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Oilsands: Not Your Average Seismic Data

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Summary

This paper is an examination of the issues inherent in processing and interpreting Athabasca oilsands plays. For example, the most common form of examining seismic data is by taking its average to produce the seismic stack. Canadian oilsands plays are Class II AVO plays, which are near zero amplitude at zero offset with a risk of amplitude cross-over with offset. Therefore, stacking all these offsets may result in poor well ties. There are many more aspects of the prestack seismic data that we need to be aware of in order to make better use of seismic data in these plays. More thought must be put into appropriate attributes and processes, which bring out the features of the reservoir that are of interest. It is the purpose of this paper to give some guidance on these issues.

Method

Multiples and Converted Waves

There have been reports of multiple attenuation being used in oilsands plays. Since the velocities in the oilsands and overburden are relatively constant at about 2200 m/s (Figure 1), high-moveout multiples are not possible. Rather, any high residual moveout events must be converted waves. Figure 1 is a test of this concept, where a well with velocities sampled well into the overburden are used to create a full elastic model of the seismic gathers. Then different components, converted waves, multiples and primaries are separated out. This model clearly shows that any high moveout events in the reservoir zone are converted waves, and multiples are basically flat. Radon transform multiple attenuation will probably introduce incorrect zero-offset amplitudes in the gathers because it is difficult for the radon transform to model the huge amplitude variation with offset expected for converted waves. This effect is worse than leaving the converted wave in the gathers. Preferred is rotation of the converted wave off the P-wave component onto the converted wave component, which is possible if multi-component seismic data has been acquired (Bale, 2011).

Stacking and AVO

Examination of the primaries in the modeled gathers (last panel of Figure 1) shows that the bulk of the amplitudes are visible on the near offsets, which then fade significantly towards further offsets to the point where they may even change polarity. Based on these characteristics, these are Class 2 AVO (Rutherford and Williams, 1989). In order to properly tie Class 2 AVO to zero-offset well log synthetics, near offset stacks or AVO intercepts are preferred. Fortunately, near offset stacks will also be little affected by converted waves, since they have negligible energy at the near offsets, as can be seen in the “Converted” panel in Figure 1. Therefore, near-offset stack is probably the easiest method of tying well log synthetics. Since the converted waves negligibly affect the near offsets and cross the far offsets at a steep angle, robust AVO fitting techniques or rotation on to principal components will significantly reduce their effect.

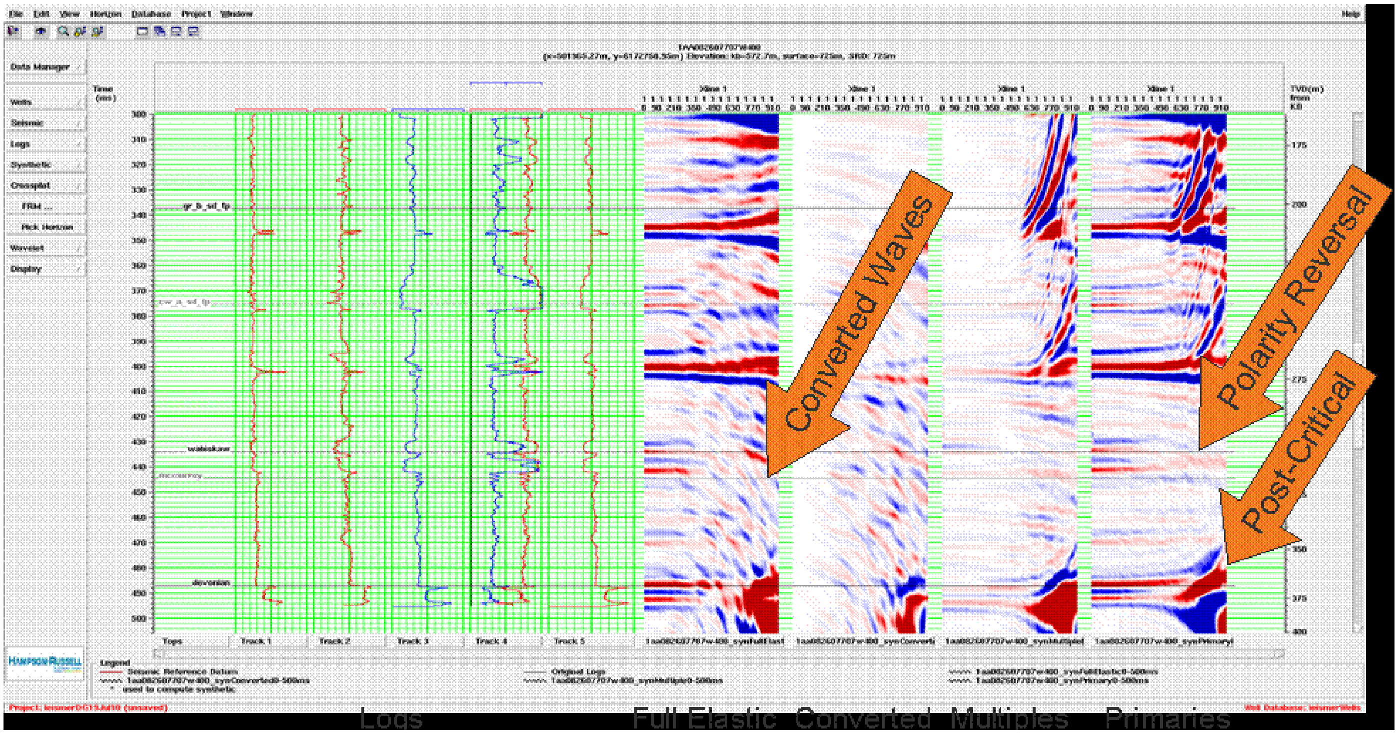

Figure 1: AVO model from oilsands well showing the presence of converted waves and polarity reversals in the McMurray reservoir zone and phase-rotated, post-critical events due to the large velocity contrast at the top of the Devonian interfering with the deepest McMurray reflections.

Azimuthal Anisotropy

Azimuthal variations have been observed above oilsands reservoirs in conventional data (Gray, 2007) and multi-component data (Whale et al, 2009). Since there is converted-wave birefringence and the shear-waves have followed almost exactly the same raypath, the effect must be due to seismic velocity anisotropy in the overburden (Bale, 2011). In Figure 2, both velocity and amplitude anisotropy are observed in the reservoir, the overburden and the underburden in the prestack data. These effects must be accounted for in order to both properly process the data (see, e.g. Gray et al, 2009) and to derive the isotropic properties of the underlying rock.

Density, AVO and Vsh

Figure 3 shows that there is a strong correlation between the gamma ray log, which is related to the shale proportion, Vsh, and density. Since density can be derived from seismic gathers using prestack AVO inversion, there is a strong possibility of using seismic to detect Vsh (see, e.g., Gray et al, 2005). Since density information is derived from wide-angle seismic reflections, therefore, it is extremely important to maintain and optimize these reflections through processing. This means, at a minimum, dealing with both azimuthal and polar anisotropy and with wide-angle noise, like the reverberations from the first breaks. Figure 4 shows that density extracted from the seismic correlates about as well with the well logs through the reservoir as the P-impedance and significantly better than with the S-impedance. The better correlation with density suggests that this bitumen reservoir behaves like an acoustic medium, i.e. sand grains floating in a liquid medium (a slurry), which is the way these reservoirs are frequently described. Therefore, this significantly better correlation of density than S-impedance makes sense for Athabasca oilsands reservoirs.

Reflections and Refractions

Figure 5 shows that for typical values of the elastic properties in oilsands over those for a carbonate, critical angles will occur at very small angles of about 30 degrees. These are angles that are frequently used in stacking and AVO. Critical angle is where the reflection changes to a refraction. There is also a phase

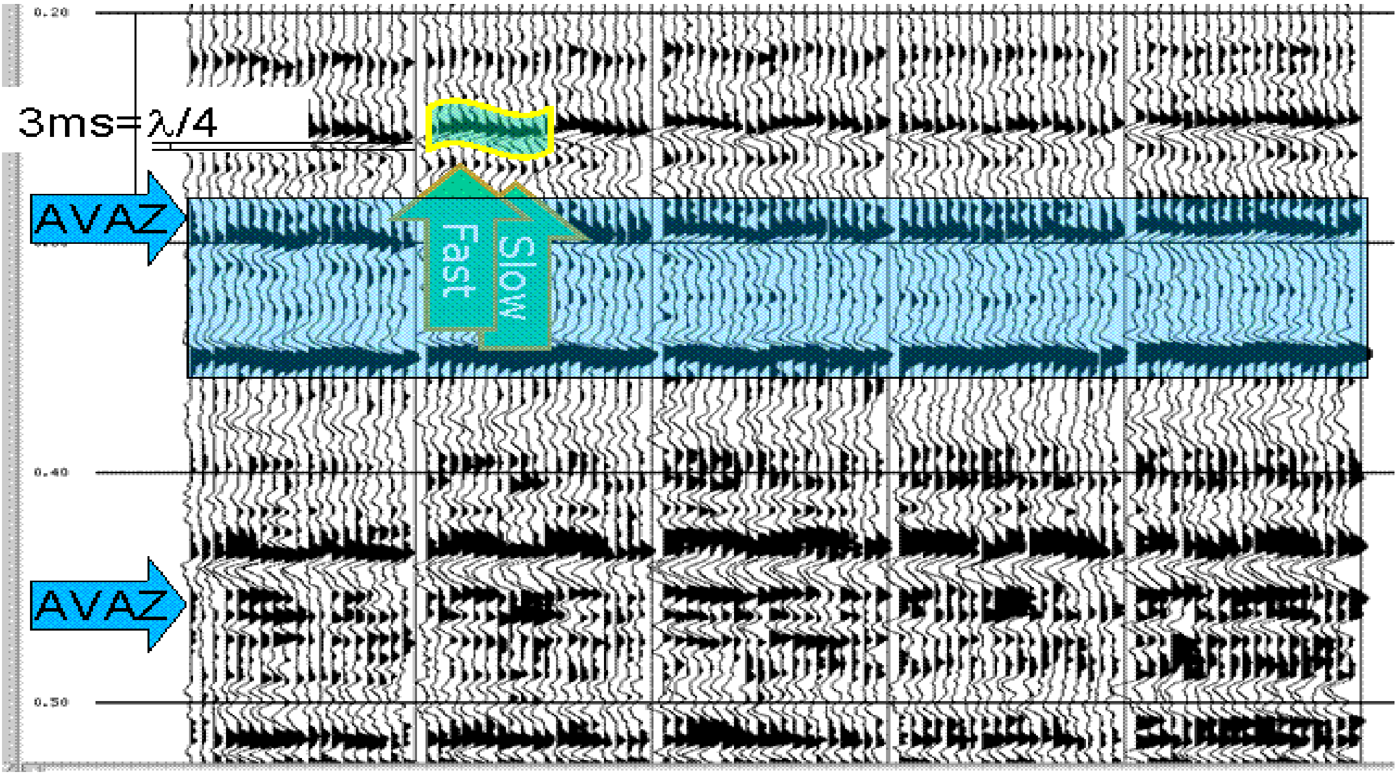

Figure 2: Azimuth-varying 350-400m offset stack showing azimuthal variations in traveltime above the reservoir at about 250 ms and amplitude variations with azimuth (AVAZ) within and below the reservoir. Azimuths range from -180 to 180 by 36 degrees.

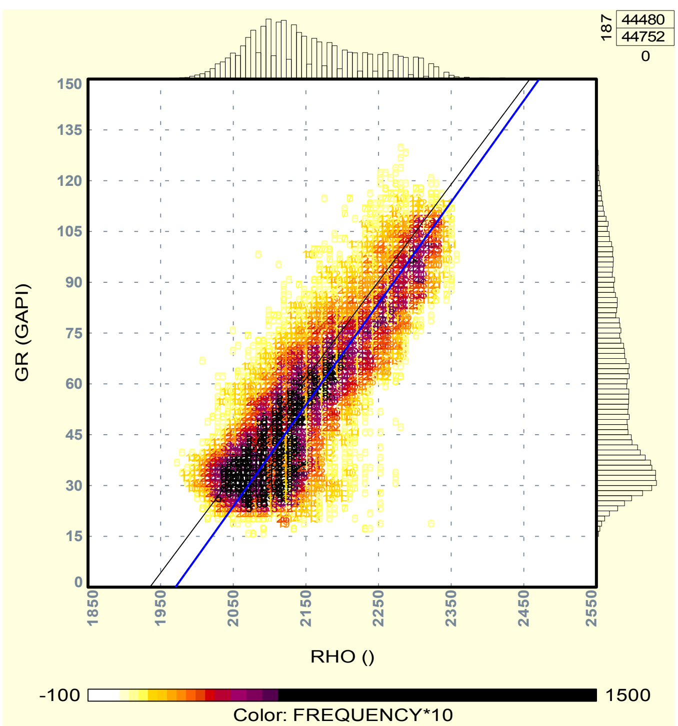

Figure 3: Gamma ray (GR) versus density (RHO) crossplot derived from 76 logs in the Long Lake area showing the strong relationship (r2 = 0.83) between these two variables.

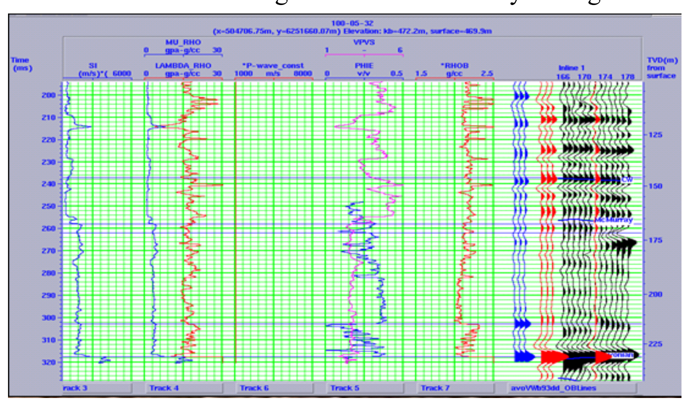

Figure 4: Density reflectivity from three-term AVO correlated to density reflectivity estimated from the wells.

Long Lake Attribute Correlations			
Well	*Attribute*		
	Rd	*Rp*	*Rs*
102-6-32-85-6W4	0.71	0.78	0.16
102-4-32-85-6W4	0.51	0.60	0.11
100-4-32-85-6W4	0.57	0.59	0.14
102-1-31-85-6W4	0.85	0.84	0.43
100-6-32-85-6W4	0.79	0.80	0.50
102-5-32-85-6W4	0.77	0.83	0.21
100-5-32-85-6W4	0.68		
100-1-31-85-6W4	0.86	0.88	0.75
Median	0.74	0.80	0.21
Average	0.72	0.76	0.33

Table 1: Typical correlations of the AVO results to density reflectivity, Rd, P-impedance reflectivity, Rp, and S-impedance reflectivity, Rs. After Gray et al, 2005.

change associated with post-critical refractions. Figure 1 shows that this phase change rotates the energy of this diffraction into the overlying oilsands reflections, making it difficult to use AVO at the base of the reservoir. Since this is the area where SAGD well pairs are most likely to be placed and we are interested in density, which is stabilized by the use of wider angles, this presents a significant problem, which remains unresolved at this time.

Discussion

There are many issues to be aware of when working with seismic data from the Athabasca oilsands area. Shown here are some of the more significant issues. It is important that you are aware of them when processing and analyzing seismic data in these areas.

Acknowledgements

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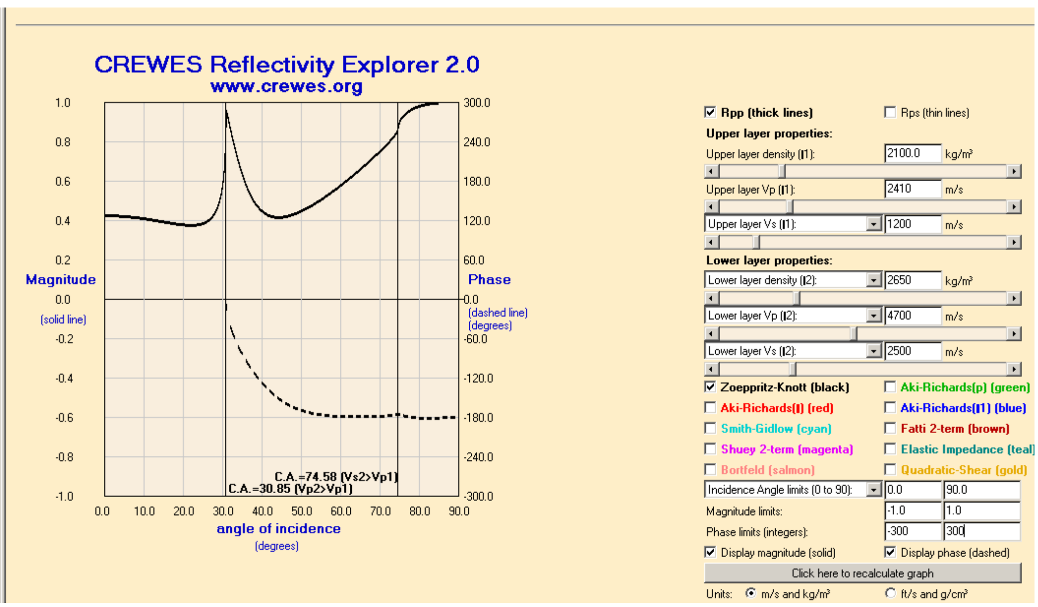

Figure 5: Typical values for oilsands elastic properties (Vp, Vs, density) indicate that critical angle will occur at ~30 degrees for the Devonian reflector. The solid line is amplitudes and the dashed line is phase in degrees.

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