after acquisition and was used to monitor overall data quality and general noise contamination.

4.4 Brute Stacks

Two brute stacks, for streamers 5 and 10, were created during the acquisition of each sailline. A constant velocity of 1480m/s was applied as the brute function to create the stacks.

4.5 Channel to Channel Amplitude Diagnostics

Similar to the shot to shot diagnostics, a single RMS value for each channel was calculated from the "data" window RMS. For each channel, every shot RMS contributes to the mean RMS amplitude value for that channel, giving a mean value for each receiver. These values were then displayed adjacently to highlight noisy channels or those with low recording sensitivity.

4.6 Offset QC

A check was carried out to comparing the 3D offset assignment derived from the modelled receiver co-ordinates with the expected direct arrival time. The offset qc was created for every channel (all cables and all shots, eg. Chan 1, 9, 17, ...105; Chan 2, 10, 18, ...106, etc).

Any errors in navigation data processing were highlighted from this qc. This allowed subsequent re-processing of the P190 navigation data to be performed where appropriate.

4.7 Near Trace Stack

A near trace stack volume was created to further verify the integrity of the seismic data. The stack was created at a 25m CDP interval thereby giving a nominal fold of 1. The volume was stacked with a single water velocity of 1480m/s. Normalised timeslices, inlines and crosslines displays were created to QC the volume.

The near trace stack was updated after every accepted sequence acquired.

4.8 3D Raw Stack

A brute 3D stack volume was created to further verify the integrity of the seismic data. The stack was created at a 3.125m CDP interval thereby giving a nominal fold of 8 for the Boomer source (3.125m shot spacing) and a nominal fold of 4 for the Sparker source (6.25m shot spacing). The volume was stacked with a single water velocity of 1480m/s. Normalised timeslices, inlines and crosslines displays were created to QC the volume.

The 3D stack was updated after every accepted sequence acquired.

4.9 Binning Control

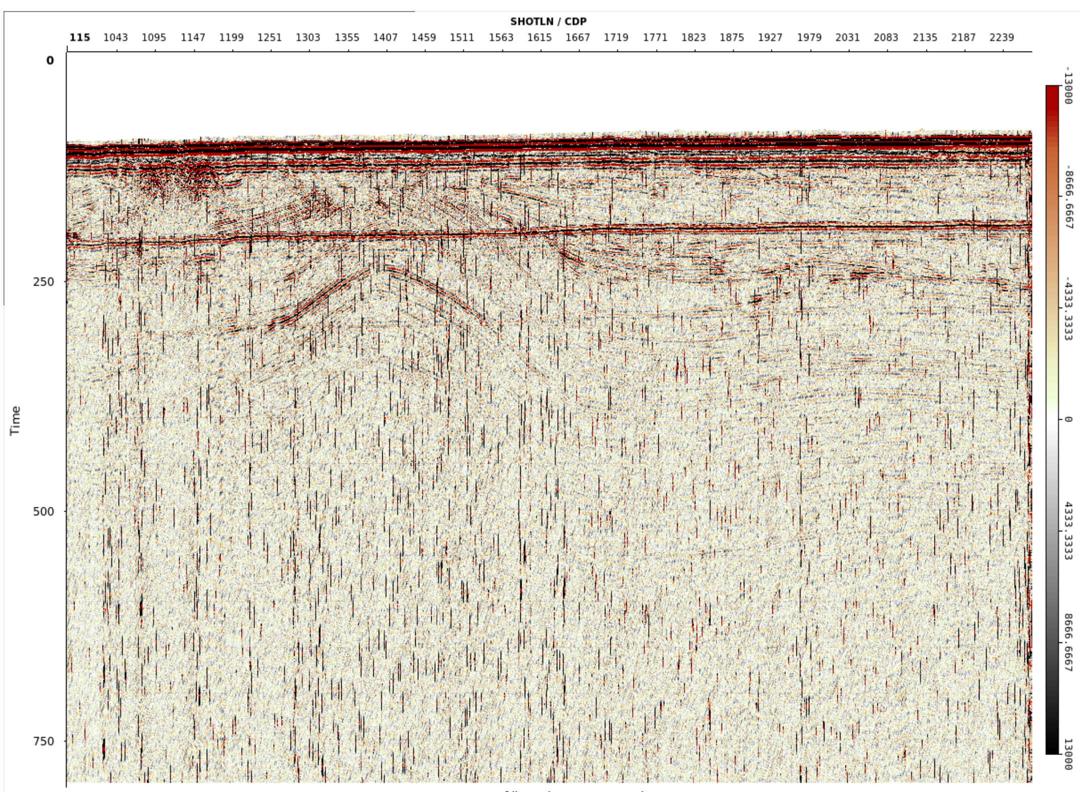
The binning process is monitored by comprehensive printed diagnostics and optional colour displays detailing:

- Acquired fold of coverage – all offsets.
- Fold following trace rejection.
- Fold following trace re-allocation.
- Final fold of coverage – all offsets.
- Mean radial distance to bin centre.
- Standard deviation of the distance from bin centre.
- Mean inline distance to bin centre.
- Mean crossline distance to bin centre.
- Number of traces rejected.
- Fold of coverage plots - Colour displays of both acquired and final fold of coverage of both restricted and full offset ranges are used to check proposed fold and offset distribution.

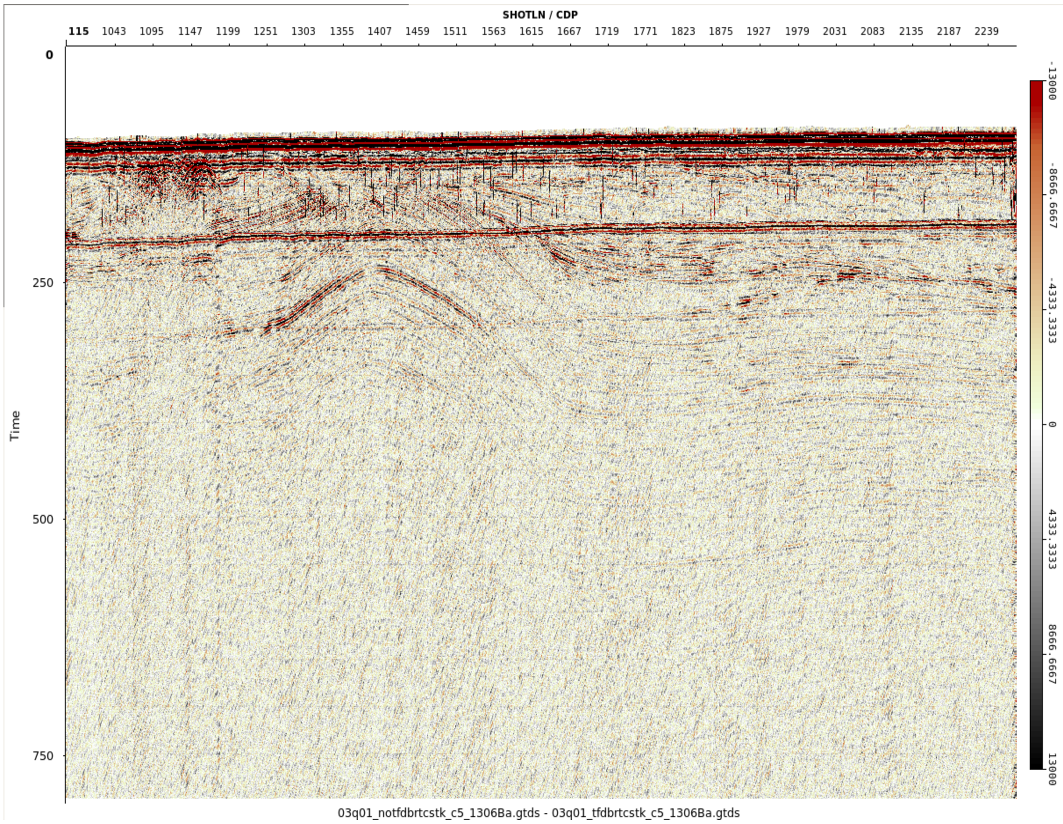
4.10 Noise Examples

4.10.1 – Random noise bursts (possible swell noise)

Line 1306B (cable 5 brute stack)



Line 1306B with noise attenuation applied (cable 5 brute stack)



4.10.2 Swell Noise

There was inevitably some swell present during the survey but only light or moderate and not considered to be problematic for final processing. The swell noise attenuation applied is described in Section 5.2.5.

5 Onshore Processing

5.1 Processing Summary

The onshore processing sequence was derived after the acquisition finished. Processing was carried out at Geotrace's Houston office.

1. Reformat SEGY– 0.25 or 0.5 ms raw shot gathers
2. Low cut filter 45(18) Hz(dB/Oct)
3. Temporal resample to 1ms sample rate with anti-alias filter
4. Bad trace edits
5. De-noise with automatic spike removal in Shot domain – 2 iterations
6. 2D SRME on common channel/shots
7. Load data to a 3D pre stack volume (3.125m x 3.125m)
8. Apply 1480m/s primary NMO
9. 3D stack
10. Deconvolution After Stack (DAS) – (Boomer data only)
11. 1D SRME and subtract
12. Interpolation of empty bins with SNIP
13. Post stack, pre-migration noise attenuation with automatic spike removal, FDNA, and FXY
14. Post stack Kirchhoff migration
15. Dip filtering (Boomer data only)
16. Time Variant Filter (Sparker data only)
17. Amplitude balancing: Measured exponential gain
18. Gun and cable static correction
19. SEGY – Final Filtered Migrated Stack
20. Scaling: 400ms Iterative AGC - optional
21. SEGY – Final Filtered Migrated Scaled Stack

5.2 Preliminary Processing

5.2.1 Low Cut Filter

Application of a 45(18) Hz (dB/oct) zero phase low cut filter was applied.

5.2.2 Designature / Debubble

No far field was available for the Boomer or Sparker sources used in the acquisition. Therefore no designature or debubble was applied in the final processing with the data being left at acquired or minimum phase.

5.2.3 Temporal resample

A 375(96) Hz (dB/Octave) anti-alias minimum phase filter was applied prior to resampling from 0.25ms (or 0.5ms) to 1ms.

5.2.4 Bad trace editing

Geotrace confirmed the single trace edits flagged during the onboard QC processing for removal.

5.2.5 Noise Attenuation

Swell noise attenuation (TFD) was tested as required but was in general not a serious issue for this project. TFD performs noise suppression with sub spectral balancing using sample-wise median thresholds within frequency sub-bands in time-frequency space. It is ideally suited to removing low-frequency noise bursts and swell noise in marine data, whilst preserving the signal amplitudes.

The initial TFD testing was conducted onboard the vessel for sequence 2 which contained minimal swell.

Due to the particular setup the standard approaches of TFD (shot or receiver domains) were unsuitable.

Alternately an automatic spike removal process was tested. The program locates high amplitude spikes and noise bursts within seismic data and replaces the affected samples with data averaged from the surrounding traces. Spikes are found by comparing the ratio between the each sample amplitude on the input trace to the RMS average. Whenever the ratio exceeds a given threshold level, that input sample is defined as a spike. The spike definition can be extended to a user-specified number of samples in time before and after the current sample. For each input trace the program sums together a number of adjacent traces to form a reference trace (after first squaring their values). The reference trace is smoothed over a time gate by applying a running average. After normalization and application of a square root, the sample values stored in the reference trace form the 2-dimensional window averages to be used in the comparisons. Amplitude despiking was applied in the shot domain.

Noise_Attenuation_Trials_CDPs&Stack_Displays.ppt

5.3 Static Corrections

The raw 3D stack provided evidence of possible static shifts. Much of these were seen to be line to line statics.

5.3.1 Offset Corrections

The 3d offsets derived from the modelled receiver locations were checked by comparing the predicted direct arrival time with that measured in the data. To do this, displays were produced of common channel sections for specific cables within selected lines. Using the predicted arrival times the data were shifted to a nominal reference time (100ms). Any deviations of the 3d offset are seen as shifts in the data away from this time. It could be seen only a few minor errors in the modelled receiver positions existed.

Further static shifts were also apparent. These occurred at the boundaries of sail lines and therefore were assumed to originate from variations in the water column.

5.3.2 Tidal Static Corrections

Predicted tidal tables, covering the period of acquisition, were provided by NCS. From these, timing shifts were extracted and applied to the data based on the time header. The application of the tidal statics was tested by creating a near trace stack.

The decision was made not to apply the tidal static corrections due to the erroneous shifts the extracted values were introducing into the data.

5.3.3 Water Column Statics

Line to line statics thought to originate from variations in the water column such as temperature changes, currents etc were evident.

To correct for these statics the following methodology was tested.

- Pick water bottom times over an nmo corrected 3D near trace cube for every inline.
- Convert picked times to a gridded 3D surface.
- Smooth raw surface using a Gaussian 11point filter to create an ideal surface.
- Subtract smoothed surface from raw to derive statics.
- Apply statics.

The decision was made not to apply any water column based static corrections in order to prevent smearing of possible faults and other natural geologic structures.

5.3.4 Displays of Static Corrections – Near Trace Stacks

The results of stages 5.3.1 – 5.3.3 can be seen in the following enclosure in which the statics corrections have been applied in the creation of near trace stack volumes.

- Statics_evaluations.ppt

5.3.5 Trim Statics

After sorting to CDP gathers, the gathers were investigated for time-variant trim statics.

It was apparent after examination of the CP sorted gathers that trim statics were not a problem and thus the decision was made not to test or apply any time-variant trim static corrections.

5.4 Pre-migration Processing

5.4.1 Surface Related Multiple Elimination (SRME)

Surface Related Multiple Elimination was applied to coincident shots and receivers each 3.125m (B) or 6.25m (S) apart. SRME is a pre-stack technique designed to attenuate surface generated multiples following studies made by Verschuur et. al. and described in a number of publications including the Journal of Seismic Exploration, 1, Jan. 1992. The method utilises the general wave equation boundary condition and makes no assumptions regarding wave behaviour in the earth. No prior model or knowledge of the sub-surface is therefore necessary.

In addition, traces were extrapolated to zero offset within the shot records.

Three iterations of SRME were performed on the data. A multiple estimate is made and subtracted from the input data. Both the results of this subtraction and the unchanged input data are passed on for further processing. Subsequent iterations use the result of the previous subtraction as input to the multiple prediction. After the final iteration, the final multiple estimate is adaptively subtracted from the original input data.

The adaptive subtraction was performed within common channel records. The multiple model was matched and subtracted as follows:

i) Match the gross amplitude difference between the input data and the multiple model. This is designed on the whole record and applied as a single point filter.
ii) Filter to match the phase.
iii) Filter to match the amplitudes.

5.4.2 3D Volume Load

Before the stack and migration processing the data were loaded to a 3D pre-stack volume using the grid definition defined in Section 3.3. The data was left on the acquired natural 3.125m CDP spacing within the load giving a final nominal fold of 8 for the Boomer data and 4 for the Sparker data.

5.4.3 Velocity Analysis

Due to the relative lack of fold a conventional velocity analysis was not possible. Trials were performed using a constant velocity of 1480m/s.

5.4.4 Final Stack

The final data were stacked and 1/N normalisation was applied where N is the number of live samples stacked.

5.4.5 Deconvolution After Stack (DAS) - Boomer data only

Due to the depth of the water bottom the Boomer data was suitable for decovolution. A water bottom gap (predictive) deconvolution after stack (DAS) was tested and found to be successful at removing interbed multiples just below the water bottom.

Various operator lengths and gaps were tested and displayed with stacks. The chosen one window deconvolution was a 10/250ms (gap/total operator length) filter applied in the space-time (X-T) domain.

Water bottom gap deconvolution was tested and confirmed for production using the following parameters:-

Minimum Prediction Lag	10 ms
Maximum Prediction Lag	250 ms
Water bottom time	50ms
Design windows	1
	Near trace 50 ms – 750 ms
	Far trace 50 ms – 750 ms
Application windows	1
	Near trace 100 ms – 750 ms
	Far trace 100 ms – 750 ms
Water bottom time	500ms
Design windows	1
	Near trace 50 ms – 750 ms
	Far trace 50 ms – 750 ms
Application windows	1
	Near trace 200 ms – 750 ms
	Far trace 200 ms – 750 ms

5.4.6 1D Surface Related Multiple Elimination (SRME)

Following the stack and before the migration processing a multiple estimate was again made and adaptively subtracted from the input data. The results of this subtraction were then passed on for further processing.

5.4.7 Interpolation of empty bins

An interpolation method was applied post stack to fill any remaining areas that lacked coverage.

SNIP is basically a signal to noise enhancement tool, it determines signal by finding the dipping plane of maximum semblance centered on the output point. It determines noise with an amplitude median/trim process within each plane.

On the same principle, data interpolation can be done. Instead of noise attenuation, the dip filter can estimate the data in missing locations. The SNIP was run in the crossline direction to fill in inlines within the crosslines.

5.4.8 Post stack noise attenuation

Following the interpolation of empty bins, Frequency Dependent Noise Attenuation (FDNA) was tested in an attempt to prevent unwanted migration artifacts during the imaging step.

FDNA (frequency domain noise attenuation) focuses more on any high frequency remnant noise remaining after stack. At the high frequency level, it can be used effectively to attenuate diffracted noise such as multiples based on discrimination of frequency content between primary and non-primary events.

FDNA operates on one ensemble at a time. Each ensemble is transformed into time-frequency space using a short time Fourier transform algorithm. The transform is separated into amplitude and phase components for each frequency sub-band. If auto-thresholding is requested then the median spectral amplitude within each requested frequency sub-band is calculated for the ensemble.

The median of these medians becomes the threshold for that ensemble. Each sample of each requested sub-band is compared against this threshold. If the sample amplitude exceeds the threshold then the median spectral amplitude of the adjacent samples within that sub-band is computed and installed at this location.

Boomer data

Number traces	10 (rolling window)
Threshold	1 x the median value
Frequency bandwidth* attacked	20-250 Hz
Taper	100 ms
Start-time	Inline 1417 100ms (contoured to water bottom time)
	Inline 2639 150ms

Sparker data

Number traces	5 (rolling window)
Threshold	2 x the median value
Frequency bandwidth* attacked	20-250 Hz
Taper	100 ms
Start-time	Inline 1600 100ms (contoured to water bottom time)
	Inline 3300 150ms

FXY was also tested to attenuate any pure random noise throughout the section.

Within a 2D stack (Inline or Crossline), flat events appear as complex sinusoidal oscillations in the F-X domain. By designing and applying complex one-step-ahead predictive operators within a sliding trace gate, the sinusoidal oscillations may be separated from the random noise which contaminates them. The width of the trace gate is selected such that curved data appear locally linear.

In 3D, the linear model is extended to include locally planar surfaces. The spatial distribution of the F-X-Y filter coefficients provides for better preservation of low amplitude events and curved surfaces than either 2D or two-pass approaches.

Frequencies	1-500Hz

Iterations	1
White noise	0%
Gate Overlap	33% each in inline, crossline, & time directions

Boomer data

Filter design widths	3 traces in both inline and crossline directions
Autocorrelation Window lengths	41 traces in both inline and crossline directions

Sparker data

Filter design widths	8 traces in both inline and crossline directions
Autocorrelation Window lengths	21 traces in both inline and crossline directions

5.5 Kirchhoff, post stack time migration

A zero offset post stack Kirchhoff algorithm was used to migrate the data. A series of Impulse responses were performed initially to establish suitable migration parameters.

An aperture of 1km with a time varying dip limit was selected for the final migration.

The single constant velocity function tested and applied in Section 5.4.3 was used as the migration velocity field.

The following parameters were chosen for production :-

Boomer data

Input & Output trace length	800ms	
Input & Output sample rate	1ms	
Input & Output grid	3.125m x 3.125m bins	
Half Aperture	1km	
Pre-conditioning	None	
Dip Limit:	Time (ms)	Angle (degrees)
	1	90
	500	80
	800	70

Sparker data

Input & Output trace length	2000ms	
Input & Output sample rate	1ms	
Input & Output grid	3.125m x 3.125m bins	
Half Apterture	1km	
Pre-conditioning	None	
Dip Limit	Time (ms)	Angle (degrees)
	1	90
	1500	80
	2000	70

5.6 Post Migration Processing

5.6.1 Dip Filtering - Boomer data only

To further attenuate the water bottom multiple a post stack dip filter was applied to the PSTM stacks. A ±4 ms / trace F-k dip filter was applied after migration.

- Dip_Filter_Trials.ppt

5.6.2 Time Variant Filter - Sparker data only

A post stack time variant filter was applied based upon a start time header which varied spatially depending upon the water depth along each line. Filtering the high frequency noise in the deepest sections of the lines enhanced the stack response of the lower frequency primary events. The filter applied was defined as follows:

Water bottom time=400ms:

Time(ms)	High Cut (dB/Oct.)
300	500 (36)
500	150 (36)
2000	100 (36)

Water bottom time=800ms:

Time(ms)	High Cut (dB/Oct.)
700	500 (36)
900	150 (36)
2000	100 (36)

Water bottom time=1600ms:

Time(ms)	High Cut (dB/Oct.)
1500	500 (36)
1700	150 (36)
2000	100 (36)

5.6.3 Amplitude Balancing: Measured Exponential gain

The final migrated section was balanced by the application of the following measured exponential gain.

Boomer data

Water bottom time=50ms:

Time (ms)	Gain (dBs)
0	0
50	7
250	10
400	11
800	15

Water bottom time=250ms:

Time (ms)	Gain (dBs)
0	0
250	10
400	11

600	13
800	15

Water bottom time=450ms:

Time (ms)	Gain (dBs)
0	0
450	11
500	12
600	13
800	15

Sparker data

Water bottom time=500ms:

Time (ms)	Gain (dBs)
0	0
500	4
800	8
1000	13
1200	12

Water bottom time=700ms:

Time (ms)	Gain (dBs)
700	0
800	2
1000	6
1200	10
1400	11

Water bottom time=1100ms:

Time (ms)	Gain (dBs)
1100	0
1200	5
1400	11
1600	14
1800	16

5.6.4 Gun and cable static

A correction for the source and receiver depths was made applying a +1.7 ms bulk shift to all Boomer data and +2.7ms bulk shift to all Sparker data.

5.6.5 Scaling: AGC

An iterative 400ms AGC was tested and optionally applied to the data.

6 Kirchoff, post stack depth migration

6.1 Initial model building

The Initial model was built using a Dix conversion of the smoothed RMS velocities derived for the migration from the 2013 2D SONGS PSTM processing as follows:

The RMS field was produced as part of the 2013 2D SONGS PSTM processing flow. Straight ray (2nd order) Kirchhoff pre-stack time migration was performed. The PSTM data was used to pick a manual RMS field.

Careful attention was paid to picking these analyses in a relatively smooth consistent manner suitable for the Kirchhoff migration process. The accurate nature of the velocities was confirmed by the migrated imaging of each 2D line, together with the “flat” NMO corrected nature of the main events across diagnostic 2D CDP gathers.

The validity of the interpreted velocity functions for the velocity line was confirmed by inspection of the following QC displays:

- Isovelocity display
- Stack section plus NMO corrected CMPs at both the velocity locations and intermediate points
- Colour areal plots of the velocities at selected isotimes were produced to verify the integrity of the 2D interpolation of the velocity field

The RMS velocity field was converted to an interval velocity field using Dix conversion. This procedure involved the following steps:

- Grid RMS velocity into 3D section
- Rotate and cut to individual Boomer and Sparker 3D geometries
- Smooth with time variable smoother
- Via DIX to time/interval
- Convert to depth
- Smooth again with depth variable smoother.

6.2 Final post-stack depth migration

Geotrace Technology’s Kirchhoff 3D depth migration is a highly efficient target-oriented or full volume pre- or post-stack migration algorithm for production of accurate depth images in areas of strong lateral velocity variation.

The algorithm is a standard Kirchhoff integral formulation incorporating temporal and spatial anti-alias protection and providing user-specified dip (including turning ray capability) and aperture control. Travel time calculation is accomplished using proprietary 2D ray tracing software based on a Wavefront Construction algorithm. The algorithm can use maximum energy, 1st arrival or shortest-path, but generally speaking we use maximum energy.

The migration implementation includes state-of-the-art enhancements for amplitude preservation during migration. Amplitude preservation incorporates a variety of weight functions that compensate for obliquity angle and geometric spreading.

Amplitude preservation follows Thierry et al (1999) and incorporates a variety of weight functions which compensate for:

- geometric spreading
- obliquity and slowness
- acquisition irregularities (Jousset et al 1999)
- ray path bending caused by a complex overburden (Beylkin determinants, Thierry et al, 1999)

Pre-computed travel-time and geometrical spreading factors are derived by a wavefront construction scheme. The approach is an implementation based on the ideas presented by Alkalifah et al (1996) and provides multi-valued travel times. Ray selection and summation is based on either first arrivals or shortest travel path / maximum energy. Alternatively, in complex areas dominated by wavefront triplications, ray selection can be abandoned and multi-branch migration operators can be constructed using all the travel time information.

The anti-aliasing is described as Lumley's triangle filtering (Anti-aliased Kirchhoff 3D migration – Lumley, Claerbout and Beve 1994, 64th Annual meeting) with Abma et al correction (Abma, Sun and Bernitas, 1999, Geophysics 64).

The Parameters used in the final migration were:

Algorithm	Kirchhoff
Input & output grid	3.125m x 3.125m bins
Maximum depth	2km
Maximum radial aperture	1km
Depth step	1m
WFC mode:	Maximum Energy

6.3 Post migration processing

Following the migration, a similar sequence to the PSTM processing was used, as described earlier in this report:

- Stretch to time domain using final velocity model

- High Cut filter (water depth dependent)
- Application of Exponential Gain
- Stretch to depth domain

The only significant differences between the time and depth post-migration sequences were the stretching between time and depth domains.

7 Delivery products

The following were confirmed as the required deliverables:-

Description	Output Medium	Number of copies
Final PSTM Migrated Stack	SEG-Y format on USB disk	1
Final PSDM Migrated Stack	SEG-Y format on USB disk	1
Final Report	CD	1

7.1 Delivery Address

Reno, Nevada

Att: Dr. Graham Kent

University of Nevada Reno (UNR)
Reno, Nevada
USA

8 Conclusion

The first objective with this project was to provide QC after acquisition of every line and a raw 3D QC stack. This was achieved with the raw stack being shown soon after acquisition completed.

The main challenge with this survey was the novel acquisition configuration of the P-cable method.

One drawback of the P-cable method is the lack of fold of coverage. This is not suited to multi-channel processing particularly many demultiple processes such as Radon demultiple and Taup transforms. This wasn't a problem with the SONGS survey as a suitable demultiple scheme was developed using both 1D and 2D SRME along with Deconvolution to attenuate much of the first water bottom multiple thru energy in order to prevent migration smearing or artifacts during the final imaging.

Another problem is that the lack of fold makes velocity estimation difficult. The use of known velocities from the 2D processing acquired over the same survey area helped in this project and allowed a final PSDM migration to be created. Over such short offsets the move out was relatively low which made the use of trim statics unnecessary for the final stack response.

The P-Cable method gives good 3D coverage for high-resolution surveys but requires modelling to be conducted for locating the receiver positions. Fortunately NCS Subsea provided accurate enough modelling of the receiver positions to not need any large corrections which would have seriously degraded the final stack due to the high sample rate and size of the errors. The high sample rate also means that water column and tidal statics have the potential to become a significant problem as well.

The noise attenuation and demultiple methods derived in the onshore phase of the processing to address the problem of noise worked very well and provided a final stack that was of higher quality than the raw onboard stack.

Examples of the key processing steps and comparisons of the raw onboard un-processed and onshore processed data can be seen in the following enclosures;

- Processing – Inlines
- Processing – Crosslines

9 Personnel

Scripps/UNR

Dr. Graham Kent	Director, Nevada Seismological Laboratory | State Seismologist Professor, Department of Geological Sciences and Engineering UNR
Neal Driscoll	Professor Geological Research Division Scripps Institution of Oceanography UCSD

Geotrace Onshore

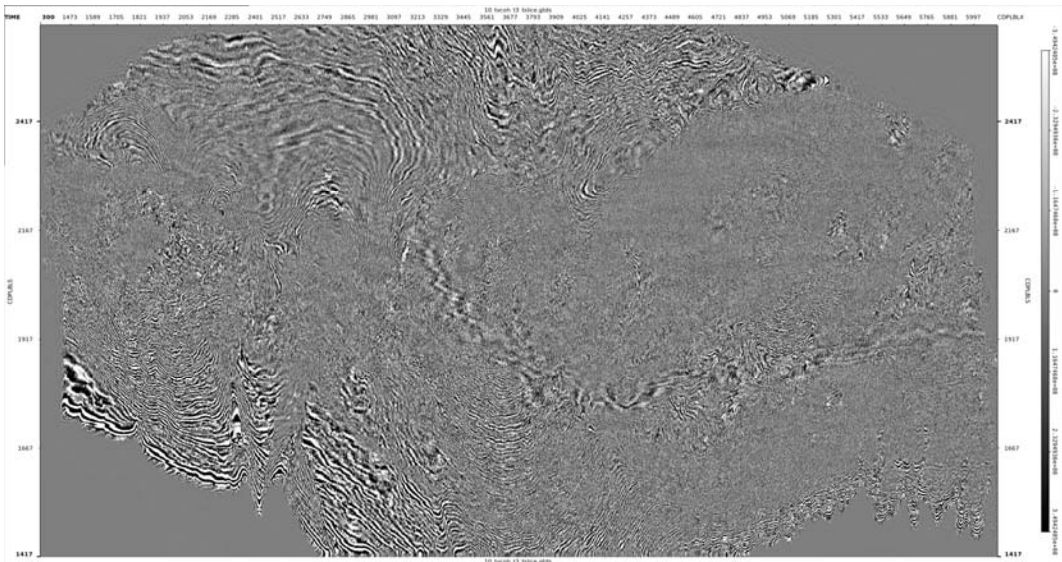
David Bannister	Technical Manager, Marine Worldwide
Joel Latchman	Processing Manager, Marine US
Frank Landers	Onshore Senior Project Geophysicist
Michael Angel	Onshore Geophysicist

Geotrace Offshore

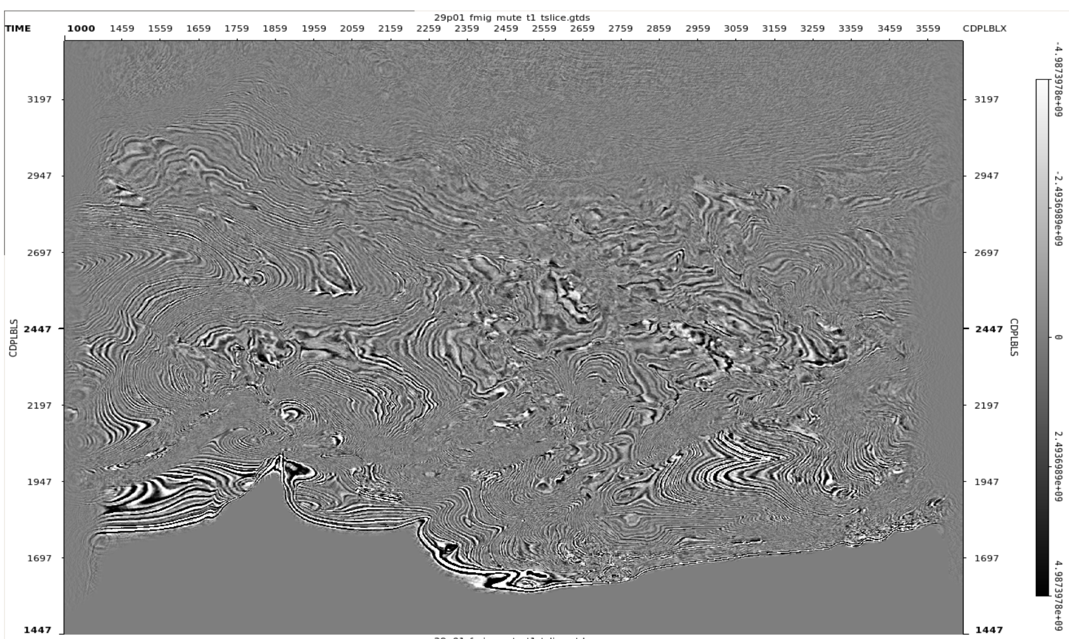
Frank Landers	Chief Marine Geophysicist
Michael Angel	Marine Geophysicist
Brian Joiner	Systems Administrator, Houston

Appendix A Final Migrated Stack Examples

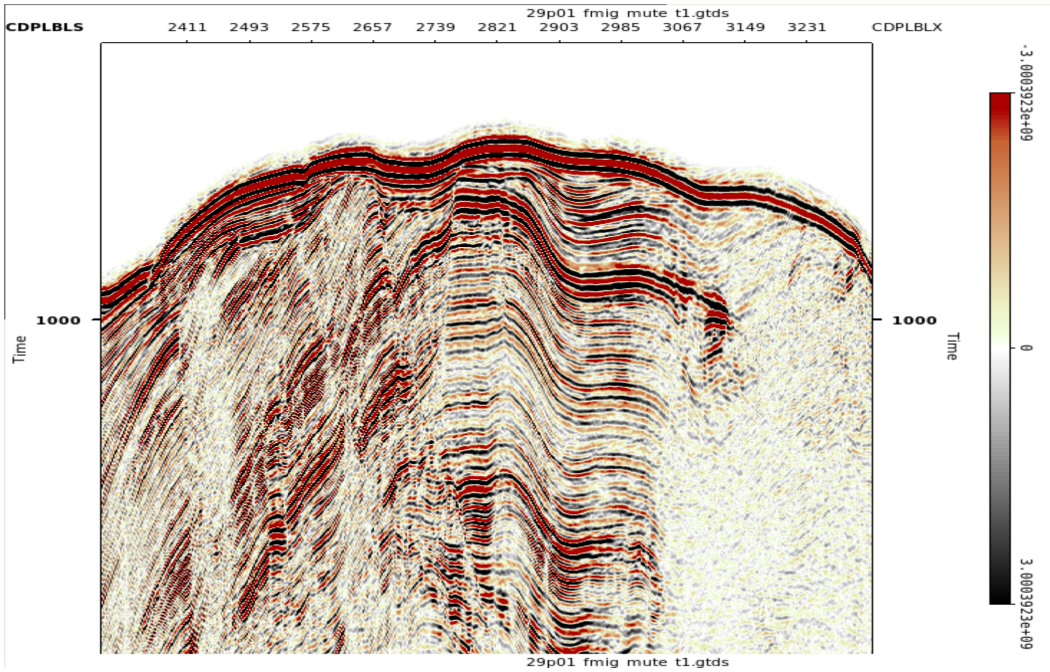
Time slice – 300ms (Boomer)



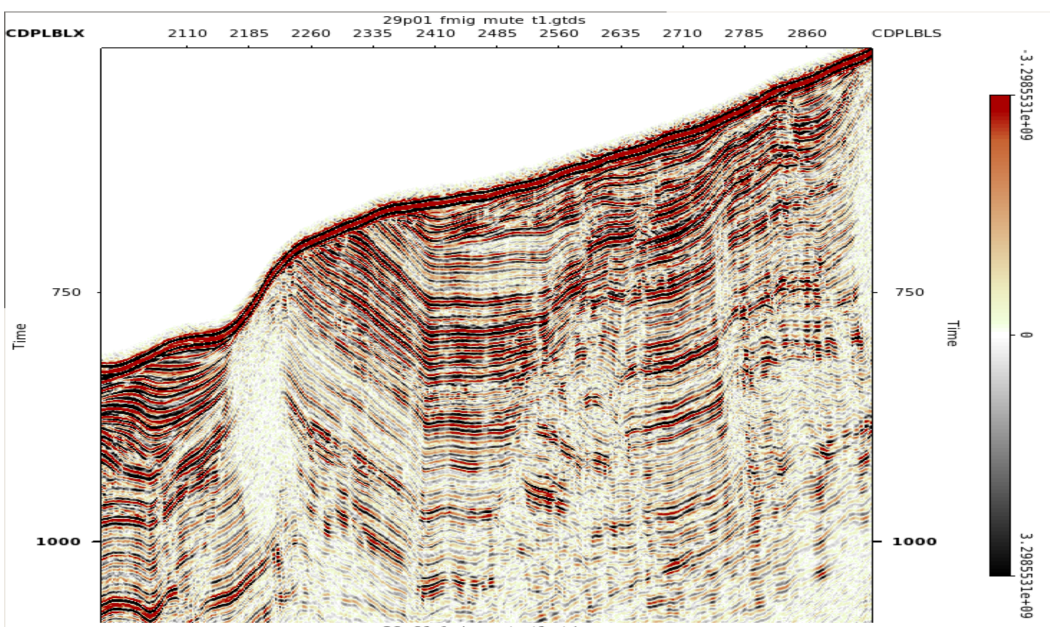
Time slice – 1000ms (Sparker)



Inline – 1755 Enlarged (Sparker)



Crossline – 2746 Enlarged (Sparker)



Appendix B Sail Line Listing

Seq No	Line Name	Bearing	FGSP	LGSP
1		NTBP	NTBP	NTBP
2	1006A	132º	2952	4616
3	1594A	312º	2236	3898
4	1018A	132º	2952	4608
9		NTBP	NTBP	NTBP
6	1606B	312º	2952	4617
7	1030A	132º	2224	3889
8	1618A	312º	2952	3836
9	1042A	132º	1560	4351
10		NTBP	NTBP	NTBP
11	1630A	312º	5514	5297
12	1630B	312º	5121	943
13	1054A	132º	1481	4426
14	1642A	312º	5517	964
15	1066A	132º	1427	4483
16		NTBP	NTBP	NTBP
17	1654A	312º	5490	964
18		NTBP	NTBP	NTBP
19	1078A	132º	1399	2142
20		NTBP	NTBP	NTBP
21	1666A	312º	5507	977
22		NTBP	NTBP	NTBP
23	1090A	132º	1381	4607
24	1678A	312º	5497	948
25	1102A	132º	1343	2986
26	1690A	312º	5491	1457
27	1114A	NTBP	NTBP	NTBP
28		NTBP	NTBP	NTBP
29	1114B	NTBP	NTBP	NTBP
30		NTBP	NTBP	NTBP
31		NTBP	NTBP	NTBP
32		NTBP	NTBP	NTBP
33		NTBP	NTBP	NTBP
34	1582A	312º	5529	946
35		NTBP	NTBP	NTBP
36		NTBP	NTBP	NTBP
37	1114C	132º	1332	4737
38	1702C	312º	5540	4850
39	1702D	312º	4719	944
40	1126A	132º	1460	4824
41		NTBP	NTBP	NTBP
42	1714A	312º	5472	2638
43	1138A	132º	1256	4867
44		NTBP	NTBP	NTBP
45	1726A	312º	4830	950
46	1150A	132	1230	1769

47	1738A	312º	5490	948
48	1162A	132º	1193	4979
49	1750A	312º	5293	2000
50	1174A	132º	1162	5042
51	1762A	312º	5601	943
52	1186A	132º	1129	5102
53		NTBP	NTBP	NTBP
54	1198A	132º	1119	5102
55	1774A	312º	5482	947
56	1210A	132º	1033	5206
57	1786A	312º	5490	947
58	1222A	132º	1002	5299
59	1798A	312º	5490	946
60	1234A	132º	1127	5325
61	1810A	312º	5518	945
62	1246A	132º	887	5385
63	1822A	312º	5559	945
64	1258A	132º	914	5433
65	1834A	312º	5530	947
66	1270A	132º	982	5469
67	1846A	312º	5104	943
68	1282A	132º	990	5521
69	1858A	312º	5506	947
70	1294A	132º	966	5538
71	1870A	312º	5556	940
72	1450A	132º	910	5538
73	1882A	312º	5491	944
74	1150B	132º	1292	4940
75	1894A	312º	5573	943
76	1078B	132º	1388	4581
77	1906A	312º	5532	944
78	1462A	132º	919	5536
79	1918A	312º	5590	945
80	1474A	132º	930	5539
81	1930A	312º	5522	944
82	1486A	132º	949	5542
83	1942A	312º	5520	945
84	1306A	132º	955	5542
85	1954A	312º	5581	943
86	1318A	132º	920	5539
87	1966A	312º	5538	943
88	1330A	132º	970	5539
89	1978A	312º	5530	947
90	1342A	132º	936	5539
91	1990A	312º	5524	944
92	1354A	132º	917	5540
93	2002A	312º	5544	946
94	1366A	132º	1007	5540
95		NTBP	NTBP	NTBP
96	1810B	312º	4143	944
97	1378A	132º	980	5540
98	2014B	312º	5578	945
99	1390A	132º	963	5540

100	2026A	312º	5525	988
101	1402A	132º	968	5539
102	2038A	312º	5530	939
103	1414A	132º	989	5541
104	2050A	312º	5568	933
105	1426A	132º	920	5540
106	2062A	312º	5566	943
107	1438A	132º	885	5543
108	2074A	312º	5532	945
109	1498A	132º	962	5538
110	2086A	312º	5522	943
111	1510A	132º	973	5541
112	2098A	312º	5529	938
113	1522A	132º	943	5543
114	2110A	312º	5520	943
115	1306B	132º	960	2255
116	1750B	312º	2300	942
117	1234B	132º	970	2243
118	1690B	312º	2114	942
119	1282B	132º	915	4960
120	2122A	312º	5522	945
121	1378B	132º	952	5538
122	2134A	312º	5502	944
123	1534A	132º	953	5543
124	2146A	312º	5517	944
125	1546A	132º	900	5539
126	2146B	312º	5530	944
127	1570A	132º	995	5538
128	2158A	312º	5566	944
129	1558A	132º	972	3287
130		NTBP	NTBP	NTBP
131		NTBP	NTBP	NTBP
132		NTBP	NTBP	NTBP
133		NTBP	NTBP	NTBP
134		NTBP	NTBP	NTBP
135		NTBP	NTBP	NTBP
136	1558D	132º	4067	5537
137	2170A	312º	5528	945
138	1546B	132º	960	5537
139	2182A	312º	5522	1178
140	1546C	132º	1006	5539
141	2194A	312º	5558	947
142	1558E	132º	973	5539
143	2206A	312º	5543	5011
144	2206B	312º	4561	944
145	1438B	132º	949	5540
146	1726B	312º	5523	949
147	1222B	132º	988	5534
148	1846B	312º	5524	947
149	1330B	132º	978	5536
150	1714B	312º	5530	948

151	1210B	132º	1055	5402
152	2002B	312º	5562	946
153		NTBP	NTBP	NTBP
154	2194B	312º	1703	942
155	1222C	132º	1030	4469
156	1570B	132º	4917	5539
157	1882B	312º	5536	4386
158	1390B	132º	4402	5546
159	1750C	312º	5589	4206
160		NTBP	NTBP	NTBP
161	1570C	132º	3940	5542
162	1798B	312º	5571	4433
163	1498B	132º	5074	5540
164	1630C	312º	5502	5111
165	2206C	312º	5083	958
166	1450B	132º	978	2660
167	1822B	312º	2331	947
168	1114D	132º	1322	1686
169	2146C	312º	1325	946
170	1114E	132º	1311	1865
201		NTBP	NTBP	NTBP
202	4927A	315º	2049	973
203	4447A	135º	962	2047
204	4915A	315º	2042	974
205	4435A	135º	985	2049
206	4903A	315º	2064	973
207	4423A	135º	960	2048
208	4891A	315º	2057	974
209	4411A	135º	987	2047
210	4879A	315º	2039	974
211	4399A	135º	1003	2047
212	4867A	315º	2035	975
213	4387A	135º	983	2043
214	4855A	315º	2037	967
215	4375A	135º	987	2046
216	4843A	315º	2036	974
217	4363A	135º	982	2047
218	4381A	315º	2033	975
219	4351A	135º	983	2048
220	4819A	315º	2045	974
221	4339A	135º	983	2047
222	4807A	315º	2049	974
223	4327A	135º	979	2042
224	4795A	315º	2050	974
225	4315A	135º	975	2049
226	4783A	315º	2054	973

227	4303A	135º	969	2047
228	4771A	315º	2062	973
229	4303B	135º	964	2046
230	4771B	315º	2036	975
231	4291A	135º	991	2047
232	4759A	315º	2022	975
233	4279A	135º	1005	2047
234	4747A	315º	2039	975
235	4267A	135º	981	2048
236	4735A	315º	2035	976
237	4255A	135º	984	2046
238	4243A	315º	2044	975
239	4243A	135º	978	2047
240	4711A	315º	2058	974
241		NTBP	NTBP	NTBP
242	4699A	315º	2066	973
243	4231A	135º	962	2048
244	4687A	315º	2061	973
245	4219A	135º	950	2048
246	4675A	315º	2066	974
247	4219B	135º	997	2047
248	4663A	315º	2044	974
249	4207A	135º	972	2045
250	4651A	315º	2041	1564
251	4195A	135º	965	2048
252	4639A	315º	2058	964
253	4183A	135º	1110	2049
254	4627A	315º	2051	975
255	4171A	135º	970	2048
256		NTBP	NTBP	NTBP
257		NTBP	NTBP	NTBP
258		NTBP	NTBP	NTBP
259	4159B	135º	1033	2045
260	4615A	315º	2042	975
261	4147A	135º	977	2049
262	4603A	315º	2045	976
263	4135A	135º	979	2046
264	4591A	315º	2046	975
265	4123A	135º	978	2046
266	4579A	315º	2044	975
267	4111A	135º	1047	2046
268	4567A	315º	2046	972
269	4099A	135º	978	2048
270	4555A	315º	2056	973
271	4087A	135º	972	2048
272	4543A	315º	2055	973
273	4075A	135º	976	2049

274	4531A	315º	2054	973
275	4063A	135º	977	2048
276	4519A	315º	2053	972
277	4051A	135º	975	2048
278	4507A	315º	2051	972
279	4039A	135º	976	2048
280	4495A	315º	2041	976
281	4027A	135º	977	2045
282	4483A	315º	2037	975
283	4015A	135º	976	2046
284	4471A	315º	2046	974
285	4003A	135º	978	2049
286	4459A	315º	2042	975
287	3991A	135º	976	2047
288	4627B	315º	2033	975
289	3979A	135º	978	2047
290	4591B	315º	2044	973
291	4195B	135º	971	2048
292	4555B	315º	2065	975
293	4183B	135º	983	2049
294	4891B	315º	2067	977
295	4111B	135º	957	2048
296		NTBP	NTBP	NTBP
297	4159C	135º	968	2054
298	3559B	315º	2043	975
299	4051B	135º	980	1902
300	3547A	315º	2065	975
301	4207B	135º	972	2046
302	3535A	315º	2047	975
303	4111C	135º	959	1993
304	3523A	315º	2047	976
305	3967A	135º	964	2047
306	3511A	315º	2027	974
307	3955A	135º	960	2048
308	3499A	315º	2053	974
309	3943A	135º	974	2049
310	3487A	315º	1886	973
311	3931A	135º	971	2049
312	3475A	315º	2082	973
313	3919A	135º	971	2048
314	3463A	315º	2052	974
315	3907A	135º	969	2050
316	3451A	315º	2054	973
317	3895A	135º	958	2047
318	3439A	315º	2029	975
319	3883A	135º	967	2046
320	3427A	315º	2050	975

321	3871A	135º	966	2047
322	3415A	315º	2039	976
323	3859A	135º	980	2046
324	3403A	315º	2062	976
325	3847A	135º	987	2047
326	3391A	315º	2041	975
327	3835A	135º	986	2049
328	3379A	315º	2048	974
329	3823A	135º	970	2050
330	3367A	315º	2032	974
331	3811A	135º	968	2047
332	3355A	315º	2058	973
333	3799A	135º	977	2048
334	2058A	315º	2058	975
335	3787A	135º	962	2050
336	3331A	315º	2055	973
337	3775A	135º	964	2047
338	3319A	315º	2057	975
339	3763A	135º	971	2047
340	3307A	315º	2049	975
341	3751A	135º	959	2047
342	3295A	315º	2053	975
343	3739A	135º	983	2047
344	3283A	315º	2036	975
345	3727A	135º	957	2047
346	3271A	315º	2063	975
347	3715A	135º	961	2047
348	3259A	315º	2055	973
349	3703A	135º	969	2049
350	3247A	315º	2054	973
351	3691A	135º	969	2049
352	3235A	315º	2050	970
353	3679A	135º	975	2049
354	3223A	315º	2052	973
355		NTBP	NTBP	NTBP
356	3667A	135º	971	2048
357	3211A	315º	2051	973
358	3655A	135º	967	2049
359	3199A	315º	2047	976
360	3643A	135º	961	2047
361	3187A	315º	2055	975
362	3631A	135º	971	2047
363	3175A	315º	2060	975
364	3619A	135º	977	2047
365	3163A	315º	2064	976
366	3607A	135º	976	2047
367	3151A	315º	2059	975

368	3595A	135º	970	2047
369	3487B	315º	2064	973
370	3583A	135º	971	2054
371	3499B	315º	2053	975
372	3571A	135º	976	2023
373	3379B	315º	2058	974
374	3643B	135º	963	2049
375	3139A	315º	2052	973
376	3823B	135º	966	2047
377	3127A	315º	2061	973
378	3895B	135º	970	2047
379	3115A	315º	2060	976
380	3751B	135º	971	2047
381	3103A	315º	2072	975
382	3943B	135º	966	1961
383	3091A	315º	2058	975
384	3031A	135º	977	2047
385	3079A	315º	2068	976
386	3019A	135º	970	2047
387	3067A	315º	2065	975
388	3007A	135º	969	2049
389	3055A	315º	2055	973
390	3571B	135º	979	2048
391	3043A	315º	2058	973
392	3775B	135º	969	2049
393	3235B	315º	2063	970
394	4351B	135º	973	2049
395	4591C	315º	2052	974
396	4075B	135º	962	2051
397	4519B	315º	2059	974
398	3631B	135º	953	2047
399	4927B	315º	2071	975
400	4135B	135º	988	2048

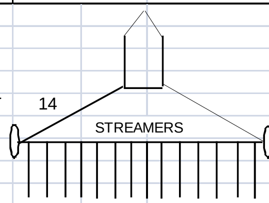
Appendix C Example Observers Log

FIELD LOG / OBSERVERS REPORT			Page 1 of 1
Date: 01 November 2013	Line Number:3271A	Water Depth(m): 500-800m	
Client: Scripps	Line Azimuth:315	Mean Velocity: NA	
Area: San Onofre	Sequence No:346	Vessel Speed: 4.0-4.5 Kts	
Vessel: R/V New Horizon	Observers: James, Jayne	Sea State: <1m, Wind: NW 4.1 Kts	

Recording System:		**Source:**	**Streamers:**
Model: Geometrics CNT-2	Low Cut Filter: NA	Type: Sparker	Type: GeoEel Solid
Recording Format: SEG-Y	Slope: NA	Array Size: 3 Tips	Sensitivity: 20 µv/µBar
Recording Media: Hard Disk	High Cut Filter: NA	Power(barM): NA	Streamers: 14
Record Length: 2000 msec	Slope: NA	Tow Depth: 2.0 m	Chls/Streamer: 8
Sample Rate: 2 kHz	Aux Ch 1: NA	Array Power: 2000 J	Total Chls: 112
Preamp Gain: 18 dB	Aux Ch 2: NA	Shot Interval: 6.25 m	Group Interval: 6.25 m
FTB Static: 0 ms	FTB Source: SPSU	Pressure: NA	Tow Depth: 2 m nominal
			Streamer Separation: 6.25 m nom.

Physical Offsets:	
Reference Point:	Stern
CRP to Stern:	0 m
Stern to Stbd Paravane:	104.5 m
Stern to Port Paravane:	104.5 m
Spread:	115 m
Stern to Source:	71 m

PORT 14



1 STBD

Chls 105-112 Chls 1-8

Recording File Name	Time UTC	Shot Point Number	FFID Number	Depth Stbd (m)	Depth Center (m)	Depth Port (m)	Water Depth (m)	Azimuth	Streamer Leakage	Remarks (SOL, EOL, sea state, problems, etc)
3271.sgy	**1635**	**2063**	**3283**	**1.4**	**1.6**	**1.5**	**296**	**315**	**023**	**SOL: 3271A SEQ: 346 UTC:1635**
3271.sgy	1703	1500	3846	1.2	1.6	1.5	311		023	Batteries: Port: 12.54V, Stbd: N/A Current:3.00A
4137.sgy	**1717**	**1209**	**4137**	**1.3**	**1.7**	**1.5**	**398**		**023**	**File Change**
4137.sgy	1727	1000	4346	1.3	1.7	1.5	355		023	Batteries: Port: 12.59V, Stbd: N/A Current:2.99A
4137.sgy	**1728**	**0975**	**4371**	**1.3**	**1.7**	**1.6**	**362**		**023**	**EOL: 3271A SEQ: 346 UTC:1728**

Appendix D Example Navigation Line Log

R/V New Horizon
NAVIGATION LINE LOG

DATE: 11-Oct-13
JULIAN DAY: 284

NCS SubSea

CLIENT: SRIPPS / Subsea Systems Inc. | SURVEY: SONGS 3-D HR Geopysical Survey, 2013 | JOB # : 446

SURVEY AREA: Southern Cal.
DEPTH SOL: 59.1 m
DEPTH EOL: 49.1 m
NAVIGATION SYSTEM USED : NCS SubSea - NavPoint Version 1.1.0.0

SMG SOL: 4 knots
SMG EOL: 4.5 knots
LINE NAME : 1006A
WEATHER
WIND SOL :
MAG DEC USED : 12.13 °

FEATHER SOL :
LINE BRG : 132 °
WIND EOL :

FEATHER EOL :
SEAS SOL :
SURVEY TYPE : *3D P-Cable Geophyiscal Survey*

SEQUENCE : 2
SEAS EOL :

PARTY CHIEF: Mike Barth / Chuck Chamberlain
CHIEF NAVIGATOR: Jesus Gaytan
NCS P.M.: Jesus Gaytan
NAVIGATOR: Shane Traceski, Dwayne Fontenot
NAVIGATION PROCESSOR : Abby Parish, Micah Hall

SP	T: (UTC)	EVENTS (NRP Pos.)	COMMENTS
		FSP	Seq001 Test sequence, Seq002 start of Job
1902	00:23	FGSP E: 444860.17 N: 3687425.80	Intermittent missed SP throughout line No source GPS throughout line
4121	01:14	LGSP E: 450124.87 N: 3682909.6	
4121	01:14	LSP	EOL

NAVIGATION OFFSETS APPLIED (meters)	
Shot Point Reference	NRP
V1 Draft Correction	3.60
NRP-COS	-70.0
CNG-CFG	-37.5
Groups per Streamer	8
Group Interval	6.25
Total Groups	112
Shot Interval	3.1
Vane wire length	104.5
Paravane Separation	115.0

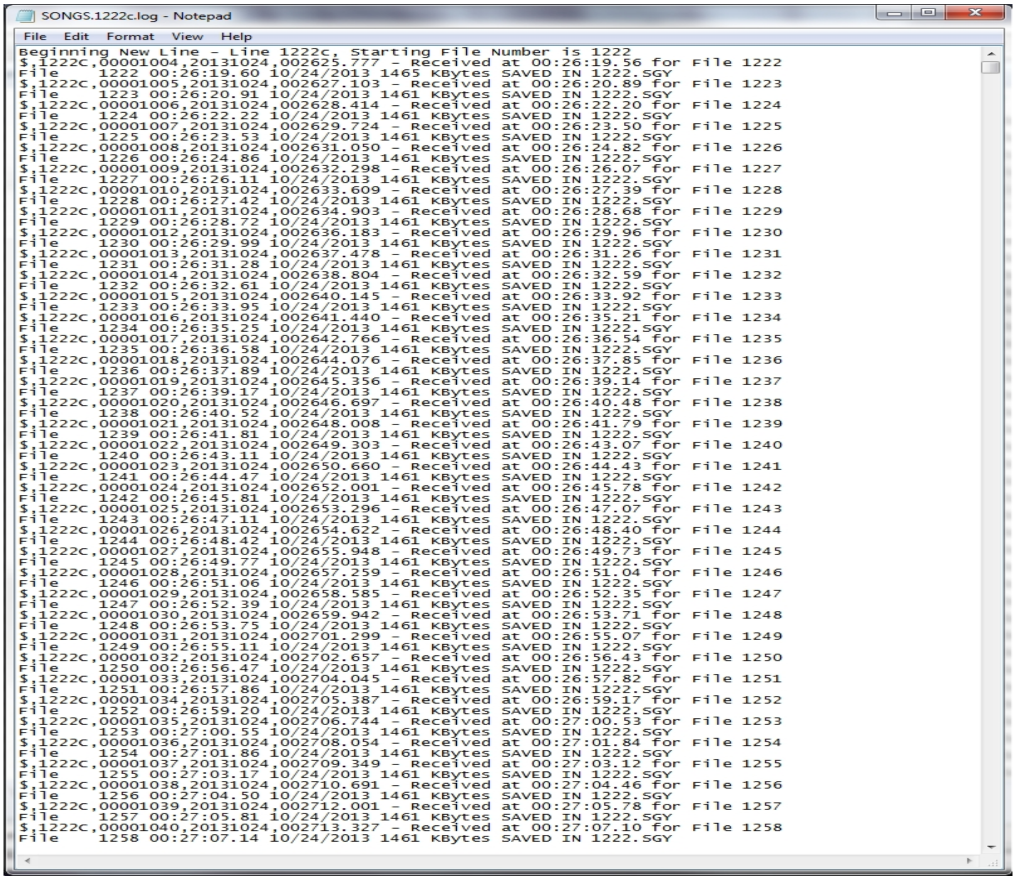
RAW FILE:
P294: 0002-1006A20131012002326.P294
P190: 0002-1006A20131012002326.P190

Strmrs. @ 2.0 m

NAVIGATION SYS-1	Ref. stations:	NAVIGATION SYS-2	Ref. stations:	NUMBER OF STREAMERS	
CNAV 2050R	CNAV RTG 098 W	Trimble SPS 361	SBAS Sta:138	14	Source: Triple Plate Boomer

COMPASSES KO'd	S3,S6,S8,S9,S12 - no tail module	GENERAL COMMENTS:	Line Status: Complete
Depths KO'd	S3,S6,S8,S9,S12 no tail module		

Appendix E Example GeoEel Log




```
Beginning New Line - Line 1222c, Starting File Number is 1222
$,1222c,00001004,20131024,002625.777 - Received at 00:26:19.56 for File 1222
File     1222 00:26:19.60 10/24/2013 1465 KBytes SAVED IN 1222.SGY
$,1222c,00001005,20131024,002627.103 - Received at 00:26:20.89 for File 1223
File     1223 00:26:20.91 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001006,20131024,002628.414 - Received at 00:26:22.20 for File 1224
File     1224 00:26:22.22 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001007,20131024,002629.724 - Received at 00:26:23.50 for File 1225
File     1225 00:26:23.53 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001008,20131024,002631.050 - Received at 00:26:24.82 for File 1226
File     1226 00:26:24.86 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001009,20131024,002632.298 - Received at 00:26:26.07 for File 1227
File     1227 00:26:26.11 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001010,20131024,002633.609 - Received at 00:26:27.39 for File 1228
File     1228 00:26:27.42 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001011,20131024,002634.903 - Received at 00:26:28.68 for File 1229
File     1229 00:26:28.72 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001012,20131024,002636.183 - Received at 00:26:29.96 for File 1230
File     1230 00:26:29.99 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001013,20131024,002637.478 - Received at 00:26:31.26 for File 1231
File     1231 00:26:31.28 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001014,20131024,002638.804 - Received at 00:26:32.59 for File 1232
File     1232 00:26:32.61 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001015,20131024,002640.145 - Received at 00:26:33.92 for File 1233
File     1233 00:26:33.95 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001016,20131024,002641.440 - Received at 00:26:35.21 for File 1234
File     1234 00:26:35.25 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001017,20131024,002642.766 - Received at 00:26:36.54 for File 1235
File     1235 00:26:36.58 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001018,20131024,002644.076 - Received at 00:26:37.85 for File 1236
File     1236 00:26:37.89 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001019,20131024,002645.356 - Received at 00:26:39.14 for File 1237
File     1237 00:26:39.17 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001020,20131024,002646.697 - Received at 00:26:40.48 for File 1238
File     1238 00:26:40.52 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001021,20131024,002648.008 - Received at 00:26:41.79 for File 1239
File     1239 00:26:41.81 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001022,20131024,002649.303 - Received at 00:26:43.07 for File 1240
File     1240 00:26:43.11 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001023,20131024,002650.660 - Received at 00:26:44.43 for File 1241
File     1241 00:26:44.47 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001024,20131024,002652.001 - Received at 00:26:45.78 for File 1242
File     1242 00:26:45.81 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001025,20131024,002653.296 - Received at 00:26:47.07 for File 1243
File     1243 00:26:47.11 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001026,20131024,002654.622 - Received at 00:26:48.40 for File 1244
File     1244 00:26:48.42 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001027,20131024,002655.948 - Received at 00:26:49.73 for File 1245
File     1245 00:26:49.77 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001028,20131024,002657.259 - Received at 00:26:51.04 for File 1246
File     1246 00:26:51.06 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001029,20131024,002658.585 - Received at 00:26:52.35 for File 1247
File     1247 00:26:52.39 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001030,20131024,002659.942 - Received at 00:26:53.71 for File 1248
File     1248 00:26:53.75 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001031,20131024,002701.299 - Received at 00:26:55.07 for File 1249
File     1249 00:26:55.11 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001032,20131024,002702.657 - Received at 00:26:56.43 for File 1250
File     1250 00:26:56.47 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001033,20131024,002704.045 - Received at 00:26:57.82 for File 1251
File     1251 00:26:57.86 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001034,20131024,002705.387 - Received at 00:26:59.17 for File 1252
File     1252 00:26:59.20 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001035,20131024,002706.744 - Received at 00:27:00.53 for File 1253
File     1253 00:27:00.55 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001036,20131024,002708.054 - Received at 00:27:01.84 for File 1254
File     1254 00:27:01.86 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001037,20131024,002709.349 - Received at 00:27:03.12 for File 1255
File     1255 00:27:03.17 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001038,20131024,002710.691 - Received at 00:27:04.46 for File 1256
File     1256 00:27:04.50 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001039,20131024,002712.001 - Received at 00:27:05.78 for File 1257
File     1257 00:27:05.81 10/24/2013 1461 KBytes SAVED IN 1222.SGY
$,1222c,00001040,20131024,002713.327 - Received at 00:27:07.10 for File 1258
File     1258 00:27:07.14 10/24/2013 1461 KBytes SAVED IN 1222.SGY
```

Appendix F Example P190 Navigation Header

0090_1342.p190.txt - Notepad

File Edit Format View Help

```
H0100SURVEY AREA                Nearshore San Diego, CA
H0101SURVEY DETAILS             SONGS PCable 2013
H0102VESSEL DETAILS             R/V New Horizon            1
H0103SOURCE DETAILS             Source 301                 1   1
H0104STREAMER DETAILS           Streamer 201   8 ch        1       1
H0104STREAMER DETAILS           Streamer 202   8 ch        1       2
H0104STREAMER DETAILS           Streamer 203   8 ch        1       3
H0104STREAMER DETAILS           Streamer 204   8 ch        1       4
H0104STREAMER DETAILS           Streamer 205   8 ch        1       5
H0104STREAMER DETAILS           Streamer 206   8 ch        1       6
H0104STREAMER DETAILS           Streamer 207   8 ch        1       7
H0104STREAMER DETAILS           Streamer 208   8 ch        1       8
H0104STREAMER DETAILS           Streamer 209   8 ch        1       9
H0104STREAMER DETAILS           Streamer 210   8 ch        1       A
H0104STREAMER DETAILS           Streamer 211   8 ch        1       B
H0104STREAMER DETAILS           Streamer 212   8 ch        1       C
H0104STREAMER DETAILS           Streamer 213   8 ch        1       D
H0104STREAMER DETAILS           Streamer 214   8 ch        1       E
H0105OTHER DETAILS              Stbd Tow Buoy              1               1
H0105OTHER DETAILS              Port Tow Buoy              1               2
H0105OTHER DETAILS              Stbd Vane                  1               3
H0105OTHER DETAILS              Port Vane                  1               4
H0200SURVEY DATE                10/10/2013
H0201TAPE DATE                  2013
H0202TAPE VERSION               UKOOA P1/90
H0203LINE PREFIX                N/A
H0300CLIENT                     San Diego Edison
H0400GEOPHYSICAL CONTRACTOR     Scripps Institute of Oceanography
H0500POSITIONING CONTRACTOR     NCS SubSea, Inc
H0600POSITIONING PROCESSING     NCS SubSea, Inc
H0700POSITIONING SYSTEM         NavPoint Integrated Navigation System
H0800COORDINATE POSITION        Centre of Source
H0900OFFSET SYSTEM TO SOURCE 1     1   2    0.00  -50.00
H0901OFFSET SYSTEM TO S1R1         1   2    45.5  -97.40
H0901OFFSET SYSTEM TO S2R1         1   2    38.5  -100.7
H0902OFFSET SYSTEM TO S3R1         1   2    31.5  -103.6
H0903OFFSET SYSTEM TO S4R1         1   2    24.5  -106.0
H0904OFFSET SYSTEM TO S5R1         1   2    17.5  -107.9
H0905OFFSET SYSTEM TO S6R1         1   2    10.5  -109.2
H0906OFFSET SYSTEM TO S7R1         1   2     3.5  -109.9
H0907OFFSET SYSTEM TO S8R1         1   2    -3.5  -109.9
H0908OFFSET SYSTEM TO S9R1         1   2   -10.5  -109.2
H0909OFFSET SYSTEM TO S10R1        1   2   -17.5  -107.9
H0910OFFSET SYSTEM TO S11R1        1   2   -24.5  -106.0
H0911OFFSET SYSTEM TO S12R1        1   2   -31.5  -103.6
H0911OFFSET SYSTEM TO S13R1        1   2   -38.5  -100.7
H0911OFFSET SYSTEM TO S14R1        1   2   -45.5  -97.40
H0912OFFSET SYSTEM TO E/S 1        1   2    0.00    29.0
H0913OFFSET SYSTEM TO ANTENNA      1   2     0.0     0.0
H1000CLOCK TIME                 GMT -0.0 Hours
H1100RECEIVER GROUPS PER SHOT    112
H1400GEODETIC DATUM AS SURVEYED WGS84       WGS84        6378137.000 298.2572236
H1401DATUM SHIFT SURVEY TO WGS84  -0.0  -0.0  -0.0-0.000-0.000-0.000-0.0000000
H1500GEODETIC DATUM AS PLOTTED  WGS84       WGS84        6378137.000 298.2572236
H1501DATUM SHIFT PLOT TO WGS84    -0.0  -0.0  -0.0-0.000-0.000-0.000-0.0000000
H1510TOWNSHIP SYSTEM            N/A
H1600DATUM SHIFT SURVEY TO PLOT    0.0   0.0   0.0 0.000 0.000 0.000 0.0000000
H1700VERTICAL DATUM                                         Sea Surface
H2600 Echosounder 1 transducer depth (Z)  3.6
H1800PROJECTION TYPE            001 UTM North
H1810TOWNSHIP RELATIVE COORDS   N/A
H1900PROJECTION ZONE            11N
H1910TOWNSHIP PRINCIPLE MERIDIANN/A
H2000GRID UNITS                 1Metres                      1.000000000000
H2001HEIGHT UNITS               1Metres                      1.000000000000
H2002ANGULAR UNITS              1Degrees
H2200LONGITUDE OF CM            129 0 0.000W
H2301GRID ORIGIN (LAT, LON)       0 0 0.000N129 0 0.000W
H2302GRID ORIGIN (E, N)           500000.00E       0.00N
H2401SCALE FACTOR               0.9996000000
H2402SCALE ORIGIN (LAT, LON)      0 0 0.000N129 0 0.000W
V1342A          1  000907332014.11N1173725.36W 441957.73688849.4  78.5291153430
E1342A          1  000907332013.47N1173724.53W 441979.03688829.7  78.5291153430
S1342A          11 000907332015.56N1173727.49W 441903.03688894.3  78.5291153430
T1342A          1 1000907332015.07N1173729.33W 441855.33688879.5  78.5291153430
```

Appendix G Final Ebcdic Headers

Boomer Final Full PSTM Stack

```
C01 Client: Scripps/UNR
C02 Area: San Onofre, offshore Southern California, USA
C03 SONGS 3D Boomer Survey: Full Offset Stack Data with Filter
C04
C05 --- Acquisition Parameters -----------------------------------
C06 Company, data             Scripps, October 2013
C07 Vessel                    R/V New Horizon
C08 Source                    Boomer, 3 plates, 0.5m depth
C09 Sp interval               3.125 m
C10 Record length             800 ms @ 0.25ms
C11 Format                    SEGY
C12 Cables                    14*50m, cable separation 6.25m, 2m depth
C13 Groups, grp int           8(112 chns), 6.25m
C14
C15 --- Processing Parameters: Geotrace 5800411 November 2013 - April 2014 --
-
C16 1. Seg-y reformat
C17 2. Low cut filter 45Hz
C18 3. Resample to 1 ms (500 Hz Nyquist) with TAA filter
C19 4. Bad trace edits           5. De-noise, 2D SRME
C20 6. Sort into 3D bins         7. Apply 1480 m/s NMO
C21 8. 2D Stack (8 fold)        9. Deconvolution, Interpolation of empty bins
C22 10. Post Stack pre-migration noise attenuation (despike+fdna+fxy)
C23 11. Post stack Kirchoff migration
C24 12. Post migration dip filtering
C25 13. Amplitude balancing (Gain)
C26 14. SEGY
C27
C28
C29 --- Byte Positions -------------------------------------------
C30
C31 Cdp-y:   181-184 (local) Cdp-y:    185-188 (local)
C32 Easting: 189-192         Northing: 193-196    Inline:   205-208
C33 Crossline:   209-212     Cdp:      213-216    Cdplbl:   217-220
C34 Waterdepth:  221-224
C35
C36
C37 Survey spheroid: WGS84 Proj.: UTM Zone 11N
C38 3d survey origin: x: 438370.4 meters y: 3686647.4 meters
C39            angle: -42 degrees
C40     END EBCDIC
```

Sparker Final Full PSTM Stack

```
C01 Client: Scripps/UNR
C02 Area: San Onofre, offshore Southern California, USA
C03 SONGS 3D Sparker Survey: Full Offset Stack Data
C04
C05 --- Acquisition Parameters ------------------------------------
C06 Company, data              Scripps, October 2013
C07 Vessel                     R/V New Horizon
C08 Source                     Sparker, 3 tips, 2m depth
C09 Sp interval                6.25 m
C10 Record length              2000 ms @ 0.5ms
C11 Format                     SEGY
C12 Cables                     14*50m, cable separation 6.25m, depth 2m
C13 Groups, grp int            8(112 chn), 6.25m
C14
C15 --- Processing Parameters: Geotrace 5800411 November 2013 - April 2014 --
-
C16 1. Seg-y reformat
C17 2. Low cut filter 45Hz
C18 3. Resample to 1 ms (500 Hz Nyquist) with TAA filter
C19 4. Bad trace edits            5. De-noise, 2D SRME
C20 6. Sort into 3D bins          7. Apply 1480 m/s NMO
C21 8. 2-D Stack, 1-D SRME        9. Interpolation of Empty Bins
C22 10. Post Stack pre-migration noise attenuation (despike+fdna+fxy)
C23 11. Post stack Kirchoff migration
C24 12. TVF, Amplitude balancing (Gain)
C25 13. SEGY
C26
C27
C28
C29 --- Byte Positions -------------------------------------------
C30
C31 Cdp-x:   181-184 (local) Cdp-y:    185-188 (local)
C32 Easting: 189-192         Northing: 193-196    Inline:   205-208
C33 Crossline:   209-212     Cdp:      213-216    Cdplbl:   217-220
C34 Waterdepth:  221-224
C35
C36
C37 Survey spheroid: WGS84 Proj.: UTM Zone 11N
C38 3d survey origin: x: 435186.3 meters y: 3681633.1 meters
C39            angle: -45.52 degrees
C40     END EBCDIC
```

Appendix H Seismic QC displays

Example seismic QC displays included

- **Fig SQC.01** Raw Shots Display
- **Fig SQC.02** Reformatted Shots Display
- **Fig SQC.03** Brute Stack
- **Fig SQC.04** Brute Stack Enlarged
- **Fig SQC.05** Near Trace
- **Fig SQC.06** Near Trace All
- **Fig SQC.07** Whole Amplitude Map
- **Fig SQC.08** Whole Frequency Map
- **Fig SQC.09** Data Amplitude Map
- **Fig SQC.10** Data Frequency Map
- **Fig SQC.11** Ambient Amplitude Map
- **Fig SQC.12** Deep Amplitude Map
- **Fig SQC.13** Sparker Brute Stack
- **Fig SQC.14** Sparker Brute Stack Enlarged

Fig SQC.01 : Raw Shots Display
Line 1114E Cables 1-14

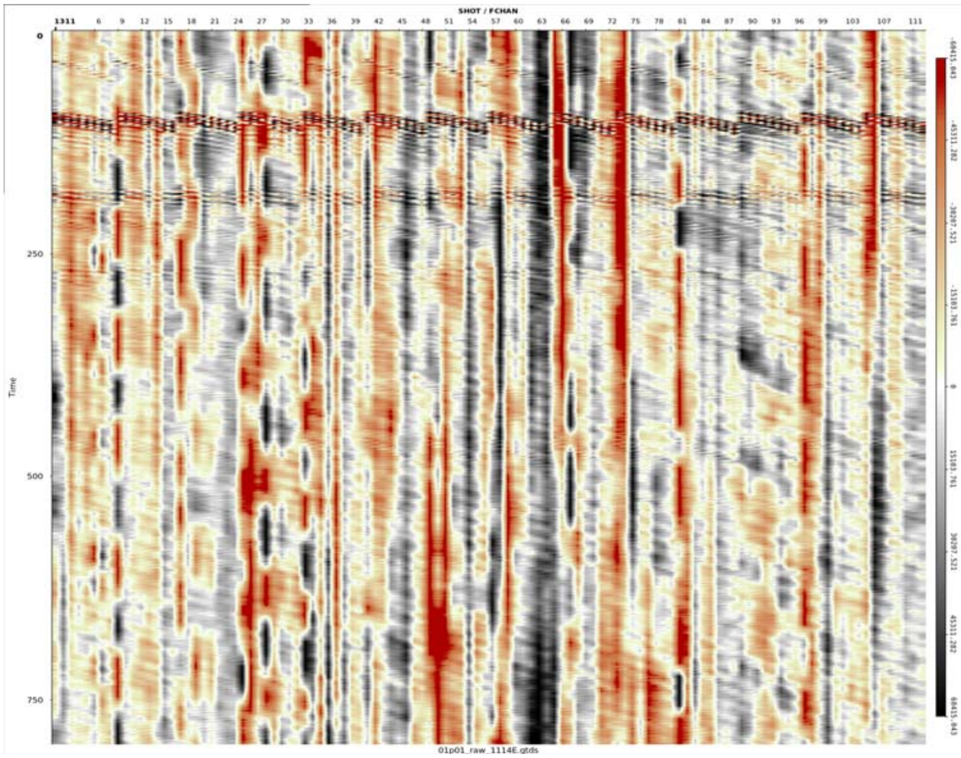


Fig SQC.02 : Reformatted Shots Display
Line 1114E Cables 1-14

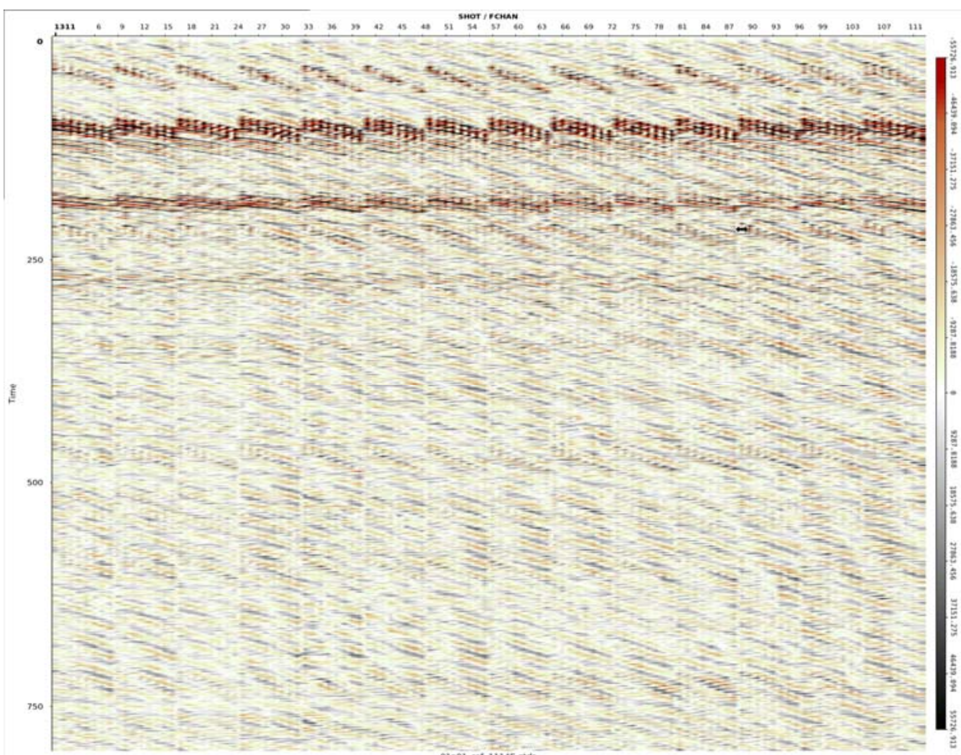


Fig SQC.03 : Brute Stack
Line 1114E Cable 5

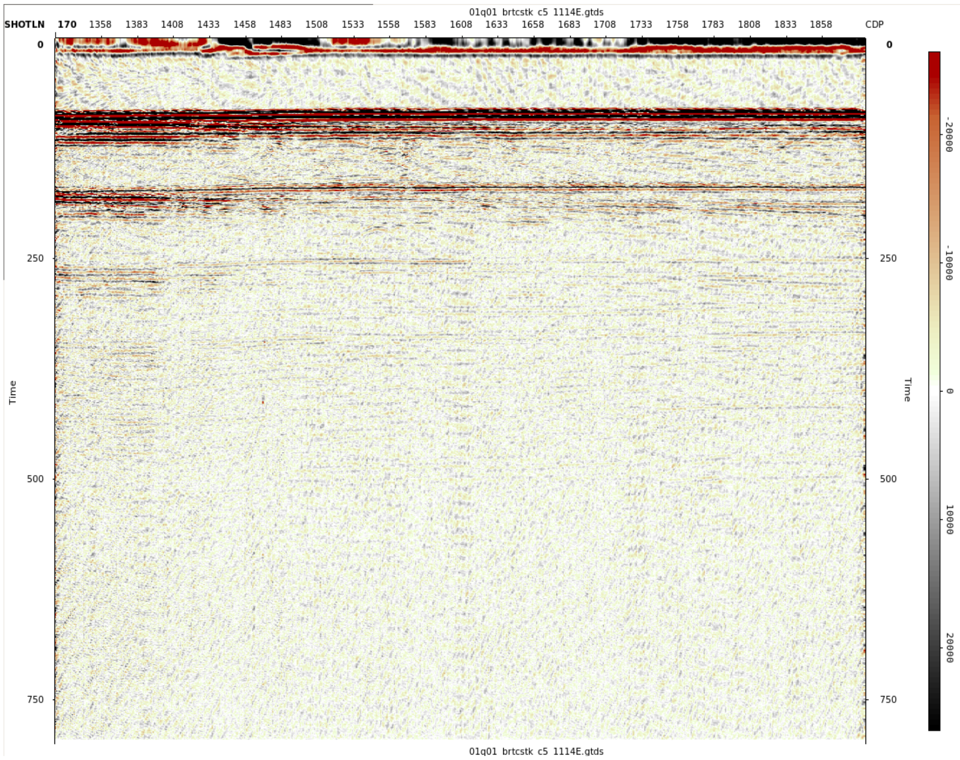


Fig SQC.04 : Brute Stack Enlarged
Line 1114E Cable 5

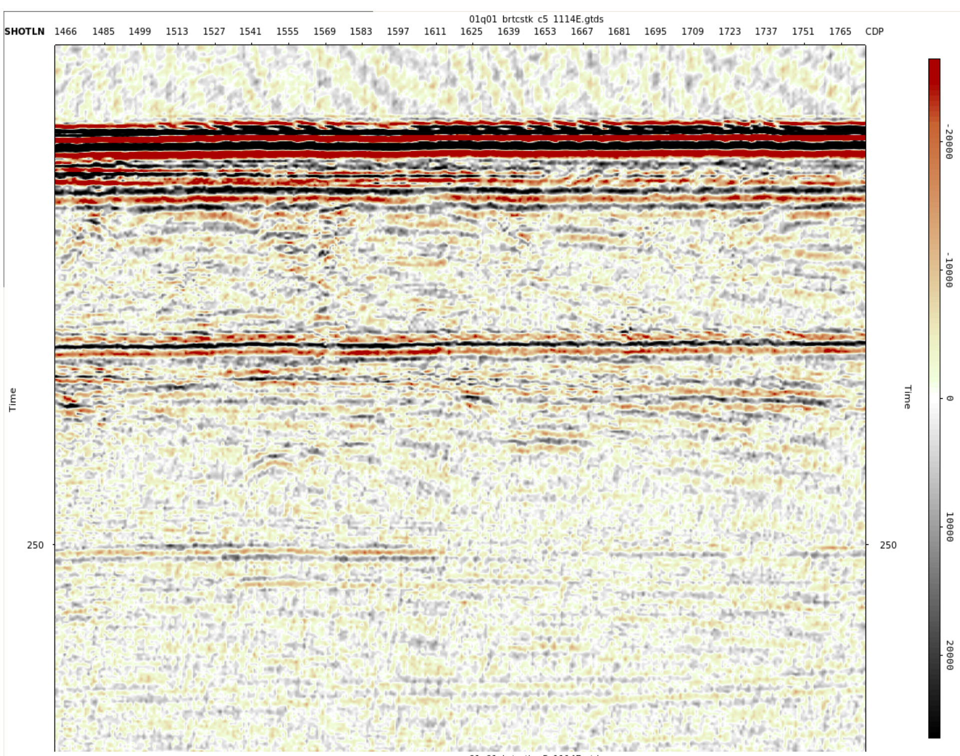


Fig SQC.05 : Near Trace
Line 1114E Cable 10

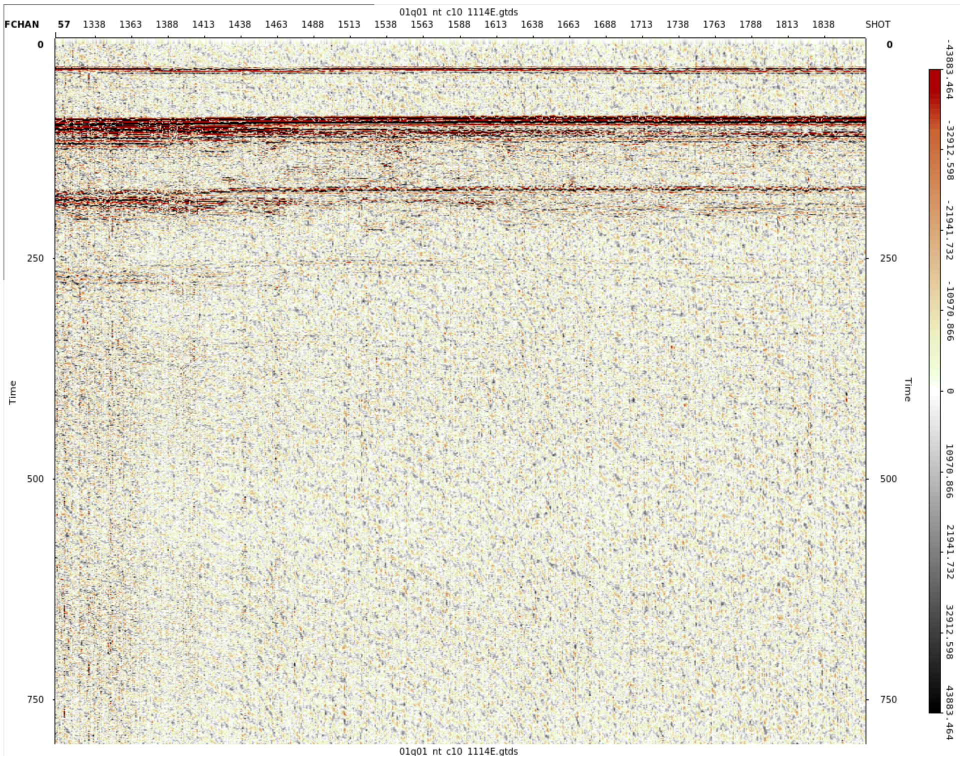


Fig SQC.06 : Near Trace All Cables
Line 1114E Shots 1311-1330

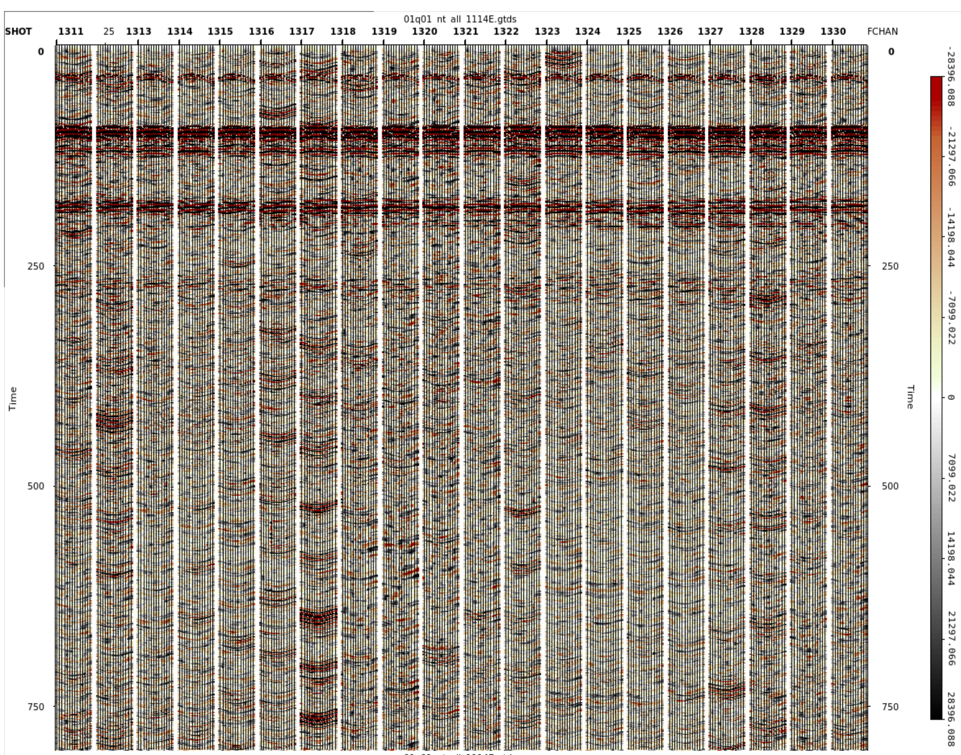


Fig SQC.07 : Whole Window Amplitude Map
Line 1114E

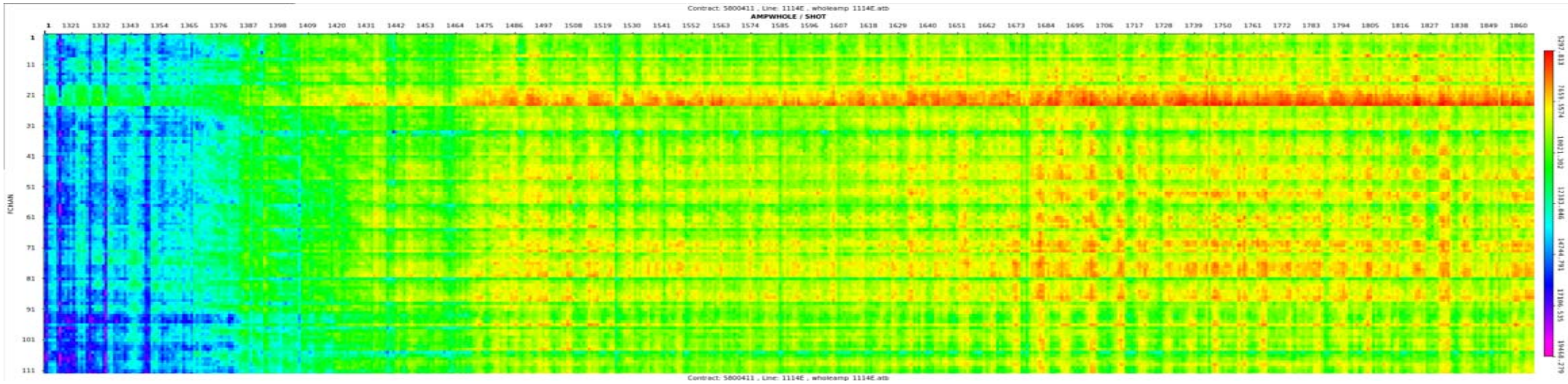


Fig SQC.08 : Whole Window Frequency Map
Line 1114E

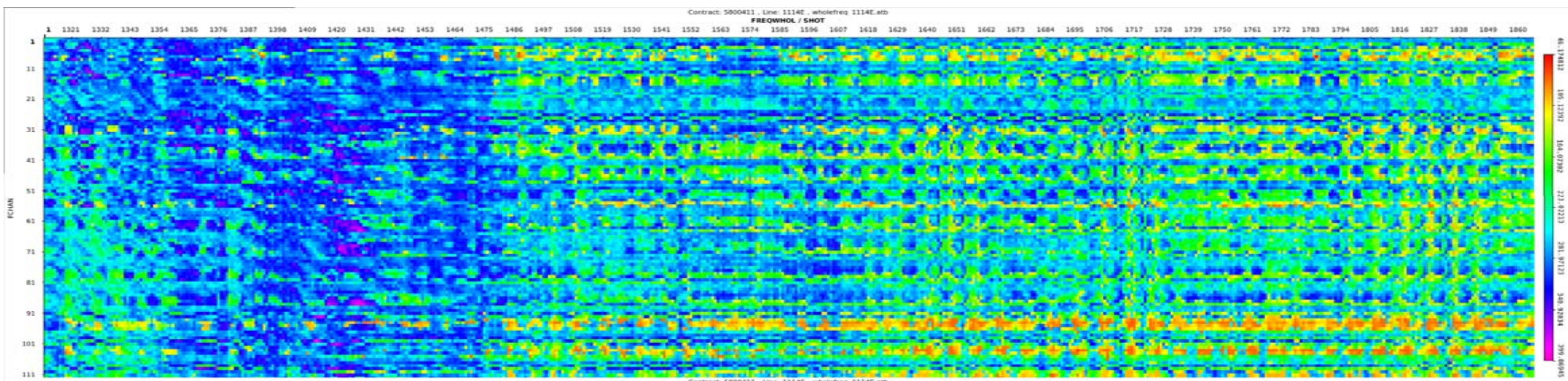


Fig SQC.09 : Data Window Amplitude Map
Line 1114E

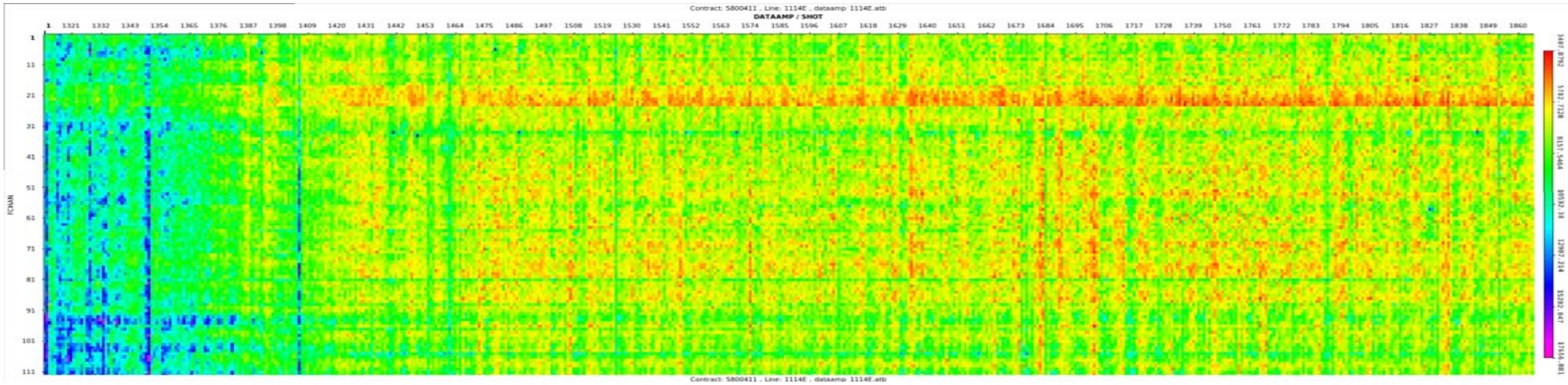


Fig SQC.10 : Data Window Frequency Map
Line 1114E

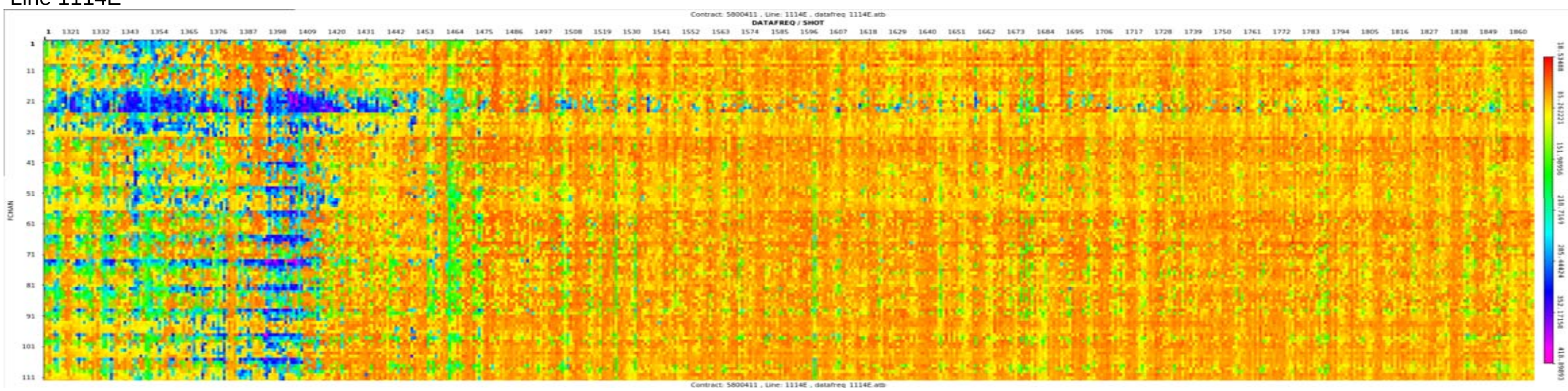


Fig SQC.11 : Ambient Amplitude Map
Line 1114E

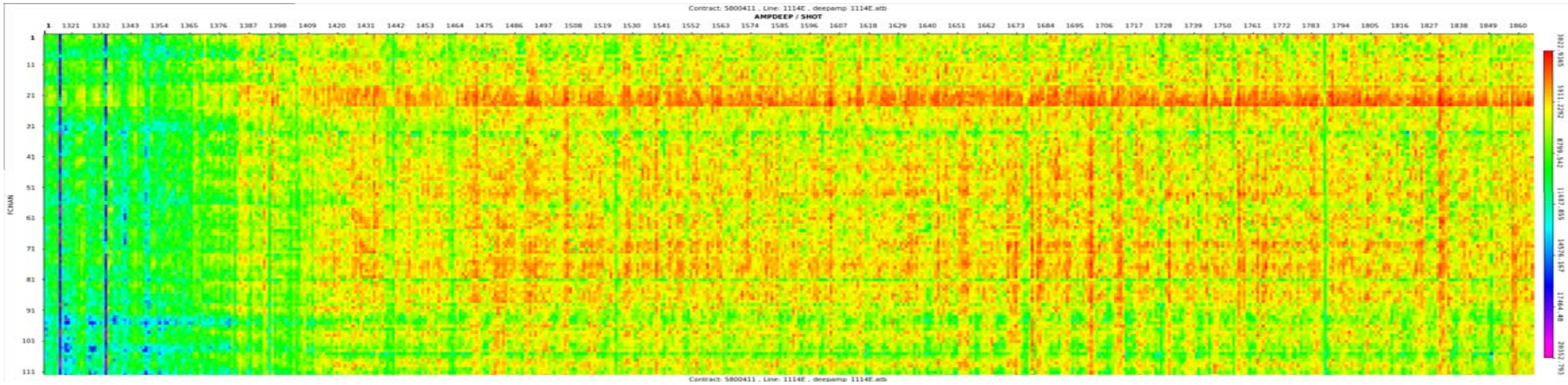


Fig SQC.12 : Deep Amplitude Map
Line 1114E

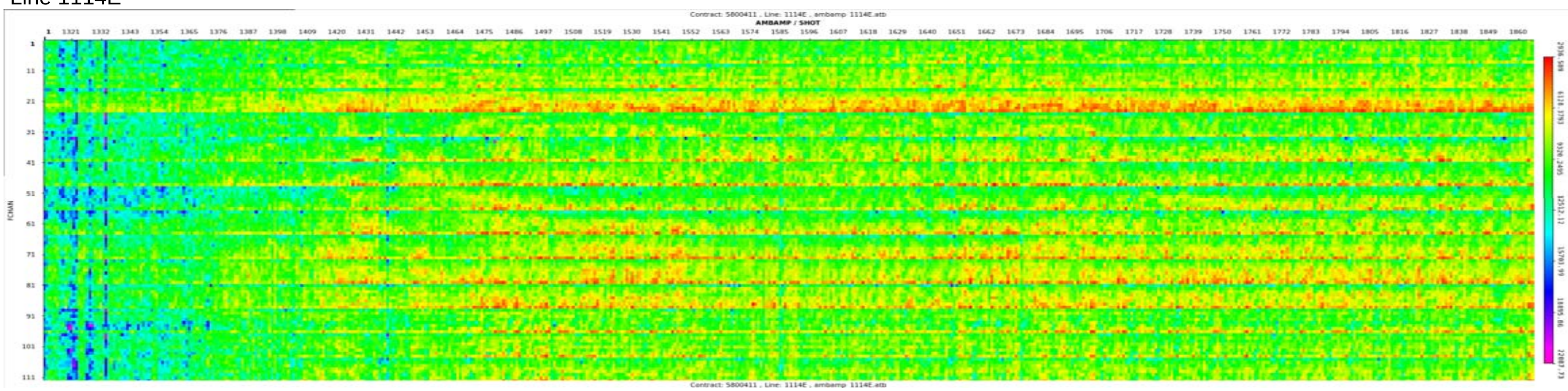


Fig SQC.13 : Sparker Brute Stack
Line 3499A Cable 5

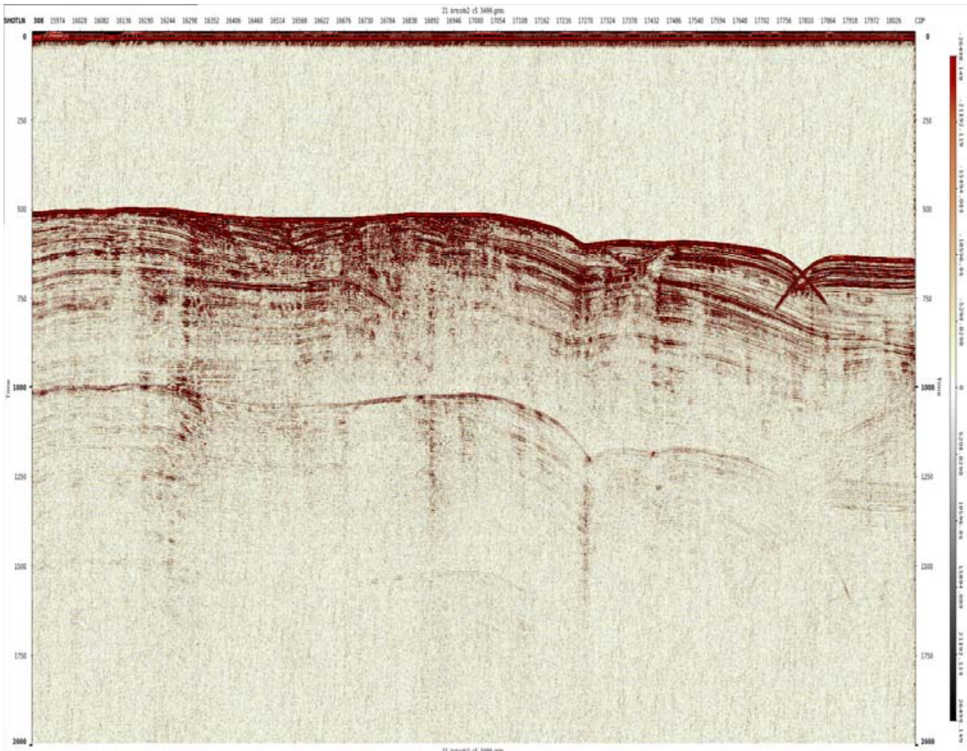


Fig SQC.14 : Sparker Brute Stack Enlarged
Line 3499A Cable 5