[PS]Recognizing Duvernay B-Carbonate Distribution and Its Potential Implications on Resource and Reserve Estimations*

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Abstract

The Upper Devonian (Frasnian) Duvernay Formation of the Woodbend Group is a geological formation found over most of central Alberta. Since 2009, the Alberta Energy Regulator (AER) has seen a sharp increase in the number of operators targeting this liquids-rich shale resource, particularly in the Kaybob–Fox Creek area. Informal lithostratigraphic members include the A shale, the B carbonate (also referred to as the middle carbonate), and the C shale. The B carbonate is recognized to be nonreservoir. Recognizing the extent of the B carbonate is important. It needs to be removed from estimates of gross formation thickness that may otherwise be rich in organic carbon for credible in-place resource estimates. This can be problematic in that there are other carbonate-rich intervals of the A and C members that need to be included in gross thickness because they can contribute to reserves in these unconventional plays.

Characterizing and Mapping the B Carbonate Member

To isolate the B member, all three members were mapped at high resolution using over 2500 wells in the study area, focusing primarily on regions of viable hydrocarbon thermal maturity in the Kaybob-Fox Creek area of west-central Alberta. The Duvernay has been classified into twelve lithofacies and three end-member rock types with decreasing reservoir quality: highly siliceous organic-rich mudstones, argillaceous mudstones, and nonreservoir carbonates (Dunn and Humenjuk, 2014). The B carbonate is equivalent to those nonreservoir carbonates, which are typically limestones (Hein, 2012). A challenge to mapping the B carbonate is to distinguish it from other carbonate-rich sections on logs. For example, one important difference was observed between Leduc reef talus and B carbonate. From log analysis alone, it can be difficult to differentiate between the two, especially where the B carbonate immediately offsets Leduc reefs. In core, the Leduc reef talus is generally identified by the presence of stromatoporoid limestones; the B carbonate primary macrofacies, however, are identified by the presence of argillaceous grey crystalline limestones. On log signatures, the B carbonate often appears as cleaning upwards on the gamma ray with thin shale breaks, unlike the Leduc's blocky and overall cleaner appearance.

Characteristic B carbonate parameters include porosity ranging from 0 to 3%, determined from a sonic-density cross-plot, and water saturations between 25 to 55%, calculated using Archie's method. The B carbonate does not contain detectable amounts of total organic carbon when calculated using Passey's method, confirming that it should be removed from gross rock volumes for the purposes of resource and reserves estimates.

Mapping in detail shows that the B carbonate is thickest in the east, while the organic-rich shales of the A and C members are thickest to the west in the Kaybob area. There is a sharp south-trending boundary where the B carbonate thins to the west and thickens to the east. The distribution of the B carbonate suggests that its distribution is controlled by paleotopography and paleobathymetry. It is thickest to the east, where waters shallowed from the depocentre of the long-recognized Duvernay west shale basin and created conditions where biological carbonate production could flourish and still be preserved in the rock record. The sharp break in the B carbonate isopach is intriguing and may represent deeper tectonostratigraphic control on paleobathymetry, perhaps even basement-related structures.

Implications of B Carbonate Distribution on Reserves Estimation

The AER is responsible for producing and publishing estimates of Alberta's energy resources and reserves by play, pool, and deposit. Estimates of in-place resources for the Duvernay were last generated by the Alberta Geological Survey (Rokosh et al., 2012). In order to support orderly development and optimize overall resource recovery, the AER is changing the way we calculate and classify reserves, moving to a richer and more probabilistic view in line with international reporting standards. Estimates of technically recoverable resources in the Duvernay from pilot wells have been created and can be applied to geological mapping of resources in the Duvernay. Critical to converting these resource numbers to recoverable reserves estimates are factors like gross and net reservoir thickness, total organic carbon content, etc. The isolation of the B carbonate from the total Duvernay play is a critical step to populating the resource and reserve estimates and also to link its distribution in the subsurface to its place on the land surface.

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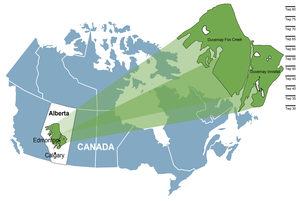
Recognizing Duvernay B-Carbonate Distribution and Its Potential Implications on Resource and Reserve Estimations

Background

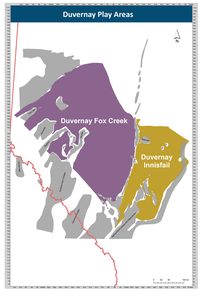
The Upper Devonian (Frasnian) Duvernay Formation of the Woodbend Group is a geological formation found over most of central Alberta. Since 2009, the Alberta Energy Regulator (AER) has seen a sharp increase in the number of operators targeting this liquids-rich shale resource, particularly in the Fox Creek area.



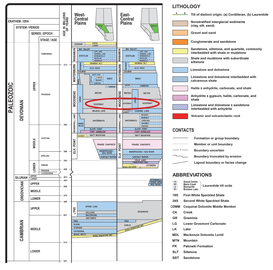
Duvernay depositional extent in central Alberta, Canada.

The AER has identified two Duvernay play areas: Duvernay Fox Creek in the west and Duvernay Innisfail in the east.

The Duvernay formation in both play areas was deposited in a shallow marine basin resulting in similar lithologies. The reservoirs within each play area are overpressured. The play areas differ in produced fluid type and AER resource type classification. Within the Duvernay Fox Creek play, oil and gas are produced from shale zones, whereas in the Duvernay Innisfail play area, primarily oil is produced from both shale and low-permeability carbonate zones.

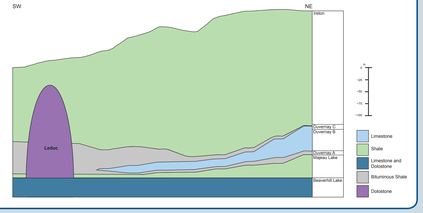


Duvernay play areas.



Section from the Alberta Table of Formations indicating vertical placement of Duvernay (see red circle).

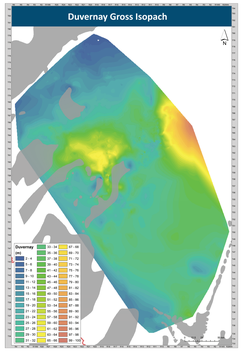
Informal lithostratigraphic members include the A shale, the B carbonate (also referred to as the middle carbonate), and the C shale. The B carbonate is recognized to be nonreservoir.

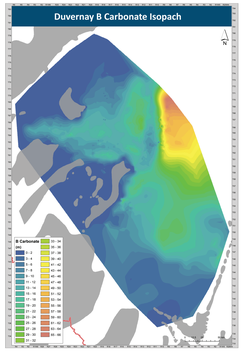


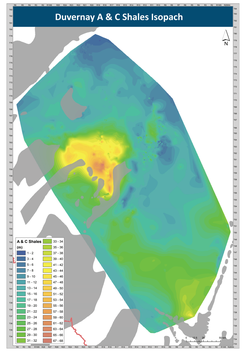
Schematic cross-section showing the Ireton, Duvernay, Majeau Lake, Beaverhill Lake, and Leduc depositional relationships.

Geological Framework

- Recognizing the B carbonate is important as it needs to be removed from estimates of gross formation thickness for credible in-place resource estimates.
- The Duvernay has been classified into three end-member rock types: highly siliceous organic-rich mudstones, argillaceous mudstones, and nonreservoir carbonates (Dunn & Humenjuk, 2014). The B carbonate is equivalent to those nonreservoir carbonates, which are usually limestones (Hein, 2012).
- The B carbonate is thickest in the east, while the organic-rich shales are thickest to the west in the Fox Creek area.
- The distribution of the B carbonate suggests that it's controlled by paleotopography and paleobathymetry. The sharp break in the B carbonate isopach in the east is intriguing and may represent deeper tectonostratigraphic control on paleobathymetry, perhaps even basement-related structures.





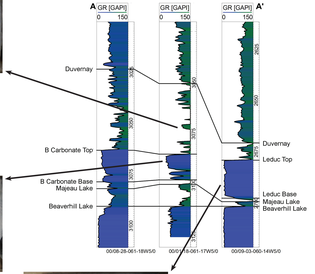


Duvernay isopach series.

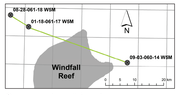
B Carbonate Versus Other Carbonate-Rich Zones

The Duvernay A and C shales are easily distinguished from the carbonate zones in core and on wireline logs. In core, the shales appear as dark brown to black, with visible oil staining. Fossils and bioturbation are occasionally observed. On wireline logs, the shales appear high on the gamma-ray log scale.

The Duvernay B carbonate is typically fine-grained, pale grey, crystalline limestone when observed in core. Fossil fragments are also commonly observed. On wireline logs, the B carbonate often appears coarsening upwards, with thin shale breaks on the gamma-ray log.



Leduc reef talus is often brecciated, with a dark brown matrix and pale brown to grey reef fragments when observed in core. Stromatoporoids are sometimes observed. On wireline logs, Leduc reef talus appears blocky on the gamma-ray log.



Cross-section A location.

A challenge to mapping the B carbonate is to distinguish it from other carbonate-rich sections on logs. For example, one important difference was observed between Leduc reef talus and B carbonate. From log analysis alone, it can be difficult to differentiate between the two, especially where the B carbonate immediately offsets Leduc reefs.

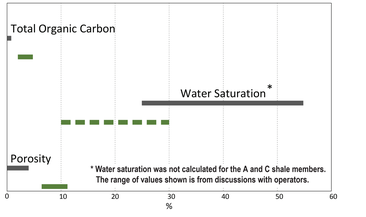
This series of images identifies the Duvernay B carbonate from Leduc reef talus.

What are the B Carbonate's Properties?

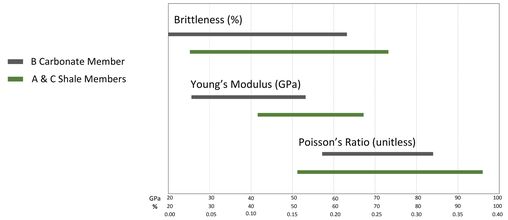
The AER characterized the petrophysical properties of the three Duvernay members to assess the reservoir quality of each. The following B carbonate parameters were investigated:

- Porosity was calculated from density and typically ranges from 0 to 4%.
- Permeability was not measured for this project but was observed in core to vary across the study area and was generally noted to be low.
- Water saturation was calculated using Simandoux's method and ranged from 25 to 55%.
- Total organic carbon was calculated using Passey's method and was typically 0% to trace amounts.
- Brittleness index was calculated from Poisson's Ratio and Young's Modulus for the Fox Creek area and ranges from 25 to 73%.

Based on the petrophysical properties calculated for the B carbonate, it was determined to be nonreservoir.



Duvernay petrophysical properties (regional).

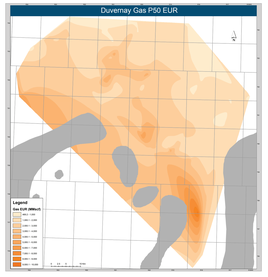


Duvernay geomechanical properties, Fox Creek area.

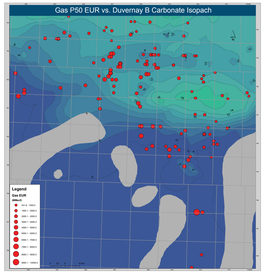
Implications on Reserves Estimates

- A long-duration linear flow model was used to characterize linear flow and validate production data points (Anderson, 2010) .
- Deterministic declines were created for wells with suitable data.
- Monte Carlo simulation was used to apply the decline characteristics to the remaining wells.
- Current production has not yet been normalized to operator conditions.

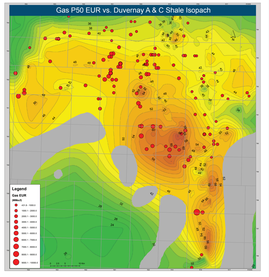
After completing the estimated ultimate recoverable (EUR) predictions across a set area, the results were plotted and compared to the location and thickness of the B carbonate. There appears to be a correlation between the gas EUR of wells in the Duvernay Formation and the presence and thickness of the B carbonate member. This becomes evident when the P50 gas EUR is plotted over the net shale thickness with the carbonate removed.



Duvernay gas P50 estimated ultimate recoverable.



Duvernay gas P50 estimated ultimate recovery versus B carbonate thickness.



Duvernay gas P50 estimated ultimate recovery versus A and C shale thickness.

Summary

The Duvernay formation is a prolific shale resource in central Alberta. Due to the fact that the shale members are the source and reservoir for hydrocarbons, and the B carbonate is determined to be nonreservoir, the presence and thickness of the B carbonate member can impact a given well's production.

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