

**AVO CALIBRATION
AND
MODELLING STUDY
LINES BHB96-100 & 108
BASS STRAIT**

FOR

BORAL

BY

**ROBERTSON RESEARCH
AUSTRALIA PTY. LTD.**

PERTH

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1. INTRODUCTION

Robertson Research was requested to carry out AVO and Inversion processing on lines BHB96-100 & BHB96-108.

Line BHB96-100 was phase matched to the well Bass-3. The results of this phase matching was applied to both lines.

The wells were drilled in the Bass Strait, Offshore Tasmania. (Figure 1)

2. METHODOLOGY

The seismic CDP gather is transformed from offset to angle using the final velocity functions. Having computed angles at each offset and time, a ROBUST Linear Regression is used to calculate the intercept and gradient of the amplitudes at each time sample. The method used is based on that described by Walden in his paper "Making AVO Sections More Robust" presented at the EAEG, May 1990. However, if the number of points (traces) for the AVO analysis is less than 10, a least squares fit is used, as the robust fit becomes unstable under these circumstances. Each sample value of each CDP is essentially replaced by a data base that stores the intercept, gradient, goodness of fit, semblance, standard deviation and the Runs statistic. The Runs statistic is used to assess the legitimacy of fitting a straight line.

The goodness of fit (GOF), semblance and Runs statistic were all used to edit values of slope (gradient) and intercept. When any of these parameters was above or below a certain user specified threshold, the slope values were zeroed.

A CDP gather with a negative intercept (reflection coefficient at zero offset) and a positive gradient is shown diagrammatically in Figure 2. The horizontal dimension in this figure is increasing offset and is plotted with the square of the Sine of the incident angle, as according to Shuey (1985) the change in amplitude will be approximately linear up to an incident angle of about 30 degrees.

The default polarity convention used in this report on all displays of synthetic and seismic data is SEG positive standard polarity. This polarity standard states (see Sheriff's Encyclopaedic Dictionary of Exploration Geophysics - Third Edition p226) that an increase in acoustic impedance is a positive reflection coefficient and is represented on a zero phase wavelet by a black peak on a variable area display.

3. SEISMIC DATA PROCESSING FLOW

The main difference between AVO processing and conventional processing apart from the need to preserve relative amplitude information is that it is normally necessary to effect a major improvement in the signal to noise ratio of the CDP gather since it is not possible to rely on stacking to attenuate the noise. CDP consistent statics were applied to each line to improve the data quality. In addition to improving the signal to noise ratio, it is also desirable to migrate the data to match the final migrated section.

51.89 km of the marine 2D seismic data lines **BHB96-100 & BHB96-108** were processed with the following processing sequence:

1. Transcription of SEGY DMO Gathers to Internal Tape Format
2. Velocity Analysis
A first pass velocity analysis at an interval of 1000m was performed.
3. Migration before Stack
Using the FK method along diffraction curves on 84 offset planes and then reforming CDP gathers.
4. Final Velocity Analysis
A final velocity analysis at an interval of 500m was performed.
5. NMO Correction and Mute
6. Base Level Equalisation
A base level trace scaling over a window of 1500ms was applied. We assume that the overall AVO effect over the window of data will be zero since it contains reflections from a large number of interfaces.
7. Residual Statics
Trim static shifts were applied 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 pilot trace consisted of 5 traces, which were weighted with varying percentage contributions.
8. Bulk Static Shift
An 8ms static shift was applied to compensate for the gun depth and the cable depth.
9. Ostrander Mix
A 3 times 3 mix across adjacent CDP gathers of traces with the same offset was applied to create Ostrander Supergathers to improve the signal to noise ratio.

10. Zero Phasing

Thus far the data has been processed minimum phase. To convert the gathers to zero phase the operators calculated to convert the migration to zero phase were applied. The derivation of these operators is described in detail in section 6.

11. Phase Rotation

A 180 degrees phase rotation was applied to tie the seismic data to the synthetic seismogram of Bass-3 and convert the data to SEG positive polarity.

PHASE MATCHING

For the phase matching, a synthetic seismograms of Bass-3 was used to match the wells to the zero phased final migrated seismic data at the well location. Using the synthetic data and the seismic data at the well location a phase matching operator was derived. The operator was analysed and its phase spectrum reduced to a constant phase shift (intercept) and a constant time shift (gradient) by linear regression. The method is described in a paper by **White, R.E., 1980, *Partial coherence matching of synthetic seismograms with seismic traces.* Geophysical Prospecting, 28, 333-358.**

Bass-3 intersects line BHB96-100 at SP 1595. The result of the phase matching using this well indicates a 180deg phase rotation is required to convert the seismic data to SEG positive polarity. Figure 3 displays the cross correlation plots between the seismic data and the synthetic seismogram of Bass-3 at the well location.

Figure 4 shows a comparison of the well synthetic and the seismic data after a 180 degree rotation has been applied. The match is thought to be good.

4. PROCESSING FOR INVERSION

The pre stack time migrated gathers that have been NMO corrected with the second pass velocities and have had a front end mute applied (step 5 in above processing flow) were used as input into the following processing sequence.

1. Base Level Equalisation
A base level trace scaling over a window of 1900ms was applied.
2. CDP Stack
The gathers were stacked with a $1/\sqrt{N}$ fold compensation.
3. Residual Migration
The data were unmigrated in the FK domain and then remigrated using the final migrated velocity field using a Kirchhoff algorithm.
4. Tau- P Dip Filter
Transformation to the Tau- P domain allowed the data to be passed if the dip was greater than the minimum dip of -7ms per output trace or less than the maximum dip of 7ms per output trace.
5. Static Shift
A 8ms static shift was applied to compensate for the gun and cable delay.
6. Zero Phasing
A statistical zero phasing method was applied to the data. Firstly an estimate to the bandwidth of the coherent data was made, then assuming the data to be minimum phase an estimate of the wavelet was made. From this estimate, the data can be converted to zero phase.

This statistically zero phased data were then phase matched.
7. Phase Rotation
A180deg phase rotation was applied to convert the seismic data to SEG positive polarity.
8. Seismic Trace Inversion
The method used is a relatively straight forward one of inverting the seismic reflection coefficient data to relative acoustic impedance and adding a low frequency component.

For line BHB96-100 the low frequency component was derived from Bass-3. This component was modelled following the structure along

the line. These modelled data were then filtered with a high cut filter of 0/0-4/8Hz and added to the relative acoustic impedance values.

The input to the low frequency trend for line BHB96-108 was modelled over from line 100 via line 105.

5. AVO PLOT DISPLAYS

For this study two sorts of reconnaissance AVO plots were produced:

- a. I*G
I stands for intercept, which is the zero offset reflection coefficient and G for gradient, which represents the change in amplitude with offset. This plot style tends to give the largest anomalies at the top and base of gas sands with low acoustic impedance.
- b. Delta Rp
This method is based on the concept of cross plotting AVO measurements. Data input to the cross plot are Rp (or intercept) and the Gradient measurement from the seismic gathers. The Robertson algorithm calculates a lithological trend from the Rp and Gradient data. This trend represents the average response of brine-filled rocks in the analysis window. Unusual rocks, like gas-filled sands are displaced from this wet trend. The Delta Rp calculation is the reflectivity separation between a data point with anomalous reflectivity and the trend. The top of a hydrocarbon saturated sand unit is displayed as a blue anomaly, whereas the base is a red anomaly.

6. INTERPRETATION AND CONCLUSIONS

The anomalies of interest occurred between SP's 1280 to 1440 on line BHB96-100 at approximately 1.6 seconds and between SP's 1200 to 1340 on line 108 at approximately 2.2 seconds.

As both anomalies display similar characteristics the following remarks will apply to both lines.

The I*G plots show an intermittent red peak followed by a more continuous red trough followed by an intermittent red peak.

The Delta Rp plots shows an intermittent red peak followed by a strong continuous blue trough followed by an intermittent red peak.

Both of the above AVO anomalies would be considered favourable in terms of porosity and/or hydrocarbon indicators. A study of the acoustic impedance plots indicates that the sands of interest have a lower acoustic impedance, or higher porosity, than the equivalent sand at Bass-3.

7. DISCLAIMER

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8. REFERENCES

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SHUEY, R.T., 1985. A simplification of the Zoeppritz equations, *Geophysics* 50, No 4, p609-614

URSIN B., 1990. Offset-Dependent Geometrical Spreading in Layered Medium. *Geophysics* 55, p492-496

WALDEN, A.T., 1991. Making AVO Sections more Robust. *Geophysical Prospecting* 39, p915-942

9. LIST OF FIGURES.**FIGURES**

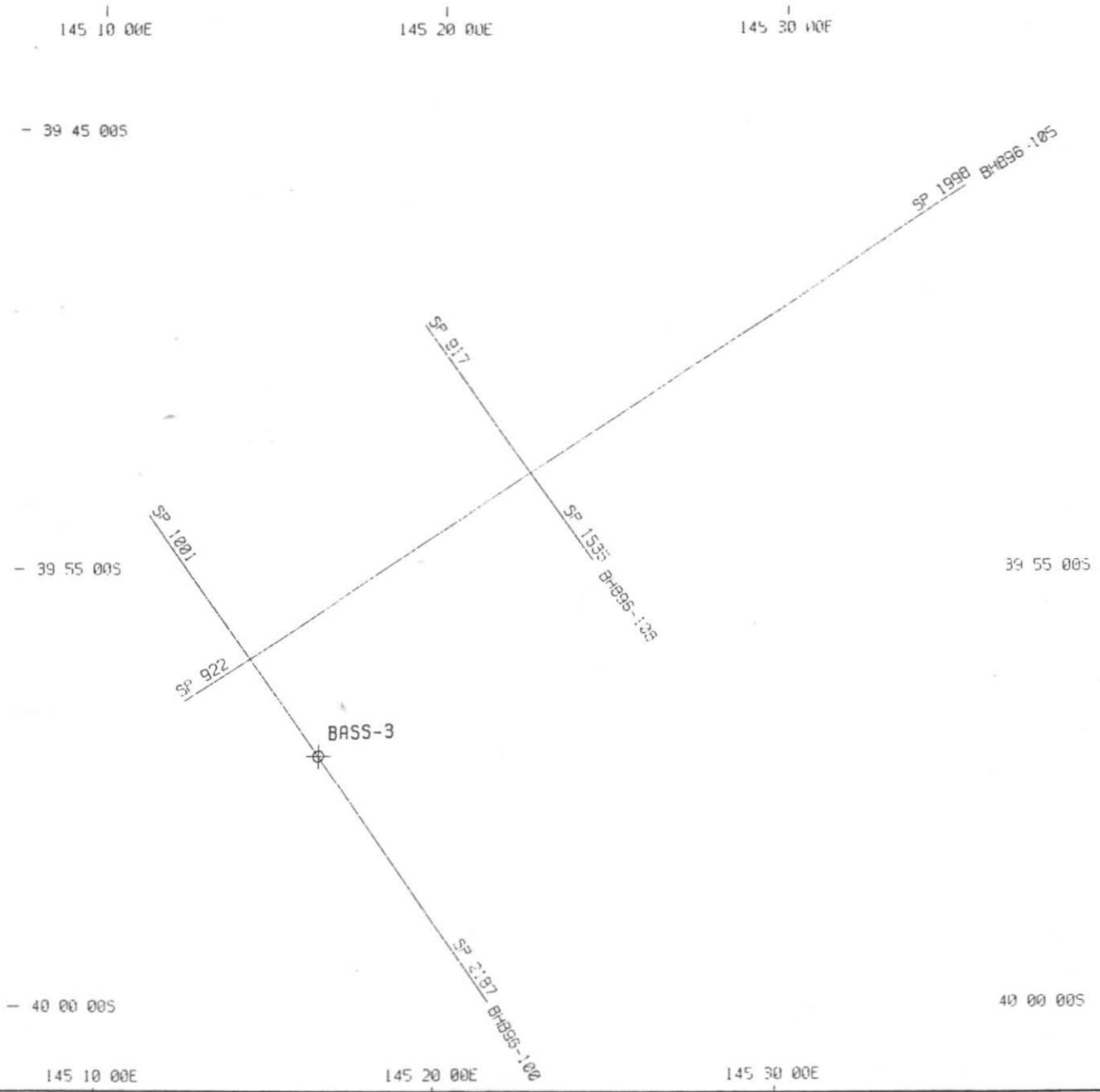
1. Location Map.
2. Linear Regression of CDP Gathers.
- 3a & b. Phase Match between Bass-3 and line BHB96-100.
4. Seismic tie between Bass-3 and line BHB96-100.

ENCLOSURES

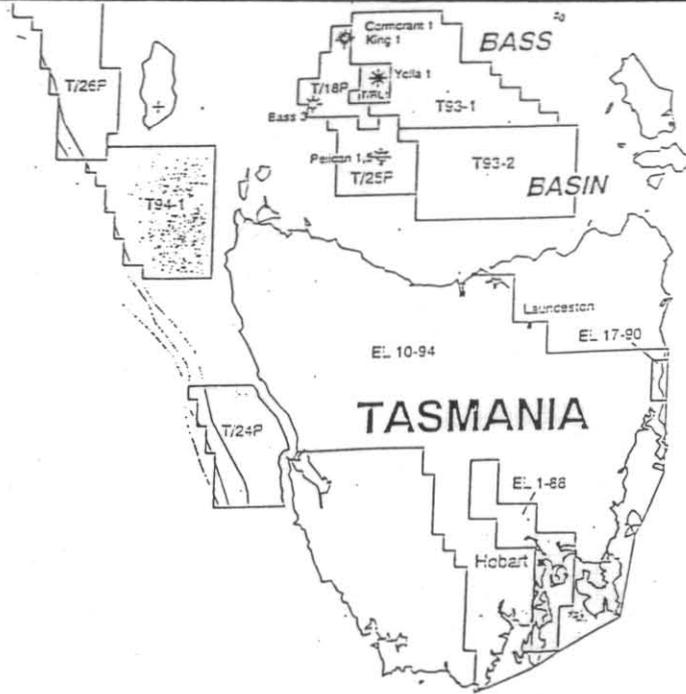
1. Acoustic Impedance – Line BHB96-100
2. Acoustic Impedance – Line BHB96-108
3. Delta Rp – Line BHB96-100
4. Delta Rp – Line BHB96-108
5. Intercept Times Gradient – Line BHB96-100
6. Intercept Times Gradient – Line BHB96-108

FIGURE 1

522012



145 10 00E 145 20 00E 145 30 00E



5 cm

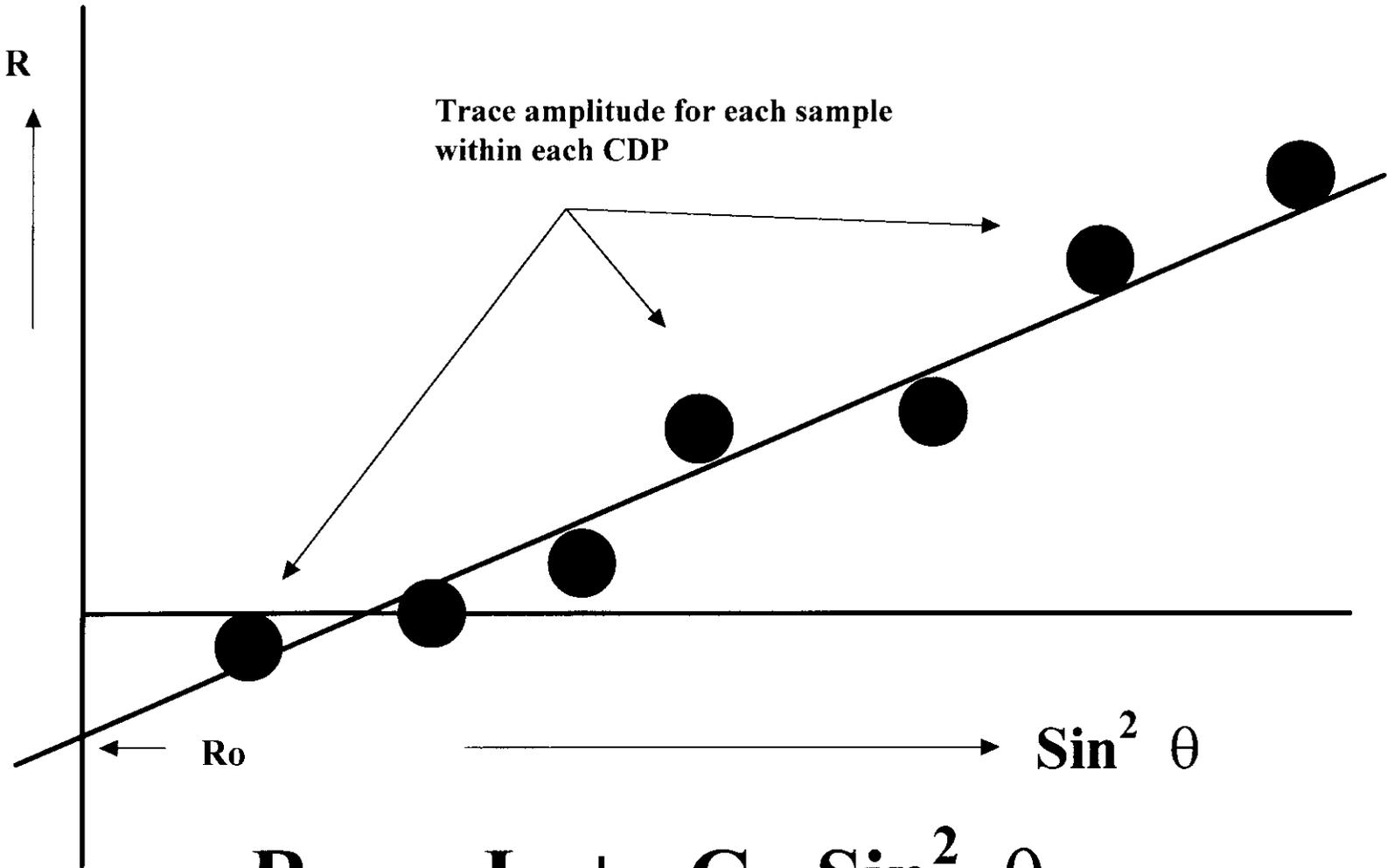


FIGURE 2

$$R = I + G \text{ Sin}^2 \theta$$

Trace Amplitude

R₀ Intercept

Gradient

tan θ = $\frac{X}{Z}$ = OFFSET * 0.5
 = DEPTH

5 cm

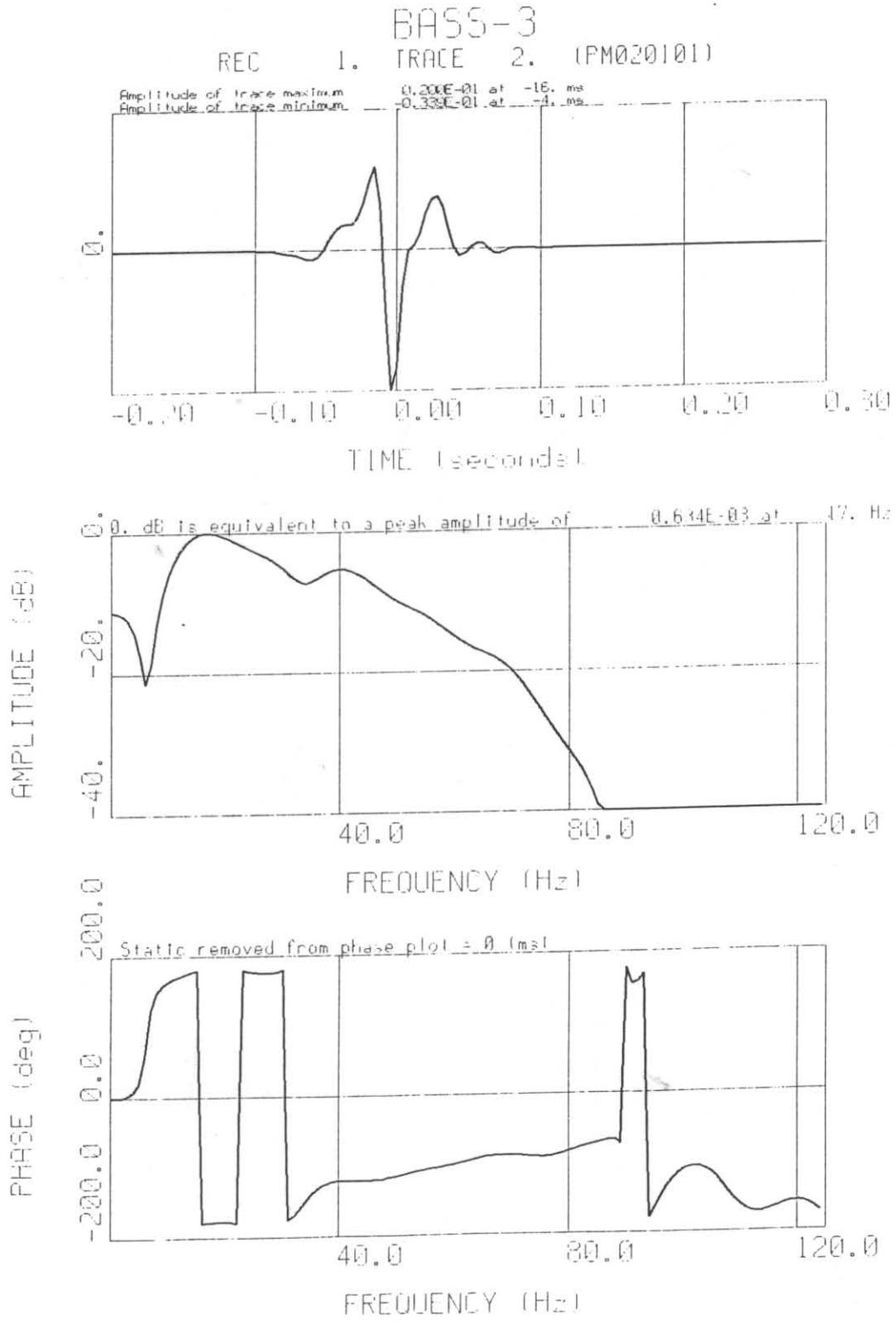
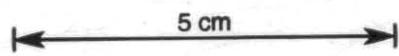


FIGURE 3a PHASE MATCH OF BASS-3 WITH LINE BHB-100



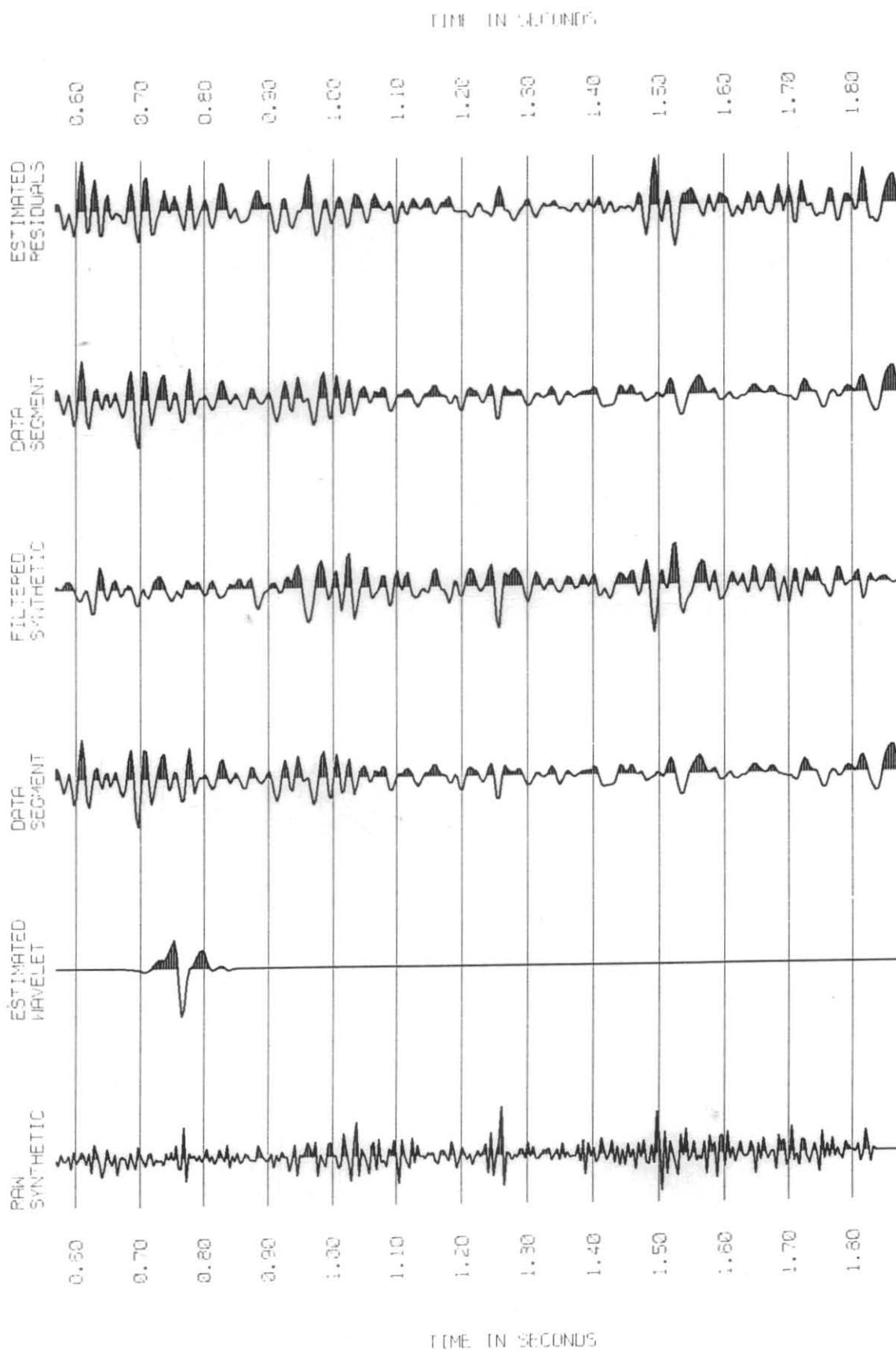
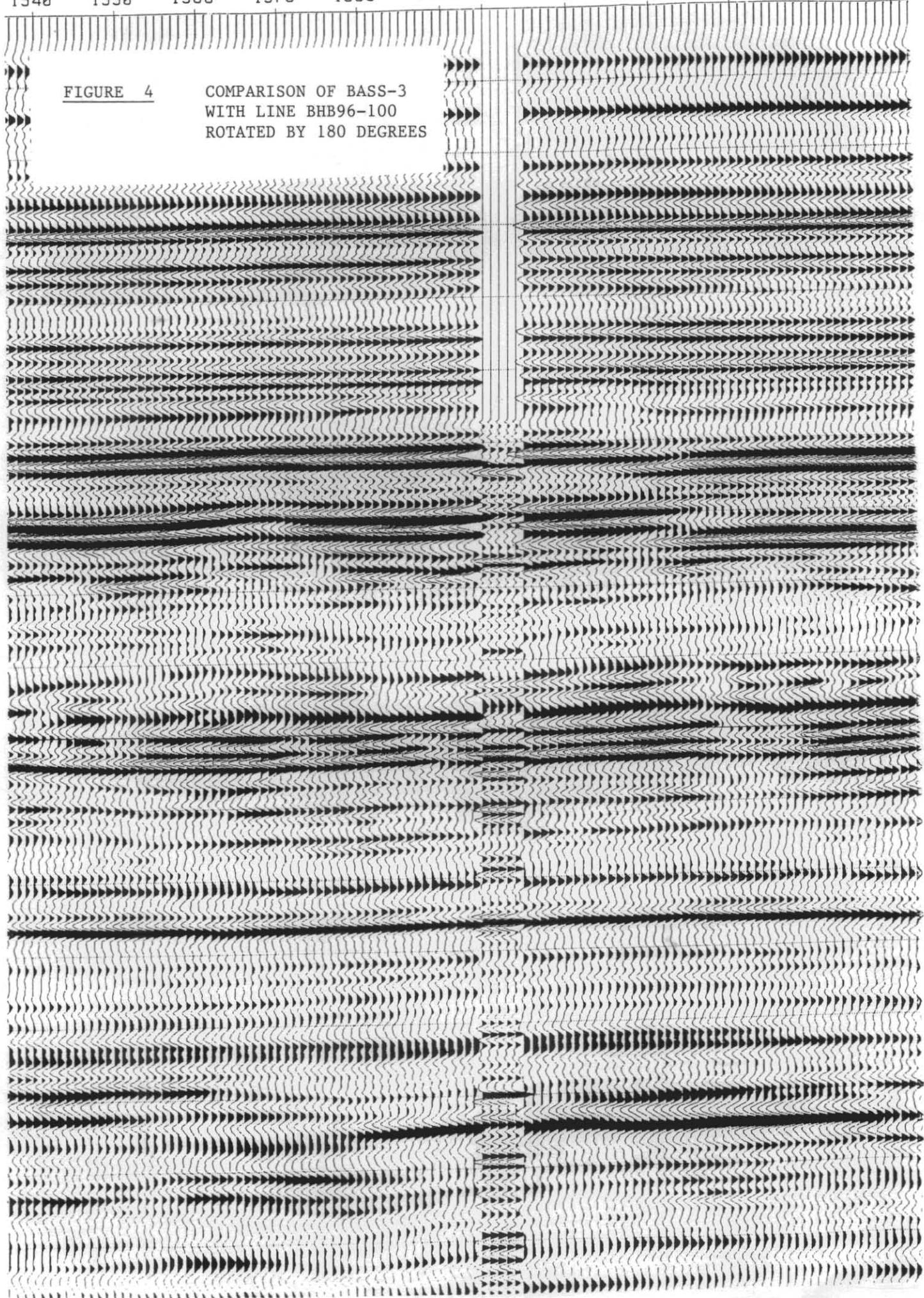


FIGURE 3b PHASE MATCH OF BASS-3 WITH LINE BHB-100

5 cm

1540 1550 1560 1570 1580 1590 0 1600 1610 1620 1630 1640

FIGURE 4
COMPARISON OF BASS-3
WITH LINE BHB96-100
ROTATED BY 180 DEGREES



522017

ENCLOSURE 1. OR-0424

LINE **BH96-100**

SP **1013 - 2092**

CLIENT **BORAL**

AREA **BASS STRAIT**

ACOUSTIC IMPEDANCE

Horizontal Scale 1:25000 Vertical Scale 1:28 cm/s

Job Number 1 059108 Date 1 May 1996

0 0.5 1.0 KILOMETRES

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PROCESSING SEQUENCE Processing record length 4 sec

PRE-STACK PROCESSING Processed to DMO MCC

VELOCITY ANALYSIS Every 100ms

PRE-STACK TIME ROTATION Using FK method

VELOCITY ANALYSIS Every 50ms

WMO APPLICATION

FRONT END FILTER

CONVERSION TO ZERO PHASE

BAND PASS FILTER

BASE LEVEL EQUALISATION

PHASE ROTATION

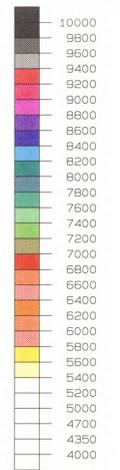
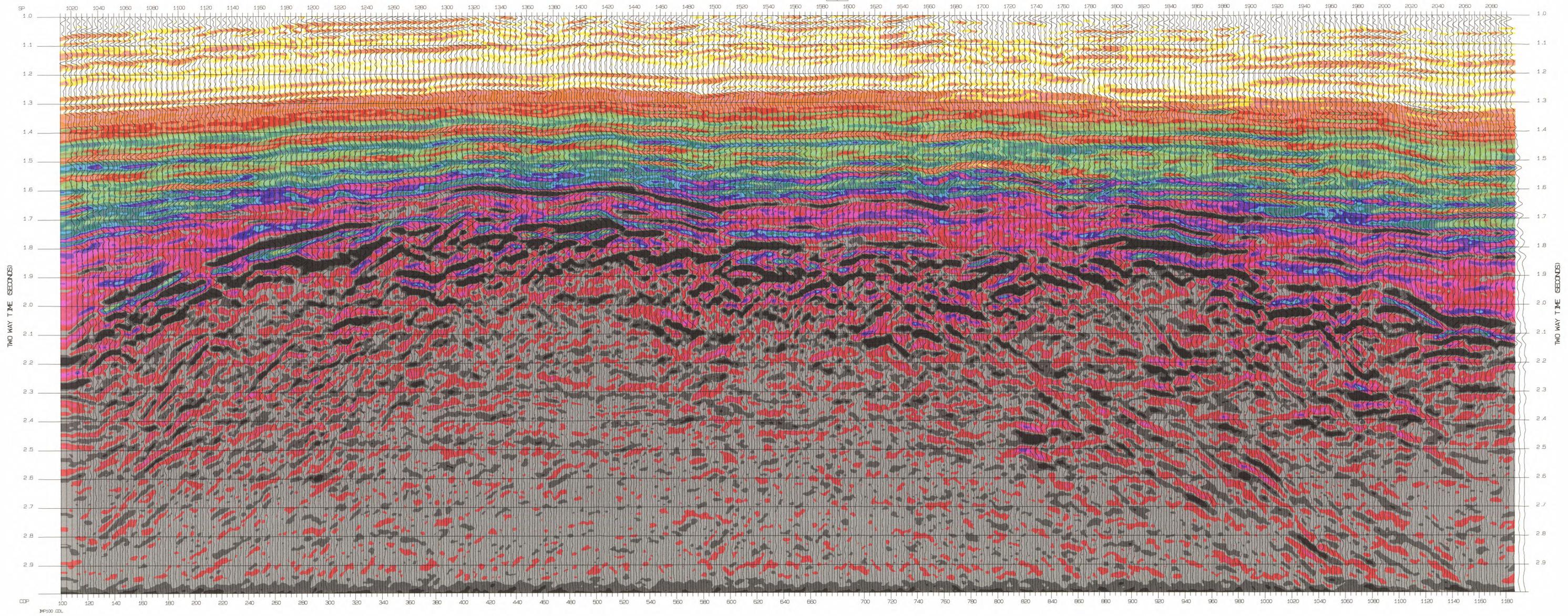
INVERSION

* A 180deg phase rotation was applied to convert data to SEG positive polarity

Inversion to R.I. using IF trend from Base-1

DISPLAY PARAMETERS

Wiggle overlay and colour shading ACOUSTIC IMPEDANCE (km/s x g/cc)



522018

ENCLOSURE 9. OR-0434

LINE BHB96-108
SP 918 - 1530
CLIENT BORAL
AREA BASS STRAIT



ACOUSTIC IMPEDANCE

Horizontal Scale: 1:25000
Job Number: 059188
Vertical Scale: 20 cm/s
Date: May 1996

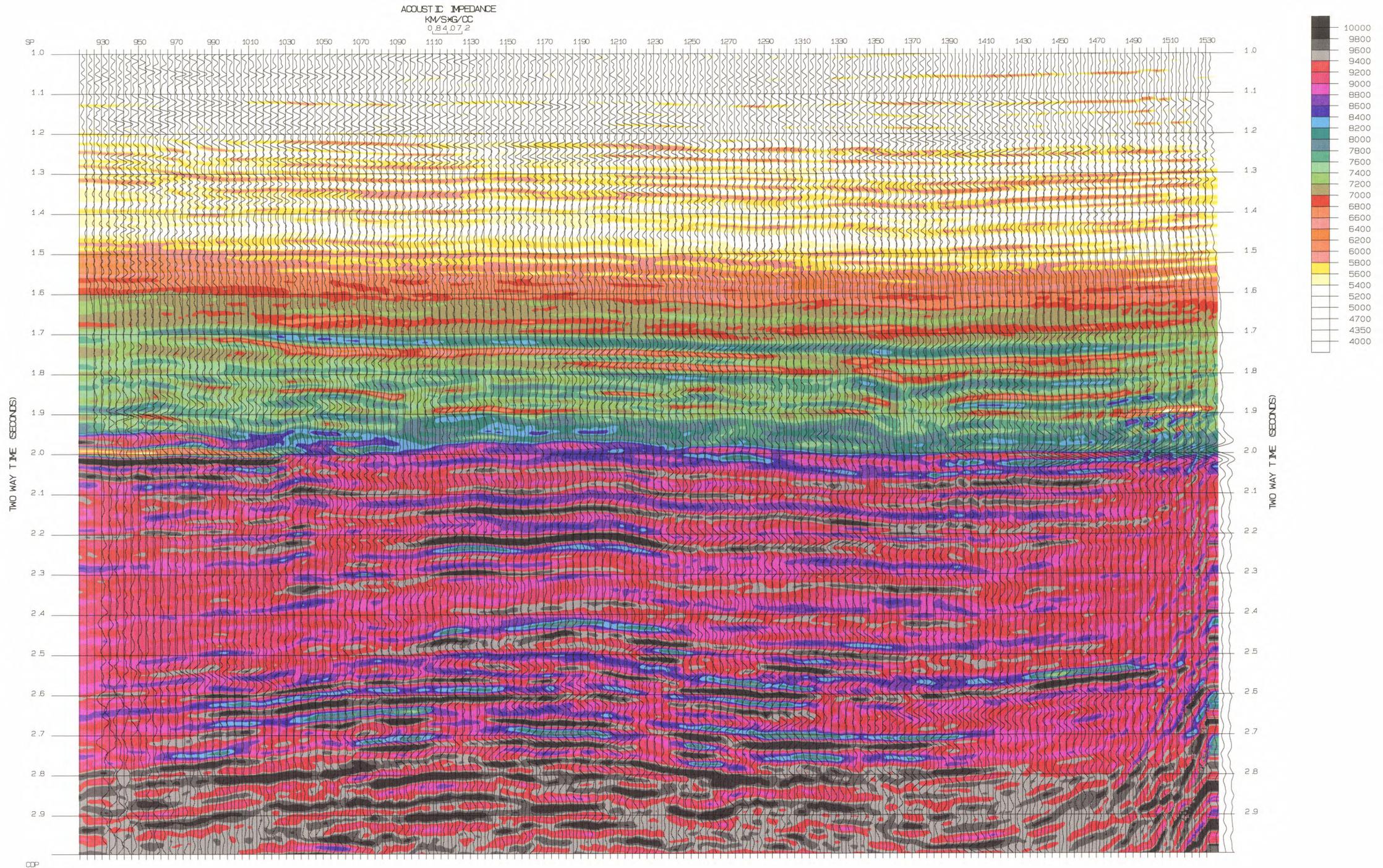


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PROCESSING SEQUENCE
PRE-STACK PROCESSING
VELOCITY ANALYSIS
PRE-STACK TIME MIGRATION
VELOCITY ANALYSIS
NMO APPLICATION
FRONT END MUTE
CONVERSION TO ZERO PHASE
BAND PASS FILTER
BASE LEVEL EQUALISATION
PHASE ROTATION
INVERSION

Processing record length: 4 sec
Processed to DMO NDC
Every 100m
Using FK method
Every 500m
x
A 180deg phase rotation was applied to convert data to SEG positive polarity
Inversion to R.I. using 'f' trend from Bass-1

DISPLAY PARAMETERS
Wiggle overlay and colour shading ACOUSTIC IMPEDANCE (km/s x g/cc)



522019

ENCLOSURE 3

OR-0424

LINE BHB96-100
 SP 1151-1850
 CLIENT BORAL
 AREA BASS STRAIT



DELTA Rp

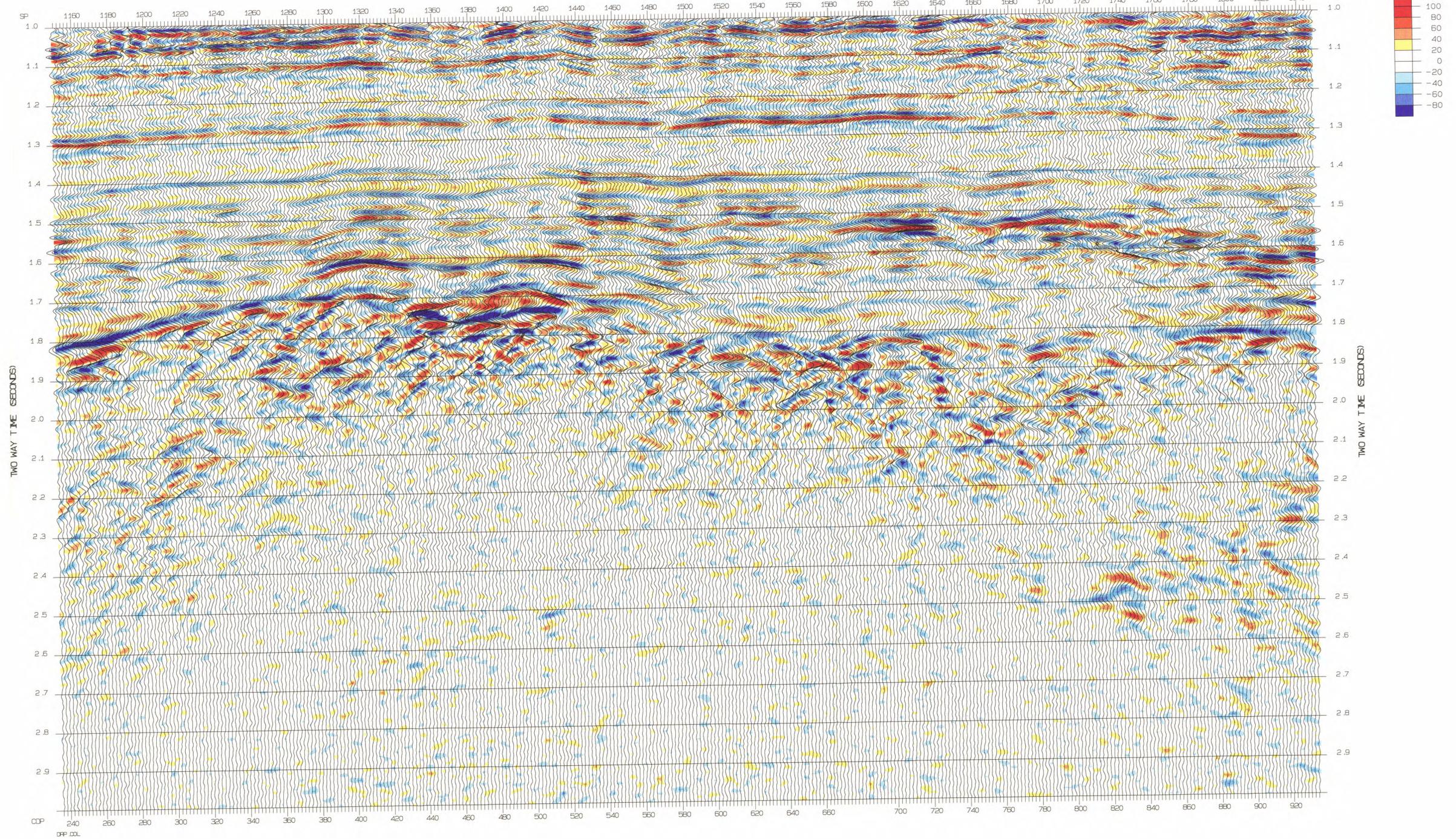
Horizontal Scale: 1:25000 Vertical Scale: 20 cm/s
 Job Number: 859188 Date: May 1986



PROCESSING SEQUENCE
 PRE-STACK PROCESSING
 VELOCITY ANALYSIS
 PRE-STACK TIME MIGRATION
 VELOCITY ANALYSIS
 NMO APPLICATION
 FRONT END MUTE
 CONVERSION TO ZERO PHASE
 BAND PASS FILTER
 BASE LEVEL EQUALISATION
 PHASE ROTATION
 RVD ANALYSIS

Processing record length: 4 sec
 Processed to DMO by NCG
 Every 100ms
 Using FK method
 Every 500ms
 z
 A 100deg phase rotation was applied to convert data to SE0 positive polarity
 Using Robust Least Squares method

DISPLAY PARAMETERS
 Wiggle overlay - Zero phase preserved amplitude stack (every 2nd CDP)
 Colour shading - Delta Rp -ve values Red, +ve values Blue



522020

ENCLOSURE 4

OR 0404

LINE	BHB96-108
SP	1100 - 1535
CLIENT	BORAL
AREA	BASS STRAIT



DELTA Rp

Horizontal Scale: 1:25000 Vertical Scale: 20 cm/s

Job Number: 859108 Date: May 1996



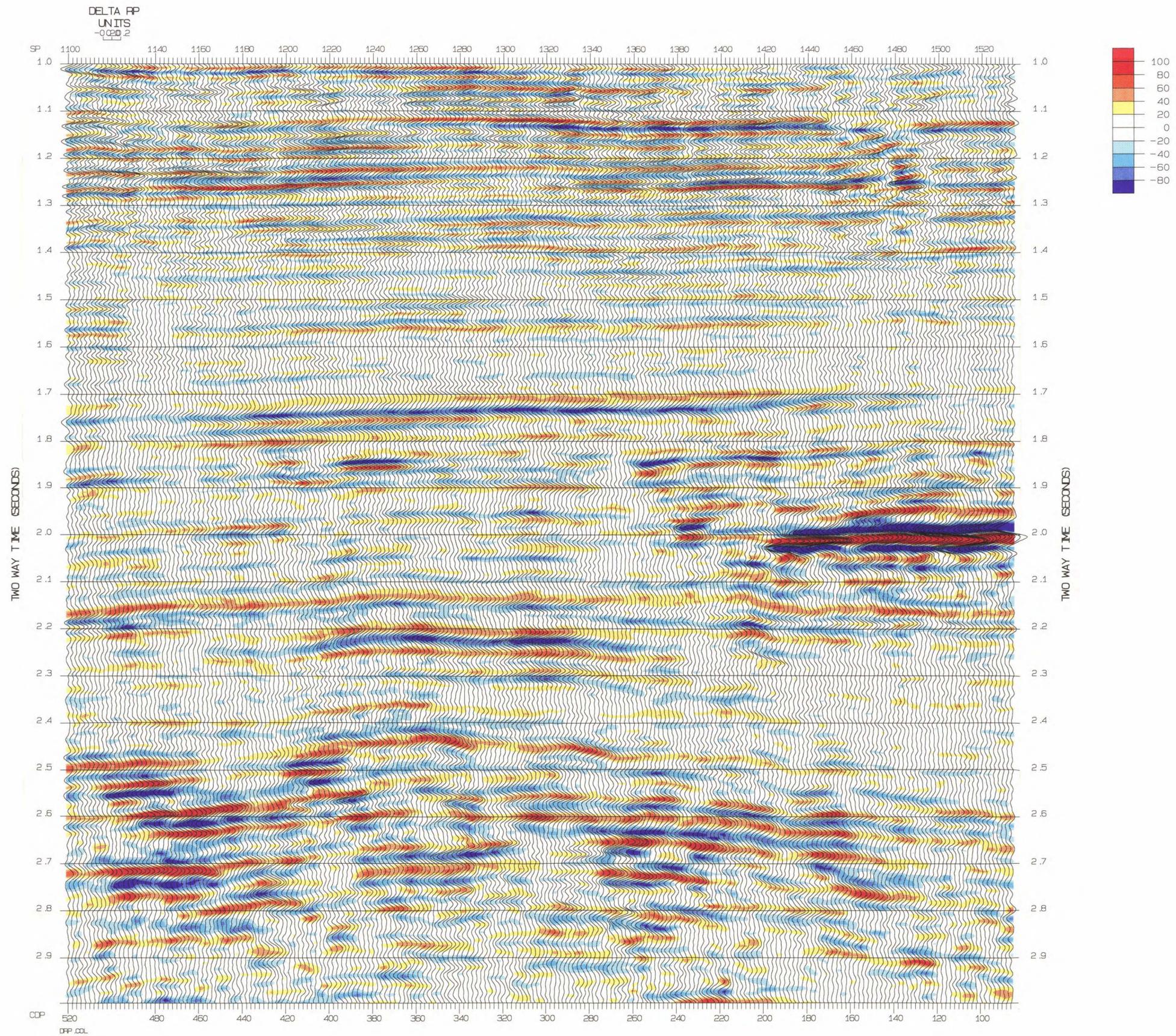


PROCESSING SEQUENCE Processing record length: 4 sec

PRE-STACK PROCESSING	Processed to DMO by MGC
VELOCITY ANALYSIS	Every 1000m
PRE-STACK TIME MIGRATION	Using FK method
VELOCITY ANALYSIS	Every 500m
NMO APPLICATION	
FRONT END MUTE	
CONVERSION TO ZERO PHASE	
BAND PASS FILTER	z
BASE LEVEL EQUALISATION	
PHASE ROTATION	A 100deg phase rotation was applied to convert data to SEG positive polarity
AVO ANALYSIS	Using Robust Least Squares method

DISPLAY PARAMETERS

Wiggle overlay - Zero phase preserved amplitude stack (every 2nd CDP)
 Colour shading - Delta Rp: +ve values Red, -ve values Blue



522051

ENCLOSURE 5 OR 0434

LINE **BH896-100**
 SP **1151 - 1850**
 CLIENT **BORAL**
 AREA **BASS STRAIT**

INTERCEPT TIMES GRADIENT

Horizontal Scale: 1:25000 Vertical Scale: 28 cm/s
 Job Number: 858188 Date: May 1996

0.0 0.5 1.0 KILOMETRES
 1:25000

Robertson Robertson Research
 Australia Pty. Ltd.

PROCESSING SEQUENCE Processing record length: 5 sec

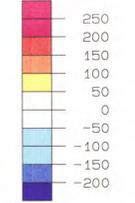
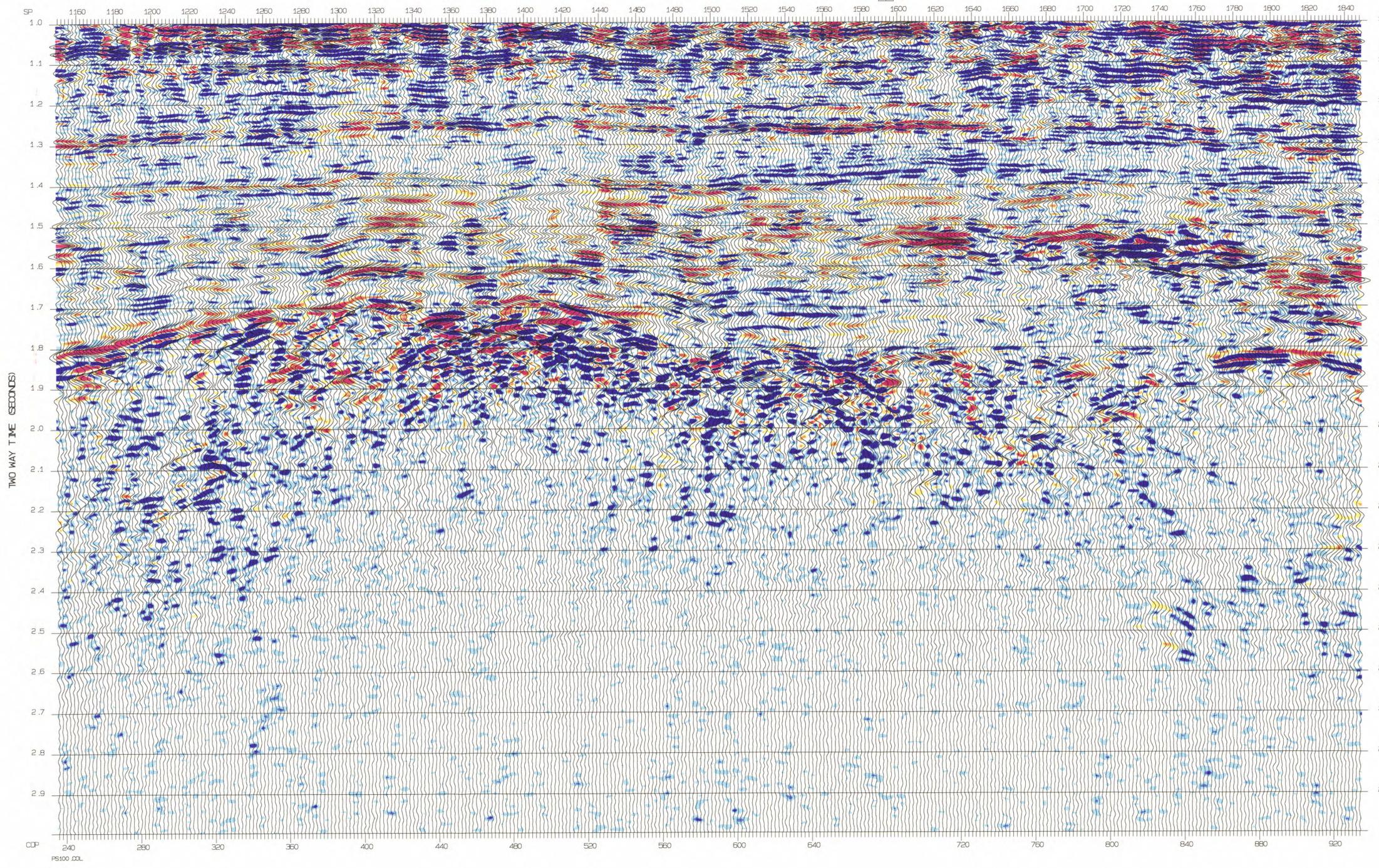
PRE-STACK PROCESSING	Processed to DMG MC
VELOCITY ANALYSIS	Every 100m
PRE-STACK TIME MIGRATION	Using FK method
VELOCITY ANALYSIS	Every 500m
NMO APPLICATION	
FRONT END MUTE	
CONVERSION TO ZERO PHASE	
BAND PASS FILTER	
BASE LEVEL EQUALISATION	
PHASE ROTATION	A 180deg phase rotation was applied to convert data to SEG positive polarity
RVD ANALYSIS	Using Robust Least Squares method

DISPLAY PARAMETERS

Wiggle overlay - Zero phase preserved amplitude stack (every 4th CDP)
 Colour shading - Intercept = Gradient: +ve values Red, -ve values Blue



UNITS
-0.020.2



TWO WAY TIME (SECONDS)

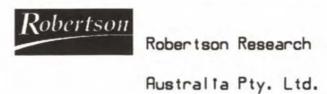
TWO WAY TIME (SECONDS)

CDP

PS100.DD

ENCLOSURE 6

OR-0424

LINE	BHB96-108
SP	1100 - 1535
CLIENT	BORAL 
AREA	BASS STRAIT
INTERCEPT TIMES GRADIENT	
Horizontal Scale# 1:25000	Vertical Scale # 20 cm/s
Job Number # 858188	Date # May 1996
	
	
PROCESSING SEQUENCE	Processing record length# 5 sec
PRE-STACK PROCESSING	Processed to DMG MGCC
VELOCITY ANALYSIS	Every 1000m
PRE-STACK TIME MIGRATION	Using FK method
VELOCITY ANALYSIS	Every 500m
NMO APPLICATION	
FRONT END MUTE	
CONVERSION TO ZERO PHASE	
BAND PASS FILTER	
BASE LEVEL EQUALISATION	
PHASE ROTATION	A 180deg phase rotation was applied to convert data to SEG positive polarity
RVO ANALYSIS	Using Robust Least Squares method
DISPLAY PARAMETERS	
Wiggle overlay - Zero phase preserved amplitude stack (every 4th CDP)	
Colour shading - Intercept * Gradient# +ve values Red, -ve values Blue	

