Petroleum Resource Potential of the Mackenzie Corridor, Canada: Conceivable Linkages with the Proposed Mackenzie Valley Natural Gas Pipeline*

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Abstract

The Mackenzie Corridor, an area along the proposed route of the Mackenzie Valley pipeline, constitutes a significant petroleum frontier province in Canada’s north. The Geological Survey of Canada has recently completed its first comprehensive exploration play-based quantitative petroleum assessment analysis of the region, the results of which are the subject of this presentation.

Objectives

Canada’s northern mainland basin is separable into two distinct geological terrane-types: the relatively undeformed platform succession underlying the plains area of Northwest Territories (the Interior Platform) and the deformed fold and thrust belt of the Cordillera in western Northwest Territories and eastern Yukon (the Northern Foreland Belt). A total of 37 oil and gas mature, immature and conceptual exploration plays have been defined and mapped in the study area, which extends from the 60th parallel, northward to, but not including, the Mackenzie Delta.

Procedure

All plays were defined on the basis of reservoir or reservoirs in which oil and/or natural gas were expected to accumulate. All aspects of the hydrocarbon system affecting each play such as source, seal, thermal maturity, trap-style, timing and exploration risks were also defined. Oil and gas play maps were then constructed to define the limits of preserved petroleum accumulations. Once the play maps were completed, compilation of all relevant petroleum data needed to perform volumetric probabilistic analyses for immature and conceptual plays and discovery process techniques for mature plays was undertaken. Probabilistic statistical analyses produced in-place play potential volumes, individual undiscovered pool size estimates, and the
number of pools expected to occur in each play. Matching techniques were used to determine the ranks of discovered pool sizes to individual pool size volumes.

**Results**
The probabilistic assessment results of total oil and gas potential (produced and remaining) for all sedimentary strata in the Mackenzie Corridor of Canada are in-place mean volumes of 6,624 MMBO of oil and 77 Tcf of gas. Although discovered reserves are substantial in the Mackenzie Corridor region, remaining resource potential is significant as exemplified by the prediction of 8 oil pools greater in size than 100 MMBO and 11 gas pools greater than 250 BCF.

**Conclusions**
Sufficient data was available in the majority of 37 defined plays established throughout the stratigraphic column from Proterozoic to Cretaceous age to predict their oil and gas endowment. This major study will provide important information for stakeholders involved in the proposed construction of the Mackenzie Valley natural gas pipeline with respect to petroleum potential adjacent or proximal to its proposed route.

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Natural Resources Canada-Geological Survey of Canada-Calgary
Major Discoveries

From Lemieux, 2007

- 1974 Tedji Lake
- 1985 Tweed Lake
- 1986 Bele, 2003 Nogha
- 1920 Norman Wells
- 1971 E Mackay
- 2004 Summit Cr.
- 2005 Stewart
- 1966 Pointed Mtn
- 1962 Kotangaale
- 1957 Beaver River
- 1961 Netla
- 1989 Arrowhead
- 1968 Cameron Hills
Petroleum Wells and Pipelines
Seismic Coverage

From Lemieux, 2007
Exploration Plays - Conventional

- 37 conventional exploration plays
  - **Interior Platform**
    - 25 plays (most containing oil & gas)
    - 4 mature oil & gas plays
    - 6 mature gas plays
    - 13 immature or conceptual oil & gas plays
    - 3 immature or conceptual oil plays
    - 2 conceptual gas plays
  - **Northern Foreland Belt**
    - 12 plays
    - 7 immature or conceptual oil & gas plays
    - 5 immature or conceptual gas plays
Mature Plays - Discovery Process

From Lemieux, 2007
Immature & Conceptual Plays

From Lemieux, 2007
Interior Platform
Cambrian Clastic Play
(Interior Platform)

- Established oil & gas play, 5 gas discoveries; 1 oil disc.
- Reservoir: Mt. Clark sandstones
  Lower Mt. Cap sandstones & dolomites
- Source: poss. gas source in Proterozoic sediments
  oil-prone algal-rich shales in Mt. Cap
- Seal: Saline River evaporites; Mt Cap shales
- Trap-styles: Flower structures; roll-over anticlines;
  stratigraphic pinchouts; onlap against basement highs
- Exploration risks: adequate reservoir; source;
  communication with source
Reservoir - Mt. Clark Formation

From Pyle et al., 2007
Cambrian Clastic Play (Interior Platform)

Petro-Canada line 8624

Largest gas discovery ranks 2nd among 105 pools

**Gas**
- P5: $642 \times 10^9 \text{ m}^3$
- P50: $247 \times 10^9 \text{ m}^3$
- P95: $83 \times 10^9 \text{ m}^3$
  (Mean: 10.8 Tcf)

**Oil**
- P5: $402 \times 10^6 \text{ m}^3$
- P50: $106 \times 10^6 \text{ m}^3$
- P95: $15 \times 10^6 \text{ m}^3$
  (Mean: 952 MMBO)
Slave Point/ Sulphur Point Edge Play
(Interior Platform)

- Established gas play, 61 discoveries; conceptual oil play
- Reservoir: Slave Point/Sulphur Point reefal carbonates
- Source: oil & gas source in organic-rich Devonian shales - Muskwa & Horn River
- Play area: 7390 sq. km. (gas play); 1800 sq. km. (oil)
- Seal: Horn River shale (lateral); Muskwa shale (top); tight Slave Point/Sulphur Point limestones (top)
- Trap-styles: dolomitized bioherms or buildups
- Exploration risks: adequate reservoir (dolomite development), adequate long-term seal
Reservoir - Slave Point/Sulphur Point

Typical, well-developed Presqu’ile-type “facies”.

dark grey replacive saddle dolomite
white, saddle dolomite cement
grey replacive saddle dolomite

G-15-919.5
Slave Point/Sul. Pt. Edge Play (Interior Platform)

Gas
- P5: $345 \times 10^9$ m$^3$
- P50: $176 \times 10^9$ m$^3$
- P95: $77 \times 10^9$ m$^3$
- (Mean: 6720 Bcf)

Oil
- P5: $115 \times 10^6$ m$^3$
- P50: $14 \times 10^6$ m$^3$
- P95: $1 \times 10^6$ m$^3$
- (Mean: 225 MMBO)

Northcor line 12 Largest undiscovered pool ranks 10th among 159 gas pools.
Bovie structural
(Interior Platform)

- Established gas play, one discovery; conceptual oil play
- Reservoirs: Paleozoic carbonates & sands; Mesozoic sands
- Source: oil & gas source in organic-rich shales (eg. Besa River, Exshaw, Garbutt)
- Seal: Besa River, Horn River, Banff shales
- Trap-styles: updip fault closures; hangingwall rollover anticlines; secondary dolomitization at structural discontinuities
- Exploration risks: adequate porosity, timing & migration in Mattson & older reservoirs
Bovie structural
(Interior Platform)

Shell line 91
Largest gas discovery ranks 2nd among 55 pools

Gas
P5: $6.5 \times 10^9$ m$^3$
P50: $1.6 \times 10^9$ m$^3$
P95: $0.3 \times 10^9$ m$^3$
(Mean: 88 Bcf)

Oil
P5: $8 \times 10^6$ m$^3$
P50: $1.3 \times 10^6$ m$^3$
P95: $0 \times 10^6$ m$^3$
(Mean: 16 MMBO)
Northern Foreland Belt
### Petroleum Systems

**Foreland Belt**

![Diagram of Petroleum Systems in the Foreland Belt](image)

- **AGE**
  - **QUATERNARY**
  - **PLEISTOCENE**
  - **TERTIARY**
    - **MIOCENE**
    - **OLIGOCENE**
    - **EOCENE**
    - **PALEOCENE**
  - **CRETACEOUS**
    - **UPPER**
      - **DURVEGAN FM**
      - **SUNSET FM**
      - **LONGFM**
      - **SCATTER FM**
    - **LOWER**
      - **DURVEGAN FM**
      - **SUNSET FM**
      - **LONGFM**
      - **SCATTER FM**
  - **JURASSIC**
  - **TRIASSIC**
  - **PERMIAN**
  - **CARBONIFEROUS**
  - **DEVONIAN**
    - **UPPER**
    - **MIDDLE**
    - **LOWER**
  - **SILURIAN**
  - **ORDOVICIAN**
  - **CAMBRIAN**
  - **PROTEROZOIC**

<table>
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<th>Age</th>
<th>Great Slave Plain</th>
<th>Mackenzie Plain-Colville Hills</th>
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<td>Proterozoic</td>
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</tbody>
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**Legend**
- **Shale**
- **Shale, thin sandstone beds**
- **Sandstone/Quartzite**
- **Conglomerate, sandstone**
- **Sediments, carbonates**
- **Limestone, dolostone**
- **Dolomite**
- **Dolostone, evaporites**
- **Evaporites**
- **Cherts**
- **Crystalline rocks**

- **Known source rock**
- **Oil discovery**
- **Gas discovery**
- **Oil and gas discovery**

**Canada**

**Natural Resources Canada**

**Ressources naturelles Canada**
Kee Scarp reef-Ramparts Platform (Foreland Belt)

- Established oil & gas play, 1 discovery (Norman Wells)
- Reservoir: Kee Scarp & Ramparts limestones
- Source: oil source in Canol black shales
- Seal: Canol shale (lateral & top)
- Trap-styles: isolated reefs; low relief shoals on platform
- Exploration risks: adequate reservoir; preservation
Reservoir- Kee Scarp/Ramparts
Kee Scarp reef - Ramparts Platform
(Foreland Belt)

Gas
P5: 24*10^9 m^3
P50: 7*10^9 m^3
P95: 0.2*10^9 m^3
(Mean: 328 Bcf)

Oil
P5: 546*10^6 m^3
P50: 166*10^6 m^3
P95: 21*10^6 m^3
(Mean: 1337 MMBO)

Largest oil discovery ranks 1st among 10 pools
Arnica/Landry platform (Foreland Belt)

- Established oil & gas play, 1 discovery (Summit Creek)
- Reservoir: Arnica/Landry/Bear Rock carbonates
- Source: Bluefish, Canol shales; shale interbeds in Ramparts Formation
- Seal: Bluefish & Canol shales (lateral & top); tight Hume argillaceous limestones (top)
- Trap-styles: overthrust & faulted anticlines; fault closures; post-depositional leaching & dissolution traps
- Exploration risks: adequate reservoir, seal, timing
Arnica/Landry platform  
(Foreland Belt)

**Gas**
- P5: $100 \times 10^9$ m$^3$
- P50: $41 \times 10^9$ m$^3$
- P95: $2 \times 10^9$ m$^3$

(Mean: 1610 Bcf)

**Oil**
- P5: $303 \times 10^6$ m$^3$
- P50: $120 \times 10^6$ m$^3$
- P95: $7 \times 10^6$ m$^3$

(Mean: 854 MMBO)

Largest gas discovery ranks 10th among 33 pools
Liard – Manetoe Gas Play (Foreland Belt)

- Established gas play, 13 discoveries (Pointed Mountain, Kotaneelee, Beaver River, Liard, Labiche)
- Reservoir: Manetoe dolomite
- Source: Besa River, Horn River shales
- Seal: Besa River & Horn River formations
- Trap-styles: faulted anticlines; post-depositional leaching & dissolution traps
- Exploration risks: adequate reservoir, timing, preservation
Liard – Manetoe Gas Play (Foreland Belt)

Largest undiscovered pool ranks 3rd among 156 gas pools

Gas

P5: 846*10^9 m³
P50: 230*10^9 m³
P95: 48*10^9 m³

(Mean: 12010 Bcf)
Unconventional Resources

- **Shale gas:** Horn River/Bluefish/Hare Indian (M. Devonian)
  Road River (Ordovician-Devonian)
  Canol/Muskwa/Imperial/Ft. Simpson
  (M-U. Devonian)
  Besa River/Exshaw/Banff (Carboniferous)
  Arctic Red/Fort St. John (M. Cretaceous)
  Boundary Creek/Smoking Hills (U. Cret.)

- **Tight gas:** U. Dev. Jean Marie shelfal carbonates
  Mackenzie Valley

- **Coal bed methane:** Mattson/Wapiti (Liard Basin)
  Little Bear/Summit Creek (Brackett Basin)

- **Oil shales:** Canol (Norman Wells area)
  Smoking Hills (Anderson Plain)
Mackenzie Corridor
Undiscovered Pool Sizes (Gas)

Pool Size Estimates (Median P50 Values)

- 2 Tcf
- 1 Tcf
- 500 Bcf
- 250 Bcf

Largest Pool
28.3 Billion m$^3$
(1 Tcf)

Twelve Pools
> 7.1 Billion m$^3$
(250 Bcf)

Pool Sizes by Rank
- Lower Cretaceous clastics-South
- Jean Marie platform & platform margin
- Cambrian clastics
- Liard Manetoe
- Arnica-Landy platform (Foreland Belt)
- Slave Point reef complexes
Mackenzie Corridor
Undiscovered Pool Sizes (Oil)

Pool Size Estimates (Median P50 Values)

Largest Pool
30.8 Million m³
(194 MMBO)

Nine Pools
> 15.9 Million m³
(100 MMBO)
37 conventional oil & gas exploration plays have been defined
25 in Interior Platform; 12 in Foreland Belt
30 have enough data for quantitative analysis

Interior Platform plays have total mean in-place potential of
1717 * 10^9 m^3 of gas (61 Tcf)
661 * 10^6 m^3 of oil (4158 MMBO)

Plays with greatest total mean potential are:
Jean Marie platform gas - 314 * 10^9 m^3 (11 Tcf)
Slave Point reef complex oil - 217 * 10^6 m^3 (1363 MMBO)

Plays with the largest undiscovered median pool size are:
Lower Cretaceous clastic-South gas - 28 * 10^9 m^3 (1.0 Tcf)
Cambrian clastic oil - 28 * 10^6 m^3 (178 MMBO)
Foreland Belt plays have total mean in-place potential of
425 \times 10^9 \text{ m}^3 of gas (15 Tcf)
384 \times 10^6 \text{ m}^3 of oil (2415 MMBO)

Plays with greatest total mean potential are:
Liard Manetoe gas - 340 \times 10^9 \text{ m}^3 (12 Tcf)
Kee Scarp reefs-Ramparts platform oil - 212 \times 10^6 \text{ m}^3 (1337 MMBO)

Plays with the largest undiscovered pool size (P50) are:
Liard Manetoe gas - 13 \times 10^9 \text{ m}^3 (0.5 Tcf)
Kee Scarp reefs-Ramparts platform oil – 30.8 \times 10^6 \text{ m}^3 (194 MMBO)

Unconventional oil & gas have not been quantitatively analyzed. However, multi-Tcf of recoverable resources have been announced from initial testing and fracturing (Horn River)
Mean Resource Potential in Project Area

**Play Definition Totals**
- 77 Tcf gas
- 6623 MMB oil

**Project Area Totals**
- 32.8 Tcf gas
- 4790 MMB oil
Thank you!

For further information:
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