Pre-stack Merging of Land 3D vintages: A case study from Charada-Mansa area of Cambay basin

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Summary

3D seismic data of seven volumes pertaining to Charada Mansa area of Cambay basin was acquired by WON basin Vadodara in different phases starting from 2003-04 to 2011-12. The data was acquired with different recording parameters and recording system. As the individual volumes were processed independently, there was difference in quality and at places it was difficult to track the events from one volume to the other. Reprocessing of the data was taken up to improve seismic imaging for mapping of the prospects within Mehsana, Mandhali, Older Cambay Shale and Olpad levels. Although no single volume was having adequate overlap with all the remaining volumes, due care was taken to devise the strategy for polarity, time shift, gain and wavelet matching. Final processing resulted in a seamless mosaic of 3D seismic volume.

Introduction

The area of study falls on the rising flanks of eastern margin fault and NE of the Nardipur low in Cambay basin, which is the main kitchen for generation of hydrocarbon in the area (fig-1). Cambay shale is the main source rock in the area. Both Older & Younger Cambay shale units representing lower delta regime are well discernible in the eastern vicinity of Mehsana horst. The Cambay shale overlying Olpad Formation is overlain by Kadi Formation that has been divided into three distinct members Mandhali, Mehsana & Chhatral separated from each other by marine transgressive shale breaks, known as lower and upper tongue.

Mandhali Member constitutes broad deltaic deposits with tidal influence, Mehsana sands are thin and lenticular and show varying stratigraphic position with respect to top of Mehsana coal. As the field is on the eastern rising flank of the Cambay basin, progressive thinning of sediments from west to east is evident. Sand thickness of Mehsana sand shows a maximum towards south-west. The coal country is prevailing along the basin margin and coal seams occur in both Kalol & Kadi formations. The Lower Mehsana Member consists of a thick pack of three major coal seams, inter-bedded with sand/silt layers. The thickness of sands in Mehsana Member varies from 10 to 12 m and in Mandhali Member from 8 to 10 m. The sand supply is from North & Northeast.

The area of study was covered by seven 3D seismic campaigns (fig-2). These campaigns were acquired over a large span of time with widely varying acquisition parameters such as bin dimension, fold, source spacing, receiver spacing, record length and with varying recording instruments under diverse acquisition conditions.

Fig-1: Area of study in Cambay Basin

In the past, these volumes were processed individually with varying processing parameters. This resulted in variation in the energy level, wavelet and time shifts with respect to each other; thereby causing difficulty in correlating the reflection events from one volume to the other. The main objective of merging of these 3D campaigns was to combine them at pre stack level and to create one consolidated 3D volume akin to a single 3D campaign over the whole area.
Input Data

3D seismic data of different vintages were acquired using various recording instruments and acquisition geometries. The recording systems which were used are SN-388, Scorpion & UL408. Number of receiver lines varied from 8 to 16 and number of channels from 432 to 12920, fold variation from 35 to 72 and far offset from 1538 to 6245 m. In general, input data quality was fair to good; however data quality of volume-B and volume-G is very poor. Strong ground roll, noise bursts, and spiky traces were observed on the shot gathers. Since the data was acquired in a long time span with varying acquisition parameters, it resulted in variation of phase and amplitude in the seismic data as well as time shift.

Processing Methodology

The input data, received in SEGY and SEGD format, were converted to local format and geometry was updated. Rigorous QC was carried out to ensure proper merging of SPS with seismic data. All the vintages had same survey coordinate reference system; hence no treatment was required in this regard. All significant attributes like common gridding, polarity check, shift study and wavelet matching were taken into account to bring each vintage on a single platform prior to merging. Processing sequence included standard signal processing techniques followed by pre-stack time migration. Due care was taken at every stage of processing to preserve the relative amplitude of the data. Each seismic campaign was processed independently up to deconvolution stage using the same grid definition and same processing parameters. General processing flow used is as follows:

1. Format conversion
2. Geometry merging and QC
3. Gain Recovery
4. Statics application
5. Initial velocity analysis & QC stacks
6. Data conditioning
7. Polarity, time shift, amplitude & phase matching
8. Deconvolution
9. First pass Velocity analysis
10. Residual statics estimation & application on individual volumes
11. Data sorting using master grid.
12. Second pass velocity Analysis
13. Second pass residual statics application
14. Target line PSTM for velocity analysis
15. RMS velocity analysis
16. Final pre-stack time migration
17. High density velocity & eta estimation
18. Multiple suppression
19. Stacking of flattened PSTM gathers
20. Random noise attenuation
21. Acquisition footprint suppression

Signal Conditioning

Spherical divergence correction using $T^n$ type gain ($n=1.5$) was applied on the data. Analysis for noise attenuation was handled carefully and judiciously with the combination of different modules. Noise strips, spikes, random and frequency dependent noise were suppressed extensively using despike and frequency dependent noise attenuation technique as well as f-k filter for linear noise suppression. Figure-3 & 4 show a shot gather before and after noise suppression.
At a later stage, after deconvolution, projection filter was applied on the data in offset class domain to suppress the random noise further.

Fig-3: Shot gather before noise suppression

Fig-4: Shot gather shown in figure-3 after noise suppression

Polarity check

Polarity of gather data of all the volumes was analyzed. It was found that the first break energy is trough in all the volumes and no data set has opposite polarity. Hence no corrective action was required in this regard.

Time shift correction

Time shifts were observed between different volumes which were analyzed and it was found that the shifts were not related with instrument delays. Statics values supplied by the data acquisition teams have different statics for the same location in overlap zones, which contributed to the time shifts.

The existing two way time maps of the area were generated in past with reference to volume-B. To meet the interpretational requirements final volume was to be generated having the two way time of the events same as the two way time of existing data volume-B. That is why time shifts were applied keeping the volume-B unchanged. However for wavelet matching and optimization of processing parameters, volume-C was used as reference, because of its good quality and central position.

Fig-5: Strategy for time shift correction with the reference volume-B

Fig-6: Stack section from volume-B and C before and after time shift correction

Challenges were faced while matching amplitude, phase and static time shifts, because all the investigation did not overlap with the reference volume Stacked data sets of different volumes were compared with the reference one in the overlap zones. Common in lines and cross lines of the adjacent volumes were considered for this analysis. Relative time shift was noted and applied on volume-A and volume-C.

In the second phase, corrected volume of C was taken as reference and further matching was
carried out. Figure-5 presents the loops adopted for time shift analysis as well as corrections applied on different datasets. Observed shifts varied from 10 ms to 75 ms. Figure-6 shows the effect of time shift correction. Finally as a quality check to verify the correctness of the matching, the two datasets G & D were analyzed and found matching.

**Amplitude and phase matching**

For amplitude and phase matching, volume-C was taken as reference and the loop shown in figure-7 was followed. Stacked data of overlap zone was used for this purpose. Amplitude and phase spectrum of reference and target input volumes were analyzed. Matching operator was designed to convert the input wavelet equivalent to the wavelet of reference volume. Using this approach wavelet matching operator was designed and applied on volume-A, B and D.

After this, wavelet matched data of volume-D was taken as reference and wavelet matching of rest of the volumes was carried out. Figure-8 shows the effect of amplitude and phase matching, where left panel is input stack, middle is reference stack and right panel is the stack of input data after wavelet matching.

**Deconvolution and Residual Statics**

3D data of volume C is falling in the central part of the area and has relatively good signal to noise ratio. Hence it was taken as reference for parameterization. Deconvolution parameters were finalized by using autocorrelation function and panels of deconvolution stack with different predictive distance and operator length. From the stack panels, it was found that 24 ms prediction distance and 200 ms operator length is optimum for the data.

Band pass filter was applied on the data with frequency range 3-6-90-100 Hz. Fig-9 shows the amplitude spectrum of the data before and after deconvolution on IL 1800 in the zone of interest. Velocity analysis was carried out on individual data sets. This was followed by the estimation and application of the first pass residual statics.
Data merging and second pass residual statics

All individual data sets were merged after application of deconvolution and first pass residual static corrections. For proper residual statics estimation and application, one has to ensure unique shot and receiver number on the merged gathers. To make them unique, shot and receiver numbers of each investigation were prefixed by different numbers. After re-numbering the shot and receiver numbers of all the volumes, full volume data was sorted and second pass residual statics was estimated and applied.

The issue of higher fold at the overlapping zone and problem of offset gaps was taken care of by fold regularization in common offset domain using the algorithm based on de-aliased Fourier reconstruction in f-kx-ky domain. To maintain the data integrity, missing traces were generated only if sufficient traces were available in the nearby bins within a diameter of 400 mt. In case of large data gaps, no traces were generated even after regularization. That is why some data gaps are still present for near offset traces.

Pre stack time migration

For RMS velocity analysis, pre-stack time migration was carried out along target velocity lines and close grid velocity analysis was carried out. Final migration job was executed using Kirchhoff’s migration algorithm. Aperture tests were done and a Full aperture of 4000 m was considered. Offset distribution was chosen as 40 m to 2560 m with an interval of 40 m for carrying out migration in offset class mode. High density velocity and eta analysis was performed to take care of residual move out present in the PSTM gathers. PSTM stack was generated after the application of parabolic radon de-multiple on flattened PSTM gathers.

Fig-11: RMS Velocity analysis panel

Fig-12: Final PSTM stack along representative inline direction

Fig-13: Final PSTM stack along representative crossline direction

Fig-14: Time Slice at 1000 ms from PSTM stack

In the final post stack process, 3D random noise attenuation using projection filter and acquisition footprint suppression using f-kx-ky filter was applied. Figure-12 to figure-14 shows the final
processed output along inline direction, crossline direction and time slice. Figure-15 and figure-16 show the comparison between post-stack merging v/s pre-stack merging of these volumes along one inline and one crossline direction

**Conclusions**

Main challenge involved in the pre-stack merging of different 3D volumes of Charada Mansa area was to handle the mismatches of static shifts, phase and amplitude variations of individual campaigns. All these issues were handled carefully with quality checks at every stage of processing. Final processed output does not show any shift or amplitude variation in any patch of the output. The final result was a seamless mosaic of 3D seismic volume without any imprint of the individual campaigns.

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