2011 CSPG CSEG CWLS Convention

Unraveling Cardium Tight Sand Paleo-depositional Trends and Subtle Structural Features using Seismic Reservoir Characterization

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Summary

Shoreface sand of the Cardium formation is one of the most prolific hydrocarbon reservoirs in the WCSB and to-date has produced 1.7 billion barrel of conventional oil. According to the recent estimates the Cardium formation may hold up to 15 Billion bbl oil in place. With new technologies like multi-stage fracing of horizontal wells and various flooding techniques the recovery factor could reach as high as 20% thus putting the remaining oil potential to be more than a billion barrel. A large amount of this remaining oil is trapped in tight sand located in the Ram River member.

Within this study seismic sequence stratigraphy, seismic geomorphology, volume curvature and neural network based facies analysis are integrated with extensive geological and well log analysis work to predict thicknesses, paleo-trends, permeability barriers and natural fracture trends within the Cardium sand. By knowing these factors better horizontal well planning can be achieved thus exploiting hidden high permeability trends. Seismic reservoir characterization using state-of-the-art tools are applied to uncover subtle stratigraphic features.

Introduction

The Wapiti-Bilbo-Kakwa area is located at the northwestern edge of the Cardium sand fairway. Cardium Main sandstone, also known as Kakwa member, has recently been added to the list of Alberta tight oil plays. The work previously published on the Cardium is mainly focused on geological and well log analysis; a few authors have used multi-component seismic to separate the conglomerates within Cardium Fm. Seismic attribute analysis of 3D data shows promising results to help build a finer facies model. 3D seismic covering the paleo-shoreline has significant geomorphologic features which could not be identified using well-log data only. Seismic amplitudes provide clue to thickness of sand, while linear filtering and dip-steering provides indicators of shore-face beach berms, channel systems and also paleo-depositional directions.

Furthermore, seismic vector quantization of waveforms link directly to the geological facies and effect of various saturations (gas, water or oil) on the seismic traces. Volume curvature analysis is another tool to help delineate the subtle surface features which help in reconstructing micro geological affects.

Seismic Reservoir Characterization

Exploration for Cardium sand is traditionally done using offset drilling, well log correlations and geological mapping. Seismic amplitude information is used but there are a few issues. The main problem with seismic amplitudes is three-fold, (1) gaps in data due to surface features do not fully heal at the Cardium level as it is a shallow zone, (2) there are numerous stacked thin sand shorefaces which cause tuning effects and (3) amplitude variations are not separable by normal mapping methods and processing techniques targeting only deeper zones.

In order to overcome these difficulties, the seismic data needs to be processed with zero-offset processing in order to recover the amplitudes which truly reflect the underlying geology. The extracted amplitudes along the horizons and other attributes like peak/trough ratio and peak-trough distance are then compared to separate some of the sand signatures from above and below. The Cardium main sand is usually 10-20 m thick and on seismic data represents itself as a peak.

The Cardium formation comprises of numerous small unconformities which makes their geometry very complex. Seismic signatures of these complexities need to be observed parallel to the depositional time lines. Seismic sequence stratigraphic tools including ‘horizon cube’ are applied to slice through the seismic to better understand the features which could create permeability barriers and thus could become detrimental to the well productivity.

Spectral decomposition with RGB color blending is a tool which is extensively used in the visualization to separate the areas of various thicknesses and to learn the frequency tuning of thin intervals. An RGB blended cube with 30, 40 and 60 Hz frequency shows the variation in the main sand separating the effects of the lithologies above and below the target tight sands.

Within the Cardium formation its seismic signature contains information from the whole interval including sands and shales and thus represents depositional facies. Neural Network based seismic facies analysis (UVQ - unsupervised vector quantisers) provides another way of analyzing the seismic data. Seismic facies map is a similarity map of actual traces to a set of model traces that represents the diversity of various trace shapes present in an interval. Although the seismic facies is very broad in recognizing seismic geomorphology, it does classify the interval into diagenetic groups which are usually associated to similar rock and fluid character of the formation.

Further to the above analysis dip-steered volume curvature attributes are helpful in defining not only the depositional trend but also the natural fracture trends which can enhance the permeability of reservoir zone.

Conclusions

High resolution sequence stratigraphy associated with seismic attribute analysis can help distinguish paleo-geographic features and natural sediment lineaments within the Cardium formation. Moreover, the areas with different lithology and fluid types can be recognized using interval analysis. Seismic reservoir characterization tools allow better development drilling and if followed in conjunction with other data may result in better application of fracture simulation and eventually better yield of oil from tight oil sand packages.

We conclude in this study that using seismic reservoir characterization along with high quality 3D data and target oriented processing can make a huge difference in understanding the geology when it comes to development drilling and locating the areas of maximum yield in tight oil play.

Acknowledgements

We would like to thank Pulse Seismic Inc. for allowing the use of their 3D dataset and Absolute Imaging Inc. for lending their technical support and the processing of the 3D.

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