3D Seismic Data Merging –A Case History in Indian Context

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SUMMARY

3D Seismic data acquisition & processing has been a dynamic concept since its inception. Initially it was thought of being highly expensive .This is the reason why 3D was being carried out at the development stage of oil and gas fields. Later on the concept of exploration 3D came into being, where the acquisition parameters were relatively crude with respect to the objective of survey thereafter high density 3D survey has come up because of the obvious reason. 4D data acquisition is an extension of 3D. Now considering only the conventional 3D surveys, many of today's exploration areas has been covered with 3D surveys which have been recorded over a period of several years using a wide variety of recording equipment, source types, spread lengths, bin dimensions, grid orientation, fold etc. This data has often been processed using variable levels of processing technology with changing objectives with time. As it is known , the goal of 3D merging is to establish a way to combine these original data sets such that one consolidated 3D volume is produced which simulates, as closely as possible, what would have been produced had all the 3D's been recorded and processed as one project. This present work is intended to match & merge multi surveys (Five surveys carried out by three different service companies) acquired in the shallow waters of western Offshore of India. Here most of the above issues have been addressed meticulously which could enable to arrive at a near perfect match meeting the geologic objectives. A comparison also has been given with the earlier processed (merged) data of same surveys to highlight the importance of decision making while addressing the issues during processing.

Introduction

Over the last two decades, many of our production and key exploration areas have been repeatedly covered with 3D seismic recording programs. In Indian context, both on shore and offshore blocks have been covered by 3D surveys with varying objective in NELP scenario. One of the major problems with any 3D is the fact that it has edges and this means that around these edges our ability to image the subsurface is compromised due to the fact that only a portion of the required recording aperture is actually available. This is further aggravated because most of 3D surveys are of irregular shape because of administrative reason (Fig.1a). If we could some how go back and re-record the data as one enormous project we would gain a significant level of imaging fidelity for several obvious reasons. Of course, this would be a prohibitively expensive process. So we have to find ways to make better use of the existing 3D data sets. Therefore, it has been a compelling necessity to merge the old surveys acquired with a wide range of acquisition parameters. Some of the companies have developed an integrated set of tools to achieve this difficult task either using post stack data, prestack data, or in combination of pre & post stack.

Key Factors For 3D Data merging

The problems involved in merging several 3Ds which have been recorded over a long period of time using widely varying acquisition and processing technology are difficult to overcome. Moreover the E&P companies have also changed their service provider of data acquisition & processing from time to time making the task more challenging. Many of the issues that have to be handled during processing are well known. However before proceeding further the first step is to identify the key issues relating to the existing project. These issues may be:-

- The survey coordinate reference systems are very often different. In that case all coordinates must be transformed to a standardized set of spheroid, datum and projection and it is also important to identify magnitudes and sources of positioning error (random or systematic)
- Bin dimensions of the data sets are often different. Here the first step must be to use a suitable interpolator which is capable of accurately interpolating aliased dips to convert each data set to approximately the same bin dimensions.
- The grid orientation of the data sets may be highly variable. Therefore re-grid has to be done or the data has to be processed on a single grid to obtain a final bin dimensions and grid orientation
- The phase of the data sets does not always match. Because we may be asked to merge 3D's with several different source types such as air gun, dynamite, vibroseis, and so on. Also, we may have different receiver types such as hydrophones, velocity phones, and in the seafloor seismic case we may have summed the data of two sensors to produce receiver and shot de-ghosted data. So a suitable phase matching filter has to be designed to match each data set to a single user chosen data set. But if well data is available the phase can be tied and corrected accordingly.

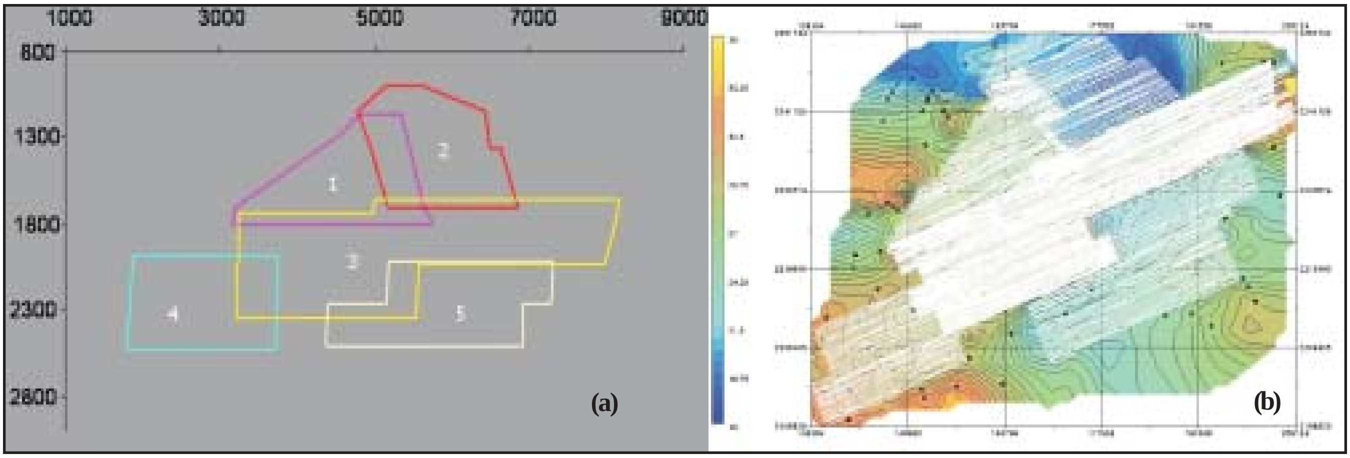


Fig. 1. (a) Displaying all five surveys acquisition grids (b) Displaying data acquisition superimposed on Bathymetry

- The bandwidth and S/N ratio rarely match. We have to adopt suitable procedure to balance the spectral component and use suitable noise attenuators to stabilize the S/N ratio.
- The horizon timing (structural static) does not always match. This may produce mis-tie and therefore need to be carefully handled.
- Key pre-stack processing flow differences may have left variable amount of multiple energy. This leaves challenge for post stack merging.
- The trace amplitude scaling often does not match. The amplitude decay rates of each 3D and smooth amplitude correction functions can be computed to match the overall amplitude levels on each 3D dataset.
- The fold in the overlapping zones does not match. The fold for each trace on the original 3D is interpolated to the new grid location. This fold is then used as a weight for normalization of the summed trace in the stacking phase of the merging process. In this way we can insure that the proper weighting is given to each 3D dataset at each output point so that the overall imaging quality will vary smoothly from one 3D prospect to the next. These problems can be overcome using a systematic, integrated approach. Not all problems can be completely solved. However many can be significantly reduced. The potential for increased value extraction from the original data set is tremendous.

Pre-stack versus post-stack merging

There are several technical advantages to begin the merging process at the original field tape stage. By beginning at the pre-stack stage many of the issues listed above can be directly addressed. Also, if we go back to the pre-stack data we can incorporate full pre-stack migration to offset bins for AVO/AVA analysis as part of the standard flow. However, we may still choose to stack up the original 3D's and use the

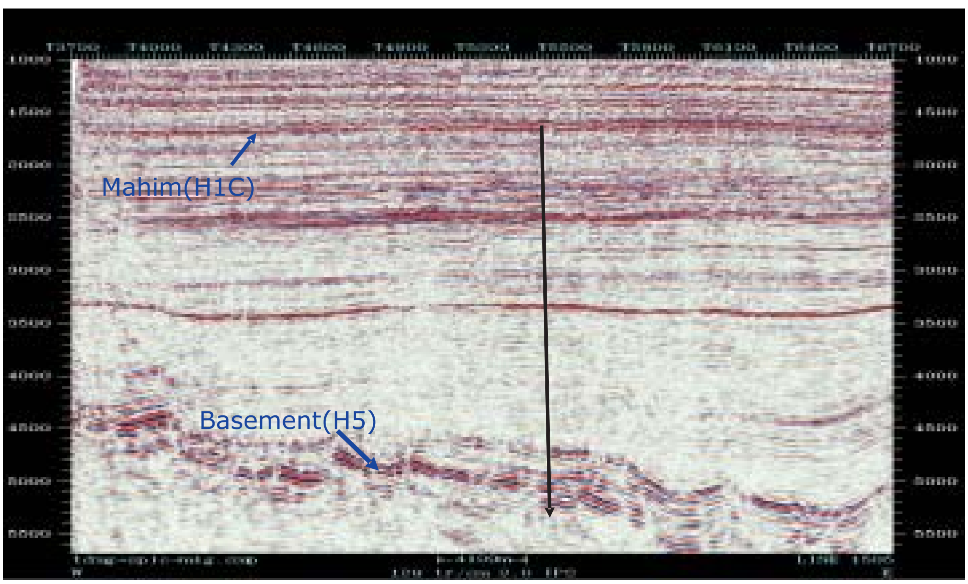


Fig. 2. Geological objective

post stack tool box approach to compute corrections for phase, amplitude spectra and static differences which are then applied back to the pre-stack data (as post stack matching tends to be more stable than pre stack due to the great reduction of noise). But some times oil companies do not have the option to start with original field data. In that case we must do the best we can in the post stack world. Very often, the field data for some of the 3Ds is available and we are asked to begin at the pre-stack stage on a subset of the 3Ds. This is easy to do such that they integrate nicely with the post stack data and it allows us to control the quality of the input on a larger portion of the final single merged 3D data set.

Addressing the Issues of Existing Project

The task here was to integrate (pre stack merging) five different surveys amounting to 70515 LKM data pertaining to the shallow waters (Fig.1b) of west coast of India. The objective was to minimize the variations across the different vintages & visualize the complete data in a single mosaic. The geologic interest was between top of Mahim (H1C) and Basement (H5) formations with time window between 1500 to 5500 ms (Fig.2). All of these five survey blocks belong to ONGC.

Data acquisition

Data of all the five prospects have been acquired in streamer mode. But these have been acquired by three different service companies in a span period of 2 years. These data have been acquired by different survey vessels with widely varying acquisition parameters as shown in table 1. Number of streamers used was also different for different survey. This poses the challenge for the task of minimizing the variation across the prospects and producing the entire volume of data as single mosaic.

Data processing

The goal of the merging of several 3Ds is to create a single 3D which simulates that would have been produced had the 3D volume been recorded by one crew at the same time and processed using the same software tools. The task is daunting as there are several key issues that must be solved in a methodical and sequential fashion using a large toolbox of batch and interactive routines. The earlier merging carried out had substantial amount of acquisition foot prints. Therefore, a close investigation was made so as to address each of the problems separately and adopt a judicious processing sequence befitting the situation. The generalized processing sequence followed in this case is given in table.2. However the critical points addressing the key issues are discussed below.

Selection of Base survey: For merging of multiple surveys the first job is to select the base survey. Here the selection of base survey was thought to be very vital. The prospect no.3 was taken as base survey. The most important advantage of taking this as base survey is that it has suitable overlap with all other four prospects. The other advantage was its shooting direction which exactly matches with two other prospects.

Table 1: Acquisition Parameters

Pros. No.	Agency	Year of Acq.	Bin size (m x m)	Fold	No. of Channels	Near Offset (m)	Far Offset (m)	Central meridian	UTM projection (degree)	Shooting Direction
1	P	2003-04	6.25x25	90	360	145	4645	75 degree East	Zone 43 North	67.27
2	C	2004-05	12.5x25	60	240	240	6240	69 degree East	Zone 42 North	65
3	L	2003-04	12.5x25	46	184	185	4785	75 degree East	Zone 43 North	67.27
4	C	2004-05	12.5x25	60	240	240	6240	69 degree East	Zone 42 North	67
5	P	2003-04	6.25x25	90	360	145	4645	75 degree East	Zone 43 North	67.27

Table 2: Processing flow

1.	Reformatting	10.	Compress (Redundancy Removal)	19.	Pre Stack Kirchoff Migration
2.	Navigation Merging	11.	Deconvolution	20.	Trace scale
3.	Minimum Phase Filter/Matching Filter	12.	Band Pas Decon Velocity	21.	Gain
4.	Static Correction	13.	First Pass Decon Velocity	22.	Random Noise Attenuation
5.	Radon Transform	14.	Second Pass DMO Velocity	23.	Time Varying Filter
6.	Flex Binning	15.	Time Variant Band Pass Filter	24.	Mute
7.	Scaling	16.	Trace Balancing	25.	SEG-Y Conversion
8.	Spherical Divergence Correction	17.	Target Line Migration		
9.	Ensemble Balance	18.	Velocity Analysis on PSTM Gather		

The survey coordinate reference systems: Fortunately data pertaining to all five prospects were acquired on WGS84 spheroid and UTM projection system. But the central meridian and zones were different. The central meridian for prospect 1, 3 & 5 was 75 degree East and it was 69 degree East for other two. Therefore the survey coordinates of prospect 2 & 4 were transformed for Central Meridian 75 East.

Bin Dimension, Offset and Fold Equalization: There were two types of bin dimensions for these five surveys. The bin size for prospect 1& 5 was 6.25m*25m where as it was 12.5m*25m for the other three prospects. Alternate channels of prospect 1 & 5 were dropped so as to produce an identical bin dimension. It also helped to produce uniform nominal foldage of 46 and identical offset ranges after the near and far offsets were restricted to 240 & 4700 mts respectively for all the prospects. It also gave rise to identical no. of channels as shown in table.4.

Selection of Grid Orientation: A super grid was selected matching to the original orientation of the base survey i.e. 67 degree (Fig.3a & b). Fortunately there was not much deviation to the shooting directions of other prospects which have orientation of 65 , 67 & 67.27 degree respectively. Therefore there was not much requirement for the issue of handling azimuthal variation. Fig 3 (a) Grid orientation (b) Super grid

Flex Binning: All most a uniform foldage distribution was obtained through flex binning. The relatively low dip of the area could allow going for a higher degree of flexing without being aliased thus solving a major issue of merging.

De-signature/Matching Filter: Generally correction filters based on the simulated far field signature (provided by the data acquisition contractor) is applied to the base survey (i.e converting the data of base survey to its minimum phase equivalent) in the first stage. Then matching filters are designed for each prospects separately and applied to match with the corrected base survey. But as we observe from the widely varying gun configuration adopted by the three contractors, the reliability of far field signature was questionable. Same conclusion was also drawn from the test results. As a result of that a classical approach to extract wavelet from the data it self was followed. The wavelet extraction was made from the base survey in the overlapping zone by the program Waveshape & shaping filter was derived by Nucleus software for converting it to its minimum phase equivalent (Fig.4). Thereafter matching filters were designed for other four prospects in the same manner by extracting the wavelets at the overlapping zone.

Linear Noise Attenuation: To get rid of the dominant linear noise , data was transformed from t-x domain to Tau- P domain through RADON transform and off mute was applied to eliminate linear noise/guided waves and then the data was brought back to t-x domain. This process could make the data free from the dominant high amplitude noise making it suitable for matching across the prospects

Amplitude, phase & static correction: For amplitude, phase & static shift analysis, STASEQ procedure of PGS Tensor software was used. This program provides a linear phase difference (i.e. relative time shift), a phase rotation difference & energy difference between traces of two datasets. The order of time shift observed was not appreciable which was

Table 3: Processing flow

Pros. No.	Central meridian	Spheroid	UTM Projection	Converted to
1	75 degree East	WGS84	Zone 43 north	
2	69 degree East	WGS84	Zone 42 north	CM:75 degree East & UTM proj : Zone 43 north
3	75 degree East	WGS84	Zone 43 north	
4	69 degree East	WGS84	Zone 42 north	CM: 75 degree East & UTM proj:Zone 43 north
5	75 degree East	WGS84	Zone 43 north	

Table 4: Bin Dimension, Offset and Fold Equalization

Pros. No.	Bin Size	Fold	No. of Channels	Near offset	Far offset	Restricted/Converted to			
						Bin size	Near offset	Far offset	Nominal fold
1	6.25x25	90	360	145	4645	12.5x25	240	4700	45
2	12.5x25	60	240	240	6240	-	-	4700	46
3	12.5x25	46	184	15	4785	-	240	4700	46
4	12.5x25	60	240	240	6240	-	-	4700	46
5	6.25x25	90	360	145	4645	12.5x25	240	4700	45

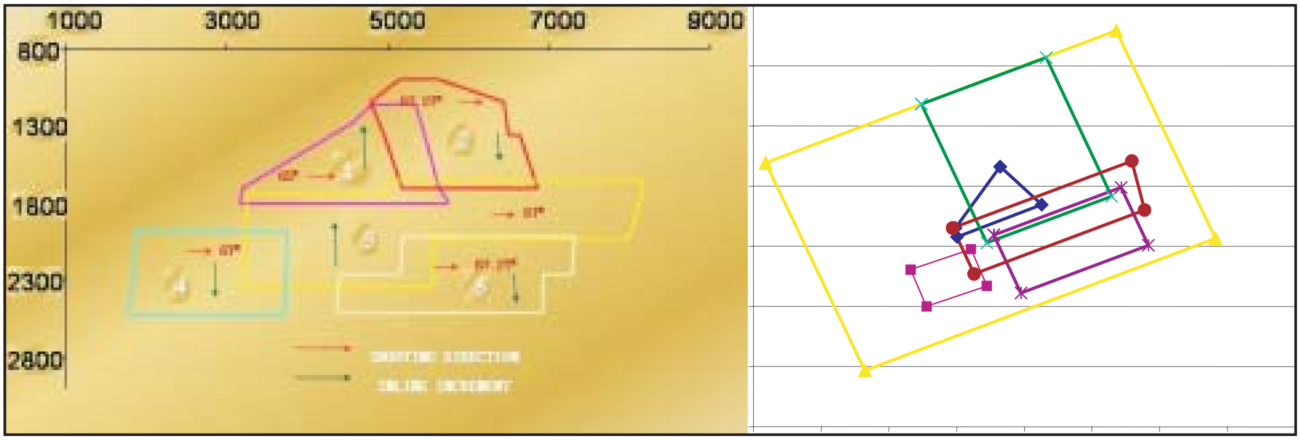


Fig. 3. (a) Grid orientation (b) Super grid

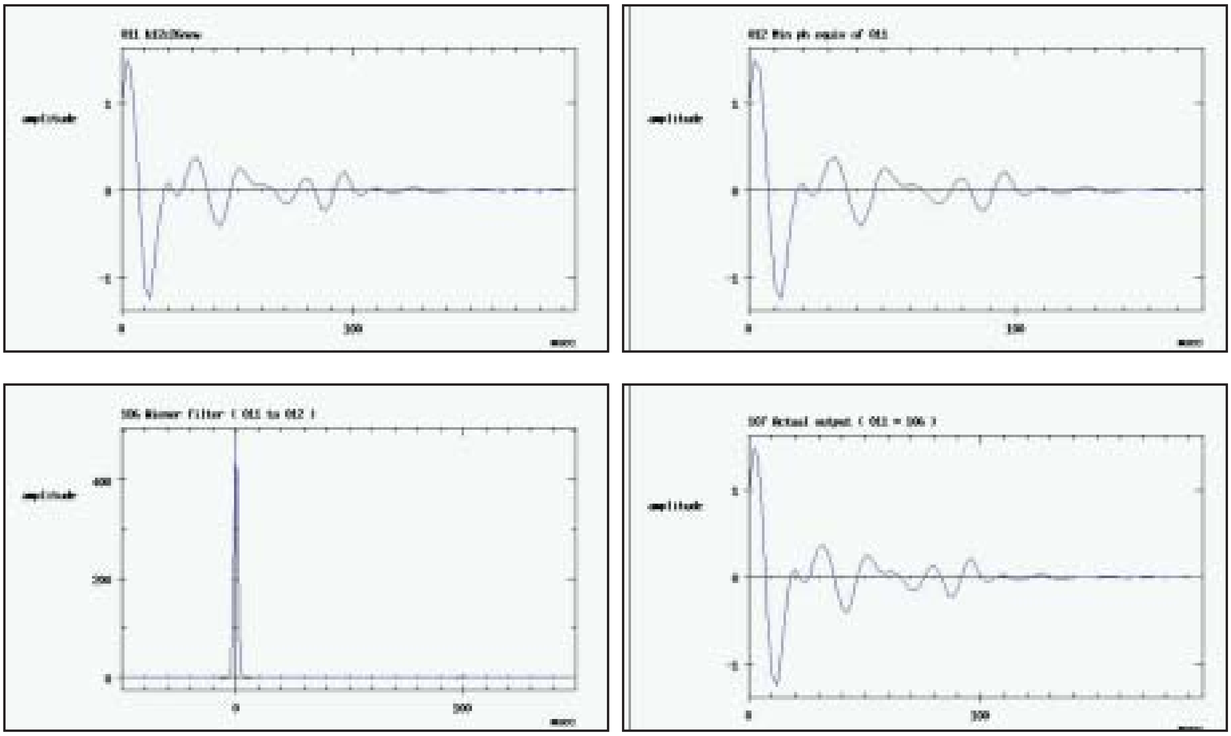


Fig. 4. Conversion to its Minimum Phase Equivalent (Base Survey)

also verified from visual inspection and therefore no correction was made. The order of phase shift was also not appreciable and therefore the correction was not attempted. However the amplitude variation between prospects with respect to the base survey was remarkable as shown in Fig.5a&b and therefore corrected.

The Bandwidth and S/N Ratio: There was not much difference in the signal band across the prospects as seen from spectral analysis. However this analysis has been carried out after the application of signature deconvolution which might have balanced the spectral component to some extent. After the application of statistical gapped decon identical bandwidth could be achieved satisfactorily.

Two approaches were used to enhance the S/N ratio by reducing the random noise component to a major extent

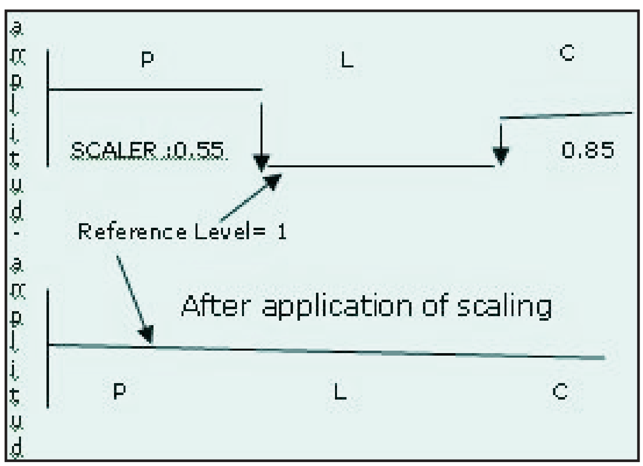


Fig. 5. (a) Amplitude difference before application of scaling

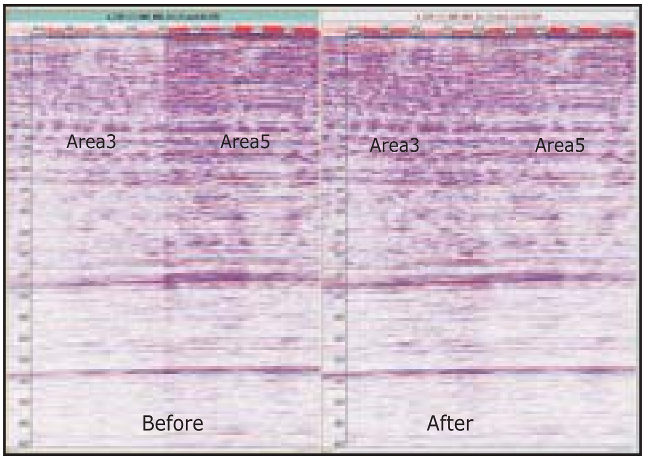


Fig. 5. (b) Amplitude correction

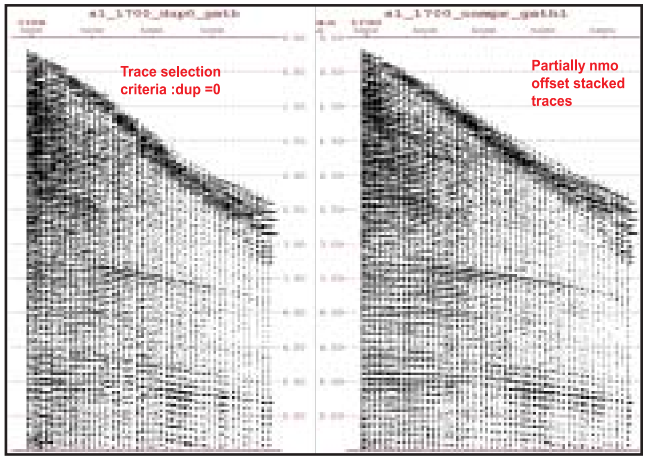
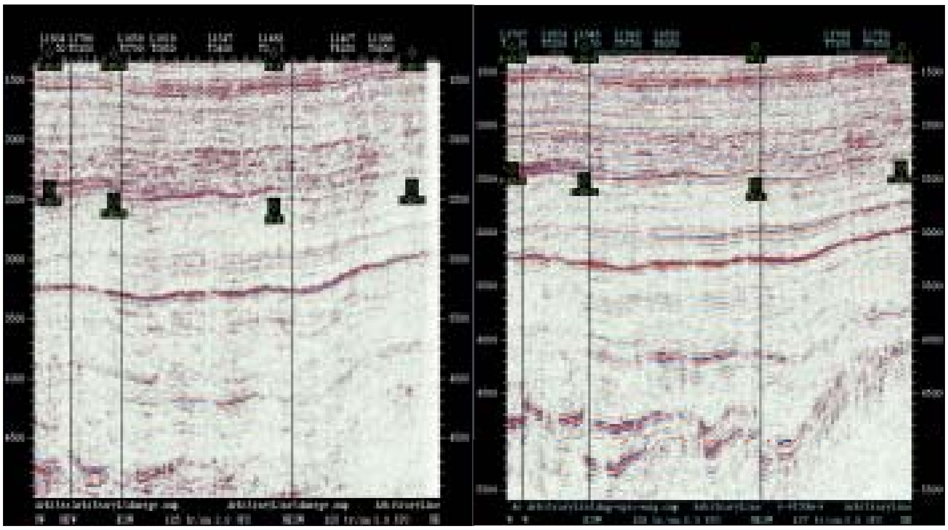


Fig. 6. Comparison on Trace Selection



Earlier processed data

Reprocessed data

Fig. 7. Comparisons with earlier processed data

making signal identical across the prospects. The 1st approach was that redundant offset traces after flex binning were not dropped, instead partial NMO correction was applied and data was summed to the offset groups by COMPRESS module of PGS tensor software. By this approach the random noise component was drastically reduced in prestack gathers as seen in Fig.6. Band pass filter also played its role very well in removing the random noise. In the 2nd approach the random noise component was further reduced by the application of frequency dependent Fxy deconvolution in post stack stage making the signal identical across the prospect. The ensemble balance applied on gather also could help in removing the amplitude bursts

Kirchoff Migration: Pre stack Kirchoff migration was performed for the entire data. The amplitude of migrated output appeared to be more stabilized across the prospect due to the very nature of Kirchoff migration.

Results: A near perfect match across the five prospects was obtained without any seam at the boundaries, (Fig.7-8). The signal stand-out and resolution within the zone of interest was much improved in comparison with earlier processed data .The deeper reflections also have been clearly brought out providing lead to deeper exploration objective . The level of confidence of correlativity was also very high as shown in Fig.9 ruling out the possibility of any geometrical error or acquisition foot print.

Conclusion

Merging of seismic data acquired in different campaigns with varying acquisitin geometry and parameters is a delicate process. Judicious addressing of each issue as befitting the situation is required to achieve the objective of processing and help the interpreter in meeting the geological objective of the survey.

Acknowledgements

Authors express their gratitude to Shri D.K.Pandey Director (E) & Shri S.V.Rao ED-COED, ONGC, for giving kind permission to present this paper. Authors are also highly thankful to Shri P.S.N.Kutty , the then Basin Manager, Western Offshore Basin, Mumbai Region and Shri I. B. Rao, GM(GP), the then Head Geophysical Services , Mumbai Region, ONGC for entrusting this

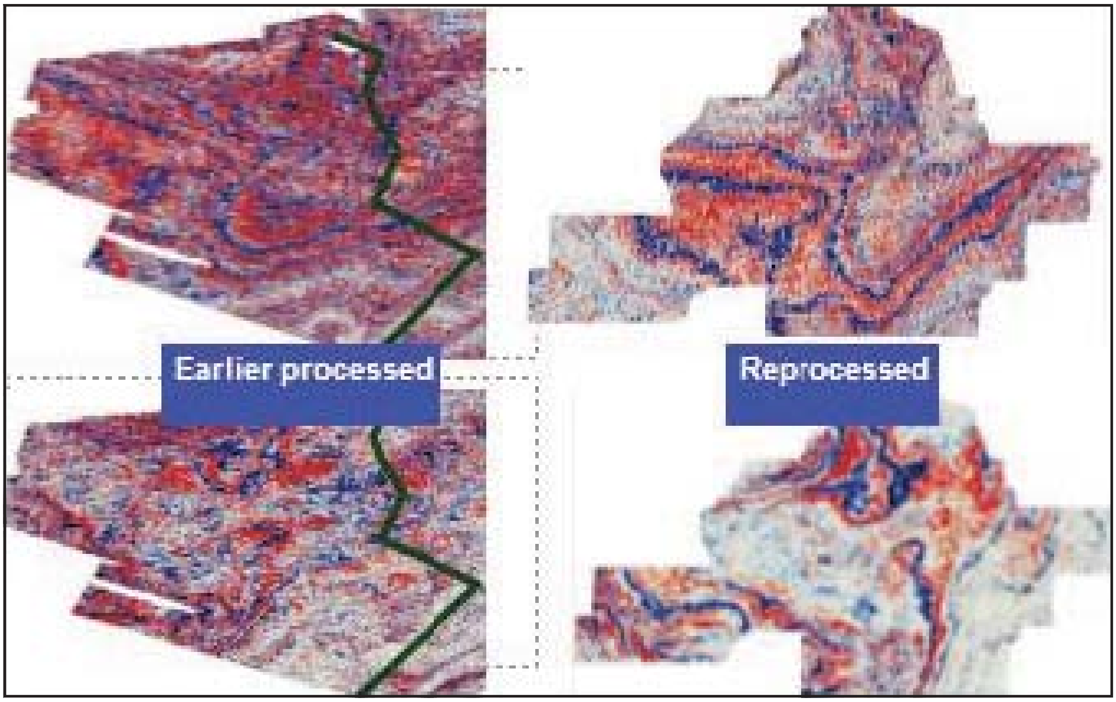


Fig. 8. Time slice from Earlier and Reprocessed data

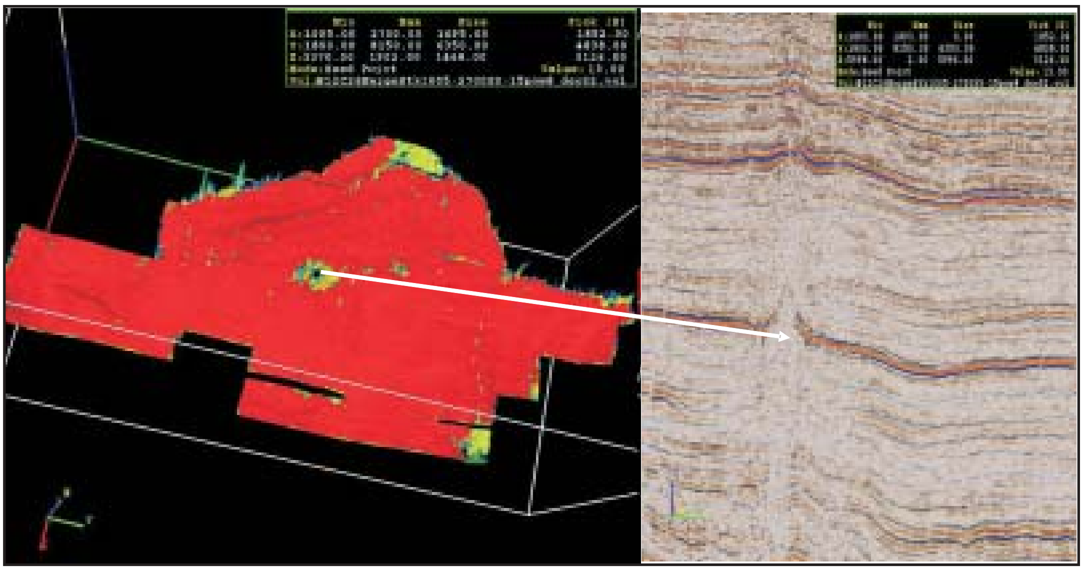


Fig. 9. Correlatiibility Map

project. Authors are fully indebted to their other fellow colleagues in SPIC namely Dr. R.K. Goel, P. C.Kalita, Mithai Lal & Rajiv Mohan. The interaction carried out with Shri S Bhusan & Rakesh Kumar of interpretation group was highly fruitful and is acknowledged. The over all support received from all the SPIC members is also acknowledged.

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