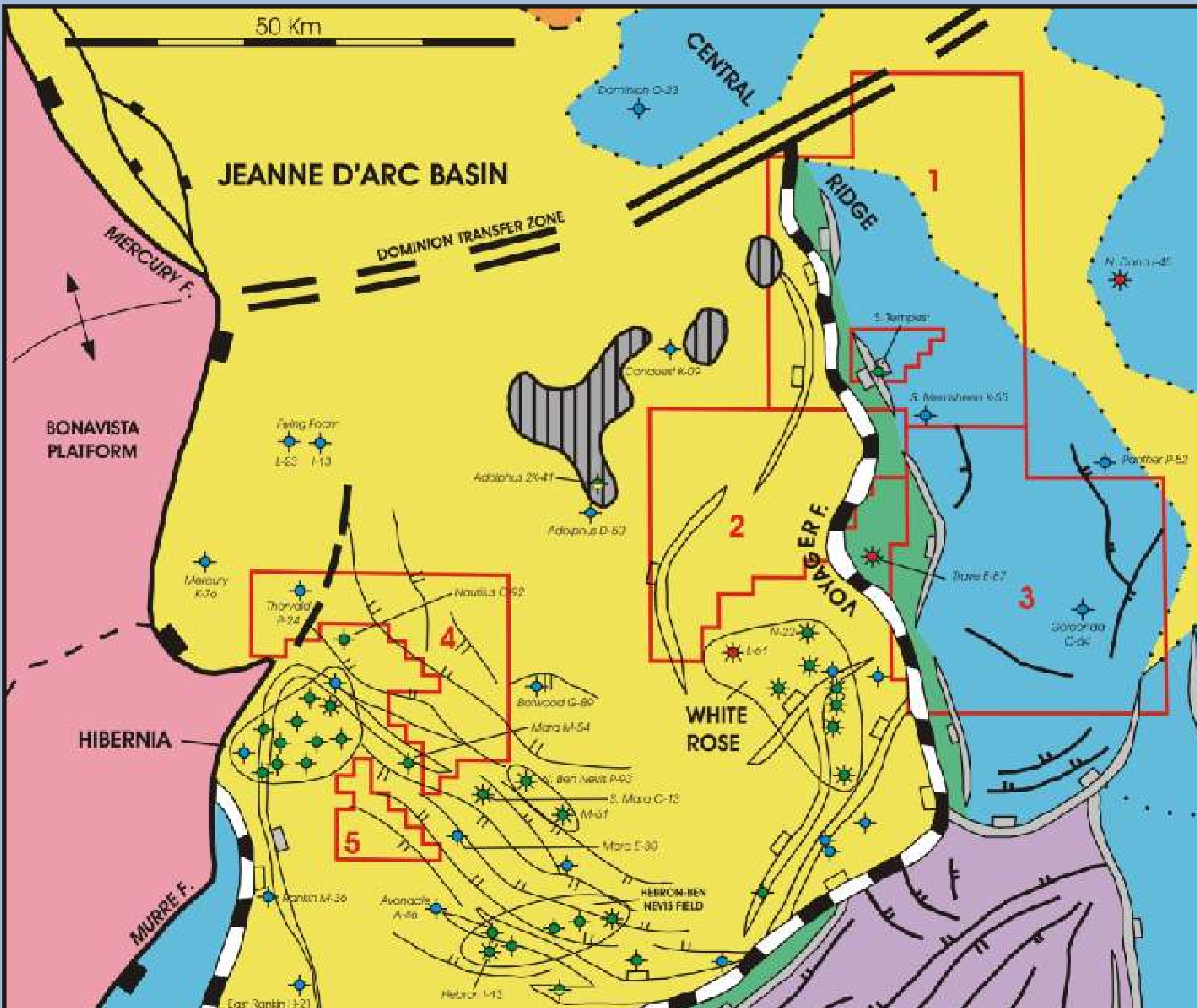
GOVERNMENT OF
NEWFOUNDLAND
AND LABRADOR

Department of Natural Resources



Newfoundland and Labrador

Call for Bids NF04-01

Report 2004-01

September 2004

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September 2004

Foreword

The Government of Newfoundland and Labrador Department of Natural Resources has prepared this report to provide general information on the geology and petroleum potential of the Grand Banks area, and specific information on five land parcels being offered in the Canada-Newfoundland Offshore Petroleum Board's (C-NOPB) Call for Bids NF04-01, which closes November 17, 2004.

Detailed information on the Call for Bids can be found at the C-NOPB's website:
http://www.cnopb.nfnet.com/

Acknowledgements
The report was written by Dr. Michael Enachescu of Memorial University and Phonse Fagan of the Department of Natural Resources (DNR). Larry Hicks of the DNR provided information on relevant wells, and Dave Hawkins (DNR) provided technical support and carried out a detailed review. Access to public domain digital seismic data was provided by the C-NOPB. Thanks are extended to Trevor Bennett of the C-NOPB for copying digital seismic data, and to Larry Nolan of the DNR Mines Branch who assisted in loading the data. Graphics were prepared by student, Mark Janes and the cover was designed by Donna Taylor of DNR. The Department of Natural Resources is grateful to Paul Einarsson and Sam Nader of Geophysical Services Inc., who provided access to proprietary seismic data over the land parcels. The report should be quoted as *Enachescu and Fagan, 2004. Newfoundland and Labrador Call for Bids NF04-01, Government of Newfoundland and Labrador, Department of Natural Resources, 35p, 20 figures*; *also available at* http://www.gov.nl.ca/mines&en/oil/call_for_bids_nf04_01.stm

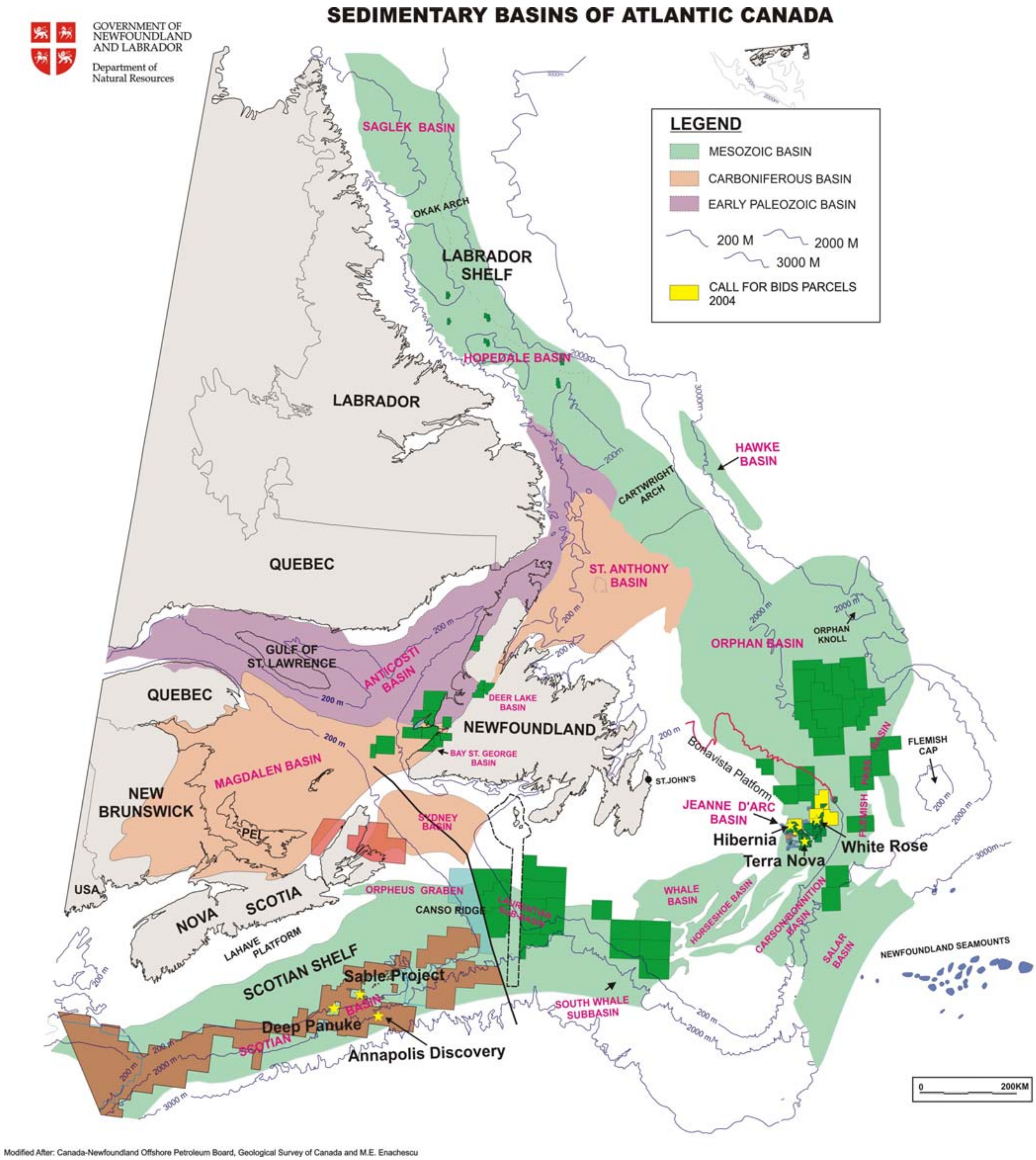


Figure 1

Atlantic Canada basins maps with land holdings. Call for Bids NF04-01 parcels shown in yellow.

INTRODUCTION

With production levels at approximately 350,000 barrels per day from two producing fields and a third field approaching first oil, the Canadian Province of Newfoundland and Labrador is emerging as a significant player on the international oil and gas stage. The primary exploration focus during the past twenty-five years has been within the proven reservoirs and shallow waters of the Jeanne d'Arc Basin, but recent landsales and the locations of seismic surveys demonstrate that the industry is ready to expand its efforts into vast untested areas, including the essentially unexplored plays along the Grand Banks continental slope and within intracratonic deep water basins such as the Orphan Basin. The best evidence of the oil industry's increased interest in this area came via a recent landsale in the Orphan Basin in which a consortium that includes ExxonMobil, Chevron Canada and Imperial Oil bid C$673[1] million (US$505 million) in work commitments for eight parcels lying in water depths ranging from two to three thousand metres. This was by far the most successful landsale in the history of the area, and included a record bid of $251 million for one parcel.

Although the first offshore drilling occurred in 1966 only 131 exploration wells have been drilled to date on the entire continental shelf around the Province of Newfoundland and Labrador. The area of jurisdiction includes about 1.6 million square km of which about half is judged to have petroleum potential. The offshore drilling has been almost entirely confined to Mesozoic age basins, although petroleum potential is also recognized in several Paleozoic basins, which in some areas are known to underlie the Mesozoic sediments. Figure 1 is a regional basins map showing the current land holdings.

The area of hydrocarbon potential is vast, and the well density is very low. By comparison consider that more than 15,000 exploration wells have been drilled in the Gulf of Mexico and more than 3500 in the North Sea. While exploration on the Newfoundland and Labrador continental shelf has been constrained by the realities of harsher climatic conditions than some other areas, it has long been proven that seismic and drilling operations can be successfully executed. It has more recently been demonstrated that profitable field development can be accomplished, as the two producing fields are estimated to be breaking even in the US$9.00 - $10.00 per barrel range. Operating costs were recently reported by the operators to be US$1.50 per barrel for the Hibernia field and US$1.89 per barrel for the Terra Nova field.

Meeting Environmental Challenges. The areas lying to the east of the island of Newfoundland and off the Labrador coast are subject to sporadic and seasonal iceberg traffic which must be taken into account when exploring or producing within this part of the Province's offshore. Although the first line of defense against icebergs is to tow them by standby vessels, the production systems have also been designed to handle unlikely situations where towing is not possible or not effective.

Thus far, the industry has met the iceberg challenge in two different ways. The Hibernia field (865 million barrels recoverable in 80 metres of water) was developed by a gravity based system constructed with a protective icewall (Figure 2).

[1] Unless otherwise stated all moneys are quoted in Canadian dollars. At the time of writing (September 2004) one Canadian dollar is worth approximately US$.75.

PRODUCTION RATES HAVE INCREASED
Production from the Hibernia oil field has increased from 150,000 bopd in its startup year of 1997 to 220,000 bopd in 2004. Production at Terra Nova, which started at 100,000 bopd in 2002, has increased to 150,000 bopd. The White Rose field will provide an additional 92,000 bopd in late 2005 – early 2006.

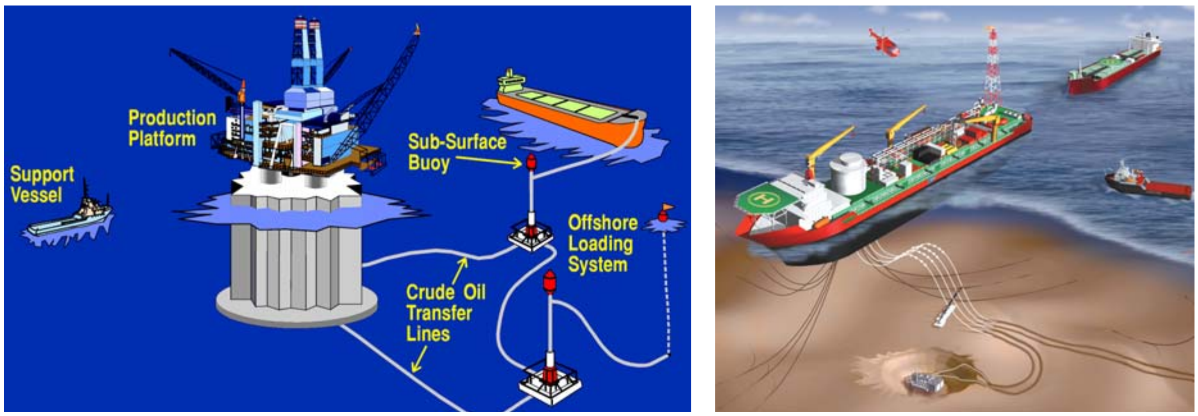


Figure 2
Schematics of Hibernia (left) and Terra Nova (right) oil production systems. Hibernia schematic courtesy of C-NOPB/HMDC, and Terra Nova courtesy of Petro-Canada.

The Terra Nova field (354 million barrels recoverable in 93 metres of water) was developed using a Floating Production Storage and Offloading system (FPSO) for which the subsea wellheads were placed in ten-metre-deep "glory holes" which were dredged into the seabed to protect them from iceberg scour. The FPSO is designed for rapid disconnect in the event of an encroaching iceberg, and the flowlines can be flushed to prevent the release of hydrocarbons into the environment. Flowlines are partially buried and in the unlikely event of scouring damage to a line, it would be replaced. The Province's third development, White Rose, is also being developed using an FPSO, with first oil anticipated in early 2006.

Recognizing the environmental challenges, the area is still considered attractive by the exploring multinationals, large independents and Canadian companies for several reasons, including: the proven petroleum resources, the high flow rates (e.g. 56,000 barrels per day from one zone within a Hibernia well), the large size of potential discoveries, the vast area of unexplored and under-explored basins, the low political risk to investment, and proximity to one of the largest energy markets in the world.

As can be expected in a modern democracy like Canada, all offshore operations are required to be carried out in a safe and environmentally responsible manner. In fact, the government of Canada and of the Province of Newfoundland and Labrador, welcome companies from around the world who wish to explore and develop these offshore basins in a safe and responsible manner. The Newfoundland and Labrador offshore area (along with offshore Nova Scotia) is one of the few offshore areas in North America, outside the Gulf of Mexico, that has active petroleum exploration and development. This activity is likely to increase in the next decade with decreasing production of conventional oil and gas from traditional onshore basins, ever increasing North American and worldwide demand, and a long-term outlook of higher oil and gas prices.

POLITICAL STABILITY AND SECURITY OF SUPPLY

Canada is a very stable democracy with a firm place among the Group of Seven industrialized countries, a member of all major international organizations and a participant in the North American Free Trade Agreement. It is the fifth largest energy producer after the United States, Russia, China, and Saudi Arabia, is a net oil and gas exporter, and the number one supplier of energy to the United States. During 2003 the US imported more oil and petroleum products from Canada than any other country, and obtained almost 90% of its natural gas imports from Canada.

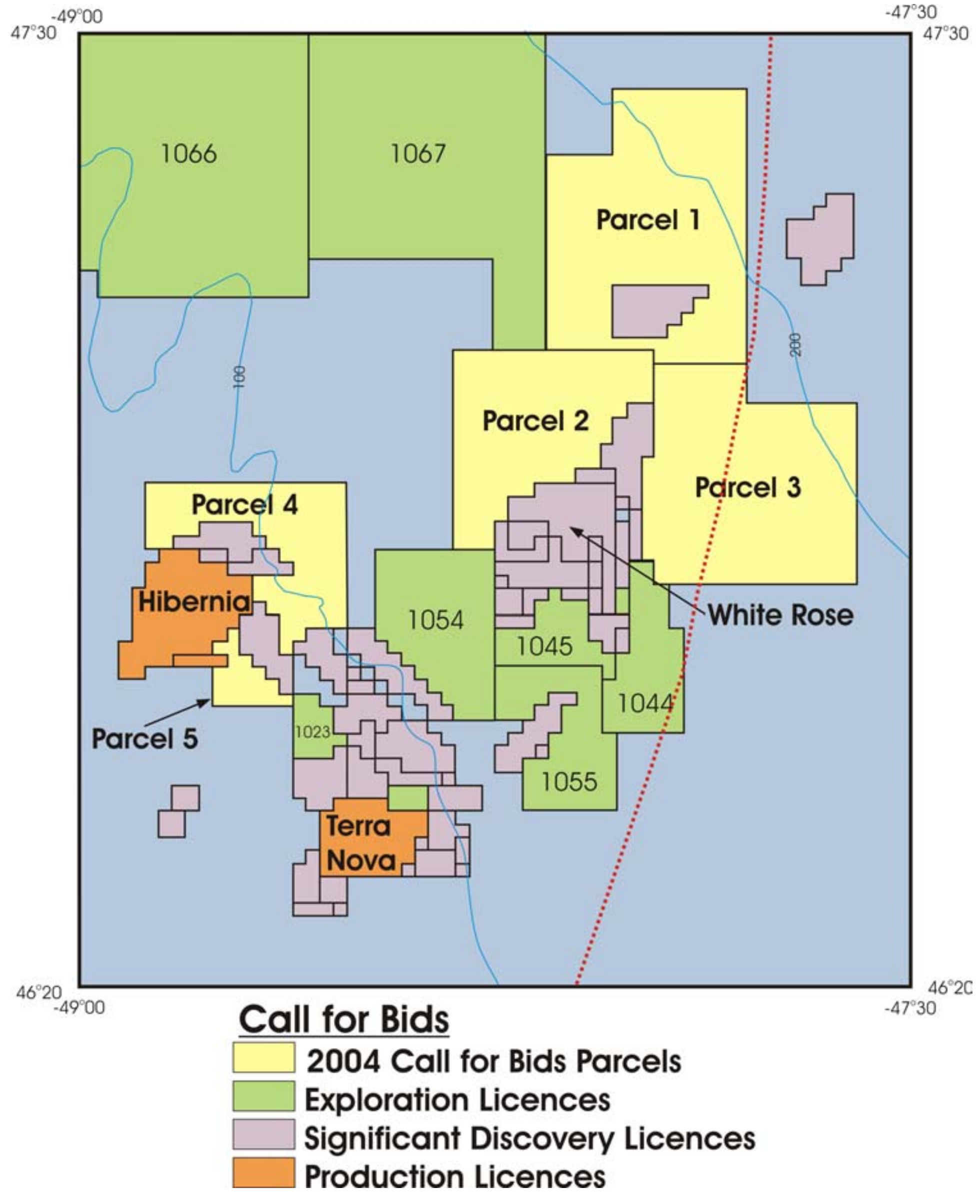
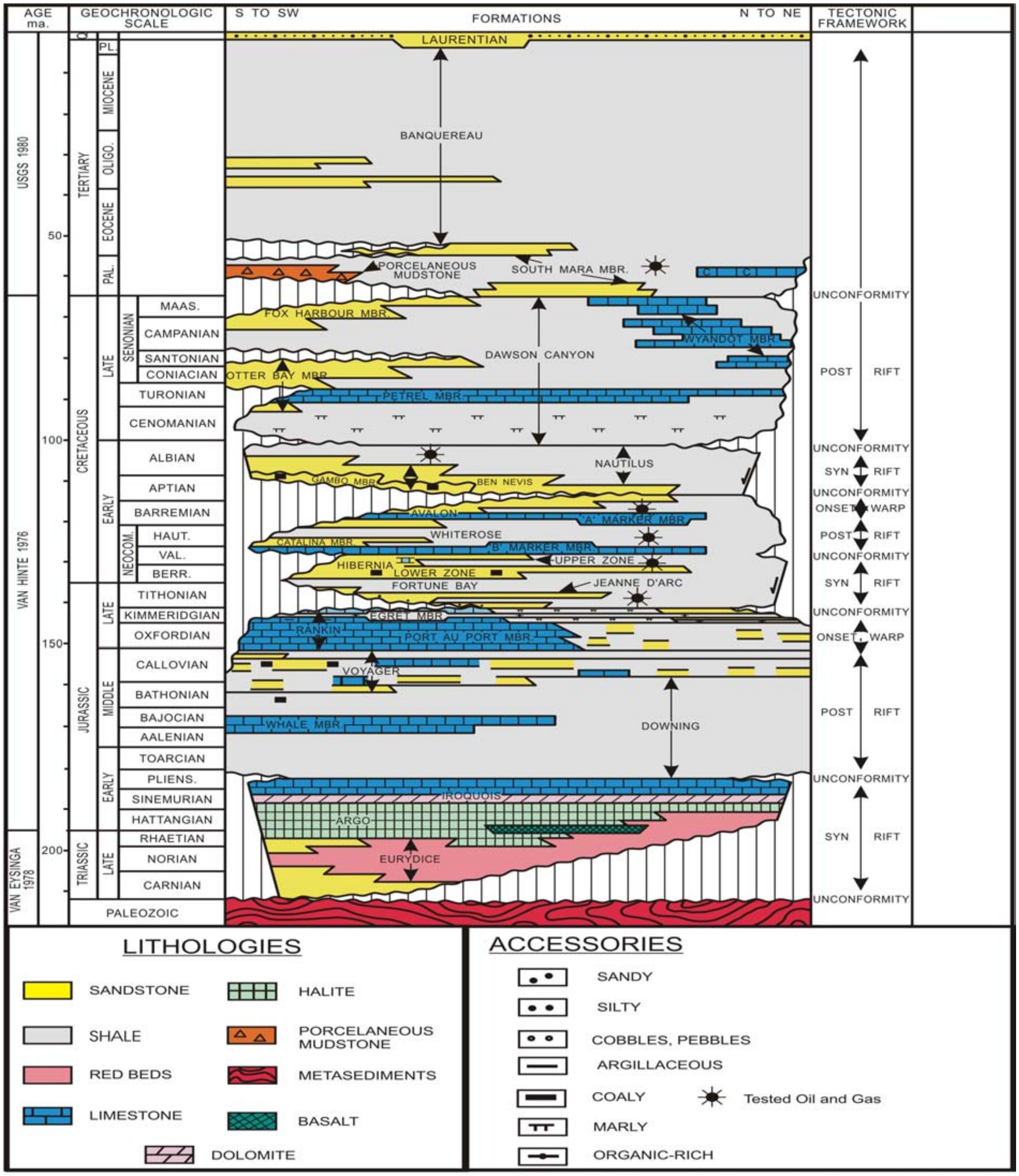


Figure 3

Call for Bids NF04-01 land parcels. Five parcels with a total area of 270,256 ha are being offered. Interested parties have until 4:00 pm November 17, 2004 to submit sealed bids to the Canada-Newfoundland Offshore Petroleum Board



Lithostratigraphy of the Mesozoic and Cenozoic sediments of the Grand Banks, Newfoundland. Courtesy of C-NOPB

Figure 4

SECTION I

EXPLORATION AND DEVELOPMENT

Offshore Newfoundland and Labrador's petroleum potential area extends over a vast region running all the way from of the Laurentian Sub-basin, across the Grand Banks (which contains the prolific Jeanne d'Arc Basin) through the deeper waters of the Flemish Pass and Orphan Basins and northward to include several basins along the Labrador shelf and slope (St. Anthony, Hawke, Hopedale and Saglek) (Figure 1). Paleozoic age basins in the Gulf of St. Lawrence on the west side of the island of Newfoundland also extend into the Province's onshore area.

To date a total of 131 exploration wells have been drilled in the Newfoundland and Labrador offshore area, of which 56 are concentrated in the Jeanne d'Arc Basin, which has been the primary focus area since the discovery of the giant Hibernia field in 1979. A total of 23 offshore fields have been discovered including 18 in the Jeanne d'Arc Basin / Central Ridge area (Figure 5), and 5 natural gas fields on the Labrador Shelf. With the successful development and high production rates of the Hibernia and Terra Nova fields, and the soon to be producing White Rose field, the multinationals, major independents and large Canadian companies are taking a fresh look at the Newfoundland offshore area. Exploration at this time is primarily in the form of large 2D seismic programs with 3D over selected areas. Extensive high quality seismic data (both exclusive and speculative data) has been (and continues to be) collected in areas such as the South Whale, Carson, Salar, Northern Jeanne d'Arc and Orphan Basins, and on the Labrador Shelf and Slope. Recent exploratory drilling has occurred in the Jeanne d'Arc Basin, the Laurentian Sub-basin (within the French jurisdictional area) and within the Flemish Pass Basin. Many of these basins have seen only one round of drilling based on the seismic data and geological understanding of the 1970s. They will now be revisited with the advantages of the many geological lessons learned over the past thirty years and much improved subsurface imaging provided by modern seismic data. An exploratory well (the first since 1987) is expected to be drilled in the iceberg-free South Whale Basin, off the south coast of the island of Newfoundland, within the next year.

Most of the current Exploration Licenses[1] (ELs) are located within and around the Jeanne d'Arc Basin, with owners including Petro-Canada, Husky, EnCana and Norsk Hydro. Other EL holders include the ExxonMobil-Chevron Canada-Imperial Oil consortium in the Orphan Basin, the Paramount-Polaris partnership in the South Whale Basin, and the Imperial Oil and ConocoPhillips-Murphy-BHP Billiton group in the Laurentian Sub-basin. A number of junior companies including Corridor Resources, Canadian Imperial Venture Corp., Ptarmigan Resources and Deer Lake Oil and Gas hold ELs in the Paleozoic Basins offshore western Newfoundland. During summer of 2004 there are 44 Exploration (ELs) in effect in the Newfoundland and Labrador offshore area. Seven are validated into the secondary term. There are also 52 Significant Discovery Licenses (SDLs), and 5 Production Licenses (PLs) covering the Hibernia and Terra Nova fields.

[1] An Exploration License provides the exclusive right to drill for a 5 year primary term which can be extended an additional 4 years if a well is drilled in the primary term. A Significant Discovery License (SDL) is the rights instrument that allows areas overlying a discovery to continue beyond the term of the Exploration License. Depending on the complexity of ownership there can be more than one SDL for a single discovery. A Production License is issued prior to the start of production from a field.

***Jeanne d'Arc Basin*.** The Jeanne d'Arc Basin contains eighteen oil and gas discoveries and, up to now, is the only significant oil province in the northwest Atlantic (Figures 5 and 6). Major oil and gas reservoirs have been found within Late Jurassic to Early Cretaceous sandstones (Jeanne d'Arc, Hibernia, Avalon and Ben Nevis sandstones; Figure 4). To date 56 exploration wells and 31 delineation wells have been drilled in the basin, along with the development wells being drilled at the Hibernia, Terra Nova and White Rose fields.

The Hibernia and Terra Nova fields are currently producing, and first oil at White Rose is expected in late 2005 or early 2006. Recently, oil production has reached record levels and there is a possibility that daily production from Hibernia and Terra Nova could reach 400,000 bopd at peak levels. White Rose field development is on schedule and within budget, and will add another 92,000 bopd to the basin's production. A fourth development is likely to occur at Hebron-Ben Nevis (414 million barrels recoverable; C-NOPB) but this project is currently on hold because of its heavier grade of crude (19^o - 21^o API).

Although many of the large structures in the basin have been drilled, many exploration opportunities remain. This is particularly true of the Late Cretaceous and Early Tertiary stratigraphic plays which have tested oil and gas in the basin but remain virtually unexplored, and of deeper rollovers and fault blocks in the central part of the basin. A 2003 delineation success at *White Rose F-04* proved that extensions to discovered fields are still to be drilled. A number of the smaller discoveries are only partly delineated and have the potential to be enlarged with additional stepout wells. Some of these smaller fields are likely to be brought on stream as satellite developments to the stand-alone projects as they progress beyond peak output.

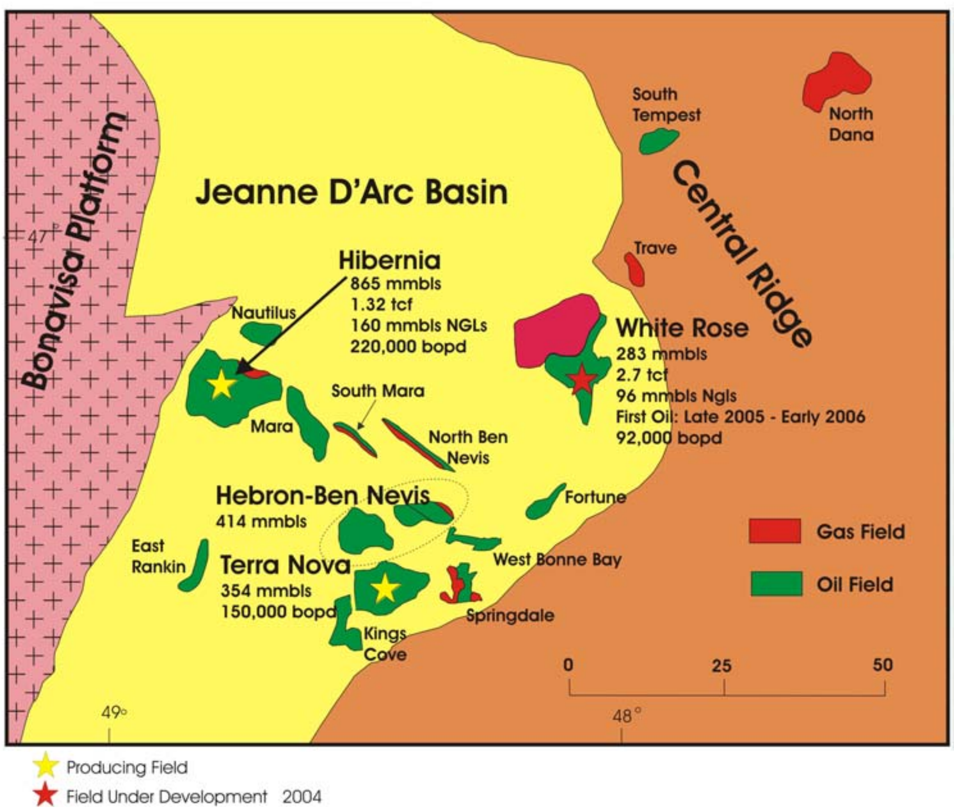


Figure 5

Jeanne d'Arc Basin discoveries. Smaller fields are expected to be developed as satellites to the stand-alone projects. Modified after C-NOPB.

The Hibernia Oil Field located 315 km east of St. John's in approximately 80m water is the largest field discovered offshore Canada. Production began in November 1997 from a GBS production system (Figure 2), and oil is delivered to market by shuttle tankers. The field was operated until recently by Hibernia Management Development Company. ExxonMobil (33.125%) assumed operatorship in 2003 with partners: ChevronTexaco (26.875%), Petro-Canada (20%), Murphy (6.5%), Canada Hibernia Holding Company (8.5%) and Norsk Hydro (5%). Current daily production of light sweet oil (36^{o}-40^{o} API) ranges from 200,000 to 220,000 bopd, and the C-NOPB's estimated recoverable oil reserves for the field have been increased from 666 to 865 million barrels since field startup. The field also contains recoverable reserves of about 1.32 Tcf of natural gas and 160 million barrels of natural gas liquids.

Natural gas produced with the oil is being re-injected to maintain reservoir pressure and for future delivery into North American markets. Approximately 275 million cubic feet per day is currently being produced with the oil, of which about 15 million per day is being consumed to power the platform. Since its startup in November 1997 Hibernia cumulative oil production had reached approximately 350 million barrels at the time of writing.

The main reservoir is the Early Cretaceous age Hibernia Sandstone, at 3700m depth, with porosities averaging about 16%, and permeabilities ranging from hundreds of milli-darcies to several darcies. One of the Hibernia development wells has established the Canadian flow-test record at 56,000 bopd from the Hibernia Sandstone. A shallower (2400m) pay zone, the Aptian age Avalon Sandstone, may contain upward of 2 billion barrels oil-in-place, but this is a lower quality reservoir that, according to various sources, may allow only a 10% recovery rate.

The field has highly deviated wells drilled from two rigs on the central Gravity Base Structure (GBS), with some of the wells setting records as the longest, high-angle, extended-reach wells in the world. Hibernia's GBS and a number of the topsides modules were built at the Bull Arm fabrication yard in Trinity Bay, Newfoundland. Modules constructed in other parts of the world were assembled at Bull Arm for integration into the topsides deck and mated with the GBS at Bull Arm.

The Terra Nova Oil Field is located 35 km south of Hibernia in 95m of water and is the second development in the basin. The field is operated by Petro-Canada (39.99%) with partners: ExxonMobil (22%), Norsk Hydro (15%), Husky (12.51%), Murphy (12%), Mosbacher (3.5%) and ChevronTexaco (1%). Production is from the Late Jurassic age Jeanne d'Arc Sandstones at a depth of 3200 metres subsea. This high quality, high productivity reservoir is a stacked, medium to coarse grained fluvial sandstone with 15-20% porosity and 100-1300 milli-darcies permeability. Individual wells have tested in excess of 40,000 bopd. The field is a structural-stratigraphic trap that covers 40 sq km and is divided into three major fault blocks referred as the Graben, East Flank and Far East blocks. Estimated recoverable reserves are 354 million barrels (C-NOPB) with potential upside from increased recovery.

Production by double-hulled FPSO with subsea well completions (Figure 2) began in January 2002. The development plan anticipates the drilling of 14 oil producers with 7 water injectors and 3 gas injectors. Produced solution gas is being re-injected into the reservoir. Current daily oil production ranges between 140,000 and 160,000 bopd with about 170 million cubic feet per day of associated gas. Approximately 14 million cubic feet of gas per day is being consumed to power the FPSO. Since first oil in January 2002 the cumulative production for the field had reached approximately 120 million barrels at the time of writing.

White Rose Oil and Gas Field is located in 120m of water on the eastern side of the Jeanne d'Arc basin, and is operated by Husky Oil (72.5%) with partner Petro-Canada (27.5%). It includes several oil and gas pools in the Avalon Formation Sandstone, deposited during the Early Cretaceous along a north-south trending shoreline paralleling the eastern margin of the Jeanne d'Arc Basin. The Avalon Sandstone at White Rose is different from the Avalon at Hibernia and Terra Nova and has fair to excellent porosity and permeability.

The oil is reservoired in a 40sq km structural-stratigraphic trap with an average of 100m Avalon sandstone oil pay, located at depths between 2800 and 3100m subsea. Estimated reserves for the entire field include 283 million barrels of recoverable oil, 2.7 Tcf of natural gas and 96 million barrels of NGL (C-NOPB). Husky estimates that they will recover between 200 and 250 million barrels from the portion of the field they are developing (the White Rose South Pool).

The White Rose South Pool was discovered in 1988 and is now being developed using subsea completions with the wellheads emplaced within three glory holes. The development will include a minimum 8 producers and 13 injectors. A 2003 delineation well (and sidetrack well) proved additional reserves when it encountered 180 metres of net pay, of which 40 metres was oil pay, approximately five km south of the previous drilling in the field. In August 2004, Husky announced that flow testing from one of its first horizontal development wells into the field indicated a productive capacity of between 25,000 and 35,000 bopd.

The project FPSO (the "Sea Rose") is currently in Marystown, on the south coast of Newfoundland, for installation of its topsides modules. Husky also recently started a program to evaluate the viability of producing and transporting natural gas from the White Rose field into North American markets. First oil from the field is expected in late 2005-early 2006 with estimated daily production of 92,000 bopd.

Hebron-Ben Nevis Oil Field consists of three discoveries (Hebron, Ben Nevis and West Ben Nevis) lying in adjacent fault blocks located to the north of the Terra Nova field in about 100 metres of water. Because of the close proximity of the three fields they would, in all likelihood, be developed as a single project. In this regard the three fields are usually referred to in the singular – as the Hebron-Ben Nevis field. The operator for the field is ChevronTexaco on behalf of partners Petro-Canada, ExxonMobil and Norsk Hydro. This field, which was discovered in 1981 and has been delineated by 6 wells, has good to excellent reservoir quality in Hibernia, Jeanne d'Arc and Ben Nevis sandstones, with an estimated 2 billion barrels of oil-in-place. The C-NOPB estimates 414 million barrels recoverable for the field and the operator estimates 400-700 million barrels recoverable, which in either case qualifies it as a strong candidate for stand alone development. However, 75% of the oil contained in shallow reservoirs (2100m) is as heavy as 19-21º API. As a result, development will require a greater number of producer/injector well pairs and the oil will command a lower price in the market. While the project is on hold at this time, the recent involvement of the two major stakeholders (ChevronTexaco and ExxonMobil) in the November 2003 record-breaking Orphan Basin landsale may indicate their long range commitment to the area and bode well for eventual Hebron-Ben Nevis development.

<u>ONE THIRD OF CANADA'S LIGHT CRUDE PRODUCTION</u>
Current Jeanne d'Arc Basin production from only two fields, Hibernia and Terra Nova, exceeds 350,000 bopd, representing more than one third of Canada's conventional light oil output.

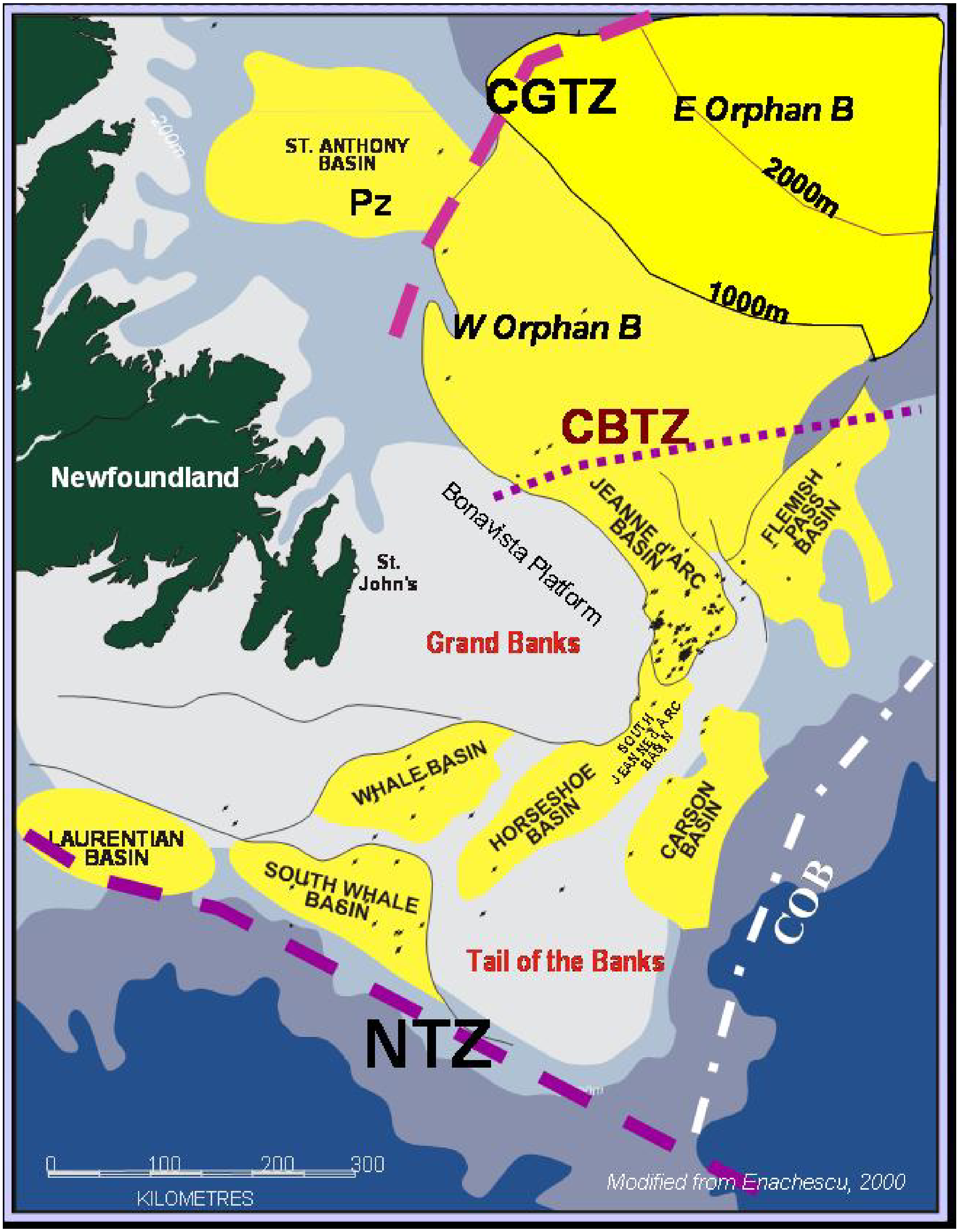


Figure 6
Distribution of Newfoundland east coast (offshore) sedimentary basins and exploration wells. NTZ=Newfoundland Transfer Zone, CBTZ=Cumberland Belt Transfer Zone, CGTZ=Charlie Gibbs Transfer Zone and COB=approximate Continent-Ocean Boundary (modified after Enachescu, 2000).

SECTION II

GRAND BANKS GEOLOGICAL FRAMEWORK

The Grand Banks is a broad bathymetric feature located on the eastern continental shelf of the island of Newfoundland. The Mesozoic basins of the area have developed through a series of three rift episodes associated with the breakup of the Pangea supercontinent that began in the Late Triassic and ended in the Late Cretaceous. Rifting was followed by thermal subsidence which lead to the deposition of an undisturbed Late Cretaceous section overlain by a thick Tertiary sequence (Figures 7 & 9). Areas of petroleum potential extend from the shallow waters of the Banks into the deeper waters of the continental slope, as well as to ultra-deep-water areas such as the Orphan Basin.

The Grand Banks rifted area (Figures 6 to 8) is bordered to the west by the Bonavista Platform, to the north by the Cumberland Belt Transform Zone (CBTZ), to the east by the continent-ocean boundary (COB) and to the south the Newfoundland Transform Fault Zone (NTFZ). The western rift shoulder, the Bonavista Platform, is a submerged and peneplained sector of the Appalachian Orogeny, partially covered by thin Upper Paleozoic, Mesozoic, and Tertiary strata and situated landward of the Murre Fault. The Murre Fault is a regional basin-bounding, crustal penetrative fault dipping oceanward. This fault and its imbricates were critical in the formation of the complex rift system on the Grand Banks. The Newfoundland Transfer Zone (NTFZ) is a major ocean transform fault that was active during the separation of North America from Africa and Iberia.

The network of basins (South Whale, Whale, Horseshoe, Carson, Flemish Pass and Jeanne d' Arc), adjacent sub-basins (Flemish Cap, Anson Graben, Salar) smaller troughs and cuvettes, have had a common evolution, but exhibit some structural and stratigraphic differences. They are separated by elongate basement ridges such as the Central Ridge, and bounded by faults that are linked at depth to the Murre detachment fault. (Figure 7).

Three major Mesozoic rifting phases have affected the Grand Banks basins:

1. Tethys rifting phase *in Late Triassic-Early Jurassic*. During this rifting episode the main basins were formed as half-grabens in the downthrown side of a major crustal detachment. The failed rift system was filled first with continental red beds, and sequentially with evaporites, carbonates and clastics. The Jeanne d'Arc Basin emerged as the deepest extensional area on the Banks. In Mid-Jurassic the proto-Atlantic opened as a narrow sea between Nova Scotia and Africa.

2. North Atlantic rifting phase in *Late Jurassic-Early Cretaceous*. Previously formed basins and new sedimentary troughs were affected by N-S trending extensional faults and E-W trending transfer faults. The Jeanne d'Arc Basin was reactivated along the Egret Fault, which forms its current southern boundary and along the Voyager Fault - its current eastern boundary. Movement on the Voyager fault was associated with the emergence of the Central Ridge as a regional high and a new source of sediment. Also during this time a large area on the southern Grand Banks that included basement ridges and platforms, as well a series of failed Triassic-Jurassic rift basins was tectonically uplifted. This area, known as the Avalon Uplift, became an additional source of coarse clastics for the Jeanne d'Arc Basin (e.g. the Jeanne d'Arc and Hibernia sandstones).

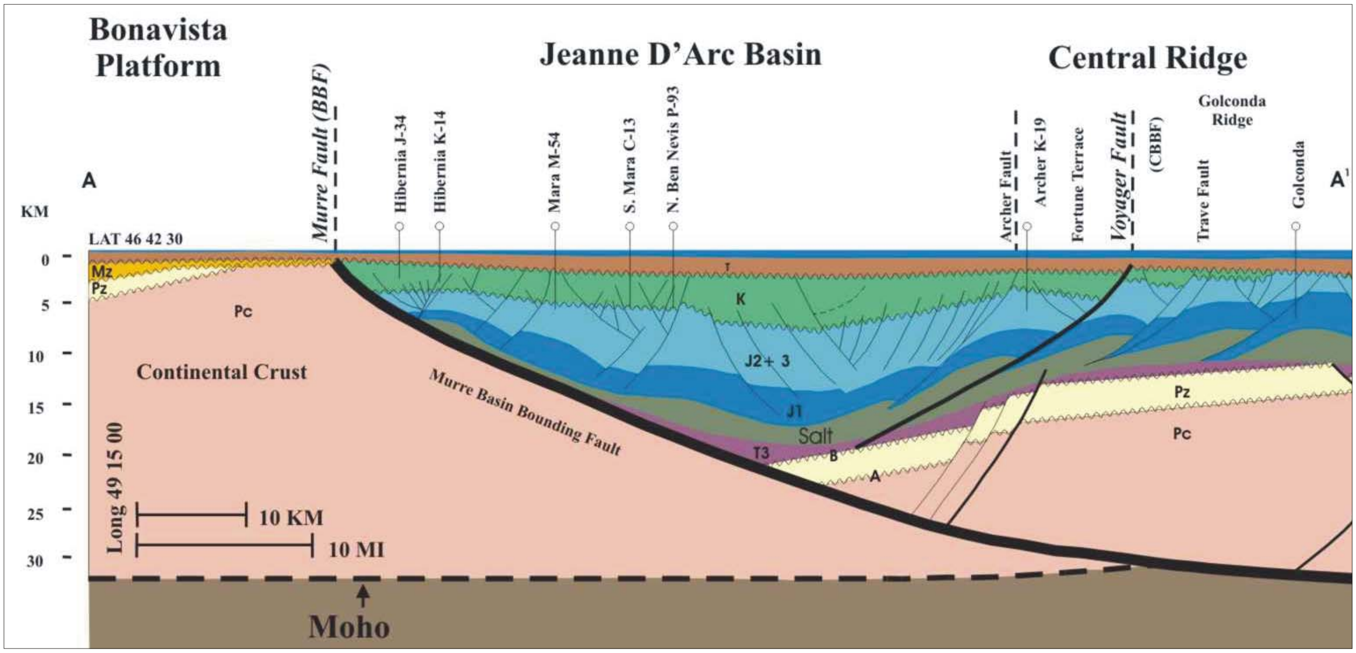


Figure 7
WSW–ENE (Dip) Geological Cross-Section A-A[1] through the Jeanne d'Arc Basin and Central Ridge (after Enachescu, 1987 and 1994). Location is given in Figure 8.

The rifting was followed by a thermal sag interlude during which the Kimmeridgean aged Egret source rock, the source rock for the existing Jeanne d'Arc Basin discoveries, was deposited. To the south of the Newfoundland Transform Fault Zone the Atlantic Ocean continued to open.

3. Labrador rifting phase *in late Early to Late Cretaceous*. During this episode numerous NW-SE trending faults severely fragmented the previously formed basins and intervening ridges. In the Jeanne d'Arc Basin, the Trans-Basin Fault Zone (TBFZ) was formed generating elongate fault blocks, horsts and grabens which were to become the primary trapping mechanisms for some of the major fields in the basin. Several imbricate faults of the Voyager Fault created terraces along the basin's eastern margin. The Avalon Formation sandstone reservoir was deposited in the south-central Jeanne d'Arc Basin and along the western flank of the Central Ridge. The Atlantic Ocean opened further, separating the Grand Banks from Iberia and the British Isles and, later, separating Labrador from Greenland.

Each of these rifting phases had associated tectonic subsidence which was followed by post-rift thermal subsidence. The initial failed rift episode was the most important of the three in that it defined the shape, orientation and size of the main basins. Subsequent rifting episodes rejuvenated tectonic movement throughout the area, leading to greater fragmentation of the preexisting basins. The associated structuring and refocusing of erosion and sedimentation created the reservoirs and traps that are recognized today in the Late Jurassic and Early Cretaceous sequences. The final regional thermal subsidence phase began in the Late Albian. Sediments deposited after this time are remarkably undisturbed, and are broken by only a few late-movement faults, and salt diapirs.

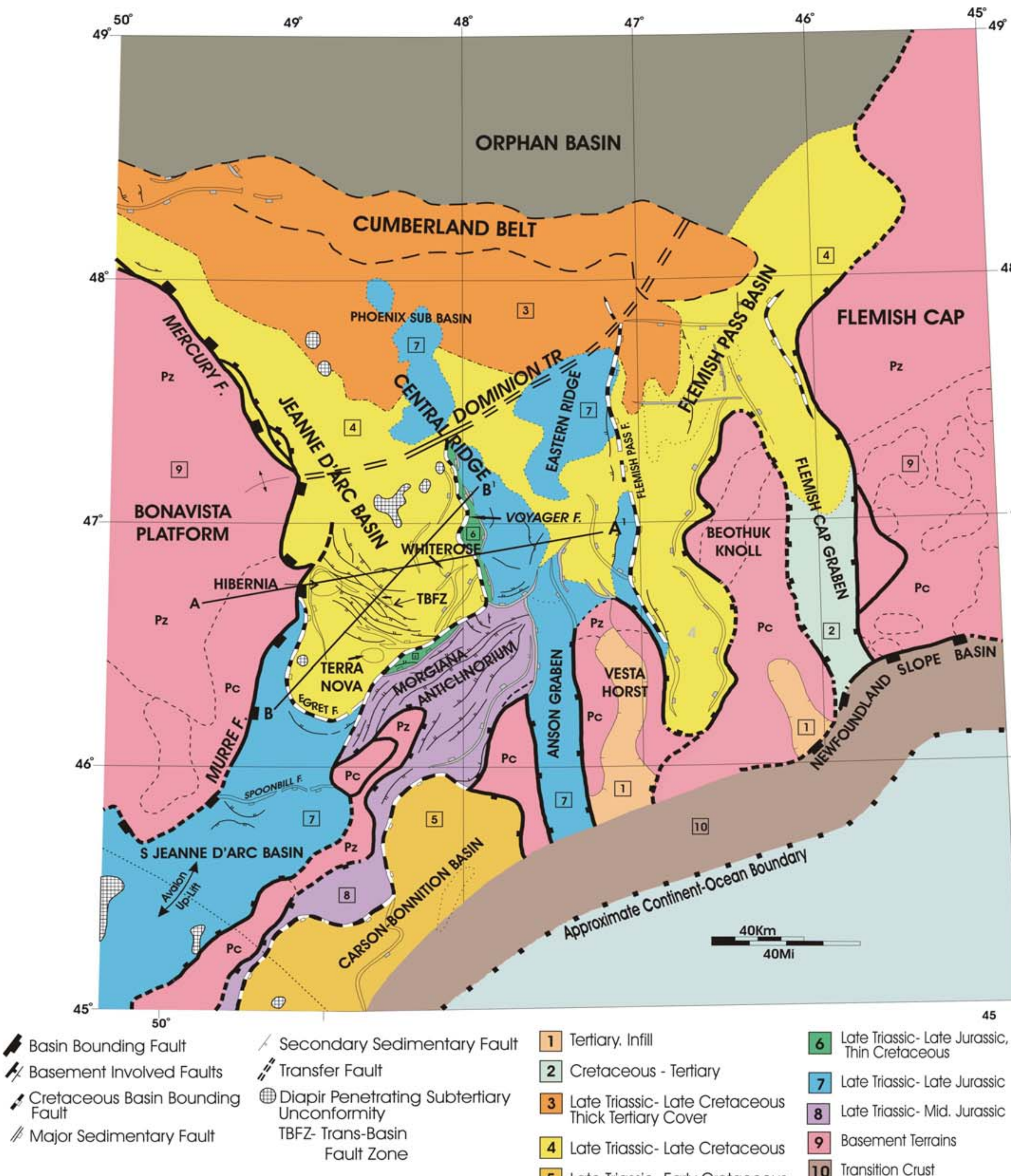


Figure 8
Tectonic and structural framework of Grand Banks.
Modified after Enachescu 1987 and 1994.

SECTION IV

PROVEN PETROLEUM SYSTEM

Source Rock and Maturation. The Kimmeridgian aged Egret Member of the Rankin Formation (Figure 4) deposited at the end of a thermal subsidence stage that followed the second rift phase is the proven oil source rock for all of the significant oil and gas discoveries on the Grand Banks. This is a marine organic-rich (TOC 2-12%) carbonatic shale that began generating hydrocarbons in Late Cretaceous, reached peak oil generation in Eocene, and in places continues to generate oil and gas up to the present. It averages 200m thickness throughout the Jeanne d'Arc Basin and has also been encountered by the drilling in the Flemish Pass Basin. Seismic character strongly suggests that this source rock will be present in the eastern half of the Orphan Basin to the north, and it is also expected to be present in some parts of the southern Grand Banks. The potential for other source rocks is recognized within the Oxfordian, Early Cretaceous and Early Tertiary.

Hydrocarbon Reservoirs. Stacked sandstones intervals within the Jeanne d'Arc, Hibernia, Catalina and Avalon formations (Figure 4) are proven quality reservoirs. Individual wells have tested in excess of 50,000 bopd from the Hibernia Sandstone at Hibernia, and in excess of 40,000 bopd from the Jeanne d'Arc Sandstone at Terra Nova. Fair to good quality reservoirs are also found in the Voyager and Ben Nevis formations. Excellent reservoirs are found in Late Cretaceous Dawson Canyon and the Paleocene South Mara formation but to date only a couple of smaller pools have been encountered at these levels. Exploratory drilling has focused primarily on the proven reservoirs of the Late Jurassic and Early Cretaceous. However, given the large size of some of the stratigraphic prospects mapped within the Late Cretaceous and Early Tertiary sequences there is clearly a real and effectively untested potential for large oil and gas pools at these shallower levels.

Hydrocarbon Traps. The main structural traps are extensional anticlines, roll-overs, faulted anticlines, faulted and tilted blocks and elongated horsts. Numerous salt induced structures such as pillows, domes, diapirs, ridges, allochthonous teardrops and turtle anticlines are common. The great majority of faults are listric normal faults, but some transfer faults, accommodation zones and local inversions due to trans-tension and halokinesis are also observed. All major traps were found to have a stratigraphic component as the accumulations are contained in continental, deltaic and shallow marine sandstones onlapping or wrapped over the main structural traps. Many complex or solely stratigraphic traps remain to be tested by drilling, as well as deeper faulted and rollover structures in the central and northern part of the Jeanne d'Arc basin.

Seals. Oil and gas accumulations are sealed by thick overlying shales abundant during the Late Cretaceous to Late Jurassic sedimentary successions (e.g. Fortune Bay, White Rose and Nautilus Shales). Also intra-formational seals are widespread within the rift stage clastic sequences. Excellent regional seals are provided by fine grained Late Cretaceous Dawson Canyon and the Tertiary Banquereau formations (Figure 4).

Migration. Expulsed hydrocarbons have migrated mainly vertically, predominantly along the numerous extensional faults. Some lateral migration occurred locally along the basin flanks. Late migration of hydrocarbons occurred within the basin marginal fans and sand filled canyons.

Exploration Potential. The Jeanne d'Arc Basin petroleum system is secured by the Kimmeridgian Egret Member of the Rankin Formation, a source rock of world-class quality that generated all the hydrocarbons found thus far in the basin. *The Late Jurassic-Early Cretaceous sandstone reservoirs of the Jeanne d'Arc, Hibernia, Avalon and Ben Nevis formations sealed by intra-formational seals and by overlying impermeable successions and sourced from the Egret Member shales is the proven, major petroleum system in the Jeanne d'Arc Basin*. The same source rock has produced accumulations within the Late Cretaceous and Early Tertiary clastic reservoirs, and is likely to have also sourced accumulations within the Late Jurassic Voyager Formation sandstones.

Exploration in the basin has focused mainly on the proven reservoirs of the Late Jurassic and Early Cretaceous, located in the down-throw of Murre and Voyager faults and along the Trans-Basin Fault Zone where most of the large oil discoveries are found. To date 56 exploration wells have been drilled in the basin, resulting in the discovery of 2.1 billion barrels recoverable oil and 5.4 trillion cubic feet of recoverable natural gas. This represents an exploratory well density of one well per 250 km^2 within the Jeanne d'Arc Basin. All exploration to date has been focused on the oil play, but this may change as investigations are currently underway toward bringing Grand Banks gas to market. The White Rose field alone contains almost 3 Tcf of recoverable gas, and the operator for this field (Husky Energy) recently issued a call for proposals on ways and means to monetize the gas. One Husky spokesman has indicated that the gas project could be more lucrative than the 250 million oil pool that is currently under development, and that first gas could occur as early as 2010.

Undiscovered potential for the Jeanne d'Arc Basin and Central Ridge was estimated at 2.39 billion barrels of recoverable oil and 13 Tcf of recoverable gas in a 2000 report published by the C-NOPB.

Future discoveries are to be found in:

a) deeper fault blocks in the Trans-Basin Fault Zone and around existing fields;
b) complexly faulted structures along the basin margins and on parts of the Central Ridge where Late Jurassic successions have not been eroded;
c) Early Cretaceous deeper rollovers in the northern portion of the basin;
d) Late Cretaceous and Early Tertiary basin margin and floor fans;
e) Paleocene and younger sandstones resulting from the erosion of older sandstones and draped over ridges, faulted blocks and salt diapirs; and
f) coarse clastics on the flanks of rotated blocks or in minibasins related to salt structures.

All of these multiple plays are present in the five parcels offered in the C-NOPB's 2004 Call for Bids. They can be identified and evaluated using the large data base of publicly released 2D and 3D seismic and well data available from the C-NOPB and GSC Atlantic. Additionally there are recently acquired speculative seismic data available over these parcels and throughout the Jeanne d'Arc Basin (and elsewhere) for purchase from geophysical contractors.

SECTION III

JEANNE D'ARC BASIN TECTONICS, STRUCTURE AND STRATIGRAPHY

The Jeanne d'Arc Basin and adjacent Central Ridge area host all of the significant oil discoveries in the Newfoundland and Labrador offshore area (there are also major gas discoveries off Labrador), including the two currently producing fields. The basin forms an elongate, roughly NE trending, half-graben, encompassing an area of about 14,000 km^2. As shown in Figure 8, it is bounded to the west by the Murre Fault, to the north by the Cumberland Belt Transfer Zone (CBTZ) lineament, to the east by the Voyager Fault and to the south by the Egret Fault. The basin deepens to the north and shallows to the south, and contains over 20 km of Upper Triassic to Cenozoic sedimentary infill in its depocentre, situated to the north of the Trans-Basin Fault Zone (TBFZ) and east of Hibernia.

The sedimentary fill of this area was deposited, structured and fragmented during repeated extensional episodes, discussed in Section II. Minor trans-tensional tectonic movements and several strong erosional interludes have also reshaped the basin and its associated ridges. The basin fill can be divided into two major stratigraphic sequences that are clearly recognizable on seismic data.

1. ***An extensional stage sedimentary sequence*** (Late Triassic to Late Cretaceous) that is strongly compartmentalised by normal fault systems and contains numerous structures;
2. ***A thermal subsidence stage sedimentary sequence*** (Late Albian to Present) that is tectonically undisturbed (i.e. no extension) in general, but contains remarkable depositional and erosional features, including basin margin and floor fans.

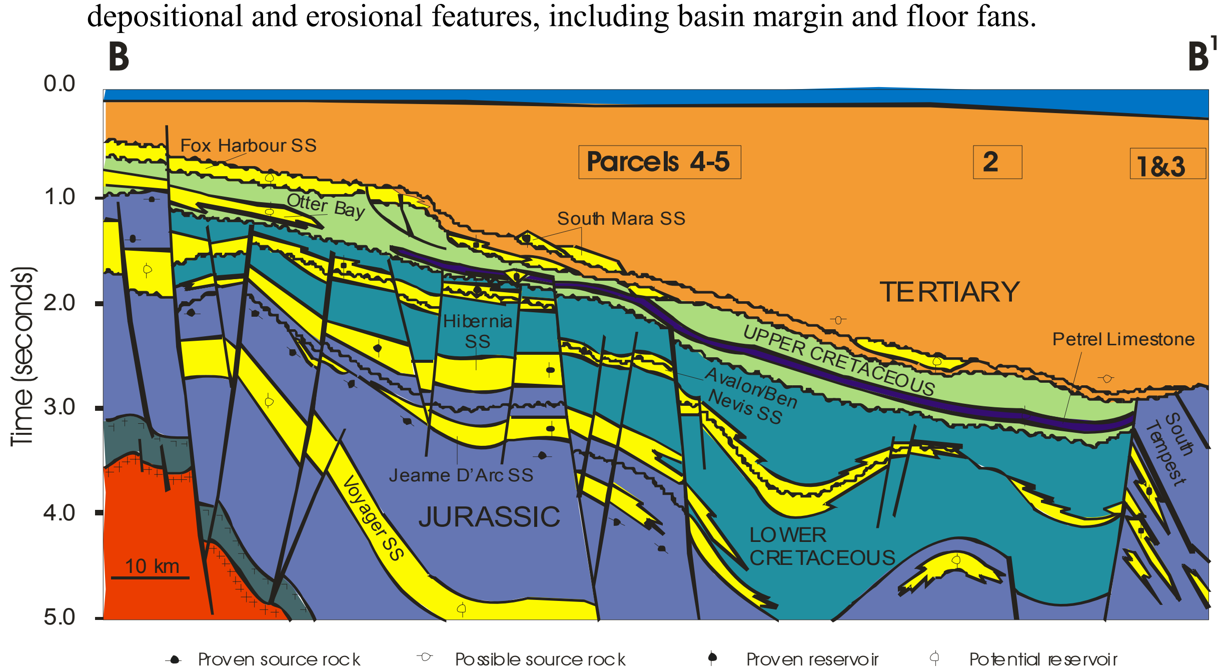


Figure 9
Simplified SW-NE cross-section of the Jeanne d'Arc Basin (in time) based on interpreted seismic data, with approximate locations of NF04-01 parcels (modified after Sinclair, 1994). Location is given in Figure 8.

Alongside extensional tectonics, prolonged halokinesis and halotectonics played an important role in basin evolution and structure. Prominent salt-cored structures are presently found throughout the Grand Banks. Salt pillows underlay the Hibernia, Terra Nova and White Rose oil fields and most of the other structural features in the basin and on the Central Ridge.

Figure 7 shows the Jeanne d'Arc Basin as a half-graben on the downthrown side of a major basin forming detachment fault (the Murre-Mercury Fault) initiated during crustal extension in the Late Triassic-Early Jurassic. This extensional fault system, with its associated antithetic, synthetic and conjugated shear faults, also caused the basin to be compartmentalised into numerous fault blocks. The major bounding faults, are separated by relay ramps that accommodated diminishing extension on one fault sector and increasing slip on the next fault sector. The major internal structure of the basin was set in the first rifting phase, and the associated evaporate deposits (Argo Salt Formation) now underlie most of the basin, forming salt pillows, diapirs and ridges. Salt induced structural and stratigraphic features played a major role in the formation of the intricate trap and reservoir systems of the Hibernia, White Rose, Terra Nova and the Hebron-Ben Nevis fields.

Jeanne d'Arc Basin extension continued during the Late Jurassic to Early Cretaceous phase of rifting and was characterised by a dominant east-west direction of extension. Basin growth occurred on the bounding faults, Murre and Voyager, and at its southern extremity marked by the Egret Fault. Uplift, non-deposition and erosion affected a broad region in the southern Grand Banks, including portions of the Jeanne d'Arc Basin. The Central Ridge developed as a separate block in the footwall of the Voyager Fault and began to emerge as a prominent and permanent regional high. Numerous north-south faults formed, especially on the Central Ridge and in the eastern portion of the basin where they played a role in the creation of the White Rose field. Salt diapirs and salt cored ridges were formed, influencing sedimentation and local fault patterns.

In the Early Cretaceous, a major Late Barremian to Early Albian unconformity marks the approximate end of the second rift phase in the Jeanne d'Arc Basin and the beginning of separation between the Grand Banks and Europe. Successive sag, rifting and then, ocean opening took place during this period. During the Aptian to Albian, northeast-southwest extension and block reorganization took place in the centre and along the margins of the Jeanne d'Arc Basin.

In the central part of the basin, towards the end of the Aptian, the Trans-Basin Fault Zone collapsed during major NE-SW oriented extension, causing deposition of the Albian aged clastics (Ben Nevis Formation) into the subsiding grabens and low fault blocks. Clastics from a southern source were also deposited in a northerly direction reaching to the northwest of the White Rose area. An eastern source of coarse clastics supplied the Avalon/Ben Nevis Sandstone along the Voyager Fault zone in the eastern White Rose area.

A general uplift of the margin took place in Late Cretaceous - Early Tertiary, probably associated with a major plate reorganization, or localized transpression related to westerly drifting of the North American plate. A final thermal subsidence occupies the entire Tertiary time. The Base Tertiary Unconformity configuration reflects a northerly tilting of the basin and a general thickening of post-rift sediments from south to north. Late salt movements and compaction rejuvenated a few larger faults which penetrate the unconformity, terminate in lower Tertiary sediments and form tectonic lineaments, but with no major structural closures. Numerous sedimentary mounded features were formed above the Base Tertiary Unconformity.

SECTION V

REQUEST FOR BIDS PARCELS

The five parcels being offered in the C-NOPB Call for Bids NF04-01 are located in the central Jeanne d'Arc Basin and Central Ridge area, close to major oil and gas fields and other significant discoveries. Water depths range from about 80 metres to 200 metres. Parcels 1 and 3 are located, predominantly, on the Central Ridge with their western extremities straddling the Voyager Fault into the Jeanne d'Arc Basin, near the White Rose oil and gas field (Figure 10). Parcel 2 is situated mostly in the eastern Jeanne d'Arc Basin to the northwest of the White Rose field. Parcels 4 and 5 are on the western side of the Jeanne d'Arc basin, adjacent to the Hibernia oil field. These parcels are very large (ranging from 70 km^2 to 911 km^2) when compared to the typical 9 sq mile (23 sq. km) section in the Gulf of Mexico. Parcels 1, 2, 4 and 5 have been explored recently and as such they benefit of excellent seismic coverage including proprietary 3D data. Parcel 3 has been explored only in the early 80s but has both older and modern dense 2D coverage. A general description of the geological setting of these parcels, a few illustrative seismic sections and results of significant wells for the plays present in the parcels are provided below.

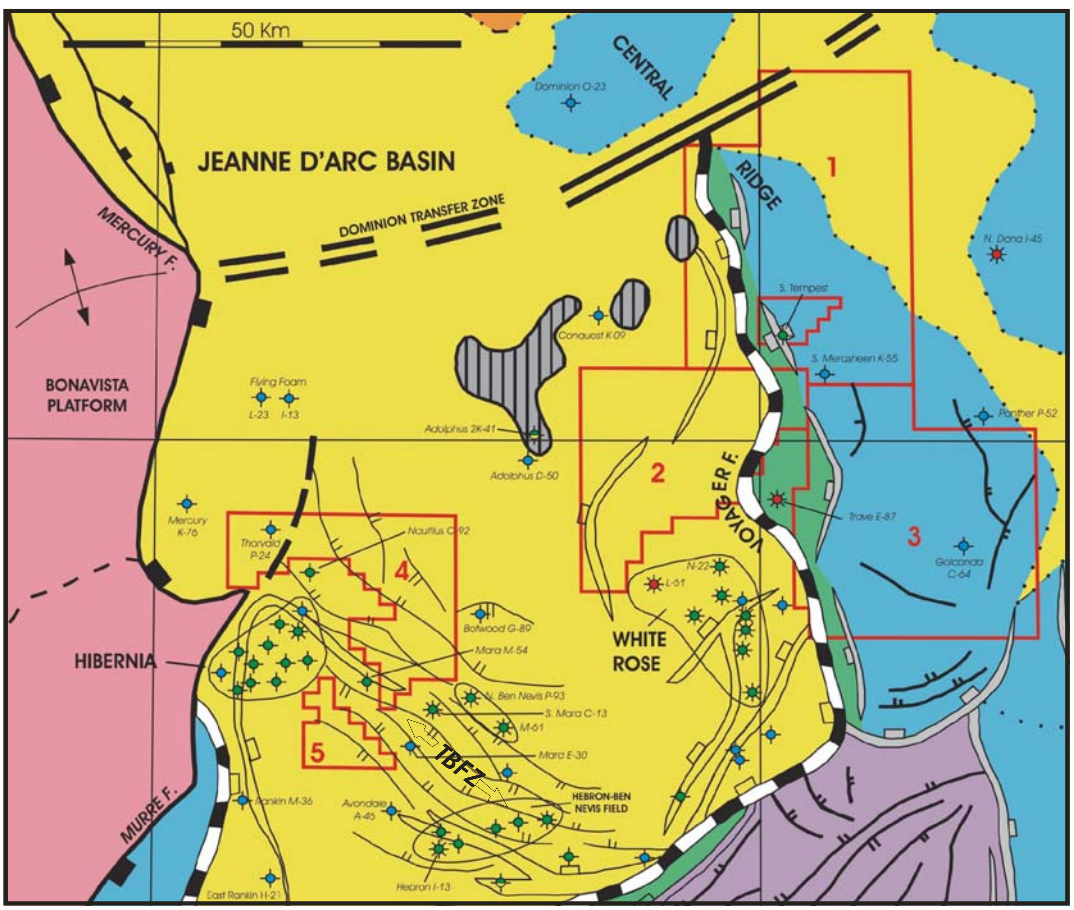


Figure 10

Location of the Call for Bids NF04-01 land parcels (numbered 1 to 5) with respect to the structural framework of the Jeanne d'Arc Basin and Central Ridge, with locations of exploratory and delineation wells. TBFZ=Trans-Basin Fault Zone (modified from Enachescu, 1987 and 2000).

Parcel 1 This parcel is mostly located on the northern plunge of the south Central Ridge and occupies an area of 91,107 hectares (Figures 10 and 11). The plays in this parcel were tested by 3 older wells. Good reservoir and light oil was found in the Late Jurassic sands of the Rankin Formation ("Tempest Sands") at *South Tempest G-88* (8 million barrels recoverable; C-NOPB), which also intersected the Egret Member source rock (Figure 4). The South Tempest Significant Discovery License is fenced within the bid parcel. To the east of the parcel the North Dana gas discovery (472 Bcf and 11 million barrels of NGLs recoverable; C-NOPB) encountered 3 gas zones in similar age reservoirs, as well as source rock. The *South Merasheen K-55* dry hole near the southern boundary of the parcel also encountered the Tempest Sands and the Egret Member source rock of the Rankin Formation.

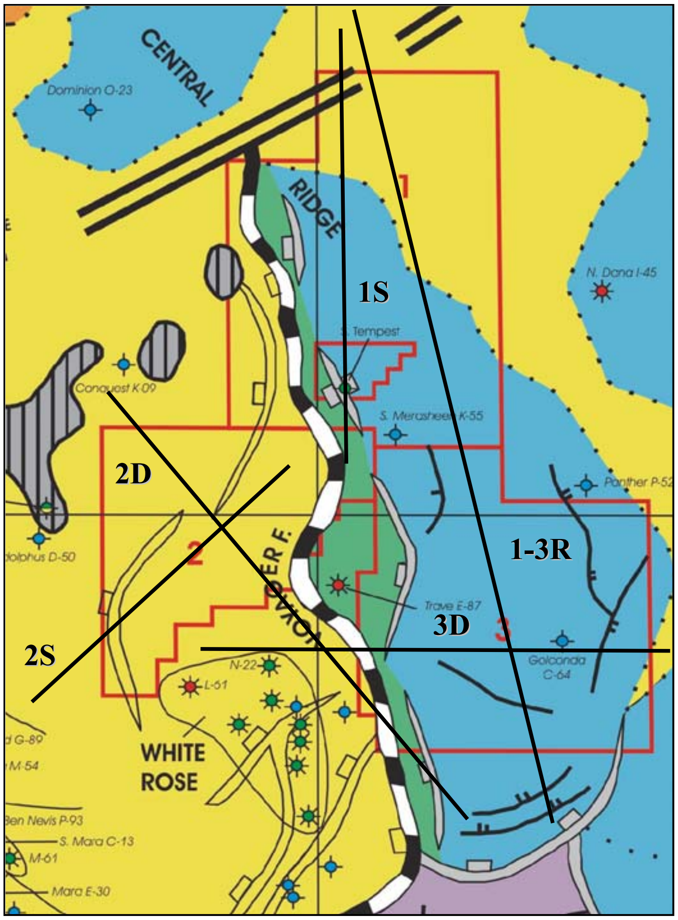


Figure 11. Locations of NF04-01 Parcels 1, 2 and 3 and of seismic sections used to illustrate the structural setting and hydrocarbon play concepts.

The main plays in Parcel 1 are faulted blocks containing Late Jurassic Tempest Sandstones of the Rankin Formation and possibly the Jeanne d'Arc Sandstone (Figures 4, 12 and 13). Younger, quality reservoirs may be encountered on the flanks and the plunge of the Ridge, and near the Dominion Transfer Zone (Figures 12 and 13).

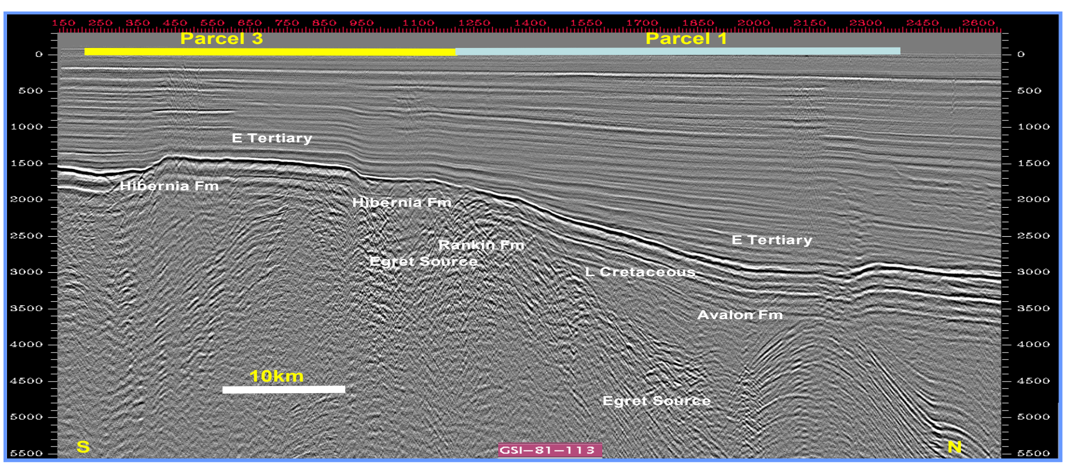


Figure 12. Regional strike seismic line (1-3R) running SSE-NNW across Parcels 1 and 3 (courtesy of GSI). Location shown in Figure 11. A reflective Base Tertiary Unconformity and the deformed rift sequence are evident.

Sub-unconformity traps of Hibernia and Avalon sandstones as well as onlap of Early Tertiary sandstones are also possible. There is excellent 2D coverage, both older (some reprocessed) in the public domain and newer data available from vendors (GSI and TGS), as well as 3D speculative coverage from WesternGeco.

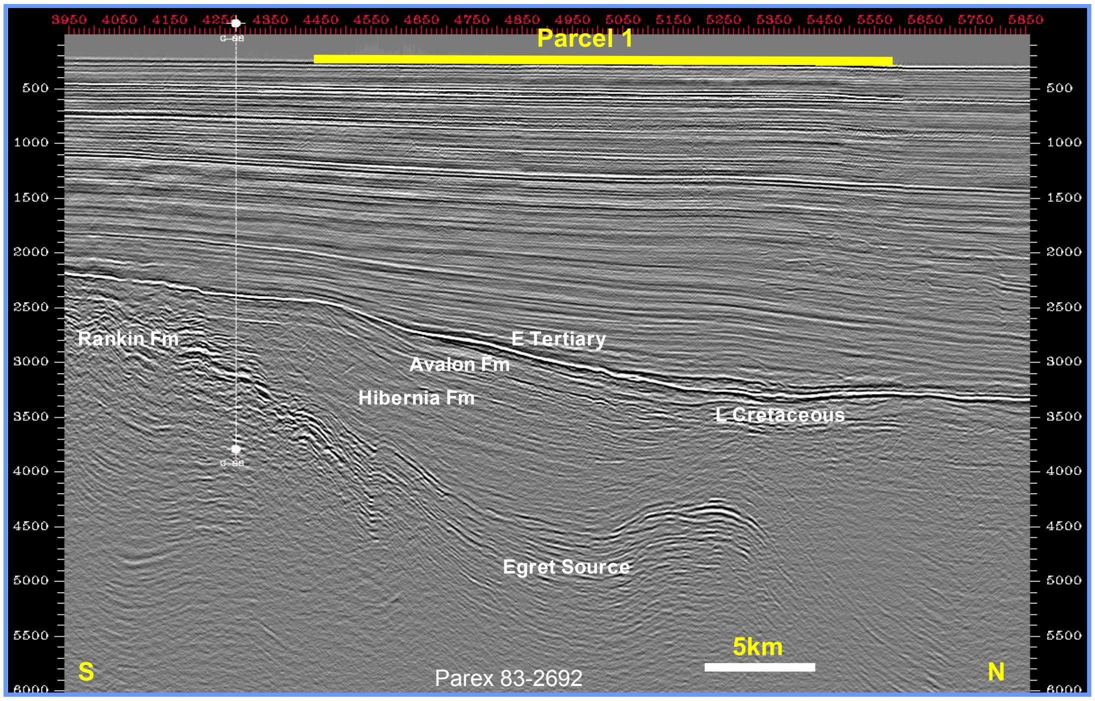


Figure 13. Strike line (1S) running north through the South Tempest G-88 well, which encountered oil in the Rankin Formation, showing several possible hydrocarbon plays in Parcel 1. Location is given in Figure 11. A deeper, untested antiform is situated in the central part of Parcel 1.

Parcel 2. Parcel 2 is located north of the White Rose oil and gas field (283 million barrels, 2.7 Tcf and 96 million barrels of NGLs recoverable; C-NOPB) and situated mainly on the eastern side of the Jeanne d'Arc Basin (Figures 10 and 11). The parcel occupies an area of about 52,125 hectares, mostly on the downthrown side of the Voyager Fault, with a small portion on the Central Ridge. The Trave gas discovery (30 Bcf and 1 million barrels of NGLs; C-NOPB) which flow tested 17 million cubic feet of gas per day from the Early Cretaceous Hibernia Sandstones lies on the eastern border of the parcel on the Central Ridge. The *White Rose N-22* well tested gas in the Avalon/ Ben Nevis and oil in the Hibernia Sands. The *White Rose L-61* well tested 11.7 million cubic feet of gas per day from the Early Tertiary South Mara Member.

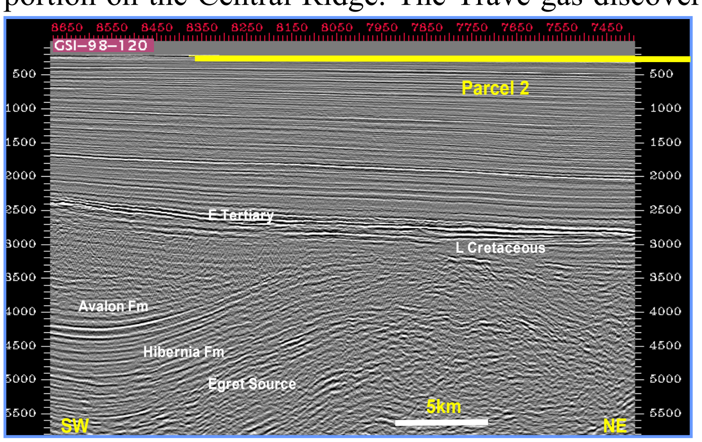


Figure 14. Strike seismic line (2S) running SW-NE through parcel 2 (courtesy of GSI) showing a large , untested antiformal feature. Location is given in Figure 11.

No exploration wells have been drilled within the block, but several adjacent wells are characteristic of the expected plays in the parcel. The main plays within the parcel are: Tertiary and Late Cretaceous basin margin sedimentary fans; imbricate fault blocks of the Voyager fault zone with Avalon/Ben Nevis and Hibernia sandstones potential; and deeper rollovers and fault blocks with Avalon/Ben Nevis potential (Figures 14 and 15). There is excellent 2D seismic coverage, including both older released data (some reprocessed), new data available from vendors (GSI and TGS Nopec), and partial 3D speculative coverage from WesternGeco.

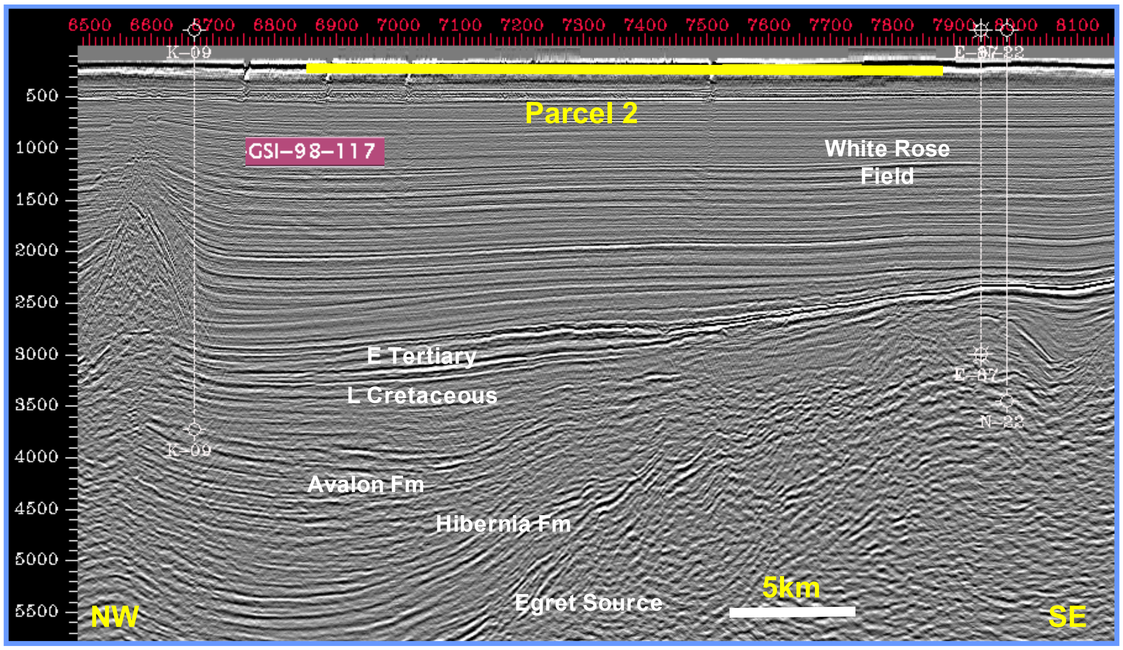


Figure 15. Dip seismic line (2D) running from the Adolphus Diapir area through Parcel 2 onto the Central Ridge near the White Rose Field (courtesy of GSI). Location is given in Figure 11.

Parcel 3. This parcel is located within the middle part of the southern Central Ridge and includes a small area that extends across the Voyager Fault into the Jeanne d'Arc Basin (Figures 10 and 11). The parcel covers an area of 84,270 hectares and is bordered to the west by the Trave Significant Discovery Area (SDA), and the White Rose SDA. The one well that has been drilled within the parcel, *Golconda C-64,* encountered a Paleocene sandstone reservoir and a series of tight Mid to Late Jurassic sandstones (Figures 11, 12 and 16). The *Panther P-52* well on the NE boundary of the parcel encountered Late Jurassic sandstones and a 73 metre section of Kimmeridgian source rock with TOCs of up to 8.22% and a Hydrogen Index exceeding 600.

The crestal part of the southern Central Ridge suffered intense erosion and Late Jurassic to Late Cretaceous rocks have been removed. Potential plays in this block include: pinchouts of Tertiary sandstones on the flanks of the Ridge; drape over the Ridge closure; sub-unconformity traps between Tertiary cover and earlier sedimentary sequences; fault blocks with porous Rankin Formation sandstones; and possible Jeanne d'Arc and Hibernia age sandstones on the western flank of the Central Ridge. A dense network of 2D seismic lines, both older (early 80s) and modern (post 1997) is now available (Figures 12 and 16). While older data is in public domain the new data is available from two geophysical vendors - GSI and TGS Nopec. Some older data have been recently reprocessed.

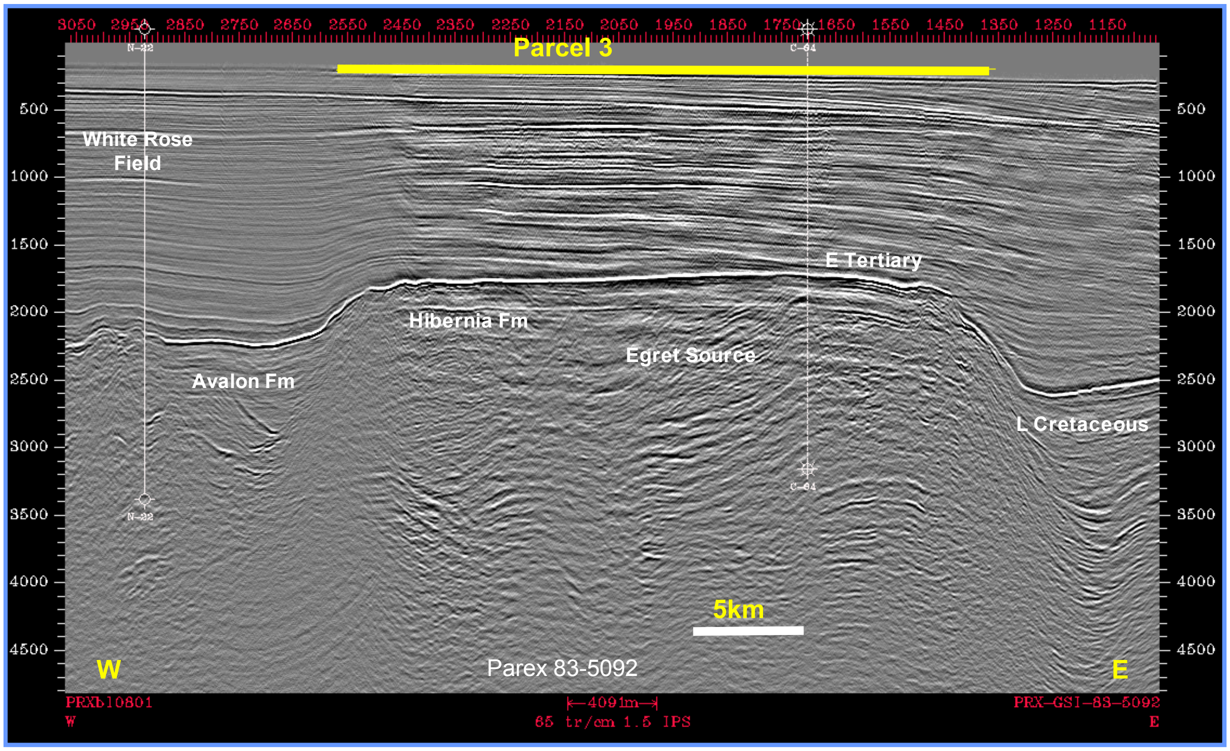


Figure 16. Dip seismic line (3D) through Parcel 3. Location in Figure 11. The wells shown are White Rose N-22, which tested oil and gas, and Golconda C-64 which had gas shows on logs.

Parcel 4. Parcel 4 includes 35,674 hectares and is located directly to the north and northeast of the Hibernia field in about 100 metres of water. It lies on the downthrown side of both the Murre Fault and Nautilus Fault - which forms the NE boundary of the Hibernia field (Figures 10 and 17).

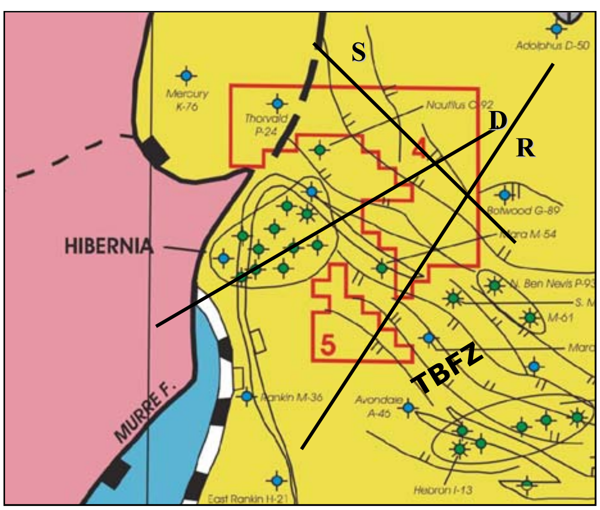


Figure 17. Location of NF04-01 parcels 4 and 5 and seismic lines used to illustrate hydrocarbon play concepts in these parcels.

The parcel borders several Significant Discovery Areas including those of the Nautilus, Mara, South Mara, North Ben Nevis and Hibernia fields. The parcel includes one exploratory well, *Thorvald P-24*, which encountered Early Tertiary, Late Cretaceous and Early Cretaceous sandstones and recovered 33^{o} API oil from a repeat formation sample in the Lower Cretaceous.

The adjacent *Nautilus C-92* discovery well flow tested a total of 4600 bopd from two zones within the Early Cretaceous Avalon-Ben Nevis Sands, and also contained good reservoir within the Hibernia Sands. Several excellent oil wells are in the immediate vicinity of this parcel, including the

Hibernia field exploration and development wells, as well as *Nautilus C-92, Mara M-54*, *South Mara C-13*, and *North Ben Nevis P-93* and *M-61*, all of which encountered multiple reservoirs and had prolific hydrocarbon tests.

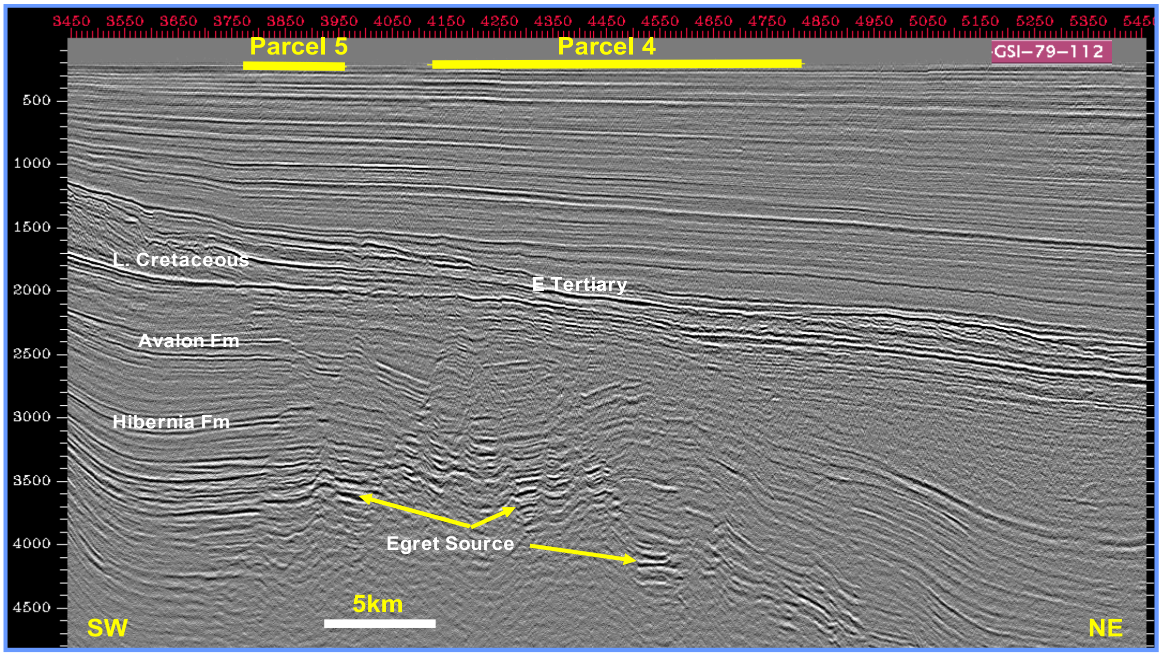


Figure 18. Regional seismic line (R) through Parcels 4 and 5 (courtesy of GSI), showing a faulted rift sedimentary sequence plunging toward the basin depocenter. Location shown in Figure 17.

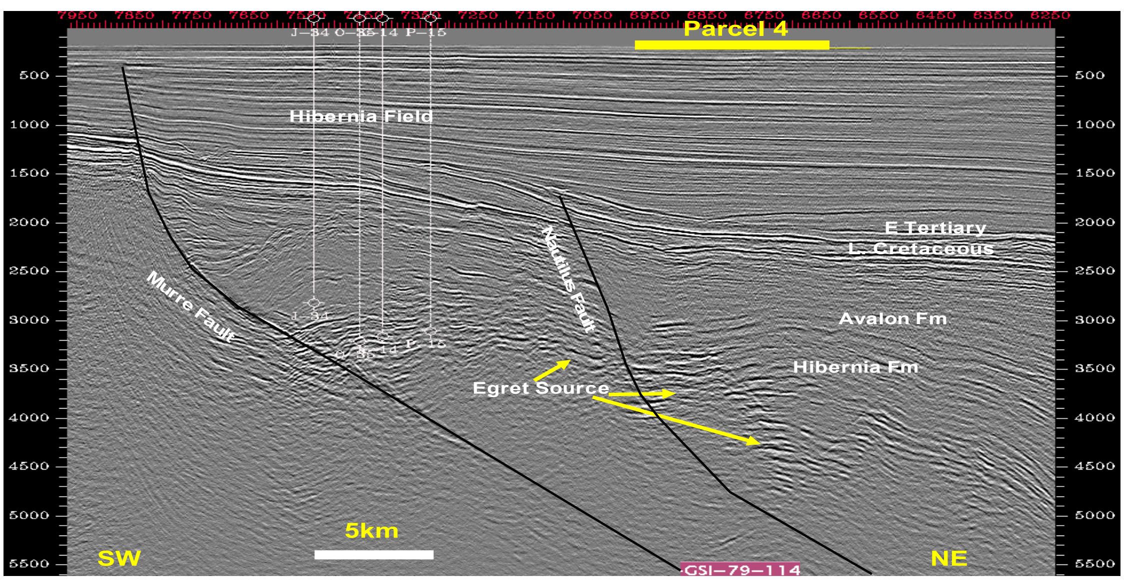


Figure 19. Dip regional seismic line (D) through Hibernia field and Parcel 4 (courtesy of GSI). A faulted rollover anticline is shown in the down-throw of Nautilus Fault. Location shown in Figure 17.

Potential plays exist within Late Cretaceous Fox Harbour and Early Tertiary South Mara sandstones that form a large apron on the western margin of the Jeanne d'Arc Basin. Another potential play exists within the faulted rollover into the Nautilus Fault (Figures 18, 19 and 20).

The block lies on trend with the Trans-Basin Fault Zone which is associated with discoveries running all the way across the basin (Figure 10 and 17). The seismic coverage is excellent with older public domain 2D data available, as well as recent 2D data from seismic contractors GSI and TGS. Partial 3D coverage is available from WesternGeco.

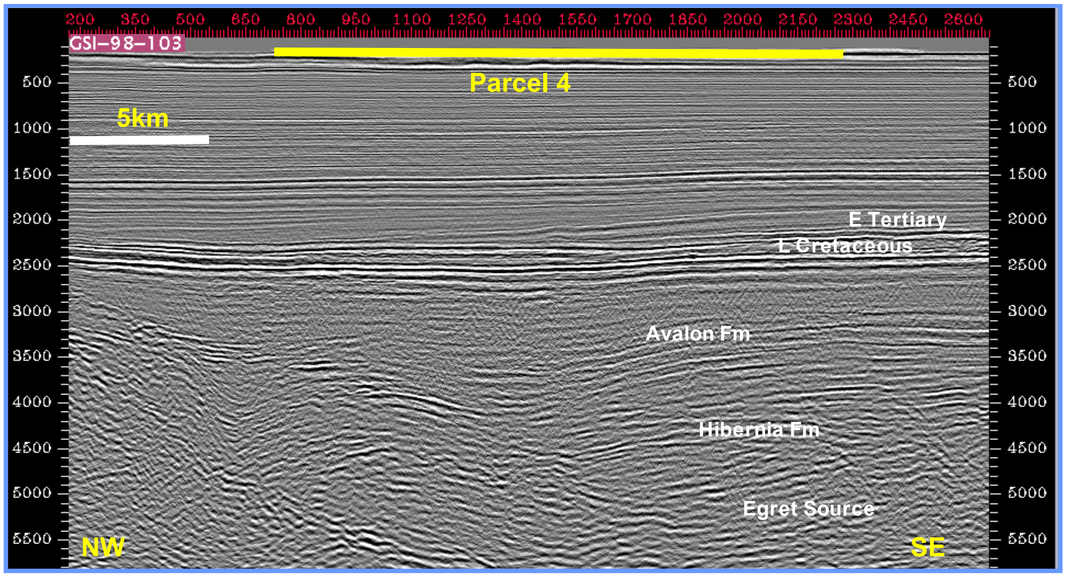


Figure 20. Strike seismic line (S) through Parcel 4 (courtesy of GSI), showing faulted anticlines and Late Cretaceous and Early Tertiary ponded clastics. Location in Figure 17.

Parcel 5. This parcel is located immediately southeast of the Hibernia field and directly west of the Mara field in approximately 100 metres of water (Figures 10 and 17). The *Mara M-54* discovery well to the NE of the parcel tested 770 bopd from the Late Cretaceous Otter Bay Sandstone and 620 bopd from the Early Tertiary South Mara Sandstone. The *Mara E-30* well encountered traces of oil in a poor quality Early Tertiary Sandstone. This was one of only three wells drilled in the basin to deliberately test an Early Tertiary fan sequence.

Abutted between the Hibernia rollover and the Trans-Basin Fault Zone the parcel contains a few large rotated fault blocks with excellent Avalon and Hibernia sandstone potential (Figures 17 and 18). Younger reservoirs in Late Cretaceous and Early Tertiary are also present in the parcel. Mature Egret source rock is also present.

Dense 2D seismic coverage is available both within the public domain and from seismic contractors, and portions of the parcel are covered by proprietary 3D seismic data.

Conclusion

The C-NOPB's Call for Bids NF04-01 includes five parcels with fair to excellent potential for oil and gas discoveries. They are located in the immediate vicinity of the Hibernia and White Rose fields and within the prolific Jeanne d'Arc Basin. Proximity to existing fields and production bodes well for both geological potential and development economics. For information on how to submit a bid go to the C-NOPB's website:
http://www.cnopb.nfnet.com/

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