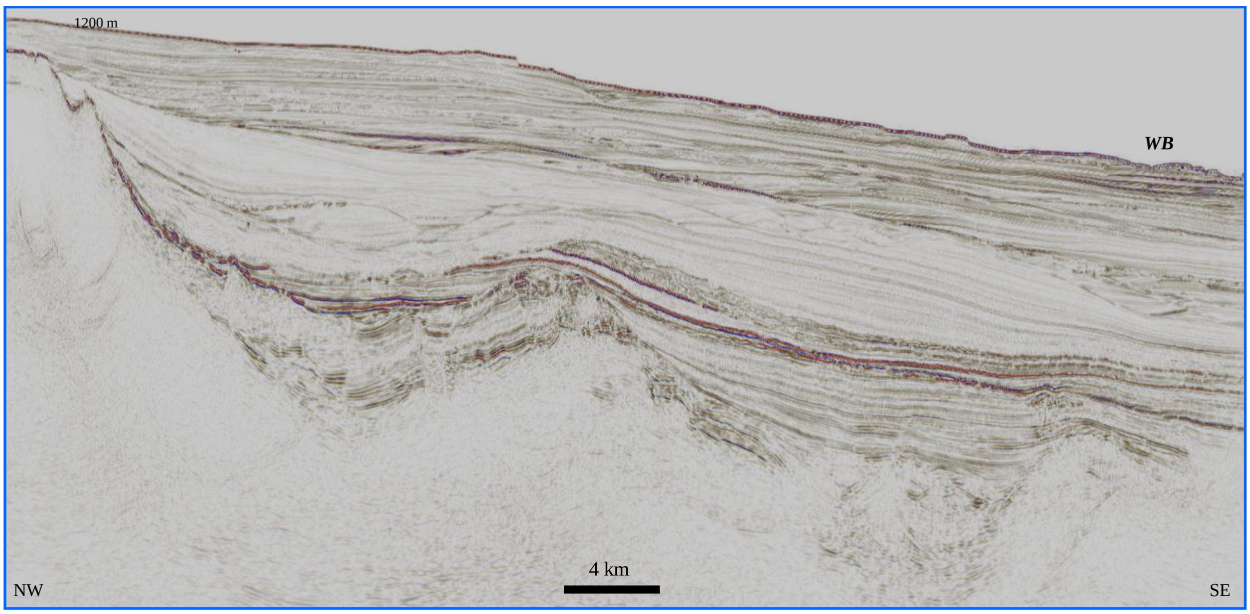
Petroleum Exploration Opportunities in the Carson Basin, Newfoundland and Labrador Offshore Area; Call for Bids NL13-02, Area "C" - Carson Basin, Parcels 1 to 4.

Government of Newfoundland Department of Natural Resources



By Dr. Michael Enachescu, P Geoph., P Geo.

November 2013

Foreword

This report has been prepared on behalf of the Government of Newfoundland and Labrador Department of Natural Resources (NL-DNR) to provide information on land parcels offered in the Canada-Newfoundland and Labrador Offshore Petroleum Board's (C-NLOPB) 2013 Call for Bids NL13-02.

This year the C-NLOPB has issued three separate Calls for Bids, including:

1. **Call for Bids NL13-01** (Flemish Pass Basin) consisting of one parcel,
2. **Call for Bids NL13-02** (Carson Basin) consisting of four parcels, and
3. **Call for Bids NL13-03** (Western Newfoundland) consisting of four parcels.

These nine parcels on offer comprise a total of 2,409,020 hectares (5,952,818 acres) distributed in four regions of the NL Offshore area situated in the Flemish Pass, Carson, Anticosti and Magdalen basins (http://www.cnlopb.nl.ca/news/nr20130516.shtml).

Call for Bids NL13-02. This report focuses on Call for Bids NL13-02 Area "C" - Carson Basin that includes four large parcels with a total area of 1,138,399 hectares (2,813,034 acres) (http://www.cnlopb.nl.ca/pdfs/nl1302.pdf). The parcels lay in shallow to deep water of the basin, east of the Grand Banks of Newfoundland and south of the Flemish Cap bathymetric features. These parcels are located within an underexplored Mesozoic sedimentary area that should include reservoir and source rocks. This 50,000 km^2 (19,305 square miles) Mesozoic-Tertiary basin is situated just south of the oil producing Jeanne d'Arc Basin (approximately 238,396 bopd in first eight months of 2013 from the Hibernia, Terra Nova, White Rose and North Amethyst oil fields) and south of the Flemish Pass Basin where the Mizzen (2009), Harpoon (2013) and Bay du Nord (2013) major discoveries were made. The Carson Basin is under-explored with only four older exploration wells drilled (two in 1973, one in 1974 and one in 1986). All four wells were drilled in the shelfal part of the basin. As detailed in this report, significant oil and gas potential exists in the four parcels offered for bids.

At the time of web-publishing this report, no exact date has been assigned for the closing of Call for Bids NL13-02. In May 2013, the C-NLOPB issued a request for proposals for the preparation of the Strategic Environmental Assessment for the Eastern Newfoundland Offshore Area. The C-NLOPB has decided that the closing date for this Call for Bids shall be 120 days after the completion of the *Eastern Newfoundland Strategic Environmental Assessment (2013)* (the "Closing Date"). Notification of the Closing Date and time shall be published on the Canada-Newfoundland and Labrador Offshore Petroleum Board's website under the heading "What's New!" (http://www.cnlopb.nl.ca/new_whats.shtml). Interested parties have until the closing date and time to submit sealed bids for Call for Bids NL13-02 (Carson Basin).

Call for Bids NL13-01. Call for Bids NL13-01 Area "C"- Flemish Pass consists of one parcel comprising 266,139 hectares (657,644 acres) located in intermediate water depths of the Flemish Pass Basin, northeast of the island of Newfoundland. The Flemish Pass Basin is a proven petroleum basin that contains the Mizzen significant oil discovery with recoverable reserves estimates in the range of 100-200 mmbbls and the recently announced high-quality, light oil find at the Harpoon O-85 (June 2013) and the major light oil discovery at Bay du Nord C-78 (August

2013), estimated by Statoil specialists at between 300 and 600 mmbbls recoverable resource (http://www.statoil.com/en/NewsAndMedia/News/2013/Pages/26Sep_exploration.aspx).

Similar to the CFB NL13-02, the closing date for this call for bids shall be 120 days after the completion of the *Eastern Newfoundland Strategic Environmental Assessment (2013)* (the "Closing Date"). Notification of the Closing Date and time shall be published on the Canada-Newfoundland and Labrador Offshore Petroleum Board's website under the heading "What's New!" (http://www.cnlopb.nl.ca/new_whats.shtml). Interested parties have until the closing date and time to submit sealed bids for Call for Bids NL13-01 (Flemish Pass).

Call for Bids NL13-03. Call for Bids NL13-03 Area "B" – Western Newfoundland and Labrador, consists of four parcels comprising 1,004,482 hectares (2,482,129,201 acres) located in the shallow waters of the Gulf of St. Lawrence, west of the island of Newfoundland. Three of the parcels are situated in the Anticosti Basin and one is located in the Magdalen Basin. The parcels are situated north and west of the Port au Port Peninsula, where a significant discovery (Port au Port #1) was recorded in 1995 and is today part of the Garden Hill South oil field.

For CFB NL13-03, the closing date shall be 120 days after the completion of the *Western Newfoundland and Labrador Offshore Area Strategic Environmental Assessment Update* (the "Closing Date"). Notification of the Closing Date and time shall be published on the Canada-Newfoundland and Labrador Offshore Petroleum Board's website under the heading "What's New!" (http://www.cnlopb.nl.ca/new_whats.shtml). Interested parties have until the closing date and time to submit sealed bids for Call for Bids NL13-03 (Western Newfoundland and Labrador). On June 21, 2013, the C-NLOPB posted *the Draft Western Newfoundland and Labrador Offshore Area Strategic Environmental Assessment Update Report* inviting the public to comment on the report. On July 12, 2013, the C-NLOPB issued a news release informing the public that the deadline for public review of the report was extended to September 27, 2013.

Call for Bids NL13-02 Report. This report should be referenced as ***Enachescu, M.E., 2013. Petroleum Exploration Opportunities in the Carson Basin, Newfoundland and Labrador Offshore Area; Call for Bids NL13-02, Area "C" – Carson Basin, Parcels 1 to 4. Government of Newfoundland Department of Natural Resources*.**

I acknowledge the contribution of earlier researchers in the area: J. Wade, A. Grant, S. Srivastava, C. Keen, D. McAlpine and many other scientists at GSC Atlantic who contributed to the Grand Banks Basin Atlas (1989) that included the shallow to intermediate water components of the Carson Basin. I also acknowledge the professionals of Mobil, Amoco, Gulf, Canterra and Petro-Canada who seismically mapped and drilled the onshelf wells in the Carson Basin that now provide ties to the deeper water seismic data. B. Tucholke, J. Austin and E. Uchupi have provided accounts of the deepwater Carson Basin referred to by them as "the Salar Basin". Thanks are due to GSC researchers J. Wielens, G. Williams and C. Jauer who produced more recent geological reviews and resource evaluation on the basin and to J-C. Sibuet, I. Sinclair, B. Wernicke and T. Tankard, who published several important papers on the geology of the area.

This work could not have been completed without valuable information provided by the C-NLOPB and Government of Newfoundland and Labrador Department of Natural Resources. I am grateful to W. Foote, D. Middleton, L. Hicks and D. Spurrell for edits and suggestions and B. Kendell, K. Waterman and J. Owens for help with illustrations.

For information on how to submit a bid in this offshore Newfoundland and Labrador Call for Bids please go to http://www.cnlopb.nl.ca/ and see the **May 17, 2013, News Release** (http://www.cnlopb.nl.ca/news/nr20130516.shtml).

Acronyms used in this report:

NL = Newfoundland and Labrador (the legal name of the Province)
NS = Nova Scotia; NSPFA = Nova Scotia Play Fairway Analysis
C-NLOPB = Canada-Newfoundland and Labrador Offshore Petroleum Board
NL-DNR = Government of Newfoundland and Labrador-Department of Natural Resources
GSC = Geological Survey of Canada
IODP = Integrated Ocean Drilling Program; ODP = Ocean Drilling Program
OETRA = Offshore Energy Technical Research Association
NL13-01, 02 and 03 = identifiers for the three 2013 Call for Bids
PL = Production Licence; EL = Exploration Licence
SDL = Significant Discovery Licence
DPA = Development Plan Application
TD = Total Depth
bopd = barrels of oil per day; mmcfd = million cubic feet per day
tcf = trillion cubic feet; bcf = billion cubic feet
bbls = barrels; mmbbls = million barrels; Bbbls = Billion barrels

Figure 1. Location of Newfoundland and Labrador's major offshore oil fields and of the Carson Basin, east of the Grand Banks of Newfoundland (yellow star).

Report Content

1. **Introduction**

This report focuses on Parcels 1 to 4 of the C-NLOPB Call for Bids NL13-02 Area "C" - Carson Basin (http://www.cnlopb.nl.ca/pdfs/nl1302.pdf). This basin is located off the east coast of the Province of Newfoundland and Labrador, Canada (Figure 1). The four parcels are situated on the shelf, slope and rise of the Atlantic Ocean in an area administered jointly by the provincial (NL) and federal (Canada) governments, through the C-NLOPB (Figures 1 and 2). These parcels are in water depths ranging from 90 to 3700 m. Numerous structural, stratigraphic and combination traps are seen on seismic data collected in the basin. During two earlier exploration cycles (1970-1986), four exploration wells were drilled, all located in the shelfal area. While unsuccessful, these wells intersected good reservoirs. Based on its structural evolution and vicinity to oil proven basins, the Carson Basin should hold oil prone, Late Jurassic source rocks.

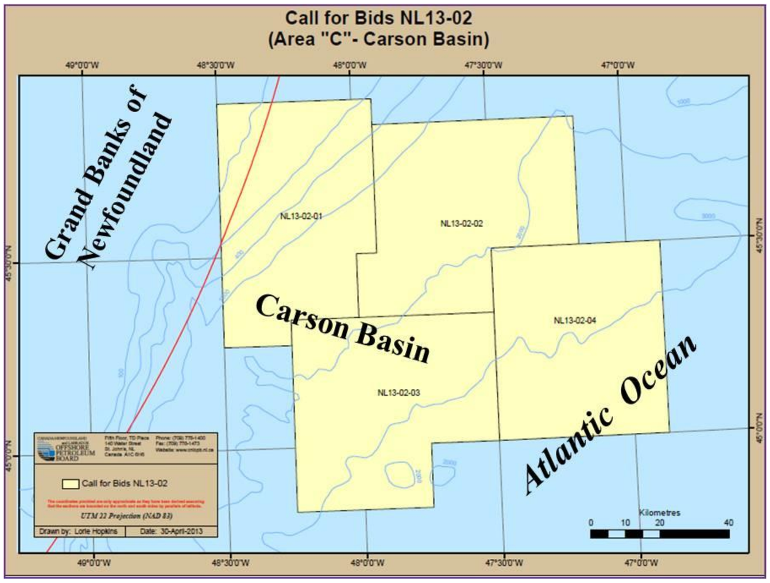


Figure 2. Location map of Call for Bids NL13-02 parcels 1 to 4. Red line is the 200 nautical mile limit.

The Carson Basin is a high-risk/high-reward exploration area and is unique in that its slope and deepwater are practically unexplored. The last licensing of deepwater blocks in the Carson Basin took place in late 1990s-early 2000s, when a dense grid of 2D lines and a 3D survey were collected by seismic companies and by operator Petro-Canada and its partners. However, at the time the operator and partners decided against drilling their mapped prospects.

The basin is close to the major producing fields of the Jeanne d'Arc Basin and also close to North America's largest petroleum markets. Only four wells were drilled during earlier exploration cycles of the 1970s and 1980s in the shelfal part the basin and no wells have been drilled on the slope and deepwater. This large Mesozoic rift basin has a similar geological evolution with the Jeanne d'Arc and Flemish Pass basins and provides a great opportunity for petroleum exploration (Enachescu, 1987, 1988 and 1992a and b; Tucholke et al., 1987; Austin et al., 1987; Atkinson and Fagan, 2000; Enachescu and Fagan, 2004, 2005 and 2009; Enachescu and Hogg, 2005; Solvason et al., 2005; Solvason, 2006; Enachescu, 2006, 2009, 2010a and b, 2011, 2012a, b and c).

This report provides general background information on current petroleum exploration and production on the East Coast of Newfoundland and Labrador and presents the geoscience information and the hydrocarbon prospectivity of the Carson Basin. It also discusses the specific geology and petroleum potential of the four parcels grouped in the Call for Bids NL13-02. They are located within the northern slope and deepwater part of the Carson Basin, where thick Mesozoic synrift and postrift sequences were identified.

More information on the geology and petroleum potential of Newfoundland and Labrador's (NL) offshore basins can be accessed at: http://www.nr.gov.nl.ca/nr/energy/petroleum/index.html and http://www.nr.gov.nl.ca/nr/energy/petroleum/offshore/offshore.html. Selected references on the geological setting and petroleum potential of the Newfoundland and Labrador offshore and specifically on the Carson Basin are provided at the end of this report.

2. **Carson Basin Subdivisions.**

Situated geographically in front of the Grand Banks of Newfoundland, the Carson Basin is a branch of the North Atlantic Mesozoic rift network (Figure 3). This network includes the Jeanne d'Arc, Flemish Pass and East Orphan basins, where intense exploration and production activity has been ongoing for the past decade. The most recent oil discoveries in the area are the Mizzen, Harpoon and Bay du Nord strikes in the Flemish Pass Basin located north of where the Call for Bids parcels are offered.

This North American continental margin basin was developed on continental and transitional crust and extends to the first occurrence of oceanic crust. The boundaries of the Mesozoic Carson Basin are loosely defined. Based on tectonic and structural setting, the position on the continental margin and composition of sedimentary fill, the Carson Basin can be divided into three distinct sectors (Figure 3):

1. **On-shelf sector**. This sector is located on the easternmost part of the Grand Banks of Newfoundland. It is separated from the Jeanne d'Arc Basin by a basement ridge trending approximately NE-SW and from the slope part of the basin by a basement ridge capped in places by Late Triassic Argo salt. This ridge is mapped under the shelf break. Late Triassic to Quaternary successions were drilled in this sector of the basin, however Late Jurassic source rocks are missing at the well locations, probably due to non-deposition on basement highs or erosion in the proximity of the Avalon Uplift.

2. **Slope and upper rise sector.** This sector is known in the literature as the Salar Basin. This sector is separated from the on-shelf part by a basement ridge trending approximately NE-SW (hinge zone) and from the deepwater basin by a tortuous fault zone and high ridge, both mapped in deepwater. From jump correlation of regional seismic markers, this sector seems to contain the entire Mesozoic sedimentary section including Late Triassic beds. Large and complex structures are mapped in this sector including those separated by deep penetrating faults.

3. **Deepwater sector**: This sector is located east of a fault system dividing the deepwater region into subregions. This Mesozoic-dominated area east of the fault zone is complexly structured. In places the Mesozoic section is thin. Tilted basement blocks, circular salt structures and transitional zone-like mounds (peridotite mounds) intertwined with minibasins containing deformed Mesozoic layers are mapped in the deepwater sector. Some of the blocks show slight inversion probably due to transtension or isostatic rebound.

The "Slope and upper rise sector" together with the "Deepwater sector" form what is known in the literature as the 'Salar Basin". All three subunits identified above and depicted in Figure 3 form the large Carson sedimentary area. For ease of reference the term "**Carson Basin**" will be used on all maps and discussions in this report.

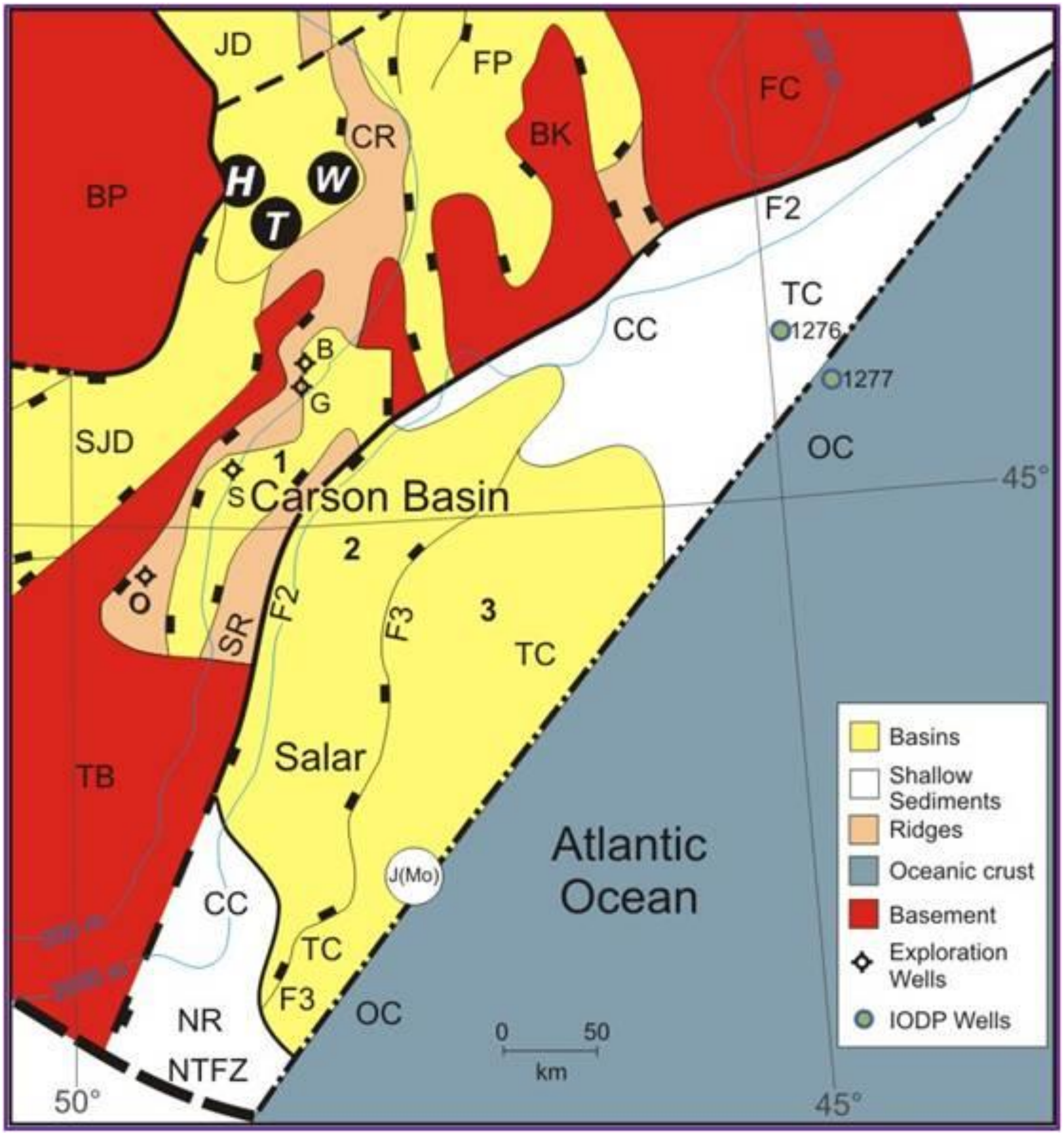


Figure 3. Location of Carson Basin in continuity with other Grand Banks shelf and slope basins and subbasins (modified after Enachescu, 1988, 1992a and b). Carson Basin subdivisions are marked on this figure as 1) On shelf sector, 2) Slope and upper rise sector and 3) Deepwater sector. Exploration wells are: O = Osprey H-84, S =Skua E-41, G = St. George J-55 and B = Bonnition H-32. Notations are: NTFZ = Newfoundland Transform Fault Zone (continent/ocean), NR = Newfoundland Ridge, TB = Tail of the Bank, SR = Salar Ridge, SJD = South Jeanne d'Arc Basin, JD = Jeanne d'Arc Basin, FP = Flemish Pass Basin, CR = Central Ridge, BP = Bonavista Platform, BK = Beothuk Knoll and FC = Flemish Cap. CC = continental crust, TC = transitional crust and OC = oceanic crust. F2 and F 3 are major fault trends in the basin. Producing oil fields are: H = Hibernia, T = Terra Nova and W = White Rose.

3. Exploration and Development Background

The Canadian province of Newfoundland and Labrador (NL) is the sole Atlantic offshore area north of Florida containing giant producing oil fields. Newfoundland and Labrador, together with the province of Nova Scotia, are the only jurisdictions allowing petroleum exploration on the eastern offshore side of the North American continent. Approximately 800,000 km^2 of Mesozoic and Paleozoic areas with oil and gas potential are distributed around the province of Newfoundland and Labrador, an area larger than the Gulf of Mexico or the North Sea.

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 45 years by industry, the Geological Survey of Canada, maritime Universities and research institutes in Canada, USA and Europe. Exploration offshore NL is regulated by the C-NLOPB but promoted by NL-DNR. Numerous NL-DNR publications and power points discuss the geological setting, petroleum exploration potential, exploration history of the East Coast of NL and the make-up of its oil and gas fields (http://www.nr.gov.nl.ca/nr/publications/energy/index.html).

3.1. NL Petroleum Production. In 2011, NL production represented 10% of Canada's total oil production, 32.5% of Canada's conventional light oil and more than 85% of Atlantic Canada petroleum output (http://www.neb.gc.ca/clf-nsi/rnrgynfmtn/sttstc/crdlndptrlmprdct/stmtdprdctn-eng.html. NL's petroleum production comes from the Hibernia, Terra Nova, White Rose, North Amethyst fields and their satellites, located in the Jeanne d'Arc Basin. Production drilling using extended reach techniques from the Hibernia Platform and the White Rose and Terra Nova FPSOs has continued during 2012-13. In each of the past 5 years, these fields have produced in the range of 250,000 to 350,000 barrels per day of light crude (30 to 35º API) from high quality Mesozoic sandstone reservoirs. With this output, NL is Canada's 3rd largest oil producer and 7th largest oil producer among all American states and Canadian provinces (after TX, AL, CA, ND, AB and SK). In 2011 NL produced 97.3 mmbbls amounting to a daily average of 266, 494 bopd. In 2012 the production fell to 197,216 bopd for a total annual production of 72.2 mmbbls due to extended maintenance programs at the Terra Nova, White Rose and North Amethyst fields. An average of 238,396 bopd was produced during the first 8 months of 2013.

Over 1.39 billion barrels have been produced to date from the NL offshore area. Taking into account recent increases in estimated reserves for the Terra Nova field, on the Grand Banks, approximately 2.2 billion barrels of proven remaining recoverable reserves/resources exist. More than 6 tcf of natural gas is discovered on the Grand Banks, but there is no gas production on a commercial basis yet. The Jeanne d'Arc Basin's developments are the only East Coast North America producing oilfields. The next offshore project Hebron, estimated to contain 707 mmbbls of reserves is being developed by ExxonMobil and its partners, with first oil expected in 2017. Its peak production is estimated to be between 150,000 and 170,000 bopd.

The latest significant oil discovery licence issued by the C-NLOPB in the area was recorded by Statoil and Husky at the Mizzen O-16 well which tested 3774 bopd of 21-22° API oil from a 25 m section of porous and permeable sandstone (Ti-3) (Haynes et al., 2012) encountered from 3201 to 3245 m. The Mizzen field is located at the border between the Flemish Pass and East Orphan Basin, approximately 300 km north of the CFB NL13-02 parcels. In June 2013, Statoil announced a light oil discovery at Harpoon O-85 in the Flemish Pass Basin approximately 10 km southeast of the Mizzen discovery and followed up with an announcement of another discovery at the Bay du Nord C-78 well in August, 2013. Bay du Nord was declared as a 300-600 mmbbls recoverable light oil accumulation, while Harpoon's resources remain to be evaluated.

3.2. Recent Production, Development and Exploration Activity. Oil and gas exploration in NL's offshore started in the early 1960s. A total of 394 exploration, delineation and development wells have been drilled offshore NL up to the end of August 2013. The first exploration well, Tors Cove D-52, was spud in 1966 within the South Whale Basin, the last one Bay du Nord C-78, was spud in July 2013, within the Flemish Pass Basin. The major fields of the Grand Banks (oil and gas) and Offshore Newfoundland (gas) were discovered during the late seventies-early eighties when high commodity prices, government incentives and industry interests produced the highest ever drilling rate in the basins (7-10 wells a year). Outlined below are current offshore NL statistics and discussions on oil production, new field development, recent exploration and research. Recent offshore drilling results in the Jeanne d'Arc, Flemish Pass and East Orphan basins and exploration trends are emphasized.

3.2.1. Oil Production. In 2011 the oil fields of the Jeanne d'Arc Basin produced 97,270,161 barrels. During 2012, the Terra Nova FPSO, White Rose FPSO and parts of the Hibernia Production Platform underwent, for different intervals of time, refits and maintenance work (e.g. http://www.noia.ca/Portals/0/NN2012_Q4_FINAL_WEB.pdf). As a consequence the annual production decreased substantially and the daily average production went under 200,000 bopd for the first time in the past 10 years. The annual oil flow was down 25.8 per cent in 2012 compared to the same period in 2011. Thus, the yearly production influenced by natural field production decline and by deferred production during repairs, reached a total of 72,181,119 barrels, a level unseen since 2001. With all fields producing at capacity during the first 8 months of 2013, the NL output reached 238,396 bopd. Based on this information one can forecast an annual oil production from all fields during 2013 of between 80 and 85 mmbbls (http://www.stats.gov.nl.ca/Statistics/Industry/PDF/Oil_Production.pdf).

3.2.2. Delineation and Development Drilling. A total of 53 delineation and 187 development wells were also drilled with the great majority located in the Hibernia, Terra Nova, White Rose and North Amethyst fields. The last delineation well, White Rose H-70, was drilled by Husky in 2013 and just prior to that Suncor spud the Terra Nova E-19 well in the Jeanne d'Arc Basin. The Mizzen F-09 delineation well drilled by Statoil in 2011 helped to establish the extent of the Mizzen oil field. In the past few years, new development wells have kept NL production above the 200,000-250,000 bopd level.

3.2.3. Producing Fields. There are three large stand-alone producing fields offshore Newfoundland: Hibernia (GBS), Terra Nova (FPSO) and White Rose (FPSO), all located in the central part of the Jeanne d'Arc Basin. The smaller North Amethyst field (68 mmbbls) produces via a subsea tieback to the White Rose FPSO, the first such satellite field development offshore in Canada. In addition, Hibernia (Hibernia Southern Extension) and White Rose (White Rose Southern Extension) have satellite fields being developed using the existing infrastructure.

Hibernia Field. This field is one of the largest conventional fields developed in North America (Arthur et al., 1982; Tankard and Welsink, 1989; Brown et al., 1989; Mackay and Tankard, 1990; Hurley et al., 1992; Sinclair et al., 1999). Two principal reservoirs of Early Cretaceous age are produced - the Hibernia and Ben Nevis-Avalon reservoirs - located at average depths of 3,700 and 2,400 mm respectively. The field produces from the world's largest concrete platform designed to withstand the impact of icebergs and is operated by Hibernia Management and Development Company Ltd. (HMDC), with ExxonMobil as the largest interest holder. Production started in the fall of 1997 with an initial production of 50,000 bopd from a then estimated recoverable reserve of 522 mmbbls. The peak production of 222,549 bopd was attained during May 2004. The most recent reserve estimate for the field climbed to 1,395 mmbbls. The increase is due to improvements in reservoir monitoring, extended reach drilling, discovery of adjacent fault blocks with reservoired oil and a deeper than prognosed oil water contact providing producible reservoir beds. The Hibernia South Extension (HSE Unit) that started producing in 2011 has estimated recoverable reserves of 215 million barrels, which will extend the life of the Hibernia project by 5-10 years. It is anticipated that Hibernia will continue to produce well into 2040s. In addition, the Ben Nevis-Avalon reservoir with estimated reserves of 182 mmbbls is proving to be a valuable secondary reservoir, contributing 14,816 bopd in the first eight months of 2013 representing 11% of the fields' production.

In 2013, HMDC acquired high quality 4D seismic survey data to be used to monitor fluid and pressure changes in the reservoirs and also aid in optimization of future development well locations.

Terra Nova Field. Discovered in 1984 by Petro-Canada, this field was the second field to be developed and started producing in 2002. Suncor, Canada's largest oil and gas producer is the operator of the field. The Late Jurassic Jeanne d'Arc Formation contains the producing sand intervals (Wilcox et al., 1991; Enachescu et al. 1994; Atkinson and Fagan, 2000; Skaug et al., 2001; Richards et al., 2010). During 2012, the Terra Nova FPSO was taken offline for 6 months for repairs which included the replacement of a water injection swivel and replacement of subsea flow lines and risers. As a results of these upgrades to the FPSO and flowlines and risers an additional 87 mmbbls of reserves have been confirmed (C-NLOPB). Thus, the regulator has estimated that recoverable reserves from the field have increased from 419 mmbbls to 506 mmbbls. This will extend the field's production life for another seven years (i.e. from 2020 to 2027). The Terra Nova field is poised to produce about 13-14 mmbbls in 2013 as another off-station program is required to conduct maintenance and repairs on the FPSO mooring chains.

White Rose Field. Several publications and presentations describe this field (http://www.cnlopb.nl.ca/pdfs/wrda_vol2.pdf; Enachescu, 2006 and 2009; Kaderali et al., 2007; Hawkins et al., 2008). The latest development support well (gas injector) on record offshore NL is the White Rose J-05 1 drilled in the summer of 2012 on the southern White Rose field. Several other production wells are planned. The White Rose Extension Project (WREP) started with the excavation of a subsea drill centre at the South White Rose Extension (SWRX) in preparation for project sanction with first oil planned in 2015. The SWRX was approved in June 2013.

Development concepts, including a wellhead platform supported by a concrete gravity structure, are being evaluated for the West White Rose extension project (WREP) in anticipation of production in the 2016/17 timeframe (http://www.cnlopb.nl.ca/environment/whiterose.shtml). This project was released from environmental assessment and on October 10, 2013, amendments to the benefits terms of the 2007 White Rose Expansion Project Framework Agreement were announced that allow for the development of West White Rose using a wellhead platform, instead of the subsea development originally planned. Husky has awarded a five-year contract for a new harsh environment semi-submersible drilling rig, The *West Mira*, scheduled for delivery in 2015.

North Amethyst Field. This is the first satellite field development at White Rose and was brought into production in 2010 (Hawkins et al., 2008; http://www.cnlopb.nl.ca/pdfs/naplan.pdf. Its development, less than four years after discovery, represents the first subsea tie-back project in Canada. With production partially shut off or down for four months, the field produced only 6.9 mmbbls during 2012. Plans call for development of the Hibernia reservoir in 2014 which will enhance production at the field.

Hebron Development. Discovered in 1980 and delineated throughout 1980s and 1990s, Hebron is both a heavy and light oil field estimated to have 707 mmbbls of recoverable resources (http://www.cnlopb.nl.ca/pdfs/disc_rr.pdf; http://www.cnlopb.nl.ca/news/pdfs/sahebdevplan.pdf; http://www.hebronproject.com/media/3908/hda_vol_2.pdf; Rees and Spratt, 2005). The interest owners are ExxonMobil Canada Properties (36% operator), Chevron Canada Limited (26.7%), Suncor Energy Inc. (22.7%), Statoil Canada (9.7%) and Nalcor Energy (4.9%). The field is located approximately 9 km north of the Terra Nova project, 32 km southeast of the Hibernia project, and 46 kilometres from the White Rose project. The water depth at Hebron is approximately 92 metres. The field will be developed using a stand-alone concrete gravity based structure (GBS) designed to store approximately 1.2 mmbbls of crude oil (Figure 4). The Bull Arm Site in NL is the primary construction site for the GBS and topsides integration.

Figure 4. Rendition of Hebron GBS (source: ExxonMobil).

Hebron development commenced in 2012 with the initial construction of the GBS and continued into 2013 with the cutting of the first steel associated with topsides fabrication. First oil is planned for 2017 and the field will flow 150,000 to 180,000 bopd at its peak production.

3.2.4. Exploration Drilling. There were 154 exploration wells drilled offshore NL up to the end of August 2013. The wells are unevenly distributed geographically, with the majority situated in the Jeanne d'Arc Basin/Central Ridge area, where all large oil discoveries are located. Currently there are 6 exploration wells in the Saglek Basin (in NL waters), 21 in the Hopedale Basin (from which only 16 are significant wells), 7 in the West Orphan Basin, 3 in the East Orphan Basin, 9 in the Flemish Pass Basin, 4 in the Carson Basin, over 30 in the South Grand Banks' basins, 2 wells in Laurentian Basin, and 6 in Paleozoic Magdalen/Anticosti basins. An average of 2 exploration wells per year was drilled in the past decade, which is a low drilling pace for such an enormous prospective offshore area.

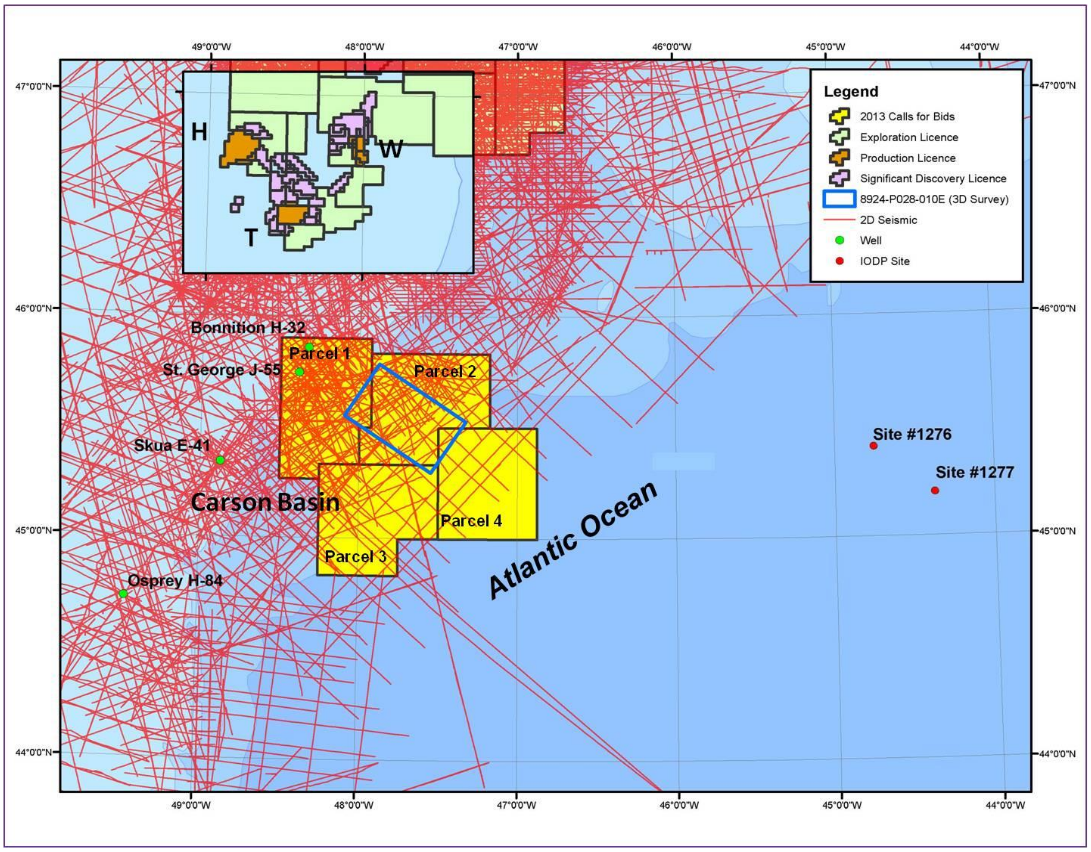


Figure 5. Location map of Call for Bids NL13-02 parcels, producing petroleum fields H = Hibernia, T = Terra Nova and W = White Rose, representative wells for the basin and selected seismic coverage in Carson Basin and environs (magenta lines). Blue rectangle represents a 3D survey collected by Petro-Canada in 2001.

While the Jeanne d'Arc Basin is still the focus of exploration and production in the NL offshore, an increasing number of important wells were drilled in the past years within the East Orphan/northern Flemish Pass basinal area. The most recent exploration wells were: a) Searcher C-87 spud in the Jeanne d'Arc Basin and abandoned by Husky Energy, b) Margaree A-49 located in East Orphan Basin spud by Statoil in EL 1074R and suspended, prior to Chevron to re-entering and drilling the main hole commencing on July 25 2013, c) Harpoon O-85 drilled by Statoil southeast of Mizzen O-16, d) Federation K-87 spud in June 2013 in the central Jeanne D'Arc and operated by Statoil and e) Bay du Nord C-78 also operated by Statoil. Harpoon O-85 and Bay du Nord C-78 were announced as light oil discoveries. The individual test results of these wells are confidential. The Bay du Nord discovery has been estimated as being 300 to 600 mmbbls by Statoil (65% interest) or 400 mmbbls recoverable by partner Husky (35%) (http://www.statoil.com/en/NewsAndMedia/News/2013/Pages/26Sep_exploration.aspx and respectively http://www.infomine.com/index/pr/PB360680.PDF).

Several other exploration wells may be drilled during 2013-2014 by Husky Oil and partners mainly in the Jeanne d'Arc Basin with several drill ready prospects identified (http://www.cnlopb.nl.ca/pdfs/hejdarc/eaupdaterev.pdf) and Statoil and partners in the Flemish Pass area (http://www.cnlopb.nl.ca/pdfs/nhdrill/ea2012update.pdf).

3.2.5. Seismic data. Over 690,000 km of 2D seismic lines and approximately 1.73 million CMP km of 3D data has been collected in the NL offshore area. The various vintage 2D seismic grids are uniformly distributed on the continental shelf and slope. There is less seismic coverage in the deep water and certain basins require more modern and higher resolution surveys. The Jeanne d'Arc and Flemish Pass basins are currently well covered by 3D seismic data. The 3D coverage is limited in the Laurentian, Carson and Orphan basins while other basins (e.g. Labrador basins, Sydney, Magdalen and Anticosti basins) have no 3D coverage. The only 3D survey in the Carson Basin was collected by Petro-Canada in 2001 and covers 1200 km^2 (Figure 5). More 3D data has been collected in 2012 in the North Grand Banks and Flemish Pass Basin, where large prospects and leads were previously identified with 2D grids. In 2012 Statoil Canada, along with partners Chevron and Repsol E&P Canada, concluded a 5,774 km^2 3D seismic program in the Flemish Pass Basin.

Also, during 2012 the MKI consortium, which includes TGS & PGS, in collaboration with Nalcor Energy, acquired 11,572 line kilometres of 2D seismic data on the Labrador continental shelf, slope and rise (e.g. Carter et al., 2013) and 7,957 line kilometres on Newfoundland's Northeast slope, which includes the Orphan, Flemish Pass and northern Jeanne d'Arc basins.

During the summer of 2013 several seismic surveys were conducted including a 3D/4D seismic monitoring survey at the Hibernia and Hebron fields and continuation of the modern, regional 2-D survey in the Labrador Sea and Northeast Grand Banks by the MKI consortium as well as GXT Technology acquiring 2-D data on the Labrador Shelf.

3.2.6. Potential Field Data. Regional, basin-wide and detailed gravity and magnetic data has been collected offshore NL by the GSC, NL Government and oil companies active in the area (e.g. Verhoef and Srivastava, 1989; Verhoef et al., 1996; Oakey and Dehler, 2004). Most of these surveys are now in the public domain. Of great value are potential field profiles recorded simultaneously with high resolution 2D reflection lines (e.g. GSI Labrador regional survey and the TGS/PGS/Nalcor 2011-13 multi-client survey). Satellite gravity data is also available from the National Oceanic and Atmospheric Administration (NOAA).

3.2.7. Other Petroleum Discoveries. Besides the four producing oil fields discussed above, there are 14 oil discoveries and 7 gas discoveries offshore NL, distributed as follows: one light oil discovery in the Paleozoic basins of Western Newfoundland (Garden Hill South that has a Production Lease since 2002 and partially renewed in 2012), 12 discoveries in the Jeanne d'Arc Basin (including Hebron, the largest, which is approved for development and Ballicatters, the most recent), 3 discoveries on the Central Ridge (South Tempest, Trave and North Dana), oil discoveries in the Flemish Pass Basin (Mizzen, Harpoon and Bay du Nord) and 5 gas discoveries in the Hopedale Basin (Snorri, Hopedale, North Bjarni, Bjarni and Gudrid) (Hawkins et al., 2008). Several of these discoveries are more than 30 years old. While several large gas discoveries were made, no gas development project is yet planned for the Grand Banks or offshore Labrador.

Little is known about the geoscience of the newest oil discoveries at Harpoon O-85 and Bay du Nord C-78. Two Statoil official communications characterize these discoveries as light oil, situated only 10, and 40 km respectively south of the Mizzen SDL awarded by C-NLOPB in 2011. A 300-600 mmbbls recoverable volume was given for the Bay du Nord oil discovery by Statoil (http://www.statoil.com/en/NewsAndMedia/News/2013/Pages/19Jun_Canada.aspx).

3.2.8. Production Licences. Currently there are 11 Production Licences awarded in the Mesozoic Jeanne d'Arc Basin to Hibernia (PLs 1001, 1005 and 1011), Terra Nova (PLs 1002, 1003 and 1004), White Rose (PLs 1006, 1007, 1009 and 1010) and North Amethyst (PL1008) oil fields. As mentioned previously, these fields produced 238,396 bopd during the first 8months of 2013. It is expected that the next major offshore project to obtain a Production Licence will be the Hebron oil field.

3.2.9 Exploration Licences. A total of 4,312,042 ha (43,120 km^2) are licensed by the C-NLOPB for offshore exploration in three areas: Grand Banks and vicinity, Labrador Sea and Western Newfoundland. As of the fall of 2013 there are 27 active ELs in the Grand Banks and vicinity distributed in 5 basins: 1 in the Sydney Basin, 7 in Laurentian Basin, 1 large consolidated EL in East Orphan Basin, 6 in the Flemish Pass Basin and 12 in the Jeanne d'Arc/Central Ridge (including the large consolidated EL 1090 R) (Figure 6). As a result of the 2012 Call for Bids when the company was the successful bidder in five parcels, Shell is the largest single exploration interest holder in this area with over 1.3 Million hectares. Six other companies, Husky, Statoil, Suncor, ConocoPhillips, Chevron and ExxonMobil, are operating ELs in the Grand Banks and vicinity.

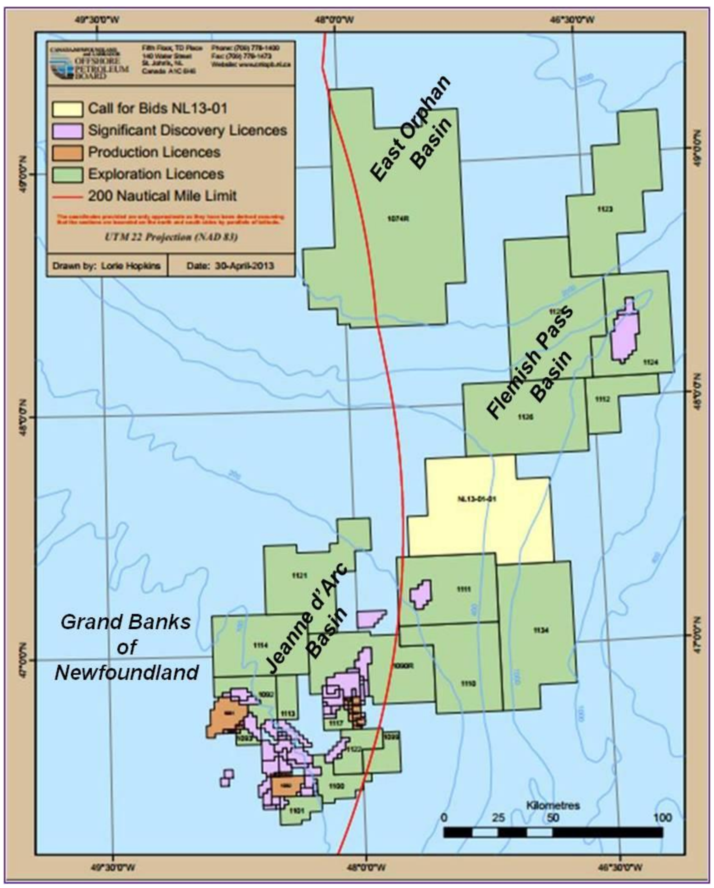


Figure 6. Current Exploration Licences (ELs), Significant Discovery Licences (SDLs) and Production Licences (PLs) in the Grand Banks and vicinity (after C-NLOPB).

In the Labrador Sea there are 4 large active ELs, totalling 939,678 ha (9,396.78 km^2). The four ELs located in the Hopedale Basin were awarded in 2008 and remain undrilled as of the summer of 2013. Husky, Chevron and Investcan are operators of these licences. Husky Oil and Gas is a leading player in both Grand Banks and Labrador Sea, with full or partial interest and operatorship in over 635,000 hectares.

Seven ELs are active in Western Newfoundland distributed in both the Anticosti and Magdalen basins. Up to recently, Ptarmigan Energy was the largest acreage holder with over 1,000,000 ha. A new entrant in the region, Black Spruce Energy has recently signed farm in agreements with Ptarmigan and Shoal Point Energy in the offshore and Enegi Oil PLc in the onshore becoming the dominant explorer for both conventional and unconventional resources in the area. The only other remaining operator, Corridor Resources operates EL 1105 in the Magdalen Basin containing the Old Harry structural prospect.

A strong indicator of the excellent exploration potential offshore Newfoundland is the high number of active Exploration Licences - 38, distributed in three areas covering eight basins. More than half of these ELs have to be drilled in the next few years to meet licensing requirements.

3.3. Carson Basin Drilling History. The shelfal part of the Carson Basin has undergone two early exploration cycles. The first one took place in the late 1960s to mid-1970s and was led by Amoco and Imperial who drilled the Osprey H-84 and Skua E-41wells (AMOCO, 1973; Figure 7). These dry wells were part of an unsuccessful drilling program in the Southern Grand Banks where Amoco drilled numerous Gulf of Mexico "look-alike" salt diapirs. In the same period, Mobil and its partner Gulf drilled Bonnition H-32 in the northern part of the basin, which was also a dry hole. This well, however, proved the existence of Late Jurassic formations in the Carson Basin (Figure 7).

The second cycle led by Canterra and Petro-Canada was in the early 1980s and ended with the drilling of St. George J-55, also a dry hole (Figure 7). By the late 1980s a large volume of seismic data had been accumulated. The four wells drilled on the shelf indicated that good reservoirs existed; however the wells were too shallow or had no access to a mature source kitchen.

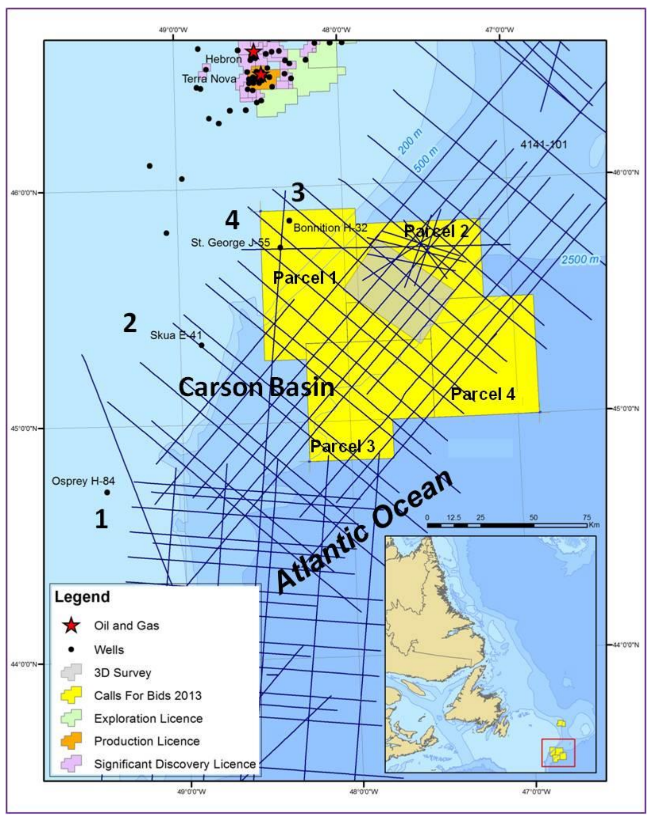


Figure 7. Location map of Call for Bids NL13-02 parcels, modern 2D regional seismic lines and 3D survey in public domain. Numbers indicate the order of exploration drilling in the Carson Basin.

During the 1960s to early 1990s, additional geoscience studies were performed by researchers from the GSC Atlantic (Bedford Institute). They produced several regional papers which included the shallower parts of the Carson Basin. The results were also entered into their comprehensive East Coast Atlas Series, Grand Banks of Newfoundland, published on the web between 1997 and 2004, updated in 2012 and available from GeoGratis.

Several American researchers from the Woods Hole Oceanographic Institution and the University of Texas at Austin have conducted a large 2D seismic reflection survey in the deeper parts of the basin and researched its poli-phase, nonvolcanic rifting. They concluded that extensional tectonics and salt diapirism control this part of the basin and named the area the Salar Basin (Austin et al., 1989; Tucholke et al., 1989).

3.4. Recent Exploration and Research Activity in Carson Basin. The most recent hydrocarbon exploration in the area took place during the late 1990s to early 2000s when the NL drilling focus moved to deeper water due to discoveries on the continental slope and rise in the Gulf of Mexico, West Africa and Brazil. Companies such as Petro-Canada (now Suncor) and partner PanCanadian (now EnCana) had two large exploration blocks (ELs 1056 and 1057) stretching into the Carson Basin's slope (ttp://www.cnlopb.nl.ca/pdfs/nl1302historic.pdf). New exclusive and multi-client 2D seismic surveys were acquired and a 3D survey was then recorded by Petro-Canada covering a few large structural prospects and leads. Regrettably, no exploration well was drilled prior to the licences' expiration as at the time (early-mid 2000s), commodity prices were low and the partners involved had better prospects in the Jeanne d'Arc Basin, Flemish Pass, Scotian Slope and elsewhere. The two ELs were released in 2006.

Since the early 2000's, the Carson Basin, had no active Call for Bids and no new seismic surveys were acquired resulting in no active Exploration Licences. However, the Canadian and International research community's interest in East Coast Newfoundland continued unabated. On the continental margin of Newfoundland studies focusing on the nature of crust in front of the Grand Banks and the timing of continental breakup between NL and Iberia have been produced by many international scientific organizations, marine institutes and universities.

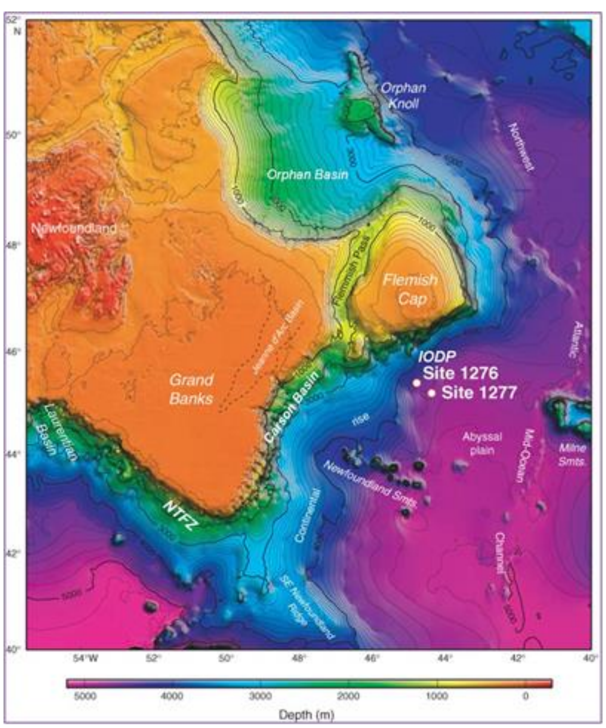


Figure 8. Bathymetry map of Grand Banks and environs including Carson Basin. The basin starts on the shelf (100 m water depth) and extends on the slope and rise (up to 4000 m water depth). The map shows the location of IODP Leg 210 drilling sites 1276 and 1277. Early Cretaceous black shales with high TOC and high HI were drilled at these locations together with intervals of coarse turbidite flows. NTFZ = Newfoundland Transform Fault Zone (map modified from IODP).

A special importance was given by the proponents and the group to pre, during and post- drilling investigations of the IODP Leg 210 located on the continental rise, south of Flemish Cap and northeast of Carson Basin (Figure 8). Due to lack of volcanics on the margins and abundance of geophysical and geological data, this area in particular and Newfoundland-Iberia transect in general have become a favourite ground for Atlantic-type conjugate margin studies.

During Leg 210 (2003) the International Ocean Drilling Project (IODP) drilled two sites south of Flemish Cap: site 1276 bottomed on transitional crust and site 1277 terminated on ultraslow emplaced oceanic crust (Tucholke, B.E., Sibuet, J.-C., and Klaus, A. (Eds.), 2007a; doi:10.2973/odp.proc.sr.210.2007). The two sites are situated just north of the Carson Basin (Figure 8). These continuous cored drill holes intersected Cretaceous organic shales (Late Albian to Turonian aged) and several thin turbidite reservoirs. The geoscientific findings of LEG 210 including discussions on the logged and cored source and reservoir rocks are detailed in the Scientific Results Proceedings (Tucholke, B.E., Sibuet, J.-C., and Klaus, A. (Eds.), 2007a, and individual chapters by Arnaboldi and Meyers, 2006; Hiscott, 2007; and Marsaglia et al., 2007).

Numerous other scientific papers were published after a new round of reflection seismic programs acquired in the region and integration of the IODP Leg 2010 results. These papers consider the NL history of rifting, dating of drilled geological formations, emplacement of transitional crust and reconstruction of the pre-breakup geological profile between the NL and Iberia conjugate margin. Several of the published papers discuss the crustal profile of the conjugate margins, models of multiphase rifting, the rotation of Flemish Cap, crustal hyperextension, transitional and oceanic crust development, non-volcanic margins and the asymmetry between the continental margin of Newfoundland and Iberia, (Funck et al., 2003; Hopper et al., 2004 and 2006; Tucholke et al., 2004 and 2007a and b; Enachescu et al., 2005; Shillington et al., 2006; Lau et al., 2006a and b; van Avendonk et al., 2006 and 2009; Robertson, 2007; Sibuet et al., 2007a and b and 2011; Karner et al., 2007; Manatschal et al., 2007; Peron-Pinvidic et al., 2007; Peron-Pinvidic and Manatschal, 2008; Reston, 2009; Peron-Pinvidic and Manatschal, 2009; Demeer et al., 2009; Welford et al., 2010 and 2012; Ady and Whittaker, 2012; Welsink and Tankard, 2012; Sibuet and Tucholke, 2012; Karner et al., 2012; GeoArctic, 2013; Sutra et al., 2013). The content of these papers has significant implications for the formation and geodynamic evolution of the Carson Basin.

Solvason in her doctoral thesis (2006) used seismic data collected during 2000 by SCREECH (Study of Continental Rifting and Extension on the Eastern Canadian shelf) and various other research and industry reflection and potential field data to identify detailed structural constitution of the Carson Basin. Her seismic mapping of the area has verified some of the previously identified fracture zones, confirmed a shelf edge basement ridge and described the structure of deeper Salar Basin (e.g. Enachescu, 1988 and 1992a and b; Tucholke et al., 1989; Solvason et al., 2005; Figure 3). According to her work, there is significant on strike structural variation along the eastern margin of the Grand Banks. Two shelf edge subbasins are described, denoted in her thesis as Carson (in the south) and Bonnition in the north, which exhibit a change in half graben polarity and are separated by a transfer fault and accommodation zone (Solvason, 2006).

Several large R&E projects were initiated and jointly administered by Nalcor and NL Department of Natural Resources through programs such as Petroleum Exploration Enhancement Program (PEEP) and Offshore Geoscience Data Program (OGDP). More details of these programs are given at http://www.nr.gov.nl.ca/nr/energy/index.html. The government of NL provided $20 million to fund the OGDP, including programs such as the offshore Newfoundland and Labrador Seep Mapping and new acquisition of regional reflection data on Labrador shelf, slope and rise and other deep water basins such as East and West Orphan and Flemish Pass. http://www.nalcorenergy.com/uploads/newsreleaseseismicsurvey13.09.11.pdf.

The regional oil seep mapping and interpretation study offshore NL was performed during 2010-2012 by Nalcor who contracted the GEO-Information division of Astrium Services on a non-exclusive basis (http://www.nr.gov.nl.ca/nr/publications/energy/nalcor_astrium_oil_seeps.pdf). This survey part of the OGDP program consisted of mapping and classifying offshore oil slicks based on satellite data from various providers. The method is a cost-effective, de-risking tool used to evaluate exploration potential for under-explored basins such as the Carson Basin and locating new dense 2D or 3D seismic grids. The data can be licensed by oil companies and is delivered as a "plug and go" GIS product (Enachescu, 2012)

A New Kinematic Plate Reconstruction of the North Atlantic between Ireland and Canada was recently carried out. This research project jointly funded by the Irish Shelf Petroleum Studies Group (ISPSG) and Nalcor Energy (on behalf of the Offshore Geoscience Data Program with the Government of Newfoundland) was performed by GeoArctic of Calgary during 2010-2012 (Ady et al., 2010; Whittaker et al., 2011; Ady and Whittaker, 2012;). The plate reconstruction project had academic and technical input from the universities, industry and government scientists from Canada and Ireland, France and Norway (http://napsaresearch.org/page/16).

The kinematic (deformable) plate reconstruction was focused on:

1) Evolution of the North Atlantic,
2) Formation of sedimentary basin on the Iberia, Newfoundland and Irish margins from Late Triassic to present time,
3) Investigation of depositional setting, and
4) Presence of petroleum systems in these extensional basins (Ady and Whittaker, 2012; Whittaker et al., 2011).

The GeoArctic modeling includes the Grand Banks/Iberia and Grand Banks/Western Ireland separation and through kinematic animation describes Grand Banks, Carson, Flemish Pass and Orphan basins formation. The final report of this study completed in 2013 is available to interested oil and gas companies who sponsored the research and as a licence to companies which want to know more about the basin geology and petroleum potential of NL offshore.

The most recent successful exploration activity offshore NL was sparked by Statoil and its partner Husky in the Flemish Pass Basin (Figures 6 and 8). The Mizzen oil field (discovered by Statoil in 2011) and the recent Harpoon and Bay du Nord oil discoveries (2013), located in intermediate water (around 1100 m) northeast of Call for Bids parcels, bode well for the possibility of encountering oil accumulations on the slope and deepwater of the Carson Basin. The Bay du Nord discovery was described as the largest light oil find in North America in the past five years.

4. Geological Overview of Mesozoic Atlantic Basins.

The North Atlantic continental margins are occupied by a complicated network of sedimentary basins, subbasins and troughs formed by extension during the breakup of Pangea and opening of the Atlantic Ocean during Late Triassic to mid-Cretaceous (AMOCO, 1973; Enachescu, 1987 and 1988; Grant, 1988; Tankard and Welsink 1987, 1988 and 1989; Ziegler, 1989; Sinclair, 1988 and 1993; Mackay and Tankard, 1990; Atkinson and Fagan, 2000; Sibuet et al., 2007; Withjack et al., 2012; Geo Arctic, 2013 and Figure 9). These basins and subbasins are today, either in continuity of structure or separated by Proterozoic basement highs, volcanic chains and sedimented ridges (Enachescu, 1992a and b; Edwards et al., 2000 and 2003; GSC, 2001). In their Mesozoic past, all the basins have been in communication at various stages during their geodynamic evolution as proven by the widespread presence of similar sedimentary deposits such as the Late Triassic salt, mid and Late Jurassic carbonate platforms, deposition of Late Jurassic source rocks and widespread distribution of cherty limestone beds, etc. Certain basins are now situated within the continental plate (e.g. Jeanne d'Arc Basin) while others occupy a divergent margin position and extend all the way to the continent-ocean boundary (e.g. Carson Basin). Basins such as the Laurentian, Carson, and Saglek were confined during rifting and became unconfined once the continental breakup took place (Enachescu, 2011 and 2012; Figure 9).

Newfoundland and Labrador's offshore basins underwent successive extensional episodes during the northerly propagation of the Tethys, Atlantic and Labrador rifting stages (Enachescu, 1987, 1988 and 1992a and b, Tankard and Welsink, 1987, 1989 and 2012, Grant et al., 1988; Grant and McAlpine, 1990; Dehler and Keen, 1993; Sinclair et al., 1992 and 1994; Driscoll et al., 1995; Atkinson and Fagan, 2000; Edwards et al, 2000 and 2003; Enachescu et al., 2012; Ady and Whittaker, 2012). Following each extensional stage, the basins were deepened and covered by a thick blanket of thermal subsidence sediments. After the final rifting stage in late Early Cretaceous a considerable sedimentary wedge of Late Cretaceous and Tertiary deposits covered the Grand Banks' basins including the Carson Basin (Enachescu, 1992a and b; Agrawal et al., 1995; Ainsworth et al., 2005; Solvason et al., 2005; Solvason, 2006). The deeper basins have preserved a working petroleum system, while several uplifted basins in the southern Grand Banks have lost their synrift reservoirs and source rocks through erosion or are too shallow for source rock maturation.

Structural inversion on the Canadian Atlantic margin has mostly affected the southern Grand Banks. Elsewhere on the margin inversion is minor and due mainly to transtension and change of direction of extension (Enachescu 1992a and b; Sinclair, 1993; Sinclair et al., 1994; Enachescu and Hogg, 2004). On the European margin the basins have been significantly inverted during the Alpine compressional pulses. No compressive events occurred in the Canadian basins after the Mesozoic rifting and drifting.

The geodynamic evolution of Newfoundland and Labrador's Mesozoic basins, their lithostratigraphic constitution, structural make-up and petroleum potential were previously discussed in numerous DNR reports and power points available on the web (http://www.nr.gov.nl.ca/nr/invest/energy.html#offshore). The following section contains a short review of the development of the Mesozoic basins on the Canadian Atlantic margin emphasizing the formation of the Carson Basin as a present day divergent margin basin.

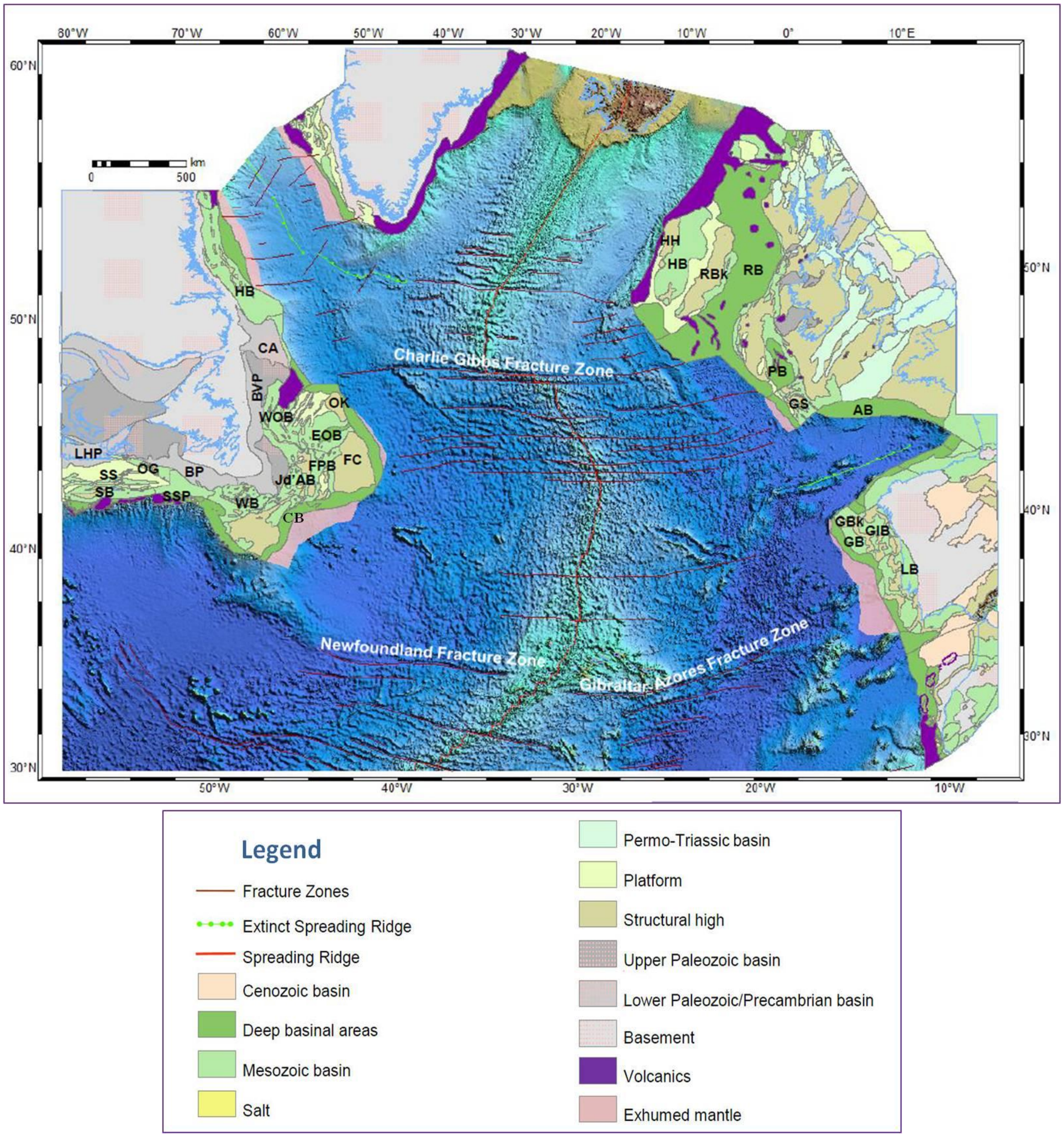


Figure 9. Regional tectonic and structural elements of the North Atlantic Ocean and its continental margins (after GeoArctic, 2013 courtesy of Ady and Whittacker). Notations are *in Canada's East Coast*: BP = Burin Platform, BVP = Bonavista Platform, CB = Carson Basin; CA = Cartwright Arch, EOB = East Orphan Basin, FC = Flemish Cap, FPB = Flemish Pass Basin, HB = Hopedale Basin, Jd'AB = Jeanne d'Arc Basin, LHP = La Have Platform, OG = Orpheus Graben, OK = Orphan Knoll, SB = Scotian Basin, SS = Scotian Shelf, SSP = Scotian Salt Province, WB = Whale Basin, WOB = West Orphan Basin; *in Ireland*: GB = Goban Spur, HB = Hutton Bank, HH = Hutton High, PB = Porcupine Basin, RB = Rockall Basin, RBk = Rockall Bank; *in Bay of Biscay*: AB = Amorican Basin; *in Iberia*: GB = Galicia Basin, GBk = Galicia Bank, GIB = Galicia Interior Basin, LB = Lusitania Basin.

The area occupied by the Grand Bank's basins, including the Carson Basin has seen two main continental rifting stages - Tethys and Atlantic - each followed by thermal subsidence. The network of basins and ridges was only mildly influenced by a third rifting stage - Labrador, which is more important for the North Grand Banks and Labrador Sea basins. The Atlantic rifting stage took place in a magma - poor setting and terminated with hyperextension, exhumation of continental mantle and ultimately, oceanic rifting. Repeated extensional episodes, salt tectonics and gravity detachments have created numerous large anticlinal structures and combination structural-stratigraphic features in which high quality sandstone reservoirs, sheltered from rift shoulders and intra-basinal highs are trapped and in places, hydrocarbon charged.

The following is a description of the three rifting stages affecting the Grand Banks' Mesozoic basins and their influence in the development of the Carson Basin (Figure 10).

A. Tethys Rift Stage. The rifting of Pangea during the Late Triassic-Early Jurassic created a multi-branched chain of intra-cratonic basins generally oriented NE-SW and extending from the Gulf of Mexico to the Barents Sea and occupying the opposite sides of the future American, African and European continents. The rift system was aborted in Early Jurassic north of Nova Scotia, but produced significant crustal thinning and resulted in the formation of numerous, linked sedimentary basins.

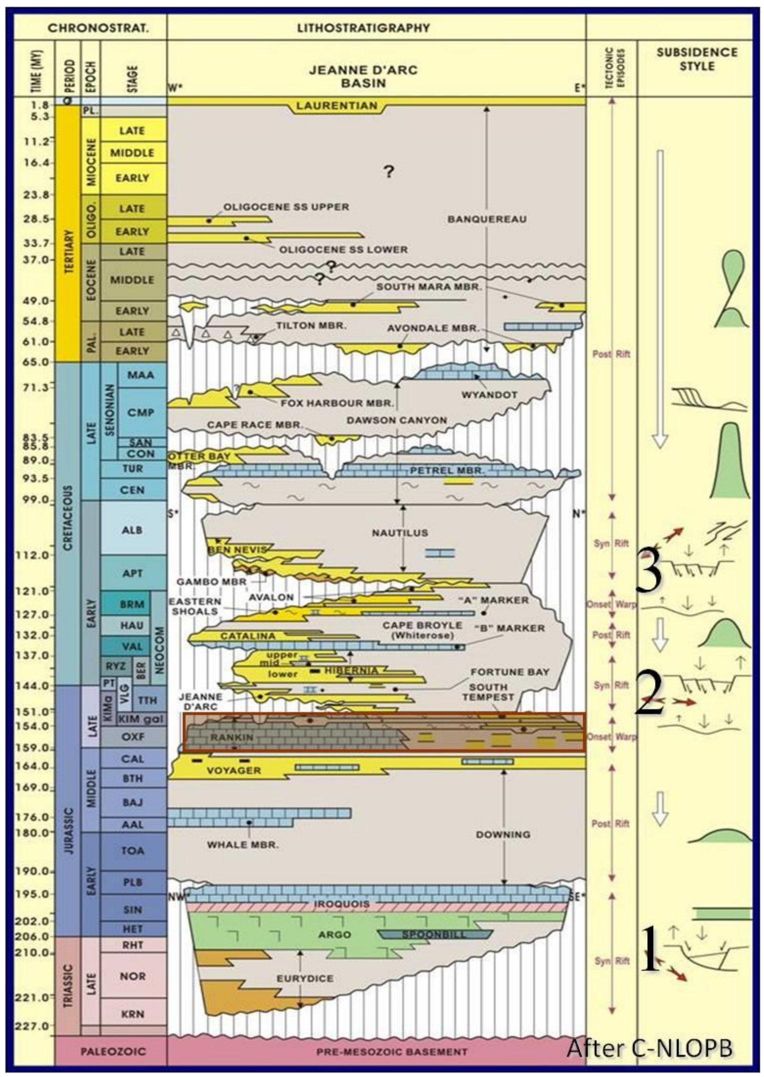


Figure 10. Litho-stratigraphy of the Jeanne d'Arc Basin and environs (after C-NLOPB, 2013 and Sinclair et al., 1995). The Carson Basin CFB area was affected by 3 stages of rifting: 1 = Tethys stage, 2 = North Atlantic stage and 3 = Labrador stage. Two stages of transtension and several stages of thermal subsidence culminating in Late Cretaceous-Tertiary with the final tilting and subsidence event also affected the area. The most important moment for the basins was the deposition of the high TOC, high Hydrogen Index marine source rock: the Egret Member of the Rankin Formation of Kimmeridgian age (c. 154 Ma). Several Oxfordian to Tithonian intervals may also be good source rocks. Albian to Cenomanian high TOC black shales were identified in ODP drilling, but these are yet unproven source rocks.

In Canada, the Tethys rift basin chain starts with the George's Bank Basin in the south, stretches through the Scotian Shelf and Slope basins and subbasins, continues with the Laurentian Basin, then reaches into the shallow water Grand Bank's basins and finally extends to the Flemish Pass and Orphan deeper water basins (Figure 11). A parallel branch has existed throughout the incipient Carson Basin and East Flemish Cap area and at that time was connected to several concomitantly formed basins, which are presently found on the Iberia Peninsula margin (e.g., Enachescu, 1987, 1988 and 1992a and b; Tankard and Welsink, 1987 and 1989; Srivastava et al., 1990a and b; Srivastava and Verhoef, 1992; Foster and Robinson, 1993; Enachescu et al., 2005 and 2010; Sibuet et al., 2007 and 2013; Fagan, 2010; Figures 9 and 11).

The early Mesozoic basin fill consists of continental and lacustrine deposits. After a marine incursion from the south and establishment of a shallow marine environment a significant amount of salt and carbonates were deposited in the basins. The presence of numerous Late Triassic-Early Jurassic salt features in the Carson Basin, similar to those identified in the Scotian Shelf and Slope and the Grand Banks' basins as well as in the conjugate Lusitania Basin, incontestably proves that the Carson Basin belongs to the Tethys rift system and had a similar evolution with its neighbouring basins (Scotian, Jeanne d'Arc, Flemish Pass basins, etc.).

South of the Newfoundland Transform Fault Zone (NTFZ), the Tethys rift stage terminates with emplacement of transitional crust followed in mid-Jurassic to Early Cretaceous by seafloor spreading and the opening of the North Atlantic Ocean between Nova Scotia and Morocco. The Laurentian Basin, located south of the NTFZ, is separated now from the southern Carson Basin by this continent/ocean transform zone and by the prominent Southeast Newfoundland Ridge of volcanic origin and several seamounts formed during Early Cretaceous.

The Tethys stage continental rifting was followed by postrift subsidence during which the Newfoundland basins and subbasins deepened and received significant amount of fine clastics. Carbonate platforms and deeper water carbonates were also formed in the basins (Figure 10).

B. Atlantic Rift Stage. A new rifting stage started in Late Jurassic and lasted through Early Cretaceous. This rifting stage enlarged the basin and produced new faults oblique to the initial faulting trend. The two intersecting fault systems caused the formation of numerous fault dependent traps throughout the Grand Banks' basins. Concomitantly salt diapirism and halotectonics created a large number of complex anticlinal features. Although several hyper-extended sectors were formed, at the end of the Atlantic extensional stage, the continental rifting was aborted for a second time in the central Grand Banks area.

The primary source rock of the Grand Banks, the Egret Member of the Rankin Formation, as well as intervals of Tithonian source rocks were deposited during this rift stage (Figure 10). The coarse clastics of the Jeanne d'Arc and Hibernia formations were deposited in alluvial, deltaic and shore line settings. Sandstones belonging to these formations are the best producible reservoirs in certain of the major oil fields on the Grand Banks. During this stage there was continuous movement on the NTFZ causing the southern side of the Grand Banks to start to uplift (Avalon Uplift).

A new thermal subsidence stage followed on the Grand Banks proper. Basin-wide limestone beds were deposited during this stage forming important seismic markers for regional mapping. However, crustal stretching and thinning continued on the easterly parallel rift trend where continental breakup between North America and Europe occurred. At the end of this rift stage, the Carson and Lusitania basins were separated by the emplacement of transitional crust.

The deep distal continental margins and the adjacent transitional zones in front of the Grand Banks referred to as the Newfoundland-Iberia rift system, were formed by ultraslow extension from early Berriasian to late Valanginian - early Hauterivian and by slow extension from early Hauterivian to the late Aptian - early Albian boundary (Sibuet et al., 2007). At the end of this episode the final break-up between Newfoundland and Iberia started (Figure 11).

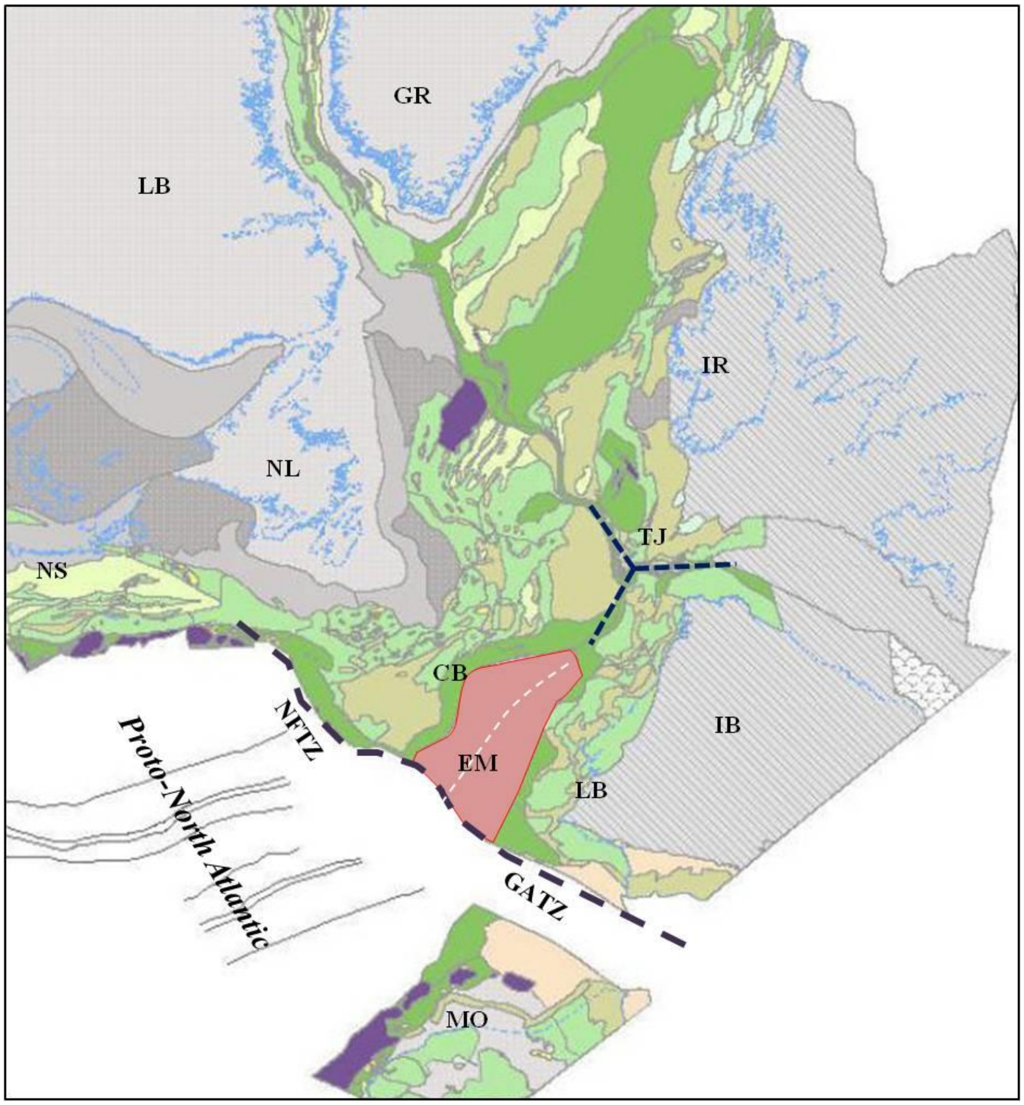


Figure 11. North Atlantic plate margins reconstruction at 136 Ma (Hauterivian) showing the end of the mantle exhumation stage and the beginning of seafloor spreading between Iberia and Newfoundland (modified after GeoArctic, 2013). Notations are: NS = Nova Scotia, MO = Morocco, NL = Newfoundland, IB = Iberia, LB = Labrador, IR = Ireland, GR =Greenland, NTFZ = Newfoundland Transform Fault Zone, GATZ = Gibraltar-Azores Transform Zone, CB = Carson Basin, EM = Exhumed Mantle and TJ is Triple Junction between Grand Banks/Iberia/Ireland. Colors legend is as in Figure 9.

C. Labrador Rift Stage. The third rift stage affecting the North Atlantic during late Early Cretaceous to mid-Cretaceous has strongly influenced the Orphan Basin and Labrador Sea basins but had a weak influence in the Grand Banks/Carson Basin. At the end of this rifting stage, the Flemish Cap separated from the Galicia Bank, the East Orphan Basin from the Porcupine Basin, the West Orphan Basin from the Rockall Trough and finally the Labrador Sea opened (Enachescu et al., 2005, Sibuet et al., 2007; Ady and Whittaker, 2012; GeoArctic, 2013).

In the Carson Basin, block rotation and fragmentation continued and crustal thinning became intense. Exhumed mantle was emplaced in the eastern (Salar) part of the basin (Figures 3, 11, 12 and 13). Several crustal sectors segmented by transfer faults were formed between the Newfoundland and Iberia margins and the crustal breakup and ocean floor spreading between Newfoundland and Iberia, took place in Albo-Aptian in three main steps propagating from south to north (Sibuet et al., 2007; GeoArctic, 2013).

During this stage the important Avalon and Ben Nevis sandstone or equivalent reservoirs were deposited (Figure 10), having their provenance from the rift shoulders or intra-basinal ridges (Hiscott et al., 1990a and b). Medium to fine recycled sandstones from the erosion and re-deposition of older sandstone reservoirs were encountered in the Jeanne d'Arc Basin (Harding 1988; Dearin, 2007).

Basin margin and basin floor sedimentary fans were also deposited throughout Newfoundland's offshore basins. Invaded by the newly formed sector of the North Atlantic, the deeper parts of Carson Basin started receiving lowstand sediments that might include sandstone turbidites. To the north, in the Labrador Sea, continental rifting started with volcanics and vulcanoclastics and continued in an alluvial-lacustrine setting where excellent reservoirs (Bjarni sandstone) and source rock (Bjarni shale) were deposited (Enachescu, 2008; Carter et al, 2013).

Cenomanian to Turonian aged organic shales were encountered in IODP Leg 2010 at both the 1276 and 1277 drilling locations, just northeast of the Carson Basin, (Arnaboldi and Mayers, 2007; Mayers and Arnaboldi, 2011; Figures 3, 12 and 13). It is expected that these high TOC, black shales will also be found in the Carson Basin and they will be mature in deeper depocenters. Also during ODP Leg 2010, several coarse sediments intervals were described as being basin floor turbidites (Marsaglia et al., 2004 and 2007; Hiscott, 2007; Hiscott et al., 2008).

According to geophysical mapping, some of Newfoundland and Labrador's individual offshore basin boundaries are loosely defined (Enachescu, 1987; Grant, 1988; Grant et al., 1988; Edwards et al., 2000 and 2003; GSC, 2001). Major faults and ridges often bound the basin, but continuity of structure and deposition is also observed between adjacent basins. This is especially true for several pairs of basins located on the shelf, slope and deepwater and such is the case with the Carson Basin.

5. Overview of Regional Geology of the Carson Basin

The Carson Basin is a complex basinal area located on the eastern divergent margin of the Grand Banks and extending from the continental shelf to water depths in the 4000 m range (Enachescu, 1987 and 1992a and b; Tucholke et al., 1989; Austin et al., 1989; Keen et al., 1990; Keen and Williams, 1990; Figures 2, 3 and 8). This approximately 30,000 km^2 large basin is a Mesozoic extensional area developed over stretched Precambrian and Paleozoic basement and now found on the continental shelf, slope and rise of Newfoundland (Grant et al., 1988; Enachescu, 1988 and 1992a and b; Solvason, 2006).

The structurally composite Carson Basin is located (see Figures 3 and 13):

a) on the continental shelf where it is known as the Carson or the Carson-Bonnition Basin (Enachescu, 1987 and 1992a and b; Grant et al., 1988; Solvason, 2006),
b) on the slope where it is known as the Salar Basin or Deepwater Carson Basin (Tucholke et al., 1989; Enachescu, 1992a and b), and
c) on the rise and abyssal plain where Mesozoic rocks overlie super-extended continental and transitional crust (Austin et al., 1989; Tucholke et al., 1989; Enachescu, 1992a and b; Solvason, 2006; Sibuet et al., 2007).

For the purpose of simplicity in this report, we elected to use the "Carson Basin" nomenclature for the entire shelf, slope and deepwater Mesozoic area located east of, and in front of the Grand Banks (Figures 12 and 13; see also Chapter 2 this report).

The Late Triassic to Early Jurassic rifting of Pangea created a chain of NE-SW oriented intracratonic basins extending from the Gulf of Mexico to the Barents Sea. The Carson and Lusitanian basins were joined and aligned parallel to the main NE-SW Mesozoic rift trend (that included the Jeanne d'Arc and the Flemish Pass basins) (Enachescu, 1987 and 1992a). The Carson Basin was a connected lateral of the main rift branch. In the late Early Cretaceous the basin detached from its Iberia pair and drifted northwestward during the North Atlantic Ocean opening. Unlike its Iberia conjugate basins, the Carson Basin was subsequently not affected by the Alpine inversion that influenced the late evolution of most of the European offshore basins.

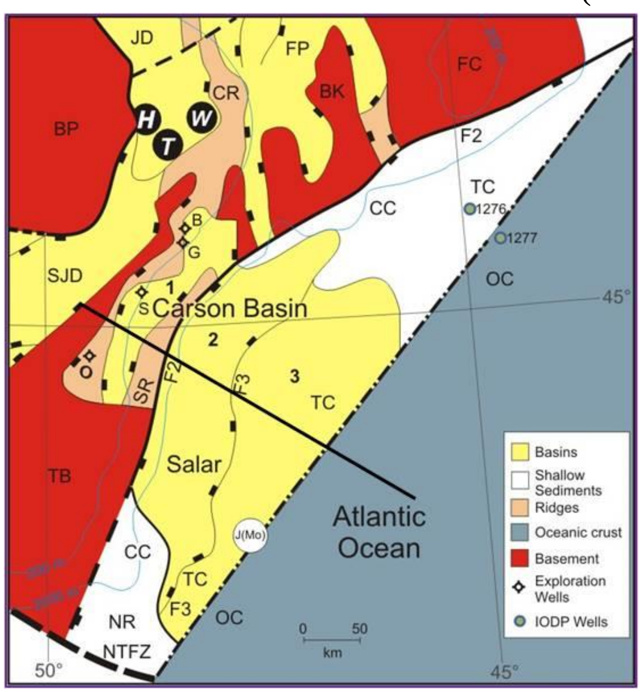


Figure 12. Tectono-structural map of the Carson Basin, indicating its three subdivisions: 1) on shelf sector, 2) slope and upper rise sector, and 3) lower rise sector. F 2 and F3 are major fault zones. The black line indicates the position of the representative geological cross-section shown in Figure.13. Other notations are described in Figure 3 (after Enachescu, 1988 and 1992a and b).

Currently the Carson Basin represents the eastern arm of the intra-cratonic network of rift basins (Enachescu 1987, 1988 and 1992a and b; Figure 9) that was initially developed on the Canadian margin during Late Triassic-Early Jurassic. The basin shared a common tectonic, structural and stratigraphic evolution from Late Triassic to late Early Cretaceous with several of the Grand Banks' basins including the oil prolific Jeanne d'Arc and Flemish Pass basins.

The area was situated on a future divergent margin and underwent extension, transtension and subsidence within a continental depression situated between the Grand Banks of Newfoundland and the Iberia Peninsula (Enachescu 1987 and 1992a and b; Grant et al., 1988; Pinheiro et al. 1996; Péron-Pinvidic et al., 2007; Sibuet et al., 2007; Deemer et al., 2009). The geological evolution of the Carson Basin was largely characterized by repeated intra-continental Mesozoic rift stages, intermediary postrift episodes, oceanic rifting and drifting and final post-rift thermal sag (see Chapter 4). Based on regional drilling and seismic mapping on the Newfoundland margin, it is assumed that the Carson Basin generally accumulated much of the same sedimentary successions that filled the Jeanne d'Arc Basin (Figure 10).

The basin's fill includes Late Triassic to Mid Jurassic red beds, salt, limestone and dolomites, followed by Late Jurassic to mid-Cretaceous predominately clastic sequences. A mostly shaley sequence which includes several basin slope and floor sandstone intervals characterizes the Late Cretaceous to Quaternary cover (Grant et al., 1988; McAlpine, 1989 and 1990; Deptuk et al., 2003). These formations were encountered in the four wells drilled on the shelf of the Carson Basin (Figures 3 and 7). The lithostratigraphy displayed by the C-NLOPB on its website that is characteristic for the Jeanne d'Arc Basin and environs can be cautiously applied to the Carson Basin (Beaudreau et al., 1986; Grant et al., 1988; Tankard et al., 1989; McAlpine, 1990; Hiscott et al., 1990; Enachescu, 1992a and b; Sinclair et al., 1995; C-NLOPB, 2013). A "South Grand Banks Lithostratigraphy" after McAlpine (1990) and orogenic events after Sinclair et al. (1995) is provided by the C-NLOPB with this Call for Bids (http://www.cnlopb.nl.ca/maps/sgblith.pdf). This blended chart includes Cretaceous lithostratigraphic nomenclature extended from the Scotian Shelf and Slope Basin into the Carson Basin. In this report we have opted to apply the Jeanne d'Arc Basin lithostratigraphic nomenclature in Figure 10 using the qualifier "equivalent" for corresponding chronostratigraphic formations and members encountered during the scarce drilling in the basin (see also http://www.cnlopb.nl.ca/well_alpha.shtml). This is done in order to stress the relationship of the Carson Basin to the network of basins on the Grand Banks.

During the Late Triassic - Early Jurassic, the Carson Basin area was first an intra-continental rift valley with red beds (Carnian to Rhetian Eurydice Formation) filling the newly created, fault bounded depressions (Grant et al., 1988; McAlpine, 1990). This setting was followed by an internal shallow sea phase interspersed with continental episodes when thick evaporite beds were deposited (Rhetian to Early Hettangian Osprey and late Hettangian to early Sinemurian Argo formations). At the Osprey H-84 location, the evaporites are dominated by halite with zones of reddish shale, dolomite, mudstone and siltstone. Several subaerial basalt flows are logged between the Argo and Osprey formations and the package provides a strong seismic marker. The Argo Formation is overlain conformably by the Iroquois Formation consisting of evaporite and dolomite units ranging in age from late Sinemurian to Toarcian. Carbonate deposition resulted from an Early Jurassic transgression and the contact between the carbonates and the evaporites is sharp (Jansa et al., 1980).

A much deeper sea occupied the area in mid to Late Jurassic when thick shale and carbonate formations were deposited (Pliensbachian to early Tithonian Downing Formation containing the Whale Member). The younger Voyager Formation (late Bathonian to early Oxfordian) is represented by interbedded sandstone, shale and limestone beds. This unit is followed by a predominantly limestone formation (Rankin Formation) that might contain interbedded sandstones and is of Early Oxfordian to Early Tithonian age. Toward the top of the Rankin Formation lies the Egret Member, a marine mudstone with high organic content which is the principal source rock of the oil discoveries in the Jeanne d'Arc Basin (Sinclair et al., 1992; Fowler and McAlpine, 1995; Magoon et al., 2005; Enachescu et al., 2010).

The Rankin Formation is capped by a major unconformity known as the Tithonian or Mid-Kimmeridgian Unconformity, above which the shallow marine clastics of the Jeanne d'Arc Formation are deposited including excellent sandstone reservoirs. The coarse to fine clastic sediments of the Hibernia, Whiterose and Avalon formations overlie the Jeanne d'Arc sandstone. These formations contain excellent reservoir sandstone separated by marine shale and mildly diachronous limestone units (Tankard and Welsink, 1989; Brown et al., 1989; McAlpine, 1990; Hiscott et al. 1990; Sinclair et al., 1992; Hurley et al., 1992; Driscoll and Hogg, 1995; Atkinson and Fagan, 2000; Noseworthy, 2003; Dearin, 2007).

A margin-wide, major Barremian to Aptian Unconformity separates the Avalon Formation from the overlying Nautilus Formation. At its base this formation contains the Ben Nevis equivalent sandstones (Harding, 1988; Dearin, 2007). The Nautilus Formation is capped by another major erosional surface, the Cenomanian Unconformity. Above this unconformity lies the transgressive Dawson Canyon Formation deposited during the entire Late Cretaceous and containing mostly shales. A basin-wide, pelagic Turonian limestone interval - the Petrel Limestone Member - divides the formation into lower and upper units. The Dawson Canyon Formation also contains several basin margin sandstones (e.g. Otter Bay and Fox Harbour members) marked by basin prograding clinoforms. These and their lowstand equivalents may be present in the Carson Basin. Diachronous pelagic chalk beds collectively known as the Wyandot Member (McAlpine, 1990; Sinclair, 1992) or Formation (Deptuk, 2003) were deposited during Late Senonian and are present in some parts of the Grand Banks area.

The base of the Tertiary (Paleocene)-end of Cretaceous is marked by a major unconformity that in places is canyonized (Enachescu, 1987 and 1992a and b; Solvason, 2006). On the basin margins, ridges and salt highs, the major and minor unconformities often coalesce. The strongest seismic amplitude unconformity on the Newfoundland margin is the ubiquitous Base Tertiary Unconformity. Coarse-grained Avondale and South Mara members are Paleocene and earliest Eocene submarine fans deposited on the basin floor, just above the Base Tertiary Unconformity. Lowstand equivalents of these members may be present on the Carson Basin's slope and rise.

The Banquereau Formation was deposited during Eocene time to the present and mainly contains deepwater shales, minor chalks and mudstones. Several Oligocene sandstone layers have been encountered on the Grand Banks that might also have corresponding turbidite mounds or basin floor fans in deepwater (Deptuk et al., 2003). Several disconformities are also present within the Banquereau Formation, which are more evident on the Grand Banks slope. A veneer of Quaternary, mostly glacial clastic deposits forms the basins' sea floor (the Laurentian unit). The seafloor is usually a "hard bottom" horizon that creates seismic multiples in shallow water.

During much of the Mesozoic, the Carson Basin was attached to its sister conjugate - the Lusitania Basin, now on the Iberian continental margin (Enachescu 1987 and 1992a and b; Pena dos Reis and Pimentel). After the continental crust thinned considerably and transitional crust was emplaced to the east, the final rift episode became oceanic during the late Early Cretaceous (Aptian-Albian). Subsequently, true oceanic rifting occurred and the Grand Banks and Iberia drifted apart (Tucholke, et al. (Eds.), 2007; Sibuet et al., 2007a and 2013; GeoArctic, 2013.

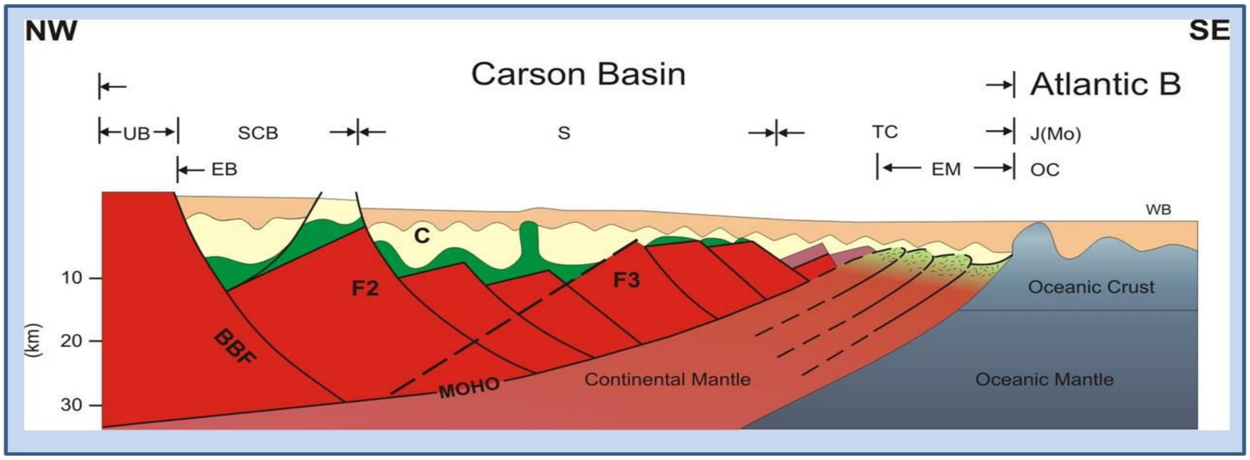


Figure 13. Schematic geological cross-section of the Carson Basin with subdivisions 1) SCB = on shelf Carson Basin sector, 2) C = Carson slope and upper rise sector and 3) lower rise sector part of S = Salar Basin (not at scale). Salt is represented in green. BBF = basin bounding fault; F 2 and F3 are major fault zone. Other notations are: UB = un-extended basement, EB = extended basement (continental crust), TC = transitional crust and EM = exhumed mantle (modified after Enachescu, 1992a and b).

Currently, the Carson Basin is separated from the Jeanne d'Arc Basin by the Morgiana Anticlinorium, from the South Jeanne d'Arc Basin by a basement ridge, and from the Flemish Pass Basin by a series of basement highs and narrow sedimentary troughs (Enachescu 1987, 1988 and 1992a and b). To the east the basin extends over the Transitional Crust and arguably spreads out to the J(M_0) magnetic anomaly lineament (Austin et al., 1989; Tucholke et al., 1989; Enachescu, 1992a and b; Srivastava et al., 2000; Sibuet et al., 2007a and b). Despite numerous published studies and regional interpretations, the principal crustal boundaries such as Continental crust to Transitional crust (CC/TC) and Transitional crust to Oceanic crust (TC/OC) remain hard to pinpoint from one seismic profile to another. In the south, the Carson Basin is limited by the South Newfoundland Ridge that contains a chain of magmatic seamounts along the Newfoundland Transform Fracture Zone (Figures 3, 9, and 13).

All major basement penetrating faults within the Carson Basin generally trend northeast-southwest and terminate towards the northern part of the basin (e.g. F2 and F3 faults). In the northern part of the basin a series of north-south oriented faults take over segmented basement blocks that belong to the Flemish Pass Basin and a series of younger grabens (Enachescu 1987 and 1992a and b; Austin et al., 1987; Solvason et al., 2005; Solvason, 2006; Figure 3 and 13). In the south, these synrift faults terminate on the Newfoundland Ridge which is younger (Cretaceous) and of volcanic origin. The great majority of faults are down-to-basin, listric normal faults, but some transfer faults and antithetic faults are observed.

A basement ridge with localized salt cover separates the on-shelf basin from the slope and deepwater parts of the basin (Enachescu, 1992a and b; Solvason, 2006). This area was previously known as the on-shelf Carson Basin. The on-shelf basin is separated from the Jeanne d'Arc Basin by a basement ridge and the Morgiana Anticlinorium (Enachescu, 1988 and 1992a and b). A major down-to-margin fault marks the basin's northwestern boundary (Figure 3 and 13).

The shelf area can be divided into a northern and a southern half graben, separated by a transfer zone (Enachescu, 1992a and b; Solvason, 2006). The northern area contains thicker Mesozoic fill, including salt, while the southern area has suffered pronounced erosion during mid-Late Cretaceous. This northern area together with the slope/deepwater area are more likely to contain mature Late Jurassic source rocks.

The slope and deepwater area contains numerous fault blocks rotated mainly down to basin and rarely down to shore. Several horsts are also observed on seismic reflection lines. The Early Cretaceous sediments including sandstone reservoirs are generally preserved to the north and eroded towards the south. The deepwater sedimentary sequences are thicker and include Triassic salt and thick Jurassic to Cretaceous successions.

Basin fill deformation is due to extension, salt movement and detachment sliding. Inversion was a late-stage event in the region and is only a secondary mechanism for trap formation. Late Triassic to Early Jurassic Argo salt forms ridges, diapirs and complex bodies. Diapiric salt is more widespread on the slope and in the deepwater. In the deepwater, the seismic and potential field data show a southeast trending, en echelon ridge and fault system interrupted by salt diapirs and volcanic mounds.

Coarse clastics sourced from the Precambrian basement terrains surrounding the basin should be present within deltaic episodes during the Late Jurassic to Early Cretaceous. Under the slope, the prerift section drops off significantly within salt induced minibasins. Large and complex Mesozoic structural and stratigraphic features are observed in the seismic data collected on the slope and upper rise. A number of these structures are salt cored.

Based on numerous studies using seismic interpretation, potential field mapping and drilling results, the basin is thought to be located on a hyperextended continental crust, was affected by salt tectonism and had minor volcanic influences. Besides some common compositional features, the Carson - Lusitania conjugate pair has many crustal, synrift structural and stratigraphic differences. This conjugate margin basin pair and the entire Newfoundland-Iberia sector of the N Atlantic have been classified as asymmetric by many authors (Tankard and Welsink, 1987; Enachescu, 1987 and 1992a and b; Keen et al., 1987; Solvason, 2006; Sibuet et al., 2007; Karner et al., 2012). The Iberian margin has a narrow continental shelf as opposed to the very large platform exhibited on the Newfoundland margin that continues with a broad slope and deepwater Mesozoic area in the Carson Basin. More importantly, a proven hydrocarbon system that produced large oil accumulations characterizes the Newfoundland continental margin and this should encourage the search for large oil fields in the Carson Basin.

6. Petroleum Geology of the Carson Basin

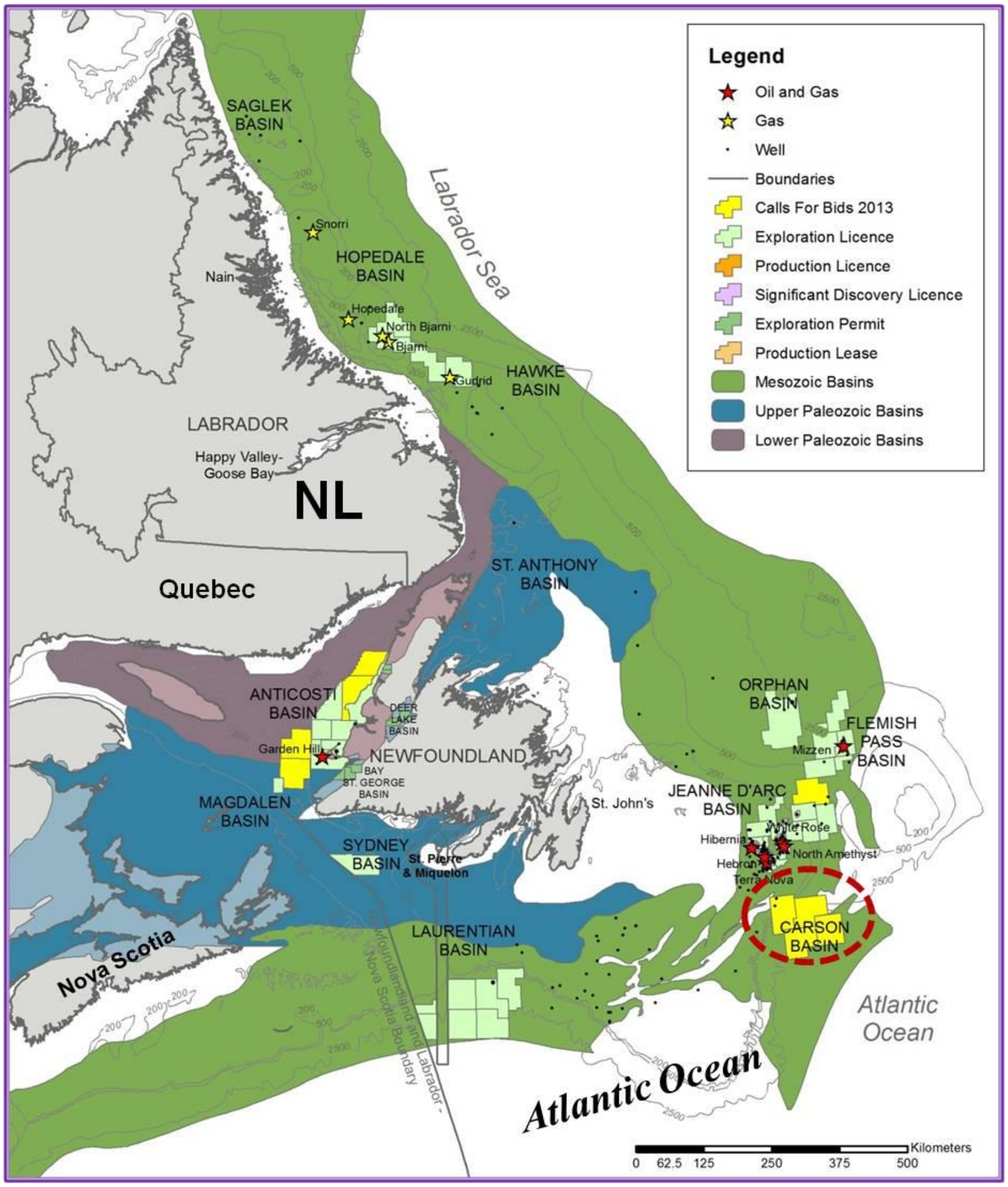


Figure 14. Atlantic Canada offshore basin map (modified after NL DNR). Mesozoic basins are depicted in green, Paleozoic basins are shown in dark blue and dark purple. Inter-basin boundaries are loosely defined in this regional map. Red stars show major producing fields and an undeveloped oil discovery in the Flemish Pass Basin. Encircled yellow blocks in the Carson Basin are the 2013 NL Call for Bids parcels 1 to 4. Observation: configuration of deep Labrador basins is after Enachescu, 2007 and 2011; new Labrador Sea basin configuration based on 2011-2012 seismic data is available on request from NALCOR and PGS (e.g. http://www.geoexpro.com/article/Beneath_the_Labrador_Sea/2e44e682.aspx).

An integral part of the network of Late Triassic-Early Jurassic chain of basins stretching across Pangea from Nova Scotia to the Norwegian Sea, the Carson Basin had a common tectono-stratigraphic evolution as other North Atlantic petroliferous basins (e.g. the adjacent Jeanne d'Arc Basin and Flemish Pass Basin). In offshore Newfoundland and Labrador, the Mesozoic basin chain starts with the Laurentian Basin in the south and ends with the Saglek Basin in the north (Figure 14).

Only four exploration wells were drilled in the 1970's and 1980's within the shallower portion of the basin (Figure 7). These abandoned wells found good potential reservoir zones but did not intersect the Kimmeridgian Egret Member source rock, probably due to wells being positioned on basement highs or salt diapirs (Enachescu, 1988 and 1992a, 2006 and 2010; Grant et al., 1988; McAlpine, 1990; Louden, 2002; Wielens et al., 2004; Solvason, 2006; Baur et al., 2009).

6.1. Source Rocks. The most significant source rock in the basin is almost certainly to be the Egret Member of the Rankin Formation of Kimmeridgian age or its equivalent. This unit is the prolific source rock that sourced all the discoveries of the Jeanne d'Arc Basin. The Egret source rock is an oil prone, marine-derived Type II carbonaceous shale with up to 9% (average 4.5%) Total Organic Carbon (TOC). Over 25 exploration wells have penetrated the Egret Member source in the Grand Banks and environs (Powell, 1985; Creaney and Allison, 1987; von der Dick, 1989; Fowler et al., 1990; Williamson, 1992; Taylor et al., 1992; Fowler and McAlpine, 1995; Huang et al., 1994 and 1996; Bateman, 1995; Williamson et al., 1996; Desilva, 1999; McCracken et al., 2000; Fowler and Obermajer, 2001; Magoon et al., 2005; Wielens et al., 2004 and 2006; Enachescu et al., 2010). The Kimmeridgian Egret shale, deposited in a semi-silled epeiric basin, is the best marine source rock within the North American Atlantic rift system.

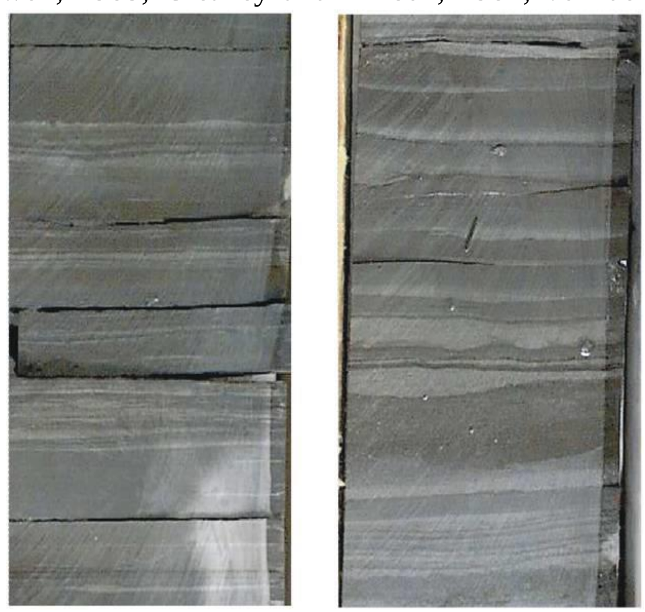


Figure 15. Kimmeridgian source rock (Egret Member of the Rankin Formation) cored in Baccalieu I-78 well, north of the Carson Basin. The cored interval is comprised of black shales and mudstones (photo provided by J. McCracken).

Several wells in the Flemish Pass-Central Ridge area have also encountered Egret sections containing Type I-II kerogen. Other source rock intervals have been identified in the Tithonian and Oxfordian shale formations. It was suggested that the Mizzen O-16 heavy oil (22° API) in the northern Flemish Pass Basin was sourced from an immature to marginally mature source rock. The Mizzen oil is considered to be partially sourced from an immature to marginally mature source rock, within the Tithonian sequence. The marine shales that separate the Tithonian reservoirs in the Mizzen oil field have 8 - 12% TOC (Haynes et al., 2012). An earlier well on the structure, Mizzen L-11 drilled in 2003 encountered 5 m pay of light oil. Noteworthy, the Harpoon and Bay du Nord oil finds have been announced as being contained in Jurassic reservoirs and it is presumed that they were generated by a Late Jurassic source rock.

According to Fowler et al. (2007), samples of oil from Mizzen L-11 show some characteristics similar to the Egret Member sourced oils from the Jeanne d'Arc Basin but there are also some differences. Fowler et al. (2007) conclude that: "These could reflect changes in the Egret Member organic facies in moving into the Flemish Pass or the mixing of hydrocarbons from multiple sources as suggested above explaining the variations in thermal maturity indicated by different classes of compounds". This may also be the case with the Late Jurassic source rocks potentially present in the Carson Basin's hydrocarbon kitchens.

Since no well in the Carson Basin has intersected the Egret Member, its presence and distribution in the basin must be inferred from the seismic data. The Top of the Rankin Formation or the Tithonian Unconformity seismic marker can be easily identified in the Jeanne d'Arc Basin's wells and from there correlated into the Carson Basin. Solvason (2006) has mapped three individual possible kitchens for the Egret Member: two of them situated on the shelf and upper slope (her "Carson and Bonnition basins") and the largest one found on the lower slope and rise in front of the Salar Ridge (her "Salar Basin" southeast of SR on Figure 3 and 13).

In a Geological Survey of Canada study, Wielens et al. (2002, 2004 and 2006) have considered that an Egret Member or an Egret equivalent source rock distributed on the slope and in the deepwater basin and having 4% average TOC, 600 Hydrogen Index (HI) and a thickness of 50 m could have generated 200 billion barrels of oil equivalent (GSC Open File 4739). Their model assumes a closed, non-breached system, which is highly unlikely to exist in the faulted and salt intruded, late synrift and postrift sequences of the basin. However a material volume of hydrocarbons may have been preserved and is now accumulated in sandstone reservoirs within structural traps located in deeper water. This is the most coveted hydrocarbon play in the basin.

A numerical 4D basin model for the frontier Carson Basin was produced by Baur et al. (2009) to provide a fast and inexpensive resource assessment. They used a Type II kerogen with a homogenous TOC of 4% and a Hydrogen Index of 60 in the model. The modeling showed that significant volumes of hydrocarbons could have been generated, from an "Egret equivalent" source rock mainly during the Late Cretaceous-Early Tertiary (also Wielens et al., 2006). Due to migration inefficiencies (seeps, alteration, etc.) the volume of oil that will be trapped is reduced to about 10%, meaning that about 5 Bbbls could be present in the reservoirs of the Carson Basin (Baur et al., 2009).

Another possible source rock is the Turonian to Albian black shale intervals drilled by IODP during Leg 210 at sites #1276 and #1277 (Arnaboldi and Mayers, 2007). These sites were located 60 km northeast of the Carson Basin. This fine grained succession is stratigraphically equivalent to the Hatteras Formation described at multiple drill sites in the western North Atlantic and with the Nautilus Formation drilled in the Grand Banks' basins (Tucholke et al., 2004; Arnaboldi and Meyers, 2007). Five dark-colored intervals that contain up to 13% TOC of both marine and terrestrial provenance were identified in the Site #1276 sequence (Mayers and Arnaboldi, 2011). The portions of this interval that had high HI in places may be thicker and mature in the deeper sedimentary troughs of the Carson Basin such as those indicated in the Cretaceous maps made by Solvason (2006) and seen on seismic sections presented in this report.

The Carson Basin has experienced an early marine incursion in the Early Jurassic similar to other Atlantic margin basins (e.g. Scotian Basin, Laurentian Basin). During this period an interior, hypersaline shallow sea occupied the newly formed rift basin, which was situated in warm latitudes. Massive salt deposits were accumulated during the time. It is possible that an algal, oil potential source rock was deposited in the Carson Basin, during Sinemurian-Pliensbachian in the earliest post-rift, hypersaline to carbonate marine environment, in a similar manner as proposed for the Scotian Basin and discussed in the comprehensive Nova Scotia Play Fairway Analysis (http://www.novascotiaoffshore.com/analysis#atlas; NSDE, 2011; also in Enachescu, 2012).

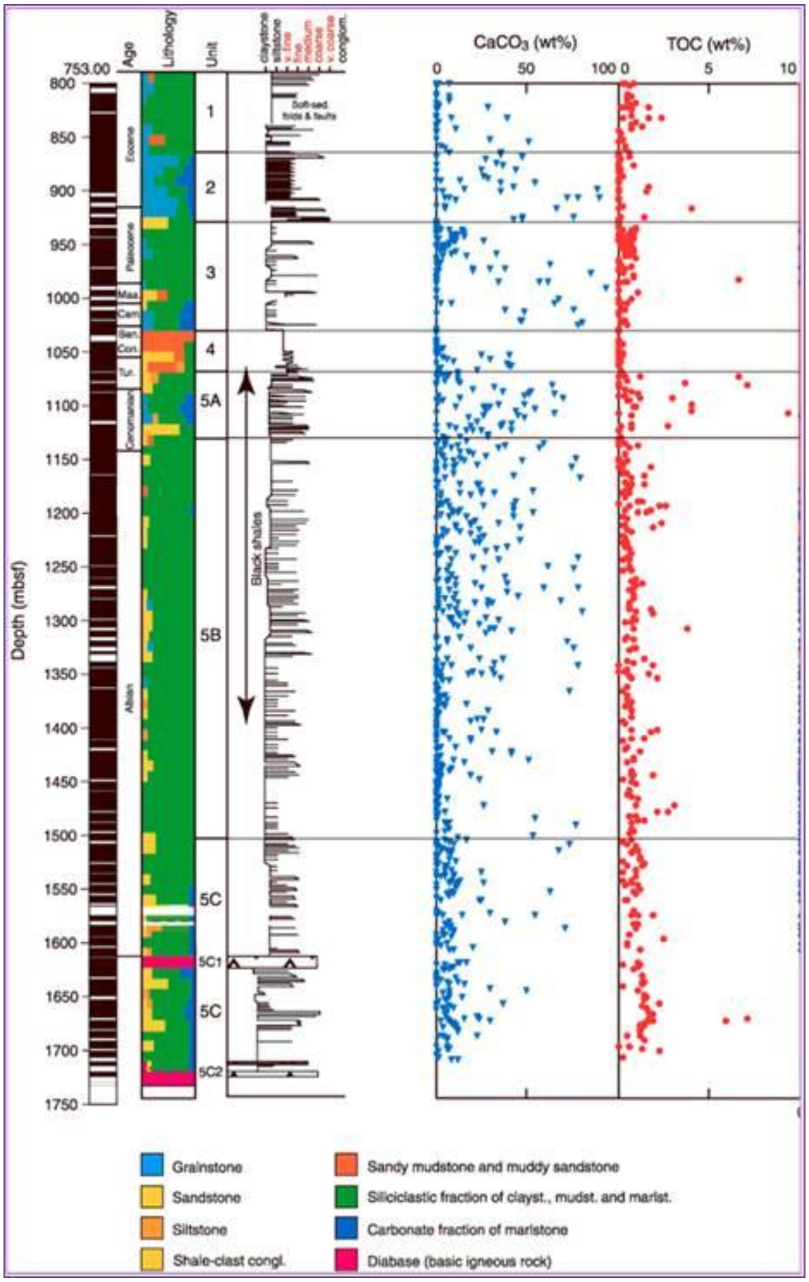


Figure 16. The Aptian to Eocene stratigraphic successions drilled by IODP during Leg 210 (2003), age and lithology of rocks, their calcium carbonate percentage, TOC (total carbon content) (modified after IODP, Tucholke, B.E., Sibuet, J.-C., and Klaus, A. (Eds.), 2007a).

In some areas of the basin where the Paleozoic forms the basin floor, a Paleozoic source rock similar to sources found in the adjacent Maritimes Basin may also be a contributor, especially to gas/condensate generation in the basin. While the Tertiary shales have shown high TOC intervals in the drilled wells, they remain unproven source rocks. Where the thickness of several deep grabens surpasses 3 km, the tertiary shales will be mature.

6.2. Reservoir Rocks. Reservoir rocks in the Carson Basin should be predominantly high porosity - high permeability sandstones of Late Jurassic to late-Early Cretaceous age similar to that encountered in the neighbouring basins (Enachescu, 1988; Tankard and Welsink, 1989; Tankard and Balkwill; 1989; Brown et al., 1989; McAlpine, 1990 and 1995; Williams et al., 1990; Hiscott et al. 1990; Sinclair et al., 1992; Hurley et al., 1992; Driscoll and Hogg, 1995; Noseworthy, 2003; Dearin, 2007; Lowe et al., 2011; Heynes et al., 2012; Cody et al., 2012). Additionally, turbidite sands of Late Cretaceous-early Tertiary should be present on the continental slope and deepwater where a major clastics depocenter was mapped (e.g. Enachescu, 1992a and b; Hogg and Enachescu, 2004, 2007 and 2008; Solvason, 2006). Porous matrix or dolomitized carbonates of Jurassic and Early Cretaceous age, may develop locally in the Carson Basin, similar to reservoirs encountered at Deep Panuke in the Scotian Basin (Wierzbicki and Harland, 2004; Kidston et al, 2005; Weissenberger et al., 2006; Eliuk, 2009) or the Cretaceous Donquin prospect, recently drilled in the Porcupine Basin offshore Ireland which is conjugate to the Flemish Pass Basin (http://www.providenceresources.com/uploads/operationalupdate-dunquinnorthwell-22july2013.pdf).

In the Jeanne d'Arc Basin the main reservoirs are sandstones of the Jeanne d'Arc Formation (Kimmeridgian-Tithonian), Hibernia Formation (Valanginian - Berriassian) and Avalon-Ben Nevis Formation (Barremian – Aptian). Additional reservoirs were found in the Voyager (Bathonian - Calovian), Rankin (Calovian - Oxfordian) formations and in the Catalina (Valanginian - Hauterivian) and Otter Bay (Touronian - Coniacian) and Fox Harbour (Campanian – Maastrichtian) members (Tankard and Welsink, 1987 and 1989; Enachescu, 1987, 1992a and b, 2000, 2007 and 2011; Brown et al., 1989; McAlpine, 1990 and 1995:Wade and MacLean, 1990; Driscoll and Hogg, 1995; Sinclair et al., 1992; Atkinson and Fagan, 2000; Deptuk et al., 2003; Enachescu, 2011 and 2012). These reservoirs show excellent qualities and contain oil, gas or both in numerous producing fields and undeveloped discoveries. In the Flemish Pass Basin, excellent reservoirs have been drilled in the Tithonian, Kimmeridgian and Early Cretaceous formations (Enachescu, 2010b, 2011 and 2012a; Enachescu et al., 2010 and 2012; Lowe et al., 2011; Haynes et al., 2012; Cody et al., 2012).

Hydrocarbons were also found in high quality Early Tertiary reservoirs such as the Avondale, Tilton and South Mara members. Descriptions of these reservoirs were given by Deptuk (2003) and Deptuk et al. (2003). Several unnamed Oligocene sandstones have also been drilled in the Grand Banks' basins.

Two of the wells drilled on the shelf of the Carson Basin, Bonnition H-32 and St. George J-55, encountered Late Jurassic and Early Cretaceous sandstone reservoirs equivalent to the Jeanne d' Arc, Hibernia and Avalon sandstones which are all producing oil in the fields of the Jeanne d'Arc Basin. These wells also intersected Late Cretaceous and Early Tertiary reservoir units (Jansa et al., 1977; Grant et al., 1988; McAlpine, 1989 and 1990; Solvason, 2006; C-NLOPB, 2013). The Osprey H-84 and Skua E-41 wells were drilled on highs and most of the formations containing reservoir are missing due either to erosion or nondeposition. An exception is the Late Cretaceous Eider Member (Ben Nevis Formation equivalent) encountered in Skua E-41 (Grant et al., 1988; Solvason, 2006).

6.3. Seals. Seal should not be a problem for hydrocarbon traps within the Carson Basin as the Extensional and Thermal Subsidence stages contain regionally distributed successions of very fine clastics, tight sandstones and regional tight carbonate beds. Good seal intervals such as the Downing, Rankin, Fortune Bay, Whiterose, and Nautilus formations were found in the four wells drilled in the Carson Basin (Figures 10 and 17).

The postrift Petrel Member (mostly Turonian), Wyandot Limestone (Campanian) and the thick syndrift Tertiary fine clastics of the Banquereau Formation are basin-wide seals.

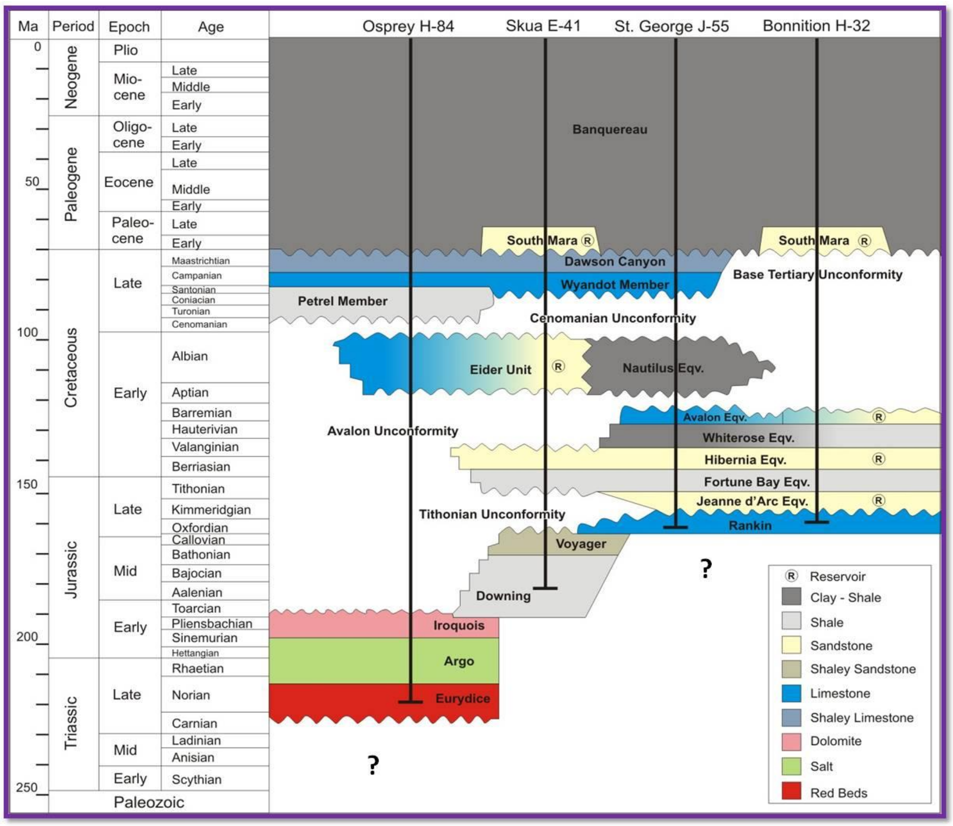


Figure 17. Chronostratigraphy of main geological formations intersected by the four exploration wells drilled on the Carson Basin shelf. These formations were described in detail by Grant et al. (1988) and McAlpine, 1990 and 1995. The Eider Unit is a southern Grand Banks succession-time equivalent to the Ben Nevis Formation from the Jeanne d'Arc Basin (figure modified after Grant et al., 1988 and Solvason, 2006).

6.4. Hydrocarbon Traps. The numerous structural traps found in the Carson Basin are associated with 1) basement highs due to recurring rifting of the Atlantic Margin, 2) gravity faulting, 3) minor transtension and inversion features, 4) differential subsidence and tilting, and 5) movement of the Argo/Osprey evaporites.

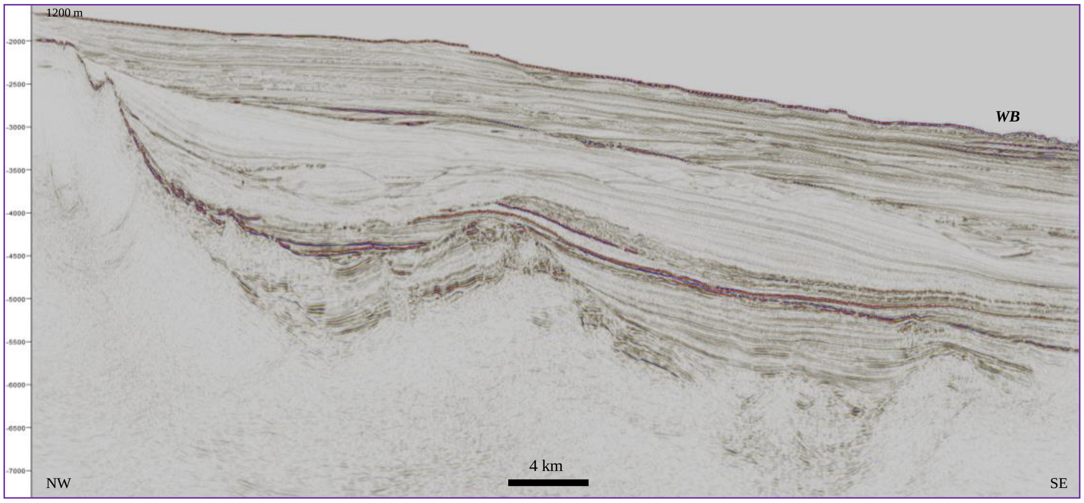


Figure 18. Uninterpreted 3D dip seismic line with examples of structural and stratigraphic traps in the northern Carson Basin (seismic line provided by C-NLOPB).

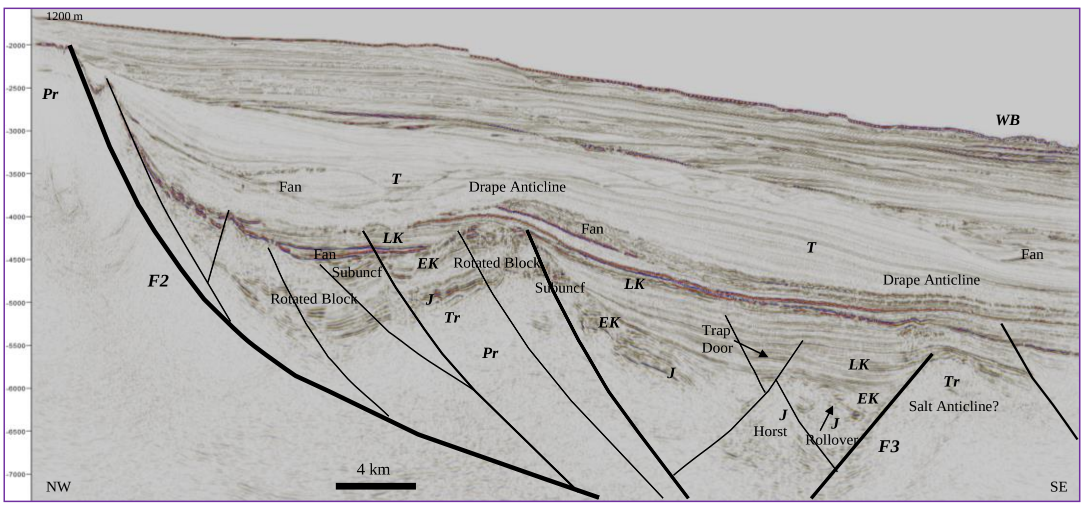


Figure 19. Interpreted 3D dip seismic line with examples of structural and stratigraphic traps in the northern Carson Basin (seismic line provided by C-NLOPB). F2 and F3 are major faults shown also in Figures 3, 12 and 13. Notations are: Pr = Precambrian basement, Tr = Triasic, J = Jurassic, EK = Early Cretaceous, LK = Late Cretaceous, T = Tertiary, Subuncf = Subunconformity trap.

The main structural trap types are extensional anticlines, roll-overs, faulted anticlines, faulted and tilted blocks and elongated horsts that may involve the basement or are restricted to the synrift sequences. The great majority of faults are down-to-basin, rift border faults and their antithetics. As shown by seismic reflection lines, the greatest majority of these faults are listric normal faults. Together with several transfer faults, these faults form horsts, ridges, fault fans and trap-door features. The most favourable structural traps contain synrift sandstone reservoirs but may also contain younger clastics.

A large variety of salt induced structures such as pillows, domes, diapirs, ridges, teardrops and turtle anticlines are common in the Carson Basin affecting both the synrift and post rift sequences. Drape anticlines are also present and observed from Late Cretaceous up to mid-

Tertiary stratigraphic levels.

Stratigraphic traps are also widespread in the Carson Basin. Paleo-valleys, basin margin and basin floor fans are abundant in the basin. Other fan-type stratigraphic traps are confined between salt structures (sandstone accumulated between salt diapirs or minibasins). Sub-unconformity traps, produced mainly by the Avalon and Base Tertiary unconformities, are also abundant. Composite structural-stratigraphic traps are common in the oil fields of the Jeanne d'Arc Basin and they should also be present in the Carson Basin.

6.5. Maturation and Migration. The Egret Member source rock is stratigraphically positioned just below the Tithonian Unconformity. It is presumed that wherever a thick Rankin Formation can be identified and mapped below the Tithonian, the Kimmeridgian (Egret Member) and Oxfordian high organic content shale sections are preserved. Wherever seismically mapped in the Grand Banks and adjacent basins, the Late Jurassic source rock intervals are characterized by strong amplitude reflectors.

The source rock intervals are missing due to intense erosion at several major unconformities in the shelfal wells even when the wells encountered a Late Jurassic sequence (Figures 3 and 17; Grant et al., 1986; Enachescu, 1992a and b, Solvason, 2006). The Rankin Formation remains preserved in two depocenters; in the outer shelf-upper slope area and in a large area in the deepwater where the Call for Bids parcels are located.

In the southernmost and northernmost reaches of the shelf, the Egret source rock is probably eroded by several overlying unconformities, the youngest one being the Base Tertiary Unconformity. However the Late Jurassic sequence containing high TOC and high Hydrogen Index intervals, should be preserved on shelf in deeper sedimentary ponds and certainly on the slope and deeper water where a large and profound basinal area develops. In the author's opinion, the Egret Member should be mature in the northern onshelf graben and in most of the deepwater area previously known as the Salar Basin and located downdip from the F2 fault (Figure 3).

In the adjacent Jeanne d'Arc Basin, the oil window occurs at burial depths between 2.5 km and 4 km (MacKay and Tankard, 1990: Williamson, 1992; Sinclair et al., 1992; Fowler and McAlpine, 1995; McCracken et al., 2000; Magoon et al., 2005; Solvason, 2006; Enachescu et al., 2010; Enachescu 2011 and 2012).

According to Wielens et al. (2006) and Baur et al. (2009) who modeled an apparent petroleum system anchored by a Late Jurassic source rock, the Carson Basin is capable of generating significant volumes of oil with similar characteristics as those presently produced in the Jeanne d'Arc Basin. If this source rock is present, the preferred migration route would be into the Jeanne d'Arc or equivalent Tithonian sandstones. A longer path migration would subsequently fill the Hibernia, Avalon, Ben Nevis and younger sandstones using the numerous extensional faults and porous conduit beds.

The timing of hydrocarbon generation in the Grand Banks and environs was during Late Cretaceous and prior to Tertiary (Bell and Campbell, 1990; Fowler and McAlpine, 1995; McCracken et al., 2000; Magoon et al., 2005; Wielens et al. 2006; Baur et al., 2009). Therefore the synrift traps will have a higher chance to be filled while the younger traps, mostly of a stratigraphic type, will have a smaller chance of charging, unless deep erosion has brought source rocks closer to the younger reservoirs.

The oils that would have been generated in the Carson Basin by the potential Egret or an equivalent source rock will have similar characteristics to those presently produced on the Grand Banks. These are light oils (30°-37° API) with high aromatics content and in high demand at the East Coast US and Central Canada refineries. The simulation presented by Wielens et al. (2002 and 2006) and Baur et al. (2009) has shown that nearly 50% of the basin is sufficiently mature to generate hydrocarbons. However, migration losses can reduce the volume of oil that might be trapped. A commonly-used rule is that about 10% may be trapped, meaning that 5 billion barrels could be still preserved in the traps of the Carson Basin (Baur et al., 2009).

6.6. Hydrocarbon Plays and Risks. The main hydrocarbon play expected to be successful in the Carson Basin will likely be:

- Anchored by a Late Jurassic source rock such as the Egret Member or equivalent; Tithonian, Callovian or Oxfordian organic shales, or a blend of several of these sources),
- Reservoired most likely in synrift Late Jurassic sandstones, or Early Cretaceous sandstone, and
- Trapped in extensional/salt related faulted anticlines with faults provided near source kitchen migration conduits.

This play has provided giant oil accumulations in the Jeanne d'Arc Basin and recently proved significant discoveries at Mizzen, Harpoon and Bay du Nord in the Flemish Pass Basin.

The main risk in the basin remains source rock quality. On basin margins and high ridges, the risk is source presence and maturity. Profound erosion at the Avalon, Cenomanian and Base Tertiary unconformity may unseal the deeper synrift reservoir or reduce the amount of sedimentary cover necessary for maturation. On the shelfal area of the basin, the Avalon Uplift has eroded the source rock. Based on drilling results from the deepwater Scotian and Laurentian basins, the sandstone reservoirs contained in the Late Cretaceous Early Tertiary fans may be poor or sandstone beds may be too thin. Late salt movement may pose a significant risk of breaching reservoirs.

There is also a risk of finding lower API oils present in shallower reservoirs. This is a situation encountered in the Jeanne d'Arc and Flemish Pass basins where several accumulations were found to contain biodegraded oil or where heavier oils were generated by a marginally mature source rock.

6.7. Significant Wells. Only four wells were drilled in the Carson Basin during two earlier exploration cycles. All were drilled on the shelfal portion of the basin. None of the wells reached the prerift basement. All the drilling locations were shallower structural prospects. No hydrocarbons were found in these wells, probably due to the lack of mature source rocks in their vicinity.

Well	Dril-led	WD (m)	Status	Location	TD (m)	Postrift Unc (m)	TD in	Reservoir Interval (m)	Source rock
Osprey H-84	1973	61	Abandoned	Grand Banks shelf	3474	1056	Eurydice Fm		Not present
Bonnition H-32	1973	102	Abandoned	Grand Banks shelf	3048	1291	Rankin Fm	S. Mara Mbr 1268-1291 Hibernia eq. 1458-1640 Jeanne d'Arc eq. 1725-2054	Not present
Skua E-41	1974	83	Abandoned	Grand Banks shelf	3339	1341	Downing Fm	S. Mara Mbr 1077-1117m Eider 1319-1341 Hibernia eq. 1341-1370	Not present
St. George J-55	1986	104	Abandoned	Grand Banks shelf	4100	1840	Rankin Fm	Hibernia eq. 2385-3006 Jeanne d'Arc eq. 3287-3714	Not present

Table 1. Exploration wells drilled in the Carson Basin's shelfal area and their main results (compiled from C-NLOPB information). All wells were drilled during an early exploration period (1970s to mid 1980s).

Based on regional drilling and seismic mapping on the Newfoundland margin, it is assumed that the Carson Basin generally accumulated much of the same sedimentary successions that filled the Jeanne d'Arc Basin (Grant and McAlpine, 1990; McAlpine, 1990; Hiscott et al., 1990; Sinclair, 1995, Driscoll and Hogg, 1995; Deptuk et al., 2007; Enachescu, 2011 and 2012).

Seismic lines containing the well locations and seismic marker correlation were presented by Keen et al. (1987), Keen and de Voogd, (1988), Grant et al. (1988), Grant and McAlpine (1990), Enachescu (1988 and 1992a and b) and Solvason (2006). As all exploration wells were drilled on the shelf, west of the major basement ridge SR (Figures 3 and 13), the seismic correlation of identified markers on the slope and deepwater is somewhat uncertain (e.g. Figures 18 and 19).

More information on the four wells are found in C-NLOPB Schedule of Wells (2013) (http://www.cnlopb.nl.ca/well_alpha.shtml) and in National Resources Canada (NRCAN) Basin Database (http://basin.gdr.nrcan.gc.ca/wells/index_e.php).

6.8. Seismic Data Quality and Availability. Seismic coverage in the Carson Basin varies from good on the shelf and poor on the slope, to excellent in deepwater. Two vintage classes of seismic surveys exist in the basin:

1) the pre-modern data acquisition (pre-1998) and
2) the modern data acquisition (post-1998).

1. The pre-modern data acquisition (pre-1998) is characterised by the use of shorter cables, usually less than 4.5 km, large space group interval and reduced number of channels. EM Navigation is used. The streamer was not steerable and at best had only frontal and tail sensors. As such, feathering was quite a problem both during acquisition and data processing. Pre-1981 data was not migrated; data collected after 1981 was post stack time migrated for structural imaging. A basemap of the released vintage seismic data available in the Carson Basin is available from C-NLOPB at http://www.cnlopb.nl.ca/pdfs/nl1302vintage.pdf.

Data quality for these surveys varies from poor to good. The seismic data deteriorates significantly under the post-rift unconformity with basement rotated blocks poorly imaged. Choppy or discontinuous reflectors abound. The salt walls and salt bottom are not well rendered by this vintage of data. Repeated water bottom and peg leg multiples are present under the shelf break and continental slope obscuring the synrift structures.

2. The modern data acquisition (post-1998) is characterised by the use of extended cables, usually longer than 4.5 km, dense space group interval and a large number of channels (more than 240). GPS navigation is used throughout the survey. The streamer had an increased degree of steerability and multiple sensors were placed along it and, as such, feathering was not a major problem during acquisition and data processing. All modern data is at least prestack time migrated and optionally depth migrated. A list of the Carson Basin released modern seismic data is available from http://www.cnlopb.nl.ca/cfb1302.shtml together with a basemap of the most recent surveys http://www.cnlopb.nl.ca/pdfs/nl1302vintage.pdf.

Data quality for these surveys varies from good to excellent. The longer cable allows better penetration and imaging of the synrift unconformity, synrift deformed infill and extended basement. The reflectors show better continuity. The salt walls and salt bottom are much better represented after careful processing by these new data grids. The Water bottom and peg leg multiples are better suppressed under the shelf break and continental slope allowing for better imaging of the synrift structures.

The C-NLOPB has posted on their website the list of exclusive and non-exclusive seismic surveys that are released and available in analogue format from their data archive. Both company owned (exclusive surveys) and seismic supplier (non-exclusive, multi-client or spec) acquired surveys are available for licensing to carry out regional and prospect seismic interpretation in the Carson Basin. The seismic digital files can be obtained from data owners which can be: a) a single or a group of oil companies (e.g. Suncor, BP Canada, ExxonMobil, Imperial Oil, etc.), b) seismic vendors (e.g. Veritas, GSI, WesternGeco, etc.), and 3) research organizations, which have been active in the area (usually GSC, or GSC involved in a partnership with foreign research groups).

Several research groups have recorded multi-channel seismic reflection (MCS) data in the area. These surveys, outlined below, cover parts of the Carson Basin:

1. the LITHOPROBE survey recorded under GSC Frontier Geoscience Project (1984-199) contains continental margin-wide seismic lines in the mid-eighties, including Line 85-2 and Line 85-4. These deep reflection lines were interpreted in the past by Keen et al. (1987), Enachescu (1987, 1988 and 1992a and b), Keen and de Voogd (1988), Louden (2002), Lau et al. (2006) and Solvason (2006),

2. the MARIPROBE survey which was part of SCREECH (Study of Continental Rifting and Extension on the Eastern Canadian Shelf) collected during the summer of 2000 as a site survey to IODP Leg 210 (Louden and Hall, 2000). The survey was also collected to further investigate Newfoundland's continental margin and create depth sections of the margins and constrain models of the lithosphere extension. Lines 401, 402 and 403 are dip lines to the margin and also cross the Carson Basin. These lines and other research and industry lines tying the ODP drillholes 1276 and 1277 have been interpreted by Solvason (2006), Lau et al. (2006), Welford and Hall (2007), Welford et al., (2010), and

3. the ERABLE survey, recorded jointly by GSC Atlantic and Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER) on and south of the Flemish Cap. The main purpose of the survey was to provide information on crustal boundaries, seismic velocity of crustal layers, geometrical constraints on rifting and regional variation of rifting style (Srivastava and Sibuet, 1992; Lau et al., 2006; Welford and Hall, 2007; Welford et al., 2010).

Gravity, magnetic, satellite and wide-angle refraction, heat flow data, seafloor topography are also available, usually at reproduction costs from different scientific organizations such as GSC, Canadian, US and European Universities, National Oceanic and Atmospheric Administration (NOAA).

Most recently (2011-2013), in collaboration with Nalcor, TGS and PGS formed the MKI Invest consortium to collect modern data in less explored basins in the Newfoundland offshore such as the Labrador Sea, Orphan and Flemish Pass and licences the selected data to interested companies to encourage exploration in these areas (Carter et al., 2013). The regional survey, may be extended in 2014 within the Carson Basin covering parts of the CFB offered parcels. This massive seismic program is managed and operated by TGS in partnership with PGS, both well-known global seismic contractors that have worked several large programs in the East Coast waters of Canada. The survey builds on regional satellite seeps study carried out by EADS subsidiary Astrium GEO-Information Services and delivered in spring 2011 (Enachescu, 2011 and 2012; http://www.nr.gov.nl.ca/nr/publications/energy/nalcor_astrium_oil_seeps.pdf).

The MKI seismic acquisition has been carried out using the Norwegian seismic ship *M/V Sanco Spirit* built in 2009 and contracted by TGS. This vessel possesses modern S&E, navigation and seismic equipment. It uses the advanced PGS GeoStreamer® technology that has dual-sensors (hydrophones collocated with geosensors), recording both pressure wave and particle motion which allows reducing receiver-side multiples.

In the first stage of processing the NL regional survey, PGS applied a swell attenuation step followed by despike, linear noise attenuation and wave field separation. In the second processing stage performed by TGS, special attention was given to multiple attenuation. The sequence includes: Tau-P decon for Water Bottom < 1500 ms, SRME, High resolution Radon demultiple, High resolution Tau-P demultiple, Residual demultiple on selected lines with steep drop off from shallow to deepwater and Radon demultiple. A final Kirchoff Pre-Stack Time Migration (PSTM) was applied. An acquisition program in the Carson Basin would likely use similar processing parameters.

In a number of earlier publications, several regional seismic sequences were interpreted in the Carson Basin by Grant et al. (1988), Keen et al. (1987), Keen and de Voogd (1988) and Enachescu (1987, 1988 and 1992a and b) using regional correlations of unconformities and several strong lithostratigraphic markers. These sequences were also slightly modified and used by Solvason (2006) in her thesis.

Based on present knowledge and amalgamation of previous seismic classification and interpretation studies, six seismic megasequences can be described in the Carson Basin:

1) the first synrift, Tethys or *aborted rift* sequence (Late Triassic-Early Jurassic),
2) the epeiric basin sequence (Early to Late Jurassic),
3) the second rift or *late rift* sequence including syn-mantle exhumation (Late Jurassic to Barremian),
4) the transition to drift (phase 1) sequence including first oceanic rift and break-up of Grand Banks from Iberia and later from Ireland (Aptian to Cenomanian),
5) the syndrift sequence (drift phase 2) including oceanic rift and break-up of Labrador and Greenland (Cenomanian to Paleocene), and
6) the passive margin sequence or final thermal subsidence and pronounced sedimentary wedge tilting (Eocene to Present).

These seismic sequences can be used by geoscience professionals in the industry to tie markers to exploration wells, regionally map the subsurface and define prospects and leads in the NL2013 Call for Bids parcels 1 to 4. A few modern reflection lines (post-1998) with first pass interpretation will be presented in this report to illustrate exploration opportunities in CFB parcels (see Figures 18 and 19 and section 7)

7. Petroleum Potential of Call for Bids NL13-02 Parcels 1 to 4

This chapter contains a description of the CFB NL13-02 Carson Basin, identifies the available seismic coverage of the exploration blocks, introduces elements of seismic interpretation on representative seismic lines and provides a description of the petroleum potential of the parcels on offer.

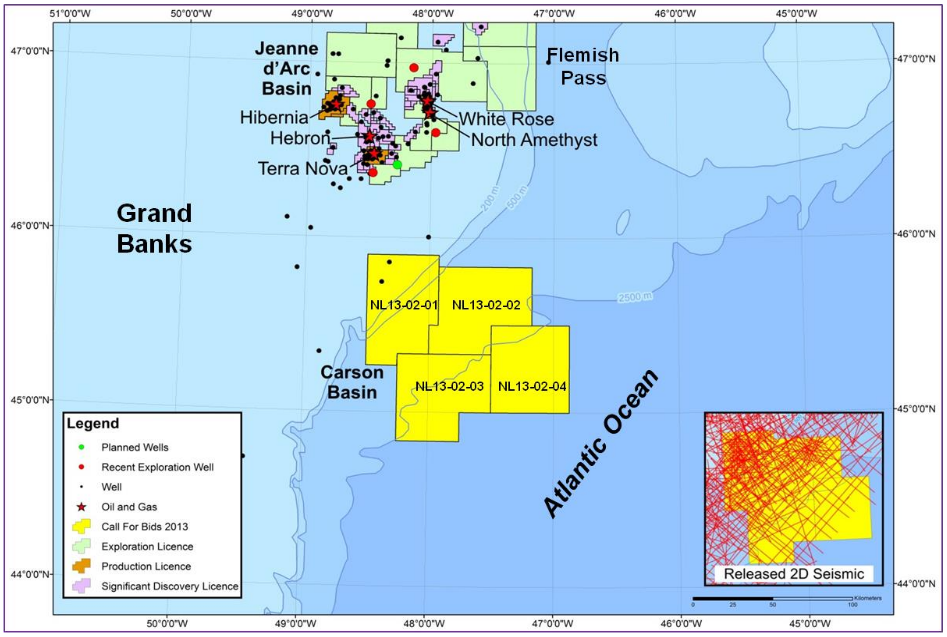


Figure 20. Regional location map of the northeastern Grand Banks and environs showing exploration and production licences, SDLs and Call for Bids NL13-02 parcels 1 through 4. The publicly released 2D seismic coverage of the parcels is shown in the lower right insert.

C-NLOPB Call for Bids NL13-02 parcels 1 to 4 are located off the east coast of the Province of Newfoundland and Labrador, Canada, in a region designated Area "C" – Carson Basin. This region is administered by the C-NLOPB on behalf of the Province of NL and the Federal Government (http://www.cnlopb.nl.ca/pdfs/nl1302.pdf). Only Parcel 2 and the northern part of Parcel 3 have been licensed for exploration in recent times (2001 to 2006). The rest of the parcels have never been explored or have not been licensed since the round of exploration in the 1980's (http://www.cnlopb.nl.ca/pdfs/nl1302historic.pdf). Offshore Newfoundland and Labrador exploration areas are typically licensed by the C-NLOPB to the party submitting the highest bid in the form of work commitments

Parcels 1 to 4 are situated in water depths ranging from 90 to 3750 m. The area of the four parcels totals 1,138,399 hectares (2,812,984 acres), making this Call for Bids one of the largest current offer on the Atlantic margins (Figure 20). Parcel size ranges from 673,177 acres or 2,724 km^2 to 719,843 acres or 2,913 km^2. Presently, there no Exploration Licences (ELs) in the Carson Basin, however more than 20 ELs are active to the northwest and north in the Jeanne d'Arc, Flemish Pass and East Orphan basins, some being located in deepwater. In 2012, four intermediate to deepwater ELs, were also acquired in the Laurentian Basin.

All four parcels comprise thick Mesozoic successions and contain large petroleum prospects and leads which are covered by a relatively dense 2D seismic grid and partially by a 2001 3D survey acquired by WesternGeco on behalf of Petro-Canada. More opportunities exist in the unlicensed region south of the present Call for Bids parcels.

7.1. Seismic Data Owners and Coverage. The parcels in Call for Bids NL13-02 are fairly well covered by a relatively dense 2D seismic grid. An exception is Parcel 4 which only has a few seismic lines in the public domain located in the eastern deeper water part of the parcel. More than 10,000 km of 2D lines of various vintages are positioned on or in the vicinity of the CFB parcels. The maps in Figures 5 and 7 contain only the publicly released lines which are available in analogue format (paper prints) from the C-NLOPB (http://www.cnlopb.nl.ca/cfb1302.shtml). The densest seismic coverage is in the shallow water and upper slope areas.

Substantial additional data exists in digital format and is available from oil companies, geoscience organizations and seismic contractors (see also section 6.8.). These organizations can provide basemaps on demand with proprietary seismic coverage and lists of prices for data licensing. Most of the contractors have their basin coverage on their website and they also advertise if they have seismic data available in the Carson Basin's Call for Bids areas.

In the Carson Basin, exclusive 2D digital data is owned mainly by Suncor (inheriting Petro-Canada's database), ExxonMobil (inheriting Mobil database), BP Canada (inheriting Amoco's database) and Husky (inheriting Husky/BowValley and Canterra databases). The older surveys recorded in the 1970s and early 1980s were used to locate and drill the four wells drilled in the shallow waters of the basin (Figure 7). Some of these surveys have been or may be reprocessed for improving resolution in the synrift sequence and imaging the prerift basement shape.

Post-1998 multi-client seismic data of good quality and with high penetration are available from several seismic contractors such as GSI, Western, Geco (now WesternGeco), Veritas (now CGG). Modern seismic data were collected and processed to pre or post-stack migration by these companies during the 1998-2003 period (http://www.cnlopb.nl.ca/cfb1302.shtml).

The 2D grid in Parcels 1 to 3 and western part of Parcel 4 has a variable 1 to 3 km spacing in the dip direction and 3 to 5 km spacing in the strike direction. Portions of parcels have denser coverage. There are two main seismic grid sets in the parcels; one oriented NW-SE in the dip direction and a second one oriented NNW-SSE in the dip direction, with both grids including perpendicular strike lines. The only 3D survey in the basin acquired by Petro-Canada in 2001 covers 1200 km^2 and is located mainly on Parcel 2.

7.2. Seismic Interpretation. Good to excellent seismic coverage exists for parcels 1, 2 and 3, allowing the interpretation of several regional markers and the mapping of large size, drillable features. Parcel 4 has little coverage in its eastern, deepwater side (Figure 20). Previously published seismic sections show the presence of a thick synrift sequence (Late Triassic to early Late Cretaceous) which fills the grabens and overlies the horsts, ridges and salt diapirs in the north-central part of the Carson Basin (e.g., Grant et al., 1988; Enachescu 1987, 1988, 1992a and b; Keen et al., 1987; Keen and de Voogd, 1988; Atkinson and Fagan, 2000; Solvason, 2006; Demeer et al., 2007; Welford et al., 2010).

The regional seismic lines demonstrate that the synrift sedimentary sequence in the Carson Basin is deformed by extension, transtension, and salt tectonics and is segmented by a high number of faults. Numerous faulted anticlines, roll-overs and basement cored anticlines are imaged (Figures 18, 19 and 21). The postrift sequence generally dips and thins basinward, toward the transitional crust area (Figures 12 and 13). Due to gravity sliding, mass transport deposits or shale detachment tectonics, there is considerable deformation of the Late Cretaceous and Early Tertiary postrift sequence on the continental slope and rise (Figures 18, 19 and 21).

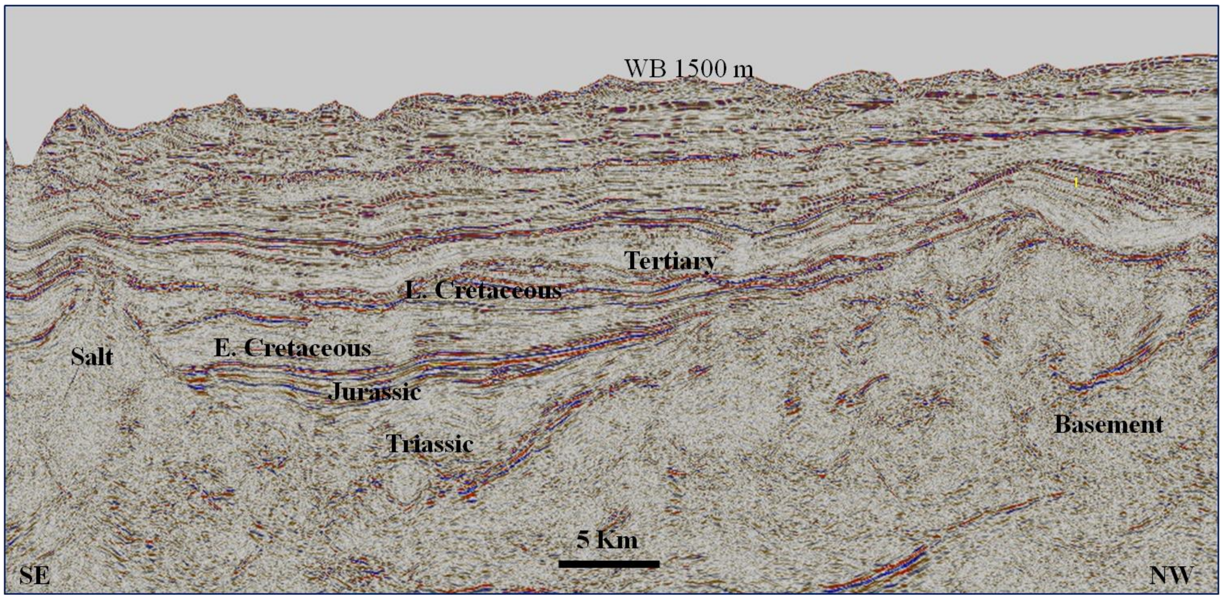


Figure 21. Possible Late Cretaceous and Early Tertiary sedimentary fans on a representative strike line in the Call for Bids NL13-02 area. Mounded features are widespread in the basin on the upper and lower slope as well as on the upper rise. Several prominent unconformities are imaged within the synrift and postrift sequences (e.g. Avalon Unconformity and Base Tertiary Unconformity). Line source: C-NLOPB.

The public domain, regional seismic lines illustrated in this report were tied with synthetic seismograms to several exploration wells in the Jeanne d'Arc Basin, Flemish Pass Basin and in the Carson Basin shelfal area. Due to thick sedimentary cover, the prerift basement (Precambrian, possibly Paleozoic in places) is hard to interpret on both older and modern data. The basement marker is easier to trace on shelf and on top of rotated blocks but is too deep or too sketchy in grabens and salt withdrawal basins (Figures 18, 19 and 21).

All Grand Banks' archetypal Mesozoic successions (Late Triassic to Quaternary) are present in the Call for Bids area. Several regional unconformities are prominent (e.g. Base Tertiary, Avalon). On the seismic sections illustrated only a few markers and formations are displayed together with major faults (e.g. Figures 18, 19 and 21, and following illustration in this chapter). The Avalon Unconformity is a fair marker and allows approximate separation of the synrift and postrift sedimentary sequences. Seismic data quality is good to excellent in the Late Jurassic to Tertiary sequences but deteriorates in the Late Triassic - Late Jurassic interval.

According to the interpretation of the extensive Carson Basin seismic grid, the Jurassic sequence that contains the source rock is thick in several depocenters, the largest one being located on the slope (Figure 18, 19 and 21). Occasionally, on top of rotated blocks and salt diapirs, the uppermost Jurassic rocks are eroded by the Avalon Unconformity. Several crustal penetrating listric normal faults affect the basement and the synrift sequence (Figures 18 and 19). The resulting rotated blocks create large anticlinal features, which are the main exploration targets in the area. The major and secondary faults are easily traceable.

As the Carson Basin stratigraphy knowledge is in its infancy due to lack of wells in deeper water and a concentration of drilled wells on highs and on a narrow strip along the shelfal part of the basin, the Jeanne d'Arc Lithostratigraphy Chart may be used to identify seismic stratigraphic sequences in the Call for Bids area (Figure 10). A more specific, locally applicable litho-stratigraphy has to be developed after drilling several wells in the deeper portions of the basin.

Quality multi-client 2D grids and the lone exclusive 3D seismic survey allow for mapping of several unconformities, formation tops, carbonate intervals, salt and sandstone markers such as: Wyandot (Base Tertiary), Petrel, Avalon Unconformity, "O" Marker, Missisauga, Top Jurassic, Middle Jurassic, Lower Jurassic, Argo Salt and, when not too deep, the Economic Basement. Some of the seismic markers are widespread and have good quality; some are poor in places and have to be tentatively traced. Also the salt diapir walls/welds are well imaged in places, but poorly discernible in other places.

To evaluate the potential of the Call for Bids parcels, the seismic data can be purchased from seismic contractors and vendors ("spec companies"), brokers or oil company owners as digital SEG-Y files. Certain older data can be obtained in hardcopy (paper) format from the C-NLOPB office in St John's, NL.

As subsurface mapping was beyond the scope of this report, only a tentative interpretation of several representative seismic lines was performed and used to illustrate the presence, type and size of hydrocarbon traps in the following sections (Figures 22 to 35).

Two 2D regional dip lines (1706-101 and 1702-101) and a 2D regional strike line (4141-101) together with a dip 3D line (4466) will be used to illustrate the structural style, seismic stratigraphy and trap potential in the Call for Bids NL13-02 parcels. These lines were selected from the extensive modern grid that allows subsurface mapping of the Carson Basin.

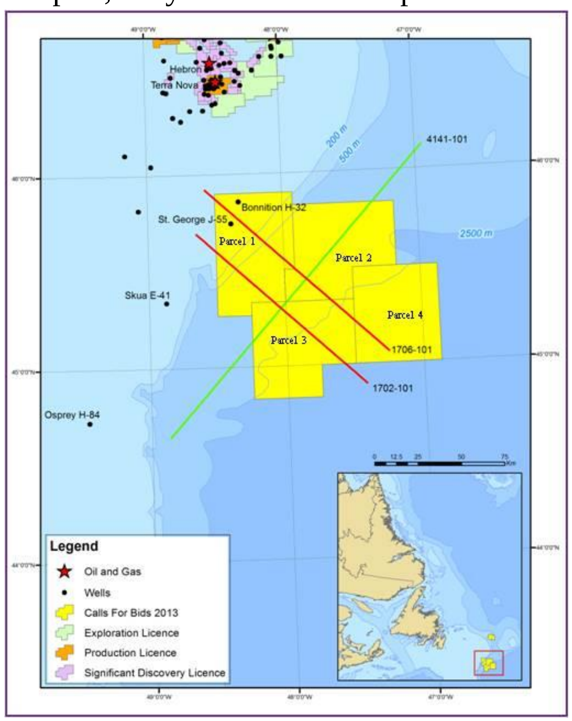


Figure 22. Location of three representative regional seismic lines used to illustrate the petroleum potential of the Call for Bids parcels 1, 2, 3 and 4. The uninterpreted and interpreted variants of these sections are shown in Figures 25, 26, 28, 29, 30, 31, 33 and 34.

7.3. Petroleum Potential of Call for Bids NL13-02 Parcel 1. Parcel 1 located in the northwestern part of the basin contains 285,864 hectares (706,385 acres) which is 122.6 times larger than a GOM OCS tract (3 by 3 square miles). The parcel is situated south of the Jeanne d'Arc and Flemish Pass basins, on the Grand Banks shelf and upper slope, in 90 - 1800 m of water (mean 650 m) (Figures 20, 22 and 23).

The public domain and multi-client 2D seismic coverage is very good for this parcel (Figure 23). Only a small portion in its southeastern part is covered by 3D data. Two wells have been drilled in the northwestern corner of the parcel: the Bonnition H-32 and St. George J-55, which were the latest two wells drilled in the basin. Both wells have encountered Jeanne d'Arc and Hibernia formation equivalents and bottomed in the Rankin Formation (Figure 17 and Table 1). Though drilled on structural highs (e.g. Grant et al., 1988; Solvason 2006), the wells did not encounter source rocks, as they were probably eroded at the Tithonian Unconformity. These wells and other shelfal wells in the adjacent basins are available for identification of seismic horizons, geological correlation and subsurface mapping of this and the adjacent parcels. Two modern, deep penetration, time migrated seismic lines (denoted 1706 and 1702) are used to illustrate the petroleum potential of this parcel (Figures 22 to 26, 30 and 31).

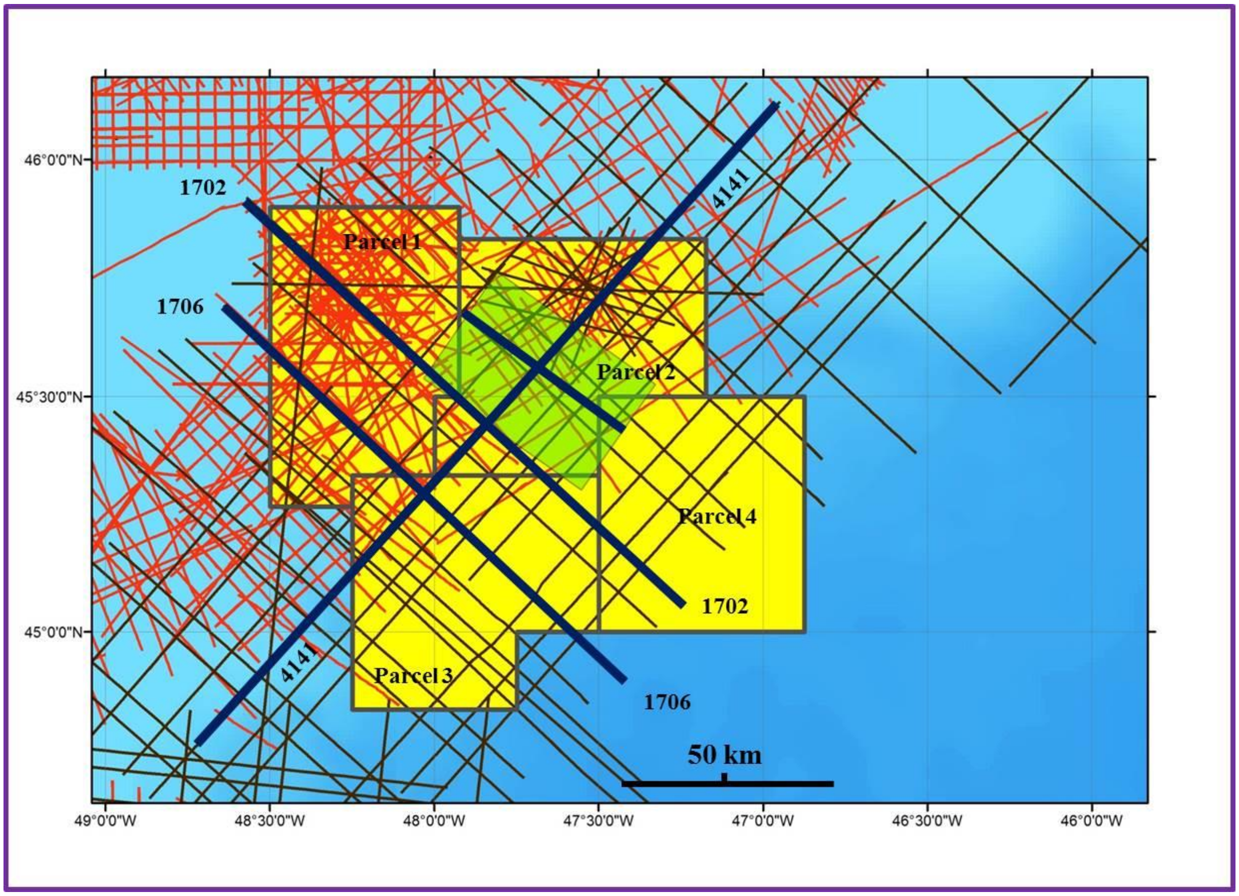


Figure 23. Location, seismic coverage of CFB parcels and of seismic lines used to illustrate this section. In red is released vintage seismic coverage and in black is released modern seismic coverage. The green rectangle represents the released 3D seismic survey. The dark blue thick lines show the locations of the seismic sections discussed in the evaluation of petroleum potential of parcels 1 to 4 (see also Figure 22).

The regional seismic dip line 1706 oriented NW-SE is used to illustrate the basin setting and petroleum potential of Parcel 1 (Figures 25 and 26). The line starts on unlicensed lands, crosses into Parcel 1 just south of Bonnition H-32 and north of St. George J-55 wells, passes through the parcel's central part, crosses into the southern part of Parcel 2, then enters the northern part of Parcel 3 and terminates in the southern part of Parcel 4. In Parcel 1, this dip line starts on shelf in 90 m of water, exits the parcel in the upper slope at approximately (1600 m WD) and continues in the adjacent parcel on the lower slope. Recorded and processed in 2001, the line has excellent quality, allowing structural and stratigraphic interpretations of the synrift and post rift sequences.

The line shows the deformation style in the northern part of the Carson Basin where major, basement involved, down-to-basin listric faults, large rollovers, rotated blocks and salt cored anticlines are present and contain successions aged from Late Triassic to Tertiary.

A deep crustal basin-bounding fault, which is probably the bounding fault of the Carson Basin, is interpreted in the western part of the parcel. The Salar Ridge (SR) delineated by one antithetic fault and one major synthetic fault is mapped immediately in the downthrown side of the bounding fault (Figures 23 to 26). The Bonnition H-32 and St. George J-55 wells are located in the vicinity of the SR. Their exact positions within the half graben seen northwest of SR are illustrated in interpreted seismic lines given by Solvason (2006) in her doctoral thesis. Both wells terminated in the Rankin Formation, but the Late Jurassic source rock intervals were eroded by the Tithonian Unconformity (Figure 17).

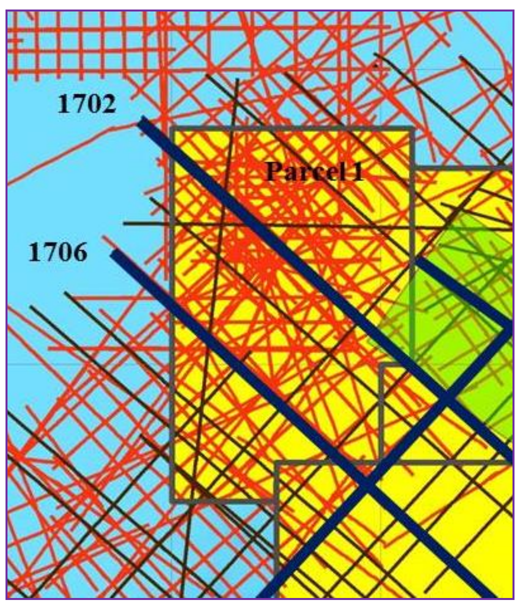


Figure 24. Location, seismic coverage of CFB Parcel 1 and of the representative seismic lines 1702 and 1706.

Two deeply rooted salt diapirs located in the footwall of the bounding fault, are the main structural features interpreted in Parcel 1 (Figures 25 and 26). Structural, stratigraphic and combination traps are created by these salt diapirs. Several culminations of these salt bodies create local anticlines in Tertiary beds. Basement tilted blocks may form the bottom of these diapirs but the prerift basement is poorly imaged and can only be ghosted beneath the massive salt intrusions. Two drape-over anticlines containing several Late Cretaceous and Early Tertiary successions separated by unconformities create large traps. Older Early Cretaceous and Jurassic synrift successions are present and structured inside salt withdrawal synclines where source rocks are probably present. Several possible sandstone fan traps with associated bright amplitude reflectors and gas chimneys can be identified on the shelf and continental slope (Figures 25 and 26). Prominent, superimposed fans are seen on these lines.

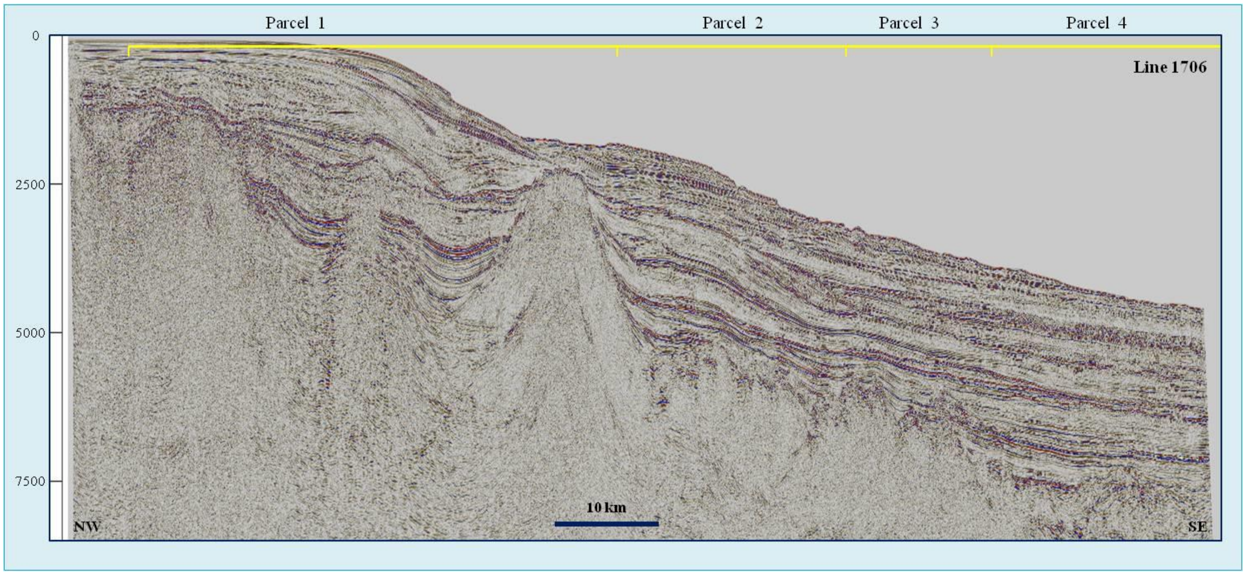


Figure 25. Uninterpreted regional 2D seismic line 1706 crossing all CFB NL13-02 parcels showing structural, tectonics and stratigraphic characteristics and possible drilling leads. For approximate line location see Figures 22 to 24. Line source: C-NLOPB.

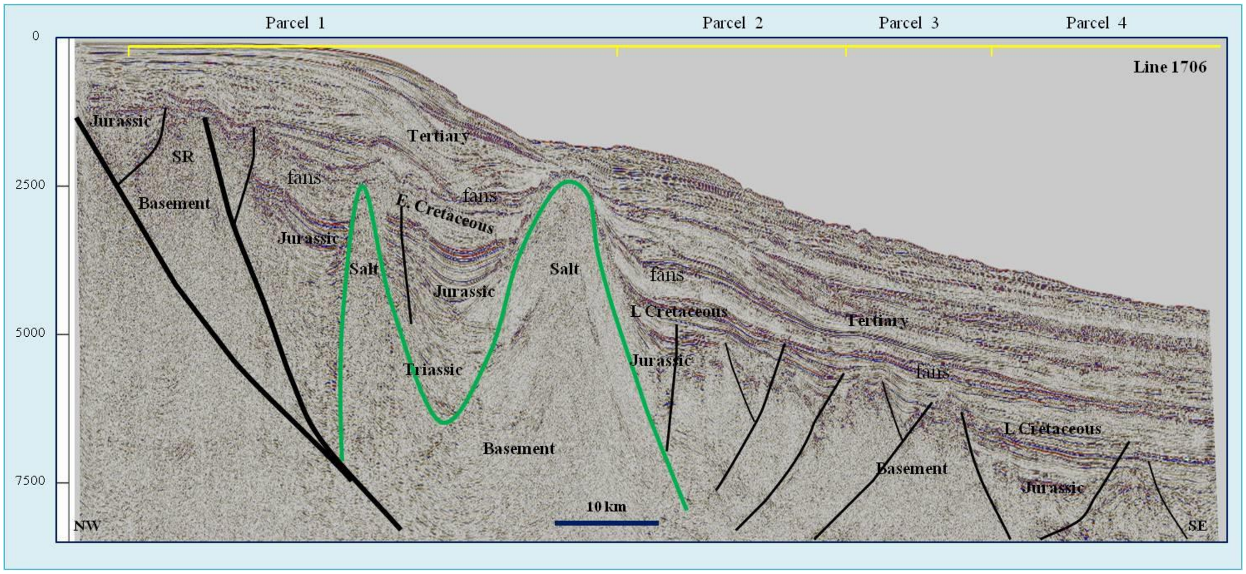


Figure 26. Interpreted regional 2D seismic line 1706 crossing all CFB NL13-02 parcels. The line shows the presence of several horsts, salt anticlines and rotated blocks in the synrift and large postrift sedimentary sequences. SR = Salar Ridge. For approximate line location see Figures 22 to 24. Line source: C-NLOPB.

These superimposed fans are also interpreted on the regional dip line 1702 (Figures 23, 30 and 31). The line shows several rotated blocks in the downthrown side of deep penetrating faults and two salt intrusions occupying the continental slope. The largest salt intrusion has triggered a drape over anticline within Cretaceous and Tertiary overlying beds. A very large syncline containing thick Jurassic and Early Cretaceous synrift infill and truncated by a major unconformity (Avalon Unconformity?) develops between the salt intrusions. The Late Jurassic rocks are sheltered by at least 3 km of sedimentary cover and are in the oil generation window.

The exploration leads visible on the two lines are 5 to 10 km wide and, if closed in the strike direction, can contain large volumes of hydrocarbons. The most encouraging characteristic for successful exploration of this parcel is the presence of a thick, Late Jurassic sequence located within inter-salt basins that may possibly contain high TOC, mature source rocks.

7.4. Petroleum Potential of Call for Bids NL13-02 Parcel 2. Parcel 2 is positioned in the northeastern part of the Carson Basin and holds 288,800 hectares (713,640 acres) which is 123.9 times larger than a GOM OCS tract. The parcel is located east of Parcel 1, north of parcels 3 and 4 and is surrounded to the east and north by unlicensed areas (Figures 22, 23 and 27). The parcel is situated south of the Jeanne d'Arc and Flemish Pass basins, on the Grand Banks slope, in 400 - 2700 m of water (mean 1700 m water depth).

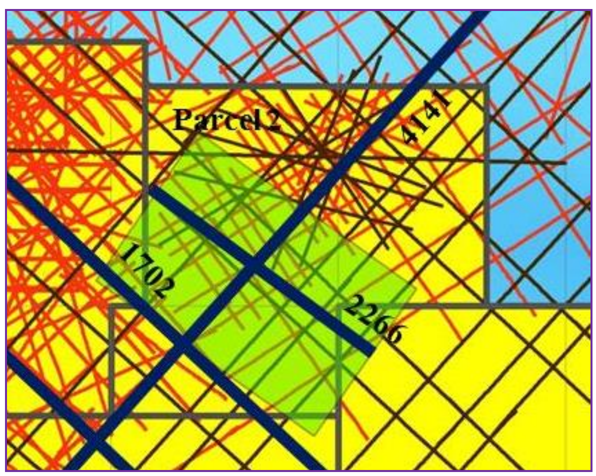


Figure 27. Location and seismic coverage of Parcel NL13-02-02 (Parcel 2)

The public domain and multi-client 2D seismic coverage is excellent in this parcel (Figures 20 and 26). The parcel has seen seismic acquisition with both 2D and 3D grids. While several excellent exploration leads were identified, the block remains undrilled. A large (1200 km^2) 3D survey with northwest-southeast inlines, collected by WesternGeco on behalf of Petro-Canada, covers the central part of the parcel where several large prospects and leads were identified on 2D grids (Figures 27, 28 and 28).

A large volume of public domain data is available in analog format from the C-NLOPB to interpret the subsurface in this parcel. Additional data in digital format is available from seismic brokers who can provide basemaps of multi-client data. Up to now, no exploration wells have been drilled in this parcel. Ties to Bonnition H-32 and St. George J-55 shelfal wells are possible using the seismic grid for identification of seismic markers, horizon correlation and subsurface mapping (Figures 7, 17, 22 and 27 and Table 1). Also, horizon ties in the Cretaceous and Tertiary intervals can be obtained from the IODP holes 1276 and 1277 (Figures 3, 5, 8 and 16) using industry lines combined with research reflection data (see section 6.8.).

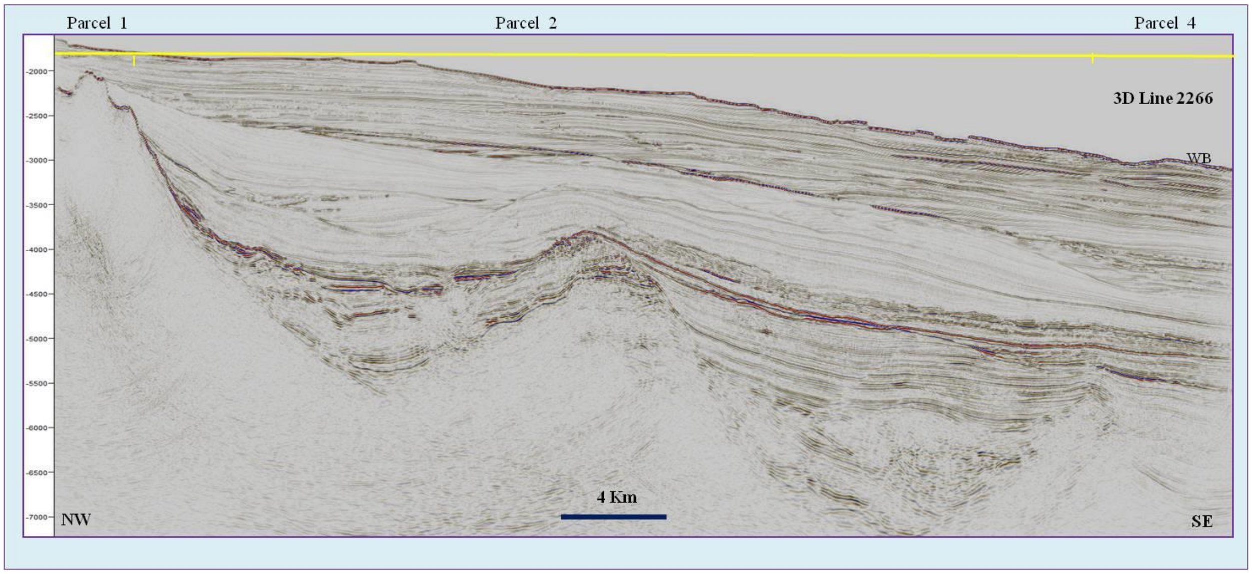


Figure 28. Uninterpreted 3D seismic line 2266 crosses the central part of Parcel 2 in a dip direction showing structural, tectonic and stratigraphic characteristics and possible drilling leads. The line starts in Parcel 1 and terminates in Parcel 4. A large rotated block, with probable salt involvement is imaged in the section. For approximate line location see Figure 23 and 27. Line source: C-NLOPB.

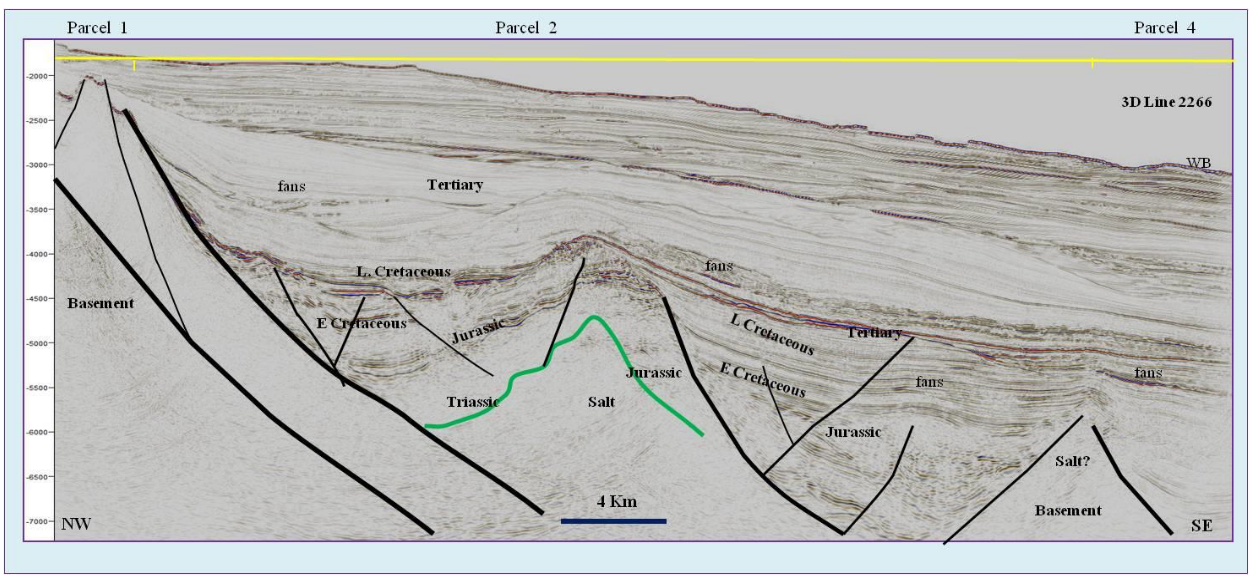


Figure 29. Interpreted 3D seismic line 2266 crossing the central part of Parcel 2 in a dip direction. Deep penetrating faults, a large rotated block, and two large half grabens containing synrift sedimentary successions are interpreted in the section. The Late Triassic salt may be involved in several of the anticlinal features seen on this section. For approximate line location see Figures 23 and 27. Line source: C-NLOPB.

As seismic data indicates, the majority of the parcel 2 is located on the middle slope where the basin is deep and complex and several solid exploration leads are identified. The hydrocarbon potential of Parcel 2 is captured using the regional 2D lines 1706 and 4141 and a 3D line extracted from the sole 3D seismic survey recorded in the area in 2001.

The regional dip line 1706 enters the parcel from the adjacent Parcel 1 and crosses Parcel 2 in its southern portion after which it exits into parcels 3 and 4 (Figures 22, and 27 to 29). In Parcel 2, seismic Line 1706 is located on the middle slope basin, down dip from a large Late Triassic salt feature. On the southeastern flank of this diapir, there are several tilted fault blocks bounded by down-to-shelf basement penetrating faults. The rotated blocks are covered by synrift successions that are better developed in the half grabens formed in the down dip side of the blocks. One horst is visible on this line but many others may be present in the parcel.

East of the major salt intrusion, several superimposed, large and asymmetrical sedimentary fans are present in the postrift successions (Figures 24 and 25). Some of these deepwater fans may be rich in lowstand deposited sandstone reservoirs. The occurrence of seismic amplitude variations and strong amplitude anomalies within these fans may indicate that they are composed of a variety of clastic deposits, some of which are hydrocarbon charged.

Regional 2D seismic line 4141 crosses the central part of CFB NL13-02 Parcel 2 in a strike direction (Figures 22, 27 to 29). The line enters the parcel from the unlicensed land in the northern Carson Basin and exits to the south into Parcel 3. The reflection line indicates the presence of numerous rotated basement blocks, several horsts, complex salt features including perched salt bodies, simple salt diapirs and numerous other structural highs found in both the synrift and postrift sedimentary sequences. A large graben is imaged in the area bordering parcels 2 and 3. A thick Jurassic sequence has accumulated in this graben located between the two large salt features. Several large sedimentary fans can also be interpreted on this strike line.

The 3D dip line (inline 2266) extracted from the Petro-Canada 3D survey acquired and processed in 2001, shows excellent data quality (Figures 27 to 29). The line is placed on the middle slope, approximately in the central part of the 3D volume and crosses the entire Parcel 2 with only a small spill over into adjacent parcels.

On its western side, the line images two basement involved listric faults (Figures 28 and 29). In the downthrown flank of the easternmost crustal detachment lies a 12 to 15 km-wide rotated basement block covered by synrift sedimentary deposits. A complex salt body may exist on top of the basement block. A large anticlinal feature forms and traps exist on both flanks of the rotated block. The Avalon Unconformity and probably the Base Tertiary Unconformity truncate the beds forming the flanks and apex of this anticlinal feature. Strong amplitude reflectors are seen in the interpreted Jurassic sequence filling the two large synclines placed on both sides of the rotated block.

The crestal part of the rotated block is occupied by a horst with Jurassic and Early Cretaceous cover that is overlain by a drape anticline containing postrift Late Cretaceous and Tertiary beds. Its northwestern flank is affected by a series of faults. For simplicity, only some faults are indicated in Figure 29. Numerous stratigraphic trapping possibilities are created by the complex erosional surfaces present on the northwestern flank of the feature. High amplitude anomalies are visible in some of the truncated reflectors. An incised valley (or canyon) can be interpreted in the middle of the western flank. Above the undulating unconformity surface, there are several large superimposed sedimentary fans or mass transport deposits (MTD).

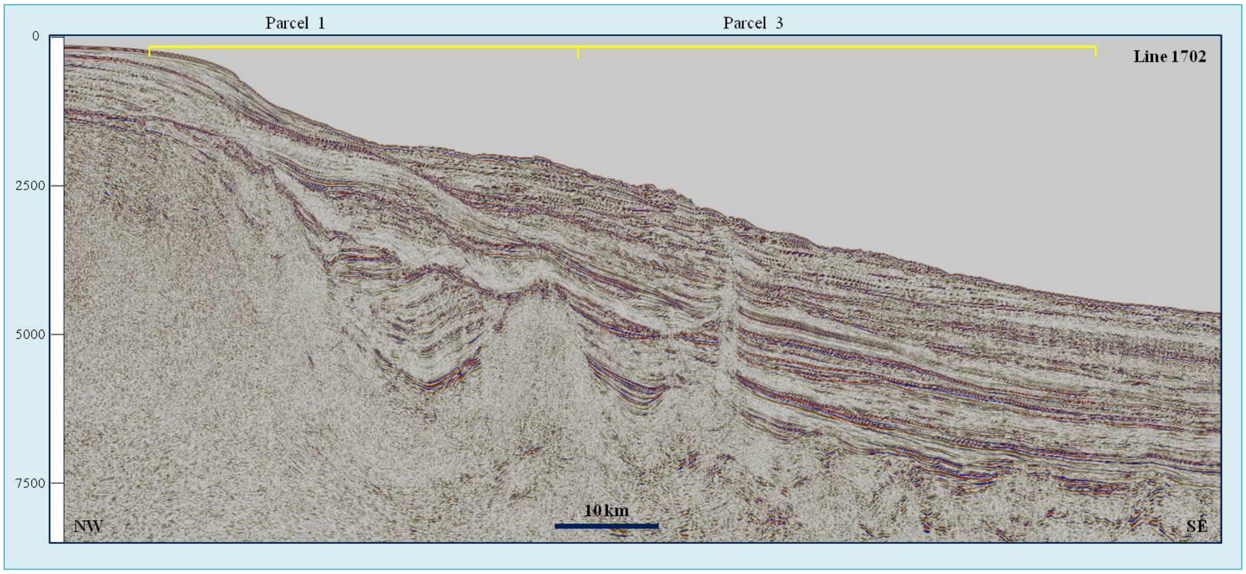


Figure 30. Uninterpreted 2D regional seismic line 1702 crossing CFB NL13-02 parcels 1 and 3 showing structural, tectonic and stratigraphic characteristics and possible drilling leads. For line location see Figures 22, 24 and 27. Line source: C-NLOPB.

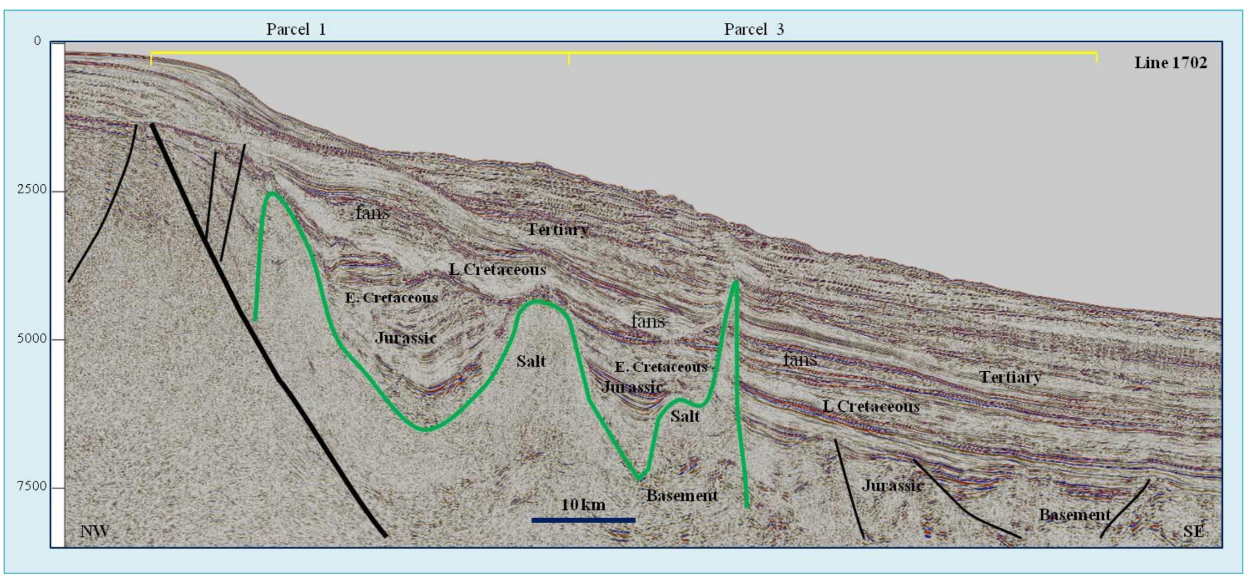


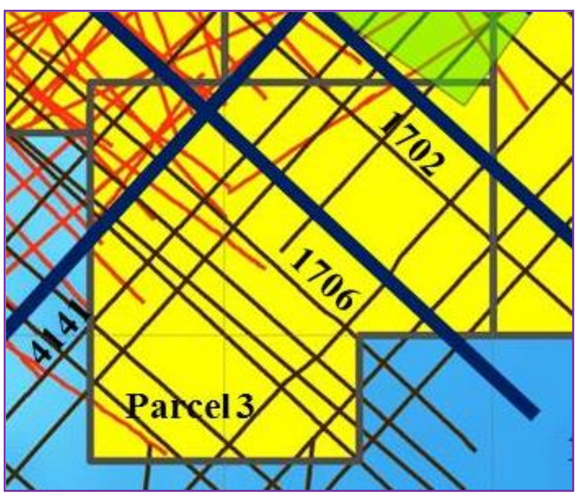
Figure 31. Interpreted 2D seismic line 1702 crossing CFB NL13-02 parcels 1 and 3 in a dip direction. Deep penetrating faults, a large rotated block, and two large half grabens containing synrift sedimentary successions are imaged in the section. Late Triassic salt may be involved in the three anticlinal features seen on this line. For approximate line location see Figure 22, 24 and 27. Line source: C-NLOPB.

The southeastern flank of this structure contains a deeper syncline, faulted in places. Several structural and stratigraphic trapping possibilities are imaged within this fault bounded syncline that may contain a thick Jurassic sequence. Multiple fans can be tracked above the postrift unconformity. This very large structure situated in Parcel 2, has many structural and stratigraphic similarities with several of the largest discoveries in the Jeanne d'Arc (e.g. Hibernia and Whiterose) and Flemish Pass (e.g. Mizzen) basins (Figures 28 and 29).

A separate structure that may be a rotated block or salt cored anticline lies in deeper water, at the border between parcels 2 and 4 (Figures 27, 28 and 29). The bounding faults are not well imaged on this line but there are many trapping possibilities on the apex and the western flank of the structure. Stratigraphic traps may also exist within the Late Cretaceous and Early Tertiary where bright amplitude reflectors and a gas chimney are present.

The two main leads illustrated on the lines crossing Parcel 2 are 5 to 8 km wide. If the leads are closed in the strike direction and surrounded by mature source rocks, they can contain large volumes of hydrocarbons. Medium size leads are also identified in the synclines located on the flanks of the leads, and above the postrift unconformity, as possible stratigraphically trapped sandstone fans.

7.5. Petroleum Potential of Call for Bids NL13-02 Parcel 3. Parcel 3 is the largest in this Call for Bids and covers 291,310 hectares (719,843 acres) which is equivalent to 125 GOM OCS tracts. Parcel 3 shares borders with parcels 1 and 2 to the north, Parcel 4 to the east and is surrounded by unlicensed lands to the west and south (Figures 22, 23 and 32).



This parcel, located on the continental slope and upper rise in 1400-3500 m of water (mean 2700 m) is well covered by several northwest/southeast grids of modern public domain, deep penetration data (Figures 20, 22, 23 and 32). Additional quality data in digital format may be available from seismic brokers owning recent Grand Banks seismic libraries. There is no exploration well drilled in this parcel. Ties to Bonnition H-22, St. George J-55 and Skua E-41 wells located on shelf and jump correlation to Flemish Pass wells can provide identification of seismic markers and allow subsurface mapping of Parcel 3.

Figure 32. Location and seismic coverage of Parcel NL13-02-03 (Parcel 3)

The structural, tectonic and stratigraphic characteristics and petroleum potential of Parcel 3 are shown by using: a) dip lines 1702 and 1706 (Figures 22 to 26, 30 and 31), and b) strike line 4141 (Figure 22, 33 and 34).

The dip line 1706 enters this parcel from Parcel 1, crosses the central part of the block and exits to the southeast into unlicensed land (Figures 25, 26 and 32). The line 1702 covers only a small portion of the parcel in its northeastern corner, after entering from Parcel 2 and exiting in Parcel 4 (Figure 30, 31 and 32).

The data quality is good in the Cretaceous and Tertiary intervals but deteriorates in the synrift sequence where Jurassic rock may have been preserved. Within the series of rotated blocks present on the continental slope within Parcel 3, there are two 5 to 6 km wide horsts that may have Late Jurassic-Early Cretaceous layers preserved on their tops and flanks (Figures 25, 26 and 32). Small synclines that may contain Late Triassic and Jurassic rocks (including source beds) are interpreted on the flanks of the horst. Drape anticlines and sedimentary fans can be seen in the postrift sequence.

The presence of salt halokinesis in the parcel is demonstrated by the presence in line 1702 of two complex salt intrusions separated by a 15 to 20 km wide syncline. This syncline confines a thick Jurassic and Early Cretaceous suite of synrift formations. There is a high probability that sandstone layers may be trapped on salt diapir flanks. A tall salt piercement is visible. This towering salt feature intrudes up to the Late Tertiary levels. Several sedimentary wedges on the flank and above noted salt features may provide stratigraphic traps. Strong amplitude seismic horizons are visible both updip and downdip of this vertical salt pillar (Figures 30 and 31).

On this line 1702 and other parallel dip lines (e.g.1706), data quality deteriorates on the lower slope, where several leads are represented by rotated blocks. More faulting should be affecting the economic basement but their direction and extent is hard to interpret on line 1706 that only covers the northeastern corner of the Parcel 3 (Figures 25, 26 and 32). Several rotated blocks and a horst can be interpreted on Line 1706. Salt may be involved in some of the deeper blocks and anticlines but data quality does not allow unambiguously interpreting salt walls and tops (Figures 25, 26, 30 and 31).

Strike line 4141 (oriented NE-SW) is located in the northwestern part of Parcel 3. The line runs parallel to the slope of the Carson Basin (Figures 32, 33 and 34). Data quality is poor under several regional unconformities and especially under the Jurassic high amplitude sequence. The seismic horizons are distorted by the presence of at least one water bottom canyon and of several mounded Tertiary deposits (fans or MTD?). There is no doubt that more faulting and salt pillows are present under the large syncline that straddles parcels 2 and 3 (Figures 33 and 34).

Several saucer shaped features are mapped within the Early Cretaceous and Tertiary rock successions, probably formed due to a combination of fan deposition, slope detachment and erosion by water bottom currents. A few of the interpreted salt diapirs and salt pillows have associated flank traps and drape anticlines.

Possible hydrocarbon leads in NL12-03 Parcel 3 include salt anticlines, rotated fault blocks, horsts, minibasin flanks and sedimentary fans (Figures 25, 26, 30, 31, 33 and 34). Most likely high TOC, mature Late Jurassic source rocks are present in the deeper synclinal kitchens found in this parcel. On this strike line and the previously described dip lines, the structural closures are 3-5 km wide and if they are well developed in the perpendicular direction, they constitute significant drilling leads in the parcel.

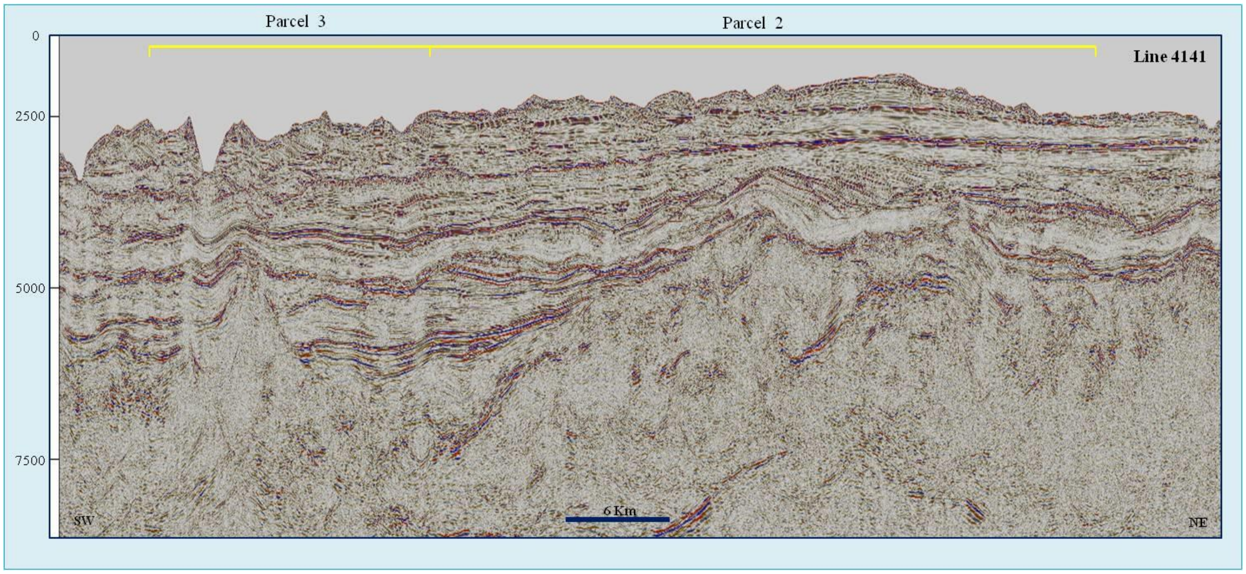


Figure 33. Uninterpreted 2D seismic line 4141 crossing the central part of CFB NL13-02 parcels 2 and 3 in a strike direction. For line location see Figures 22, 23, 24, 27and 32. Line source: C-NLOPB.

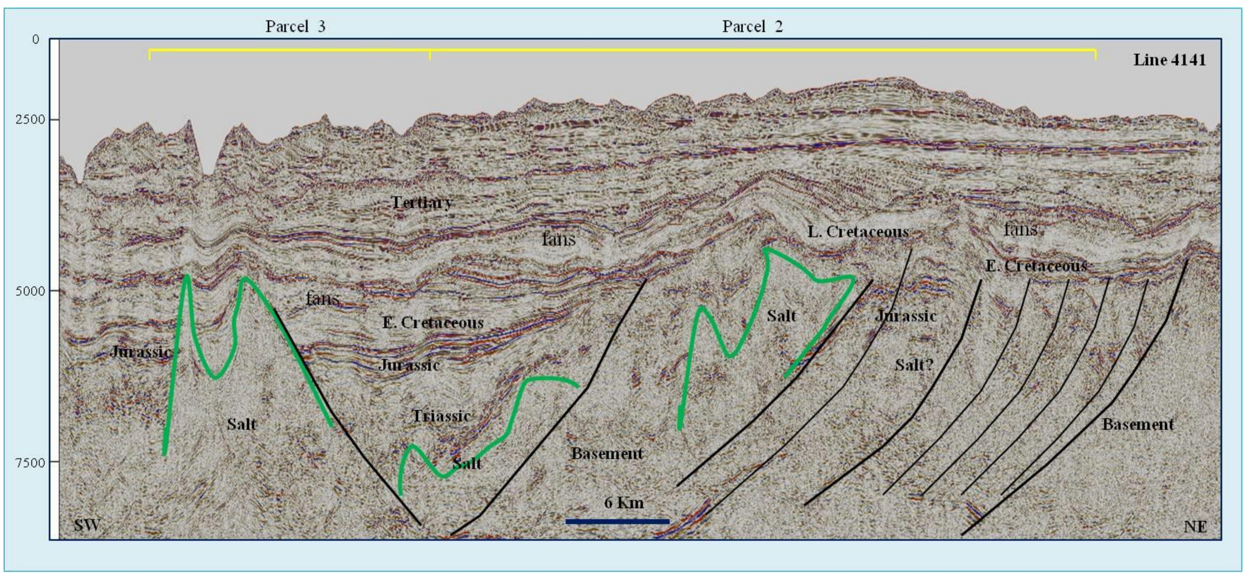


Figure 34. Interpreted regional 2D seismic line 4141 crossing the central part of CFB NL13-02 Parcel 2 and the northwestern corner of Parcel 3 in a strike direction. The line shows the presence of numerous rotated basement blocks, several horsts, complex salt features with associated salt anticlines, perched salt bodies and numerous other structural highs found in both the synrift and postrift sedimentary sequences. A large local depocenter where a thick Jurassic sequence is accumulated lies between the two large salt features and is imaged in the area bordering the parcels. Several large sedimentary fans can also be interpreted on this strike line. For approximate line location see Figures 22, 23, 24, 27and 32. Line source: C-NLOPB.

7.6. Petroleum Potential of Call for Bids NL13-02 Parcel 4. Parcel 4 covers 272,425 hectares (673,177 acres) in the northeastern part of the Carson Basin. The parcel's area is 116.9 times bigger than the standard GOM OCS tract. The parcel borders on Parcel 2 and unlicensed lands to the north, unlicensed deepwater area to the east and south and parcels 2 and 3 to the west

(Figures 22, 23 and 35). This parcel is located on the lower slope and rise, in 2100-3700 m of water (mean 3000 m).

No wells were drilled on this parcel. Seismic ties to all four of the Carson Basin wells on shelf can be made using the post-1998 grid of modern regional lines. For the postrift sequence only, the seismic horizons can also be correlated using IODP sites 1276 and 1277. Seismic coverage is good in the western part of the parcel but there are no publicly released lines extending into the easternmost part. Additional data in digital format may be available from seismic brokers (Figures 22, 23 and 35).

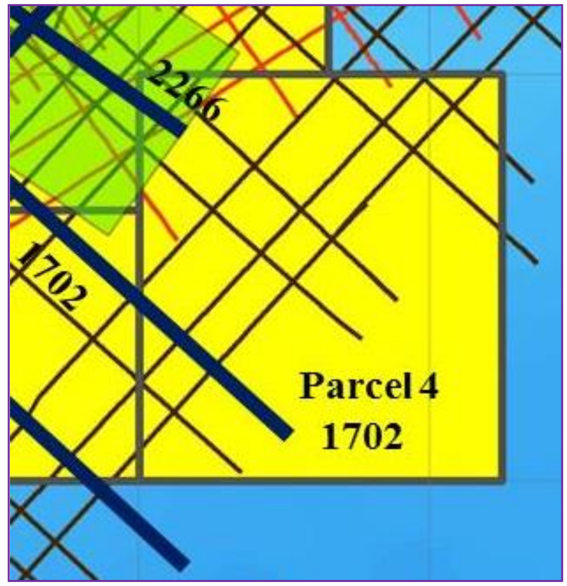


Figure 35. Location and seismic coverage of Parcel NL13-02-04 (Parcel 4).

The structural, tectonic and stratigraphic characteristics and petroleum potential of Parcel 4 is illustrated using the regional dip line 1706 (Figure 35). The data quality is generally good on this line but the quality deteriorates within the synrift sequence. The prerift unconformity is not well imaged, however the younger unconformities can be easily tracked (Figure 25).

Line 1706 enters Parcel 4 on its western side after crossing a small portion of Parcel 3 (Figures 22, 23 and 35). Considerable thickness of synrift and postrift successions including deepwater sandstone reservoirs and Late Jurassic shale formations should exist in the parcel. The seismic line shows the presence of a Late Triassic-Late Jurassic syncline bounded by two faults dipping in opposite direction and located between two horst blocks (Figures 25 and 26).

A 4 to 5 km wide horst block is imaged in the central part of Parcel 4, which may have Late Jurassic to Early Cretaceous units preserved on its top. Similar sizeable horsts and drape anticlines may be present in the rest of the parcel that may form drillable leads. More seismic data acquisition is needed to define all leads and prospects in Parcel 4.

8. Prospects and Leads

Several considerable sized leads can be interpreted within the Late Jurassic to Early Tertiary basin fill in Parcels 1 to 4 of the Call for bids NL13-02 using the available seismic grid. The representative seismic lines discussed in this report (Figures 18, 19, 22 to 34) are part of a regular regional grid that together with other more irregular grids and the 3D survey (covering mostly Parcel 2) should allow adequate recognition and mapping of prospects and leads located in the four parcels.

With the limited 2D lines available, only several large leads were identified and discussed in each of the four parcels. Additional seismic coverage obtained from seismic vendors or oil companies will help interested companies to confirm the prospects and leads indicated in Section 7. It is evident that several leads have significant lateral and vertical dimensions. Based on regional considerations, a multi-pay play is possible for some of these leads. Seismic mapping was beyond the scope of this report. Using the available 2D seismic grid (Figures 5, 7, 20 and 23) one can estimate that leads will be as large as 30-150 km^2.

The economic basement marker remains poorly imaged under the deformed salt, thick synrift infill and several erosional unconformities. Picking the top of basement is easier on several tilted blocks and horsts that all form good exploration leads, especially when surrounded by Jurassic synclines and covered by a Late Jurassic-Early Cretaceous sequence.

The typical hydrocarbon play is ***a structural high (extensional anticline, roll-over anticline, horst, rotated block, faulted anticline, salt anticline or drape anticline), with any of the Jeanne d'Arc, Hibernia, Avalon equivalent sandstones (primary target) and/or Late Cretaceous and Paleocene sandstone (secondary target) sourced from Late Jurassic marine source rocks.***

Undoubtedly the Carson Basin's main hydrocarbon play is structural. As shown by the seismic examples presented in this report, it involves porous mid-Jurassic to Early Cretaceous sandstones trapped by listric fault triggered rotated blocks and roll-over anticlines. Salt induced diapirs, perched salt highs, and turtle shell anticlines are also viable structural plays. Drape over anticlines within younger formations are associated with any of the structures noted. The representative seismic lines demonstrate that the basin is rich in extensional and salt related traps. Late Cretaceous and Tertiary sequences are less affected by normal faults but are deformed by salt diapirism and gravity sliding. Each of the four parcels contains large structural closures, where a 3.5-5.5 km deep well can test the synrift and postrift sandstone plays.

At shallower depth, within the Late Cretaceous-Early Tertiary successions, there are several large and very large fan-like features mappable on both 2D and 3D data. These lowstand stratigraphic units may be rich in sandstone and become important drilling targets. The sedimentary fans within postrift sequences provide a very attractive secondary play in this Call for Bids.

Source rocks are found at expulsion depths of 3000-6000 m beneath the mud line in salt evacuation mini-basins and deep basement grabens. A GSC study performed during 2000s estimated a high resource number for the basin. When a probabilistic resource number was calculated by adding several risk factors, a total of 5 Billion barrels of oil was estimated to be present in the slope and deep water Carson Basin (Wielens et al. 2004 and 2006; Baur et al., 2009). The Albian to Touronian interval contains high TOC, black shale units in the IODP holes drilled south of the Flemish Cap. These shales may be mature source rocks in deeper synclines of the Carson Basin (Section 6.1; Arnaboldi and Meyers, 2007).

Seals should not be a problem in the Carson Basin. Seismic amplitude variations and large gas chimneys are seen in the late Early Cretaceous, Late Cretaceous and Early Tertiary sequences. The main geological risks on these parcels are the quality of the reservoir and access to sufficient oil prone source rock. These risks should be mitigated by the large size of the structural leads identified in the parcels, some of which were described in Section 5. Almost certainly, the large and complex feature identified in Parcel 2 using both 2D and 3D seismic coverage can be considered a drillable prospect at this time.

9. Discussion

Exploration in the Carson Basin is at a very early frontier stage. Only four wells have been drilled in the shelfal part of the basin. Good reservoir intervals have been logged in the Bonnition H-32 and St. George J-55 wells, which have encountered Late Jurassic and Early Cretaceous sandstone reservoirs equivalent to Jeanne d' Arc, Hibernia and Avalon sandstones.

No source rock has been intersected to date as all drilled wells were located on basement or salt highs. On the continental slope and rise, the main source rock for the area, the Egret Member of the Rankin Formation or its equivalent, as well as any other Late Jurassic, high TOC source interval, should be present and in the mature range. This is particularly realistic within the basin's basement lows and inter-salt depressions.

CFB NL13-02 parcels are much larger when compared with a Gulf of Mexico standard tract varying between 116.9 times larger for Parcel 4 to 125 times larger for Parcel 3 (Table 2). Good post-1998, high quality 2D seismic coverage is publicly available in three of the parcels to image and map hydrocarbon traps. Additional high quality digital seismic data is available from seismic contractors. Parcel 2 has good 3D coverage and two other parcels have only minor 3D seismic coverage. The deepwater part of Parcel 4 needs further 2D seismic coverage.

Parcel	Basin	Area ha	Area Acres	GOM tracts
1	Carson	285,864	706,385	122.6
2	Carson	288,800	713, 640	123.9
3	Carson	291,310	719,843	125.0
4	Carson	272,425	673,177	116.9

Table 2. Call for Bids NL13-02 parcel size comparison.

Portions of these parcels, especially those located in deepwater, have never been explored. Numerous petroleum prospects and leads were identified with the modern and older seismic data and are waiting to be drilled and delineated. The parcels are in a region with large extensional and salt induced traps, known reservoirs, mature source rocks and proven migration paths. The parcels contain multiple reservoir targets within synrift/syndrift sandstone reservoirs at 3500-6500 m depth that can be drilled and tested using semi-submersible rigs or drill ships.

The recent large volume light oil discoveries in the intermediate deep waters of the neighboring Flemish Pass Basin at the Mizzen, Harpoon and especially Bay du Nord wells, shine a new light on this underexplored basin and on its favourable setting in the Late Jurassic marine source rock depositional belt.

The exploration risks are recognized in regard to reservoir quality, source rock quality, overpressure and fault sealing. About two dozen ELs located to the north in the Flemish Pass, Jeanne d'Arc and East Orphan basins and to the south in the Laurentian Basin are active and thus, exploration logistics can be coordinated and the costs of mob/demob drilling rigs or seismic vessels could be shared.

The cost of an offshore well in these parcels would likely be in the range of CAD $80-100 million depending on the depth to the target. Additional costs will be incurred to test an eventual discovery. Located in the deepwater and influenced by the warm Gulfstream current, the basin is less affected by the presence of ice or icebergs.

The Carson Basin in offshore Newfoundland is close to one of the world's largest oil markets comprising the industrial regions of Central Canada, Eastern United States and Western Europe. Canada is a country with a stable political and financial system and has a long tradition in oil and gas exploration.

The Canadian province of Newfoundland and Labrador has a marine petroleum exploration tradition of more than 45 years. The province has more than 15 years offshore oil production expertise that includes both Gravity Based Structures (at Hibernia and in construction for Hebron) and Floating Production Storage and Offloading Systems (Terra Nova and White Rose).

The Province obtains 33% of the nominal GDP from the oil and gas industry and is actively encouraging exploration of offshore areas especially in its less explored basins. There is a robust regulatory regime in the offshore area including HS&E. The Provincial Government encourages offshore exploration, however, safety of workers and protection of environment are paramount.

10. Conclusions

- Carson Basin, a divergent margin basin in our day, had a similar tectonic and structural evolution with adjacent Jeanne d'Arc and Flemish Pass basins, including basement extension, synrift sediment deformation and salt diapirism.
- Basin fill and stratigraphic divisions are also similar with the neighbouring Jeanne d'Arc and Flemish Pass basins and include equivalent reservoir and source rock formations.
- Deep basement penetrating faults, synthetic and antithetic intra-basement faults, highly rotated fault blocks, deep half-grabens and asymmetric horsts, mantle exhumation at the continental margins and high beta factors (3-5) provide strong evidence for the deepwater Carson Basin hyperextension.
- Numerous structural traps are interpreted in the Carson Basin associated with 1) basement fragmentation and rotation due to recurring rifting of the Atlantic Margin, 2) gravity detachment faulting, 3) minor transtension and inversion features, 4) differential subsidence and tilting, and 5) movement of the Argo/Osprey evaporites.
- Stratigraphic trap types such as slope and basin floor fan, sub-unconformity truncation, and canyon fill, abound on the continental slope and in the deeper basin.
- If quality reservoirs are discovered, these structural, stratigraphic and combination traps can hold reserves in the range of several Billion barrels.
- Based on relation and continuity of sedimentation with Grand Banks' basins, the Egret Member equivalent or/and other Late Jurassic source rocks should be present in the basin and when below 3000 m mud line, generate significant quantities of oil.
- The basin represents a lateral, parallel belt of the Late Jurassic source rock superhighway connecting the Canadian East Coast with Ireland and Northwest Europe offshore.
- Amplitude anomalies in the Cretaceous and Tertiary successions are related to several of the identified structural or stratigraphic traps.
- The oil of the Grand Banks is generally light sweet crude, with a density of 30-37° API, high percentage aromatics and low sulphur content.
- Cretaceous high TOC, source rocks of Albian and Cenomanian to Touronian age which were drilled in 2003 during the IODP Leg 210 (known as Cretaceous black shale, or Hatteras Formation) should be present in the basin and be mature in its deeper grabens.
- A structural high (roll-over anticline, horst, rotated block, faulted anticline, salt anticline or drape over anticline), with any of the Jeanne d'Arc, Hibernia, Avalon equivalent sandstones (primary target) and/or Paleocene sandstone (secondary target) sourced from Late Jurassic marine source rocks (mainly Egret Member equivalent) is the main hydrocarbon play in the basin.
- There is significant hydrocarbon potential beyond the basement ridge that marks the end of the shallow water Carson Basin, i.e. on the continental slope of the Grand Banks and in deeper water where numerous structural, stratigraphic and combination traps is interpreted on the seismic lines.
- Modern and older 2D and 3D coverage seismic coverage exists in the basin for evaluating potential drilling targets with the opportunity for new modern multiclient data to be acquired.

- GSC Atlantic researchers performed a basin modeling exercise based on seismic mapping during early 2000s to add to the exploration in this basin and assigned a potential resource of 5 Billion barrels oil to the deeper part of the basin.
- Interpretation of 2D and 3D seismic data in the parcels suggests that several undrilled leads as large as 50 to 150 km^2 (~ 12,350 to 37,000 acres) are present.
- Large parcels approximately 120 times bigger than the Gulf of Mexico standard block are offered, allowing oil companies entrance in an unexplored Atlantic margin basin, close to large producing fields and huge North American and European oil markets.
- This is a high-risk high-reward, frontier type of exploration not unlike the acreage already licensed in the Scotian and Laurentian deepwater basins and elsewhere on the Atlantic margins - the right type of play that can produce high impact, billion barrels - size discoveries.
- The Call for Bids NL13-02 Parcels 1 to 4 contains a variety of large and very large oil prospects and leads that can improve any Canadian and multinational oil company's portfolio of highly prospective drilling targets.

11. Further Reading

Ady, B. E., Whittaker, R. C., Alvey, A., Roberts, A. M, and N. J. Kusznir, 2010. A New Kinematic Plate Reconstruction between Ireland and Canada. Atlantic Ireland 2010 Conference, Dublin, Abstract and Poster.

Ady, B.E. and R.C. Whittaker, 2012. A New Kinematic Plate Reconstruction of the North Atlantic between Ireland and Canada. Atlantic Continental Margin, Third Conjugate Margins Conference 2012, Central and North Atlantic, Trinity College, Dublin, Ireland, Abstract Volume, p.2-3.

Agrawal, A., Williamson, M. A., Coflin, K. C., Dickie, K., Shimeld, J., McAlpine, K. D., Altheim, B., Thomas, F. J., Semper, T. and V. Pascucci, (1995). Sequence stratigraphic analysis of the Late Cretaceous-Palaeogene formations in the Jeanne d'Arc Basin, offshore eastern Canada, in J. S. Bell, Bird, T. D., Hillier, T. L., and P. L. Greener (eds.), Proceedings of the oil and gas forum 1995, Geological Survey of Canada Open File 3058, p. 241-245.

Ainsworth, N.R., Riley, L.A. and I.K. Sinclair, 2005. A Mid-Cretaceous (upper Barremian-Turonian) lithostratigraphic and biostratigraphic framework for the Hibernia oilfield reservoir sequence, Jeanne d'Arc Basin, Grand Banks of Newfoundland, In Petroleum resources and reservoirs of the Grand Banks, Eastern Canadian Margin, R. Hiscott and A. Pulham (ed.), GSC 43, p.45-72.

AMOCO Canada Petroleum Company Ltd. and Imperial Oil Ltd., 1973. Regional Geology of the Grand Banks, Bulletin of Canadian Petroleum Geology, Vol. 21.

Arnaboldi, M. and P. Meyers, 2007. Data report; multiproxy geochemical characterization of OAE-related black shales at Site 1276, Newfoundland Basin, In: Tucholke, B., Sibuet, J-C et al., Proceedings of the Ocean Drilling Program; scientific results; drilling the Newfoundland half of the Newfoundland-Iberia transect; the first conjugate margin drilling in a nonvolcanic rift; covering Leg 210; sites 1276 and 1277.

Arthur, K.R., Cole, D.R., Henderson G.G.L. and D.W. Kushnir, 1982. Geology of the Hibernia Discovery. AAPG Special Volumes, Volume M 32, The Deliberate Search for the Subtle Trap, p. 181 - 195.

Atkinson, I. and P. Fagan, 2000. Sedimentary Basins and hydrocarbon potential of Newfoundland and Labrador, Government of Newfoundland and Labrador Report 2000-01, available at http://www.nr.gov.nl.ca/nr/publications/energy/sedimentarybasins.pdf.

Austin J.A., Tucholke, B.E. and E. Uchupi, 1989. Upper Triassic-Lower Jurassic salt basin southeast of the Grand Banks, Earth and Planetary Science Letters, Volume 92, Issue 3-4, p. 357-370.

Bateman, J., 1995. Mineralogical and Geochemical Traits of the Egret Member Oil Source Rock (Kimmeridgian), Jeanne D'Arc Basin, Offshore Newfoundland, Canada, M Sc Thesis, Dalhousie University, 400p.

Baur, F., Wielens, H. and R. Littke, 2009. Basin and Petroleum Systems Modeling at the Jeanne d'Arc and Carson Basin offshore Newfoundland, Canada, SEG RECORDER, September 2009, p 28-36.

Beaudreau, R., Meehan P., Wishart, H. and S. Harding, 1986. Mesozoic stratigraphy of the Jeanne d'Arc Basin. Program and Abstracts, CSPG Convention, Canada's Hydrocarbon Reserves for the 21st Century. p. 28.

Bell, J.S. and Campbell, G.R., 1990. Petroleum resources: in Geology of the Continental Margin of Eastern Canada, Keen, M.J. and Williams, G.L. (Eds.), The Geology of North America, Vol. I-1, Geol. Sur. Can., p. 679-719.

Brown, D. M., McAlpine, K. D. and R. W. Yole, 1989. Sedimentology and sandstone diagenesis of Hibernia Formation in Hibernia oil field, Grand Banks of Newfoundland AAPG Bulletin, v. 73, p. 557-575.

Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB), 2013. Schedule of Wells - Newfoundland offshore area; http://www.cnlopb.nl.ca/well_intro.shtml.

Carter, J.E., Cameron, D., Wright R. and E. Gillis, 2013. New Insights on the Slope and Deep Water Region of the Labrador Sea, Canada, 75th EAGE Conference & Exhibition incorporating SPE EUROPEC, London 2013.

Cody, J., Hunter, D., Schwartz, S., Marshall, J., Haynes, S., Gruschwitz, K. and M. McDonough, 2012. A Late Jurassic Play Fairway Beyond the Jeanne d'Arc Basin: New Insights for a Petroleum System in the Northern Flemish Pass Basin, 32nd Annual GCSSEPM Foundation Bob F. Perkins Research Conference, Houston, Tx., p. 599-608.

Creaney, S. and B.H. Allison, 1987. An organic geochemical model of oil generation in the Avalon/Flemish Pass sub-basins, east coast Canada, Bull. Can. Petrol. Geol. 35, p. 12–23.

Dearin, A., 2007. Provenance of the Ben Nevis Formation sandstone, White Rose Field, Jeanne D'Arc Basin, Newfoundland, Canada, M Sc Thesis, Memorial University.

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.

Deemer, S., Jeremy, H., Solvason, K., Helen Lau, K.W. Louden K., Srivastava S and J.-C. Sibuet., 2009. Structure and development of the southeast Newfoundland continental passive margin: derived from SCREECH Transect 3, Geophys. J. Int. 178, p. 1004–1020.

Deptuck, M.E., MacRae, R.A., Shimeld, J.W., Williams, G.L. and R.A Fensome, 2003. Revised upper Cretaceous and Paleogene lithostratigraphy and Depositional history of the Jeanne d'Arc basin, offshore Newfoundland, Canada, American Association of Petroleum Geologists Bulletin, v. 87, no. 9, p. 1459-1483.

Desilva, N., 1999. Sedimentary basins and petroleum systems offshore Newfoundland and Labrador, In Petroleum Geology of Northwest Europe: Proceedings of the 5th Conference, Edited by A.J. Fleet and S.R. Boldy. Geological Society, London, p. 501-515.

Driscoll, N.W. and J.R. Hogg, 1995. Stratigraphic Response to Basin Formation: Jeanne d'Arc Basin, Offshore Newfoundland. In J. J. Lambiase (ed.) Hydrocarbon Habitat in Rift Basins, Geological Society Special Publication, n. 80, p.145-163.

Driscoll, N.W., Hogg, J.R., Karner, G.D. and N. Christie-Blick, 1995. Extensional Tectonics in the Jeanne d'Arc basin: Implications for the timing of Break-up Between Grand Banks and Iberia. In Scrutton, R.A., M. Stoker, G.B. Shimmield, and A.W. Tudhope (eds.) The Tectonics, Sedimentation and Palaeoceanography of the North Atlantic Region Geological Society Special Publication, n. 90, p.1-28.

Edwards, A., P., Moir, P. and Coflin, K., 2000. Structure and isopach maps of the Jeanne d'Arc Basin, Grand Banks, Newfoundland. Geological Survey of Canada, GSC Open File 3755

Edwards, T., Jauer, C.D., Moir, P. And Wielens, J.B.W. (Eds.), 2003: Tectonic Elements; East Coast Basin Atlas Series; Grand Banks of Newfoundland, Geological Survey of Canada, Open File 1795.

Enachescu, M. E., 1987. Tectonic and structural framework of the Northeast Newfoundland continental margin, Sedimentary basins and basin-forming mechanisms, (eds.) Beaumont, Christopher and Tankard, Anthony J. Basins of Eastern Canada and worldwide analogues, CSPG Memoir 12, Atlantic Geoscience Society Special Publication, vol. 5, p.117-146.

Enachescu, M. E., 1988. Extended basement beneath the intracratonic rifted basins of the Grand Banks of Newfoundland. Canadian Journal of Exploration Geophysics, 24, p.48-65.

Enachescu, M. E., 1992a. Enigmatic basins offshore Newfoundland, Canadian Journal of Exploration Geophysics, vol. 28, no. 1, p. 44-61.

Enachescu M.E., 1992b. Basement extension on the Newfoundland continental margin (Canadian east coast), in International Basement Tectonics Association Publication no. 7, pp. 227–256, ed. Mason R., Kluwer Academic Publishing, the Netherlands.

Enachescu, M.E., 2006. Call for Bids NL06-1, Parcels 1, 2 and 3, Regional Setting and Petroleum Geology Evaluation, DNR; http://www.nr.gov.nl.ca/nr/invest/cfb_nl06_01_jab.pdf.

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; http://www.nr.gov.nl.ca/nr/invest/cfb_nl07_2_hopedale.pdf.

Enachescu, M.E., 2009. Petroleum Exploration Opportunities in Jeanne d'Arc Basin, Call for Bids NL09-1, DNR; http://www.nr.gov.nl.ca/nr/invest/jeanne_d_arc_presentation.pdf.

Enachescu, M.E., 2010a. Petroleum Exploration Opportunities in Jeanne d'Arc Basin, Call for Bids NL10-01, DNR; http://www.nr.gov.nl.ca/nr/invest/enachescuNL10_1.pdf.

Enachescu, M.E., 2010b. Petroleum Exploration Opportunities in Flemish Pass and Orphan Basins, Call for Bids NL10-02 and NL10-03 (Area "C" Flemish Pass/Central Ridge), DNR; http://www.nr.gov.nl.ca/nr/invest/enachescuNL100203.pdf.

Enachescu, M.E., 2011. Petroleum Exploration Opportunities in Area "C" - Flemish Pass/North Central Ridge Call for Bids NL11-02; http://www.nr.gov.nl.ca/nr/invest/enachescu_NL1102Flemish.pdf

Enachescu, M.E., 2012a. Call for Bids NL12-02, Parcel 1, Petroleum Exploration Opportunities in the Flemish Pass Basin, Government of Newfoundland and Labrador Department of Natural Resources; http://www.nr.gov.nl.ca/nr/invest/energy.html

Enachescu, M.E., 2012b. Petroleum Exploration Opportunities in the Laurentian Basin, Offshore Newfoundland and Labrador Call for Bids NL12-01, DNR; http://www.nr.gov.nl.ca/nr/invest/CFB1201EnachescuComplete.pdf.

Enachescu, 2012c. Call for Bids NL12-01, Parcels 1 to 6, Petroleum Exploration Opportunities in the Laurentian Basin, Government of Newfoundland, DNR, http://www.nr.gov.nl.ca/nr/invest/cfb1201laurentianbasinenachescu.pdf.

Enachescu and Fagan, 2004. Newfoundland and Labrador Call for Bids NF04-01, Government of Newfoundland and Labrador, Department of Natural Resources, 35p, 20 figures; http://www.nr.gov.nl.ca/nr/invest/cfb_nl04_01_jab.pdf

Enachescu, M.E. and P. Fagan, 2005. Call for Bids NL05-01, Parcels 1, 2 and 3 Regional Setting and Petroleum Geology Evaluation; http://www.nr.gov.nl.ca/nr/invest/cfb_nl05_01_jabn.pdf

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

Enachescu, M.E. and P. Fagan, 2009. Petroleum Exploration Opportunities in Laurentian Basin, Call for Bids NL 09-2 Newfoundland and Labrador DNR, power point presentation, available athttp://www.nr.gov.nl.ca/nr/invest/final_laurentian_basin_presentation.pdf.

Enachescu, M.E. and J. Hogg, 2004. Compression modified extensional structures (CMES) of the Canadian Atlantic passive margin. CSPG/CSEG/CWLS Annual Convention, Calgary.

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

Enachescu, M.E., Harding, S.C. and D.J. Emery, 1994. Three-dimensional seismic imaging of a Jurassic paleodrainage system, Offshore Technology Conference Proceedings, Houston. OTC Paper 7390: p. 179-191.

Enachescu, M., Kearsey, S., Hardy, V., Sibuet, J-C., Srivastava, S., Hogg, J., Smee, J. and P. Fagan, 2005. New Insights in the Tectonic and Structural Evolution and Petroleum Systems of the Orphan Basin, Atlantic Canada. Extended Abstract, 8p, 7 fig., 2005 AAPG Conference, Calgary, Canada.

Enachescu, M.E, S. Kearsey, V. Hardy, J-C. Sibuet, J. Hogg, S. Srivastava, A. Fagan, T. Thompson and R. Ferguson, 2005. Evolution and Petroleum Potential of Orphan Basin, Offshore Newfoundland, and its Relation to the Movement and Rotation of Flemish Cap Based on Plate Kinematics of the North Atlantic, Gulf Cost Society of Sedimentary and Petroleum Mineralogists (GCSSEPM) Perkins Conference, Petroleum Systems of Divergent Continental Margin Basins, paper on CD-Rom, 25 figs, p. 75-131.

Enachescu, M., Hogg, J., Fowler, M., Brown, D., and I. Atkinson, 2010. Late Jurassic Source Rock Super-Highway on Conjugate Margins of the North and Central Atlantic (offshore East Coast Canada, Ireland, Portugal, Spain and Morocco), in Conjugate Margins II, Lisbon 2010, Metedo Directo, v. VIII, p. 79-82, HYPERLINK http://metododirecto.pt/CM2010/index.php/vol/article/view/243.

Enachescu, M.E, Foote, W., Atkinson, I and J. Hogg., 2012. 2012 Exploration and Production Update on the Mesozoic Basins, Newfoundland and Labrador, Atlantic Continental Margin, Central and North Atlantic Conjugate Margin Conference, Dublin.

Fagan, P., 2010. A Study of the Structural and Stratigraphic History of the Laurentian Basin, Offshore Eastern Canada, M Sc Thesis, Memorial University.

Foster, D.J. and A.G. Robinson, 1993. Geological History of the Flemish Pass Basin, Offshore Newfoundland, Bulletin of the AAPG, v.77, p. 588-609.

Fowler, M.G. and K.D. McAlpine, 1995. The Egret member, a Prolific Kimmeridgian Source Rock from Offshore Eastern Canada, In Source Rock Case Studies, B. Katz, (Ed.), Springer-Velag, p. 111-130.

Fowler, M.G. and M. Obermajer, 2001. Gasoline range and saturate fraction gas chromatograms of Jeanne d'Arc Basin crude oils, Geological Survey of Canada Open File Report #D3945.

Fowler, M.G., Snowdon, L.R., Stewart, K.R. and K. D. McAlpine, 1990. Rock-Eval/TOC data from nine wells located offshore Newfoundland. Open File 2271. Geol. Surv. Can. p. 72.

Fowler, M.G., Obermajer, M., Achal, S. and M. Milovic, 2007. Results of geochemical analyses of an oil sample from Mizzen L-11 well, Flemish Pass, offshore Eastern Canada, Geological Survey of Canada, Open File 5342, 3 p.

Funck, T., Hopper, J.R., Larsen, H.C., Louden, K.E., Tucholke, B.E. and W.S. Holbrook, 2003. Crustal structure of the ocean-continent transition at Flemish Cap: Seismic refraction results, J. Geophys. Res., 108, 2531.

Geological Survey of Canada (GSC) Atlantic, 2001. East Coast Basin Atlas Series, Grand Banks of Newfoundland Basin Atlas; Edwards, T; Moir, P; Coflin, K. GSC, Open File 3755, 2001, 1 CD-ROM, http://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/downloade.web&search1=R=212098.

GSC, 2013. Basin Data Base, Geological Survey of Canada, Atlantic, Dartmouth, N.S. http://basin.gdr.nrcan.gc.ca/index_e.php.

GeoArctic, 2013. Plate Reconstruction Project Final Report. Multi-client Report available on request.

Grant, A.C. (comp.), 1988. Depth to basement of the Continental Margin of Eastern Canada, Geological Survey of Canada, Map 1707A, scale 1:5,000,000, http://apps1.gdr.nrcan.gc.ca/mirage/db_results_e.php.

Grant, A.C. and K.D. McAlpine, 1990. The Continental margin around Newfoundland, 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. 239-292.

Grant, A. C., Jansa, L. F., McAlpine, K. D., and A. Edwards, 1988. Mesozoic-Cenozoic geology of the eastern margin of the Grand Banks and its relation to Galicia Bank, in G. Boillot, E. L. Winterer et al. (eds.), Proceedings of the Ocean Drilling Program, Scientific Results: College Station, TX, 103, p.787-807.

Harding S., 1988. Facies Interpretation of the Ben Nevis Formation in the North Ben Nevis M-61 Well, Jeanne D'Arc Basin, Grand Banks, Newfoundland Sequences, Stratigraphy, Sedimentology: Surface and Subsurface - Memoir 15, 1988, p. 291-306.

Haynes, S., McDonough, M., Gruschwitz, K. Johnson T. and E. Stacey, 2012. Mizzen - An Overview of the First Oil Discovery in the Flemish Pass Basin, East Coast Offshore Newfoundland 51

Hawkins, D., Dillabough, G., Ruelokke M. and F. Way, 2008. Small Field Development and Subsea Tieback Technologies, OTC Paper 19270, 12p.

Hiscott, R.N., 2007. Paleoflow directions of Albian basin-floor turbidity currents in the Newfoundland Basin. In Tucholke, B.E., Sibuet, J.-C. and Klaus, A. (Eds.), Proc. ODP, Sci. Results, 210, College Station, TX (Ocean Drilling Program), p. 1-27.

Hiscott, R. N., Wilson, R. C. L., Harding, S. C., Pujalte, V., D. Kitson, 1990a. Contrasts in Early Cretaceous depositional environments of marine sandbodies, Grand Banks - Iberia, Bulletin of Canadian Petroleum Geology, 38, p. 203-214.

Hiscott, R.N., Wilson, R.C.L., Gradstein, F.M., Pujalte, V., Garcia-Mondejar, J., Boudreau, R.R. and H.A. Wishart, 1990b. Comparative stratigraphy and subsidence history of Mesozoic rift basins of North Atlantic. AAPG Bulletin, 74, p. 60-76.

Hiscott, R.N., Marsaglia, K.M., Wilson, R.C.L., Robertson, A.H.F., Karner, G.D., Tucholke, B.E., Pletsch, T. and R. Petschick, 2008. Detrital sources and sediment delivery to the early post-rift (Albian–Cenomanian) Newfoundland Basin east of the Grand Banks: results from ODP Leg 210. Bull. Can. Pet. Geol., 6(2), p. 69–92.

Hogg, J. R. and M. E. Enachescu, 2004. Deepwater Mesozoic and Tertiary Depositional Systems Offshore Nova Scotia and Newfoundland, Atlantic Canada, Deep-Water Sedimentary Systems of Arctic and North Atlantic Margins Conference, Abstract and Presentation, Stavanger, Norway.

Hogg, J. R. and M. E. Enachescu, 2007. Exploration Potential of the Deepwater Petroleum Systems of Newfoundland and Labrador Margins, 2007, OTC #19053.

Hogg J. and M. Enachescu, 2008. The Mesozoic Atlantic Canada offshore margin: History of exploration, production and future exploration potential. Central Atlantic Conjugate Margin Conference, Halifax, NS.

Hopper, J.R., Funck, T., Tucholke, B.E., Larsen, H.C., Holbrook, W.S., Louden, K.E., Shillington and D. H. Lau, 2004. Continental breakup and the onset of ultraslow seafloor spreading off Flemish Cap on the Newfoundland rifted margin, Geology, 32, p. 93–96.

Hopper, J.R., Funck, T., Tucholke, B.E., Louden, K.E., Holbrook, W.S. and H.C. Larsen, 2006. A deep seismic investigation of the Flemish Cap margin: implications for the origin of deep reflectivity and evidence for asymmetric break-up between Newfoundland and Iberia, Geophys. J. Int., 164, p. 501-515.

Huang, Z., Williamson, M., Fowler, M. and D. McAlpine, 1994. Predicted and measured petrophysical and geochemical characteristics of the Egret Member oil source rock, Jeanne d'Arc Basin, offshore eastern Canada: Marine and Petroleum Geology, v. 11, no. 3.

Hurley, T. J., Kreisa, R. D., Taylor, G. G. and W. R. L. Yates, 1992. The Reservoir Geology and Geophysics of the Hibernia Field, Offshore Newfoundland: Chapter 4, M 54 Giant Oil and Gas Fields of the Decade 1978-1988.

Jansa, L. F., Gradstein, F. M., Williams, G. L. and W.A.M. Jenkins, 1977. Geology of the Amoco Imp. Skelly A-l Osprey H-84 well, Grand Banks, Newfoundland. Pap. Geol. Surv. Can., 77-21:17.

Jansa, L.F. Bujak, J.P. and G.L. Williams, 1980. Upper Triassic salt deposits of the western North Atlantic, Canadian Journal of Earth Sciences 17, 547–5.

Kaderali, A., Jones, M. and J. Howlett, 2007. Whiterose seismic with well data constraints: A case history, The Leading Edge 26, p. 742-754.

Karner, G.D., Johnson, C.A. Mohn, G. and G. Manatschal, 2012. Depositional Environments and Source Distribution across Hyper-Extended Rifted Margins of the North Atlantic: Insights From the Iberia-Newfoundland Margin, Third Central & North Atlantic Conjugate Margins Conference Trinity College Dublin, 22-24 August 2012.

Keen, C.E. and B. de Voogd, 1988. The continent-ocean boundary at the rifted margin off eastern Canada: new results from deep seismic reflection studies, Tectonics, 7, p. 107-124.

Keen, M J and G. Williams, (eds.), 1990. Geology of the continental margin of eastern Canada, Geological Survey of Canada, Geology of Canada Series no. 2, 1990; Alt Series Geological Society of America, Geology of North America Series VOL I-1.

Keen, C. E., Boutilier, R., de Voogd, B., Mudford, B. and M. E. Enachescu, 1987. Crustal geometry and extensional models for the Grand Banks, eastern Canada: constraints from deep seismic reflection data, in Sedimentary Basins and Basin-Forming Mechanisms, edited by C. Beaumont & A. Tankard, vol. 12, p. 101-115, Canadian Society of Petroleum Geologists.

Keen, C.E., Loncarevic, B.D., Reid, I., Woodside, J., Haworth, R.T., and H. Williams, 1990. Tectonic and geophysical overview, Chapter 2, In Geology of the Continental Margin of Eastern Canada, M.J. Keen and G.L. Williams, (eds.), Geological Survey of Canada, The Geology of Canada, p. 33-85.

Kidston, A.G., Brown, D.E., Smith, B.M. and B. Altheim, 2005. The Upper Jurassic Abenaki Formation, offshore Nova Scotia: A seismic and geologic perspective, Canada Nova Scotia Offshore Petroleum Board, Halifax, Nova Scotia, 168 p., http://www.cnsopb.ns.ca..

Lau, K.W.H., Louden, K.E., Funke, T., Tucholke, B.E., Holbrook, W.S., Hopper, J. and H.C. Larsen, 2006a. Crustal structure across the Grand Banks-Newfoundland basin continental margin (Part I)-results from a seismic refraction profile, Geophys. J. Int., 167, p. 127-156.

Lau, K.W.H. et al., 2006b. Crustal structure across the Grand Banks Newfoundland basin continental margin (Part II)-results from a seismic reflection profile, Geophys. J. Int., 167, p. 157-170.

Louden, K.E., 2002, Tectonic evolution of the East Coast of Canada, CSEG Recorder, vol.27, no.2, p. 37-48.

Louden, K.E. and J. Hall, 2000. The MARIPROBE Program: a Canadian MARGINS Initiative, GeoCanada 2000, Conference CD, Abstract No. 187, 4 p.

Lowe, D.G., P.J. Sylvester, and M.E. Enachescu, 2011. Provenance and paleodrainage patterns of Upper Jurassic and Lower Cretaceous synrift sandstones in the Flemish Pass Basin, offshore Newfoundland, east coast of Canada: AAPG Bull., v. 95. no. 8., p. 1295-1320.

Magoon, L.B., T. L. Hudson, and K. E. Peters, 2005. Egret-Hibernia(!), a significant petroleum system, northern Grand Banks area, offshore Eastern Canada: AAPG Bulletin, v. 89, no. 9, p. 1203-1237.

Marsaglia, K.M., Pavia, J.A. and S.J. Maloney, 2007. Petrology and provenance of Eocene-Albian sandstones and grainstones recovered during ODP Leg 210: implications for passive margin (rift-to-drift) sandstone provenance models. In Tucholke, B.E., Sibuet, J.-C., and Klaus, A. (Eds.), Proc. ODP, Sci. Results, 210: College Station, TX (Ocean Drilling Program), p. 1-47.

Marsaglia, K.M., Arnaboldi, M., Hiscott, R.N., Pletsch, T.K., Robertson, A., Shirai, M., Wilson, R.C., Engstrom, A., Manatschal, G., Shryane, T., Leckie, R.M. and Ocean Drilling Program Leg 210 Shipboard Scientific Party, 2004. Results from recent deep-water drilling in the Newfoundland Basin, east of Hibernia Field. AAPG Bull, 88(13):92.

Mayers, P.A. and M. Arnaboldi, 2011. Organic Geochemical Characterization of Mid-Cretaceous Black Shales from ODP Site 1276 in the Newfoundland Basin, American Geophysical Union, Fall Meeting 2011, abstract #PP21C-1812.

McAlpine, K. D. 1989. Lithostratigraphy of fifty-nine wells, Jeanne d'Arc Basin Open-File Report - Geological Survey of Canada.

McAlpine, K.D., 1990. Mesozoic stratigraphy, sedimentary evolution, and petroleum potential of the Jeanne d'Arc basin, Grand Banks of Newfoundland. Geological Survey of Canada Paper 89-17, p.1-50.

McCracken, J.N., A. Haager, K.I. Saunders and B.W. Veilleux, 2000, Late Jurassic Source Rocks in the northern Flemish Pass Basin, Grand Banks of Newfoundland: CSEG Conference Abstracts GeoCanada 2000, Abstract 1151, Calgary.

Mackay, A.H. and A. J. Tankard. 1990. Hibernia Oil Field-Canada, Jeanne d'Arc Basin, Grand Banks, Offshore Newfoundland , AAPG Special Volumes, Structural Traps III: Tectonic Fold and Fault Traps, p.145-175.

Noseworthy, D., 2003. Depositional evolution and structural synthesis of the B marker (limestone) member, Whiterose formation, Jeanne d'Arc, offshore Newfoundland, M Sc Thesis, Memorial University of Newfoundland.

NS Department of Energy (NSDE), 2011. ATLAS: Play Fairway Analysis Offshore Nova Scotia, Halifax, Nova Scotia; http://www.novascotiaoffshore.com/analysis.

Oakey, G.N. and S.A., Dehler, 2004. Atlantic Canada Magnetic Map Series: Atlantic Canada, Geological Survey of Canada, Open File 1813, 1:3000000.

Pena dos Reis, R.P. and N.L.V. Pimentel, 2009. The Lusitanian Basin (Portugal): Tectono-Sedimentary Evolution and Petroleum Systems. The Lusitanian Basin (Portugal) and Its North-American Counterparts - A Comparative Approach. AAPG European Annual Conference. AAPG Search and Discover Article #90099.

Péron-Pinvidic, G., Manatschal, G., Minshull, T.A. and D.S Sawyer, 2007. Tectonosedimentary evolution of the deep Iberia-Newfoundland margins: evidence for a complex breakup history, Tectonics, 26(2):TC2011.

Pinheiro, L.D., Wilson, R. C. L.; Pena dos Reis, R., Whitmarsh, R.B. and A. Ribeiro, 1996. The western Iberia margin; a geophysical and geological overview. Proceedings of the Ocean Drilling Program, Scientific Results, 149, p. 3-23.

Powell, T.G., 1985. Paleogeographic implications for the distribution of upper Jurassic source beds: Offshore Eastern Canada, Bulletin of Canadian Petroleum Geology, vol.33, no.1, p.116-119.

Rees, M.E. and D.A. Spratt, 2005. An Integrated Fault Seal Study of the Hebron/Ben Nevis Oilfield, Offshore Newfoundland, in Hiscott, R.; Pulham, A. (eds.) Petroleum Resources and Reservoirs of the Grand Banks, Eastern Canadian Margin, Spec. Paper 43, Geol. Assoc. of Canada. p. 146-153.

Reston, T., 2009. The structure, evolution and symmetry of the magma-poor rifted margins of the North and Central Atlantic: a synthesis, Tectonophysics, 468, p. 217-237.

Richards, F.W., Vrolijk, P.J., Gordon, J.D. and B.R. Miller, 2010. Reservoir connectivity analysis of a complex combination trap: Terra Nova Field, Jeanne d'Arc Basin, Newfoundland, Canada, In Jolley, S.J.; Fischer, Q.J., Ainsworth, R.B., Vrolijk, P.J., Delisle, S., Reservoir Compartmentalization. Special Publication 347. Geological Society, London, p. 333-355.

Robertson, A.H.F., 2007. Evidence of continental breakup from the Newfoundland rifted margin (Ocean Drilling Program Leg 210): Lower Cretaceous seafloor formed by exhumation of subcontinental mantle lithosphere, and the transition to seafloor spreading. In Tucholke, B.E., Sibuet, J.-C., and Klaus, A. (Eds.), Proc. ODP, Sci. Results, 210: College Station, TX (Ocean Drilling Program), p. 1-69.

Shillington, D.J., Holbrook, W.S., Van Avendonk, H.J.A. Tucholke, B.E., Hopper, J.R., Louden, K.E., Larsen, H.C. and G.T Nunes, 2006. Evidence for asymmetric nonvolcanic rifting and slow incipient oceanic accretion from seismic reflection data on the Newfoundland margin, J. Geophys. Res., 111:B09402.

Sibuet, J.-C. and Tucholke, B. E. 2012. The geodynamic province of transitional lithosphere adjacent to magma-poor continental margins. In Conjugate Divergent Margins. Edited by W. U. Mohriak, A. Danfort, P. J. Post, D. E. Brown, G. C. Tari, N. Nemcock and S. T. Sinha. 369, Geological Society of London, Special Publications.

Sibuet, J.C., Rouzo S. and S. Srivastava, 2011. Plate tectonic reconstructions and paleo-geographic maps of the central and north Atlantic oceans, NSPFA Atlas Annex13.

Sibuet, J.-C., Srivastava, S. and G. Manatschal, 2007. Exhumed mantle forming transitional crust in the Newfoundland-Iberia Rift and associated magnetic anomalies. *J. Geophys. Res.*, 112:B06105.

Sibuet, J. C., Srivastava, S.P., Enachescu, M. and G.D. Karner, 2007. Early Cretaceous motion of Flemish Cap with respect to North America; implications on the formation of Orphan Basin and SE Flemish Cap-Galicia Bank conjugate margins, Geological Society Special Publications, p. 63-76.

Sibuet, J-C., Rouzo, C. and S. Srivastava, 2013. Revue Canadienne de Science de la Terre, December 2012, Volume 49 (12), p. 1395-1415.

Sinclair, I.K., 1988. Evolution of Mesozoic-Cenozoic sedimentary basins in the Grand Banks area of Newfoundland and comparison with Falvey's (1974) rift model, Bulletin of Canadian Petroleum Geology, v. 36; no. 3; p. 255-273.

Sinclair, I.K., 1993. Tectonism: the dominant factor in mid-Cretaceous deposition in the Jeanne d'Arc Basin, Grand Banks. Marine and Petroleum Geology, v. 10, p. 530-549.

Sinclair, I.K., 1995. Sequence stratigraphic response to Aptian-Albian rifting in conjugat margin basins: A comparison of the Jeanne d’Arc basin, offshore Newfoundland, and the Porcupine basin, offshore Ireland. In: Scrutton, R.A., Stoker, M.S., Shimmield, G.B Tudhope, A.W. (Eds.), The Tectonics, Sedimentation and Paleooceanography of the North Atlantic Region. Geological Society Special Publication, vol. 90, p. 29–49.

Sinclair, I. K., McAlpine, K. D., Sherwin, D. F. and N. J. McMillan, 1992. Part 1: Geological Framework, in Petroleum resources of the Jeanne d'Arc Basin and environs, Grand Banks, Newfoundland, Geological Survey of Canada paper 92-8, p. 1-38.

Sinclair, I.K., Shannon, P.M., Williams, B.P.J., Harker, S.D. and J.G. Moore, 1994. Tectonic control on sedimentary evolution of three North Atlantic borderland Mesozoic basins. Basin Research, v. 6, p. 193-218.

Sinclair, I.K., Evans, J.E., Albrecthsons, T.A. and L.J. Sydora, 1999. The Hibernia Oil Field - Effects of episodic tectonism on structural character and reservoir compartmentalization, in Fleet, A.J., and Boldy, S.A.R. (eds.), Petroleum Geology of Northwest Europe, Proceedings of the 5th Conference, p. 517-528.

Skaug, M., Kerwin, K and J. Katay, 2001. Reservoir Development Plan for the Terra Nova Field, Paper OTC 13024. 30 April–3 May 2001, Offshore Technology Conference, Houston, Texas, p. 9.

Solvason, K.L.M., 2006. Crustal structure and formation of the Southeast Newfoundland continental margin, PhD thesis, Memorial University of Newfoundland, St. John's, NL.

Solvason, K.L.M., Hall, J., Enachescu, M., Demeer, S., Helen Lau K. W., Louden, K., Holbrook, S., Hopper, J. R., Larsen, H. C. and B. Tucholke, 2005. Carson and Salar Basins and the Newfoundland-Iberia Connection AAPG Search and Discovery Article #90039©2005 AAPG Calgary, Alberta.

Srivastava, S. P. and C. R. Tapscott, 1986. Chapter 23 - Plate kinematics of the North Atlantic, in P. R. Vogt, B. E. Tucholke (eds.), The Geology of North America, Volume M, The Western North Atlantic Region: Geological Society of America, p. 379-404.

Srivastava, S. and J. Verhoef, 1992. Evolution of Mesozoic sedimentary basins around the north Central Atlantic: a preliminary plate kinematic solution, in J. Parnell (ed.), Basins on the Atlantics seaboard: Petroleum geology, sedimentology and basin evolution: Geological Society, Special publications, London, p. 397-420.

Srivastava, S. and J.-C. Sibuet, 1992. A joint AGC and IFREMER geophysical cruise to the Newfoundland and Orphan Basins, Cruise Report CSS Hudson 92-22 Mission Erable (Unpublished Report), 121 p., Geological Survey of Canada, Dartmouth, N.S. and Institut Français de Recherche pour l'Exploitation de la Mer, Centre de Brest.

Srivastava, S. P., Roest, W. R., Kovacs, L. C., Oakey, G., Levesque, S., Verhoef, J. and R. Macnab, 1990a. Motion of Iberia since the Late Jurassic: results from detailed aeromagnetic measurements in the Newfoundland Basin, Tectonophysics, 184, p. 229-260.

Srivastava, S.P., Roest, W.R., Kovacs, H L., Schouten C. and K. Klitgord, 1990b. Iberian plate kinematics: A jumping plate boundary between Eurasia and Africa, Nature, v.344, p.756-759.

Srivastava, S.P., Sibuet, J-C., Cande, S., Roest, W.R. and I.D. Reid, 2000. Magnetic evidence for slow seafloor spreading during the formation of the Newfoundland and Iberian margins. Earth and Planetary Science Letters, 182, p. 61-76.

Tankard, A. J. and H. J. Welsink, 1987. Extensional tectonics and stratigraphy of the Hibernia oil field, Grand Banks, Newfoundland. AAPG Bulletin. v. 71, p. 1210-1 232.

Tankard, A.J. and H.J. Welsink, 1988. Extensional tectonics, structural styles and stratigraphy of the Mesozoic Grand Banks of Newfoundland. in: Manspeizer , W. (ed.), Triassic-Jurassic Rifting: Continental Break-up and the Origin of the Atlantic Ocean and Passive Margins, Part A. Development in Geotectonics, v 22, p.129-165.

Tankard, A.J. and H.J. Welsink, 1989. Mesozoic extension and styles of basin formation in Atlantic Canada. in: Tankard, A.J. and Balkwill, H.R. (eds.), Extensional Tectonics and Stratigraphy of the North Atlantic Margins, American Association of Petroleum Geologists, Memoirs, 46, p. 175–195.

Tankard, A.J., and H.R. Balkwill, 1989. Extension tectonics and stratigraphy of the North Atlantic Margins: Introduction, Chapter 1, in A.J. Tankard and H.R. Balkwill, (eds.), Extensional Tectonics and Stratigraphy of the North Atlantic Margins, AAPG Memoir 46, p. 1-6.

Tankard, A.J., Welsink. H.J. and W.A.M. Jenkins, 1989. Structural styles and stratigraphy of the Jeanne d'Arc Basin, Grand Banks of Newfoundland. In Tankard A.J., and Balkwill, H.R. (eds.), Extensional Tectonics and Stratigraphy of the North Atlantic Margins. AAPG Memoir 46, p. 265-282.

Taylor, G.C., Best, M.E., Campbell, G.R., Hea, J.P., Henao, D. and R.M. Procter, 1992. Part II–Hydrocarbon potential, in Petroleum resources of the Jeanne d'Arc basin and environs, Grand Banks, Newfoundland: Geological Survey of Canada, Paper 92-8, p. 39-48.

Tucholke, B.E., Austin, J.A. Jr. and E. Uchupi, 1989. Crustal Structure and Rift-Drift Evolution of the Newfoundland Basin, in Extensional Tectonics and Stratigraphy of the North Atlantic Margins, Vol. 46, p. 247–263, eds. Tankard, A.J. & Balkwill, H.R., AAPG Memoir, Tulsa, OK, USA.

Tucholke, B.E. et al., 2004. Proc. Ocean Drill. Program, Init. Repts., Vol. 210 [Online]. Available from: http://www-odp.tamu.edu/publications/210_IR/210ir.htm.

Tucholke, B.E., Sibuet, J.-C., and Klaus, A. (Eds.), 2007a. Proc. ODP, Sci. Results, 210: College Station, TX (Ocean Drilling Program).

Tucholke, B. and J.-C., Sibuet, 2007. Leg 210 synthesis: tectonic, magmatic and sedimentary evolution of the Newfoundland-Iberia rift, Proceedings of the Ocean Drilling Project Scientific Results, 210, p. 1-56, http://www-odp.tamu.edu/publications/210_SR/synth/synth.htm

Tucholke, B., Sawyer, D., and J.-C. Sibuet, 2007b. Breakup of the Newfoundland-Iberia rift, in Imaging, mapping and modelling continental lithosphere extension and breakup, edited by G. Karner, G. Manatschal, & L. Pinheiro, vol. 282, p. 9-46, Geological Society of London, Special Publications.

Van Avendonk, H.J.A., Holbrook, W.S., Nunes, G.T., Shillington, D.J., Tucholke, B.E., Louden, K.E., Larsen, H.C. and J.R Hopper, 2006. Seismic velocity structure of the rifted margin of the eastern Grand Banks of Newfoundland, Canada, J. Geophys. Res., 111(B11):B11404.

Van Avendonk, H. J., Lavier, L. L., Shillington, D. J. and G. Manatschal, 2009. Extension of continental crust at the margin of the eastern Grand Banks, Newfoundland, Tectonophysics, 468(1–4), p. 131–148.

Verhoef, J. and S.P. Srivastava, 1989. Correlation of sedimentary basins across the North Atlantic as obtained from gravity and magnetic data, and its relation to the early evolution of the North Atlantic. AAPG Memoir, 46, p. 131-147.

Verhoef, J., Roest, W. R., Macnab, R., Arkani-Ahmed, J. and Members of the Project Team, 1996. Magnetic anomalies of the Arctic and North Atlantic oceans and adjacent land areas. Open file 3125. Geological Survey of Canada.

von der Dick, H. Meloche, J.D. Dwyer, J. and P. Gunther, 1989. Source-rock geochemistry and hydrocarbon generation in the Jeanne d'Arc basin, Grand Banks, offshore eastern Canada, Journal of Petroleum Geology **12**, p. 51-68.

Weissenberger, J.A.W., R.A. Wierzbicki, and N.J. Harland, 2006, Carbonate sequence stratigraphy and petroleum geology of the Jurassic Deep Panuke Field, offshore Nova Scotia, Canada, in P.M. Harris and L.J. Weber, eds., Giant Hydrocarbon reservoirs of the World: From rocks to reservoir characterization and modeling, AAPG Memoir 88/SEPM Special Publication, p. 395-431.

Welford, J. K. and J. Hall, 2007. Crustal structure across the Newfoundland rifted continental margin from constrained 3-D gravity inversion, Geophysical Journal International, 171, p. 890-908.

Welford, J.K., Smith J.A., Demeer S., Srivastava S.P. and J.-C. Sibuet, 2010. Structure and rifting evolution of the northern Newfoundland Basin from Erable multichannel seismic reflection profiles across the southeastern margin of Flemish Cap, Geophysical Journal International 180 (3), 976-998.

Wielens, J.B.W., Jauer C.D. and G.N. Oakey, 2002. New insights into petroleum potential from multidisciplinary data integration for the Carson Basin, Grand Banks of Newfoundland: Open-File Report - Geological Survey of Canada, Report: 3025.

Wielens, H., Jauer, C. and G.L. Williams, 2004. Data synthesis for the Carson Basin, offshore Newfoundland: Results of 4-D petroleum system modelling Geological Survey of Canada, Open File 4739.

Wielens, J.B.W., C.D. Jauer and G.L. Williams, 2006. Is there a viable petroleum system in the Carson and Salar Basins, offshore Newfoundland? Journal of Petroleum Geology, Vol. 29(4), p. 303-326.

Wierzbicki R. and N. Harland, 2004. Diagenetic Model: Deep Panuke Reservoir, Offshore Nova Scotia, Canada, Search and Discovery Article #40136.

Wilcox, L.B., Couturier, D.E. and M.D. Hewitt, 1991. The integration of geophysical, geological and well test studies into a reservoir description for the Terra Nova oilfield offshore eastern Canada, Topic 11, Proceedings of the Thirteenth World Petroleum Congress. John Wiley & Sons, Chichester, p. 1–9.

Williams, G.L., Ascoli, P., Barss, M.S., Bujak, J.P., Davies, E.H., Fensome, R.A. and M.A. Williamson, 1990. Biostratigraphy and related studies: Offshore eastern Canada. Chapter 3 in M.J. Keen and G.L. Williams (eds.), Geology of the Continental Margin off Eastern Canada. Geological Survey of Canada, Geology of Canada, no. 2, p. 89-137 (also Geological Society of America, The Geology of North America, v. I-1).

Williamson, M.A., 1992. The subsidence, compaction, thermal and maturation history of the Egret Member source rock, Jeanne d'Arc Basin, offshore Newfoundland. Bulletin of Canadian Petroleum Geology, v. 40, p. 136-150.

Williamson, M.A., Bateman, J., McAlpine K.D. and M.G. Fowler, 1996. Cyclicity in the Egret Member (Kimmeridgian) oil source rock, Jeanne d'Arc Basin, offshore eastern Canada, Marine and Petroleum Geology, V. 13, No. 1, p. 91-105.

Withjack, M.O., Schlische, R W., and P E Olsen, 2012. Development of the passive margin of Eastern North America: Mesozoic rifting, igneous activity, and drifting, in Roberts, D.G., and Bally, A.W., eds., Regional Geology and Tectonics, Volume 1B—Phanerozoic Rift Systems and Sedimentary Basins, New York, Elsevier, p. 301-335.

Whittaker, R. C., Ady, B.E. and K. Stolfova, 2011. A New Deformable Plate Reconstruction of the Irish - Newfoundland Conjugate Margin, CSPG Convention, Calgary, AB, Abstract.

Ziegler, P.A. 1989. Evolution of the North Atlantic; An overview extensional tectonics and stratigraphy of the North Atlantic margins. In Extensional tectonics and stratigraphy of the North Atlantic margins, Edited by A.J. Tankard, and H.R. Balkwill. AAPG Memoir, 46, p. 111-129.

Additional sources of information:

C-NLOPB website HYPERLINK: http://www.cnlopb.nl.ca

Newfoundland and Labrador Department of Natural Resources website HYPERLINK: http://www.nr.gov.nl.ca/nr/energy/index.html

C-NSOPB HYPERLINK http://www.cnsopb.ns.ca

IODP Information HYPERLINKS
http://www-odp.tamu.edu/publications/citations/cite210.html
http://www-odp.tamu.edu/publications/prelim/210_prel/210toc.html

GeoArctic, 2013 North Atlantic Plate Deformation Report

GeoArctic, 2013. A New Kinematic Plate Reconstruction between Ireland and Canada, Final Project Report, May, 2013 © *Irish Shelf Petroleum Studies Group (ISPSG) and Nalcor Energy*

According to the report foreword "This study was carried out by GeoArctic Ltd and its subcontractors for PIPCO RSG Limited". The project was jointly funded by the Irish Shelf Petroleum Studies Group (ISPSG) of the Petroleum Infrastructure Programme (PIP) and Nalcor Energy, on behalf of the Offshore Geoscience Data Program (OGDP) with the Government of Newfoundland and Labrador. The report is copyrighted by ISPG and Nalcor Energy.

More information on this kinematic (deformable) plate reconstruction project and its deliverable can be obtained by contacting Nalcor Oil and Gas (http://www.nalcorenergy.com/oil-and-gas.asp), NL Department of Natural Resources (http://www.nr.gov.nl.ca/nr/energy/index.html), both in St John's, NL, Petroleum Infrastructure Programme (PIP) (http://www.pip.ie/page/1) in Dublin, Ireland or GeoArctic (http://www.geoarctic.com) in Calgary, AB.

End Report