The promise of 3C 3D seismic data for improved imaging and reservoir characterization in the Alberta oil sands

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Summary

A 3D 3C seismic data set from the Athabasca Oil Sands region was processed and interpreted. The vertical and radial geophone components were processed as the PP and PS seismic data. PP and PS seismic data were processed to stack using Vista and ProMAX processing software. Prestack PP gathers were generated for analysis. Stacked datasets were correlated with regional well control and pervasive reflection horizons were picked. The main hydrocarbon reservoir, the McMurray formation was studied based on the PP and PS seismic datasets. A large Upper McMurray aged channel feature was found running through the seismic volume. Truncations of regional seismic character were found at the McMurray channel location. A model-based post stack impedance inversion is performed on the PP seismic data. Interval RMS amplitude and impedance reveal in-situ natural gas and higher quality reservoir; these findings are correlated with geological control. A model-based pre-stack inversion was performed. The pre-stack inversion P impedance volume showed better differentiation of regional McMurray units than the post stack inversion.

Introduction

The projected growth of the hydrocarbon extraction industry in Alberta is heavily weighted in the bituminous sand deposits. By 2030, 1.8 million bbl/day will be added to oil sands production (CAPP, 2015). Multicomponent seismic reflection data is useful for understanding the subsurface geology. The benefits of collecting and processing both the PP and PS reflections for improved reservoir understanding is studied in this paper. A recently acquired commercial seismic volume acquired in Northeast Alberta was processed and interpreted. No contemporary drilling or production activity is occurring in the study area. Both the PP and PS seismic volumes have been processed to stack. Pre-stack gathers have also been output for AVO analysis. The stacked datasets have a high signal to noise ratio, conducive to detailed geological interpretation. The PP pre-stack gathers have relatively high signal to noise ratio, however the PS pre-stack gathers have more limited interpretability. Regional interpretations have been completed for the stacked datasets. Seismic stratigraphy, regional structure and potential hydrocarbon sweet spots have been identified through joint PP-PS interpretation. The main interpretation techniques utilized include: horizon mapping, structure mapping, amplitude mapping and isochron analysis. Post-stack and pre-stack joint and individual inversions have provided several sources of rock physics volumes. The inversion techniques are high-graded based on their ability to predict well data.

Theory and/or Method

An intense history of hydrocarbon exploration and production has been conducive to a solid understanding of the subsurface in Northeast Alberta. Conventional and unconventional oil and gas plays have been targetted for several decades. There are three major sedimentary sequences which play a role in this part of the basin. The Paleozoic carbonates and shales make up the oldest sedimentary component, on top of which the Cretaceous clastics lie. Within the Cretaceous clastics are the major oil sands reservoirs and their corresponding caprock. The overburden is Quaternary glacial till and fluvial sediments. A generalized stratigraphic chart is shown in Figure 1.

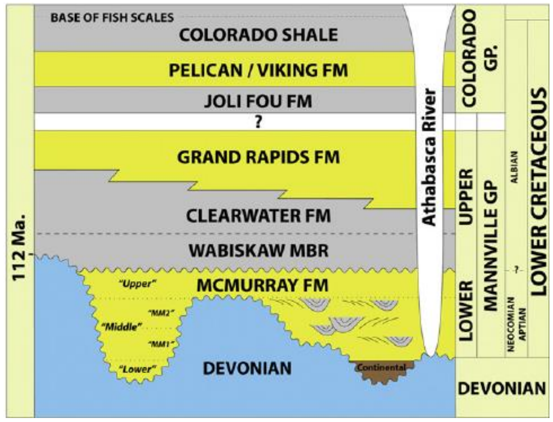

FIG. 1. Stratigraphy in the Athabasca Oil Sands (Todorovic-Marinic et al. 2015).

Processing was done jointly between the PP and PS seismic data. Geologically, the main interval of interest extends from the surface to the Paleozoic Unconformity (Devonian Beaverhill Lake Group). The Cretaceous-Devonian contact has a large P and S acoustic impedance contrast, generating high amplitude reflections that appear on both the PP and PS seismic datasets. This bright reflection is at approximately 500 ms and 850 ms on the raw PP and PS volumes respectively. Example raw shot records for the vertical and radial geophone components are shown in figure 2. Standard PP and PS processing techniques were used and data was processed both for post-stack interpretation and inversion and pre-stack interpretation and inversion. Figure 3 shows fully processed post-stack seismic data examples of the PP and PS data.

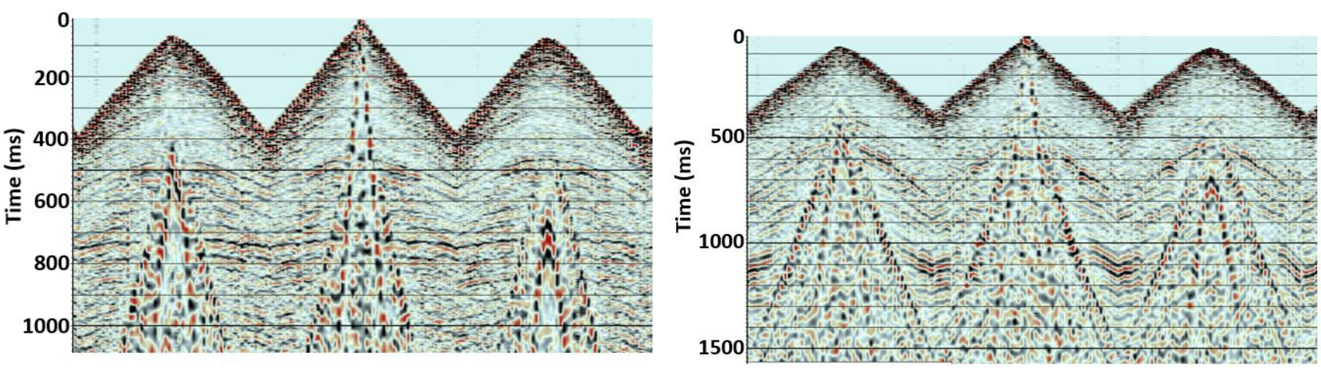

FIG. 2. Example vertical (left) and radial (right) shot gathers.

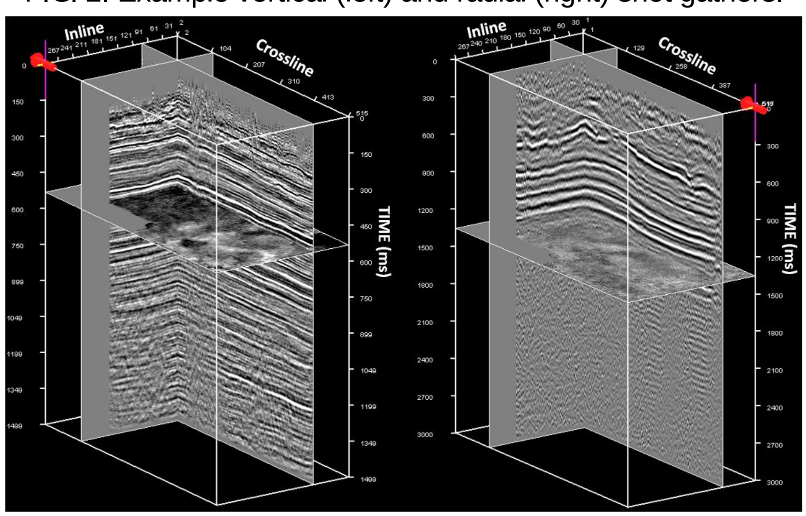

FIG. 3. Fully processed PP (left) and PS (right) seismic data.

Examples

Following a regional interpretation, post-stack and pre-stack inversions were completed to enhance reservoir understanding. Model-based generalized linear inversion was used. An example of the angle gathers used in the pre-stack inversion are shown in figure 4. A comparison of the pre-stack and post-stack inversion outputs in the reservoir interval (McMurray Fm) is shown in figure 5.

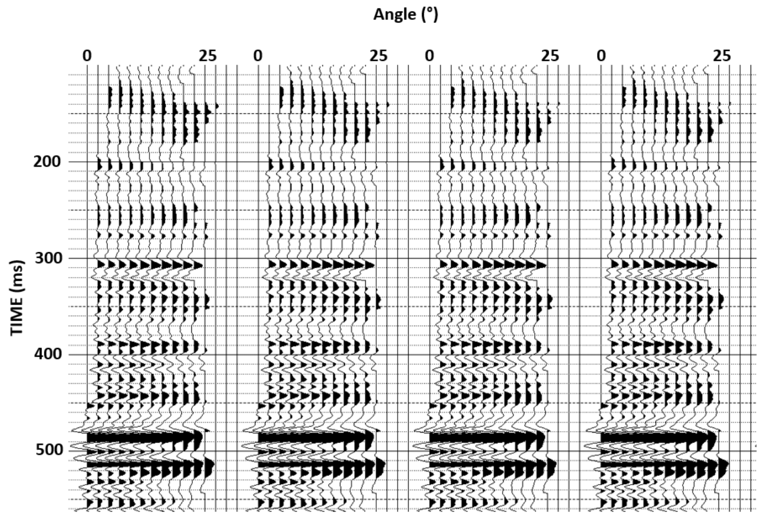

FIG. 4. Example angle gathers used as pre-stack inversion input.

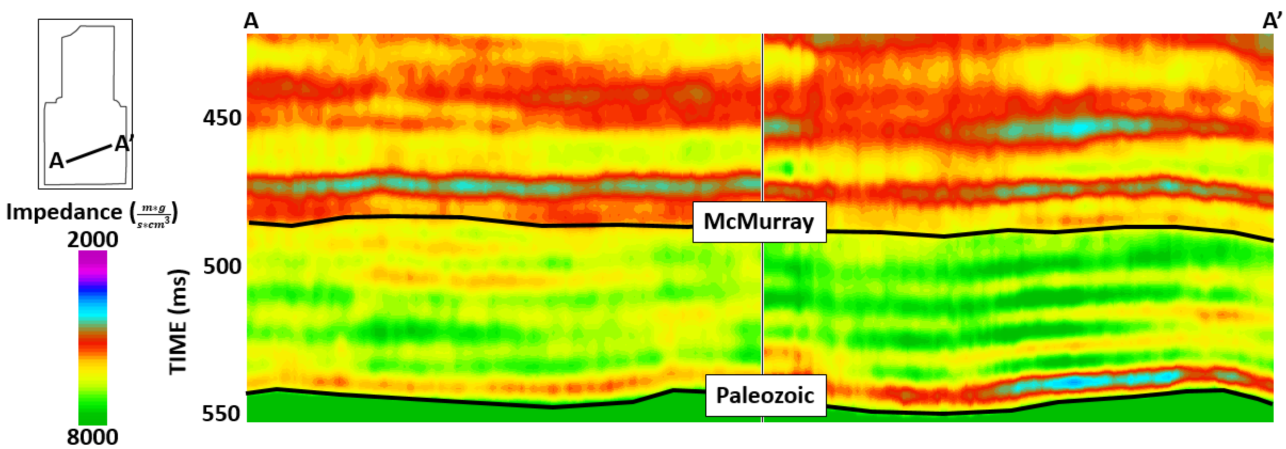

FIG. 5. Post-stack (left) and pre-stack (right) inversion results in the main reservoir interval.

Conclusions

In this project, a 3C 3D seismic dataset was analyzed. The 3D seismic data was acquired in 2013 in the Athabasca Oil Sands region of Northeast Alberta. The inline and crossline geophone components were rotated into radial and transverse converted wave components. The vertical and radial geophone components were processed into PP and PS stacked datasets. PP prestack data was processed and conditioned for prestack inversion. The post stack volumes' regional geology were interpreted based on synthetic seismogram ties to well control. The main geological discontinuities were found to be relatively pervasive reflection horizons on both the PP and PS stacked seismic data. A large incised valley fill of McMurray B2 age was identified from the seismic data. Interval RMS maps based on a model based post stack pp impedance inversion and PP seismic amplitude showed where potential hydrocarbons and porous reservoir were present.

Going forward, there is still much that can be done with the multicomponent seismic dataset used for this project. A PP-PS joint inversion can provide a secondary source of rock property volumes. These joint inversion outputs will be compared to the prestack inversion outputs. Multiattribute analysis has been used to predict well log attributes outside of density, impedance and Vp/Vs. Rops and Lines (2005) made viscosity predictions using multiattribute analysis and Hampson et al., (2001) were able to accurately predict well log properties using least squares minimization and two neural networks. An important next step in this project will be using multiattribute analysis to predict key well log properties such as porosity and gamma ray.

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