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Borehole Seismic Imaging (BSI) Method to Ensure the Drill Bit Goes Where You Intend – A Haynesville Case Study

For many years, surface seismic data have been a valuable tool for the planning and drilling of horizontal wells. When available, it can provide a clear picture of the regional dips and structural complexity of the target reservoir. Unfortunately, for many shale reservoirs, surface seismic does not provide the resolution needed to identify small-scale features that are critical to the success of a horizontal well. This is especially true for Louisiana's Haynesville formation, where small faults can alter the optimum trajectory of the well bore.

When 3D seismic data is unavailable or of insufficient quality, new time- and cost-efficient technologies like Borehole Seismic Imaging (BSI) and Wellbore Trajectory Imaging (WTI) can provide high-resolution, localized seismic detail for operational decision support.

WTI is a 2D application of BSI directed along the planned trajectory of a horizontal well. In the case of a recent Haynesville project, WTI provided a timely image used to alter the planned trajectory of a horizontal well to account for a small fault that changed the local dip of the reservoir that would otherwise have caused the horizontal to go out of zone.

The design and planning of this survey included a complete illumination analysis to confirm that the target reservoir depth would be properly imaged, as well as a detailed acquisition work plan that corresponded to the drilling of the well. The goal was to occupy the vertical section of well after the casing was completed, but prior to the drilling of the horizontal phase.

The survey design included two setting depths of an 80-level geophone array and 49 vibrator source point locations that would be occupied twice. Upon data acquisition, the raw field data were delivered to the processing center via satellite for immediate processing. The data quality was very good and preliminary processing proceeded without any significant issues. An important factor in the success of this project was the high-resolution result obtained from the time-domain method used for imaging. This method preserved the highest frequencies created by the vibrator source (8-80 Hz sweep) and highlighted small discontinuities in the reservoir.

Key to this method is the upward-continuation process that produces pseudo receivers at the surface of the earth that can then be processed using conventional processing algorithms, such as surface-consistent statics, surface-consistent deconvolution and time-domain NMO velocity analysis. Once statics and velocities are resolved, the data are migrated using a standard pre-stack time-domain Kirchhoff algorithm. After migration, the data are analyzed for residual moveout, muted and stacked and final data filtering and enhancements are applied. For this project, the final time-domain image was delivered for interpretation two days after the data arrived in the processing center.

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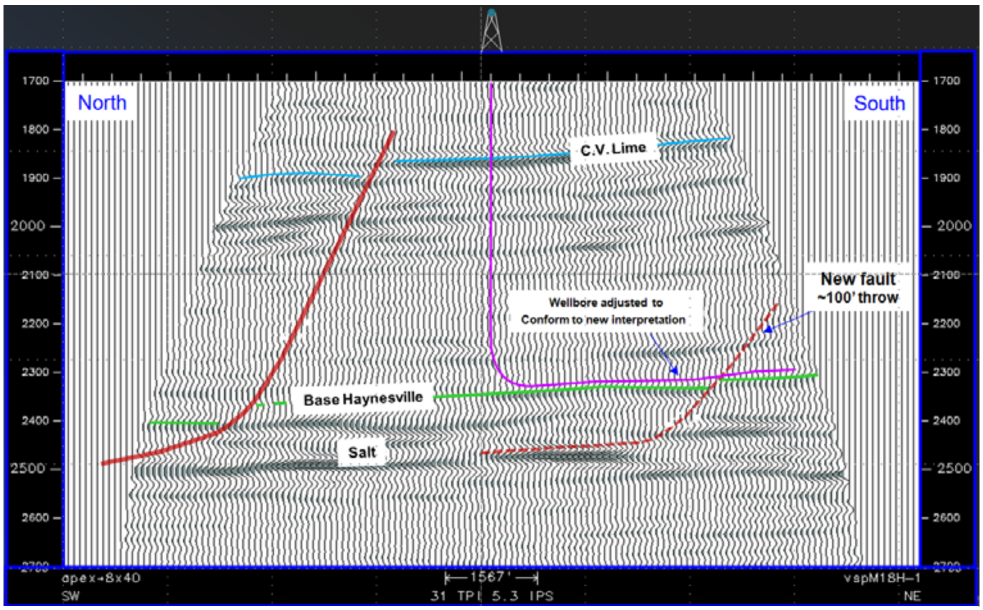
Interpretation of the 2D time-domain image took only hours and clearly showed that a relatively small fault existed along the length of the planned lateral. It also indicated that original well trajectory, based on the regional dip determined from well control and nearby 2D surface seismic, was inappropriate for the subtle local variations present near this well location. Adjustments to the well trajectory were made and subsequent drilling resulted in the wellbore staying in-zone throughout the entire length.



Interpretation of the final time-domain image showing the location of the target Base Haynesville and the new fault that was interpreted to intersect the planned wellbore.

The careful survey design and planning and the efficient, timely acquisition, processing and interpretation of this borehole seismic project proved to be critical in the ultimate success in guiding of the horizontal drill bit. Large geophone arrays and high-resolution processing methods provided the technical means for producing a useful image, but the timing of the entire effort made it both a technical and commercial success and more importantly, costly drilling mistakes were avoided.

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