Volumetric Fault Enhancement Applications

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.

The authors have discussed in detail the pre-conditioning of seismic data for attribute generation in the various articles they have published.

Such pre-conditioning 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 a vertical slice from the energy-ratio coherence attributes generated from the seismic data volumes before and after data conditioning. Notice that the prominent fault probability 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.

In this article, we discuss the enhancement of faults and axial planes of folds by pre-conditioning 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 pre-conditioning of seismic data for attribute generation in the various articles they have published.

Fault Likelihood or Probability Attribute

When such pre-conditioned 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 linear features are aligned with the fault orientations, while the smaller ones in the blue highlighted area are not quite well defined.

While the vertical displays shown...
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 interpretations can be carried forward to the next step in terms of their correlations with production data.

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