GC Spectral Decompostion Helps Define Channel Morphology*

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General Statement

When we see a rainbow, it is visually appealing – and the natural tendency is to appreciate its aesthetic qualities rather than study it on an analytical basis, as frequency sub-bands decomposed from white light. In a similar vein, geoscientists studying seismic waves can derive results from the data as a composite signal, as well as gain insight by studying the data decomposed into frequency component parts.

Spectral decomposition has been employed in seismic interpretation for more than two decades, evolving from a niche technique to a commonly used approach due to its advantages in channel delineation, gas reservoir detection and thin-bed interpretation. Since it was formally introduced, several methods of spectral decomposition have emerged, from the popular short time Fourier transform (STFT) and continuous wavelet transform (CWT), to less frequently used methods such as matching pursuit, S-transform, chirprit transform and wavelet packet transform.

Each approach has its advantages and disadvantages, but most of these approaches have in common some kind of operation between the seismic data and serial kernel functions with closed form expressions (Figure 1):

- In STFT, sine, cosine and window functions are used.
- In CWT, a mathematic wavelet is used.
- In S-Transform, the Gaussian function is used.

In geophysical terms, these operations are designated as convolution, essentially some kind of multiplication and summation carried out in a running-window manner.

Example

Seismic data is a collection of reflection events from the subsurface. There are diffractions, refractions and noise, but these are minor considerations when used for oil and gas exploration and reservoir characterization. These subsurface reflection events can overlap, partially or completely, depending on frequency and depth, making some geologic features indistinguishable. However, when seismic data is decomposed into individual frequency components – as done in spectral decomposition – some subsurface events can be distinguished at certain frequency components, such as the channels in Figure 2.

Sometimes, it is not just one particular frequency component that reveals the geological features – several frequency components can reveal different parts or aspects of the subsurface features. In this case, color blending is often used to put several frequency components together into one map and let us see them simultaneously.

In Figure 2b, RGB color blending is used to put three frequency components together by designating a low frequency component as red, and with middle and high frequency components as green and blue, respectively. The high frequency components are more responsive to the narrow and thin parts of channels, while lower frequency components are more responsive to wide and thick parts of channels, such as point bars.

Combining these frequency components together not only makes the overall morphology of the channel system clearer, but also makes it possible to analyze the heterogeneity of the individual channel. For example, the detailed internal variation of the large north-south channel in Figure 2b can be seen.

Conclusion

This article has shown the advantages of spectral decomposition in methodology and practice – but it does have drawbacks that sometimes challenge even the experienced practitioners. One of the most significant problems in spectral decomposition is the side-lobe effect: a fake event created by spectral decomposition that has nothing to do with the subsurface geology. I describe this effect in another article – and introduce a new spectral decomposition method developed to address the problem.

Acknowledgment

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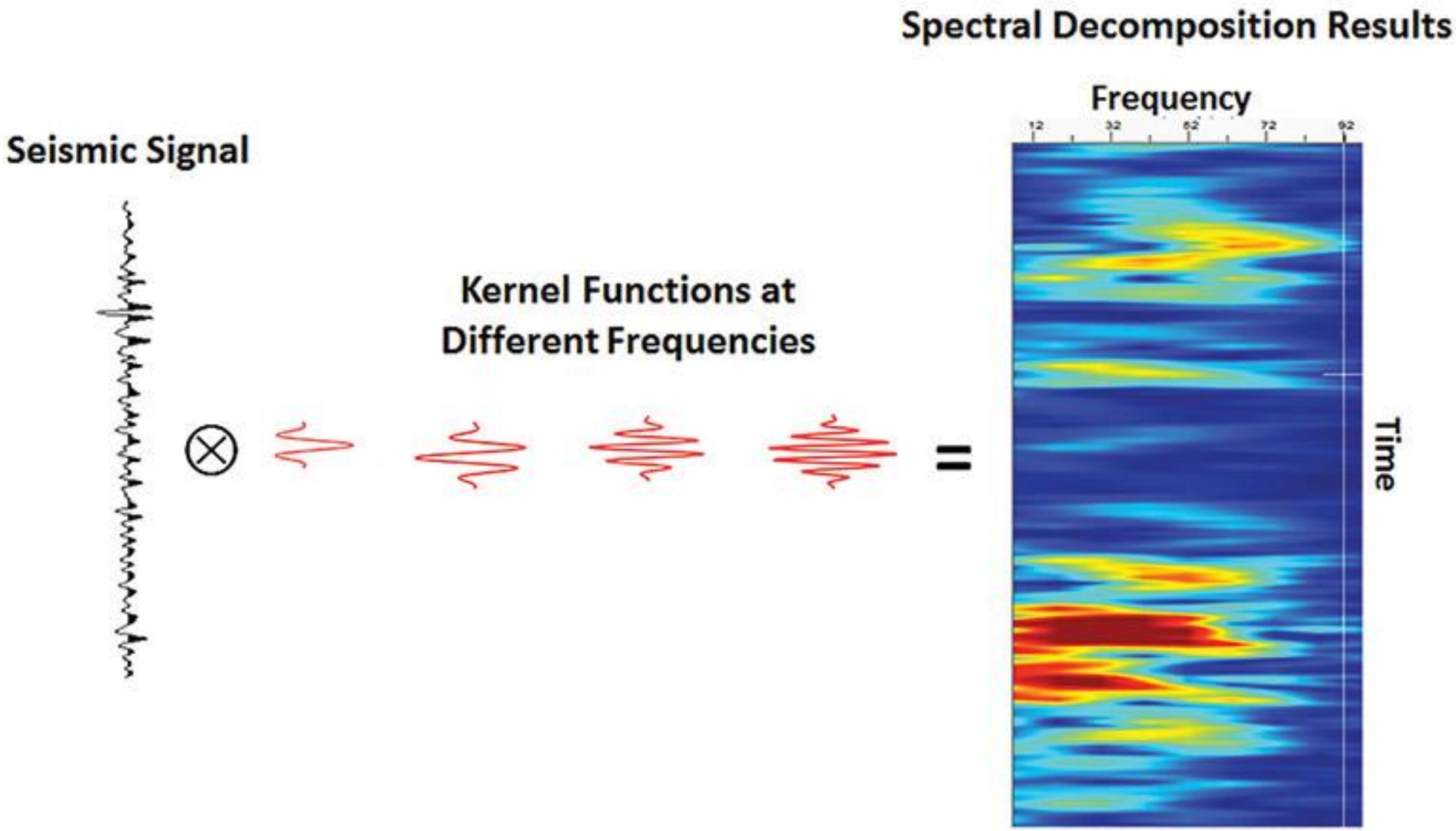

Figure 1. Illustration of spectral decomposition.

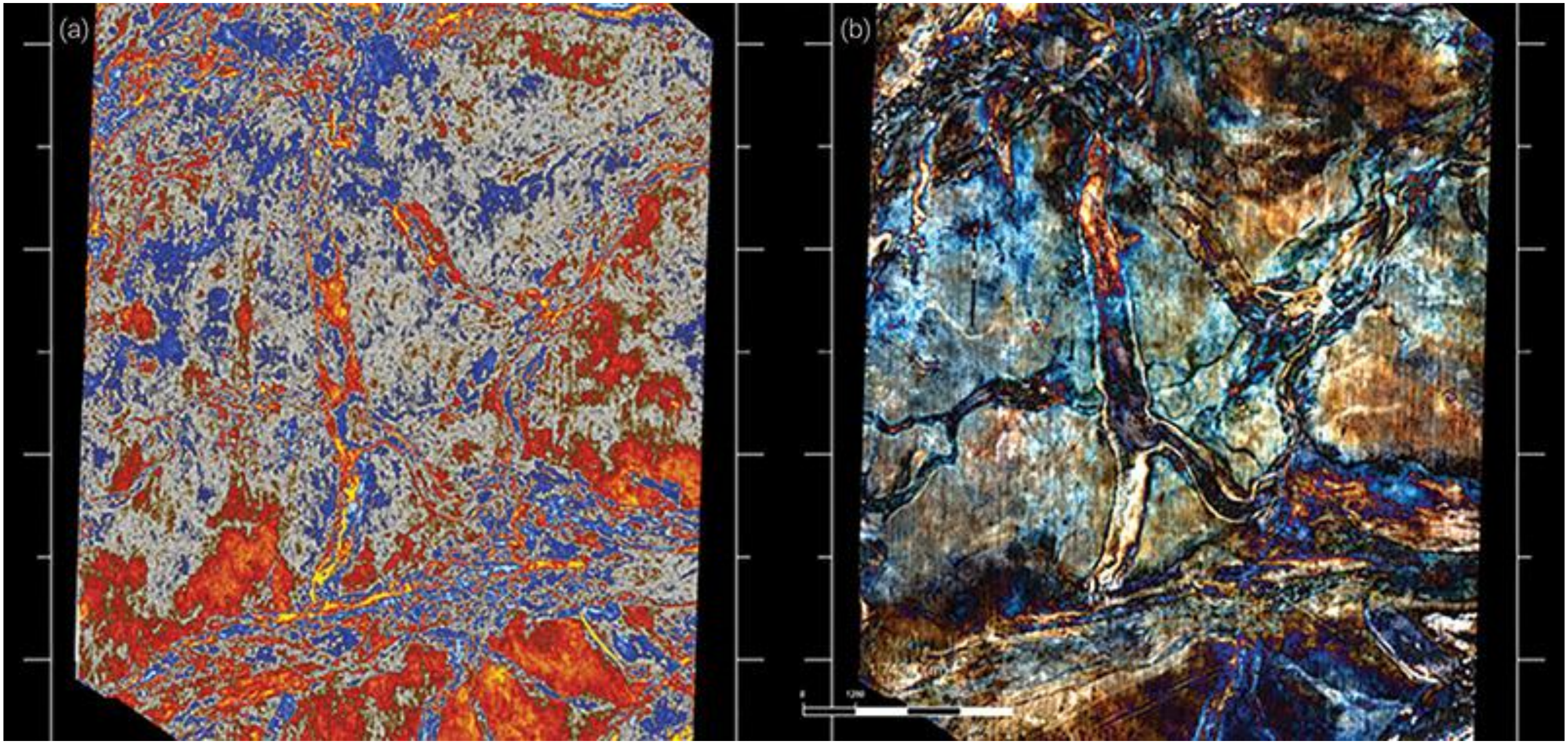

Figure 2. (a) Horizon slice of original seismic data, and (b) Color-blend of three spectral decomposition components.