Seismic Attributes for Stratigraphic Feature Characterization

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Summary / Introduction

Among the various geophysical techniques available for characterizing faults/fractures and other subtle stratigraphic features, 3D seismic attributes are particualrly useful for identifying these features and zones amenable to fractures that fall below seismic resolution. A very useful feature of 3D seismic is the fine sampling of data over the region of interest, giving a more accurate representation of the areal extent of the features. Also, while seismic amplitude changes associated with the features of interest may not be readily noticeable on vertical sections, horizontal sections (time or horizon slices) may yield distinctive patterns that the human interpreter is able to recognize and associate with well-established geologic models… Through such models, seismic attributes allow an interpreter to reconstruct a paleo depositional environment and/or deformation history. In this paper we discuss the application of poststack attributes for detection of faults and fractures. Dip-magnitude, dip-azimuth and coherence attributes have been used for the detection of faults/fractures and other stratigraphic features for the past 10-15 years. We will demonstrate the how volumetric curvature, which measures lateral changes in dip and azimuth provide additional insight.

Discontinuity attributes

Seismic attributes that highlight discontinuities in the seismic data are useful for fault and fracture characterization.

Dip-magnitude and dip-azimuth

Rijks and Jaufred (1991) showed that horizon-based dip-magnitude and dip-azimuth are useful in delineating subtle faults whose displacements measure only a fraction of a seismic wavelet. A skilled interpreter recognizes alignments of such subtle offsets in map view as being either faults or artifacts.

Coherence

Bahorich and Farmer (1995) introduced the coherence attribute which computes coherence coefficients from seismic amplitudes on adjacent traces using a crosscorrelation technique.

Subsequent algorithms based on semblance and eigenstructure led to more accurate coherence computation than initially demonstarted.

The coherence images clearly reveal buried deltas, river channels, reefs and dewatering features. The remarkable detail with which stratigraphic features show up on coherence displays, with no interpretation bias and some previously unidentifiable even with close scrutiny, appeal to interpreters.

Example: In Figures 1a and b, we show a comparison horizon slices 36 ms below a flattened marker extracted through the seismic amplitude and coherence volumes. The coherence volume was generated using a semblance algorithm.. Notice the clarity with which the channel system stands out on the coherence display, which would be difficult to decipher from the seismic alone.

Curvature

Lisle (1994) demonstrated the correlation of a curvature measure (Gaussian) with open fractures measured on outcrops. Though the exact relationship between the open fractures, paleostructure and present-day stress is not yet clearly understood, different (Roberts, 2001; Hart et al., 2002; Sigismondi and Soldo, 2003; Massafero et al., 2003) have demonstrated the use of seismic measures of reflector curvature to map subtle features and predict fractures. A significant advancement in this direction has been the multispectral volumetrjc computation of curvature (Al-Dossary and Marfurt, 2006). By first estimating the volumetric reflector dip and azimuth that represents the best single dip for each sample in the volume , followed by computation of curvature from adjacent measures of dip and azimuth, a full 3D volume of curvature values is produced. There are many curvature measures that can be computed, but the most-positive and most-negative curvature measures are perhaps the most useful in that they tend to correlate most directly with conventional interpretation work flows. An attractive feature of curvature computation is the ability to be able to perform multi-spectral analysis of curvature which depicts different features at different scales of analysis (Chopra and Marfurt, 2007).

Example : Figure 2 shows a comparison of chair displays with the seismic profiles (vertical) intersecting the coherence, most-positive and most-negative curvature volumes, for a 3D seismic volume from Alberta. Notice that while the coherence display is featureless in the areas of high coherence (white) areas, the most-positive curvature shows the fault/fracture detail at that level. Any interpretation carried out on the curvature attribute needs to be correlated with the seismic, to make sure that the attribute makes geologic sense, which is why these chair displays werte created. In Figure 3 we show a chair display for seismic (vertical) and a time slice from the most positive and negative curvature volumes. The localized fault/fracture detail seen on the curvature displays is more than seen on the coherence and can also be clearly be correlated with the seismic.

Conclusions

Seismic attributes are very useful for characterization of faults and fractures in 3D seismic data volumes. Coherence measure lateral changes in waveform. Sobel filters measure lateral changes in amplitude. Curvature measures lateral changes in dip and azimuth. In general, which attribute best illuminates a given geologic feature depends as much on the underlying geologic textures and lithologies as on the seismic data quality. However, we find that most-positive and most-negative curvature attributes offer provide better illumination of faults and fractures than other attributes.

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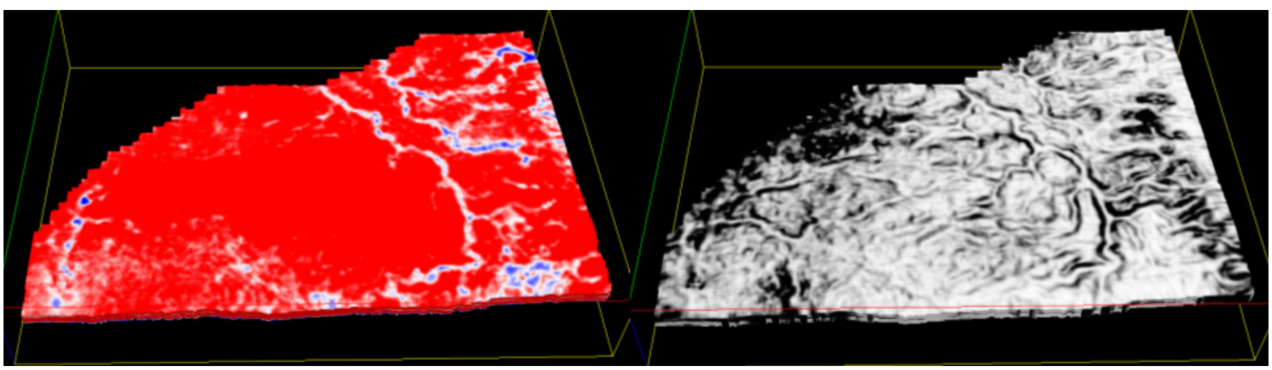

Figure 1: Horizon slices 36 ms below a flattened marker through (a) a seismic data volume from northern Alberta, (b) the computed coherence volume Notice that as compared with the amplitude slice, the coherence slice very nicely shows the channel system at this level. *(Data courtesy of Arcis Corporation, Calgary*)

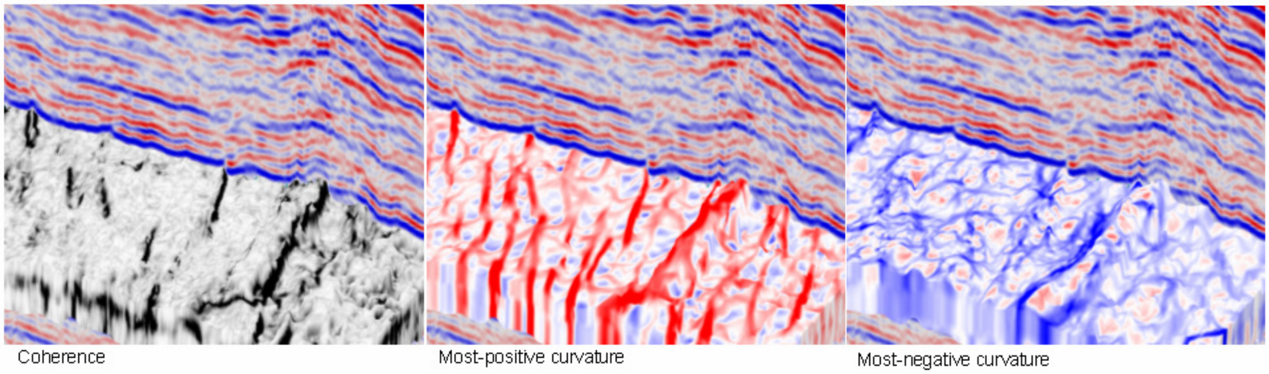

Figure 2: Chair displays showing seismic profiles intersecting (a) coherence, (b) most-positive curvature, and (c) most-negative curvature strat-cubes. Notice that except the prominent ones, the fault indications seen on the seismic are not revealing enough on the coherence strat-cube. The most-positive curvature (Figure 2b and most-negative curvature strat-cubes however indicate the fault information, the red lineaments (on the most-positive curvature display) and the blue lineaments (most-negative curvature display), show the upthrown and the downthrown signatures on these displays.. *(Data courtesy of Arcis Corporation, Calgary*)

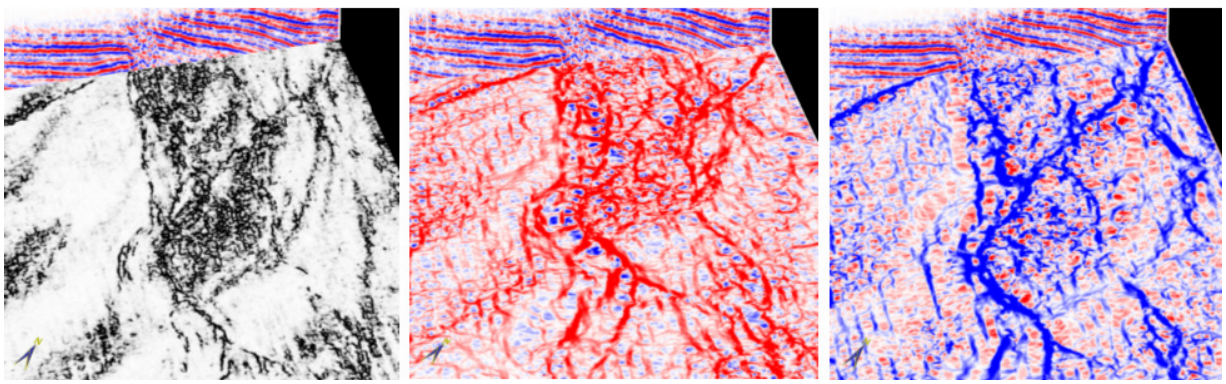

Figure 3: Chair displays showing seismic profiles intersecting (a) coherence, (b) most-positive curvature, and (c) most-negative curvature time slices. Notice the fault/fracture detail seen on the curvature displays is a lot more than seen on the coherence display. (Data courtesy of Rally Energy, Calgary)