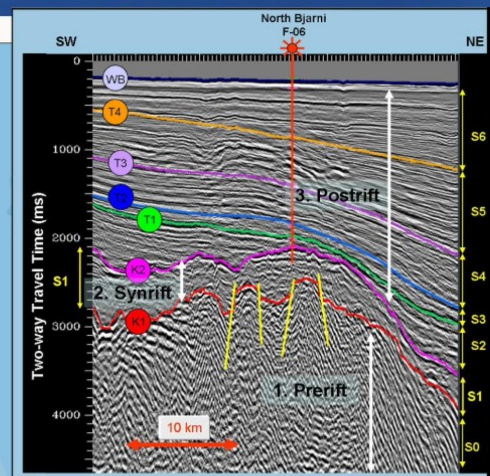
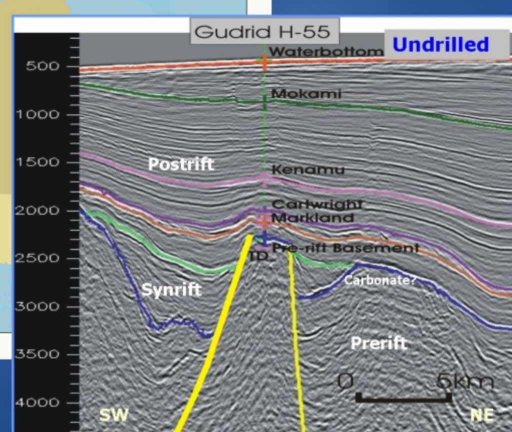
NEWFOUNDLAND AND LABRADOR
CALL FOR BIDS NL07-2
Labrador Shelf





Government of Newfoundland and Labrador
Department of Natural Resources
www.nr.gov.nl.ca/nr/

Newfoundland Labrador

Foreword

This report has been prepared on behalf of the Government of Newfoundland and Labrador Department of Natural Resources (NLDNR) to provide information on land parcels being offered in the Canada-Newfoundland & Labrador Offshore Petroleum Board's (C-NLOPB) 2007 Call for Bids NL07-2. The Board has issued two separate Calls for Bids, including:

1. **Call for Bids NL07-1** (West Newfoundland and Labrador) consisting of one parcel;
2. **Call for Bids NL07-2** (Labrador Offshore Region) consisting of four parcels.

These five parcels comprise a total of 991,458 hectares.

Call for Bids NL07-1. Call for Bids NL07-1 consisted of a single parcel of 51,780 hectares (127,951.20 acres), located in 450m water depth within the Gulf of St. Lawrence. The bid for this parcel situated within the Paleozoic basin of West Newfoundland offshore was concluded on November 30, 2007. The C-NLOPB announced on December 4, 2007, that it had accepted a bid from Corridor Resources Inc. in the amount of $1,521,000 for the parcel located in the Paleozoic Magdalen Basin. The Exploration Licence, EL 1105 was issued to Corridor Resources Inc. on January 15, 2008. The EL 1105 is valid for 9 years, if a well is drilled in the acreage.

Call for Bids NL07-2. This report focuses on Call for Bids NL07-2 that includes four parcels with a total area of 939,678 hectares (2,321,994.9 acres) within the Labrador Sea. These Hopedale Basin parcels are located within a Mesozoic exploration area with a proven petroleum system where large gas fields were discovered in an earlier exploration phase (1972-1983). As detailed in this report, significant oil and gas potential exists in the four parcels offered for bids. Acknowledging that parcel locations are in a lesser known Frontier basin, this is the first time that C-NLOPB has issued a Call for Bids (CFB) extending into the following year. The normal approach is to issue a CFB in the Spring that closes in the Fall of the same year. In this case bidders were given a period of approximately 14 months to evaluate the geoscience data and petroleum potential of the parcels. During this time, numerous conference talks and posters describing the petroleum potential of the basin in general and of the landsale parcels in particular were presented at Canadian and International scientific and professional conferences and at exploration trade fairs. On July 4, 2008, the C-NLOPB issued a notice to potential bidders, that since the strategic environmental assessment (SEA) of the area was not finalized, the closing date for Call for Bids NL07-2 would be extended. On July 28, 2008, the C-NLOPB issued a notice to potential bidders on the results of the SEA, indicating that there will be no changes to the terms or conditions of the sample licences as provided in the Call For Bids and that **the closing date for Call For Bids NL07-2 (Labrador Offshore Region) is at 4:00 p.m. Newfoundland Standard Time, on September 10, 2008.**

This report should be referenced as ***Enachescu, M.E., 2008. Call for Bids NL07-2, Parcels 1 to 4, Regional Setting and Petroleum Geology Evaluation, Government of Newfoundland and Labrador, Department of Natural Resources*.**

I acknowledge the contribution to the writing of this report of earlier researchers and explorers in the area such as J. McMillan, R. McWhae, D. Umpleby, H. Balkwill, A. Grant, S. Srivastava, S. Bell, G. Williams and C. Keen. Also, I acknowledge the professionals of the Eastcan group of companies who mapped and drilled the early discoveries in the Labrador Sea, the many researchers of the GSC Atlantic who contributed to the 1989 issued Labrador Basin Atlas and of the geoscience specialists of the NLDNR and C-NLOPB who provided information and a

number of illustrations used for the completion of this report. In addition, I recognize the contribution of Memorial University's basin evaluation research group.

For information on how to submit a bid in this Call for Bids go to: http://www.cnlopb.nl.ca/ and see the **May 18, 2007 News Release**.

Acronyms used in this report:

NL = Newfoundland and Labrador (the legal name of the Province)
C-NLOPB = Canada-Newfoundland and Labrador Offshore Petroleum Board
NLDNR = Government of Newfoundland and Labrador-Department of Natural Resources
NL07-1and 2 = identifiers for the two 2007 Call for Bids
CFB = Call for Bids
GSC = Geological Survey of Canada
PL = Production Licence
EL = Exploration Licence
EP = Exploration Permit (onshore only)
SDL = Significant Discovery Licence
DPA = Development Plan Application
TD = Total Depth
md = millidarcy
bopd = barrels of oil per day
mmcfd = million cubic feet per day
tcf = trillion cubic feet
bcf = billion cubic feet
mmbbls = million barrels

Figure 1. Location of Newfoundland and Labrador major offshore oil discoveries and of the Hopedale Basin in the Labrador Sea (yellow star).

Report Content

Foreword

1. **Introduction**

This report focuses on Parcels 1 to 4 of the C-NLOPB Call for Bids NL07-2, which are located off the east coast of the Province of Newfoundland and Labrador, Canada. All four parcels are situated on the shelf of the Labrador Sea in an area administered by the Canada-Newfoundland and Labrador Offshore Petroleum Board on behalf of the Province of NL and the Federal Government. The landsale parcels are within the Hopedale Basin in water depths ranging from 100 to 1000 metres. Presently, there are no active Exploration Licences (ELs) on the Canadian side of the Labrador Sea. Five Significant Discovery Licences (SDLs) are presently registered with the C-NLOPB, for a total area of 28,085 hectares (69,399.5 acres). The last active ELs within the Canadian Labrador Sea were awarded in the late 1970s and by 1983 exploration efforts stopped due to a collapse of commodity prices. Except for geoscience research, seabed investigations and environmental work, no other exploration related activity has taken place since then in the Labrador Sea. However, regional 2-D seismic surveys were conducted every season between 2002 and 2007 by GSI and these data are available for licensing. Several petroleum exploration licences are active on the Greenland side of the Labrador Sea, within a more northerly basin trend (West and South of Disko Island) and involve operators such as DONG, Chevron, Husky, ExxonMobil, Encana, Cairn, PA Resources and NUNAOIL A/S.

Parcel 1 is located within the southern Hopedale Basin, while parcels 2 to 4 run northerly paralleling the jagged coastline of Labrador. The offered parcels contain three SDLs where natural gas was tested at significant flow rates from the Bjarni, North Bjarni and Gudrid structures. These SDLs, awarded by the C-NLOPB in 1987, are located within Parcels 1 and 3 and their total area of 17, 921 hectares (44,283.7 acres) is excluded from the NL07-02 Call for Bids.

This report provides general background information on petroleum exploration and production on Newfoundland and Labrador's East Coast, and general geoscience information and hydrocarbon prospectivity of the Canadian Labrador Sea, emphasizing the Hopedale Basin area. It also discusses the specific geology and petroleum potential of the four parcels grouped in Call for Bids NL07-02, all located within the southern part of the Hopedale Basin.

More information on the geology of the Newfoundland and Labrador (NL) and its offshore petroleum potential, including evaluations of earlier Call for Bids parcels, can be accessed at:
http://www.nr.gov.nl.ca/mines&en/publications/offshore/
http://www.nr.gov.nl.ca/mines&en/oil/

Additional petroleum related reports from the Department of Natural Resources are available at:
http://www.nr.gov.nl.ca/mines&en/oil/publications

Selected references on the geological setting and petroleum potential of the Newfoundland and Labrador offshore and Canadian Labrador Sea basins are also provided at the end of this report.

2. Exploration and Development Background

Exploration for oil and gas offshore Labrador is much less known than exploration carried out on the Grand Banks, where significant oil production takes place from three large fields and upcoming gas development projects are in an early stage of preparation. While over 15 tcf of gas resources has been discovered offshore Atlantic Canada, the only current gas production off East Coast Canada is from the Sable Project, offshore Nova Scotia. This started on 31 December 1999, and currently produces about 400 MMm^3 per month or 460 mmcfd. Gas exploration *per se* is a new development in the NL offshore basins and it is triggered by high commodity prices and increased demands from Central Canada and Northeast USA markets.

The Canadian provinces of Newfoundland and Labrador (NL), Nova Scotia (NS) and the Nunavut Territory (NU) are the only jurisdictions north of Florida allowing offshore petroleum exploration on the Atlantic side of the North American continent.

Approximately 600,000 sq km with oil and gas potential are distributed around the Province of Newfoundland and Labrador (NL) in Mesozoic and Paleozoic basins. Continental margin research and offshore oil and gas exploration have been carried out on the Atlantic region of the Province of NL for more than 4 decades. The following sections will discuss the setting and history of East Coast of Newfoundland and Labrador petroleum exploration within the regional, provincial, and international context (Figures 1 and 2).

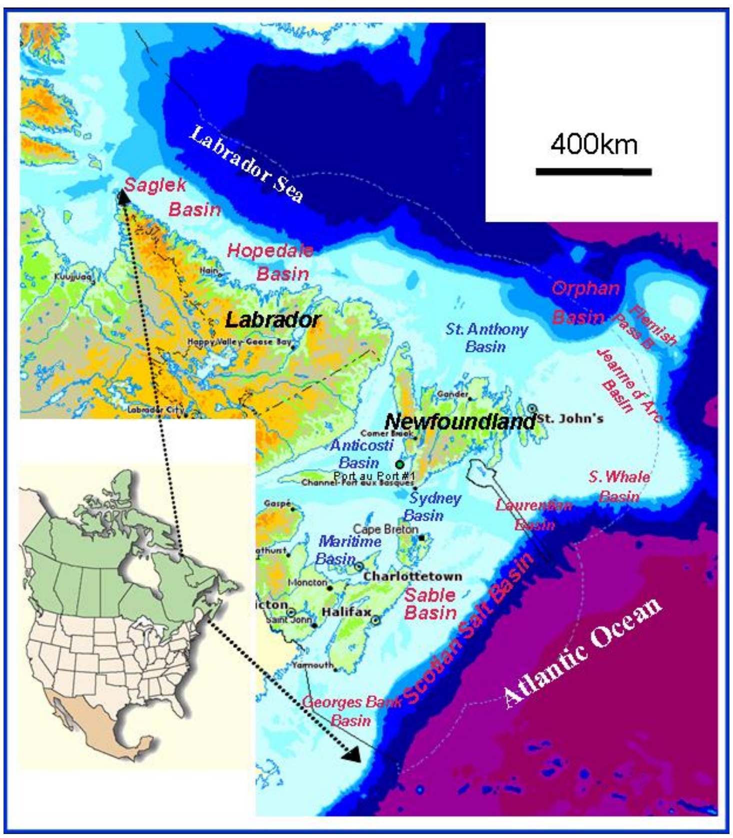


Figure 2. Atlantic Canada offshore basins map. Mesozoic basins are labelled in red, Paleozoic basins are in labelled in blue (bathymetry map from NRCan). Hopedale Basin is one of the Labrador Sea basins located on the continental shelf, slope and rise.

2.1. NL Petroleum Production

Three large fields (Hibernia, Terra Nova and White Rose) have been developed in the Jeanne d'Arc Basin which lies to the east of the Island of Newfoundland in 80 to 150 metres of water (Figures 1 to 3). These fields collectively produced approximately 368,000 barrels per day of light crude (average 35º API) from Mesozoic sandstones during 2007. They are the only producing offshore oilfields on the Atlantic coast of North America, north of the Gulf of Mexico. A fourth project, Hebron-Ben Nevis (731 million barrels recoverable reserves/resources) is expected to be developed over the next few years. A number of smaller fields or extensions of existing fields will also be brought on as satellite developments using the current infrastructure and subsea installations.

The Jeanne d'Arc Basin is only one of many Mesozoic basins and sub-basins located in Atlantic Canada (Enachescu, 1987; Tankard and Welsink, 1989; Grant and McAlpine, 1990; Enachescu and Fagan, 2004, 2005a and 2005b; Enachescu and Hogg, 2005; Enachescu, 2005 and 2006c and Figures 1 to 3). More than 10 tcf of technically recoverable gas has been discovered in the Jeanne d'Arc (Grand Banks) and Hopedale (Labrador Sea) basins, but to date only oil developments have occurred in the province. The oil is delivered by tanker to markets in eastern North America and the solution gas produced with the oil (about 435 mmcfd) is being reinjected for pressure maintenance and future exploitation, with a portion being used to fuel the production systems. However, given the future energy demand in North America, stakeholders in NL gas development are already investigating the commercial and technical aspects of natural gas development from Newfoundland and Labrador waters. Except for the rapidly declining Sable Project on the Scotian Shelf, there are no other offshore producing gas fields on the eastern coast of North America. The Deep Panuke field, estimated to contain 0.8 to 1 tcf of gas in a Jurassic dolomitic reservoir, will be developed in the next few years to produce at a rate of 200,000-300,000 mmcfd. On land, the McCully development in New Brunswick is producing more than 25 mmcfd and has brought greater attention to the petroleum potential of the Atlantic Canada Paleozoic basins.

The petroleum resources and exploration potential of the Grand Banks area, especially the Jeanne d'Arc Basin, as well as the Atlantic Canada onshore and offshore Paleozoic basins were the subject of previous NL government reports available from NLDNR or from the web (Atkinson and Fagan, 2000; Smee, 2003; Enachescu and Fagan, 2004 and 2005b; Fagan and Hicks, 2005; Enachescu, 2006c, d and e; NLDNR, 2008; Hawkins et al., 2008).

The Labrador Shelf was explored for petroleum during the 1970s and early 1980s and several large gas deposits were discovered. As the exploration focus was for oil at that time, gas price was low and development technology was not available, these fields were not developed. Their presence, however, proves the existence of a rich petroleum system (McMillan, 1982; Balkwill, 1987; Bell et al., 1989; Balkwill et al., 1989; De Silva, 2003; Meneley, 2003; Klassen, 2005; Enachescu, 2006a, and b; Enachescu et al., 2006).

From a logistics point of view, offshore Labrador is more challenging than the Grand Banks and Orphan Basin areas but it had a higher drilling success ratio during the early (1970-1983) exploration phase. Any significant quantity of natural gas (3-4 tcf) added to the already discovered reserves will bring Labrador's gas economic threshold closer to realization. It will also have a rapid and significant impact on the economy of the region and the Province and is supported by the provincial government.

2.2. Atlantic Canada Exploration Update

Newfoundland and Labrador's area of petroleum potential extends outside of the confines of the Jeanne d'Arc Basin where the Hibernia, Terra Nova, White Rose, Hebron and a series of smaller fields are located. The continental margin of Atlantic Canada stretches on for more than three thousand kilometres from Georges Bank, at the Canada/United States border to the northern tip of Labrador (Figures 1 to 3).

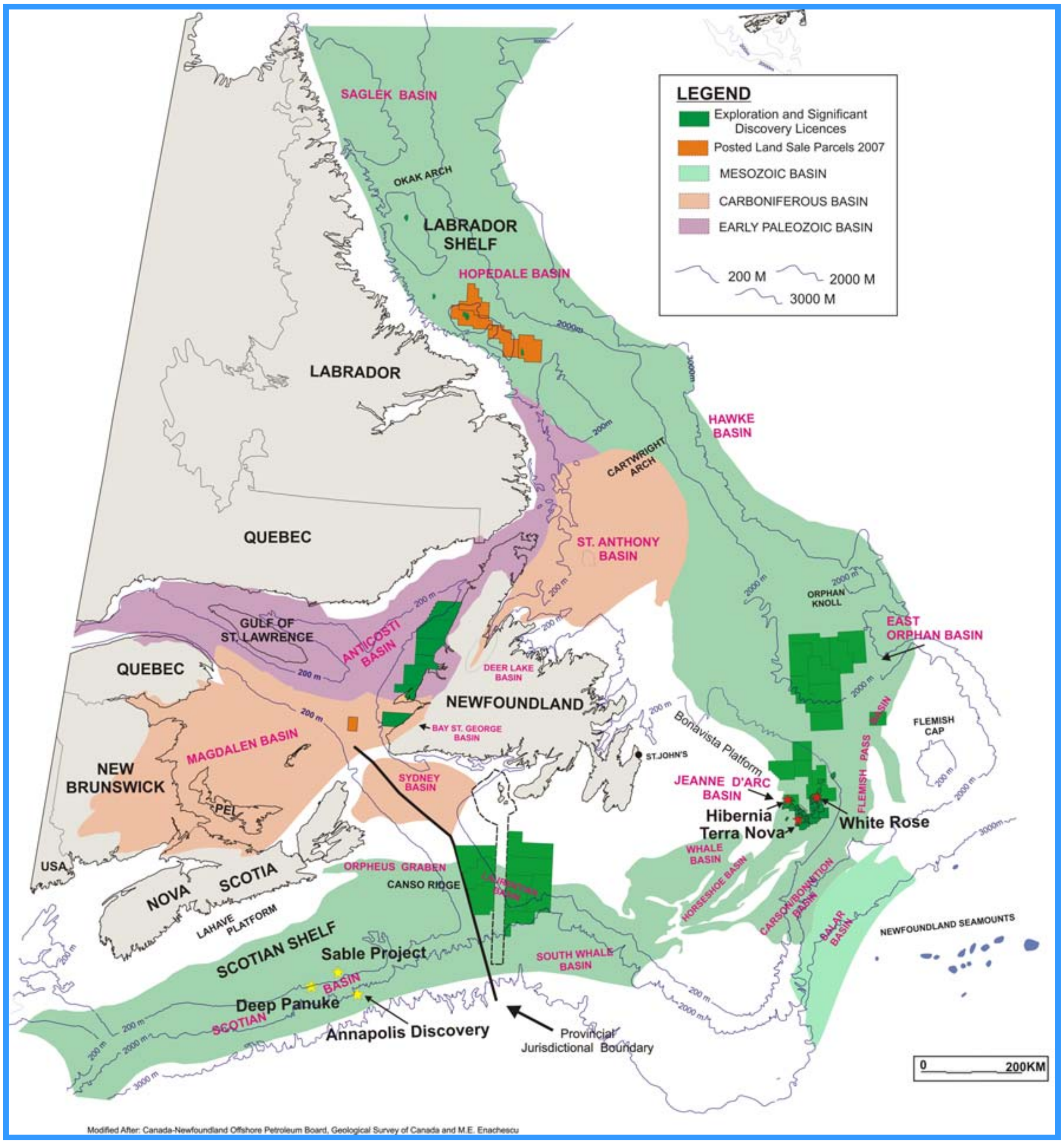


Figure 3. Regional map of the Mesozoic and Paleozoic basins of Atlantic Canada including NL land tenure as of spring 2008. In orange, within the Hopedale Basin, are Call for Bids NL 07-2 parcels 1 to 4; (map modified after the GSC, C-NLOPB and Enachescu, 2005).

Mesozoic sedimentary basins are found all along the East Coast of NL, trending from the Laurentian Basin in the south, across the Grand Banks basins, through the deeper waters of the Flemish Pass and Orphan basins, and extending north-westward to include several basins along the Labrador shelf and slope (Figures 1 to 3). Some of these basins are incised on a Paleozoic pre-rift basement, which at several locations contains important secondary reservoirs. Paleozoic basins surround the island of Newfoundland and are located in the Gulf of St Lawrence area to the west, Sydney Basin to the south, Bonavista Platform to the east and St. Anthony Basin to the north. They also form the upper part of the pre-rift basement of the Grand Banks and Labrador Sea (Figures 1 to 3).

A total of 137 exploration and 48 delineation wells (as of December 2007) were drilled in the 0.6 million km^2 offshore NL area (Hawkins et al., 2008). These wells are predominantly located in the Mesozoic basins; only 5 wells (4 of which were onshore to offshore locations) were drilled for Paleozoic plays in the West Newfoundland offshore.

Exploratory drilling offshore Newfoundland and Labrador began in mid 1960's and since that time exploration wells have been drilled in twelve Mesozoic and Paleozoic basins with the highest number of wells concentrated in the Jeanne d'Arc Basin. From a frontier exploration point of view, all the basins along the margin can be considered to have hydrocarbon potential. Most of the basins are sparsely drilled, and some have been explored only by reflection seismic and are yet to be drilled (Atkinson and Fagan, 2000; Enachescu, 2005, 2006a, b, c, d and e; Enachescu and Hogg, 2005; Fagan and Hicks, 2005; Enachescu and Fagan, 2005a and b). Up to now, large discoveries have been made in two areas: the Hopedale Basin on the Labrador Shelf and Jeanne d'Arc Basin within the Grand Banks, with only oil being presently produced from the latter area (Enachescu, 2005 and 2006a b, c, d and e; Enachescu and Fagan, 2004 and 2005a and b; Figures 1, 2 and 3). To date the main exploration target offshore NL has been within the Grand Banks' Mesozoic basins which are: petroleum proven; contain a prolific Late Jurassic source rock; have high quality Late Jurassic to Tertiary sandstone reservoirs; and present a multitude of structural, stratigraphic and combination traps.

A complete discussion of NL Paleozoic and Mesozoic petroleum basins including petroleum potential and seismic examples is given by Enachescu 2006c, d and e and is available at:
http://www.nr.gov.nl.ca/mines&en/oil/

Only an exploration update is provided here.

Paleozoic Basins of the West Newfoundland offshore area includes: a) the Lower Paleozoic Anticosti basin to the north, b) the Carboniferous Magdalen Basin to the south and c) the Bay St. George Subbasin (an arm of the Magdalen Basin) situated south of the Port-au-Port Peninsula (Figures 3 and 4). The most recent stakeholder maps of western Newfoundland include the offshore Exploration Licences awarded during the 2006 and 2007 landsales and the parcels posted in Call for Bids NL08-3 & 4 (Figures 2 to 4). The Call for Bids NL08-3 & 4 are to be concluded on **14 November 2008**. A presentation of the general geology, seismic coverage and petroleum potential of the parcels included in these two 2008 Calls for Bids (West Newfoundland offshore and Sydney Basin is given by Enachescu (2006b and c) and is available from http://www.nr.gov.nl.ca/mines&en/oil/

There are 8 active ELs in the offshore Paleozoic basins (6 ELs located in the Anticosti Basin and 2 ELs in the Magdalen Basin) for a total area of 1,079,230 hectares (Figures 3 and 4).

To date, over 12,000 line km of 2D seismic data has been collected and 5 wells drilled, with one light oil discovery recorded onshore at the Port-au-Port #1 well. All these wells were located close to the Port-au Port Peninsula; some were drilled from onshore-to-offshore to minimize costs (Atkinson and Fagan, 2000; Fagan and Hicks, 2005; Enachescu, 2006d and e; NLDNR, 2008; Foote, 2008).

The level of exploration activity during 2006-2007 was relatively low, but should be picking up during the summer of 2008, when older, reprocessed seismic data will be re-interpreted and several seismic programs may be executed, including a 3D program conducted by GSI (900 km^2). The Shoal Point 2K-39Z well is directionally drilled from an onshore location to an offshore subsurface structure beneath EL 1070. This well which targets porous dolomite reservoir is operated by Shoal Point Energy on behalf of CIVC and PDI Production Inc. (PDIP). At the time of writing, this well was nearing TD. PDIP is also planning a production well from the Garden Hill South Field (from a side track within the original Hunt/PanCanadian Port au Port #1 discovery well), where positive production tests were recorded in the past. Additionally, Vulcan Minerals and its farmin partner Investcan, are planning a well for the fall/winter of 2008 in the onshore portion of the Bay St. George Basin, and a well is expected to be drilled by the several onshore partners in the Parsons Pond permits within the next year or so. It is worth mentioning that Canada has significant light oil and gas production from Paleozoic sedimentary rocks and over 20% of world oil reserves originate in Paleozoic strata.

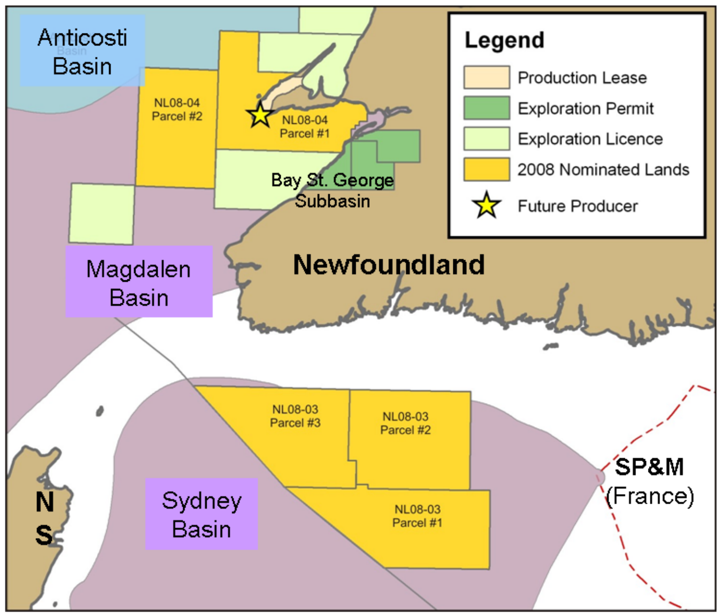


Figure 4. Location of Call for Bids NL08-3 and 4 parcels; NS = Nova Scotia, SP&M = Saint Pierre and Michelon jurisdiction area (modified after the C-NLOPB and NLDNR).

<u>Mesozoic Basins.</u> As in past years, the largest petroleum related expenditures took place in the *Jeanne d'Arc Basin* where development of the Hibernia, Terra Nova and White Rose field have seen a total of 40 producers, injectors and delineation wells being drilled since January 2005 to maintain production levels of 350-400,000 bopd and to access additional reserves. While both Hibernia rigs are being maintained in a drill ready state, only a single drilling team was retained. Production and transportation operations continue to be conducted in a safe manner and no significant environmental problems have occurred.

Exploration activity was focused on the *Orphan Basin* during the winter of 2006-7 where a true wildcat, Great Barasway F-66, was drilled. This well, located in 2450 m water depth investigated a large extensional anticline located on the southerly plunge of the Central Orphan High in the eastern Orphan Basin (Enachescu et al., 2005; Hardy, 2007). The well was designated a “tight hole” and no results are yet available in the public domain. Pending rig availability and partners' approval, another wildcat is planned by the partnership for the 2009 season.

While large exploration licenses were awarded in 2004 to ConocoPhillips (CP) and its partners (Enachescu, 2006c), no exploration well has been yet drilled in the Laurentian Basin. Two large

3D programs were executed in 2005 and several large Mesozoic features were identified in water depths of approximately 2000 meters, but drilling was postponed due to unavailability of a deepwater rig. Exploration drilling has yet to occur even though the structure of the natural gas royalty regime was published as part of the Energy Plan.

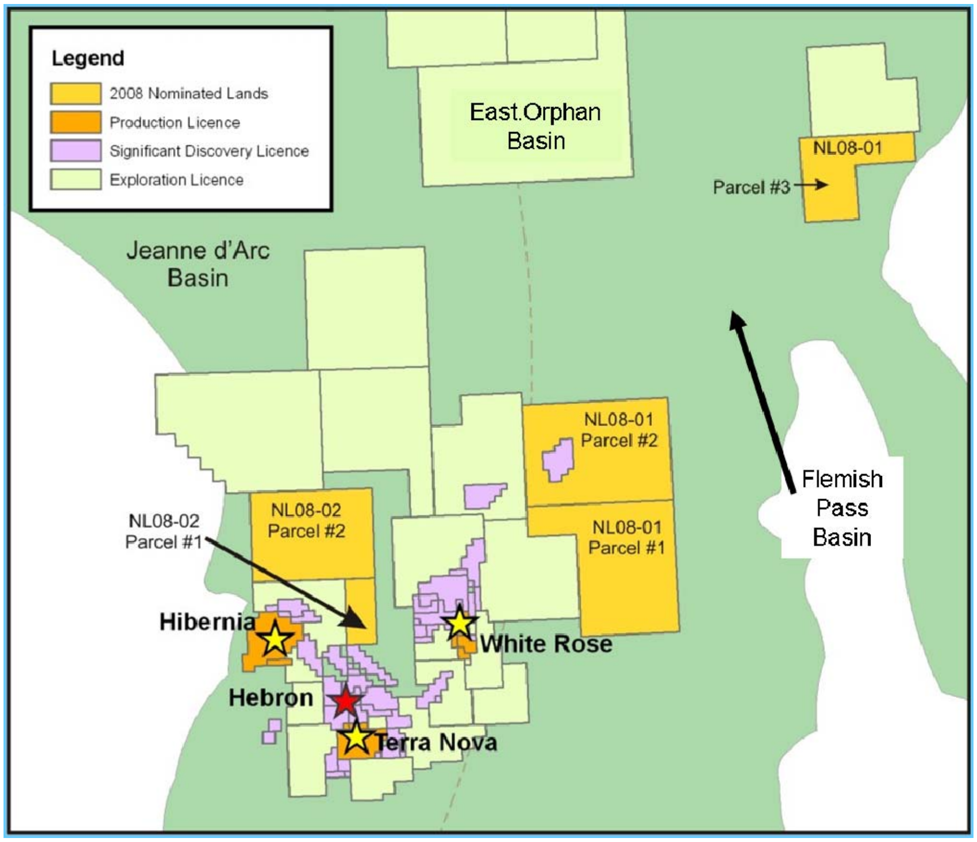


Figure 5. Location of Call for Bids NL08-1 (Jeanne d'Arc Basin) and of Call for Bids NL08-2 parcels (Flemish Pass Basin; (basin map after Enachescu, 1987; landsale map after the C-NLOPB and NLDNR).

Within the larger White Rose area, Husky's delineation drilling proved additional reserves in the South and West White Rose pools and also confirmed an additional independent oil accumulation within the Avalon/Ben Nevis reservoir at North Amethyst K-15. In November 2007, the C-NLOPB issued two new Production Licences (PL-1007 and PL-1008) to Husky Oil Operations Limited (72.5%) and Petro-Canada (27.5%) for the White Rose field. Husky is already developing several satellite fields, with North Amethyst being the first of those expansion fields to enter production toward the end of 2009. Another delineation well at West Bonne Bay F-12 found oil in the Upper Hibernia reservoir. In late 2008, Husky and StatoilHydro will participate in a follow up well to the Mizzen discovery on Exploration License EL 1049 located in about 1100m of water in the Flemish Pass Basin.

During 2007, several well site surveys totalling 675 km of 2D HR seismic data were completed by Husky on their East Trave, Triton, Emerald and North Amethyst prospects in the Northern Jeanne d'Arc region. Petro-Canada completed a 3D seismic survey, acquiring some 20,842 CMP km on their North Mara prospect. In addition to the above, a 1747 line km electromagnetic resistivity survey was conducted by operator ExxonMobil Canada in the Orphan Basin during the 2006-7 seasons.

Several exploration wells are planned over the next few years by Husky, Petro-Canada and StatoilHydro to validate their exploration licences located within the central and western *Jeanne D'Arc Basin.* StatoilHydro and partners are executing a large multipurpose seismic program in the Jeanne d'Arc Basin during 2008, comprising about 2500 square kilometer of 3D and 4D survey data. StatoilHydro will operate the southern part of the program area covering exploration licenses 1100 and 1101 and the Terra Nova Production License, and Husky Energy will operate the northern part of the survey, which includes the White Rose Production License.

Several new exploration parcels in the Jeanne d'Arc and Flemish Pass basins were nominated this summer for the Call for Bids NL08-1&2 (Figure 5). This landsale, one of the largest to be held in the past few years, will be concluded **28 November 2008.**

2.3. Labrador Sea Exploration History

Two major Cretaceous-Tertiary basins, Hopedale and Saglek basins, comprise most of the Labrador continental margin. The Hopedale Basin was explored from the 1960s into the early 1980s. During this early exploration round 120,000 km of 2D seismic data was recorded and 21 wells were drilled. This exploration cycle, while successful for gas discoveries, was followed by two decades of inactivity, due to low gas prices and remoteness of the area.

Petroleum exploration of the Labrador Sea started with potential field surveys followed by acquisition of refraction and reflection data. Aeromagnetic surveys were completed by Tenneco (1966 – 1967), Geoterrex (1974), Eastcan Group (1976) and Petro-Canada (1980). Gravity surveys were completed by Eastcan (1973) and ESSO Resources (1974). The Geological Survey of Canada (GSC) integrated the various potential field surveys and produced regional maps. These maps indicated that a thick wedge of sediments existed on the shelf and several sedimentary basins occupy the continental margin off Labrador. Several papers which discussed the above surveys results indicated the Labrador Sea was formed by continental rifting and sea floor spreading during Mesozoic (e.g. Vogt and Avery, 1974; Srivastava, 1978).

Simultaneously, between 1965 and 1969 the Atlantic Geoscience Centre of GSC led seismic surveys across the Labrador continental margin. All of these surveys confirmed that above the tilted and stretched Paleozoic and Precambrian basement there is a wedge of sediments thickening away from the shoreline. Analysing early refraction data, Mayhew et al. (1970) proposed that the Mesozoic and Tertiary sedimentary sequences were more than 7 kilometres thick in places. The rough morphology of the Labrador margin and the thickness of sedimentary fill units were interpreted from reflection seismic by Grant (1972).

The initial GSC investigations into the geology and geophysics for offshore Labrador heralded the presence of a large sedimentary basin and this attracted oil companies to the petroleum potential of the region. The first petroleum exploration licence was awarded in 1966. Using energy sources such as vaporchoc, and more recently compressed air sources, reflection lines were recorded by companies such as GSI and CGG, some as proprietary data and some on behalf of a number of Canadian and foreign companies that had acquired large tracts of land along the shelf of the Hopedale and Saglek basins. Several of the companies involved in petroleum exploration in Labrador joined together in the early seventies to form the Eastcan Group that remained the most active Labrador explorer up to the early 1980s. The Eastcan Group was comprised of seven companies; among them were Sun Oil (USA, now Suncor), Amerada Minerals (USA), AGIP (Italy, now ENI), Aquitaine (France, now TOTAL), Gulf Canada (now ConocoPhillips) and later Petro-Canada. The Group's operator was initially Total of France and then Petro-Canada. Other companies involved in Labrador exploration were Chevron, Tenneco, Amoco, Columbia Gas, Deminex, Canterra, and a series of smaller companies taking advantage of the National Energy Program benefits offered to Canadian companies.

Drilling started in 1971 with the spudding of the first Labrador well, Leif E-38. Other wells followed throughout the 1970s including Bjarni H-81 in 1973-4, Herjolf M-92 in 1976, Hopedale E-33 in 1978 and Tyrk P-100 in 1979. Two or three drilling units were active in some years, and while oil was the intended target, only gas discoveries, some of large size, were made during this exploration cycle. The first significant discovery well was Bjarni H-81, drilled in 1973 by Eastcan et al. Drill stem tests produced 365,287 m^3/day (12.9 mmcfd) from an Early Cretaceous sandstone reservoir (C-NLOPB). Four other significant discoveries were recorded in the Hopedale Basin and one in the Saglek Basin (Figure 6), the largest, North Bjarni, is estimated to hold 2.2 tcf of recoverable resources. All of these discovery wells were abandoned and Significant Discovery Licences were issued to the drilling partners.

After the 1970s exploration drilling and seismic mapping, the litho-stratigraphic nomenclature of the Labrador Shelf sequence was developed within the Eastcan Group and defined in key papers by McWhae and Michel (1975), Gradstein and Williams (1976), Umpleby (1979), McWhae et al. (1980), Gradstein and Srivastava (1980) and McMillan (1982). The formations and members described by these authors forms the established lithostratigraphic chart reproduced in numerous other papers and documents including the monumental GSC Labrador Atlas (Bell et al., 1989). Several other classic papers discussed the general structural and tectonic framework of the Labrador Basin including works by Mayhew et al. (1970), Laughton (1971), Grant (1972, 1975, and 1980), King and McMillan (1975), Haworth et al. (1976a and b), Cutt and Laving (1977), Srivastava (1978), Keen (1979 and 1982), Royden and Keen (1980), Srivastava (1978) and Srivastava et al. (1981). A thorough portrayal of Labrador Sea basins based on interpretation of accumulated seismic data, well information and geochemical results was provided by the GSC in their comprehensive Labrador Atlas (compiled by Bell et al., 1989).

More recently the Labrador basins, Labrador continental margin and Labrador oceanic crust formation were the subject of investigations and publications by Roest and Srivastava (1989), Chalmers (1991), Srivastava and Verhoef (1992), Dehler and Keen (1993), Chalmers and Laursen (1995), Srivastava and Keen (1995), Osler and Louden (1995), Chian et al. (1995), Srivastava and Roest (1995 and 1999) and Louden (2002). Using a new set of seismic data (GSI 2002-2007) Enachescu et al. (2006 and 2007), Enachescu (2006a and b), Martin and Enachescu (2007), Enachescu and Einarsson (2007), Martin (2007) and Stead (2008) extended the Hopedale Basin description into the deeper parts of the basin and to the outer shelf and slope area (up to 3,000 m water depth). This will help to further evaluate the petroleum potential of the Hopedale Basin.

2.4. Exploration Results

The Hopedale Basin, the target of the recent Call for Bids, was explored in the 1970s and into the early 1980s during which 21 wells were drilled. Several wells did not reach their petroleum targets and only 16 wells provide significant data in terms of basin analysis. The recorded success rate of 31% is very high for a frontier basin. This success rate would be even higher if exploration would have been actually carried out for gas instead of oil as no 3D, AVO analysis, DHI investigation, LMR, etc., were performed at the time. During this early exploration cycle, several large and medium size gas fields were discovered *while exploring for oil*. Within the Hopedale Basin, fields such as Bjarni/North Bjarni complex (3.1 tcf), Snorri (0.1 tcf), Hopedale (0.1 tcf) and Gudrid (0.9 tcf) were found (Drummond, 1998; De Silva, 2003; Meneley, 2003; Enachescu and Fagan, 2005a and b; Klassen, 2005 and Figure 6). These wells tested between 8 and 20 mmcfd. Excellent clastic reservoirs were drilled within the Early and Late Cretaceous and Early Cenozoic successions and within Paleozoic carbonates, preserved in places within basement.

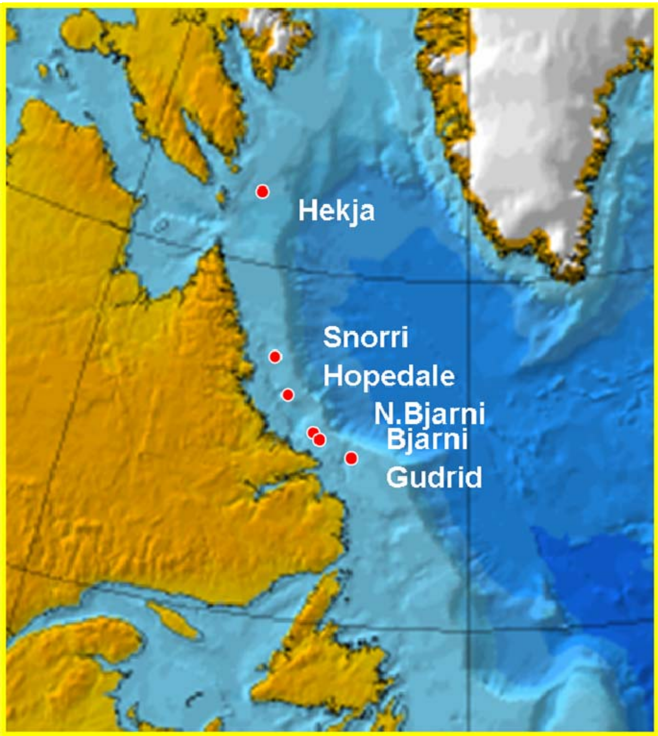


Figure 6. Location of gas discoveries on the Labrador shelf

As the exploration focus was centered on oil at that time, these gas fields were not developed. Their presence, however, proves the existence of a rich petroleum system (Enachescu, 2006a and b). When compared to more southerly Grand Banks basins, the Hopedale Basin is relatively unexplored due to its northerly location and harsh physical environment. All drilling took place exclusively on the shelf in water depth between 100 and 350m. Wells were usually drilled 2500-3500m deep, targeting Cretaceous sandstones draped over basement highs. No drilling has occurred in the basin since 1983. The outer shelf, slope and deep water regions remain completely untested. Well history reports and various information (logs, check-shot surveys, formation tops, drill stem tests, etc.) are publicly available from the Canada-Newfoundland Labrador Offshore Petroleum Board (C-NLOPB a and b) and from the Geological Survey of Canada (GSC) Basin website.

The C-NLOPB estimates that the Hopedale Basin carries 4.2 tcf of gas resources. The undiscovered gas potential of the Canadian Labrador basins is estimated at 22 tcf (Bell and Campbell, 1990; Drummond, 1998). Recent research that extends the basin into the deep water could imply higher undiscovered hydrocarbon potential. Numerous structural and stratigraphic traps remain undrilled. Especially attractive are features located on the outershelf and upper slope, drillable with dynamically positioned rigs or vessels (Enachescu, 2006a and b; Martin, 2007 and Stead, 2008).

3. Regional Geology of the Labrador Sea

The Labrador continental margin is an Atlantic-type extensional margin formed during the Early Cretaceous as an arm of the main North Atlantic rifted zone. During its evolution, the region was subjected to repeated orogenies, peneplaining, rifting, continental mantle exhumation, drifting, seafloor spreading between Labrador and Greenland, oceanic rift cessation, ridge abandonment and significant thermal subsidence (Dehler and Keen, 1993; Srivastava and Verhoef, 1992;

Srivastava and Roest, 1999; Roman, 1999; Chalmers and Pulversaft, 2001; Louden, 2002; Enachescu, 2005; Enachescu et al., 2006; Enachescu, 2006a and b; Enachescu et al., 2007; Martin 2007 and Stead 2008).

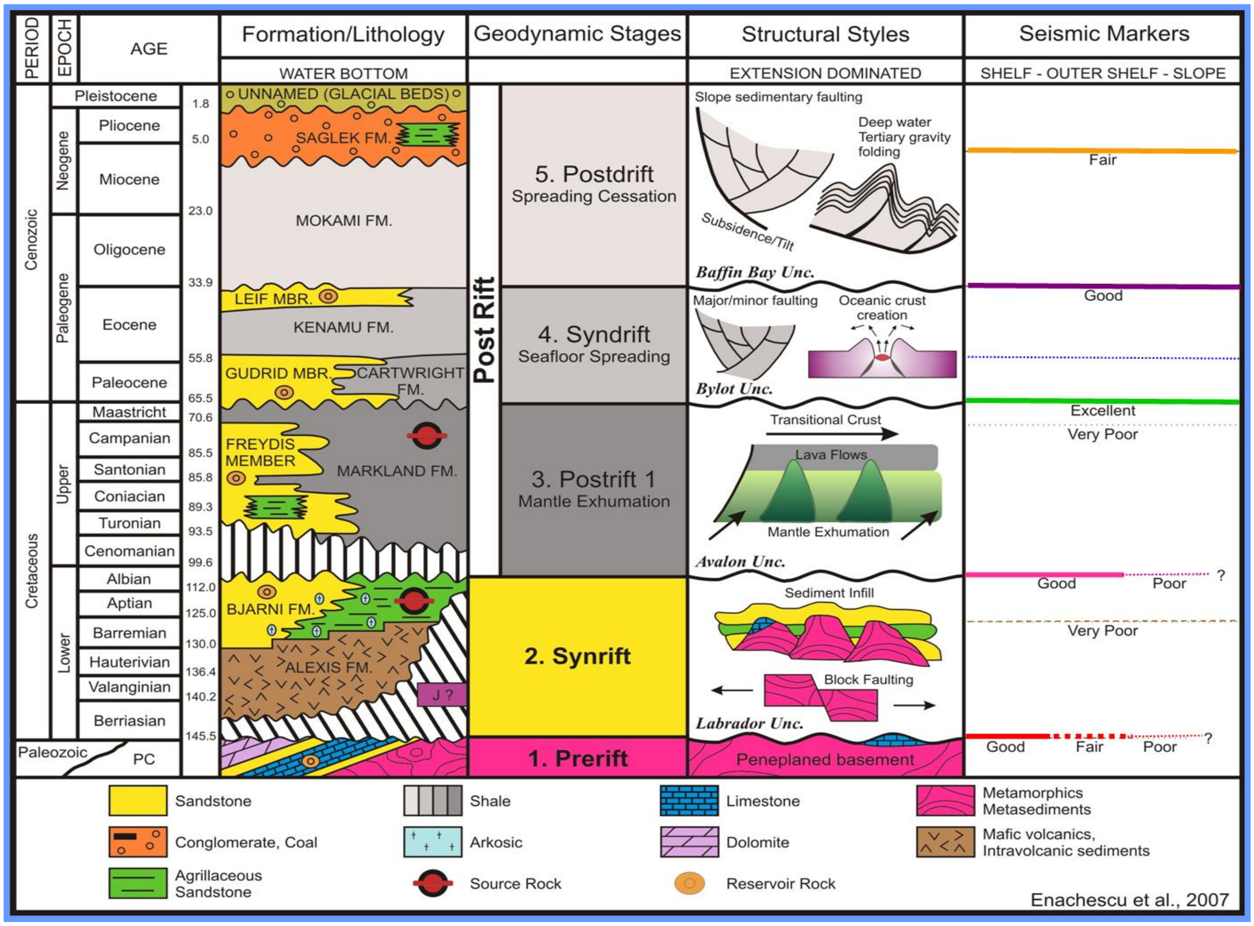


Figure 7. Generalized lithostratigraphy (after Umpleby, 1979; McWhea, 1980; Balkwill et al., 1990; Bell, 1989 and C-NLOPB), geodynamic stages, structural style and main seismic markers of the Labrador Sea basins (after Enachescu, 2006a and b; Enachescu et al., 2007).

As part of the Mesozoic intracontinental basin network formed between North America and North Africa and Europe, the Labrador margin has first order geologic attributes for classification as a non-volcanic Atlantic-type margin (Balkwill, 1987; Bell et al., 1989; Balkwill et al., 1990; Keen et al., 1990 and 1994; Dehler and Keen, 1993; Srivastava and Verhoef, 1992; Louden et al., 1996; Srivastava and Roest, 1999; Roman, 1999; Chalmers and Pulversaft, 2001; Louden, 2002; Enachescu, 2005a and b; Enachescu et al., 2006; Enachescu, 2006a and b; Enachescu and Martin, 2007; Martin, 2007; Enachescu et al., 2007; Stead 2008). These passive margin attributes include:

a) A large, almost flat continental shelf and a more steeply inclined continental slope;
b) An outer shelf and slope containing a thick prism of seaward-dipping Late Cretaceous and Tertiary clastic sediments;
c) Presence of alternate half-graben/horst geometry resulting from continental crust extension during rifting;

d) Lack of significant lateral compression, even though occurrences of compressional modified extensional structures were documented (Enachescu and Hogg, 2006);
e) Landward onlap or fault bounding of the synrift sedimentary sequence;
f) Existence of an early volcanic-volcanogenic sequence (Alexis Formation);
g) Presence of a deep water transitional crust segment including flood basalts, intrusions, possible gabbros, peridotites and serpentinized peridotites; and
h) Gradual transition to pure oceanic crust identified by magnetic lineation.

The basin fill exclusively contains terrigenous clastic sediments of Cretaceous, Tertiary and Quaternary age derived from widespread erosion of central Canada as well as from more proximal erosion of coastal uplands and intra-basinal ridges during rifting and separation of Greenland and North America. Unlike other North Atlantic sedimentary regions, the Labrador Basin does not contain salt. Enachescu (2006a and b) and Memorial University graduate students Martin (2007) and Stead (2008), upon synthesizing the results of the earlier exploration cycle (1970-1983), using the lithostratigraphic charts and tectonic evolution described by Umpleby (1979), McWhea (1980), Balkwill (1987) and Bell et al. (1989), and performing seismic stratigraphic interpretation on a new grid of regional seismic lines (GSI surveys 2002-2007), have divided the Labrador Basin into 5 major tectono-stratigraphic megasequences. The following sequence classification corresponding to major tectonic stages adapted from Enachescu, (2006a and b), Martin and Enachescu (2007), Martin (2007) and Stead (2008), is used in this report:

1. *Prerift Basement* (Precambrian - Early Paleozoic) formed during repeated orogenic episodes. It consists of Precambrian metamorphic and magmatic rocks (1.9-1.0 Ga) of the Grenville, Makkovik and Nain provinces of the Canadian shield as well as Paleozoic clastic and carbonate rocks dated Ordovician (Taylor, 1979 and 1981; Bell and Howie, 1990; Williams, 1995 and 2003; Williams et al., 1999; Atkinson and Fagan, 2000; Hall et al., 2002; Fagan and Hicks, 2005; Schwartz, 2008). At the contact between the prerift basement and synrift rocks is the regional Labrador Unconformity.
2. *Synrift Sequence* (Barremian - Albian) consisting exclusively of intracontinental deposits formed during continental rifting. Rift basin fill started with the volcanic rocks of the Alexis Formation including basaltic lava flows and volcanoclastics associated with crustal thinning. Deposition continued with a major influx of clastics including alluvial arkosic sandstones, microconglomerates, coals and lacustrine shales of the Bjarni Formation. The sequence is capped by the Avalon Unconformity.
3. *Postrift1 or Predrift Sequence* (Cenomanian – Maastrichtian) formed after the end of the intra-continental extension and during the exhumation of the continental mantle and its attachment to the stretched continental crust. Exhumed mantle and sepentinite ridges are yet unproven by drilling (Chian et al., 1995; Chian and Louden, 1994; Reston et al., 2001; Louden 2002; Enachescu, 2006a and b; Enachescu et al., 2007; Enachescu and Einarsson, 2007; Sibuet et al., 2007; Stead 2008). During the formation of this transitional crust, the sea invaded the rifted area depositing fine clastics of the Markland Formation (shale and siltstone) and the near shore, Freydis Member quartzose sandstone. The sequence is contained between the Avalon and Baylot unconformities.
4. *Syndrift* (Paleocene - Eocene) formed during the sea floor spreading and attachment of the oceanic crust to the previously formed transitional crust. The widespread fine clastics of the

Cartwright and Kenamu formations were deposited during this tectonic stage. Marginal marine and probably lowstand sandstones of the Gudrid and Leif members were also deposited. The syndrift sequence is bounded by Baylot and Baffin Bay unconformities.

5. *Postdrift Sequence* (Oligocene – Quaternary) formed after the cessation of seafloor spreading. Thick fine clastics of the Mokami Formation followed by coarse clastics of the Saglek Formation were set down during a period of increased thermal subsidence on the Labrador margin. The younger deposits were eroded from the near shelf and redeposited on the outer shelf and slope. Progradation of the paleo-shoreline is evident within this sequence. The younger slope deposits are undivided as they have not been penetrated yet by drilling. Deposition continued to recent time with a significant thickness of glacial beds being accumulated.

Postrift1 or Predrift Sequence, Syndrift Sequence and Postdrift Sequence altogether form the classic Postrift or the Thermal Subsidence Stage in the evolution of the Labrador rift system.

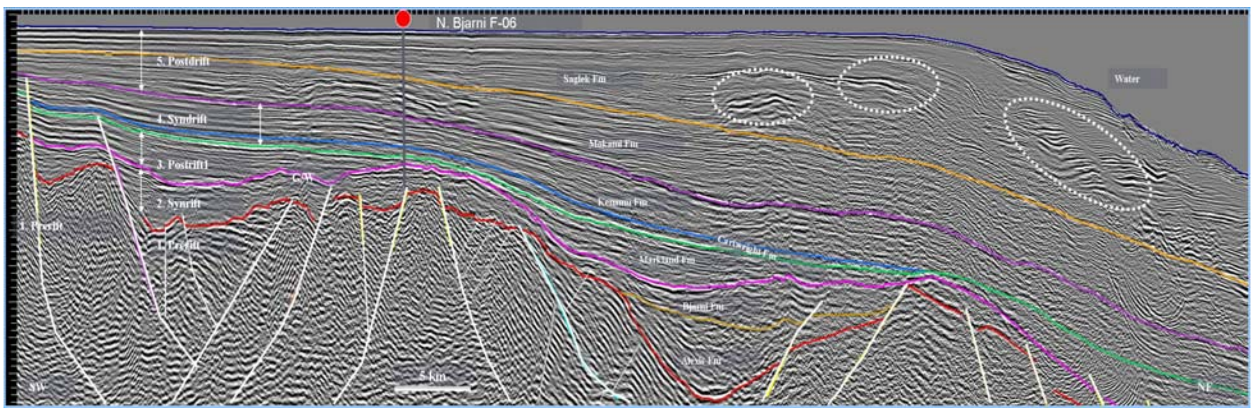


Figure 8. Regional seismic section (courtesy of GSI) across the Labrador continental margin at the latitude of N. Bjarni field in Hopedale Basin. Visible are major faults, regional seismic markers, the gas/water contact at N. Bjarni gas field and several amplitude anomalies in the postdrift sequence (modified after Martin and Enachescu, 2007).

As illustrated by seismic sections recorded in the Labrador Basin, the synrift formations fill the grabens and overlie the ridges. Synrift sedimentary rocks are deformed by NNW-SSE, along strike faults and ENE-WNW transfer faults. The postrift sedimentary units generally dip and thicken basinward. They are less deformed on the shelf, draping over the gentle postrift unconformity. More deformation of the postrift sequence is seen on the continental slope and rise due to gravity or shale detachment tectonics.

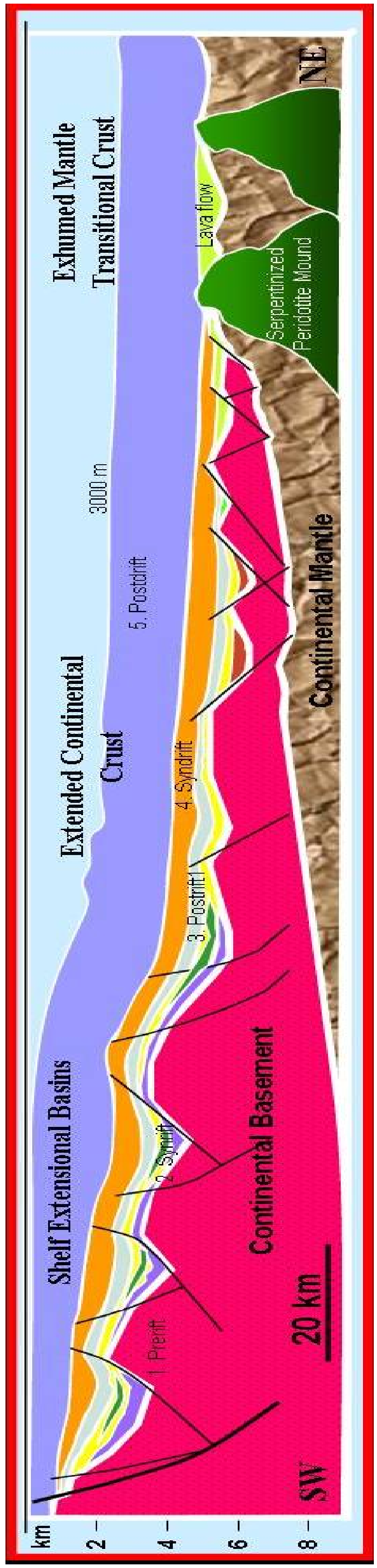


Figure 9. Regional geological cross-section across the Labrador continental margin at the latitude of Hopedale Basin (after Enachescu, 2007).

3.1. Hopedale Basin

The Hopedale Basin lies within the southern part of the Labrador Sea, being positioned north of the St. Anthony Basin and Cartwright Arch (Figures 3 and 10). The basin is approximately 500 kilometres long and up to 200 kilometers wide, and is situated in water depths ranging from 100 to 3000 metres (Balkwill, 1987; Balkwill et al., 1990; Enachescu, 2006a and b). The Hopedale Basin is the southernmost rift basin within the Labrador Sea and is positioned just north of the Orphan Basin which is an area of current exploration drilling by Chevron, ExxonMobil, Imperial Oil and Shell (Figures 2 and 3). The basin is situated between 55º and 59º latitude North (same latitude as North Sea). The on-shelf part of the basin is located in water depths of up to 450 m. The shelf was recently glaciated and contains several banks, plateaus and troughs (Bell et al., 1989). The continental slope is relatively gentle and less sculptured by canyons as compared to the Scotian Shelf or southern Grand Banks margins.

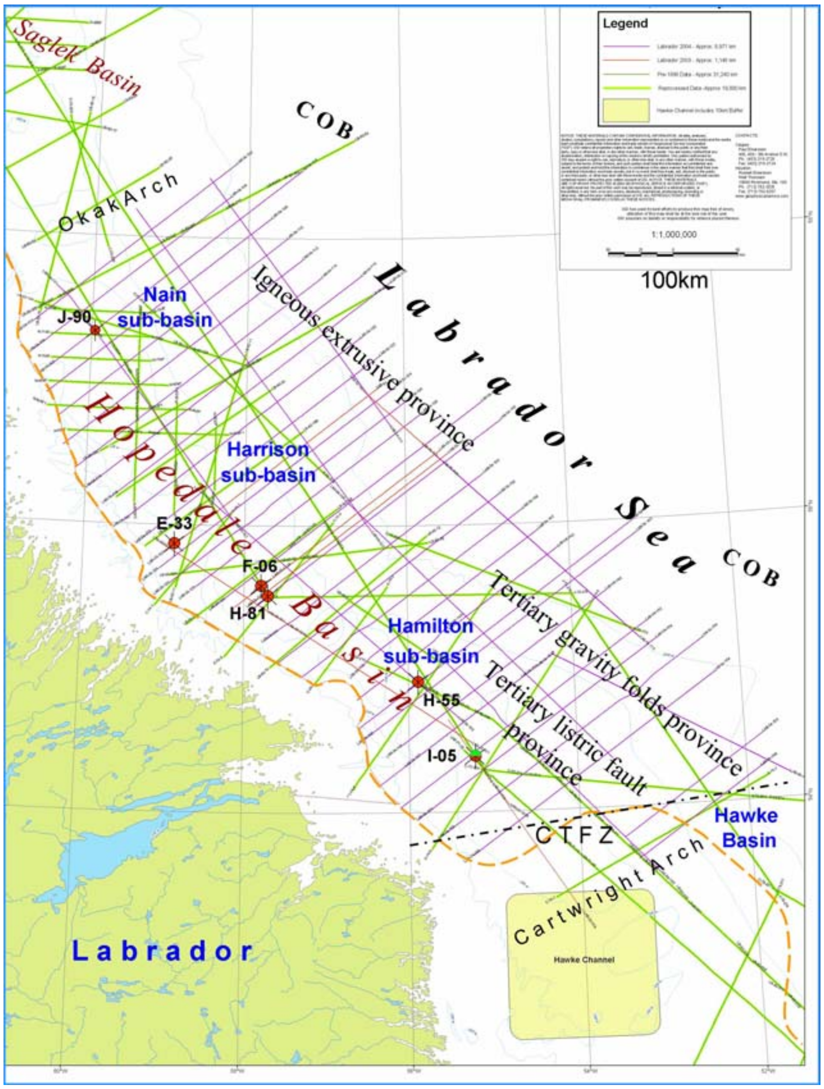


Figure 10. Main structural subdivisions of the Hopedale Basin, gas discoveries, oil show (North Leif I-05) and 2002-2005 regional seismic data base (courtesy of GSI) used to build this map and illustrate this report. Annotations are: COB = Continent-Ocean Boundary; CTFZ=Cartwright Transform Fault Zone

Geologically, the Hopedale rift basin is bounded: a) to the west by the onlap of Mesozoic beds onto a prerift basement hinge zone or in places by a down-to-the sea basin-bounding fault; b) to the south by the Cartwright Transfer Fault Zone (CTFZ) separating it from the Cartwright Arch and Hawke Basin; c) to the east by the lineament marking the Continent-Ocean Boundary (COB) that is placed beyond the eastern end of the seismic survey and d) to the north by the Okak Arch and an implied transfer zone separating it from the Saglek Basin (Figure 10). On the western flank of the basin, cratonic basement is disrupted by a complex system of Cretaceous rift faults. This faulted area ranges in width from 40 km in the north to 120 km in the south (Balkwill, 1987; Bell et al., 1989). Several subdivisions of the Hopedale Basin: *Nain, Harrison, Hamilton sub-basins, Tertiary listric fault province, Tertiary gravity folds province and Igneous extrusive province*, were introduced and discussed by Enachescu (2006a and b).

3.2. Saglek Basin

The Saglek Basin is located in the northern Labrador Sea, the Davis Strait area and on the southeast Baffin Island shelf (Figures 1 to 3). Even less explored than the Hopedale Basin, this basin contains only 9 exploration wells, all drilled on the shelf during the period from 1975-1982. One large gas discovery with NGLs (estimated between 2.3 and 3 tcf resources) was made at Hekja O-71. The well was located in a water depth of 350 m and encountered 44 m of net gas pay in a Paleocene reservoir (Gudrid Member equivalent) with 16% porosity and 10 md of permeability. While 6 wells were drilled in the NL sector of the Saglek Basin, no significant discovery was made.

This basin had a similar geological evolution to its more southerly sister and contains similar formation to those in the Hopedale Basin (Figure 7), but contains a larger distribution of synrift and postrift volcanics. The Saglek Basin previously described by Bell et al., (1989), Balkwill et al., (1990), Klose et al., (1982), Williamson et al., (2001) and Funck et al., (2007), and shown in Figures 2, 3 and 10, is the focus of a future NLDNR report.

4. Petroleum Geology of the Hopedale Basin

The Hopedale Basin is floored by Proterozoic metamorphic rocks and in places by Paleozoic strata including reservoir quality Ordovician carbonates. The basement was significantly stretched during Early Cretaceous when volcanics and then continental clastics were deposited (Figures 7 to 9). These synrift stage deposits contain the Bjarni Formation which includes both the excellent, thick Bjarni sandstone reservoir facies and quality petroleum source rocks. Following rifting, the continental mantle rocks which emerged to the bottom of the invading early Late Cretaceous sea, were modified by encroaching seawater and serpentinized. During this predrift stage, more clastics of the Markland Formation and Freydis Member including reservoir and source rocks were deposited in an enlarged and slightly subsiding basin (Figures 7 to 9).

A drift stage followed when Labrador and Greenland separated and oceanic crust was emplaced between the two departing continental plates. For the duration of this stage, clastics of the Cartwright and Kenamu formations were deposited along the Labrador margin. Two other sandstone members, Gudrid and Leif, were deposited in coastal and probably also in deep water settings. A final postdrift stage followed when the movement of Greenland away from Labrador and the development of oceanic (basaltic) crust ceased. Throughout this stage shelfal erosion and redeposition of sediments took place enlarging Labrador's continental margin and accommodating a great amount of subsidence in both the Hopedale and Saglek basins. The fine clastics of the Mokami Formation followed by the coarse clastics of the Saglek Formation and by unnamed glacial beds were deposited during this stage.

The Hopedale Basin discoveries made in the 1973-1983 exploration cycle have estimated total resources of 4.2 tcf of natural gas and 123 million barrels of NGL of 50-60º API (C-NLOPB). One complex structure formed by the adjacent Bjarni and North Bjarni fields contains more gas than the currently producing Sable Project (composed of 5 medium-size fields offshore Nova Scotia) or the large (2.7 tcf) White Rose gas cap in the Jeanne d'Arc Basin (Figures 6 and 8).
Therefore, a proven petroleum system exists in the Hopedale Basin and there are high expectations for further hydrocarbon discoveries in this basin. The following section on the Hopedale Basin petroleum system(s) is written following accounts by Umpleby (1979), McWhea

(1980), Balkwill et al. (1987), Bell et al. (1989), Fowler et al. (1995), Enachescu (2006a and b), Martin (2007) and Stead (2008), reviewing the exploration documents in the C-NLOPB archive and the limited petroleum geology literature on the area.

4.1. Source Rocks

Several Mesozoic intervals with medium to rich source rocks have been recognized from drilling and geochemical analyses (Powell, 1979; Rashid et al., 1980; McMillan, 1982; Balkwill, 1987; Bell et al., 1989; Balkwill et al., 1990; Fowler et al., 2005). Historically, the Markland shales have been considered the main source rock for the Labrador Sea gas accumulations (e.g., McWhae et al., 1980; Balkwill and McMillan, 1990; Bell et al., 1989). Fowler et al. (2005) documented that the Bjarni Formation shale intervals have high organic content, are mature and constitute the principal source rock for the area, including the Hopedale Basin. Graduate research work (sponsored by PRAC, NSERC and PPSC) at Memorial University based on geochemical parameters provided by GSC and seismic lines donated by GSI, shows increased source rock presence and adequate maturation on the outer shelf and slope (Enachescu 2006a and b; Martin and Enachescu, 2007; Martin, 2007; Stead 2008).

Bjarni Formation shale. Recent Rock-Eval analysis of cuttings, geochemical analysis of organic rich intervals and organic petrology shows that the best source rock occur in the Early Cretaceous Bjarni Formation and contains mostly Type III terrestrial organic content (Fowler et al., 2005). The source interval is quite thick (more than 500 m) at Herjolf M-92 well having a TOC of 5%. Additionally, coal seams are present in the Bjarni Formation that can generate gas. Bjarni shales are located mostly in the synrift depressions and show thickening in the numerous half-grabens in the outer shelf and on the slope. An average depth of 3,335 meters to R_0>0.7 (source maturity indicator) was computed by Martin (2007) as minimum depth of burial of Bjarni shales in order to generate hydrocarbons. This average depth to maturation was used to produce a “kitchen” map for the Bjarni Formation, which shows an increased amount of possible Bjarni source rock on the eastern part of the shelf and in deepwater. The un-biodegraded, 32° API oil encountered at North Leif I-05 shows immaturity (Fowler et al., 2005) but more mature source rock and reservoired oil may exist in deeper parts of the basin.

Markland Formation shale.Until recently, Cenomanian to Maastrichtian Markland Formation was considered the main source rock for the Labrador gas (GSC, 1989; De Silva, 2003; Maneley, 2003; Klassen, 2005; Enachescu and Fagan, 2005a). According to these authors the fine grained Markland Formation includes high TOC shales (1% to 4%) and is also a terrestrial dominated source rock with some marine influence (Type II and III source rock). As noted previously, an average depth of 3,335 meters to R_0>0.7 was computed by Martin (2007) from Hopedale Basin wells as the minimum depth of burial of Markland shales in order to generate hydrocarbons. Martin’s (2007) study agrees with the GSC Atlas (Bell et al., 1989) that the Markland Formation is mature in a very large area situated downdip from the wells drilled on the inner shelf. Time Structure and Isopach maps of the Markland Formation show that the gas discovery wells within the Hopedale Basin lie outside of the region where source rock maturity is predicted. However, their structures are opened to updip hydrocarbon migration from the more easterly half-grabens where shales are mature. Unlike the intermittent presence of the Bjarni shale, the Markland Formation is a thick, regional shale that can provide a very large hydrocarbon kitchen.

As mentioned above, the Labrador Basin Atlas (Bell et al., 1989) indicates that when vitrinite reflectance values (Ro) for Markland shales are greater than 0.7%, shales are buried deep enough to generate hydrocarbons. Issler and Beaumont (1987) suggest that Ro values of 0.6 are sufficient for source maturation; other authors conclude that hydrocarbon sources start generating gas even at lesser values of 0.4-0.6 Ro. Even with lower Ro values, the Bjarni and Markland shales in the region west of the discovery wells are not buried to the appropriate depth to generate large quantities of hydrocarbons. Some of the initial wells drilled closer to the Mesozoic onlap edge had no chance of mature source rocks or of being in the path of hydrocarbon migration. Mapping and geochemical studies point toward the areas east of the chain of discovery wells as the most likely hydrocarbon kitchen for the gas and condensate accumulations and for future discoveries.

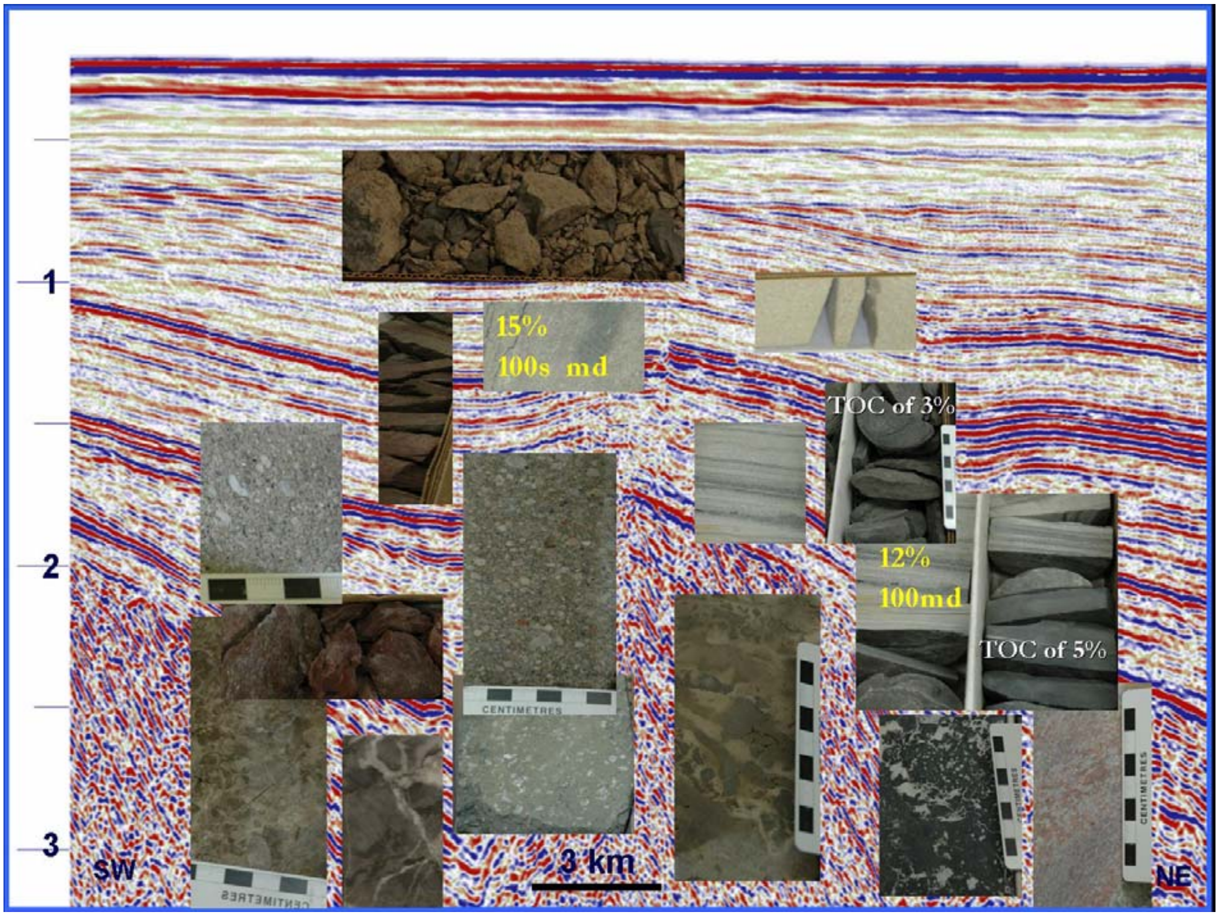


Figure 11. Cores retrieved from Hopedale Basin wells superimposed on a generic seismic line (courtesy of GSI) through a basement high. Bsm = basement rocks including granites and granodiorites; Carb = Basement limestones and dolomites (Ordovician); Alexis Formation basalts and volcanoclastics; Bjarni Formation sandstones (reservoir) and shale (source rock); Markland shales (source rock); Freydis and Gudrid members sandstones and Kenamu shale (seal).

Other source rocks. Paleozoic sedimentary rocks are organically overmature and are unlikely to have generated hydrocarbons in the Labrador Sea basins. Some of the younger formations (Cartwright, Kenamu and Mokami) are predominantly shaly and may contain source rock intervals. If this is the case, they will be mature only on areas near the shelf break, on the slope and in some deepwater troughs.

Late Jurassic source rocks? Several indications that Kimmeridgian source rocks may extend in the Labrador Sea from the oil proven Grand Banks and SW Ireland offshore basins were presented in the literature (e.g., Bojesen-Koefoed et al., 1999 and 2004; Sønderholm et al., 2003;

http://www.dgu.dk/ghexis/Ghexis-22.htm#4; Enachescu et al., 2008). A series of small and deep sub-basins are observed from new seismic data in the outer shelf and slope area. These smaller sub-basins may have started extending earlier (in Late Jurassic) or the epicontinental Late Jurassic Sea present on the Grand Banks and offshore Ireland may have sent arms between Labrador and Greenland, depositing organic rich shales. Increased exploration activity has taken place across the sea on Greenland's continental margin where indications of older sequences, including Late Jurassic source rocks, have been observed in outcrop and on seismic data. The Late Jurassic shales are high TOC, high HI, Type I source rocks that have generated the prolific Jeanne d'Arc Basin oil and gas fields. However this hypothesis is unproven by direct geologic results, as no wells have been drilled in areas suspected to contain older then Cretaceous rocks on either margins of the Labrador Sea.

4.2. Reservoir Rocks

Up to now, gas and condensate accumulations and oil shows have been found in Bjarni and Gudrid sandstones and Ordovician carbonates.

Bjarni sandstone. During the initial intra-continental extension, elongated rift valleys and intervening ridges have received a major pulse of coarse clastics that formed the predominantly sandy Bjarni Formation. The most widespread reservoir, the Bjarni sandstone, is thick in half-grabens and thins on the ridges, showing syntectonic deposition. This Early Cretaceous synrift, non-marine arkosic sandstone, is the main reservoir in the Hopedale Basin. As some of the in-graben thickening is caused by the presence of Bjarni source rocks, this creates fortuitous source/reservoir juxtaposition. The Top of the Bjarni Formation is a good quality marker that can be mapped with relative confidence on the modern seismic data basinward of the Bjarni field and North Leif lineament and into the deepwater. However, as proven by the Roberval C-02 well, some of the high blocks are void of Bjarni sandstones due to non-deposition or postrift erosion.

The Bjarni sandstone has good to high porosity (12% average) and good permeability (average 100 md). In the North Bjarni F-06 well the porosity was 19% while at Bjarni H-81 and Hopedale E-33 wells, Bjarni sandstone porosity had values of 20% and 11% respectively (C-NLOPB). These excellent reservoir parameters make the Bjarni sandstone an ideal petroleum reservoir.

Lower Paleozoic Carbonate. The Paleozoic prerift "basement" contains sedimentary rocks that cannot be written off as exploration targets, as two large gas discoveries have been made in the carbonates. The Gudrid discovery (924 bcf recoverable) tested 20 mmcfd from an Ordovician dolomite with 10% porosity and the Hopedale discovery (105 bcf recoverable) tested 20 mmcfd from a Paleozoic (Ordovician?) limestone with 8% porosity. These carbonate reservoirs were intersected in Gudrid H-55, Hopedale E-33, Roberval K-92, South Hopedale L-39, and Tyrk P-100 wells. The Paleozoic carbonate reservoirs (limestone and dolomites) seem to be present mostly in the southern part of the Hopedale Basin. These carbonates were dated as Ordovician (e.g. Schwartz, 2008; C-NLOPB). The carbonate reservoirs below the acoustic basement are difficult to interpret on 2D seismic data. A combination of reflection data and high-resolution potential field data might help to discriminate between metamorphic/intrusive and carbonate basement areas.

Other reservoirs. *The Freydis Member* of the Markland Formation (Coniacian-Scampanian) is a shallow-marine, shoreline sandstone that has an average porosity of 15% and permeabilities in the range of a few hundred millidarcies. It was encountered in the Freydis B-87, Gilbert F-53, Ogmund E-72 and Skolp E-07 wells, some located far from the 2008 landsale area. Due to poor reflectivity contrast with encasing shales and with the limited distribution, the Freydis Member cannot be regionally mapped with present seismic data density (Bell et al., 1989; Martin, 2007).

Younger sandstones with reservoir properties have been deposited in the basin during intermittent Neogene and Paleogene uplift of the basin flank (Labrador Peninsula), and related turbidites may have accumulated on the continental slope and in the deepwater. Turbidites and any other lowstand sand deposits are plays that are yet undrilled in the Hopedale Basin or anywhere on the Grand Banks and Labrador slope. The Tertiary sandstones encountered on the shelf have high porosity (up to 25%) and permeability values.

The Gudrid Member of the Cartwright Formation (Paleocene) was intersected by several wells located on the inner continental shelf. Seismically, it has an associated high amplitude marker but its tracking into the outer shelf and deep water becomes difficult due to low seismic resolution and lack of tie points. The GSC Labrador Atlas (Bell et al., 1989) and MSc thesis work by Martin (2007) and Stead (2008) indicate the Gudrid sandstone marker is probably not present beyond the shelf edge. The Gudrid sandstone tested gas at the Snorri J-90 well - the only well of the five significant discoveries in the basin to test gas from the Paleocene sandstone. The Gudrid Member porosity at the Snorri J-90 well was 18% (C-NLOPB). *The Leif Member* of the Kenamu Formation (Late Eocene) was penetrated by several wells within the Hopedale Basin, among which Gudrid H-55, Hopedale E-33 and Roberval C-02 are closer to the landsale area. It is difficult to seismically correlate and track the Leif Member away from the wells that have intersected this sandstone.

4.3. Seals

Seals should not be a problem in the Labrador Sea. Numerous tight intervals exist in all postrift sequences (predrift, syndrift and postdrift sequences). The Hopedale Basin has a high percentage of fine clastics facies in all marine successions following the synrift main sandy pulse. Both the Markland and Kenamu formations are excellent regional seals. On the inner shelf, faults are usually restricted to the synrift and predrift sequences and die out in the predominately shaly Mokami and Kenamu formations.

4.4. Hydrocarbon traps

Numerous types of structural, stratigraphic and combination traps were identified in seismic data in the Hopedale Basin. However, early successful drilling of the Bjarni sandstone on structural highs made this the favourite hydrocarbon play in the basin. The Bjarni sandstone is widespread on the Labrador shelf and was derived from both rift shoulders and from intra-basinal ridges.

Repeatedly, traps drilled on the Labrador shelf were anticlinal features resulting from the Bjarni Formation draping over basement ridges or forming fault bounded horsts. A large number of horsts and fault blocks are seen on the new seismic data, some forming impressive exploration leads. Drape over these high blocks, onlap and lateral pitchouts of Bjarni and younger sandstones are other possible hydrocarbon plays. Also, extensional anticlines modified by compression are located on the outer shelf and remain undrilled to date (Enachescu and Hogg, 2006; Figure 12).
Paleozoic limestones and dolomites found on the tops or sides of higher basement blocks often have reservoir properties (Figure 11). On the outer shelf and slope, listric faults and associated rollovers could be exploration targets (Figure 13).

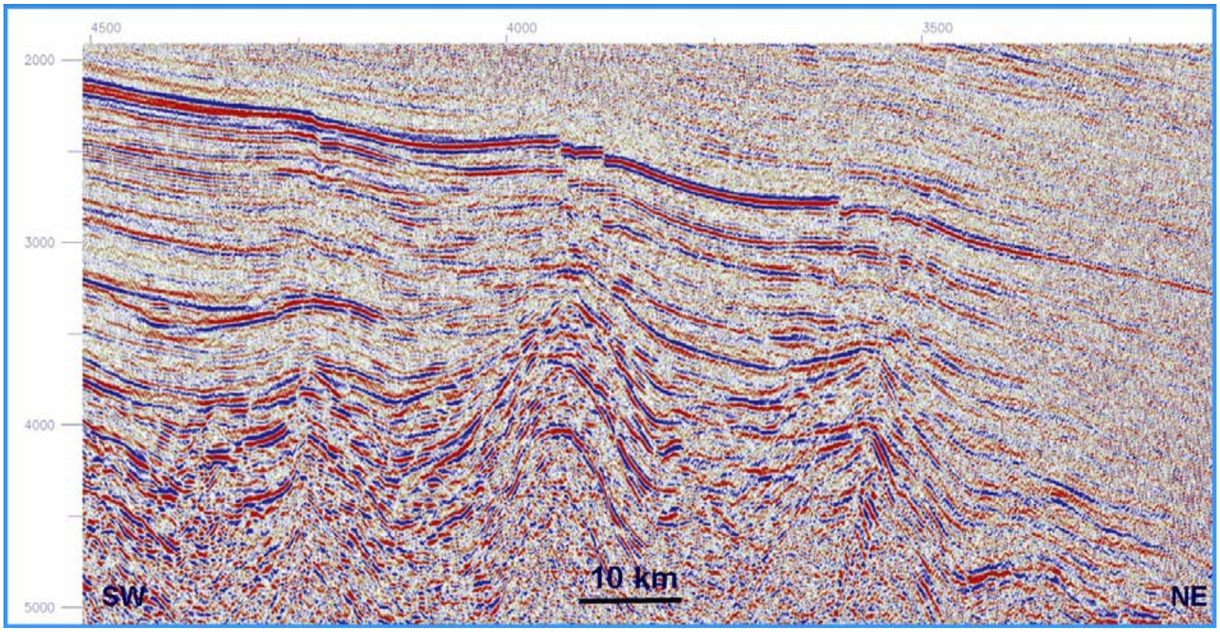


Figure 12. Dip seismic line (courtesy of GSI) across Hopedale Basin showing several structural highs with Bjarni and younger sandstones with reservoir potential. Extensional anticlines appear modified by mild compression.

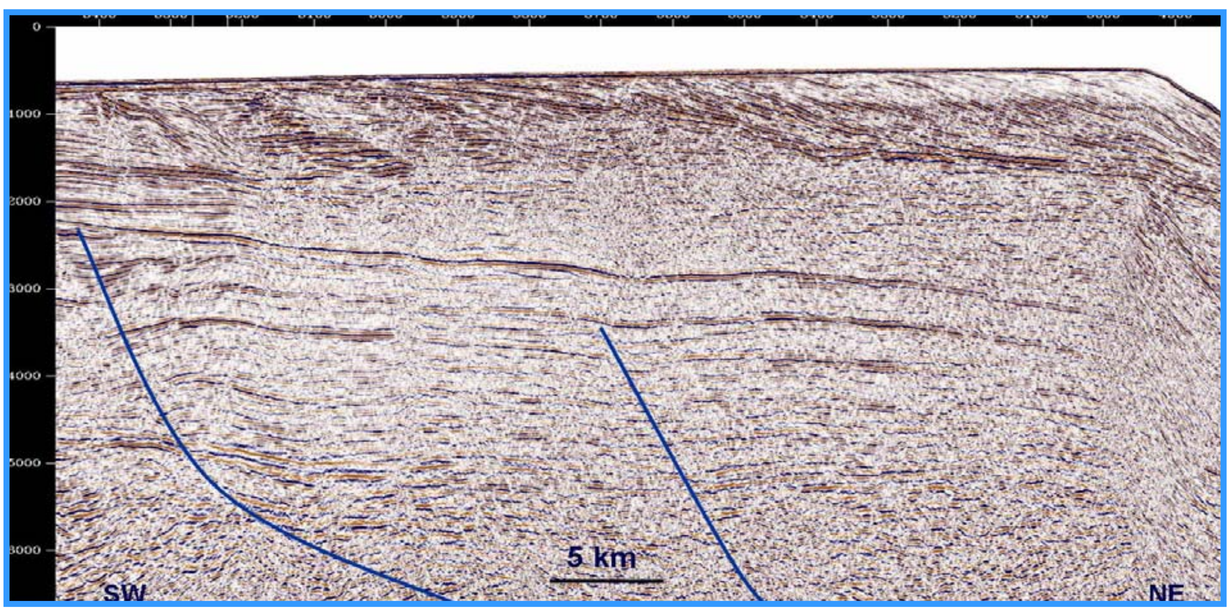


Figure 13. Dip seismic line (courtesy of GSI) across Hopedale Basin showing large rollover anticlines triggered by listric faults.

Other traps are anticlines and rotated blocks that are poorly imaged beneath the shelf breaks and in deepwater and that need potential field data for improved definition. Rollovers due to gravity induced listric faulting and compressional anticlines (shale detachment) over basement or transitional crust are other types of structural traps present. Although previously undrilled, there are probably more stratigraphic traps along the slope and in deepwater. Traps of this nature may consist of lenses of sandstones (turbidite) of the Freydis, Gudrid or Leif sandstones' deepwater equivalents encased within thick shales.

4.5. Maturation and Migration

Gas discoveries in the Hopedale Basin prove that source rocks in the basin are mature and migration of hydrocarbon to trapped reservoirs took place. It is largely accepted that the Hopedale Basin had a high geothermal gradient of 2.7º C/ 100 m and that source rocks started expelling wet gas after reaching burial depths of approximately 2,500 m probably in Late Oligocene - Early Miocene time (GSC, 1987; De Silva, 2003). While we agree with these authors that state that source rocks should start expelling hydrocarbons at about 2,500 meters depth, adequate source maturation for both Bjarni and Markland shales should occur at depths of about 3,335 meters (corresponding to R_0>0.7). These subsea depths for source rocks occur just east of the Gudrid-Bjarni-Snorri wells lineament and suggest a very large kitchen exists on the outer shelf slope and rise (Enachescu, 2006a, b; Martin, 2007). The gas accumulations in horst blocks and drape anticlines have benefited from lateral migration of hydrocarbons from the eastern deeper troughs where Cretaceous source rocks should be mature (Powell, 1979; Enachescu and Martin, 2007; Martin 2007). According to Fowler et al. (2005) the oil window should be deeper at 3,000-3,500 m. The N. Leif I-05 well contained waxy crude which was believed to be generated from terrestrial Type II and III kerogens found within the partially mature Bjarni Formation (Issler and Beaumont, 1987).

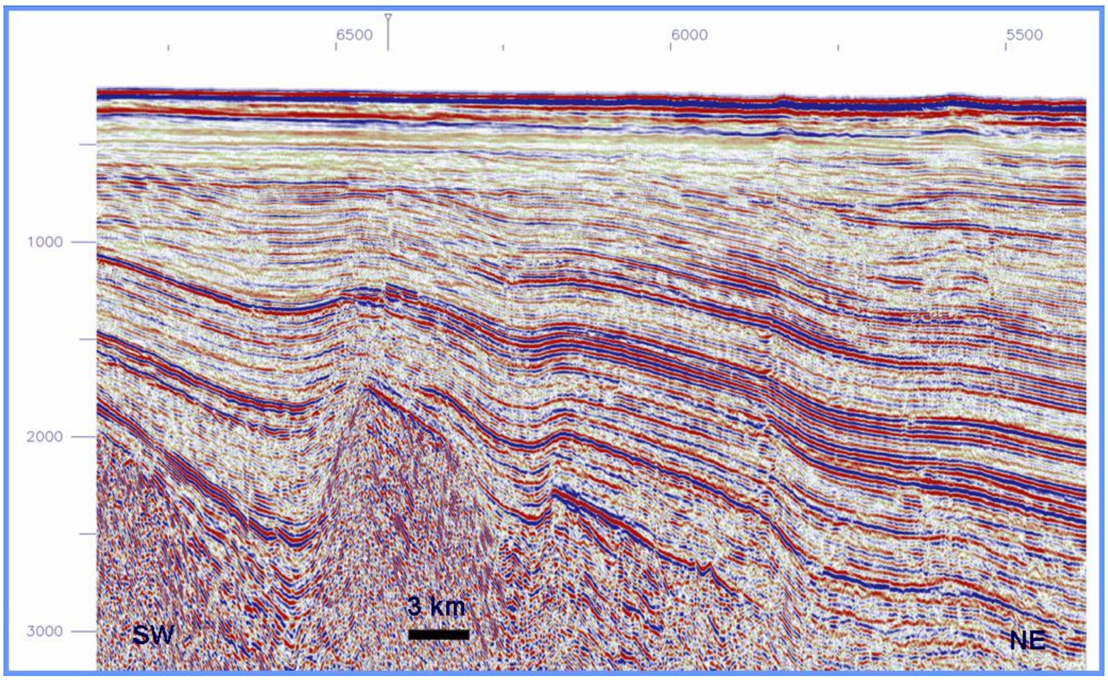


Figure 14. Dip seismic line (courtesy of GSI) across the Hopedale Basin showing large basement rotated blocks, Bjarni drape anticlines and amplitude anomalies in the synrift and postrift sequences.

Numerous seismic amplitude anomalies and other Direct Hydrocarbon Indicators (flat spots, gas chimneys, frequency attenuation, bright spots along faults, etc.) are present in the basin, therefore indicating hydrocarbon migration and accumulation (Figures 8, 11-13; Chapter 5 and Enachescu, 2006a and b).There is no doubt that a prolific petroleum system(s) described in the above sections, exists in the Hopedale Basin and should extend north into the Saglek Basin and eastward into the outer shelf and slope of the Labrador Sea.

5. Petroleum Potential of 2006 Call for Bids Parcels 1 to 4

The four Call for Bids NL07-2 parcels 1 through 4 cover a total area of 939,678 hectares (2,321,994.9 acres) within the Labrador Sea. All parcels are located within the south - central part of the Hopedale Basin between 54º and 55º 30' North latitude, in water depths generally ranging from 130 to 400 metres (Figures 15 and 16). In their easternmost parts, just near the shelf break, Parcels 1, 2 and 4 stretch in to deeper water (more than 400 m and touching 500 m). The magenta area in Figure 15 laying directly west of the parcels represents the Labrador Inuit Settlement Area offshore Zone. For information on the Labrador Inuit Settlement agreement, go to: (http://www.laa.gov.nl.ca/laa/liaclaims/default.htm).

Geologically, the parcels fall within an area with a thick synrift sedimentary fill overlain by basinward thickening postrift sedimentary successions. The parcels are situated on the continental margin of Labrador. The basinal structure in the landsale area is characterized by several parallel extensional ridges and elongated half-grabens offset by oblique transfer faults. The Late Cretaceous to Cenozoic sedimentary cover that blankets the extended basement thickens from 2 km in the west to about 8 km in the east (Figures 8 and 9). The seismic section in Figure 8 crosses Parcels 3 and 4 at the latitude of the N. Bjarni F-06 discovery well, while the geologic cross-section in Figure 9 is a generic subsurface section typical for the structure and stratigraphy of this part of the Hopedale Basin.

Figure 15. Location map for the Parcels 1 to 4 offered for licensing at the Call for Bids NL07-2 offshore Labrador. The Zone = (magenta area).

Several location maps of the Hopedale Basin showing the Call for Bids parcels, exploration wells and existing Significant Discovery Licences within the parcels are shown in Figures 3, 15, and 16. Under the legislation, the SDLs are held by interest owners involved in the gas discovery, and these areas are excluded from the landsale parcels. Nevertheless, the parcels are very large, with the typical size exceeding 100 times the area of the standard Gulf of Mexico

OCS tract (Table 1). This allows for each individual parcel to hold several large structural and stratigraphic features capable of containing several tcf of gas.

Call for Bids Labrador	Area	Area	Area	GOM tract
CFB NL07-2	Hectares	Sq Km	Acres	multiples
Parcel #1	236,981	2,370	585,592.80	103.3
Parcel #2	236,525	2,365	584,466.00	103.1
Parcel #3	233,712	2,337	577,514.90	101.8
Parcel #4	232,460	2,325	574,421.20	101.3
TOTAL	939,678	9,397	2,321,994.9	409.5

Table 1. CFB NL07-2 Parcels 1 to 4 areas compared to standard GOM OCS tract size (3 by 3 miles).

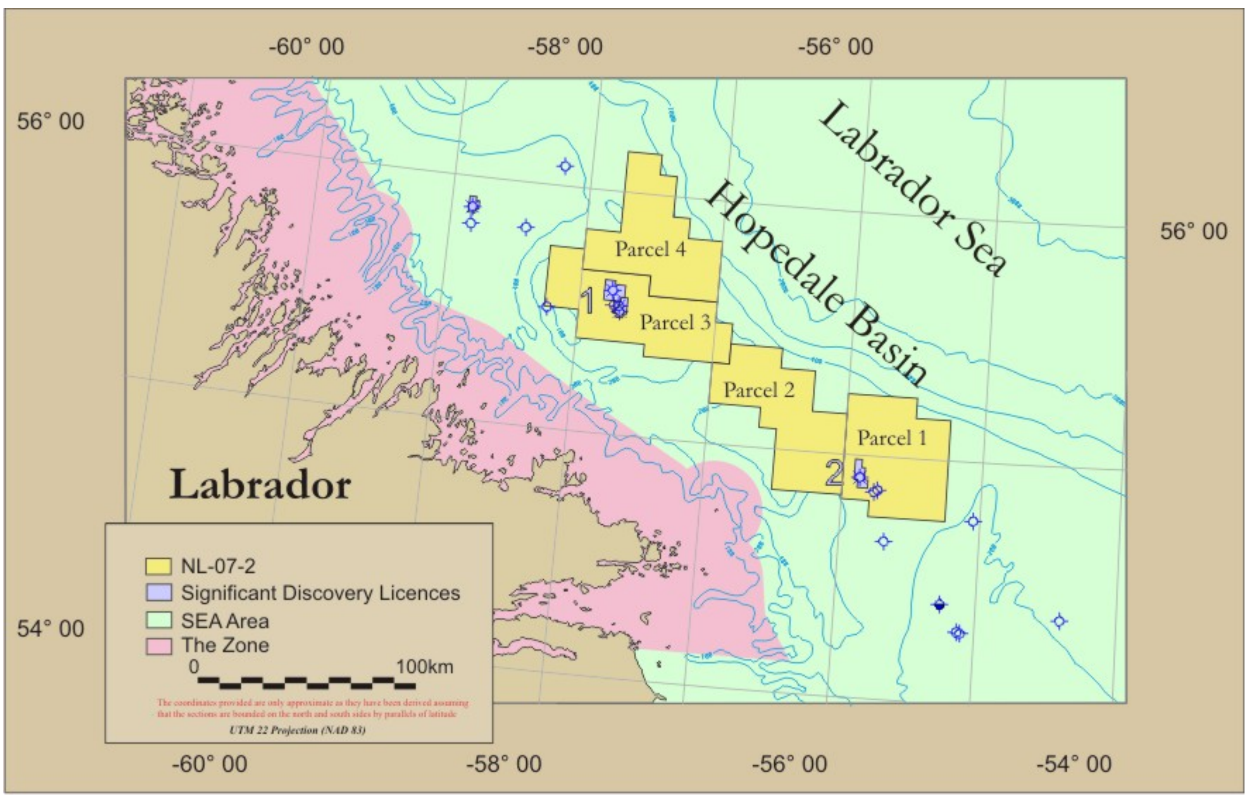


Figure 16. Location map for the Parcels 1 to 4 offered for licensing at the Call for Bids NL07-2 offshore Labrador. Annotations are: 1 = Bjarni/North Bjarni gas field SDLs; 2 = Gudrid gas field SDL; SEA = Strategic Environment Assessment (light green area); The Zone = (magenta area).

The Cretaceous source rocks are mature in the area and good reservoir rocks were intersected within the Call for Bids parcels and environs (Enachescu, 2006a and b; Martin and Enachescu, 2007, Martin, 2007). Out of seven exploration wells drilled on these offshore parcels during

1970-1982, four were gas discoveries. Six other wells were drilled on trend in the southern vicinity of the parcels, one of which, the North Leif I-05 well had the most northerly oil show on the East Coast of the N. Atlantic. North of the parcels, another six wells were drilled, with Hopedale E-33 proving to be a 105 bcf gas discovery. As mentioned in section 4, a Late Jurassic oil source rock may exist in the deeper parts of the basin where earlier sag or localized rift troughs may have formed between Labrador and Greenland. Dyke swarms running parallel to the southwest Greenland coast were dated at 150 to 160 million years, suggesting that Mesozoic extension in the Labrador Sea may have began as early as late Jurassic.

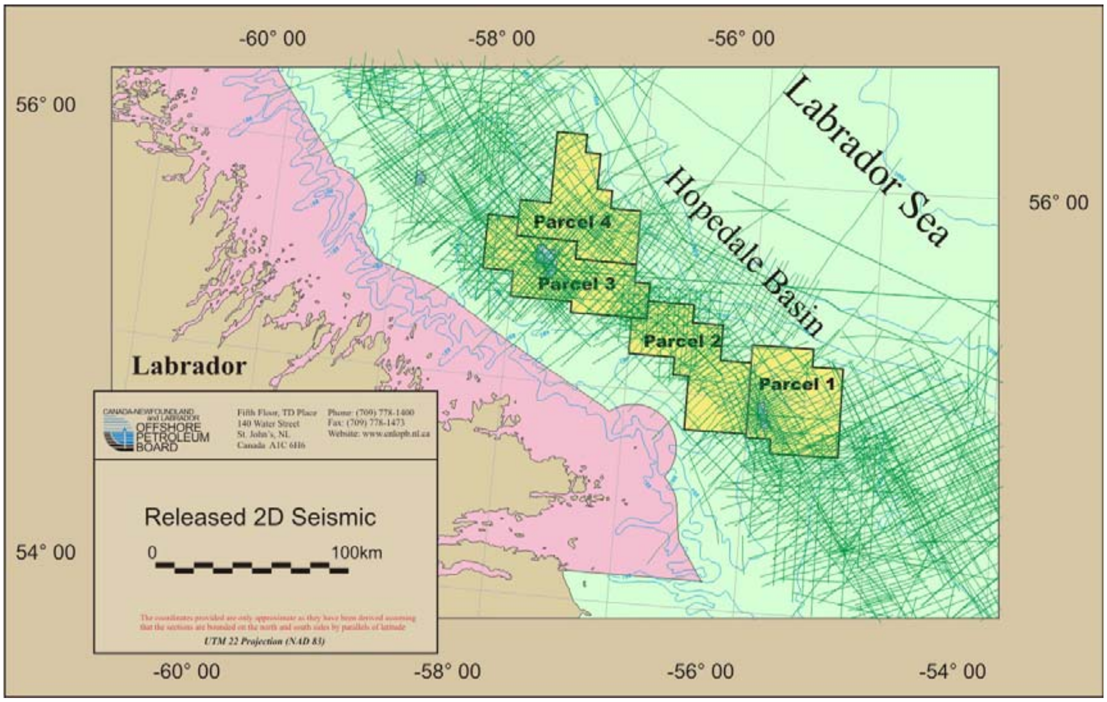


Figure 17. Seismic Base Map showing the pre-1990 recorded and released seismic lines covering the CFB NL07-2 parcels and environs. Map includes both exclusive and non-exclusive data.

Only parcels 1 and 3 have been previously drilled, while parcels 2 and 4 are yet undrilled. The exploration wells within the parcels will be discussed in more detail in Sections 5.1 - 5.4. Additional information on these and other offshore Newfoundland and Labrador wells can be obtained from C-NLOPB Schedule of Wells (C-NLOPB, and http://www.cnlopb.nl.ca/well_ne.shtml), GSC Atlantic East Coast Basin Atlas (http://basin.gsca.nrcan.gc.ca/index_e.php) or from the Government of Newfoundland and Labrador Department of Natural Resources.

Complete well history reports and cores for offshore wells are available from the C-NLOPB. Lithostratigraphic logs are available from Canstrat (http://www.canstrat.com/canlogix/eastcoast/index.html) and a complete suite of digital well logs for most of the Labrador wells can be obtained from IHS (http://energy.ihs.com/Products/). Well results and logs, and well to well correlations are also contained in the GSC Labrador Atlas (Bell et al.,1989 and http://gsc.nrcan.gc.ca/org/atlantic/pub_e.php). The regional bathymetry of the Labrador shelf shows several banks and saddles, but the water bottom is generally smooth and except for iceberg scours, without major hurdles for exploration drilling or subsea development.

Seismic data coverage is good to excellent for all the bid parcels and environs and is adequate for a regional study and lead and prospect definition. A large volume (over 25,000 linear km) of 1970-1982 vintage 2D seismic lines in the area are available in hard copy format from the C-NLOPB, while some reprocessed older data and digital files are available from data vendors or petroleum companies with a seismic library in the area (Figure 17). Most of this data was recorded with short streamer length (2.6 to 3.5 km) that preclude deep penetration, adequate multiple suppression and proper migration of the deeper events.

A comprehensive non-exclusive (spec) data grid was acquired during 2003-2007 by Geophysical Service Incorporated of Calgary (GSI) and is available for immediate licensing (http://www.geophysicalservice.com/default.asp?webpage=291). Lines are spaced at 5, 10 and 20 kms and denser in areas of interest, and were acquired using long streamer length (minimum 6 km) and similar recoding parameters. Dip (NE-SW), strike (NW-SE) and well tie lines were collected and processed using modern multiple elimination routines and prestack time migration (Figure 18).

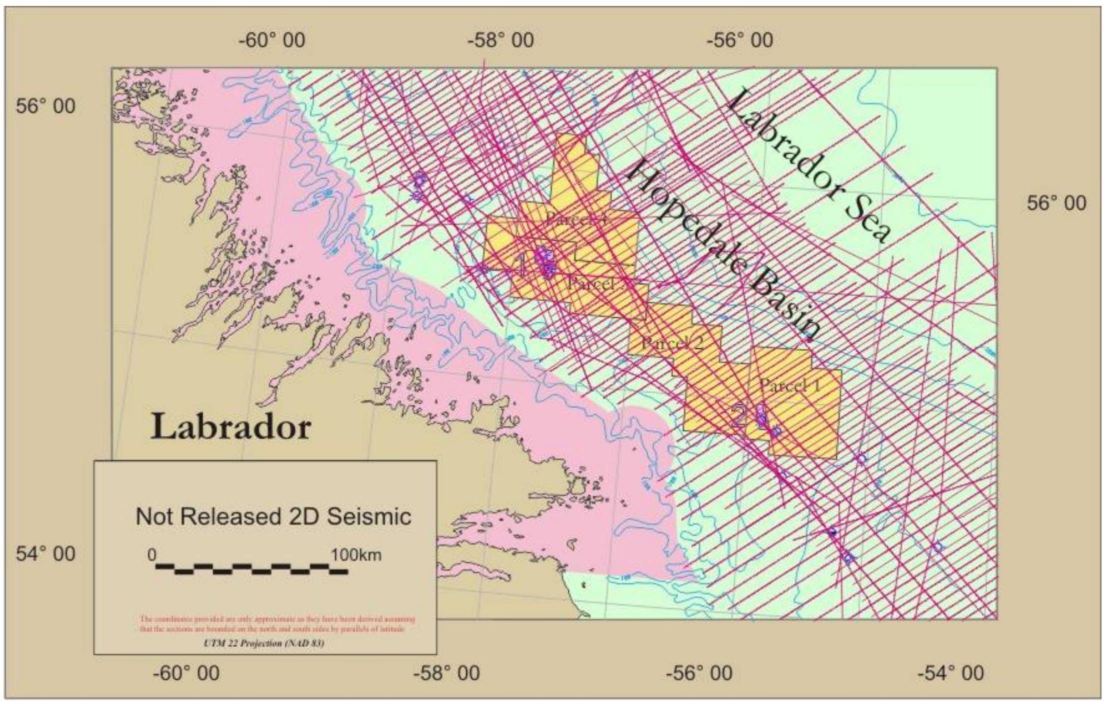


Figure 18. Seismic Base Map showing the post-2003 spec seismic lines recorded by GSI and covering the CFB NL07-2 parcels and environs. All lines are available for licensing in digital format.

In addition, GSI has reprocessed their pre-1990 non-exclusive data that is also available for licensing. All GSI data are available in digital, ready for workstation, format. The old (pre-1990) and new (post-2003) data over the landsale parcels form an impressive coverage for an offshore frontier area (Figure 19). No 3D survey has been acquired to date in the Labrador Sea.

The quality of older 2D seismic data is fair to poor; some lines are unmigrated, have water bottom multiples and poor penetration beneath the postrift unconformity. The quality of the modern seismic data is good to excellent for all parcels. Some water-bottom multiples, while greatly diminished, are still visible in areas with shallow basement or at the shelf break (Figure 8). This is due to the presence of a hard water bottom in the area.

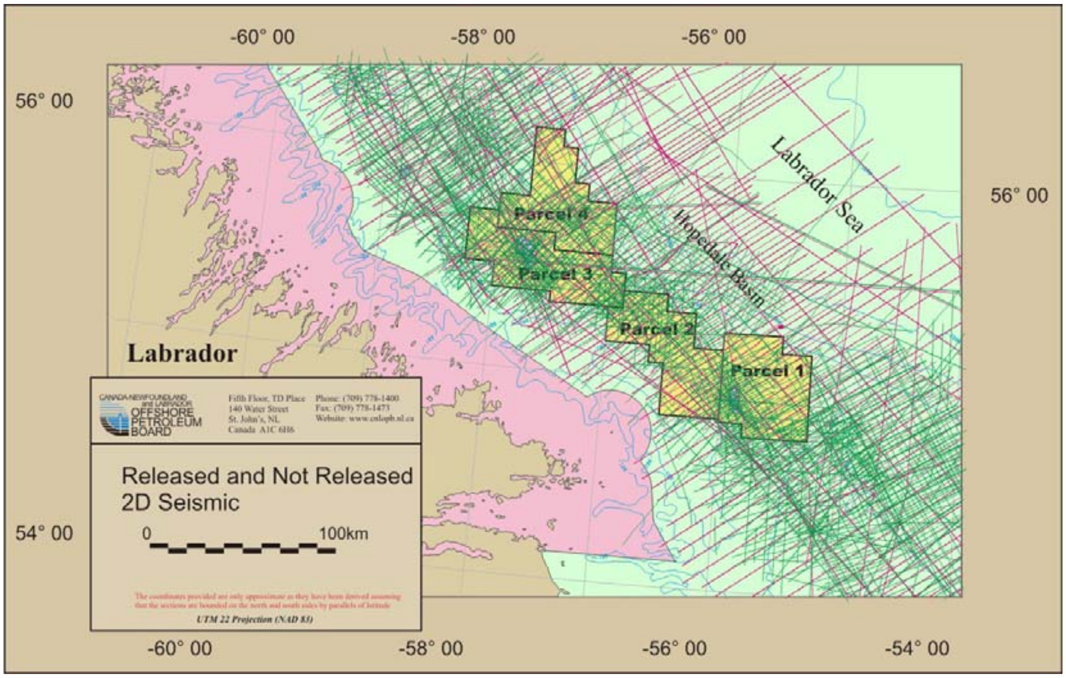
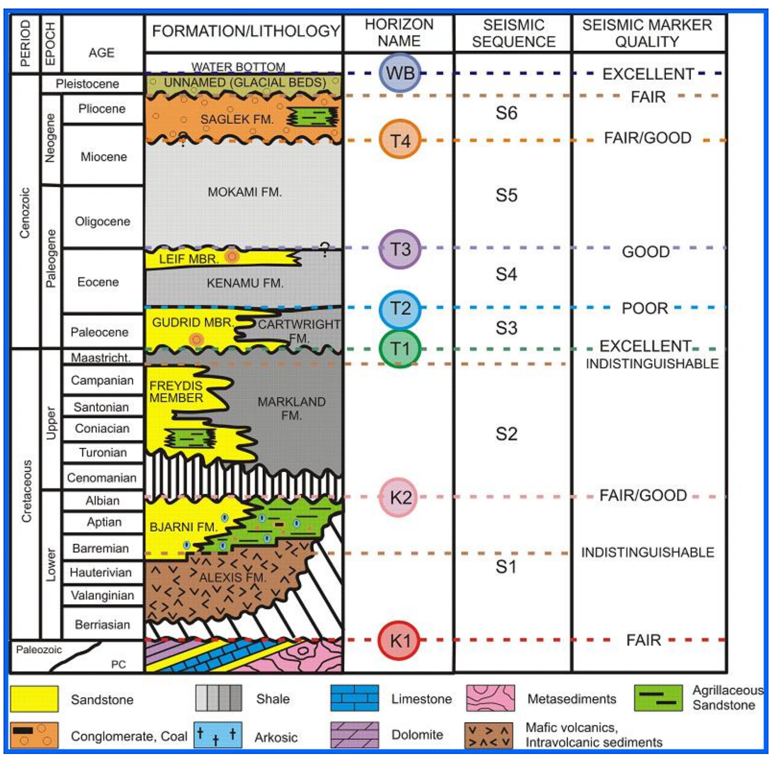


Figure 19. Seismic Base Map showing the complete seismic coverage existing in the CFB NL07-2 parcels and environs.



Using the GSI dataset, seven key seismic horizons can be defined and interpreted within the Hopedale Basin including the CFB07-2 landsale area. These regional markers can be tracked with varying degrees of confidence from the shelf into the deepwater area (Figures 8, 20 to 22). The seven seismic markers are matched to regional unconformities and geologic formation tops previously described by Umpleby (1979), McWhea et al. (1980), McMillan (1982), Balkwill (1987), Balkwill et al. (1990), Bell et al. (1989) and Enachescu (2006a and b). While some of the sandstone members have a seismic signature close to the basin edge their deep water equivalents are harder to track.

Figure 20. Lithostratigraphy, seismic horizons, seismic sequences and quality of seismic markers in the Hopedale Basin (after Martin and Enachescu, 2007).

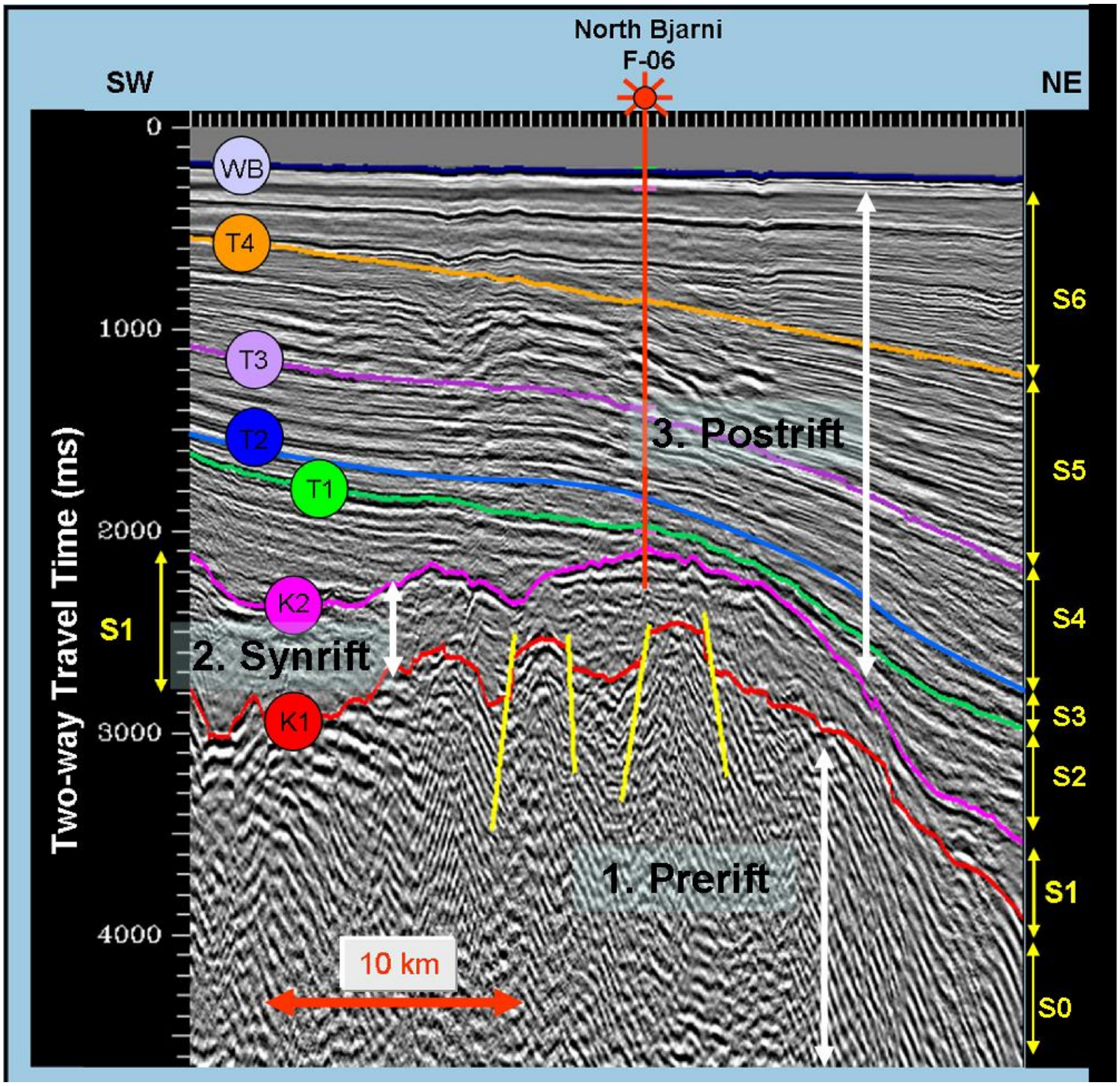


Figure 21. Seismic line (courtesy of GSI) within CFB NL07-2 Parcel 3 showing seismic horizons, seismic megasequences and sequences (after Martin and Enachescu, 2007).

On the seismic lines, several prominent seismic markers can firstly be used to separate the Prerift, Synrift and Postrift megasequences (Figure 21). The Hopedale Basin seismic sections can then be subdivided into seven major seismic sequences: prerift (S0), synrift (S1), postdrift1 or predrift (S2), syndrift1 (S3) syndrift2 (S4), postdrift1 (S5) and postdrift 2 (S6). These seven major seismic sequences are bounded by the K1, K2, T1, T2, T3, T4 and WB markers as described in details by Enachescu (2006a and b), Martin and Enachescu (2007) and Martin (2007) (Figure 21 and 22). Geologically, the seismic markers correspond to: 1) Labrador Unconformity or prerift basement (K1); 2) Avalon Unconformity or top Bjarni Formation (K2); 3) Baylot Unconformity or top Markland Formation or base Tertiary (T1); 4) top Cartwright Formation/Gudrid Member (T2), 5) Baffin Bay Unconformity or top Kenamu Formation (T3), 6) top Mokami Formation (T4), 7) top Saglek Formation and glacial beds (WB) (Figures 8, 20 to 22; Enachescu et al. 2006 and Martin and Enachescu, 2007). Other seismic markers, found especially on the inner shelf are more local and can be related to Freydis, Gudrid and Leif sandstone Members. Certain seismic markers on the outer shelf and slope have not yet been tied to stratigraphic members; many of the markers in the younger T3 and T4 sequences have not been drilled and their lithology and petroleum potential remain unknown. Regional GSC potential field data and detail profiles that were simultaneously recorded with the reflection data by GSI are also available for parcel interpretation.

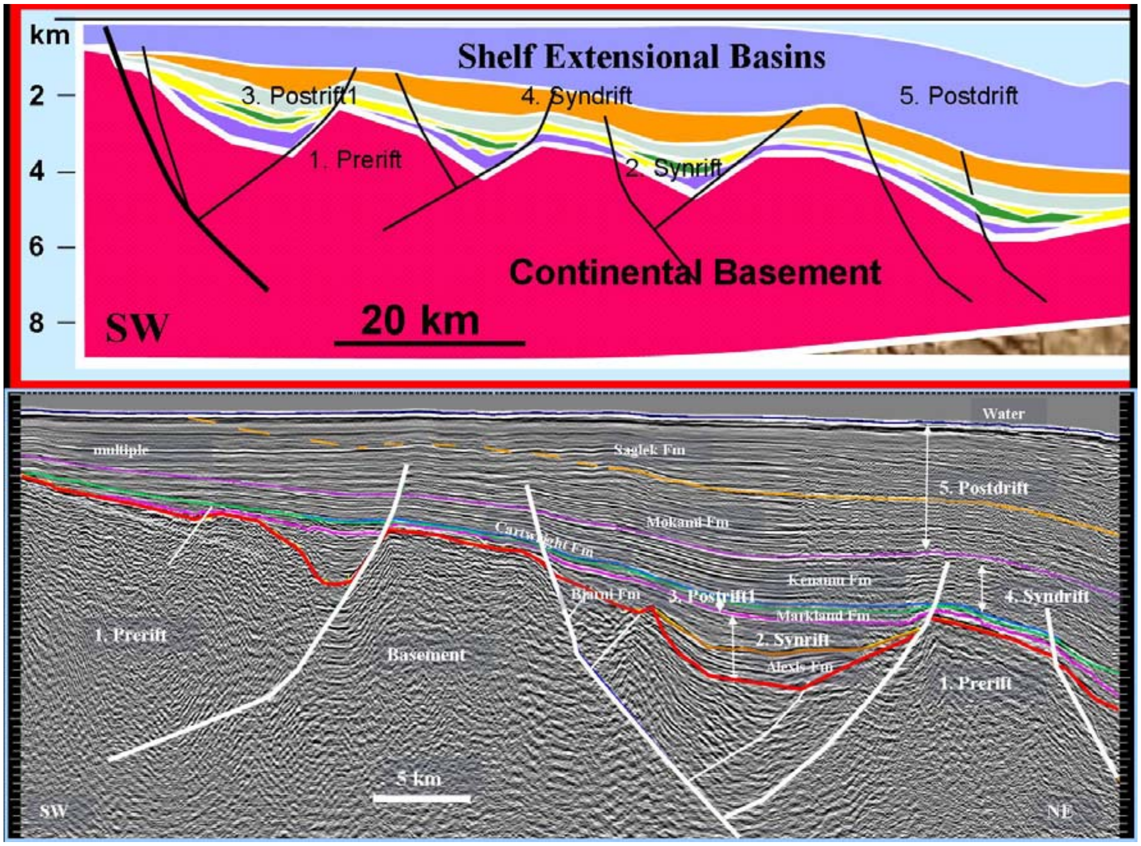


Figure 22. Seismic line (courtesy of GSI) within CFB NL07-2 area showing seismic horizons, faults and main seismic sequences (modified after Enachescu et al., 2006; Martin and Enachescu, 2007).

5.1 Parcel 1

Parcel 1, the most southerly parcel of this landsale is located north of the Cartwright Saddle and covers an area of 236,981 hectares (585,592.8 acres) in water depths ranging from 220 m to 500 m (most of the parcel lies within 200 to 300 metres of water). To the south, east and north the parcel borders Crown Land (unlicensed exploration land and available for posting), while to the west, it is adjacent to Parcel 2 (Figure 24).

This block is 103 times larger than a GOM OCS tract (5760 acres). The parcel surrounds the fenced-in Gudrid SDL (5643 hectares) which was issued in 1987. This SDL is operated by Petro-Canada (21.35%) on behalf of partners ConocoPhillips (34.61%), Husky Oil (17.13%), Suncor (10%), ENI (10%) and 177293 Canada. The Gudrid H-55 field is estimated to contain 0.92 tcf of natural gas and 6 mmbbls of liquids. The Gudrid condensate is extremely rich in saturated hydrocarbons and formed as a result of thermal degradation of terrestrial organic matter at moderate maturation levels (Powell, 1979; Nantais, 1984).

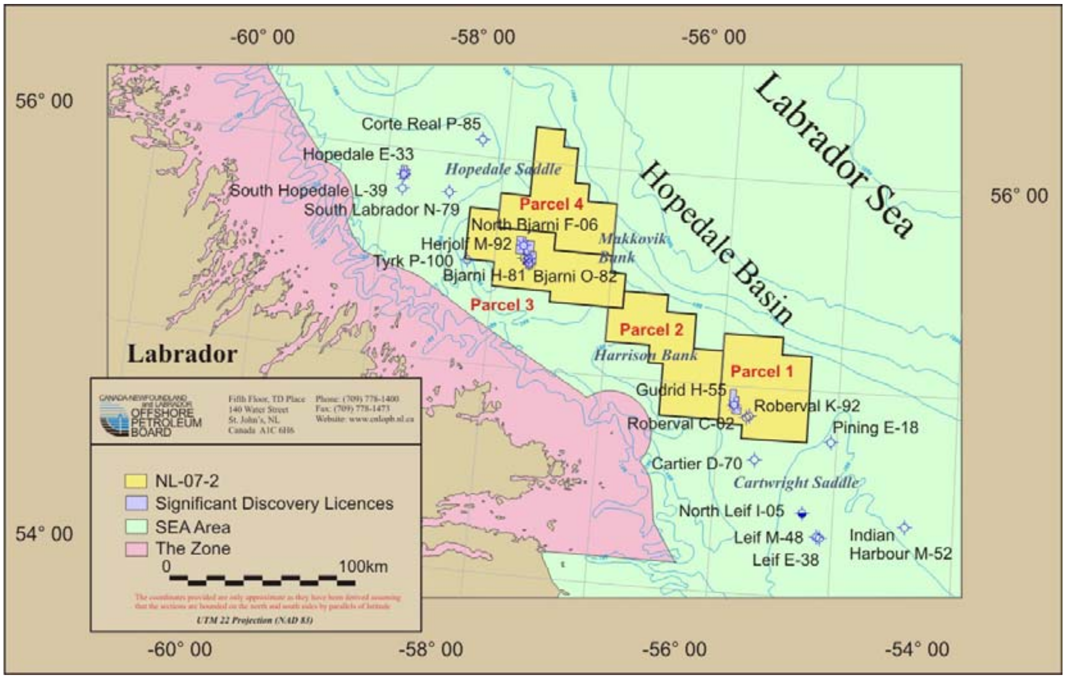
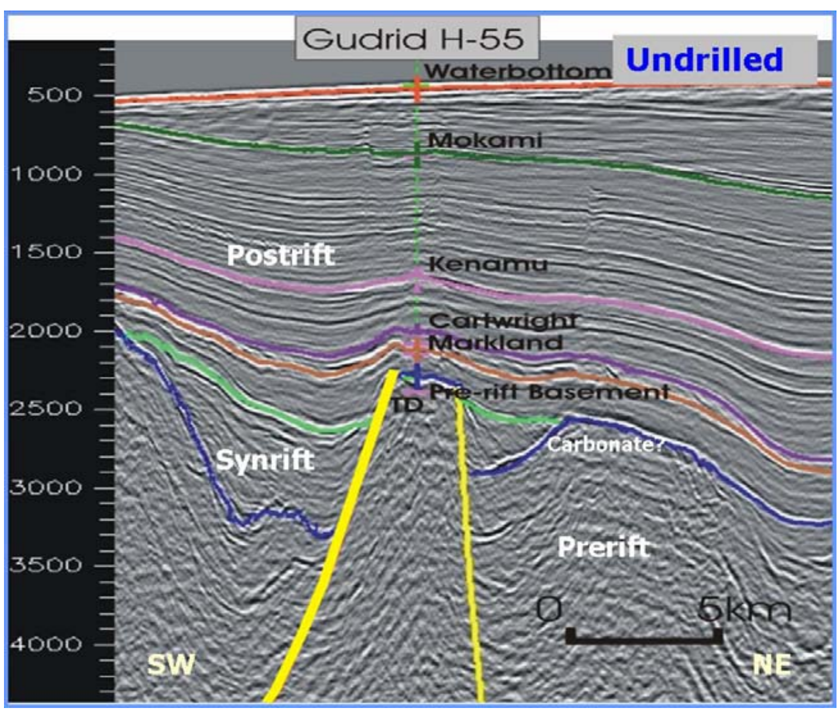


Figure 24. Location map for the CFB NL07-2 parcels and exploration wells in the Hopedale Basin.

Three wells have been drilled in Parcel 1: Gudrid H-55 (gas and condensate discovery), Roberval K-92 and the follow up Roberval C-02 (both D&A). The Gudrid H-55 well was drilled in 1974, in 299 m of water, to test a rotated basement block and its associated drape - over anticline (Figure 25). The well tested up to 20 mmcfd from a fractured Ordovician dolomite with 10% average porosity. The Gudrid dolomite has 64 m net pay in the interval 2633 - 2806m. This Paleozoic erosional outlier rests upon Precambrian basement. Two DSTs were performed at the 2,756 - 2,772 m and 2,663 - 2,723 m subsea intervals. No Bjarni reservoir was found draping the horst, and the shallower Freydis and Gudrid sand members were wet.

Figure 25. Dip (NE-SW) seismic section (courtesy of GSI) located in CFB07-2 Parcel 1 and showing the Gudrid H-55 gas field and an undrilled lead (modified after Enachescu et al., 2008 and Stead, 2008).



The Roberval K-92 and C-02 wells targeted carbonates on a basement high just south of the Gudrid discovery but both wells were dry and abandoned. Roberval K-92 well intersected potential reservoir rocks in Leif and Gudrid members, Bjarni

Formation and Paleozoic dolomites but no hydrocarbons were seen on logs or RFT tests. The Roberval C-02 also intersected wet Paleogene sandstone reservoirs.

Parcel 1 lies entirely within the southern part of the Hopedale Basin where the presence of a petroleum system was proven by the discovery of the Gudrid gas field. Mature source rocks of Bjarni and Markland formations should be present both west and east of the Gudrid-Roberval lineament. South of the parcel, the North Leif I-05 well recovered 23 barrels of 33º API oil from Early Cretaceous Bjarni sandstone. The oil was un-biodegraded, waxy and had high pour point indicating that the source rock from which the hydrocarbon was generated is rich in terrestrial organic material. The North Leif oil show may indicate an increased chance of finding oil in areas such as east of the Gudrid location where source rocks should be more mature and may generate oil.

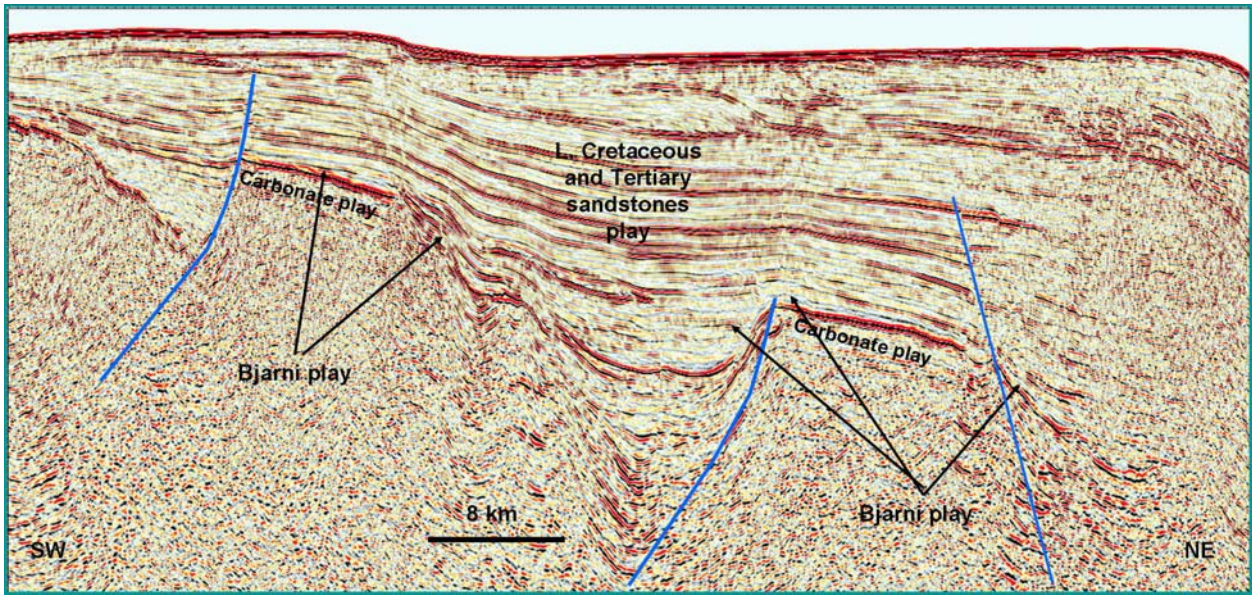


Figure 26. Dip (NE-SW) seismic section (courtesy of GSI) through Parcels 1 and 2, Hopedale Basin, showing structural setting and types of hydrocarbon plays.

Parcel 1 is well covered by modern, time migrated 2D seismic data that is available in digital, workstation ready format from GSI. Paper copies of older data can be obtained for reproduction cost from the C-NLOPB and may be available for purchase from oil companies previously active in the area. Seismic lines older than 1990 are relatively poor quality and were acquired with shorter offsets that are detrimental to multiple elimination. If not already done by the data owners, this data would need to be reprocessed prior to interpretation. Currently, there are sufficient numbers of modern and older lines available to define and map all the large and intermediate size leads in Parcel 1.

The seismic sections in Figures 25 and 26 show the types of potential petroleum traps in Parcel 1, including: a) rotated blocks and horsts that might preserve porous and permeable Ordovician dolomites and limestones; b) drape over basement highs of Cretaceous (Bjarni and Freydis) and Paleogene (Gudrid and Leif) sandstone reservoirs; c) onlaps and pinchouts of synrift Bjarni and younger sandstones on the flanks of basement highs and d) deeper basement highs and anticlines in the outer shelf and slope. The drilling depth to reservoir targets increases from 3,000 m on the western side of the parcel to 5,000 m on the eastern side. Several large features including basement high blocks with areas of closure between 10 and 100 km^2 are visible on the seismic data covering this parcel (Figures 25 and 26). Due to the confidentiality of the non-exclusive seismic lines the above mentioned features cannot be located on the map nor interpreted, but shown only as play concepts. The exploration potential of Parcel 1 is considered to be in the range of 2-3 tcf of gas, with oil being a probable occurrence on more westerly prospects. Dense bi-directional or 3D seismic surveys will be needed to firm up the leads in Parcel 1.

5.2 Parcel 2

Parcel 2 is located northwest of Parcel 1, southeast of Parcel 3 and northeast and southwest of Crown Land, in water depth ranging between 150 m and 500 m, with most acreage lying in approximately 200 m of water (Figures 15, 16 and 27). Parcel 2 occupies an area of 236,525 hectares (584,466 acres) over the bathymetric feature known as Harrison Bank. This parcel is 103 times larger than a GOM OCS tract. No exploration wells have been drilled in this Hopedale Basin parcel but gas discovery wells were drilled about 10 km east at Gudrid H-55 and approximately 50 km northwest at the Bjarni well locations. Results and geological setting of the Gudrid discovery were discussed in Section 5.1. A complete discussion of the Bjarni/North Bjarni composite field will be presented in Section 5.3.

As is the case for the other parcels, Parcel 2 is located in an area with mature source rocks, with good to excellent reservoir rocks, in both the synrift and postrift sequences. Under a northeasterly thickening sedimentary cover, the extended basement dips basinward (Figures 26 and 27). The postrift basin fill has the general aspect of a regional monocline interrupted by gentle anticlines where clastic layers draped over basement highs. The source rocks are more mature in the eastern, deeper part of the parcel, where both gas and oil potential exist. Structurally, the area is dominated by a succession of half grabens and rotated blocks. Although faulting of the overlying Tertiary layers in the upper basin fill is minimal; several major faults are seen to penetrate the postrift sequences (Figures 26 and 27). Several strike-slip transfer faults are observed on the potential field data but these are seismically difficult to interpret and map.

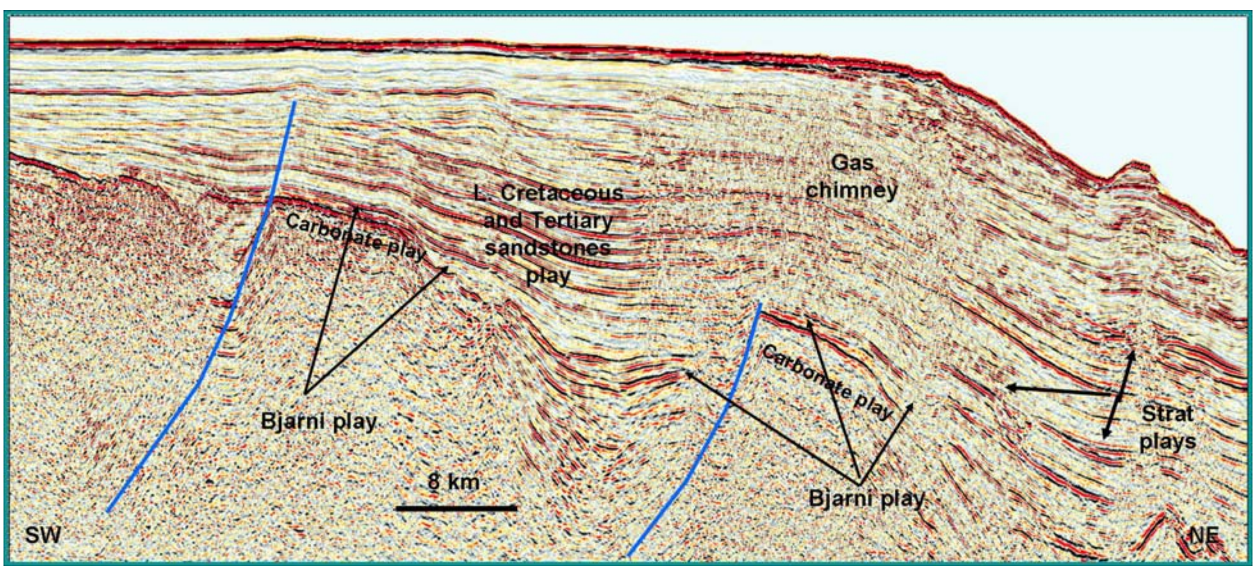


Figure 27. Dip seismic section (courtesy of GSI) showing types of hydrocarbon plays in Parcel 2 and environs, Hopedale Basin.

The main hydrocarbon play in the parcel (and also in the entire basin), results from basement block rotation due to deep penetrating normal faults which were active during the synrift stage. Some of the faults propagate well into the postdrift sequences, with decreasing throw in younger formations. The Bjarni sandstone, which is seen to onlap or drape over the rotated basement blocks or large fault bounded highs is the primary reservoir target in the parcel. Possible fractured and dolomitized Ordovician carbonate outliers preserved on top of the high blocks constitute a secondary play. The depth to prerift basement in the parcel varies from 2,000 m in the southwest to about 4,500 m in the northeast. Overlying Late Cretaceous and Tertiary sands that have been folded into gentle anticlines provide other viable targets. On the outer shelf and the upper slope there is evidence of stratigraphic trapping of possible early Tertiary and younger sands deposited during lowstand episodes. Good regional and local thick shale seals are present in the parcel.

Leads with areas ranging between several square kilometers to tens of square kilometers are visible on the seismic lines and regional time structural maps. As seen in Figure 27 rotated blocks are 8 to 10 km wide and can be 5 to 10 kilometers in length. A number of fault dependent closures capable of holding several tcf of gas can be mapped within Parcel 2. Numerous seismic amplitude anomalies (bright spots, gas chimney, etc.) are also observed in both synrift and postrift sequences showing hydrocarbon migration and accumulation at multiple levels.

Modern, workstation ready, time migrated 2D seismic sections covering Parcel 2 and environs are available in digital format from GSI. Strike, dip and well tie lines can be licensed in SEGY format from GSI and other vendors. Older data vintages may also be obtainable for cost from oil companies that have previously explored the area. The C-NLOPB can provide paper copies of older data but seismic grids older than 1990 are of relatively poor quality and were acquired with shorter offsets that are detrimental to multiple elimination. Some of the older grids over the parcel were reprocessed with good results. There is a sufficient number of modern and older lines available to define and map all the large leads present in Parcel 2.

5.3 Parcel 3

Parcel 3 covers an area of 233,712 hectares (577,514.9 acres) within the central Hopedale Basin. This exploration block is 101.8 times larger than a GOM OCS tract. The parcel is located on the Makkovik Bank and south of the Hopedale Saddle, in water depths of between 120 m and 220 m (Figures 15 and 16). On the Labrador shelf, the water bottom is gently dipping toward the northeast, with most of the parcel lying in about 150 m of water. To the southeast the parcel borders with Parcel 2, to the north with Parcel 4 and to the southwest, northwest and northeast with available Crown Land.

This parcel was a key area in the history of exploration of the Canadian Labrador Sea, as 1) the first large discovery was found here, and 2) through years of follow up exploration, the largest composite field Bjarni/North Bjarni was mapped and delineated in this parcel (Figures 6, 8, 28 and 29). The Bjarni (185A) and North Bjarni (185B) SDLs have been active since 1987 and cover an area of 12,278 hectares. These SDLs are excluded from the landsale parcel. The operator of both SDLs is Petro-Canada (21.35%) acting on behalf of its partners ConocoPhillips (34.61%), Husky Oil (17.13%), Suncor (10%), ENI (10%) and 177293 Canada. As the partnership structure in the two SDLs is similar, these fields could be easily unitized and simultaneously developed under a single Development Plan Application. There can be little doubt that the Bjarni/North Bjarni combined field will be the first candidate for development in the basin.

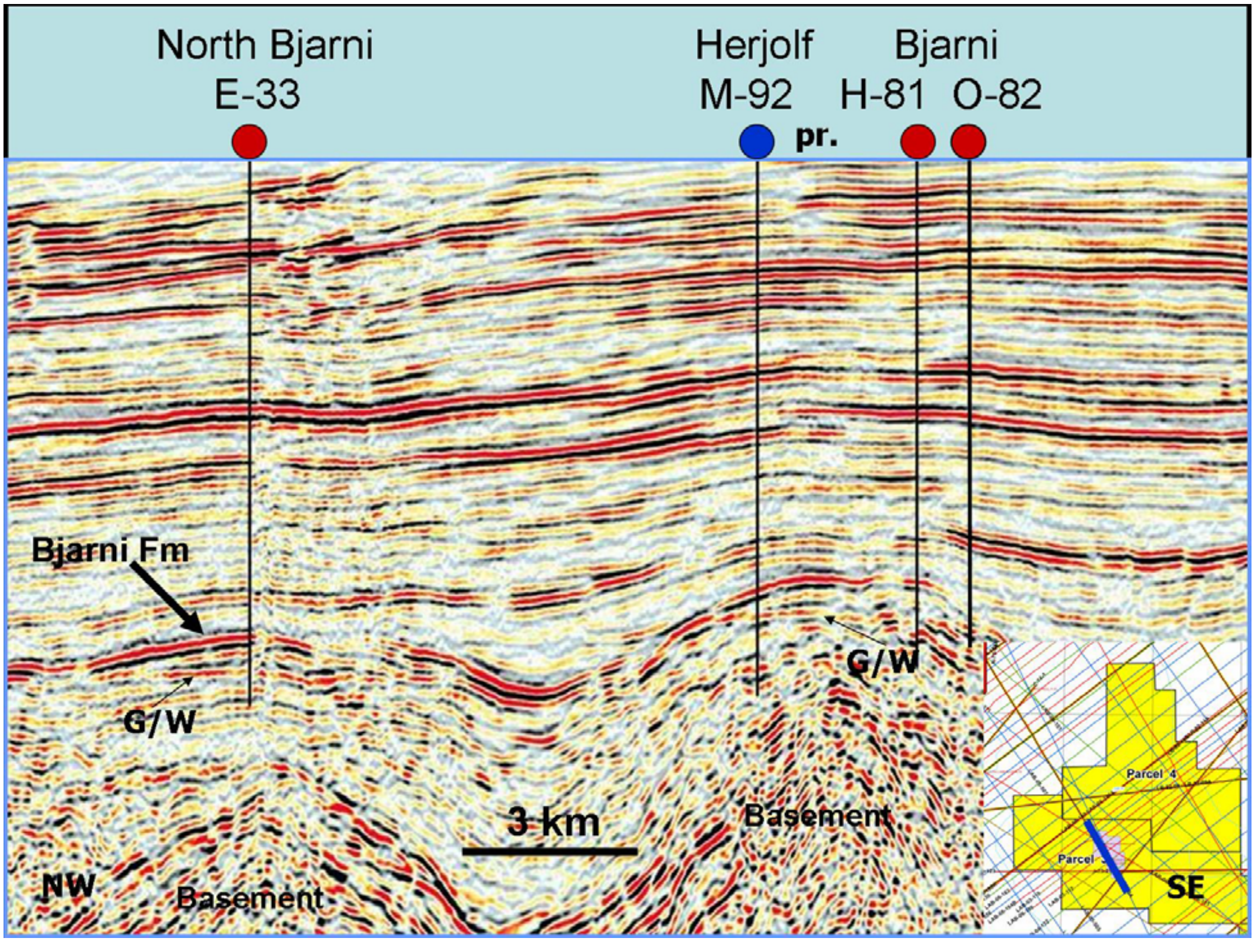


Figure 28. Tie (NW-SE) seismic line (courtesy of GSI) through Bjarni and North Bjarni gas fields, Parcel 3, Hopedale Basin. Two flat spots marking the gas/water contacts for the two fields are visible on this seismic section.

Four wells have been drilled in Parcel 3. Three of them were gas discovery wells: Bjarni H-81 (drilled in 1973 in 140.2 m of water, tested in 1974); Bjarni O-82 (drilled in 1979 in 142.6 m of water, tested repeatedly in 1980 and 1981); and North Bjarni F-06 (drilled in 1980 in 150 m water depth, had no successful DSTs due to mechanical problems).

The Bjarni H-81 well tested 12.9 mmcfd and 100 barrels condensate per day from the 2,150.7 m - 2,255.5 m interval. The successful hydrocarbon play at H-81 was the Bjarni sandstone reservoir draped over a basement high. The Bjarni Formation was intersected between 2,150 m and 2,257 m, having 107 m of gross pay and 86 m of net pay sand, with 12-30% porosity (average 20%) and good permeability values averaging 100 millidarcies.

The Bjarni O-82 delineation well located 4 km north-northwest from H-81 in 142.6 m of water, encountered the Bjarni Formation at 2,285 m and had 313 m gross sand pay. The O-82 well tested gas and condensate at rates up to 7.1 mmcfd from the intervals 2,362 m - 2,366 m and 2,369 m - 2,373 m.

A delineation well, Herjolf M-92 was drilled in 1976 (in 139 m of water), 3.9 km from H-81 and encountered more than 1,153 m of Early Cretaceous continental sediments, out of which 915 m was Bjarni sandstone, but it was water-bearing (with only traces of gas). Modern seismic data indicates that this well was drilled just outside of the flat spot marking the gas/water contact of the Bjarni field (Figure 28). Excellent cores of Bjarni sand and shale were obtained from this well, and these proved invaluable in field evaluation. Significantly, the Herjolf M-92 well returned older synrift rocks, dated as Berriassian (135-142 mmy), being only about 10 million years younger than the age of the Kimmeridgian source rock deposition on the Grand Banks!

The Bjarni structure was the first significant gas discovery in the basin and it is estimated to contain 859 bcf gas and 31 mmbls of condensate. This accumulation is probably uneconomic for a stand-alone development, even with current natural gas prices. The Bjarni structure is a drape anticline cored by a complex basement high. The structure is fault bounded to the southwest and plunges toward the northeast. The Bjarni sandstone thickens on the flanks of the drape anticline but the structure is not filled to the spill point.

The North Bjarni is a separate geological structure located about 10 km northwest of the Bjarni H-81 discovery in 150m of water. Here also, the Lower Cretaceous Bjarni sandstones are draped over a complexly faulted basement high. The Bjarni Formation was encountered at 2,423 m subsea. The structure has 194 m of Bjarni net pay, making it one of the thickest pay sections of any offshore well drilled in Canada. At this location, Bjarni sandstone has a 17% average porosity. The structure appears to be filled to the spill point. Unfortunately no test rates were obtained at this location due to mechanical failure. However, two RFTs recovered gas from the reservoir and gas flow was recorded to surface. In addition, about 1.5 m of reservoir core was recovered. A volume of 2.235 tcf gas and 82 mmbbls NGL is assigned by the C-NLOPB to this field.

Just outside of the western corner of the parcel, Tyrk P-100 well was drilled on a shallow basement high and reached TD at 1706 m after intersecting the Bjarni and Gudrid sandstones but encountering no hydrocarbons. Four other wells were drilled northwest of the parcel: Hopedale E-33, South Hopedale L-39 (delineation well), South Labrador N-79 and Corte Real P-85. While all of these wells penetrated good reservoirs, only Hopedale E-33, drilled in 1978, was a gas discovery. This well is 75 km northwest on structural trend from the Bjarni fields. Hopedale E-33 well tested 19.5 mmcfd from the interval 1,983 m - 1,997 m (in Paleozoic carbonate) and 14.2 mmcfd from the interval 1,948 m - 1,959 m (in Bjarni sandstone). The feature may be a structural-stratigraphic trap that has gas in both Bjarni sandstone (with 26% porosity) and in prerift Ordovician dolomite (with 8% porosity). An estimated resource of 105 bcf and 2mbls NGL was assigned to this field by the C-NLOPB.

As proven by the two discussed fields, Parcel 3 is also located in an area with mature source rocks where generation and migration from adjacent half-grabens took place. Good to excellent quality, thick reservoir rocks of the synrift Bjarni Formation were encountered in all wells drilled in the parcel. Several rotated fault blocks covered by synrift clastics and a succession of basinward dipping postrift sedimentary formations characterize the parcel (Figures 26 to 29). The source rocks are more mature in the eastern, structurally deeper part of the parcel, where both gas and oil potential may exist. Numerous faults were active at the basement level but only several faults penetrate the reservoir interval and the covering postrift clastic succession.

While two large highs in the blocks were previously drilled at the Bjarni and North Bjarni location, several other intermediate and smaller structural and combination traps adjacent to the fields, remain undrilled. These satellite features may add up significant volumes to the already discovered natural gas reserves. Several of these features are accompanied by seismic amplitude anomalies.

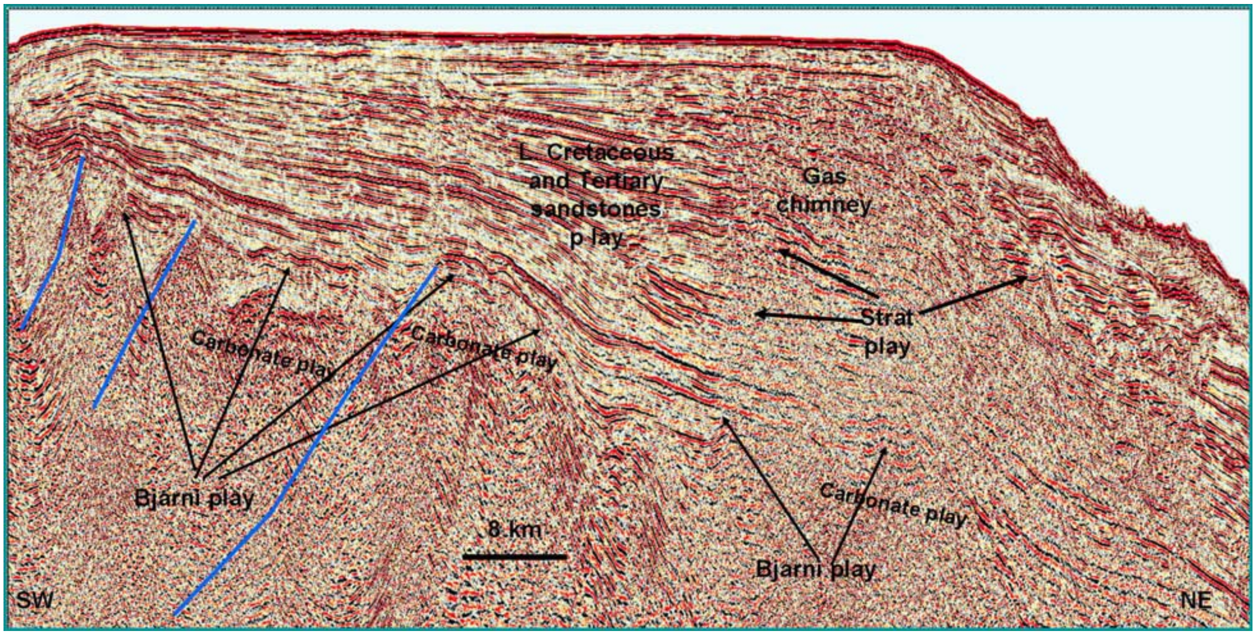


Figure 28. Dip seismic section (courtesy of GSI) showing types of hydrocarbon plays in Parcel 3, 4 and environs, Hopedale Basin.

Parcel 3 is well covered by modern 2D seismic data that is available in digital format from GSI. This data is time migrated and is of excellent to fair quality. The majority of the lines are dip lines diagonally covering both Parcels 3 and 4, but strike and well tie lines are also available. Older data can be obtained from the C-NLOPB and may be available for purchase from the oil companies previously active in the area (Husky, Petro-Canada, Total, ConocoPhillips, etc.). Seismic grids older than 1990, are of poor quality and were acquired with shorter offsets that are detrimental to multiple elimination. However, if the original field tapes can be retrieved, older lines can be reprocessed prior to interpretation. Nevertheless, there are a sufficient number of modern lines available to define and map all the large petroleum leads contained in Parcels 3 or those that might extend in the neighbouring Parcels 2 and 4.

5.4 Parcel 4

This is also a large parcel covering an area of 231,460 hectares (574,421.2 acres) within the Hopedale Basin. This exploration block is 101.8 times larger than a GOM OCS tract. It is located northeast of Parcel 3 where the basin’s major discoveries, Bjarni and North Bjarni gas field are located. Parcel 4 overlaps both the Makkovik Bank and Hopedale Saddle and extends from the shelf (250 m water depth) into water depths greater than 500 m at the shelf break. To the southeast the parcel borders Parcel 3 and to the northwest, northeast and east it is surrounded by Crown Land.

Even though the parcel was explored in the 1970s and early 1980s, no drilling has occurred within or in the immediate vicinity of this parcel (Figure 24). However, two dry exploration wells were drilled on the Hopedale Saddle, both located approximately 30 km from the northeastern border of the parcel. The South Labrador N-79 well was drilled in 1980 and reached TD at 3,571 m in basement. While the Bjarni reservoir was encountered, it was wet. The Corte Real P-85 was spudded in late 1981 (in 438 m of water) and was one of the last wells drilled in the Hopedale Basin during the initial exploration cycle. The well had tested a faulted rollover within the postrift sequence, with the primary target being porous sandstones. After several reentries the well reached TD in Markland shales and was abandoned in 1985.

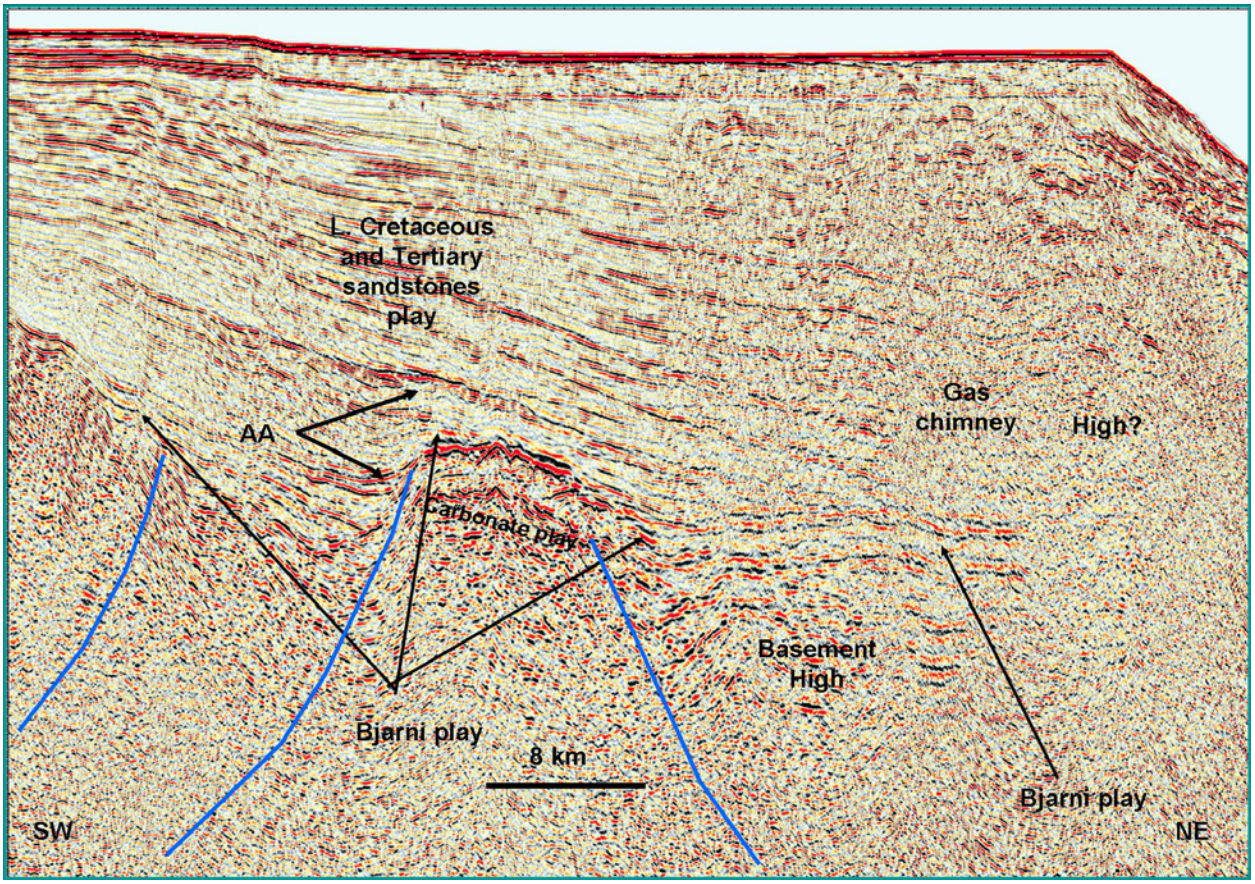


Figure 29. Dip seismic section (courtesy of GSI) showing types of hydrocarbon plays in Parcel 3 (westernmost side) and 4, Hopedale Basin.

Parcel 4 is located in the central Hopedale Basin, eastward of the Bjarni/North Bjarni ridge, in an area where basement is deeper and the covering postrift sediments are thick. The basin is generally deeper in this parcel than in the Parcels 1 to 3, and deepens to 7-8 km toward the Hopedale Saddle area and Labrador slope (Figures 28 and 29). Both structural and stratigraphic plays are identified on seismic data crossing Parcel 4. For example, Figure 30 shows the onlap of Bjarni sandstone on a complex basement high and a possible slope fan characterized by a package of high amplitude reflectors that might indicate gas charged sandstones. In this parcel, target depths for drilling through Bjarni Formation and to basement vary from 3,500 m to 5,000 m (Figures 28 and 29).

The petroleum system in this area is similar to the one discussed for Parcel 3. Any Cretaceous and early Tertiary source rocks should be mature in this parcel and lateral migration to westerly traps should be straightforward as carrier beds and faults are available (Figures 28 and 29). The main play is structural, as represented by fault bounded closures of the Bjarni Formation draped over Precambrian rotated blocks or horsts. Carbonate platform reservoirs may also be preserved on top of crystalline basement. Better processing of the seismic data is needed to image deeper parts of the basin in order to define these targets and investigate the presence of carbonate outliers. Several sedimentary deformations are observed in the postrift sequence, some showing amplitude anomalies possibly indicating the presence of lowstand coarse clastics.

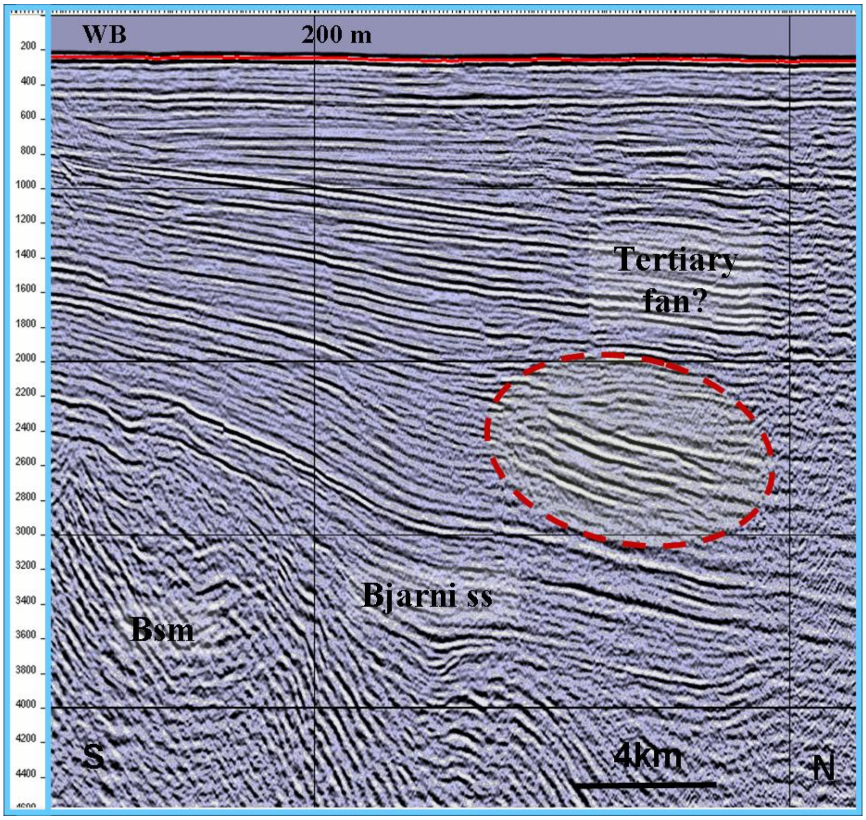


Figure 30. Seismic sections (courtesy of GSI) showing stratigraphic play in Parcels 3 and 4.

The most extensive seismic grid in the parcel and environs is the GSI data set recorded during 2003 - 2007. This prestack time migrated data set is offered for licensing in digital format. Additional older GSI lines reprocessed to prestack time migration are available. As well, pre-1990 seismic lines are available from the C-NLOPB in hard copy for reproduction costs and probably from some oil companies that own data in the area. These data may be purchased in digital form (SEGY files) directly from the original owners. The existing data base ensures that leads in Parcel 4 can be adequately mapped.

5.5. Parcel Summary

Several medium size and large leads have been identified in the four Call for Bids NL07-2 parcels using the new GSI data set supplemented by historical grids. Quite a few of these leads have areas between 20 and 100 square kilometres and can contain 2 to 3 tcf of gas in sandstone and carbonate reservoirs or significant amounts of oil in sandstone reservoirs.

The cost of an offshore well in the Labrador Sea is not trivial, but it compares with the cost of drilling in the Arctic, Deep Gulf of Mexico or offshore Sakhalin Island. Summer only exploration drilling is possible in the Labrador Sea, using dynamically positioned, arctic reinforced, rigs and vessels. Fields can be developed using pipelines tied to onshore processing facilities, Gas to Electricity methods, sub-bottom completion with FPSO, seasonal field development, etc. All these methods are viable in a medium to high price ($8-12 mmbtu) gas regime. The viability of a subsea pipeline to the island of Newfoundland together with LNG infrastructure or alternatively a marine CNG project for the Grand Banks and the Labrador gas, have been recently considered and analysed from an economic point of view by Power and Costello (2008).

Exploration in the Labrador Sea is recommencing after more than 30 years. New mapping with modern data in the discussed parcels will lower the geological risk for finding gas in the Hopedale Basin. Moreover, new discovered additions to the existing Gudrid and Bjarni / N. Bjarni reserves on Parcels 1 and 3 will certainly lower the economic risk and create the required resource threshold for a Labrador Sea gas development. Three other factors need to be considered when bidding for exploration parcels in Labrador offshore: 1) the Province of NL and Canada have some of the lowest world political risk; 2) there are 1250 kilometres of coastline with petroleum potential in the Hopedale and Saglek basins; and 3) insatiable markets for clean energy are present in Eastern and Central Canada and north-eastern USA and they can be supplied from offshore Newfoundland and Labrador.

6. Discussion

Despite its relative proximity (when compared to Canadian Arctic basins) to the industrially developed regions of central Canada, and to the vast markets of the eastern United States, exploration in the Labrador Sea region is still at a very early frontier stage. The four parcels offered in this landsale are located within the Labrador Shelf's southernmost frontier, the Hopedale Basin, where numerous oil and gas prospects and leads have been identified using modern and older seismic data.

While exploration for offshore oil in the Hopedale Basin occurred in the 1970s and early 1980s, no systematic effort has yet been undertaken to find natural gas. As it stands, the 4.2 tcf of gas resources that have been discovered, mostly in two of the parcels offered at this landsale, is a by-product of oil exploration. With abundant terrestrial and probably marine interludes of source rock deposition and numerous synrift and postrift structural and stratigraphic trapping possibilities, the Hopedale Basin has significant undrilled petroleum potential. Only 16 wells have reached planned targets at significant depths resulting in five gas discoveries, with one, North Bjarni F-06 in Parcel 3, proving a giant gas discovery (Figures 5, 21 and 24). Although the estimated resources in Parcel 3 exceed those of the White Rose or Sable Island fields, and the Gudrid field in Parcel 1 is comparable in size to the Deep Panuke field, these remain stranded resources (Enachescu, 2006a and b). Additional important gas resources can be proven by drilling the large features identified in the CFB NL07-2 parcels.

Advancements in seismic acquisition and processing techniques coupled with regional geological studies are key to successful drilling of high-risk, high-reward frontier areas such as the Hopedale Basin. Hopefully, new 2D and 3D seismic surveys supplemented by hydrocarbon detection methods (AVO, LMR, CEMS, etc.) will encourage companies to develop the existing discoveries, explore for new ones in the landsale parcels and search for new plays within and outside of the present landsale area. Important improvements in the offshore regulatory regime in the Newfoundland and Labrador offshore region were recently introduced by the Federal and Provincial governments, and the work continues. One excellent initiative that will considerably reduce the overall cost of drilling is the introduction of discretionary requirements related to flow testing of the first well drilled on a geological feature (Government of Canada, 2006). The new Energy Program released by the Government of NL in 2007 establishes a flexible Offshore Natural Gas Royalty Regime and emphasizes the importance of developing the Labrador gas resources. The Government of NL has “designed an Offshore Natural Gas Royalty Regime that recognizes the cost and shares the risk associated with various natural gas developments. The Regime will automatically provide a lower royalty return from the more costly and remote natural gas projects and a higher return from lower risk /lower cost projects. For a project that develops new infrastructure and is the pioneer project, the province is prepared to consider modifications to the rate structure within the Offshore Natural Gas Royalty Regime to reflect that higher project risk and infrastructure investment if economics warrant such consideration” (http://www.nr.gov.nl.ca/energyplan/).

With the recent increases in North American natural gas prices and the obvious need to develop new supply areas, serious discussions have begun on ways and means to bring the Labrador natural gas to market. Possible modes of transportation under consideration include pipeline, Compressed Natural Gas, Liquefied Natural Gas, Gas-to Electricity and Gas to Liquid tankers.

7. Conclusions

The natural gas discoveries in the Hopedale Basin were collateral finds during the search for oil fields. However, a 30% success rate was recorded in this frontier basin. After several reassessments of the Labrador Sea gas potential and five successive seasons (2003-2007) of modern seismic acquisition and processing, four Hopedale Basin exploration parcels, totaling 939,678 hectares (2,321,995 acres) are offered by the C-NLOPB for an exploration landsale (CFB NL07-2) which closes on 10 September 2008 at 4:00 p.m., Newfoundland Standard Time. All these parcels are very large exploration blocks - each one being more than 100 times larger than a typical Gulf of Mexico OCS tract. The four parcels lie mostly on the shelf in 100 m to 400 m water depth in areas where drilling by dynamically positioned rigs and vessels can be performed during the summer season. The recognized risks in regard to harsh climate conditions and remoteness of the basin are mitigated by the presence of very large undrilled features, high quality reservoirs and widespread, mature source rocks. The presence of large, gas charged structural closures in the landsale area is already demonstrated as Parcels 1 and 3 already contain SDLs protecting gas fields discovered during an earlier exploration period. The principal petroleum system for this basin involves continental sandstone as the reservoir rock with hydrocarbon charge provided by coeval lacustrine shales or coal intervals.

The Hopedale Basin had a complex geological evolution, starting with intra-continental rifting in the Early Cretaceous (possible Jurassic sag) and followed by significant thermal subsidence that allowed for the accumulation of a thick wedge of passive margin sedimentary rocks. The large gas discoveries made during the 1970-1982 exploration cycle in the shallow Labrador Sea proved the presence of a rich petroleum system. No follow-up drilling has taken place and only during the past few years has exploration returned with the acquisition of modern, high quality 2D reflection seismic data. The new seismic data allows the extension of the geophysical mapping into outer-shelf and deepwater domains and shows the presence of several previously unknown large depocenters and anticlinal features. The alluvial synrift Bjarni sandstone was encountered in most of the wells within or adjacent to the parcels and is recognized as the main reservoir target, but additional high quality reservoirs have also been encountered in the prerift, synrift and syndrift sequences. There is likely to be a much wider distribution of the Bjarni Formation sandstone extending seaward to the outer shelf and deepwater regions. The Bjarni Formation also contains interbedded shales with terrestrial organic content that constitute an excellent type III source rock. Source rocks are also present in Late Cretaceous and Early Tertiary sequences. These source rocks should be mature in the majority of the area covered by Parcels 1 through 4 and beyond into the deeper water depocentres. While the occurrence of a Late Jurassic marine source is still unproven on the Canadian side of the rift, it has been documented on the conjugate margin off West Greenland (Sønderholm et al., 2003; http://www.dgu.dk/ghexis/Ghexis-22.htm#4)

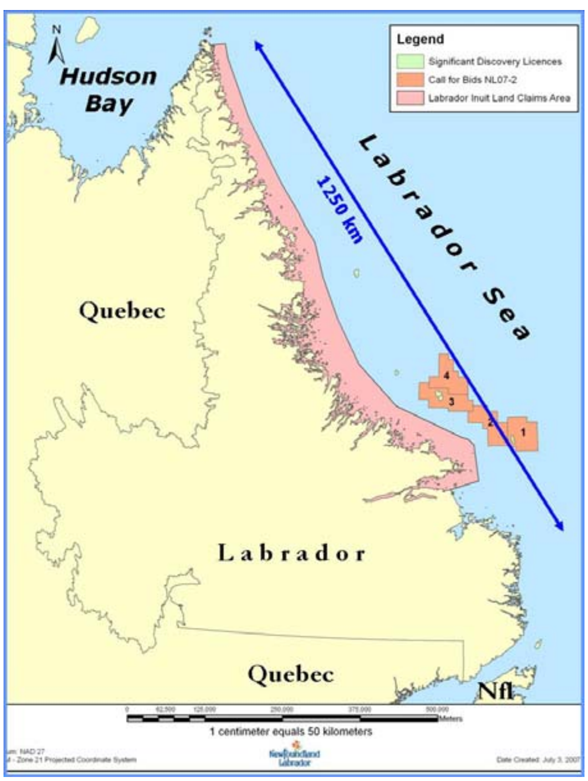
Although the proven petroleum system (anchored by the Early Cretaceous Bjarni lacustrine shale) will predominantly generate gas, more mature lacustrine source rocks or an older marine source (Jurassic?) capable of generating oil may exist in the basinal troughs located on the outer shelf, continental slope and rise. Additional reservoirs are recognized in the Ordovician limestones and dolomites preserved as erosional remnants on top of the prerift rotated blocks. High flow rates were recorded from both the Early Cretaceous Bjarni sandstone and the Ordovician carbonate (8-28 mmcfd). Other reservoirs include Late Cretaceous and Tertiary marine sandstones and their lowstand equivalents, which may present large targets on the outer shelf and slope. As indicated by the newly acquired seismic data, several large (10 to 60 km^2), untested structural and stratigraphic traps, some accompanied by amplitude anomalies, are identifiable on the new seismic data. The four landsale parcels may contain an additional 3-5 tcf of natural gas reserves and the potential for oil discoveries on the outer shelf should not be ignored.

A dense coverage of modern 2D data, better seismic imaging and strategic recording of data into the deepwater, supplemented by new geochemical studies, have improved our understanding of the geodynamic evolution and the exploration potential of the Labrador Shelf basins. The discovered gas has remained stranded due to its more remote location and some logistical challenges (such as iceberg management) that made it less attractive when cheap gas was widely available elsewhere. However, higher energy prices and world political considerations are changing our perception on the Labrador gas. The area’s proven resource of non-associated gas is substantial and the potential resource is enormous. No doubt, challenges to exploration and production of the hydrocarbons from Hopedale Basin remain great and many, but the demand for cleaner energy, increased commodity prices, improved government regulations, large size of prize, technological advancements and relative proximity to the largest world markets will make the Hopedale Basin and the rest of the Labrador Shelf an attractive petroleum exploration area in the coming years. The CFB NL07-2 parcels are well positioned to host additional gas reserves and present a significant opportunity to advance the proven resources of the basin to an economic threshold for development.

8. Acknowledgements

This report draws heavily on past work by J. McMillan, R., McWhae, D. Umpleby, H. Balkwill, A. Grant, S. Srivastava, S. Bell, G. Williams and C. Keen, numerous explorationists of the Eastcan group of companies and other researchers from GSC Atlantic that contributed to the 1989 issue of Labrador Basin Atlas. I also acknowledge the contributions of Memorial University graduate students M. Martin (now at BP Canada) and J. Stead (now at C-NLOPB) who produced original research on the Hopedale Basin. Thanks are due to the Pan-Atlantic Petroleum Systems Consortium (PPSC), especially Dr. Jim Wright and Ian Atkinson, P. Geo for setting the petroleum basin research group at MUN and encouraging new exploration studies in the Labrador basins. Gratitude is due to Paul and Davey Einarsson of Geophysical Service Incorporated who provided access to new seismic data in the basin, D. Chown, P. Colton, A. Feir and S. Nader for assistance with workstations and data access, and GSI's Precision Seismic for Labrador seismic data processing.

Phonse Fagan, A.J. Fagan Consulting Inc., Ian Atkinson of Newfoundland Hydro and Larry Hicks of the Department of Natural Resources provided suggestions and edits to this report, earlier texts and various power point presentations on the subject. The report could not be done without information provided by C-NLOPB and Government of Newfoundland and Labrador Department of Natural Resources who provided information and a number of illustrations used for the completion of this report. I wish to thank W. Foote, D. Spurrell, L. Stead, A. Lake and B. Kendell (GNLNR) for graphics assistance, editing and final report organizing and D. Hawkins, L. Manuel (C-NLOPB) for access to information and illustrations. Thanks are also due to PR-AC, NSERC and PPSC who funded graduate studies, Halliburton Graphics (Landmark) for student access to workstations, IHS for digital log information and Canstrat for stratigraphic logs.



Further Reading

Atkinson, I. and Fagan, P., 2000. Sedimentary Basins and Hydrocarbon Potential of Newfoundland and Labrador, Government of Newfoundland and Labrador Report 2000-01, also available at http://www.gov.nl.ca/mines&en/oil

Balkwill, H.R., 1987. Labrador Basin; structural and stratigraphic style; sedimentary basins and basin-forming mechanisms, Atlantic Geoscience Society Special Publication, 5, p. 17-43.

Balkwill, H.R., McMillan, N.J., Maclean, B., Williams, G.L. and Srivastava, S.P., 1990. Geology of the Labrador Shelf, Baffin Bay, and Davis Strait, Chapter 7 in Geology of the Continental Margins of Eastern Canada, M.J. Keen and G.L. Williams (ed.); Geological Survey of Canada, Geology of Canada, no.2, p. 293-348.

Bell, J.S., Howie, R.D., McMillan, N.J., Hawkins, C.M., and Bates, J.L., 1989. Labrador Sea, East Coast Basin Atlas series. Geological Survey of Canada, Canada.

Bell, J.S. and Howie, R.D., 1990. Paleozoic geology; Chapter 4 in Geology of the Continental Margins of Eastern Canada, M.J. Keen and G.L. Williams (ed.); Geological Survey of Canada, Geology of Canada, no.2, p. 141-165.

Bell, J.S. and Cambell, G.R., 1990. Petroleum Resources, Chapter 12 in Chapter 7 in Geology of the Continental Margins of Eastern Canada, M.J. Keen and G.L. Williams (eds.); Geological Survey of Canada, Geology of Canada, no.2, p. 677-720.

Bojesen-Kofoed, J.A., Christiansen, F.G., Nytoft, H.P. and Pedersen, A.K., 1999. Oil seepage onshore West Greenland: evidence of multiple source rocks and oil mixing. In: Fleet, A. J. & Boldy, S.A.R. (eds) Petroleum Geology of Northwest Europe: Proceedings of the 5th Conference, p. 305-314, London: Geological Society.

Bojesen-Koefoed, J.A., Nytoft, H.P. and Christiansen, F.G., 2004. Age of oils in West Greenland: was there a Mesozoic seaway between Greenland and Canada?. Geological Survey of Denmark and Greenland Bulletin 4, p. 49-52

Canada-Newfoundland and Labrador Offshore Petroleum Board, 2008. Schedule of Wells [online]. Available from http://www.cnlopb.nl.ca

Canada-Newfoundland and Labrador Offshore Petroleum Board, 2003. Properties of gas bearing reservoirs [online]. Available from http://www.cnlopb.nl.ca

Canadian Aeromagnetic Data Base, 2007. Geoscience Data Repository, Geological Survey of Canada, Earth Sciences Sector, Natural Resources Canada, Government of Canada.

Chalmers, J.A., 1991. New evidence on the structure of Labrador Sea/Greenland continental margin, Journal of the Geological Society of London, 148, p. 899-908.

Chalmers, J.A. and Laursen, K.H., 1995. Labrador Sea: the extent of continental and oceanic crust and the timing of the onset of seafloor spreading, Marine and Petroleum Geology, 12, p. 205-217.

Chalmers, J.A. and Pulvertaft, T.C.R., 2001. Development of the continental margins of the Labrador Sea; a review; non-volcanic rifting of continental margins; a comparison of evidence from land and sea, Geological Society Special Publications, 187, p. 77-105.

Chian, D., Louden, K.E. and Reid, I., 1995. Crustal structure of the Labrador Sea conjugate margin and implications for the formation of nonvolcanic continental margins, Journal of Geophysical Research, 100, p. 24-24,253.

Cutt, B.J. and Laving, J.G., 1977. Tectonic elements and geologic history of the south Labrador and Newfoundland continental shelf, eastern Canada, Bulletin of Canadian Petroleum Geology, 25, p. 1037-1058.

Dehler, S.A. and Keen, C.E., 1993. Effects of rifting and subsidence on thermal evolution of sediments in Canada's East Coast basins, Canadian Journal of Earth Sciences = Journal Canadien des Sciences de la Terre, 30, p. 1782-1798.

De Silva, N., 2003. Offshore Labrador: Exploration History – Gas Potential. NOIA Seminar.

Drummond, K.J., 1998. East coast gas-the big picture. CERI Eastern Canadian Natural Gas Conference, Halifax, Nova Scotia.

Enachescu, M.E., 1987, Tectonic and structural framework of the Northeast Newfoundland continental margin; in Sedimentary Basins and Basin-forming mechanisms, C. Beaumont and A.J. Tankard (eds.), Canadian Society of Petroleum Geologists, Memoir 12, p.117-146.

Enachescu, M. and Fagan, P., 2004. Newfoundland and Labrador Call for Bids NF04-01, Government of Newfoundland and Labrador, Department of Natural Resources, 35p, 20 fig.; also available at http://www.gov.nl.ca/mines&en/oil/call_for_bids_nf04_01.stm

Enachescu M. E., 2005. Offshore Newfoundland and Labrador: An Emerging Energy Powerhouse. Offshore Technology Conference Paper #17570, Houston, Tx, 8p., 13 figures.

Enachescu M. and Fagan, P., 2005a. Newfoundland's Grand Banks presents untested oil and gas potential in eastern North America, Oil and Gas Journal, February 14, vol. 103, 6, p. 32-39.

Enachescu, M. and Fagan, P., 2005b. Newfoundland and Labrador Call for Bids NF05-01, Parcels 1, 2 and 3, Regional setting and petroleum geology evaluation, Government of Newfoundland and Labrador, Department of Natural Resources, 35p, 27 fig.; also available at http://www.gov.nl.ca/mines&en/oil/call_for_bids_nf04_01.stm

Enachescu, M.E. and Hogg, J.R., 2005. Exploring for Atlantic Canada's next giant petroleum discovery. CSEG Recorder, v. 30, no. 5. p.19-30.

Enachescu, M.E., Kearsey, S., Hardy, V., Sibuet, J., Hogg, J., Srivastava, S.A., Fagan, A., Thompson, T., and Ferguson, R., 2005. Evolution and petroleum potential of Orphan Basin, Offshore Newfoundland, and its relation to the movement and rotation of Flemish Cap Basin on plate kinematics of the North Atlantic, 25th Annual Bob F. Perkins Research Conference: Petroleum Systems of Divergent Continental Margin Basins.

Enachescu, M., 2006a. Hopedale Basin-1: Favorable geology, advanced technology may unlock Labrador's substantial resources, Oil and Gas Journal, 19 June.

Enachescu, M., 2006b. Hopedale Basin-2: Atlantic off Labrador poised for modern exploration round, Oil and Gas Journal, 26 June.

Enachescu, M.E., 2006c. Call for Bids NL06-1, Jeanne d'Arc Basin, Parcels 1 to 3, Regional Setting and Petroleum Geology Evaluation, Government of Newfoundland and Labrador, Department of Natural Resources, p. 1-55**.**

Enachescu, M.E., 2006d. Call for Bids NL06-2, Sydney Basin, Parcels 1 to 3, Regional Setting and Petroleum Geology Evaluation, Government of Newfoundland and Labrador, Department of Natural Resources, p. 1-55.

Enachescu, M.E., 2006e. Call for Bids NL06-3, Western Newfoundland and Labrador Offshore Region, Parcels 1 to 5, Regional Setting and Petroleum Geology Evaluation, Government of Newfoundland and Labrador, Department of Natural Resources, p. 1-58.

Enachescu, M. and Hogg, J., 2006. Compression modified extensional structures (CMES) of the Canadian Atlantic passive margin. Abstract, CSPG/CSEG/CWLS Annual Convention, Calgary.

Enachescu, M.E., Kearsey, S., Hogg, J., Fagan, A.J., Einarsson, D., Atkinson, I., and Hardy, V., 2006. Hopedale Basin, offshore Labrador, Canada: Structural and tectonic framework and exploration potential. SEG 2006 Annual Meeting, New Orleans, LA.

Enachescu, M.E., Einarsson, P. and Feir, A., 2007. Extent of sedimentary basins and oceanic crust domain in the northern Labrador Sea, CSPG Gussow Geoscience Conference, Banff, Alberta.

Enachescu, M. and Einarsson, P., 2007. Trans-Labrador Sea Modern Reflection Data Show Unorthodox Rift, Oral presentation 2007 CSPG/CSEG Convention, Eastern Frontier Basins of Canada Session, May 14-17, Calgary, AB.

Enachescu, M. E., Martin, M., Stead, J., Hall, J., Carroll, A. and Einarsson, P., 2008. Hopedale Basin Exploration Potential, East Coast Atlantic Canada, 2008 AAPG Annual Convention and Exhibition, San Antonio, TX.

Enachescu, M. E., Einarsson, P., Martin, M. and Stead, L., 2008. Exploration opportunities in the Hopedale Basin, Labrador Sea, Province of Newfoundland and Labrador, Canada, CSPG/CSEG Joint Convention, Calgary, AB.

Fagan, P. and Hicks, L., 2005. Hydrocarbon Potential of Parcels 4-7, Canada-Newfoundland Offshore Petroleum Board Call for Bids NL05-01, GNLNR publication.

Foote, W., 2008. Overview of Oil and Gas Activity in Western Newfoundland and Labrador, Presentation at NOIA Conference, St John's, NL.

Fowler, M.G., Stasiuk, L.D. and Avery, M., 2005. Potential petroleum systems in the Labrador and Baffin shelf areas, offshore eastern Canada. GAC/MAC/CSPG/CSSS, Halifax, NS. Geological Society of Canada. 2007. Atlantic Basin website [online]. Available from http://gsca.nrcan.gc.ca/BASIN/index_e.php

Funck, T., Jackson, H. R., Louden, K. E. and Klingelhöfer, F., 2007. Seismic study of the transform-rifted margin in Davis Strait between Baffin Island (Canada) and Greenland: What happens when a plume meets a transform. Journal of Geophysical Research, Vol. 112, p. B04402-B004308.

Geological Survey of Canada (GSC): http://www.gsca.nrcan.gc.ca/BASIN/

Geophysical Services Incorporated, 2007. GSI website [online]. Available from http://www.geophysicalservice.com.

Government of Newfoundland and Labrador Natural Resources (GNLNR), 2007. Energy Plan, Focusing our Energy, 102p., http://www.nr.gov.nl.ca/energyplan/

Government of Newfoundland and Labrador Natural Resources (GNLNR), 2008. Oil and Gas Report-February 2008, Petroleum Development.

Gradstein, F.M. and Srivastava, S.P., 1980. Aspects of Cenozoic stratigraphy and paleoceanography of the Labrador Sea and Baffin Bay; Cenozoic history in and around the northern Atlantic and Arctic oceans, Palaeogeography, Palaeoclimatology, Palaeoecology, 30: 261-295.

Gradstein, F.M. and Williams, G.L., 1976. Biostratigraphy of the Labrador shelf; part 1. 349, Geological Survey of Canada, Calgary, AB, Canada (CAN), Canada (CAN).

Grant, A.C., 1972. The continental margin off Labrador and eastern Newfoundland; morphology and geology, Canadian Journal of Earth Sciences = Journal Canadien des Sciences de la Terre, 9, p.1394-1430.

Grant, A.C., 1975. Structural modes of the western margin of the Labrador Sea, Paper - Geological Survey of Canada, no.74-30, Offshore geology of eastern Canada; Vol.2, Regional geology, p. 217-231.

Grant, A.C., 1980. Problems with plate tectonics; the Labrador Sea, Bulletin of Canadian Petroleum Geology, 28, p. 252-278.

Grant, A.C. and McAlpine, K.D., 1990. The continental margin around Newfoundland. In: M.J.Keen and G.L.Williams (eds). Geology of the Continental Margin of Eastern Canada. Geological Survey of Canada, Geology of Canada 2, p. 239-292.

Hall, J., Louden, K.E., Funck, T. and Deemer, S., 2002. Geophysical characteristics of the continental crust along the LITHOPROBE ECSOOT Transect: a review. Canadian Journal of Earth Sciences v. 31, p. 569-587.

Hardy, V., 2007. Cretaceous evolution and seismic stratigraphy of the Orphan Basin. MSc Thesis (Geophysics), Memorial University of Newfoundland.

Hawkins, D., Dillabough, G., Ruelokke, M. and Way, F., 2008. Small Field Development-Offshore Newfoundland and Labrador, Canada. OTC Paper 19270, 12p.

Haworth, R.T., Grant, A.C. and Folinsbee, R.A., 1976a. Geology of the continental shelf of southeastern Labrador; in Report of Activities, Part C, Geological Survey of Canada, Paper 76-1C, p. 61-70.

Haworth R.D., Poole, W.H., Grant, A.C. and Sandford B.V., 1976b. Marine geoscience survey northeast of Newfoundland; in Report of Activities, Part A, Geological Survey of Canada, Paper 76-1A, p. 7-15.

Keen, C.E., 1979. Thermal history and subsidence of rifted continental margins; evidence from wells on the Nova Scotian and Labrador shelves, Canadian Journal of Earth Sciences = Journal Canadien des Sciences de la Terre, 16, p. 505-522.

Keen, C.E., 1982. The continental margins of eastern Canada; a review; dynamics of passive margins, Geodynamics Series, 6, p. 45-58.

Keen, C.E., Loncaravic, B.D., Reid, I., Woodside, J., Haworth, R.T. and Williams, H., 1990. Tectonic and Geophysical overview; Chapter 2 in Geology of the Continental Margins of Eastern Canada, M.J. Keen and G.L. Williams (ed.); Geological Survey of Canada, Geology of Canada, no.2, p. 31-85.

Keen, C.E., Potter, P. and Srivastava, S.P., 1994. Deep seismic reflection data across the conjugate margins of the Labrador Sea. Canadian Journal of Earth Sciences, v. 31, p. 192-205.

King, A.F. and McMillan, N.J., 1975. A mid-Mesozoic breccia from the coast of Labrador, Canadian Journal of Earth Sciences, 12, p. 44-51.

Klassen, H.J., 2005. Labrador Shelf Petroleum System: A Review, Offshore Newfoundland and Labrador, Canada. AAPG Convention, Calgary AB.

Klose, G. W., Malterre, E., McMillan, N. J. and Zinkan, C. G., 1982. Petroleum exploration offshore southern Baffin Island, northern Labrador Sea, Canada, in Arctic Geology and Geophysics, edited by A. F. Embry and H. R. Balkwill, Mem. Can. Soc. Pet. Geol., 8, p. 233–244

Issler, D.R. and Beaumont, C., 1987. Thermal and subsidence history of the Labrador and west Greenland continental margins; sedimentary basins and basin-forming mechanisms, Atlantic Geoscience Society Special Publication, 5, p. 45-69.

Laughton, A.S., 1971. South Labrador Sea and the evolution of the North Atlantic, Nature (London), 232, p. 612-616.

Louden, K., 2002. Tectonic evolution of the east coast of Canada. CSEG Recorder, p. 37-48.

Louden, K.E., Osler, J.C., Srivastava, S.P. and Keen, C.E., 1996. Formation of oceanic crust at slow spreading rates; new constraints from an extinct spreading center in the Labrador Sea, Geology (Boulder), 24, p. 771-774.

Martin, M., 2007. Seismic Stratigraphy and Tectono-structural framework of the Bjarni Area, Hopedale Basin, Labrador Sea. MSc Thesis (Geophysics), Memorial University of Newfoundland, St. John's, NL.

Martin, M. and Enachescu, M.E., 2007. New Geoscience Data and Interpretation of the Region Around Bjarni/North Bjarni Field, Hopedale Basin. Poster presentation 2007 CSPG CSEG Convention, May 14-17, Calgary, AB.

Mayhew, M.A., Drake, C.L. and Nafe, J.E., 1970. Marine geophysical measurements on the continental margins of the Labrador Sea, Canadian Journal of Earth Sciences, 7, p. 199-210.

McWhae, J.R.H. and Michel, W.F.E., 1975. Stratigraphy of Bjarni H-81 and Leif M-48, Labrador shelf, Bulletin of Canadian Petroleum Geology, 23, p. 361-382.

McWhae, J.R.H., Elie, R., Laughton, D.C. and Gunther, P.R., 1980. Stratigraphy and petroleum prospects of the Labrador shelf, Bulletin of Canadian Petroleum Geology, 28, p. 460-488.

McMillan, N.J., 1982. Canada’s east coast: the new super petroleum province. Technology, p. 95-109.

Meneley, R.A., 2003. Exploration History of Frontier Basins in Canada - Ignore It At Your Peril. Abstract and presentation, CSPG/CSEG Convention.

Nantais, P., 1984. Regional Hydrocarbon Potential of the Labrador Shelf. GSC Atlantic, Open File 1197.

Osler, J.C. and Louden, K.E., 1995. Extinct spreading center in the Labrador Sea; crustal structure from a two-dimensional seismic refraction velocity model, Journal of Geophysical Research, 100: 2261-2278.

Powell, T.G., 1979. Geochemistry of Snorri and Gudrid condensates, Labrador shelf; implications for future exploration; current research, part C, Paper - Geological Survey of Canada, 91-95.

Power, L and Costello, K., (2008). A Scooping Level Assessment of the Monetization of Newfoundland and Labrador’s Offshore Natural Gas Reserves. Module III-MOGS 6099 Project, Memorial University of Newfoundland, Master of Oil and Gas Studies (MOGS), 99 p.

Rashid, M.A., Purcell, L.P., and Hardy, I.A., 1980. Source rock potential for oil and gas of the east Newfoundland and Labrador shelf areas; facts and principles of world petroleum occurrence, Memoir - Canadian Society of Petroleum Geologists, 589-607.

Reston, T.J., Pennell, J., Stubenrauch, A., Walker, I., and Perez-Gussinye, M., 2001. Detachment faulting, mantle serpentinization, and serpentinite-mud volcanism beneath the Porcupine Basin, southwest of Ireland, Geology (Boulder), 29: 587-590.

Roest, W.R. and Srivastava, S.P., 1989. Sea-floor spreading in the Labrador Sea; a new reconstruction, Geology (Boulder), 17, p. 1000-1003.

Schwartz, S., 2008. Diagenesis and porosity evolution of the lower Palaeozoic carbonate and Cretaceous-Tertiary siliciclastic reservoir intervals, Labrador shelf. MSc (Geology), Memorial University of Newfoundland, St. John's, NL.

Sibuet, J., Srivastava, S.P., and Manatschal, G., 2007. Exhumed mantle forming transitional crust in the Newfoundland-Iberia rift and associated magnetic anomalies.

Smee, J., 2003. Hydrocarbon Potential of Parcels 1-12, C-NOPB call for bids NL 03-1, Orphan Basin Offshore Newfoundland, prepared by G & G Exploration Consulting Limited.

Sønderholm, M., Nøhr-Hansen, H., Bojesen-Koefoed, J.A., Dalhoff, F. & Rasmussen, J.A., 2003. Regional correlation of Mesozoic-Palaeogene sequences across the Greenland-Canada boundary. Danmarks og Grønlands Geologiske Undersøgelse Rapport 2003/25, 176 pp.

Srivastava, S.P., 1978. Evolution of the Labrador Sea and its bearing on the early evolution of the north Atlantic, The Geophysical Journal of the Royal Astronomical Society, 52: 313-357.

Srivastava, S.P., Falconer, R.K.H., and MacLean, B., 1981. Labrador Sea, Davis Strait, Baffin Bay; geology and geophysics; a review; geology of the north Atlantic borderlands, Memoir - Canadian Society of Petroleum Geologists, 7, p. 333-398.

Srivastava S.P. and Verhoef, J., 1992. Evolution of Mesozoic sedimentary basins around the North Central Atlantic: a preliminary plate kinematic solution. In Parnell, J. (ed.), Basins of the Atlantic Seabord: Petroleum Geology, Sedimentology and Basin Evolution. Geological Society Special Publication No. 62, p. 397-420.

Srivastava, S. P. and Keen, C. E., 1995. A deep seismic reflection profile across the extinct Mid-Labrador Sea spreading centre, Tectonics, vol.14, no.2. p. 372-389.

Srivastava, S.P., and Roest, W.R., 1995. Nature of the thin crust across the southwest Greenland margin and its bearing on the location of the ocean-continent boundary, in Rifted ocean-continent boundaries, Banda E., Torni, M. Talwani, M. (eds), NATO Advanced Science Institutes Series, Series C: Mathematical and Physical Sciences, vol. 463, p. 95-120.

Srivastava, S.P. and Roest, W.R., 1999. Extent of oceanic crust in the Labrador Sea, Marine and Petroleum Geology, 16, p. 65-84.

Stead, J.E., 2008. Geological Comparison of the South Hopedale and West Orphan Basins, Northwest Atlantic Margin. MSc (Geophysics), Memorial University of Newfoundland, St. John's, NL.

Tankard, A.J. and Welsink, H.J., 1989. Mesozoic extension and styles of basin formation in Atlantic Canada; extensional tectonics and stratigraphy of the north Atlantic margins, AAPG Memoir, 46, p. 175-195.

Taylor, F.C., 1981. Precambrian geology of the Canadian north Atlantic borderlands; Geology of the North Atlantic Borderlands, Memoir - Canadian Society of Petroleum Geologists, 7, p. 11-30.

Taylor, F.C., 1979. Reconnaissance geology of a part of the Precambrian shield, northeastern Quebec, northern Labrador and Northwest Territories. Geological Survey of Canada, Canada, Memoir 393, 99p.

Umpleby, D.C., 1979. Geology of the Labrador Shelf, Paper 79-13 - Geological Survey of Canada, 34.

Vogt, P.R. and Avery, O.E., 1974. Detailed magnetic surveys in the northeast Atlantic and Labrador Sea, Journal of Geophysical Research, 79, p. 363-389.

Williams, H. (ed.), 1995. Geology of the Appalachian-Caledonian orogen in Canada and Greenland, Geological Survey of Canada, Geology of Canada, Ottawa, no.6.

Williams, H., Dehler, S.A., Grant, A.C., and Oakey, G.N., 1999. Tectonics of Atlantic Canada: Geoscience Canada, v. 26, no.2, p. 51-70.

Williams, H., 2003. Geologic Ancestors to the Atlantic: The Geology of Newfoundland, Newfoundland Quarterly, V. 96, No 3, Issue 410, http://www.newfoundlandquarterly.ca/fall03/rock.php.

Williamson, M.-C., Villeneuve, M. E., Larsen, L. M., Jackson, H. R., Oakey, G. N. and Maclean, B., 2001. Age and petrology of offshore basalts from the Southeast Baffin Island shelf, Davis Strait, and the Western Greenland continental margin, paper presented at Joint Annual Meeting, Geol. Assoc. of Can.–Mineral. Assoc. of Can., St. John’s, NL, Canada.