PETROLEUM EXPLORATION IN NORTHERN CANADA

A Guide to Oil and Gas Exploration and Potential

Northern Oil and Gas Directorate
Indian and Northern Affairs Canada

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Editor: G. R. Morrell

Contributors: G.R. Morrell, M. Fortier, P.R. Price and R. Polt

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PREFACE

Petroleum Exploration in Northern Canada has been published to mark the reopening of vast regions of the North to new exploration rights issuance, the first in 25 years in the mainland Northwest Territories.

Oil and gas activity on lands north of 60° under federal jurisdiction has a long history, extending back to the discovery of the Norman Wells Oil Field in 1919. Exploration rights issued throughout the 1960s and 1970s covered almost all of the prospective sedimentary basins in the North.

In the 1970s, the government instituted a freeze on the issuance of new exploration rights in order to facilitate the Aboriginal land claims process in general, and the accompanying land selection process in particular. At the time, it was not anticipated that the land claims process would take so long to conclude; two decades passed before the signing of recent land claim settlements. In the intervening years, almost all historical exploration rights have lapsed.

The rights issuance process was re-introduced after the settlement of land claims in the Beaufort-Mackenzie Basin in 1989, in the High Arctic in 1991, and in the mainland Northwest Territories in 1994. The significant response to the recent renewal of issuance of exploration rights in the mainland territories may, in fact, signal a new cycle of petroleum exploration in the North.

The hiatus in rights issuance and hence in oil and gas activity has, no doubt, created a similar hiatus in companies’ knowledge of the petroleum potential of the North. This publication offers both a quick look at the majority of potential petroleum-bearing basins, and a more comprehensive summary of the petroleum geology, exploration history and oil and gas potential of each basin. It provides potential explorers with a handy reference to acquaint themselves with the significant potential the North has to offer.

M. Fortier
A/Director
Northern Oil and Gas Directorate
# CONTENTS

## ACKNOWLEDGEMENTS

## PREFACE

## CHAPTER 1 - INTRODUCTION

- Significance of the Oil and Gas Resources of Northern Canada .................................. 1
- Producing Fields North of 60° .................................................................................. 1
- Existing and Proposed Pipelines ............................................................................. 4
- Key Reading and References .................................................................................. 5

## CHAPTER 2 - MACKENZIE VALLEY, SOUTHERN TERRITORIES AND INTERIOR PLAINS.

- Southern Northwest Territories and Southeastern Yukon ........................................ 7
- Mackenzie Plain ..................................................................................................... 17
- Peel Plain and Plateau ............................................................................................ 23
- Northern Interior Plains - the Colville Hills ......................................................... 28
- Great Bear Basin .................................................................................................... 32
- Anderson and Horton Plains .................................................................................. 36

## CHAPTER 3 - NORTHERN YUKON

- Eagle Plain Basin .................................................................................................... 39
- Whitehorse Basin .................................................................................................... 45
- Kandik Basin .......................................................................................................... 49
- Bonnet Plume Basin ............................................................................................... 55
- Old Crow Basin ........................................................................................................ 57

## CHAPTER 4 - MACKENZIE DELTA AND BEAUFORT SEA

- Southern Mackenzie Delta and Tuktoyaktuk Peninsula ....................................... 59
- Beaufort-Mackenzie Basin ...................................................................................... 65

## CHAPTER 5 - CANADIAN ARCTIC ISLANDS

- Banks Basin ............................................................................................................ 74
- Arctic Islands: Sverdrup and Franklinian basins .................................................... 78
  - Sverdrup Basin .................................................................................................... 83
  - Franklinian Basin ............................................................................................... 90
  - Arctic Continental Terrace Wedge ........................................................................ 96

## CHAPTER 6 - EASTERN ARCTIC

- Lancaster Sound Basin ............................................................................................ 97
- Baffin Bay .............................................................................................................. 102
- Saglek and Lady Franklin basins (Southeastern Baffin shelf) ................................ 105
- Paleozoic Basins of the Arctic Platform (Foxe and Southampton basins) .......... 107
Figure 1. Sedimentary basins of northern Canada.
CHAPTER 1 — INTRODUCTION

Canada north of 60° latitude largely comprises two territorial jurisdictions - the Northwest Territories and Yukon. The surface area of the territorial lands amounts to approximately 40% of the entire land surface of Canada. A further vast area is covered by shallow seas along the continental shelves of the Arctic and North Atlantic oceans and within the Arctic archipelago. Fifty per cent of this region is underlain by sedimentary rocks and the remainder by metamorphic and igneous rocks of the Canadian Shield.

This publication is a reference for those interested in the oil and gas resources of northern Canada. Key geographic information, a summary of petroleum geology, exploration history, and oil and gas potential for each basin appear in the following pages. The order of treatment follows a clockwise progression beginning at the Alberta-British Columbia border at 60°N, north to the Beaufort Sea, northwest to the Arctic Islands, east to the shores of Baffin Bay and south to the Hudson Strait.

Geographical boundaries between provinces and territories do not reflect the underlying geology. The Western Canada Sedimentary Basin extends from Alberta and British Columbia into the Northwest Territories and Yukon, and north to the Beaufort Sea. Similarly, the offshore basins of the eastern Arctic mark the northeastern terminus of the North Atlantic rift system. The pattern of exploration, in contrast, has been strongly influenced by geography; thus the density of drilling in the Western Canada Sedimentary Basin south of 60°N is much greater than further north despite comparable geology and significant oil and gas potential. Northern Canada comprises a mosaic of sedimentary provinces each with differing geological history and petroleum potential. Some - the Sverdrup Basin of the Arctic Islands is an example - are unique in North America; others, such as the Tertiary basin of the Mackenzie Delta-Beaufort Sea, have similarities to the Mississippi Delta of the Gulf of Mexico.

This catalog describes 19 exploration regions of northern Canada which in most cases conform to the extent of underlying sedimentary basins (Fig. 1). Our definition of “basin” is deliberately loose and may not conform with a rigorous technical definition. It recognises that structural or geographic discontinuities separating areas with common petroleum geology subdivide the territories into theatres of operation where costs bear a consistent relationship to exploration risk and potential reward. The rigour of treatment of individual basins varies according to perceived potential: basins with low potential are summarized briefly, with more detailed treatment reserved for basins with high potential.

At the end of each section there is a brief list of key references. This is not intended to be a comprehensive bibliography. The quantity of research in many of these areas is voluminous and those interested are urged to contact the organizations and individuals listed at the end of the introduction.

Significance of the Oil and Gas Resources of Northern Canada

The western provinces of Canada are the principal producing regions of oil and gas in Canada. Eighty-three per cent of gas production and 86% of oil production has come from the province of Alberta alone. However, the principal producing basins are mature and large discoveries are becoming increasingly rare. Remaining established reserves plus discovered resources in the Northwest Territories and Yukon represent 23% of conventional light crude oil and 26% of conventional natural gas remaining in Canada (Figs. 2, 3). Frontier undiscovered potential is much higher at 48% of potential recoverable gas and 59% of potential recoverable oil (National Energy Board, Canadian Energy - Supply and Demand 1993 - 2010, 1994, excluding potential assigned to “other” frontier basins).

The basins of northern Canada contain substantial reserves and a long inventory of discovered resources of both oil and gas. This is one of the last extensive and under-explored hunting grounds for conventional gas and oil remaining in the North American continent. Discoveries made within the next few years can expect to contribute to supply to meet a building continental demand for gas and an increasing share of domestic oil production.

Producing Fields North of 60°

As of 1994, four fields are producing hydrocarbons from the Northwest Territories and Yukon. The Kotaneelee and Pointed Mountain gas fields lie just north of the border with British Columbia at 60°N. These are linked to the Westcoast Energy Inc. pipeline system in British Columbia. Two oil fields are also under production. The largest, Norman Wells, lies at latitude 65°15’N on the Mackenzie River. Oil flows by
pipeline south to Alberta. Bent Horn field on Cameron Island in the Arctic Islands produces from a single well, and oil is transported by tanker to a refinery at Montreal.

**The Norman Wells field (Fig. 4)**

Most of Imperial Oil Ltd.'s Norman Wells field lies beneath the Mackenzie River southwest of the townsit of Norman Wells. The central processing unit is located on the north bank of the river within the Norman Wells townsite and overlies the northern edge of the field. Originally developed as a producing field during the Canol Project in the 1940s with small volumes of oil exported via the Canol Pipeline to Whitehorse, subsequent production was very limited until the mid-1980s when the construction of the Norman Wells pipeline to Alberta saw a major expansion of field facilities.

Today, 98% of field reserves of 37.3 x E6 m³ (235 million barrels) are developed. Reservoir pressure is maintained in 165 production wells by water injection through 156 injector wells across a field-wide five spot pattern. Although most onshore wells in the Norman Wells townsite and on Goose and Bear islands are vertical, the larger proportion of the field has been developed by wells slant-drilled from artificial islands in the Mackenzie River or from along the banks of the river. Future development drilling along the edge of the

**Figure 2. Conventional light crude oil - remaining reserves and other discovered resources in Canada.**

**Figure 3. Conventional natural gas - remaining reserves and discovered resources in Canada.**

pool will utilize horizontal drilling in a search for greater efficiencies for both production and injection wells.

Production from Norman Wells was 1.79 x E6 m³ (11.3 million barrels) in 1993, with cumulative production of approximately 16 x E6 m³ (100 million barrels). About 43% of oil in place is expected to be recovered. The operator is actively pursuing schemes to augment recovery and develop reserves peripheral to the field. Together, development drilling and enhanced recovery methods applied to the existing production patterns could sustain the currently high rates of production. However, present indications are that production from the field has started to decline.

**Figure 4. Norman Wells production.**
### Historical Highlights

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before 1789</td>
<td>Indians make use of petroleum seepages along the Mackenzie River at Bosworth Creek.</td>
</tr>
<tr>
<td>1789</td>
<td>Alexander Mackenzie logs “petroleum” seepages from the lower Ramparts during his exploration of the Deh Cho (Great River).</td>
</tr>
<tr>
<td>1800’s</td>
<td>Dene Indians and Hudson’s Bay Co. traders use Fort Good Hope tar springs as their principal source of pitch. In 1860, the Canadian oil industry began with the discovery of oil at Petrolia in southern Ontario.</td>
</tr>
<tr>
<td>1887</td>
<td>Emile Petitot notes “Asphalt in great quantities”.</td>
</tr>
<tr>
<td>Early 1911</td>
<td>A Dene named Karkassee directs the attention of J.K. Cornwall (of the Northern Trading Co.) to “flotsam oil” along the banks of the Mackenzie, leading to the identification of oil seepages at Norman Wells.</td>
</tr>
<tr>
<td>1913-1914</td>
<td>Area of seepages at Norman Wells staked by Bosworth - at the same time as the Turner Valley discovery in Alberta.</td>
</tr>
<tr>
<td>1919</td>
<td>Imperial Oil buys Norman Wells prospect from J.K. Cornwall.</td>
</tr>
<tr>
<td>1920</td>
<td>Northwest Discovery No. 1 flows oil from fractures in the Canol Formation. “Oil comes to surface to black globules . . . trenches fill with oil”.</td>
</tr>
<tr>
<td>1942</td>
<td>Canol Project. Limited development of the Norman Wells field to fuel the war effort in the Pacific. In the following year, oil began flowing through the Canol pipeline to Whitehorse, Yukon at rates of 3000 barrels per day.</td>
</tr>
<tr>
<td>1944</td>
<td>Production reaches 4400 barrels per day but ceases after the war. The pipeline was dismantled in the late 1940’s.</td>
</tr>
<tr>
<td>Late 1960’s</td>
<td>Permitting of frontier lands for exploration results in extensive geophysical exploration and drilling in the Mackenzie Valley and Delta.</td>
</tr>
<tr>
<td>1974</td>
<td>The “oil shock” intensifies concern about domestic supply, resulting in the development of incentive programs for frontier exploration and a surge in exploration.</td>
</tr>
<tr>
<td>1977</td>
<td>After extensive public consultation with regard to environment and social sensitivities, the Berger Commission recommends that no pipeline be built along the Yukon north shore to Alaska and that a ten year moratorium be placed on pipeline construction in the Mackenzie Valley. Government ceases land disposition until Native land claims are settled.</td>
</tr>
<tr>
<td>1975-1985</td>
<td>Exploration drilling intensifies throughout the Canadian frontier and especially in the Mackenzie Delta and Beaufort Sea.</td>
</tr>
<tr>
<td>1984</td>
<td>Settlement of Inuvialuit land claim (Western Arctic region).</td>
</tr>
<tr>
<td>1986</td>
<td>Norman Wells facilities expand and a pipeline is built to southern markets. Field put on full development for the first time. Fall in oil prices curbs new investment in frontier exploration.</td>
</tr>
<tr>
<td>1989</td>
<td>Exploration rights made available in the Mackenzie Delta/Beaufort Sea region for the first time in 20 years.</td>
</tr>
<tr>
<td>1994</td>
<td>Lands again available for exploration following settlement of Native land claims in mainland N.W.T.</td>
</tr>
</tbody>
</table>

### Bent Horn Field (Fig. 5)

Panarctic Oils Ltd.’s Bent Horn field produced 321,469 m³ (2.02 million barrels) of oil in 1993. Oil continues to flow from the single producing well with no indications of declining rate. Production is exported from Cameron Island by a specially reinforced tanker, the M.V Arctic, originally built for operations in the Great Lakes. The tanker makes two and sometimes three trips per year between the field and the Pointe aux Trembles refinery in Montreal.

### Kotaneelee Gas Field, Yukon Territory (Fig. 6)

Kotaneelee field lies in the extreme southeastern Yukon, close to the border with British Columbia. After being suspended for ten years, production resumed in 1991 following the upgrading of gas-handling facilities, workover of one well and re-drilling of a second well. Cumulative production to the end of 1993 was 1271 x E6 m³ (44.9 bcf).

### Pointed Mountain Gas Field (Fig. 7)

The Pointed Mountain gas field lies in the southwest corner of the Northwest Territories, close to the border of British Columbia and Yukon. The field has been on production since 1972 and is now in the late stages of exploitation. Cumulative production to the end of 1993 was 8.6 x E9 m³ (303 bcf).
Existing and Proposed Pipelines

Norman Wells oil pipelines

The Canol Project, commenced in 1942, saw limited development of the Norman Wells oil field and the construction of 160 km of 6” pipe and 800 km of 4” pipe to Whitehorse, Yukon Territory. In the following year, oil began flowing through the Canol pipeline to the Whitehorse refinery at rates of 3000 barrels (476 m³) per day. Production reached 4400 barrels (700 m³) per day but ceased after the war. The pipeline was dismantled in the late 1940s. The products pipeline which ran from Whitehorse to Skagway, Alaska, is now operated by Yukon Pipelines Ltd. to import petroleum products to the Yukon.

The modern Norman Wells pipeline is a 305 mm diameter oil pipeline connecting Imperial Oil’s Norman Wells oilfield to Zama (Alberta) 860 km (539 miles) to the south. The pipeline has 3 pumping stations with an average throughput of 4800 m³ (30,000 barrels) per day. Spare capacity exists on this pipeline and throughput could be increased substantially by augmenting compression. Additional spare capacity will also develop over the next decade as production from the field declines.

Proposed Pipelines

The Beaufort Sea contains the largest concentration of gas and oil discoveries in the Canadian frontier with about half the discoveries onshore and the remainder in relatively shallow water in the Beaufort Sea. In 1992, an export licence was awarded by the National Energy Board to a consortium proposing the development of $292.9 \times 10^{12} \text{ m}^3 \ (10.339 \text{ tcf})$ of gas reserves in the

**Figure 5. Bent Horn oil production.**

**Figure 6. Kotanelee gas production.**
Mackenzie Delta. Although the application for a gas pipeline connecting the Mackenzie Delta to southern markets has yet to be made, two general routes have been suggested: one follows the Mackenzie Valley to Norman Wells, thence south to the Alberta border; and a second follows the Dempster Highway into the Yukon to connect with the proposed Alaska Natural Gas Transportation System. Much of the pipeline capacity in northern Alberta and the United States has been “pre-built” in anticipation of this latter project.

A large diameter oil pipeline exploiting the Amauligak field in the Beaufort Sea was suggested when this field was being considered for development in the mid-eighties. Low oil prices caused this project to be indefinitely postponed. A more modest suggestion has been for a smaller diameter oil pipeline connecting the smaller onshore oil discoveries of the delta to Norman Wells. Such a pipeline could exploit developing spare capacity on the Norman Wells to Zama link.

All pipeline development must cope with the great distances and difficult terrain of northern Canada and involves large capital cost. Such ventures require some stability in medium to long term outlook in gas and oil prices. Offshore production directly into tankers is an alternative possibility for offshore Beaufort discoveries. Test production from Amauligak was exported to Japan via Alaska/Beaufort Sea route in the summer of 1986.

Key Reading and References

General Geology


Other


Northern Oil and Gas Directorate. 1993. Regulating oil and gas activities on Canada's northern frontier lands.

Addresses and Contacts

Northern Oil and Gas Directorate

10 Wellington Street, Hull, Quebec K1A OH4

Rights Issuance, Information Packages:
Ms. M. Fortier, A/Director
Tel: (819) 997-0878
National Energy Board

311-6th Avenue S.W., Calgary, Alberta T2P 3H2

Seismic Data, Geological Reports, Information Packages:
  Mr. R. Klaubett
  Frontier Information Office
  Energy Resources Branch
  Tel: (403) 299-3113

Frontier Regulation, drilling and production operations, field development:
  Mr. T. Baker, Chief Conservation Officer
  Engineering Branch
  National Energy Board
  Tel: (403) 299-2790

Environmental Concerns:
  Dr. K. Sato
  Environment Branch
  National Energy Board
  Tel: (403) 299-3675

Geological Survey of Canada, Calgary

3303-33rd St. N.W., Calgary, Alberta T2L 2A7

Dr. A. Embry
  Regional Geology Subdivision
Dr. L. Snowdon
  Energy and Environment Subdivision

Core and Sample Inspection:
  Mrs. Elspeth Snow
  Tel: (403) 299-3539