3D3C seismic data at the Brooks experimental CO_2 injection site

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ABSTRACT

We processed and interpreted a 1 km^2 baseline 3D3C seismic survey acquired in May, 2014, at the Field Research Station near Brooks in Southern Alberta. This area is the site of planned experimental CO_2 injection into shallow Upper Cretaceous sandstones and where various technologies for monitoring the behaviour of the injected gas and cap rock integrity will be assessed. One of these technologies is timelapse 3D3C seismic data.

Processing of the PP and PS seismic data included noise attenuation and signal enhancement processes, Gabor deconvolution and post-stack time migration. After processing the PP and PS seismic data, we tied them to well logs using synthetic seismograms. We interpreted and mapped several key horizons on the PP and PS 3D data and registered the two data volumes. Vp/Vs was calculated from the registered horizon times for three intervals and also derived for the data volume through a joint PP-PS post-stack inversion.

INTRODUCTION

A Field Research Station (FRS) has been established near Brooks in Southern Alberta by the Containment and Monitoring Institute (CaMI), which is part of Carbon Management Canada (www.cmcghg.com/business-units/cami) (Figure 1) in section 22, T17 R16W4M. This section of land is leased by Cenovus Energy and is within the Countess Field. The numerous wells in the area have encountered oil and gas in many Upper and Lower Cretaceous formations. The plan at the FRS is to inject small amounts (up to 1000 tonnes per year) of CO_2 into shallow sandstones and to assess the efficiency and sensitivity of various technologies for monitoring the behaviour of the injected CO_2 and cap rock integrity. The first injection, planned for 2016, will be into the Upper Cretaceous Basal Belly River Formation, which is a water-wet sandstone, with possible further target sandstones in the Medicine Hat and Second White Speckled Shale formations (Figure 2). A new well, 10-22-017-16-W4M, was drilled to a depth of 550 m in early 2015 and the gamma ray correlated to the other two wells in Section 22 (Figure 3). This well will be used as the injection well and new observation wells will be drilled.

3D PS SEISMIC DATA PROCESSING

In May, 2014, a 1 km^2 baseline 3D3C seismic survey was acquired by Tesla Exploration. The survey was designed to acquire data at a source interval of 10 m along lines spaced 100 m apart in an outer grid and 50 m apart in an inner grid. Receivers were also spaced at 10 m along lines spaced 100 m and 50 m apart in the outer and inner grids (Figure 4). The source was two Tesla Envirovibes and the receivers were three-component. Further details about the field acquisition may be found in Lawton et al. (2014).

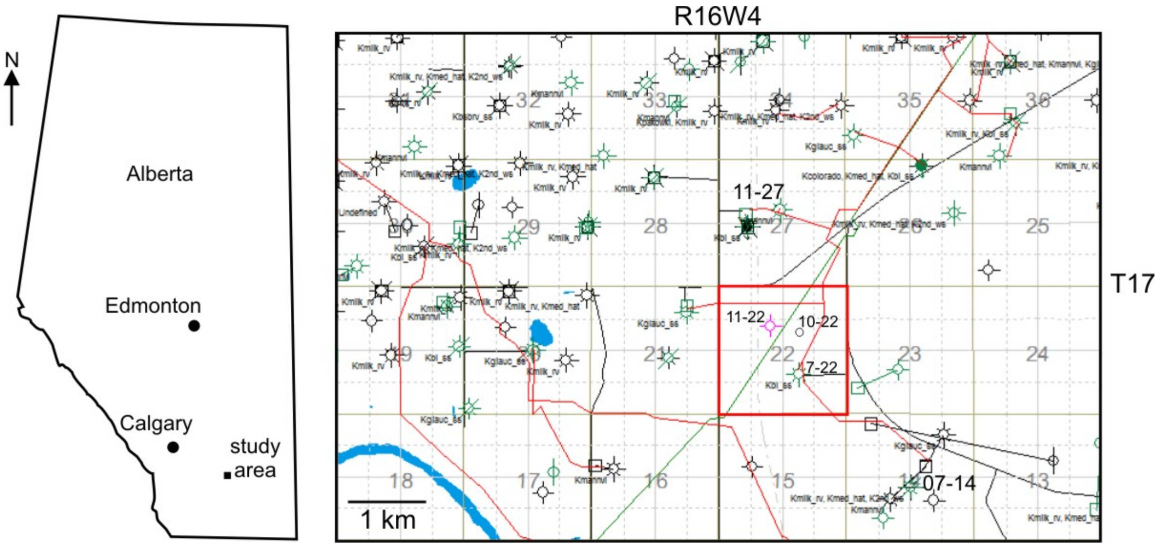

FIG. 1: The study area in Southern Alberta, with Section 22 highlighted in red. The annotations next to the wells show producing zones.

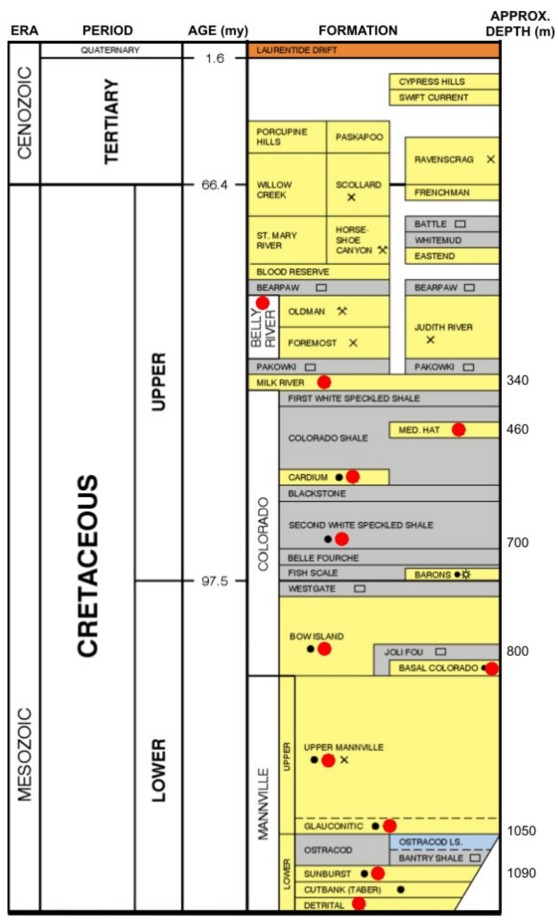

FIG. 2: Stratigraphic chart showing producing formations (after ERCB). Red dots indicate gas-producing formations. Our primary injection target is the Basal Belly River sandstone with possible secondary targets in the Medicine Hat and Second White Speckled Shale formations.

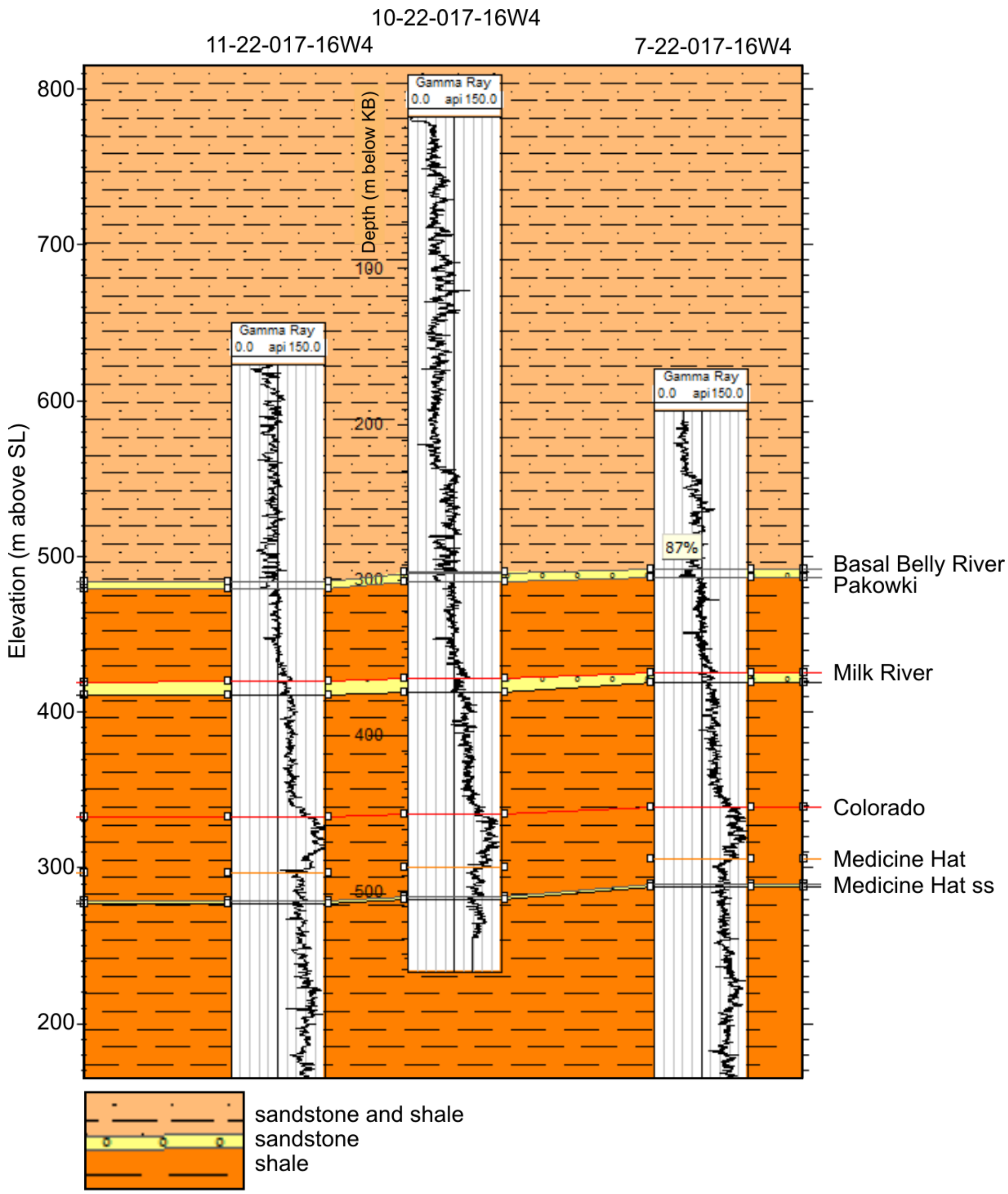

FIG. 3: Correlation of gamma ray logs across Section 22. The locations of the wells are shown in Figures 1 and 4. The primary sandstone of interest is the Basal Belly River.

The processing and interpretation of the PP data are discussed in Isaac and Lawton (2014). For the PS data we followed a similar processing stream as for the PP data, including air blast attenuation, spike and noise edits, and surface wave noise attenuation. We also applied Gabor deconvolution (Margrave and Lamoureux, 2002) and a spatial filter applied after NMO in the shot domain to help bring out the signal in the shallow section of interest.

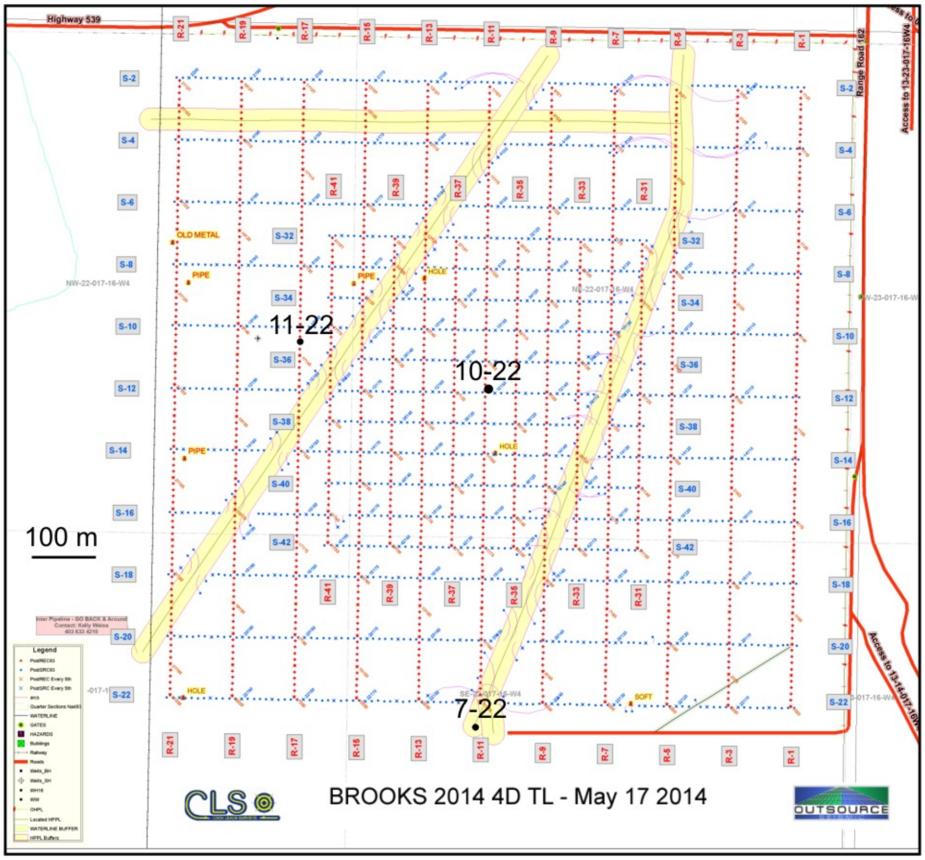

FIG 4: The layout of the 3D survey processed and interpreted for this study. The three wells shown in Figure 3 are annotated. 10-22 is the new well drilled in 2015.

Figure 5a shows part of a field shot gather from the PS data. Figure 5b shows the same partial gather after application of noise attenuation, Gabor deconvolution and hand statics. The event seen at about 0.6-0.7 s on the processed gathers has a moveout velocity of about 1750 m/s and is believed to be a converted wave event.

We applied the refraction and residual shot statics calculated for the PP data. We then created receiver stacks and obtained the static for each receiver station by calculating the shift necessary to flatten a reflection at about 1.0 s. This is a valid technique for calculating receiver statics in an area of flat geology, such as at Brooks (Harrison, 1992; Cary and Eaton, 1993). We also used this technique on the shot gathers to calculate a small residual shot static.

We applied a noise-attenuation filter to NMO-corrected shot gathers then removed this NMO. Prior to exporting the processed gathers for import into Vista we also applied statics to final datum to avoid any issues with incorrect CDP statics being applied at a later stage in the processing.

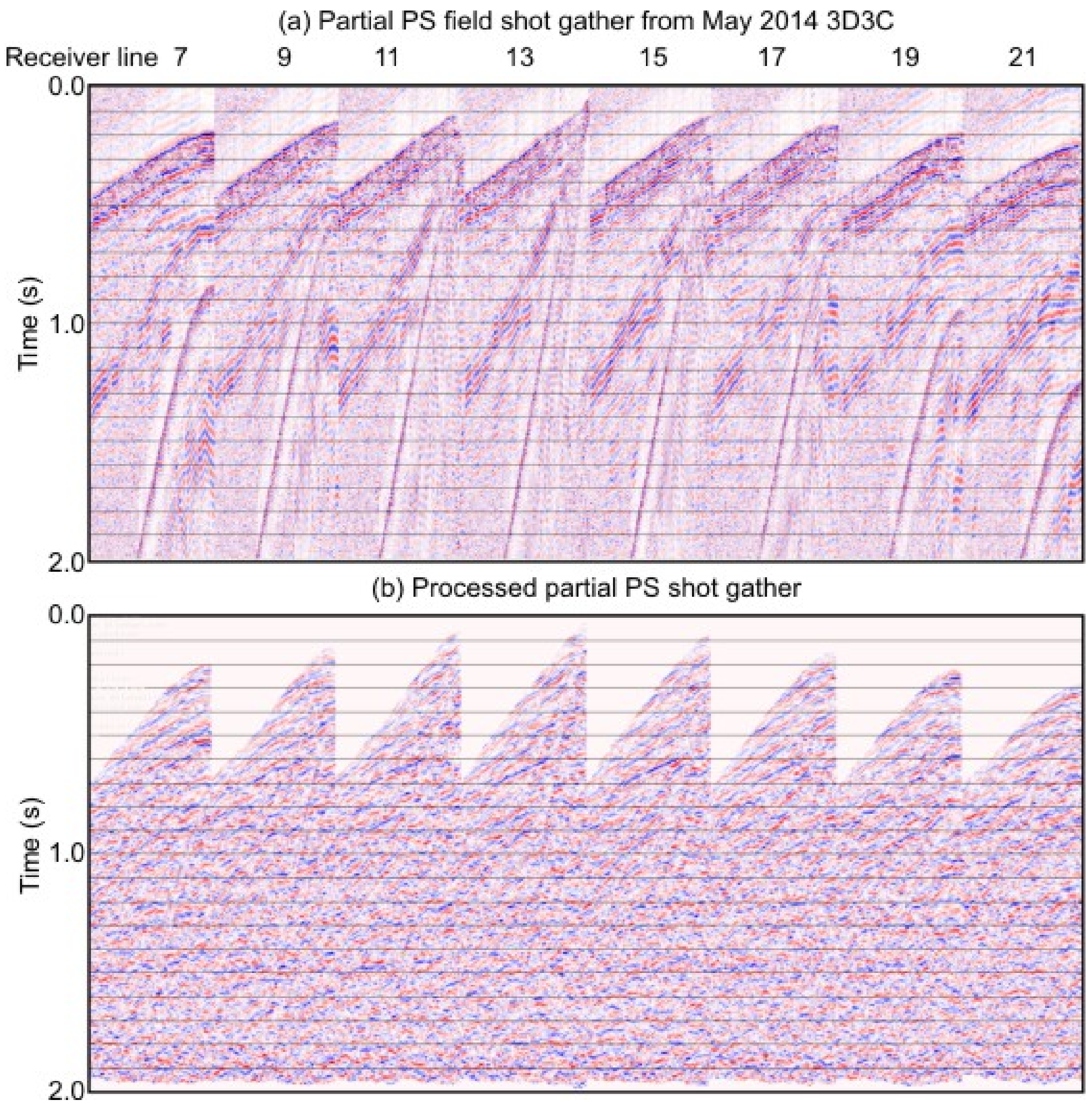

FIG. 5: Part of a PS shot gather before (a) and after (b) noise attenuation, statics and deconvolution.

We imported the processed data into Vista for the 3D3C asymptotic binning as this option was not at that time available in SeisSpace. We binned the data into common conversion points (CCP) using Vp/Vs of 2.2, which we estimated for the shallow zone of interest using a dipole sonic log from well 01-07-018-15W4 (Figure 6).

Velocities were picked, the data stacked into the CCP bins, and a post-stack migration applied. After migration we also applied a 3-trace fxy deconvolution. Figure 7 shows the final migrated PP and PS data along inline 101, which runs through the centre of the survey along a source line. We cannot tie the two datasets by visual inspection because of differences in frequency content and seismic character and it is very important that the events we correlate on the PP and PS datasets correspond to the same depths. Therefore we must tie each data set to well data.

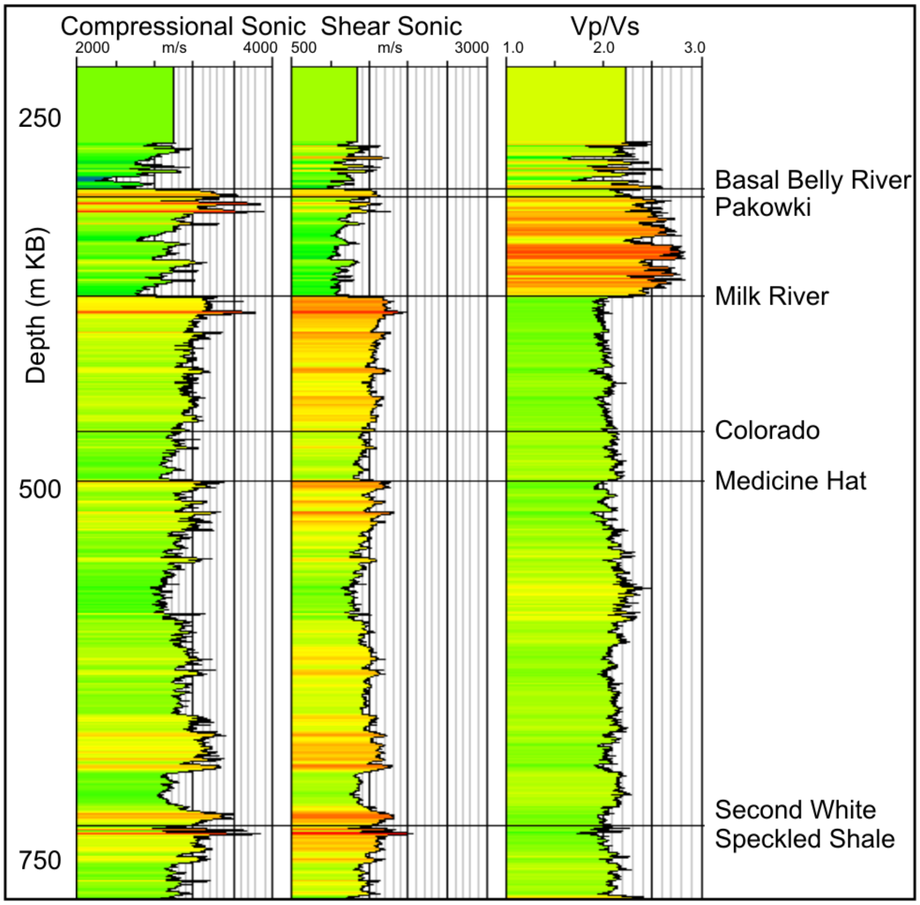

FIG. 6: Compressional and shear sonic logs from well 01-07-018-015W4 over the zone of interest and Vp/Vs calculated from them.

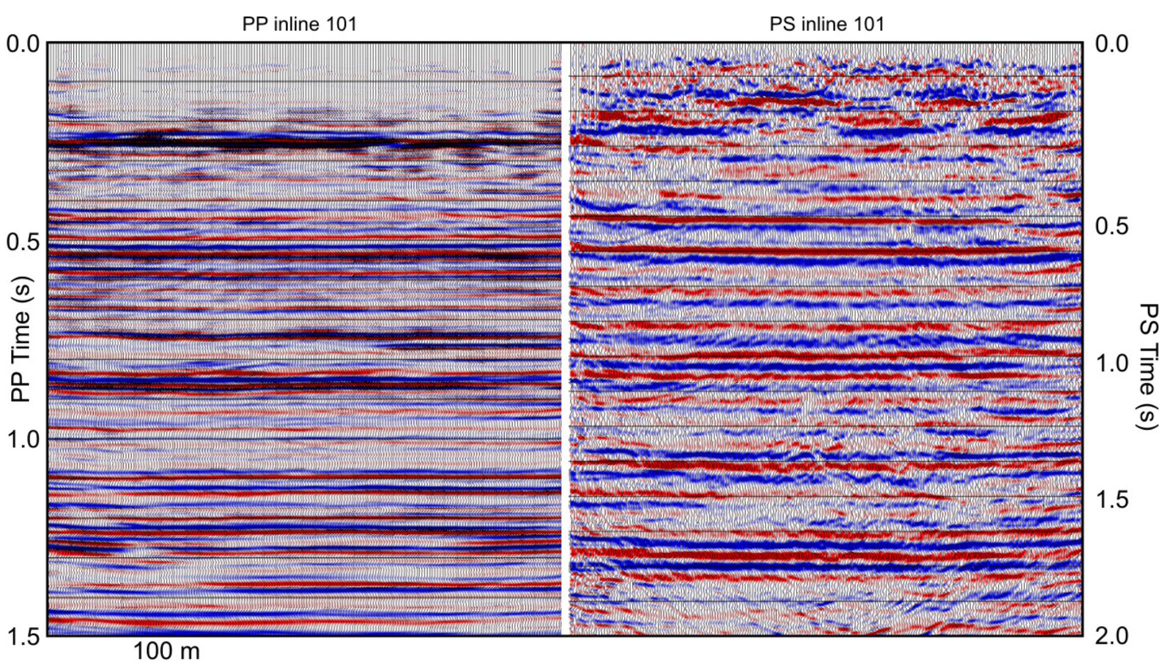

FIG. 7: Corresponding migrated PP and PS data along inline 101.

We identified reflectors on the PP volume by tying some traces to PP synthetic seismograms created from the sonic log of well 07-22-017-016W4, which we selected for the good quality of its sonic log. Tying the PP data to the well was an interesting little study in itself and a detailed discussion can be found in Isaac and Lawton (this volume).

To tie the PS data we created a shear sonic log by Castagna's mud rock equation (Castagna et al, 1985) and created a PS synthetic seismogram with an extracted wavelet. The PS data tie the PS synthetic seismogram very well. These PP and PS seismic data to well log ties are shown in Figure 8.

After identification of the reflectors on the PP and PS data, we interpreted and mapped several horizons: Basal Belly River, Colorado event, Second White Speckled Shale, Base Fish Scales and Mannville. Figure 9 shows interpreted PP inline 101 from the centre of the survey, and Figure 10 shows the corresponding PS line with interpreted horizons. The Colorado event was not particularly strong but was the best event to correlate in the interval between the Basal Belly River and Second White Speckled Shale which would separate an analysis interval containing the Basal Belly River sandstone from one containing the Medicine Hat sandstone. In Figure 11 we show the registered PP and PS sections in PP time. The registration is based upon correlation of the horizons annotated on the figure. From these horizons we obtained Vp/Vs maps for the intervals Basal Belly River-Colorado event, Colorado event-Second White Speckled Shale and Second White Speckled Shale-Mannville (Figures 12 a, b, and c, respectively). We chose the interval Second White Speckled Shale-Mannville because we considered that the interval Second White Speckled Shale-Base Fish Scales was too thin for meaningful Vp/Vs analysis (Asuaje and Lawton, 2015). The Basal Belly River-Colorado event is also rather thin but we wanted to analyse an interval that did not also contain the Medicine Hat sandstone along with the Basal Belly River sandstone in case both these sandstones are injected with CO_2.

After registering the PP and PS data, we performed a joint PP-PS post-stack inversion. Figure 13 shows Vp/Vs obtained from this inversion along inline 101.

CONCLUSIONS

We processed and interpreted a new baseline 3D3C survey from the CO_2 Field Research Station near Brooks. The data were processed to attenuate noise and enhance signal. Significant differences between the processing of the PS data compared with the PP data included the application of receiver statics, PS velocity analysis, CCP binning and bandpass filters.

Both PP and PS data sets were tied to well data using synthetic seismograms and we interpreted the important horizons. After registration of the PP and PS data we mapped Vp/Vs over selected intervals. A poststack joint PP-PS inversion was also completed.

We intend to compare these results to those obtained from monitor 3D3C surveys obtained after CO_2 injection.

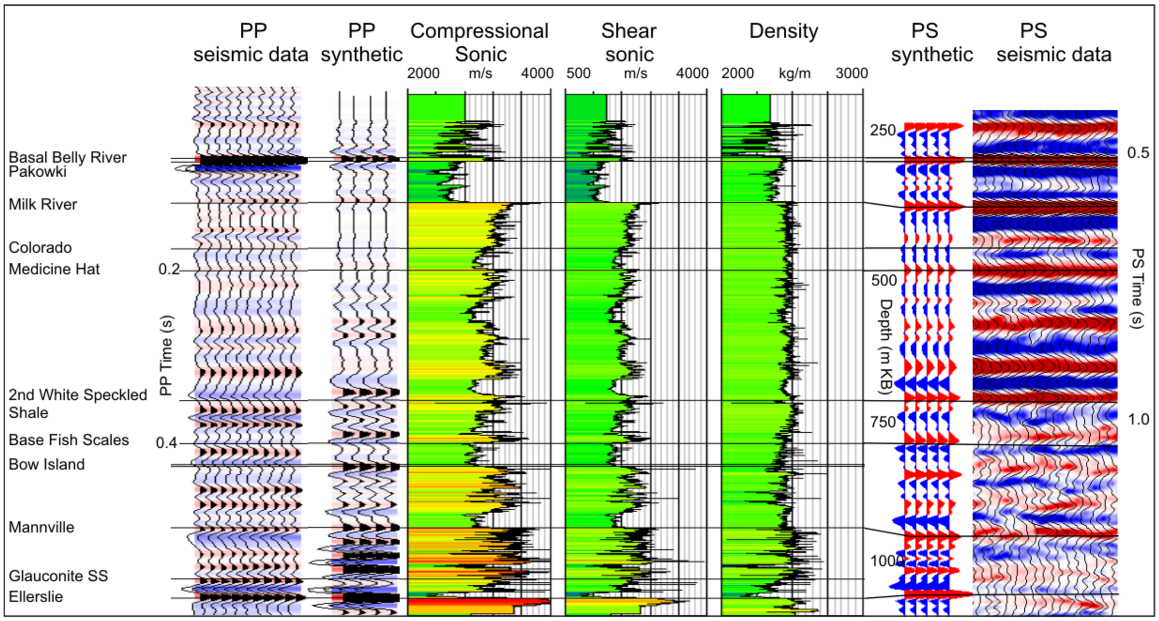

FIG. 8: Tie between PP data, well 07-22-017-016W4, and PS data.

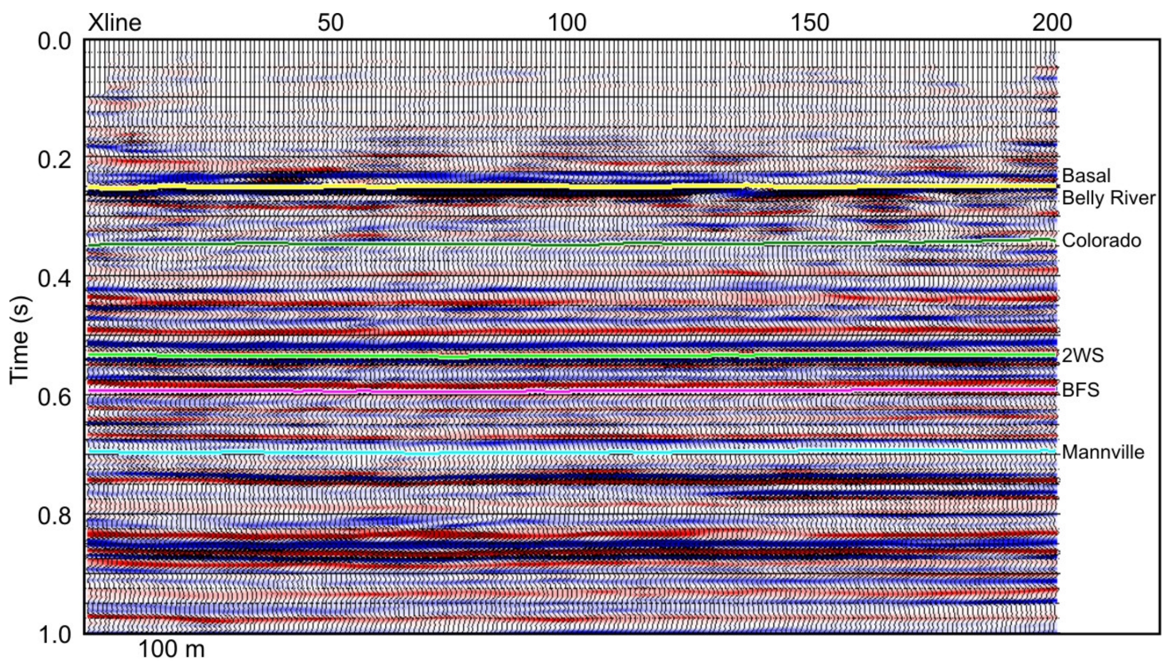

FIG. 9: Interpreted migrated inline 101 from the PP dataset.

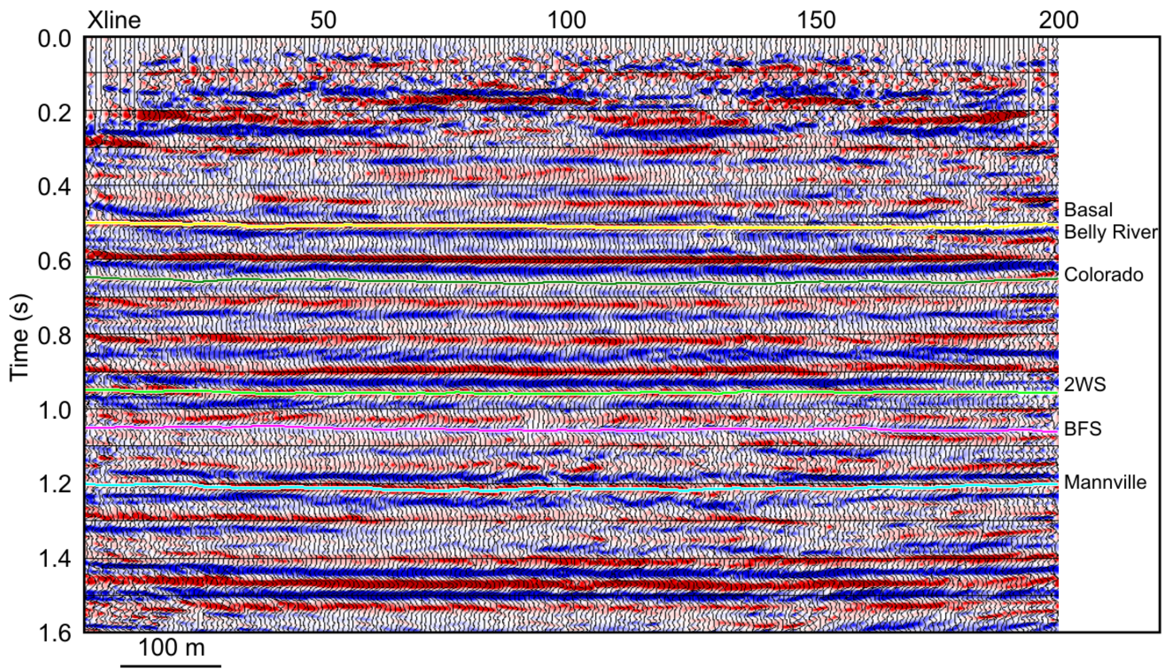

FIG. 10: Interpreted migrated inline 101 from the PS dataset.

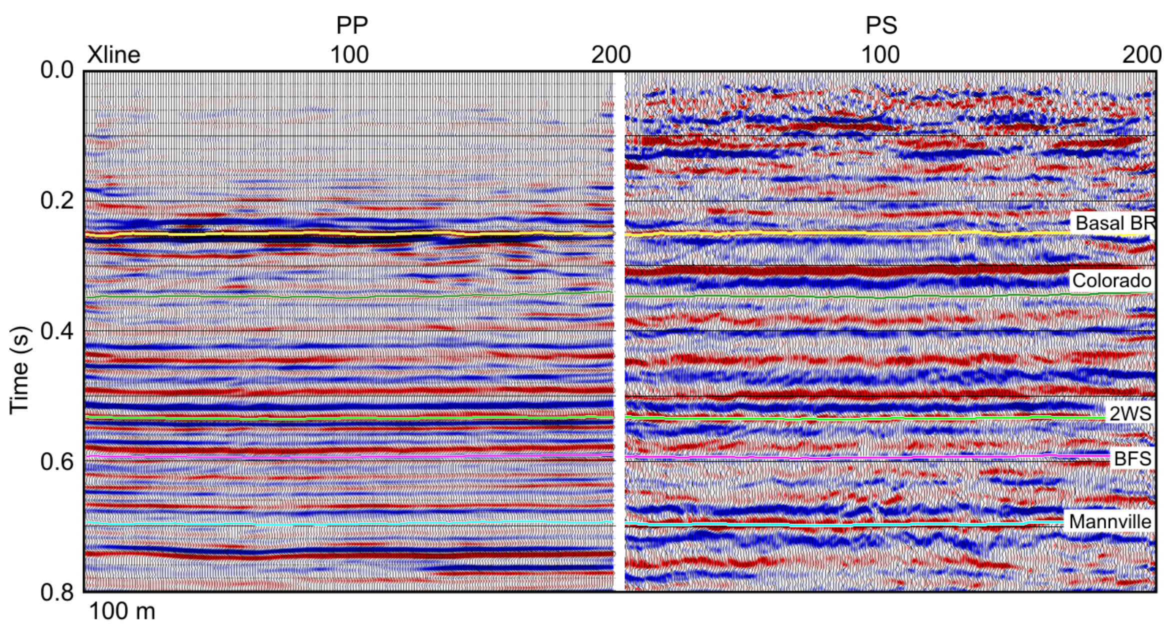

FIG. 11: Registered PP and PS data displayed together in PP time. The registration is based upon correlation of the annotated horizons.

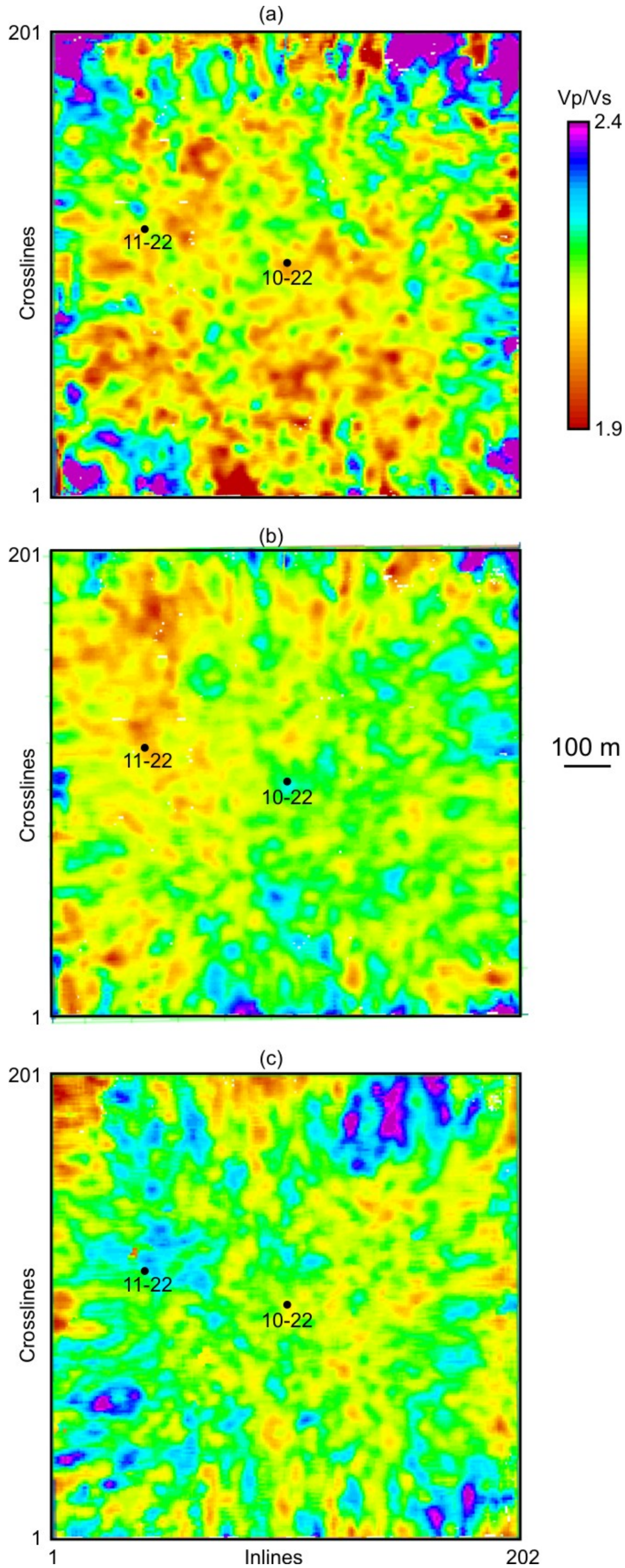

FIG. 12: Vp/Vs for (a) Basal Belly River-Colorado event, (b) Colorado event-Second White Speckled Shale and (c) Second White Speckled Shale-Mannville, calculated from picked horizon values.

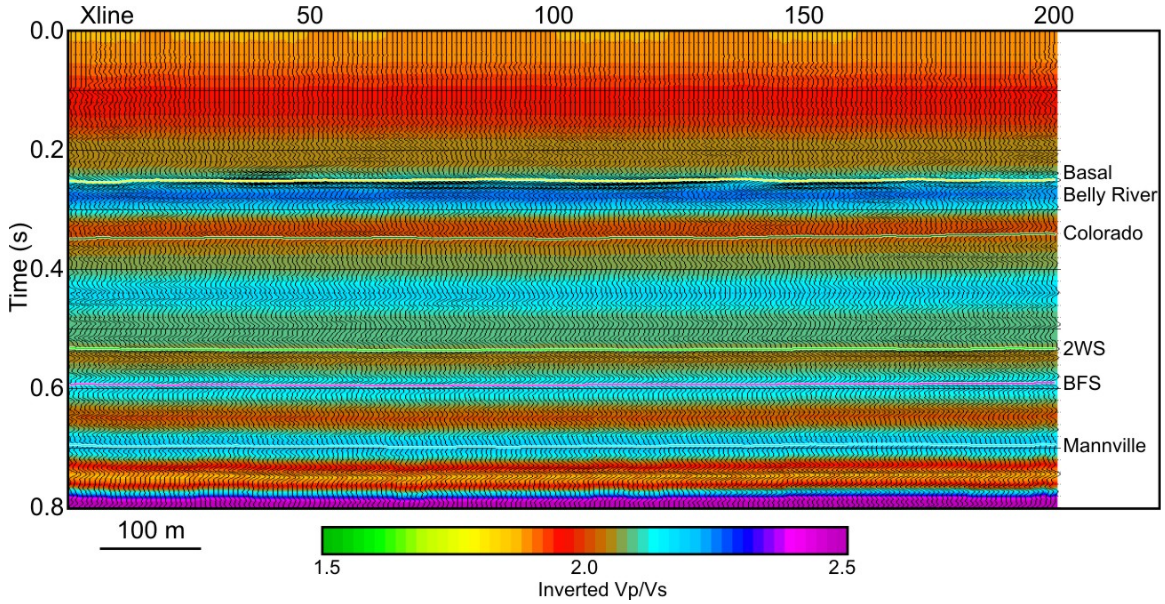

FIG. 13: Inverted Vp/Vs for inline 101.

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