# Petroleum Reservoir and Source Rock Potential in Lower and Middle Paleozoic strata of Peel Plateau and Plain, Northwest Territories and Yukon


**L.P. Gal, Northwest Territories Geoscience Office, Yellowknife, NT; L.J. Pyle, Geological Survey of Canada – Pacific, Sidney, BC;**
**T.L. Allen & T.A. Fraser, Yukon Geological Survey, Whitehorse YT; T. Hadlari, Y. Lemieux, & W.G. Zantvoort, Northwest Territories Geoscience Office, Yellowknife, NT**


Regional Geoscience Studies & Petroleum Potential, Peel Plateau & Plain

NORTHWEST TERRITORIES GEOSCIENCE OFFICE — RESEARCH • ANALYSIS • INFORMATION

YUKON GEOLOGICAL SURVEY

CANADA 1912 — GEOLOGICAL SURVEY · COMMISSION GÉOLOGIQUE

## INTRODUCTION

Peel Plateau and Plain (Peel Region) lies along the northern Mackenzie Corridor in the NWT and Yukon (Figure 1). Peel Region has widespread hydrocarbon potential yet is under-explored and its geological history is poorly understood. More than 70 exploratory wells have been drilled here (Figure 2). Some of these wells had encouraging hydrocarbon shows, yet no major discoveries have been reported. This poster presents some preliminary observations and analyses of porosity/permeability and Rock-Eval/TOC from outcrop samples of Lower Paleozoic rocks from Peel Region.


*Figure 1: Peel Region location map (bold red outline). Mackenzie Corridor in red dashed outline*

The ***Regional Geoscience Studies and Petroleum Potential, Peel Plateau and Plain*** Project is a multidisciplinary, collaborative partnership among Northwest Territories Geoscience Office, Geological Survey of Canada, Yukon Geological Survey; with university and industry involvement.


*Figure 2: Peel Region well locations*

## STRATIGRAPHY

This poster is concerned with reservoir and source rock potential of the Lower and Middle Paleozoic (and Proterozoic) section (Figure 3) in the Peel Region. Cambrian to Silurian strata lie unconformably on Proterozoic rocks, typically Katherine Group sandstone/quartzite. The Cambrian to Silurian succession records the transition from an epicratonic sea in the Cambrian to passive continental margin setting in the Ordovician and Silurian. Lower and Middle Devonian strata in the Peel Plateau and Plain include a series of shelf carbonates that pass westward into basinal shales. The carbonates are overlain stratigraphically by shale, including important hydrocarbon source rocks.

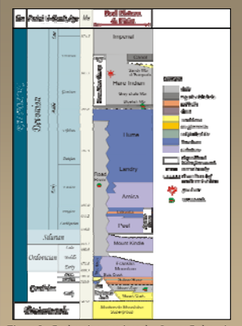


*Figure 3: Peel region stratigraphy, Lower Paleozoic, modified from Morrow et al., 2006.*

## Proterozoic and Cambrian RESERVOIR POTENTIAL

Cambrian Mount Cap/Mount Clark Formation quartz sandstone is a possible reservoir unit, restricted to eastern Peel region (figures 4,5). Mount Cap (?) Formation sandstones in outcrop are variably glauconitic and / or quartz-cemented but appeared to have some porosity (Table 1, Figure 6). Petrographic examination of Mount Clark and Katherine Group quartz sandstones indicates that they are tight.

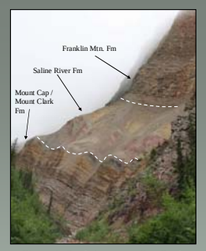


*Figure 4: Cambrian strata, Fan Creek, southeast Peel Region. Saline River Fm is about 30 m thick.*

*Figure 5: Cambrian Mount Cap Fm glauconitic and quartz sandstone.*

*Figure 6: Photomicrograph of Mount Cap Fm glauconitic (arrows) quartz sandstone. Sample 06LP-21-14, plane polarized light. Red scale bar = 0.5 mm.*

| Sample Number | Formation | Porosity (%) | Permeability (mD) |
|---|---|---|---|
| 06LP-21-13 | Mount Cap / Mount Clark quartz cemented sandstone | 4.4 | 0.03 |

*Table 1: Measured porosity and permeability from Cambrian outcrop sample.*

## Cambrian to Silurian RESERVOIR POTENTIAL

Cambrian-Ordovician Franklin Mountain and Ordovician-Silurian Mount Kindle formations are dominantly tight dolo-mudstones, but some significant porous beds do exist (tables 2, 3). Coarse-grained, vuggy (hydrothermal?) stratiform dolomite was found in zones tens of metres thick, in Franklin Mountain Formation, at several sections along the Mackenzie Mountain front (figures 7-9). Mount Kindle Formation was locally observed to be sucrosic with intercrystalline porosity, and vuggy and / or moldic / fenestral dissolution porosity was seen where silicified fossils had been removed (figures 10-11). A redbed facies locally found at base Franklin Mountain Formation includes beds of immature quartz sandstone, variably carbonate cemented (figures 12-13).

*Figure 7: Vuggy coarse-grained (hydrothermal?) Franklin Mountain Fm dolomite in foreground. Near Flyaway Creek, adjacent eastern Peel Plateau. White dashed line indicates Proterozoic / Franklin Mountain Fm contact, yellow arrow indicates vuggy coarse-grained dolomite. Large boulder in foreground about 70 cm high.*

*Figure 8: Sample 06LP-13-01 core plug, Franklin Mountain Fm dolomite. See Table 2 for porosity.*


*Figure 9: Photomicrograph of sample 06LG-10-01, Franklin Mountain Fm vuggy dolomite, note late calcite (yellow arrow). Plane polarized light. See Table 2 for porosity.*

*Figure 10: Typical outcrop weathering, Mount Kindle Fm dolomite with silicified stromatolites, Gayna River.*

*Figure 11: Fenestral vugs, Mount Kindle Fm dolomite, Powell Creek.*

| Sample Number | Formation | Porosity (%) | Permeability (mD) |
|---|---|---|---|
| 06LP-09-01 | Mount Kindle | 3.2 | 0.11 |
| 06LP-12-06 | Mount Kindle | 3.8 | 1.90 |
| 06LP-13-05 | Mount Kindle | 5.1 | 0.05 |

| Sample Number | Formation | Porosity (%) | Permeability (mD) |
|---|---|---|---|
| 06LP-04-02 | Franklin Mountain | 9.4 | 1.07 |
| 06LG-10-01 | Franklin Mountain | 4.4 | 0.29 |
| 06LP-13-01 | Franklin Mountain | 6.5 | 0.09 |

*Table 2 (top) and Table 3 (bottom): Measured porosity and permeability from Cambrian to Silurian dolomite outcrop samples.*

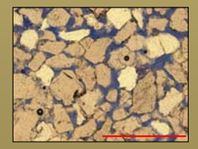

*Figure 12: Photomicrograph of sample 06LP-16-01, Franklin Mountain Fm "redbeds", immature quartz sandstone. Plane polarized light, red scale bar = 0.5 mm.*

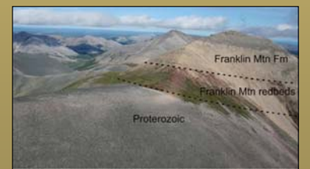


*Figure 13: Franklin Mountain Fm basal "redbed" unit, near Elbow Creek, adjacent south central Peel Plain.*

For updates, information and downloads:
http://www.nwtgeoscience.ca/petroleum/PeelPlateau.html

## Lower Devonian RESERVOIR POTENTIAL

Lower Devonian Arnica Formation sucrosic medium grained dolomite with intercrystalline porosity is common, in gross intervals of tens of metres, and individual beds on the decimetre to metre-scale (figures 14-15). Sucrosic dolomite is rarer in underlying Peel Formation (Figure 16). At the eastern limit of Arnica Formation in eastern Peel Plain, dissolution breccias occur (Figure 17) which are gradational with Bear Rock Formation breccia (Figure 18), and interfinger with Fort Norman Formation evaporites (Figure 19). At its western limit, Arnica Formation includes fossiliferous limestone biostromes (Figure 20) which may be porous in subsurface.

*Figure 14: Arnica Fm sucrosic dolomite.*

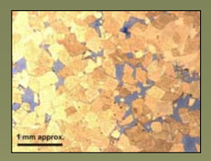


*Figure 15: Photomicrograph of Arnica Fm sucrosic dolomite. Sample 06LG-10-02, plane polarized light. See Table 4 for porosity.*

*Figure 16: Peel Fm sucrosic dolomite.*

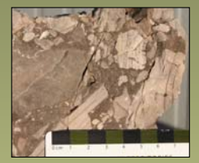

*Figure 17: Arnica Fm breccia.*

*Figure 18: Bear Rock Fm breccia.*

| Sample Number | Formation | Porosity (%) | Permeability (mD) |
|---|---|---|---|
| 06LG-10-02 | Arnica | 6.0 | 1.94 |
| 06LP-13-10 | Arnica | 4.2 | 0.06 |
| 06LP-22-09 | Arnica breccia | 6.1 | 1.99 |

*Table 4: Measured porosity and permeability from Arnica Fm outcrop samples.*


*Figure 19: North limb of Imperial anticline, Stratigrapher Cliffs, eastern Peel Plain. Light coloured Fort Norman Formation is overlain (contact indicated) by darker weathering, oil stained Arnica Fm dolomite (about 25 m exposed).*

*Figure 20: Mackenzie Mountain front near Snake River. Arnica Formation includes light coloured fossiliferous limestone biostromes, resistant rib here is about 15 m wide.*

## Middle Devonian RESERVOIR POTENTIAL

Middle Devonian Ramparts Formation is a producing reservoir (240 million barrels) at Norman Wells, to the southeast in Mackenzie Plain The reefal Kee Scarp member is distributed in the eastern Peel Plain, mainly comprising thamnopora-stromatoporoid packstone to wackestone (figures 21-24). Porosity and permeablity are variable (Table 5).

*Figure 21: Resistant ridge formed by reefal Kee Scarp member (basal contact indicated) of Ramparts Fm, west of Powell Creek, adjacent southeastern Peel Plain.*

*Figure 22: Resistant bluff of stromatoporoid -brachiopod floatstone at Airport Creek in northeast Peel Plain.*

*Figure 23: Boulder of typical thamnopora-stromatoporoid packstone, west of Powell Creek.*

*Figure 24: Medium bedded thamnopora wackestones to packstone, near lateral edge of "reef", west of Powell Creek. Hammer for scale (circled).*

| Sample Number | Formation | Porosity (%) | Permeability (mD) |
|---|---|---|---|
| 06LP-19-01 | Ramparts | 0.5 | 0.05 |
| 06LP-20-04 | Ramparts | 10.6 | 0.87 |

*Table 5: Measured porosity and permeability from Ramparts Fm limestone outcrop samples*


## SOURCE ROCK POTENTIAL

The Middle Devonian Bluefish Member (basal Hare Indian Formation), shale ramp (or "Carcajou") member of Ramparts Formation, and Upper Devonian Canol Formation are the best quality source rocks in the Peel area (figures 25-28). These are dark brown to black and bituminous shale, with dominantly Type I, oil-prone kerogen (Figure 29); Canol Formation also contains cherty, siliceous and blocky-weathering shale. Data suggests these units vary from immature in the northeast to over-mature in the southwest Peel region. Widespread, thick source rock units in older strata are rare to absent, although there are some black shales in Middle Devonian Hume Formation (Figure 30) and Cambrian Mount Cap Formation (Figure 31). Table 6 summarizes Rock-Eval data from samples collected in 2006.


*Figure 25: Bluefish Member, Hare Indian Fm, Rumbly Creek, southeast Peel Plateau. Basal contact indicated. About 7 m of Hume Fm is exposed below the contact in the foreground.*


*Figure 27: Canol Fm, Shortcut Creek, southern Peel Plain. Basal contact indicated. Bluff is about 20 m high.*


*Figure 26: Ramparts Fm, Bell Creek, southeast Peel Plain. Base Ramparts Fm and base reefal member indicated. Ramparts shale ramp / platform facies is about 15 m thick here.*

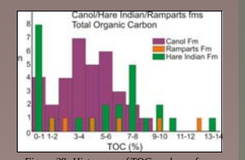


*Figure 28: Histogram of TOC analyses from Canol, Ramparts, and Hare Indian fms collected from outcrops in 2006.*

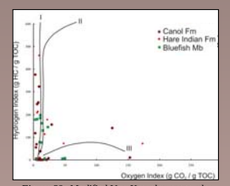


*Figure 29: Modified Van Krevelen cross-plot (hydrogen index versus oxygen index) for Canol and Hare Indian fms samples.*

*Figure 30: interbedded limestone and shale in lower Hume Fm, southern Peel Plain. Hammer for scale.*

*Figure 31: interbedded dark shale and dolomite in Mount Cap Fm. Imperial River, southeast Peel Plain. Hammer for scale (circled).*

| Age | Formation/Unit (number of samples) | TOC (weight %) range | S1 range | S2 range | Tmax (°C) Range |
|---|---|---|---|---|---|
| undefined | Canol? (11) | 0.03-12.17 | 0.01-2.37 | 0.05-31.45 | 436-574 |
| Upper Devonian | Canol (25) | 3.1-8.29 | 0.01-1.81 | 0.02-21.77 | 424-610 |
| Middle Devonian | Hare Indian (10) | 0.05-13.31 | 0.01-2.37 | 0.03-27.93 | 429-458 |
| Middle Devonian | Bluefish (13) | 0.48-10.10 | 0.01-1.64 | 0.04-15.55 | 445-607 |
| Middle Devonian | Ramparts (6) | 1.92-12.43 | 0.06-0.88 | 2.05-34.48 | 449-459 |
| Middle Devonian | Hume (4) | 0.07-5.68 | 0.01-0.21 | 0-0.02 | 427-608 |
| Lower Devonian | Landry (1) | 0.13 | 0.00 | 0.03 | 449 |
| Cambrian | Mount Cap (2) | 0.16-0.21 | 0-0.01 | 0.03-0.05 | 505-563 |
| Cambrian - Devonian | Road River (1) | 2.28 | 0.02 | 0.04 | 609 |
| Proterozoic | Katherine (1) | 0.45 | 0.01 | 0.05 | 561 |

*Table 6. Ranges for Rock-Eval VI parameters and Total Organic Carbon (TOC) analyses for samples collected in 2006 from Proterozoic to Middle Paleozoic outcrops.*

## SUMMARY

Field work to date suggests the best reservoir potential is in coarse vuggy dolomite lenses in Franklin Mountain and Mount Kindle formations, various porosity types in Arnica Formation, and locally in Ramparts Formation. The best source rocks are in the Middle to Upper Devonian shales. The challenge is to identify where source and reservoir rocks could be in juxtaposition. Beyond this, questions of timing of migration, trap formation, and preservation need be addressed.

**See also posters by T.L. Allen & T.A. Fraser and L.J. Pyle et al. at this conference**


*Reference Cited:*

***Morrow, D.W., Jones, A.L., and Dixon, J., 2006.*** *Infrastructure and resources of the Northern Canadian Mainland Sedimentary Basin; Geological Survey of Canada, Open File 5152, 59 p.*


William C. Gussow Geoscience Conference — CSPG