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Technologies Enhance Eagle Ford 3-D

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HOUSTON–Seismic data acquired in the Eagle Ford Shale play in South Texas are dominated by high-amplitude reflections from subsurface carbonates and Jurassic-age salt, and the combination of onshore acquisition and data processing challenges can produce noisy 3-D seismic data volumes that are difficult to interpret and accurately model.

Structurally oriented noise reduction techniques remove noise from the acquired data while preserving seismic signal, creating a 3-D volume that is easier to interpret. Seismic attributes calculated on the cleaner data provide a better picture of the subtle stratigraphy in the Eagle Ford play area.

The Eagle Ford is a marine shale that was deposited during the Upper Cretaceous period. It is still an emerging unconventional play, with a little more than 100 Eagle Ford wells drilled as of the end of the third quarter of 2010. As with other U.S. shale plays, it was pioneered by independent oil and gas companies, but now is attracting the attention of the majors.

Importantly, given the higher valuation for crude oil relative to natural gas on a Btu equivalent basis, the Eagle Ford is proving competitive with other shale plays because of its higher liquid content and lower well costs. While it is primarily a gas play, oil has been discovered in the southwest portion of the trend, and the Eagle Ford has reasonably definable "windows" of mainly dry gas, liquids-rich gas and crude oil production.

Moreover, the Eagle Ford has a higher carbonate-to-shale percentage, which makes it more brittle, and therefore, better suited to hydraulic fracturing than more ductile shales. In addition, the Eagle Ford is not as highly pressured as other gas shales, namely the Haynesville.

Geophysical support for the play will become more and more critical as many companies receive the processed 3-D data sets from surveys shot over the area in 2010-11. The depth, thickness and mineralogy of the shale can vary significantly over short distances and at different scales. Seismic attributes can be a critical factor in identifying these changes.

Sandwiched between the Austin Chalk and the Edwards formation, the Eagle Ford can be overwhelmed by these bright reflectors. In addition, drilling in this play has moved quickly from vertical to horizontal wells. Therefore, accurate and interpretable seismic data are more vital than ever to well success and economics. Seismic attributes can be utilized as operators move from understanding the Eagle Ford as a "source rock" to understanding it in a "reservoir" context.

Live Oak County, Tx., is the site of several discovery wells in the Eagle Ford play, and many more wells are planned to spud in the near future. As geophysical work on a 3-D seismic volume acquired at the Sinor Ranch Field in Live Oak County illustrates, data conditioning and attribute analysis of Eagle Ford 3-D seismic can help increase operators' understanding of the geologic context of the play dramatically.

Geologic Setting

After the rifting that occurred during the Jurassic age, the Cretaceous period was relatively quiescent in the northern Gulf of Mexico. In the early Cretaceous, shelf-edge reefs developed along the boundary between the continental shelf and Gulf of Mexico basin. In the late Cretaceous, no reefs formed, and the Eagle Ford was deposited during a transgression that covered the reefs with lime mud and shale.

The Eagle Ford consists of a lower transgressive unit of dark shales and an upper highstand of unit shales and limestones. The lower unit was deposited in a lower-energy, poorly-oxygenated environment and is more oil prone. The upper unit accumulated in a higher-energy, shallower-water environment during a regressive high stand and is gas prone.

There is a regionally recognizable unconformity at the base of the Eagle Ford, and the Austin Chalk lies unconformably on top of the Eagle Ford. The Austin Chalk/Eagle Ford Shale contact represents the Turonian-Coniacian boundary 89 million years ago during the late Cretaceous. In Live Oak County, these strata are underlain by Jurassic salt.

The Eagle Ford Shale is located at medium depths of 4,000-12,000 feet, and is up to 300 feet thick in places. The early Cretaceous shelf edge (Edwards trend) cuts through the middle of Live Oak County, trending southwest-to-northeast. Most of the production occurs near the convergence of the Stuart City Reef trend and the Sligo Reef trend.

The Eagle Ford has long been known as the source rock to the overlying Austin Chalk, and geologists have recognized for years that it contained oil and gas. However, it has been within only the past few years that the industry began to investigate the shale's potential as an unconventional reservoir, following on the dramatic success of plays such as the Barnett, Haynesville and Marcellus shales. Going forward, structural and stratigraphic information will be crucial to reservoir characterization, and with a relatively small number of wells drilled into the trend to date, operators must rely heavily on seismic data to provide geologic constraints.

Data Conditioning

Seismic data acquired over the Eagle Ford Shale can be noisy as a result of both acquisition and processing effects. The lithology in the area includes carbonates, shales, clastics and salt. The Eagle Ford is fairly deep at up to 12,000 feet, and two-way seismic energy travel times can be more than three seconds. It is important to image the Eagle Ford as accurately as possible, because small changes in the character of the reflector may imply significant changes in reservoir characteristics such as porosity. Therefore, noise reduction (or data conditioning) becomes a very important processing step.

The input data for the Sinor Ranch Field project consisted of a 3-D post-stack seismic data volume from Seitel, which was acquired in 2007 with a vibroseis source and processed through prestack time migration. A structurally oriented mean noise filter was applied that utilized precomputed dip and azimuth volumes to steer the filter. Two iterations of the filter with a small filter length produced the best results.

Figure 1 shows a seismic line over the Eagle Ford Shale in Live Oak County. The original data show significant "chatter," probably related to processing artifacts (panel A at top). Applying a structurally-oriented noise filter to the data significantly reduced the noise while preserving amplitude and edges (panel B).

The difference volume between the original and the conditioned lines (panel C at bottom) indicates that a significant amount of dipping coherent noise was removed by the filter, increasing the reflector continuity in the Eagle Ford section while preserving signal. The precomputed dip and azimuth steering volumes allow the filter to recognize and preserve geological events.

Figure 2 shows time slices at 1,376 milliseconds from the original data (image A at left) and the conditioned data volume (image B at right). This type of noise was visible at all time levels in the data.

FIGURE 1

Differences between Original And Conditioned Data

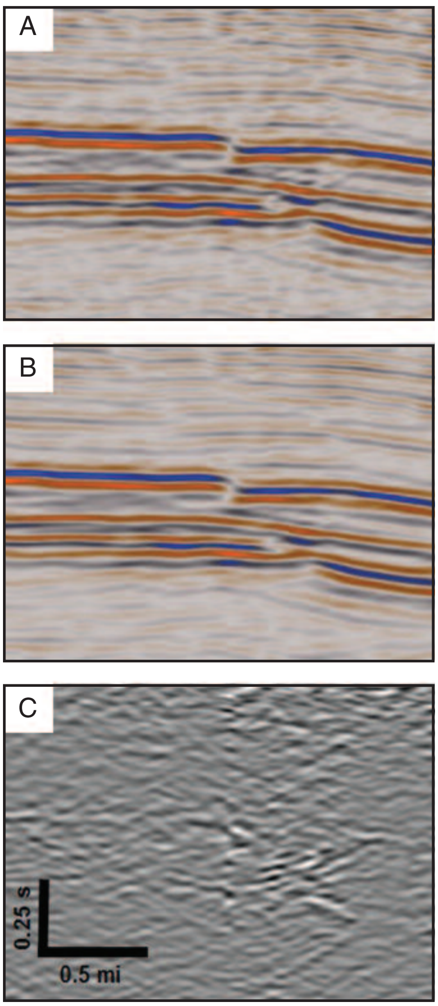
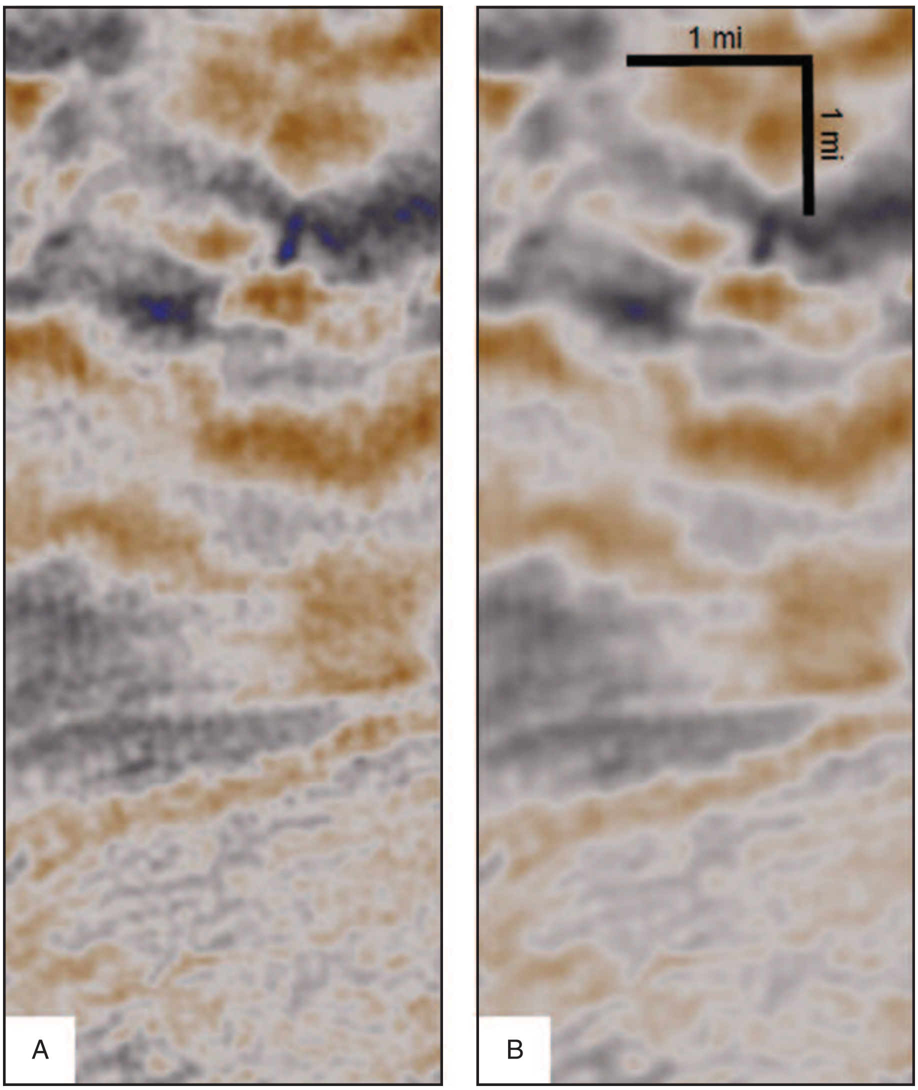


FIGURE 2

3-D Seismic Time Slices (Original versus Conditioned Data)



Plays in the Eagle Ford can consist of subtle stratigraphic traps, so it is crucial to preserve all geologic information contained in the seismic data. The noise-reduced, conditioned data allow for much better performance of horizon autotrackers, fault interpretation and attribute analysis.

Attribute Analysis

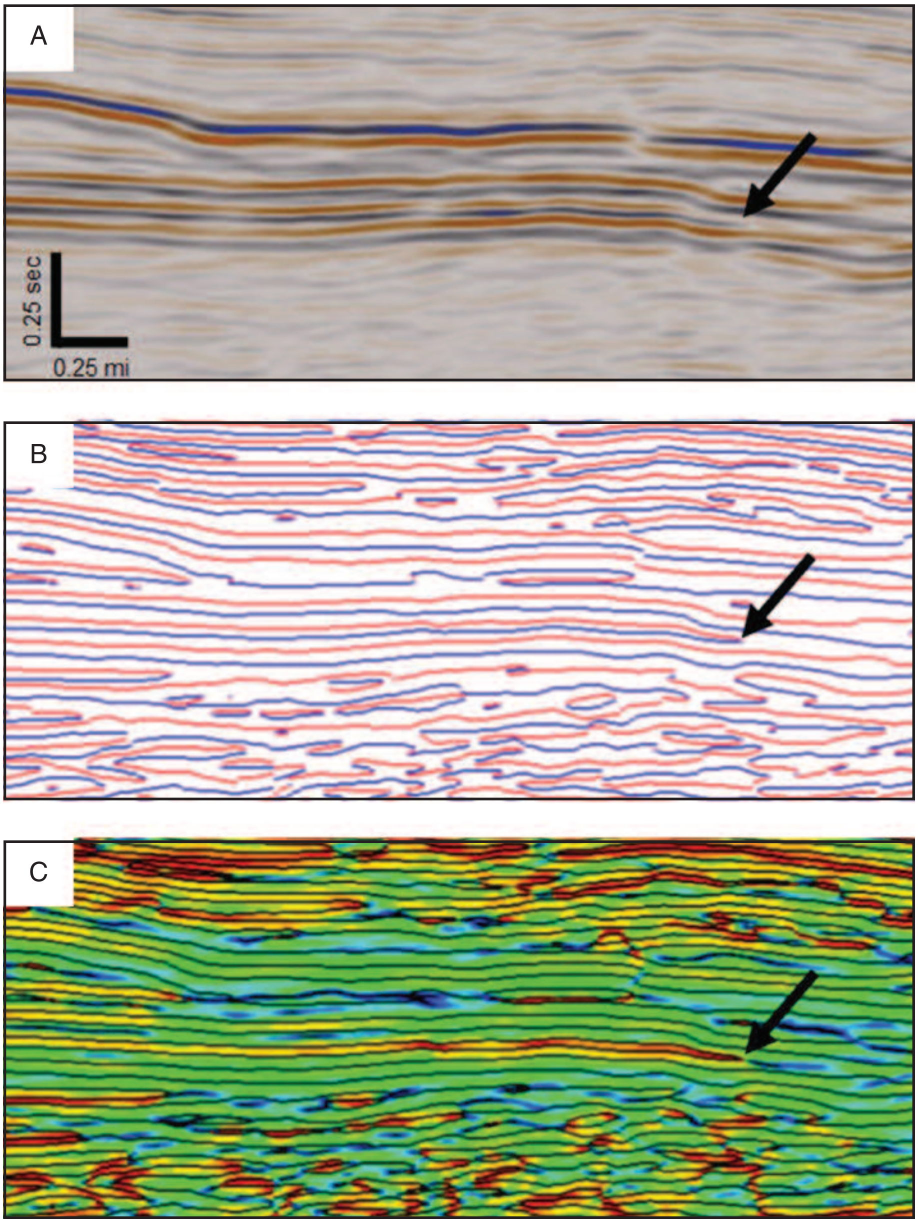
Volumetric seismic attribute measurements can be a valuable interpretation tool if tailored to the given geologic setting. Hundreds of seismic attributes can be derived from the data, many of which can be computed in a matter of minutes on a desktop computer workstation.

Moreover, attributes can be calculated on 3-D seismic data volumes, rather than horizon surfaces or time intervals. With access to this vast amount of data, it is important to understand the appropriate application of various seismic attributes in order to produce the best interpretation possible. Several attributes were used to enhance subtle stratigraphic features on the Sinor Ranch Field 3-D data set from Live Oak County.

Industry research efforts in the Eagle Ford have focused on using 3-D data to help identify high-quality reservoir sweet spots and local faults. With production rates varying significantly over short distances, attribute analysis and other seismic techniques can help identify the best production areas, as well as faults that might create drilling hazards. Seismic also can identify the Eagle Ford/Austin Chalk contact, which is often difficult to detect

FIGURE 3

Thin Bed Pinch-Out from Attribute Analysis



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with logging data.

After applying the noise filter, a number of seismic attributes were calculated in order to better characterize the Eagle Ford. One example is a bed-form attribute (Figure 3), which was created to highlight the relationship between seismic strata within the data set, including features such as pinch-outs and clinoforms. Since it is phase-based, this attribute is also useful for mapping through low-amplitude features.

In the seismic line in Figure 3, the noise-reduced data show indications of pinch-outs, but it is difficult to identify exact locations (A). The bed-form attribute clearly shows the location of the bed termination (B).

The bed-form attribute then was combined with a regional instantaneous frequency attribute. Instantaneous frequency is calculated using a Hilbert transform and can be used to interpret geology. For example, high values can indicate sharp interfaces or thin beds, while larger-scale low-frequency areas can indicate unconsolidated sands. When the bed-form attribute is combined with an instantaneous frequency attribute, both the pinch-out and the continuation of the thin bed can be identified, as indicated by the high frequencies in red (C).

Merged with the bed-form attribute, instantaneous frequency can provide a detailed stratigraphic display. This combined attribute revealed pinch-outs and thin beds in the vicinity of the Eagle Ford reflector. This multiattribute combination was created from the conditioned data, which already had improved reflector continuity, so there was a significant improvement in interpretability.

The opacity of the instantaneous frequency attribute was set so that only the high frequencies corresponding to the thin bed attribute in Figure 3 were visible. A geobody based on these parameters was extracted from the instantaneous frequency attribute to produce a 3-D map of the thin bed (Figure 4). This geobody reflector terminates in one direction against a fault (background) and appears to pinch out in the other direction (foreground). This edge corresponds to the location of the arrow in image C in Figure 3.

As demonstrated using the Sinor Ranch Field 3-D volume in Live Oak County, data conditioning is critical to improving the interpretability of land seismic data over the prospective Eagle Ford Shale. The structurally-oriented noise reduction technique increases reflector continuity while preserving edges, amplitude and frequency content.

Seismic attributes derived from conditioned data more likely are related to geology than to acquisition or processing artifacts. Bed-form and smoothed instantaneous frequency attributes aid interpretation of the Eagle Ford across the 3-D volume by highlighting thin beds and pinch-outs. ❒

FIGURE 4

Geobody Extracted from Instantaneous Frequency Attribute