[GC]Reflector Convergence and Rotation Attributes Facilitate Seismic Stratigraphy Interpretation*

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General Statement

Seismic stratigraphy requires interpreters to analyze the geometrical configurations and termination patterns of seismic reflection events. Maps of distinct families of these reflection behaviors usually can be interpreted to determine where distinct depositional processes occur across the mapped area. Reflection patterns such as toplap, onlap, downlap and erosional truncation are used as architectural elements to reconstruct the depositional environments imaged by seismic data.

Using such seismic-depositional environment maps – together with well control and modern and paleo analogues – allows interpreters to produce probability maps of "most-likely" lithofacies. Although coherence and curvature are excellent for delineating some seismic stratigraphic features, they have limited value in imaging classic seismic stratigraphy features such as onlap, progradation and erosional truncation.

Here we examine how newer volumetric attributes facilitate seismic stratigraphic analysis of large 3-D seismic volumes.

Reflection Convergence

Changes in reflector dip, reflection terminations, erosional unconformities and angular unconformities are relatively easy to recognize by visual inspection of vertical seismic sections. To translate visual recognition of these features to a numerical-recognition process, a first step is to compute volumetric estimates of vector dip at each data sample.

Next, the mean and standard deviations of these vector dips are calculated in small windows about each data sample. Conformable reflections will have small standard deviations of their reflection dips, while non-parallel events such as angular unconformities will have high standard deviation.

In 2000, Barnes computed a vertical derivative of apparent dip along a user-defined azimuth, and used that calculation to define whether reflections diverged or converged. In this methodology, converging reflections show a decreasing change in dip while divergent reflections show increasing change in dip. Marfurt and Rich (2010) built upon this method and generated 3-D estimates of reflector-convergence azimuths and
magnitudes. In order to represent the vector nature of reflector convergence in different azimuthal directions, they employed a 2-D color wheel to indicate reflector dip and azimuth.

Reflection Rotation

Compressive deformation and wrench faulting cause fault blocks to rotate. The extent of rotation depends on the size of the block, the lithology and the stress levels. As individual fault blocks undergo rotation, higher stresses and fracturing may occur at block edges. Natural fractures are partially controlled by such fault-block rotation and partially depend on how individual fault segments intersect.

Fault-block rotation also can control depositional processes by providing increased accommodation space in subsiding areas and enhancing erosional processes in uplifted areas. In view of the importance of fault block rotation, interpreters need a seismic attribute that allows the rotation of fault blocks to be better analyzed.

Examples

In Figure 1, we show the behavior of reflection convergence for a channel with and without levee/overbank deposits for four scenarios:

● Deposition within the channel that shows no significant convergence.

● Deposition within the channel such that the west channel margin converges toward the west and the east channel margin converges toward the east.

● Deposited sediments within the channel that do not converge at the margins, and levee/overbank deposits that converge toward the channel (west deposits converge toward the east and vice-versa).

● Strata within the channel and levee/overbank deposits that converge to the channel margins.

We carried out the computation of both reflector convergence and reflection rotation for a suite of 3-D seismic volumes from Alberta, Canada. Figure 2 shows a 3-D chair view of a coherence time slice spanning a channel system, co-rendered with reflector-convergence attributes.

Using the scenarios presented in Figure 1, our interpretation of the zone within the yellow dotted ellipse is that levee/overbank deposits converge toward the channel margin to the northeast (magenta) and southwest (green). In Figure 3 we show a time slice through a reflector-rotation volume. Notice the horst and graben features show considerable contrast and can be interpreted as distinct geologic regimes. An equivalent display is shown in Figure 4, with a time slice through a reflector-convergence attribute. In this case, the thickening and thinning of reflectors appear to be controlled by rotated fault blocks.

Conclusions

Application of two attributes, namely reflector convergence and reflector rotation, are shown for two different 3-D seismic volumes. These attributes provide complementary information to that provided by amplitude, coherence and curvature attributes.

Reflector convergence measures the magnitude and direction of thickening and thinning of reflections. Reflector rotation about faults is demonstrated to be valuable for mapping wrench faults.

Acknowledgments

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References

Barnes, A.E., 2000, Weighted average seismic attributes: Geophysics, v. 65/1, p. 275-285.

Marfurt, K.J., and J. Rich, 2010, Beyond curvature-volumetric estimates of reflector rotation and convergence: 80th Annual SEG Annual Meeting, 17-22 October 2010, Denver, Colorado, Document 2010-1467, 6 p.

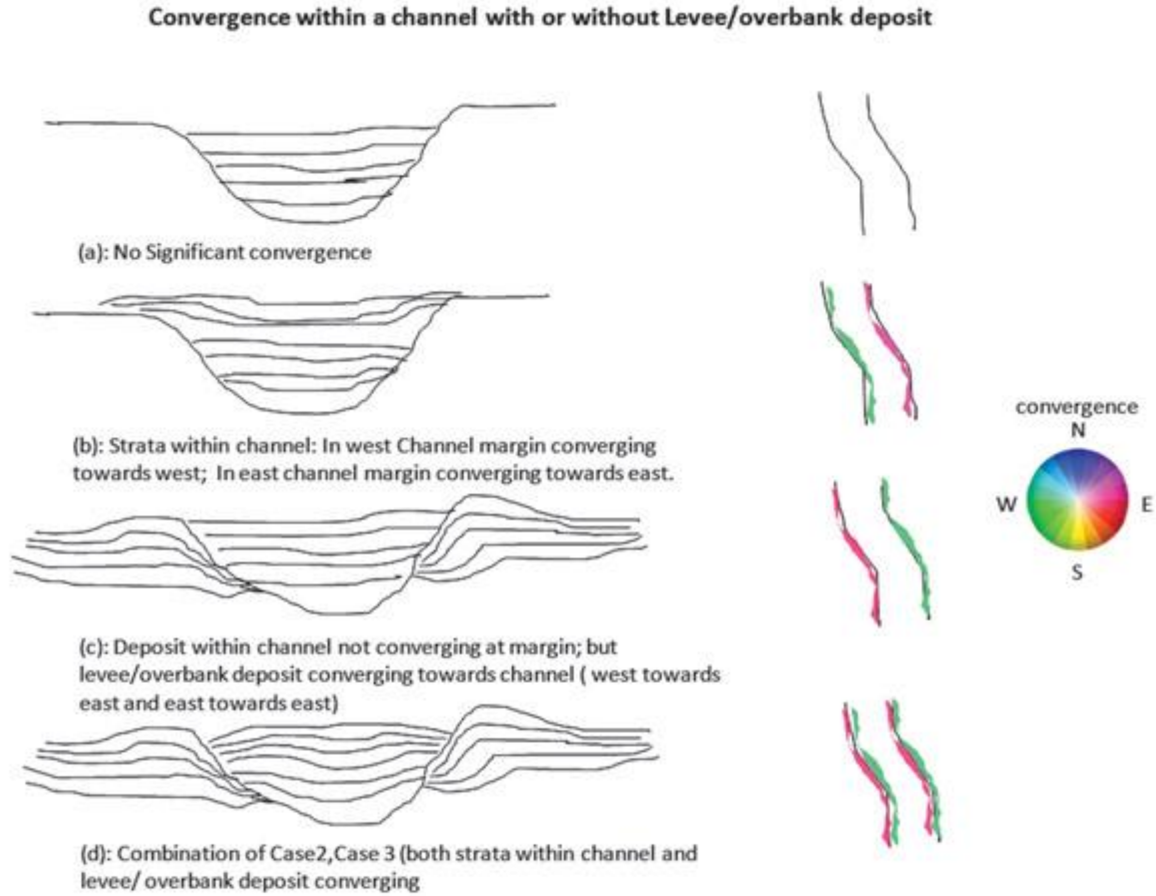

Figure 1. Cartoons demonstrating convergence within a channel, with and without associated levee/overbank deposits. (a) Strata within the channel show no significant convergence, (b) strata within the channel converge toward both west and east channel margins, (c) strata within the channel do not converge at the margins, but levee/overbank deposits do. (d) A combination of cases (b) and (c), where strata within the channel and levee/overbank deposits both converge at the channel margins. Azimuths of reflection convergence are defined by the color wheel. Interpretation courtesy of AAPG member Supratik Sarkar, University of Oklahoma.

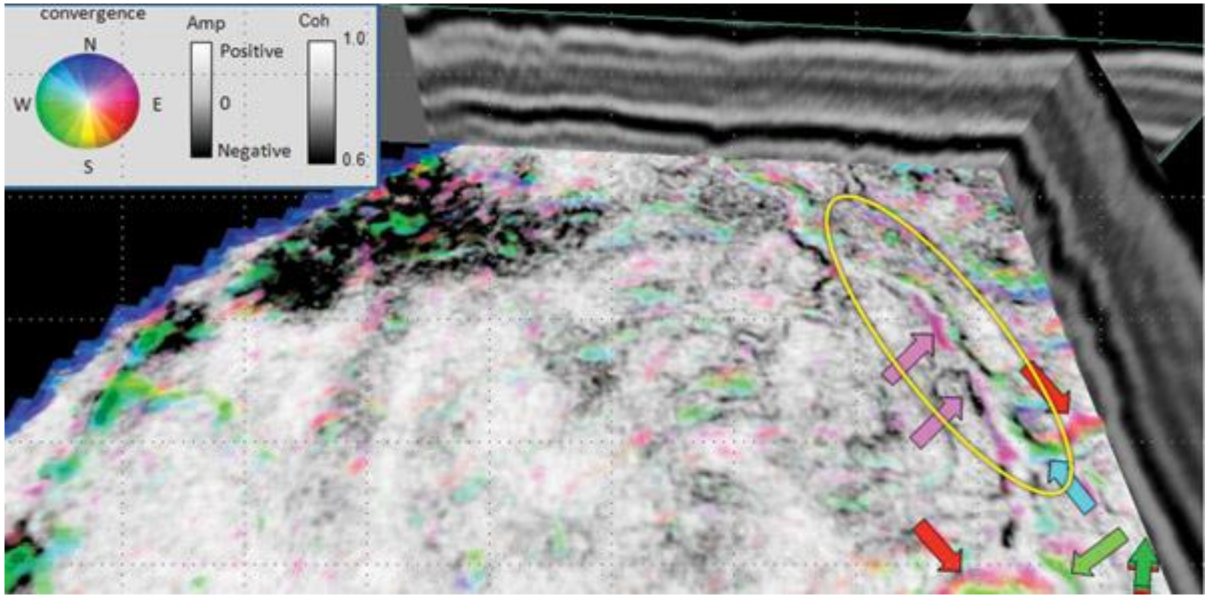

Figure 2. Three-D chair view with a coherence time slice across a channel system as the horizontal section. This slice is co-rendered with reflector-convergence azimuth defined by the 2-D color wheel at the upper left. In view of the scenarios discussed in Figure 1, we interpret the zone within the yellow dotted ellipse to be a levee/overbank deposit converging toward channel margin.

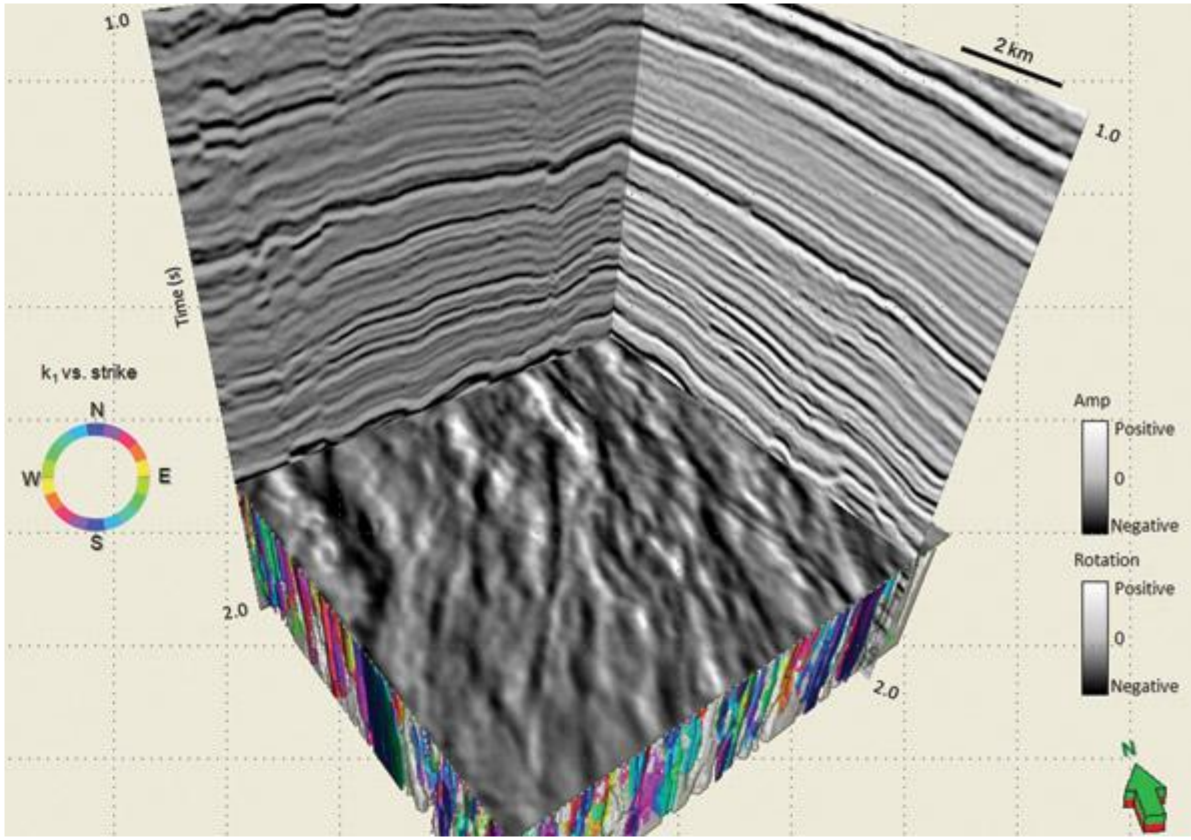

Figure 3. Time slice at t=1.710 seconds through a volume of reflector rotation. Horst and graben blocks show considerable contrast and can be interpreted as separate units.

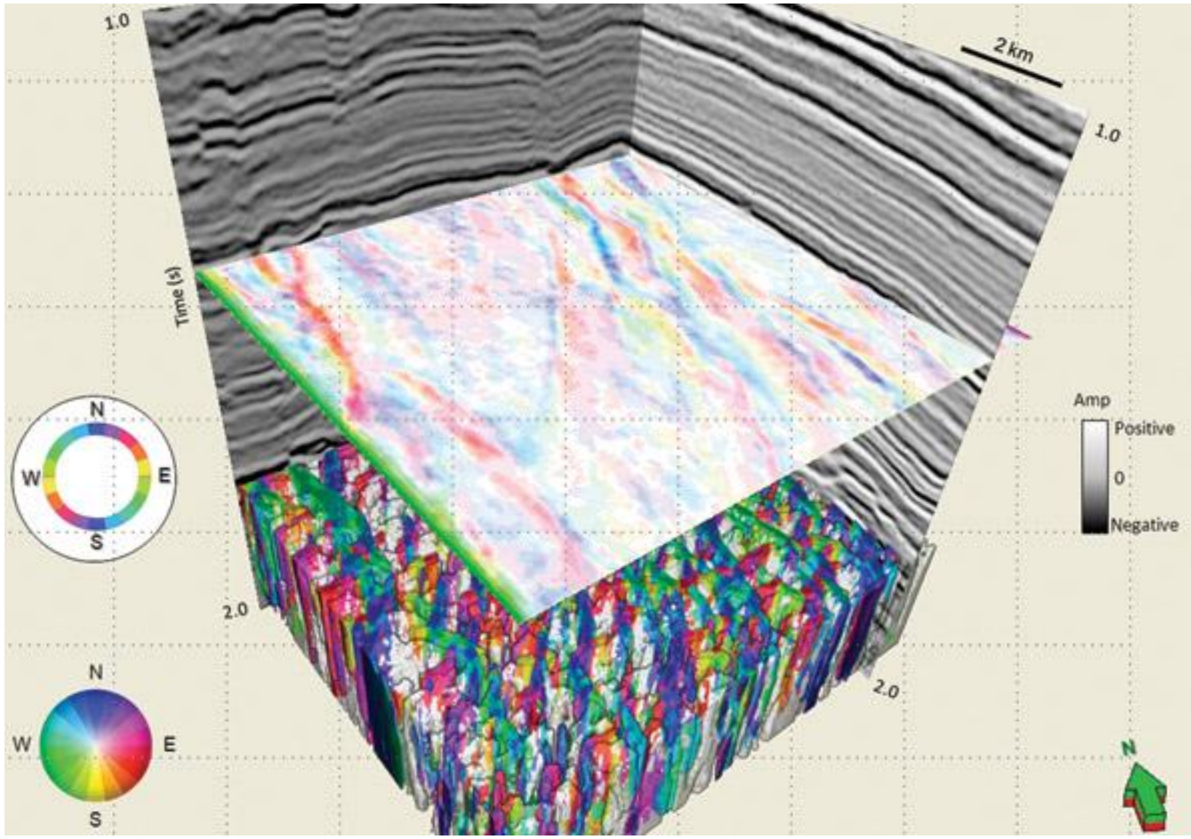

Figure 4. Time slice at t=1.330 seconds through a reflector-convergence volume. Blue indicates reflectors pinching out to the north, red to the southeast and cyan to the northwest. Below the time slice we show the most-positive principal curvature lineaments displayed in 3-D with more-planar features rendered transparent.