Thin-Bed Reflectivity – An Aid to Seismic Interpretation

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Summary /Introduction

Enhancing the bandwidth of surface seismic data has always been a desirable goal for geoscientists. Conventional wisdom dictates that in the presence of noise and consequent broadening of the seismic wavelet during its subsurface journey, the resolution limit is a quarter of the dominant wavelength of the data. This limit follows from the Widess model, which is essentially a special case of a realistic model. Based on an analytical analysis of a realistic model, it is found that the seismic amplitude and frequency vary continuously far below the conventional view of the limit of seismic resolution and it is possible to infer thickness below the seismic sample rate. This implies that frequency beyond the seismic data bandwidth can be recovered.

The Method

If the average spectrum of a seismic wavelet is centered around 30Hz, which is usually the case, reservoirs having a thickness less than 25 m, may not have top and base reflectors resolved. Stratigraphic targets are usually set to look for reservoirs 10 m or less in thickness. Attempts to achieve such objectives often lead to frequency enhancement procedures to be followed on surface seismic data.

Seismic sections are expected to bear a striking resemblance to geological cross-sections. When this happens, interpretation becomes straight-forward. If this does not happen, seismic interpreters resort to the art of geological interpretation of the seismic data based on their knowledge of the basic principles of geology and geophysics and their experience. In the practical scenario a certain amount of imagination is relied on when the bandwidth of the data is not supportive of the interpretation. Thin-bed reflectivity inversion helps the seismic interpreters by narrowing the gap between the two extremes mentioned above.

Portniaguine and Castagna (2005) discuss a post stack spectral inversion method that resolves thin layers below the tuning thickness. This method is driven by geological rather than mathematical assumptions and keys on aspects of local the frequency spectrum obtained by using spectral decomposition. This spectral or thin-bed reflectivity inversion (commercial name is ThinMan^{TM} and is proprietary technology of Fusion Petroleum Technologies) outputs a reflectivity series and its apparent resolution is far superior to the input seismic. This aspect makes the method ideal for detailed delineation and characterization of thin reservoirs. Applications of this method in deconvolving the complex seismic interference patterns from seismic data are changing the conventional mind set of interpreters and yield interpretable stratigraphic patterns with remarkable detail. This is a novel way of extracting reflection detail and removing the seismic wavelet without blowing up noise at high frequencies, with corresponding improvement in seismic resolution.

The method essentially consists of following steps:

1. Making accurate estimation of a time and space varying set of wavelets from the data. For this purpose having some well control is desirable. In the absence of any well control, a statistical method of wavelet estimation is adopted.
2. Wavelets estimated in step 1 are removed from the data using seismic inversion with spectral constraints that have their roots in spectral decomposition procedures. It is important to note that no starting earth model or interpretation is used in the inversion procedure. The trace-by-trace procedure requires no starting model and has no lateral continuity constraints.

Examples

Figure 1 shows a comparison of a segment of a section from Alberta, before and after reflectivity inversion. After reflectivity inversion, notice how much reflection detail one gets to see in terms of not only extra reflection cycles, but also the fault detail.

Once the thin-bed reflectivity is derived from the input seismic volume using for example, a wavelet derived from an existing well, an interpreter would like to ascertain the associated uncertainty of the inversion process by using a blind well test. This is a good way to test the accuracy of the inversion process. Our experience with such exercises suggests that thin-bed spectral inversion will tie favorably with the other wells on the 3D volume (not used in the wavelet extraction process).

Figure 2 shows a comparison of a segment of an input seismic section (Figure 2a) with an equivalent segment generated from the derived thin-bed reflectivity after convolving it with a band pass wavelet with a high end of 120 Hz (Figure 2b). Notice the enhanced resolution of the section in terms of the extra cycles; the individual reflection cycles can now be tracked clearly leading to more accurate and meaningful interpretation which may be carried out on such data.

Seismic attributes are a great help in extracting information from the data and are being used by geologists, geophysicists and petrophysicists for mapping features from basin to reservoir scale. Features not clearly seen on the seismic displays can be seen on the derived seismic attributes and there has virtually been an explosion in both the development and application of seismic attributes. Attribute computation done on data with enhanced resolution prove to be very useful for mapping onlap and offlap or other features thereby facilitating the mapping of parasequences and the direction of sediment transport.

Figure 3 shows a comparison of a stratal slice through coherence attribute generated for both the input and the enhanced-resolution volume. Notice the significant impact enhanced resolution has on the coherence attribute providing increased lateral resolution of the channel system as well as the faulting seen to the left.

Conclusions

The thin-bed spectral inversion method discussed here is a novel way of removing the wavelet from the seismic data and extracting reflectivity. For data with high signal-to-noise ratio, thicknesses far below tuning can be resolved. Appreciable noise in the data deteriorates the performance of the inversion outside the frequency band of the original seismic data, but the method still enhances high frequencies within the band without blowing up noise as conventional deconvolution would do. Nevertheless, the highly resolved seismic data retrieved in the form of reflectivity data is very useful for making accurate interpretations and proves to be advantageous in many ways.

Acknowledgements

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References

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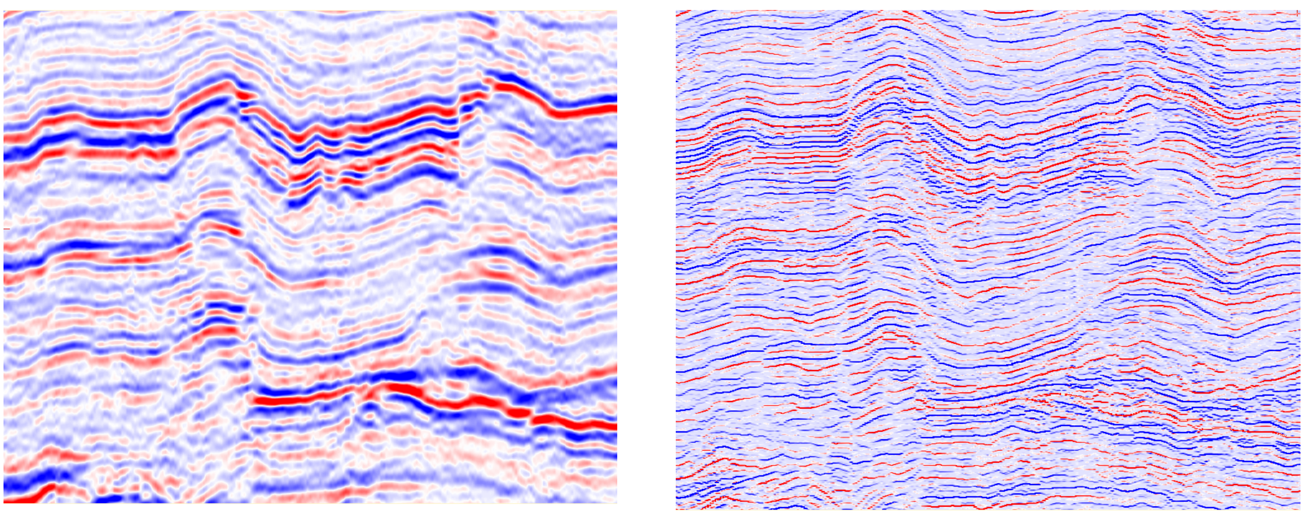
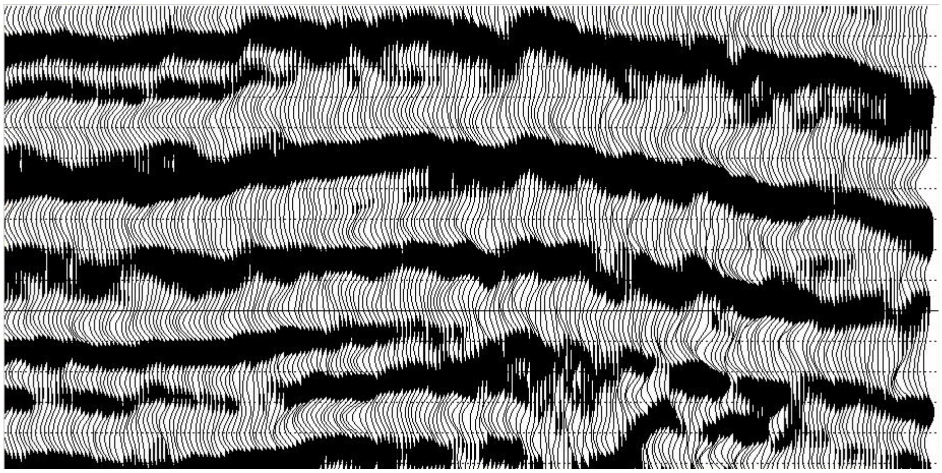
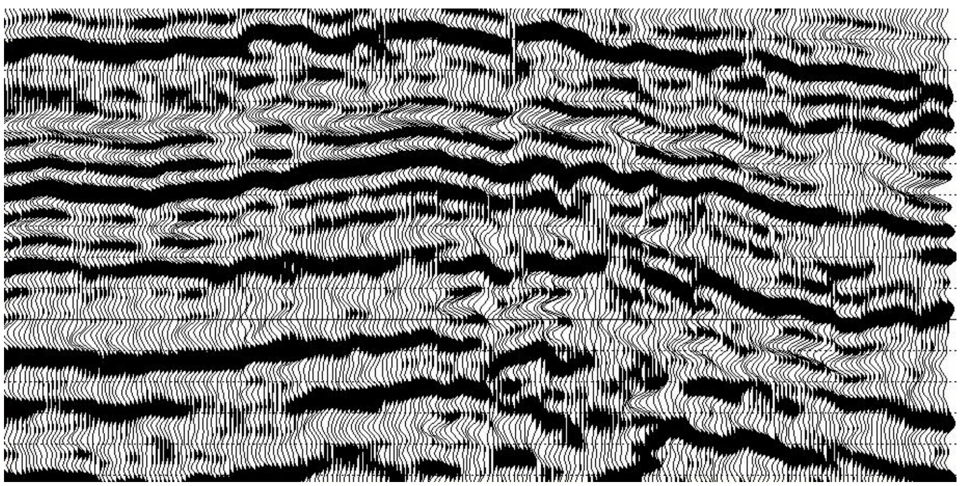


(a) (b)

Figure 1: shows a comparison of the conventional seismic section with its derived thin-bed reflectivity. Notice how much more reflectivity detail can be seen as compared with the input section. *(Data courtesy: Arcis Corporation, Calgary)*

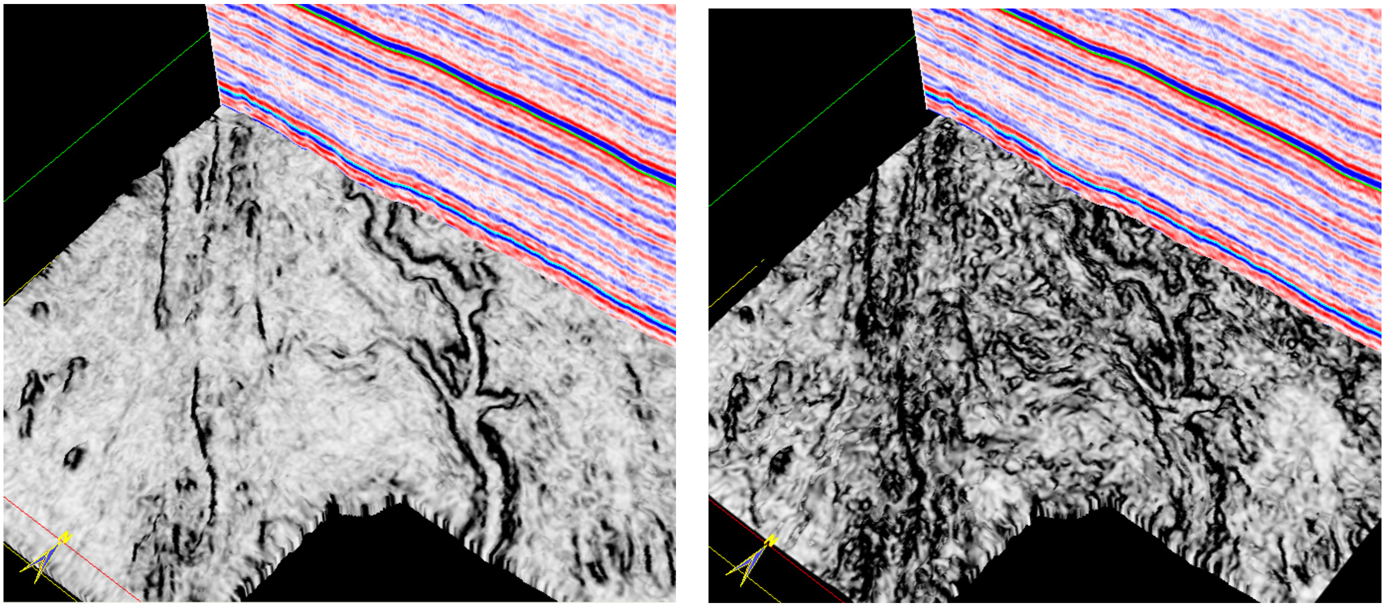


(a)



(b)

Figure 2: shows comparison of a segment of a seismic section from the input band-limited seismic (Figure 2a) and the derived equivalent section from the thin-bed reflectivity convolved with a 5-120 Hz band pass wavelet (Figure 2b). Notice the enhanced resolution of the section in Figure 2b. *(Data courtesy: Arcis Corporation, Calgary)*



(a) (b)

Figure 3: Strat-slices from coherence attribute derived from (a) the band-limited seismic, (b) thin-bed reflectivity convolved with a 5-120 Hz band pass wavelet. Features can be seen with a better definition and clarity on such attribute slices. *(Data courtesy: Arcis Corporation, Calgary)*