Seismic Data Processing Report

By : ***Velseis Processing***

For: ***ORIGIN ENERGY Resources Ltd***

Project: ***VIC/P41 (v)***
2D Marine Reprocessing

Area: ***Otway Basin AUSTRALIA***

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Velseis

Integrated Seismic Technologies

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1. Introduction

1.1. Scope of Report

This report describes the reprocessing of seismic data for Origin Energy Resources Ltd. The project is situated in Otway basin, Victoria, Australia.

The project consists of reprocessing 2D marine seismic lines which extend into VIC/P41(v) permit and comprises both 1980 and 2002 vintage data, for a total of 244 km over 32 lines in the shallow water .

1.2. Purpose of Processing

The objectives of the reprocessing were to maximize resolution at the Waarre Formation, in the target range of around 2000-3000ms as well as to improve resolution of the faults through the reservoir section.

2. Data Acquisition

2.1. Data Acquisition Parameters

The following table is the summary of acquisition parameters of the two seismic surveys:

Survey -->	**1980**	**2002**
Line Prefix	OP80	OEP02
No. channels	96	444
Group interval	25m	12.5m
SP interval	25m	25m
Acquisition fold	48	111
Streamer length	2400m	5550m
Record length	5s	6s
Sample rate	2ms	2ms
No. of lines	10	22
2D Km total	97.6 km	146.2 km

The observer's logs were used to assign geometry for OEP02 lines. The observer's logs were not available for survey OP80. The acquisition parameters of this vintage were taken from plot labels of seismic sections from the previous processing.

The following table details the acquisition parameters for each of the survey:

Parameter Type	**Surveys 2002 (OEP lines)**	**Survey 1980 (OP lines)**
Survey Details		
Survey carried out by	Multiwave Geophysical	N/A
Vessel	R/V Polar Duke	Eugene McDermott
Acquisition period	Nov 2002	Dec.1980-Jan 1981
Shot Point interval	25 metres	25 metres
Receiver interval	12.5 metres	25 metres
Number of traces per shot point	444	96
Nominal stacking fold	111	48
Energy Source		
Sources	Air Gun	Air Gun
Gun Depth	5 meters	6 metres
Volume	2400 cu. ins.	550 cu. ins
Pressure	2000 psi	N/A
Receiver Spread		
Near trace offset	140 metres	Varies: 169 to 275 m
Near channel number	444	96
Number of groups (channels)	444	96
Group Interval	12.5metres	25 metres
Streamer Depth	7, 8 or 9 metres	13 metres
Streamer Length	5550metres	2400 metres
Instruments		
Recording System	Syntron Syntrak 960/24	DFS V
Recording format	SEG-D 6250 BPI	SEG-B, 1600 BPI
Record length	6000 or 5000ms	5000ms
Sample Interval	2 msec	2 msec
Record Filter:		
• Low cut	3Hz, 6dB/Oct	out
• High cut	206Hz, 276 dB/Oct	128 Hz, 72 dB/Oct
Digital Filter Delay	0 ms	51.2 ms
Navigation (trace headers of final data)		
Reference UTM Datum	GDA 94	GDA 94

2.2. List of Lines Processed

There are 32 lines from 2 surveys totalling of **243.8** km 2D marine seismic data.

	line_no	SOL	EOL	Sp_No	Km	FCDP	LCDP	Near Offset	Cab. D, m	Sou. D, m
1	OEP02-02	2100	2388	289	*7.2*	*1*	*798*	140	9	5
2	OEP02-04	2200	2585	386	*9.6*	*1*	*992*	140	8	5
3	OEP02-05	1815	2056	242	*6.0*	*1*	*704*	140	8	5
4	OEP02-07	1999	1752	248	*6.2*	*185*	*716*	140	8	5
5	OEP02-09	1947	1702	246	*6.1*	*193*	*712*	140	8	5
6	OEP02-11	1790	2010	221	*5.5*	*1*	*662*	140	8	5
7	OEP02-13	2207	2002	206	*5.1*	*1*	*632*	140	9	5
8	OEP02-15	2265	2027	239	*6.0*	*95*	*698*	140	9	5
9	OEP02-17	1875	2122	248	*6.2*	*1*	*716*	140	9	5
10	OEP02-19	2140	2408	269	*6.7*	*1*	*758*	140	8	5
11	OEP02-21	2335	2032	304	*7.6*	*151*	*828*	140	7	5
12	OEP02-23	2145	2405	261	*6.5*	*1*	*742*	140	7	5
13	OEP02-25	2450	2190	261	*6.5*	*144*	*742*	140	7	5
14	OEP02-27	1860	2116	257	*6.4*	*1*	*734*	140	7	5
15	OEP02-29	2414	2146	269	*6.7*	*101*	*758*	140	7	5
16	OEP02-31	2100	1831	270	*6.7*	*125*	*760*	140	7	5
17	OEP02-33	1820	2065	246	*6.1*	*1*	*712*	140	7	5
18	OEP02-35	2410	2106	305	*7.6*	*176*	*830*	140	7	5
19	OEP02-37	1780	2040	261	*6.5*	*1*	742	140	7	5
20	OEP02-39	2180	2432	253	*6.3*	*1*	*726*	140	8	5
21	OEP02-41	1740	1978	239	*6.0*	*1*	*698*	140	8	5
22	OEP02-43	2246	1897	350	*8.7*	*170*	*920*	140	8	5
					146.2					
23	OP80-5A	1580	1900	321	*8.0*	*1*	*736*	218	13	6
24	OP80-9A	1590	1855	266	*6.6*	*1*	*626*	259	13	6
25	OP80-11A	2035	2287	253	*6.3*	*1*	*600*	210	13	6
26	OP80-13	90	310	221	*5.5*	*1*	*536*	264	13	6
27	OP80-18	190	1684	1495	*37.4*	*1*	*3084*	172	13	6
28	OP80-19A	4025	4242	218	*5.4*	*1*	*530*	250	13	6
29	OP80-21	1515	1775	261	*6.5*	*1*	*616*	262	13	6
30	OP80-27A	30	340	311	*7.8*	*1*	*716*	275	13	6
31	OP80-29	1420	1702	283	*7.1*	*1*	*660*	199	13	6
32	OP80-31	1388	1670	283	*7.1*	*1*	*660*	169	13	6
					97.6					
		Total km			**243.8**					

About 50 % of OEP02 Lines and line OP80-27A have a reverse shooting direction (decreasing shot point number direction). First CDP (FCDP) number starts at the beginning of shooting for all lines.

3. Processing Sequence

3.1. Parameters

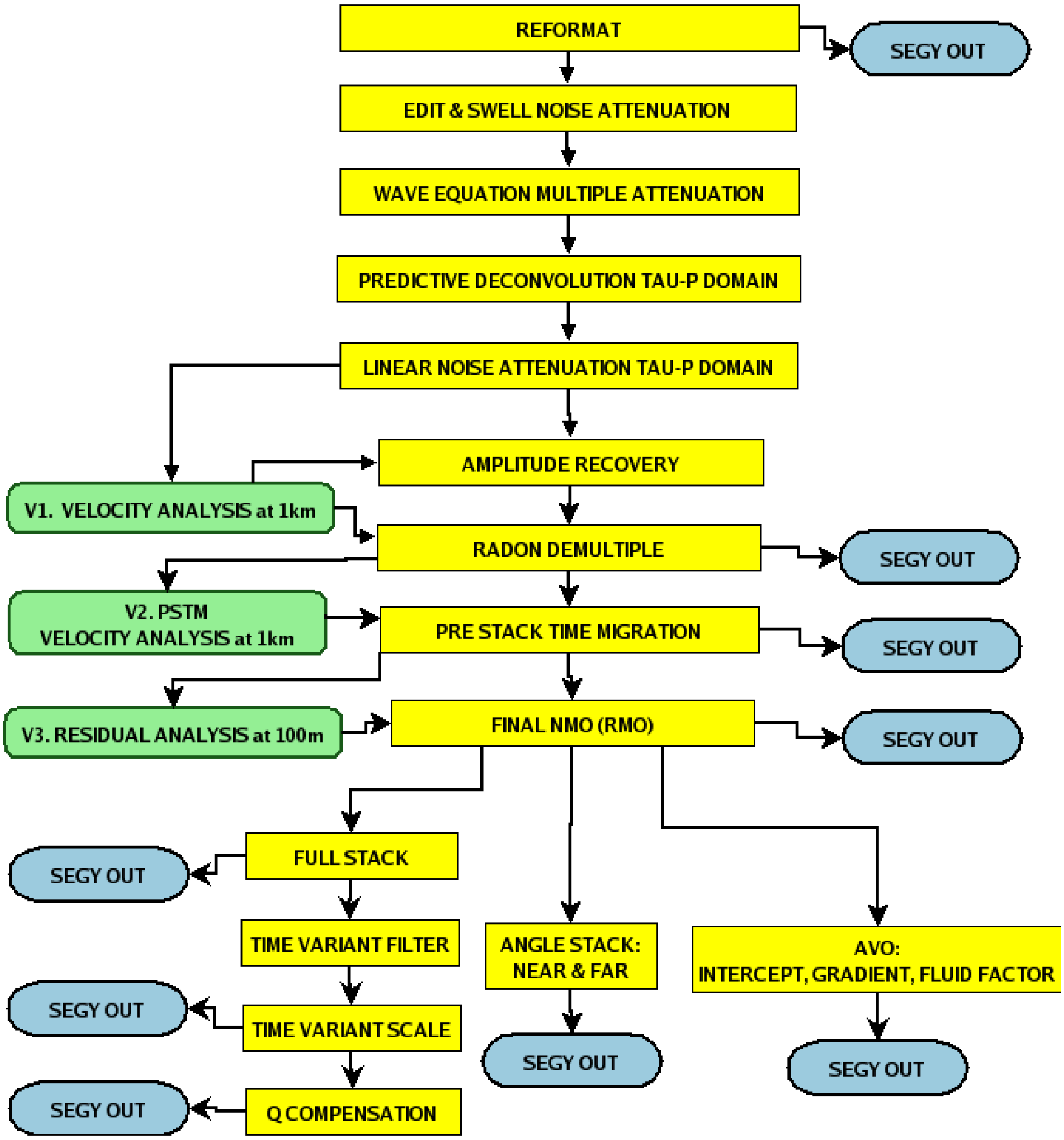
The 32 lines of 2D seismic data of 2 vintages totalling 244 kms have been processed with the following parameters:

Processing length	:	6 seconds for OEP02 5 seconds for OP80
Processing sample rate	:	2 milliseconds
Resampling	:	None
Maximum stacking fold	:	48 (OP80 series lines) 111 (OEP02 series lines)
Datum plane	:	Mean sea level

3.2. Final Processing Sequence

3.2.1. Flow chart

Two vintages have been processed with similar processing sequences:



3.2.2. Details

3.2.2.1. Pre Stack Data Processing

- **Transcription** to ProMAX internal data format
  - Record length /OEP02 lines/: 6144 ms
  - Record length /OP80 lines/ : 5120 ms
- **Geometry** trace headers load. Information assigned to each trace includes source, receiver and CDP locations, and offsets.
- **Bad Trace and Shots Edit**.

  Observers log information was used for OEP02 lines.
- **Gun delay correction** : -51.2 ms >>> *OP80 lines only*
- **Low cut** minimum phase filter: 4Hz 18 dB/oct
- **Amplitude recovery**
  - Initial (reversible) Time/Power constant of 2 was applied to compensate for the effects of spherical divergence.
- **Amplitude Spike edits**.
  - Amplitude threshold 20
- **FK filter**.
  - The velocity FK filter was used to remove a strong "air blast" noise with low velocity. 500-1200 m/s rejection velocity was used at max frequency of 20Hz.
  - AGC 300ms wrap was applied as well.
- **Impulsive and Swell noise attenuation**:
  - Noisy trace editing was performed using despike by time variant standard deviation.
  - NMO of 2000m/s was used for protection of first arrivals and strong events.
- **Wave Equation Multiple Rejection**. (WEMR)
  - Estimation and subtraction of multiple was performed using :
  - Average water depth: 36 meters
  - Water velocity: 1500m/s
  - Maximum time shift: 80msec
- **Spatial Antialias FK Filter** >>> *OEP02 lines only*
  - K=0.25-0.45,
  - NMO protection using velocity 2000m/s

- **Processing in Tau-p domain**

  Multiple attenuation can be achieved with greater success when performing predictive deconvolution in the Tau-P domain as opposed to the time domain. Slant stacks were created by transforming samples in the time and offset domain to Tau (intercept time) and P (Slowness) using the radon transform. The periodicity of multiples is much more pronounced and therefore likely to be better attenuated with prediction deconvolution operators in the Tau-P domain. Also a linear noise removal can be efficiently removed using muting in Tau-p gather.

  The following Tau-p processing was applied:

  - Transform forward:
    - *OEP 02 data*
      - Number of P-values 580
      - Minimum P-value of interest (ms) -800.
      - Maximum P-value of interest (ms) 3790.
      - Reference offset for delta moveout 5677.5
    - *OP80 data*
      - Number of P-values 312
      - Minimum P-value of interest (ms) -520.
      - Maximum P-value of interest (ms) 3790.
      - Reference offset for delta moveout 2700
  - Predictive Deconvolution:
      - Operator 320ms, gap 20 ms, window 200-3500ms
  - Linear Noise attenuation: Mute applied in Tau-p Domain
  - Tau-p transform reverse

- **Trace drop** 2:1 >>> *OEP02 lines only*
  - input receiver interval: 12.5m
  - output receiver interval: 25m

- **Velocity Analysis 1st pass**

  Velocities were picked using the ProMAX interactive velocity picking package (IVA). IVA uses velocity spectra, moved out gathers and stacked panels to assist in a careful interpretation of stacking velocities. As the velocity function is altered, revised gathers and stacks are produced until optimised stacking velocities are achieved.

  Velocities were picked at locations of 1.0 km apart. Each panel consisted of 15 CDPs stacked using 13 velocity functions centred around the regional velocity function. 7 CDPs of 15 were used to sum into common offset stacked supergather at each location.

- **Normal Moveout Correction** using 1st pass velocities (V1).

- Update of **Spherical Divergence Correction**:
  - offset variant spherical divergence correction using 1st pass velocity analysis
  - additional 1dB/sec correction

- **Radon Demultiple Filter**

NMO corrected CDP gathers were transformed into the Radon domain. An interactive filter was designed and applied to remove modelled energy with a delta-t range of 98ms to 470ms on the far offset of OEP02 data. A smooth taper was used in the shallow where low fold tends to give spurious results.

The following radon transform was performed for OEP02 lines:

♦ Number of P-values	306
♦ Transform range	–480 to +3200 ms
♦ Reference offset for P-values	5700m
♦ Delta-t cut range	98-470ms
♦ AGC wrap	300ms

The parameters were adjusted for a shorter cable of OP80 lines:

♦ Number of P-values	306
♦ Transform range	–480 to +1400 ms
♦ Reference offset for P-values	2650m
♦ Delta-t cut range	48-198ms

- **Velocity Analysis 2nd pass** (V2). PSTM Velocity Analysis at 1000m intervals.
  - Kirchhoff Pre Stack Time Migration was run using V1 velocity fields.
  - Velocities were picked on Migrated data using the ProMAX interactive velocity picking package (IVA)
- **Pre Stack Time Migration (PSTM).**
  - A Kirchhoff pre-stack time algorithm was used to migrate common offset binned data.
  - Migration velocity: V2 (PSTM)
  - Aperture: 4000m.
  - Anti-alias option.

- **Residual Moveout correction 100m interval**

In order to improve the final stacking velocity and final stack image, a high density Residual Moveout correction (100m interval) was applied after Residual velocity Auto picker.

Residual Moveout Correction flattens events on migrated gathers in a procedure analogous to Normal Moveout Correction. The Residual Moveout Correction assumes that the residual moveout is hyperbolic function of offset, just like normal moveout.

$$t = \sqrt{t_0^2 + R_T x^2}$$

The equations for Residual Normal Moveout use the Residual Parameter **R** in place of inverse velocity squared. Residual moveouts can be positive or negative, reflected in the sign of R.

The residual velocity analysis is carried out on NMO corrected cdp gathers (with V2).

Min and Max squared reciprocal velocity (slowness) are used to define the corridor for maximum in minimum residual correction.

- R scan +/-30 (OEP02 lines) or +/-10 (OP80 lines) and time smoothing operator 400ms was used for Residual velocity Auto picker.

- **Outer and Inner trace muting**
- **Stack**

Traces are summed within a common midpoint (cmp) gather. The post stack trace is scaled by the square root of the sum of fold for each sample in the trace.

3.2.2.2. Post Stack Data Processing

- **Gun and Cable Static Correction**:
  - +9 msec for OEP02 lines (2002 vintage)
  - + 12 msec for OP80 lines (1980 vintage)

- **Time Variant Filtering**.

Frequency (Hz)	*Time (ms)*
6-8-90-110	0- 700
4-6-70-80	1000-1300
3-6-60-70	2200-2500
3-6-40-50	5000-6000

- **Time Variant Scaling**.

Scalar	*Gate(ms)*
1.0	0-1600
1.6	1600-3200
1.35	3200-EOT

The scalar was applied from gate centre to gate centre.

- **Q Compensation**

Phase Q compensation was applied using 40Hz of Frequency of Q model.
Interval Q values were calculated by multiplying the regional interval velocity by 0.0328. The following interval velocity (m/s) was used:
T0-V1500, T200-V2350, T600-V2500, T1000-V3000, T1800-V3750, T2600-V4520, T3200-V4900, T4500-5800, T5200-V5800.

Then the interval Q values (Q inst) were converted to effective Q values:

$$Qeff = \frac{T}{\int_0^T \frac{1}{Qinst} d}$$

The Final Migration was archived and delivered to client with and without Q compensation.

- **Phase Matching**

Phase matching was tested in order to match OP80 data to OEP02. However it was decided to deliver the final data without phase matching applied.

3.2.2.3. AVO Processing

Input data for AVO processing was PSTM CDP gathers with final NMO correction.
Near and Far angle Stacks and three AVO attributes Stacks were produced.

- Near angle Stack of 0-18 degrees
- Far angle Stack of 19-36 degrees
- AVO intercept
- AVO gradient
- AVO fluid factor

The following regional interval velocity was used for incident angle calculation:
T0-V1500, T200-V2350, T600-V2500, T1000-V3000, T1800-V3750, T2600-V4520, T3200-V4900, T4500-5800, T5200-V5800.

Maximum 36 degree of incident angle was used for AVO Stacks.

3.2.2.4. CGM Displays

CGM files of Final Migration (without Q compensation) were generated for each line:
horizontal scale : 1:25000 (20 traces per cm)
vertical scale of 10 cm per second.

The post stack FK filter was applied prior to CGM to gently remove a migration noise below 1500ms.

A side panel outlining the acquisition and processing parameters was produced.

3.2.3. Navigation

Origin Energy provided UTM XY coordinates within reprocessing range for each 5th shot point.
The coordinates were interpolated and saved the coordinates as XY SP coordinates to the Segy trace headers of the final Stacked data.

- ✓ GDA94 Geodetic Datum was used

3.2.4. Specific Problem

The reprocessing ranges of all lines, except for OP80-18, were very short. They are just shallow water “tails” of 2D marine lines. Thus nominal (maximum) CDP fold for the lines was about 60% of the data only. It caused poor PSTM images in the edges of lines with low CDP fold.

Moreover, all OEP02 lines with decreasing SP numbers (off shore shooting direction) had a streamer bend at the beginning of lines. The traces affected by the bend had to be rejected from processing.

The field data of the OEP02 series lines also was of poor quality. This was due to a high swell noise for most of the lines. Swell heights exceeded 3 m affecting up to 25% of the traces.

4. Final Documents and Tapes

The following final products were delivered to Origin Energy:

Deliverable Products	**Format**	**Media**		**Competed date**
I. Gathers				
1.Raw SP Gathers (Geom & SP-XY Nav.)	*SegY*	**DLT**		10/03/2006
2.Pre-PSTM CDP Gathers (Radon, no NMO)	*SegY*	DVD/**DLT**		28/02/2006
3.Post-PSTM CDP Gathers (RMO +)	*SegY*	**DLT**		10/03/2006
4.Post-PSTM CDP Gathers (unNMO)	*SegY*	**DLT**		10/03/2006
II. Stack				
5.Raw Migrated Stack	*SegY*	DVD		16/02/2006
6.Final Migrated Stack	*SegY*	CD		8/02/2006
7.Final Migrated Stack with Q compensation	*SegY*	DVD		16/02/2006
8.Near Angle Stack	*SegY*	DVD		16/02/2006
9.Far Angle Stack	*SegY*	DVD		16/02/2006
III. AVO				
10. Intercept	*SegY*	DVD		16/02/2006
11. Gradient	*SegY*	DVD		16/02/2006
12. Fluid Factor	*SegY*	DVD		16/02/2006
IV. Velocity				
13. First Pass Velocity **Vrms** (Radon)	ASCII	DVD		16/02/2006
14. PSTM Migration Velocity RMS Field	ASCII	DVD		16/02/2006
15. Residual Velocity RMO Field	ASCII	DVD		16/02/2006
16. SP XY Coordinates (GDA94)	ASCII	DVD		16/02/2006
V. CGM files Final Migration	CGM	DVD		28/02/2006
VI. Processing Report	pdf	CD		3/04/2006

5. Testing (Technical Notes Hyperlinks)

Following is the list of technical notes provided to Origin Energy during the lifetime of the project. These technical notes describe testing carried out, with supporting figures.

5.1. Pre Stack Preprocessing

Technical Note-1

5.2. Linear Noise Attenuation (LNA)

Technical Note-2

5.3. Deconvolution

Technical Note-3

5.4. Radon Demultiple

Technical Note-4

5.5. PSTM

Technical Note-5

5.6. Final Velocity

Technical Note-6

6. Annexes

6.1. Personnel involved in reprocessing

The data was processed by *Velseis Processing Pty. Ltd*., Brisbane, Australia.
Tatiana Gerus was the project leader.

The *Origin Energy Resources Limited* representative was **Mike Lonergan.**

6.2. Software

Velseis Processing utilizes ProMAX 3D processing software. This is a totally interactive system allowing the user to view data processing at each stage, producing a final result of the highest quality.

The software executes on a quad processor Sparc 20 Sun workstation and a 27 node, dual CPU/node Linux cluster. Data is viewed via X terminals networked to the main system, each terminal has a high definition monitor to enable accurate representation of the digital data in pixel form.

Velseis Processing is committed to offering a premium product, the software development undertaken by ProMAX resulting in processing algorithms which are state of the art.

6.3. Disclaimer

This report has been prepared in good faith and with all due care and diligence. It is based on the seismic and other geophysical data presented and referred to, in combination with the author's experience with the seismic technique, and as tempered by the geological and stratigraphic evidence presented in various forms and through discussions with client representatives.

As such, the report represents a collation of opinions, conclusions and recommendations, the majority of which remain untested at the time of preparation. In the light of these facts it must be clearly understood that Velseis Processing Pty. Ltd., its proprietors and employees cannot take responsibility for any consequences arising from this report.