GC Volumetric Fault Enhancement Applications*

Satinder Chopra[1] and Kurt J. Marfurt[2]

Search and Discovery Article #41869 (2016)
Posted August, 29, 2016

*Adapted from the Geophysical Corner column, prepared by the authors, in AAPG Explorer, August, 2016. Editor of Geophysical Corner is Satinder Chopra (schopra@arcis.com). Managing Editor of AAPG Explorer is Brian Ervin.

[1]Arcis Seismic Solutions, TGS, Calgary, Canada (schopra@arcis.com)
[2]University of Oklahoma, Norman, Oklahoma, USA

General Statement

Coherence is an iconic attribute available on most interpretation workstations and it helps with the characterization of small and large-scale faults, large structures, fault truncations, buried channels, reef edges and unconformities. There are various algorithms available for coherence computation, each having its advantages and limitations in terms of the quality of coherence imaging of the features of interest and run times associated with them.

The quality of the input surface seismic data has a strong bearing on the quality of the coherence attribute generated, and for that matter any attribute that is generated therefrom. Due to operator aliasing, acquisition footprint and other noise, almost all coherence data volumes computed from 3-D land surveys benefit from further conditioning of the input amplitude data. Such data conditioning may include reduction of cross-cutting and random noise, sharpening or enhancement of discontinuities, spectral balancing and interpolation of missing traces.

Edge Enhancement

It is quite common to enhance edges on photographic images with the use of mathematical second derivative "Laplacian of Gaussian" filters. Similar filters have been used to enhance lateral structural and stratigraphic discontinuities in 3-D seismic data. Geological features comprising channels and fault trends seen on sharpened coherence displays are crisper and easier to interpret than they are on equivalent coherence displays without sharpening.

Similar but more focused workflows are now available that design directional filters, skeletonize discontinuities and generate preconditioned volumes for subsequent volumetric fault extraction. In this article, we discuss the enhancement of faults and axial planes of folds by preconditioning of seismic data followed by directional smoothing and edge enhancement, thereby enhancing geological features of interest for effective interpretation. The authors have discussed in detail the preconditioning of seismic data for attribute generation in the various articles they have published.

Such preconditioning suppresses noise and improves the lateral and vertical resolution of the signal for effective attribute analysis. One of the techniques for reducing noise and edge enhancement of discontinuities is the structure-oriented filtering with Kuwahara sharpening, which preserves the edges by selecting the most coherent patch of data around each sample in the seismic volume. With the use of overlapping windows, the best window can be determined for filtering such that not only the lateral, but vertical resolution can be improved about fault edges.

In Figure 1, we show a vertical slice through a 3-D seismic volume from British Columbia, Canada. The seismic data were subjected to two passes of structure-oriented filtering with Kuwahara sharpening. Notice the crisp definition of the faults and the higher signal-to-noise ratio of the filtered amplitude data.

In Figure 2, we show the equivalent vertical slices from the energy-ratio coherence attributes generated from the seismic data volumes before and after data conditioning. Notice that the near-vertical low-coherence anomalies corresponding to faults and large fractures are often overprinted by near-horizontal low-coherence anomalies parallel to stratigraphy. While useful for stratigraphic interpretation, these features often interfere with computer-aided fault interpretation.

Fault Likelihood or Probability Attribute

When such preconditioned data are put through the workflow for volumetric fault enhancement mentioned earlier, one of the main attributes generated is the fault probability volume. In Figure 3, we show an equivalent section from the fault probability volume, generated for seismic data with two-passes of Kuwahara structure-oriented filtering. Notice how the prominent fault probability lineaments image and align the fault discontinuities, while the smaller ones in the blue highlighted area are not quite well defined.

While the vertical displays shown in the earlier figures convey the value-addition in terms of smoothing and crisp definition of the fault lineaments, in Figure 4a we exhibit time slice at t=1300 ms from the fault probability volume generated for data with two passes of Kuwahara structure-oriented filtering. Finally, we display 3-D volume visualization and correlation of the fault probability volume and its co-rendering with 3-D seismic data in Figure 4b. Such fault-enhanced visualization facilitates their interpretation.

Conclusions

The volumetric fault image enhancement workflow described earlier provides a means of interpreting fault probability attributes for linear discontinuities. This approach helps in the manual interpretation of faults on workstations, and it provides a useful input for software designed for automatic extraction of fault planes. The methodology followed in this workflow enhances the desired orientation of linear geologic features, and their interpretations can be carried forward to the next step in terms of their correlations with production data.

Acknowledgement

We wish to thank Arcis Seismic Solutions, TGS, Calgary for permission to present this work.

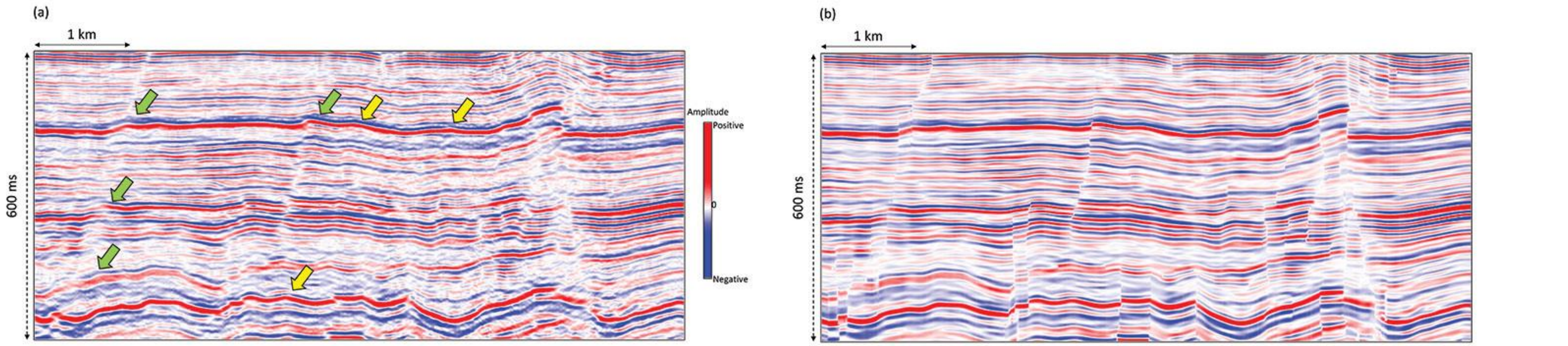

Figure 1. Vertical slices through the seismic amplitude volume (a) before, and after (b) two passes of Kuwahara structure-oriented filtering. Notice how cross-cutting noise inconsistent with structural dip is suppressed, amplitudes consistent with structural dip are preserved, while discontinuities are sharpened with filtering. Green arrows indicate the footwall of a fault, while yellow arrows indicate folds that may be associated with pop-up features. Size of analysis window is 5 traces by 11 2-ms samples. (Data courtesy: Arcis Seismic Solutions, TGS, Calgary, Canada)

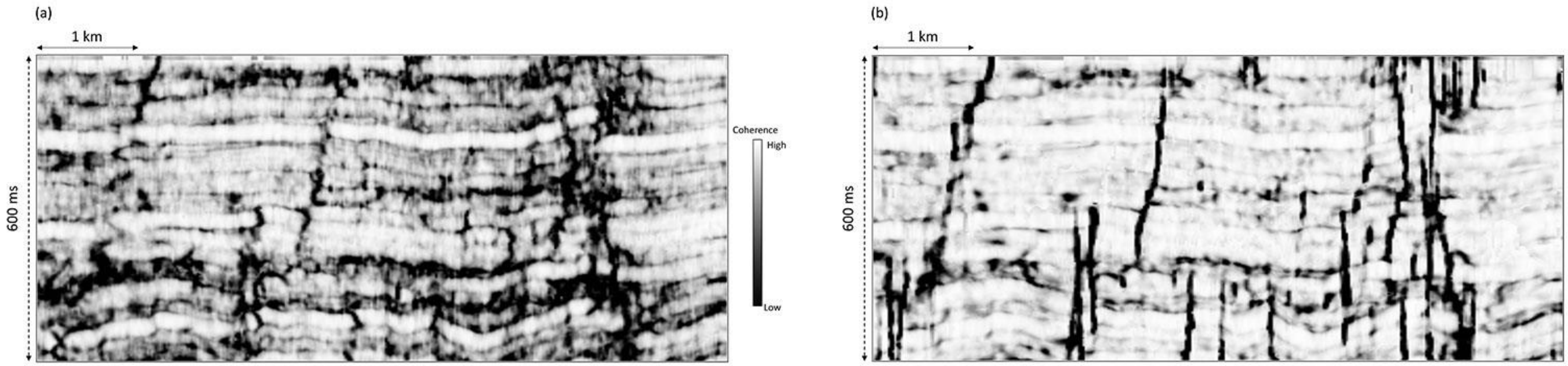

Figure 2. The same vertical slice as shown in Figure 1, through the coherence volumes, (a) before, and (b) after data conditioning. The coherence attribute exhibits low values parallel to structure, some of which correlate to unconformities and others which correlate to areas of low signal-to-noise ratio.

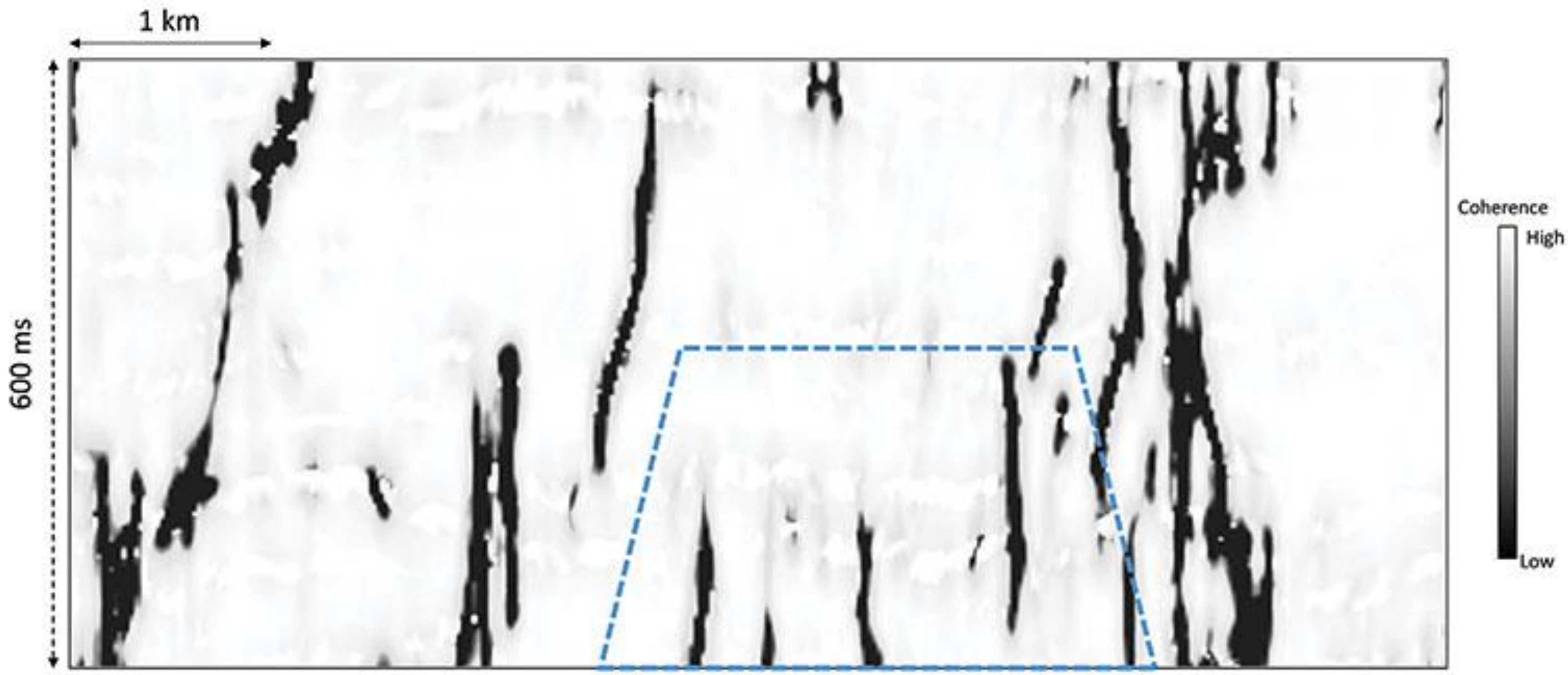

Figure 3. The same vertical slice as shown in Figure 1, through the fault probability volume generated with seismic data put through two passes of Kuwahara structure-oriented filtering. The low coherence horizontal striping seen on the displays in Figure 2 is now suppressed and the vertical discontinuities are seen clearly.

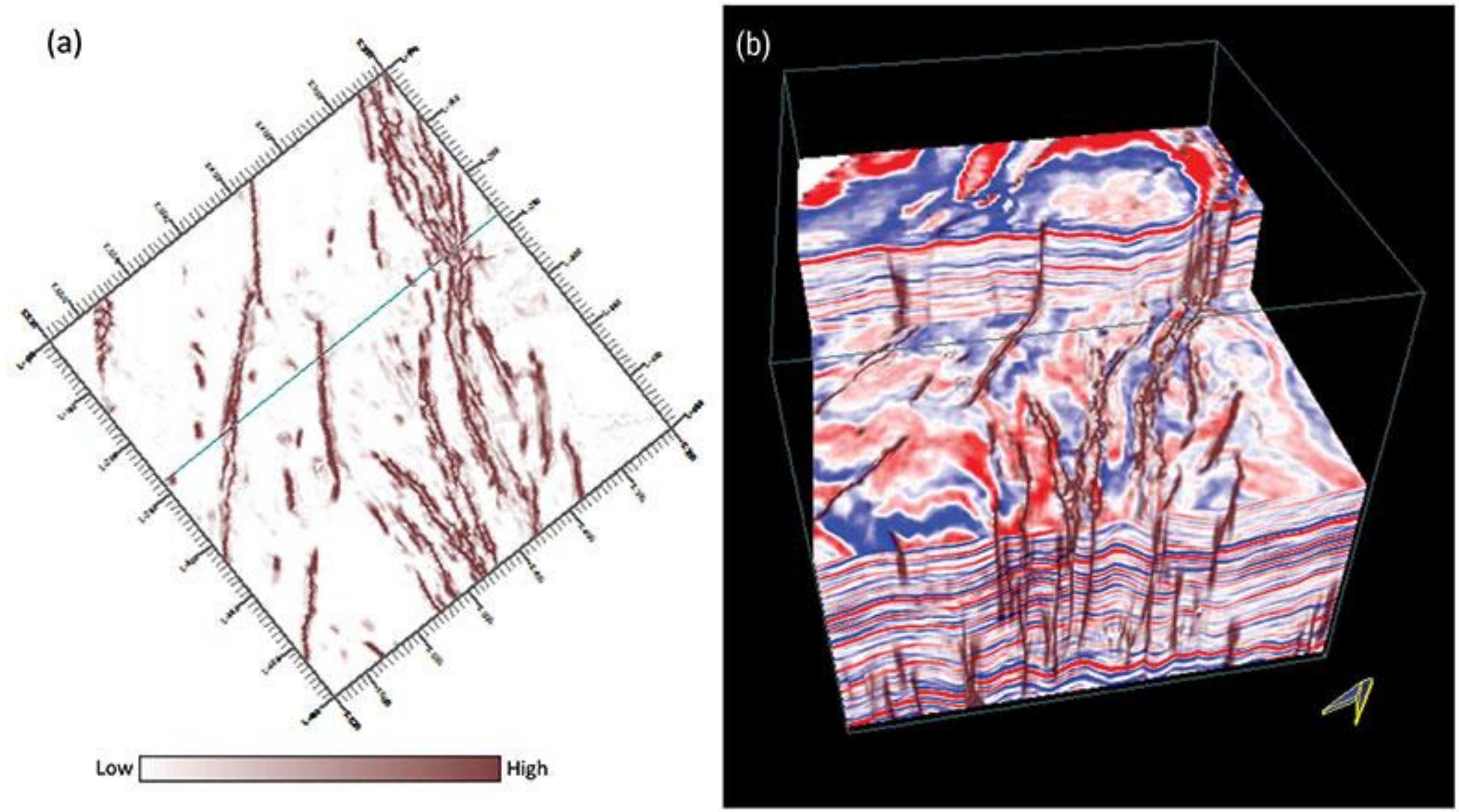

Figure 4. (a) Time slices at t=1300 ms through fault probability volumes computed with two passes of Kuwahara principal component structure-oriented filtering. Discontinuities subparallel to reflector dip have been suppressed. Note the improved continuity and extent of the faults where the fault enhancement algorithm has joined previously disjoint fault segments. (b) The seismic volume co-rendered with the fault probability volume, providing a useful way of carrying out fault interpretation.