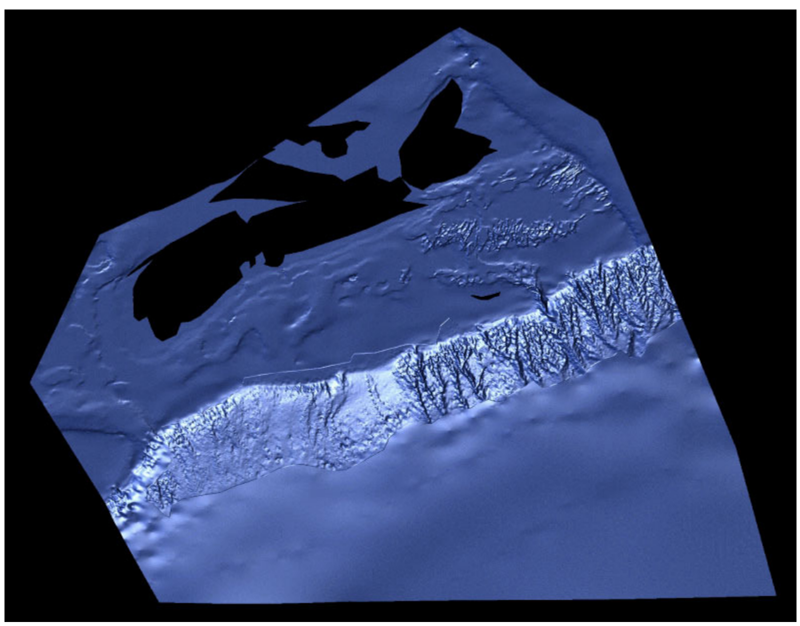
Canada-Nova Scotia
Offshore Petroleum Board

HYDROCARBON POTENTIAL OF THE DEEP-WATER SCOTIAN SLOPE

Executive Summary



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DISCLAIMER

While every effort was made to ensure the timeliness and accuracy of the information, data, material and interpretations (the "Information") contained in this report – "Hydrocarbon Potential of the Deep-Water Scotian Slope" - the Canada-Nova Scotia Offshore Petroleum Board assumes no liability or responsibility whatsoever for the completeness, accuracy or usefulness of any of the Information. The Information in the document is provided solely for general public information purposes and is provided strictly "as is."

The precise locations of the five Geochemistry sites selected from specific seismic lines representative of the different play types along the slope margin are not given in this report. This information was specifically omitted to eliminate any possibility of "high-grading" a particular area and compromising regulatory integrity and independence of the Canada-Nova Scotia Offshore Petroleum Board. Furthermore, the exact locations of the seismic lines published in this report, with permission, are also not provided in order to protect the proprietary rights of the owners of this data and respecting Section 122 of the Canada-Nova Scotia Offshore Petroleum Resources Accord Implementation Act.

ABSTRACT

The Canada-Nova Scotia Offshore Petroleum Board has recently completed a geological basin evaluation and numerical assessment of the hydrocarbon potential for the deep-water slope region, offshore Nova Scotia. The Scotian Slope lies in water depths of 200 to 4000 metres and extends 850 kilometers from the United States international border in the southwest, to the Newfoundland provincial border in the northeast. Within this region, no previous resource assessments have been published.

This basin evaluation is based on the interpretation of 30,000 kilometers of regional 2-D seismic data, with stratigraphic correlations to shelf wells, industry seismic lines, deep crustal regional seismic data, and Deep Sea Drilling Project well-bores. The major challenge was mapping the top and base of the ubiquitous, mobile Argo Salt. Twelve hydrocarbon play types were identified throughout the region. All are salt-related to varying degrees. Supra-salt minibasins and salt flank plays for Cretaceous and Tertiary age reservoirs are widespread, as well as sub-salt plays. Some of these plays are well defined, others less so. Geochemical models were created and included three known source rocks and three potential source rocks. All are interpreted to have undergone maturation and expelled significant quantities of oil and gas. The stochastic numerical analysis employed probability distributions for all input parameters. Local data were used wherever possible, plus other data from global analogue basins.

The assessment results are presented as probability distributions for oil, gas, solution gas, and natural gas liquids for each of the 12 plays, and, a statistically summed total. Both in-place and recoverable hydrocarbon resource values were generated. Because the petroleum system(s) have yet to be proved in the deepwater slope, this analysis also included geological risk factors. The undiscovered gas potential for the deepwater Scotian Slope is forecast at 15 to 41 trillion cubic feet, depending on the assumed geological risk factors. Similarly, the undiscovered oil potential is 2 to 5 billion barrels. This oil potential is very significant, and conforms to the high oil-to-gas discovery ratios encountered in other deepwater areas of the circum-Atlantic region.

RÉSUMÉ

L'Office Canada - Nouvelle-Écosse des hydrocarbures extracôtiers vient de terminer l'évaluation du bassin géologique et l'analyse numérique du potentiel en hydrocarbures du talus continental au large de la Nouvelle-Écosse. Cette région s'étend par des fonds de 200 à 4000 mètres; elle débute à 850 kilomètres de la frontière américaine, au sud-ouest, et se termine à la frontière terre-neuvienne, au nord-est. Aucune évaluation des ressources de cette région n'avait été publiée auparavant.

L'évaluation de ce bassin se fonde sur l'interprétation de données sismiques régionales bidimensionnelles, incluant des corrélations stratigraphiques aux puits forés dans la plate-forme continentale, aux profils sismiques produits par l'industrie, aux données sismiques régionales de la croûte profonde et aux trous de sondage effectués par le Deep Sea Drilling Project. Le principal défi à surmonter a été de cartographier le

sommet et la base de la vaste formation salifère Argo d'origine allochtone. On a décelé la présence de douze types de zones d'hydrocarbures. Elles sont toutes à des degrés variables liées au sel. Les mini-bassins dans le sommet de formations salifères et dans leurs flancs sont répandus dans les réservoirs crétacés et tertiaires. Il en est de même des zones d'hydrocarbures au-dessous des formations salifères. Certaines zones d'hydrocarbures sont bien définies, d'autres moins. On a créé des modèles géochimiques dans lesquels on a inclus trois roches mères connues et trois roches mères potentielles. Les données d'interprétation indiquent qu'elles ont toutes subi une période de maturation et qu'elles ont expulsé d'importantes quantités de pétrole et de gaz. Pour les analyses stochastiques numériques, on a utilisé, quand c'était possible, des données locales que l'on a combiné à d'autres données provenant de bassins analogues dans le monde.

Les résultats de l'évaluation sont présentés comme des distributions de probabilité pour le pétrole, le gaz, le gaz dissous et les liquides de gaz naturel pour chacune des douze zones d'hydrocarbures et comme une somme totale statistique. On a généré des valeurs en ressources pour les hydrocarbures en place et récupérables. Étant donné que l'on n'a pas encore prouvé la présence de système(s) pétroliers dans le talus profond, l'analyse comporte des facteurs de risques géologiques. Les prévisions du potentiel en gaz non découvert dans le talus continental profond au large de la Nouvelle-Écosse indiquent entre 15 et 41 trillions de pieds cubes, selon les facteurs de risques géologiques utilisés. Le potentiel de pétrole non découvert varie entre 2 et 5 milliards de barils. Le potentiel de pétrole est très important et est conforme aux rapports élevés de découverte pétrole-gaz obtenues pour les autres zones très profondes de la région circum-atlantique.

EXECUTIVE SUMMARY

In September 2001, the Canada-Nova Scotia Offshore Petroleum Board (the Board) determined that an evaluation of the hydrocarbon potential was required for the deep-water Scotian Slope region under its jurisdiction. Industry's pro-activity in permit acquisition, exploration seismic acquisition and drilling, the development and production of Sable gas and application for development of the Deep Panuke gas discovery indicated the need for the Board to have a comprehensive assessment of the offshore potential.

Industry's recent interest in the deep-water off Nova Scotia has been driven by their tremendous successes in other deep-water basins in the Gulf of Mexico, offshore Brazil and West Central Africa. Indeed, these Atlantic-facing look-alike basins have attributes very similar to the Nova Scotia region and were used as analogues for the deepwater slope assessment.

Historically, the Geological Survey of Canada (GSC) carried out resource assessments of Canada's frontier regions and the oft-quoted number of 18 trillion cubic feet (discovered + potential) for the Scotian Shelf is sourced from their 1983 report. In 2001, the Canadian Gas Potential Committee (CGPC) assessed the Shelf region and arrived at a similar value but subdivided the region into assessment areas equivalent to the geological sub-basins such as the Sable Subbasin, Orpheus Graben, Jurassic Abenaki Carbonate Bank Edge, etc. However, there remained no publicly-available assessment of the deep-water slope region.

The Scotian Slope is approximately 65% the size of the Shelf region. It is 850 km long, stretching from the United States border in the southwest to the Newfoundland provincial border in the northeast, and with an average width of slightly less than 100 km from the shelf edge in 200 m of water out to 4,000 m of water, encompassing an area of 80,000 km^2.

Hydrocarbon resource assessment consists of two major components; geological basin evaluation and numerical analyses. The basin evaluation included significant original work in geology, geophysics and geochemistry by the Board staff. Stratigraphic correlations from the Shelf to the deep-water Slope were generated and required integration with the work of the Deep Sea Drilling Project (DSDP) and correlative charts with the analogue global basins. An extensive digital dataset of a regional 2-D speculative seismic survey of 30,000 km was obtained from TGS-NOPEC. Interpretations of the ubiquitous allochthonous salt features and regional sedimentary mega-sequences were carried out. Mapping of key horizons including the top and base of the salt was instrumental in the basin study phase. Geochemical modeling of petroleum source rock potential was carried out by Dr. P.K. Mukhopadhyay (Halifax) and indicated the potential for oil and gas in significant quantities along the Slope. The various anticipated trapping styles, based on seismic interpretation, resulted in a total of 12 individual plays to be assessed.

The numerical analyses were undertaken in-house using probability distributions for all input parameters with Excel™ spreadsheets and the @Risk™ software. Volumetric parameters, recovery factors, oil/gas ratios, etc. were estimated using local data wherever possible plus available worldwide analogue data. Mr. K.J. Drummond (Calgary) provided the Excel™ templates and acted as an objective observer during the "number-crunching" phase of the study.

During the study period, discussions and liaison were ongoing with staff from the provincial Nova Scotia Department of Energy, GSC, NEB and CNOPB. Board staff also participated in an assessment workshop in Calgary including leading assessors from primarily Canada and the United States, and several international deep-water geoscience symposia.

This assessment is therefore a forecast of what the offshore potential could be given the simultaneous occurrence of numerous geological assumptions. The results of the evaluation are presented as probability distributions for oil, gas, solution gas and natural gas liquids for each of the 12 defined plays. These were statistically summed and total values defining both in-place and recoverable resources were generated. The analyses also included values for geological risk factors at both the play and prospect level. It is thus very important to acknowledge that calculated upside potentials for these various plays also have a downside possibility and so any conclusions or expectations drawn from these should be cautiously employed.

The assessment results are summarized in the following table for oil and gas only. The values for minimum (90% probability of occurrence), mean, and maximum (10% probability) are shown for the unrisked and risked recoverable values. The risked category is used because the petroleum system(s) have not yet been proven. Given certain degrees of success over time, the individual plays can be unrisked or "de-risked" and the values increased.

Therefore, the Board's assessment of the undiscovered gas potential for the deep-water slope offshore Nova Scotia reveals the potential for between 15 and 41 trillion cubic feet (Tcf) of gas depending on the assumed geological risk factors. The oil potential of 2 to 5 billion barrels (BB) is very significant and in keeping with the high oil to gas discovery ratios seen in other global deep-water areas. The lateral ranges for the unrisked and risked categories indicate the broad spectrum of possible outcomes. Additionally, the associated gas and natural gas liquids (not shown here) are also significant.

CATEGORY	**Min – Mean - Max GAS (Tcf)**	**Min – Mean - Max OIL (BB)**
Unrisked Recoverable	**31 – 41 – 53**	**3 – 5 – 6**
Risked Recoverable	**5 – 15 – 28**	**0 – 2 – 3**

No basin assessment can stand alone and relative comparisons are needed with other similar basins in Canada and worldwide. If the estimated ultimate recovery (EUR) per unit area for the Scotian Slope is calculated, it appears to be in line with other Canadian frontier regions such as the Beaufort-MacKenzie Basin, the Labrador Shelf and the Sverdrup Basin in the Arctic Islands. If some or all of the 12 plays defined in the assessment are eventually proven, the slope region will have a much higher global ranking and approach that of offshore Brazil in hydrocarbon richness per unit area, but with a smaller total area.

The impact of these numbers, on a risked basis, is to basically double the gas potential of offshore Nova Scotia while adding significant oil potential. In other words, adding the traditional 18 Tcf from the shelf to a risked value of 15 Tcf for the slope gives a total potential of 33 Tcf. Similarly, adding the traditional 1 BB of oil (and liquids) to the 2 BB for the slope offers a total potential of 3 BB of oil.

CONCLUSIONS

Conclusions can be expressed on the basis of the geological basin evaluation and the results of the numerical analyses. The results of our assessment are encouraging and substantially add to Nova Scotia's offshore hydrocarbon potential. This first step in attempting to assess the deep-water Scotian Slope contains various levels of uncertainty, but as new drilling results come forth it becomes a matter of revision and updating.

Basin Evaluation

Offshore Nova Scotia and the analogue basins of the Gulf of Mexico, offshore Brazil and West Central Africa are all passive margins with progradation of dominantly siliciclastic sediments over a mobile salt substrate and up-dip hydrocarbon production within a deltaic complex. The conjugate basins offshore Morocco have yet to encounter commercial quantities of hydrocarbons on its shelf.

A major difference is timing of the continental break-up and ages of salt deposition, source rocks and reservoirs. The North Atlantic rifted in Late Triassic to Early Jurassic while the South Atlantic rifted in Early Cretaceous about 100 million years later. The GOM in the Central Atlantic area underwent prolonged rifting from early Jurassic though only accumulated its thick sedimentary succession over the past 40 million years. Nevertheless, although the ages of rifting and breakup are different, the inherent geological processes are the same.

The analogue basins have proven petroleum systems with large discoveries in the billion-barrel range on an oil-equivalent basis, while the Scotian Slope's petroleum system(s) have yet to be proven.

Geochemical analyses and one-dimensional modeling indicate the potential for multiple source rock intervals with favourable maturation and expulsion of hydrocarbons and the expectation for varying oil/gas ratios across the basin.

Interpretation of 30,000 km of 2D seismic data was carried out defining ten geologic markers. The stratigraphic correlations were extended from wells on the Shelf as well as the deep ocean scientific seismic profiles and the Deep Sea Drilling Project wellbores. The single greatest challenge was mapping the top and base of the ubiquitous mobile Jurassic Argo Salt.

Seismic mapping shows a very similar salt tectonic-influenced structural style of play types and trapping configurations. There are supra-salt, inter-salt and sub-salt play types common to the analogue basins. The inter-salt mini-basins are major submarine focal points for turbidite deposition of reservoir-grade coarse clastics and hydrocarbon source organic matter. Folds and anticlinal structures formed through sediment loading and salt withdrawal near the crest of the slope provide excellent large-size traps. Sub-salt plays throughout the geologic section are attractive because the overlying salt provides a perfect seal for trapped hydrocarbons. Folds created along the leading edge of the mobile salt can provide excellent structural traps and seals.

Major submarine canyons are observed on the present-day seafloor and can be mapped in the subsurface, particularly at major times of relative sea level lowstands in the Tertiary and Cretaceous. These submarine canyons are necessary for providing conduits for coarse-grained turbidite fan deposits that provide both reservoir and source material.

All the important ingredients of source, seal and trap are interpreted to be present along the deep-water Slope with the degree of uncertainty being addressed by the geologic risk factors at both the prospect and the play level.

Numerical Analysis

Numerical analysis were run on twelve individual plays and statistically summed for a total. All input parameters were entered as minimum, most likely and maximum values with Monte Carlo simulation of 10,000 iterations. The results are expressed as *risked* and *unrisked*, *in-place* and *recoverable* values for gas, oil, solution gas and natural gas liquids.

All of the assessment work was completed in-house by Board staff with outside expertise employed as required. The assessment software employed was user-friendly, very transparent and facilitated revisions. The broad range of the assessment results is thus sufficiently robust to have a shelf life until such time as there is significant new information from additional seismic data, wells and the like.

The highest-rated plays are turbidite fans lying on the floors and flanks of inter-salt mini-basins, and upper slope turbidite fans in a structured regime associated with listric down-to-basin faults and salt features. The sub-salt plays are rated lower, but this is partly a function of poorer seismic imaging of the sub-salt strata in the data available to the assessors. The top six plays account for 86% of the total assessment value.

The *undiscovered potential* for the deep-water Slope off Nova Scotia on a *risked mean recoverable basis* is 15 Tcf of gas and 1.7 BB of oil with solution gas of 2.6 Tcf and natural gas liquids of 0.5 BB.

The plays are conceptual because to date the petroleum system(s) are not proven. The overall play adequacies vary from 16% to 64% (average 30%) for the 12 plays identified.

The *undiscovered potential* on an *unrisked mean recoverable basis* (i.e. proven plays by discovery) is 41 Tcf of gas and 4.7 BB of oil with solution gas of 7.5 Tcf and natural gas liquids of 1.2 BB.

The forecast window, in very general terms, therefore is 15 to 41 Tcf of gas and 1.7 to 4.7 BB.

The potential of the Scotian Slope, on a risked basis, doubles the gas potential and triples the oil potential for Nova Scotia's portion of the overall Scotian Basin.

The predicted *hydrocarbon richness per unit area* places the Scotian Slope within the range of other Canadian frontier basins such as the Labrador, Sverdrup and Beaufort Basins and below the richer proven basins in the Gulf of Mexico and offshore Brazil and West Africa.

This assessment is a first step in what is an acknowledged and accepted subjective exercise. As new data and information, especially drilling results, becomes available, revisions and updates can readily be made to the existing study.
