Thin-Bed Reflectivity Inversion and Seismic Interpretation

Satinder Chopra*
Arcis Corporation, Calgary, AB, Canada
schopra@arcis.com

Yong Xu
Arcis Corporation, Calgary, AB, Canada

John Castagna
University of Houston, Houston, TX, Canada

and

Rainer Tonn
Oilexco, Calgary, AB, Canada

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

Thin-bed spectral inversion method is a novel way of removing wavelet from the seismic data and extracting reflectivity (Castagna et al 2003; Portniaguine and Castagna 2005; Chopra et al 2006). This inversion process does not require stringent assumptions for its performance. It does not require any *a priori* model, any reflectivity assumptions or horizon constraints and neither is a well constraint mandatory, though having at one well control point is helpful. 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.

Examples

Figure 1 shows a comparison of a segment of a seismic section from Alberta in the foothills of the Rocky Mountains, and its equivalent reflectivity section. 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. Any correlation with a log curve will show how religiously the kinks on the curve follow the reflection detail on the reflectivity section.

Next we discuss a recent application of thin-bed reflectivity inversion to a dataset from the North Sea. Even though a good workflow including LMR inversion and neural network analysis was established, the hydrocarbon identification remained a challenge. In particular, the difference in the OWC on the East and West flank of the field was puzzling. To find a solution to this problem, higher resolution seismic data was necessary. The thin-bed reflectivity inversion process delivered a tool to refine the interpretation, and allowed the identification of individual connected or disconnected sand layers (figure 2). The high resolution thin-bed reflectivities enabled the interpreter to map the OWC, which is expressed by a flat spot. Furthermore, it was found that the thin-bed reflectivity data set could be tied to key stratigraphic intervals. At the end of the workflow a reliable map of the sands was created and additional upside potential was established.

Finally, a significant aspect that needs to be mentioned is about an important attribute of the reflection process that seismic interpreter looks for (in addition to four other attributes, namely, reflection polarity, strength, continuity and relationship to other reflections). While thin-bed reflectivity serves to provide four of these characteristics clearly, the reflection character can be studied by convolving the reflectivity with a wavelet of a known frequency bandpass. This will not only provide an opportunity to study reflection character associated with a feature(s) of interest, it will also serve to get a confirmation on its close match with the original data. Figure 3 shows a segment of a seismic section from the input seismic data and the same segment from the reflectivity volume convolved with a bandpass wavelet with a high end of 120 Hz. Notice the higher resolution that has been achieved as well as the fact that lateral changes in wavelet character can now be studied.

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

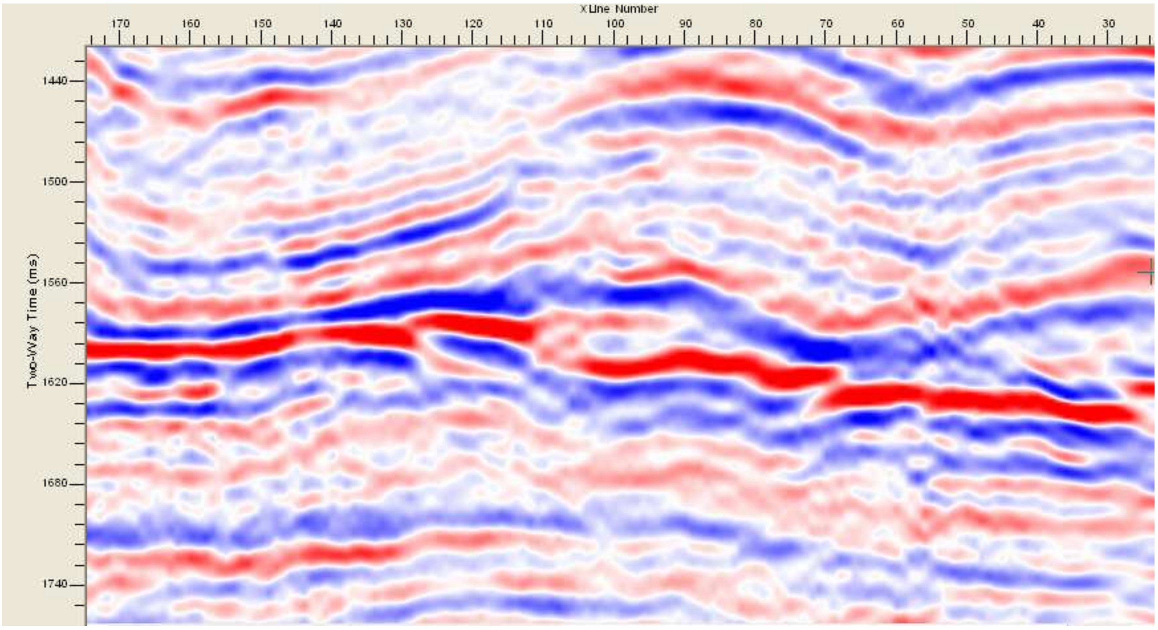
We thank Arcis Corporation, Calgary and Oilexco, Calgary, for permission to present and publish this work.

References

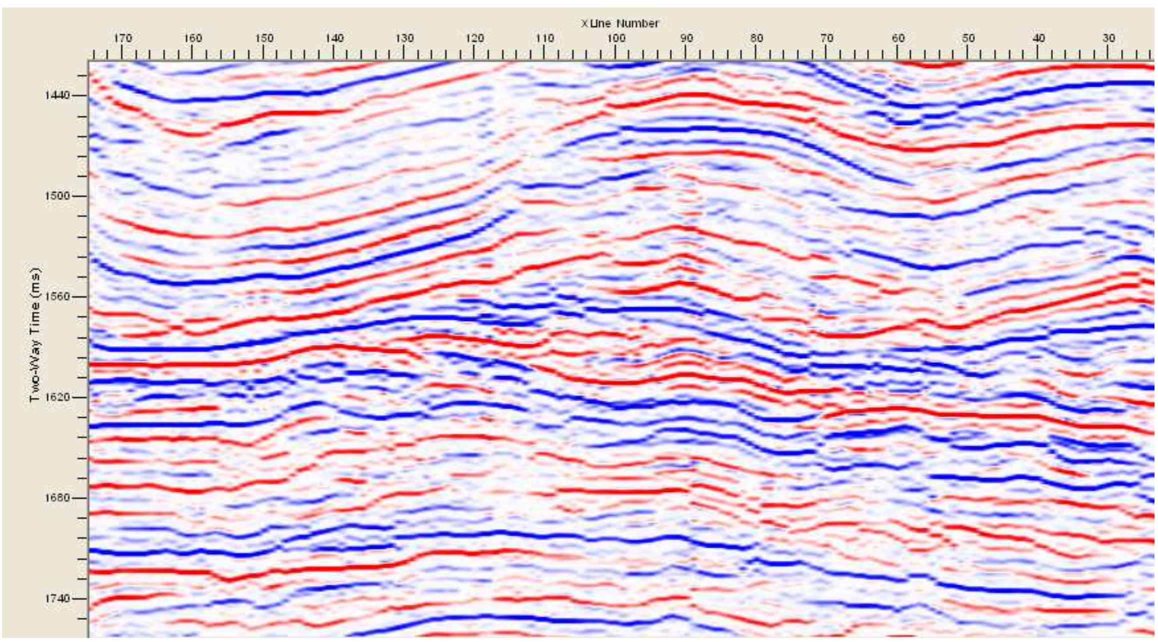
Castagna, J. P., S. Sun and R.W. Siegfried, 2003, *Instantaneous spectral analysis: Detection of low-frequency shadows associated with hydrocarbons,* The Leading Edge, 22, 120.

Chopra, S, Castagna, J.P., Portniaguine, O., 2006, *Seismic resolution and thin-bed reflectivity inversion*, CSEG Recorder, 31, no. 1 p19-25.

Portniaguine, O. and J. P. Castagna, 2005, *Spectral inversion: Lessons from modeling and Boonesville case study*, 75th SEG Meeting, 1638-1641.



(a)



(b)

Figure 1. Shows a comparison of (a) the band-limited seismic section and (b) the equivalent derived thin-bed reflectivity section. The display contrast for the reflectivity has been enhanced purposely to bring out the resolution detail that can be seen. Data courtesy: Arcis Corporation, Calgary. Fig. 2: The thin-bed reflectivity inversion allows picking individual sand intervals (fig. 2a) while the neural network solution displays one sand-body only (fig. 2b). However, only the combined interpretation of the Vshale and the reflectivity volume makes the correlation from one channel to the next successful. The flat spot, which marks the OWC, can be correlated and serves as a tool to identify hydrocarbons. The seismic section is tied to several wells. Data courtesy of Oilexco, Calgary.

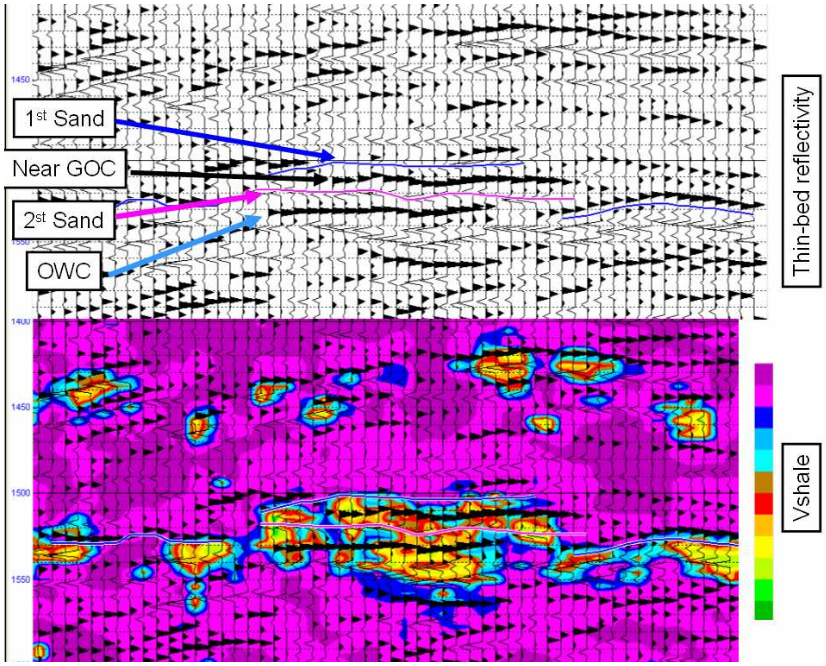


Figure 2. The thin-bed reflectivity inversion allows picking individual sand intervals (fig. 2a) while the neural network solution displays one sand-body only (fig. 2b). However, only the combined interpretation of the Vshale and the reflectivity volume makes the correlation from one channel to the next successful. The flat spot, which marks the OWC, can be correlated and serves as a tool to identify hydrocarbons. The seismic section is tied to several wells. Data courtesy of Oilexco, Calgary.

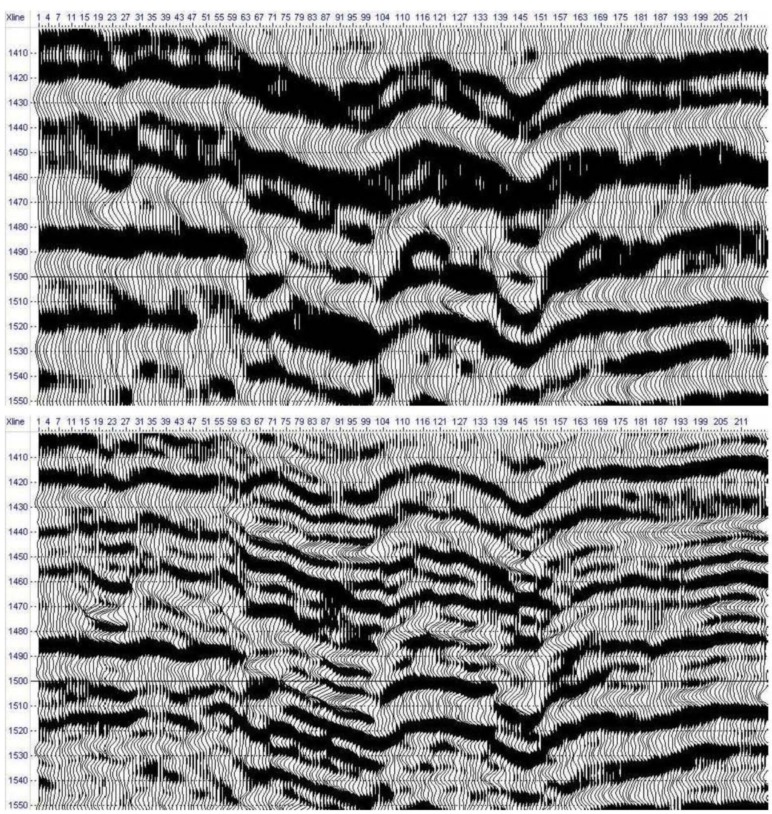


Figure 3. shows a segment of a seismic section from the input seismic data and the same segment from the reflectivity volume convolved with a bandpass wavelet with a high end of 120 Hz. Notice the higher resolution that has been achieved as well as the fact that lateral changes in wavelet character can now be studied. Data courtesy of Arcis Corporation, Calgary.