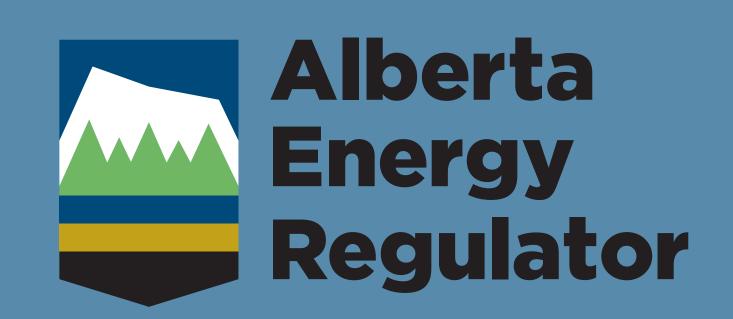
Stefan Walter Krista Beavis **Courtney Whibbs** Sean Stricker **Adam Preston** Jim Jenkins Fran Hein

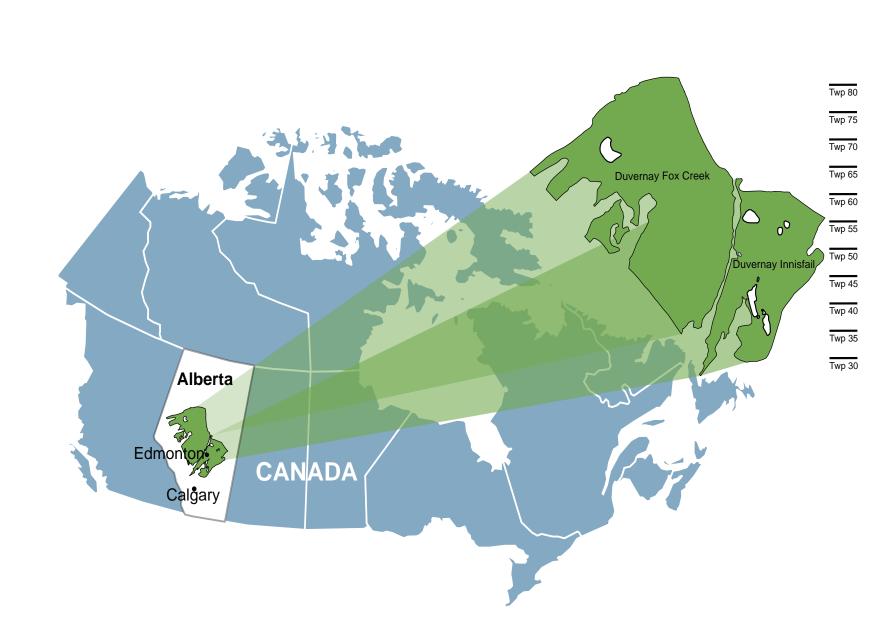
Alberta Energy Regulator Suite 1000 250 – 5th Street SW

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



Background

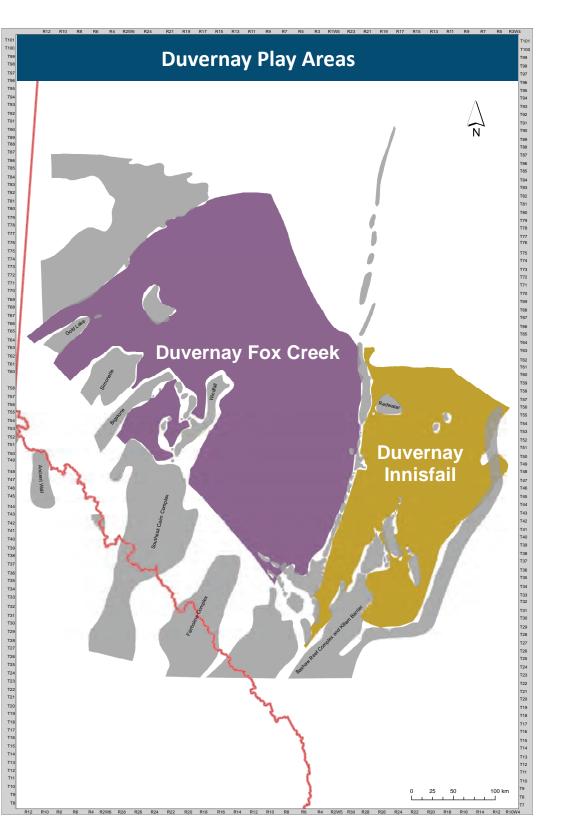
The Upper Devonian (Frasnian) Duvernay Formation of the Woodbend Group is a geological formation found over most of central Alberta. Since 2009, the Alberta Energy Regulator (AER) has seen a sharp increase in the number of operators targeting this liquids-rich shale resource, particularly in the Fox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



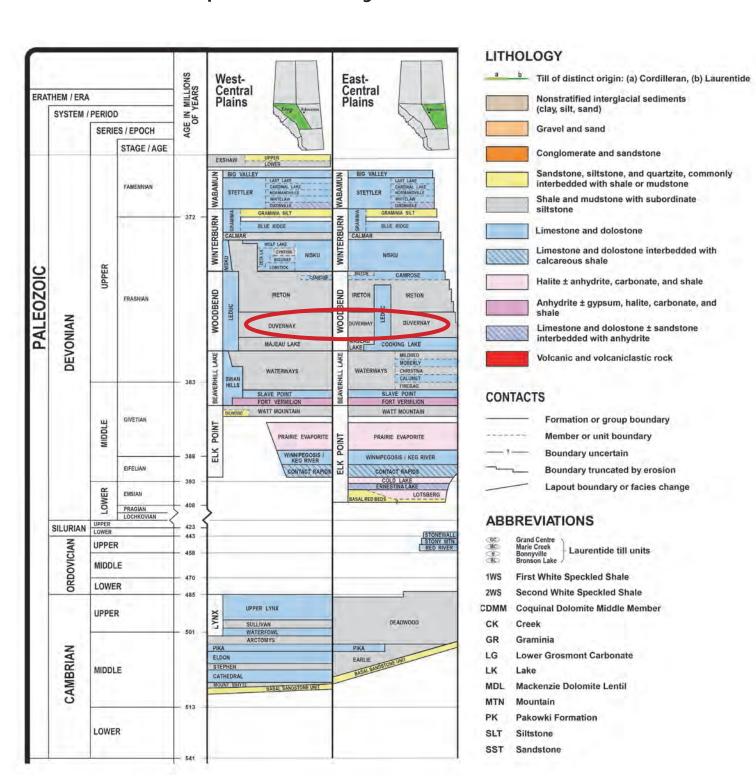
Duvernay depositional extent in central Alberta, Canada.

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.

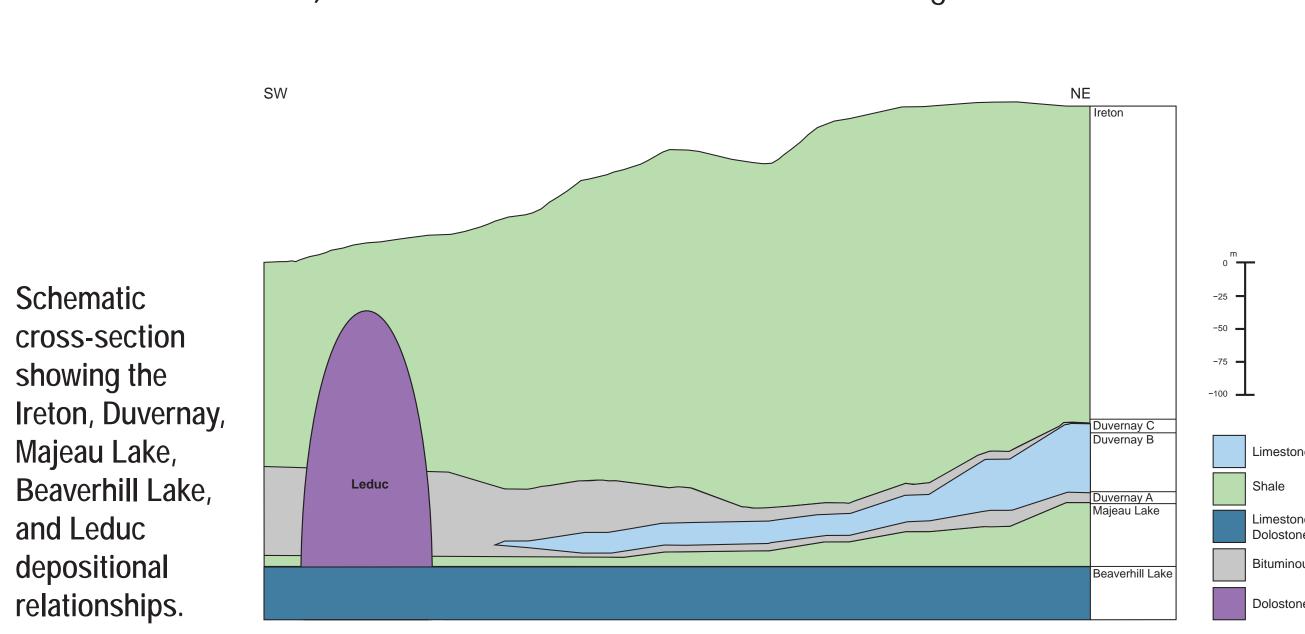


Duvernay play areas.



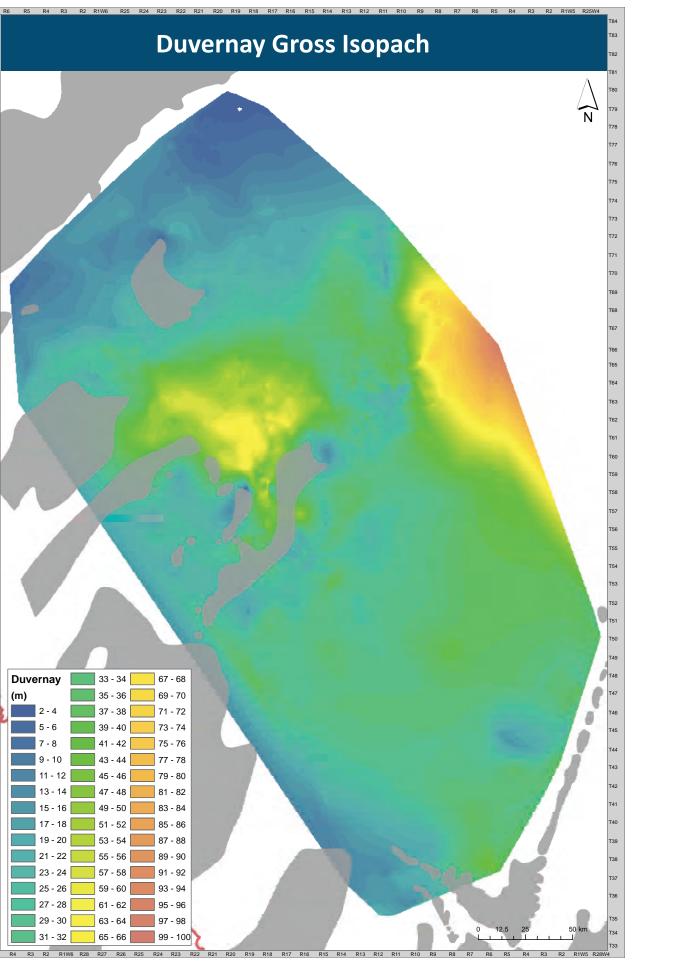
Section from the Alberta Table of Formations indicating vertical placement of Duvernay (see red circle).

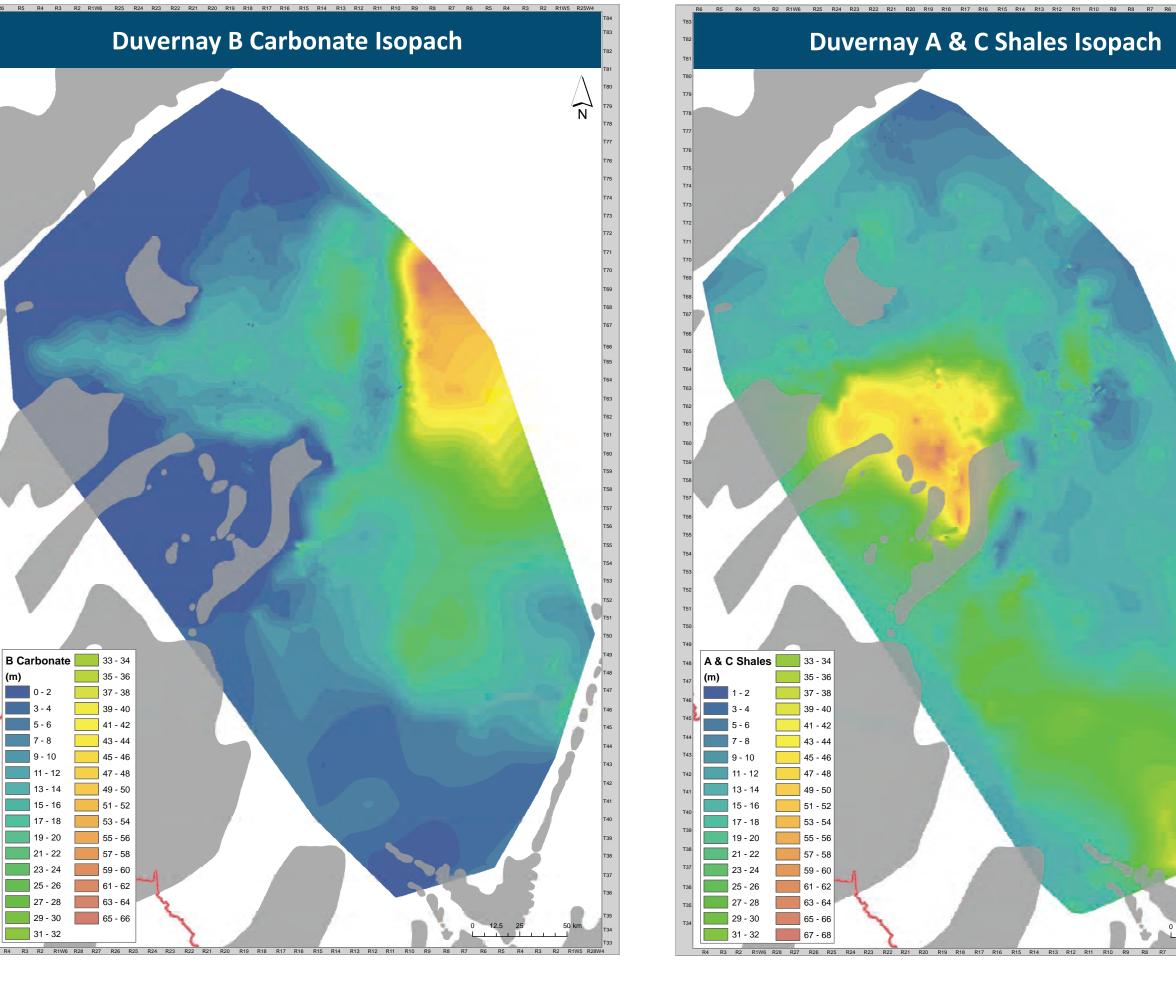
Informal lithostratigraphic members include the A shale, the B carbonate (also referred to as the middle carbonate), and the C shale. The B carbonate is recognized to be nonreservoir.



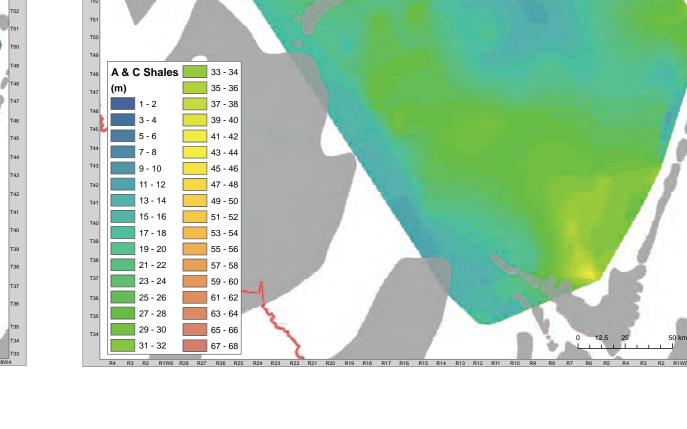
Geological Framework

- 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



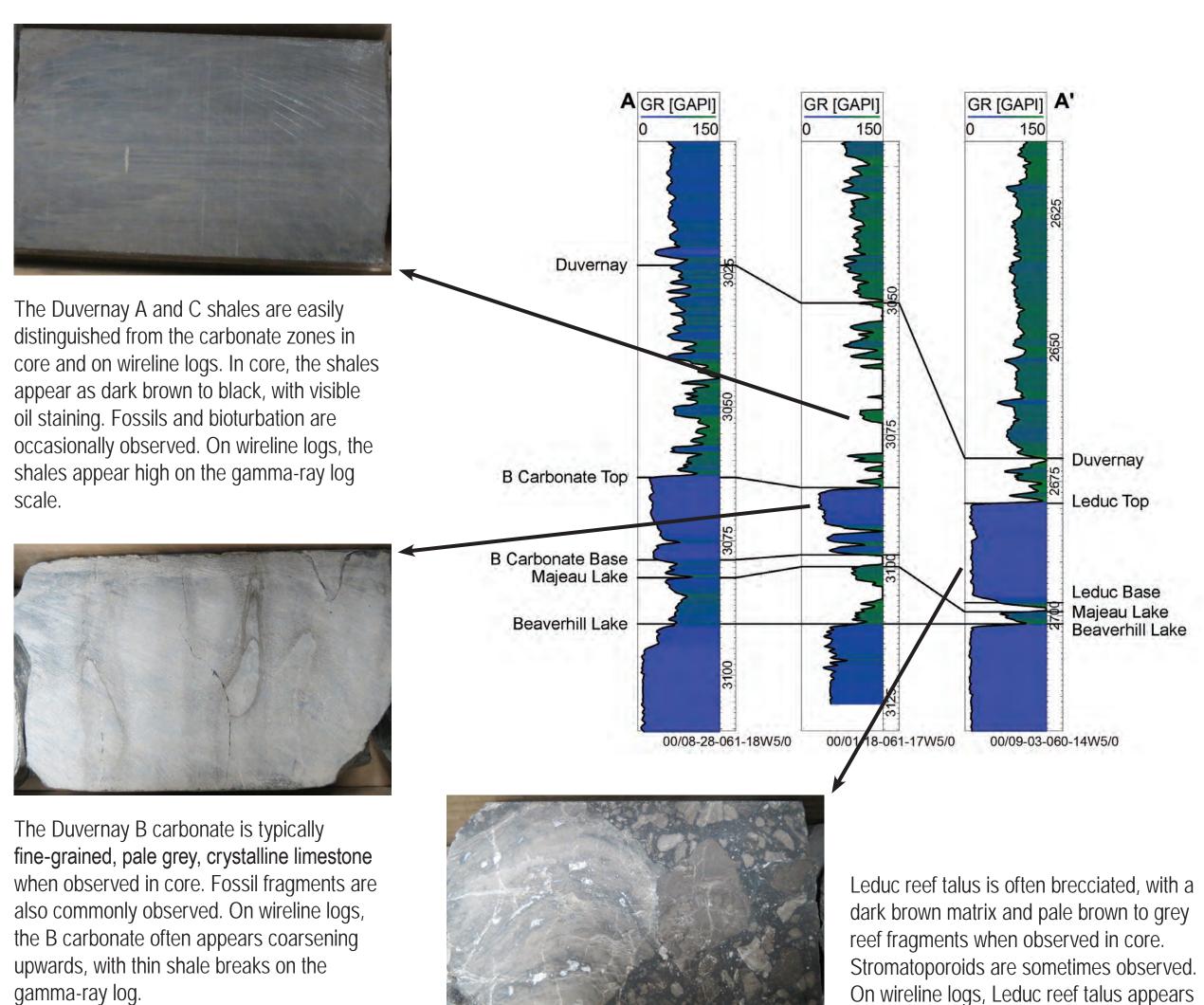


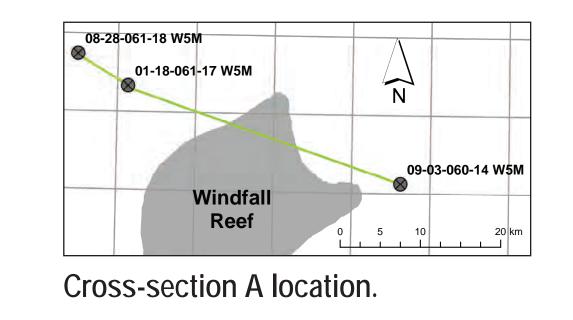
blocky on the gamma-ray log.



Duvernay isopach series.

B Carbonate Versus Other Carbonate-Rich Zones





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.

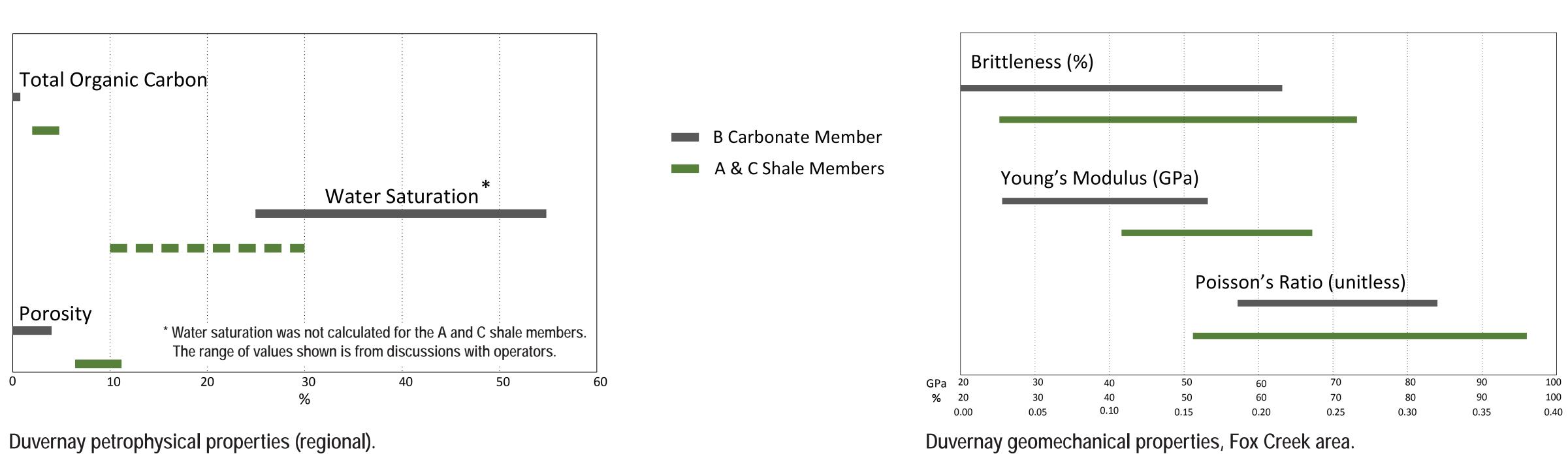
This series of images identifies the Duvernay B carbonate from Leduc reef talus.

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%.

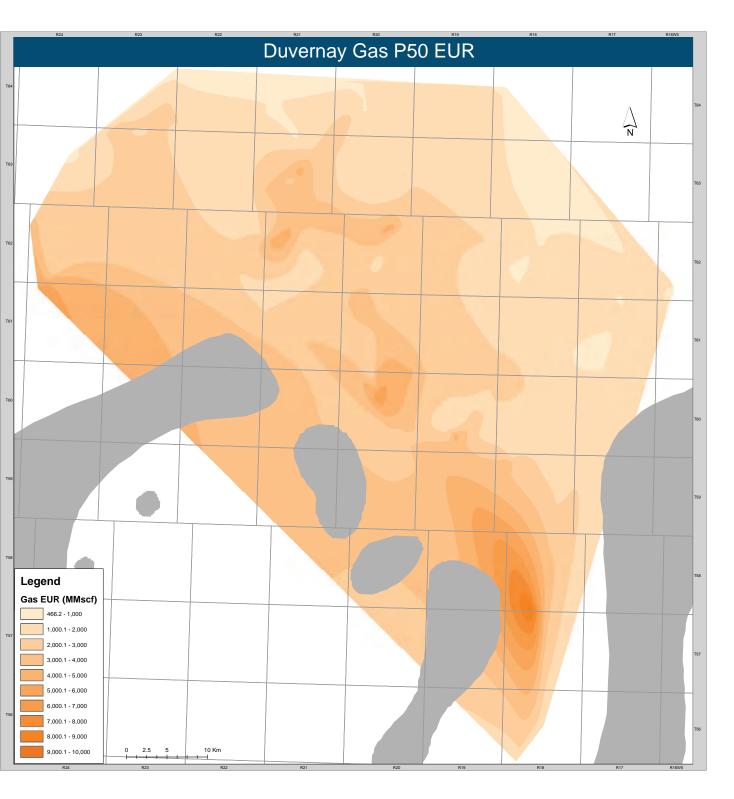
Based on the petrophysical properties calculated for the B carbonate, it was determined to be nonreservoir.



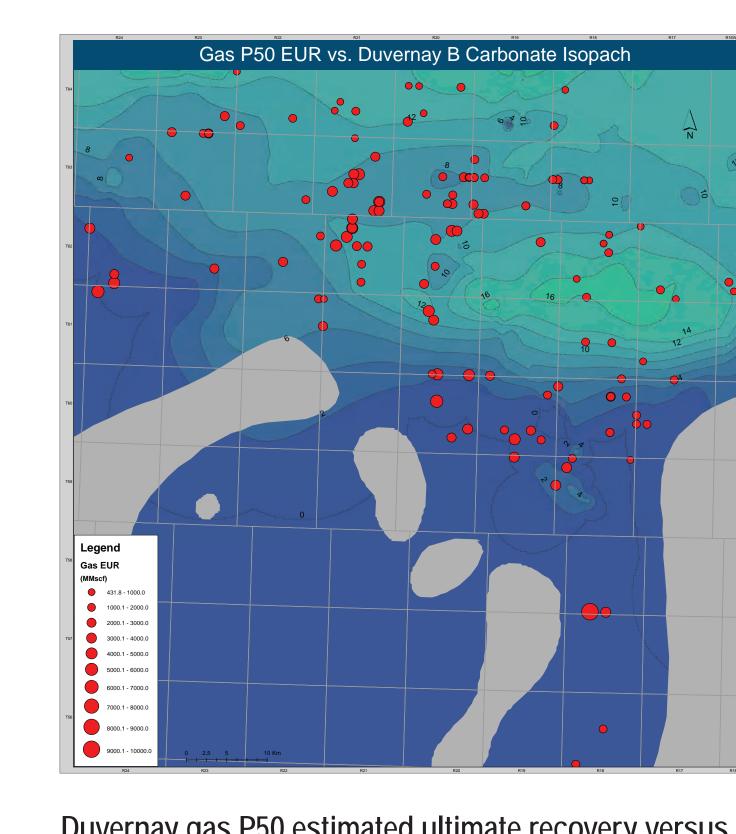
Implications on Reserves Estimates

- 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.

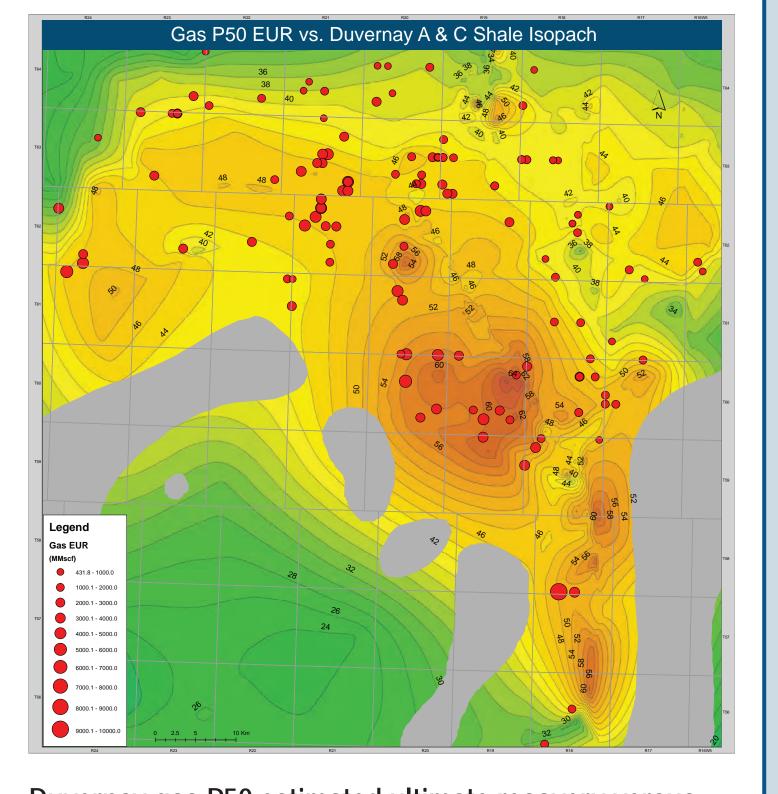
After completing the estimated ultimate recoverable (EUR) predictions across a set area, the results were plotted and compared to the location and thickness of the B carbonate. There appears to be a correlation between the gas EUR of wells in the Duvernay Formation and the presence and thickness of the 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.

Acknowledgements

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