PS Regional Characterization of Shale Gas and Shale Oil Potential, Northwest Territories, Canada*

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Abstract

Unconventional gas and oil plays, particularly those hosted by shales, demonstrate great resource potential and productive capacity in petroleum basins throughout North America. Where there is abundant conventional production and drilling, companies use existing wellbore and analytical data to identify and appraise shale gas and shale oil plays. Confirming resource potential and commercial producibility requires extensive analysis of these data, followed by field experiments to optimize drilling and completion procedures.

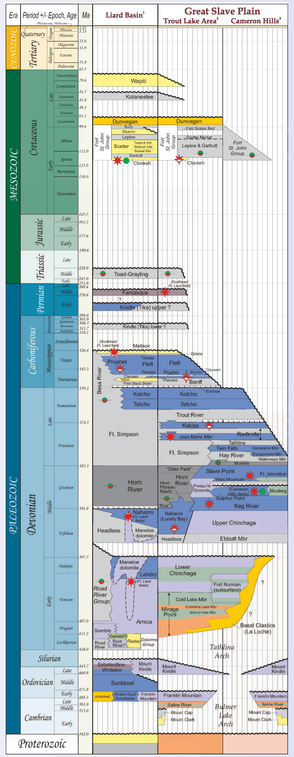
In more remote areas, such as the Northwest Territories, exploration and assessment work to date has focused almost exclusively on conventional reservoirs and petroleum systems. While it is apparent that NWT shales equivalent to producing or prospective shales in Alberta and B.C. must contain shale gas and oil, systematic efforts to quantify these resources are just beginning. Work proposal bids of more than $534 million on 11 parcels in the Central Mackenzie Valley, made by major operating companies in June 2011, indicate a high level of industry interest in shale prospectivity.

Petrel Robertson Consulting Ltd. and the Northwest Territories Geoscience Office have recently completed a study to systematically assess, at a regional level, shale gas and oil potential in the NWT. Analytical work and production information from equivalent shales in other areas, particularly in adjacent northeastern B.C., provide valuable insights in support of this analysis. Two study areas, based on stratigraphy and well control density, are defined: the southern Liard - Great Slave Study Area, and the northern Peel - Mackenzie Study Area. In Liard - Great Slave, good shale gas and oil potential is seen in the Devonian Muskwa-Horn River, Devonian/Mississippian Exshaw Formation, and Cretaceous Fort St. John Group. Other thick shales, such as the Fort Simpson, Kotcho, and Banff, do not contain sufficient organic material to present attractive targets. In Peel - Mackenzie, the Devonian Horn River Group and parts of the Cretaceous Slater River Formation are prospective for shale gas and oil, while the Imperial and Arctic Red shales are organic-lean, and thus less prospective.

LIARD - GREAT SLAVE STUDY AREA

STRATIGRAPHIC COLUMN

Liard – Great Slave features a thick, carbonate-dominated Paleozoic section, truncated beneath a profound regional sub-Cretaceous unconformity. Middle Devonian Horn River shales are highly prospective for gas and liquids, and are the main focus of this poster. Lesser prospectivity has been documented in the Upper Devonian Fort Simpson, Devonian to Carboniferous Banff/Exshaw/Besa River, and Cretaceous Fort St. John Group.



Fort St. John

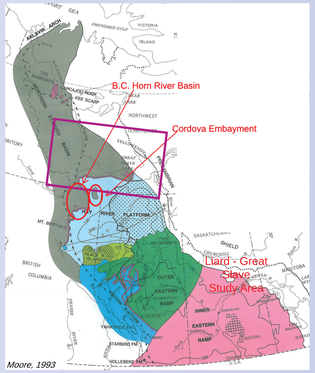
Banff/Exshaw/ Besa River

Fort Simpson

Horn River

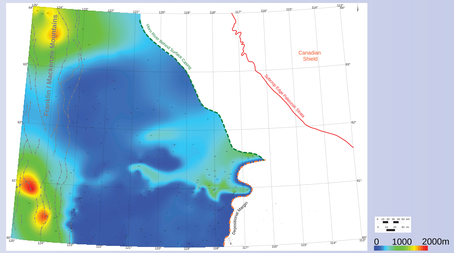
HORN RIVER PALEOGEOGRAPHY

This regional paleogeographic reconstruction by Moore (1993) shows most of the NWT to have been a starved basin during Horn River (Middle Devonian) time, lying north of stacked carbonate buildups of the Hay River Platform. Horn River shales in the Horn River Basin of northern British Columbia, at the southern edge of the starved basin, are currently being developed for dry gas production. Equivalent shales are being explored in the adjacent Cordova Embayment.



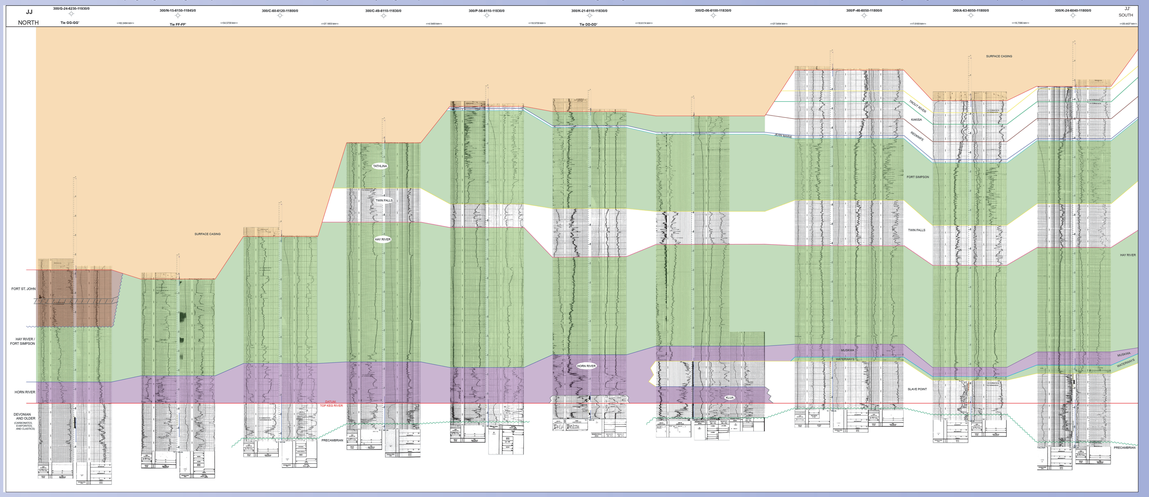
GROSS THICKNESS

Horn River shales are thin (less than 25 metres) in southern Liard-Great Slave Plain area, atop Slave Point platform carbonates (see Stratigraphic Cross-section JJ-JJ'). They thicken northward from the platform margin, and westward / northwestward into thick (more than 200 metres) basinal equivalents.



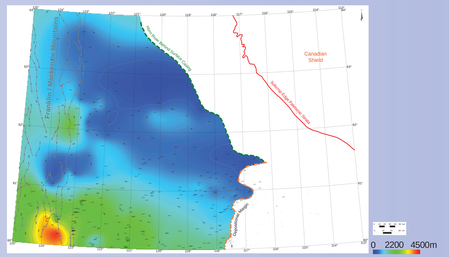
STRATIGRAPHIC CROSS-SECTION JJ-JJ'

North-south stratigraphic cross-section JJ JJ' shows thick Horn River shales (highlighted purple) in the northern starved basin passing southward into platform carbonates of the Slave Point Formation. A thin, organic-rich equivalent termed the Muskwa Shale can be traced further southward above the Slave Point carbonates. Horn River / Slave Point strata are capped by thick, basin-filling shales of the Fort Simpson Formation (highlighted green). Note the contrast in gamma-ray log responses between the two shales – higher gamma values in the Horn River and Muskwa indicate high organic content (TOC).



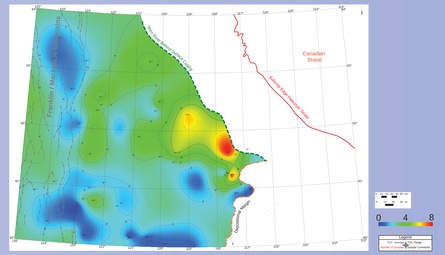
DEPTH TO FORMATION

Horn River shales are buried to depths of 4000 metres in the Liard Basin (far southwest). Moving eastward onto the North American craton, erosion beneath the pre-Cretaceous unconformity has removed younger strata to the point that the top Horn River is behind surface casing in wells to the northeast. Surficial glacial sediments and difficulty of access preclude mapping of outcrop equivalents further eastward.



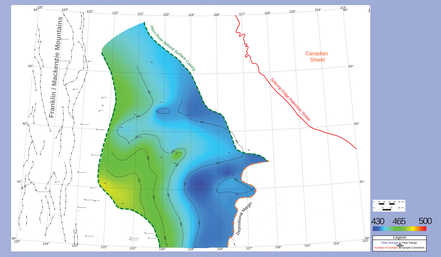
TOTAL ORGANIC CARBON (TOC)

TOC values are measured from sample cuttings in most wells; there are thus relatively few values in each wellbore, and values tend to be widely scattered. Generally higher values in several wells in the east, where the shales are less mature, indicate that the Horn River was originally organic-rich. Lower values in more thermally mature areas to the west are interpreted to indicate that some of the organic matter has generated free hydrocarbons.



T_{MAX}

T_{max} data, a measure of source rock maturity, have been gathered historically for conventional source rock assessment. Relatively scarce data demonstrate a clear trend of increasing maturity westward, where there has been more subsidence and greater burial depths. The Horn River is sufficiently mature to generate gas in the west, and liquid hydrocarbons in the east. West of the dashed line, S2 values are generally very low, and thus T_{max} values are not reliable.



SUMMARY
LIARD – GREAT SLAVE AREA

BEST PROSPECTIVITY

Muskwa – Horn River (Devonian)
- Moderate to good TOC
- Maturity – dry gas to southwest; liquids-rich in central and eastern areas
- Thickness > 100m basinward of carbonate platform
- Analogue – prolific dry gas production from Horn River Basin immediately to the south

MODERATE PROSPECTIVITY

Fort St. John (Cretaceous)
- Moderate TOC; higher levels in basal organic-rich intervals
- Maturity – gas to wet gas in southwest; oil to east
- Thickness – several hundred metres, but organic-rich intervals <50m
- Analogue – >100 BCF/mi2 gas-in-place mapped to south in B.C., not tested

Exshaw (Devonian-Mississippian)
- Good to excellent TOC
- Maturity – liquids-rich to oil
- Limited distribution, relatively thin (<25m)
- Analogue – liquids-rich gas tested to south in Horn River Basin

POOR PROSPECTIVITY

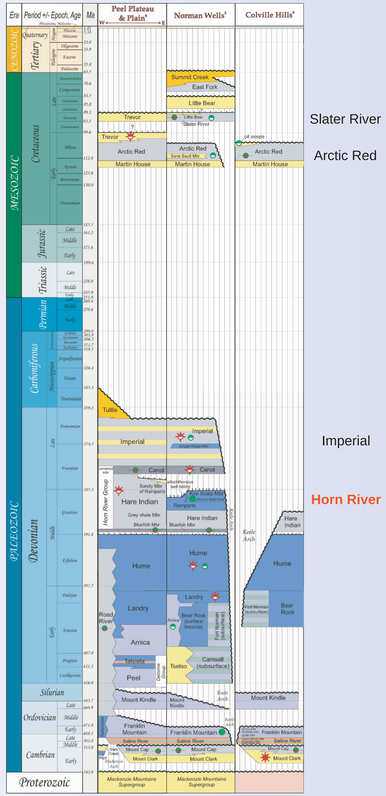
Fort Simpson (Devonian)
- Poor (<1%) TOC, no organic-rich intervals
- Maturity – dry gas to southwest; liquids-rich in central and eastern areas
- Thickness - >500m in south, thins northward
- Equivalent strata in Horn River Basin show moderate porosity, clay-rich mineralogy

Banff (Mississippian)
- Low to moderate TOC; some organic-rich intervals in outcrop equivalent to west
- Maturity – oil to east; little data to west (gas?)
- Thickness - >700m in southwest; thins sharply eastward to zero edge

PEEL – MACKENZIE STUDY AREA

STRATIGRAPHIC COLUMN

Peel - Mackenzie features a thick, carbonate-dominated Paleozoic section, truncated beneath a profound regional sub-Cretaceous unconformity. Middle Devonian Horn River shales are highly prospective for gas and liquids, and are the main focus of this poster. Lesser prospectivity has been documented in the Upper Devonian Imperial Formation, and Cretaceous Arctic Red and Slater River shales.

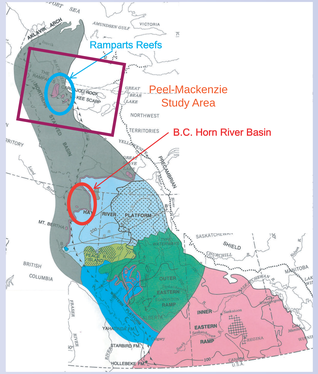


Stratigraphic column after Jones and Gal, 2007.

HORN RIVER PALEOGEOGRAPHY

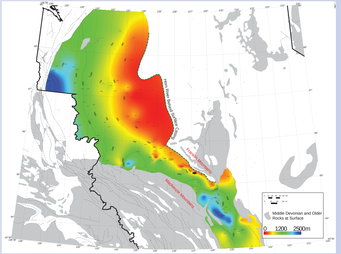
This regional paleogeographic reconstruction by Moore (1993) shows most of the NWT to have been a starved basin during Horn River (Middle Devonian) time, lying north of stacked carbonate buildups of the Hay River Platform. Horn River shales in the Horn River Basin of northern British Columbia, at the southern edge of the starved basin, are currently being developed for dry gas production. Equivalent shales are being explored in the adjacent Cordova Embayment.

Thick carbonate buildups of the Ramparts Formation / Kee Scarp Member, within the Horn River Group, host a large conventional light oil pool at Norman Wells in Peel-Mackenzie study area. They have been a major focus of conventional exploration in the NWT.



DEPTH TO FORMATION

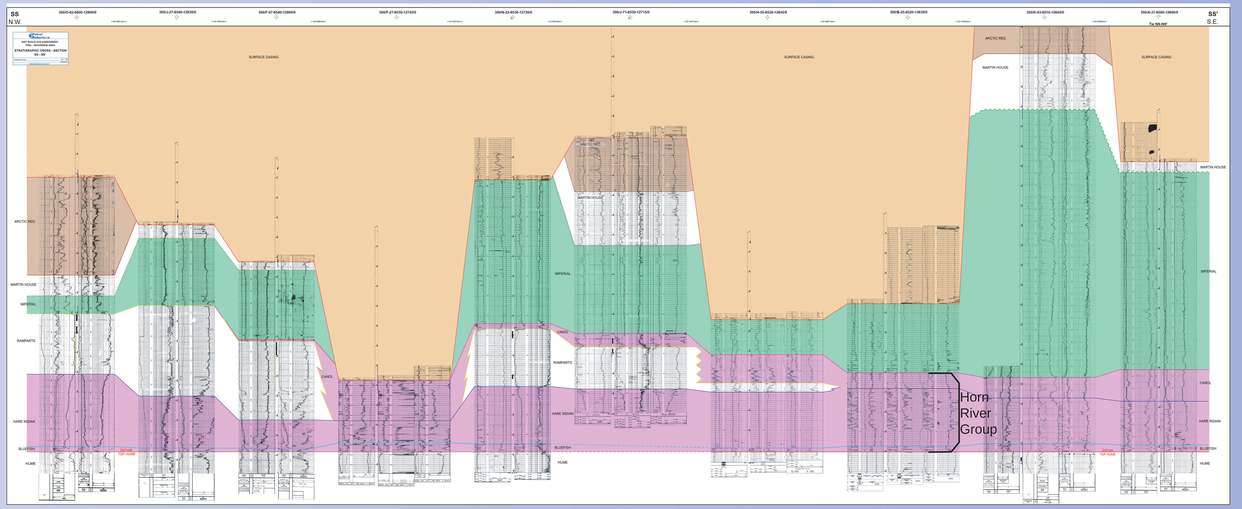
Horn River shales are buried to depths of more than 2000 metres in the foredeep in front of the Mackenzie Mountains. Erosion beneath the pre-Cretaceous unconformity has removed younger strata to the point that the top Horn River is behind surface casing in wells to the northeast.



STRATIGRAPHIC CROSS-SECTION SS-SS'

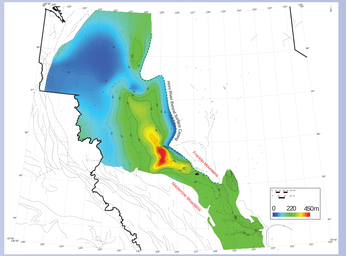
Northwest-southeast stratigraphic cross-section SS-SS' shows thick, organic-rich Horn River shales (highlighted purple) in the southeast. To the northwest, clean carbonates of the Ramparts Formation / Kee Scarp Member occupy much of the Horn River section. Horn River / Ramparts strata are capped by thick, basin-filling shales of the Fort Simpson Formation (highlighted green), and the Fort Simpson is truncated northwestward beneath the pre-Cretaceous unconformity.

Thrust faulting at the front of the Mackenzie Mountains to the west causes the abrupt variations in amount of stratigraphic section preserved at each location.



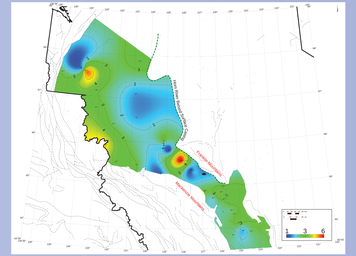
GROSS THICKNESS

Horn River shales are more than 300 metres thick in some western basinal areas, and are truncated northeastward, primarily beneath the pre-Cretaceous unconformity. Major thrust faults associated with the Mackenzie and Franklin Mountains produce abrupt thickness variations in the southeast. Further north, the top of the Horn River Group is lost behind surface casing. Rampart/Kee Scarp reefs, part of the Horn River Group, make up much of the central thick area, which reaches close to 500 metres.



TOTAL ORGANIC CARBON (TOC)

TOC values are measured from sample cuttings in most wells; there are thus relatively few values in each wellbore, and values tend to be widely scattered. As a result, it was not possibly to calculate reliable average TOC values in many wells, nor to draw meaningful contours across the map sheet. Numerous TOC values greater than 5% and averages in excess of 3% indicate an organic-rich shale. Recent sampling from outcrops in the Mackenzie and Franklin Mountains provides additional evidence of the organic-rich nature of Horn River shales (Pyle et. al., 2011).



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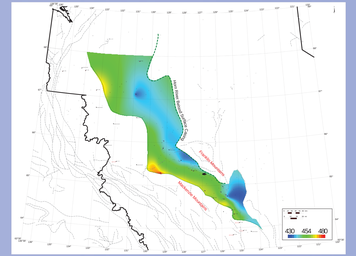

SUMMARY
PEEL – MACKENZIE AREA

BEST PROSPECTIVITY

Horn River (Canol / Hare Indian / Bluefish) (Devonian)

- Moderate to good TOC
- Maturity – oil in Central Mackenzie Valley; more gas-prone to northwest
- Thickness > 100m basinward of carbonate buildups (Ramparts Fm)
- Recent targeted outcrop studies show Type II kerogen, high TOC, mature for oil, and high silica content
- Analogue – prolific dry gas production from Horn River Basin in B.C.

MODERATE PROSPECTIVITY

Slater River (Cretaceous)

- Moderate to good TOC; higher levels (6-8%) in organic-rich intervals
- Maturity – oil window
- Thickness – 200-500m, but organic-rich intervals <50m
- Limited distribution, has not been tested

POOR PROSPECTIVITY

Imperial (Devonian)

- Poor (<1%) TOC, no organic-rich intervals
- Maturity – oil in Central Mackenzie Valley; more gas-prone to northwest
- Thickness - >1000m in western foredeep, thins eastward
- Equivalent to Fort Simpson in Liard-Great Slave area

Arctic Red (Cretaceous)

- Low to moderate TOC; no organic-rich intervals
- Maturity – oil in Central Mackenzie Valley; sparse data
- Thickness – >1500m in western foredeep, thins eastward

REGIONAL CHARACTERIZATION OF SHALE GAS AND SHALE OIL POTENTIAL, NORTHWEST TERRITORIES, CANADA

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INTRODUCTION

Unconventional gas and oil plays, particularly those hosted by shales, demonstrate great resource potential and productive capacity in petroleum basins throughout North America. Where there is abundant conventional production and drilling, companies use existing wellbore and analytical data to identify and appraise shale gas and shale oil plays. Confirming resource potential and commercial producibility requires extensive analysis of these data, followed by field experiments to optimize drilling and completion procedures.

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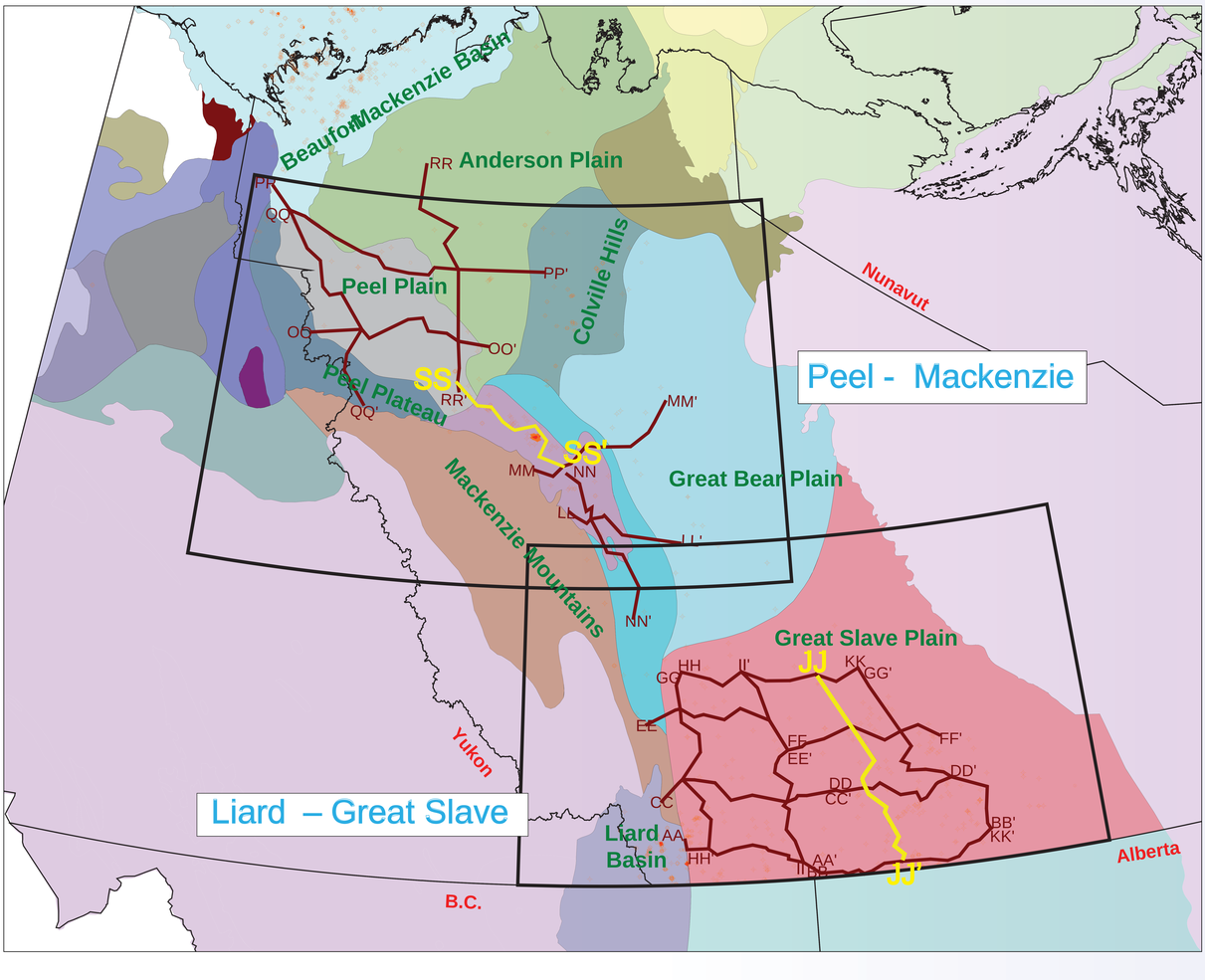
This poster focuses on the most prospective shale unit – the Devonian Horn River Formation, which is equivalent to the producing shales of the Horn River Basin in adjacent northeastern British Columbia.

STUDY AREAS

Two study areas, based on stratigraphy and well control density, are defined: the southern Liard – Great Slave Study Area, and the northern Peel – Mackenzie Study Area. Each spans a number of exploration regions (labelled on the map), which reflect both subsurface geology and surface geographic features. For the Liard – Great Slave study area, regional cross-section JJ-JJ' has been selected to illustrate subsurface stratigraphy, while cross-section SS-SS' illustrates subsurface stratigraphy for Peel-Mackenzie.



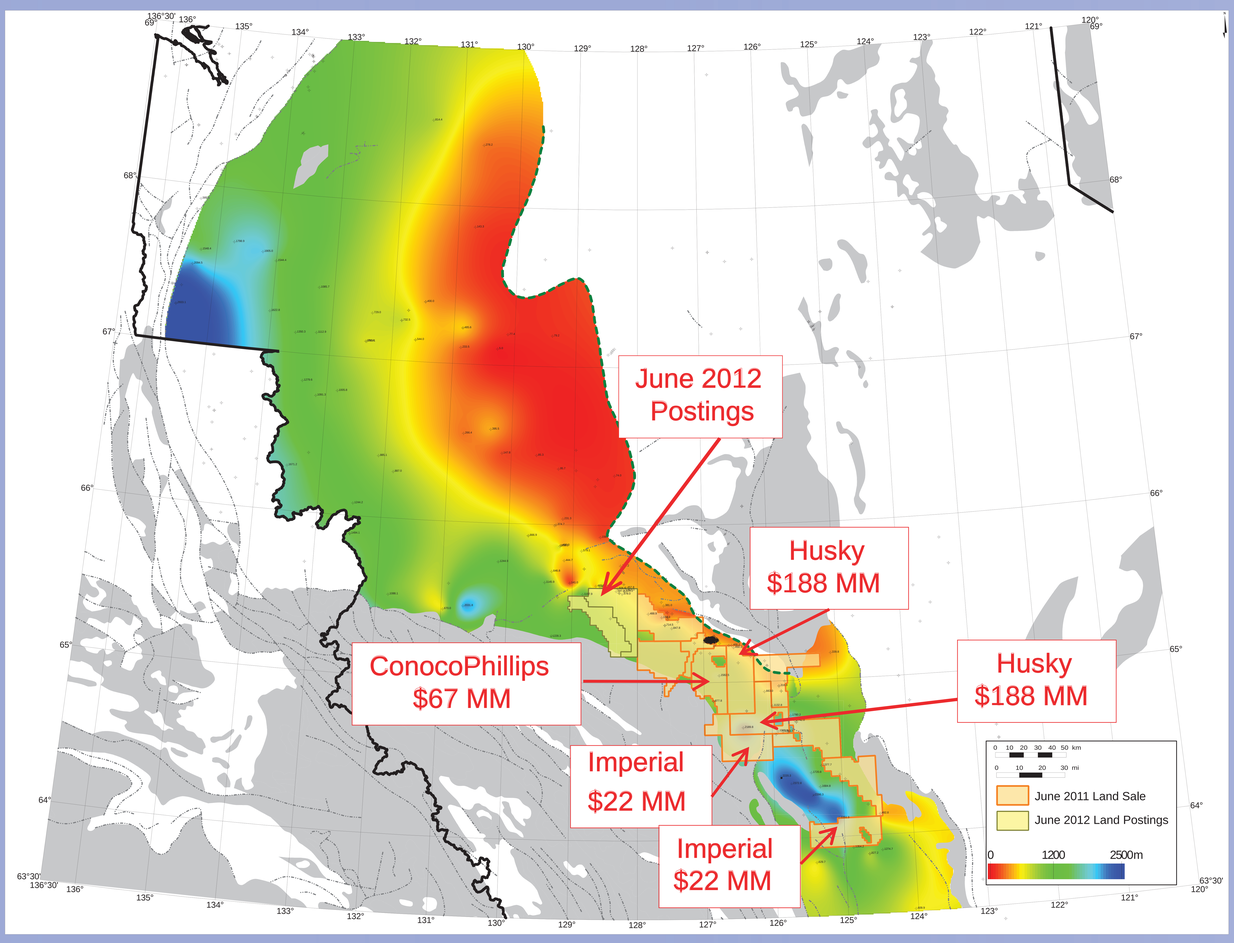
CURRENT EXPLORATION STATUS

Exploration in Northwest Territories is constrained by remote access, lack of infrastructure, and the limited (although substantial) size of conventional prospects. The enormous unconventional oil and gas resources of the Horn River shales have proven to be a “game-changer”, however, and several companies are actively prospecting.

In June 2011, five companies posted work proposal bids totaling more than $534 million on 11 parcels of land covering almost 900,000 ha (2.22 million acres). Husky Energy, ConocoPhillips, and MGM Energy have all announced programs focused on oil potential from Horn River shales.

Two additional parcels, totalling more than 154,000 ha (381,000 acres) have been posted for disposition in mid-2012. Additional lands may be posted in the future, depending upon strategic consultations with First Nations in the area.

PEEL - MACKENZIE STUDY AREA
LAND SITUATION MAP
(HORN RIVER GROUP DEPTH TO FORMATION MAP)



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