Interpretation-driven Seismic Data Conditioning - A case study from Cambay Basin, Gujrat, India

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Summary

High resolution seismic data with undistorted amplitude and phase provide valuable information of the reservoir and minimize the uncertainty in quantitative prediction of reservoir geometry. Reservoir characterisation is more sensitive to data quality than those of structural interpretation.

The motivation behind this study is to emphasise the fact that interpretation of seismic data and computation of seismic attributes is not just a process to press button on workstation but to examine the input data in terms of signal to noise ratio as well as frequency contents.

In the present case, an attempt has been made to improve the Post stack seismic data by adding low as well as a part of high frequencies derived from well data. In this process, seismic wavelet effects is removed from seismic which can be minimum phase and again it is reshaped to zero phase wavelet. Two blocks were selected from Cambay basin to understand the suitability of the process.

Similarly, pre-stack gather data has been conditioned by gather alignment and application of residual NMO corrections, trim statics and super gather. The undesired pre-stack phenomena are to be removed prior to quantitative interpretation based on pre stack data. Data enhancement has been tried on PSTM as well as Gather data by application of super gather, trim statics and application of radon.

Introduction

To be able to meet the demand of reservoir engineers for analysis of rock physics and reservoir characterization, the importance of data conditioning increases many folds before its utilisation for quantitative interpretation and reservoir characterization with specialised study as Direct Hydrocarbon Detection (DHI).

Need for better data quality increases as exploration and exploitation of hydrocarbons become difficult especially in the areas like Cambay basin having complex geology with thin sands. Today, the noise is an increasing challenge and Data enhancement is in demand of time in Oil and Gas Industries.

In case of Post stack seismic data, it is recommended either for reprocessing or attempt is made to enhance the data with some utility available with interpretation software as Q compensation filter, trace mixing and dip scan etc.

In pre-stack data conditioning approach one has to go back to CDP gathers and make sure that data is clean before stacking of data. It might prove necessary to apply a more efficient mute function for betterment of data quality. Simple band pass filtering and random noise attenuator can be very effective on migrated stack subject to its availability with interpretation workstation.

Geology and Background

The 3-D seismic data set of southern block (Jambusar-Broach block) and central block (Mehsana-Ahmedabad block) of Cambay Basin (figure 1), recorded with 36 fold and sampling interval of 4 ms was taken for the study.

Figure 1: Study area showing case study areas with rectangles with index map of Cambay basin

As a rare opportunity, the author was associated with all stages from data acquisition (A) to
processing (P) and finally with interpretation (I). The care was taken to maintain the data quality for complete cycle of API. It is assumed that care has been taken to improve the horizontal and vertical resolution during data acquisition by experimentation for fixing the charge and shot hole depth etc. as shown in figure 2 with shot hole gather data.

![Shot no.](image)

**Figure 2:** Shot hole gather seismic data showing the target reflectors at shallower as well as deeper in raw data with clarity

Standard 3-D processing sequence has been applied with quality control at every processing stage. As observed, the final processed data with a broad band frequency in the range of 40-50 Hz is far better than earlier 2-D seismic data. The comparison of both set of data is shown in figure 3 highlighted with circle for shallower as well as rectangle for deeper events.

![Comparison of old 2-D and new 3-D seismic section](image)

**Figure 3:** Comparison of old 2-D and new 3-D seismic section

Since the data was already reprocessed with latest technology of PSTM data processing techniques, it was not possible to recommend for reprocessing again. With help of available package of data enhancement and image enhancement package in interpretation, an attempt was made to improve the data of north/central block (case 1) as well as south block (case 2) of Cambay Basin before proceeding for any advanced study. In both cases, first of all the PSTM data was taken for further improvement and conditioning. Later on gather data of Jambusar-Broach (case 2/ area 2) was taken for conditioning. Each one is discussed separately.

Objective of Data quality enhancement or improvement was for better imagination and visualization of seismic data before structural mapping and reservoir characterization.

**Methodology for Data conditioning and discussion of results**

**Post stack Seismic data (case 1)**

From the seismic interpreter’s point of view, there are two types of noise: those the interpreter can address through some relatively simple process applied to the post stack migrated data volume and those that require reprocessing of pre-stack data. Now a days, there are some data enhancement utility with few interpretation software as dip scan filter, spectral shaping of seismic data, Q compensation, thin bed sparse spike reflectivity inversion etc. The interpreter can address random noise and acquisition footprints through band pass filter, trace mixing and zero phasing etc.

![Low and high frequency information taken from sonic log and added to seismic](image)

**Figure 4:** Low and high frequency information taken from sonic log and added to seismic

Seismic data is band-limited, reducing resolution and quality at deeper level. Generally, high
frequency dominates in shallower part and lower frequency in deeper part or reservoir level. Low Frequency Compensated Model (LFM) Inversion includes both seismic data and well data, where well data serves to add the low frequency information below seismic frequency range below 10Hz as well as part of high frequency and to constrain the inversion. The power spectrum of normal seismic and well log is shown in Figure 4 where low and high frequency shown with red and blue ellipse has been added to seismic. Also, the scaling factor which relates the well and seismic reflectivity is applied during the low frequency compensated inversion process.

As shown in figure, seismic data does not have frequency below 10Hz due to limitation of natural frequency of geophone whereas the low frequency exists with log data. Low frequency is taken from log and superimposed on seismic spectrum during low frequency model building and computation of absolute acoustic impedance. In this process, time variant wavelet is removed from seismic data and the reflectivity is extracted to image the thickness far below the seismic resolution using a matching pursuit of sparse spike inversion. In addition to enhanced image of thin reservoir, these frequency-enhanced image have proven useful in mapping subtle on laps and off laps combined with better visualisation of thin layers.

Figures 5 and 6 show the seismic lines (before and after data enhancement) near exploratory well W from Mehsana-Ahmedabad block in central part of Cambay basin. Note that the amplitude spectrum shows the increase in frequency from 40Hz to 60Hz at shallower level and from 30 Hz to 45 Hz at lower level after data enhancement. The amplitude spectrum for each data set is also shown to make it clear about the frequency enhancement in vertical section at corner. The spike (noise) shown with yellow ellipse in normal has been removed in enhanced section. Also, frequency broadband can be observed in figure showing the enhancement of frequency.

This loss of energy and frequency at deeper level is due to absorption of energy during wave propagation in sediments. The high frequency has been added from well log information during model building and visualisation becomes easier whereas traditional stack data have lack of high frequencies above 35 Hz. The well has collected information being very close to formation and reservoirs whereas seismic has been recorded from surface. Therefore, logs information contents more details in term of frequency and energy. Basically, an attempt has been made to exploit this information and add to seismic. Notice the increased details in terms of extra cycle developments with ellipse at deeper level and rectangle at shallower level. In addition to facilitate detail information, these enhanced volumes serve as input for generating attribute volume with high resolution showing details.

Comparison of time slice at 1600ms before and after data enhancement and extracted from corresponding volume is shown in Figure 6. The image of fault /anomalous feather between Well W1 and W2 has been clearly brought out in slice extracted from enhanced volume.

Figure 5: Vertical seismic section from Ahmedabad-Mehsan block in wiggle form to show the effect of data enhancement

Figure 6: Comparison of time slices at 1600ms extracted from Normal seismic (left) and enhanced seismic (right) showing effect of data enhancement
Effects of data enhancement on Attribute analysis

Figure 7 show the stratal slices though coherence cube computed from original seismic data as well as frequency enhanced data. Notice the significantly increased definition of structural feature

Figure 7: Coherence slice at 1400ms extracted from normal seismic (left side) and enhanced seismic volume showing difference with rectangle and ellipse.

After running the data through the cleaning phase, we evaluate the enhancement of frequency contents of the input seismic data and its impact on the seismic attribute analysis as coherence. Time slice at 1400 ms from variance cube generated for normal and enhanced data indicate the difference of normal seismic and enhanced seismic volumes. The coherence cube time slice (left side in figure) extracted from normal seismic is not able to show the details as observed in coherence/variance slice (right side of figure) extracted from enhanced volume.

Post stack seismic data (case 2)

To test the affectivity of method, the data set of Jambusar-Broach block (case 2 / area 2) was also taken and the process was repeated to test its

Figure 8: Vertical time section before and after data enhancement in Jambusar-Broach block stability. The vertical section as well as time slice at reservoir level is shown in figure 8 and figure 9. The effect of data enhancement is clearly noticed with better visualisation and details.

Figure 9: Comparison of time slices at 2500ms extracted from Normal seismic (left) and enhanced seismic (right) showing effect of data enhancement

Frequency enhancement through Inverse-Q

There are many approaches for the frequency enhancement of seismic data as some of them have been described. But frequency enhancement using Inverse-Q filter is simplest, effective, fast and readily available with many interpretational software applications. It is useful for enhancement of post stacks seismic data for structural interpretation as well as seismic gather data for AVO analysis. Therefore, this method of Q-compensation was preferred over others methods and analysis was done on the data set of Jambusar-Broach block. The visualisation of fault and truncation of events, marked with rectangle and ellipse are much clearer in enhanced section than normal section as shown in figure 10. Color bar, gain and time scale used for both panels is same to make one to one comparison.

The essence of Q (absorption) theory is that absorption causes a seismic pulse to broaden and decrease in amplitude in the time domain while losing spectral bandwidth in the frequency domain. An inverse \( Q \) (absorption)-filtering procedure attempts to remove the \( Q \)-effect to produce high-resolution seismic data. There are many ways to
estimate Q, of which the most popular is spectral ratio method. But due to the error in correct Q determination, often a series of constant Q values are taken and corresponding filter is designed on the basis of the theory of exponential attenuation of source spectrum with time. Here we have applied a constant Q=100 for the selected time window, 1500-3000ms.

Figure 10: Comparison of normal and Q-compensated section showing better visualisation of faults and truncation of events.

Seismic gather conditioning

Seismic Gather conditioning is basic but an important issue with AVO analysis even if the care has been taken for NMO correction, trace editing etc. Due to the presence of residual velocity, the events of the CDP gathers are not flat which is common problem to affects the accuracy of AVO attributes and its derivatives. If data is not enhanced and events are not properly aligned before AVO analysis or angle stack analysis, then the qualitative and quantitative interpretations of reservoir and its properties using these attributes carry large uncertainty. The outer mute is shown with red curve in figure 11. In the present case study, the following steps were attempted and a significant improvement was noticed.

- Inner and outer mute to remove the effect of shot generated noise and unaligned traces at far offset due to NMO stretching effect
- Band-pass filtering to eliminate high frequency noise
- Trim statics to remove the residual statics and align the signal
- Super gather to remove the effects of localised noise.

Figure 11: Seismic gather conditioning and data enhancement

Figure 11 shows the seismic gather before and after conditioning. Gather conditioning increases signal to noise ratio with flattening of the events and increase horizon continuity. Conditioned gather data has been utilised for AVO analysis, segment offset stacking and full offset stacking.

Conclusions

Only certain types of noise can be addressed and data can be enhanced in term of frequency and continuity of seismic events. However, if the seismic data is affected by multiples or inaccurate velocities during stacking of gather data and migration of seismic data, then the data cannot be enhanced significantly by interpreter and it has to go back for reprocessing with revised parameters.
The data enhancement takes small overhead time but provide a significant detailed result. The entire process takes few hours for optimisation and selection of parameters for the enhancement of 3-D volume without recommending for repetition of survey and reprocessing especially in highly complex area having terrains in onland and complex offshore area.

The importance of data conditioning increases with fast track seismic data interpretation projects especially in case of quantitative interpretation using AVO analysis and simultaneous inversion.

Inverse Q compensation method of data enhancement is simple, fast and readily available with many interpretation software modules.

Seismic data conditioning have advantage over normal seismic by increasing the capacity to auto-track the horizons, suppress the post stack noise, and improve vertical as well as horizontal resolution of structural interpretation and stratigraphic interpretation.

The largest difference between raw and conditioned gather data looks at far angle because of the stretching in the far angle traces.

We find that attribute run on enhanced seismic data which have high signal to noise ratio and higher frequency exhibits better feature without any masking and make seismic more informative than normal and conventional seismic data.

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References

Chopra S et. al. 2011: Coherence and Curvature attributes on pre-conditioned seismic data : The Leading Edge April 2011

Mikhail Bekulov et al ; 2009; Prestack data enhancement with partial common reflection surface stack: Geophysics vol 74,