FUGRO SEISMIC IMAGING PTY LTD

SEISMIC DATA PROCESSING REPORT
FOR
THE DEPARTMENT OF PRIMARY INDUSTRIES VICTORIA

Location : Otway Basin, Victoria
Surveys : 2009 Seismic Reprocessing Processing
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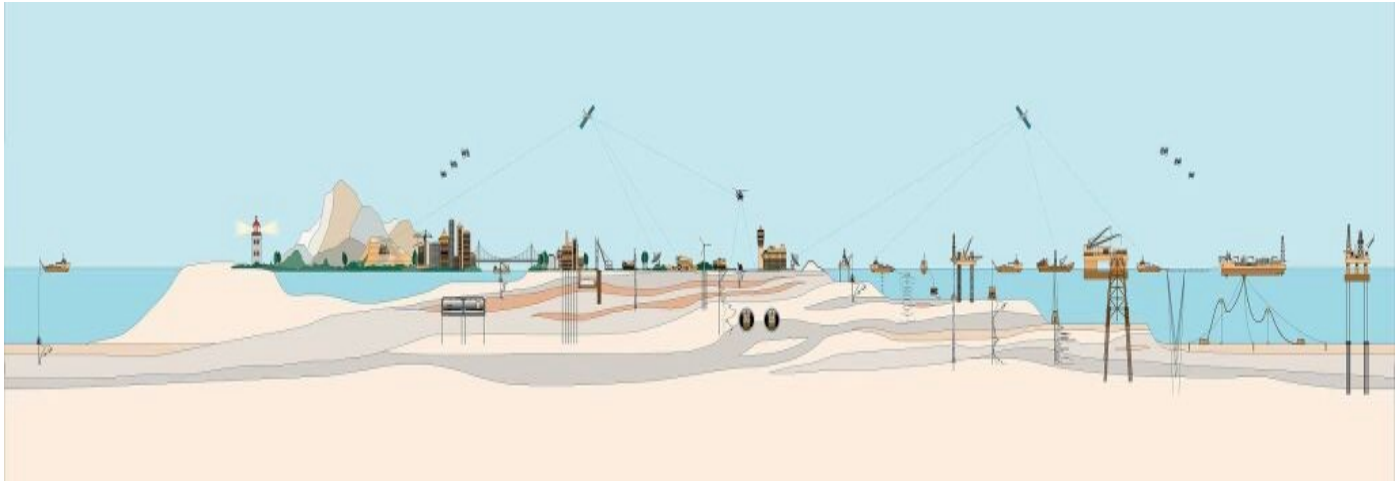

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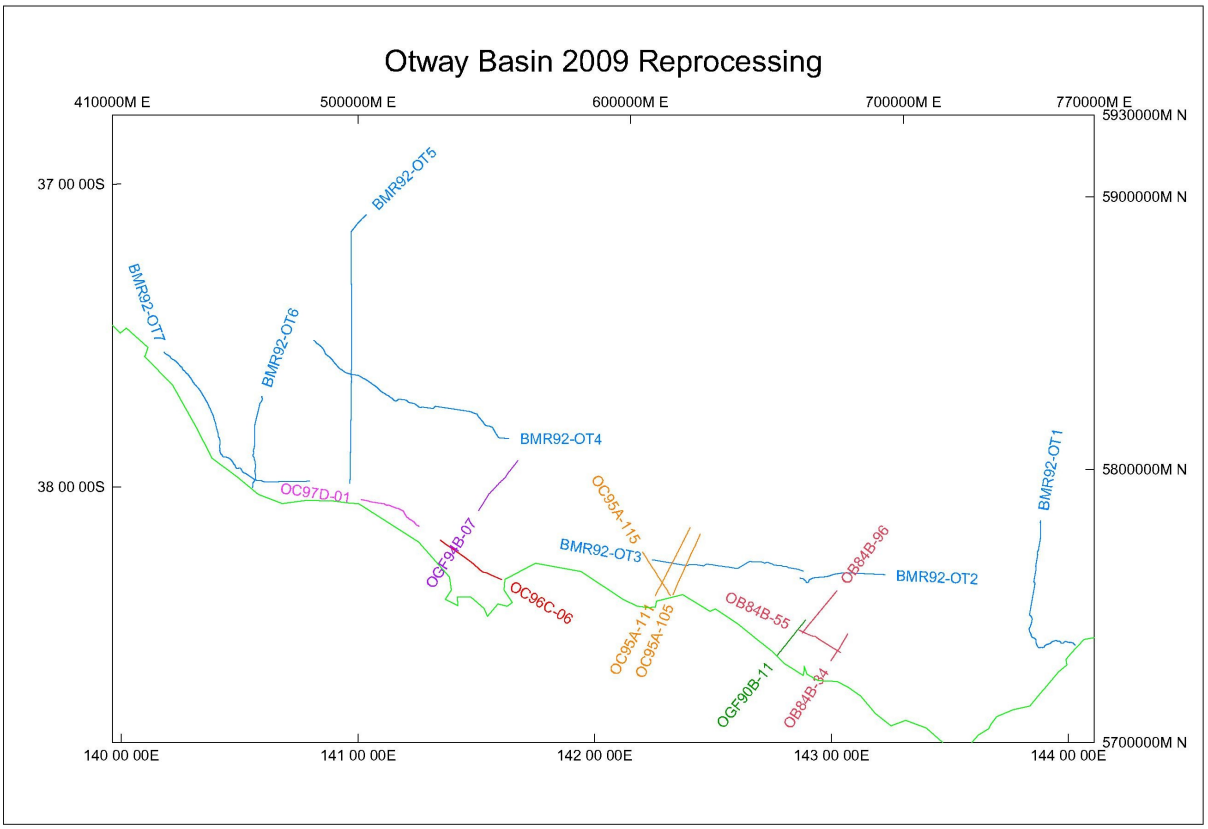
1 Introduction

The data being reprocessed for The Department of Primary Industries Victoria can be thought of as two basic grouping: the industry lines and the BMR lines. The BMR lines consisted of 7 regional lines acquired in 1992 with recording to 20 seconds. The “industry” lines were less regional, recorded by various oil companies to 4 or 5 seconds, and generally of much higher fold. They turned out to be two quite different data types to reprocess with in many respects two different approaches and influences. The industry lines were processed through a flow able to take advantage of the higher fold data. The lower fold BMR lines turned out to be a bit more challenging and were processed slightly differently accordingly. Both processing flows have been described separately in this report.

2009 Otway Basin Reprocessing Line Listing						
Survey	***Line***	***First CDP***	***Last CDP***	***First VP***	***Last VP***	***Length (km)***
COLAC	BMR92-OT1	1	2359	1001	2315	65.95
CAMPERDOWN	BMR92-OT2	1	1266	1004	1661	33.15
WARRNAMBOOL	BMR92-OT3	1	2263	1001	2166	58.35
CASTERTON	BMR92-OT4	1	3369	1000	2753	87.7
PENOLA	BMR92-OT5	1	4016	1000	3020	101.05
KONGORONG	BMR92-OT6	1	1324	1001	1678	34.85
LAKE NONNEY	BMR92-OT7	1	3204	995	2632	82
HALLADALE	OGF90B-11	1	1497	160	930	15.46
TIMBOON	OB84B-34	1	2860	100	1542	11.58
TIMBOON	OB84B-55	1	4322	160	2339	17.44
TIMBOON	OB84B-96	1	4960	100	2607	20.06
TOWER HILL	OC95A-105	1	3229	70	1700	24.47
TOWER HILL	OC95A-111	1	3722	100	1966	28.01
TOWER HILL	OC95A-115	1	2503	102	1366	18.98
ANNYA	OGF94B-07	1	2334	378	1550	29.33
TREWALLA	OC96C-06	1	2681	102	1450	26.98
MALSEED	OC97D-01	1	3221	100	1734	24.53


Otway Basin 2009 Reprocessing
410000M E
500000M E
600000M E
700000M E
770000M E
5930000M N
5900000M N
5800000M N
5700000M N
37 00 00S
38 00 00S
140 00 00E
141 00 00E
142 00 00E
143 00 00E
144 00 00E
BMR92-OT5
BMR92-OT7
BMR92-OT6
BMR92-OT4
BMR92-OT1
BMR92-OT3
BMR92-OT2
OC97D-01
OGF94B-07
OC96C-06
OC95A-115
OC95A-111
OC95A-105
OB84B-96
OB84B-55
OGF90B-11
OB84B-34

2 Acquisition Parameters

The surveys were acquired using the parameters listed below.

1984 Timboon Seismic Survey Acquisition Parameters	
Data recorded by	Geosystems Crew 205
Date recorded	01/05/84
Seismic source	Vibroseis
Source pattern	3vibrators inline 8m pad to pad
Sweeps per VP	6 Varisweeps
Vib Moveup	4 m
Sweep Frequency	11-60- 12-65 13-70 14-75 15-80 10-60 Hz
Sweep Length / Type	8 seconds / linear
Sweep Taper	
Source Centre	Mid Station
VP interval	40 m
Recording system	Geocor IV
Record length	4 seconds correlated zero phase
Sample rate	2 ms
Tape format	Geosystems 16 bit integer
Field filters	
Data channels	512
Coverage	52 fold
Geophone type	L21A 10 Hz
Geophone array	6 in line
Element spacing	1.3 m
Group interval	8 m

1990 Halladale Seismic Survey Acquisition Parameters	
Data recorded by	Haliburton Geophysical Services
Date recorded	01/04/90
Seismic source	Vibroseis
Source pattern	4 vibrators 12m pad to pad
Sweeps per VP	2
Vib Moveup	
Sweep Frequency	8 – 90 Hz
Sweep Length / Type	10 seconds / linear
Sweep Taper	250 ms
Source Centre	Mid Station
VP interval	20 m
Recording system	MDS-14
Record length	4 seconds correlated zero phase
Sample rate	4 ms
Tape format	Segb
Field filters	0 – 93 Hz
Data channels	120
Coverage	60 fold
Geophone type	SM4 U 10 Hz
Geophone array	12 in line
Element spacing	1.8 m
Group interval	20 m

1992 BMR Seismic Survey Acquisition Parameters	
Data recorded by	BMR
Date recorded	March – June 1992
Seismic source	Dynamite
Charge	10 kg
Depth	30 m (average)
Source Centre	Mid Station
SP interval	300 m or 600 m
Recording system	Sercel SN 368
Record length	20 seconds
Sample rate	2 ms
Tape format	SEG-D
Field filters	8 - 178 Hz
Data channels	120
Coverage	5 or 10 fold
Geophone type	SM4 U 10 Hz
Geophone array	16 in line
Element spacing	3 m
Group interval	50 m

1994 Annya Seismic Survey Acquisition Parameters	
Data recorded by	Geco Prakla Crew 161
Date recorded	01/04/94
Seismic source	Vibroseis
Source pattern	3 vibrators 12m pad to pad
Sweeps per VP	
Vib Moveup	
Sweep Frequency	6 – 100 Hz
Sweep Length / Type	5 seconds / linear
Sweep Taper	300 ms
Source Centre	Mid Station
VP interval	20 m
Recording system	I/O System One
Record length	5 seconds correlated zero phase
Sample rate	2 ms
Tape format	Segd
Field filters	3 – 120 Hz
Data channels	300
Coverage	150 fold
Geophone type	SM4 U 10 Hz
Geophone array	12 in line
Element spacing	1.66 m
Group interval	20 m

1995 Tower Hill Seismic Survey Acquisition Parameters	
Data recorded by	Geosystems Crew 205
Date recorded	01/02/95
Seismic source	Vibroseis
Source pattern	3 vibrators 12m pad to pad
Sweeps per VP	
Vib Moveup	
Sweep Frequency	8 – 120 Hz
Sweep Length / Type	5 seconds / linear
Sweep Taper	200 ms
Source Centre	Mid Station
VP interval	15 m
Recording system	Geocor IV
Record length	5 seconds correlated zero phase
Sample rate	2 ms
Tape format	Geosystems 16 bit integer
Field filters	
Data channels	400
Coverage	200 fold
Geophone type	SM4 U 10 Hz
Geophone array	6 in line
Element spacing	2.5 m
Group interval	15 m

1996 Trewalla Seismic Survey Acquisition Parameters	
Data recorded by	Geco Prakla Crew 161
Date recorded	01/08/96
Seismic source	Vibroseis
Source pattern	3 vibrators 12m pad to pad
Sweeps per VP	
Vib Moveup	
Sweep Frequency	8 – 120 Hz
Sweep Length / Type	10 seconds / linear
Sweep Taper	
Source Centre	Mid Station
VP interval	20 m
Recording system	I/O Ststem One
Record length	5seconds correlated zero phase
Sample rate	2ms
Tape format	Segd
Field filters	3 – 180 Hz
Data channels	350
Coverage	175 fold
Geophone type	SM4 U 10 Hz
Geophone array	12 in line
Element spacing	1.66 m
Group interval	20 m

1997 Malseed Seismic Survey Acquisition Parameters	
Data recorded by	Geosystems Crew 205
Date recorded	01/03/97
Seismic source	Vibroseis
Source pattern	4 vibrators 12m pad to pad
Sweeps per VP	
Vib Moveup	
Sweep Frequency	8 – 120 Hz
Sweep Length / Type	10 seconds / linear
Sweep Taper	200 ms
Source Centre	Mid Station
VP interval	15 m
Recording system	Geocor IV
Record length	5seconds correlated zero phase
Sample rate	2ms
Tape format	Geosystems 16 bit integer
Field filters	0 – 93 Hz
Data channels	400
Coverage	200 fold
Geophone type	SM4 U 10 Hz
Geophone array	6 in line
Element spacing	2.5 m
Group interval	15 m

3 Parameter Testing

Parameter testing was comprehensive and was conducted almost separately on both the BMR and industry lines.

Most of the early testing for the Industry were performed on line OB84B-96, line OGF90B-07 and line OGF90B-11 . These included gain recovery, surface wave noise attenuation, FK, and deconvolution. A PSTM test was performed on line OC95A-115. Additional tests were performed where appropriate (i.e. mute tests on other vintages).

Initial testing for the BMR lines was performed on line BMR92-OT1. These included gain recovery tests, FK tests and a few other early tests. Once we'd seen some brute stacks line BMR92-OT3 seemed a more representative line and subsequent tests were run on this line. The FK filtering that was working well on the industry lines was not on the low fold BMR lines so a different approach was then taken. The data was treated in a more amplitude preserving way employing de-spike, TFDN, and surface wave noise attenuation in place of FK filtering. Velocity analysis was approached slightly differently to accommodate the low fold and offset plane processing like DMO or PSTM were not able to be used with this low fold and offset distribution.

A summary of testing for certain processes is given below.

Gain recovery tests

Time-frequency de-noise (TFDN module): tested application in shot, common offset and CDP domains, with and without NMO corrections, and optimised noise thresholds and application times.

Surface wave noise attenuation (SWNA module): varied the velocity parameter, frequency range and application times.

FK filter tests employing different velocities for attenuation, and with application with NMO and statics applied.

Deconvolution: tested spiking and predictive deconvolution using various gaps.

Surface consistent amplitude corrections.

Surface consistent residuals: tested two different algorithms, different windows, and pilot definitions.

Inverse Q filtering: tested different values of Q and maximum allowed amplitude boost.

Spectral balance: tested different output spectrums.

Random noise attenuation (RANNA module).

Outer trace mute: varied mute times to avoid residual coherent noise and the influence of NMO stretch.

Band-pass filter: varied filter frequencies and application times to optimise frequency content while also attenuating noise.

Pre- and post-stack scaling: tested different automatic gain control (AGC) window sizes for single and dual-window AGCs. Also looked at different gated scales.

Post stack Taup filtering: varying dips and addback of original data.

4 Processing Sequence – BMR Lines

4.1 Field Tape Transcription

Field data were converted from SEG-Y format to FSI's internal format . Of note for the BMR data there were two trace one's: the first was an auxiliary, the second the data channel 1.

4.2 Gain Recovery

Gain recovery is used to compensate for spherical divergence and absorption losses. For the BMR recorded data this was achieved with a $T^{1.5}$ gain function. For the industry lines we employed the function: Gain(db) = 1.0t + 6log(t) + 30.

4.3 Geometry Assignment

The receiver locations and shot information is input to spread sheets within the green mountain millenium package. For the BMR lines this was a reasonably time consuming process. The information came from various sources. Shotpoint receiver relationships came from printouts provided by GA. The production uphole depths and times were extracted from a report on the previous processing. The coordinate information had to be first converted to the required GDA94 projection. The industry lines were a little more straight forward with scans of observer's reports available, and with no shot depth / uphole time concerns being vibroseis. Again though the coordinate information had to be converted in some cases. The coordinate conversions were kindly done and new coordinates supplied by the Department of Primary Industries Victoria.

4.4 Crooked Line Processing

Whilst the "industry" lines were essentially straight the 1992 BMR lines were not. Our crooked line binning program (CLINGER) employs the geometry information from green mountain or SPS information to derive the optimal bin positions along a 2D line. It then assigns candidate traces to those bins based on a ranking scheme that ideally would finish with one primary candidate trace per CDP per offset plane. There are a number of parameters within the program that can be altered to achieve the best cdp fit for certain situations. Output CDP intervals are generally set to half the nominal group interval. QC plots here involve displays of the original XY coordinates, all (or a percentage for higher fold data) of the midpoint information, the line of best fit as well as interim calculated paths, etc. A fold display is always checked during this calculation as well.

4.5 Surface Consistent Amplitude Corrections

The amplitude of any trace is affected by various factors, including the shot strength, response and coupling of the receivers, trace offsets and the geology. Surface Consistent Amplitude Recovery (SCAMP) is designed to analyse amplitudes in a surface consistent manner. It estimates the amplitude variations due to various components and computes weighting levels for each component, using the Gauss-Seidel iterative method. Amplitude weightings were applied using the shot, receiver station, and offset components in this case.

4.6 Despike

DSPIKE will zero (or down-weight) windows in traces which have an abnormal peak-to-median ratio or a mean which lies outside a specified standard-deviation. Multiple traces are used to establish the mean, median and standard-deviation in windows around each trace in turn. Portions of traces which are deemed to contain bad data may be down-weighted or zeroed. If some specified percentage of a trace is killed in this way, the whole trace may be flagged as dead.

Parameters for DSPK	
Domain	Shot
Length of Sliding Window	100 ms
Number of Traces in Operator	7
Number of Windows in Operator	7
Max Peak to Median Ratio	21
Max Standard Deviation	9
Scaler to Downweight Bad Windows	1
Threshold For Flagging Dead	50.00%

4.7 Time Frequency De-Noise

The TFDN module first transforms all traces in a short sliding time window to the frequency domain. There, it then compares the amplitude spectrum of each trace with those of the neighbouring traces in order to identify anomalies. The 'neighbourhood' is defined by a horizontal window comprising a certain number of traces. The amplitude at each frequency is compared with the median of the amplitudes of the neighbouring traces. If the amplitude exceeds the median by more than that a certain factor, then the amplitude at that frequency is set equal to the median. Noise attenuation is sometimes better achieved when using the lower quartile value instead of the median value, and the frequency range over which TFDN operates may be restricted. The noise attenuation performed by TFDN is localised in both time and frequency, minimising the side-effects on genuine data, and thus allowing amplitude-preserved processing.

An initial, mild pass of TFDN was used to identify and attenuate very high amplitude spikes in the shot records before SWNA. The TFDN parameters are shown below.

Parameters for TFDN	
Domain	Shot
Time Window	800 ms,8ms move-up
Horizontal Window	16 traces
Comparison Statistic	Lower quartile
Threshold	4
Frequency Range	0 - 12 Hz

4.8 Surface Wave Noise Attenuation

The surface wave noise attenuation module SWNA was used to attenuate shot generated and vehicle noise. SWNA first transforms all traces to the Fourier domain. A mix of adjacent traces is then performed at each frequency using a tapered box filter, the width of which depends both on frequency and a velocity parameter. The offset range over which traces are mixed is equal approximately to the ratio between the specified velocity and frequency. The SWNA parameters are given below.

Parameters for SWNA	
Frequency Range	0-20 Hz
Surface Wave Velocity	600 m/s

4.9 Time-Frequency De-Noise

Two passes of TFDN were used to further reduce noise amplitudes. The TFDN parameters for the two passes are given below.

Parameters for TFDN		
Domain	shot	shot
Time Window	800ms 8ms moveup	400ms 4ms moveup
Horizontal Window	32 traces	18 traces
Comparison Statistic	Lower quartile	Lower quartile
Threshold	4	4
Frequency Range	0-16 Hz	0-22 Hz

4.10 Surface Consistent Amplitude Corrections

The amplitude of any trace is affected by various factors, including the shot strength, response and coupling of the receivers, trace offsets and the geology. Surface Consistent Amplitude Recovery (SCAMP) is designed to analyse amplitudes in a surface consistent manner. It estimates the amplitude variations due to various components and computes weighting levels for each component, using the Gauss-Seidel iterative method. Another pass of surface consistent amplitude corrections was run and applied now that we have done most of the noise attenuation.

4.11 Deconvolution

Surface consistent deconvolution assumes that a seismic trace consists of the convolution of a number of components which go together to produce the seismic trace. For example, each shot, each geophone position, each CDP and each trace offset (or channel number) contributes its own spectral modification to the seismic trace. Surface consistent deconvolution attempts to reverse this process by extracting the original log spectra (one for each shot, each geophone etc.) from all of the original data. This is done by averaging the log spectra for each shot, each geophone station, each CDP and each distance and then using a Gauss-Seidal iterative technique to isolate the individual components. The final deconvolution step assume that all data is minimum phase. For this data only the shot and receiver components were employed. A two window deconvolution was employed the parameters of which are shown below.

Parameters for SCDCN		
Design gate at Near Offset	200 – 4000 ms	1900 – 7000 ms
Design gate at Far Offset	1900 – 4500 ms	2300 – 7500 ms
Operator Length	120ms	120ms
Predictive Gap	20 ms	20 ms
White Noise	1.00%	1.00%

4.12 Refraction Statics

Refraction statics are used to help reduce the structural biases introduced by weathering anomalies. Here refraction breaks were picked using Green Mountain Geophysics “Millennium” series refraction statics package. The “GMG – Millennium” package then used the measured travel time from shot to receiver to extract information about the near surface layer. Over many shots and many receivers, it was determined whether the ray paths are direct arrivals or refracted along one of the layers modeled by the package. A model was developed to estimate the velocities and the delay times for each refractor under each source and each station.

4.13 Sort to CDP Gathers

Shot records were sorted into common depth point gathers using crooked line geometry, with a nominal fold and CDP interval of 10 or 5 and 25 m, respectively.

4.14 First Pass Velocity Analysis

The first pass velocities were picked at 1km intervals using FSI's interactive velocity analysis program, MGIVA. The velocity interpretation was performed on both a semblance display and a 20 CDP stacked panel repeated with a suite of velocity functions in the range +/-25 % from a seed function. Neighbouring velocity functions were superimposed on the current location for easy recognition of velocity trends, and the semblance interpretation was assisted with an interval velocity curve. A CDP gather, interactive stack and velocity mapping tool were also used in the MGIVA analysis.

4.15 First Pass Residual Statics

FSI's surface-consistent residual statics package, NEBULA, computes statics based on summed cross-correlations at source and receiver locations. A pilot trace is constructed at each CDP using a weighted mix of stacked traces. Cross-correlations of the pilot trace with traces in the respective CDP gather, within a certain time window, are summed into buffers for each source and receiver station number. These summed correlations are then resampled and picked to derive a static value. Five iterations were performed using the parameters given below (the actual time windows employed were data dependent and altered slightly along each line).

Residual Statics Parameters	
Traces in pilot	9 traces
Time window	100-2500 ms
Maximum allowed shift	25 ms

4.16 Second Pass Velocity Analysis

The second pass velocity analysis was performed on gathers with first pass residuals statics applied. The first pass velocity field was used for the seed velocity functions, and analyses were performed at 1km intervals. For the second pass velocities 44 cdp's were used in the stack panels and the velocities analysis locations were targeted to coincide with shot centres. This produced a stack panel with a half spread, full spread, half spread mixture up shallow. This is a traditional single fold approach to velocity analysis and was employed here to help us better delineate the very shallow velocities in the low fold data.

4.17 Second Pass Residual Statics

The second pass residual statics was run on CDP gathers that were NMO corrected using the second pass velocity field. Another five iterations were performed with similar parameters to the first pass residuals.

4.18 Spectral Balance

The SPECB module allows equalisation of the amplitude spectrum throughout a given frequency range on a trace by trace basis. Each trace is filtered with each of the frequency pass bands specified, equalised using the TVEQ parameters specified, and summed, thereby balancing the spectrum. The data was balanced to an output spectrum of 10 – 72 Hz.

4.19 NMO Correction

Fourth order NMO corrections was performed using the third pass velocity functions.

4.20 Mute

An outer trace mute was applied to remove residual coherent noise on the outer traces and to reduce contamination from the effects of NMO stretch on the far offsets. The mute times as a function of offset are given below.

Outer Trace Mute Times	
Offset (m)	***Time (ms)***
288	0
528	300
828	500
1428	800
1983	1200
2975	2000
6000	3000

4.21 Pre-Stack Scaling

The CDP gathers were scale to compensate for amplitude irregularities by scaling each trace using a progressively increasing (from 250ms to 2000ms) gated scale.

4.22 Statics Application to Sea Level

A final statics correction was applied to reference the data to mean sea level instead of surface. To avoid losing data shallower than the final datum, the data was bulk shifted down by 200 ms prior to this final static correction, producing a new time origin -200 ms. Two lines, BMR92-OT1 and BMR92-OT2, were corrected to a 100m datum.

4.23 CDP Trim Statics

Here we applied a residual statics program which applies static shifts to traces on a CDP-consistent basis, using cross-correlations of NMO-corrected CDP gather traces with a CDP pilot trace for each depth point. The Parameters employed were as follows:

CDP Residual Statics Parameters	
Traces in pilot	9 traces
Time window	100-2500 ms(nominal)
Maximum allowed shift	10 ms

4.24 Common Depth Point Stack

The traces within each CDP gather were summed using 1/N stack compensation.

4.25 Migration

A finite difference wave equation method was employed for migration. This method uses the technique of 'downward continuation' in order to map the reflectors to their true time position. This process effectively uses a model where the receivers are successfully positioned not at the surface, but deeper and deeper into the earth. At each new position, the 'lens' like effect of the previous layer is removed and the whole section beneath is seen without this distortion. The upward travelling energy which is detected can be considered to arise from sources placed along the various seismic horizons. The step size used here was 12 ms. The final stacking velocities were smoothed for the migration.

4.26 Post-Stack Random Noise Attenuation

The RANNA module performs noise attenuation using a method based on the forward-backward linear prediction theory. RANNA was used here to attenuate incoherent noise on the raw stack.

Parameters for RANNA	
Filter Length	7 traces
Input Traces per Filter Prediction	7 traces
White Noise Percentage	1%
Sliding Window Length	2500 ms

4.27 Band-Pass Filter

Unwanted noise that lay outside the frequency range of the desired reflection data was removed by the application of a series of time variant filters. A cosine-squared taper was employed between the pass band and cut-off frequencies. The filter parameters are listed below.

Band-Pass Filter Frequencies				
Time (ms)	***Lower Cut-Off Frequency (Hz)***	***Lower Pass Band Frequency (Hz)***	***Upper Pass Band Frequency (Hz)***	***Upper Cut-Off Frequency (Hz)***
200	18	22	75	85
500	13	17	70	80
1300	10	14	55	65
2000	8	12	50	60
3000	6	10	45	55
4000	6	10	40	50

4.28 Post-Stack Scaling

A progressively increasing gated scale (from 250ms to 2000ms) was again employed to further scale the data.

4.29 Tau-p Filter

This process applies a time-variant dip filter to stacked data. The process is implemented by transformation of input data trace blocks of user-specified size into the Tau-P domain. Editing of the data in this domain permits the retention of data within specified dip limits at any time. Linear interpolation is used between user-specified times and dips. The Tau-P data may be optionally weighted by semblance if required. The edited data is then transformed back into the T-X domain in trace blocks of user-specified size, and an inverse filter to correct the spectral effects of the double transformation is applied. The traces actually output are a weighted sum of the output from adjacent transforms whose origins lie on either side of the output trace position, to which has been applied any requested mix-back of the original data.

Parameters for TVDIP	
Time	Dip Limits
200	+/- 4 ms/tr
500	+/- 6 ms/tr
1000	+/- 8 ms/tr
4000	+/- 12 ms/tr

Addback Parameters for TVDIP	
Time(ms)	Addback of Original Data
200	30.00%
400	55.00%
1000	55.00%
2000	65.00%

5 Processing Sequence – Industry Lines

5.1 Field Tape Transcription

Field data were converted from SEG-Y format to FSI's internal format .

5.2 Gain Recovery

Gain recovery is used to compensate for spherical divergence and absorption losses. For the industry lines we employed the function: Gain(db) = 1.0t + 6log(t) + 30.

5.3 Phase Conversion

An autocorrelation of the sweep on one of the auxiliary traces was retrieved for each vintage. From these we design a filter to convert each autocorrelation to it's minimum phase equivalent. Visual QC of the input and output wavelets is performed as well as spectrum analysis. Care is taken to assure slopes of frequency spectrum are appropriate.

5.4 Geometry Assignment

The receiver locations and shot information is input to spread sheets within the green mountain millenium package. For the industry lines we were provided with scans of observer's reports. There were some vintages where the coordinate information had to be converted to the AGD94 projection. The coordinate conversions were kindly done and new coordinates supplied by the Department of Primary Industries Victoria.

5.5 Crooked Line Processing

Whilst the "industry" lines were essentially straight they were treated the same as the BMR lines and were run through our crooked line program to address any small fluctuations in dirrection . Our crooked line binning program (CLINGER) employs the geometry information from green mountain or SPS information to derive the optimal bin positions along a 2D line. It then assigns candidate traces to those bins based on a ranking scheme that ideally would finish with one primary candidate trace per CDP per offset plane. There are a number of parameters within the program that can be altered to achieve the best cdp fit for certain situations. Output CDP intervals are generally set to half the nominal group interval. QC plots here involve displays of the original XY coordinates, all (or a percentage for higher fold data) of the midpoint information, the line of best fit as well as interim calculated paths, etc. A fold display is always checked during this calculation as well.

5.6 FK Filter

The program FXMUCH carries out F-K filtering by an 'F-X' method. This is performed by multiplication in the frequency domain and convolution in the spacial. In order to reduce aliasing issues and to improve accuracy nmo and full statics were applied prior to and removed after FK filtering. The FK filter design employed a full cosine taper from 0 to 2000 m/sec.

5.7 Refraction Statics

Refraction statics are used to help reduce the structural biases introduced by weathering anomalies. Here refraction breaks were picked using Green Mountain Geophysics “Millennium” series refraction statics package. The “GMG – Millennium” package then used the measured travel time from shot to receiver to extract information about the near surface layer. Over many shots and many receivers, it was determined whether the ray paths are direct arrivals or refracted along one of the layers modeled by the package. A model was developed to estimate the velocities and the delay times for each refractor under each source and each station.

5.8 Sort to CDP Gathers

Shot records were sorted into common depth point gathers using crooked line geometry, with a nominal fold and CDP interval of 200 and 7.5 m, respectively.

5.9 Deconvolution

Surface consistent deconvolution assumes that a seismic trace consists of the convolution of a number of components which go together to produce the seismic trace. For example, each shot, each geophone position, each CDP and each trace offset (or channel number) contributes its own spectral modification to the seismic trace. Surface consistent deconvolution attempts to reverse this process by extracting the original log spectra (one for each shot, each geophone etc.) from all of the original data. This is done by averaging the log spectra for each shot, each geophone station, each CDP and each distance and then using a Gauss-Seidal iterative technique to isolate the individual components. The final deconvolution step assume that all data is minimum phase. For this data only the shot and receiver components were employed. A one window deconvolution was employed the parameters of which are shown below.

Parameters for SCDCN	
Design gate at Near Offset	200 – 2400 ms
Design gate at Far Offset	1500 – 2800 ms
Operator Length	120ms
Predictive Gap	2 ms
White Noise	0.10%

5.10 First Pass Velocity Analysis

The first pass velocities were picked at 1km intervals using FSI's interactive velocity analysis program, MGIVA. The velocity interpretation was performed on both a semblance display and a 20 CDP stacked panel repeated with a suite of velocity functions in the range +/-25 % from a seed function. Neighbouring velocity functions were superimposed on the current location for easy recognition of velocity trends, and the semblance interpretation was assisted with an interval velocity curve. A CDP gather, interactive stack and velocity mapping tool were also used in the MGIVA analysis.

5.11 First Pass Residual Statics

FSI's surface-consistent residual statics package, NEBULA, computes statics based on summed cross-correlations at source and receiver locations. A pilot trace is constructed at each CDP using a weighted mix of stacked traces. Cross-correlations of the pilot trace with traces in the respective CDP gather, within a certain time window, are summed into buffers for each source and receiver station number. These summed correlations are then resampled and picked to derive a static value. Three iterations were performed using the parameters given below (the actual time windows employed were data dependent and altered slightly along each line).

Residual Statics Parameters	
Traces in pilot	9 traces
Time window	100-2800 ms
Maximum allowed shift	25 ms

5.12 Second Pass Velocity Analysis

The second pass velocity analysis was performed on gathers with first pass residuals statics applied. The velocity interpretation was performed on both a semblance display and a 20 CDP stacked panel repeated with a suite of velocity functions in the range +/-25 % from a seed function. Neighbouring velocity functions were superimposed on the current location for easy recognition of velocity trends, and the semblance interpretation was assisted with an interval velocity curve. A CDP gather, interactive stack and velocity mapping tool were also used in the MGIVA analysis. The first pass velocity field was used for the seed velocity functions, and analyses were performed at 1km intervals.

5.13 Second Pass Residual Statics

The second pass residual statics was run on CDP gathers that were NMO corrected using the second pass velocity field. Another two iterations were performed with similar parameters to the first pass residuals.

5.14 DMO

DMO operates on each offset plane at a time, after NMO, to make it look like one recorded at zero offset. The partial migration applied by DMO relocates dipping events in non-zero offset planes such that dispersed common mid-point gathers are restored to true CDP gathers and the events may then be stacked with the velocity appropriate for zero dip events. Log Stretch DMO employing the Hale algorithm was used here to achieve a partial pre stack migration with good amplitude preservation on steeply dipping data.

5.15 Third Pass Velocity Analysis

The third pass velocity analysis was performed on gathers with both passes of residuals statics and DMO applied. The velocity interpretation was performed on both a semblance display and a 20 CDP stacked panel repeated with a suite of velocity functions in the range +/-25 % from a seed function. Neighbouring velocity functions were superimposed on the current location for easy recognition of velocity trends, and the semblance interpretation was assisted with an interval velocity curve. A CDP gather, interactive stack and velocity mapping tool were also used in the MGIVA analysis. The second pass velocity field was used for the seed velocity functions, and analyses were performed at 0.5km intervals.

5.16 NMO Correction

Fourth order NMO corrections was performed using the third pass velocity functions.

5.17 Mute

An outer trace mute was applied to remove residual coherent noise on the outer traces and to reduce contamination from the effects of NMO stretch on the far offsets. The mute times as a function of offset are given below.

Outer Trace Mute Times	
Offset (m)	***Time (ms)***
50	0
200	200
440	300
650	480
2000	1500
3000	2000

5.18 Pre-Stack Scaling

The CDP gathers were scale to compensate for amplitude irregularities by scaling each trace using a 1000 ms AGC scale.

5.19 Statics Application to Sea Level

A final statics correction was applied to reference the data to mean sea level instead of surface. To avoid losing data shallower than the final datum, the data was bulk shifted down by 200 ms prior to this final static correction, producing a new time origin -200 ms.

5.20 CDP Trim Statics

Here we applied a residual statics program which applies static shifts to traces on a CDP-consistent basis, using cross-correlations of NMO-corrected CDP gather traces with a CDP pilot trace for each depth point. The Parameters employed were as follows:

CDP Residual Statics Parameters	
Traces in pilot	7 traces
Time window	300-4000 ms(nominal)
Maximum allowed shift	8 ms

5.21 Common Depth Point Stack

The traces within each CDP gather were summed using 1/N stack compensation.

5.22 Migration

A finite difference wave equation method was employed for migration. This method uses the technique of 'downward continuation' in order to map the reflectors to their true time position. This process effectively uses a model where the receivers are successfully positioned not at the surface, but deeper and deeper into the earth. At each new position, the 'lens' like effect of the previous layer is removed and the whole section beneath is seen without this distortion. The upward travelling energy which is detected can be considered to arise from sources placed along the various seismic horizons. The step size used here was 12 ms. The final stacking velocities were smoothed for the migration and slowed down at depth to the following percentages: 0 – 2000ms 100% 3000ms 90% 4000ms 85% and 5000ms 80%

CDP Residual Statics Parameters	
Time	Percentage of Velocity
0	100.00%
2000	100.00%
3000	90.00%
4000	85.00%
5000	80.00%

5.23 Band-Pass Filter

Unwanted noise that lay outside the frequency range of the desired reflection data was removed by the application of a series of time variant filters. A cosine-squared taper was employed between the pass band and cut-off frequencies. The filter parameters are listed below.

Band-Pass Filter Frequencies				
Time (ms)	***Lower Cut-Off Frequency (Hz)***	***Lower Pass Band Frequency (Hz)***	***Upper Pass Band Frequency (Hz)***	***Upper Cut-Off Frequency (Hz)***
800	10	15	80	90
1700	13	17	60	70
2500	10	14	50	60
3500	8	12	35	45

5.24 Post-Stack Scaling

A dual window AGC with window lengths of 1000 ms and 400 ms and 50% application.

5.25

6 Processing Sequence Diagrams

BMR Lines Processing Flow

Field Tape Transcription
↓
Data QC
↓
Geometry
↓
Gain Recovery
↓
Surface Consistent Amplitude Corrections
↓
Despike
↓
Time Frequency De-Noise
↓
Surface Wave Noise Attenuation
↓
Time-Frequency De-Noise (Two Passes)
↓
Surface Consistent Amplitude Corrections
↓
Deconvolution
↓
First Break Statics
↓
Velocity Analysis (First Pass)
↓
Residual Statics (First Pass)
↓
Velocity Analysis (Second Pass)
↓
Residual Statics (Second Pass)
↓
Spectral Balance
↓
NMO Correction
↓
Mute
↓
Pre-Stack Equalisation
↓
Floating Datum to Sea Level Statics
↓
CDP Trim Statics
↓
Stack
↓
Migration
↓
Random Noise Attenuation
↓
Bandpass Filter
↓
Scaling
↓
Tau-p Filter
↓
Equalisation

Industry Lines Processing Flow

Field Tape Transcription
↓
Data QC
↓
Geometry
↓
Zero to Minimum Phase Conversion
↓
Gain Recovery
↓
FK Filter
↓
Refraction Statics
↓
CDP Gather
↓
Deconvolution
↓
Velocity Analysis (First Pass)
↓
Residual Statics (First Pass)
↓
Velocity Analysis (Second Pass)
↓
Residual Statics (Second Pass)
↓
DMO
↓
Velocity Analysis (Third Pass)
↓
NMO Correction
↓
Mute
↓
Pre-Stack Equalisation
↓
Floating Datum to Sea Level Statics
↓
CDP Trim Statics
↓
Stack
↓
Migration
↓
Bandpass Filter
↓
Scaling

7 Final Displays

Displays of final stacks and migrations were produced in CGM+ format with horizontal and vertical scales of 1:62,500 (63.5 traces/inch) and 10 cm/s, respectively. The BMR lines were also displayed to 20 seconds at 2.54 cm/s.

8 Archives

The raw and final stacks together with the migration of each line were written onto DVD in SEGY format. A summary of the SEGY trace headers and archive listing are given below.

Summary of SEGY Headers		
Byte	***Type***	***Description***
17-20	I4	Shotpoint number x 100
21-24	I4	CDP number
41-44	I4	Elevation of receiver station closest to CDP
193-196	I4	CDP Easting
197-200	I4	CDP Northing
37-40	I4	Source Residual Static
99-100	I4	Receiver Residual Static
101-102	I2	Static of receiver station closest to CDP (post-stack SEGY only)
103-104	I2	Floating datum static
109-110	I2	Time of first sample

Archive Listing				
Tape Number	***Media***	***Lines***	***Description***	***Format***
882FS001DVD	DVD	All Lines	Raw Stack	SEGY
882FS001DVD	DVD	All Lines	Final Stack	SEGY
882FS001DVD	DVD	All Lines	Raw Migration	SEGY
882FS001DVD	DVD	All Lines	Migration	SEGY
882FS001DVD	DVD	All Lines	Final Stacking Velocities	Western
882CG002DVD	DVD	All Lines	Final Stack Display	CGM+
882CG002DVD	DVD	All Lines	Migration Display	CGM+
882PR005CD	CD	All Lines	Final Processing Report	PDF

9 Data Disposition

Data	*Date sent*	*Destination*
10 x 3590 cartridges containig field data. tape # PE037721, PE037912, PE038124, PE038929, PE039031, PE039113, PE039115, PE039256, PE039257, PE039490 4 x 3490 cartridges containing Field Data, Tape # PE39700 to PE39703 2 x 3590 cartridges containing Field Data for Halladale SS Tape # F0398694 & Stoneyford Tape # F0220426 (Access Tape #s) 1 x DVD Containing Field Support Data for Otway Onshore 1 x DVD Containing Field Support Data 1 x DVD containing BMR92 Regional lines SEGY Data 1 x DVD containing BMR- Otway regional lines Seis-sectionimage files (CGM) 2 x DVDs containing SEGY Shot Ordered Data 1 x DVD containing Ancillary field data.	4 Jun 2010	Department of Primary Industries Victoria Level 9, 55 Collins Street Melbourne VIC 3000 Australia Attn: Robert Harms

10 Conclusion

The 2009 Otway basin reprocessing project proved to be a real mixture of data. The 1992 BMR lines were dynamite, recorded to 20 seconds, and more regional with a 50m group interval and 300m or 600m shot intervals. This proved to be quite a different data set from the other high fold smaller group interval data that we have been refering to as the “Industry lines”. There were to a certain extend also different objectives / influences imposed on them. Maher Megallaa was interested in what would be of interest to oil companies that might take up some of the acreage. This resulted in some consultation with Dolores Connolly at Essential on parameters of the industry lines. The more regional 20 second recording for the 1992 lines was of more interest to GA in Canberra.

Whilst we started out looking at both datasets together, over the course of time the processing began to diverge. There were some things to sort out early – getting all the coordinates in GDA94 projection for instance. Once this was achieved, the processing proceeded fairly well on the industry lines. Unfortunately the BMR lines proved more challenging. We ended up mostly completing the industry lines before going back to take a fresh look at the BMR lines. The BMR lines were then retested with a new set of parameters found that were better suited to the low fold data.

Personnel

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