Getting Better Shear-wave Data over Heavy Oil: Rational for Buried Acquisition

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Summary

Burying receivers has advantages for coupling and for time-lapse repeatability. Depending on depth of burial we believe it may also offer the possibility of recording improved shear-wave data. Shear waves are of interest for monitoring heavy oil because of sensitivity to the changes in viscosity associated with heating the bitumen. Often shear waves suffer in resolution because of near surface attenuation, reducing their value. By placing receivers at depth below the unconsolidated layer, we expect to record higher resolution shear-wave data, better suited to monitoring temperature effects. We here describe a survey over a heavy oil reservoir intended to test this idea.

Introduction

The near surface is a major source of problems affecting seismic data. There are good geophysical reasons to believe that burying 3-C receivers below the near surface weathering layer may lead to a dramatic improvement in the resolution and quality of recorded data, particularly the mode-converted (PS) shear waves. In the absence of any attenuation, it is easily shown that PS data would have substantially higher vertical resolution than PP data, because of the shorter wavelengths associated with any given frequency. This is demonstrated in Figure 1 which shows a comparison of prestack depth migrated PP and PS images from the Marmousi-2 dataset, which is an elastic finite difference modelled dataset with no absorption. As seen in Figure 1, the resolution of PS is superior to PP, the opposite of our usual experience.

We believe there are two main reasons why this advantage for PS resolution is seldom observed in practice. The first is the negative effect of shear-wave splitting on the resolution of the PS data. This can be addressed by performing splitting analysis and a layer stripping correction, as has become standard practice in most 3-C processing. The second reason is the presence of low velocity highly attenuative near surface layers which adversely affect the transmission of higher shear-wave frequencies. The shear waves are more damaged than compressional waves because typically shear wave Q is lower than P-wave Q. Furthermore, as shown in Bale and Stewart (2002, "The impact of attenuation on the resolution of multicomponent seismic data", SEG Expanded Abstracts), the typical low Vs values in the near surface (in particular leading to high Vp/Vs values), further exacerbates the effect.

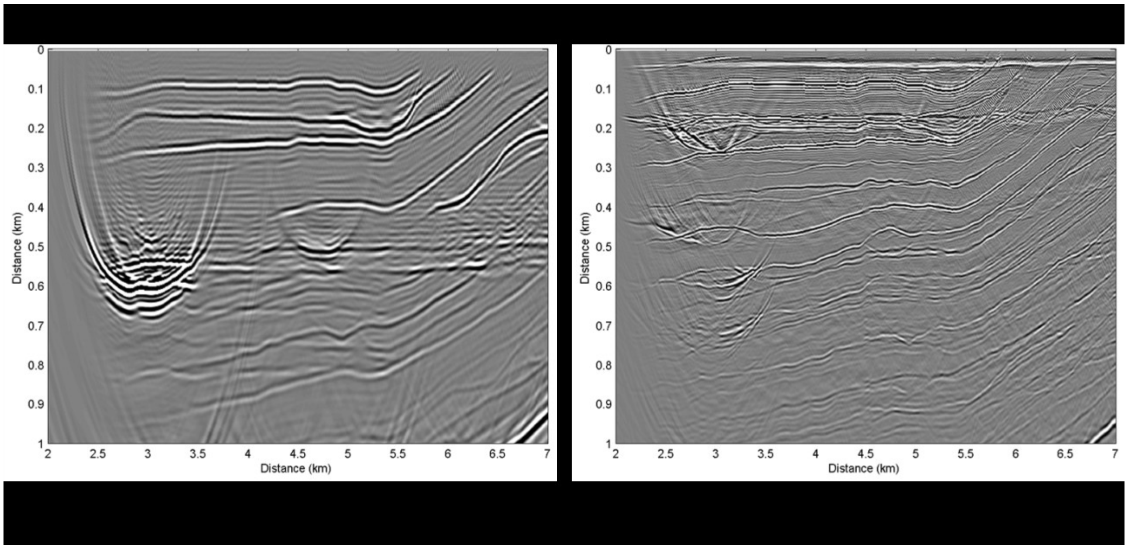

Figure 1. Comparison of prestack depth migrated PP and PS images from elastic finite difference Marmousi-2 dataset (from Bale, R.A., 2006, doctoral thesis, University of Calgary). Note the higher resolution on the PS section.

Recent work has demonstrated that for a heavy oil dataset acquired in Canada, we do observe very low values of shear-wave Q. The analysis was performed on receivers buried at 12m and was done by first separating the up- and down-going shear waves using a polarization method (DeMeersman, 2011), then using spectral division to estimate Q.

These observations strongly suggest that we would obtain a significant improvement in the useable bandwidth and therefore depth resolution of the PS data if we could place our 3-C receivers below the attenuative, low velocity weathering layer.

Oil Sands Field Test

The Whitesands pilot project is located in the Athabasca oil sands near Conklin, Alberta. The pilot project is testing a process called Toe-to-Heel-Air-Injection (THAI^{TM}) which is an in-situ combustion process used for the recovery of bitumen and heavy oil. It combines a horizontal production well with a vertical air injection well placed at the toe. The Whitesands pilot project is designed around three well pairs producing from a central facility. Air injection commenced on the first well pair in July 2006. Air injection on the second well pair was initiated in January 2007 and on the third pair in June 2007.

The position and progress of the combustion front has been monitored using tilt meters, passive seismic and active 4D seismic. Each of the three methods can identify the combustion zone but the 4D method provides the most reliable and detailed information. Compressional and shear velocities for bitumen are extremely sensitive to temperature. As the bitumen is heated by the combustion process the velocity decreases causing distinct time-delay anomalies on timelapse (4D) seismic. For the pilot project, these time-delay anomalies indicate that the combustion front is moving from the toes of the wells, where the air injectors are located, towards the heels. Downhole thermocouples are used to measure the temperature and hence provide control/calibration points.

In 2011 Petrobank Energy and Resources Ltd. and CGGVeritas began a joint project using permanent buried 3-component sensors. The permanent sensors will provide long term cost savings, better data quality and improved repeatability. For the 2011 survey the permanent sensors were collocated with the surface sensors. Side-by-side comparisons of the two surveys will demonstrate the differences in the two acquisition geometries. The surface sensors were Sercel DSU's at a group interval of 10m. The permanent sensors were OYO 3-component nails buried 18m and at a group interval of 20m. We chose to bury the permanent senses at a depth of 18m ensuring they were below the poorly consolidated/gravel layer. At one location we had a permanent sensor at 18m (in clay), another at 8m (in gravel) and a surface sensor.

We will use this permanent array for continued active and passive monitoring. We will also use the buried sensors to study the effects attenuation caused by the near surface.

Conclusion

Motivated by the advantages of buried sensors for time-lapse monitoring, as well the opportunity to record better shear-wave data, multicomponent acquisition has been conducted with sensors buried at 18m depth, coincident with a surface dataset. We hope to present preliminary analysis and comparisons between buried and surface data in our presentation.

References

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DeMeersman, K. [2011] S-wave attenuation within the weathering layer of an Alberta heavy oil field, submitted to CSEG, this convention.