Seismic Data Processing Report

Carried out by:  CGG
For:  SANTOS Ltd
Area:  AMADEUS BASIN, NORTHERN TERRITORY
Survey:  SOUTHERN AMADEUS 2D
Method:  2D Land Processing

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CONTENTS

1. Introduction 2
   1.1 Scope of report 2
   1.2 Location 2
   1.3 Scope of work 2
   1.4 Geology 3
   1.5 Purpose and objectives of processing 3
   1.6 Processing logistics 3

2. Data Acquisition 4
   2.1 Acquisition parameters 4

3. Processing sequence 5
   3.1 Final processing sequence 5

4. Process and parameter testing 6
   4.1 Testing strategy 6
   4.2 Reformat 6
   4.3 Pre-Processing 7
   4.4 Denoise 7
   4.5 Statics 8
   4.6 Deconvolution 9
   4.7 Amplitude adjustment 10
   4.8 DMO & Bin Regularization 11
   4.9 Imaging 12
   4.10 Stack 13
   5.1 Post-Stack 14

5. Final Products 14
   5.1 Archive SEGY Stacks 14

6. Conclusions and recommendation 15

7. Personnel 15
   7.1 CGG Personnel 15
   7.2 Santos Personnel 15

8. Appendix 15
   8.1 Amadeus 2D line list 15
   8.2 Segy header byte positions 16
   8.3 Sample Segy Ebcidic header 16
   8.4 List of Figures – AMSAN13B-02 19
   8.5 Sample Shots 20
   8.6 Sample Line Stacks 22
Introduction

1.1 Scope of report

This report describes the seismic data processing of 14 2D lines from the South Amadeus 2D Survey consisting of about 1600 kms The final processing datum is 500m above mean sea level. A list of the lines are given in Appendix 8.1

1.2 Location

The 2013 Amadeus 2D survey covered in this report is located in the Amadeus Basin as shown in the figure a.

![Amadeus Basin](image)

Figure a: Amadeus Basin

1.3 Scope of work

14 2D lines totaling 1600 Line km were processed through a PreSTM sequence. A list of the lines are given in Appendix 8.1
1.4 Geology
The intracratonic Neoproterozoic to early Carboniferous Amadeus basin occupies much of the southern quarter of the Northern Territory and extends about 150km into Western Australia, covering about 170,000 sq kms. It has a maximum sediment thickness of 14 km.

1.5 Purpose and objectives of processing
To obtain pre-stack migrated sections of the data with improved shallow and deep structural imaging.

1.6 Processing logistics
Test results and intermediate products were made available to Santos via ftp in Segy format.
1 Data acquisition

2.1 Acquisition parameters

<table>
<thead>
<tr>
<th>General Parameters</th>
<th>Southern Amadeus 2D 2013 survey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acquisition contractor</td>
<td>TERREX Seismic crew 403</td>
</tr>
<tr>
<td>Original client</td>
<td>SANTOS</td>
</tr>
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<td>August-November 2013</td>
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<td>1600 Line km</td>
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<td>No. channels per shot record</td>
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<td>Receiver interval</td>
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<td>VP and Receiver numbering</td>
<td>Increment 1</td>
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Source Parameters

| Source type                  | Vibroseis                                           |
| Vibration type              | I/O AHV 4                                            |
| Vib Control                 | VE464                                                |
| Number of Vibrators         | 3 Vibes Inline, centred on half station, 70% force    |
| Sweep frequency             | 5-90Hz, 8-80Hz, 10-80Hz, 10-82Hz, 12-80Hz            |
| Sweep type                  | Linear                                               |
| Sweep length                | 8 secs                                               |
| Number of sweeps per VP     | 2                                                    |
| Front & Back – end tapers   | 500 msec/300msec                                     |

Instrumentation

| Recorder                    | Sercel SN428                                        |
| Filters                     | Hi cut 0.8 Nyquist Linear Phase Low cut out          |
| Data Format                 | SEG-D                                               |
| Auxiliaries                 | TB, 100Hz, Pilot, DPG Ref, Sweep Auto-Correlation    |
1 Processing Sequence

3.1 Final processing sequence

1. Pre-STM Processing Sequence

- Reformat
  - Reformat from SEGY into Geovation format.
  - Navigation merge and trace header update.
  - Geometry QC.

- Pre-processing
  - Crooked line binning.
  - Gain recovery using Spherical Divergence Correction (TV² gain curve).
  - Global amplitude scalar corrections per line
  - Vibroseis: minimum phase filter application (Sweep dependent).
  - Initial automatic statistical editing of noisy traces (SPASM despike) in shot domain.
    → QC stack using elevation statics and single velocity function
  - First break picking
    → QC Shotpoint gathers overlay with first break picks

- Denoise
  - Frequency dependent RNA (FDNAT despike) in shot domain, 1 pass.
    → QC stack using elevation statics and raw velocity
  - Frequency dependent RNA (FDNAT despike) in receiver domain, 1 pass.
    → QC stack using elevation statics and raw velocity
  - Adaptive groundroll attenuation (AGORA) in shot domain, 1 pass.
    → QC stack using elevation statics and raw velocity
  - Adaptive groundroll attenuation (AGORA) in receiver domain, 1 pass.
    → QC stack using elevation statics and raw velocity
  - Frequency dependent RNA (FDNAT) in shot domain, 1 pass.
    → QC stack using elevation statics and single velocity function

- Statics
  - 2D refraction statics modelling (using GEOSTAR) to 500m datum.
    → QC stack using 2D refraction statics
  - Statics correction to floating datum plane.
  - Velocity analysis every 2000m using refraction statics – V1 velocity
    → QC stack using refraction statics and V1 vels.

- Q phase only (Q80 @ 0ms, Q80@ 5000ms)

- Surface consistent Deconvolution
  - Spike deconvolution, Operator length 200ms, window 300ms -3000ms
  - Surface consistent residual statics, window 400ms -2500ms.
    → QC stack of residual statics with V1 vels

- Amplitude adjustment
  - Surface consistent amplitude correction, window 400ms -3500ms (Source, Receiver and offset terms applied)
    → QC stack of SCAC

- Velocity analysis every 1km using 2D refraction statics – V2 velocity
  → QC stack using V2 vels.
Surface consistent residual statics, window 400m -2500ms.
  → QC stack of residual statics.
• Frequency dependent RNA (SPARC denoise) in CDP domain, 1 pass.
  → QC stack using refraction statics and V2 velocity
• Frequency dependent RNA (SPARC denoise) in offset domain, 1 pass.
  → QC stack using refraction statics and V2 velocity
♦ Frequency dependent RNA (CADZO filtering) in offset domain, 1 pass.
  → QC stack using refraction statics and V2 velocity
♦ Forward and Reverse DMO
  Dip moveout correction and bin harmonization in 25m offset classes.
  → QC stack of DMO in both forward & reverse options.
♦ PreSTM Migration
• Migration velocity analysis
  → QC stack with migration velocity
• Kirchhoff migration using smoothed migration velocities,
  (Dip 90° @ 0ms to 5000ms)
  → QC stack of raw migration
• Residual move out correction (HDPIC)
  → QC stack of residual moveout correction
• CMP consistent time-variant trim statics
• Pre-stack AGC (Gate 500ms)
• PSTM stack using final outer XT stacking mute
♦ Post stack
• Post stack time variant filter
  (Butterworth 15,18,80,72 @ 0ms -1200ms, 8,18,60,72@ time 1500ms -3000ms
  8,18,50,72@ time 3500ms -5100ms

4 Process and Parameter Testing

4.1 Testing strategy
Reasonable testing was done for the processing of this survey.
Parameter verifications were done at some important steps and the line used for this purpose were
AMSAN13B-02.
Test results were primarily supplied direct to Santos via ftp link.

4.2 Reformat

4.2.1 Reformat
The Amadeus 2D 2013 dataset was acquired by Terrex seismic crew 403. CGG received this dataset
in SEG D format and then converted the data from SEG D to internal Geovation format. Data received
was cross-correlated. Processing sample rate was 4ms. Processing record length was 5 secs.

4.2.2 Navigation merge
All the data navigation merge was done internally with supplied SPS files. All applied final SPS survey
information were archived as per the deliverables.
The final datum of all the four surveys survey is 500m above mean sea level.
4.2.3 Trace header update and geometry QC
Geometry QC is done on shotpoints by using Linear Moveout plots and plotting the first break times on the shotpoints. Trace headers were updated with the geometry and binning information. Shot to receiver offsets were now true offsets and took into consideration the crooked line geometry and actual shot and receiver locations.

4.2.4 2D Crooked line binning
All the 2D lines were processed as crooked lines. With crooked line processing a mean CMP line is steered through the densest concentration of midpoints. There are controls over the relative contributions of near and far offsets and on the amount of smoothing of the subsurface line. The CMP line is then divided into equally sized 12.5m bins. Binning results in individual midpoints being assigned to their nearest bins. Midpoints outside the specified maximum lateral distances from the bin centres can be dropped. Maximum lateral offset set for all datasets was 400m.

4.3 Pre-processing

4.3.1 Gain recovery
The loss of amplitude as a function of time is a result of several factors such as geometrical spreading of the wavefront, absorption of the signal and conversion into S-waves.
Decision – A TV² spherical divergence correction was applied to the data.

4.3.2 Global amplitude scalar
A coefficient was calculated for each line separately to bring the average amplitude to the same level for all the lines. The coefficient was calculated by using the entire dataset for each line and normalizing the RMS amplitude values to a specified level for each line. After calculation the scalar was multiplied to each sample of the dataset.

4.3.3 Minimum phase conversion
One of the requirements for Wiener-Levinson deconvolution is for the input data to be minimum phase. To convert our data to minimum phase we must first derive a phase-shift filter that will convert the Klauder wavelet into its minimum phase equivalent. The Klauder wavelet is the autocorrelation of the pilot sweep, the effective source pulse of the vibrator that was sent into the earth. The calculated phase-shift filter is then applied to the seismic data to convert it to minimum phase.
The minimum phase conversion operator was derived from the recorded sweep AC found in the auxiliary channel. Details of the minimum phase operator derivation can be found in the following technote: TESTING\TN01_MINPHASE_LINE02_PH123ST.pptx

4.4 Denoise

4.4.1 De-spiking
Automatic statistical trace editing is carried out to detect and remove spikes, high amplitude noise bursts and noisy traces. Spikes were replaced by interpolated data and noise bursts were scaled down to expected levels or edited based on a threshold value. Module SPASM were tested and used. SPASM is a despike process removing high amplitude spikes. SPASM were used in the shot point domain.

4.4.2 Frequency dependent Noise editing
CGG module FDNAT was used for this denoise. FDNAT attenuates high amplitude noise in decomposed frequency bands. It uses frequency-dependent and time-variant amplitude threshold
values in defined trace neighbourhoods to detect and suppress noise specific to different frequency ranges and different times.

4.4.3 Adaptive groundroll attenuation (AGORA)
Groundroll was the biggest challenge in the datasets. CGG module AGORA (adaptive ground roll attenuation) was used for the linear noise attenuation. AGORA is a data-driven approach performing a shot by shot adaptive ground roll attenuation in a two dimensional mode even with an irregular offset distribution.
Testing was carried out on lines AMSAN13B-02. The elevation static was applied prior to linear noise modeling and subtraction and removed afterwards.

4.5 Statics

4.5.1 Elevation Statics
Brute stacks were created using elevation statics correction only.

4.5.2 First break picking
Automatic First break picking is done using CGG batch module FBPICK in shot point domain. Automatic first break picks were QCed and edited with CGG interactive application GEOSTAR.
Another interactive application FBPICK was also used for the global QC of the first break picks.
For all the datasets, first breaks were picked for all traces in the shot records but only offsets in the range 0-1000m were used for the modeling and inversion to calculate the refraction statics.
Following technote shows some samples of first break picks.
TESTING\TN02\LINE11\FRST_BREAK_Examples.pptx

4.5.3 Refraction statics modeling
The interactive application GEOSTAR was used for refraction static modeling. It involves both inputs of picked first break times from shot records and an initial near surface model.
GEOSTAR works in the following manner:
1. Define near surface control points at discrete locations. It defines weathering thickness and velocity in the initial model.
2. Build a smooth layered near surface model for the whole survey. This involves
   (a) defining the number of refractors in the model,
   (b) smoothing the weathering thickness and velocity.
3. Compute arrival times that would occur if this earth model was correct.
4. Perform iterative model updates (Layered Model Inversion) to minimize the errors between the actual and modeled arrival times. The computed arrival times from the model are compared to the actual picked times. The model is updated to minimize the error between the two.
5. Statics are then calculated for the optimized model using its velocities and refractor depths. A constant replacement velocity is usually used from base of refractor to processing datum.
6. If using a proper Uphole survey the statics can be calibrated to the Upholes. However on this survey no Uphole survey was acquired and hence no calibration was possible.

It is to be noted that the GEOSTAR software does not update the weathering velocity coming from the initial model, in its iterations, only the weathering depth is updated. If the first break arrivals show an increase in static compared to that predicted by the initial model then the iterated model will show an increase in weathering depth with the weathering velocity being left largely unaltered. The truth may be that the deduced weathering depths are actually shallower and weathering velocities slower than those predicted in the final model. The total static is however correct. It is directly related to the variable of weathering depth divided by weathering velocity.
1000 m/sec velocity was used for the weathering layer velocity. A replacement velocity of 2000m/sec was used to correct from the base of the weathering to a flat datum 500m datum. The seismic data was stacked using GEOSTAR refraction statics and compared to one using the elevation statics. GEOSTAR outputs two types of statics: the long wavelength component and the short wavelength residual component.

Details of the refraction statics modeling done for line 09 can be found in the following technical note: TESTING\TN03_LINE09_REFRACTION_STATICS_modeling.pptx

4.5.4 Static correction to Floating Datum Plane
The low frequency (regional) component of the statics was obtained by smoothing the statics. This is the regional Floating Datum Plane. Conventional wisdom is to have the statics smoothed over one cable length and this was done for all four surveys.

The high frequency (residual) component is the difference between the total refraction static and the low frequency component. It was applied at this stage and corrects the data to the Floating Datum Plane which is close to the ground surface. All further pre-stack processing is done using the Floating Datum Plane as t=0 reference.

4.5.5 Velocity analysis (1st Pass)
Velocity analysis was made every 2km using the refraction statics solution. Reference velocity for all lines was an initial single velocity function derived internally. Each analysis location comprised of 35 CMPs stacked with 60 velocity functions about a central function. Optimum velocity functions were selected from mini-stacks comprised 35 CMPs stacked with the 60 velocity functions, NMO corrected gathers of the central CMP, and a contoured semblance display based on the power of stack.

CGG Interactive tool Pacesetter was used for velocity analysis.

4.6 Deconvolution

4.6.1 Inverse Q filtering (Phase only)
Inverse Q filtering is used to restore spectral balance in the wavelet and removes the non-stationary phase components from the seismic data that occur due to the effects of absorption and dispersion. Q80 @0ms and Q80@5000 for phase correction was applied before surface consistent deconvolution.

4.6.2 Surface consistent deconvolution
Deconvolution is used to remove the filtering effects of the earth. In doing this it compresses the wavelet and increases the resolution of the data. It is also designed to remove reverberations and multiples in the data. In surface consistent deconvolution each trace is expressed as the combination of the convolution of the earth’s reflectivity series with four filters characterized respectively by
- The shot point position
- The receiver position
- The CDP or geology
- The shooting distance

The same source filter is used for traces belonging to the same shot point and similarly one receiver filter is used for traces belonging to the same receiver position, etc. As it is generally desirable to retain the effects of the ‘geology’, we do not apply the CMP filter.

Testing was done with slight variations of operator length & windows.
Decision: multi-channel surface consistent deconvolution using Geovation module DECSC with Spike operator, length 200ms and design window 300ms- 3000ms with zero phase output.
These parameters were used for all lines and provided the best results concerning horizon continuity, preservation of dips, frequency content and multiple attenuation. Details of deconvolution testing can be found in the following technotes:

TESTING\TN04_AMADEUS_2D_SC_Decon_test.ppt
TESTING\TN05_AMADEUS_2D_SC_Decon_op_length_tests.ppt

4.6.3 Surface consistent residual statics (1st Pass)

After first pass velocity picking, residual static corrections are needed as primary refraction statics do not totally compensate for the high frequency effects of near-surface velocity variation. Surface consistent residual reflection statics correct for the high frequency statics component that is usually missing in the primary statics. They do not correct large static anomalies or long wavelength statics. Automatic residual statics corrections involve two parts:

(a) Picking time values within an analysis window after primary static correction, NMO and mute.
(b) The time picks are then decomposed into the following components: structural terms, residual moveout terms, source location terms, and receiver location terms. Output is a statics file containing individual static shifts associated with each source and receiver location.

Surface consistent residual statics showed improvement in the continuity of the main horizons. Checks were made that they did not degrade the data and notably that there were no cycle skips. The time window used for residual statics was 400ms-2500ms.

4.7 Amplitude adjustment

4.7.1 Surface consistent amplitude correction

Surface consistent gain corrections correct for high frequency spatial variations in trace amplitude that are due to surface coupling (both vibrator and geophone coupling) and to varying near-surface ground conditions.

Spatial amplitude variations have two components:

(a) A low frequency regional component caused by geology.
(b) A high frequency component due to variations in source and receiver coupling.

Correction for high frequency amplitude variations involves two phases:

(1) An offset term correcting for regional amplitude decay with increasing offset.
(2) A surface consistent term correcting for the high frequency component.

Surface consistent amplitude correction was computed and applied after surface consistent deconvolution and 1st pass surface consistent residual statics. The amplitude vs. offset gain curve was derived for each line and applied before SC amplitude corrections for source and receiver were calculated on each line using time window 400ms-3500ms.

4.7.2 Velocity analysis (2nd Pass)

2nd pass velocity analysis were done every 1km after 1st pass residual statics. Each analysis location comprised of 35 CMPs stacked with 60 velocity functions about a central function. Optimum velocity functions were selected from mini-stacks comprised 35 CMPs stacked with the 60 velocity functions, NMO corrected gathers of the central CMP, and a contoured semblance display based on the power of stack.

4.7.3 Surface consistent residual statics (2nd Pass)

2nd pass of residual statics was calculated after 2nd pass of velocity analysis. Time window 400ms - 2500ms was used to calculate the residual statics.
4.7.4 Frequency dependent RNA in CDP domain
Random noise attenuation (for noise bursts) was performed in CDP domain where alternate CDP gathers were flipped back-to-back. This allowed denoising of the near and far traces at the edges. 1 pass of CGG module SPARC and 1 pass FDNAT modules were used for it and the whole frequency range was targeted for the RNA.

4.7.5 Frequency dependent RNA in offset domain
Random noise attenuation (also for noise bursts) to improve S/N ratio was performed in offset domain by sorting the data in offset classes. 1 pass of SPARC and 1 pass of CADZO filtering were used for this stage and the whole frequency range was targeted for the RNA.

4.8 DMO & Bin Regularisation

4.8.1 2D regularization and trace interpolation
2D regularization and trace interpolation was tested in offset classes. The data was divided in 240 offset classes in the interval of 25m. CGG module REG2D was used for this regularization. In REG2D input data are processed in spatial blocks and merge into the output flow with a taper. The regularization was performed in the CDP and offset domains. As an alternative 2D Kirchhoff DMO was also tested to perform dip-moveout corrections as well to harmonise the offset bins. It was decided to use the DMO option for production. The DMO was reversed prior to PSTM.

4.8.2 Radon demultiple
Radon Demultiple typically removes multiples characterized as events with a slower velocity than the primary events. Testing comprises of identifying the ideal difference in move-out between multiples and primaries. The following diagram shows the typical parameters of the HR Radon transform.

The values of DTMIN & DTMAX define the parabolic transform range, and DT the increment between p-traces. Typically, these values are reduced to decrease the runtime of the production while ensuring no quality is lost. However, with technology available today, there is no need to make any compromise, and hence the best of these parameters are used. The DTCUT parameter defines the difference in
moveout between multiple and primary once an NMO correction has been applied. Radon demultiple was tested with application from time 700ms with a taper of 200ms with DTCUT 150ms with DTMIN $-$100ms and DTMAX 5000ms. The radon demultiple result but did not show much improvement to the data and it was not used in production.

### 4.9 Imaging

#### 4.9.1 Migration velocity analysis
Migration velocity analysis was done on migrated gathers. The dips used for the migration was $60^\circ$ @ 0ms, $60^\circ$ @ 500ms, $65^\circ$ @ 2000ms and $75^\circ$ @ 5000ms dip and an aperture of 6000m.
Migration velocity analysis was done at a CDP interval of 500m.

#### 4.9.2 Pre-STM
Migration velocities for each line were smoothed for Pre-PSTM. Diplimit was fixed at $90^\circ$ @ 0-5000ms. A time variant aperture of 750m @ 0ms, 5000m@2000ms and 8000m@5000ms was used for the production pstm. The pstm was run in 25m offset classes after reversing the DMO applied in the previous step. Details of pstm parameter testing done on line 02 can be found in the following technote: [TESTING\TN06_Line02_PSTM_parameter_tests.pptx](TESTING\TN06_Line02_PSTM_parameter_tests.pptx)

#### 4.9.3 Residual velocity analysis
After PSTM production the migration velocity field was removed and velocities were repicked in order to improve the stacking response. This was done by use of high density automatic bispectral velocity picking using the module HDPIC.
In HDPIC two orthogonal attributes are picked rather than the conventional 2$^\text{nd}$ and 4$^\text{th}$ order velocities. The attributes picked are the time delay between near and far offsets “dtn” and the intercept of the shifted hyperbola “$\tau_0$”. Simple algebra converts these to velocity (Vrms) and anellipticity (Eta) fields. These parameters are uncorrelated and can be subsequently filtered separately.
The pstm velocity field is the reference velocity. This reference velocity field along with user defined maximum and minimum values of velocity and anellipticly, are used to define the 2D picking corridor used by HDPIC. A $50^\circ$ angle mute was applied for the picking.
Output of HDPIC are raw residual Vrms and Eta fields. These are subsequently filtered using geostatistical methods to define a smooth residual Vrms and Eta field and are combined with the reference fields to output a new Vrms and Eta field for every CDP.

#### 4.9.5 Time-variant Trim(flattening) statics
CGG module FLATN was was used for this process. Trace to trace differential statics are picked on nmo-corrected gathers. The program cross-correlates data in a short window around a given time-sample. This is done by sliding along the offset direction, using 5 trace groups with a 1 trace slide.
Details of RMO & trim statics testing done on line 02 can be found in the following technote: [TESTING\TN07_AMADEUS_2D_RMO_and_TVtrim_statics.ppt](TESTING\TN07_AMADEUS_2D_RMO_and_TVtrim_statics.ppt)

#### 4.9.6 Pre-stack automatic gain correction (AGC)
Final PSTM stacks was created with pre-stack AGC. Pre-stack AGC gates applied were 500ms @ time 0ms-5000ms.
5.0 Stack

5.0.1 Stacking mute
The following outer XT was applied for all lines with the exception of line 03 & line 09.
The outer XT mute was:

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<th>Offset (m)</th>
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<tr>
<td>333</td>
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The space-variant outer XT mute for line 03
CDP(SOL-2000) CDP(2100-EOL)

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<th>Time (ms)</th>
<th>Offset (m)</th>
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<td>6000</td>
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The space-variant outer XT mute for line 09
CDP(SOL-1500) CDP(1700-2800)

<table>
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5.0.2 Stack
The data was stacked using 1/n stack compensation. Nominal fold was 240.

5.0.3 Static correction to final datum
Static correction to final datum was made by applying the regional CDP floating datum statics component. The final datum for all datasets is 500m flat datum with a replacement velocity of 2000m/s.
To avoid losing data above datum a 100ms downward time shift was also applied. Output record length was 5100ms for the stacks.
5.1 Poststack

5.1.1 Random Noise Attenuation

CGG module SPARN (projective filtering in FX domain) was tested for random noise attenuation. Three different options with increasing efficiency were analysed. As all versions were found to ‘harm’ data, it was decided not to apply any post-stack RNA. Details can be found in following technote:

TESTING\TN08_AMADEUS_2D_Post_stack_RNA_test.ppt

5.1.3 Time variant filter

Various inclusive panels covering the full sweep bandwidth were looked at. The following TVF was applied for all lines to produce an additional final stack data set. Butterworth filter:

- (15, 18, 80, 72) @ 0ms-1200ms
- (8, 18, 60, 72) @ 1500ms-3000ms
- (8, 18, 50, 72) @ 3500ms-5100ms

Details can be found in following technote:

TESTING\TN09_AMADEUS_2D_Post_stack_Filter_test.ppt

5.1.4 Time variant Scaling

Post stack scaling was tested by application of the following options:

1. Single window – whole trace
2. 500ms overlapping windows – 50% overlap
3. 1000ms overlapping windows – 50% overlap
4. Adaptive AGC with 1000ms long window & 400ms short window

The decision was not to apply any post-stack scaling as no improvement was noticed. Details can be found in following technote:

TESTING\TN10_AMADEUS_2D_Post_stack_Scale_test.ppt

5 Final Products

5.1 Archive SEGY Stacks

The following deliverables were archived and sent to Santos:

- Final PSTM full stack
- Final PSTM full stack with TVF

5.2 Archive ASCII files

- The following deliverables were archived and sent to Santos
- Elevation Statics
- Refraction Statics
- Residual Statics (sum of all iterations)
- Final Statics (all together)
- Final velocity dataset
- Processing Report (MS Word)
6 Conclusions and Recommendation
The processing of the Amadeus 2D did take much longer than expected. A lot of time was spent in trying to improve the imaging of events in the poor S/N ratio areas termed as “dim zones” which had poor reflectivity. The final products delivered did show reasonably good imaging in these areas.

7 Personnel

7.1 CGG Personnel
Project Leader – Raj Pillai
Geophysicist – Katy Sutherland

7.2 Santos Personnel
Sergey Vlasov from Santos supervised the processing of this survey.

8 Appendix

8.1 Amadeus 2D line list

<table>
<thead>
<tr>
<th>Line</th>
<th>Min VP</th>
<th>Max VP</th>
<th>Min CDP</th>
<th>Max CDP</th>
<th>Line KM</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMSAN13B-01</td>
<td>1960</td>
<td>16515</td>
<td>1000</td>
<td>29459</td>
<td>363.88</td>
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<td>AMSAN13B-02</td>
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<td>4814</td>
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<td>8565</td>
<td>87.35</td>
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<td>1000</td>
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<td>1000</td>
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<td>AMSAN13B-09</td>
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<td>8776</td>
<td>101.45</td>
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<td>1746</td>
<td>1000</td>
<td>2490</td>
<td>18.65</td>
</tr>
</tbody>
</table>

Note that the Line km here is calculated from the distance between the first and last Shot station.
8.2 SEGY header byte positions

SEGY header byte positions of archived stacks

<table>
<thead>
<tr>
<th>Description</th>
<th>Bytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequential trace count within a line</td>
<td>5-8</td>
</tr>
<tr>
<td>CDP number</td>
<td>21-24</td>
</tr>
<tr>
<td>Bin fold</td>
<td>33-34</td>
</tr>
<tr>
<td>CMP x coordinate</td>
<td>73-76</td>
</tr>
<tr>
<td>CMP y coordinate</td>
<td>77-80</td>
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<tr>
<td>Source refraction static correction</td>
<td>99-100</td>
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<tr>
<td>Receiver refraction static correction</td>
<td>101-102</td>
</tr>
<tr>
<td>Total statics</td>
<td>193-194</td>
</tr>
<tr>
<td>Regional static correction</td>
<td>233-236</td>
</tr>
<tr>
<td>Shot elevation</td>
<td>45-48</td>
</tr>
<tr>
<td>Receiver elevation</td>
<td>41-44</td>
</tr>
<tr>
<td>Elevation scalar</td>
<td>69-70</td>
</tr>
<tr>
<td>Shot point number</td>
<td>17-20</td>
</tr>
<tr>
<td>Receiver number</td>
<td>195-196</td>
</tr>
<tr>
<td>Line number</td>
<td>9-12</td>
</tr>
</tbody>
</table>

8.3 Sample SEGY EBCIDIC Header

8.3.1 SEGY Headers of PSTM stack

COMMENT
CLIENT : SANTOS      SURVEY : SOUTH AMADEUS 2D PROCESSING
COMPANY : CGG        DATE : JULY 2013
DATA : FINAL PSTM STACK
TRACE LENGTH: 5100 MS
LINE NUMBER: AMSAN13B-#1#  SAMPLE RATE : 4 MS FORMAT : SEGY FORMAT 32BIT
SPHERIOD:GRS80        PROJECTION:UTM-53    GEODETIC DATUM:GDA94
ACQUISITION PARAMETERS:
FORMAT:SEGD SWEEP FREQ:#14# #15# HZ SWEEP LENGTH:8 SECS CHANNELS:480 SYMM SPLIT
FOLD:240 SOURCE:VIBROSEIS SHOT INT:25M RECEIVER INT25M
SEGY BYTE INFO:
BYTES 009-012 = LINE NUMBER  BYTES 017-020 = SHOTPOINT NUMBER
BYTES 021-024 = CMP NUMBER  BYTES 033-034 = STACKING FOLD
BYTES 081-084 = BIN X  BYTES 085-088 = BIN Y
BYTES 041-044 = RECEIVER ELEVATION(M)
BYTES 045-048 = SHOT ELEVATION(M) BYTES 099-100 = SRC REF STATIC
BYTES 101-102 = RCV REF STATIC BYTES 193-194 = TOTAL STATIC
BYTES 109-110 = TIME OF FIRST SAMPLE
BYTES 233-236 = REGIONAL STATICS (TO SHIFT FROM FDP TO DATUM)
STATICS DATUM = 500m, REPLACEMENT VELOCITY = 2000 m/sec,
BULK SHIFT = 100ms DOWNSHIFT
PROCESSING PARAMETERS:
1.REFORMAT TO CGG FORMAT
2.GEOMETRY MERGE WITH SEISMIC
3.MINIMUM PHASE CORRECTION AND RESAMPLE TO 4 MS
4.SPHERICAL DIVERGENCE CORRECTION
5.DESPIKE
6.LINEAR NOISE ATTENUATION (AGORA - SHOT AND RECEIVER DOMAIN)
7.SPIKING DECONVOLUTION - SURFACE CONSISTENT(OP 200ms, W300ms-3000ms)
8.STATICS CORRECTION TO FLOATING DATUM - REFRACTION STATICS NEW VR AND SRD
9.1ST PASS VELOCITY ANALYSIS 10.1ST PASS RESIDUAL STATICS(W 300MS-2500MS)
11. SURFACE CONSISTENT AMPLITUDE CORRECTIONS
12. VELOCITY ANALYSIS 2ND PASS  13. RESIDUAL STATICS 2ND PASS (W 300MS-2500MS)
14. DENOISE CDP AND OFFSET DOMAIN
15. PRESTACK KIRCHHOFF FW & RV DMO (25M OFFSET CLASSES-NOMINAL 240 FOLD)
16. PRESTACK KIRCHHOFF MIGRATION (IN OFFSET CLASSES)
17. HIGH DENSITY VELOCITY ANALYSIS (RMO WITH ANISOTROPIC CORRECTIONS)
18. CDP CONSISTENT TIME VARIANT TRIM STATICS
19. PRESTACK SCALING (500MS), MUTE (XT MUTE) AND STACK
20. REGIONAL STATICS - FLOATING DATUM TO 500M DATUM WITH 100ms DOWNSHIFT
ENDCOM

8.3.2 SEGY Headers of PSTM stack with TVF

COMMENT
CLIENT : SANTOS  SURVEY : SOUTH AMADEUS 2D PROCESSING
COMPANY : CGG  DATE : JULY 2013
DATA : FINAL PSTM STACK WITH TVF
TRACE LENGTH : 5100 MS
LINE NUMBER: AMSAN13B-#1#  SAMPLE RATE : 4 MS  FORMAT : SEGY FORMAT 32BIT
SOURCES : CMP NUMBER    STACKING FOLD
SEGY BYTE INFO:
BYTES 009-012 = LINE NUMBER    BYTES 017-020 = SHOTPOINT NUMBER
BYTES 021-024 = CMP NUMBER    BYTES 033-034 = STACKING FOLD
BYTES 081-084 = BIN X    BYTES 085-088 = BIN Y
BYTES 041-044 = RECEIVER ELEVATION (M)
BYTES 045-048 = SHOT ELEVATION (M)
BYTES 101-102 = RCV REF STATIC
BYTES 109-110 = TIME OF FIRST SAMPLE
BYTES 233-236 = REGIONAL STATICS (TO SHIFT FROM FDP TO DATUM)
STATICS DATUM = 500m, REPLACEMENT VELOCITY = 2000 m/sec,
BULK SHIFT = 100ms DOWNSHIFT
PROCESSING PARAMETERS:
1. REFORMAT TO CGG FORMAT
2. GEOMETRY MERGE WITH SEISMIC
3. MINIMUM PHASE CORRECTION AND RESAMPLE TO 4 MS
4. SPHERICAL DIVERGENCE CORRECTION
5. DESPIKE
6. LINEAR NOISE ATTENUATION (AGORA - SHOT AND RECEIVER DOMAIN)
7. SPIKING DECONVOLUTION - SURFACE CONSISTENT (OP 200ms, W300ms-3000ms)
8. STATICS CORRECTION TO FLOATING DATUM - REFRACTION STATICS NEW VR AND SRD
9. 1ST PASS VELOCITY ANALYSIS 10. 1ST PASS RESIDUAL STATICS (W 300MS-2500MS)
11. SURFACE CONSISTENT AMPLITUDE CORRECTIONS
12. VELOCITY ANALYSIS 2ND PASS  13. RESIDUAL STATICS 2ND PASS (W 300MS-2500MS)
14. DENOISE CDP AND OFFSET DOMAIN
15. PRESTACK KIRCHHOFF FW & RV DMO (25M OFFSET CLASSES-NOMINAL 240 FOLD)
16. PRESTACK KIRCHHOFF MIGRATION (IN OFFSET CLASSES)
17. HIGH DENSITY VELOCITY ANALYSIS (RMO WITH ANISOTROPIC CORRECTIONS)
18. CDP CONSISTENT TIME VARIANT TRIM STATICS
19. PRESTACK SCALING (500MS), MUTE (XT MUTE) AND STACK
20. TVF - 15-80HZ (0-1200MS)/8-60HZ (1500-3000MS)/8-50HZ (3500-5000MS)
21. REGIONAL STATICS - FLOATING DATUM TO 500M DATUM WITH 100ms DOWNSHIFT
ENDCOM
8.3.3 SEGY Headers of PSTM GATHERS

COMMENT
CLIENT : SANTOS   SURVEY : SOUTH AMADEUS 2D PROCESSING
COMPANY: CGG   DATE : JULY 2013
DATA : PSTM GATHERS
TRACE LENGTH: 5000 MS
LINE NUMBER: AMSAN13B-#1# SAMPLE RATE : 4 MS FORMAT : SEGY FORMAT 32BIT
SPHERIOD:GRS80   PROJECTION:UTM-53   GEODETIC DATUM:GDA94
ACQUISITION PARAMETERS:
FORMAT:SEGD SWEEP FREQ:#14#-#15# HZ SWEEP LENGTH:8 SECS CHANNELS:480 SYMM SPLIT
SEGY BYTE INFO:
BYTES 009-012 = LINE NUMBER   BYTES 017-020 = SHOTPOINT NUMBER
BYTES 021-024 = CMP NUMBER   BYTES 037-040 = SHOT-RECEIVER OFFSET
BYTES 041-044 = RECEIVER ELEVATION(M)   BYTES 045-048 = SHOT ELEVATION(M)
BYTES 099-100 = SHOT REFRACTION STATIC
BYTES 101-102 = RECEIVER REFRACTION STATIC
BYTES 233-236 = REGIONAL STATICS (TO SHIFT FROM FDP TO DATUM)
STATICS DATUM = 500m, REPLACEMENT VELOCITY = 2000 m/sec,
PROCESSING PARAMETERS:
1.REFORMAT TO CGG FORMAT
2.GEOMETRY MERGE WITH SEISMIC
3.MINIMUM PHASE CORRECTION AND RESAMPLE TO 4 MS
4.SPHERICAL DIVERGENCE CORRECTION
5.DESPIKE
6.LINEAR NOISE ATTENUATION (AGORA - SHOT AND RECEIVER DOMAIN)
7.SPIKING DECONVOLUTION - SURFACE CONSISTENT(OP 200ms, W300ms-3000ms)
8.STATICS CORRECTION TO FLOATING DATUM - REFRACTION STATICS NEW VR AND SRD
9.1ST PASS VELOCITY ANALYSIS 10.1ST PASS RESIDUAL STATICS(W 300MS-2500MS)
11.SURFACE CONSISTENT AMPLITUDE CORRECTIONS
12.VELOCITY ANALYSIS 2ND PASS 13. RESIDUAL STATICS 2ND PASS(W 300MS-2500MS)
14.DENOISE CDP AND OFFSET DOMAIN
15.PRESTACK KIRCHHOFF FW & RV DMO (25M OFFSET CLASSES-NOMINAL 240 FOLD)
16.PRESTACK KIRCHHOFF MIGRATION (IN OFFSET CLASSES)
17.HIGH DENSITY VELOCITY ANALYSIS (RMO WITH ANISOTROPIC CORRECTIONS)
18.CDP CONSISTENT TIME VARIANT TRIM STATICS
19.OUTPUT PSTM GATHERS WITH NMO 20. DATA TO SEGY
ENDCOM

8.3.4 SEGY Headers of RAW SHOT GATHERS

COMMENT
CLIENT : SANTOS   SURVEY : SOUTH AMADEUS 2D PROCESSING
COMPANY: CGG   DATE : JULY 2013
DATA : RAW SHOT GATHERS (AFTER IDENT)
TRACE LENGTH: 5000 MS
LINE NUMBER: AMSAN13B-#1# SAMPLE RATE : 2 MS FORMAT : SEGY FORMAT 32BIT
SPHERIOD:GRS80   PROJECTION:UTM-53   GEODETIC DATUM:GDA94
ACQUISITION PARAMETERS:
FORMAT:SEGD SWEEP FREQ:#14#-#15# HZ SWEEP LENGTH:8 SECS CHANNELS:480 SYMM SPLIT
SEGY BYTE INFO:
BYTES 009-012 = FIELD REC NO   BYTES 017-020 = SP NUMBER
BYTES 021-024 = CMP NUMBER
BYTES 149-152 = CMP X
BYTES 153-156 = CMP Y
BYTES 037-040 = SHOT-RECEIVER OFFSET
BYTES 073-076 = SHOT X
BYTES 077-080 = SHOT Y
BYTES 041-044 = RECEIVER ELEVATION(M)
BYTES 081-084 = RECEIVER X
BYTES 085-088 = RECEIVER Y
BYTES 101-102 = RECEIVER REFRACTION STATIC
BYTES 045-048 = SHOT ELEVATION(M)
BYTES 099-100 = SHOT REFRACTION STATIC
BYTES 086-089 = RECEIVER NO
BYTES 065-068 = RECEIVER NO
BYTES 197-200 = LINE NUMBER
BYTES 233-236 = REGIONAL STATICS (TO SHIFT FROM FDP TO DATUM)

STATICS DATUM = 500m, REPLACEMENT VELOCITY = 2000 m/sec,

PROCESSING PARAMETERS:
1. REFORMAT TO CGG FORMAT
2. GEOMETRY MERGE WITH SEISMIC
3. DATA TO SEGY
ENDCOM

8.4 List of Figures-AMSAN13B-02

Fig 8.5.01 AMSAN13B-02 RAW GATHERS after geometry merge
Fig 8.5.02 AMSAN13B-02 GATHERS after spike editing
Fig 8.5.03 AMSAN13B-02 GATHERS after spike editing & LNA
Fig 8.6.01 AMSAN13B-02 STACK after geometry merge (with elevation correction statics)
Fig 8.6.02 AMSAN13B-02 STACK after Trace edits & LNA (with elevation correction statics)
Fig 8.6.03 AMSAN13B-02 STACK after SC Deconvolution (with elevation correction statics)
Fig 8.6.04 AMSAN13B-02 STACK after SC Deconvolution (with modelled refraction statics)
Fig 8.6.05 AMSAN13B-02 STACK after 1st pass Residual Statics
Fig 8.6.06 AMSAN13B-02 STACK after 2nd Pass velocities & 2nd Pass Residual Statics
Fig 8.6.07 AMSAN13B-02 STACK after Denoising in cdp & offset domains
Fig 8.6.08 AMSAN13B-02 STACK after Kirchhoff FW DMO (25 m offset classes)
Fig 8.6.09 AMSAN13-02 STACK after Kirchhoff RV DMO followed by Kirchhoff PSTM
Fig 8.6.10 AMSAN13-02 PSTM STACK after RMO(residual moveout) & CMP trim statics
8.5 Sample Shots – AMSAN13B-02

Fig 8.5.01 AMSAN13B-02 RAW GATHERS after geometry merge

Fig 8.5.02 AMSAN13B-02 GATHERS after spike editing
Fig 8.5.03 AMSAN13B-02 GATHERS after spike editing & LNA
8.6 Sample Line stacks – AMSAN13B-02

Fig 8.6.01 AMSAN13B-02 STACK after geometry merge (with elevation correction statics)

Fig 8.6.02 AMSAN13B-02 STACK after Trace edits & LNA(with elevation correction statics)
Fig 8.6.03 AMSAN13B-02 STACK after SC Deconvolution (with elevation correction statics)

Fig 8.6.04 AMSAN13B-02 STACK after SC Deconvolution (with modelled refraction statics)
Fig 8.6.05 AMSAN13B-02 STACK after 1st pass Residual Statics

Fig 8.6.06 AMSAN13B-02 STACK after 2nd Pass velocities & 2nd Pass Residual Statics
Fig 8.6.07 AMSAN13B-02 STACK after Denoising in cdp & offset domains

Fig 8.6.08 AMSAN13B-02 STACK after Kirchhoff FW DMO (25 m offset classes)
Fig 8.6.09 AMSAN13-02 STACK after Kirchhoff RV DMO followed by Kirchhoff PSTM

Fig 8.6.10 AMSAN13-02 PSTM STACK after RMO(residual moveout) & CMP trim statics