Utilizing Frequency Based Seismic Attributes for Improving Seismic Data for Structural Interpretation: A Case Study from OIL's Operational Areas, Upper Assam Basin

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Keywords

Median filtering, Graphic equalizer, Cosmetic enhancement

Summary

Seismic attributes are derived entities of the seismic data and help to decipher features of interests to the seismic interpreters, otherwise difficult to be identified from the conventional seismic data. In this paper, an attempt has been made to utilize frequency based seismic attributes on 3D seismic data in one of OIL's operational fields of Upper Assam Basin to enhance a deeper reflector of interest. The frequency of seismic waves traveling through the subsurface is attenuated with depth. Hence, at the deeper levels, it becomes difficult to identify the reflection boundaries in seismic data due to the narrowing down of the frequency spectrum with the attenuation of high frequencies. In such cases, frequency based seismic attributes help in resolving the reflectors by highlighting the frequencies of events of interest.

In this case study, a combination of median-filter attribute followed by graphic equalizer attribute, and cosmetic enhancement is applied on PSTM 3D seismic volume (focus given in the time window 2400ms-2800ms) to bring out the continuity of reflectors for structural interpretation.

Introduction

Seismic data acquired in the oil and gas industry is focused to understand the structure and stratigraphy of the subsurface. However, the seismic data is contaminated with noise even after various noise filtering techniques have been applied during the processing of the seismic data. Hence, increasing seismic data quality by enhancing the signal and reducing the noise is desirable. Seismic attributes are effective tools to seismic interpreters to enhance the subtle features and reduce the noise in the data. Over the years, different seismic attributes have been used for enhancing seismic quality. Hesthammer and Fossen (1997) have shown the utilization of median-filter attribute maps to filter the effect of seismic noise. In this case study, an attempt made to use median filter on the original 3D PSTM seismic volume to suppress the background random noise and increase the S/N ratio. The application of median filter on the data helps in reducing the high frequency component in the data, thus, increasing the lateral continuity of the reflector of interest.

Splitting the seismic data in to discrete frequency intervals followed by application of filtering techniques and reconstruction of the data for enhancing signals and reducing noise in particular frequency levels has been demonstrated by Helmore (2009). The use of spatial filtering techniques primarily affect the central pass-band, a frequency splitting approach can be more useful for highlighting targeted frequencies in the data. An attempt is made to apply different weights to discrete frequency levels in the median filtered data to enhance the lateral continuity of the event of interest.

Increasing the frequency content of the seismic data has been of prime interest to increase the vertical and horizontal resolution of the seismic data. Significant efforts are made in seismic data processing to enhance the frequency content of the data as much as possible with respect to the acquisition parameters. Several methods of frequency enhancement both in the pre-stack and post-stack data have been developed. Some of these methods include deconvolution techniques, time variant spectral whitening, spectral-decomposition based inversion for seismic reflectivity (Chopra et. al., 2006) and others. Subsequent to apply of median filter and graphic equalizer attributes on data, an attribute cosmetic enhancement using loop reconvolution (Young and Wild, 2005) applied for bandwidth extension of the seismic data. This will help the interpreter to perform horizon interpretation at places of lesser confidence with higher uncertainity.

Geology of the study area

The study area is situated within the main producing area of OIL's operational areas, Upper Assam Basin (Figure-1), on the southern flank of the Basement high and in front of the NE-SW trending Naga thrust in the south. The Upper Assam Basin is a Tertiary sub-basin of the Assam-Arakan geological province located in the north eastern part of India subcontinent. It is a southeast dipping foreland part basin and bounded in the northwest by the Eastern Himalayans, in south by the Naga-Patkai hills, in the northeast by Mishmi hills and in the southwest by

Mikir Hills and Shillong Plateau. The Upper Assam Basin came in to existence during Cretaceous and Early Cenozoic period and was located in a passive continental margin facing an open sea (OIL unpublished report, 2002). The basin received clastic sediments in varied shallow marine to paralic and non-marine (deltaic, fluvial) environmental condition in different geological times during Tertiary age.The basement is dipping to the South, South-East and North-East direction. The basin comprises of about 4 km thick sediments at central high and more than 7 km thick sediments of mostly Tertiary and Quaternary age. Since the discovery of oil at Digboi in a Supra-thrust anti-clinal dome in late nineteenth century, extensive exploration activities have been carried out in the basin and established number of hydrocarbon fields.

In this study, Eocene age formation was prime interest for structural interpretation and the expected depth range around 3500mts-4500mts.

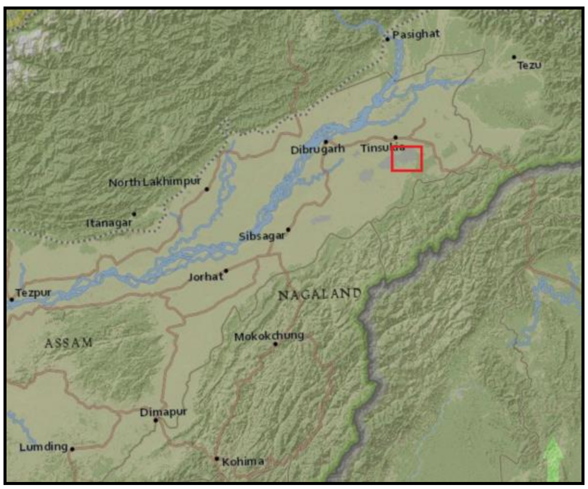

Figure 1: Study area (shown as red box) from OIL's operational areas, Upper Assam Basin

Seismic attributes and their applications

The difficulty of mapping the reflector at target formation has directed towards use of combination of various seismic attributes for enhancement of seismic for structural interpretation. During the course of seismic attribute analysis, Median filtering followed by graphic equalizer seismic attribute and cosmetic enhancement attribute has been utilized to fulfill the objective.

i) Median filtering

Median filter is one of the popular seismic attribute for removal of random noise with high amplitudes also known as salt and pepper noise in seismic data. Unlike mean filter with smearing effects on faults and stratigraphic edges, median filter allows edge-preserved smoothing of seismic data (Hall, 2007). In this attribute, a filter operator is first designed which scans through the entire seismic cube. This 3D filter is typically of odd dimensions of fixed width (eg: 3 X 3 or 5 X 5). The filter is moved through the 3D seismic volume and at each location, the median data value of all the samples under consideration in the 3D analysis window is output at the center of the operator. Large filter width favors noise reduction while smaller filter width preserves local structural details. In this work, median filter with different filter widths have been applied on the seismic data to understand the effect of filter width. Based on the results obtained by the application of median filter with different filter widths (figure 2(b) and 2(c)) on the original 3D PSTM seismic volume (figure 2(a)), the filter width of 5 X 5 and vertical window of 5 samples was considered optimum for removing the random noise and increasing the lateral continuity of the reflector of interest. On comparison of the frequency spectrum of the original PSTM volume (figure 2(d)) with the frequency spectrum of the median filtered volume (figure 2(e)), it was clear that the application of median-filter in the data helps to enhance particular frequency range with focus to target reflector.

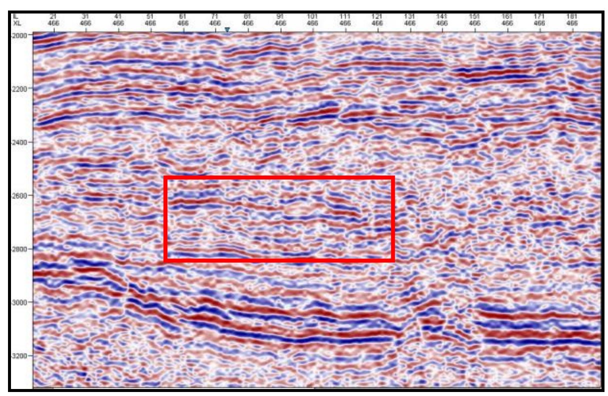

Figure 2(a): Original 3D PSTM seismic data with highlight on the zone of interest

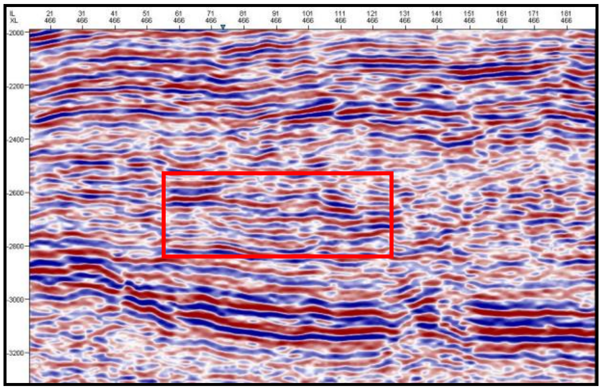

Figure 2(b): Median filter with filter width of 3X3 applied on original 3D PSTM seismic data.

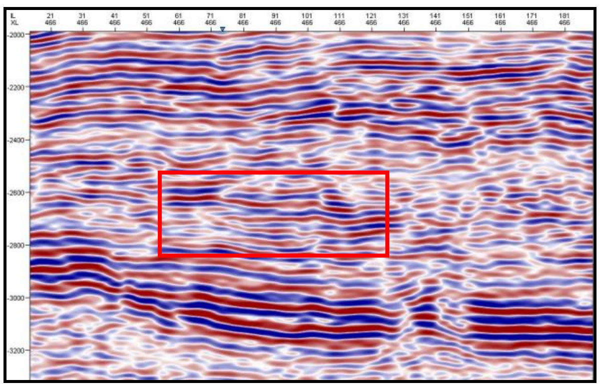

Figure 2(c): Median filter with filter width of 5X5 applied on original 3D PSTM seismic data. The highlighted part shows an increase in continuity and resolution of the event of interest

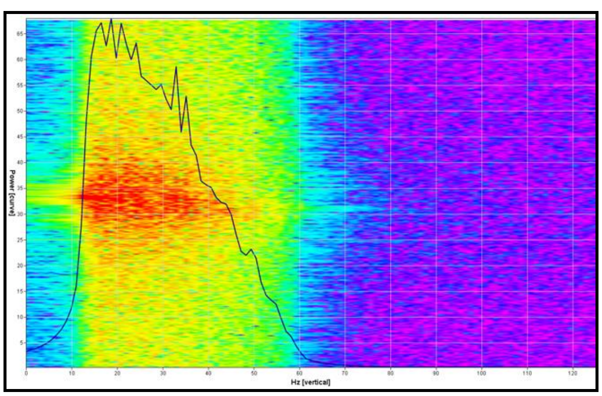

Figure 2(d): Frequency spectrum of original 3D PSTM seismic data

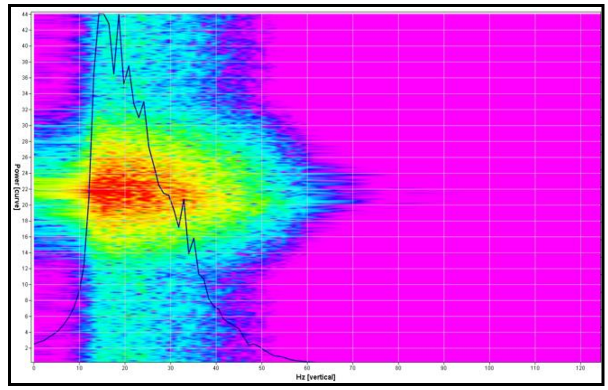

Figure 2(e): Frequency spectrum of median-filtered 3D PSTM seismic data showing an attenuation of high frequency component from the original seismic data

ii) Graphic equalizer for enhancing frequency

The graphic equalizer seismic attribute acts as a virtual instrument to enhance or reduce the selected frequency component of the seismic data. It can be used to apply high, low or band-pass filters to the input data. This attribute is similar to frequency split filtering in which the seismic data is divided into discrete intervals of frequencies. The amplitude spectrum of median filtered seismic data at event of interest has given understanding that almost plateau like frequency range from 10 Hz to 30 Hz with gradual decimation from 20 Hz to 30 Hz.

For frequency boost up of the seismic data, different weights are applied to the frequency bands. In the frequency range 20-30 Hz higher weight, 10-20 Hz lower weight and rest of the frequency bands are given no weightage. The seismic data is then reconstructed by combining the different frequencies together to provide the frequency enhanced seismic output. The frequency spectrum corresponding to the output seismic cube is shown in figure 3(b). The output cube (figure 3(a)) has better reflector continuity for the event of interest and can be utilized by the interpreter for better structural interpretation.

It is to be noted that the spatial filtering techniques primarily affects the central-pass band frequency of the seismic data which makes frequency splitting approach of increasing seismic quality different from the other methods. The graphic equalizer seismic attribute can also be used directly on the original seismic volume. However, in the dataset used, it was found that the seismic conditioning was better when an iterative workflow was adapted by first applying median filter on the data and then apply graphic equalizer on the median-filtered volume.

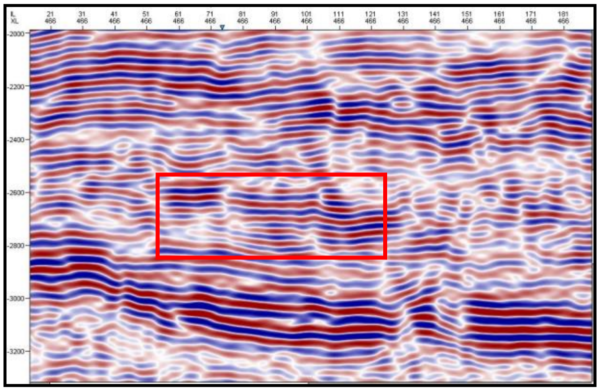

Figure 3(a): Graphic equalizer applied on the median filtered data to boost frequencies of interest. The highlighted area has better continuity of events which gives more confidence in seismic interpretation

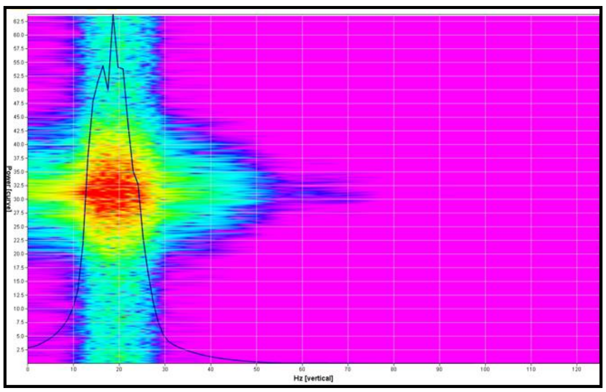

Figure 3(b): Frequency spectrum of the graphic-equalized seismic volume showing dominance of frequencies in between 10-30 Hz

iii) Cosmetic enhancement using loop reconvolution

Cosmetic enhancement is another specialized attribute aimed at increasing the high frequency content of the seismic data to bring out the possible structures and pinch-outs more prominently. Cosmetic enhancement of seismic data works on the principle of Frequency optimized loop reconvolution (FOX) (Young and Wild, 2005). The essence of this technique is to generate a sparse-spike reflectivity series weighted by the interpolated amplitudes at all of the maxima and minima locations and convolving the resultant reflectivity series with a suitable high frequency wavelet.

As a part of study, cosmetic enhancement has been applied on the median filtered volume generated from the original data. The cosmetic enhancement resulted in the bandwidth extension of the high frequency component of the dataset (figure 4(b)). Also, the sharpness of the events in the resultant cube (figure 4(a)) can be used by the interpreter for more accurate seismic interpretation.

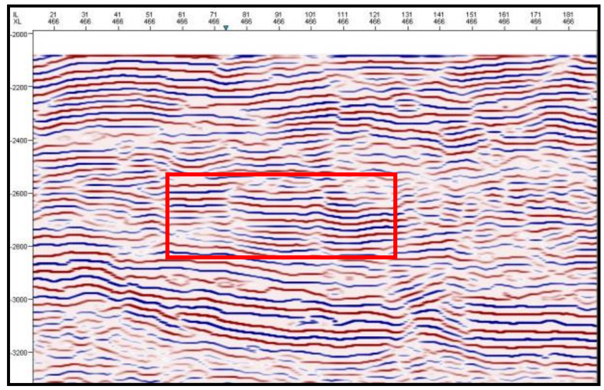

Figure 4(a): Cosmetic enhancement of median filtered seismic data showing an increase in the sharpness of the events and also pinch-outs and truncations of events

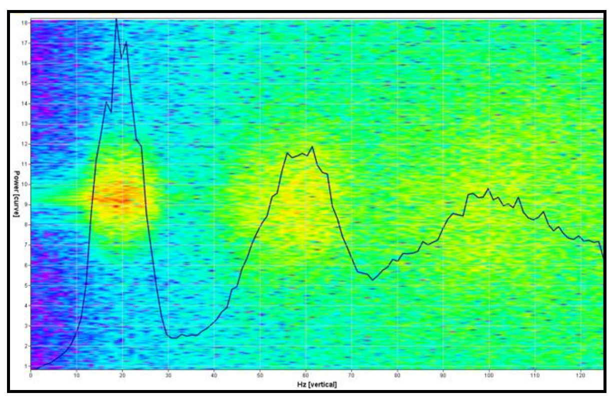

Figure 4(b): Frequency spectrum of data after cosmetic enhancement showing a bandwidth extension with the high frequency component

Results and Conclusions

Specific workflow through utilization of frequency based attributes was developed and applied on a 3D PSTM volume of OIL's operational areas, Upper Assam basin for enhancement of seismic event which was difficult to identify and interpret in the original seismic volume. Median filter provided a quick tool for the interpreter to remove the random noise from the data. Application of graphic equalizer attribute helped in increasing the lateral continuity of the reflector. Cosmetic enhancement contributed to the sharpness of the events and also helped the interpreter a lot while structural interpretation. At places where seismic horizon was difficult to interpret, a combination of these attributes helped in increasing the resolution of particular events and gives confidence in the structural interpretation. However, these attributes can sometimes remove information from the data which are important for the interpreter, and hence should be used with proper caution and quality control.

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