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Seeing between a rock and a hard place

Windows-based visualization of high-frequency seismic volumes optimizes reservoir potential in a channel play.

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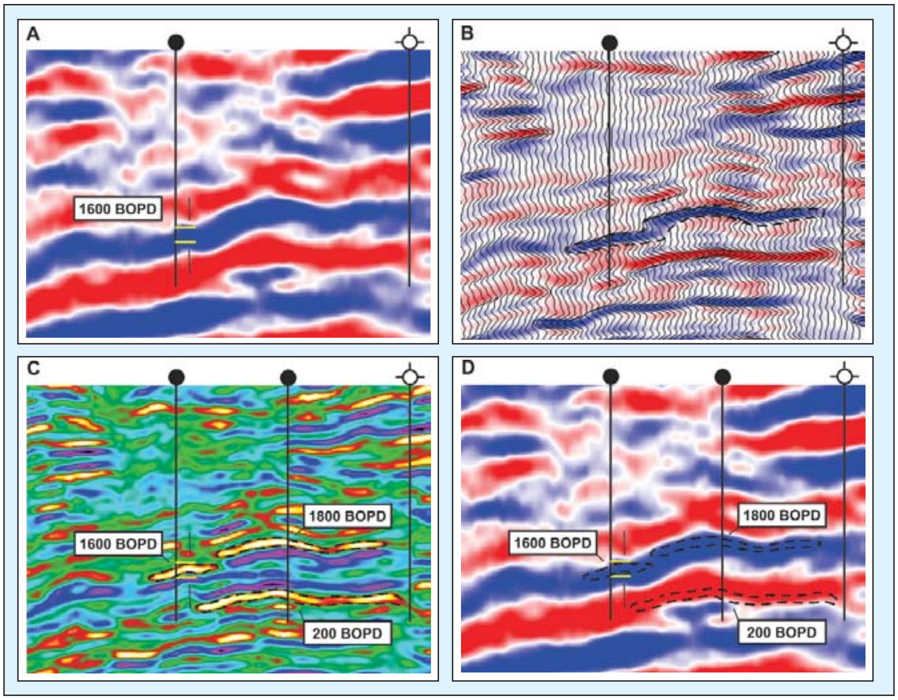

Figure 1. Seismic sections from the Lake Maracaibo Basin project. (a) Drilling based on normal frequency data yielded one successful well and one dry hole. (b) HFI on the same line reveals how the sand pinches out before the dry hole. (c) Relative Acoustic Impedance on the HFI data delineate three distinct sand bodies. (d) The new interpretation superimposed on the normal frequency data. (High Frequency Imaging is a trademark of Geotrace Technologies Inc. All images courtesy of Geomodeling)

Braided fluvial reservoirs can host significant volumes of hydro-carbons, being high net/gross ratio, and are often considered to be relatively easy to characterize. But this is not always the case, as confirmed in a recent study conducted by Houston-based reservoir services company Geotrace Technologies Inc. The Misoa Sandstone reservoir in Venezuela's Lake Maracaibo Basin shows consistent permeability distributions and can be easily correlated using logging interpretation. However, a dry hole drilled a little more than 300 ft (100 m) away from a known producer within the Misoa Formation could not be correlated with an adjacent well. A solution using seismic interpretation technology and an enhanced imaging process identified the source of the discontinuity and helped Geotrace optimize its client's drilling program.

"Clients want to visualize as much detail as possible about their data and get a clear picture of the play," said Karen Pate, a senior reservoir geologist at Geotrace. "Since your interpretation is only as good as the data you put in — as they say, 'garbage in, garbage out' — we make sure that the attributes we generate for interpretation are the best ones to run for visualizing the most subtle plays." To meet this objective, Pate implements an interpretation workflow that combines the use of Geomodeling's VisualVoxAt seismic interpretation software and Geotrace's proprietary High Frequency Imaging (HFI) process.

HFI is applied to post-stack amplitude data to extract the seismic bandwidth more efficiently than conventional whitening or deconvolution programs. The process uses technology that recovers the high-frequency data encoded in the lower end of the seismic spectrum. Whereas typical seismic data is limited to about 40 Hz or 50 Hz of usable frequency, HFI can yield upwards of 100 Hz of valid data. The processed data aids in resolving subtle structural events and very thin beds, as thin as 10 ft to 15 ft (3 m to 5 m).

"An interpreter will use High Frequency Imaging in the same way one would use a sharpened pencil," Pate said. "The sharper the pencil, the finer the detail you can add to your picture."

After HFI processing, HFI volumes and normal frequency volumes are loaded into the Geomodeling software along with any wells or horizons. Geotrace's approach is to generate seismic attributes from both volumes and compare the results to determine the play type. By visualizing the high-frequency data alongside the normal frequency results, the interpreter can extract stratigraphic details and fault information that may be overlooked in standard displays.

The software enables the interpreter to reorganize stack data into a "strata-grid" or sub-volume that removes structural bias and renders data with respect to potential depositional surfaces. The strata-grid aids in visualizing the data as a stratigraphic sequence and can be generated from one or more picked horizons using a waveform picker.

When HFI and normal frequency volumes are loaded into the software, the interpreter can generate attributes and determine which attributes are best to focus on. The cross-plotting tool allows the user to compare relationships between different attributes and datasets in real time. Users can digitize polygons on cross-plots and identify corresponding features in 2-D or 3-D seismic, well or map views. Conversely, they can also select zones of interest in seismic or map view

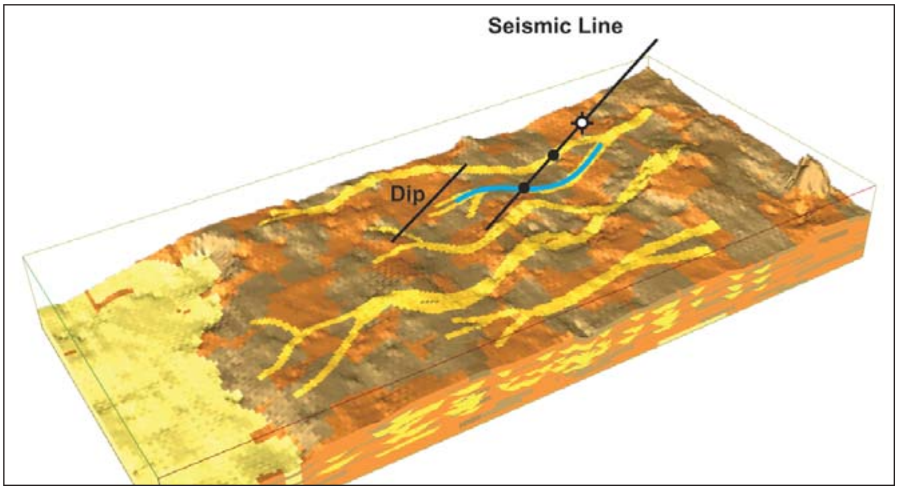

Figure 2. The new interpretation using HFI shows how the water follows the stratigraphic boundaries of the reservoir.

and see corresponding data clusters in the cross-plots.

"Once we cross-plot seismic attributes and well curves, we can define attribute clusters for further investigation," said Pate. "We then apply tools like seismic facies classification and spectral decomposition to extract very subtle events and to cross-check our HFI interpretation."

Pate's visualization workflow was successfully implemented to improve a drilling program in the Lake Maracaibo Basin. Based on normal frequency seismic interpretation, the client originally drilled a well within the Eocene Misoa Sandstone reservoir and penetrated a unit that produced 1,600 bo/d (Figure 1a). The success prompted the drilling of another well updip along the same sand unit. Despite good correlation in the normal frequency data, the result was a dry hole.

Applying the HFI process to the same line images and visualizing them showed that the sand pinches out before the dry hole (Figure 1b). Relative Acoustic Impedance (RAI, an attribute that helps to delineate sand bodies) on the HFI product revealed that the updip sand may not be continuous with the sand penetrated by the first well (Figure 1c). Furthermore, the RAI delineated a lower potential sand body that was not penetrated by either well. A third well was drilled to test the potential sand and confirmed the non-communication of the reservoir (Figure 1c). The upper sand unit had pressures that differed from that of the original well and was estimated to yield 1,800 bo/d as opposed to the 1,600 bo/d of the original unit. The lower unit, while also an oil sand, produced only 200 bo/d. Overlaying the new interpretation over the original normal frequency data shows that the discontinuities would have been very difficult to identify without the aid of enhanced imaging (Figure 1d).

Based on the results, Pate and her colleagues attributed the discontinuous nature of the sands to a depositional environment consistent with a braided channel system. The new interpretation explains why a previous water injection program in the project area was unsuccessful (Figure 2).

"The original geological interpretation was a blanket sand, where the sand was either eroded or faulted out of a few wells," she said. "When the water was injected in the downdip well to increase production, the water didn't sweep the intended wells. Instead, it followed the stratigraphic boundaries of the channel reservoir."

To better understand the depositional environment, unsupervised neural network facies classification was applied to the normal frequency volumes and the HFI volumes. The HFI facies maps clearly delineate a meandering channel morphology, which is obscured in the normal frequency data (Figure 3). The channel interpretation was further confirmed by running seismic attributes such as semblance, instantaneous phase, instantaneous frequency and RAI. Spectral decomposition was applied to the seismic volumes to visualize subtle events often associated with channel systems. The process breaks down the seismic signal into its frequency components and generates t uning cubes consisting of multiple frequency slices (amplitude and phase maps tuned to a given frequency). "It's another tool for seeing more details from the data," said Pate, "We can easily scroll through frequency slices to see subtle structures like those you would find in a braided channel environment."

By combining the HFI process with the visualization and attribute analysis capabilities in the software, Geotrace extracted the details in its client's data with better resolution than offered by conventional workflows. "It allows us to assess reservoir potential much more quickly and make informed decisions before placing the next well," Pate said. "The workflow decreases cycle times for our clients, reduces the risks and provides better return for the companies we serve." **E&P**

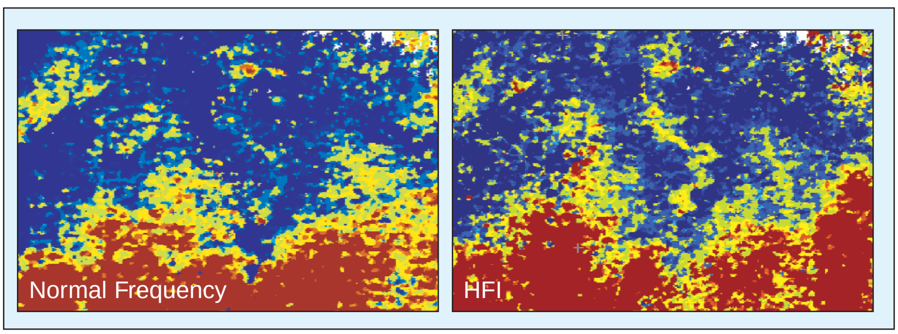

Figure 3. Seismic facies maps generated from neural network classification of normal frequency and HFI volumes. The meandering channel morphology is enhanced in the HFI data.