

## Mapping Reservoir Properties of the Horn River Shale in the Horn River Basin, Northeastern British Columbia, Canada

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### Summary

The Horn River Basin (HRB) contains substantial energy resources, predominantly unconventional natural gas that is accompanied by geothermal resources in the Devonian Horn River Group (HRG), comprised of the organic-rich Muskwa, Otter Park, and Evie formations (Fig. 1). The complex nature of the HRG shale, characterized by heterogeneous mineralogy, low formation porosity with intricate pore structures, and ultra-low matrix permeability, have posed significant challenges for resource extraction.

In this study, we present an integrated approach to derive reservoir parameters and provide a basin-scale overview of the petrophysical characteristics of the HRG shale. Our primary objectives are to explore the relationships among reservoir properties and well logs, and to develop petrophysical models to determine key reservoir properties, including total organic carbon (TOC) content, porosity, permeability, and water saturation. The model predictions from the proposed empirical models based on inputs from well logs and/or mineral derivatives from a machine learning (ML) method (Hu et al., 2023) are generally aligned well with core measurements, offering valuable insights for evaluating reservoir quality of the HRG shale.

We further examined the relationship between permeability and pore throat size using the Winland (as described first in Kolodzie, 1980) and Aguilera (2002) equations, quantifying the permeability as a function of pore throat and highlighting the significance of pore throat size played in controlling permeability magnitude. In addition, compared to core measurements, the nuclear magnetic resonance logging (NMR) data show comparable total porosity but discrepancies in effective and free-fluid porosities. Core permeability values range broadly from  $10^{-13}$  to 1 mD, with most data falling between  $10^{-5}$  and  $10^{-3}$  mD. However, NMR permeability values are predominantly between  $10^{-4}$  and 1 mD, underscoring the limitations of using NMR tool for permeability interpretation in the HRG shale with extremely low permeability.

The detailed petrophysical analysis indicates that the Muskwa Formation exhibits the highest quartz content, porosity, and permeability, along with the lowest carbonate content, particularly in the northern regions of the HRB. In contrast, the Otter Park Formation shows the lowest quartz content, the highest clay content, and the lowest TOC, porosity, and permeability. Conversely, the Evie Formation generally displays the highest carbonate and TOC contents, the lowest clay content, and the highest average effective porosity among the core samples. Additionally, all three formations show similar trends of increasing quartz content and decreasing clay content toward the north and northwest. This pattern is consistent with previously identified geomechanical and geological features, suggesting that the increasing brittleness in the northwest part of the basin is largely attributed to the greater distance from the sediment source. Spatial trends indicate that variations in TOC content, porosity, and permeability are positively correlated with quartz content; however, these relationships are diminishing due to the presence of substantial clay and/or carbonate towards the southern region of the Horn River Basin.

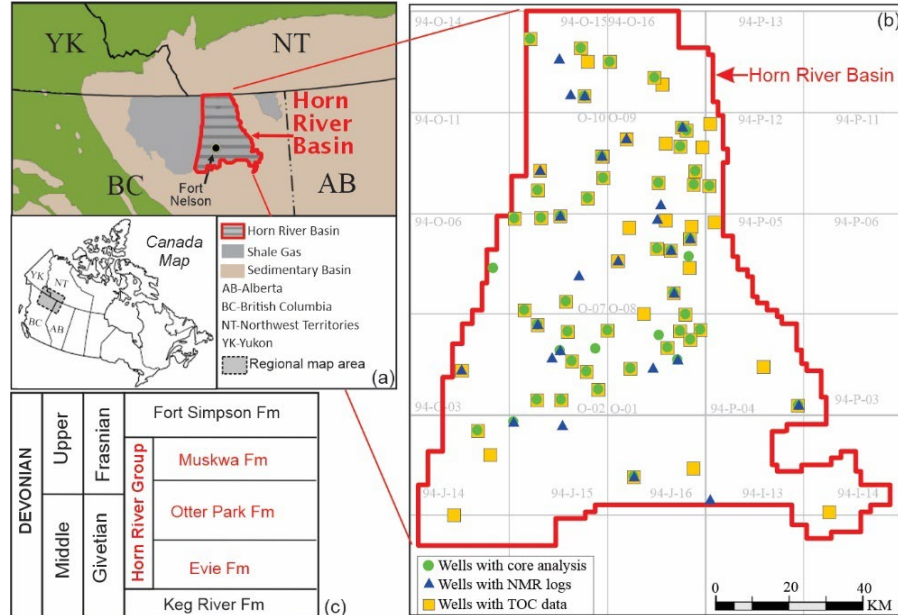


Figure 1. Map showing the location of the study area in Western Canada (a), the vertical wells where various types of core measurements are available for this study (b), and schematic stratigraphic chart of the Horn River Group in the Horn River Basin (c).

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