Hydrocarbon Resources

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HYDROCARBONS: THE BASICS

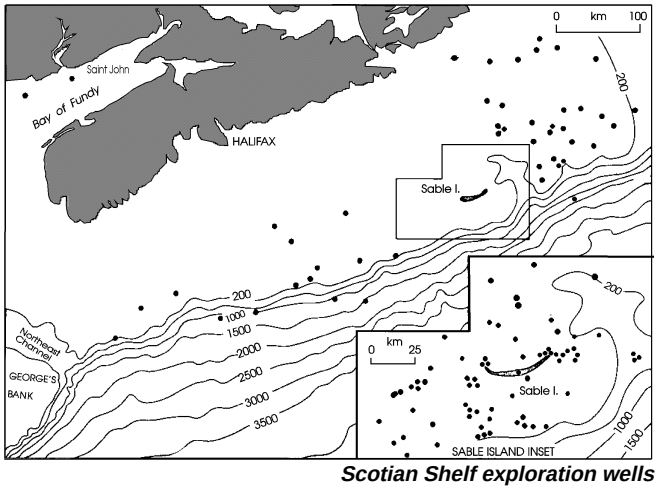
Deep beneath Georges Bank lie rocks which may contain hydrocarbon deposits of oil and gas. What are hydrocarbons? How do they form? How and where do large deposits develop? Why is there interest in exploring for them on Georges Bank? This paper explores these questions.

Hydrocarbons include natural gas, condensate, and crude oil. Their building blocks are two elements, hydrogen and carbon.

Hydrocarbons are one type of *fossil fuels* – decayed, fossilized remains of plants & animals, changed by the temperature and pressure under the ground into fuels we can burn. Coal and peat are also fossil fuels, as well as the flammable parts of tar sands and oil shales.

Natural gas is a mix of hydrocarbons that are gases at normal temperature and air pressure – mostly methane, with ethane, propane, and butane, and some non-hydrocarbon gases such as hydrogen sulphide (H_2S), carbon dioxide (CO_2), and nitrogen.

Condensate is a thin liquid found along with natural gas, and is similar in consistency to gasoline – in fact, is also known as "natural gasoline". It *condenses* out of the mix when natural gas is extracted from the ground, and pressure and temperature change.



Scotian Shelf exploration wells

Crude oil is a liquid mix of oily compounds, which may contain sulphur and various heavy metals. It varies from thin to extremely viscous.

On Nova Scotia's offshore, the Cohasset-Panuke (CoPan) project has been producing condensate from the Scotian Shelf since 1992. Sable Offshore Energy Inc. (SOEI) will begin production of natural gas and some condensate from a number of wells near Sable Island, in 1999 . The Hibernia development on the Grand Banks off Newfoundland recently began producing crude oil.

Human society has become very dependent on the energy contained in hydrocarbons and other fossil fuels. Companion papers, *The Energy Context* and *How We Use Energy*, focus on energy policy issues and our fossil fuel consumption. This paper's thrust is on the how, what, and where of hydrocarbon geology.

THE GEOLOGY OF HYDROCARBONS – SOME ESSENTIALS ABOUT OIL AND GAS

Hydrocarbons usually occur in specific types of underground rocks. All oil and gas fields have four general features—known to geologists as sources, structure, reservoirs, and seals.

The *sources* are sedimentary rocks, principally *shales*. These rocks contain carbon from dead plants and animals which were deposited when the rocks were formed from sediments millions of years ago – for example, fine clay, rich in plankton, built up over eons at the bottom of an ancient sea. The organic remains gradually rot, and are buried and compressed by new sediments.

The underground heat and pressure, if conditions are right, change the carbon from the rocks into hydrocarbons. Oil tends to form in rocks which were deposited in the basins of ancient seas, with the carbon largely coming from marine plants and animals.

Gas, on the other hand, frequently comes from deposits which contain carbon largely from land plants such as trees and woody debris. Either way, suitable source rocks have to be present for hydrocarbons to form.

When hydrocarbons form, they gradually seep from the source rock and travel along the path of least resistance, usually up, to areas of lower pressure. Gas and oil are lighter than water, and tend to collect in relatively high pockets.

Since the rock layers hydrocarbons encounter on their way vary in shape and composition, and lie at odd angles to one another, the gas and oil often follows a winding migration path. Often the movement is through porous rocks such as sandstone formed from sand deposits, or through faults & other breaks in the rock.

Usually, one or more broad rock trends or *traps* help funnel the hydrocarbons into small areas. Common traps include salt domes (dome-like structures formed by the flowing of salt deposits under pressure), ancient reefs, and areas where folding and faulting of the rock layers create suitable pockets.

Petroleum geologists hope to find underground traps that contain hydrocarbons; to do this, they look at the types and combinations of rock layers there. Below is a very simple example of such a structure.

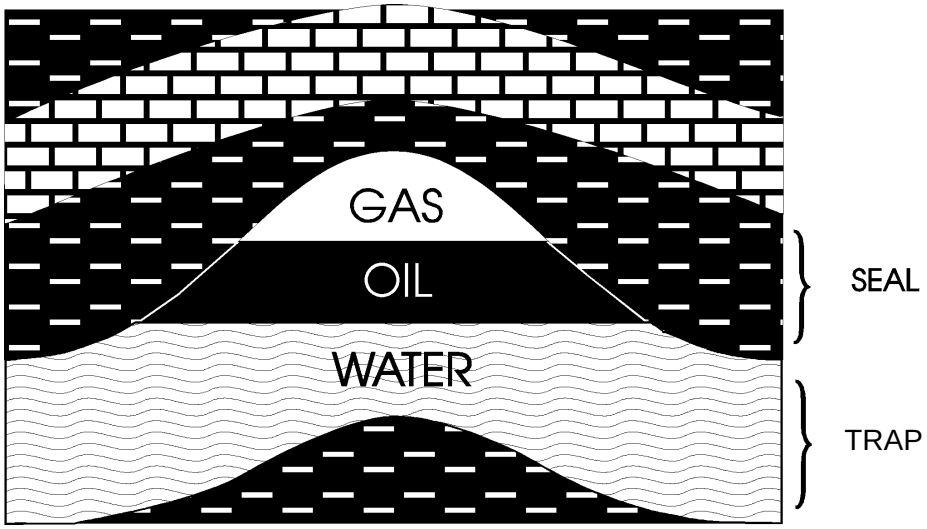
It is one thing for a potential trap to exist; it is another to be able to get at hydrocarbons which may be there. Coarse sandy sediments form porous rocks, such as sandstone, which act as *reservoirs* for underground hydrocarbons.

Because they are so porous, reservoir rocks allow hydrocarbons both to collect inside them, and to pass through so that the gas or oil can be extracted. Geologists and geophysicists can determine from seismic studies and exploratory drilling whether suitable reservoir rocks may be present.

Finally, there must be a *seal* — a layer of rock above the reservoir rocks to prevent the hydrocarbons from moving further upward. Common seals include shales, carbonate rocks such as limestone, and evaporites (rocks such as salt and anhydrite, the source rock for gypsum).

Offshore hydrocarbons which do not end up trapped within rock formations continue moving up, and eventually *vent* in the ocean.

Many of the basins on the Scotian Shelf and the Gulf of Maine show signs of venting. It forms pits called 'pock-marks', which can be detected using depth sounders. A famous example on dry land is the LaBrea Tar Pits in California, whose sticky seepage has trapped animals for many thousands of years.



offshore oil hydrocarbon structure

IS THERE OIL AND GAS UNDER GEORGES BANK?

Geologists and geophysicist use *seismic surveys* to identify rock structures which may make it possible for hydrocarbons to form and gather. If rocks with more than 0.5% carbon are present, so may be hydrocarbons.

Most of what we know about the potential for oil and gas on the north-eastern part of Georges Bank comes from seismic surveys carried out by oil companies before the moratorium was put into place, as well as some nearby wells.

The types and groupings of rock layers determined from such surveys have been compared with those found in the Sable Island region on the Scotian Shelf

Results from exploratory drilling on the US side of Georges Bank came up dry. But the Canadian part of the Bank has quite different geology.

and the US sector of Georges Bank, whose geological characteristics are well-known.

It turns out that *two* distinct geological regions with significant differences in their potential hydrocarbon reserves lie under Georges Bank.

Much of the Canadian portion is within the *Scotian Basin*. This area has similar rock structures to those that have yielded major hydrocarbon discoveries near Sable Island, with rocks formed under roughly the same conditions and time scales.

A fault zone which lies roughly along the Canadian-USA border separates the Scotian Basin from *Georges Basin*, which lies under the western portion of Georges Bank. Sedimentary rocks in the Georges Basin appear to have much lower potential for oil or gas; nine exploratory wells drilled on the United States side in the late 70s and early 80s yielded only dry holes.

The gas, condensate, and light oil reserves which have been found on the Scotian Shelf around Sable

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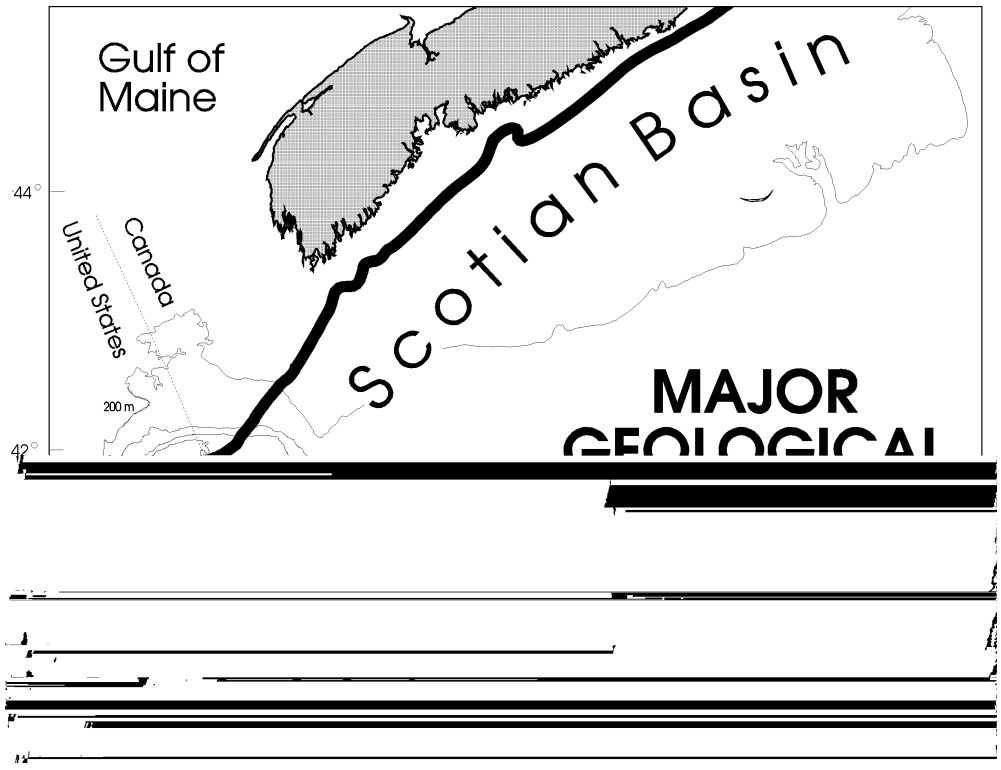


REFINED HYDRO-CARBONS

Hydrocarbons naturally contain unwanted substances like sand, water, and gases (e.g. hydrogen sulphide, the sour in Alberta 'sour gas') which are removed before sale.

Crude oils are processed in refineries to make gasoline, kerosene, diesel, heavy gas oil and lubricating oil. Natural gas may be burned directly after it has been cleaned, or can be refined to separate it into different products (e.g. propane, butane, helium).

WHAT MAKES AN OFFSHORE FIELD WORTH DEVELOPING?

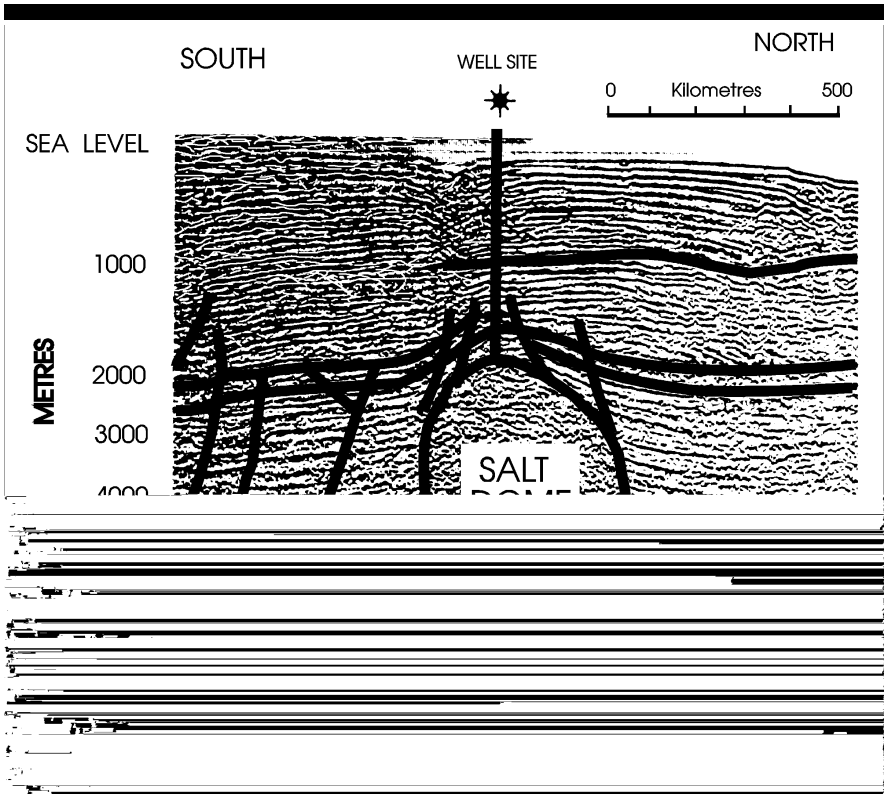
Even if there are lots of hydrocarbons in an offshore field, companies will only be interested in developing the field if they can make money at it.

Enough oil or gas is needed to make exploiting the reserve financially feasible. It must be possible to remove the oil or gas with current methods, *and* in a socially and environmentally acceptable way .

Site-specific conditions, from water depth to particular characteristics of the rock formations, can change costs up or down.

Expenses include building offshore facilities; drilling; and paying taxes and royalties to governments, and interest on money borrowed to carry out the project. Other issues include the desired rate of return to investors, and government policies that affect the investment climate.

Confirmed buyers for the end-product over the life of the project are needed. Current and projected market prices for the products must be enough to support all development costs.



Interpreted seismic section, showing possible hydrocarbon flow lines

WHY IS THE OIL AND GAS INDUSTRY INTERESTED IN GEORGES BANK?

The individual gas deposits, known in the industry as *plays*, on the Canadian sector of Georges Bank may well be equivalent to those on the Scotian Shelf, and condensate deposits could even be larger.

Reserves on Georges Bank are estimated at 150 billion cubic metres (bcm) of natural gas, and 0.17 billion cubic metres of oil and condensate. By comparison, total reserves (estimated resources, both discovered and potential) on the Scotian Shelf are estimated at 512 bcm of natural gas and 170.7 mcm of oil and condensate.

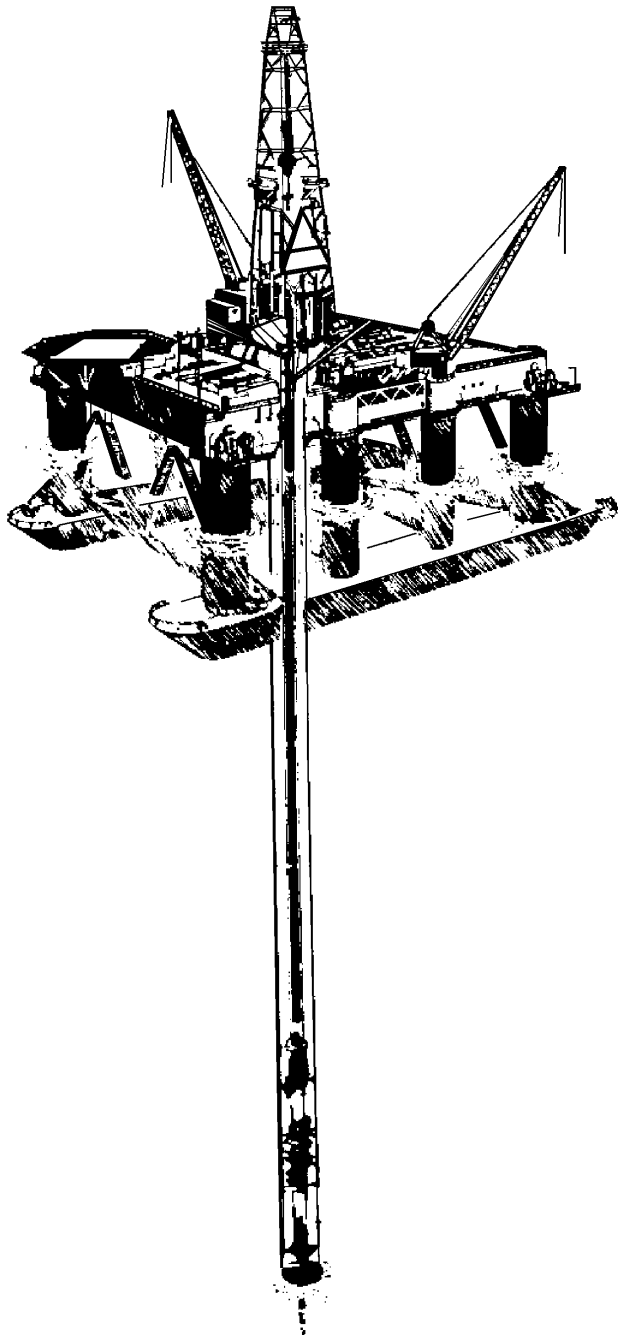
On the Canadian portion of Georges Bank, the sedimentary rocks having potential for hydrocarbons are at most 10 kilometres thick, less than the usual altitude of a typical passenger jet. Sediment layers are thicker where reserves have been found on the Scotian Shelf – up to 12 kilometres.

GEORGES BANK AND OFFSHORE EXPLORATION

We don't know precisely how exploration and development would proceed on Georges Bank *if* the moratorium were lifted. However, if reserves are large enough to warrant development, the path would probably be similar to that followed on the Scotian Shelf and Grand Banks. The process would probably proceed somewhat more quickly on Georges Bank than on those projects, however, simply because more knowledge exists about how to handle offshore development now that the Cohasset Project and Hibernia are in production, and the Sable project is being developed.

Exploration on the Bank would doubtless include both seismic studies and exploratory wells. Together, these would supply information on the geological structures in the seabed, and show whether hydrocarbons are present and in what quantities.

A good deal of seismic work has already been carried out examining the rock layers under the Bank; the seismic data need to be updated, however —although the rock hasn't changed significantly in the past few years, seismic techniques have! Today's imaging provides much more precise information than was possible a decade ago, and allow a much better picture of the best spots to drill exploratory wells.



Oil and gas exploration and development on Nova Scotia's offshore is regulated by the Canada Nova Scotia Offshore Petroleum Board, which issues *exploration Licences* covering a particular part of the seabed to oil and gas companies; these licences require at least one exploratory well to be drilled within five years. Licenses to explore on Georges would, of course, only be granted if the moratorium were lifted, and then only after a bidding and negotiating process.

Two exploratory wells had been proposed on Georges by 1988 — Texaco Growler P-24 (42° 5' N, 66° 3' W, 135 m) and Texaco Hunky Dory H-88 (41° 47' N, 65° 57' W, 97 m), but neither was sunk before the moratorium on drilling began. Exploration would be an iterative process; analysis of the first drilling results would pinpoint promising locations for further exploratory wells.

Several wells would be drilled until reliable estimates of recoverable and financially rewarding reserves could be obtained. Finally, a plan for development would be created, if enough oil and/or natural gas had been found.

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OTHER DEVELOPMENTS ON OFFSHORE ATLANTIC CANADA

The four ongoing hydrocarbon developments on the East Coast all differ, but elements of these successful projects may be applied to development on Georges Bank.

Hibernia

The Hibernia project on the Grand Banks produces crude oil. It has a concrete central gravity-based platform and oil storage facility which sits on the seabed. All wellheads are located within the central structure; oil is piped into tankers to take it to shore.

Terra Nova

Terra Nova on the Grand Banks is the most recently approved offshore development. Its design is similar to Hibernia's, although with a floating, rather than fixed, central platform. This will require sub-sea completions and flow lines to bring oil to the floating platform.

The Cohasset Project

Exploration for hydrocarbons began on the Scotian Shelf in the mid-sixties. In 1967, the first well was drilled, on Sable Island; since then, over 150 wells have been sunk in the area.

In 1992, the Cohasset and Panuke fields (Cohasset Project) were developed in shallow (35m) water west of Sable Island, the first commercial production of hydrocarbons on Canada's East Coast.

The Cohasset Project has a central "jack-up" rig; light oil flows to it through seabed piping from the other wells, which are jackets installed on pilings in the seabed. Tankers then take the oil to onshore refineries.

Sable Offshore Energy Project

The Sable Offshore Energy Project (SOEP) is the second offshore development near Sable Island. It is the successor to the proposed Venture Project of the 1980s, which received regulatory approval but was never built. SOEP's primary product will be natural gas, with a small amount of condensate extracted as well; there are six fields, three of which will be developed first, and the others later.

SOEP's central Thebaud well will have a central processing jacket and staff quarters installed on the seabed. Remote wellhead platforms at each of the fields in the development feed into Thebaud by pipelines on the sea floor. There gas and condensate will be de-watered and transferred by an undersea pipeline to mainland Nova Scotia.

Since SOEP began, reserve estimates for its area have increased. Fourteen "significant" additional fields, have also been identified. SOEP is seen as a 'seed' project—one that will lead to development of other, less immediately attractive fields in the area.

SOEP and the Cohasset Project's products are similar to those likely to be found on Georges Bank; it seems probable that the facilities and overall designs of all three projects would be somewhat similar, *if* approval for drilling were ever given on Georges. However, the initially indicated areas for exploration on Georges Bank are deeper than the Sable Island sites and an alternate (and yet to be designed) approach may be developed.

jack-up rig at the Cohasset Project field

WHAT'S IN NATURAL GAS?

Hydrocarbons		Other Substances	
methane (C_2H_4)	70-98%	nitrogen	trace-15%
ethane (C_2H_6)	1-10%	helium	none-5%
propane (C_3H_8)	trace-5%	hydrogen sulphide	none-substantial*
butane (C_4H_{10})	trace-2%	carbon dioxide	none-substantial*
pentane (C_5H_{12})	trace-1%		
hexane (C_6H_{14})	trace-.5%		

* natural gases are occasionally found which are predominantly hydrogen sulphide or carbon dioxide

Is there oil and gas under Georges Bank? (from page 3)

Island come from rocks formed from sediments deposited in ancient deltas, mainly from the Cretaceous period (160 million years ago). As the organic matter in deltas comes mostly from runoff from the land, large amounts of natural gas have been found in these formations, along with condensate and very light crude oil.

Given that the rock formations underlying the Canadian portion of Georges Bank appear to be similar to those around Sable Island, gas and condensate, and possibly light oil would probably also be found under that portion of Georges, *if* the geology is right.

However, no exploratory wells have been drilled on the Canadian side; the nearest one was the Bonnett P-23 on Browns Bank, 90 km to the northeast. Any predictions will remain highly speculative until such wells are drilled.

Georges Bank and offshore exploration (from page 5)

Exploratory drilling and seismic work might continue during the preparatory stages of developing the project. Steps in actual development include drilling a series of production wells, installing production facilities and equipment, and establishing a system to transfer product to tankers or onshore facilities (depending on what kind of hydrocarbon was found, and how much).

Overall, this could be a lengthy process, lasting a decade or more. Subsequent reserves would be developed commercially only if it was profitable.

Georges Bank is different from other areas of offshore development in Canada. It is a relatively small area, closer to major potential markets in New England. However, the areas with good hydrocarbon potential on Georges are in deeper water than existing offshore projects — which would drive up exploration and development costs

Actual exploration and development scenarios have not been developed for Georges Bank, since evaluation of the area is still at an early stage compared with other parts of the Canadian offshore. Research efforts stalled in the mid-sixties because of the Canada/US marine boundary dispute and, subsequently, the Canada/Nova Scotia moratorium on oil and gas exploration activities on the Bank.

Certainly, the oil and gas industry is keenly interested in proceeding with exploration and development on Georges Bank. But guessing about whether or not this interest will ever lead to actual producing wells on Georges can only be speculative right now.

THE PHYSICAL PROPERTIES OF HYDROCARBONS

The physical properties of hydrocarbons – whether they are gases or liquids, how easily they catch fire, and how they burn – depend on their chemical structure.

All types of hydrocarbons contain a series of carbon atoms which are linked together. Each type of hydrocarbon has its own unique length of "carbon chain", and the length influences what form each substance takes.

Hydrocarbons with short carbon chains tend to be gases, and those with long chains of more than 10 carbon atoms, tend to be liquids. The simplest carbon compound found in natural gas is methane, which contains only one carbon atom and is normally a gas. Its chemical shorthand is CH_4, which stands for one carbon and four hydrogen atoms.

Hydrocarbons are often referred to by the number of carbon atoms they have. For example, propane (the gas used in barbecues) is a 'C3' hydrocarbon – it contains three carbon atoms. Lubricating oil, on the other hand, is a mix of 'C26' to 'C40' hydrocarbons, with much longer chains of 26 to 40 carbons.

GLOSSARY

Commercial discovery – the finding of reserves of oil or gas that justify the investment of capital and effort to bring the discovery into production.

Condensate – a light liquid hydrocarbon found along with natural gas.

Crude Oil – a naturally liquid petroleum.

Established reserves – reserves estimated to allow for varying use due to fluctuating energy prices; they are approximately the proven reserves plus half the probable reserves.

Hydrocarbon – a substance composed of carbon and hydrogen; refers particularly to oil, gas and other energy-rich compounds.

Jack up rig – a drill rig which has legs that can be extended to the sea floor.

Natural gas – a mixture of gaseous hydrocarbons.

Porous rock – rock which contains open spaces that allow substances to move through it.

Probable reserves – additional amounts believed to exist with reasonable certainty on the basis of geological information.

Sour gas – an acid natural gas containing a significant amount of hydrogen sulfide.

Proved reserves – determined on the basis of drilling results, production experience and historical trends.

Recoverable reserves – those that can be produced with current technology.

Seismic survey – a study carried out to look at rock layers in the earth. Seismic surveys use a source of loud sounds at the surface and capture echoes from rock layers to estimate depth of the layers as well as their density.

Significant discovery – the finding of oil or gas on a geological structure in quantities showing potential for sustained production.

Wellhead platform – the structure mounted at the site of a production well.

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WHAT IS CANADA'S SHARE OF WORLD OIL AND GAS?

Canada is a comparatively minor player in terms of conventional oil and gas reserves, holding only 0.75% and 2.0% of proven reserves respectively. However, we have approximately 50% of the world's known reserves of heavy oil, which is found in oil sands and requires costly and extensive processing to withdraw it.

The former Soviet block and the Middle East hold the majority of the world's gas reserves; the Middle East also surpasses all others in proven oil reserves.

As large as they sound, the reserves (total and estimated) on Georges Bank and the Scotian Shelf are but a tiny fraction of proven world oil and gas reserves.