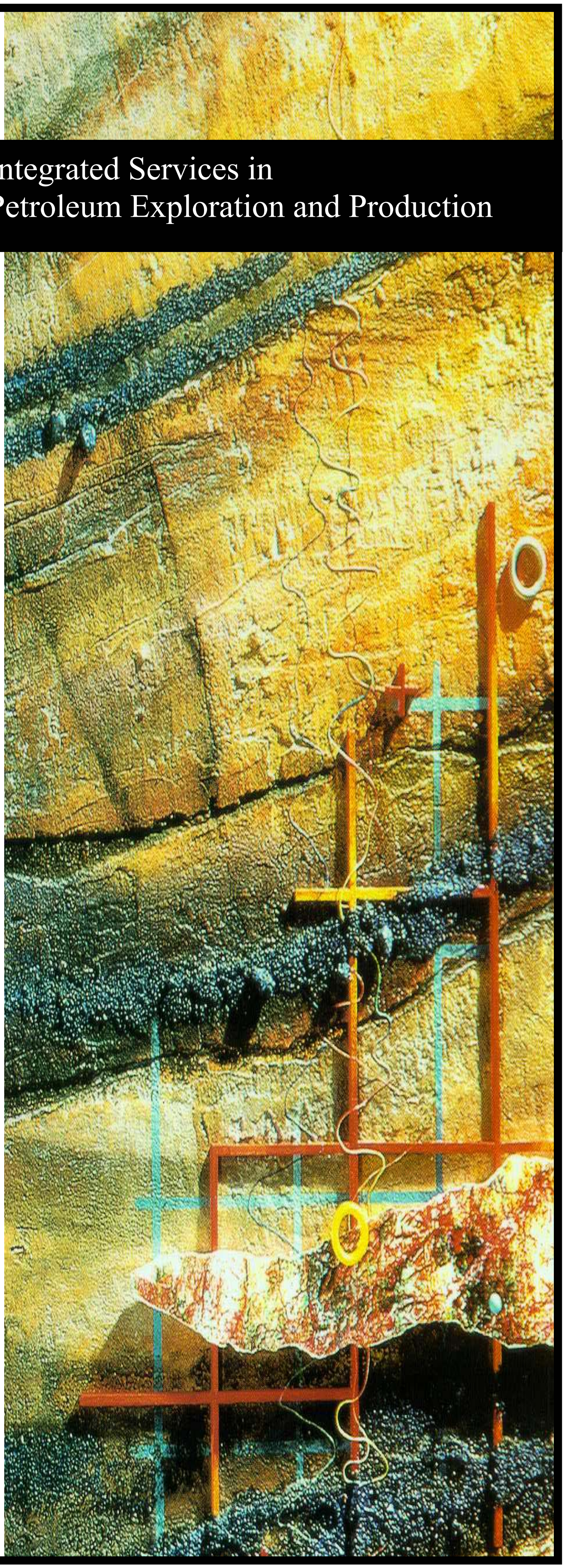
Integrated Services in
Petroleum Exploration and Production



Processing Report

for

Seismic Australia

Project:

Otway-Sorell 2D
Acquisition 2002

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1.0 INTRODUCTION

The Otway-Sorell 2D Acquisition 2002 survey was acquired in conjunction with an exclusive program and consisted of 42 lines totalling 2034.3km. The survey was acquired between 1st November and 18th December. This data was acquired for Woodside Energy Ltd and partners in and around petroleum exploration permits Vic/P43 and T/30P in the Otway and Sorell basins. Seismic data processing was targeted to provide the best lateral and vertical resolution into fault blocks associated with Jurassic to Mid-Cretaceous rifting. Close attention was paid to amplitude integrity and preserving the character of seismic reflection information. Acquisition was undertaken by the Fugro-Geoteam AS vessel MV Geo Arctic and data processing was performed on the pre-stack data at Robertson Research Australia's office in Perth

1.1 PERSONNEL

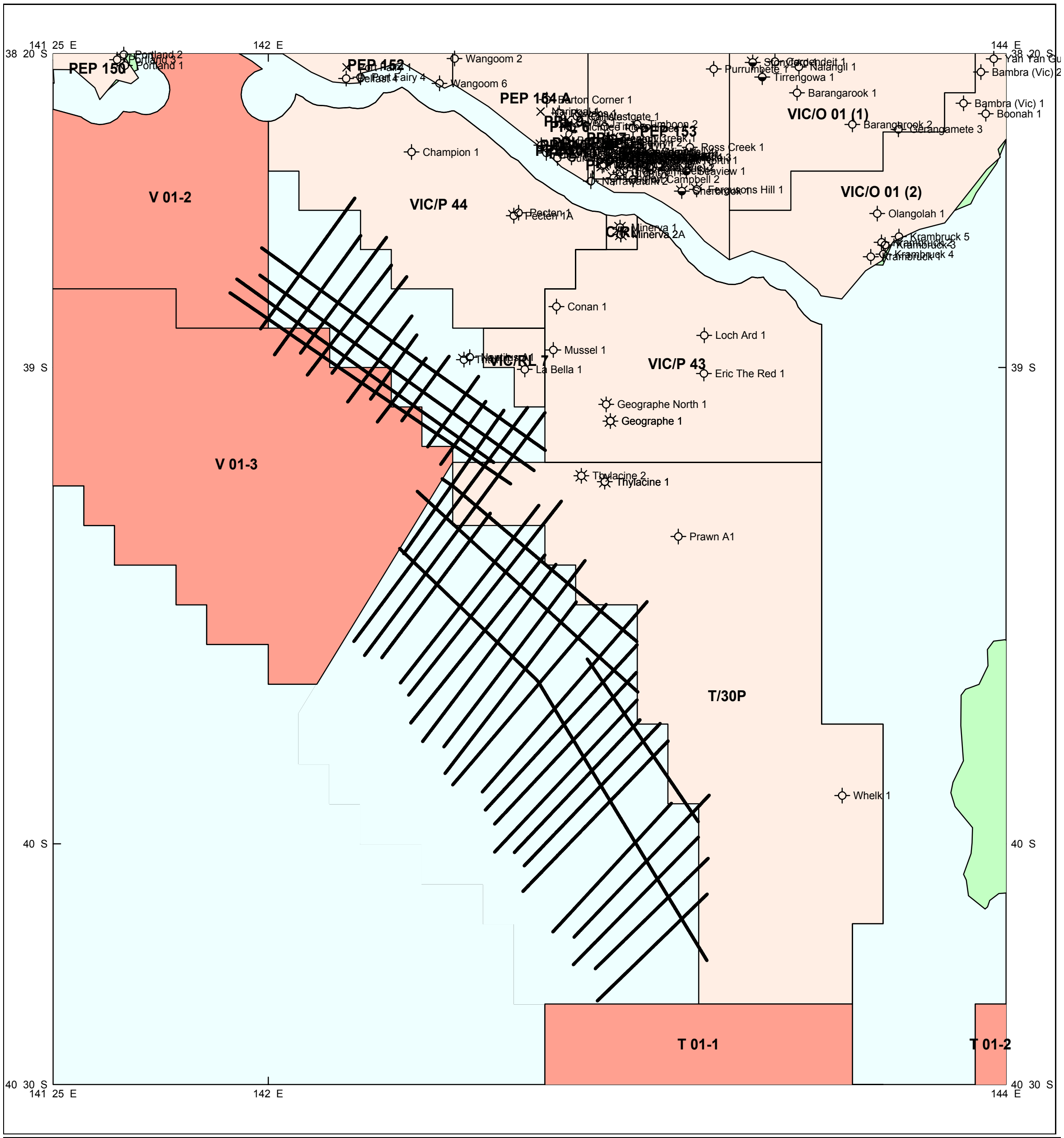
Robertson Research Australia.

Kelly Beauglehole	Processing Manager
Simon Stewart	Senior Geophysicist
Gail Dias	Geophysicist
Francis Foo	Geophysicist
Winnie Killick	Senior Geophysicist

Seismic Australia

Jan Ostby	Geophysical Projects Manager
Michael Davidson	Geophysicist
Robin Lowe	Data Administrator

1.2 SURVEY MAP


141 25 E
142 E
144 E
38 20 S
39 S
40 S
40 30 S
PEP 150
Portland 2
Portland 1
PEP 152
Belfast 4
Port Fairy 4
Wangoom 2
Wangoom 6
PEP 154 A
Barton Corner 1
Champion 1
Ross Creek 1
Purrumbete 1
Nalangil 1
Tirrengowa 1
Barangarook 1
VIC/O 01 (1)
Barangarook 2
Gerangamete 3
Bambra (Vic) 2
Bambra (Vic) 1
Boonah 1
Fergusons Hill 1
VIC/O 01 (2)
Olangolah 1
Krambruck 5
Krambruck 3
Krambruck 4
V 01-2
VIC/P 44
Pecten 1A
Minerva 1
Minerva 2A
Conan 1
Loch Ard 1
Mussel 1
VIC/RL 7
La Bella 1
VIC/P 43
Eric The Red 1
Geographe North 1
Geographe 1
V 01-3
Thylacine 2
Thylacine 1
Prawn A1
T/30P
Whelk 1
T 01-1
T 01-2

2.0 PARAMETER TESTING

Extensive testing was performed to determine the optimum processing sequence. Testing procedures were conducted on selected survey, line DS02-212, and were performed by Kelly Beauglehole and Simon Stewart of Robertson Research Australia, with significant input from Jan Ostby and Michael Davidson of Seismic Australia. A processing sequence was established for the area with parameters varied to account for changing water depth and survey vintage geometry.

Parameter selection was made with consideration for the processing objective of improving the imaging of complex structural patterns in particular, tilted fault blocks beneath the edge of the Continental Margin. All components of the processing sequence were reviewed for their efficacy in the application to the processing objectives, and to the optimisation of their parameters. Particular attention was focused on the parameterisation of processes such a signature deconvolution, multiple attenuation and predictive deconvolution.

Test	Format			
	Shot Record	CDP Gather	STACK	Velocity Analysis
Shot record displays	✓			
Gain recovery: Amplitude decay analysis	✓			
Gain recovery: exponential gain	✓			
F-K filter (shot domain, various cuts)	✓		✓	
F-K filter with NMO (shot domain, various cuts)	✓		✓	
F-K filter (shot and receiver domain)	✓		✓	
F-K filter with NMO (shot and receiver domain)	✓		✓	
Signature deconvolution	✓		✓	
Multiple attenuation: F-K method		✓	✓	✓
Multiple attenuation: F-X method		✓	✓	✓
Multiple attenuation: Radon method		✓	✓	✓
Predictive deconvolution (before stack)			✓	
Fourth order NMO correction		✓	✓	
Outer and inner trace mutes		✓	✓	
Predictive deconvolution (after stack)			✓	
Migration velocity slowing			✓	
Bandpass filter and Post stack scaling			✓	
Noise attenuation			✓	

3.0 COMMENTS & CONCLUSION

Processing the Otway-Sorell data set yielded good data quality despite variations in water depths and geology along the lines.

Due to the variations in water depths and geology covered in this survey, special care was taken with spatially varying parameters according to water depths. Designature design windows, mutes, pre-stack predictive deconvolution design and application windows, dip limits and bandpass filters were adjusted according to water depths. Radon demultiple and in the case of some lines a residual radon demultiple was applied which eliminated strong multiples below the shelf.

The use of pre-stack time migration gave a better definition of steep dips surrounding the structure of complex geology.

4.0 GENERAL PROCESSING SEQUENCE

TRANSCRIPTION
|
RESAMPLE (from 2 ms to 4 ms)
|
BULK STATIC CORRECTION (gun and recording delays)
|
GAIN RECOVERY
|
F-K FILTER (shot and receiver domains) (with NMO correction)
|
SIGNATURE DECONVOLUTION
|
CDP GATHER
|
PRELIMINARY VELOCITY ANALYSIS (4km intervals)
|
FIRST PASS VELOCITY ANALYSIS (2 km intervals)
|
RADON MULTIPLE ATTENUATION
|
FX MULTIPLE ATTENUATION
|
PREDICTIVE DECONVOLUTION
|
DMO
|
SECOND PASS VELOCITY ANALYSIS (1 km intervals)
|
NMO CORRECTION & MUTES
|
PRE-STACK SCALING
|
CDP STACK
|
GUN & CABLE STATIC CORRECTIONS
|
MINIMUM TO ZERO PHASE CONVERSION
|
MIGRATION WITH PRE-MIGRATION SCALING
|
TAU-P FILTER
|
BANDPASS FILTER
|
POST STACK SCALING

5.0 PROCESSING TECHNIQUES

A brief description of each of the processes used in the processing sequence follows:

The table below shows the processing length (in seconds) used.
All data were processed at 4ms.

Survey	Processing Record Length
DS02	12.0
OR01	8.0

Please note that parameters are spatially varied according to water depths for processes such as signature deconvolution, predictive deconvolution, mutes, bandpass filters and percentages of reduction in migration velocity functions.

Parameters shown in this section for these processes are applicable for the seafloor time at 100 milliseconds.

5.1 TRANSCRIPTION

Field data were converted to Robertson's internal format for processing. RRA's internal processing format is trace sequential, with samples in 32 bit IEEE floating point. At intermediate processing stages the data is stored on magnetic tape in sixteen-bit integer with a gain ranging scalar for each trace.

Survey	Field tape format
DS02	SEGD
OR01	SEGD

5.2 GAIN RECOVERY

A gain function was applied to the data set to compensate for amplitude decay. The function applied used 40 log (t) compensation for inelastic attenuation and spherical divergence losses. (t = two way travel time in milliseconds).

5.3 RESAMPLE

Data were resampled from 2 ms to 4 ms sample rate. Resampling is performed in the frequency domain and effectively applies a "brick-wall" zero phase anti-alias filter at Nyquist.

5.4 LOW CUT FILER

A low cut filter of 6 Hz at 12 dB/oct was applied to data.

5.5 SWELL NOISE ATTENUATION

Swell noise attenuation was achieved by normalization of the amplitude spectra of 'swell' traces, in the low frequency band which is typically boosted by swell noise. Swell traces were selected by examination of the amplitude spectra of traces in the frequency range 32 - 94 Hz, then flagging the traces exhibiting highest mean amplitude. A scalar is computed to normalise frequencies of the swell traces to the mean of the non-swell traces. This scalar is applied fully from 0 - 16 Hz, and tapered to no scaling at 32 Hz and above.

5.6 MULTI CHANNEL FILTER (SHOT & RECEIVER DOMAIN)

A symmetrical "velocity" filter was designed in the F-K domain to preserve the primary reflection signal and to discriminate against coherent dipping noise trains. The filter employs a full cosine-squared taper from k = 0 to the velocity intercept at each frequency, beyond the velocity cut, the attenuation is greater than 40 dB. The input data was conditioned with a 300 ms AGC, and the scalars preserved for removal subsequent to the application of the F-K filter. A cut off velocity of 1750 m/sec was used. NMO was applied before, and removed after the application of the filter. The function used for NMO was derived from first pass velocities.

5.7 RECEIVER ARRAY SIMULATION

Receiver array simulation was applied as shown below. A time varient trace mix was performed down NMO curves using first pass velocities. The data were mixed to establish the desired output illustrated in the following table:

Time (ms)	Trace weights
0	0-1-2-1-0
3000	0-1-2-1-0
7000	1-2-3-2-1

5.8 SIGNATURE DECONVOLUTION

Robertson Research's signature deconvolution routine is based on Taner's method for estimating a minimum phase signature from a mixed phase record. The method involves the application of an inverse exponential gain to the data to force the essentially mixed phase data to minimum phase before the Wiener double inverse method (which presumes minimum phase input) is used to derive the minimum phase source signature. However, as this gain will affect the shape of the derived wavelet, it is then removed before deconvolving with the original un-gained data.

A data derived 300 ms wavelet, designed using all offsets was chosen for the sequence. An exponential gain function of -15 dB/sec was applied and removed in the wavelet estimation in accordance with Taner's method of minimum phase conditioning. The output minimum phase wavelets were shaped to a bandwidth of 6-80 Hz with filter slopes of 18 dB/oct for the low-cut and 48 dB/oct for the high-cut.

Offsets (m)	Design windows
500	500-3500 ms
4122	3000-5600 ms

5.9 CDP GATHER

The shot records were sorted into common depth point gathers, with the maximum fold and spacing of the gathers shown below:

Survey	Fold	CDP Interval (m)
DS02	93	12.5
OR01	140	12.5

5.10 FIRST PASS VELOCITY ANALYSIS

First pass velocities were determined using Robertson's interactive velocity analyses program "MGIVA" on a workstation. Each analysis comprised a 30 CDP stacked panel, repeated 15 times, with a different NMO velocity function used each time plus a central CDP gather. The velocity function ranged at +/-0 %, +/-5%, +/-10%, +/-15%, +/-20%, +/-26%, +/-32%, and +40% from a central velocity function which was the interpolated value of the regional velocity functions based on water depths. Analyses were performed at 2 km intervals. The determined velocity functions were then used for NMO correction for FK filtering, radon demultiple and as the central functions for the second velocity analyses.

5.11 RADON MULTIPLE ATTENUATION

Attenuation of multiples was achieved using the parabolic Radon transform method. Normal moveout corrections were performed using first pass velocities. The CDP gathers were then transformed into the Tau-P domain using 277 p values between maximum offset delta t values of -1200 ms and +7000 ms. In the Tau-p domain the primaries were muted out, leaving the multiple energy to be transformed back into the T-X domain before subtraction from the original CDP gather.

Mutes used were as follows:

Delta-T	Start and End times in ms
-1200	0-8304
110	0-8304
120	0-4700
158	0-3500
234	0-2800
364	0-2200
494	0-1875

775	0-1340
1146	0-875
1407	0-600
7000	0-600

The onset of multiple modelling and subtraction was varied with respect to seafloor depth, as described in the table below;

Seafloor twt	Modelling and subtraction commencement time
200	600 ms
1000	1650 ms
2000	2700 ms
3000	3750 ms
4000	4750 ms

A 200ms AGC was applied prior to, and removed after, multiple attenuation.

5.12 PREDICTIVE DECONVOLUTION

Predictive deconvolution was utilised to attenuate any remnant short period reverberations. Typically, two design and application windows were used, with white noise of 0.1%. The parameters used are tabulated below:

Windows	**1**	**2**
Operator Lengths	240 ms	320 ms
Gaps	32	48
Near trace Design windows	300-3000 ms	2000-6000 ms
Far trace Design windows	3800-6300	3700-7000
Near trace Application start times	0 ms	2500 ms
Far trace Application start times	0 ms	3400 ms

5.13 DIP MOVEOUT

Robertson Research's DMO program applies 2D convolution operators to map the data accurately from non-zero to zero offset in the manner described by Deregowski and Rocca (1981). The convolution is conveniently implemented by the summation method, and applied to traces in common offset order. This procedure achieves the desirable partial migration, whereby traces with common mid-points, but different source-receiver offsets, relate to the same sub-surface locations after DMO, for all dips. After DMO all reflection events appear, for the purposes of normal moveout correction, to have originated from horizontal reflectors. Therefore, optimum stack response for all reflector dips can be obtained from conventional moveout corrections based on velocity functions undistorted by reflector dips.

93 common offset planes used in DMO for DS02 and OR01.

5.14 PRE-STACK TIME MIGRATION

Offsets were regularised and partially stacked to form 93 common offset planes. Migration was performed in the frequency-wavenumber domain on the common offset planes using Stolt's F-K method with a constant velocity of 1500 m/s.

5.15 SECOND PASS VELOCITY ANALYSIS

Second pass velocities were determined using Robertson's interactive velocity analyses program "MGIVA" on a workstation. Each analysis comprised a 30 CDP stacked panel, repeated 9 times, with a different NMO velocity function used each time plus a central CDP gather. The velocity function ranged at +/-3 %, +/-6%, +/-10%, +/-16%, +/-20% and +25% increments from a central velocity function which was the interpolated value of the first pass velocity functions. Analyses were performed at 1 km intervals.

5.16 NMO CORRECTION

Fourth order NMO correction was performed using the final picked velocity functions.

5.17 OUTER TRACE MUTE

A post-NMO outer trace mute was applied for two main reasons :

- to remove any coherent noise on the outer traces and
- to reduce contamination from the effect of NMO stretch on the far offsets.

Mute application was varied on sea floor times. For a two way time of 100ms the following mute was applied.

Offset distance (m)	*Application times (ms)*
280	0
330	200
640	600
2400	1775
4200	2975
6150	4300
7150	4900

5.18 PRE-STACK SCALING

A dual window, time variant AGC method was used for pre stack scaling. The negative effects normally associated with AGC are avoided by employing two different length windows to determine the amplitude model (using the minimum of the two mean amplitudes determined at each sample), then conditioning the model by a weighted mix with the amplitude model derived from a single window per trace.

Parameter summary:

Survey: DS02 and OR01
Window lengths of 1200 ms and 400 ms
Equalization applied: 60
Short window stopped 8000 ms

5.19 INNER TRACE MUTE

A post NMO inner trace mute was applied to help remove remnant multiple energy still apparent on the inner traces following Radon multiple attenuation:

Mute application was varied on sea floor times. For a two way time of 100ms the following mute was applied.

Offset distance (m)	*Application times (ms)*
150	900-tmax
650	1800-tmax
800	2100-tmax

5.20 COMMON DEPTH POINT STACK

The traces within each common depth point gather were summed using 1/root(N) stack compensation. The maximum fold produced and output CDP interval processed are tabulated below:

Survey	**Fold**	**CDP Interval (m)**
DS02	93	12.5
OR01	93	12.5

5.21 STATICS

A static compensation for gun and cable depths was applied. The static value applied was calculated using average gun and cable depths supplied in the observer's reports and/or original processed sections. Values with a variation of +/-1 ms, are tabulated here:

Survey	**Static Correction applied (ms)**
DS02	12
OR01	11

5.22 INVERSE MIGRATION

FK migration was used to do the forward modelling, which was performed using a constant velocity of 1500 m/s to demigrate the data set.

5.23 ZERO PHASE CONVERSION

Data were converted from minimum phase to zero phase. The spectral estimate was made using the Wiener-Levinson double inverse method.

5.24 WAVE EQUATION MIGRATION

A steep dip second order 65-degree finite difference migration scheme was used. The migration model velocities were based on laterally smoothed stacking velocities with the following percentages of reduction.

Time (ms)	*% of velocity*
0	100
5000	100
7000	90
9000	80
tmax	65

5.25 BAND PASS FILTER

Unwanted noise that lay outside the frequency range of the desired reflection and diffraction data was removed by the application of a series of zero phase time variant filters. These filters are defined by a frequency trapezoid, with cosine squared taper between the end frequency pairs, F1, F2 and F3, F4. There is a unit response in the range F2 to F3 Hz, and full attenuation for frequencies lower than F1 and higher than F4.

Filter application was varied on sea floor times. For a two way time of 100ms the following filter was applied.

Parameter summary:

Application times (ms)	Frequency limits (Hz)
1200	4/8-60/70
2000	4/8-40/70
3000	4/6-30/40
5000	3/5-20/30
7000	3/5-15/25

5.26 POST STACK SCALING

A dual window, time variant AGC method was used for post stack scaling. The negative effects normally associated with AGC are avoided by employing two different length windows to determine the amplitude model (using the minimum of the two mean amplitudes determined at each sample), then conditioning the model by a weighted mix with the amplitude model derived from a single window per trace.

Parameter summary:

Survey: DS02 and OR01
Window lengths of 1200 ms and 400 ms
Equalization applied: 50
Short window stopped 8000 ms

5.27 TAU-P FILTER

Tau-p filtering provides an effective time variant dip filter, and enhances coherent events while discriminating against random noise. Semblance enhancement of the data in the Tau-p domain, together with editing of sections of the Tau-p plane, permits retention of data within specified dip limits at any time and enhancement of these dips after transformation back into x - t space.

Dip limits used were:

ms/trace	*Time (ms)*
+/-5	1000
+/-4	3000
+/-2	6500

Time variant percentages of addback used for both surveys were:

Time (ms)	*% Addback (unfiltered)*
1000	70
3000	60
Tmax	60

5.28 TRACE MIX

A 1:2:1 trace mix was preformed on the data set prior to archiving.

5.27 PHASE ROTATION

All data sets were phase rotated 180 degrees for SEG negative polarity.

6.0 SURVEY DESCRIPTION

The following table relates the survey and the sections for the corresponding processing and acquisition information.

Survey Information

Survey	Processing Parameters	Acquisition Parameters
DS02	Section 7.1	Section 8.1
OR01	Section 7.2	Section 8.2

7.0 PROCESSING SEQUENCE

7.1 Survey: DS02 and OR01

TRANSCRIPTION
|
GAIN RECOVERY/RESAMPLE
|
LOW CUT FILTER
|
SWELL NOISE ATTENUATION
|
F-K FILTER (shot and receiver domains) (with NMO correction)
|
TRACE DECIMATION
|
SIGNATURE DECONVOLUTION
|
CDP GATHER
|
FIRST PASS VELOCITY ANALYSIS (2 km intervals)
|
RADON MULTIPLE ATTENUATION
|
PREDICTIVE DECONVOLUTION
|
DMO
|
PRE-STACK TIME MIGRATION
|
SECOND PASS VELOCITY ANALYSIS (1 km intervals)
|
NMO CORRECTION & MUTES
|
PRE-STACK SCALING
|
CDP STACK
|
GUN & CABLE STATIC CORRECTIONS
|
FORWARD FK MIGRATION
|
MINIMUM TO ZERO PHASE CONVERSION
|
MIGRATION WITH PRE-MIGRATION SCALING
|
BANDPASS FILTER
|
POST STACK SCALING
|
TAU-P FILTER
|
TRACE MIX
|
PHASE ROTATION 180 DEGREES

8.0 ACQUISITION PARAMETERS

8.1 Survey: DS02

Description	**DS02 (10 Seconds)**
Data recorded by:	FUGRO-GEOTEAM
Date recorded:	2001
Vessel:	R/V Geo Artic
Seismic source:-	
Type:	Airgun array
Pressure/Volume:	2157 psi
Depth:	6 metres (average)
Shot interval:	37.5 metres
Recording system:-	
Format:	SEGD-8058
Record length:	10 seconds
Sample interval:	2ms
Filters:Low	4 Hz@18dB/Oct.
:High	206Hz@265dB/Oct.
Streamer:-	
Streamer length:	7130.5 metres
Streamer depth:	10 metres (average)
Number of groups:	560
Near group number:	1
Group interval:	12.5 metres
Near group offset:	146 metres (average)
SP annotation:	CMP Position

8.2 Survey: OR01

Description	**OR01 (8 Seconds)**

Data recorded by:	GEOTEAM-FUGRO
Date recorded:	2001
Vessel:	R/V Geo Artic
Seismic source:-	
Type:	Airgun array
Pressure/Volume:	2157 psi
Depth:	6 metres (average)
Shot interval:	25 metres
Recording system:-	
Format:	SEGD - 8058
Record length:	8 seconds
Sample interval:	2ms
Filters:Low	4 Hz@18dB/Oct.
:High	206Hz@265dB/Oct.
Streamer:-	
Streamer length:	7130.5 metres
Streamer depth:	10 metres (average)
Number of groups:	560
Near group number:	1
Group interval:	12.5 metres
Near group offset:	146 metres (average)
SP annotation:	CMP Position

APPENDIX A

Line Listing

Sqn	Line Name	SP Range	CDP Range	Km
Survey : DS02				
1	DS02-100	101-2284	1-6829	81.900
2	DS02-101	101-2209	1-6604	79.088
3	DS02-102	101-2077	1-6208	74.138
4	DS02-103	101-2226	1-6655	79.725
5	DS02-105	101-2471	1-5026	59.280
6	DS02-107_A	101-1956	1-5845	69.600
7	DS02-108_A	100-1320	1-3940	45.788
8	DS02-110_A	101-3308	1-9901	120.300
9	DS02-200	101-1113	1-3316	37.987
10	DS02-201	101-1024	1-3049	34.650
11	DS02-202	101-1006	1-2995	33.975
12	DS02-203	101-968	1-2881	32.550
13	DS02-204	101-866	1-2575	28.725
14	DS02-205	101-773	1-2296	25.238
15	DS02-206	101-597	1-1768	18.637
16	DS02-207	101-603	1-1786	18.863
17	DS02-208	101-601	1-1780	18.788
18	DS02-209A	101-644	1-1909	20.400
19	DS02-210	101-585	1-1732	18.188
20	DS02-211	101-1193	1-3556	40.987
21	DS02-212	101-1917	1-5728	68.138
22	DS02-213	101-1985	1-5932	70.688
23	DS02-214_A	101-1801	1-3658	42.180
24	DS02-215	101-1501	1-4480	52.538
25	DS02-216	101-1636	1-4885	57.600
26	DS02-217	639-2643	1362-5364	50.130
27	DS02-218	101-1477	1-4408	51.638
28	DS02-219	101-1552	1-4633	54.450
29	DS02-220	101-1440	1-4297	50.250
30	DS02-221	101-1570	1-4687	55.125
31	DS02-222	101-1661	1-4960	58.538
32	DS02-223	101-2186	1-4456	52.150
33	DS02-224	101-2028	1-4140	48.200
34	DS02-225	101-1391	1-4150	48.413
35	DS02-226	101-1796	1-3676	42.400
36	DS02-227	101-1925	1-3934	45.630
37	DS02-228	1720-3657	3524-7392	48.480
38	DS02-229	101-1180	1-3517	40.500
39	DS02-230	101-1310	1-3907	45.375
40	DS02-231	101-1201	1-3580	41.288
41	DS02-232	101-1073	1-3196	36.487
42	DS02-233	101-1043	1-3106	35.362