OFFSHORE OPPORTUNITY - 2022 CALL FOR BIDS

SOUTH CARSON BASIN/EAST TAIL OF THE BANK - NEWFOUNDLAND AND LABRADOR

EXECUTIVE SUMMARY

In June 2017, the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB) announced a Sector in the South Eastern Newfoundland land tenure region (NL02-SEN – Figure 1). As part of the land tenure process this area follows a 4-year cycle (low activity region). A Call for Nominations for Parcels for the Sector was issued in September 2020, but in April of 2021 the schedule was revised. The Call for Bids planned for NL02-SEN will now have the associated Call for Nominations (Parcels) in the fall of 2021, the opening of the Call for Bids in the spring of 2022. The Call for Bids will close in the fall of 2022.

The Sector area is a fragment of the North Atlantic Mesozoic rift network and includes the slope and deepwater portion of the southeastern Carson Basin, and the slope and deepwater in front of the Tail of the Bank. Parts of the area were previously identified in academic publications as the Salar Basin. The Sector is considered highly prospective for hydrocarbons because of proximity to the Jeanne d'Arc and Flemish Pass basins, both of which contain world-class oil fields. Recently, modern 2D and 3D seismic surveys were collected in the Sector. Despite dense recent and historic 2D seismic coverage, the Sector area remains underexplored. A large 3D survey was acquired in 2020 in the southern part of the Sector.

The area was last licensed for exploration drilling in the late 1960s-early 1970s, but the seismic data quality at the time was poor and no wells were drilled outside of the Grand Banks continental shelf. The nearby existing shelfal and intermediate water depth wells penetrated reservoir and source rocks. Several geologic markers identified in the wells can be used for ties to the modern seismic data and construct regional and prospect exploration maps.

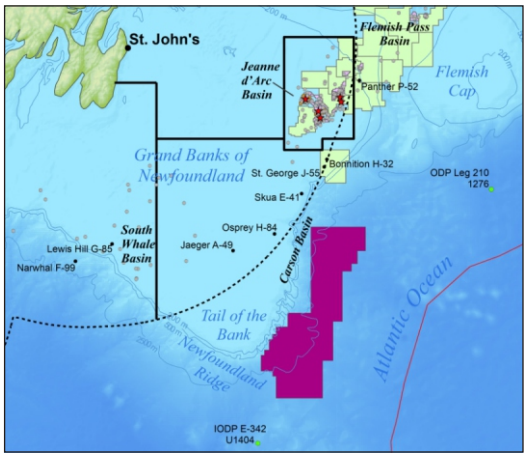


Figure 1. 2022 Calls for Bids Sector (purple polygon). Red line is UNCLOS boundary, black dashed line is 200 nmi limit, and light green blocks are exploration licences.

OVERVIEW

Located on the east coast of Canada, the province of Newfoundland and Labrador (NL) is the country's only offshore oil producing region. Since 1997, the province's five producing fields - Hibernia, Terra Nova, White Rose, North Amethyst, and Hebron have produced in excess of 2 billion barrels of oil. The great majority of produced oil is light (32-35° API), while the most recent developed field, Hebron, is producing a mixture of light and intermediate API oil. The NL offshore area now produces over 192,900 bopd and output is estimated to increase to approximately 400,000 bopd when the Hebron field reaches peak production. With substantial undiscovered oil and gas resource estimates and very large prospective acreage with only little having been held under licence, the region holds great potential. This potential can be further realized in the 2023 Call for Bids Sector (Figure 1).

KEY ATTRIBUTES

- Sector totals 2,520,448 ha (22,704 km^2) and will be divided into multiple parcels.
- Water depths ranges from 500 to 3,600 m.
- Opportunity to explore an untested, unexplored Atlantic Margin region.
- Competitive fiscal regime with low political risk.
- Modern and historic seismic coverage including a recent 3D survey over the basin.
- Virtual Exploration Data Room available.
- Proximity to both North American and European markets.
- A successful bid is based solely on highest bid amount.
- For more information, visit www.cnlopb.ca

Newfoundland & Labrador CANADA

REGIONAL GEOLOGY OF THE ATLANTIC MARGIN

The Late Triassic to Early Jurassic initial rifting of Pangea created a series of NE-SW oriented intracratonic basins extending from the Gulf of Mexico to the Barents Sea. In eastern Canada, the Mesozoic rift basin chain starts 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 deepwater South Whale and shallow water Whale and Horseshoe basins. On the easternmost part of the Grand Banks sits the shallow to deepwater Carson Basin comprised of several synrift subbasins and ridges overlain by a plate margin prism of syndrift sediments.

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 into deeper water Flemish Pass and Orphan basins. Two other major extensional stages have taken place in these basins during the Late Jurassic-Early Cretaceous and late Early Cretaceous that created conditions for viable petroleum systems and of numerous hydrocarbon traps. Thick clastic intervals that preserve good to excellent porosity and permeability have been deposited during these stages. Further to the northwest, seaward of the Labrador Peninsula, are the Hawke, Holton, Hopedale, Chidley, Saglek, and Henley extensional basins, formed during the Labrador-Greenland breakup in the Cretaceous.

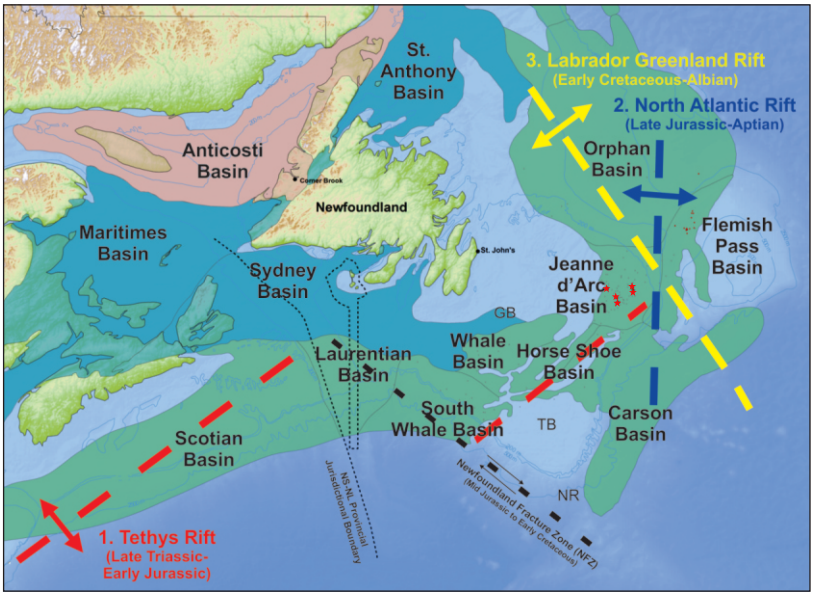


Figure 2. Regional geology of the Canadian Atlantic Margin showing main basins and phases of extension. Red stars are producing fields. GB: Grand Banks, NR: Newfoundland Ridge, TB: Tail of the Bank. Modified by Enachescu (2020).

Most of the Grand Banks' Mesozoic basins are confined, residing on continental crust. Several other basins are unconfined, located at attenuated continental margin, opposite their European conjugate basins in offshore Ireland (northeastern parts of Flemish Pass and Orphan basins) and Iberia (Carson Basin). Other Atlantic oblique and perpendicular rift branches, for instance the hydrocarbon-rich Aquitaine Basin and Viking Graben, also formed during the same series of extensional events.

BASIN NOMENCLATURE

A few recent conference and web presentations have described portions of the 2023 Call for Bids Sector as part of a deepwater, loosely defined **"Flemish Basin"** (e.g., Masotti, 2020). While we agree with the petroleum geoscience content of these presentations, we have strong reservations with the use of the Flemish Basin term for the area.

The Flemish Basin nomenclature was scarcely used in the past by a group of authors from the Geological Survey of Canada (GSC) and labeled on a very limited number of maps and illustrations, but the terminology was never used in the text of their published papers (Jansa et al., 1980; Grant and McAlpine, 1990; GSC, 2003). Several other nomenclatures such as Outer Carson Basin, Salar Basin, Deepwater Carson-Bonnition Basin, Newfoundland Basin, East Newfoundland Basin, Southeast Newfoundland Basin, etc., were also used in the past by the GSC, academia and industry for parts of the deepwater area east and southeast of Grand Banks (Keen, 1985; Keen et al., 1987; Enachescu, 1987; Grant et al., 1988; Tucholke et al.,1989; Grant and McAlpine, 1990; Enachescu, 1992; Foster and Robinson, 1993; Atkinson and Fagan, 2000; Louden, 2002; Wielens et al., 2004 and 2006; Lau et al., 2006; Tucholke and Sibuet, 2007; Karner et al., 2012; Enachescu, 2013; Enachescu and Hogg 2014; Cameron et al, 2019; Causer et al., 2020).

There are already three other well-defined structural and tectonic units offshore Newfoundland that include the name "Flemish": a) the **Flemish Pass Basin** that contains recent large oil discoveries, b) **Flemish Graben**, a little explored, smaller branch off the previous, and c) the very large undeformed continental block known as **Flemish Cap**.

The above naming is directly related to the long-time mapped bathymetric low known as the Flemish Pass adjacent to the Flemish Cap bathymetric high. **To avoid any confusion and for simplification of the area's nomenclature, we recommend the use of Carson Basin for the entire area containing synrift sediments and the post rift cover, all the way south to the slope, rise and abyssal plain in front of the Tail of The Bank (also known as South Bank High)**. This definition was also suggested by Grant et al. (1988). It is also worth mentioning that the C-NLOPB has never used the term Flemish Basin nor the Salar Basin for the offshore area southeast of Grand Banks, and industry exploration

BASIN NOMENCLATURE (continued)

teams have rarely employed this terminology. The Salar Basin, a term that appears in several early publications and is still in use in the literature, was first defined as a southeastern extension into the slope and deepwater of the intracratonic network of shelfal Late Triassic-Early Jurassic rift basins (Austin and Tucholke et al., 1989; Austin et al., 1989; Enachescu, 1992). It is clear from mapping that Carson and the adjacent Salar basins are only partially separated by a rotated basement ridge, had similar geological evolutions during Grand Banks multistage rifting and they were in communication.

Why use Carson Basin nomenclature for the entire sedimentary area southeast of the Grand Banks? Mainly because there was a common geological evolution for today's shallow, slope and deep-water regions during the synrift stages, and during the syndrift stage when Newfoundland separated from Iberia. As proven in the next section, there is a similar structural and tectonic setting between shelfal, slope and deepwater settings in front of southeastern Grand Banks. Other arguments are: a) the presence of red beds, salt and carbonates on the shelf and deepwater, b) continuation of major unconformities and c) sourcing in a NW-SE direction of postrift successions from the Grand Banks after continental breakup. However, the prerift basin becomes increasingly thinner to the south and located mostly on the slope, while the postrift successor basin increases in thickness away from the slope maintaining more or less an equal width until reaching abyssal waters. The use of "Newfoundland Basin" could be reserved for the syndrift section, containing only Late Cretaceous and Tertiary sediments on top of transitional or oceanic crust.

There is an uninterrupted continuation of geological strata and tectonic style between the 2023 Call for Bids area and the shelfal Grand Banks. Moreover, as the following sections will show, most of the seismic and chronostratigraphic correlations and petroleum geology referrals of a southeastern divergent margin are done using the on-shelf Carson Basin wells.

SOUTH EASTERN NEWFOUNDLAND AREA GEOLOGY

The Carson Basin can be divided into three distinct physiographic regions (Figures 3, 4 & 5) based on tectonic and structural setting, position on the continental margin, and composition of sedimentary fill (Enachescu, 1992 and 2013; Enachescu and Hogg, 2014):

- Shelf – The shallow water, continental shelf region was historically known as the Carson-Bonnition Basin. Located on the easternmost part of the southern Grand Banks, the shelf region is separated from the 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. Late Triassic to Quaternary successions were drilled on the shelf during the early 1970s and mid-1980s (Figure 4). While Late Jurassic Kimmeridgian and Tithonian shales of the Rankin Formation were drilled, no quality source rock was encountered at these locations. Late Jurassic source rocks are likely absent due to a lack of restricted marginal marine environment, non-deposition on basement highs, or possible erosion of source rock intervals due to the proximity to the Avalon Uplift.
- Slope and Upper Rise – The intermediate to deepwater, slope and upper rise region is historically known in academic publications 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 salt and red beds strata (Figure 5). Mapping in the area reveals large and complex structures including those separated by deep penetrating faults. The basin continues to the south along the Tail of the Bank margin with Late Jurassic to Early Cretaceous strata accumulated in several mini-basins and a Late Cretaceous to Tertiary syndrift sedimentary wedge including slope fans and lowstand deposits.

SOUTH EASTERN NEWFOUNDLAND AREA GEOLOGY (continued)

- Deepwater – The southern slopes and easternmost continental rise area where Mesozoic rocks overlie thin, hyperextended crust was referred to as the Salar Basin, Deepwater or Outer Carson Basin, or Southeast Newfoundland Basin. This region is generally located east of a fault system, which divides the deepwater section into sub-regions. The area is structurally complex with thinner extensional stage sedimentary sequence above the densely segmented basement by both margin parallel faults and NW-SE transfer faults. 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 2023 Call for Bids Sector encompasses the southern part of the Carson Basin Mesozoic extensional area, which contains Jurassic to Early Cretaceous faulted fill overlain by a thick wedge of syndrift sequences including submarine fans. Several large structural and stratigraphic traps are mapped over stretched Lower Paleozoic and Precambrian basement and over transitional crust (Figures 3, 4 & 5).

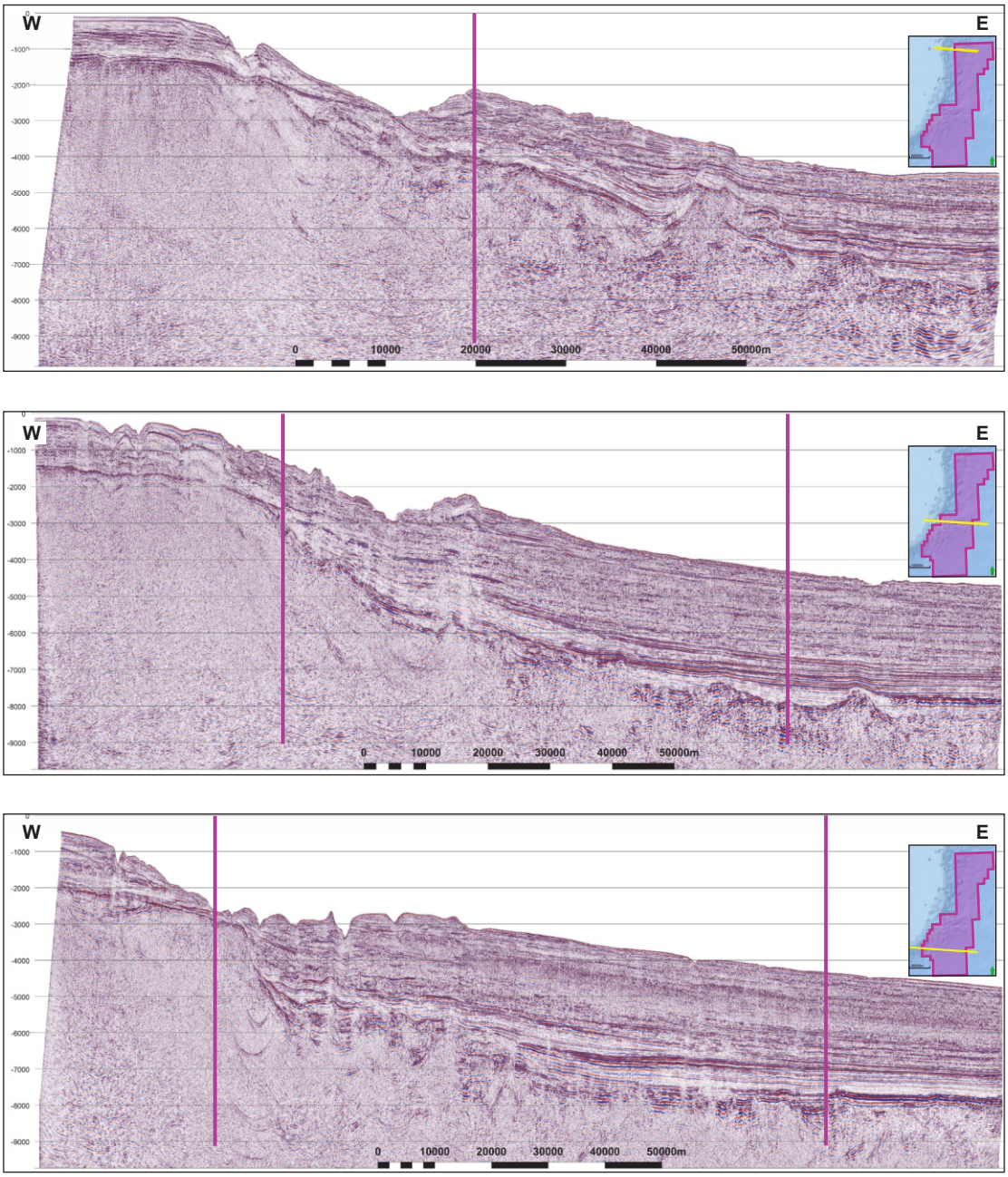


Figure 3. Representative dip seismic lines through the northern, central and southern part of Sector NL02-SEN. The uninterpreted sections show the tectonic structural setting of the shelf, slope and deepwater Carson Basin. The purple lines mark the sector boundary.

SOUTH EASTERN NEWFOUNDLAND AREA GEOLOGY (continued)

The Mesozoic-rifted Carson Basin represents the easternmost arm of the intracratonic 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, which was followed by an internal shallow and deepening sea stage interspersed with continental and marginal marine sedimentation. The Canadian 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. Hence, 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.

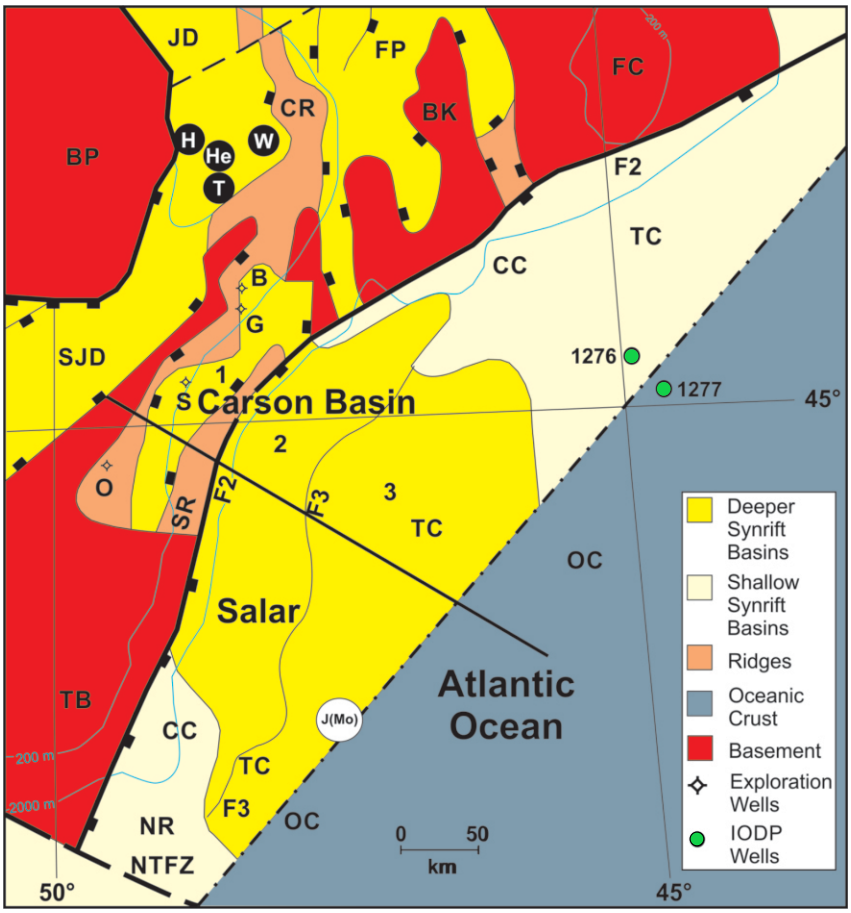


Figure 4. Location of Carson Basin in relation to other Grand Banks shelf and slope basins and subbasins (modified after Enachescu, 1988, 1992 and 2013; Enachescu and Hogg, 2014). Black line shows th location of the schematic geological cross-section in Figure 5. Subdivisions are marked as 1) On-shelf 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 = Bonnition 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 Knolland, 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, W = White Rose and He = Hebron. The black line shows the location of the generalized geological cross-section illustrated in Figure 5.

CARSON BASIN GEOLOGY

The Carson area is separated from the Jeanne d'Arc Basin by the Morgiana Anticlinorium, from the South Jeanne d'Arc Basin by a thin basement ridge, and from the Flemish Pass Basin by a series of NNE-SSW oriented basement highs and narrow sedimentary troughs. A major fault marks the basin's northwestern boundary. Towards the south, the Carson Basin's sedimentary area is separated from the South Grand Banks Basin by a basement high called Tail of the Bank (TB), which extends southward all the way to the Newfoundland Ridge (NR) (Figures 1 to 5).

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 clastic sequence. A predominantly shaly sequence including several basin slope and floor sandstone intervals (fans?) characterize the Late Cretaceous to Cenozoic 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 Bonnition and Carson Basins, respectively. The northern shelf region contains thicker Mesozoic fill, while the southern area has suffered pronounced erosion during the mid-Late Cretaceous. Early Cretaceous sediments including sandstone reservoirs are generally preserved to the north and eroded towards the south. In the south, the Late Cretaceous and Tertiary strata form a thick clastic wedge.

The northern deepwater sedimentary depocenter includes Triassic salt and thick Jurassic to Cretaceous successions. Under the slope, the pre-rift section drops off significantly with rotated blocks and 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. Salt features are missing in the southern part of the basin but above the red beds and basement, salt beds may exist intercalated with shale and other evaporites.

There is one exploration licence active in the central part of Carson Basin (Figure 1). The less explored southern region of the basin, which is located in front of Tail of the Banks has a distinct structural setting. This portion of the 2023 Call for Bids is characterized by basement rotated blocks with intervening mini-basins containing synrift deposits preserved under a thick postrift sedimentary cover. The postrift stage succession contains numerous possibilities of stratigraphic trapping up-slope and at the contact with the Newfoundland Ridge.

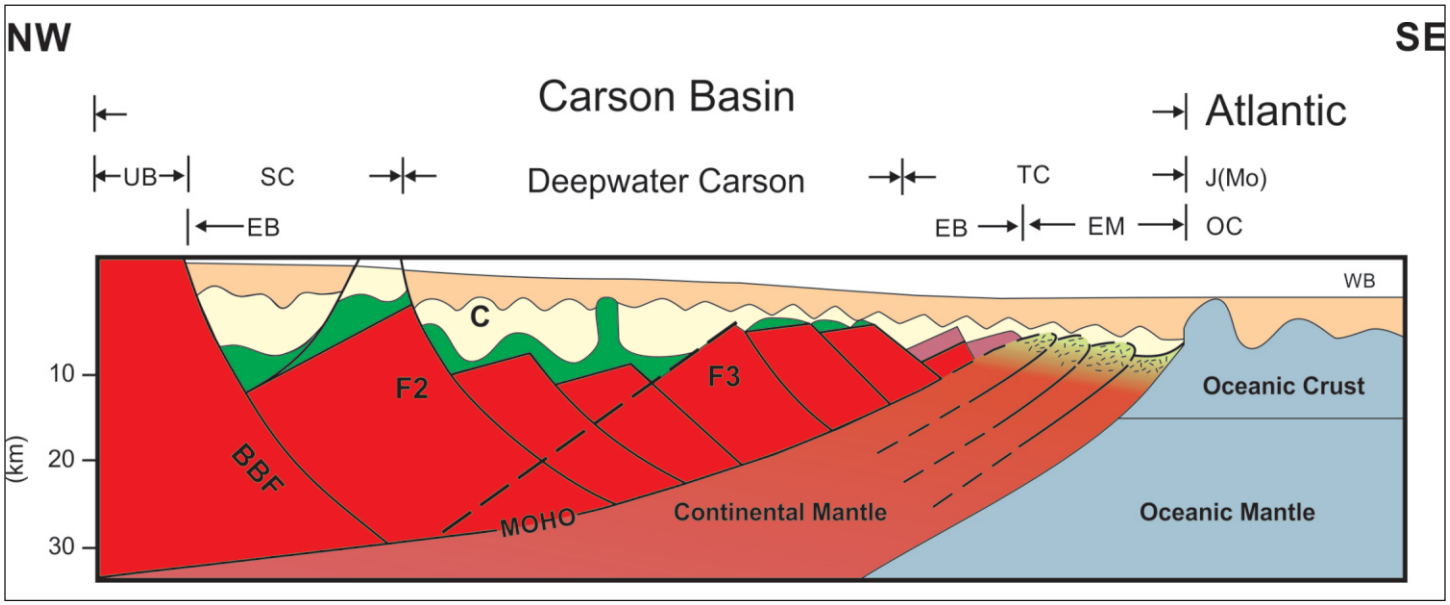


Figure 5. Schematic geological cross-section of the Carson Basin (modified after Enachescu, 1992). Location of cross-section is given in Figure 4. Abbreviations are: UB = unextended basement; BBF = basin bounding fault, WB = water bottom, EM = exhumed mantle, EB = extended basement; C = end of extensional 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.

CARSON BASIN GEOLOGY (continued)

Basin fill deformation is due to extension, salt movement (mostly in the northern basin) and detachment sliding. Inversion was a late-stage event and appears to be only a secondary mechanism for trap formation. Diapiric salt is more widespread on the slope and in the deepwater of the northern basin. In the southern part of the basin, diapiric salt is absent. Seismic reflection and potential field data show an en echelon fault system, ridges and mini-basins trending approximately parallel to the shelf break's mega fault and offset by transfer faults.

Clastic deposits sourced from a number of Paleozoic and Precambrian basement terrains surrounding the basin should be present within deltaic episodes deposited during the Late Jurassic to Early Cretaceous. Likewise, postrift coarse clastics sourced from incised canyons on the Grand Banks are deposited on the faulted slope and upper rise in front of the Tail of the Bank forming an impressive passive margin sedimentary wedge.

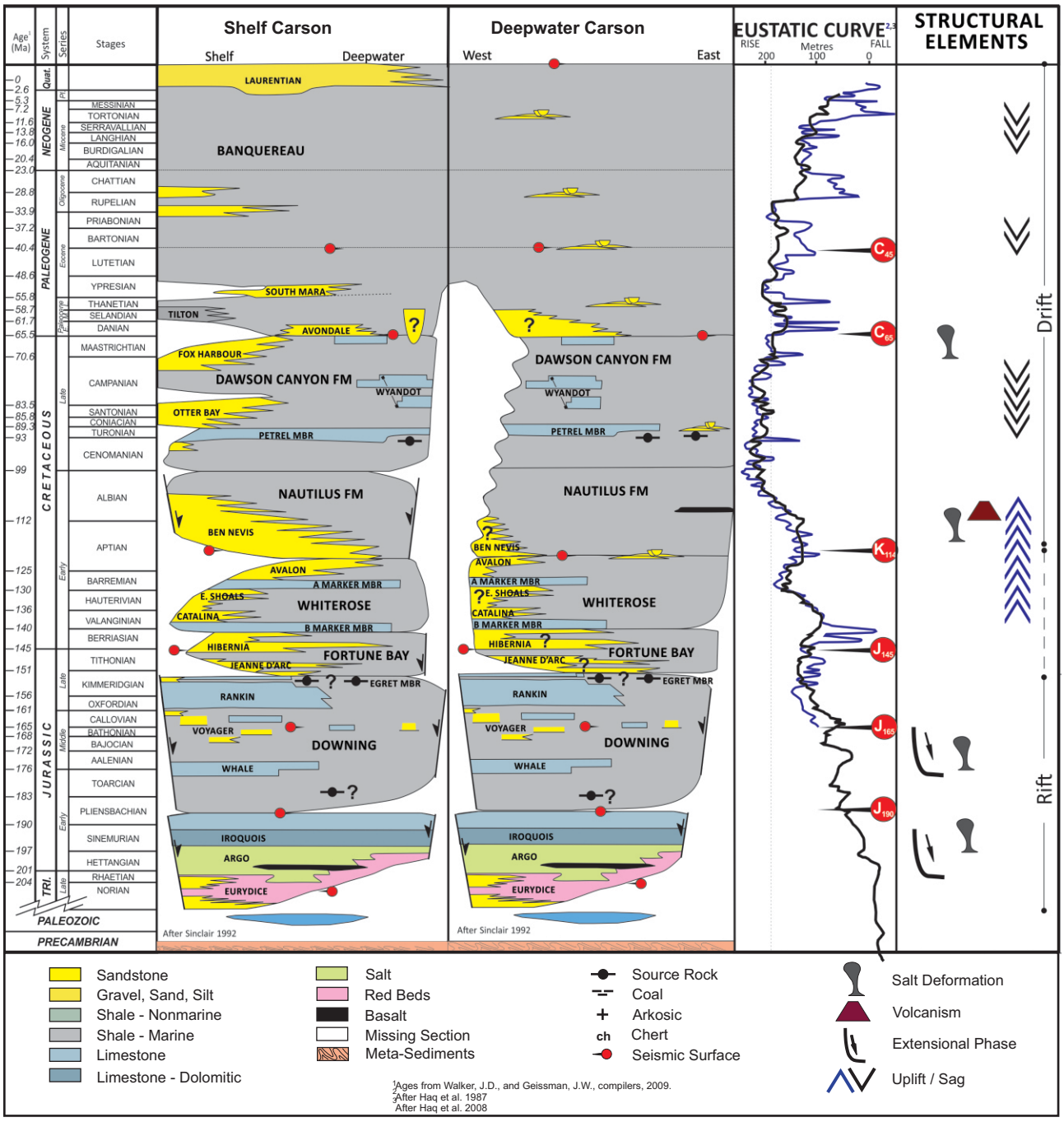


Figure 6. Stratigraphic chart for shelf and deepwater Carson Basin. Modified from Nalcor Energy (2018).

PETROLEUM GEOLOGY: OVERVIEW

The slope and deepwater portion of the Carson Basin included in the 2023 Call for Bids Sector is part of Newfoundland's Mesozoic network of basins, which have preserved a significant Late Jurassic to 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 that helped to preserve a potentially hydrocarbon-bearing synrift sequence. Due to proximity and similar tectonic evolution, it is anticipated that the Call for Bids area will contain similar oil prone petroleum systems (anchored by Kimmeridgian Egret Member or Tithonian source rocks) as those proven in the Jeanne d'Arc and Flemish Pass Basins. Additionally, Cretaceous source rock beds may have reached maturation within the thick sedimentary wedge shown by seismic data (Figure 3).

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 was deposited eastward of a major basin-bounding fault and consists of a structured synrift succession of coarse and fine-grained clastics (red beds), evaporites, and various carbonate lithologies ranging in age from Late Triassic to Middle Jurassic (Figure 6). These in turn are overlain by a Late Jurassic to late Early 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 between Grand Banks and Iberia. The postrift sedimentary sequence contains numerous intervals that have positive seismic AVO responses for the presence of hydrocarbons (Mitchell et al, 2019; BeicipFranlab, 2019).

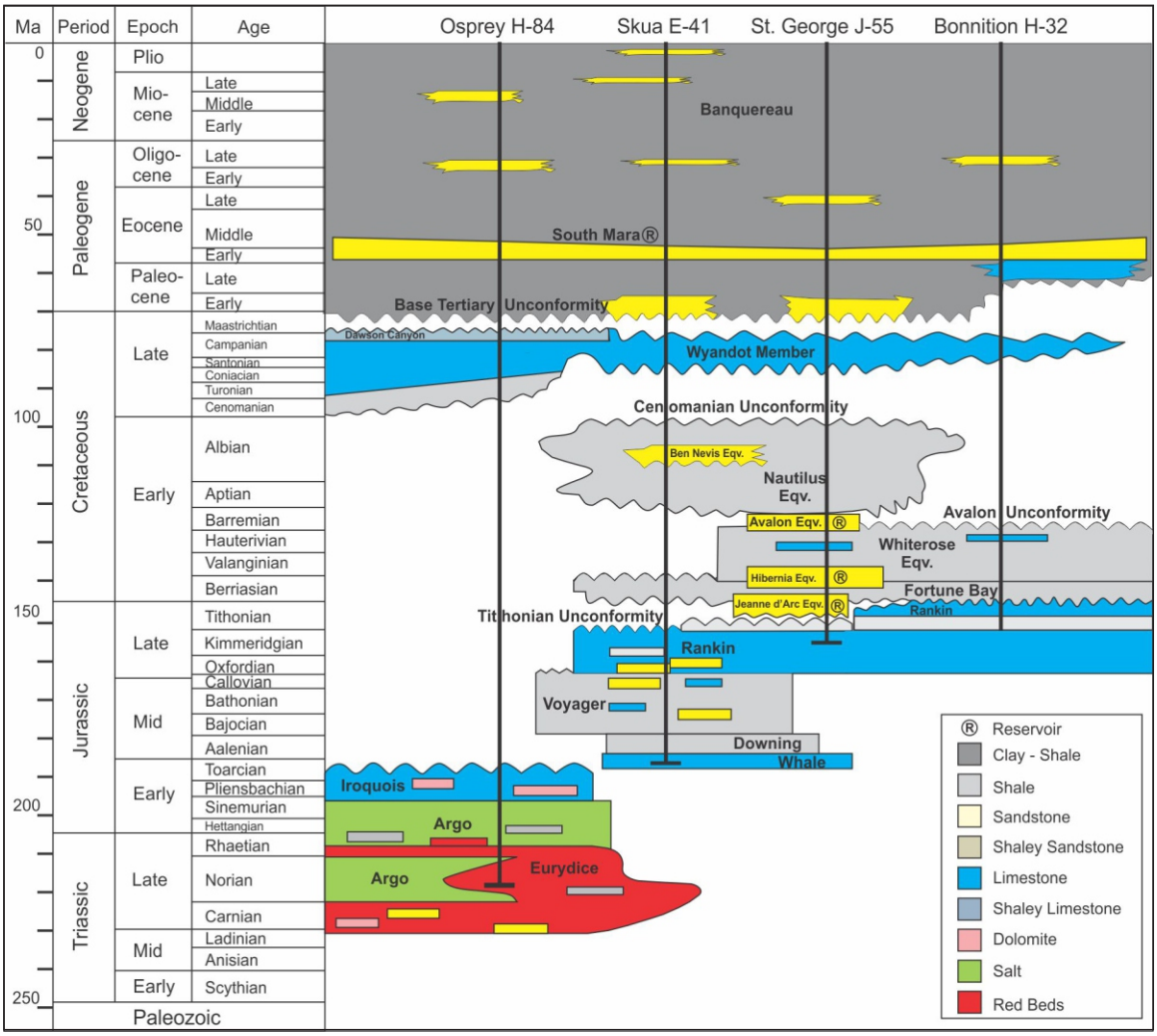


Figure 7. Chronostratigraphy of shelfal wells drilled to date in the Carson Basin using biostratigraphic data (Hogg & Enachescu, 2020).

PETROLEUM GEOLOGY: OVERVIEW (continued)

As no specific lithostratigraphic chart exists for the Carson Basin, a modified Jeanne d'Arc chart can be adopted (Figure 6) and used in conjunction with the bio- and lithostratigraphic well correlation diagram built along the four shelfal exploration wells (Figure 7). With no wells drilled in the Sector, it is possible though, that the deepwater stratigraphy of southern Carson Basin is more like the stratigraphy of the Nova Scotian Basin (e.g. CNSOPB Geocience Open File Report 2018002MF and Figure 8 in this report). The Narwhal and Lewis Hill wells drilled in the neighboring South Whale Basin have intersected sedimentary successions including reservoir sandstone and carbonate intervals typical for the Nova Scotia shelf and slope.

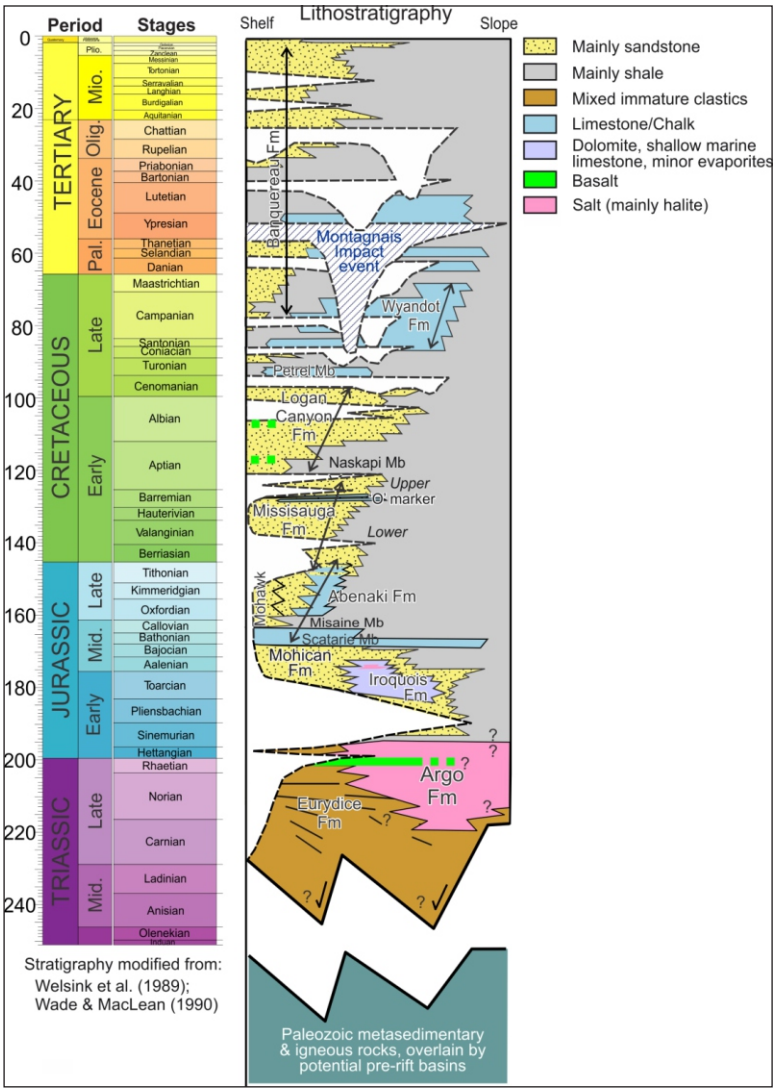


Figure 8. Scotian Basin stratigraphic chart (C-NSOPB, 2021).

The early rift fill consists of a red bed sequence (Eurydice Formation) that may contain terrigenous (lacustrine?) source and reservoir rocks. This was followed by deposition of the Late Triassic-Early Jurassic Argo salt, coeval with salt deposited in other Grand Banks and Lusitania basins. The salt became mobile starting in the Jurassic, creating intrusions and salt-induced structures in the overlying sedimentary section of the northern basin. In tandem with salt deposition, it is possible that high total organic carbon (TOC) marine shales were also deposited either as intercalations or capping the halite. Only a stratified salt succession may exist in the southern part of the basin where the Call for Bids is located.

To date, the only producing petroleum system on the Grand Banks and environs that is feeding hydrocarbons into Late Jurassic to Tertiary sandstone reservoirs is sourced by the Late Jurassic marine shales known as the Egret Member of the Rankin Formation in the Jeanne d'Arc Basin or the Tithonian in the Flemish Pass Basin. Although the eastern Grand Banks slope and deepwater regions have not been drilled, oil prone source rocks such as the Egret member shale, should be present in several Late Jurassic intervals identified on seismic reflection data. 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. In the nearby Flemish Pass, a proven source rock is the Tithonian shale of the informally known Bodhran Formation (e.g. Haynes et al., 2014). These Late Jurassic shales are world-class source rocks with high TOC and HI values. These source rocks are expected to be present in the intermediate and deepwater portions of the Carson Basin.

PETROLEUM GEOLOGY: OVERVIEW (continued)

The potential for other source rocks is recognized in the Paleozoic, Early and mid-Jurassic, Early and Late Cretaceous, and Early Tertiary. High TOC Albian and Cenomanian-Turonian black shale intervals were cored during Ocean Drilling Program (ODP) Leg 210, Site 1276), located south of the Flemish Cap and approximately 250-300 km northeast of the 2023 Call for Bids area (Figure 1). Also, the Integrated Ocean Drilling Program (IODP) hole at 1407 of Expedition 342 (Figure 1) located approximately 100 km south of the Call for Bids Sector, on the Newfoundland Ridge, recovered Cenomanian-Turonian organic black shale.

Reservoir rocks are present in all stages of basin development. Producing and wet clastic reservoirs with porosities in the 18-25% range and permeabilities between 100 md and 3 D range are associated mostly with the Grand Banks synrift stages (Figure 6). Quality sandstone reservoirs were encountered on the shelf in several wells located near the NW boundary of the basin (Figures 1 & 7). High quality reservoirs have been drilled by several wells in the South Whale Basin located southwest of Tail of the Bank. The Late Barremian sandstones intersected in the Lewis Hill G-85 well have porosities in the range of 20-22% (Figure 9).

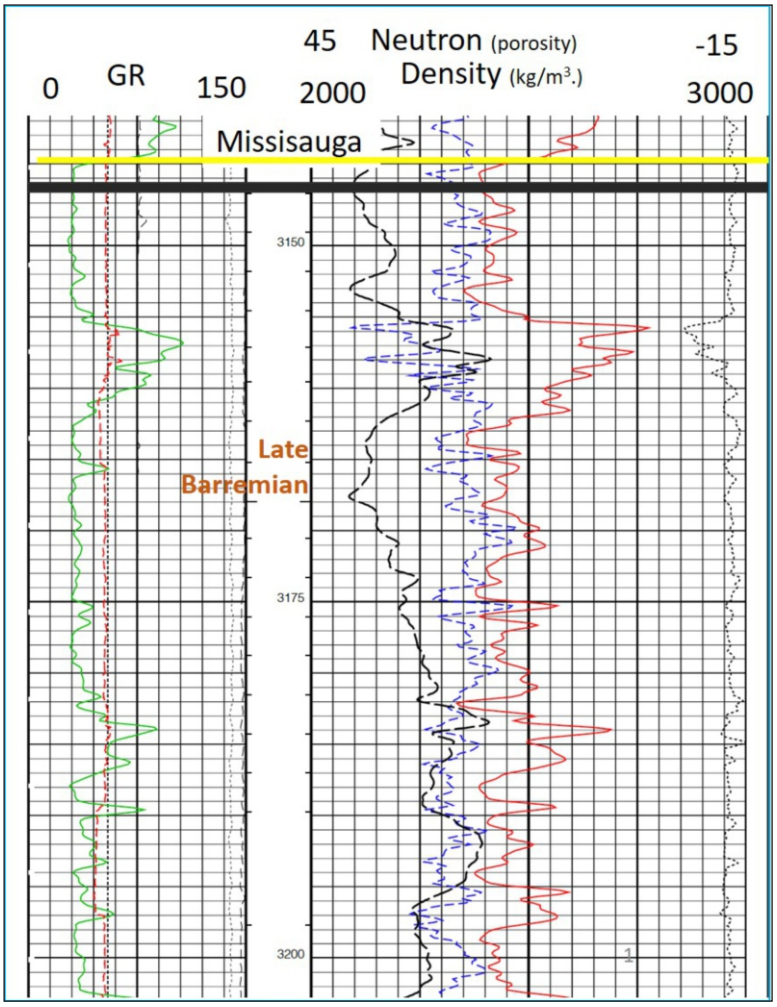


Figure 9. Mississauga (Late Barremian) good quality reservoir in Lewis Hill G-85 well located in South Whale Basin. Logs are: Gamma in Green, Neutron Porosity in blue and Density in red. Sands are well developed, clean, (neutron-density approach) 20-22% porosity; filter cake indicating permeability shown throughout the Mississauga.

A multitude of structural and combination hydrocarbon traps were formed in the basin during the repeated extensional and minor transtensional episodes. Prolonged salt halokinesis also produced a number of large traps in the northern part of the Carson Basin. Several possible salt anticlines are present in the Sector. Basement rotated blocks and potentially sealed mini-basins are mapped in the Sector area. Stratigraphic traps are associated with slope formation, basin tilting, and fan development in front of the slope. These large stratigraphic traps have a significant presence on the slope and deepwater of the Sector area.

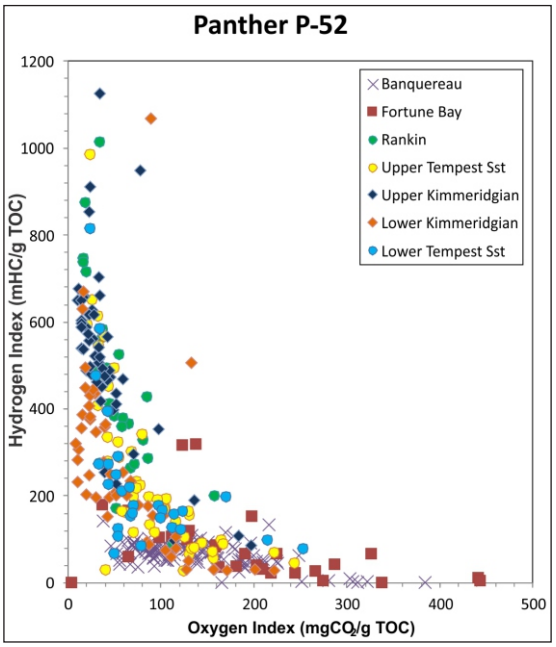
PETROLEUM GEOLOGY: SOURCE ROCKS

During the Late Jurassic, the area experienced, in places, a restricted sea setting similar to the Jeanne d'Arc and Flemish Pass basins, leading potentially to the deposition of significant thicknesses of oil generating source rock. This Late Jurassic time interval is responsible for sourcing all the current oil fields in the Jeanne d'Arc Basin.

The most significant source rock offshore Newfoundland is the Egret Member of the Kimmeridgian Rankin Formation or its equivalent (Figure 6). 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 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 encountered more than 500 m of Tithonian and Kimmeridgian Rankin Formation marine source rock (Figures 1, 10, 11 & 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%.



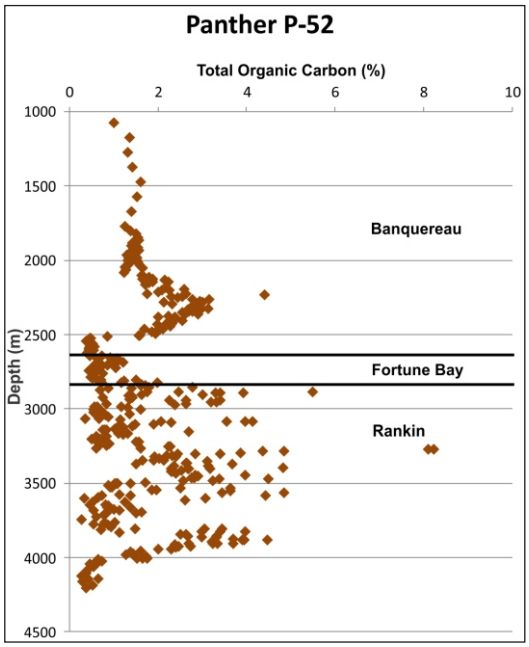


Figure 10 (left). Panther P-52 modified van Krevelen graph. Data from Geological Survey of Canada (2012).

Figure 11 (right). Panther P-52 total organic content versus depth. Data from Geological Survey of Canada (2012).

Tithonian (Jurassic) source rocks first identified at the 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%. Most recent offshore Newfoundland wells drilled east of Bay du Nord, Cappahyden K-67/K-67Z and Cambriol G-92, encountered hydrocarbons, probably sourced from Tithonian or Kimmeridgian shales. Although yet unproven, there is potential for these source rocks to be present further south in the 2023 Call for Bids area.

Numerous regional seismic sections show that the Central Ridge, Flemish Pass Basin and parts of Carson 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.

Late Jurassic shales that generated the giant Hibernia field on the Grand Banks of Newfoundland, are the main source rocks in other hydrocarbon prolific Atlantic Margin basins, including the Viking Graben, Aquitaine Basin and Norwegian Sea.

PETROLEUM GEOLOGY: SOURCE ROCKS (continued)

Well	Spud date	Well Status	Location	Water Depth (m)	Total Depth (MD) (m)	TD Formation	Reservoir	Source Rock	Shows
Aster C-93A	December, 2014	Abandoned	South Flemish Pass Basin	560	3,678	Jurassic	Hibernia Sandstone Equivalent	Eroded/NDE	Fluorescence only
IODP SITE U1407	July, 2012	Scientific Research	~100 km South of Tail of the Bank	3,075	3,394	Mid Cretaceous	No Reservoir Observed	OAE-2 Cenomanian/Turonian, TOC 4-17%, Immature	
Lewis Hill G-85	July, 2005	Abandoned	South Whale Basin	100	3,218	Mississauga	Logan Canyon & Mississauga	Verrill Canyon, Barremian, Type 3 early Generation window below 3,000m	No shows observed
ODP 210-1276	July, 2003	Scientific Research	South of Flemish Cap	4,549	6,297	Mid Cretaceous	No Reservoir Observed	OAE-2 Cenomanian/Turonian OAE-1b Lower Albian	
Narwhal F-99	July, 1987	Abandoned	South Whale Basin	1,577	4,585	Verill Canyon/Basalt	Missisauga (Hauterivian)	Teriary oil prone, immature, Early Cretaceous/L. Jurassic gas prone early maturity	No shows observed
Golconda C-64	October, 1986	Abandoned	Outer Ridge Complex	173	4,451	Downing Formation - Whale Member	Paleocene Sandstone	Not Present - Eroded	Minor gas show
St. George J-55	April, 1986	Abandoned	Carson Basin - Shelf	105	4,100	Rankin	Avalon, Hibernia, Jeanne d'Arc	Not Present/NDE	No shows observed
Panther P-52	January, 1985	Abandoned	Outer Ridge Complex	191	4,203	Rankin	Tempest Sandstone	Tithonian & Kimmeridgian	Trace Oil Stain and Fluorescence
Skua E-41	August, 1974	Abandoned	Carson Basin - Shelf	83	3,238	Downing Formation - Whale Member	Banquereau, Fox Harbour, Ben Nevis	Not Present	Minor Gas Show
Bonnition H-32	December, 1973	Abandoned	Carson Basin - Shelf	102	3,048	Rankin	Banquereau	Not Present	No shows observed
Osprey H-84	July, 1973	Abandoned	Carson Basin - Shelf	61	3,474	Eurydice	Banquereau & South Mara	Not Present	Minor Show
Jaeger A-49	August, 1972	Abandoned	South Grand Banks/Avalon Uplift	56	938	Cenomanian Unconformity/Basement	No Reservoir Observed	Not Present	No shows observed

Table 1. Exploration wells drilled near Call for Bids Sector in South Eastern Newfoundland land tenure region. Eq = Equivalent, Fm = formation, Mbr = member, OAE = Oceanic anoxic event, Sst = sandstone, TOC = total organic carbon, NDE = Not Deep Enough. Data from C-NLOPB.

Seismic mapping in the Carson Basin and specifically in the Sector area indicates that Late Jurassic source rock are present and are widespread. Based on seismic interpretation and well correlation, a Late Jurassic section is indicated in the synrift section and especially within the mini-basins created between the tilted basement blocks (Figures 14 & 15). East of Tail of the Bank, the presence of Late Jurassic strata is harder to infer from seismic data under the thick postrift sedimentary cover. However, there is a possibility of their preservation in the proximal grabens in front of the complex basin bounding fault zone.

The Mesozoic section in the Call for Bids area may be underlain by Carboniferous, gas generating paludal and coaly source beds similar to those observed further west in the Maritimes Basin. Cretaceous and Early Tertiary shales have shown several intervals with high TOC in industry and research wells, however they are yet unproven as source rocks. They may become a hydrocarbon contributor when adequately covered by thick drift stage sediments such is the case in the Sector area.

SCIENTIFIC WELLS: CRETACEOUS SOURCE ROCK POTENTIAL

In 2003, the ODP drilled two sites south of the Flemish Cap and 350 km northeast of the NL02-SEN Sector (Figures 1 & 4). 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 intersected a fine-grained succession including high TOC and HI Cretaceous black shales and thin, coarse-grained turbidite reservoirs (Figure 12) and Marsaglia et al., 2004 & 2007; Hiscott, 2007; Hiscott et al., 2008; Enachescu, 2014).

In ODP Leg 210, the Cretaceous Turonian to lower Albian-uppermost Aptian(?) shale succession (Unit 5) 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 (Figure 13). 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 & Mayers, 2007; Mayers & 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 & Mayers, 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 (Mayers & 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 document (Figures 3, 14, and 15).

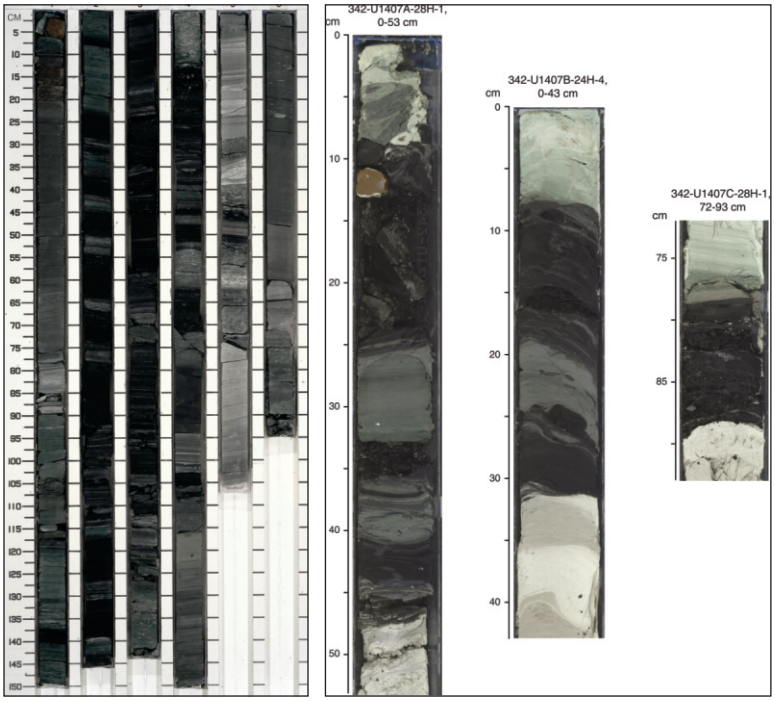


Figure 12 (left). ODP Leg 210, Site 1276 core photo of Cenomanian-Turonian shales. From Tucholke et al. (2004).

Figure 13 (right). IODP Expedition 342, Site U1407 core photo of Cenomanian-Turonian shales. From Norris et al. (2014).

SCIENTIFIC WELLS: CRETACEOUS SOURCE ROCK POTENTIAL (continued)

In 2012, the IODP cored potential Cretaceous source rock on the Newfoundland Ridge, during Expedition 342, Site U1407 (Figures 1 & 13). A riser-less, continuous coring, drilling system was deployed during E-342. The drilling system and schedule limited the total thickness of sediments that could be penetrated. Due to these limitations, U1407 was located on a ridge as the targeted Eocene sediments were assumed to be shallower on the ridge than in the basin below. Even given these limitations, U1407 TD'd in mid-Cretaceous sediments at 309 m below seafloor.

Black shale was found at 230 m below seafloor in Cenomanian/Turonian sediments. The black shales were approximately 10 m thick and consisted of thinly bedded organic black shales in nanofossil chalk. The black shale sediments were immature with a Tmax of less than 415º C. The kerogen was primarily Type II and TOC ranged between 4% and 17%. As you leave the ridge top, the basin thickens considerably, and if 1407 been drilled 50 km westward it certainly would have encountered much thicker sediments and perhaps it would have found mature sediments.

PETROLEUM GEOLOGY: RESERVOIR AND SEAL

Based on regional seismic interpretations, it appears the Jeanne d'Arc and Flemish Pass Basins were in communication with the Carson Basin area during the Late Jurassic to Early Cretaceous. There is potential for both good reservoir rocks and seals throughout this interval.

Therefore, the Call for Bids Sector area is also expected to contain reservoirs with good porosity and 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 that were drilled on the shelf encountered a number of Jurassic to Early Cretaceous sand intervals exhibiting fair to excellent porosity (Table 1 & Figure 7). 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. Channels and large paleovalleys are seen on southern Grand Banks seismic lines eroding into granite and granodiorite batholites. Throughout the Jurassic and Cretaceous this area was uplifted and erosional material was carried down slope into the basins.

From an exploration perspective, reservoir sands can be envisioned in a number of stratigraphic and structural settings. In the Sector 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 postrift 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. Postrift Petrel and Wyandot limestone as well as syndrift Banquereau formation fine clastics form basin-wide seals.

PETROLEUM GEOLOGY: TRAP STYLES

A series of significant structural, stratigraphic, and combination traps are identified on seismic data in the area (Figures 14 & 15).

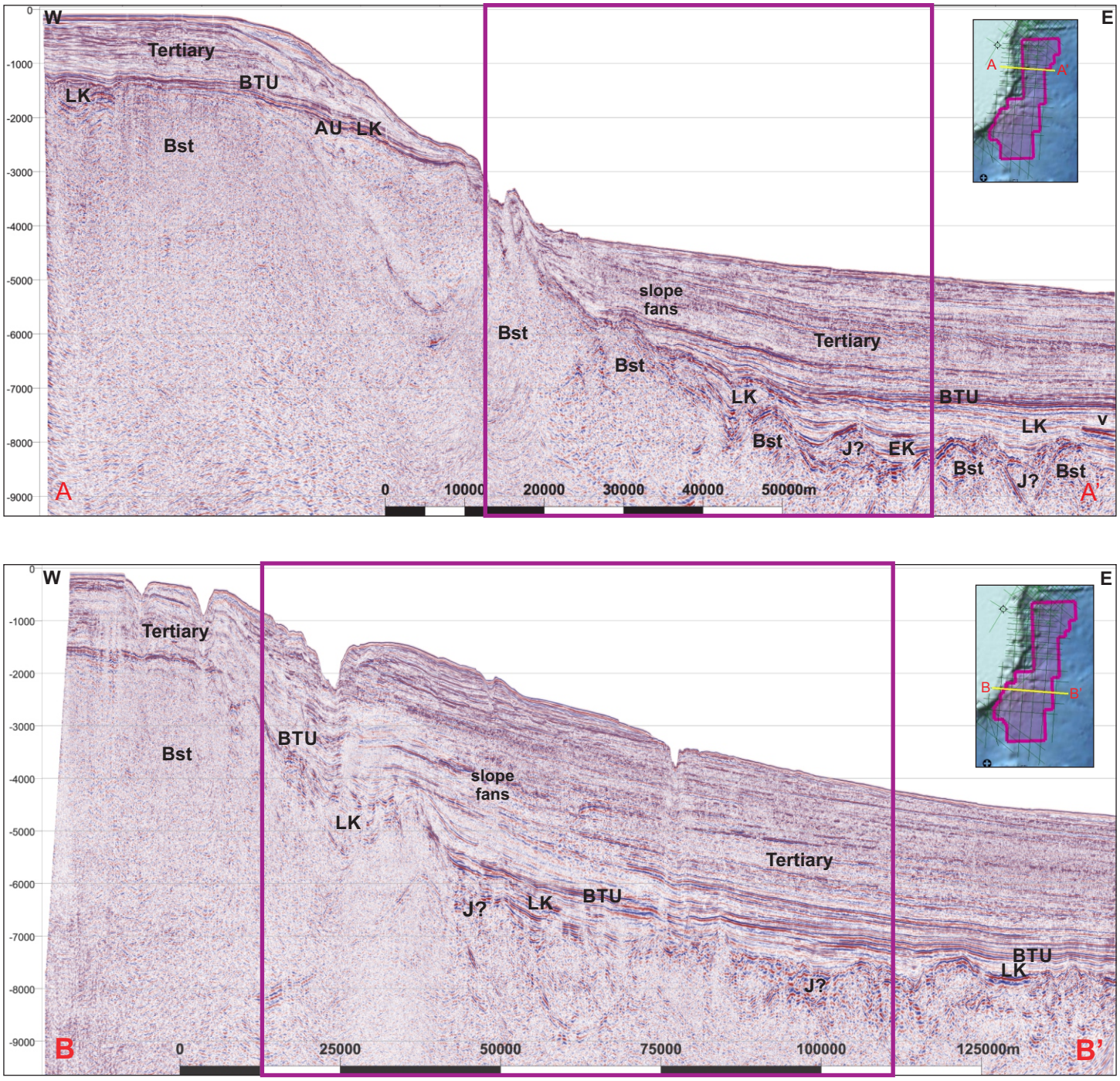


Figure 14. Non-privileged seismic lines through the 2023 Call for Bids Sector. Purple boxes mark the Sector boundary. Bst - Basement, BTU - Base Tertiary Unconformity, EK - Early Cretaceous, LK - Late Cretaceous, J - Jurassic, v - volcanics. Data from the C-NLOPB.

PETROLEUM GEOLOGY: TRAP STYLES (continued)

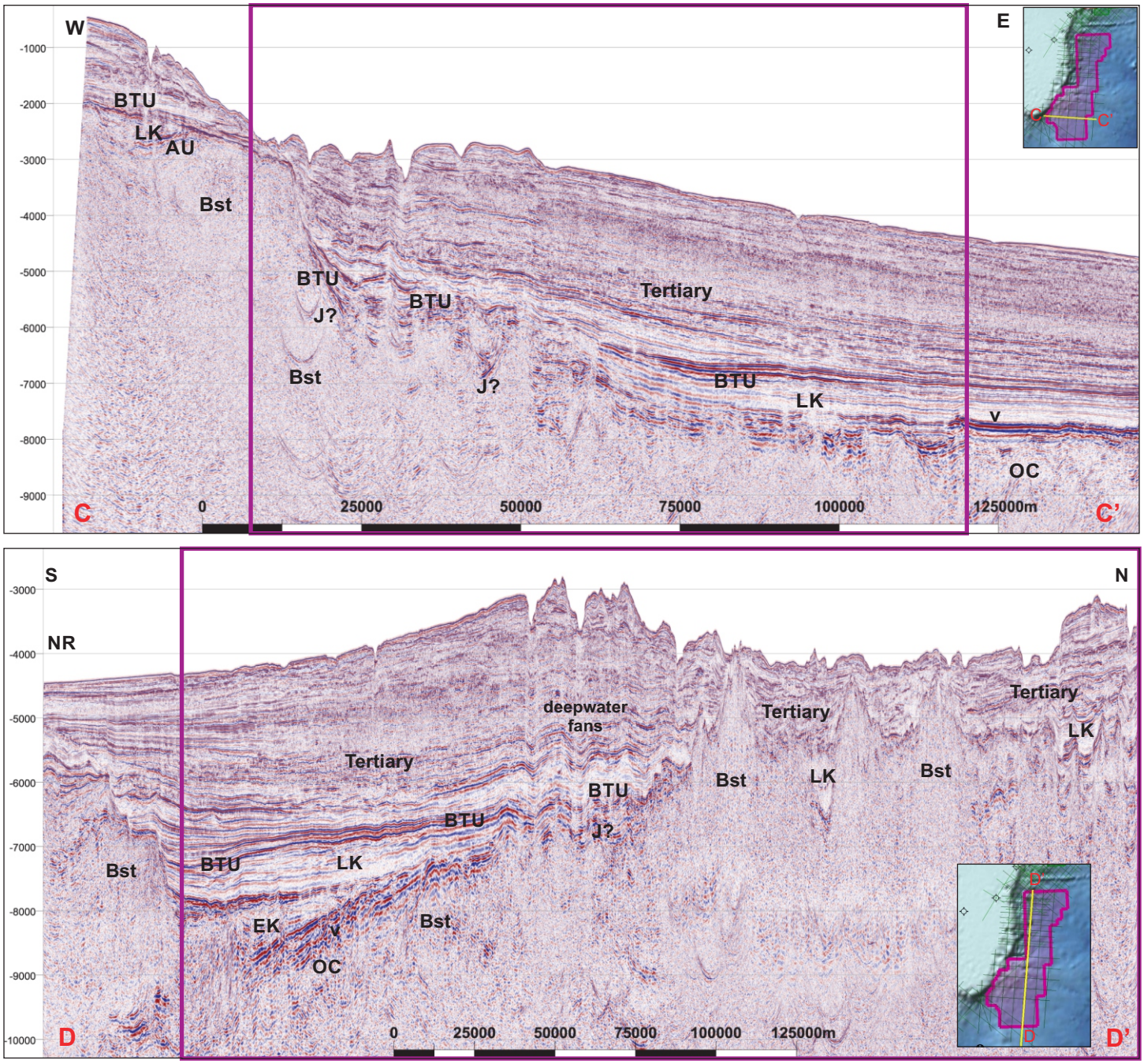


Figure 15. Non-privileged seismic lines through the 2023 Call for Bids Sector. Purple boxes mark the Sector boundary. Bst - Basement, BTU - Base Tertiary Unconformity, EK - Early Cretaceous, LK - Late Cretaceous, J - Jurassic, NR - Newfoundland Ridge, OC - oceanic crust, v - volcanics. Data from the C-NLOPB and available on a subscription-basis in the Department of Industry, Energy and Technology's Exploration Data Room at www.hydrocarbonassets.com.

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 shelf, quality source rocks were never deposited or were eroded. The best potential for hydrocarbon pools will most likely be within the extended region on the slope and deepwater within the synrift sequence. The seismic lines crossing the Sector can easily be tied to the continuous cored hole and seismic lines collected at site 1276, Leg 2010. The Early to Late Cretaceous sequence identified at Site 1276 containing the "black shale" (Type II) and turbidite intervals is bounded by major seismic markers that can be regionally mapped.

PETROLEUM GEOLOGY: TRAP STYLES (continued)

The northern part of the Sector contains numerous rotated fault blocks and several salt anticlines. Regional seismic interpretation in the Grand Banks and particularly in the Tail of the Bank region show the prerift basement as a mega-anticline with its axis-oriented NW-SE. Erosion of synrift sediments that included quality sandstone reservoirs in the southern branches of the Grand Banks rift systems may have supplied reworked sandstones into the slope and deepwater regions. As shown in the Lewis Hill and Narwal wells, long-lasting erosion of the Tail of the Bank has supplied coarse clastics during the Late Jurassic-Early Cretaceous synrift stage and during the postrift stage both southwesterly into South Whale Basin, and southeasterly into the deepwater Carson Basin.

Seismic interpretation of historic and modern seismic data shows the existence of a deep basin in front of a large crustal detachment fault approximately following the shelf break. Seismic mapping shows that structural traps are present throughout the Sector. The larger petroleum traps are closer to the basin bounding fault. Their formation can be attributed to multi-stage rifting and breakup along the North Atlantic margin, leading to extensional and gravity faulting, block rotation, compartmentalization, minor transtension, inversion, differential subsidence, and regional tilting. Trap styles include but are not limited to rotated / tilted fault blocks, rollover anticlines related to extensional faulting, compression modified extensional anticlines, elongated horst and graben structures involving basement or restricted to synrift sequences, and drape features over basement highs / rotated fault blocks. Significant structural complexity is created by both down-to-basin and down-to-margin normal fault systems affecting the basement, creating traps such as tilted blocks, horsts, and elongated ridges. Several oblique normal faults and transfer faults have also been mapped, creating further structural traps. Closer to the magmatic Newfoundland Ridge, other structural and combination traps are created by various intrusions formed during thinning of the crust and Cretaceous breakup.

Numerous possible stratigraphic traps are present on the slope. 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. It is worth mentioning that this play has never been targeted by exploration offshore.

PETROLEUM GEOLOGY: PLAYS AND RISKS

The main hydrocarbon play expected to be successful in the South Carson Basin/East Tail of the Bank 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 these sources,
- Reservoired most likely in synrift Late Jurassic or Early Cretaceous sandstones, and
- Trapped in extensional/salt related faulted anticlines with faults providing source migration conduits.

This structural play has provided giant oil accumulations in the Jeanne d'Arc Basin and proved significant discoveries at Mizzen, Harpoon, Bay du Nord, and most recently Cappahayden and Cambriol wells 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 rock presence and maturity. The Late Cretaceous-Tertiary sequence is thick enough to provide sedimentary cover necessary for maturation and preservation.

There is also some risk of finding lower API oils present in shallower Late Cretaceous-Tertiary 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. However, excellent quality oils (low sulfur, 30-35° API) have been found in the majority of offshore Newfoundland’s large discoveries. As the Sector area can be considered a true exploration frontier, we cannot underestimate the possible occurrence of other undrilled play types, such as slope fans fed by Cretaceous or early Tertiary source rocks, that have been successful on other Atlantic margins.

PETROLEUM GEOLOGY SUMMARY

The South Carson Basin/East Tail of the Bank area represents a high risk, high reward petroleum play on the Newfoundland Atlantic Margin. The offered Sector is located in an underexplored, undrilled area but in relative proximity to proven prolific hydrocarbon basins where the giant oil accumulations of the Jeanne d'Arc Basin are producing and the significant discoveries in the Flemish Pass Basin at Bay du Nord, Harpoon, Baccalieu and possibly others are slated for future development.

Multiple trap types are conceptualized in the Sector area: large structural fault-bounded closures and mini-basins with synrift beds, Cretaceous fans, Tertiary lowstand submarine fans, and channel complexes. Some of the exploration locations mapped contain multiple stacked targets. The trap will likely be sourced from world-class Late Jurassic source rock with little or no contribution from other possible source beds in the Cretaceous.

Conventional plays that are expected to be successful in the Carson Basin, with analogues to the adjacent Jeanne d'Arc Basin, will likely contain sandstones that are time equivalent to Late Jurassic Jeanne d'Arc, Early Cretaceous Hibernia and late Early Cretaceous Avalon and Ben Nevis reservoirs. On the other hand, the late synrift and early postrift beds may contain sandstone reservoirs analogous to Nova Scotia Early Cretaceous Mississauga and Logan Canyon reservoirs as identified in the Narwhal, Lewis Hill and other wells drilled in the south Grand Banks.

Late Cretaceous-Early Tertiary lowstand clastics are expected to have significant play potential on the basin's slope and upper rise. The main play risk is considered to be charge, notably source rock presence and maturity.

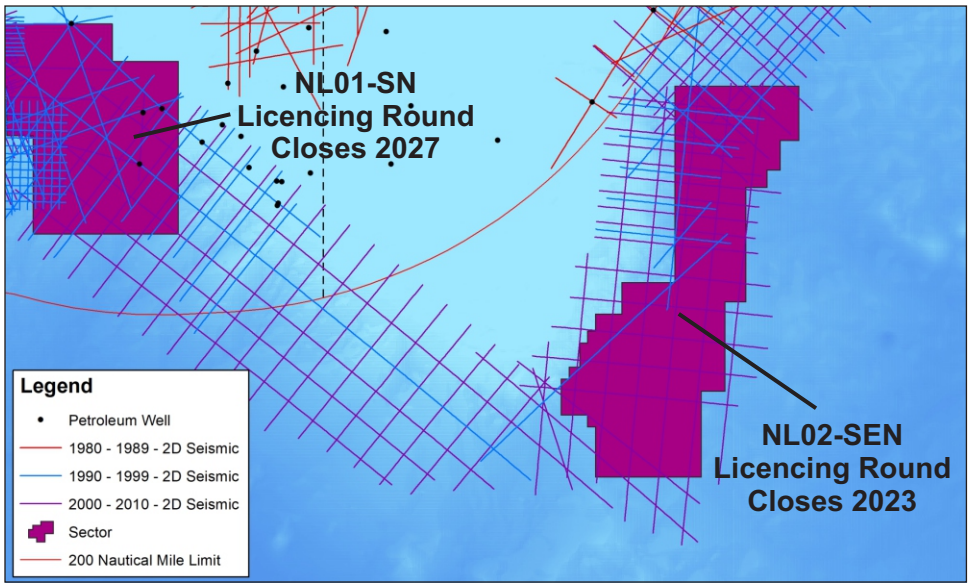


Figure 16. Non-privileged seismic data coverage in Carson Basin area over 2023 Call for Bids Sector. Data courtesy of C-NLOPB. Data also available in the Department of Industry, Energy and Industry's virtual Exploration Data Room.

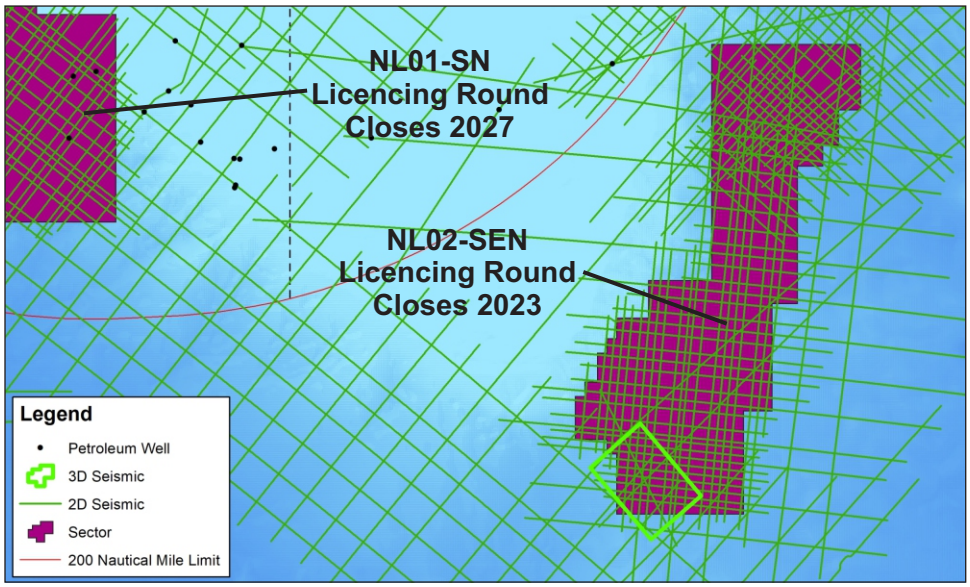


Figure 17. Privileged 2D and 3D seismic data available for purchase in Carson Basin area over 2023 Call for Bids Sector. Data courtesy of Nalcor Energy.

SEISMIC DATA

Good to excellent 2D seismic grids, both modern and historic, are available for the area (Figures 16 &17). Excellent modern seismic coverage exists over several extensional structures located on the slope including a 3D survey recorded during the 2020 acquisition season.

Seismic data quality is good to excellent in most of the area but deteriorates at the shelf break due to the presence of multiples, in steep slope areas and at the faulted and fragmented basement.

Seismic mapping (e.g. Figure 18) is possible using high quality regional seismic markers such as carbonate intervals within clastics, sandstone within shales, and several widespread unconformities. Good local markers and detachment surfaces within the postrift sedimentary wedge can also be easily mapped. Main and secondary faults are readily traceable.

Seismic ties to shelf exploration wells, to the deepwater ODP research wells and to the Grand Banks and Flemish Pass oil discoveries are possible using the long regional lines covering the shelf and deepwater and crossing significant wells.

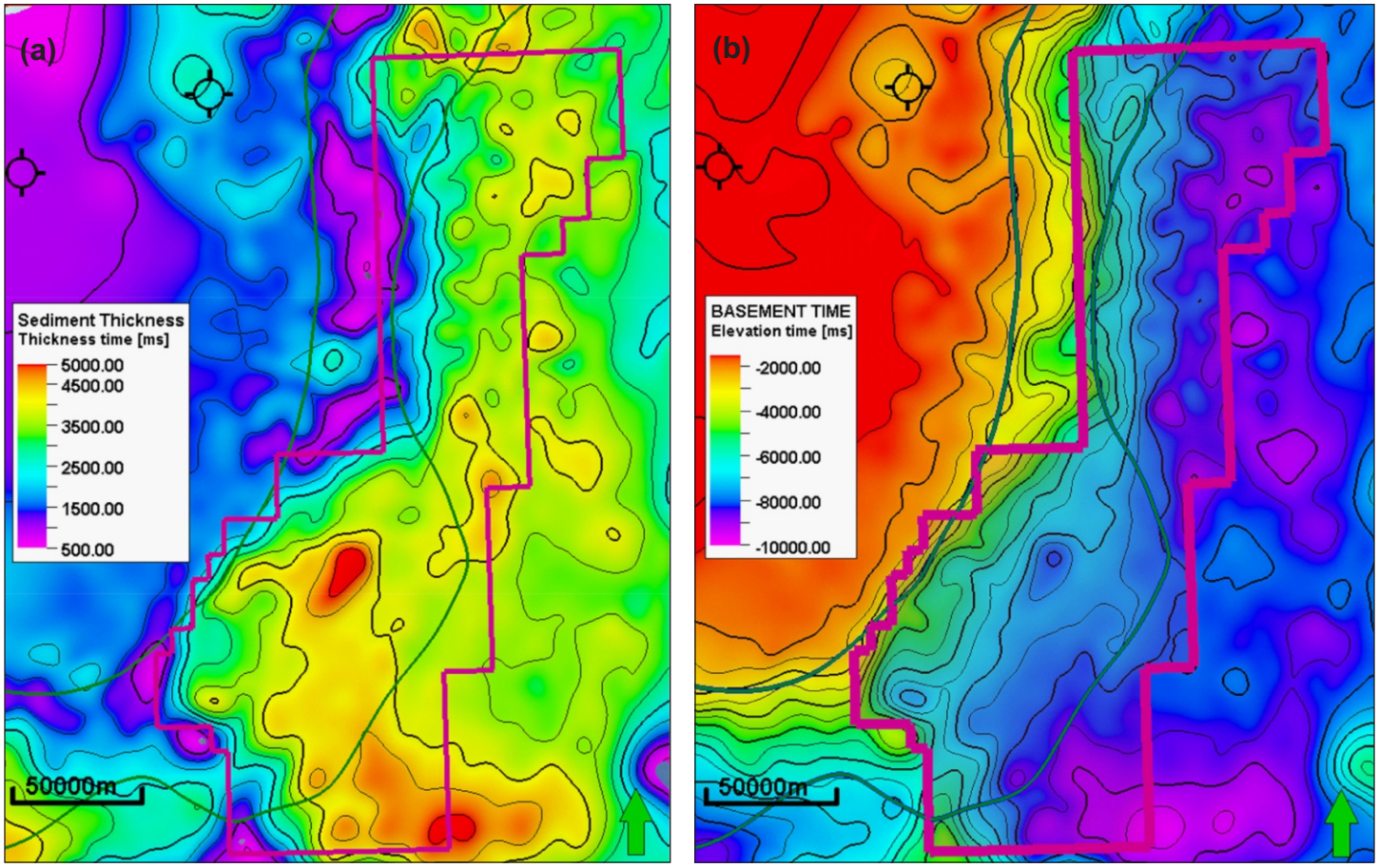


Figure 18. Time structure maps showing the (a) Water bottom to base Mesozoic sediment time thickness and (b) Base Mesozoic time structure. Contour interval is 500 ms. Green lines mark approximate 1,000 m (left) and 3,000 m water depths (right). Purple polygon marks the 2023 Call for Bids Sector.

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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 Industry, Energy and Technology** is responsible for providing information, 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 Petroleum Geoscience Division from previously published studies, papers, and recent in-house geologic and geophysics work. Edited and reviewed by Michael Enachescu and John Hogg.

Author: Petroleum Geoscience Division

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