A New Year's Resolution: "Think Thin"

Spectral Decomposition Applications Beyond the Seismic Bandwidth

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Spectral decomposition of seismic traces has existed since the earliest days of seismology. A new paradigm in the use of spectral information has developed over the last fives years beginning with the pioneering work of Greg Partyka, Kurt Marfurt and others at Amoco Research. The fundamental change in thinking has resulted from workstation technology that has allowed the rapid computation and visualization of Fourier spectra calculated with small windows as a continuous attribute. Such spectra are dominated by local reflectivity patterns. Anomalous geological features such as channels and hydrocarbon filled reservoirs can have anomalous frequency responses. Thus, visualizing the data at discrete frequencies may reveal anomalous or diagnostic behavior not readily apparent on the broad-band seismic data. Recently, wavelet transform techniques have been used to reveal spectral characteristics of individual composite reflections. A number of examples will be shown to illustrate differences in frequency response of composite reflections caused by thin hydrocarbon reservoirs. It is interesting to note that for thin reservoirs, seismic attenuation is a secondary effect, and frequency spectra are dominated by the reflectivity spectra. The result is that low impedance gas reservoirs often have anomalously high peak frequencies that can be used as a diagnostic hydrocarbon indicator.

According to the Widess model (which consists of an isolated thin bed) the peak frequency of the seismic response is higher than that of the wavelet; below 1/8th of a wavelength the seismic response becomes the derivative of the wavelet and does not change shape with changing thickness. Our experience with spectral decomposition has led to the surprising conclusion that the Widess model of thin bed response is a very special case that is very different from most combinations of reflection coefficients. When the reflection coefficients at the top and base of a thin bed are not exactly equal and opposite, a more general behavior is observed where the peak frequency decreases as thickness decreases well below the tuning frequency. This tells us that the seismic response is more sensitive to thin beds than thought previously.

In fact, we find that encoded in the spectral decomposition of a seismic trace is information that exceeds the bandwidth of the actual seismic signal and allows us to make inferences about thin beds that are far thinner than classical limits of seismic resolution. Such knowledge can be used to remove the seismic wavelet without magnifying noise and can thus be used to produce high resolution reflectivity sections that are far superior to conventional seismic sections in resolution and interpretability.

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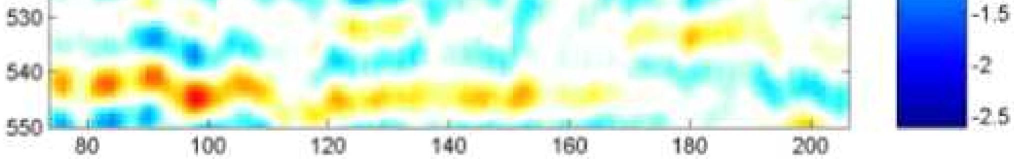
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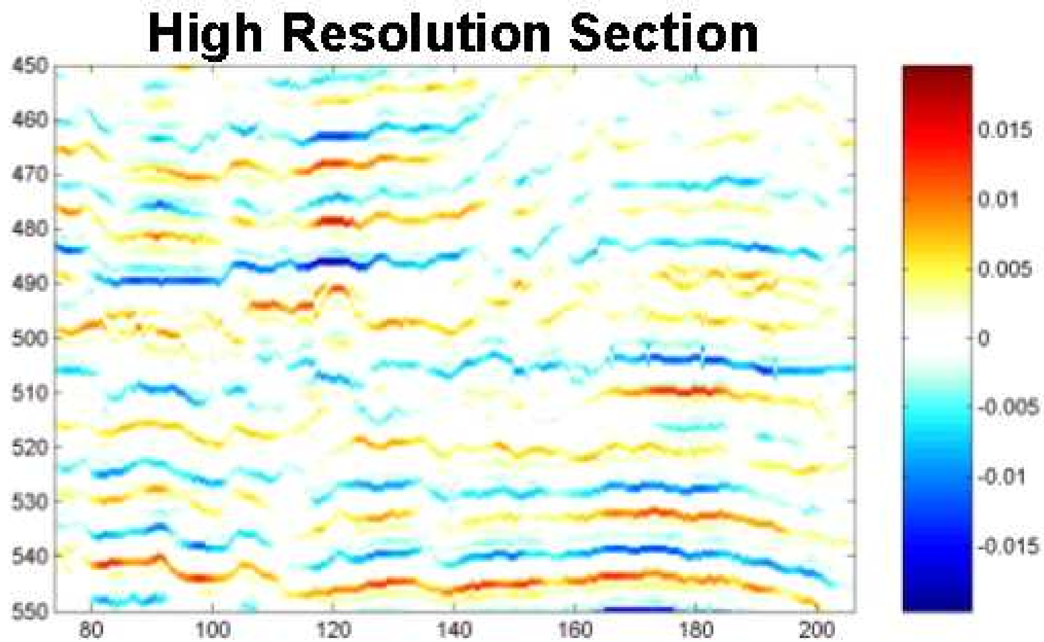
High Resolution Section
450
460
470
480
490
500
510
520
530
540
550
80
100
120
140
160
180
200
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0.01
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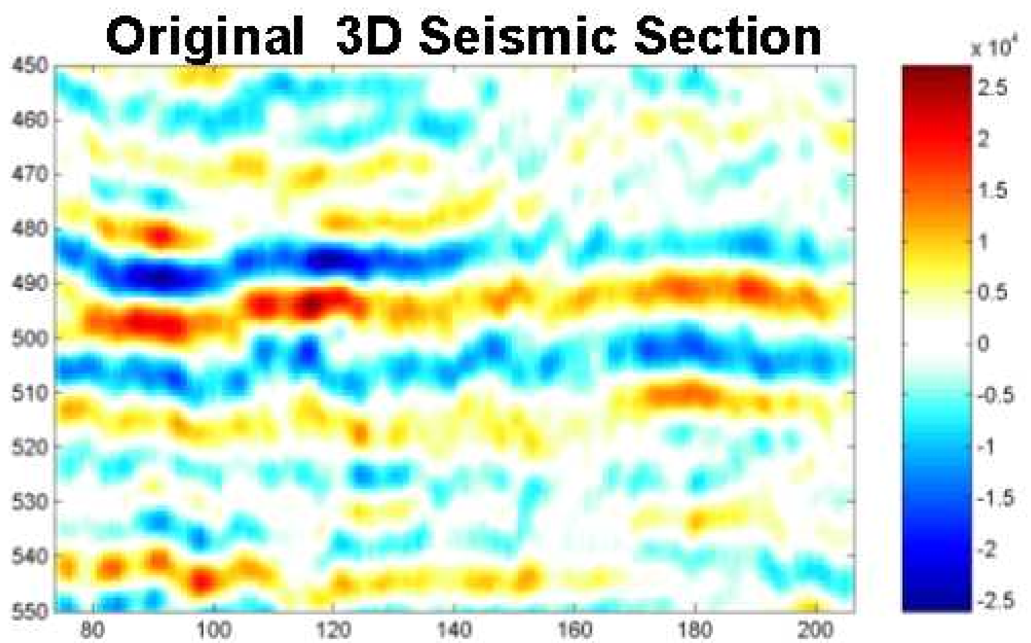
-0.005
-0.01
-0.015


Original 3D Seismic Section
450
460
470
480
490
500
510
520
530
540
550
80
100
120
140
160
180
200
x 10⁴
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5