geoconvention
Calgary • Canada • May 12-14 2025

Seismic velocity determination by using stratigraphic emphasis to predict pore pressure distribution in the Upper Devonian Duvernay Formation from the Western Canada Sedimentary Basin, Alberta

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Summary

The Upper Devonian Duvernay Formation is one of the leading unconventional shale resources in the Western Canada Sedimentary Basin (WCSB). Well-testing results show that the Duvernay Formation is characterised by an overpressure gradient reaching 18-20 kPa/m. This study refined the interval velocities from 3D seismic data in the Fox Creek area to predict formation pressure in the Duvernay and the overlying Ireton Formations between the studied wells. This is done using the modified Eaton's method, seismic attributes, and the predicted formation pressure, which is accurately validated using well-pressure measurements. The interval velocity field was refined by correcting the original seismic velocity field with a correction factor from comparing seismic and well-log-derived velocities. The refined interval velocities in the Duvernay Formation were validated with the core ultrasonic velocity data available in a calibration well. The obtained predicted formation pressure gradient cube can help model the lateral changes of horizontal stresses within the Duvernay and Ireton Formations across the study block and minimise the risks of induced seismicity associated with hydraulic fracturing.

Method

The use of seismic information (e.g., interval velocities) to predict pore pressure is common in the oil and gas industry; however, the interval velocities derived from seismic processing (e.g., stacking velocities) do not have enough vertical and lateral resolution for pore pressure prediction.

This study was performed to refine the interval velocities from a 3D seismic cube in the Fox Creek area to predict the Duvernay formation pressure and the pressure of the overlying Ireton Formations between the wells by using the modified Eaton method. The interval velocity field was refined by adding a stratigraphic emphasis in the model construction and by applying a correction factor derived from the comparison between the interval velocity in wells obtained from the time-depth relationship and the 3D seismic velocities (Figure 1). The correction factor was propagated between the wells using a trend estimated from seismic attributes.

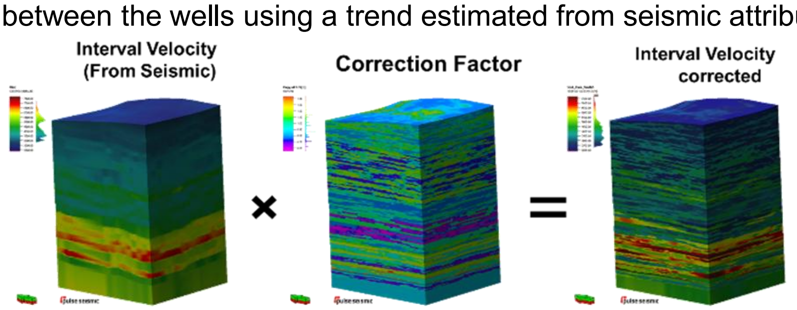

Figure 1. Example of the correction of Seismic velocities.

Results

The refined interval velocity field has better vertical and lateral resolution and is consistent with the lithology of the entire lithostatic column. For the Duvernay Formation, the predicted velocity was cross-validated with core measurements showing velocities between 3700 to 6300 m/s. Two velocity trends were identified within these velocities: lower velocities, which can be related to the upper Duvernay, which is mainly constituted by kerogen-rich shales, and higher velocities associated with the middle Duvernay constituted kerogen-lean carbonate-rich shales (Figure 2).

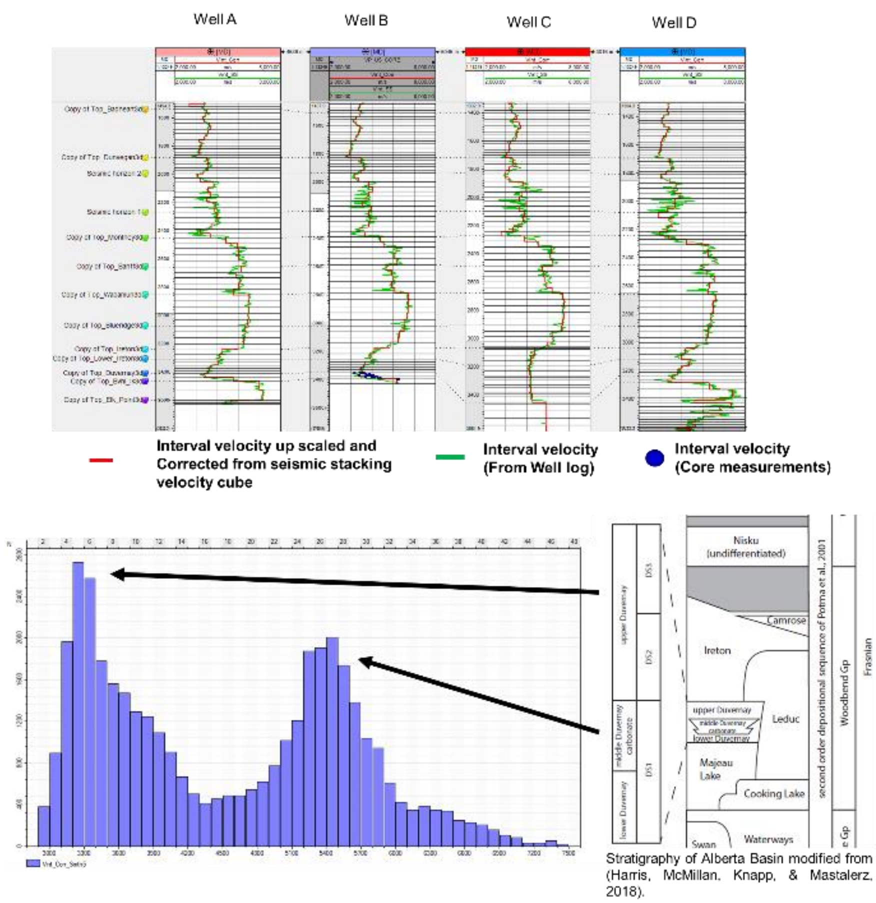

Figure 2. Comparison of the interval velocities from wells, interval velocities corrected, and ultrasonic velocities measured in cores from the Duvernay Formation.

Discussion

Pore pressure prediction using seismic data (i.e. interval velocities) is commonly used in the industry because seismic response reflects the contrast of acoustic impedance related to the subsurface rocks' velocity and density.

Even though the velocity field used in this project has a satisfactory resolution, rock velocities are influenced by factors such as lithology, porosity or even fluid content, which can lead to a variation in the pore pressure prediction.

Since Eaton's method is based on the Normal Compaction Trend (NCT) deviations, some values of abnormal pressure can be obtained, and these values can be related to velocities above NTC; therefore, the selection of this trend is crucial for the calculations, which rely mainly on the analyst's expertise and the available well pressure formation data.

Conclusions

The refined interval velocity field has reasonable vertical and lateral resolution, supported by the stratigraphic emphasis obtained from the seismic response (seismic attributes). It is consistent with rock lithology (e.g., higher values in the kerogen-lean carbonate-rich shales of the middle Duvernay and lower velocities in the kerogen-rich shales of the lower Duvernay).
The predicted pore pressure gradient obtained from our refined seismic interval velocities ranges from 15 to 18 KPa/m, comparable with the values of the formation pressure gradient obtained from well-testing data, ranging from 15 to 20 KPa/m in the study area.

Acknowledgements

We thank Pulse Seismic for providing multi-component 3D seismic data for this project and SLB for the consolidated license to the University of Alberta. This work was funded by NSERC (Natural Science and Engineering Research Council of Canada, Discovery Grant) through grant RGPIN-2019-04397 and NSERC DGECR-2019-00186.

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