Petroleum Resource Assessment of the Arctic Circle/Dempster Highway Study Area

by
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January 2001
Whitehorse, Yukon

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ISBN 1-55018-978-6

FOREWORD

On November 19, 1998, the Government of Canada transferred to the Government of Yukon the administrative legislative powers and responsibilities of managing onshore oil and gas resources. Yukon oil and gas resources are now governed under the Yukon *Oil and Gas Act*.

A study of the petroleum resources of the Arctic Circle/Dempster Highway in the Yukon Territory was undertaken by Geological Survey of Canada (GSC) in response to a request from the Government of Yukon. Assessment of petroleum resource potential is important for forming regulatory policies for these resources and for providing a basis for planning and issuing exploration rights.

EXECUTIVE SUMMARY

This study was undertaken by the Geological Survey of Canada on behalf of the Yukon government as part of its on-going oil and gas resources management program. The objective of this study was to investigate the hydrocarbon resource potential of the Arctic Circle/Dempster Highway Region in the Yukon. A quantitative analysis was designed to give a numerical estimate of resources that could exist in the study area. In the absence of defined pools with established reserves, probability distributions of reservoir parameters and marginal risk factors are used to generate a range of hydrocarbon potential estimates indicating the uncertainties involved in the analysis of frontier conceptual plays.

The Arctic Circle/Dempster Highway study area straddles three physiographic regions or tectonic elements in northern Yukon. From west to east, these regions or elements are the Eagle Plain or Foldbelt, Richardson Mountains or Anticlinorium, and the Peel Plateau and Plain which are part of the Interior Platform. The Eagle Foldbelt and Richardson Anticlinorium are tectonic elements included in the Frontal Belt of the Cordilleran Orogen while the Peel Plateau and Plain are part of the stable Interior Platform. Elements in the Cordilleran Orogenic System are characterized by numerous angular unconformities, diverse structural trends, fold bundles, and abundant faults indicating the crustal instability for the region. On the other hand, the Interior Platform is characterized by relative crustal stability and structural simplicity.

The quantitative hydrocarbon assessments were derived using the Geological Survey of Canada's (PETRIMES) assessment methodology system. The assessments included analyses of 5 conceptual plays, each of which incorporated the calculation or estimation of field size parametric data, numbers of prospects and exploration risks. Five speculative exploration plays were also defined but they are described qualitatively due to insufficient information. The median estimate for total gas potential for all Arctic Circle/Dempster Highway plays is 39 billion m^3 of in-place gas. There are no discovered reserves in the Arctic Circle/Dempster Highway region, but 4 gas fields larger than 3,000 million m^3 (100 BCF) of gas are expected. Significant gas potential is predicted for the Peel and Eagle Lower Paleozoic facies transition plays and the Peel Upper Paleozoic clastics play, even though geological risk factors are substantial in the plays. Geochemical evidence indicates that there is probably not much oil potential in the study area.

CONTENTS

INTRODUCTION

This study was undertaken by the Geological Survey of Canada on behalf of the Yukon territorial government as part of its ongoing oil and gas resource management program. The objective of this study was to investigate the hydrocarbon resource potential of the Arctic Circle/Dempster Highway Region in the Yukon (Figure 1, 2). A quantitative analysis was designed to give a numerical estimate of resources that could exist in the study area. In the absence of defined pools with established reserves, probability distributions of reservoir parameters and marginal risk factors were used to generate a range of hydrocarbon potential estimates representing the uncertainties involved in the analysis of frontier conceptual plays.

Regional petroleum resource assessments have been prepared periodically for various sedimentary basins in Canada by the Geological Survey of Canada. These studies incorporate systematic basin analysis with subsequent statistical resource evaluations (Podruski, *et al.*, 1988; Wade, *et al.*, 1989; Sinclair, *et al.*, 1992; Reinson, *et al.*, 1993; Bird, *et al.*, 1994; Dixon, *et al.*, 1994; Hannigan, *et al.*, 1998, 1999). This study summarizes the assessment of oil and gas potential of the Arctic Circle/Dempster Highway Region of northern Yukon.

This report provides an overview of the petroleum geology of the Arctic Circle/Dempster Highway Region and presents quantitative estimates of the oil and gas resources contained therein. This geological and resource framework will assist government agencies in evaluating land-use and moratorium issues, and petroleum industry companies in pursuing future exploration opportunities.

ACKNOWLEDGEMENTS

The author would like to acknowledge staff at GSC-Calgary for their insight and geological expertise on this area, specifically, J. Dixon, L.S. Lane, B.C. MacLean, D.W. Morrow, D.G. Cook and K.G. Osadetz.

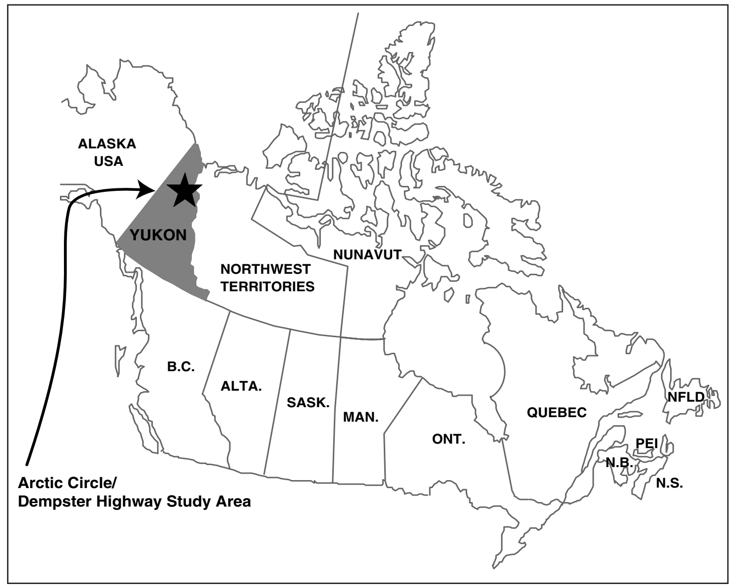
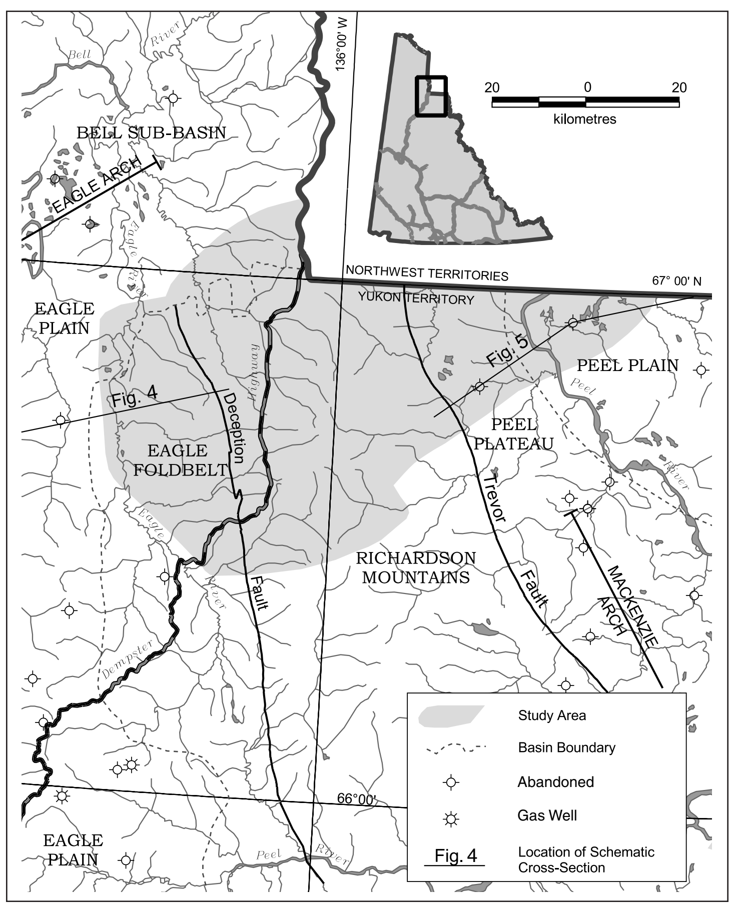


Figure 1. *Arctic Circle/Dempster Highway study area location map.*

Figure 2. *Physiographic subdivisions and index map of study area. Schematic cross-section locations are shown.*



TERMINOLOGY

The terminology and procedures used in this report follow those outlined in Reinson, *et al.* (1993) and are summarized below.

Oil is defined as any naturally occurring liquid that, at the conditions under which it is measured or estimated, is primarily composed of hydrocarbon molecules and is readily producible from a borehole.

Natural gas is defined as any gas (at standard pressure and temperature, 101.33 kPa and 15^{o}C) of natural origin comprised mostly of hydrocarbon molecules producible from a borehole (Potential Gas Committee, 1990). Natural gas may contain significant amounts of non-hydrocarbon gas such as H_2S, CO_2 or He. In this study, non-hydrocarbon gas was not considered due to lack of information on gas compositions in these basins.

Raw gas is unprocessed natural gas, containing methane, inert and acid gases, impurities and other hydrocarbons, some of which can be recovered as liquids. *Non-associated gas* is natural gas that is not in contact with oil in a reservoir. *Associated gas* is natural gas that occurs in oil reservoirs as free gas. *Solution gas* is natural gas that is dissolved in crude oil in reservoirs. In this report, insufficient information is available in order to differentiate non-associated, associated, and solution gas. All gas figures reported represent initial raw gas volumes.

Resource indicates all hydrocarbon accumulations known or inferred to exist. *Resource, resource endowment* and *endowment* are synonymous and can be used interchangeably. *Reserves* are that portion of the resource that has been discovered, while *potential* represents the portion of the resource that is not discovered but is inferred to exist. The terms *potential* and *undiscovered resources* are synonymous and may be used interchangeably.

Gas-in-place indicates the gas volume found in the ground, regardless of what portion is recoverable. *Initial in-place volume* is the gross volume of raw gas, before production. *Recoverable in-place volume* represents the volume expected to be recovered with current technology and costs. These definitions can be applied to oil volumes as well.

A *prospect* is defined as an untested exploration target within a single stratigraphic interval; it may or may not contain hydrocarbons. A prospect is not synonymous with an undiscovered pool. An undiscovered pool is a prospect that contains hydrocarbons but has not yet been tested. A *pool* is defined as a discovered accumulation of oil or gas typically within a single stratigraphic interval, that is separate, hydrodynamically or otherwise, from another hydrocarbon accumulation. A *field* consists of one or more oil and/or gas pools within a single structure or trap. Similar to most frontier regions, the assessment of the Arctic Circle/Dempster Highway Region's petroleum resources is based on estimates of field rather than pool sizes. A *play* is defined as a family of pools and/or prospects that share a common history of hydrocarbon generation, migration, reservoir development and trap configuration.

Plays are grouped into two categories: *established* and *conceptual* plays. *Established plays* are demonstrated to exist due to the discovery of pools with established reserves. *Conceptual plays* are those that have no discoveries or reserves, but which geological analyses indicate may exist. Established plays are categorized further into *mature* and *immature* plays depending on the adequacy of play data for statistical analysis. Mature plays are those plays that have sufficient numbers of discoveries within the discovery sequence so that the *discovery process model* of the PETRIMES assessment procedure is of practical use (Lee and Tzeng, 1989; Lee and Wang, 1990; Lee, 1993). Immature plays do not have a sufficient number of discoveries with established reserves to properly apply the model. Conceptual play analysis was applied exclusively in this study due to the lack of any discovered pools with established reserves.

METHOD AND CONTENT

This report incorporates two essential components; geological basin analysis and statistical assessment. Basin analysis fundamentally describes and characterizes the exploration play. Fields and prospects in a play form a natural geological population that can be delimited areally. Once a play is defined, a numerical and statistical resource assessment is undertaken using field or prospect data from that specific play.

RESOURCE ASSESSMENT PROCEDURE

The analysis of the Arctic Circle/Dempster Highway area began with the compilation and synthesis of information on regional geology and hydrocarbon occurrence. This included a survey of National Energy Board (NEB) public files and a search of pertinent publications. The NEB files contain information submitted as part of exploration agreements, and they often contain seismic lines and maps.

The aim of this data compilation was to initiate basin analysis in order to provide background for the definition of hydrocarbon occurrence models. Models for hydrocarbon entrapment or play types in the study area were developed by examining the hydrocarbon systems and, when possible, using analogous plays to extrapolate certain play parameters.

Play definition and estimation of reservoir parameters formed the input for a systematic statistical analysis which allowed a quantitative analysis of the undiscovered resource.

Geological Play Definition

Definition of play type and play area are essential in the geological basin analysis that precedes any numerical resource evaluation procedure. A properly defined play will possess a single population of pools and/or prospects that satisfies the assumption that geological parameters within a play can be approximated by a family of lognormal distributions. A mixed population derived from an improperly defined play adds uncertainty to the resource estimate. Pools and/or prospects in a specific play form a natural geological population which is characterized by one or more of the following: age, depositional model, structural style, trapping mechanism, geometry, and diagenesis. Prospects or areas within a basin or region can be assigned to specific plays on the basis of a commonality of some or all of these geological elements.

Compilation of Play Data

Since conceptual plays have no defined pools or discoveries, probability distributions of reservoir parameters such as prospect area, reservoir thickness, porosity, trap fill, and hydrocarbon fraction are needed. Prospect size can then be calculated using the standard “pool”-size equation. Seismic, well, and outcrop data prove particularly useful in identifying the limits for sizes of prospect area and reservoir thickness as well as porosity limits. Geochemical data are useful in identifying prospective areas as well as the composition of the hydrocarbon accumulations, i.e. oil-vs-gas proneness. Research in similar hydrocarbon-bearing basins is also important in order to provide reasonable constraints on reservoir parameters as well as contributing further information on other aspects of petroleum geology that may prove useful for the study.

Conceptual Play Analysis

There are several methods for estimating the quantity of hydrocarbons that may exist in a play, region or basin (White and Gehman,1979; Masters, 1984; Rice, 1986; Lee, 1993). Petroleum assessments undertaken by the Geological Survey of Canada are currently based on probabilistic methods (Lee and Wang, 1990) that are developed in the Petroleum Exploration and Resource Evaluation System, PETRIMES (Lee and Tzeng, 1989). The conceptual hydrocarbon plays defined in the Arctic Circle/Dempster Highway region were analysed by applying a subjective probability approach to the reservoir parameters. The lognormal option in PETRIMES was utilized since experience indicates that geological populations of pool parameters can be adequately represented by lognormal distributions.

Conceptual resource assessments in the frontier regions use field-size estimates rather than pool-size predictions as derived from mature and immature play analysis. A field consists of one or more oil/gas pools or prospects in a single structure or trap. Probability distributions of oil and gas field sizes are computed by combining probability distributions of reservoir parameters, including prospect area, reservoir thickness, porosity, trap fill, hydrocarbon fraction, oil shrinkage, and gas expansion.

Probability distributions of oil and gas field sizes were combined with estimates of numbers of prospects (from seismic and play area mapping) and exploration risks to calculate play potential and to estimate sizes of undiscovered fields.

Exploration risks at a play or prospect level are determined on the basis of the presence or adequacy of geological factors necessary for the formation of petroleum accumulations. Essential factors are reservoir, seal, source rock, timing of hydrocarbon generation, trap closure and preservation. Appropriate marginal probabilities are assigned to each geological parameter to obtain risk factors. The Arctic Circle/Dempster Highway conceptual plays have high probabilities for existence (low risk). Within each play, certain prospect-level risks are high and these are assigned appropriate risk factors. Exploration risk is an estimate, incorporating all risk factors, of the percentage of prospects within a play that are expected to contain hydrocarbon accumulations.

Due to the nature of conceptual assessment results and since no discovered pool sizes can be used to constrain sizes of undiscovered accumulations, the uncertainty of oil and gas play potential and pool-size estimates for a given range of probabilities is necessarily greater than the limits derived by discovery process analysis used in assessing mature plays.

REGIONAL GEOLOGY

Two distinct structural and genetic regional geological regimes are present in northern Yukon. The vast majority of the northern Yukon occupies the northern part of the Cordilleran Orogen. An area in the extreme northeastern corner of Yukon occupies a portion of the ancestral North American craton where little Phanerozoic deformation has taken place. This area of ancestral North America is known as the Interior Platform.

There are two major geological components within the Cordilleran Orogen of northern Yukon separated by the northwest-trending Tintina fault: the northeastern region, part of the morphogeological Frontal Belt, comprising a thick assemblage of older sedimentary rocks that were deposited on a relatively stable geological basement, and the southwestern area, representing the amalgamated and accreted geological terranes containing the younger, more complex assemblage of varying rock-types (Hart, 1999). The rocks northeast of the Tintina Trench are mainly sedimentary rocks deposited on the ancient North America margin.

The western edge of the ancient North America craton extended far out into the ancient Pacific Ocean. This submerged continental shelf of crystalline basement rocks is at least 1.7 billion years old and the rocks are present throughout northern Yukon beneath both the Interior Platform and the Cordilleran Orogen. These rocks provided the stable continental platform upon which sediments, dominantly consisting of limestone and sandstone, were deposited for over a billion years (Hart, 1999). Shale, sandstone and chert accumulated in regions of deeper water known as basins. Thus, the two depositional environments (platform and basin) gave rise to distinct sedimentary packages, dominated by limestone and shale, respectively. These shale and limestone packages are now in fault contact with each other. The Mackenzie platform accumulated between 5 and 25 km of dominant limestone and sandstone. The limestone accumulated during quiescent times in warm, shallow and clear water. The sandstone was derived from detritus eroded from the Canadian Shield. In the Richardson Trough, limestone growth was limited due to deeper water and currents depositing sands were not strong. Instead, this basin or trough accumulated mud and biogenic silica forming shales and cherts.

The Arctic Circle/Dempster Highway study area straddles three physiographic regions or tectonic elements in northern Yukon (Figure 2). These regions or elements from west to east are the Eagle Plain or Foldbelt, Richardson Mountains or Anticlinorium, and the Peel Plateau and Plain. The Eagle Foldbelt and Richardson Anticlinorium are tectonic elements included in the Frontal Belt of the Cordilleran Orogen while Peel Plateau and Plain are part of the stable Interior Platform. Elements in the Cordilleran Orogenic System are characterized by numerous angular unconformities, diverse structural trends, fold bundles, and several faults indicating the crustal instability of the region. On the other hand, the Interior Platform is characterized by relative crustal stability and structural simplicity.

The Eagle Foldbelt is flanked on the east by the Richardson Anticlinorium and truncated to the north by the Aklavik Arch Complex. In the central and western part of the foldbelt, the Upper Cretaceous Eagle Plain Group of sandstone and shale predominate on surface, and these rocks are gently folded (Norris, 1997b). To the southeast, Middle and Late Paleozoic clastics are widely exposed. The north-northwest trending folds are commonly symmetrical and open (Norris, 1997b). The belt is a roughly rectangular structural depression and it has undergone two periods of deformation: the Laramide compressional episode producing folds and contraction faults, and then an early to mid-

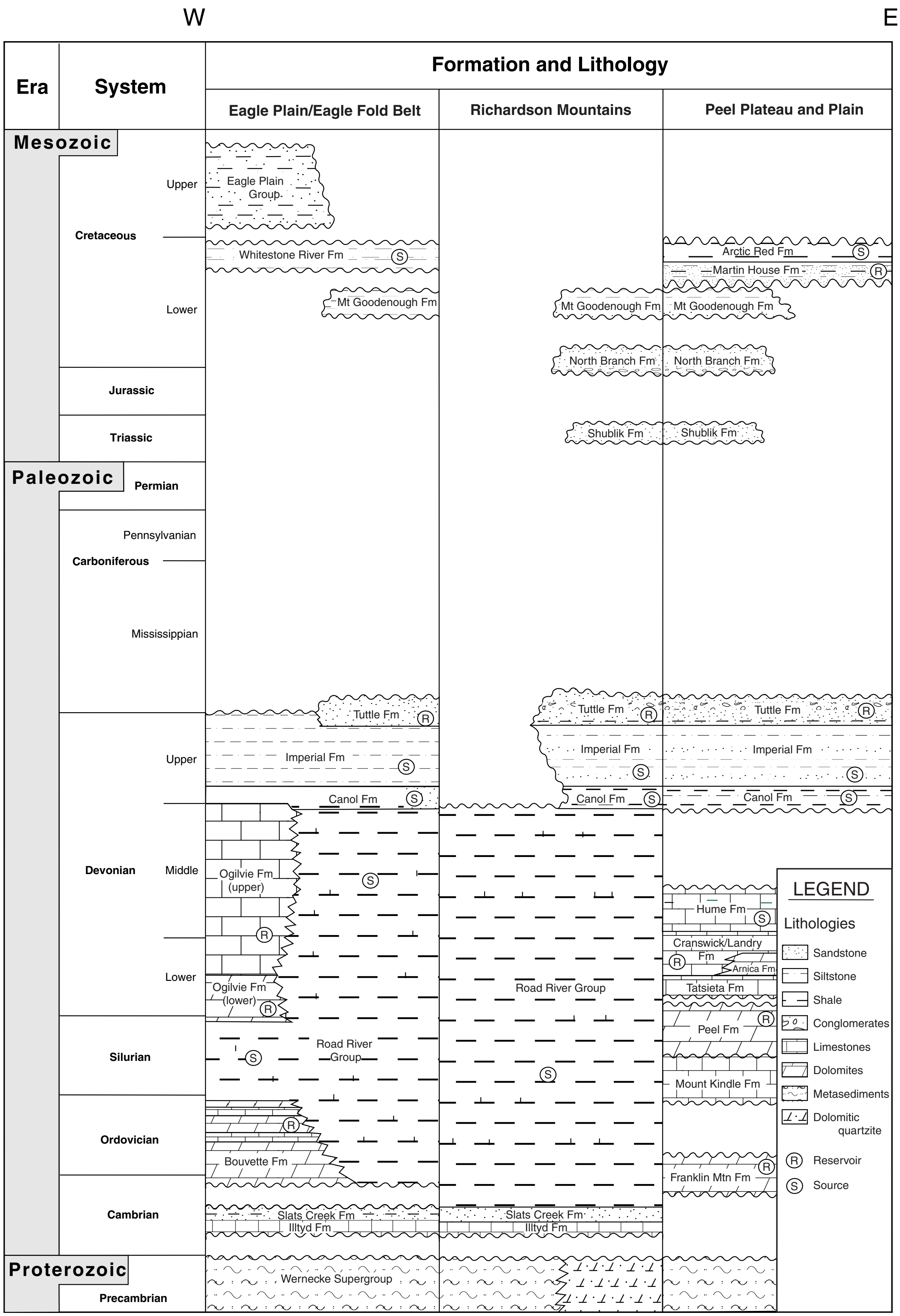


Figure 3. *Stratigraphic column for Arctic Circle/Dempster Highway study area.*

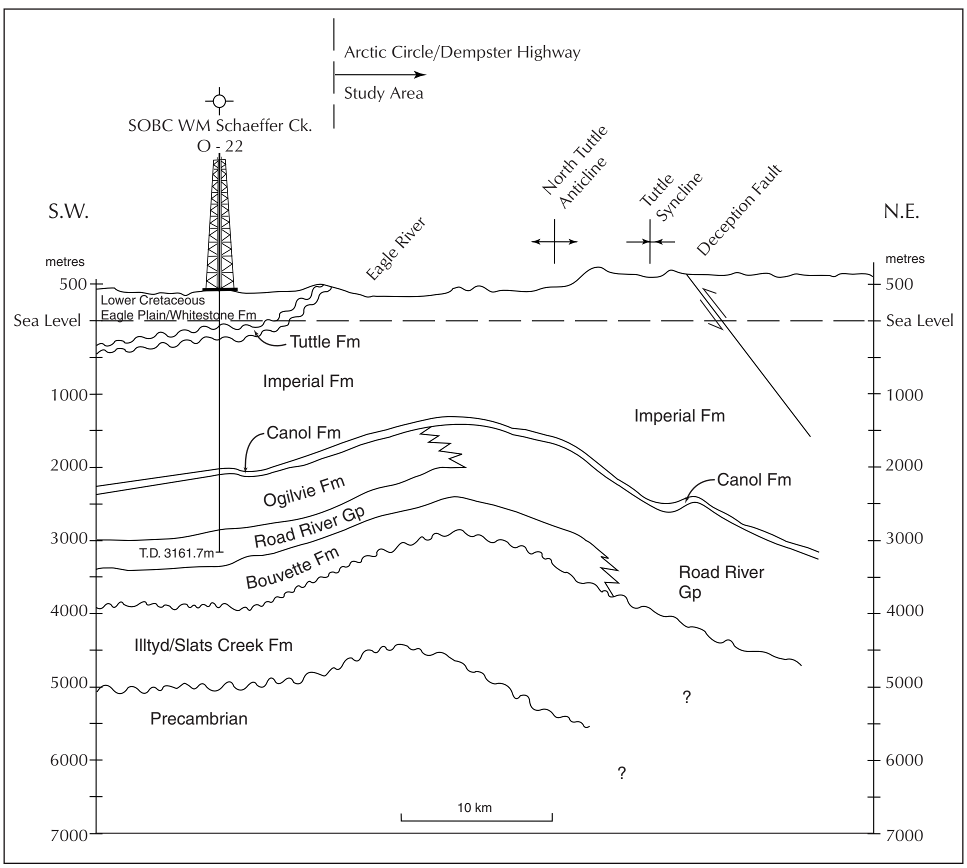
Tertiary episode of differential uplift of the Aklavik Arch Complex creating structures truncated by faulting.

The Richardson Anticlinorium is a broad north-plunging anticlinal structure located between the Interior Platform to the east and the Eagle Foldbelt to the west (Norris, 1997b). The Anticlinorium is bounded on the east by the Trevor Fault and the west by Deception Fault (Figure 2). The Anticlinorium was formerly a trough during early and middle Paleozoic time. On the flanks of the anticlinorium, deep water shales and argillaceous limestones comprise the Late Cambrian to Middle Devonian Road River Group (Figure 3). In the core of the anticlinorium, Middle Cambrian Slats Creek sandstones and Lower Cambrian limestone of the Illtyd Formation overlie the Wernecke Supergroup with angular unconformity (Norris, 1997b; Figure 3). There are numerous north-trending curvilinear, near-vertical faults throughout the anticlinorium that constitute the Richardson Fault Array. This fault array is the underlying structural control for both the Richardson Anticlinorium and Trough. Reactivation of faults in the late Cretaceous and continuing intermittently to the mid-Tertiary caused the inversion of the Paleozoic trough into the post-mid-Tertiary anticlinorium.

The northern Interior Platform is a relatively undeformed supracrustal wedge adjacent to the Frontal Belt (Norris, 1997b). The formations are layer-parallel and flat-lying to very gently dipping to the west. Carbonates and clastics unconformably overlie Proterozoic sedimentary and igneous rocks.

The Eagle Plain basin is a structural depression that is surrounded by deformed belts bringing Paleozoic rocks to the surface (Hamblin, 1990). The Eagle Arch (Norris, 1981c) is an east-west trending pre-Mesozoic upwarp of Paleozoic strata beneath Eagle Plain

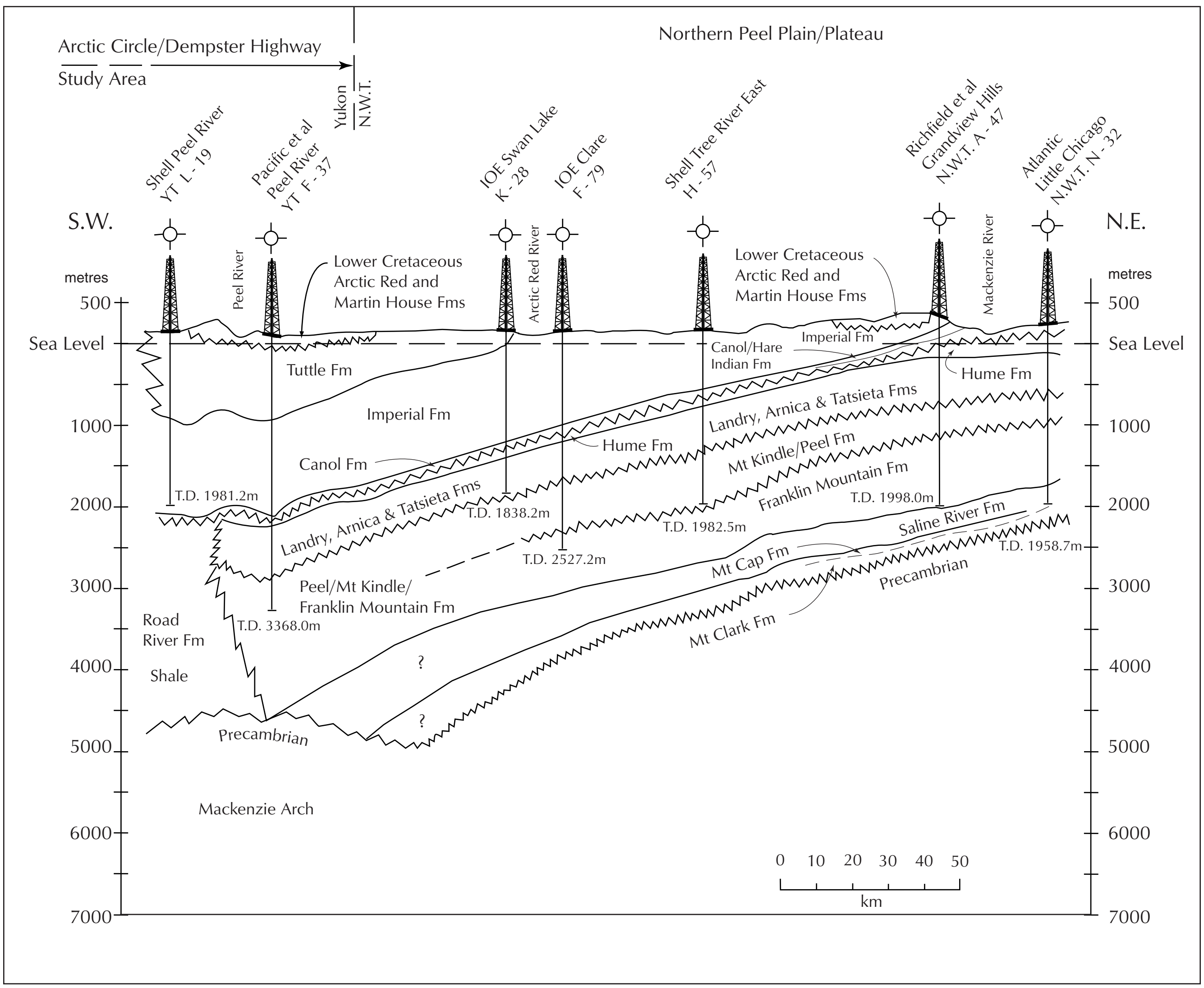
Figure 4. *Schematic cross-section, Eagle Fold Belt.*



which separates the shallower northern portion of the basin (Bell subbasin) from the southern element containing a thicker and more complete stratigraphic section (south Eagle subbasin) (Figure 1; Northern Oil and Gas Directorate, 1995b).

There are between 4,000 and 6,000 m of Lower Cambrian to Upper Cretaceous sedimentary strata in the study area (Figures 3, 4, 5). Proterozoic basement consists of metasediments including orthoquartzites, dolomitic quartzites, shales and argillites. This thick supracrustal Proterozoic wedge unconformably overlies Hudsonian granites and metamorphics that comprise the westward continuation of the Canadian Shield underneath the northern Interior Platform and the Cordilleran Orogen (Norris and Dyke, 1997). Unconformably overlying these metasediments within the Eagle Fold Belt and the Richardson Mountains are 450 to 600 m of massive bedded white pelletoid limestone of the Illtyd Formation of Early Cambrian age (Figures 3, 4; Fritz, 1997). These rocks are abruptly overlain by sandstones and siltstones of the Middle Cambrian Slats Creek Formation (Figure 3). The Slats Creek Formation attains a maximum observed thickness of 1,600 m in and near Richardson Trough and thins westward to a feather edge (Fritz, 1997; Morrow, 1999). Equivalent Lower and Middle Cambrian strata are absent in the Peel Plateau region of the study area due to non-deposition of Mount Clark, Mount Cap

Figure 5. *Schematic cross-section, Peel Plain and Plateau.*



and Saline River formations on the Mackenzie-Peel Arch (Figure 5). Periods of subaerial exposure of the Arch has erosionally truncated and removed Middle and Cambrian strata (Pugh, 1983; Cecile *et al.*, 1997; Morrow, 1999).

The development of the Lower Paleozoic Richardson Trough between the Yukon Stable Block to the west and the Mackenzie-Peel Shelf to the east influenced greatly the deposition of Lower Paleozoic sediments. The north- to northwest-trending Richardson Trough (Gabrielse, 1967; Pugh, 1983; Norris, 1985a) defined a region of slope and basinal shale and argillaceous limestone deposition that separated two broad regions of shallow-water shelf carbonate deposition to the west and east (Morrow, 1999). The Richardson Trough remained a negative physiographic feature from Early Cambrian to Devonian time.

Subsequent to deposition of Slats Creek sands in Middle Cambrian time, the more typical strata consisting of shales and argillaceous limestones of the Road River Group were deposited in the Trough and along its margins (Figures 3, 4, 5). Silurian-aged Road River Group shales were also deposited on the Yukon Stable Block directly overlying the Ordovician Bouvette Formation (Morrow, 1999) (old name: 'Unnamed carbonate sequence', Norford, 1997) (Figures 3, 4). The Road River Group has an average thickness of 500 m, but in the main depocentre in Richardson Trough, it attains a thickness of 3,000 m.

The Ordovician carbonate shelf facies are represented by the Bouvette Formation to the west in the Eagle Fold Belt and the Franklin Mountain Formation beneath the Peel Plateau to the east. The Bouvette Formation consists of dolostones and lesser limestone with an average thickness of 1,000 m. The Late Cambrian to Early Ordovician Franklin Mountain Formation ranges in thickness from about 375 to 780 m. The Franklin Mountain dolostones unconformably overlie Precambrian basement in the study area and is in turn unconformably overlain by Late Ordovician to Silurian Mount Kindle Formation (Figures 3, 5; Norford and Macqueen, 1975; Norford, 1997). Thicknesses of Mount Kindle strata range from 200 to 440 m in the Peel Plateau area. Mount Kindle rocks consist of fossiliferous lime mudstones and shaly limestones (Pugh, 1983).

Unconformably overlying the Mount Kindle Formation in the Peel Plateau area is a sequence of slightly argillaceous and silty dolostone designated the Peel Formation (Pugh, 1983). The age of the Peel Formation ranges from Late Silurian to earliest Devonian (Pugh, 1983). Average thickness of the Peel Formation is about 220 m, although the thickest subsurface section of the Peel occurs in the Pacific Peel F-37 well located in the study area (341 m, Morrow, 1999). Immediately overlying the Peel Formation is a thin regionally developed limestone and green shale unit called the Tatsieta Formation. Average thickness in the subsurface is only about 60 m. Age is probably Early Devonian.

Meanwhile, carbonate shelf deposition in southwestern Eagle Fold Belt took place consisting of an argillaceous and shaly limestone unit called the Michelle Formation (not shown on Figure 3) (Norris, 1985a, Morrow, 1999). Age of the Michelle Formation is thought to be Early Devonian (Morrow, 1999). Continuation of marine transgression over the entire Peel shelf led to deposition of shallow-water, subtidal, open marine clean carbonates of the Arnica and Landry formations (Figures 3, 5). Directly above Landry or Cranswick (old name) limestones, limestones and argillaceous limestones of the Hume Formation were deposited. Total thickness of the Arnica to Hume sequence averages about 600 m (Figures 3, 5; Morrow, 1999).

Contemporaneous with deposition of the Arnica to Hume succession, the Ogilvie carbonate succession was accumulating in Eagle Fold Belt (Figures 3, 4). Ogilvie rocks consist predominantly of a thick bedded limestone sequence. In the study area, the lower part of the Ogilvie Formation is primarily dolostone (Figure 3). The Ogilvie sequence varies from zero to 1,200 m thick (South Tuttle N-05 well) in the Arctic Circle/Dempster Highway study area. Shale deposition meanwhile continued within and on the flanks of Richardson Trough to the east (Road River Group).

A rapid rise of sea level in early Late Devonian time led to the uniform deposition of the euxinic siliceous black shales of the Canol Formation across the entire Peel Shelf and the Yukon Stable Block as well as overlying the Road River Group in Richardson Trough (Figures 3, 4, 5; Morrow, 1999). This unit marked the end of shallow-water carbonate platform or shelf deposition in the region (Morrow and Geldsetzer, 1992). Thicknesses of Canol shales vary from about 40 m beneath Peel Plateau to 125 m at South Tuttle N-05 well in the Eagle Fold Belt directly southwest of the Arctic Circle/Dempster Highway study area (Pugh, 1983). The Canol Formation conformably underlies the clastic Late Devonian Imperial Formation, which principally consists of shales, and siltstones with minor sandstones. Imperial Formation thicknesses vary from 750 to 1,750 m in the study area. The Imperial Formation is in turn conformably overlain by coarse clastic rocks of the Tuttle Formation of uppermost Devonian-lower Carboniferous age (Norris, 1997a; Richards *et al.*, 1997). Conglomerates, sandstones and shales having thicknesses up to 1,250 m occur in the study area. Pronounced truncation beneath several regional unconformities has removed all of the upper Paleozoic rocks in some portions of the study area (Richards *et al.*, 1997).

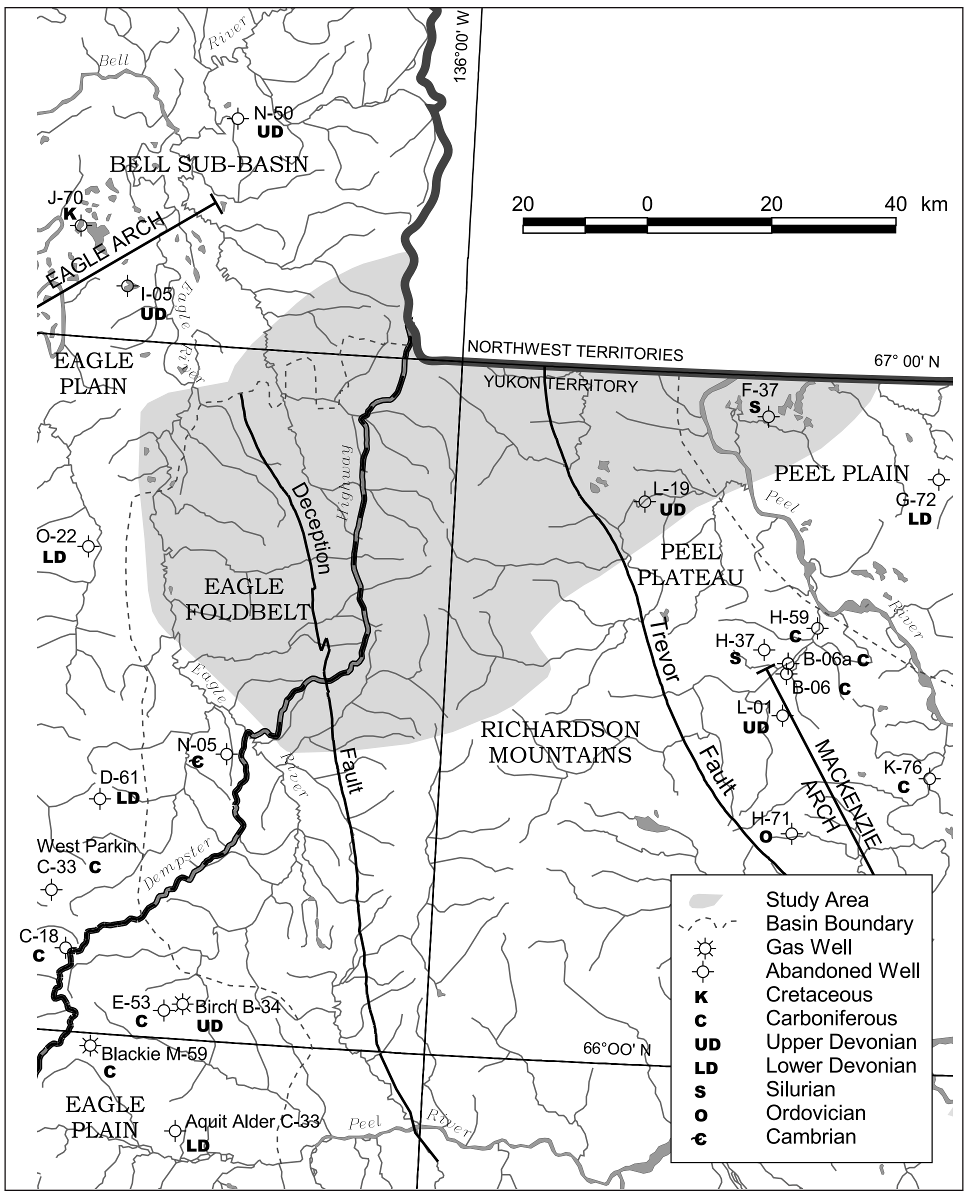
Isolated outcrops of Triassic Shublik sands and Upper Jurassic-Lower Cretaceous North Branch conglomerates and sandstones remain as remnants of Triassic to Lower Cretaceous clastic deposition (Norris, 1997c; Poulton, 1997). Sedimentation during a rifting tectonic episode characterized subsequent Mesozoic clastic deposition in Neocomian-Aptian time with emplacement of sands, silts and shales in nearshore and inner shelf environments (Mount Goodenough Formation) (Dixon, 1997). Sediment source was derived from the southeast. A subsequent Albian rifting and compressional tectonic phase associated with a major transgression resulted in the deposition of the shales and thin sandstones of the Martin House Formation overlain by shales of the Arctic Red Formation in the Peel Plateau area (Dixon, 1997). Meanwhile to the west, a shelf environment collected mud, silt and minor sand that formed the Whitestone River Formation in the Eagle Fold Belt. A compressional phase then ensued in the post-Albian, forming better defined foreland basins adjacent to the Cordilleran Orogen. The Cenomanian to middle Maastrichtian Eagle Plain Group in the Eagle Fold Belt consists of interbedded sandstones and shales deposited in an inner- to mid-shelf environment accommodated in a shallow foreland basin north of the earlier-formed Cordilleran Orogen (Dixon, 1997).

PETROLEUM GEOLOGY

EXPLORATION HISTORY

Surface exploration commenced in the mid-1950s in both Eagle Plain and Peel Plateau areas. The first well drilled in Eagle Plain was the Peel Plateau Eagle Plain YT No. 1 N-49 (not shown on Figure 6) well completed in 1958 and classified as dry and abandoned. In Peel Plateau, drilling commenced in 1965 with the spudding of the Shell Peel River YT J-21 well (not shown on Figure 6) again dry and abandoned. Since then, an additional 35 wells in Eagle Plain and 18 wells in the Peel Plateau area have been drilled. Five out of the 36 wells in Eagle Plain are classified as discovery wells: 1 oil, 2 gas and 2 oil and gas wells, all in southern Eagle Plain sub-basin. Among these discovery wells, 5 individual oil and 10 gas accumulations or pools were defined (National Energy Board, 1994). No discoveries were made in the Peel Plateau and Plain area, although significant flows of sweet gas

Figure 6. *Well identification and penetration map.*



were encountered in the IOE Tree River H-38 well (Northern Oil and Gas Directorate, 1995a) (not shown on Figure 6) and the Mobil Peel River H-71 well (Pugh, 1983) (Figure 6).

In the Arctic Circle/Dempster Highway study area, only two wells were drilled, both in Peel Plateau and Plain (Shell-Peel River YT L-19 and Pacific et al Peel River YT F-37; Figure 6). Both wells are dry and abandoned. Adjacent to the southwest boundary of the study area in the Eagle Fold Belt, the South Tuttle N-05 well was completed (Figure 6). This well encountered a significant gas flow from lower Ogilvie dolostones.

In Eagle Plain, 9,952 line-kilometres of two-dimensional (2D) seismic surveys were acquired. Only 8% of these lines were shot since 1975 and no three-dimensional seismic has been run to date. Most of the coverage is concentrated in the southern end of the basin in the vicinity of the existing discoveries. The largest regional seismic program was completed by Chevron in 1971 including the few lines surveyed within the Arctic Circle/Dempster Highway study area (Figure 7; Chevron Standard Ltd, 1971). During the

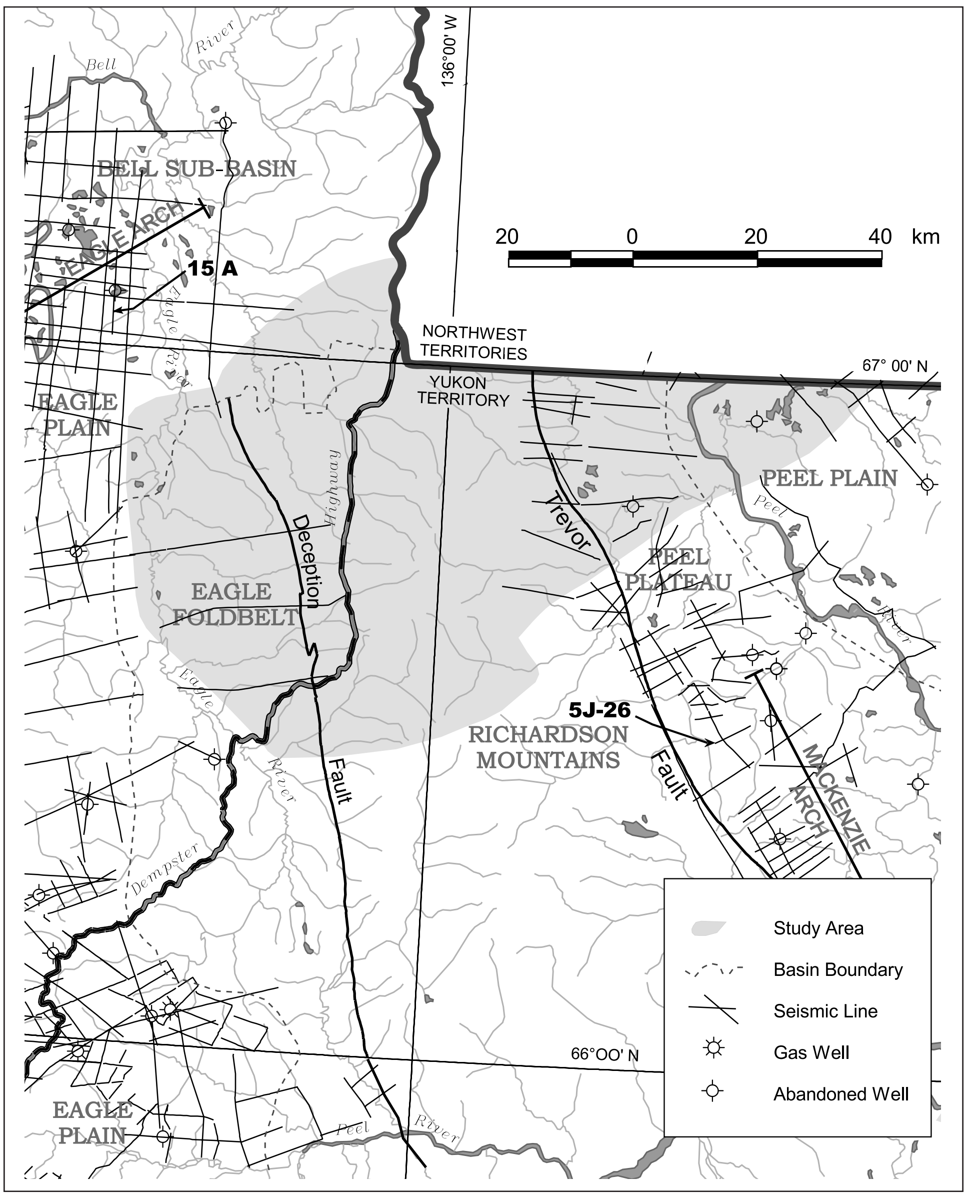


Figure 7. *Location of historical seismic lines. Seismic sections 15A and 5J-26 locations are shown.*

1960s and 1970s, approximately 6,000 kilometres of seismic data were acquired in the Yukon portion of the Peel Basin. About 500 kilometres of line data are available to the public in the NEB files. Particularly relevant for the Arctic Circle/Dempster Highway study area is the Mobil Oil Canada regional survey conducted in 1976 over the disturbed belt or Peel Plateau (Figure 7; Mobil Oil Canada, Ltd., 1976).

Covering the study area are 1:250,000 scale geological maps by members of 'Operation Porcupine.' These maps were compiled by D.K. Norris, the co-ordinator of the regional Geological Survey of Canada mapping project (Norris, 1981a, 1981b, 1981c, 1981d). Norris also published a regional geological map for the northern Yukon and northwestern District of Mackenzie at a scale of 1:500,000 (Norris, 1984).

RESERVOIRS

UPPER PROTEROZOIC

The upper Proterozoic supracrustal wedge contains interbeds of red and green shales, deep-water diamictites, sandstones, and carbonates. The several hundred metre thick unit may have sufficient fracture porosity for accumulation of hydrocarbons.

CAMBRO-ORDOVICIAN

The Cambrian Illtyd Formation typically consists of lime mudstone and pelletal lime wackestone. There are several oolitic and oncolitic beds in the upper part of the formation. Adjacent to high-angle faults within the Illtyd, the carbonate has been altered to marble. These rocks probably have no or little primary porosity but secondary fracture porosity may be present. The overlying Slats Creek sandstones and chert-pebble conglomerates are weakly metamorphosed and probably have no primary porosity, but secondary fracture porosity may exist.

The Late Cambrian to Early Ordovician Franklin Mountain Formation typically consisting of dolostone with lesser limestone, has various strata suitable for reservoirs, specifically karsted and vuggy horizons in dolostones as well as oolitic carbonate sand bodies in the 'middle Rhythmic member' (Morrow, 1999). In the subsurface of Eagle Plain, the Late Cambrian to Late Ordovician Bouvette Formation consists of interbedded dolostones and limestones adjacent to the Richardson Trough. Biostromal or bioclastic layers or karsted and vuggy dolostones are present in strata of the Bouvette Formation in the Eagle Fold Belt. Vuggy porosity and pyrobitumen have been observed in Ordovician carbonates capped by Road River shales in subsurface Eagle Plain (Norford, 1997). However, all four wells penetrating this sequence encountered water in the carbonates (Moorhouse, 1966; Martin, 1973).

SILURIAN

A major facies variant of the Mount Kindle Formation is noted in the subsurface of Peel Plateau adjacent to Richardson Trough. The Mount Kindle dolostones pass into fossiliferous lime mudstones and shaly limestones in the Arctic Circle/Dempster Highway study area. There are porous zones in this formation as indicated by the Peel H-71 well to the south which tested gas in the Mount Kindle Formation. The porous zone in this well is stratigraphically closed on its up-dip side by Road River shale in the Richardson Trough (Pugh, 1983).

DEVONIAN

Numerous carbonate shelf units have been identified as potential reservoirs in the Arctic Circle/Dempster Highway region. In the Eagle Fold Belt to the west of the shale-filled Richardson Trough, Lower to Middle Devonian Ogilvie Formation has tested gas to surface. Vuggy porosity has been noted in the lower dolomite member of the Ogilvie Formation in the South Tuttle N-05 well (Martin, 1973; Norris, 1985a). Slightly porous crinoidal packstones and wackestones have been observed in the dolomitic Ogilvie Formation. Gas has also been recovered from the upper limestone member of the Ogilvie Formation. Stromatoporoidal biostromes and bioherms are present at the top of the Ogilvie Formation in western Eagle Plain. Also, limestones with late fracturing, dolomite cementation and dolomitization develop secondary porosity in the upper Ogilvie unit (Morrow, 1999).

Beneath Peel Plateau, porous zones in Lower Devonian Peel dolomites and Middle Devonian Landry and Arnica carbonates occur sporadically. Pugh (1983) reported rocks of the Arnica Formation producing gas in the Peel River H-71 well. Morrow (1999) indicated that gas was recovered from the Landry Formation in the Cranswick A-42 well and from Arnica dolostones in the Taylor Lake K-15 well in southern Peel Plateau.

The Upper Devonian-Lower Mississippian Tuttle Formation comprises part of a clastic wedge depositional system. It consists of repeated cycles of fine- to coarse-grained fluvio-deltaic sandstones and conglomerates with intervening shales (National Energy Board, 1994, 1999). Tuttle coarse clastics occur in the Eagle Fold Belt and the Peel Plateau and Plain. Generally, the Tuttle sandstones are poorly sorted and are distinguished by the presence of kaolinite and quartz overgrowths resulting in low porosities and permeabilities. However, sorting and potential reservoir qualities improve to the south. Many channel-like sand bodies with abrupt basal contacts, observed on well-logs and in well samples, indicate possible hydrocarbon accumulation sites. Significant porosities such as 16% at the Chance M-08 well and 5% at the Birch B-34 well in southern Eagle Plain produced significant gas flows (National Energy Board, 1994; Northern Oil and Gas Directorate, 1995b).

CRETACEOUS

The Lower Cretaceous Martin House Formation in Peel Plateau and Plain generally shows petrophysical characteristics indicating poor quality reservoirs. However, there are locally developed reservoir quality sandstones in this formation (Dixon, 1999). Good porosity has been observed in some of the Martin House sandstones in the Hume River wells of Peel Plain (Dixon, 1999). Even though the Martin House sandstones are thin-bedded and argillaceous, they are porous in parts. There may be minor sandstone horizons in the overlying shaly Arctic Red Formation that are considered to be reservoir quality. In the Eagle Fold Belt, the dominant reservoir horizon is present in the Fishing Branch Formation in the Upper Cretaceous Eagle Plain Group. The sandstone is a salt and pepper, fine-grained, medium sorted, subangular to subrounded cherty marine sand. The sands are quite often clean. Porosities range up to 22% in the Chance M-08 well in southern Eagle Plain (National Energy Board, 1994). Dixon (1992) identified a lower sandstone member in the shale-dominant Parkin Formation of the Eagle Plain Group as having better reservoir potential than the overlying Fishing Branch Formation due to excellent sealing above and below by shale. However, he did point out that porosity in this member is highly variable.

SEALS

With respect to Paleozoic carbonate shelf reservoirs, a good lateral seal is obtained at the carbonate to shale facies transition from carbonate bank into basinal shales deposited in Richardson Trough (Figure 3). Canol and Road River shales also act as regional top seals for lower Paleozoic formations. Intraformational shales form local top seals for Upper Devonian and Cretaceous reservoirs. The Lower Cretaceous Whitestone River Formation in Eagle Plain is a shaly regional top seal for reservoirs truncated by the sub-Cretaceous unconformity (Northern Oil and Gas Directorate, 1995b). In Peel Plateau, the Martin House sandstones are both overlain and partially underlain by shales, providing good seals to vertical migration of fluids (Dixon, 1999).

TRAPS

A variety of structural, stratigraphic and combination traps occur in Paleozoic and Mesozoic sedimentary strata throughout the region. Even though most well locations with Paleozoic targets in Eagle Plain were drilled along crests of Laramide anticlinal culminations, the most effective hydrocarbon traps and reservoirs may have formed previous to Tertiary time, when the most active oil migration may have occurred.
The Lower Paleozoic carbonate to shale transition is favourable for entrapment of hydrocarbons in combined structural and stratigraphic traps (Morrow, 1999). Davidson (1994) described a pre-Laramide episode of compressional tectonics which produced a series of long-wavelength anticlines involving Lower Paleozoic strata (these traps more likely occur in western Eagle Plain). Trapping of Upper Paleozoic Tuttle sandstones bodies occur when sandstone pinches out or within the formation against Upper Devonian Imperial Formation. Combined stratigraphic-structural traps beneath the Lower Cretaceous unconformity may occur in upper Paleozoic clastic reservoirs. Regarding Cretaceous reservoirs, the principal trapping mechanism is the development of broad, low-amplitude anticlines associated with the Laramide Orogeny. Lane (1996) identified an Early Tertiary triangle zone configuration within the Jura-Cretaceous succession in northeastern Eagle Plain in the Bell subbasin.

Several potential reservoirs subcropping beneath unconformities along plunging anticlines and stratigraphic traps constitute available sites for natural gas accumulation from both Paleozoic and Mesozoic source rocks.

SOURCE ROCKS

Link *et al.* (1989) and Link and Bustin (1989) conducted a regional petroleum source potential and organic maturation study over the entire region of northern Yukon Territory. They surmised that the principal organic-rich source rock in the region for Lower Paleozoic reservoirs is the black bituminous shale of the Canol Formation. Residual kerogen, measured as total organic carbon (TOC), varies between 2.4 and 8.6% TOC. Another significant organic-rich source rock is the Road River Formation (Figure 3). Link *et al.* (1989) rated the overall source rock potential of the Road River Formation as poor but there are some Road River rocks in the Richardson Anticlinorium yielding high TOC values of up to 9.6%. Type I and II kerogens have been reported from Road River shales, so at one time this sequence contained excellent source rocks for oil. The occurrence of gas in wells penetrating Lower Paleozoic strata is consistent with present-day overmaturity of organic material in these rocks (Link and Bustin, 1989). There is often residual bitumen in both the surface and subsurface in the region. Modelling performed by Link and Bustin

(1989) indicates that Road River and Canol source rocks became thermally mature in Carboniferous to early Mesozoic time. Gas originally encased in some of these reservoirs has escaped leaving residual bitumen behind in some of the Lower Paleozoic reservoirs.

Upper Devonian Imperial Formation shales are reported as mature with fair to good gas source potential. Carboniferous Ford Lake shales in southern Eagle Plain is an important source rock which is currently mature for oil and has fair to good gas potential. The Lower Cretaceous Arctic Red Formation is generally lean in organic carbon with Type III terrestrial kerogens. In Eagle Basin, the Lower Cretaceous Whitestone River Formation contains Type II and III kerogens but is marginally mature. Mesozoic strata are unlikely to have generated much hydrocarbon and if it did occur, gas would have been most likely created (Dixon, 1992). Gas generated from Paleozoic source rocks may have been trapped in Cretaceous reservoirs due to vertical migration of fluids.

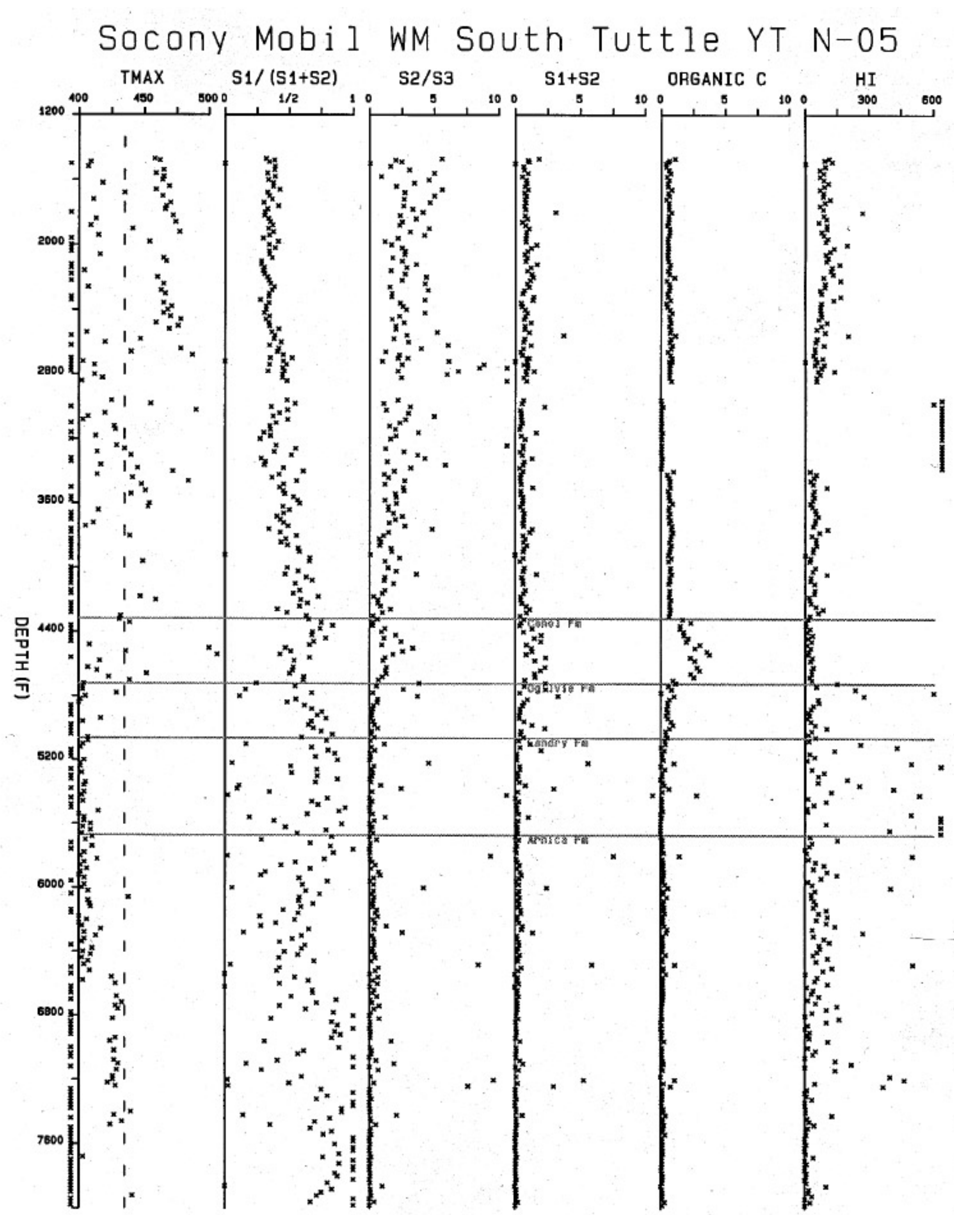


Figure 8. *Depth plot of Rock-Eval analyzer data for strata in the South Tuttle N-05 exploration well (Snowdon, 1987).*

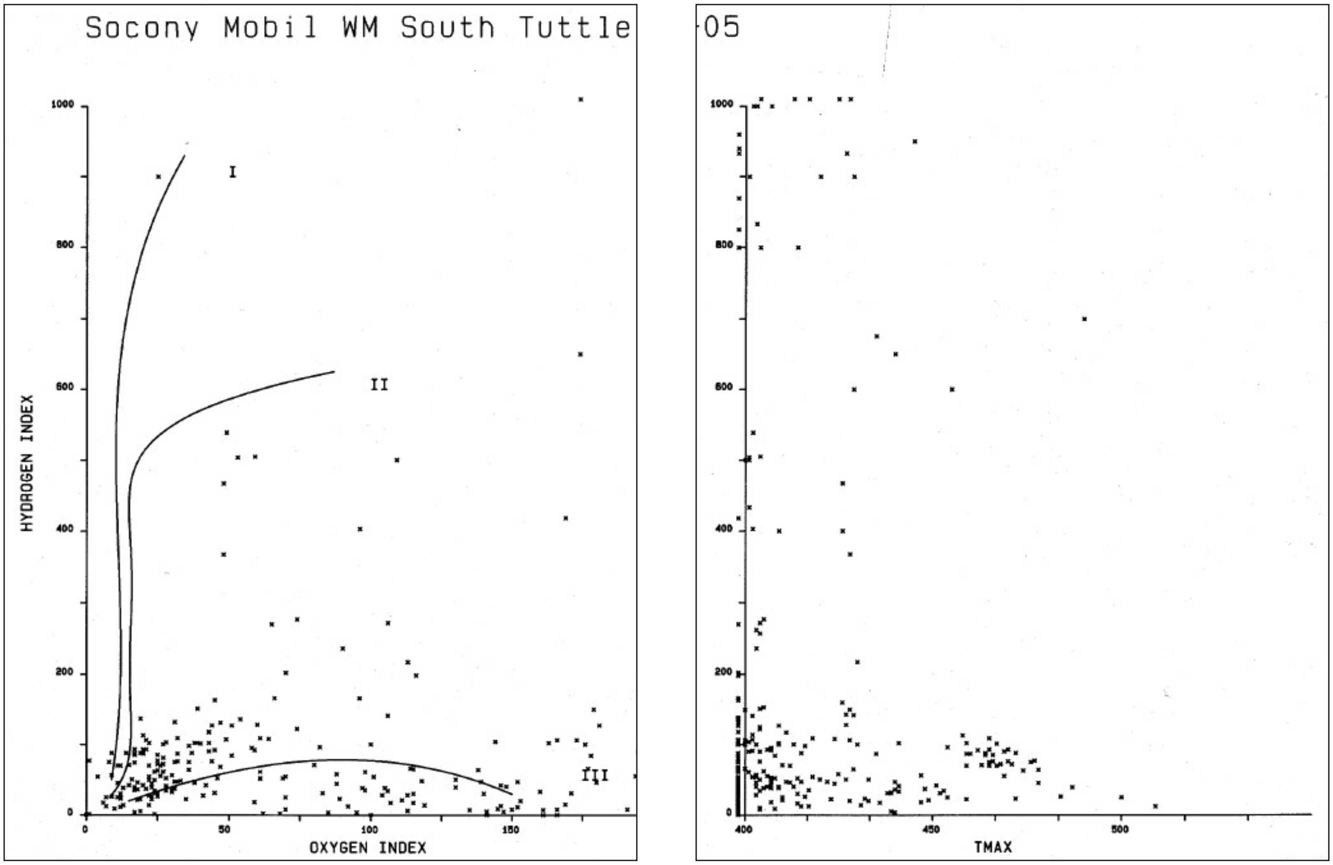


Figure 9. *Van Krevelen and pseudo-Van Krevelen diagrams for strata in South Tuttle N-05 exploration well (Snowdon, 1987).*

A Rock-Eval analysis was performed on the Socony Mobil South Tuttle N-05 well adjacent to the southwest boundary of the Arctic Circle/Dempster Highway study area (see Figure 6 for well location; Figures 8, 9 for analysis) (Snowdon, 1987). This well is collared in the Imperial Formation. The shallowest samples obtained indicate a very high level of thermal maturity (T_{max} of about 460°C or equivalent to about 1.2% R_o), which indicates that organic matter has been significantly altered due to deep burial under a substantial thickness of sediment and this sediment has been subsequently removed by deep erosion (Figure 8). The TOC values are very low for the entire well except in the Canol Formation where TOC approaches 4% (Figure 8). This indicates that before thermal maturation, the Canol unit contained in excess of 10% TOC, most of which is lost in the form of bitumen and gas (Snowdon, 1987). The hydrogen index value (HI) and S2/S3 ratios are low or scattered because of the high thermal maturity. The Van Krevelen diagrams indicate that the Paleozoic source rocks are overmature and now generate gas, but oil-prone organic matter was once present in this well (Figure 9; Snowdon, 1987). Type III kerogens now predominate in these rocks signifying gas-prone source material.

Regarding Cretaceous source rocks, another Rock-Eval analysis was carried out on the Arctic Red F-47 well located in the foreland basin of the Peel Plateau to the southeast of the study area (not shown on Figure 6) (Dixon, 1999). In this well, the penetrated Cretaceous succession consisted of the Trevor and Arctic Red formations. Arctic Red strata have an organic content between 1.0 and 1.5% to 1,670 m below which organic carbon is generally less than 1.0%. The mature oil zone begins at surface, according to T_{max} data, and then becomes overmature at 1,710 m. Therefore, the lowermost strata in the Arctic Red Formation and all of the underlying Martin House Formation is in the overmature zone (Dixon, 1999). However, in the Arctic Circle/Dempster Highway study area to the northwest, the Cretaceous succession is much thinner with Arctic Red Formation overlying Martin House Formation and no Trevor strata are present. These rocks are interpreted to be thermally immature for oil generation, but gas generation may occur from Arctic Red source rock.

In Eagle Plain, Rock-Eval was run on Cretaceous strata in the Chance No. 1 L-08 well to the south of the Arctic Circle/Dempster Highway study area. It was concluded that Mesozoic strata under Eagle Plain generally has low TOC values (less than 2%) and few potential source rocks were identified, except for the upper part of the Whitestone River Formation (Dixon, 1992). Type III terrestrial organic matter is prevalent in Mesozoic strata and T_{max} values indicate low levels of maturity in Mesozoic rocks. Therefore, Mesozoic strata is unlikely to have generated much hydrocarbon in the Eagle Plain, and if they did, gas was the most likely product (Dixon, 1992).

TIMING OF HYDROCARBON GENERATION

Modelling by Link and Bustin (1989) of Paleozoic source rocks indicate that these rocks passed through the 'oil window' before the end of Mesozoic time. This indicates that the probable most effective trapping configurations are ones formed previous to Tertiary time during active oil migration. So far, most wells drilled seeking Paleozoic targets in Eagle Plain were drilled on Laramide anticlinal structures that may not necessarily represent the most efficient trap. The post-Mesozoic traps that have been tested would most likely have gathered small amounts of gas created in the later stages of the main hydrocarbon generation episode. Therefore, pre-Tertiary traps and reservoirs would have been favourable sites for accumulation of liquid hydrocarbons during late Paleozoic to Mesozoic times. The lower Paleozoic carbonate/shale facies transition bordering the Richardson Trough is favourable for trapping hydrocarbons in pre-Laramide stratigraphic/structural traps. Davidson (1994) interpreted pre-Laramide anticlines involving Lower Paleozoic strata in south-central and western Eagle Plain. These anticlines trapped hydrocarbons previous to the Laramide Orogeny. The pre-Upper Devonian source rocks do not generate oil at the present day, but gas continues to be generated. Mesozoic source rocks, if buried deep enough, can generate gas that can be trapped in Laramide-related folds.

HYDROCARBON SHOWS

The most direct indication of hydrocarbon potential in a frontier area is the occurrence of hydrocarbon shows. Numerous indications of hydrocarbon shows and some discoveries have been reported in both the Eagle Plain and Peel Plateau areas (Kunst, 1973; Martin, 1973; Pugh, 1983; Norris, 1985a, 1985b; Hamblin, 1990; Dixon, 1992, 1999; National Energy Board, 1994, 1999; Northern Oil and Gas Directorate, 1995a, 1995b; Norris and Hughes, 1997; Morrow, 1999). The most significant natural gas flow in the Arctic Circle/Dempster Highway study area was recorded in the adjacent South Tuttle N-05 well where 28,540 cubic metres of gas per day was recovered from the lower dolomite member of the Ogilvie Formation (Figures 5, 9; National Energy Board, 1994). This gas flow emanated from a carbonate shelf bank just west of the Devonian carbonate/shale facies boundary where interfingering of black shales and carbonates produced a favourable site for hydrocarbon accumulation (Figures 6, 10). Gassy mud was also retrieved from the Ogilvie limestone further east in central Eagle Plain. In the carbonate/shale facies transition zone in the Peel Plateau area, gas-cut mud and gas-cut salt water were recovered from Mount Kindle carbonates in the Pacific Peel F-37 well in the Arctic

Circle/Dempster Highway study area (Figures 6, 14; Pugh, 1983; National Energy Board, 1999). Further south in Peel Plateau, bitumen was recorded in the Hume Formation limestones in the Shell Trail River H-37 well and a gas 'kick' was recorded in the Mobil Peel H-71 well in the Landry Formation. In the same well, gas was recovered at a flow rate of 2,200 cubic m of gas/day from the Mount Kindle Formation (Pugh, 1983).

The Tuttle sands also have significant natural gas indications in both Eagle Plain and Peel Plateau. Discoveries at both Chance and Birch in southern Eagle Plain have been recorded (National Energy Board, 1994) to the southwest of the study area. Gassy water has also been recovered from the Whitefish I-05 well in the Bell Sub-basin northwest of the study area (Figures 6, 18). In the Peel Plateau area, gas cut water and mud was observed in two wells south of the study area (Shell Peel River B-06, and Shell Peel River L-01; Figures 6, 21; National Energy Board, 1999). Gas-cut water from Fishing Branch sands were recovered in two wells in eastern Eagle Plain adjacent to the Arctic Circle/Dempster Highway study area (Whitefish J-70 and West Parkin D-61; Figures 6, 24; National Energy Board, 1994).

HYDROCARBON ASSESSMENT

The Arctic Circle/Dempster Highway hydrocarbon assessment was undertaken in order to provide quantitative estimates of total oil and gas potential and possible sizes of undiscovered fields in the region. Hydrocarbon assessments of basins or regions are usually based on analyses of a number of exploration plays. The Arctic Circle/Dempster Highway assessment was divided into ten exploration plays based on petroleum geological considerations such as structural style, dominant reservoir lithology and thermal maturity. Five conceptual gas plays and five speculative gas plays were identified in the Arctic Circle/Dempster Highway study area. The five conceptual plays had sufficient information to attempt a statistical analysis to obtain estimates of resource potential and sizes of undiscovered fields. The speculative plays had insufficient information for statistical analysis and will be discussed later in a qualitative manner.

EAGLE LOWER PALEOZOIC CARBONATE/ SHALE FACIES TRANSITION GAS PLAY

CONCEPTUAL HYDROCARBON PLAY

Play definition

This play encompasses all gas prospects occupying pre-Laramide combination stratigraphic and structural traps associated with the Lower Paleozoic carbonate/shale facies transition in the Eagle Fold Belt adjacent to the former Richardson Trough, now the Richardson Anticlinorium (Figure 10). Carbonate reservoirs included in this play range in age from uppermost Cambrian to Middle Devonian. The play area is limited to the east and north by the Silurian carbonate/shale facies boundary and to the west by the shelfward extension of the carbonate/shale facies change.

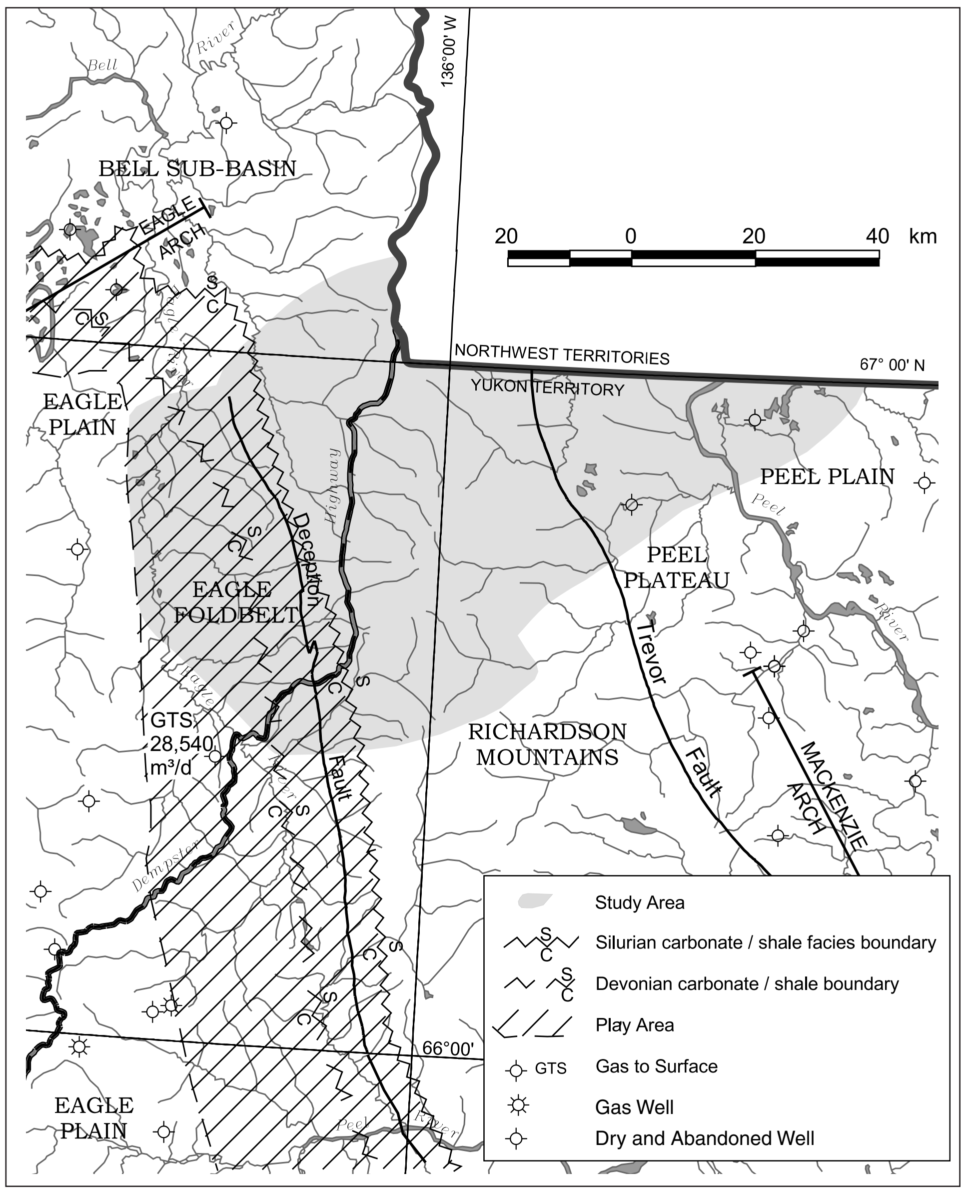


Figure 10. *Eagle Lower Paleozoic carbonate/shale facies transition play map.*

Geology

The principal prospective targets in the Eagle Lower Paleozoic carbonate/shale facies transition play are carbonate shelf edges of the Cambro-Ordovician Bouvette Formation and Lower and Middle Devonian Ogilvie Formation containing a lower dolomite and an upper limestone member. The thickness of the prospect succession ranges from about 2,400 to 2,900 m. These carbonate units interfinger and underlie an excellent source rock in laterally equivalent Road River Group shales that were deposited in deeper water to the east in the Richardson Trough. The Road River shales have high TOC and Type I or II kerogens, suitable for oil generation during initial stages of hydrocarbon formation. However, maturation studies (Link and Bustin, 1989; Snowdon, 1987) indicate that at present day these rocks are overmature, implying natural gas is the only hydrocarbon that is currently generated. The presence of bitumen in wells indicates that oil generation occurred when Lower Paleozoic rocks were thermally mature (Carboniferous to early Mesozoic).

Road River shales also act as good lateral seal for potential hydrocarbon accumulations located within Lower Paleozoic carbonate shelf edges. The Middle Devonian Ogilvie carbonate to shale transition is illustrated by Chevron seismic section 15A (Figure 11, at back of report). The edge is located where the seismic response below the Canol Formation changes from high-amplitude events which correspond to the impedance contrast of the interbedded shale and carbonate of the of the Ogilvie and Bouvette (old name: Gossage) formations to a quiescent zone corresponding to the more uniform lithology associated with the Road River shales.

The Lower Paleozoic carbonates also underlie another excellent source rock, the Upper Paleozoic Canol Formation, consisting primarily of black shales. The organic-rich Canol Formation contains residual kerogens of between 2.4 and 8.6% TOC. Both the Canol and

Natural Gas Plays (In-place volumes) Play name	Expected no. of fields (mean)	Median play potential (in-place) (million m³)	Mean play potential (in-place) (million m³)	Median of largest field size (in-place) (million m³)
Eagle Lower Paleozoic carbonate/shale facies transition	4	10,946	13,793	5,334
Peel Lower Paleozoic carbonate/shale facies transition	4	11,552	13,551	5,203
Eagle Upper Paleozoic clastics stratigraphic/structural	0.66	N/A	1,063	N/A
Peel Upper Paleozoic clastics stratigraphic/structural	2	5,666	8,382	5,626
Jura-Cretaceous clastics structural	4	3,854	4,663	1,773
Total gas plays*		**39,079**	**42,188**	

* The totals are statistically derived. They are retrieved from the basin empirical distribution table in Appendix 2. The median total of basin potential is the value at 50%.

Table 1. *Hydrocarbon potential in the Arctic Circle/Dempster Highway study area.*

Road River shales may act as reservoir seals for potential hydrocarbons in the underlying Paleozoic carbonates beneath Eagle Fold Belt.

Porous strata has been observed at various stratigraphic levels within Lower Paleozoic strata, specifically biostromal or bioclastic layers and karsted and vuggy dolostones in the Bouvette Formation, and slightly porous crinoidal wackestones and packstones within the Ogilvie Formation (Morrow, 1999). Significant gas flow from the Ogilvie Formation occurred at the Socony Mobil South Tuttle N-05 well, adjacent to the Arctic Circle/Dempster Highway study area (Figure 10).

Most drillholes testing Lower Paleozoic carbonates in Eagle Plains were located on crestal regions of Laramide anticlines. However, if Lower Paleozoic rocks passed through the 'oil window' before the end of Mesozoic time, then the most efficient traps would

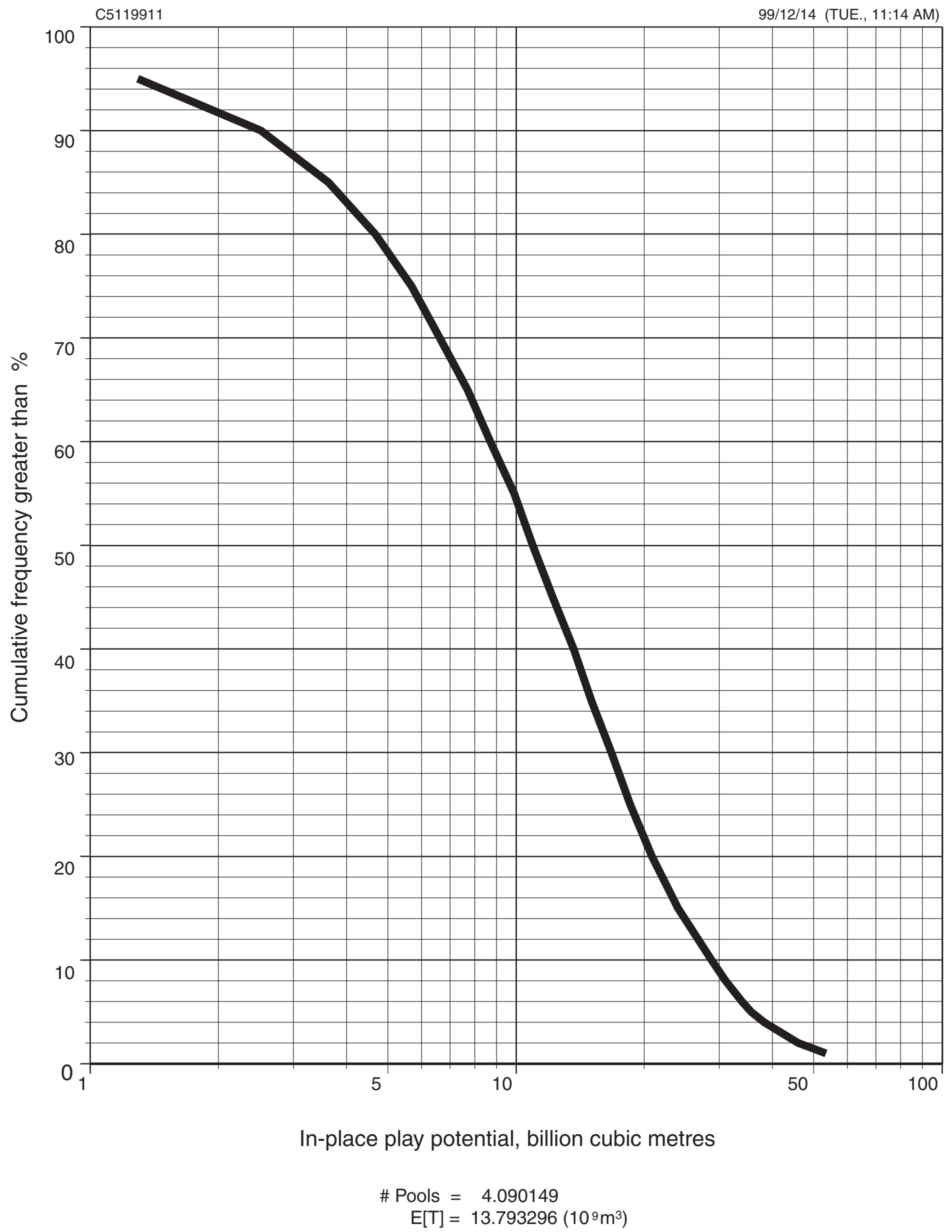


Figure 12. *Estimate of in-place gas potential of the Eagle Lower Paleozoic carbonate/shale facies transition play. Median value of probabilistic assessment is 10,946 million m^3 of in-place gas distributed in 4 fields.*

have formed previous to Tertiary time, during the period of active oil migration. The Laramide traps gather modest amounts of hydrocarbons produced in the latter stages of gas generation from Lower Paleozoic source rocks. Therefore, the lower Paleozoic carbonate to shale transition play is favourable for the trapping of significant hydrocarbons in pre-Laramide combined structural and stratigraphic traps. This relationship is evident in the comparison of hydrocarbon potential and individual field size where Laramide-related exploration plays (i.e. Jura-Cretaceous structural) have less significant volumes predicted than pre-Laramide plays (Lower Paleozoic and Upper Paleozoic combination stratigraphic/structural plays) (Table 1).

A similar exploration play has been defined in the Western Canada Sedimentary Basin in northeastern British Columbia; the Keg River platform - July Lake mature play (Reinson

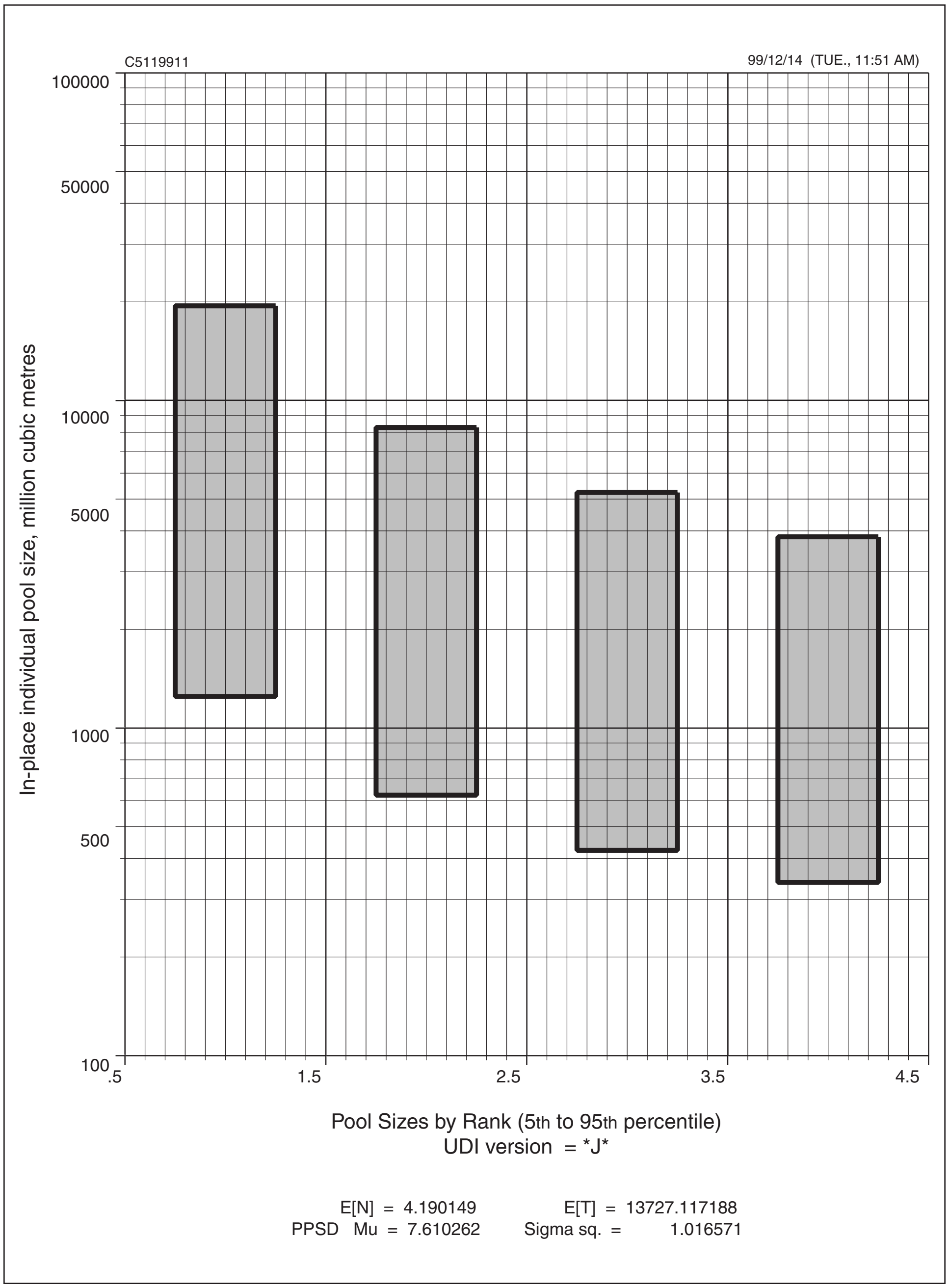


Figure 13. *Field-size-by-rank plot of the Eagle Lower Paleozoic carbonate/shale facies transition gas play. Median value of the largest predicted field size is 5,334 million m^3 of in-place gas.*

et al, 1993). The gas pools and prospects in this play occur in Lower Keg River ramp-platform carbonates which are overlain or trapped by shales of the Horn River or Klua formations. This play was used as an analogue in the establishment of some of the probability distributions used in the calculations of both pool or field size distributions and number of fields distributions (Appendix 1).

Exploration risks

All of the Arctic Circle/Dempster Highway conceptual plays are believed to exist (a play-level marginal probability of 1.0). However, within each play, geological risk factors associated with individual prospects are evaluated in order to derive the exploration risk for the entire play. Significant prospect-level risks interpreted in this play are the presence of reservoir facies and adequate seal (Appendix 1). Even though some wells penetrating Lower Paleozoic carbonates showed significant gas flows as well as good porosity and permeability, other rocks in the play area were tight. Seal was interpreted as not adequate in some prospects. On the other hand, low risk, that is, high marginal probability, was assigned to adequacy of source rock and timing of hydrocarbon generation with respect to trap formation (Appendix 1).

Play potential

The Eagle Lower Paleozoic carbonate/shale facies transition play has an estimated in-place median gas potential of 11 billion m^3 in the Arctic Circle/Dempster Highway study area (Figure 12; Table 1). If the 95^{th} and 5^{th} percentiles representing the limits of expected potential are used, then there is a 90% chance that the resource potential is in the range of 1.3 to 36 billion m^3 in-place. The mean value of the number of predicted fields is 4 for the play. The largest undiscovered field is expected to contain 5.3 billion m^3 of gas (median value) (Figure12; Table 1). One field with a volume greater than 3 billion m^3 of gas is predicted to occur in this carbonate play (Figure12) (See Appendix 2 for computation outputs).

PEEL LOWER PALEOZOIC CARBONATE/ SHALE FACIES TRANSITION GAS PLAY

CONCEPTUAL HYDROCARBON PLAY

Play definition

This hydrocarbon play encompasses all combination stratigraphic/structural traps involving Lower Paleozoic carbonate reservoirs in the carbonate/shale facies transition zone on the eastern fringe of the former Richardson Trough (Figure 14). This is a similar play to the Eagle Lower Paleozoic play on the opposite side of the Richardson Trough. Carbonate reservoirs included in this play range in age from uppermost Cambrian to Middle Devonian. The play area is limited to the west by the Silurian carbonate/shale facies boundary and to the east by the shelfward extension of the carbonate/shale facies change.

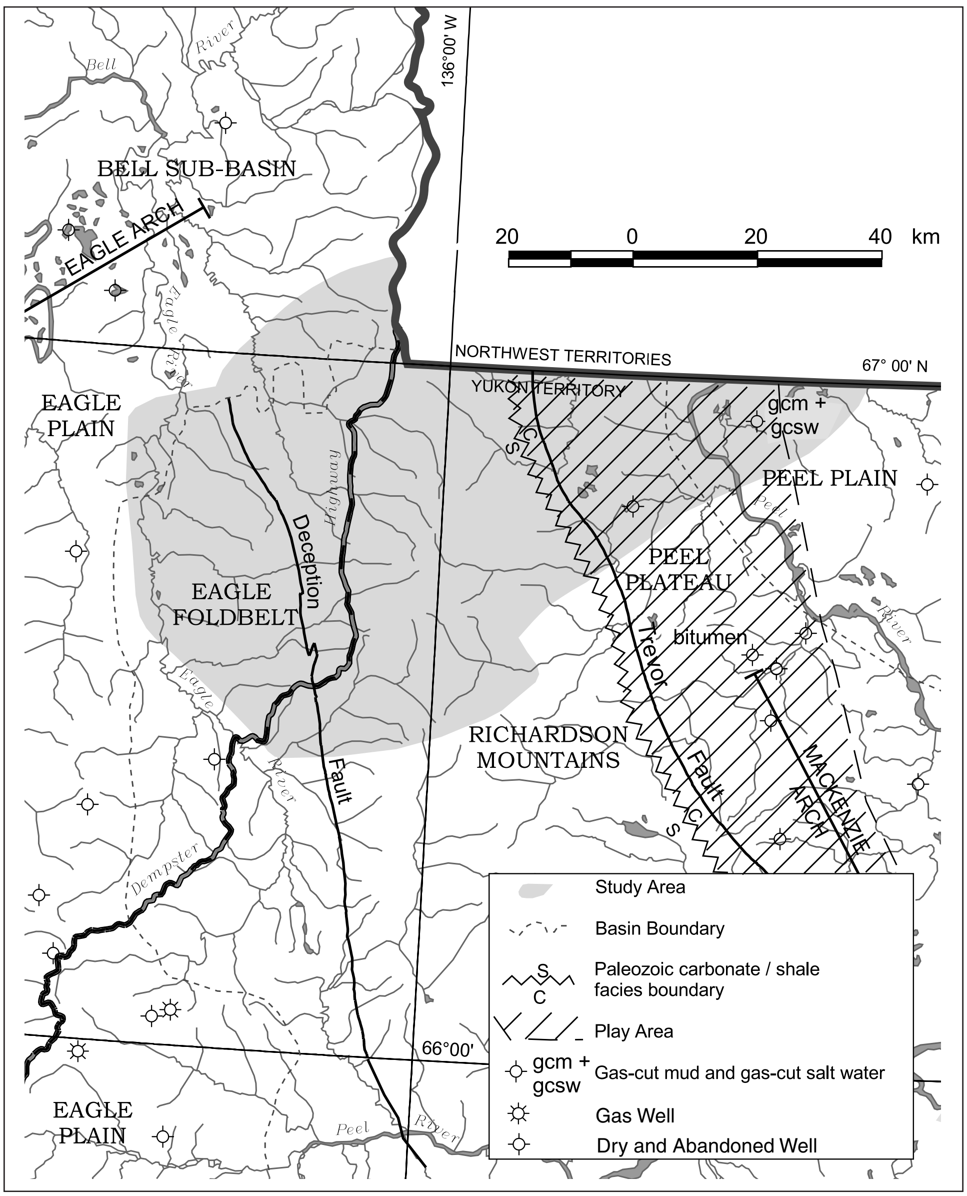
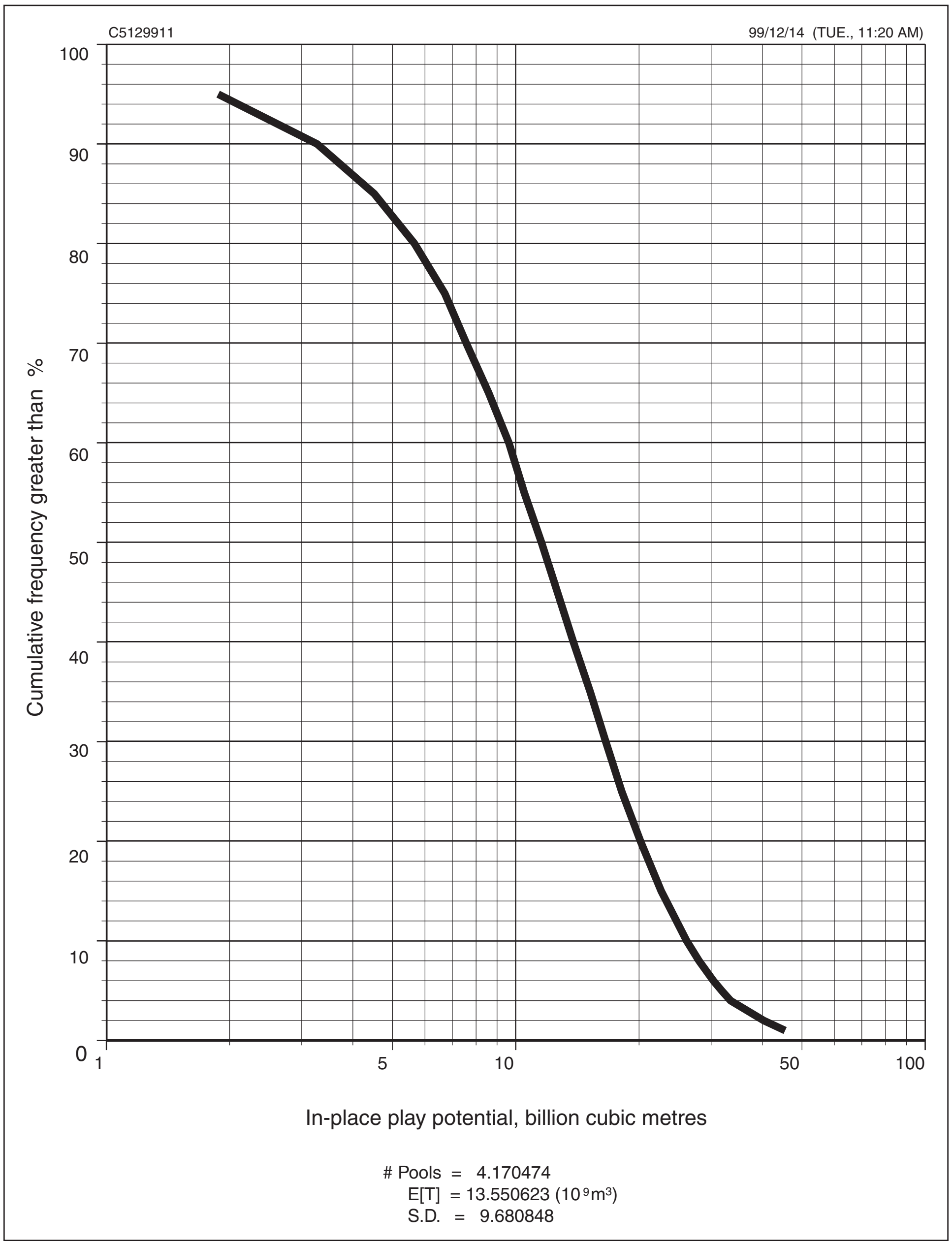


Figure 14. *Peel Lower Paleozoic carbonate/shale facies transition play map.*

Geology

In this play, the prospective targets are carbonate shelf edges of the Cambro-Ordovician Franklin Mountain Formation, Silurian Mount Kindle Formation and Lower and Middle Devonian Peel, Arnica and Landry formations. The thickness of the prospect succession ranges from about 1,450 m to 1,900 m. These carbonate units interfinger with an excellent source rock of the laterally equivalent Road River Group shales that were deposited in deeper water to the west. The stacking of the shelf-edge carbonates adjacent to and interfingered with potential source rocks and seals creates multiple potential targets. The Road River shales have high TOC and Type I or II kerogens, suitable for oil generation in pre-Mesozoic time. However, maturation studies (Link and Bustin, 1989) indicate that these source rocks are presently overmature, so gas is currently generated. The occurrence of bitumen in wells indicates that oil generation occurred when Lower

Figure 16. *Estimate of in-place gas potential of the Peel Lower Paleozoic carbonate/shale facies transition gas play. Median value of probabilistic assessment is 11,552 million m³ of in-place gas distributed in 4 fields.*



Paleozoic rocks were thermally mature in Carboniferous to early Mesozoic time. The Road River shales also provide good lateral seal for the hydrocarbon accumulations occurring within the carbonate shelf edges.

Figure 15 (at back of report) illustrates seismic line 5J-26 acquired by Mobil Oil Company during a regional survey conducted in 1976 (Mobil Oil Canada, Ltd., 1976) over the disturbed belt in the Peel facies transition zone. Compression fracturing may have produced the anomalies (coloured blue) in the Mount Kindle Formation.

The Lower Paleozoic carbonates underlie another excellent source rock, the Upper Paleozoic Canol Formation, consisting of siliceous black shales. The organic-rich Canol Formation contains residual kerogens of between 2.4 and 8.6% TOC. Both the Canol and Road River shales provide potential reservoir seals for gas accumulations in the underlying carbonates of Peel Plateau.

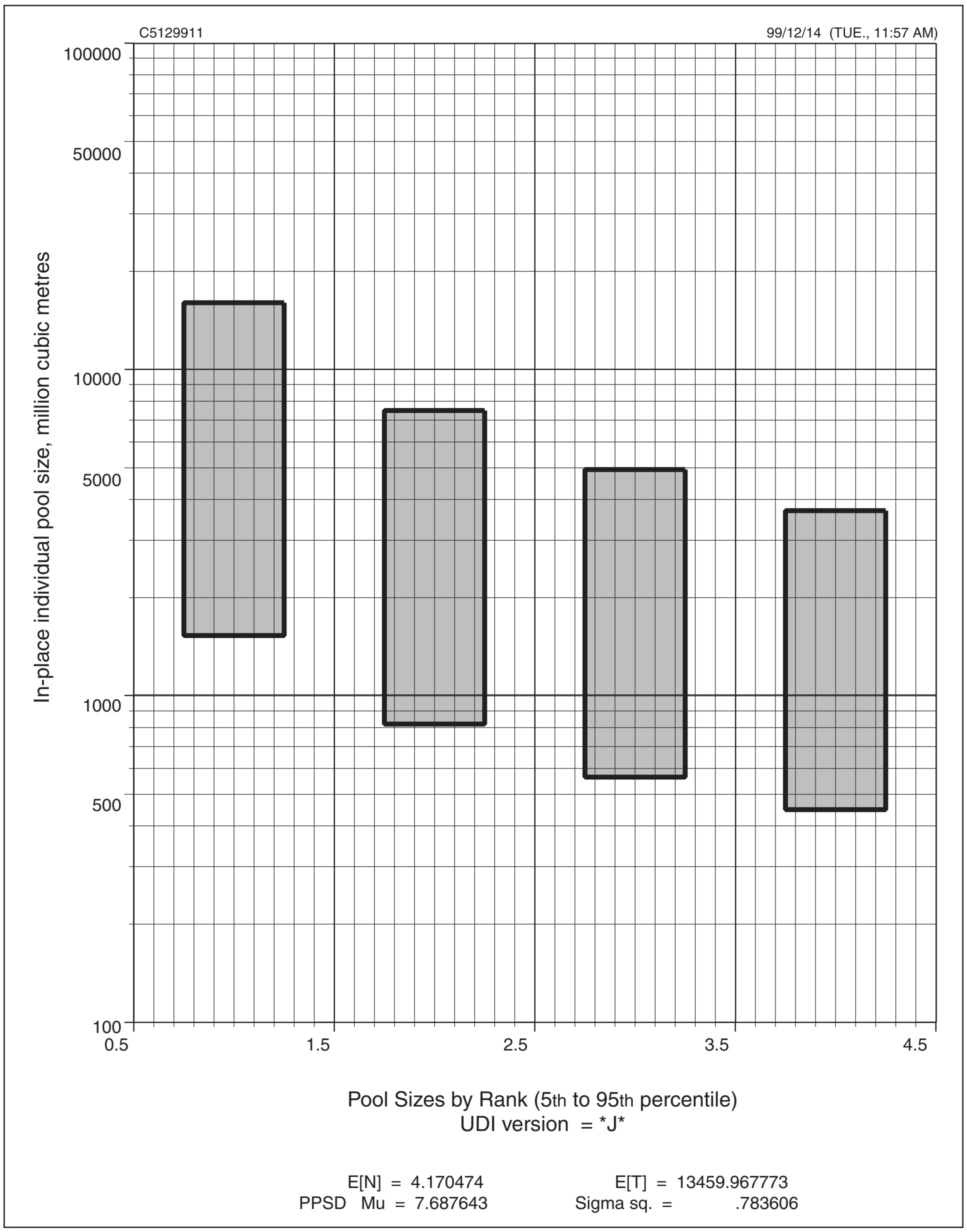


Figure 17. *Field-size-by-rank plot of the Peel Lower Paleozoic carbonate/shale facies transition gas play. Median value of the largest predicted field size is 5,203 million m³ of in-place gas.*

Porous strata has been observed at various stratigraphic levels within the Lower Paleozoic strata, specifically biostromal or bioclastic layers in the Mount Kindle Formation, oolitic carbonate sand bodies in the Franklin Mountain Formation, and karsted and vuggy dolostones in the Franklin Mountain Formation (Morrow, 1999). Significant gas flow occurred at the Mobil Gulf Peel H-71 well from the Mount Kindle Formation south of the Arctic Circle/Dempster Highway study area (not shown on Figure 14). Within the study area, gas-cut mud and gas-cut salt water were recovered from the Mount Kindle Formation in the Pacific Peel F-37 well.

The structural complications associated with the carbonate/shale transition create the opportunities for the stratigraphic/structural trapping configurations, diagenetic porosity development and migration (Northern Oil and Gas Directorate, 1995a, 1995b).

Exploration risks

Due to similarity of plays, the exploration risk factors are similar for both the Peel and Eagle Lower Paleozoic carbonate/shale facies transition plays. See Appendix 1 for marginal probabilities of geological risk factors.

Play potential

Estimates of the potential for the Peel Lower Paleozoic carbonate/shale facies transition gas play show a median in-place volume of 11.55 billion m^3 distributed in 4 fields (mean value) (Figures 16, 17, Table 1). The 95 to 5 range for estimated resource gas potential for the play is 1.9 to 31.8 billion m^3 in-place (Appendix 2). The largest undiscovered gas field is predicted to contain 5.2 billion m^3 (median value) (Figure 17). One field greater in size than 3 billion m^3 of in-place gas is predicted to occur in this play (Figure 17, Appendix 2).

EAGLE UPPER PALEOZOIC CLASTICS STRATIGRAPHIC/ STRUCTURAL GAS PLAY

CONCEPTUAL HYDROCARBON PLAY

Play definition

This hydrocarbon play involves all structures and prospects in the area of subcrop of the Tuttle and Imperial formations to the west of Paleozoic outcrop in the Eagle Fold Belt and within the Bell Sub-basin (Figure 18). Only a small portion of the play area in southeastern Bell Sub-basin is located within the Arctic Circle/Dempster Highway study area.

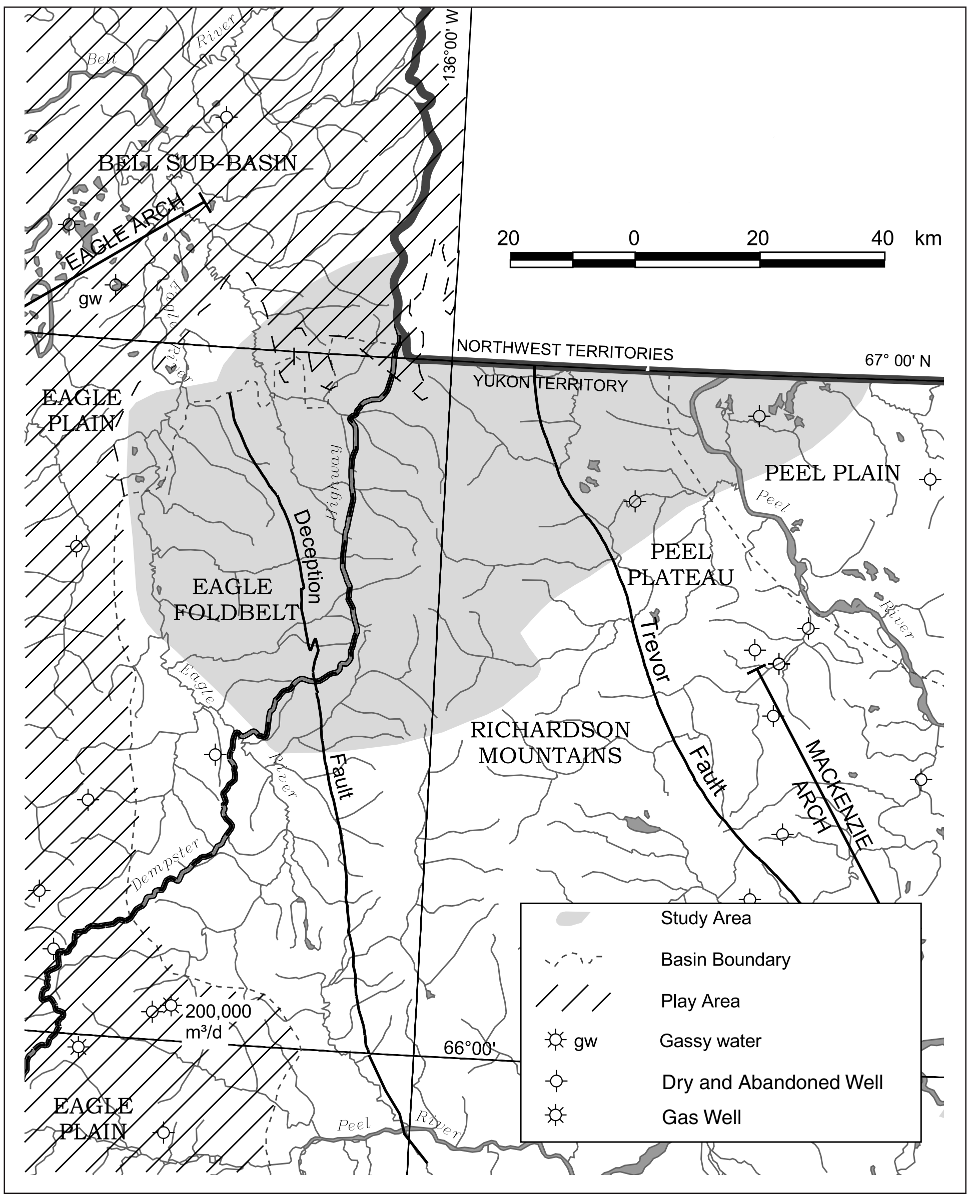


Figure 18. *Eagle Upper Paleozoic clastics stratigraphic/ structural play map.*

Geology

The principal prospective target in this Upper Paleozoic play is the coarse clastics of the Upper Devonian-Lower Carboniferous Tuttle Formation (Figure 3). In Eagle Plain, gas flows to surface occurred in four out of 25 wells penetrating Tuttle Formation. The thickness of the Tuttle Formation ranges from 750 to 1,420 m. Stratigraphic traps occur where the sandstone pinches out into Imperial shale or sandstone bodies pinch out within the formation. A structural overprint associated with the Laramide orogeny was imposed on these traps to form the combination trapping configurations.

The Tuttle Formation consists of a mixture of chert conglomerates, very poorly sorted quartz and chert sandstone, siltstone and shale. These sands are fluviodeltaic in nature and commonly have kaolinite and quartz overgrowths in their pores. Sandstone bodies in delta front facies are potential reservoirs (Pugh, 1983).

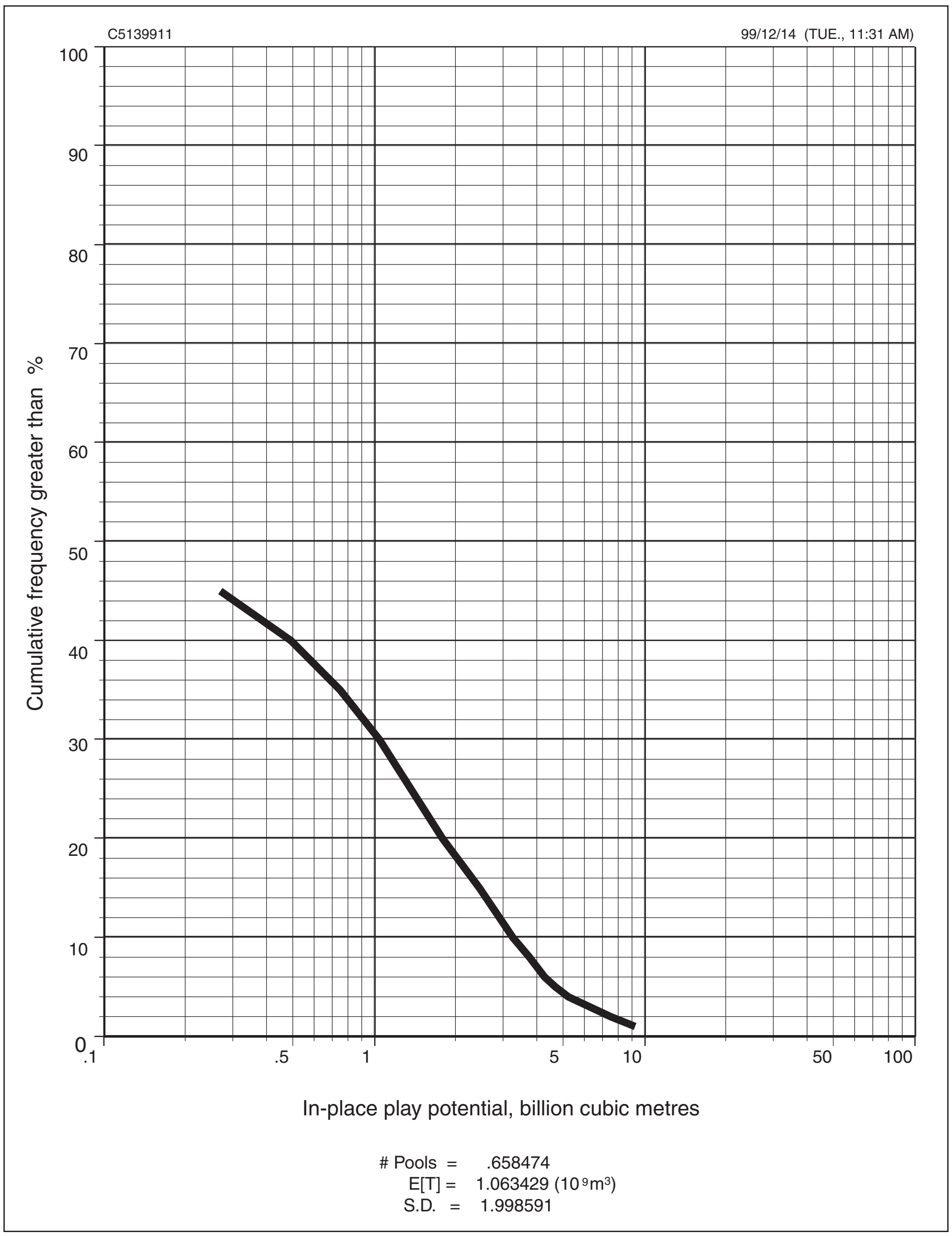


Figure 19. *Estimate of in-place gas potential of the Eagle Upper Paleozoic clastics stratigraphic/structural gas play. Mean value of probabilistic assessment is 1,063 million m^3 of in-place gas. This model predicts no fields are expected in this play.*

There are excellent and abundant underlying Lower Paleozoic source rocks, specifically Road River Group, Canol and Ford Lake shales. Lesser source rock potential is recognized in shale beds of the immediately underlying Imperial Formation (Figure 3). These Paleozoic source rocks are currently overmature for oil generation, but gas generation may still occur.

Sandstones and conglomerates in the Tuttle Formation, and to a lesser extent, in the Imperial Formation, have some reservoir potential, although porosity is typically low in these rocks. Fairways of enhanced porosity of Tuttle sands are of restricted areal extent. Bitumen plugging of pores also occurs.

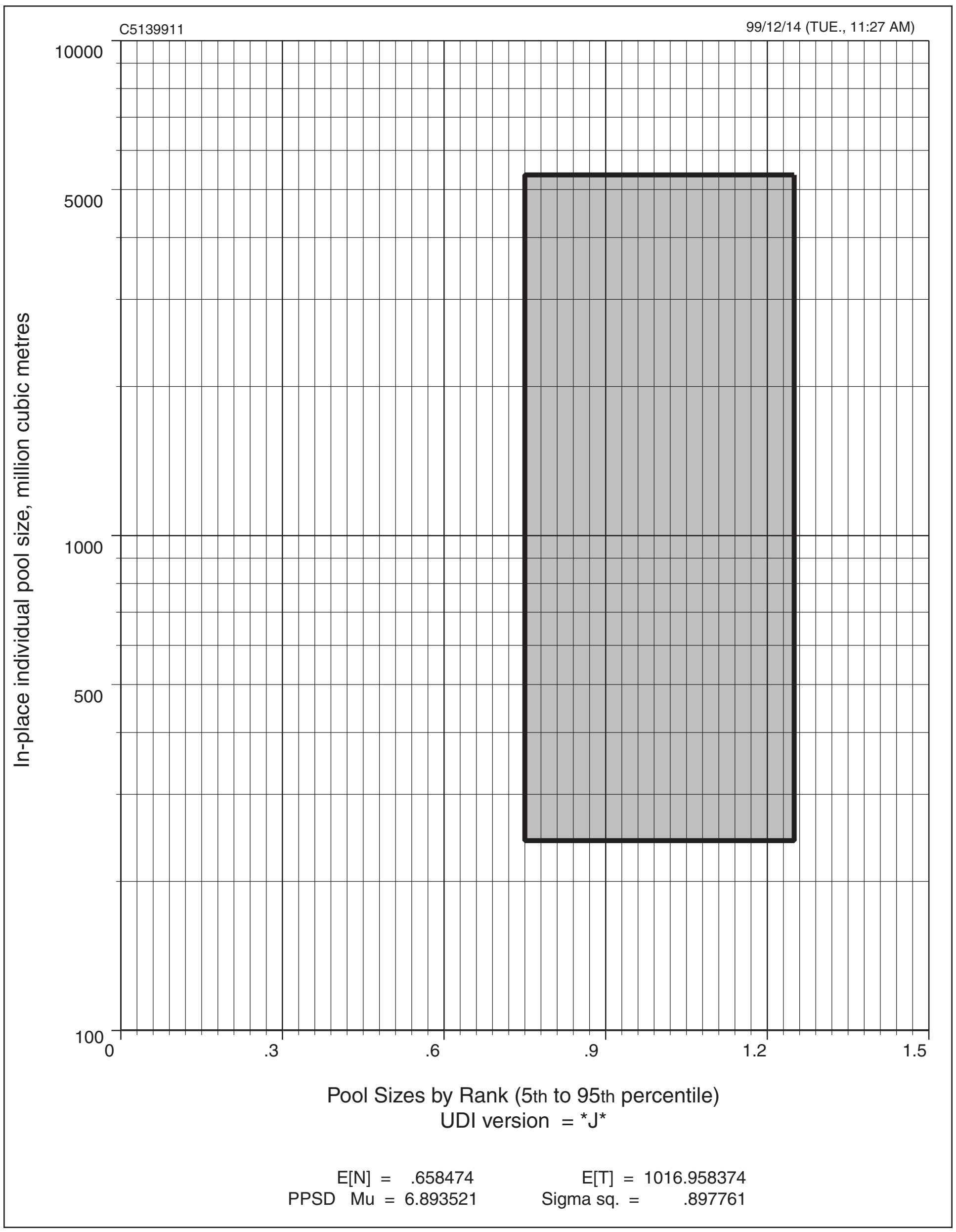


Figure 20. *Field-size-by-rank plot of the Eagle Upper Paleozoic clastics stratigraphic/structural gas play. This field size is not appropriate since the model predicts no fields are present in the play.*

Exploration risks

Significant geologic risk factors for the Eagle Upper Paleozoic clastics play are adequacy of reservoir and preservation (Appendix 1). The Tuttle sandstone is generally poorly sorted with kaolinitic matrix and quartz overgrowths. Fresh-water flushing may occur in some areas due to proximity of Paleozoic outcrop. Source rock is more than adequate and timing is not a problem since gas generation is likely still occurring.

Play potential

This play has an estimated in-place mean gas potential of 1.1 billion m^3 (Table 1; Figure 19). No median for gas potential was predicted in this model, i.e., no cumulative frequency of 50% was retrieved for the curve (see Figure 19). The mean value of the number of predicted fields is 0.66. This estimate of less than one for expected number of fields indicates that the model predicts no fields are expected in the very small play area included within the Arctic Circle/Dempster Highway study area (Figure 18). Therefore, the largest undiscovered gas field generated by PETRIMES and illustrated in Figure 20 is meaningless, and thus no value for the largest field size was listed in Table 1.

PEEL UPPER PALEOZOIC CLASTICS STRATIGRAPHIC/ STRUCTURAL GAS PLAY

CONCEPTUAL HYDROCARBON PLAY

Play definition

This Paleozoic clastic play includes all prospects in the area of subcrop of Tuttle and Imperial formations to the east of Trevor Fault in Peel Plateau and Plain (Figure 21).

Geology

The Tuttle Formation consists of repeated cycles of discontinuous conglomerates and sands, interbedded with shale and siltstone. This formation subcrops to the north and east and shales out to the southwest. The Tuttle and Imperial formations have some reservoir

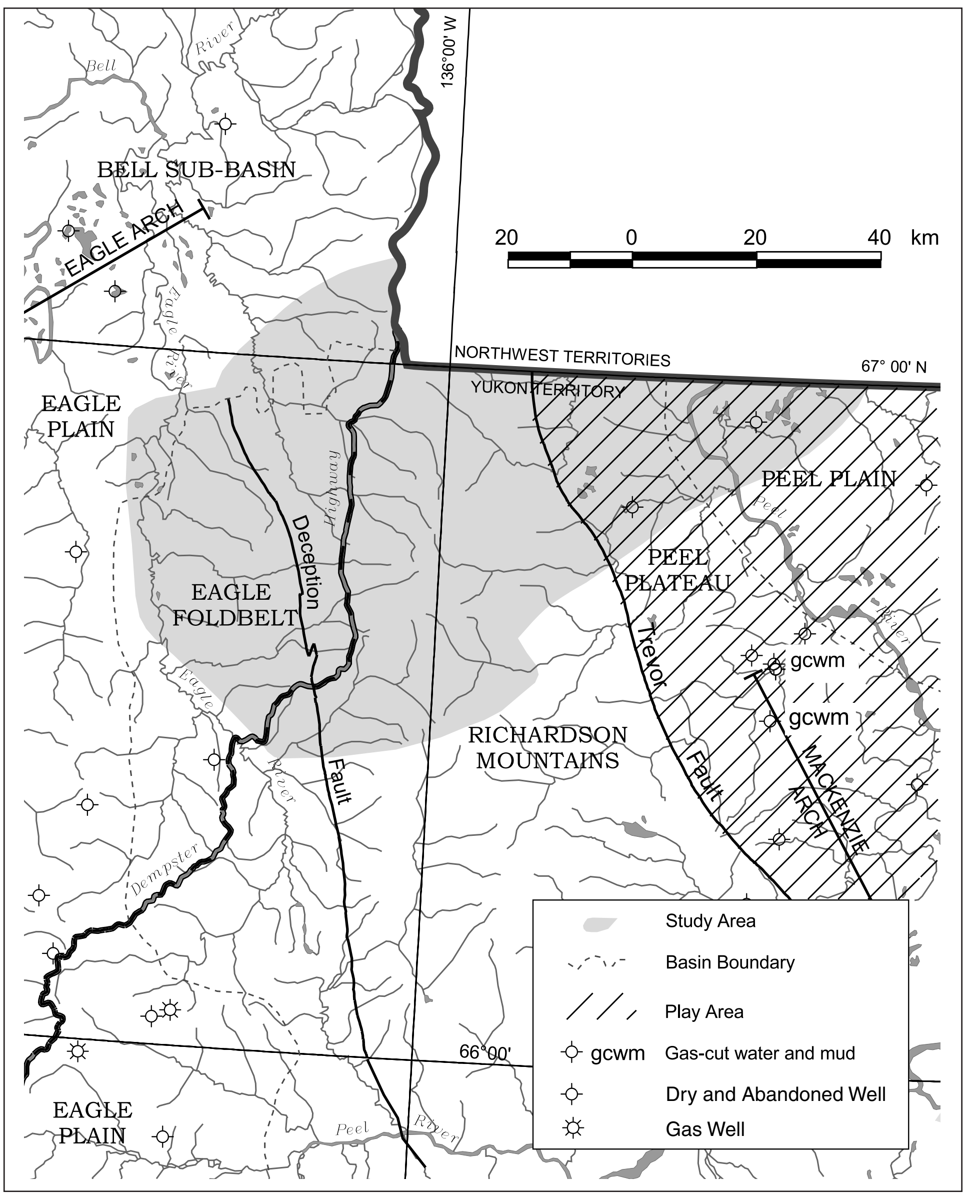


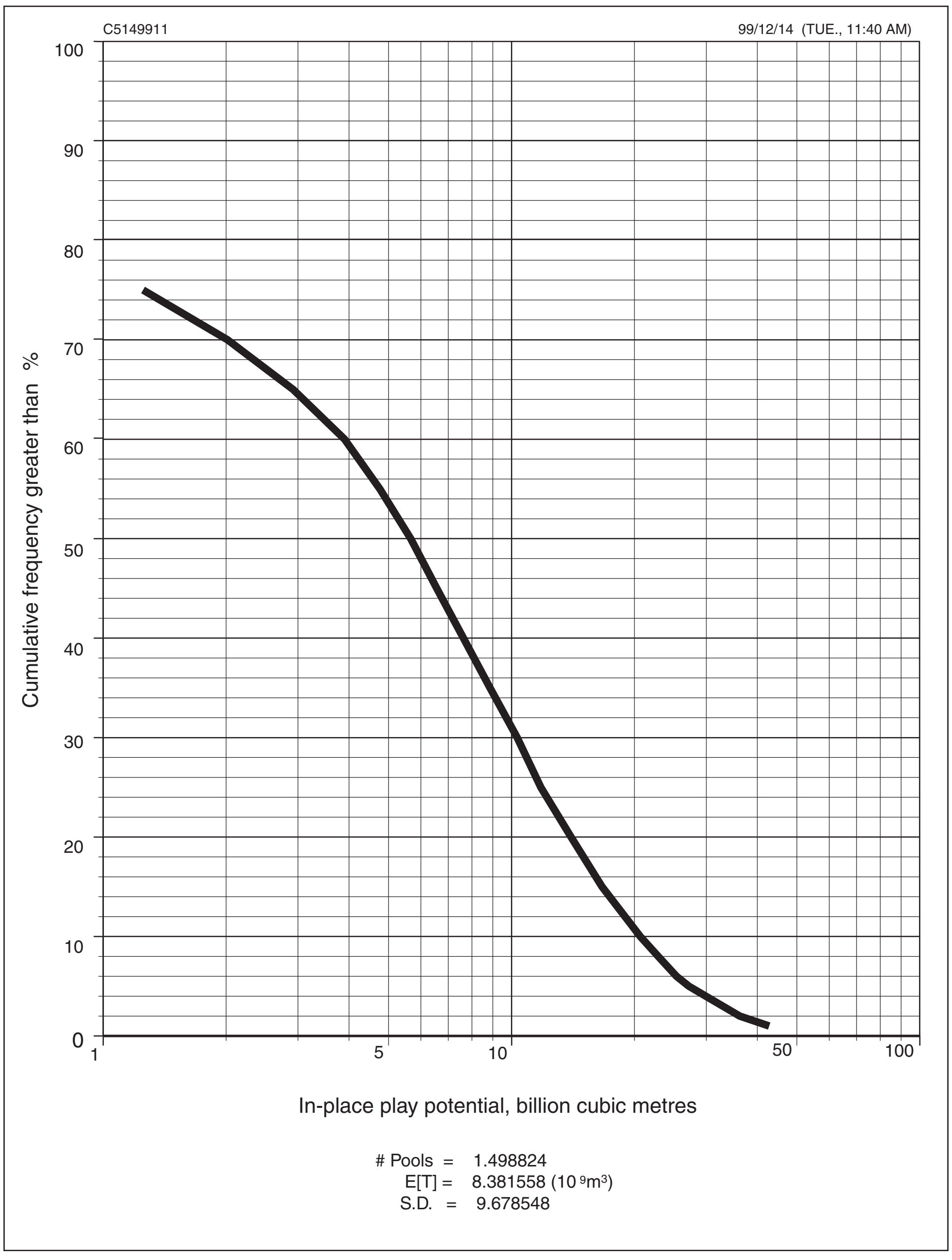
Figure 21. *Peel Upper Paleozoic clastics stratigraphic/ structural play map.*

potential, although porosity is generally poor in these rocks. However, some wells in the area show significant intervals of porous sand, such as 20% porosity in the Peel River L-01 well to the south of the study area and similar zones in Peel River F-37 well in the Arctic Circle/Dempster Highway study area. Potential traps involving Tuttle sands may be present on localized highs, up-dip along north-south trending thrust faults or stratigraphically enclosed within shale.

Exploration risks

Significant risk factors noted in this play are adequacy of reservoir as well as adequate seal and preservation. As noted before, porosity is generally poor in these rocks due to kaolinite and quartz overgrowth in pores. Early oil migration from Lower Paleozoic source rock may plug pores with bitumen. However, secondary porosity development

Figure 22. *Estimate of in-place gas potential of the Peel Upper Paleozoic clastics stratigraphic/ structural gas play. Median value of probabilistic assessment is 5666 million m³ of in-place gas distributed in 2 fields.*



associated with Laramide structural movements occurred in some areas of the play. The likelihood of fresh-water flushing of reservoirs due to proximity of outcrop, as well as the overlying Cretaceous sand acting as a thief zone for hydrocarbons above the Tuttle subcrop, both contribute to the risk associated with adequate preservation.

Play potential

The median in-place gas resource potential for the Peel Upper Paleozoic clastics stratigraphic/structural play is 8.4 billion m^3 distributed in 2 fields (expected value) (Figures 22, 23; Table 1). The in-place median volume for the largest undiscovered field for the play is 5.6 billion m^3 (Figure 23). In this play, both fields have predicted median in-place volumes greater than 3 billion m^3 of natural gas.

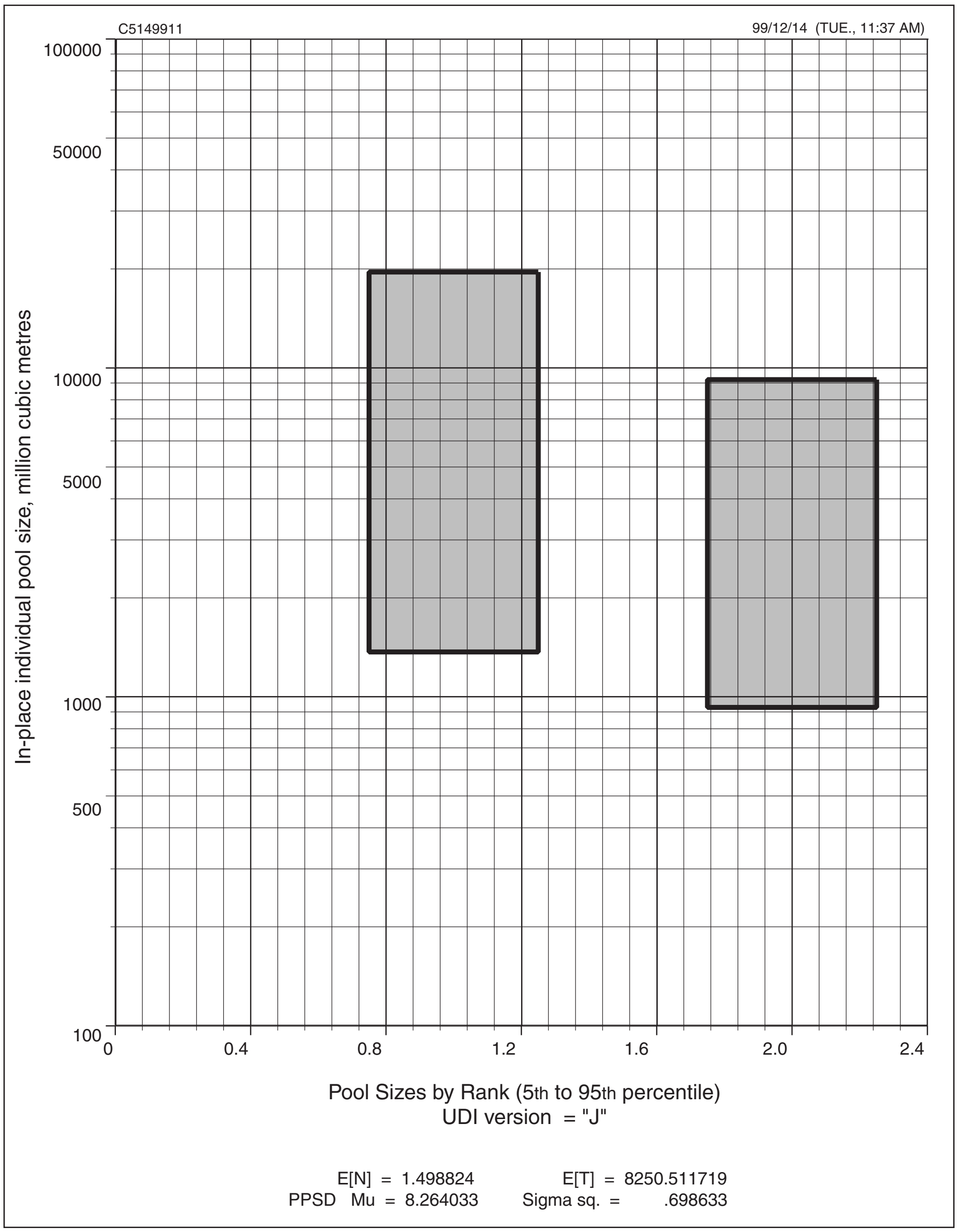


Figure 23. *Field-size-by-rank plot of the Peel Upper Paleozoic clastics stratigraphic/structural gas play. Median value of the largest predicted field size is 5,626 million m^3 of in-place gas.*

JURA-CRETACEOUS CLASTICS STRUCTURAL GAS PLAY

CONCEPTUAL HYDROCARBON PLAY

Play definition

This play includes all structures and prospects occurring in Jurassic and Cretaceous clastics in the eastern portion of Eagle Plain, in Bell Sub-basin and Peel Plateau and Plain (Figure 24). Reservoirs range in age from Late Jurassic to Early Cretaceous.

Geology

The principal prospective targets in the Mesozoic succession are the Martin House Formation in Peel Plateau and the lower sandstone member of the Parkin Formation and the overlying Fishing Branch Formation in the Eagle Plain Group on Eagle Plain. There are sandstone members in the overlying Burnthill Creek and Cody Creek formations of the

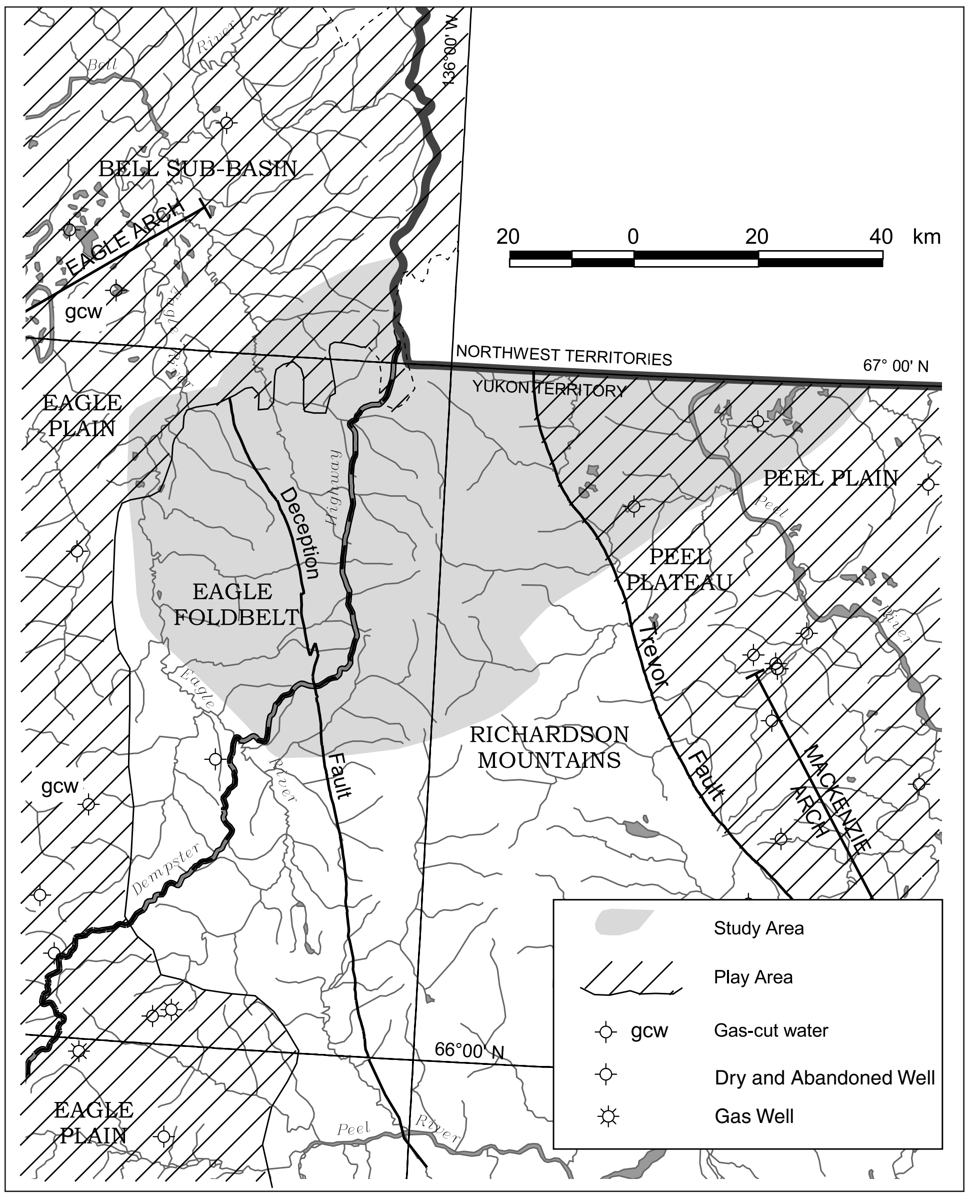


Figure 24. *Jura-Cretaceous clastics structural play map.*

Eagle Plain Group that have good porosity but these rocks are widely exposed on surface and there is great potential for fresh-water recharge (Dixon, 1992). Generally, porosity and permeability are considered to be poor quality in the Martin House Formation in Peel Plateau and Parkin and Fishing Branch formations of Eagle Plain. However, thicknesses and porosities are highly variable throughout the area and reservoir quality sandstones have been locally developed.

Rock-Eval analyses have shown that Cretaceous source rocks are generally immature with terrestrial-derived organic carbon, so if hydrocarbons are produced they would be minor and most likely gas (Dixon, 1992, 1999). Gas accumulation may also occur in Mesozoic reservoirs as a result of vertical migration from potential Paleozoic source rocks (e.g. Canol shale). The Martin House and Parkin formations are both overlain and underlain by shales providing good seals to vertical migration of fluids.

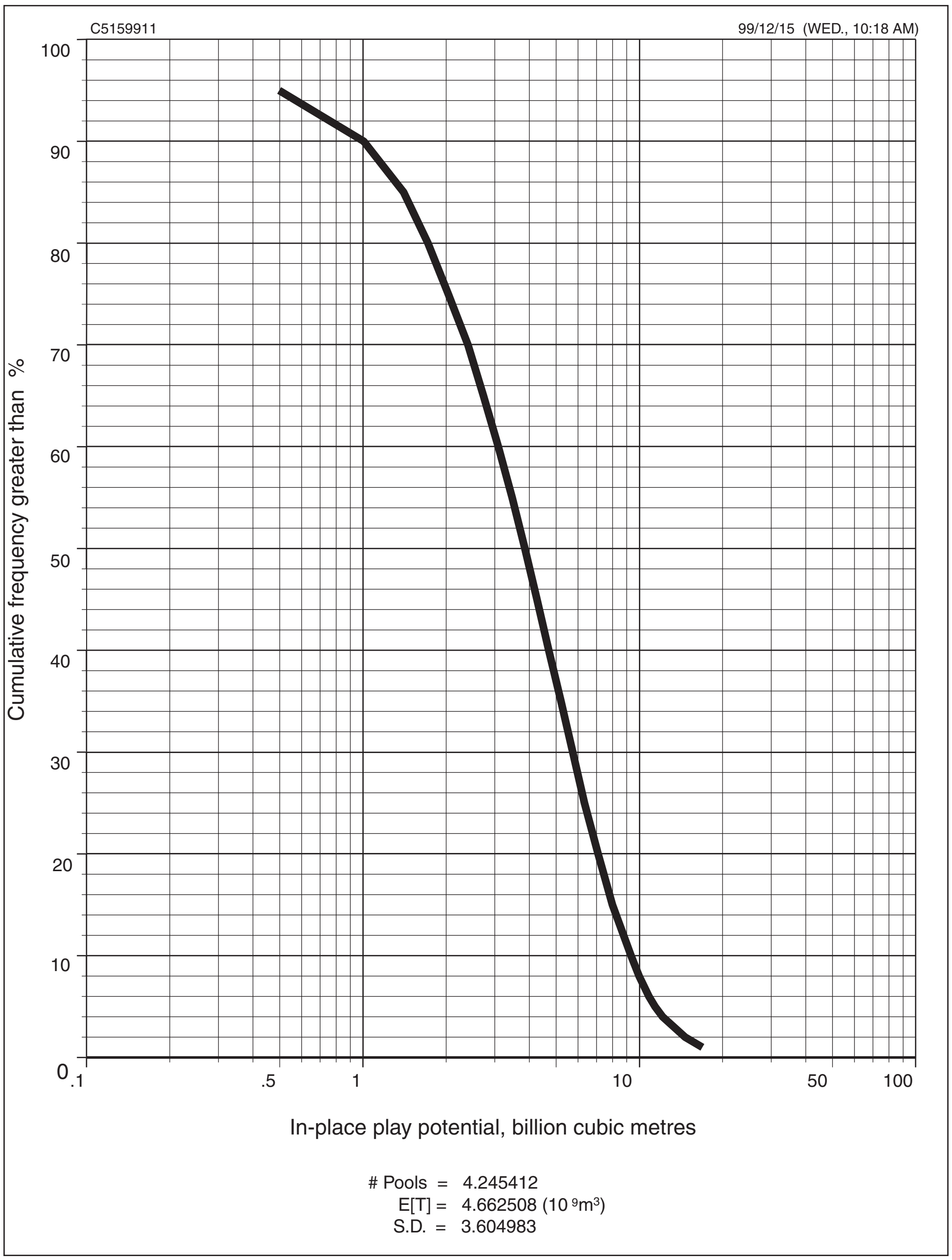


Figure 25. *Estimate of in-place gas potential of the Jura-Cretaceous clastics structural gas play. Median value of probabilistic assessment is 3,854 million m³ of in-place gas distributed in 4 fields.*

Trap types involving Jura-Cretaceous strata include Laramide-related anticlinal structures and stratigraphic traps in fluvial and valley-fill deposits. Early Tertiary triangle zone structures incorporating Eagle Plain Group strata in northeastern Eagle Plain may also trap hydrocarbons (National Energy Board, 1994; Lane, 1996). These trapping configurations are expected to be rather small.

Exploration risks

Important risk factors integrated in the analysis of this exploration play are the presence of reservoir facies and adequate seal (Appendix 1). The wide variability in reservoir quality requires a substantial risk be applied at the prospect level. The fact that shales in the Eagle Plain Group and Arctic Red Formation provide good top seal for certain prospects, while reservoirs in other prospects may be breached by erosion calls for

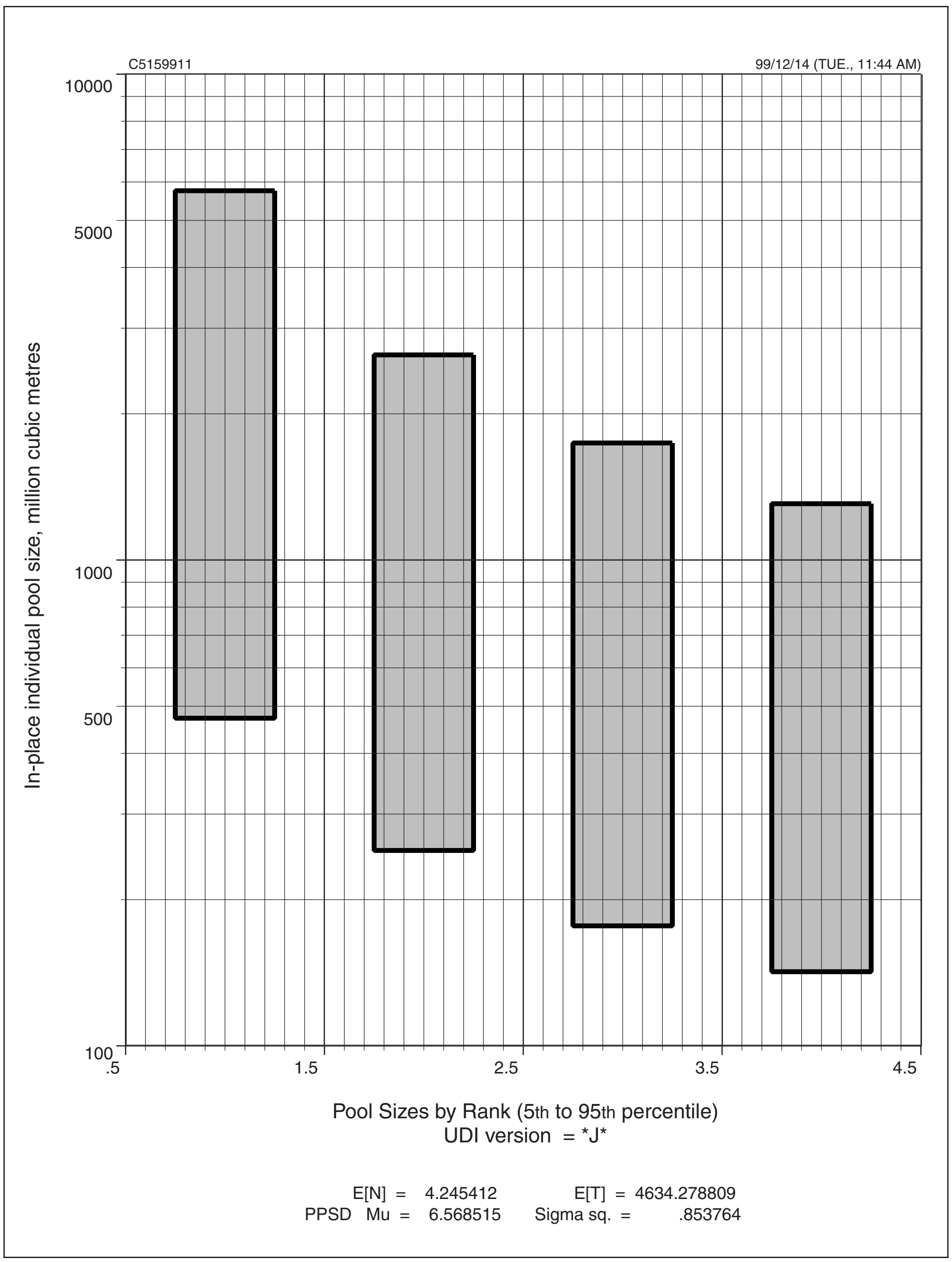


Figure 26. *Field-size-by-rank plot of the Jura-Cretaceous clastics structural gas play. Median value of the largest predicted field size is 1,773 million m³ of in-place gas.*

some risk be applied to adequacy of seal. The presence of a fair to moderate Mesozoic and good Paleozoic source rock in the succession indicates a low risk be assigned to adequacy of source.

Play potential

This play has an estimated median resource potential of 3.85 billion m^3 of in-place natural gas (Figure 25; Table 1). The range of estimates for the resource potential is 0.5 to 11.4 billion m^3 in-place. The expected number of gas fields in the play is 4 (mean value) with the largest field having a volume of 1.7 billion m^3 (Figure 26; Table 1). No fields were expected with volumes greater than 3 billion m^3 in this play (Appendix 2).

SPECULATIVE HYDROCARBON PLAYS

There are five exploration plays that may be present in the Arctic Circle/Dempster Highway study area, but insufficient information is available to properly determine whether the play actually exists, or, if it has been established outside the study area, whether the play indeed extends into the area of interest.

An Ogilvie stromatoporoid reefal play has been recognized by many in western Eagle Plain just west of the Arctic Circle/Dempster Highway study area (Martin, 1973; Pugh, 1983; Norris, 1985a, 1997a; Morrow, 1999). A reef-like carbonate of presumed lower Middle Devonian age was recorded at the top of the Ogilvie Formation in the Chevron North Parkin D-61 well (Pugh, 1983). The reef occurs near the eastern margin of the Yukon Stable Block and may have developed during emergence of the adjacent Richardson Trough (Norris, 1985a; 1997a). There is no evidence to indicate whether this possible exploration play continues into the Arctic Circle/Dempster Highway study area (see Morrow, 1999; his Figure 55). This stromatoporoidal Ogilvie limestone does have reservoir potential in part. Gas was tested to surface in the North Parkin well penetrating this Ogilvie reefal facies (Pugh, 1983).

On the west side of Eagle Plain, dolomitized and fractured Ogilvie carbonate occurs, closely resembling characteristics of the Manetoe dolomite of the Liard Basin (Morrow and Cook, 1987; Morrow, 1999). This pre-Laramide stratigraphic play consists of tight Ogilvie limestone that was fractured and dolomitized in late Paleozoic time before oil generation and migration occurred. These dolomitized masses were enhanced by vertical permeability (Morrow, 1999). It is possible a similar hydrothermal dolomite play could occur within the Lower Paleozoic carbonates along both east and west fringes of the Richardson Trough.

Stratigraphic traps in Mount Kindle carbonates at the overlying sub-Devonian unconformity may occur adjacent to the Mackenzie Arch in Peel Plateau (Kunst, 1973). This play would be high risk due to tight carbonates and argillaceous limestones dominating these rocks. Effective top seal, however, would be attained in the overlying limy layers of the Peel Formation.

It is possible that hydrocarbons may have accumulated in Cambrian rocks such as Illtyd limestones and Slats Creek clastics trapped by Laramide-related structures. These structures could be present within the north-plunging Richardson Anticlinorium in the Richardson Mountains. Lack of reservoir quality strata and overmaturity are significant geological risk factors that are expected to be present in this play. Secondary fracture porosity may have developed in these rocks.

A similar secondary fracture play may occur in Proterozoic metasedimentary rocks beneath the Richardson Anticlinorium. However, thermal maturity considerations may inhibit preservation of hydrocarbons in these rocks.

DISCUSSION OF ASSESSMENT RESULTS

RESOURCE POTENTIAL

The median estimate of total hydrocarbon potential for the Arctic Circle/Dempster Highway region (from all plays) is 39 billion m^3 (1.4 TCF) of in-place gas (Table 1). (Note that the total median estimate for the Arctic Circle/Dempster Highway study area is not arithmetically derived by adding together the hydrocarbon potentials of individual plays. This number is derived using statistical techniques). High confidence (95% probability)

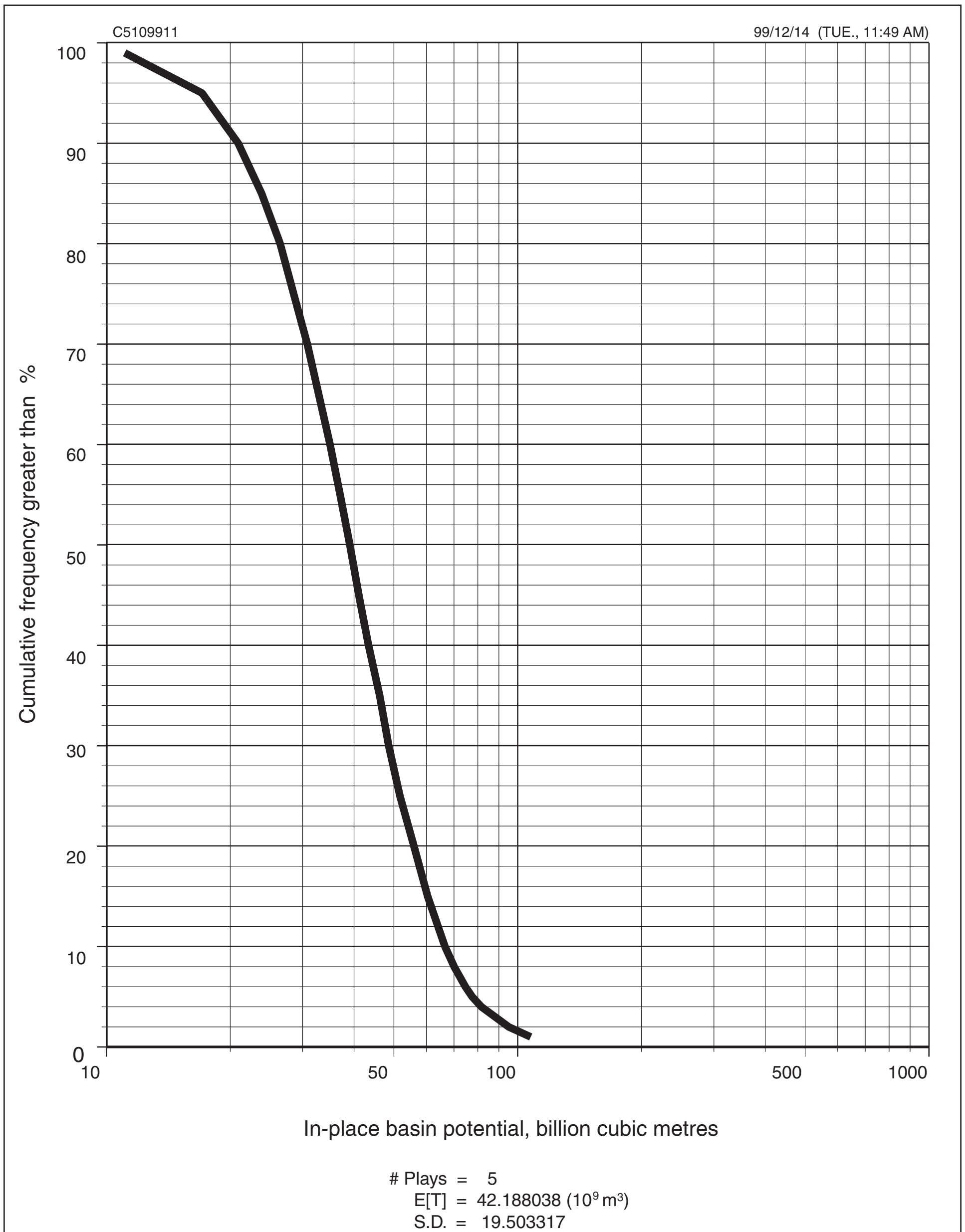


Figure 27. *Estimate of total gas potential for the Arctic Circle/Dempster Highway study area. Median value of probabilistic assessment is 39,079 million m^3 of in-place gas.*

and speculative (5% probability) estimates of total gas potential are 17 and 78 million m^3 (603 and 2,738 BCF), respectively (Figure 27). Individual field-size estimates display similar probability-dependent variations. The wide range of estimates of total potential and field sizes are typical of frontier region assessments and reflect the geological uncertainties in quantifying lightly explored or conceptual exploration plays.

RESOURCE DISTRIBUTIONS

The highest gas potential or volume occurs in the Peel Lower Paleozoic carbonate/shale facies transition play followed closely by the equivalent play on the Eagle Fold Belt (Table 1). The largest individual gas field is expected to occur in the Peel Upper Paleozoic clastic play, with a median size estimate of 5.6 billion m^3 (199 BCF) of in-place gas.

The assessment results indicate the Lower Paleozoic carbonate/shale facies transition plays (both Eagle and Peel) are expected to contain about 65% of the region's total gas resource volume and 4 of the 6 largest fields, a concentration reflecting the greater number of reservoir horizons within the thick Lower Paleozoic succession as well as the greater likelihood of significant hydrocarbon accumulations in pre-Laramide traps from main episodes of hydrocarbon generation. In contrast, gas resource distribution in the younger Jura-Cretaceous clastic rocks, where relatively small fields are predicted, illustrates the numerous small structural and stratigraphic trapping configurations in this play as well as less significant secondary gas generation.

ASSESSMENT RESULTS AND EXPLORATION HISTORY

The exploration risks estimated in the assessment suggest success rates for exploratory drilling in the Arctic Circle/Dempster Highway study area should average about 1 in 8. The absence of discoveries among the 2 wells drilled to date is reasonable. Historically, the first significant hydrocarbon discovery in a frontier region is often preceded by many unsuccessful exploration wells. Seismic coverage is sparse in the region so many significant structures have not been recognized.

CONCLUSIONS

The hydrocarbon resource potential of the Arctic Circle/Dempster Highway study area has been evaluated through regional hydrocarbon play assessments. The quantitative assessments were derived using the Geological Survey of Canada's (PETRIMES) assessment methodology system. The assessments included analyses of 5 conceptual plays, each of which incorporated the calculation or estimation of field size parametric data, numbers of prospects and exploration risks. Hydrocarbon volumes reported for these conceptual plays are total statistical estimates of the resource present 'in place,' not the volumes that are economically producible. Individual field-size determinations are important in identifying which plays are attractive for exploration programs.

The median estimate for total gas potential for all Arctic Circle/Dempster Highway plays is 39 billion m^3 of in-place gas (Figure 27; Table 1).

The potential for significant hydrocarbon accumulations in the Arctic Circle/Dempster Highway assessment region is achieved by the combined presence of numerous and diverse trapping configurations, good to excellent petroleum source rocks in favourable stratal positions and reservoir-quality strata in some parts of the stratigraphic column. However, significant risks associated with lack of porosity development in Paleozoic and Mesozoic strata, fresh-water flushing of Mesozoic reservoirs, and thermal maturity considerations reduces overall hydrocarbon potential. Thermal maturity studies indicate that no significant oil potential is considered to be present in the area. Significant gas potential is predicted for Lower Paleozoic carbonate edges in carbonate/shale transition zones in the Eagle and Peel areas.

The complex geology and anticipated high exploration risks associated with all exploration plays suggest that considerable amounts of new seismic data and more exploration wells may be required to properly evaluate the region's hydrocarbon potential.

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APPENDIX 1

INPUT DATA FOR ARCTIC CIRCLE/DEMPSTER HIGHWAY HYDROCARBON ASSESSMENTS

The following tables present the probability distributions of reservoir parameters, number of prospects, and marginal probabilities of geological risk factors used as input for the various conceptual statistical analyses discussed in this paper. These estimates are based on subjective opinion, partly constrained by reservoir data and information from analogous hydrocarbon-bearing basins.

1. EAGLE LOWER PALEOZOIC CARBONATE/SHALE FACIES TRANSITION GAS PLAY

Table 1.1a. **Probability distributions of reservoir parameters**

Geological variable	Unit of measurement	Probability in upper percentiles 1.00	Probability in upper percentiles 0.50	Probability in upper percentiles 0.01	Probability in upper percentiles 0.00
Area of closure	km^2	0.4	5	40	90
Net pay	m	2	15	60	110
Porosity	decimal fraction	0.05	0.1	0.15	0.2
Gas saturation	decimal fraction	0.55	0.65	0.75	0.8
Gas compressibility factor	decimal fraction	0.882	0.9	0.918	0.92
Reservoir temperature	Celsius	74	74	74	74
Reservoir pressure	kPa	27580	27580	27580	27580

Table 1.1b. **Marginal probabilities of geological risk factors**

Geological factors	Marginal probability	Play level	Prospect level
Presence of closure	0.85		x
Presence of reservoir facies	0.60		x
Adequate seal	0.7		x
Adequate timing	0.9		x
Adequate source	1		x

Table 1.1c. **Probability distribution for number of prospects**

Geological variable	Probability in upper percentiles 0.99	Probability in upper percentiles 0.5	Probability in upper percentiles 0.00
Number of prospects	7	10	22

2. PEEL LOWER PALEOZOIC CARBONATE/SHALE FACIES TRANSITION GAS PLAY

Table 1.2a. Probability distributions of reservoir parameters

Geological variable	Unit of measurement percentiles	Probability in upper percentiles 1.00	Probability in upper percentiles 0.50	Probability in upper percentiles 0.01	Probability in upper 0.00
Area of closure	km^2	0.4	5	40	90
Net pay	m	20	30	40	41
Porosity	decimal fraction	0.02	0.06	0.12	0.2
Gas saturation	decimal fraction	0.7	0.77	0.8	0.81
Gas compressibility factor	decimal fraction	0.941	0.96	0.979	0.98
Reservoir temperature	Celsius	93	93	93	93
Reservoir pressure	kPa	28101	28101	28101	28101

Table 1.2b. Marginal probabilities of geological risk factors

Geological factors	Marginal probability	Play level	Prospect level
Presence of closure	0.85		x
Presence of reservoir facies	0.60		x
Adequate seal	0.7		x
Adequate timing	0.75		x
Adequate source	1		x

Table 1.2c. Probability distribution for number of prospects

Geological variable	Probability in upper percentiles 0.99	Probability in upper percentiles 0.5	Probability in upper percentiles 0.00
Number of prospects	8	11	20

3. EAGLE UPPER PALEOZOIC CLASTICS STRATIGRAPHIC/STRUCTURAL GAS PLAY

Table 1.3a. Probability distributions of reservoir parameters

Geological variable	Unit of measurement	Probability in upper percentiles 1.00	Probability in upper percentiles 0.50	Probability in upper percentiles 0.01	Probability in upper percentiles 0.00
Area of closure	km^2	0.4	5	40	90
Net pay	m	1	4	8	10
Porosity	decimal fraction	0.02	0.07	0.2	0.3
Gas saturation	decimal fraction	0.6	0.8	0.9	0.95
Gas compressibility factor	decimal fraction	0.804	0.82	0.836	0.85
Reservoir temperature	Celsius	39	39	39	39
Reservoir pressure	kPa	28150	28150	28150	28150

Table 1.3b. Marginal probabilities of geological risk factors

Geological factors	Marginal probability	Play level	Prospect level
Presence of closure	0.7		x
Presence of reservoir facies	0.5		x
Adequate seal	0.7		x
Adequate timing	0.7		x
Adequate preservation	0.7		x

Table 1.3c. Probability distribution for number of prospects.

Geological variable	Probability in upper percentiles 0.99	Probability in upper percentiles 0.5	Probability in upper percentiles 0.00
Number of prospects	2	4	10

4. PEEL UPPER PALEOZOIC CLASTICS STRATIGRAPHIC/STRUCTURAL GAS PLAY

Table 1.4a. Probability distributions of reservoir parameters

Geological variable	Unit of measurement	Probability in upper percentiles 1.00	Probability in upper percentiles 0.50	Probability in upper percentiles 0.01	Probability in upper percentiles 0.00
Area of closure	km^2	0.4	5	40	90
Net pay	m	15	25	35	40
Porosity	decimal fraction	0.09	0.13	0.18	0.2
Gas saturation	decimal fraction	0.5	0.7	0.85	0.9
Gas compressibility factor	decimal fraction	0.784	0.8	0.816	0.82
Reservoir temperature	Celsius	37	37	37	37
Reservoir pressure	kPa	10101	10101	10101	10101

Table 1.4b. Marginal probabilities of geological risk factors

Geological factors	Marginal probability	Play level	Prospect level
Presence of closure	0.7		x
Presence of reservoir facies	0.5		x
Adequate seal	0.7		x
Adequate timing	0.7		x
Adequate preservation	0.7		x

Table 1.4c. Probability distribution for number of prospects

Geological variable	Probability in upper percentiles 0.99	Probability in upper percentiles 0.5	Probability in upper percentiles 0.00
Number of prospects	8	10	20

5. JURA-CRETACEOUS CLASTICS STRUCTURAL GAS PLAY

Table 1.5a. Probability distributions of reservoir parameters

Geological variable	Unit of measurement	Probability in upper percentiles 1.00	Probability in upper percentiles 0.50	Probability in upper percentiles 0.01	Probability in upper percentiles 0.00
Area of closure	km^2	0.1	5	50	105
Net pay	m	2	10	20	30
Porosity	decimal fraction	0.03	0.06	0.09	0.1
Gas saturation	decimal fraction	0.55	0.65	0.75	0.8
Gas compressibility factor	decimal fraction	0.764	0.78	0.796	0.8
Reservoir temperature	Celsius	53	53	53	53
Reservoir pressure	kPa	15101	15101	15101	15101

Table 1.5b. Marginal probabilities of geological risk factors

Geological factors	Marginal probability	Play level	Prospect level
Presence of closure	0.75		x
Presence of reservoir facies	0.5		x
Adequate seal	0.7		x
Adequate source	0.9		x

Table 1.5c. Probability distribution for number of prospects

Geological variable	Probability in upper percentiles 0.99	Probability in upper percentiles 0.5	Probability in upper percentiles 0.00
Number of prospects	10	15	30

APPENDIX 2

OUTPUT FOR ARCTIC CIRCLE/DEMPSTER HIGHWAY HYDROCARBON ASSESSMENTS

The following text presents the output generated by the PETRIMES hydrocarbon assessment program using the conceptual play analysis procedure. For each play, the MPRO, PSRK and PSUM modules are presented. MPRO generates the number of pools distribution and risks for the play. PSRK gives the individual pool sizes by rank and PSUM indicates the Monte Carlo simulation for the pool size distribution. (Note: In text, field sizes are indicated rather than pools. In frontier conceptual plays, insufficient geological and engineering information is available to define individual pool accumulations in single structures). PSUM modules for total oil and gas potential on a basin-scale are also presented.

PETRIMES MODULE MPRO

```
NO. OF POOLS DISTRIBUTION AND RISKS
***********************************

UAI        C5119911
PLAY       Eagle Lower Paleozoic facies transition
Assessor   Peter Hannigan
Geologist  Peter Hannigan
Remarks    Arctic Circle study area Hydrocarbon Assessment
Run date   WED, DEC  8, 1999,  2:36 PM


USER SUPPLIED PARAMETERS
------------------------
   DO YOU WANT TO STORE ON DB?           >    Y
   OIL (O) OR GAS (G) ?                  >    G


A) Risks
   -----

               GEOLOGICAL FACTOR              MARGINAL PROBABILITY
               -----------------              --------------------

   PLAY LEVEL     Overall Play Level Risk        =       1.00

   PROSPECT LEVEL Presence of Reservoir Facies ( 2)       .60
                  Adequate Seal               ( 4)       .70
                  Adequate Timing             ( 5)       .90
                  Presence of Closure         ( 1)       .85
                  ---------------------------------------------------
                  Overall Prospect Level Risk    =        .32

   EXPLORATION RISK:                             =        .32


B) No. of Prospects Distribution
   -----------------------------

   Minimum       =     7
   Maximum       =    22
   Mean          =   12.73
   S.D.          =    4.53

   Frequency   No. of Prospects
   ---------   ----------------

     99.00           7
       95            8
       90            8
       80            9
       75            9
       60           10
       50           10
       40           13
       25           16
       20           18
       10           20
        5           21
        1           22
        0           22


C) No. of Pools Distribution
   -------------------------

   Minimum       =     0
   Maximum       =    17
   Mean          =    4.09
   S.D.          =    2.21

   Frequency   No. of Pools
   ---------   ------------

     98.18           0
       95            1
       90            2
       80            2
       75            2
       60            3
       50            4
       40            4
       25            5
       20            6
       10            7
        5            8
        1           10
        0           17

Note: The no. of pools
distribution is saved in the
database with UDI= 6201GB4
```

PETRIMES MODULE PSRK

```
INDIVIDUAL POOL SIZES BY RANK
WHERE N IS A RANDOM VARIABLE
*****************************

UAI        C5119911
PLAY       Eagle Lower Paleozoic facies transition
Assessor   Peter Hannigan
Geologist  Peter Hannigan
Remarks    Arctic Circle study area Hydrocarbon Assessment
Run date   WED, DEC  8, 1999,  2:49 PM


USER SUPPLIED PARAMETERS
------------------------
   DO YOU WANT TO STORE ON DB ?          > Y
   DO YOU WANT TO USE MPRO OUTPUT?       > Y
   MIN. AND MAX. POOL RANKS?             >      1     8
   DO YOU USE LOGNORNAL ASSUMPTION?      > Y
   DO YOU WANT TO USE PPSD OUTPUT?       > Y

A) Basic Information
   -----------------
   TYPE OF RESOURCE      =Gas In-place
   SYSTEM OF MEASUREMENT =S.I.
   UNIT OF MEASUREMENT   =M cu m  (19)

B) Lognormal Pool Size Distribution
   --------------------------------
   Summary      mu      = 7.6103     MEAN   = 3356.1
   Statistics   sig. sq= 1.0166     S.D.   = 4457.1

   Upper        99.99% = 47.492     60.00% = 1563.7     15.00% = 5740.2
   Percentiles  99.00% = 193.39     55.00% = 1778.6     10.00% = 7349.5
                95.00% = 384.46     50.00% = 2018.8      8.00% = 8324.2
                90.00% = 554.54     45.00% = 2291.5      6.00% = 9680.5
                85.00% = 710.01     40.00% = 2606.3      5.00% = 10601.
                80.00% = 864.11     35.00% = 2977.3      4.00% = 11795.
                75.00% = 1022.7     30.00% = 3425.5      2.00% = 16010.
                70.00% = 1189.8     25.00% = 3985.1      1.00% = 21074.
                65.00% = 1368.9     20.00% = 4716.5       .01% = 85816.

C) No. of Pools Distribution
   -------------------------
   Lower Support     =   0
   Upper Support     =  17
   Expectation       =   4.09
   Standard Deviation=   2.21

D) Pool Sizes By Rank
   ------------------

   Pool Rank                   Distribution

        1     MEAN   = 7257.1     S.D.   = 7114.4     P(N>=r)= .98180
              99%    = 559.81     75%    = 3103.7     10%    = 14484.
              95%    = 1248.3     50%    = 5334.2      5%    = 19453.
              90%    = 1804.1     25%    = 8985.7      1%    = 34612.

        2     MEAN   = 3383.6     S.D.   = 2621.0     P(N>=r)= .90333
              99%    = 293.08     75%    = 1601.8     10%    = 6563.4
              95%    = 623.81     50%    = 2745.4      5%    = 8275.7
              90%    = 909.70     25%    = 4411.2      1%    = 12754.
```

```
3     MEAN   = 2194.1     S.D.   = 1602.4     P(N>=r)= .74700
      99%    = 211.55     75%    = 1056.5     10%    = 4232.6
      95%    = 423.61     50%    = 1816.7      5%    = 5239.3
      90%    = 605.56     25%    = 2901.6      1%    = 7707.0

4     MEAN   = 1636.7     S.D.   = 1149.5     P(N>=r)= .55193
      99%    = 175.65     75%    = 807.39     10%    = 3128.7
      95%    = 338.03     50%    = 1370.9      5%    = 3835.9
      90%    = 473.79     25%    = 2170.1      1%    = 5511.1

5     MEAN   = 1317.3     S.D.   = 890.31     P(N>=r)= .37379
      99%    = 155.72     75%    = 670.84     10%    = 2484.1
      95%    = 291.94     50%    = 1116.6      5%    = 3023.6
      90%    = 403.04     25%    = 1742.6      1%    = 4276.5

6     MEAN   = 1101.7     S.D.   = 719.24     P(N>=r)= .23851
      99%    = 141.61     75%    = 578.34     10%    = 2048.8
      95%    = 260.15     50%    = 943.70      5%    = 2479.9
      90%    = 354.77     25%    = 1451.7      1%    = 3469.1

7     MEAN   = 940.60     S.D.   = 596.86     P(N>=r)= .14382
      99%    = 129.76     75%    = 506.12     10%    = 1728.6
      95%    = 234.22     50%    = 812.08      5%    = 2083.7
      90%    = 316.05     25%    = 1234.4      1%    = 2892.5

8     MEAN   = 816.59     S.D.   = 505.82     P(N>=r)= .80364E-01
      99%    = 119.65     75%    = 448.52     10%    = 1485.3
      95%    = 212.66     50%    = 709.48      5%    = 1784.7
      90%    = 284.36     25%    = 1067.5      1%    = 2462.9
```

E) The mean of the potential = 13680.

PETRIMES MODULE PSUM

```
MONTE CARLO SUM SIMULATION
POOL SIZE DISTRIBUTION
**************************

UAI        C5119911
PLAY       Eagle Lower Paleozoic facies transition
Assessor   Peter Hannigan
Geologist  Peter Hannigan
Remarks    Arctic Circle study area Hydrocarbon Assessment
Run date   WED, DEC  8, 1999,  2:50 PM


USER SUPPLIED PARAMETERS
------------------------
   DO YOU WANT TO STORE IN DATA BASE ?   >    Y
   OIL (O) OR GAS (G) ?                  >    G
   BRITISH OR S.I. UNIT OF MEASUREMENT?  >   SI
   RECOVERABLE RESOURCES?                >    N
   DO YOU WANT TO USE MPRO OUTPUT?       >    Y
   DO YOU ASSUME LOGNORMAL DISTRIBUTION? >    Y
   DO YOU WANT TO USE PPSD OUTPUT?       >    Y
   DO YOU COMPUTE CONDITIONAL POTENTIAL? >    N

A) Basic Information
   -----------------
   TYPE OF RESOURCE      =Gas In-place
   SYSTEM OF MEASUREMENT =S.I.
   UNIT OF MEASUREMENT   =M cu m  (19)

B) Lognormal Pool Size Distribution
   --------------------------------
   Summary      mu     = 7.6103     MEAN   = 3356.1
   Statistics   sig. sq= 1.0166     S.D.   = 4457.1

   Upper        99.99% = 47.492     60.00% = 1563.7     15.00% = 5740.2
   Percentiles  99.00% = 193.39     55.00% = 1778.6     10.00% = 7349.5
                95.00% = 384.46     50.00% = 2018.8      8.00% = 8324.2
                90.00% = 554.54     45.00% = 2291.5      6.00% = 9680.5
                85.00% = 710.01     40.00% = 2606.3      5.00% = 10601.
                80.00% = 864.11     35.00% = 2977.3      4.00% = 11795.
                75.00% = 1022.7     30.00% = 3425.5      2.00% = 16010.
                70.00% = 1189.8     25.00% = 3985.1      1.00% = 21074.
                65.00% = 1368.9     20.00% = 4716.5       .01% = 85816.

C) NO. OF POOLS DISTRIBUTION
   -----------------------------
   Lower Support     =    0
   Upper Support     =   17
   Expectation       =      4.09015
   Standard Deviation=      2.21271
```

```
D) Summary Statistics for 4000 Simulations
   ---------------------------------------

   Play Resource:    (  B cu m    )
   ------------------------------
     Minimum     = .0000000E+00  Maximum           = 120.6160
     Expectation = 13.79330      Standard Deviation= 11.59260

   EMPERICAL DISTRIBUTION:
   ----------------------
     Greater than    Play
     Percentage      Potential
     ------------    -----------
        100.00         .00000E+00
         95.00         1.2931
         90.00         2.5159
         85.00         3.6282
         80.00         4.6765
         75.00         5.6831
         70.00         6.6187
         65.00         7.6927
         60.00         8.7000
         55.00         9.8981
         50.00         10.946
         45.00         12.193
         40.00         13.655
         35.00         15.036
         30.00         16.752
         25.00         18.537
         20.00         20.848
         15.00         24.009
         10.00         28.778
          8.00         31.048
          6.00         33.921
          5.00         35.681
          4.00         38.244
          2.00         45.984
          1.00         53.447
           .01         119.27
           .00         120.48
```

PETRIMES MODULE MPRO

```
NO. OF POOLS DISTRIBUTION AND RISKS
***********************************

UAI        C5129911
PLAY       Peel Lower Plaeozoic facies transition
Assessor   Peter Hannigan
Geologist  Peter Hannigan
Remarks    Arctic Circle study area Hydrocarbon Assessment
Run date   WED, DEC  8, 1999,  3:16 PM


USER SUPPLIED PARAMETERS
------------------------
   DO YOU WANT TO STORE ON DB?           >    Y
   OIL (O) OR GAS (G) ?                  >    G


A) Risks
   -----

               GEOLOGICAL FACTOR              MARGINAL PROBABILITY
               -----------------              --------------------

   PLAY LEVEL     Overall Play Level Risk        =       1.00

   PROSPECT LEVEL Presence of Reservoir Facies ( 2)       .60
                  Adequate Seal                ( 4)       .70
                  Adequate Timing              ( 5)       .90
                  Presence of Closure          ( 1)       .85
                  ----------------------------------------------------
                  Overall Prospect Level Risk    =        .32

   EXPLORATION RISK:                             =        .32


B) No. of Prospects DistributionC) No. of Pools Distribution
   -----------------------------   -------------------------

   Minimum       =     8           Minimum       =     0
   Maximum       =    20           Maximum       =    16
   Mean          =   12.98         Mean          =    4.17
   S.D.          =    3.58         S.D.          =    2.04

   Frequency   No. of Prospects    Frequency   No. of Pools
   ---------   ----------------    ---------   ------------
     99.00           8               98.73          0        Note: The no. of pools
       95            9                 95           1        distribution is saved in the
       90            9                 90           2        database with UDI= 6201GB4
       80           10                 80           2
       75           10                 75           3
       60           11                 60           3
       50           11                 50           4
       40           13                 40           4
       25           16                 25           5
       20           17                 20           6
       10           19                 10           7
        5           20                  5           8
        1           20                  1          10
        0           20                  0          16
```

PETRIMES MODULE PSRK

```
INDIVIDUAL POOL SIZES BY RANK
WHERE N IS A RANDOM VARIABLE
*****************************

UAI        C5129911
PLAY       Peel Lower Plaeozoic facies transition
Assessor   Peter Hannigan
Geologist  Peter Hannigan
Remarks    Arctic Circle study area Hydrocarbon Assessment
Run date   THU, DEC  9, 1999, 11:52 AM


USER SUPPLIED PARAMETERS
------------------------
   DO YOU WANT TO STORE ON DB ?          > Y
   DO YOU WANT TO USE MPRO OUTPUT?       > Y
   MIN. AND MAX. POOL RANKS?             >      1     8
   DO YOU USE LOGNORNAL ASSUMPTION?      > Y
   DO YOU WANT TO USE PPSD OUTPUT?       > Y

A) Basic Information
   -----------------
   TYPE OF RESOURCE      =Gas In-place
   SYSTEM OF MEASUREMENT =S.I.
   UNIT OF MEASUREMENT   =M cu m  (19)

B) Lognormal Pool Size Distribution
   --------------------------------
   Summary      mu     = 7.6876     MEAN   = 3227.4
   Statistics   sig. sq= .78361     S.D.   = 3519.8

   Upper        99.99% = 81.086     60.00% = 1743.0     15.00% = 5459.5
   Percentiles  99.00% = 278.20     55.00% = 1951.6     10.00% = 6782.4
                95.00% = 508.57     50.00% = 2181.2      8.00% = 7566.1
                90.00% = 701.48     45.00% = 2437.9      6.00% = 8638.2
                85.00% = 871.47     40.00% = 2729.6      5.00% = 9355.2
                80.00% = 1035.5     35.00% = 3067.9      4.00% = 10274.
                75.00% = 1200.6     30.00% = 3469.8      2.00% = 13435.
                70.00% = 1371.2     25.00% = 3962.8      1.00% = 17102.
                65.00% = 1550.8     20.00% = 4594.7       .01% = 58675.

C) No. of Pools Distribution
   -------------------------
   Lower Support     =   0
   Upper Support     =  16
   Expectation       =   4.17
   Standard Deviation=   2.04

D) Pool Sizes By Rank
   ------------------

   Pool Rank                      Distribution

        1     MEAN   = 6561.9     S.D.   = 5307.7     P(N>=r)= .98727
              99%    = 775.01     75%    = 3281.4     10%    = 12380.
              95%    = 1531.6     50%    = 5203.3      5%    = 16023.
              90%    = 2082.5     25%    = 8165.8      1%    = 26545.

        2     MEAN   = 3363.0     S.D.   = 2209.3     P(N>=r)= .92581
              99%    = 422.41     75%    = 1832.3     10%    = 6119.9
              95%    = 820.22     50%    = 2889.7      5%    = 7491.7
              90%    = 1134.6     25%    = 4336.7      1%    = 10943.
```

```
3      MEAN   = 2263.0     S.D.   = 1419.2     P(N>=r)= .78768
       99%    = 306.51     75%    = 1243.2     10%    = 4098.6
       95%    = 564.21     50%    = 1974.6      5%    = 4940.0
       90%    = 770.15     25%    = 2952.3      1%    = 6935.4

4      MEAN   = 1715.0     S.D.   = 1045.6     P(N>=r)= .59319
       99%    = 253.32     75%    = 953.35     10%    = 3088.9
       95%    = 448.55     50%    = 1504.5      5%    = 3697.0
       90%    = 601.45     25%    = 2241.3      1%    = 5095.2

5      MEAN   = 1395.9     S.D.   = 826.11     P(N>=r)= .39632
       99%    = 223.43     75%    = 791.57     10%    = 2489.5
       95%    = 385.45     50%    = 1231.7      5%    = 2964.8
       90%    = 509.54     25%    = 1819.3      1%    = 4037.9

6      MEAN   = 1186.8     S.D.   = 680.98     P(N>=r)= .23867
       99%    = 203.69     75%    = 688.20     10%    = 2091.5
       95%    = 344.84     50%    = 1054.2      5%    = 2479.7
       90%    = 450.88     25%    = 1540.3      1%    = 3346.6

7      MEAN   = 1035.9     S.D.   = 577.21     P(N>=r)= .13094
       99%    = 188.75     75%    = 613.47     10%    = 1804.0
       95%    = 314.82     50%    = 926.22      5%    = 2130.4
       90%    = 407.98     25%    = 1338.6      1%    = 2854.0

8      MEAN   = 920.50     S.D.   = 499.29     P(N>=r)= .65155E-01
       99%    = 176.56     75%    = 555.37     10%    = 1585.4
       95%    = 290.82     50%    = 827.85      5%    = 1865.6
       90%    = 374.08     25%    = 1184.5      1%    = 2483.8
```

E) The mean of the potential = 13424.

PETRIMES MODULE PSUM

```
MONTE CARLO SUM SIMULATION
POOL SIZE DISTRIBUTION
**************************

UAI        C5129911
PLAY       Peel Lower Plaeozoic facies transition
Assessor   Peter Hannigan
Geologist  Peter Hannigan
Remarks    Arctic Circle study area Hydrocarbon Assessment
Run date   THU, DEC  9, 1999, 11:53 AM


USER SUPPLIED PARAMETERS
------------------------
   DO YOU WANT TO STORE IN DATA BASE ?   >    Y
   OIL (O) OR GAS (G) ?                  >    G
   BRITISH OR S.I. UNIT OF MEASUREMENT?  >   SI
   RECOVERABLE RESOURCES?                >    N
   DO YOU WANT TO USE MPRO OUTPUT?       >    Y
   DO YOU ASSUME LOGNORMAL DISTRIBUTION? >    Y
   DO YOU WANT TO USE PPSD OUTPUT?       >    Y
   DO YOU COMPUTE CONDITIONAL POTENTIAL? >    N

A) Basic Information
   -----------------
   TYPE OF RESOURCE      =Gas In-place
   SYSTEM OF MEASUREMENT =S.I.
   UNIT OF MEASUREMENT   =M cu m  (19)

B) Lognormal Pool Size Distribution
   -------------------------------
   Summary      mu     = 7.6876     MEAN   = 3227.4
   Statistics   sig. sq= .78361     S.D.   = 3519.8

   Upper        99.99% = 81.086     60.00% = 1743.0     15.00% = 5459.5
   Percentiles  99.00% = 278.20     55.00% = 1951.6     10.00% = 6782.4
                95.00% = 508.57     50.00% = 2181.2      8.00% = 7566.1
                90.00% = 701.48     45.00% = 2437.9      6.00% = 8638.2
                85.00% = 871.47     40.00% = 2729.6      5.00% = 9355.2
                80.00% = 1035.5     35.00% = 3067.9      4.00% = 10274.
                75.00% = 1200.6     30.00% = 3469.8      2.00% = 13435.
                70.00% = 1371.2     25.00% = 3962.8      1.00% = 17102.
                65.00% = 1550.8     20.00% = 4594.7       .01% = 58675.

C) NO. OF POOLS DISTRIBUTION
   ------------------------------
   Lower Support     =    0
   Upper Support     =   16
   Expectation       =      4.17047
   Standard Deviation=      2.03812
```

D) Summary Statistics for 4000 Simulations

```
Play Resource:    (  B cu m    )
------------------------------
  Minimum     = .0000000E+00  Maximum           = 82.75508
  Expectation = 13.55062      Standard Deviation= 9.680848

EMPERICAL DISTRIBUTION:
----------------------
  Greater than    Play
  Percentage      Potential
  ------------    -----------
     100.00          .00000E+00
      95.00          1.8748
      90.00          3.2706
      85.00          4.5111
      80.00          5.6573
      75.00          6.7058
      70.00          7.5702
      65.00          8.5881
      60.00          9.6180
      55.00          10.486
      50.00          11.552
      45.00          12.638
      40.00          13.824
      35.00          15.194
      30.00          16.582
      25.00          18.142
      20.00          20.165
      15.00          22.653
      10.00          26.140
       8.00          28.027
       6.00          30.383
       5.00          31.840
       4.00          33.475
       2.00          40.347
       1.00          45.483
        .01          81.869
        .00          82.666
```

PETRIMES MODULE MPRO

```
NO. OF POOLS DISTRIBUTION AND RISKS
**********************************

UAI        C5139911
PLAY       Eagle Upper Paleozoic clastics
Assessor   Peter Hannigan
Geologist  Peter Hannigan
Remarks    Arctic Circle study area Hydrocarbon Assessment
Run date   WED, DEC  8, 1999,  4:09 PM


USER SUPPLIED PARAMETERS
------------------------
   DO YOU WANT TO STORE ON DB?           >    Y
   OIL (O) OR GAS (G) ?                  >    G


A) Risks
   -----

                  GEOLOGICAL FACTOR               MARGINAL PROBABILITY
                  -----------------               --------------------

   PLAY LEVEL     Overall Play Level Risk        =       1.00

   PROSPECT LEVEL Presence of Reservoir Facies ( 2)       .50
                  Adequate Seal                ( 4)       .70
                  Adequate Timing              ( 5)       .70
                  Adequate Preservation        ( 8)       .70
                  Presence of Closure          ( 1)       .70
                  ----------------------------------------------------
                  Overall Prospect Level Risk    =        .12

   EXPLORATION RISK:                             =        .12


B) No. of Prospects Distribution          C) No. of Pools Distribution
   -----------------------------             -------------------------

   Minimum       =     2                     Minimum       =     0
   Maximum       =    10                     Maximum       =     7
   Mean          =    5.49                   Mean          =     .66
   S.D.          =    2.38                   S.D.          =     .81

   Frequency   No. of Prospects              Frequency   No. of Pools
   ---------   ----------------              ---------   ------------

     99.00          2                          48.22          0
       95           3                            40           1
       90           3                            25           1
       80           3                            20           1
       75           3                            10           2
       60           4                             5           2
       50           4                             1           3
       40           6                             0           7
       25           7
       20           8
       10           9
        5          10
        1          10
        0          10
```

Note: The no. of pools distribution is saved in the database with UDI= 6201GB4

PETRIMES MODULE PSRK

```
INDIVIDUAL POOL SIZES BY RANK
WHERE N IS A RANDOM VARIABLE
*****************************

UAI        C5139911
PLAY       Eagle Upper Paleozoic clastics
Assessor   Peter Hannigan
Geologist  Peter Hannigan
Remarks    Arctic Circle study area Hydrocarbon Assessment
Run date   WED, DEC  8, 1999,  4:11 PM

USER SUPPLIED PARAMETERS
------------------------
   DO YOU WANT TO STORE ON DB ?          > Y
   DO YOU WANT TO USE MPRO OUTPUT?       > Y
   MIN. AND MAX. POOL RANKS?             >      1     2
   DO YOU USE LOGNORNAL ASSUMPTION?      > Y
   DO YOU WANT TO USE PPSD OUTPUT?       > Y

A) Basic Information
   -----------------
   TYPE OF RESOURCE      =Gas In-place
   SYSTEM OF MEASUREMENT =S.I.
   UNIT OF MEASUREMENT   =M cu m  (19)

B) Lognormal Pool Size Distribution
   --------------------------------
   Summary      mu      = 6.8935     MEAN   = 1544.4
   Statistics   sig. sq= .89776      S.D.   = 1862.4

   Upper        99.99% = 29.071     60.00% = 775.47     15.00% = 2632.1
   Percentiles  99.00% = 108.78     55.00% = 875.20     10.00% = 3320.2
                95.00% = 207.48     50.00% = 985.87      8.00% = 3732.5
                90.00% = 292.73     45.00% = 1110.5      6.00% = 4301.3
                85.00% = 369.26     40.00% = 1253.3      5.00% = 4684.5
                80.00% = 444.11     35.00% = 1420.3      4.00% = 5178.7
                75.00% = 520.32     30.00% = 1620.3      2.00% = 6901.2
                70.00% = 599.83     25.00% = 1868.0      1.00% = 8935.1
                65.00% = 684.32     20.00% = 2188.5       .01% = 33433.

C) No. of Pools Distribution
   -------------------------
   Lower Support     =   0
   Upper Support     =   7
   Expectation       =    .66
   Standard Deviation=    .81

D) Pool Sizes By Rank
   ------------------

   Pool Rank                     Distribution

        1     MEAN    = 1807.8     S.D.   = 2071.9     P(N>=r)= .48223
              99%     = 123.11     75%    = 629.23     10%    = 3854.6
              95%     = 241.87     50%    = 1195.8      5%    = 5353.7
              90%     = 346.83     25%    = 2224.9      1%    = 9952.1

        2     MEAN    = 880.81     S.D.   = 751.10     P(N>=r)= .14076
              99%     = 92.994     75%    = 389.83     10%    = 1762.8
              95%     = 170.27     50%    = 672.37      5%    = 2286.3
              90%     = 233.42     25%    = 1128.5      1%    = 3689.6

E) The mean of the potential =  995.76
```

PETRIMES MODULE PSUM

```
MONTE CARLO SUM SIMULATION
POOL SIZE DISTRIBUTION
**************************

UAI        C5139911
PLAY       Eagle Upper Paleozoic clastics
Assessor   Peter Hannigan
Geologist  Peter Hannigan
Remarks    Arctic Circle study area Hydrocarbon Assessment
Run date   WED, DEC  8, 1999,  4:38 PM


USER SUPPLIED PARAMETERS
------------------------
   DO YOU WANT TO STORE IN DATA BASE ?   >    Y
   OIL (O) OR GAS (G) ?                  >    G
   BRITISH OR S.I. UNIT OF MEASUREMENT?  >   SI
   RECOVERABLE RESOURCES?                >    N
   DO YOU WANT TO USE MPRO OUTPUT?       >    Y
   DO YOU ASSUME LOGNORMAL DISTRIBUTION? >    Y
   DO YOU WANT TO USE PPSD OUTPUT?       >    Y
   DO YOU COMPUTE CONDITIONAL POTENTIAL? >    N

A) Basic Information
   -----------------
   TYPE OF RESOURCE      =Gas In-place
   SYSTEM OF MEASUREMENT =S.I.
   UNIT OF MEASUREMENT   =M cu m  (19)

B) Lognormal Pool Size Distribution
   -------------------------------
   Summary      mu     = 6.8935     MEAN   = 1544.4
   Statistics   sig. sq= .89776     S.D.   = 1862.4

   Upper        99.99% = 29.071     60.00% = 775.47     15.00% = 2632.1
   Percentiles  99.00% = 108.78     55.00% = 875.20     10.00% = 3320.2
                95.00% = 207.48     50.00% = 985.87      8.00% = 3732.5
                90.00% = 292.73     45.00% = 1110.5      6.00% = 4301.3
                85.00% = 369.26     40.00% = 1253.3      5.00% = 4684.5
                80.00% = 444.11     35.00% = 1420.3      4.00% = 5178.7
                75.00% = 520.32     30.00% = 1620.3      2.00% = 6901.2
                70.00% = 599.83     25.00% = 1868.0      1.00% = 8935.1
                65.00% = 684.32     20.00% = 2188.5       .01% = 33433.

C) NO. OF POOLS DISTRIBUTION
   -----------------------------
   Lower Support     =    0
   Upper Support     =    7
   Expectation       =       .65847
   Standard Deviation=       .81304
```

```
D) Summary Statistics for 4000 Simulations
   ---------------------------------------

   Play Resource:    (  B cu m    )
   ------------------------------
     Minimum     = .0000000E+00  Maximum           = 29.68745
     Expectation = 1.063429      Standard Deviation= 1.998591

   EMPERICAL DISTRIBUTION:
   ----------------------
     Greater than    Play
     Percentage      Potential
     ------------    -----------
        100.00          .00000E+00
         45.00          .26973
         40.00          .49215
         35.00          .74895
         30.00          1.0458
         25.00          1.3683
         20.00          1.7906
         15.00          2.4537
         10.00          3.2604
          8.00          3.7566
          6.00          4.2727
          5.00          4.6868
          4.00          5.2330
          2.00          7.4936
          1.00          9.2391
           .01          26.127
           .00          29.331
```

PETRIMES MODULE PSRK

```
INDIVIDUAL POOL SIZES BY RANK
WHERE N IS A RANDOM VARIABLE
*****************************

UAI        C5149911
PLAY       Peel Upper Paleozoic clastics
Assessor   Peter Hannigan
Geologist  Peter Hannigan
Remarks    Arctic Circle study area Hydrocarbon Assessment
Run date   THU, DEC  9, 1999,  8:52 AM


USER SUPPLIED PARAMETERS
------------------------
   DO YOU WANT TO STORE ON DB ?          > Y
   DO YOU WANT TO USE MPRO OUTPUT?       > Y
   MIN. AND MAX. POOL RANKS?             >      1     4
   DO YOU USE LOGNORNAL ASSUMPTION?      > Y
   DO YOU WANT TO USE PPSD OUTPUT?       > Y

A) Basic Information
   ----------------
   TYPE OF RESOURCE      =Gas In-place
   SYSTEM OF MEASUREMENT =S.I.
   UNIT OF MEASUREMENT   =M cu m  (19)

B) Lognormal Pool Size Distribution
   -------------------------------
   Summary      mu     = 8.2640     MEAN   = 5504.7
   Statistics   sig. sq= .69863     S.D.   = 5534.9

   Upper        99.99% = 173.39     60.00% = 3140.9     15.00% = 9231.1
   Percentiles  99.00% = 555.34     55.00% = 3494.7     10.00% = 11330.
                95.00% = 981.61     50.00% = 3881.7      8.00% = 12562.
                90.00% = 1329.9     45.00% = 4311.6      6.00% = 14237.
                85.00% = 1632.3     40.00% = 4797.2      5.00% = 15350.
                80.00% = 1920.9     35.00% = 5356.7      4.00% = 16770.
                75.00% = 2208.9     30.00% = 6017.0      2.00% = 21604.
                70.00% = 2504.2     25.00% = 6821.3      1.00% = 27133.
                65.00% = 2812.9     20.00% = 7843.9       .01% = 86903.

C) No. of Pools Distribution
   ------------------------
   Lower Support     =   0
   Upper Support     =  10
   Expectation       =   1.50
   Standard Deviation=   1.23

D) Pool Sizes By Rank
   -----------------

   Pool Rank                      Distribution

        1     MEAN   = 7459.1     S.D.   = 6731.2     P(N>=r)= .77710
              99%    = 728.28     75%    = 3252.9     10%    = 14877.
              95%    = 1369.6     50%    = 5626.3      5%    = 19577.
              90%    = 1910.3     25%    = 9427.7      1%    = 33037.

        2     MEAN   = 3914.2     S.D.   = 2798.4     P(N>=r)= .43962
              99%    = 533.38     75%    = 1982.5     10%    = 7393.8
              95%    = 929.00     50%    = 3225.1      5%    = 9214.0
              90%    = 1241.5     25%    = 5056.0      1%    = 13810.
```

```
3     MEAN   = 2812.0     S.D.   = 1808.1     P(N>=r)= .18990
      99%    = 454.25     75%    = 1532.7     10%    = 5132.9
      95%    = 762.87     50%    = 2397.6      5%    = 6261.3
      90%    = 997.07     25%    = 3626.9      1%    = 8970.2

4     MEAN   = 2270.0     S.D.   = 1357.5     P(N>=r)= .66433E-01
      99%    = 409.13     75%    = 1299.4     10%    = 4036.4
      95%    = 672.08     50%    = 1977.7      5%    = 4858.6
      90%    = 866.44     25%    = 2915.9      1%    = 6779.1
```

E) The mean of the potential = 8202.1

PETRIMES MODULE PSUM

```
MONTE CARLO SUM SIMULATION
POOL SIZE DISTRIBUTION
**************************

UAI        C5149911
PLAY       Peel Upper Paleozoic clastics
Assessor   Peter Hannigan
Geologist  Peter Hannigan
Remarks    Arctic Circle study area Hydrocarbon Assessment
Run date   THU, DEC  9, 1999,  8:53 AM


USER SUPPLIED PARAMETERS
------------------------
   DO YOU WANT TO STORE IN DATA BASE ?   >    Y
   OIL (O) OR GAS (G) ?                  >    G
   BRITISH OR S.I. UNIT OF MEASUREMENT?  >   SI
   RECOVERABLE RESOURCES?                >    N
   DO YOU WANT TO USE MPRO OUTPUT?       >    Y
   DO YOU ASSUME LOGNORMAL DISTRIBUTION? >    Y
   DO YOU WANT TO USE PPSD OUTPUT?       >    Y
   DO YOU COMPUTE CONDITIONAL POTENTIAL? >    N

A) Basic Information
   -----------------
   TYPE OF RESOURCE      =Gas In-place
   SYSTEM OF MEASUREMENT =S.I.
   UNIT OF MEASUREMENT   =M cu m  (19)

B) Lognormal Pool Size Distribution
   -------------------------------
   Summary      mu     = 8.2640     MEAN   = 5504.7
   Statistics   sig. sq= .69863     S.D.   = 5534.9

   Upper        99.99% = 173.39     60.00% = 3140.9     15.00% = 9231.1
   Percentiles  99.00% = 555.34     55.00% = 3494.7     10.00% = 11330.
                95.00% = 981.61     50.00% = 3881.7      8.00% = 12562.
                90.00% = 1329.9     45.00% = 4311.6      6.00% = 14237.
                85.00% = 1632.3     40.00% = 4797.2      5.00% = 15350.
                80.00% = 1920.9     35.00% = 5356.7      4.00% = 16770.
                75.00% = 2208.9     30.00% = 6017.0      2.00% = 21604.
                70.00% = 2504.2     25.00% = 6821.3      1.00% = 27133.
                65.00% = 2812.9     20.00% = 7843.9       .01% = 86903.

C) NO. OF POOLS DISTRIBUTION
   -----------------------------
   Lower Support     =    0
   Upper Support     =   10
   Expectation       =      1.49882
   Standard Deviation=      1.22940
```

```
D) Summary Statistics for 4000 Simulations
   --------------------------------------

   Play Resource:    (  B cu m    )
   ------------------------------
     Minimum     = .0000000E+00  Maximum           = 92.61460
     Expectation = 8.381558      Standard Deviation= 9.678548

   EMPERICAL DISTRIBUTION:
   ----------------------
     Greater than    Play
     Percentage      Potential
     ------------    -----------
        100.00          .00000E+00
         75.00          1.2521
         70.00          2.0156
         65.00          2.9188
         60.00          3.9005
         55.00          4.7602
         50.00          5.6659
         45.00          6.5615
         40.00          7.6247
         35.00          8.8603
         30.00          10.329
         25.00          11.798
         20.00          13.993
         15.00          16.666
         10.00          20.674
          8.00          22.879
          6.00          25.357
          5.00          27.197
          4.00          29.935
          2.00          36.232
          1.00          42.770
           .01          91.501
           .00          92.503
```

PETRIMES MODULE MPRO

```
NO. OF POOLS DISTRIBUTION AND RISKS
***********************************

UAI         C5159911
PLAY        Jura-Cretaceous clastics structural
Assessor    Peter Hannigan
Geologist   Peter Hannigan
Remarks     Arctic Circle study area Hydrocarbon Assessment
Run date    THU, DEC  9, 1999,  9:25 AM


USER SUPPLIED PARAMETERS
------------------------
   DO YOU WANT TO STORE ON DB?           >    Y
   OIL (O) OR GAS (G) ?                  >    G


A) Risks
   -----

                  GEOLOGICAL FACTOR               MARGINAL PROBABILITY
                  -----------------               --------------------

   PLAY LEVEL     Overall Play Level Risk        =       1.00

   PROSPECT LEVEL Presence of Reservoir Facies ( 2)       .50
                  Adequate Seal                ( 4)       .70
                  Adequate Source              ( 6)       .90
                  Presence of Closure          ( 1)       .75
                  ----------------------------------------------------
                  Overall Prospect Level Risk    =        .24

   EXPLORATION RISK:                             =        .24


B) No. of Prospects Distribution              C) No. of Pools Distribution
   -----------------------------                 -------------------------

   Minimum       =    10                         Minimum       =     0
   Maximum       =    30                         Maximum       =    18
   Mean          =   17.97                       Mean          =    4.25
   S.D.          =    5.98                       S.D.          =    2.29

   Frequency   No. of Prospects                  Frequency   No. of Pools     Note: The no. of pools
   ---------   ----------------                  ---------   ------------     distribution is saved in
                                                                              the database with UDI=
     99.00          10                             98.16           0          6201GB4
       95           11                               95            1
       90           11                               90            2
       80           12                               80            2
       75           13                               75            3
       60           14                               60            3
       50           15                               50            4
       40           18                               40            5
       25           23                               25            6
       20           24                               20            6
       10           27                               10            7
        5           29                                5            8
        1           30                                1           11
        0           30                                0           18
```

PETRIMES MODULE PSRK

```
INDIVIDUAL POOL SIZES BY RANK
WHERE N IS A RANDOM VARIABLE
*****************************

UAI        C5159911
PLAY       Jura-Cretaceous clastics structural
Assessor   Peter Hannigan
Geologist  Peter Hannigan
Remarks    Arctic Circle study area Hydrocarbon Assessment
Run date   THU, DEC  9, 1999,  9:26 AM


USER SUPPLIED PARAMETERS
------------------------
   DO YOU WANT TO STORE ON DB ?          > Y
   DO YOU WANT TO USE MPRO OUTPUT?       > Y
   MIN. AND MAX. POOL RANKS?             >      1     8
   DO YOU USE LOGNORNAL ASSUMPTION?      > Y
   DO YOU WANT TO USE PPSD OUTPUT?       > Y

A) Basic Information
   -----------------
   TYPE OF RESOURCE      =Gas In-place
   SYSTEM OF MEASUREMENT =S.I.
   UNIT OF MEASUREMENT   =M cu m  (19)

B) Lognormal Pool Size Distribution
   --------------------------------
   Summary      mu      = 6.5685     MEAN   = 1091.6
   Statistics   sig. sq= .85376      S.D.   = 1267.6

   Upper        99.99% = 22.924     60.00% = 563.64     15.00% = 1856.0
   Percentiles  99.00% = 83.012     55.00% = 634.23     10.00% = 2327.8
                95.00% = 155.82     50.00% = 712.31      8.00% = 2609.2
                90.00% = 217.97     45.00% = 800.01      6.00% = 2996.2
                85.00% = 273.38     40.00% = 900.19      5.00% = 3256.3
                80.00% = 327.30     35.00% = 1016.9      4.00% = 3590.8
                75.00% = 381.95     30.00% = 1156.4      2.00% = 4751.3
                70.00% = 438.77     25.00% = 1328.4      1.00% = 6112.2
                65.00% = 498.94     20.00% = 1550.2       .01% = 22134.

C) No. of Pools Distribution
   -------------------------
   Lower Support     =   0
   Upper Support     =  18
   Expectation       =   4.25
   Standard Deviation=   2.29

D) Pool Sizes By Rank
   ------------------

   Pool Rank                     Distribution

        1      MEAN   = 2283.8     S.D.   = 1967.5     P(N>=r)= .98163
               99%    = 225.85     75%    = 1084.1     10%    = 4398.4
               95%    = 472.50     50%    = 1772.7      5%    = 5755.6
               90%    = 661.68     25%    = 2847.8      1%    = 9738.2

        2      MEAN   = 1150.4     S.D.   = 798.64     P(N>=r)= .90753
               99%    = 125.66     75%    = 597.47     10%    = 2141.8
               95%    = 252.47     50%    = 972.77      5%    = 2643.7
               90%    = 356.93     25%    = 1493.8      1%    = 3918.5
```

```
3     MEAN   = 775.45     S.D.   = 510.56     P(N>=r)= .76361
      99%    = 92.939     75%    = 408.26     10%    = 1434.6
      95%    = 176.60     50%    = 667.25      5%    = 1741.2
      90%    = 245.44     25%    = 1019.0      1%    = 2473.0

4     MEAN   = 590.65     S.D.   = 376.33     P(N>=r)= .58094
      99%    = 77.686     75%    = 316.16     10%    = 1084.8
      95%    = 142.11     50%    = 512.13      5%    = 1306.0
      90%    = 193.94     25%    = 777.55      1%    = 1817.1

5     MEAN   = 481.81     S.D.   = 297.48     P(N>=r)= .40542
      99%    = 68.883     75%    = 263.77     10%    = 875.56
      95%    = 122.80     50%    = 420.80      5%    = 1048.2
      90%    = 165.20     25%    = 632.72      1%    = 1439.5

6     MEAN   = 408.88     S.D.   = 244.97     P(N>=r)= .26408
      99%    = 62.830     75%    = 229.11     10%    = 734.43
      95%    = 109.87     50%    = 359.66      5%    = 875.30
      90%    = 146.14     25%    = 534.86      1%    = 1190.8

7     MEAN   = 355.39     S.D.   = 207.24     P(N>=r)= .16159
      99%    = 58.092     75%    = 203.35     10%    = 631.33
      95%    = 99.997     50%    = 314.58      5%    = 749.67
      90%    = 131.76     25%    = 462.96      1%    = 1012.8

8     MEAN   = 314.24     S.D.   = 178.86     P(N>=r)= .92307E-01
      99%    = 54.172     75%    = 183.13     10%    = 552.62
      95%    = 92.002     50%    = 279.67      5%    = 654.16
      90%    = 120.26     25%    = 407.73      1%    = 878.79
```

E) The mean of the potential = 4610.9

PETRIMES MODULE PSUM

```
MONTE CARLO SUM SIMULATION
POOL SIZE DISTRIBUTION
**************************

UAI        C5159911
PLAY       Jura-Cretaceous clastics structural
Assessor   Peter Hannigan
Geologist  Peter Hannigan
Remarks    Arctic Circle study area Hydrocarbon Assessment
Run date   THU, DEC  9, 1999,  9:28 AM


USER SUPPLIED PARAMETERS
------------------------
   DO YOU WANT TO STORE IN DATA BASE ?   >    Y
   OIL (O) OR GAS (G) ?                  >    G
   BRITISH OR S.I. UNIT OF MEASUREMENT?  >   SI
   RECOVERABLE RESOURCES?                >    N
   DO YOU WANT TO USE MPRO OUTPUT?       >    Y
   DO YOU ASSUME LOGNORMAL DISTRIBUTION? >    Y
   DO YOU WANT TO USE PPSD OUTPUT?       >    Y
   DO YOU COMPUTE CONDITIONAL POTENTIAL? >    N

A) Basic Information
   -----------------
   TYPE OF RESOURCE      =Gas In-place
   SYSTEM OF MEASUREMENT =S.I.
   UNIT OF MEASUREMENT   =M cu m  (19)

B) Lognormal Pool Size Distribution
   --------------------------------
   Summary      mu     = 6.5685     MEAN   = 1091.6
   Statistics   sig. sq= .85376     S.D.   = 1267.6

   Upper        99.99% = 22.924     60.00% = 563.64     15.00% = 1856.0
   Percentiles  99.00% = 83.012     55.00% = 634.23     10.00% = 2327.8
                95.00% = 155.82     50.00% = 712.31      8.00% = 2609.2
                90.00% = 217.97     45.00% = 800.01      6.00% = 2996.2
                85.00% = 273.38     40.00% = 900.19      5.00% = 3256.3
                80.00% = 327.30     35.00% = 1016.9      4.00% = 3590.8
                75.00% = 381.95     30.00% = 1156.4      2.00% = 4751.3
                70.00% = 438.77     25.00% = 1328.4      1.00% = 6112.2
                65.00% = 498.94     20.00% = 1550.2       .01% = 22134.

C) NO. OF POOLS DISTRIBUTION
   ------------------------------
   Lower Support     =    0
   Upper Support     =   18
   Expectation       =      4.24541
   Standard Deviation=      2.28804
```

```
D) Summary Statistics for 4000 Simulations
   ---------------------------------------

   Play Resource:    (  B cu m    )
   ------------------------------
     Minimum     = .0000000E+00  Maximum           = 33.58017
     Expectation = 4.662509      Standard Deviation= 3.604983

   EMPERICAL DISTRIBUTION:
   ----------------------
     Greater than    Play
     Percentage      Potential
     ------------    -----------
        100.00         .00000E+00
         95.00         .49739
         90.00         1.0069
         85.00         1.4031
         80.00         1.7181
         75.00         2.0352
         70.00         2.3986
         65.00         2.7283
         60.00         3.0889
         55.00         3.4668
         50.00         3.8541
         45.00         4.2624
         40.00         4.7011
         35.00         5.2037
         30.00         5.7412
         25.00         6.3301
         20.00         7.0923
         15.00         7.9887
         10.00         9.3328
          8.00         9.9780
          6.00         10.830
          5.00         11.394
          4.00         12.133
          2.00         14.644
          1.00         16.907
           .01         31.037
           .00         33.326
```

PETRIMES MODULE PSUM

```
MONTE CARLO SUM SIMULATION
POOL SIZE DISTRIBUTION
**************************

UAI        C5109911
PLAY       All gas plays
Assessor   Peter Hannigan
Geologist  Peter Hannigan
Remarks    Arctic Circle study area Hydrocarbon Assessment
Run date   THU, DEC  9, 1999, 11:56 AM


USER SUPPLIED PARAMETERS
------------------------
   DO YOU WANT TO STORE IN DATA BASE ?   >    Y
   OIL (O) OR GAS (G) ?                  >    G
   BRITISH OR S.I. UNIT OF MEASUREMENT?  >   SI
   RECOVERABLE RESOURCES?                >    N
   DO YOU COMPUTE CONDITIONAL POTENTIAL? >    N

A) Basic Information
   -----------------
   TYPE OF RESOURCE      =Gas In-place
   SYSTEM OF MEASUREMENT =S.I.
   UNIT OF MEASUREMENT   =M cu m  (19)

B) PLAY POTENTIAL DISTRIBUTION
   ------------------------------


   Summary      MEAN   = 13.793     S.D.   = 11.593
   Statistics   B cu m

   Upper       100.00% = .00000E+00 55.00% = 9.8981     10.00% = 28.778
   Percentiles  95.00% = 1.2931     50.00% = 10.946      8.00% = 31.048
                90.00% = 2.5159     45.00% = 12.193      6.00% = 33.921
                85.00% = 3.6282     40.00% = 13.655      5.00% = 35.681
                80.00% = 4.6765     35.00% = 15.036      4.00% = 38.244
                75.00% = 5.6831     30.00% = 16.752      2.00% = 45.984
                70.00% = 6.6187     25.00% = 18.537      1.00% = 53.447
                65.00% = 7.6927     20.00% = 20.848       .01% = 119.27
                60.00% = 8.7000     15.00% = 24.009       .00% = 120.48

   Summary      MEAN   = 13.551     S.D.   = 9.6808
   Statistics   B cu m

   Upper       100.00% = .00000E+00 55.00% = 10.486     10.00% = 26.140
   Percentiles  95.00% = 1.8748     50.00% = 11.552      8.00% = 28.027
                90.00% = 3.2706     45.00% = 12.638      6.00% = 30.383
                85.00% = 4.5111     40.00% = 13.824      5.00% = 31.840
                80.00% = 5.6573     35.00% = 15.194      4.00% = 33.475
                75.00% = 6.7058     30.00% = 16.582      2.00% = 40.347
                70.00% = 7.5702     25.00% = 18.142      1.00% = 45.483
                65.00% = 8.5881     20.00% = 20.165       .01% = 81.869
                60.00% = 9.6180     15.00% = 22.653       .00% = 82.666

   Summary      MEAN   = 1.0634     S.D.   = 1.9986
   Statistics   B cu m
```

```
Upper       100.00% = .00000E+00 20.00% = 1.7906      4.00% = 5.2330
Percentiles  45.00% = .26973     15.00% = 2.4537      2.00% = 7.4936
             40.00% = .49215     10.00% = 3.2604      1.00% = 9.2391
             35.00% = .74895      8.00% = 3.7566       .01% = 26.127
             30.00% = 1.0458      6.00% = 4.2727       .00% = 29.331
             25.00% = 1.3683      5.00% = 4.6868

Summary      MEAN   = 8.3816     S.D.   = 9.6785
Statistics   B cu m

Upper       100.00% = .00000E+00 40.00% = 7.6247      6.00% = 25.357
Percentiles  75.00% = 1.2521     35.00% = 8.8603      5.00% = 27.197
             70.00% = 2.0156     30.00% = 10.329      4.00% = 29.935
             65.00% = 2.9188     25.00% = 11.798      2.00% = 36.232
             60.00% = 3.9005     20.00% = 13.993      1.00% = 42.770
             55.00% = 4.7602     15.00% = 16.666       .01% = 91.501
             50.00% = 5.6659     10.00% = 20.674       .00% = 92.503
             45.00% = 6.5615      8.00% = 22.879

Summary      MEAN   = 4.6625     S.D.   = 3.6050
Statistics   B cu m

Upper       100.00% = .00000E+00 55.00% = 3.4668     10.00% = 9.3328
Percentiles  95.00% = .49739     50.00% = 3.8541      8.00% = 9.9780
             90.00% = 1.0069     45.00% = 4.2624      6.00% = 10.830
             85.00% = 1.4031     40.00% = 4.7011      5.00% = 11.394
             80.00% = 1.7181     35.00% = 5.2037      4.00% = 12.133
             75.00% = 2.0352     30.00% = 5.7412      2.00% = 14.644
             70.00% = 2.3986     25.00% = 6.3301      1.00% = 16.907
             65.00% = 2.7283     20.00% = 7.0923       .01% = 31.037
             60.00% = 3.0889     15.00% = 7.9887       .00% = 33.326
```

C) NO. OF PLAYS DISTRIBUTION

```
------------------------------
Lower Support     =    5
Upper Support     =    5
Expectation       =      5.00000
Standard Deviation=       .00000
```

D) Summary Statistics for 4000 Simulations

```
--------------------------------------
Basin Resource:   (  B cu m    )
------------------------------
  Minimum     = 3.848532    Maximum           = 162.9515
  Expectation = 42.18804    Standard Deviation= 19.50332

EMPERICAL DISTRIBUTION:
----------------------
```

Greater than Percentage	Basin Potential	Greater than Percentage	Basin Potential
100.00	3.8485	40.00	43.377
99.00	11.077	35.00	46.171
95.00	17.079	30.00	48.576
90.00	20.910	25.00	51.723
85.00	23.843	20.00	55.932
80.00	26.448	15.00	60.424
75.00	28.521	10.00	66.555
70.00	30.794	8.00	70.074
65.00	32.821	6.00	74.624
60.00	34.981	5.00	77.529
55.00	36.998	4.00	81.606
50.00	39.079	2.00	95.115
45.00	41.098	1.00	107.57
		.01	159.89
		.00	162.65

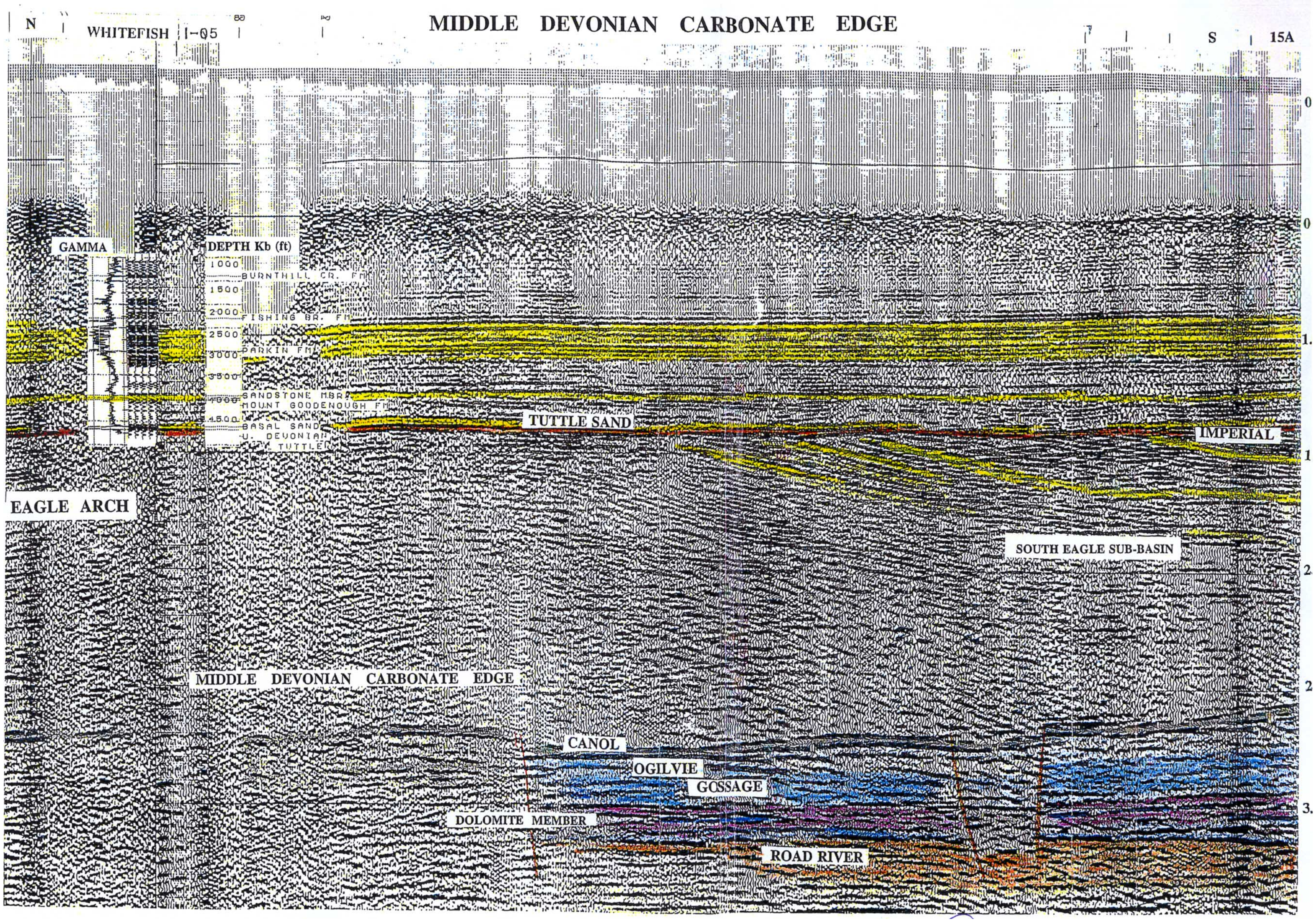
N
WHITEFISH I-05
MIDDLE DEVONIAN CARBONATE EDGE
S
15A
GAMMA
DEPTH Kb (ft)
1000
BURNTHILL CR. FM
1500
2000
FISHING BR. FM
2500
PARKIN FM
3000
3500
4000
SANDSTONE MBR
MOUNT GOODENOUGH FM
4500
BASAL SAND
U. DEVONIAN
TUTTLE SAND
IMPERIAL
EAGLE ARCH
SOUTH EAGLE SUB-BASIN
MIDDLE DEVONIAN CARBONATE EDGE
CANOL
OGILVIE
GOSSAGE
DOLOMITE MEMBER
ROAD RIVER

Figure 11.

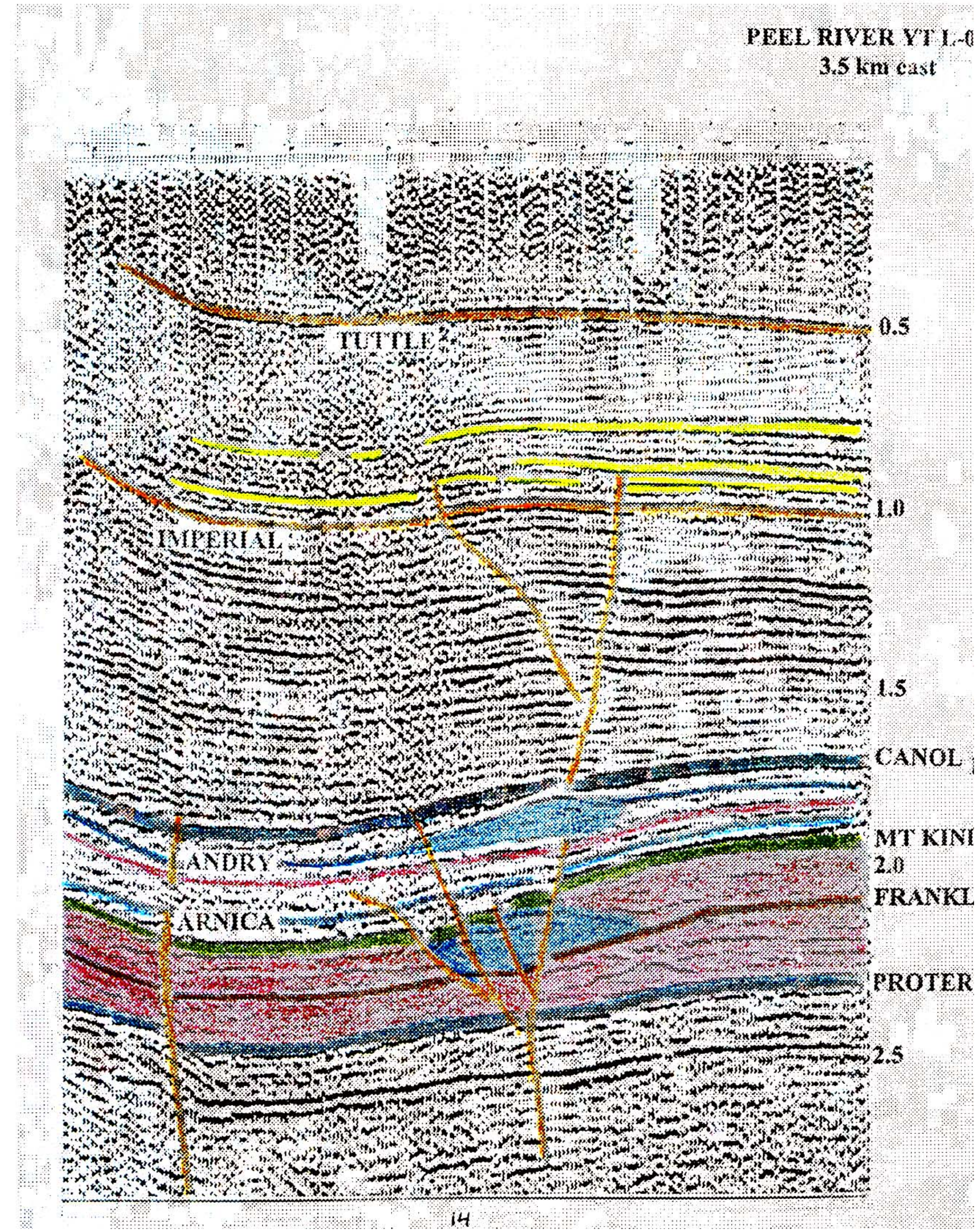
PEEL RIVER YT L-0
3.5 km east
TUTTLE
0.5
IMPERIAL
1.0
1.5
CANOL
ANDRY
MT KIN
2.0
FRANKL
ARNICA
PROTER
2.5
14

Figure 15.