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Frequency Enhancement – A Comparative Study

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Summary

Seismic waves propagating in the subsurface are attenuated. This loss is frequency dependent i.e. higher frequencies are absorbed more rapidly than lower frequencies resulting in narrow frequency spectrum. Since the seismic trace is a convolution of many overlapping reflections it is often difficult to identify the exact reflection boundary. So there is a need to for a method to enhance seismic data to make subtle geologic features more easily identifiable. Enhanced seismic data shows a significant increase in resolution of reservoir stratigraphy, pinchouts, structures as the event can appear more sharply defined and less affected by low frequency noise. But enhancement of higher frequency, in most of the times, leads to increase in noise levels along with higher resolution. In this paper, an attempt has been made, to outline and compare several frequency enhancement techniques on a single dataset. The dataset used here is from a 3D shallow water survey off western coast of India with a clastic-carbonate setup.

Introduction

Often we come across examples where the seismic volume leads to interpretations which involve complex fault patterns, subtle stratigraphic plays or reservoir extent. In such cases more accurate stratigraphic interpretation is required, but the available bandwidth of seismic data may be inadequate to image the proper resolution of the target.

This problem can be addressed by having reasonable good quality of data and it can be done by some frequency restoration procedure that improves the vertical resolution. This enables confident mapping of horizons of interest, clarifies detailed geological settings, and leads to more profitable seismic exploration.

There are many approaches (Chopra et. al. 2007, Young 2005,) for the frequency enhancement of seismic data, that ranges from spiking deconvolution, Q-compensation, Spectral Whitening, Loop Reconvolution ,Curvature attribute etc. In this paper, we have compared some techniques along with these frequency enhancement methodologies.

Theory and Methodology

A large portion of hydrocarbon bearing reservoir are below the resolution limit of seismic data. Even if we are able to detect them, it is difficult to map and characterize the extent without increasing the bandwidth. This problem is more pronounced in compact lithologies and carbonates. Research and development of algorithms to measure and compensate for the effects of higher frequency attenuation in seismic data have been ongoing efforts for several decades.

The main objective of this study is to enhance the frequency content of the data set, which can be used for stratigraphic interpretation.

The study area is from west coast of India which has wide spread carbonate sedimentation in the Mid Miocene age and a thick clastic sediments in post Miocene period.

This study will help in interpretation (1) To delineate porosity pods within carbonate layers (2) in delineation of transgressional shale providing top-seal for entrapment (3) to image clear fault geometry, including minor faults (4) In defining bed terminations which can be useful for wedge out prospects.

Figure1. shows a stacked seismic time section of a line along with the well logs. The same line has been used in different enhancement procedures and the results are compared along with their spectrums.

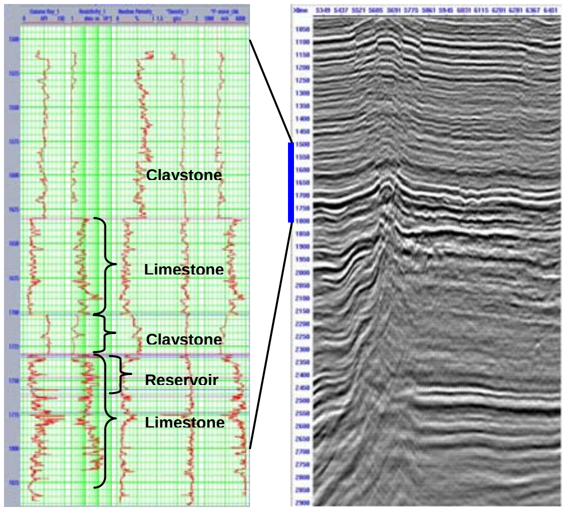

Figure 1: Log and seismic Time section for present study

Conventional Methods

- *Spiking Deconvolution :*

One of the conventional step of improving the resolution is spiking deconvolution (Yilmaz, 1987) which designs an inverse filter to compress the seismic wavelet into an impulse. Figure2. illustrates the stack section after spiking deconvolution.

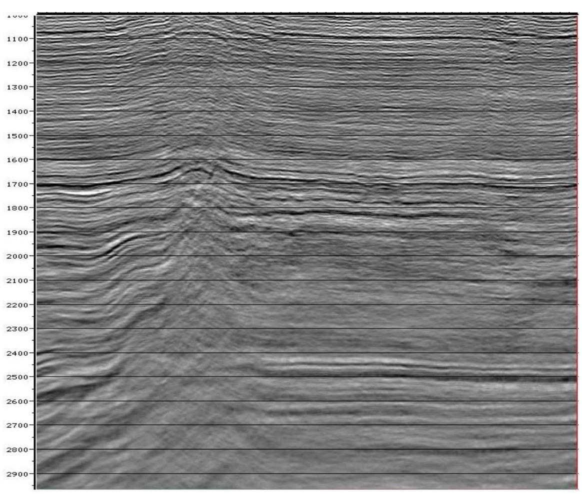

Figure 2: Stack after Spiking deconvolution

- *Q compensation :*

Another commonly used measure to compensate the frequency loss is the inverse Q filter. The essence of Q 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*-filtering procedure attempts to remove the *Q*-effect to produce high-resolution seismic data. There are many ways to estimate Q, of which 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. Figure3. shows the section after Q-compensation.

New Methods

- *Loop Reconvolution* :

An innovative method of cosmetic enhancement of seismic data has been described by Young (Young, 2005) which is based on loop reconvolution principle. This procedure generates a sparse spike reflectivity from seismic, weighted by interpolated amplitude at all maximum and minimum. Then a suitable broad band wavelet can be convolved with the resulting series followed by spatial filtering for smoother appearance. Irrespective of whether this technique actually recover any missing or hidden information from the data , it can help in interpretation because events can appear more sharply defined and less affected by low frequency, characteristic to conventional seismic data. Figure4. shows the stack section after this process.

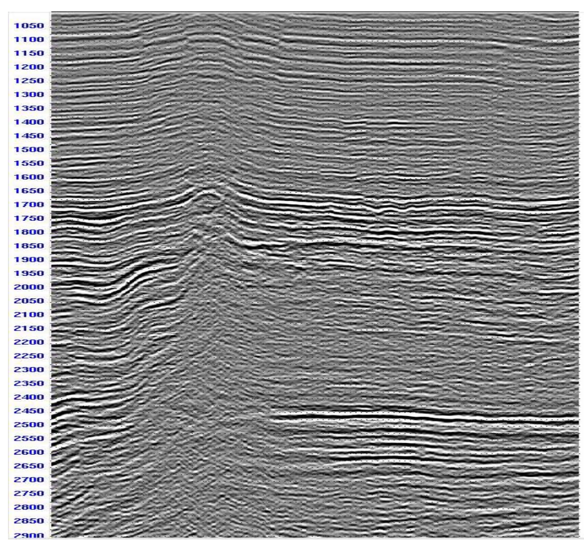

Figure 3: Stack after inverse Q filtering

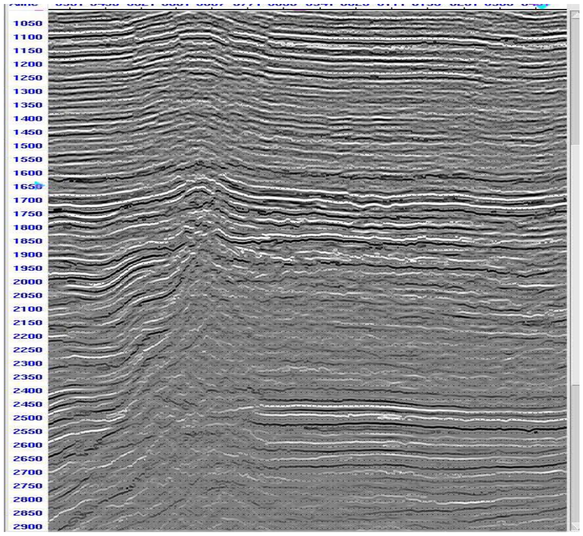

Figure 4: Stack after Loop reconvolution

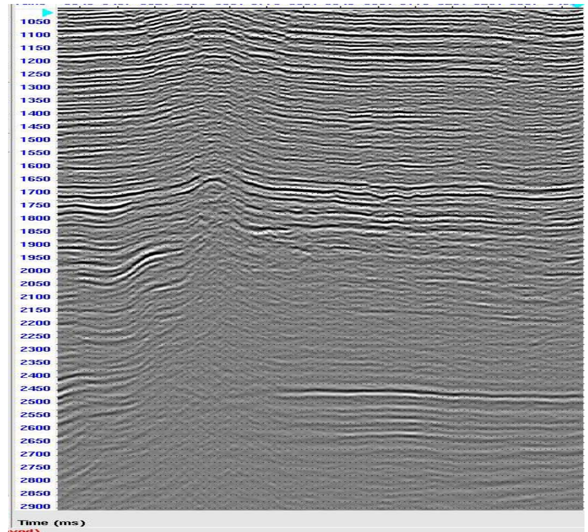

Figure 5: Curvature section

- *Curvature Attribute* :

One of the recent advancement to enhance the small scale features in seismic is to use curvature attribute. Curvature is a measure of concavity or convexity of a surface so that sharp turns will have larger curvature. Curvature attributes along the horizon have been shown (Chopra 2007, Roberts 2001) as a measure of predicting subtle faulting and fracturing which are below seismic resolution, from surface seismic data. With respect to seismic trace it can also be used to enhance peaks & troughs of seismic, as it is the rate of bending of a trace. It can identify the relative peak and trough of a trace. Figure5. shows the corresponding curvature section generated by using second derivative. As evident from the figure curvature is enhancing the higher frequency part of the seismic but lower frequencies are lost. Since we need a broadband spectrum, so a way to overcome this problem is to get lower frequency part of the spectrum from the input data and merge it with the higher frequency curvature section. Figure6. shows the same section after frequency merge.

Comparision of spectrum of various methods :

how much reliable they are? Which one should be used? Whether we will recover any missing information which are lost due to the attenuation of higher frequencies?

One way to check the effectiveness is to estimate the signal and noise spectrum after the enhancement. Figure8. shows the respective signal & noise spectrums. As evident from the figure the input data had a 10 db difference between the signal & noise level at higher frequencies 80-85Hz. This difference has decreased after the spectral enhancement i.e. the noise has also been boosted. The difference is 10db, 9db, 6db & 4.5 db (Figure.11) respectively for curvature enhancement, inverse Q filter, spiking deconvolution and loop reconvolution. This suggest that the boosting of noise

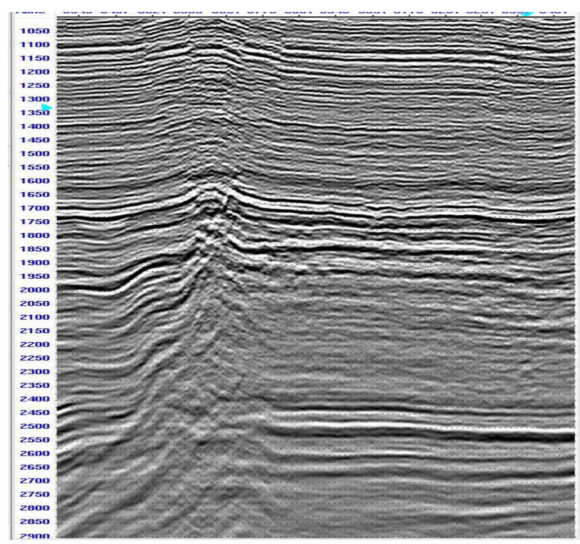

Figure 6: Stack after Frequency merge with curvature

is minimum in curvature enhancement procedure compared to others.

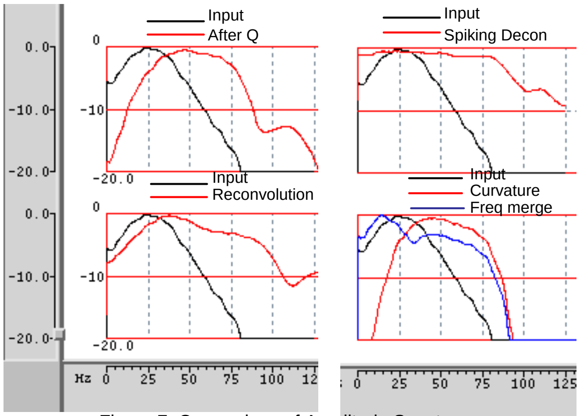

Figure 7: Comparison of Amplitude Spectrum

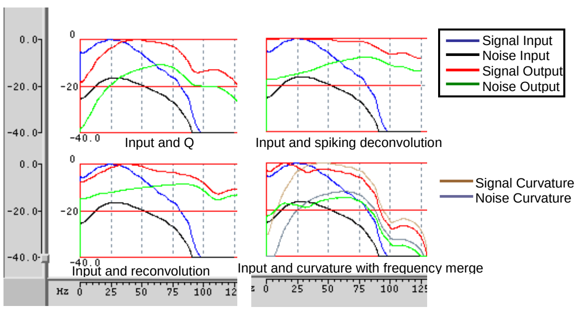

Figure 8: Signal & Noise spectrum comparison. Black & blue color respectively shows S&N spectrum of input.

Figure 9: Stack after commercial proprietary enhancement

This data has also been undergone a commercially available one dimensional convolution method. The results are shown in Figure9. and spectrums are shown in Figure10. These results show that the faults are now more visually enhanced, horizon auto tracker is more stable and doublets have become discrete events so that subtle changes can be identified.

Conclusion

The results have decreased the interpretational uncertainty to some extent. The poor reflection zone in the seismic volume now shows greater reflection detail and continuity.

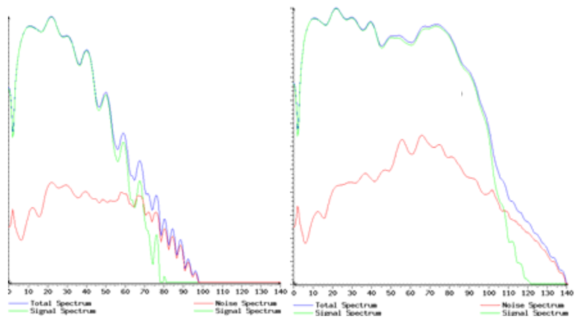

Figure 10: Signal & Noise Spectrum after commercial technique

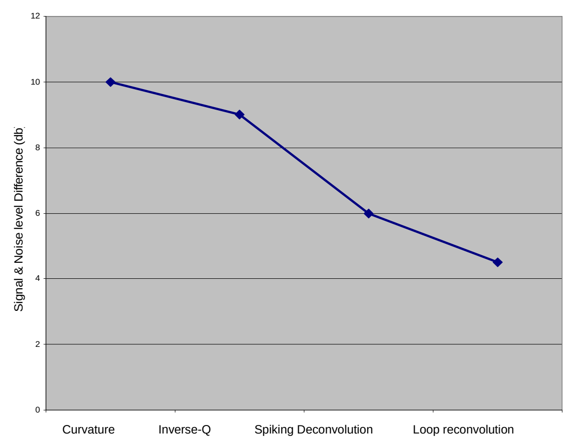

Figure 11: Comparison of noise level between different methods

These methods are quick and easy to implement especially the curvature attribute has a lot of scope for data enhancement. Still all these methods are susceptible to noise in the data. So to get a better bandwidth, input data should have a good S/N ratio. Also there is a limit to any bandwidth enhancement procedure and hence the method has to be conservative in approach, not to stretch it beyond the available useful information in the data.

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