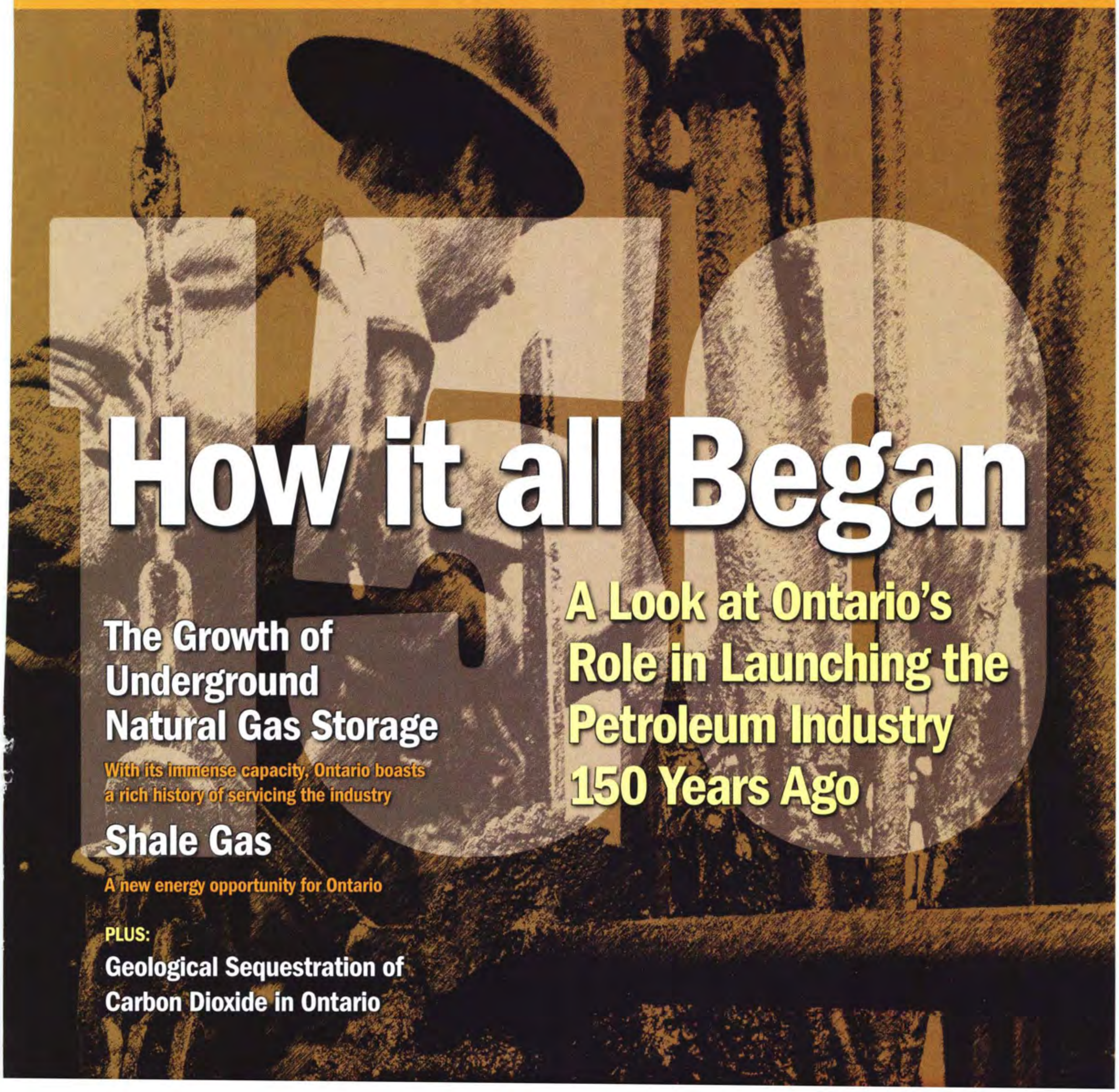
ONTARIO OIL & GAS

A publication of the Ontario Petroleum Institute

JUNE 2008



How it all Began

A Look at Ontario's Role in Launching the Petroleum Industry 150 Years Ago

The Growth of Underground Natural Gas Storage

With its immense capacity, Ontario boasts a rich history of servicing the industry

Shale Gas

A new energy opportunity for Ontario

PLUS:

Geological Sequestration of Carbon Dioxide in Ontario

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2008 EDITION

PUBLISHED FOR THE ONTARIO PETROLEUM INSTITUTE

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JuneWarren PUBLISHING

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Canadian Publications Mail Product Agreement: # 40069240

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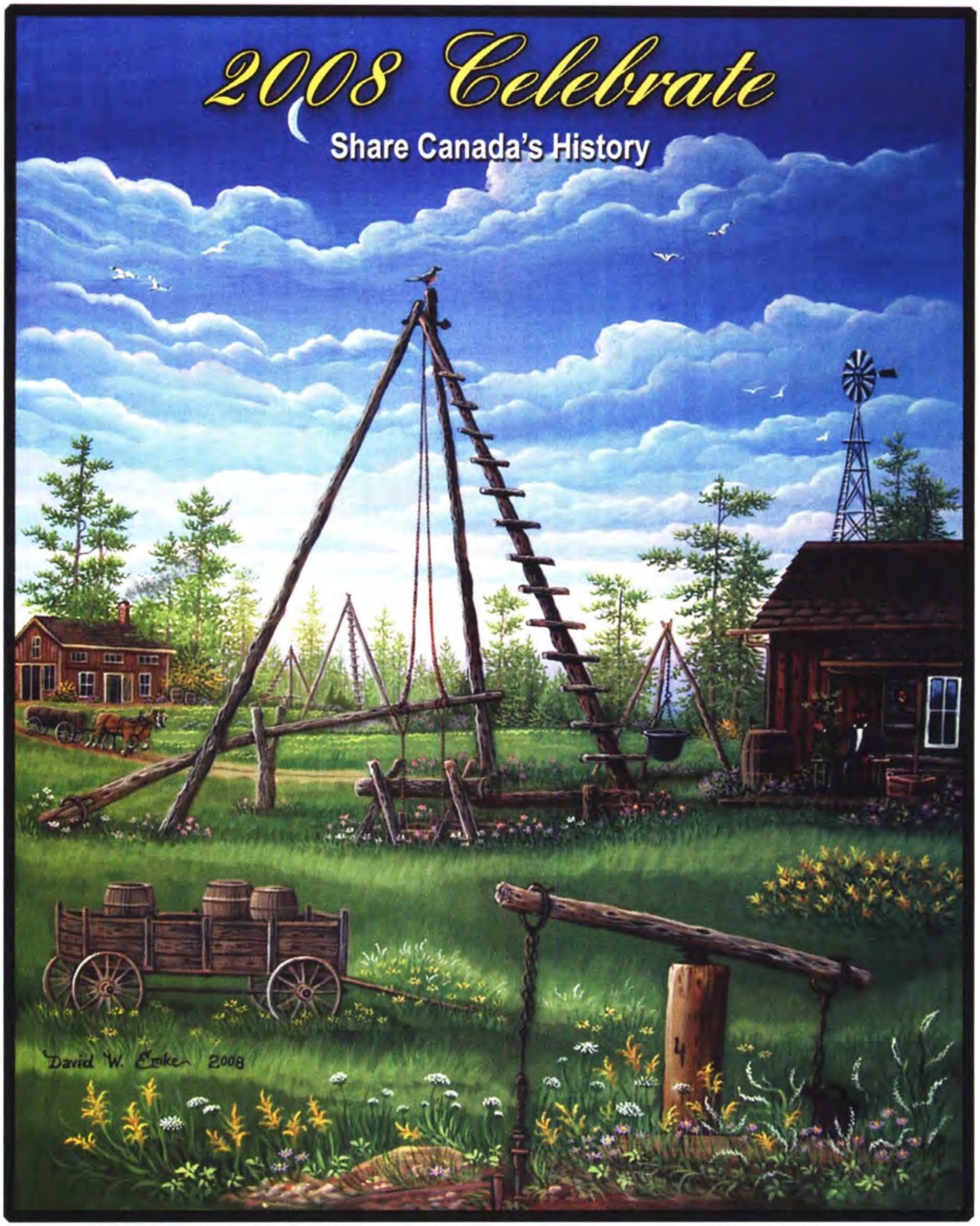

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A Message from the Minister of Natural Resources

It is a pleasure to convey my best regards to *Ontario Oil & Gas* magazine, a publication that provides valuable opportunities for readers to stay in touch with the emerging trends and technologies of your industry.

The oil and gas sector is an important contributor to Ontario's economy. This year marks a significant milestone for the industry in Ontario as it celebrates 150 years of pumping commercial crude oil in southwestern Ontario. Last year, Ontario's oil and natural gas production was valued at almost $150 million; hydrocarbons, which were stored in our underground storage reservoirs, were valued at $3 billion; and salt produced from solution mining operations was valued at $40 million.

Your industry has a long history of impressive accomplishments in the province, and there are many exciting and innovative opportunities on the horizon. For example, I understand that your industry is using horizontal drilling technology to access oil resources beneath the waters of Lake Erie, as well as 3-D seismic to locate previously undiscovere d reservoirs of oil and natural gas. These innovative operations demonstrate that your industry is leading the way in creating high-value jobs and opportunities right here in Ontario.

I know that the Ontario Petroleum Institute is working very closely with my ministry's Petroleum Resources Centre in London, Ont., on revisions to Ontario regulation 245/97 under the *Oil, Gas and Salt Resources Act*. The Ministry of Natural Resources will continue to work in partnership with the oil and gas industry as we sustainably manage this vital natural resource for the benefit of all Ontarians.

– Donna Cansfield
Ontario Minister of Natural Resources

Geological Sequestration of Carbon Dioxide in Ontario

By Terry Carter
Ministry of Natural Resources, London, Ont.

Michael Lazorek
Ministry of Natural Resources, London, Ont.

Andrew Hewitt
Ministry of Natural Resources, London, Ont.

Photography by Joey Podlubny

The increasing content of carbon dioxide (CO_2) in the world's atmosphere is directly linked to emissions of CO_2 from the combustion of fossil fuels such as coal, oil, and natural gas. Fossil fuels provide 80 per cent of the energy consumed in the world each year and this proportion is not expected to decrease in the near future. Thus, meaningful reductions in global CO_2 emissions into the atmosphere, at least in the near term, will require mitigation of the emissions from fossil fuels. Geological sequestration of CO_2, also known as carbon capture and storage, may provide part of the solution.

In 2003, Canada's total emissions of CO_2 were estimated at 740 mega tonnes (Mt) with Ontario responsible for 206 Mt. Of the Ontario emissions, 77 Mt were from large industrial point sources such as coal-burning power plants, cement plants, petrochemical plants, and iron and steel manufacturers with 45 Mt of these emissions occurring in the Hamilton to Sarnia corridor on the edge of two of the largest sedimentary basins in North America. This juxtaposition of point-source emitters and sedimentary basins favourable for geological sequestration of CO_2 is the most important criteria for establishing potential for implementation of this potential solution.

Considerable knowledge of the science and technology of carbon capture and storage has already been acquired. The technology is already in use by the oil and gas industry but no full-scale operations exist at other types of industrial facilities. Some uncertainties related to cost and reliability of capture technology remain, with research now underway to address these issues.

What is CO_2 sequestration?

In simple terms, sequestration of carbon dioxide is the capture of CO_2 from anthropogenic sources before it can be released into the atmosphere, or the removal of CO_2 directly from the atmosphere, coupled with permanent storage of the captured CO_2 to keep it isolated from the atmosphere. The world's natural carbon cycle removes large amounts of CO_2 from the atmosphere (e.g. photosynthesis, mineral weathering, dissolution in seawater), but at a rate insufficient to match the increased emissions due to human activity.

Numerous strategies have been proposed to remove more CO_2 from the atmosphere. We can use natural terrestrial processes such as no-till farming to increase carbon content in the soil or tree planting to increase CO_2 capture by photosynthesis. We can use mineral carbonation reactions with magnesium silicate minerals (ultramafics) to remove CO_2 from exhaust gases at thermal power plants. We can inject CO_2 into deep ocean basins where high pressure and cold temperature will sequester the CO_2 as a liquid phase on the ocean floor. One of the most promising strategies is geological sequestration of the carbon dioxide in deep underground rock formations, also known as carbon capture and storage (CCS).

CCS is a technical process that involves capturing CO_2 from large point sources, purifying the emissions to maximize the CO_2 content, and transporting the CO_2 to a storage site where it is injected, using a specially constructed well, into deep geological formations for permanent storage. Once it is injected into these rocks, it reacts over very long periods of time with mineral components and fluids in the rocks to form stable compounds that permanently trap the CO_2. Several variations on CCS are proposed and include injection into: depleted oil and gas reservoirs; geological structures such as salt domes, coal beds, organic shale beds, and depleted reservoirs; oil reservoirs for enhanced oil recovery; and saline aquifers. Also proposed is storage in solution-mined salt caverns. Research indicates that the volume of pore space available in deep saline aquifers far exceeds that of enhanced oil recovery projects and depleted hydrocarbon reservoirs, and offers perhaps the best potential for CO_2 sequestration in the landlocked areas of the world. Numerous estimates suggest that global storage capacity is sufficient to accommodate at least 150 years of the world's total annual anthropogenic emissions.

Saline aquifers are deep formations of porous and permeable rock that contain salt water in the pore spaces and, in Ontario, are located below the deepest sources of potable water. In addition to porosity and permeability, other important characteristics of the storage formation include the presence of a suitable impermeable cap rock, a pressure and temperature regime suitable for injection and storage of CO_2 in a "supercritical" or liquid phase, proximity to large point sources of CO_2 emissions, and a well-characterized migration route for the sequestered gas. Potential risks must also be characterized, with special attention paid to seismic activity, faults, fractures, and unplugged wellbores that could provide a pathway for CO_2 to escape to the surface and any effects on proven and potential oil and gas reservoirs.

Potential CCS spin-off benefits for the Ontario petroleum industry include enhanced oil recovery from known reservoirs.

Given the geologic conditions encountered in southern Ontario, CO_2 will exist as a liquid below a depth of approximately 865 m. This is desirable because as a liquid it will more readily mix and dissolve in water and it takes up much less volume than as a gas. This minimum depth also helps ensure that there is sufficient rock above the injection interval to act as an impermeable seal. This is important since the liquid CO_2 is less dense than water and will rise to the top of the porous interval in the saline aquifer.

Is the geology of Ontario well suited for geologic sequestration of CO_2?

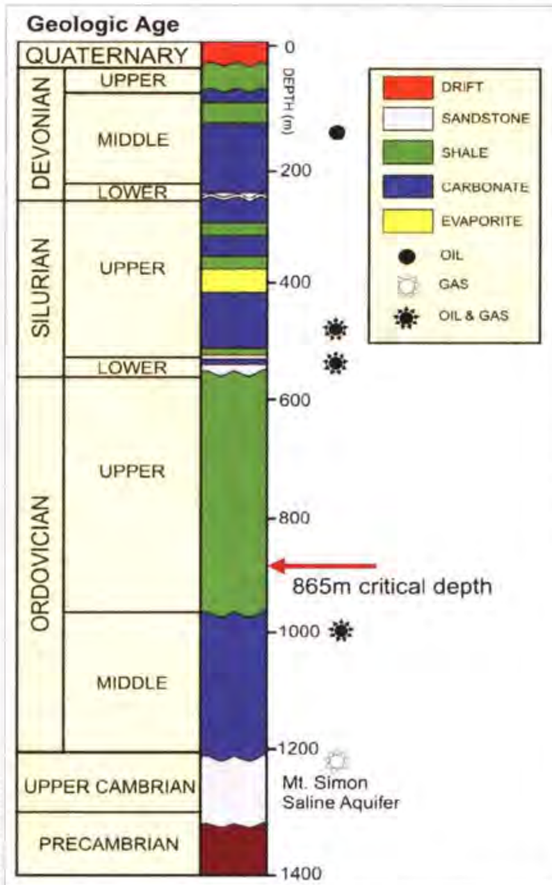
Four major sedimentary basins occur within Ontario. In northern Ontario, sedimentary rocks occur within the Moose River and Hudson Bay basins but these basins tend to be too shallow for carbon dioxide storage. They are also remote from large point sources of CO_2 emissions and thus are presently impractical for consideration as candidates for geological sequestration.

Southern Ontario is located on the edge of two of the largest sedimentary basins in eastern North America, the Michigan and Appalachian basins, containing thick accumulations of sedimentary rocks. Rocks within these basins were originally horizontal, but have subsequently tilted and deformed forming a northeast-trending ridge known as the Algonquin Arch. Because of this, the thickness of the rocks increases westerly into the Michigan Basin and southerly into the Appalachian Basin, reaching a maximum thickness of about 1,400 m beneath Lake Erie and at the southern tip of Lake Huron, and much greater thicknesses beneath the neighbouring U.S. states. Extensive development of porosity and permeability is evidenced by the presence of oil and gas reservoirs and regional saline water aquifers in these basins.

There are several geologic options for CO_2 sequestration in Ontario. Saline aquifers, oil and gas reservoirs, and solution-mined salt caverns, all located within the Michigan and Appalachian basins in southern Ontario, have the best near-term potential. There is also longer-term potential for use of mineral carbonation reactions with ultramafic rocks in the extensive Canadian Shield rocks of northern Ontario. ▶

Saline aquifers offer the largest storage capacity in Ontario. Saline aquifers occur within the sedimentary bedrock in the basins of southern Ontario and Hudson Bay, generally at depths greater than a few tens of metres and located below and isolated from freshwater aquifers. Waters within these deep aquifers contain elevated concentrations of salt and sulphur and are generally not suitable for drinking, irrigation, or other domestic purposes.

While most of the other sedimentary formations are too shallow for CCS, the Upper Cambrian-age Mount Simon Formation of the Michigan and Appalachian basins is considered the best candidate for CO_2 storage. The Mount Simon Formation is a porous sandstone underlying large parts of southern Ontario and the neighbouring U.S. states. The formation thickens to the west under Lake Huron and into Michigan and to the south under Lake Erie and the adjacent states and pinches out over the top of the Algonquin Arch. It is sealed by approximately 600 m or more of non-porous Ordovician limestones and shales, which form an excellent barrier to upward movement of fluids.



CREDIT: MNR

Idealized stratigraphic section through Paleozoic sedimentary rocks in the Sarnia area of Ontario showing Mt. Simon saline aquifer.

Preliminary studies have indicated the potential to store up to 730 Mt of CO_2 in saline aquifers in the Mount Simon sandstones within southern Ontario. While Ontario's capacity to geologically store CO_2 in saline aquifers is modest, significant opportunities for carbon sequestration exist in the midwest region of the United States, in the same rocks being considered for storage in Ontario. More than 475 Gt of capacity are estimated for the states bordering on southern Ontario including Indiana, Kentucky, Maryland, Michigan, Ohio, Pennsylvania, and West Virginia. Ultimately, Ontario may need to tap into this capacity.

Oil and gas reservoirs in Ontario are found at a variety of depths and in different rock types mainly restricted to southwestern Ontario; to date neither oil nor natural gas has been discovered in the Hudson Bay and Moose River basins or in eastern Ontario. Sequestration of CO_2 would take place either by injection into depleted oil and gas pools or into producing oil pools. In depleted pools, the CO_2 would occupy the pore space left by the extraction of the oil and gas and would be confined within the same boundaries as the original pool. The capacity is limited by issues with shallow depths of the reservoirs in Ontario, large numbers of unplugged wells, and limited pore volume. Individual reservoirs may prove to be technically suitable but require further study to confirm.

CO_2 can also be injected into active oil pools to enhance oil production in a process known as enhanced oil recovery (EOR). The CO_2 repressurizes the reservoir and mixes with the remaining oil, making it less viscous and more mobile. This results in recovery of additional oil that would have been left behind by conventional production methods. Studies show that most of the CO_2 remains in the reservoir. There are presently no EOR projects in Ontario due largely to lack of a cheap local source of CO_2.

CO_2 can also be injected into solution-mined salt caverns for both permanent and temporary storage. Ontario produces large quantities of salt from solution mining operations and has a number of abandoned caverns where salt extraction no longer occurs. Unfortunately, the Salina Group from which the salt is produced occurs at too shallow a depth in most of Ontario to provide the necessary conditions for storage of CO_2 as a liquid. Depth of salt beds beneath Lake Huron is unknown but if deep enough there may be potential for construction of salt caverns for storage beneath the lake.

One other opportunity for geological sequestration of CO_2 in Ontario is the use of mineral carbonation reactions. Canadian Shield rocks in northern Ontario contain surface outcrops of ultramafic rocks and waste rock piles at mines. These rocks are comprised predominantly of magnesium silicate minerals. When exposed to the atmosphere these minerals undergo a slow natural reaction with CO_2 to form a stable mineral known as magnesite, which permanently traps the CO_2 in the mineral fabric. Studies are in progress on how this natural process can be accelerated and adapted for use to capture CO_2 in the exhaust gases of large industrial facilities such as cement plants and thermal power plants.

WHAT IS THE STATUS OF THIS TECHNOLOGY?

A variety of capture processes are at various stages of technical readiness and commercial viability. These processes are complex, capital intensive, and generally integrated with an existing set of facilities. The technology exists and is in use at petroleum facilities, but has not yet been adapted and installed at a full-scale industrial operation such as a coal-fired generating station.

In the Sleipner Vest gas field in the North Sea, about 1 million tonnes per year of CO_2 are removed from the natural gas and injected into sandstones of the 250 m thick Utsira Formation about 1,000 m below the seabed. Injection started in September 1996. The cost of capture and injection, rather than venting it, is economically justified to avoid a Norwegian tax of approximately C$50 per tonne of CO_2 emitted to the atmosphere in offshore oil and gas operations.

Worldwide, CO_2 is used for EOR in more than 70 projects, mainly relying on naturally occurring sources. In the United States, more than 100,000 tonnes of CO_2 are used annually for EOR. In Canada, EnCana Ltd. of Calgary, Alta., is purchasing CO_2 from the Great Plains coal-gasification plant at Beulah, N.D. The CO_2 is piped 330 km to be used for EOR in the Weyburn oilfield in Saskatchewan. This is the largest EOR operation in Canada and will extend the life of the field as much as 25 years, while at the same time storing a million tonnes of CO_2 annually in the oil reservoir.

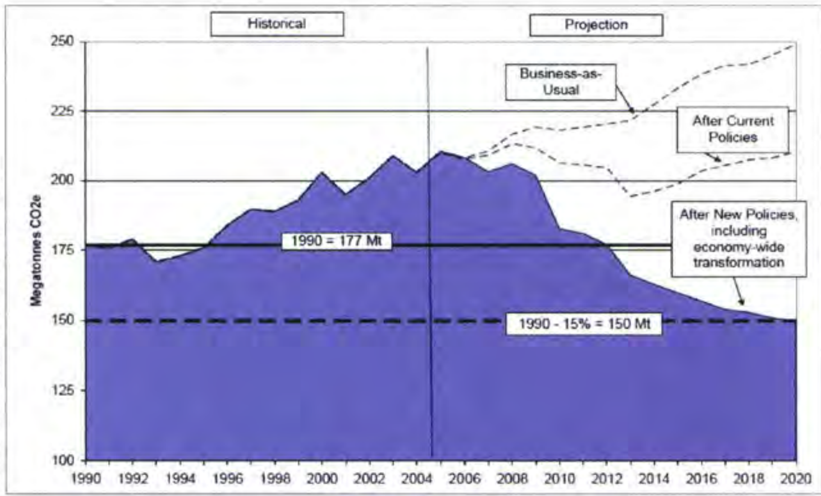
The United States has formed seven regional carbon sequestration partnerships to work on studies, pilots, and plans for a CCS demo with support from the U.S. Department of Energy. The seven partnerships include more than 350 state agencies and governments, universities, and private companies, spanning 41 states, two Indian nations, and four Canadian provinces. The Midwest Regional Carbon Sequestration Partnership includes all the states bordering on southern Ontario. The partnerships have been in operation since 2003 and are preparing to conduct CO_2 injection tests at selected sites in 2008 and 2009 as part of phase 2 of their ongoing studies.

In Canada, the Canadian Clean Power Coalition has been evaluating Oxy-fuel and gasification as technologies that deploy CCS and replace conventional combustion of coal. The Integrated CO_2 Network (ICO_2N), in consultation with government, non-government organizations, and respected researchers, seeks to harness the broad range of expertise and resources required to fast-track development of a national CCS system. This network would combine investments in infrastructure and technology with the development of a CO_2 marketplace, supported by appropriate federal and provincial policy, government and private funding, and an effective regulatory framework. ICO_2N represents key industries ranging from minerals and metals refining, fertilizer production, and electrical generation, to petroleum extraction and refining.

Carbon capture and storage initiatives in Ontario

The global climate change agenda is moving the industrial world towards a carbon-constrained economy. Carbon capture and storage is evolving as a viable option for managing emissions from stationary sources while helping the world's industrial base secure its future in a "greener" environment.

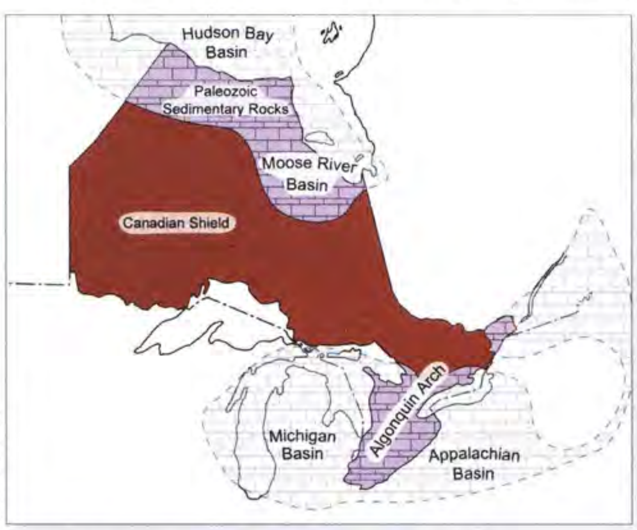
Ontario's Speech From The Throne of Nov. 29, 2007, adopted the 15 per cent absolute (as opposed to intensity) target of reduction of carbon dioxide emissions by the year 2020 (1990 being the base year). Existing policies, which include ending Ontario's use of coal for meeting its electricity needs, still leave Ontario with carbon dioxide annual emissions higher than those of any year from 1990–2007. This leaves a lot of room for new policies to address other sources of emissions, namely those from the transportation and industrial sectors.



CREDIT: GOVERNMENT OF ONTARIO

Ontario's greenhouse gas emissions and projected future levels.

Should Ontario's Action Plan adopt "new policies" that include managing emission from its industrial sector, such new policies may very well incorporate geological storage as a viable option for managing its industrial emissions of CO_2. Potential spin-off benefits for the Ontario petroleum industry and wider industrial sector include availability of carbon dioxide for enhanced oil recovery from known reservoirs, and provision of expertise, supplies and services for drilling of wells, construction of pipelines, construction of compressors, and consulting services.



CREDIT: MNR

Major rock types and sedimentary basins in Ontario.

The Ministry of Natural Resources is currently conducting an internal analysis of the feasibility of implementing this technology in Ontario as part of the government's climate change strategy, including further geoscientific studies. Participation by industry would be critical to the success of any resulting initiative.

Further reading

Carter, T.R., Gunter, W., Lazorek, M., and Craig, R., 2007. *Geological sequestration of carbon dioxide: a technology review and analysis of opportunities in Ontario*; Ontario Ministry of Natural Resources, Applied Research and Development Branch, CCRR-07, 24 p.

Internet

www.co2network.gc.ca
www.fossil.energy.gov/programs/sequestration/partnerships
www.gogreenontario.ca

The Environment,

PHOTO: JOEY PODLUBNY

The oil and gas industry in Ontario is in its 150th year of developing the natural hydrocarbon resources in the province. While the volume of oil and gas that is and has been produced may not be large when compared to western Canada, the proximity of the resources to appropriate infrastructure and markets, the quality of the produced product, and the relatively shallow depths of the reservoirs yield attractive returns on investments.

The industry operates in geographic areas that have seen steady and significant growth in population and urbanization since the discovery of oil in 1858 in Oil Springs, and the interaction between landowners, the general public, and industry continues to evolve. In Ontario, mineral rights are generally

Industry, Landowner Link

By K.J. O'Shea
M.Sc., F.G.A.C., P.Geo. (Ontario), P.Geol. (Alberta)
Partner, Dillon Consulting Ltd.

owned by landowners, such that landowners often have a direct financial stake in the development of the resource. This has often resulted in a partnering of landowner and industry in developing and producing the resource.

Over the past 15 years, with the emergence of the environmental movement and the subsequent increased environmental scrutiny from the regulators in the province, the relationship between landowners and industry has, in some cases, become somewhat more difficult. With the increase in oil prices over the past few years, many companies have reported substantial profits, which have received widespread media attention. As a direct result of the perceived increase in value of produced hydrocarbons, landowners (and governments) are seeking greater compensation for allowing industry on their land, and increasingly request that potential environmental impairment and risk, both perceived and real, be part of that compensation.

In Ontario, as with our oil and gas industry counterparts throughout North America, access to the resource requires access to land, which in turn requires an appropriate relationship with landowners who have become more than passive stakeholders. The industry has been working to address the concerns of the landowners through increased operational diligence to reduce impacts, and increased levels of dialogue with stakeholders to improve understanding of the industry. ►

However, we have been reluctant to engage both the landowners and the public in discussions of risk and reward, and while we will typically share risk amongst companies, we have not typically brought in the landowners as risk-sharing partners. In Ontario, as a result of the landowners owning the mineral rights, they share in the rewards of successful development and exploitation. Perhaps we need to modify the approach to development so that landowners become true partners in the development of the resource, sharing the risk, the responsibility, and the reward.

Unfortunately, the erosion of public understanding of the direct relationship between development and production of hydrocarbons, and the nature of our modern society and standard of living, often makes it difficult to achieve the level of partnership that we may need in the future to be able to reach the resource. As an industry, we must do a better job of educating landowners and government regulators about what we do, and our impact on the environment and on the Canadian and world economies.

The upstream oil and gas industry in Ontario has a good record with respect to interaction with the environment. The record is in part due to the low pressures and volumes of produced products, and in part due to the nature of our shallow soils in many of the producing areas of the province. The environmental legacy of development from the historical industry is largely related to old wellbores, and compared to environmental issues faced by other industries (such as downstream oil and gas, manufacturing, etc.), is minor. Although produced formation waters in Ontario are high in dissolved solids, brine-related impacts are rare and typically localized. Historically, spills were left to "remediate" over time. Interestingly, the locations of some of the early spills and gushers can no longer be determined based solely on the current environmental condition of the sites. Hydrocarbons degrade and brine spills are diluted and dissipated.

The modern industry in Ontario operates in a manner similar to oil and gas operations around the world. The current regulatory regimes require that environmental impairment be addressed in a timely fashion, and has financial incentives to ensure compliance. Numerous industry-based standard practices are followed to reduce future environmental costs. In Ontario it is not uncommon to see oil and gas wells and facilities being operated immediately adjacent to agricultural fields, with no apparent affect. By working with landowners and government regulators, the industry in Ontario has been active for 150 years. Working together, the stakeholders can ensure that the industry will continue to function and prosper for the next 150 years. OG

Dave Collyer.

Energy for a planet

When Canada's historic oil boom ended in the late 1880s, that first generation of Canadian "hard oilers" went on to apply their impressive technological know-how to the challenge of opening up the world's great oilfields and ushering in the oil age.

Today the world faces quite a different energy challenge. Yet the need for creativity and practical thinking is unchanged, points out Shell Canada president Dave Collyer.

"At Shell," Collyer says, "we believe that as solutions are being developed, the world must face three hard truths:

1. "The first is that global demand for energy is accelerating. Some statistics show that energy use in 2050 may be twice as high or higher than it is today. What's driving this? Predominantly population growth and higher levels of prosperity.
2. "The second is that the supply of 'easy oil' will not keep up. While demand is accelerating, conventional oilfields in mature basins are going into decline. Other resources such as oil shale and Canada's oilsands are being developed, but they come with technological challenges and higher costs.
3. "The third hard truth is that using more energy now means more carbon dioxide emitted at a time when climate change looms large as a critical global issue."

So what does the world need to address these truths?

Collyer says that a broad portfolio of energy sources is needed. "More oil and gas, more renewables, and likely more coal and nuclear. We also need a huge drive for energy efficiency," he says.

"A barrel of oil saved is better than one discovered. Governments need to implement smart greenhouse gas emission regulations internationally in a coordinated and efficient way, addressing the life cycle from production to consumption of energy. And we need new technology now more than ever before: to increase recovery of oil and gas, to deliver breakthroughs in renewable energy sources, to enable the cleaner use of coal, to increase efficiency, to sequester CO_2, and to do all of this at a lower cost than is possible today.

"Which brings us back to Lambton County, where Canada's oil industry began 150 years ago, and to western Canada, regions where Shell is looking to invest in long-term projects to help the world meet its energy needs while providing advanced carbon management technologies," Collyer says.

"Innovation, problem-solving, and technical know-how—just like 150 years ago, the world needs all we have to offer."

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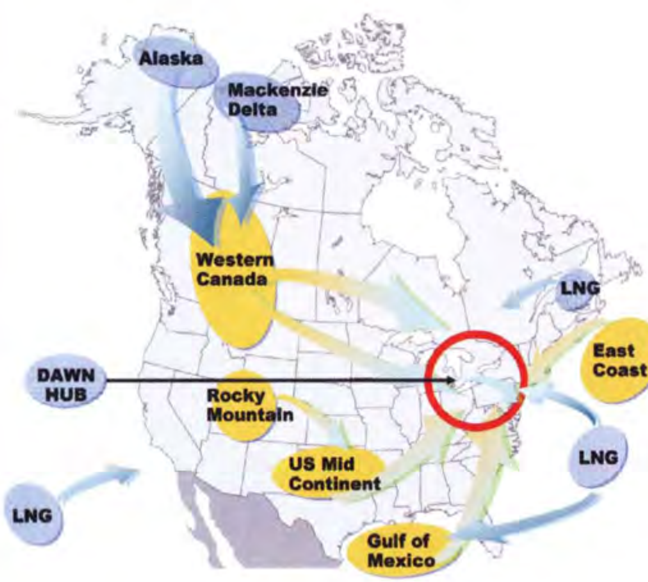

Dawn plays an important role in connecting multiple supply basins to Eastern Markets

INVESTING TO MEET CUSTOMER DEMAND

- Union Gas is investing in excess of $350 million to complete a three phase expansion of its Dawn to Parkway transmission system over the 2006-2008 period. This will increase capacity by approximately 1.2 billion cubic feet per day, providing storage and transporation customers the ability to ship more natural gas from the Dawn Hub to downstream markets.
- Union Gas is also investing more than $150 million to expand its storage capacity in 2008 and 2009, to provide new capacity and services required by its customers.

Pantera Rig #3 at Dawn 156 Field

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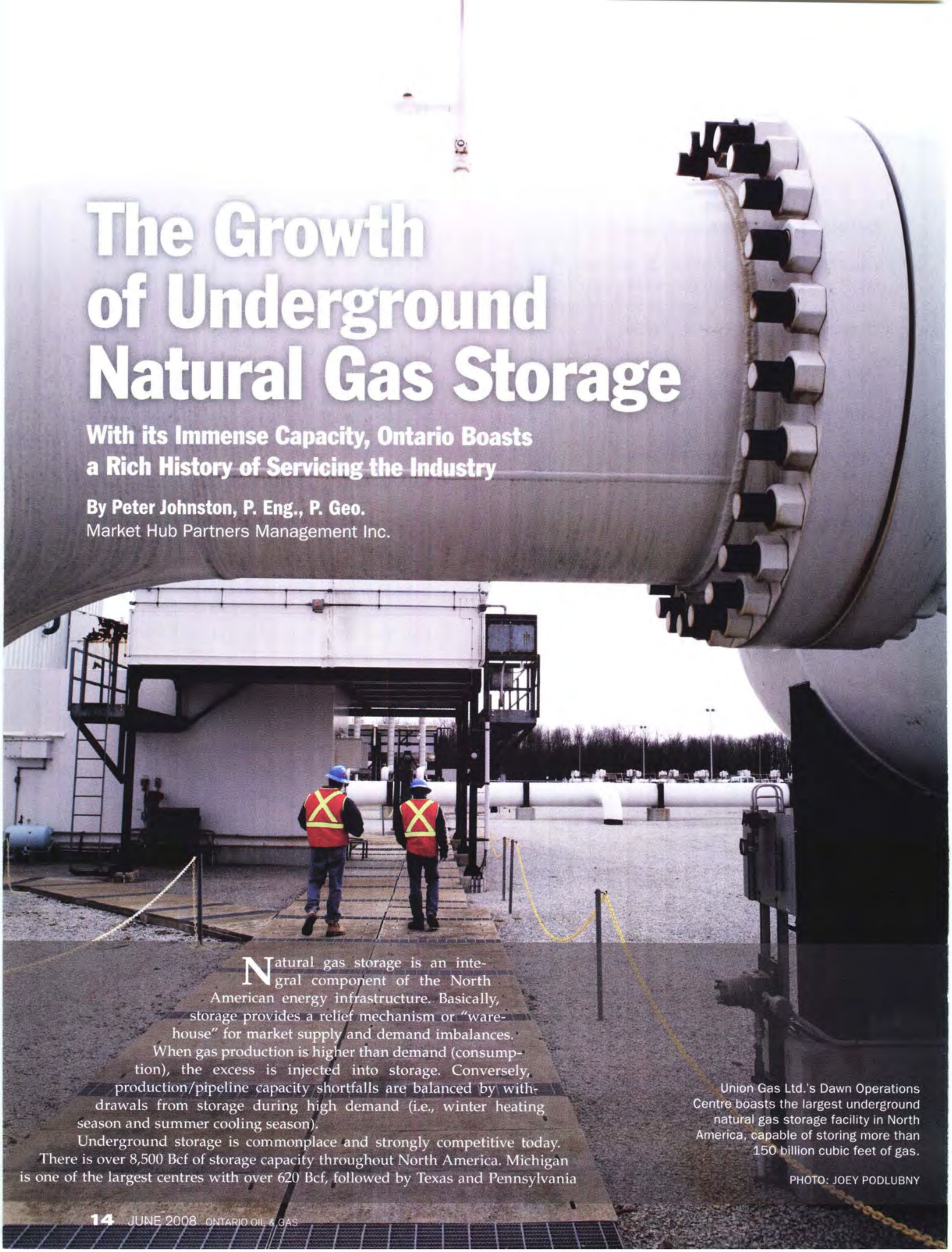


The Growth of Underground Natural Gas Storage

With its Immense Capacity, Ontario Boasts a Rich History of Servicing the Industry

By Peter Johnston, P. Eng., P. Geo.
Market Hub Partners Management Inc.

Natural gas storage is an integral component of the North American energy infrastructure. Basically, storage provides a relief mechanism or "warehouse" for market supply and demand imbalances. When gas production is higher than demand (consumption), the excess is injected into storage. Conversely, production/pipeline capacity shortfalls are balanced by withdrawals from storage during high demand (i.e., winter heating season and summer cooling season).

Underground storage is commonplace and strongly competitive today. There is over 8,500 Bcf of storage capacity throughout North America. Michigan is one of the largest centres with over 620 Bcf, followed by Texas and Pennsylvania

Union Gas Ltd.'s Dawn Operations Centre boasts the largest underground natural gas storage facility in North America, capable of storing more than 150 billion cubic feet of gas.

PHOTO: JOEY PODLUBNY

with close to 400 Bcf each. Ontario, by comparison, supplies markets with 250 Bcf of working storage capacity. Figure 1 compares the top 20 states and provinces by working capacities.

Depleted production reservoirs are the most common underground storage containers. By virtue of their commercial hydrocarbon reserves, they have demonstrated they can contain gas for millions of years. Production data over time provides additional containment information as well as size and flow characteristics important for engineering and economical analyses for converting potential reservoirs to storage service. No chicken-and-egg paradox here. Exploration and production had to happen first. Its history must also be reviewed to establish an understanding of the growth of storage in Ontario.

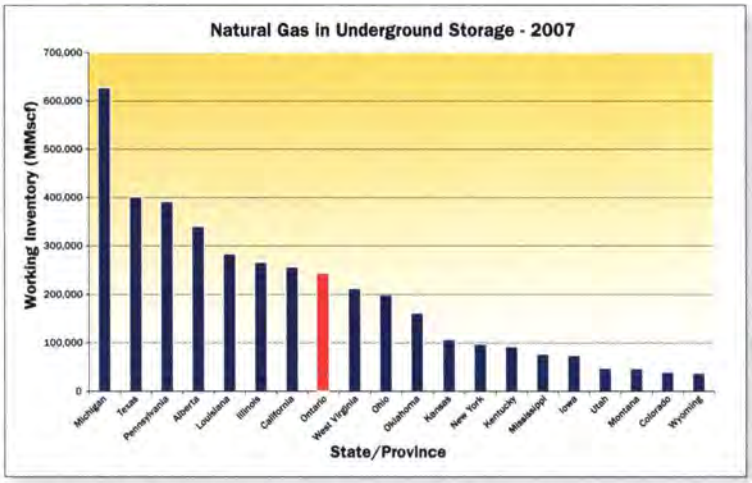


Figure 1: Top 20 underground storage states and provinces.

The culmination of the 19th century saw the birth of the natural gas industry in Essex, Ont. Additional reserves were subsequently discovered in several counties north of Lake Erie, from Essex to Niagara. Distribution infrastructures expanded to meet growing local demands. A few decades of demand growth was eventually curbed by dwindling local supplies (Figure 2). Alternative economical sources of natural gas rapidly become a necessity.

Storing natural gas in a depleted underground reservoir was a new concept first tested in 1915 at a gas field in Welland, Ont. Commercial development of natural storage reservoirs commenced in the United States with approximately 50 depleted reservoirs successfully converted to storage operations during the ensuing 27 years. Canada's first commercial storage field, Dawn 47–49, was placed in service in 1942. This development was mainly driven by the need to offset dwindling local natural supplies.

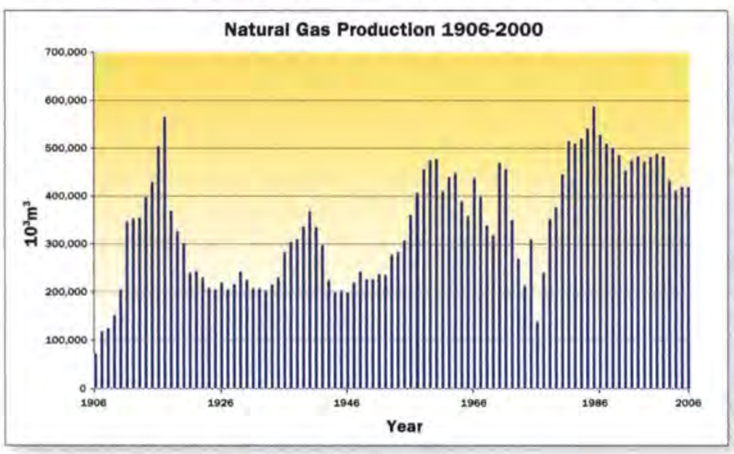


Figure 2: Ontario natural gas production.

The first gas commercially injected underground in Ontario did not arrive from any producing field. In fact, it wasn't even "natural." It was a by-product, still gas, from Imperial Oil's Sarnia Refinery, located approximately 50 km away. The refinery produced in the neighbourhood of 5 to 10 million standard cubic feet per day (MMscf/d) of still gas. The majority of production occurred during the summer when customer-heating demand was low. The newly converted Dawn 47–49 reservoir provided 3.4 Bcf of working storage space for the unconsumed summer gas by-product. A neighbouring depleted reservoir, Dawn 59–85, was commissioned for underground storage a year later. These two reservoirs provided the only storage in Ontario for the next 14 years.

Several transcontinental pipelines were built during the 1940s and '50s to bring abundant reserves of natural gas to the growing markets of Ontario and the American northeast population centres. Pipeline gas was first imported into Ontario in 1944 via the Ojibwa crossing near Windsor. Supplies were only allowed to ship across the international border between April 1 and Nov. 1 due to a combination of low heating demand in U.S. markets during this time and optimizing pipeline capacity year-round. However, Ontario market demands were also low. The imported natural gas therefore needed to be injected into the existing underground storage reservoirs and displaced the still gas from refineries. Additional natural gas imports arrived across international pipeline connections constructed in the Niagara region. This "season" was (and still is) referred to as the "injection season" by the industry.

Discoveries were also made in Lambton County, Ont., which assisted with meeting demand. These new producers, together with growing pipeline supplies from the United States, stimulated market growth in the region between the late 1940s and early '60s. Several of these discoveries would later contribute to the region's storage development.

Natural gas deliveries began arriving from the younger Western Canadian Sedimentary Basin via the newly constructed, 2,300 km trans-Canadian pipeline, owned and operated by TransCanada Pipeline Ltd. (TCPL), to Ontario and Quebec during the mid- to late 1950s. TCPL established long-term contracts with several local distribution companies and started delivering over 100 Bcf per year.

As the industry grew, so did the benefits of storage. Pipelines were optimized year-round, which aided in managing transportation costs. Having inventories close to market provided distribution companies and their customers with security of supply. Natural gas prices and transportation costs were lower during injection seasons, which helped offset higher winter season prices. Pipeline capacity limitations experienced during peak winter weather conditions were augmented with storage inventories. ▶

A local distribution company signed a 20-year storage contract in 1958 to service the Greater Toronto area. Additional storage was developed in the late 1950s to early '60s using two depleted reservoirs discovered nearly a decade earlier. The Payne and Waubuno reservoirs expanded Ontario's storage capacity another 18 Bcf, bringing the total to over 25 Bcf.

The increasing importance of storage in Ontario led to the organization of user groups, ratepayers, and landowners. These groups approached government lobbying for standard rates and policies. Storage regulation ramped up in the province in the early 1960s. A landmark study, *The Langford Commission Report*, resulted. The study provided a definition of how the provincial government should be involved. It said:

"The role of the provincial government with respect to [natural gas] storage should be that of controlling and regulating it only in so far as is necessary to ensure efficient and economical development of the industry."

It also included five key recommendations:

1. *The right to develop and operate storage areas should be granted only to experienced and competent companies.*
2. *The use of storage facilities should be placed on a priority basis with the distribution companies having first call.*
3. *Storage rights in Ontario should remain under the jurisdiction of the province.*
4. *Storage rights in Ontario should be used primarily for the people of Ontario.*
5. *An authoritative body should be created to regulate and advise on all phases of the natural gas industry in Ontario.*

Storage development was primarily governed by these recommendations for the ensuing four decades. Distribution companies grew storage "as needed." They were required to demonstrate that proposed developments were safe, economically viable, technically sound, and in the public's interest.

Natural gas price fluctuations increased significantly around the turn of the millennium and accentuated another contribution from storage, short-term marketing or trading. Distribution companies operating storage assets were challenged to compete in such a market with unregulated companies who were profiting off rate-regulated storage services. As long as sufficient storage was available to meet its customers' needs, distribution companies had little incentive to further grow storage assets.

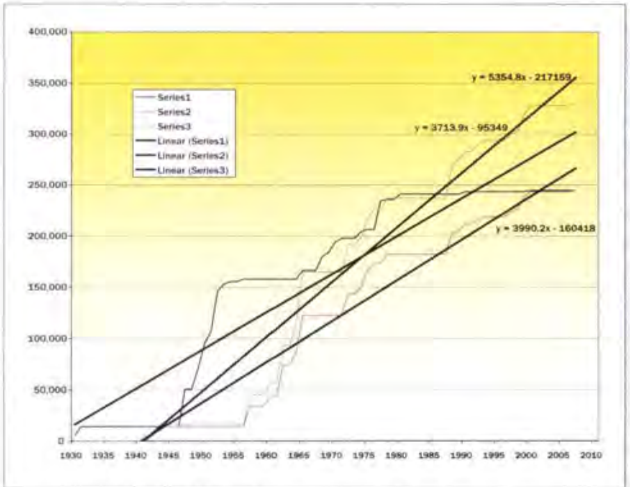


Figure 3: Ontario discoveries vs. storage development.

PHOTO: JOEY PODLUBNY

Union Gas began storing natural gas underground at its Dawn facility in the 1940s.

Deregulation of storage was well underway in the United States and the industry continued to grow at a healthy pace. Ontario development in the market was virtually non-existent for the distribution companies. This hiatus was temporary as the regulatory body initiated a forum to discuss the merits of deregulating the industry in Ontario.

Interest groups from all points of the industry compass debated the issue of storage deregulation for many months. Their efforts culminated with a regulatory decision in favour of deregulating storage while reserving sufficient existing storage to meet current and foreseeable demands of consumers in Ontario. Details of the decision can be found in the Ontario Energy Board's report, *Natural Gas and Electricity Interface Review*. The required incentives were provided and local storage growth resumed in a competitive marketplace.

Storage designation still requires demonstrating several of the recommendations stated in the *Langford Commission Report*. Companies must demonstrate they are technically and financially capable of developing storage safely and in the public's interest. They are not required to provide evidence regarding a storage project's economic viability as that becomes fundamentally regulated by markets.

Figure 3 reviews the incremental discovery and storage expansion in Ontario. Reservoir discoveries that were considered storage candidates averaged 3.714 Bcf per year. Conversion to storage generally lagged about 10 years behind discovery. Time lags are necessary to allow for the determination of reservoir appropriateness for potential storage operations. Production-pressure declines determined the potential capacity. Well information and performance elicited internal reservoir characteristics. Storage conversion occurred at a slightly higher pace of 3.99 Bcf per year discounting delta pressuring (pink line). Overall storage space, including delta pressuring (green line), averaged 5.355 Bcf per year between 1941 and 2007.

Several factors continue to challenge growth in the industry today. They include escalating land, development, and operating costs; diminished exploration activities in mature basins; and declining seasonal commodity price spreads. Financial experts agree that the nature of the storage business is cyclical. The ebb and flow of storage growth will continue with industry participants contributing to enhance one of Ontario's natural assets.

The Oil and Gas Plays of Ontario

By Michael Lazorek
Ministry of Natural Resources, London, Ont.
Terry Carter
Ministry of Natural Resources, London, Ont.

The oil and gas industry in Ontario has had a long and storied history since the first commercial well was dug at Oil Springs in 1858. Today, the Ontario industry remains small but profitable with total cumulative production of over 86 MMbbl of oil and nearly 1.3 Tcf of natural gas from rocks ranging from Cambrian to Devonian in age (Table 1).

While oil and gas exploration and production has declined in recent years, part of this is due to the fevered activity in the northeastern United States and western Canada drawing investment dollars, exploration personnel, and equipment away from Ontario. With inflated costs and a slowdown in activity in western Canada, investors should find Ontario attractive with high producer netbacks, low royalties and leasing costs, convenient access to exploration data, low transportation costs, easy road access, and numerous untested prospects in five classic petroleum plays.

All of Ontario's oil and gas discoveries and production to date are found in southern Ontario in Paleozoic rocks of the Michigan and Appalachian basins. Commercial quantities of oil and gas have been discovered at several stratigraphic intervals and comprise five principal plays: CAM—structural and stratigraphic traps in Cambrian sandstones and sandy dolomites; ORD—hydrothermal dolomite reservoirs in middle Ordovician limestones; CLI—stratigraphic traps in lower Silurian sandstones and associated carbonates; SAL—reefs and structural traps in middle Silurian carbonates; and DEV—structural traps in Devonian fractured, dolomitized carbonates and sandstones (Figures 1 and 2).

Cambrian Play (CAM)

The sedimentary rocks of the Michigan and Appalachian basins in southern Ontario are separated by a ridge known as the Algonquin Arch. During late Cambrian time, most of Ontario was covered by warm shallow seas, which deposited sandstone, limestone/dolomite, and sandy limestones and dolostones over all of southern Ontario, including the arch. However, much of the Cambrian and Lower Ordovician sediments were subsequently eroded away during early Ordovician time leaving the crest of the arch almost completely bare of Cambrian sedimentary rocks. The focus of exploration of the Cambrian plays is therefore restricted to the basins bordering the arch, with all of Ontario's Cambrian production to date occurring from rocks in the Appalachian Basin (Figure 3).

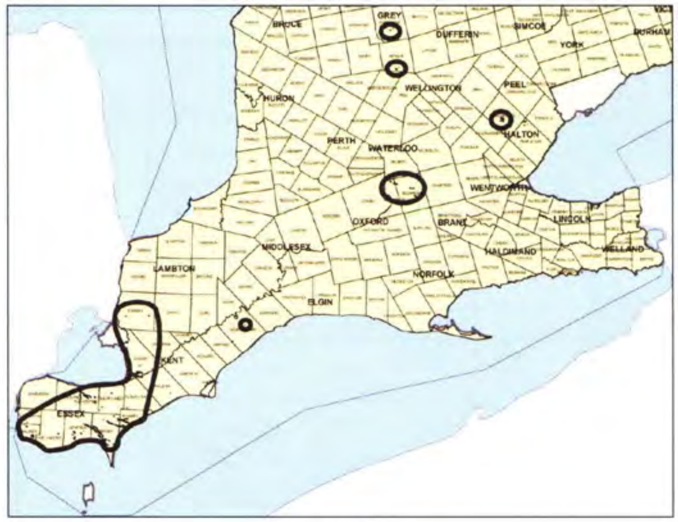
Cambrian reservoirs occur as 1.) structural traps associated with faulting and 2.) stratigraphic traps along the Cambrian sub-crop edge (Figure 4). Structural traps occur where fault blocks of porous and permeable Cambrian sandstones and sandy dolostones are juxtaposed against the overlying less permeable Ordovician shales and limestones. Stratigraphic traps occur where Cambrian sedimentary rocks are truncated or pinch out up-dip along both sides of the arch in the Michigan and Appalachian basins. Overlying Middle Ordovician shales and limestones provide a cap rock.

Discovered pool sizes range up to a maximum of 1.8 MMbbl of oil and 31 Bcf of natural gas at depths ranging from 700 to 1,200 m. A total of only 1,050 wells have been drilled to test Cambrian targets to the end of 2007 in a prospective area of 48,000 sq. km. Of the 22 Cambrian pools discovered in southern Ontario since 1923, 11 are still active.

There is still considerable potential for the Cambrian in Ontario. Bailey Geological Services Ltd. and Cochrane estimated the potential reserves in the stratigraphic pinch-out type play to be 180 Bcf of gas and 19.1 MMbbl of oil, and for the structural play, 42 Bcf of gas and 112.3 MMbbl of oil. However, by the end of 2006, only 5.2 MMbbl of oil and 30 Bcf of gas had been produced from both play types combined. Although the Michigan side of the arch has not produced any commercial quantities of oil or gas, favourable trapping conditions exist. Exploration strategies need to incorporate mapping of the Cambrian erosional limit to assist in locating future prospects.

A recent study also suggests that some of the sandstones mapped as Cambrian in the pinch-out play are actually a sandy facies of the Middle Ordovician Shadow Lake Formation. More oil and gas may be trapped in isolated lenses of Shadow Lake sands preserved in depressions on the crest of the Algonquin Arch, and would constitute a new play type. ▶

Cambrian Play



Ordovician Play

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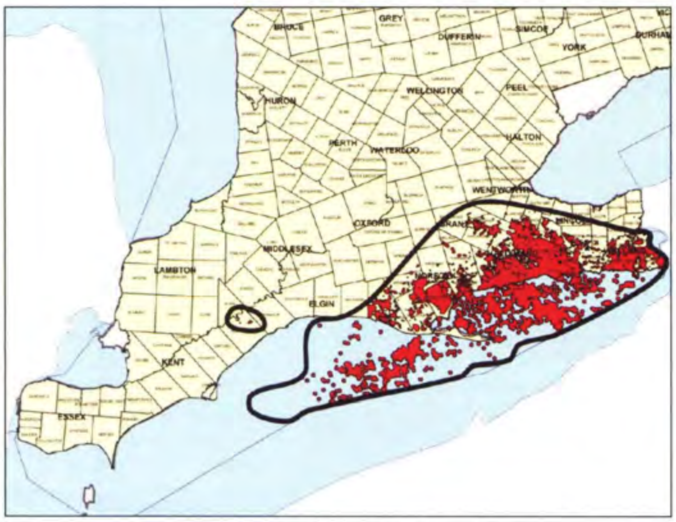
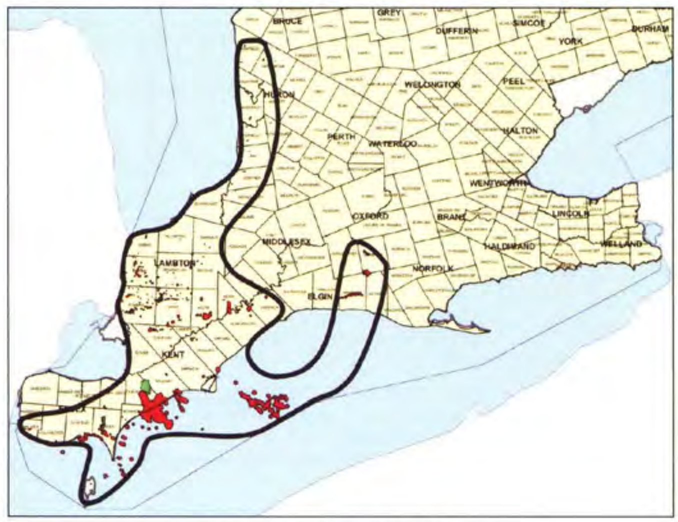


Silurian - Sandstone Play



Silurian - Salina - Guelph Play

Devonian Play

Interval	**Cumulative Production through 2006**			
	OIL (m3)	OIL (bbls)	GAS (x1000 m3)	Bcf
DEV	7,035,308	44,250,756	0	0
SAL	2,285,983	14,378,400	22,806,196	805.4
CLI	7,520	47,304	11,055,927	390.4
ORD	3,536,097	22,241,382	1,134,633	40.1
CAM	828,475	5,210,955	844,943	29.8
Total	13,693,383	86,128,797	35,841,700	1,265.7

CREDIT: MNR

Table 1: Cumulative oil and gas production in Ontario.

Figure 1: Approximate boundaries of principal oil and gas producing areas (past and current) in southwestern Ontario, with counties shown for reference.

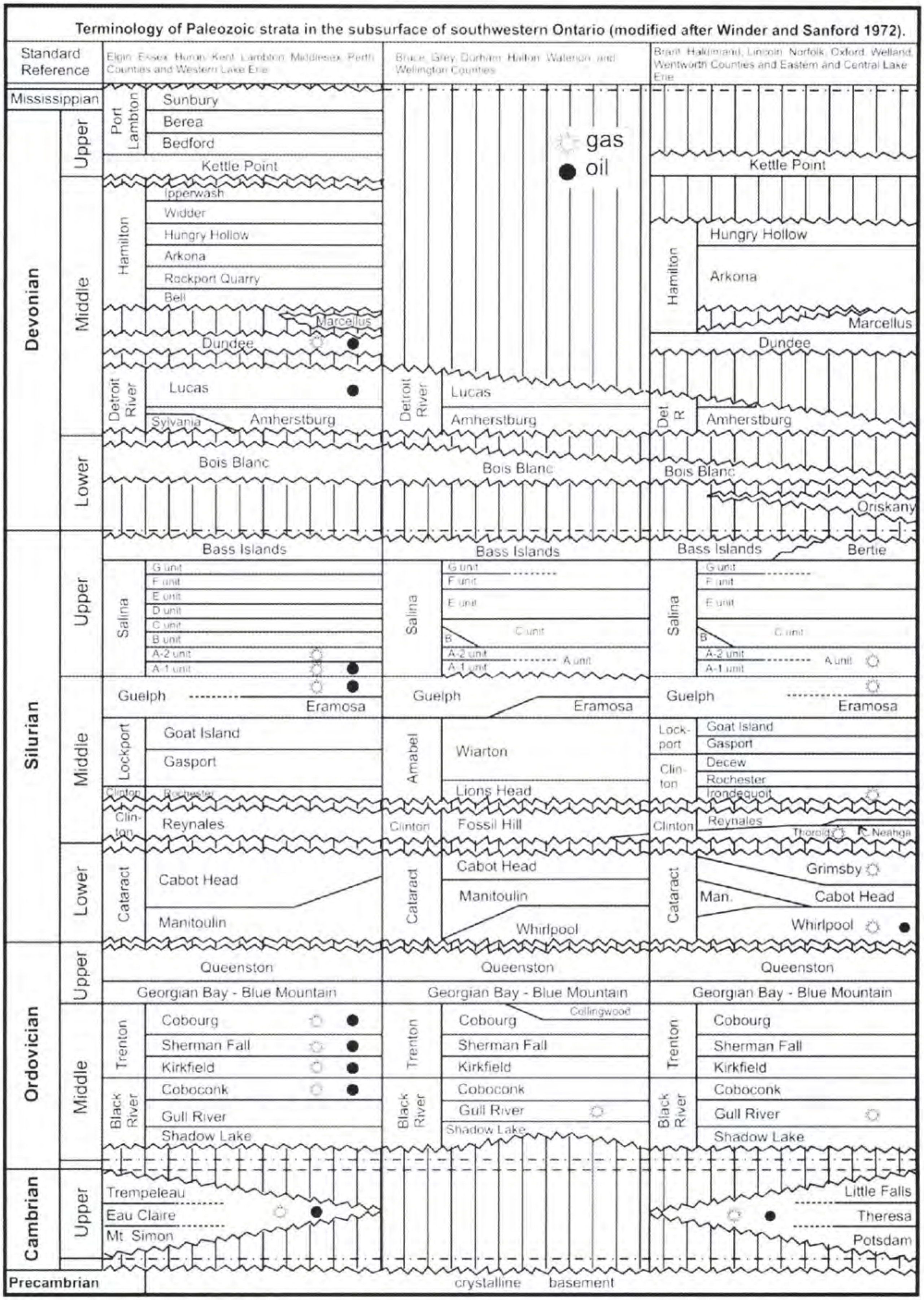


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Figure 2: Subsurface stratigraphy of southwestern Ontario.

Ordovician Play (ORD)

The Ordovician play in Ontario is a continuation of the prolific Trenton-Black River Group hydrothermal dolomite play of Ohio, Indiana, Pennsylvania, West Virginia, Michigan, and New York. The play has seen production of more than 485 MMbbl of oil and 1 Tcf of gas from Ohio and Indiana and more than 146 MMbbl of oil and 275 Tcf of gas in Michigan, most notably from the Albion-Scipio field. In New York State, the Trenton-Black River Group has produced over 154 Bcf of gas since 1995 and accounted for 80 per cent of the state's gas production in 2005.

Ordovician gas was first discovered in the late 1800s and was in commercial production at the turn of the century. Successful application of seismic techniques by Ontario-based exploration companies in the early 1980s led to a string of new discoveries and rejuvenated this play. A recent reassessment of Trenton-Black River oil and gas reserves estimated total potential reserves of 281 Bcf of gas and 39.7 MMbbl of oil in Ontario. The report was highly favourable for continued exploration because 85 per cent of the gas volume and 43 per cent of the oil volume has yet to be discovered.

Oil and gas in these pools are trapped in Middle Ordovician carbonates of the Trenton and Black River Groups where the regional limestones have been dolomitized and fractured adjacent to vertical wrench faults (Figure 5). The faults are believed to have provided a conduit for movement of hydrothermal waters, which subsequently altered the limestone to porous and permeable dolostone in the immediate vicinity of the faults. The resulting linear hydrothermal dolomite reservoirs reach up to 14 km in length and several hundred metres in width. The marine shales of the overlying Blue Mountain Formation provide a vertical cap to the reservoirs with unaltered limestones limiting their lateral extents. Porosities and permeabilities can vary widely, both laterally and vertically, resulting in pods and sweet spots of enhanced porosity and permeability.

Discovered pool sizes in Ontario range up to a maximum of 6.1 MMbbl of oil and 14 Bcf of natural gas at an average depth of 800 to 850 m. Approximately 1,150 wells have been drilled to date to test Ordovician targets in a prospective area of over 130,000 sq. km. Most of the recently drilled wells have been horizontal. Several ▶

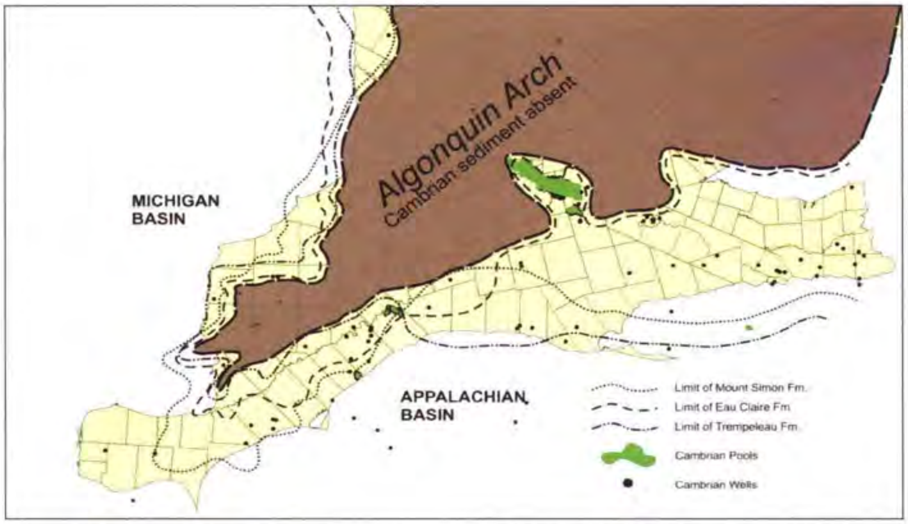

Figure 3: Subcrop limits of Cambrian sandstones in Ontario. Modified from Trevail, 1990.

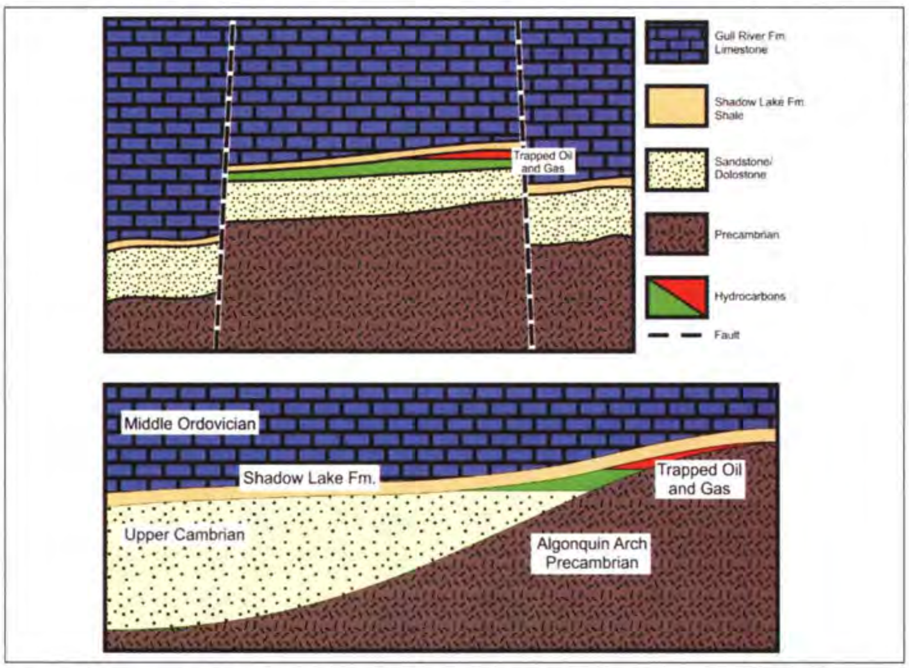

Figure 4: Trapping styles in Cambrian sandstones. Top, structural trap associated with faulting. Bottom, pinch-out style trap along Algonquin Arch. Modified from Bailey Geological Services Ltd. and Cochrane, 1984.

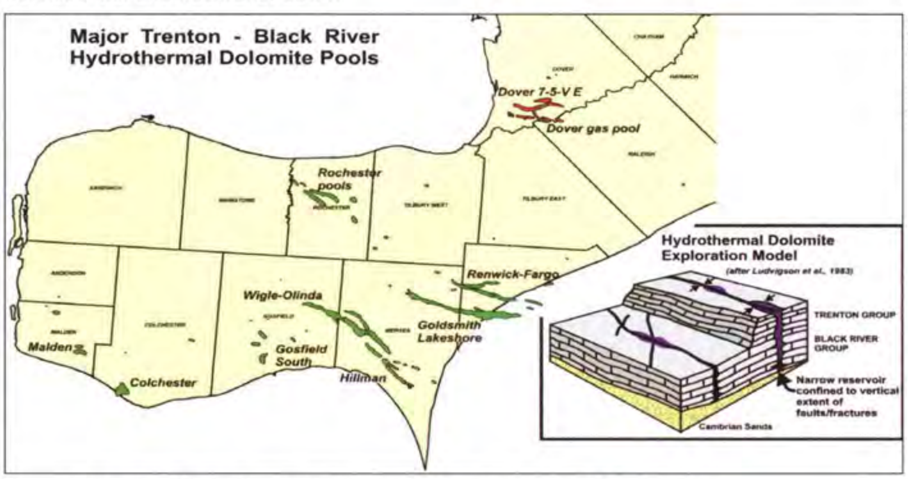

Figure 5: Trenton-Black River hydrothermal dolomite pools and exploration model. Modified from Golder Associates (2005).

CREDIT: MNR

Figure 6: Silurian sandstone subcrop edges in Ontario. Modified from Bailey Geological Services and Cochrane, 1986.

CREDIT: MNR

Figure 8: Reef belts in Ontario. Modified from Coniglio et al., 2003.

long-reach horizontal wells have been drilled since 1998 to exploit extensions of the pools beneath Lake Erie. Drilling for oil from wells located on the lake is not permitted.

Current exploration methods focus on 2-D and 3-D seismic. Typically a subtle but resolvable structural depression over the dolomitized zone can be seen in the seismic section, as well as vertical displacement of the underlying Precambrian crystalline basement rocks and a change in the seismic character occurring at the boundary between the highly porous dolomite and the unaltered limestone.

Silurian Sandstone Play (CLI)

Gas-prone sandstones of Lower to early Middle Silurian age constitute the oldest Silurian strata in southern Ontario. They underlie an extensive area beneath the Niagara peninsula and eastern and central Lake Erie (Figure 6), extending south through Pennsylvania, Ohio, and New York, and into northern Kentucky. The sandstones have been a historically important source of natural gas production since gas was first discovered in Welland Township in 1889. By the end of 2006, 236 Bcf of gas had been produced onshore and 152 Bcf had been produced from beneath Lake Erie, with all of the Lake Erie production coming since the early 1960s.

During early Silurian time, large amounts of sand, silt, and clay were eroded from highlands to the south and were deposited into the Appalachian Basin. Sediment grain sizes fine to the northwest into Ontario. Sand deposition was restricted to the Appalachian side of the Algonquin Arch. Within this wedge of clastic sediments, porous sands are generally confined to the Whirlpool Formation and the Grimsby and Thorold formations of the Clinton and Cataract Groups. They occur as extensive regional blankets and in channels and bars. Natural gas occurs wherever there is good porosity development, making this a classic continuous distribution style of play.

The continuous nature of the reservoir makes it impractical to define pool boundaries and size with any confidence. Average depth of the reservoirs ranges from as little as 150 m up to 500 m. Gross pay thickness varies from a few metres to several tens of metres in several pay zones, with some production occurring from the immediately overlying carbonates of the Irondequoit and Reynales formations (Figure 7).

The Silurian sandstone play is a mature play, but exploration and development drilling is continuing in areas not previously drilled. Bailey Geological Services and Cochrane estimated proven recoverable gas reserves of 260 Bcf from Lake Erie of which 106 Bcf of gas is yet to be produced.

Silurian Carbonate Play (SAL)

The late Middle to Upper Silurian saw a return to warm equatorial seas over what is now southern Ontario and Michigan. These conditions were ideal for the formation of barrier and patch reef complexes in the warm shallow waters of the Ontario Platform, and for the formation of towering pinnacle reefs in the deeper waters sloping into the Michigan Basin (Figure 8). In Ontario, these reefal carbonates are known as the Guelph Formation, while in Michigan they are known as

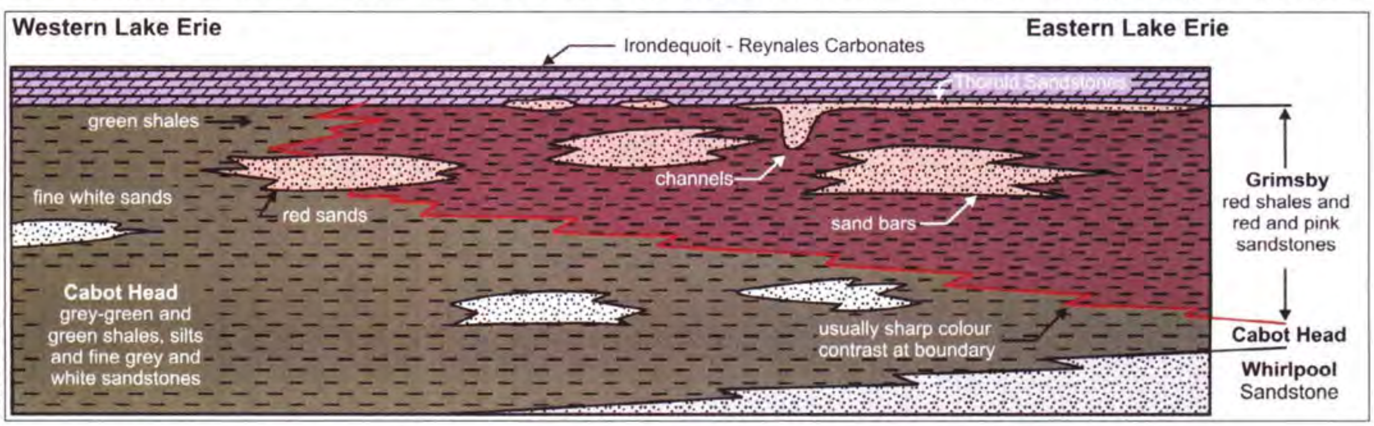

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Figure 7: Conceptual cross-section through the Cabot Head–Grimsby strata of eastern Lake Erie showing lateral facies changes. Modified from Bailey Geological Services and Cochrane, 1985.

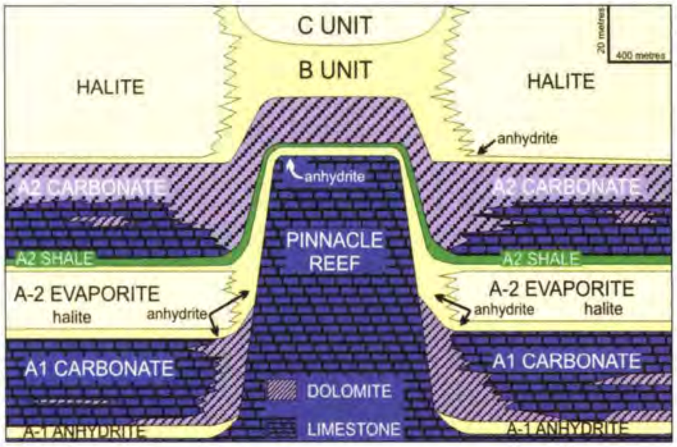

Figure 9: Summary of lower Salina Group units overlying and adjacent to Guelph Formation pinnacle reefs in Lambton County. Modified from Carter et al., 1994.

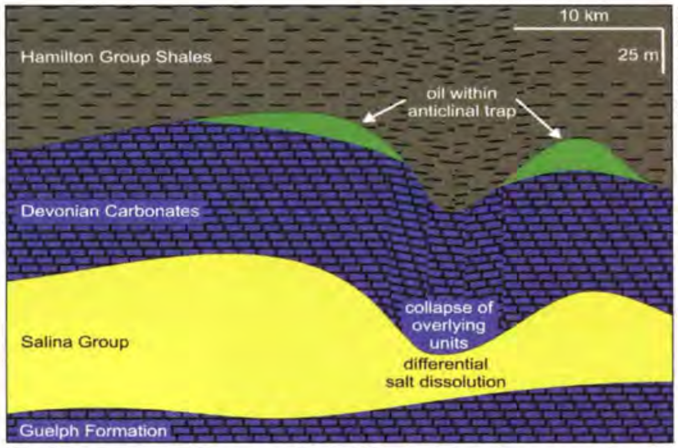

Figure 10: Conceptual model of Devonian structural traps formed by differential salt dissolution in the Salina Group.

the Niagaran. The Guelph reefs were subsequently buried by carbonates, evaporites, and minor shales of the Upper Silurian Salina Group (Figure 9). Hydrocarbon reservoirs occur within the Guelph Formation reefs and the A-1 Carbonate and A-2 Carbonate units of the Salina Group.

Within the Guelph Formation, three distinct reef types are seen. Pinnacle reefs are reef buildups greater than 50 m in height and extend through the subsequent deposition of A-1 carbonate. They occur in the pinnacle reef belt running through Lambton, Huron, and Bruce counties. Incipient reefs are less than 50 m in height and occur in the same reef belt. Patch reefs also exhibit less than 50 m of buildup but underlie very large geographic areas. Most of these reefs have been dolomitized. Oil and gas reservoirs occur within all three reef types and are sealed by impermeable anhydrites and carbonates of the overlying Salina A-2 and A-1 units.

Hydrocarbons also occur in dolomitized sections of the Salina A-1 and A-2 Carbonate units where porosity is developed and a trapping mechanism exists. Hydrocarbon traps most commonly occur on the upthrown side of regional faults and in structural drapes over reef buildups in the underlying Guelph Formation.

Discovered pool sizes range up to a maximum of 280 Bcf of natural gas in the patch reefs. Pinnacle reefs may contain up to 42 Bcf of natural gas and 1.6 MMbbl of oil. Depths range from 300 to 700 m. Thirty pinnacle reefs have been converted to natural gas storage with total working gas volume of 243 Bcf of natural gas. Approximately 5,000 wells have been drilled to date to test targets in these middle Silurian carbonate rocks.

This is a mature play with opportunities for further discoveries both on and offshore. There is potential for conversion of additional reefs for use as natural gas storage reservoirs. While early exploration methods focused on gravity anomalies to locate pinnacle reefs, both 2-D and 3-D seismic have become far more important in combination with careful study of drill cuttings samples to identify reef proximity indicators. Careful mapping of dolomitization patterns and thickness of the A-1 Carbonate Unit may also provide a useful guide to undiscovered pinnacle reefs.

Devonian Play (DEV)

In 1858, James Miller Williams dug the first commercial oil well in North America into shallow Middle Devonian carbonate rocks at Oil Springs, Ont. After 150 years, oil is still produced from this area. By the end of 2006, total cumulative oil production from the Middle Devonian totalled more than 44.3 MMbbl and oil continues to be produced from six active pools.

Oil production from Devonian rocks is confined to the Lucas and Dundee formations and a sandy facies of the Lucas locally referred to as the Columbus. Only minor gas production has been reported from the Devonian carbonates of Ontario, but there may be potential for shale gas in overlying black shales. The Devonian rocks are restricted to the western portion of southwestern Ontario. Reservoirs consist of fractured, microporous limestones, dolomitic siliciclastics, sand-rich limestones, and fractured limestones with no associated matrix porosity. All of the Devonian oil pools are located on structural domes, which are the result of differential dissolution of salt beds in the underlying Salina Group (Figure 10).

Discovered pool sizes range up to a maximum of 18.4 MMbbl of oil at depths not exceeding 150 m. Secondary recovery methods have proven very effective in extending the life of these older pools. Water injection in the Rodney Pool resulted in a 232 per cent increase in daily production and 55 per cent recovery of original in-place oil.

The Devonian oil reservoirs are a mature play and only two small pools have been discovered since the 1949 discovery of the Rodney Pool in the Columbus sands. This may be due more to a lack of modern exploration effort specifically targeting Devonian reservoirs rather than a lack of targets. The shallow depth and potentially large pool size make this play worthy of further investigation, despite its long history of exploitation. Detailed mapping and interpretation of subsurface structures will be key in locating these targets. OOG

For more information

Armstrong, D.K. and Carter. T.R. 2006. *An updated guide to the subsurface Paleozoic stratigraphy of southern Ontario*; Ontario Geological Survey, Open File Report 6191, 214 p.

Bailey Geological Services and Cochrane, R.O., 1984–1990. *Evaluation of the conventional and potential oil and gas reserves of Ontario*; Ontario Geological Survey, Open File Reports 5498, 5499, 5555, 5578, 5722.

Golder Associates, 2005. *Hydrocarbon resource assessment of the Trenton-Black River hydrothermal dolomite play in Ontario*; Ontario Oil, Gas and Salt Resources Library, 35 p., 27 figures, 8 tables, 11 cross-sections, 7 pool maps, 4 appendices.

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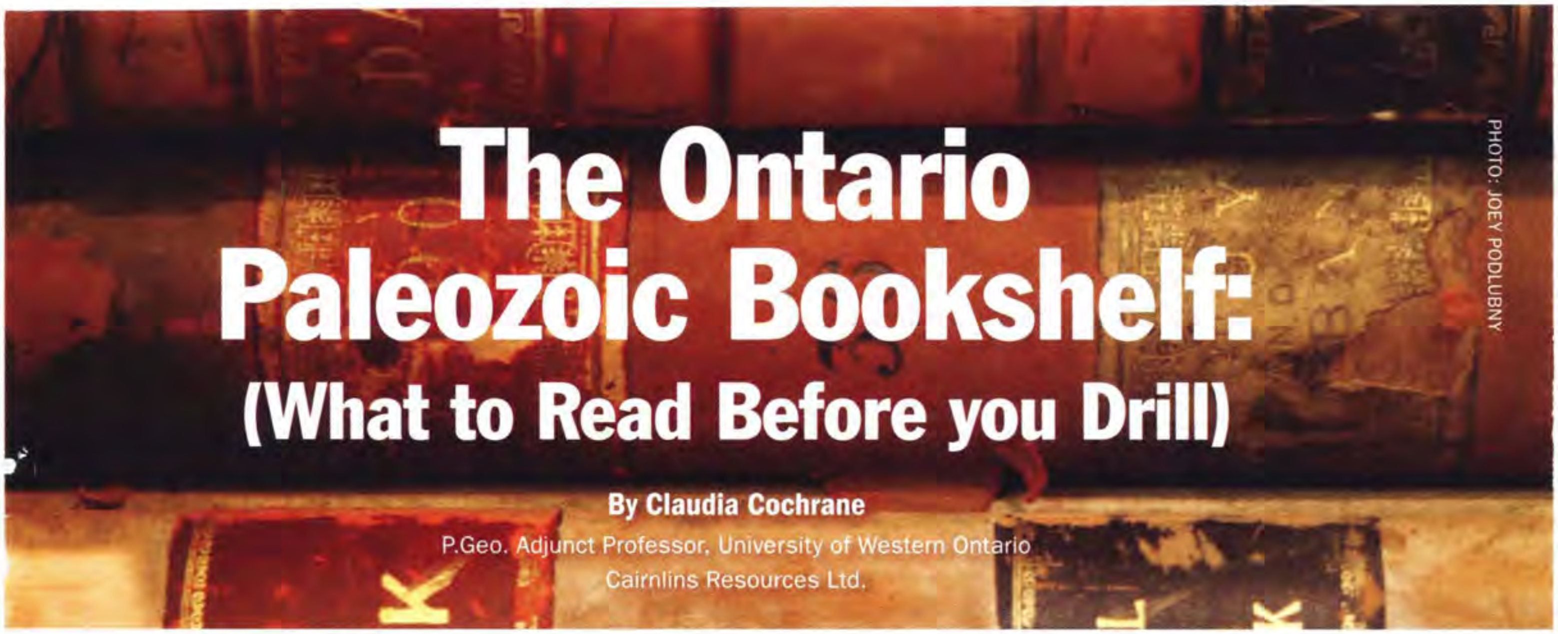

The Ontario Paleozoic Bookshelf: (What to Read Before you Drill)

PHOTO: JOEY PODLUBNY

By Claudia Cochrane

P.Geo. Adjunct Professor, University of Western Ontario

Cairnlins Resources Ltd.

You have just been informed that as of today you are in charge of the new Ontario Exploration Branch of your company and management eagerly awaits your first drilling prospect to be presented on this day next month. You know nothing about the geology of Ontario.

Where to start? There are hundreds, perhaps thousands of articles and books produced by industry and academia. Most are far too detailed for the non-specialist; many of the old classics have been superseded; some are out of print.

What follows is an entirely subjective review of the essential literature for petroleum geoscientists practicing in Ontario today. It's based on 40 years of experience—as a student, consultant, and teacher—usually in haste and always under pressure. There are many other excellent and useful documents out there. But these are the ones to which this geoscientist has returned, time after time and project after project. They should be enough to get you started.

Most, if not all the cited works are available at the Oil, Gas & Salt Resources (OGSR) Library located in London, Ont., where well-cutting samples, core, geophysical logs, and digitized sample data are stored as well. Many are also retained by university libraries.

For those who like to start with the big picture and ease slowly into the details, *Ontario Rocks* is a user-friendly, lavishly illustrated, armchair geological tour of Ontario. Nick Eyles, a University of Toronto professor, has directed this book largely to students and the general public. However, he has not scrimped on technical explanations, and although definitely outcrop oriented, the images are a beacon to sample-loggers mentally burrowing throughout the subsurface of Ontario.

After *Ontario Rocks*, serious geoscientists should consult the final word on the subject in *Geology of Ontario* put out by the Ontario Geological Survey. With two volumes of text and one of maps and charts, it will take up almost a foot of your bookshelf space. For our purposes, however, you can narrow your attention to Chapter 20, "The Paleozoic and Mesozoic Geology of Ontario." This tome pulls together information from many geological survey memoirs and maps published about specific areas over the years. It also updates the classic *Geology and Economic Minerals of Canada* and fleshes in the more general *Decade of North American Geology*.

For those who still think that Ontario sedimentary rocks result in simple layer-cake stratigraphy, Bruce Sanford and his colleagues from the Geological Survey of Canada have a surprise in store. *Plate Tectonics: A Possible Controlling Mechanism in the Development of Hydrocarbon Traps in Southwestern Ontario* was the first public recognition of the importance and complexity of faulting in southwestern Ontario. The authors established a conceptual framework for the faulting system across the whole area and tied it in with plate tectonics. The message, first delivered to a stunned audience at the Ontario Petroleum Institute in 1983, was subsequently published in the *Bulletin of Canadian Petroleum Geology*. This classic little paper, some 20 pages long, also provides an introduction to the major producing horizons in southwestern Ontario.

These same exploration horizons were later featured in an article entitled "Play by Play Action" written by a team of practicing geologists in the first OPI magazine published in 2004. They are reviewed once again in this issue:

1. Cambrian sandstones and dolomites
2. Middle Ordovician hydro-thermal dolomites
3. Lower Silurian sandstones
4. Silurian reefs and carbonates
5. Middle Devonian carbonates

That the fault system would be more elaborate in this part of Ontario should not really have been regarded as such a novelty. The Southwestern Ontario peninsula, bounded by the Great Lakes on three sides and the Precambrian Shield to the north, consists of a foreland basin on the east and an intracratonic basin on the west, separated by an arch down the centre. The whole area has been affected not only by the Appalachian tectonic activity described in *Plate Tectonics*, but by underlying Precambrian basement structures as well. Further light was shed on the faulting system in *Oil and Gas Accumulations and Basement Structures, Southern Ontario*.

By this time, one of the producing horizons may have caught your imagination and you are ready for a review in greater ▶

depth (no pun intended). Industry consultants Bruce Bailey and Robert Cochrane were commissioned by the Ontario Geological Survey to conduct the publication of a series of studies for the *Evaluation of the Conventional & Potential Oil & Gas Reserves (of the Cambrian, Ordovician, Silurian and Devonian) of Ontario* in which they describe and evaluate the geology and reserves of all the major fields, horizon by horizon.

All five producing formations are also well-illustrated in *Subsurface Geology of Southwestern Ontario: A Core Workshop*. This ambitious workshop was offered to members of the Eastern Section of the American Association of Petroleum Geologists at a conference hosted by the OPI. Terry Carter, subsurface geologist at the Petroleum Resources Centre of the Ministry of Natural Resources, coordinated the combined contributions from himself and other workers in the field.

For an introduction to the individual producing horizons, there are two major sources of references. Not surprisingly perhaps, the original series of "papers" published by the geologists at the Geological Survey of Canada in Ottawa during the 1950s and 1960s have stood the test of time and are still relevant and useful. For the Cambrian, consult Sanford & Quillian 1959; Sanford 1961 for the Ordovician; and Sanford 1965 and Koepke & Sanford 1966 for the Silurian carbonates and sandstones. More recently, at the dawn of the 21st century, Bruce Bailey has delivered a series of talks, summarizing a lifetime of knowledge obtained as a subsurface petrologist. These have been published in the *Proceedings of the Ontario Petroleum Institute*, more affectionately known as the "OPI Golden Volumes." He covered the Silurian reefs in 1999, 2000, and 2002; and the Cambrian in 2001, 2003, and 2005. In the same category, Leigh Smith, a professor at Queens University, delivered a most elegant paper to the OPI about cyclic sea level fluctuations illustrated by Silurian reefs, but applicable to other horizons as well.

And for the future, recognizing that a quarter-century has passed since the Bailey and Cochrane 1983–1990 editions, various bodies within the Ontario government have commendably launched an on-going project to modernize this work. As such, *Hydrocarbon Resource Assessment of the Trenton-Black River Hydrothermal Dolomite Play in Ontario* is the first in a series of welcome updated publications.

Core Workshops are very ambitious contributions to geological understanding anywhere, and are a most helpful introduction to the producing horizons. Ontario is no exception. Terry Carter and others produced a Core Workshop on Silurian reefs at the 1994 Geological Association of Canada Conference held in Waterloo, Ont. Bruce Bailey and Leigh Smith also covered Silurian reefs a few years later at the Eastern Section of the American Association of Petroleum Geologists hosted by the OPI in London. Ian Colquhoun prepared a Core Workshop for this conference as well, based on the findings of his recently defended Ph.D. thesis.

Once the theory has been absorbed, a practical guide to the application of all that knowledge is most welcome. And in Ontario we have an excellent manual for that very purpose produced by Derek Armstrong from the Ontario Geological Survey and Terry Carter—*An Updated Guide to the Subsurface Paleozoic Stratigraphy of Southern Ontario*. This open file report has a discussion of each formation and a review of the nomenclature to update a classic lexicon originally written by Gordon Winder, from the University of Western Ontario. It has also updated a set of standard sample and log picks originally produced by Ron Beards while he was the Ministry of Natural Resources's subsurface geologist. Beards was assisted by Gordon Winder and other industry geologists. In a great leap forward for practicing geologists, with this new 2006 publication, each formation is now linked with referenced outcrop exposures, and a core, log, and well sample reference for on-the-spot consultation in the OGSR Library.

There are a couple of other papers that assist with mapping and interpreting data derived from the rocks. Ernest Brisco from Brisco & O'Rourke Land Surveyors presented a short and pithy explanation of the Ontario grid system to the OPI. It unravels the mysteries of our 200-acre units bounded by lot and concession lines, an older layout that differs from much of North America. More recently, Terry Carter and Arthur Castillo have provided a guide of how to use GIS and digital well data for 3-D subsurface mapping in Ontario. We have come a long way since the first subsurface computer maps of southwestern Ontario were generated at the University of Western Ontario by Ph.D. student Robert Brigham. At that time, the data was recorded on punched cards and the information saved on a magnetic computer tape. Nonetheless, he produced some excellent contour maps, period by period, that revealed the broad subsurface structure of the whole area.

And finally, going on the premise that the best geologists are the ones who see the most rocks, it is time to rise from the armchair or the microscope and go out into the field. The best overall guide for all of southern Ontario, from basin to basin is still the first. In 1972, Gordon Winder and Bruce Sanford took delegates from all over the world who were attending the 24th International Geological Congress in Montreal out to see what southern Ontario had to offer. They explained the geology over the two basins and the arch, from stop to stop, all the way from Cambrian and Ordovician exposures in the Ottawa-Kingston area to the classic Devonian fossil-collecting sites of Lambton County.

More recently, some great field trip guidebooks for specific horizons have been published that delve a little more into the paleogeography and incorporate the most up-to-date scholarship. Terry Carter and his colleagues gave a demonstration of their ideas on basement structures with a field trip for the Waterloo GAC meeting. Derek Armstrong and W.R. Goodman revealed some excellent examples of Guelph reef exposures in the Bruce Peninsula at the Eastern Section of the American Association of Petroleum Geologists. Cam Tsujita, a paleontologist from the University of Western Ontario, and his colleagues have illustrated the paleogeography and paleoecology of those classic Devonian sites with beautiful interpretive drawings and lucid explanations. And finally, for the shear fun of it, the late Simon Haynes used to regularly take out energetic and thirsty OPI delegates to tour wineries and terrains in the Niagara Peninsula area. His guidebook, *Wine, Geology and Glaciolacustrine Soils of the Niagara Escarpment*, is still available from the OPI for those who wish to follow in his exuberant footsteps.

If I had to distill all the above into a two-week introduction in preparation for prospecting, I would start by *Ontario Rocks*; followed by a more diligent perusal of *Geology of Ontario*, with particular attention to the maps and charts. Then I would go out into the field taking the Winder and Sanford 1972 tour, supplemented by the above-mentioned period-specific guidebooks. Returning to London, I would ensconce myself in the Oil, Gas & Salt Resources Library to find out what the rocks have to tell me—with Armstrong & Carter 2006 as my mentor. OG

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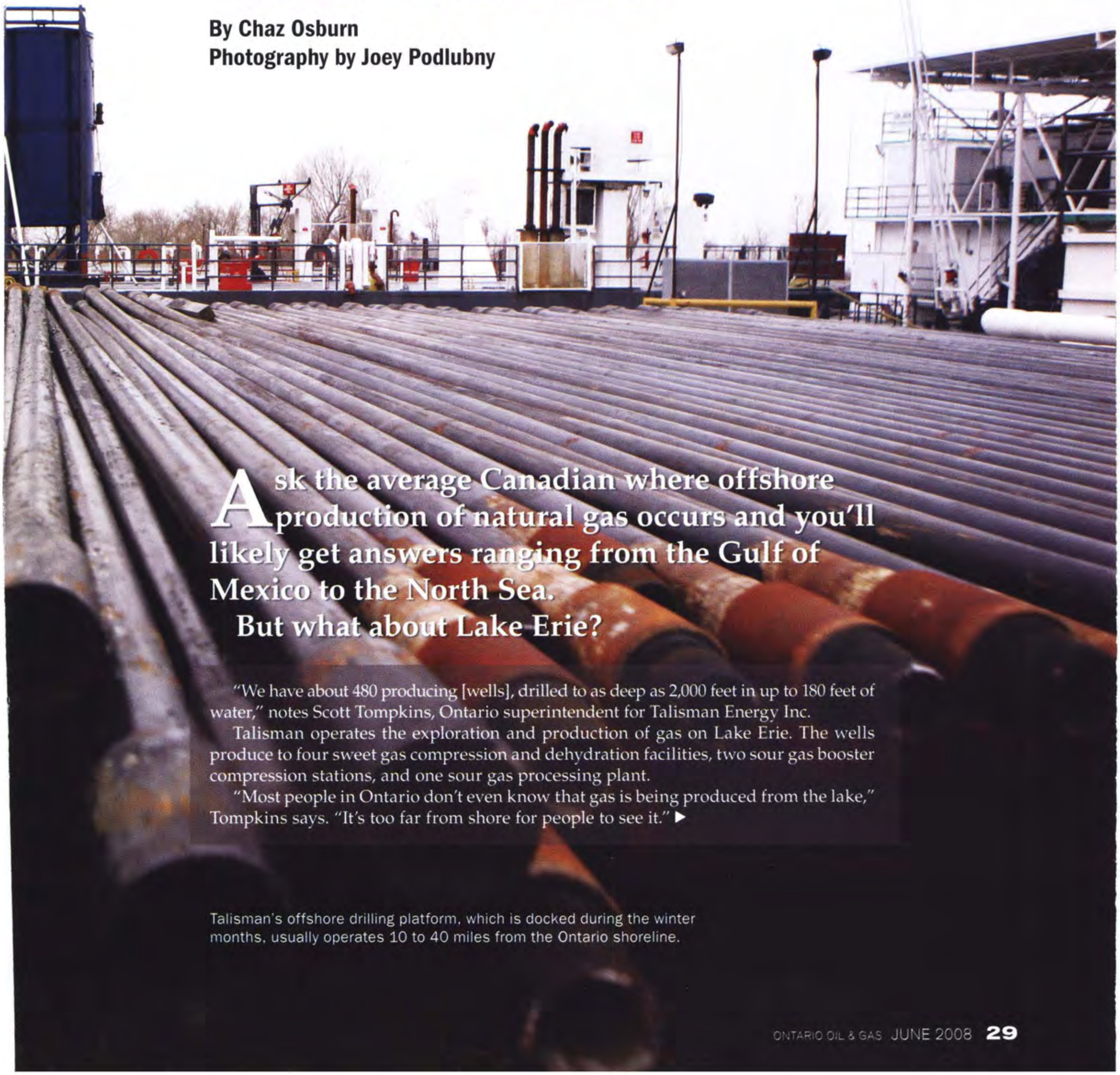
Lake Erie Helps Feed Ontario's Gas Needs

By Chaz Osburn
Photography by Joey Podlubny



Ask the average Canadian where offshore production of natural gas occurs and you'll likely get answers ranging from the Gulf of Mexico to the North Sea.

But what about Lake Erie?

"We have about 480 producing [wells], drilled to as deep as 2,000 feet in up to 180 feet of water," notes Scott Tompkins, Ontario superintendent for Talisman Energy Inc.

Talisman operates the exploration and production of gas on Lake Erie. The wells produce to four sweet gas compression and dehydration facilities, two sour gas booster compression stations, and one sour gas processing plant.

"Most people in Ontario don't even know that gas is being produced from the lake," Tompkins says. "It's too far from shore for people to see it." ▶

Talisman's offshore drilling platform, which is docked during the winter months, usually operates 10 to 40 miles from the Ontario shoreline.

Scott Tompkins.

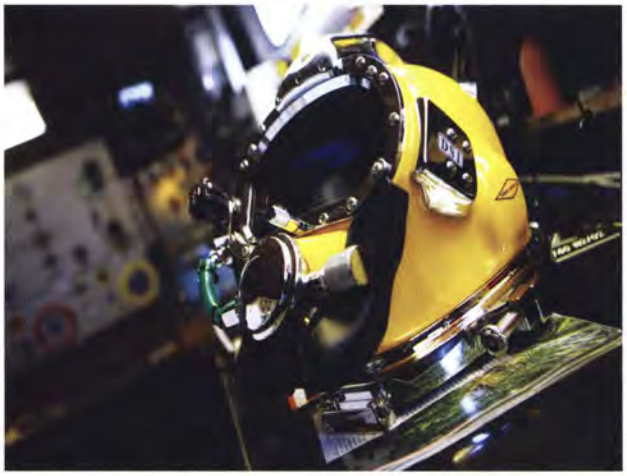
"Ontario's the biggest market in Canada for natural gas."

Scott Tompkins,
Ontario superintendent for Talisman Energy Inc.

The drilling primarily occurs 10 to 40 miles from the Ontario shoreline. A network of pipelines runs along the bottom of the lake—the shallowest of the five Great Lakes—connecting the wellheads to the various Talisman facilities on land. Wells are located in an area from about Port Alma, southwest of Chatham-Kent, to Port Colborne, which is about 40 km west of Fort Erie.

The wells are regularly inspected and maintained by divers who work for Talisman. Safety is the first concern—the divers, wearing helmets equipped with lights and television cameras, can do their work in the sometimes murky and muddy lake bottom.

Most of the gas produced from the lake is sent to Union Gas. "Ontario's the biggest market in Canada for natural gas," points out Tompkins, who has worked for Talisman for 27 years.



A helmet used by a diver who inspects offshore wells.

Talisman in Ontario

Key dates in Talisman Energy's history in the province:

1977: Pembina Exploration Ltd. begins operations in Ontario.

1980s: Pembina's Ontario operations grow through drilling and some small acquisitions.

1994: Pembina buys the assets of Telesis Oil and Gas, which more than doubles Pembina's staff and operating wells.

1997: Talisman buys Pembina.

SOURCE: TALISMAN ENERGY INC.

Ontario has a long history of producing natural gas. Onshore production in the province began in Welland County in the late 1860s. The first offshore gas production on Lake Erie began in the early 20th century. Since then about 2,000 wells are believed to have been drilled in the lake.

Initial offshore drilling involved platforms that were within easy reach of the shoreline, but by the 1940s, wells were drilled up to a mile from shore. Today, drilling is done with rigs mounted on barges.

Talisman operates one drilling barge, *Dr. Bob,* and one completion barge, *Miss Libby*. Generally the barges are sent out in mid- to late-May and return to shore in October. Drilling does not occur every year. In fact, this year only the completion barge will be sent out.

"Lake Erie's the only Great Lake with offshore gas production," observes Tompkins, adding that the United States does not produce gas from its side of the lake. As well, neither country drills for oil on any of the Great Lakes.

"There's no oil [production] offshore, no oil at all," Tompkins explains. "You're not allowed to produce oil offshore."

Talisman, however, does produce oil on land in Ontario. The company operates major oil producing areas in Essex and Kent counties, comprising 157 producing wells and four production-gathering facilities in Renwick, Goldsmith, Hillman, and Rochester. Operations are concentrated in the Wheatley, Leamington, and Belle River areas of Ontario, with some wells producing inside the town of Leamington, according to the company. Talisman is the largest oil and gas producer in Ontario, accounting for approximately 60 per cent of the province's daily production. OG

Ontario Oil, Gas & Salt Resources Library is an Important Resource

PHOTO: OPI

Richard E. Ostrowski
Facilities & Program Administrator, Ontario Oil, Gas & Salt Resources Library

PHOTO: OPI

The Ontario Oil, Gas & Salt Resources Library (OGSRL) is the home of Ontario's Paleozoic geology, housing rock samples from 15,000 drillings, field reports, and priceless publications portraying sedimentary sequence and intricate properties of discovered reservoirs. From shale gas to pinnacle reefs to hydrothermal conduits of the Ordovician to Cambrian sands, southern Ontario's geology is just as vibrant and promising as its infrastructure on the surface. Advances in information technology present us with opportunities to take advantage of geospatial mapping, enormous database compilation, reservoir calculations, and bringing vast amounts of paper data to life in digital formats.

The library offers a variety of digital information such as geological formation intervals, completion reports, production history (on-going project), geophysical logs, and oil, gas, and water analyses. All well spots are posted free of charge at www.ogsrlibrary.com in a comprehensive database describing each of the 25,000 wells. The web interface is also evolving as we strive to accommodate and educate the industry and public in general.

The OGSRL can trace its origins to the late 1800s, when the Geological Survey of Canada solicited voluntary submissions of drill cuttings and core from oil and gas wells drilled in Ontario and other parts of the country.

In recent years, the Ontario Geological Survey and the Ministry of Natural Resources funded two major projects. Thanks to those projects, the library is proud to offer publications that shed light from a more modern angle on existing discoveries and remaining potential. The first project focused on hydrothermal dolomite plays of the Ordovician age where numerous Ordovician pools were used as examples and related stratigraphy was illustrated with several cross-sections developed with the help of the library's staff and resources.

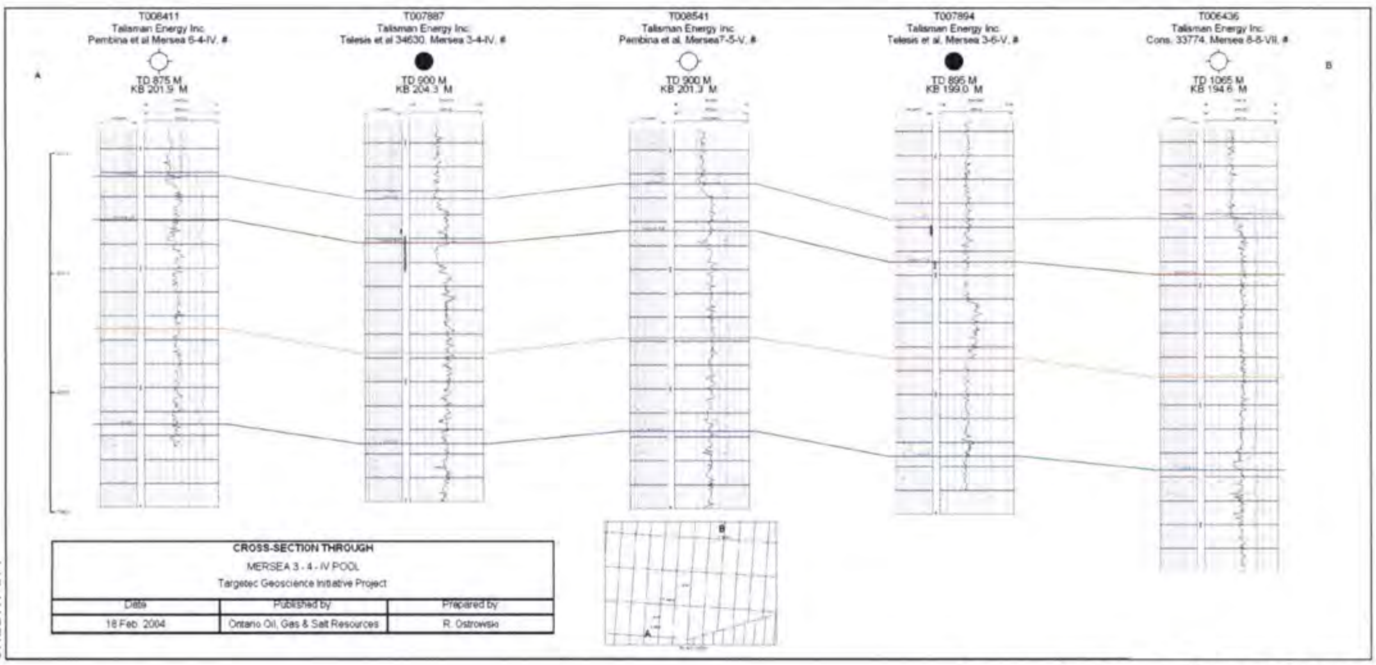
With a much broader scope, the second project evaluated the entire sedimentary sequence of southern Ontario and neatly described producing formations illustrated on regional-scale cross-sections. Due to the generosity of our members, the government, and our industry, we continue to receive support for data and publications development.

Members of the OGSRL benefit from discounts on facility usage, subsurface digital data, updates to Ontario Base Maps, and custom-built petroleum GIS layers such as pool boundaries and cumulative pool production data.

History

The OGSRL can trace its origins to the late 1800s, when the Geological Survey of Canada solicited voluntary submissions of drill cuttings and core from oil and gas wells drilled in Ontario and other parts of the country. This informal collection evolved into the establishment of a core and drill cuttings sample processing, storage, and study facility in Ottawa. In 1950, a similar facility was established in Calgary and all western Canada drill cuttings samples were transferred to Calgary. In 1971, the Ontario cores and drill cuttings samples were shipped to the new Petroleum Resources Laboratory in London, Ont. The lab was owned and operated by the Ontario Ministry of Natural Resources. In 1987, the collection was moved to its current location in a building located near Highway 401. In 2007, the facility underwent an expansion providing capacity for an estimated 30 years of continued collection of drill core and samples.

The Ontario Ministry of Natural Resources, pursuant to the *Oil, Gas and Salt Resources Act R.S.O. 1990*, formed the Trust. A Trust Agreement, dated Feb. 16, 1998, was signed with the original Trustee, the Ontario Oil, Gas & Salt Resources Corporation, and responsibilities for operation of the library were transferred to the Trustee. The Ontario Petroleum Institute (OPI) is the sole shareholder in the Ontario Oil, Gas & Salt Resources Corporation. Of significant importance, this partnership between the Ontario government and industry continues and grows. The committee overseeing the OGSRL encompasses the Trustee and membership from Salt Solution Mining Industry, Cavern Storage, Natural Gas Storage, Exploration of Oil and Natural Gas, and Consultants to the industry.



CREDIT: OPI

Cross-section through, Mersea 3-4-IV pool.

OGSRL Top 10

Top 10 reasons to contact the Ontario Oil, Gas & Salt Resources Library

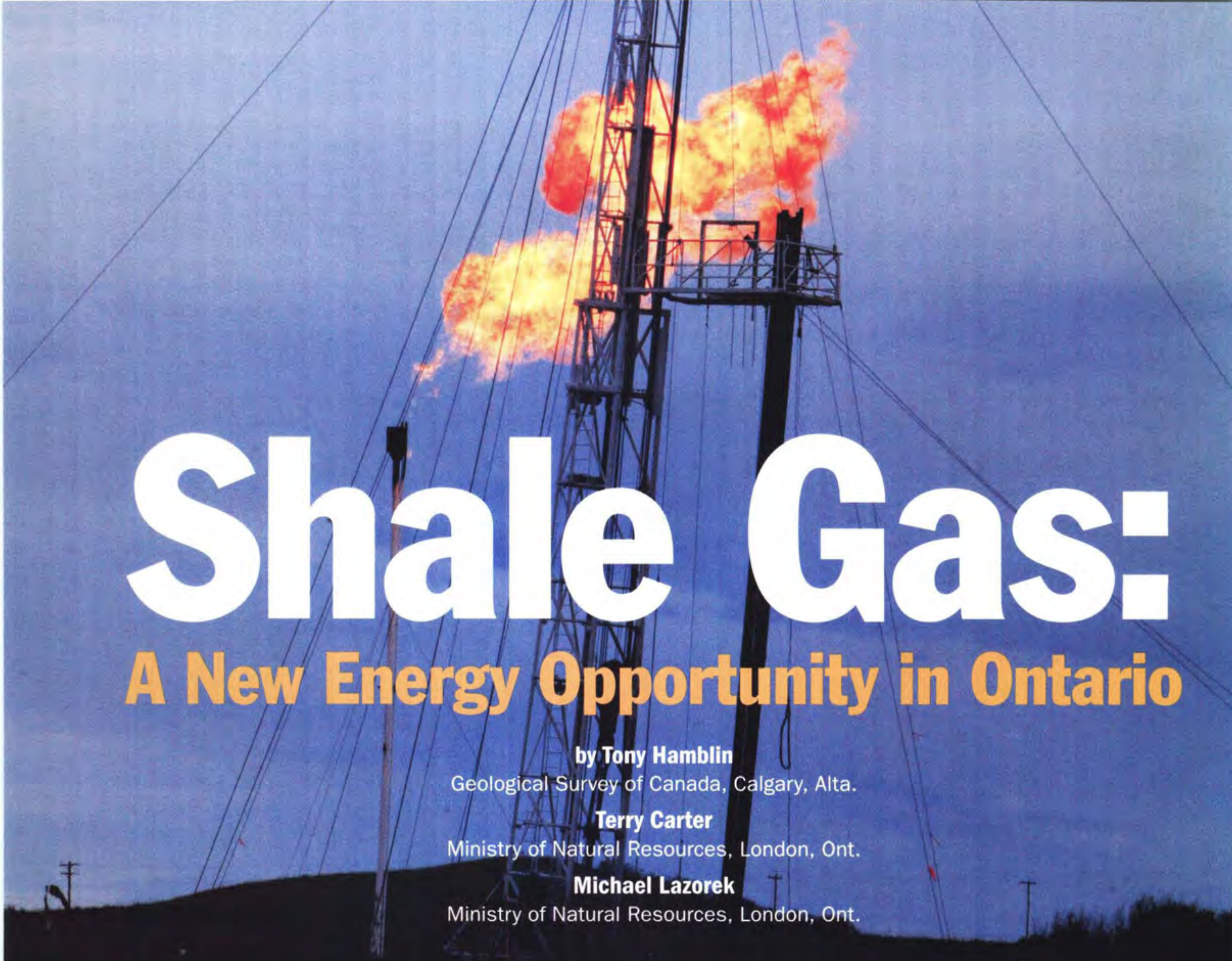
1. Unique, one of a kind facility in all of Ontario, housing sedimentary geology data
2. Core and drill cuttings from 15,000 holes
3. Digital geology, geophysics, and production data
4. Publications on reservoir characteristics
5. Government liaison and joint project undertaking
6. Knowledgeable staff—management, geospatial, database, and geology
7. Exceptional service and unique membership benefits
8. Website development into a comprehensive resource
9. Exposure and promotion at all Eastern Section Meetings of the American Association of Petroleum Geologists
10. Exciting perspectives on undiscovered potential resources of southern Ontario

Focus of membership

The Trust focuses on three geographical markets: Ontario, Alberta, and the Midwestern and Northeastern United States. The target client is usually the operator of oil, gas, solution mining, natural gas storage, oilfield fluid disposal or petroleum product storage wells in the province of Ontario, or a consultant providing services to these operators. Outside of Ontario, the target clients are resource exploration companies considering new locations for investment or activity. Providing information services to the oil, gas, salt, and hydrocarbon storage and resources industries, both to operators, service providers, and consultants, continues to be the principal focus.

Clients obtain data and information principally through personal visits to the OGSRL, by telephone inquiry, and most often via email. Six staff members are there to answer your questions, and on-site equipment and a lab are available to make your research convenient while visiting the starting place for your exploration in Ontario.

As more and more information is available in digital form, the Internet becomes more important as a distribution method. Digital files are mailed out on CD, emailed over the Internet, or more commonly downloaded from the OGSRL website. Content on the library's website will continue to grow and will remain a priority for publishing and marketing new information and presenting existing information in more accessible formats. O&G



Shale Gas:

A New Energy Opportunity in Ontario

by Tony Hamblin
Geological Survey of Canada, Calgary, Alta.

Terry Carter
Ministry of Natural Resources, London, Ont.

Michael Lazorek
Ministry of Natural Resources, London, Ont.

Shale gas plays in the United States have attracted a lot of attention in the oil and gas industry recently and have become one of the hottest gas plays in North America. The Barnett shale in the Fort Worth Basin in Texas has been the most recent focus of activity and, according to a 2006 article in the *Oil and Gas Investor*, gross gas production from the Barnett exceeds one billion cubic feet per day (Bcf/d). Although the Barnett has garnered most of the recent attention, natural gas is produced from shales in several other basins in North America. Canadian companies are beginning to take a serious look at shale gas potential in Canada. And, according to a recent report by the Geological Survey of Canada, some of the best prospects in Canada may be located in Ontario.

Shale gas production has a surprisingly long and successful history in the United States dating back to 1821. It emerged as a viable modern-play concept after major tax incentives in the 1980s, and now represents approximately four per cent of that nation's supply from thousands of wells in several major producing plays in mature basins. Each play type has a distinctive set of geological characteristics and has required considerable study, effort, and expense to develop successful exploitation techniques. This experience can be used as a guide for Canadian explorationists.

WHAT IS SHALE GAS?

Shale gas is an unconventional energy resource. Unconventional resources are typically of large volumes, dispersed pervasively over wide geographic areas within reservoir rocks of low and/or variable permeability that are closely related to the source rocks. They are characterized by low flow rates, long production life, and unusual pressure regimes. Exploration and exploitation of unconventional gas resources commonly require large land positions, greater drilling densities, increased surface infrastructure, and greater technological investment.

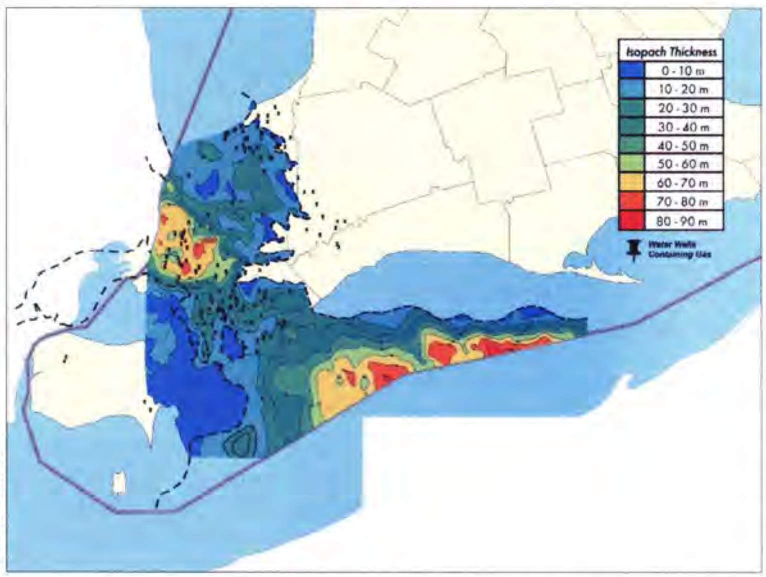
In simple terms, shale gas is natural gas produced from reservoir rocks composed dominantly of shale. The shales form self-enclosed petroleum systems where source, reservoir, seal, and trap are all present in the same thick, shaley succession. The gas may be stored by adsorption onto insoluble organic matter or high-surface-area clays in the shale itself, trapped in fractures in the shale, or trapped in pore spaces in the shale or in associated interbeds of coarser-grained more porous sediments. The volume of adsorbed gas increases with the amount of organic matter and surface area. Therefore, organic-rich fine-grained rocks are the most likely hosts. Subnormal reservoir pressures, or overpressures, are common. The contained gas may result from any combination of three sources: primary thermogenic decomposition of organic matter, secondary thermogenic cracking of oil, or biogenic microbial decomposition of organic matter.

Initial flows may be high but short-lived (tapping the "free" gas residing in fractures and matrix porosity), followed by a very long history of lower flow rates (slowly accessing the gas adsorbed onto micro-porous clays and organics). Fracture stimulation is almost always required to achieve commercial production. Ultimate recovery rates may be rather low (about 20 per cent) but the original initial gas in place may be enormous.

Shale is the most common lithology in many sedimentary basins. Consequently, gas shales represent a potentially large, technically recoverable gas resource. As production from conventional reservoirs in North America continuously declines in the future, gas from unconventional reservoirs may become increasingly important for energy security in the future.

History of shale gas exploration in U.S.

The first known shale gas production in North America occurred in 1821 when local townsfolk drilled a well 8.3 m deep at Fredonia, N.Y., after the accidental ignition of a gas seepage, making this the oldest hydrocarbon play in North America. The well was completed in the Upper Devonian Dunkirk shale and the gas piped through hollowed logs to light the nearby houses. Shale gas development spread westward along the southern shore of Lake Erie into Ohio, Illinois, and Kentucky during the 1860s to 1880s. Throughout these decades, there was no attempt to exploit the correlative rocks across the border in Ontario.



CREDIT: MNR

This map was generated from more than 3,800 subsurface picks from the Ontario Oil, Gas, and Salt resources database. More than 180 occurences of surface gas in the shallow drift.

In 1976, the U.S. Department of Energy initiated its Eastern Gas Shale Project and in 1980, introduced the Section 29 tax credit to stimulate development of unconventional hydrocarbon resources. This quickly led to successful exploration and significant production of shale gas in the Appalachian, Michigan, and Illinois basins (Antrim, Ohio, New Albany, and Chattanooga shales), and in the Fort Worth, Texas, (Barnett shale) and San Juan (Lewis shale) basins. Although the tax credit expired in 1992, exploitation has continued at a high rate, and these three areas still represent the primary shale gas production in North America. Approximately 36,000 wells have now been drilled in the United States for shale gas targets.

The Antrim shale in northern Michigan is the most prolific shale gas play in the eastern United States and is the lithologic and stratigraphic equivalent of the Kettle Point formation in southern Ontario. Over 2.5 trillion cubic feet (Tcf) of natural gas has been produced to date from over 8,000 wells. Production in 2006 totalled 140 Bcf. Most production is from depths of 100 to 500 m. Total in-place resource estimates for the Antrim range from 35 to 76 Tcf, with an additional 86 to 160 Tcf for the equivalent Ohio/New Albany shales. Much of the gas generated within the Antrim is of biogenic (bacterial) origin, has been adsorbed onto the organic constituents, and produces through a complex fracture network. Because the gas is biogenic, gas content correlates directly with Total Organic Carbon (TOC). The gas is predominantly methane with modest amounts of CO_2 and was generated in the shallow groundwater environment during the last 22,000 years by bacterial consumption of the organic matter contained in the shale. The reservoir is continually replenishing itself.

Characteristics of a good shale gas play

Obviously, significant organic content and significant permeability are the two basic factors that must be present for large resources to be created and produced. Most shales retain good natural porosity, even at depth, allowing good storage capacity. Organic content can be as low as the 1 per cent TOC range, but certainly values greater than the 3 per cent TOC range are preferable. Fine grained deposits are the most common sedimentary rocks, but thicknesses of 10 m or more are required. Thicknesses of hundreds of metres of shaley strata are preferable, but organic-rich, productive intervals of only tens of metres are necessary to be commercially successful, depending on local depth. Thermal maturity can be low, but only in special circumstances where fractured shales exist at surface within the zone of biogenic methanogenesis. For most cases, thermal maturity at or above the oil window, and into the gas window, is preferred.

Significant gas content must be established, preferably above 40 standard cubic feet per ton. Significant natural permeability, above that normally offered by the original shales, should be present in the form of fractures or thin siltstone/bioclastic carrier beds. Alternatively, it must be easily created in brittle rocks through fracture stimulation. Depths may be anywhere from surface to several thousand metres, although very shallow plays may require special circumstances and may yield water-wet biogenic gas from thermally immature strata. Deeper targets yield dry thermogenic gas from mature mudstones through more expensive drilling.

Despite the generalities discussed above, there is one clear lesson from the plays developed to date. Each potential shale gas play must be evaluated separately to find the correct balance of all the various factors, appraise the predictability, and properly assess its economic possibilities. ▶

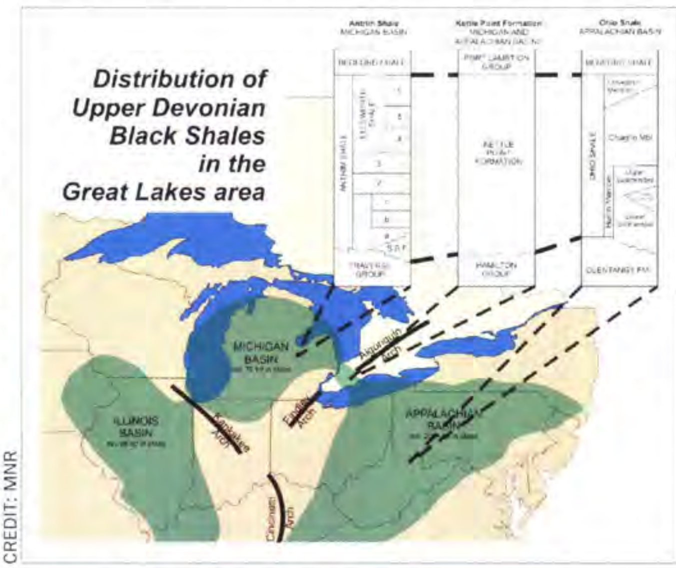
Where are the prospective areas in Ontario?

A recent report by the Geological Survey of Canada (Hamblin, 2006) has documented all the shaley strata in Canada that may be prospective sources of natural gas. Those judged to have the best potential in Ontario are the Collingwood/Blue Mountain, Kettle Point, and Marcellus shales, all located in southwestern Ontario.

Collingwood/Blue Mountain (Upper Ordovician)

The Upper Ordovician Collingwood member of the Lindsay formation and the lowermost 2 to 15 m of the overlying Blue Mountain Formation (Rouge River member) of southwestern Ontario are organic-rich mudstones with long histories of importance in petroleum geology. These two associated units are present over a large area of southern Ontario and are the stratigraphic equivalent of the Utica shales of northern New York State.

The Collingwood calcareous shales have been known to be petroliferous since the earliest reports of the Geological Survey of Canada and were the object of early attempts to process oil shales in the 1860s. An extensive program to evaluate the oil shale potential of the Collingwood was pursued by the Ontario Geological Survey in the 1980s. The Collingwood has TOC up to 11 per cent, is marginally mature, and has likely sourced some oils that are reservoired in Cambrian and Ordovician traps in southern Ontario.



Distribution of Upper Devonian black shales and nomenclature modified from Russell, 1985. Total gas in place estimates from Martini et. al., 2003.

The overlying Blue Mountain Formation is dominantly composed of soft, laminated, non-calcareous grey to dark grey shale up to 75 m thick. However, the lower 2 to 15 m of the formation, referred to as the Rouge River Member, are typically dark brownish and more organic-rich. This lower part of the Blue Mountain generally has TOC content of 1 to 5 per cent, and these strata are thermally mature.

A number of shallow gas wells were drilled in central southern Ontario in the mid-20th century and reportedly recovered significant flows of gas from the overlying Georgian Bay and Queenston units. Natural gas has been anecdotally reported from water wells in the greater Toronto area for decades, and a number of water wells in central southern Ontario produce water with gas from these strata.

Marcellus

The Marcellus Formation shale (late Middle Devonian age) comprises black bituminous shale, which occurs beneath glacial drift along the north shore of Lake Erie and in the subsurface beneath the central portion of the lake. The Marcellus is up to 25 m thick, averaging 17 m, in Ontario. It conformably but sharply overlies the Dundee carbonates, and is sharply overlain by glacial drift or the Hamilton Group grey shales in Ontario, New York, and Michigan.

Outcrops of Marcellus are not known anywhere in Ontario, but it appears to be present immediately beneath glacial drift and is likely exposed on the bottom of Lake Erie. TOC content is very variable, with average values in the 4 to 13 per cent range. The organic matter is marginally mature to mature right at the onset of oil generation. Nuisance gas shows are common in the uppermost few metres of the Marcellus where it subcrops beneath the glacial drift, suggesting the possibility of a biogenic gas play.

Kettle Point

The Upper Devonian Kettle Point Formation of southwestern Ontario is an organic-rich black shale that forms the bedrock beneath an area exceeding 4,000 sq. km both onshore and beneath Lake Erie and the southern tip of Lake Huron. Only three outcrops are known. It is stratigraphically and lithologically equivalent to the highly productive Antrim shale of adjacent Michigan, Ohio shale of Ohio, and New Albany shale of New York.

The Kettle Point is overlain over most of its outcrop area by glacial drift. Although the maximum known thickness is 105 m, the preserved thickness is generally much less, averaging about 28 m. The lower 10 m of the formation is famous for unusually large, spherical calcite concretions ("kettles") exposed at the type section at Kettle Point on the shore of Lake Huron. TOC values range from 3.6 to 15 per cent in the black shales. The Kettle Point is thermally immature throughout southwestern Ontario.

Early reports of the Geological Survey of Canada refer to the common seepage of natural gas from the thick sand and gravel deposits that overlie the Kettle Point Formation. Water well records commonly report natural gas in the groundwater in the same area and petroleum well records document gas shows in the upper few metres of the Kettle Point. This gas may be of shallow biogenic origin similar to gas produced from the Antrim shale in Michigan. Scientific studies to test this hypothesis are underway.

Summary

There is significant potential for a shale gas play in the organic-rich shales of southern Ontario. The best prospects may be for biogenic gas in the Kettle Point, Marcellus, and Collingwood/Blue Mountain, where these formations are directly overlain by glacial drift. Dry, thermogenic gas from greater depths may be present. Water well and petroleum well records document the occurrence of natural gas. But can it be commercially recovered? OG

Further reading

Hamblin, A.P. (2006). The "shale gas" concept in Canada: A preliminary inventory of possibilities; Geological Survey of Canada, Open File Report 5384, 103 p.

Oil and Gas Investor, January 2006. "Shale Gas."

Ontario's Role in Launching the Oil Industry

By Chaz Osburn

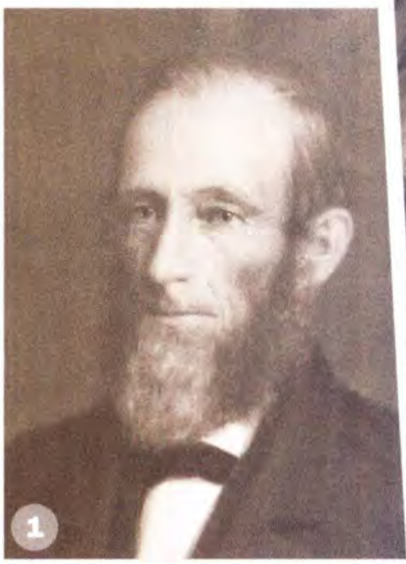
PHOTOS: OPI

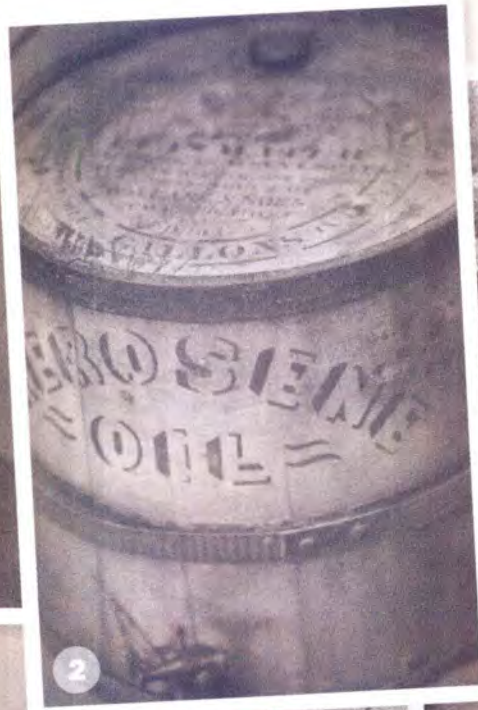
Ontario has a rich petroleum history, which traces its roots back 150 years, and includes notable events such as the well at Comber, which was drilled in November 1904 (main photo). A historical well, still producing today, with original pumpjack operated by a jerker-line system (inset).

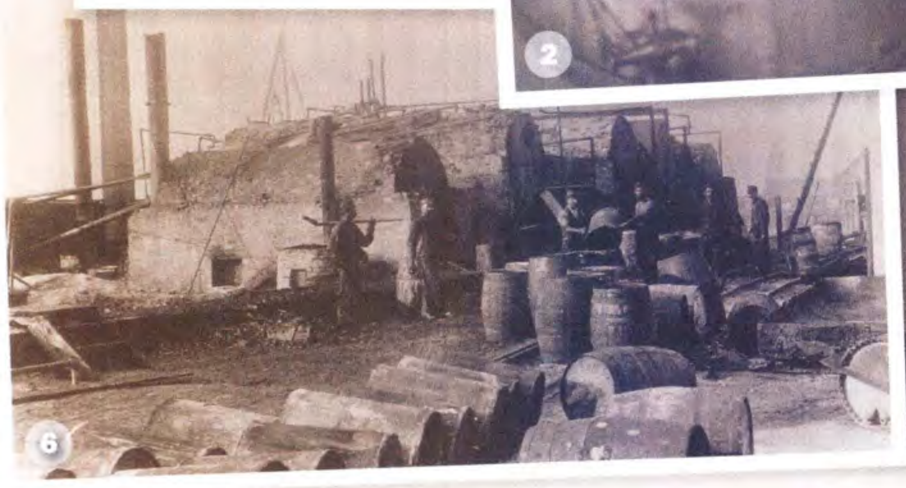
Ontario's importance in launching the petroleum industry 150 years ago cannot be understated. The list of oil firsts—first commercial oil well in North America, first petroleum company, first oil exchange, to name a few—is truly remarkable.

But to understand Ontario's role requires some background.

In the early to mid-19th century, there was no such thing as the incandescent light bulb, something we take for granted. Most people in North America relied on fires, candles, and lamps that burned whale oil (and later coal oil) to light their homes. Generally the light was dim. In some cases it was smoky and smelly. ▶







Whale oil was highly prized, but there were problems.

"Whale oil was hard to get," points out Connie Bell, manager of the Oil Museum of Canada near Oil Springs, Ont. Author-historian Earle Gray also notes that it was costly. "Whale oil had become prohibitively expensive—sperm oil in the United States fetched $1.77 a gallon in 1856—as sailors hunted whales to the edge of extinction," he writes in *Ontario's Petroleum Legacy: The Birth, Evolution and Challenges of a Global Industry*.

Enter Abraham Gesner of Nova Scotia. Gesner is credited with developing a process in the 1840s that refined coal, tar, and eventually oil into a fuel he called kerosene. Kerosene burned much brighter than candles or even whale oil.

While the popularity and production of kerosene took off, two brothers—Charles and Henry Tripp—arrived in Enniskillen Township in Lambton County, Ont., in the 1850s to mine bitumen to produce asphalt for paving streets and sealing ships.

Enniskillen Township was in what was then western Canada. The countryside was flat, swampy, and overgrown with trees, but early surveys showed it contained "gum beds," or bitumen deposits.

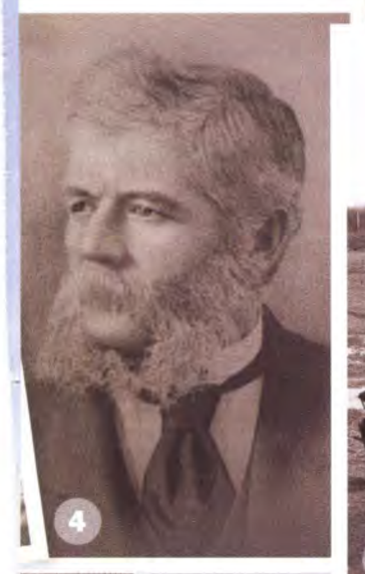
"The barrier that faced settlers was a surface of impervious clay, 14 metres to 24 metres thick, deposited as glacial drift or ground moraine near the end of the last Ice Age about 18,000 years ago," according to *Ontario's Petroleum Legacy*. "When it rained, the water could not soak into the ground. The land was so flat that the water had nowhere to run, except at the edges of Bear Creek that cut across the northern part of the township and Black Creek to the south."

The Tripps are worth mentioning for several reasons. They formed the world's first oil company, the International Mining and Manufacturing Co., in 1854. Charles Tripp, Gray writes, produced asphalt "by boiling the bitumen in open cast-iron pots. Tripp sent a 1,450-pound sample of the asphalt to the Hamilton Gas Company, which on February 7, 1855 reported that this yielded 4,600 cubic feet of gas (130 cubic metres) in three hours, and that the gas provided 10 per cent to 15 per cent more illumination than gas distilled from coal."

Also that year, Gray continues, a sample of the asphalt "was included in Canada's exhibits at the Universal Exhibition at Paris and received an honourable mention. Better yet, Tripp's company received a large order for asphalt to help pave the streets of Paris."

However, Charles Tripp was not a good businessman and, looking for investors in his oil company, approached a Hamilton, Ont., entrepreneur named James Miller Williams. Williams had found success first by building carriages—the Cadillac of carriages in those days—and then railway cars, and was apparently looking for a new venture at the time.

"It was almost inevitable that Tripp, in need of investors for his new International Mining and Manufacturing Company,



1. Early oil pioneer John Fairbank went on to become Canada's largest oil producer in the early 20th century.
2. An early kerosene barrel on display at the Oil Museum of Canada.
3. The Licks No. 1 well in Kent County was the first big well in the field at 200 bbl/d. The well was spud in September 1862 and completed in May 1863.
4. James Miller Williams dug the first oil well in North America.
5. The Shaw well, located at the tripod in the foreground, was the site of Canada's first oil gusher.
6. Reducing stills in Petrolia in the 19th century.
7. Early petroleum products on display at the Oil Museum of Canada.
8. Early oil deliveries were made with horse-drawn tanks.

PHOTOS: OPI, JOEY PODLUBNY

would make a pitch to Williams, but the shrewd carriage maker was probably too cautious to put money into that particular vehicle," Gray writes in his book.

Gray explains that Williams saw the potential in distilling bitumen into lamp oil, acquired property near Oil Springs, and dug his first well in 1858 (Gray believes Williams discovered oil no later than July 1858) at the site of what is now the Oil Museum of Canada. Accounts vary, but the well is believed to have yielded crude around 14 ft deep.

But Williams did more than just dig a well. "He found the oil. He refined the oil. He sold the oil," says Bell.

Writes Gray: "In 1859, the year after his discovery, he reportedly drilled what was then a deep oil well, the same year that 'Colonel' Edwin Drake brought in the first American commercial oil well at Titusville, Pennsylvania. The Williams well was twice as deep as Drake's. To drill it, Williams made the first oil-field application of the spring-pole drilling rig to thump, thump, thump a heavy chisel-type drill bit and sinker bar through the ground."

The spring-pole rig was truly innovative. It consisted of a tree, 15 to 20 ft long, anchored at the ground one end and resting about a third of its length on a Y-shaped trunk. From the thin end of the tree, men tied a rope and attached to it a heavy chisel. Also tied to the rope, sometimes in a triangular pattern, were other ropes with stirrups. Gray writes that the "drillers kicked down then allowed the pole to spring back, pounding the bit through the hole. The stirrups were soon replaced by treadles, on which drillers rocked back and forth to lower and spring back the spring pole."

Eventually steel cable replaced rope, "leading to the cable-tool rigs that drilled nearly all of the early American oil wells until the first decades of the 20th century," Gray notes.

By 1861, Gray continues, Williams had five oil wells and was referring to his venture as the Canadian Oil Co. Williams went on to become a respected businessman and would eventually represent Hamilton in the Legislative Assembly of Ontario. But despite all those accomplishments, digging that first well forever sealed Williams' place not only in Canada's history, but that of the world as well.

Perhaps no one summarizes Williams' legacy better than Gray's *Ontario's Petroleum Legacy*:

"To classify the 1858 well dug by James Miller Williams as simply North America's first commercial oil well is to understate vastly the significance. Miller, of course, did more than dig an oil well: he established the first successful oil producing, refining, and marketing business. Nowhere in the world before 1858 was there a sustained and integrated petroleum industry. It would rise to become the world's biggest business in much of the 20th century."

As oil prices continue to skyrocket, it could be the world's biggest business for quite some time. O&G

TIMELINE: OIL FIRSTS

1830s...

1834
World's first recorded purchase of a property for its oil reserves.

1850s...

1852
World's first petroleum company established.

1858
First commercial oil well in North America is dug in Enniskillen Township in Lambton County, Ont. World's first speculative oil boom begins.

1859
First oil periodical in Canada established.

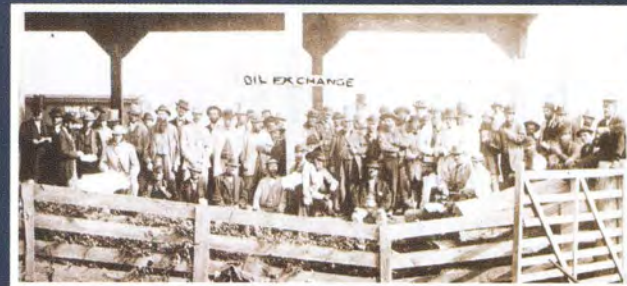


PHOTO: OPI

1860s-90s

1860
Canada's first successful oil well drilled. World's first oil exchange opens for trading.

1862
Canada's first oil gusher. Canada's second oil boom begins.

1863
John Fairbanks invents the jerker-line system to pump multiple wells.

PHOTO: JOEY PODLUBNY

1866
First well "torpedoed" with nitroglycerine in Canada.

1880
Founding of Imperial Oil refineries in London and Petrolia.

1891
Frasch Process, a method for removing sulphur from oil that was developed by German-American chemist Herman Frasch while working in Ontario, is patented.

1910s...

1913
First offshore drilling for natural gas on Lake Erie.

1914
First gas gusher drilled in Canada.

1950s-80s

1955
Largest petrochemical complex in Canada is established in Sarnia along the St. Clair River.

PHOTO: JOEY PODLUBNY

1982
North America's first natural gas trading hub established.

SOURCES: ENCYCLOPEDIA BRITANNICA, INTERNATIONAL JOINT COMMISSION, OIL MUSEUM OF CANADA

In for the Long Haul

Fairbank Family of Oil Springs Has Been Producing Oil Longer Than Any Other in the World

By Chaz Osburn
Photography by Joey Podlubny

The Fairbank family has been pumping crude longer than any other family in history. John Henry Fairbank—a 29-year-old American who had left his wife and children on a farm in Niagara Falls, Ont.—had come to Oil Springs, Ont., in what was then western Canada for a surveying job in the late 1850s. In a classic case of serendipity, one thing led to another and Fairbank would go on to become Canada's biggest oil producer.

But 40 years ago, this was of little importance to Charles "Charlie" Fairbank III, John Henry's great-grandson. He did not want a career as an oilman.

"I saw how much work my dad put into it," explains Fairbank, a soft-spoken man with a thick gray beard and eyes that sparkle when he speaks of the birth of what we know today as the oil industry. Fairbank recalls that in the late 1960s, "no one was making any money. Everyone was leaving. It was like the family farm. Costs were going up but prices stayed the same—this was over a period of 50 years—so I wanted to do much more interesting things."

Why did he change his mind?

"I came back here one spring and my dad said, 'Come out to the oilfield,'" Fairbank continues. "Well, within a half-hour, I found there was something really quite exciting about Oil Springs. I was hooked and wanted to come back."

His father, Charles Fairbank II, who also ran a hardware business in nearby Petrolia, didn't want his son rushing into things.

"Something to fall back on"

"My dad felt I would lose my shirt," Fairbank chuckles, "so I told him I would become a schoolteacher. Then once I had my permanent teaching certificate, I would come back and deal with the oil business. If I lost my shirt, I would have something to fall back on. It gave him comfort."

Fairbank eventually returned to his home. The timing couldn't have been better.

"I came back in 1973, about two months before the Arab Oil Embargo and the price of oil shot up," he says with a smile. But he quickly adds, "It was a matter of timing, not ability." ▶

Charles "Charlie" Fairbank III, great-grandson of Canadian oil pioneer John Henry Fairbank, is passionate about preserving the history of the early petroleum industry.

An electric motor powers Fairbank Oil's jerker-line system.

Fairbank, who today operates the world's longest-producing oilfield, explains that his passion about the oil business grew once he began to recognize the important role his family played in launching the global multi-billion-dollar oil industry.

"When I was a kid growing up, the debate was who drilled the first well, who dug the first well," he says. "It took a while to figure out that was beside the point. It was semantics. Then I started to look at my family and realized we had probably been in business longer than anyone in the world."

In fact, oil has flowed from wells on the Fairbank property near Oil Springs since Fairbank's great-grandfather dug his first well in 1861 on land he had leased. Today the Fairbank family has 320 wells that produce 65 bbl. But this is no ordinary oilfield. It's as much of a living history museum as anything.

On a warm spring day this year, Fairbank is showing visitors the Fairbank Oil Properties. The smell of crude permeates the air. Seated behind the wheel of his dented maroon Chevrolet pickup truck and clad in jeans and a tan shirt, Fairbank is talking about his great-grandfather.

"He was probably the earliest at controlling production to control price," Fairbank says as he stops the truck to point out a landmark. Yes, John Henry Fairbank was an entrepreneur, he concedes, but "the entrepreneurship was recognizing the need."

Recognizing a need, of course, had brought other pioneers to Oil Springs even before John Henry Fairbank. Two of those men, Charles and Henry Tripp, founded North America's first commercial oil business in 1854, the International Mining and Manufacturing Co. The Tripps had come to the area to produce asphalt from the "gum beds" to seal ships and pave roads.

The Tripp wells

According to *The Story of Fairbank Oil*, which was written by Fairbank's wife, Patricia McGee, Fairbank in the 1990s "stumbled upon" two hand-dug wells and the gum beds that were developed by the Tripps, which are now on property Fairbank owns.

Could it be that one of these wells yielded oil even earlier than the one dug by James Miller Williams in 1858 just several hundred metres away at what is now the Oil Museum of Canada?

"We won't go there," Fairbank answers.

Fairbank leads his visitors through the brush and melting snow to the gum beds. It's still possible to find pieces of bitumen, he says as he begins scanning the ground.

"There," he says, bending to hold up a piece about the size of a charcoal briquette for a photograph.

"How about this?" one of the visitors asks, holding up a smaller piece of what appears to be bitumen. "Is this from the gum bed?"

Fairbank studies the object for a moment. "No," he answers. "I think what you have there is animal waste."

A few minutes later, Fairbank takes his visitors to the site of Hugh Nixon Shaw's oil well, also on the Fairbank property. If you don't recognize the name, you should. Shaw brought in Canada's first gusher in 1862.

Standing on a hill overlooking the site, which is marked by a wooden tripod—a reproduction of the earliest derricks used in Canada—it's easy to imagine Shaw's surprise as nearby Black Creek and the surrounding terrain began filling with crude. One can imagine women and children frantically running to and fro, scooping the oil up with pails to try to salvage what they could before the gusher was finally plugged with a leather bag containing flax seed.

How Fairbank Oil got its start

The Fairbank family—one of just a handful still producing oil in Lambton County, Ont.—traces its beginnings in the oil business to John Henry Fairbank.

Fairbank, according to *The Story of Fairbank Oil* by Patricia McGee, was a 29-year-old American who was offered a surveying job in Oil Springs, Ont., for a wealthy widow named Julia Macklem. Macklem had purchased some property that was once owned by Charles Tripp. Tripp, along with his brother, Henry, had produced asphalt from "gum beds" that could be found on the ground.

In his newest book, *Ontario's Petroleum Legacy: The Birth, Evolution and Challenges of a Global Industry*, author-historian Earle Gray writes that in 1861, Fairbank was asked to subdivide Macklem's property into 198 half-acre lots for sale or lease to wildcatters and speculators but that it wasn't long before the man was "smitten by the wildcatter's bug."

Gray goes on to write that when Fairbank was finished with the surveying job, he borrowed $500 from his father-in-law, leased a half-acre plot, "and dug and cribbed a well through the clay." He called the well "Old Fairbank."

The turning point, Gray continues, did not come until November 1863 when Fairbank "coaxed 45 barrels of oil from his well in 24 hours," and noted in his diary that his $150 net profit was "the biggest ever made by me or probably I shall ever make."

"How wrong he was," Gray writes. "He sold his half-acre Oil Springs property in 1865 for $6,000, focused on bringing in deeper wells at Petrolia, and in the late 19th century and early years of the 20th, was Canada's largest oil producer."

From there, Fairbank opened "the largest hardware store west of Toronto" in Petrolia, according to *The Story of Fairbank Oil.* Gray writes that Fairbank also created and owned a bank with a partner, and helped finance a railway spur from Petrolia to Wyoming, Ont., and later the Canadian Pacific Railway.

Gray writes Fairbank also "acquired a business that made boilers, tanks and stills for the oil fields; was chief of Petrolia's volunteer fire brigade; and served one term as a Liberal member of Parliament."

Fairbank's great-grandson, Charles "Charlie" Fairbank III, says the Fairbank family has been selling oil to Imperial Oil longer than any other family. In *The Story of Fairbank Oil*, the earliest records show that Fairbank's first sale to Imperial was on Aug. 12, 1880.

Fairbank died in 1914.

While spring rods are no longer used to pump the oil from the ground, there are still active wells on the Fairbank Oil property.

While today plugging a gusher with a leather bag filled with seed may seem a bit rudimentary, it was downright high-tech in 1862. In fact, much of the technology still used to pump crude on the Fairbank property was cutting edge for its time. Oil is still brought from the ground via a process known as the jerker-line system, a method for pumping oil from several wells using a central motor. At one time, steam engines were used to power the pump jacks. Now electricity is used. The oil flows to storage tanks and is collected by Imperial Oil.

Fairbank Oil has supplied Imperial with crude since 1880. "We've been selling to Imperial longer than anyone in the world," Fairbank says.

It's a fact that Fairbank is proud of. Like a modern-day John the Baptist, Fairbank seems willing to tell anyone who will listen about the roles his family and the towns of Oil Springs and Petrolia played in the development of the oil industry. And he is grateful an event like the 150th anniversary of the world's first commercial oil well has brought extra attention to the area.

"When I was growing up in Petrolia, it was a town that was very, very proud of its heritage," Fairbank says. "But its time had gone. Its industry had left. It had memories, which were very important. But what they talked about was important, much more important than Petrolia thought it was.

"They tend to demean your accomplishments if you're from a small town. But we have gravitas, as they say now."

That and an oil heritage that is unsurpassed anywhere in the world.

A large model at the Oil and Gas Museum of Canada shows visitors where oil and gas comes from.

Museums Hold Oil Treasures

Photography by Joey Podlubny

If you haven't done so yet, it's worth the drive to see the site of the first commercial oil well in North America and explore the humble beginnings of the global petroleum industry.

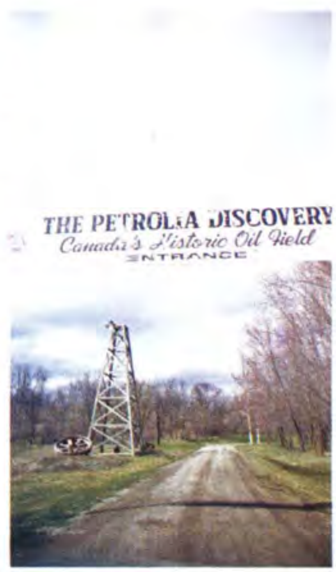
That first well, dug by James Miller Williams in 1858, exists on the grounds of the Oil Museum of Canada, which is immediately south of Oil Springs, Ont. Signs along Highway 21 will lead you there.

Not only does the well remain, but so does the "gum bed"—an area where oil seeped to the surface, which drew oilmen to the region in the first place. In fact, although the gum bed has been fenced off, you can see bitumen is again coming to the surface just outside the bed.

Inside the museum are models and artifacts not only from the immediate area, but from around the world as well. One of the things you'll learn is the global impact those early oilmen played in getting oil production off the ground in other countries around the world.

Just a few kilometres north of Oil Springs, off Highway 21, is Petrolia, which bills itself as "the cradle that rocked the oil industry." There you'll find the Petrolia Discovery, which boasts a working oilfield. You can view old pumpjacks and a jerker-line system and discover what a spring pole was used for. You'll also see early tools, what was used to store and transport oil, and much more.

The Oil and Gas Museum of Canada includes, among other things, a large collection of antique clocks and a wooden bicycle.



A working oilfield is located at Petrolia Discovery.

Site of the first commercial oil well in North America.

DIFFICULT, YES. IMPOSSIBLE, NO.

50 YEARS AGO, SHELL INVESTED IN THE ATHABASCA OIL SANDS IN CANADA WITHOUT KNOWING WHEN IT COULD VIABLY EXTRACT THE OIL.

FIVE DECADES LATER, PRODUCTION FROM THE OIL SANDS IS MAKING CANADA A GLOBAL PROVIDER OF OIL.

SOMETIMES IT PAYS TO PERSEVERE (AND TO HAVE A LEAP OF IMAGINATION IN THE FIRST PLACE).

THE PIONEERING SPIRIT OF THE MID-1850s OIL DISCOVERY IN CANADA IS A TRADITION THAT LIVES ON TODAY.

WE WILL CONTINUE TO APPLY CREATIVE, PERSISTENT PROBLEM SOLVING TO SECURE A RESPONSIBLE ENERGY FUTURE.

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