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

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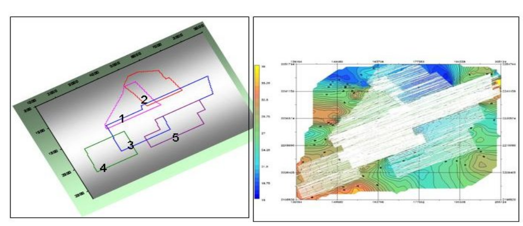
Summary

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 comparably crude with respect to the objective of survey. Later on high density 3D survey has come up because of the obvious reason. 4D data acquisition is an extension of 3D (Repeated 3D survey). Multi component recording needs some special care. 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 also often been processed using variable levels of processing technology with changing objectives with time. Pre stack & post stack imaging has been also a guiding factor for adopting variable parameters. 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 literally 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. In an Indian context this factor is more aggravated because most of our 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 global compelling factor for merging the old surveys acquired with a wide range of acquisition parameters in different times. Some of the companies have developed an integrated set of tools to achieve this difficult task either using post stack data, pre-stack data, or in combination of pre & post stack.



(a) (b)

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

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 extremely difficult to overcome. Moreover the E&P companies also have 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 major 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 also is 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 (if required) 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 (as some software has the module to re-grid) 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, land dynamite, land 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 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.

- 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 misstie and therefore carefully handled.

- Key pre-stack processing flow differences may have left highly 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 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 surveys blocks belong to ONGC.

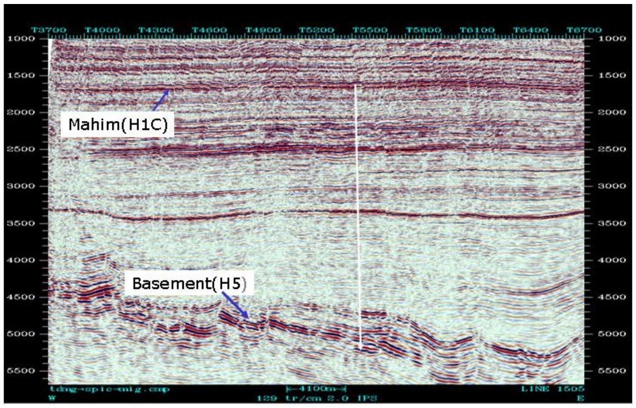


Fig 2 Geological objective

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 leaves behind 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 what would have been produced had the 3D’s been recorded by one crew at the same time and had been 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 approach 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 to 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 of 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 being the central one. The other advantage was its shooting direction exactly matches with other two prospects. This was also comparatively bigger in size.

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 zones for prospect 1, 2 & 5 were 43 North where as it was 42 North for the other two prospects. The central meridian for prospect 1, 2 & 5 was 75 degree East and it was 69 degree East for other two. Therefore the survey coordinates of prospect 3 & 4 were transformed for Central Meridian 75 East & UTM projection zone 43 degree north to that of base survey (table 3).

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. 67.27 degree (Fig.3a & b). Fortunately there was not much deviation to the shooting directions of other prospects which have orientation SW of 65 , 67 degree respectively. Therefore trace interpolation was not required and there was not much requirement for the issue of handling azimuthal variation.

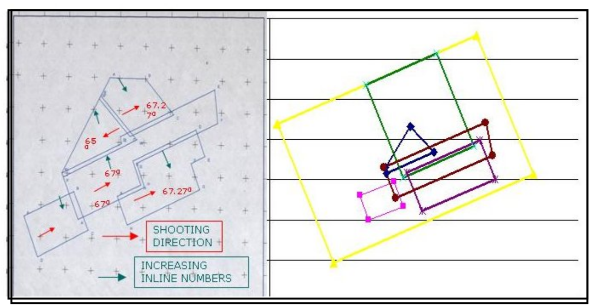


Fig 3 (a) Grid orientation (b) Super grid

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 key issue of merging.

Designature/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 with the logic that the applicability of the statistical method rests upon the size of the error rather than the question of whether an error exists due to a basic assumption. This logic could hold good in real world. The wavelet extraction was made from the base survey at the overlapping zone by the program WAVESHAPE & shaping filter was derived by Nucleus software for converting it to its minimum phase equivalent (Fig.4). There after matching filters were designed for all other four prospects in the same manner by extracting the wave lets 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 predominated high amplitude noise making it suitable for matching across the prospects

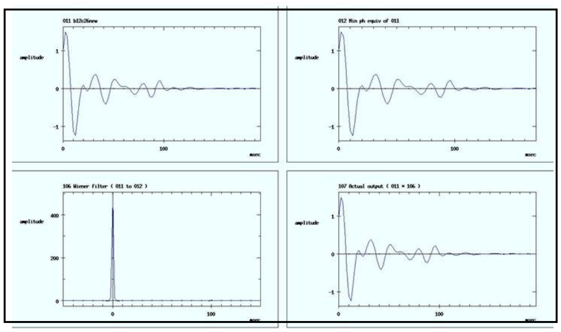


Fig.4 Conversion to its Minimum Phase Equivalent (Base Survey)

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 to time shift), a phase rotation difference & energy difference between traces of two datasets when compared. The order of time shift observed was not appreciable which was 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.

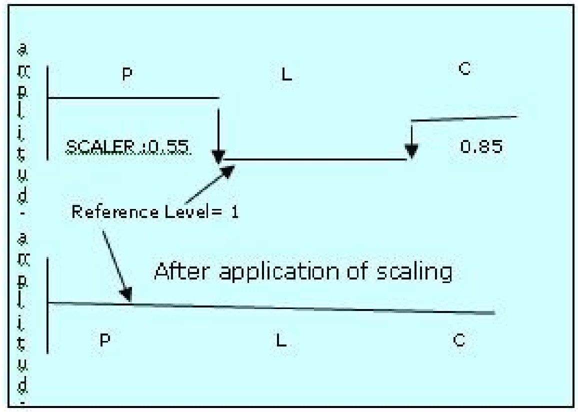


Fig5.a Amplitude difference before application of scaling

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 & therefore further spectral balancing was not attempted in later stage.

Two approaches could enhance the S/N ratio by reducing the random noise component to a major extent 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 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 F-xy 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

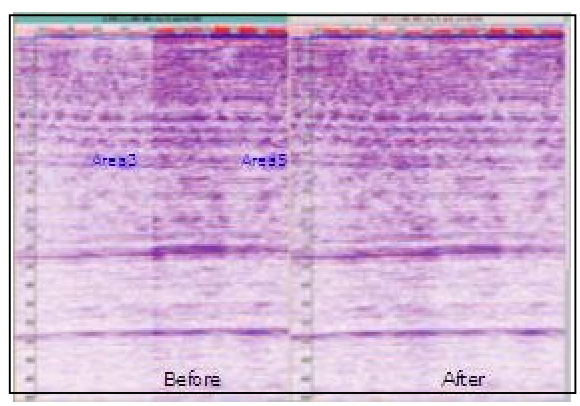


Fig.5b Amplitude correction

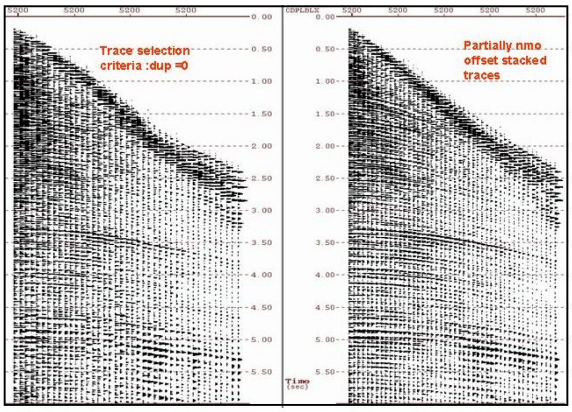
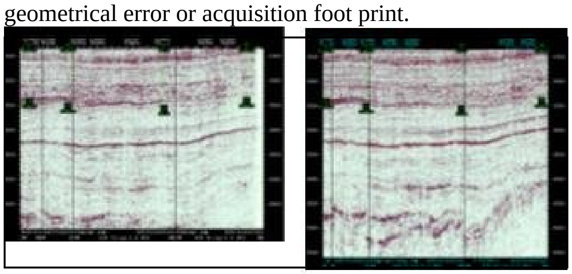


Fig.6 Comparison on Trace Selection

Kirchoff Migration: Kirchoff migration was performed in pre stack for the entire data as single mosaic. The amplitude of migrated output appeared to be more stabilized across the prospect due to the very nature of Kirchoff migration. The due care taken during the velocity analysis on migrated gather perhaps played vital role for giving a good migration output. Picking of RMS velocity was very trivial as velocity inversion encountered frequently.

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 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.



Earlier processed data Reprocessed data

Fig .7 Comparisons with earlier processed data

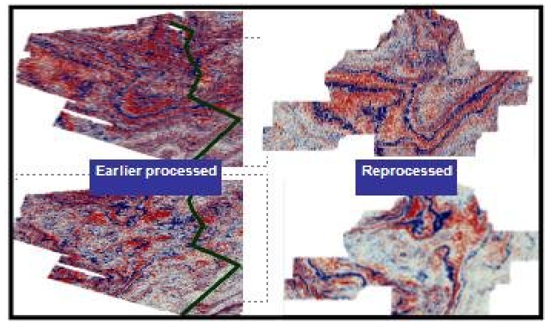


Fig.8 Time slice from earlier and Reprocessed

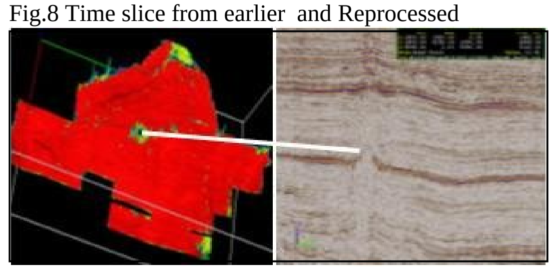


Fig.9 Correlatiibility Map

Conclusion

Merging of several surveys is a process of value extraction from original data. The issues relating to one project may not be same as the other. How ever a judicious attempt for addressing the each issue befitting to the situation can help in achieving the objective of project as it is demonstrated No process is ultimate. Processing is known to be more of an art than science. Quality improvement is a dynamic concept and there is always a scope for improvement. With those views the near perfect match/merging achieved for the five prospects is a value extraction from the original data will not only help the interpreter in meeting the geologic objective set for but also will help to understand the value extraction from legacy data .

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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	Shooting Direction (degree)
1	P	2003-04	6.25 X 25	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& 2004-05	6.25 X 25	90	360	145	4645	75 degree East	Zone 43 north	67.27

Table 2: Processing flow

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

Table 3: Coordinates Transformation

Pros. No.	Central meridian	Spheroid	UTM Projection	Converted To
1	75 degree East	WGS84	Zone 43 north	-
3	69 degree East	WGS84	Zone 42 north	CM: 75 degree East & UTM proj: Zone 43 north
2	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	6.25 X 25	90	360	145	4645	12.5 X 25	240	4700	45
2	12.5X25	60	240	240	6240	-	-	4700	46
3	12.5X25	46	184	185	4785	-	240	4700	46
4	12.5X25	60	240	240	6240	-	-	4700	46
5	6.25 X 25	90	360	145	4645	12.5 X 25	240	4700	45