

OFFSHORE OPPORTUNITY - 2019 Call for Bids



CARSON BASIN AREA - NEWFOUNDLAND AND LABRADOR

EXECUTIVE SUMMARY

On April 3, 2019, the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB) announced a Call for Bids for the South Eastern Newfoundland land tenure region. As part of the land tenure process, this area follows a 4-year cycle (low activity region). A sector was identified in the region in June 2015 (NL01-SEN), then a Call for Nominations for Parcels was announced in August 2018 and closed in November 2018. The Call for Bids was announced April 3, 2019 and will close November 6, 2019 at 12:00 p.m. NST.

The Call for Bids area which includes the Carson Basin is considered highly prospective for hydrocarbons, and represents part of the North Atlantic Mesozoic rift network. This network includes the Flemish Pass, East Orphan, and Jeanne d'Arc basins where intense exploration and production activity has been ongoing for the past decade. Despite good seismic coverage, the area remains mostly underexplored with only four wells on the shelf and no wells in the deep water (Figure 1).

OVERVIEW

Located on the east coast of Canada, the province of Newfoundland and Labrador is the country's only offshore oil producing region. Since 1996, the province's five producing fields – Hibernia (1997), Terra Nova (2002), White Rose (2005), North Amethyst (2010), and Hebron (2017) – have produced in excess of 1.8 billion barrels of light oil (32 - 35° API). The Newfoundland offshore area now produces over 225,000 bopd and output is estimated to increase to approximately 400,000 bopd when the Hebron field reaches peak production. Recently, the Province reached a tentative agreement with Equinor Canada (formerly Statoil) to develop the Bay du Nord oil discovery in the Flemish Pass Basin. The project is expected to deliver first oil by 2025.

With substantial undiscovered oil and gas resource estimates and 1.8 million km² of prospective acreage with less than 7% having been held under licence, the NL offshore holds great potential. This potential will be further realized in the 2019 Call for Bids (Figure 1).

KEY ATTRIBUTES

- The Call for Bids area consists of 9 parcels, totals 2,270,472 hectares (22,704 km²), and encloses Exploration Licence 1136 currently held by ExxonMobil, Suncor Energy, and Total E & P Canada Ltd.
- Water depths range from 60 to 3,500 m.
- Modern seismic coverage including ties to representative wells.
- Competitive fiscal regime with very low political risk.
- Proximity to both North American and European markets.
- The Call for Bids closes at 12 p.m. NST on November 6, 2019.
- The successful bid is based solely on work commitment.
- For more information, visit www.cnlopb.ca

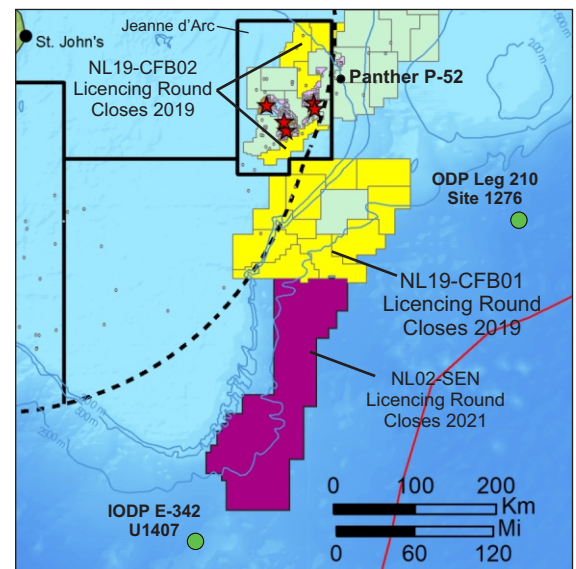


Figure 1. 2019 and 2021 Calls for Bids area. Red line is UNCLOS boundary and black is 200 nmi limit.



REGIONAL GEOLOGY OF THE ATLANTIC MARGIN

The Late Triassic to Early Jurassic rifting of Pangea created a series of NE-SW oriented intra-cratonic basins extending from the Gulf of Mexico to the Barents Sea. In eastern Canada, the Mesozoic rift basin chain starts with the George's Bank Basin, offshore Nova Scotia, and stretches through the Scotian shelf and slope basins, including the Laurentian Basin, located between Cape Breton and Newfoundland (Figure 2). Further east along the southern Grand Banks are the shallow to deep water South Whale and shallow water Whale and Horseshoe basins. Around the Tail of the Bank sits the shallow to deepwater Carson Basin.

Northwards of the Carson Basin, the Mesozoic rift basin chain includes the shallow water Jeanne d'Arc Basin and the parallel, Central and Eastern Ridges, before sloping downwards into the deepwater Flemish Pass and Orphan Basins. Further to the northwest, seaward of Labrador, is the Hawke, Holton, Hopedale, Chidley, Saglek, and Henley extensional basins.

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.

Other oblique and perpendicular rift branches, for instance the Bay of Fundy, Orpheus Graben, Aquitaine Basin, and Viking Graben also formed during the same series of extensional events.

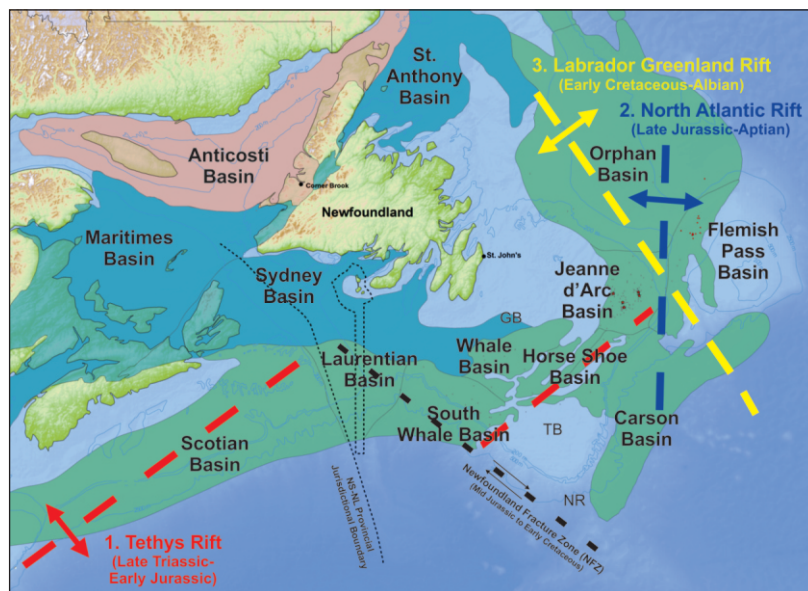


Figure 2. Regional geology of the Canadian Atlantic Margin showing main basins and phases of extension. Red stars are producing fields. GB: Grand Banks, NR: Newfoundland Ridge, TB: Tail of the Bank. Modified by Enachescu (2020).

SOUTH EASTERN NEWFOUNDLAND AREA GEOLOGY

The Carson Basin can be divided into three distinct physiographic regions (Figures 3 & 4) based on tectonic and structural setting, position on the continental margin, and composition of sedimentary fill:

- **Shelf** – The shallow water, continental shelf region was historically known as the Carson-Boninion Basin. Located on the easternmost part of the southern Grand Banks, the shelf region is separated from the northern Jeanne d'Arc Basin by a basement ridge trending approximately NE-SW and from the easterly slope part of the basin by a basement ridge capped in places by Late Triassic Argo salt. This ridge is mapped under the shelf break (Figure 11). Late Triassic to Quaternary successions were drilled on the shelf during the early 1970s and mid-1980s; however Late Jurassic source rocks were missing at the well locations, probably due to non-deposition on basement highs or erosion due to the proximity to the Avalon Uplift.
- **Slope and Upper Rise** – The intermediate to deep water, slope and upper rise region, historically known as the Salar Basin. This region is separated from the shelf by a basement ridge trending approximately NE-SW (forming a hinge zone) and from the deepwater region by a tortuous fault zone and high ridge. Based on regional seismic markers, the region appears to contain the entire Mesozoic sedimentary section including Late Triassic strata (Figure 11). Mapping in the area reveals large and complex structures including those separated by deep penetrating faults.
- **Deepwater** – The rise to abyssal plain area where Mesozoic rocks overlie a super-extended crust was referred to as the Salar Basin. This region is located east of a fault system which divides the deepwater section into sub-regions. The area is structurally complex with thin Mesozoic cover in places. Mapping reveals an assortment of tilted basement blocks, circular salt structures and transitional zone-like mounds (peridotite mounds?) intertwined with mini-basins containing deformed Mesozoic layers. Some of the blocks appear slightly inverted, probably due to transtension or isostatic rebound.

The 2019 Call for Bids block encompasses a Mesozoic extensional area developed over stretched Lower Paleozoic and Precambrian basement on the Canadian Atlantic Margin.

SOUTH EASTERN NEWFOUNDLAND AREA GEOLOGY (continued)

The Mesozoic-rifted Carson Basin represents the easternmost arm of the intra-cratonic network of rift basins developed on the Canadian margin during Late Triassic to Early Jurassic.

During the Late Triassic to Early Cretaceous, the future Carson Basin area was an intra-continental rift valley followed by an internal shallow sea stage interspersed with continental sedimentation. The divergent margin underwent extension, transtension and subsidence and over time a widening, thickening depression developed between the Grand Banks of Newfoundland and the Iberia Peninsula.

After considerable thinning of continental crust and emplacement of transitional crust to the east, the final rift episode became oceanic during the late Early Cretaceous (Aptian-Albian), leading to separation and drift of the Grand Banks from Iberia. Therefore, up to the late Early Cretaceous, the Carson Basin area shared a common tectonic and structural evolution with several other Grand Banks basins, including the oil proven Jeanne d'Arc and Flemish Pass Basins.

CARSON BASIN GEOLOGY

The Carson area is separated from the Jeanne d'Arc Basin by the Morgiana Anticlinorium and from the South Jeanne d'Arc Basin by a thin basement ridge and from the Flemish Pass Basin by a series of NNE-SSW basement highs and narrow sedimentary troughs. A major fault marks the basin's northwestern boundary.

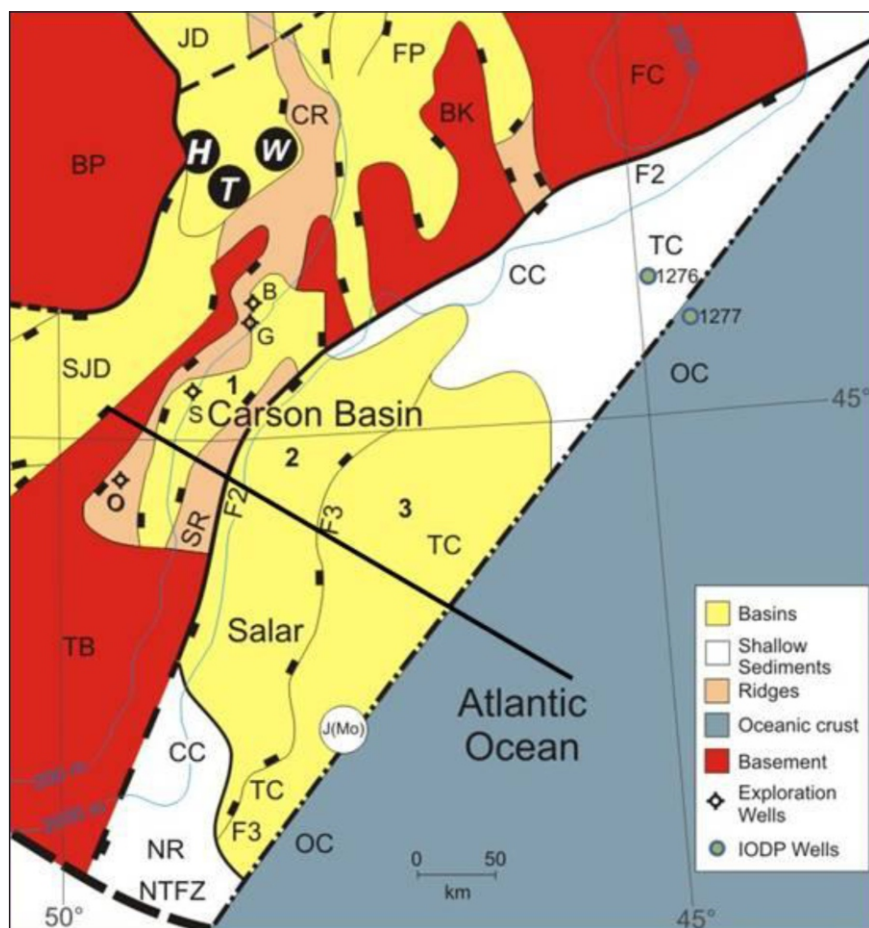
Within the Carson Basin, sedimentary fill includes Late Triassic to Mid Jurassic red beds, salt, limestones, and dolomites, followed by a Late Jurassic to mid-Cretaceous largely clastic sequence. A predominantly shaly sequence including several basin slope and floor sandstone intervals (fans?) characterize the Late Cretaceous to Quaternary cover.

The shelf area can be divided into a northern and a southern half graben, separated by a transfer zone. These two areas were historically called the Bonniton and Carson Basins, respectively. The northern region contains thicker Mesozoic fill, while the southern area has suffered pronounced erosion during mid-Late Cretaceous (Figure 11). Early Cretaceous sediments including sandstone reservoirs are generally preserved to the north and eroded towards the south (Figure 11).

The deepwater sedimentary sequences include Triassic salt and thick Jurassic to Cretaceous successions. Under the slope, the pre-rift section drops off significantly within salt induced mini-basins. Large and complex Mesozoic structural and stratigraphic features are observed under the slope and upper rise, a number of which are salt cored.

Figure 3. Location of Carson Basin in continuity with other Grand Banks shelf and slope basins and subbasins (modified after Enachescu, 1988, 1992). Subdivisions are marked as 1) On-shelf sector, 2) Slope and upper rise sector and 3) Deepwater sector. Exploration wells are: O = Osprey H-84, S = Skua E-41, G = St. George J-55 and

B = Bonniton H-32, Green circles = ODP Leg 210 wells. Notations are: NTFZ = Newfoundland Transform Fault Zone (continent/ocean), NR = Newfoundland Ridge, TB = Tail of the Bank, SR = Salar Ridge, SJD = South Jeanne d'Arc Basin, JD = Jeanne d'Arc Basin, FP = Flemish Pass Basin, CR = Central Ridge, BP = Bonavista Platform, BK = Beothuk Knoll and FC = Flemish Cap. CC = continental crust, TC = transitional crust and OC = oceanic crust. F2 and F3 are major fault trends in the basin. Producing oil fields are: H = Hibernia, T = Terra Nova and W = White Rose. The black line shows the track of the generalized geological cross-section illustrated in Figure 4.



CARSON BASIN GEOLOGY (continued)

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

Coarse-grained clastics sourced from Precambrian basement terrains surrounding the evolving basin should be present within deltaic episodes deposited during the Late Jurassic to Early Cretaceous.

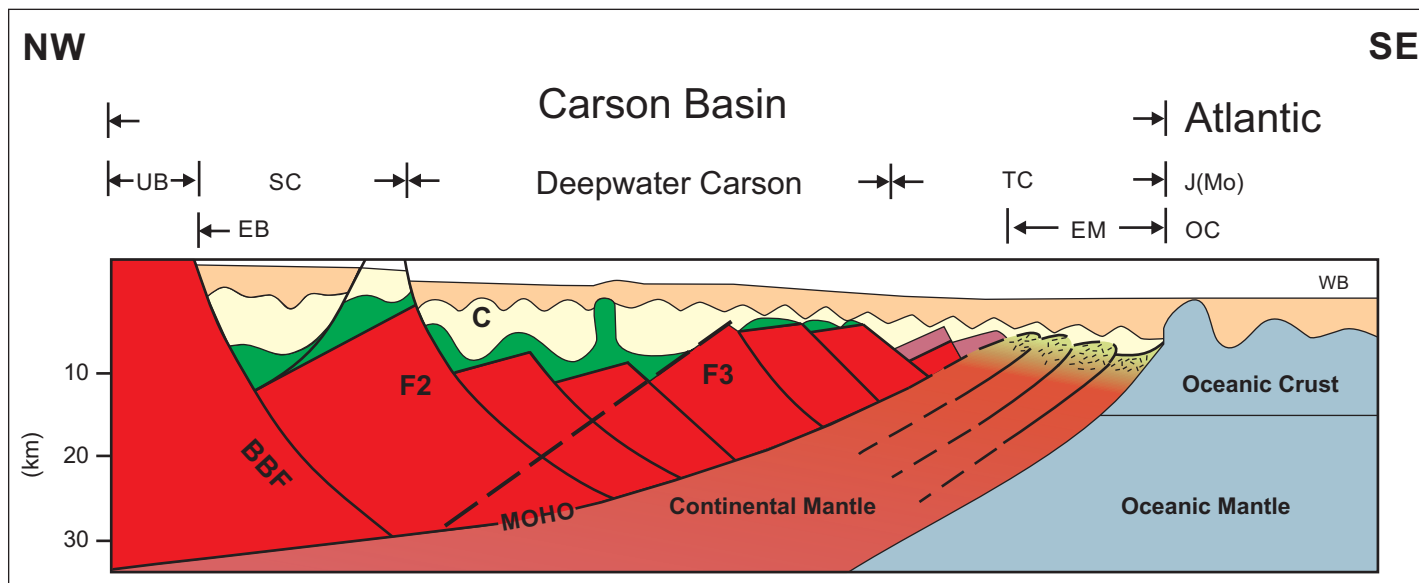


Figure 4. Schematic geological cross-section of the Carson Basin (modified after Enachescu, 1992). Location of cross-section is given in Figure 3. Abbreviations are: UB = unextended basement; BBF = basin bounding fault, WB = water bottom, EM = exhumed mantle, EB = extended basement; C = end of extensional stage unconformity (Avalon); SC = onshelf Carson Basin; all underlain by continental crust. TC = transitional crust region and includes highly extended continental crust intruded and overlain by lava flows. OC = old oceanic crust formed during the Tethys rifting stage. Small Mesozoic rift sedimentary and volcano sedimentary cuvettes are present in the transitional zone. East of J(Mo) magnetic anomaly and ridge, only Atlantic rift stage oceanic crust and syndrift sediments occur. From left to right patterns indicate: continental basement, salt structures in the basin, intrusions, lava flows and extended old oceanic crust, and Atlantic stage oceanic crust.

PETROLEUM GEOLOGY: OVERVIEW

The on-shelf, slope, and deepwater portion of the Carson Basin included in the 2019 Calls for Bids area is part of Newfoundland's Mesozoic network of basins which has preserved a significant Late Jurassic – Early Cretaceous sedimentary sequence. While the inner shelf was being eroded during the Avalon Uplift, the remainder of the basin started to subside and was blanketed by a thick Late Cretaceous – Tertiary cover which helped to preserve a potentially hydrocarbon bearing syn-rift sequence. Consequently, it is anticipated that the Call for Bids area will contain an identical oil prone petroleum system (anchored by Kimmeridgian Egret Member source rock) as that proven in the Jeanne d'Arc and Flemish Pass basins.

Despite being adjacent to the hydrocarbon prolific Jeanne d'Arc Basin, the Carson Basin remains underexplored, and untested on the slope and deepwater. In the early 1970s and mid-1980s, exploration wells drilled on the shelf were unsuccessful. This has been attributed to a lack of charge due to non-deposition and/or erosion of source rock at the well locations.

The Carson Basin's oldest infill consists of a structured syn-rift succession of coarse and fine-grained clastics (red beds), evaporites, and various carbonate lithologies ranging in age from Late Triassic to Middle Jurassic (Figure 5). These in turn are overlain by a Late Jurassic to late Late Cretaceous (Albian) succession deposited during two additional rifting stages and subsequently deformed by halokinetics. Finally, the Late Cretaceous to Tertiary section contains a relatively thick succession of mainly fine clastics and thin carbonates, which appear mounded on the slope and parallel-bedded elsewhere. These were deposited during the thermal subsidence stage that started with transitional crust formation, followed by continued oceanic rifting and drifting accompanied by oceanic crust formation.

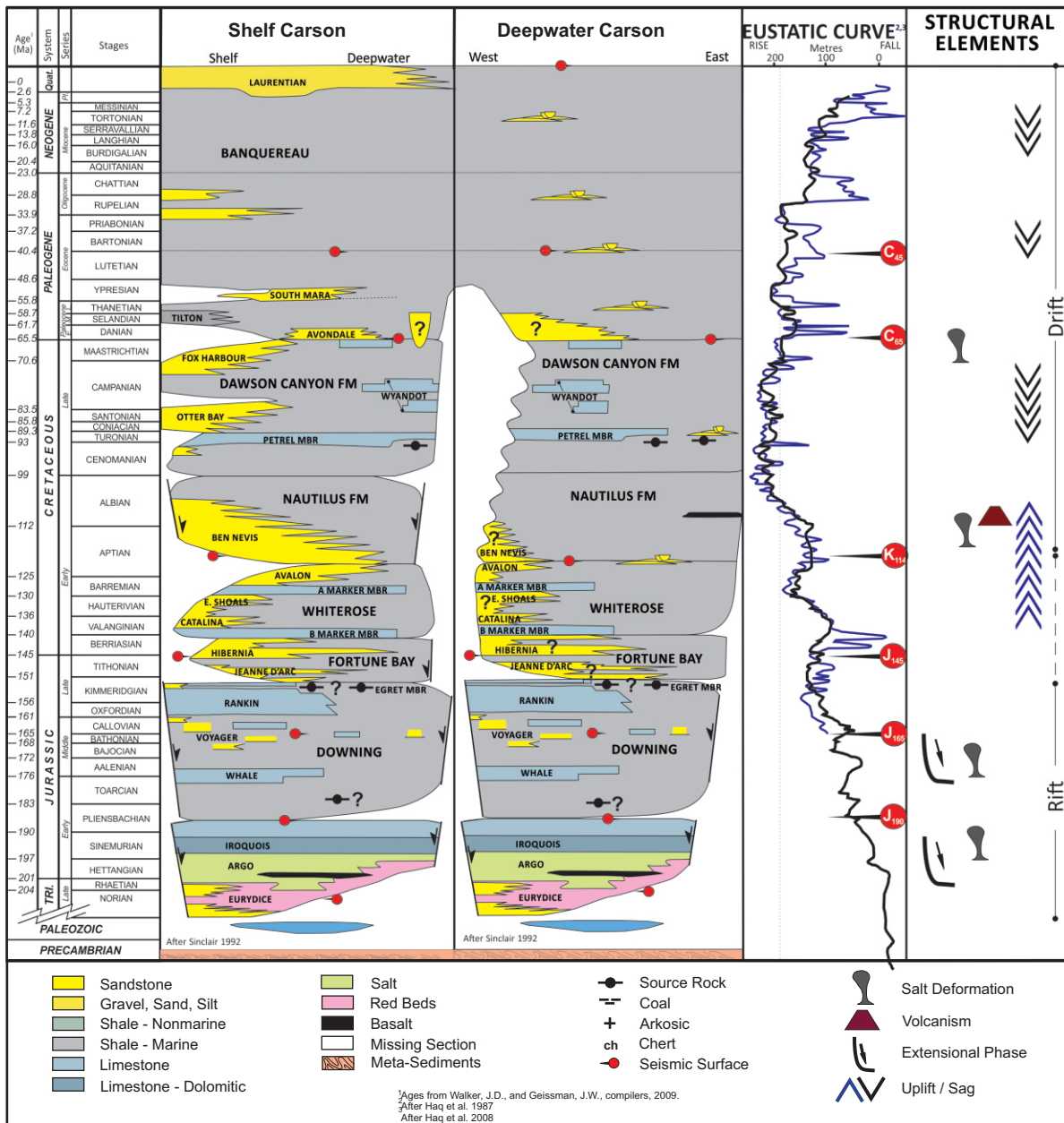


Figure 5. Stratigraphic chart for shelf and deepwater Carson Basin. Modified from Nalcor Energy (2018).

The early basin fill contains the red beds sequence that may contain terrigenous (lacustrine?) source rocks.

The Triassic Argo salt deposited during the Tethys syn-rift stage became mobile starting in the Jurassic, creating intrusions and salt-induced structures in the overlying sediment package. In tandem with salt deposition, it is possible that high total organic carbon (TOC) marine shales were also deposited.

To date, the only proven petroleum system on the Grand Banks and environs that is feeding hydrocarbons into Late Jurassic to Tertiary sandstone reservoirs is sourced by the Egret Member of the Rankin Formation. This system is expected to be present in the intermediate and deep water portion of the Carson Basin. The Egret Member is primarily a thinly interbedded and finely laminated marlstone and calcareous shale possessing an organic-rich Type II marine-derived kerogen intermixed with a secondary, terrestrial Type III kerogen. The Egret Member has a 2-9% TOC range (average 4%) and a Hydrogen Index (HI) between 100 and 600 mg HC/g TOC. Geochemical studies indicate the Egret Member is generally mature when buried deeper than 2,800 – 3,000 m. Although the slope and deepwater regions have not been drilled, oil prone source rocks should be present in several Late Jurassic intervals identified on seismic reflection data. The potential for other source rocks is recognized in the Paleozoic, Early Jurassic, Early and Late Cretaceous and Early Tertiary sequences. High TOC black shale intervals were cored during Ocean Drilling Program (ODP) Leg 210, Site 1276 (Figures 1 & 8), located south of the Flemish Cap and approximately 200 km east of the 2019 Call for Bids area and at Integrated Ocean Drilling Program (IODP) hole 1407 of Expedition 342 (Figures 1 & 9), at the Tail of the Grand Banks.

PETROLEUM GEOLOGY: OVERVIEW (continued)

Reservoir rocks are present in all stages, although good quality clastic and carbonate reservoirs can be localized to deltaic and littoral environments. Quality sandstone reservoirs were encountered on the shelf in several wells located near the NW boundary of the basin.

A multitude of structural and combination hydrocarbon traps were formed in the basin during the extensional and minor transtensional episodes and prolonged salt halokinesis.

PETROLEUM GEOLOGY: SOURCE ROCKS

The Call for Bids area is part of a network of Late Triassic – Early Jurassic rift basins developed during the break-up of Pangea. The basin experienced an early lacustrine stage similar to other Atlantic margin basins (e.g. Scotian Basin) and an interior sea stage similar to the Jeanne d'Arc and Flemish Pass basins, leading potentially to deposition of significant thicknesses of oil generating source rock. The most significant of which should be the Egret Member of the Kimmeridgian age, Rankin Formation or its equivalent (Figure 5). This unit is responsible for sourcing all the current oil fields in the Jeanne d'Arc and other Atlantic Margin basins, including the Viking Graben and Norwegian Sea.

In the Jeanne d'Arc Basin, the Egret Member is a Type II, oil prone source rock with up to 9% TOC, with a TOC average between 3.5 and 4.5%. It was deposited in a semi-silled, epeiric basin and represents the best marine source rock within the North American Atlantic rift system. At present, over 25 exploration wells on the northern Grand Banks have penetrated the Egret Member source, including wells within the Central Ridge – Flemish Pass area.

In the Central Ridge – southern Flemish Pass area, the **Panther P-52** well (Figure 1) encountered more than 600 m of Tithonian and Upper / Lower Kimmeridgian age, Rankin Formation marine source rock (Figures 6, 7, & Table 1). The 310 m thick Upper Kimmeridgian section averaged 2.4% TOC with a maximum value of 8.2%. HI values range up to 989 mg HC/g TOC (Geochem Labs, 1986). The rocks are deemed moderately mature and primarily oil prone with associated gas. For the 209 m thick Lower Kimmeridgian source interval, TOC values also average about 2.4% with HI values ranging up to 387 mg HC/g TOC (Geochem Labs, 1986).

At **Golconda C-64**, located approximately 25 km south of Panther, the well was drilled on a salt cored, anticlinal Jurassic structure which has been truncated by the Base Tertiary Unconformity (Table 1). The oil-prone Egret Member source is not present, but underlying Voyager (Oxfordian) shales do exhibit TOC values up to 3.5%.

Approximately 50 km to the east and lying within the Flemish Pass South basin, the **Kyle L-11** well encountered Cretaceous strata unconformably overlying basement. The anticipated Jurassic section was either eroded or not deposited at the well location (Table 1).

Regionally, throughout the Central Ridge / Outer Ridge Complex – south Flemish Pass Basin, strong amplitude reflectors often associated with a Late Jurassic source rock appear mappable on seismic lines. 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 half grabens and rotated blocks that contain synrift sedimentary sequences.

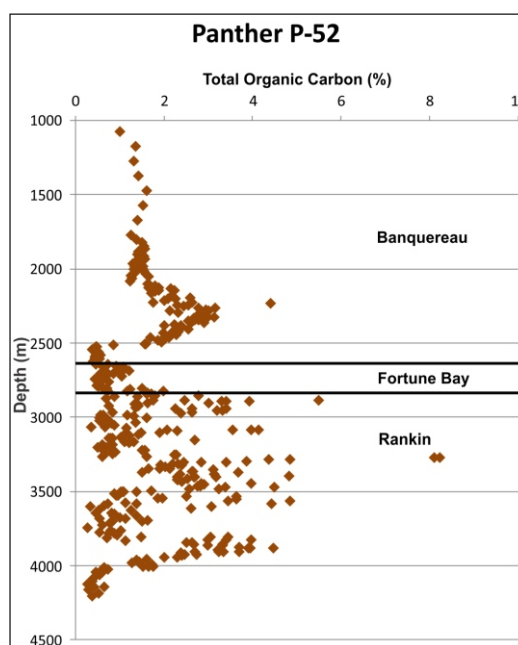
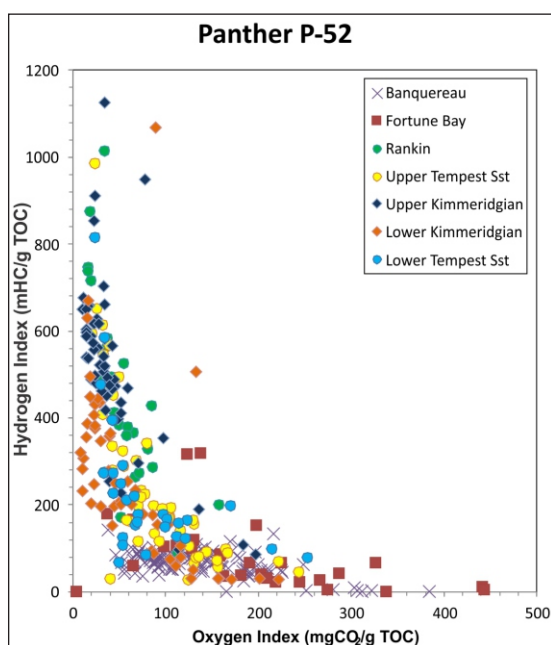


Figure 6 (left). Panther P-52 modified van Krevelen graph. Data from Geological Survey of Canada (2012).

Figure 7 (right). Panther P-52 total organic content versus depth. Data from Geological Survey of Canada (2012).

PETROLEUM GEOLOGY: SOURCE ROCKS (continued)

Tithonian age (Jurassic) source rocks first identified at Baccalieu I-78, Panther P-52, and Lancaster G-70 wells in the Flemish Pass area and more recently in Mizzen and Bay du Nord wells in the Flemish Pass Basin are mostly shale having TOCs between 2 and 4%. Although unproven, there is potential for these source rocks to be present further south in the Call for Bids area.

The Mesozoic section in the Call for Bids area may be underlain by Carboniferous age, gas generating paludal and coaly source beds similar to those observed further west in the Maritimes Basin. Tertiary shales also show some high TOC intervals, however they are yet unproven as source rocks.

The key question for the Call for Bids area is whether the Egret source member or other Late Jurassic sources are present. Based on seismic interpretation and correlation, a Late Jurassic section is indicated in the on-shelf and intermediate to deepwater Carson Basin.

PETROLEUM GEOLOGY: CRETACEOUS SOURCE ROCK POTENTIAL

In 2003, the ODP drilled two sites south of the Flemish Cap and 150 km east of the Carson Basin area. Sites 1276 and 1277 of Leg 210 terminated on transitional crust, and ultraslow emplaced ocean crust, respectively (Tucholke, B.E., Sibuet, J.C., & Klaus, A. (Eds.), 2007; doi:10.2973/odp.proc.sr.210.2007). These continuous cored drill holes (Figure 8) intersected a fine-grained succession including high TOC and HI Cretaceous black shales and thin, coarse-grained turbidite reservoirs (Marsaglia et al., 2004 & 2007; Hiscott, 2007; Hiscott et al., 2008).

Well	Drill Year	Well Status	Location	TD (m) below RKB	TD Formation	Reservoir Interval	Source Rock	Shows
Wells in the Call for Bids								
Bonnyton H-32	1973	Abandoned	Bonnyton Basin - shelf	3,048	Rankin	Banquereau	Not Present	No shows observed
St. George J-55	1986	Abandoned	Bonnyton Basin - shelf	4,100	Rankin	Avalon, Hibernia, Jeanne d'Arc	Not Present	No shows observed
Skua E-41	1974	Abandoned	Carson Basin - shelf	3,339	Whale Mbr. (Downing Fm)	Banquereau, Fox Harbour, Ben Nevis	Not Present	Minor Gas Show
Wells near the Call for Bids								
Osprey H-84	1973	Abandoned	Carson Basin - shelf	3,474	Eurydice	Banquereau, South Mara	Not Present	Minor Show
Panther P-52	1985	Abandoned	South Central Ridge	4,203	Rankin	Tempest Sst.	Tithonian & Kimmeridgian	Trace Oil Stain and Fluorescence
Golconda C-64	1987	Abandoned	South Central Ridge	4,451	Downing	Paleocene Sst. - thin	Not Present - eroded	Minor Gas Show
Aster C-93A	2015	Abandoned	Flemish Pass Basin	3,678	Jurassic	Hibernia Sst. eq.	Eroded/ NDE	Fluorescence Only
ODP Leg 210 Hole 1276	2003	Scientific Research	South of Flemish Cap	6,297	Mid Cretaceous	No Reservoir Observed	OAE-2 Cenomanian/Turonian OAE-1b lower Albian	
IODP E-342 Hole U-1407	2012	Scientific Research	~100 km S. of Tail of Grand Banks	3,394	Mid Cretaceous	No Reservoir Observed	OAE-2 Cenomanian/Turonian TOC 4-17%, Immature	

Table 1. Exploration wells drilled in vicinity of 2019 Calls for Bids in South Eastern Newfoundland land tenure region. Eq = Equivalent, Fm = formation, Mbr = member, OAE = Oceanic anoxic event, Sst = sandstone, TOC = total organic carbon. Data from C-NLOPB.

SCIENTIFIC WELLS: CRETACEOUS SOURCE ROCK POTENTIAL (continued)

In 2012, the IODP cored potential Cretaceous source rock approximately 200 km south of the Tail of the Grand Banks on Expedition 342, Site U1407 (Figures 1 & 9).

The Cretaceous, Turonian to lower Albian-uppermost Aptian(?) age shale succession (Unit 5) encountered in ODP Leg 210 is greater than 700 m thick. It consists of gravity-flow deposits and non-calcareous hemipelagic mudstones interspersed with approximately 5% finely laminated, organic rich, black calcareous shales and marlstones. TOC is up to 10% in some of the organic rich shale beds, mostly due to the influx of terrestrial or mixed terrestrial/marine organic matter under somewhat reducing conditions. Exceptions to mainly terrestrial organics took place during Oceanic Anoxic Event (OAE) 2 (Unit 5A – Cenomanian-Turonian) and OAE 1b (Unit 5C – lower Albian) when thin, laminated black shales exhibiting TOCs between 3 and 7% and HI values ranging from 230 to 450 mg HC/g TOC were deposited. Geochemical data indicate a marine, algal origin (Type II) for this organic matter. Similar, although immature, finely laminated, organic rich black OAE 2 shales were also encountered at Site U1407 of IODP E-342. The OAE 2 shale beds observed at both deepwater locations are generally thin and immature. However, more mature and thicker OAE sediments may exist in the intervening 700 km between Site 1276 and Site U1407, possibly creating a source rock fairway. Traced back towards the slope/rise, the OAE 2 and OAE 1b shales, if present, may be thicker within restricted mini-basins, buried deeper or covered by a thicker sequence of Tertiary sediments than that observed in the ultra-deep environment.

The Cenomanian to Turonian aged organic shales encountered in ODP Leg 210 (Arnaboldi & Meyers, 2007; Meyers & Arnaboldi, 2011) are expected to also be found in the Carson Basin and may be mature in deeper depocenters. The Turonian-Albian black shale intervals are also possible source rock intervals (Arnaboldi & Meyers, 2007).

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

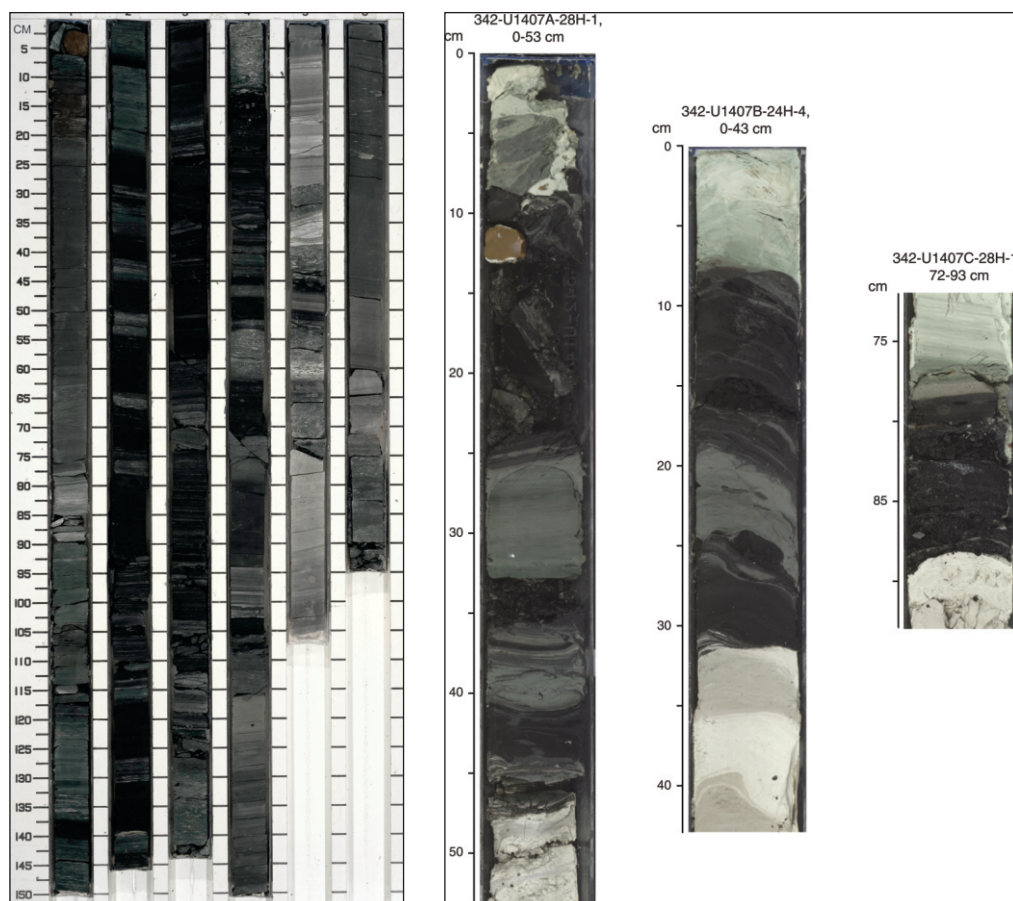


Figure 8 (left). ODP Leg 210, Site 1276 core photo of Cenomanian-Turonian shales. From Tucholke et al. (2004).

Figure 9 (right). IODP Expedition 342, Site U1407 core photo of Cenomanian-Turonian shales. From Norris et al. (2014).

PETROLEUM GEOLOGY: RESERVOIR AND SEAL

Based on seismic interpretation, it appears the Jeanne d'Arc and Flemish Pass Basins were in communication with the Carson Basin area during the Late Jurassic to late-Early Cretaceous. Therefore, the Call for Bids area is also expected to contain high porosity, high permeability, quartz-rich sand intervals deposited in marine shoreface to deepwater settings similar to those observed in the northern Grand Banks basins.

The Bonnition H-32 and St. George J-35 wells drilled on the shelf encountered a number of Jurassic to Early Cretaceous sand intervals exhibiting fair to excellent porosity (Table 1 & Figure 10). These sand intervals are time equivalents to the Jeanne d'Arc, Hibernia, Avalon, Ben Nevis, and South Mara reservoir sands and were deposited as valley fill, deltaic and shoreline sequences. Further seaward beyond the shelf edge, turbiditic sands, slope channel sands, and basin floor fans are expected.

In addition, the Late Cretaceous - Early Tertiary sequence has a real and effectively untested potential for large oil and gas pools, especially in the deepwater area where a major clastic depocenter can be mapped. In all likelihood, however, secondary migration would be required to fill these turbidite, channel, and basin floor fan sands.

From an exploration perspective, reservoir sands can be envisioned in a number of stratigraphic and structural settings. However, having good reservoir rock is great but academic without a suitable trap and sealing mechanism to contain any generated hydrocarbons. In the Call for Bids area, seal risk should be minimal due to the abundance of fine clastics, tight sandstones and tight, fine grained deepwater limestones, all deposited at various times during synrift and post-rift extensional and thermal subsidence events. On the shelf, formations such as Downing, Rankin, Fortune Bay, Whiterose, and Nautilus should provide an adequate seal for trapped hydrocarbons. Post-rift Petrel and Wyandot Limestone as well as syn-drift Banquereau formation fine clastics also form basin-wide seals.

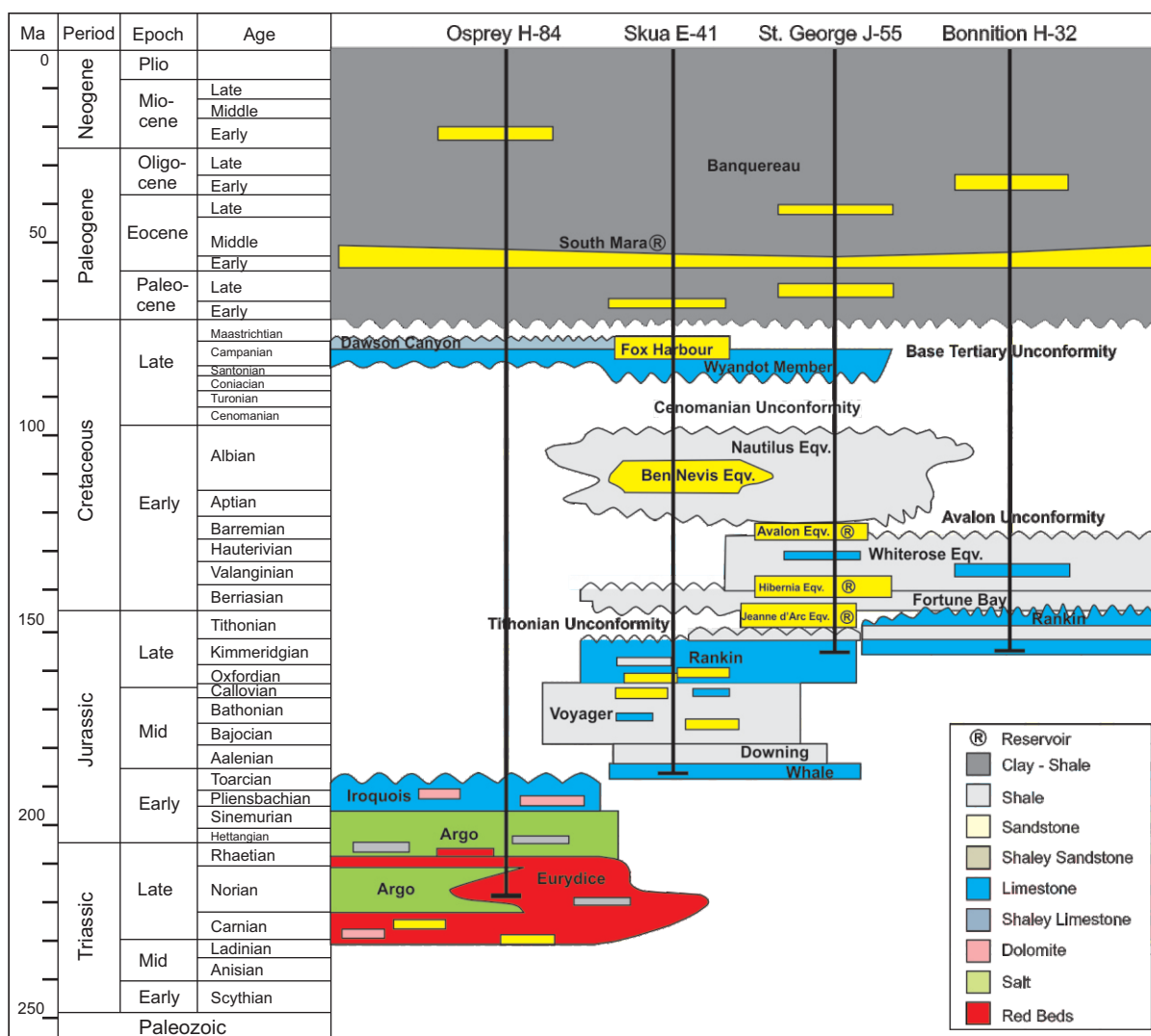


Figure 10. Chronostratigraphy of wells drilled to date (all shelfal) in the Carson Basin using biostratigraphic data (Hogg & Enachescu, 2019).

PETROLEUM GEOLOGY: TRAP STYLES

A series of significant structural, stratigraphic, and combination traps are identified on seismic data collected over the Call for Bids area. The four wells drilled on the Carson Basin shelf targeted Early Cretaceous and Late Jurassic structural closures and although unsuccessful, they provide insight into the regional petroleum potential. On the shallow shelf, viable source rocks were never deposited or were eroded, likewise, further offshore Jurassic source rocks do not appear to be present beneath transitional crust and exhumed mantle. The best potential for hydrocarbons will most likely be within the extended basement region (intermediate to deepwater Carson), generally between 500 m to 3000 m water depth.

Based on seismic interpretations, structural traps are plentiful in the deeper water region. Their formation may be attributed in part to multi-stage rifting along the Atlantic margin, leading to gravity faulting, minor transtension, inversion, differential subsidence, regional tilting and halokinesis related to Argo formation evaporites. Trap styles include but are not limited to rotated / tilted fault blocks, rollover anticlines related to extensional faulting, compression modified extensional anticlines, halokinetic structures like salt cored anticlines, elongated horst and graben structures involving basement or restricted to syn-rift sequences and drape features over basement highs / rotated fault blocks. 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 have been mapped.

Stratigraphic traps are present in the region, becoming predominant towards the Southeast Newfoundland Ridge. Trap styles include but are not limited to paleo-valleys, sub-unconformity truncations, pinchouts, and basin margin to basin slope / floor fans and associated feeder channels.

PETROLEUM GEOLOGY: PLAYS AND RISKS

The main hydrocarbon play expected to be successful in the Carson Basin will likely be:

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

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

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

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

PETROLEUM GEOLOGY: PLAY SUMMARY

The Carson Basin area represents a vastly underexplored high-risk, high reward petroleum play on the Newfoundland Atlantic Margin in intermediate proximity to proven prolific hydrocarbon regions, the giant oil accumulations of the Jeanne d'Arc Basin and the emerging, recently proven significant discoveries at Mizzen, Harpoon, and Bay du Nord in the Flemish Pass Basin.

Main play risk is considered to be charge, notably source rock presence and maturity.

Multiple play types are conceptualized in the Carson Basin, including large structural fault-bounded closures, salt-induced anticlines, mini-basin traps, Cretaceous fans, Tertiary lowstand submarine fans and channel complexes, salt wall stratigraphic traps and deep sub-salt plays. These will likely be sourced by a world-class Late Jurassic source rock.

Conventional plays that are expected to be successful in the Carson Basin, with analogues to the adjacent Jeanne d'Arc Basin, will likely be Late Jurassic Jeanne d'Arc equivalent sandstones, Early Cretaceous Hibernia equivalent sandstones, and late Early Cretaceous Avalon and Ben Nevis equivalent sandstones.

Late Cretaceous and Early Tertiary lowstand clastics are expected to have significant play potential on the basin's slope and upper rise.

SEISMIC DATA

Good to excellent 2D seismic grids are available for the area (Figures 12-15). However the deepest parts of the easternmost parcels have reduced coverage.

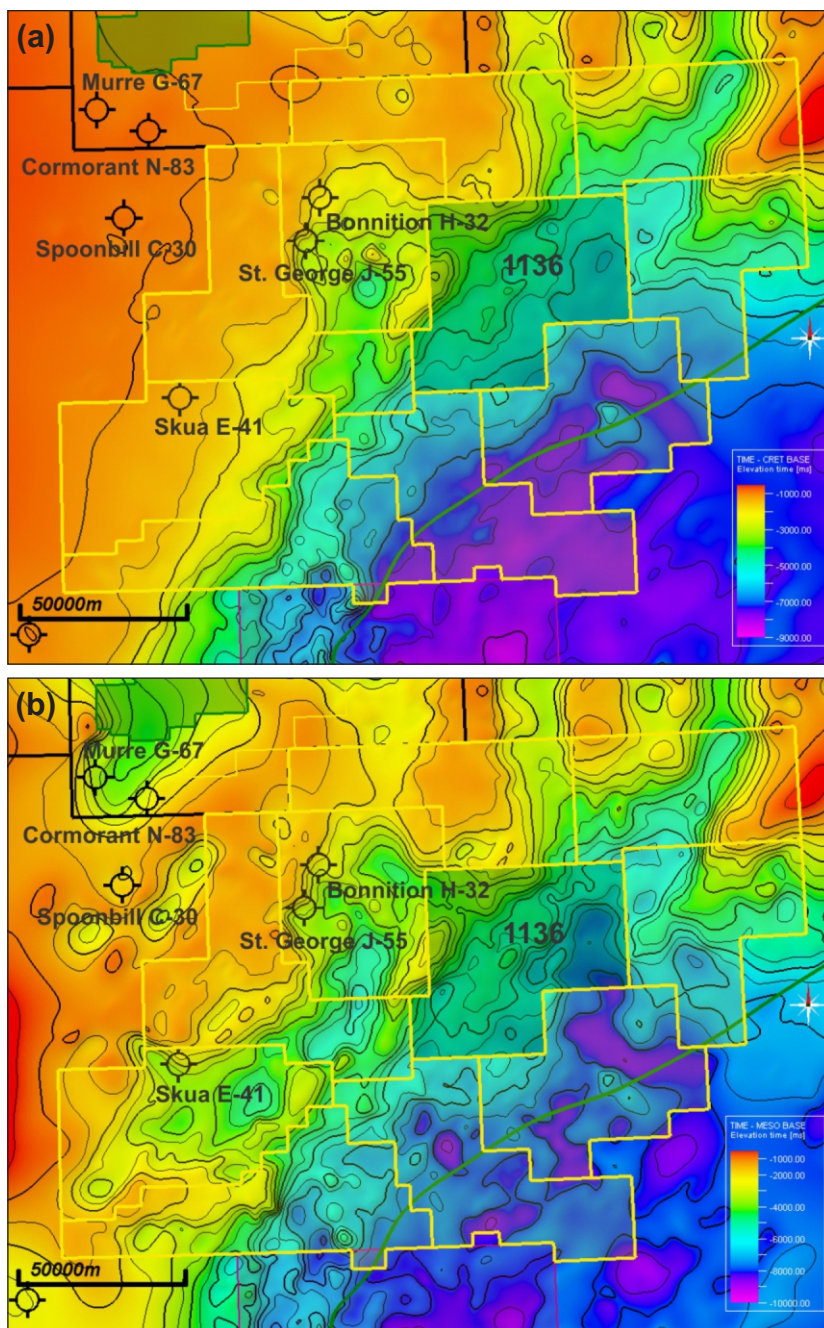
Excellent modern seismic coverage exists (Figures 13 & 15) over several extensional and salt induced structures located on the slope.

Seismic data quality is good to excellent in most of the parcels but deteriorates around salt features and due to the presence of multiples in steep slope areas (Figures 16 & 17).

Seismic mapping is possible using high quality regional seismic markers such as carbonate intervals within clastics and several wide-spread unconformities. Good local markers and detachment surfaces within the post-rift sedimentary wedge can also be easily mapped. Main and secondary faults are readily traceable, and salt walls/welds are relatively well imaged.

Seismic ties to shelf wells and to the nearest oil discoveries (Hibernia, Terra Nova, Hebron and White Rose) are possible using the long regional lines covering the shelf and deepwater.

Figure 11. Time structure maps based on regional public 2D seismic data that show the (a) Base Cretaceous and (b) Base Mesozoic. Mapping suggests the NW portion of the Carson Basin, near the St George J-55 and Bonniton H-32 wells, is mostly Cretaceous-filled and the SW area, near the Skua E-41 well, is mostly Jurassic-filled. Contour interval is 500 ms. Green line marks approximate 3,000 m water depth. Yellow lines mark the 2019 Call for Bids parcels surrounding exploration licence 1136.



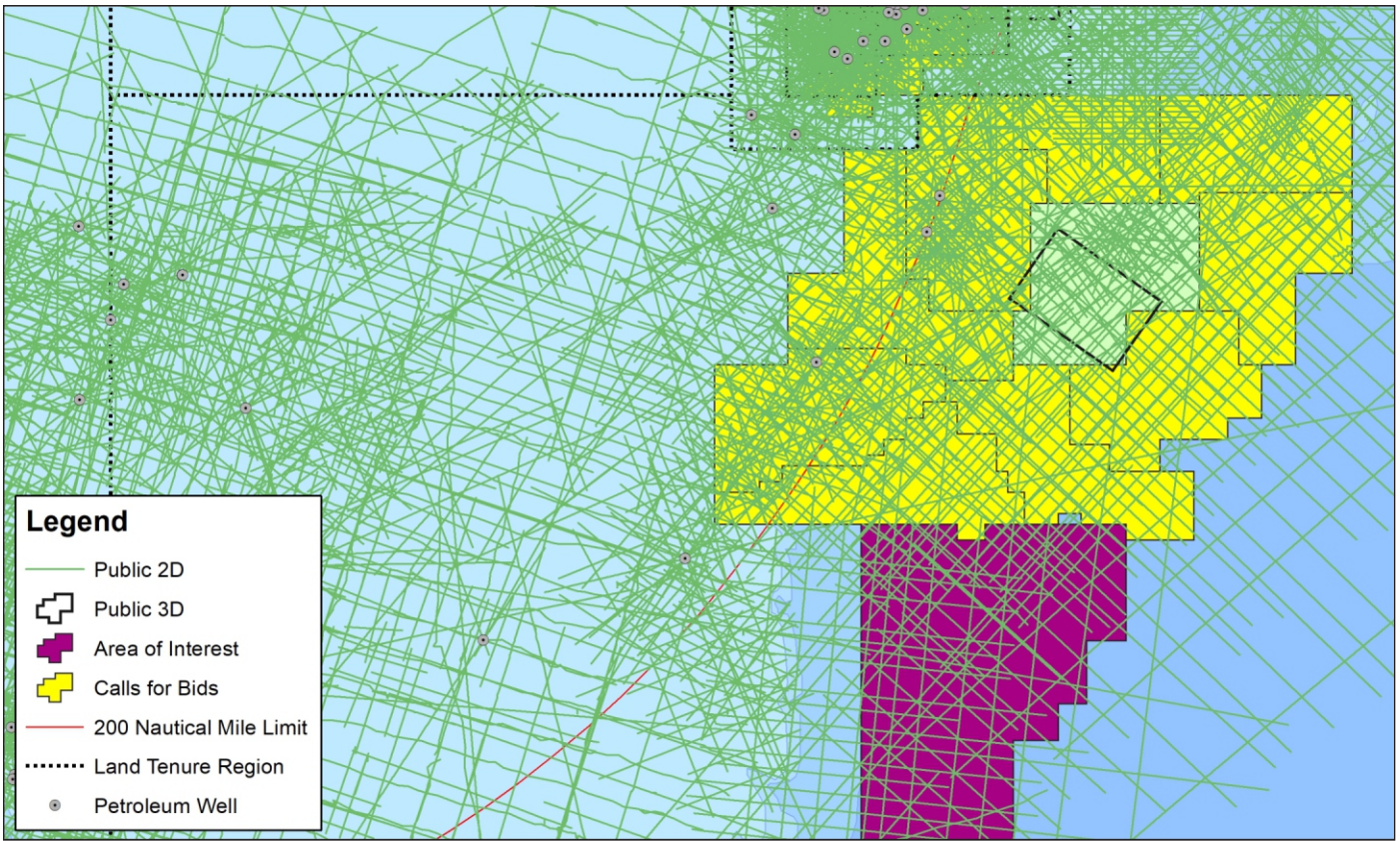


Figure 12. Non-privileged seismic coverage in Carson Basin area over 2019 Call for Bids. 20,179 kms of 2D available. Data courtesy of C-NLOPB.

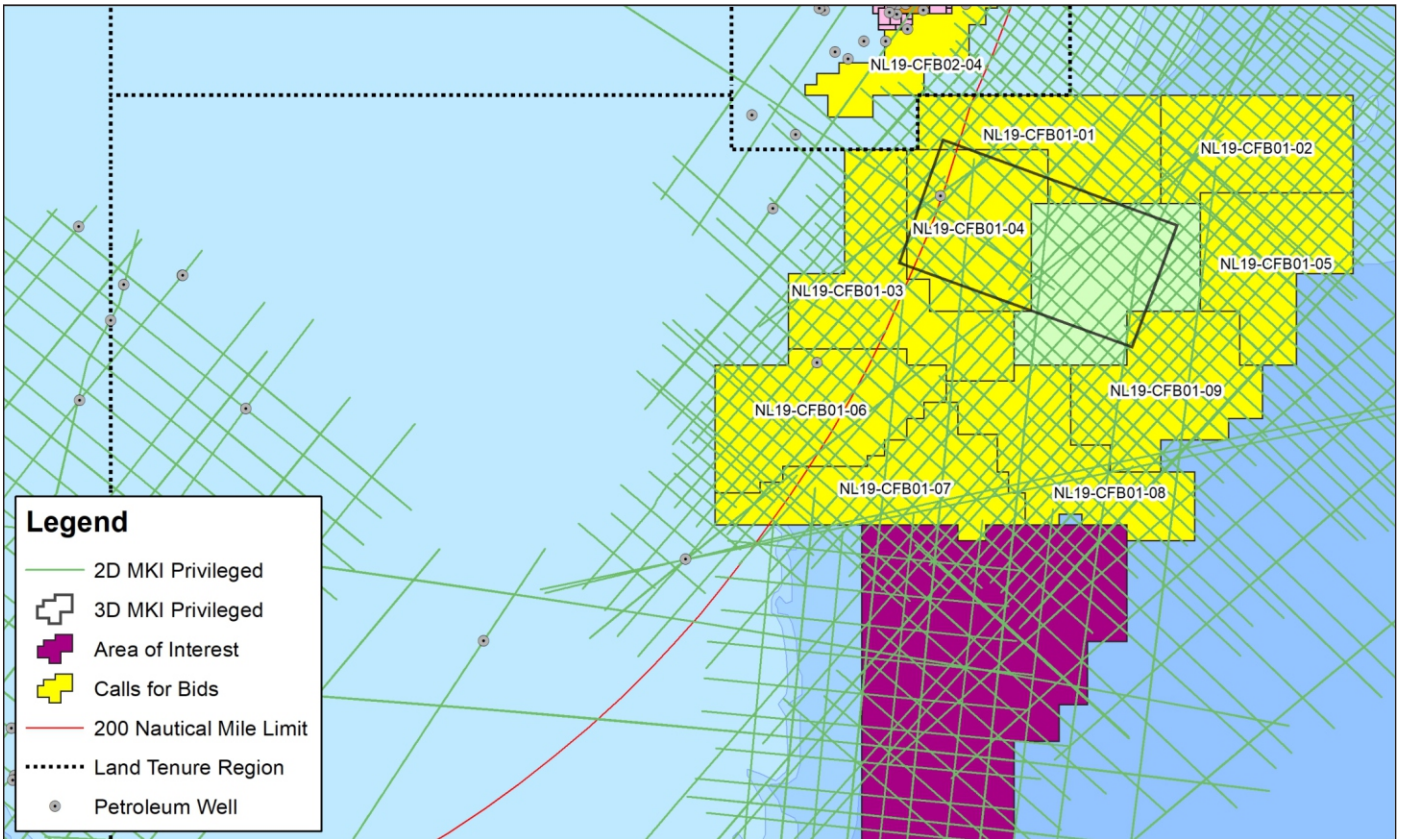


Figure 13. Privileged seismic data available for purchase over 2019 Call for Bids. 31,205 kms of 2D and 7,850 km² of 3D available. Data courtesy of TGS/PGS/MKI.

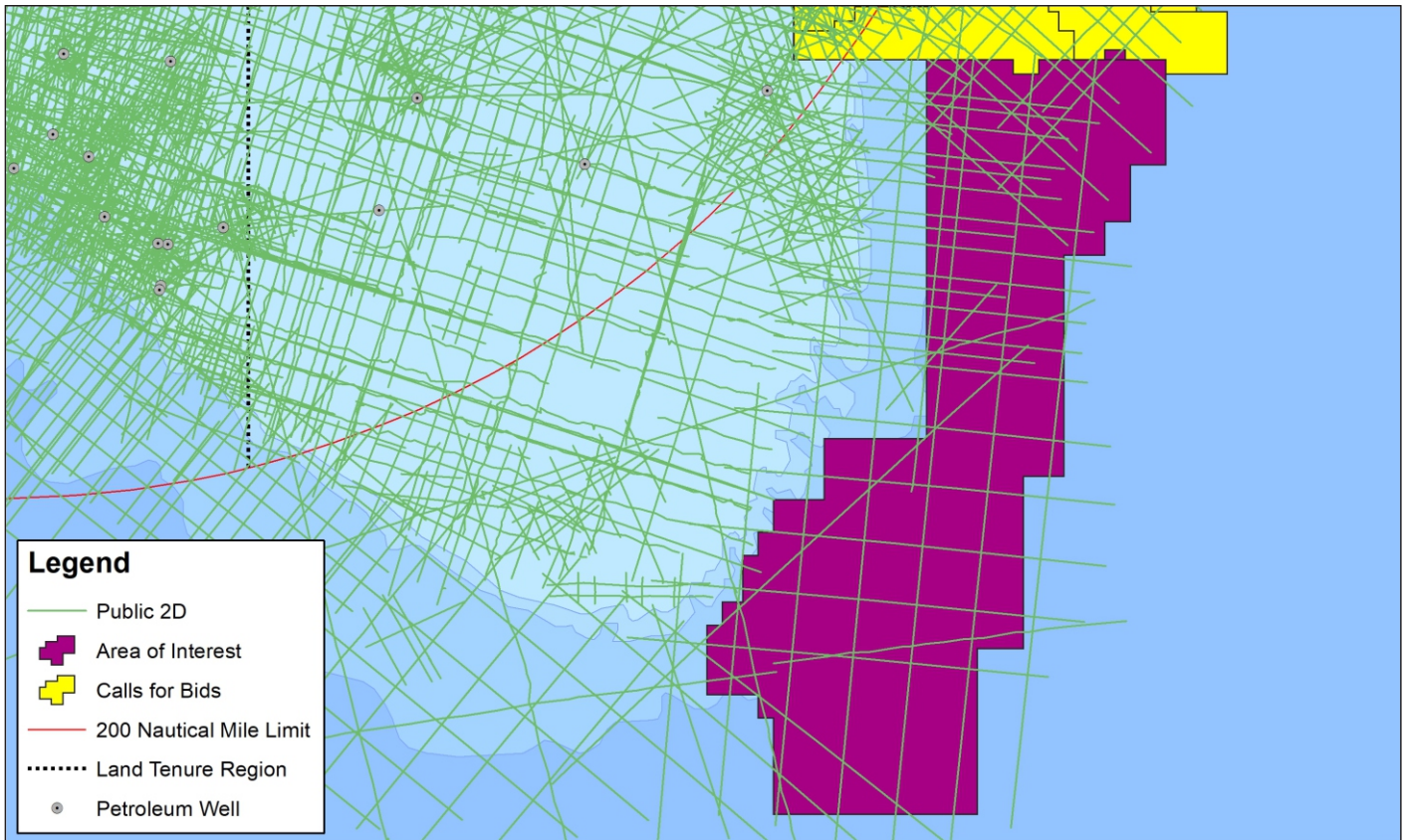


Figure 14. Non-privileged seismic data coverage in Carson Basin area (2021 Call for Bids). 5,000 kms of 2D available. Data courtesy of C-NLOPB.

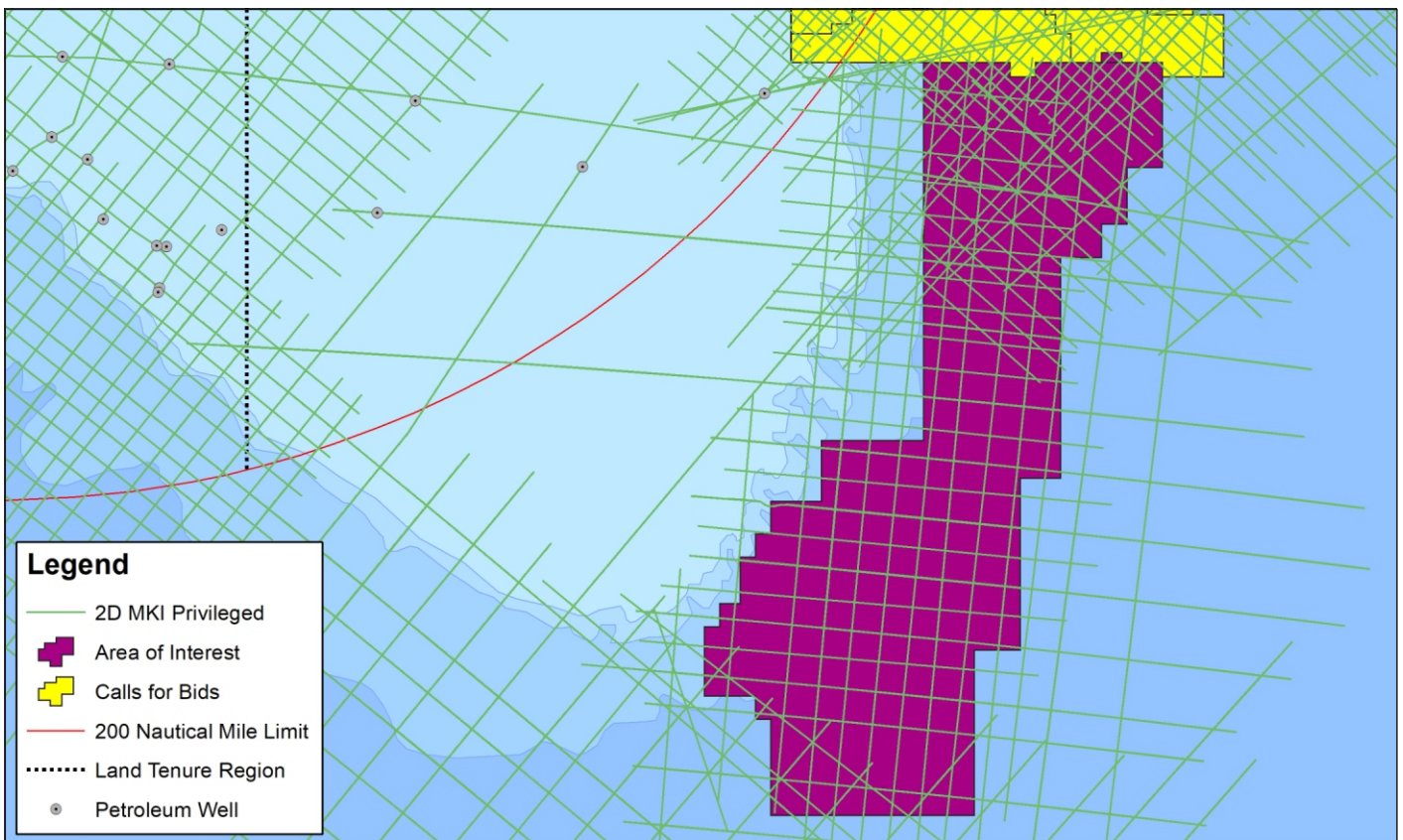


Figure 15. Privileged seismic data available for purchase in Carson Basin area (2021 Call for Bids). 19,163 kms of 2D available. Data courtesy of TGS/PGS/MKI.

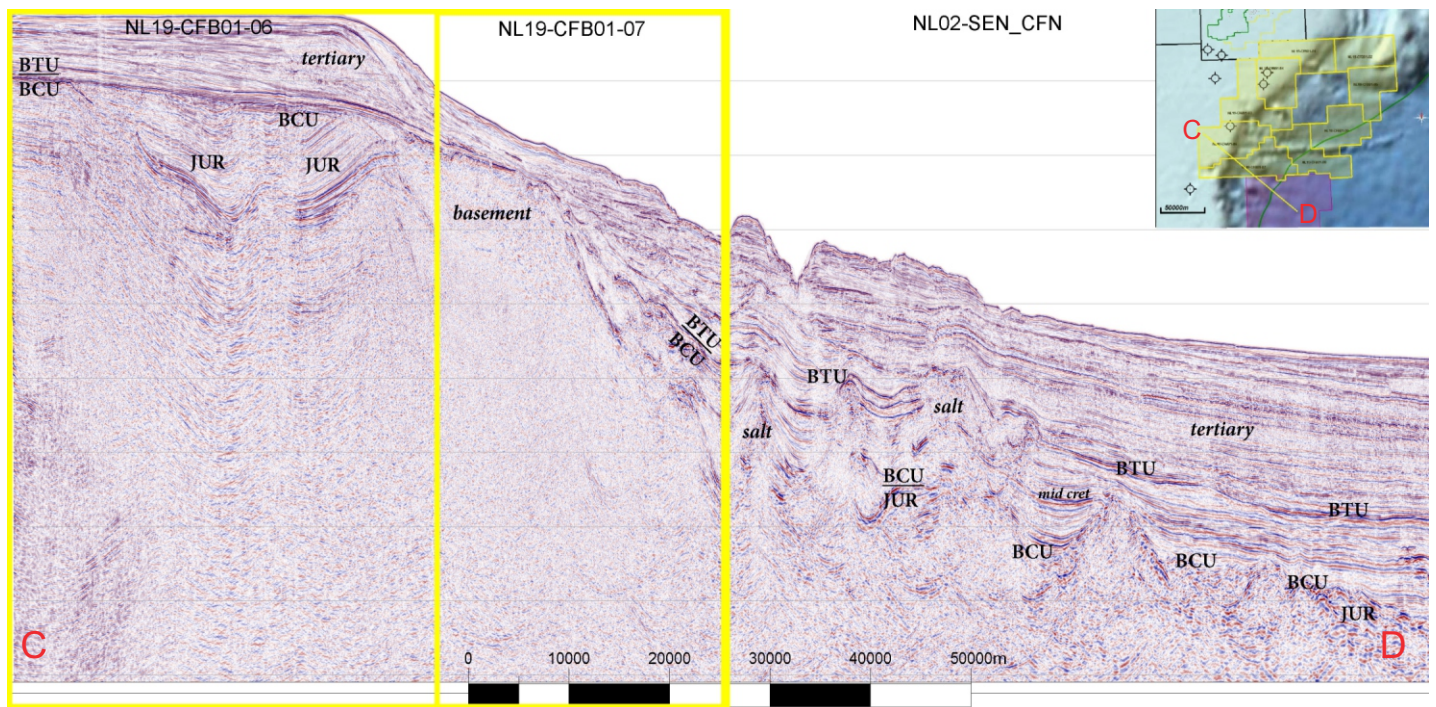
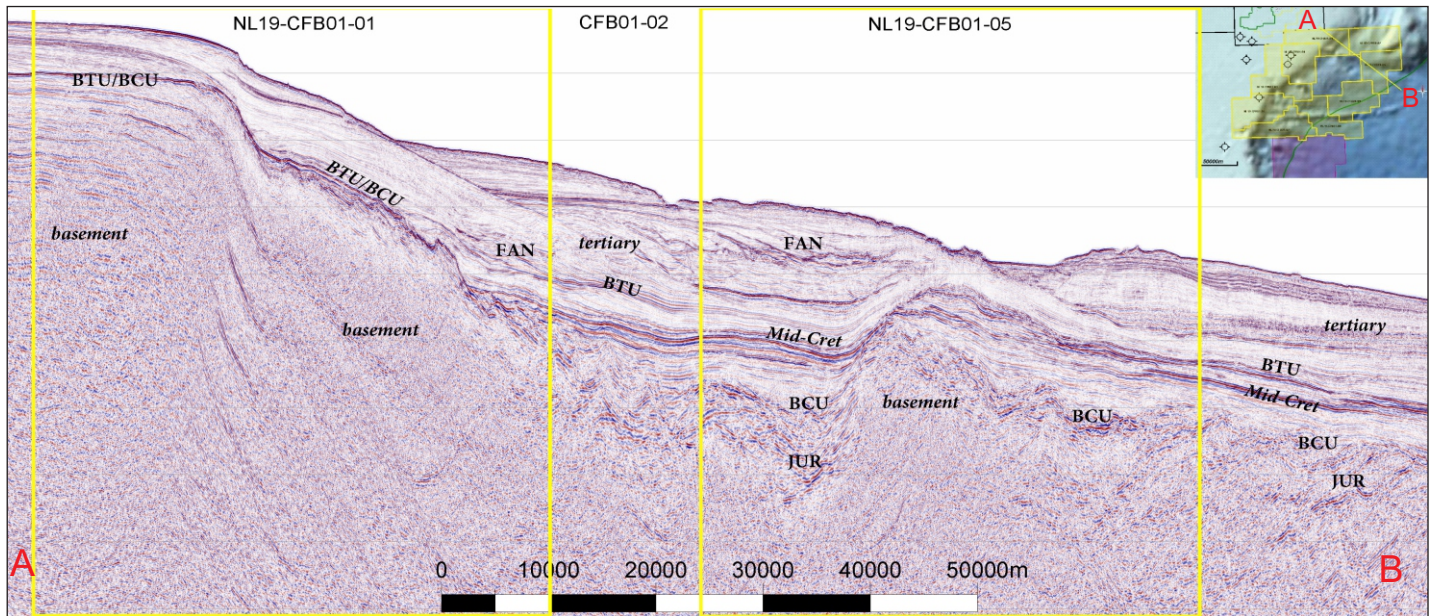


Figure 16. Public-domain seismic lines through the Carson Basin Call for Bids area. Yellow boxes mark extent of the 2019 Call for Bids area. BTU - Base Tertiary Unconformity, CRET - Cretaceous, BCU - Base of Cretaceous Unconformity, JUR - Jurassic.

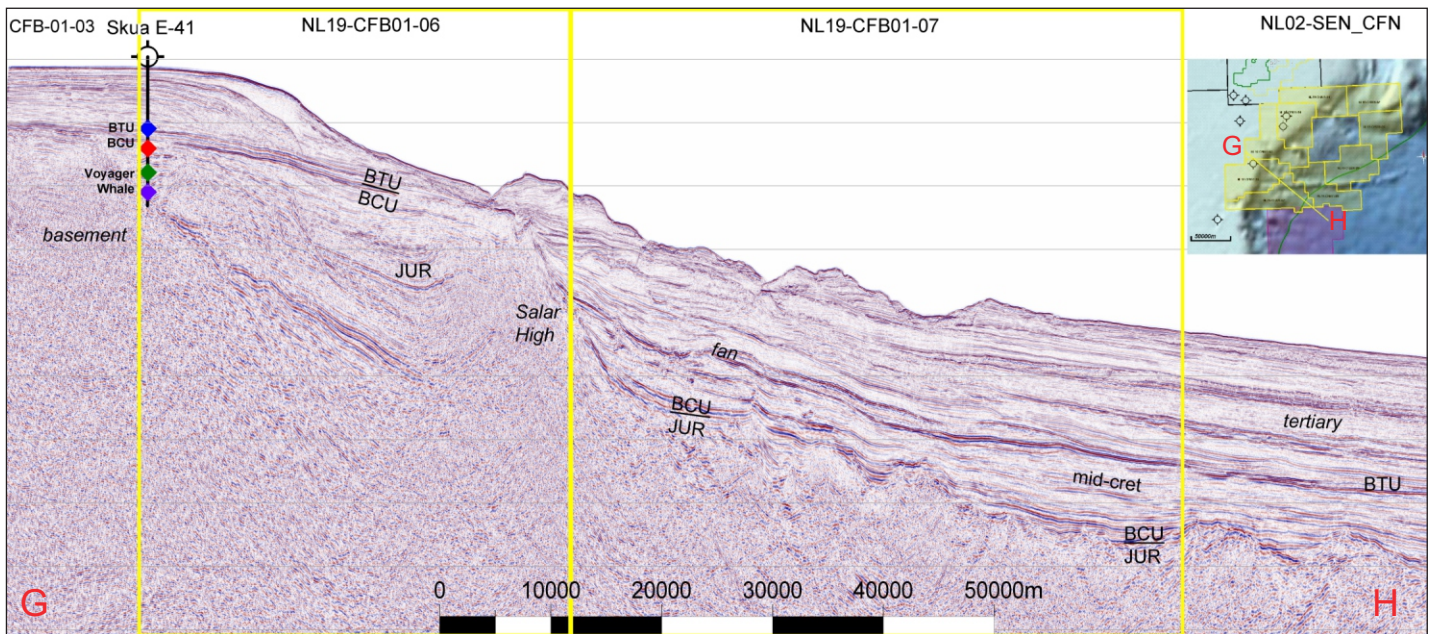
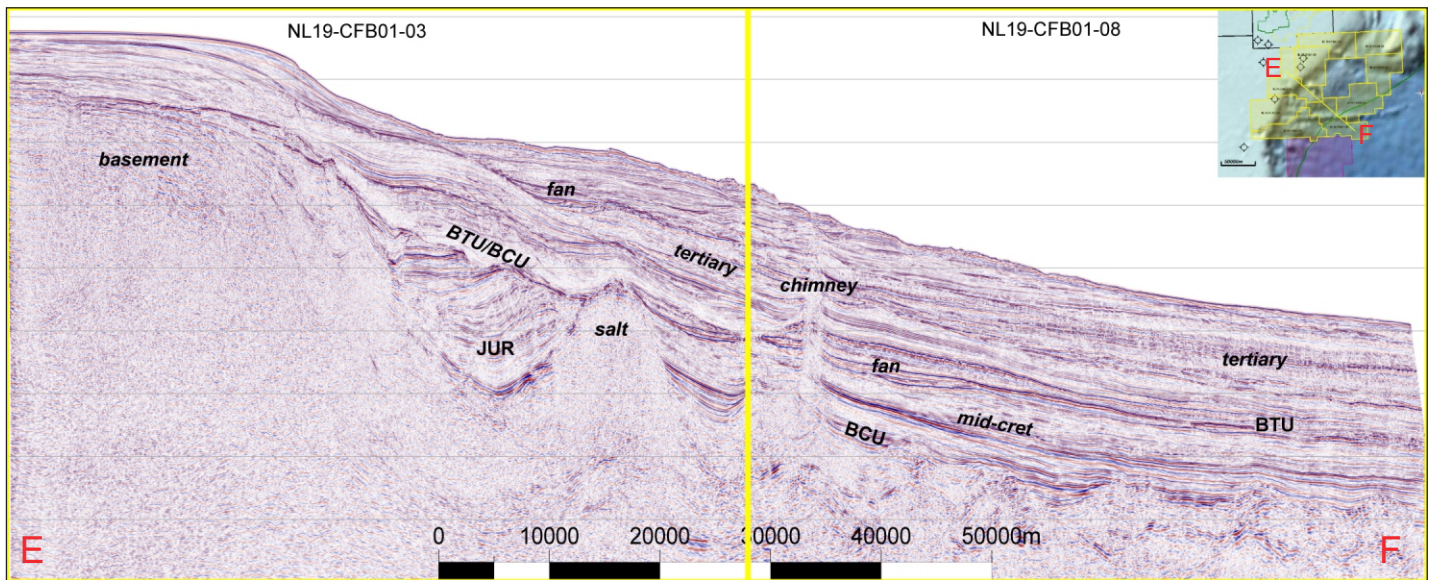


Figure 17. Public-domain seismic lines through the 2019 Call for Bids in the Carson Basin. The Skua E-41 well is projected (~5 km SW) onto the seismic line. Yellow boxes mark the 2019 Call for Bids parcels. BTU - Base Tertiary Unconformity, CRET - Cretaceous, BCU - Base of Cretaceous Unconformity, JUR - Jurassic.

Data from the C-NLOPB and available on a subscription-basis in The Department of Natural Resources' Exploration Data Room at www.hydrocarbonassets.com

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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 Department of Natural Resources from previously published studies, papers, and Department of Natural Resources work. Edited and reviewed by M. Enachescu.

Author: Department of Natural Resources

