AAPG EXPLORER
GEOPHYSICAL CORNER

The Final Touch: Attributes Prove Their Worth

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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.

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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.

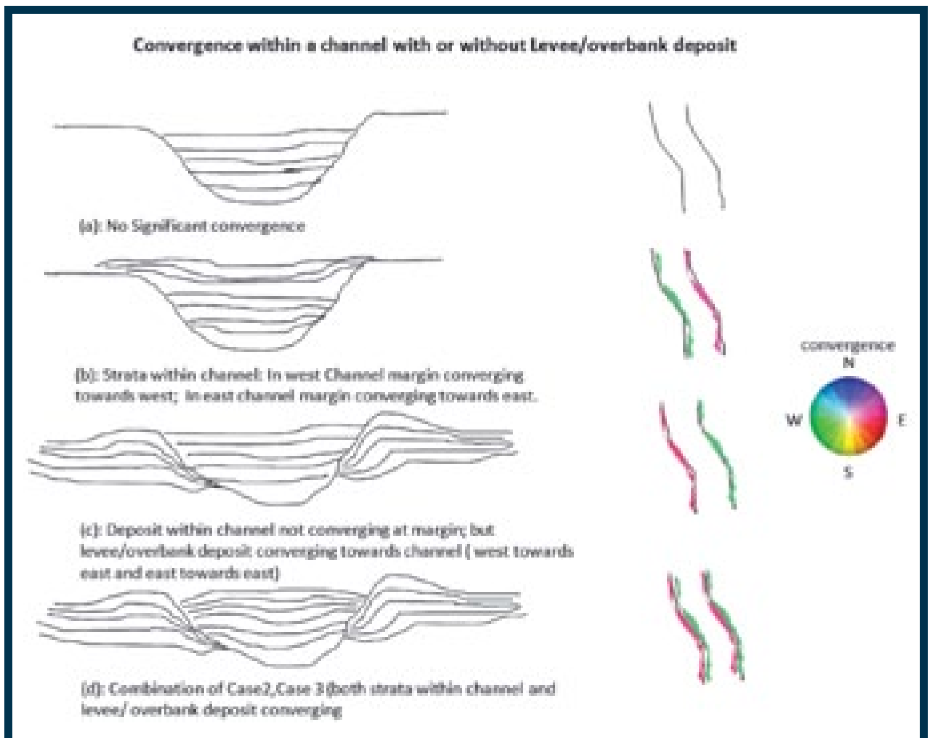

Figure 1 – Cartoons demonstrating convergence within a channel, with and without associated levee/overbank deposits. (a) Strata within the channel show no significant convergence; (b) strata within the channel converge toward both west and east channel margins. (c) Strata within the channel do not converge 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.

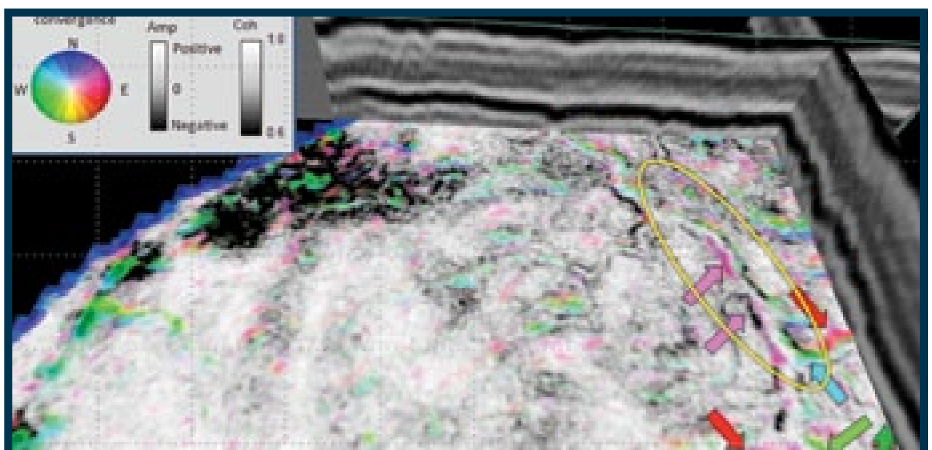

Figure 2 – Three-D chair view with a coherence time slice across a channel system as the horizontal section. This slice is co-rendered with reflector-convergence azimuth defined by the 2-D color wheel at the upper left. In view of the scenarios discussed in figure 1, we interpret the zone within the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

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.

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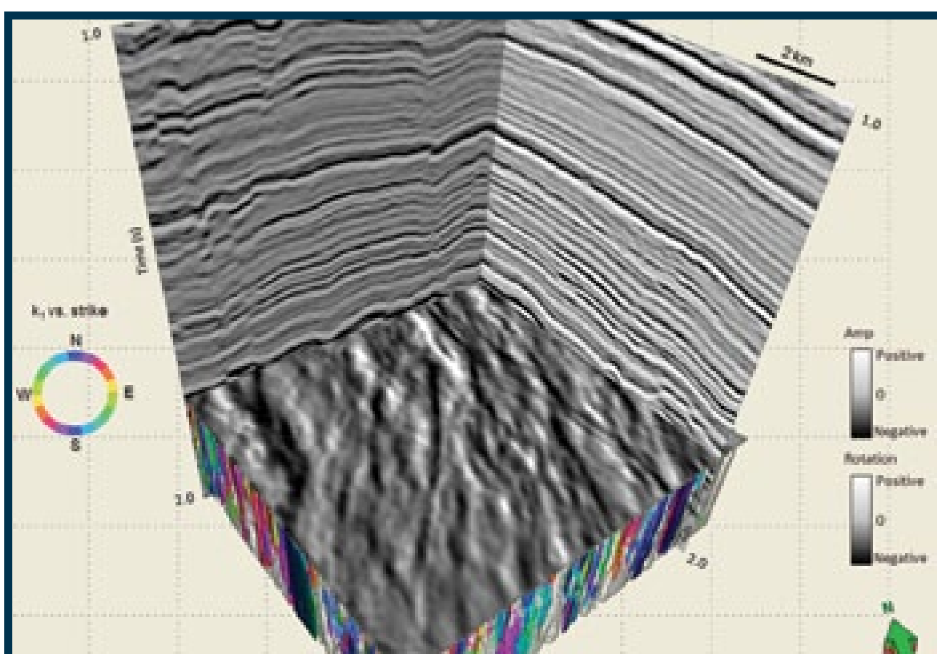

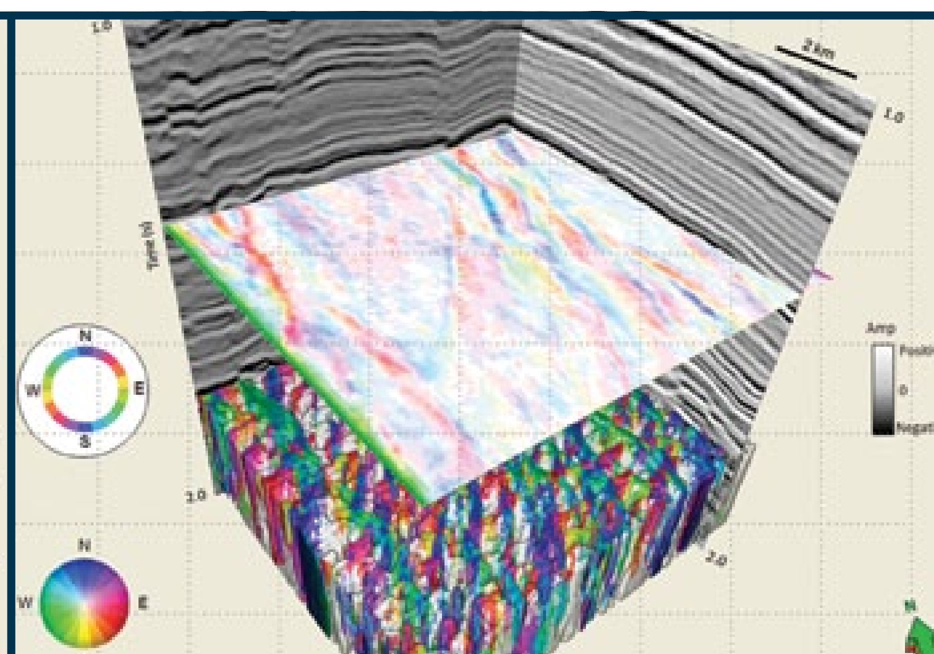

Figure 3 (left) – Time slice at t=1.710 seconds through a volume of reflector rotation. Horst and graben blocks show considerable contrast and can be interpreted as separate units.
Figure 4 (right) – Time slice at t=1.330 seconds through a reflector-convergence volume. Blue indicates reflectors pinching 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.

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- 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. E

We thank Arcis Corporation for permission to show the data examples, as well as for the permission to publish this work.

(Editor's note: AAPG member Satinder Chopra is with Arcis Corp., Calgary, Canada, and AAPG member Kurt J. Marfurt is with the University of Oklahoma, Norman, Okla.)

Satinder Chopra, an award-winning geoscientist who has contributed numerous papers to Geophysical Corner over the past several years, will be the column's new editor.

He replaces Bob Hardage, who has been the Geophysical Corner editor since January 2006. Hardage, a senior research scientist at the Bureau of Economic Geology in Austin, Texas, is beginning his term as president of the Society of Exploration Geophysicists.

Chopra, an AAPG Distinguished Lecturer and winner of the 2010 AAPG George C. Matson Award for his paper, "Delineating Stratigraphic Features Via Cross-Plotting of Seismic Discontinuity Attributes and Their Volume Visualization," is chief geophysicist (reservoir), at Arcis Corporation, Calgary, Canada.

In the last 27 years he has worked in regular seismic processing and interactive interpretation, but has spent more time in special processing of seismic data involving seismic attributes including coherence, curvature and texture attributes, seismic inversion, AVO, VSP processing and frequency enhancement of seismic data.

He has published seven books and more than 220 papers and abstracts.

He is the past chief editor of the CSEG RECORDER, a past member of the SEG's Leading Edge editorial board and the ex-chairman of the SEG Publications Committee.

In addition to AAPG, he is a member of SEG, CSEG, CSPG, CHOA (Canadian Heavy Oil Association), EAGE, APEGGA (Association of Professional Engineers, Geologists and Geophysicists of Alberta) and TBPG (Texas Board of Professional Geoscientists).

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for additional studies on the matter.

The study confirmed that distance from drill wells does have an effect on leak accidents, but there is no evidence of hydraulic fracturing fluid contamination in groundwater sources.

Duke also recently published a study that proposes seven safeguards to minimize negative impacts from hydraulic fracturing, including baseline data, safety requirements, mandated disclosure of chemical data and regulatory programs.

- Resources for the Future, an independent, non-partisan research organization, received a grant to investigate its study, titled "Managing the Risks of Shale Gas: Identifying a Pathway Toward Responsible Development."

The 18-month review will survey experts and the public, analyze risk drivers, assess federal and state regulations and make recommendations to reduce risks.

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Internationally, hydraulic fracturing for shale gas already has been banned in France, Australia's New South Wales province and in the Karoo region of South Africa. The United Kingdom and New Zealand are continuing the practice but taking careful steps along the way.

With clear, thorough scientific research, implementation of best practices and effective communication to the public, the United States can lead by example during this controversial time. E