

# Petroleum Exploration Opportunities in Saglek Basin, Area “C”-Labrador Offshore Region Call for Bids NL11-03



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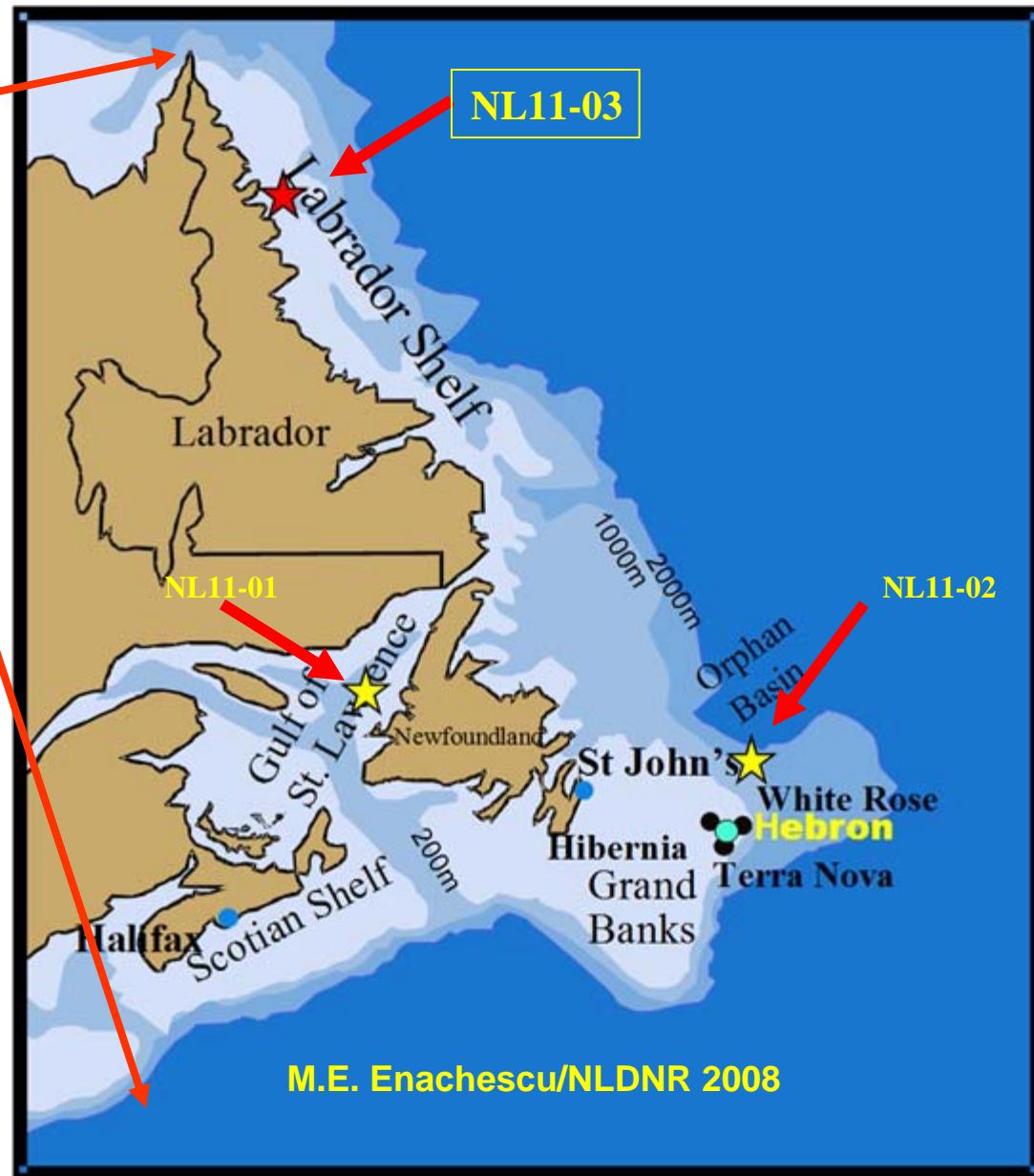
On Behalf of NL DNR  
October 2011





## Acknowledgements

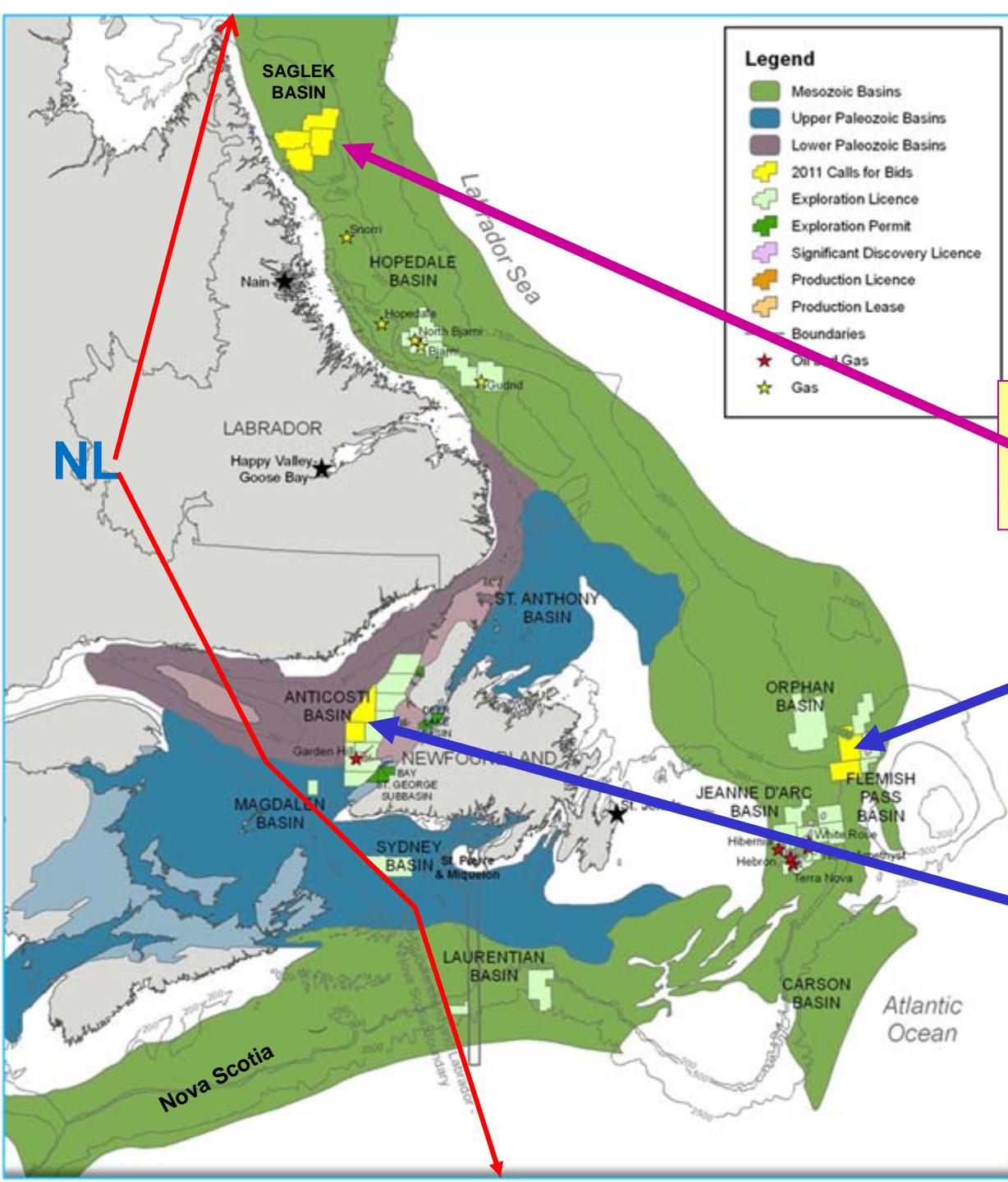
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- Ian Atkinson, Phonse Fagan;
- Dianne Noseworthy of C-NLOPB;
- Dave Brown, CNSOPB
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- This work could not have been performed without valuable information provided by C-NLOPB and Government of Newfoundland and Labrador Department of Natural Resources.



★ = position of CFB NL11-03 Parcels

# **Presentation Content**

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- 4. Petroleum Geology of Labrador Basins**
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- 8. Conclusions**



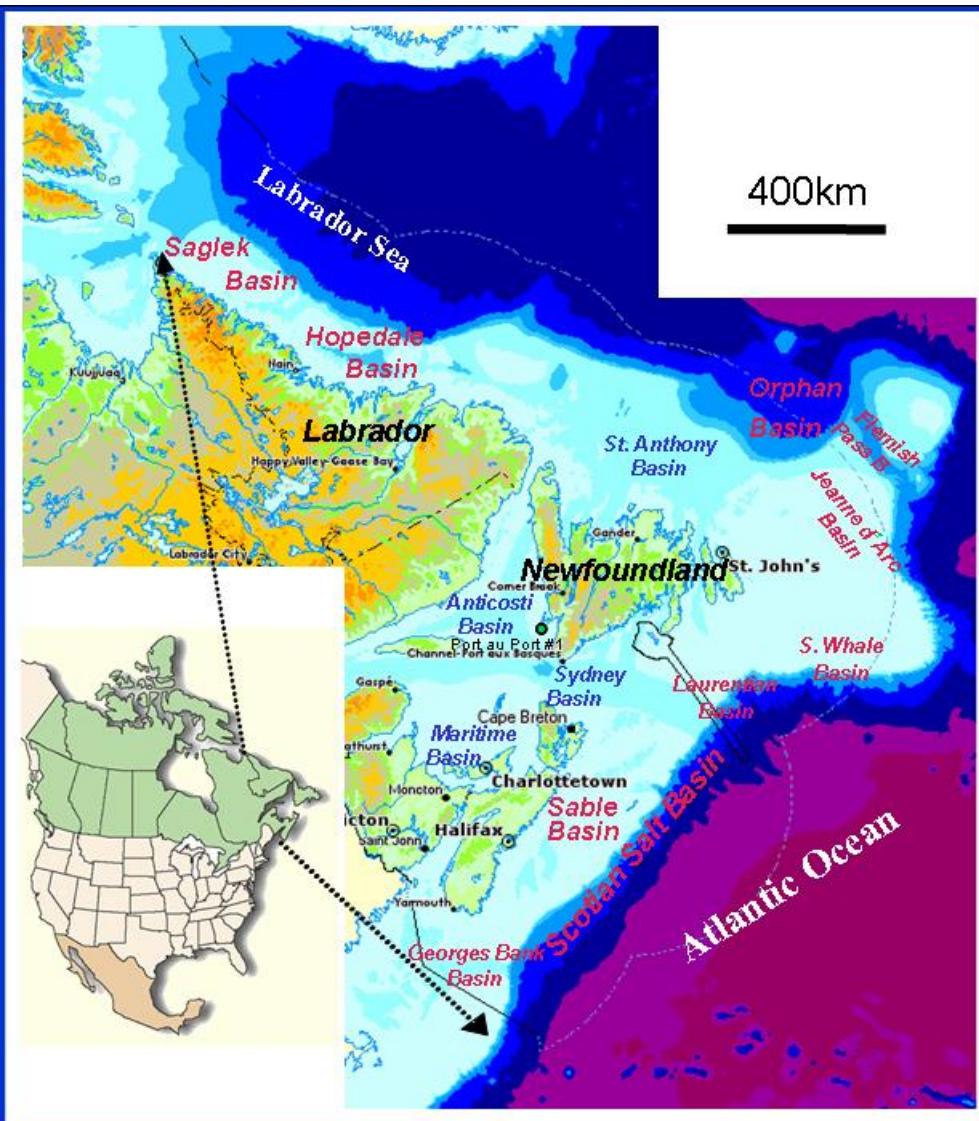
# NL CFB 2011: Three CFB in four basins

- CFB NL11-03  
Saglek Basin

- CFB NL11-02  
Flemish Pass/  
Orphan/Central Ridge

- CFB NL11-01  
Anticosti Basin

# Atlantic Canada Offshore Basins



Blue Text: Paleozoic Basins

Magenta Text: Mesozoic Basins

## NL Mesozoic Basins

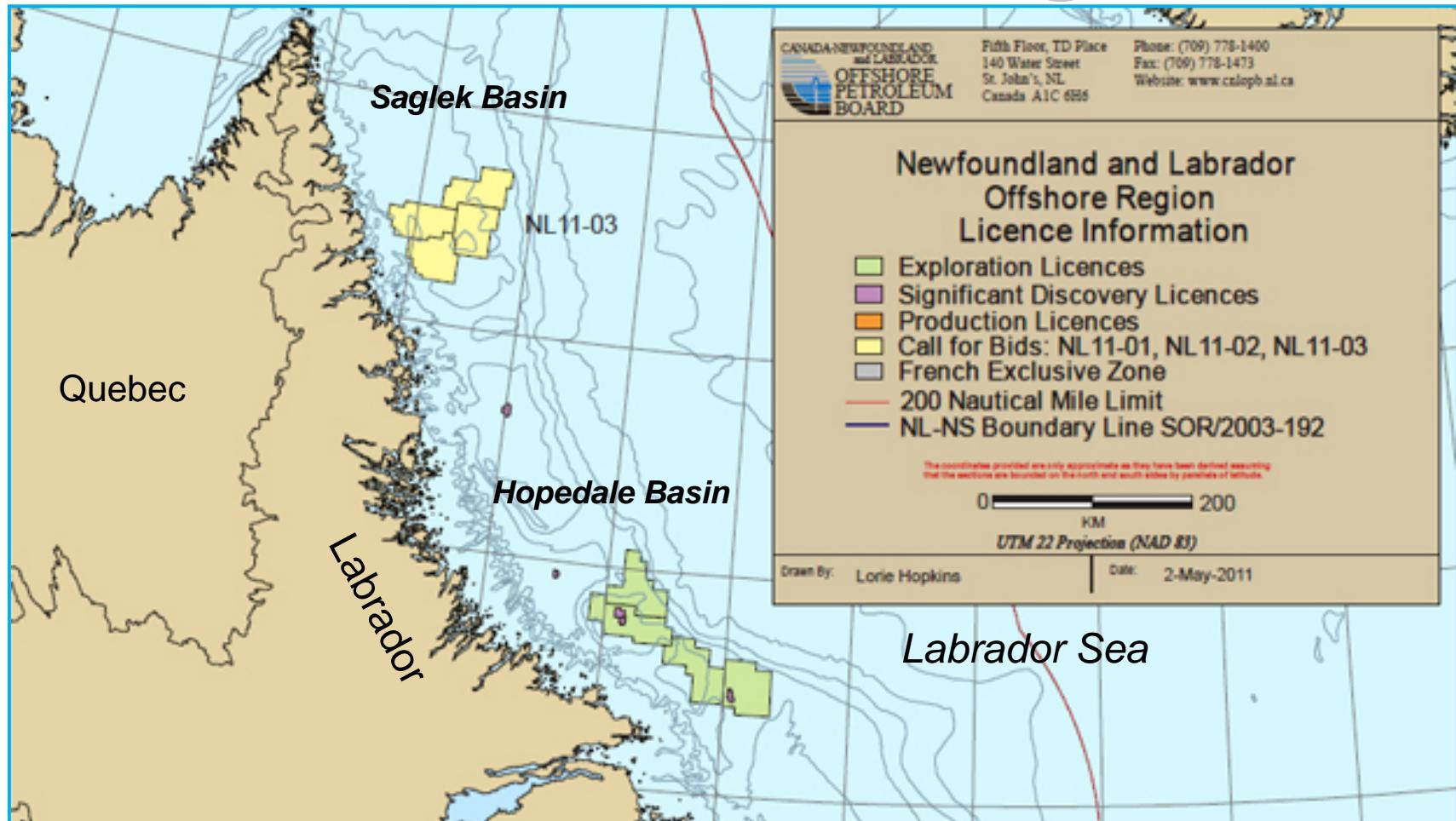
- Laurentian
- South Whale
- Jeanne d'Arc
- Flemish Pass
- East Orphan
- Hopedale
- Saglek

**Blue writing above:** Mesozoic basins with ongoing exploration

# 1. Introduction

- CFB NL11-03 parcels 1 to 4 are the first four blocks offered in the Saglek Basin by the C-NLOPB. It has been more than thirty years since exploration activity occurred in this basin under the auspices of the COGLA.
- The total area covered by the Call for Bids is 811,511 ha; each parcel, located on the shelf, is approximately 200,000 ha
- All four parcels are situated in relatively shallow water (ranging from 120 to 330 m)
- Parcels 1 to 4 are located north of Hopedale Basin where large gas fields such as Bjarni–North Bjarni, Hopedale, Gudrid and Snorri, were discovered in an earlier exploration phase (1970s to early 1980s)
- The four parcels are located south of the Hekja gas field, located in the same basin but in a different jurisdiction (Nunavut Territory)

# First Call For Bids in Saglek Basin



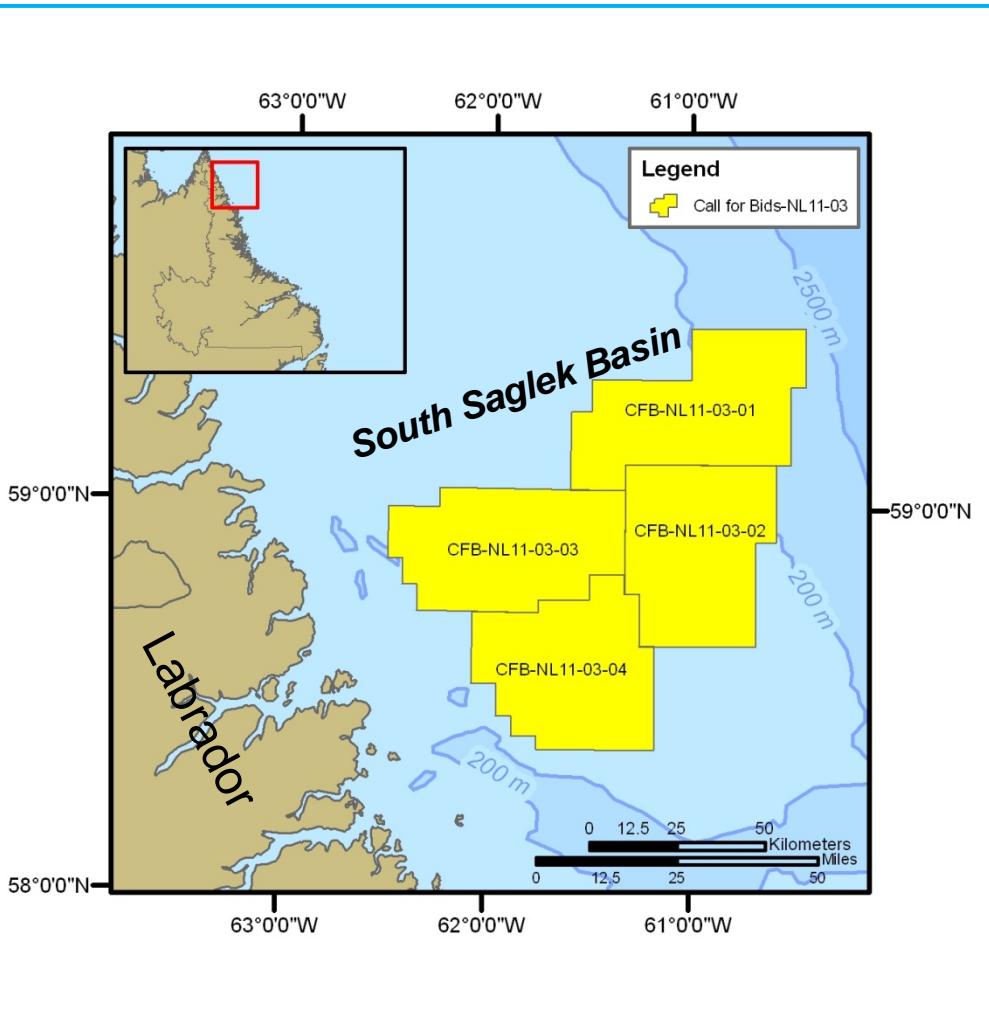
This is the first modern Call for Bids (CFB) in Saglek Basin and first activity in more than 30 years but is the second CFB targeting the Mesozoic-Cenozoic basins of the Canadian Labrador Sea.

# Observations

- References introduced in this presentation are listed in associated reports and presentations posted on the website:  
<http://www.nr.gov.nl.ca/mines&en/oil/>
- Certain parts of this presentation are repeats or updates of text and illustrations contained in the power points and report produced by Enachescu, 2008 and available at:  
<http://www.nr.gov.nl.ca/nr/invest/energy.html#offshore>  
[http://www.nr.gov.nl.ca/nr/invest/cfb\\_nl07\\_2\\_hopedale.pdf](http://www.nr.gov.nl.ca/nr/invest/cfb_nl07_2_hopedale.pdf)
- Other references quoted in this presentation are available from the word wide web scientific publication sites such as: lyellcollection, searchanddiscovery, sciencedirect, cspg, etc.

# Offshore Labrador Region

## 2011 Call for Bids

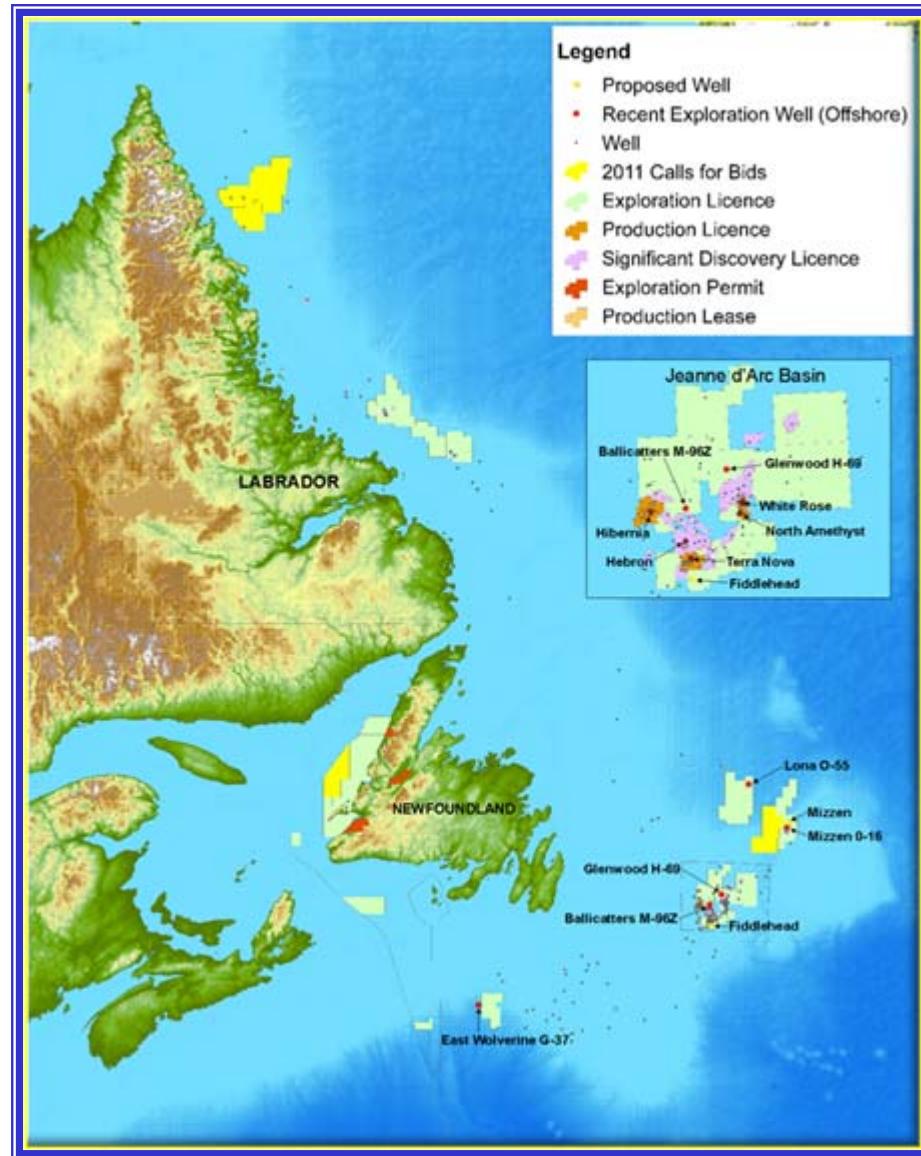


- **CFB NL11-03**  
consists of four large parcels (each one approximately 200,000 ha), located in shallow to intermediate deep waters of the South Saglek Basin
- **Call for Bids closes**  
**November 15, 2011**  
**at 4 p.m. NL time**

## **2. Exploration Background**

- **NL Historic E&P Activity**
- **NL Petroleum Production**
- **Participation of Nalcor Energy**
- **Offshore Labrador Research and Exploration Projects**
- **Large Mesozoic Offshore Under-Explored Basins**
- **Recent E&P Activity in Atlantic Mesozoic Basins**
- **Labrador Basins Exploration History**
- **Labrador Basins Geoscience History**
- **Labrador Offshore Land Situation 2011**
- **Recent Offshore Labrador Exploration Activity**

# NL Historic E&P Activity



## Wells Drilled

Exploration (Total)	231
Offshore	147
Onshore	84
Delineation	52
Development	170

## Discoveries

Oil	20
Gas	7

## Current Holdings

Exploration Licences (ELs)/Permits (EPs)	42
Significant Discovery Licences (SDLs)	52
Production Licences (PLs)/Leases	11

# NL Petroleum Production

- **1.25 Bbls** produced to date mainly from three fields - Hibernia, Terra Nova and White Rose developed in the Mesozoic Jeanne d'Arc Basin, on the East Coast of Newfoundland. A fourth field, North Amethyst, started producing in 2010
- These fields have produced in the range of 250,000 to 360,000 barrels per day of light crude (30 to 35° API) from Mesozoic sandstones in each of the past 5 years
- Currently NL produces between **250-300,000 bopd** monthly
- Over 100 MMbbls produced in 2010; daily average of **275, 866 bopd**
- NL production represents 12.5% of Canada's total oil production, 35% of Canada's light oil and more than 80% of Atlantic Canada petroleum output

# NL Petroleum Production (Cont.)

- NL is the second largest hydrocarbon producing province in Canada
- Production to date is from the Jeanne d'Arc Basin only; more than **1.8 Bbbls** proven remaining recoverable reserves/resources exists
- Jeanne d'Arc Basin developments are the only producing offshore oilfields on the Atlantic coast of North America
- A fifth large field, Hebron, estimated to contain 581 MMbbls recoverable reserves/resources (C-NLOPB) will be developed starting in 2012 with first oil expected in 2017. Additional 150 Mbbls recoverable reserves are associated with Ben Nevis/West Ben Nevis fields
- Satellite fields are now adding to production of Hibernia and White Rose oil fields

# Participation of Nalcor Energy

- Legislation to create the province's energy corporation, Nalcor Energy, wholly owned by the Government of NL  
<http://www.nalcorenergy.com>
- Through Nalcor, the Province negotiated equity positions in several offshore fields: White Rose Growth Projects (including North Amethyst, West White Rose, South White Rose Extension) (5%), Hebron (4.9%) and Hibernia Southern Extension (10%)
- On 31 May 2010 Nalcor obtained first oil production from its 5% participation in the North Amethyst field, establishing the company as an emerging provincial-owned upstream oil and gas player in the Atlantic continental margin
- The Energy Plan provided a framework for a price based Offshore Natural Gas Royalty Regime and introduced the concept of a “pioneer project”

# Participation of Nalcor Energy (Cont.)

- During 2009, Nalcor acquired an average of 67 per cent working interest in three onshore exploration permits in the Parsons Pond area on the Great Northern Peninsula
- In 2010, Nalcor completed the drilling of two onshore exploration wells in the Parsons Pond area, Seamus and Finnegan, and completed testing of the Seamus well
- Seamus well drilled to an onshore record depth of 3,160 metres
- Non-commercial natural gas was encountered in both wells
- The results of drilling and testing of these wells and seismic analysis have greatly advanced the understanding of Western NL petroleum geology
- The extensive datasets gathered from the wells can be extrapolated to several of the offshore exploration licences
- Nalcor continues to pursue other investment opportunities and supports the province's efforts to promote exploration

# Offshore Labrador Research and Exploration (R&E) Projects

- Several large R&E projects are jointly administered by Nalcor and NL Department of Natural Resources through programs such as Petroleum Exploration Enhancement Program (PEEP) and Offshore Geoscience Data Project (OGDP). Details of these programs are given at <http://www.nr.gov.nl.ca/mines&en/oil/>
- Government of NL provided \$20 million to fund the OGDP, including programs such as the Seep Mapping in Labrador Sea and new acquisition of regional reflection data on Labrador shelf and deep water basins
- In 2010-11 an offshore NL regional oil seep mapping and interpretation study was funded by OGDP and awarded to Astrium/Infoterra. Mapping natural oil seeps at sea allows judicious targeting of new seismic data acquisition, minimizing the geologic uncertainty and reducing overall exploration risk. The study results are available for licensing to oil companies

# Offshore Labrador Research and Exploration (R&E) Projects (Cont.)

- A gas hydrate study involving the NL shelf, slope and deepwater was recently initiated  
<http://www.releases.gov.nl.ca/releases/2011/intrd/0818n07.htm>
- A Plate Tectonic Kinematic Model for North Atlantic regions project was initiated in 2010 by Nalcor/DNR in collaboration with PIP/PAD of Ireland and awarded to GeoArctic. The model includes the Labrador/Greenland separation and Labrador basin formation. The resulting study and kinematic animation will be available to funding agencies and also for licensing to oil companies
- A large-scale, multi-client seismic 2D program in the Labrador offshore was announced (Nalcor participation funded through OGDP) and commenced data acquisition this year by a partnership of experienced global contractors (TGS in collaboration with PGS)

# Regional oil seep mapping and interpretation study offshore NL

## Key Features

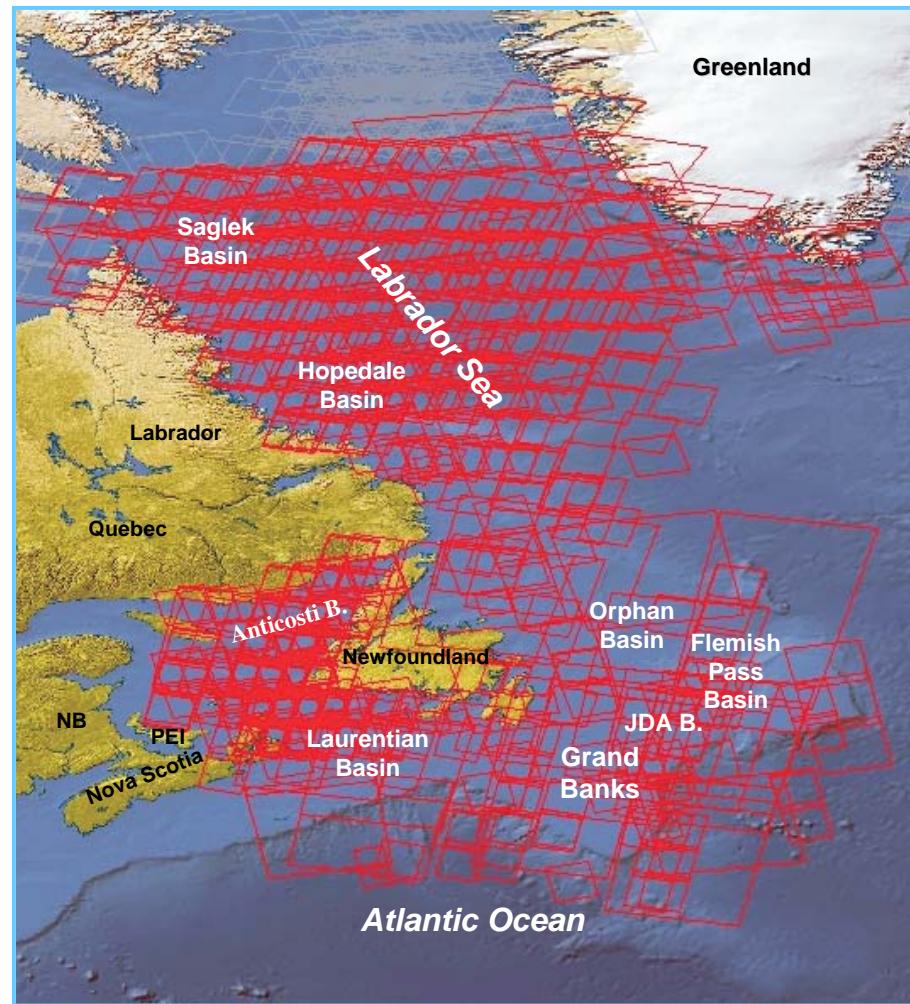
- Part of the OGDP program; Nalcor contracted the GEO-Information division of Astrium Services on a non-exclusive basis
- Cost-effective, de-risking tool used to evaluate exploration potential for both under-explored and mature offshore basins and locate new seismic grids
- Study covered offshore areas of NL totalling approximately 1.5 million km<sup>2</sup> and was linked to SW Greenland
- Mapping and classifying of offshore oil slicks based on satellite data from various providers
- Data can be licensed by oil companies and is delivered as a “plug and go” GIS product

## Survey Objectives

- Hydrocarbon screening of frontier basins (e.g. Anticosti, Laurentian, East Orphan, Flemish, Saglek basins)
- Risk-ranking of basins and sub-basins prior to new exploration
- Monitoring spatial characteristics of the oil slick over areas of existing production
- Planning sea surface and sea-bottom geochemical programs
- Designing new 3D and 2D seismic programs and integration with older surveys
- Link geological and geophysical interpretation from onshore to offshore basins
- Environmental monitoring: environmental risk assessment, impact statement or full environmental baseline

JDA B. = Jeanne d'Arc Basin; PEI = Prince Edward Island; NB = New Brunswick

Enachescu, 2011



# Plate Tectonic Kinematic Model Project for North Atlantic Regions

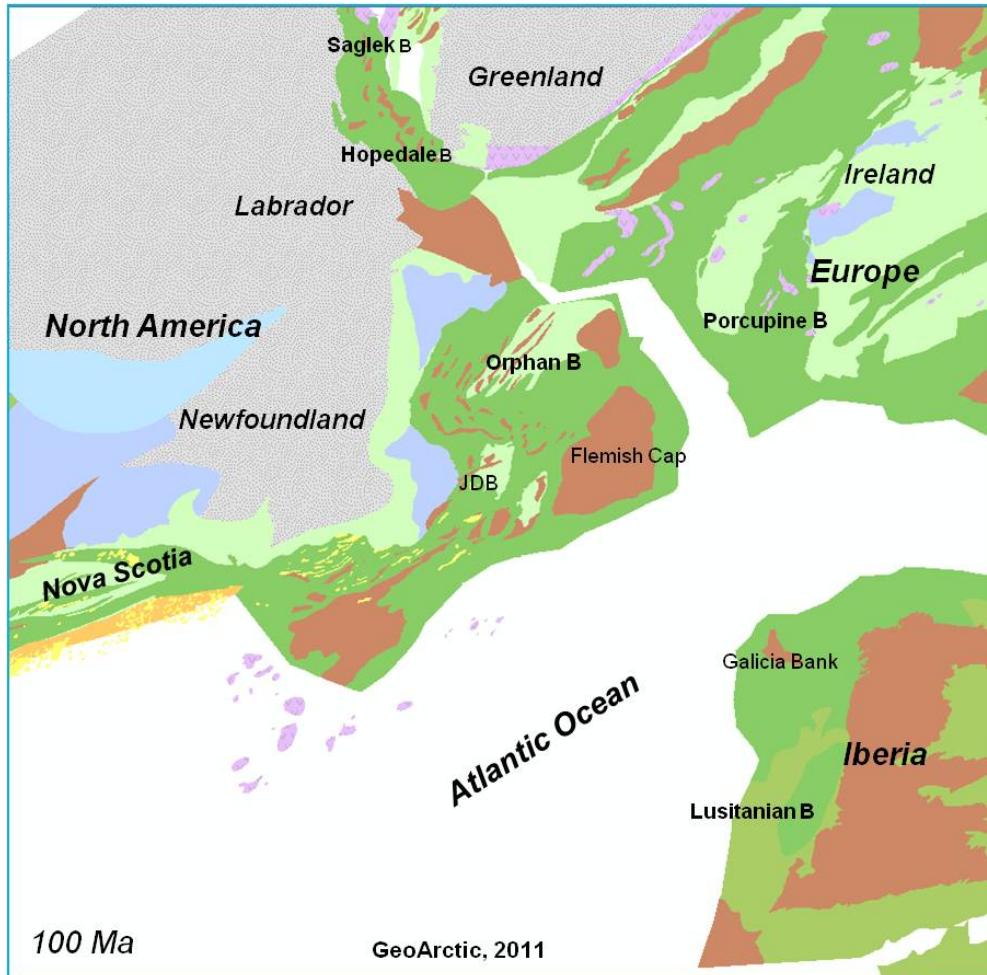
## Key Features

- A joint research project funded by Nalcor/DNR and Irish Shelf Petroleum Studies Group (ISPSG-this group includes oil companies active in Western Ireland offshore and the Irish Petroleum Affair Directorate)
- To be managed and carried out by GeoArctic of Calgary
- Academic and technical input from the universities, industry and government scientists from Canada and Ireland
- Based on new acquired data and survey results as well as data donated by TGS and ION
- Final product to be a kinematic animation model of plate movement that will include the Labrador Sea opening

## Project Objectives

- Refit the prerift continental margins on both sides of Atlantic minimising overlaps and gaps
- Determine major controls/mechanisms for North Atlantic basin formation and evolution, crustal stretching, rifting, uplift
- Determine relationship of major basins and structural highs between Eastern Canada and Ireland
- Determine effect of major fault systems along the NW-SE Labrador-Biscay trend on the evolution of adjacent basins
- Predict Jurassic sedimentation for Orphan, Flemish Pass, southern Rockall, Hatton and southernmost Porcupine basins with greater confidence
- Evaluate prominent highs such as Flemish Cap and Orphan Knoll as possible sediment sources for the southern Porcupine and Rockall basins
- Evaluate potential for Palaeozoic reservoirs and source rocks in the region

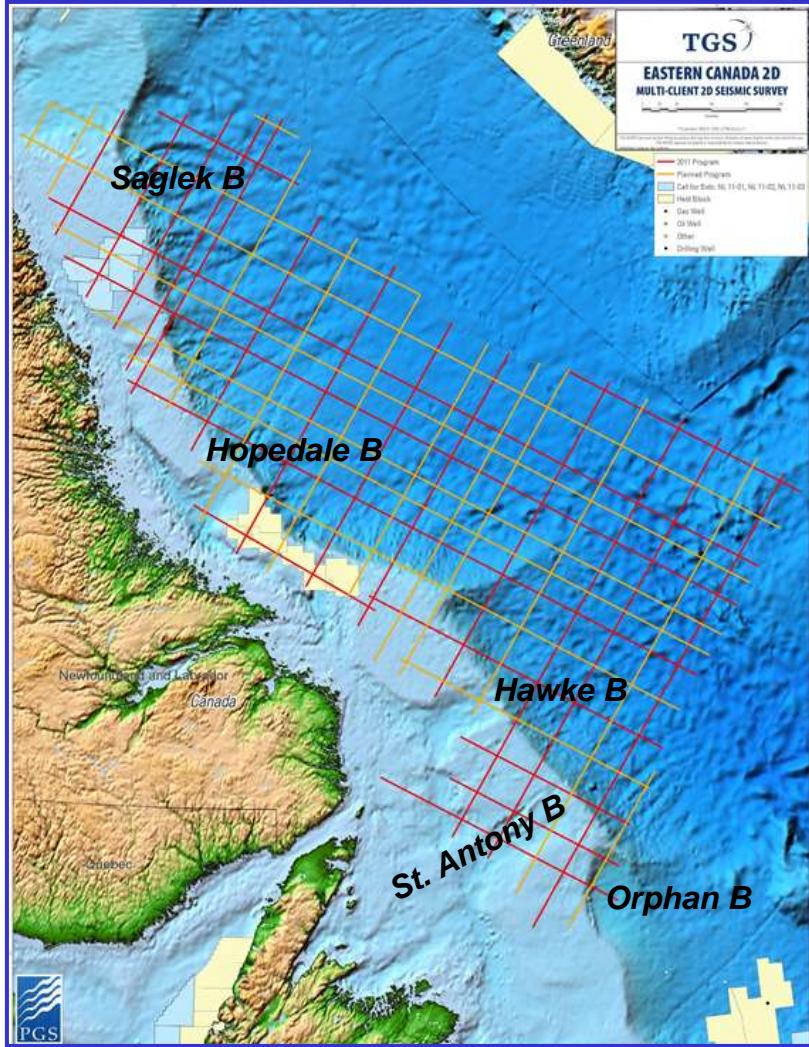
# Plate Tectonic Kinematic Model for North Atlantic Regions (Cont.)



JDB = Jeanne d'Arc Basin

Reconstructed geological configuration of North Atlantic-Labrador Sea basins, seaways and continental fragments during Late Albian (after GeoArctic, 2011, provisional map)

# Seismic Survey to Further Exploration Efforts in Offshore NL



Nalcor initiated a large multi-client survey to be recorded north of existing Grand Banks' major oil discoveries. The project is a joint commercial/research project funded 1/5<sup>th</sup> by Nalcor through NL Department of Natural Resources' Offshore Geoscience Data Program (OGDP) and has other industrial funding partners. This Frontier seismic program utilizes advanced seismic acquisition and processing techniques



*M/V Sanco Spirit*

<http://subseaworldnews.com/wp-content/uploads/2011/09/TGS-and-PGS-Join-Forces-to-Acquire-2D-Seismic-Survey-Offshore-Canada.jpg>

# Seismic Survey to Further Exploration Efforts in Offshore NL (Cont.)

## Key Features

- Program managed and carried out by TGS in partnership with PGS, both well known global seismic contractors, that have worked several large programs in Canadian East Coast waters
- Survey builds on regional satellite seeps study carried out by EADS subsidiary Astrium GEO-Information Services and delivered in spring 2011 (see slide 18)
- Seismic acquisition uses the 2009 built Norwegian seismic ship *M/V Sanco Spirit* contracted by TGS. This Canadian flagged vessel possesses modern S&E, navigation and seismic equipment (see slide 21)
- Vessel will use the advanced PGS GeoStreamer®Technology that has dual-sensors (hydrophones collocated with geosensors), recording both pressure wave and particle motion which allows for better suppression of receiver ghosts and increased frequency bandwidth
- Plans are for 22,000 km multi-client 2D data to be collected during two seasons (2011-2012) with initial data to be available to clients during the fourth quarter of 2011

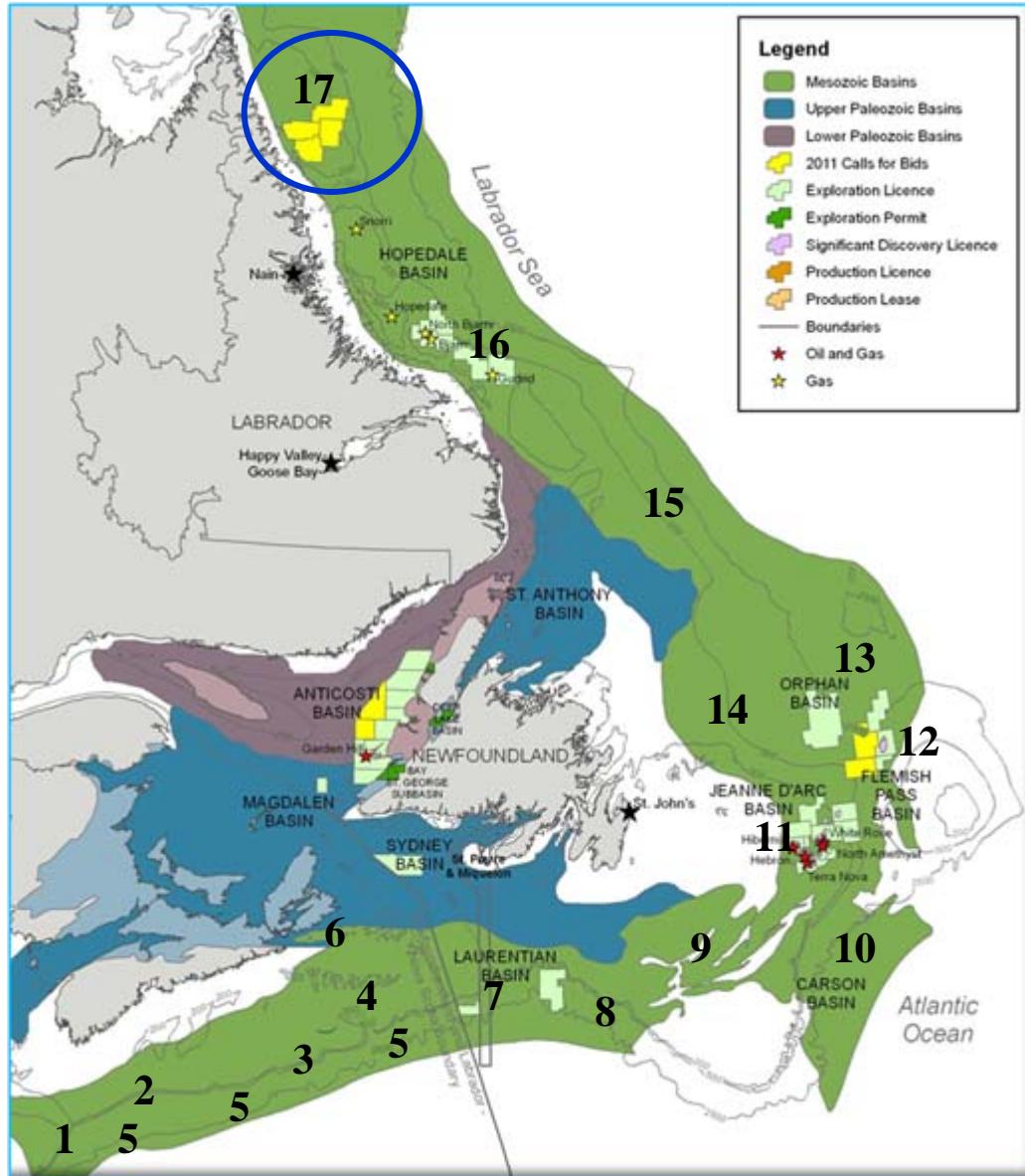
## • Project Objectives

- Understand the frontier region petroleum potential and promote the province's offshore prospectivity in a vast area north of Grand Banks
- Investigate the subsurface structure and stratigraphy on the Labrador shelf, slope and deepwater and extend geological knowledge beyond the present 200 nautical miles exclusive economic zone (EEZ)
- Cover areas nominated in the C-NLOPB Call for Bids NL-11-03 or in vicinity of the offered blocks
- Data collection over the northern Orphan Basin, parts of Paleozoic St. Anthony Basin, the poorly known Hawke Basin, Hopedale Basin where 4 ELs are active and Saglek Basin, the object of present Call For Bids offering 4 blocks
- Connect to seismic lines from the West Greenland margin where there is significant drilling activity: three wells were drilled in 2010 and a four well program is planned by Cairn and partners for 2011

# Large Mesozoic Under-Explored Basins in Atlantic Canada

- Canada's Atlantic Provinces, including Newfoundland and Labrador, were affected by the latest Wilson Cycle that was initiated with continental rifting in Triassic, and culminated with the breakup of Pangea and creation of Atlantic Ocean
- This process also resulted in the formation of North American continental margin that on strike, shows a shelf of variable width
- The North American Continental margin includes a series of variable size rift basins, subbasins and troughs separated by ridges starting in Florida, continuing on both onshore and offshore East Coast USA, developing offshore Nova Scotia, then passing through the Grand Banks of Newfoundland and Orphan area, changing direction into the Labrador Sea and Baffin Bay and terminating in the Arctic Ocean
- These basins show uneven accumulation of synrift sediments and usually exhibit a thick post rift/pассив margin prism of clastic and carbonate deposits
- Several northern basins (Sable, Jeanne d'Arc, Flemish Pass and Labrador basins) have working petroleum systems

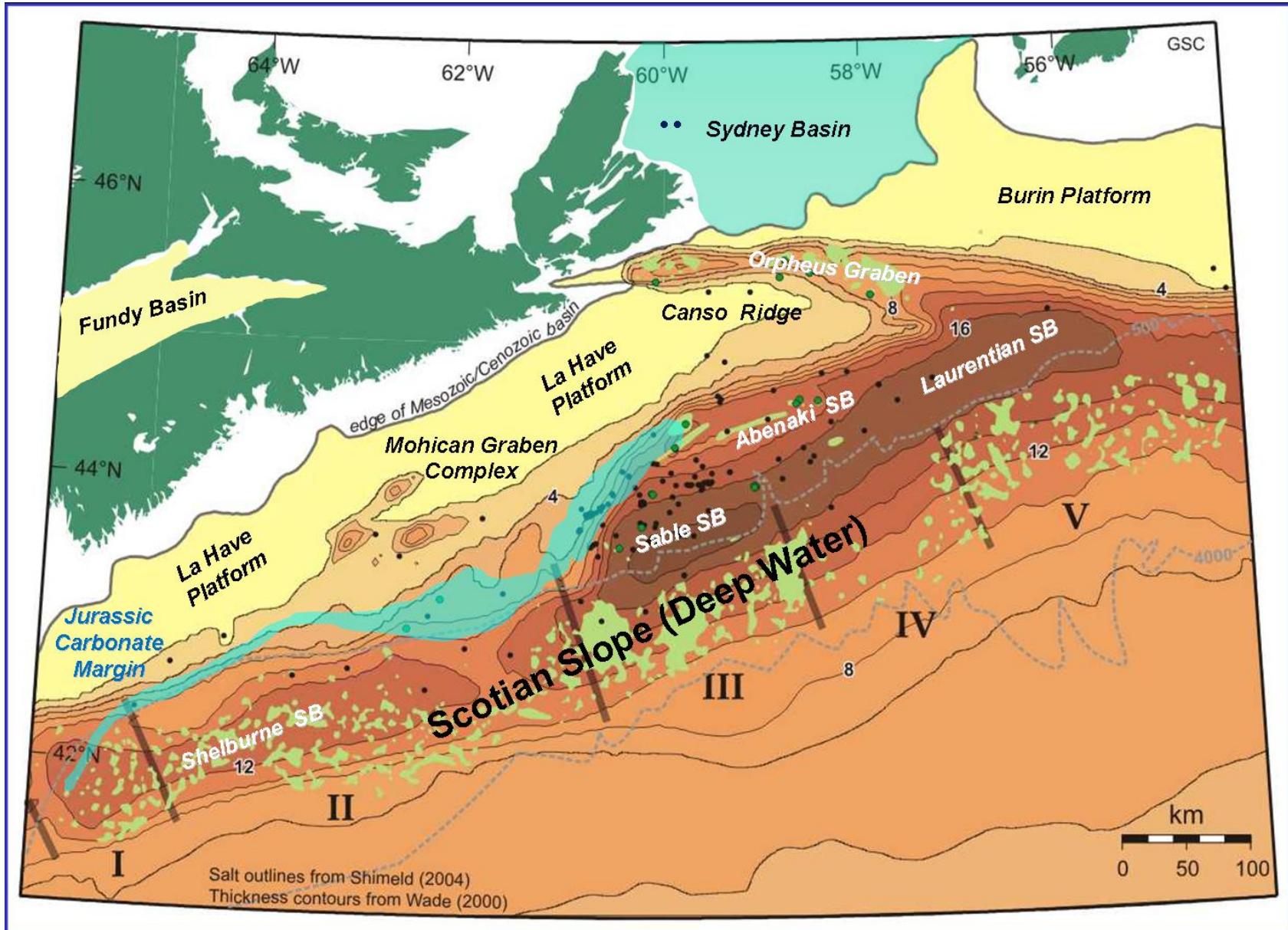
# Atlantic Canada Mesozoic Basins



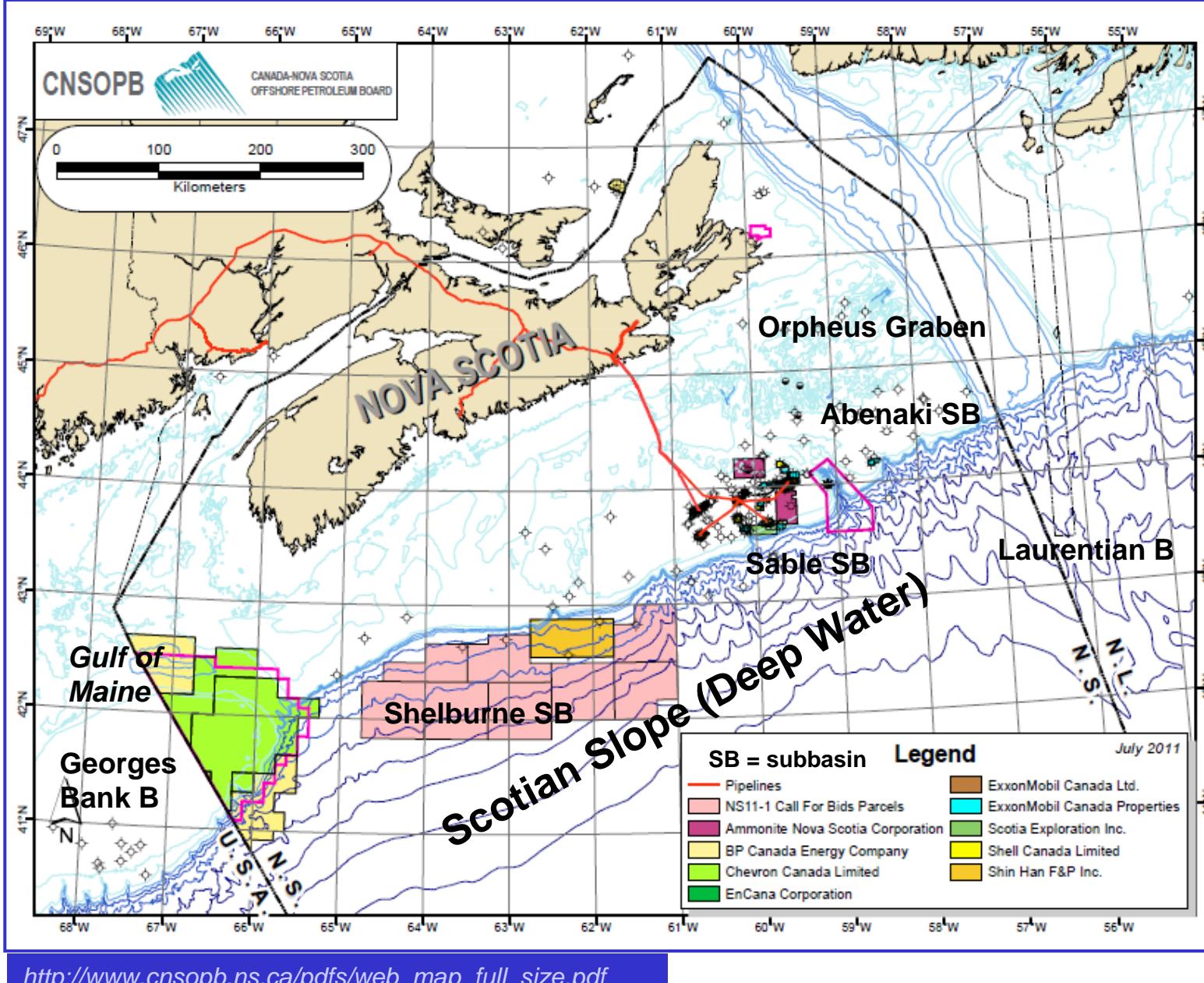
# Large Mesozoic Under-Explored Basins in Atlantic Canada (Cont.)

## Nova Scotia

- A total of 127 exploration wells have been drilled in the Nova Scotia offshore since 1967 resulting in 23 significant oil and gas discoveries. Since 2003, 20 wells have been drilled: 10 development/delineation and 10 exploration. A comprehensive Geoscience Project was commissioned by Nova Scotia's Offshore Energy Technical Research Association (OETRA) and contracted to RPS Energy of the UK. The **Play Fairway Analysis** was finished this year and indicates a diversity of remaining and new exploration opportunities in the NS offshore and most interesting, points out the existence of an Early Jurassic Type I to II marine source rock ([www.novascotiaoffshore.com](http://www.novascotiaoffshore.com)).
- **Georges Bank** basin is the southernmost part of the large Mesozoic sedimentary area known as the Scotian Basin (see next slide). The basin is a typical rifted to passive margin basin and is mostly in the USA's Gulf of Maine. Due to fishery and environmental concerns, the basin is under an exploration moratorium since the early 1980s, recently extended to Dec. 31 2015 (Georges Bank Prohibition Zone). The basin is covered with 1970s and early 1980s 2D seismic lines that were recently reprocessed. Ten wells were drilled in the US side of the basin with no shows. The NS side remains undrilled, and large exploration permits are held by Chevron (previously Texaco Canada) and BP Canada but remain dormant as no exploration activities are permitted
- **Shelburne** subbasin is a large, virtually unexplored rift subbasin situated on the southern shelf and slope. Only a single well has been drilled on the upper slope, with 12 unsuccessful wells on the shelf. Numerous traps and plays are identified, and on the upper slope, the main risk is finding thick quality reservoirs. This basin has an active EL. Seven large blocks on the continental slope are offered by CNSOPB at the Call for Bids NS11-1 to be concluded on January 10, 2012



Subbasins (SB), salt distribution (in pale green) and sectors (I to V) of Scotian Basin (After Kinston et al., 2002; Shimeld , 2004 and GSC; map provided by CNSOPB)



**Observation:** For offshore Nova Scotia the term subbasin (SB) is used to denote a subdivision of the regional, all encompassing Scotian Shelf and Slope Basin. The term basin (B) is sometimes used for same structural units

# Large Mesozoic Under-Explored Basins in Atlantic Canada (Cont.)

## Nova Scotia

- **Sable** Subbasin is located in the vicinity of Sable Island and contains a thick accumulation of Late Jurassic-Late Cretaceous carbonate and deltaic sediments. The great majority of gas discoveries offshore Nova Scotia were recorded in this area (Venture, S. Venture, N. Triumph, Alma, Thebaud). These large fields were discovered by ExxonMobil and partners in the 1970s-1980s. Their Sable Offshore Energy Project is now producing about 300 MMcf/d that feeds into a pipeline that carries the gas to the NE USA. The Copan project (Lasmo, and later PanCanadian) operated from 1992 to 1999, was the first Canadian offshore development and produced 44.5 MMBbls of light oil. After its exhaustion in 1999, PanCanadian drilled into a low amplitude anomaly underlying the Panuke field that proved to be a gas-filled, Late Jurassic Abenaki formation dolomitized reef. The Deep Panuke field is being developed by Encana and is scheduled to produce ~250 MMcf/d gas by mid-2012. Many other small and medium sized discoveries, and numerous undrilled fault blocks with good potential are located in the basin
- **Abenaki** Subbasin, is located between the Laurentian Basin and Sable Subbasins occupying parts of the shelf and the slope. About a dozen wells were drilled in this basin, with several having good oil and gas shows. Good reservoirs and source rocks have been intersected in several wells. Rotated blocks, roll-over anticlines, salt anticlines, salt minibasins and slope fans are the typical traps in this subbasin. Numerous features, especially smaller fault bounded closures on shelf and large rotated blocks near the shelf break and on the slope remain undrilled

# Large Mesozoic Under-Explored Basins in Atlantic Canada (Cont.)

## Nova Scotia

- **Scotian Slope (Deep Water)** occupies the slope and deep water of the Nova Scotia margin. This 80,000+ km<sup>2</sup> area was strongly affected by basement extensional tectonics, salt movement, gravity folding and faulting. The basin contains a thick Jurassic, Cretaceous and Tertiary sedimentary fill with several known oil and gas prone source rocks. Autochthonous and allochthonous salts formed numerous structural, stratigraphic and combination hydrocarbon traps. Only six wells were drilled in this part of the Scotian Basin in the past ten years. A significant gas discovery was made at Annapolis G-24 that intersected a cumulative 30 m of net pay. Gas shows were present in two other wells where effective sand reservoirs were encountered, thus confirming a working petroleum system. In spite of being covered by dense 2D and several large 3D seismic surveys, this region remains poorly explored and most play types are untested
- **Orpheus Graben** is a narrow, fault bounded, funnel-shaped subbasin containing large Argo salt-induced structures modified by transtension along the Cobéquid-Chedabucto fault system. The graben contains up to 10 km of Upper Triassic and Lower Jurassic synrift strata, overlain by a relatively thin succession of Upper Jurassic to Lower Tertiary sediments. Mobilization of Argo salt within this confined basin has produced numerous structural traps. Two of the salt-induced structures, and five shallow closures on the graben margin, were drilled without success in the early 1970s exploration cycle. Mature source rocks have been intersected during drilling. There is no current exploration activity in this subbasin

# Large Mesozoic Under-Explored Basins in Atlantic Canada (Cont.)

## Nova Scotia

- **Sable** subbasin is located in the vicinity and seaward of Sable Island and contains a thick accumulation of Late Jurassic-Early Cretaceous carbonate and deltaic sediments. The great majority of gas discoveries offshore Nova Scotia were recorded in this area (Venture, S. Venture, N. Triumph, Alma, Thebaud). These larger fields were bound by Exxon Mobil and partners in the Sable Offshore Energy Project that is now producing about 300 MMcf/d into the pipeline. The Copan project operated from 1992 to 1999, was the first Canadian offshore development and produced 44.5 MMBbls of light oil. After its exhaustion in 1999, PanCanadian drilled a deeper well into a lower amplitude anomaly that proved to be a gas filled Late Jurassic dolomitized reefal member, and thus discovered the Deep Panuke field. Developed by Encana, this field is scheduled to produce gas in the fall of 2011. Several other small and medium size discoveries and undrilled fault blocks with good potential are located in the basin
- **Abenaki** subbasin, is located between the Laurentian Basin and Sable subbasins occupying parts of the shelf and the slope. About a dozen dry holes were drilled in this basin, but several wells had good oil and gas shows. Good reservoirs and source rocks have been intersected in a number of wells. Rotated blocks, roll-over anticlines, salt anticlines, salt mini basins and slope fans are the typical traps in this subbasin. Numerous features, especially smaller fault bounded closures on shelf and large rotated blocks near the shelf break and on the slope, remained undrilled

# Large Mesozoic Under-Explored Basins in Atlantic Canada (Cont.)

## Newfoundland

- **Laurentian** Basin is a typical Atlantic margin deep basin formed by extensional tectonics and influenced by salt movements. The basin has accumulated thick Jurassic and Cretaceous sediments and was strongly canyonized during Tertiary. The basin was under a long lasting exploration moratorium due to international and provincial border disputes, both resolved in early 2000s. A dry hole, Bandol #1, was drilled during 2001 in the French waters by ExxonMobil and partners. The hydrocarbon plays are similar to those encountered on the Scotian shelf and slope and include listric fault blocks, rollover anticlines, salt cored anticlines and slope sedimentary fans. An unsuccessful exploration well, East Wolverine G-37, was drilled in early 2010, by ConocoPhillips and BHP Billiton, to test a deep-water prospect. Two deep water ELs are active in the basin. Numerous leads and prospects remain undrilled in shallow, intermediate and deep water
- **South Whale** Basin was intensively explored during the late 1960s - early 1970, targeting seismically expressed salt diapirs. More than 20 wells were drilled in the basin and its vicinity and all were unsuccessful. Only a noteworthy heavy oil show was encountered in Heron H-73 well. After more than a 20 year pause, exploration was renewed in early-mid 2000s when Lewis Hill G-85 well was drilled in the central part of the basin. The well remained short of Jurassic layers, intersected good Late Cretaceous reservoirs, but failed to encounter hydrocarbons. Some deeper areas in the central and deep water parts of the basin may have preserved the Late Jurassic reservoirs and source rock interval. There is no current exploration in the basin

# Large Mesozoic Under-Explored Basins in Atlantic Canada (Cont.)

## Newfoundland

- **South Grand Banks** was also explored in the earliest Grand Banks exploration phase when about 15 wells were drilled in the Whale, Horseshoe, shelfal Carson and South Jeanne d'Arc Basin. These basins, started along an abandoned arm of the Tethys rift system, contain thick Late Triassic to early Late Jurassic formations, including thick, mobile Argo salt. The basins were elevated during the Early Cretaceous Newfoundland Transfer Zone active stage and the Avalon Uplift episode and most of its Late Jurassic reservoirs and source rocks, as well as Early Cretaceous reservoirs were eroded. These basins have low to no potential for hydrocarbons in Mesozoic rocks, but Paleozoic rocks that form the rifted basement may have potential
- **Carson** Basin has no ongoing exploration but there is significant petroleum potential in the deep water part of the basin. The shelfal part of the basin was severely eroded during the Avalon Uplift emplacement (Avalon Unconformity). Four wells were drilled in the basin and penetrated a section from Triassic to Neogene in age but no hydrocarbons were encountered. A recent 4D petroleum system study by Geological Survey of Canada Atlantic has indicated that hydrocarbons were generated in significant amounts. A 3D survey exists on the slope of this basin. No drilling has been carried out on the slope, where seismic data indicate presence of large structural and stratigraphic features

# Large Mesozoic Under-Explored Basins in Atlantic Canada (Cont.)

## Newfoundland

- **Jeanne d'Arc** Basin is the only North American East Coast basin containing giant producing oil fields. The fields produce light crude (30 to 35°API) from Late Jurassic-Early Cretaceous sandstones. During 2010, the basin's main fields: Hibernia, Terra Nova, White Rose and several satellites, produced at an average of 275,000 bopd rate. A true supergiant, Hibernia has produced 765 MMbbls as of the end of September 2011, with an estimated 630 MMbbls of remaining reserves. The Hebron oil field (17 to 27°API), presently the largest light oil development in Canada, will have first production in 2017. Smaller fields located in the basin wait for innovative development solutions. One exploration well, Statoil's Fiddlehead D-83, located in EL 1101 just south of Terra Nova field, is being drilled this fall. There are 15 current ELs in the basin and vicinity that must be drilled soon. Moreover, numerous deeper structural and stratigraphic features located in the central and northern part of the basin and on its eastern flank remain to be drilled. The Late Jurassic Egret Member is a world-class source rock which may have charged several other major accumulations in this prolific basin
- **Flemish Pass** Basin has become the second NL Mesozoic basin to record a significant oil discovery. Mizzen O-16 well, drilled in 2009 by Statoil, tested at a rate 3774 bopd from a Late Jurassic sandstone interval and proved an oil accumulation (22°API). Only 7 wells were drilled in the basin. Two large ELs adjacent to Mizzen SDLs were awarded at the 2010 Call for Bids. Mizzen F-09 delineation well was drilled in SDL 1047 this summer but results are still confidential. Two 3D surveys were carried out in the basin during 2011 by Chevron (partially in the Orphan Basin) and Statoil. There are several large undrilled structures in this intermediate deep water area where Late Jurassic source rocks were logged by several wells

# Large Mesozoic Under-Explored Basins in Atlantic Canada (Cont.)

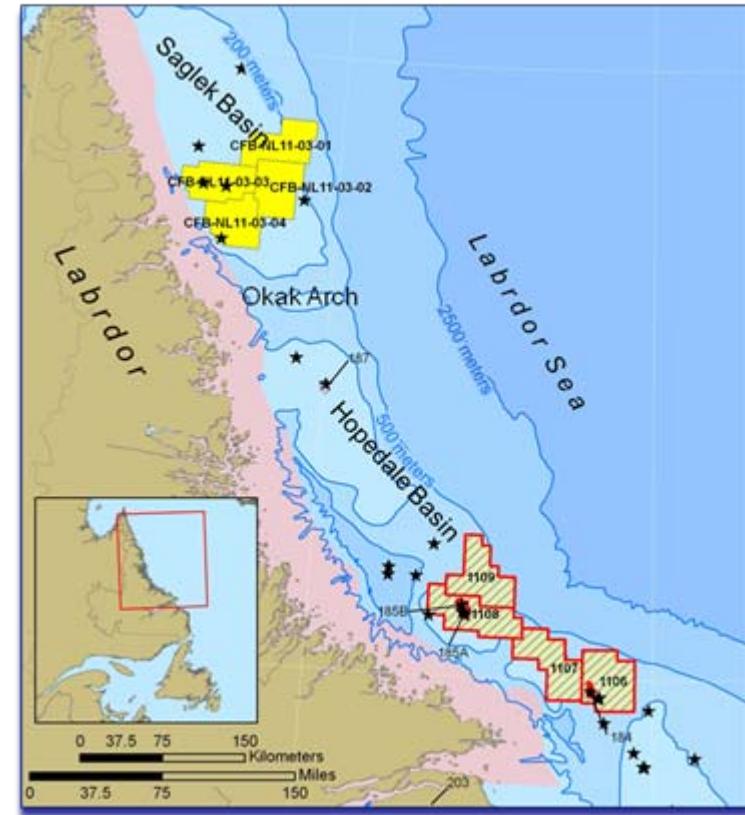
## Newfoundland

- **East Orphan** Basin (EOB), is a highly attenuated Mesozoic-Tertiary sedimentary area situated north and northeast of the Grand Banks of Newfoundland in water depths ranging between 1500 and 3500m. This large Mesozoic sedimentary area was the focus of NL deep water exploration for the past 10 years. Large 2D and 3D seismic programs and CSEM surveys were conducted and 2 deep wells were drilled, but they were unsuccessful (Great Barasway F-66 and Lona O-55). A large consolidated EL 1074R, validated by the drilling of these wells and now in its second exploration phase, still contains large undrilled structures. According to several geodynamic models, the Late Jurassic source rocks should be present in some of the elongated troughs, seismically mapped in the basin. One of the CFB NL11-02 blocks, is located close to the Mizzen SDL and extends in the southern East Orphan Basin
- **West Orphan** Basin (WOB) formed during the Late Jurassic-Early Cretaceous extension and is a relatively younger rift basin than East Orphan Basin. The White Sail Fault Zone separates the two basins. The basin had seven dry holes in the early eighties and has not seen drilling since. While good reservoirs and very large structural traps were tested, neither significant hydrocarbon flows nor Kimmeridgian source rocks were encountered. There are thick Cretaceous and Tertiary fine clastic intervals rich in TOC that may be mature in sectors of this basin

# Large Mesozoic Under-Explored Basins in Atlantic Canada (Cont.)

## Labrador

The Labrador margin contains two Mesozoic basins, Hopedale and Saglek, separated by the Okak Arch. The basins were initiated during the continental rifting and oceanic spreading that resulted in the separation of the Canadian north-eastern regions of Labrador and Baffin Island from Greenland, and the formation of the Labrador Sea. The basins contain basement rotated blocks and horsts covered by synrift and postrift sediments and separated by elongated troughs. The basement contains Lower Paleozoic carbonate rocks that have preserved reservoir quality. During Tertiary rift reactivation and passive margin fill, several episodes of transtension led to the formation of compression modified extensional structures.



# Large Mesozoic Under-Explored Basins in Atlantic Canada (Cont.)

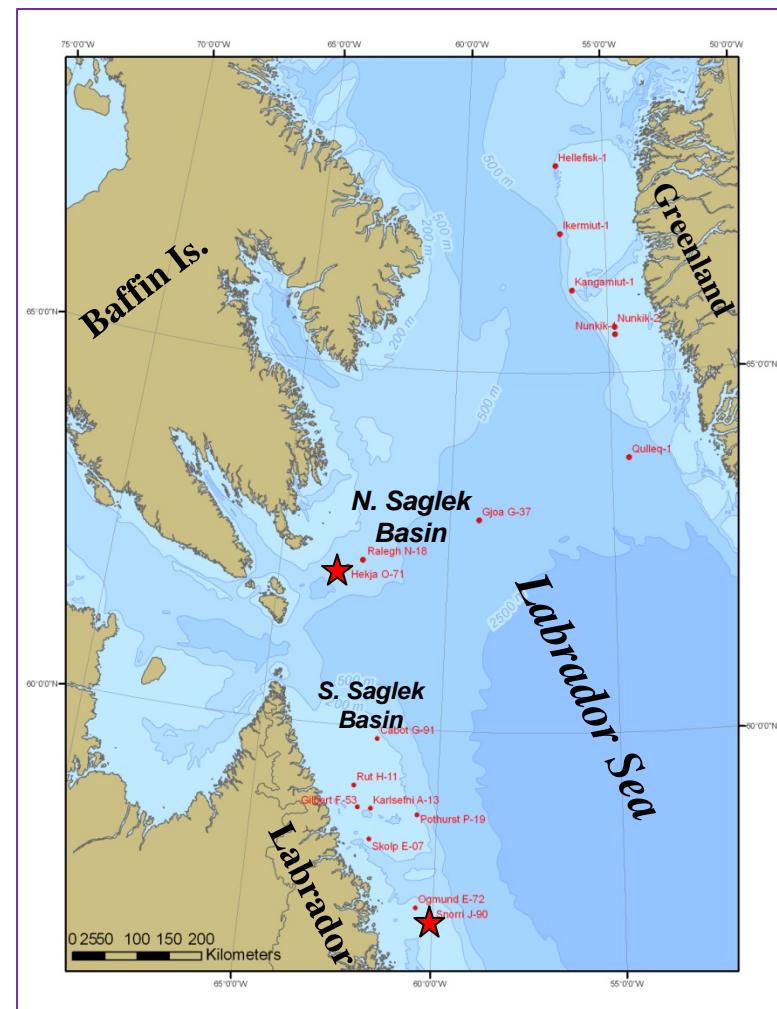
## Labrador

- **Hopedale** Basin is a mildly explored area which contains several large gas discoveries from the 1970s to early 1980s period. The complex Bjarni-North Bjarni gas field is estimated to contain 3Tcf in Early Cretaceous sandstones. None of the early discoveries have been developed. The basin was the object of a NL Call for Bids issued in 2007 and concluded in 2008 with the licensing of 4 large parcels (ELs 1106 to 1109). Several 2D seismic programs were conducted during 2009-2011 over these ELs but no new exploration well has been drilled yet. A large 2D multi-client seismic survey is being conducted by TGS and partners (including PGS and Nalcor) during 2011-2012 and will cover this basin and its environs. The second basinward lineament of highs, the deep ridge marking on places the slope break and the slope are practically unexplored
- **Saglek** Basin is located in the northern part of the Labrador Sea, the Davis Strait area and on the southeast Baffin Island shelf and slope. The basin contains only 9 exploration wells, all drilled on the shelf during the period 1975 to 1982. One large gas discovery with NGLs (estimated between 2.3 and 3 Tcf resources) was made at Hekja O-71 in the northern part of the basin, offshore Nunavut territory. While 6 wells were drilled in the NL sector of the Saglek Basin, no significant petroleum discovery was made. Unlike the North Saglek Basin that is located within an important transfer zone affected by effusive and intrusive magmatic rocks, the South Saglek Basin is dominated by extensional tectonics and has only minor volcanics. The basin is practically unexplored east of the first lineament of basement highs

# Saglek Basin Exploration Wells

Well No	Well Name	Basin	TD (m)	Status
1	Karsefni A-13	S. Saglek	4149	D&A
2	Cabot G-91	S. Saglek	290	D&A
3	Skolp E-07	S. Saglek	2968	D&A
4	Gilbert F-53	S. Saglek	3608	D&A
5	Hekja O-71	N. Saglek	4566	Gas well
6	Raleigh N-17	N. Saglek	3998	D&A
7	Rut H-11	S. Saglek	4474	D&A
8	Pothrust P-19	S. Saglek	3992	D&A
9	Gjoa G-37	N. Saglek	3858	D&A

Yellow = Deep wells; Red =Shallow well



★ = Gas and Condensate Discovery

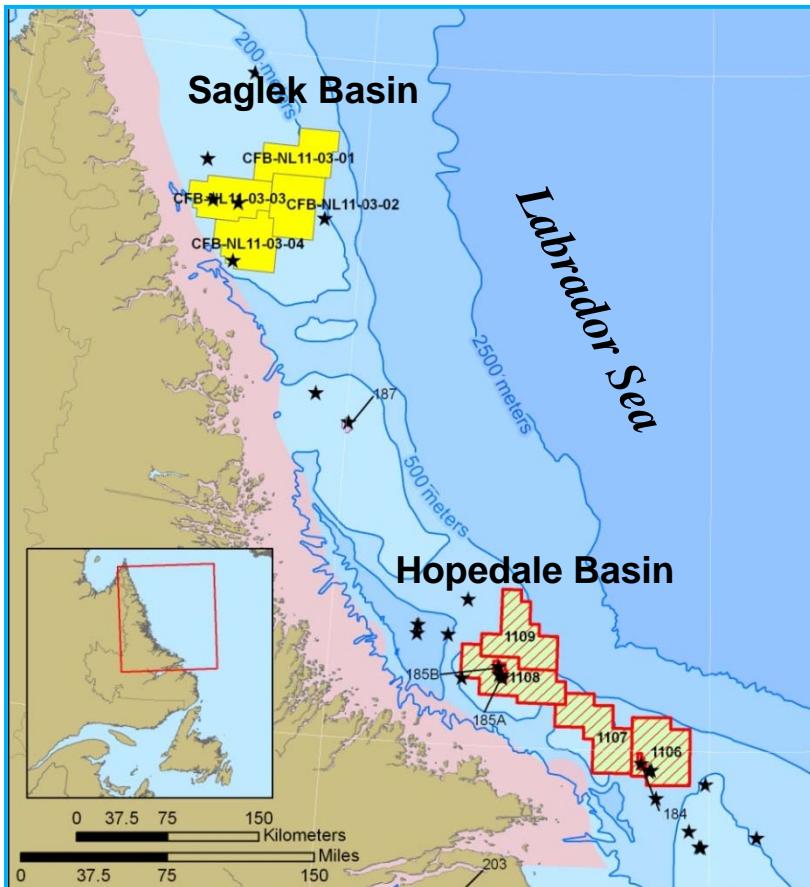
# Recent E&P Activity in Atlantic Mesozoic Basins

- In the past 5 years, industry exploration in NL's Mesozoic basins consisted of 2D and 3D seismic data acquisition, various CSEM surveys and drilling
- Exploration drilling took place in the following basins: Laurentian (East Wolverine G-37), Jeanne d'Arc (North Amethyst K-15, Ballicaters M-96 and M-96Z, and Glenwood H-69), Flemish Pass (Mizzen F-09) and East Orphan (Great Barasway F-66 and Lona O-55)
- While 4 parcels were licensed in 2008 in the Labrador Sea, no new drilling has taken place in the Hopedale Basin. The first term of the licenses will expire in 2014

# Recent E&P Activity in Atlantic Mesozoic Basins (Cont.)

- New exploration licences have been issued and consolidation/relinquishment of older issued ELs has taken place in East Orphan, Jeanne d'Arc and Laurentian basins
- Large 3D surveys were collected in Jeanne d'Arc, Flemish Pass and East Orphan basins while basin-wide 2D grids were collected in Labrador Sea
- As of the summer of 2011 there are more than \$ 900 million in exploration commitments to be undertaken by interest owners in Mesozoic basins
- **The most exciting outcome of the last exploration cycle 2005-2010: A new offshore NL basin, Flemish Pass, has been proven to contain hydrocarbons in significant accumulations**

# Labrador Basins Exploration History



- Hopedale and Saglek basins were explored in the 1970s and into the early 1980s when more than 200,000 km of 2D data was recorded and 30 wells were drilled: 21 in Hopedale Basin (HB) and 9 in Saglek Basins (SB)
- Only 24 wells reached their target; 16 wells in HB and 8 wells in SB.; only 5 significant wells exist in the NL part of SB
- There is a 1 in 3 success ratio for gas in HB and 1 in 8 success ratio for gas in the Saglek Basin. None of the wells were drilled for gas
- Six SDLs were awarded: 5 offshore Labrador (Snorri, Hopedale, N Bjarni, Bjarni, Gudrid) in HB and one for Hekja offshore Nunavut in SB

# Labrador Basins Exploration History (Cont.)

- The initial GSC investigations into offshore Labrador's geology and geophysics that included potential field, refraction and reflection data, has indicated the presence of large sedimentary basins and attracted oil companies to the petroleum potential of the region. The first petroleum exploration licence was awarded in 1966
- In an early exploration phase (1966-1982), seven majors and independent companies: Total, AGIP (now ENI), Sun (now Suncor), Aquitaine (now Husky), Gulf (now ConocoPhillips), Amerada (now Hess) and later Petro-Canada (now Suncor), formed an exploration group known as Eastcan Group interpreting the subsurface geology, sharing exploration costs and drilling in the Labrador Sea with the intention of finding oil initially with Eastcan (Total) as operator, followed by Petro-Canada. Drilling started in 1971 with the spudding of the first Labrador well, Leif E-38

# Labrador Basins Exploration History

## (Cont.)

- Other companies such as Chevron, BP, ESSO, Canterra, Paddon Hughes, Westmin, Columbia Gas, Aberford, Brinco, American Eagle, Oakwood, Amoco, Deminex, Forest, Tenneco, etc., were present but participated in the drilling of a limited # of wells (e.g. Hopedale E-33)
- During this exploration phase, five gas tests were obtained and 5 Significant Discovery Licences (SDLs) are presently registered with the C-NLOPB, for a total area of 28,085 hectares (69,399.5 acres)
- Some of the small and intermediate Canadian companies involved in the final wells drilled in the basins, took advantage of the financial incentives provided by the government's National Energy Program (NEP) instituted around 1980
- During the earlier exploration phase, the last ELs within the Canadian Labrador Sea were awarded in the late 1970s and by 1983 exploration efforts stopped due to a collapse of commodity prices. The last well drilled in the area, South Hopedale L-39, was terminated in 1983
- After a long break, the first Call for Bids in the Labrador Sea and the first activity in more than 25 years occurred in 2008 and was very successful as four large ELs were awarded

# Labrador Basins Geoscience History

- During and after the 1970s exploration drilling and seismic mapping effort, the litho-stratigraphic nomenclature of the Labrador Shelf sequence was developed within the Eastcan Group and defined in key papers by McWhea and Michel (1975), Gradstein and Williams (1976); Umpleby (1979), McWhae et al. (1980), Gradstein and Srivastava (1980) and McMillan (1982). The formations and members described by these authors were used to establish the lithostratigraphic chart published in numerous other papers
- Several other classic papers discussed the general structural and tectonic framework of the Labrador Basin including works by Mayhew et al. (1970), Laughton (1971), Grant (1972, 1975 and 1980), King and McMillan (1975), Haworth et al. (1976a and b), Cutt and Laving (1977), Srivastava (1978), Keen (1979 and 1982), Royden and Keen (1980), Srivastava (1978) and Srivastava et al. (1981)

# Labrador Basins Geoscience History (Cont.)

- A synthesis of the earlier geoscience and petroleum exploration knowledge on the Canadian Labrador Sea sedimentary basins was undertaken in the mid-eighties by the Geological Survey Atlantic funded by the Frontier Geoscience Program. The result of this study is the Monumental volume titled “East Coast Basin Atlas Series: Labrador Sea” compiled by Bell et al. and published in 1989
- The Atlas contains structural and tectonic maps and cross-sections over the four NL11-03 parcels and it is an essential read for new entrants in the Saglek Basin

# Labrador Basins Geoscience History (Cont.)

- The Labrador Atlas, is a thorough portrayal of the Labrador Sea basins and contains the following major sections: a) Seismic coverage; b) Bathymetry map; c) Quaternary geology, including maps, seismic lines, photos; d) Deep water sediment maps; e) Bedrock geology map; f) Lithostratigraphy (5 cross-sections); g) Biostratigraphy presented with the help of cross-sections, zonations, burial histories, columnar section illustrating biostratigraphy and organic geochemistry; h) Structure, illustrated by seismic lines, crustal cross-sections and maps; i) Isopach/facies maps; j) Paleogeography; k) Geochemistry and petroleum occurrence maps; l) Geophysical maps: magnetic, gravity, crustal stress, earthquake epicenters and crustal thickness; m) Seafloor spreading maps

# Labrador Basins Geoscience History (Cont.)

- More recently, the Labrador offshore basins, continental margin and geodynamic evolution were the subject of investigations and publications by Roest and Srivastava (1989), Chalmers (1991), Srivastava and Verhoef (1992), Dehler and Keen (1993), Chalmers and Laursen (1995), Srivastava and Keen (1995), Osler and Louden (1995), Chian et al. (1995), Srivastava and Roest (1995 and 1999), Louden (2002), etc.
- Using a new set of seismic data (GSI 2002-2007) Enachescu et al. (2006 and 2007), Enachescu (2006a and b), Martin and Enachescu (2007), Enachescu and Einarsson (2007), Martin (2007) and Stead (2008) extend the Labrador basin study into the deeper parts of the basin and to the outer shelf and slope area (up to 3,000 m water depth), and helped evaluate its further petroleum potential
- A contractor's report on Labrador basins potential field mapping in conjunction with the interpretation of representative regional seismic lines was recently finished and is available from GSI (Enachescu and Lyatsky, 2009)

# Geophysical Survey History

- Company and multi-client reconnaissance, regional and prospect marine seismic grids and potential field data were collected during mid 1960s to early 1980s, allowing the mapping of prerift basement, volcanics, postrift unconformity and several strong markers that could be correlated to sandstone intervals. Based on these geophysical maps, 29 exploration wells were drilled in the Canadian Labrador Sea
- Except for geoscience research, seabed investigations and environmental work, no other exploration activity has taken place in the Labrador Sea during 1983 to 2002.
- Modern regional 2-D seismic surveys were conducted by GSI between 2002 and 2008, covering both Saglek and Hopedale basins with dip and strike lines
- In 2009 Husky operated a large 2D seismic survey over several ELs in the Hopedale Basin
- No 3D survey was acquired yet in the Canadian side of the Labrador Sea
- 3D seismic surveys and CSEM were collected on Greenland side of the Labrador Sea where several petroleum exploration licences are active within a more northerly basin trend (West and South of Disko Island). West Greenland exploration includes companies such as Cairn, DONG, Chevron, Husky, ExxonMobil, Encana, PA Resources and NUNAOIL A/S. Two of these, Chevron and Husky, are also present in the Hopedale Basin

# Labrador Offshore Land Situation 2011

- **Hopedale Basin SDLs**

1. Gudrid	5,643 Hectares	operated by ConocoPhillips
2. Bjarni	4,686 Hectares	operated by Suncor Resources
3. N. Bjarni	7,592 Hectares	operated by Suncor Resources
4. Snorri	7,264 Hectares	operated by Suncor Resources
5. Hopedale	2,900 Hectares	operated by Husky Oil

- **Saglek Basin SDL**

1. Hekja	11,184 Hectares	operated by Husky Oil
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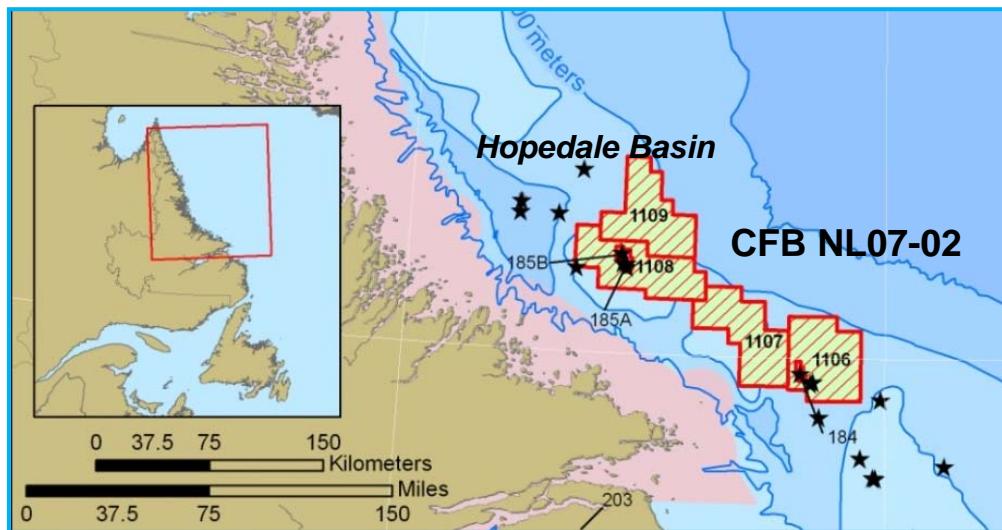
- **Hopedale Basin ELs Awarded November 2000**

1. EL 1106	236,981 Ha	operated by Husky Oil
2. EL 1107	236,525 Ha	operated by Vulcan/Investcan
3. EL 1108	233,712 Ha	operated by Husky Oil
4. EL 1109	232,460 Ha	operated by Chevron

# Recent Labrador Call for Bids Results

CFB NL07-02 was concluded with the awarding in September 2008 of all four parcels as following:

EL No.	Basin	Size (ha)	Date Issued	Bid Size \$	Operator	Other Partners
1106	Hopedale	236,981	2008	<b>10 MM</b>	Husky Oil	
1107	Hopedale	236,525	2008	<b>9.6 MM</b>	Vulcan	Investcan
1108	Hopedale	233,712	2008	<b>120 MM</b>	Husky Oil	Suncor
1109	Hopedale	232,460	2008	<b>50 MM</b>	Chevron	



# Recent Offshore Labrador Exploration Activity

- The most recent exploration phase started in early 2000s with the acquisition of modern 2D seismic reflection data by GSI. Older data recorded during 1970-1982 was simultaneously reprocessed
- The new data recorded by GSI during 2003-2008, totalling over 35,000 km was collected over the Hopedale and Saglek basins, with special attention to tying the discovery wells and other significant wells
- Two modern GSI trans-Labrador Sea lines totalling 1,500 km connecting the Labrador and Greenland margins were also recorded
- Gravity and Magnetic data was recorded by GSI simultaneously with the seismic data

# Recent Offshore Labrador Exploration Activity

- In early-2000s, the GSC initiated a new research project focused on Labrador basins that included high resolution palynology dating of sedimentary formations, rethinking of geodynamic evolution and a new look at the basins' petroleum systems
- In 2008 C-NLOPB awarded four Hopedale Basin ELs, located in the southern part of the basin, where 4 gas discoveries were made in an earlier exploration phase
- A large 2D seismic program was conducted by Husky during 2010 consisting of 5550 km. The grid partially covers Husky's operated ELs 1106 and 1108 and Vulcan's operated EL 1107
- Based on 3D seismic and CSEM surveys, Cairn and partners drilled 2 wells in West Greenland in 2010 that had hydrocarbon shows. Once publicly released, the results of these wells, will add considerably to the geological knowledge of the northern Labrador Sea region

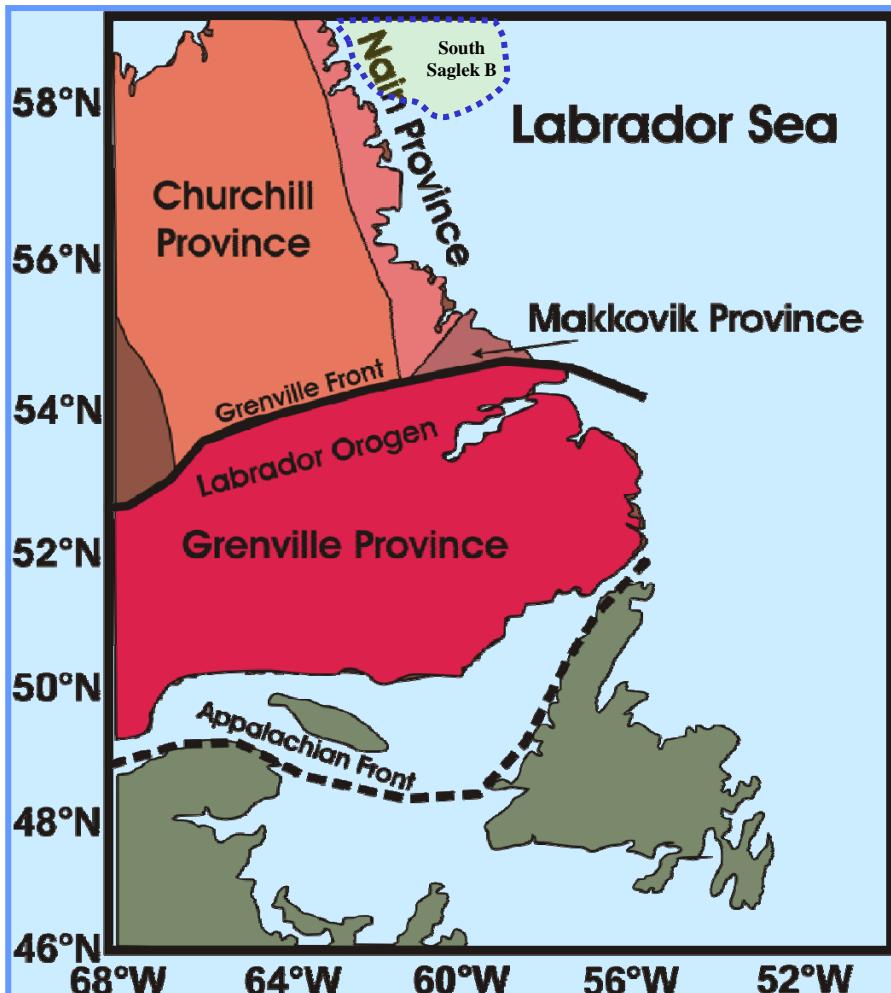
# Recent Geoscience Studies

- Labrador Sea regional petroleum geoscience studies were carried out at Memorial University during 2004-2009, finalized with several largely disseminated professional papers and with Master's thesis by Martin (2007), Stead (2008) and Schwartz (2008)
- New palynological and paleoenvironment studies were carried out during the past decade by GSC Atlantic (Williams, 2007 several studies; Dehler et al., 2007; Dickie et al., 2009)
- A new tectonostratigraphic evolution of the Labrador margin was proposed by Dickie et al. (2010 and 2011)
- Regional tectonic studies in the Baffin Bay area including the Saglek Basin, were carried out by Oakey (2005-2009) and Oakey et al. (2009)
- A 4-D geochemical modeling and integrated petroleum system study of the northern portion of Saglek Basin was performed by GSC Atlantic (e.g., Jauer et al., 2006; Wielens et al., 2007; Wielens and Jauer, 2009)
- SAR study of the sea surface hydrocarbon slicks coupled with identification of sea-bottom and seismic hydrocarbon indicators in the North Saglek Basin was published by Jauer et al., 2009 and Jauer and Budkewitsch (2010)

# 3. Regional Geology of Labrador Basins

- Economic Basement
- North Atlantic Rifting
- Labrador Continental Margin
- Labrador Margin Geological Cross-section
- Tectono-Stratigraphic Megasequences
- Stratigraphy, Geodynamic Stages, Structural Style and Seismic Markers
- Representative Regional Seismic Section

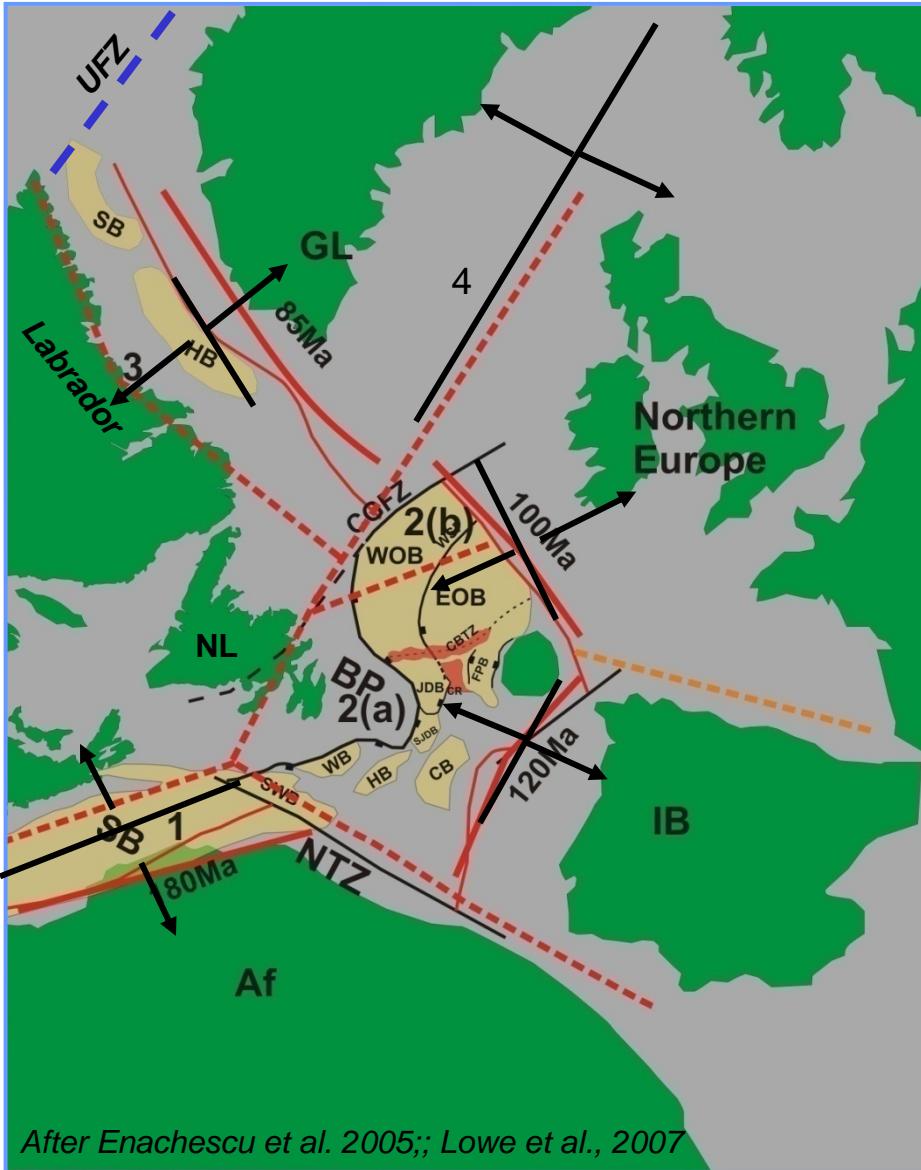
# Economic Basement Offshore Labrador



Modified from Funck et al., 2001; Stead, 2008

- Prerift basement along the Labrador Shelf consists of Precambrian metamorphic and magmatic rocks as well as Paleozoic clastics and carbonates
- Basement in the North, including under the Saglek Basin, is the Nain Province terrane, aged between 1.9 and 1.8 Ga
- Basement in the South is Grenville Province terrane, aged between: 1.6 and 1.0 Ga
- On the southern Labrador Shelf, an unmetamorphosed Lower Paleozoic carbonate platform sequence underlies the Mesozoic sediments; Paleozoic remnant blocks may also exist under the Saglek Basin
- Precambrian metamorphic rocks, granites, tight Paleozoic carbonates and thick basalt and diabase intervals form the economic basement for Labrador basins

# North Atlantic Rifting



**Labrador basins were formed by intra-continental and oceanic rifting. There were four continental rifting phases in the N Atlantic region:**

- 1. Tethys rift phase** during Late Triassic to Early Jurassic
- 2. North Atlantic Rift phase** during Late Jurassic to Berriasian
- 3. Labrador Sea Rift phase** during Berriasian to Albian
- 4. Greenland/Europe rift phase** during Late Cretaceous-Eocene

**Abbreviations are** GL = Greenland, IB = Iberia, Af = Africa plates; SB = Saglek Basin, HB = Hopedale Basin, WOB = West Orphan Basin, EOB = East Orphan Basin, JDB = Jeanne d'Arc Basin, FPB = Flemish Pass Basin, SJDB = South Jeanne d'Arc Basin, CB = Carson Basin, HS = Horseshoe Basin, WB = Whale Basin, SWB = South Whale Basin, SB = Scotian Basin, UFZ = Ungava Fault Zone CGFZ = Charlie Gibbs Fracture Zone, CBTZ = Cumberland Fault Transform Zone, NTZ = Newfoundland Transform Zone

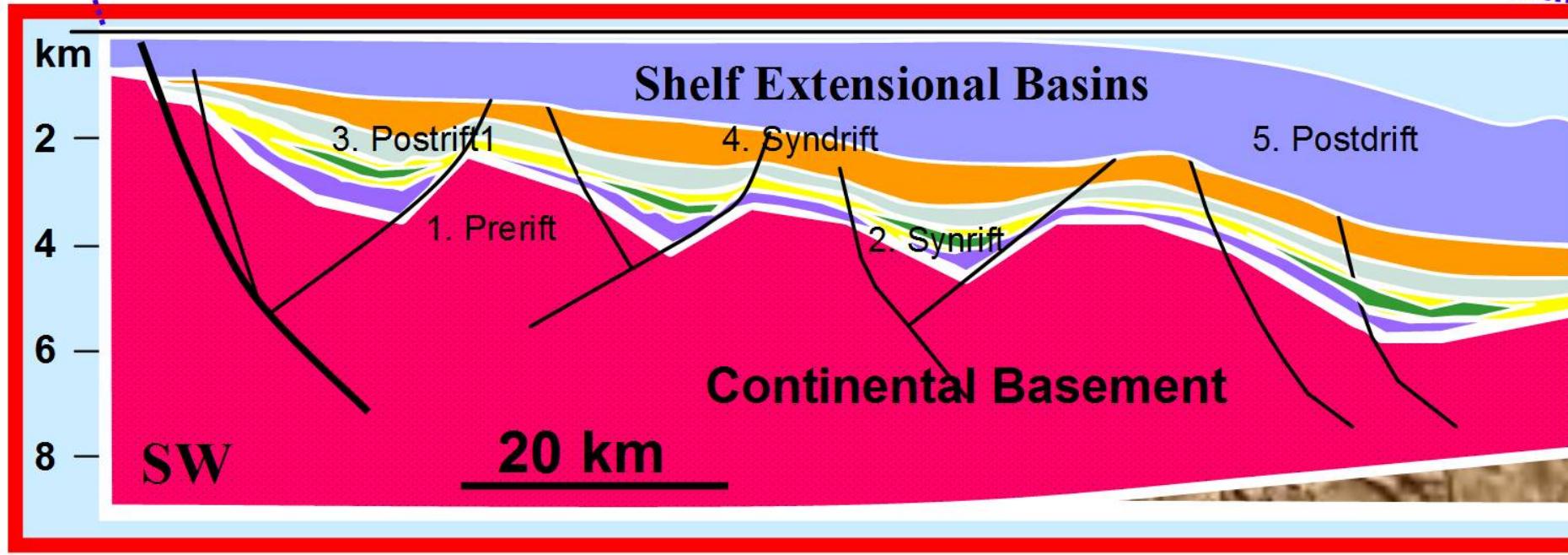
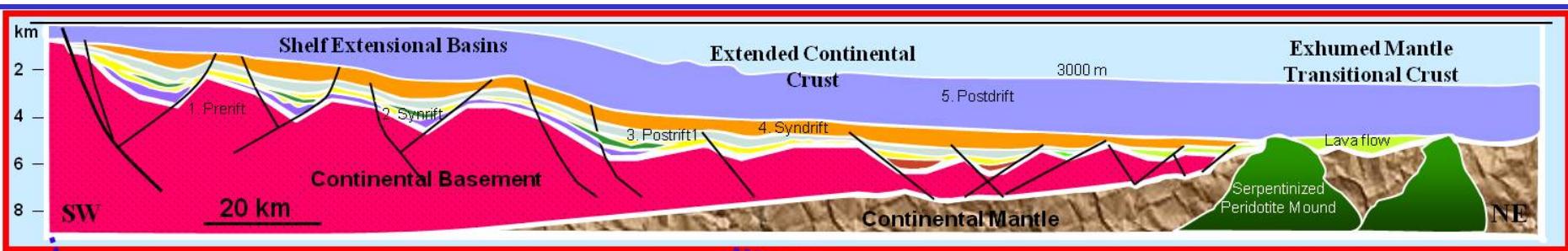
# Labrador Continental Margin

- The Labrador continental margin is an Atlantic-type extensional margin formed during Early Cretaceous as an arm of the main North Atlantic rifted zone. The region was subjected to repeated orogenies, peneplaining, rifting, continental mantle exhumation, transtension, drifting, seafloor spreading between Labrador and Greenland, oceanic rift cessation, rotation, ridge jump, ridge abandonment and significant thermal subsidence (Srivastava and Verhoef, 1992; Dehler and Keen, 1993; Srivastava and Roest, 1999; Roman, 1999; Chalmers and Pulversaft, 2001; Louden, 2002; Enachescu, 2005; Enachescu et al., 2006; Enachescu, 2006a and b; Enachescu et al., 2007; Dehler et al., 2007; Enachescu 2008; Oakey 2005 and 2007; Dickie et al., 2010)
- Part of the Mesozoic intracontinental basin network formed between North America and North Africa and Europe, the Labrador margin has first order attributes for classification as a non-volcanic Atlantic type margin (Balkwill, 1987; Bell et al., 1989; Balkwill et al., 1990; Keen et al. 1990 and 1994; Dehler and Keen, 1993; Srivastava and Verhoef, 1992; Louden et al., 1996; Srivastava and Roest, 1999; Roman, 1999; Chalmers and Pulversaft, 2001; Louden, 2002; Enachescu, 2005a and b; Enachescu et al., 2006; Enachescu, 2006a and b; Enachescu and Martin, 2007; Martin, 2007; Enachescu et al., 2007; Stead 2008; Dickie et al., 2010)

# From Continental Extension to Passive Margin

- These passive margin attributes include:
  - A large, almost flat continental shelf and a more steeply inclined continental slope
  - An outer shelf and slope containing a thick prism of seaward dipping Late Cretaceous and Tertiary clastic sediments
  - Presence of alternate half-graben/horst geometry resulting from continental crust extension during rifting; Labrador Sea half-grabens are filled with Early Cretaceous sedimentary rocks and volcanics
  - Lack of significant lateral compression, while some compressional modified extensional structures exist
  - Landward onlap or fault bounding of the synrift sedimentary sequence
  - Existence of an early volcanic-volcanogenic sequence (Alexis Formation)
  - Presence of a deep water transitional crust segment including basalt floods, intrusions, possible gabbros, peridotites and serpentinized peridotites
  - Gradual transition to pure oceanic crust identified by magnetic lineation
- Labrador basin sedimentary fill is composed almost exclusively of clastics. Minor, thin limestone beds are rarely intersected in the drilled wells
- Tertiary and Late Cretaceous volcanics are significant only in the N. Saglek Basin (Enachescu, 2008; Jauer et al., 2009; Jauer and Budkewitsch, 2010)

# Labrador Margin Geological Cross-section



# Offshore Labrador Tectono-Stratigraphic Megasequences

- The basin fill contains exclusively terrigenous clastic sediments of Cretaceous, Tertiary and Quaternary age derived from widespread erosion of central Canada and local erosion of coastal uplands and intra-basinal ridges during the rifting and separation of Greenland and North America. A mega-drainage system located in Northern and Central Canada and Hudson Bay Area introduced a very thick (10 Km+) sedimentary column in Saglek Basin (Klose et al., 1982; Trettin, 1991). Unlike other North Atlantic sedimentary regions, the Labrador Basin does not contain salt
- Enachescu (2006 a and b) and MUN graduate students Martin (2007) and Stead (2008) synthesized the results of the earlier exploration cycle (1970-1983), by using the lithostratigraphic charts and tectonic evolution of Umpleby (1979), McWhea (1980), Balkwill (1987) and Bell et al. (1989), and by performing seismic stratigraphic interpretation on a new set of regional seismic lines (GSI surveys 2002-2007). As a result, the Labrador basin fill was divided into 5 major tectono-stratigraphic megasequences. This tectono-stratigraphic scheme with some modifications suggested in recent studies by the GSC will be used in this presentation

# Offshore Labrador Tectono-Stratigraphic Megasequences (cont.)

**1. Prerift Basement (Precambrian to Early Paleozoic)** formed during repeated orogenic episodes. It consists of Precambrian metamorphic and magmatic rocks (1.9-1.0 Ga) of the Grenville, Makkovik and Nain provinces as well as Paleozoic clastics and carbonates (dated Ordovician) (Taylor, 1979 and 1981; Bell and Howie, 1990; Williams, 1995 and 2003; Williams et al., 1999; Atkinson and Fagan, 2000; Hall et al., 2002; Fagan and Hicks, 2005; Schwartz, 2008). At the contact between the prerift basement and synrift rocks is the regional Labrador Unconformity

**2. Synrift Sequence (Barremian - Albian)** that consists exclusively of intracontinental deposits formed during continental rifting. Rift basin fill started with the volcanics of the Alexis Formation including basaltic lava flows and volcanoclastics associated with crustal thinning. Deposition continued with a major pulse of clastics including alluvial arkosic sandstones, microconglomerates, coals and lacustrine shales of the Bjarni Formation. The sequence is capped by a pervasive unconformity (the Avalon Unconformity)

# Offshore Labrador Tectono-Stratigraphic Megasequences (Cont.)

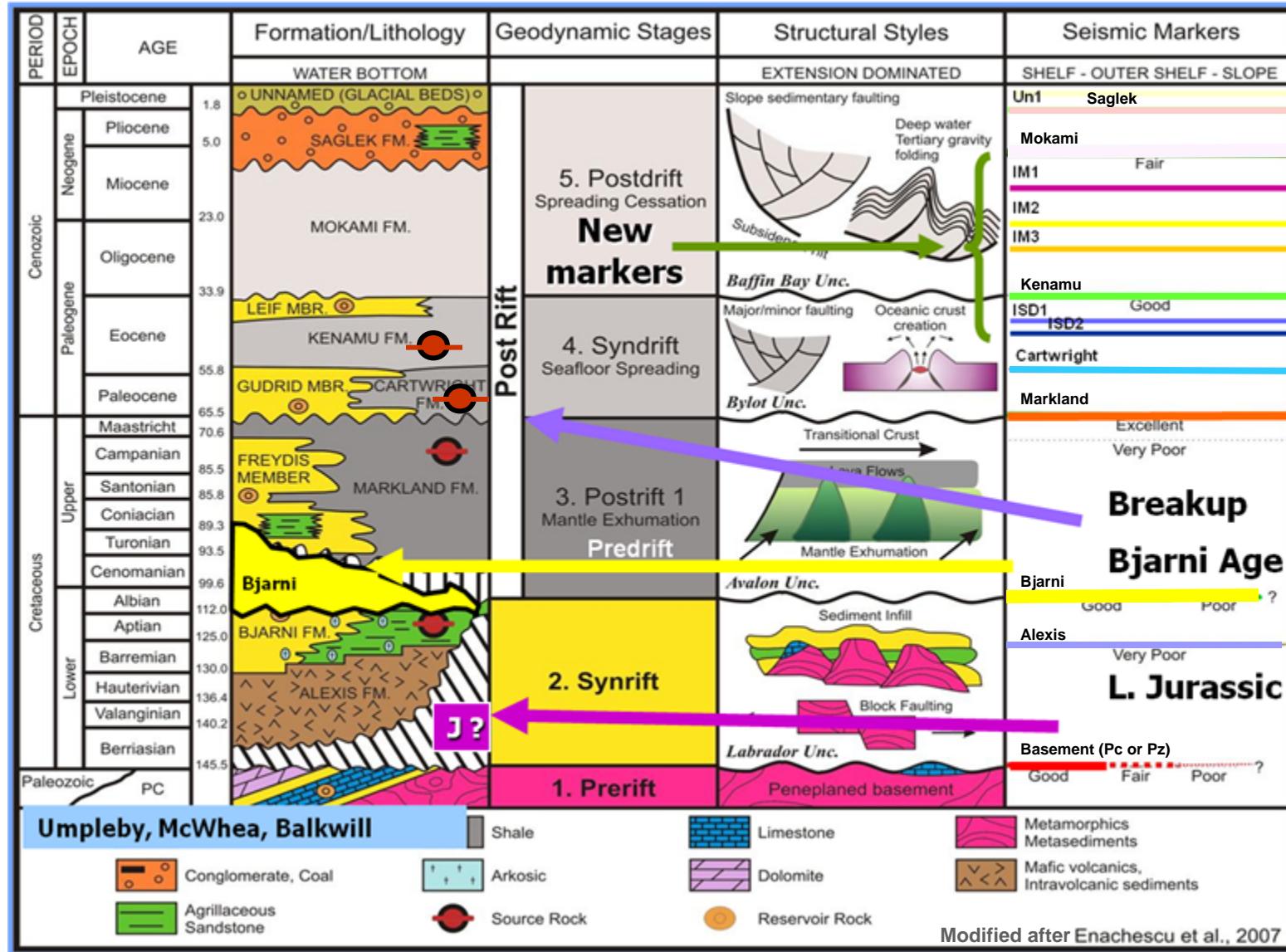
3. **Postrift1 or Predrift Sequence (Cenomanian – Maastrichtian)** was formed after the end of the intra-continental extension and during the exhumation of the continental mantle and its attachment to the stretched continental crust. Exhumed mantle and serpentinite ridges are yet unproven by drilling (Chian et al., 1995; Chian and Louden, 1994; Reston et al., 2001; Louden 2002; Enachescu, 2006a and b; Enachescu et al., 2007; Enachescu and Einarsson, 2007; Sibuet et al., 2007; Stead 2008). During the formation of this transitional crust, sea invaded the rifted area depositing the fine clastics of the Markland Formation and the near shore, Freydis Mbr quartzose sandstone. The sequence is contained between Avalon and Baylot unconformities
4. **Syndrift (Paleocene - Eocene)** formed during the sea floor spreading and attachment of the oceanic crust to the previously formed transitional crust. The widespread fine clastics of the Cartwright and Kenamu formations were deposited during this tectonic stage. Marginal marine and probably lowstand sandstones of the Gudrid and Leif members were also deposited. The syndrift sequence is bounded by Baylot and Baffin Bay unconformities

# Offshore Labrador Tectono-Stratigraphic Megasequences (Cont.)

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

***Observation:*** Postrift1 or Predrift Sequence, Syndrift Sequence and Postdrift Sequence all form the classic Postrift or the Thermal Subsidence Stage in the evolution of the Labrador continental margin.

# Offshore Labrador Stratigraphy, Geodynamic Stages, Structural Style and Seismic Markers



# Offshore Labrador Stratigraphy, Geodynamic Stages, Structural Style and Seismic Markers

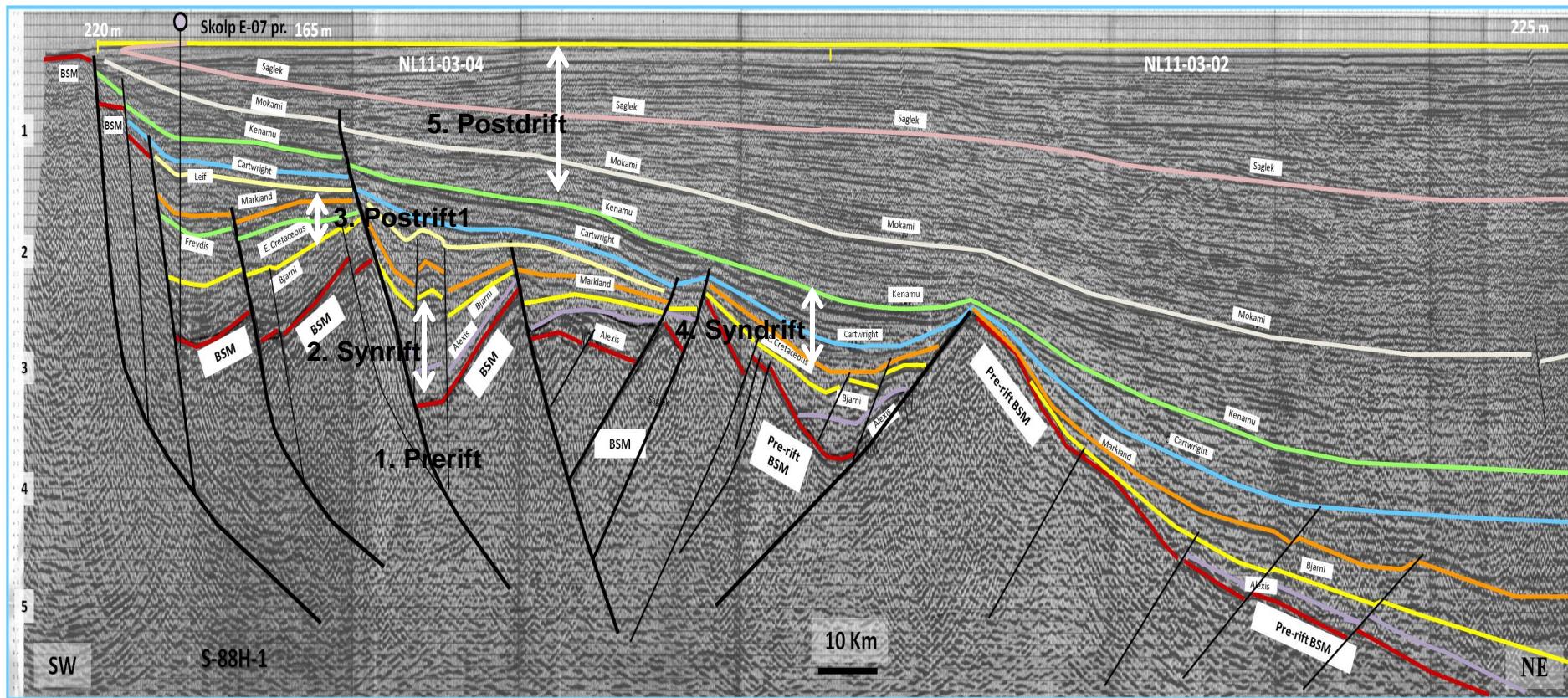
## *Observation on the chart:*

- Seismic markers are interpreted from GSI 2003-2007 seismic data set made available to MUN through a company data donation
- New Tertiary markers ISD1 and ISD2, IM1, IM2, IM3 and UN1 are introduced on the slope (Enachescu and Lyatski, 2010)
- The first true oceanic crust (continental breakup) occurs after mantle exhumation and deposition of Markland Formation (end of Cretaceous)
- According to new GSC studies, the age of Bjarni Formation may span from Barremian to Turonian and may vary in age in different parts of the Labrador margin (Dickie et al., 2010 and 2011)
- Late Jurassic sediments including Kimmeridgian marine shale may have been deposited in an epicontinental sea preceding Labrador-Greenland rifting and may be preserved in deeper, local depocenters. Late Jurassic is marked with a question mark on the chart as these rocks have not been encountered in drilling

# Representative Seismic Section

- As illustrated by previously introduced seismic sections from Labrador basins, the synrift sequence (Alexis and Bjarni formations) fills the grabens and overlies some of the horsts and ridges (e.g. Enachescu, 2008; Enachescu et al., 2009 and [http://www.nr.gov.nl.ca/nr/invest/cfb\\_nl07\\_2\\_hopedale.pdf](http://www.nr.gov.nl.ca/nr/invest/cfb_nl07_2_hopedale.pdf))
- Synrift sedimentary rocks are deformed by NNW-SSE, along strike faults and ENE-WNW transfer faults
- The postrift sediments generally dip and thicken basinward, and are less deformed on the shelf, draping over synrift structures and paralleling the postrift unconformity.
- Considerable deformation of the postrift sequence occurs on the slope and rise due to gravity or shale detachment tectonics

# Representative Seismic Section



Interpreted dip seismic section S-88H-1 crossing South Saglek Basin in the CFB NL11-03 area. The line interpretation shows main formations and members, major faults, geodynamic stages, structural style and main seismic markers (see slide 63). Seismic line source: C-NLOPB.

# Tectono-Stratigraphic Summary

- Labrador basins are floored by Proterozoic metamorphic rocks, and in places by Paleozoic strata including quality reservoirs in Ordovician carbonates. The basement was significantly stretched during Early Cretaceous when first volcanics and then continental clastics were deposited
- Separated by uplifted blocks, several individual basins formed. The horsts, grabens and elongated blocks developed during this stage have produced the present day structural framework of the margin
- The synrift stage deposits contain the Bjarni Formation that includes both excellent Bjarni sandstone reservoir and quality petroleum source rocks. The Bjarni sandstones were deposited on the horsts and within the grabens and elongated troughs
- Following rifting, the continental mantle emerged to the bottom of the invading early Late Cretaceous sea, was modified by encroaching seawater and serpentinized. During this predrift stage more clastics of the Markland Formation and Freydis Member including reservoir and source rocks were deposited in an enlarged and slightly subsiding basin
- Postrift intrusive and effusive volcanics are widespread in the northern part of the Saglek Basin

# Tectono-Stratigraphic Summary

## (Cont.)

- A drift stage followed when Labrador and Greenland separated and oceanic crust was emplaced between the two parting pieces of continent. During this stage, clastics of the Cartwright and Kenamu formations were deposited on the Labrador margin. Two other sandstone members, Gudrid and Leif, were deposited in coastal and probably in deep water settings
- Several changes in the direction of extension took place during this stage producing strike-slip movements within the sedimentary fill deposited on top of the transitional and oceanic crust. These movements translated into several regional markers and unconformities especially visible on the slope and deep water
- A final postdrift stage followed after the movement of Greenland away from Labrador ended and the emplacement of oceanic (basaltic) crust ceased. The Greenland microplate then started to detach from the European Plate
- A major paleo-drainage system was feeding immense quantities of sediments into the Saglek Basin. At the same time, shelfal erosion and redeposition of sediments took place. This massive sediment input enlarged Labrador's continental margin and produced a great amount of subsidence in both the Hopedale and Saglek basins. The fine clastics of the Mokami Formation followed by the coarse clastics of the Saglek Formation and by unnamed glacial beds were deposited during this stage

# **4. Petroleum Geology of Saglek Basin**

- Exploration Results of the Labrador Basins**
- Source Rocks**
- Reservoir Rocks**
- Seals**
- Hydrocarbon Traps**
- Maturation and Migration**
- Petroleum Prospects Risks**

# Exploration Results of the Labrador Basins

**Hopedale Basin:** 5 gas discoveries found while searching for oil

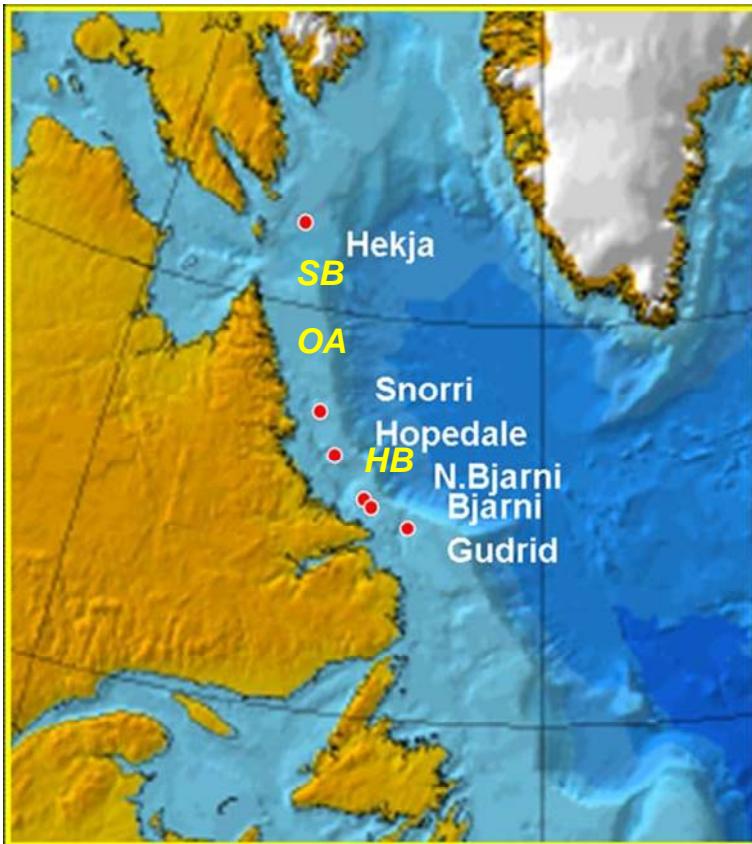
<b>Discovery</b>	<b>Date</b>	<b>Recoverable Reserves</b>
➤ Bjarni H-81	(1973)	0.9 Tcf
➤ Gudrid H-55	(1974)	0.9 Tcf
➤ Snorri J-90	(1975)	0.1 Tcf
➤ Hopedale E-33	(1978)	0.1 Tcf
➤ North Bjarni F-06	(1980)	2.2 Tcf

**Saglek Basin:** one large gas discovery in North Saglek Basin

➤ Hekja O-71	(1979/80)	2.3 Tcf
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Undiscovered gas potential is estimated at 22 Tcf  
(Drummond, 1998; Bell and Campbell, 1990 and Enachescu, 2006)

# Characteristics of the Labrador Discoveries



Well	Gas MMcf/d	Condensate Bblsd	Source	Reservoir
Hekja	9.4	107	Cartwright, Kenamu? fms	Gudrid ss
Snorri	9.8	235	Bjarni Shale	Gudrid ss
Hopedale	14.2 19.5	310 500	Bjarni shale Bjarni shale	Bjarni ss Ordovician carbonate
N. Bjarni*	-	-	Bjarni shale	Bjarni ss
Bjarni	20	774	Bjarni shale	Bjarni ss
Gudrid	20	113	Bjarni shale	Ordovician dolomite

\* = No flow rates due to mechanical failure. N. Bjarni is a separate closure located north of the Bjarni discovery

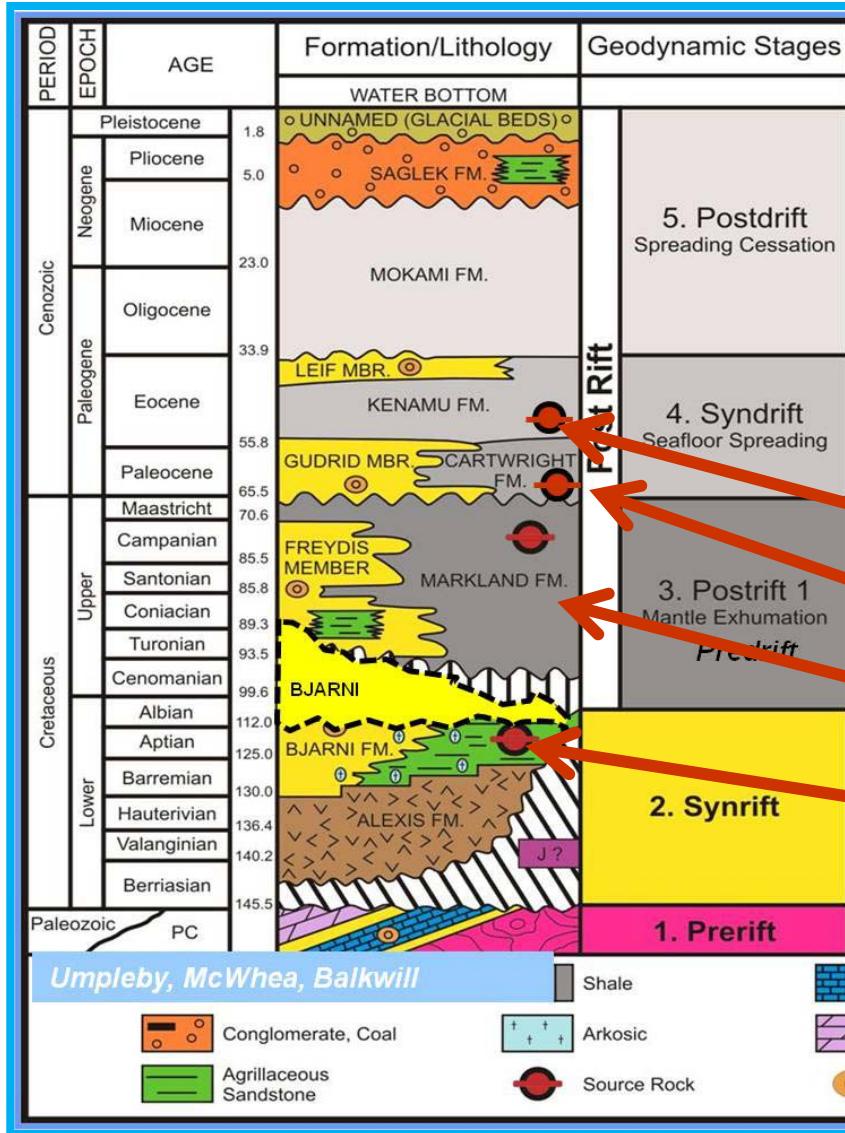
# Exploration Results of the Labrador Basins (Cont.)

- **Hopedale Basin** discoveries made in the 1973-1983 exploration cycle have an estimated total resource of 4.2 Tcf of natural gas and 123 million barrels of NGL of 50-60° API (C-NLOPB). One complex formed by adjacent Bjarni and North Bjarni fields contains more gas than the currently producing Sable Project (composed of 5 medium size fields offshore Nova Scotia) or the large (2.7 Tcf) White Rose gas cap in the Jeanne d'Arc Basin
- **Saglek Basin** had only a small number of exploration wells during 1973-1983 exploration cycle. Out of the 8 significant wells, the Hekja O-71 well drilled in 1979 and terminated in 1980, encountered 44 m of net gas pay in a Paleocene to Eocene reservoir (Gudrid Member equivalent). The Hekja structure has an estimated total resource of 2.3 Tcf
- At least two proven petroleum systems exists in the Labrador basins, given that the source rocks of the 2 discoveries were found to be different, and therefore there are high expectations for further gas and oil discoveries
- The following section on Labrador petroleum systems is written following accounts by Umpleby (1979), McWhea (1980), Balkwill et al. (1987), Bell (1989), Fowler et al. (1995), Fowler (2005), Enachescu (2006a and b), Martin (2007), Stead (2008), Dickie et al. (2010), Jauer and Budkewitsch (2010), exploration documents in the C-NLOPB archive and the limited petroleum geology literature on the area

# Source Rock

- Several Mesozoic intervals with medium to rich source rocks have been recognized from drilling and geochemical analyses (Powell, 1979; Rashid et al., 1980; McMillan, 1982; Balkwill, 1987; Bell et al., 1989; Balkwill et al., 1990; Fowler et al., 2005; Enachescu, 2008; Dickie et al., 2010)
- Historically, the Markland shales have been considered the main source rock for the Labrador Sea gas accumulations (e.g., McWhae et al., 1980; Balkwill and McMillan, 1990; Bell et al., 1989)
- Fowler et al. (2005) documented that the Bjarni Formation shale intervals have high organic content, are mature and constitute the principal source rock for the Labrador basins. He also identified the Paleocene and Eocene shale of Saglek Basin as having high TOC and being mature in the basin
- Graduate research work done (sponsored by PR-AC, NSERC and PPSC) at Memorial University based on geochemical parameters provided by GSC and seismic lines donated by GSI, shows increased source rock presence and adequate maturation on the outer shelf and slope (Enachescu 2006a and b; Martin and Enachescu, 2007; Martin, 2007; Stead 2008)
- Numerous amplitude anomalies and other Direct Hydrocarbon Indicators (flat spots, gas chimneys, frequency attenuation, bright spots along faults, etc.) are present in the basin showing hydrocarbon migration and accumulation (e.g. Enachescu, 2006a and b; Enachescu, 2008; Martin, 2008)

# Source Rock (Cont.)



Early Cretaceous to Eocene intervals with medium to rich source rocks have been recognized from drilling in Labrador basins

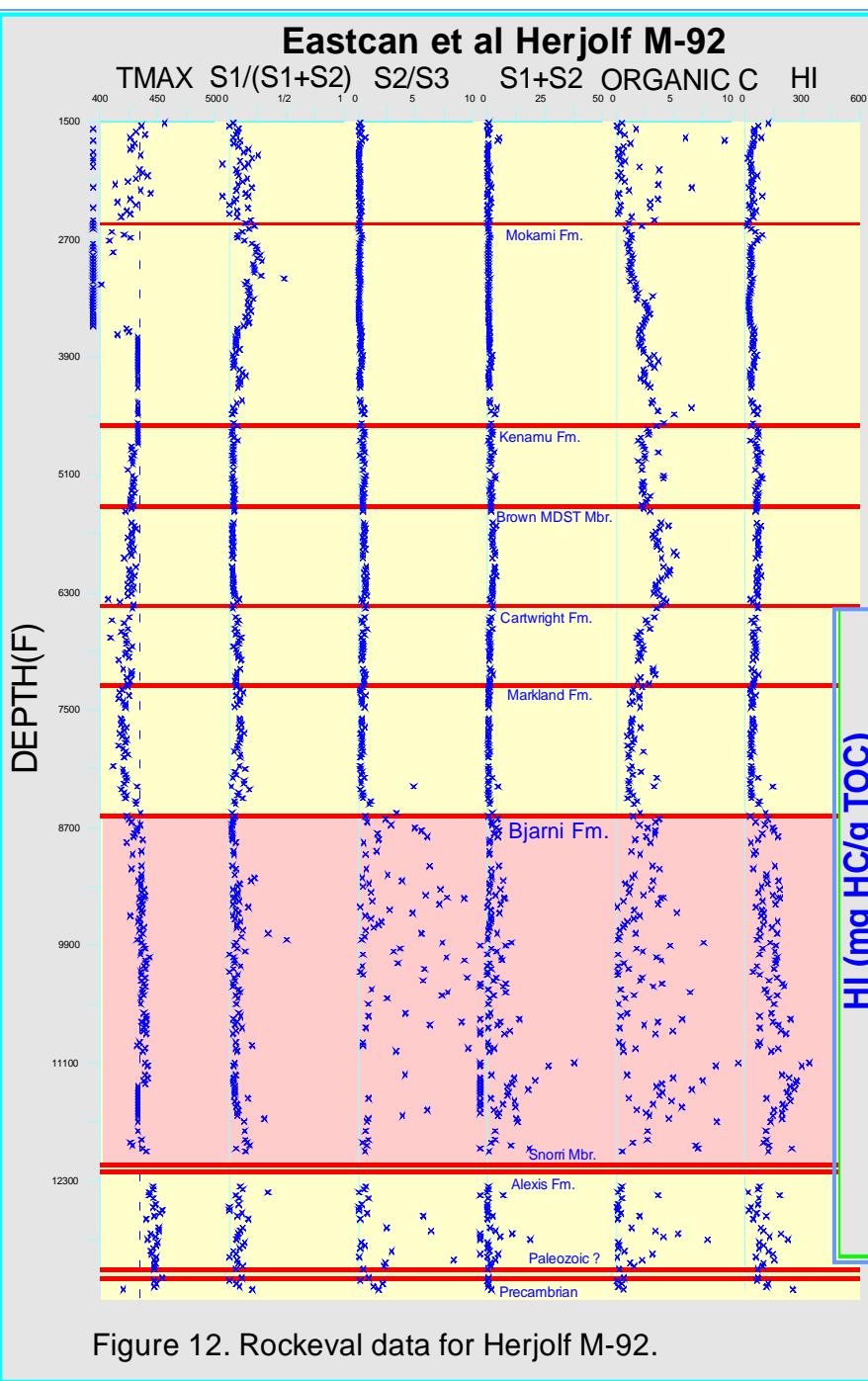
- *Kenamu Shale*
- *Cartwright Shale*
- *Markland Shale*
- *Bjarni Shale*

# Source Rock (Cont.)

## Bjarni Formation shale

- Rock-Eval analysis of cuttings, geochemical analysis of organic rich intervals and organic petrology shows that the best source rocks occur in the Early Cretaceous Bjarni Formation and contains mostly type III terrestrial organic content (Fowler et al., 2005). The source interval is quite thick (more than 500 m) at Herjolf M-92 well and has TOC of 5%. Additionally coal seams are present in the Bjarni Formation that can generate gas. Bjarni shales are located mostly in the synrift grabens. Often, the Bjarni Formation shows thickening in grabens located on the outer shelf and on the slope.
- An average depth of 3335 meters to  $R_o > 0.7$  (source maturity indicator) was computed by Martin (2007) as minimum depth of burial of Bjarni shales in order to generate hydrocarbons. This average depth to maturation was used to produce a “kitchen” map for the Bjarni Formation, that shows increased amount of possible Bjarni source rock on the eastern part of the shelf.
- The un-biodegraded oil encountered at North Leif I-05 (33° API) shows immaturity (Fowler et al., 2005) but more mature source rock and reservoired oil may exist in deeper parts of the basin

## Eastcan et al Herjolf M-92



# Bjarni Shale Source Rock

## Reservoir and source rock juxtaposition

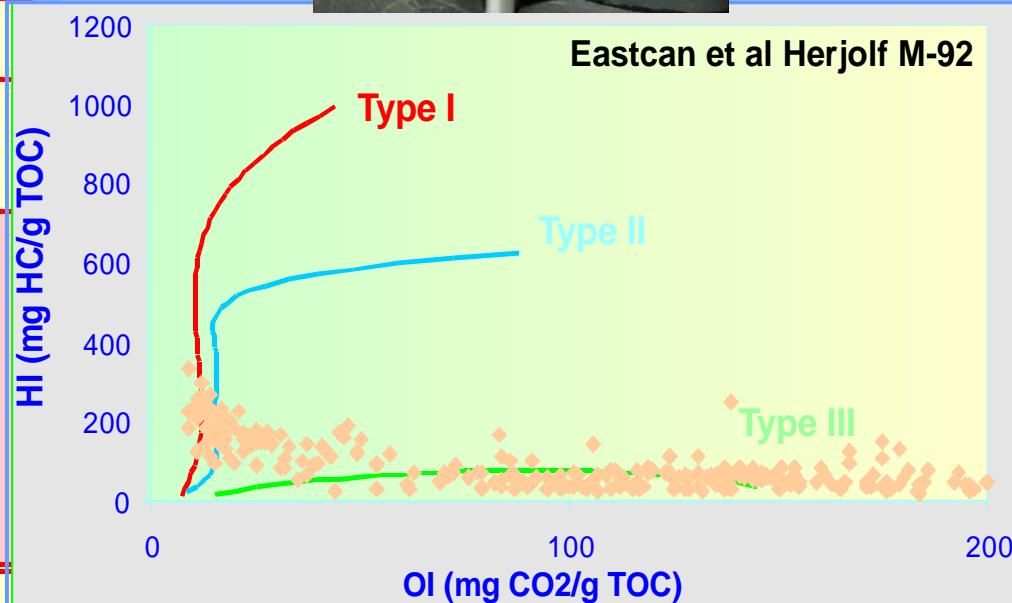
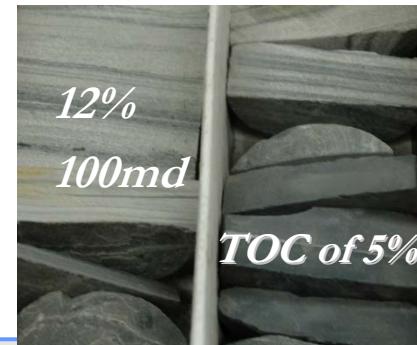


Figure 13. Cross-plot of rockeval hydrogen and oxygen indices for Herjolf M-92.

from Fowler et al., 2005

Figure 12. Rockeval data for Herjolf M-92.

Enachescu, 2011



# Source Rock (Cont.)

## Markland Formation shale

- Until mid-2000s, the Cenomanian to Maastrichtian aged Markland Formation was considered the main source rock for the Labrador gas (GSC, 1989; De Silva, 2003; Maneley, 2003; Klassen, 2005; Enachescu and Fagan, 2005a). According to these authors, the fine grained Markland Formation includes high TOC shales (1 to 4%) and is also a terrestrial dominated source rock with some marine influence (type II and III).
- An average depth of 3335 meters to  $R_o > 0.7$  was computed by Martin (2007) from Hopedale Basin wells as the minimum depth of burial of Markland shales in order to generate hydrocarbons. The Martin (2007) study agrees with the GSC Atlas (Bell, 1989) that the Markland Formation is mature in a very large area situated downdip from the wells drilled on the inner shelf
- Time Structure and Isopach maps of the Markland Formation show that the gas discovery wells within Hopedale Basin lie outside of the region where maturity is predicted. However, their structures are opened to updip hydrocarbon migration from more easterly half grabens where shales are mature. Unlike the intermittent presence of Bjarni shale, the Markland Formation is a thick, regional shale that can provide a very large hydrocarbon kitchen

# Source Rock (Cont.)

## Markland Formation shale

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

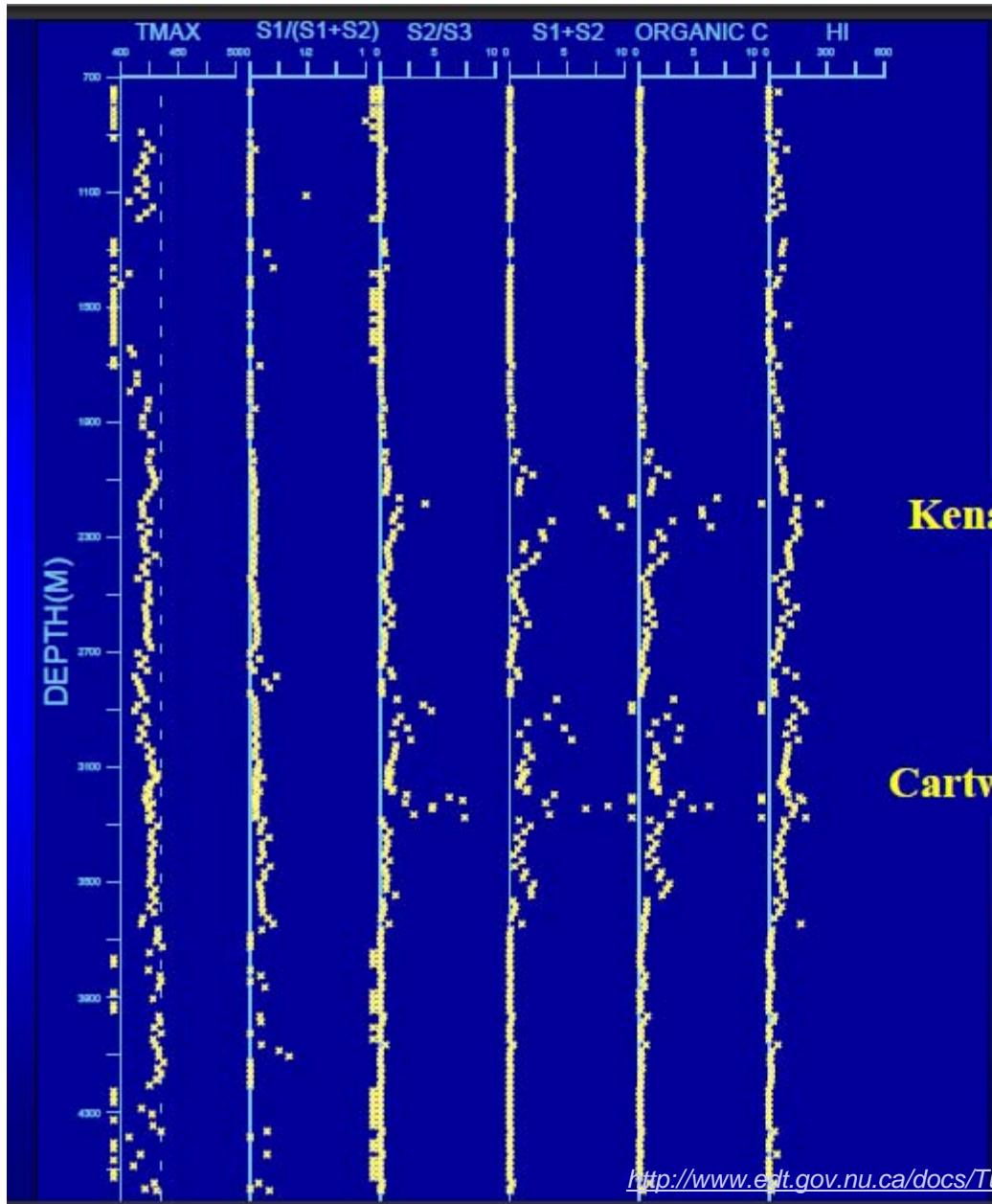
# Source Rock (Cont.)

## Cartwright Formation shale

- Fowler (2005) researched the source rock for Hekja gas and condensate field and found that both the Cartwright and Kenamu formations have coaly silicilastic sediments and coals intervals with high TOC
- Paleocene aged Cartwright Formation contains marine shales with TOC generally ranging from 1 to 3%, but values of up to 10% have been observed. The hydrogen index is usually low (less than 200) but a thick zone in the Hekja well was reported to have high resinite content (oil-prone) and a hydrogen index of 400  
[http://inac-ainc.info/nth/og/pubs/prosp/c6\\_sagl-eng.pdf](http://inac-ainc.info/nth/og/pubs/prosp/c6_sagl-eng.pdf)

## Kenamu Formation shale

- Eocene Kenamu Formation, consisting of marine shales and siltstones, overlies and oversteps the Cartwright Formation onto slope of the basin. TOC averages 1.5 but coaly intervals with TOC ranging from 2.5 to 10%, were encountered. The hydrogen index is generally low
- Both Cartwright and Kenamu mudstones are type III to type II source rocks and are thermally immature in Hekja O-71 and other shelfal wells. However, they will be mature if buried in deeper troughs, areas near the shelf break and on the slope (more than 4000 m)



# Hekja M-71

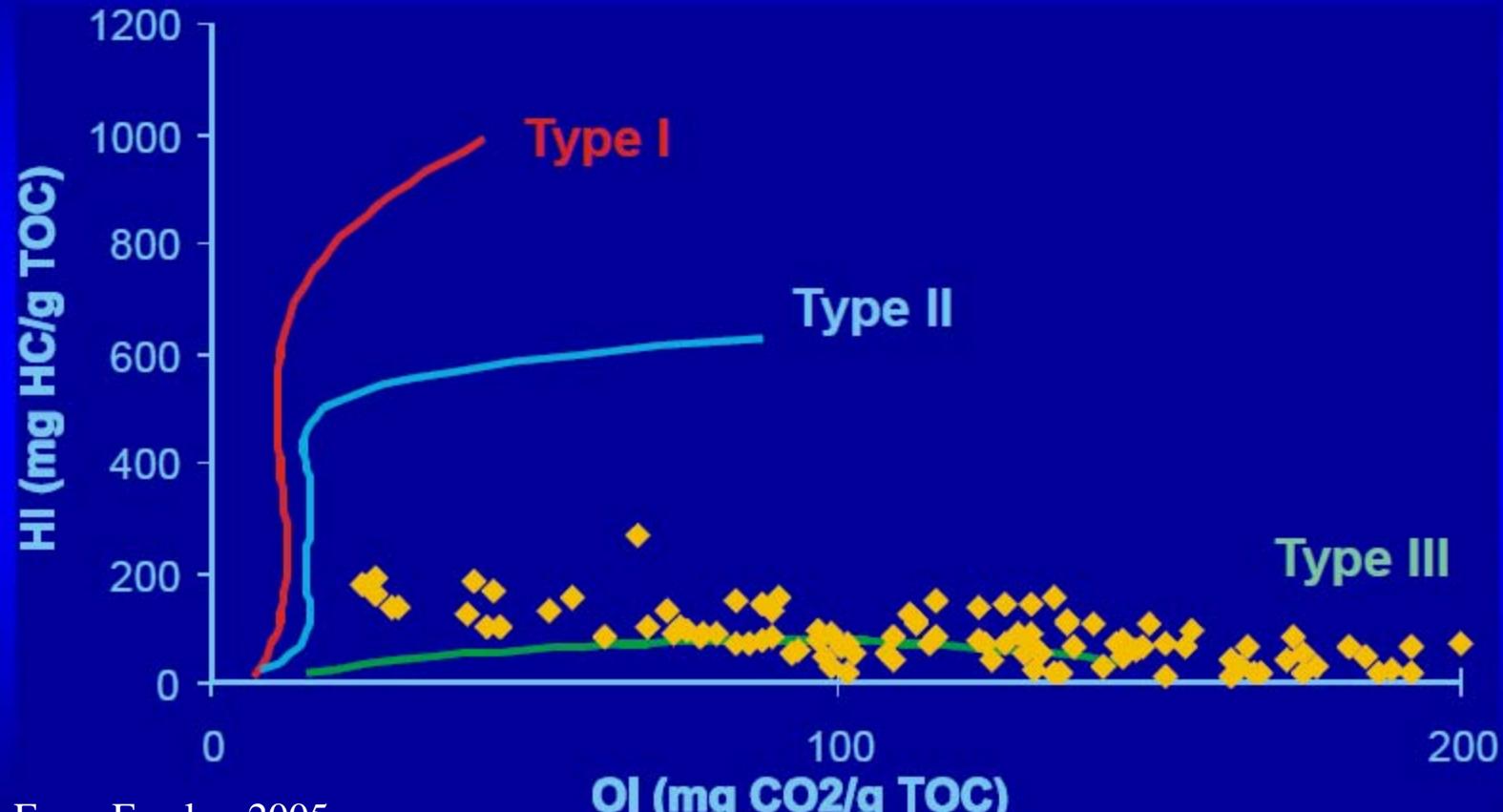
## North Saglek B.

### Geochemical Parameters

TOC rich  
intervals in  
Eocene-Lower  
Paleocene section



## Hekja M-71



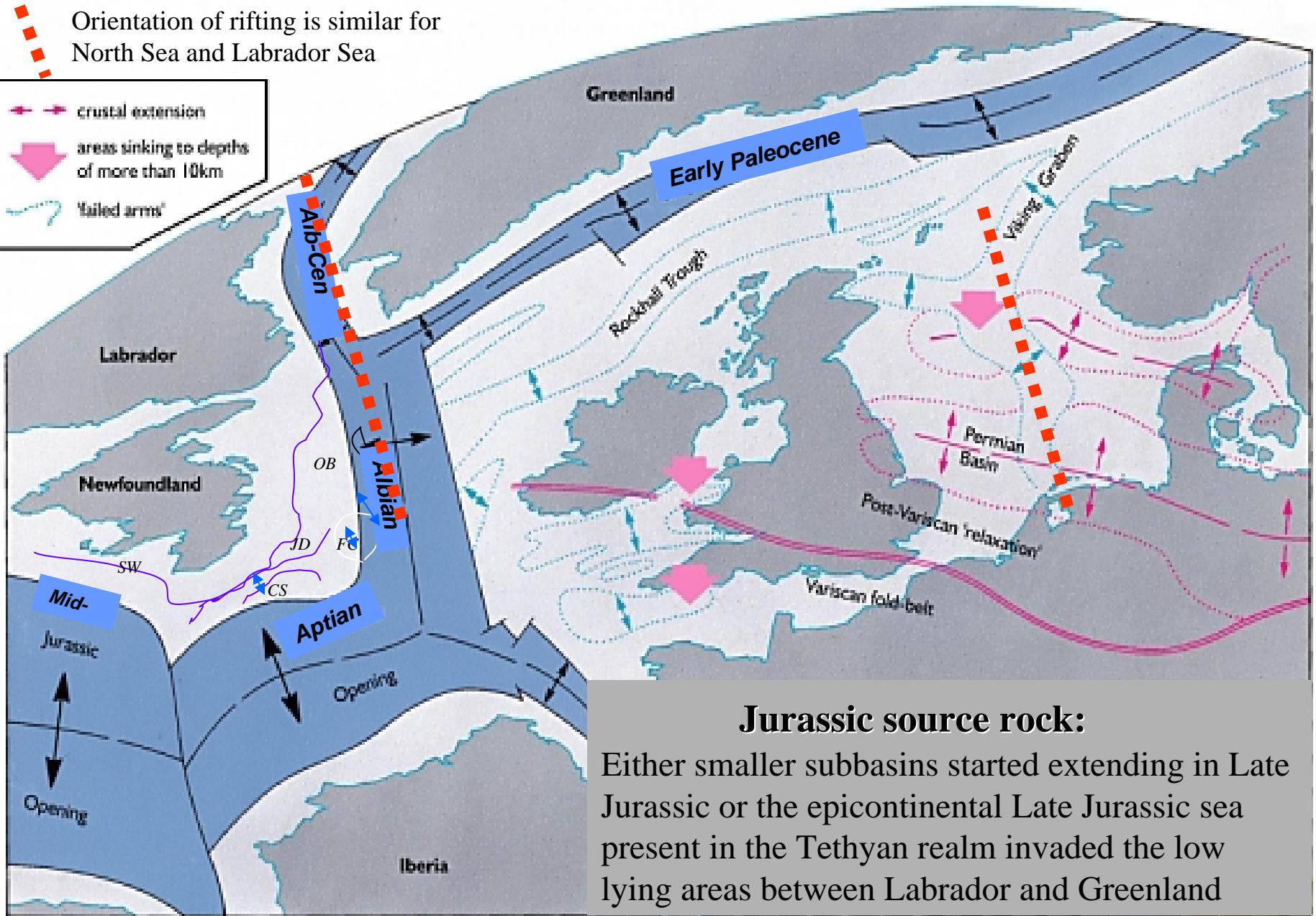
Coaly siliciclastics and coals containing Type III and occasionally liptinite-enriched Type III-II source rock (Fowler, 2005)

# Source Rock (Cont.)

## Other Source Rocks

- **Paleozoic sediments** are overmature and are unlikely to generate hydrocarbons in the Labrador Sea
- **Late Jurassic source rocks?** Several indications that a Kimmeridgian source rock may extend in the Labrador Sea from the oil proven Grand Banks and SW Ireland offshore basins, were presented in the literature (e.g., Bojesen-Koefoed et al, 1999 and 2004; Sønderholm et al., 2003; <http://www.dgu.dk/ghexis/Ghexis-22.htm#4>; Enachescu et al, 2008 and 2010). A series of smaller and deeper subbasins are observed from mapping more recent seismic lines extending in the outer shelf and slope area. These smaller subbasins may have started extending earlier (in Late Jurassic rather than Early Cretaceous) or the epicontinental Late Jurassic Sea present on the Grand Banks and offshore Ireland may have encroached the sags between Labrador and Greenland, depositing organic rich shales
- Increased exploration activity has taken place across the Labrador Sea on Greenland's continental margin where indications of older sequences, including Late Jurassic source rocks, have been observed in outcrop and on seismic data. The Late Jurassic shales of the North Atlantic are high TOC, high HI, type I source rocks that have generated the prolific Jeanne d'Arc Basin oil and gas fields

Orientation of rifting is similar for North Sea and Labrador Sea



### Jurassic source rock:

Either smaller subbasins started extending in Late Jurassic or the epicontinental Late Jurassic sea present in the Tethyan realm invaded the low lying areas between Labrador and Greenland

Map modified after <http://www.ukoaa.co.uk/issues/storyofoil/geological>

# Late Jurassic Source Rock

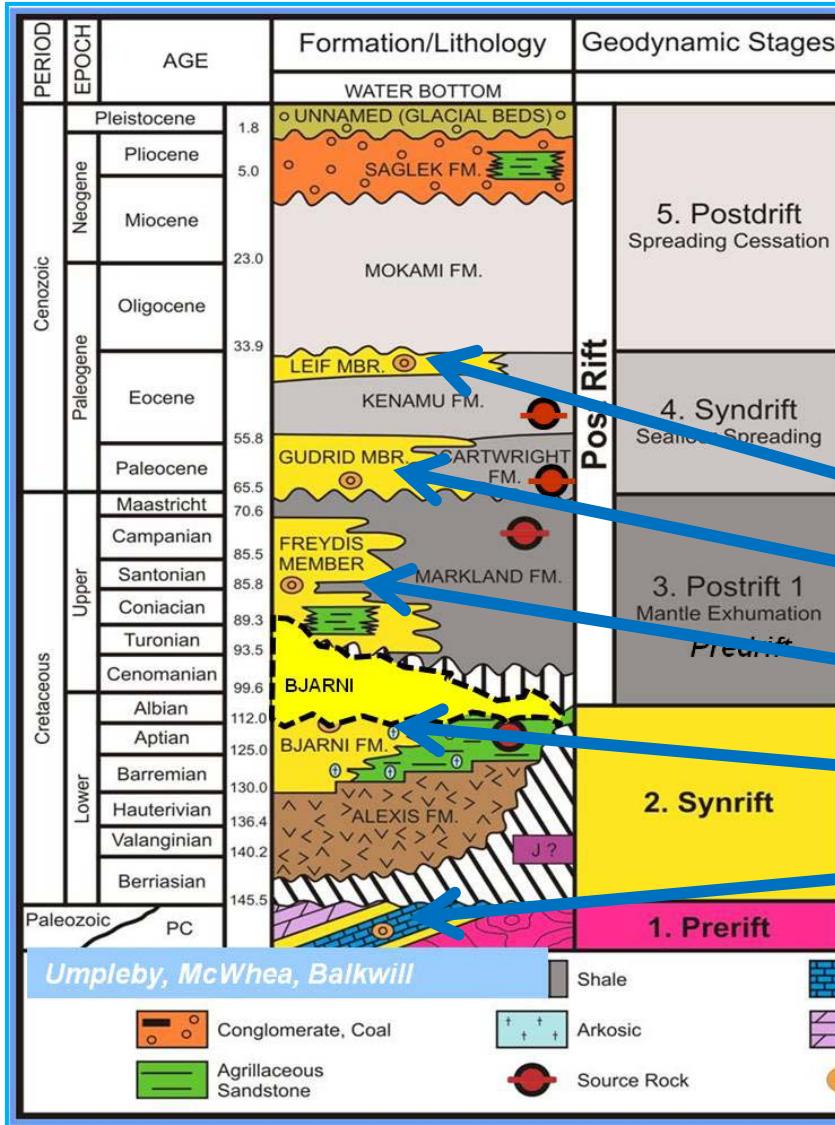
- Oil fields in Jeanne d' Arc Basin were generated from Late Jurassic source rock
- Proven Late Jurassic source rock in Flemish Pass Basin and in Porcupine Basin
- Seismic correlation of Late Jurassic source rock in East Orphan Basin
- Possible Late Jurassic source rock in Labrador Basins



# Reservoir Rock

- Up to now, gas and condensate (54° API) reserves were found in Bjarni (synrift) and Gudrid (postrift) sandstones and Ordovician carbonates (prerift basement) in the Hopedale Basin
- Minor, high-wax immature oil (33° API) was found at North Leif I-05 in the Bjarni Sandstone
- Gas and condensate reserves were found in Gudrid sandstones in the North Saglek Basin

# Reservoir Rock (Cont.)



Carbonates in basement and Cretaceous to Early Tertiary sandstone intervals with good reservoir properties have been recognized from drilling in Labrador basins

- Leif Mbr SS
- Gudrid Mbr SS
- Freydis Mbr SS
- Bjarni SS
- Ordovician carbonates

# Reservoir Rock (Cont.)

## Bjarni sandstone (Barremian to Turonian)

- During the initial intra-continental extension, a major pulse of coarse clastics was deposited in the newly formed rift valleys. This predominantly sandy Bjarni Formation represents the most widespread, most successful reservoir in the Labrador basins. The sandstone is thick in grabens but thins on the ridges, showing syntectonic deposition. Some of the in-graben thickening indicated by seismic data is caused by the presence of lacustrine shales (Bjarni source rocks). This creates fortuitous source/reservoir juxtaposition
- The Top Bjarni Formation is a good quality marker that can be mapped with relative confidence on the modern seismic data basinward of the Bjarni field and North Leif lineament and into the deepwater. However, as proven by several wells (e.g. Roberval C-02) some of the high blocks are void of Bjarni sandstones due to non-deposition or postrift erosion

# Reservoir Rock (Cont.)

## Bjarni sandstone (Barremian to Turonian)

- This Early Cretaceous synrift, non-marine arkosic sandstone, is the main reservoir in the Hopedale Basin. In the Saglek Basin, the Bjarni sandstone was only encountered at Skolp E-07, where it was cored
- The Bjarni Formation was interpreted on seismic sections in the entire Saglek Basin including in the Call for Bids NL11-03 area
- According to the Properties of Gas Bearing Reservoirs (C-NLOPB), the Bjarni Formation has good to high porosity (12% average) and good permeability (average 100 md)
- In the North Bjarni F-06 well the porosity encountered was 19% while at Bjarni H-81 and Hopedale E-33 wells, the Bjarni sandstone porosity had values of 20% and 11% respectively. These excellent reservoir parameters make the Bjarni sandstone an ideal petroleum reservoir

# Reservoir Rock (Cont.)

## Lower Paleozoic Carbonate (Ordovician)

- The Paleozoic “basement” contains sedimentary rocks that cannot be written off as exploration targets, as two large gas discoveries have been made in the carbonates. The Gudrid discovery (924 Bcf recoverable) tested 20 MMcf/d from an Ordovician dolomite with 10% porosity and the Hopedale discovery (105 Bcf recoverable) tested 20 MMcf/d from a Paleozoic (Ordovician) limestone with 8% porosity. These carbonate reservoirs were intersected in Gudrid H-55, Hopedale E-33, Roberval K-92, South Hopedale L-39, and Tyrk P-100 wells. These carbonates were dated Ordovician (e.g. Schwartz, 2008; C-NLOPBA)
- The carbonate reservoirs (limestone and dolomites) seem to be present mostly in the southern part of the Hopedale Basin. However, Paleozoic rocks are present on Baffin Island and probably offshore West Greenland and may be present as floor portions of the Saglek Basin, including the Call for Bids NL11-03 area
- The carbonate reservoirs within the seismic basement are difficult to interpret on 2D seismic data. Only a combination of reflection data and high resolution potential field may discriminate between metamorphic/intrusive, synrift and postrift volcanics and carbonate basement

# Reservoir Rock (Cont.)

## Freydis Member of the Markland Fm (Cenomanian to Campanian)

- The Freydis sandstone is a shallow marine, shoreline sandstone that has an average porosity of 15% and permeabilities in the range of a few hundreds of millidarcies
- This sandstone was deposited during the final stage of Labrador intra-continental extension, when the continental mantle was exhumed and before the start of real breakup
- The sand was drilled within thick Markland shale intervals, a beneficial position if these shales would exhibit high TOC and have reached maturation
- Freydis Mbr was encountered in wells such as Freydis B-87 and Ogmund E-72 in the Hopedale Basin. In the Saglek Basin, the sandstone was intersected in the Gilbert F-53 and Skolp E-07 wells located within the NL11-03 parcels
- Due to poor reflectivity contrast with encasing shales and limited distribution the Freydis Member cannot be regionally mapped with seismic data (Bell et al., 1989; Martin, 2007)

# Reservoir Rock (Cont.)

## Gudrid Member of the Cartwright Fm (Paleocene)

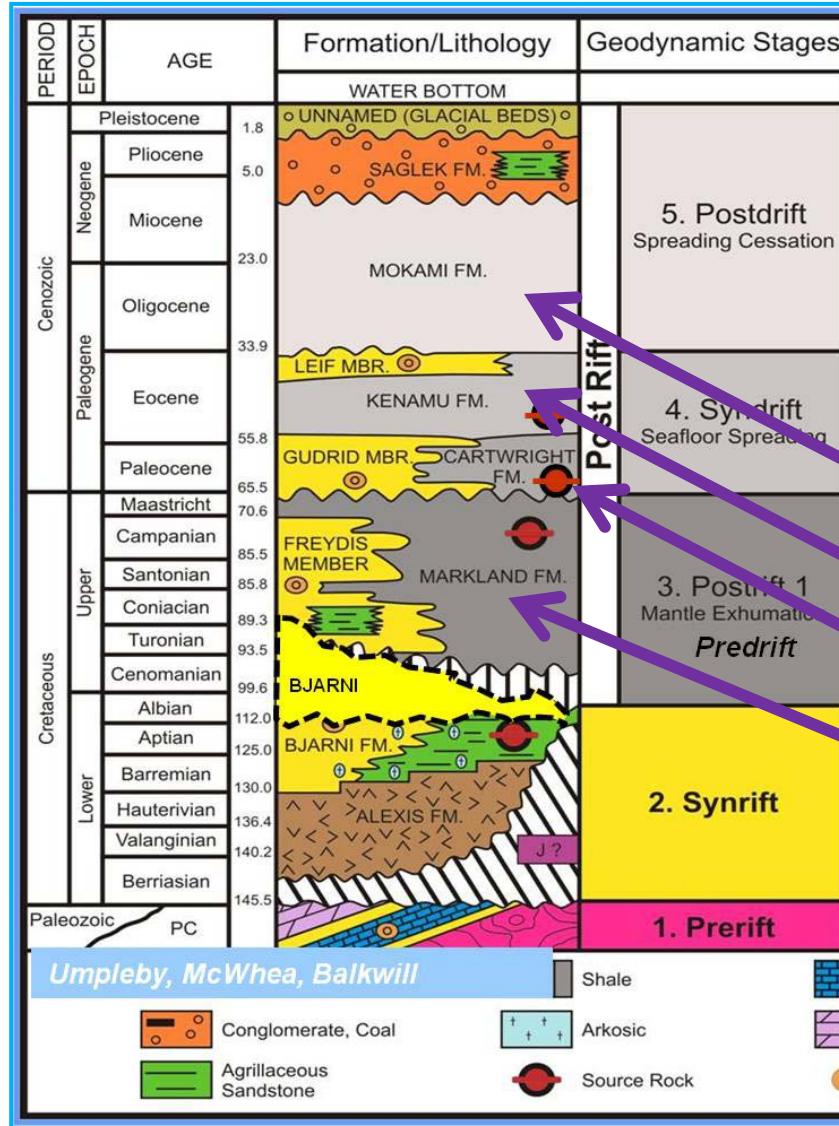
- The Gudrid Member was intersected by several wells located on the inner shelf. Seismically, it has an associated strong amplitude marker but is difficult to track into the outer shelf and deep water due to low seismic resolution and lack of tie points. The GSC Atlas (Bell et al., 1989) and M Sc thesis work by Martin (2007) and Stead (2008) indicate that the Gudrid sandstone marker is probably not present beyond the shelf edge
- The Gudrid sandstone tested gas at the Snorri J-90 well - the only well of the significant discoveries to test gas from the Paleocene sandstone. The Gudrid Member porosity at the Snorri J-90 well was 18% (C-NLOPB)
- In the South Saglek Basin, the Gudrid equivalent sandstone was encountered at the Karsefni A-13 well located within the CFB NL11-03 area
- In the North Saglek Basin, the Gudrid equivalent sandstones were intersected at the Hekja O-71 and Gjoa G-37 wells
- The Hekja O-71 gas and condensate discovery with an estimate of 2.3-3 Tcf of gas was found in the lower Eocene Gudrid sandstone that has 44 m of net gas pay with 16% porosity and 10 md of permeability

# Reservoir Rock (Cont.)

## The Leif Member of the Kenamu Fm (Late Eocene)

- The Leif Member was penetrated by several wells within the Hopedale Basin (eg. Gudrid H-55, Hopedale E-33 and Roberval C-02). It is difficult to seismically correlate and track the Leif Member away from the wells that have intersected this sandstone
- In the North Saglek Basin, the Leif Mbr sandstone was drilled and cored at Hekja O-71
- A thick (200 m) Leif Mbr sandstone was drilled in the South Saglek Basin within or close to the Call for Bids NL11-03 area (e.g. Karsefni A-13, Rut H-11 and Skolp E-07). At the Pothrust P-19 well located just basinward from NL11-03-02 parcel, a highly porous and permeable Leif sandstone interval was encountered at 3976 m. The well had to be abandoned due to an uncontrollable water flow in the well
- Related turbidites of both Gudrid and Leif sandstones may have been accumulated on the slope and in deepwater. The turbidite and any other lowstand sand deposits are plays that are yet undrilled in the Labrador basins

# Seals



Seals should not be a problem in the Canadian Labrador Sea basins. Numerous fine clastics, tight intervals are present in all postrift sequences

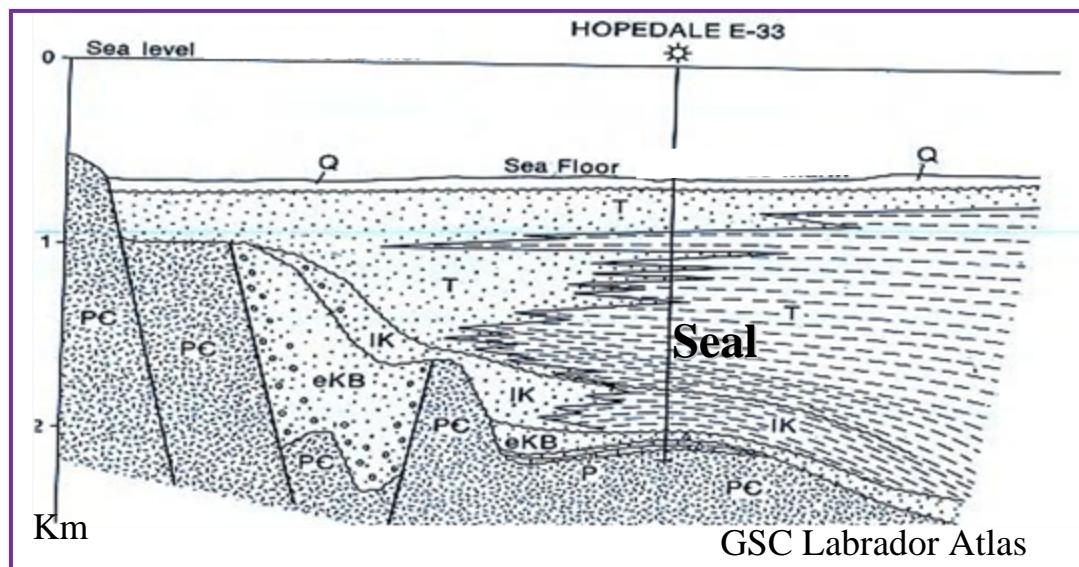
- **Mokami Shale**
- **Kenamu Shale**
- **Cartwright Shale**
- **Markland Shale**

# Seals (Cont.)

## Markland, Cartwright, Kenamu, Mokami formations shale (Cenomanian to mid-Miocene)

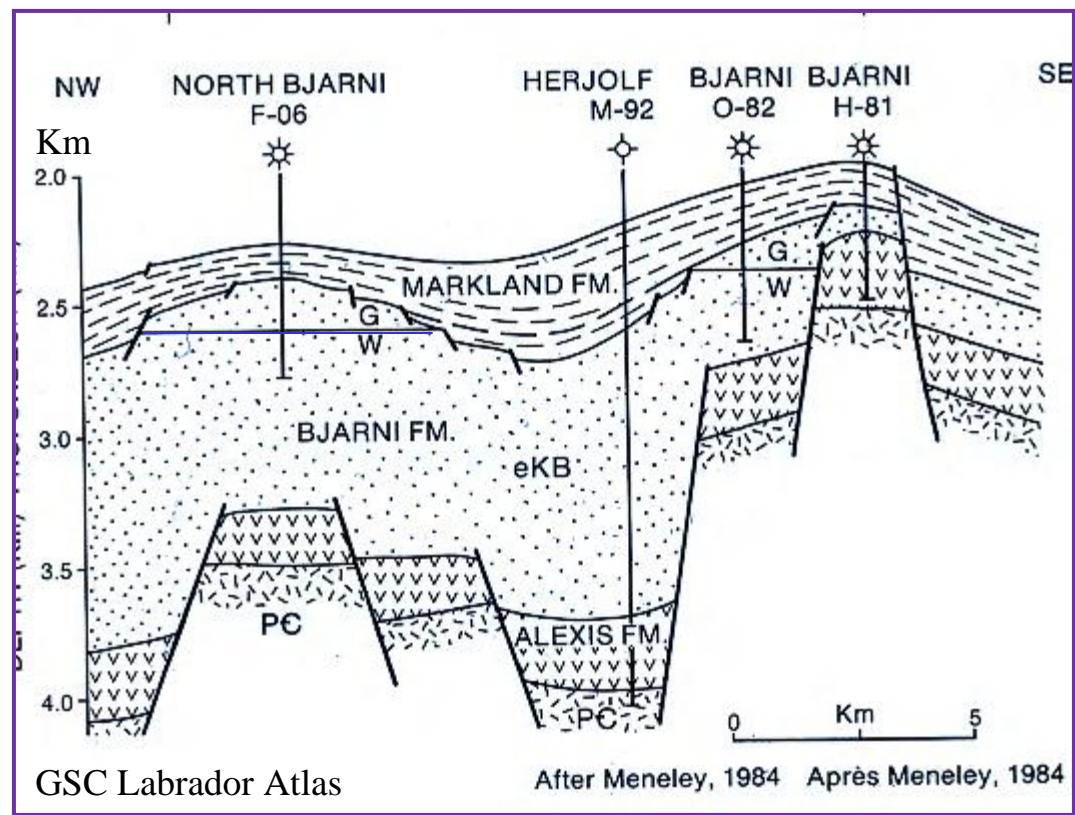
- The Hopedale Basin has a high percentage of fine clastics in all marine successions following the synrift main sandy pulse.
- Both Markland and Kenamu formations constitute excellent regional seals
- On the inner shelf faults are usually restricted to the synrift and predrift sequences and die upward in the predominately shaly Mokami and Kenamu formations. This prevents trap breaching

Notations are: PC = Precambrian Basement; P = Paleozoic carbonate; eKB = Early Cretaceous Bjarni Fm; IK = Late Cretaceous Markland Fm; TG = Paleocene Gudrid ss; T = Tertiary sequences; Q = Quaternary deposits



# Hydrocarbon Traps

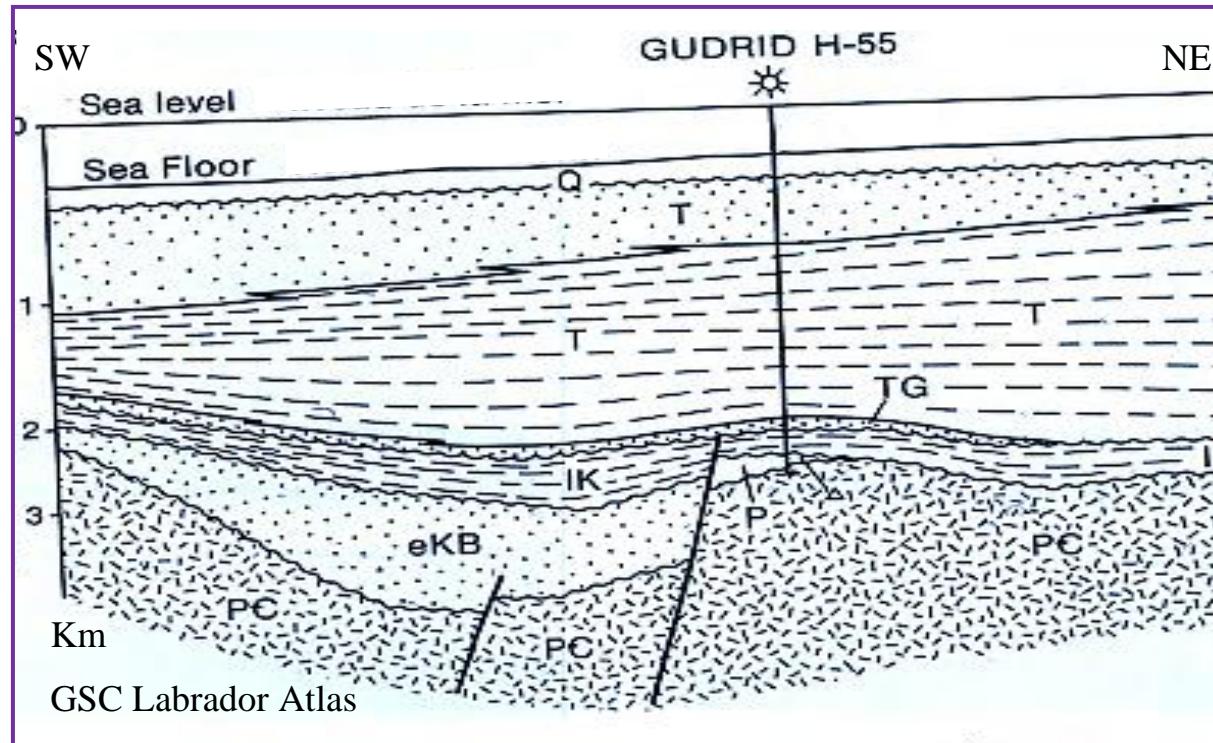
- Successful drilling of the Bjarni sandstone on structural highs made this the favourite hydrocarbon play in the basin. The Bjarni ss is widespread on the Labrador shelf and was derived from both rift shoulders and from intra-basinal ridges. Traps drilled repeatedly on the shelf were anticlinal features resulting from Bjarni Formation draping over basement ridges or forming fault bounded horsts. A large number of horsts and fault blocks are seen on the seismic data, some forming impressive exploration leads. Drape over these high blocks, onlap and lateral pitchout of Bjarni and younger sandstones are other possible hydrocarbon plays



PC = Precambrian Basement  
G/W = Gas/Water Contact

# Hydrocarbon Traps (Cont.)

- Paleozoic limestones and dolomites (Ordovician) found on the tops or sides of higher basement blocks often have reservoir properties



Notations are: PC = Precambrian Basement; P = Paleozoic carbonate; eKB = Early Cretaceous Bjarni Fm; IK = Late Cretaceous Markland Fm; TG = Paleocene Gudrid ss; T = Tertiary sequences; Q = Quaternary deposits

# Hydrocarbon Traps (Cont.)

- On the outer shelf and slope, exploration targets include listric faults and their associated rollover
- Extensional anticlines modified by compression are located on the outer shelf and slope and remain undrilled to date
- Other traps are large anticlines that are poorly imaged beneath the shelf breaks and in deepwater, rollover due to gravity induced listric faulting and compressional anticlines (shale detachment) over basement or transitional crust
- Although previously undrilled, there are probably more stratigraphic traps along the slope and in deepwater. These traps will consist of lenses of sandstones (turbidite) of the Freydis, Gudrid or Leif sandstone deepwater equivalents encased in thick shales (Enachescu, 2008)

**Structural traps in the Saglek Basin are associated with extension of the prerift basement, transtension along transfer faults, gravity faulting and sliding and shale detachment faults**

# Maturation and Migration

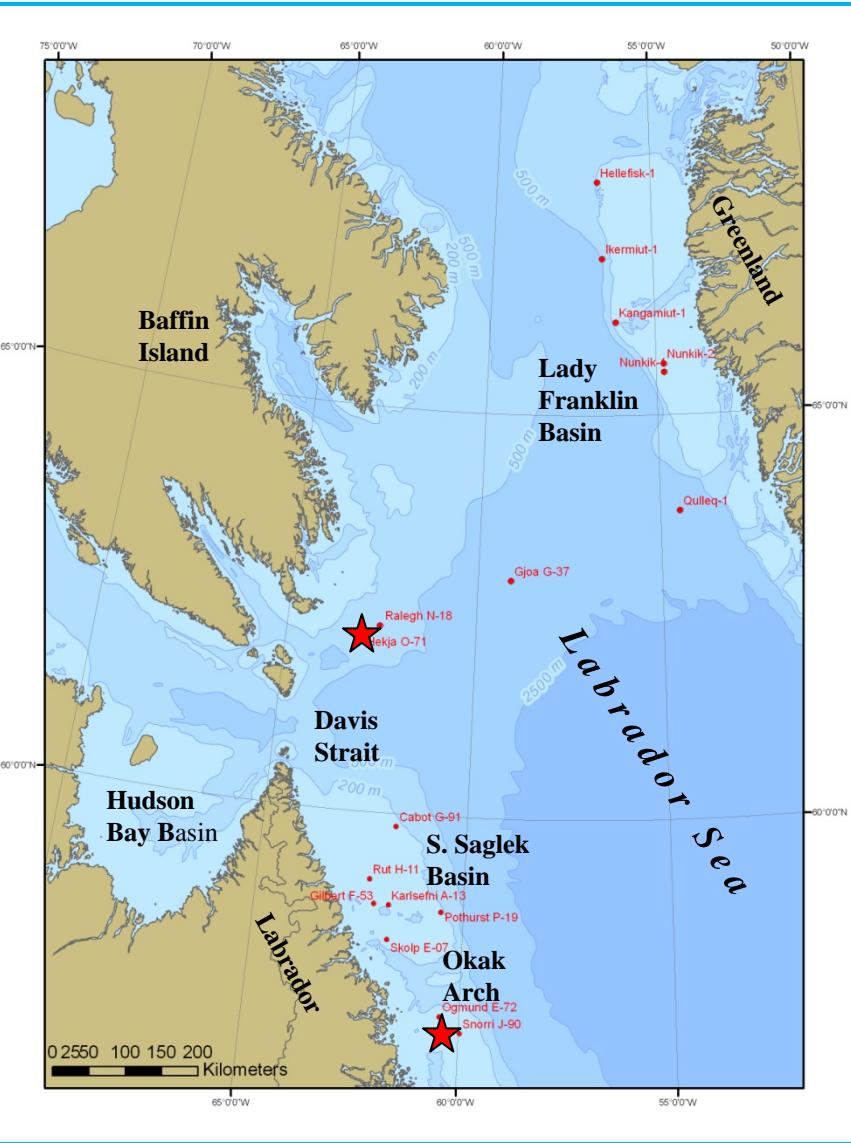
- The gas discoveries found in the Labrador basins prove that source rocks are mature and migration of hydrocarbons to reservoirs occurred
- The Hopedale Basin has a high thermal gradient (2.7° C/100m). Source rocks started expelling wet gas after reaching depths of approximately 2,500 m probably in Late Oligocene - Early Miocene time (GSC, 1987; De Silva, 2003)
- Full source maturation for both Bjarni and Markland shales should occur at depths of about 3335 meters (corresponding to  $R_0 > 0.7$ ), east of the Gudrid-Bjarni-Snorri wells' lineament. A very large hydrocarbon kitchen should be present on the outer shelf slope and rise (Martin, 2007)
- The gas accumulations in horst blocks and drape anticlines have benefited from lateral migration of hydrocarbons from the eastern deeper troughs where Cretaceous source rocks should be mature (Powell, 1979; Enachescu and Martin, 2007; Martin 2007, Enachescu, 2008).

# **Maturation and Migration (Cont.)**

- According to Fowler et al. (2005) the oil window should be deeper at 3,000-3,500 m. The North Leif I-05 well contained waxy crude which was believed to be generated from terrestrial types II and III kerogens found within the partially mature Bjarni Formation (Issler and Beaumont, 1987)
- There is no doubt that several prolific petroleum systems exist in the Labrador basins that will extend to the South Saglek Basin in the area of CFB NL11-03

**The Bjarni, Markland, Cartwright and Kenamu source rocks should be all in the mature to overmature range when reaching depths below 3000 m**

# Saglek Basin Petroleum Geology



- Exploration drilling, detailed geochemical investigations, regional geological studies and seismic mapping of reservoir and source rock intervals performed in the Labrador basins, have shown that all the prerequisites for viable hydrocarbon systems are clearly satisfied
- While 5 wells (see slide 101) have been drilled in NL's part of the Saglek Basin resulting in a D&A status, this basin is mostly unexplored and contains “high risk - high reward” frontier type of oil, gas and condensate plays

# Saglek Basin Wells

Well No	Well Name	Basin	Year	Operator	WD (m)	TD (m)	TD in	Core	DST	Observation
1	Karsefni A-13	South Saglek	1975	Eastcan	175	4149	Basement	2 cores: Cartwright ss (Gudrid eq.) and Basement	2 Gudrid ss and Leif ss	D&A
2	Cabot G-91	South Saglek	1976	Eastcan	180	290	Plio-Pleistocene glacial beds	NO	NO	Shallow abandoned
4	Skolp E-07	South Saglek	1978	Eastcan	166	2968	Precambrian gneiss	7 cores: 3 in Markland Fm, 2 in Freydis ss, 1 in Bjarni ss, 1 in Bsm	NO	D&A
3	Gilbert F-53	South Saglek	1979	Petro-Canada	183	3608	Basement	3 cores: 2 in Freydis ss and 1 in Basement	2 RFS in Freydis ss	D&A
5	Hekja O-71	North Saglek	1979	Aquitaine	350	4566	Lower Cretaceous Basalts	3 cores: 1 in Leif ss, 1 in Cartwright Fm (Gudrid eq.) and 1 in Upper Cretaceous Basalts	Flowed gas and condensate from Gudrid ss	Gas well , 44m net pay; Intersected volcanics
6	Raleigh N-17	North Saglek	1979	Canterra	339	3858	Lower Cretaceous Basalts	NO	NO	D&A Intersected volcanics
7	Rut H-11	South Saglek	1981	Petro-Canada	124	4474	Diabase Intrusive	NO	NO	D&A
8	Pothrust P-19	South Saglek	1982	Petro-Canada	193	3992	Leif Sandstone	NO	NO	D&A, uncontrolled Water flow
9	Gjoa G-37	North Saglek	1982	Esso	1000	3998	Markland Fm	1 in Paleocene clastics (Gudrid eq.) within volcano-clastic interval	NO	D&A Intersected volcanics

red = discovery; Lime = shallow well

Enachescu, 2011

# Saglek Basin Petroleum Geology

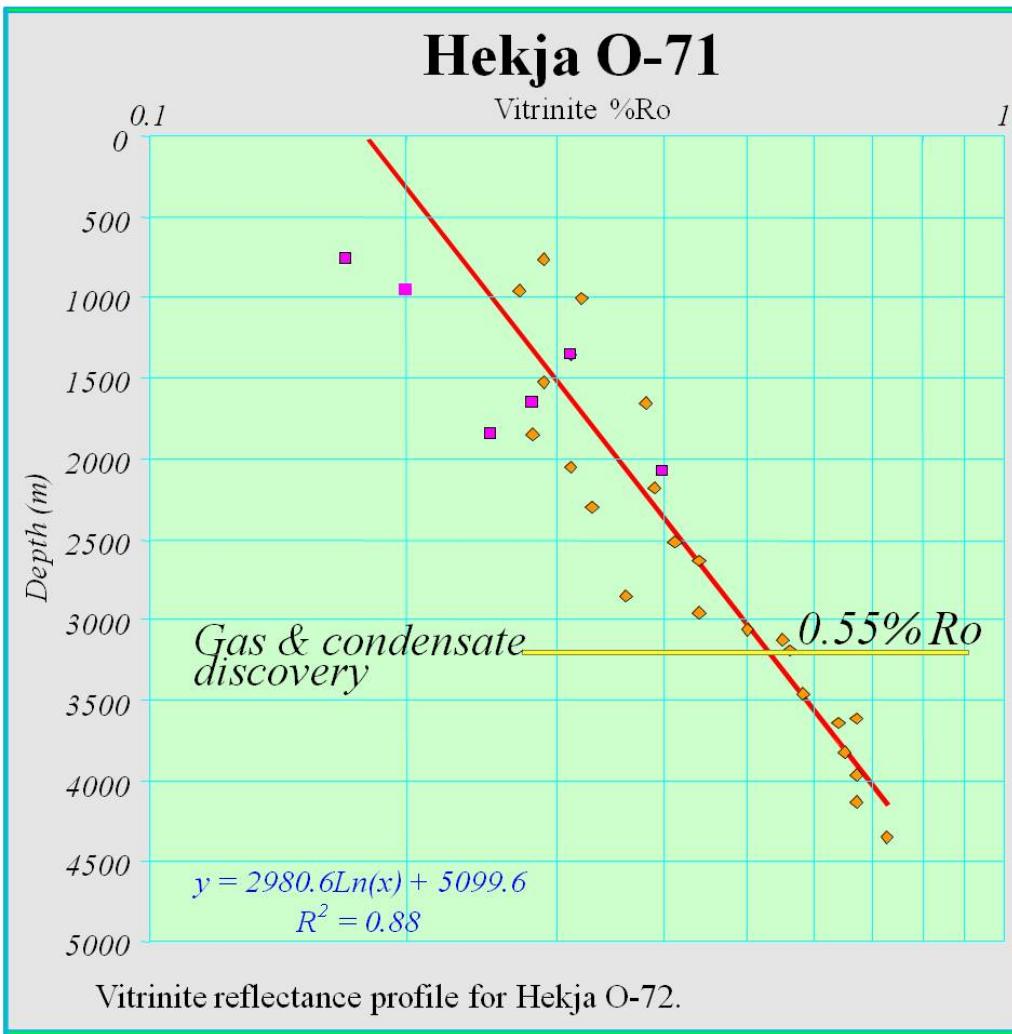
## (Cont.)

- The Saglek Basin is the most northerly Labrador Sea Basin of the Labrador Mesozoic-Tertiary basins, covering over 160,000 sq km north of the Okak Arch and extending north of the Davis Strait into Baffin Island shelf and slope
- The basin has similar structural, tectonic and stratigraphic characteristics with the Hopedale Basin. However, considerable volumes of volcanic rocks are present in the Saglek Basin, especially in its northern part
- The eight wells drilled in the basin during the 1970's to early 1980's proved the presence of both source and reservoir rock within the basin. The Hekja O-71 well located in 350 m water depth, discovered natural gas (2.3 Tcf) and NGLs in Paleocene/Eocene sandstones
- Only 5 wells were drilled in the basin's southern part under the NL authority. In addition, the Cabot G-91 well was abandoned at 290 m.

# Saglek Basin Petroleum Geology (Cont.)

- The basin contains rock sequences ranging in age from Early Cretaceous to Quaternary, in places over 10 km thick
- Prospects and leads were identified on the basin's large shelf (up to 160 km) and on the untested slope and deepwater
- In early exploration, a first ridge lineament located near the shoreline was targeted with three wells Rut H-11, Gilbert F-53 and Skolp E-07, of which all were D&A due to lack of mature source rocks in vicinity
- A second ridge lineament was only tested by the Karsefni A-13 well that was D&A
- While it has encountered an excellent reservoir, the Pothrust P-19 well, was terminated before reaching its deeper target
- Recent reprocessing of older seismic data, the identification of marine surface seeps from satellite data and the acquisition of some new regional seismic data has improved our knowledge of the basin's geology and petroleum potential. However, the Saglek Basin remains one of the most underexplored basins on the Canadian east coast

# Saglek Basin Source Rock Maturity



- Hekja gas/condensate (54 API°), discovery in Saglek Basin found in a Paleocene (Gudrid equivalent) reservoir
- Probable source rocks are Cartwright (Paleocene) and Kenamu (Eocene) formations
- Source rocks include coaly siliciclastics and coals containing Type III and liptinite-enriched Type III-II organic matter (less common)
- Source rock at the Hekja reservoir level is of much lower maturity than the reservoired hydrocarbons, suggesting significant migration (Fowler et al., 2005)

From Fowler, 2005

Enachescu, 2011

# Is there any Late Jurassic source rock in the Labrador Sea, specifically Saglek Basin?

*Possible!*

- Within deeper, untested subbasins
- Structural equivalent to E Orphan Basin and Lady Franklin Basin in W Greenland
- Jurassic fingerprinting of oil seeps on Greenland side
- Reworked Jurassic dinoflagellates in the Quallaq-1 well offshore Greenland
- Late Jurassic dykes onshore West Greenland

# Hydrocarbon Plays

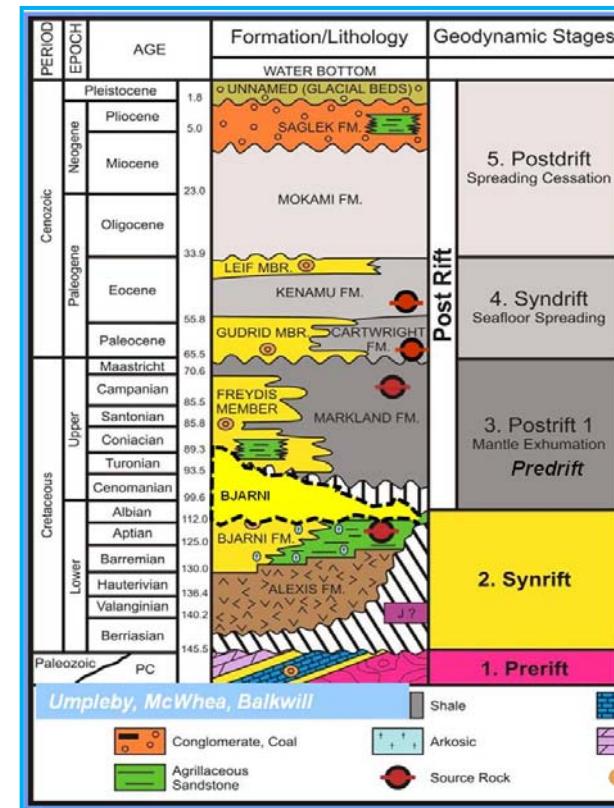
Several conventional plays are recognized in Labrador Sea that are valid in the South Saglek Basin:

- **Proven**

- 1) Bjarni synrift sandstones
- 2) Freydis postrift sandstone
- 3) Gudrid syndrift sandstones
- 4) Leif syndrift sandstone

- **Possible**

- 5) Passive margin slope clastics
- 6) Ordovician carbonates



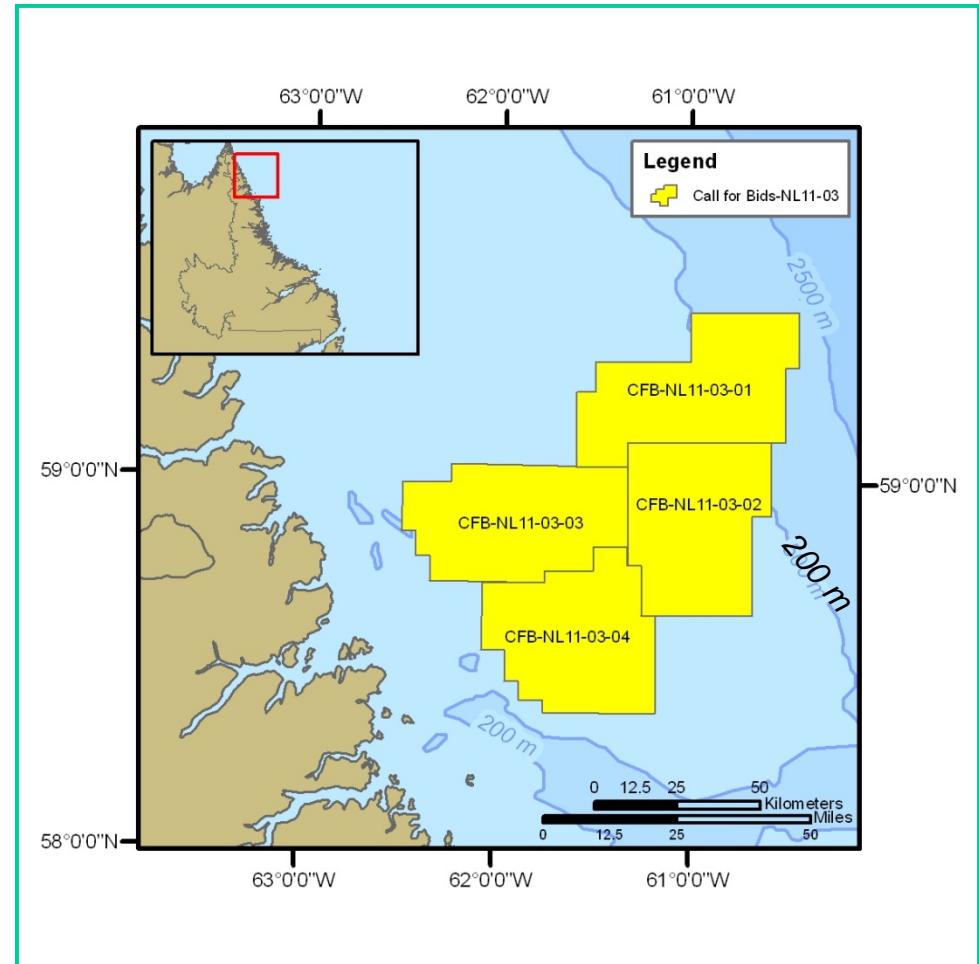
# Petroleum Prospect Risks

- Trap formation for the Bjarni sand was simultaneous with its deposition and accumulation of thick Bjarni source rock in the intervening grabens. With source and reservoir juxtaposition, hydrocarbon migration takes sandstone carrier beds updip into structural highs
- While Markland, Cartwright and Kenamu shales are present in the South Saglek basin, they have to be buried to at least 3000 m to start generating oil. Hekja gas and condensate were not generated at the location and this implies that medium distance migration takes place in the basin
- The main prospect risk is drilling structural closures without presence of quality reservoir or source rock in vicinity however closure breaching should not be a great risk in the basin
- The presence of volcanics is a considerable risk for trap destruction and seismic imaging beneath basalt flows and intrusives, especially in the northern part of the basin and in deep water

**OBSERVATION: The five gas discoveries and the presence of oil in the North Leif I-05 well demonstrate that source rocks are mature and that gas and oil were generated in the Labrador Basins and migrated into traps**

# 6. Petroleum Potential of Call for Bids NL11-03 Parcels

- Call for Bids NL11-03 includes four large parcels located in the South Saglek Basin, Labrador Sea
- These are relatively shallow water parcels (average water depth below 200 m), located in vicinity of proven hydrocarbon occurrences in the Hopedale Basin to the south and North Saglek Basin to the north
- Parcels are located on the inner and outer shelf of the basin where large structural and composite traps are seen on seismic data



# Petroleum Potential of Call for Bids NL11-03 Parcels

- C-NLOPB Call for Bids NL11-03 parcels are located off the east coast of the Labrador Peninsula, in the Province of Newfoundland and Labrador, Canada
- All four parcels are situated in an area designated Area “C” – Labrador Offshore Region, administered by the Canada-Newfoundland and Labrador Offshore Petroleum Board on behalf of the Province of NL and the Federal Government  
[\(http://www.cnlopb.nl.ca/news/pdfs/cfb11\\_03.pdf\)](http://www.cnlopb.nl.ca/news/pdfs/cfb11_03.pdf)
- The Call for Bids parcels are within the Saglek Basin in water depths ranging from 120 to 330 metres
- Presently, there are no active Exploration Licences (ELs) or SDLs in the NL part of the Saglek Basin, named South Saglek Basin in this presentation

# Call for Bids NL11-03

## Saglek Basin, Labrador Sea

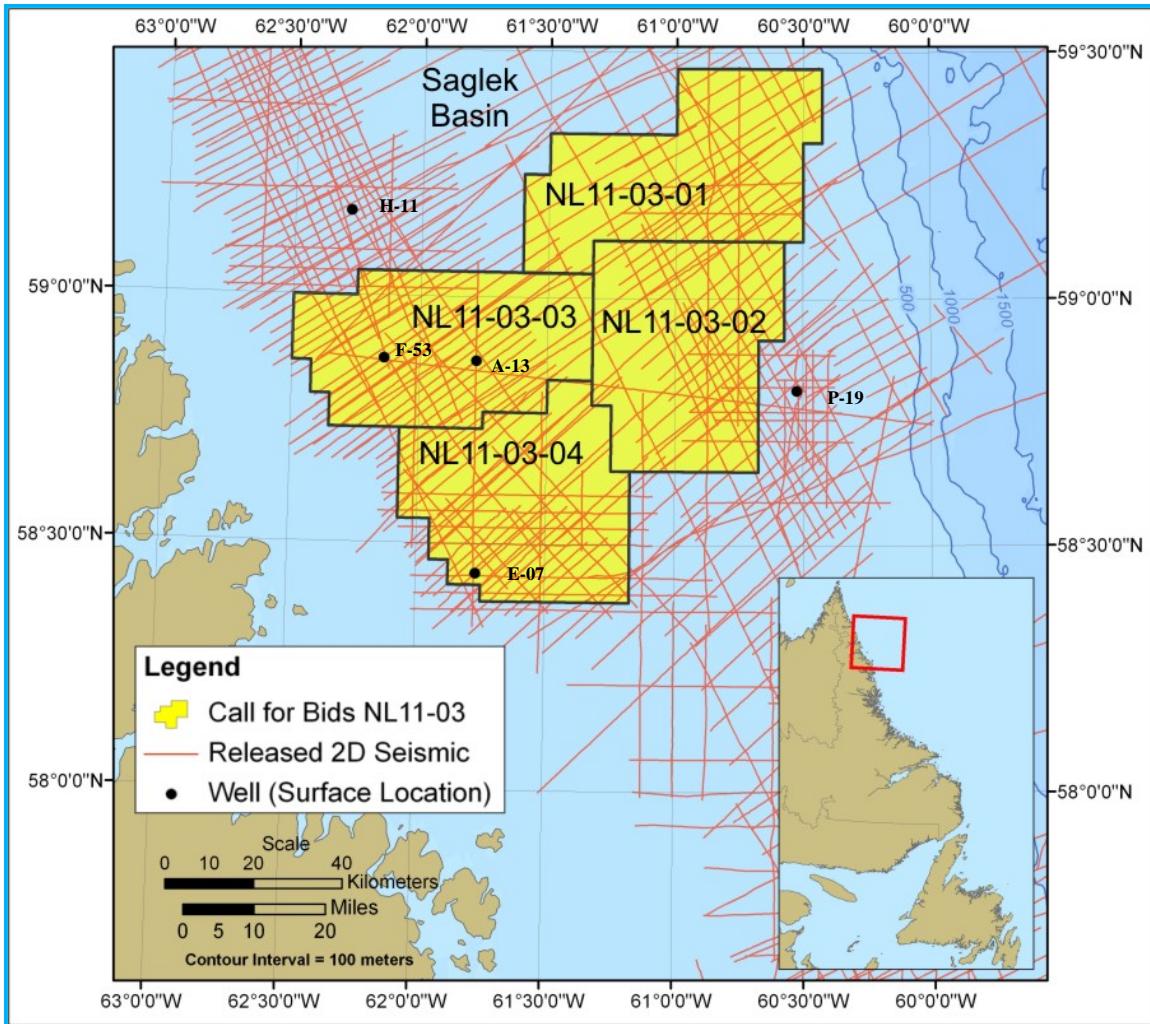
Call for Bids Labrador	Area	Area	Area	GOM tract
CFB NL11-03	Hectares	Sq Km	Acres	multiples
Parcel #1	207,144	2,071	511,864	88.9
Parcel #2	201,056	2,011	496,820	86.2
Parcel #3	204,483	2,045	505,289	87.7
Parcel #4	198,828	1,988	491,315	85.3
<b>TOTAL</b>	<b>811,511</b>	<b>8,115</b>	<b>2,005,288</b>	<b>348.1</b>

Offshore Labrador exploration areas in NL11-03 are licensed by the C-NLOPB to the party submitting the highest bid in the form of work commitments

# Wells of Significance for CFB NL11-03

- The most significant well for the area-Hekja O-71, was drilled in 1979 approximately 300 km north of the four CFB NL11-03 parcels. The well intersected 44 m of pay and flowed gas and condensate from the Gudrid sandstone (interval 3212 to 3251 m)
- Another important well, North Leif I-05 (33° API), tested immature oil in the Bjarni sandstone proving that oil has been generated in the Labrador basins and may form large accumulations
- Other important wells are located in the Hopedale Basin (Snorri, Bjarni, North Bjarni, Hopedale and Gudrid gas and condensate discovery wells). These discoveries have proved resources of 4.2 Tcf (C-NLOPB). The discovery wells are located approximately 300 km south of the CFB parcels. Gas and condensate were tested from Bjarni, Gudrid and Paleozoic reservoirs
- Within or in the immediate vicinity of the parcels, 5 wells (A-13, E-07, F-53, H-11 and P-19) encountered good reservoirs in Bjarni, Freydis, Gudrid and Leif sandstones but had no hydrocarbons, most likely due to lack of mature source rock in the vicinity
- The South Saglek Basin's Cabot G-91 (very shallow well) and Pothrust P-19 (encountered overpressure) did not reach their final targets to be properly evaluated. Pothrust P-19 intersected a very good reservoir which was water filled
- Cores of reservoir intervals in South Saglek Basin were taken from these wells and are available for viewing at the C-NLOPB Core Repository

# Seismic Coverage



- The Call for Bids NL11-03 Parcels 1 to 4 are well covered by a relatively dense 2D seismic grid.
- The adjacent map contains only the released data available in analogue format from C-NLOPB.
- Data in digital format is available from oil companies and seismic contractors
- The grid has a 2 to 4 km spacing in the dip direction and 5 to 15 km spacing in the strike direction

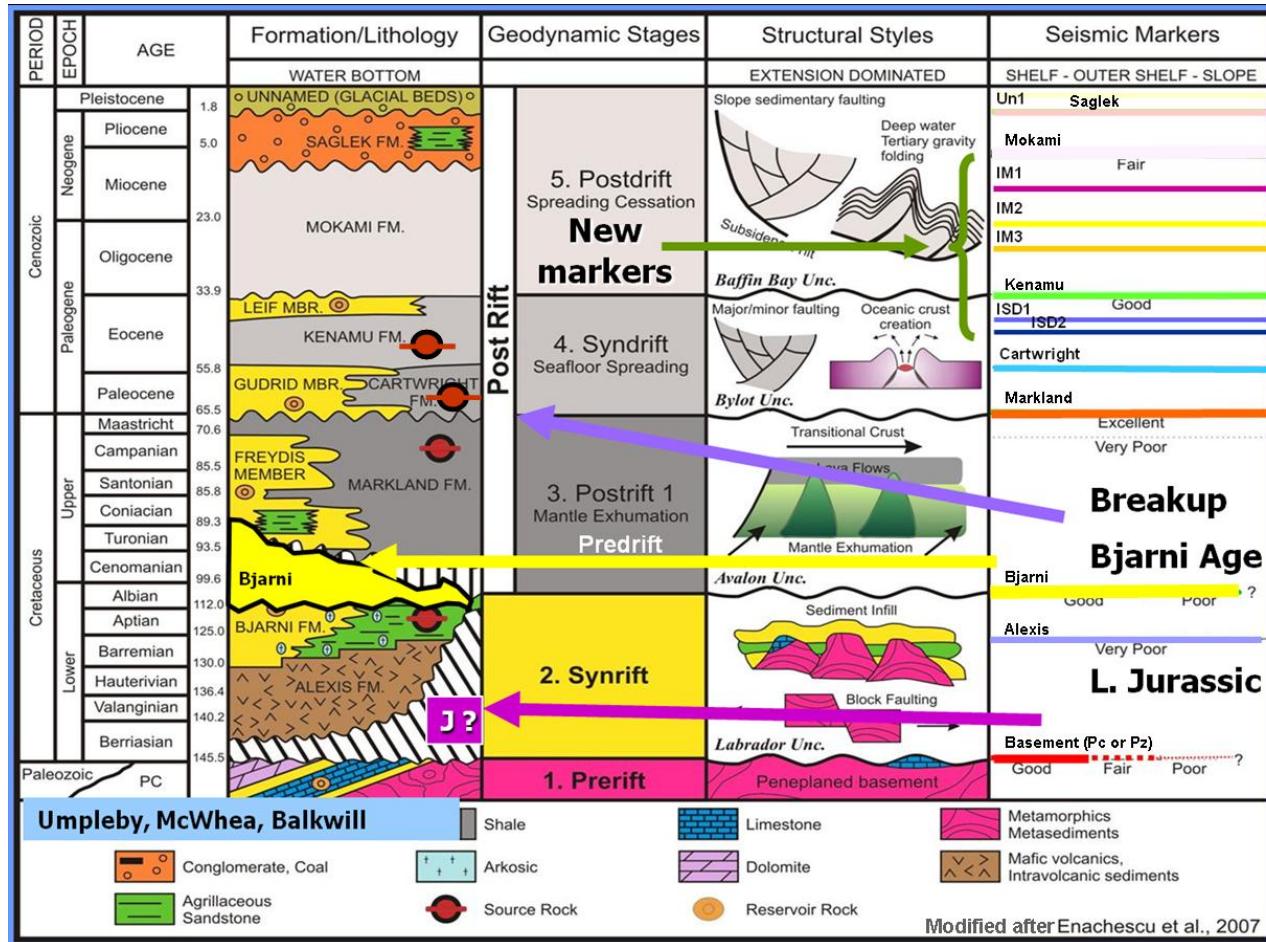
# Seismic Coverage

- Oil company digital data is held mainly by the partners in the Eastcan group of companies and Suncor (inheriting the Petro-Canada data base). The various surveys recorded in the 1970s and early 1980s were used to locate and drill the wells in the Saglek Basin
- The seismic grid that covers the CFB NL11-03 parcels (see slide 112) is in the public domain and therefore releasable in analogue format
- Multi-client seismic data from the same era are available from seismic contractors. GSI of Calgary has a large grid of reprocessed multi-fold seismic data available for licensing in digital format
- GSI has collected modern seismic data in the Labrador basins during the 2003-2008 period and about 5000 km of the grid is positioned in the Saglek Basin, tying the essential wells and covering the CFB parcels
- During 2011-2012 TGS in collaboration with PGS will collect up to 5300 km of GeoStreamer data (pressure+velocity sensitive sensors) in the Labrador Sea including CFB NL11-03 areas

# Seismic Interpretation

- Regional seismic lines shown in this presentation were tied with synthetic seismograms to several exploration wells in the South Saglek Basin
- Early Cretaceous to Quaternary successions are present in the area including several regional unconformities. On the illustrative seismic sections only a few markers and formations are displayed together with major faults (see slide 115)
- The seismic lines show the basin as a sedimentary wedge dipping and thickening toward the northeast above an extended basement. The wedge of younger sediments rests on the postrift unconformity that drapes a block faulted basement consisting of horsts, grabens and rotated blocks. In the grabens and overlying the higher blocks are older sediments belonging to the synrift and predrift sequences (Alexis, Bjarni and Markland formations)
- Several thick-skin normal faults affect both the Nain Province Basement and the sedimentary infill

# Seismic Markers

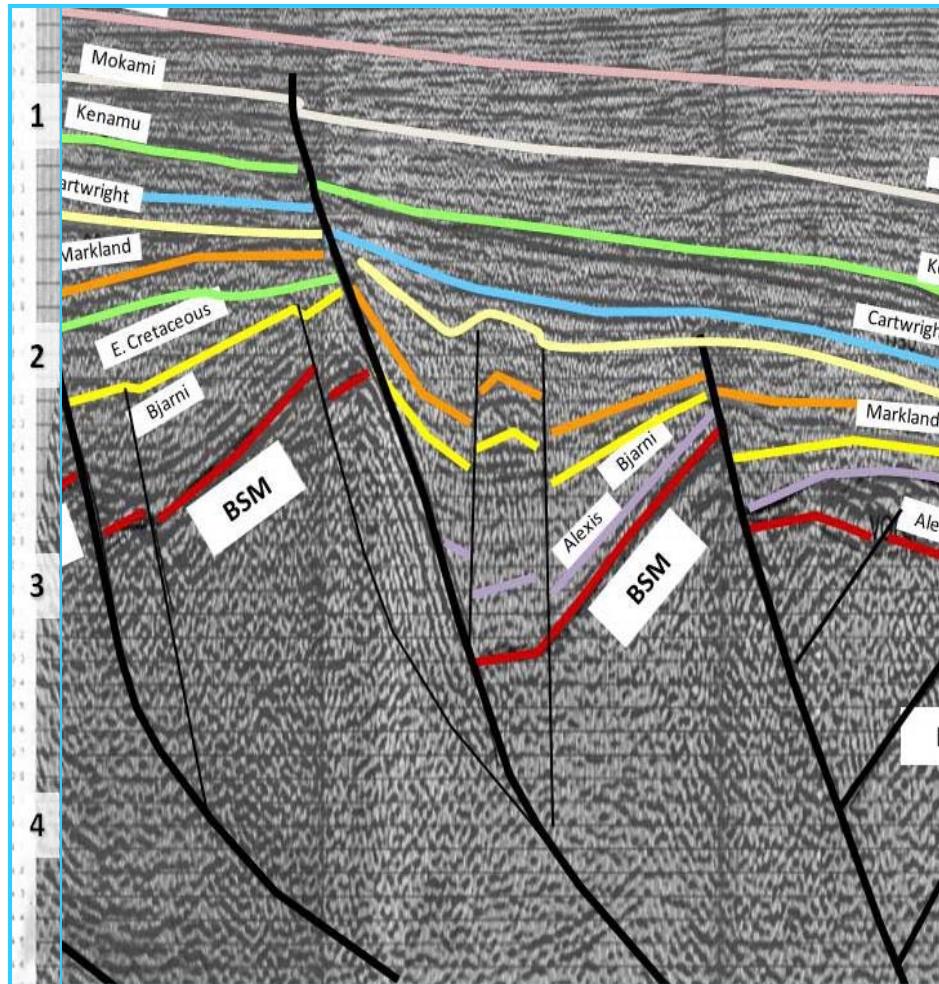


# South Saglek Basin Lithostrat Chart & Seismic Markers used in this presentation

***Observation:*** Only the main seismic markers are interpreted in the seismic sections used to illustrate this presentation

# Seismic Interpretation

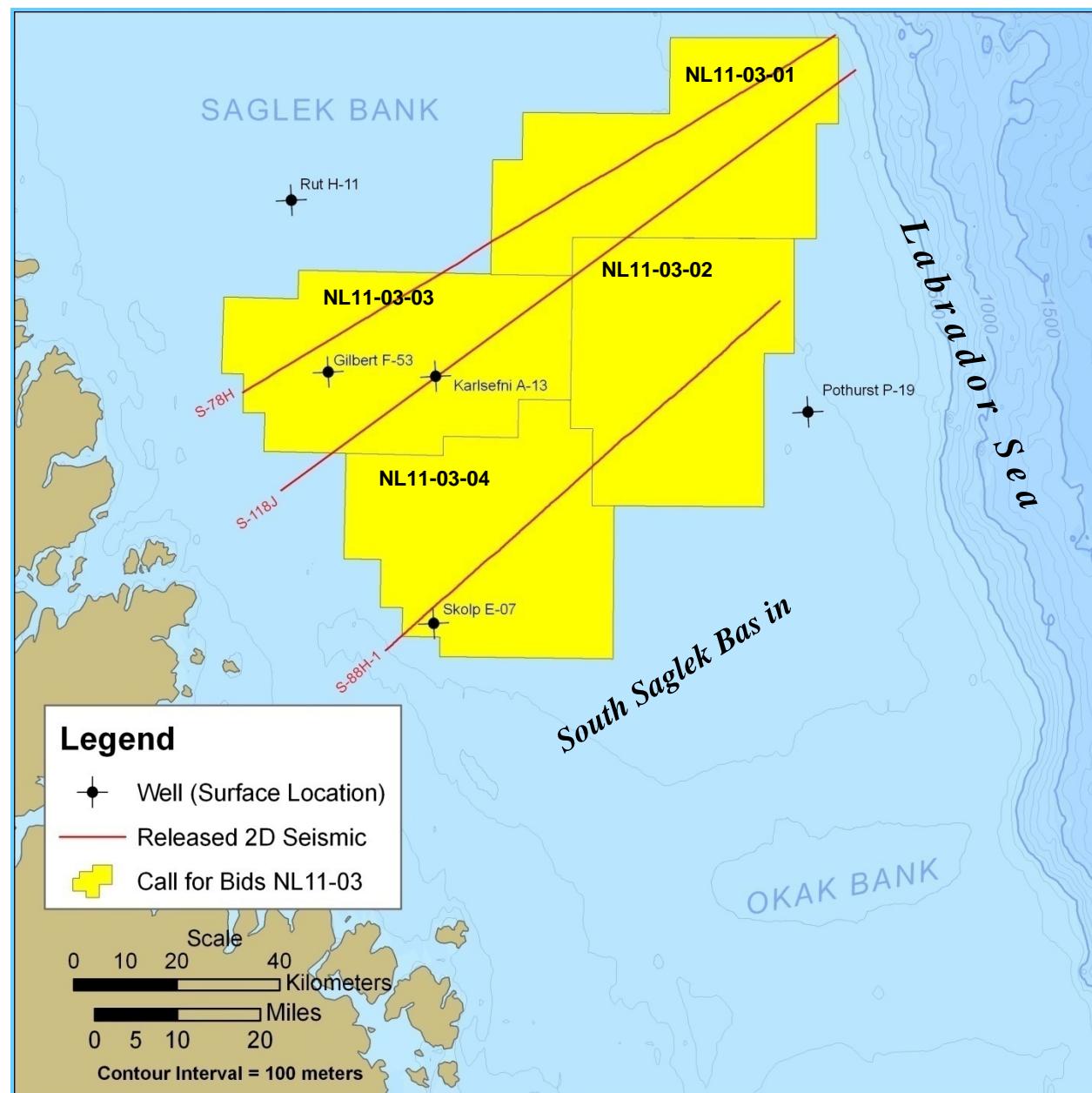
- Using the available seismic grid, several plays can be interpreted within the Early Cretaceous to Eocene basin fill in the NL11-03 Parcels 1 to 4. The typical play is *Structural high (Horst, Rotated Block, Drape Anticline or Roll-over Anticline), with any of the Bjarni, Freydis, Gudrid, Leif sandstones (primary target) and/or Paleozoic carbonates (secondary target)*
- In all four parcels there are locations, where 2.5-4 Km deep wells can test the synrift and postrift sandstone plays, and the possible Paleozoic carbonate reservoir



Line 88H-1 Source: C-NLOPB

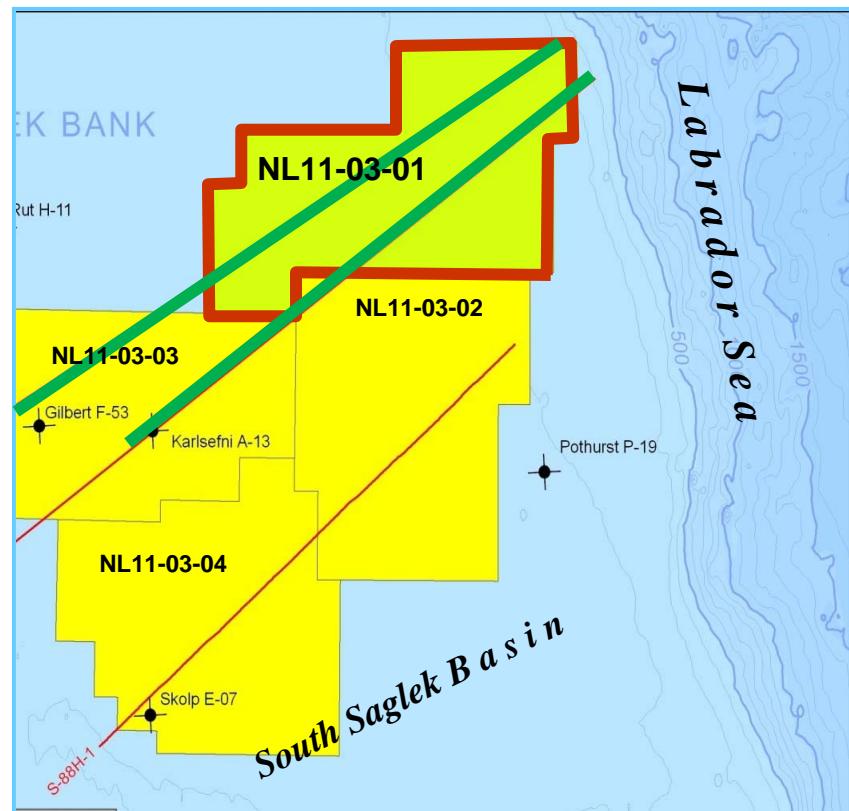
# Seismic Interpretation (Cont.)

**Three lines: S-78H, S-118J and S-88H-1 are interpreted to illustrate the structural-stratigraphic style of the South Saglek Basin and the petroleum potential of the four CFB NL11-03 parcels**

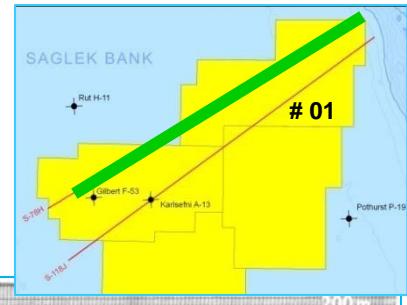


# 6.1 Petroleum Potential of Call for Bids NL11-03 Parcel 1

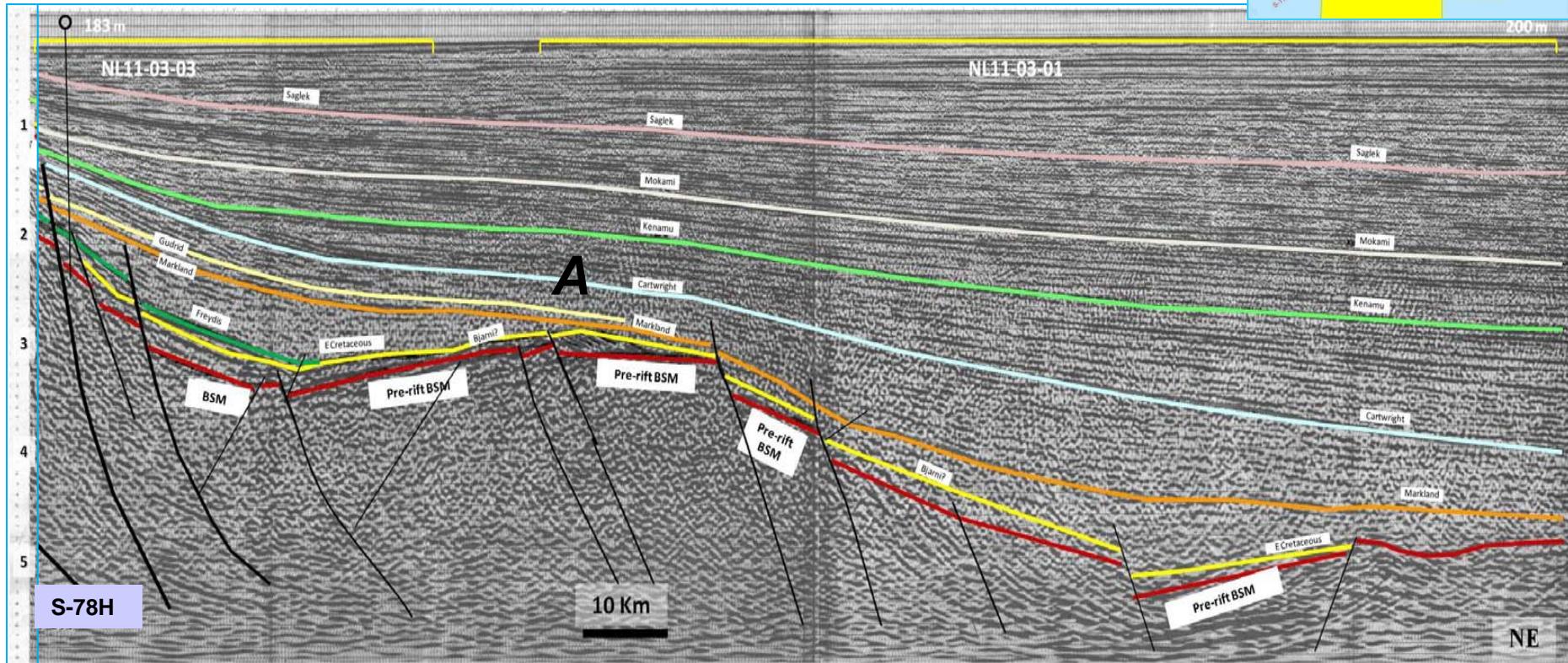
- Parcel 1 covers 207,144 ha (511,864 acres) in the eastern part of the South Saglek Basin seaward from Parcel NL11-03-03 and north of parcel NL11-03-02
- This shallow water parcel (150-330 m, 195 m average water depth) is located on the outer shelf in an area where no wells have been drilled yet
- The seismic horizons are interpreted using ties from the Gilbert F-53 and Karsefni A-13 wells



# Seismic Line S-78H



Gilbert F-53 pr

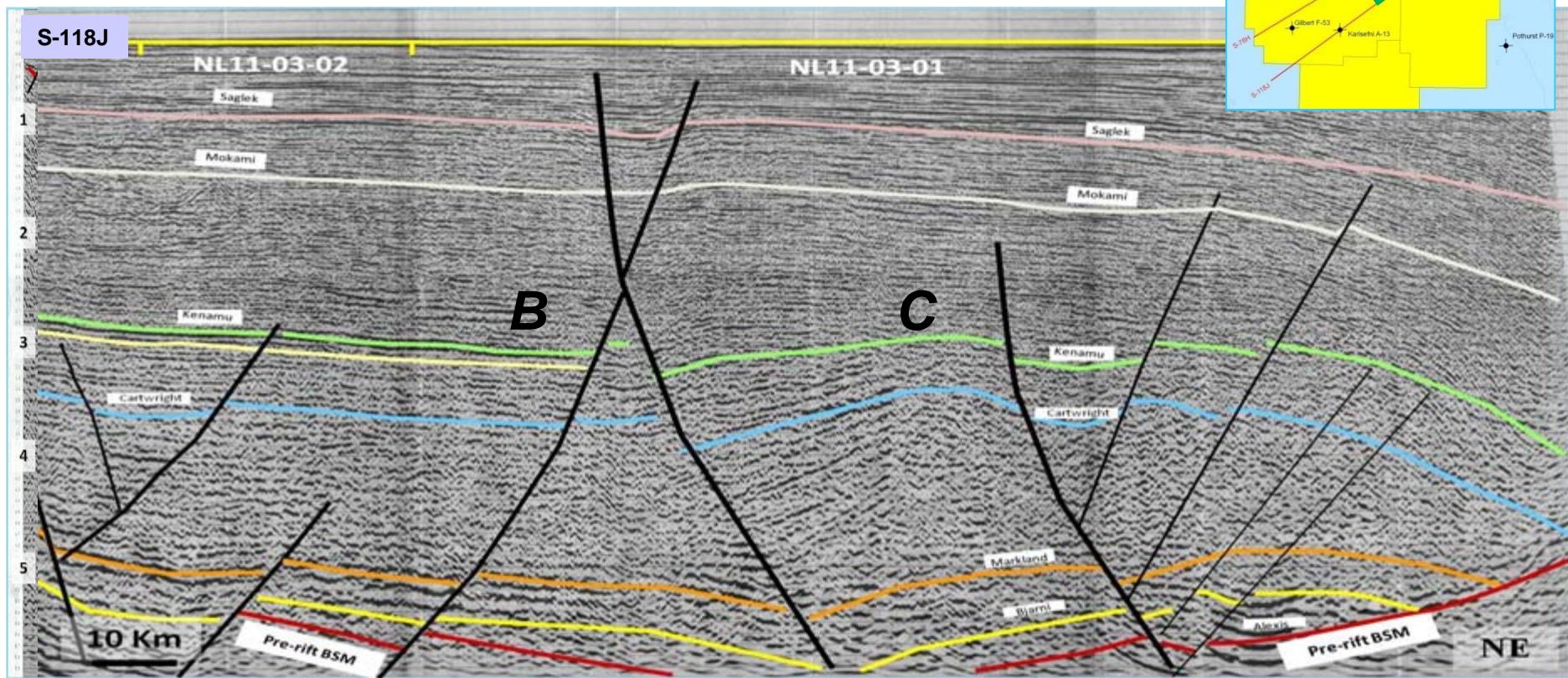


Interpreted dip seismic section S-78H crossing Parcel NL11-03-01. The sedimentary infill thickens towards the northeast. No major postrift fault is interpreted in this line. A large basement high **A** is cut by several faults. Drilling opportunities for structural and combination traps exist on the top and on the flanks of the basement high (seismic line source: C-NLOPB).

# Seismic Line S-78H

- This dip line S-78H (SW-NE) is located in the northern part of Parcel NL11-03-01, extending into this parcel from the abutting parcel NL11-03-03
- The line is positioned over the outer shelf part of the South Saglek Basin
- The postrift sequences dramatically thicken towards the northeast, rolling gently over a large basement high located in the western part of the parcel
- Over the basement high and on its flanks, the synrift sequence is at medium depth (3-4 km) and it is in a trapped position
- The basement high “A” is faulted in several places and some of these faults may extend upward in the postrift fill setting fault traps
- Since the basement, synrift and early postrift sediments rapidly deepen towards the northeast, no basement/synrift structural trap is reachable in the rest of the parcel. However, younger sandstones in stratigraphic traps, may exist and be mappable with modern data. Some counter-dip faults trapping sandstone members may exist that cannot be interpreted with the data quality of this seismic line. Lowstand sandstone bodies may extend on the outer shelf forming stratigraphic traps
- Considerable thickness of synrift and postrift formations (Cartwright, Kenamu and Mokami) including high TOC shale may exist and generate hydrocarbons in the eastern trough seen on this line

# Seismic Line S-118J

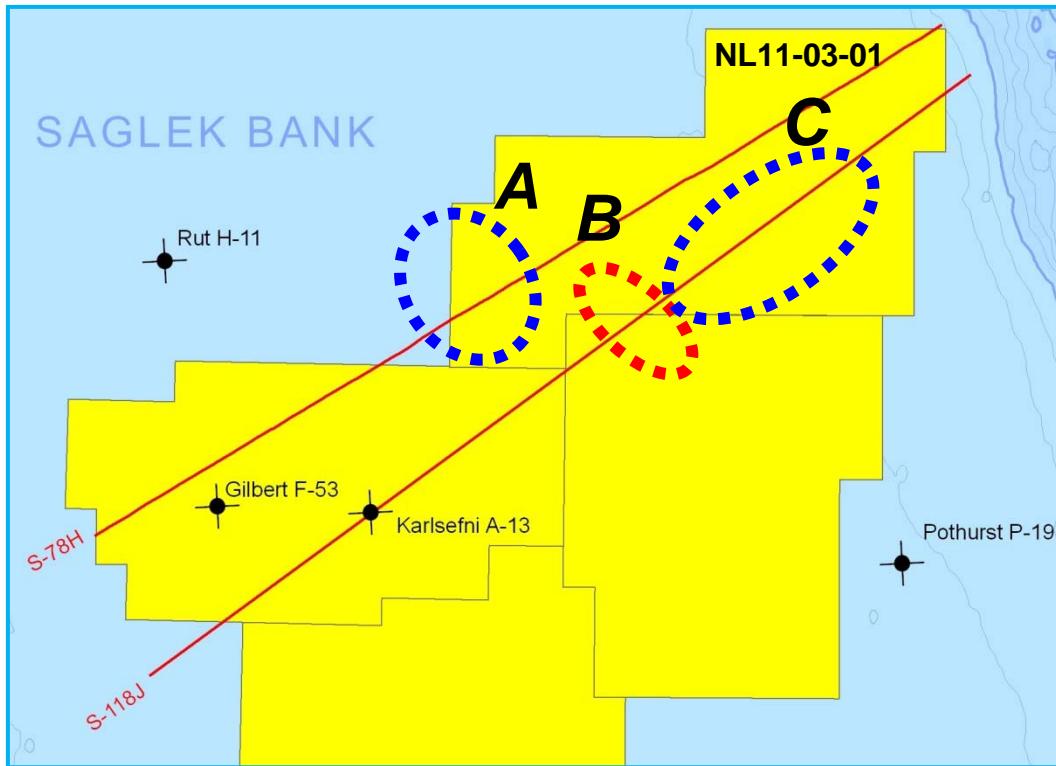


Interpreted dip seismic section S-118J crossing Parcel NL11-03-01. The sedimentary formations thicken towards the northeast segmented in places by major normal listric faults. One horst “B” and several rotated blocks are interpreted. A large roll-over anticline “C” dominates the subsurface in Parcel 1 (seismic line source: C-NLOPB).

# Seismic Line S-118J

- This dip line S-118J (SW-NE) is located in the central part of Parcel NL11-03-01, extending into this parcel from the adjoining parcels NL11-03-02 and -03
- The line is positioned over the outer shelf part of the South Saglek Basin
- The prerift basement, synrift and postrift sequences gently deepens towards the northeast and are compartmentalized by deep-penetrating normal faults; several of the thick-skin faults affect the younger sedimentary succession of the Mokami and Saglek formation. The synrift sequence is too deep to be a target on this line
- Two major listric faults with throws larger than 60 m and opposite dips interrupt the regional gradient and setup a horst “B” and a rollover anticline “C” in the parcel
- The width of the horst in this seismic line is about 7 km at the Kenamu Formation, increasing to about 30 km at depth. This horst may constitute a large structural trap, if closure can be proven by intersecting strike lines. Potential intervals include Leif, Gudrid and Freydis sandstones
- A large listric, eastward dipping fault has triggered a large roll-over anticline. This anticline denoted “C” (slide 121) is segmented by faults into a western and an eastern flank. The western flank forms a sizable rotated block (30-40 km) that might have an independent closure
- The roll-over anticline C is faulted in its central part, where a central graben is visible (similar to Terra Nova Central Graben). The western flank of the roll-over is also faulted and may contain prospective Leif and Gudrid sandstones or their low-stand equivalents

# Parcel NL11-03-01



= Possible closed horst feature in Parcel NL11-03-01

= Possible closed fault block and roll-over in Parcel NL11-03-01

## Summary

### Structural leads:

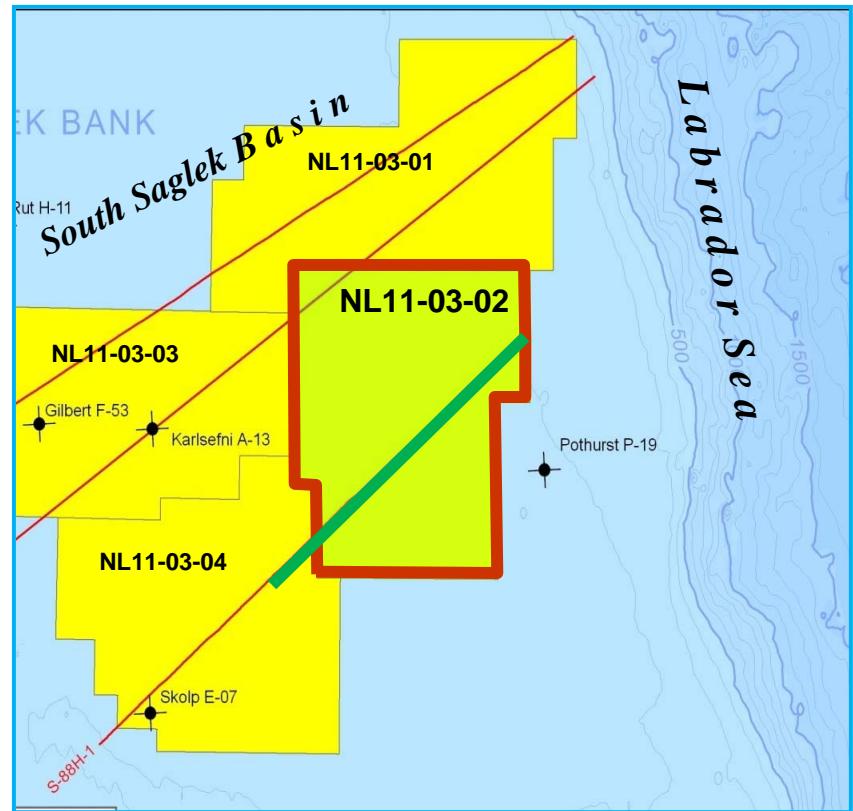
- Large and complex basement structure “A” and medium size horst “B” in the western part
- A large collapsed roll-over anticline “C” is divided by faults in two rotated blocks
- The dominant roll-over anticline “C” includes a central collapse zone, in the eastern part of the parcel
- Strike lines are needed to confirm closure of these leads

### Stratigraphic leads:

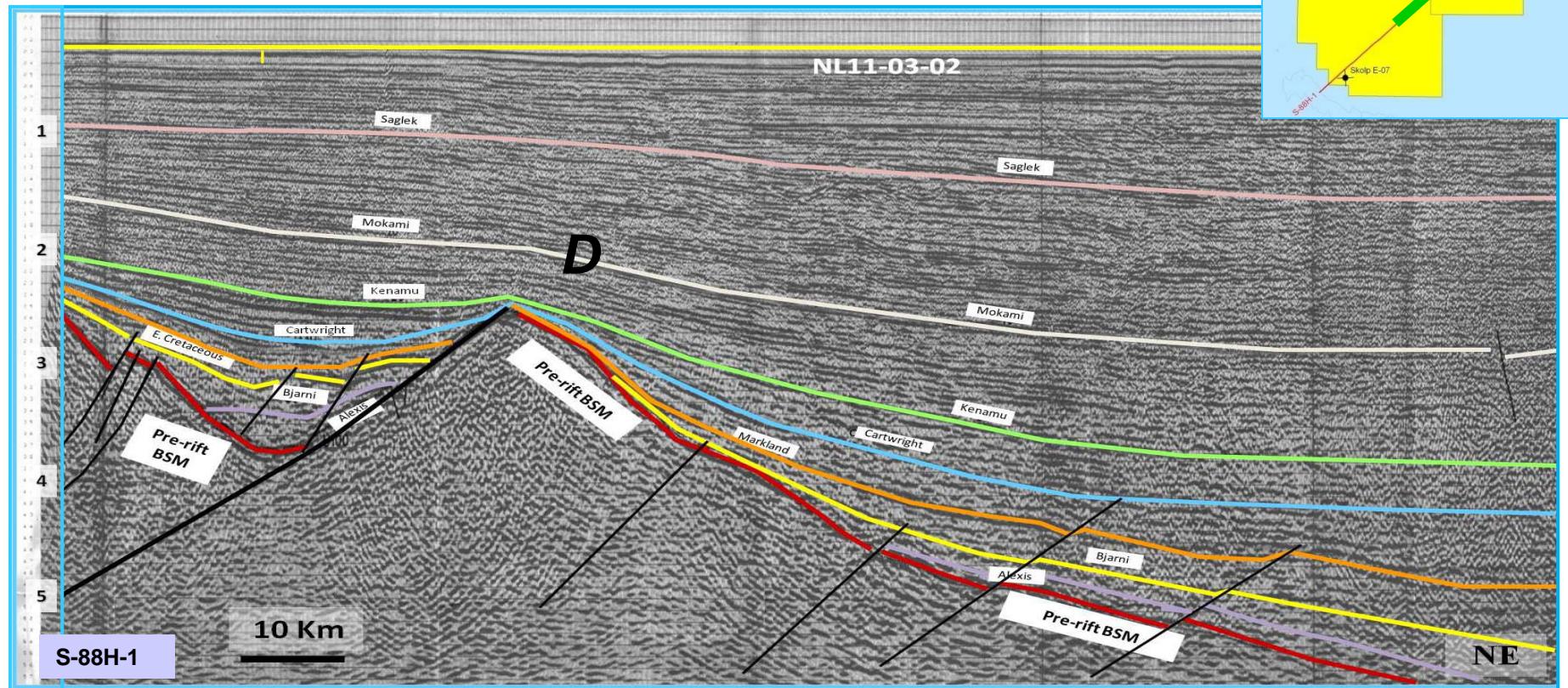
- Low stand equivalent of the Gudrid and Leif sandstones may exist in the parcel as lenses and sand fans

# 6.2 Petroleum Potential of Call for Bids NL11-03 Parcel 2

- Parcel 2 covers 201,056 ha (496,820 acres) in the south western part of the South Saglek Basin, seaward from Parcels NL11-03-03 and -04
- This shallow water parcel (160-220 m, 185 m average water depth) is located on the outer shelf
- No exploration wells have been drilled in the parcel
- The seismic horizons are interpreted using ties from the Skolp E-07 wells and Pothrust P-19 (drilled just 8 km east of the parcel)



# Seismic Line S-88H-1

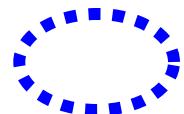
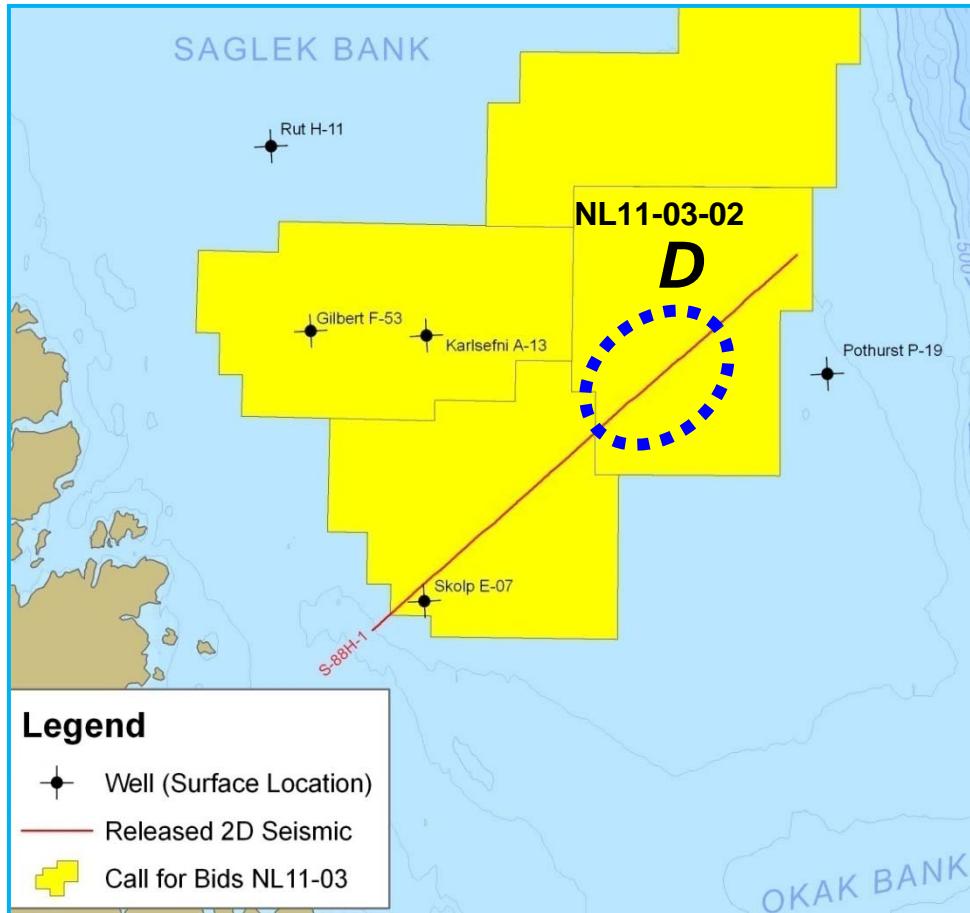


Interpreted dip seismic section S-88H-1 crossing Parcel NL11-03-02. The post rift sedimentary formations thicken considerably towards the northeast. A large rotated basement block "D" occupies the western part of the parcel. Drilling opportunities for structural and combination traps exist on the top and on the flanks of this basement block (seismic line source: C-NLOPB).

# Seismic Line S-88H-1

- This dip line S-88H-1(SW-NE) is located in the central part of Parcel NL11-03-02, extending from Parcel NL11-03-04
- The line is positioned over the outer shelf part of the South Saglek Basin
- The postrift sequences dramatically thicken towards the northeast, rolling gently over the large basement high “D” (previous slide ) located in the western part of the parcel
- A counter-dip, fault-bounded, large basement block D is the dominant structural feature in the parcel
- Over the basement high D and its flanks the early postrift sequences are relatively shallow (approximate 3.5 km) and in a trapped position
- The basement of the eastern flank is faulted in several places and the faults extend upward in the synrift and early postrift cover
- Several smaller blocks are in a trapped position in the western graben where the Bjarni sandstone may be present
- As the seismic line is of poor quality, no major faults are interpreted in the later basin fill above the rotated block. However counter-dip faults may exist setting fault traps in the postrift sedimentary successions
- Thick synrift and postrift shales of the Bjarni, Cartwright, Kenamu and Mokami formation may have high TOC and generated hydrocarbons in both the western graben and the large eastern trough, seen on this line

# Parcel NL11-03-02



= Possible rotated block closure in Parcel NL11-03-02

## Summary

### Structural leads:

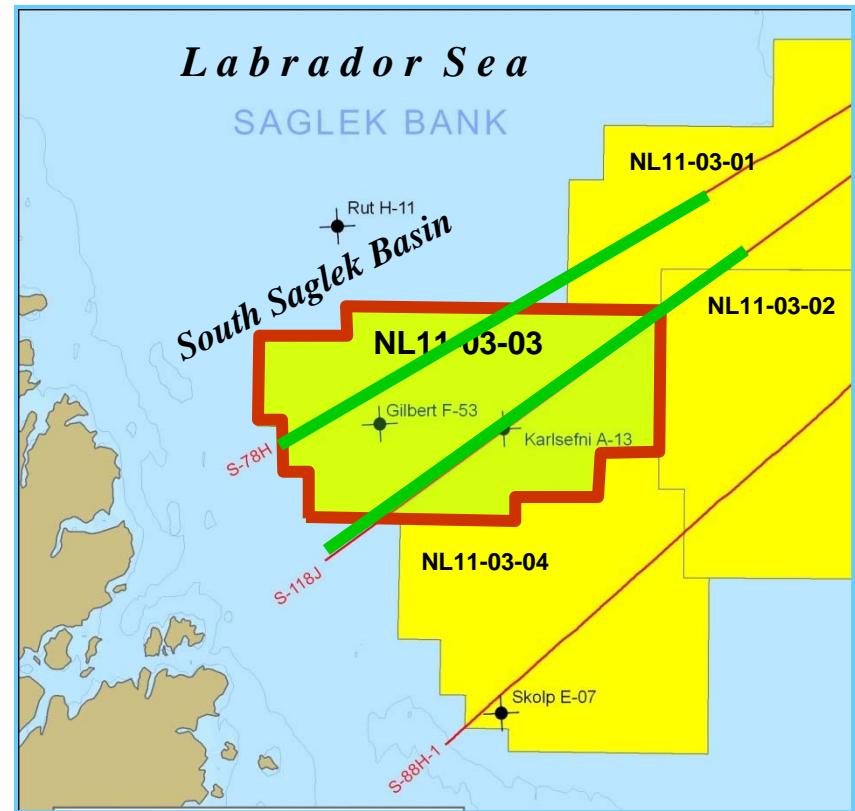
- A large size rotated basement block “D” exists in the western portion of the parcel
- Fault bounded traps may have formed in the postrift succession
- Onlapping synrift sandstones may be trapped in front and on the shoulder of the rotated block “D”
- Strike lines are needed to confirm closure of the leads

### Stratigraphic leads:

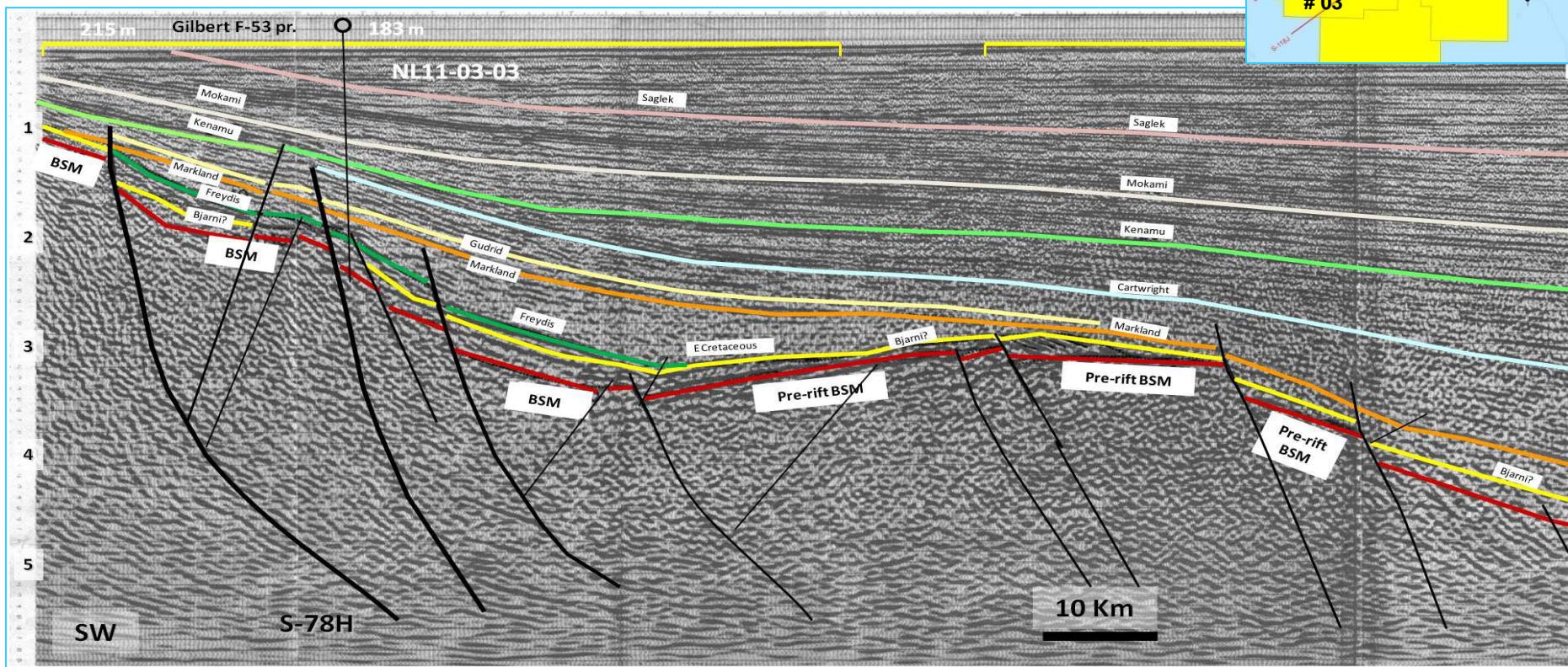
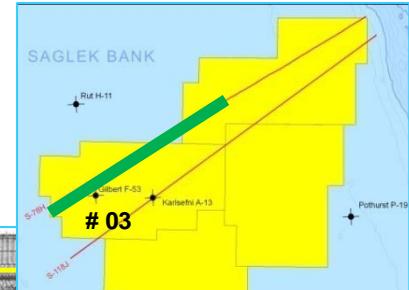
- Low stand postrift sandstones may exist in the parcel as sandstone lenses and sand fans

# 6.3 Petroleum Potential of Call for Bids NL11-03 Parcel 3

- Parcel 3 covers 204,483 ha (496,820 acres) in the eastern part of the South Saglek Basin on the inner shelf
- This shallow water parcel (120-330 m, 175 m average water depth) contains two early exploration wells Gilbert F-53 and Karsefni A-13 which both encountered good reservoir rocks
- The seismic lines crossing this parcel were interpreted using geological ties to the F-53 and A-13 wells



# Seismic Line S-78H

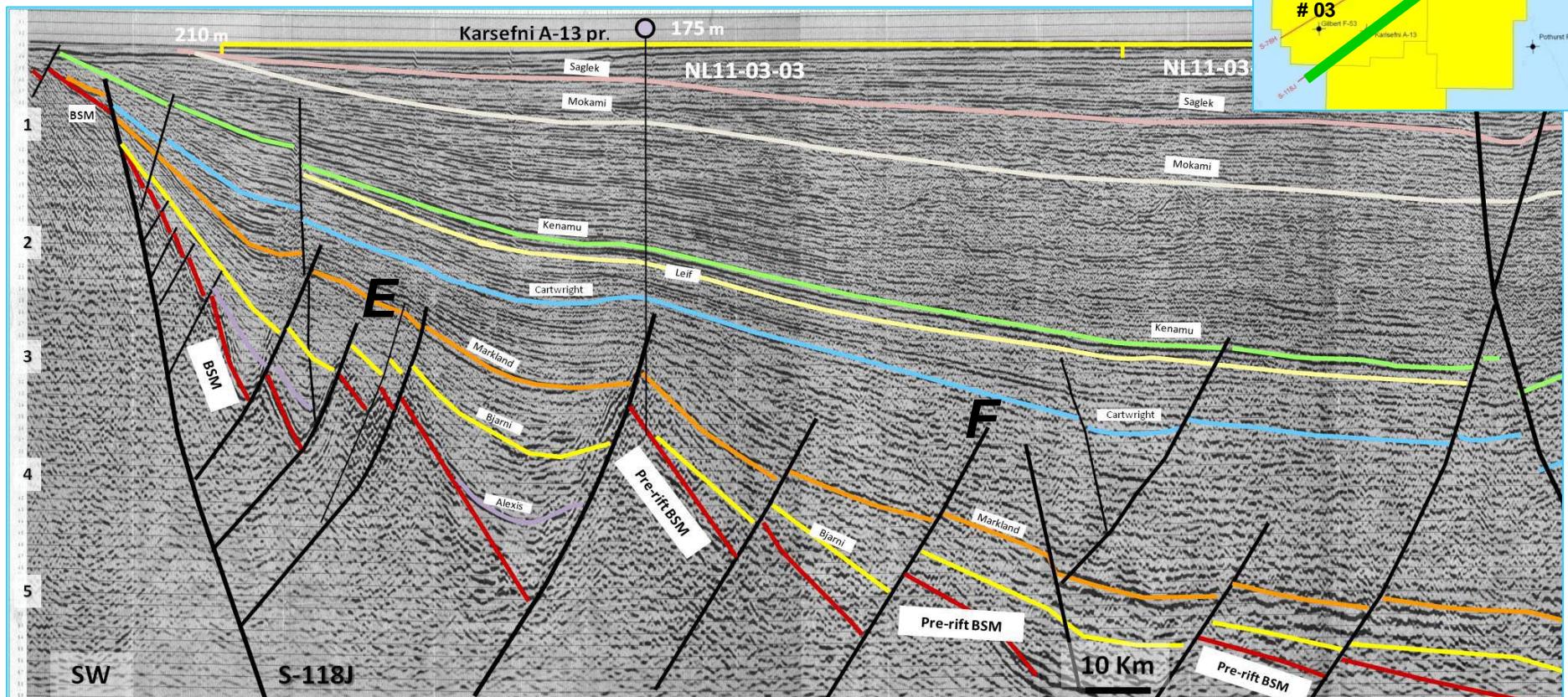


Interpreted dip seismic section S-78H crossing Parcel NL11-03-03. The sedimentary formations thicken towards northeast. Several major basement faults are seen in the western part of the line. One complexly faulted horst was drilled by the Gilbert F-53 well. Drilling opportunities for structural and combination traps exist within a larger trough occupying the eastern part of the line (seismic line source: C-NLOPB).

# Seismic Line S-78H

- This dip line S-78H (SW-NE) is located in the northern part of Parcel NL11-03-03, exiting the parcel into adjoining Parcel NL11-03-01
- The line is positioned over the inner shelf part of the South Saglek Basin
- The postrift sequences thicken towards the northeast filling a large basement trough and then rolling over the large basement high located in Parcel 1
- Several deep penetrating rift faults are defining the western part of the parcel
- A complexly faulted horst block was drilled by the Gilbert F-53 well that intersected good reservoir in Freydis sandstone
- Several fault blocks can be interpreted on the flanks of the regional basement trough, which if proven by strike lines may become drilling targets
- Postrift successions gently dipping eastward may be cut by counter-dip faults forming fault traps. These faults are not imaged on this seismic line due to its poor data quality
- Possibilities of stratigraphic traps (e.g. onlaps, pinchouts and truncations) may exist in the central part of the parcel
- Considerable thickness of synrift Bjarni and postrift Markland organic shales may exist and generate hydrocarbons in the eastern trough seen on this line

# Seismic Line S-118J

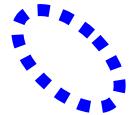
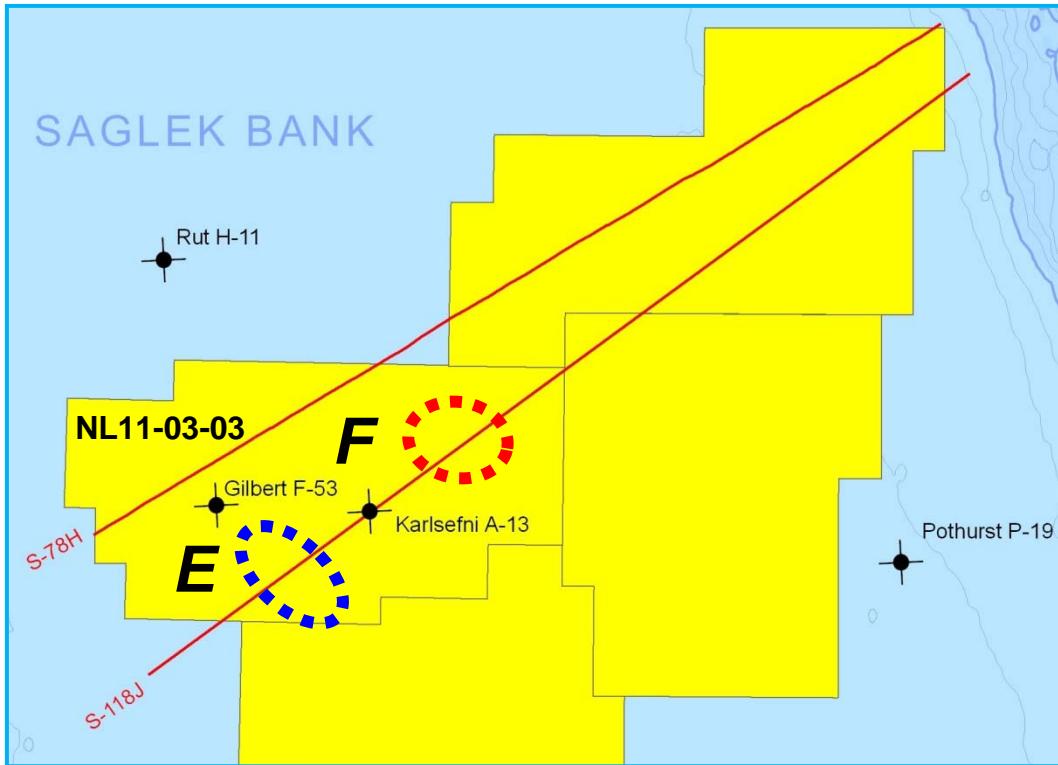


Interpreted dip seismic section S-118J crossing Parcel NL11-03-03. The sedimentary formations thicken towards northeast. The basement, synrift and postrift 1 sequences (see slide 115) are segmented by numerous down-to-shore normal faults. One rotated block was drilled while several large others ("E" and "F") remain undrilled (seismic line source: C-NLOPB ).

# Seismic Line S-118J

- This dip line S-118J (SW-NE) is located in the central part of parcel NL11-03-03, crossing the Karsefni A-13 well location and then extending to parcels NL11-03-02 and -01
- The line is positioned over the shelfal part of the South Saglek Basin close to the basin's edge
- The prerift basement, the synrift and the postrift sequences gently deepens towards northeast. The succession is compartmentalized by several deep-penetrating normal faults. Several rotated basement blocks with synrift and postrift cover are interpreted in this line
- One of the rotated blocks was drilled by the Karsefni A-13 well. The location missed the Bjarni sandstone but the well encountered good reservoirs in the Gudrid and Leif sandstone members. Alternative locations may exist in front of the block or in a lower position on its eastern flank
- A large, faulted rotated block “E” (previous slide) remains undrilled west of Karsefni A-13. East of the A-13 location there are several deeper rotated blocks including a horst “F” containing synrift and postrift sequences that might have reservoir sandstones
- The synrift (Bjarni) and lower postrift (Markland, Cartwright and possibly Kenamu) organic shales should be mature both east and west of the A-13 well
- Numerous stratigraphic trapping opportunities can be seen on this seismic line

# Parcel NL11-03-03



= Possible closed rotated block in Parcel NL11-03-03



= Possible closed horst in Parcel NL11-03-03

## Summary

### Structural leads:

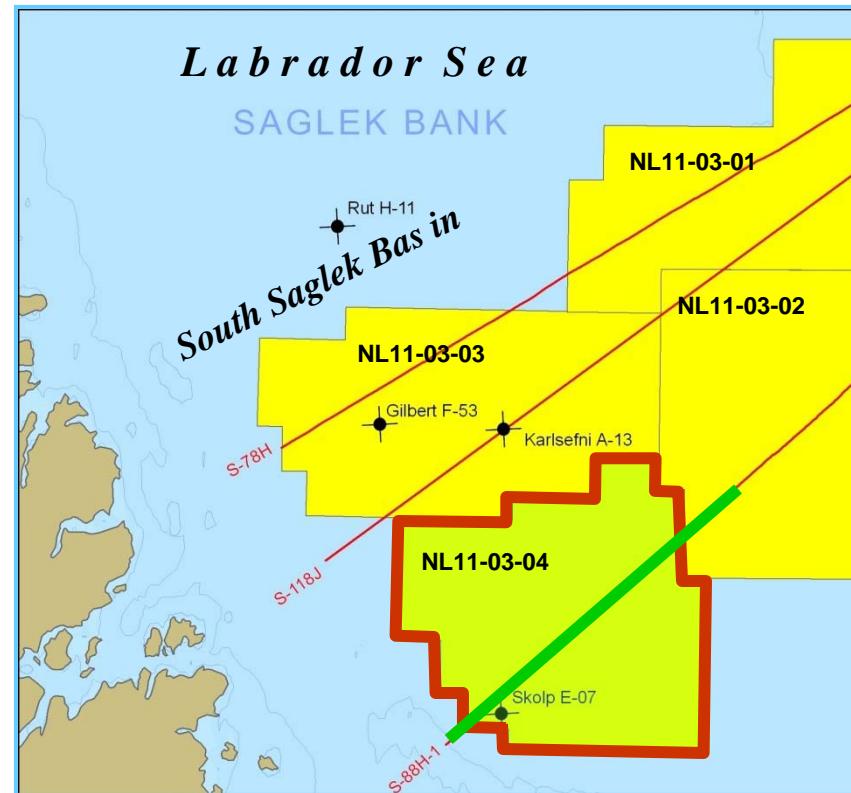
- Medium size basement rotated block “E” in the southwestern portion of the parcel
- A medium size, deeper horst “F” located in the northeastern part of the parcel
- As shown by the interpreted seismic sections S-78H and S-118J, several other rotated blocks are present in the parcel

### Stratigraphic leads:

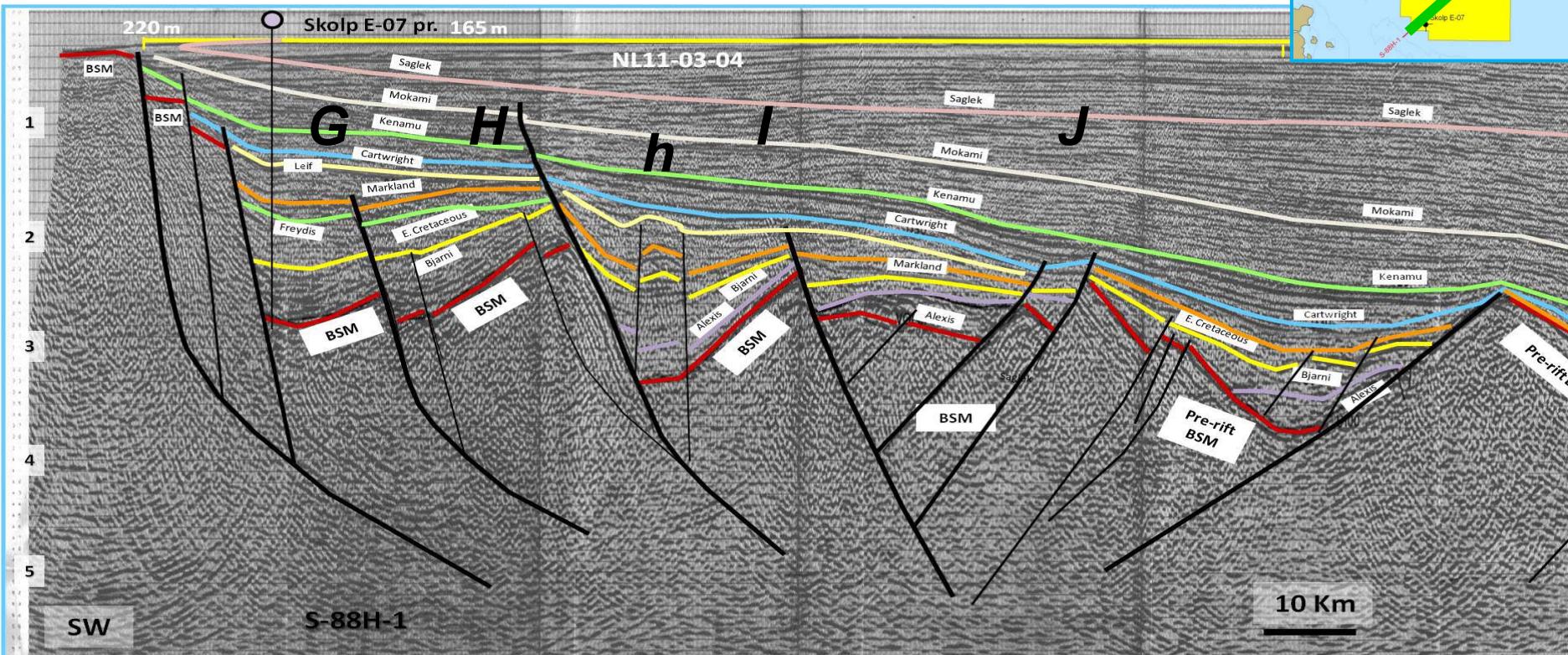
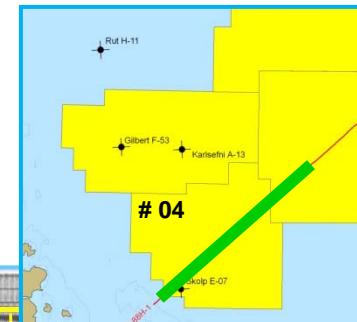
- Freydis, Gudrid and Leif sandstones may be trapped in the parcel (onlaps, pinchouts, truncations). Some sandstone lenses and sand fans may exist in the eastern part of parcel

# 6.4 Petroleum Potential of Call for Bids NL11-03 Parcel 4

- Parcel covers 198,828 ha (491,315 acres) in the southwestern part of the Saglek Basin
- This shallow water parcel (120-210 m, 160 m average water depth) is located on the Labrador Sea's inner shelf
- The parcel is located near the basin bounding fault (or "hinge zone" in other interpretations)
- The parcel contains an early exploration well Skolp E-07 that allows for good seismic horizon ties



# Seismic Line S-88H-1

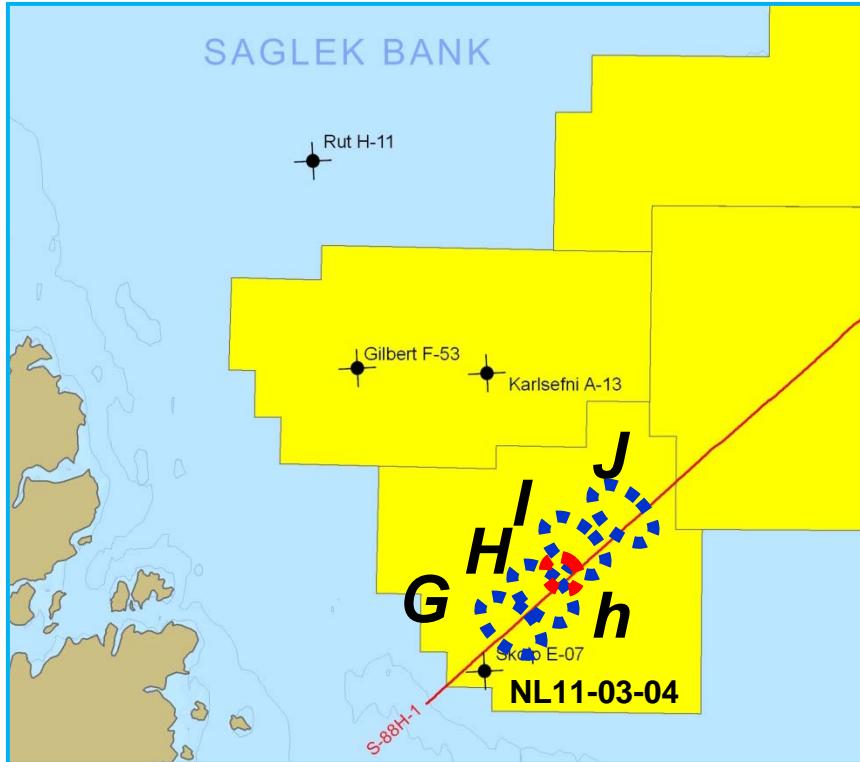


Interpreted dip seismic section S-88H-1 crossing Parcel NL11-03-04. The basin fill thickens towards the northeast. The bounding fault and several imbricates are seen in the western part. A faulted block was drilled by the Skolp E-07 well. Drilling opportunities for structural and combination traps exist east of E-07 where several rotated blocks and a horst (G,H, h, I, J) are interpreted (seismic line source: C-NLOPB).

# Seismic Line S-88H-1

- This dip line S-88H-1 (SW-NE) is located in the central part of Parcel NL11-03-04, exiting the parcel eastward into Parcel NL11-03-02
- The line is positioned over the inner shelf of the South Saglek Basin
- The prerift basement and the synrift are dissected by numerous faults creating many trapping possibilities
- The first rotated block in the basin was drilled by the Skolp E-07 well. The well intersected reservoir intervals in both Freydis and Bjarni sandstones
- Two rotated blocks “G” and “H” with the possibility of Bjarni and Freydis sandstone reservoirs exist east of the E-07 location. The lead “H” presents trapping possibilities in both the upthrown and downthrown side of a major extensional fault
- Another rotated block “I” with potential for Bjarni and Freydis sandstones, is defined by a major basement fault. A small horst “h” exists in the graben between the H and I structural highs
- The complex roll-over/rotated block lead “J” is seen in the eastern part of the parcel. Several drilling locations are viable for this lead as it is surrounded by lows where source rocks should be mature
- Some of the basement faults may extend to the Cartwright and Kenamu level, allowing for sandstone members to be trapped. However, seismic data quality does not allow a proper evaluation of this option
- The basement trough which is situated between parcels 2 and 4 shows a considerable thickness of synrift (Bjarni) and postrift (Cartwright, Kenamu and Mokami) successions including mature, high TOC shales

# Parcel NL11-03-04



= Possible closed rotated blocks in Parcel NL11-03-04



= Possible horst in Parcel NL11-03-04

## Summary

### Structural leads:

- Two rotated blocks, “G” and the larger “H”, east of Skolp E-07, in the downthrow of the basin bounding fault
- A deeper rotated block “I” in the central part of the parcel
- A complex roll-over/rotated block lead “J” in the eastern part of the parcel
- All leads need confirmation by strike lines and mapping

### Stratigraphic leads:

- Several stratigraphic trapping mechanisms such as pinchout, onlap, truncation may exist in the eastern part of the parcel

# Comments on Seismic Data

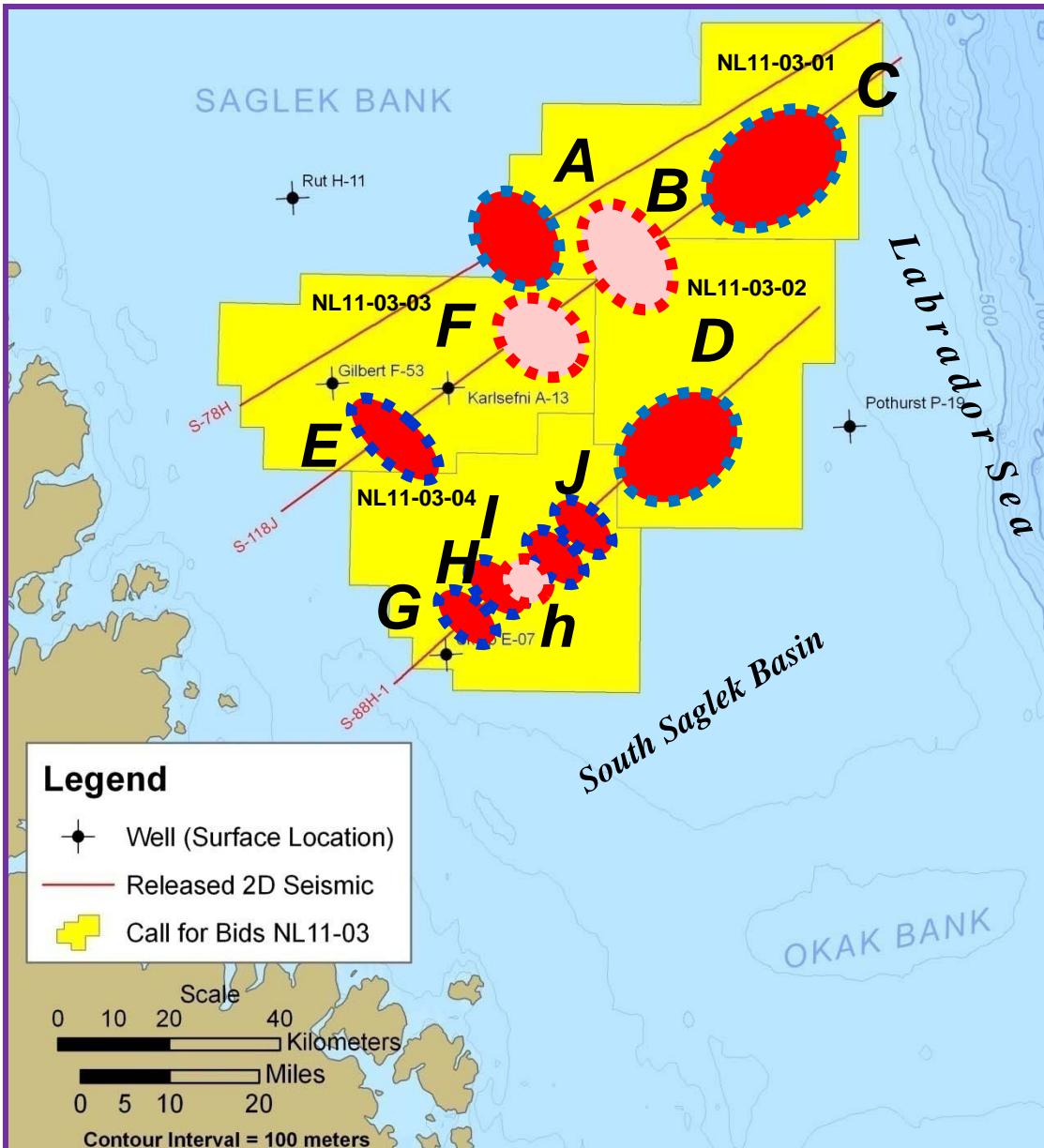
- Seismic coverage can be purchased as digital data from vendors such as GSI, TGS, CGG or data brokers and as hard copies for inspection, for the nominal cost of reproduction, from C-NLOPB in St. John's, NL
- Retrieving the original field data and re-processing old lines to pre-stack depth migration is needed to better image leads in the four parcels
- Access to modern digital data recorded during the past decade by GSI and TGS/PGS is necessary to firm up the Saglek Basin leads and define drillable prospects
- New acquisition of 2D reflection data is necessary to better delineate structural plays such as horsts and rotated blocks and investigated stratigraphic anomalies in postrift clastic sequences and prerift carbonates

# Prospects and Leads

- The area's main hydrocarbon play is structural; it involves porous synrift Bjarni sandstone and/or postrift Freydis, Gudrid and Leif sandstones; multiple reservoirs may exist at some locations as proven by some of the basin's wells
- The area is well structured. A multitude of fault dependant leads can be interpreted within the four parcels
- The leads are large sized extensional features; the great majority are rotated blocks, bounded by normal faults which may be either down-to-basin or down-to- shore
- There are two identified horst type leads
- Several leads are of a complex basement faulted anticline type; a drape of synrift sediments over the top of these features is possible and some fault dependant closure of younger reservoirs may also have occurred
- Mature source rocks may be found in the synrift sequence and in the organic shales of the post rift sequence in deeper grabens, troughs and deeper subbasins on the slope

# CFB NL11-03

## Summary of Leads



- = Possible closed rotated block in Parcels NL11-03
- = Possible closed horst in Parcels NL11-03

Closure may vary in size from 20 to 200 sq km. All leads interpreted in the representative seismic lines (slides 119, 121, 125, 129, 131 and 135) need better seismic coverage and horizon mapping to be confirmed

# Prospects and Leads (Cont.)

- Good seals such as regional shales are present in all parcels
- Several large petroleum leads within the CFB parcels were mapped by companies active in the area in the 1970s and early 1980s (Eastcan Group, Petro-Canada, etc.)
- Regional seismic interpretation reports and annexed time structural maps at several horizons and isochron maps for the basin including the CFB NL11-03 parcels are available from the C-NLOPB archive and can be inspected and copied for bid evaluation
- Main geological risks on these parcels are the presence of fault dependent closures, reservoir quality and access to mature source rock. These risks are somewhat mitigated by the large size of the structural traps identified in these parcels

**OBSERVATION: If closures can be proven by mapping the area's 2D seismic coverage, each of the structural closures "A" to "J" is capable of holding up to a billion barrels of oil or several Tcf of gas**

# 7. Discussion

- Exploration in NL Saglek Basin, located in the Canadian Labrador Sea, is still in an early frontier stage
- The Saglek Basin is a very large, lightly explored extensional/transtensional marine basin situated at the latitude of Northern Europe
- Numerous hydrocarbon prospects and leads that were identified with old seismic data, remain to be defined by modern data and are waiting to be drilled
- No exploration has been carried out in the Saglek Basin since the early 1980s
- Five large gas fields and a significant show of light oil have been recorded in the Canadian Labrador Sea after 24 wells reached targets without the use of 3D surveys, or advanced seismic attribute studies
- Significant exploration activity is taking place northeast of Saglek Basin in the West Greenland continental margin
- CFB NL11-03 parcels are very large when compared with a Gulf of Mexico standard section (more than 80 times larger)
- Parcels contain multiple targets within Early Cretaceous, Late Cretaceous and Early Tertiary sandstone reservoirs at depths between 2500-4500 m which can be tested by drilling

# Discussion (Cont.)

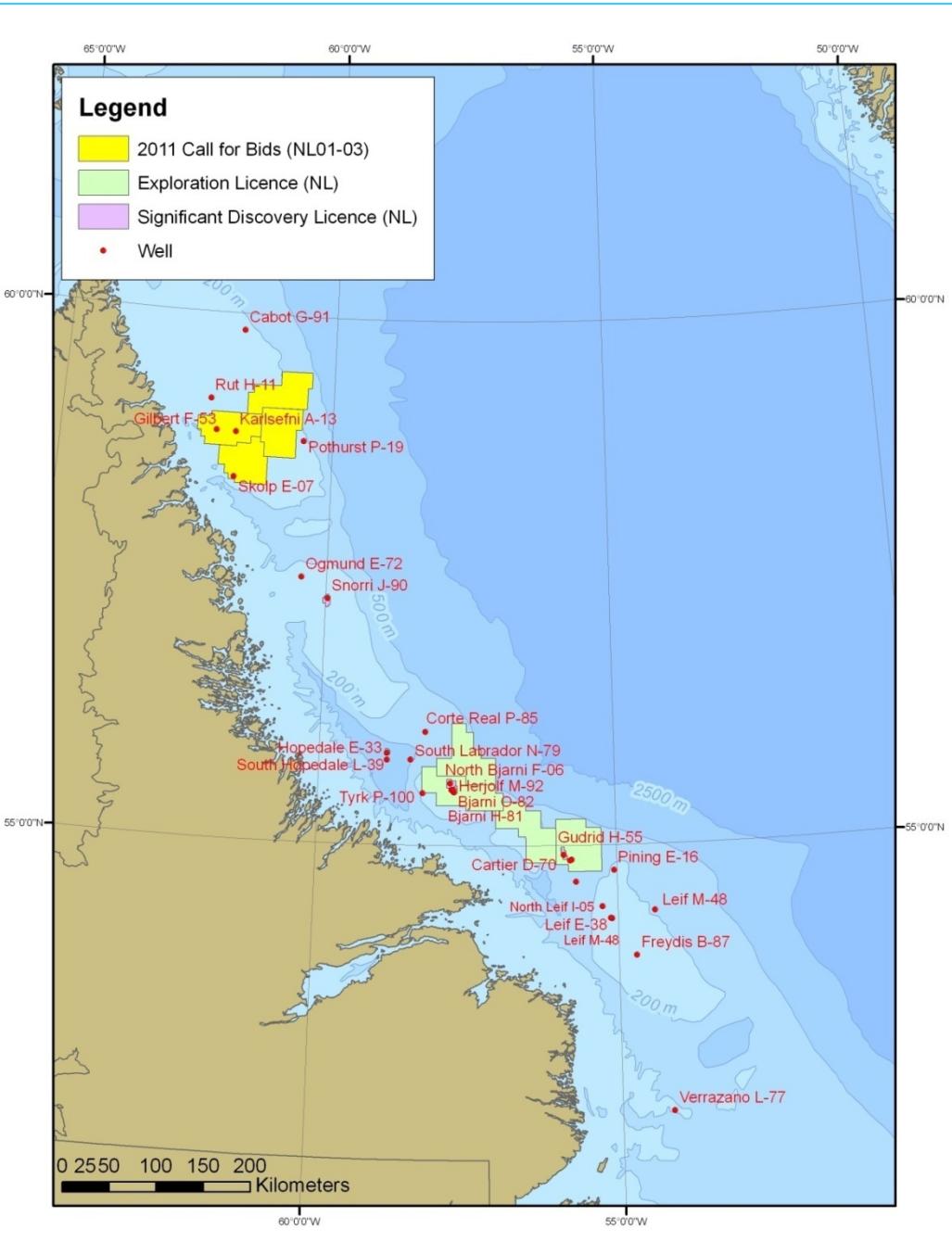
- Geological risks associated with fault closure, reservoir quality and source rock maturation; can be assessed with new mapping using reprocessed and/or modern seismic data.
- The structural traps identified in the Saglek Basin can host resource estimates of hundreds of million barrels and/or several Tcf of natural gas
- A 6-year (Period 1) +3-year (Period 2) = 9-year term Exploration Licence is set by C-NLOPB for Saglek Basin (Area “C”). Licence awards are based on highest work commitment bid
- Royalty regime is well established and competitive placing offshore NL in the middle to-upper tier of world’s favorable areas for petroleum exploration and production
- Canada has a stable political and financial system and a long tradition in oil and gas exploration
- The Province of NL obtains 27.5% of the nominal GDP from the oil and gas industry and is actively encouraging exploration of the Labrador offshore area
- 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

# 8. Conclusions

- Four large parcels located offshore Labrador in the South Saglek Basin are available for licensing in the C-NLOPB's Call for Bids NL11-03 which closes on November 15, 2011, 4 p.m. NL time
- The parcels are in a region with large extensional and inversion traps, known reservoirs, mature source rocks and proven migration paths
- This is the first Call for Bids in the basin and the first activity in more than 30 years. The Call is the second in recent years that targets the Mesozoic-Cenozoic basins of the Labrador Sea
- The basin contains Cretaceous and Early Tertiary source rocks which are known to be generating hydrocarbons while the same age reservoirs have tested hydrocarbons in the region
- Large fault-bounded blocks such as horsts and tilted blocks may have closure at the Bjarni synrift reservoir and Freydis, Gudrid and Leif postrift levels. Closures may vary in size from 20 to 120 sq km
- Numerous types of structural, stratigraphic and combination traps were identified with seismic data in the Labrador basins
- Indication of natural oil slicks in the area were obtained using satellite imaging. The Saglek Basin has all the fundamentals to become an important petroleum province

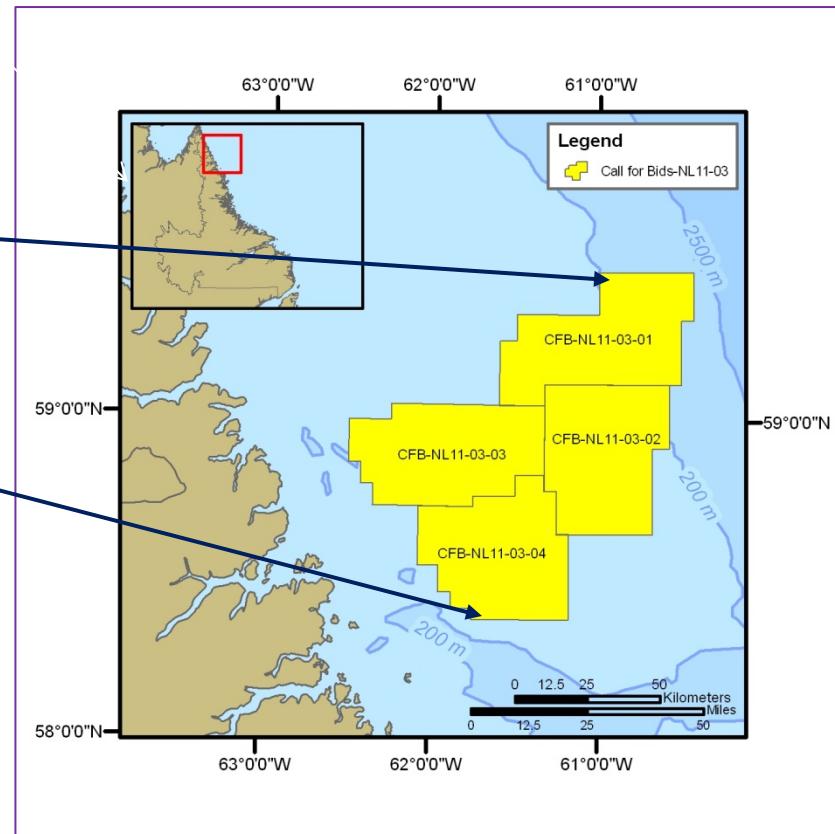
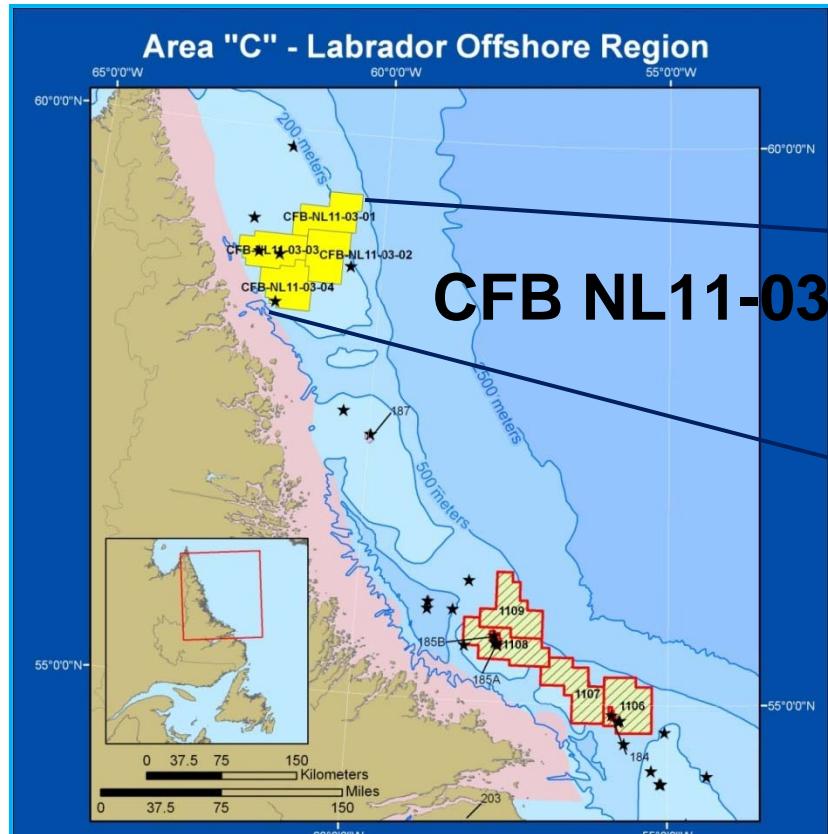
# Conclusions (Cont.)

- Good quality and relatively dense 2D seismic coverage is available in Parcels 1 to 4 to image and map petroleum traps in the synrift and postrift sequences
- All the parcels are situated in water depths varying between 120 m and 330 m (average less than 190m). The leads are located at distances of 40 to 120 km from the shore line
- The “A” to “I” leads (see slide 140) defined in parcels NL11-01-01, -02, -03 and -04 are situated in a practically unexplored basin, but close to Canadian, NE American and Western Europe markets
- Recognized risks related to reservoir quality, source rock and migration are mitigated by the presence of very large undrilled features.
- Estimated sizes of unrisked reserves are up to several billion barrels of oil or several Tcf of natural gas, that may be present in the structural leads identified in the area
- These parcels provide excellent petroleum resource prospects to seasoned operators with available funds for new seismic data collection and exploration drilling in a truly North American under-explored basin



# Exploration Opportunity

- Four large parcels in the South Saglek Basin
- 6+3 years exploration term licences
- Proven petroleum systems
- **Call for Bids closes on November 15, 4pm, NL time**



*Thank you for your Attention!*

