Delineating Sand Channels using 3D-3C Seismic Data: Manitou Lake Heavy Oilfield, Saskatchewan

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Summary

Exploration targets of this survey (undertaken in the Manitou Lake heavy oilfield, Saskatchewan) include the Colony and Sparky sand channels, both members of the Cretaceous Mannville Group. These intervals are currently producing oil and gas in the area. Our goal is to investigate the usefulness of 3C-3D seismic data in discriminating sand versus shale and finding hydrocarbon-filled porosity. Detailed registration of PP and PS sections followed by joint inversion aims to reduce the uncertainty of traditional channel interpretation and improve well targeting. Seismic attributes as AVO, simultaneous inversion, and LMR methods can complement the information for drilled wells and possibly identify new drilling locations.

Introduction

The Manitou Lake oilfield is located in west-central Saskatchewan, close to the Lloydminster area. Hydrocarbon reservoirs in the lower Cretaceous fluvial sand channels occur at about 550m depth for the Colony and 610m depth for the Sparky. The Colony is a sand member of the Pense Formation, and the Sparky of the Cantuar Formation in the Mannville group. Their thicknesses may be up to10m. The oil gravity in this area is around 12°API. Well log analysis indicates that the sand channels can have high porosities with values upwards of 30%, and high permeability.

The Manitou Lake 3C-3D seismic survey was acquired for Calroc Energy Inc. by Kinetex Inc. near Manitou Lake, Saskatchewan, in February 2005. It covers an area of approximately 10 km^2, with twenty one south-north receiver lines and eighteen west-east source lines, with 200 m line spacing and 50 m station spacing (Lu et al., 2006). The vertical (largely PP) and the radial (mostly PS) component data have been processed to final migrated volumes by Hanxing Lu and Kevin Hall of the CREWES Project. The processing flow for Manitou Lake data includes deconvolution, time-variant spectral whitening and FD migration after stack.

Rock properties

In this study, three well logs: A11-17, C10-17 and C7-16 were used to evaluate the relations between different rock properties and the elastic parameters. The logs included natural gamma (GR), spontaneous potential (SP), density, neutron and density porosity, caliper, and resistivity. Only well A11-17 had an S-wave sonic log. Shear sonic logs are helpful in interpreting converted-wave data through the construction of PS-wave synthetic seismograms. Low Vp/Vs values (less than 2.15) indicate sand intervals. The change of

Vp/Vs value in the reservoir is not only due to the variation of porosity, but related to the shale volume and water saturation. Water saturation can increase the Vp/Vs value for both, sand and shale (Yong Xu, 2002).

PP and PS interpretation

The interpretation of the PP migrated volume was undertaken by correlating well logs to the seismic data and picking horizons based upon well control. Figure 1 shows the well log correlation with seismic at the A11-17 location. From left to right we can see the following curves a) Porosity (brown), Gamma Ray (blue), SP (red), Density (blue), Resistivity (black), S (blue) and P(red) sonic logs, Vp/Vs (red) value and correlated with the PP seismic and b) sonic logs (P wave sonic in red and shear sonic in blue) the Gamma-ray curve (blue), SP (red), and Density for the PS interpretation. Figure 1 a) shows that at the Colony sand

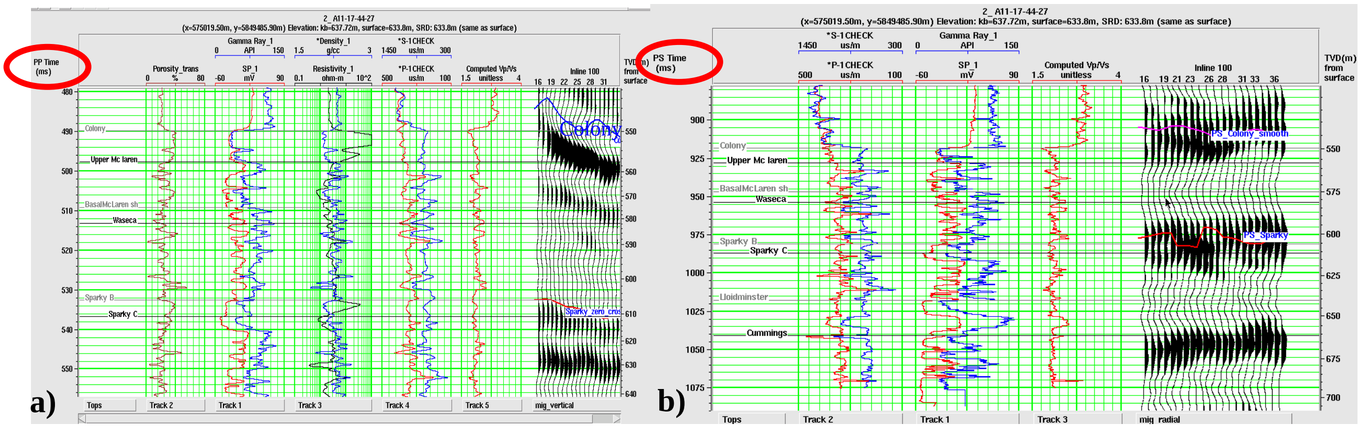

Figure 1.a) Porosity, Gamma Ray, SP, Density, Resistivity, S and P sonic logs, Vp/Vs at well location A11-17 in PP time b) Seismic and well log correlation in PS time at well location A11-17 in PS time

there is an increase in porosity, a sharp decrease on the Gamma Ray and SP, a density decrease, an increase in resistivity, an increase on the shear sonic and almost no increase on the P-wave sonic, followed by a lower Vp/Vs value. P waves are sensitive to the changes in the pore fluid, which on the other hand does not affect the velocity of S-waves. Vp/Vs gives the best differentiation regarding the lithology - with values between 1.70-2.15 for sands and for shales from 2.15-3 (Quijada and Stewart, 2008).

Registration

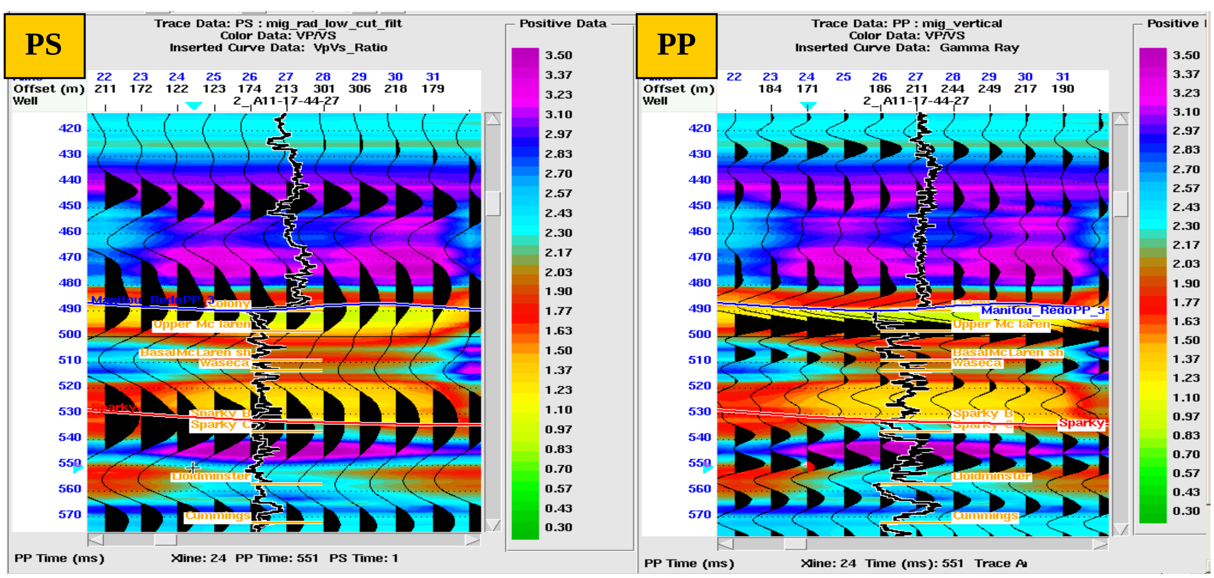

Figure 2.Well A11-17: Registration and horizon match using the Hampson Russell ProMC software package. The Colony horizon is in blue and the Sparky in red. Background colors give the Vp/Vs values from time thickness ratios. Sand channels are interpreted as having values less than 2, in yellow.

There are some challenges when processing the mode-converted data: some issues include separation of P wave arrivals and the large magnitude of shear-wave statics. Registration can be also interesting. As seen in Figure 2, on the PS section registered in PP time (left), the Colony and Sparky B and C sands sand are picked on a peak, compared with the PP (right) section where they are picked on trough.

Method and Interpretation

An interactive registration based on gamma function (related to P and S velocity ratios) was performed in the Transform software after horizons were re-picked. The basis for this registration was to focus on high and low energy zones using the amplitude envelope. Spectral enhancement was performed before applying the post stack recursive inversion.

After registration, the Colony and Sparky PS and PP amplitude maps showed better results than the previous interpretation. Higher amplitudes indicate the sand channels as in Figure 3.We note a better delineation of the sand channel (circled in white) at the Colony and at Sparky level, where a previous drilling location did not encounter the reservoir. The "dry hole" was based only on conventional PP seismic data interpretation.

Several techniques as AVO analysis (a direct hydrocarbon indicator in clastic rocks, based on a detected class 3 anomaly, showing bight spots) followed by simultaneous inversion, LMR, fluid factor, elastic impedance, separate inversions of PP and PS data and joint inversion after the registration in PP time, were used in attempt to extract pore fluid and lithology information from the seismic and well log data. The results were compared with combinations of seismic attributes as amplitude, curvature and coherence on both, PP and PS volumes. The results from the Vp/Vs values combined with the fluid factor (that shows the highest values within the channel boundaries) show the best correlation with the well productivity. The localized lateral changes in amplitudes and curvature co-rendered at the Colony and Sparky horizons from the PP and PS volumes helped to recognize the geologic features, as in Figure 3.

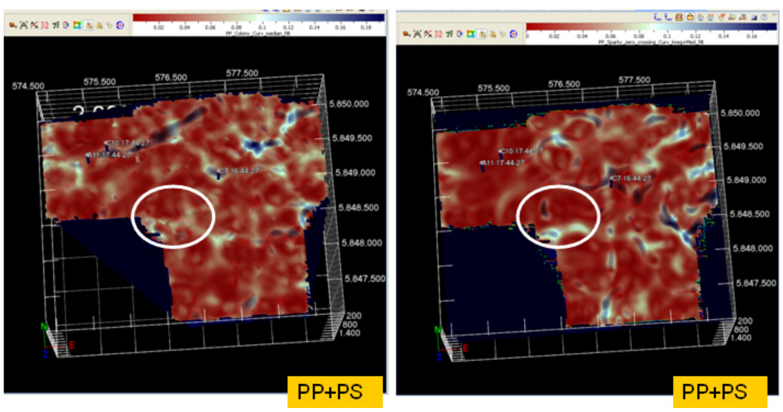

Figure 3.Left: the Colony and right: Sparky horizons in Transform software. PP+ PS Curvature is co-rendered at the Colony (left) and Sparky (right) interpreted horizons.

Figure 4) provides our result for the Vp/Vs map at the Colony sand channel. The black arrow indicates: a) a possible reservoir based on PP data showing lower values of Vp/Vs, whereas on b) the PS volume shows high Vp/Vs values at the same location. Our confidence in the interpretation will increase looking at the Vp/Vs values at c) after the joint inversion of PP and PS (registered in PP time) migrated stacks and d) after the simultaneous inversion following the AVO analysis performed on prestack gathers (P impedance, S impedance, density and Vp/Vs volumes were compared).

Conclusions

This paper outlines some of the mechanics of interpreting multicomponent seismic data. Differences in PP and PS attributes can assist with interpreting sand development, due to the direct response of PS data largely to lithology. Attributes computed from PP and PS volumes show different geologic features.

Sandstones have larger S-wave velocities; hence oil- and gas- saturated sand channels can be manifest with relatively low Vp/Vs values (less than 2.15). The channels can be filled with sands and/or shales, with similar P-wave impedances.

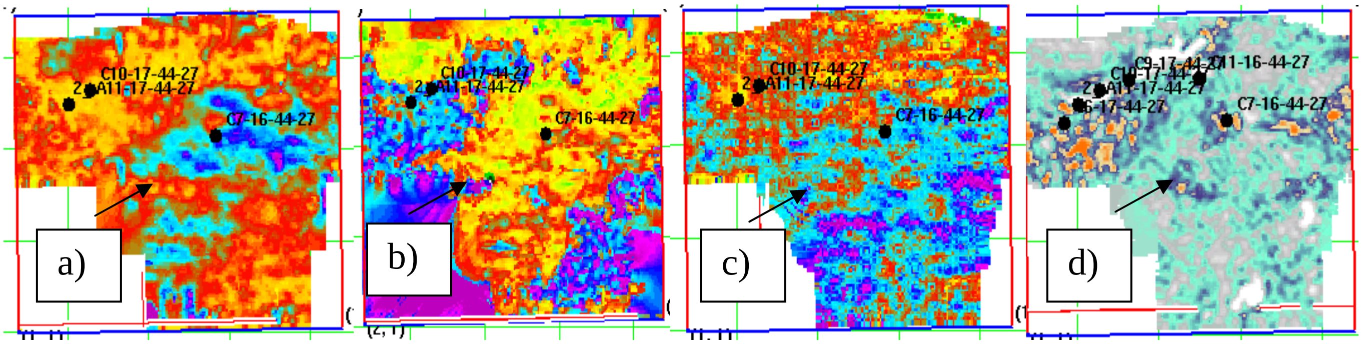

Figure 4.Vp/Vs values at the Colony horizon: a) on PP data after registration (blue color shows high ratio values), b) on PS data after registration (blue color shows high ratio values), c) after joint inversion (blue color shows high ratio values) in ProMC package and d) after AVO analysis followed by simultaneous inversion on prestack gathers (the reservoir is shown in white color, highest Vp/Vs are in blue and orange)

From the dipole sonic log, we find that S-wave impedance is higher in the sands than in shales.

The fluid factor shows the highest anomalous values within the channel boundaries.

Vp/Vs values from joint inversion combined with Vp/Vs derived from AVO simultaneous inversions are useful in delineating the reservoir. Vp/Vs values extracted from the PS volume (after registration) computed from traveltimes shows different result than the PP seismic data. The result shows similarities with the simultaneous inversion (from the AVO analysis).

The lithology predictions from inverted rock properties show good correlation to the wells. AVO and inversion minimizes the uncertainty in sand and shale identification, contributing to optimal well placement.

Acknowledgements

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