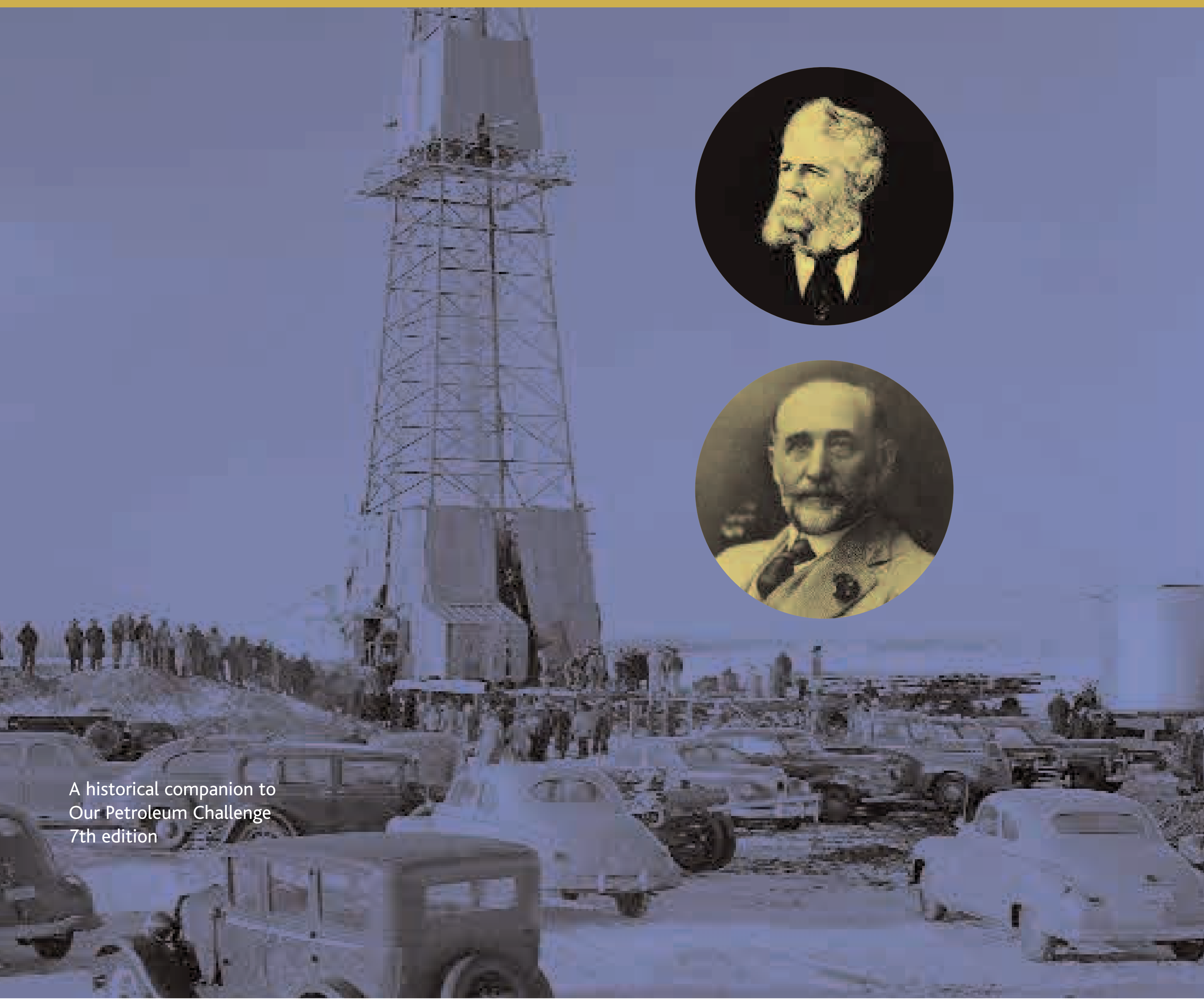
Evolution

Of Canada's oil and gas industry



A historical companion to
Our Petroleum Challenge
7th edition

EVOLUTION of Canada's oil and gas industry

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About this publication

EVOLUTION is an enhanced version of historical material that appeared in the first six editions of *Our Petroleum Challenge,* published by the Petroleum Communication Foundation between 1978 and 1999. The seventh edition of *Our Petroleum Challenge* includes a brief historical overview of the Canadian oil and gas industry, along with coverage of today's conventional, oilsands, offshore, Arctic, midstream and downstream operations. *EVOLUTION* is intended for readers seeking a more complete and detailed historical perspective.

The oil and gas industry has been an important part of Canada's economy since the mid-19th century, but almost every aspect has changed in ways the founders could not have imagined. This booklet describes the industry's evolution from hit-or-miss, trial-and-error pioneering in the 1850s to the advanced science and technology of the 21st century. First, however, it briefly explains where petroleum is found and how it got there. The second section of the booklet describes the development of the industry prior to the Leduc discovery in 1947. The remainder of the booklet outlines the evolution of the modern petroleum industry since 1947.

A bibliography provides sources for further information. A glossary of specialized industry terms can be found in *Our Petroleum Challenge* or at www.centreforenergy.com.

Measurement and terminology

In 1979, the Canadian petroleum industry converted from the Imperial to the metric system of measurement. Most oil and gas operations in Canada are conducted in metric units such as metres and litres. This booklet uses metric measurement only.

Some Imperial units, such as the barrel of oil and the cubic foot of natural gas, remain in common usage in the industry because Canadians are involved in the world crude oil trade and the continental natural gas market. For a full conversion and measurement list, see pages 53-55.

In this publication, the term "petroleum" includes natural gas, natural gas liquids and bitumen, as well as crude oil. Gasoline is not abbreviated as "gas" to avoid confusion with natural gas (methane) and other gases.

About the covers

James Miller Williams (upper inset) of Hamilton, Ontario, was the "founding father" of the Canadian oil industry. He dug and drilled the first commercial oil wells in south-western Ontario and established North America's first integrated oil company. Eugene Coste (lower inset) was the pioneering entrepreneur of Canada's natural gas industry, first in Ontario and later in Alberta. Imperial Oil unveiled the discovery of a major crude oil field near Leduc, Alberta, on February 13, 1947 (main photo). The Leduc discovery marked the birth of the modern Canadian oil and gas industry. The back cover shows oil sands pioneer Sidney Ells.

Evolution of an industry

Canada has a vast endowment of crude oil and natural gas resources. Developing these resources today provides hundreds of thousands of jobs for Canadians and contributes to our national wealth and trade balance. Natural gas, petroleum products and the goods and services derived from them play a vital role in almost every aspect of our economy and lifestyle.

Canadians' present petroleum-based prosperity is due to events that occurred on two very different time scales. During a half-billion years of Earth's history, nature formed hydrocarbons in the types of sedimentary rocks that are under parts of every province and territory. Over the past century and a half, Canadians became skilled in extracting, processing and transporting this buried wealth. Canadian companies and individuals have played a role in developing petroleum resources at home and around the world.

There are both costs and benefits to producing and using crude oil and natural gas. As each cubic metre is consumed, companies must search for new resources to replace that production. Equally important, there is the potential for adverse effects on land, water, air, plants and animals, and human health and safety. The benefits may be enjoyed in one region, while the costs are borne in another. Oil and gas development can also positively or negatively affect Aboriginal communities and others in rural and remote areas. Government regulation and public consultation are key tools in managing the social and environmental effects of petroleum development and making sure that economic benefits are achieved.

Before examining the industry's evolution and its effects on Canadian life, however, it is important to understand the industry's geological base.

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Key definitions

Hydrocarbons are compounds of hydrogen and carbon. The simplest hydrocarbon is methane (CH_4), composed of one carbon atom and four hydrogen atoms.

Natural gas is mainly methane, although it can occur in nature as a mixture with other hydrocarbons such as ethane, propane, butane and pentane and with other substances such as carbon dioxide, nitrogen, sulphur compounds and/or helium. These components are separated from the methane at processing plants located near the producing fields.

Crude oil is a naturally occurring liquid mixture of hydrocarbons. It typically includes complex hydrocarbon molecules – long chains and rings of hydrogen and carbon atoms. The liquid hydrocarbons may be mixed with natural gas, carbon dioxide, saltwater, sulphur compounds and sand. Most of these substances are separated from the liquid hydrocarbons at field processing facilities called batteries.

Bitumen is a semi-solid hydrocarbon mixture. The bitumen in Alberta's oilsands is the world's largest known hydrocarbon resource.

Gasoline is a complex mixture of relatively volatile hydrocarbons, with or without small quantities of additives, suitable for use in spark-ignition engines.

Petroleum is a general term for all the naturally occurring hydro-carbons – natural gas, natural gas liquids, crude oil and bitumen.

Natural gas liquids are ethane, propane, butane and condensates (pentanes and heavier hydrocarbons) that are often found in natural gas; some of these hydrocarbons are liquid only at low temperatures or under pressure.

Liquefied natural gas (LNG) is supercooled natural gas that is maintained as a liquid at or below -160° C. LNG occupies 1/640th of its original volume and is therefore easier to transport if pipelines cannot be used.

Fluids are either liquids or gases – substances whose molecules move freely past one another and that have the tendency to assume the shape of a container. Most forms of petroleum, except some bitumen, are fluids.

Petroleum regions of Canada

CANADA'S SEVEN HYDROCARBON REGIONS
Percentage of Canada's estimated conventional hydrocarbon resources

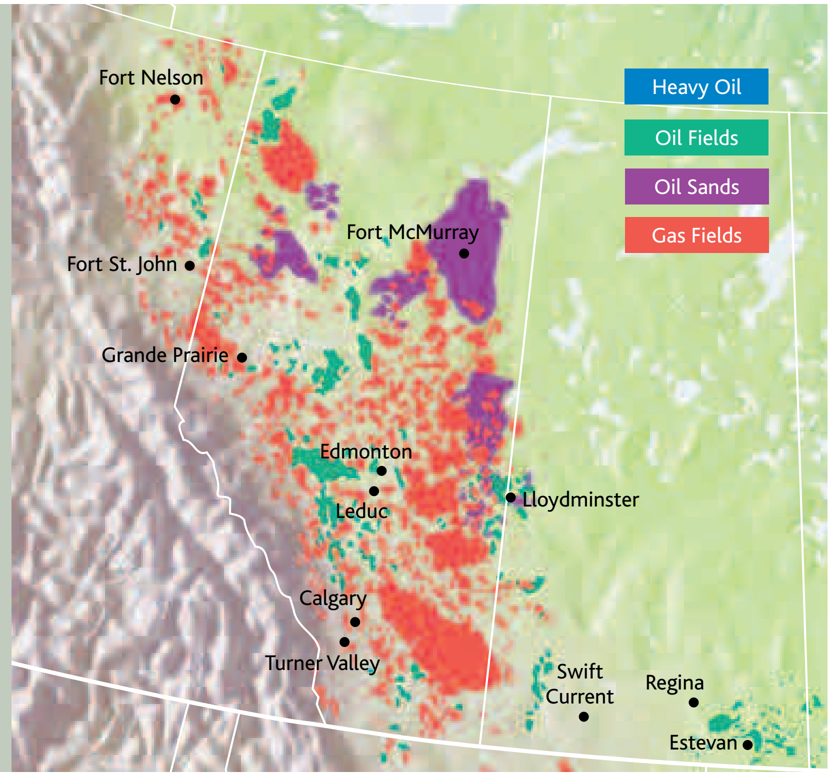
Region	
Western Canada Sedimentary Basin*	57%
Atlantic Margin	18%
Arctic Cratonic	10%
Arctic Margin	6%
Pacific Margin	4%
Intermontane	3%
Eastern Cratonic	2%

* Excluding oilsands bitumen

NOTE: These estimates were prepared by the Geological Survey of Canada to indicate the ultimate geological potential of sedimentary regions. They are useful to indicate the order of magnitude of various regions' resources, but are not the same as reserves that have been determined by actual drilling and can be produced economically. In some areas, such as the Western Canada Sedimentary Basin, a significant proportion of reserves have already been produced, but most of the resources remain in place. Also note that the estimates do not include natural gas from coal, gas hydrates or the vast bitumen resources in the Alberta oilsands. Bitumen is a semisolid form of petroleum, dense and resistant to flow.

Source: Geological Survey of Canada

Petroleum regions of Canada



1 Western Canada Sedimentary Basin

Canada has seven large regions of sedimentary rocks – the kind of rocks that may contain crude oil and natural gas. These hydrocarbon regions are the Western Canada Sedimentary Basin, the Atlantic Margin, the Arctic Cratonic, the Arctic Margin, the Pacific Margin, the Intermontane, and the Eastern Cratonic.

Maps 1 and 2 show the regions of Western and Eastern Canada that account for nearly all of the nation's current crude oil and natural gas production. Map 3 shows the historic crude oil and natural gas fields in southwestern Ontario, which continue to produce petroleum on a small scale.

Other significant producing areas are the Norman Wells oil field and the Fort Liard natural gas field, both in the Northwest Territories. In addition, the Bent Horn field in Nunavut produced modest amounts of crude oil from 1985 to 1996. The Ikhil field in the Mackenzie Delta has supplied natural gas to Inuvik, Northwest Territories, since 1999.

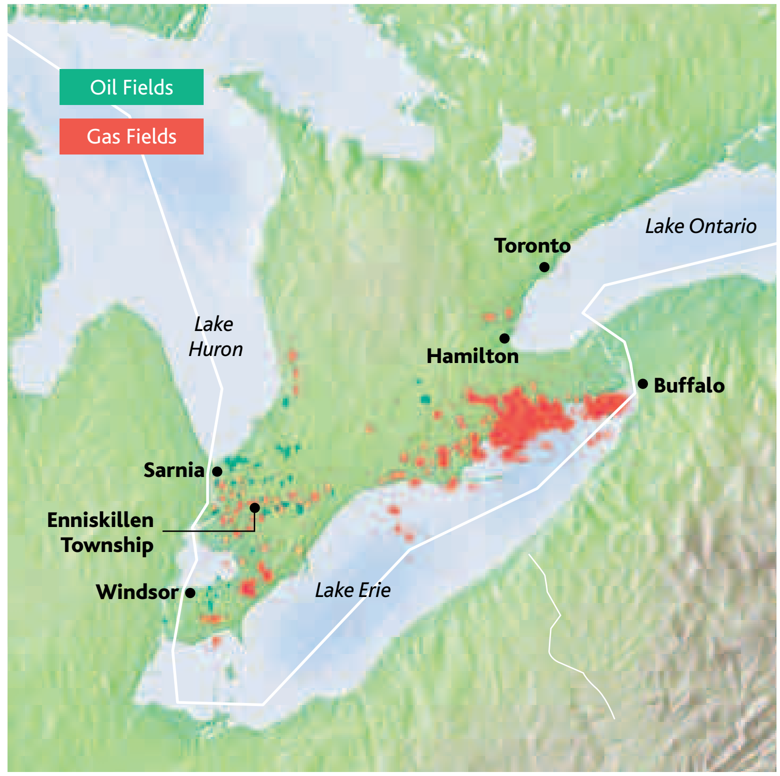
To date no commercial petroleum has been produced along the Canadian West Coast.

At a glance

Western Canada Sedimentary Basin

- Includes parts of all four western provinces, the Northwest Territories and the Yukon
- In 2003, accounted for about 87 per cent of Canada's crude oil and 97 per cent of its natural gas production
- Natural gas first discovered in 1883 near Medicine Hat, Alberta, with subsequent discoveries throughout the basin
- Major sour gas discoveries since the 1920s in Alberta, British Columbia and the Northwest Territories
- Historically significant crude oil discoveries: Turner Valley, Alberta, in 1914, 1924 and 1936; Norman Wells, Northwest Territories, in 1920; and Leduc, Alberta, in 1947
- Heavy crude oil discovered at Wainwright, Alberta, in 1923

❷ Eastern Canada Sedimentary Basins



❸ Southern Ontario Producing Areas

- Bitumen, contained in oilsands, is the world's largest known petroleum resource
- Bitumen has been upgraded into light, low-sulphur synthetic crude oil since 1967
- Elemental sulphur began to be extracted from sour gas in 1952
- First natural gas from coal (coalbed methane) produced commercially in southern Alberta in 2002

Eastern Canada Sedimentary Basins

- Onshore natural gas discovered in 1859 in New Brunswick, but flared as a waste product
- Small volumes of crude oil and natural gas produced from onshore wells in New Brunswick from 1911 to 1991
- First offshore exploratory well drilled off Prince Edward Island during the Second World War
- Drilling off the shores of Nova Scotia and Newfoundland and Labrador began in 1966
- First major crude oil discovery in 1979 at Hibernia site on the Grand Banks off Newfoundland and Labrador
- Terra Nova and White Rose crude oil fields discovered in 1984
- First crude oil production in 1992 from the Panuke and Cohasset fields near Sable Island offshore of Nova Scotia
- Crude oil production began from Hibernia platform in 1997
- Natural gas production began in 1999 near Sable Island
- Terra Nova crude oil production began in 2002, to be followed by White Rose in 2005 and eventually by development of nearby fields such as Hebron, Ben Nevis and West Ben Nevis
- Onshore exploration continues in all the Atlantic provinces and Quebec, with some small-scale natural gas production since 2003 in New Brunswick and since 1980 in Quebec

Southern Ontario Producing Areas

- North America's first commercial oil well located in Enniskillen Township in 1858
- Natural gas discovered in 1866, used for heating and lighting since 1889
- Provided crude oil for the refining industry centred near Sarnia since the 19th century
- Relatively small amounts of crude oil and natural gas production continue today

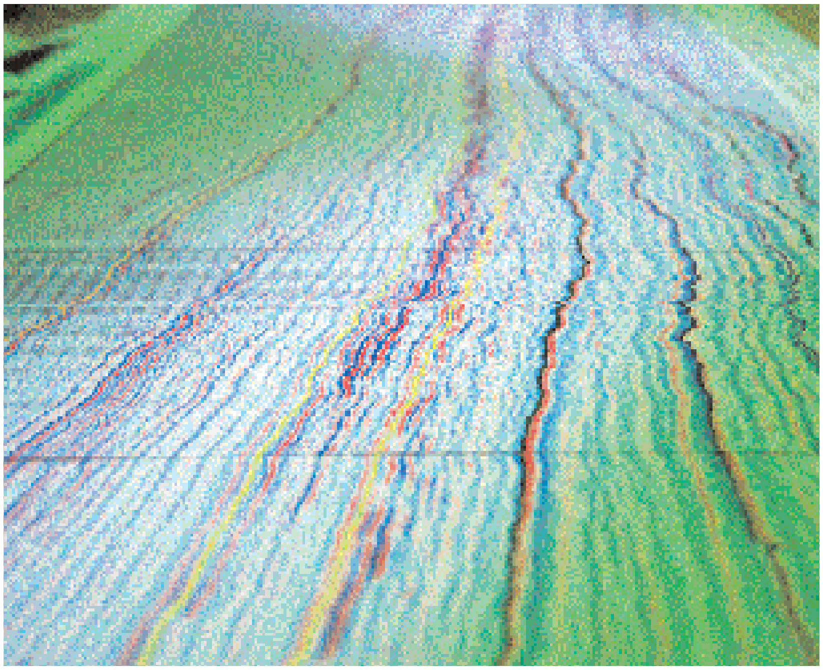
Section 1

Riches in rocks

Source: ConocoPhillips

Canada is endowed with large areas underlain by petroleum-bearing rock. From the very beginning, our oil and gas industry has been focused on finding and developing this resource and turning it into useful products that enhance our lives. The rocks came first – a long, long time before humans.

Geology and geophysics
Geologists depend on clues such as rock outcroppings to determine where crude oil or natural gas might be found. The best indication is crude oil or natural gas seeping to the surface, but much can also be learned from previous drilling in the area (if any), the characteristics and topography of rock formations, and the similarities to other areas known to produce crude oil or natural gas. Since the 1920s, the science of geophysics has provided an additional powerful tool, the seismic survey, to develop a more complete "picture" of deeply buried rock formations. Geophysicists can identify the structures most likely to contain petroleum, but the only way to find out for sure is to drill a well.



Source: Brian Harder

Geology – origins of crude oil and natural gas

The Earth is about 4½ billion years old. According to the organic theory of petroleum formation, the earliest of the sediments that produce almost all crude oil and natural gas were deposited about 560 million years ago.

To understand the time scale involved, imagine that one second equals one year. If you started counting one number per second, you would reach one million in 11½ days, and one billion in 31½ years. On this accelerated time scale, petroleum resources have been accumulating for more than 16 years and the Canadian petroleum industry, nearing its 150th birthday, has been around for 2½ minutes.

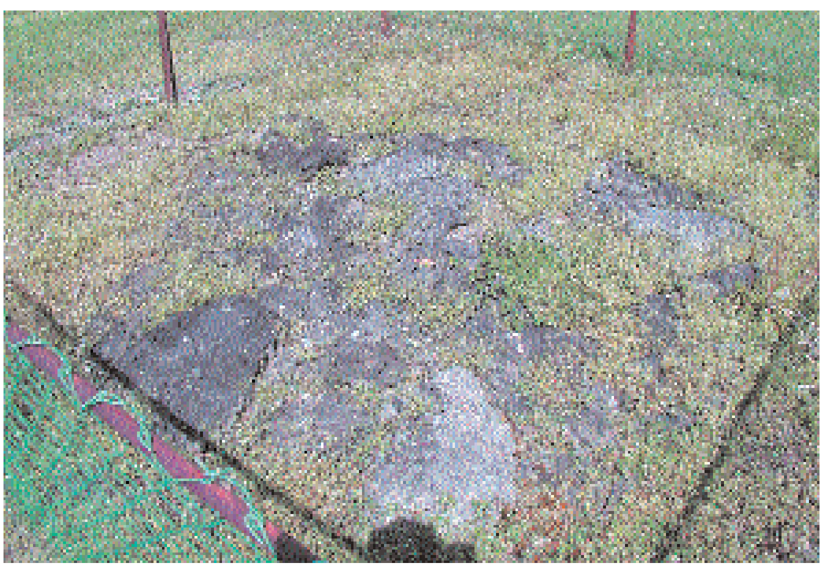
The Earth is not the fixed, solid mass that we usually envision. It is actually a sphere of solids and molten rock that are gradually but continuously moving and changing. For example, South America is drifting away from Africa at about the speed your fingernails grow. Earthquakes and volcanoes are reminders of the Earth's instability and changing face.

The Earth's crust is divided into numerous tectonic plates. These plates push against and override each other, rise and fall, tilt and slide, buckle and crumple, break apart and merge together. As a result, sediments from the bottom of ancient seas can today be found in rocks on the tops of mountains. In fact, the 8,850-metre summit of Mount Everest is marine limestone, formed from coral reefs in an ancient sea.

For more than half a billion years, photosynthesis has made life as we know it possible on Earth. Plants and algae absorb solar energy and use it to convert carbon dioxide (CO_2) and water into oxygen and sugar. Additional processes convert sugar into starch and cellulose. These carbohydrates and other organic materials from decaying organisms eventually settle on land or on the bottoms of lakes and seas.

Did you know?

Most crude oil and natural gas originate from plant and animal life that thrived in oceans and lakes millions of years ago.



Seep near Canada's first oil well in Ontario.

Source: Robert D. Bott

As the organic materials become more deeply buried, heat and pressure transform them into solid, liquid or gaseous hydrocarbons known as fossil fuels – coal, crude oil or natural gas, respectively. Coal is formed from the remains of terrestrial (land-based) plants. Peat moss is an example of the type of material that becomes coal. Crude oil is typically derived from marine (water-based) plants and animals, mainly algae, that have been gently "cooked" for at least one million years at a temperature between 50° and 150° C. Natural gas can be formed from almost any marine or terrestrial organic materials, under a wide variety of temperatures and pressures.

Due to their buoyancy and the pressure created by the overlying rock layers, crude oil and natural gas seldom stay in the source rock in which they are formed. Instead, they move through the underground layers of sedimentary rocks until they either escape at the surface or are trapped by a barrier of less permeable rock.

Most of the world's petroleum has been found trapped in porous rocks under a layer of relatively impermeable rock. In such reservoirs, the petroleum is not collected in an underground "lake" but rather is held in the pores and fractures of rock like water in a sponge. These reservoirs are often long distances away from the original source.

A seep occurs when hydrocarbons migrate to the Earth's surface. Over time, huge amounts of these hydrocarbons have been degraded by bacteria or escaped into the atmosphere. Flowing water can also wash away hydrocarbons. Sometimes only the lighter, more volatile compounds are removed, leaving behind reservoirs of heavier types of crude oil.

The Alberta oilsands are different from most petroleum reservoirs, in both size and how they were formed. Fifty million years ago, huge volumes of oil migrated upward and eastward through more than 100 kilometres of rock until they reached large areas of sandstones at or near the surface. Bacteria then degraded the hydrocarbons for millions of years. Geologists believe the original volume of crude oil digested by the micro-organisms was at least two or three times larger than what now remains as bitumen, and yet the Alberta oilsands are still the world's largest known hydrocarbon resource.

Bacteria usually degrade the simplest hydrocarbons first, converting them into carbon dioxide and water, and leave behind the big hydrocarbon molecules such as asphalt and other substances that cannot be digested such as nickel. The bacteria may also modify some of the simpler sulphur molecules, leaving complex sulphur compounds. As a result, there are more heavy hydrocarbons, complex sulphur compounds and metals in bitumen than in conventional crude oil. This makes extraction and processing more difficult and expensive.

Source: Suncor

Oilsands mining
Oilsands mines in the Athabasca region near Fort McMurray, Alberta, have provided an increasing proportion of Canadian crude oil production since 1967. Thick, sticky bitumen – a semi-solid form of petroleum – is extracted from the sand and upgraded into a synthetic crude oil similar to light, low-sulphur conventional crude oil.

Did you know?

At 8,850 metres above sea level, the summit of Mount Everest is actually limestone from an ancient seabed.

Not written in stone

The above description is based on the organic theory of the origins of petroleum. It is the most widely accepted theory among geologists, and it appears to explain how most of the world's crude oil and natural gas reservoirs ended up in the places where they have been found. However, there are other theories, including the inorganic theory that maintains hydrocarbons were trapped inside the Earth during the planet's formation and are slowly moving towards the surface. Scientists continue to explore the possibility that some hydrocarbons might be formed from non-fossil sources and might be found at greater depths than known crude oil and natural gas resources. Laboratory experiments and deep drilling have provided some evidence in support of this theory.

Where is petroleum found?

Crude oil and natural gas are found in sedimentary rocks formed over millions of years by the accumulation of sand, silt, mud and the remains of living creatures in sedimentary basins. Canada has seven distinct regions or domains of sedimentary rocks. Every province and territory includes at least a portion of a sedimentary basin. These basins cover the majority of the land area of Alberta and Saskatchewan and large areas off the East Coast.

The most productive hydrocarbon area is the Western Canada Sedimentary Basin, which includes most of Alberta and Saskatchewan and parts of British Columbia, Manitoba, Yukon and the Northwest Territories. In 2003, the Western Canada Sedimentary Basin accounted for 87 per cent of Canada's crude oil and 97 per cent of natural gas production. The Geological Survey of Canada (GSC) estimates this basin contained 57 per cent of Canada's original in-place conventional petroleum resources. This figure does not include natural gas from coal or the non-conventional bitumen resources of the Alberta oilsands, the world's largest known petroleum resource. The vast majority of current crude oil and natural gas exploration and production activities are concentrated in the Western Canada Sedimentary Basin.

The Atlantic Margin extends along the East Coast from the U.S. border to the coast of Baffin Island. This area is the site of major offshore crude oil and natural gas deposits discovered since the 1970s. The region's first crude oil production was from 1992 to 1999 from the Cohasset and Panuke oil fields off Nova Scotia, and much larger oil production began in 1997 from the Hibernia project off Newfoundland and Labrador. Terra Nova, another project in the same vicinity, began crude oil production in 2002, and the White Rose project is scheduled to begin production in 2005. The region's first natural gas production began in 1999 from the Sable Offshore Energy Project off Nova Scotia. The Geological Survey of Canada estimates that the Atlantic Margin contained 18 per cent of Canada's original in-place conventional petroleum resources. It is an increasingly important contributor to the nation's petroleum supply.

Substantial crude oil and natural gas resources have also been identified in the Arctic Islands, Beaufort Sea and the Mackenzie Valley, but development has been slow due to Aboriginal land claims, the long distance from markets and the absence of pipeline systems. Two regions of sedimentary rocks – the Arctic Margin and the Arctic Cratonic regions – are estimated to hold 16 per cent of Canada's total conventional petroleum resources. (Cratonic rocks are those that have been relatively undisturbed since pre-Cambrian times, generally found in interior areas of continents.) The only production to date has been tanker shipments of crude oil from 1985 to 1996 from the Bent Horn well in the Arctic Islands (Arctic Cratonic region), and natural gas production from the Ikhil field in the Mackenzie Delta (Arctic Margin region) since 1999 to supply the community of Inuvik 50 kilometres away. One tanker load of crude oil was also shipped to Japan in 1986 following an extended production of the Amauligak discovery well in the Beaufort Sea (Arctic Margin).

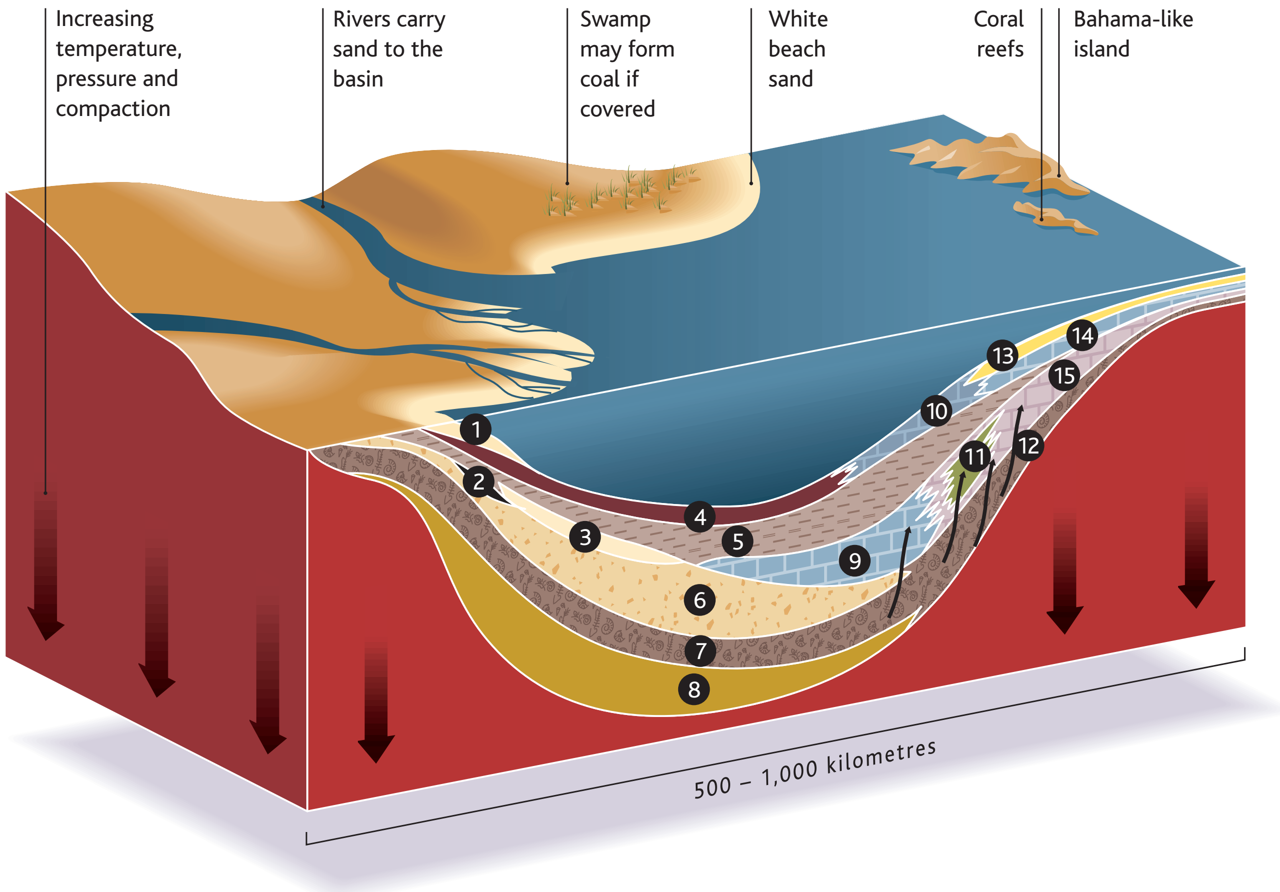
The Eastern Cratonic region includes parts of Manitoba, Nunavut, Ontario, Quebec, the Maritime provinces and Newfoundland and Labrador. However, this region's sedimentary rocks are estimated to contain just two per cent of Canada's original in-place conventional petroleum resources. One area of Eastern Cratonic rock is the portion of the Michigan Basin that includes an area of southern Ontario and the adjacent Great Lakes. This area has been producing crude oil since the 1850s, and it continues to produce a small portion (less than one per cent) of Canada's current crude oil and natural gas supply.

The Intermontane region is the area of British Columbia and the Yukon located between the Canadian Rockies and the West Coast mountain ranges. There has been some exploration in Intermontane areas, which are estimated to contain three per cent of Canada's original in-place conventional petroleum resources.

The Pacific Margin off the B.C. coast is estimated to contain another four per cent of the nation's original in-place conventional petroleum resources, but there has been no exploration since 1972 when the federal and provincial governments imposed moratoria on offshore oil and gas activities in the area. (Since 2001, the B.C. and federal governments have been reviewing the bans; a federal panel began hearings in 2004.)

Formation of a sedimentary basin

Petroleum is most often found in a sedimentary basin. A sedimentary basin is a depressed area of the Earth's crust where tiny plants and animals lived or were deposited with mud and silt from streams and rivers. These sediments eventually hardened to form sedimentary rock. The soft parts of plants and animals, exposed to heat and pressure over millions of years, gradually changed to oil and natural gas. Temperature, pressure and compaction of sediments increase at greater depths.



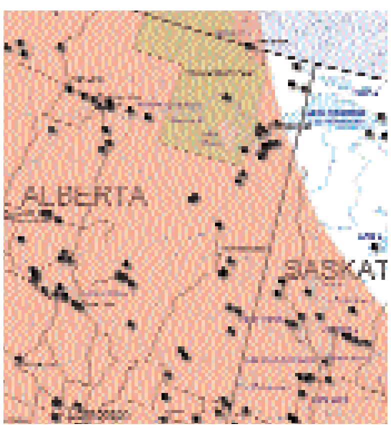
Legend

1. Delta sand
2. Coal
3. White sandstone (compacted beach sand)*
4. Black mud settled from ocean water
5. Shale formed by compaction of mud
6. Brown sandstone (formed by compaction of river and delta sand)*
7. Ancient shale (the heat down here turns organic matter into oil)
8. Ancient sandstone*
9. Limestone (compacted lime mud)*
10. Lime mud washed offshore
11. Ancient reef*
12. Oil migrates from shale to the reef and forms an oil reservoir*
13. Lime, sand and shell debris
14. Limestone (rock) formed by compaction of lime sediment*
15. Dolomite formed by groundwater altering limestone*

* Potential future oil or gas reservoir

Section 2
The early industry

Source: Northwest Territories archives N-1979-073.0567

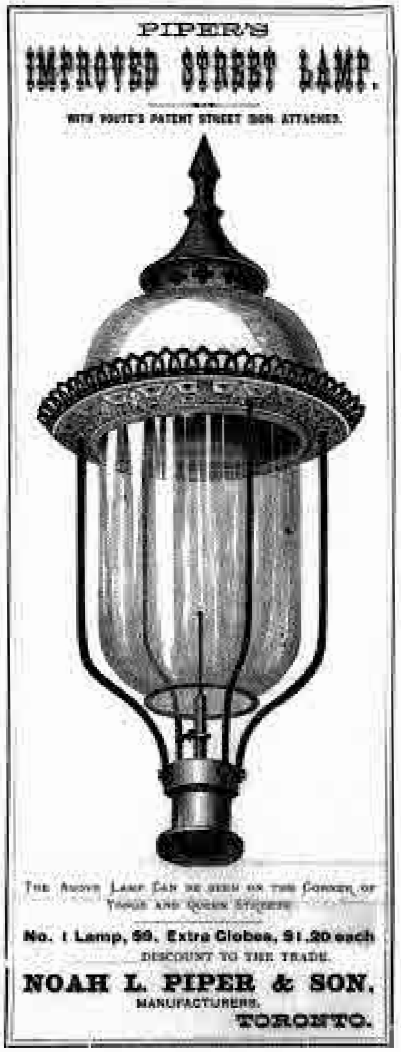


Source: Natural Resources Canada.

Athabasca region

Aboriginal people in Western Canada sometimes sealed their canoes with a mixture of spruce gum and the tar-like residues from oil seeps and oilsands deposits. In September 1714, Hudson's Bay Company fur trader James Knight recorded in his journal at Fort York (in what is now Manitoba) that Indians told him of a "great river" far inland where "there is a certain gum or pitch that runs down the river in such abundance that they cannot land but at certain places." Five years later, another fur trader on the western shore of Hudson's Bay, Henry Kelsey, recorded that a Cree named Wa-Pa-Sun had brought him a sample "of that gum or pitch that flows out of the banks of the river." Thus, the first word of the West's petroleum resources reached Europeans more than 35 years before any of them set foot in the territory that would become Alberta.

Since the earliest recorded history, there have been accounts of crude oil and natural gas seeping to the Earth's surface. The oil was used to caulk boats and buildings, grease wheels and dress the wounds of people and animals. Until the refining process was developed in the 1850s, oil was not commonly used as fuel because of its foul-smelling fumes.



Source: Enbridge Inc

A 19th century street lamp advertisement.

Let there be light

Natural gas fed the celebrated "perpetual fires" at Delphi in Greece, Baku on the Caspian Sea and other sites in the ancient world. In the third century AD, the Chinese transported natural gas in bamboo pipes to light their temples. They also used natural gas heat to extract salt from water.

Discoveries of crude oil and natural gas became more common in the 18th and 19th centuries as people dug deeper wells in search of water. "Rock oil" or petroleum (from the Latin roots *petra* for rock, and *oleum* for oil) was once a popular patent medicine in Canada and the United States.

Although natural gas was used in some areas, it was mostly coal gas that provided the "gas lights" in European and North American cities in the 19th century. Coal was heated in a closed vessel to produce a flammable mixture of hydrogen, carbon monoxide and methane. Coal gas first lit the streets of London, England, in 1807, Montreal in 1836, and Toronto in 1841.

In North America, people tapped safer, cleaner-burning natural gas for the same purpose as early as 1821 when it was piped through hollow logs to Fredonia, New York – "the best lit city in the world." However, natural gas was not widely used elsewhere until the end of the 19th century when better drilling techniques and cast iron pipes were developed.

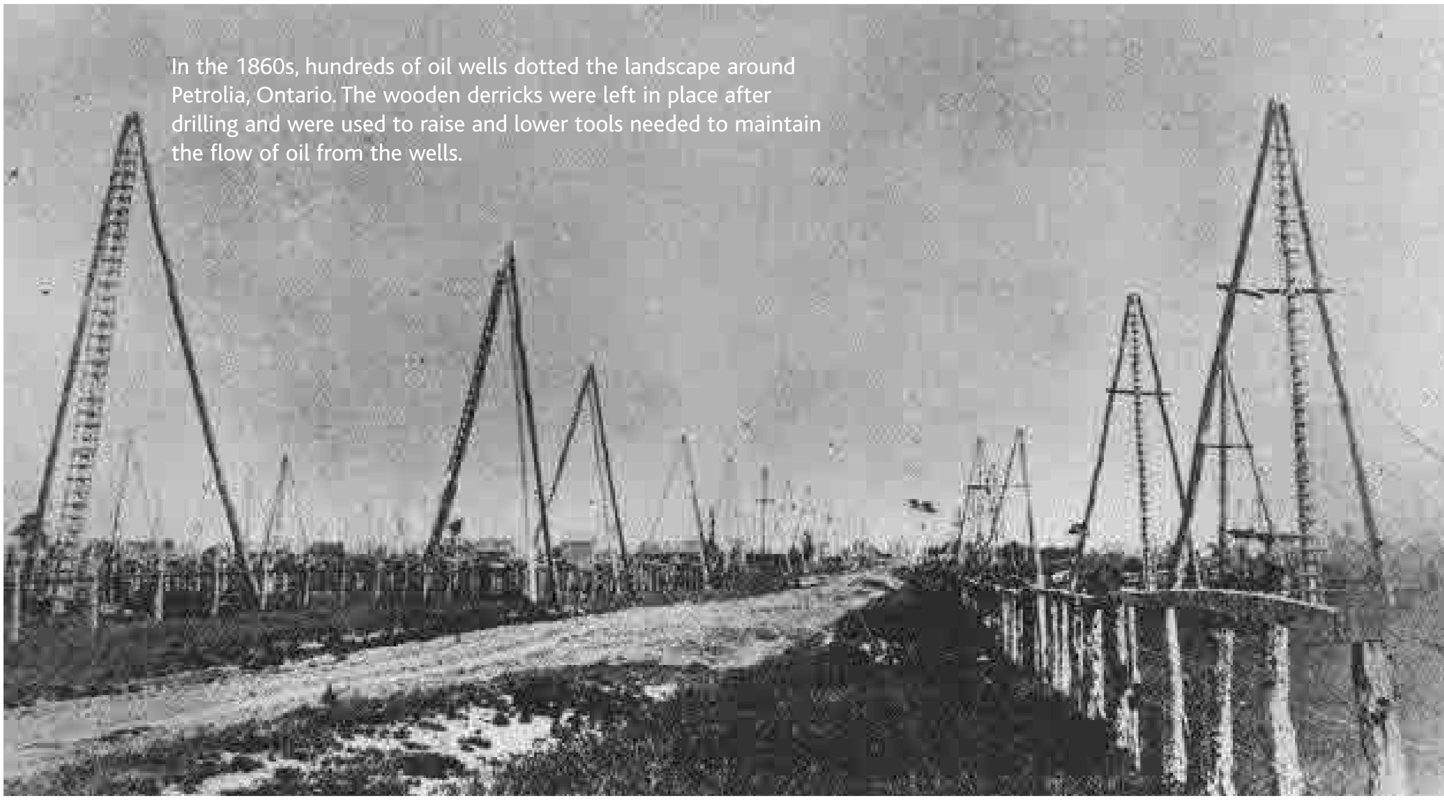
The demand for improved lighting also led directly to the first widespread use of crude oil. The need was urgent. By the 1850s, the best available lamp oil, obtained from whale blubber, was selling for $2.50 U.S. per gallon, or 66 cents per litre – a lot of money in those days, equivalent to about $55 U.S. per gallon in 2003. Growing demand for this oil decimated whale populations, putting some species at risk of extinction.

Did you know?

Prior to the development of the internal-combustion engine late in the 19th century, gasoline was often discarded as waste.

Light and heat in the 20th century. An Edmonton family's parlor in 1933.

Source: Glenbow Archives ND-3-6587b

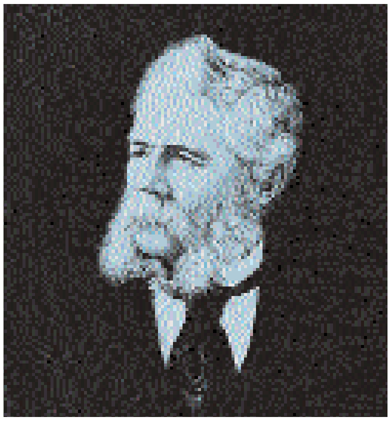


In the 1860s, hundreds of oil wells dotted the landscape around Petrolia, Ontario. The wooden derricks were left in place after drilling and were used to raise and lower tools needed to maintain the flow of oil from the wells.

Source: Glenbow Archives, Calgary, Canada, NA-302-9

Birth of an industry

The Canadian crude oil industry was born in a boggy area of southwestern Ontario, Enniskillen Township, in and around the neighbouring hamlets of Oil Springs and Petrolia. From humble beginnings in the 1850s, the industry brought several decades of great prosperity, and continues to produce small amounts of crude oil a century and a half after the first discovery.



Source: BP Canada Energy Company

James Miller Williams, a carriage maker from Hamilton, Ontario, was the first man to bring in a commercial oil well in North America.

North America's first oil company

In 1850, geologist Thomas Sterry Hunt of the Geological Survey of Canada reported seepages of crude oil in the swampy "gum beds" of Enniskillen Township, Lambton County, Ontario. A year later, businessman Charles N. Tripp of Woodstock, Ontario, founded the International Mining and Manufacturing Company to exploit the asphalt beds and oil springs. It was the first registered oil company in North America.

Tripp obtained a chemist's report indicating the crude oil could be used to produce solvents, lamp fuel and other chemicals. It prompted him to build the first asphalt production plant, winning an honourable mention for this product at the Universal Exhibition in Paris in 1855.

In the same year, Tripp sold his company to James Miller Williams, a carriage maker from Hamilton, Ontario. The energetic Williams soon discovered that the deeper he dug, the more oil flowed into the hole. By 1858, his 15-metre-deep well was producing significant quantities of crude oil. From the producing wells around Oil Springs and Petrolia, Williams' company transported crude oil 200 kilometres to Hamilton, refined it there and sold lamp oil and other products. It was the first fully integrated petroleum company in North America, and Williams is often called the founding father of Canada's petroleum industry.

Tripp and Williams owed their successes in part to the work of another Canadian. Between 1846 and 1853, Abraham Gesner of Halifax, Nova Scotia, developed a technique for producing a new synthetic lamp oil from coal. He obtained a patent on this product – originally called 'keroselain' but soon afterwards known as kerosene – and opened his first plant in New York in 1854. In 1855, American chemist Benjamin Silliman Jr. applied the same process, called fractional distillation, to a sample of Pennsylvania rock oil and found it produced high-quality lamp oil.

The first oil boom

In 1859, self-proclaimed "Colonel" Edwin Drake found a practical way to produce large quantities of crude oil when he used a cable-tool drilling rig to punch into an oil reservoir at Oil Creek in Pennsylvania. His well was important because it penetrated a layer of rock into the pressurized oil below. Williams also drilled through rock into a producing formation sometime in 1858 or 1859, although there is some uncertainty about exactly when he went from digging to drilling.

Crude oil was already being produced from wells in Ontario and eastern Europe, but the publicity surrounding Drake's well unleashed the first real oil boom. Especially in U.S. references, it is often cited as the beginning of the modern oil era.

During the oil boom of the 1860s and 1870s, entrepreneurs set up about 18 small, primitive refineries in and around the Enniskillen Township oil wells. (By 1866, a thriving town also sprang up in the oilfield; Petrolia, sometimes spelled Petrolea in the early years, was formally incorporated as a municipality in 1874.) However, most of the Ontario crude contained undesirable sulphur compounds, which caused odours, and the products had trouble competing with those from Pennsylvania and Ohio. In addition, the output from most wells was small.

The sulphur in "sour" crude oil was a serious problem for the oil-refining industry until 1888 when Herman Frasch, a German-American chemical engineer, invented a process to extract the sulphur compounds using copper oxide powder. The Frasch process was used after 1895 to treat petroleum products in the Canadian oil industry.

Hard oilers

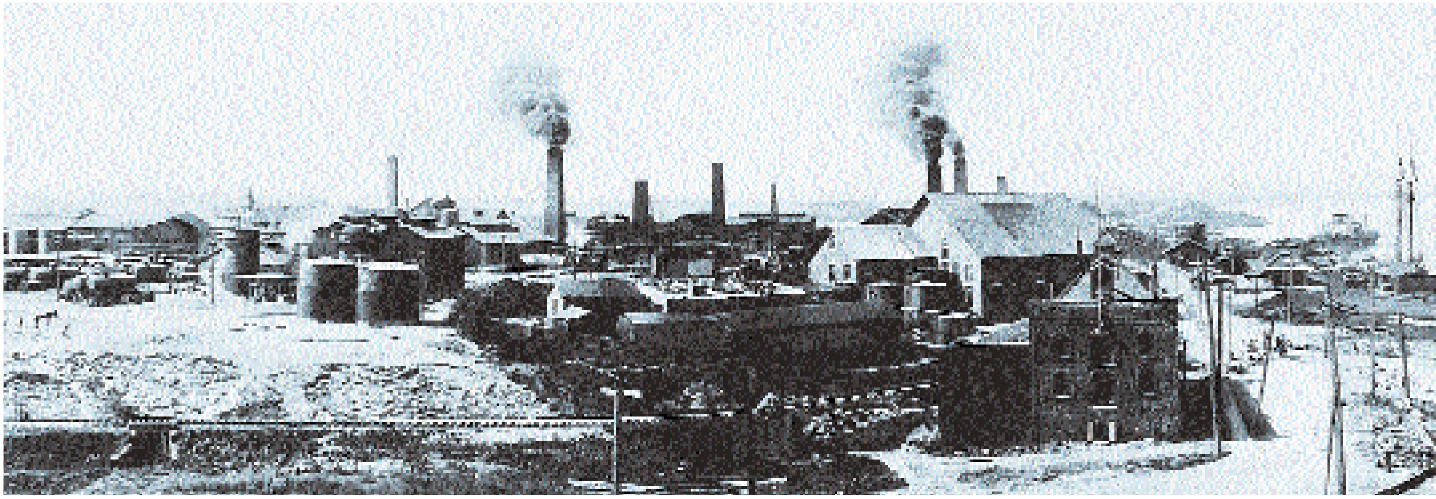
As the first drilling boom tapered off around Petrolia, experienced Canadian drillers and their bosses took their skills to other new oil fields

Geological Survey of Canada

The Geological Survey of Canada (GSC) was established in 1842. It was Canada's first scientific agency, and one of the nation's first government organizations of any kind. The GSC's initial focus was to look for coal and other minerals. Throughout its long history, the GSC has played a key role in gathering, recording and analyzing basic information about Canada's natural resources and other important aspects of the nation's geology.

Petrolia opera house.

Source: Robert D. Bott



Lamp oil for Canadians
In the 19th century, southwestern Ontario was Canada's petroleum-producing centre. The oil was refined into kerosene and other products.

Source: Imperial Oil Limited

around the world. The Canadian drillers called themselves "hard oilers." It was certainly hard work, depending on luck as much as geological knowledge, but the name may also have referred to the hard rock through which they drilled. Beginning around 1874 and continuing for about half a century, the hard oilers worked in exotic locales such as Russia, the Middle East, Indonesia and South America, but they called Petrolia "home." The wealth of the hard oilers built elegant Victorian homes and even an opera house in the Ontario town.

Early refineries

In the late 19th century, as oil fields were developed in southwestern Ontario and elsewhere around the world, the oil industry focused almost entirely on making and selling kerosene, also known as lampolene. Paraffin, grease and lubricating oil found ready markets, but the more volatile products were considered a dangerous nuisance. Gasoline was often just discarded as waste.

The first refineries were no more complicated than a tea kettle or a whisky still. Crude oil was heated in a closed vessel to vapourize the lighter, more volatile hydrocarbons. As the vapour cooled, the liquids would condense. A little cooling would capture kerosene, while more cooling would collect gasoline. The remaining heavy oil and coke – known as the residuum – could be removed and burned to provide heat for the next cooking cycle. Processing residuum with chemicals produced lubricants, waxes and asphalt.

Although kerosene lamps would be widely used for another 50 years – and some are still lighting remote cabins today – the oil industry faced the prospect of a long, slow decline after cities such as Toronto, Montreal and Ottawa introduced electric lighting in the 1880s.

The Imperial Oil Company Limited

Partly to fend off competitors such as John D. Rockefeller's Standard Oil Trust, 16 Ontario producing and refining companies merged in 1880 to form the Imperial Oil Company Limited. Imperial Oil consolidated its refining operations in 1898 at Sarnia, Ontario, on the south end of Lake Huron. This gave the company access to U.S. crude oil supplies to supplement Ontario's declining production.

In 1898, Rockefeller acquired control of Imperial Oil and merged it with Standard Oil's other Canadian affiliates. When U.S. courts broke up the Standard Oil Trust in 1911, Imperial Oil became an affiliate of Rockefeller's new flagship, Standard Oil of New Jersey (renamed Exxon Corporation in 1972 and ExxonMobil in 1999). Although Imperial Oil never lost its title as Canada's largest integrated oil company, it soon faced competition from affiliates of U.S. and British rivals as well as a number of homegrown Canadian firms.

As the industry expanded early in the 20th century, many firms began to seek vertical integration – pulling together all aspects of the business from exploration to retail sales within one company. These followed in the footsteps of the world's first integrated oil company created by Canadian oil pioneer James Miller Williams in Hamilton, Ontario, in 1866.

Internal combustion triumphs

Human life was transformed by the development of the internal-combustion engine late in the 19th century. By 1905, automobiles powered by spark-ignited gasoline engines were clearly outperforming steam- and electric-powered rivals. The gasoline engine dominated the rapidly growing auto market and spun the propellers of the first airplanes.

Oil companies recognized the potential of this new market for fuels and lubricants, and became heavily involved as sponsors and promoters of races, tours, shows and other events for automobiles and airplanes. This involvement continued through the following century – and is still evident at auto races and car shows.

Meanwhile, a sparkless engine design, invented by Rudolph Diesel in 1892, gained popularity as the power for industrial machinery and ships. However, diesel engines were too heavy for mobile use until Robert Bosch invented the fuel injector in 1924 and began commercial production in 1927. As diesel engines improved, they were used for locomotives, trucks, tractors, buses, military vehicles and eventually automobiles. Diesel engines were even used in some aircraft in the late 1920s and 1930s, including one that stayed aloft without refueling for 84 hours and 32 minutes, an endurance record unsurpassed from 1931 to 1986. (Interestingly, fuel-efficient diesel engines for light aircraft began attracting renewed attention in the late 1990s.) Diesel fuel is similar to kerosene and considerably less volatile than gasoline.

A crucial decision on naval power

At sea, engineers discovered that thick, black bunker oil – another former waste product of refining – fired boilers as efficiently as coal but required far less labour. Winston Churchill, the minister in charge of the Royal Navy, made a crucial decision in 1911 to switch the fleet from coal to oil. This was essential, he believed, for Britain to retain mastery of the seas as military tension grew between Britain and Germany.

The First World War, from 1914 to 1918, established crude oil as a key strategic commodity. Horses and trains gave way to tanks, trucks, airplanes, motorcycles and automobiles – all powered by gasoline. In the 1920s, consumers rushed to buy automobiles, much improved by production methods developed during the war. Service stations opened across Canada to provide gasoline, lubricants and repairs.

Then came the Great Depression of the 1930s. The symbol of prairie poverty was the "Bennett buggy," a car pulled by a team of horses because the owner could not afford gasoline.

Source: Imperial Oil Limited

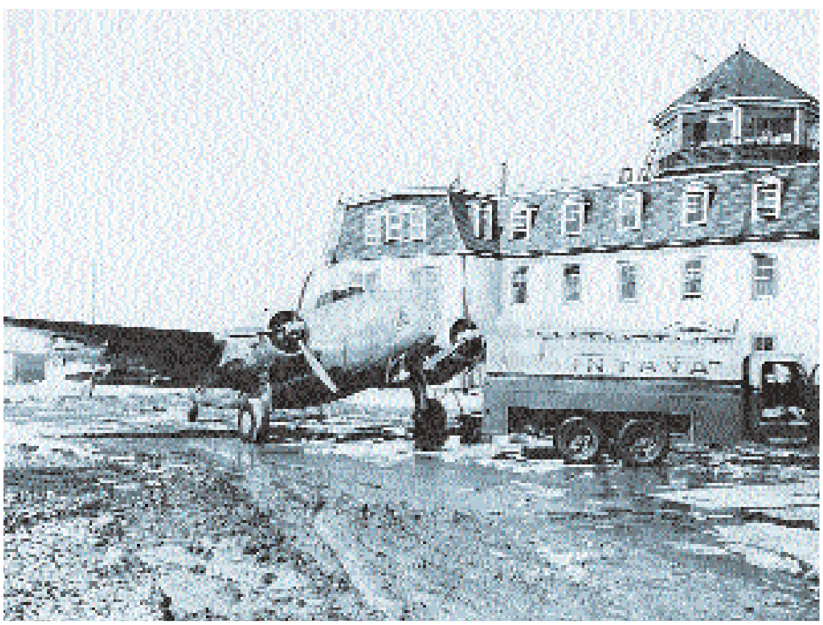
Hitting the road
A group of businessmen in Windsor, Ontario, established the Ford Motor Company of Canada in 1904, a year after Henry Ford began manufacturing cars in Detroit, Michigan. In 1907, Col. R.S. McLaughlin converted his family's carriage company at Oshawa, Ontario, into an automobile plant (the precursor of General Motors of Canada). From a mere handful at the turn of the century, the number of cars on Canadian roads had soared to 50,000 by 1913. According to Statistics Canada, there were about 18.6 million road motor vehicles registered in Canada in 2002. Of this total, 17.5 million or 94 per cent were passenger cars and light vehicles such as pickup trucks and minivans. The remainder consisted of 79,300 buses, 350,000 motorcycles and mopeds, and 644,300 truck tractors and trucks weighing at least 4,500 kilograms. In addition to these road motor vehicles, 4.2 million trailers and 1.4 million off-road, construction and farm vehicles were also registered.

Did you know?

The 159-litre barrel, used as a standard measure for crude oil since the 1850s, was the size of barrel adopted in the 15th century by the kings of England and Norway as the standard container for herring.

Source: Imperial Oil Limited

Ted Link, Imperial Oil's legendary geologist, led the discovery of crude oil at Norman Wells, Northwest Territories, in 1920. Link later played a major role in the Leduc discovery near Edmonton.



Source: Imperial Oil Limited

Gasoline from Turner Valley
The availability of gasoline from crude oil produced in Turner Valley near Calgary was one reason British Empire air crews trained in Western Canada during the Second World War.

A growing reliance on oil imports

In the late 19th century and early 20th century, Canadian oil companies relied on imported crude oil, mainly from the United States, to supplement the declining production of south-western Ontario. After 1911, when naval fleets began converting from coal to oil, the government urged the industry to find and develop domestic oil supplies.

The far-reaching exploration efforts had one success – a crude oil discovery by Imperial Oil in 1920 at Norman Wells in the Northwest Territories – but it was too far from markets. A small refinery was built at Norman Wells in the 1920s to supply fuel oil and gasoline to the surrounding region, and a larger one was completed there in 1939. Smaller discoveries at Turner Valley, southwest of Calgary, Alberta, provided fuel for nearby areas after 1914. Heavy crude oil, discovered near Wainwright, Alberta, in 1923, was used to produce asphalt for paving and roofing. However, until the giant Leduc discovery near Edmonton in 1947, Canada depended on imports for up to 90 per cent of crude oil supplies.

Canadian companies concentrated for several decades on finding and developing crude oil resources abroad, mainly in Central and South America and the Caribbean. Many Canadian geologists and engineers learned their trade in tropical jungles. Tanker fleets were a key component of the larger Canadian oil companies.

Lessons from the Second World War

Oil played a dominant role in the Second World War. Many Allied air victories were assisted by the availability of high-octane gasoline from British and U.S. refineries. Armies in North Africa, Europe and the Soviet Union were crippled when their oil supplies were interrupted. Lack of oil helped end the effectiveness of the Japanese navy in the Pacific and destroyed Japan's domestic economy in the final year of the war.

Wartime oil shortages hit Canada too. Gasoline rationing affected everyone. German U-boats sank dozens of tankers carrying oil to Eastern Canada from the Gulf of Mexico and South America.

The wartime experience showed Canadians the danger of relying so heavily on imports. To shorten the East Coast tanker voyage, a pipeline was built in 1943 from Portland, Maine, to refineries in Montreal, Quebec. A year later, the U.S. Army Corps of Engineers completed the Canol Pipeline, an expensive, but short-lived, pipeline system carrying crude oil from Norman Wells to a new refinery at Whitehorse, Yukon, and refined oil products to Fairbanks and Skagway, Alaska. The Canol pipeline only operated for a year and was dismantled by 1947. The Whitehorse refinery was also dismantled and transported by truck and train to provide the original components in 1948 for Imperial Oil's Strathcona refinery in Edmonton (built in the aftermath of the nearby Leduc discovery).

During the war, the Alberta and federal governments stepped up research on ways to extract usable oil products from the vast bitumen resources of the Athabasca oilsands. As the war ended, Canada's conventional crude oil supplies were so limited that Imperial Oil seriously considered using a German technology (the Fischer-Tropsch process) to convert western Canadian natural gas into gasoline.

Wartime experience also demonstrated the advantages of diesel engines in tanks and other heavy equipment. Most notably, diesel power helped Soviet tanks to outperform gasoline-powered German tanks on the eastern front. By the end of the war, diesel engines were well-established as the preferred propulsion for military vehicles, railway locomotives, trucks, tractors, buses, and many types of boats and ships.

The mechanization of farming and forestry, delayed by the Depression, sped ahead in the labour-short, commodity-hungry 1940s. Work horses soon disappeared from wheat fields and logging operations. The first jet engines for airplanes appeared as the war ended. They burned jet fuel, a product similar to kerosene and diesel fuel.

Getting more products from oil

After the automobile gained popularity early in the 20th century, refiners faced a problem. For each litre of natural crude oil they processed, the conventional distillation process only produced about one-quarter of a litre of gasoline. Refiners wanted a higher yield from the oil to meet rising demand for gasoline.

Source: Glenbow Archives, Calgary, Canada, NA-1446-24

Eugene Coste, an entrepreneur from southwestern Ontario, was the first Canadian to find and develop natural gas resources on a large scale.

In 1914, Imperial Oil added a process called "cracking" to its Sarnia refinery. Thermal cracking uses heat to break large hydrocarbon molecules into smaller molecules used to make gasoline.

Cracking was later improved by the use of catalysts. This became known as "cat cracking" and was used specifically during the Second World War to meet the demand for high-octane aviation fuels. Imperial Oil introduced cat cracking at its Sarnia refinery in 1940. Hydrocracking – a process that breaks up the carbon-rich molecules of heavier oil and adds hydrogen in the presence of a catalyst – subsequently produced another improvement in gasoline output.

The invention of nylon in 1936, the first plastic made from petroleum products, set off a wave of petrochemical innovation that continues today. During the Second

Source: Oil Museum of Canada or Fairbank Collection/National Archives

Primitive drilling
The spring pole was used to drill early oil wells in Ontario. The bit was suspended from the pole on a cable or shaft. The driller jumped on the pole to push down the bit, and then jumped off so the flexible pole could lift up the apparatus.

World War, the federal government built a major petrochemical facility at Sarnia to produce synthetic rubber. Most of Canada's petrochemical plants today are located near Sarnia, Montreal and Edmonton.

Did you know?

Medicine Hat, Alberta, was celebrated in *Ripley's Believe It or Not* for burning its lights 24 hours a day, because it was cheaper than hiring a lamplighter. (Continuous burning also extended the life of the lamp mantles.)

Blue flames

The other fuel of the petroleum era, natural gas, did not reach most Canadian cities until large, long-distance pipelines were built in the late 1950s. However, it had been available to some Canadians since the 1880s.

Natural gas had been discovered in New Brunswick in 1859 and in southwestern Ontario in 1866, but the early discoveries were not developed. Gas found with oil in Ontario was considered a waste product – either burned (flared) or vented into the atmosphere – until pioneer entrepreneur Eugene Coste came along.

In 1889, Coste began drilling for natural gas in Essex County, Ontario, to supply nearby communities with fuel for lighting, heating and cooking. A year later, he drilled a well near Niagara Falls, Ontario, and began exporting natural gas to Buffalo, New York. By 1895, Coste was pipelining Essex County natural gas to Windsor, Ontario and across the river to Detroit, Michigan. As the natural gas supply dwindled, the Ontario government moved to protect consumers and banned Coste's exports in 1901.

Natural gas in Alberta

In Western Canada, a crew working for the Canadian Pacific Railway (CPR) accidentally found natural gas while drilling for water at Langevin Siding near Medicine Hat, Alberta, in 1883. The gas was used for cooking and heating at the nearby CPR section house. After another discovery just outside the town in 1890, village leaders in Medicine Hat borrowed a CPR rig and began drilling to supply natural gas for the cooking, heating and lighting needs of the town. Private citizens even drilled their own personal wells.

Natural gas helped Medicine Hat and nearby Redcliff to attract industries such as plaster and brick manufacturing and meat processing. The natural gas was even compressed in metal bottles to provide lighting on CPR passenger trains. When the author Rudyard Kipling visited in 1907, he was impressed by the booming economy and sights such as a giant natural gas-powered engine and a huge flare from a newly drilled well. He told the local newspaper, "This part of the country seems to have all hell for a basement and the only trapdoor appears to be in Medicine Hat." The handy energy supply was envied by other towns across the prairies.

Early drilling techniques

Cable-tools to rotary rigs

From the 1850s to the 1930s, most of Canada's crude oil and natural gas wells were drilled with a primitive device called a cable-tool rig. The heavy, chisel-like bit was suspended on a cable and dropped repeatedly into the rock at the bottom of the hole.

Cable-tool drilling was very slow, hard work – and sometimes very dangerous. Progress of just 100 metres per month was not uncommon. A modern rig can sometimes drill that far in less than a day. The bits had to be pulled and sharpened frequently. Drillers poured water into the wellbore and removed the cuttings by bailing out the resulting "mud." If the bit encountered a reservoir, the pressure could shoot the tool up through the rig like a bullet out of a rifle barrel.

Rotary rigs, predecessors of the types used today, were introduced in Texas in the 1890s and in Turner Valley, Alberta, in 1925. However, they were not used widely in Canada until exploration in Turner Valley in 1936 indicated there were larger oil reservoirs to be found at greater depths than earlier discoveries. After the Second World War, most cable-tool rigs were retired in favour of rotary rigs, although a few cable-tool rigs have continued to operate in southern Ontario.

The first well-logging instruments appeared in Canada in the 1920s. One version combined a camera, a plumb bob and a compass. This primitive deviation gauge was lowered to a given depth and snapped a picture of the compass and the weighted line. The developed picture would tell drillers if the well was tilted and, if so, in what direction. A simpler instrument for this purpose was just a heavy glass bottle filled with acid; when this was left in the hole for a while, the acid would etch a line on the inside of the bottle. These instruments helped avoid a common problem of wells veering far off course in the tilted and fractured underground rock formations near Turner Valley.

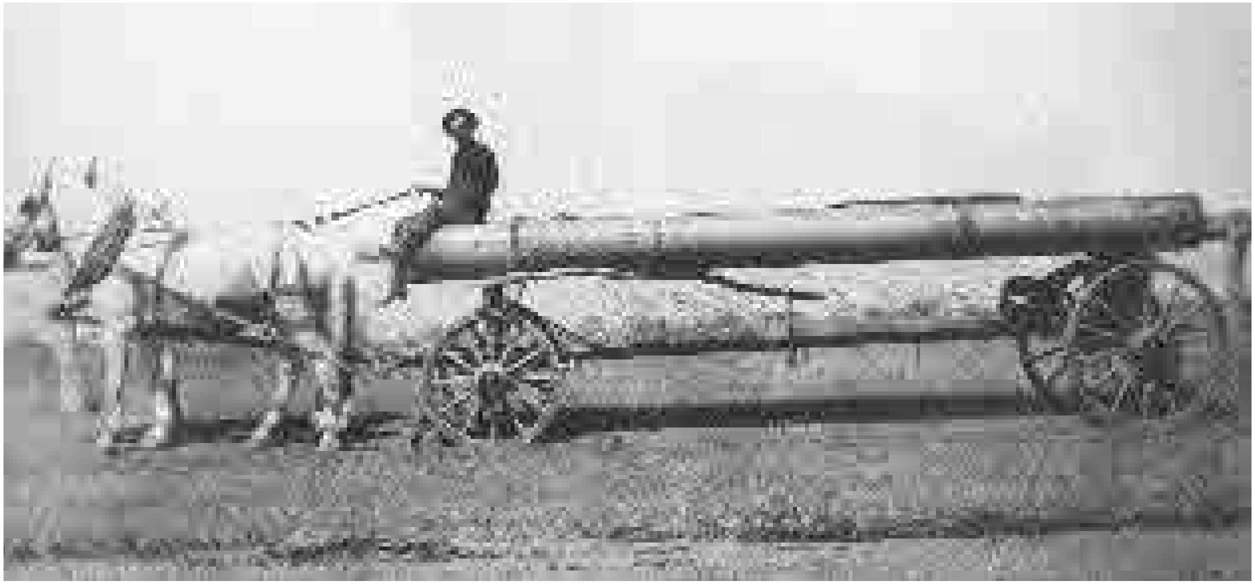
The first modern well-logging instrument measured the electrical resistance in rocks around the wellbore; a higher resistance often indicated the presence of crude oil. Electric logging, invented in France in 1927, was first used in Canada on a well near Turner Valley in 1939. More sophisticated well-logging instruments, designed to measure many characteristics of the wellbore and the surrounding rock, were introduced in the 1950s, and new instruments continue to be developed and introduced in the field.

Did you know?

Early cable-tool rigs used from the 1860s to the 1930s would typically drill about 100 metres per month. A modern rig can sometimes drill this far in less than a day.

Source: Robert D. Bott

Early drilling tools
Hand-forged drilling tools were used in the 19th century on oil wells in southwestern Ontario. Each tool was designed for a specific purpose, such as removing an obstruction from the wellbore or scraping the walls of the hole.



Source: Glenbow Archives, Calgary, Canada, NA-4048-1

The Bow Island to Calgary pipeline
Horses pulled lengths of 406-millimetre-diameter pipe from railway sidings to the route of the Bow Island to Calgary pipeline in 1912. Steam-powered trenching machines dug the ditch for the 270-kilometre pipeline, but men and horses did most of the other work.

After his Ontario wells ran dry in 1904, Eugene Coste moved west with a bold plan to supply all the towns of southern Alberta with natural gas. He drilled along CPR rights-of-way and found gas at a half-dozen places, including a huge discovery called "Old Glory" at Bow Island in eastern Alberta in 1909.

In 1912, Coste's Canadian Western Natural Gas Company built a 270-kilometre pipeline from Bow Island to Calgary. At the time, it was one of the longest and largest-diameter gas pipelines ever built. The city already had a 40-kilometre coal gas system, established in 1903, which supplied 1,800 customers, and the natural gas was considered a great improvement. "The natural product has supplanted the artificial," declared the Calgary Herald.

Edmonton switched to natural gas in 1923 after completion of a 130-kilometre pipeline from Viking, Alberta. Many southern Alberta communities, and a few in Saskatchewan and southwestern Ontario, used natural gas for cooking and heating. However, electricity was quickly taking over the lighting market.

Underground mysteries

Early petroleum explorers simply looked for areas where crude oil and natural gas were seeping to the surface or had been encountered accidentally when drilling water wells. This unsophisticated but locally effective technique led to the discoveries of southern Ontario crude oil in the 1850s and 1860s, eastern Alberta natural gas in 1883, Turner Valley crude oil and natural gas in 1914, and Norman Wells crude oil in 1920.

The understanding of geological structures also grew as the oil and gas industry expanded. As early as 1861, T. Sterry Hunt of the Geological Survey of Canada described how hydrocarbons would pool in the crests (anticlines) of folded sedimentary layers. This same "anticlinal theory" helped entrepreneur Bill Herron select the most promising site to drill near Turner Valley in 1914.

Some of the successes were fleeting. For instance, the Geological Survey of Canada reported seeps along Oil Creek near Waterton in southwestern Alberta in 1870, and for many years local residents collected the crude oil by soaking it up with gunny sacks. When a well was finally drilled in 1902, it reportedly flowed oil, and this set off a five-year exploration boom, based in a shanty town optimistically named Oil City. However, the first well's production quickly dwindled, and all the other wells were dry, leading to a suspicion that the "gusher" had been a fraud. Ironically, the jury is still out on the crude oil potential of this region, which is now part of Waterton Lakes National Park. Nearby areas produce substantial volumes of natural gas.

Underground mysteries were gradually unravelled by the developers of the Turner Valley oil field southwest of Calgary. Each of the three waves of exploration successes around Turner Valley – beginning in 1914, 1924 and 1936 – was based on an improved understanding of the area's complex geology and hydrocarbon distribution. Each time, a larger accumulation was found at a greater depth than the previously discovered producing pool.

Based on apparently promising surface geology in the area, Canada's first offshore well was drilled from an artificial island off Prince Edward Island between 1943 and 1945. The well reached a depth of nearly 4,500 metres and cost $1.25 million (equivalent to $14.2 million in 2003). At the time, it was believed to be the most expensive well ever drilled anywhere. However, it did not find commercial quantities of oil or gas.

The emerging science of geophysics

Advances in earth sciences and instrumentation during the 1920s and 1930s paved the way for the dramatic improvement in drilling success rates in the following decades. As geophysics became more sophisticated and precise, it was no longer necessary to rely solely on surface geology and drilling results to determine where to drill next.

Increasingly accurate gravimeters and magnetometers allowed the mapping of small variations in the Earth's gravity and magnetic fields. As this data could be correlated with the location of known crude oil and natural gas fields, it helped geologists to determine where new fields might be found. Instruments such as the early "torsion balance" gravity meter bore some resemblance to the traditional dowser's divining rods, and geophysicists are still sometimes known as "doodlebuggers." (A doodlebug is any kind of instrument or gadget with no recognized scientific method but supposedly able to find oil, gas, water or minerals; the term also refers to someone looking for oil or water using non-scientific means.)

The most important tool of modern geophysics, the seismic survey, originated from attempts during the First World War to locate enemy artillery by measuring sound waves traveling through the ground. It became evident that the sound waves spread at different rates through different kinds of rock. A German scientist, Ludger Mintrop, patented the first seismic surveying method in 1919, and two British scientists patented a similar method a year later. Mintrop's company first applied the method to oil and gas fields in Oklahoma in 1921 and helped find a major oil field, Orchard Park, in Texas in 1924. The first Canadian seismic survey was conducted in the Turner Valley field in 1929.

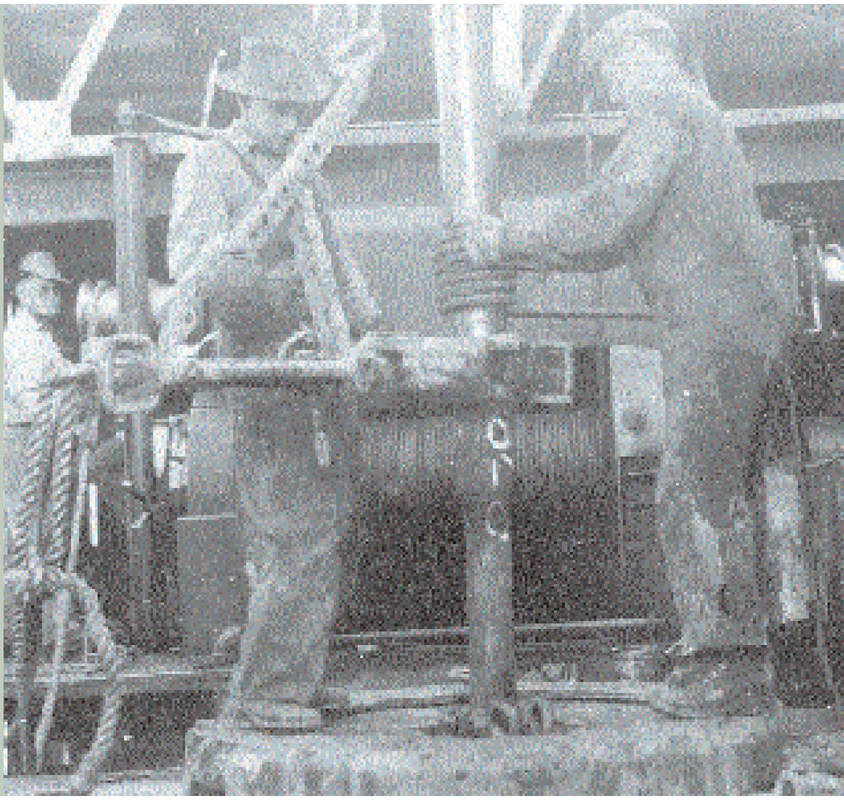
Seismic knowledge and methods improved over the next two decades. More accurate recording instruments, developed during the Second World War, made geophysics a full partner in petroleum exploration. A seismic survey led to Shell Canada's major natural gas discovery at Jumping Pound, west of Calgary, in 1944.

In 1946, Imperial Oil commissioned a major seismic survey in Canada on an east-west line across central Alberta. The survey was originally planned for southern Saskatchewan, but was moved to Alberta after the Saskatchewan government was rumoured to be considering a takeover of the oil and gas industry. The Alberta survey indicated a large, potentially oil-bearing formation – which turned out to be a Devonian reef, similar to the structure of the Norman Wells field far to the north. The target was located near Leduc, a hamlet south of Edmonton. Imperial Oil decided to drill an exploratory well there during the following winter.

Prior to its big success at Leduc, Imperial Oil had drilled 133 wells in western Canada without finding a major new oil field. Although there had been a number of smaller crude oil and natural gas discoveries, the company was on the verge of abandoning exploration in Western Canada. (The oft-repeated story about 133 "dry holes" or non-commercial wells prior to Leduc was perpetuated, in part, by driller Verne Hunter who received the nickname "Dry Hole.") The Leduc discovery was certainly a reward for great perseverance, but equally important it marked the arrival of seismic as a key exploration tool.

Section 3

After Leduc - The modern oil and gas era



Source: Glenbow Archives, Calgary, Canada, NA-5470-3

A tough, dirty job
Success of the Leduc well created opportunities for thousands of oil workers, many of them returning to civilian life after military service. The influx threatened to overwhelm the small town of Leduc, so Imperial Oil helped to build a new community, Devon, just north of the No. 1 well, to house its workers. A roughneck on a rig in 1947 earned about 90 cents an hour, equivalent to $9.45 in 2003. No special training was required, and many young Albertans went directly from the farm to the rig.

Drillers on the Leduc rig

The pivotal event in Canadian oil history occurred on February 13, 1947, when Imperial Oil finally struck oil at its Leduc No. 1 exploratory well. It marked the beginning of Canada's transition from oil-poor to oil-rich.

The Leduc well had penetrated a Devonian reef similar to the one discovered at Norman Wells in 1920. It led to a series of discoveries in the area around Edmonton. Within a year, a major oil boom was underway in Western Canada. There were also several large finds of natural gas in Alberta in the 1940s.

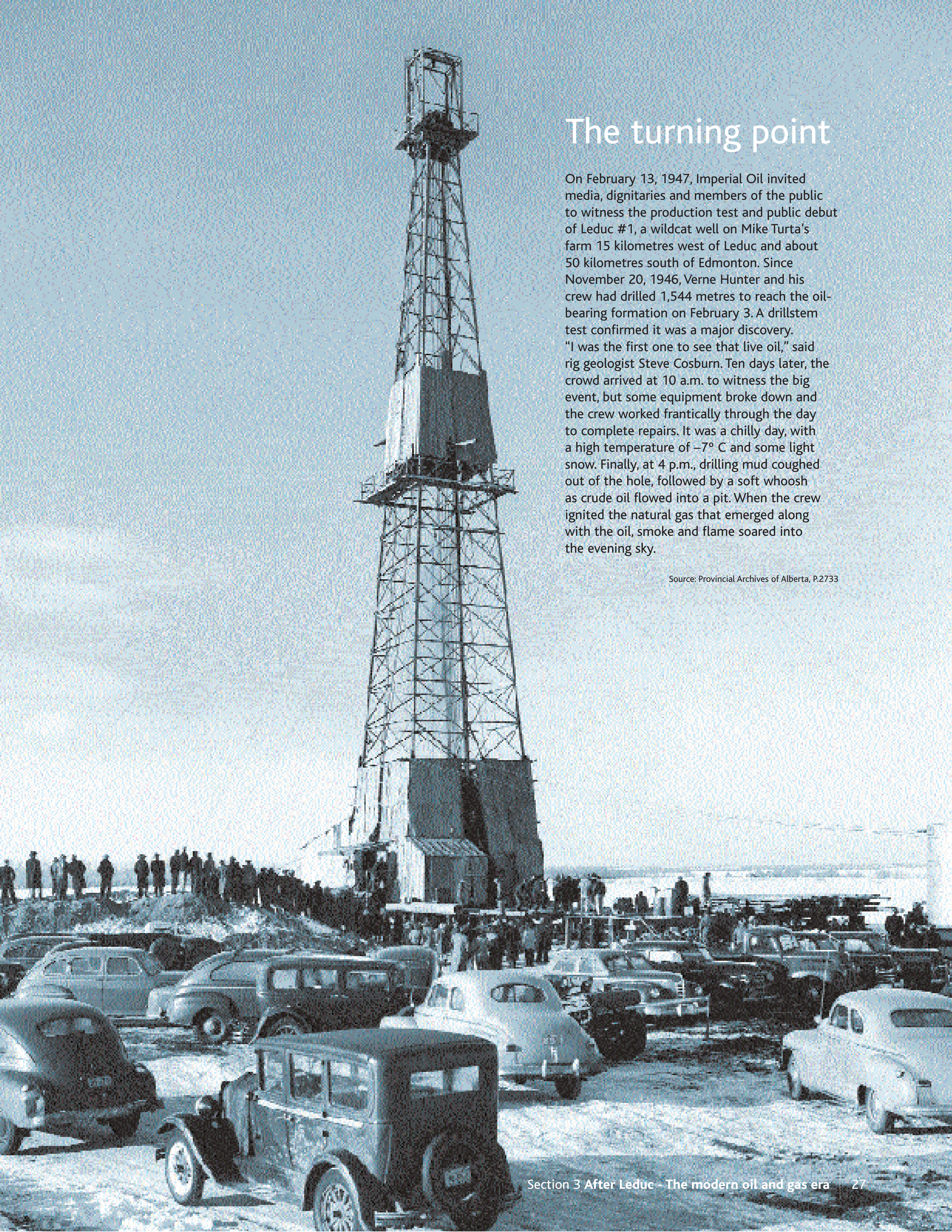
Crude oil and natural gas discoveries

Crude Oil (green)

1. 1851 Petrolia, Ont.
2. 1914 Turner Valley, Alta.
3. 1920 Norman Wells, N.W.T.
4. 1923 Wainwright, Alta.
   1924 Turner Valley, Alta.
5. 1947 Leduc, Alta.
6. 1951 Daly, Man.
7. 1953 Midale, Sask.
8. 1953 Pembina, Alta.
9. 1957 Swan Hills, Alta.
10. 1957 Clarke Lake, B.C.
11. 1965 Rainbow Lake, Alta.
12. 1966 Pointed Mountain, N.W.T.
13. 1969 Atkinson Point, N.W.T.
14. 1973 Panuke-Cohasset, N.S.
15. 1973 Bent Horn, Cameron Island
16. 1977 West Pembina, Alta.
17. 1979 Hibernia, Nfld.
18. 1981 Hebron-Ben Nevis, Nfld.
19. 1984 Amauligak, N.W.T.
20. 1985 Terra Nova, Nfld.
21. 1985 White Rose, Nfld.

Natural Gas (red)

1. 1859 New Brunswick
2. 1866 Southwestern Ontario
3. 1883 Medicine Hat, Alta.
4. 1889 Essex County, Ont.
5. 1904 Cessford, Alta.
6. 1904 Suffield, Alta.
7. 1909 Bow Island, Alta.
8. 1954 Westerose South, Alta.
9. 1955 Elmworth, Alta.
10. 1956 Crossfield, Alta.
11. 1956 Clarke Lake, B.C.
12. 1959 Brazeau River, Alta.
13. 1959 Waterton, Alta.
14. 1961 Kaybob South, Alta.
15. 1962 Edson, Alta.
16. 1962 Yoyo, B.C.
17. 1965 Sierra, B.C.
18. 1969 Drake Point, Nunavut
19. 1969 Parson's Lake, N.W.T.
20. 1972 Thebaud, N.S.
21. 1979 Venture, N.S.
22. 1980 Issungnak, N.W.T.
23. 1983 Hamburg, Alta.
24. 1986 Caroline, Alta.
25. 1997 Fort Liard, N.W.T.
26. 1997 Shackleton, Sask.
27. 2000 Ladyfern, B.C.
28. 2002 Greater Sierra, B.C.
29. 2002 Monkman, B.C.



The turning point

On February 13, 1947, Imperial Oil invited media, dignitaries and members of the public to witness the production test and public debut of Leduc #1, a wildcat well on Mike Turta's farm 15 kilometres west of Leduc and about 50 kilometres south of Edmonton. Since November 20, 1946, Verne Hunter and his crew had drilled 1,544 metres to reach the oil-bearing formation on February 3. A drillstem test confirmed it was a major discovery. "I was the first one to see that live oil," said rig geologist Steve Cosburn. Ten days later, the crowd arrived at 10 a.m. to witness the big event, but some equipment broke down and the crew worked frantically through the day to complete repairs. It was a chilly day, with a high temperature of –7° C and some light snow. Finally, at 4 p.m., drilling mud coughed out of the hole, followed by a soft whoosh as crude oil flowed into a pit. When the crew ignited the natural gas that emerged along with the oil, smoke and flame soared into the evening sky.

Source: Provincial Archives of Alberta, P.2733

The Leduc discovery was followed by years of stunning exploration successes in Western Canada. These included discoveries at Daly, Manitoba, in 1951; Midale, Saskatchewan, and Pembina, Alberta, in 1953; Swan Hills, Alberta, and Clarke Lake, British Columbia, in 1957; Rainbow Lake, Alberta, in 1965; and West Pembina, Alberta, in 1977.

Large post-war discoveries of crude oil and natural gas in Western Canada reduced anxiety about the nation's dependence on imported oil supplies. Development brought economic growth to crude oil and natural gas producing areas, especially in Alberta. Jobs were created in an array of new businesses from drilling to pipelining and refining. Pipelines were built east to Sarnia and west to Vancouver to provide markets for the new production. The pipelines were among the largest industrial projects ever undertaken in Canada. By 1953, large volumes of Canadian oil were flowing to new markets.

In the early 1950s, crude oil replaced coal as Canada's largest source of energy. Canadians embraced the new products and services of the oil age, from shiny cars and plastics to air travel. In most regions of Canada, wood and coal furnaces were steadily replaced with cleaner, more convenient oil or natural gas heating.

The discovery of huge natural gas reservoirs in Alberta and improvements in the technology of pipelining created new possibilities. After much political wrangling, pipelines brought natural gas to Vancouver, Winnipeg, Toronto and Montreal in the late 1950s.

The old coal gas systems were shut down, and natural gas was soon providing clean, inexpensive energy for homes and businesses from British Columbia to Quebec. Natural gas also was a raw material for making fertilizer and other chemical products. Natural gas liquids – mainly propane and butane – found industrial uses and offered an alternative heating fuel for more remote regions.

After oil prices began to rise sharply in the 1970s, many consumers and industries switched their furnaces from heating oil to natural gas. In the 1980s, some consumers and fleet operators, such as taxi companies, converted their vehicles to run on propane or, in a few instances, natural gas.

The growing importance of geophysics

Geological science continued to evolve rapidly in the following decades. Once the geologists knew what formations contained crude oil and natural gas, seismic surveys allowed geophysicists to map the structures.

In the 1960s, the processing, presentation and interpretation of seismic data was revolutionized by the introduction of computers, digitally recorded data, and the common-depth-point method of shooting and recording. The reliability of seismic data improved dramatically, and this greatly improved the chances of drilling success. These sophisticated geophysical techniques then helped explorers to find more elusive targets such as the pinnacle reefs at Rainbow Lake and Zama in northern Alberta. Early seismic surveys left a trail of shotholes and cutlines across the landscape. These scars were slow to heal in forest and muskeg areas. New technologies have greatly reduced the land disturbance. Offshore seismic surveys use compressed air to generate signals and a towed array of hydrophones to receive the reflections.

Source: Imperial Oil Limited

Geophysical surveys
After the Leduc discovery in 1947, workers across Western Canada laid out thousands of kilometres of seismic lines to locate geological traps containing crude oil and natural gas.

Did you know?

Three-dimensional seismic surveying was introduced in the search for crude oil and natural gas in the 1980s.

Frontier exploration and development

Geophysics became even more crucial as companies turned their attention to frontier areas of Northern Canada and East Coast and West Coast offshore areas. Onshore and offshore seismic surveys played a key role in identifying sites for drilling, but scientists also used other techniques to narrow down the search. Satellite surveying helped to outline regional geological structures and to search for surface signs of possible crude oil and natural gas deposits. Aerial surveys – photographing the surface and measuring magnetic fields, gravity and radiation – also aided in identifying the sedimentary basins likely to contain petroleum. However, the presence of oil or gas could only be confirmed by drilling.

Off the coast of British Columbia, 14 wells were drilled in the late 1960s but failed to find commercial quantities of crude oil and natural 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. Various assessments of the area's potential indicate it could contain large crude oil and natural gas reserves. A provincial scientific review panel reported in 2002 "there is no inherent or fundamental inadequacy of the science or technology, properly applied in an appropriate regulatory framework, to justify retention of the B.C. moratorium." However, both levels of government would have to approve any renewed exploration.

Some frontier efforts in the Northwest Territories met with success, such as 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. However, a group of oil and gas companies with interests in the Mackenzie Delta and the Mackenzie Valley Aboriginal Pipeline Corporation (MVAPC) announced in 2002 their intention to begin preparing regulatory applications needed to develop onshore natural gas resources in the Mackenzie Delta, as well as a 1,300-kilometre Mackenzie Valley Pipeline. A preliminary information package for the project was submitted to federal and territorial authorities in June 2003. If approved, the project could begin shipping natural gas by 2010.

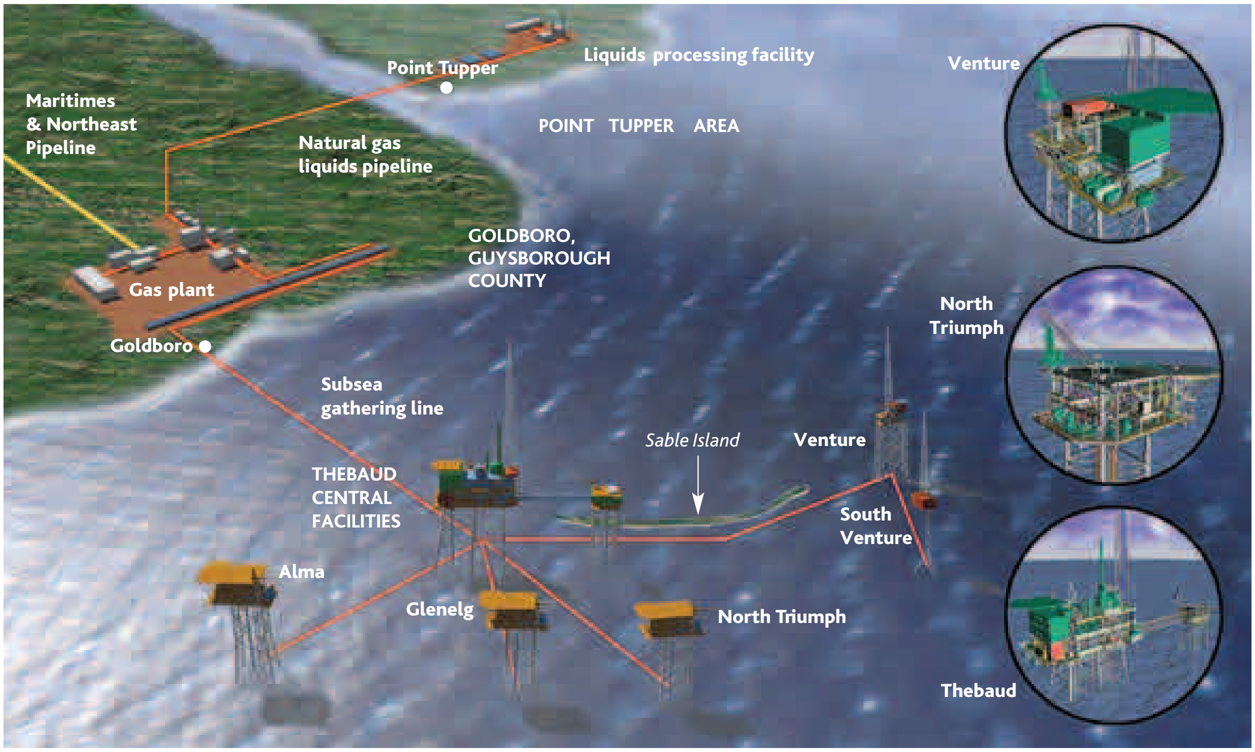
After drilling the industry's first deep East Coast offshore well off Prince Edward Island in 1943, Mobil Oil Canada acquired the first East Coast offshore petroleum licences in 1959 in the Sable Island area and initiated the first seismic survey there in 1960. Since that time, more than one million kilometres of seismic data have been recorded off the East Coast. Drilling began off Newfoundland and Labrador in 1966 and off Nova Scotia in 1967. The industry has drilled more than 380 offshore wells since then.

Natural gas was first found near Sable Island off the coast of Nova Scotia in 1968. Natural gas and crude oil discoveries off Nova Scotia in the 1970s included the Panuke-Cohasset oil fields, which began production in 1992, and the Venture natural gas field, which began production in 1999. These were followed by the first big crude oil discoveries off Newfoundland and Labrador at the Hibernia field in 1979, where production began in 1997, and the Terra Nova field in 1984, which began production in 2002. The White Rose field, also discovered in 1984, is due to begin production in 2005.

Under agreements reached in 1985 with Newfoundland and Labrador and in 1986 with Nova Scotia, the federal government and those provinces jointly manage offshore crude oil and natural gas resources. Federal-provincial boards issue and administer exploration and development rights, protect the environment, ensure safe working conditions, collect and distribute information, and manage resources with the goal of maximum recovery and minimum waste.

Source: Imperial Oil Limited

Drilling in the Mackenzie Delta
Exploratory drilling began in the Mackenzie Delta in 1963. By the mid-1970s, large reserves of natural gas had been discovered – the largest discovery, the Taglu field, was made in 1971 – but development awaited construction of a pipeline to southern markets.

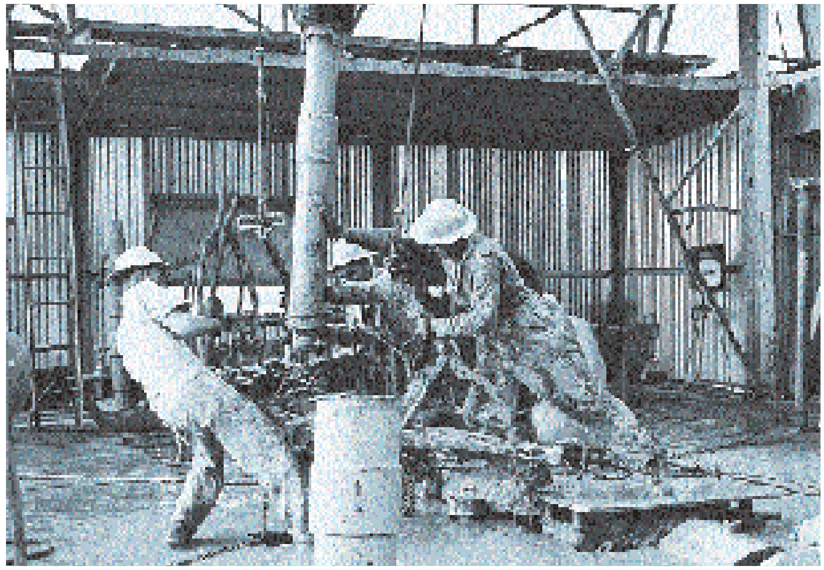


Source: Sable Offshore Energy Inc.

Sable Island natural gas
Natural gas began flowing from offshore wells near Sable Island in 1999, the culmination of exploration and development efforts that began nearly 40 years earlier.

West Coast drilling
Sedco 135-F, the first offshore drilling vessel constructed in Canada, was commissioned in a dockside ceremony in Victoria in 1967. The semi-submersible platform cost $10 million to construct and was capable of drilling to depths of 3,700 metres. It drilled wells off the West Coast between 1967 and 1969.

Source: Shell Canada Limited



Source: BP Canada Energy Company

On the rig floor
By the 1950s, workers wore metal hard hats in dangerous jobs such as threading sections of pipe on drilling rigs. Over the following decades, training and safety equipment reduced the risks in crude oil and natural gas field workplaces. Improvements included better hard hats, safety glasses, protective footwear and fire-retardant clothing. Automated equipment also reduced the number of "brute strength" tasks.

Safe and efficient drilling

In 1949, the Petroleum Industry Training Service (PITS) was founded by the Canadian Association of Oilwell Drilling Contractors, the Alberta government, and another industry association that later became part of the Canadian Association of Petroleum Producers. PITS has become a key centre for training Canadian workers, including many who work in frontier and offshore areas. Specialized skills for offshore operations are taught at institutions such as the Marine Institute and the Offshore Safety and Survival Centre in Newfoundland and Labrador and the Marconi campus of the Nova Scotia Community College.

The drilling industry expanded rapidly from the 1940s to the 1970s, and contractors placed an increasing emphasis on worker safety and training. Rigs became more complicated. Environmental regulations required that greater care be taken in preparing and restoring sites. Hundreds of millions of dollars were spent to ensure safety and environmental protection during exploration and production.

In the 1980s, even higher standards for rig operation and worker training were established. One catalyst was the sinking of an offshore drilling platform, the Ocean Ranger, 300 kilometres off Newfoundland and Labrador, with the loss of the entire 84-person crew. Another turning point was a major release of sour gas containing toxic hydrogen sulphide in 1982 from a well blowout near Lodgepole, Alberta. The blowout lasted 68 days, and two workers died during operations to control the well. Wide-ranging inquiries followed both incidents and led to major changes in equipment and operations. Companies adopted environmental and safety management systems that emphasized training and prevention. Reporting and analysis of "near-miss" incidents were key elements of these management systems.

Significant improvements were also made in the formulation and handling of the drilling fluids (mud) used to control well pressure, cool the drill bit and return rock cuttings to the surface. Until the 1980s, the used fluid was dumped in pits or sumps at well locations, but now the fluid is separated from the cuttings and reused. Companies are cleaning up the sites of former waste pits.

Horizontal drilling, a technology originally developed to extend wells from offshore platforms, was adapted for onshore use in Western Canada in the late 1980s. New rig designs, downhole mud motors and equipment such as measurement-while-drilling (MWD) tools made it possible to drill wells that curve from vertical to horizontal and stay in a horizontal producing layer for distances that may extend up to nine kilometres. In fact, it is now possible to drill horizontal laterals – additional drainage wells branching off from a wellbore.

The new drilling techniques enable the operator to avoid disturbing an environmentally sensitive area on the surface by drilling a series of wells from a single location. These wells can reach a larger area of petroleum-bearing rock and allow for the recovery of more oil or gas. This approach has become a vital tool for improving recovery, especially from heavy oil reservoirs. In 2003, about 1,700 wells – seven per cent of the wells drilled in Canada – were drilled horizontally.

Conservation and regulation

Crude oil and natural gas production was sometimes a chaotic business until the 1930s when governments stepped in to bring order to production practices. Alberta, the heartland of the Canadian petroleum industry in those days, was a leader in introducing measures to conserve the resource.

Early practices were often wasteful. Operators of adjacent wells tapping the same reservoir would rush to produce as much as they could before the crude oil or natural gas flowed from the neighbour's well. This practice, called competitive drainage, caused a premature loss of reservoir pressure and left large quantities of potentially recoverable petroleum in the ground.

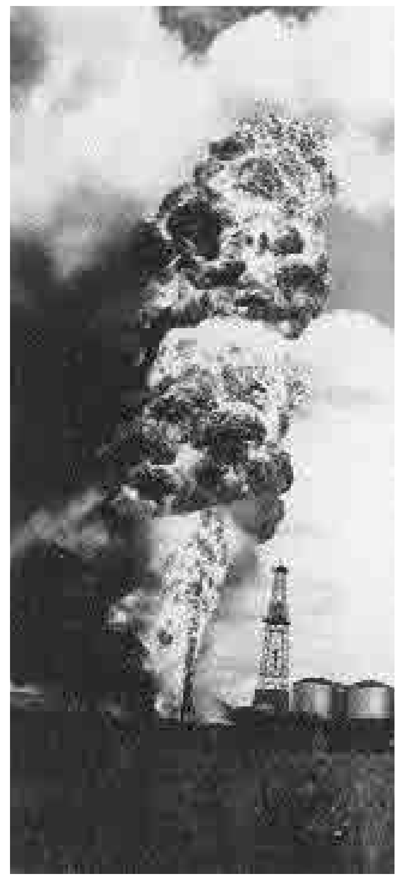
In the 19th century when Western Canada was surveyed and began to be settled, the federal government generally retained rights to the minerals underlying the land. These Crown mineral rights had been transferred from the federal government to the western provinces in 1930. The federal government, and later the provinces, issued exploration licences on land with Crown mineral rights and collected royalties as the "owner's share" of production if resources were found and developed. The Alberta government decided to exercise its authority more directly after a large new oil find at Turner Valley in 1936.

In 1938, the Social Credit provincial government established the Petroleum and Natural Gas Conservation Board – now the Alberta Energy and Utilities Board or EUB – to ensure orderly development of the resource.

The board's initial efforts were partially thwarted during the Second World War when the federal government's Wartime Oil Company encouraged companies operating in Turner Valley to develop the field more intensely so as to increase crude oil production in support of the war effort. However, the board gained invaluable experience and established a regulatory framework before the Leduc discovery in 1947 ushered in the era of large-scale oil and natural gas development.

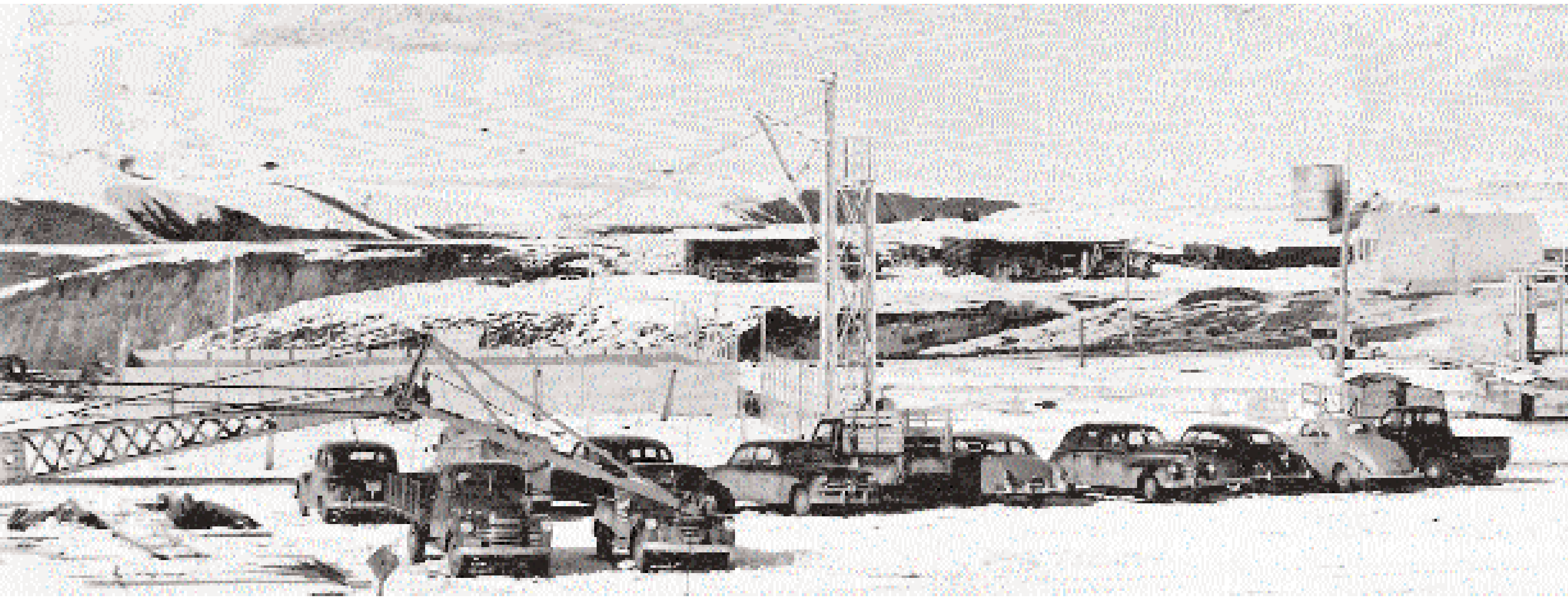
The early regulations dealt with issues such as well spacing and also ensured that production did not exceed the rates dictated by good engineering practice. Other producing provinces and the federal government also eventually enacted conservation regulations, although not as comprehensive as those in Alberta.

Government regulations expanded to cover many aspects of exploration and production, from technical specifications and safety rules to environmental protection and public consultation. Although regulations sometimes increased costs, they enabled companies to compete using the same ground rules.



Source: Glenbow Archives, Calgary, Canada, NA-67-143

Turner Valley
In Turner Valley, the largest oil field in Alberta prior to the Leduc discovery in 1947, widespread flaring of natural gas produced along with oil resulted in a huge waste of the resource and also reduced the reservoir pressure needed for oil production.



Jumping Pound Sulphur Plant, 1952.

Source: Shell Canada

Sweetening sour gas

Petroleum is "sour" if it contains significant quantities of sulphur compounds such as hydrogen sulphide (H2S). The first major sour crude oil and natural gas deposits in Western Canada were found near Turner Valley, southwest of Calgary, Alberta, beginning with the famous Royalite No. 4 discovery in 1924.

Along with natural gas, the wells produced a substantial quantity of liquids, called condensate. The condensate, also known as naphtha or casing-head gasoline, could be burned in the cars of the day without any further refining. However, there was no mistaking the foul-smelling exhaust of a vehicle fuelled with Turner Valley condensate, commonly known as "skunk oil" in the 1920s and 1930s.

Despite the presence of about 1.5 per cent hydrogen sulphide, some of the natural gas was used, without treatment, to heat homes and light streets in the area. Unwanted gas was burned in the open air (flared). The huge flare pit near Turner Valley was nicknamed "Hell's Half Acre." Residents of Calgary and southern Alberta learned to live with the odour, which they sometimes referred to as "the smell of money" in reference to the value of the accompanying oil and gas.

In 1924, the first plant to "scrub" H2S from natural gas was built in Turner Valley. Most of the recovered H2S was either flared or vented directly into the atmosphere. Such practices were common in Alberta until the 1950s (and flaring continues to be used today to dispose of small quantities of sour gas, although there has been a determined effort to reduce or eliminate the practice).

In 1952, the first sulphur recovery plant was built at Jumping Pound in the foothills west of Calgary. The impetus for change came from the discovery by Shell Canada Limited in 1944 of a major sour gas reservoir at Jumping Pound. This was followed by a similar find in 1948 by British American Oil at Pincher Creek in the southwest corner of the province. More discoveries followed in a band east of the Rockies, extending into the Fort St. John area of British Columbia.

Acid rain

Between 1983 and 1989, a comprehensive $10.4-million study called the Acid Deposition Research Program (ADRP) was undertaken to measure the effects of sulphur and nitrogen oxides on the Alberta environment. The oil and gas industry is a major source of these emissions, which cause acid rain.

Funded by industry and government, with participation from scientists and the general public, the ADRP conducted several important studies. One compared the health of residents near the Pincher Creek sour gas plants with a community without sour gas emissions. It found the Pincher Creek residents "healthy by any Canadian standard" although there was a small increase in respiratory symptoms near the plants.

Another ADRP study collected extensive air quality data and concluded that "regional scale impacts of acid rain in Alberta are not demonstrated today, and likely are absent."

Research is continuing on the effects of emissions associated with oil and gas operations on soil, plants, livestock and humans.

Increasing sulphur recovery

As natural gas production increased, a market for sulphur developed in the fertilizer, mineral refining and pulp and paper industries. For example, sulphuric acid was needed to extract uranium from ore produced by mines in the Northwest Territories, Saskatchewan and Ontario. (The United States, which had traditionally provided sulphur for Canadian needs, restricted exports during the Korean War to ensure supplies for its munitions plants.) Sulphur recovery thus served two purposes: to sweeten sour gas for residential and industrial use, and to produce elemental sulphur as a valuable by product.

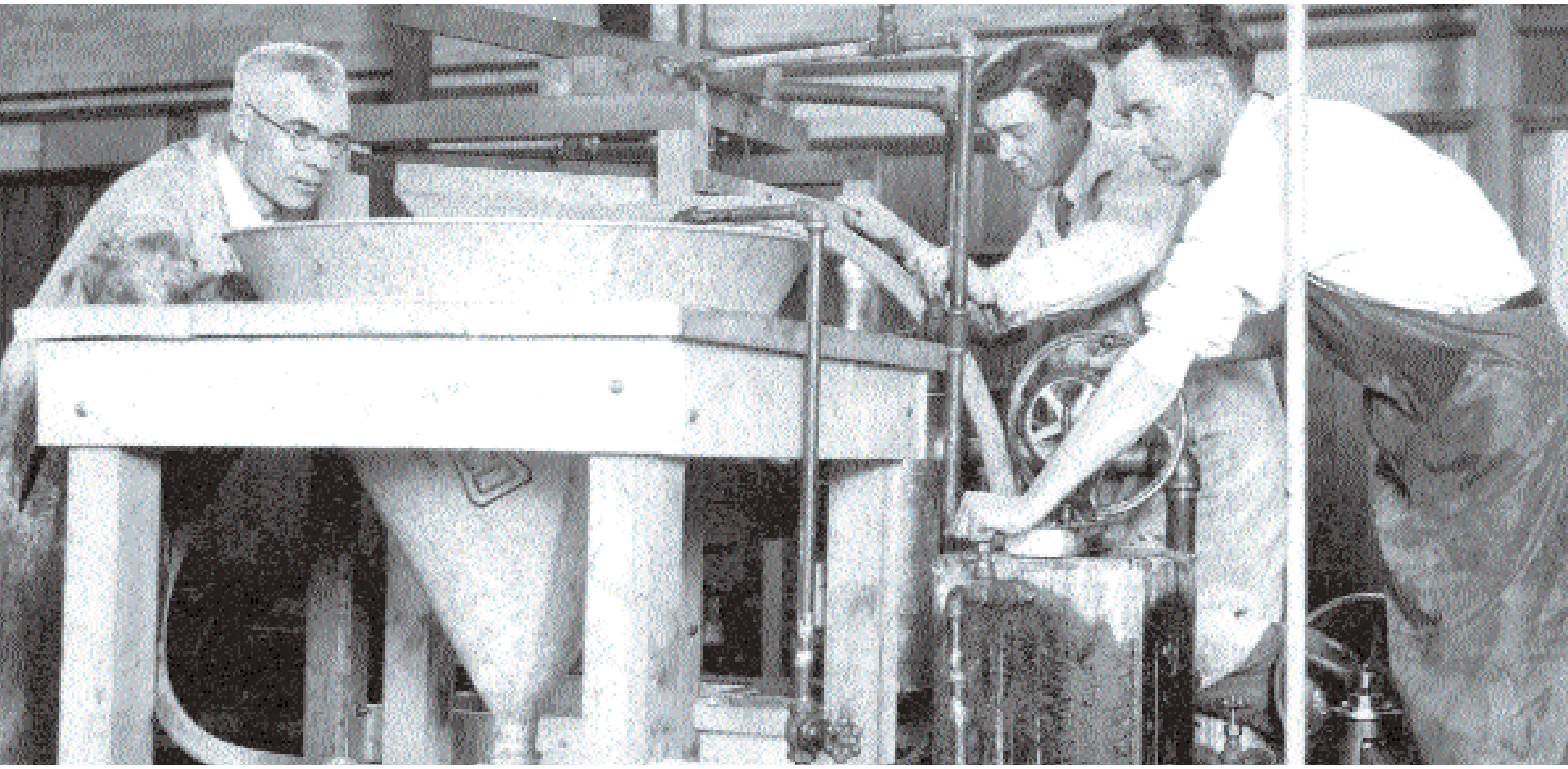
In 1961, Alberta established air quality standards – including limits on H2S and sulphur dioxide (SO2) emissions – and gave industry five years to comply. The first response was to build taller exhaust stacks to disperse the pollutants more widely, but the longer-term approach was to improve the efficiency of sulphur recovery processes. The rising value of sulphur on world markets also provided an economic incentive.

Average sulphur recovery at processing plants increased from 88 per cent in the 1950s to 95 per cent in 1971. By the late 1970s, large gas plants were being built with recovery rates greater than 99 per cent. In 1988, Alberta's average sulphur plant recovery rate was 98 per cent. Due to stronger regulations and improved technology, the rate is now nearly 99 per cent throughout the province.

British Columbia generally followed Alberta's lead in both regulation and industry practices; average sulphur recovery at B.C. plants is currently greater than 99 per cent. The relatively small amount of H2S produced along with conventional crude oil and natural gas in Saskatchewan is flared or incinerated.

Using new technologies, many developed in Canada, the industry kept pace with increasingly stringent regulations. Total volumes of natural gas production grew considerably, but total emissions of SO2 continued to decline between 1995 and 2000.

In addition to sulphur compounds, considerable volumes of carbon dioxide (CO2) are present in raw natural gas. Thus far, the processing plants have simply separated CO2 from the gas stream and vented it to the atmosphere. Due to concern about the effect of greenhouse gases such as CO2 on global climate, research is now underway on other options such as reinjecting CO2 underground.



Pioneer scientist
Karl Clark (left) of the Alberta Research Council developed a method for separating bitumen from sand. This process was key to the eventual development of large-scale oilsands mining projects.

Source: Syncrude Canada Ltd

Oil from sands – the elusive bonanza

Canada's largest petroleum resource, the Athabasca oilsands, was easy to find. Natives were already using the tar-like bitumen to caulk their canoes when the first European explorers arrived in the 18th century. Alexander Mackenzie wrote in the 1790s of bituminous seeps along the Athabasca into which a six-metre pole could be inserted "without the least resistance." The oil potential was evident when 19th century geologists visited the area.

> *" Long after the noises [of the camp] ceased I lay and thought of the not far-distant future when other sounds than those would wake up the silent forest; when the white man would be busy, with his ready instrument steam, raising the untold wealth which lies buried beneath the surface, and converting the present desolation into a bustling mart of trade."*
>
> *– Diary of John Macoun, September 7, 1875, written at a camp by the Athabasca River near the present-day location of Fort McMurray. When the journal was published, the editor titled this entry "Prophetic Vision."*

Source: University of Alberta Archives

Sidney Ells
Sydney Ells, an engineer with the federal Department of Mines, demonstrated the first commercial uses of the oilsands. Ells was the first to suggest the use of hot water to separate the bitumen from the sand.

John Macoun of the Geological Survey of Canada (GSC) visited the Athabasca oilsands in northeastern Alberta in 1875 and reported on the "tar mingled with sand." After a further report by R.G. McConnell and George Dawson of the GSC, Parliament passed a bill in 1893 authorizing funds for the agency to investigate the oilsands as a source of petroleum.

Successes and failures

To evaluate the crude oil potential of the oilsands region of Alberta, drilling began in 1894. However, crews unexpectedly struck a reservoir of natural gas near the Athabasca River at Pelican Portage. The well blew wild for 21 years before it finally was brought under control. (Back then, developers had neither the equipment nor the resources to control blowouts in remote locations.)

Sidney Ells, an engineer in the federal Department of Mines, found one possible commercial use for the oilsands in 1915 when he shipped several tonnes by water, sleigh and rail to Edmonton for road paving. It made a poor surface because it would not harden, and the transportation cost was high. Nonetheless, the material was used on roads for a number of years, and one shipment was actually sent to Ottawa for a demonstration project.

Ells realized that some processing would have to be done on-site, and was the first to suggest hot water as a means of separating bitumen from sand. In 1925, Karl Clark of the Alberta Research Council perfected a method using hot water and caustic soda, which is the basis for the system used in most oilsands mining projects today. Newer projects have eliminated caustic soda, however, thus returning to Ells' original concept.

Meanwhile, businessman R.C. Fitzsimmons founded the International Bitumen Company in 1927 and built a small plant near Bitumount, 80 kilometres north of Fort McMurray, to produce bitumen for roofing and road surfacing. The operation had some technical success, but little profit, and went broke in the late 1930s.

Abasand Oils Ltd., a more ambitious project that used hot water and solvents to extract the bitumen, was established in 1936. It was the first to obtain gasoline and fuel oil as well as asphalt from the bitumen. Unfortunately, just as it was beginning to operate efficiently, the Abasand plant burned to the ground.

During the Second World War, the federal government rebuilt the Abasand plant. The Alberta government underwrote a similar mining-refining project on the Bitumount site immediately after the war. Both operated long enough to demonstrate that their technology could work.

Technological advances

Interest in the oilsands waned for about a decade after the Leduc conventional crude oil discovery in 1947. In the 1950s, however, a number of oil companies looked again at the oilsands area's great potential. The most dramatic proposal in that era called for the detonation of an underground atomic explosive device to melt the bitumen. In 1959, the Alberta Oil and Gas Conservation Board released a report on the potential of nuclear devices in the oilsands, but the idea was not pursued.

Great Canadian Oil Sands (GCOS) won approval for the first of the modern oil sands projects in 1964 and began production in 1967. This started the transformation of Fort McMurray area, including nearby Waterways (then a separate community), from a fur trading post, river port and railway outpost of 1,300 people into the bustling city of nearly 50,000 that it is today.

Source: Glenbow Archives, Calgary, Canada, ND-3-7666a

Oilsands for road paving
In 1915, with great effort, Sidney Ells shipped several tonnes of oilsand by water, sleigh, and rail to Edmonton for a road paving experiment. Two additional shipments were sent to Ottawa for similar trials on Wellington Street and on Parliament Hill. Other notable oilsands paving projects of the day included the access road to the Jasper Park Lodge in Jasper National Park, Alberta, and 22 blocks of sidewalk in Camrose, Alberta.

The difference between heavy and light oil

The "weight" of different crude oils can be measured on either the metric density scale (kilograms per cubic metre) or the American Petroleum Institute gravity scale (°API). Government authorities in Canada only distinguish between "heavy" and "light" crude oil types, while various other definitions are used by the industry. The illustration shows definitions suggested by the Petroleum Society of the Canadian Institute of Mining and Metallurgy.

Light crude oil contains many small, hydrogen-rich hydrocarbon molecules. Light oil flows easily through wells and pipelines. When light oil is refined, it produces a large quantity of transportation fuels such as gasoline, diesel and jet fuel. Light oil commands the highest price per barrel.

Heavy crude oil contains many large, carbon-rich hydrocarbon molecules. Additional pumping is needed to make heavy oil flow through wells and pipelines. Heavy crude oil contains a smaller proportion of natural gasoline and diesel fuel components and requires much more extensive refining to make transportation fuels. Heavy oil commands a lower price and the difference in price per barrel is called the differential.

Synthetic crude oil is a hydrocarbon liquid produced by upgrading conventional heavy oil or bitumen extracted from oilsands. The mixture consists of hydrocarbons derived from heavy crude oil or bitumen through the addition of hydrogen and/or the removal of carbon. Synthetic crude oil sells at a premium price compared to most other crude oils.

The Great Canadian Oil Sands Operation, now part of Suncor Energy Inc., combined the features of an open-pit mine and an oil upgrader. It was initially designed to produce up to 5,000 cubic metres per day of synthetic crude oil. The plant pioneered technology that would unleash the potential of the world's largest known oil resource, but breakdowns, freeze-ups and fires created many challenges in the early years.

Expanding operations

In 1978, Syncrude Canada Ltd. – a consortium of oil companies and the federal and provincial governments – opened a far bigger, 20,000-cubic-metre-per-day mining and upgrading project near the Great Canadian Oil Sands Operation site. The government partners eventually sold their interests in Syncrude. Both projects produce light, low-sulphur synthetic crude oil.

Although the federal government controlled Canadian conventional oil prices from 1974 to 1985, the oil sands projects were allowed to charge world prices to help overcome their high cost of production. When oil prices were deregulated in 1985 and then fell sharply in 1986, the projects were forced to cut costs and improve productivity. They eventually succeeded thanks to technological improvements and innovative management.

In the 1990s, oil sands mining costs were less than one-half of what they were in the 1970s. As the economics of the operations improved, the companies also invested substantially in systems to reduce emissions and other environmental impacts.

The economics of oilsands projects improved in the late 1990s due to changes in provincial royalties and federal taxes, rising crude oil prices and the continuing improvements in oil sands technology. These developments led to a series of new project announcements. If all are built, they will eventually quadruple production of bitumen and upgraded crude oil. In 2002, oilsands mining projects produced more than 69,000 cubic metres per day of synthetic crude oil.

In-situ bitumen

Imperial Oil Company Limited originally planned an upgrading megaproject at Cold Lake, Alberta, but dropped that plan in the early 1980s because of falling oil prices. However, Imperial continued development of in-situ bitumen production. A number of similar projects, mostly using steam to improve recovery, produced increasing volumes of heavy oil and bitumen in Alberta and Saskatchewan in the 1980s and 1990s. Most of the newer in-situ projects used an Alberta-developed technology called steam-assisted gravity drainage (SAGD). In SAGD, two parallel horizontal wells are drilled through the underground oil sands formation; steam is injected into the upper well, and heated bitumen flows into the lower well. In-situ production of oilsands bitumen was 49,500 cubic metres per day in 2002.

The Husky Energy Lloydminster Upgrader and the NewGrade Upgrader at Regina process part of the in-situ bitumen production into synthetic crude oil, while the remainder is diluted with natural gas liquids and shipped by pipeline to U.S. refineries. Both upgraders have high-efficiency facilities to remove 99.9 per cent of the sulphur from the heavy oil they process.

What's the difference between synthetic crude oil and synthetic oil?

Synthetic crude oil is produced by breaking, or "cracking," the long molecular chains that make up bitumen and heavy oil into much smaller molecules, removing carbon and stabilizing the new, smaller molecules with hydrogen. The end result of this process, called upgrading, is a substance with composition, densities and viscosities similar to conventional light crude oil. The term synthetic is used because the original hydrocarbon mix of the bitumen or heavy oil has been altered.

Synthetic oil refers primarily to lubricants that are developed from synthetic base stocks rather than refined crude oil. These base stocks are made from molecules designed and synthesized for specific lubrication purposes.

Moving oil and natural gas

Before the Second World War, only a few pipeline systems existed in Canada. One oil pipeline connected Sarnia refineries to Ohio oil fields and another extended from Turner Valley to Calgary. Pipelines also carried natural gas from producing areas in Alberta to local distribution systems in Calgary and Edmonton.

The pipeline construction boom

During the Second World War, security concerns led to construction of the pipeline from Portland, Maine, to Montreal, Quebec, which is still in operation. Another project, the Canol pipeline system, connected Norman Wells in the Northwest Territories to the Yukon and Alaska, but was shut down after a year because it was expensive, inefficient and no longer needed for military purposes. The Canol project cost $134 million – a huge amount at that time, equivalent to $1.6 billion in 2003 – and its construction involved 4,000 troops and 12,000 civilians.

The great postwar discoveries in Western Canada sparked a long-lasting boom in pipeline construction. At the same time, improvements in welding methods and the quality of steel pipe and construction equipment made longer-distance, higher-pressure crude oil and natural gas transportation systems possible.

The first section of the Interprovincial Pipe Line Inc. (now Enbridge Pipelines Inc.) crude oil pipeline was laid from Edmonton to Superior, Wisconsin, in 1950. It was then the largest single-season pipeline construction project in the world. Initially, fast tankers carried crude oil from Superior to Sarnia, Ontario, during the ice-free shipping season on the Great Lakes. The pipeline was extended to Sarnia in 1953 and its capacity expanded repeatedly as crude oil production from Western Canada increased.

The Trans Mountain Pipeline Company (now Terasen Inc.) crude oil pipeline running from Edmonton to Vancouver was completed in 1953. The line crosses environmentally sensitive areas, including Jasper National Park, and difficult, mountainous terrain. In 1957, the Westcoast Energy Inc. system began delivering natural gas from north-eastern British Columbia to the lower mainland and to U.S. markets in the Pacific Northwest.

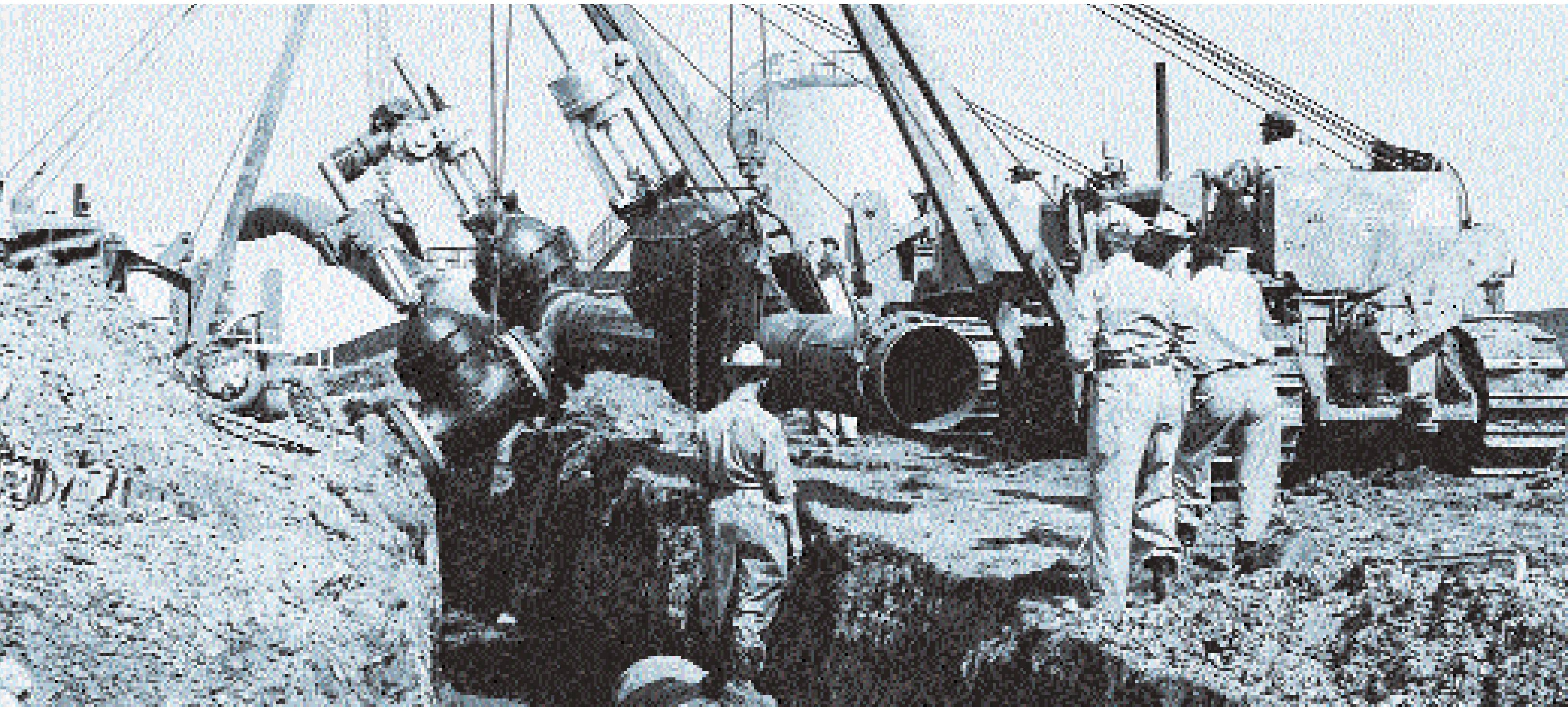
After a long and heated parliamentary debate in 1956, the federal government agreed to support the building of the TransCanada PipeLines Limited natural gas pipeline across the Prairies and through the rocks and bogs of northern Ontario. Natural gas began flowing from Alberta to Ontario and Quebec in 1958.

The pipelines continued to expand over the following decades, by adding pumping or compression capacity, laying additional pipe, or both. Computers and remote controls, introduced in the 1960s, helped make the systems more efficient. An extensive network of pipelines was also developed to carry natural gas liquids such as ethane, propane and butane, which became crucial feedstocks for the petrochemical industry.

During the energy crises of the 1970s, pipelines were again politically controversial. To reduce dependence on imported oil, the federal government financed the extension of Interprovincial's pipeline from Sarnia to Montreal.

Meanwhile during the 1970s, the First Nations, Inuvialuit and environmentalists argued vehemently against a proposal for a natural gas pipeline through the Mackenzie Valley in the Northwest Territories. Although an alternative plan for a pipeline carrying both Alaskan and Mackenzie Delta natural gas down an Alaska Highway route was eventually approved, the project was shelved because of lower natural gas prices and a surplus of natural gas production in Western Canada and the United States. A new proposal for a Mackenzie Valley natural gas pipeline was announced in 2002.

In 1985, Interprovincial completed a pipeline to carry light crude oil from Norman Wells to Alberta. As the first permanent, buried pipeline in the Canadian Arctic, it demonstrated new ways of building and operating such lines with minimal environmental impact.



Source: Enbridge, Inc

The world's longest oil pipeline
The Interprovincial crude oil pipeline (now part of Enbridge Inc.) was built between Edmonton, Alberta, and Superior, Wisconsin, in 1950, and extended to Sarnia, Ontario, in 1953. Later additions connected the system to refineries in Chicago and Montreal and as far south as Oklahoma. Another branch of the Enbridge system, completed in 1985, extends from northern Alberta to the oil field at Norman Wells in the Northwest Territories. The pipeline system was – and remains – the world's longest crude oil pipeline network.

In the late 1980s and the early 1990s, the pipeline systems again expanded their capacity. Natural gas lines transported greater volumes to U.S. and Canadian markets, and oil lines carried increasing amounts of heavy crude oil and refined products. Several new oil pipelines were built to serve the heavy oil and oil sands areas of Alberta and to transport crude oil from Western Canada into the Rocky Mountain States.

The Maritimes & Northeast pipeline was built in 1999 to bring natural gas to markets in the Maritime provinces and northeastern United States from natural gas fields 160 kilometres off Nova Scotia. An undersea pipeline brings the natural gas to the shore. The Canadian portion of the main line stretches 568 kilometres from Goldboro, Nova Scotia to St. Stephen, New Brunswick. A smaller, 124-kilometre pipeline transports natural gas from the main transmission pipeline near Stellarton, Nova Scotia, to Halifax. Another 110-kilometre pipeline transports natural gas from the main transmission pipeline near Big Kedron Lake, New Brunswick, to Saint John. U.S. markets served by the pipeline include Maine and Massachusetts.

Deregulation

In the late 1980s, free trade and deregulation of natural gas prices opened up new opportunities for Canadian natural gas producers, U.S. and Canadian consumers, and pipeline companies. Gas transmission companies, which formerly bought natural gas in producing areas and resold it to distribution companies in consuming areas, became open to all shippers, more like oil pipelines and railways. However, pipeline tolls, construction plans and operating standards continued to be regulated.

Provincial governments also continued to regulate the rates charged by local distribution companies for transporting natural gas to consumers, businesses and other end users. However, governments began to permit "market pricing" of the energy component of consumers' bills. In some provinces, beginning with Ontario in 1998, independent marketers were allowed to sell natural gas to end users in competition with local distribution companies.

Arctic exploration

Fears about depleting oil and natural gas resources in Western Canada, combined with government incentives for frontier exploration, sparked a far-reaching search for new supplies in the 1970s and early 1980s. This well was located on an artificial island in the Beaufort Sea.

Source: Imperial Oil Limited

Crude oil and natural gas in the political arena

During the boom years after Leduc, two kinds of companies emerged. The independents were generally smaller and were often controlled by Canadian owners and managers. They wanted to sell their crude oil and natural gas as quickly as possible. Their rivals were the larger companies that were usually affiliated with foreign firms. These majors wanted to ensure the most economical oil supplies for their refineries and could take a longer-term view of marketing.

The situation was complicated until 1970 because the United States produced more oil than it consumed, so there was not much market there for growing Canadian production. The independent producers wanted Montreal refineries to use Alberta oil, while the majors preferred to refine more economical imported crude. The debate brought oil into the political arena.

Natural gas was already a political issue. In the early 1950s, the Alberta government delayed marketing natural gas outside Alberta until it was assured there was enough for the province's own long-term needs. Then there was a prolonged wrangle between competing companies' proposals to carry natural gas east to Ontario. The Liberal government of prime minister Louis St. Laurent finally chose the all-Canadian route of TransCanada PipeLines Limited and invoked closure to speed the necessary legislation through Parliament in 1956.

The Liberals were defeated a year later. After the election, Conservative prime minister John Diefenbaker appointed a Royal Commission on Energy. The commission's findings led to the creation in 1959 of the National Energy Board to oversee interprovincial and international energy trade.

In 1961, the Diefenbaker government settled the dispute over who would supply Montreal refineries. Under the government's National Oil Policy, Montreal could continue to use imported crude, while refineries west of the Ottawa Valley would use Western Canadian oil.

Low crude oil and natural gas prices in the 1960s encouraged rapid growth in Canadian petroleum consumption. However, low pricing caused financial difficulties for many Canadian oil and gas firms and led to takeovers by foreign companies.

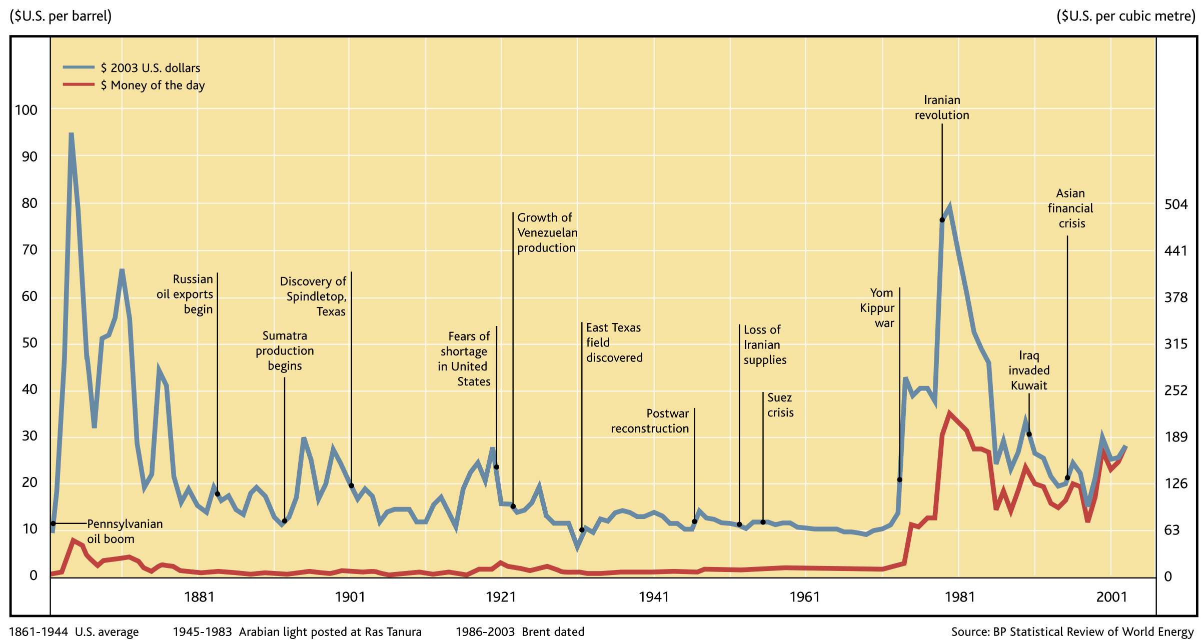
Through the late 1950s and 1960s, there were fewer and fewer large discoveries in Alberta, British Columbia and Saskatchewan. Some companies redirected exploration efforts to the sedimentary basins off the east and west coasts and in the Canadian Arctic, where they hoped to emulate the bonanza arising from the 1968 Prudhoe Bay oil discovery in Alaska. There were some finds, mostly natural gas rather than crude oil.

In 1971, the National Energy Board refused to approve additional long-term natural gas exports on the grounds that proved reserves were no longer sufficient for expected Canadian demand and existing export commitments. At the same time, influential think-tanks such as the Club of Rome issued dire forecasts about looming global shortages of petroleum and other resources. This prompted a growing debate over the security of Canada's energy supplies. The debate overlooked an important economic principle – that higher prices would stimulate industry to develop additional supplies.

Global energy crises

The Arab oil embargo of October 1973 set off the first global energy crisis. Responding to nationalist concerns about foreign ownership, as well as the oil embargo, then-prime minister Pierre Trudeau's Liberal minority government imposed a

HISTORICAL CRUDE OIL PRICES



The price shocks of 1973-74 and 1978-79 ended a 20-year decline in world oil prices. Allowing for inflation, the price in 1999 was about the same as in 1926.

sweeping series of measures in late 1973:

- government-decreed "made-in-Canada" crude oil prices well below world levels
- a tax on oil exports to subsidize the suddenly expensive imports that still supplied Eastern Canada
- the establishment of Petro-Canada as a Crown oil company, and
- government-financed extension of the Interprovincial Pipe Line Inc. (now Enbridge Pipelines Inc.) oil pipeline from Sarnia to Montreal.

The measures gave short-term price relief to Canadian consumers, but delayed the efficiency gains that world market prices prompted in other countries. Petroleum-producing provinces and many oil industry leaders objected to the federal policies. Despite the policies, however, the industry grew and even prospered in the late 1970s, in part because natural gas prices were allowed to rise much more rapidly than crude oil prices.

The National Energy Program

A second international oil crisis, following the Iranian revolution in 1978-79, led to even greater government intervention in the industry. The National Energy Program (NEP) of October 1980 reinforced the made-in-Canada price policy. It took away a large share of production revenues through new taxes, and paid frontier exploration incentives to companies according to their level of Canadian ownership.

The NEP ran into problems immediately. The oil-and-gas-producing provinces fought bitterly against what they saw as a federal intrusion into their jurisdiction. Some companies redirected their investment to the United States.

A severe recession and very high interest rates in the early 1980s caused financial disaster for firms with high debt loads; many had borrowed to take advantage of NEP incentives based on Canadian ownership levels. Crude oil and natural gas drilling slumped, oil production continued to decline, industry growth slowed, and profits plunged. World oil prices did not rise as predicted and soon actually began to fall. This upset the economic forecasts of governments and companies.

Deregulation and competition

Soon after winning the 1984 federal election, then-prime minister Brian Mulroney's Conservative government started to dismantle the NEP. An agreement called the Western Accord deregulated crude oil prices in June 1985, and Canada's borders were opened to imports and exports. Natural gas prices were deregulated more gradually. The government phased out the complex system of taxes and incentives and decided to privatize Petro-Canada, which began to sell shares to the public in 1991.

Through deregulation, the Canadian petroleum industry finally obtained market prices for its products. However, the world oil price dropped 50 per cent in 1986 and recovered slowly except for a brief upward spike when Iraq invaded Kuwait in August 1990. During more than a decade of competitive pricing and deregulation, crude oil and natural gas prices varied considerably on a yearly, monthly and even daily basis.

Relatively low crude oil and natural gas prices were not the only problems facing the industry after 1986. Prices also fell sharply for sulphur – a by-product of the industry. Meanwhile, the operating costs for older producing fields rose steeply, and there were additional expenses for environmental protection, surface access, regulatory fees and public consultation.

Between 1986 and 1992, relatively high interest rates created a heavy burden for companies with large amounts of debt, and low profits made it difficult to attract equity investment. Many companies laid off staff and sold assets or merged with stronger firms. With lower interest rates, improved commodity prices and more efficient operations, the industry began to prosper again in the mid-1990s. Despite a dip in crude oil prices in the late 1990s, the industry was on a more even keel as the United States provided a reliable and growing market for Canadian energy.

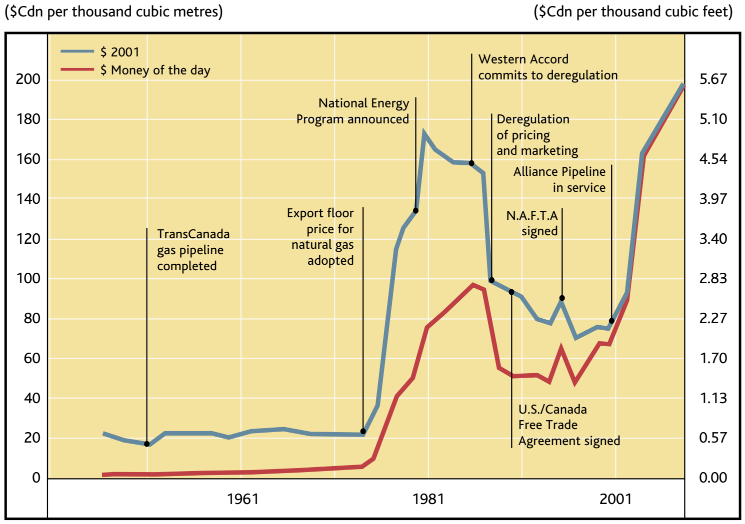
Only the pipeline and natural gas distribution companies – utilities whose rates of return were established by regulatory boards – emerged relatively unscathed from the industry-wide slump of the late 1980s and early 1990s. Many pipeline companies subsequently negotiated incentive tolling agreements with producers. These agreements encouraged pipelines to become more efficient and to share the cost savings with customers. As U.S. demand for Canadian crude oil increased, the pipeline between Sarnia and Montreal, originally built to carry Western Canadian crude oil eastward, was reversed in 1999 so that it now brings imported and offshore Canadian oil production westward to Ontario refineries.

The downstream refining and retailing sector also went through a major transition after the "oil shocks" of the 1970s. Cars became more fuel-efficient and more complex to maintain, which meant that Canada needed fewer refineries and conventional gasoline stations. Between 1990 and 2003, the number of retail service stations in Canada declined by almost one-third, from about 19,000 to 13,000.

Environmental protection, including reformulation of fuels, added to refining and marketing costs at a time when competition was intense. Taxes raised the price of gasoline in Canada. Recession and global over-capacity hurt the petrochemical producers in the late 1980s and early 1990s, although they recovered in the mid-1990s.

HISTORICAL WESTERN CANADA NATURAL GAS PRICES

($Cdn per thousand cubic metres) ($Cdn per thousand cubic feet)



Source: Canadian Association of Petroleum Producers

Historical Natural Gas Prices

Natural gas prices in Canada rose steeply after the 1973 Arab oil embargo, and natural gas became a major source of revenue for Canadian oil and gas companies. Allowing for inflation, the price reached a peak in 1980 that was not exceeded until 2001. Prices moderated in the 1980s and 1990s due to the large increase in supply brought on by the earlier high prices. Periodic shortages of pipeline capacity from Western Canada to consuming regions also affected prices. Strong demand, combined with increased pipeline capacity, led to a new upsurge in prices since 1999.

Wetlands conservation area in northern Alberta. Source: Suncor Energy

The environment – a growing awareness

During most of the early petroleum era, consumers used crude oil and natural gas because they were inexpensive, readily available and convenient. Protecting the environment was not a major concern, although petroleum was generally cleaner-burning than the coal or wood it replaced.

In the 1960s, however, Canadians started to worry about the urban air pollution caused by industrial activity and vehicles. People living near crude oil and natural gas production facilities, processing plants, pipelines, refineries and service stations became increasingly concerned about impacts on human health and the environment. Governments brought in regulations to protect air and water quality.

Industry responded by progressively reducing environmental impacts. Explorers and producers found better ways to prevent spills and blowouts. Industry co-operatives were established to deal with spills that might affect water resources. There were major advances in waste management and land reclamation methods.

New technologies greatly reduced the sulphur dioxide emissions from gas processing plants. Pipeline companies stepped up their maintenance and monitoring programs. Refineries decreased emissions of air and water pollutants. Gasoline retailers installed corrosion protection on underground fuel storage tanks and upgraded spill-prevention training.

Canadian refiners eliminated the use of a lead compound as a gasoline additive in 1990, completing a phase-out that had begun in 1973. Further reductions in environmental impacts were achieved in the 1990s as the industry improved refinery efficiency, reduced the sulphur content of fuels, reformulated gasoline, captured hydrocarbon vapours, and worked with stakeholders to better understand public concerns.

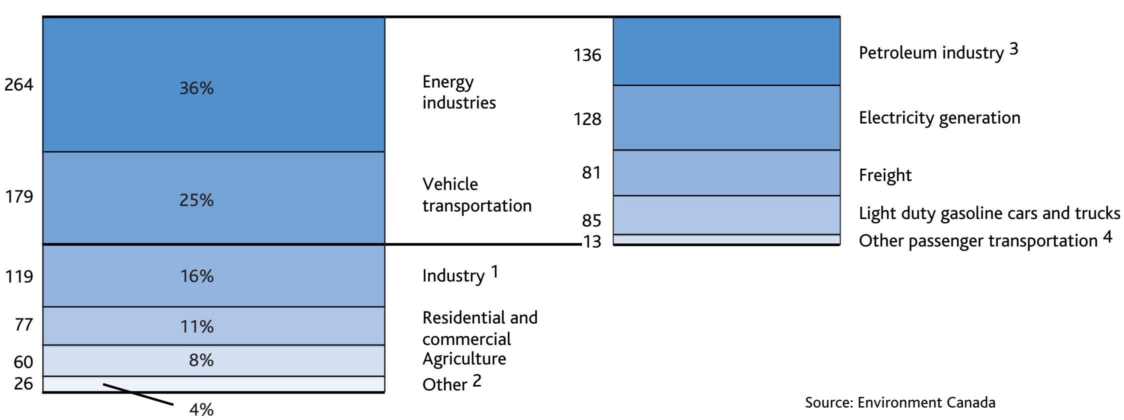
The international oil-supply crises of 1973 and 1979 stirred new concerns about industrialized societies' reliance on crude oil resources and led governments, consumers and industry to focus on energy conservation. One result was an improvement in the fuel efficiency of motor vehicles. Oil consumption was reduced sharply through conservation, a switch to alternative fuels and the introduction of more efficient engines and furnaces. In many instances, natural gas replaced oil products.

At the United Nations Conference on Environment and Development (Earth Summit) in Rio de Janeiro in 1992, Canada and more than 160 other nations adopted a philosophy of sustainable development – development that meets today's needs without compromising the ability of future generations to meet their needs. The nations also agreed to begin limiting emissions of greenhouse gases that may contribute to global climate change. They set a target of stabilizing emissions at 1990 levels by the year 2000, a goal which was not achieved for a wide range of reasons.

In 1997, world leaders reached an agreement in Kyoto, Japan, to further limit greenhouse gas emissions early in the 21st century. In December 2002, Canada ratified the Kyoto Protocol obliging the nation to reduce its greenhouse gas emissions to six per cent below 1990 levels by 2012. In February 2003, the federal government committed \$1.7 billion towards a climate change action package. The strategy includes measures to encourage conservation in the residential sector and support

2000 CANADIAN GREENHOUSE GAS EMISSIONS - ALL SECTORS

CO_2 emissions (million tonnes CO_2 eqivalent)



1 Includes industrial processes, manufacturing, solvent and other products, construction, mining and other fuel combustion.
2 Includes land use change and forestry, and waste.
3 Upstream and downstream activities, including pipelines and fugitive emissions.
4 Includes motorcycles, light-duty diesel vehicle (cars), propane and natural gas vehicles, and the passenger portion of air (81%) and rail (3%) travel.

Increases in coal consumption for electricity and steam generation, growth in fossil fuel production (mainly for export), and increases in Canadian transportation energy consumption have affected emission growth in recent years.

for renewable energy, in particular wind and solar power, as well as alternative fuels such as ethanol and biodiesel, clean-coal technology, hydrogen fuel cells and initiatives that store carbon dioxide rather than release it into the atmosphere.

In April 2003, the Canadian Association of Petroleum Producers released the Calculating Greenhouse Gas Emissions guide, which provides CAPP members with a standardized approach to benchmarking and estimating greenhouse gas emissions. CAPP and its members said they intend to work with federal, provincial and territorial governments on a plan that allows Canadians to continue to benefit from the production and export of oil and natural gas while promoting technological advances that lead to long-term solutions to climate change.

A continually evolving industry

Some things have not changed since the 19th century. Hundreds of wells around Oil Springs, Ontario, still produce crude oil with essentially the same technology used in the 1860s. Fractional distillation, the process invented by Abraham Gesner in the 1840s, is still the heart of a modern oil refinery. Natural gas systems like those pioneered by Eugene Coste still deliver clean-burning fuel to consumers. The corporate descendent of Coste's company still operates in Calgary, and Imperial Oil, founded in 1880, continues to be a major part of the Canadian oil and gas industry. The drill bit is still the only way to confirm that a particular rock formation will actually produce crude oil or natural gas.

Yet, there have been profound changes in every facet of the industry too. The products and uses for petroleum have multiplied many times over the years, as have the expectations of consumers. The application of emerging science and technology has made possible a precision in finding and producing crude oil and natural gas that could not have been imagined even a few decades ago. There is far less waste, in both the production and use of crude oil and natural gas, and fewer effects on the environment. The health and safety of workers and the public have become central considerations in planning and operations. Perhaps most important, the body of knowledge about all the aspects of petroleum has continued to grow, helping to ensure that the nation's hydrocarbon wealth will be used wisely and well.

Legacies

The legacies of the oil and gas industry's long history in Canada include:

- a vast body of knowledge about the nation's geology and petroleum resources, available to all industry participants through federal and provincial reporting requirements and databases
- highly skilled professional and technical personnel, many with international experience
- extensive experience with challenging resources (sour gas, heavy oil, oilsands) and with challenging environments such as the Arctic and offshore
- an infrastructure of plants, pipelines and facilities supporting and linking every aspect of a far-reaching industry
- training and educational institutions to prepare workers and specialists for the industry's needs
- laws, policies and regulatory authorities to ensure the industry operates in the public interest.

However, past practices also led to impacts on land, air and water resources and affected plants, animals and humans. As scientific knowledge expanded and society's expectations increased, government and industry continually raised performance standards and attempted to address the effects of earlier activities. Similarly, there was an ongoing improvement in measures to protect the health and safety of workers and nearby residents.

Readers should turn to *Our Petroleum Challenge*, 7th Edition, to learn more about the ways science and technology are used today to find, produce, process, deliver and utilize crude oil and natural gas as well as the challenges we face in developing and using these resources. Current information about Canada's oil and gas industry is available through the Centre for Energy web portal at www.centreforenergy.com.

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Selected bibliography

The following publications provide additional information about the Canadian and international petroleum industries. Note that some of these publications may only be available through reference libraries or private collections. A more complete bibliography of petroleum history references is posted on the website of the Petroleum History Society: http://petroleumhistory.ca (bibliography URL: http://petroleumhistory.ca/history/phsBiblio3.pdf).

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Online information sources

The Centre for Energy portal (www.centreforenergy.com) provides an overview of the Canadian oil and gas industry, a timeline, glossary and links to Web sites with relevant historical information.

Additional online historical resources include:

Black Gold: Canada's Oil Heritage	**http://collections.ic.gc.ca/blackgold**
Canadian Petroleum Hall of Fame	**www.canadianpetroleumhalloffame.ca**
Canadian Petroleum Interpretive Centre (Leduc)	**www.c-pic.org**
Heavy Oil Science Centre (Lloydminster)	**www.lloydminsterheavyoil.com**
History of Development: Alberta's Natural Resources	**http://collections.ic.gc.ca/ABresources/history/index.html**
Nickle's History (Daily Oil Bulletin)	**http://www.nickles.com/history/**
Nova Scotia Petroleum Directorate	**http://www.gov.ns.ca/petro/nsoilgasindustry/history.htm**
Oilsands Discovery Centre (Fort McMurray)	**www.oilsandsdiscovery.com**
Petroleum History Society	**www.petroleumhistory.ca**
Petrolia Discovery (Ontario)	**www.petroliadiscovery.com**

Turner Valley (Alberta) Gas Plant Historical Site
http://www.cd.gov.ab.ca/enjoying_alberta/museums_historic_sites/site_listings/turner_valley/index.asp

Measurement

Crude oil, natural gas liquids and refined oil products

In metric (Système International or SI), a standard unit of volume measurement is the cubic metre (m3). A cubic metre is simply the volume of fluid held by a container with dimensions of one metre by one metre by one metre. One cubic metre of oil would fill 1,000 one-litre milk cartons.

The traditional North American unit of oil measurement is the barrel. The barrel, which holds 159 litres or 42 U.S. gallons, was the original container used to store and transport crude oil during the horse and wagon era. Barrels are commonly abbreviated as bbl. A standard bathtub holds about one barrel of oil.

Canadians collectively use more than 250,000 cubic metres (1.5 million barrels) of crude oil each day. This is equivalent to the volume of about 600 public swimming pools. Volumes of gasoline and motor oils are normally measured in litres in Canada, and in U.S. gallons and quarts in the United States.

Before 1979, Canada used the Imperial measurement system. One Imperial gallon is equal to 4.546 litres, and there are 35 Imperial gallons in a barrel.

Liquid measurement conversions

To convert from:	To:	Multiply by:
Cubic metre	Barrel	6.292
Barrel	Cubic metre	0.15891
Litre	Barrel	0.006292
Barrel	Litre	158.91
Litre	Cubic metre	0.001
Cubic metre	Litre	1000.0

Other conversions

1 kilogram	=	2.2 pounds
1 metre	=	3.28 feet
1 kilometre	=	0.62 miles
1 centimetre	=	0.4 inches
1 hectare	=	2.47 acres
1 U.S. gallon	=	3.79 litres
1 Imperial gallon	=	4.55 litres
1 barrel	=	35 Imperial gallons/42 U.S. gallons

Natural gas

In SI, the official basic unit for natural gas volume measurement is one thousand cubic metres (10^3 m^3), measured at standard temperature and pressure (15° Celsius, 101.325 kilopascals).

The volume occupied by a large office desk is almost one cubic metre. This amount of natural gas would heat water for about 600 cups of coffee.

The following units and abbreviations are commonly used:

1 thousand cubic metres = 10^3 m^3
Energy used by one water heater for a year

1 million cubic metres = 10^6 m^3
Enough to heat 180 homes for one year*

1 billion cubic metres = 10^9 m^3
Enough to heat 180,000 homes for one year*

*Varies according to house size and weather conditions.

In the U.S. and Imperial systems, the basic unit for natural gas volume measurement is the cubic foot (cf) measured at standard temperature and pressure (60° Fahrenheit, 14.73 pounds per square inch). Common multiples are one thousand cubic feet (Mcf), one million cubic feet (MMcf), one billion cubic feet (Bcf) and one trillion cubic feet (Tcf).

Energy

The joule is the basic SI unit used to measure energy content. One joule is the equivalent of the energy required to heat one gram of water by approximately one quarter of one degree Celsius, or to lift a 100-gram object (such as a television remote control) one metre vertically. Since the joule is such a small unit of energy, the natural gas industry normally works in large multiples. Completely burning one wooden match would release the equivalent of approximately 1,000 joules.

1 thousand joules (10^3 J)	=	1 kJ (kilojoule)
1 million joules (10^6 J)	=	1 MJ (megajoule)
1 billion joules (10^9 J)	=	1 GJ (gigajoule)
1 trillion joules (10^{12} J)	=	1 TJ (terajoule)
1 million gigajoules (10^{15} J)	=	1 PJ (petajoule)
410 MJs	=	Used by one home in a day*
150 GJs	=	Used by one home in a year*

*Varies according to house size and weather conditions.

In the U.S. and Imperial systems, energy content is measured in British Thermal Units (BTUs). One BTU is the heat required to raise the temperature of one pint of water one degree Fahrenheit.

Natural gas measurement conversions

To convert from:	To:	Multiply by:
Cubic metre	Cubic foot	35.301
Cubic foot	Cubic metre	0.028
1,000 cubic metres (10^3 m^3)	Million cubic feet (MMcf)	0.035
Million cubic feet (Mmcf)	1,000 cubic metres (10^3 m^3)	28.328
Joule	BTU	0.00095
BTU	joule	1054.615
Gigajoule	Million BTUs (MMBTU)	0.948
Million BTUs (MMBTU)	Gigajoule	1.055

About the author

The author of the 5th, 6th and 7th editions of *Our Petroleum Challenge,* Robert Bott is a Calgary-based writer, editor and consultant who specializes in energy, forestry and the environment. Over the past three decades, he has written about energy issues as a journalist with United Press International and *The Calgary Herald,* managing editor of *Energy Magazine,* writer for the CBC-TV program "Business Watch," editor of energy articles for The Canadian Encyclopedia, columnist for *The Calgary Herald* and *Oilweek,* and as a contributor to magazines such as *Canadian Business, Report on Business Magazine, Financial Post Magazine, Saturday Night* and *Canadian Geographic.*

Bott was co-author of *Life after Oil: An Alternative Energy Strategy for Canada* (Hurtig, 1983) and author of *Mileposts: The Story of the World's Longest Petroleum Pipeline* (Interprovincial Pipeline, 1989). In the 1990s, he helped to develop and write the Backgrounder series of publications for the Petroleum Communication Foundation. He is the recipient of four National Journalism Awards, one Western Magazine Award, and a Lifetime Achievement Award from the Petroleum History Society.

Evolution

of Canada's oil and gas industry

A historical companion to *Our Petroleum Challenge,* 7th Edition

The Canadian Centre for Energy Information (Centre for Energy) is a non-profit organization created in 2002 to meet a need for information about all parts of the Canadian energy sector from oil, natural gas, coal, thermal and hydroelectric power through to nuclear, solar, wind and other sources of energy.

From freestanding information kiosks to our print publications and Web portal, the Centre for Energy delivers accurate, factual and current information on Canadian energy.

We believe that an informed public makes better business decisions related to energy, chooses careers in energy, invests in energy and uses energy more wisely.

For current information about the Canadian Centre for energy Information and its publications, please visit www.centreforenergy.com

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