GC Some Seismic Instantaneous Bandwidth Attribute Applications*

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Search and Discovery Article #42515 (2020)
Posted April 6, 2020

*Adapted from the Geophysical Corner column, prepared by the authors, in AAPG Explorer, May, 2020. Editor of Geophysical Corner is Satinder Chopra (schopra@arcis.com). Managing Editor of AAPG Explorer is Brian Ervin. AAPG © 2020. DOI:10.1306/42515Chopra2020

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General Statement

The bandwidth of a signal is a measure of the breadth of its spectrum, often expressed as the distance measured in Hertz (or better still, in octaves) between the half-power points of a smooth spectrum. Bandwidth is the best measure of resolution. Narrow-band, low-frequency spectra cannot represent thin beds, while narrow-band, high-frequency spectra provide ringy, ambiguous images of thin beds. Ideally, the bandwidth is estimated by directly measuring the data spectrum using either Fourier transforms or spectral decomposition. In contrast, most interpretation packages include an instantaneous bandwidth attribute defined as the ratio of the derivative of the instantaneous envelope to the instantaneous envelope itself. An alternative measure is to estimate two times the standard deviation of the spectrum about its mean. The mathematics of both approximations assume the seismic data exhibit an approximately Gaussian spectrum – a poor assumption if the processing shop has worked hard to make the spectrum as flat as possible. Given this limitation, instantaneous bandwidth still can be quite useful.

In general, temporally short seismic events exhibit high bandwidth, while temporally broad and/or ringing events exhibit narrow bandwidth. Instantaneous bandwidth is a sample-by-sample computation that is commonly used to measure vertical and lateral changes in attenuation. Seismic data undergo two types of attenuation: intrinsic attenuation, in which mechanical energy is converted to heat energy and is only a function the rate of compression/dilation (the frequency); and geometric attenuation, in which interference phenomena give rise to constructive and destructive interference. For random heterogeneities, geometric attenuation decreases the higher frequency components of the spectrum. For more ordered and less commonly encountered heterogeneities such as sabkhas, coal cyclothems, and laterally periodic fractures, some frequencies may be attenuated, and others enhanced. If the lower components of the spectrum are unchanged and the upper part attenuated, the bandwidth decreases.

Although first introduced to the seismic community in the 1970s, only a limited number of published articles show the value of this attribute. In this column, we show the value of bandwidth when applied to data from the Utica area of Eastern Ohio, United States and from the Gulf of Mexico.

Multiple versus Merged Surveys

Many mature areas for hydrocarbon exploration are covered by adjacent or overlapping 3-D seismic surveys acquired by different operators at different times using different technology. These surveys very commonly exhibit different amplitudes frequencies and phase responses in which the differences in frequency and phase might be simple – such as the use of different geophones with different resonant frequencies, or more complex, depending on the details of statics, filtering, velocity analysis and imaging. Ideally, these surveys are reprocessed from the original common shot gathers to provide a merged survey with a consistent datum, amplitude and phase. Although the amplitudes of the measured spectral components are consistent, because of differences in vibrator sweeps and geophone responses, some surveys will have only recorded a narrower spectrum, giving rise to changes in bandwidth across the survey.

There are several methods used during processing to enhance the frequency content of the seismic data. Starting with the application of the traditional time-variant spectral whitening, which might distort the seismic amplitudes, one might use inverse Q-filtering, spectral decomposition-based methods and thin bed reflectivity inversion.

We have demonstrated the application of some of these methods in previous installments of Geophysical Corner: Relative Acoustic Impedance Defines Thin Reservoir Horizons, Search and Discovery Article #40435, and Spectral Balancing Can Enhance Vertical Resolution, Search and Discovery Article #41357.

In this article, we demonstrate the application of two such methods of frequency enhancement applied to a merge of two-component seismic surveys. We refer to the two methods as 1 and 2; the performance comparison of these methods is not the focus of this analysis. In Figure 1a, we show a segment of a seismic section from the merged surveys that exhibits more high frequency content to the left and less high frequency content on the right, resulting in lower vertical resolution. The overall frequency content of the displayed time window is shown in the inset as well as the average half-power bandwidth for the entire survey. Equivalent sections after the application the methods 1 and 2 are shown in Figure 1a and 1c. Note that the application of method 2 provides a superior image to that of method 1.

Figure 2 shows the instantaneous bandwidth attribute computed for the input and two frequency-enhanced volumes shown in Figure 1. Notice the higher instantaneous bandwidth on the left and lower instantaneous bandwidth on the right halves of Figure 2a and 2b. In contrast, the instantaneous bandwidth in Figure 2c is much better balanced. This application demonstrates that the instantaneous bandwidth attribute can be used as an aid to assess the applications of different frequency-enhancement procedures.

Imaging Salt Bodies

In many regions of the world, oil and gas accumulations are found trapped against salt domes. Consequently, the flanks of salt domes are considered potential exploration targets. For this reason, the boundaries of salt bodies need to be imaged and interpreted well. More recently, object extraction machine learning applications have aimed to pick or interpret salt bodies in an automated fashion, employing neural network applications that rely on differences between the signature of the seismic signal outside and inside the salt domes. In Figure 3, the seismic signature within the salt body is lower amplitude and lower frequency content than the sedimentary layers around it. The time slices in Figure

3a and 3b show low values of instantaneous envelope and bandwidth within the salt dome and higher values in the sedimentary layers. These observations indicated that both attributes are good candidates to use in training a neural network for salt body extraction.

Conclusion

Quantitative estimates of seismic data quality include measures of continuity, signal-to-noise ratio, and temporal resolution. The instantaneous bandwidth attribute is a good first-order measure of temporal resolution and can be used to map lateral and vertical changes in seismic data quality and to discriminate between different seismic facies. The instantaneous bandwidth can also be useful in ascertaining not only the frequency content of the signal, but also to recognize noise that may contaminate the data.

Acknowledgement

The first author would like to thank Gary Margrave for drawing his attention to the instantaneous bandwidth attribute.

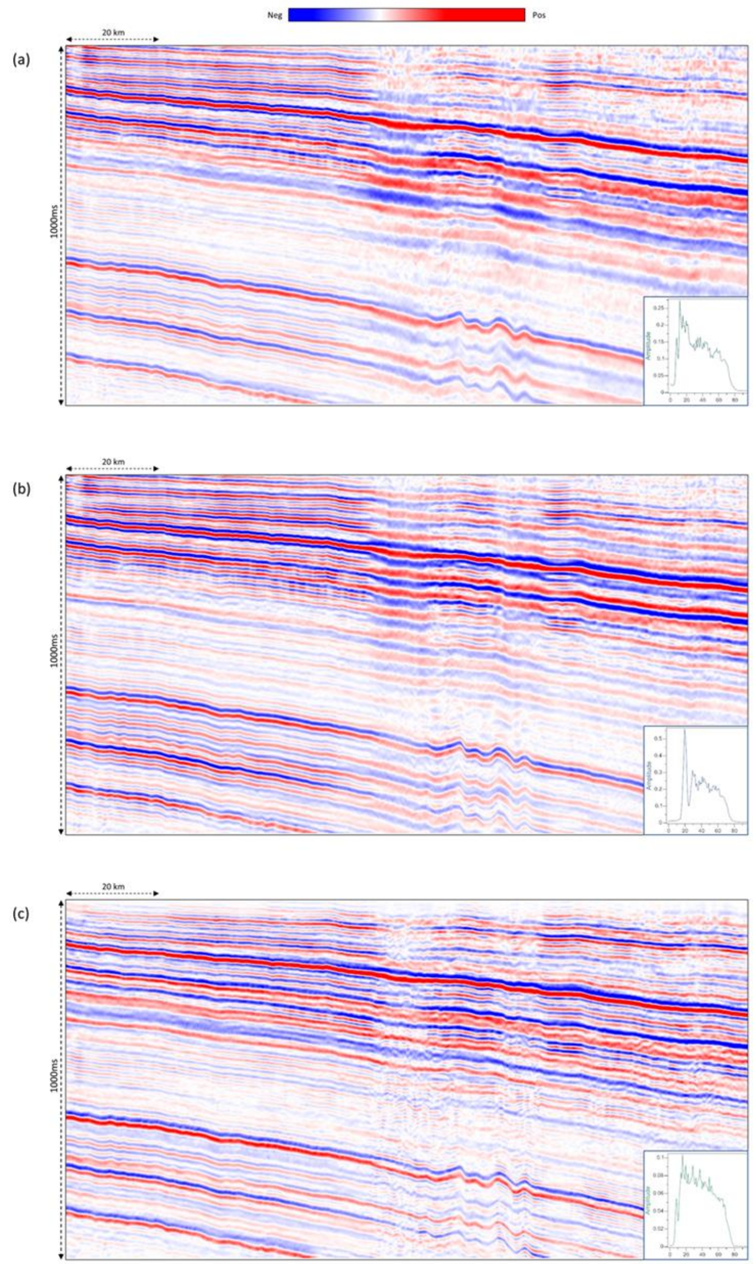

Figure 1. Segment of an inline section from a merged (a) seismic data volume, (b) the data volume spectrally balanced using method 1, and (c) the data volume spectrally balanced using method 2. Data courtesy of TGS, Houston and Global Geophysical data; Global Geophysical data presented with permission of Geophysical Pursuit, Inc. (exclusive agent).

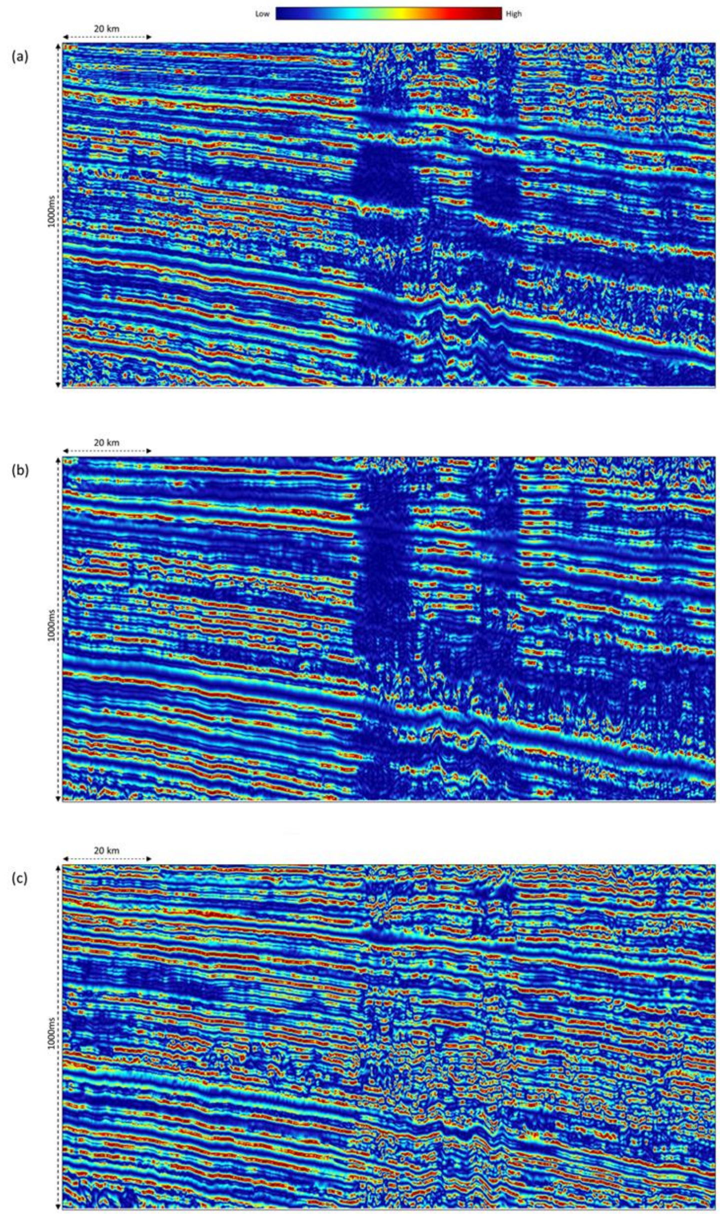

Figure 2. Equivalent segment of the inline sections as shown in Figure 1 from the instantaneous bandwidth volume computed on the merged (a) seismic volume, (b) the seismic data volume spectrally balanced using method 1, and (c) the seismic data volume spectrally balanced using method 2. Data courtesy of TGS, Houston and Global Geophysical data; Global Geophysical data presented with permission of Geophysical Pursuit, Inc. (exclusive agent).

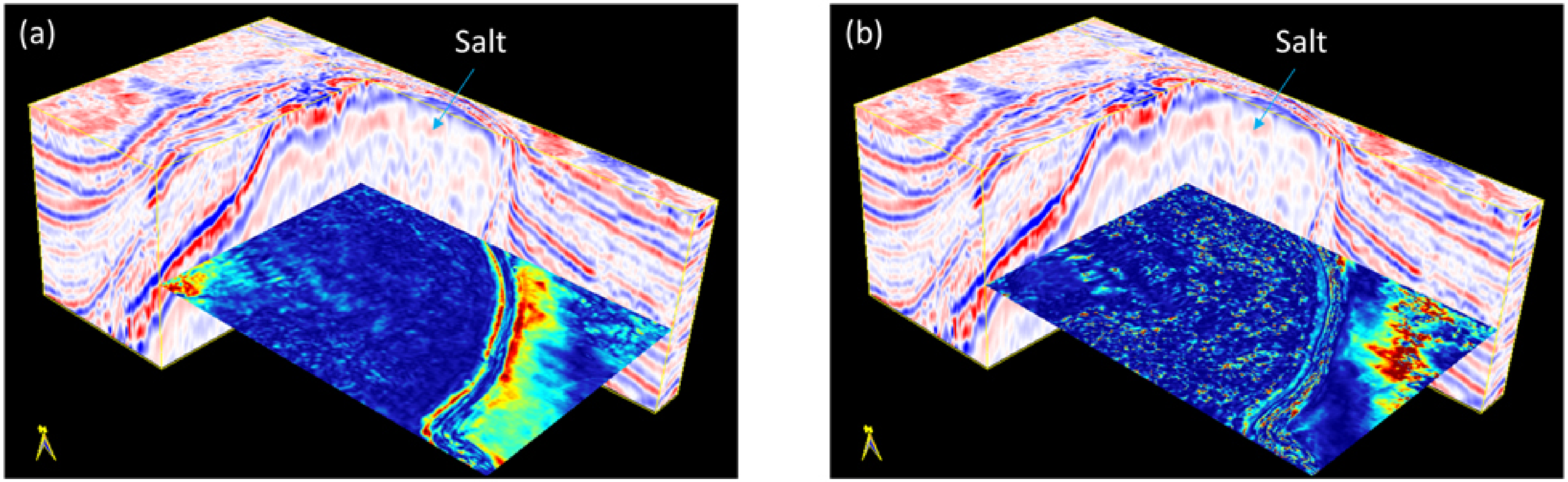

Figure 3. A seismic sub-cube shown correlated with a time slice at 3,470 milliseconds from the (a) amplitude envelope, and instantaneous bandwidth volumes. Notice the weaker seismic amplitude levels seen within the salt dome, which also exhibit small amplitude envelope values as well as lower instantaneous bandwidth values. The seismic data is from the Thunderhorse area in the Gulf of Mexico. Data courtesy of TGS.