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Characterization of the Wolfcamp Formation in the Midland Basin Using Probabilistic and Deterministic Inversion Methods

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Abstract

The Midland Basin in West Texas hosts significant unconventional resources, primarily within the Wolfcamp and Spraberry formations. The Wolfcamp formation comprises a thick sequence of interbedded organic-rich mudrocks and carbonates deposited across the basin floor during the early Permian period. In this study, we utilize the Flying Dutchman 3D seismic dataset to characterize the Wolfcamp through a comprehensive seismic inversion workflow. Pre-stack AVO inversion is applied to seismic data to obtain elastic properties, which were subsequently used to estimate rock properties (porosity, clay and limestone content). Moreover, a probabilistic inversion termed Direct Probabilistic Inversion (DPI) was performed to estimate facies probabilities to distinguish key lithologies within the target interval. Results demonstrate significant lateral and vertical variations in reservoir properties that align with known depositional patterns, enabling improved differentiation between clastic-rich and carbonate-dominated zones. This integrated approach highlights the practical application of advanced seismic inversion and rock physics methodologies in enhancing reservoir characterization in heterogeneous unconventional plays.

Method

Given the Wolfcamp formation’s pronounced lithological variability and vertical heterogeneity, advanced reservoir characterization techniques are crucial for informed development decisions. An integrated deterministic and probabilistic inversion workflow was applied to characterize the Wolfcamp formation. A pre-stack AVO inversion was conducted to estimate elastic properties such as acoustic impedance, Vp/Vs ratio, and density. Subsequently, these elastic attributes were utilized to estimate rock property volumes—porosity, clay and limestone content—using a calibrated rock physics model. Lastly, a probabilistic inversion was performed utilizing a Bayesian-based one-step inversion technique (Jullum and Kolbjornsen, 2016). This approach integrated geological constraints and seismic AVO modeling to estimate facies probabilities, enhancing the interpretation of the subsurface lithology and reducing uncertainty in reservoir characterization.

Results and Conclusions

Inversion results clearly illustrate spatial variations in acoustic impedance that align closely with estimated porosity and facies probabilities, enabling precise delineation of reservoir heterogeneity. Zones interpreted as siliceous mudstones exhibit high porosity, moderate clay and low limestone content, correlating strongly with high probabilities of organic-rich shale facies. Similarly, areas dominated by carbonate-rich lithologies show lower porosity, increased limestone, and correspondingly reduced probabilities of organic-rich shale.

The integration of deterministic AVO inversion, calibrated rock physics modeling, and Direct Probabilistic Inversion effectively identifies distinct stratigraphic layers reflective of known depositional environments. This integrated workflow significantly enhances the ability to predict sweet spots and non-productive zones, therefore supporting more informed and efficient reservoir development decisions in the Wolfcamp formation.

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