Seismic Characterization of CO_2 in Coals

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Summary

A high resolution 3D surface seismic survey was aquired by the University of Calgary at a pilot project site in Alberta for testing enhanced coalbed methane (CBM) production using CO_2. The multi-well pilot project, in the Pembina Field of west-central Alberta, intends to test the Ardley coals for CO_2 injection, enhanced CBM production, and CO_2 sequestration. The seismic survey captured the condition of the reservoir after formation permeability tests, which involved injecting a small volume of CO_2 into the target Mynheer coal seam, but before commencement of continuous CO_2 injection. Anomalies are seen in the seismic data which are possibly attributable to changes in the physical properties of the coal due to CO_2 adsorption.

Introduction

An enhanced pilot project has been initiated in the Pembina field to test the Ardley Coals for enhanced CBM and CO_2 sequestration. A seismic survey, acquired before the commencement of continuous injection, was designed to assess the initial reservoir character of the target coal seam as well as other seams and the encasing sediments. The survey does not capture true baseline conditions because ~180 tonnes of CO_2 had been injected into the reservoir before the 3D survey was acquired. This gas was injected to test the formation production properties and injectivity. The survey thus served to assess the detectability of the small volume of CO_2 in a thinly bedded and seismicly tuned reservoir.

Figure 1 illustrates the petrophysical logs from the injection well. The Ardley Coal Zone is represented by several seams. The Val D'Or and Arbour seams (Pana, 2007) are closely spaced at 358m depth from surface. The two seams total approximately 10 m of gross thickness. The Silkstone seam is at a depth of 404 m and is approximatly 4 m thick. The Myhneer seam is at 414 m depth and is approximately 8 m thick. The approximately 36m of sediment between the Val D'Or/Arbour seam and the Silkstone seam consists of approximately 36 m of shale and Arbour/Silkstone channel sandstones (Pana, 2007). Previous seismic surveys targetting coal zones in Alberta (e.g. Lawton, 1985) have shown promise for resolving relatively thin coal seams.

The Myhneer coal seam was targeted for the ECBM experiement. During initial testing of the reservoir permeability, 180 tonnes of CO_2 was injected into the seam. The focus of this work was to characterize the coal zones and determine if the small CO_2 volume can be detected in the 3D surface seismic data.

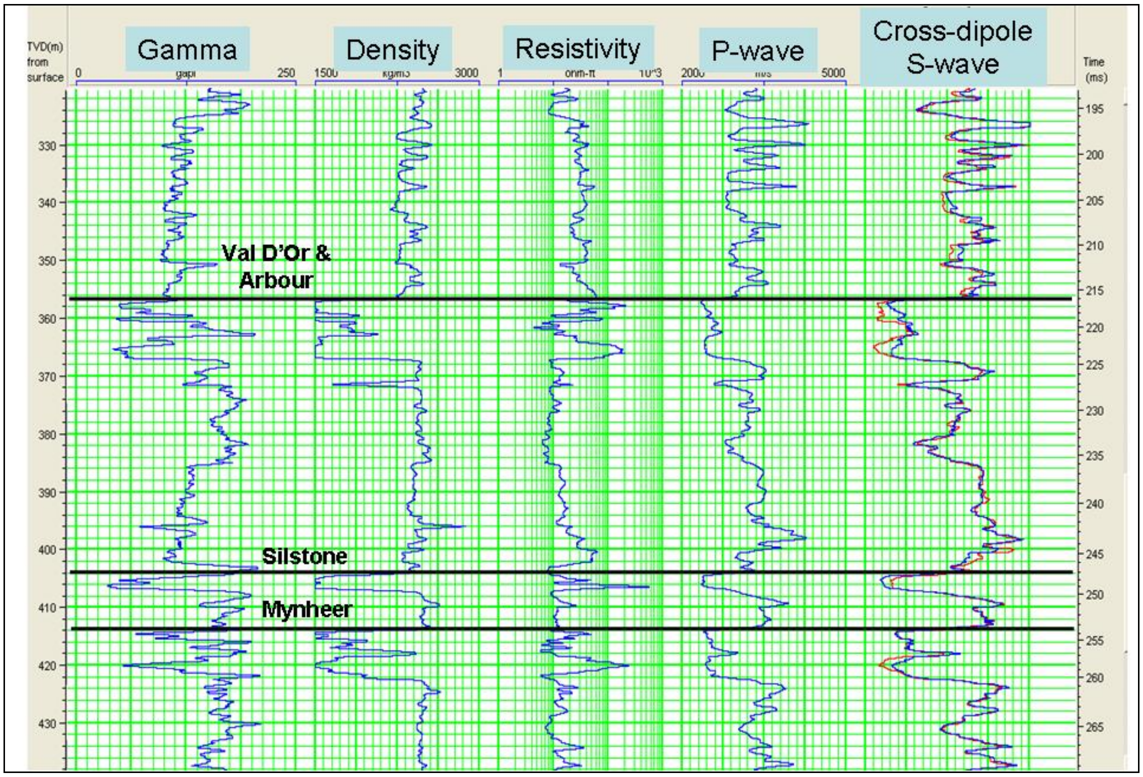

Figure1: Petrophysical logs from the injection well showing the Ardley Coal Zone

3D Seismic Survey Design

The total patch was 560 m by 560 m with 60 m spacing of receiver lines and source lines. Source and receivers were spaced at 10 m intervals along the shot and reciever lines. The full 3D receiver spread was single-component geophones, while a single line of 3C geophones was laid out over the injector well. The University of Calgary's Enviro Minivibe generated four vertically stacked sweeps from 10-150 Hz over 12 seconds. The layout for the vertical component geophones and the associated fold map are illustrated in Figure 2.

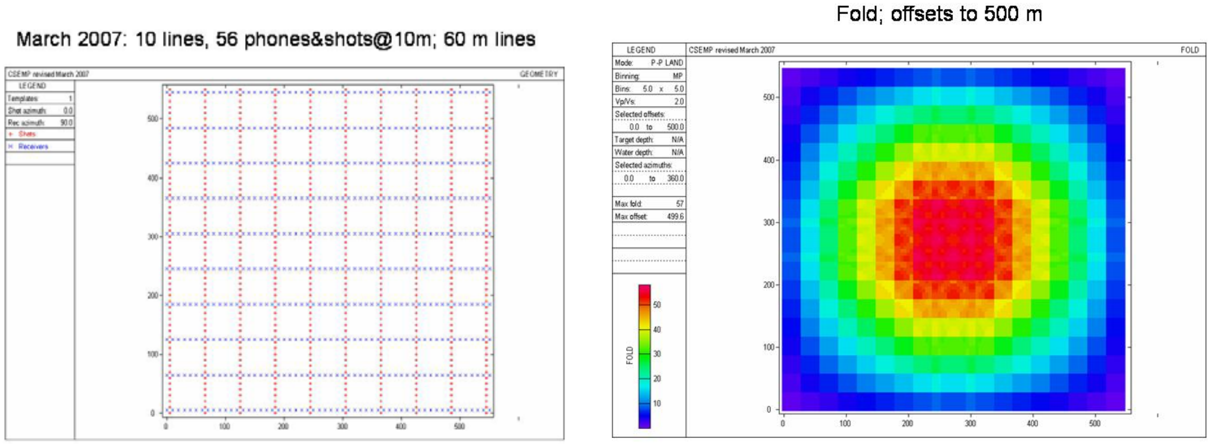

Figure 2: On the left is the layout design for the vertical component 3D baseline 3D survey. Receiver lines run east-west and source lines run north-south. On the right is the expected fold for the PP survey

Interpretation

The Ardley Coals gently dip to the southwest in the study area. Figure 3 shows a vertical component in-line section and the amplitude extraction at the trough 4ms earlier than the Mynheer Coal event. An amplitude anomaly is evident in the vicinity of the injector well. The anomalous amplitude measure around the perimeter of the survey is likely due to lack of fold in that region.

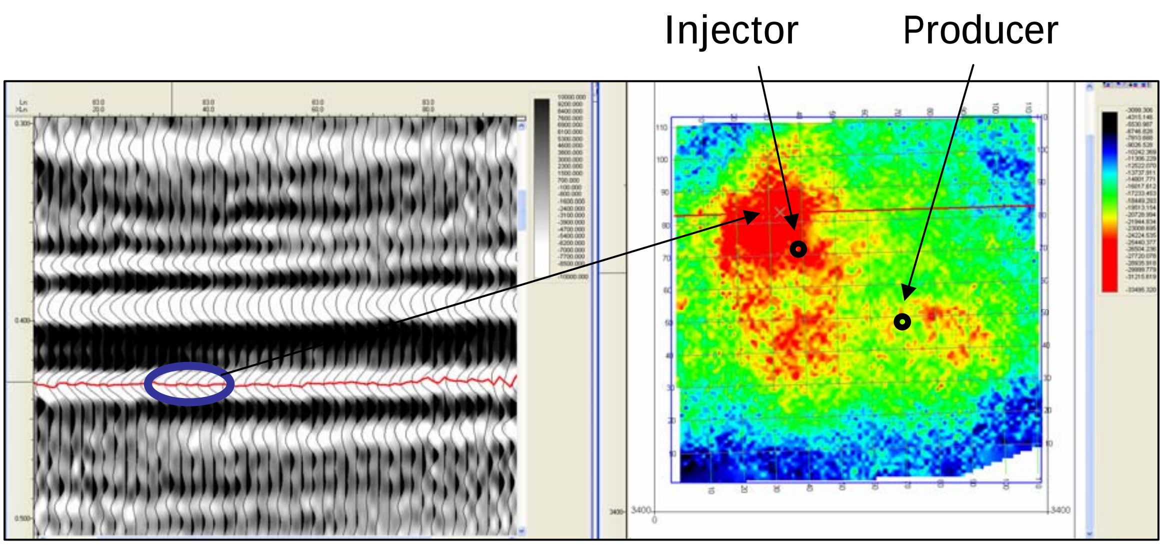

Figure3: Vertical component data. On the left is the pick of the target coal event. On the right is the amplitude map of the picked event. The line displayed on the left is the east-west (inline) line just north of the injector well. The blue circle on the left highlights the high amplitude anomaly that is shown by the red colour on the right hand side.

The post stack PP data was inverted for acoustic impedance using a sparse spike inversion method (Hampson Russell, Strata Ver 7.2). The result is illustrated in Figure 4. Good impedance resolution of the coals and the shales and sands above and below the coals is achieved. An extraction of the acoustic impedance from the Mynheer seismic pick (4ms bulk shift below the seismic trough event) is also shown in Figure 4. A slightly anomalous higher impedance region is identified to the soutwest of the injection well location. This increased impedance coincides with the expected location of the CO_2 cloud near the injection well which had previously been stimulated with a hydraulic fracture.

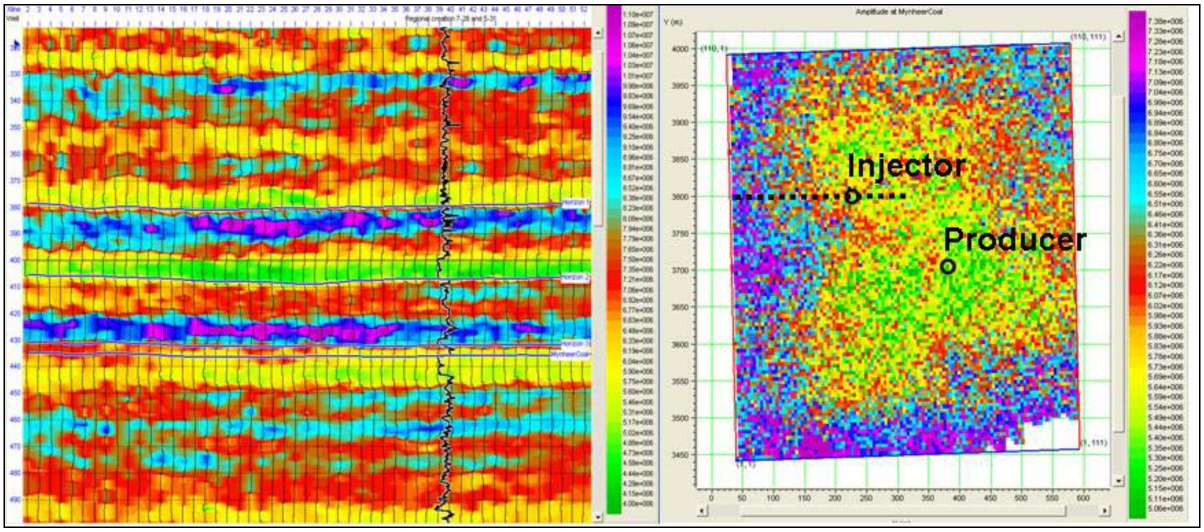

Figure 4: Acoustic impedance section and horizon impedance slice at the Mynheer seismic event. The density log is imposed over the section. Note that the dynamic range is not the same between the two images.

Figure 5 illustrates the converted wave data which is stacked into a 2D line to maximize fold. Effective resolution is comparable to that achieved from the PP data.

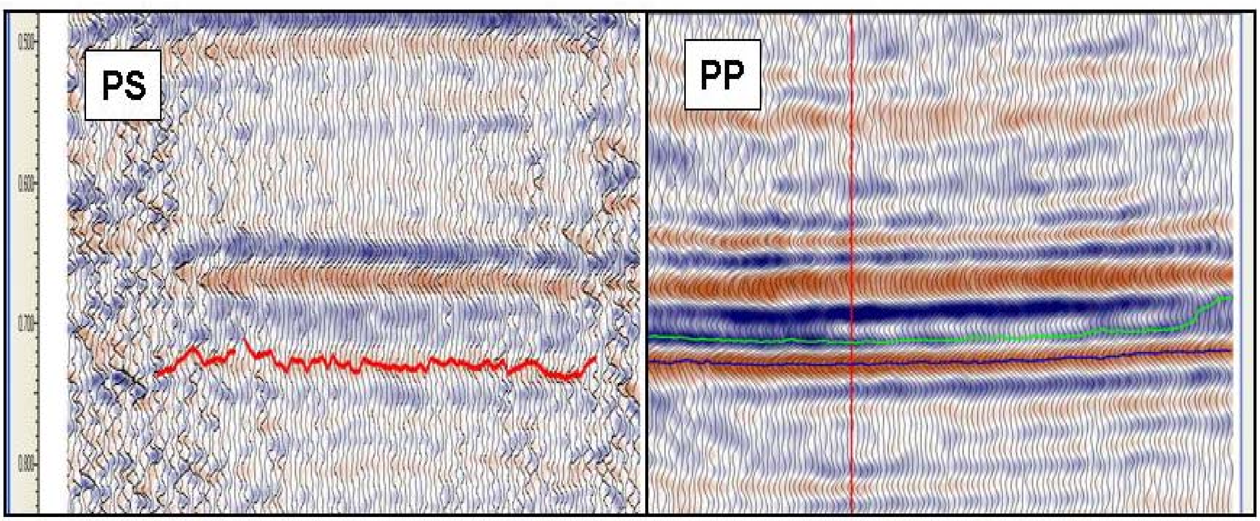

Figure 5: Comparison of the PS data (left) which has been stacked into an E-W 2D line and the comparable PP data (right) at the well location (red line). The Arbour/Mynheer Coal event is picked in red on the PS section.

Conclusions

The seismic image of the Ardley coals shows amplitude and impedance variations in the data volume near the injector well. A possible reason for the anomalous response is due to the effects of CO_2 in the coal, possibly related to swelling. Further investigation of the elastic properties of the coals will involve pre-stack analysis and inversion and studies of variable amplitude tuning.

Acknowledgements

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