Introduction

Western Canada Sedimentary Basin (WCSB) has been a target of unconventional oil and gas development for the last 10-15 years. Seismic data interpretation and inversion have been critical in reducing the uncertainty and finding the best target areas. Unconventional development of oil- and gas-bearing shales/marls has been improving over the last decade. Seismic inversion, rock physics and geomechanics have been implemented in many areas to target the high yield focus areas. Montney formation of Triassic age and Duvernay shale of Devonian age have been two targets where the development has been steadily increasing.

This study applies the pseudo-well modelling and trace-match inversion workflow to highlight areas of higher productivity. Pseudo-well modelling considers various geological variables related to overlying and underlying strata as well as the variability of the shale unit itself. Pseudo-well simulation concept was introduced by de Groot et.al, 1996 and subsequently applied to stochastic inversion studies (Ayeni et. Al., 2007).

Method

Pseudo-well modelling and trace matching trace-match inversion have been applied to solve various geological problems. A large set of pseudo-wells are simulated using variations in rock properties, bed thicknesses, geological superposition, and elastic parameters. The set of pseudo-wells are constrained by geological knowledge and existing wells such that they represent realistic expectations and uncertainties in the area. Trace matching algorithm is used via synthetic-seismic correlation or Machine Learning to achieve stochastic inversion results where the simulated properties of pseudo-wells are known.

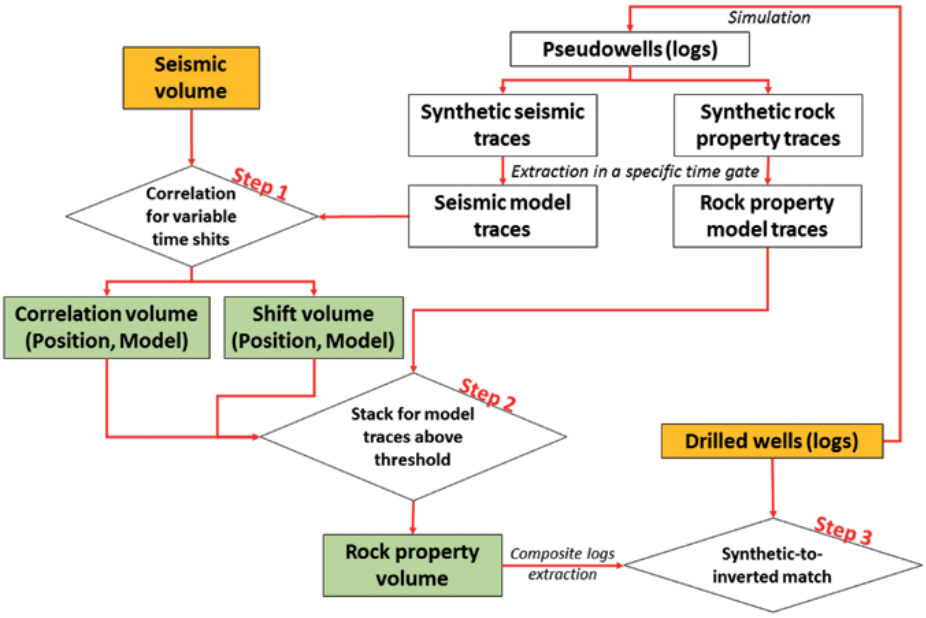

Figure 1 *Trace-match Inversion Workflow after Huck and Roth 2013*

More than one set of seismic data attributes, including deterministic inversion results can be used in the trace matching process thus reducing the errors. Angle-stacks can also be used to achieve AVO variability and their relation to fluid effects.

Trace matching part of the algorithm using the correlation and shift volumes can now be replaced by machine learning workflow where the pseudo-wells are used to detect the maximum correlation with seismic data using similar constraints.

Case Study # 1: Devonian Duvernay shale

During Devonian time WCSB was part of a carbonate coastline west of Laurentia super-continent. Warm equatorial climate created reef complexes including renowned Leduc Reef trend. Duvernay formation is a name used for organic rich off-reef shale and marls (Fig.1).

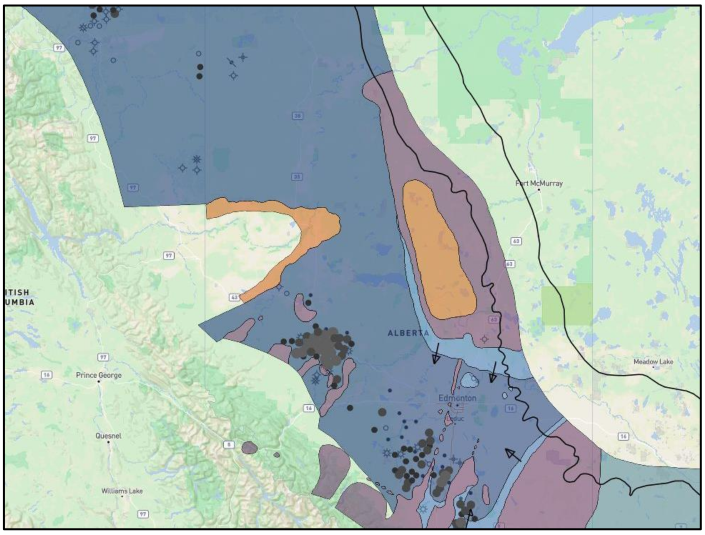

Figure 2 *Depositional setting of Devonian reefs and Duvernay off-reef shales*

Oil and gas are produced from Duvernay through horizontal drilling and hydraulic fracking. To understand sweet spots within Duvernay the parameters such as Total Organic Content (TOC), maturity, brittleness, natural fractures, and stress ratios are desirable. Elastic parameters derived from seismic can be correlated to above parameters and can be quantified to mark sweet spots. Rock physics analysis is carried out on 20 well penetrations to understand the variations of each parameters.

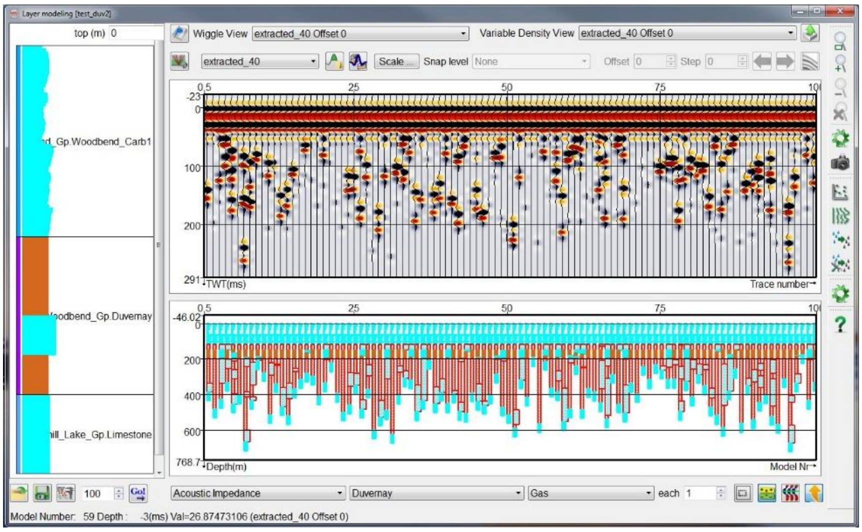

Figure 3 *Pseudo-well models generated using 70% limestone and 30% marl. The extent of carbonate layers change the seismic properties and thus provide better inversion results.*

In the area of study Duvernay formation is clayey at the top with low brittleness while it become calcareous near the base where it overlies Cooking Lake carbonate platform.

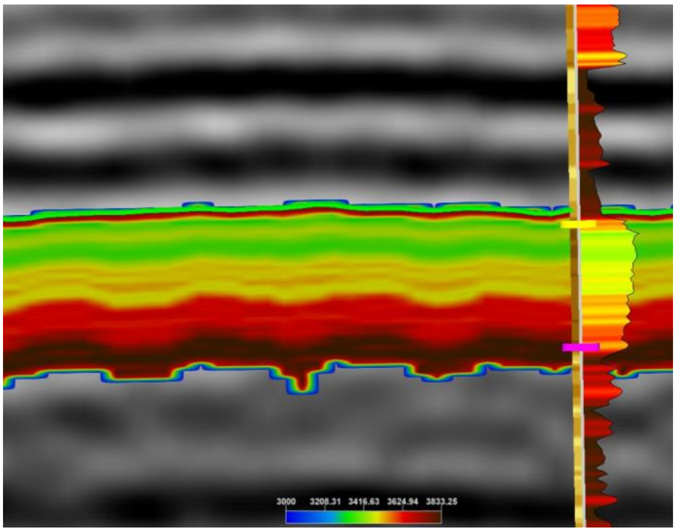

Figure 4: *Trace-match inversion results compared to GR log overlay filled with P-impedance color spectrum.*

Duvernay inversion through trace matching have greater validity within the small window and thus provides a better target landing opportunity into the most brittle zone with highest organic content.

Case Study # 2: Triassic Montney Fm.

Montney formation of Triassic age is a thick siltstone/shale sequence deposited in deep sea environment on the west coast of North American shield. The Montney formation is preserved in Alberta and British Columbia and can range in thickness from 10-300 meters.

Pseudo-well modelling in the Montney Fm. is more complex due to angular unconformity at the top of the formation. In the areas where the formation is within 50-100 meters it is less known if the units penetrated in the wells are carried to the adjacent area as downlap or have been eroded. Pseudo-well modelling considers not only changes in lithology but also the stratigraphic distribution. Interpreted sequence stratigraphic surfaces from the seismic data are used to introduce intermediate layering.

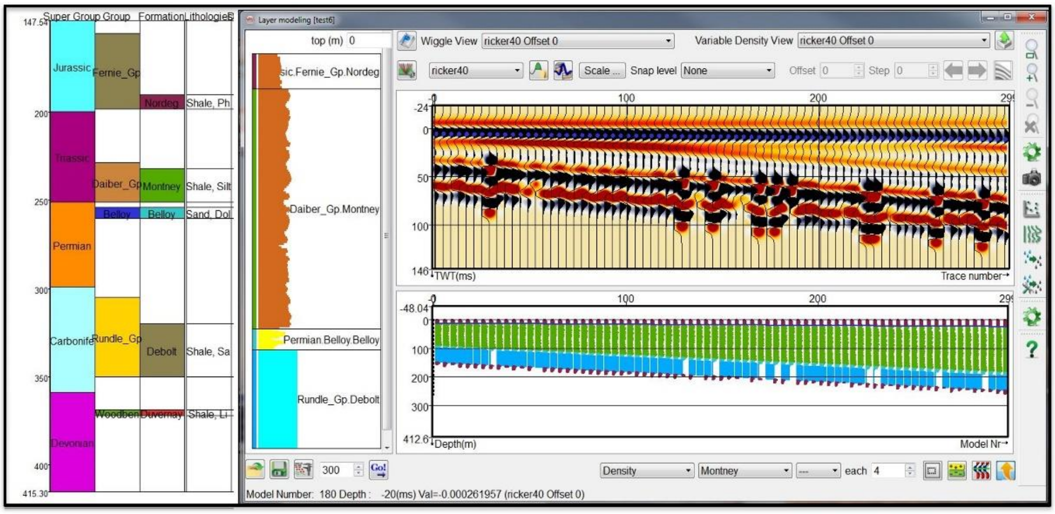

Figure 5 *Pseudo-well modelling of Montney interval along with variation in the overlying strata and thickness.*

Four pseudo-well sets of 300 each are added together to create a composite set with 1200 pseudo-wells. Thickness of underlying Permian Belloy formation is also varied to create realistic scenario of erosion before the deposition of Montney. As the Belloy formation may be completely eroded, variation in underlying Mississippian Debolt also affects the properties of Montney.

Once the variability of the geology is incorporated, trace matching is carried out using a threshold of 80% match. This means that only the inversion traces with more than 0.8 correlation will pass through the next scoring criteria. After the trace matching all the traces within 3D will be populated by the individual property values associated with each pseudo-well model that achieved the highest score.

Integration and Scalability

The results obtained with trace-match inversion workflow are compared to the pre-stack rock property inversion. Within a small stratigraphic window, the properties are significantly better correlated to the real values. In this inversion method there is no direct use of fixed a-priori information and thus the inversion can be carried out on 3Ds where there are no existing wells.

The inversion process allows the use of 1-5 seismic volumes as input and the volumes can be combinations of various angle limited stacks and/or inversions.

Trace-match inversion workflow is scalable to solve many geophysical inversion problems that are difficult to solve using conventional deterministic or stochastic methods. In the unconventional development it is shown that subtle differences in the TOC and maturity could be detected.

References

de Groot, P., Bril, A.H., Floris, F.J. and Campbell, A.E. [1996] Monte Carlo simulation of wells. Geophysics, 61, 631-638.

Ayeni, G.O., Huck, A. and de Groot, P. [2007] The HIT Cube; matching Monte Carlo simulated pseudo-wells to seismic data for predictions with uncertainties. 69th EAGE Conference & Exhibition, London.

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