Seismic Reservoir Characterization of a Gas Shale Utilizing Azimuthal Data Processing, Pre-stack Seismic Inversion and Ant Tracking

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Summary

Prospective hydrocarbon-bearing zones in the subject gas shale are characterized by gas entrapped in the sediment matrix with some additional open-fracture component. This gas is economically recovered by horizontal drilling and fracturing. However, well placement close to faults is a significant risk factor due to expected mineralization of the fault and nearby shales.

A wide azimuth 3D survey was acquired to highlight areas exhibiting seismic velocity anisotropy for detection of open fractures. Sweet spots would be areas of anomalously low Poisson's ratio (PR), away from faults, with high velocity anisotropy. This study documents the results of an integrated workflow of data processing, pre-stack seismic inversion and Ant Tracking to successfully characterize faults and fractures and to identify sweet spots in the subject gas shale.

During data processing, azimuthal anisotropy analysis was done to determine the dominant direction of Vfast and Vslow. In general, there is good agreement between the azimuthal seismic data processing fractogram and Ant Tracking results. Corrections for HTI medium were applied prior to VTI anisotropic Kirchhoff prestack time migration (KPSTM). Two full azimuth 3D seismic volumes were created: a prestack volume as input for inversion and a stacked volume as input for Ant Tracking.

ISIS simultaneous inversion was done on prestack data to invert for acoustic impedance (AI) and Poisson's ratio (PR). A blind test of the inverted attributes is very encouraging. Areas of low PR away from faults are thought to be promising hydrocarbon leads or prospects.

Ant Tracking reduces the risk of drilling near faults by providing a high resolution image of fractures and faults beyond what can be interpreted from conventional seismic data.

The resulting integration of Poisson's ratio, anisotropy, and Ant Tracking results provide effective delineation of areas with superior porosity/charge, areas with open fractures, and areas with faulting, outlining likely sweet spots as well as areas better avoided in drilling.

Integration of azimuthal anisotropic data processing with pre-stack seismic inversion and Ant Tracking provides a superior tool to explore for gas in gas shale.

Introduction

Gas shales are a major play in North America. We present a workflow that addresses the main seismic components of the play: primary gas storage, secondary gas storage, and non-reservoir due to mineralization near faults.

Primary storage in the subject gas shale is in the sediment matrix. Simultaneous prestack inversion of the seismic data to Poisson's ratio targets this matrix-stored gas.

Secondary storage in the subject gas shale is in open fractures. Seismic processing for the detection of horizontal anisotropy in the shale targets the gas stored in fractures.

Mineralization of faults and adjacent shale is reservoir risk. This risk is addressed through a detailed imaging of the fault planes.

Method

Delineation of Matrix Storage of Gas

Simultaneous prestack inversion of the seismic data for Poisson's ratio proved to be effective in delineating areas of low Poisson's ratio that are thought to indicate the primary, more siliceous, relatively more porous, gas-charged sweet spots.

Because the subject gas shale is thought to produce primarily from sediment matrix rather than open fractures, the inversion was run on a full-azimuth basis. In a shale where open fractures are more important, we would recommend running the inversion twice, once on the fast-direction data (as determined by the azimuthal anisotropic data processing) and separately on the slow-direction data. The fast-direction measurement should give a good measure of the matrix-only effects of lithology, porosity, and charge. The slow direction would provide, by comparison, a measure of the effects of gas-charged open fractures.

Delineation of Gas-Charged Open Fractures

Azimuthal velocity analysis for anisotropy was used to delineate areas of abundant open fracturing. Integration with the fault-delineation work confirms the client's concern that some fault features would be mineralized, although there are some faults that show a lack of anisotropy and are therefore believed to have no mineralization.

The analysis was done using an efficient, full-azimuth technique. This technique was adequate for this area due to the lack of significant structure. In areas of significant dip, we recommend a sectored approach.

An attempt was made to detect amplitude variations with azimuth, but the data were not adequate to do so. This experience is not uncommon in azimuthal anisotropic analysis of conventional onshore data.

Detailed Imaging of Faulting

Ant Tracking was applied and found to be effective for enhancement of the imaging of the faults. The client commented that the Ants had delineated fault features that had previously been overlooked.

Faults were viewed by the client as reservoir risk due to expected mineralization of the faults and adjacent shale. Integration with the anisotropic analysis confirmed this for most faults. Some faults, however, lacked the diagnostic low anisotropy expected with mineralization.

Integration of Inversion, Anisotropy, and Ant Track Results

Sweet spot delineation was quite effective on the Poisson's ratio cube. As expected, the main sweet spot was separated from less prospective rock by the main fault, which had low anisotropy along much of its length, suggesting mineralization.

Low anisotropy and high Poisson's ratio values at the western end of the southernmost fault feature illustrate probable mineralization of both the fault and adjacent shale, but this lateral mineralization of the shale was not common in the study area as a whole. Although most of the fault features showed evidence of mineralization (high Poisson's ratio or low anisotropy), many of the fault features did not. Lateral continuation of the main sweet spot across the main fault where the main fault "en echelons" raises the possibility that the mineralized faults are capable of trapping.

Finally, the client drilled a pilot test well prior to the completion of our analysis. That well location was in an area that was ultimately flagged by this study as poor due to high Poisson's ratio and low anisotropy. That well was deemed non-commercial by the client. A Sonic Scanner run in that well had results consistent with the mineralized main fault and also with the general structural pattern seen by the Ant Tracking.

Conclusions

The integration of Poisson's ratio, azimuthal anisotropic analysis, and Ant Tracking provides effective delineation of areas with enhanced porosity and charge, areas with open fractures, and areas with faulting, revealing likely gas shale sweet spots as well as areas to be avoided in drilling.

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