Geophysical Corner

Multispectral Coherence Attribute Applications

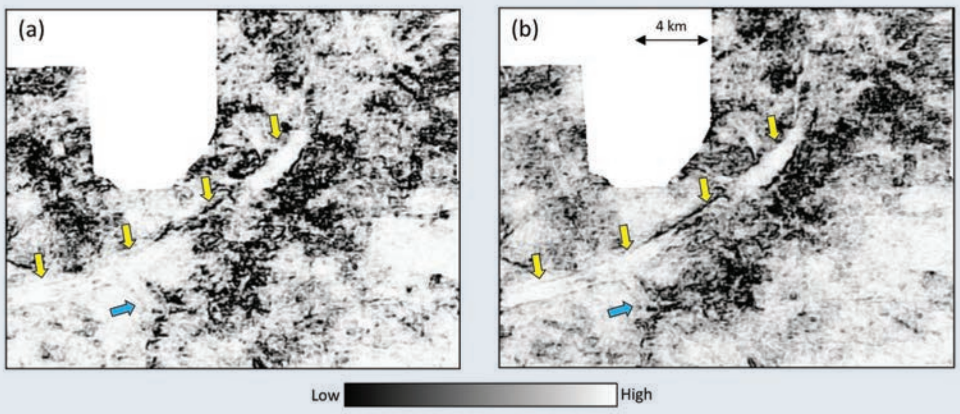

Figure 1 (above): Strata slices 86 milliseconds below a prominent marker at about 850 milliseconds through the (a) broadband coherence, and (b) multispectral coherence volumes generated on seismic data acquired over the STACK trend in Oklahoma. Yellow block arrows indicate a channel more clearly on the multispectral coherence. Similarly, an offshoot channel is seen more clearly on multispectral coherence as indicated by the blue arrow. Data courtesy of TGS, Houston.

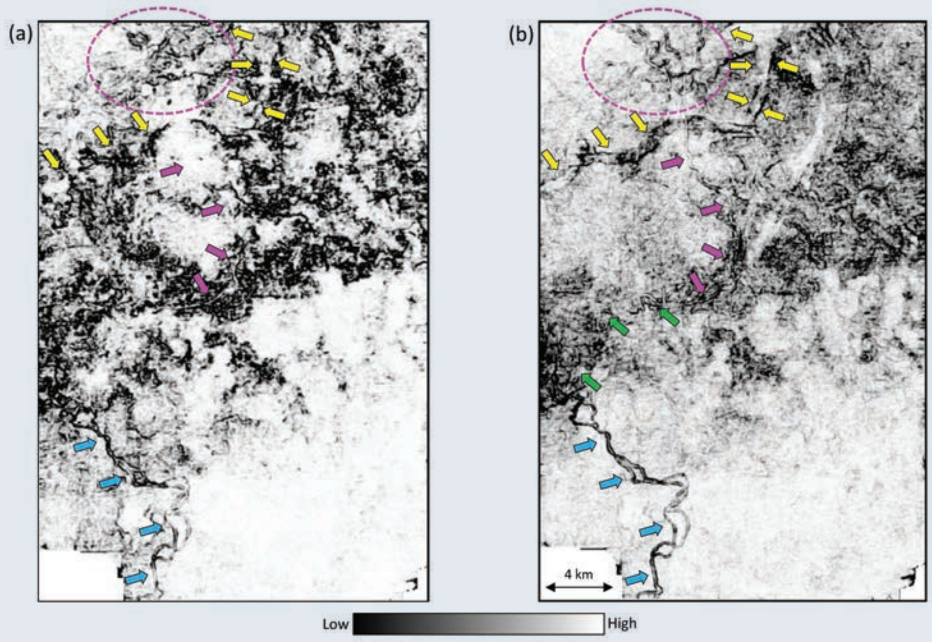

Figure 2 (right): Stratal slices 160 milliseconds below a prominent marker at about 850 milliseconds through the (a) broadband coherence, (b) multispectral coherence volumes generated on seismic data acquired over the STACK trend in Oklahoma. Notice the better definition of the channel features as indicated by the yellow and magenta arrows as well as in the highlighted area. There is at least one channel feature running north-south as indicated by the blue, green, magenta arrows as well as the highlighted portion on top. Data courtesy of TGS, Houston.

Coherence is an iconic attribute that finds its place in most workstation interpretation software packages. Much has been written about this attribute and the usefulness of its applications. The geologic feature imaging in three-dimensional seismic data volumes is done well by the coherence attribute as three-dimensionality is an essential ingredient of its computation. Ever since the first cross-correlation-based coherence algorithm was introduced way back in 1995, other algorithms have also been developed, including semblance-based, eigenstructure-based, prediction error filter-based, gradient structure tensor-based and energy ratio-based. These algorithms vary in how they handle lateral variations in amplitude, phase and waveform, and thus have different sensitivities to geology, spectral bandwidth and seismic noise.

For coherence computation, first an analysis window consisting of a fixed number of samples in the inline, crossline and time directions is constructed along structural dip. In the eigenstructure-based coherence computation, a covariance matrix is then constructed from the selected samples and solved, i.e. the eigenvalues and eigenvectors are determined. The ratio of the first eigenvalue (by definition the largest) to the sum of all the eigenvalues is the value of the eigenstructure coherence at the sample at the center of the unit cube. The analysis window is then shifted by one sample at a time in the inline, crossline and time directions, and the above process repeated. The result is a coherence volume, which is ready for interpretation.

CHOPRA

The energy ratio-based coherence algorithm is a slightly more general computation in that the energy of the coherent component of the seismic traces is divided by the total energy of those traces within the analysis, and the process is repeated for all the samples in the broadband three-dimensional seismic volume. We have shown in an earlier Geophysical Corner article (March 2015) that coherence run on spectrally decomposed seismic volumes, or the derived voice components, often delineate edges that are best analyzed at or near the tuning frequency of a given formation. In general, shorter, more vertically-limited faults and channel edges are often better delineated at higher frequencies, while through-going faults are often better delineated at lower frequencies.

Recent Advance

With such observations in mind, an advancement has been made recently in energy ratio-based coherence computation. Instead of computing covariance matrices from the input seismic volume, covariance matrices are computed on voice components at different frequencies (see the March 2015 Geophysical Corner) derived from the input broadband seismic data volume and oriented along structural dip, summing them and computing eigenvectors of the summed matrix. We denote such a computation as "multispectral coherence."

We demonstrate the application of multispectral coherence on two different 3-D seismic volumes, one from the STACK trend in Oklahoma in the United States, and the other from the Montney Dawson area in British Columbia, Canada.

Figure 1 shows stratal slices 86 milliseconds below a prominent marker tracked at close to 850 milliseconds from the broadband coherence (figure 1a), and multispectral coherence (figure 1b), generated from voice components derived from the input seismic data at 20 to 60 Hertz at increments of 5 Hertz. Notice the channel feature indicated with yellow block arrows is much better defined on multispectral coherence than the broadband coherence. Similarly, a small offshoot channel indicated with the blue block arrow is seen better-defined on the multispectral coherence.

Figure 2 shows stratal slices 160 milliseconds below a marker at close to t=850 milliseconds on the same data volume shown in figure 1. The channel features seen lower down on the displays (blue arrows) are very clearly seen on the multispectral coherence. The channel feature indicated with magenta arrows, and then the channels in the highlighted area of the magenta ellipse are all better defined on multispectral coherence. Another channel feature indicated with yellow arrows is more clearly noticeable on multispectral coherence. In fact, there is at least one channel that runs almost north to south from the highlighted area, through by the side of the magenta arrows, green arrows and to the blue arrows that can now be interpreted.

In figure 3 we show a similar comparison of coherence stratal slices 36 milliseconds above a marker at roughly t=1,700 milliseconds on a 3-D seismic volume from the Montney-Dawson area in British Columbia in Canada. The multispectral coherence was generated by using 12 selected voice component volumes from 20 Hertz to 75 Hz at increments of 5 Hertz. Notice the definition of faults running almost north-south and indicated by the yellow blue and green arrows to be well-defined on multispectral coherence.

One observation that is common in all the above figures is that a better signal-to-noise ratio is seen on multispectral displays than the broadband coherence displays. Multispectral coherence enhances discontinuities seen across multiple frequencies and suppresses discontinuities (such as noise) seen on only one or two spectral components.

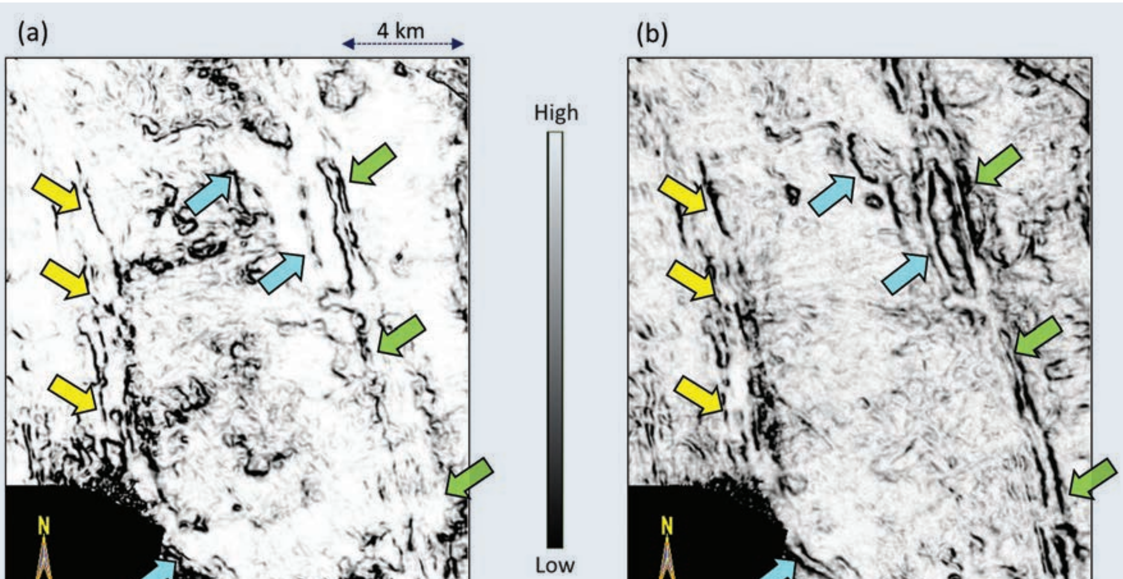

Figure 3: Stratal slices 36 milliseconds above a marker at roughly 1,700 milliseconds through the (a) broadband coherence and (b) multispectral coherence volumes. Notice, the overall better definition of faults indicated with yellow, cyan and green arrows. The seismic data are from the Montney-Dawson area in British Columbia, Canada. Data courtesy of TGS, Calgary.

Conclusions

Multispectral coherence computation from input seismic data volumes yield more accurately-defined geologic features, which would help with their interpretation. Overall, the displays exhibit better signal-to-noise ratio than the broad band coherence. The computation of multispectral coherence is more time consuming than broadband coherence, and hence would be somewhat more expensive. In general, the added value in terms of interpretation would be well worth the extra time and expense. E

(Editors Note: The Geophysical Corner is a regular column in the EXPLORER, edited by Satinder Chopra, chief geophysicist for TGS, Calgary, Canada, and a past AAPG-SEG Joint Distinguished Lecturer.)

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