Acquisition Geometry and Pre-Stack Data Interpolation Comparisons for Oil Sands AVO Applications

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Introduction

The benefits of a reservoir characterization incorporating seismic data have long been recognized. In the oil sands, deterministic methods are being more widely accepted and utilized to provide high resolution reservoir predictions. With any characterization method, the quality of the input seismic data is the single most significant factor affecting the accuracy of the final result so it is therefore worthwhile investigating ways of improving the quality of the seismic data.

This study compares AVO, inversion and final reservoir characterization products created with various seismic acquisition geometries to assess the effects and significance of acquisition parameter selections on the outcomes of the process. Various seismic acquisition geometries are simulated by a combination of dropping real data and interpolating missing data (Spitz, 1991; Lui and Sacchi, 2004). Reservoir characterization results are determined using seismic volumes that are combinations of acquired and interpolated data. Both model data and real data are shown to illustrate the effects.

Method and Results

Model data was derived from a synthetic elastic-wave AVO gather with traces created at 1-meter intervals over the range of 0 to 500 meters. From this ideal data set, variations and deficiencies were imposed to represent real examples of acquisition geometry. Pseudo 3Ds were created by repeating the same synthetic gather but with slight variations in certain parameters. In particular, the offset of the first trace was varied from 5m to 70m in one pseudo 3D and in another one, the offset interval was varied from 5m to 20m. In the oil sands, due to the shallow location of the zone of interest, the maximum offset in the field is almost always sufficient to image the angles required for AVO, so this parameter was not varied.

The real data incorporated in the study was a subset of the Nexen/Opti Long Lake South 3D seismic data as shown in the map in figure 1. The actual acquisition geometry was used for the ‘benchmark’ reservoir characterization products. The data was then depopulated in two ways; every second shot and receiver station were removed creating a dataset with one-quarter the original fold (version 1) and every second shot and receiver line were removed from the original data, again creating a dataset with one-quarter the original fold (version 2). In addition, each of the three volumes (original and decimated versions 1 and 2) were interpolated to recreate a version of the original data that was dropped. In total therefore, six real data volumes were processed and compared at all stages of the reservoir characterization workflow.

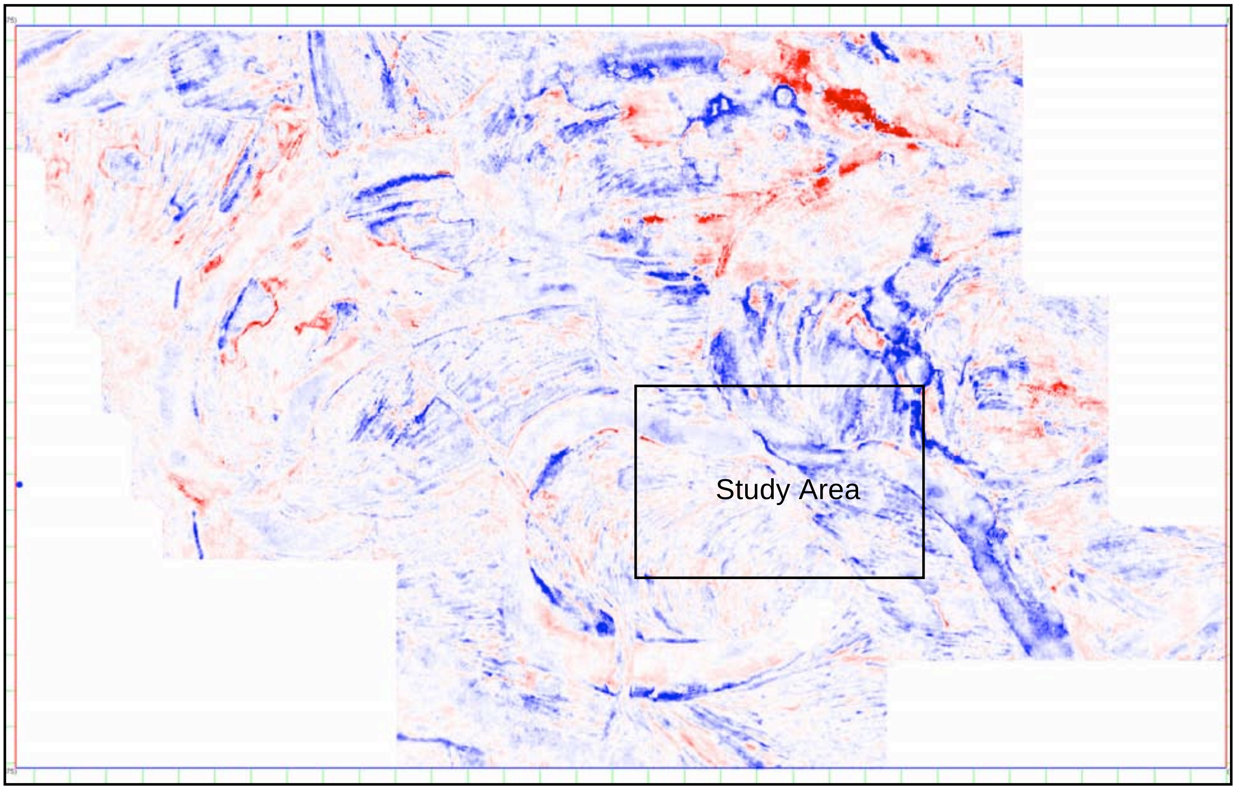

Figure 1: Time slice near the top of the McMurray reservoir of the Nexen/Opti Long Lake South 3D seismic data. The subset of data used in this acquisition study is shown in the black outline.

The modeled cdp gather was used to populate all the bins of a synthetic 3D and specific cross-line ranges were chosen to demonstrate the result of the intentional geometry modifications. AVO and inversion were run on the synthetic 3D using the known velocity and impedance fields from the well. Figure 2 shows the response of the calculated P-impedance and S-impedance to variation in the offset of the first trace in the gather. Since the impedance is known and constant throughout the synthetic 3D, the variation in calculated impedance values is caused only by the change in the offset of the near trace.

The reservoir characterization workflow (Weston Bellman, 2009) uses AVO (amplitude vs offset) analysis to separate the compressional (P-wave) and shear (S-wave) components of the seismic data. The resulting components are used to calculate the physical rock properties through inversion and multi-attribute analysis (Goodway et al., 1997, Russell et al., 1997). When these attributes are classified based on well log and core analysis, the result is a seismic volume transformed to a detailed lithological characterization of the reservoir within the zone of interest. Figure 3 shows the results of this transformation and classification process for a portion of a line in the original 3D volume.

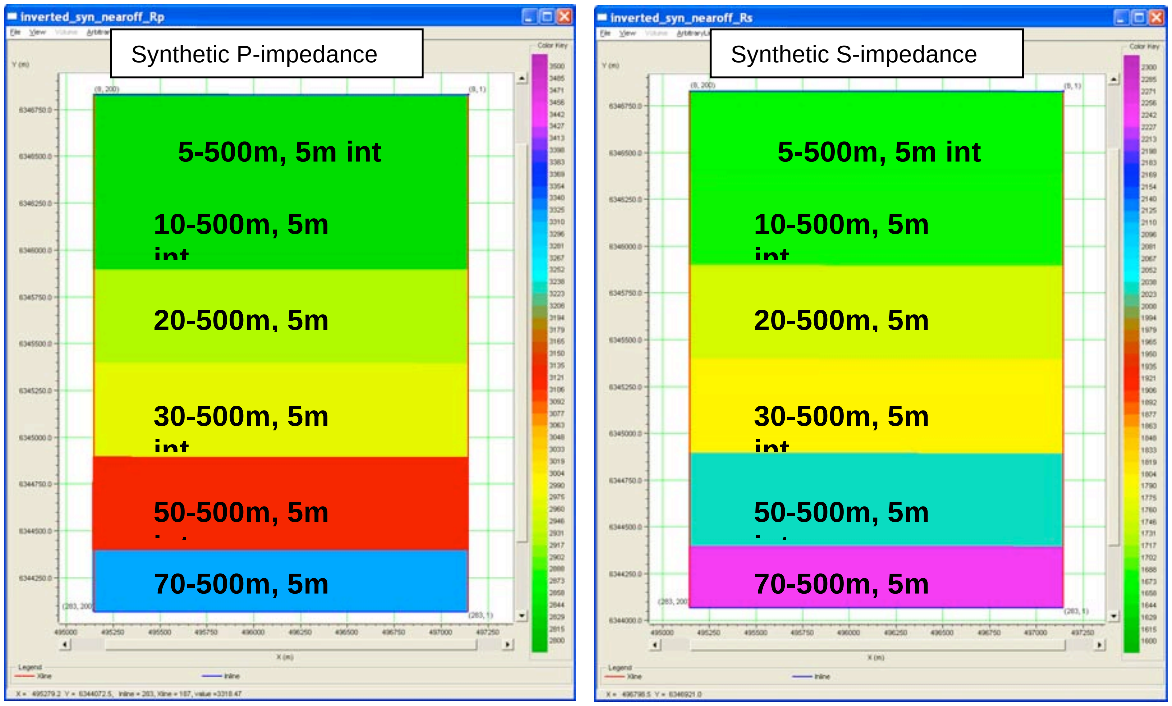

Figure 2: Constant time slices through the synthetic P-impedance and S-impedance volumes. The zones of near offset variation are labeled.

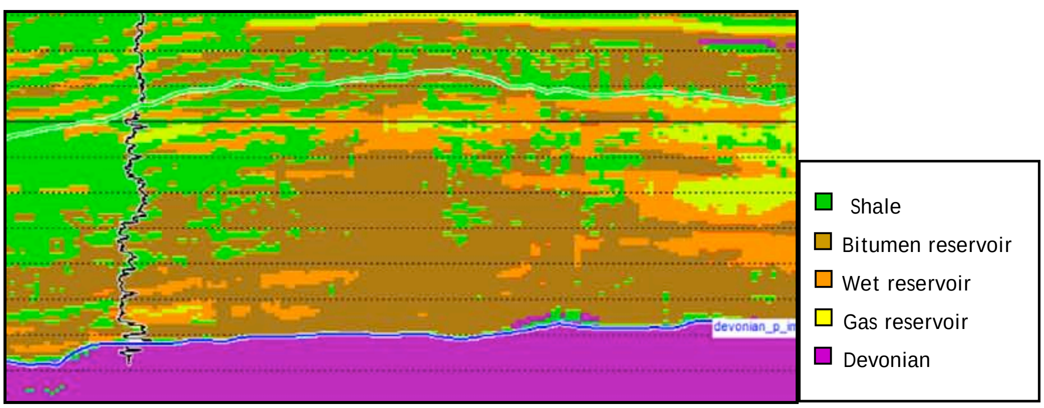

Figure 3: 3D profile through a well in the project area. A gamma ray log is shown at the well location and the colours represent lithology and fluids. This reservoir characterization is done using the original acquisition geometry data.

Conclusions

This study highlights the need for careful consideration of seismic acquisition geometry for AVO applications. AVO and other quantitative interpretation processes rely on accurate measurements derived from pre-stack seismic data and acquisition parameters can have a significant effect on the outcome. If seismic acquisition parameters are not optimal, the effect can be mitigated by recreating missing data using pre-stack interpolation.

Acknowledgements

We would like to thank the management at Nexen Canada Inc. and Opti Canada Inc. for allowing us to present these results.

References

Goodway, W., Chen, T., and Downton, J., 1997, Improved AVO fluid detection and lithology discrimination using Lame petrophysical parameters; “Lambda*rho”, “mu*rho” and “lambda/mu fluid stack”, from P and S inversions: 1997, 67th Annual International Meeting., SEG Expanded Abstracts, p183-186.

Lui, B., and Sacchi, M. D., 2004, Minimum weighted norm interpolation of seismic records: Geophysicis, 69, pp 1560-1568.

Russell, B., Hampson, D., Schuelke, J., and Quirein, J., 1997, Multi-attribute Seismic Analysis: The Leading Edge, October, 1997, p1439.

Spitz, S., 1991, Seismic trace interpolation in the F-X domain: Geophysics, 56, pp 785-794.

Weston Bellman, L. M., 2009, Integrated 3d reservoir characterization for oil sands evaluation, development and monitoring: CSPG Gussow Geoscience Conference abstracts; Banff, Alberta, October, 2009.