

## Introduction

As part of the new Geological Survey of Canada Geo-mapping for Energy and Minerals program (GEM), a new project on the hydrocarbon potential of the Hudson Bay and Foxe basins has been initiated. Partners in this project include National Energy Board, Northern and Indian Affairs Canada, the Manitoba, Ontario, Quebec and Nunavut governments, and Canadian universities.

Hudson Bay Basin and Foxe Basin are intracratonic basins that cover a large area of Nunavut and significant onshore segments of Manitoba, Ontario and Quebec (Figure 1). These basins, which form close to 25% of Canada's landmass, constitute today's frontier in the areas of both geoscience and hydrocarbon systems knowledge. Very little hydrocarbon exploration has been done in these basins, and the latest round of exploration dates back more than 25 years.

The project aims to document the characteristics of potential hydrocarbon systems in the successions of the Hudson Bay and Foxe basins by reassessing available geoscience data and acquiring new data in areas or domains that currently present knowledge gaps. As part of this new project, a re-examination and eventual re-interpretation of well data from northeastern Manitoba (Figure 2) is underway. Similar studies will be carried out on material from onshore wells in northern Ontario and offshore wells under National Energy Board jurisdiction.

During the course of this project, new samples of archived core will be taken and petrographically analyzed. Moreover, new knowledge about hydrocarbon reservoirs and plays needs to be tested for the Hudson Bay Basin; for example, the concept of hydrothermal dolomite units (Davies and Smith, 2006) was not available at the time of the last round of exploration. Hydrothermal dolomite units are highly brecciated and their seismic expression (e.g., the seismic 'sags'; Davies and Smith, 2006) has been tentatively identified on available industry seismic images (Figure 3; Dietrich et al., 2009).

## Hydrocarbon exploration history

Three exploratory wells were drilled onshore in the Hudson Bay Lowlands area during 1966 to 1970. The first exploratory well, Sogepet Aquit Kaskattama Prov. #1 (57° 04' 18.487°N. Lat., 90° 10' 29.408°W. Long.) located 300 km southeast of Churchill, was drilled by Aquitaine Company of Canada. The well reached a depth to Precambrian of 896 m. The second well Houston et al. Comeault #1 (56° 40' N. Lat., 90° 55' W. Long.) was drilled in 1968 by Houston Oils to a depth of 648 m. The third well, Merland et al. Whitebear Creek #1 (57° 23' N. Lat., 92° 28' W. Long.) was drilled north of York Factory in 1970 by Merland Explorations Limited and reached a depth of 427 m.

Three offshore wells were drilled by Aquitaine more than 300 km east of Churchill. Aquitaine et al. Hudson Walrus A-71 (58° 30' 02°N. Lat., 87° 10' 51° W. Long.) was drilled in 1969 to the Silurian to a depth of 1197 m. In 1974, Aquitaine et al. Narwhal South No. 1 (58° 07' 56.287°N. Lat., 84° 08' 16.787°W. Long.) and Aquitaine et al. Polar Bear C-11 (58° 30' 08.377°N. Lat., 86° 47' 13.157° W. Long.) were drilled to the Precambrian to a depth of approximately 1600 m. No commercial quantities of oil was discovered in any of the above noted wells.

In 1981, the federal government granted oil and gas exploration rights covering 28.9 million hectares, to the Trillium Consortium (Canadian Occidental, Ontario Energy Corporation and Sogepet Limited). As a result approximately 5000 km of offshore seismic was run in 1982 in the area. Canada Oil and Gas Land Administration approved a similar program in 1983 by ICG Resources (in partnership with Petro-Canada and Sogepet Limited), who conducted a 3000 km seismic survey.

These surveys were followed by two exploratory wells drilled in 1985. The first well, Trillium Soquip Onexco et al. Beluga 0-23 (59° 12' 54.4°N. Lat., 88° 33' 26.67°W. Long.), was drilled by the Trillium consortium to a depth of 2215 m and was abandoned dry. The second well, ICG Sogepet et al. Netsiq N-01 (59° 50' 48°N. Lat., 87° 30' 59.5°W. Long.), was drilled to a depth of 1040 m by the ICG consortium and was also abandoned dry.

No further intense oil and gas exploration has been conducted in the Hudson Bay Basin area since 1985.

## Geological setting

The Hudson Bay Basin consists primarily of shallow marine to peritidal Upper Ordovician to Upper Devonian carbonate sequences with locally abundant evaporite (Upper Silurian) and nearshore clastic rocks (Lower Devonian); poorly constrained Mesozoic sediments are interpreted as locally overlying the Paleozoic succession (Norris, 2003). In Manitoba, the Hudson Bay Basin is represented by the Paleozoic carbonate succession of the Hudson Bay Lowlands (HBL) in the northeastern corner of the province. The HBL consist of a progressive erosional truncation of the Devonian, Silurian and Ordovician formations, from youngest in the northeast to oldest in the southwest, towards the basin margin (Figure 2).

## Burial and maturation history

In the past, industry has claimed that the Hudson Bay Basin was never buried deeply enough for the generation of hydrocarbons out of known source rocks. This claim of supposed lack of significant burial was based on the presence of non-mature oil shale that crops out on Southampton Island and of a 2.5 km thick succession deduced from the low quality seismic data available for the central part of Hudson Bay. However, new thermochronological dating (apatite fission track and (U-Th)/He) results from northern Ontario and southwestern Manitoba suggest that erosion of up to 3.4 km of Paleozoic strata occurred in that southern reach of the basin (Feinstein et al., 2009; K.G. Osadetz, pers. comm., 2009), as well as unexpected high geothermal gradients (> 46°C/km) throughout the burial history. The 2.5 km of burial might therefore represent a minimum preserved depth estimate, whereas the amount of burial and thermal conditions of the succession might actually have been significantly greater, at least locally. The recent documentation of possible pockmarks (fluid escape features) in the northern reach of Hudson Bay could indicate that active hydrocarbon venting out of the basin occurred (Dietrich et al., 2009).

It is also critical to consider that current understanding of the maturation history of the Paleozoic succession in these basins is based almost entirely on maximum temperature ( $T_{max}$ ) values generated by the Rock Eval™ analysis of samples (Zhang, 2008). However, in the Paleozoic successions of eastern Canada,  $T_{max}$  has proven to be an unreliable indicator of the burial history. Instead, reflectance of organic material or bitumen has been shown to provide more precise maturation data (Roy, 2008).

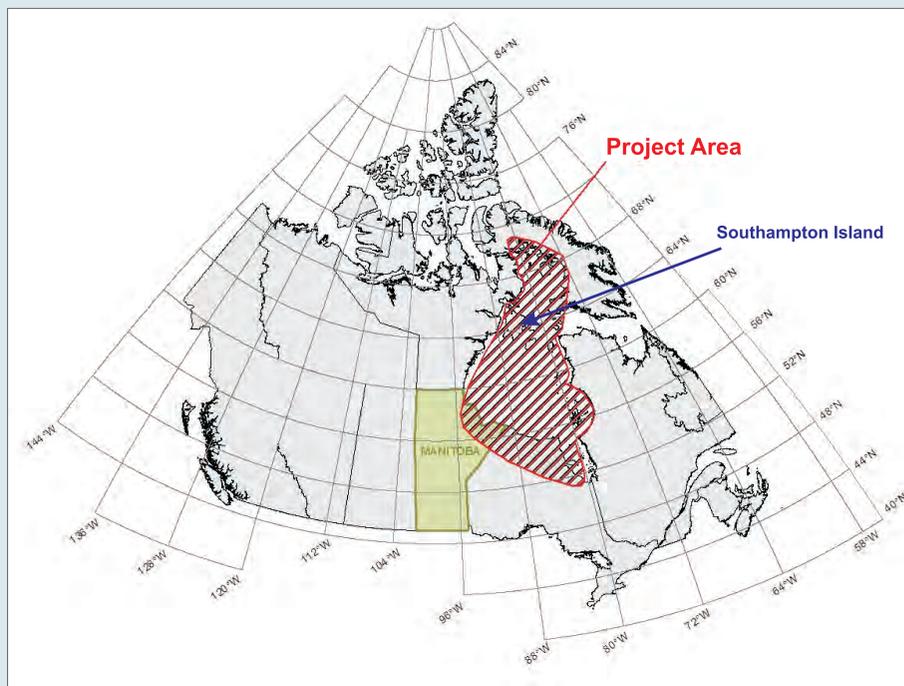


Figure 1: Location of the Hudson Bay and Foxe Basins Project area.

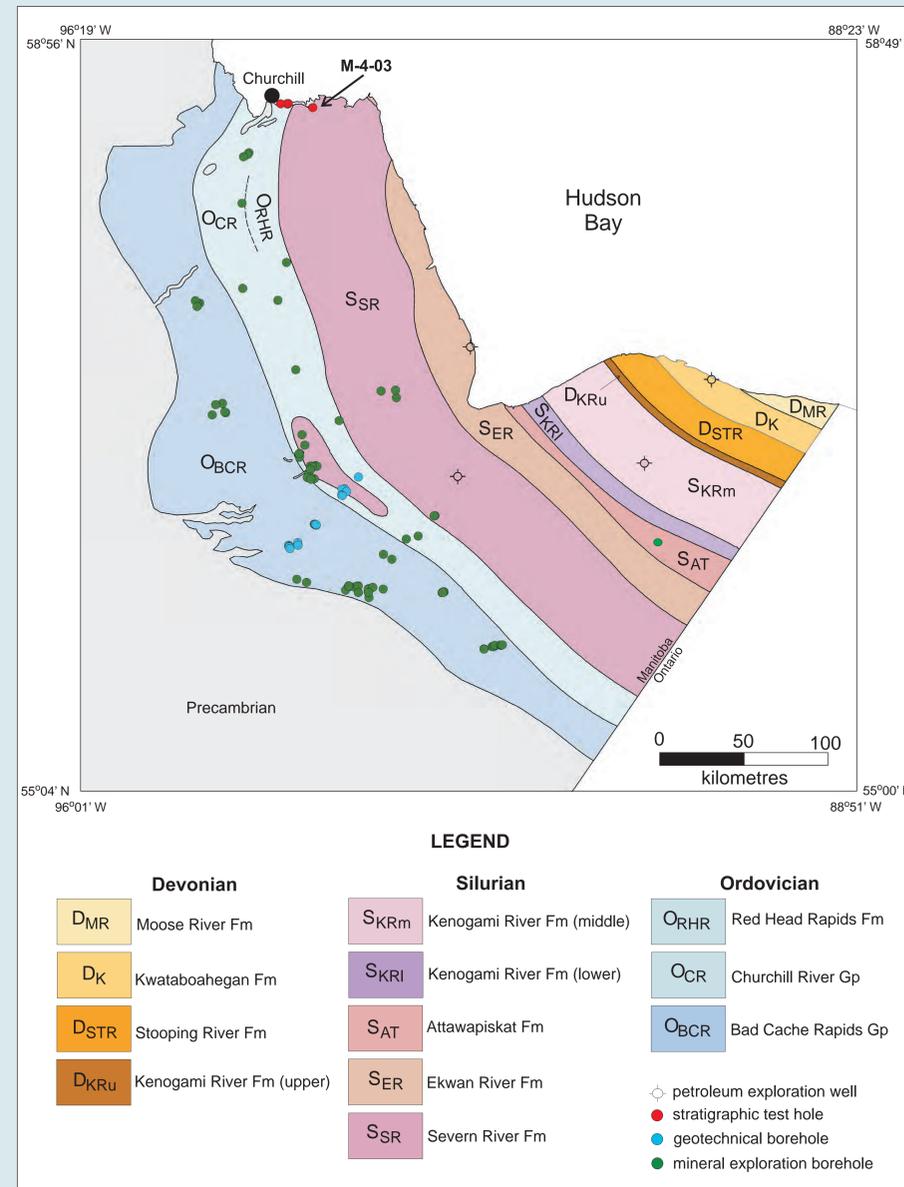


Figure 3: Geological map of the Hudson Bay Lowlands in northeastern Manitoba, showing drillhole sites located on, or near, where the Hudson Bay Basin carbonate strata is present.

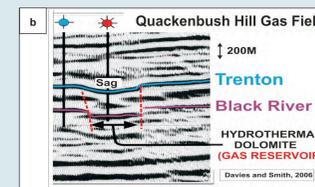
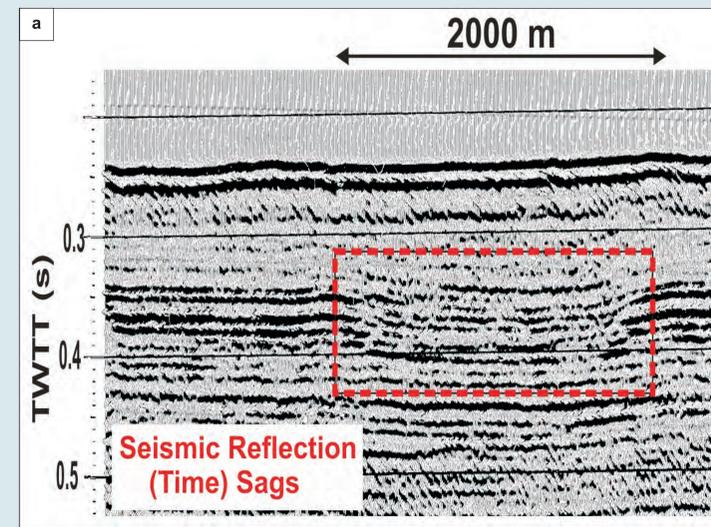


Figure 3: (a) Seismic line from central Hudson Bay showing a potential hydrothermal dolomite sag; (b) analogue of a hydrothermal dolomite exploration gas target seen as a platform (fault) sag on a seismic line from the Quackenbush Hill Gas field in the Michigan Basin.



Figure 4: Ordovician hydrothermal dolomite sample from Southampton Island, northwest Hudson Bay.

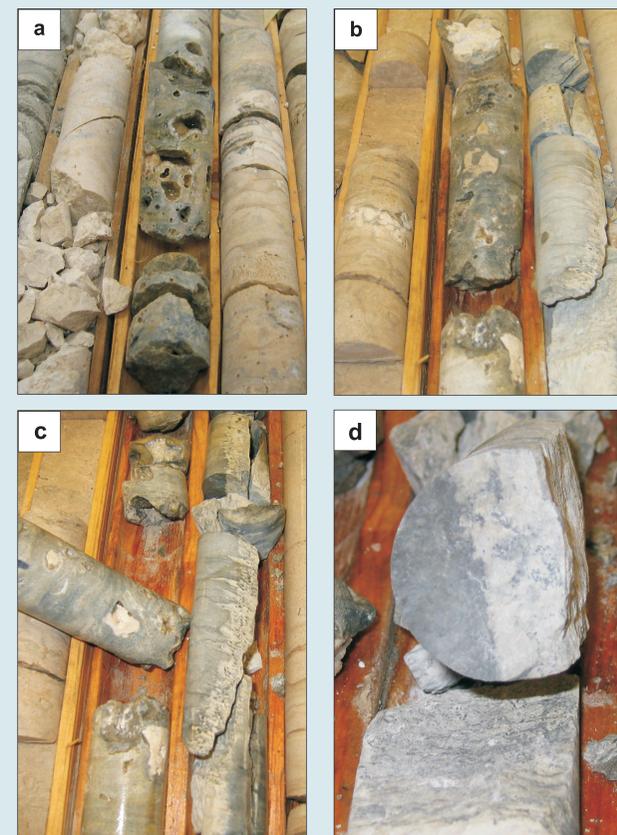


Figure 5: Core photos of M-4-03 showing: (a) dissolution vugs in limestone with dolomite coating walls and late calcite cement; (b) dissolution vugs in limestone with fine sucrosic dolomite filling pore spaces; (c) forced replacement of limestone by dolomite, dark specks are bitumen droplets in dolomite, and 30 cm long open vertical fracture which controlled dolomitization; (d) cross-section of controlled dolomitization along fracture wall. Core diameter is 2 inches.

## Purpose and procedures

Over the last few decades, a number of exploration (hydrocarbons, base metal) and geotechnical (Manitoba Hydro) wells have been drilled in the Manitoba onshore extension of the Hudson Bay basin. Re-evaluation of these drillholes and cores is necessary because a significant number of exploration targets in nearby intracratonic basins that are now recognized as world class reservoirs (e.g., hydrothermal dolomite in the Michigan basin (Figure 3b); Hurley and Budros, 1990) were previously unknown and their characteristic lithology (sucrosic or saddle dolomite) not described. New samples from Southampton Island (Figure 4; Dietrich et al., 2009), tentative re-examination of core descriptions and new core data suggest that this type of potential reservoir is likely present in the Ordovician and Silurian rocks of the northern part of the Hudson Bay Basin.

Archived core from the HBL is currently being re-examined, and samples will be analyzed by the following methods:

- Polished thin sections will be cut for dolomite petrography to assess the origin and burial evolution of reservoir forming dolomite; these samples will also be analyzed for stable isotopes and fluid inclusions.
- Samples from cuttings and cores of Paleozoic sandstone and Precambrian metamorphic basement rocks will be sent for apatite fission track and (U-Th)/He analysis to reconstruct the burial and exhumation history; the apatites used here will be chemically characterized to better constrain the thermal models.
- Samples from cuttings and cores will be analyzed for vitrinite reflectance to reconstruct the maximum burial temperature and the evolution of geothermal gradients through time; thin sections of organic matter will be examined under the microscope for reflectance; in addition, any palynomorphs present will provide precise age constraints.
- Samples from cuttings and cores will be sent for Rock-Eval™ analysis to determine their potential for indicating the presence of organic-rich, hydrocarbon source-rock intervals.

## Preliminary results from core descriptions

Cores from eight wells were re-logged this summer with particular emphasis on features that would have been overlooked or not been given much attention during the last round of exploration. Core M-4-03, drilled by the Manitoba Geological Survey in 2003 and preliminarily described in Young et al. (2003), showed interesting features that suggest the presence of hydrothermal dolomite. Megascope examination of the M-4-03 core showed intervals with dissolution vugs in limestone characterized by the presence of sucrosic dolomite coating walls and late calcite cement (Figure 5a). Other dissolution vugs in limestone in this same core showed fine sucrosic dolomite filling pore spaces (Figure 5b), forced replacement of limestone by dolomite (which gives the illusion of the dolomite 'intruding' the limestone; Figure 5c), dark bitumen droplets (possibly due to forced maturation of local organic matter; Figure 5c), and extensive vertical fractures (which controlled dolomitization pathways; Figure 5c and Figure 5d). All these features have been sampled and will be studied at the microscopic level to determine if they represent hydrothermal dolomite or are the product of some other diagenetic mechanism.

## Economic considerations

A better understanding and a modern synthesis of the geoscience and hydrocarbon systems of the Hudson Bay and Foxe basins aims to encourage industry to consider this region for future hydrocarbon exploration. Manitoba's primary advantage lies in the fact that it manages at Churchill the only deepwater port in northern waters; therefore, any exploration activities, resulting hydrocarbon production, development and related infrastructure would provide significant economic growth and stimulus to northern Manitoba.

There has been little modern exploration done in the Hudson Bay Basin and resource estimates are difficult given what little information there is available for such a large area. Although discovery of large hydrocarbon reserves is possible, but not certain (Hamblin, 2008), preliminary resource assessments have been attempted. The most recent estimate by Procter et al. (1984) put undiscovered oil potential at 130 x 106 m<sup>3</sup>, and undiscovered gas potential at 90 x 109 m<sup>3</sup> for the area including the Hudson Bay Basin and other small surrounding adjacent basins.

## Acknowledgments

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