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Investigating resource play potential using 3D Models: The Montney Formation of Western Canada

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Summary

The Early Triassic Montney Formation is one of the premier resource plays in North America, with over 12 years of unconventional exploration and development. Typically, unconventional resource plays are heterogeneous in terms of stratigraphic architecture and depositional facies. The Montney play is principally a siliciclastic system, which contrasts to many North American shale plays, such as the Eagle Ford and Wolfcamp, which are associated with the intercalation of carbonates and shales.

The Montney play is a self-sourced petroleum system with both source rock and tight reservoir intervals. Tight siltstones associated with turbiditic lobe facies and longshore drift deposits form major unconventional targets with reservoir effectiveness dependent upon thickness, along with petrophysical and geomechanical properties of the siltstones. The distribution of hydrocarbon charge within the play is impacted by the organic content and maturation of intraformational source rock horizons, along with stratigraphic trapping beneath the regional Doig unconformity.

In this study, the juxtaposition of organic-rich shales and organic-lean silts is characterised within a sequence stratigraphic framework and represented within a 3D burial model. This approach enables the prediction of reservoir heterogeneity and charge.

Within the Montney play, the siltstone facies which form tight reservoirs are typically associated with lowstand systems tract, whilst organic-rich shales associated with maximum marine flooding for intraformational source rocks. Depositional facies are controlled by the influx of siliciclastics and the influence of storm and fair-weather wave activity, which vary with changes in relative sea-level. Three third order sequences are identified within the Montney Formation, with siltstone tight reservoir units recognized within the progradational packages of sequences 1 and 3. However, sequence 2 is associated with coarser bioclastic carbonate event beds which have contrasting petrophysical characteristics to the siltstone units, and are not considered as prospective reservoirs. The type of organic matter within the Montney is also heterogeneous with both type II marine kerogen and type III/IV terrestrial kerogen present. This has implications for the hydrocarbon phase and fluid types generated across the play.

Depositional architecture, petrophysical properties, geochemical properties, pressure conditions and thermal conditions for the Montney play are integrated within a 3D burial model to map expulsion and charge into the siltstone tight reservoir units. This model identifies sweet spots within the play, such as those within the third sequence of the Montney Formation beneath the Doig Unconformity. Erosion beneath this unconformity has removed proximal shoreface facies within the upper part of the Montney Formation restricting the lateral migration of hydrocarbons out of the Montney petroleum system. Furthermore, the Doig Formation overlying the

unconformity is a regional top seal that inhibits vertical migration. These factors result in stratigraphic sweet spots where high hydrocarbon saturation is encountered within brittle tight siltstone reservoir zones.

Theory

The Western Canada Sedimentary Basin (WCSB) is located in north-western Canada, stretching from the Canadian Shield in the east, to the frontal thrust of the Rocky Mountains in the west. During the Early Triassic the WCSB was located on the western margin of the super continent Pangea, which at this time was characterised by subduction leading to the creation of the Cordilleran orogen and foreland basin development across the WCSB. The Montney Formation is deposited across the deep central part of this foreland and was deposited on a mud-dominated ramp in an epeiric setting. Stacked, sand-prone shoreface successions are preserved in the east, whilst more distal mud-prone deposits are recognised in the west. Storm-influenced sedimentation is recognised and below storm wave base fine-grained sandstones were deposited as turbidites within a succession of hemipelagic muds (Crombez et al., 2016). Westward of the Alberta Basin, we infer outboard paleohighs that allowed the development of restricted circulation on the deeper parts of the ramp (Golding et al., 2016). The Montney has formed one of the region's major sources of hydrocarbons since the first discovery in 1961. Since the development of hydraulic fracturing in the early 2000s the Montney has become the leading unconventional resource play in the WCSB, having cumulatively produced approximately 2 billion barrels of oil equivalent (BOE). This exploration has been focused on the distal, fine-grained sediments of the Montney Formation, with over 10,000 wells drilled in low porosity and very low permeability sediments. The National Energy Board of Canada estimates that the Montney Formation contains marketable resources of 449 TCF of gas, 14.5 Bbbl of natural gas liquids (NGLs), and 1.13 Bbbl of oil (Sereda, 2017).

Understanding the Montney Formation from a sequence stratigraphic perspective enables a more detailed interpretation of the stratigraphic architecture and variability of the formation to be made. This in turn provides greater insight into the different unconventional play types identified within the formation. The stratigraphic succession can be characterised as three eustatically influenced depositional sequences deposited above the Permo-Triassic Boundary, which constitutes a major unconformity and mass extinction event.

In the Montney Formation, three distinctive sets of westward prograding, third order sequences are observed. Deposition of the source rock intervals occurred in the oldest and youngest of these sequences (Crombez et al., 2017). The older source rock is connected to its associated shoreface sandstones and contributed to conventional Lower Triassic plays further to the east. The younger source rock associated with the third sequence has a different stratigraphic organisation, due to the occurrence of a syn-Triassic tectonic episode that uplifted the eastern parts of the ramp and removed the younger shoreface sandstones (Rohais et al., 2016). This erosion resulted in the removal of a lateral migration pathway. The duration of the hiatus was short, and the unconformity was draped by the phosphatic, organic-rich shales of the Middle Triassic Doig Formation.

The understanding of this stratigraphic interval is integrated within a 3D basin model. The key inputs are all derived from public-domain datasets and include: a depth framework, lithological information, paleo-digital elevation models, vitrinite reflectance, pressure and heatflow data data.

Observations

The results of the WCSB model suggest that towards the east, much of the play is in the early oil window at maximum burial, however across much of the central and western parts of the basin the play is within the late oil to gas window. The late oil window is preferred for unconventional exploration as the oil typically has a lower viscosity and gas drive helps to drive production, resulting in higher initial production rates and more efficient recovery.

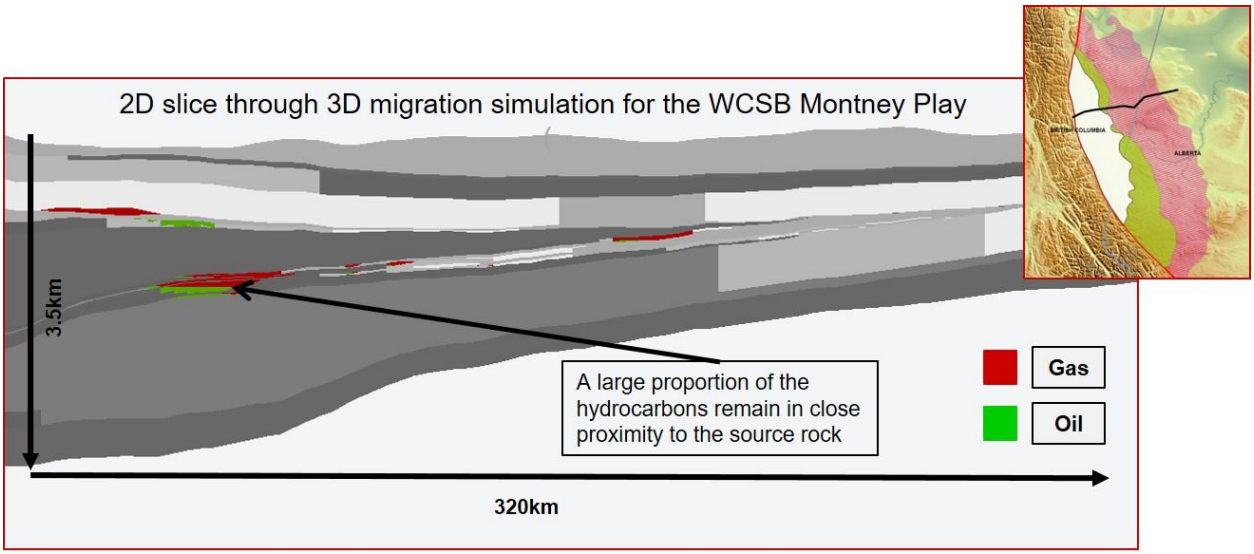

Figure 1: 2D section through the 3D basin model highlighting adjacent charge reservoir system for the third sequence of the Montney Formation. Red = trapped gas, green = trapped oil.

It is suggested that the hydrocarbons generated from the youngest parts of the Montney Formation remain trapped within the Montney petroleum system and cannot be expelled because of the development of the base Doig Unconformity (Ducros et al., 2015). Montney sourced hydrocarbons remain largely in-situ due to the unique combination of source rock quality and sedimentary architecture. This play relies upon the inefficient expulsion of hydrocarbons from moderate-quality source rocks, sealed by transgressive shales overlying the Dog unconformity. This combination impedes lateral and updip migration, retaining the hydrocarbons within a tight reservoir. Modelled migration simulations for the Montney Formation unconventional resource support this play type and indicate that a large proportion of the expelled hydrocarbons remained in close proximity to the source rock (Figure 1). Furthermore, truncation of the Montney Formation and deposition of the sealing Doig Formation took place

prior to expulsion. Expelled hydrocarbons were, therefore, trapped in the play, rather than migrating up-dip.

The model outputs identify the third sequence as containing the richest pay zone within the Montney (Figure 1). A basin-wide unconventional screening workflow was applied to identify play risk and to calculate the volume of hydrocarbon in-place per unit area across the play. The presence, maturity and depth of organic-rich facies constitute low risk across the play fairway. The main factor influencing risk and the volume of hydrocarbon in-place is the thickness of the reservoir interval. Nevertheless, resource-rich areas are identified within the play. Some of these high-graded areas have already beenexploited and coincide with a high density of production wells. However, a resource-rich north-west to south-east trending fairway with relatively few production wells is identified. This area appears to be under exploited and is a viable play extension that may warrant further consideration.

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