Seismic Processing
and
Depth Imaging
Final Report

for

Apache Energy Ltd

Survey: Gippsland East 3-D

HGP2002A (2002)
Tuskfish (2003)
Elver (2007)

Location: Vic/P59

April 30 2008

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Section 1: Overview

1.1 INTRODUCTION

This processing report covers the Time processing and Pre-Stack Depth Imaging of three overlapping surveys over Apache Energy Ltd's acreage in the Gippsland Basin, offshore southeast Australia. The Gippsland East program covered permits Vic/P59, Vic/P46, Vic/L20, Vic/L6 and intrudes into Vic/P49 and Vic/L5 (Figure 1.1 below).

The work was performed by 3DGeo Inc at its offices in Houston, Texas, USA during April 2007-April 2008

The three overlapping surveys as defined by the Request For Services (RFS) are as follows:

Survey	Area (sq km)	Date Acquired	Processing
HGP2002A	680	2002	Time Pre-processing
Tuskfish	1050	2003	
Elver	650	2007	Pre-processing and PSTM
Total Project after Merge	2402		Kirchhoff Pre-Stack Depth Migration

Gippsland Basin is Australia's most prolific oil province. The region is characterized by a large scale and complex system of submarine canyons in the overburden, with a large percentage of high velocity carbonate fill. This system cuts into a lower velocity clay sequence. Producing fields in the Gippsland Basin consist of shallow (1.0-2.5 sec) structures at the top of the Latrobe group with maximum structural dips of up to 20 degrees. Beneath the existing Top of Latrobe accumulations there are also smaller and more complex intra-Latrobe and Golden Beach traps. These deeper structures lie in a series of tilted fault blocks and are often overlain and sealed by volcanics. The depths of these deeper structures vary between 3.0-5.0 seconds (TWT), with structural dips of up to 30 degrees.

The project objective was to process the newly acquired Elver program and reprocess HGP2002A through state-of-the-art Time processing preparatory to merging both surveys with the Tuskfish pre-processed CDP gathers provided by Apache Energy. With a unified seismic data volume fully merged after data matching of phase, amplitude, and time, 3-D Pre-Stack Depth Migration (PSDM) and 3-D iterative velocity modeling was performed to provide a clearly focused 3-D subsurface image with reflection energy accurately positioned in depth. A Depth imaging technique was required especially in the eastern part of the Gippsland East program where water depths increased rapidly and deeply incised submarine canyons as well as a highly incised and rugose shelf slope precluded accurate positioning of reflectors using Time processing due to the highly variable travel-times through this overlying medium (Figure 1.2 below).

In the early stages of the project the HGP2002A area was increased to 800 sq km by adding approx 120km in the southwest to fully image the specific subsurface areas of interest to Apache.

Additionally, it was noted that the Tuskfish pre-processed gather data received by Apache contained noticeable remnant multiple interference and it was agreed to apply Radon Demultiple to these data in order to further attenuate this unwanted energy prior to the merging of the Tuskfish program with Elver and HGP2002A.

As the Elver survey was new acquisition, a 12.5 x 25m final pre-stack time migration (PSTM) volume was provided to Apache in October 2007 as an initial interpretation volume pending the later delivery of the full 2402 sq km unified PSDM volume in April 2008.

While all original surveys employed a 12.5 x 25m standard binning methodology, the Tuskfish program was acquired orthogonal to Elver and HGP2002A. As a result, all data were binned within a common 12.5 x 12.5m grid and final volumes processed either 12.5 x 25m (for Elver PSTM) or 25 x 25m output grid for the final 2402 sq km Gippsland East 3-D PSDM volume.

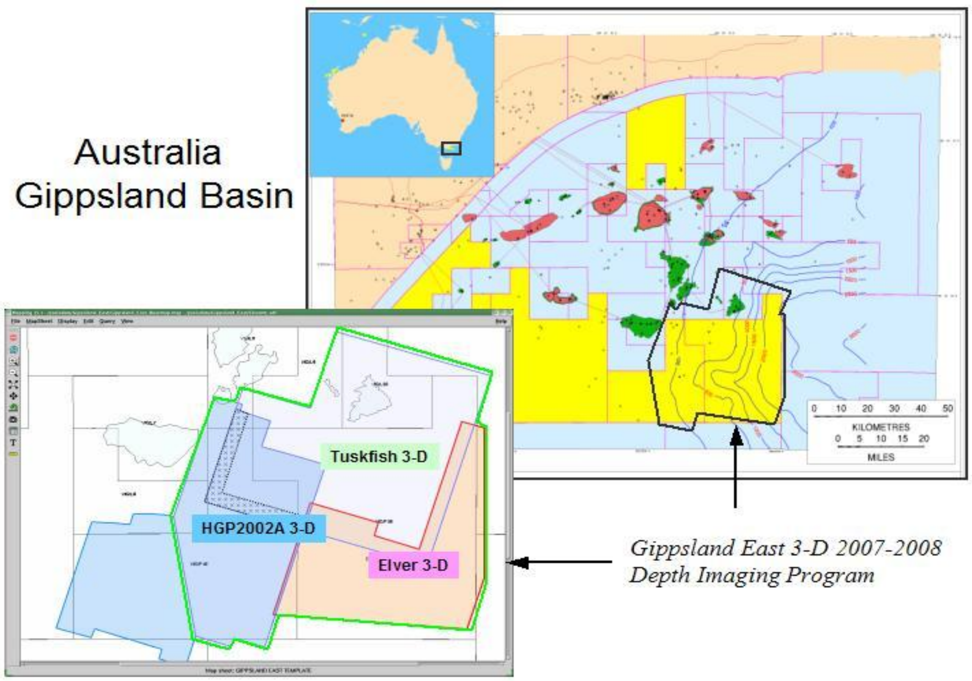


Figure 1.1 Gippsland East 3-D Location Map

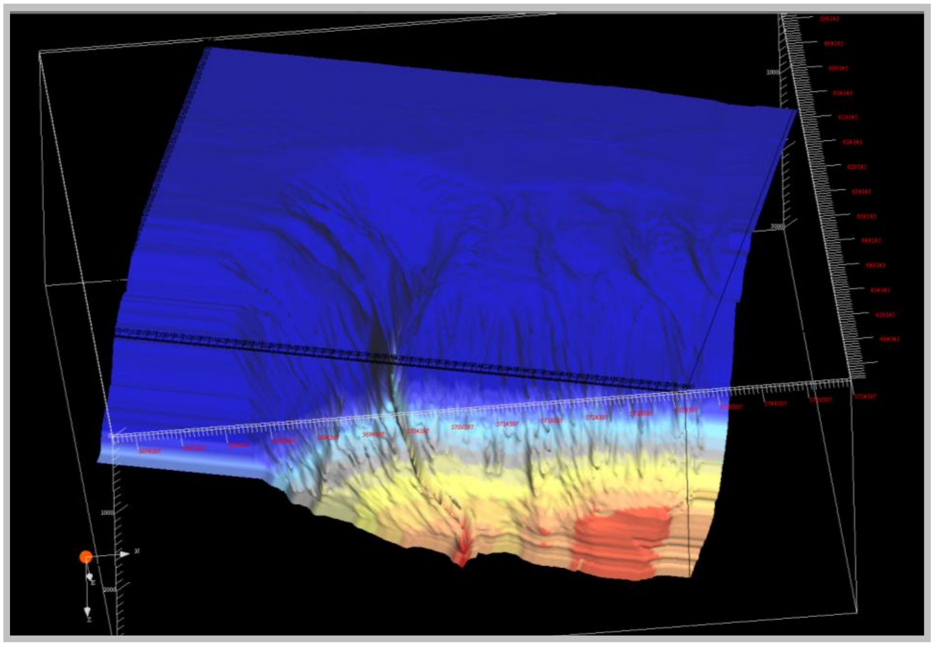
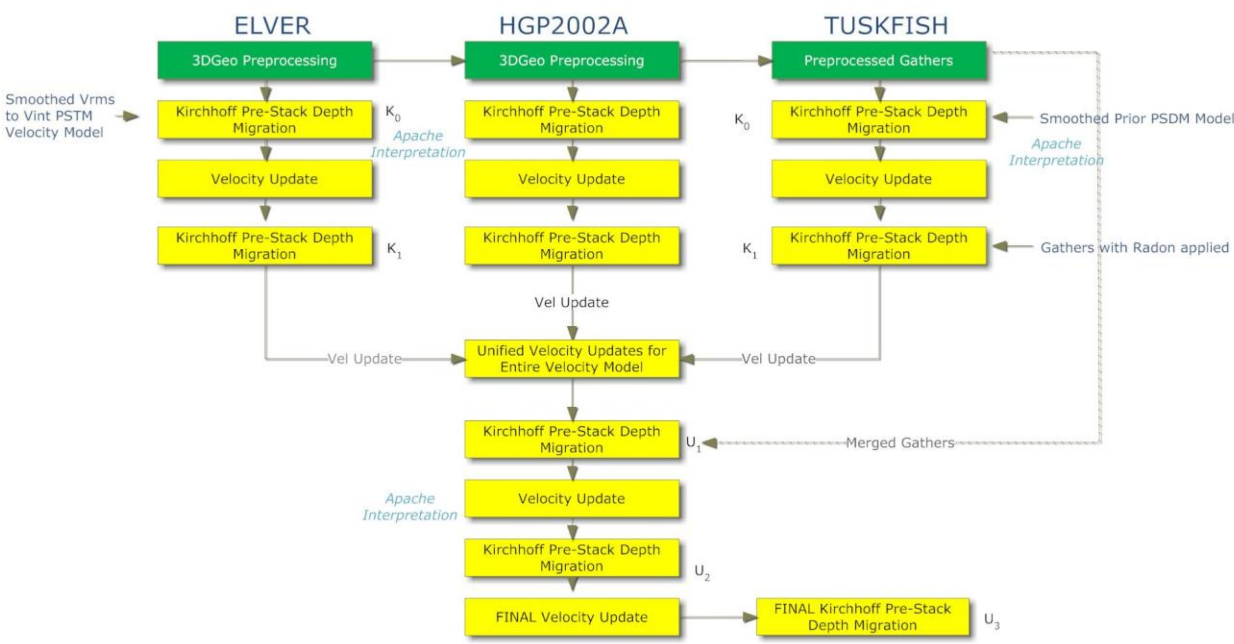


Figure 1.2 Bathymetry outline highlighting incised canyon and slope rugosity

The proposed processing strategy to allow parallelism in the combined workflow and convergence towards a final unified 3-D depth migrated volume is outlined in the following



graphical representation of the concept.

In the final workflow, a total of five PSDM iterations (Iterations 0-4) was performed as described in the depth imaging section of the report.

The report is divided into two sections covering each of the key stages – Time and Depth – in detail.

1.2 PERSONNEL

3DGEO	
Walt Ritchie	Senior VP. Seismic Services
Wilfrid Milan	Senior Processing Supervisor
James Leberknight	Processing Geophysicist
Alexey Artyomov	Senior Geophysicist
Jose Omana	Senior Imaging Geophysicist
Cristi Lupascu	Senior Geophysicist
Emmy Zhang	Geophysical Support
APACHE ENERGY	
Paul Bouloudas	Client Representative
Rob Kneale	Interpretation

1.3 EQUIPMENT

All of the processing was done in the 3DGeo's Houston seismic processing facility. Large scale Linux-based cluster systems supported by large Terabyte scale RAID provided the parallel computing infrastructure.

Time processing was performed using Paradigm's "Disco/Focus" software systems while the depth imaging utilized 3DGeo's internally developed 3-D velocity modeling and 3-D pre-stack imaging environment. Landmark "Promax" and SMT "Kingdom Suite" also played auxiliary roles in supporting the primary processing systems.

1.4 ACQUISITION

HGP2002A

General

Vessel	MV Geco Beta
Area	800 sq km (reprocessed area)
Heading	~198degrees
Date	August 2002

Streamer

Cable Type	Nessie 4 sections/Nessie 3 bubbles
Number of Streamers	8
Group Interval	12.5m
Streamer Length	4600m
Streamer Depth	8m (+/-1m)
Streamer Separation	100m
Number groups per streamer	368
Streamer Tracking	Sonardyne SIPS

Recording

Recording System	TRIACQ v2.0
Recording Format	SEGD 8015 rev 2
Record Length	6144ms
Sample Period	2ms
Hi-cut Filter	180 Hz/18 dB per octave
Lo-cut Filter	3 Hz/18 dB per octave
Media	IBM 3590

Source

Source	Bolt air guns
Number sources	2
Source Separation	50m
Shotpoint interval	18.75m (flip/flop)
Array Volume	3542 cu in
Operating Pressure	2000 psi
Source Depth	7m (+/- 0.5m)
Number sub-arraye per source	3

TUSKFISH 3-D

General

Vessel	MV Western Monarch
Area	~1050 sq km
Heading	~108degrees
Date	January 2003

Streamer

Cable Type	Thompson Marconi Sentry Solid
Number of Streamers	8
Group Interval	12.5m
Streamer Length	5000m
Streamer Depth	8m (+/-1m)
Streamer Separation	100m
Number groups per streamer	400
Streamer Tracking	

Recording

Recording System	I/O MSX
Recording Format	SEGD 8058 rev 2
Record Length	6600ms
Sample Period	2ms
Hi-cut Filter	0.75 Nyquist
Lo-cut Filter	2 hz
Media	IBM 3590

Source

Source	Bolt air guns
Number sources	2
Source Separation	50m
Shotpoint interval	18.75m (flip/flop)
Array Volume	3542 cu in
Operating Pressure	2000 psi
Source Depth	7m (+/- 0.5m)
Number sub-arraye per source	3

ELVER 3-D

General

Vessel	MV Western Trident
Area	~650 sq km
Heading	~193 degrees
Date	March-April 2007

Streamer

Cable Type	Thompson Marconi Sentry Solid
Number of Streamers	8
Group Interval	12.5m
Streamer Length	4000m
Streamer Depth	8m (+/-1m)
Streamer Separation	100m
Number groups per streamer	320
Streamer Tracking	TRINAV GPS

Recording

Recording System	TRIACQ v5.0
Recording Format	SEGD
Record Length	6000ms
Sample Period	2ms
Hi-cut Filter	206 Hz/264 dB per octave
Lo-cut Filter	2 Hz/12 dB per octave
Media	IBM 3590

Source

Source	Bolt air guns
Number sources	2
Source Separation	50m
Shotpoint interval	18.75m (flip/flop)
Array Volume	3000 cu in
Operating Pressure	2000 psi
Source Depth	7m (+/- 0.5m)
Number sub-arrays per source	

Gippsland East 3-D
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Section 2: Time Processing

2.1 Processing Summary

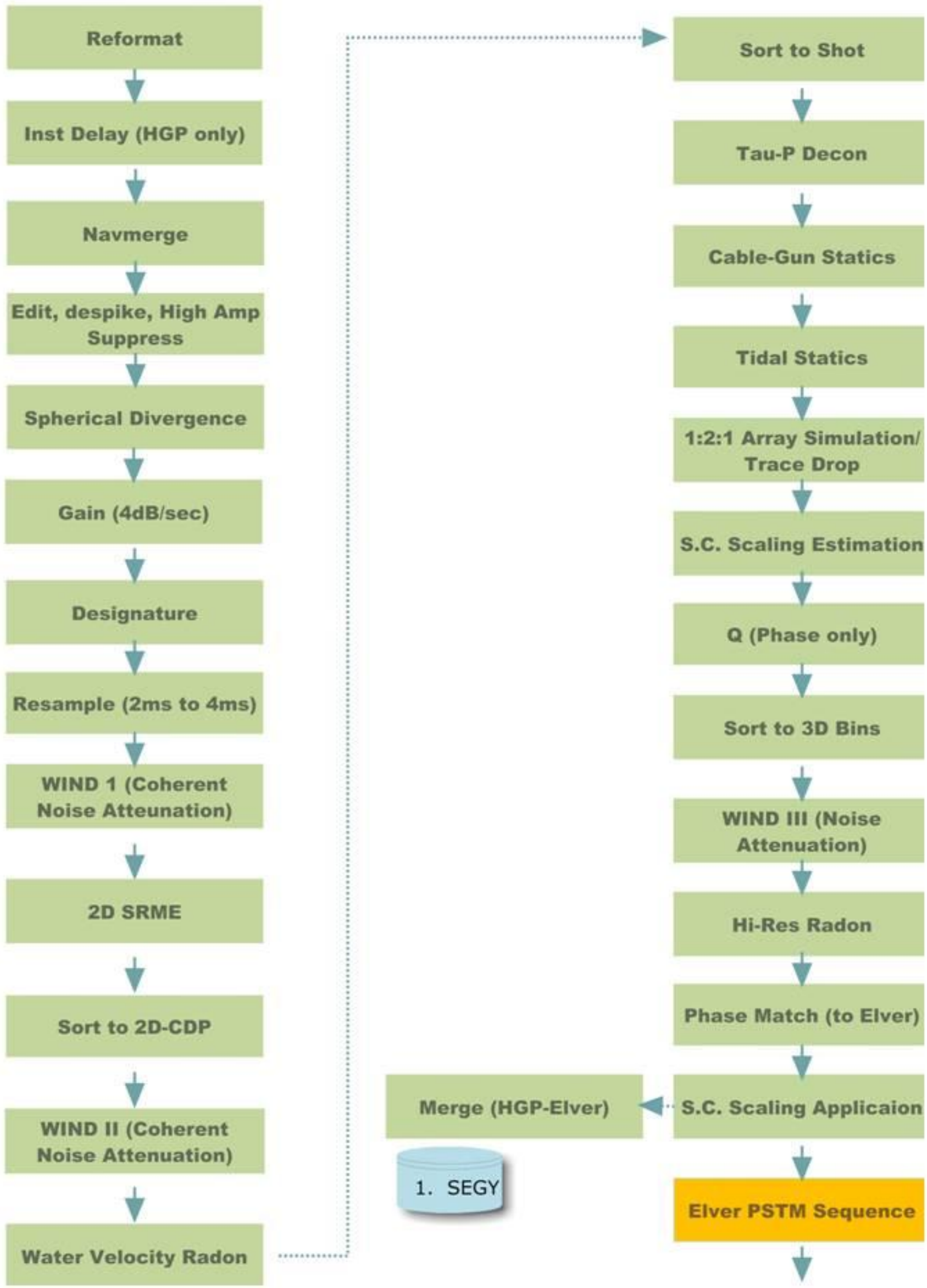
As the major goal of this project was to provide a unified 3-D PSDM volume, the first key stage was to effectively time process the individual surveys and merge the data volumes from the three surveys into a single, fully integrated signal-enhanced unit that would provide the basis for a successful iterative 3-D velocity modeling and depth migration campaign.

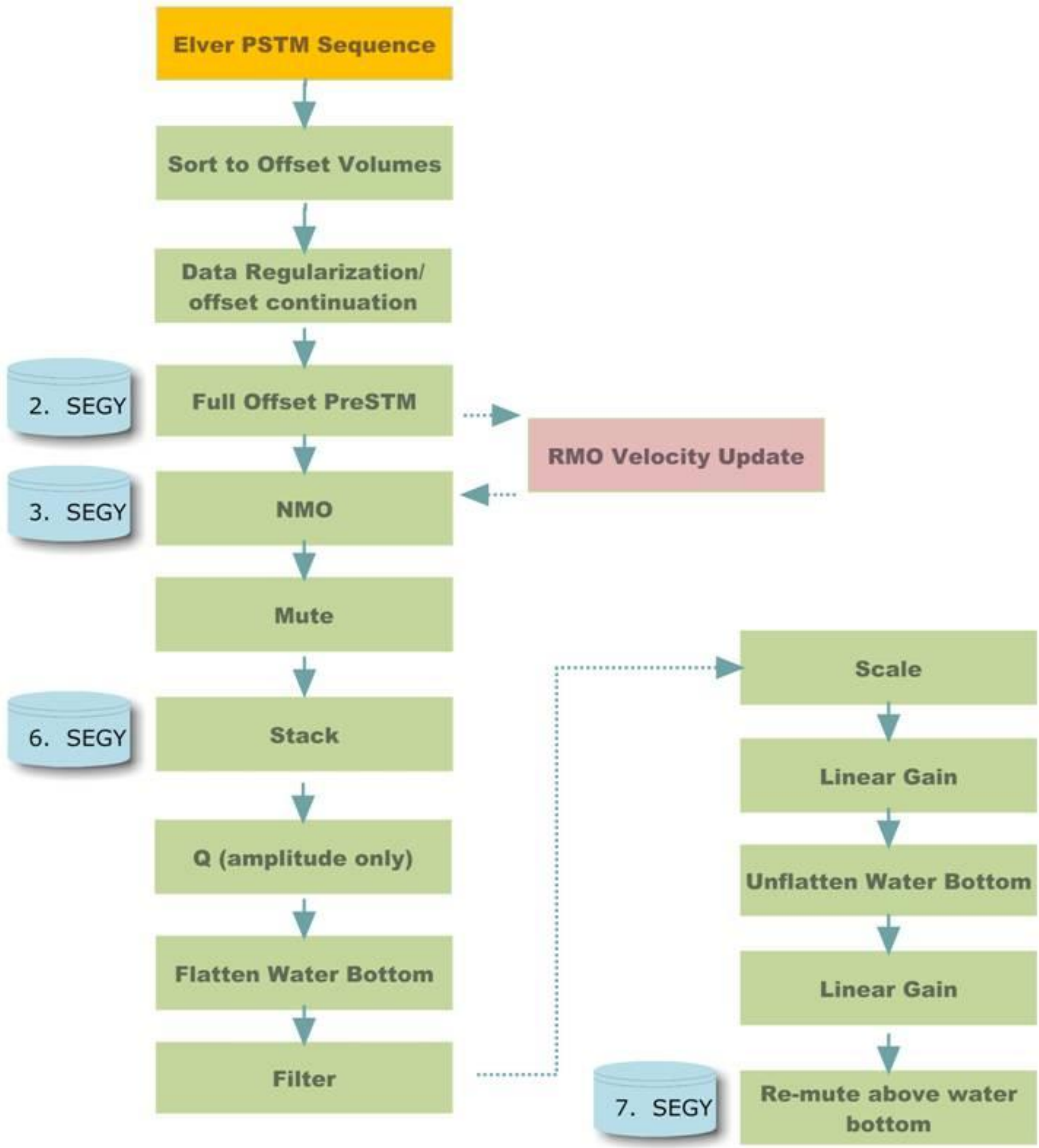
As the HGP2002A and Elver surveys shared closely aligned acquisition parameterization, parallel pre-stack time processing of the two projects was undertaken using Elver as the master survey. HGP2002A data as delivered to 3DGeo suffered from initial readability problems requiring additional effort to be formatted suitable for the reprocessing stage. A summary description of the problem and 3DGeo's solution is outlined in the Appendix. While these HGP data were being analyzed and integrity checks performed, initial testing progressed on the Elver data after its receipt on May 10 2007, liaising closely with the Apache Energy representative. As parameters were finalized and as HGP data became available, the validity of the selected parameters was verified on the HGP data.

In parallel, inspection of Tuskfish pre-processed gathers received for later integration into the unified PSDM workflow revealed the presence of interfering residual multiple energy on these gather data. As it was considered that this interfering energy may inhibit the ability to ability to perform useful migration velocity analysis, Apache approved the application of high resolution Radon demultiple to these data.

With each of the three data sets being optimally time processed, the stage was set for a successful integration of the surveys into a single unified volume after phase and amplitude matching of the data sets with Elver as master survey. In the HGP and Tuskfish overlap area, testing provided an effective fold merge strategy taking into consideration the orthogonality of the surveys resulting from the different shooting azimuth of Tuskfish relative to its partner surveys.

The Time processing flow is summarized below and described in detail in the following sections.

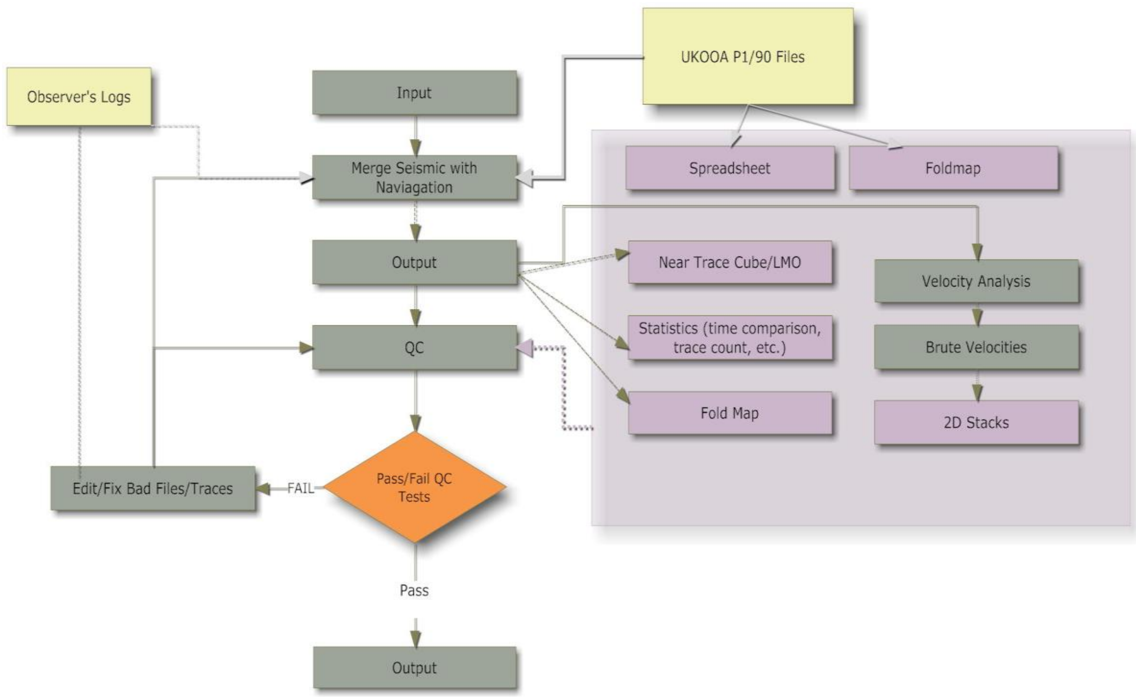

Reformat
Inst Delay (HGP only)
Navmerge
Edit, despike, High Amp Suppress
Spherical Divergence
Gain (4dB/sec)
Designature
Resample (2ms to 4ms)
WIND 1 (Coherent Noise Atteunation)
2D SRME
Sort to 2D-CDP
WIND II (Coherent Noise Attenuation)
Water Velocity Radon
Sort to Shot
Tau-P Decon
Cable-Gun Statics
Tidal Statics
1:2:1 Array Simulation/ Trace Drop
S.C. Scaling Estimation
Q (Phase only)
Sort to 3D Bins
WIND III (Noise Attenuation)
Hi-Res Radon
Phase Match (to Elver)
S.C. Scaling Applicaion
Merge (HGP-Elver)
1. SEGY
Elver PSTM Sequence


Elver PSTM Sequence
Sort to Offset Volumes
Data Regularization/
offset continuation
2. SEGY
Full Offset PreSTM
RMO Velocity Update
3. SEGY
NMO
Mute
6. SEGY
Stack
Q (amplitude only)
Flatten Water Bottom
Filter
Scale
Linear Gain
Unflatten Water Bottom
Linear Gain
7. SEGY
Re-mute above water
bottom

2.2 Time Processing Sequence (Production)

2.2.1 Preparation of Navigation Data

In anticipation of subsequent processes including navigation merge and QC, UKOOA P1/90 datasets were converted to .fmt format, which is internally used by Disco/Focus. These navigation data were also used to create a single-sample stack and navigation-only derived fold map, and also to create a spreadsheet containing vital information to be added to the data headers (including sequence min/max ffid, shooting direction, and "ffidseq" which uniquely identifies every shot record in the entire survey). These spreadsheets, for both HGP and Elver, can be found in Appendix E.



2.2.2 Reformat to FOCUS Format

The basic function of the tape transcription process was to reformat demultiplexed field tape data from SEGD to FOCUS format. Full word, 32 bit floating point data at hydrophone amplitude was maintained.

2.2.3 Edit Auxiliary Channels (HGP only)

The HGP field data contained auxiliary channels 1-36 which did not contain seismic data. These channels were edited prior to subsequent processing.

2.2.4 Instrument Delay (HGP only)

A bulk static shift of -5.6ms was applied to the data in order to correct for the recording instrument filter delay. The filter delay was due to acquisition using Nessie 3 bubbles with a Nessie 4 streamer.

2.2.5 Navigation Merge

True x and y coordinates of the source and receiver locations as well as other header information such as gun-id and water depth were merged with the seismic data based on shotpoint number. The difference between seismic time and navigation time was also recorded for subsequent QC.

2.2.6 Grid Definition: Pre-processing

The final grid, which incorporates all three datasets, is as follows.

Inline	Crossline	X	Y
0001	0701	662851	5666442
0001	6700	686023	5737760
6300	0701	587967	5690773
6300	6700	611140	5762090

Bin Size	12.5x12.5m
Azimuth	72 degrees

2.2.7 Data Integrity QC

Several steps were taken to ensure the integrity of the seismic data and/or the navigation merge process. QC steps included:

- The times (Julian day, hour, minute, second) between that found on the seismic data headers and the P1/90 files were compared. Time differences greater than 3 seconds were considered anomalous.
- Any missing ffids or channels on the nav-merged data were identified.
- Fold maps generated from the seismic data and the navigation data were compared.
- A near-trace cube and LMO- QC was conducted.
- 2D stacks were generated from gun #1 and cable #4 for each sequence. A brute velocity analysis was performed prior to the stack generation. (RMS velocities, provided by the client for HGP, were sufficient for the initial brute stacks.) These stacks, as well as sample shot records, were visually inspected for data quality.

Individual fold maps for HGP, Elver, and Tuskfish as well as the combined program are provided in Appendix G.

2.2.8 Field Data Edits

Records and traces flagged as bad in the Observer's logs or those identified as having anomalous amplitudes from the data integrity QC step were edited from the processing sequence. Any sail lines containing substantial gaps were split into their separate component segments.

2.2.9 Corrupted Data Recovery

The data integrity QC process revealed a significant number of shot records from HGP containing corrupted channels. Fortunately we were able to recover most of this data and few shot records were lost as a result of these corrupted channels. Any shot records that did not pass the initial QC went through a rigorous repair process before subsequent reapplications of navigation-merge and/or QC. The data recovery methodology is described in Appendix A.

2.2.10 Despike

Spikes and other anomalously high amplitudes were removed.

2.2.11 Spherical Divergence Correction

Time-variant trace scaling functions were applied to the data to compensate for the decay in amplitude resulting from the propagation of a seismic wave from a point source in a layered medium. To correct for this geometric spreading, the inverse of the amplitude decay factor (A) was computed and applied to the data where A= 1/(T*V^2), T being the two-way travel time and V being a regionally averaged velocity function.

2.2.12 Exponential Gain

Gain function	4 dB per second
Time of application	0.0 – 4.0 seconds

2.2.13 Deterministic Designature

A designature operator was modeled from a far-field source signature provided by Apache in order to remove the source effects from the data and also to convert the data to its zero-phase equivalent.

Note that the -62ms instrument delay has been incorporated into the Elver designature operator.

2.2.14 Resample

Data was resampled from 2ms to 4ms. A zero-phase anti-alias filter was applied prior to resample.

2.2.15 Lo-cut filter

A 3 Hz low cut filter was applied to attenuate the low frequency bias from the data.

2.2.16 Hi-cut filter

A high cut filter of 83Hz (36 dB/octave) was applied to attenuate the high frequency noise from the data

	Filter Cutoff	Slope
Low Cut	3Hz	18 dB/octave
High Cut	83Hz	36 dB/octave

2.2.17 Sort

The data were split into its component cable-gun combinations in order to create individual subsurface lines for each swath.

2.2.18 Noise Attenuation using WIND-based workflow

WIND is an amplitude-preserving suite of process workflows used to attenuate noise without adversely affecting the data ("signal"). WIND is typically custom-designed to address specific signal-noise conditions particular to any given project. The general principle of the WIND concept is to separate the data signal from the noise and attacking only the noise using appropriate techniques (e.g. FK, Radon, etc.) and domains (e.g. common offset, common receiver, etc.) The final result is obtained by a controlled addback of the conditioned "noise" record to the "signal" record. A description of the methodology as applied to the Elver and HGP2002A data is contained in Appendix B.

WIND was applied in three stages within the production processing sequence. This first application predominantly addressed swell and cable strum noise as well as coherent noise noted on the raw data. Despike was followed by a frequency bandwidth-dependent anomalous noise suppression, and a final FK-based linear noise suppression in a combined workflow (see Appendix B) that addressed the majority of the noise present on the data. Residual random and coherent noise on the data were further attenuated by the WIND II and WIND III applications described later.

2.2.19 Velocity Analysis

Velocities (Pass 1) were picked using noise attenuated WIND cable-gun/channel gathers on a 1km x 1km grid. Prior to picking, the sample gathers were treated with a mild Radon demultiple filter, AGC, predictive deconvolution, and a bandpass filter as follows.

Radon	-70 to +680ms at 2800m	434 p-values
Deconvolution	240ms operator	32 ms gap
AGC	500 ms gates	
Bandpass Filter	4-55Hz	36 dB/octave

Eta analysis was also conducted at this time to assess the contributions of far-offset and/or the effects of anisotropy. For each velocity location, multi velocity function (MVF) stacks, semblances and gathers were displayed interactively, allowing the stacking velocities to be interpreted.
Velocities were QC'd by the client to check the validity of the picks and provide feedback regarding predominant trends in the region. Figure 2.1 illustrates a typical velocity analysis display.

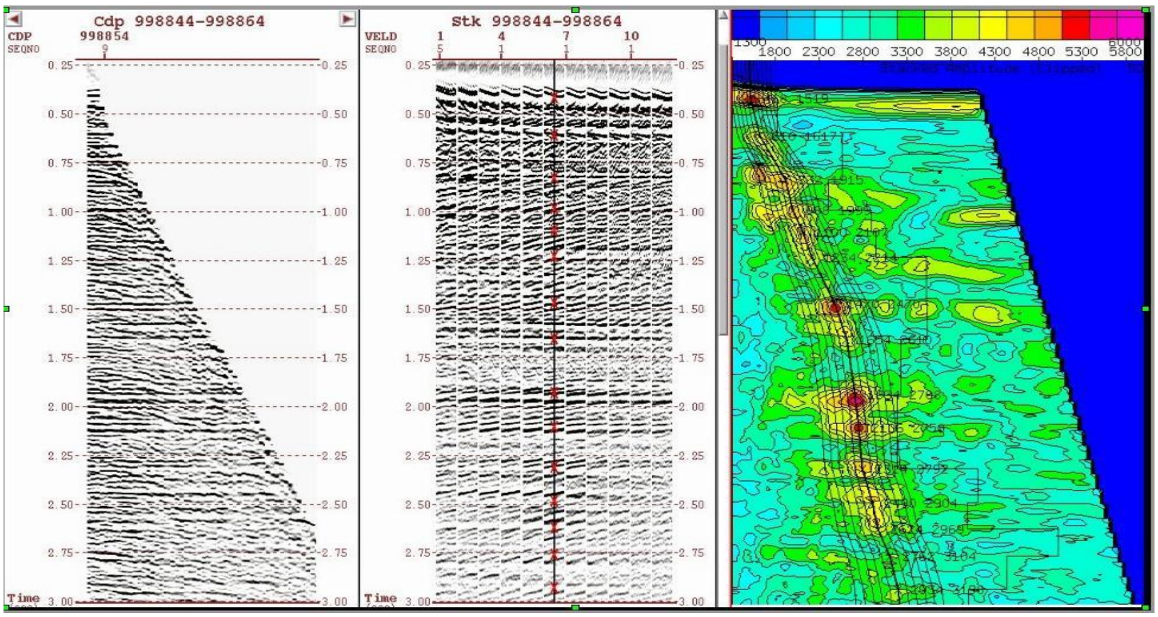


Figure 2.1 Typical Velocity Analysis Display

2.2.20 Pre-stack Mute

A final mute was chosen, in collaboration with the client, to be applied pre-stack. This mute was water bottom time dependent. See Section 2.4.2 below for the selected final mute parameters.

2.2.21 QC stack

A 3D stack volume was created from the WIND data and the Pass 1 velocities. Spherical divergence and programmed gain corrections were applied in this process. Selected inlines, crosslines and timeslices from the stack were displayed for QC.

2.2.22 Water Bottom Time Interpretation Trace Header Merge

Certain processes, including the application of the spherical divergence correction, depended on accurate water bottom times. Those times derived from the P1/90 navigation data proved to be inadequate for production work. Hence new water bottom times were subsequently picked on the stack volumes (or on the client PSTM volume for HGP). While these new interpolated water bottom times were substantially better than the P1/90 values, the severe rugosity of the water bottom made it extremely difficult, if not impossible, to precisely map this horizon. This proved to be a crucial factor in later depth imaging stages. Apache was able to provide bathymetry data which was sufficiently accurate to enable successful continuation of the project. Final water bottom times in the data headers were updated as soon as they were available.

2.2.23 2D SRME

Surface-related (water bottom) multiples were evident throughout the survey area. The first step in attacking these multiples was a 2D SRME scheme that models the multiples and later removes them though an adaptive subtraction routine.

Spherical divergence gain correction was removed prior to SRME and reapplied afterwards.

2.2.24 Noise Attenuation (WIND II)

The SRME corrected data went through a second pass of WIND in CDP domain to further attenuate remaining swell and linear noises persisting in the data. In a similar manner to WIND I, data were first split by frequency and addressed as follows using AMPSCAL multi-channel high amplitude noise attenuation. AMPSCAL suppressed anomalously high amplitudes falling above a specified threshold reducing them to the average amplitude level.

Frequency Range	# traces in average	Amplitude threshold
<14Hz	31	x 1.8 average amplitude
>14Hz	31	x 2.8 average amplitude

Following the AMPSCAL application, an FK domain dip filter rejecting dips greater than +12ms/trace was applied. Shuey's (1985) AVO modeling formula was invoked to model signal for separation of noise from the signal prior to the FK application to the noise set, thus preserving signal amplitude integrity during the process.

2.2.25 Water Velocity Radon

In order to further attenuate the strong water bottom multiple, Radon demultiple was applied at this stage using the water velocity for NMO. 434 P-values covering a moveout range of -70 to 680 ms at an offset of 3800m was employed. The data were sorted to 2D CDP domain prior to this process. Afterwards the data was sorted back to the gun-cable domain.

Moveout Range	-70ms to +680ms
Reference Offset	3800m
P-values	434

Note that Radon was used to model the multiples and subtracted in the time domain.

2.2.26 Tau-P Deconvolution

Further efforts to attenuate multiples involved transforming the shot ordered data to the tau-p (Radon) domain. From this point the periodicity of the multiples can be more readily identified and addressed using a predictive (gap) deconvolution in tau-p space. .

Operator Length	87 pts @ 4ms
Gap Length	32ms

AGC in time domain was applied to the data prior to the tau-p implementation to stabilize the transform and removed after the transformation back to time domain.

2.2.27 Cable-Shot Statics

The gun depth of 7m and the cable depth of 8m caused the need for a 10 ms static shift on the data

Gun depth	7m
Cable Depth	8m
Shift Applied	10ms

2.2.28 Tidal Statics

Tidal Static corrections were applied to the data.

2.2.29 Trace Decimation (array simulation)

Traces were mixed using a 1:2:1 weighting scheme, and then the even traces were dropped. Differential NMO was applied before the trace drop

2.2.30 Source Consistent Amplitude Scaling Estimation

SCAC scalars were estimated in both the common channel and common source domain.

2.2.31 Q Compensation

In order to address inelastic attenuation, phase-only Q-compensation was applied with Q value=100.

2.2.32 Sort

The data was sorted to CDP domain for subsequent processing.

2.2.33 Noise Attenuation (WIND III)

A final implementation of a WIND-based noise reduction workflow using AMPSCAL was applied to address residual noise as well as certain noises amplified by the deconvolution process. Similar to WINDII, the following was implemented.

Frequency Range	# traces in average	Amplitude threshold
<14Hz	31	x 1.8 average amplitude
>14Hz	31	x 2.8 average amplitude

Following the AMPSCAL application, an FK domain dip filter rejecting dips greater than +10ms/trace was applied using the Shuey AVO method described in 2.2.24.

2.2.34 High Resolution Radon

Hi-res Radon was conducted using 851 p-values with moveouts ranging from -380 to +380 ms at an offset of 3000m to model the multiples.

Moveout Range	-380ms to +380ms
Reference Offset	3000m
P-values	851

The difference is computed in the time domain subtracting modeled multiple from the original trace for the final result. CDP fold is considered to avoid low fold Radon artifacts using linear interpolation as follows:
Fold= 1: keep 100% original trace
Fold= 30: keep 0% original trace
This Radon was applied to the final CDP gathers for Elver and HGP, as well as Tuskfish.

2.2.35 Match Filter

Both HGP and Tuskfish Radon gathers were matched to Elver. The methodology is discussed later in the report under Merging.

2.2.36 Source Consistent Amplitude Scaling Application

Application of the scalars computed in 2.2.30

2.2.36 Merge

Because of the common azimuths and geometry, HGP and Elver gathers were merged into one common pre-migration archive dataset in 2.2.37 and Tuskfish gathers were also collected together as a pre-migration archive dataset. A more detailed discussion follows later in the report.

2.2.37 Output

Final Radon gathers were produced and output to SEGY.

2.2.38 Sort to Common Offset Bins

At this point there were working sets of gathers (suitable for migration) for each survey.
These gather datasets were sorted into common offset bins (200-4000m, increment =100).
Offsets were regularized in this process.

2.2.39 Output Bin Relationships

	Nominal bin spacing (m)
HGP	12.5 x 25.0
Elver	12.5 x 25.0
Tuskfish	25.0 x 12.5
Gippsland East Full volume	12.5 x 12.5

Surveys were placed in a common 12.5 x 12.5m grid as follows:

	Inline increment	Crossline increment
HGP	2	1
Elver	2	1
Tuskfish	1	2

2.3 Pre-Processing Parameter Testing

Validation tests were conducted to determine parameterization to optimize data quality for the 3-D pre-stack depth imaging of the merged surveys. A further objective of the testing was to ensure consistency across the surveys for an effective merge without compromising the individual integrity of each survey. Two sail line swaths from and HGP (Seq009 and Seq057) and two from Elver (Seq090 and Seq094) were selected for testing. These swaths were chosen to represent both deep and shallow areas of the survey.

2.3.1 Lo-Cut Filter (zero phase)

Low Cut ranges to be tested were:

Low Cut (Hz)	Slope (dB/octave)
2.0	18.0
3.0	18.0
4.0	18.0
5.0	18.0

3Hz was chosen because it was the smallest value that successfully addressed the low frequency bias from the data. (See figure 2.2).

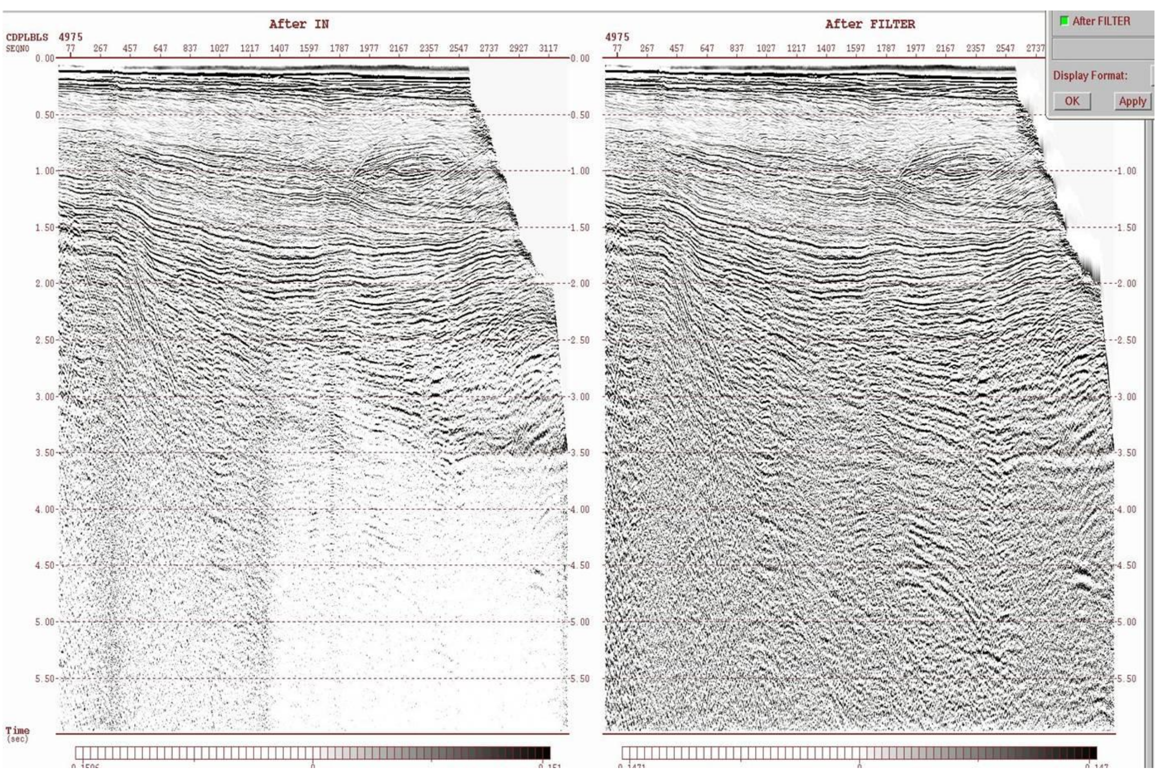


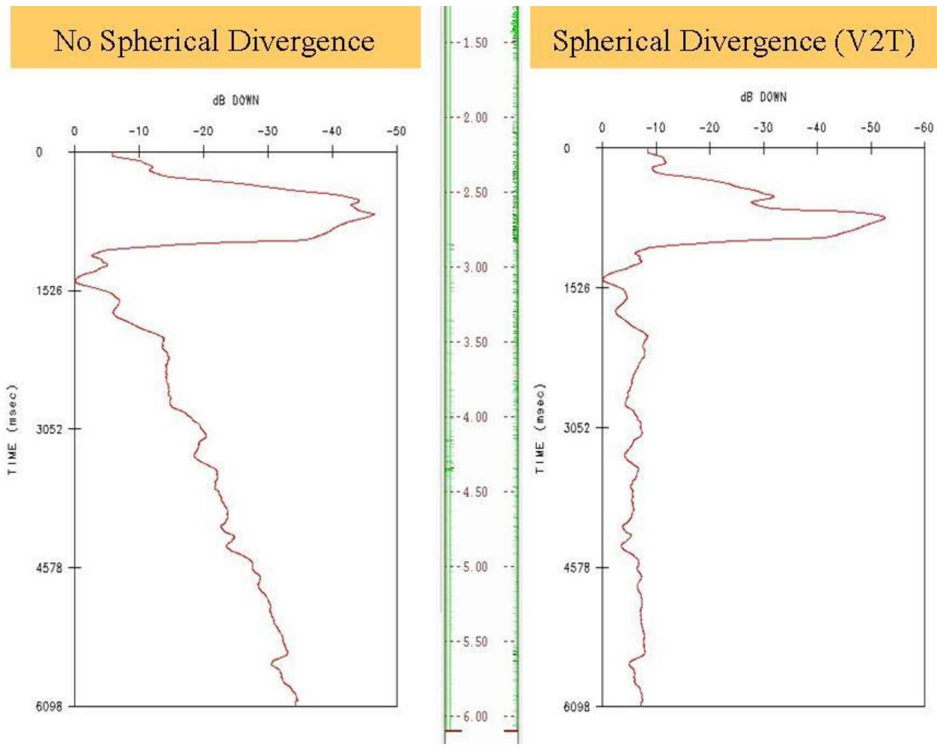
Figure 2.2 HGP Stack with and without Lo-Cut Filter (3Hz – zero phase)

2.3.2 Amplitude Recovery

To test the spherical divergence correction, we tested the application of a factor of 1/TV^2 and 1/TV^3 with the former chosen. (See Figure 2.3, 2.4)

Figure 2.3 illustrates typical gain curves of stacked data with and without the application of the spherical divergence correction.

Figure 2.3 Gain Curves



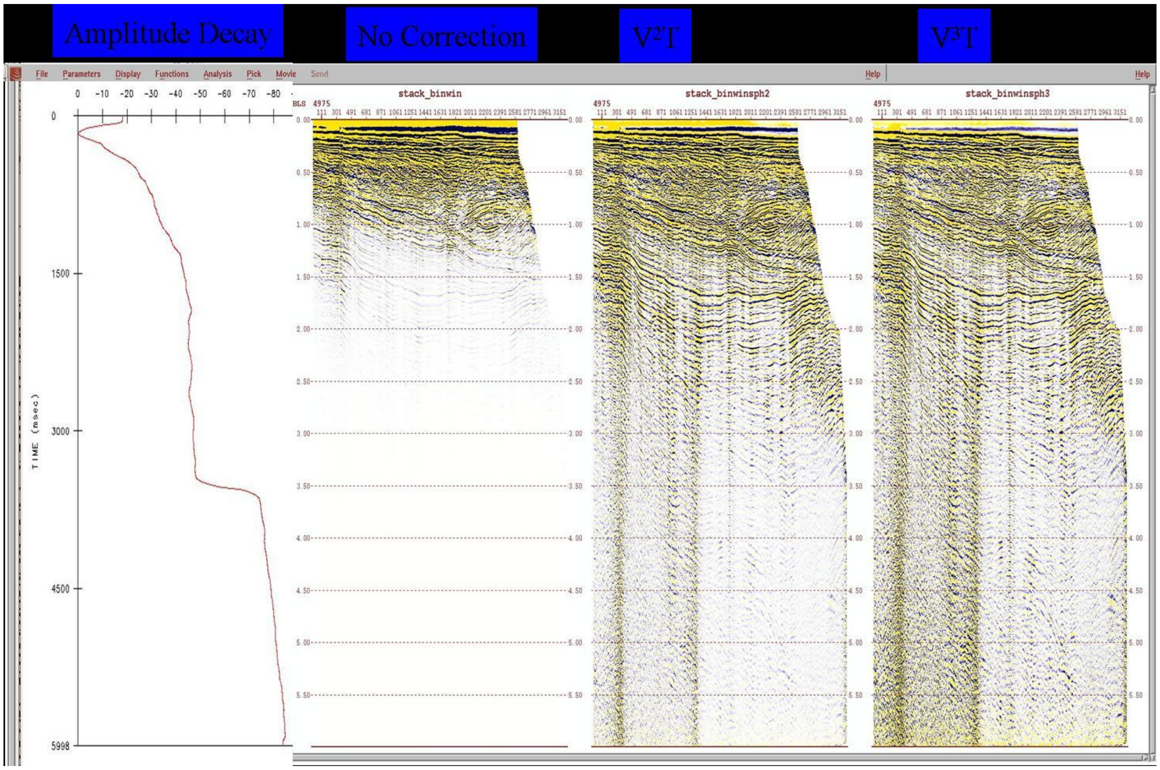


Figure 2.4 Spherical Divergence Corrections

2.3.3 Deterministic Designature

A designature operator was modeled from a source signature in order to remove the source effects from the data and also to convert the data to its zero-phase equivalent. Three different vintages of source signature were compared in order to obtain the best filter:

- The first wavelet was a far-field recorded source signature that was provided by the client.
- The second was derived statistically from the data (Burg method).
- The third wavelet was generated by flattening a rugose near-trace gather and stacking the flattened data.

Since these three methods yielded similar results, we opted for the far field recorded source signature from the client. Figures 2.5 and 2.6 depict the source signatures and designature operators for HGP and Elver. These figures demonstrate that the convolution of the source signature and the designature operator indeed yield a zero-phase wavelet.

Note that the -62ms instrument delay has been incorporated into the Elver designature operator.

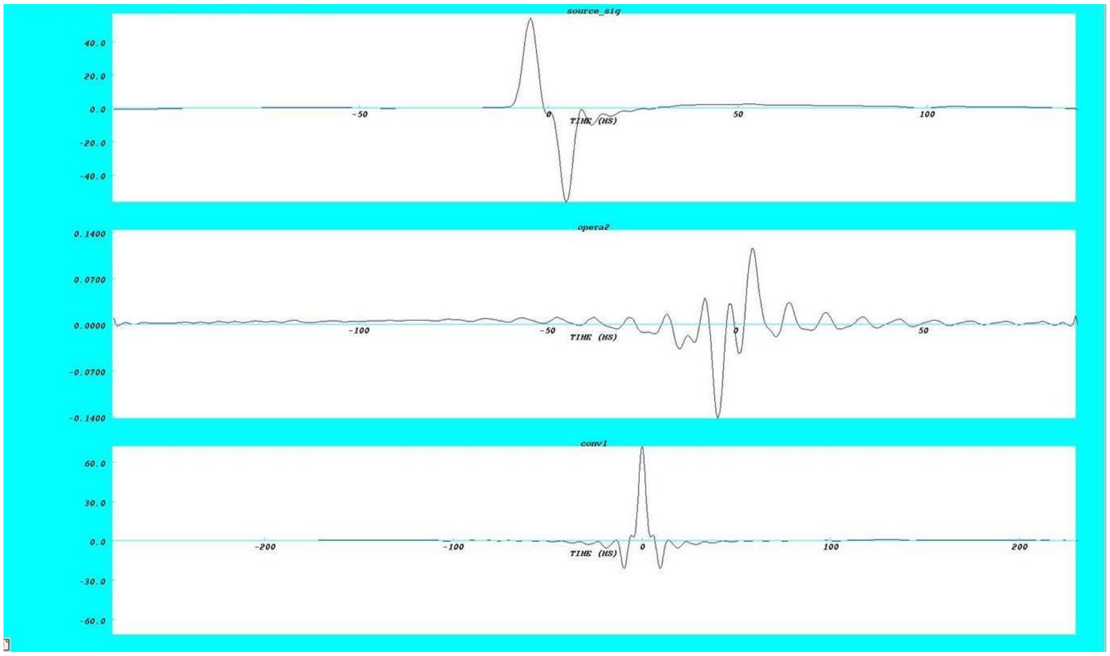


Figure 2.5 Designature Operator HGP (5hz boxcar)

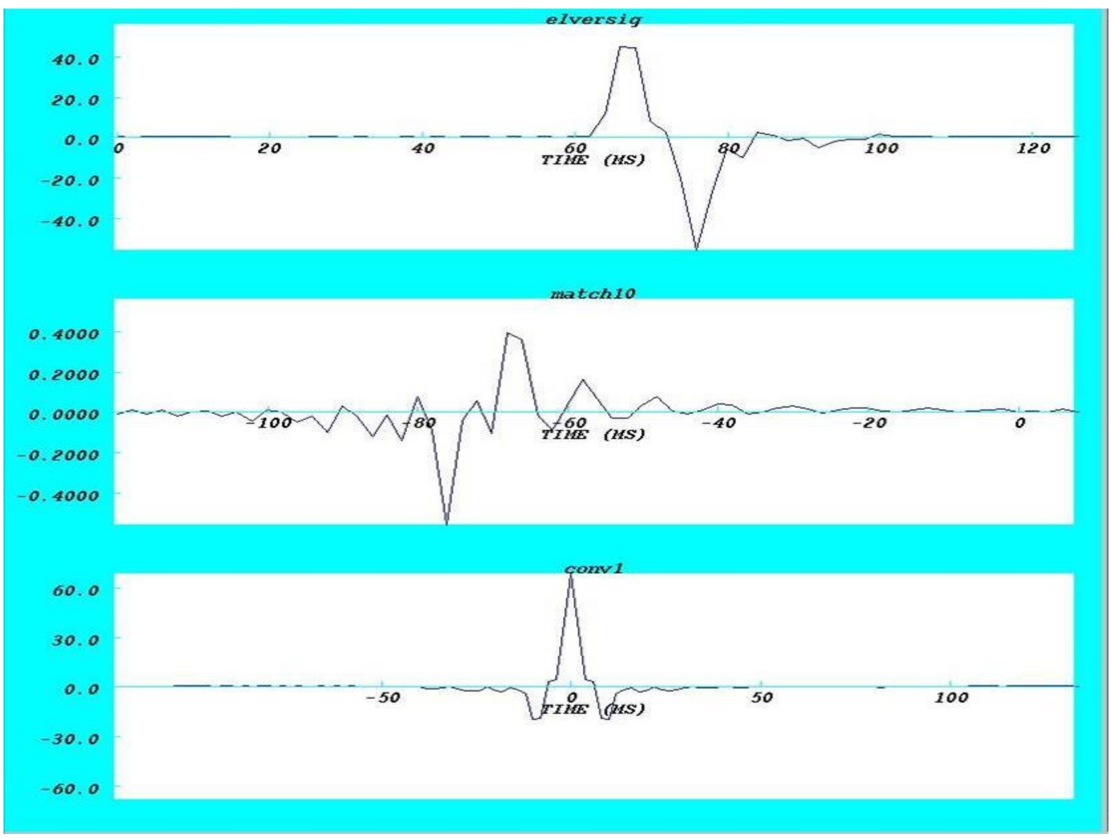


Figure 2.6 Designature Operator Elver

2.3.4 Noise Attenuation (WIND)

Several different parameters (frequency bands, domains) were tested in the WIND process. This was dependent on the class of noise to be addressed.

In addition to heavy swell noise, there was also strong direct arrival energy which was especially evident near the ends of the sail lines when the boats were turning. For these reasons, our initial WIND sequence was in the shot domain, and linear noise attenuation processes were employed, with a starting frequency of 3 Hz.

2.3.5 Multiple Attenuation

Multiples were attacked using a multi-stage approach. SRME, Water-Velocity Radon, and Tau-P deconvolution were followed by high resolution Radon demultiple. Each one of these processes resulted in improvements in the stacks and gathers, as demonstrated in the Appendices. The demultiple parameters for each process application were tested before production implementation. The following parameters were selected:

Water Velocity Radon:

Moveout Range	-70ms to +680ms
Reference Offset	3800m
P-values	434

Tau-P Deconvolution

Operator Length	87 pts @ 4ms
Gap Length	32ms

2.3.6 Tidal Statics

The utility of tidal statics application was tested before its incorporation into the final production sequence. Figure 2.7 and 2.8 demonstrate a minor improvement in the stack response upon the application of tidal statics.

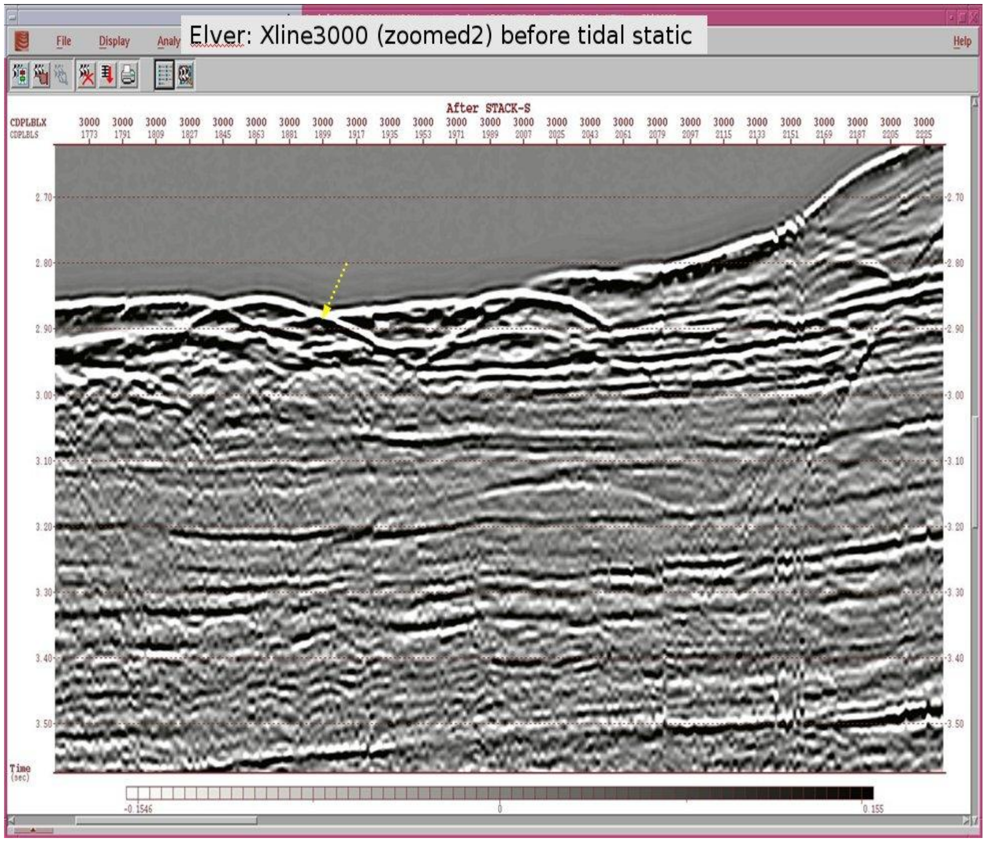


Figure 2.7 Elver before tidal static, xline 3000

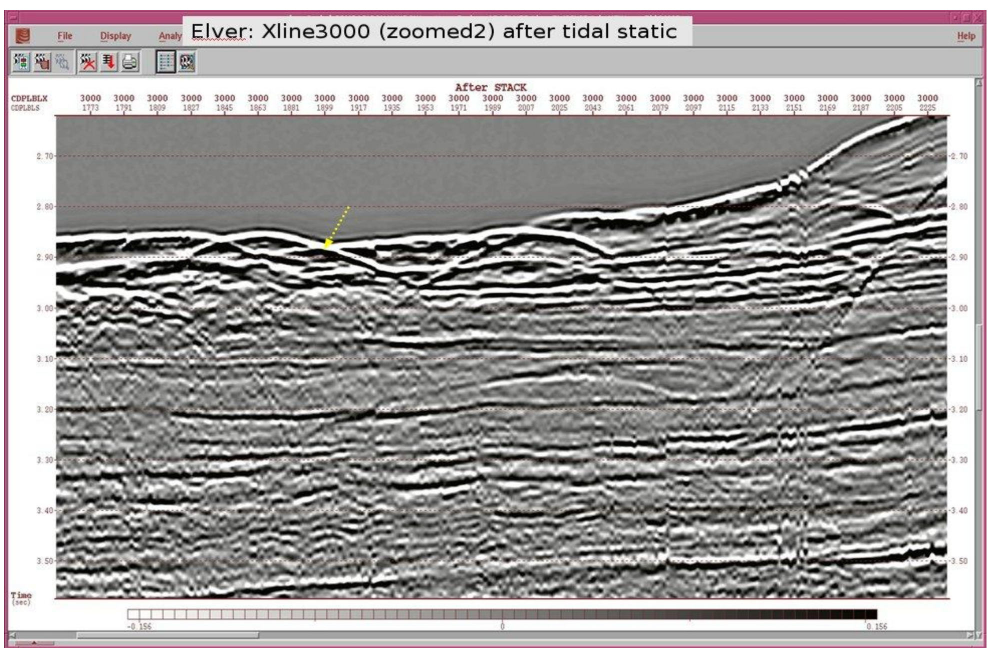


Figure 2.8 **Elver after tidal static, xline 3000**

2.4 Pre-Stack Time Migration

2.4.1 Elver Parameterization

In addition to its key role in the three survey merge, Elver also underwent a fast-track stand-alone Pre-Stack Time Migration (PSTM). Two Iterations of PSTM were conducted. The first iteration started with a smoothed version of the final Pre-Migration stacking velocity. This first run was followed by a vertical update, and the resultant velocity was used as the initial velocity model for Elver (PSTM velocity). This velocity model was also the starting point for the subsequent PSDM campaign.

The following migration parameters were employed:

Migration Method	Kirchhoff Curved Ray with headwave killer
TT generation	Straight ray above WB, Curved below
Bin Size	12.5 x 25m
Output Offset Range	0.2 – 4.0 km (39 offset bins)
Anti-alias Operator	37.5 x 37.5m
Aperture – top angle	45 degrees
Aperture – max angle	70 degrees
Aperture radius	4000m

2.4.2 Post-Processing

The Elver PSTM gathers went through the following post-processing sequence:

- Inverse NMO,
- NMO with residual moveout corrected velocities
- Mute
- Stack (normalization based on the number of live samples)
- Q Compensation (Q=100 amplitude only).

As noted below, key processes were generally referenced to Water Bottom. This was accomplished by flattening to Water Bottom, process application and re-referencing to Sea Level after process application.

Final Mute Parameters

Water Bottom Time (ms)	Offset (m)	Time (ms)
100	400	0
	500	284
	800	776
	1550	1412
	2250	1928
	3850	3280
	5550	3988
300	800	0
	1050	776
	1300	1240
	2000	1776
	3850	2896
	5550	3600
500	750	0
	900	604
	1600	1532
	2750	2356
	3550	2992
	4050	3548
	5500	4156
1000	1200	0
	1350	1140
	1900	1984
	2800	3552
	5500	4344
1500	1450	0
	2000	2000
	2450	2556
	3400	3520
	5550	5344
2000	1800	0
	2600	2176
	2900	3472
	5550	5348

Additionally, the final post-processing included filtering and scaling, as described below:

Time-variant Bandpass Filter

Start (ms)	End (ms)	Lo Cut (Hz)	Slope (dB/oct)	Hi Cut (Hz)	Slope (dB/oct)
0	500	12	18	85	36
1000	1500	10	18	75	36
2000	2500	8	18	65	36
4000	4500	4	18	35	36
5000	6000	2	18	25	36

Referenced to water bottom.

AGC time-variant scaling referenced to water bottom.

TIME (ms)	Window (ms)
0	250
2000	2000

WB referenced interpolated between above control points

Followed by gain curve:

TIME (ms)	GAIN (dB)
0	0
6000	-18

WB referenced

then

TIME (ms)	GAIN (dB)
0	0
3500	0
6000	-12

Zero Time referenced.

Figures 2.9, 2.10 and 2.11 depict a representative timeslice, inline and crossline, from the Elver PSTM. More information on the migration velocities can be found in Section 3.

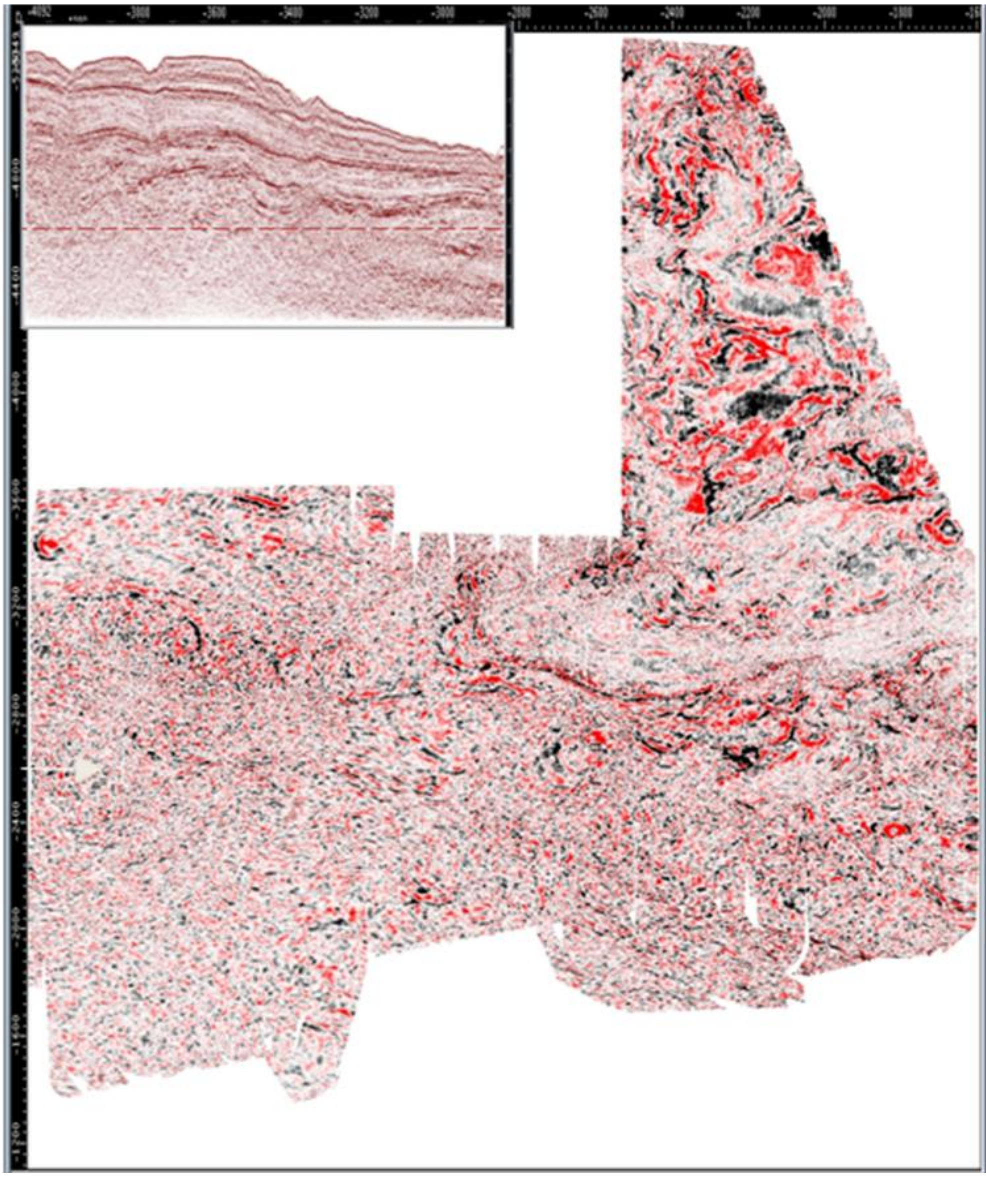


Figure 2.9 Timeslice at 4.0 seconds

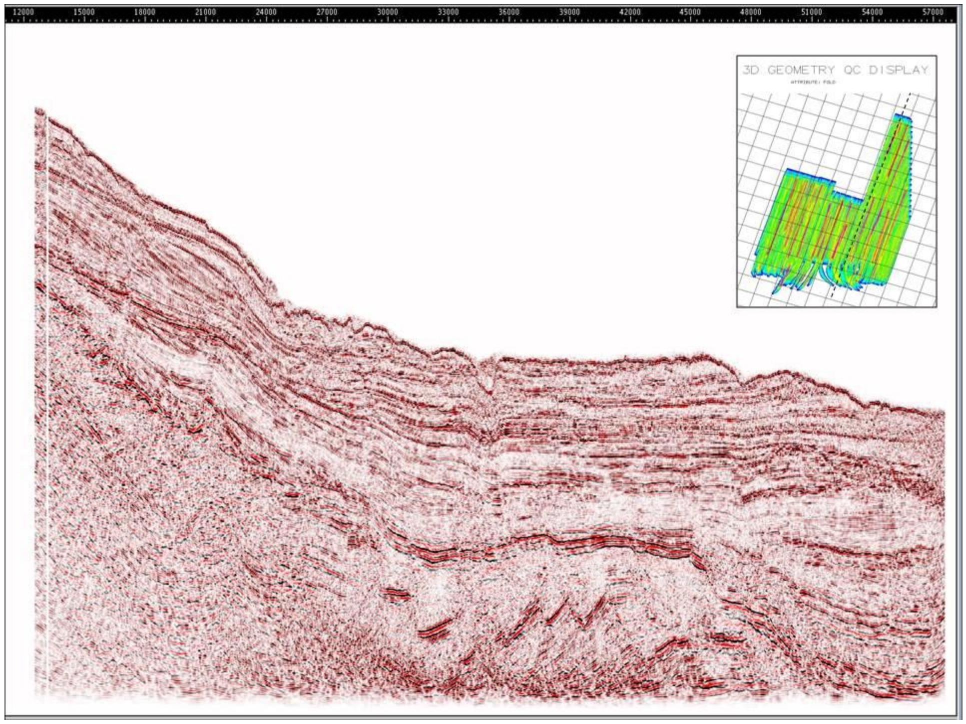


Figure 2.10 Elver PSTM final with post and mute, example inline

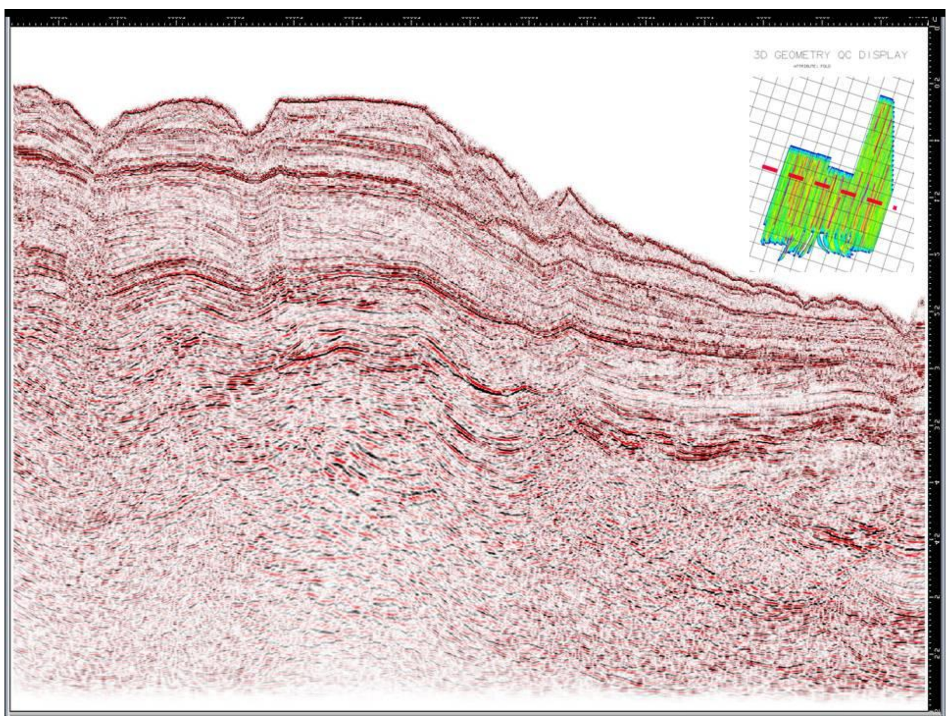


Figure 2.11 Elver PSTM final with post and mute, example crossline

2.5 Merging the Surveys

An essential step prior to entering the PSDM phase was to successfully integrate the three projects. Because of the similarities in the acquisition of the surveys and the compatibility of the selected processing flows, the data matched well with only minor phase/time shift requirements.

The following images show a closed loop section indicating the good fit of the programs

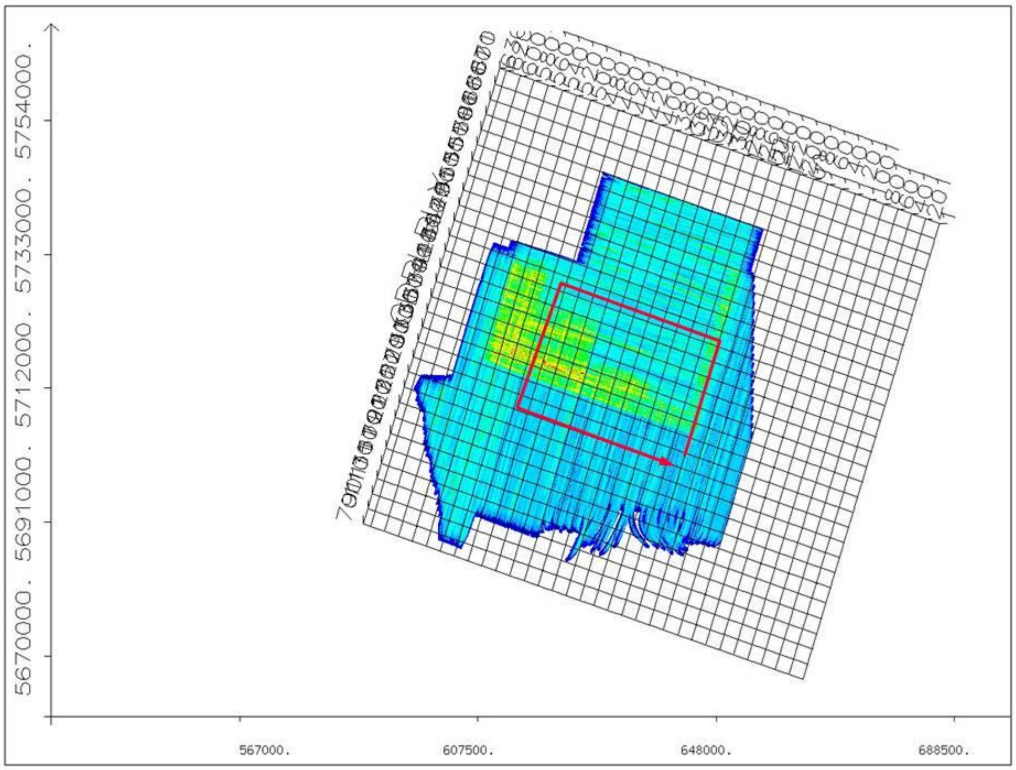


Figure 2.12 Track for profile below selected from merged final stack volume

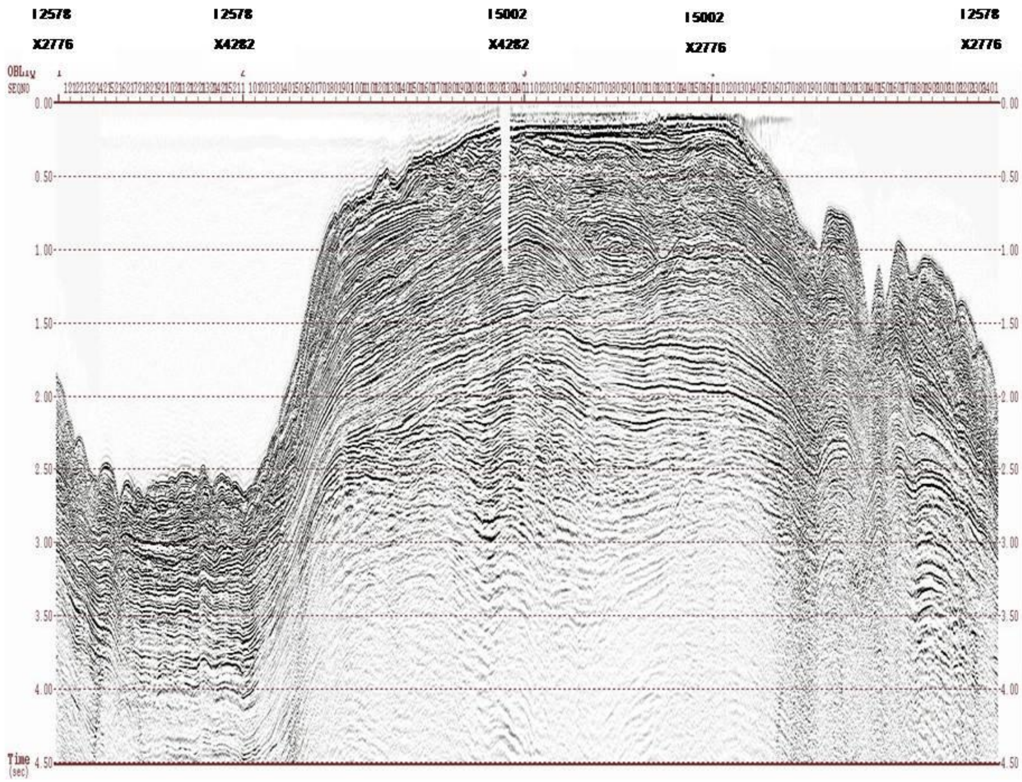


Figure 2.13 Profile extracted along the track outlined in above figure

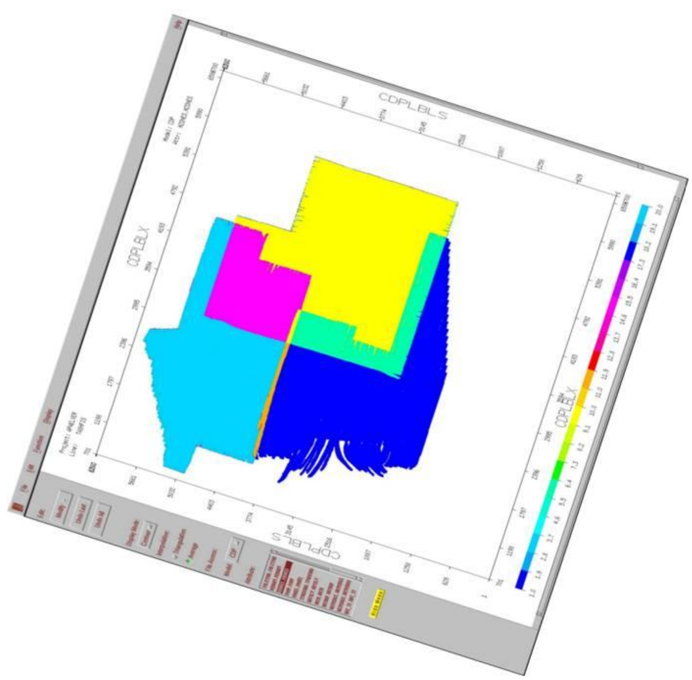


Figure 2.14 Program outline showing large HGP-Tuskfish overlap area (purple)

As indicated in the above figure there was limited overlap between Elver and HGP and Elver and Tuskfish but a larger overlap area between Tuskfish and HGP. There was observed, however, an apparent difference in data quality between HGP and the other surveys with HGP appearing noisier. There was significant overlap between the HGP and Tuskfish programs as observed in the figure below. Testing of various overlap options was undertaken to determine whether all HGP and Tuskfish gather data should be allowed to contribute to the merged volume or whether preference should be given to the Tuskfish program.

A series of comparisons of the two data sets at co-incident locations within the overlap zone indicated that the major signal contribution was from the Tuskfish data set. As a result, HGP was allowed to contribute only within a boundary area to Tuskfish as shown in the figure below.

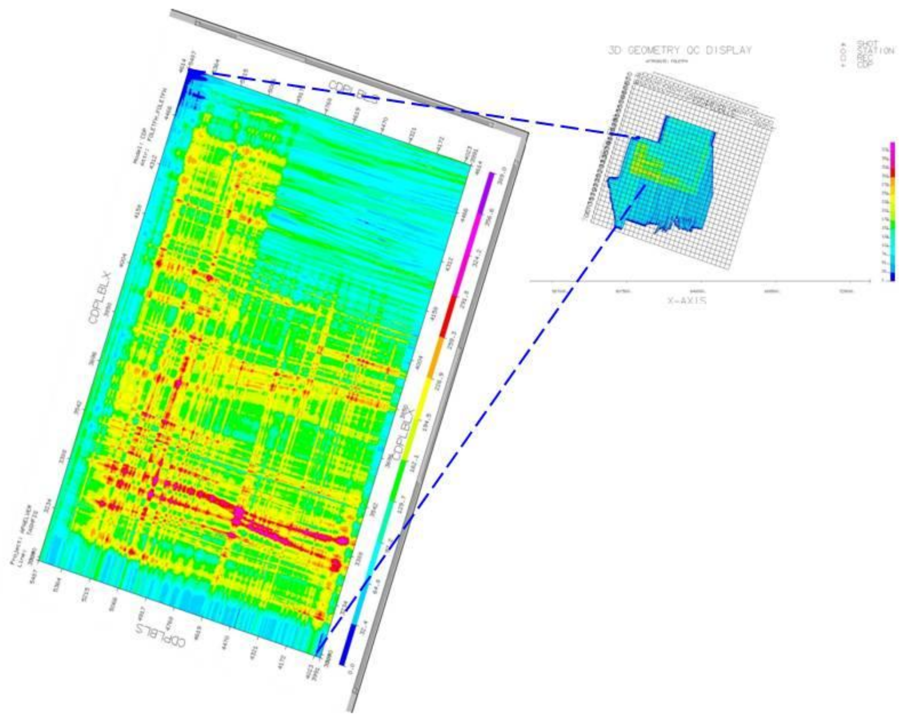


Figure 2.15 HGP and Tuskfish combined subsurface coverage

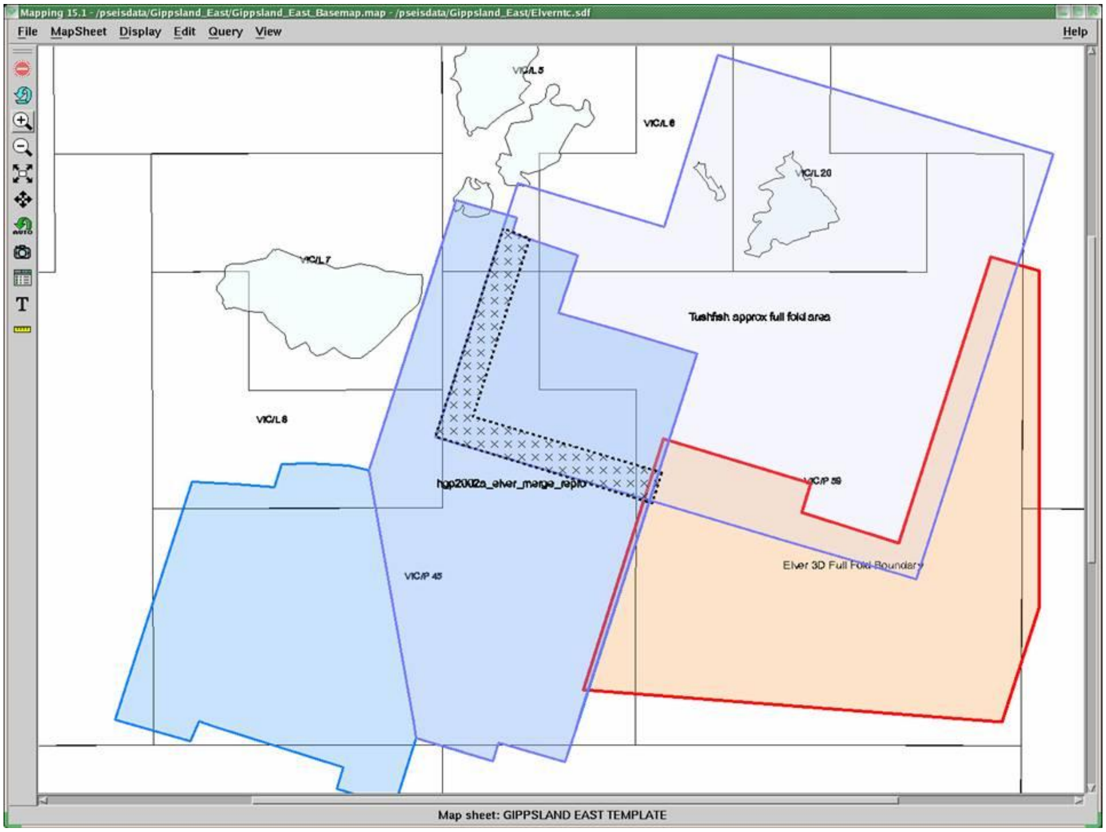


Figure 2.16 HGP contribution in merge zone restricted to stippled zone only

Gippsland East 3-D
Gippsland Basin, Offshore Australia

Seismic Time Processing
And
Pre-Stack Depth Imaging
Final Report

Section 3: Pre-Stack Depth Processing

3.1 Introduction

The imaging objectives for Gippsland East included the integration of three 3-D seismic surveys, Elver, HGP and Tuskfish.

For the initial stages of velocity model building, each survey was treated independently since there were some significant differences between them. Tuskfish was shot orthogonal to Elver-HGP and was already a mature survey in terms of velocity (initial velocity model provided by Apache), while Elver was a new exploration survey and HGP had some time imaging products available.

For Elver, 2 iterations of PSTM and 2 iterations of PDSM (totaling 4 iterations of vertical velocity update) defined its velocity model building process. Tuskfish, on the other hand, ran through a single iteration of tomographic update since the initial velocity model was already mature. HGP went through only one iteration of vertical update since it was away from the canyon area (one of the major challenges for Gippsland East) and thus considered less complex than Elver. Table 1 provides a summary of the migration iterations for each survey.

Once each of the surveys had a reasonably mature velocity model, an initial unified velocity model was built integrating the individual pieces. The unified velocity model ran through 2 iterations of tomographic update, producing the final velocity model.

Among the major challenges encountered in imaging Gippsland East was the canyon located in the middle of the survey. The canyon has high rugosity, very small features (in terms of seismic resolution) and extends through a vast area. Initially, there was a picked water bottom horizon available for Tuskfish, but no information for Elver since it was a new survey. 3DGeo attempted to interpret the water bottom for Elver, but the highly rugose zones were mis-picked leading to an incorrect water column in the velocity model. This was solved by incorporating the bathymetry data provided by Apache, although there are still some areas where problems in the water bottom definition can be easily seen, probably caused by inaccuracies in the bathymetry measurements.

	Elver	HGP	Tuskfish	Unified
PSTM 0	Figure 1	N/A	N/A	N/A
PSTM 1	Figure 2	N/A	N/A	N/A
PSDM 0	Figure 3 (No bathymetry)	Figure 6, 7 (No bathymetry)	Figure 9	N/A
PSDM 1	Figure 4 (After bathymetry)	Figure 8 (After bathymetry)	Figure 10	N/A
PSDM 2	Figure 5	N/A	N/A	N/A
Unified PSDM 1	N/A	N/A	N/A	Figures 11, 12 and 13
Unified PSDM 2	N/A	N/A	N/A	Figures 14, 16 and 18
Unified PSDM 3	N/A	N/A	N/A	Figures 15, 17 and 19

Table 3.1 Migration iteration and Figure cross-reference for Gippsland East.

3.2 Velocity model building for Elver

Elver data went through 4 iterations of vertical update for its velocity model building stage, 2 iterations using PSTM gathers and 2 iterations using PSDM gathers. The initial RMS velocity field for Elver, shown in Figure 3.1, was derived using a smoothed version of the stacking velocity.

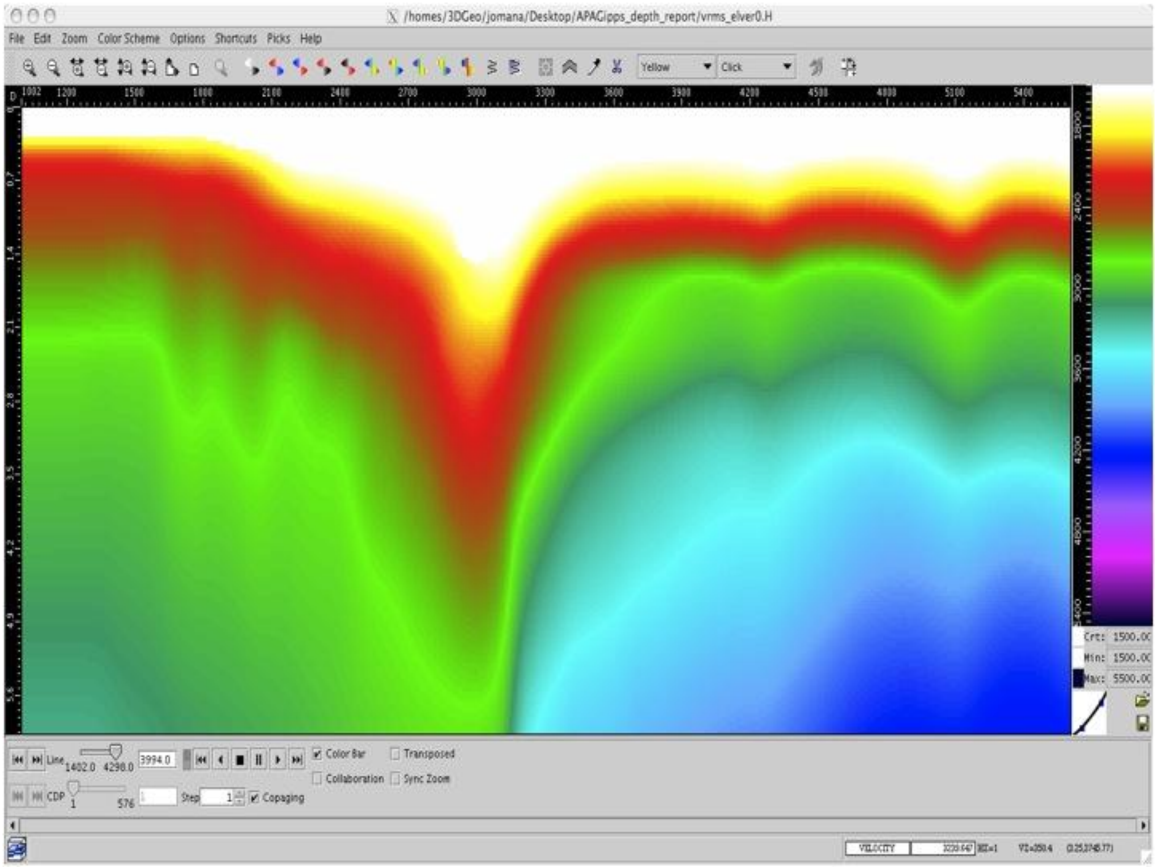


Figure 3.1 Initial RMS velocity field for Elver, Inline 4000.

For the velocity update stage, Kirchhoff migrations ran using 4000m maximum offset (max offset for Elver), at 100m offset increment and output a migrated volume on a 25x25m grid. Because of the high rugosity of the sea floor, the velocity was updated using a dense subsurface grid of 100x100m. Figure 3.2 shows the RMS velocity field for Elver after the first iteration of vertical update.

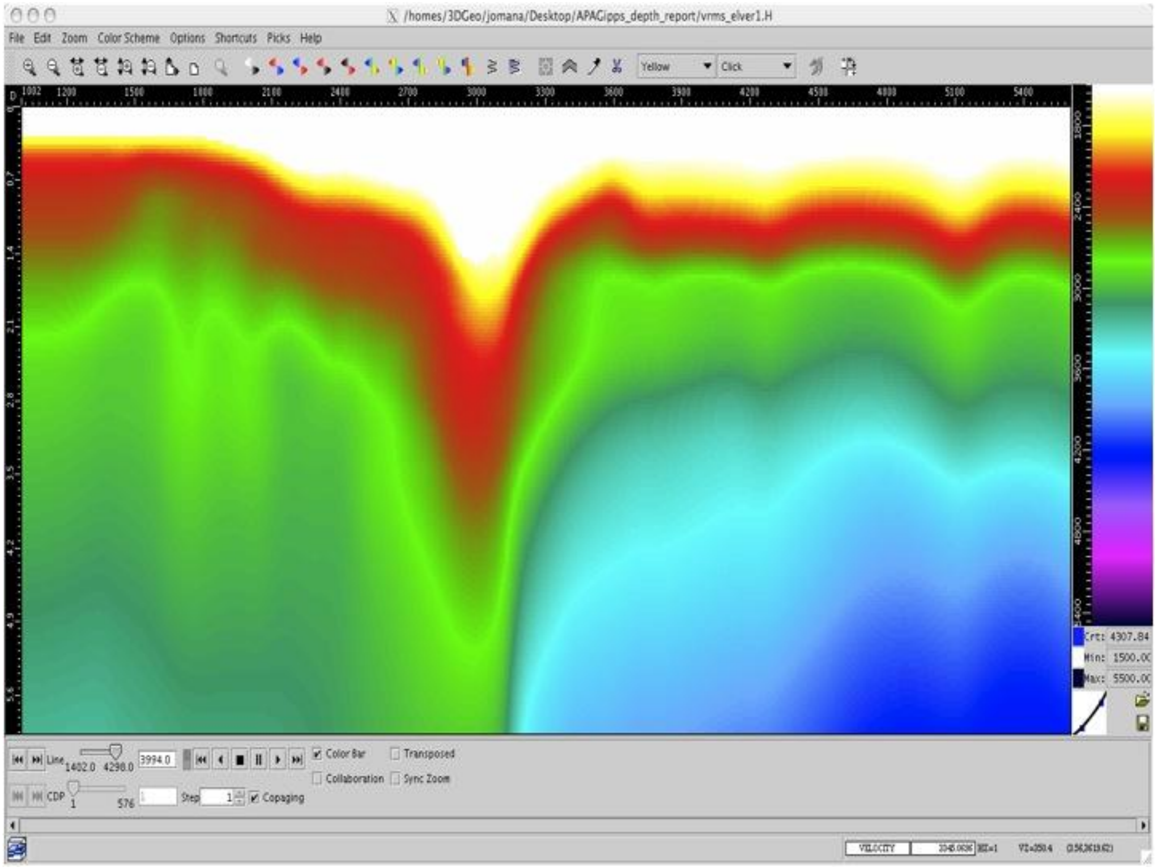


Figure 3.2 RMS velocity field for Elver after first iteration of vertical update, Inline 4000.

After the first iteration of vertical update, the second PSTM ran using the velocity field from Figure 3.2 as the migration velocity. The output gathers were used again in a 100x100m grid to run the second pass of vertical update, the updated RMS velocity field was then inverted using a constrained Dix inversion (to avoid velocity artifacts) to produce Elver's initial velocity model depicted in Figure 3.3.

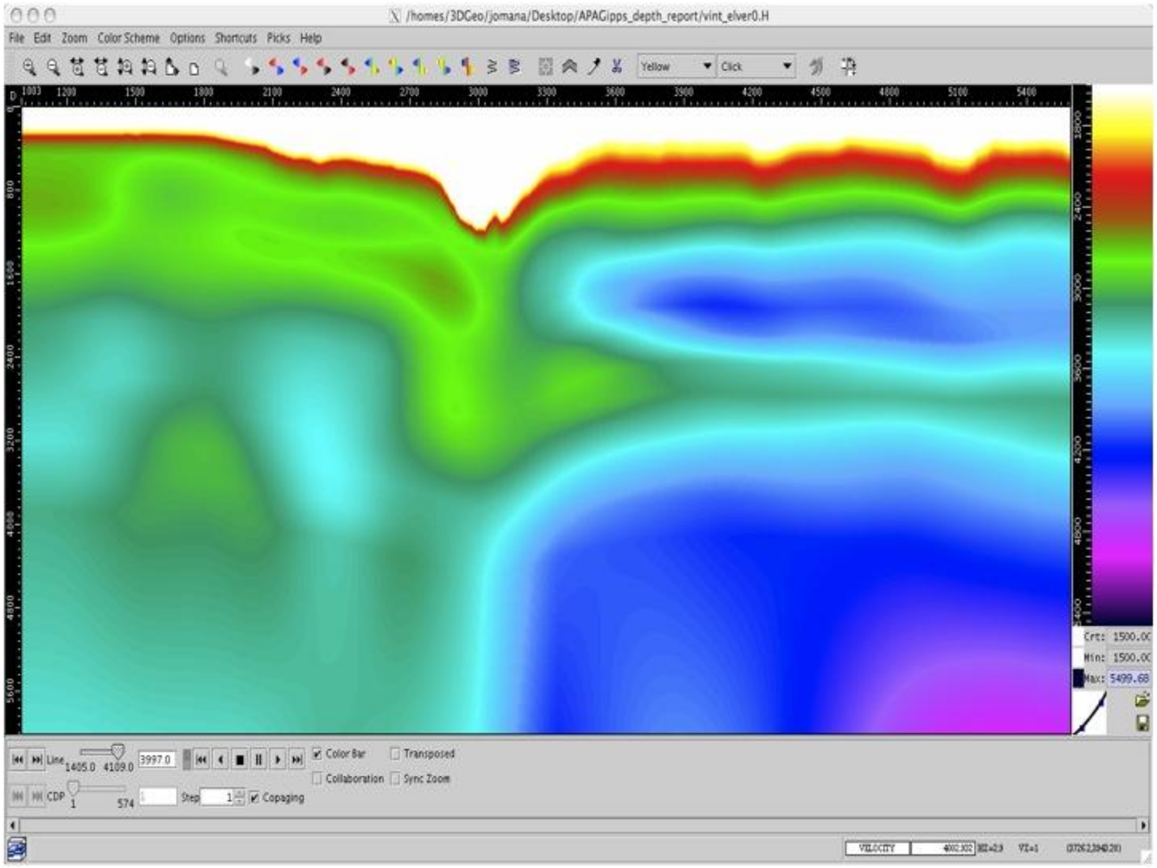


Figure 3.3 Initial interval velocity model for Elver, Inline 4000.

Since Elver's acquisition layout had a polygonal shape velocities from the client's provided velocity model for Tuskfish were used to extend Elver and make it rectangular.

After building the initial velocity model for Elver, the first PSDM showed a lot of problems in the definition of the water bottom for the canyon area. This was related to the lack of resolution for the water bottom horizon used to build the initial model.

To solve this problem, Apache provided a high resolution (25x25m) bathymetry map, which was incorporated into the vertical update followed by the first PSDM.

Figure 3.4 shows the velocity model for Elver after the first iteration of vertical update on a 100x100m grid of PSDM gathers and the incorporation of the bathymetry data.

A milder velocity gradient in the Tuskfish area was introduced for the first velocity update, for lateral smoothness of the model, since there was no migrated data in this zone.

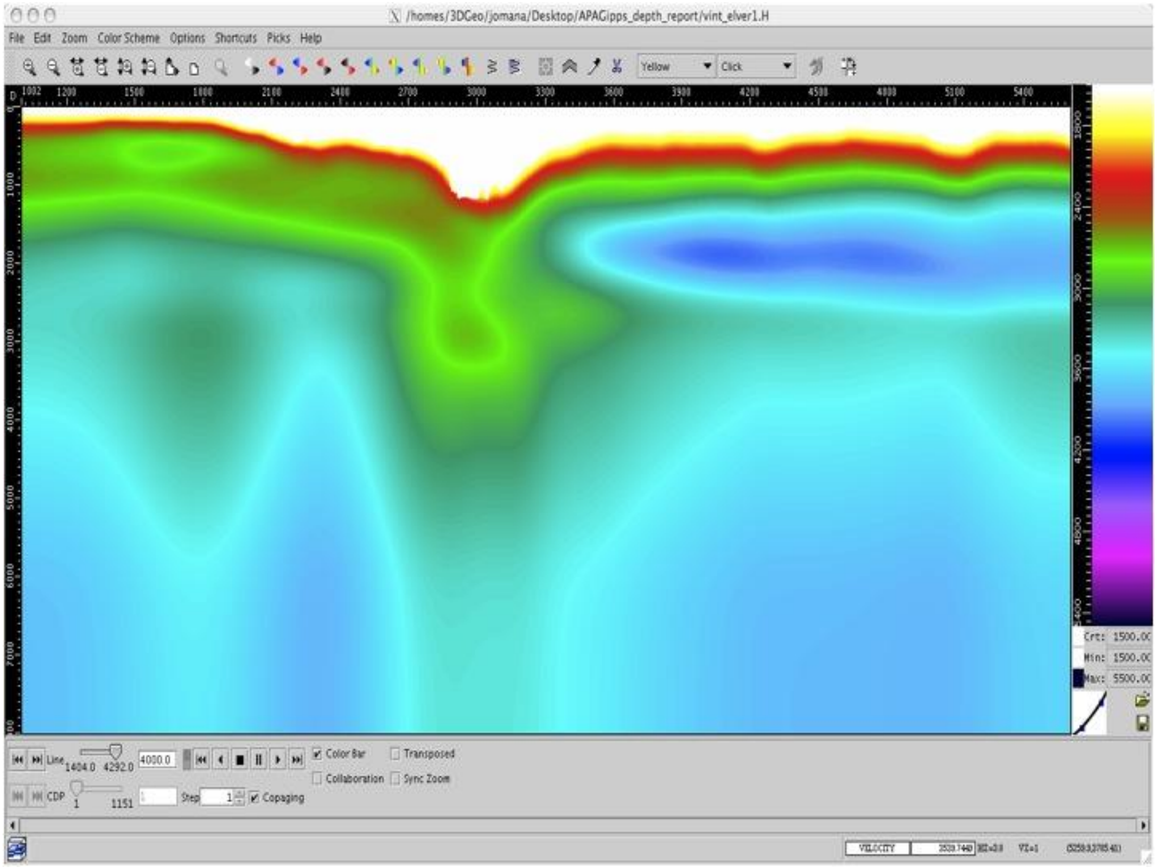


Figure 3.4 Interval velocity model for Elver after first iteration of vertical update, inline 4000.

The second Elver PSDM ran using the velocity model from Figure 3.4. This second PSDM was followed by the second iteration of vertical update, producing the velocity model in Figure 3.5.

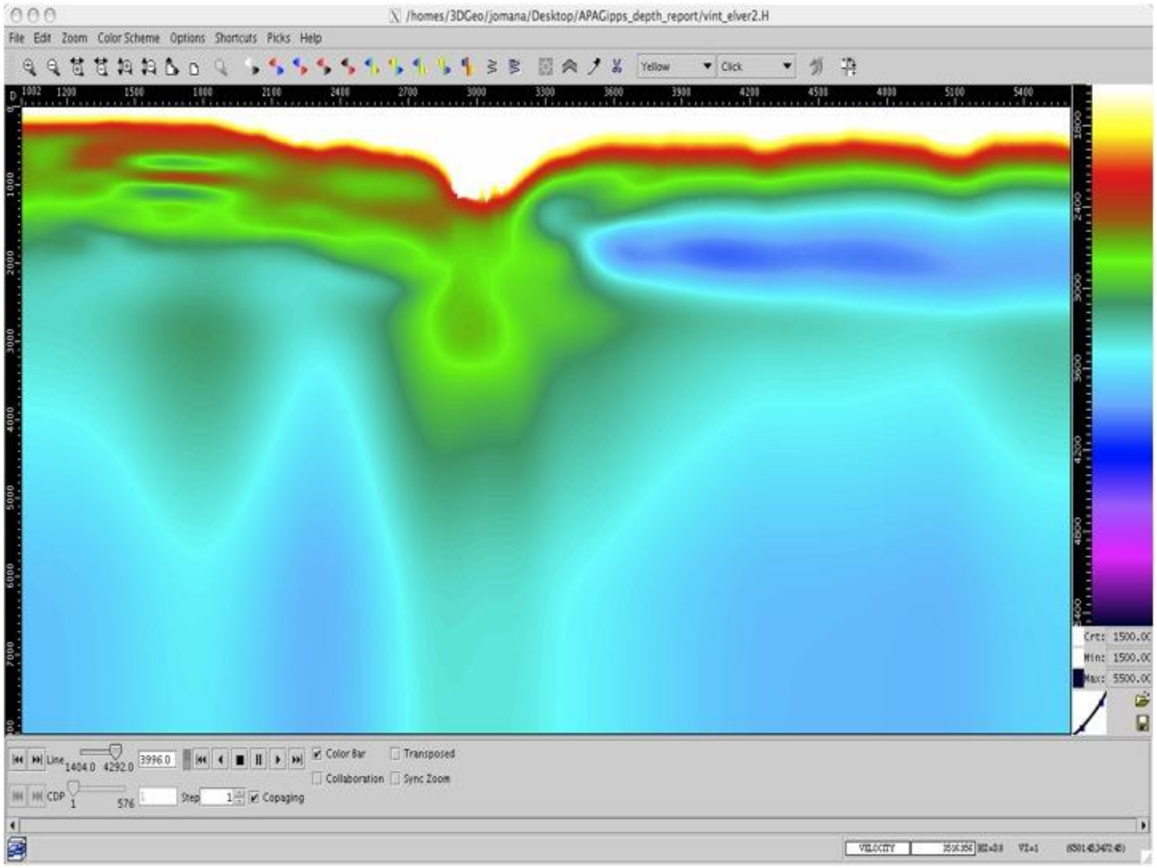


Figure 3.5 Interval velocity model for Elver after second iteration of vertical update, inline 4000.

At this point, the individual velocity update for Elver was stopped, leaving further velocity analysis for the unified volume Elver-HGP-Tuskfish.

3.3 Velocity model building for HGP

HGP data went through one iteration of vertical update in PSTM gathers for its velocity model building stage. The initial RMS velocity field for HGP, shown in Figure 3.6, was used to generate target PSTM gathers in a 100x100m grid. Those gathers were used to update the velocity field using vertical update. The updated velocity was smoothed, producing the results shown in Figure 3.7.

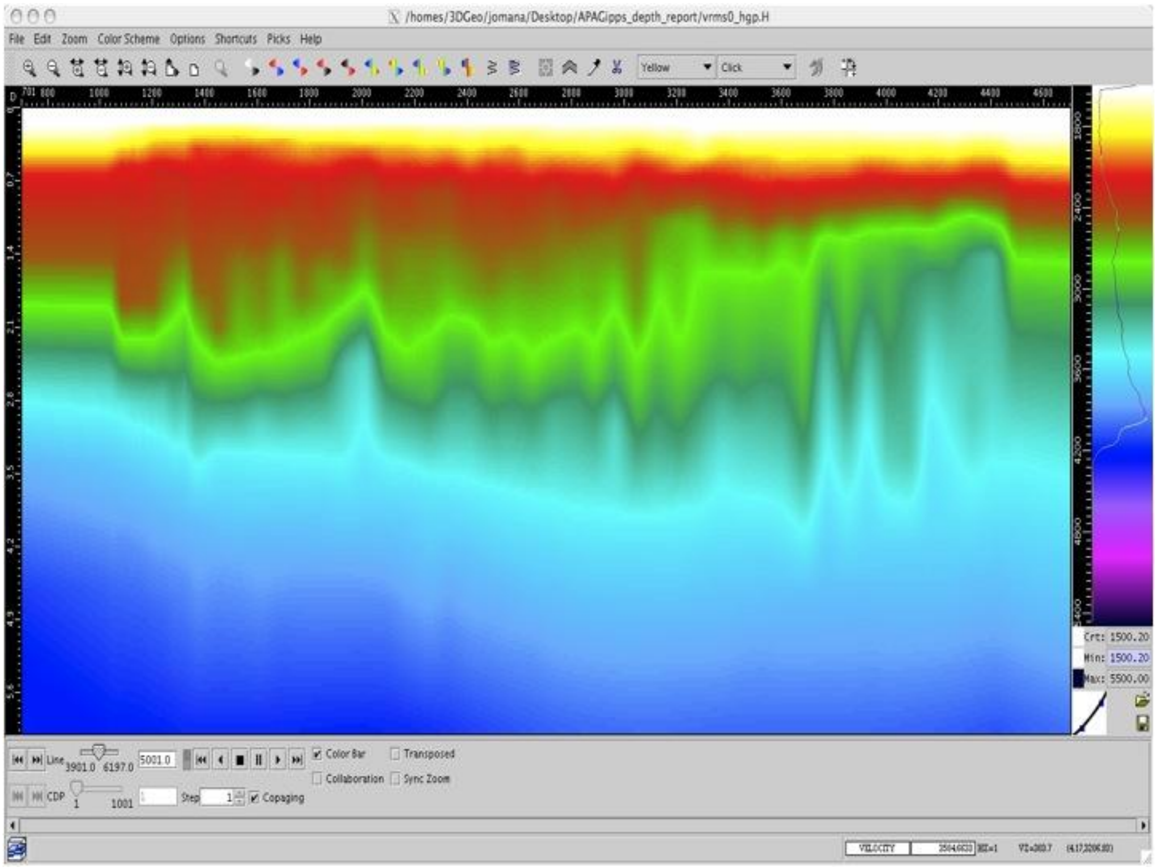


Figure 3.6 Initial RMS velocity field for HGP, inline 5000.

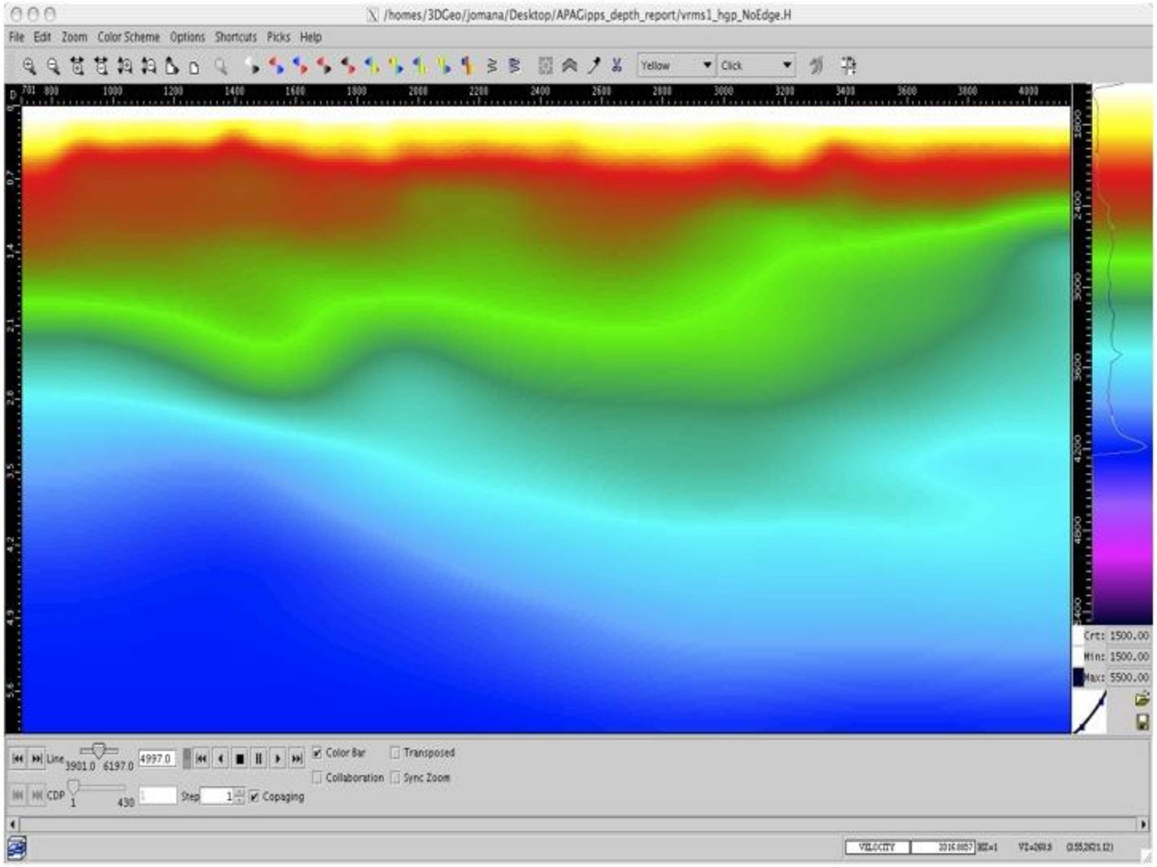


Figure 3.7 RMS velocity field for HGP after first iteration of vertical update and smoothing, inline 5000.

HGP's initial velocity model in Figure 3.8, was obtained from the smooth RMS velocity through a constrained Dix inversion. As in the Elver case, the provided Tuskfish velocity model was used to extend the model to a rectangular volume. This velocity model was used as HGP's contribution for the unified initial velocity model.

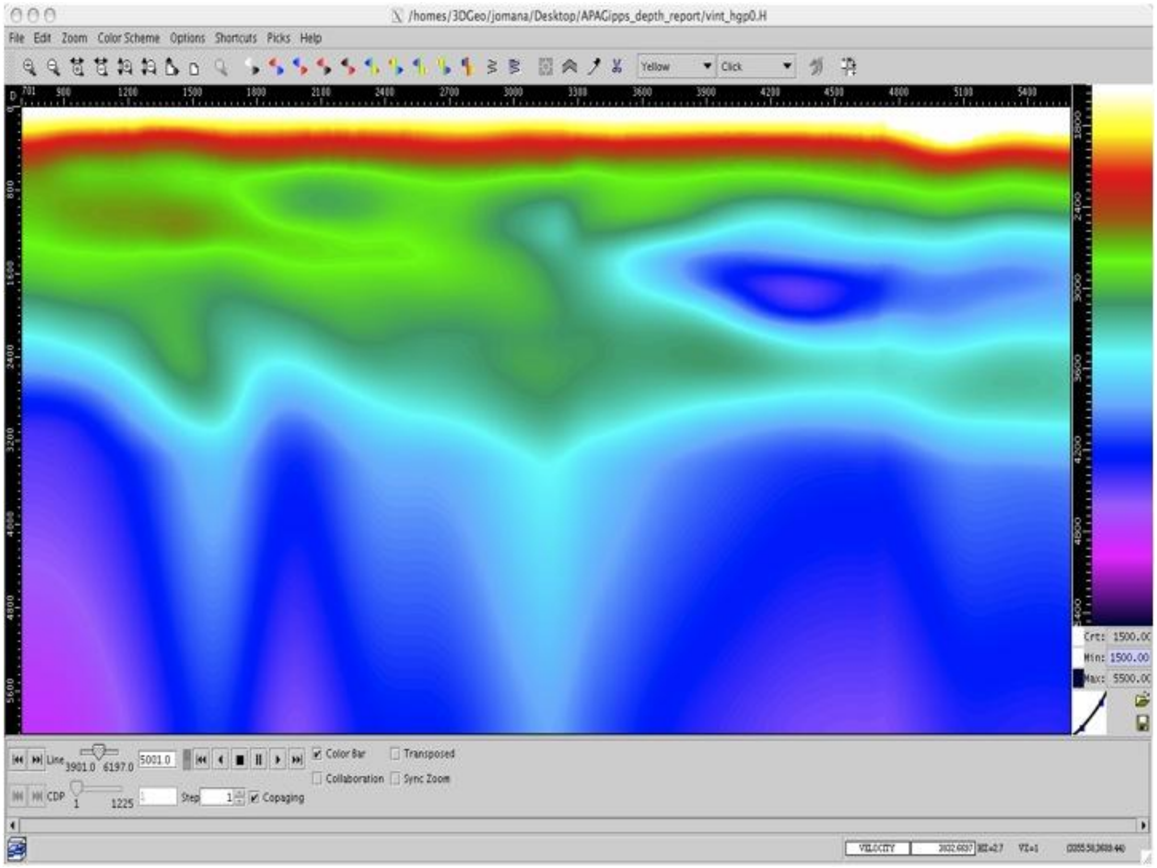


Figure 3.8 Initial interval velocity model for HGP, inline 5000.

3.4. Velocity model building for Tuskfish

The initial velocity model for Tuskfish in Figure 3.9 was provided by Apache and comes from previous iterations of PSDM and velocity update. Right from the beginning it was observed that the Tuskfish data had strong remnant multiple would complicate the velocity model building process. Additional Radon demultiple for Tuskfish was recommended, approved and applied.

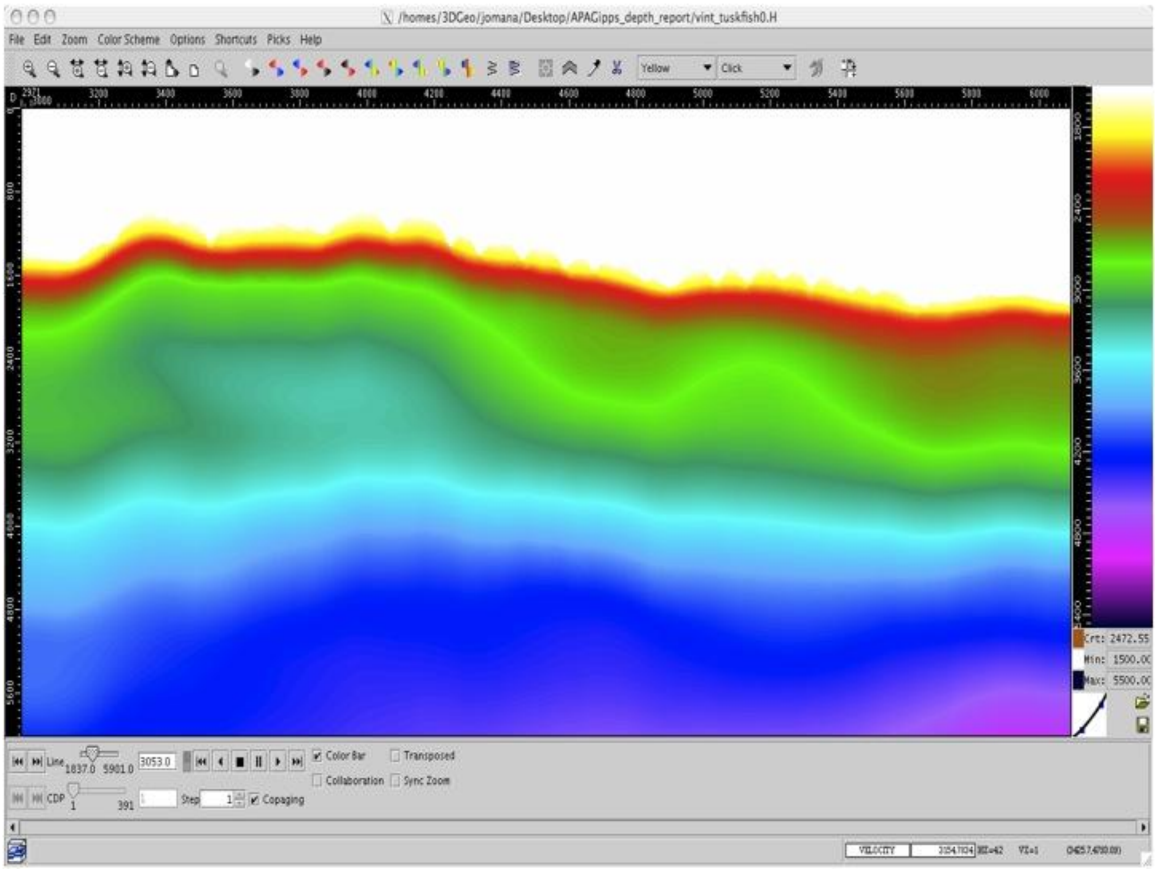


Figure 3.9 Initial velocity model for Tuskfish, inline 3050.

Since Tuskfish's initial velocity model was considered mature enough it was decided to run velocity update using tomography.

The first tomographic update attempt used residual RMS velocities, which fit the migration depth errors in the gathers using a hyperbolic approximation. This method proved to overcorrect the velocity, especially in the rugose seafloor area. A second method (based in the residual curvature of the gathers), which directly picks the depth error in order to build the tomographic equations, was successfully implemented. Figure 3.10 shows Tuskfish's velocity model after tomographic velocity update.

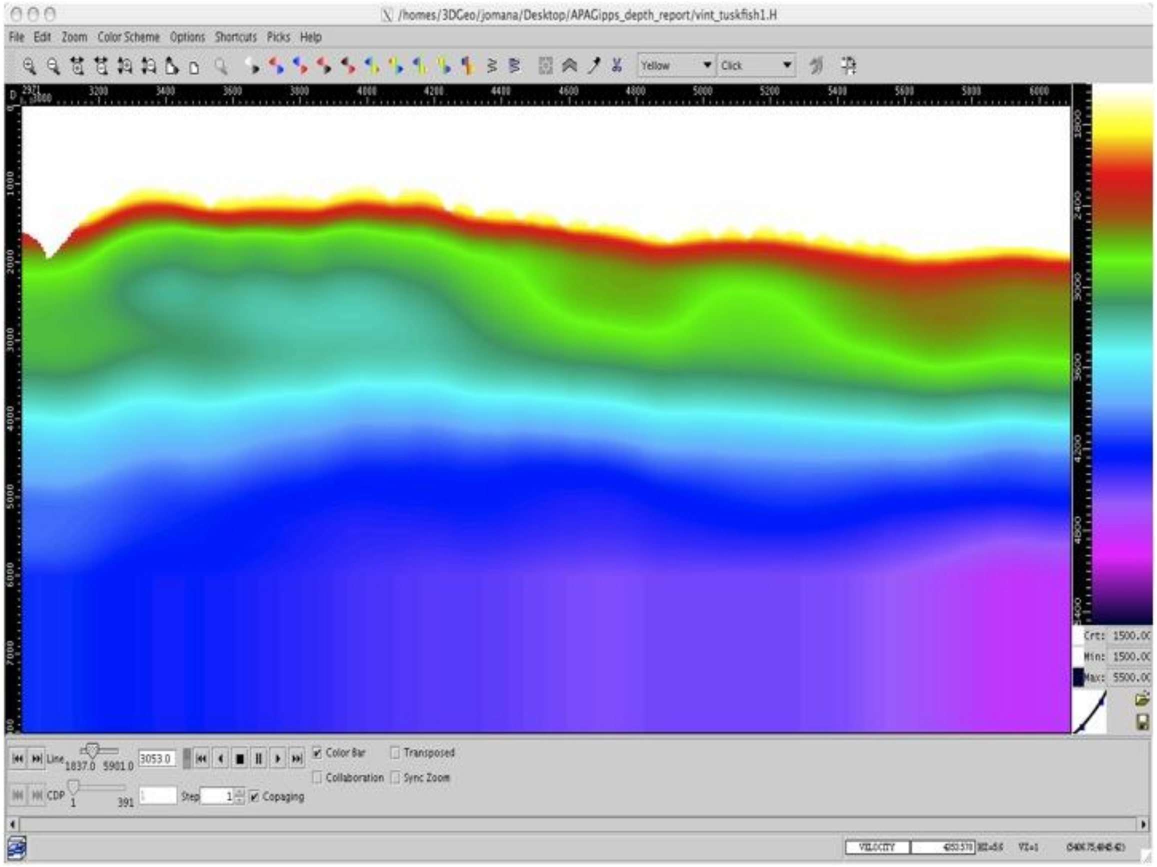


Figure 3.10 Interval velocity model for Tuskfish after first iteration of tomography, inline 3050.

The velocity model after tomography showed most of the velocity changes towards the canyon area, where it also benefited with the incorporation of the bathymetry data, as seen in Figure 3.10. Also, the tomographic update for Tuskfish ran only up to 6Km depth, and the model was later extended to 8Km depth for the initial unified model building.

3.5. Velocity model building for Gippsland East

In order to create the unified initial velocity model, the best velocity models from each survey were merged together. Models from Figure 3.5 for Elver, Figure 3.8 for HGP and Figure 3.10 for Tuskfish make the composite initial velocity model for Gippsland East.

To avoid edge effects and abrupt lateral velocity discontinuities, the composite model was smoothed using an operator of 750x750x250m.

Figures 3.11, 3.12 and 3.13 show the initial velocity model for Gippsland East.

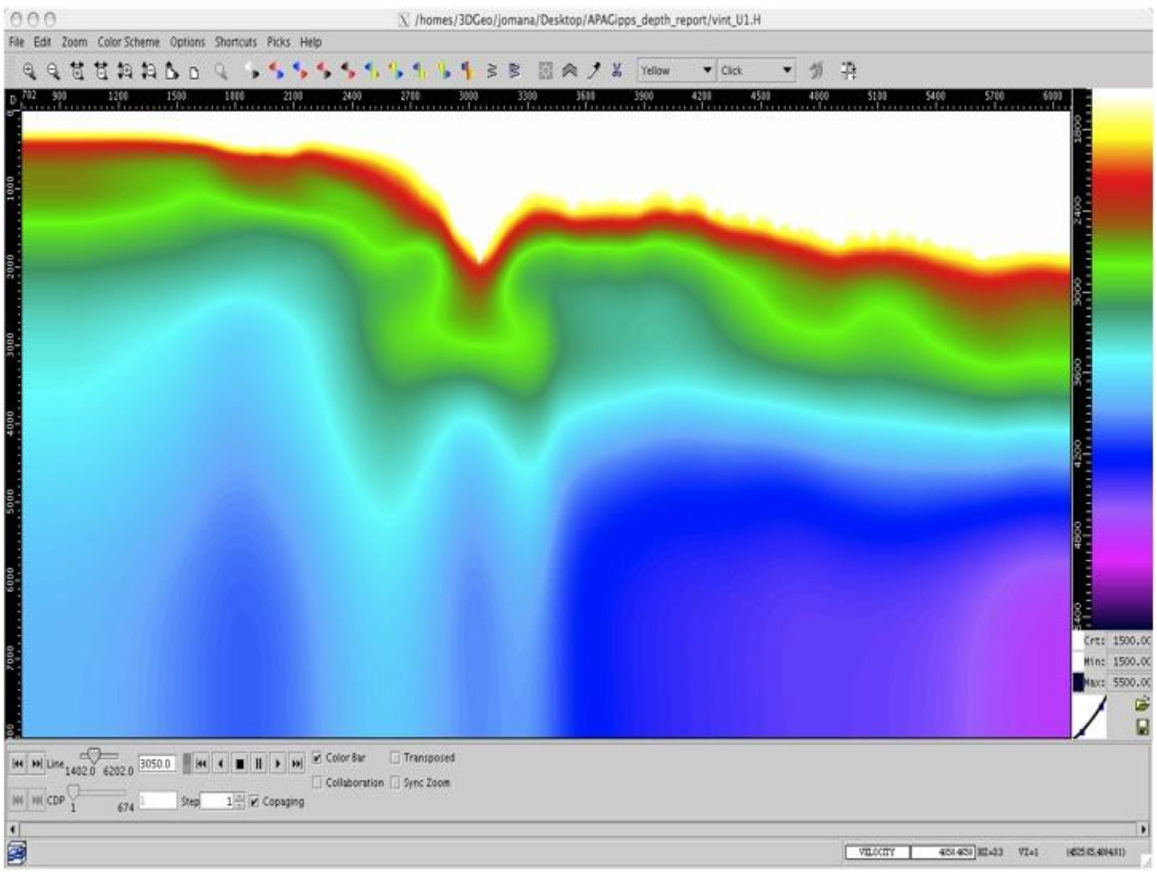


Figure 3.11 Unified initial velocity model, inline 3050.

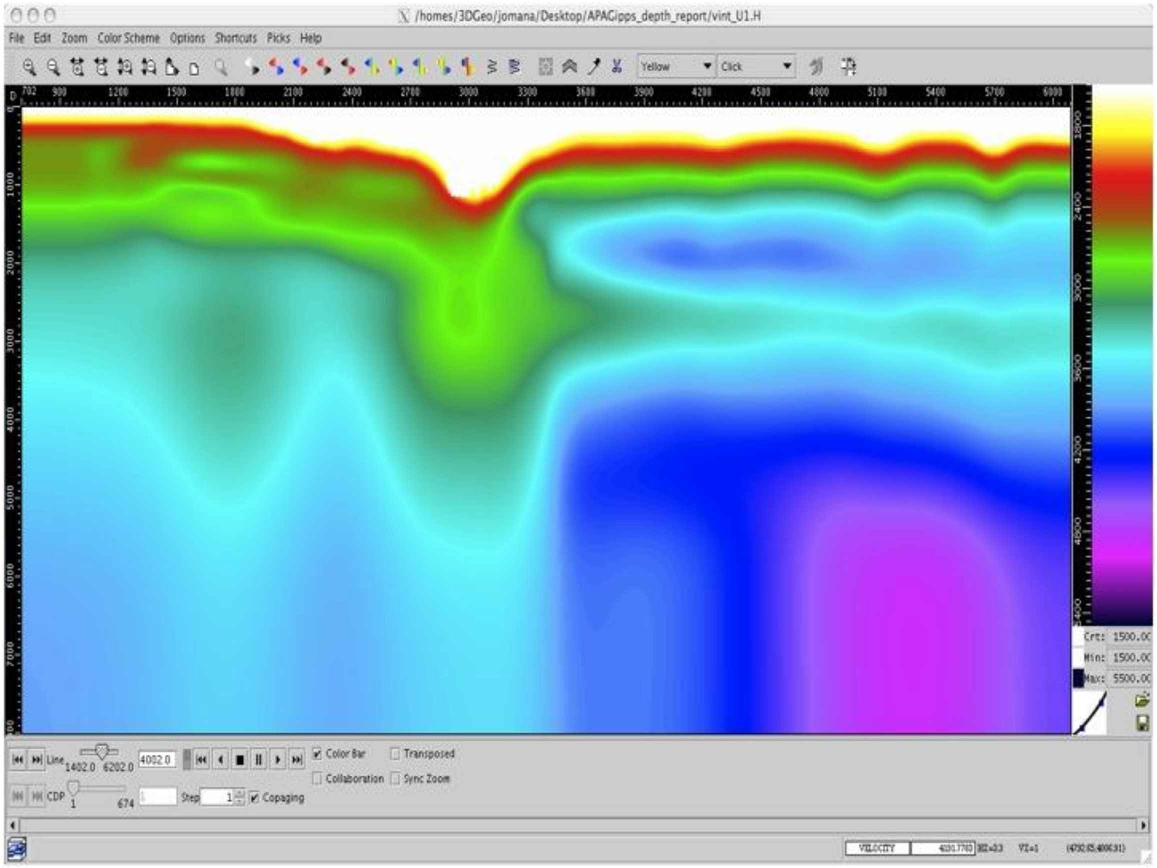


Figure 3.12 Unified initial velocity model, inline 4000.

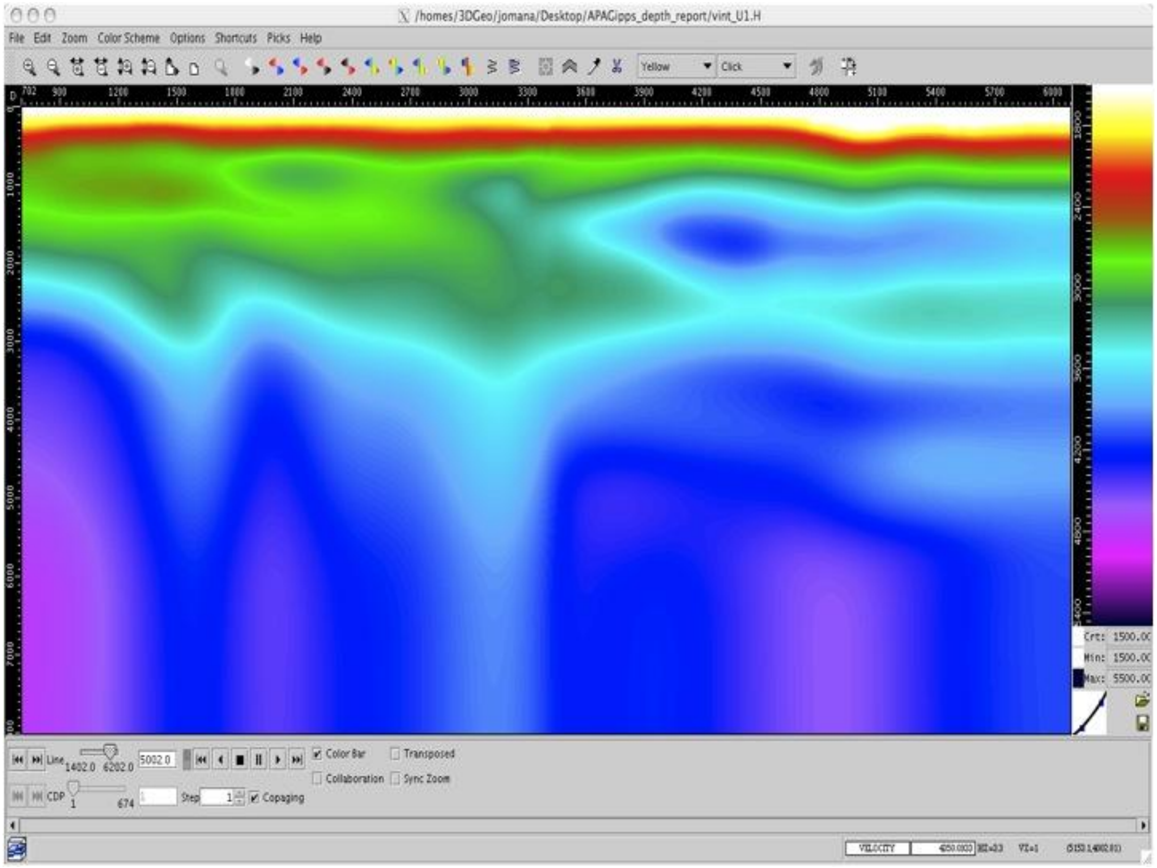


Figure 3.13 Unified initial velocity model, inline 5000.

To update the initial unified velocity model, two iterations of tomography based on residual curvature were implemented.

Figures 3.14 to 3.19 show the velocity models for the first and second iteration of tomography for inlines 3050, 4000 and 5000. It is noticeable that high frequency velocity features start to be added with each iteration.

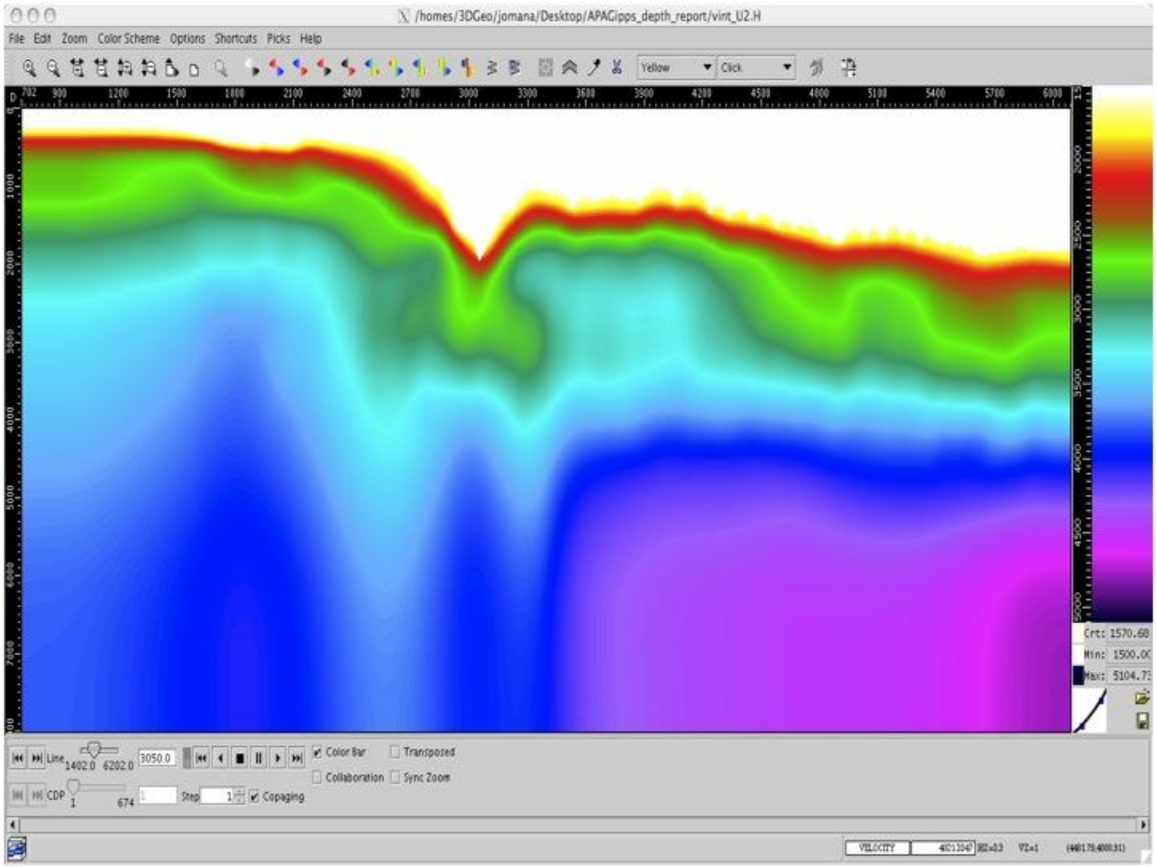


Figure 3.14 Unified velocity model after first iteration of tomography, inline 3050.

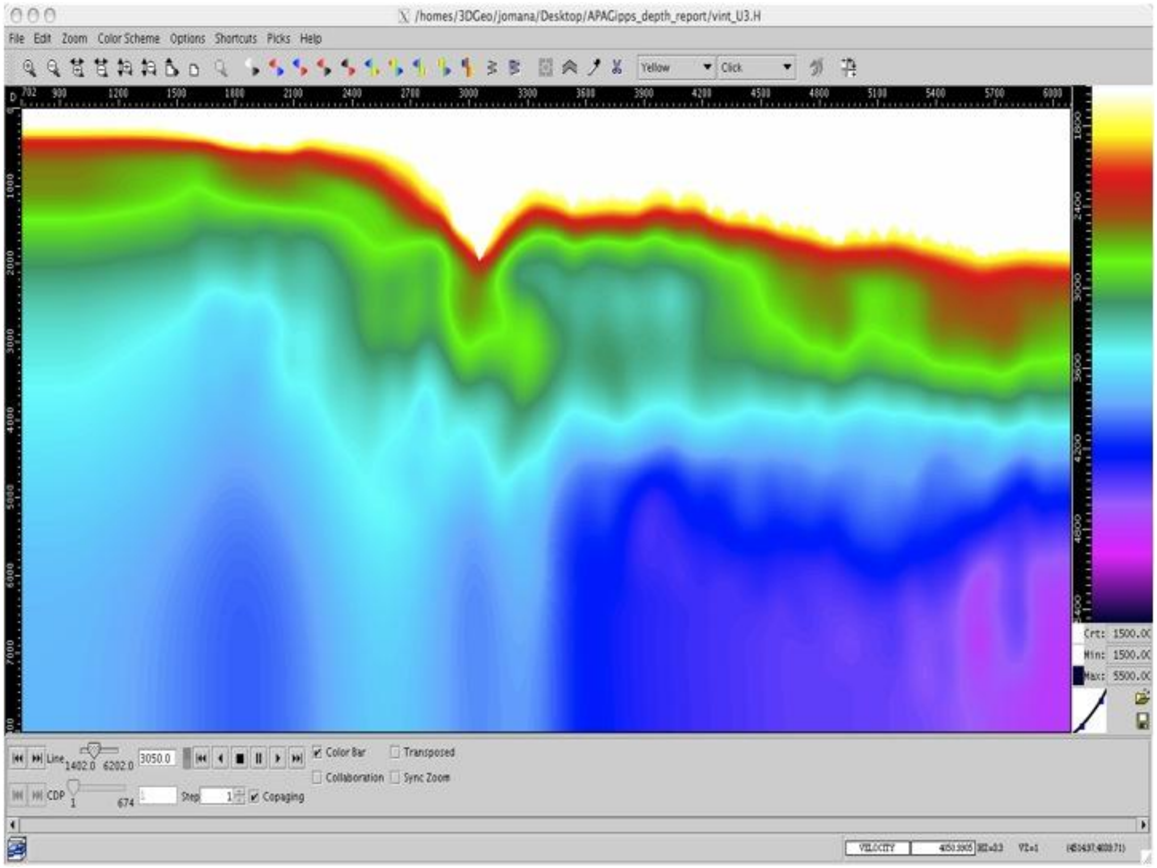


Figure 3.15 Unified velocity model after second iteration of tomography, inline 3050.

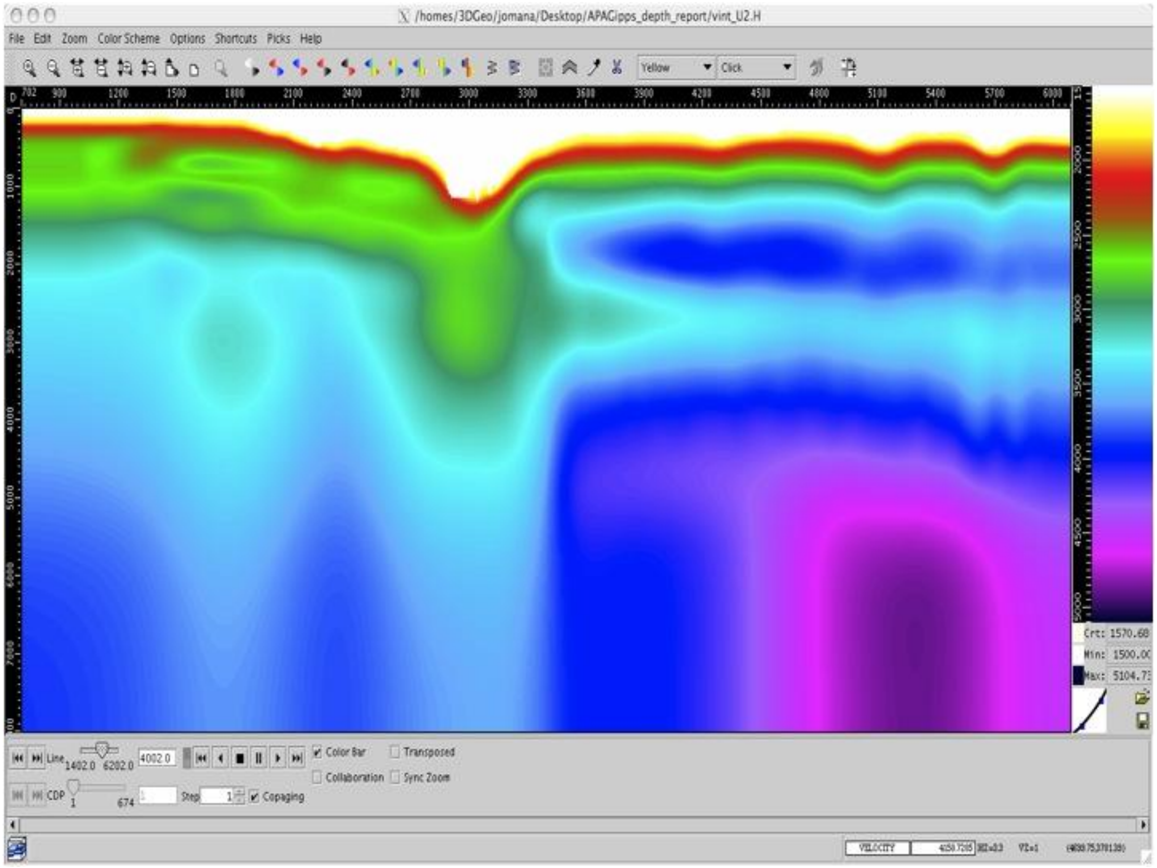


Figure 3.16 Unified velocity model after first iteration of tomography, inline 4000.

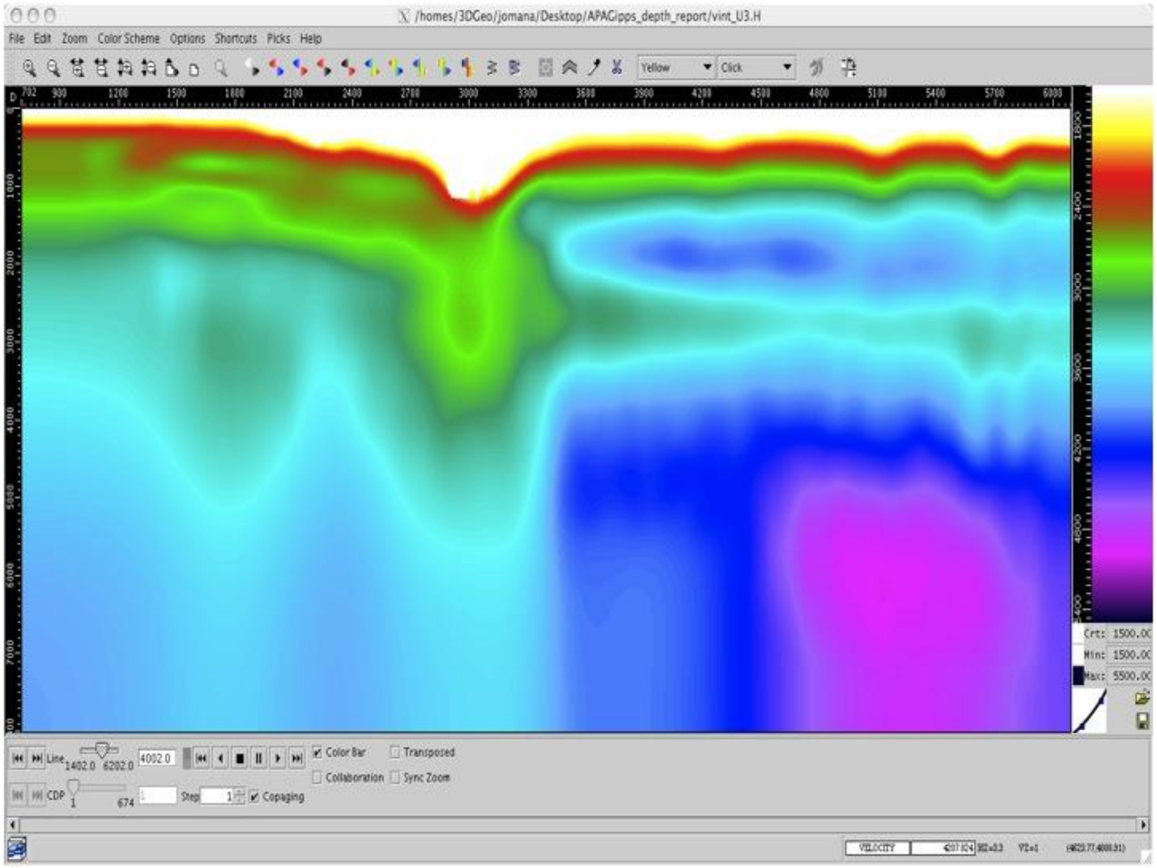


Figure 3.17 Unified velocity model after second iteration of tomography, inline 4000.

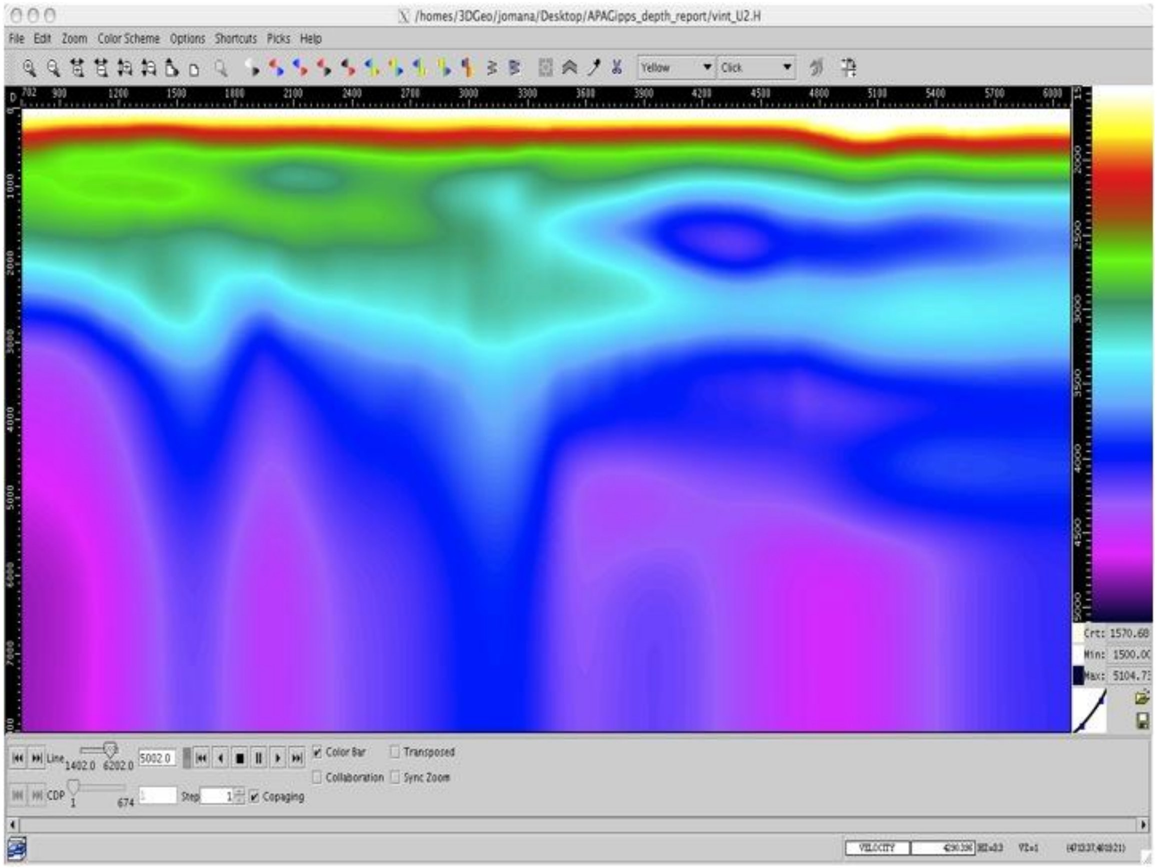


Figure 3.18 Unified velocity model after first iteration of tomography, inline 5000.

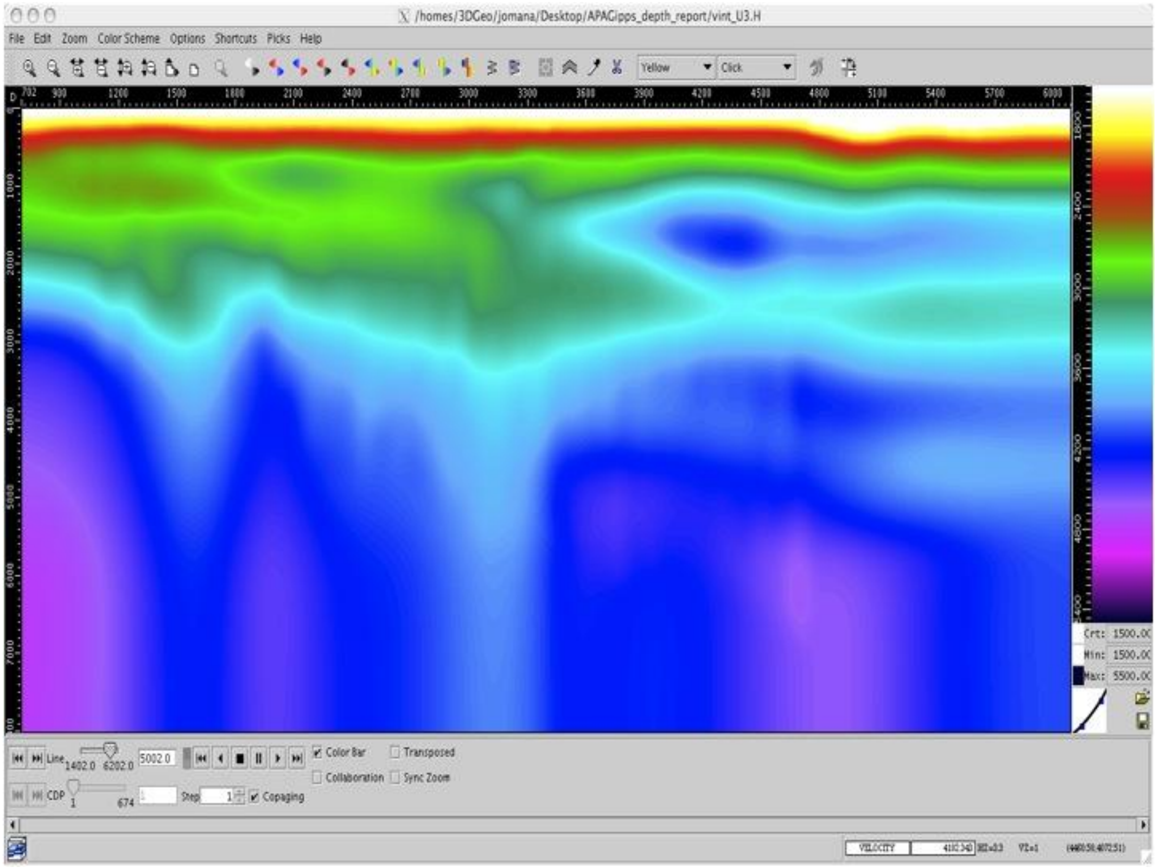


Figure 3.19 Unified velocity model after second iteration of tomography, inline 5000.

The concept behind residual curvature analysis (RCA tomography) is updating of the velocity in a 3-D sense in a manner that minimizes the residual depth error for each iteration. After migration the stacked volume goes through an automatic "dip field" or "event" picking process to estimate the reflectors for the ray tracing stage of the tomography.

Figure 3.20 shows an example of the picked seismic reflectors on the second iteration of PSDM stack volume.

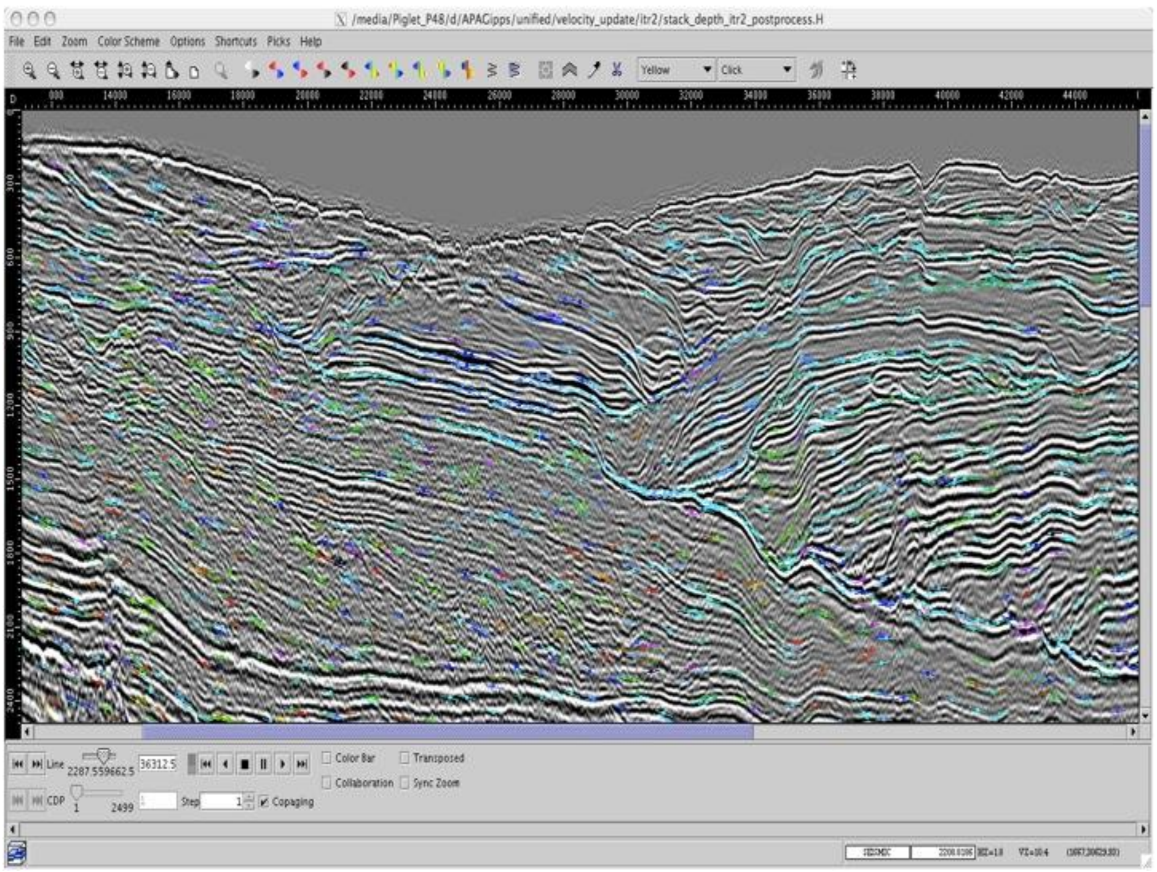


Figure 3.20 Reflector picks overlaid on second PSDM stack, inline 4306.

For each seismic event picked in the stack volume, a correspondent event is analyzed and picked in the migrated gathers. The event tracking in the gather domain uses coherence and wavelet attributes to pick complex moveout, which is the main advantage of RCA tomography over the residual velocity method.

Figure 3.21 shows the residual curvature picks overlaid on the second iteration of PSDM. It is important to mute and clean the migrated gathers before picking, to avoid picking artifacts or anomalous curvatures that could affect the velocity inversion.

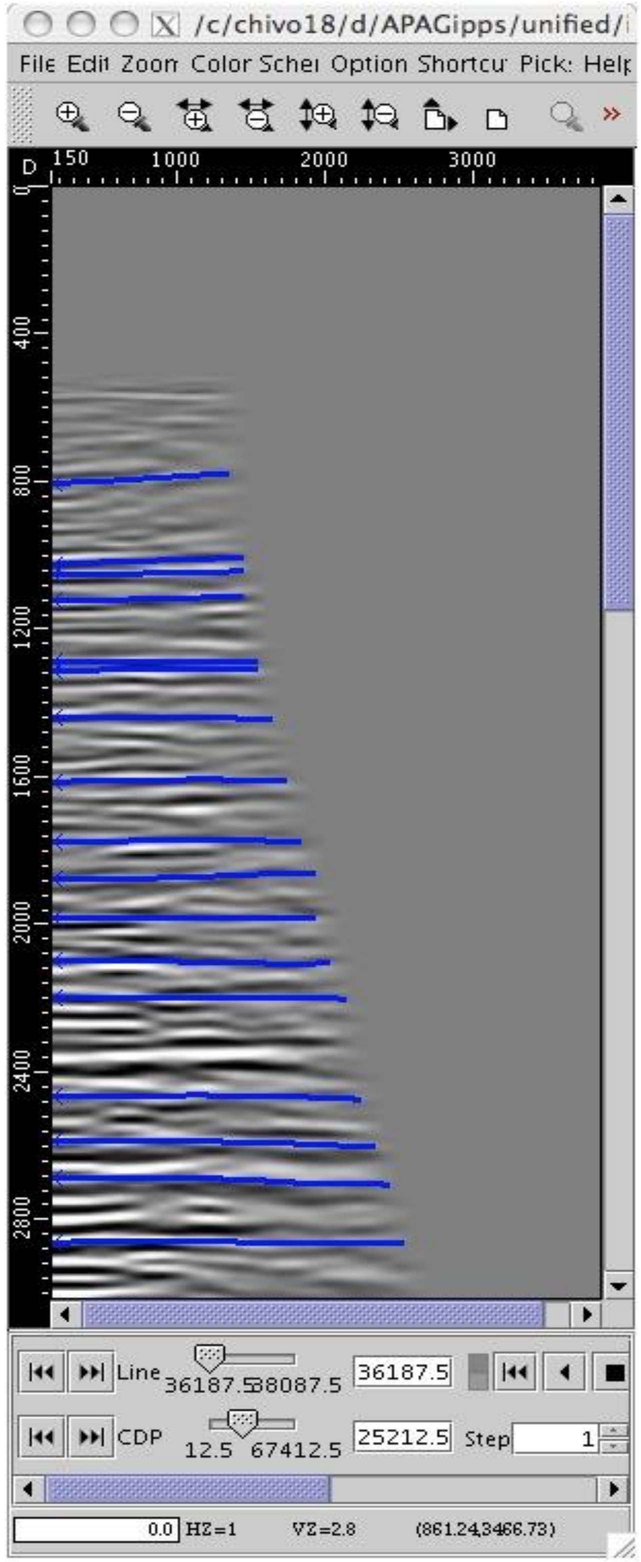


Figure 3.21 Residual curvature picks overlaid on second iteration of PSDM gathers.

The reflector picks from Figure 3.20, their associated residual curvature error picks from Figure 3.21 and the migration velocity model, are the elements needed to run RCA tomography. Interpreted horizons provided by Apache were also used to constrain the tomography and incorporated as part of the picked seismic events.

Tomography's goal is to produce a velocity model that produces flat gathers after migration. This is achieved by finding the optimal velocity that minimizes the pick residual curvature (residual depth errors). Figure 3.22 shows an example of the progressive flattening of the migrated gathers for each tomography iteration.

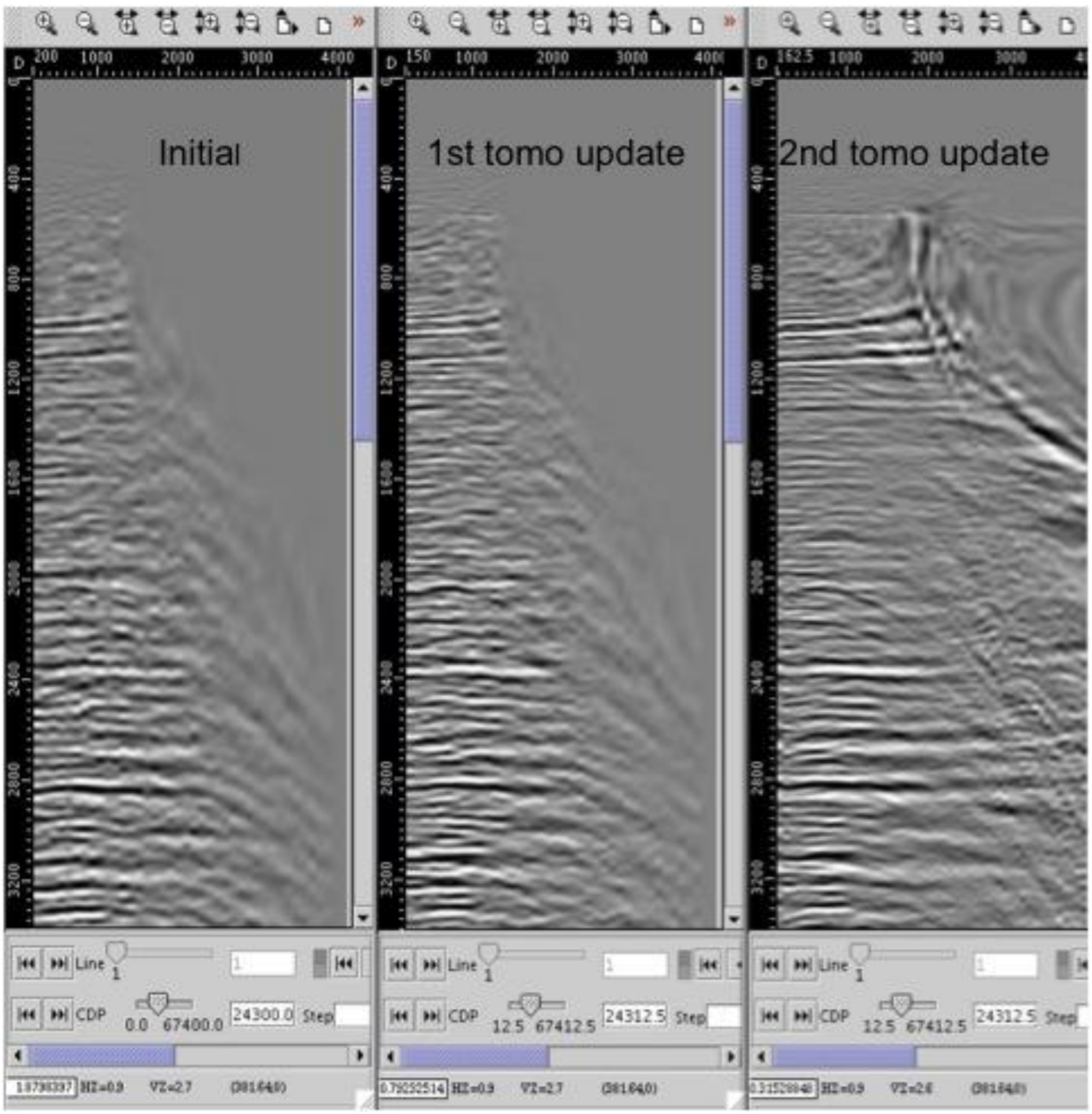


Figure 3.22 PDSM gather for initial velocity model, first and second iteration of tomography. The progression to a flatter gather can be noticed.

In order to QC and guarantee the convergence of the velocity model to a global solution that flattens the seismic gathers, the residual RMS velocity error is quantified after each iteration of velocity update. The RMS velocity error measures the residual curvature using a hyperbolic approximation, which is then used to calculate the relative velocity error.

Figures 3.23, 3.24 and 3.25 show the relative velocity error after each tomographic iteration. The transition from blue to red represents the relative velocity error scale from 95% (velocity %5 too slow) to 105% (velocity 5% too fast), with 100% and white color representing perfect flatness in the gather.

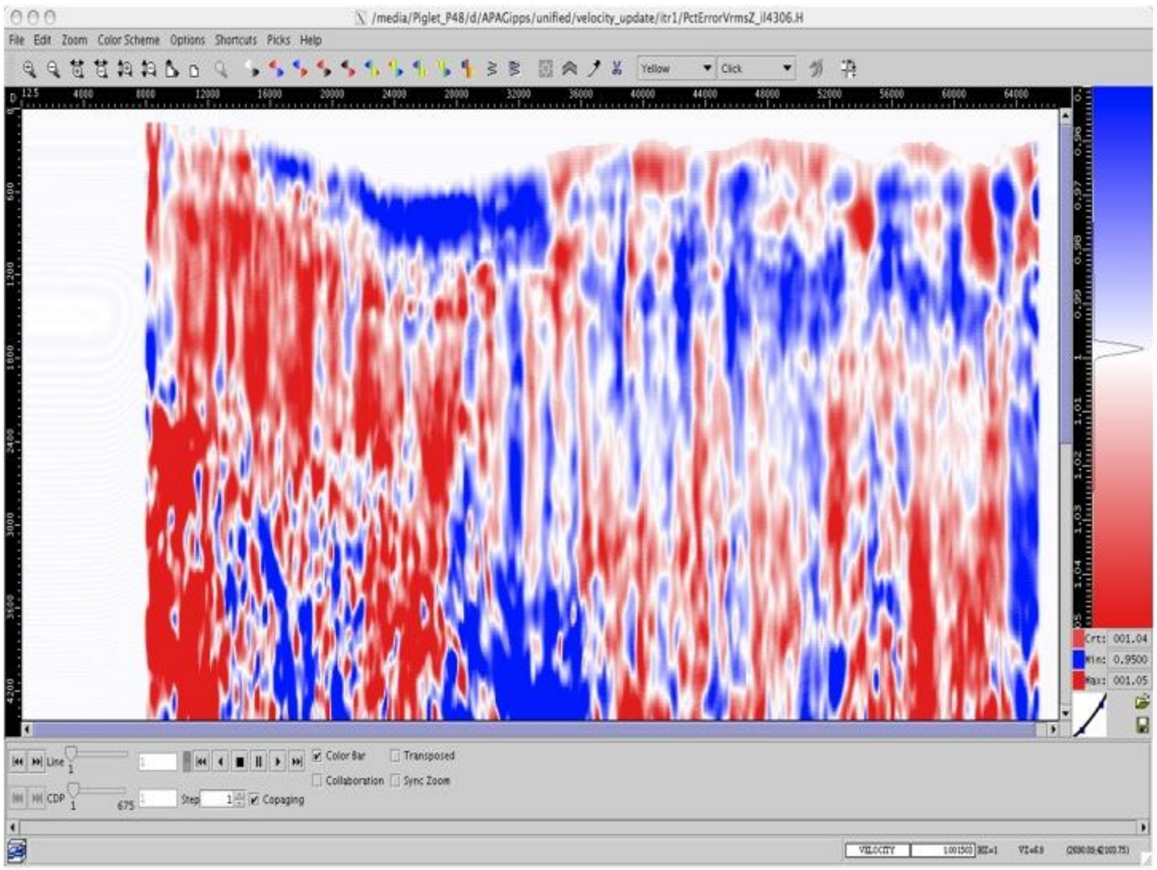


Figure 3.23 Relative velocity error after PSDM iteration 1, inline 4306.

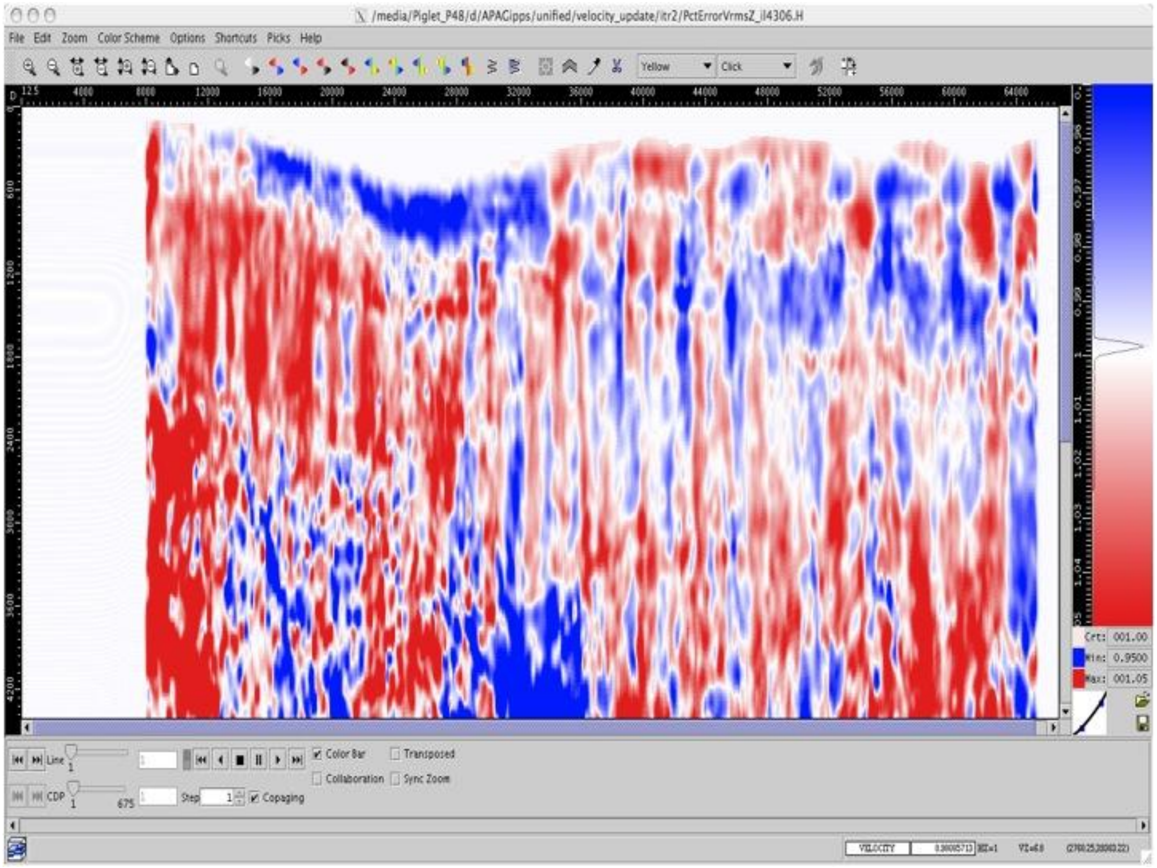


Figure 3.24 Relative velocity error after PSDM iteration 2, inline 4306.

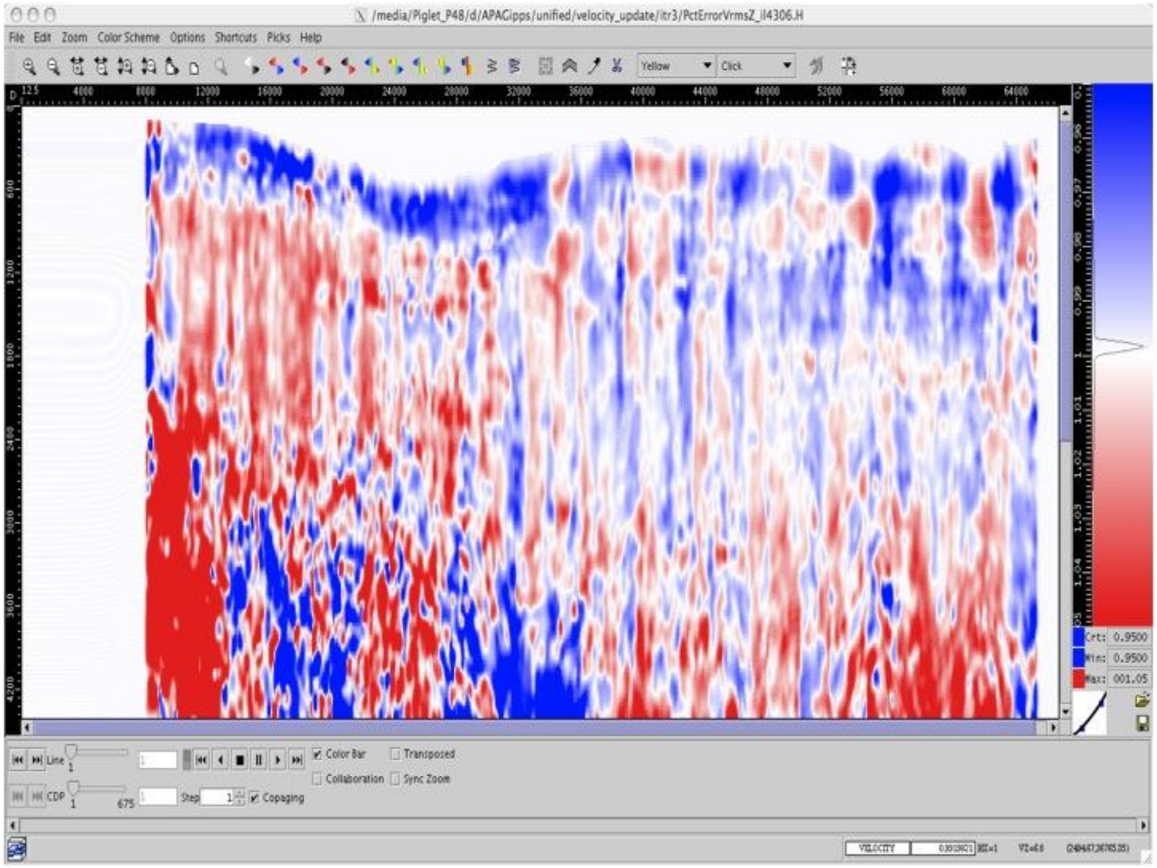


Figure 3.25 Relative velocity error after PSDM iteration 3, inline 4306.

From Figures 3.23, 3.24 and 3.25, it can be seen (by the fading of the color strength) that the velocity error is decreasing with each velocity update iteration. The relative velocity error attribute is very useful when QCing flatness of the migrated gathers since it is a 3D volumetric representation of the residual curvature.

Another way of quantifying and measuring the velocity model convergence is to analyze histograms for the velocity error for each velocity update iteration. Figures 3.26, 3.27 and 3.28 show the velocity error distribution for the data from Figures 3.23, 3.24 and 3.25 respectively.

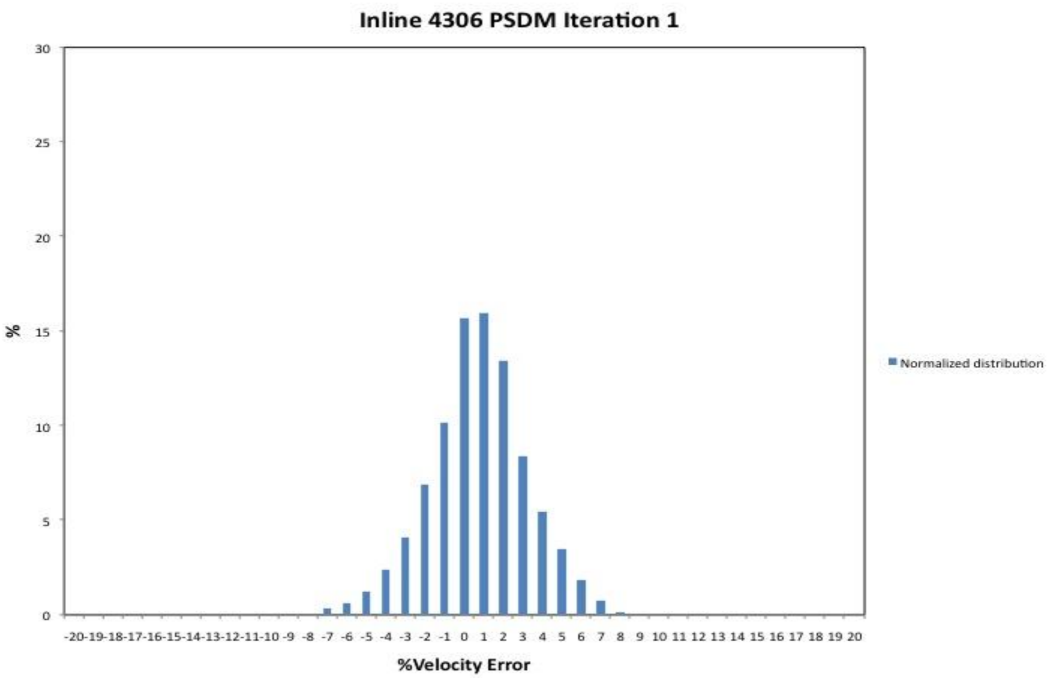


Figure 3.26 Histogram for the RMS velocity error, inline 4306 after PSDM iteration 1.

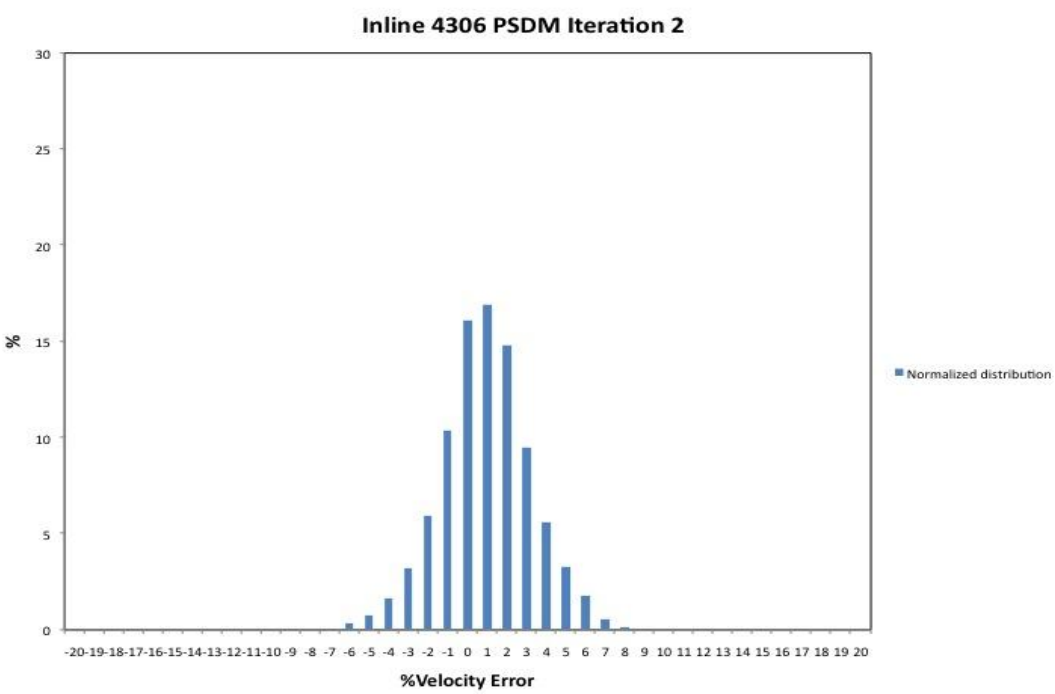


Figure 3.27 Histogram for the RMS velocity error, inline 4306 after PSDM iteration 2.

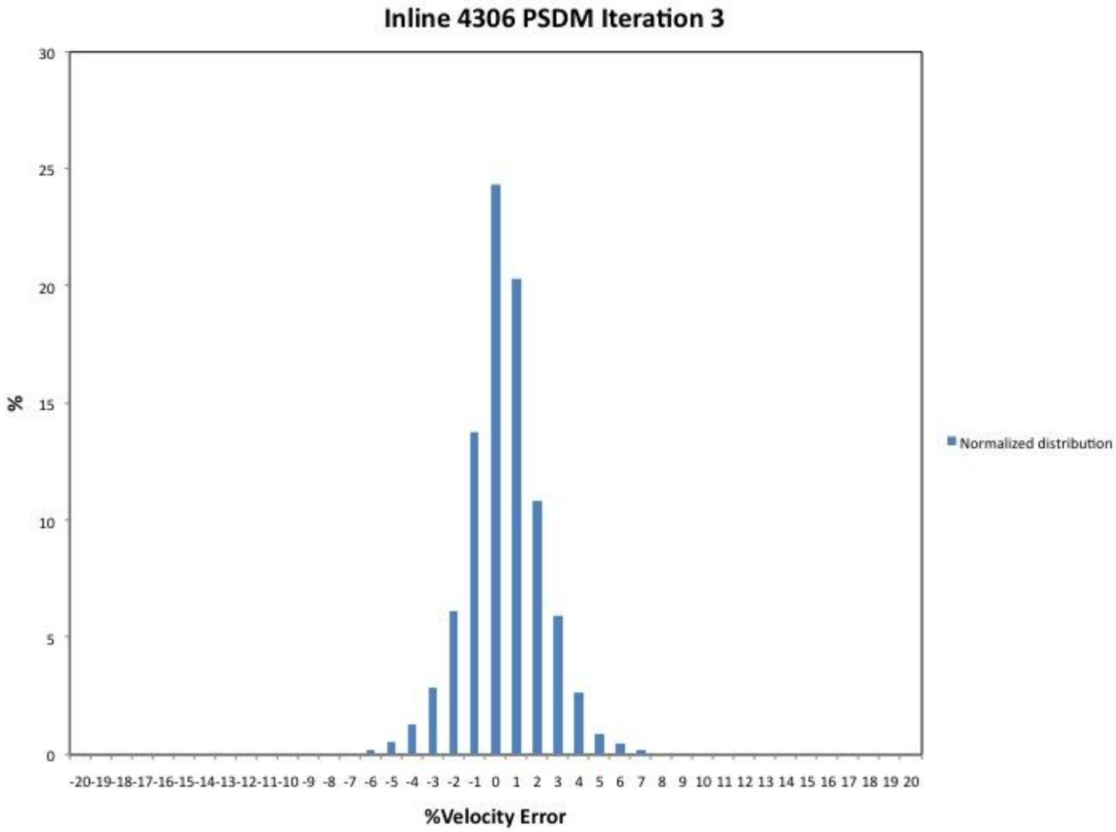


Figure 3.28 Histogram for the RMS velocity error, inline 4306 after PSDM iteration 3.

The histograms show the relative velocity error distribution after each tomography iteration. The horizontal axis is the relative velocity error, while the vertical axis represents its normalized volumetric distribution. Clearly, with each iteration, the relative velocity error margin narrows down, showing the convergence towards flatter gathers.

Finally, to illustrate the uplift in imaging quality after each tomography iteration, Figures 3.29-3.31 show the raw stack for inline 4306 for the initial, first update and second update velocity model respectively.

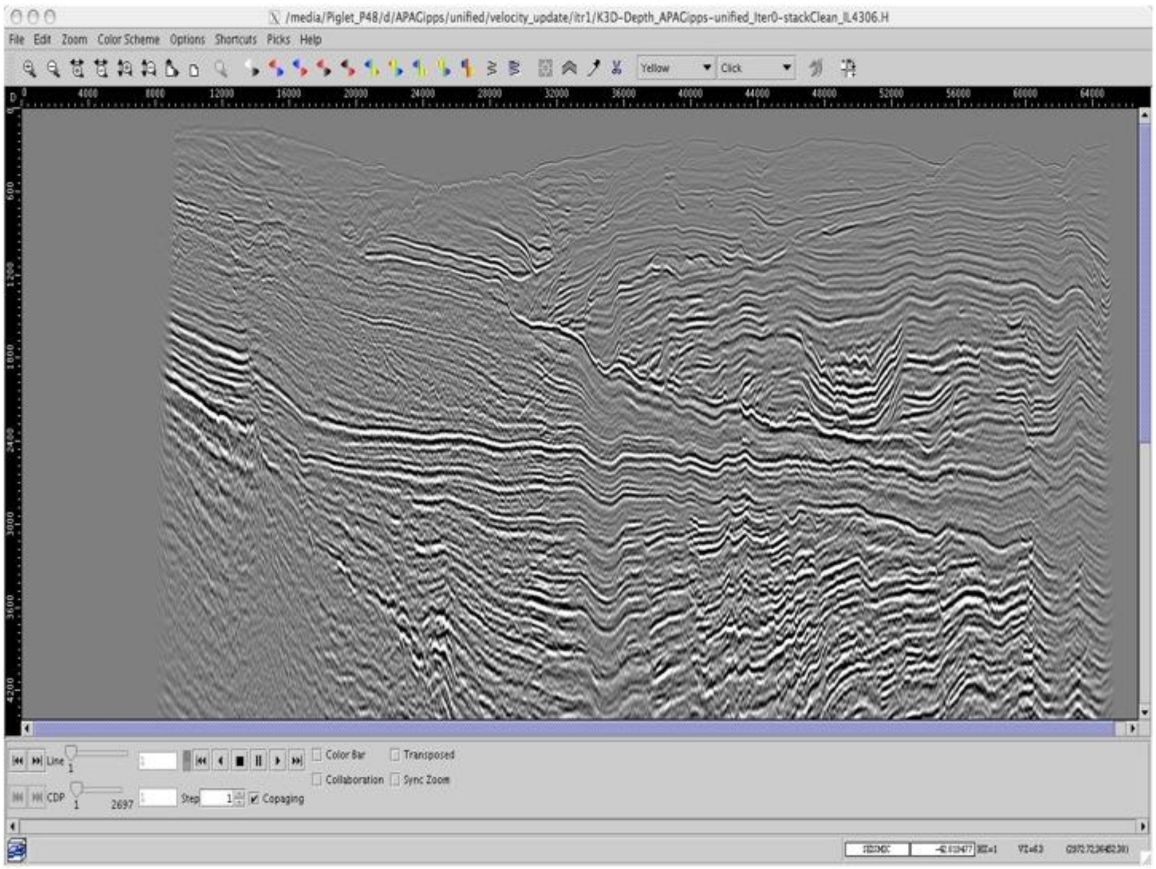


Figure 3.29 Raw stack after initial velocity model PSDM, inline 4306.

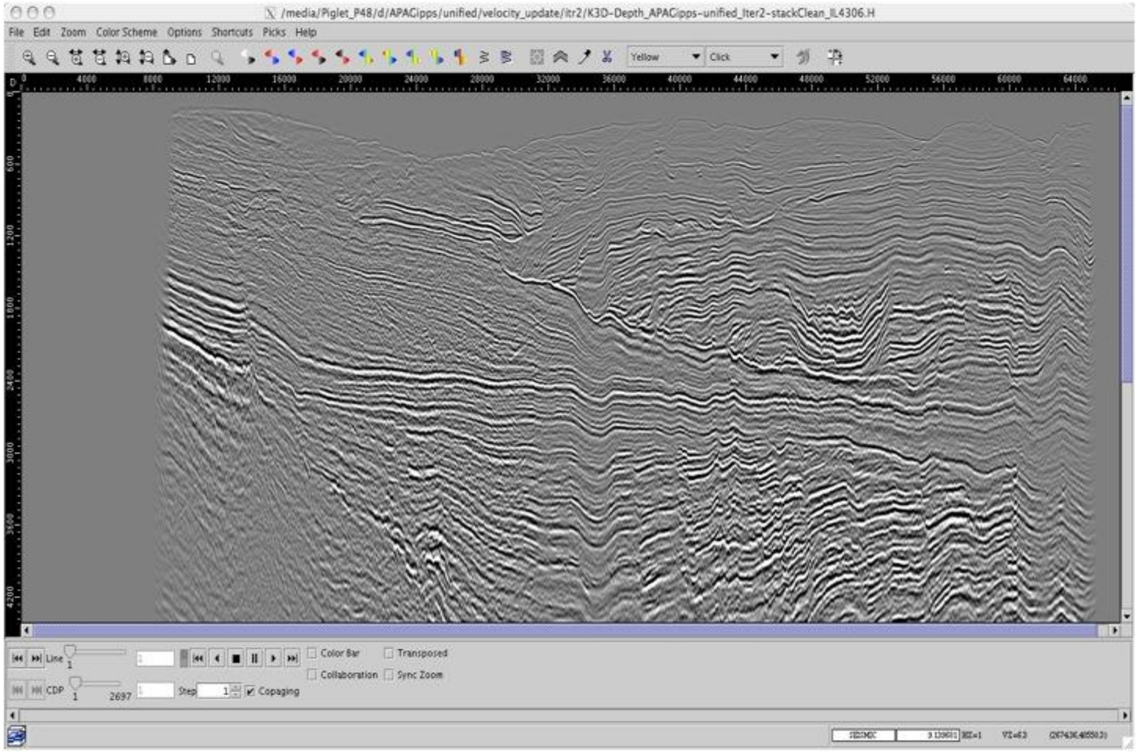


Figure 3.30 Raw stack after first tomographic update PSDM, inline 4306.

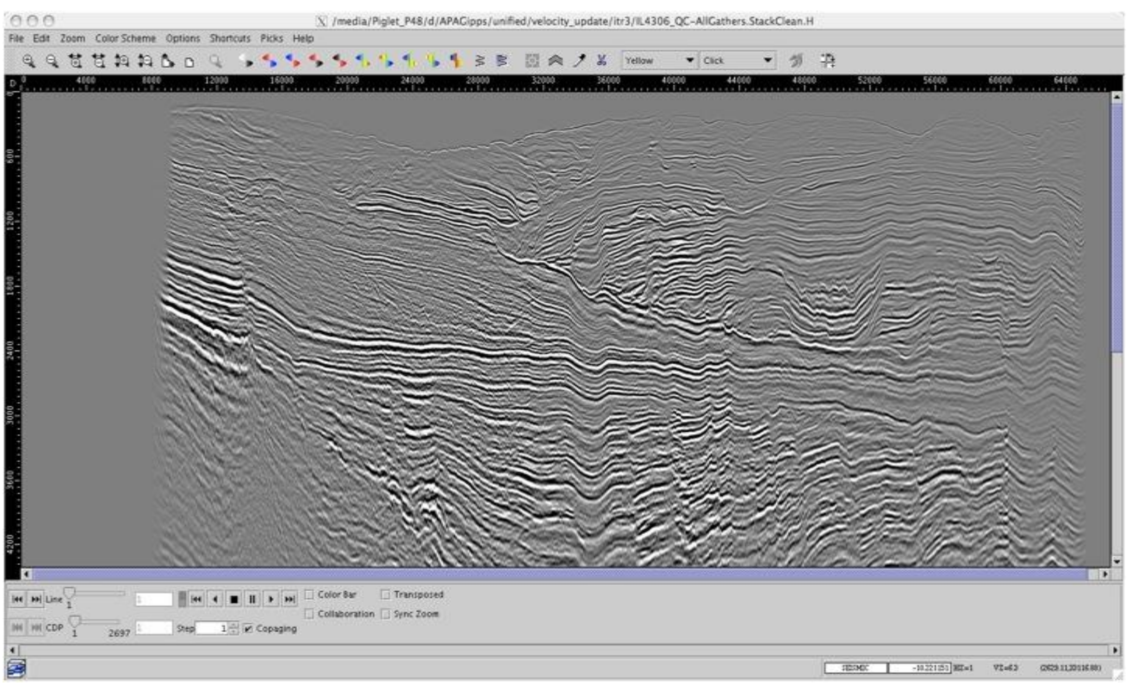


Figure 3.31 Raw stack after second tomographic update PSDM, inline 4306.

3.6. Migration parameters

All the migration iterations for Gippsland East used the Kirchhoff algorithm. Kirchhoff was chosen based on its ability to handle different survey azimuths since the Tuskfish acquisition layout was orthogonal to HGP-Elver.

Several migration tests (aperture, anti-alias operator, frequency content) ran to optimize the final migration parameters. After Apache's approval, the final migration parameters were as follows:

Velocity Model Grid	100 x 100 x 10m
TT Shooting Grid	150 x 150m
TT Table Grid	100 x 100 x 50m
TT Max Time (1-way)	9.0 seconds
TT Algorithm	Wavefront reconstruction: shortest travel path
Input bin size	12.5 x 25m
Input data length	6.0 seconds (@ 4ms)
Output bin size	25 x 25m
Output image live area	2402 sq km
Output Depth range	0 to 8000m (5m depth step)
Output Offset range	200-5000m (75m increments)
Migration Aperture	4000m
Migration max frequency	70 Hz
Migration anti-alias operator	37.5 x 37.5m

Note offset ranges varied by survey as noted in 1.4. During offset binning, data were binned in 75m increments with the first offset bin centered at 200m (spanning 162.5m to 237.5m) and the final bin at 5000m. As a result, the effective offset ranges for each survey during the final migration were as indicated in the following table

	Min Offset(m)	Max Offset(m)	# Traces
ELVER	200	4175	54
HGP2002A	200	4775	62
TUSKFISH	200	5000	65

***Note**: Gather header offsets reflect front-end of each offset bin i.e. 165, 237, 312……*

3.7 Migration Post-Processing - HDVA

As part of the post-migration products a high density velocity analysis (HDVA) was implemented on a 100m x 100m grid. HDVA was picked using residual RMS velocity error in the time domain and its purpose is to help with the flattening of the migrated gathers. Figures 32 and 33 show migrated gather with and without the application of HDVA.

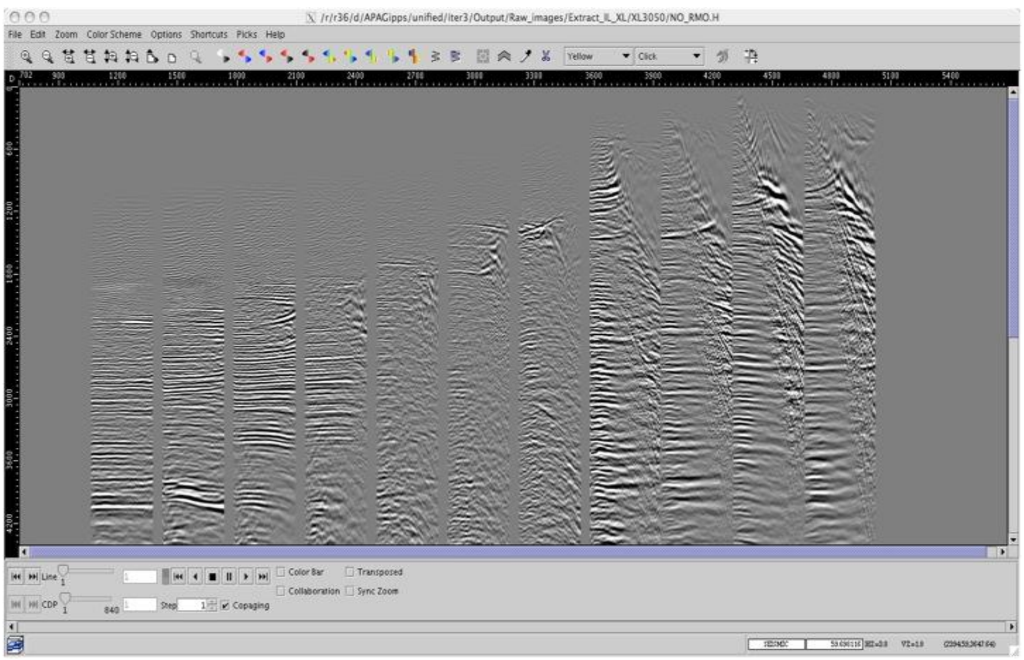


Figure 3.32 Gather before HDVA correction, crossline 3050.

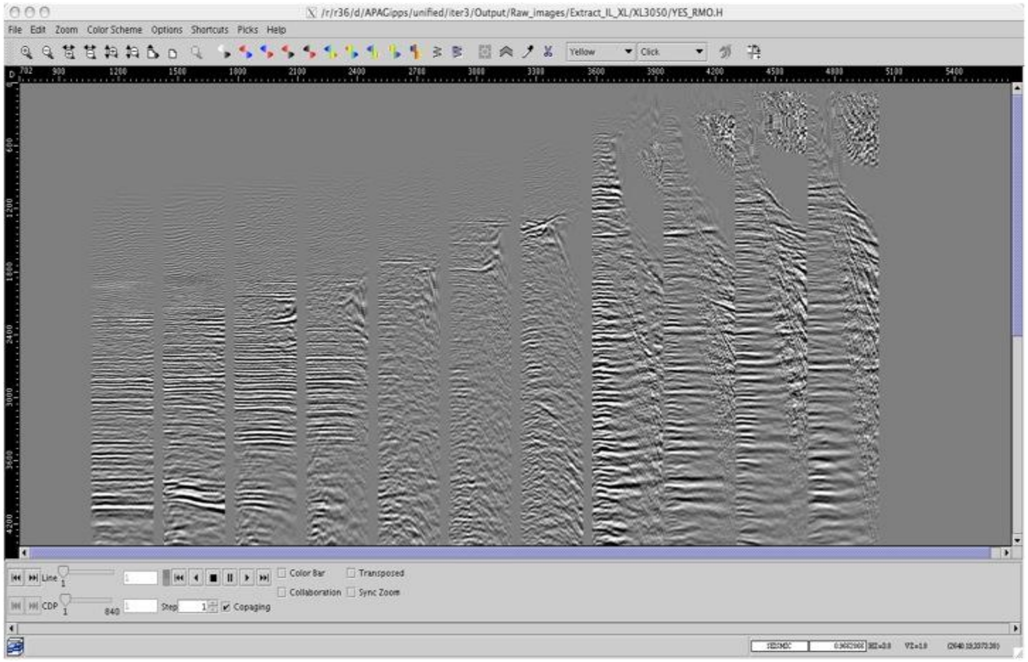
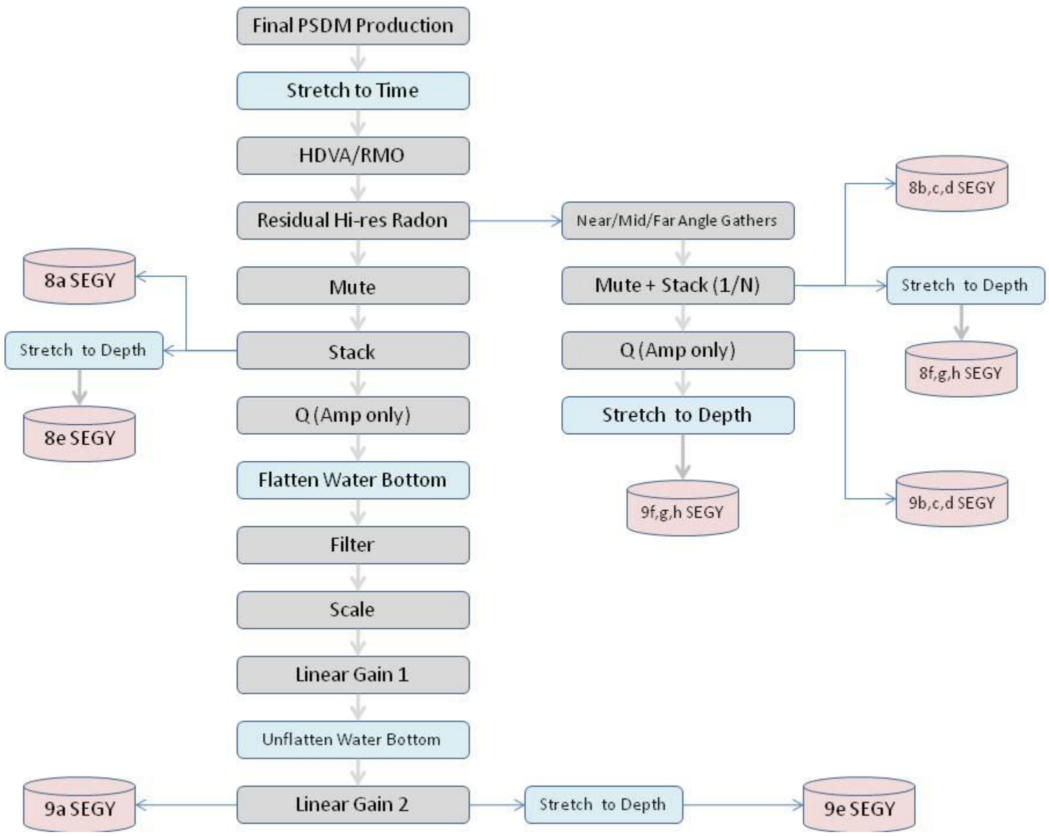


Figure 3.33 Gathers after HDVA correction, crossline 3050.

3.8 Post-Migration Processing - Final

After completion of the iterative depth migration stage and the availability of depth migrated common image gathers, the following workflow was implemented to provide the final fully-imaged and processed deliverables to Apache.



The post-migration Radon was applied to the depth-imaged gathers to attenuate remnant multiple energy both to provide an improved Final Stack but also to provide gathers more amenable to future attribute evaluation.

The Radon application was as follows:

Radon	-300ms to +300ms at 2000m
Modeling the Multiple (attenuating)	-300ms to +60ms
Difference Original Trace	(P+M) – Radon (M) = P
Addback	60% at 500m taper to 20% at 1800m
No Addback	>1800m

The final mute schedule employed prior to stack using 1/SQRT(N) stack fold compensation was:

Outer (On):

	Offset (m)	**TWT (ms)**
100	400	0
	500	284
	800	776
	1550	1412
	2250	1928
	3850	3280
	5550	3988
300	800	0
	1050	776
	1300	1240
	2000	1776
	3850	2896
	5550	3600
500	750	0
	900	604
	1600	1532
	2750	2356
	3550	2992
	4050	3548
	5500	4156
1000	1200	0
	1350	1140
	1900	1984
	2800	3552
	5500	4344
1500	1450	0
	2000	2000
	2450	2556
	3400	3520
	5550	5344
2000	1800	0

	Offset (m)	TWT (ms)
	2600	2176
	2900	3472
	5550	5348

Inner (Off):

Depth (ms)	Offset(m)	TWT (ms)
100	200	1500
	500	2500
	550	6000
500	200	2000
	500	3000
	550	6000
1000	200	2500
	500	3500
	550	6000
2000	200	3500
	500	4500
	550	6000

Amplitude only Q =100 (with 6 dB/sec) was applied complementary to the phase only Q implemented during the pre-processing stage.

After stack, a time-variant Bandpass filter was applied as follows:

Start (ms)	End (ms)	Low Cut (Hz)	Slope (dB/oct)	High Cut (Hz)	Slope (dB/oct)
0	500	12	18	85	36
1000	1500	10	18	75	36
2000	2500	8	18	65	36
4000	4500	4	18	35	36
5000	6000	2	18	25	36

Referenced to water bottom.

Finally, AGC time-variant scaling referenced to water bottom.

TIME (ms)	Window (ms)
0	250
2000	2000

WB referenced interpolated between above control points

Followed by gain curve:

TIME (ms)	GAIN (dB)
0	0
6000	-18

WB referenced

then

TIME (ms)	GAIN (dB)
0	0
3500	0
6000	-12

Zero Time referenced

For these time domain processes, it was required to perform depth-time conversion for application and subsequent time-depth conversions to provide the final depth volumes using the final velocity model. Except where noted, the processes above were generally referenced to Water Bottom. This was accomplished by flattening to Water Bottom, process application and re-referencing to Sea Level after process application.

As augmented products, a suite of Angle Stacks were generated from the depth migrated gathers converted to Time using the following angle degree ranges:

	Angle Range
Near	05-15
Mid	15-25
Far	25-35

These Angle Stacks used 1/N fold compensation during stack. Two sets of volumes were generated:
Raw: no post-processing applied
Final: amplitude only Q compensation (Q=100).

SUMMARY

The Gippsland East project has successfully pre-processed and merged three large 3-D surveys into a single fully-unified 2402 sq km Depth volume fully integrated through five iterations of 3-D velocity modeling, updating and 3-D pre-stack depth migration. Supported by the state-of-the-art Time pre-processing, the final seismic data volume provides Apache with an important subsurface information database to aid its continuing hydrocarbon evaluation of its Gippsland Basin properties.

As well as the final PSDM data volume, detailed velocity information is now available via the final interval velocity-depth model that, when used in conjunction with the available well data, provides subsurface information free of the spatial distortions induced in standard Time processing by the highly depth-variable overlying water layer and a very rugose water bottom.

The project has also provided the 2007 Elver survey with an accompanying fully processed 3-D pre-stack Time migrated volume. Auxiliary attribute final volumes using selected angle stacks are also available to support stratigraphic evaluation within the project area.

As well as the logistics of carefully managing ultra-large data sets through compute-intensive processes, the significant issues encountered and successfully addressed included:

- Rigorous QC of incoming data sets and recommendations for improvement (e.g. Tuskfish multiple attenuation).
- Multiple contamination was a common feature of each survey requiring multi-stage or cascaded application to successively address the different multiple classes contained in the data. This included a post-migration stage after conversion of PSDM gathers from depth to time.
- Matching, merging and binning strategy for three large surveys including addressing the orthogonal azimuth acquisition of Tuskfish versus its partner surveys.
- Assessment of the potential contribution of HGP and Tuskfish in the presence of a noisier HGP data set.
- Maintaining flexibility by adapting the processing flow and additional intermediate analyses and products to fully assess workflow options. This included the generation of multiple sets of 3-D PSTM and PSDM target lines and also including large segments of Elver "turns" data up to and including the intermediate depth stages to assess their subsurface contribution potential to the total program (see Appendix C).
- Additional effort was required to integrate the individual survey velocity models during the early to intermediate stages of the iterative PSDM process. This was necessary to fully address edge effects and obtain a single internally consistent, geologically plausible single model for the unified stage(s) of the PSDM process.

- The joint effort between 3DGeo and Apache interpretation staff to expeditiously update the large-scale subsurface horizon information during the iterative PSDM process.
- The requirement for accurate and detailed spatial definition of the water bottom bathymetry to improve the focusing ability of the PSDM process. This was successfully accomplished except in the canyon area where further improvement opportunity has been identified.
- Continuous long-distance co-ordination and co-operation between 3DGeo's Houston office and Apache Perth Australia. The joint effort and commitment to close communication and collaboration of the parties was a major factor in assuring the successful project outcome.

As the ability with available external bathymetry and production-oriented processing to precisely define with full accuracy the highly variable water bottom, there remained an opportunity to improve the subsurface imaging below the deeply incised major canyon areas. In certain of these areas, lack of full accuracy in the water bottom profile (and, hence, the 3-D depth-interval velocity model used to generate the final PSDM volume) has precluded the delivery of optimally focused and spatially positioned information below and proximate to these areas of highest water bottom variability. The use of wave equation pre-stack depth migration techniques capable of handling the possible multi-pathing associated with these difficult zones is recommended to provide a clearer water bottom image for improved picking and definition of the water bottom. This will allow the overburden velocity model to be more correctly defined and allowing clearer subsurface imaging in these most difficult areas.

ACKNOWLEDGEMENTS

3DGeo expresses its gratitude to Apache personnel involved with the Gippsland East project for their significant contribution of the success of this project.
Paul Bouloudas, Apache Energy's processing coordinator for the project, for his complete co-operation throughout. He provided the support, communication, information and technical insights that kept the project on track.
Rob Kneale, Apache Energy interpreter, provided interpretation insights and rapid feedback especially during the depth imaging stage that allowed 3DGeo to maintain continuity of the iterative modeling and updating process.
Jim Ross, Apache Energy geophysical manager, provided full support throughout the duration of the project.

Gippsland East 3-D
Gippsland Basin, Offshore Australia

Seismic Time Processing
And
Pre-Stack Depth Imaging
Final Report

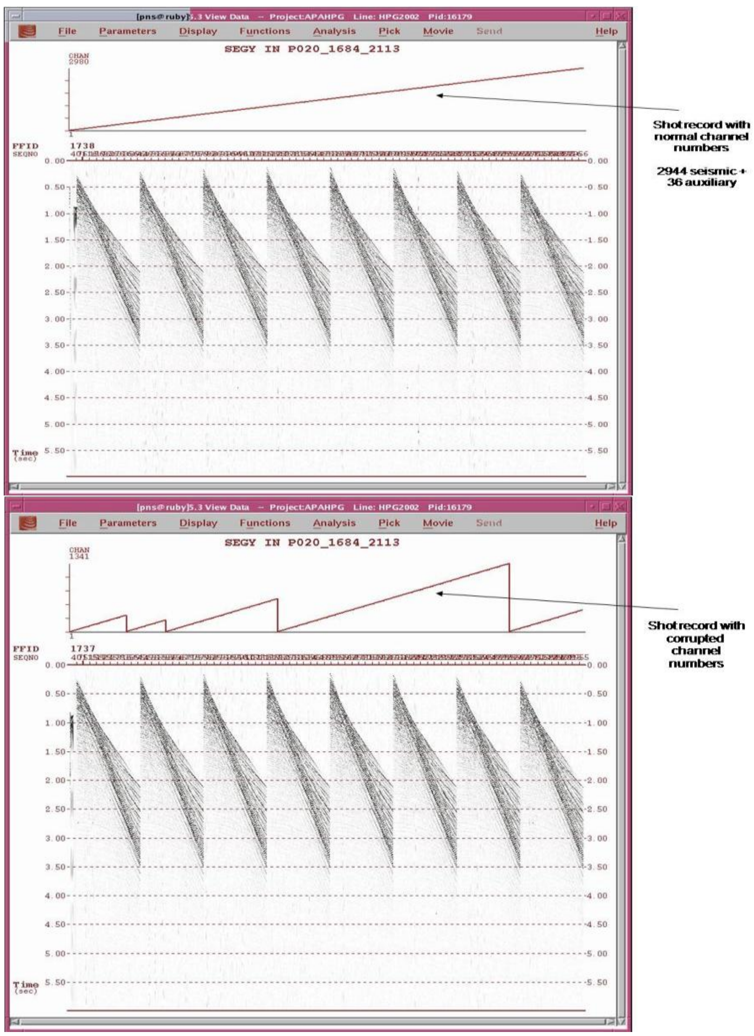
Appendices

APPENDIX A
HGP Data Corruption Summary

After receipt of the final HGP data disc on May 15 2008, a channel/FFID corruption problem was identified within the HGP data set. Approximately 25% of the data files (26 sail lines out of 99 total sail lines) exhibited some degree of the problem described below with approx 1% of the data within any file affected.

On SEGY headers of the data provided by Apache, the channel number was located in bytes 13-17. Normally it ranged from 1 to 2980 for 8 streamers data and from 1 to 2244 for 6 streamers data (2944/2208 seismic + 36 auxiliary channels). However, on certain files the channel number continuously "reset" to 1 at random locations within the records. It was noted that there was normally one or two missing traces prior to these locations.

The following figures illustrate the nature of the problem identified.



There was no channel number-related information in the SEGY header that provided channel within streamer position as this was presumably not mapped across during SEGD-SEGY reformat. Only cable number was provided on bytes 183-184. Due to random nature of the resetting described above, the absence of this channel/streamer relationship information complicated any channel recovery process. After analysis of the problem(s), a methodology was developed to resolve the issue as outlined below:

1. Drop auxiliary channels to make the number of traces on all records the same (test records do not have auxiliary channels)
2. Recombine ensembles with constant number of traces per ensemble - 2944 for 8 cables data and 2208 for 6 cables data
3. Reassign FFID number by taking the value from first trace and propagating it across record. This assumes that channel #1 does not have corrupted FFID trace header. If it does, it will be identified by a comparison of time in trace header and time in navigation - see step 6.
4. Reassign channel number by sequentially numbering traces within record
5. For QC of the ensemble combination, acquisition time (seconds) is displayed on top of selected shot records (headers containing time were not corrupted). If data from a different shot goes into the record, trace header with SECOND would not be constant.
6. Time value in seismic trace header is checked against time in navigation file for every shot record as part of the standard navigation merge QC and, also, to check if FFID is assigned properly in step 3
7. LMO corrected shot record displays are generated to identify if there is any problem with channel or FFID assignment or other navmerge problems.
8. Near trace stack volume is generated for channel fix QC and navmerge QC

Using the above procedure, during the period from data receipt to June 12, data were successfully recovered allowing the HGP2002A pre-processing phase to proceed. As well as the specific problem described above, other similar problems (e.g. channel corruption only) were successfully resolved.

The following table summarizes the data sets affected.

Disk Location	Spectrum ID	Line	FFFID	LFFID	FSP	LSP	Reel No	AGSO Ref
USB1	3495957	GP02-1344P020	1684	2113	1684	2113	GB92270091	P00563196
USB1	3495962	GP02-1168P021	2562	2133	2562	2133	GB92270096	P00563201
USB1	3495963	GP02-1168P021	2132	1703	2132	1703	GB92270097	P00563202
USB1	3495964	GP02-1168P021	1702	1273	1702	1273	GB92270098	P00563203
USB1	3495965	GP02-1168P021	1272	1143	1272	1143	GB92270099	P00563204
USB1	3495966	GP02-1360P022	1254	1683	1254	1683	GB92270100	P00563205
USB4	3496167	GP02-1520J061	0989	1418	0989	1418	GB92270301	P00563406
USB4	3496168	GP02-1520J061	1419	1848	1419	1848	GB92270302	P00563407
USB4	3496169	GP02-1520J061	1849	2278	1849	2278	GB92270303	P00563408
USB4	3496170	GP02-1520J061	2279	2708	2279	2708	GB92270304	P00563409
USB4	3496171	GP02-1520J061	2709	3138	2709	3138	GB92270305	P00563410
USB4	3496172	GP02-1520J061	3139	3395	3139	3395	GB92270306	P00563411
USB4	3496173	GP02-1120A062	2993	2564	2993	2564	GB92270307	P00563412
USB4	3496174	GP02-1120A062	2563	2134	2563	2134	GB92270308	P00563413
USB4	3496175	GP02-1120A062	2133	1704	2133	1704	GB92270309	P00563414
USB4	3496176	GP02-1120A062	1703	1274	1703	1274	GB92270310	P00563415
USB4	3496177	GP02-1120A062	1273	1141	1273	1141	GB92270311	P00563416
USB4	3496178	GP02-1296B063	1254	1683	1254	1683	GB92270312	P00563417
USB4	3496179	GP02-1296B063	1684	1952	1684	1952	GB92270313	P00563418
USB4	3496180	GP02-1488J064	0989	1418	0989	1418	GB92270314	P00563419
USB4	3496181	GP02-1488J064	1419	1848	1419	1848	GB92270315	P00563420
USB4	3496182	GP02-1488J064	1849	2278	1849	2278	GB92270316	P00563421
USB4	3496183	GP02-1488J064	2279	2708	2279	2708	GB92270317	P00563422
USB4	3496184	GP02-1488J064	2709	3138	2709	3138	GB92270318	P00563423
USB4	3496185	GP02-1488J064	3139	3396	3139	3396	GB92270319	P00563424
USB4	3496186	GP02-1760J065	3275	2846	3275	2846	GB92270320	P00563425
USB4	3496187	GP02-1760J065	2845	2416	2845	2416	GB92270321	P00563426
USB4	3496188	GP02-1760J065	2415	1986	2415	1986	GB92270322	P00563427
USB4	3496189	GP02-1760J065	1985	1556	1985	1556	GB92270323	P00563428
USB4	3496190	GP02-1760J065	1555	1126	1555	1126	GB92270324	P00563429
USB4	3496191	GP02-1760J065	1125	0877	1125	0877	GB92270325	P00563430
USB4	3496192	GP02-1504P066	0989	1418	0989	1418	GB92270326	P00563431
USB4	3496193	GP02-1504P066	1419	1848	1419	1848	GB92270327	P00563432
USB4	3496194	GP02-1504P066	1849	2278	1849	2278	GB92270328	P00563433
USB4	3496195	GP02-1504P066	2279	2708	2279	2708	GB92270329	P00563434
USB4	3496196	GP02-1504P066	2709	3138	2709	3138	GB92270330	P00563435
USB4	3496197	GP02-1504P066	3139	3395	3139	3395	GB92270331	P00563436
USB4	3496198	GP02-1760K067	2662	2233	2662	2233	GB92270332	P00563437
USB4	3496199	GP02-1760K067	2232	1803	2232	1803	GB92270333	P00563438
USB4	3496200	GP02-1760K067	1802	1373	1802	1373	GB92270334	P00563439
USB4	3496201	GP02-1760K067	1372	0943	1372	0943	GB92270335	P00563440
USB4	3496202	GP02-1760K067	0942	0876	0942	0876	GB92270336	P00563441
USB4	3496203	GP02-1520K068	0989	1418	0989	1418	GB92270337	P00563442
USB4	3496204	GP02-1520K068	1419	1848	1419	1848	GB92270338	P00563443
USB4	3496205	GP02-1520K068	1849	2278	1849	2278	GB92270339	P00563444
USB4	3496206	GP02-1520K068	2279	2708	2279	2708	GB92270340	P00563445
USB4	3496207	GP02-1520K068	2709	3395	2709	3395	GB92270341	P00563446
USB4	3496208	GP02-1648P069	3278	2851	3278	2851	GB92270342	P00563447
USB4	3496209	GP02-1648P069	2850	2421	2850	2421	GB92270343	P00563448
USB4	3496210	GP02-1648P069	2420	1991	2420	1991	GB92270344	P00563449
USB4	3496211	GP02-1648P069	1990	1561	1990	1561	GB92270345	P00563450
USB4	3496212	GP02-1648P069	1560	1131	1560	1131	GB92270346	P00563451
USB4	3496213	GP02-1648P069	1130	0877	1130	0877	GB92270347	P00563452
USB4	3496214	GP02-1552A070	0989	1221	0989	1221	GB92270348	P00563453
USB4	3496215	GP02-1824A071	1153	1066	1153	1066	GB92270349	P00563454
USB4	3496216	GP02-1632P027	0989	1418	0989	1418	GB92270350	P00563455
USB4	3496217	GP02-1632P027	1419	1848	1419	1848	GB92270351	P00563456
USB4	3496218	GP02-1632P027	1849	2278	1849	2278	GB92270352	P00563457
USB4	3496219	GP02-1632P027	2279	2708	2279	2708	GB92270353	P00563458
USB4	3496220	GP02-1632P027	2709	2925	2709	2925	GB92270354	P00563459
USB4	3496221	GP02-1632P027	3115	3392	3115	3392	GB92270355	P00563460
USB4	3496222	GP02-1632J073	3279	2850	3279	2850	GB92270356	P00563461
USB4	3496223	GP02-1632J073	2849	0876	2849	0876	GB92270357	P00563462
USB4	3496224	GP02-1632J073	2140	1711	2140	1711	GB92270358	P00563463
USB4	3496225	GP02-1632J073	1710	1281	1710	1281	GB92270359	P00563464
USB4	3496226	GP02-1632J073	1280	0877	1280	0877	GB92270360	P00563465
USB4	3496227	GP02-1536J074	1489	1918	1489	1918	GB92270361	P00563466
USB4	3496228	GP02-1536J074	1919	2348	1919	2348	GB92270362	P00563467
USB4	3496229	GP02-1536J074	2349	2522	2349	2522	GB92270363	P00563468
USB4	3496230	GP02-1632A075	2904	3126	2904	3126	GB92270364	P00563469
USB4	3496231	GP02-1664J076	2932	2503	2932	2503	GB92270365	P00563470
USB4	3496232	GP02-1664J076	2502	2073	2502	2073	GB92270366	P00563471
USB4	3496233	GP02-1664J076	2072	1643	2072	1643	GB92270367	P00563472
USB4	3496234	GP02-1664J076	1642	1213	1642	1213	GB92270368	P00563473
USB4	3496235	GP02-1664J076	1212	0877	1212	0877	GB92270369	P00563474
USB4	3496236	GP02-1488K077	2208	2637	2208	2637	GB92270370	P00563475
USB4	3496237	GP02-1488K077	2638	3067	2638	3067	GB92270371	P00563476
USB4	3496238	GP02-1488K077	3068	3396	3068	3396	GB92270372	P00563477
USB4	3496239	GP02-1952P078	3270	2841	3270	2841	GB92270373	P00563478
USB4	3496240	GP02-1952P078	2840	2411	2840	2411	GB92270374	P00563479
USB4	3496241	GP02-1952P078	2410	2407	2410	2407	GB92270375	P00563480
USB4	3496242	GP02-1952P078	2406	2093	2406	2093	GB92270376	P00563481
USB4	3496246	GP02-2032P080	3268	2839	3268	2839	GB92270380	P00563485
USB4	3496247	GP02-2032P080	2838	2409	2838	2409	GB92270381	P00563486
USB4	3496248	GP02-2032P080	2408	2127	2408	2127	GB92270382	P00563487
USB4	3496252	GP02-1840P082	3273	2844	3273	2844	GB92270386	P00563491
USB4	3496253	GP02-1840P082	2843	2414	2843	2414	GB92270387	P00563492
USB4	3496254	GP02-1840P082	2413	2045	2413	2045	GB92270388	P00563493
USB4	3496258	GP02-1936P084	3271	2842	3271	2842	GB92270392	P00563497
USB4	3496259	GP02-1936P084	2841	2412	2841	2412	GB92270393	P00563498
USB4	3496260	GP02-1936P084	2411	2086	2411	2086	GB92270394	P00563499
USB5	3496387	GP02-1728J130	3065	0876	3065	0876	GB92270521	P00563626
USB5	3496388	GP02-1728K131	2052	1503	2052	1503	GB92270522	P00563627
USB5	3496389	GP02-1728K131	1502	0876	1502	0876	GB92270523	P00563628
USB5	3496390	GP02-1536K132	1278	1827	1278	1827	GB92270524	P00563629
USB5	3496391	GP02-1536K132	1828	2377	1828	2377	GB92270525	P00563630
USB5	3496392	GP02-1536K132	2378	2906	2378	2906	GB92270526	P00563631
USB5	3496393	GP02-1536K132	2907	2927	2907	2927	GB92270527	P00563632
USB5	3496394	GP02-1536K132	2928	3394	2928	3394	GB92270528	P00563633

APPENDIX B
WIND Noise Attenuation

To fully address the range of coherent and random noises that can degrade seismic data and inhibit signal analysis, 3DGeo has developed a suite of process workflows to attenuate noise without affecting the data ("signal") and, thus, maintaining relative signal amplitude information. WIND is typically custom-designed to address specific signal-noise conditions and is typically applied in a cascaded manner with several applications throughout the processing sequence. In this way, noises can be attacked in a progressive manner eliminating certain noises before addressing other noises with different characteristics. Alternatively, severe noises can be addressed several times at different stages and/or in different domains.

Noise attenuation is accomplished by first separating the data signal from the noise and attacking only the noise using appropriate techniques (e.g. FK, Radon etc.) and domains (e.g. common offset, common receiver etc.). The final result is obtained by a controlled addback of the conditioned "noise" record to the "signal" record. To illustrate the methodology, the first pass of noise attenuation, WIND I, as applied to the Elver and HGP data sets is outlined below. There were two basic noise components addressed.

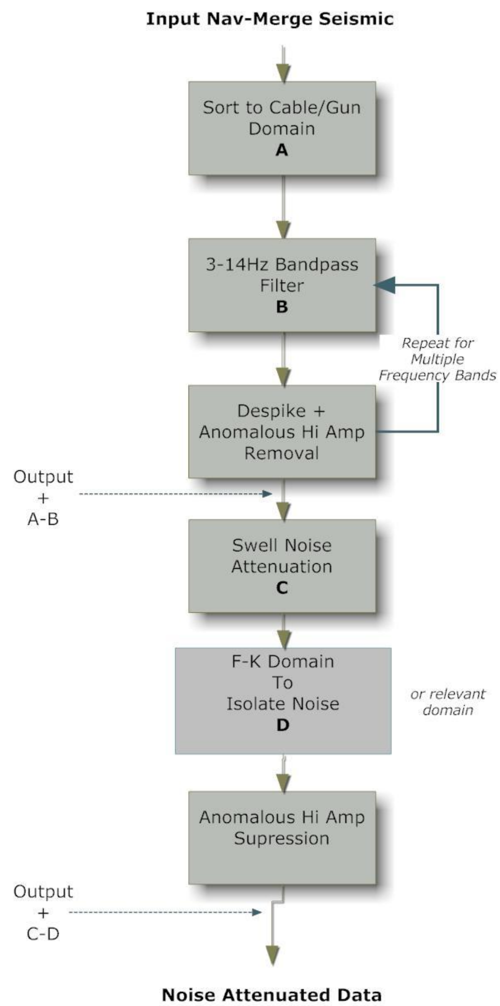
- Swell Noise Attenuation
- Linear Noise (first pass)

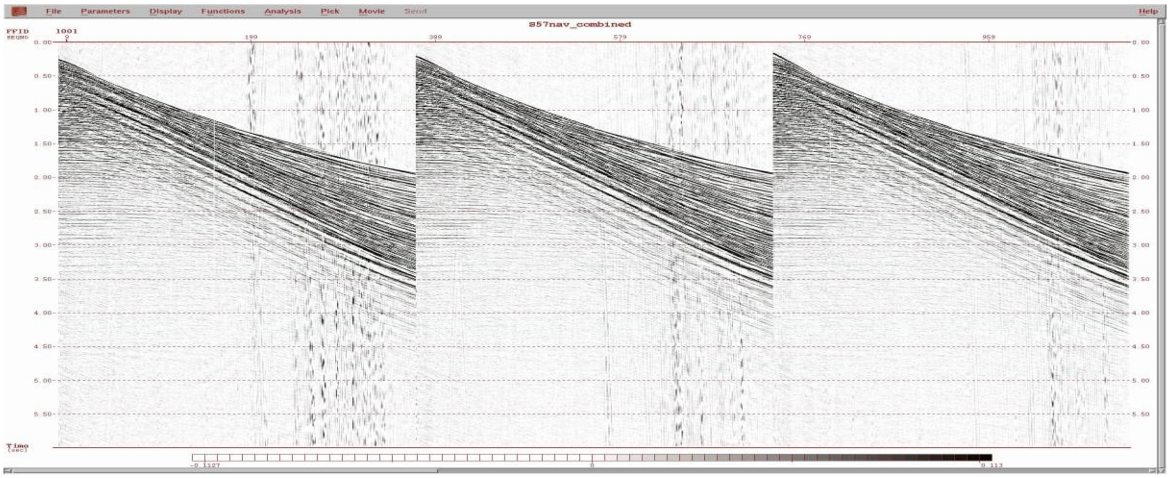
Swell Noise

1. Copy Original trace pre-filtered with low cut LC 3 Hz (18 dB/oct.)
2. Filter Original trace for the desired working frequency band - in this case 3Hz (18 dB/oct) to 12 Hz (36 dB/oct) – to obtain the Filter trace.
3. Calculate difference of the Original trace and the Filter trace for the Difference trace.
4. To the Filter trace, apply Despike and AMPSCAL (anomalous high amplitude suppression) whereby energy exceeding a supplied maximum amplitude threshold is reduced to the average amplitude level of the Filter Trace i.e. noise suppressed new Filter trace.
5. Add the "Difference" trace (step 3) to the new Filter trace (step 4)
6. From step 5, this new trace with the swell noise attenuated is processed in increasing frequency bands. In the cases of Elver and HGP, the following inputs for each increasing frequency band are the outputs of the previous application:
   a. 3-12hz
   b. 12-25hz
   c. 25-45hz
   d. 45hz high pass

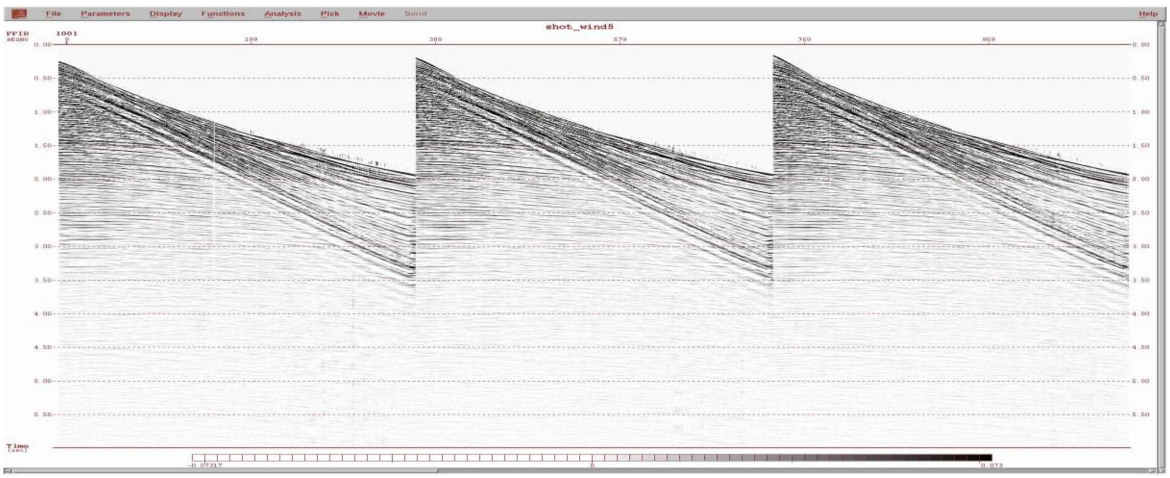
Linear Noise

- Copy Original Trace (input is the final output of the Swell Noise phase)
- Apply FK domain filtering (or any other Domain filtering) to isolate the Noise preserving the linear noise component – "noise" trace.
- Calculate the difference from the Original trace (step 1) and the "Noise" trace (Step 2). This will create the "Difference" trace – dominantly signal.
- Because of the *high amplitude* nature of the linear noise, apply anomalous high amplitude suppression (AMPSCAL) to attenuate the linear noise in the "Noise trace". The objective at this stage is to reduce the noise to a more controllable amplitude level not necessarily to fully eliminate strong noise trains in this single pass either in the FK domain or any other domain.
- Add the "Difference" trace (step 3) to the new noise attenuated trace (step 4). *Note that no filtering has been applied to signal in any domain so no artifacts or amplitude/frequency changes have been generated.*

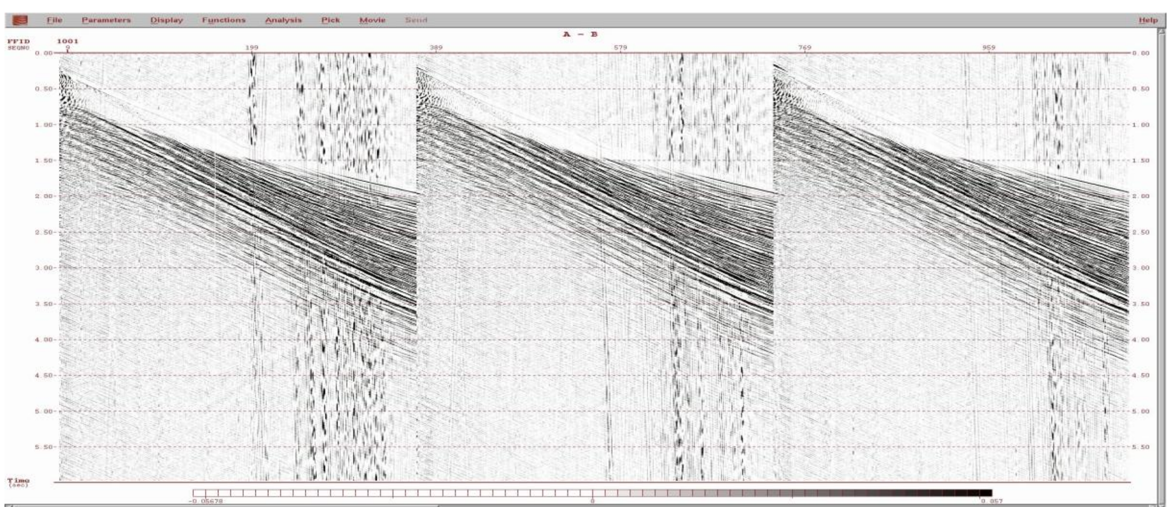




Typical shot/cable record



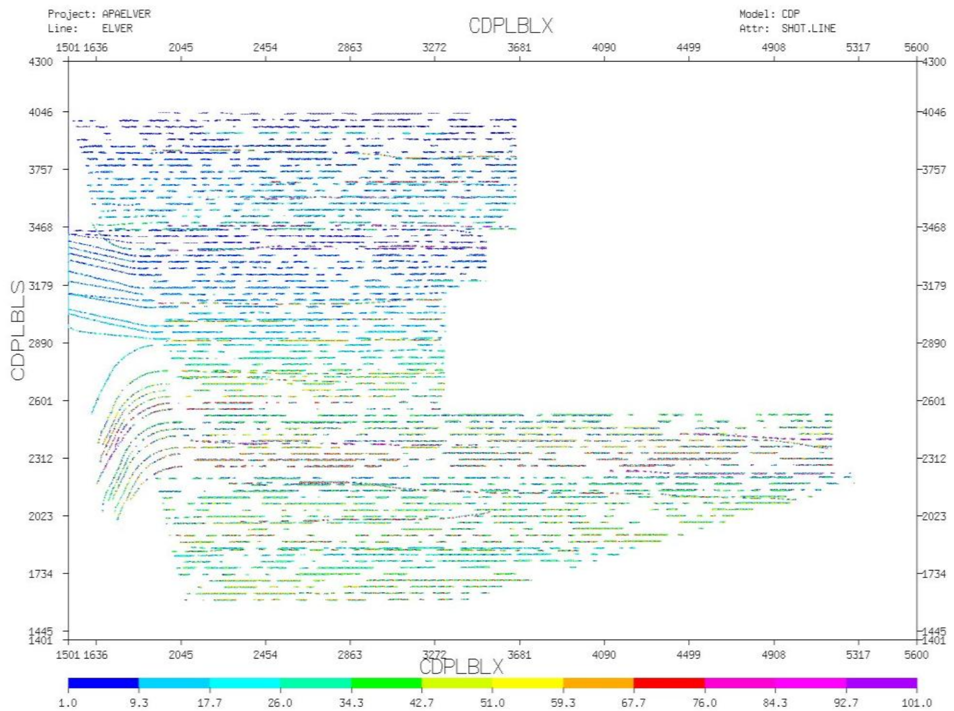
With WIND applied



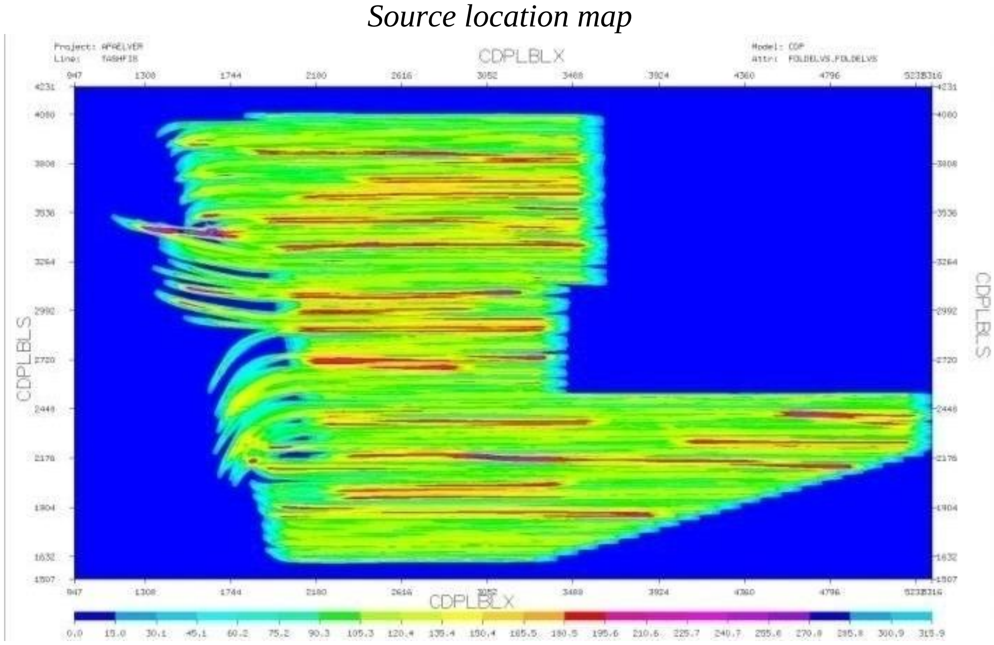
Difference

APPENDIX C
Incorporating Elver Turns Data

The source location and fold coverage plots for the Elver 2007 acquisition program shown below indicated the presence of seismic data recorded during vessel turns.



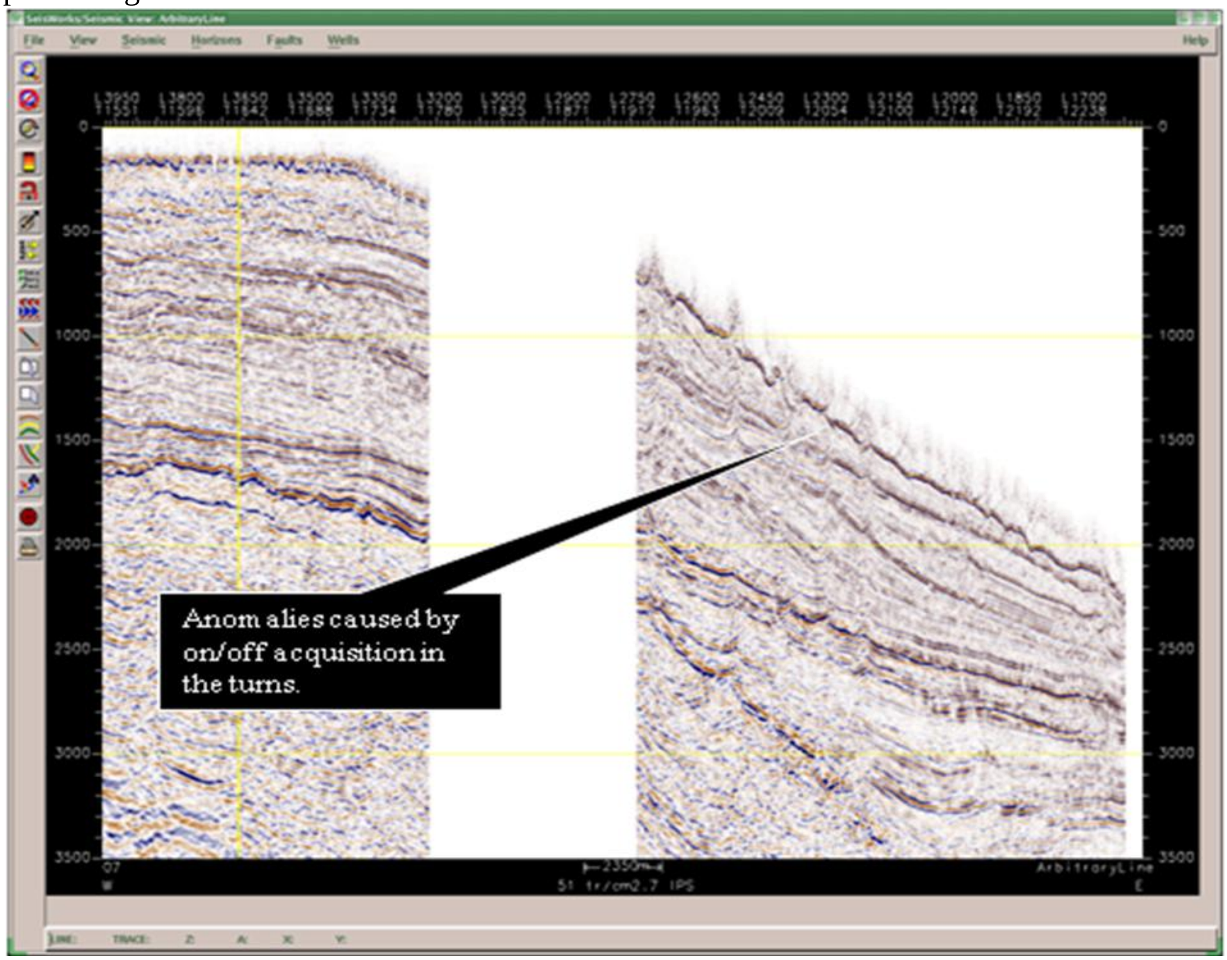
Source location map



CDP fold coverage map

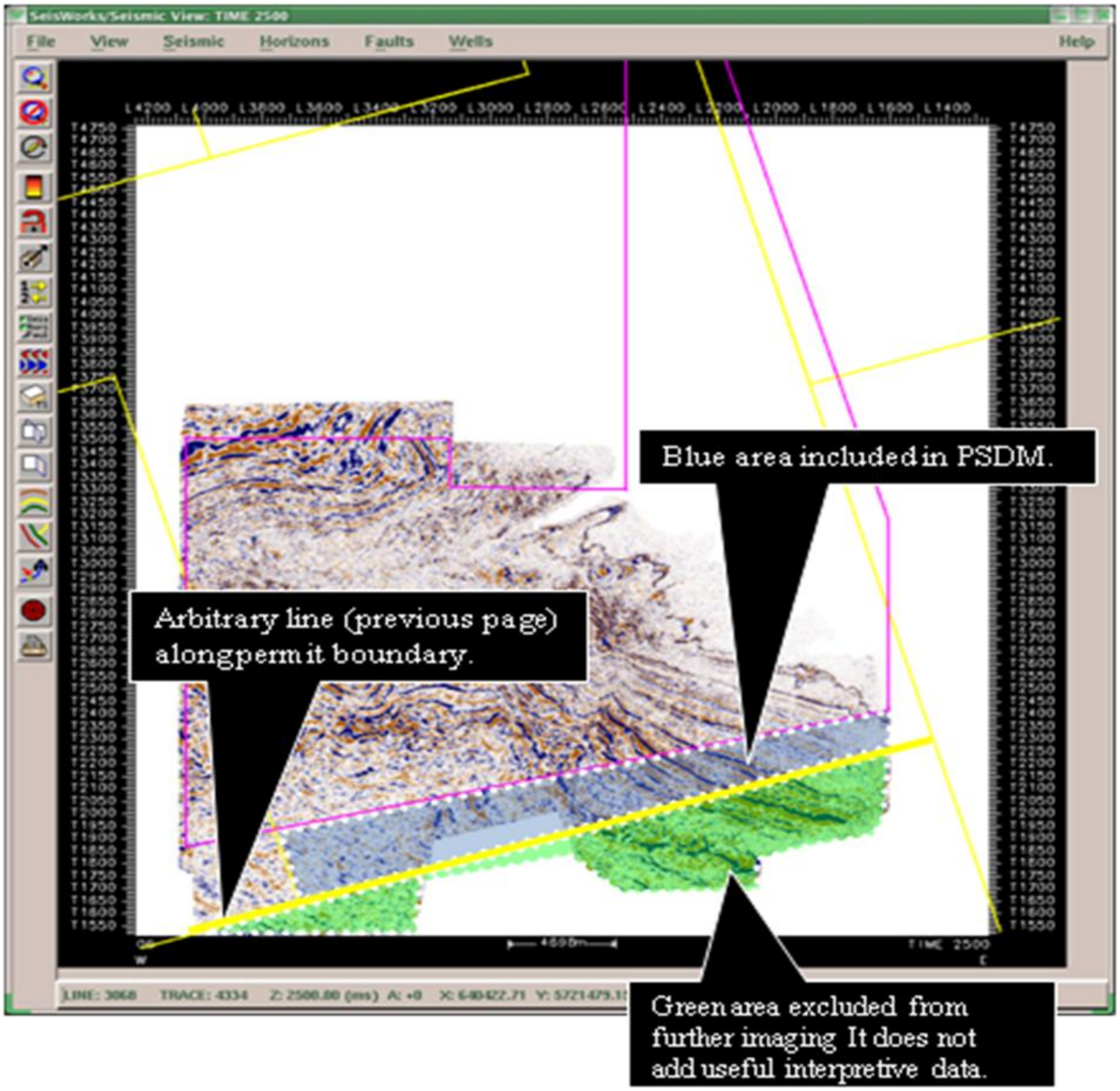
During pre-processing of the Elver 3-D volume, Apache elected to retain these data during the Time processing to assess its potential contribution to the final 3-D depth migration processing. This increased the total areal coverage of approx 650 sq km as defined in the RFS to approximately 920 sq kms in order to capture the turns data contribution. These data were included in the final Elver PSTM volume delivered to Apache.

As a result of this additional areal contribution, the total Gippsland East data set expanded to over 2500 sq km with resulting additional cost for 3-D pre-stack depth migration. A detailed review, however, of the available PSTM data determined that certain artifacts as noted in the following figure were likely to inhibit the fidelity of the 3-D pre-stack depth processing.



Arbitrary line extracted along southern Elver boundary

As a result, Apache decided to limit the contribution from these turns in the southern edge of the Elver project. The following diagram indicates the final contributing area from the southern part of the Elver program that resulted in a final total depth imaged area for the Gippsland East project of 2402 sq km.



The limits of the arbitrary line intersection with the Blue area boundary line are given by:

Inline 1600 Crossline 2660

Inline 3660 Crossline 1630

APPENDIX D
Deliverables Summary

Gippsland East Deliverables					
Apache Deliverables	**RFS Deliverbale Number**	**Archive Reference Number**	**Formal Description**	**Generic Description**	**Media**
Pre-Stack					
	1	**1**	Raw cmp ordered gathers - no nmo (All surveys).	Raw 3D binned Radon gathers, no NMO.	LTO-3
	2	**2**	Raw PreSTM cmp ordered gathers - no nmo (Elver).	Raw Elver 3D PreSTM gathers, no NMO, no mute.	LTO-3
	3	**3**	Raw PreSTM cmp ordered gathers - with nmo (Elver).	Raw Elver 3D PreSTM gathers, +NMO, no mute.	LTO-3
	4	**4**	Raw PreSDM cmp ordered gathers - no nmo (in twt) (All surveys).	Raw 3D PreSDM gathers, no NMO, no mute.	LTO-3
	5	**5**	Raw PreSDM cmp ordered gathers - with nmo (in twt) (All surveys).	Raw 3D PreSDM gathers, + NMO, no mute.	LTO-3
		5a	Raw Tuskfish cmp ordered Radon gathers - no NMO.	Raw 3D binned new Radon gathers, no NMO.	
Post-Stack					
	6	**6**	Raw PreSTM stack data (full angle).	Elver fast track PreSTM raw volume.	DLT
	7	**7**	Final PreSTM stack data (full angle).	Elver fast track PreSTM post volume.	DLT
	8	**8a**	Raw PreSDM stack data in twt (full angle).	Raw psdm2time full angle stack.	DLT
	8	**8b**	Raw PreSDM stack data in twt (near angle).	Raw psdm2time near angle stack.	DLT
	8	**8c**	Raw PreSDM stack data in twt (mid angle).	Raw psdm2time mid angle stack.	DLT
	8	**8d**	Raw PreSDM stack data in twt (far angle).	Raw psdm2time far angle stack.	DLT
	8	**8e**	Raw PreSDM stack data in depth (full angle).	Raw psdm full angle stack.	DLT
	8	**8f**	Raw PreSDM stack data in depth (near angle).	Raw psdm near angle stack.	DLT
	8	**8g**	Raw PreSDM stack data in depth (mid angle).	Raw psdm mid angle stack.	DLT
	8	**8h**	Raw PreSDM stack data in depth (far angle).	Raw psdm far angle stack.	DLT
	9	**9a**	Post processed PreSDM stack data in twt (full angle).	Post processed psdm2time full angle stack.	DLT
	9	**9b**	Post processed PreSDM stack data in twt (near angle).	Post processed psdm2time near angle stack.	DLT
	9	**9c**	Post processed PreSDM stack data in twt (mid angle).	Post processed psdm2time mid angle stack.	DLT
	9	**9d**	Post processed PreSDM stack data in twt (far angle).	Post processed psdm2time far angle stack.	DLT
	9	**9e**	Post processed PreSDM stack data in depth (full angle).	Post processed psdm full angle stack.	DLT
	9	**9f**	Post processed PreSDM stack data in depth (near angle).	Post processed psdm near angle stack.	DLT
	9	**9g**	Post processed PreSDM stack data in depth (mid angle).	Post processed psdm mid angle stack.	DLT
	9	**9h**	Post processed PreSDM stack data in depth (far angle).	Post processed psdm far angle stack.	DLT
Support Data					
	10	**10a**	Final PreSTM RMS velocity data (Apache ASCII).	Elver rms velocity field in Apache/Wetsern 3D format.	DLT
	10	**10b**	Final PreSTM RMS velocity data (SEGY).	Elver rms velocity field in SEGY format.	DLT
	11	**11a**	High density stacking velocity data (Apache ASCII).	vrms(t) + nmo(t) in Apache/Western 3D format.	DLT
	11	**11b**	High density stacking velocity data (SEGY).	vrms(t) + nmo(t) in SEGY format.	DLT
	12	**12a**	PreSDM velocity model data (Apache ASCII).	vint(z) in Apache/Western 3D format.	DLT
	12	**12b**	PreSDM velocity model data (SEGY).	vint(z) in SEGY format.	DLT
	12	**12c**	PreSDM velocity model data (Apache ASCII).	vint(t) in Apache/Western 3D format.	DLT
	12	**12d**	PreSDM velocity model data (SEGY).	vint(t) in SEGY format.	DLT
	13	**13a**	PreSDM velocity model data (Apache ASCII).	vrms(t) in Apache/Western 3D format.	DLT
	13	**13b**	PreSDM velocity model data (SEGY).	vrms(t) in SEGY format.	DLT
	14	**14**	Not required.	Not required.	-
	15	**15**	Bin centre data.	Bin centre data.	CD
	16	**16**	Not required (incorporated into item 17).	Not required (incorporated into item 17).	-
	17	**17**	Final processing report.	Final processing report for time and depth components.	CD

APPENDIX E
LINE SUMMARIES

ELVER

NAV-ID	SEQ-NO	FSP	LSP	FFID	RANGE
1008	P001	1053	2202	1	1150
1024	P003	746	2202	1151	2607
1040	P005	781	2201	2608	4028
1056	A040	1194	1970	4029	4805
1056	P007	785	2201	4806	6222
1072	P009	790	2201	6223	7634
1088	P011	795	2201	7635	9041
1104	J095	1030	2201	9042	10213
1104	P013	800	2201	10214	11615
1120	P015	804	2201	11616	13013
1136	P017	816	2201	13014	14399
1152	P019	814	2201	14400	15787
1168	J093	1400	2201	15788	16589
1168	P021	830	2201	16590	17961
1184	P023	823	2201	17962	19340
1200	P025	828	2200	19341	20713
1216	J097	1200	2200	20714	21714
1216	P027	833	2200	21715	23082
1232	P029	837	2200	23083	24446
1248	P031	842	2200	24447	25805
1264	P033	847	2200	25806	27159
1280	J099	1081	2200	27160	28279
1280	P035	851	2200	28280	29629
1296	P037	910	2200	29630	30920
1312	P002	2046	468	30921	32499
1328	P004	2093	654	32500	33939
1344	P006	2093	572	33940	35461
1360	A039	1341	775	35462	36028
1360	J094	2092	998	36029	37123
1360	P008	2092	1332	37124	37884
1376	P010	2092	524	37885	39453
1392	P012	2092	650	39454	40896
1408	P014	2092	640	40897	42349
1424	P016	2092	640	42350	43802
1440	A038	2092	1844	43803	44051
1440	P018	1853	1022	44052	44883
1456	P020	2092	670	44884	46306
1472	P022	1964	620	46307	47651
1488	A096	1963	1036	47652	48579

ELVER

NAV-ID	SEQ-NO	FSP	LSP	FFID	RANGE
1488	P024	1855	680	48580	49755
1504	P026	1963	660	49756	51059
1520	P028	1962	1045	51060	51977
1536	A098	1962	1050	51978	52890
1536	P030	1688	1050	52891	53529
1552	P032	1961	625	53530	54866
1568	P034	1961	631	54867	56197
1584	J092	1960	1064	56198	57094
1584	P036	1960	731	57095	58324
1600	P041	1960	700	58325	59585
1616	P045	1959	1073	59586	60472
1632	P049	1958	1078	60473	61353
1648	P053	1956	1083	61354	62227
1664	J083	1957	1088	62228	63097
1664	P061	1957	722	63098	64333
1680	P065	1957	1092	64334	65199
1696	J081	1640	1097	65200	65743
1696	P069	1956	760	65744	66940
1712	P073	1956	732	66941	68165
1728	P077	1955	778	68166	69343
1744	P088	1955	841	69344	70458
1760	P090	1954	725	70459	71688
1776	P043	3205	1121	71689	73773
1792	P047	3205	695	73774	76284
1808	P051	3205	755	76285	78735
1824	P055	3205	787	78736	81154
1840	A085	3205	2649	81155	81711
1840	J086	2100	1139	81712	82673
1840	P063	3205	1139	82674	84740
1856	P067	3205	791	84741	87155
1872	P071	3205	797	87156	89564
1888	P075	3205	1154	89565	91616
1904	J101	2500	3312	91617	92429
1904	P079	3205	915	92430	94720
1920	P042	1040	3312	94721	96993
1936	A084	1275	3100	96994	98819
1936	P046	1346	3288	98820	100762
1952	P050	1049	3219	100763	102933
1968	P054	1054	3150	102934	105030
1984	P062	1059	3081	105031	107053
2000	P066	1064	3011	107054	109001
2016	P070	1068	2942	109002	110876
2032	J100	1303	2110	110877	111684
2032	P074	1073	2873	111685	113485
2048	P078	1335	2804	113486	114955

ELVER

NAV-ID	SEQ-NO	FSP	LSP	FFID	RANGE
2064	P091	1082	2735	114956	116609
2080	P089	1087	2666	116610	118189
2096	J082	1092	2420	118190	119518
2096	P044	1130	2597	119519	120986
2112	P048	1097	2528	120987	122418
2128	P052	1115	2459	122419	123763
2144	P056	1106	2390	123764	125048
2160	P064	1111	2321	125049	126259
2176	A076	1115	2252	126260	127397
2192	P072	1120	2182	127398	128460
2208	P080	1125	2113	128461	129449
2224	P087	1130	2044	129450	130364

HGP

NAV-ID	SEQ-NO	FSP	LSP	FFID	RANGE
21008	P001	2984	1144	1	1841
21024	P003	2984	1144	1842	3682
21040	P005	2983	1144	3683	5522
21056	P007	2983	1144	5523	7362
21072	P009	2982	1144	7363	9201
21088	A023	2982	1143	9202	11041
21088	J033	2400	1143	11042	12299
21104	P013	2982	1143	12300	14139
21120	A062	2981	1143	14140	15978
21136	P017	2981	1143	15979	17817
21152	P019	2981	1143	17818	19656
21168	P021	2980	1143	19657	21494
21184	P025	2980	1143	21495	23332
21200	J029	2980	1143	23333	25170
21200	K031	2900	1143	25171	26928
21200	P027	2980	1143	26929	28766
21216	P002	1266	3102	28767	30603
21232	P004	1266	3102	30604	32440
21248	P006	1266	3102	32441	34277
21264	P008	1266	3101	34278	36113
21280	P010	1266	3101	36114	37949
21296	A014	1363	2309	37950	38896
21296	B063	1266	1900	38897	39531
21296	P012	2300	3101	39532	40333
21312	P016	1266	3100	40334	42168
21328	P018	1266	3100	42169	44003
21344	P020	1266	3100	44004	45838
21360	P022	1266	3099	45839	47672
21376	P024	1266	3099	47673	49506
21392	P026	1266	3098	49507	51339
21408	J129	2030	3081	51340	52391
21408	P028	1266	3098	52392	54224
21424	J032	1266	3098	54225	56057
21424	P030	1266	3098	56058	57890
21440	P034	1001	3097	57891	59987
21456	A042	1001	3395	59988	62382
21472	P057	1001	3394	62383	64776
21488	J064	1001	3394	64777	67170
21488	K077	2220	3394	67171	68345
21488	P059	1001	3394	68346	70739
21504	P066	1001	3393	70740	73132
21520	J061	1001	3393	73133	75525
21520	K068	1001	3085	75526	77610
21520	P055	1001	3393	77611	80003

HGP NAV-ID	SEQ-NO	FSP	LSP	FFID	RANGE
21536	J074	1500	2500	80004	81004
21536	K132	1310	3300	81005	82995
21536	P050	1001	3392	82996	85387
21552	A070	1001	1219	85388	85606
21552	P048	1210	3392	85607	87789
21568	J114	1330	2820	87790	89280
21568	P046	1001	3392	89281	91672
21584	P036	1001	3391	91673	94063
21600	A053	2470	3391	94064	94985
21600	P038	1001	2800	94986	96785
21616	P044	1001	3390	96786	99175
21632	A075	2916	3124	99176	99384
21632	J073	3141	878	99385	101648
21632	P072	1001	3390	101649	104038
21648	P069	3093	878	104039	106254
21664	A051	3075	2991	106255	106339
21664	J076	2920	878	106340	108382
21664	P039	3000	878	108383	110505
21680	A052	2612	2174	110506	110944
21680	P035	3035	878	110945	113102
21696	P037	2987	878	113103	115212
21712	P047	2993	878	115213	117328
21728	J130	2921	2630	117329	117620
21728	K131	2020	1105	117621	118536
21728	P049	2945	878	118537	120604
21744	P054	2907	878	120605	122634
21760	J065	2855	878	122635	124612
21760	K067	2650	878	124613	126385
21760	P056	2867	878	126386	128375
21776	J060	2829	878	128376	130327
21776	K115	2350	2010	130328	130668
21776	P045	2791	878	130669	132582
21792	P043	2757	878	132583	134462
21808	P041	2713	878	134463	136298
21824	A071	1141	1067	136299	136373
21824	P058	2669	878	136374	138165
21840	P082	2645	2047	138166	138764
21856	P089	2641	2053	138765	139353
21872	J098	2599	2060	139354	139893
21872	P095	2593	2060	139894	140427
21888	J117	2525	2310	140428	140643
21888	P106	2557	2067	140644	141134
21904	J112	2505	2074	141135	141566
21904	P108	2473	2074	141567	141966
21920	P100	2439	2081	141967	142325
21936	P084	2403	2087	142326	142642

HGP

NAV-ID	SEQ-NO	FSP	LSP	FFID	RANGE
21952	P078	2369	2094	142643	142918
21968	J102	2299	2101	142919	143117
21968	P093	2325	2101	143118	143342
21984	P110	2295	2108	143343	143530
22000	J104	2255	2115	143531	143671
22000	K121	2271	2115	143672	143828
22000	P097	2231	2115	143829	143945
22016	P087	2195	2121	143946	144020
22032	P080	2167	2128	144021	144060
22048	P091	2155	2135	144061	144081

APPENDIX F

Archival Data: Header Examples

RFS DELIVERABLE ITEM#1 – RAW CMP ORDERED GATHERS -NO NMO (ALL SURVEYS)
(NOTE THIS EXCLUDES TUSKFISH, WHICH IS ITEM#5A)

.
******************************** EBCDIC Header********************************
C01 CLIENT: APACHE ENERGY LTD. PROCESSING CONTRACTOR: 3DGEO INC.
C02 PROJECT: ELVER/HGP MERGE DATA TYPE: RADON GATHERS (BEFORE PSDM/PSTM)
C03 PROJECTION: UTM ZONE:55S SPHEROID: WGS-84 DATUM WGS-84
C04 ACQUIRED BY: WESTERN-GECO VESSEL: WESTERN TRIDENT
C05 SHOT/RECIVER INT: 18.75MTS(FLIP FLOP)/12.5M 2 SOURCES 8 STREAMERS
C06 ---- DATA HISTORY DEC/05/2007 ----
C07 DATA REFORMATING ;DSIGNATURE;NAV. MERGE;EDIT;DSPIKE;RESAMP 4MS.
C08 WIND (SWELL NOISE ATTENUATION);2D SRME;WATER VEL. RADON;TAU-P DCON (32MS.);
C09 TIDAL STATICS;TRACE MIX 1-2-1WITH DNMO;EVEN TRACE DROP;SORT TO CMP GATHERS;
C10 SURFACE CONSISTENT SCALING;CABLE & SHOT STATICS;SPHDIV & GAIN; QCOMP
C11 (PHASE ONLY));HIRES RADON & WIND; MATCH FILTER (HGP to ELVER); SORT
C12
C13
C14
C15
C16 SAMPLE RATE: 4 MS. DATA LENGTH: 6000MS.
C17 --------------------GRID INFORMATION----------------------------------
C18 ON TAPE INLINES(CDPLBLS) FROM 1592 TO 6168 INC 2
C19 ON TAPE XLINES (CDPLBLX) FROM 0819 TO 5349 INC 1
C20 ORIGINAL BIN 12.5 X 12.5 MTS. AZIMUTH: 72 DEG.
C21 INLINE XLINE X Y
C22 0001 0701 662851 5666442
C23 0001 6700 686023 5737760
C24 6300 0701 587967 5690773
C25 6300 6700 611140 5762090
C26
C27 -------------------HEADER INFORMATION--------------------------------
C28 INLINE(CDPLBLS) BYTES 181X4 INT XLINE(CDPLBLX) BYTES 185X4 INT
C29 CDP-X BYTES 189X4 INT CDP-Y BYTES 193X4 INT
C30 REC-X BYTES 081X4 INT REC-Y BYTES 085X4 INT
C31 SHT-X BYTES 073X4 INT SHT-Y BYTES 077X4 INT
C32 CDP BYTES 021X4 INT OFFSET BYTES 037X4 INT
C33 WBTTIME BYTES 197X4 INT
C34
C35
C36

RFS DELIVERABLE ITEM#2 – PSTM GATHERS -NO NMO (ELVER)

```
******************************** EBCDIC Header ********************************
C01 CLIENT: APACHE ENERGY LTD.       PROCESSING  CONTRACTOR: 3DGEO INC.
C02 PROJECT: ELVER   DATA TYPE:KIRCHHOFF 3D PSTM FAST TRACK
C03 PROJECTION: UTM ZONE:55S SPHEROID: WGS-84 DATUM WGS-84
C04 ACQUIRED BY: WESTERN-GECO VESSEL: WESTERN TRIDENT
C05 SHOT/RECIVER INT: 18.75MTS(FLIP FLOP)/12.5M 2 SOURCES 8 STREAMERS
C06 ---- DATA HISTORY  ----
C07 REFORMAT;INST DELAY (HGP ONLY);NAVNMERGE;EDITS;DESPIKE;SPH DIV;GAIN;
C08 DESIGNATURE;PRE-FILTER;RESAMPLE;SORT;COHERENT NOISE ATTENUATION (WIND);
C09 SPH DIV REMOVE;2D SRME;SPH DIV;WIND;SORT;WATER VELOCITY RADON;SORT;
C10 TAU-P DECON (AGC RAP);TIDAL STATICS;ARRAY SIMULATION;S.C. SCALING;
C11 TRACE DROP;Q (PHASE ONLY);SORT;WIND;HIGH RES RADON;COMMON OFFSET PLANE
C12 REG;KIRCHHOFF 3D PSTM;INVERSE NMO
C13
C14
C15
C16 SAMPLE RATE: 4MS.                DATA LENGTH: 6000MS.
C17 --------------------GRID INFORMATION----------------------------------
C18 ON TAPE INLINES(CDPLBLS) FROM 1592 TO 4092 INC 2
C19 ON TAPE XLINES (CDPLBLX) FROM 1108 TO 5349 INC 1
C20 ORIGINAL BIN 12.5 X 12.5 MTS.   AZIMUTH: 72 DEG.
C21 INLINE      XLINE       X           Y
C22 0001        0701        662851      5666442
C23 0001        6700        686023      5737760
C24 6300        0701        587967      5690773
C25 6300        6700        611140      5762090
C26
C27 -------------------HEADER INFORMATION--------------------------------
C28 CDP        BYTES  21X4    INT    CO-SCA  BYTES   71X2    INT
C29 SOU_X      BYTES   73X4   IBMFL  SOU_Y   BYTES   77X4    IBMFL
C30 REC_X      BYTES   81X4   IBMFL  REC_Y   BYTES   85X4    IBMFL
C31 CDP-X      BYTES  181X4   INT    CDP-Y   BYTES  185X4    INT
C32 INLINE     BYTES  189X4   INT    XLINE   BYTES  193X4    INT
C33 WD_TWT     BYTES  197X4   IBMFL  WD_DEP  BYTES  201X4    IBMFL
C34 OFFSETWT   BYTES  213X4
C35
C36
```

RFS DELIVERABLE ITEM#3 – PSTM GATHERS -WITH NMO (ELVER)

```
******************************** EBCDIC Header ********************************
C01 CLIENT: APACHE ENERGY LTD.      PROCESSING  CONTRACTOR: 3DGEO INC.
C02 PROJECT: ELVER   DATA TYPE:KIRCHHOFF 3D PSTM FAST TRACK
C03 PROJECTION: UTM ZONE:55S SPHEROID: WGS-84 DATUM WGS-84
C04 ACQUIRED BY: WESTERN-GECO VESSEL: WESTERN TRIDENT
C05 SHOT/RECIVER INT: 18.75MTS(FLIP FLOP)/12.5M 2 SOURCES 8 STREAMERS
C06 ---- DATA HISTORY  ----
C07 Reformat;Inst delay (HGP only);Navnmerge;Edits;Despike;Sph div;Gain;
C08 Designature;Pre-filter;Resample;Sort;Coherent noise attenuation (Wind);
C09 Sph div remove;2D SRME;Sph div;Wind;Sort;Water velocity Radon;Sort;
C10 Tau-p decon (AGC rap);Tidal statics;Array simulation;S.C. scaling;
C11 Trace drop;Q (phase only);Sort;Wind;High res Radon;Common Offset Plane
C12 Reg;Kirchhoff 3D PSTM
C13
C14
C15
C16 SAMPLE RATE: 4MS.              DATA LENGTH: 6000MS.
C17 --------------------GRID INFORMATION----------------------------------
C18 ON TAPE INLINES(CDPLBLS) FROM 1592 TO 4092 INC 2
C19 ON TAPE XLINES (CDPLBLX) FROM 1108 TO 5349 INC 1
C20 ORIGINAL BIN 12.5 X 12.5 MTS.   AZIMUTH: 72 DEG.
C21 INLINE     XLINE       X          Y
C22 0001       0701        662851     5666442
C23 0001       6700        686023     5737760
C24 6300       0701        587967     5690773
C25 6300       6700        611140     5762090
C26
C27 -------------------HEADER INFORMATION--------------------------------
C28 CDP       BYTES  21X4   INT    CO-SCA  BYTES  71X2   INT
C29 SOU_X     BYTES  73X4   IBMFL  SOU_Y   BYTES  77X4   IBMFL
C30 REC_X     BYTES  81X4   IBMFL  REC_Y   BYTES  85X4   IBMFL
C31 CDP-X     BYTES  181X4  INT    CDP-Y   BYTES  185X4  INT
C32 INLINE    BYTES  189X4  INT    XLINE   BYTES  193X4  INT
C33 WD_TWT    BYTES  197X4  IBMFL  WD_DEP  BYTES  201X4  IBMFL
C34 OFFSETWT  BYTES  213X4
C35
C36
```

RFS DELIVERABLE ITEM#4 – PSDM GATHERS -NO NMO (ALL SURVEYS)

```
******************************** EBCDIC Header ********************************
C01 CLIENT: APACHE ENERGY LTD.       PROCESSING  CONTRACTOR: 3DGEO INC.
C02 PROJECT: ELVER-HGP-TUSKFISH MERGE   DATA TYPE:KIRCHHOFF 3D GATHERS PSDM U3 RAW
C03 PROJECTION: UTM ZONE:55S SPHEROID: WGS-84 DATUM WGS-84
C04 ACQUIRED BY: WESTERN-GECO VESSELS: WESTERN MONARCH (TUSKFISH), WESTERN TRIDENT
C05 (ELVER), GECO BETA (HGP). SHOT/RECIVER INT: 18.75MTS(FLIP FLOP)/12.5M 2 SOURCES 8 STREAMERS
C06 ---- DATA HISTORY  ----    GENERATED ON ---- APRIL/15/2008
C07 Reformat;Inst delay (HGP only);Navmerge;Edits;Despike;Sph div;Gain;
C08 Designature;Pre-filter;Resample;Sort;Coherent noise attenuation (Wind);
C09 Sph div remove;2D SRME;Sph div;Wind;Sort;Water velocity Radon;Sort;
C10 Tau-p decon (AGC rap);Tidal statics;Array simulation;S.C. scaling;
C11 Trace drop;Q (phase only);Sort;Wind;High res Radon;Common Offset Plane
C12 Reg;Kirchhoff 3D PSDM; Time Conversion; HDVA-RMO; High res Radon, INMO
C13
C14
C15
C16 SAMPLE RATE: 4MS.                DATA LENGTH: 6000MS.
C17 --------------------GRID INFORMATION---------------------------------
C18 ON TAPE INLINES(CDPLBLS) FROM 1582 TO 6172 INC 2
C19 ON TAPE XLINES (CDPLBLX) FROM 1088 TO 6082 INC 2
C20 ORIGINAL BIN 12.5 X 12.5 MTS.   AZIMUTH: 72 DEG.
C21 INLINE      XLINE        X           Y
C22 0002        0700        662835      5666434
C23 0002        6700        686011      5737764
C24 6300        0700        587963      5690761
C25 6300        6700        611139      5762091
C26
C27 -------------------HEADER INFORMATION--------------------------------
C28 CDP        BYTES   21X4    INT    CO-SCA  BYTES   71X2    INT
C29 SOU_X       BYTES   73X4    IBMFL   SOU_Y   BYTES   77X4    IBMFL
C30 REC_X       BYTES   81X4    IBMFL   REC_Y   BYTES   85X4    IBMFL
C31 CDP-X       BYTES   181X4   INT     CDP-Y   BYTES   185X4   INT
C32 INLINE      BYTES   189X4   INT     XLINE   BYTES   193X4   INT
C33 WD_TWT      BYTES   197X4   IBMFL   WD_DEP  BYTES   201X4   IBMFL
C34 OFFSETWT    BYTES   213X4
C35
C36
```

***Note**: Gather header offsets reflect front-end of each offset bin i.e. 162, 237, 312……*

RFS DELIVERABLE ITEM#5 – PSDM GATHERS -WITH NMO (ALL SURVEYS)

```
******************************** EBCDIC Header ********************************
C01 CLIENT: APACHE ENERGY LTD.       PROCESSING  CONTRACTOR: 3DGEO INC.
C02 PROJECT: ELVER-HGP-TUSKFISH MERGE   DATA TYPE:KIRCHHOFF 3D GATHERS PSDM U3 RAW
C03 PROJECTION: UTM ZONE:55S SPHEROID: WGS-84 DATUM WGS-84
C04 ACQUIRED BY: WESTERN-GECO VESSELS: WESTERN MONARCH (TUSKFISH), WESTERN TRIDENT
C05 (ELVER), GECO BETA (HGP). SHOT/RECIVER INT: 18.75MTS(FLIP FLOP)/12.5M 2 SOURCES 8 STREAMERS
C06 ---- DATA HISTORY  ----    GENERATED ON ---- APRIL/15/2008
C07 Reformat;Inst delay (HGP only);Navmerge;Edits;Despike;Sph div;Gain;
C08 Designature;Pre-filter;Resample;Sort;Coherent noise attenuation (Wind);
C09 Sph div remove;2D SRME;Sph div;Wind;Sort;Water velocity Radon;Sort;
C10 Tau-p decon (AGC rap);Tidal statics;Array simulation;S.C. scaling;
C11 Trace drop;Q (phase only);Sort;Wind;High res Radon;Common Offset Plane
C12 Reg;Kirchhoff 3D PSDM; Time Conversion; HDVA-RMO; High res Radon
C13
C14
C15
C16 SAMPLE RATE: 4MS.              DATA LENGTH: 6000MS.
C17 --------------------GRID INFORMATION----------------------------------
C18 ON TAPE INLINES(CDPLBLS) FROM 1582 TO 6172 INC 2
C19 ON TAPE XLINES (CDPLBLX) FROM 1088 TO 6082 INC 2
C20 ORIGINAL BIN 12.5 X 12.5 MTS.   AZIMUTH: 72 DEG.
C21 INLINE      XLINE        X           Y
C22 0002       0700       662835      5666434
C23 0002       6700       686011      5737764
C24 6300       0700       587963      5690761
C25 6300       6700       611139      5762091
C26
C27 -------------------HEADER INFORMATION--------------------------------
C28 CDP        BYTES  21X4   INT    CO-SCA  BYTES   71X2    INT
C29 SOU_X       BYTES  73X4   IBMFL   SOU_Y  BYTES   77X4   IBMFL
C30 REC_X       BYTES  81X4   IBMFL   REC_Y  BYTES   85X4   IBMFL
C31 CDP-X      BYTES  181X4   INT    CDP-Y  BYTES  185X4   INT
C32 INLINE     BYTES  189X4   INT     XLINE  BYTES  193X4   INT
C33 WD_TWT      BYTES  197X4  IBMFL   WD_DEP BYTES   201X4   IBMFL
C34 OFFSETWT    BYTES  213X4
C35
C36
```

***Note**: Gather header offsets reflect front-end of each offset bin i.e. 162,237, 312…….*

RFS DELIVERABLE ITEM#5A – RAW CMP ORDERED RADON GATHERS -NO NMO (TUSKFISH)

```
******************************* EBCDIC Header ********************************
C01 CLIENT: APACHE ENERGY LTD.      PROCESSING  CONTRACTOR: 3DGEO INC.
C02 PROJECT: TUSKFISH  DATA TYPE: RADON GATHERS (BEFORE PSDM/PSTM)
C03 PROJECTION: UTM ZONE:55S SPHEROID: WGS-84 DATUM WGS-84
C04 ACQUIRED BY: WESTERN-GECO VESSEL: WESTERN MONARCH
C05 SHOT/RECIVER INT: 18.75MTS(FLIP FLOP)/12.5M 2 SOURCES 8 STREAMERS
C06 ---- DATA HISTORY  NOV/16/2007 ----
C07 INPUT PRE-PROCESSED CDP GATHERS; HIRES RADON;
C08 MATCH FILTER (TUSKFISH to ELVER); QCOMP(PHASE ONLY)
C09
C10
C11
C12
C13
C14
C15
C16 SAMPLE RATE: 4 MS.              DATA LENGTH: 6000MS.
C17 --------------------GRID INFORMATION----------------------------------
C18 ON TAPE INLINES(CDPLBLS) FROM 1932 TO 5812 INC 1
C19 ON TAPE XLINES (CDPLBLX) FROM 2972 TO 6100 INC 2
C20 ORIGINAL BIN 12.5 X 12.5 MTS.   AZIMUTH: 72 DEG.
C21 INLINE      XLINE        X           Y
C22 0001       0701       662851      5666442
C23 0001       6700       686023      5737760
C24 6300       0701       587967      5690773
C25 6300       6700       611140      5762090
C26
C27 -------------------HEADER INFORMATION--------------------------------
C28 CDP        BYTES  21X4   INT    CO-SCA  BYTES  71X2   INT
C29 SOU_X      BYTES  73X4   IBMFL  SOU_Y   BYTES  77X4   IBMFL
C30 REC_X      BYTES  81X4   IBMFL  REC_Y   BYTES  85X4   IBMFL
C31 CDP-X      BYTES  181X4  INT    CDP-Y   BYTES  185X4  INT
C32 INLINE     BYTES  189X4  INT    XLINE   BYTES  193X4  INT
C33 WD_TWT     BYTES  197X4  IBMFL  WD_DEP  BYTES  201X4  IBMFL
C34 NAV-ID     BYTES  205X4  INT    SEQ-NO  BYTES  209X4  INT
C35 OFFSETWT   BYTES  213X4  IBMFL  SURVEY  BYTES  217X4  INT
C36 NOTE: SURVEY =1 FOR ELVER,10 FOR TUSKFISH,20 FOR HGP
```

RFS DELIVERABLE ITEM#6 – RAW PSTM STACK (ELVER)

```
******************************* EBCDIC Header ********************************
C01 CLIENT: APACHE ENERGY LTD.       PROCESSING  CONTRACTOR: 3DGEO INC.
C02 PROJECT: ELVER   DATA TYPE:KIRCHHOFF 3D PSTM FAST TRACK(RAW)
C03 PROJECTION: UTM ZONE:55S SPHEROID: WGS-84 DATUM WGS-84
C04 ADQUIRED BY: WESTERN-GECO VESSEL: WESTERN TRIDENT
C05 SHOT/RECIVER INT: 18.75MTS(FLIP FLOP)/12.5M 2 SOURCES 8 STREAMERS
C06 ---- DATA HISTORY  ----
C07 DATA REFORMATING ;DSIGNATURE;NAV. MERGE;EDIT;DSPIKE;RESAMP 4MS.
C08 WIND (SWELL NOISE ATTENUATION);2D SRME;WATER VEL. RADON;TAU-P DCON (32MS.);
C09 TIDAL STATICTS;TRACE MIX 1-2-1WITH DNMO;EVEN TRACE DROP;SORT TO CMP GATHERS;
C10 SURFACE CONSISTENT SCALING;CABLE & SHOT STATICS;SPHDIV & GAIN; QCOMP(PHASE ONLY
C11 HIRES RADON & WIND;COMMON OFFSET PLANE REG;KIRCHCHOFF 3D PSTM;MUTE;STACK;
C12
C13
C14
C15
C16 SAMPLE RATE: 4MS.                DATA LENGTH: 6000MS.
C17 --------------------GRID INFORMATION----------------------------------
C18 ON TAPE INLINES(CDPLBLS) FROM 1592 TO 4092 INC 2
C19 ON TAPE XLINES (CDPLBLX) FROM 1108 TO 5349 INC 1
C20 ORIGINAL BIN 12.5 X 12.5 MTS.   AZIMUTH: 72 DEG.
C21 INLINE       XLINE         X            Y
C22 0001       0701       662851       5666442
C23 0001       6700       686023       5737760
C24 6300       0701       587967       5690773
C25 6300       6700       611140       5762090
C26
C27 -------------------HEADER INFORMATION--------------------------------
C28 INLINE(CDPLBLS) BYTES 181X4 INT        XLINE(CDPLBLX) BYTES 185X4 INT
C29 CDP-X          BYTES 189X4 INT        CDP-Y         BYTES 193X4 INT
C30 REC-X          BYTES 081X4 INT        REC-Y         BYTES 085X4 INT
C31 SHT-X          BYTES 073X4 INT        SHT-Y         BYTES 077X4 INT
C32 CDP           BYTES 021X4 INT        OFFSET        BYTES 037X4 INT
C33 WBTTIME        BYTES 197X4 INT
C34
C35
C36
```

RFS DELIVERABLE ITEM#7 – FINAL PSTM STACK (ELVER)

```
******************************* EBCDIC Header ********************************
C01 CLIENT: APACHE ENERGY LTD.       PROCESSING  CONTRACTOR: 3DGEO INC.
C02 PROJECT: ELVER   DATA TYPE:KIRCHHOFF 3D PSTM FAST TRACK(WITH POST)
C03 PROJECTION: UTM ZONE:55S SPHEROID: WGS-84 DATUM WGS-84
C04 ADQUIRED BY: WESTERN-GECO VESSEL: WESTERN TRIDENT
C05 SHOT/RECIVER INT: 18.75MTS(FLIP FLOP)/12.5M 2 SOURCES 8 STREAMERS
C06 ---- DATA HISTORY  ----
C07 DATA REFORMATING ;DSIGNATURE;NAV. MERGE;EDIT;DSPIKE;RESAMP 4MS.
C08 WIND (SWELL NOISE ATTENUATION);2D SRME;WATER VEL. RADON;TAU-P DCON (32MS.);
C09 TIDAL STATICTS;TRACE MIX 1-2-1WITH DNMO;EVEN TRACE DROP;SORT TO CMP GATHERS;
C10 SURFACE CONSISTENT SCALING;CABLE & SHOT STATICS;SPHDIV & GAIN; QCOMP(PHASE ONLY
C11 HIRES RADON & WIND;COMMON OFFSET PLANE REG;KIRCHCHOFF 3D PSTM;MUTE;STACK;
C12 QCOMP (FREQUENCY ONLY);FILTER;AGC
C13
C14
C15
C16 SAMPLE RATE: 4MS.                DATA LENGTH: 6000MS.
C17 --------------------GRID INFORMATION----------------------------------
C18 ON TAPE INLINES(CDPLBLS) FROM 1592 TO 4092 INC 2
C19 ON TAPE XLINES (CDPLBLX) FROM 1108 TO 5349 INC 1
C20 ORIGINAL BIN 12.5 X 12.5 MTS.   AZIMUTH: 72 DEG.
C21 INLINE      XLINE        X           Y
C22 0001        0701        662851      5666442
C23 0001        6700        686023      5737760
C24 6300        0701        587967      5690773
C25 6300        6700        611140      5762090
C26
C27 -------------------HEADER INFORMATION--------------------------------
C28 INLINE(CDPLBLS) BYTES 181X4 INT        XLINE(CDPLBLX) BYTES 185X4 INT
C29 CDP-X         BYTES 189X4 INT        CDP-Y         BYTES 193X4 INT
C30 REC-X         BYTES 081X4 INT        REC-Y         BYTES 085X4 INT
C31 SHT-X         BYTES 073X4 INT        SHT-Y         BYTES 077X4 INT
C32 CDP           BYTES 021X4 INT        OFFSET        BYTES 037X4 INT
C33 WBTTIME        BYTES 197X4 INT
C34
C35
C36
```

RFS DELIVERABLE ITEM#8A – RAW PSDM STACK IN TIME

```
******************************* EBCDIC Header ********************************
C01 CLIENT: APACHE ENERGY LTD.       PROCESSING  CONTRACTOR: 3DGEO INC.
C02 PROJECT: ELVER   DATA TYPE:KIRCHHOFF 3D STACK PSDM U3 RAW 2TIME
C03 PROJECTION: UTM ZONE:55S SPHEROID: WGS-84 DATUM WGS-84
C04 ACQUIRED BY: WESTERN-GECO VESSEL: WESTERN TRIDENT
C05 SHOT/RECIVER INT: 18.75MTS(FLIP FLOP)/12.5M 2 SOURCES 8 STREAMERS
C06 ---- DATA HISTORY  ----    GENERATED ON ---- APRIL/08/2008
C07 Reformat;Inst delay (HGP only);Navnmerge;Edits;Despike;Sph div;Gain;
C08 Designature;Pre-filter;Resample;Sort;Coherent noise attenuation (Wind);
C09 Sph div remove;2D SRME;Sph div;Wind;Sort;Water velocity Radon;Sort;
C10 Tau-p decon (AGC rap);Tidal statics;Array simulation;S.C. scaling;
C11 Trace drop;Q (phase only);Sort;Wind;High res Radon;Common Offset Plane
C12 Reg;Kirchhoff 3D PSDM; Stretch 2 time; HDVA; NMO; Mute; Stack
C13
C14
C15
C16 SAMPLE RATE: 4MS.                DATA LENGTH: 6000MS.
C17 --------------------GRID INFORMATION---------------------------------
C18 ON TAPE INLINES(CDPLBLS) FROM 1502 TO 6172 INC 2
C19 ON TAPE XLINES (CDPLBLX) FROM 1088 TO 6082 INC 2
C20 ORIGINAL BIN 12.5 X 12.5 MTS.   AZIMUTH: 72 DEG.
C21 INLINE      XLINE        X           Y
C22 0002        0700        662835      5666434
C23 0002        6700        686011      5737764
C24 6300        0700        587963      5690761
C25 6300        6700        611139      5762091
C26
C27 -------------------HEADER INFORMATION-------------------------------
C28 CDP        BYTES  21X4    INT     CO-SCA  BYTES   71X2    INT
C29 SOU_X      BYTES  73X4    IBMFL   SOU_Y   BYTES   77X4    IBMFL
C30 REC_X      BYTES  81X4    IBMFL   REC_Y   BYTES   85X4    IBMFL
C31 CDP-X      BYTES  181X4   INT     CDP-Y   BYTES   185X4   INT
C32 INLINE     BYTES  189X4   INT     XLINE   BYTES   193X4   INT
C33 WD_TWT     BYTES  197X4   IBMFL   WD_DEP  BYTES   201X4   IBMFL
C34 OFFSETWT   BYTES  213X4
C35
C36
```

RFS DELIVERABLE ITEM#8E – RAW PSDM STACK IN DEPTH

```
******************************* EBCDIC Header ********************************
C01 CLIENT: APACHE ENERGY LTD.      PROCESSING  CONTRACTOR: 3DGEO INC.
C02 PROJECT: ELVER   DATA TYPE:KIRCHHOFF 3D STACK PSDM U3 RAW
C03 PROJECTION: UTM ZONE:55S SPHEROID: WGS-84 DATUM WGS-84
C04 ACQUIRED BY: WESTERN-GECO VESSEL: WESTERN TRIDENT
C05 SHOT/RECIVER INT: 18.75MTS(FLIP FLOP)/12.5M 2 SOURCES 8 STREAMERS
C06 ---- DATA HISTORY  ----    GENERATED ON ---- APRIL/08/2008
C07 Reformat;Inst delay (HGP only);Navnmerge;Edits;Despike;Sph div;Gain;
C08 Designature;Pre-filter;Resample;Sort;Coherent noise attenuation (Wind);
C09 Sph div remove;2D SRME;Sph div;Wind;Sort;Water velocity Radon;Sort;
C10 Tau-p decon (AGC rap);Tidal statics;Array simulation;S.C. scaling;
C11 Trace drop;Q (phase only);Sort;Wind;High res Radon;Common Offset Plane
C12 Reg;Kirchhoff 3D PSDM; Stretch 2 time; HDVA; NMO; Mute; Stack
C13 Stretch to depth
C14
C15
C16 SAMPLE RATE: 5MTS.              DATA LENGTH: 8000MTS.
C17 --------------------GRID INFORMATION----------------------------------
C18 ON TAPE INLINES(CDPLBLS) FROM 1502 TO 6172 INC 2
C19 ON TAPE XLINES (CDPLBLX) FROM 1088 TO 6082 INC 2
C20 ORIGINAL BIN 12.5 X 12.5 MTS.   AZIMUTH: 72 DEG.
C21 INLINE      XLINE        X           Y
C22 0002       0700       662835       5666434
C23 0002       6700       686011       5737764
C24 6300       0700       587963       5690761
C25 6300       6700       611139       5762091
C26
C27 -------------------HEADER INFORMATION--------------------------------
C28 CDP       BYTES   21X4    INT     CO-SCA  BYTES   71X2    INT
C29 SOU_X      BYTES   73X4    IBMFL   SOU_Y   BYTES   77X4    IBMFL
C30 REC_X      BYTES   81X4    IBMFL   REC_Y   BYTES   85X4    IBMFL
C31 CDP-X      BYTES   181X4   INT     CDP-Y   BYTES   185X4   INT
C32 INLINE     BYTES   189X4   INT     XLINE   BYTES   193X4   INT
C33 WD_TWT     BYTES   197X4   IBMFL   WD_DEP  BYTES   201X4   IBMFL
C34 OFFSETWT    BYTES   213X4
C35
C36
```

RFS DELIVERABLE ITEM#9A – FINAL PSDM STACK IN TIME

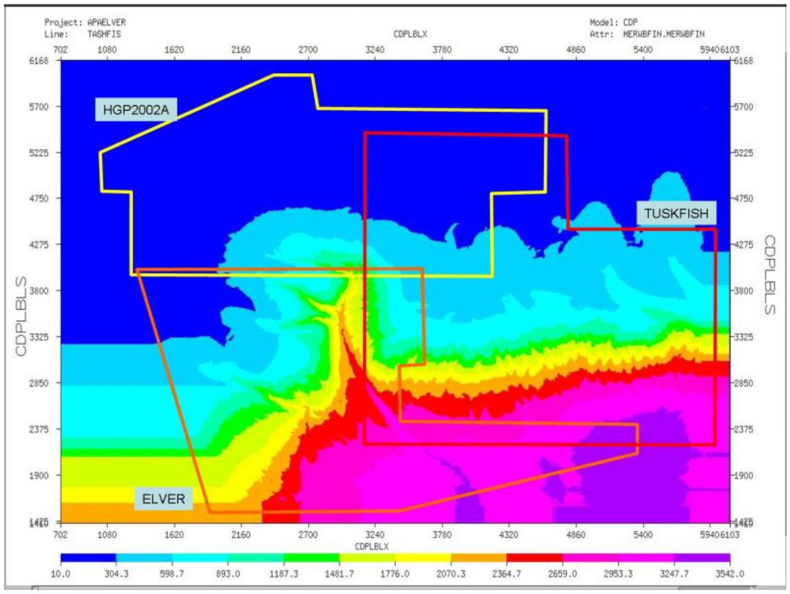
```
******************************* EBCDIC Header ********************************
C01 CLIENT: APACHE ENERGY LTD.       PROCESSING  CONTRACTOR: 3DGEO INC.
C02 PROJECT: ELVER   DATA TYPE:KIRCHHOFF 3D STACK PSDM U3 WITH POST 2TIME
C03 PROJECTION: UTM ZONE:55S SPHEROID: WGS-84 DATUM WGS-84
C04 ACQUIRED BY: WESTERN-GECO VESSEL: WESTERN TRIDENT
C05 SHOT/RECIVER INT: 18.75MTS(FLIP FLOP)/12.5M 2 SOURCES 8 STREAMERS
C06 ---- DATA HISTORY  ----    GENERATED ON ---- APRIL/07/2008
C07 Reformat;Inst delay (HGP only);Navnmerge;Edits;Despike;Sph div;Gain;
C08 Designature;Pre-filter;Resample;Sort;Coherent noise attenuation (Wind);
C09 Sph div remove;2D SRME;Sph div;Wind;Sort;Water velocity Radon;Sort;
C10 Tau-p decon (AGC rap);Tidal statics;Array simulation;S.C. scaling;
C11 Trace drop;Q (phase only);Sort;Wind;High res Radon;Common Offset Plane
C12 Reg;Kirchhoff 3D PSDM; Stretch 2 time; HDVA; NMO; Mute; Stack; QComp
C13 (Frequency only); Filter; AGC; Gain
C14
C15
C16 SAMPLE RATE: 4MS.               DATA LENGTH: 6000MS.
C17 --------------------GRID INFORMATION---------------------------------
C18 ON TAPE INLINES(CDPLBLS) FROM 1502 TO 6172 INC 2
C19 ON TAPE XLINES (CDPLBLX) FROM 1088 TO 6082 INC 2
C20 ORIGINAL BIN 12.5 X 12.5 MTS.   AZIMUTH: 72 DEG.
C21 INLINE      XLINE        X           Y
C22 0002        0700        662835       5666434
C23 0002        6700        686011       5737764
C24 6300        0700        587963       5690761
C25 6300        6700        611139       5762091
C26
C27 -------------------HEADER INFORMATION-------------------------------
C28 CDP        BYTES  21X4   INT    CO-SCA  BYTES  71X2   INT
C29 SOU_X      BYTES  73X4   IBMFL   SOU_Y  BYTES  77X4   IBMFL
C30 REC_X      BYTES  81X4   IBMFL   REC_Y  BYTES  85X4   IBMFL
C31 CDP-X      BYTES  181X4  INT    CDP-Y  BYTES  185X4  INT
C32 INLINE     BYTES  189X4  INT    XLINE  BYTES  193X4  INT
C33 WD_TWT     BYTES  197X4  IBMFL   WD_DEP BYTES  201X4  IBMFL
C34 OFFSETWT   BYTES  213X4
C35
C36
```

RFS DELIVERABLE ITEM#9E – FINAL PSDM STACK IN DEPTH

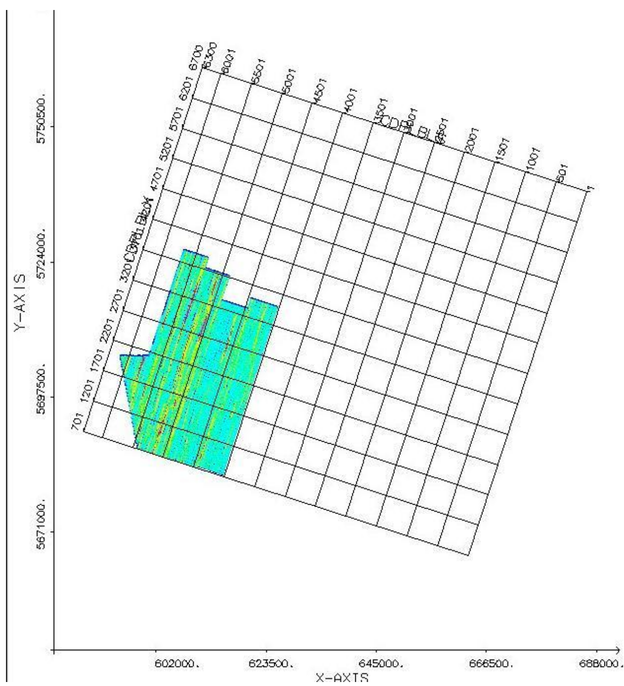
```
****************************** EBCDIC Header ********************************
C01 CLIENT: APACHE ENERGY LTD.       PROCESSING  CONTRACTOR: 3DGEO INC.
C02 PROJECT: ELVER   DATA TYPE:KIRCHHOFF 3D STACK PSDM U3 WITH POST
C03 PROJECTION: UTM ZONE:55S SPHEROID: WGS-84 DATUM WGS-84
C04 ACQUIRED BY: WESTERN-GECO VESSEL: WESTERN TRIDENT
C05 SHOT/RECIVER INT: 18.75MTS(FLIP FLOP)/12.5M 2 SOURCES 8 STREAMERS
C06 ---- DATA HISTORY  ----    GENERATED ON ---- APRIL/08/2008
C07 Reformat;Inst delay (HGP only);Navnmerge;Edits;Despike;Sph div;Gain;
C08 Designature;Pre-filter;Resample;Sort;Coherent noise attenuation (Wind);
C09 Sph div remove;2D SRME;Sph div;Wind;Sort;Water velocity Radon;Sort;
C10 Tau-p decon (AGC rap);Tidal statics;Array simulation;S.C. scaling;
C11 Trace drop;Q (phase only);Sort;Wind;High res Radon;Common Offset Plane
C12 Reg;Kirchhoff 3D PSDM; Stretch 2 time; HDVA; NMO; Mute; Stack; QComp
C13 (Frequency only); Filter; AGC; Gain, Stretch to depth
C14
C15
C16 SAMPLE RATE: 5MTS.               DATA LENGTH: 8000MTS.
C17 --------------------GRID INFORMATION----------------------------------
C18 ON TAPE INLINES(CDPLBLS) FROM 1502 TO 6172 INC 2
C19 ON TAPE XLINES (CDPLBLX) FROM 1088 TO 6082 INC 2
C20 ORIGINAL BIN 12.5 X 12.5 MTS.   AZIMUTH: 72 DEG.
C21 INLINE      XLINE        X          Y
C22 0002        0700       662835     5666434
C23 0002        6700       686011     5737764
C24 6300        0700       587963     5690761
C25 6300        6700       611139     5762091
C26
C27 -------------------HEADER INFORMATION--------------------------------
C28 CDP        BYTES  21X4    INT     CO-SCA  BYTES   71X2    INT
C29 SOU_X      BYTES  73X4    IBMFL   SOU_Y   BYTES   77X4    IBMFL
C30 REC_X      BYTES  81X4    IBMFL   REC_Y   BYTES   85X4    IBMFL
C31 CDP-X      BYTES  181X4   INT     CDP-Y   BYTES   185X4   INT
C32 INLINE     BYTES  189X4   INT     XLINE   BYTES   193X4   INT
C33 WD_TWT     BYTES  197X4   IBMFL   WD_DEP  BYTES   201X4   IBMFL
C34 OFFSETWT   BYTES  213X4
C35
C36
```

APPENDIX G

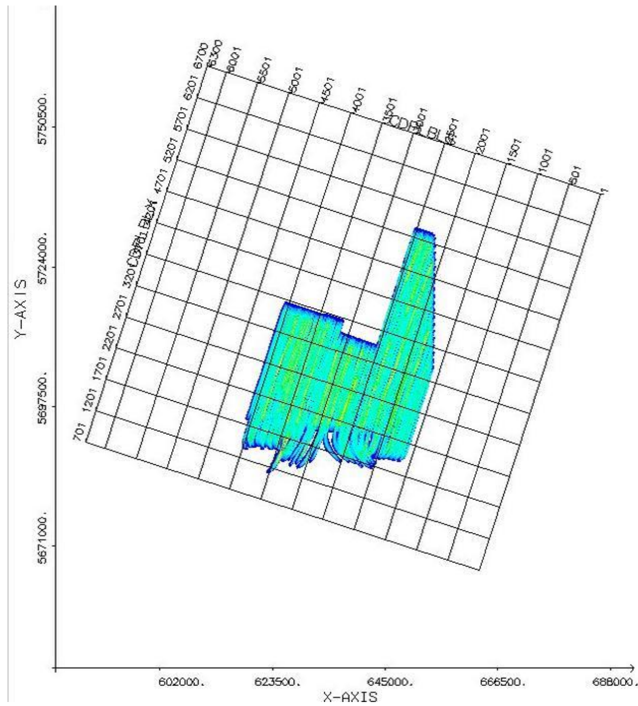
REPRESENTATIVE IMAGES



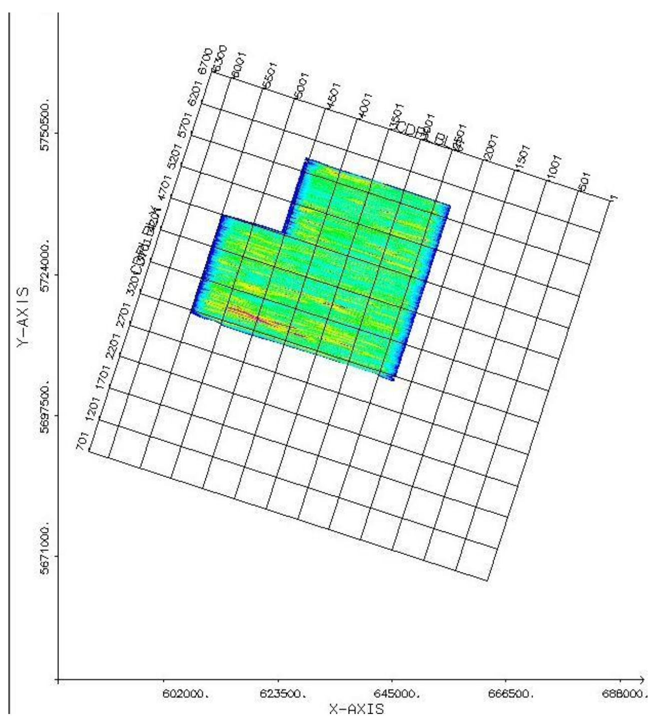
Survey outline and Bathymetry



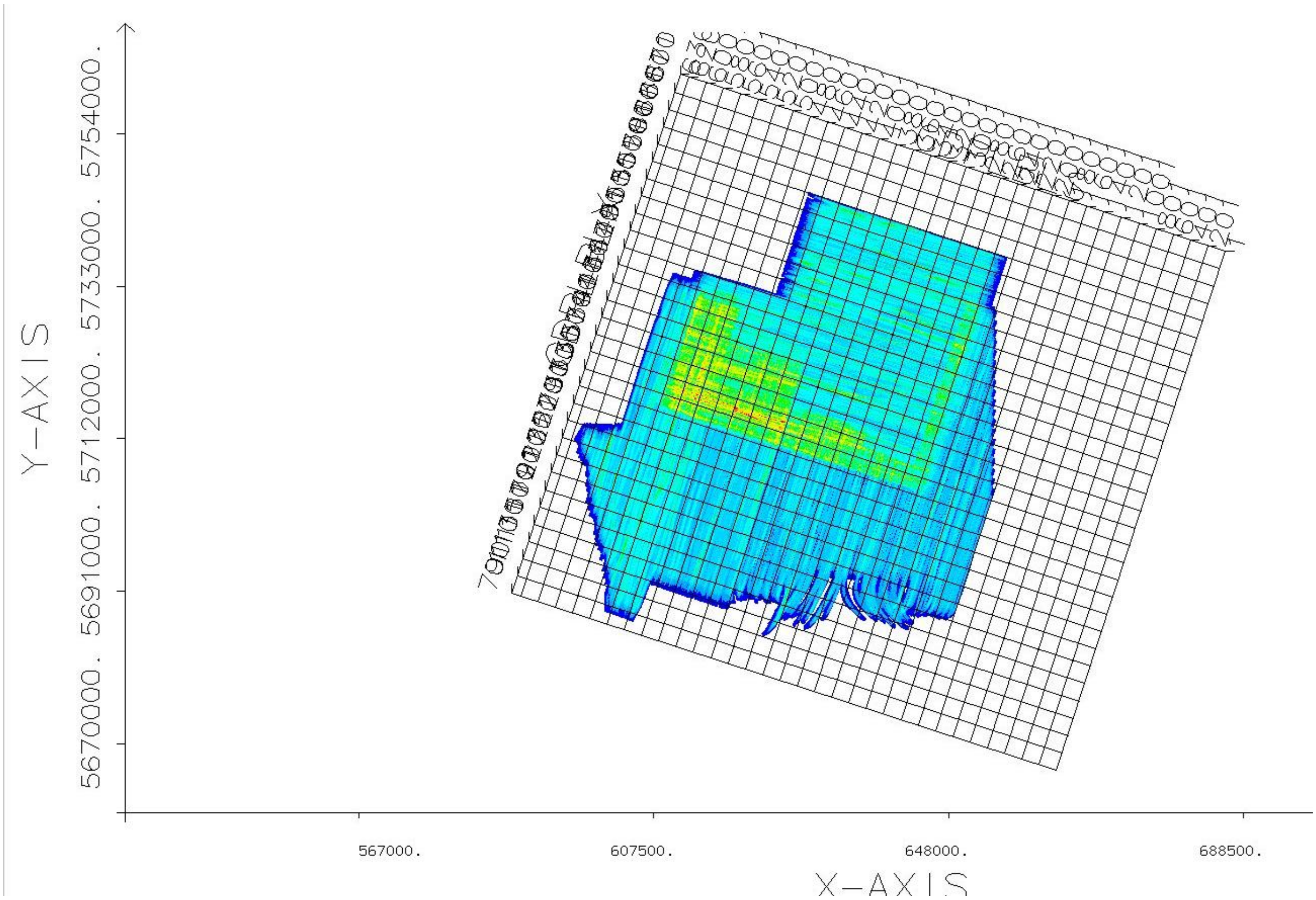
Fold coverage: HGP2002A



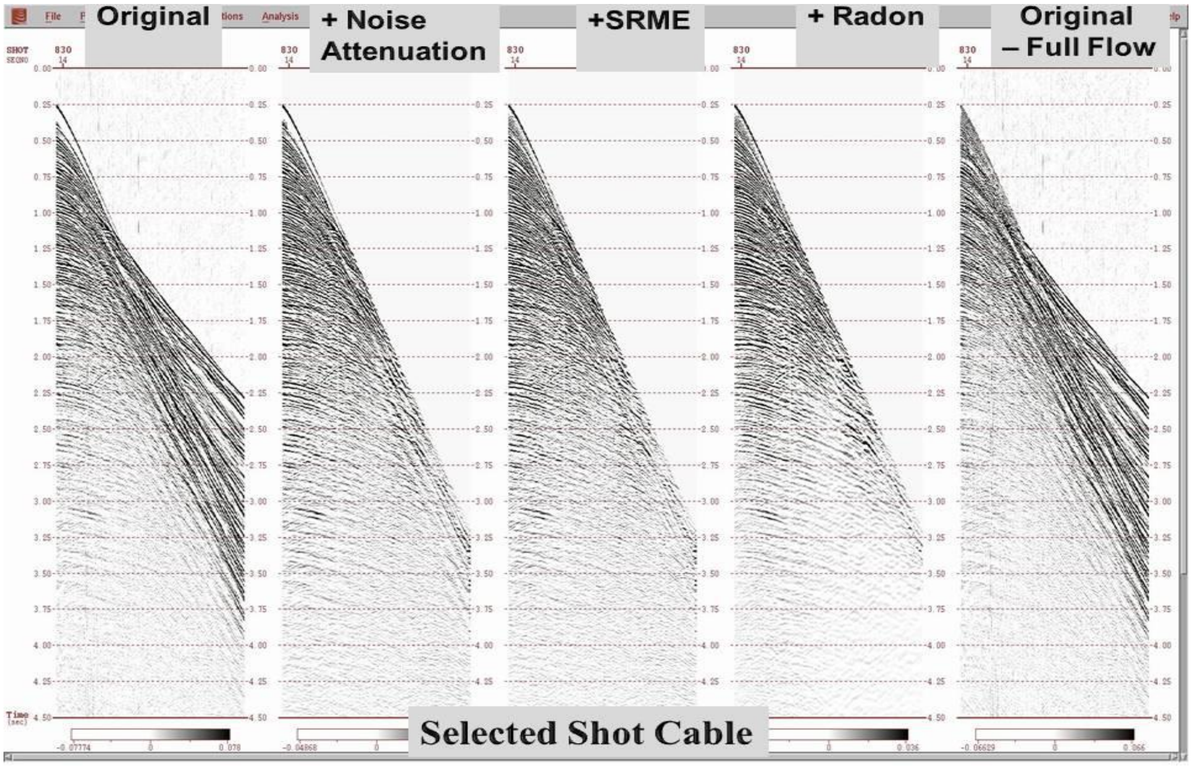
Fold coverage: Elver



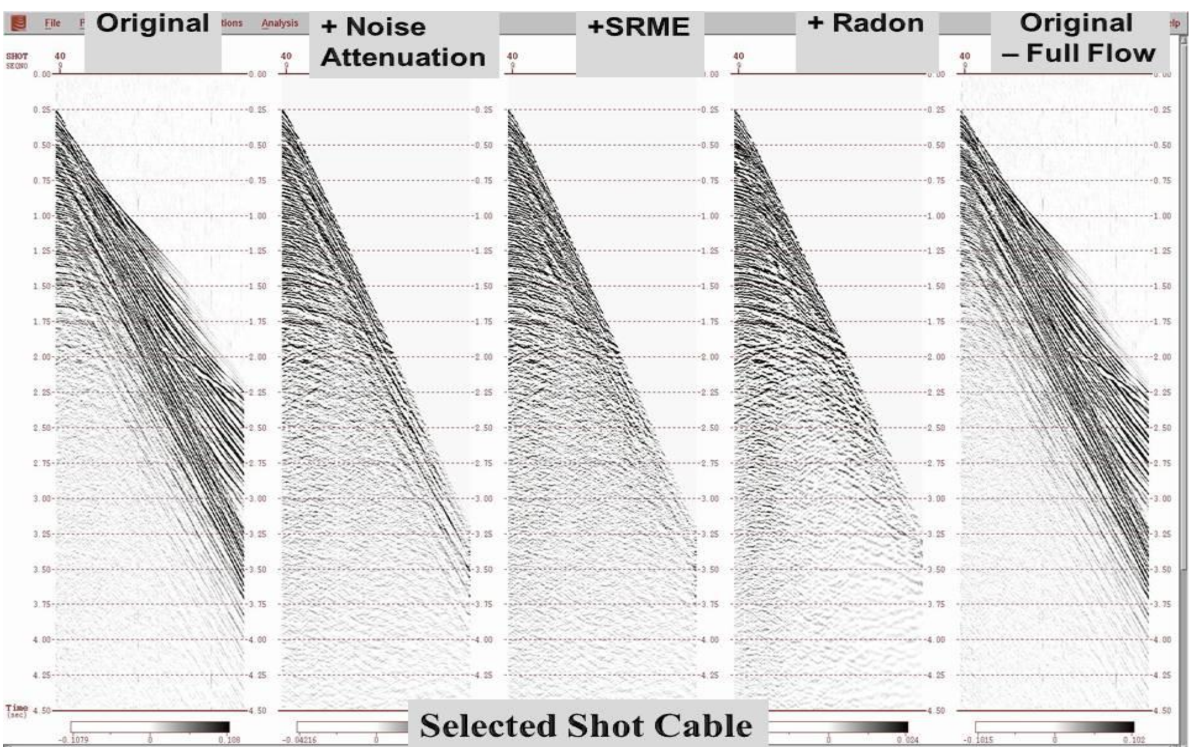
Fold coverage: Tuskfish



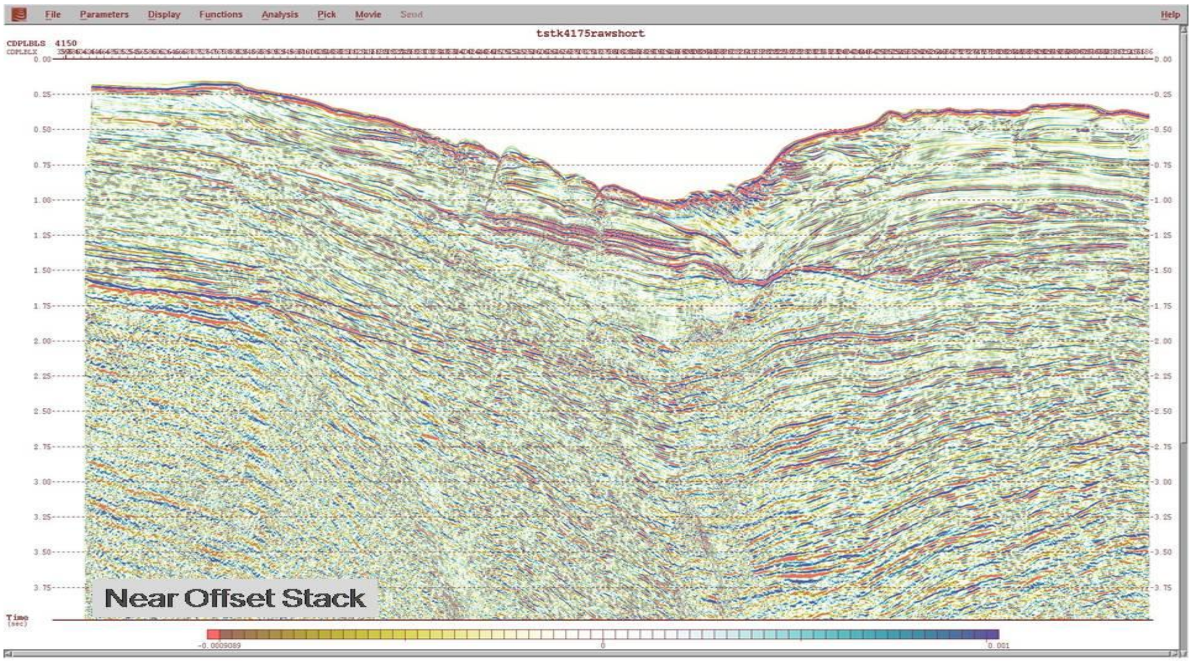
Fold coverage: Combined Gippsland East program



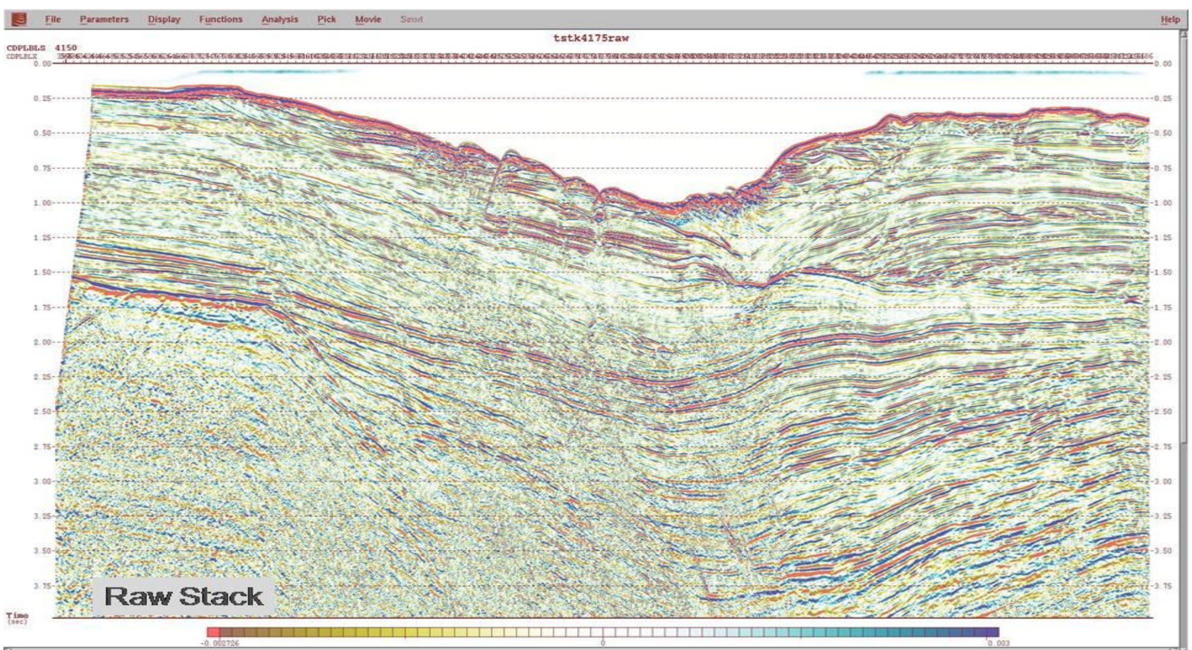
HGP representative Front-end processing progression –cable A



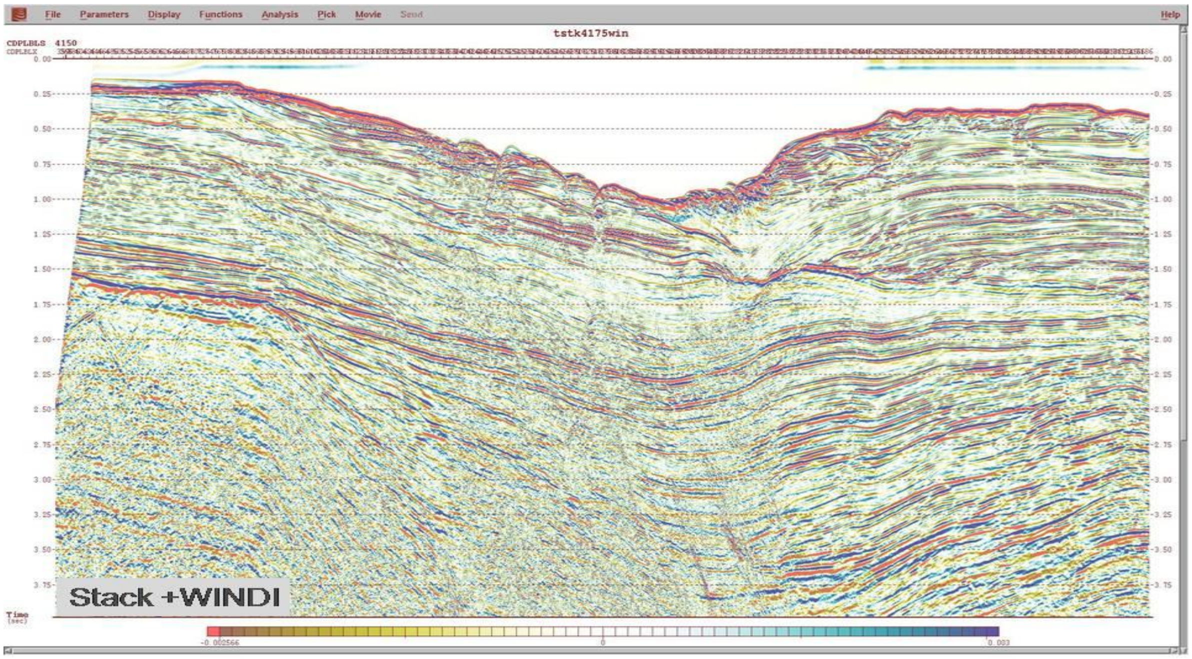
HGP representative Front-end processing progression –cable D



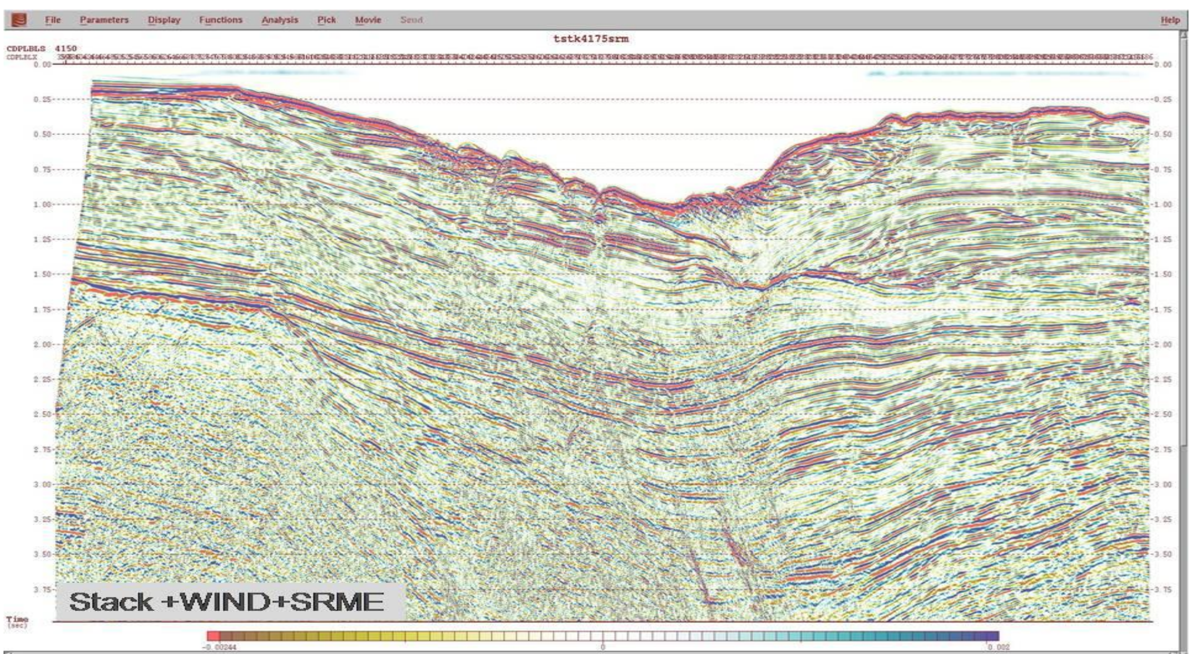
HGP QC Near Offset Stack



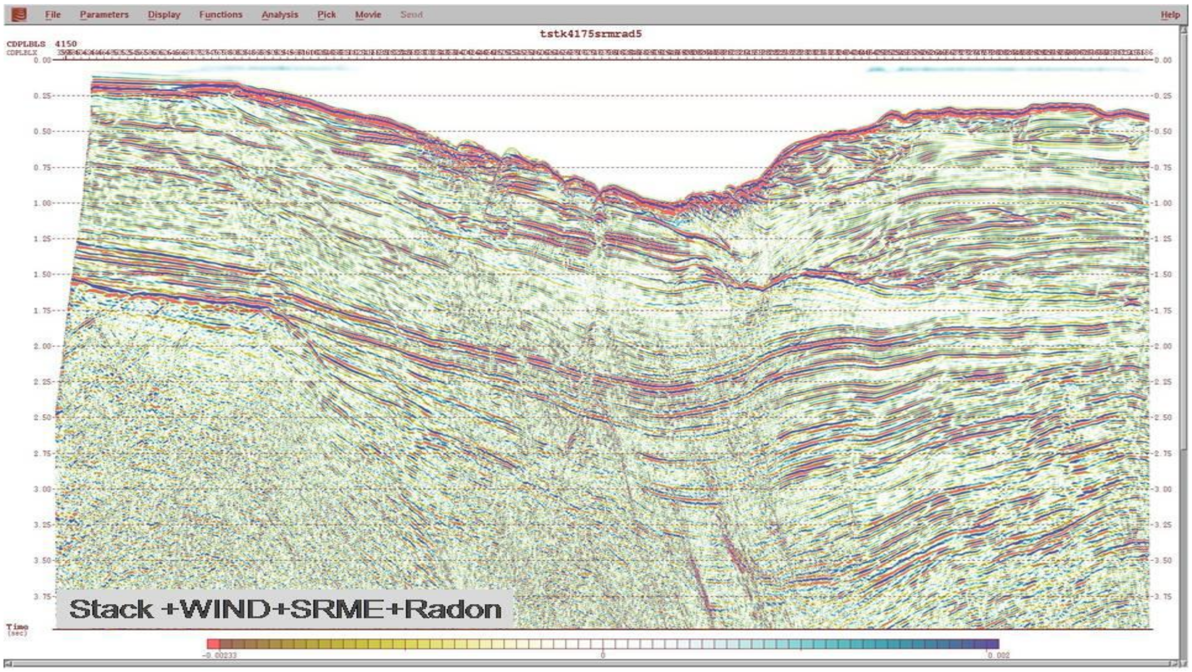
HGP QC Raw Stack



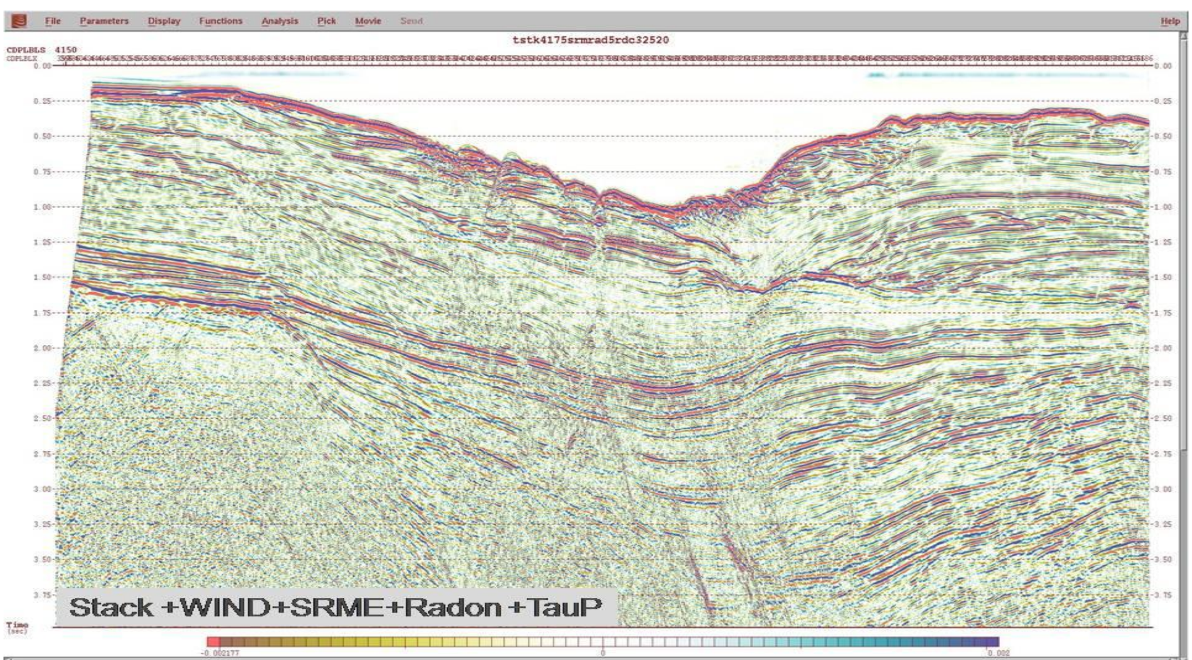
HGP QC Raw Stack+WIND



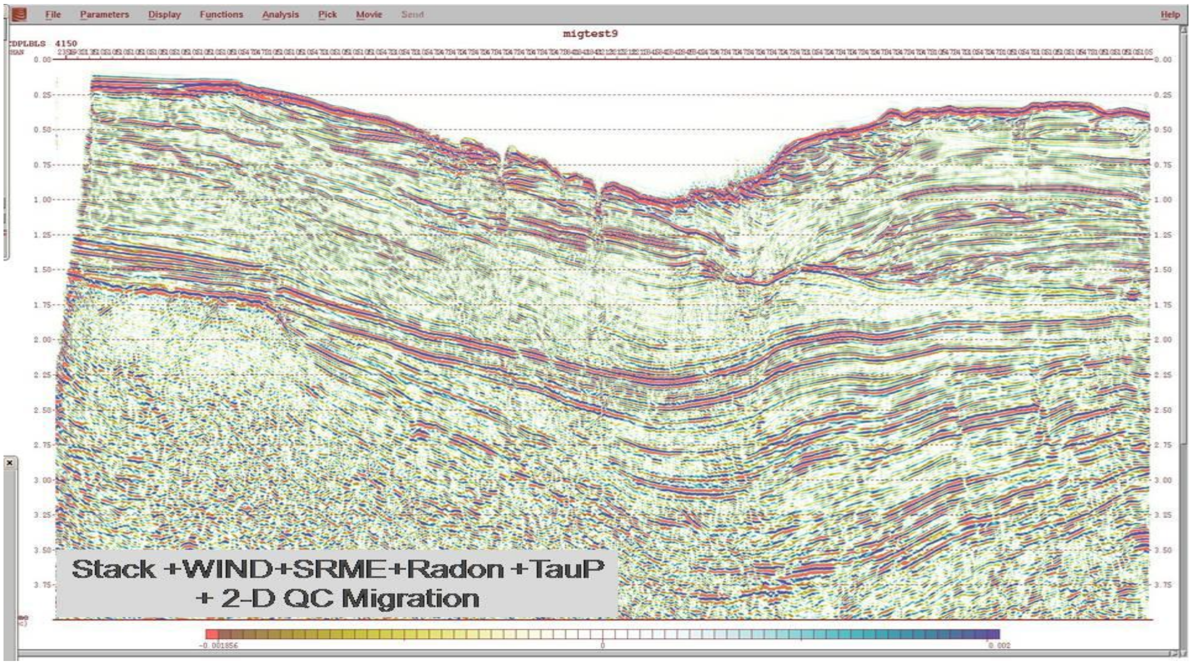
HGP QC Raw Stack+WIND+SRME



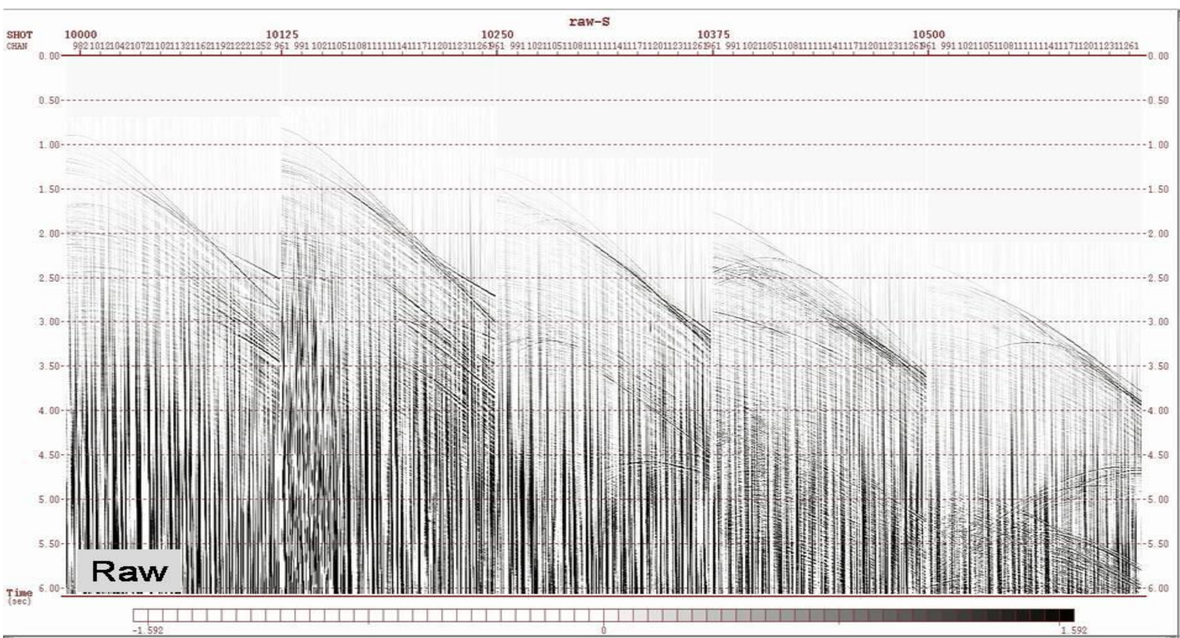
HGP QC Raw Stack+WIND+SRME+Radon



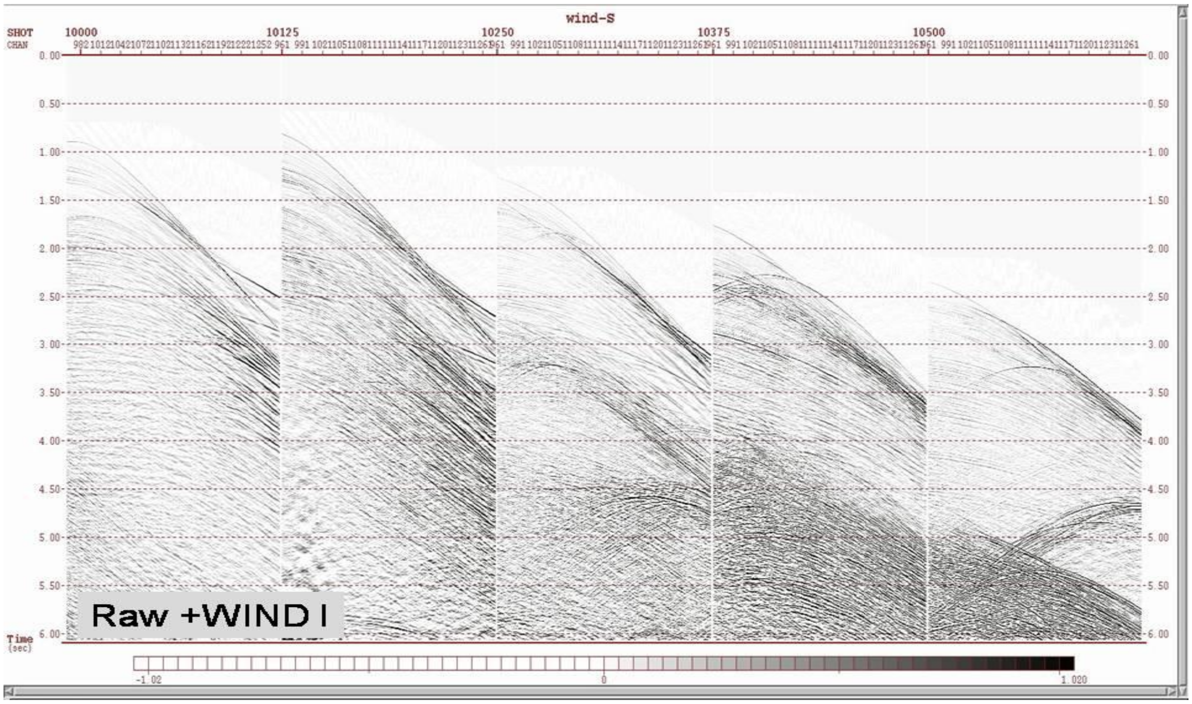
HGP QC Raw Stack+WIND+SRME+Radon+TauP



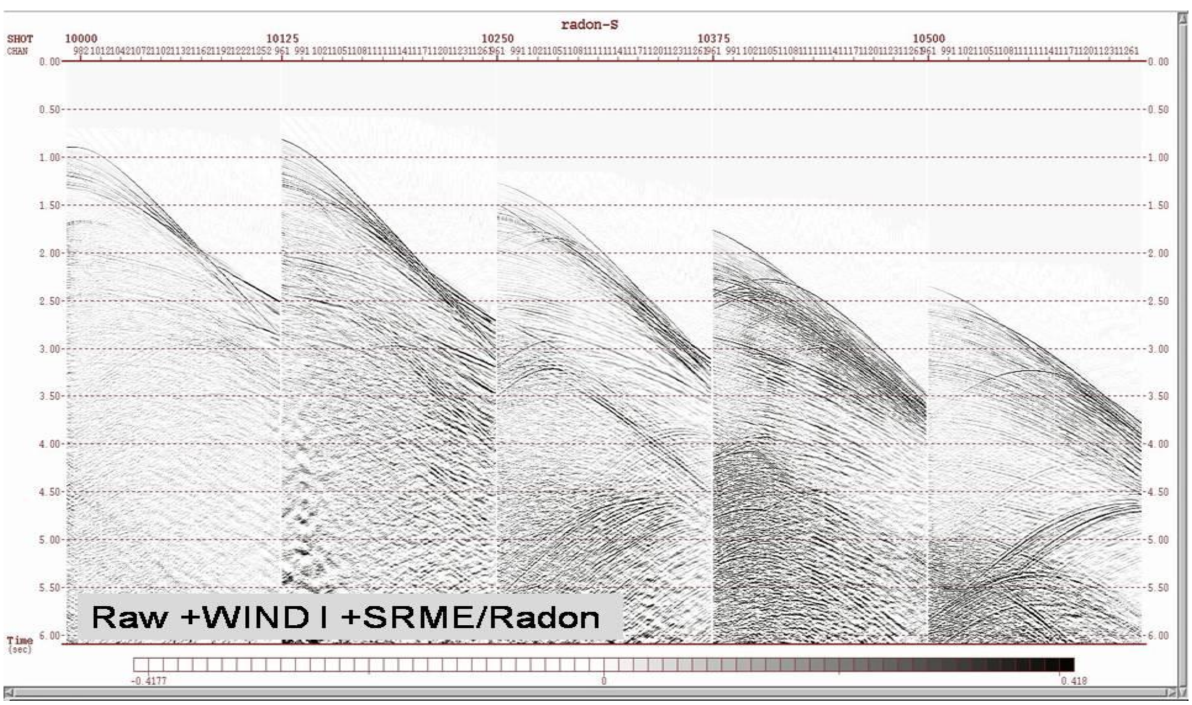
HGP QC Raw Stack+WIND+SRME+Radon+TauP+2-D QC Migration



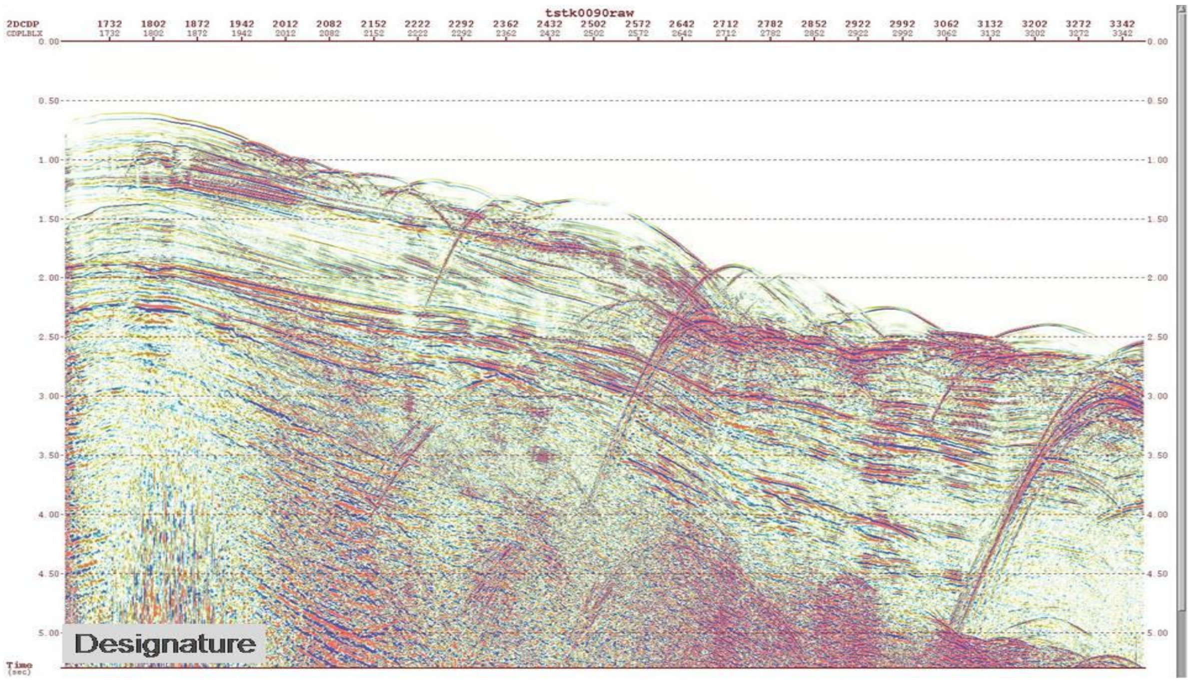
Elver Raw Shot/Cable



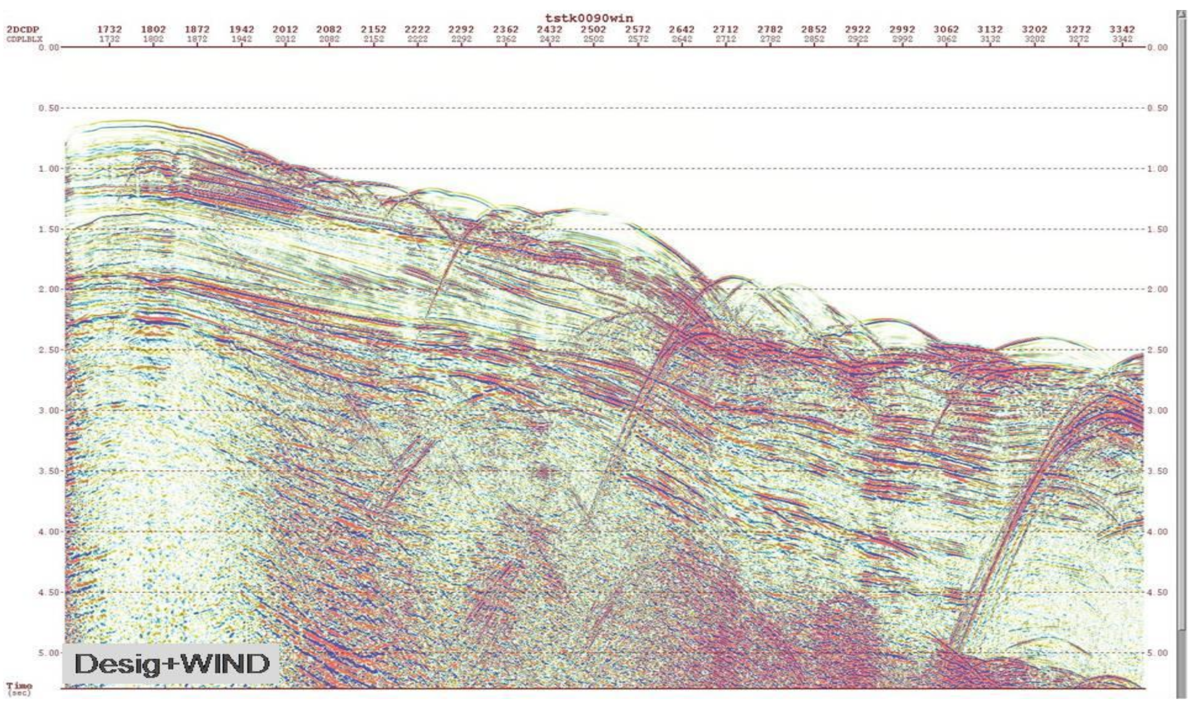
Elver Raw Shot/Cable+WIND



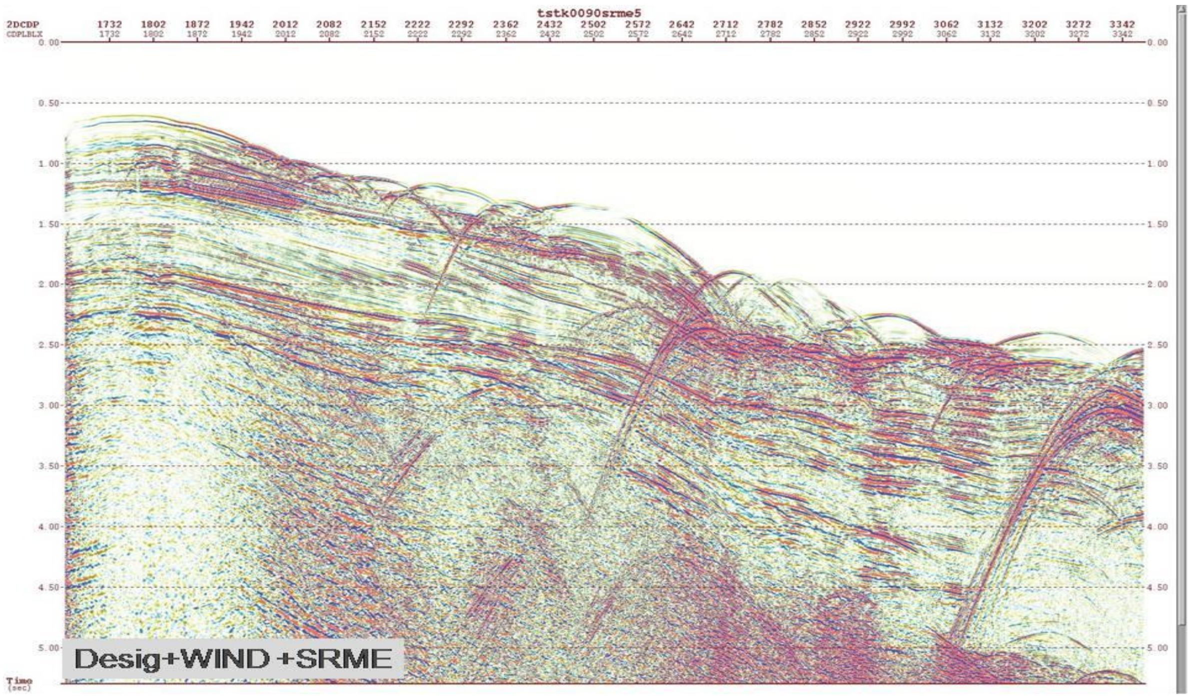
Elver Raw Shot/Cable+WIND+SRME/Radon



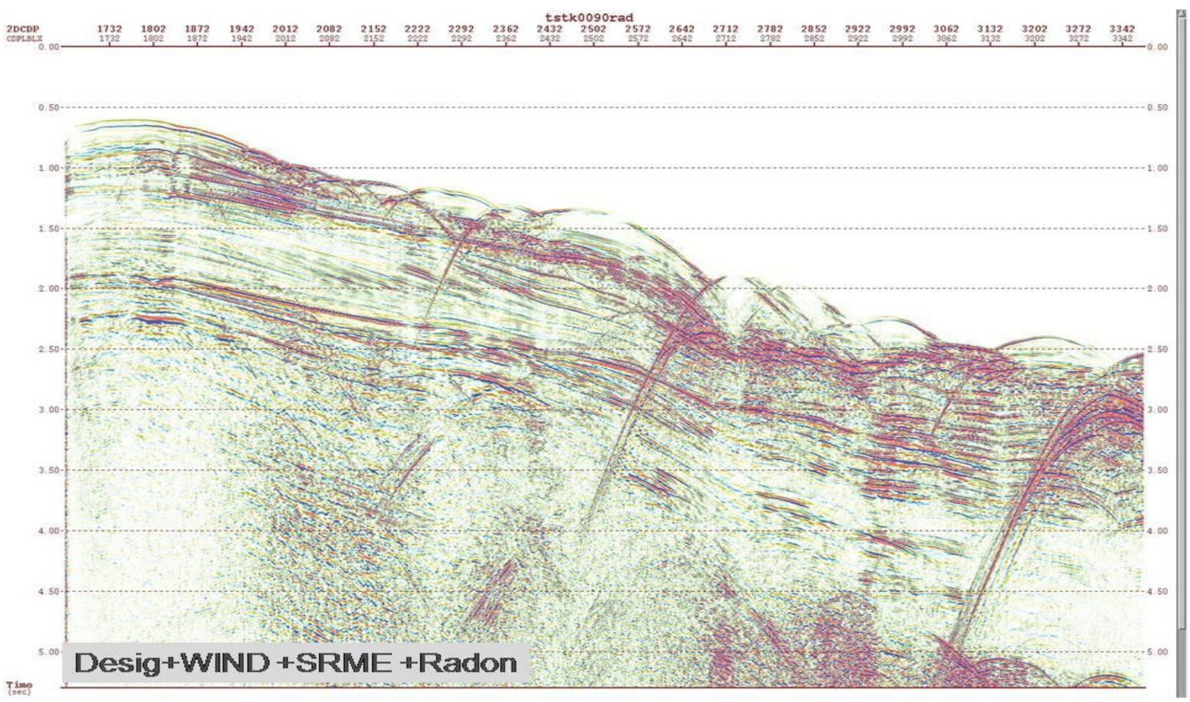
Elver QC Stack through Designature



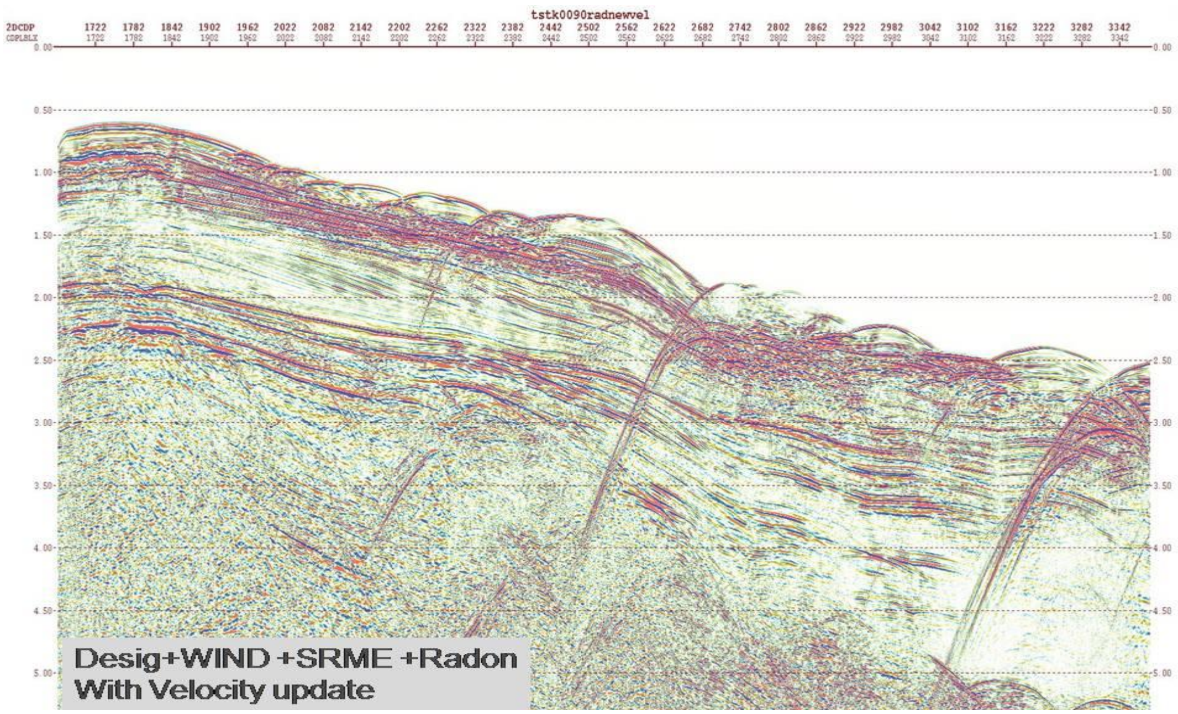
Elver QC Stack: Desig+WIND



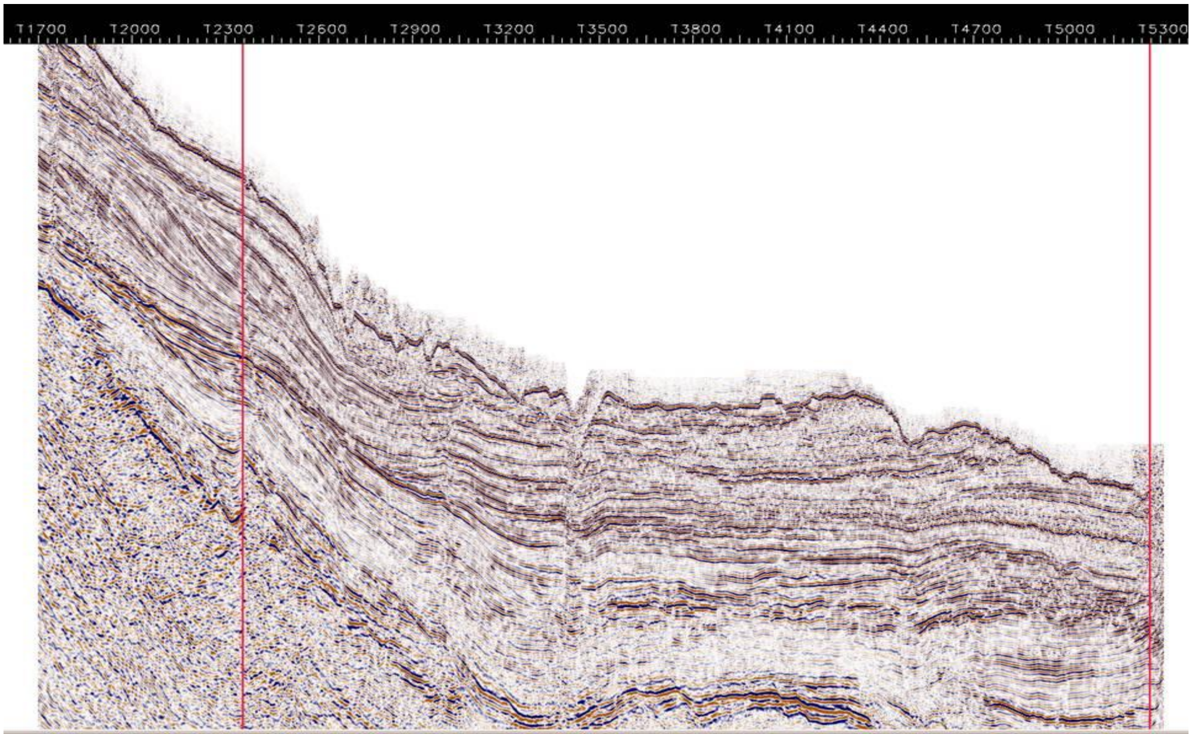
Elver QC Stack: Desig+WIND+SRME



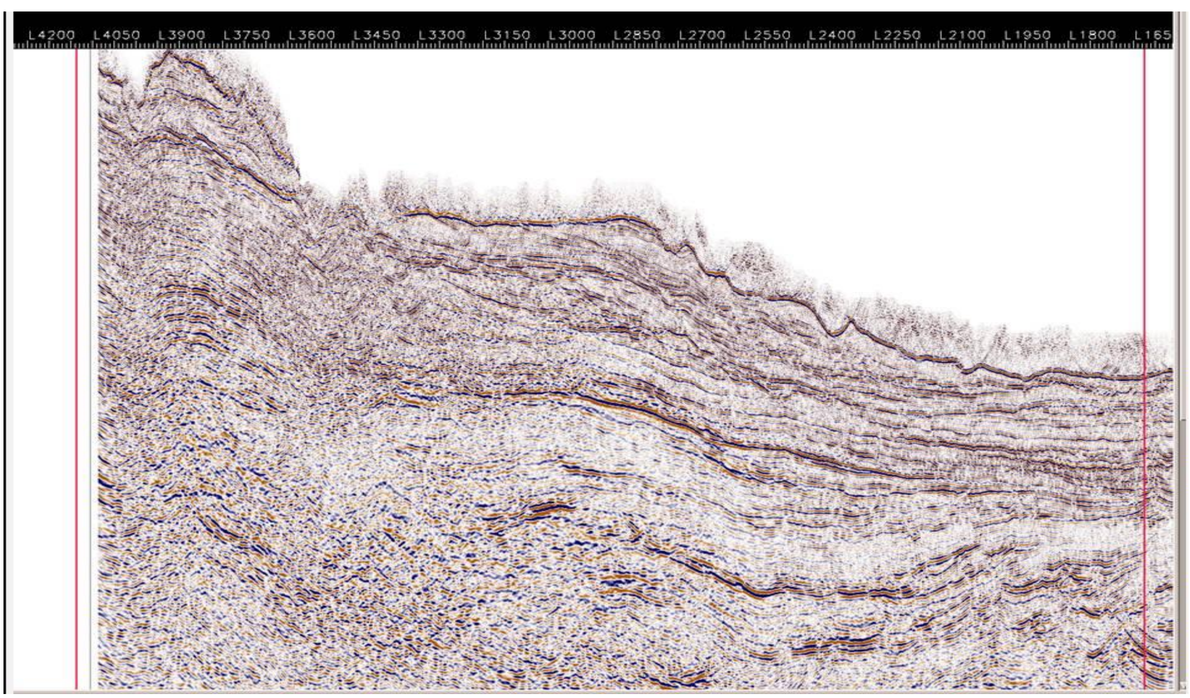
Elver QC Stack: Desig+WIND+SRME+Radon



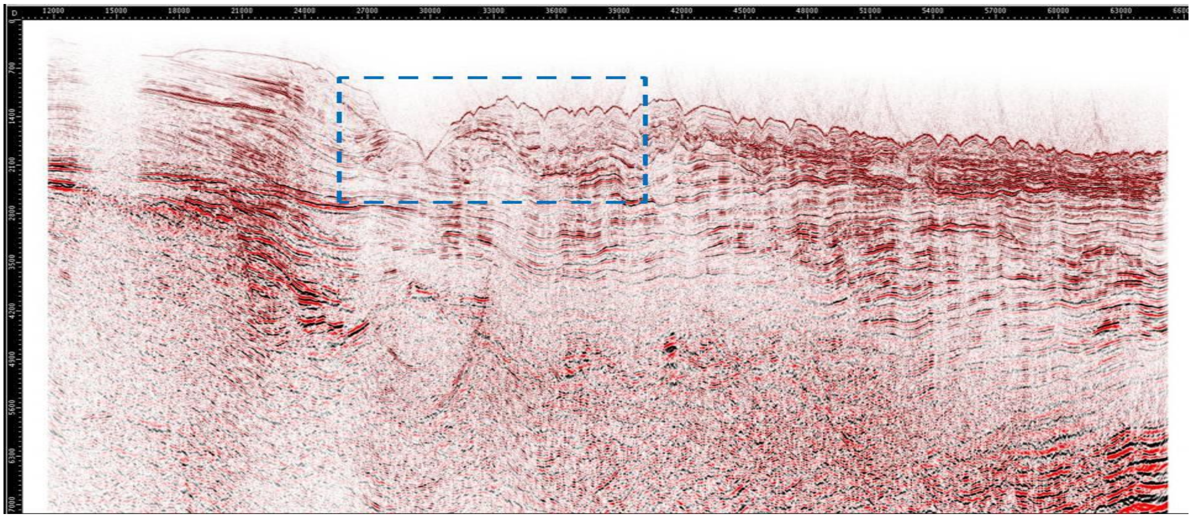
Elver QC Stack: Desig+WIND+SRME+Radon+Velocity update



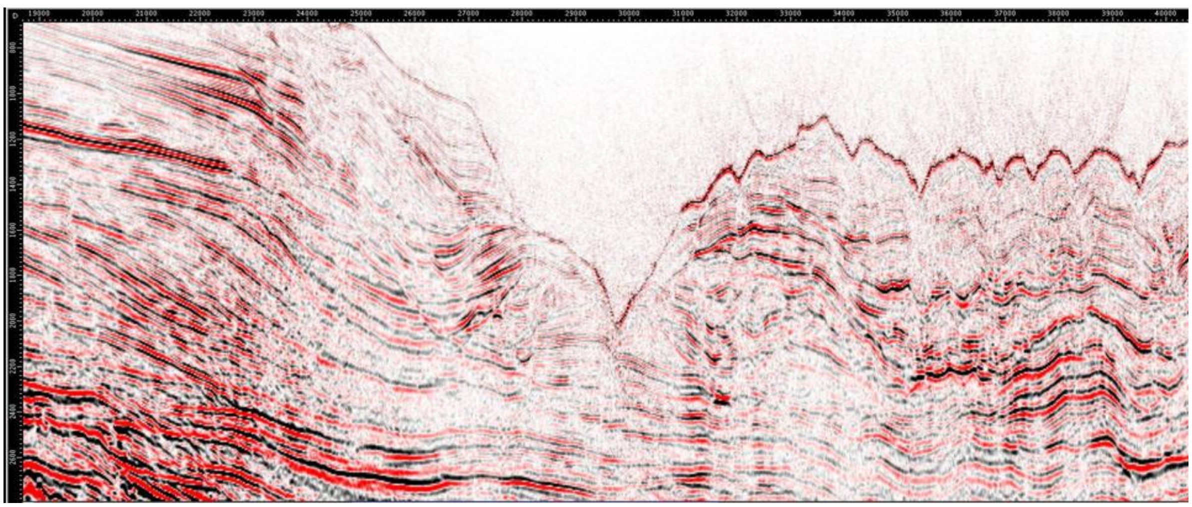
Example PSTM: Inline 2338



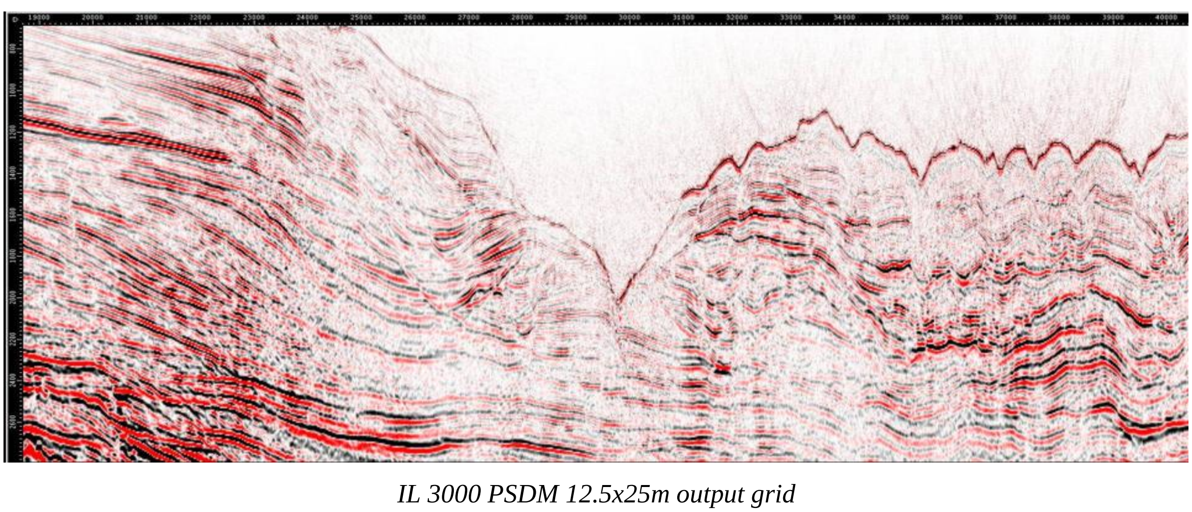
Example PSTM: Crossline 2995



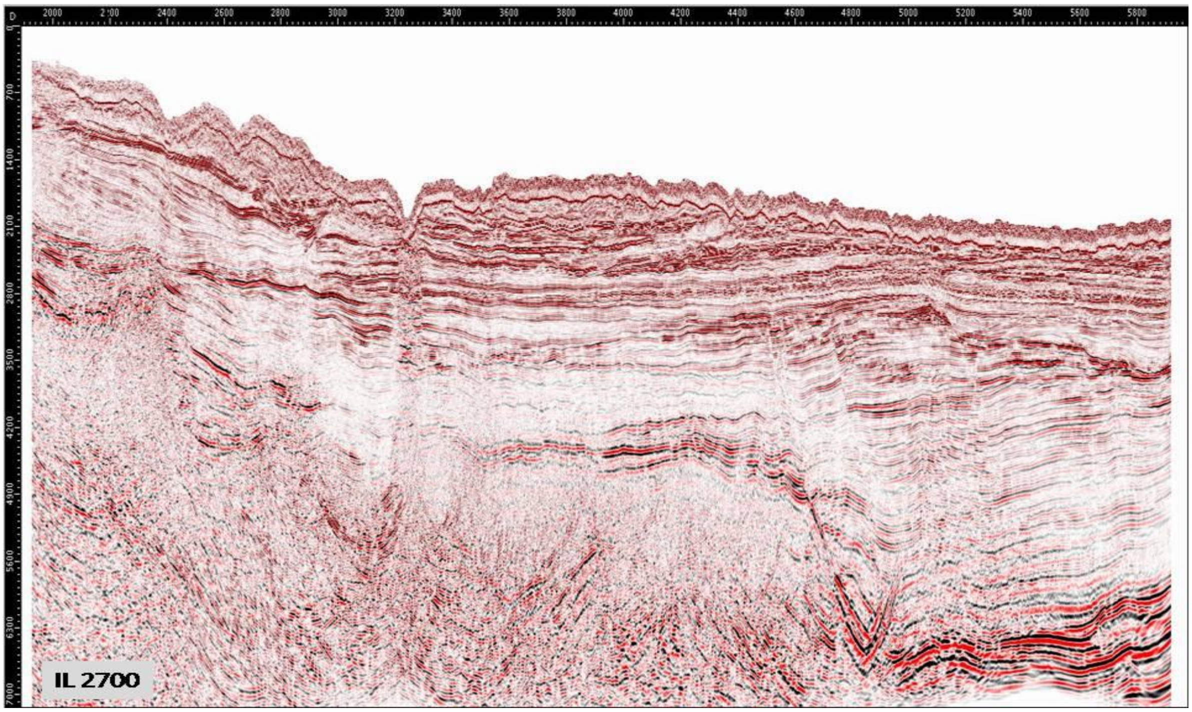
IL 3000 PSDM



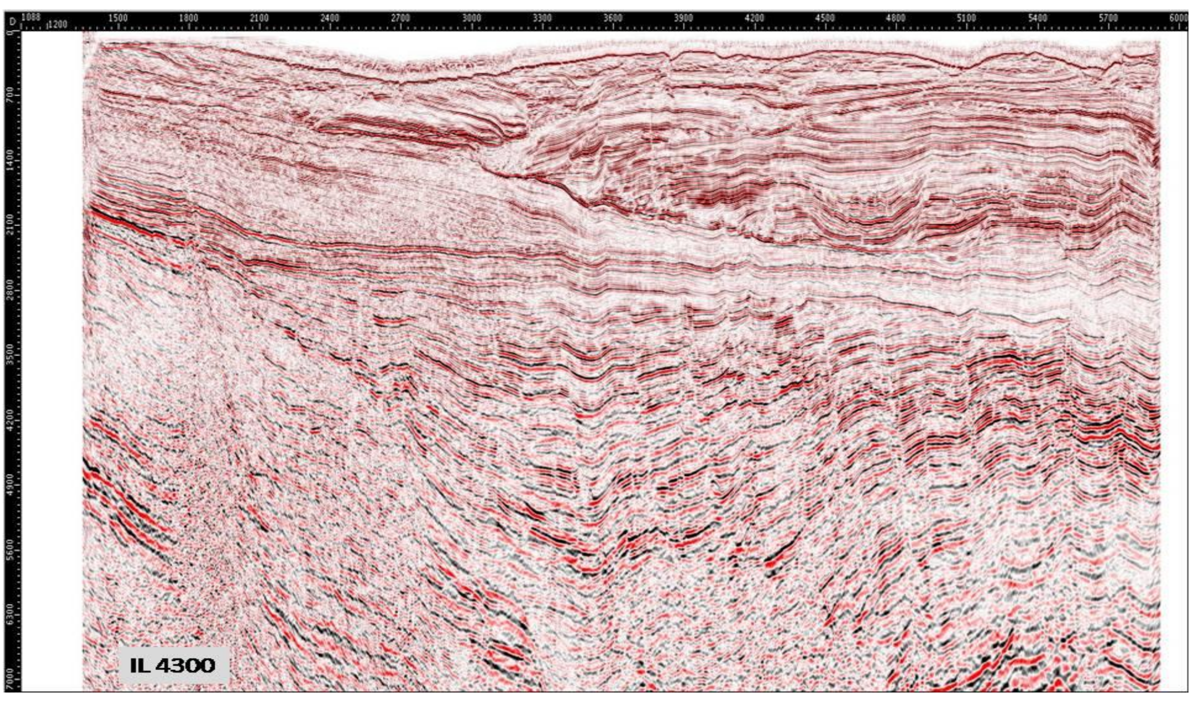
IL 3000 PSDM 25x25m output grid



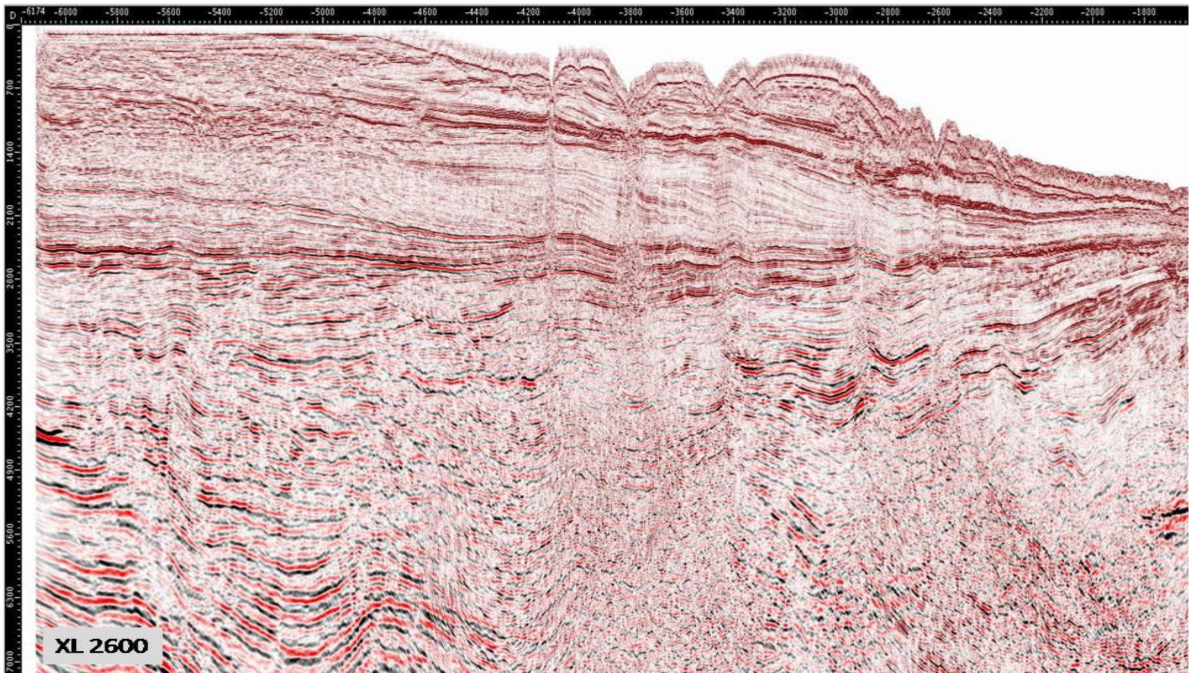
IL 3000 PSDM 12.5x25m output grid



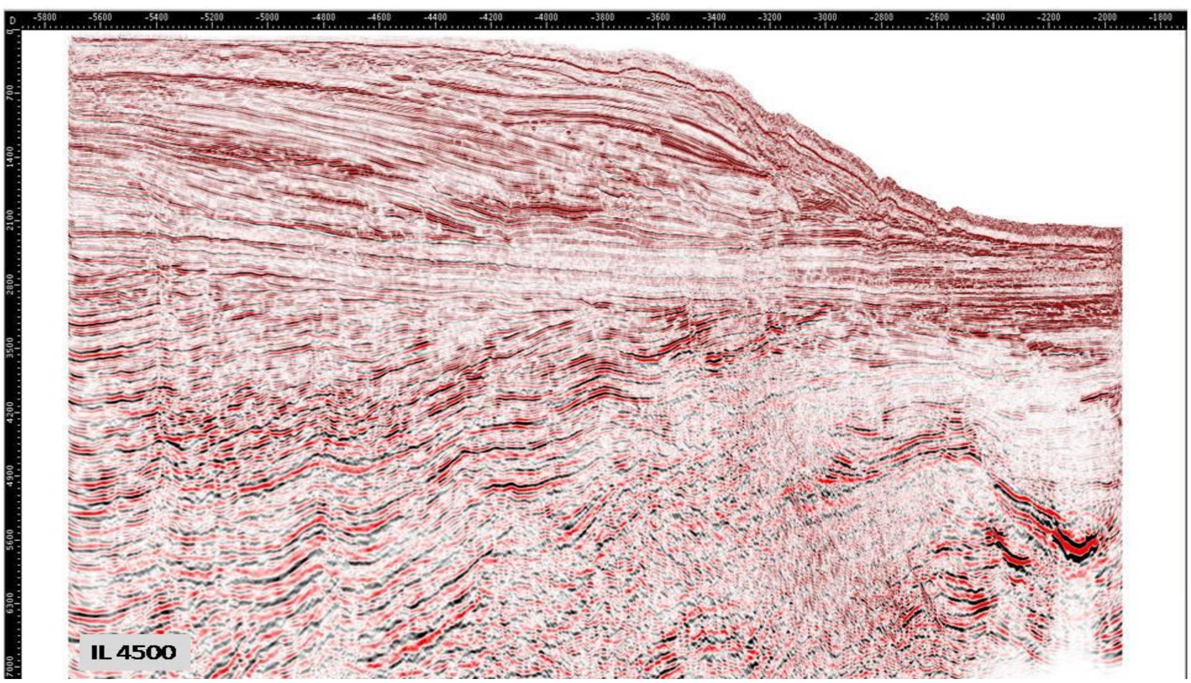
IL 2700 Final PSDM (Water bottom unmuted)



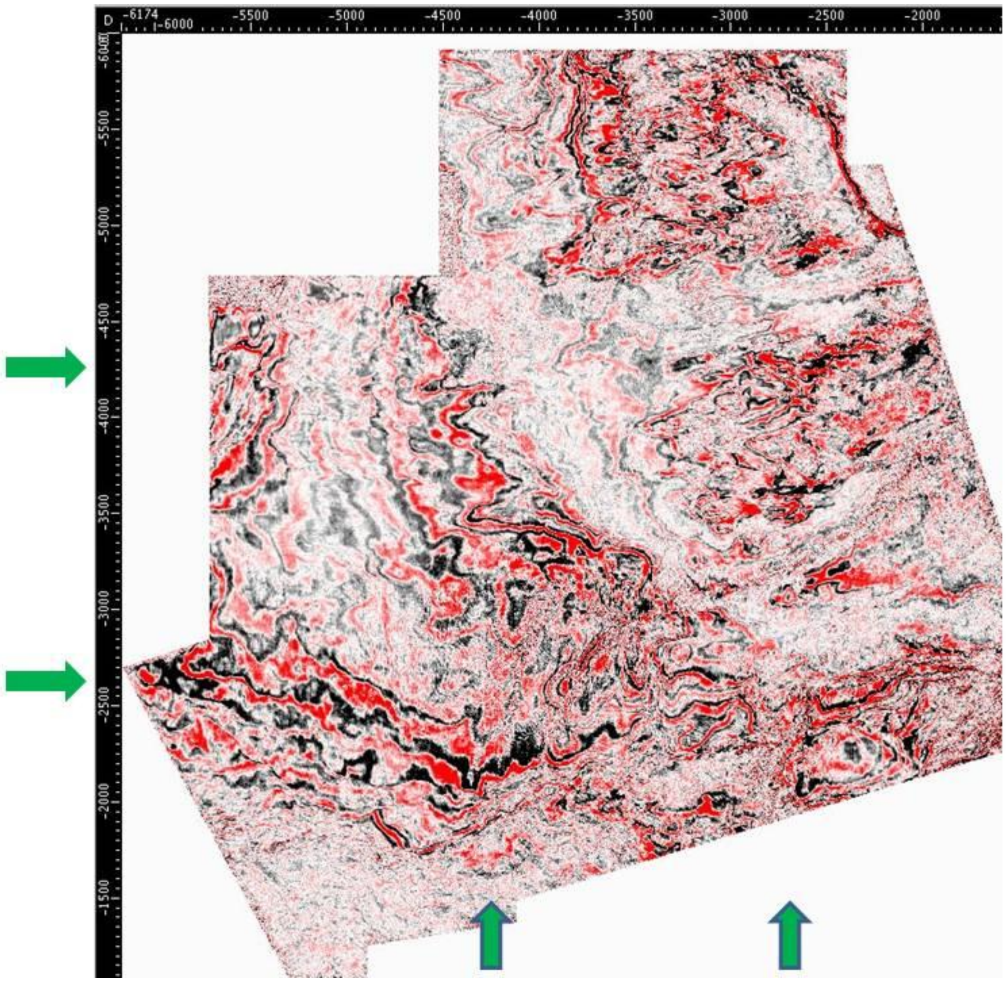
IL 4300 Final PSDM (Water bottom unmuted)



XL 2600 Final PSDM (Water bottom unmuted)



XL 4500 Final PSDM (Water bottom unmuted)



Depth Slice at 2500m showing positions of above PSDM vertical profiles