

OFFSHORE OPPORTUNITY - 2018 LICENCE ROUND



2018 CALL FOR BIDS, CENTRAL RIDGE/SOUTH FLEMISH PASS, NEWFOUNDLAND AND LABRADOR

EXECUTIVE SUMMARY

- In April 2018, the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB) announced a Calls for Bids for Exploration Licences in the Eastern Newfoundland and Jeanne d'Arc Regions, as well as a Calls for Bids for a Production Licence in the Jeanne d'Arc Region. Within the Eastern Newfoundland area, three parcels were issued in the Central Ridge/South Flemish Pass (CR/SFP) area (Figure 1). As proven by several significant discoveries in nearby Significant Discovery Licences (SDLs), these parcels are highly prospective for large hydrocarbon accumulations.
- The area remains largely underexplored, with only four wells within the sector and seven in the vicinity despite the proven presence of active petroleum systems and good seismic coverage. Northeast of the sector, in the Flemish Pass Basin two SDLs, Mizzen and Bay du Nord, have been recently awarded for large oil accumulations and two yet to be delineated discoveries, Harpoon and Baccalieu, have been made in recent years. Bids close in November 2018 for this potentially prolific hydrocarbon region located in the Central and Eastern Ridges and Flemish Pass Basin area.

OVERVIEW

- Located on Canada's East Coast, the province of Newfoundland and Labrador has sustained significant levels of industry interest in its highly prospective offshore basins. Since first oil at Hibernia in 1997, the province's five producing fields of Hibernia, Terra Nova, White Rose, North Amethyst, and most recently Hebron have produced more than 1.75 billion barrels of light oil (32 - 35° API). The Newfoundland offshore area now produces over 230,000 bopd and the output is estimated to increase to 400,000 bopd when the Hebron field reaches peak production. Other large and medium-sized oil discoveries made in several basins may advance to development stage in the next decade.
- With substantial undiscovered resource estimates totaling 6 billion barrels of oil and 60 trillion cubic feet of natural gas, the region holds great potential. Land available in this 2018 Call for Bids offers explorers opportunities for substantial new discoveries (Figure 1).

KEY ATTRIBUTES

- The Central Ridge/South Flemish Pass (CR/SFP) Calls for Bids consists of 3 parcels (NL18-CFB01-14, NL18-CFB01-15 & NL18-CFB01-16) totaling 632,806 hectares (6,328 km²).
- Additional 2018 Calls for Bids are posted in the Orphan Basin.
- Parcels are located in shallow to intermediate water, from 180 to 1,300 m.
- Competitive fiscal regime with very low political risk.
- Modern seismic coverage including ties to representative wells.
- Proximity to both North American and European markets.
- Open and transparent land management and bid processing system.
- Winning bidder granted exploration rights on a work commitment basis.
- Bids close at 12:00 pm NST on November 7, 2018.
- For more information, visit www.cnlopb.ca

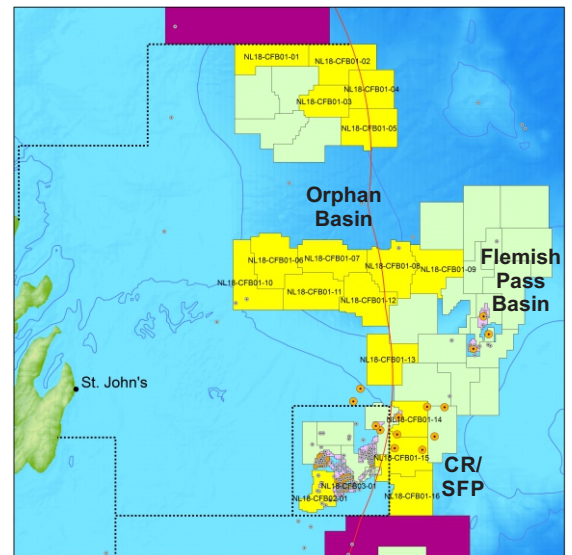


Figure 1. 2018 Call for Bids parcels (in yellow). The Central Ridge/South Flemish Pass (CR/SFP) area is discussed in this brochure.

ATLANTIC MARGIN BASINS REGIONAL GEOLOGY

- The 160,000 km² Jeanne d'Arc Basin/Central and Eastern Ridge/Flemish Pass Basin is a Mesozoic extensional area developed over stretched Precambrian and Paleozoic basement on the Canadian Atlantic Margin (e.g. Enachescu, 1987, 1988, and 1992; Tankard and Welsink, 1987; Grant & McAlpine, 1990).
- Late Triassic to Early Jurassic rifting of Pangea created a series of NE-SW oriented intracratonic basins extending from the Gulf of Mexico to the Barents Sea. Offshore Newfoundland basins are part of this Mesozoic rift system. Oblique and perpendicular rift branches (e.g. Bay of Fundy, Orpheus Graben, Aquitaine Basin, Viking Graben, Labrador Sea) also formed during the same series of extensional events.
- In eastern Canada, the Mesozoic rift basin chain starts with the George's Bank Basin, offshore Nova Scotia, stretches through the Scotian shelf and slope basins, and continues into the Laurentian Basin, located between Cape Breton and Newfoundland. To the north, the Mesozoic rift basin chain extends into the shallow-water Grand Banks basins of offshore Newfoundland that includes the Jeanne d'Arc Basin and Central and Eastern ridges, before extending to the deepwater Flemish Pass and Orphan basins (Figures 2 and 3).
- Most of the Newfoundland Mesozoic basins are confined, residing on continental crust within the Grand Banks and environs. Several other basins are unconfined, located at the continental margin, opposite their European conjugate basins in offshore Iberia and Ireland.

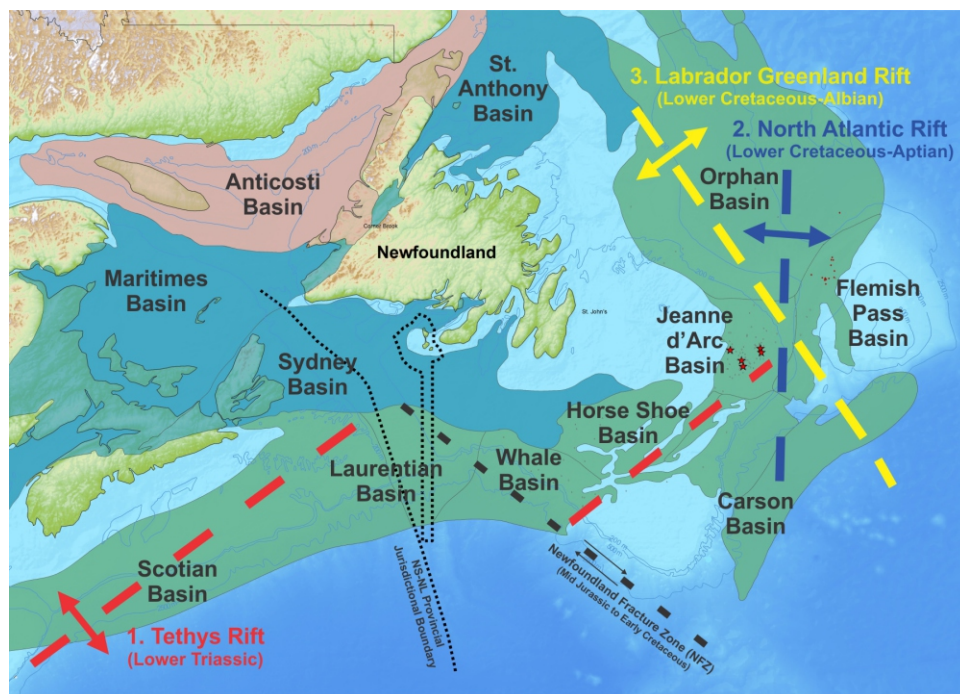


Figure 2. Regional geology of the Canadian Atlantic Margin, showing main basins and phases of extension. Red stars are producing fields.

CENTRAL RIDGE/SOUTH FLEMISH PASS GEOLOGY

- The offered CR/SFP Call for Bids are situated in a N-S trending area that covers portions of the Central and Eastern Ridges, Morgiana Anticlinorium, Vesta Horst, Anson Graben, and southwestern Flemish Pass Basin, which are structural units within the Mesozoic rifted area (Figure 3). To the south, the Anson Graben is a structural low connecting the Flemish Pass Basin to the Carson Basin. The CR/SFP Call for Bids is located on the shelf and intermediate waters of the bathymetric feature known as the Flemish Pass, a submarine large channel separating the Grand Banks of Newfoundland and Flemish Cap (Figure 3).
- A double failed rift structural model was proposed by Enachescu (1987 & 1988) for the Jeanne d'Arc and Flemish Pass basins which in their central part are separated by a complex elevated area known as the Central and Eastern Ridges (Figure 4). In the south, the two ridges are separated by an intermediate deep depression that can be considered a branch of either the Jeanne d'Arc Basin or the Flemish Pass Basin. The southernmost part of the CR/SFP Call for Bids is occupied by the pair of structural subunits known as the Anson Graben and Vesta Horst.

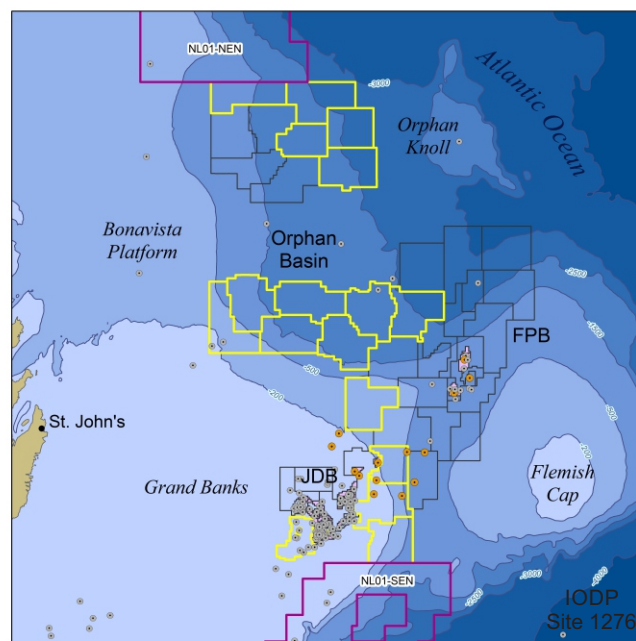


Figure 3. Orphan Basin and Central Ridge/South Flemish Pass 2018 Call for Bids (yellow). Areas of Interest (purple), exploration licences (black), significant discovery licences (pink), sectors (purple), exploration wells (grey), and key area wells in orange (see Table 1).

CENTRAL RIDGE/SOUTH FLEMISH PASS GEOLOGY (continued)

- The most recent oil discoveries offshore Newfoundland (Mizzen, Harpoon, Bay du Nord, and Baccalieu) were made in the Flemish Pass Basin located in the bathymetric low named Flemish Pass. Flemish Pass is a saddle shaped mid-slope basin in approximately 1,100 metres water depth, bounded to the west by the Grand Banks and to the east by the isolated plateau-like Flemish Cap high (Campbell et al., 2002). The present Flemish Pass bathymetry was carved by the Labrador current mostly during the Late Tertiary and Quaternary. Generally, the Flemish Pass paleo-bathymetric low resides over the large Mesozoic half-graben known as the Flemish Pass rift basin.
- The CR/SFP Calls for Bids is situated just east of the Jeanne d'Arc Basin, occupying parts of the South Central Ridge, Eastern Ridge, the inter-ridge unnamed depression, the southwestern flank of the Flemish Pass Basin, northeastern Morgiana Anticlinorium, and northern part of Vesta Horst and Anson Graben (e.g. Enachescu, 2010 and 2013; Figure 4). The Central and Eastern Ridges, Flemish Pass Basin, and the rest of the geological subunits present in the CR/SFP Calls for Bids, share a similar geodynamic evolution with the Jeanne d'Arc Basin where giant fields such as Hibernia, Terra Nova, White Rose, and Hebron are producing oil from synrift Late Jurassic and Early Cretaceous sandstones. Specifically, all these Mesozoic basinal subunits share: a) common structural-tectonic evolution, b) comparable depositional regime throughout the Late Triassic to late Early Cretaceous, and c) similar petroleum system.
- Formation of the structural subunits covered by the CR/SFP Calls for Bids is related to Mesozoic continental rifting followed by the opening of the North Atlantic Ocean. Intra-continental crustal extension and formation of several sedimentary basins and the intervening ridges located offshore Newfoundland started in the Late Triassic and ended in the Late Early Cretaceous.
- Three main extensional phases influenced the final structural make-up of the region:
 1. Tethys Phase, during Late Triassic-Early Jurassic;
 2. North Atlantic Phase, during Late Jurassic to Early Cretaceous; and
 3. Labrador Phase, during late Early Cretaceous (Figure 2).
- The initial phase of rifting affected a large part of the North American Atlantic region, forming a chain of intracontinental rift basins and troughs stretching from Florida to offshore Newfoundland's Grand Banks/Flemish Cap/Orphan Knoll area. The Late Triassic-Early Jurassic extensional phase was oriented mostly in a NE-SW direction and created rift basins along the Nova Scotia and Newfoundland margin with similar tectonic and lithostratigraphic characteristics. Numerous horsts, grabens, and rotated blocks formed. Following the first crustal extensional stage, a proto-Atlantic Ocean opened off Nova Scotia, while a long-lived transform margin separated the newly formed oceanic crust domain from the still connected continental block of Grand Banks-Europe.
- The second rifting phase on Newfoundland margin, dated Late Jurassic-Early Cretaceous and oriented in approximately N-S direction, further created rotated blocks and anticlines. The basinal area was enlarged, deepened, and segmented by numerous faults, affecting both basins and ridges. During the late Early Cretaceous, a strong reactivation of rifting took place around the Newfoundland margin resulting regionally in further modification of basin shapes and locally in more faulting of already formed structures.
- The final breakup and ocean floor spreading between Newfoundland and Iberia took place in several steps during the Aptian, followed by separation of the northeastern Newfoundland margin from southwestern Ireland during the Albian.
- In the northern Flemish Pass and the Orphan Basin, episodes of extension may have continued into Mid and Early Late Cretaceous. Inter-phase thermal subsidence and a final, intensive Late Cretaceous to present time subsidence has increased and deepened the basinal area and produced a significant oceanward and northward tilting. Finally, the separation of Greenland from Europe and the Iceland hot spot may have also influenced the final structural setting of the northern Grand Banks. Salt deposition and movement were prevalent in the Jeanne d'Arc Basin but they are minor in the ridges and southern Flemish Pass Basin. Mild salt swells may have influenced formation of salt-induced anticlines and associated faulting.

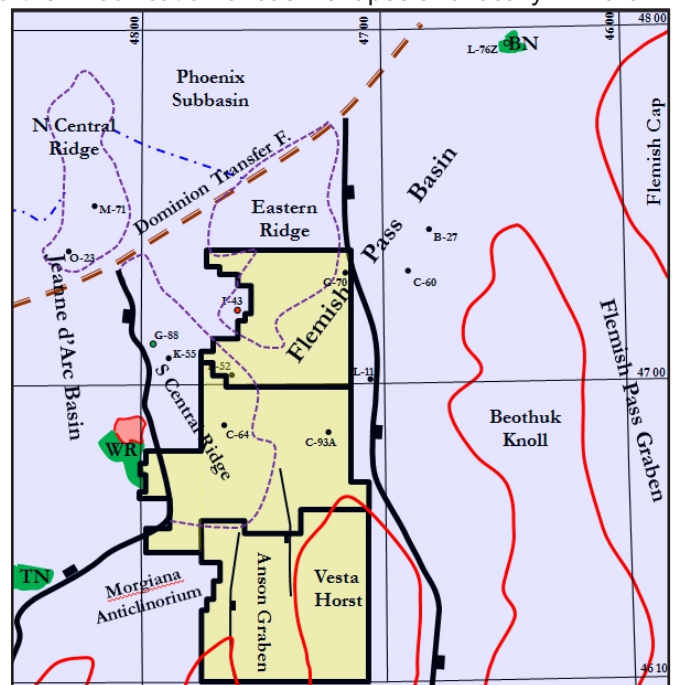


Figure 4. Central Ridge/South Flemish Pass Basement Geology. 2018 Area of Interest (beige). WR: Whiterose, TN: Terra Nova.

CENTRAL RIDGE/SOUTH FLEMISH PASS GEOLOGY (continued)

- The CR/SFP Call for Bids area contains several structural-tectonic subunits and had a complex geodynamic evolution characterized by repeated intra-continental Mesozoic rift phases, transtensional episodes, intermediary, and final post-rift thermal subsidence stages, mild salt diapirism, and a pronounced crustal inversion event at the end of Cretaceous and is marked by a regional Cretaceous-Tertiary unconformity.
- During the Late Jurassic to Early Cretaceous, deposition of coarse-grained clastics including reservoir sandstones was widespread in the basins and on the ridges, especially within large paleodrainage systems and deltaic episodes.

CENTRAL RIDGE/SOUTH FLEMISH PASS BASIN: LITHOSTRATIGRAPHY

- The double rift system is compartmentalized by major basement detachment faults, but the Jeanne d'Arc and Flemish Pass Basins and the intervening ridges share a common evolution and arguably, comparable stratigraphy (Hogg, 2001; Enachescu, 2010 & 2011; Enachescu et al., 2010). There was continuity of deposition during the Late Triassic and Jurassic between the two basins as the intra-basinal high was still depressed and part of the same regional rift basin.
- Due to its location on several Grand Banks geological subunits, a hybrid Jeanne d'Arc-Flemish Pass lithostratigraphic column can be used for the sedimentary sequences within the CR/SFP Call for Bids area (Figure 5). As shown by previous regional studies, there are temporal and stratigraphic equivalency between the Jeanne d'Arc lithostratigraphic formations and members that were formally defined by the Geological Survey of Canada (e.g. McAlpine, 1990; Grant & McAlpine, 1990; Fowler & McAlpine, 1995; Driscoll & Hogg, 1995) and the informal nomenclature introduced by industry for the Flemish Pass Basin reservoir intervals (Hogg, 2001; Enachescu, 2002 & 2003; Haynes et al., 2013; Gruschwitz et al., 2013; Ainsworth et al., 2015).

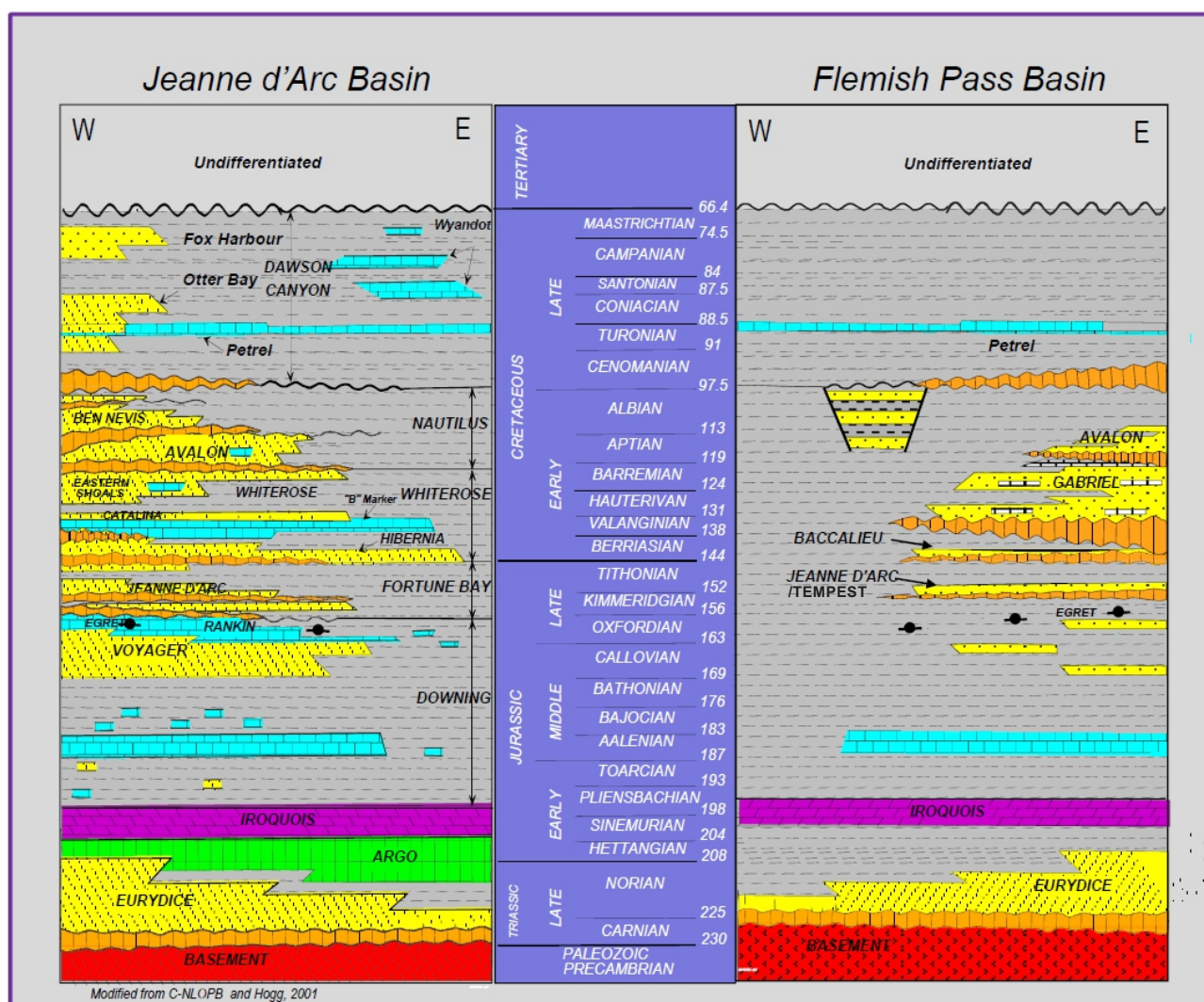


Figure 5. Stratigraphic charts for Central Ridge/South Flemish Pass Area. Modified from C-NLOPB and Hogg (2001).

CENTRAL RIDGE/SOUTH FLEMISH PASS BASIN: LITHOSTRATIGRAPHY (continued)

- The area's basement is part of the Appalachian Avalon terrane, consisting of Precambrian metamorphic, volcanogenic, and granitic units, and of Paleozoic (Cambrian to Carboniferous) sedimentary rocks including platform carbonates and deltaic to fluvial red bed clastics. None of the wells drilled within the CR/SFP Call for Bids drilled into the basement (Figure 4). Two wells outside of the CR/SFP Call for Bids, Bonanza M-71 to the northwest and Kyle L-11 to the east, terminated in prerift basement as represented by metasediments. While the Geological Survey of Canada and C-NLOPB researchers did not identify prerift basement in any of the Flemish Pass Basin's discovery wells listed in Table 1, Ainsworth et al. (2015) recognized at the bottom of Mizzen O-16 "metasediments" of questionable Paleozoic age, comprising dark grey to greyish black non-calcareous fissile claystones. No significant volcanics have been drilled in the region and the presence of subaerial or intrusive volcanic rocks are not seen on seismic data.
- The synrift formations deposited during the initial Late Triassic-Early Jurassic rifting phase such as the Eurydice Formation red beds, the Argo Formation evaporites, or the Iroquois Formation limestones and dolomites were not encountered in the wells drilled within or in the vicinity of the CR/SFP Calls for Bids (Figure 4). However, based on seismic interpretations they are presumed to exist on the ridges and in deeper half-grabens. The Argo Formation may form salt pillows and anticlines or occur as bedded evaporitic deposits. Some of the oldest sedimentary rocks drilled in the area were from the mid-Jurassic Downing Formation including the Whale Limestone Member, encountered at the bottom of the Golconda C-64 well, which was located on a deeply eroded anticline in the South Central Ridge. Surprisingly, the well intersected numerous mid-Jurassic sandstone beds, but the reservoirs were tight. Another older interval might have been encountered at the bottom of the Aster C-93A well where cuttings were dated Late Early Jurassic.
- During the second phase of rifting (Late Jurassic-Early Cretaceous), a predominantly clastic succession accumulated in the Grand Banks' basins and ridges. Marine organic shales were deposited in a shallow, restricted sea during the Kimmeridgian and Tithonian, not unlike the depositional conditions of the Egret Member source rock in the Jeanne d'Arc Basin (Figure 5). Both the Lancaster G-70 and Panther P-52 wells were drilled on the slope between the Central Ridge and Flemish Pass Basin and encountered high quality marine organic shales dated Tithonian and Kimmeridgian that were earlier described as Egret Member of the Rankin Formation. Outside of the CR/SFP Calls for Bids, four of the seven wells listed in Table I encountered Kimmeridgian source rocks and two wells terminated short of the Late Jurassic succession. Only the Kyle L-11 well that was drilled on a basement high did not encounter source rock beds.
- Due to tectonism and eustasy, marine shale deposition was interrupted by episodes of continental deposition of alluvial, deltaic, and shoreface fine to coarse-grained sandstones that are known as the Jeanne d'Arc, Hibernia, and Avalon formations in the Jeanne d'Arc Basin and their equivalent Tithonian, Baccalieu, and Gabriel sandstones in the Flemish Pass Basin (Figure 5). Good reservoir quality sandstones were penetrated by the shallow wells on the Central Ridge and intermediate water depth wells in the Flemish Pass Basin when they targeted large faulted anticlines or onlapping sequences.
- Kimmeridgian-aged Tempest sandstones are coarse-grained clastic intervals, deposited either as turbidites or deltas and intercalated within the marine shales of the Rankin Formation. The Tempest sandstones were intersected in two of the Calls for Bids' wells and in four of the wells in its vicinity (Table I; Figure 4). Tempest sandstone along with the Callovian-aged Voyager sandstone encountered on the eastern flank of Jeanne d'Arc Basin are some of the oldest reservoir rocks tested in the Grand Banks. Both sandstones have uneconomic hydrocarbons reservoirs at several locations within the Calls for Bids area.
- The Tithonian reservoirs (Ti-0 to Ti-4) drilled in the recent Flemish Pass Basin discoveries (Mizzen, Bay du Nord, Harpoon, etc.) are informally known in the industry as Bodhrán Formation sandstones. This formation is equivalent to the Jeanne d'Arc Formation, which provides reservoir quality sandstones for several of the Grand Banks major fields (Table I). The Baccalieu F-89 well was drilled updip of the Baccalieu I-78 well and encountered hydrocarbons in the Early Cretaceous Baccalieu Formation (time equivalent to the Hibernia Formation in the Jeanne d'Arc Basin).
- Clastic sedimentation consisting of continental, shelfal, and shallow water depositional environments continued throughout the Cretaceous. Within the deeper parts of the basins, turbiditic systems were deposited on the slope and continue to the toe of slope. These reservoirs can be important exploration targets on the flanks of the Central and Eastern Ridges. Towards the end of the Cretaceous, clastic deposition was in places interrupted only by thin limestone deposition (e.g. Wyandot Member; Figure 5).
- Interpreted on seismic, several Early Tertiary prograding wedges, slope fans, and turbidites are present in the Calls for Bids area. Other sandstone bodies are visible as drape over the basement ridges or onlap the strong amplitude Base Tertiary Unconformity. Due to rapid subsidence and an increasingly deepwater environment, shale deposition took place during the Tertiary. The Tertiary Banquereau Formation shales, siltstones, and claystones cover both ridges and grabens within the Calls for Bids area (Figures 4 & 5).

CENTRAL RIDGE/SOUTH FLEMISH PASS BASIN: SEVERAL GEOLOGICAL PROVINCES

- The CR/SFP Call for Bids can be subdivided into several structural subunits (Figures 4 & 6; Enachescu, 1987):
 - The **Dominion syncline** formed along the Dominion Transfer Zone that occupies the northern part of the CR/SFP Calls for Bids;
 - The **South Central Ridge** occupies most of the southwestern side of the CR/SFP Calls for Bids and is covered by thick Jurassic and Early Cretaceous sedimentary successions;
 - The **Eastern Ridge** is a high basement block also containing Jurassic and Cretaceous sediments;
 - The **Southwestern Flemish Pass Basin** including the structural graben between the Central and Eastern Ridges;
 - The structural low known as the **Anson Graben** that marks a continuity zone between the Flemish Pass and Carson Basins;
 - The northernmost part of the **Morgiana Anticlinorium**, a high, basement block that contains mostly Late Triassic to Jurassic synrift successions sitting directly below the Base Tertiary Unconformity;
 - Vesta Horst**, a southern basement high that in its northern part is covered by Jurassic synrift sediments.

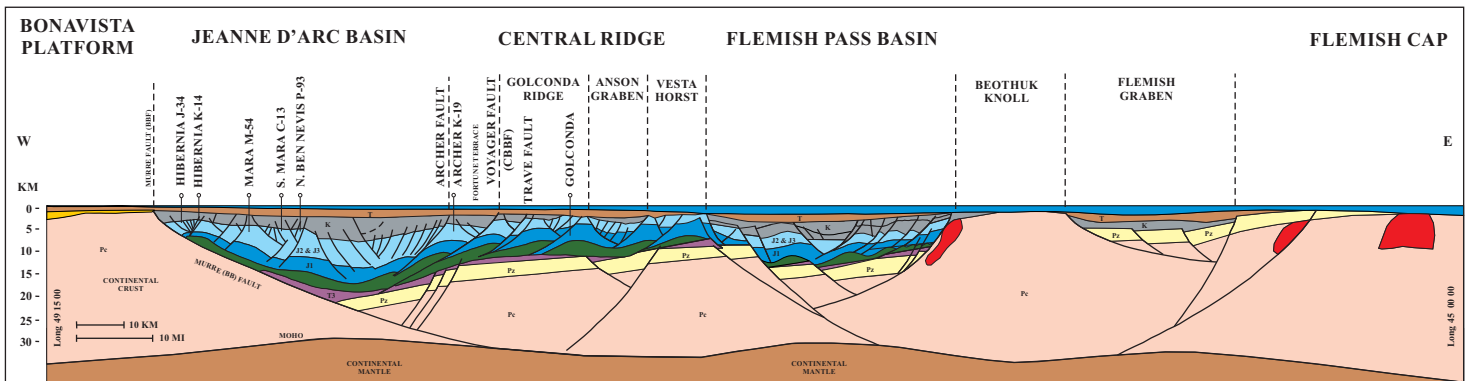


Figure 6. Regional cross-section showing basement horst, graben, and rotated block lineaments.

PETROLEUM GEOLOGY: OVERVIEW

- With only four wells within the CR/SFP Call for Bids and several others in the vicinity, the CR/SFP Call for Bids can be considered a frontier exploration area despite its proximity to the producing Jeanne d'Arc Basin and proven Flemish Pass Basin. Moreover, several wells in the CR/SFP Call for Bids and vicinity had significant oil and gas shows including South Tempest G-88 that tested 1,250 bopd of 42° API oil from Late Jurassic-aged Tempest sandstones.
- The shallow water wells located on the ridges and the ramp into the Flemish Pass were drilled on fault-bounded basement highs, targeting Late Jurassic and Early Cretaceous sandstone reservoirs. The CR/SFP Call for Bids' South Central Ridge wells were located on its eastern flank, Panther P-52 on a structural-stratigraphic trap, and Golconda C-64 on a salt-induced anticline. The two wells drilled within the South Flemish Pass Basin, Lancaster G-70 and recently Aster C-93A, targeted fault-bounded domal structures and encountered reservoir intervals but were unsuccessful in finding hydrocarbons. However, the Lancaster G-70 well encountered thick Late Jurassic Type II - III high quality source rocks.
- Northeast of the CR/SFP Call for Bids are the most recent Significant Discovery Licences awarded to the Statoil/Husky partnership for the Mizzen and Bay du Nord fields. The fields are covered by recent 3D seismic data. Currently, the owners are investigating various development scenarios for these oil fields that are located in intermediate water depths. These fields and other discoveries have confirmed the Flemish Pass Basin as a new petroleum province offshore Newfoundland and Labrador and should encourage more exploration in the area.
- Most of the land in the vicinity of the CR/SFP Call for Bids has been acquired in historical Call For Bids by companies such as Statoil, ExxonMobil, Suncor, Chevron, Nexen, Husky, BP, and Noble Energy. Exploration licence (EL) 1135, located just north of the CR/SFP Call for Bids, received the largest bid recorded in Canadian offshore exploration history in the 2013 Call For Bids. Other companies such as Total and Anadarko have acquired interests in Flemish Pass ELs. South of the offered CR/SFP Call for Bids, a long-anticipated test of the Carson Basin's slope should take place in the coming years and prove if source rock is present in the eastern Grand Bank's deepwater. More than \$1.5 billion Canadian dollars of work commitment expenditures have been bid for the ELs in the Flemish Pass and Jeanne d'Arc basins to date and exploration drilling is expected to increase in the coming years.

PETROLEUM GEOLOGY: RESERVOIRS AND SEALS

- Reservoir rocks in the Central/Eastern Ridges and the Flemish Pass Basin consist of good porosity, high permeability, quartz-rich sandstones that were mainly deposited during the synrift phases. Additionally, postrift turbidite and lowstand sandstones should be present in the Late Cretaceous and Tertiary successions, especially on the flanks of the ridges, on basement highs, and the margins of the Flemish Pass Basin.
- The most prolific reservoirs in the neighboring basins, which are producing at the Hibernia, Terra Nova, White Rose, and Hebron fields, are the Jeanne d'Arc (Tithonian), Hibernia (Berriasian-Valanginian), Avalon (Barremian), and Ben Nevis (Aptian-Albian) sandstones (Figure 5). Between the Avalon sandstone and the Ben Nevis sandstone there is a regional unconformity known as the Avalon Unconformity. These reservoirs are well described in literature (e.g. Mc Alpine, 1990, Driscoll & Hogg, 1995; Richards et al., 2010; Development Plan Applications for Hibernia, Terra Nova, White Rose, & Hebron). The equivalent Late Jurassic - Early Cretaceous sandstones with good quality reservoir properties (porosity 18-24%; permeability 100 - 3000 mD) should be present in parts of the ridges and structural lows in the CR/SFP Call for Bids.
- The Kimmeridgian-aged Tempest sandstones were intersected in two wells within the CR/SFP Call for Bids and four other adjacent wells (see Table 1). At the South Tempest G-88 oil discovery, Tempest sandstones had porosities up to 15% and average permeabilities of 739 mD. The well tested 1,250 bopd of 42° API from 4,109 - 4,117 m below mud line (BML) in addition to two other intervals that drill stem tested light oil.
- Several Tithonian sandstone reservoirs were first encountered in the three Mizzen wells (L-11, O-16, and F-09) and are equivalent to the Jeanne d'Arc Formation in the Jeanne d'Arc Basin. The most recent stratigraphic nomenclatures in the Flemish Pass Basin (Haynes et al., 2012 & 2013; Gruschwitz et al., 2013; Cody et al., 2013) have introduced the informal terms of Ti-0, Ti-1, Ti-2, Ti-3, and Ti-4 for the Tithonian sandstone intervals encountered in the Mizzen field and Bay du Nord fields. Ainsworth et al. (2015) say these sandstone intervals are within a Tithonian succession that consists of an interbedded sequence of claystones and sandstones/conglomerates and are described as braided fluvial sandstones encased in shale and limey mudstone by Haynes et al. (2013). According to Cody et al. (2013), these Tithonian sandstones were sourced from a north and northeast direction and locally from the Flemish Cap granodiorites. The Mizzen field has an average porosity of 21% and an average permeability of 1.2 D. The Bay du Nord field has an average porosity of 22 - 26%. Similar reservoirs have been encountered in Bay du Nord delineation wells and other abandoned wells.
- A full-diameter core obtained from the Mizzen F-09 well was described by Haynes et al. (2014) as having six lithofacies in the Ti-3 interval and a high net to gross (>75%) ratio. Similar time equivalent coarse-grained clastics may be present in the northeastern portion of the CR/SFP Call for Bids.
- In several Flemish Pass wells, the Baccalieu sandstone was found to have good reservoir properties and consisted of several stacked sandstone layers. The sandstone is described as being coeval with the Hibernia Formation and Berriasian in age, but in other publications it is shown as straddling the Tithonian-Berriasian boundary (e.g. Lowe et al., 2011).
- East of the CR/SFP Call for Bids, the Gabriel sandstone was intersected in the Gabriel C-60 and Tuckamore B-27 wells straddling the center axis of the Flemish Pass Basin (Figure 4, Table 1). In the C-60 well, the Gabriel sandstone was described as a Hibernia Formation equivalent reservoir (Esso et al., 1981). Stacked sandstones had porosities between 10 and 20% and numerous oil shows. A core from the Gabriel sandstone taken between 4436.5 and 4451.9 m was reported as bleeding oil along a sand/shale interface.
- Finding adequate seal rocks should not be a problem in the area as thick intra-formational shale intervals and thick overlying shale formations basin-wide were drilled in the synrift sequence. Both extensional and thermal subsidence stages on the Grand Banks contain regionally distributed successions of very fine-grained clastics, tight sandstones, and regionally tight carbonate beds. Good seal intervals such as the Downing, Rankin, Fortune Bay, Whiterose, and Nautilus formations or their equivalents were found in the wells drilled in the basin. The younger shales of the Dawson Canyon and Banquereau formations form excellent regional seals.
- The main seal for the Mizzen and Bay du Nord fields is the marine shale of Berriasian-Valanginian age, equivalent to Hibernia Formation shales. The oil fields have many faults that are sealed by the White Rose, Nautilus, and Dawson Canyon shales. Moreover, the thermal subsidence sequence spanning from Late Cretaceous to present contains proven regional seals and are predominantly shale, claystone, and mudstone (Dawson Canyon and Banquereau formations).

PETROLEUM GEOLOGY: SOURCE ROCKS

- The most significant source rocks in offshore Newfoundland are the Late Jurassic Tithonian and Kimmeridgian shales. In the Jeanne d'Arc Basin, the Kimmeridgian Egret Member of the Rankin Formation is the predominant source rock for all producing light oil accumulations. This unit is equivalent to the prolific Kimmeridgian source rocks of numerous Atlantic Margin basins, including the Viking Graben and Norwegian Sea. In the Jeanne d'Arc Basin, the Kimmeridgian Egret Member is a Type II, oil prone source rock with up to 9% total organic carbon (TOC). The average TOC content varies from 3.4 wt.% in the west to 2.8 wt.% in the east of the Jeanne d'Arc-Central Ridge area. Similarly, the average hydrogen index (HI) decreases from 560 mg HC/g TOC in the west to 410 mg HC/g TOC in the east while source rock thickness ranges from 50 m to over 600 m at Panther P-52.
- The Panther P-52 well encountered more than 600 m of marine source rock in three intervals, all within the oil window with average TOCs greater than 2% (maximum 8.2%) and average HIs greater than 400 (maximum >1000) (Figures 7, 8, & 11; Enachescu & Hogg, 2007; Enachescu et al., 2010).
- According to Magoon et al. (2005), the burial history chart for the Egret Member source rock in the Jeanne d'Arc Basin indicates that petroleum expulsion began at about 120 Ma at 3,800 m burial depth BML, peak generation occurred at about 100 Ma at 5,000 m depth BML, and was spent or depleted after burial to 5,600 m BML during the Late Cretaceous (90 Ma). Magoon et al.'s (2005) conclusions should also be valid for the CR/SFP Call for Bids located just east of Jeanne d'Arc Basin.
- As proven by wells drilled within the CR/SFP Call for Bids or immediate vicinity, the Central Ridge, Eastern Ridge and the graben in-between contains Late Jurassic source rock. Drilled in the mid-1980s, the Lancaster G-70 and Panther P-52 wells have intersected marine source rock (Table 1). The source rock intervals in these two wells were recently identified as containing both Tithonian and Kimmeridgian aged organic shales.
- Several wells located near the CR/SFP Call for Bids: Bonanza M-71, North Dana I-43, South Tempest G-88, and South Merasheen K-55 have also intersected the Kimmeridgian-aged Egret Member source rock (Table 1). Two other earlier wells near the CR/SFP Call for Bids, Dominion O-23 in the North Central Ridge and Gabriel C-60 in the Flemish Pass Basin, TD'd above the Base Cretaceous Unconformity, missing the source rock layers. Nevertheless, a strong amplitude reflector often associated with Late Jurassic source rock beds are mappable below the well bottom on seismic lines. Only Kyle L-11, drilled on a basement high and missed the source rock, which was either eroded or not deposited at the well location (Table 1). In the case of Golconda C-64, it was drilled on a Jurassic high that is truncated by the Base Tertiary Unconformity and its source rock beds were eroded on top of the anticline (Table 1). However, the typical source beds seismic signature can be interpreted down-dip from the anticlinal axis.
- The Tithonian source rocks, first identified in the Flemish Pass, are mostly shale with 2 - 4% average TOC. The presence of rich Tithonian-aged source rock intervals (~3% TOC) were proven first in the Baccalieu I-78, Panther P-52, and Lancaster G-70 wells, and more recently in Mizzen and Bay du Nord wells in the neighbouring Flemish Pass Basin (<http://exploration.nalcorenergy.com/licensing-rounds/2015-eastern-newfoundland-region-nl-01-en/resource-assessment/>). The Lancaster G-70 and Panther P-59 wells are located within the Calls for Bids and intersected thick source rocks that were first defined as Kimmeridgian, but recently re-assessed as being both Tithonian and Kimmeridgian-aged.

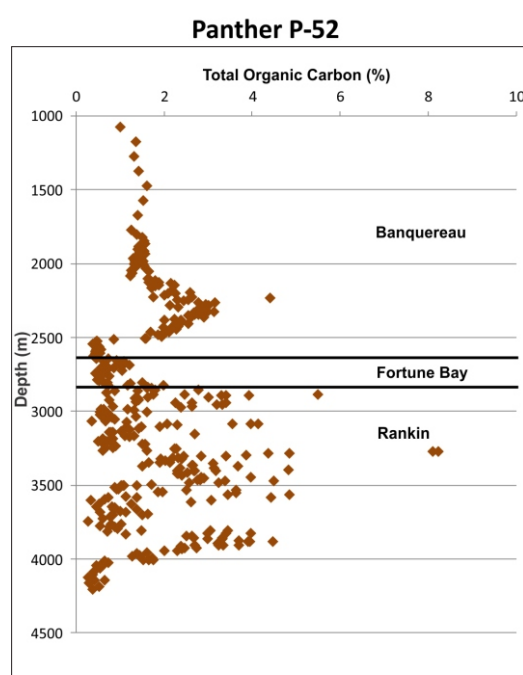
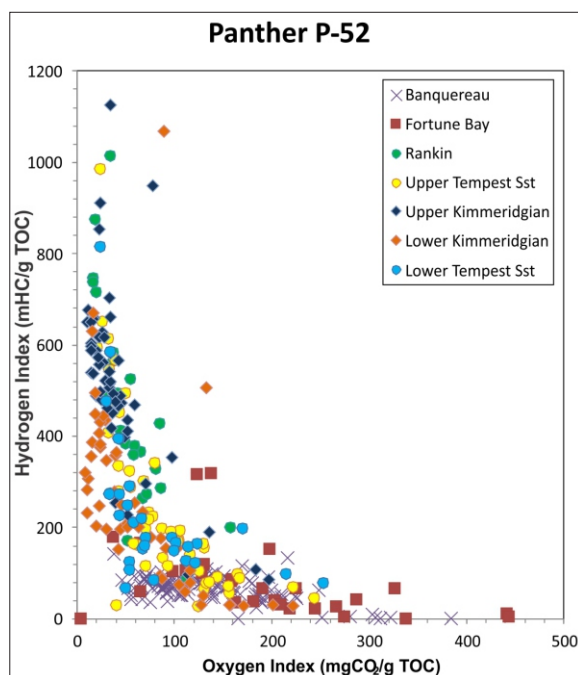


Figure 7 (left). Panther P-52 modified van Krevelen graph. Data from Geological Survey of Canada (2012).

Figure 8 (right). Panther P-52 total organic content versus depth. Data from Geological Survey of Canada (2012).

PETROLEUM GEOLOGY: SOURCE ROCKS (continued)

- Predominant kerogen in the Tithonian sedimentary succession is Type II and therefore oil-prone. In the Flemish Pass Basin both Kimmeridgian and Tithonian aged source rocks were intersected (e.g. at Baccalieu I-78). Egret Member beds in the Flemish Pass Basin average 130 m thick, have a TOC range between 1.9 and 13% (2.3% average), and a HI range of 197 - 586 (328 average) (McCracken et al., 2000). The marine shales that separate the Tithonian reservoirs in the Mizzen oil field have 8 - 12% TOC (Haynes et al., 2012).
- The Bay Du Nord field and the Harpoon O-85 well were light sweet crude discoveries of 30 - 37° API. The light oil is sourced from mature Kimmeridgian and Tithonian marine organic shales buried to 3,000 m BML. Whereas, the Mizzen field that has medium gravity oil (22° API) is interpreted to originate from immature to marginally mature source rock within the Tithonian shale intervals intercalated within the Tithonian sands.
- Other rich TOC intervals in Late Jurassic rocks (Type II kerogen) were encountered elsewhere in the Grand Banks basins in the Callovian to Oxfordian successions (Rankin and Voyager formations). Younger source rocks were also intersected in Cenomanian-Turonian aged intervals in the Jeanne d'Arc and Orphan basins. Turonian to Albian black shale intervals were drilled by the Ocean Drilling Program (ODP) at site #1276 during Leg 210, 60 km SE of the Flemish Pass Basin (Figures 3 & 9; Arnaboldi & Mayers, 2007), and International Ocean Discovery Program (IODP) Expedition 342 at site 1407 (Figure 10). Five dark-colored intervals that contain up to 13% TOC of both marine and terrestrial provenance were identified in the Site #1276 sequence (Mayers & Arnaboldi, 2011). These intervals have high HI in places. These shales may be thicker and mature in the deeper sedimentary troughs of the Flemish Pass Basin such as those seen on seismic sections (Figure 14). None of these source rock intervals have been proven to generate petroleum accumulations, but if covered by sufficiently thick Tertiary deposits they could be in the maturation window in the CR/SFP Call for Bids.
- Recent resource assessment studies in the Flemish Pass area were produced by BeicipFranlab on behalf of Nalcor (<http://exploration.nalcorenergy.com/exploration-reports/resource-assessments/>) and showed that the average burial depth at which the 0.6% vitrinite reflectance (Ro) threshold, *i.e.*, the top of the early oil window, is reached is around 3,200 m BML for a 29 to 33°C/km average geothermal gradient, while the initiation of the gas condensate generation zone (> 1.3% Ro) seems to occur around 4,500 m BML. The same studies showed that the above-mentioned Late Jurassic and Cretaceous source rocks could generate significant quantities of oil in the Flemish Pass and Orphan Basins located north of CR/SFP Call for Bids. A thorough evaluation of the geology and petroleum potential of this CR/SFP area will be issued by BeicipFranlab and Nalcor prior to the Calls for Bids' closing date.
- Numerous regional seismic sections show that the ridges and Flemish Pass Basin were connected during the Late Jurassic to the oil prolific Jeanne d'Arc Basin and that the seismic signature of marine organic shales ("hot shale") can be recognized in the CR/SFP Call for Bids' half grabens and rotated blocks that contain synrift sedimentary sequences.

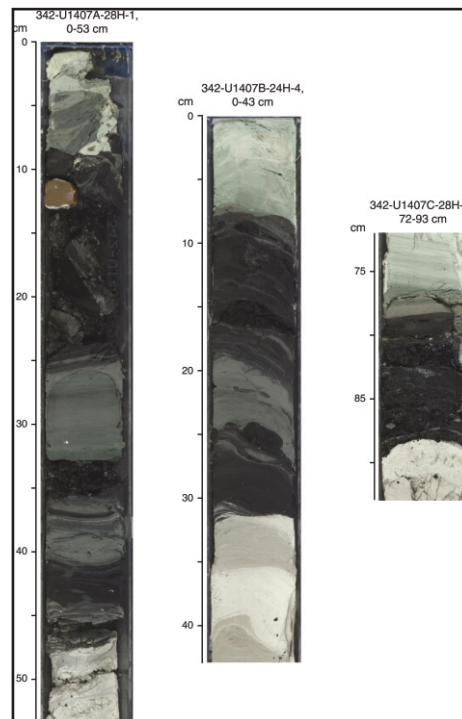
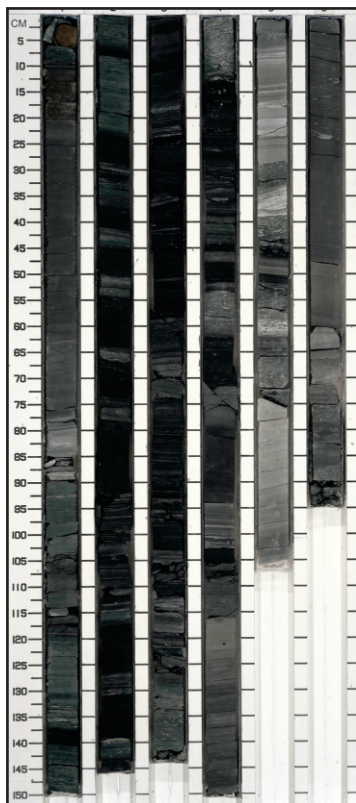


Figure 9 (left). ODP Leg 210, Site 1276 core photo of Cenomanian-Turonian shales. From Tucholke et al. (2004).
Figure 10 (middle). IODP Expedition 342, Site 1407 core photo of Cenomanian-Turonian shales. From Norris et al. (2014).
Figure 11 (right). Luminesced core photo of Panther P-52 well Tempest sandstones and Kimmeridgian shales. From C-NLOPB.

PETROLEUM GEOLOGY: TRAP STYLES

- A series of significant structural, stratigraphic, and combination traps are identified on seismic data collected in the CR/SFP Call for Bids area. The early wells were located on the South Central Ridge and within the southern Flemish Pass Basin and drilled into fault-bounded rotated basement blocks, targeting Early Cretaceous and Late Jurassic reservoirs (Table 1). Similar large structural closures remain undrilled in the CR/SFP Call for Bids and several large submarine fan features mapped with 2D and 3D seismic data are yet to be drilled.
- Structural traps in the CR/SFP Call for Bids are associated with:
 1. Multi-phase rifting of the Atlantic Margin,
 2. Transtension and inversion, and
 3. Subsidence and tilting.
- The main structural trap types are rotated/tilted fault blocks, extensional anticlines, rollovers, multi-side fault bounded anticlines, elongated horsts, and onlap or drape features over basement highs. Local inversion due to transtension is also a trapping mechanism resulting in compression-modified extensional anticlines.
- The majority of faults in the basin are down-to-basin or down-to-margin listric normal faults, but some oblique normal faults and transfer faults exist forming horsts, ridges, and trap-door features. Fault sealing is essential for all of the producing or discovered fields in the Jeanne d'Arc and Flemish Pass Basins.
- Stratigraphic traps are widespread in the CR/SFP Call for Bids, especially in the postrift sequence. Sub-unconformity traps, paleo-valleys, basin margin, slope, and basin floor fans are interpreted on seismic data and form large geophysical anomalies.

PETROLEUM GEOLOGY: PLAYS AND RISKS

- Multiple play types are conceptualized in the CR/SFP Call for Bids area. Conventional plays include:
 1. Late Jurassic Tithonian and Kimmeridgian sandstones – associated with fault bounded closures
 2. Early Cretaceous sandstones – associated with fault bounded and stratigraphic-structural closures
 3. Late Early Cretaceous and Early Tertiary sandstones associated with lowstand stratigraphic closures
- These plays are formed when the above reservoirs are trapped in roll-over anticlines, listric fault bounded blocks, multi-fault closures, and drapes over basement highs.
- The main hydrocarbon play expected to be successful in the CR/SFP will be:
 - Anchored by a Late Jurassic source rock such as the Egret Member or equivalent; Tithonian, Callovian, or Oxfordian organic shales, or a blend of several of these sources;
 - Reservoired most likely in synrift Late Jurassic or Early Cretaceous sandstones, and
 - Trapped in extensional related faulted anticlines with faults acting as source kitchen migration conduits. Salt may induce anticlines on the ridges and southern part of the Flemish Pass Basin, but salt is present only as pillows in this region of the Grand Banks.
- The typical hydrocarbon play in the CR/SFP Call for Bids is a structural high such as an extensional anticline, roll-over anticline, horst, rotated block, faulted anticline, drape anticline, with any of the Late Jurassic-Early Cretaceous fluvio-deltaic and upper to middle shoreface complexes (primary target) and/or Late Cretaceous and Paleocene submarine fan sandstones (secondary target) all with hydrocarbons sourced from Late Jurassic (Kimmeridgian, Tithonian) marine source rocks.
- Based on the area of closure and typical reservoir thicknesses in neighboring oil discoveries, the identified traps could contain 100 to 500 mmbbls recoverable resource.
- Locally, reservoir quality, source rock presence and quality, and sealing across faults are considered to be the main geological risks. Presence of leaking fault seals and thief zones may preclude filling of reservoirs to the spill-point as is the case in the Mizzen field. In Cretaceous sandstone reservoirs in the Grand Banks fields some carbonate cementation is present but acts more like baffles than barriers to production.
- Overpressure should not be a significant technical risk in the CR/SFP Call for Bids, except for wells targeting reservoirs deeper than 4000 m.

WELL DATA

- Only four wells have been drilled in the CR/SFP Call for Bids area, two on the shelf in the Central Ridge and two in intermediate waters in the southern Flemish Pass Basin (see Table 1). All four wells were unsuccessful but three of the wells, Lancaster G-70, Panther P-52, and Golconda C-64 had good petroleum shows. Panther P-52, drilled in 1985 on 2D seismic data, is known as the well with the thickest Tithonian and Kimmeridgian (Egret Member) predominantly Type II source rock interval on the entire Grand Banks.

Well	Drilled	WD (m)	Status	TD (m)	Location	Reservoir	Source Rock	Hydrocarbon Shows	Notes
Wells within the sector:									
Lancaster G-70	1986	726	Abnd	5701	FPB	JD & Tempest ss	Ti.. & Kimm.	Gas	Oil in FL
Panther P-52	1985	191	Abnd	4203	SCR	Tempest ss	Ti.. & Kimm.	Oil	Oil in FL
Golconda C-64	1987	172	Abnd	4451	SCR	Paleocene ss, thin	Eroded	Gas	
Aster C-93A	2015	560	Abnd	3678	FPB	Hibernia ss	Eroded/ NDE	-	
Wells near the sector:									
Bonanza M-71	1982	195	Abnd	5295	NCR	Tempest ss	Kimm.	Gas	
Dominion O-23	1974	161	Abnd	3998	NCR	E. Cret. thin, poor	Deeper, NP	-	
Gabriel C-60	1979	1109	Abnd	5171	FPB	Gabriel ss	Deeper, NP	Oil and gas	
North Dana I-43	1984	221	Abnd Gas	5304	ER	Tempest ss	Kimm.	Tested 12.8 MMcf/d	
S. Tempest G-88	1981	158	Adnd Oil	4675	SCR	Tempest ss	Kimm.	Tested 1250 bopd	42° API
S. Merasheen K-55	1988	166	Abnd	3545	SCR	Tempest ss	Kimm.	RFS oil	23° API
Kyle L-11	1986	1119	Abnd	4200	FPB	Aval & Hib. poor ss	No	-	
Recent discoveries in Flemish Pass Basin:									
Mizzen O-16	2009	1095	Abnd Oil	3756	FPB	Ti-3; Ti-1&2 wet	Ti.	Tested 2300 bopd	22° API
Bay du Nord L-76Z	2015	1177	Abnd Oil	3770	FPB	Ti-3	Ti.	Tested 6353 bopd	38° API
Harpoon O-85	2013	1160	Abnd Oil	3377	FPB	Ti-4	Ti.	MDT samples	34° API

Table 1. Exploration wells drilled within or in vicinity of the CR/SFP Call for Bids. Abnd = Abandoned, Aval = Avalon, bopd = barrels of oil per day, ER = Eastern Ridge, FL = Fluid inclusions, FPB = Flemish Pass Basin, Hib = Hibernia, JD = Jeanne d'Arc, Kimm = Kimmeridgian, MDT = Modular Formation Dynamics Test; NCR = North Central Ridge, NDE = Not Deep Enough, NP = Not Penetrated, RFS = Repeat Formation Sampler, SCR = South Central Ridge, ss = sandstones, Ti = Tithonian sandstone. Data from C-NLOPB.

WELL DATA (continued)

- Just outside of the CR/SFP Call for Bids, five out of the seven wells had hydrocarbon shows and four penetrated rich Late Jurassic marine source rocks. The South Tempest G-88 well tested 1,250 bopd of 42° API from the Kimmeridgian-aged Tempest sandstone and defined a small oil accumulation (8 mmbbls). Its trap is a three-sided fault bounded tilted block in the South Central Ridge.
- Northeast of the CR/SFP Call for Bids in the Flemish Pass Basin, two large Significant Discovery Licences were recently awarded for the Mizzen (2014) and Bay du Nord (2017) oil fields to the Statoil (65%) and Husky Energy (35%) partnership. Other discoveries (Harpoon O-85 and Baccalieu I-78) and petroleum shows were recorded in several exploration wells (Table 1) drilled by the same partnership.
- The oil discovered at several well locations in the Flemish Pass Basin and on the Central and Eastern ridges are sourced by the Egret or an equivalent source rock that have similar characteristics to those presently being produced on the Grand Banks. These light oils (30° - 37° API) with high aromatic content are in high demand by the refineries on the east coast USA and central Canada.
- Several exploration licences situated just north and northeast of the CR/SFP Call for Bids could be drilled in the coming years within the ridges and Flemish Pass Basin, in areas with proven source rock presence.
- All of these well results are in the public domain. Well reports and paper copies of logs are available from the C-NLOPB. Digital logs can be obtained for a fee from vendors. Well results are also provided by the Geological Survey of Canada.

SEISMIC DATA

- Good to excellent seismic coverage exists for this CR/SFP Call for Bids (Figures 12 & 13).
- Over 12,000 km of 2D and 1,500 km² of 3D seismic is available to the public from the C-NLOPB (Figure 12). An interactive mapping tool is available from the Department of Natural Resources that shows the non-privileged data that is available over the 2018 Call for Bids (<http://www.nr.gov.nl.ca/nr/energy/petroleum/offshore/offmaps.html>). Publicly available data is defined as non-exclusive/speculative surveys that are five years or older. Exclusive surveys enter the public domain after 10 years.
- Over 2,500 km of modern 2D seismic data is available for purchase from seismic vendors (Figure 13). A new 5 km by 5 km grid has been acquired by Multi-Klient Invest AS since 2011. This data is processed to wave equation time migration or depth migration. Nalcor and TGS have presentations available that introduce and comment on the seismic data available.
- Seismic quality is excellent in the Late Jurassic to Tertiary sequence where reservoirs are present; data deteriorates in the Late Jurassic to Late Triassic interval (Figure 14). Prerift basement is mappable in places. Within synrift formations, high quality regional seismic markers exist such as carbonate and sandstone intervals. The best regional markers are widespread unconformities such as the Base Tertiary, Avalon, and Base Cretaceous unconformities.
- A number of large undrilled structural, stratigraphic, and combination traps have been mapped in the CR/SFP Call for Bids using the extensive historical and modern seismic data including several 3D swaths (Figures 12 & 13). Seismic mapping of leads and prospects, proven reservoir and source rocks, and proximity to light oil production and world-class discoveries make the CR/SFP Call for Bids an attractive area for petroleum exploration.
- Regional geology, seismic interpretation, well information, basin modeling, and a resource evaluation study will be provided by BeicipFranlab and Nalcor and released prior to closure of the Calls for Bids.

SEISMIC DATA (continued)

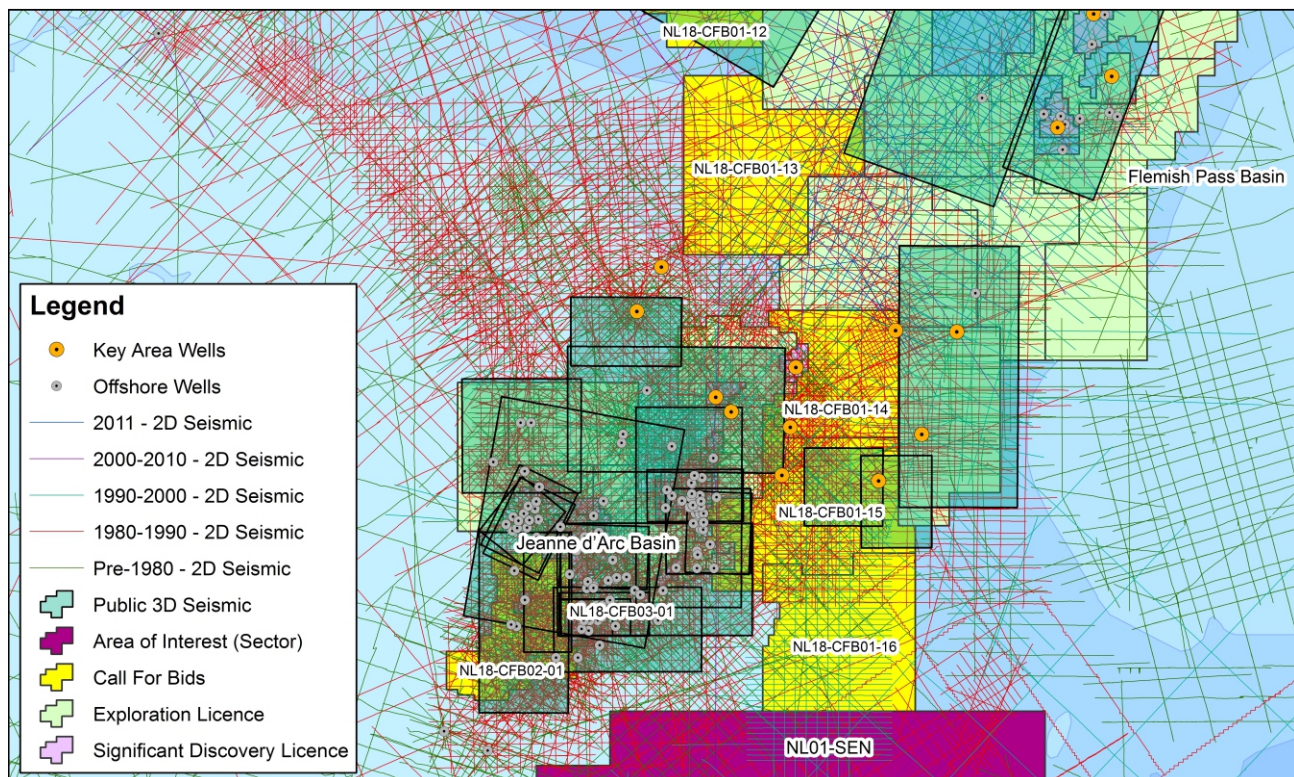


Figure 12. Select public domain seismic coverage. Map available at Department of Natural Resources (<http://www.nr.gov.nl.ca/nr/energy/petroleum/offshore/offmaps.html>). Key area wells in orange (see Table 1). Data from C-NLOPB.

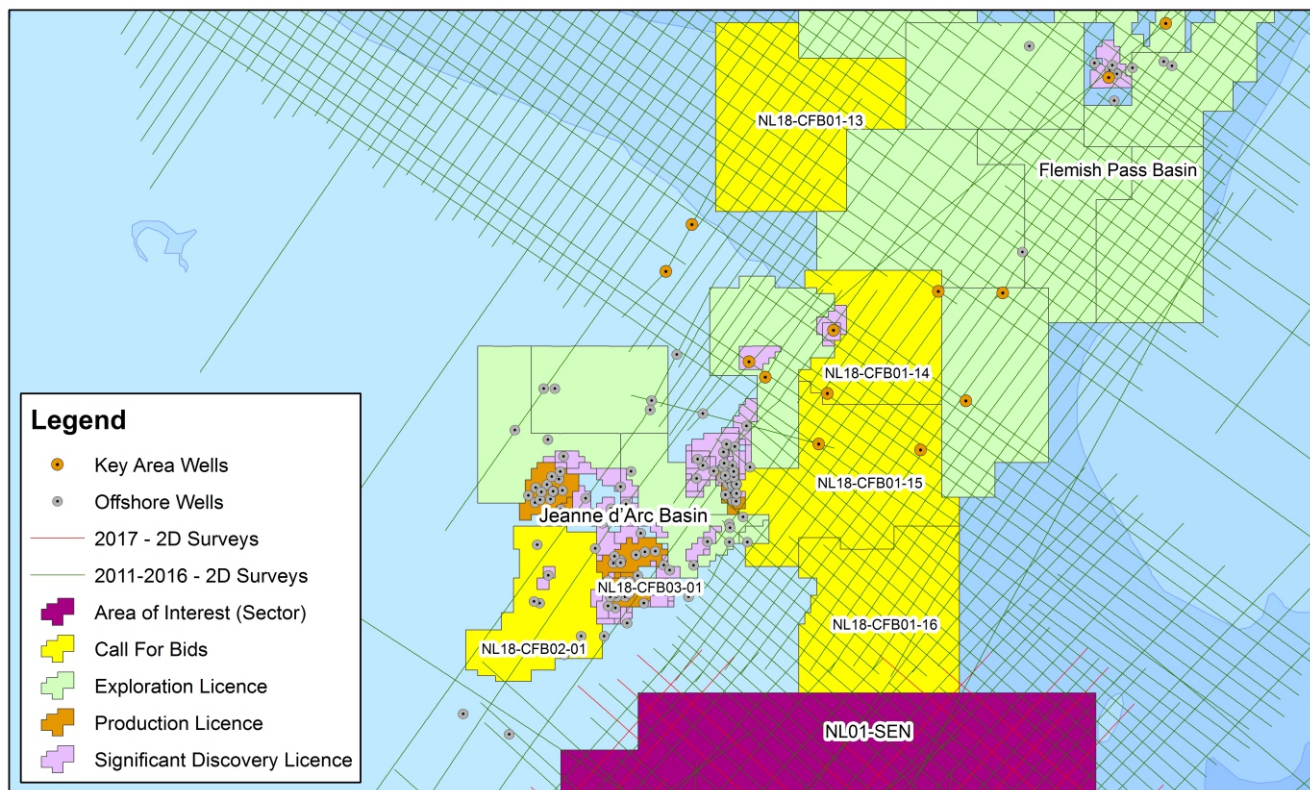
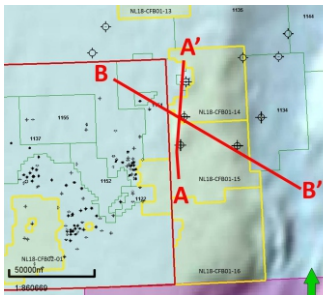
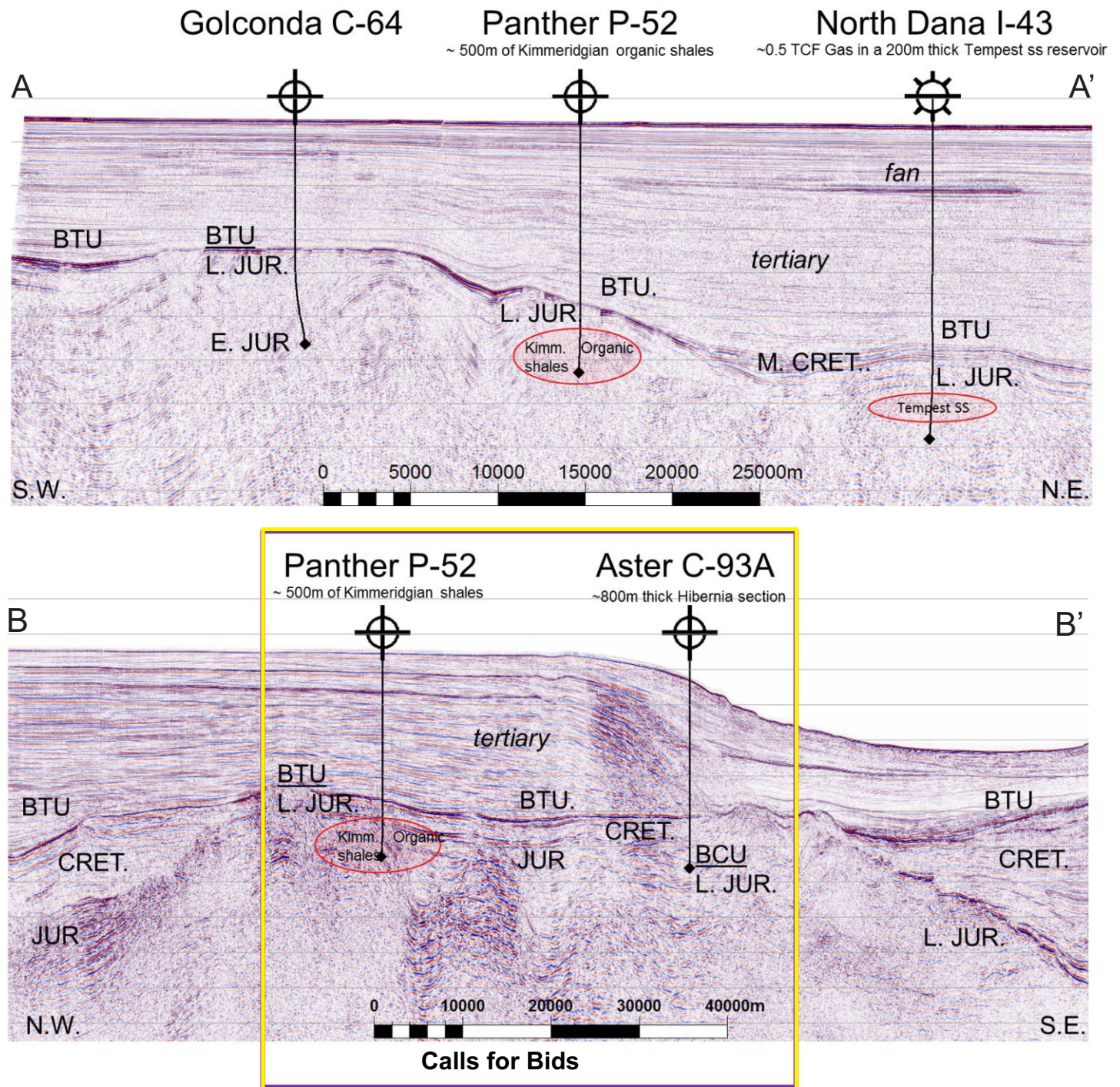


Figure 13. TGS/PGS/Nalcor Energy modern seismic data coverage. Key area wells in orange (see Table 1). Data courtesy Nalcor Energy.

SEISMIC DATA (continued)



Legend

- BTU: Base Tertiary Unconformity
- CRET: Cretaceous
- BCU: Base Cretaceous Unconformity
- L. JUR: Late Jurassic
- JUR: Jurassic
- E. JUR: Early Jurassic

Figure 14. Selected public domain 2D seismic sections through the CR/SFP Call for Bids. Wells are on-line except Aster C-93A, which is 2 km NE of profile A-A'. Data from C-NLOPB.

SEISMIC DATA (continued)

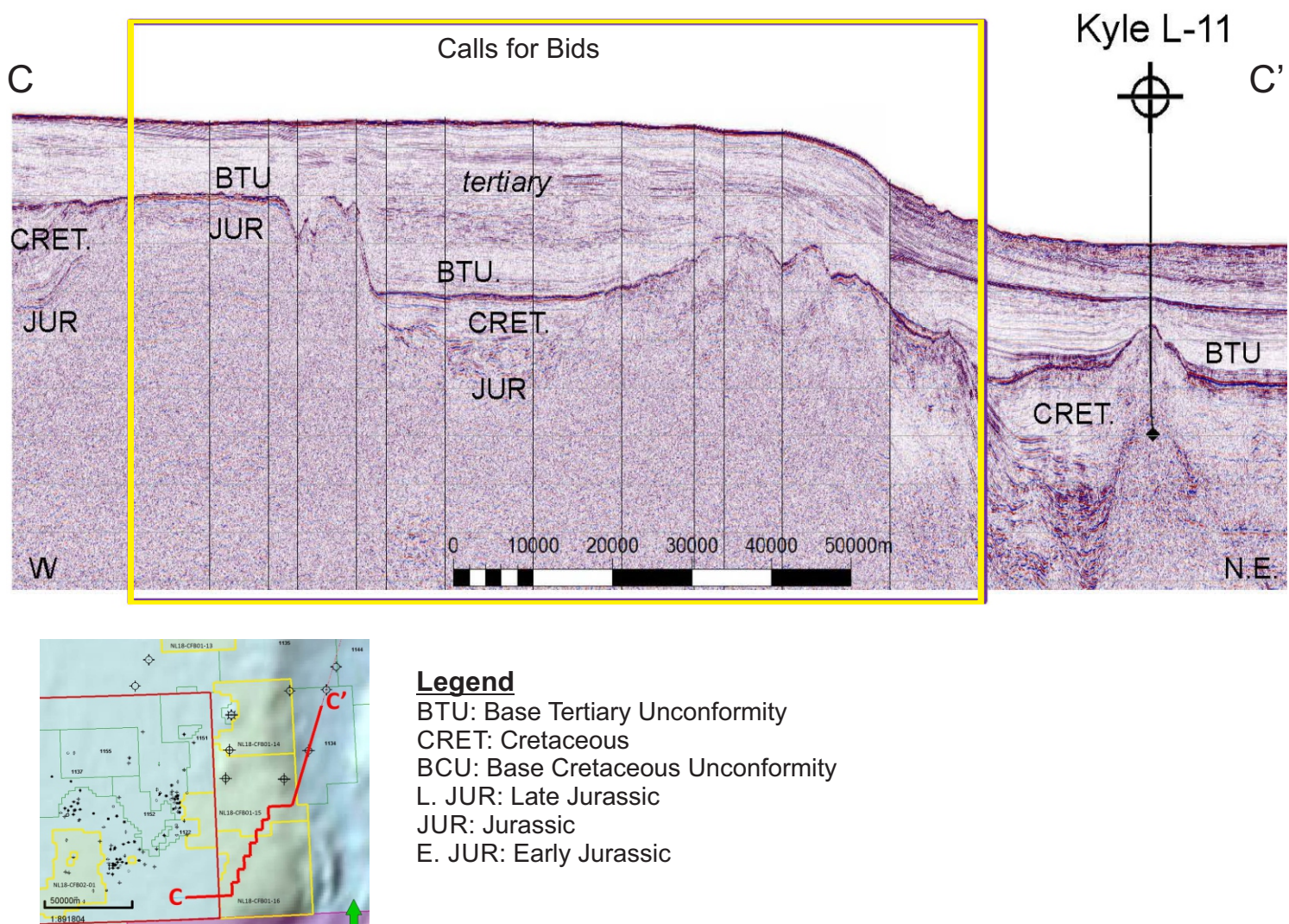


Figure 14 (continued). Selected public domain 2D seismic section through the CR/SFP Call for Bids. Data from C-NLOPB.

ADDITIONAL INFORMATION AND CONTACTS

For more information, the following contacts are:

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MANDATE AND ROLES

The **Canada-Newfoundland & Labrador Offshore Petroleum Board (C-NLOPB)** is mandated to interpret and apply the provisions of the Atlantic Accord and the Atlantic Accord Implementation Acts to all activities of operators in the Canada-Newfoundland and Labrador Offshore Area and to oversee operator compliance with those statutory provisions.

Their role is to facilitate the exploration for and development of petroleum resources, including health and safety of workers, environmental protection, effective management of land tenure, maximum hydrocarbon recovery and value, and Canada/Newfoundland and Labrador benefits.

As Offshore Regulator and Administrator for the Areas of Interest, the C-NLOPB are the primary contact for participation in this resource opportunity. They operate a registry to record exploration, significant discovery and production licences and information related to these interests for public review. They are also the curators of all geoscientific data pertaining to the Newfoundland and Labrador Offshore Area. The C-NLOPB has no active role in promotion of the Province's hydrocarbon resources.

The **Government of Newfoundland and Labrador, Department of Natural Resources** is responsible for providing marketing and promotional services to foster the exploration, development and production of the Province's hydrocarbon resources internationally as well as promoting the maximization of fiscal and industrial benefits through the negotiation, development, administration and monitoring of petroleum project agreements and legislation.

Compiled by A. Krakowka from previously published studies, papers, and Department of Natural Resources work.

Author: Department of Natural Resources

