Post-stack Seismic Geomorphology of Bakken Shale using Spectral Decomposition, Curvature and Waveform Facies Analysis – Southern Alberta Study

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The Bakken petroleum system is one of the most prolific shale oil plays in the US and Canada. The resource play is generally known as Bakken shale oil and consists of different play types. The Bakken is a technology-driven play showing a clear trend of increasing production rates over time, as drilling techniques and well completion design have become more sophisticated. The formation comprises in general of an upper and lower shale members and a mixed siliciclastic middle member, which is usually referred to as Middle Bakken dolomite unit. The shale zones are the source of hydrocarbons for the fractured dolomite reservoirs in the middle. Geological factors also have a larger impact on productivity than technological improvements (1). In the last few years seismic companies have been shooting high fidelity seismic over the play. Seismic with the help of reservoir characterization tools can be used to differentiate lateral variations in geology. In addition, the structural interpretation of deeper zones can shed new light to the depositional control over shale organic content.

We propose the following workflow which should be considered as a standard procedure when first interpreting the seismic data for the exploration program of any size. Briefly, the workflow consists of not only picking horizons and visually understanding the area, but to derive several attributes and apply state-of-the-art principles of seismic geomorphology before performing any quantitative inversion of geomechanical attributes through AVO, VVAZ, AVAz etc.

The Bakken Shale formation was entirely undeveloped until the oil and gas industry developed new technologies for horizontal drilling and fracking. Since then, development of this formation throughout Montana, North Dakota, Saskatchewan and Manitoba has been unprecedented. In the past 5 years the Bakken Shale has already doubled the proven oil reserves of the USA, with growing estimates of over 40 billion barrels of oil.

As has been shown in different reports the Alberta Bakken Petroleum System (ABPS – Upper Devonian and Lower Mississippian) is an example of an emerging new unconventional tight oil resource play and is a natural extension of the Bakken system. The ABPS consists of three potential reservoir zones: Big Valley/ Stettler carbonates, Middle Bakken/ Exshaw dolomitic siltstone and overlying Basal Banff carbonates (2).

For this study seismic geomorphology, volume curvature, and neural network based facies analysis are integrated with intensive geological analysis of the area to de-risk future exploration program.

Explor acquired the Alberta Bakken 3D in the fall / winter of 2011 / 2012 as a multi-client survey. The seismic data was acquired by SAExploration using the Fairfield ZLand Nodal System. In many parts of the world, complicated acquisition environments such as dense infrastructure, rugged terrain, urban areas and extreme climates pose threats to operational efficiencies. This true cable-free nodal system makes it possible to tackle any job in many environments quickly and more safely.

Seismic data processing of this 3D was done by Absolute Imaging Inc in the spring of 2012. Although there were some challenges with wind noise, which is common in this area the overall quality of the data was very good. Both a post stack and pre stack time migration were produced with a processing flow that focused on robust static solutions, detailed velocity analysis, minimal trace smoothing and high resolution imaging. Attention to detail and strong collaboration between Absolute and Explor was essential to the success of this project.

Seismic attribute analysis of 3D data shows promising results to help build a model at the scale of few meters. 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.

Spectral decomposition with RGB color blending (Fig. 1) 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 40, 60 and 80 Hz frequency shows the variation in the main sand separating the effects of the lithologies above and below the target tight sands.

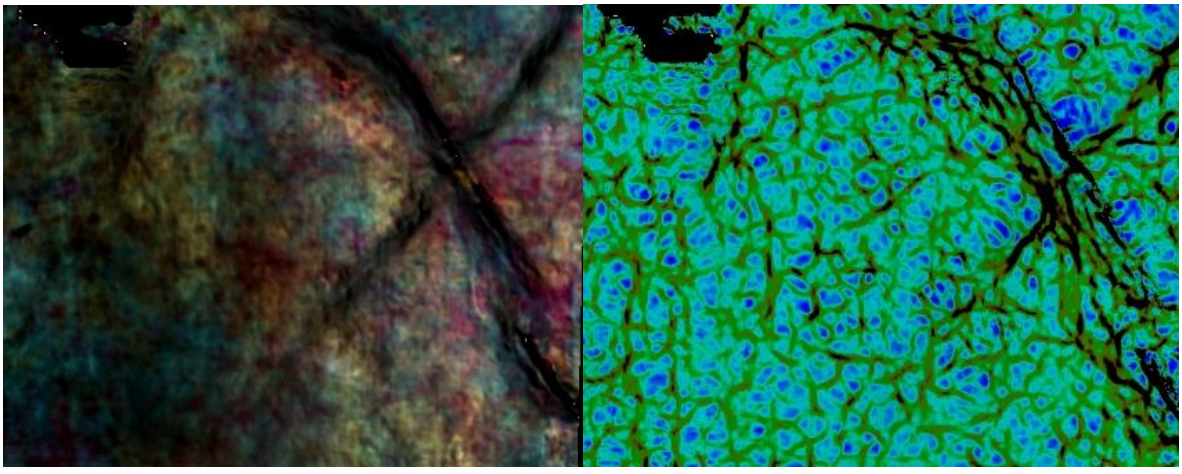

Fig. 1 *Left*: Color Blended display of Spectral Decomposition for Middle Bakken interval (40, 60, 80 Hz) and *right*: Most positive Curvature attribute to the right.

Furthermore, seismic vector quantization of waveforms (Fig. 2) links directly to the geological facies and effect of high organic content and reservoir pressures. Volume curvature analysis is another tool to help delineate the subtle surface features which help in reconstructing micro geological affects.

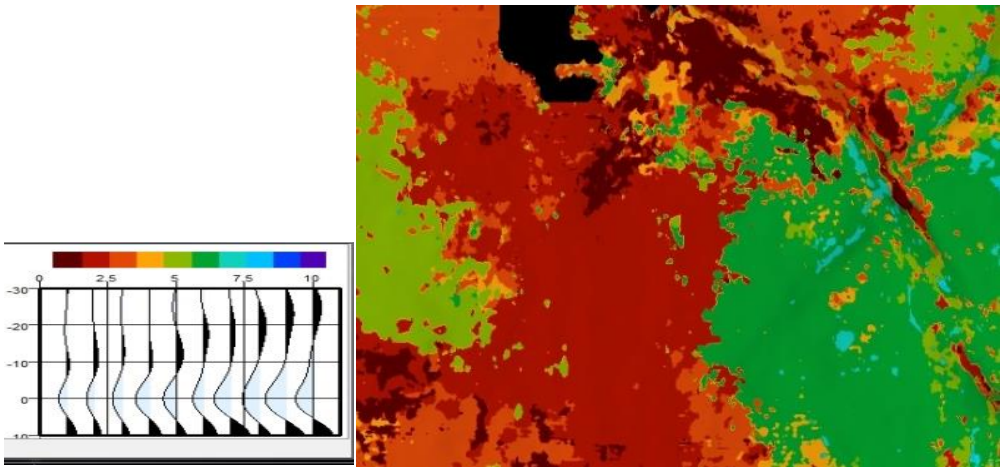

Fig. 2 Seismic un-supervised vector quantization of waveforms performed for Bakken 3D (10 classes, time gate -30, 10).

Conclusions

This is the first application of seismic geomorphology and seismic attribute analysis for this data. Application of seismic reservoir characterization methods such as thorough seismic attribute analysis and seismic geomorphology can help to tremendously de-risk an exploration program.

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References

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