



Integrated Services in
Petroleum Exploration and Production

**Processing Report
for
Seismic Australia**

**Project:
Otway-Sorell
Albatross
2D Exclusive Acquisition 2002**

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1.0 INTRODUCTION

The Otway-Sorell Albatross 2D Exclusive Acquisition 2002 survey was acquired between 1st November and 18th December 2001 and consisted of 43 lines totalling 1882.3km. 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 targetted 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 at Robertson Research Australia's office in Perth

1.1 PERSONNEL

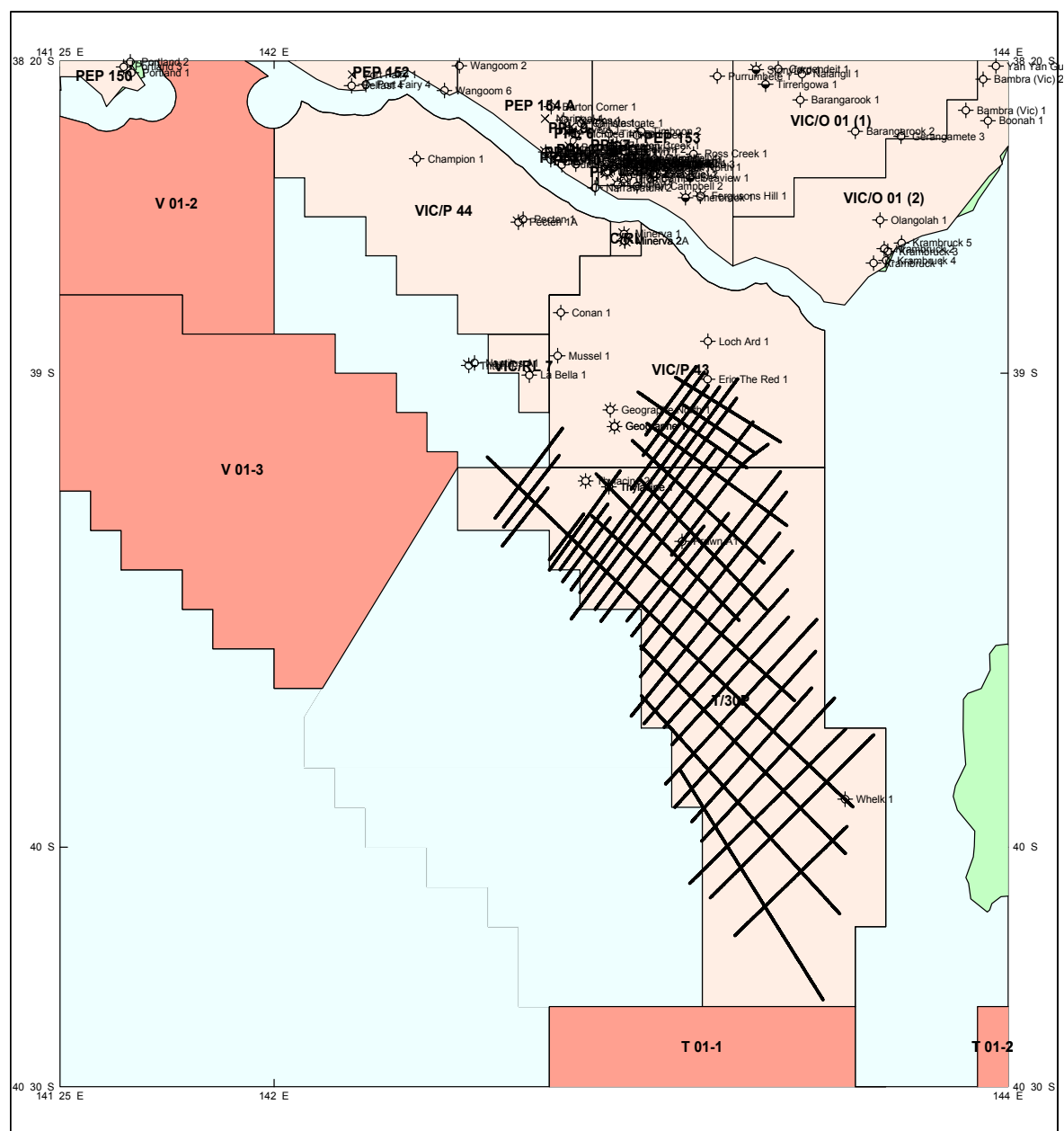
Robertson Research Australia.

Kelly Beaglehole	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



Extensive testing was performed to determine the optimum processing sequence. Testing procedures were conducted on selected survey, line OR01-17, and were performed by Kelly Beaglehole 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.

Application of noise attenuation post migration resulted in a cleaner more coherent section but may have caused some loss of higher frequencies in the data. Tests were conducted on line OR01-09 with and without noise attenuation and it was concluded that any losses in Frequency in the target zone were minimal.

Absorption of Frequencies due to the Earth (Q) were tested for using inverse Q. Although the inverse Q sections showed improved overall frequency content. It was not applied to the final migrated product.

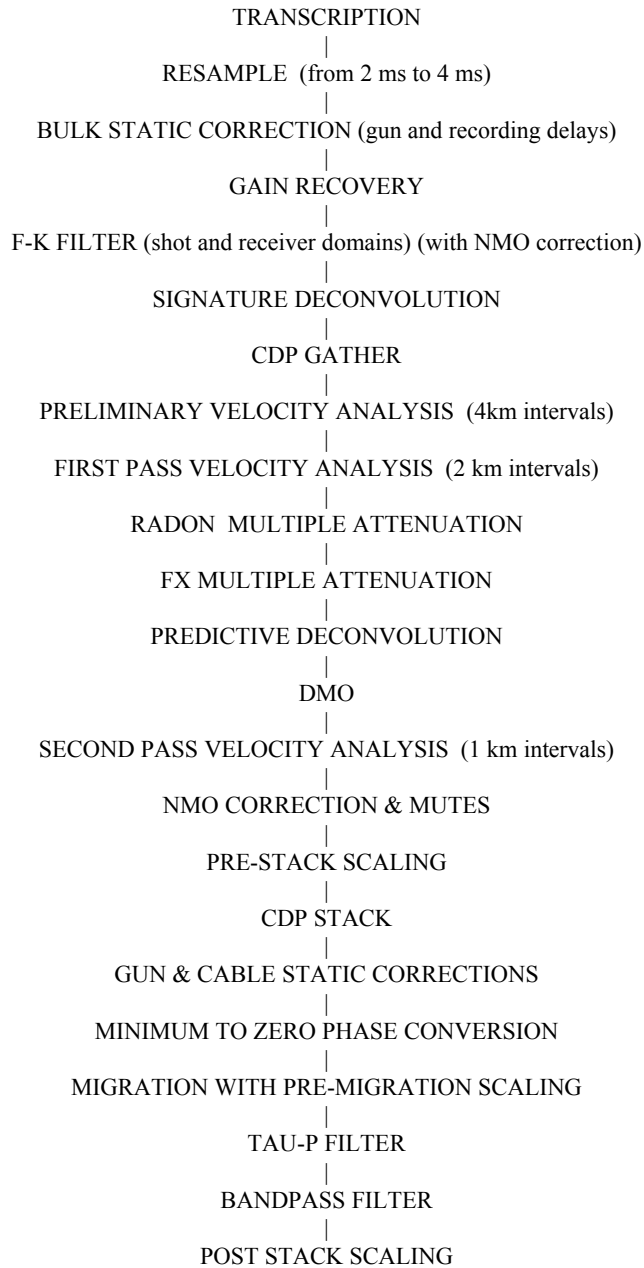
Some evidence of first and possibly second bounce direct water bottom multiples are present in the shallow water data. The primary technique used for removing multiples was radon demultiple with an application time of 500ms below the seafloor. Hence, in the shallow water the first and second bounce multiples are relying solely on prestack deconvolution and stack for attenuation. Improved attenuation of these multiples could be achieved using an FK demultiple in the shallow section, Tau-P deconvolution or wave equation demultiple.

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



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
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
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 FILTER**

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 variant 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)
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 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.

<i>Offset distance (m)</i>	<i>Application times (ms)</i>
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: 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.

<i>Offset distance (m)</i>	<i>Application times (ms)</i>
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)
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)
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.

<i>Time (ms)</i>	<i>% of velocity</i>
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: 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:

<i>ms/trace</i>	<i>Time (ms)</i>
+/-5	1000
+/-4	3000
+/-2	6500

Time variant percentages of addback used for both surveys were:

<i>Time (ms)</i>	<i>% Addback (unfiltered)</i>
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.

5.29 PHASE ROTATION

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

5.30 ANGLE STACKS

Input data for angle stack generation was taken from step 5.14, pre-stack migrated gathers. The original t squared gain function was removed from the data and replaced with a Spherical Divergence correction using the Ursin approximation. The final velocity field was gridded and smoothed to generate the velocity field for the angle mutes. From testing, a 0 to 40 degree angle mute was selected and applied to the gathers after 4th order NMO correction had been applied to the data. To trim off over stretched data in the shallow section and to remove residual multiples on the inner offset, the angle mute was combined with an offset - time mute. The data was then split into near and far offset groups determined by the midpoint between live data samples after muting. A $1/n$ scaling function was used when producing the near and far angle stacks.

The post stack sequence through steps 5.21 to 5.25 was applied to the data, along with a residual dB scaling function and the production zero phasing filter.

In addition to the angle stacks, average sine squared theta calculations were generated for both the near and far offset datasets.

6.0 SURVEY DESCRIPTION

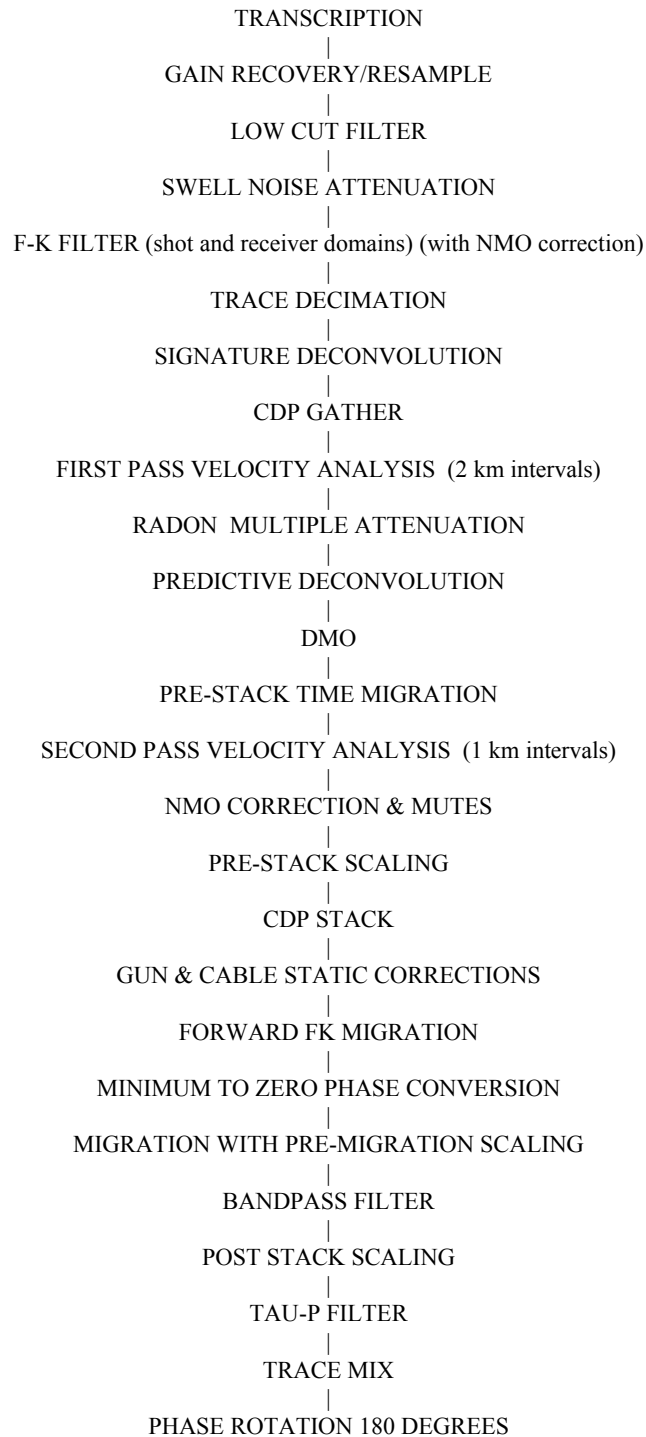
The following table relates the survey and the sections for the corresponding processing and acquisition information.

Survey Information

Survey	Processing Parameters	Acquisition Parameters
OR01	Section 7.1	Section 8.1

7.0 PROCESSING SEQUENCE

7.1 Survey: OR01



8.0 ACQUISITION PARAMETERS

8.1 Survey: OR01

<i>Description</i>	OR01 (8 Seconds)
<i>Data recorded by:</i>	FUGRO-GEOTEAM
<i>Date recorded:</i>	2001
<i>Vessel:</i>	R/V Geo Artic
<i>Seismic source:-</i>	
<i>Type:</i>	Airgun array
<i>Pressure/Volume:</i>	2157 psi
<i>Depth:</i>	6 metres (average)
<i>Shot interval:</i>	25 metres
<i>Recording system:-</i>	
<i>Format:</i>	SEGD - 8058
<i>Record length:</i>	8 seconds
<i>Sample interval:</i>	2ms
<i>Filters:Low</i>	4 Hz@18dB/Oct.
<i>:High</i>	206Hz@265dB/Oct.
<i>Streamer:-</i>	
<i>Streamer length:</i>	7130.5 metres
<i>Streamer depth:</i>	10 metres (average)
<i>Number of groups:</i>	560
<i>Near group number:</i>	1
<i>Group interval:</i>	12.5 metres
<i>Near group offset:</i>	146 metres (average)
<i>SP annotation:</i>	CMP Position

APPENDIX A

Line Listing

Sqn	Line Name	SP Range	CDP Range	Km
Survey : OR01				
1	OR01-02	101-1731	1-3540	40.775
2	OR01-03	101-1249	1-2576	28.725
3	OR01-04	101-1794	1-3666	42.350
4	OR01-05	101-866	1-1810	19.150
5	OR01-06	101-1815	1-3708	42.875
6	OR01-07	101-852	1-1782	18.800
7	OR01-08	101-2026	1-4130	48.150
8	OR01-09	101-2470	1-5018	59.250
9	OR01-10	101-2677	1-5432	64.425
10	OR01-11	101-2603	1-5284	62.575
11	OR01-12_A	101-4843	1-9764	118.575
12	OR01-13	101-2697	1-5472	64.925
13	OR01-15	101-1991	1-4060	47.275
14	OR01-16_A	101-2849	1-5776	68.725
15	OR01-17	101-2460	1-4998	59.000
16	OR01-18	101-2613	1-5304	62.825
17	OR01-19A	101-1491	1-3060	34.775
18	OR01-19B	101-1249	1-2576	28.725
19	OR01-21	101-1567	1-3212	36.675
20	OR01-27_A	101-2310	1-4698	55.250
21	OR01-35A	101-2191	1-4460	52.275
22	OR01-37	101-2065	1-4208	49.125
23	OR01-39	101-1779	1-3636	41.975
24	OR01-41	101-1924	1-3926	45.600
25	OR01-43	101-2147	1-4372	51.175
26	OR01-45	101-2251	1-4580	53.775
27	OR01-47	101-1557	1-3192	36.425
28	OR01-W03	101-957	1-1992	21.425
29	OR01-W05	101-798	1-1674	17.450
30	OR01-01	101-639	1-1362	13.475
31	OR01-14	2471-5193	5026-10464	68.075
32	OR01-23	2186-4305	4456-8688	53.000
33	OR01-25	2028-4237	4140-8552	55.250
34	OR01-29	1796-3931	3676-7940	53.400
35	OR01-31	1925-3657	3934-7392	43.325
36	OR01-33	101-1720	1-3524	40.500
37	ORV01-03	101-904	1-1886	20.100
38	ORV01-05	101-1077	1-2232	24.425
39	ORV01-06	101-1353	1-2784	31.325
40	ORV01-07A	101-1318	1-2714	30.450
41	ORV01-08	101-926	1-1930	20.650
42	ORV01-10	101-1265	1-2608	29.125
43	OR01-W01B	1801-2846	3686-5770	26.150