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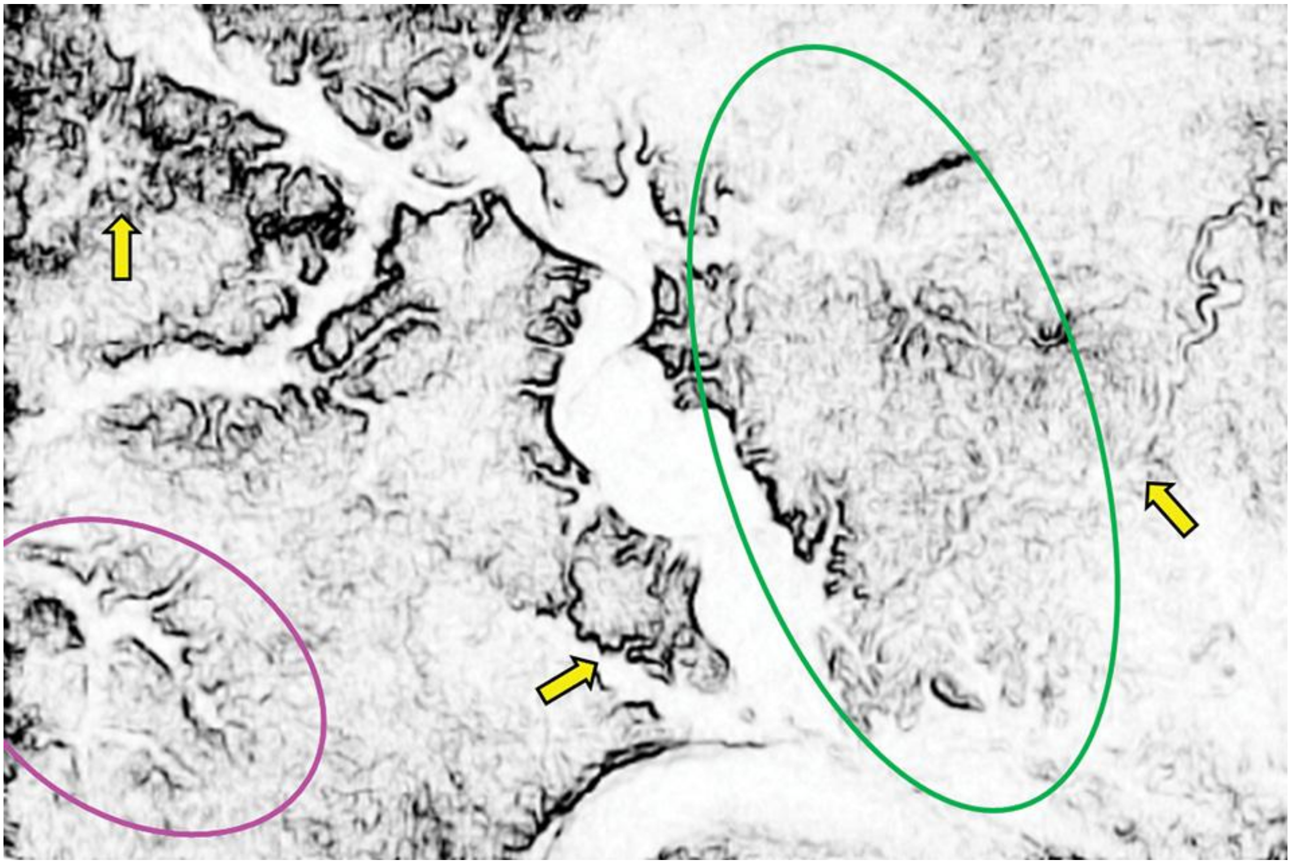

Multiazimuth Coherence Attribute Applications

September 2018 | Satinder Chopra , Kurt Marfurt

In the July 2018 Geophysical Corner, we discussed the applications of the multispectral coherence attribute and demonstrated the resulting higher signal-to-noise ratio and enhanced discontinuity definition. The underlying assumption is that different frequency voice components (or more simply, the band-pass filtered version of the seismic data) see discontinuities differently. All interpreters have been annoyed when a clear through-going fault seen on a vertical slice through the seismic amplitude volume appears to have holes in the discontinuity on a vertical slice through the corresponding coherence volume. Most commonly, these holes occur when reflectors corresponding to different geologic horizons happen to “line-up” across the fault. While such alignments may occur on the broadband data (the sum of the spectral components), or even one or more of the spectral components, it is rare that they line up on all of the spectral components. For more details on the computation, please refer to the July Geophysical Corner .

The concepts of coherence computed on multiple spectral components can be extended to coherence computed on multiple azimuthally-limited amplitude volumes. All three-dimensional seismic surveys are designed to record a range of azimuths, where discontinuities are better illuminated by some ray paths – typically those ray paths orthogonal to an edge, rather than ray paths parallel to the edge. Thus, the illumination of subsurface faults, fractures and stratigraphic edges varies with azimuth. During seismic processing, all offsets and azimuths are migrated (imaged) independently. While most interpreters pick horizons and faults and identify stratigraphic features on the stack of all these migrated traces, more quantitative interpretations use offset-limited (or incident-angle limited) sub-stacked volumes for amplitude variation with offset and prestack inversion analysis. Other technical specialists may use azimuthally-limited sub-stacks of the migrated traces to estimate the presence and orientation of fractures or of the intensity and orientation of the maximum horizontal stress. What many interpreters do not realize is that the cost of providing a full stack or of multiple offset-limited and/or azimuthally limited stacks is basically the cost of making extra intermediate volumes. The processing shop migrates the same number of traces (and needs to construct an accurate velocity model) for all three of these workflows. It is critical that the oil company client explicitly request such intermediate volumes as part of the processing workflow, whether they anticipate using them immediately or not. Once the project is completed, these intermediate volumes are rarely archived.

Discontinuities are seen at different azimuths for three reasons.

The first is associated with the physics of wave propagation, where the larger amount of back-scattered energy is experienced by rays traveling perpendicular to a discontinuity. Rays travelling parallel to a discontinuity are also diffracted, but only as forward-scattered energy.

The second is geometrical, where a discontinuity imaged in the perpendicular direction will appear sharper, while the same discontinuity will appear more diffuse in a parallel direction.

The third reason is associated with seismic processing. Our seismic velocities are rarely perfect. A sharp discontinuity seen on a near-perpendicular azimuth can be stacked and then blurred with the smoother discontinuity seen on the parallel azimuth.

The value of computing coherence on azimuthally-limited sub-stacked volumes has been recognized almost from the beginning of coherence. Figure 1 shows an example from a wide-azimuth ocean bottom seismometer survey acquired offshore West Africa. On the basis of the orientation of faults in the volume, four

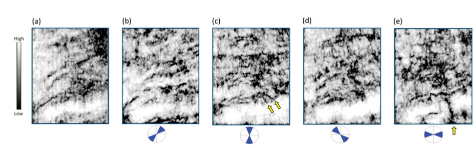

Figure 1: Time slices at 1,312 milliseconds through coherence volumes from the all-azimuth coherence shown in (a), and azimuth-limited seismic volumes shown at 22.5 to 67.5 degrees, 67.5 to 112.5 degrees, 112.5 to

157.5 degrees, and 157.5 to 202.5 degrees (b) to (e). Noticeable differences can be seen between the coherence displays as indicated by the yellow arrows. The data are from offshore West Africa.

azimuths were generated (22.5 to 67.5 degrees, 67.5 to 112.5 degrees, 112.5 to 157.5 degrees, and 157.5 to 202.5 degrees). Figure 1 shows time slices at 1,312 milliseconds through four coherence volumes computed from four azimuthally-limited seismic volumes. In addition to the strong northeast-southwest trending faults, the faults in the orthogonal direction are also imaged well, as shown by the yellow arrows. It has also long been recognized that attributes computed from such sub-volumes exhibit a lower signal-to-noise ratio than those computed from the full-azimuth stack.

Multiazimuth Coherence

While OBS and node acquisition has become much more common over the past decade, wide-azimuth data acquisition has become almost standard in onshore 3-D surveys acquired in North America, particularly those acquired for resource plays where estimates of the maximum horizontal stress help define drilling and completion of horizontal wells. All of the larger acquisition companies can acquire and process wide azimuth 3-D seismic data that results in either offset-sector or offset-vector-tile binning. The key steps in the processing of these volumes are the azimuthally-compliant premigration noise attenuation, 5-D interpolation to a set of regularly sampled (typically at 30 degrees) azimuthal spokes (or sectors), azimuthal velocity analysis, and spoke by spoke post migration noise attenuation.

Similar to multispectral coherence, the covariance matrices are computed from the azimuthally-limited seismic volumes and oriented along structural dip, summed and then put through eigenvector computation of the summed matrix. Such a computation is referred to as multiazimuth coherence.

Application to Modern Wide-azimuth Surveys

We demonstrate the application of multiazimuth coherence on a seismic volume from the STACK trend, in Oklahoma. In figure 2 we first show the stratal slices 22 milliseconds below a marker horizon at approximately 1,950 milliseconds, through the traditional all-azimuth energy ratio coherence and the multiazimuth energy ratio coherence volumes. Note the enhanced definition of the northeast-southwest en echelon faults and the other east-west fault lineaments on the multiazimuth coherence display.

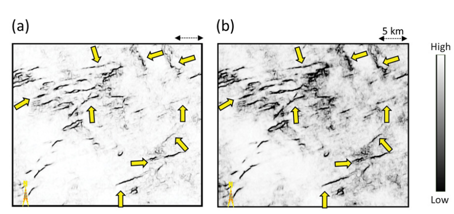

Figure 2: Stratal slices 22 milliseconds below a marker horizon at approximately 1,950 milliseconds from (a) all azimuth energy ratio coherence, and (b) multi-azimuth energy ratio coherence. Notice the more emphasized definition of the fault lineaments on the multi-azimuth coherence. The seismic data is from

the STACK trend in Oklahoma. Data courtesy of TGS, Houston.

Figure 3 show a similar set of stratal slices 78 milliseconds below a marker at 1,700 milliseconds through the traditional all-azimuth energy ratio coherence and the multiazimuth energy ratio coherence volumes. Note the overall better definition of the main channel features, especially the smaller channel features enclosed in the highlighting magenta and green ellipses.

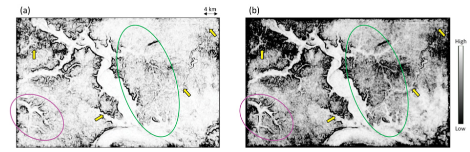

Figure 3: Stratal slices 78 milliseconds below a marker horizon at approximately 1700ms from (a) all azimuth energy ratio coherence, and (b) multi-azimuth energy ratio coherence. Notice the enhanced definition of the channel features on the multi-azimuth coherence as shown in the magenta and green highlighted areas. The seismic data is from the STACK trend in Oklahoma. Data courtesy of TGS, Houston.

In summary, we state that multiazimuth energy ratio coherence computed by summing the covariance matrices in the computation windows from the different azimuthally-sectored seismic volumes exhibit higher signal-to-noise ratio and higher lateral resolution on the displays. We find such improved resolution coherence attribute volumes prove to be most useful in the interpretation of discontinuity features such faults and stratigraphic edges. With wide azimuth surveys becoming more commonly available, we encourage interpreters to request the resulting azimuthally-limited sub-stack volumes as part of their interpretation workflows.

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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Satinder Chopra

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