Time lapse view of the Blackfoot AVO anomaly

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SUMMARY

In the Blackfoot field, southeast of Calgary there is an incised glauconitic valley system . From well logs in this area, synthetic seismic gathers and amplitude versus offset (AVO) curves indicate that at top of the formations of Glauconitic Channel Top (GLCTOP) and the Shunda-Mississippian (MISS), the AVO effects are quite obvious. Several seismic surveys were done in this area (Blackfoot 3D survey in 1993, Blackfoot 3C-3D survey in 1995, Blackfoot 3C-2D survey in 1997), and the AVO effects are shown in these migrated offset-limited sections.

INTRODUCTION

The acquisition parameters of the 1993 and 1995 seismic surveys were different. In the 1993 survey, the receiver line interval was 300m and the source line interval was 360m. The source was 4kg of dynamite at a depth of 21m. The receiver interval was 60m and the shotpoint interval was 60m. The survey area covered approximatly 12km from north to south and 10km from east to west. The Glauconitic patch is about 3.6km from north to south and 2.4km from east to west, which is a small portion of the 1993 3D survey. We extracted all the sources located in the Glauconitic patch and reprocessed the data. For the 1995 seismic 3C-3D survey the receiver line interval of the Glauconitic patch was 255m and 495m for the Beaverhill Lake area. The source was 4kg of dynamite at a depth of 18m. The source line spacing was 210m, while the receiver group interval and the source interval was 60m for both areas (Figure 2). We processed all the data for both areas and after migration the in-lines and cross-lines of the Glauconitic patch were extracted. Figure 3 shows the CDP coverage for the 1995 survey where the offset range is from 0m to 2900m. The CDP folds for the 1993 (max. 45) and the 1995 (max. 172) seismic surveys are shown in Figure 1 and Figure 3 respectively.

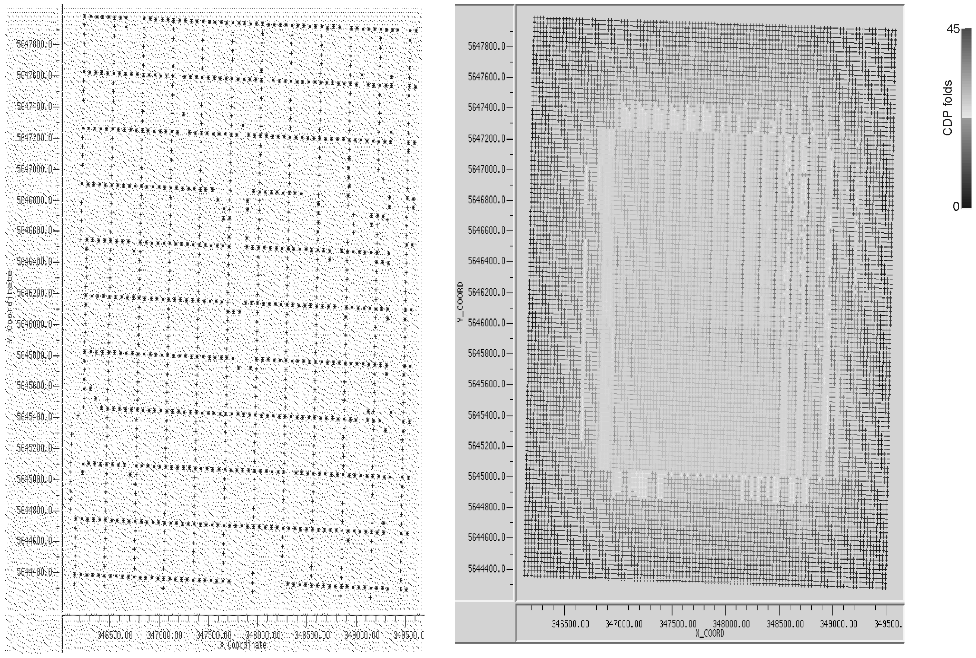

Figure 1 The 1993 seismic survey acquisition and corresponding CDP folds, the maximum CDP folds was 45.

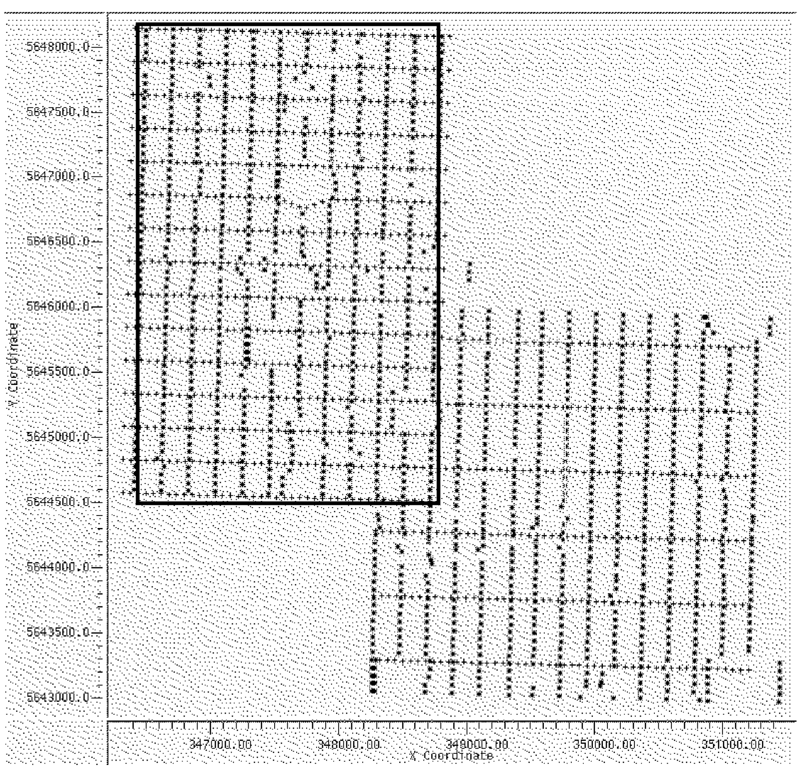

Figure 2 The 1995 3C-3D seismic survey shows acquisition of the Glauconitic patch (outlined) and the Beaverhill Lake area (not outlines).

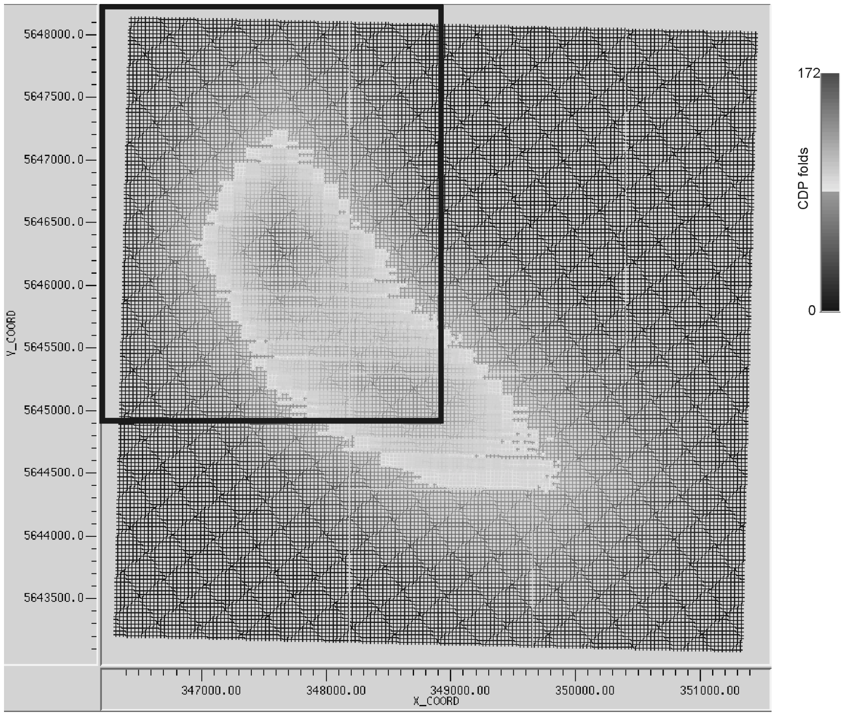

Figure 3 The 1995 CDP fold map, the maximum CDP folds was 172. The solid square is the Glauconitic patch.

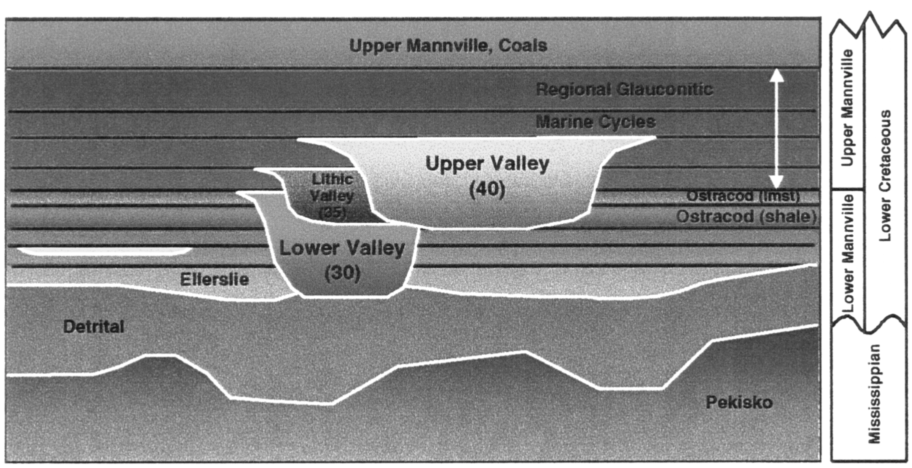

Figure 4 Schematic view of the incised valley system for the Blackfoot field.

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In the Blackfoot area, the producing formation is a cemented channel of sand deposited as incised valley-fill sediments in a clastic sequence that unconformably overlie carbonates of the Mississippian era (Margrave et. al., 1998).

Oil and gas in the Blackfoot field are produced from Glauconitic Formation of the Upper Mannville Group, which locally consists of three different incised-valleys: Upper, Lithic and Lower incised-valleys (Figure 4)(Dufour et. al., 1999).

AVO has proven useful in hydrocarbon exploration. Our AVO analysis only is based at this stage on P-P data. After reprocessing the 1993, 1995 and 1997 data, six volumes of the migrated offset-limited sections for each data set were generated. The offset ranges were 0-450m, 225-675m, 450-900m, 675-1035m, 900-1350m, and all offsets. The reason for the maximum offset of 1350m is the trace mute. We intend to keep the same coverage in the zone of interest for all offset-limited ranges.

From well logs synthetic seismograms were generated and compared with the seismic data. The AVO effects can be seen in several well locations. Therefore, oil and gas detection might be predicted within the reservoir.

RESULTS

The 1993 1C-3D, 1995 3C-3D and 1997 3C-2D data sets were reprocessed with improved statics (Lu et al., 1998). From the results of the migrated 2D line, a Glauconitic channel can be seen very clearly as the Upper, Lithic and Lower channels of an incised-valley system (Figure5). The migrated seismic section of the 1997 data is shown in Figure 5. Time-slices for the 1995 P-P data in Figure 6 were flattened at the regional Glauconitic formation (LMAN).

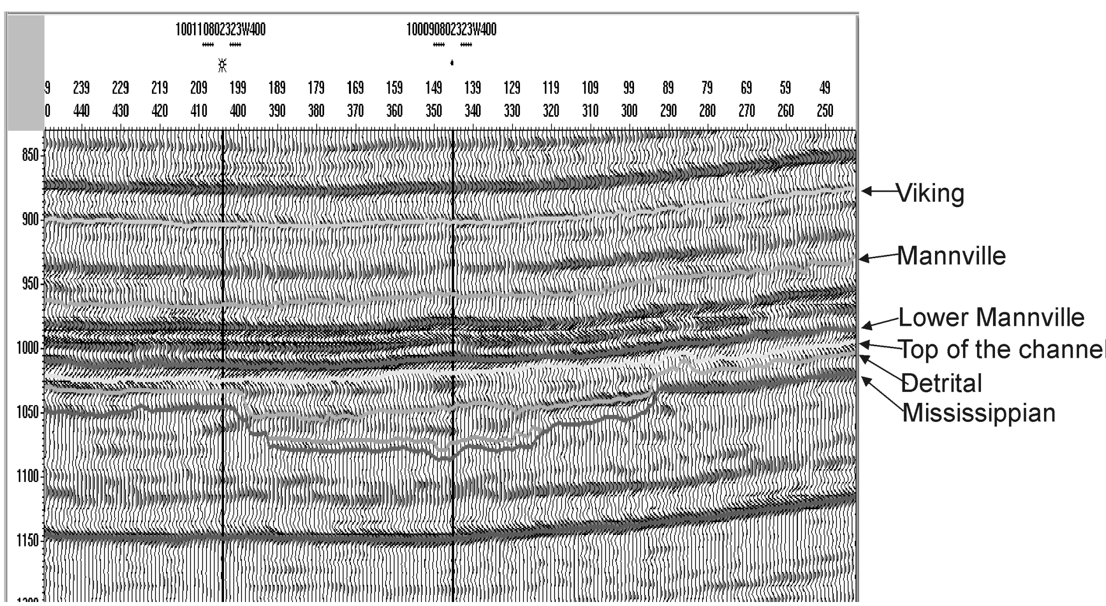
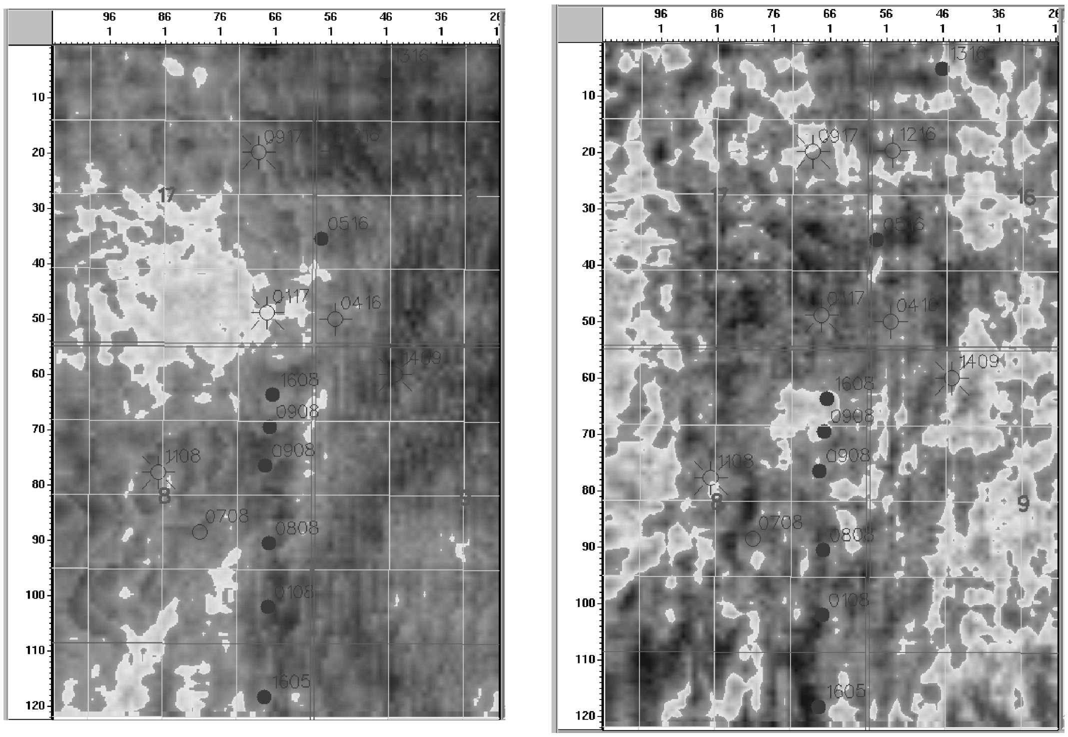


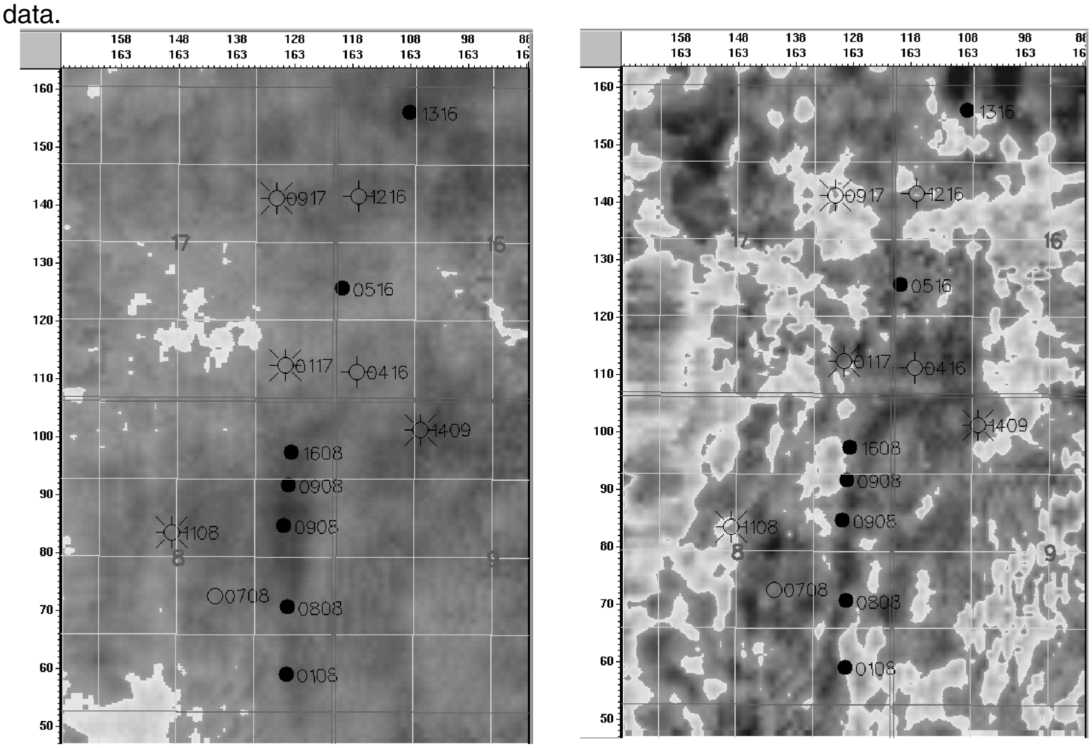
Figure 5 Migrated seismic section for the 1997 P-P 2D data.

The Glauconitic channel system runs from south to north through the Blackfoot area (Figure 6) and is about 1560m below the surface. This is evident from the negative amplitude anomalies (blue/dark) that show a trend through the producing oil wells.

The Upper channel anomalies indicate a wide channel, while the Lower channel is much narrower.



Time slices of Upper channel at 1060ms (left) and Lower channel at 1074ms (right) for 1993 data.



Time slices of Upper channel at 1060ms (left) and Lower channel at 1076 ms (right) for 1995 data.

Figure 6 Extracted amplitude from P-P data along the Upper channel is on the left, and along the Lower channel is on the right. Amplitude anomalies are shown in both of the Upper and Lower channel. These migrated sections were flattened at regional Glauconitic or Lower Mannville (LMAN) to 1050 ms.

Well 0808 is located at inline70, xline129 in the 1995 data, and at inline91 xline67 in the 1993 data. The gas producing formation of the well is mainly in the Upper channel, while oil and gas is produced in the Lower channel. Figure 7a shows that the migrated seismic section (1995) ties well with the zero-offset synthetic seismogram. Figure 7b shows the P-impedance and P-sonic logs and the corresponding synthetic. The synthetic seismogram with offsets from 10m to 1300m is shown in Figure 7c. Figure 7d shows the amplitude should increase with offset at the GLCTOP and DET formations. The parameters used for computing the synthetic above the log are: Vp=2840m/s, Vs=1420m/s, and density=2.3 g/cm3.

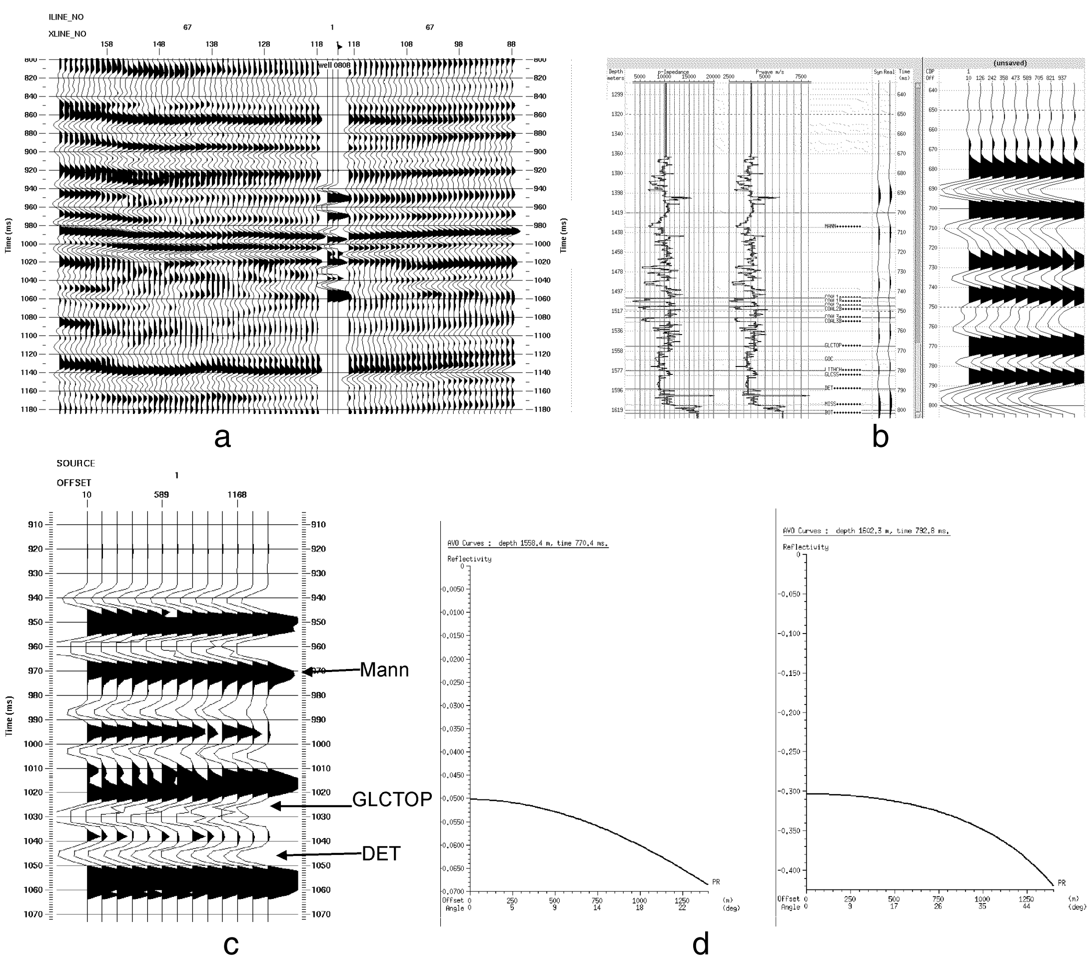
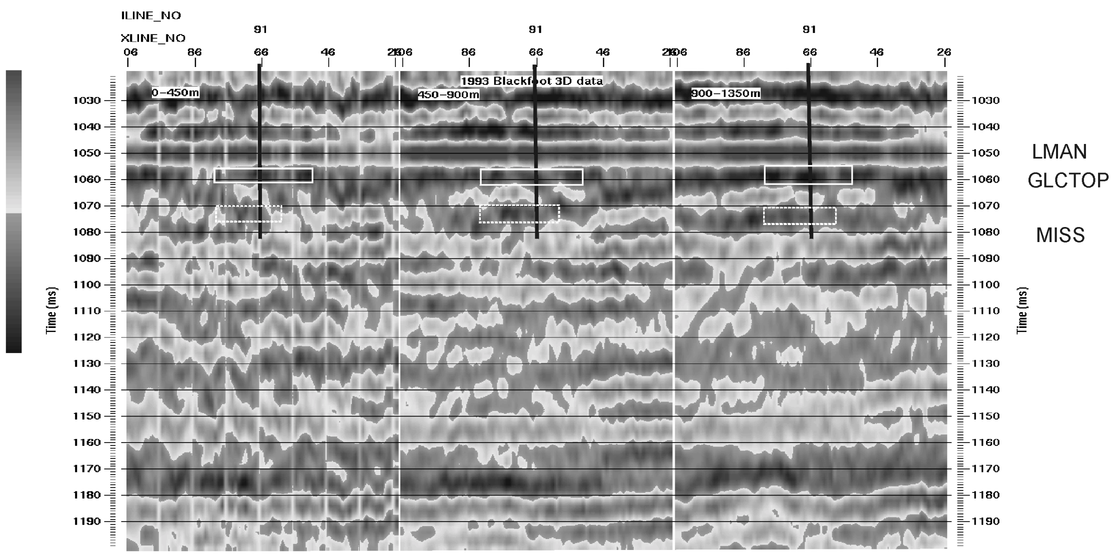


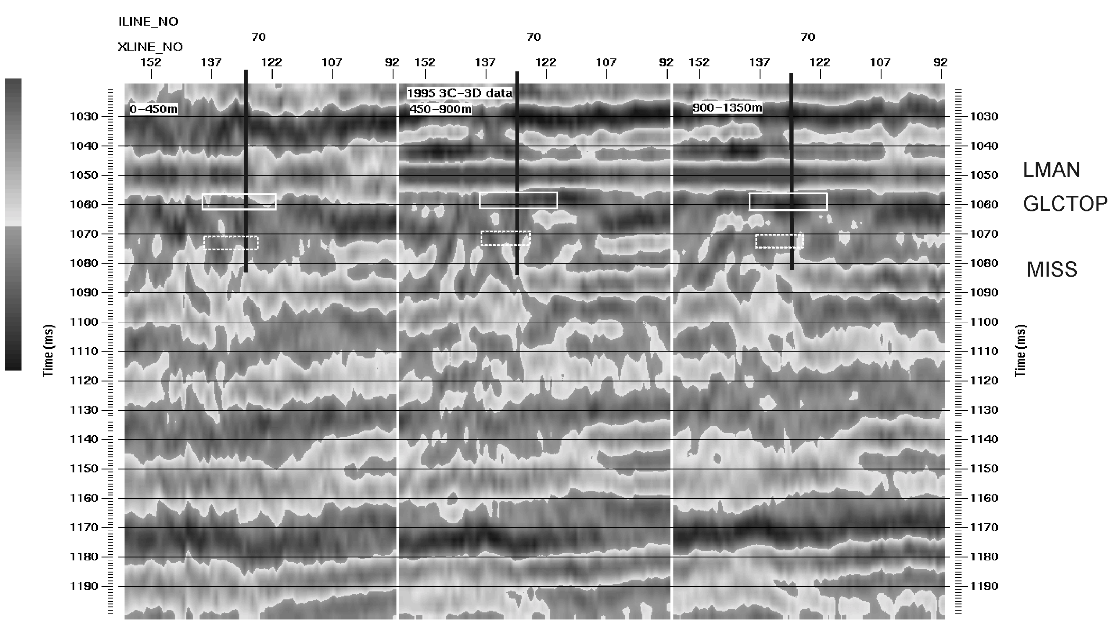
Figure 7 (a) Real seismic data ties with synthetic seismic from well 0808. (b) P-impedance and P-sonic of well 0808 and it's synthetic seismic with offset (primary only); (c) Synthetic seismogram with offset 10-1350m (primary only). (d) AVO curves at depth 1558m and 1620m are corresponding to GLCTOP and DET respectively. From the synthetic (d), the amplitude should increase with offset.

The same processing parameters used for the 1995 data were applied to the 1993 data. The velocity function obtained from 1995 processing was applied to the 1993 data to get offset-limited volumes. Also, the 1995 migration velocities were used to migrate these 1993 volumes.

Similar AVO effects can be seen in both the 1993 (Figure 8a) and 1995 (Figure 8b data. The amplitude increases from the near-offset stacked section to the far-offset section. These migrated sections are offset-limited and flattened to 1050 ms at the Lower Mannville formation.



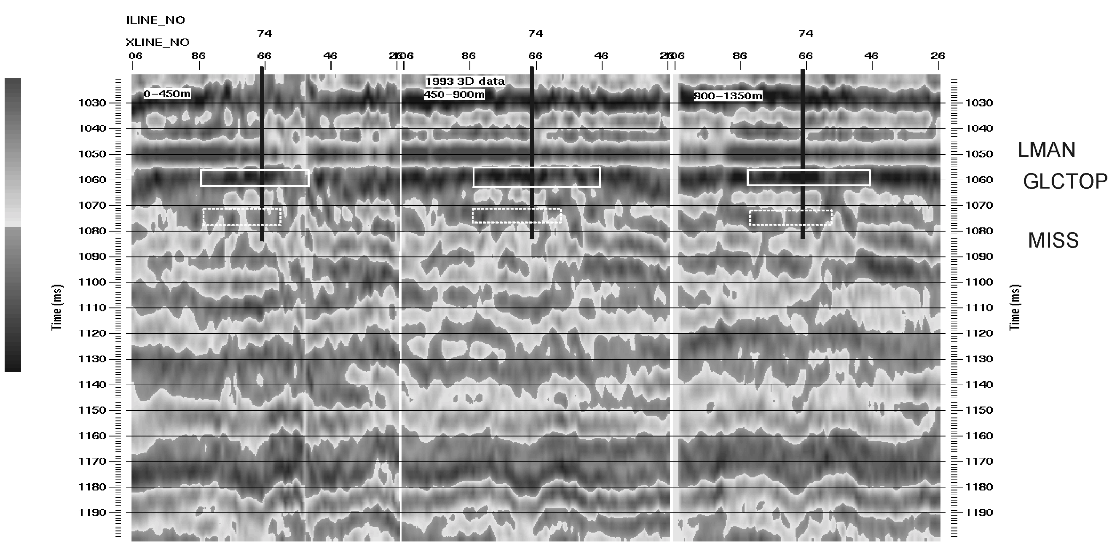
(a) 1993 Blackfoot 3D data.



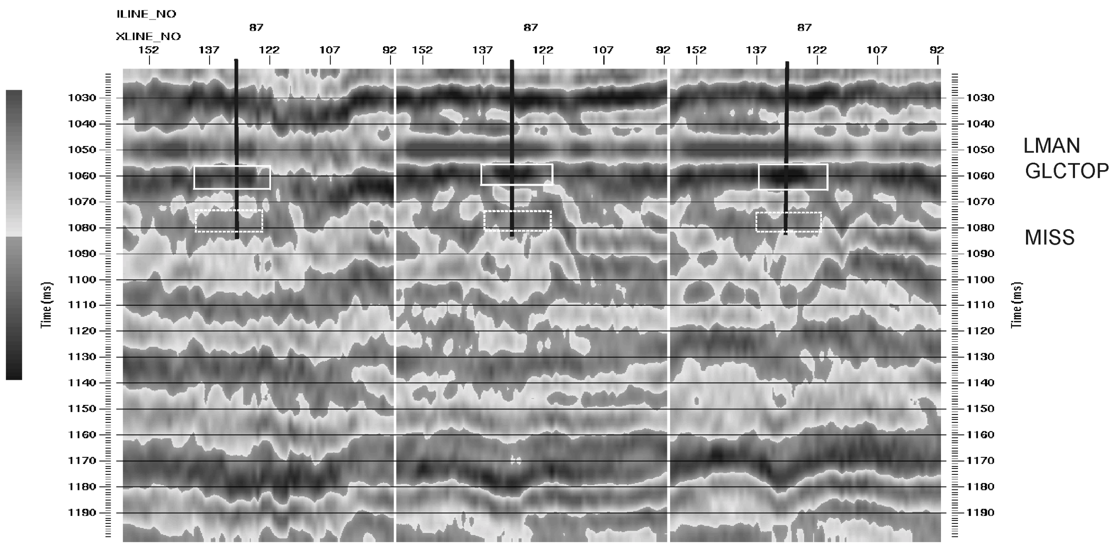
(b) 1995 Blackfoot 3C-3D data.

Figure 8 Migrated limited-offset sections for (a) the 1993 Blackfoot 3D data inline 91 and (b) the 1995 Blackfoot 3C-3D data inline 70. The limited-offset section 0-450m is on the left, 450-900m in the middle, and 900-1350m on the right. The sections were flattened at the Lower Mannville. The solid white square identifies the Upper channel and the dashed white squares indicate the Lower channel. The solid black line indicates the location of the well 0808.

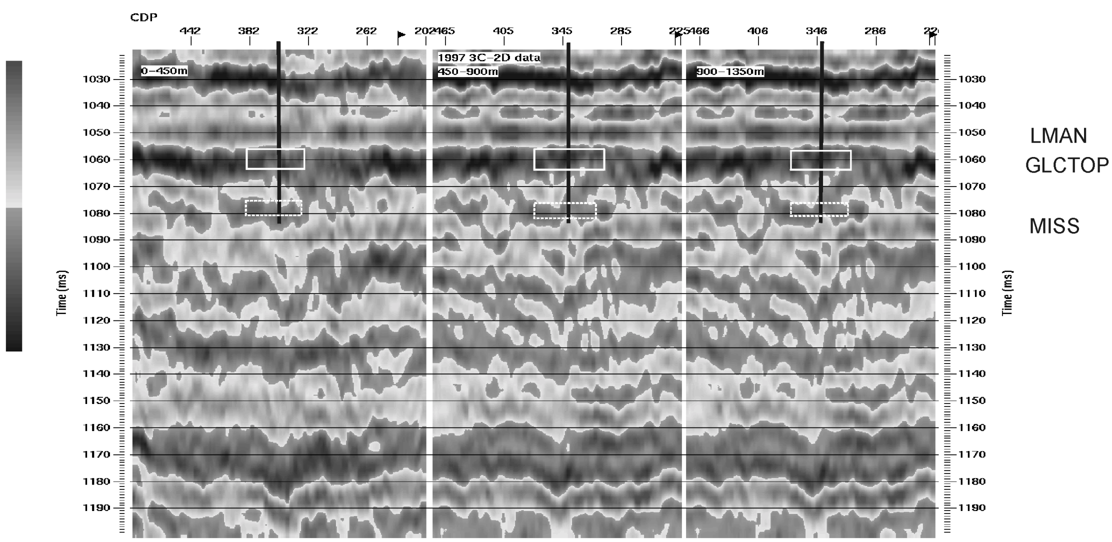
The location of another producing well (100/0908) for the different data are as follows: inline74 and xline67 for the 3D 1993 data; inline 87 and xline129 for the 3C-3D 1995 data; and CDP 343 for the 3C-2D 1997 data. Although recently recorded P-sonic, and shear sonic logs stopped at the top of the Glauconitic channel for the well 0908, AVO effects can be seen in the different offset ranged of the migrated sections in all of the 1993 (Figure 9a), the 1995 (Figure 9b) and the 1997 (Figure 9c) data.



(a) 1993 Blackfoot 3D data.



(b) 1995 Blackfoot 3C-3D data.



(c) 1997 Blackfoot 3C-2D data.

Figure 9 Migrated limited-offset sections for (a) the 1993 Blackfoot 3D data inline74, (b) the 1995 Blackfoot 3C-3D data inline 87, and (c) the 1997 3C-2D data. The limited-offset section 0-450m is on the left, 450-900m in the middle, and 900-1350m on the right. The sections were flattened at the Lower Mannville. The solid white square identifies the Upper channel and the dashed white squares indicate the Lower channel. The solid black lines indicate the location of well 100/0908.

Well 0416 is a shale plugged dry well within the Upper Glauconitic channel, located at inline 50 and xline55 in the 1993 data, and at inline111 and xline117 in the

1995 data. When comparing this well with the 0808 well, the Upper, Lithic and Lower channel are not as apparent.

Figure 10a shows that the 1995 migrated seismic section ties with zero-offset synthetic seismogram quite well. The elastic parameters for making the synthetic are: Vp=2840m/s, Vs=1420m/s, and density=2.3g/cm3. Figure 10b shows the P-impedance log and the related synthetic seismogram. The synthetic seismogram with offset from 10m to 1300m is shown in figure 10c. Figure 10d shows the variation of the amplitude with offset at the GLCTOP and DET formations and that these amplitude variations with offset are not obvious.

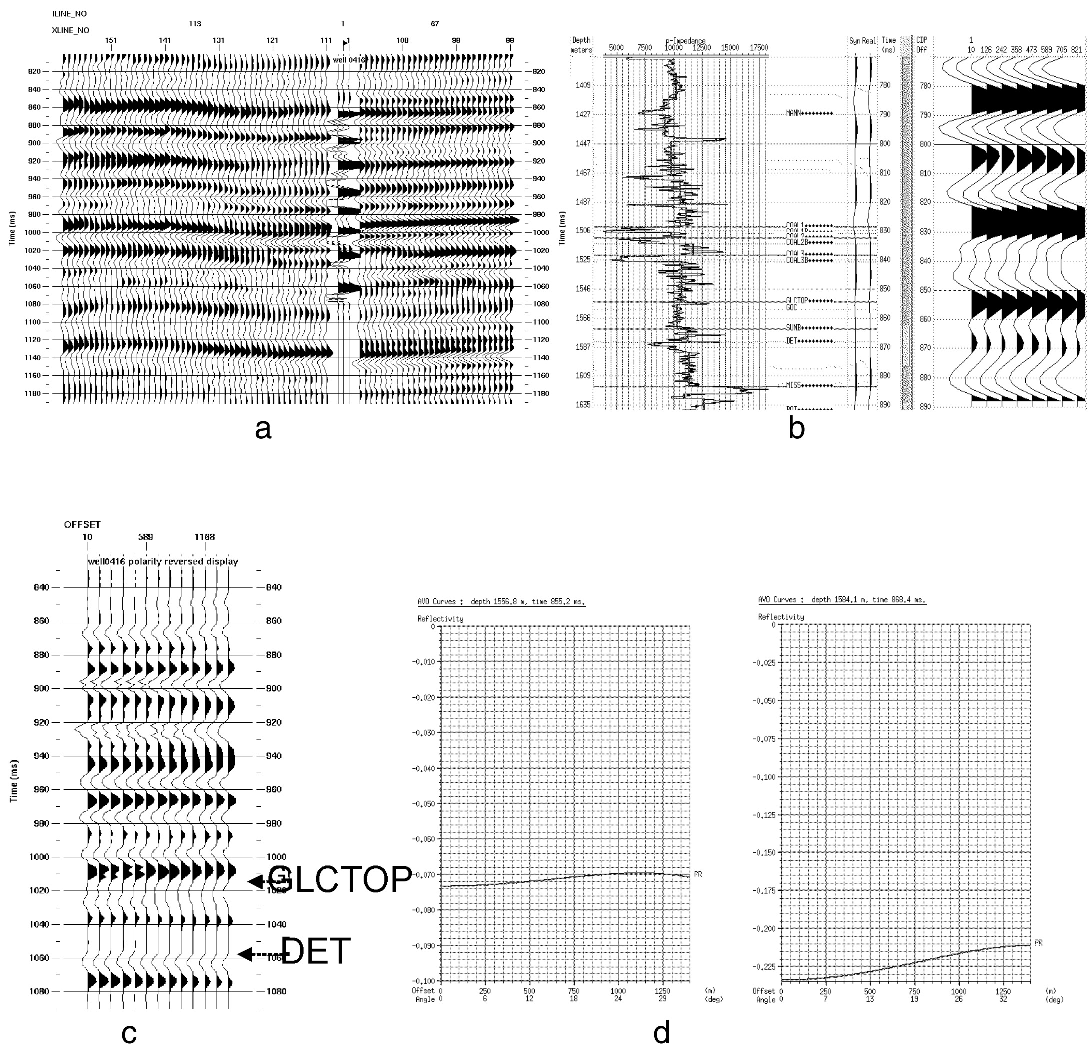
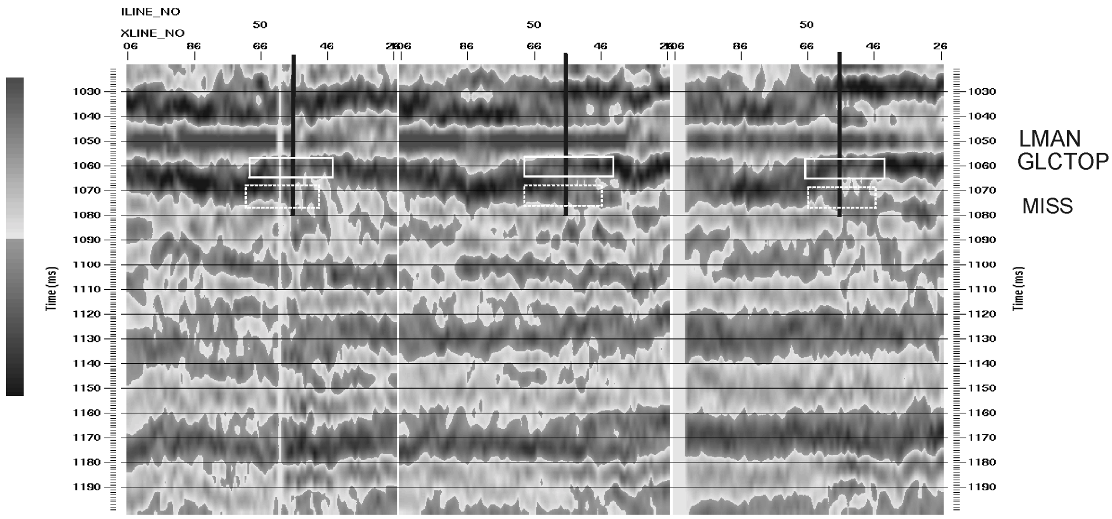
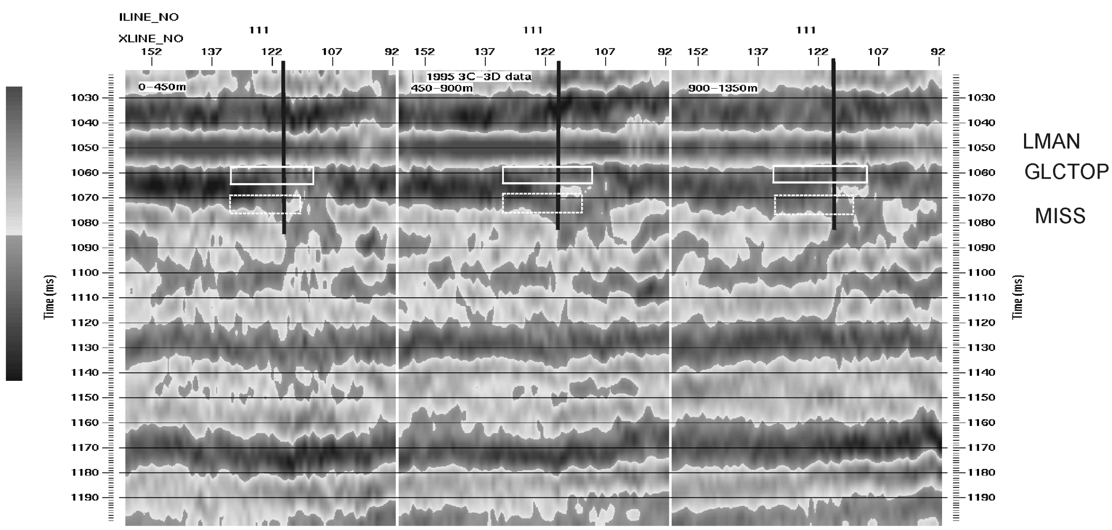


Figure 10 (a) Real seismic data ties with synthetic seismogram from well 0416. (b) P-impedance of well 0416 and it’s offset synthetic (primary only), (c) Synthetic seismic with offset 10-1350m (primary only). (d) AVO curves at depth 1556m and 1584m corresponding to GLCTOP and DET respectively. This shows that the amplitude varies slightly with offset.

Figure 11a and 11b show there is no simple relationship between amplitude and offset. Figure 11a is the 1993 data, and Figure 11b the 1995 data. They were flattened at 1050 ms of the Lower Mannville.



(a) 1993 Blackfoot 3D data.



(b) 1995 Blackfoot 3C-3D data.

Figure 11 Migrated limited-offset sections for (a) the 1993 Blackfoot 3D data inline50, and (b) the 1995 Blackfoot 3C-3D data inline 111.The limited-offset section 0-450m is on the left, 450-900m in the middle, and 900-1350m on the right. The sections were flattened at the Lower Mannville. The solid black lines indicate the location of well 0416.

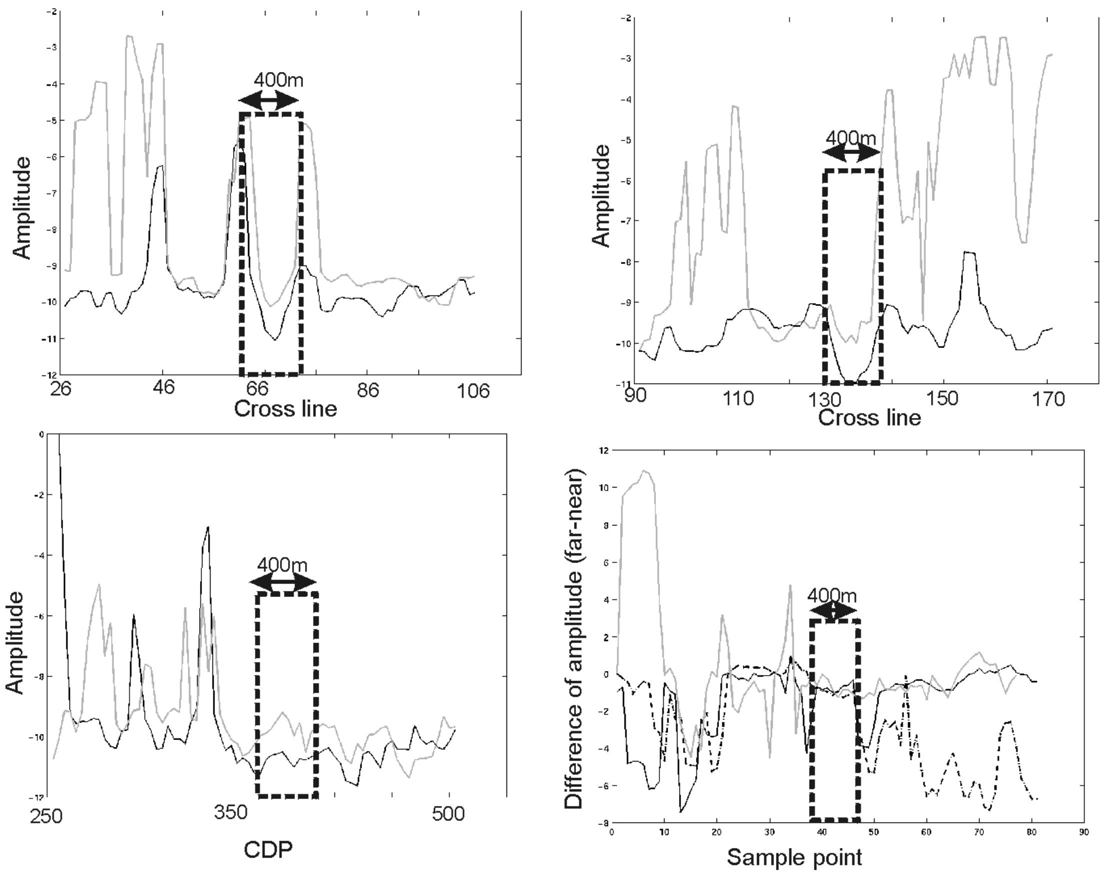


Figure 12 (a). The amplitude of inline 91 (1993 data) extracted from Figure 8 at time 1060 ms. The gray line is for near offset, the black line for far offset. The square indicates the channel location. (b) Amplitude of inline 70 (1995 data) extracted from Figure 8(b) at time 1060ms. (c) Amplitude of 3C-2D 1997 data (CDP 250-500) extracted from 9(c) at time 1060ms. (d) The comparison of the amplitude difference of near and far offsets for the three data sets. The difference of 1993 is shown by the gray line, 1995 is shown by the black line, 1997 is shown by the dashed line.

In order to examine the changes in the amplitude from near to far offset, and to compare the amplitudes changes in the three different data sets (1993, 1995 and 1997), the amplitudes were extracted from the migrated sections for well 0808 at time 1060 ms (Upper channel). Figures 12a, 12b, 12c show the amplitudes for the near and far offsets for 1993, 1995 and 1997 data respectively. The dashed squares identify the channel locations for all these three data sets. Figures 12(a), (b), and (c) indicate negative amplitudes for both near offset and far offset. The far offsets are generally more negative than the near offsets. An AVO event is prominent in the Upper channel (dashed square) where the far offset are more negative than near offsets. This is indicative of a gas/oil-sand. Figure 12d shows the differences in amplitudes between far and near offset for the 1993, 1995 and 1997 data sets. This shows that the difference in amplitudes has been more negative relative to increasing time (i.e. 1993 to 1997 data) in the Upper channel. This indicates an increasing AVO anomaly in the Upper channel relative to time.

DISCUSSION

The migrated offset-limited sections have low signal-to-noise ratio in the near and far offset ranges. This signal-to-noise ratio varies with offset range which can be seen in Figure 8b and Figure 9b. Amplitude changes in different offset ranges should be larger than the noise level in order to get reliable AVO effects.

Another concern is the resolution. In the data the dominant frequency is about 50-60 Hz and the average velocity in the in zone of interest is about 4500m/s, so in these offset-limited seismic sections, the AVO effect actually is the average effects in half wavelength. When calculating an AVO curves from well logs, a high frequency wavelet can be used to compute a synthetic, and an AVO curve at a certain depth can be obtained. The seismic section does not have high resolution. It is difficult to get very accurate AVO analysis results, however, the AVO effects still can be seen in migrated offset-limited seismic sections. The amplitudes tend to increase from the near-offset to far-offset range.

FUTURE WORK

The CDP gathers were used to see the amplitude variation with offset, but the signal-to-noise ratio was not high enough to get the expected results. Therefore, image gathers created by 3D pre-stack migration could be used to do AVO analysis.

ACKNOWLEDGEMENT

We would like to thank the sponsors of the CREWES Project for their financial support of this work and PanCanadian Petroleum for letting us to use the Blackfoot 1993 3D and well data. We also thank our colleagues in CREWES for their contribution to this project.

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