Alder Flats 2D and 3D Seismic Programs

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ABSTRACT

A pilot project that aims to enhance coalbed methane production is being undertaken in west-central Alberta. The project involves injecting carbon dioxide into a reservoir in an attempt to accelerate methane desorption from the coals. Time-lapse seismic monitoring is planned for the project during the injection and production cycle. A trial 3C-2D survey was acquired by the University of Calgary at the project site in March of 2007. The pre-stack and post-stack PP response compares favorably with the modeling results. Prior to commencement of CO_2 injection, a 3D baseline survey with 8 vertical component receiver lines and one 3C receiver line was acquired in June, 2007, by the University of Calgary. An amplitude extraction of the target coal event in the stacked PP data shows interesting variability that may be an imprint of production and injectivity tests conducted on the reservoir before the baseline survey was acquired.

INTRODUCTION

CO_2 will be injected into a coal seam at a depth of 415 meters below surface. It is expected that the injected CO_2 will enhance desorption of methane from the coal which will be produced from a nearby well. However, it is also expected that the coal will swell after exposure to CO_2 (Mazumber, 2006). The process must be executed with delicacy to minimize the loss of permeability as a result of coal swelling. Figure 1 illustrates the project's conceptual design.

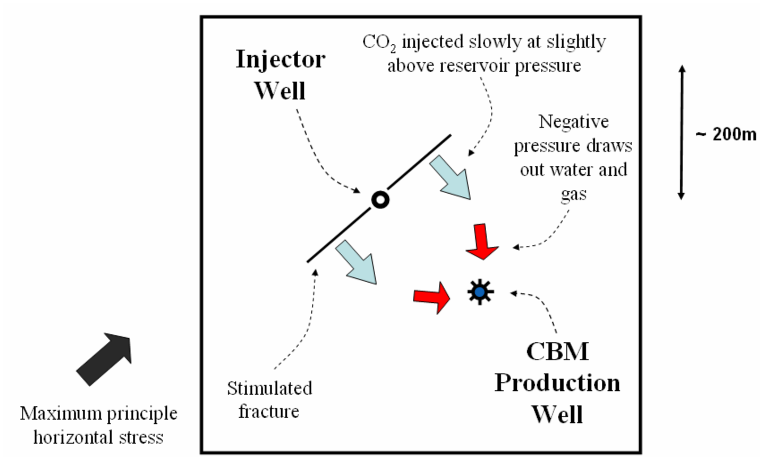

FIG. 1. Conceptual design of the ECBM and CO_2 storage pilot project.

Figure 2 shows the petrophysical logs from the injection well. The Ardley Coal Zone of the Paleocene Scollard Formation in west-central Alberta has been selected for the study. The coals are associated with alluvial plain/fluvial sediments, have moderately low ash content (16-19%), are laterally persistent and are relatively thick (Richardson et al., 1988). In an area close to the study site the Ardley coals have been found to have a rank range from high volatile C to high volatile B bituminous (Dawson et al., 2000).

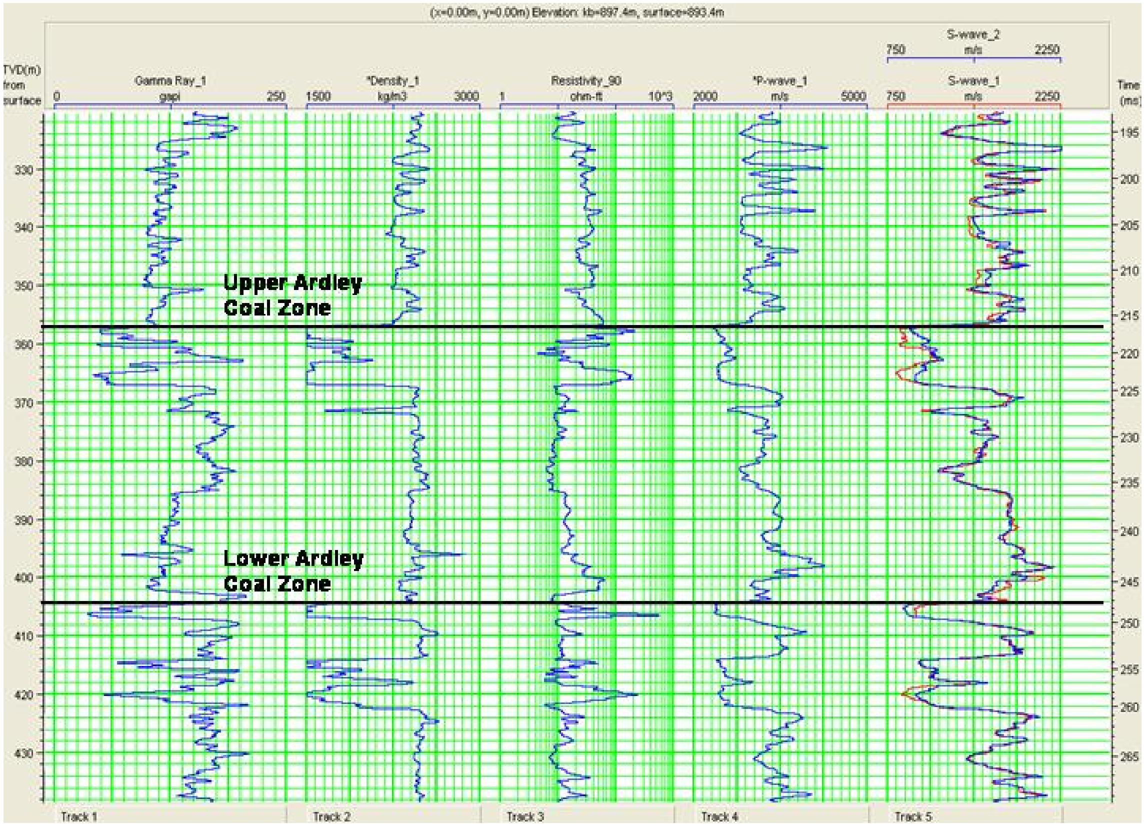

FIG. 2. The petrophysical logs from the injection well showing the Ardley Coal Zones. CO_2 injection will be into the Lower Ardley Coal Zone.

At the study site, the Upper Ardley Coal Zone is found between 357 m and 372 m below surface and the Lower Ardley Coal Zone is found between 404 m and 423 m. The proposed production will be from the Lower Ardley Coal Zone.

3C-2D SURVEY

A 3C-2D survey was acquired with the University of Calgary's Enviro Mini-vibe and ARAM acquisition system in March, 2007. The ground conditions were frozen, with ice on the road along which the survey was undertaken. The receiver spread was 720 m long with a receiver spacing of 5 m. Source spacing was also 5 m with additional source points off either end of the receiver spread. Sweeps were from 10 Hz to 250 Hz with 4 diversity stacks. Figure 3 illustrates the acquisition program.

FIG. 3. Alder Flats 3C-2D survey. Vibe in action on the left and a tap test in progress on the right.

The vertical component data were processed first. Figure 4 illustrates a raw shot record of the vertical component data. The coal event is between 250 and 400 ms. Ground roll noise dominates the near offset traces. Additionally, at far offsets, refracted energy interferes with the coal reflections. The Radial Trace Filtering Promax tool as developed by CREWES was used to suppress this non-random noise (Henley et al., 1999). The result is depicted in Figure 5. First break and ground roll noise is significantly reduced.

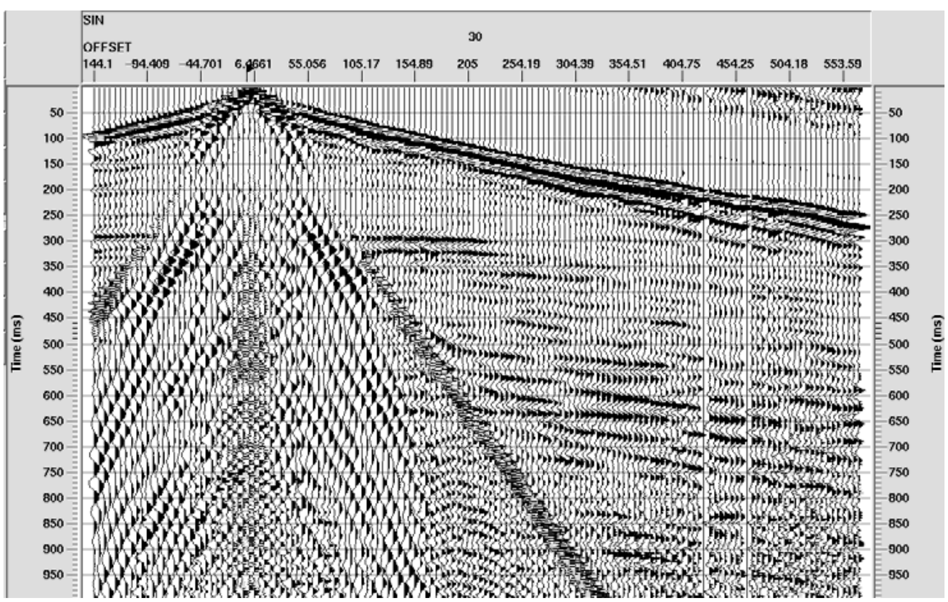

FIG. 4. A vertical component raw shot record. The coal events are between 250 and 400 ms.

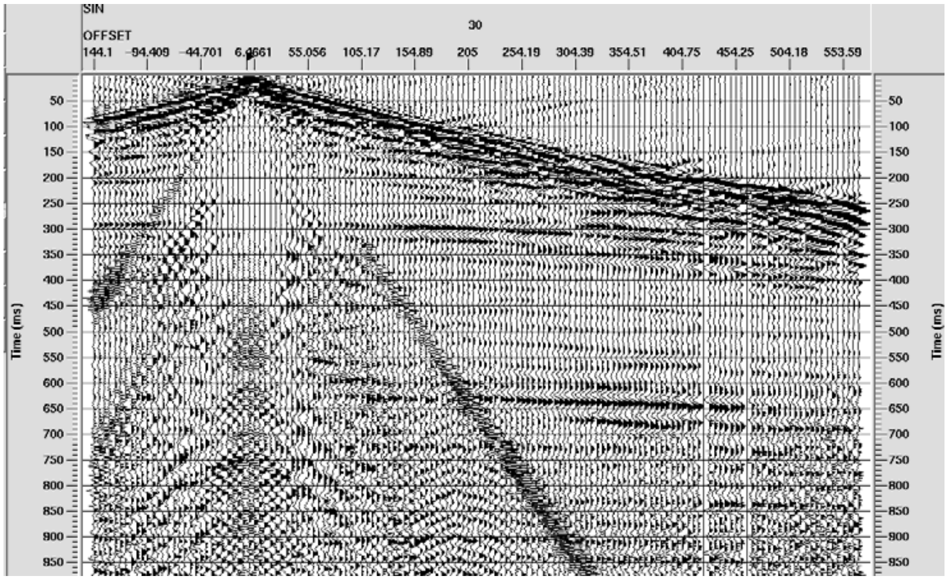

FIG. 5. A vertical component shot record after three passes of radial trace filtering.

Figure 6 shows that ground role, air blast, and refracted energy remain in the data. As well, a possible inter-bed multiple is seen approximately 40 ms after the primary coal events. From modeling, it is known or anticipated that there should be two strong trough and peak events. However, as seen in Figure 6, three pairs of events appear in the recorded data. To further reduce noise, suppress multiples, and remove the source wavelet, Gabor deconvolution was applied (Margrave et al., 2002) in the xt domain and then in the radial trace domain. The results are shown in Figure 7.

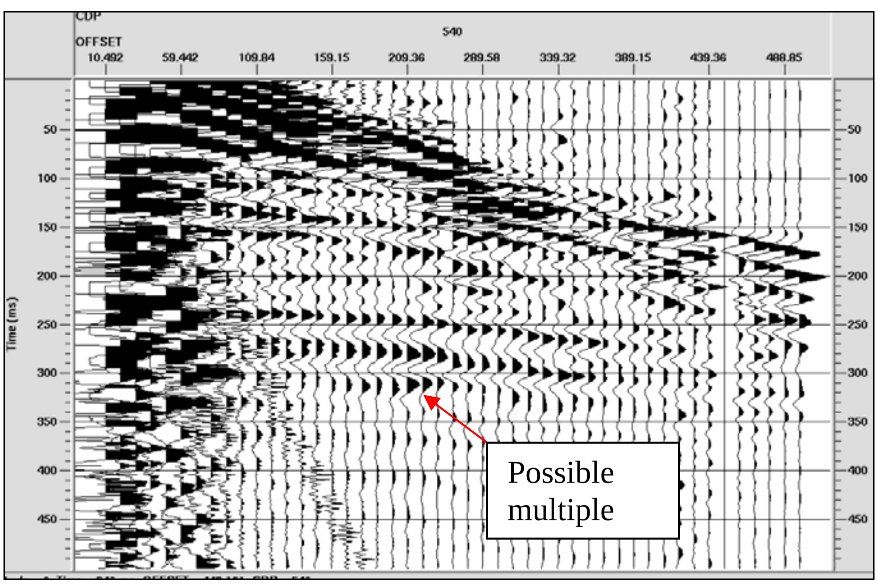

FIG. 6. Seismic record showing the coal events in a shot record after radial trace filtering. Note the possible inter-bed multiple just after 300 ms. The figure shows vertical component data.

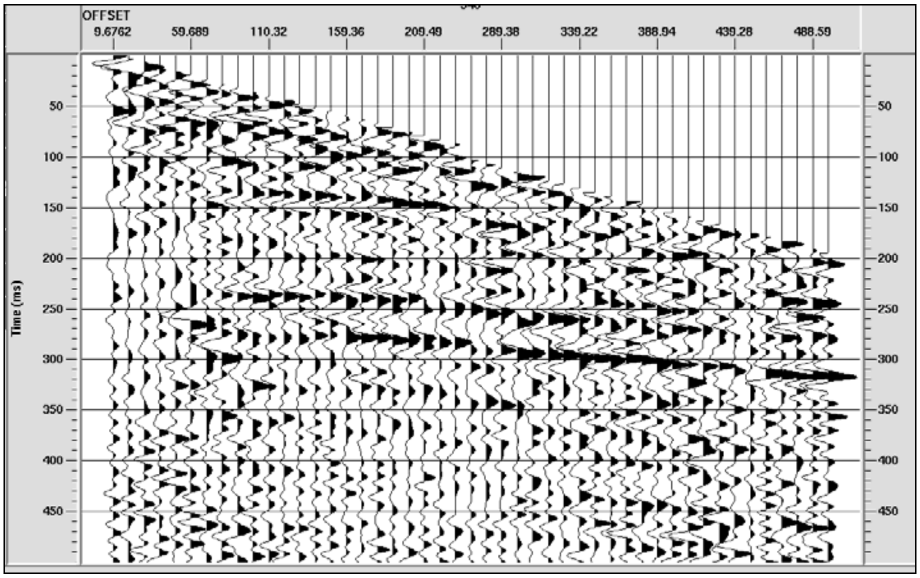

FIG. 7. Seismic record showing the coal event after Gabor deconvolution is applied in the xt and the rt domain. The figure shows vertical component data.

Figures 8 and 9 compare the results of pre-migration stacked data with and without applying Gabor deconvolution in the rt domain, respectively. The differences are subtle. Figure 10 shows the migrated section tied to a synthetic seismogram generated with a zero-phase 8-15-70-90 Hz Ormsby wavelet.

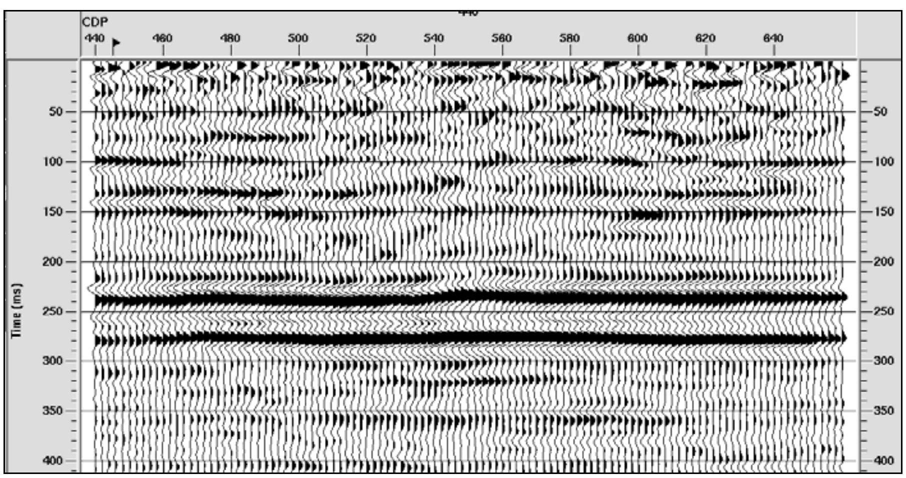

FIG. 8. Stacked vertical component data with Gabor deconvolution applied in the xt domain alone.

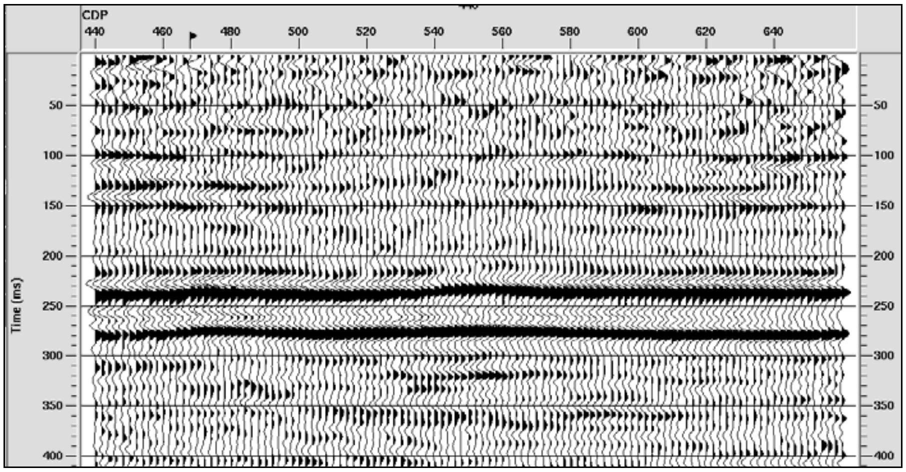

FIG. 9. Stacked vertical component data with Gabor deconvolution applied in the xt and rt domains.

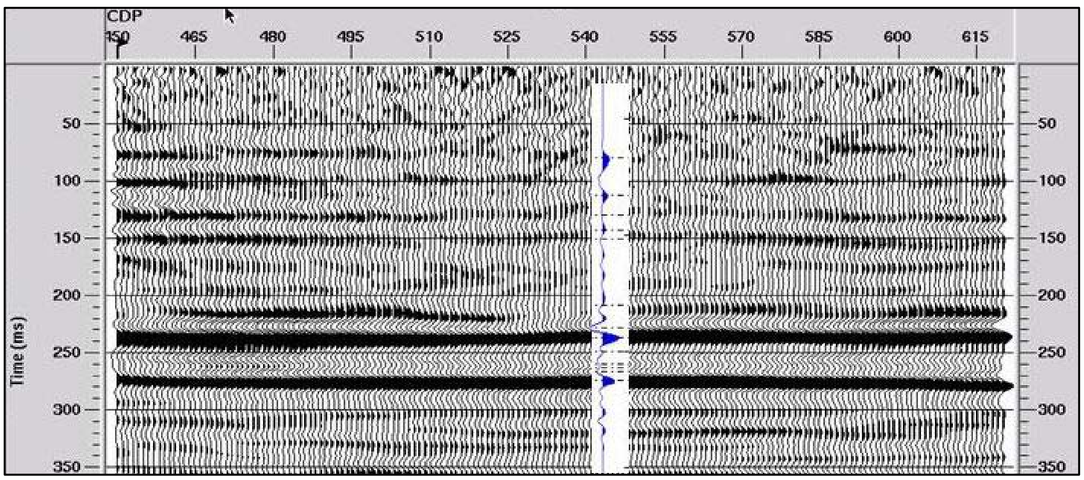

FIG. 10. Time migrated vertical component section showing a synthetic tie. The Ardley Coals are between 220 and 280 ms.

The data were processed using a flow recommended by Downton (2005) for AVO analysis. Figure 11 illustrates CDP gathers for the vertical component data and a synthetic seismogram AVO gather. The synthetic seismogram is constructed using the well data and a 8-15-70-90 Hz Ormsby wavelet. The modeling predicts that the coal events will have a negative amplitude at zero offset and that the overall amplitude will increase (trending toward zero amplitude) with offset to give a positive AVO gradient. The field data support this prediction. Figure 12 illustrates the AVO gradient and intercept attributes extracted from the data.

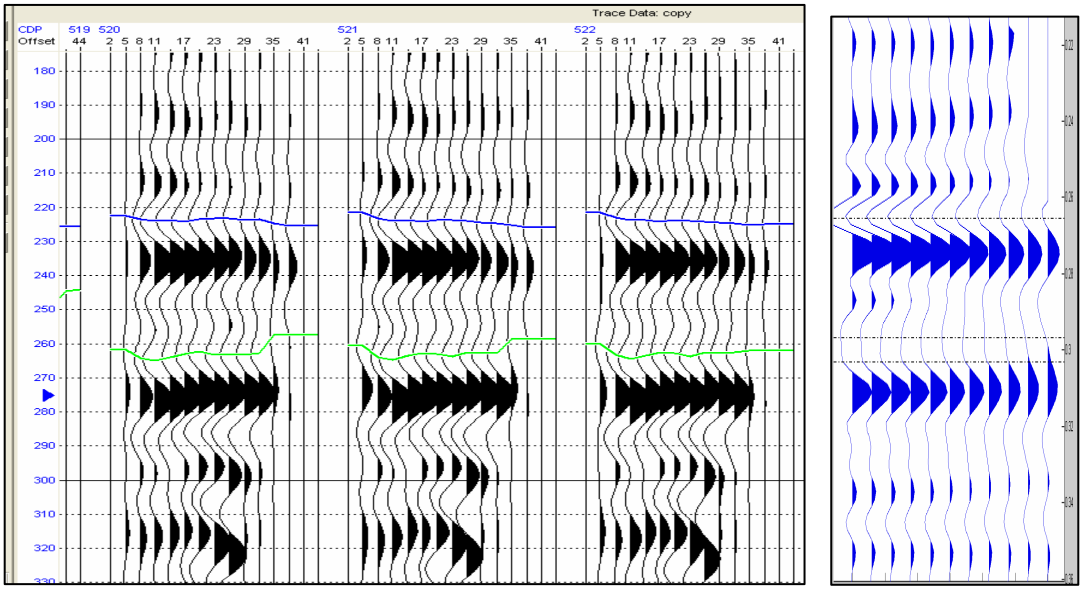

FIG. 11. CDP gathers of the vertical component data. The blue event correlates to the Upper Ardley Coals and the green event correlates to the upper seam of the Lower Ardley Coals. The AVO synthetic seismogram on the right is for comparison.

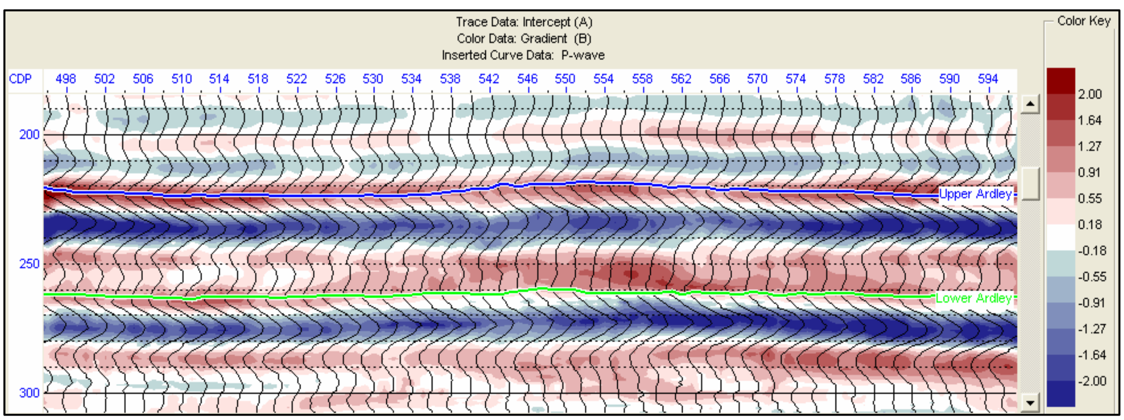

FIG. 12. AVO attributes from the vertical component data. The trace is the AVO zero-offset intercept and the color represents the AVO gradient. The blue event correlates to the Upper Ardley Coals and the green event correlates to the upper seam of the Lower Ardley Coals.

The inline converted wave data did not yield an interpretable stacked image. This is still being investigated.

3D SURVEY

In June of 2007, the University of Calgary acquired a 3D survey at the Alder Flats site. The survey was acquired before CO_2 injection had commenced.

The total patch was 560 m by 560 m with 60 m spacing of receiver lines and source lines. Source and receivers were themselves spaced at 10 m intervals. 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.

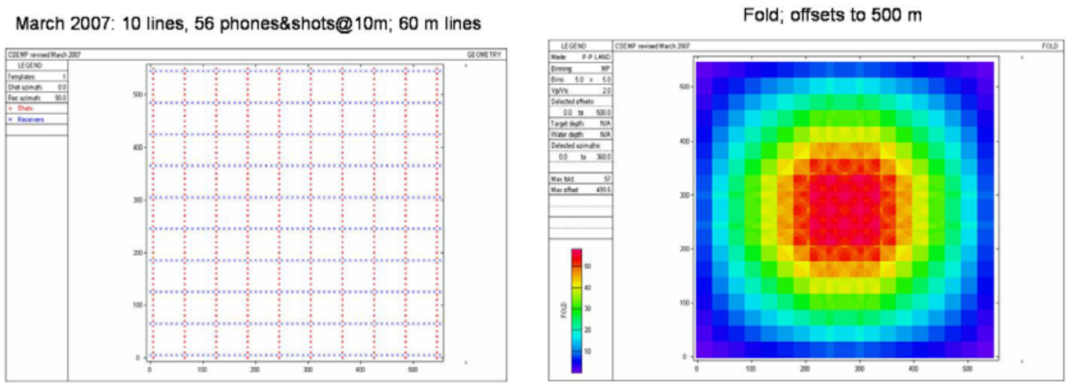

FIG. 13. On the left is the layout design for the vertical component 3D baseline 3D survey. Receiver lines run east-west and source lines run north-south. On the right is the expected fold for the PP survey.

Figure 14 shows a vertical component amplitude extraction at the later of two dominant trough events. This event is taken to correspond to the target coals. There appears to be a phase shift between the 2D data and the 3D data which is not yet understood. Some acquisition footprint is evident as a patchy diagonal texture. An amplitude anomaly is evident in the vicinity of the injector well. The low amplitude measure around the perimeter of the survey is likely due to lack of fold in this region. Figure 15 illustrates the time structure of the target event. The horizon dips to the WSW.

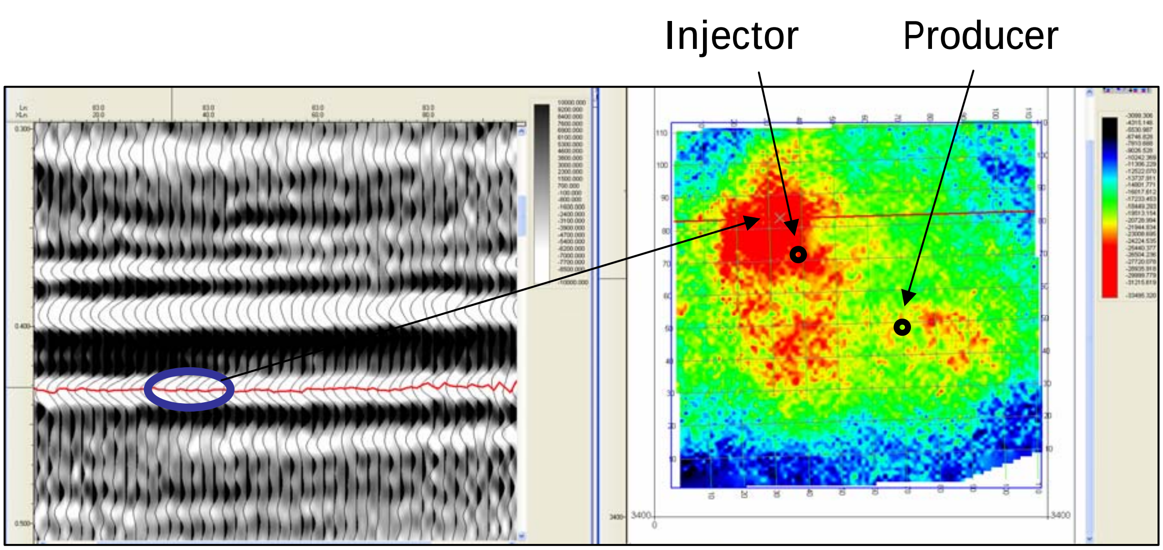

FIG. 14. Vertical component data. On the left is the pick of the target coal event. On the right is the amplitude map of the picked event. The line displayed on the left is the east-west (inline) line just north of the injector well. The blue circle on the left highlights the high amplitude anomaly that is shown by the red colour on the right hand side.

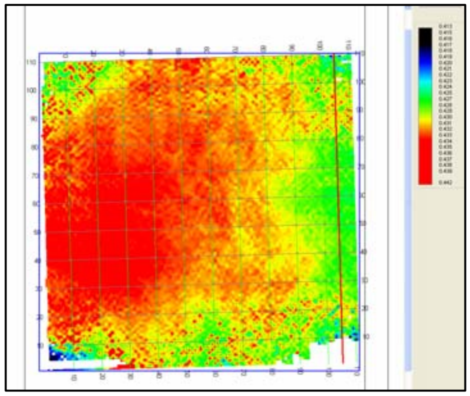

FIG. 15. Time structure map of the target coal event

Figure 16 illustrates the amplitude of the trough event that occurs at an earlier time than the target event. This is believed to correlate to the Upper Ardley Coals. This trough pick is less consistent than the target coals, which is surprising since the Upper Ardley is dominated by a thick coal seam and should be a clean seismic event. Further investigation is warranted.

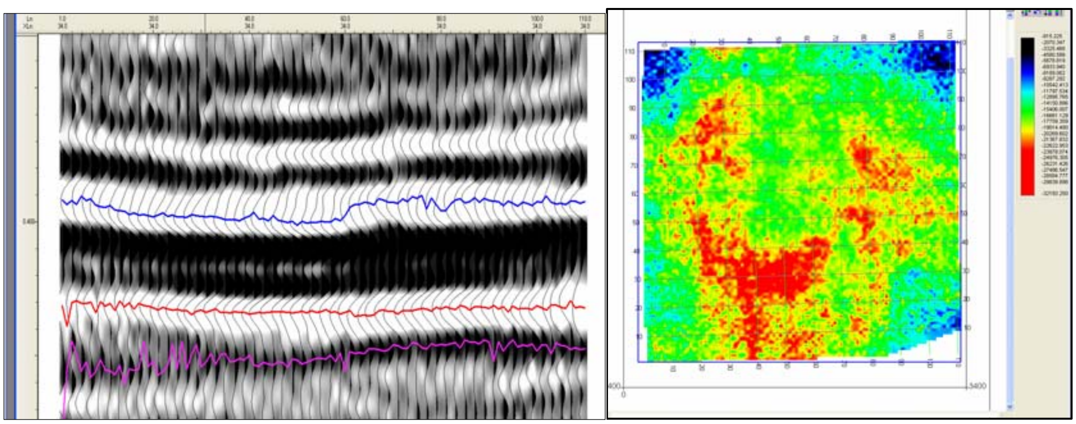

FIG. 16. On the left is an N-S section. The amplitude extracted from the blue horizon is shown on the right.

DISCUSSION

The results from the 3D survey indicate an amplitude anomaly in the vicinity of the injection well (Figure 14). The meaning of this anomaly has not yet been interpreted. Although the "baseline" survey was acquired before CO_2 injection had commenced, the reservoir was not in its native condition. The production well had been in operation for some time before the site was selected for the pilot project. Thus a production imprint would be expected around the producer. Additionally, although CO_2 injection had not started, the injection well had been stimulated with a water and sand injection induced fracture. Water and a small amount of CO_2 had been injected and some portion of these had been re-produced to test permeability of the coals at the injection well. These procedures may have resulted in a reservoir with a heterogeneous distribution of water saturation, fractures, and possible CO_2 effects.

CONCLUSIONS

A 3C-2D survey and a 3D survey were acquired at the Alder Flats site. Pre-stack and post-stack modeling compares well with the results of the 2D PP data. The 3D survey was recorded with a full spread of vertical component receivers and a single line of 3C receivers. An amplitude extraction of the target coal event shows interesting variability. The meaning of this variability will form the focus of future work to examine tuning and coal petrophysical indicators.

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REFERENCES

Dawson, F.M., D.L Marchioni, T.C. Anderson and W.J. McDougall, 2000, An assessment of coalbed methane exploration projects in Canada: Geological Survey of Canada, Bulletin 549, 217 pages.

Downton, J., 2005, Seismic parameter estimation from AVO inversion, Doctorate Thesis, University of Calgary

Henley, D. C., 1999, Radial trace computational algorithms at CREWES: CREWES Research Report, 11.

Margrave, G. F., Henley, D. C., Lamoureux, M. P., Iliescu, V. I., and Grossman, J. P., 2002, An update on Gabor deconvolution: CREWES Research Report, **14**.

Mazumber, S., Karnik, A., Wolf, K.H., 2006, Swelling of Coal in Response to CO_2 Sequestration for ECBM and its Effect on Fracture Permeability, SPE 97754.

Richardson, Sarah E., and Lawton, D. C., 2002. Time-lapse seismic imaging of enhanced coalbed methane production: a numerical modeling study: CREWES Research Report, **14**.