Pre Stack Merging of 3D Land and OBC (3D-2C) Transition zone data – A Case history from Ramnad sub basin, India

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Key words

Pre-stack Merging, Ocean bottom cable (OBC), PZ summation, Regularization

Abstract

This work discusses practical aspects of merging multi-vintages of seismic 3D Land and OBC (3D-2C) surveys. These 3D surveys were acquired during various field seasons and different parties using different equipment's. The reprocessing project comprises pre-stack merging of seismic data followed by pre-stack time migration of five seismic vintages. The final workflow and methodology presented in this work were designed based on several tests carried out at each processing step. The reprocessing of the data was carried out to improve seismic imaging at Nannilam, Bhuvangiri, Andimadam & basement levels.

Introduction

Ramnad sub-basin and its continuation in Palk Bay-Gulf of Mannar area are bounded in the northwest by Pattukottai - Mannargudi ridge and in the southeast by Mandapam-Delft ridge. The sub basin holds over 6000m thick sediments, ranging in age from Lower Cretaceous to Recent. The synrift sedimentary column comprises mainly shale and sandstone in the Andimadam Formation and Sattapadi Shale Formation. Sag phase sedimentation, represented by the upper Cretaceous Bhuvanagiri, Kudavasal Shale, Nannilam, Porto Novo shale is predominantly alternations of sand and shale with minor limestone development. This is overlain by major part of the passive margin sequences ranging from Paleocene to Recent that were deposited on shelf slope regime with eastward shifting coast line. The siliciclastic sequences of the passive margin stage are interspersed with major limestone intervals corresponding to Eocene and Miocene periods.

Present case study involves the pre stack merging of different data sets acquired in Land and Transition zones of Ramnad Palk Bay tectonic block of Cauvery basin. Figure - 1 shows location map of the area.

Figure - 1: Location map of survey areas

Challenges

The land data of Ramnad area was acquired by various Geophysical field crews during different field seasons using SM24 Geophones and ION recording system. Whereas 3D-2C OBC transition zone data of Palk-Bay in the east coast of India was acquired using different sensor types (Geophones, Hydrophones and Dual sensors), different sources (Explosives & Airguns) and SERCEL 428XL recording system. Table 1 shows acquisition parameters of five volumes. Figures - 2 & 3 shows the scheme of shots and different sensors used in OBC data acquisition. Figure - 4 shows the shot gather with different sensor types.

SIG No. / Field Season	RAMNAD (LAND)-A	RAMNAD (LAND)-B	RAMNAD (LAND)-C	RAMNAD (LAND)-D	Palk Bay 3D OBC-2C (Land / Marine)
Type of shooting	End on-Orthogonal	End on-Orthogonal	End on-Orthogonal	End on-Orthogonal	Central-Orthogonal
Shooting direction	SW-NE	SW-NE	SW-NE	SW-NE	-
Bin size (mXm)	20X20	20X20	20X20	20X20	12.5X12.5
Foldage	70 (7*10)	70 (7*10)	70 (7*10)	70 (7*10)	92
GI (m) / SI (m)	40 / 40	40 / 40	40 / 40	40 / 40	25 / 25
RLI (m)	360	360	360	360	450
SLI (m)	320	320	320	320	300 / 150
No. of Receiver lines	14	14	14	14	4 / 8
Channels per line	160	160	160	160	540
No. of Channels	2240	2240	2240	2240	2208 / 4416
Near offset (m)	100	100	100	100	18
Far offset (m)	6400	6400	6400	6400	6977 / 7116
Receiver Type	SM-24 Geophone	SM-24 Geophone	SM-24 Geophone	SM-24 Geophone	SG-10 Geophone, P-44 Hydrophone & ZF-44 Dual Sensor
Source Type	Explosive	Explosive	Explosive	Explosive	Explosive & Airgun
Seismograph	I/O Scorpion	I/O Scorpion	I/O Scorpion	I/O Scorpion	SERCEL 428XL
Recording Format	IO-SEG Y	IO-SEG Y	IO-SEG Y	IO-SEG Y	SEGD 8058
Record Length (Sec)	10	10	7	7	6
Sampling Rate (ms)	2	2	2	2	2

Table - 1. Acquisition parameters of five volumes

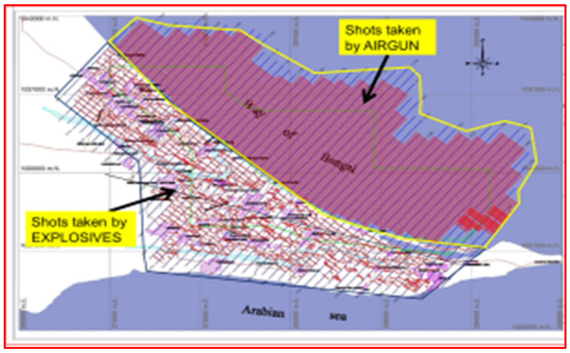

Figure - 2: Scheme of source types used in OBC acquisition.

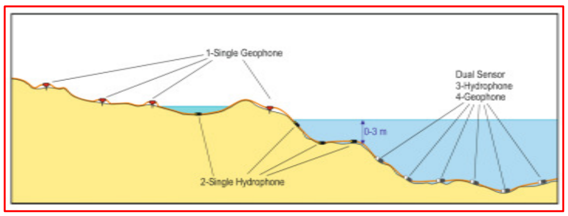

Figure - 3: Scheme of receiver types used in OBC acquisition.

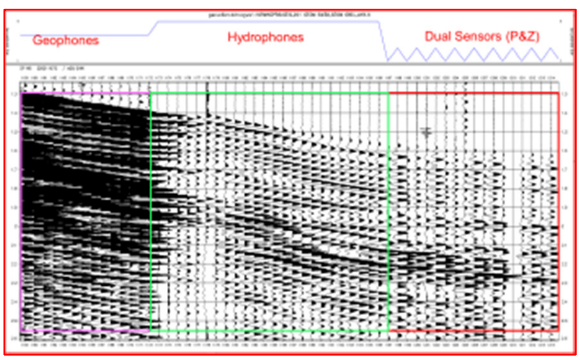

Figure - 4: Raw shot gather with different sensors

The main challenges in the data processing were PZ summation of dual sensors and wavelet matching for different sources, receivers and instruments. Broadly, the processing steps included PZ summation and standard signal conditioning with special care to noise attenuation for improving event coherency maintaining the geological objectives.

Processing work Flow

Ramnad and OBC field data were converted into internal format and polarity of data of all the volumes was analyzed. It was found that the first break energy is appearing as trough in all data sets. Geometry was defined with respective bin sizes. Field statics and Spherical divergence correction were applied on the data. Figure - 5 shows combined brute stack of all the volumes.

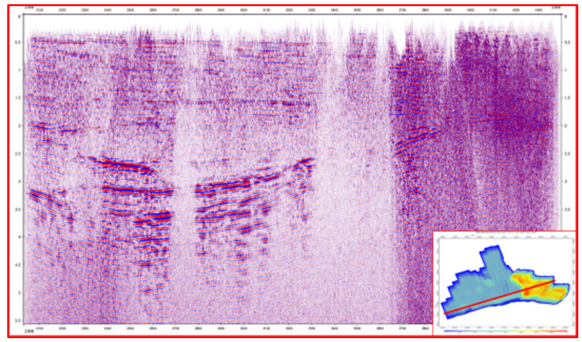
Figure - 5: Brute stack all five volumes

Further processing steps were divided into two phases. In first phase, both the data sets were individually processed for signal conditioning and wavelet matching.

Second phase, two datasets were combined with master grid for further processing. Figures - 6a & 6b shows processing flow adopted.

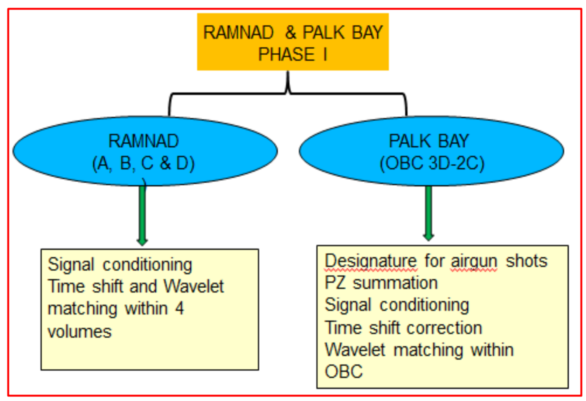

Figure - 6a: Processing flow chart-1

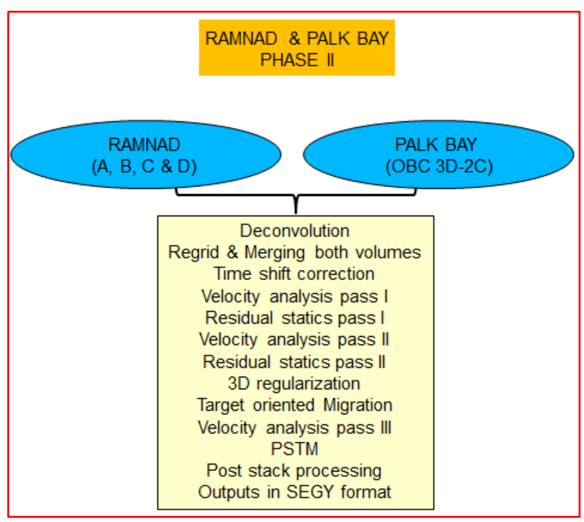

Figure - 6b: Processing flow chart-2

Phase - 1

1.1 Signal Conditioning of Ramnad land data

a. Denoise

Noise strips, spikes, random and frequency dependent noise were suppressed extensively using De-spike, Frequency Dependent Noise Attenuation technique and Coherent noise attenuation and signal enhancement tool for Ramnad data sets.

b. Time Shift and Wavelet matching within Ramnad Land data

No time shift was found between four volumes of Ramnad. Four volumes of RAMNAD were acquired with same recording instruments, same sources and receivers. No phase difference was observed. Figure - 07 shows locations analyzed for matching within Ramnad data. Figure - 08 explains no time shift observed at overlap zones within Ramnad land data.

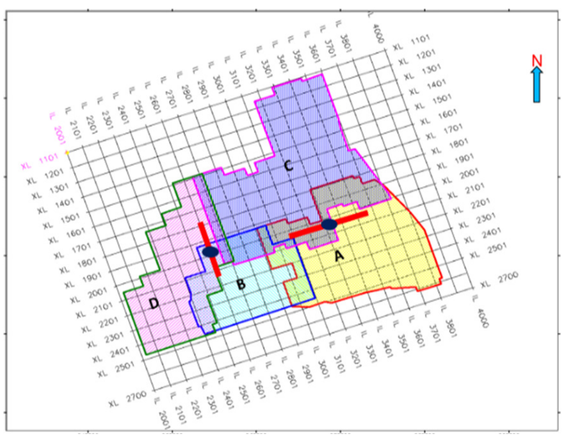

Figure - 7: Locations analyzed for matching within Ramnad land data

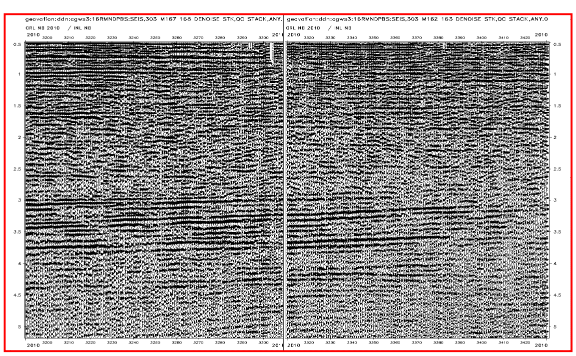
Figure – 8: Stacks at overlap zones showing no time shift between land data

1.2 Conditioning of OBC data

a. Source designature of airgun shots

Air-gun source was used during acquisition of Palk-Bay data in shallow water zones. Deghosting and debubble operator was generated using the far-field signature provided. The operator was applied on shot gathers acquired with air-gun source. Figure - 9 shows stack before and after designature.

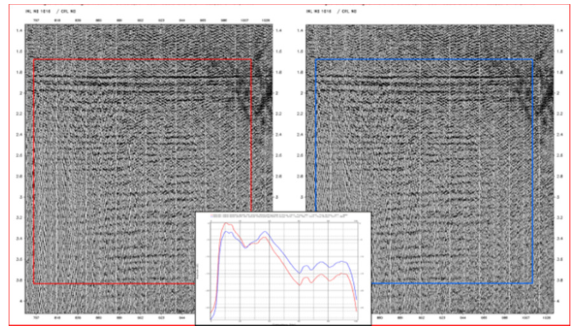
Figure - 9: Stack before and after source designature

b. PZ summation of dual sensors

Data in Palk-Bay area was acquired with three types of sensors single Geophones on land, single hydrophone in shallow water and dual sensors (Geophone and Hydrophone i.e. Pressure component (P) & Vertical component (Z)) in transition zone. The two components P and Z of dual sensors were needed to be summed after calibration to attenuate receiver side ghost and noise. Figure - 10 shows the steps followed for PZ summation.

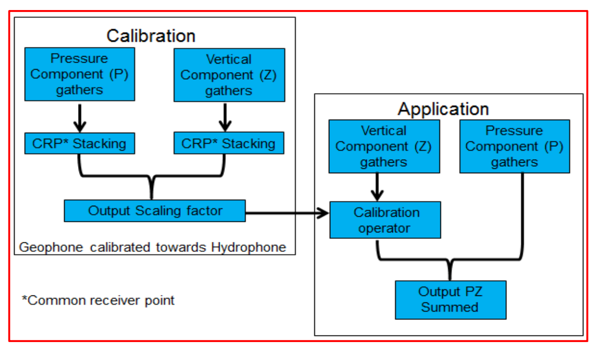

Figure - 10: Steps followed for PZ summation

Data acquired with dual sensors were separated for PZ summation from both land shots and marine shots of the geometry merged gathers of OBC data. The pressure (P) & vertical (Z) components were separated individually & denoised with same parameters. Further both the data were synchronized to check and retain both PZ components exist without duplication in each shot - receiver pair.

Common receiver stacks were generated for both components separately and further denoised for generating calibration operator. Geophone (Z) data was calibrated and matched towards Hydrophone (P) using common receiver stacks and operator was generated for each receiver. Calibration operator was applied on Geophone (Z) data and both components were summed together. Figure - 11 shows the stacks of both components and PZ summed.

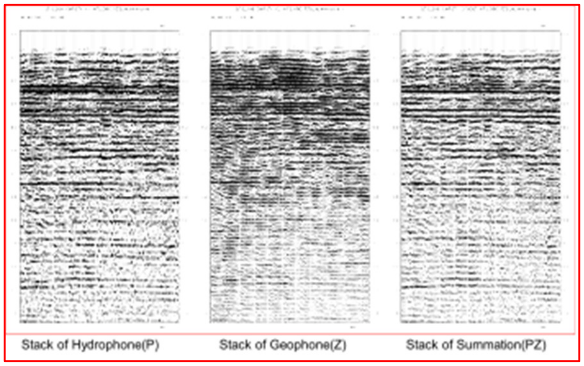

Figure - 11: Stacks of individual components and PZ summed gather

c. Signal Conditioning

Noise strips, spikes, random and frequency dependent noise were suppressed extensively using De-spike, Frequency Dependent Noise Attenuation technique and Coherent noise attenuation and signal enhancement tool for OBC data sets. Figure - 12 shows shot gather before and after noise suppression and difference.

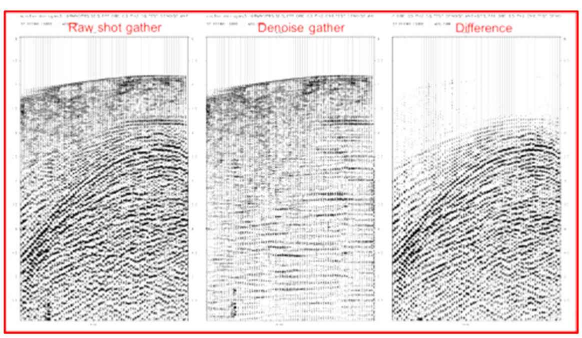

Figure - 12: Raw shot gather before and after denoise with difference

d. Time Shift and Wavelet matching within OBC

After PZ summation, transition zone data had three types of traces: recorded by hydrophones only, PZ summed traces (now having calibrated towards hydrophones), recorded by geophones planted in land area. The hydrophone traces being recorded by an accelerometer were integrated to match with geophone which measures the velocity. Figure - 13 shows the location analyzed for wavelet matching within OBC data. Figure-14 shows input hydrophone trace (left) and the same traces after integration (right). Figure-15 shows an input gather with three weak hydrophone traces (left) & the same traces after integration and scaling (right). Time shift of minus 18 ms (up) was applied on integrated gathers of Hydrophone and PZ summed data to correct the time shift with respect to geophone traces.

Full fold overlap zone did not exist within OBC data for wavelet matching analysis. Hence wavelet matching could not be applied.

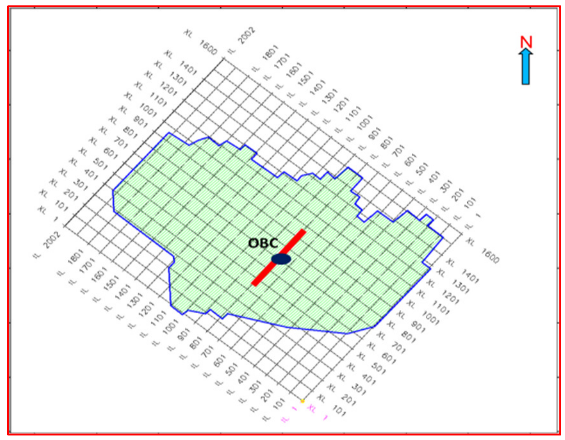

Figure - 13: Locations analyzed for matching within OBC data

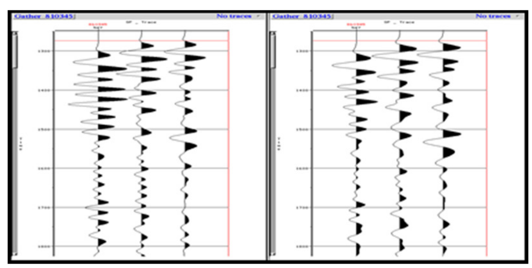

Figure - 14: Input Hydrophone trace (left) & Same traces after integration (right)

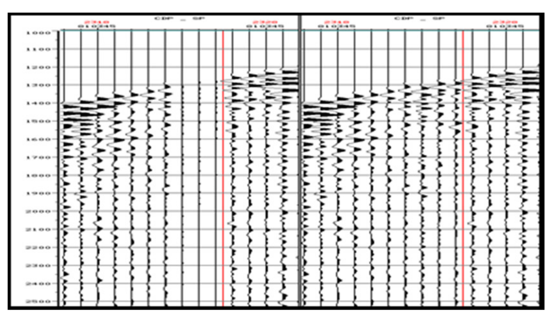

Figure - 15: Input gather with three weak hydrophone traces (left) & same traces after integration and scaling (right)

Phase - 2

2.1 Re-gridding, matching and combining of all volumes

Combined data of all volumes was re-gridded with master grid (bin size of 20mX20m) before deconvolution. The data posed a formidable challenge while attempting the amplitude, phase and static time shifts matching. Stacked data set of volume OBC data overlapping with the reference volume Ramnad was compared in the overlap zone. Figure - 16 shows locations analyzed for wavelet matching between Ramnad and OBC data. Common IL and XL of the overlapping zone were considered and the relative time shift was applied. Observed time shift of plus 12ms (down) was applied on OBC volume. Figures - 17 & 18 show Stack sections of Ramnad land & Palk Bay (OBC) at overlap zones before and after time shift application.

Full fold overlap zone did not exist among Ramnad land and OBC data volumes for wavelet matching analysis. Hence wavelet matching could not be applied.

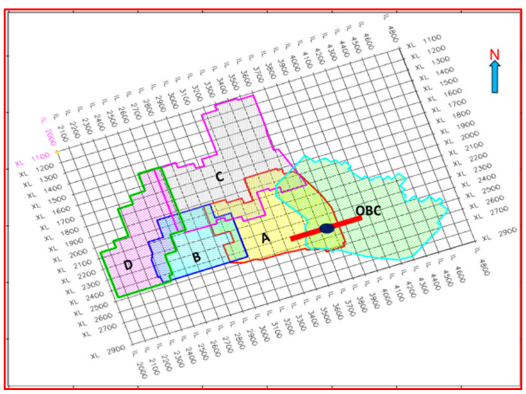

Figure - 16: Locations analyzed for matching between Ramnad and OBC data

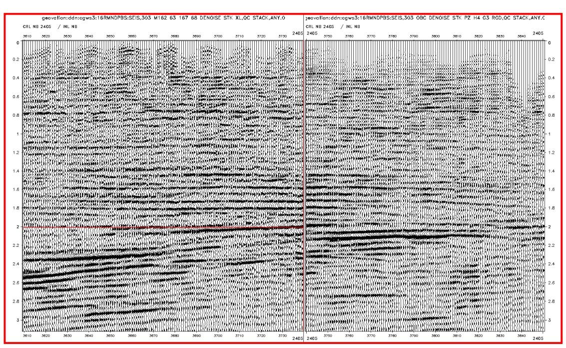

Figure - 17: Stack sections of Ramnad land & Palk Bay (OBC) at overlap zones before time shift application

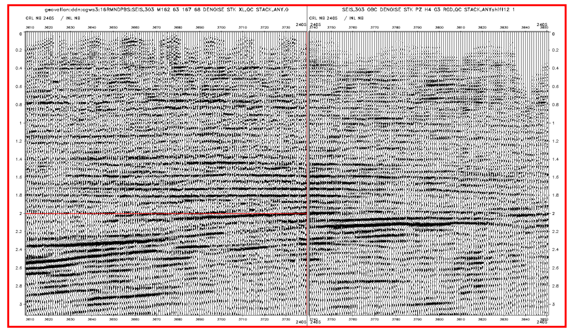

Figure - 18. Stack sections of Ramnad land & Palk Bay (OBC) at overlap zones after time shift application

2.2 Deconvolution

Auto correlation of representative denoised gathers were analyzed and operator length of 240ms was chosen based on the ringing present in auto correlation function. With the operator length of 240ms, Decon stacks were generated with predictive distances of 2ms, 10 ms, 12 ms, 16 ms, 20 ms, 24 ms, 32ms and 40ms for prediction distance(PD) finalization. On the basis of test results, prediction distance of 32ms and operator length of 240ms was adopted and applied on the data as final decon parameters. Band pass filter 2-4-80-90 Hz was applied on the data.

2.3 Velocity Analysis & Residual statics

First velocity analysis was done on Deconvolution applied CMP gathers at an interval of 1000 m x 1000m. Computed velocity volume was used to generate Decon Stacks. First computed velocity volume was used to calculate first pass residual statics. Second pass velocity analysis was carried out in the grid of 1000 m x 1000 m on first pass residual statics applied decon gathers. This refined velocity volume was used for estimation of second pass residual statics. Stack was generated after the application of two passes of residual statics. Residual Stack showed fair degree of improvement as compared to Decon Stack.

2.4 Data Regularization

Residual statics applied gather was taken as input for 3D data regularization. In general, fold varied from 1-320. A few gaps owing to missing near offsets were observed, which necessitated Data Regularization. Considering the fold variation, ninety offset classes were generated. Offset class increment of 80 m was chosen for offsets upto 7200m. Each offset classes were regularized using bin size of 20mX20m. Figure - 19 shows the Fold map before and after regularization. Figure - 20 shows a gather before and after regularization.

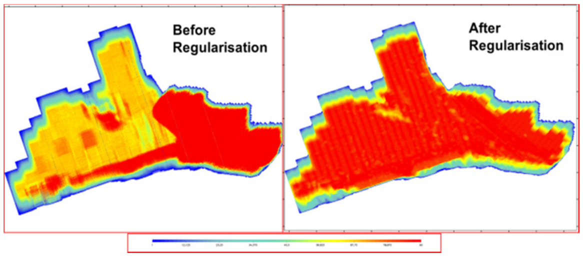

Figure - 19: Fold map before and after regularization

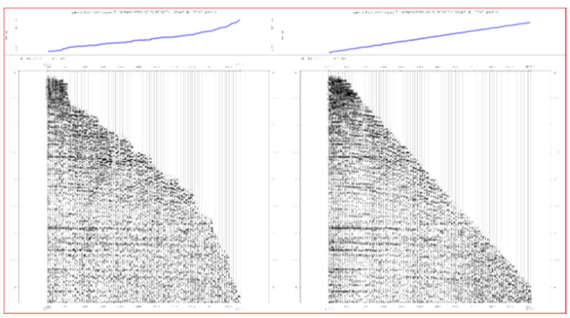

Figure - 20: Shot gather before and after regularization

2.5 Pre Stack Time Migration (PSTM)

Regularized & residual statics applied Decon gathers were used for migration aperture testing. Different migration apertures of 4000, 5000 6000, 7000 & 8000m were tested. The section with aperture of 7000m was optimal; hence it was finalized for production migration with Dip limit of 70°.

Target line time migration was run using smoothed stacking velocity. Gathers were generated for target line at an interval of 500 m. RMS velocity analysis was carried out at 500 m x 500m interval on PSTM gathers. Final PSTM was run for 90 offset classes and PSTM gathers were generated using smoothed RMS velocity. Random noise attenuation was carried out on PSTM gathers.

2.6 Post stack processing

High density velocity and anisotropy picking was carried out at a close grid of 200mX200m for better flattening of PSTM gathers before stacking. Post stack processing on final outputs included random noise attenuation using fx projection filter and acquisition foot print removal in F-kx-ky domain. Final results of PSTM stack & time slice after post stack processing are shown in Figures - 21 & 22.

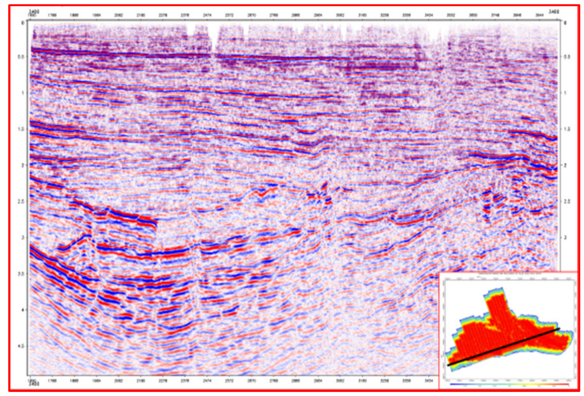

Figure - 21: Final PSTM stack at Crossline 3400

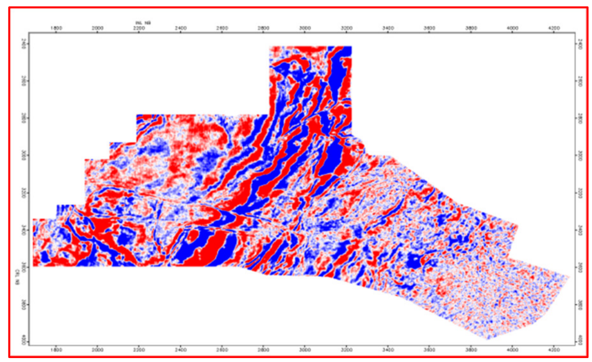

Figure - 22: Time slice at 3100ms

Conclusions

Five vintages of 3D seismic data acquired at Ramnad sub basin including a OBC, were processed for better continuity and fault definition. Broadly, the processing steps included standard signal conditioning followed by pre-stack time migration. Emphasis was given during PZ summation, noise suppression and velocity analysis, which resulted in better imaging of the sub-surface. Irregular offset distributions across bins were effectively accounted for 3D regularization. Kirchhoff Pre-stack time migration with 7000 m as full aperture was used for production PSTM with refined RMS velocities. Post migration processing for random noise suppression and acquisition footprint attenuation was applied to yield final PSTM stack volume.

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Views expressed in this work are entirely of the authors only and do not reflect those of ONGC.

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