A multicomponent 3D seismic data study from an oil sands field, Alberta, Canada

Bobby J. Gunning, Don C. Lawton and J. Helen Isaac, CREWES project, University of Calgary*

Summary

Oil sands in the Athabasca region of Alberta are a major hydrocarbon resource. Kelly and Lawton (2012) utilized time-lapse seismic data to study the McMurray formation in the Athabasca region with a detailed geological interpretation of their pre-steam baseline survey. Isaac (1996) processed and interpreted multicomponent 3D seismic data in a heavy oil field in Northeast Alberta, obtaining excellent converted wave volumes. In this project, a multicomponent 3D seismic dataset is used to image and characterize an Athabasca oil sands field. The data provided consists of fully processed PP seismic data, and three-component raw seismic data. The PP data is used for an initial, full volume interpretation including: picking several key reflection horizons, well log ties and post-stack impedance inversion. Joint processing of the PP and PS components is currently underway with promising PS reflectivity being observed.

Introduction

A multicomponent 3D baseline seismic dataset, acquired in 2013, was provided by Canadian Natural Resources Limited (CNRL). The fully processed, stacked PP seismic data and raw three-component shot gathers were provided for use in this project. This paper outlines the preliminary interpretation of the PP seismic volume and the progress to date of the processing of the converted-wave seismic volumes. The analysis of the PP seismic data includes: stratigraphic interpretation with the aid of well control, seismic attribute maps and volumes, time slices and stratal slices for sedimentary structure identification, and post-stack inversion. To date, the converted-wave dataset processing includes: geometry assignment, rotating inline and crossline geophone data into radial and transverse components, and utilizing PP shot statics and estimation of PS receiver statics through receiver stacks. Processing the multicomponent data to an interpretable point, and utilizing the PP and PS seismic volumes, converted to depth, for joint lithological interpretation is a main objective of this project. Individual post-stack, prestack and joint post-stack and pre-stack inversions will be generated from the seismic volumes to develop geomechanical and rock property volumes. The full seismic data volumes are being analyzed, with the focus on the main oil sands reservoir, namely the McMurray Formation and the cap-rock sequence (shales in the Colorado and upper Manville Group). The goal is to use multicomponent seismic data to characterize the reservoir and caprock sequences.

A stratigraphic chart for the Athabasca region is shown in Figure 1.

Data

Raw vertical and rotated radial and transverse geophone data are displayed in Figures 2a, 2b and 2c respectively.

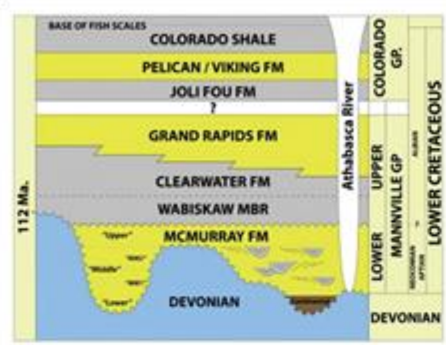

FIG 1: General stratigraphy of the Athabasca region, Alberta. Grey units are shales, yellow units are sandstones and blue units are carbonates (modified from Todoroivc-Marinic et al. 2015).

The PP shot gather in Figure 2a shows several bright reflections in the first 1.0 s of the data. The reflections at a zero offset time of ~500ms originate from the Paleozoic Unconformity (Devonian), which is the economic basement in this project. The converted-wave reflection interpreted to from this Unconformity can be seen on Figure 2b at ~1100 ms on maximum offset traces. The transverse component (Figure 2c) shows little coherent energy at this stage of the processing, so further processing will be undertaken assuming isotropic velocities initially.

There are several regionally extensive geological markers with impedance contrasts large enough to generate bright seismic reflections. Several of these reflections were correlated to well data through synthetic seismograms. Seismic reflection picks were made for: Base Fish Scales, Viking Fm, Grand Rapids Fm, Clearwater Fm, McMurray/Wabiskaw Fm and the top Devonian Unconformity (Figure 1). There are several pervasive reflections stratigraphically deeper than this unconformity, but available well control does not reach these depths. An example seismic to synthetic well-tie is shown in Figure 3 and an example of an in-line section from the P-wave volume, with major reflections identified, is shown in Figure 4.

3C3D data from an oil sands field

Post-stack inversion of the PP seismic data reveals interesting reservoir details. A low-frequency inversion input model was created using the smoothed horizon picks and a sonic log from within the survey area. This low-frequency model was inverted through 10 iterations to produce the final inversion volume; an inline from the inverted volume is shown in Figure 5, including a test with a blind well. The correlation coefficient of the seismic inversion with data from the blind well is 0.85, which suggests that the inversion is robust. An interval RMS impedance map was generated for the upper reservoir, depicted in Figure 6. Interpretation of the volume based on reservoir csuggests that the higher quality reservoir correlates to higher RMS impedance.

An example receiver stack from the PS component is shown in figure 7. This stack has been only lightly processed. There are several sets of reflections present. Consistent reflection quality exists across the section and within the interval of interest between 400 ms and 1200 ms. The Paleozoic Unconformity is a reflection at approximately 1200 ms.

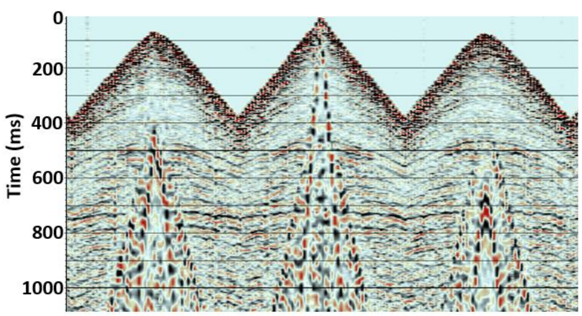

FIG 2a: Vertical geophone component raw shot record example.

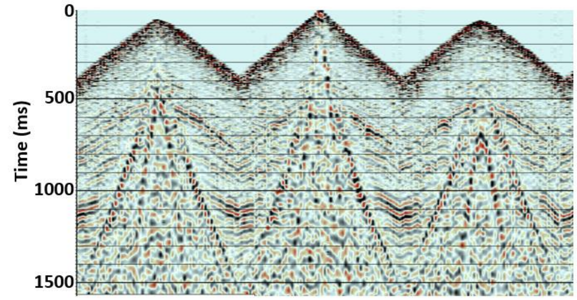

FIG 2b: Radial geophone component raw shot record example.

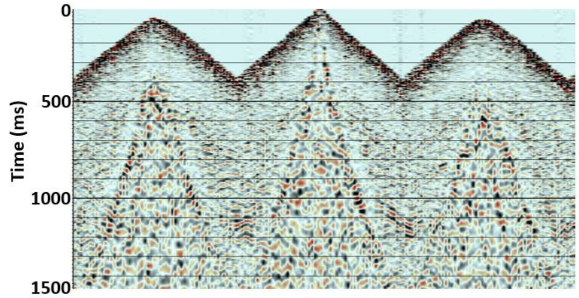

FIG 2c: Transverse geophone component raw shot record example

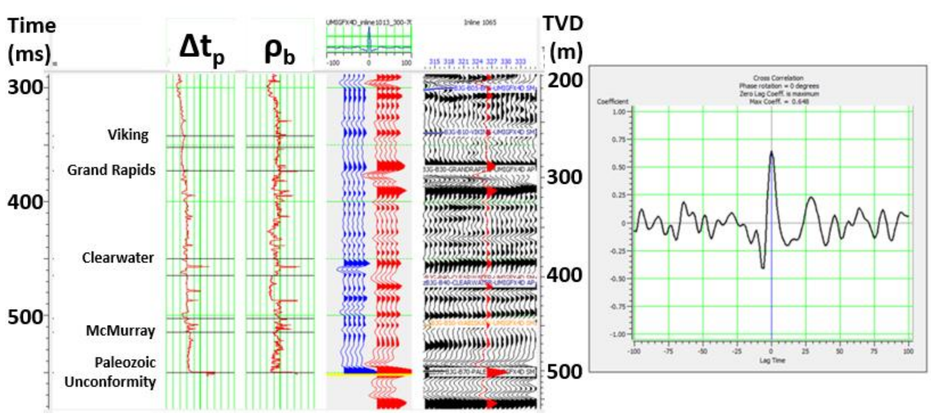

FIG 3: Example seismic to synthetic seismogram tie and associated crosscorrelation. The synthetic traces are blue and seismic traces are red.

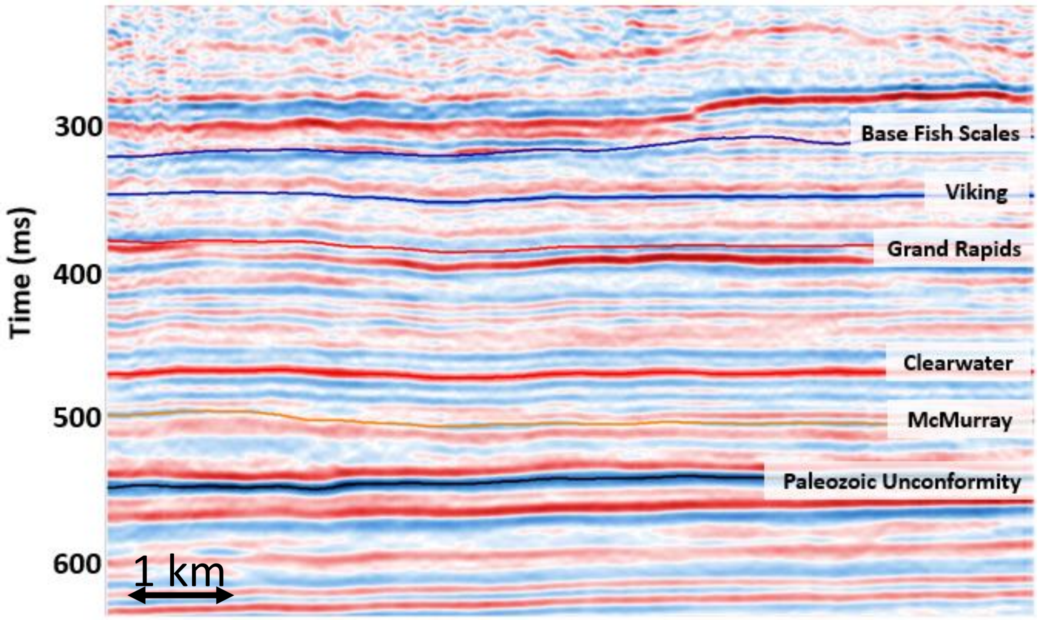

FIG. 4: Type section depicting the main geological horizons in the project area. Generally the region is not heavily structured and reflection seismic character remains quite constant regionally.

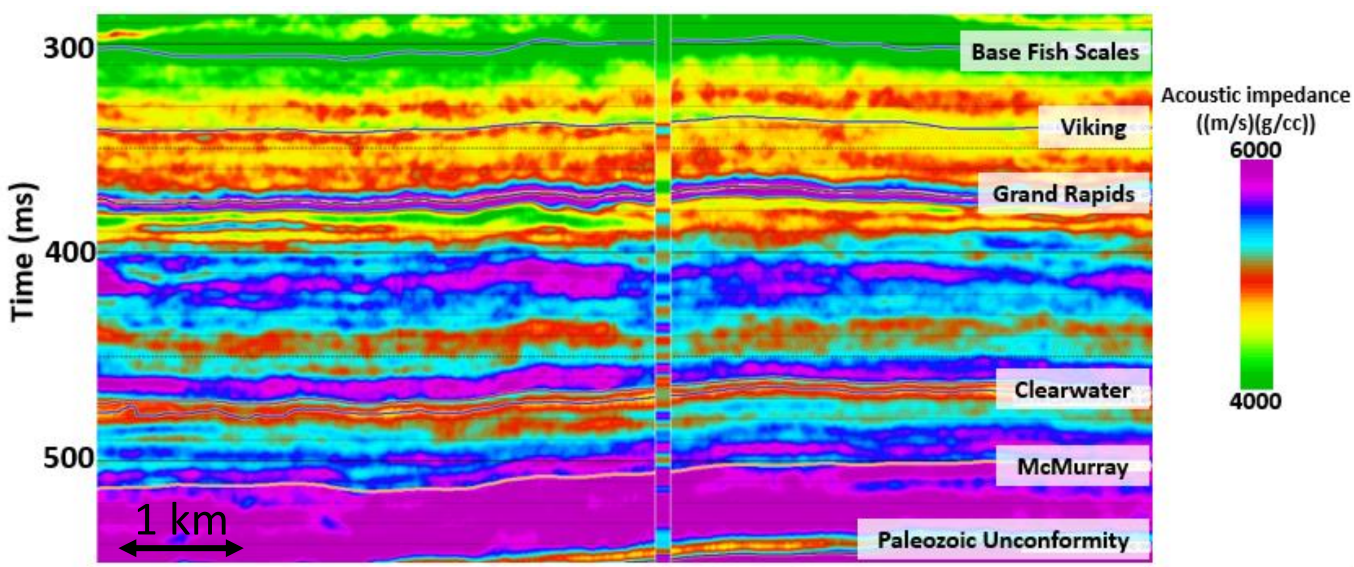

FIG 5: Post-stack impedance in-line from the inverted volume, with a blind well test. The inversion included a low frequency model based on stratigraphic interpretation and a sonic log from a well proximal to the section.

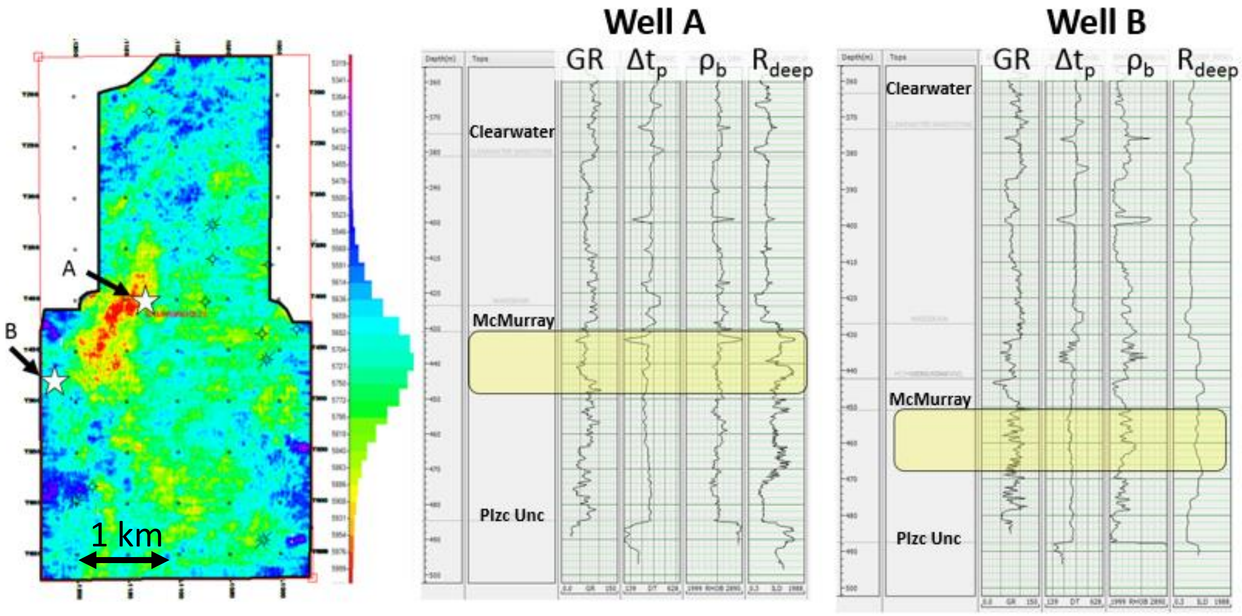

FIG. 6: Upper McMurray RMS impedance from a post-stack inversion. Impedance is higher at the location of well A than at the location of well B. Well A shows a thicker sand interval through the McMurray Formation compared to well B.

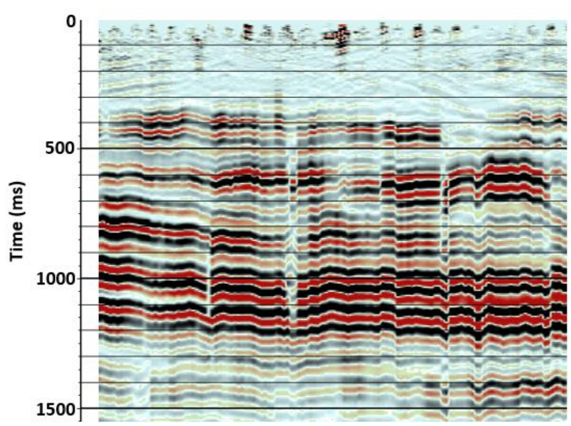

FIG. 7: Radial component receiver stack. Paleozoic Unconformity is approximately in the lowermost bright PS reflection set, ~ 1200 ms.

Conclusions

A 2013 multicomponent seismic dataset is currently being analyzed. The PP seismic data and the raw shot gathers are available for use in this project. The raw inline and crossline geophone components were rotated into radial and transverse components. Reflection energy is generally limited to the vertical and radial component geophones, which suggests isotropic media. A preliminary interpretation consisting of well tying, horizon picking and impedance inversion have been completed. Geological interfaces are regionally extensive and reflection events are easily picked on the PP stacked dataset. Interval RMS impedance correlated with well control reveals regions with increased reservoir quality in the Upper McMurray. Preliminary radial component receiver stacks display several reflection events in the zone of interest.

Acknowledgements

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