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A case study of an offset-dependent synthetic seismogram.

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Summary

We processed a small 3D3C seismic survey acquired in May, 2014, in Southern Alberta, Canada. We created PP and PS synthetic seismograms from dipole sonic and density logs to enable us to identify the reflectors seen on the seismic data, especially in the shallow zone of interest, and to register the two data sets.

The seismic character of the PP data does not match that of the default normal incidence synthetic seismogram at the top of the Upper Cretaceous Milk River Formation. A synthetic offset gather shows a high amplitude zero-offset response with a decrease in amplitude with offset and a change in polarity at an incidence angle of 35°. The stacked synthetic offset gather has a response matching that of the PP seismic data stacked with all offsets. The normal incidence synthetic has a better character match to the seismic data stacked using only the near offsets.

The character of the PS seismic data matches that of the PS synthetic seismogram well.

Introduction

A Field Research Station (FRS) has been established by the Containment and Monitoring Institute (CaMI), which is part of Carbon Management Canada (http://www.cmcghg.com/business-units/cami). The plan at the FRS is to inject small amounts (up to 1000 tonnes per year) of CO_2 into shallow sandstones in order to assess the efficiency and sensitivity of various technologies for monitoring the behaviour of the injected CO_2 and for assessing caprock integrity. The first injection, planned for 2016, will be into the water-wet Upper Cretaceous Basal Belly River sandstone, with possible further targets in the Medicine Hat and Second White Speckled Shale formations.

A small baseline 3D3C seismic survey was acquired in 2014. The source was the University of Calgary's Envirovibe at a source interval of 10 m along 20 lines spaced 50 m and 100 m apart. 3C receivers were also spaced at 10 m along lines spaced 50 m and 100 m apart. The closer line spacing is located in the centre of the acquisition area.

The PP data were processed through a fairly standard flow, which included refraction and residual static corrections, air blast attenuation, spike and noise edits, Gabor deconvolution (Margrave and Lamoureux, 2002) and post-stack finite difference migration. Processing of the PS data after rotation into radial and transverse components was similar to that of the PP data with the exception of the application of S-wave receiver statics based upon flattening an event on stacked receiver gathers (Harrison, 1992) and binning by asymptotic conversion points (Tessmer and Behle, 1988) using Vp/Vs of 2.2, which was obtained from dipole logs.

Synthetic seismograms

We used Geosyn software to create synthetic seismograms to tie to the data and to identify reflections. We observe a very poor character match between the seismic data and synthetic data at the top of the Milk River Formation (Figure 1). The Milk River Formation is a thin near-shore to terrestrial unit exhibiting the seismic characteristics of a high impedance sandstone.

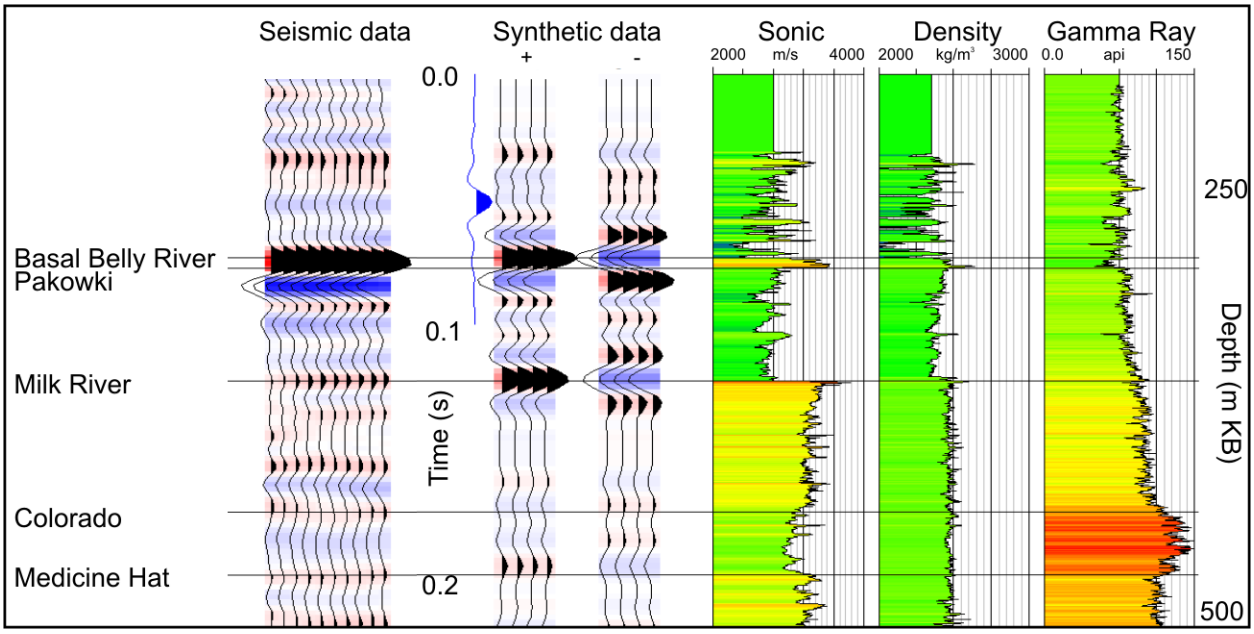

Figure 1: Migrated PP seismic data tied to normal incidence synthetic seismogram. Notice the poor character match at the Milk River.

We had used the default parameters of a normal incidence synthetic seismogram so we created an offset-dependent synthetic to investigate possible amplitude variations with offset. Since the calculation of an offset-dependent synthetic seismogram requires a shear sonic log, we initially used dipole logs from a well 8 km away then we derived a shear sonic from the compressional sonic for a well in the study area using Castagna`s mud-rock relationship (Castagna et al., 1985).

Figure 2 shows the migrated seismic data stacked with all offsets, the stacked synthetic offset gather and the synthetic offset gather showing a change in polarity at the top of the Milk River Formation at an offset of 250 m. The program calculated the amplitudes using the Aki-Richards 2-term equation (Aki and Richards, 1980). This is an example of a Class 1 (Rutherford and Williams, 1989) or Type 1 (Young and LoPiccolo, 2003) AVO anomaly. The high impedance interface, with its decrease in Poisson`s Ratio, exhibits a high amplitude positive reflection coefficient at the near offsets, a decrease in amplitude with offset and a reversal of polarity at an incidence angle of 35°. We obtain an improved match for the Milk River between the migrated seismic data stacked with all offsets and the stacked offset synthetic gather.

We also stacked and poststack migrated the seismic data with limited offsets (<250 m) and observe a much better character match with the normal incidence synthetic seismogram at the Milk River (Figure 3) than with the seismic data migrated using all offsets.

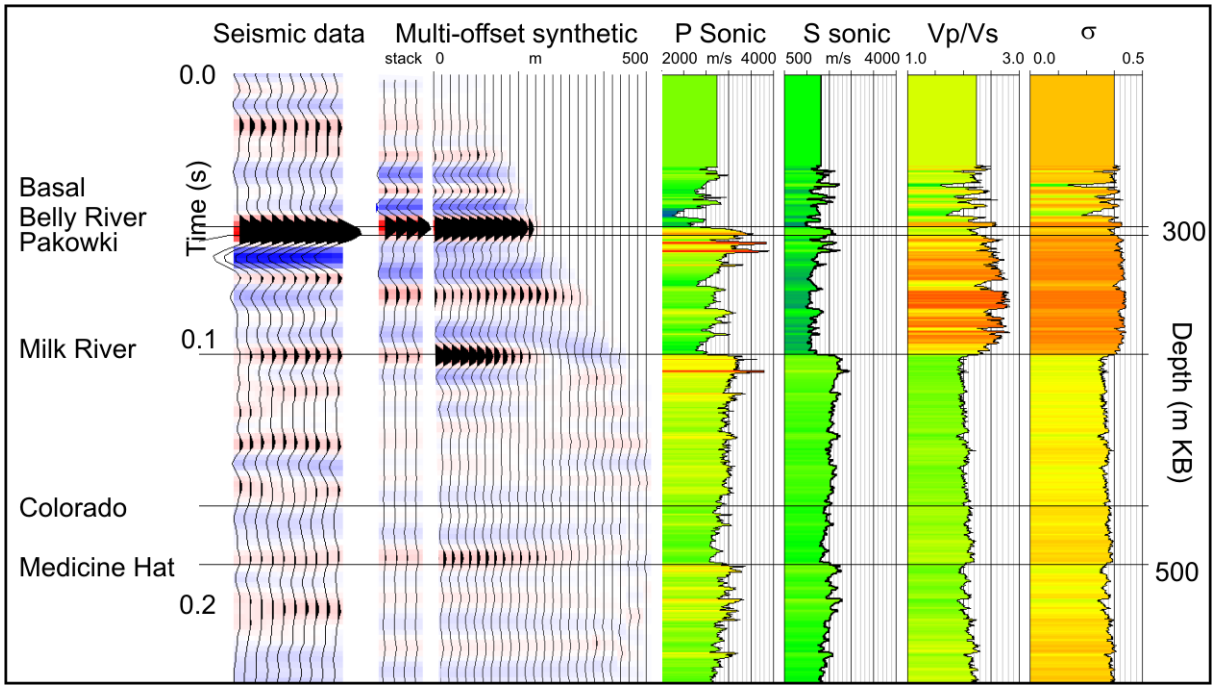

Figure 2: Migrated full-offset seismic data tied to stacked offset synthetic seismogram. Notice the improvement in the tie at the Milk River compared that of the normal incidence synthetic seismogram in Figure 1.

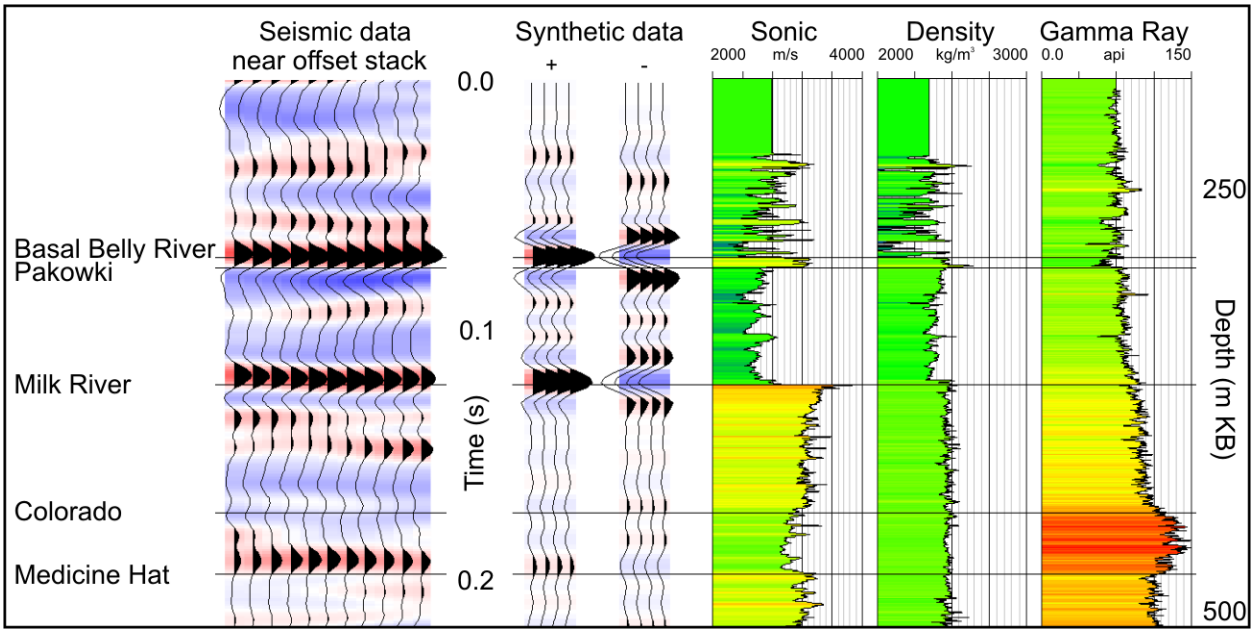

Figure 3: Migrated limited-offset seismic data tied to normal incidence synthetic seismogram. Notice the improvement in the character match at the Milk River compared to that of the full offset migrated seismic data in Figure 1.

We used Geoview software to create a PS synthetic seismogram. The character of the migrated PS data matched that of the stacked PS synthetic seismogram very well (Figure 4).

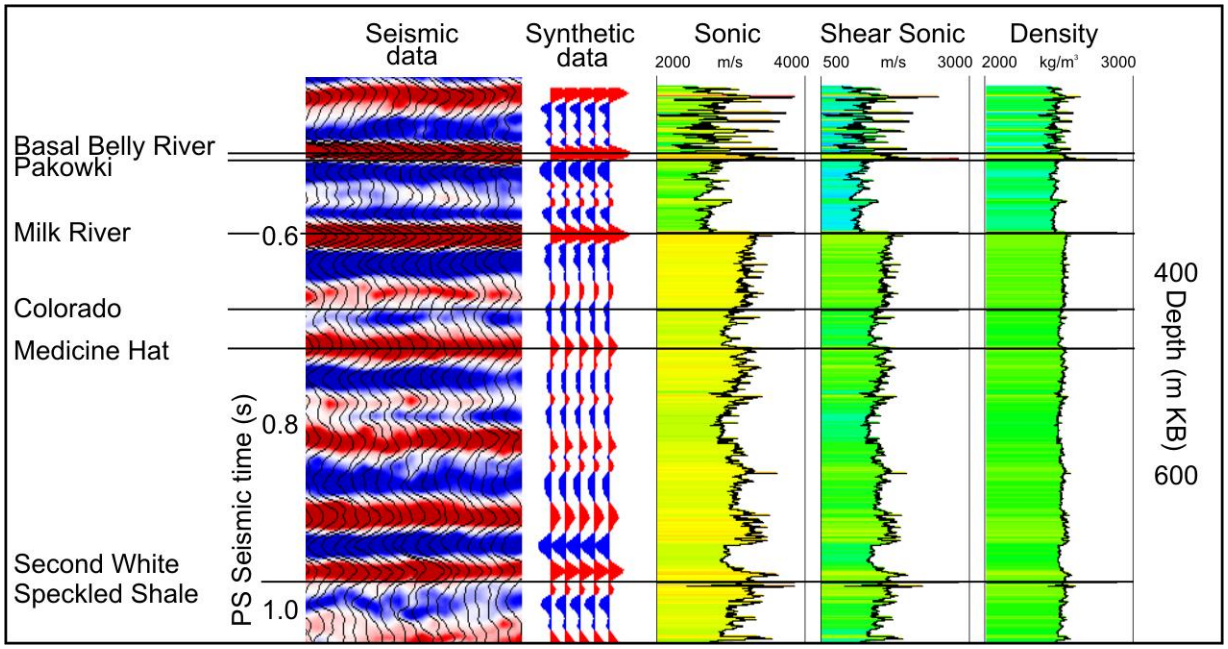

Figure 4: Migrated PS seismic data tied to the PS synthetic seismogram.

Conclusions

We observe a poor seismic character match between migrated PP seismic data and a default normal incidence PP synthetic seismogram for a high impedance sandstone (the Milk River Formation). The offset synthetic seismogram shows a decrease in amplitude then a change in polarity with offset and the stacked offset synthetic seismogram reveals a different response for the Milk River event than is seen on the normal incidence synthetic seismogram. Seismic data stacked and migrated using only the near offsets shorter than 250 m match the normal incidence synthetic seismogram while the seismic data stacked and migrated using all offsets match the stacked offset synthetic seismogram. The migrated PS data shows a good character match with the PS synthetic seismogram.

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