Application of Seismic Stratigraphy, Multi-attribute Analysis and Neural Networks to Mitigate Risk in New Exploration Frontiers – West Newfoundland Example

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Summary

The study covers a 3D data set from the western Newfoundland in Parsons Pond area. The area is of high interest, according to the recent estimates, hydrocarbon potential of the area is 2-4 Billion BOE. Western Newfoundland's Anticoste basin is on trend with Paleozoic back arc basins west of the Appalachian thrust belt like the Knox, Ellenberger and Beekmantown producing areas. The primary target reservoir in the area consists of the dolomitized carbonate bank of St. George Group, which is of Middle Ordovician age. The closest well to the survey is located 100 miles to the south at Port au Port peninsula.

The objective of the study is to de-risk a frontier prospect pre-drill, using the latest seismic interpretation techniques and integrate the seismic analysis with the knowledge of the regional geology. The data was schematically investigated for the timing of structural development to time trap development. To identify areas with preferential reservoir properties two techiques were applied. In section view the sequence stratigraphy build-ups and internal architectures were investigated using the digital SSIS workflow. In slice/horizon view a neural network based multi-attribute classification is applied in order to determine the areas of high potential reservoir (dolomitization). In addition, a similarity cube has provided additional indications of shear zones and karsting which is critical for play productivity. The data was further investigated for signatures of vertical fluid migration that could identify either dolomitization due to hydrothermal brines and/or the presence of leaking hydrocarbons.

Introduction

West Newfoundland is one of the few areas in Canada which has not been explored extensively. Although earlier wells were drilled onshore Newfoundland back in 19th century and numerous oil seeps are present in the area, the offshore part of the basin remained undrilled. The recent interest in all Paleozoic basins of North America and the discovery of extensive reserves in Marcellus, Ellenberger, Knox etc have renewed interest for the basin. In addition, new methods of seismic attributes analysis and sequence stratigraphy are now routinely applied in other areas to reduce the exploration risk (see Posamentier, 2005).

Pre-processing

Due to a strong acquisition footprint in the seismic data before all of the seismic analyses we applied a structural oriented median filter to preparation of seismic data. In figure 1 a comparison is given of the seismic data quality before and after filtering.

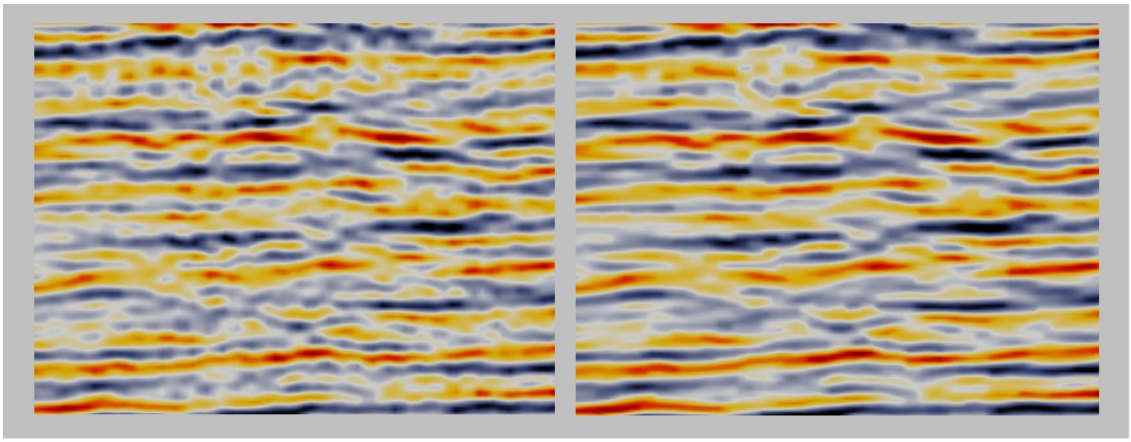

Figure 1: Left original seismic displayed on a crossline showing a strong aqcuistion footprint. Right, the same seismic section after cleaning the data with a structurally oriented median filter.

Sequence Stratigraphic Interpretation.

Modern tools for sequence stratigraphic interpretation allow us to do a pre-drill investigation of the data for changes in reservoir properties within a formation as well as subtle stratigraphic traps. We applied the SSIS workflow described by de Bruin et al, 2007. The SSIS workflow allowed us to break out packages with specific stacking patterns (aggradation, progradation), type of stratal termination and internal architecture of the reflectors. These observations were used to identify zones with higher probability of having good reservoir properties. See Figure 2 for a typical result.

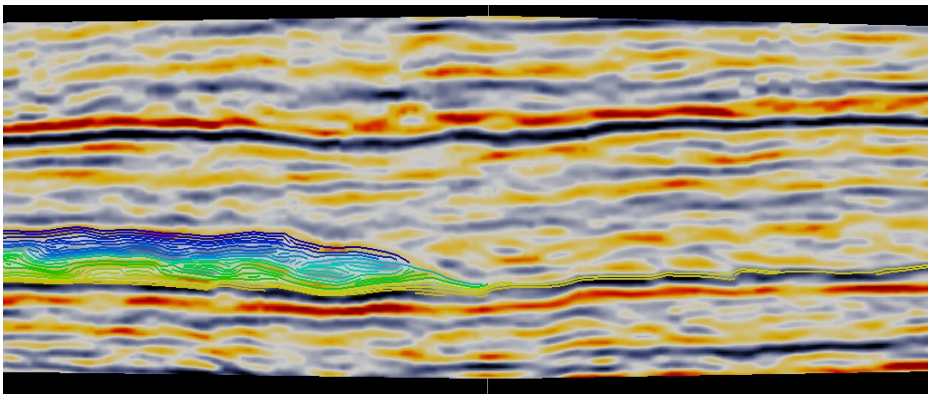

Figure 2: Sequence Stratigraphic Analysis of St. George Group reveals internal architecture prone to dolomitization

Seismic Attributes and Segmentation

Hydrothermal dolomitization has been one of the major processes of reservoir development in many areas of North America. Similar Devonian age fields in Western Canada like Clarke Lake, Ladyfern, Yoyo and Sierra had large porosity development through karsting and dolomitization. Thus it is believed dolomitization is pivotal to the reservoir development in this area. As karsting within a formation triggers the dolomitization process, we used seismic attributes and neural networks to identify areas with karts morphology, such as rounded collapse features and radial fracturing.

According to Cooper et. al., 2001 the faulting in the area also controls the dolomitization process. Analysis of the similarity cube helps in finding areas of faulting, shearing and karsting. The karst features are visible on strata slice through similarity cube at 76 ms below the top carbonate platform (Figure 3).

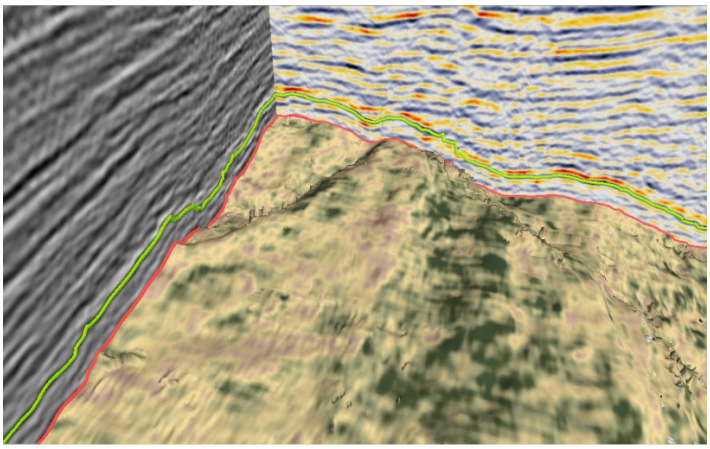

Figure 3: Enhanced view of the karsting features within the carbonate bank

The zones of karsting have different seismic signature than otherwise solid carbonate platform. Neural Network based facies analyses help us reduce the risk especially related to lithological variations within the zone of interest (Figure 4). Identification of the right seismic facies brings us one step closer to the answer but not having a modeled well does not allow us to verify the type of rocks to be encountered at the prospect location. Instead, the features were interpreted using their morphology to identify sedimentary origin and diagenesis.

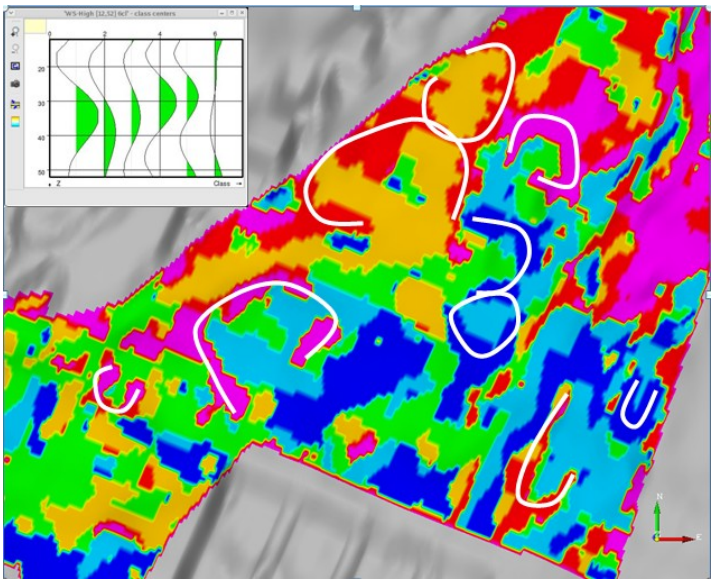

Figure 4: Neural Network based seismic segmentation over the zone of interest. Semi-circular features possibly relate to karsting within the carbonate platform.

Hydrocarbon migration and trapping indicators

Figure 5 shows an example of a rounded discontinuity at the prospective reservoir formation indicating karsting with a gas chimney above. The gas chimney was highlighted by a neural network object detection workflow described in Ligtenberg, 2005. With the current knowlegde of the area the gas chimney can be interpreted as vertical hydrocarbon migration from the source rocks around the St George Group, as evidence of hydrothermal circulation causing karsting, or a combination of both. The extend of the chimney gives us a clue about the timing of these processes as the chimney was at least active at an age equal or younger than the youngest formation it intersects with.

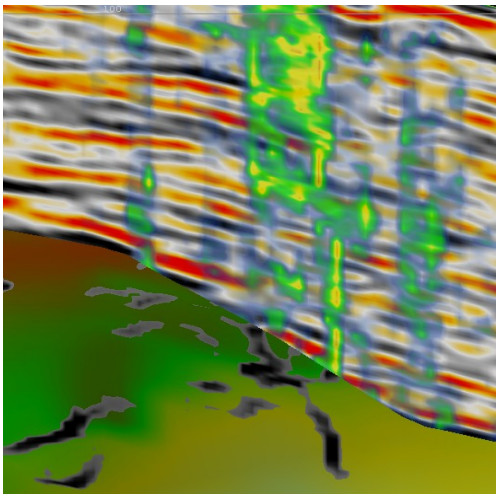

Figure 5: In grey scale, on the horizon a rounded feature highlighted with the similarity attribute, indictating karsting. On the section signatures of vertical fluid flow are enhanced by a neural network and highlighted by the green-yellow-orange color

Conclusions

The risk in frontier exploration can be reduced by analyzing fully the burial history through sequence stratigraphic principles and by finding indicators of right lithology through multi-attribute seismic facies analysis and advanced reservoir characterization. Reservoir characterization tools have shown great success in the areas of in-fill drilling but are rarely used to detect interpretation integrity and risk analysis for exploration frontiers. This study explains the schematic application of the integrated reservoir characterization and sequence stratigraphy.

Acknowledgements

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References

De Bruin, G., McBeath, K. and Hemstra, N., 2007, Unravelling a carbonate system: technical advances in seismic sequence stratigraphy, First Break, volume 25 May 2007

Ligtenberg, H., 2005. Detection of fluid migration pathways in seismic data: implications for fault seal analysis, Basin Research, March 2005, volume 17, p. 141-153.
Michael Enachescu, 2007, Prospectivity of Parson's Pond area, GSI internal presentation.

Cooper, M., Weissenberger, J., Knight, I., Hostad, D., Gillespie, D., Williams, H., Burden, E., Porter-Chaudhry, J., Rae, D., and Clark, E., 2001; Basin evolution in western Newfoundland: New insights from hydrocarbon exploration; AAPG Bulletin, V. 85, No. 3 (March 2001), P. 393-418.

Posametier, H.W. 2005, 3D Seismic Vizualization Techniques, In: DORE, A. G. & VINING, B. A. (eds) Petroleum Geology: North-West Europe and Global Perspectives—Proceedings of the 6th Petroleum Geology Conference, 1565–1576. q Petroleum Geology Conferences Ltd. Published by the Geological Society, London