GEOPHYSICALCORNER

Is It a Subtle Fault, or Just Noise?

The Geophysical Corner is a regular column in the EXPLORER, edited by R. Randy Ray. This month's column is titled "Recognizing Faults in Seismic Data."

By ALISTAIR R. BROWN

Long gone are the days when faults appeared only as steps on vertical seismic sections. If we use today's better data and exploit modern workstation tools available, we should do a much better job of recognizing and understanding faults in 3-D seismic data.

Faults cause breaks in continuity of seismic horizons. These discontinuities generate diffraction patterns and, before the days of seismic migration, diffraction patterns were what the seismic interpreter sought as an indication of faulting.

Migration in 2-D will collapse diffractions to some extent, whereas migration in 3-D should do much better. Major faults are still recognized on vertical sections and their throw estimated by offset in character correlation. For this, double-gradational color is the best mode of display.

Spatial patterns of faulting are revealed on time slices (or depth slices). These horizontal sections must be used in conjunction with vertical sections to establish sensible fault geometries.

Composite and chair displays are established ways of combining these orthogonal sections together. In a chair display, one looks at a horizontal slice where it intersects a vertical section. You are able to see a fault's map pattern along with its offset in a cross-section view. Various other kinds of volumetric display also help to study and visualize faults.

Much of the science of fault detection concerns the recognition of subtle faults. On a normal vertical section a single-gradational color scheme, such as gradational gray (Figure 1), is usually best, as this type of display enhances the terminations of low amplitude events.

The detection of subtle faults, however, is highly dependent on good data quality and high signal-to-noise ratio. Some extra care and attention in data collection and processing is always beneficial.

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Coherence is an invention of five years ago that has had a beneficial impact on fault recognition. The coherence transformation suppresses the continuity of seismic reflections and emphasizes discontinuities such as faults.

Coherence data is best viewed as time slices or as a whole coherence cube. In good quality data, faults can be strikingly evident and spatial patterns of faulting can be clearly discerned.

Figure 2 is a time slice through a salt dome showing the common pattern of radial faults. The upper half of the time slice is in coherence and the lower half is the normal time slice display in amplitude. Note how the faults are more clearly visible in coherence.

Coherence is of less benefit in poor data and can sometimes be quite ambiguous. Different algorithms from various vendors can give different results. Certain versions are designed to overcome particular data

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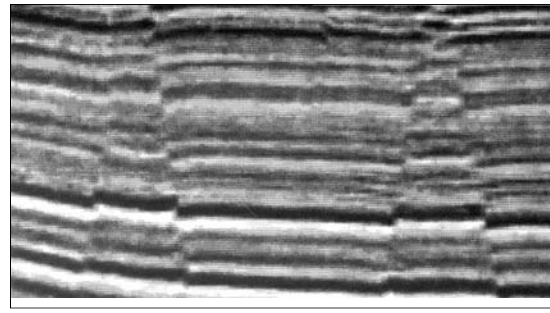

Image courtesy of Landmark

Figure 1 – Single-gradational color improves the visibility of subtle faults on vertical sections. Black is at one extremity of the color bar and white the other.

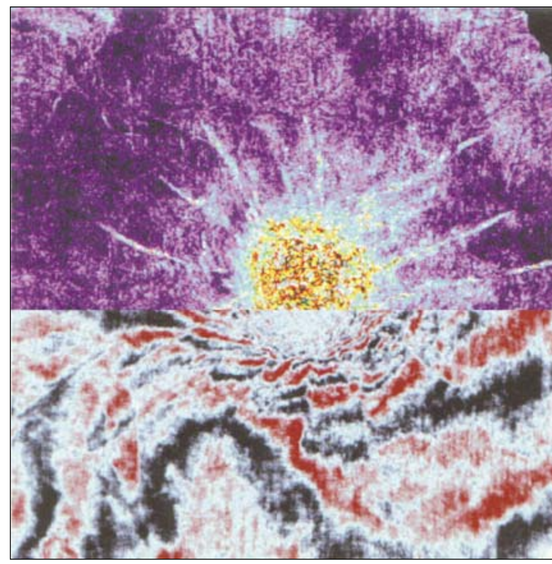

Image courtesy of Landmark.

Figure 2 – Coherence (above) is here compared with normal amplitude (below) for a time slice through a salt dome.

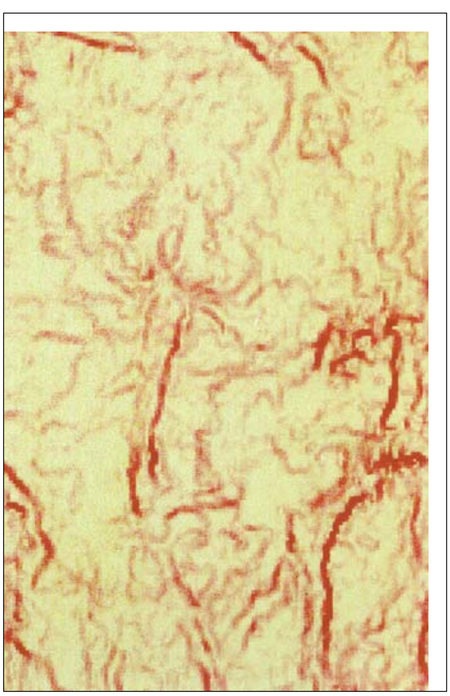

Figure 3a

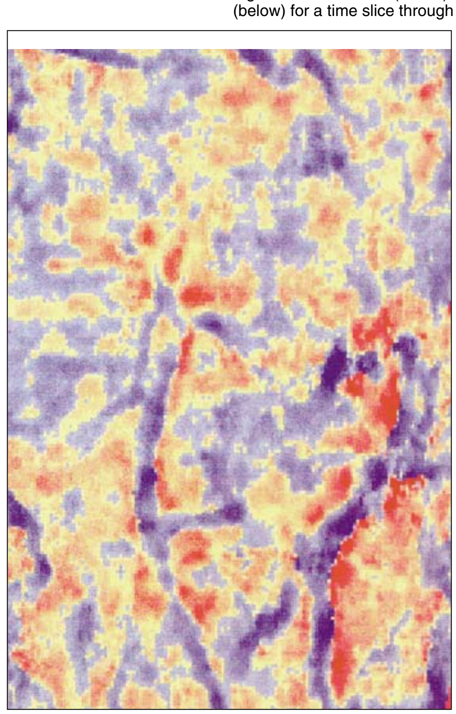

Figure 3b

Figures 3a & 3b – Dip display (3a) and residual (3b) for a horizon in the Cooper Basin of South Australia. The grabens are about 100m across.

Images courtesy of Santos.

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problems such as high dip and poor signal-to-noise ratio.

Once the major faults have been recognized and the tectonic framework established, machine autotracking should be used to complete horizon surfaces. The autotracker follows the crest of an identified peak or trough with very high precision. The resultant time (or depth) values contain information on subtle faults – but also noise.

An important part of fault recognition is then scrutinizing these horizon surfaces in an attempt to distinguish geology from noise.

Time-derived horizon attributes are used for this purpose. Several of these are available on modern workstations and the most important are dip, azimuth, edge and residual.

Figures 3a and 3b (page 40) show dip and residual for the same horizon. Dip is the magnitude of dip of the local surface dip vector. Residual is the difference between the horizon surface and its spatially-smoothed equivalent. We look at these attributes in map form and judge what appears geologic.

In Figure 3 combination, pairs of brown anomalies on the left (3a) correspond to blue anomalies on the right (3b). The strength of the anomalies over background noise and the arcuate pattern support the interpretation of fault grabens.

The edge map of Figure 4 clearly distinguishes the short north-south faults from the long arcuate one. The arcuate fault is about seven kilometers long and looks impressive on the edge map – however, it has negligible throw and is barely visible on any vertical seismic section. It was first recognized on this edge display and appears to be caused by an igneous intrusion.

As shown, the use of time-derived attributes can be a primary method of fault recognition. We do not have to observe a clear break on a vertical section. However, the interpreter typically looks at an appropriately oriented vertical section and may see a minor interruption at the anomaly position. Commonly this was not recognized during the mainstream of the interpretation.

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Distinguishing subtle faults from various kinds of noise is always a value judgement, so experience is useful. Interpreters tend to look at more than one type of time-derived attribute and seek the same feature on each as cross-validation.

The two panels of Figure 3 show the grabens on both the dip and residual displays; some of the minor wiggly features, probably noise, occur on only one.

Three-dimensional seismic data today typically contains an enormous amount of geologic detail. Faults are clearly an important part of this information.

The modern interpreter must use all the interpretation tools available to find and understand the faults affecting the reservoir. With practice and experience, one can extract the subtle but valuable details inherent in the data.

(Editor's note: Alistair Brown is a consulting reservoir geophysicist based in Dallas. He has been an AAPG/SEG Distinguished Lecturer and is the author of AAPG Memoir 42, Interpretation of Three-Dimensional Seismic Data*, which is in its fifth edition.)*

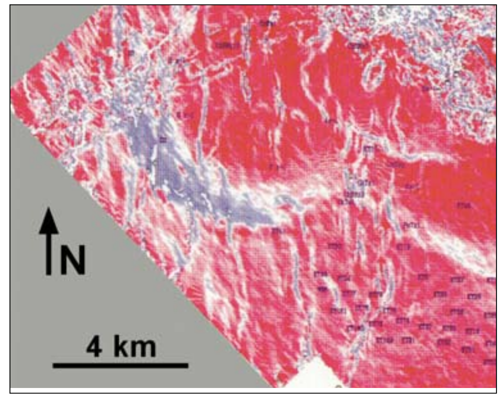

Figure 4 – Edge display showing two distinct styles of faulting in the Neuquen Basin of Argentina.

Image courtesy Petrolera San Jorge.