Searching for sand in Saskatchewan: Manitou Lake 3C-3D Seismic Project

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Summary

Lower Cretaceous fluvial sands channels with high porosity and permeability in the Manitou Lake area of Saskatchewan contain important oil and gas reserves. Well logs and synthetic seismograms are used to correlate the PP and PS seismic sections, from a 3C-3D seismic survey, to better delineate the Colony and Sparky reservoir sands. Mode-converted (PS) seismic amplitudes can complement traditional PP channel interpretation. Amplitude maps at the Colony sands show different aspects of the channel interpretation. Lithology and fluid discrimination based on Vp/Vs values are derived from the inverted PP and PS (registered in PP time) sections. Detailed registration of multicomponent seismic data aims to reduce the uncertainty and improve well targeting.

Introduction

Exploration targets of this survey 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 see if the interpretation of 3C-3D seismic data can help discriminate sand versus shale and find gas-charged porosity.

We know from previous work that increasing sand yields greater porosity. A larger porosity can lower the P-wave velocity. So, a good reservoir should have a lower Vp value. The presence of hydrocarbons also lowers the Vp. The S-wave velocity is often seen to increase from shale to sand. Hence, Vp/Vs is lowered in sandstones. The interpretation of P-wave seismic reflection data can lead to ambiguous conclusions in certain exploration situations. Differentiation of prospective channel sands and non-productive shales could be problematic due to the similarity in P wave impedance of these two lithologies. We expect PS data to be a direct measurement of the channel system, knowing the fact that should respond largely to the lithology and less to the fluid content.

Acquisition and Processing

The Manitou Lake 3C-3D survey was acquired for Calroc Energy Inc. by Kinetex Inc. in February 2005, covering an area of approximately 10 km², 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). Figure 1 shows the location of this area, and an amplitude map on the interpreted Colony horizon. A channel-like feature is evident.

Lithology Differentiation and Geology

The logs available in this study include the gamma ray (GR), spontaneous potential (SP), density (RHOZ), resitivity, and sonic logs. All wells have a P-wave sonic while an S-wave sonic is available for well A11-17. Figure 2 shows Vp/Vs versus gamma ray for this well. We can note lower GR values in the Manville Group and a sharp contrast between the shales above Colony and sands.

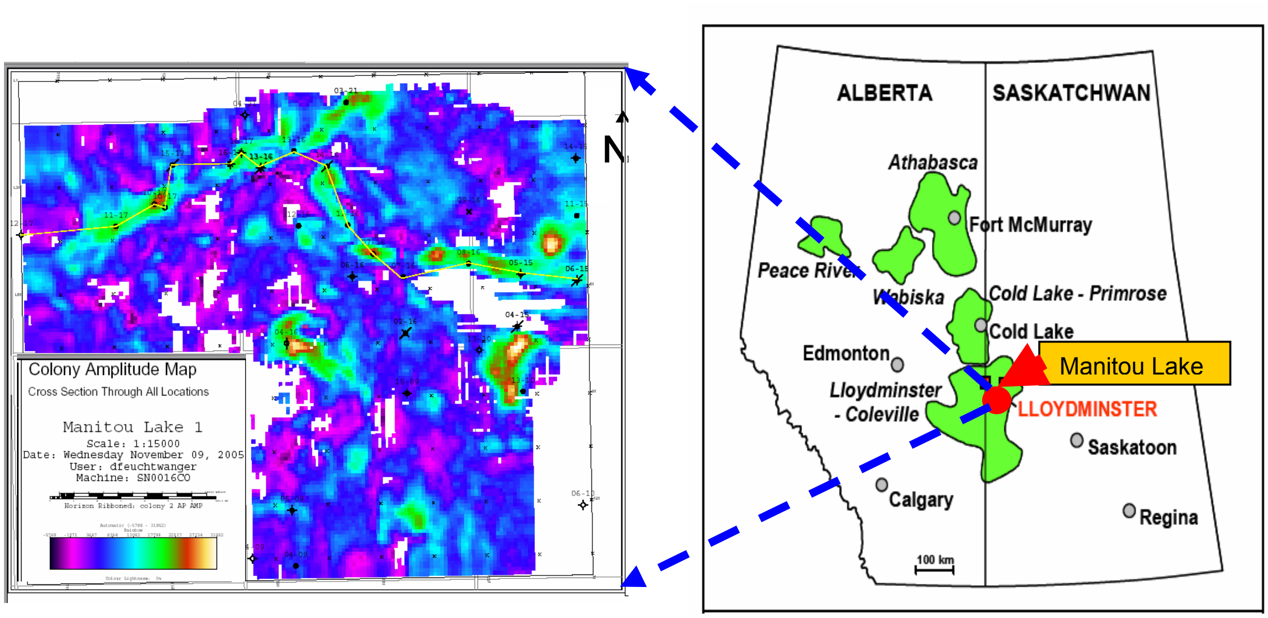

Figure 1: Left: Amplitude map for the Colony sand. Right: Map of major heavy-oil deposits of Alberta and Saskatchewan, and location of the study area (after Watson, 2004)

The Colony sand member consists of shales, siltstones, coals and sandstones. Deposition of this member occurred in an extensive complex of channels sandstones, encased within siltstones, shales, coals and thin sheet sandstones.

The Sparky member is informally grouped into the middle Mannville, which is dominated by sheet sandstone development, with narrow, channel sandstones and shales also present. These units have been interpreted as a delta-front facies with associated tidal-flat, tidal-channel, and beach environments. The sheet sandstones in Sparky are commonly 6-9 m thick, and can be traced laterally for several tens of kilometers; however, they are commonly broken by thick ribbon-shaped deposits or sandstone pinchouts (Putnam, 1982).

Manville marks a clear separation between the predominant sands and the overlaying marine shales of the Colorado and Belly River Group.

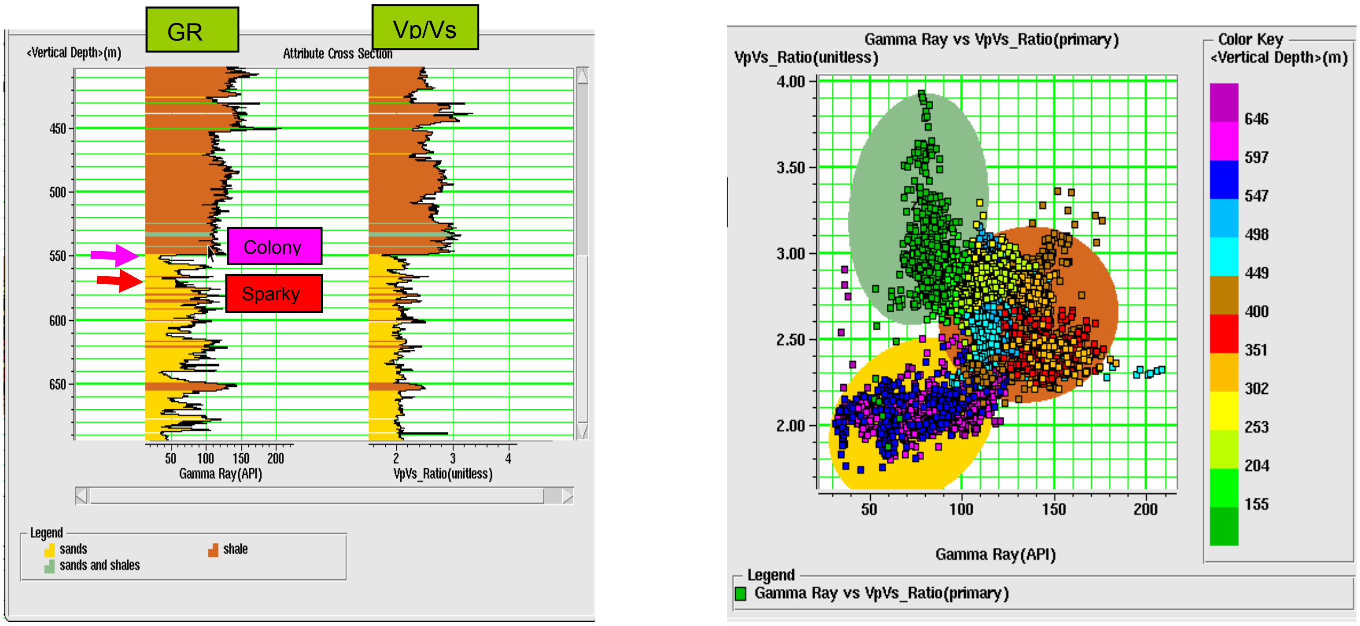

Figure 2: Gamma ray versus Vp/Vs for well A11-17. Left: Cross-section for well A11-17 delineating three zones with different lithology. Low values in the gamma ray log indicate permeable sand intervals with high porosities. The selected types of lithology are: sands (yellow), shales (brown) and sand/shales (olive). Right: Cross-plot for well A11-17 delineating the three zones with different lithology.

Analysis and Interpretation

After a geological review of the area, P-wave interpretation was undertaken using logs, synthetics and PP-seismic volume to identify horizons. Time structure maps and isochron maps were helpful to determine the time thickness between horizons. With the generation of amplitude maps the channel system is evident, see Figure 3. A P-wave model was generated and PP inversions were undertaken. We were looking for the anomalies, trying to understand the reservoir.

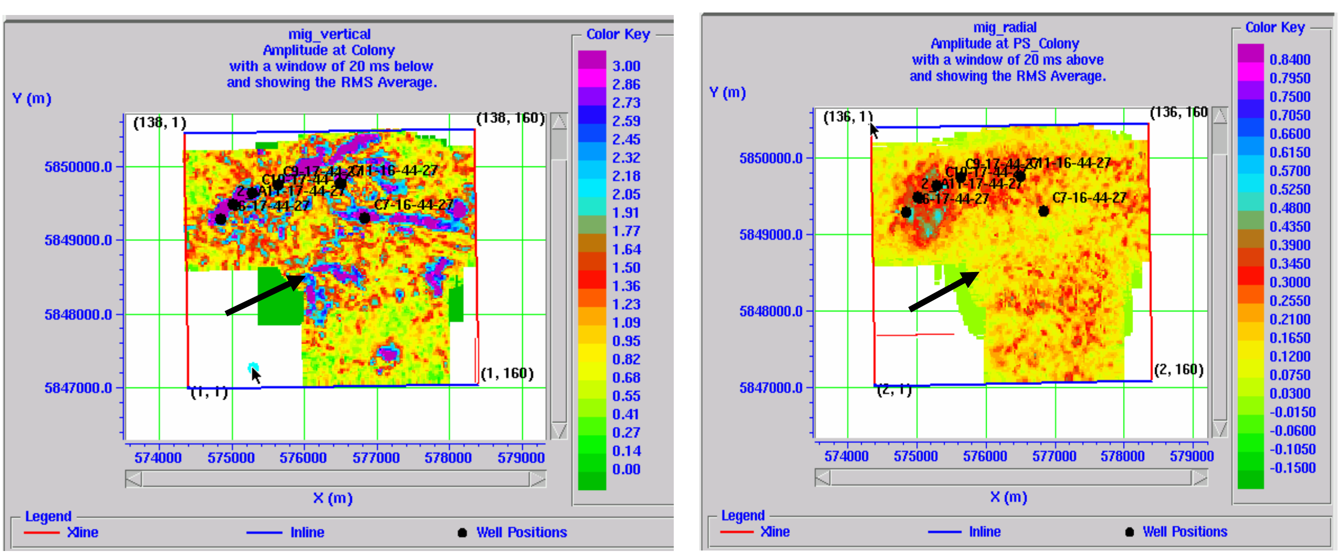

Figure 3: .Left: PP-RMS amplitude map for in a 20ms window below the Colony sand, Right: PS-RMS amplitude map with a 20ms window below the Colony sand. High RMS amplitude is believed to be a direct PS seismic response to the presence of channel lithology. Black arrows show a drilling location that did not encounter reservoir, based previously only on PP amplitude maps.

The next step was to create the PS synthetic seismograms. In the logs without a dipole sonic, shear logs were created using the Castagna equation. The PS synthetic seismogram was correlated with the PS seismic volume in PS time. Registration was done in PP time, trying to shrink the PS section to match the PP section, as in Figure 4. We consider PS data to be a direct measurement of the channel system, given that PS data should respond largely to lithology. In Figure 3(right), a PS amplitude map can help us to better understand the unsuccessful drilling location. After registration, a PS model in PP time was created for inversion. The ratio of the PP inversion to the PS inversion is shown in Figure 5. On left, the yellow colour represents the sands and corresponds to the Colony (pink arrow) and Sparky (red arrow) horizons, showing the sand channels. Brown colour shows the shales, olive shows the mixed sands and shales. On right, we can see the amplitude map at the Colony sand. The black arrow shows an unsuccessful drilling location, based previously only on PP amplitude maps.

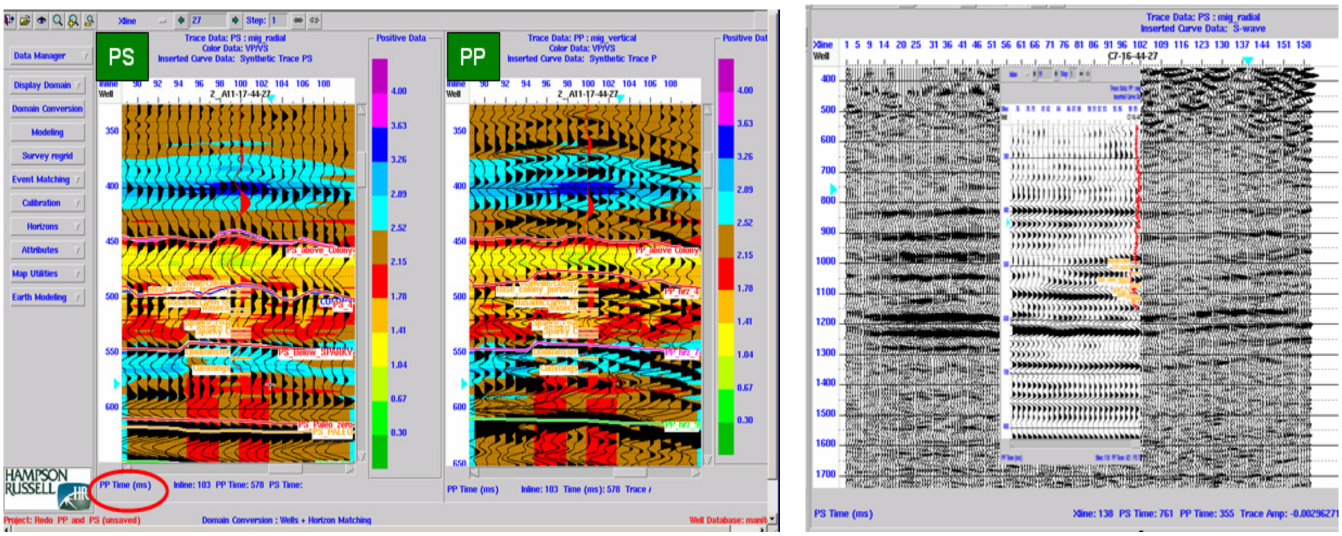

Figure 4: .Left: PP and PS interpretation after registration and horizon match at well location 2A-11. The Vp/Vs ratio derived from horizon-based registration is shown in color. Right: stretched PP section to match the PP section in PS time, to identify horizons at well location C7-16.

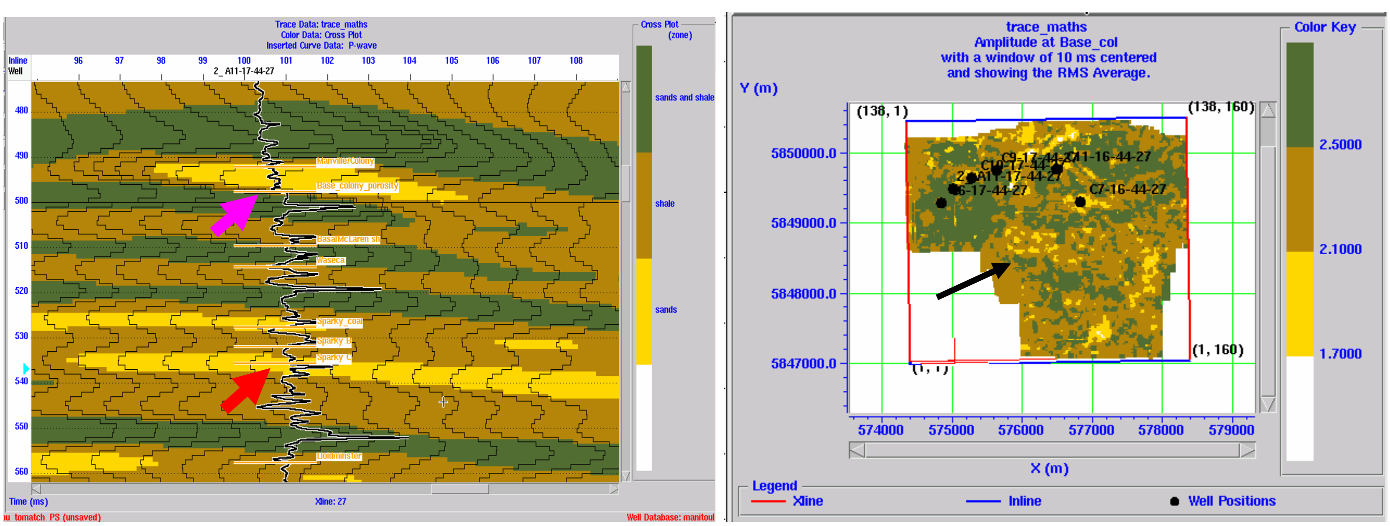

Figure 5: Vp/Vs as calculated from the ratio of PP impedance to PS impedance in PP time. In colors: sands in yellow, shales in brown and mixed sands and shales in olive. Left: ratio of inversions at well A11-17. Pink arrow shows the Colony and red arrow shows the Sparky C sands. Right: Vp/Vs map - amplitude with a 10ms RMS window above the base of Colony sand. Black arrow shows an unsuccessful drilling location, based previously only on PP amplitude maps.

Conclusions

PS data is helpful in the planning and risking of new drilling locations. Differences in PP and PS amplitude maps can assist with drilling positioning, due to the direct response of PS data largely to lithology. Oil and gas saturated sand channels should give relatively low Vp/Vs values, a P impedance decrease and an S impedance increase. The channels can be filled with sands and/or shales, with similar P-wave impedances. From the dipole sonic log, we find that S-wave impedance is higher in the sands than in shales. The ratio of the PP inversion to the PS inversion (Vp/Vs from amplitudes) in PP time is useful in delineating the reservoir. Vp/Vs values computed from time thickness ratios can help in estimating the rock type as well as delineating reservoirs.

Work continues on this project. AVO, fluid substitution, and simultaneous PP and PS inversions are the next steps.

Acknowledgements

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