Canada – significant production

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LINCOLN SEA
SVERDRUP BASIN
BAFFIN BAY
BEAUFORT SEA
ARCTIC PLATFORM
Taglu
Amauligak
Parsons Lake
Niglintgak
ALASKA
Mackenzie Delta
Dawson
Norman Wells
FOXE BASIN
Nunavut
Yukon
Fort Norman
Northwest Teritories
Baker Lake
Whitehorse
Yellowknife
Skagway
Juneau
Fort Resolution
Fort Smith
HUDSON BAY
Queswell Basin
Fort McMurray
Churchill
Hazelton
Prince Rupert
Prince George
Alberta
Saskathewan
Manitoba
Queen Charlotte Basin
British Columbia
Edmonton
Nechako Basin
Prince Albert
Winona Basin
Nechako Basin
Ontario
Calgary
Saskatoon
Georgia Basin
Vancouver
Turner Valley
Victoria
Regina
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Fernie Basin
Thunder Bay
PACIFIC OCEAN
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Western Canada Sedimentary Basin
Arctic Cratonic
Pacific Margin
Atlantic Margin
Arctic Margin
Intermontane

and huge potential

Canada's hydrocarbon resources are both plentiful and varied. In addition to conventional resources of light to medium crude oil and gas that have been tapped for more than 150 years, unconventional resources like oil sand, coal bed methane, tight gas, shale gas and gas hydrates represent a vast potential for the future.

Canada's seven hydrocarbon regions comprise both onshore and offshore sedimentary basins. The main hydrocarbon province is the Western Canada Sedimentary Basin, which has been producing significant quantities of both oil and gas since the late 1940's. Also of great importance are the offshore basins on the Atlantic Margin including several giant and major oil and gas fields in the Grand Banks area. Canada's oil and gas history did, however, start in southwestern Ontario more than 150 years ago on the north side of Lake Erie, and petroleum production still continues here on a small scale. Also shown on this map are the enormous oil sand deposits in Alberta (in black) that represent a huge potential for unconventional oil resources that rival Saudi Arabia in reserves. The Mallik 2L-38 research well of the Mallik 2002 Gas Hydrate Research Programme in the Mackenzie Delta is also marked.
Source: Petroleum Communication Foundation

Halfdan Carstens

The Canadian oil and gas industry dates back to the 1850's when carriage maker James Miller Williams, often called the founding father of Canada's petroleum industry, dug a 15-metre-deep well in Ontario. Petrolia later developed into a boomtown in the 1860's and the 1870's when hundreds of wells were sunk around the small town. Significant quantities of crude oil were produced, which was then transported 200 km for refining and then sold as lamp oil.

Today oil is still pumping in the Petrolia fields driven by a central power plant, just as it was in the old days. At Petrolia, such a field has been set aside as a living museum, a major historic recreational exhibit.

Petroleum was, however, known long time before the 19th century by the Indians who made use of seepages along the Mackenzie River. This is the same area where the Norman Wells oil field still produces, and will do so for another 20 years.

A 100-year wait

In the late 19th century and early 20th century, the Canadians relied on imported oil to supplement the declining production from the Eastern Cratonic basins of the Lake District in Ontario. Exploration efforts in the Northwest Territories succeeded in finding oil at Norman Wells in 1920, but it was too far away from the market at that time. Smaller discoveries were made at Turner Valley in 1914, southwest of Calgary, and provided fuel for nearby areas. Heavy oil found in Alberta in 1923, was used to produce asphalt.

The Canadian oil industry did, however, change dramatically when Imperial Oil struck oil in the well that was named Leduc #1 on February 3 1947, 50 kilometres south of Edmonton. Until then, Canada depended on imports for 90 percent of its supplies.

The giant Leduc discovery led to a series of other major oil and gas discoveries in the area around Edmonton. Within a year, a major oil boom was underway in Western Canada with important discoveries made in Alberta, Saskatchewan, Manitoba and British Columbia, all in the Western Canada Sedimentary Basin, upon which Edmonton became the capital of the Canadian oil industry. As a consequence, crude oil replaced coal as Canada's largest source of energy some 50 years ago.

The subsequent discovery of huge gas fields in Alberta (e.g. Medicine Hat, now nick-named the "Gas City", close to the Dinosaur Provincial Park), combined with improvements in the technology of pipelining, made natural gas a clean and inexpensive energy source. Natural gas was also a raw material for making fertilizer and other chemical products.

Huge potential

Canadian oil and gas production comes mainly from three different sources: the

Shale gas: Huge volumes

Shale gas is conventional natural gas that is produced from reservoirs predominantly composed of shale with lesser amounts of other fine-grained rocks rather than from more conventional sandstone or limestone reservoirs. The gas shales are often both the source rocks and the reservoir for the natural gas.

The gas can be stored in three ways: adsorbed onto insoluble organic matter (kerogen), trapped in the pore spaces of the fine-grained sediments or confined in fractures interbedded within the shale itself.

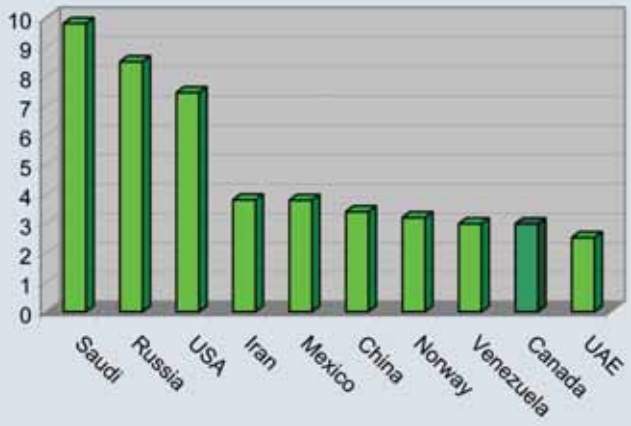
Natural gas has been produced from shale in minor quantities since the 1800's. Widespread development did not occur until the 1980s when a U.S. government tax incentive program stimulated exploration and development of unconventional reservoirs, including gas shales.

There has been no commercial shale gas production in Canada to date. The Gas Technology Institute conducted a study of Canadian gas shale potential that was released in 2003. This study estimated over 860 Tcf of natural gas (150 billion barrels of o.e.) in the gas shales *(in place)*. Thus, if only a fraction of Canada's gas shale resource could be recovered, it would represent a significant addition to Canada's natural gas reserves.

Enormous oil reserves

Canada's total oil production was 3.1 million barrels per day (bopd) in 2004. It has been increasing steadily since 1999, as both new oil sands and offshore projects have come on stream to replace aging fields in the Western Canada Sedimentary Basin. Also, it is expected that oil sands production will increase significantly in coming years and offset the decline in Canada's conventional crude oil production.

In the BP Statistical Review of World Energy 2004 Canada's proven oil reserves is estimated to 16.9 billion barrels of oil. It ranks as no. 11 in the world with respect to oil reserves. According to Oil and Gas Journal; however, Canada has 178.8 billion barrels of proven oil reserves in 2005 when taking into account the oil sand deposits in Alberta. The only country with higher reserves is Saudi Arabia. According to the Alberta Energy and Utility Board, the initial volume of crude bitumen in place is estimated to approximately 260 billion m^3 (1.6 trillion barrels), with 11 per cent or 28 billion m^3 (175 billion barrels) recoverable under current economic conditions.



Oil production in millions of barrels per day for the world's ten largest producers.
Source: BP Statistical Review of World Energy 2004

© Randulf Valle

Arctic Canada, where land and water blur in its barren, flat landscape, is a huge frontier petroleum province with a minimum of wells drilled. Vast amounts of gas found in the Mackenzie Delta may start flowing within five years.

Western Canada Sedimentary Basin, the oil sands deposits of northern Alberta and the offshore fields. However, the potential for significant future exploitation of conventional hydrocarbons includes British Columbia onshore and offshore basins that have hitherto seen virtually no exploration, the under-explored Arctic basins of Yukon, Northwest Territories and Nunavut, and the Atlantic Margin. Also, Canada has huge amounts of unconventional hydrocarbon resources such as oil sands, tight gas, coalbed methane and possibly also gas hydrates.

Western Canada Sedimentary Basin

The Western Canada Sedimentary Basin (WCSB), underlying most of Alberta and parts of British Columbia, Saskatchewan, Manitoba, Yukon and the Northwest Territories, and extending all the way to the Beaufort Sea, has been the main source of Canadian oil and gas production since the late 1940's. The Petroleum Communication Foundation (PCF) estimates that 57 percent of Canada's conventional hydrocarbon resources are found in this basin. However, more than 80 percent of the oil and gas produced to date come from Alberta alone.

Canadian oil companies

Several hundred companies are exploring for oil and gas in Canada. The Canadian Association for Petroleum Producers (CAPP) represents 150 member companies who produce more than 98 percent of Canada's natural gas, crude oil and oil sands, while The Small Explorers and Producers Association of Canada (SEPAC) represents the interests of 400 emerging and junior conventional oil and gas companies.

Canada has a privatized oil sector that has witnessed considerable consolidation in recent years, according to IEA. The largest integrated operator in the country is Imperial Oil, majority owned by ExxonMobil. In 2002, Alberta Energy Company and PanCanadian Energy merged to create EnCana, Canada's largest independent upstream operator. Other significant oil producers in Canada include Talisman Energy, Nexen, Suncor, EOG Resources, Husky Energy, and Apache Canada.

The Canadian government formed Petro-Canada in 1975 in an effort to reduce the dominance of U.S. companies in Canada's oil industry. The company received considerable initial resources from the Canadian government in its early years. In 1991, the Canadian government began to privatize Petro-Canada, and in late 2004, the government sold its remaining 20% stake in the company.

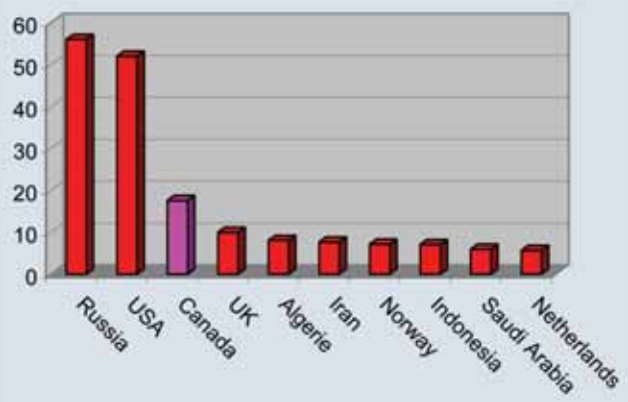
Unconventional reservoirs is for the future

In 2003, Canada produced almost 18 billion cubic feet (500 billion m^3) of natural gas per day, which is the third-highest level in the world behind Russia and the United States.

Canada's natural gas production is concentrated in the Western Canada Sedimentary Basin. Almost 80% of current natural gas production comes from this area, according to the International Energy Administration.

Canada's proven natural gas reserves are close to 60 Tcf (10.8 billion barrels of o.e.) at the end of 2003. Canada thus only ranks 19th in the world. Reserves have decreased steadily the last 10 years, and at current rates, production will completely deplete proven reserves in less than ten years. This may easily change, however, if the vast gas resources in Arctic Canada are explored at an intensified rate.

The National Energy Board has estimated that the ultimate gas resources of Canada to more than 10 times the current reserve estimate. Future gas production in Canada may rely on many resources; such as conventional reservoirs (including Arctic, Atlantic Margin and Pacific coast gas fields), tight gas sands, coal bed methane (see the following article on the huge potential for natural gas in British Columbia), shale gas, and – possibly – gas hydrates.



Gas production in billion cubic feet per day for the world's ten largest producers. Source: BP Statistical Review of World Energy 2004

Coal bed methane

Methane gas produced from coal seams is a relatively new source of natural gas. While substantial production started only in the early 1990's, Coal bed methane (CBM) now represents approximately nine percent of total United States natural gas production. Similar exploration for and development of CBM has only just started in Canada, Australia, Africa and Europe.

CBM is recovered from coal seams which are generally either too deep, of too poor a quality, or otherwise unsuitable for mining the coal itself as a resource.

Methane occurs in coal seams in varying quantities. The quantity of the gas per ton of coal, the gas quality, the permeability of the coal, the cost of completing and dewatering producing wells, and the cost of connecting these wells to suitable pipelines and distribution systems determine whether a CBM project is economically viable.

CBM production is still in its infancy in Canada, with the first wells drilled only in 1997, and according to IEA, there is a strong belief that CBM production will eventually replace the decline in conventional natural gas production.

Coal is Canada's most abundant fossil fuel and also contains the principal component of natural gas - methane. In place resource estimates for CBM in Canada, (concentrated in British Columbia and Alberta) vary greatly, from about 150 trillion to more than 3,000 trillion cubic feet (540 billion barrels of o.e.) of gas. The potential is thus enormous.

Henry Goodrich Mobile Offshore Drilling Unit drills wells for Terra Nova.

Icebergs are one of the challenges that faces the oil and gas operations on the Grand Banks offshore Newfoundland. Towing is necessary to redirect to another pass.

The undeformed portion of the WCSB beneath the Interior Plains can be viewed as a simple wedge of Phanerozoic (Cambrian-Quaternary) strata above Precambrian crystalline basement. The wedge tapers from a maximum thickness of about 6000 m in the axis of the Alberta Syncline (just east of the foothills front) to a zero-edge in the northeast along the Canadian Shield. The differentially eroded upper surface of the bedrock exposes basin strata as old as Ordovician and as young as Palaeocene (Geological Atlas of the Western Canada Sedimentary Basin.)

The Devonian contains more than 50 percent of Western Canada's initial recoverable oil reserves. Most of the marketable gas reserves, close to 50 percent, comes from Cretaceous reservoir rocks.

The age of many of the fields has led to a steady decline in conventional oil production, and it is expected that oil sands will completely supplant conventional sources as the focus of future oil production in this enormous basin, according to the International Energy Administration (IEA).

Atlantic Margin

Canada has considerable, proven offshore oil reserves, which have received more attention in recent years due to the decline in production of conventional crude oil from the WCSB. So far, nearly all offshore production of oil has occurred in the Jeanne d'Arc Basin off Newfoundland, while gas is being produced in the Scotian Basin further south.

Oil and gas exploration has a 40-year-old history on the Atlantic Margin. Mobil Oil Canada acquired the first offshore licences in 1959 in the Sable Island area and subsequently initiated the first seismic survey in 1960. Drilling began off Newfoundland and Labrador in 1966 and off Nova Scotia in 1967. The industry has drilled more than 350 offshore wells since then.

Natural gas was first found near Sable Island off the coast of Nova Scotia in 1968, while both gas and oil were discovered off Nova Scotia in the 1970's: the Panuke-Cohasset oil field, (began production in 1992) and the Venture natural gas field (began production in 1990). These were followed by the first big oil discoveries off Newfoundland and Labrador.

The Hibernia field, discovered in 1979, contains an estimated 615 million barrels of recoverable oil. Production in Hibernia began in 1997, and the field produced some 203,000 bopd in 2003. The Terra Nova field was discovered in 1984 and began operations in 2002 with an average production of 134,000 bopd in 2003.

Discovered in 1984, the White Rose offshore oil field is located in the Jeanne d'Arc Basin 350 km east of Newfoundland and Labrador. It is due to begin production in late 2005 or early 2006, with a potential peak capacity of 90,000 bopd. The field consists of both oil and gas pools and con-

tains an estimated 200-250 million barrels of recoverable oil.

The Scotian Basin, off the coast of Nova Scotia, is the centre of natural gas production on the Atlantic coast. The Sable Offshore Energy Project (SOEP) began production in 1999. SOEP encompasses numerous offshore fields, with the Alma and South Venture fields the latest brought on-line. SOEP produced 400 Mmcf/d of natural gas in 2003, and production should increase by 125 Mmcf/d in 2005, when the South Venture field comes completely on-stream.

There are plans to commence natural gas production in the near future also from both the Hibernia and White Rose fields that contain a combined 4 Tcf (720 million b.o.e.) in recoverable natural gas reserves. In addition, the huge and complex Hebron/Ben Nevis discovery (600 million barrels of heavy oil) is waiting in line to be developed.

There is also significant exploration activity in the Orphan Basin, located in the deep waters north of the Jeanne d'Arc Basin. Further north, in the Labrador Basin, several "stranded" gas discoveries, like Snorri, Bjarni and Gudrid, are waiting for better times and improved technology.

The Petroleum Communication Foundation (PCF) estimates that 18 percent of Canada's conventional hydrocarbon resources are found along the Atlantic Margin.

The Pacific Coast

Off the coast of British Columbia (B.C.), 14 wells were drilled in the late 1960s but failed to find commercial quantities of oil and gas. Environmental concerns, mainly about proposed oil tanker traffic from Alaska, led the federal and B.C. governments to impose moratoria on offshore oil and gas activities in 1972.

It is widely believed, based on various assessments of the area's potential, that the Pacific coast off British Columbia may contain 10 billion barrels of oil and 40 Tcf (7.2 billion b.o.e.) of gas *in place*. However, there has been no production to date on the Pacific coast because of a federal ban on offshore oil activities in the Pacific Ocean. The provincial government of British Columbia has continually lobbied to lift this ban, hoping to begin production by 2010.

The Arctic

Northern Canada comprises a mosaic of sedimentary provinces, each with differing

Oil sands

Oil sands, also known as "tar sands" because of their asphalt consistency, represent an enormous resource. According to Oil and Gas Journal, Canada is second only to Saudi Arabia in oil reserves because of these deposits. The problem is that removing the crude oil is technologically difficult, may be unfriendly to the environment and is expensive. Nevertheless, the oil sands have contributed to the recent boom in Canada's oil production.

Oil sands contain deposits of bitumen; a heavy, viscous oil. Lighter hydrocarbons must be added to the bitumen to allow it to flow. The bitumen is processed into "synthetic crude", and in general it takes about 1.16 barrels of bitumen to make 1 barrel of synthetic crude.

The oil sand deposits were originally giant oil reservoirs, but following the Laramide orogeny some 30-60 million years ago, the oil percolated to the surface upon which the lighter components evaporated and microbes eat the remaining hydrocarbons. The deposits are primarily located in sandstones of Early Cretaceous age

Shallow oil sands deposits can be mined in open-pit surface mines, while deeper in situ deposits require other recovery methods. The production of synthetic crude from oil sands is, however, with present day technology, only economically viable with synthetic crude prices in the USD 25-30 range. The oil sands industry is also heavily reliant upon water and natural gas, which is necessary in both the extraction of bitumen from oil sands and the upgrading of bitumen to synthetic oil.

Present output from the oil sands is approximately 1 million bopd. A significant increase is predicted in the coming years, 1.7 million barrels a day by 2010, increasing to 2.8 million barrels a day in 2015 and 3.6 million barrels a day in 2020. The last number is substantially higher than Canada's present output in total and in particular from conventional oil.

The Athabasca oil sands deposit in northern Alberta is the largest oil sands deposit in the world. There are also sizable oil sands deposits on Melville Island in the Canadian Arctic, and two smaller deposits in northern Alberta.

Tight reservoirs

Tight reservoirs with natural gas are those that have permeabilities less than 0.1 millidarcy. A generally accepted industry definition of "tight" are also those reservoirs that do not produce economic volumes of natural gas without assistance from massive stimulation treatments or special recovery processes and technologies. Poor permeability is primarily due to fine-grained sediments, compaction, or cementation of pore spaces by carbonate or silicate precipitated from water within the reservoir.

In some cases, production is drawn from marginal quality reservoirs within conventional producing regions, and in some cases from locally higher permeability strata within tight formations. The expansion of infill drilling in the shallow gas play of southeast Alberta and southwest Saskatchewan was due in part to recognition of the tight nature of many of the sandstone reservoirs in this area.

It is only recently, with the advent of higher commodity prices and development techniques such as horizontal and directional drilling, underbalanced drilling, directional fracturing and carbon dioxide and nitrogen fracturing fluids that tight sands have become exploration targets.

Recent activity in the Deep Basin area of Alberta and British Columbia is also driven in part by recognition of tight gas reservoirs. The largest sale of petroleum and natural gas rights (generally referred to as land sales) in Canadian history was in British Columbia in 2003, targeting tight carbonates in northeastern British Columbia using advanced drilling and completion technologies.

geological history and petroleum potential. Some – such as the Sverdrup Basin of the Arctic Islands - are unique in North America. Others, such as the Tertiary Mackenzie Delta, have similarities to the Mississippi Delta of the Gulf of Mexico. The basins contain substantial reserves and a long inventory of discovered resources of both oil and gas. Northern Canada should be considered one of the last under-explored hunting grounds for conventional gas and oil remaining in North America.

The pattern of exploration has been strongly influenced by geography and challenging logistics; 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 a significant oil and gas potential.

Some frontier efforts in the Northwest Territories have met with success, such as the natural gas discoveries in the Mackenzie Delta, crude oil in the Beaufort Sea and huge natural gas reserves in the Arctic Islands. Because of high development and transportation costs, and the availability of supplies closer to densely populated southern regions, these discoveries have not yet been developed. Close co-operation with local communities and the province's aboriginal people is a necessity to achieve this.

The Mackenzie Delta, located in the Northwest Territories, holds an estimated 10 Tcf (1.8 billion b.o.e.) of recoverable natural gas reserves. There are three large, proven natural gas fields in the Mackenzie Delta: Taglua (3 Tcf), Parsons Lake (1.8 Tcf), and Niglintgak field (1 Tcf).

Arctic Canada is underexplored. Future efforts require improved technology.

Fantastic potential

Canada has vast reserves of conventional oil and gas that rank among the world's largest. If we also include unconventional oil and gas, Canada may – as illustrated in this article – have more hydrocarbon resources than any other country in the world, including Saudi Arabia and Russia.

The future of these resources depends on the future price of energy as well as developments in technology. However, the future is already here, as liquid oil is now being produced from the sticky "tar sands" and gas is tapped in small quantities from unconventional reservoirs.

Gas hydrates

Naturally occurring gas hydrates have been mapped worldwide since the 1970's. They appear in two different geological environments, in marine sediments on the outer continental margins, and below permafrost in arctic regions. In Canada gas hydrates may thus be found in both environments.

A significant part of the earth's fossil fuel seems to be stored as gas hydrates. Published estimates show that the total volume of methane in gas hydrates varies between 10^{15} to 10^{19} m^3 (the latter number equals 10 million trillion m^3) (GEO ExPro No.2, 2004). "If these estimates are anywhere close to being true, then the gas hydrates have twice the order of magnitude than the remaining conventional methane resources," says Timothy S. Collett in USGS.

Consequently, gas hydrate research has increased dramatically the last five to ten years. A research programme was carried out at the gas hydrate field Mallik in the Mackenzie Delta in 2002 (GEO ExPro No.2, 2004). The purpose was to carry out a full-scale production test by means of a 1200 m deep production well and two observation wells 40 m apart. Two zones were tested by two different methods, and for the very first time, gas from gas hydrates was produced. The flare from the tower confirmed that the gas hydrates could be a technical success when the gas saturation is great enough.

A gas hydrate field has also been discovered along the Cascadia Continental Margin outside Vancouver Island. Leg 146 of the Ocean Drilling Program in 1994 was designed to provide estimates of the volume of fluid associated with accretionary sedimentary wedges. A wealth of data pertaining to the in-situ nature of gas hydrates on the Cascadia margin was collected through the drilling of three wells.

It is still unknown how much gas could be present and eventually recovered in the Canadian gas hydrates.

Photo: Tim Collett, USGS

The flares from the gas tower at Mallik 2L-38 confirmed that gas hydrates can be technically produced when the gas saturation is great enough.