Petroleum Resource Assessment of Bonnet Plume Basin, Yukon Territory, Canada

by
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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 Bonnet Plume Basin 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 ongoing oil and gas resources management program. The objective of this study was to investigate the hydrocarbon resource potential of the Bonnet Plume Basin in Yukon. A quantitative analysis was utilized to derive a numerical estimate of resources that may exist in the basin. Due to the absence of defined pools with established reserves, probability distributions of reservoir parameters and marginal risk factors are employed to generate a range of hydrocarbon potential estimates which indicate the uncertainties involved in the analysis of frontier conceptual plays.

The Bonnet Plume Basin is both a physiographic and structural depression located near the eastern margin of the Frontal Belt of the Cordilleran Orogen in northern Yukon. It lies asymmetrically on the west flank of the Richardson Anticlinorium near its southern limit. The basin was developed by down-dropping of components of the Richardson Fault Array commencing in early Late Cretaceous time. Local reversals in relative displacements, from Late Cretaceous to Tertiary time, created the successor basin in which clastics were deposited.

The hydrocarbon potential volumes were derived using the Geological Survey of Canada's PETRIMES assessment methodology system. This resource study embraced analyses of three conceptual plays, each of which incorporated the estimation of field-size parametric data, numbers of prospects and exploration risks. Three speculative exploration plays were also defined but they are described qualitatively due to insufficient information. The median estimate for total gas potential for all Bonnet Plume plays is 25 billion m^3 of in-place gas. There are no discovered reserves in the Bonnet Plume region, but 2 gas fields greater than 3000 million m^3 (100 BCF) are expected. Significant gas potential is predicted for one play only: the Lower Paleozoic facies transition play, even though geological risk factors are substantial in the play. Geochemical evidence indicates that there is probably not much oil potential in the study area.

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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 Bonnet Plume Basin in Yukon (Figures 1). A quantitative analysis was used to derive a numerical estimate of resources that may exist in the basin. Due to the absence of defined pools with established reserves, probability distributions of reservoir parameters and marginal risk factors were utilized to generate a range of hydrocarbon potential estimates which indicates the uncertainties involved in the analysis of frontier conceptual plays.

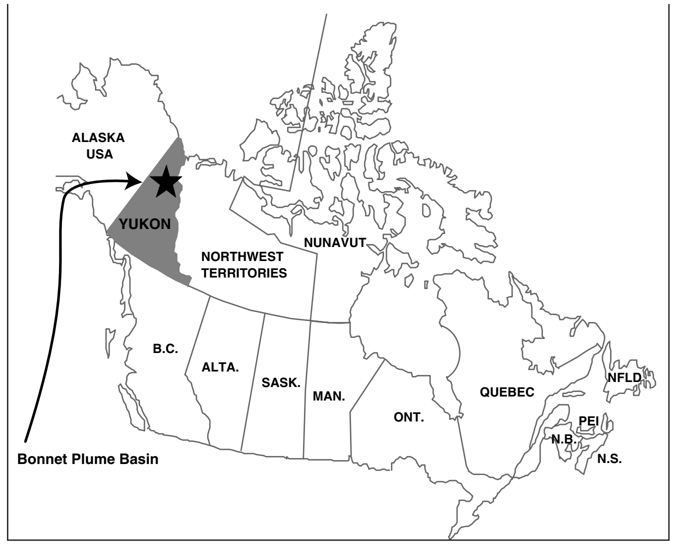

Figure 1. *Bonnet Plume Basin location map.*

Regional petroleum resource assessments have been prepared periodically for numerous 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 e*t al*, 1989; Sinclair e*t al*, 1992; Reinson e*t al*, 1993; Bird e*t al*, 1994; Dixon e*t al*, 1994; Hannigan e*t al*, 1998, 1999; Hannigan, in press). This paper summarizes the assessment of oil and gas potential of the Bonnet Plume Basin of northern Yukon.

This report provides an overview of the petroleum geology of the Bonnet Plume region and presents quantitative estimates of the oil and gas resources contained therein. The geological and resource framework for the region will assist government agencies in evaluating land-use and moratorium issues, and petroleum industry companies in pursuing future exploration opportunities.

ACKNOWLEDGEMENTS

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TERMINOLOGY

The terminology and procedures used in this report follow those outlined in Reinson e*t 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 have 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 been tested as yet. 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 Bonnet Plume Basin'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.

Speculative plays are a type of conceptual play that have insufficient geological information for quantitative analyses. Therefore, these plays are only described qualitatively. Often, there is some doubt whether these plays actually exist in the area of interest.

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 properly defined, a numerical and statistical resource assessment is undertaken using relevant geological data and information for that specific play.

RESOURCE ASSESSMENT PROCEDURE

The analysis of the Bonnet Plume 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, although no seismic survey has been completed in the area.

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 components in geological basin analysis preceding 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. Mixed populations derived from improperly defined plays add 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 of 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 in 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 Bonnet Plume 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 represented adequately by lognormal distributions.

Conceptual resource assessments in 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 are then 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 Bonnet Plume conceptual plays are expected to exist (the low play-level risk of 1.0 was assigned to each play). 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 are available to constrain sizes of undiscovered accumulations, the uncertainties in oil and gas play potential and pool size estimates for a given range of probabilities are necessarily greater than the ranges derived by discovery process analysis used for assessing mature plays.

REGIONAL GEOLOGY

Two distinct structural and genetic regional geological regimes are present in northern Yukon. The vast majority of northern Yukon occupies the northern portion 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 which is 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 younger, more complex assemblages 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 rock is at least 1.7 billion years old and is present throughout northern Yukon beneath both the Interior Platform and the Cordilleran Orogen. These rocks, in part, provided the stable continental platform upon which sediments, dominantly consisting of limestone and sandstone, were deposited over a period of billion years (Hart, 1999). Shale, sandstone and chert accumulated in basinal regions of deeper water. 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 Interior Platform amassed between 5 and 25 km of dominant limestone and sandstone. The limestone accumulated during quiescent times in warm, shallow and clear water. The sandstone consists of detritus eroded from the Canadian Shield. In Richardson Trough, a basinal area, limestone growth was limited due to deeper water, and currents depositing sands were not strong. Accordingly, this basin or trough accumulated mud and biogenic silica that formed shales and cherts, respectively.

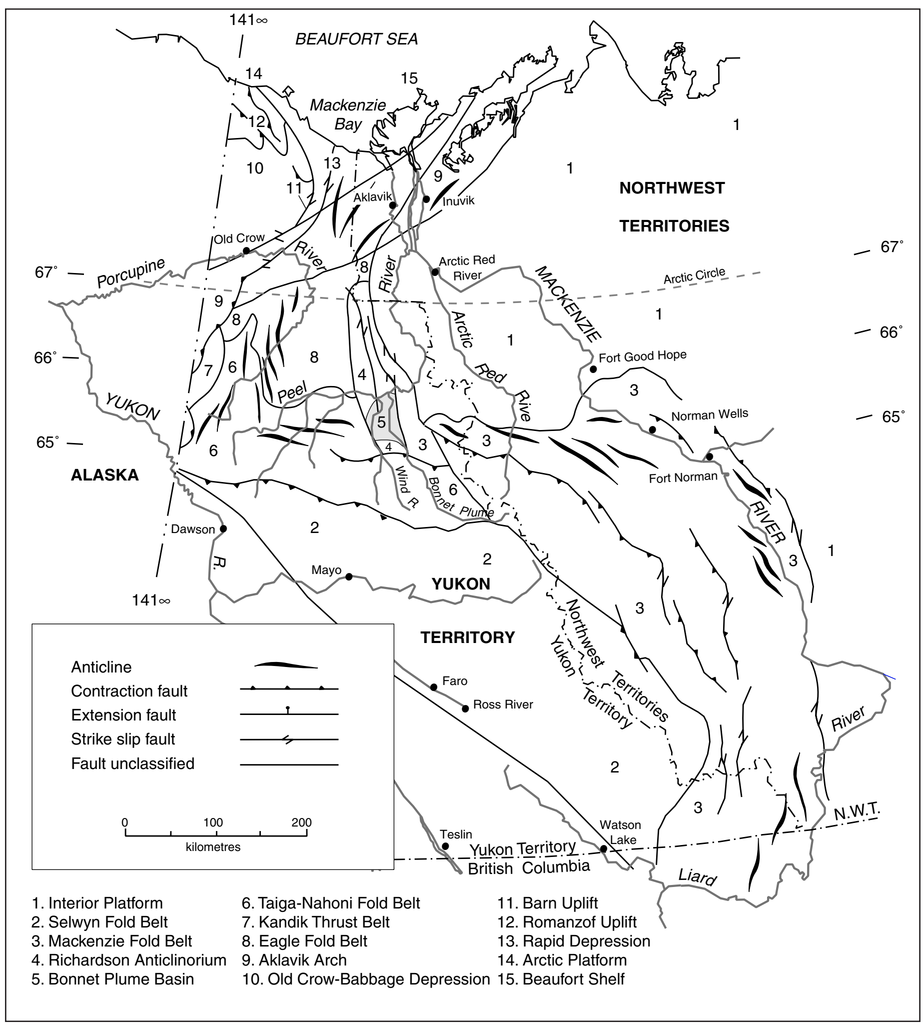


Figure 2. *Index map of the northern Cordillera and Interior Platform of Canada, showing the Bonnet Plume Basin in relation to the other tectonic elements (from Norris and Hopkins, 1997).*

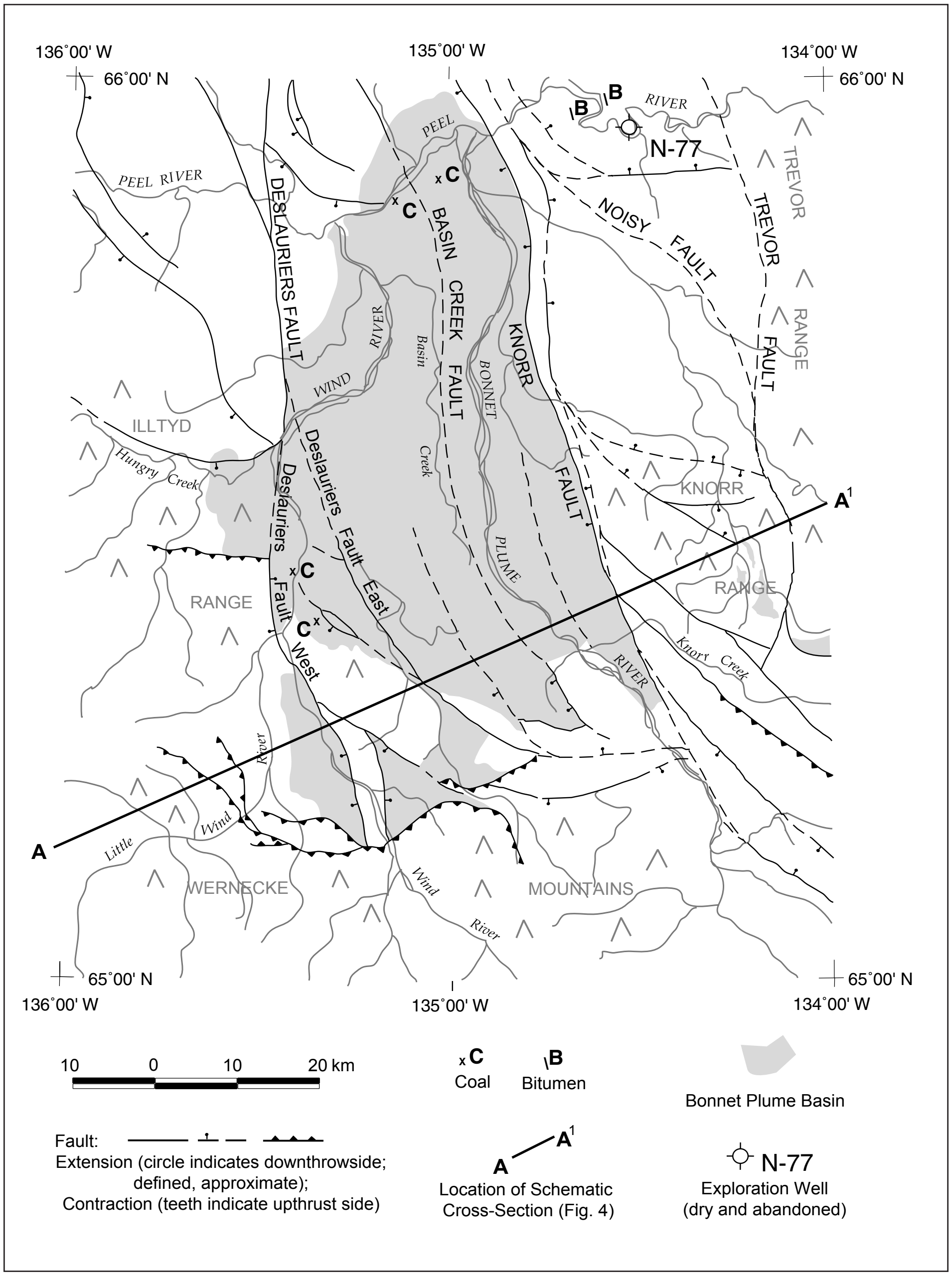


***Figure 3.** Bonnet Plume Basin. Stippled pattern denotes areas of Cretaceous clastic sediment cover indicating areal extent of the Mesozoic Bonnet Plume Basin. Schematic cross-section location is shown (Fig. 5). Major faults are shown.*

The Bonnet Plume Basin is both a physiographic and structural depression located near the eastern margin of the Frontal Belt of the Cordilleran Orogen in northern Yukon (Figure 2). It lies asymmetrically on the west flank of the Richardson Anticlinorium near its southern limit (Norris and Hopkins, 1977). The basin was developed by down-dropping of components of the Richardson Fault Array, commencing in early Late Cretaceous time. Local reversals in relative displacement from Late Cretaceous to Tertiary time created the successor basin into which clastic strata were deposited (Figure 3). These strata are the youngest rocks within the basin and consist of sandstone, shale, conglomerate and coal of the Late Cretaceous to early Tertiary Bonnet Plume Formation.

The Richardson Anticlinorium is a broad north-plunging anticlinal structure located between the Interior Platform to the east and the Eagle Foldbelt, part of the Yukon Stable Block, to the west (Figure 2) (Norris, 1997). The anticlinorium is bounded on the east by the Trevor Fault and the west by Deception Fault. It coincides in position with the early and middle Paleozoic Richardson Trough (Norris, 1997). On the flanks of the anticlinorium, deep water shales and argillaceous limestones comprise the Late Cambrian to Middle Devonian Road River Group (Figure 4). In the core of the anticlinorium, Middle Cambrian Slats Creek sandstones and conglomerates and Lower Cambrian limestones and dolostones of the Illtyd Formation overlie the Proterozoic Wernecke Supergroup with angular unconformity (Norris, 1997; Figure 4). There are numerous north-trending curvilinear, near-vertical faults throughout the anticlinorium that constitute the Richardson Fault Array. This fault array makes up the underlying structural control for both the Richardson Anticlinorium and Trough. Reactivation of faults in the late Cretaceous, with intermittent movements until mid-Tertiary, caused the inversion of the Paleozoic trough into the post-mid-Tertiary anticlinorium.

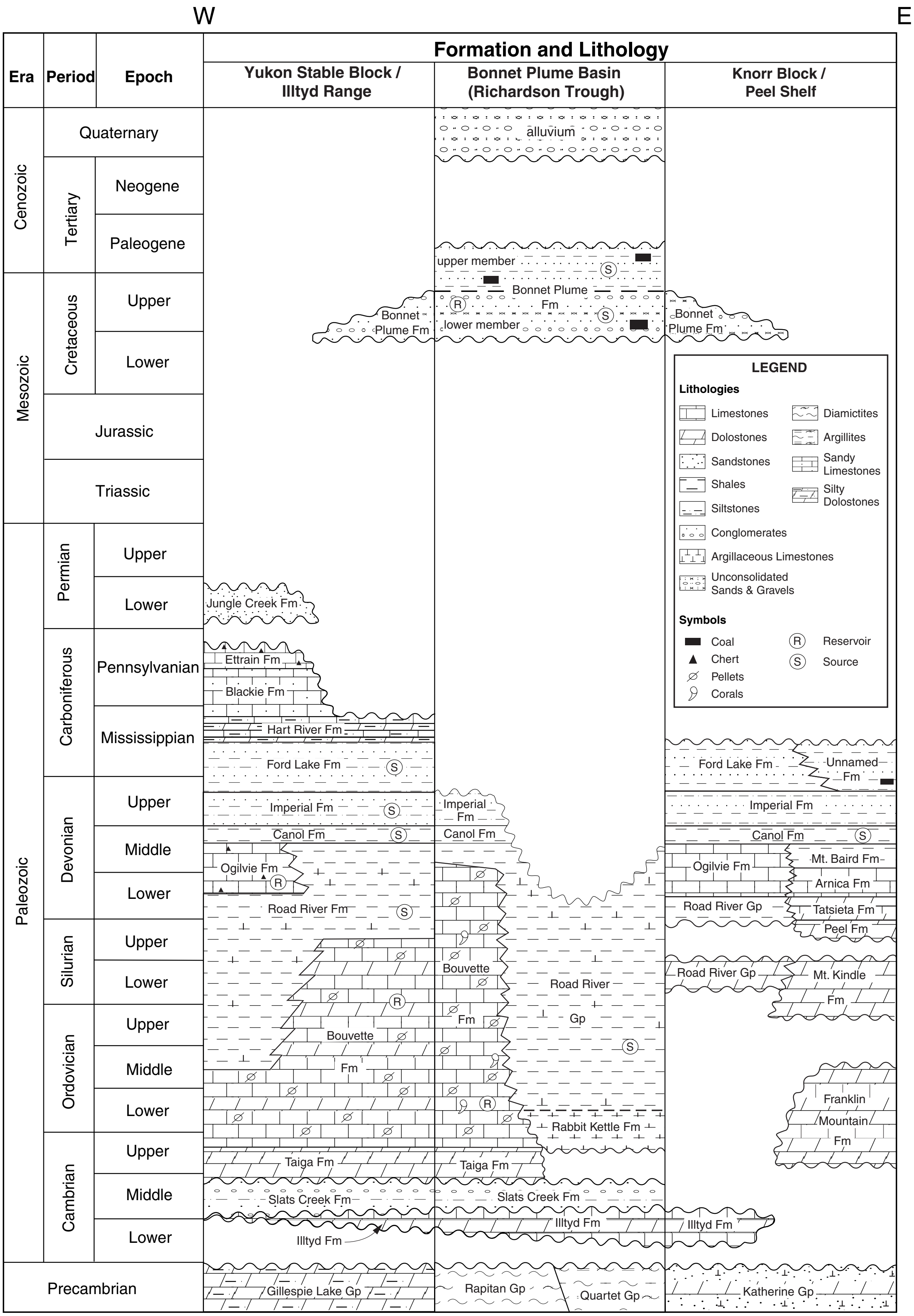


Figure 4. *Stratigraphic table for the Bonnet Plume area.*

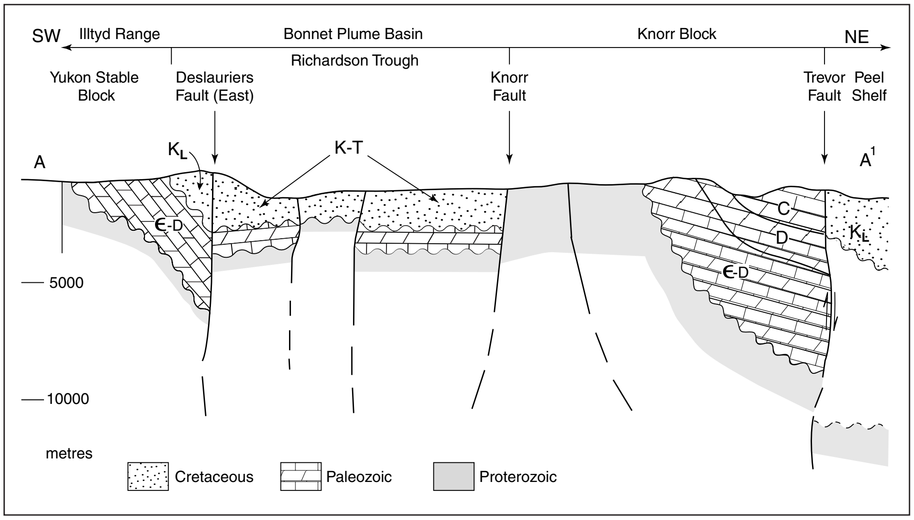


Figure 5. *Schematic cross-section, Bonnet Plume Basin (after Norris and Hopkins, 1977).*

The two structures that have contributed most significantly to the development of the basin are the Knorr and Deslauriers faults (Figure 3) which constitute part of the Richardson Fault Array (Norris, 1997). The Knorr Fault bounding the east side of the Bonnet Plume Basin separates Late Cretaceous to Tertiary clastics preserved in the basin and Proterozoic to Devonian rocks of the Knorr Block to the east. Similarly, the Deslauriers faults (consisting of an eastern and western splay) on the west boundary of the basin separates Cretaceous rocks from Devonian to Lower Cretaceous sediments of the Illtyd Block to the west (Figure 5 illustrates the lateral extent of these various tectonic elements). The displacement on these structures in post-Paleocene time resulted in relative uplift of the outer blocks of the array with contemporaneous depression of inner blocks preserving the Bonnet Plume Formation in the core of the anticlinorium (Norris, 1997).

One of the most noteworthy features of the basin is the interruption of east-trending structures leading into the basin from the Mackenzie foldbelt to the east and the Taiga-Nahoni foldbelt to the west. This feature contrasts with the apparent continuity of south-trending fault structures of the Richardson Anticlinorium beneath the basin (Norris, 1982). Folds and fault blocks in the Taiga Range to the west terminate eastward abruptly against the Deslauriers Fault and apparently do not continue eastward beneath the basin. Similarly, west-trending folds and high-angle normal faults of the Mackenzie Mountains are curtailed at the Knorr Fault. The continuity of faults of the Richardson Fault Array beneath Bonnet Plume Basin, on the other hand, indicates the fundamental role the array plays in differentiating the Mackenzie Foldbelt from the remainder of the Cordilleran Orogen (Norris, 1997).

PRECAMBRIAN-CAMBRIAN

There are between 1,600 and 7,500 m of Lower Cambrian to Lower Tertiary sedimentary strata in the study area (Figures 4, 5). Proterozoic basement consisting of metasediments includes argillites, silty dolostones, limy sandstones and diamictites. This thick supracrustal Proterozoic wedge unconformably overlies Hudsonian granites and metamorphics that comprise the westward continuation of the Canadian Shield beneath the Cordilleran Orogen (Norris and Dyke, 1997).

Unconformably overlying these metasediments within the Illtyd Range and Richardson Mountains are 375 to 1,085 m of silty, pelletal limestone and massive dolostone of the Illtyd Formation of Early Cambrian age (Figure 4; Fritz, 1997; Morrow, 1999). These rocks thin very promptly westward beneath the Slats Creek Formation (Figure 4). The Illtyd Formation is abruptly overlain by sandstones, siltstones and conglomerates of the Middle Cambrian Slats Creek Formation (Figure 4). The Slats Creek Formation attains a maximum observed thickness of 1,525 m in and near Richardson Trough and thins westward to 300 m in eastern Yukon Stable Block areas (Fritz, 1997; Morrow, 1999). Equivalent Lower and Middle Cambrian strata are absent in the Peel Shelf region to the east due to non-deposition of Mount Clark, Mount Cap and Saline River formations over the Mackenzie-Peel Arch. Periods of subaerial exposure of the Arch has erosionally truncated and removed Middle and Lower Cambrian strata (Pugh, 1983; Cecile e*t al*, 1997; Morrow, 1999).

Middle and Upper Cambrian dololaminites and dolomudstones of the Taiga Formation unconformably overlie Slats Creek sediments in western Richardson Trough and the eastern portion of the Yukon Stable Block to the west (Morrow, 1999). Maximum thickness of 600 m is attained in the Wernecke Mountains, but, like its Middle Cambrian counterpart, it thins swiftly to the west.

LOWER PALEOZOIC

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, 1985) defined a region of deep-water slope and basin shale and argillaceous limestone deposition separating two broad regions of shallow-water shelf carbonate deposition (Morrow, 1999). The Richardson Trough remained a negative physiographic feature from Early Cambrian to Devonian time.

Subsequent to deposition of Upper Cambrian Taiga sediments, the more typical strata of shales and argillaceous limestones of the Road River Group were deposited in the trough and along its margins (Figure 4). Road River Formation shales were also deposited upon the Yukon Stable Block overlying and interfingering with the Ordovician and Silurian Bouvette Formation (Morrow, 1999) (old name: ‘Unnamed carbonate sequence’, Norford, 1997) (Figure 4). The Road River Group retains thicknesses ranging between 150 and 700 m in the Bonnet Plume area (Morrow, 1999). In the Richardson Trough, a lower limy member of the Road River Group called the Rabbit Kettle Formation consisting of argillaceous limestones occurs, and it ranges in age from Late Cambrian to Early Ordovician. Mid-Paleozoic uplift and erosion of the Knorr Block removed much of the older Road River shales and argillaceous limestones resulting in Lower to Upper Silurian cherty limestones of the Road River Group directly overlying Precambrian basement (Figure 4).

The Lower Paleozoic carbonate shelf facies are represented by numerous formations throughout the area (Figure 4). The Upper Cambrian to Mid-Devonian Bouvette Formation, consisting of pelletal and coralline limestones and lesser dolostones, retains thicknesses up to 1,000 m in the Bonnet Plume area. This formation occurs as a carbonate shelf within the Illtyd Range and throughout the Yukon Stable Block to the west and as isolated buildups, for example, the Royal Mountain Platform south of the basin.

Similarly, east of Richardson Trough beneath Peel Plateau, the carbonate shelf facies is represented by the Late Cambrian to Early Ordovician Franklin Mountain Formation which attains an average thickness of 375 m. The Franklin Mountain dolostones unconformably overlie Precambrian basement in the area and is in turn unconformably overlain by the Late Ordovician to Silurian Mount Kindle Formation (Figure 4; Norford and Macqueen, 1975; Norford, 1997). The average thickness of Mount Kindle strata is about 380 m. Mount Kindle rocks consist of dolostones in the immediate area (Morrow, 1999). 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 this formation ranges from Late Silurian to earliest Devonian

(Pugh, 1983) and average thickness in the area is about 200 m. Immediately overlying the Peel Formation is a relatively thin regionally developed limestone unit called the Tatsieta Formation. Average thickness of this unit is about 160 m and its age is probably Early Devonian. The Tatsieta Formation is distinguishable from the underlying Peel Formation by its limestone content; the content is generally greater in Tatsieta strata. Lime mudclast breccias are often present in this formation. Bouvette carbonate deposition continued at this time in isolated platform bodies in Richardson Trough, specifically the Royal Mountain Platform. Basin- and slope-facies Road River deposition also occurred throughout the trough.

A shallow-water marine environment that prevailed over the entire Peel shelf led to deposition of subtidal, open marine clean carbonates of the Arnica Formation (Figure 4). Directly overlying Arnica limestones, Mount Baird shales were deposited, intimating a basinal depositional setting below effective wave-base (Morrow, 1999). Total thickness of the Arnica to Mount Baird sequence averages about 825 m (Figure 4; Morrow, 1999).

Contemporaneous with deposition of the Arnica to Mount Baird succession, the Ogilvie carbonate succession was accumulating upon Knorr Block and the Yukon Stable Block (Figure 4). Ogilvie rocks consist predominantly of thick-bedded limestones, which are cherty in part. Formation thicknesses are relatively thin, about 100 to 125 m. Deep-water shale deposition, meanwhile, continued within and on the flanks of Richardson Trough (Road River Group).

In the Knorr Range, Macqueen, 1974 and Williams, 1988 identified about forty carbonate masses within the upper Road River Group sequence. These masses range in size from 10 metres in width and thickness to nearly 1000 metres in length by 40 m thick. These masses appear to be concordant and lie within one stratum in the Road River Formation (Norris, 1985). Macqueen, 1974 and Lenz, 1972 refer to these masses as pinnacle reefs due to their fossil content and pinnacle knob shape. However, Cook and Mullins, 1983 and Williams, 1988 interpret these masses as channel deposits due to their conglomeratic texture and sparse bioclastic limy mud matrix.

CARBONIFEROUS

A rapid rise of sea level in early Late Devonian time led to uniform deposition of the euxinic siliceous black shales of the Canol Formation across the entire Peel Shelf and Yukon Stable Block as well as in Richardson Trough directly overlying the Road River Group (Figure 4; Morrow, 1999). This unit marked the termination of shallow-water carbonate platform or shelf deposition in the region (Morrow and Geldsetzer, 1992). Thicknesses of Canol shales vary from about 60 m in the Knorr Block to 150 m in the Illtyd Range. The Canol Formation conformably underlies the clastic Late Devonian Imperial Formation, which principally consists of shales, and siltstones with minor sandstones. Imperial strata thicknesses vary from 250 to 1,500 m in the Bonnet Plume area.

In the Yukon Stable Block area to the west of the basin, the Imperial Formation is conformably overlain by fine-grained clastic rocks of the Ford Lake Formation of uppermost Devonian-lower Carboniferous age (Bamber and Waterhouse, 1971; Richards e*t al*, 1997). However, in the basin itself, Imperial shales and siltstones are unconformably overlain by the Mesozoic Bonnet Plume Formation. Coarse-grained clastics of equivalent Tuttle Formation were deposited north of the study area. The Ford Lake Formation, consisting of shales and siltstones with subordinate sandstones, onlap northward over deltaic facies of the Tuttle Formation indicating an early Carboniferous transgression (Richards e*t al,* 1997). Average thickness of the Ford Lake Formation in the study area is about 300 m. Upon the Peel Shelf to the east of Knorr Block, there are unnamed correlatives of the Ford Lake succession consisting of both marine and non-marine shale, siltstone, sandstone and coal (Figure 4; Richards et *al*, 1997).

Succeeding Ford Lake shales in the Illtyd Range and Yukon Stable Block are carbonate ramp limestone deposits of the Hart River Formation. These limestones are often cherty and spicular and well-laminated. Thicknesses of 250 m are reached in the northern portion of the basin area. The Hart River and underlying transgressive deposits of the Ford Lake Formation jointly form a transgressive/regressive sequence (Richards et *al*, 1997). Immediately overlying Hart River carbonates in the Yukon Stable Block immediately west of Illtyd Range, sandy limestones of the Blackie Formation and its partly correlative cherty limy carbonate sequence (Ettrain Formation) are deposited. Unconformably overlying the Carboniferous Blackie and Ettrain formations in eastern Yukon Stable Block are Permian siliciclastics of the Jungle Creek Formation.

Pronounced truncation beneath several regional unconformities have removed all upper Paleozoic rocks in some parts of the study area, specifically Richardson Trough and Bonnet Plume Basin (Richards et *al*, 1997). No Triassic or Jurassic strata have been mapped in the area.

MESOZOIC

A major unconformity separates Upper Cretaceous/Eocene Bonnet Plume non-marine sediments from underlying Paleozoic rocks (Figure 4). Two members of the Bonnet Plume Formation have been recognized: a lower member of Late Cretaceous age containing conglomerate, sandstone and coal, and a late Late-Cretaceous-Eocene finer-grained upper member consisting of sandstones, shales and coals (Figure 4; Mountjoy, 1967; Norris and Hopkins, 1977; Long, 1978, 1987; Norris, 1982; Dixon, 1986, 1992, 1997). Strata comprising the complete Bonnet Plume succession are restricted to the Bonnet Plume depression. Isolated outcrop remnants of lower member clastic rocks, specifically upon the Knorr Block to the east (Figure 3), indicate that "Ancestral Bonnet Plume Basin" covered a much greater area (Norris and Hopkins, 1977). The Bonnet Plume clastic succession is interpreted to have been deposited in a non-marine alluvial and fluvial environment (Norris and Hopkins, 1977). Long (1981) re-emphasized this interpretation with a detailed description of non-marine alluvial depositional facies occurring within this strike-slip basin. Mountjoy (1967) estimated up to 1,500 m of poorly consolidated clastic sedimentary material exists in the basin. Norris and Hopkins (1977), however, interpret that thicknesses for Bonnet Plume strata are much less, more likely ranging up to 900 m.

Dixon (1997) infers the Bonnet Plume Formation was deposited during a Late Cretaceous to Early Tertiary compressional phase of tectonism when considerable quantities of coarse clastic sediment was deposited in a well-defined foreland setting established at that time north of the Cordilleran Orogen. The Bonnet Plume Basin was situated in a fluvial/fan-delta setting immediately north of the sediment source. The relatively recent Laramide tectonic episode gave rise to major thrust faults in the Wernecke Mountains south of the basin as well as normal faults and folds throughout the basin area. Older tectonic elements were overprinted by these younger orogenic events. In many instances, these archaic elements, specifically faults, were rejuvenated (Dixon, 1986).

PETROLEUM GEOLOGY

EXPLORATION HISTORY

Petroleum exploration in the Bonnet Plume Basin has been quite limited. No seismic survey has been attempted in the basin and no wells have been drilled (Northern Oil and Gas Directorate, 1995). The nearest well is the Toltec Peel River YT N-77 well drilled in 1968, 20 kilometres to the northwest in the Peel River valley (Figure 3). The well encountered Imperial Formation at surface and subsequently penetrated Road River Group shales to total depth and was classified as dry and abandoned. It was testing an anticlinal structure discovered by Stelck (1944) near two albertite dykes exposed on surface. These bitumen exposures indicate that hydrocarbons were present at one time in the subsurface and that structural control was essential for seepage of hydrocarbons from Lower Paleozoic rocks to the surface.

An east-west gravity profile was acquired across the centre of the basin in 1979 (Sobczak and Long, 1980). The main purpose of the survey was to determine if gravity methods could be used to interpret structure in areas with limited surface control and no subsurface information. Thicknesses of coal-bearing sequences with respect to underlying Paleozoic and Proterozoic rocks can be estimated from gravity profiles, if there are sufficient density contrasts between the two successions. By using a two-layer model, it was determined that the maximum thickness of the Bonnet Plume Formation in the centre of the basin is about 880 m, much less than the 1,500 m thickness interpreted to the north (Mountjoy, 1967).

A geological map at a scale of 1:250,000 covering the area (Wind River map-sheet, 106E) studied by members in 'Operation Porcupine' was compiled by D.K. Norris, the co-ordinator of the regional Geological Survey of Canada mapping project (Norris, 1982). 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

In this assessment study, the potential Paleozoic reservoir units on the Peel Shelf are excluded since these rocks were already considered in the Peel hydrocarbon assessment study (Figure 4; also see Figure 5; National Energy Board, 1999). Therefore, reservoir descriptions and defined hydrocarbon plays for the Bonnet Plume Basin study disregard these potential carbonate reservoirs.

LOWER PALEOZOIC

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 (Morrow, 1999). Fritz (1997) describes numerous carbonate buildups in the region. Massive cliff-forming clean pelletoidal limestones with cores of thick-bedded vuggy dolostones are typical constituents in these buildups (Fritz, 1997). These rocks probably have no or little primary porosity but secondary fracture porosity may be present. The overlying Slats Creek sandstones, siltstones and chert-pebble conglomerates are weakly metamorphosed and probably have no primary porosity, but secondary fracture porosity may exist. Upper Cambrian dololaminites and dolomudstones of the Taiga Formation probably contain little or no primary porosity.

In the subsurface of southeastern Yukon Block, Illtyd Range and adjacent to Richardson Trough, the Upper Cambrian to Upper Ordovician Bouvette Formation, consisting of interbedded dolostones and pelletoidal and coralline limestones, constitutes the principal reservoir unit of the Lower Paleozoic carbonate shelf successions. Biostromal or bioclastic layers or karsted and vuggy dolostones are potential reservoir strata in the Bouvette Formation in the area. Dolomite-cemented crackle breccias below bed contacts indicate karsting activity (Morrow, 1999). Vuggy porosity and pyrobitumen have been observed in Ordovician carbonates capped by Road River shales in subsurface Eagle Plain to the northwest (Norford, 1997). However, all four wells penetrating this sequence encountered water in the carbonates (Moorhouse, 1966; Martin, 1973).

Slightly porous crinoidal wackestones may be present in limestone lithofacies of the Ogilvie Formation in the Yukon Stable Block. These limestones have been interpreted as having been deposited basinward or seaward of the Ogilvie shelf margin, part of the basinal succession. They do not likely contain stromatoporodial biostromes and bioherms that occur at the top of the Ogilvie Formation in other areas, especially western Eagle Plain to the northwest (Morrow, 1999). Also, upper Ogilvie limestones that underwent late fracturing, dolomite cementation and dolomitization noted in the Inexco Porcupine G-31 well in northwestern Eagle Plain (Morrow, 1999) are not expected to be present in Ogilvie rocks near Bonnet Plume Basin.

MESOZOIC-CENOZOIC

The Bonnet Plume Formation is a thick succession of poorly-consolidated sediments with coarse-grained sandstone and conglomerate horizons dominating in the lower member. These coarser-grained sedimentary horizons often show fair to good porosity (Mountjoy, 1967; Norris and Hopkins, 1977). The poorly cemented strata may provide sufficient permeability for hydrocarbon production.

SEALS

With respect to Paleozoic carbonate shelf reservoirs, good lateral seal is achieved at the carbonate-to-shale facies transition zone from carbonate bank into basinal shales in Richardson Trough where potential reservoir facies interfinger with shaly strata (Figure 4). Canol and Road River shales may act also as regional top seals for lower Paleozoic reservoirs. Intraformational shales form local top seals for Cretaceous reservoirs. In southern Bonnet Plume Basin, overthrust Proterozoic and Paleozoic sheets provide top seal for underlying Cretaceous strata.

TRAPS

A variety of structural, stratigraphic and combination traps occur within Paleozoic and Mesozoic sedimentary strata throughout the region. Pre-Laramide traps are more favourable for accumulating hydrocarbons since the primary episode of hydrocarbon generation commenced in Early Paleozoic time and terminated before the end of Mesozoic time. The Lower Paleozoic carbonate to shale transition relationship is ideal for entrapment of primary hydrocarbons in combined structural and stratigraphic traps (Morrow, 1999). These combination traps often consist of stratigraphic pinch-outs or wedge-outs of porous strata in impermeable shaly rocks with a secondary structural overprint. Considering Cretaceous reservoirs, the principal trapping configurations are related to the development of curvilinear anticlines and block fault traps associated with the Laramide Orogeny. Also, porous ancient channel-fills, sealed laterally and vertically by impermeable strata, may occur in the non-marine fluvial Bonnet Plume Formation.

SOURCE ROCKS

Link e*t 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 4). Link e*t al* (1989) rated the overall source rock potential of the Road River Formation as poor, but Road River rocks are present in the Richardson Anticlinorium yielding TOC values up to 9.6%. Type I and II kerogens are present in Road River shales, so at one time this sequence may have been an excellent source rock for oil. The occurrence of gas in wells penetrating Lower Paleozoic strata in surrounding areas to the northwest in Eagle Plain and northeast in Peel Plateau (Veezay Geodata, 1983; Pugh, 1983; National Energy Board, 1994, 1999) is consistent with present-day overmaturity of organic material within these rocks (Link and Bustin, 1989). Often, residual bitumen occurrences are present in the North Yukon region. Specifically, two bitumen intrusions were discovered by Stelck (1944) along the Peel River in a resistant sandstone bed of the Ford Lake Formation. Modelling performed by Link and Bustin (1989) indicates that Road River and Canol source rocks became thermally mature in Carboniferous to early Mesozoic time. Oil or gas originally encased in some of these reservoirs has escaped, leaving residual bitumen in several Lower Paleozoic rocks.

Upper Devonian Imperial Formation shales are mature with fair to good gas source potential. Carboniferous Ford Lake shales in southern Yukon Stable Block are another important source rock, currently mature for oil with fair to good gas potential. The Upper Cretaceous to Eocene Bonnet Plume Formation contains terrestrial plant remains encased in sub-bituminous coal seams. The organic carbon content consists entirely of Type III kerogens implying biogenic gas generation is possible in these marginally mature rocks. Mesozoic strata are unlikely to have generated much hydrocarbon and if hydrocarbon generation did occur, gas rather than oil would have been most likely produced. Also, gas generated from Paleozoic source rocks may have been trapped in Cretaceous reservoirs due to vertical migration of fluids.

TIMING OF HYDROCARBON GENERATION

Modelling by Link and Bustin (1989) of Paleozoic source rocks indicate that they passed through the 'oil window' before the end of Mesozoic time. This implies that the probable most effective trapping configurations are ones formed previous to Tertiary time during the period of active oil migration. Most exploration wells drilled so far seeking Paleozoic targets in the region were drilled on Laramide anticlinal structures that most likely do not represent the most efficient trapping mechanism. The post-Mesozoic traps that have been tested, likely gathered relatively minor amounts of gas created in the later stages of the main hydrocarbon generation episode. Therefore, pre-Tertiary traps and reservoirs were the more favourable sites for accumulation of 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. 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 thermogenic 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. The presence of two bitumen intrusions to the north of the basin indicate the probable likelihood of hydrocarbons occurring in the area. Coal seams in the Bonnet Plume Basin itself are direct indications of coal potential and possible coal-bed methane potential. Coal seams may also represent a free gas source for Cretaceous reservoir strata.

HYDROCARBON ASSESSMENT

The Bonnet Plume 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. In the Bonnet Plume area, six exploration plays were defined based on petroleum geological considerations such as structural style, dominant reservoir lithology and thermal maturity. Three conceptual gas plays and three speculative gas plays were identified in the Bonnet Plume study area. The three 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 thus, are described qualitatively.

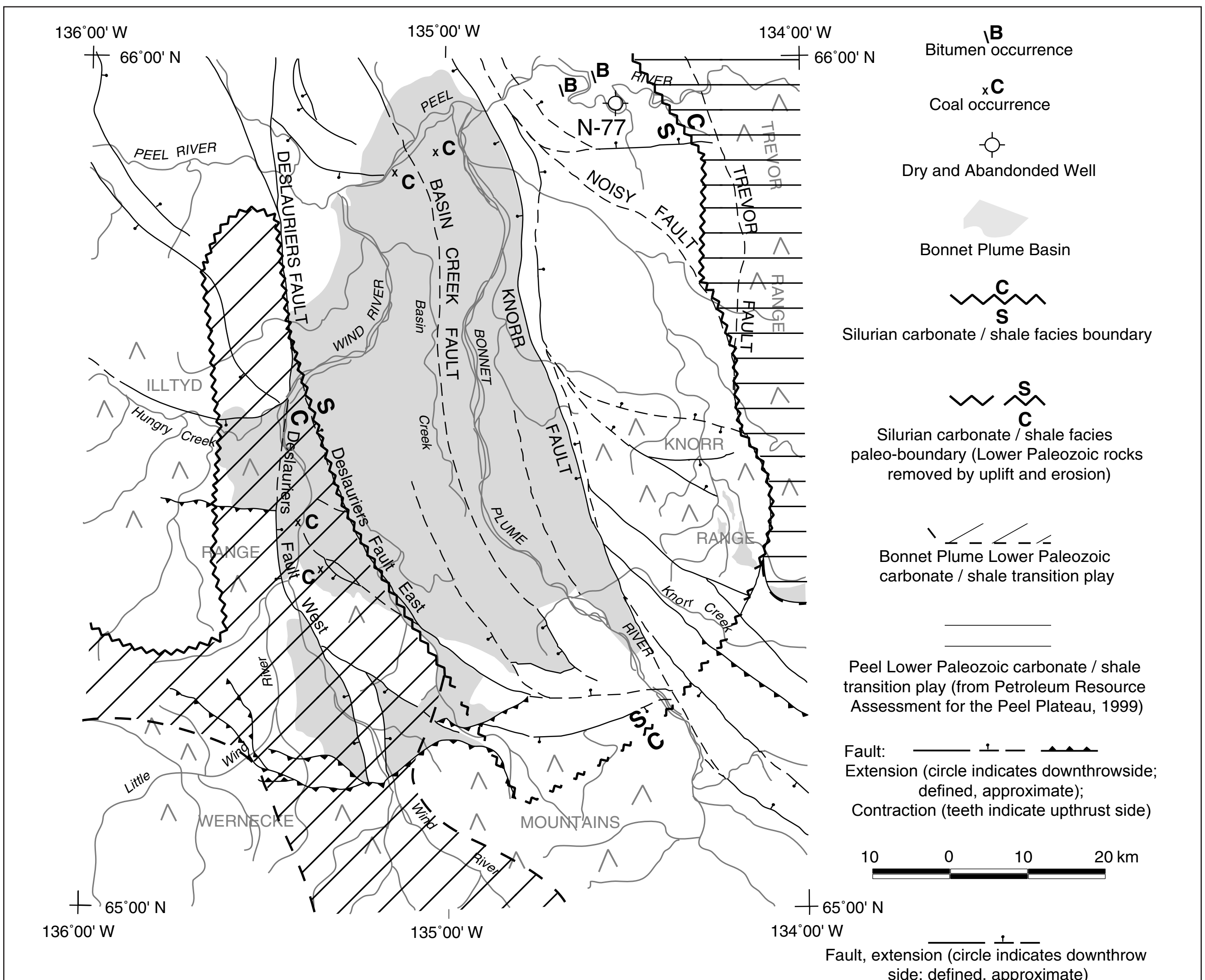
LOWER PALEOZOIC CARBONATE/ SHALE FACIES TRANSITION GAS PLAY

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 Illtyd Block adjacent to the former Richardson Trough, now the Richardson Anticlinorium (Figure 6). The play area lies directly west and south of the Cretaceous Bonnet Plume Basin (Figure 6). Carbonate reservoirs included in this play range in age from uppermost Cambrian to Middle Devonian. The play area is for the most part limited by the Silurian carbonate/shale facies boundary (Williams, 1988; Cecile and Norford, 1991) and by the shelfward extension of the carbonate/shale facies change. Lower Paleozoic rocks in many areas of the Wernecke Mountains south of the basin have been uplifted and subsequently removed by erosion which also limits the play area in that region (Figure 6; also see Norris, 1982).

Figure 6. *Lower Paleozoic carbonate/shale facies transition gas play.*



Geology

The principal prospective target in the Lower Paleozoic carbonate/shale facies transition play is the carbonate shelf margin of the Cambro-Devonian Bouvette Formation. The thickness of the prospect succession ranges from about 500 to 1,000 m. This carbonate unit interfingers and underlies an excellent source rock in laterally equivalent Road River Group shales which were deposited in deeper water environments in the Richardson Trough. Ogilvie carbonates are secondary potential reservoirs in the area. 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 likely the sole hydrocarbon phase that is currently being generated. The presence of bitumen in outcrop indicates that oil generation may have occurred when Lower Paleozoic rocks were thermally mature (Carboniferous to early Mesozoic). Road River shales can also act as good vertical and lateral seal for potential hydrocarbon accumulations occurring within the Lower Paleozoic carbonate shelf edges. Lower Paleozoic carbonates also underlie another excellent source rock; the Upper Paleozoic Canol Formation, primarily consisting of black shales. The organic-rich Canol Formation contains residual kerogens of between 2.4 and 8.6% TOC. Both Canol and Road River shales may act as reservoir seals for potential hydrocarbons in underlying Paleozoic carbonate traps.

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).

Most drillholes testing Lower Paleozoic carbonates in Eagle Plains to the northwest 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 have formed previous to Tertiary time, during the period of active oil migration. Thus, the Laramide-related traps gathered 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 most favourable for the trapping of significant volumes of hydrocarbons in pre-Laramide combined structural and stratigraphic traps. This relationship is evident in the comparison of hydrocarbon potential and their individual field sizes among the assessed plays where Laramide-related exploration plays (e.g. Upper Cretaceous-Tertiary plays) predict less significant volumes than the older pre-Laramide play (Lower Paleozoic combination stratigraphic/structural) (Table 1).

Table 1: *Hydrocarbon potential in Bonnet Plume Basin, Yukon Territory*

Play name	Expected no. of fields (mean)	Median play potential (in-place) (million m^3)	Mean play potential (in-place) (million m^3)	Median of largest field size (in-place) (million m^3)
Lower Paleozoic carbonate/ shale facies transition	6	17,027	20,383	6,673
Upper Cretaceous-Tertiary clastics	6	1,305	1,732	503
Upper Cretaceous clastic subthrust	2	425	549	312
Total Bonnet Plume Basin	**14**	**25,374**	**28,799**	

A similar exploration play was defined in the Eagle Plains area; the Ogilvie and Gossage carbonate stratigraphic play (National Energy Board, 1994). The gas pools and prospects in this play occur where porous carbonates interfinger against tight basinal shale. This play was considered to be a suitable candidate as an analogue play for the purpose of establishing probability distributions used in the computations of field size and number of field distributions (Appendices 1, 2).

Exploration risks

All of the Bonnet Plume conceptual plays are assumed to exist (indicated by 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

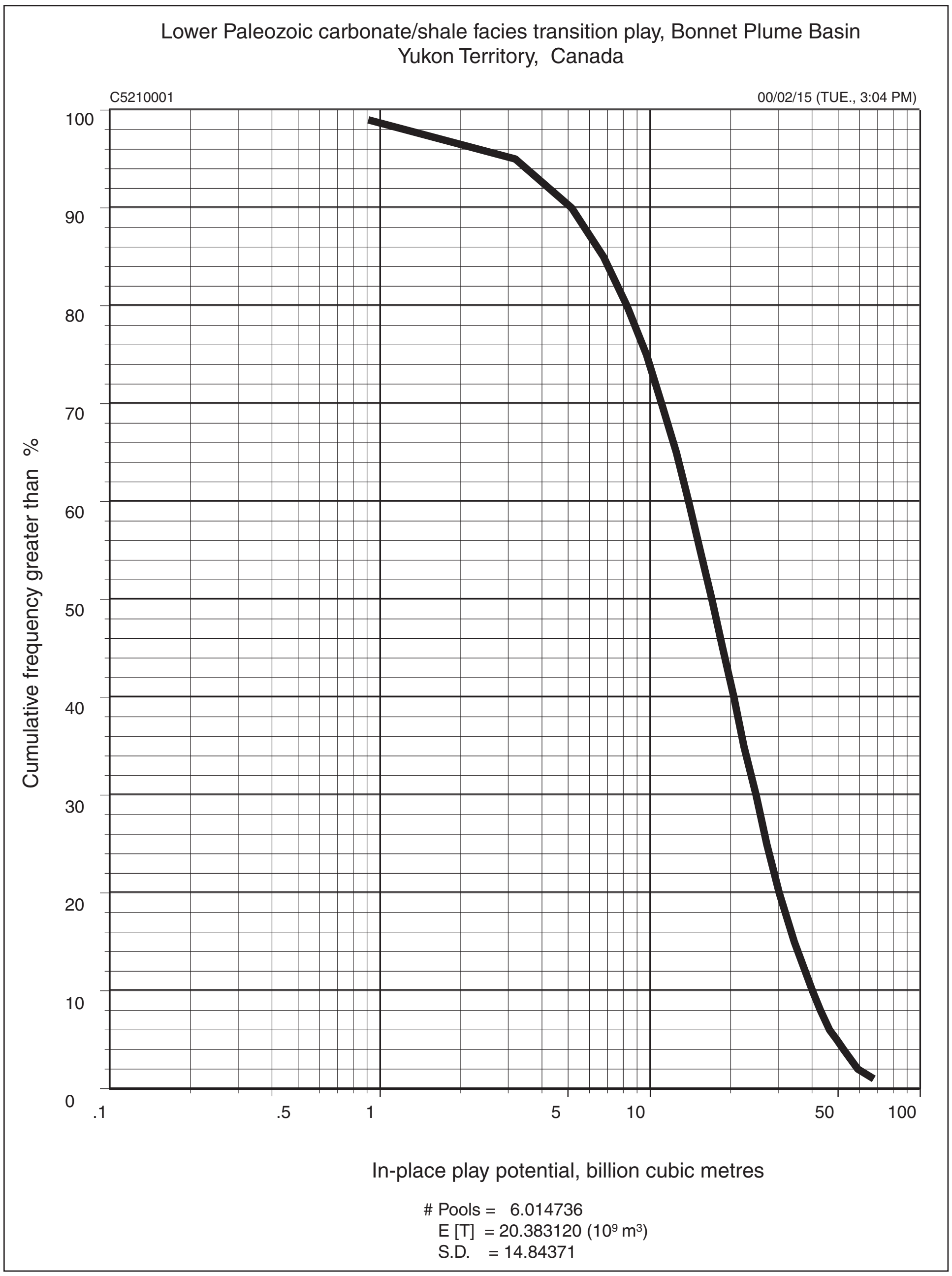
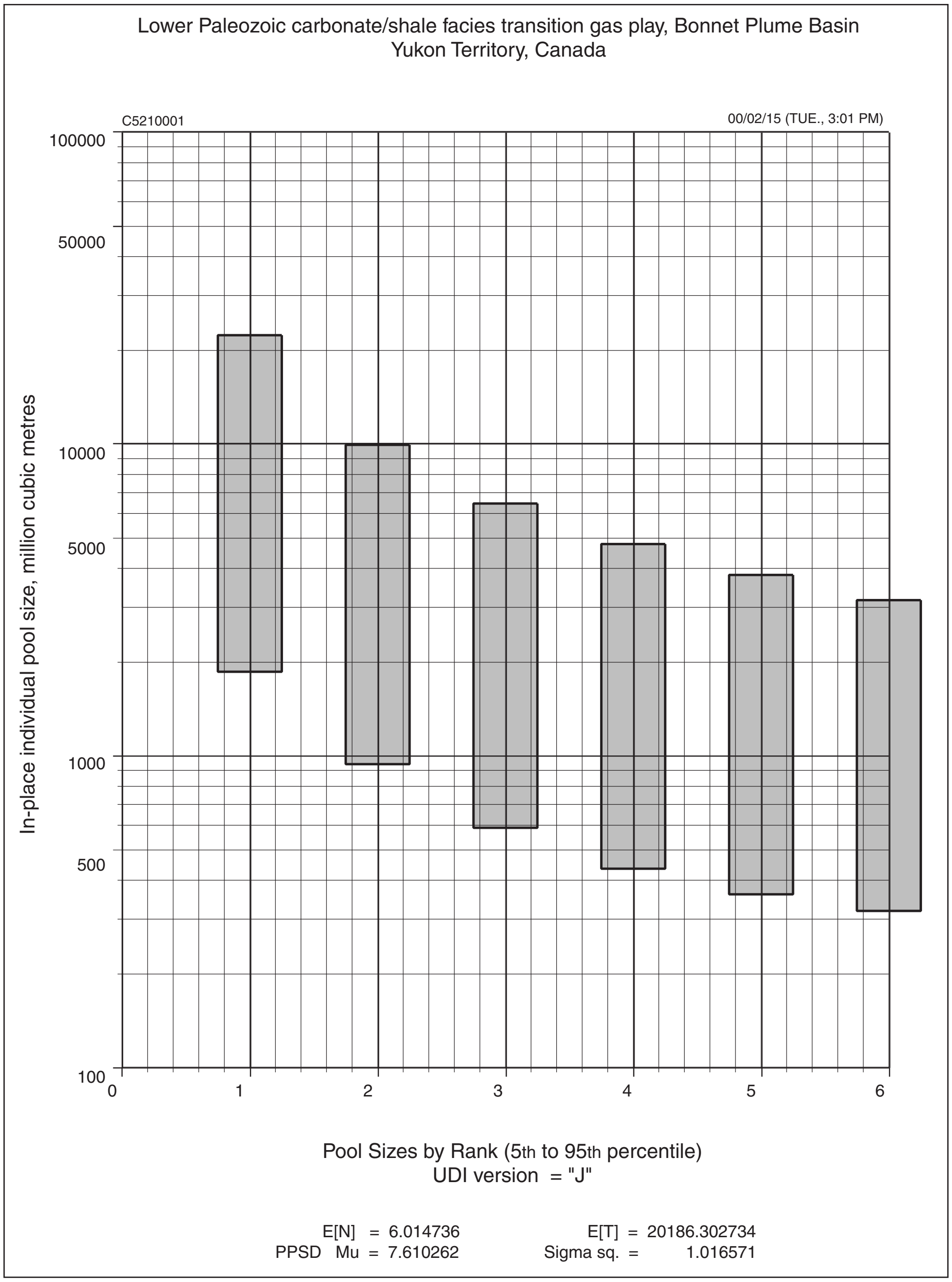


Figure 7. *Estimate of in-place gas potential of the Lower Paleozoic carbonate/shale facies transition play. Median value of probabilistic assessment is 17,027 million m^3 of in-place gas distributed in 6 fields.*

entire play. Significant prospect-level risks interpreted in this play are presence of reservoir facies and adequate seal (Appendix 1). Even though some of the wells penetrating Lower Paleozoic carbonates in the Eagle Plains had indications of good porosity and permeability, other rocks in that play area were tight. An identical reservoir facies risk factor was assigned to the Bonnet Plume play. Seal was interpreted as not adequate in some prospects. On the other hand, low risk, or in other words high marginal probability, was assigned to the adequacy of source rock and the timing of hydrocarbon generation with respect to trap formation (Appendix 1).

Figure 8. *Field-size-by-rank plot of the Lower Paleozoic carbonate/shale facies transition gas play. Median value of the largest predicted field size is 6,673 million m³ of in-place gas.*



Play potential

The Lower Paleozoic carbonate/shale facies transition play has an estimated in-place median gas potential of 17 billion m^3 in the Bonnet Plume area (50 percentile value on Figure 7; Table 1). If the 95 and 5 upper percentiles representing the range of expected potential is specified, then there is a 90% chance that the resource potential resides within the range of 3.2 to 49 billion m^3 in-place. The mean value of the number of predicted fields is 6 for the play. The largest undiscovered field is expected to contain 6.7 billion m^3 of gas (median value) (Figure 8; Table 1). Two fields with volumes greater than 3 billion m^3 of gas are predicted to occur in this carbonate play (median values in Figure 8) (See Appendix 2 for computation outputs). Three billion m^3 (100 BCF) is an arbitrary in-place gas volume defined as a minimum individual field size required to foster interest among explorationists for a particular exploration play in a frontier region of Canada.

UPPER CRETACEOUS-TERTIARY CLASTIC GAS PLAY

CONCEPTUAL HYDROCARBON PLAY

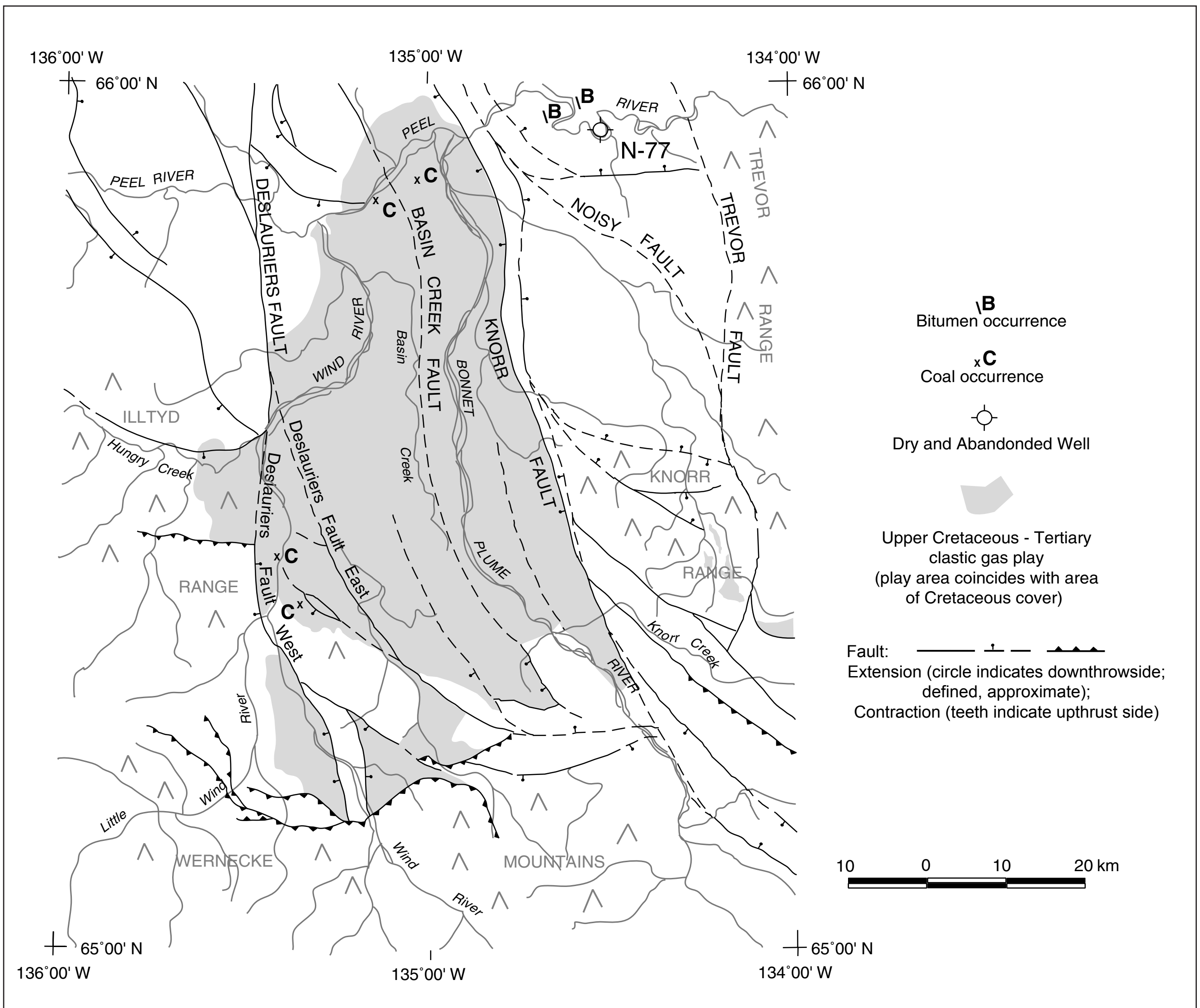
Play definition

This play includes all structures and prospects occurring in Upper Cretaceous to Eocene Bonnet Plume Formation clastics in the Bonnet Plume Basin (Figure 9). The play area coincides with the area of Cretaceous cover in the Bonnet Plume region.

Geology

The principal prospective target in this Mesozoic-Cenozoic succession is the conglomerate- and sandstone-rich lower member of the Bonnet Plume Formation. There are sandstone beds in the upper member of the Bonnet Plume Formation that have fair porosity but these rocks are widely exposed on surface and there is great potential for freshwater recharge. Generally, porosity and permeability is considered to be

Figure 9. *Upper Cretaceous-Tertiary clastic gas play (play area coincides with area of Cretaceous cover (stippled pattern)).*



poor quality in the Bonnet Plume Formation. However, thickness and porosity are highly variable throughout the area and reservoir-quality sandstones have been locally developed.

Regionally, Rock-Eval analyses indicate that Cretaceous source rocks, containing terrestrial-derived organic carbon, are generally immature, suggesting that generated hydrocarbons are minor and most likely consisting of 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 lower member of the Bonnet Plume Formation is commonly overlain and laterally adjacent to intraformational shales which provide adequate sealing integrity for migrating fluids.

Trap-types involving Cretaceous-Tertiary strata include Laramide-related anticlinal structures and block fault traps in fluvial and valley-fill deposits. Stratigraphic pinch-outs of porous strata within impermeable strata are expected to be common trapping configurations in the play. These traps are expected to be rather small.

The structural traps developed as a result of Laramide deformation which is post-Santonian in age. Source rocks in Bonnet Plume strata are most likely immature but there is sufficient organic matter available to generate biogenic gas. This dry gas may be trapped in these Laramide structures. Thermogenic gas may also accumulate in Mesozoic reservoirs as a result of vertical migration of hydrocarbons from subcropping potential Paleozoic rocks such as Canol and Road River shales. These source rocks have passed through the oil window during Paleozoic and Mesozoic time when oil was likely generated and have become overmature. Gas generation, however, may still be taking place.

An analogous exploration play involves the Upper Cretaceous and Tertiary fluvial strata occurring within the Kandik Tertiary/Upper Cretaceous non-marine oil and gas play in Kandik Basin straddling the Yukon/Alaska boundary to the west of the Bonnet Plume area (Hannigan e*t al*, 1999). The reservoirs in this basin consist of a heterogeneous mixture of conglomerate, sandstone, and mudstone with thin horizons of coal trapped in numerous stratigraphic pinch-out and small structural traps. The non-marine strata is thermally immature, while underlying Paleozoic source rocks are mature.

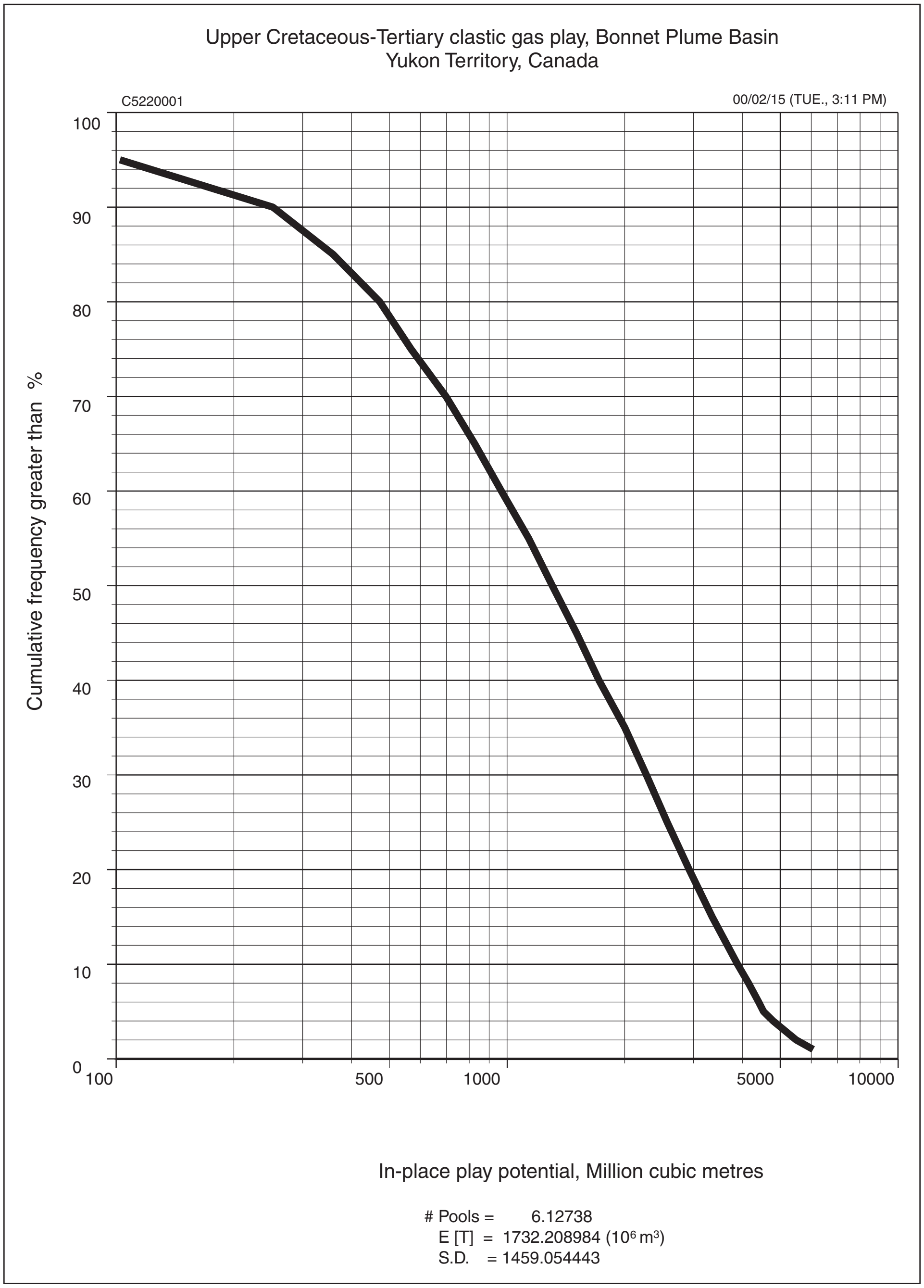
Exploration risks

Important risk factors integrated in the analysis of this exploration play are presence of reservoir facies and adequacy of seal (Appendix 1). The Bonnet Plume sandstones and conglomerates are often porous and poorly cemented so the existence of at least some reservoir (facies) in individual closures is considered to be certain; thus, the exploration risk factor for presence of reservoir is set at 1.0. Since intraformational shales in the Bonnet Plume Formation provide good top seal for certain prospects, but elsewhere reservoirs in other prospects are breached by erosion, it is necessary to apply some risk to adequacy of seal. The presence of a fair Mesozoic and good to excellent Paleozoic source rock in the succession suggests a low risk be assigned to adequacy of source.

Play potential

This play has an estimated median resource potential of 1.3 billion m^3 of in-place natural gas (Figure 20; Table 1). The range of estimates for the resource potential is 0.1 to 4.5 billion m^3 in-place. The expected number of gas fields in the play is 6 (mean value) with the largest field having a volume of 0.5 billion m^3 (Figure 21; Table 1). No fields were expected with volumes greater than 3 billion m^3 in this play (Appendix 2).

Figure 10. *Estimate of in-place gas potential of the Upper Cretaceous-Tertiary clastic gas play. Median value of probabilistic assessment is 1,305 million m*^{3} *of in-place gas distributed in 6 fields.*



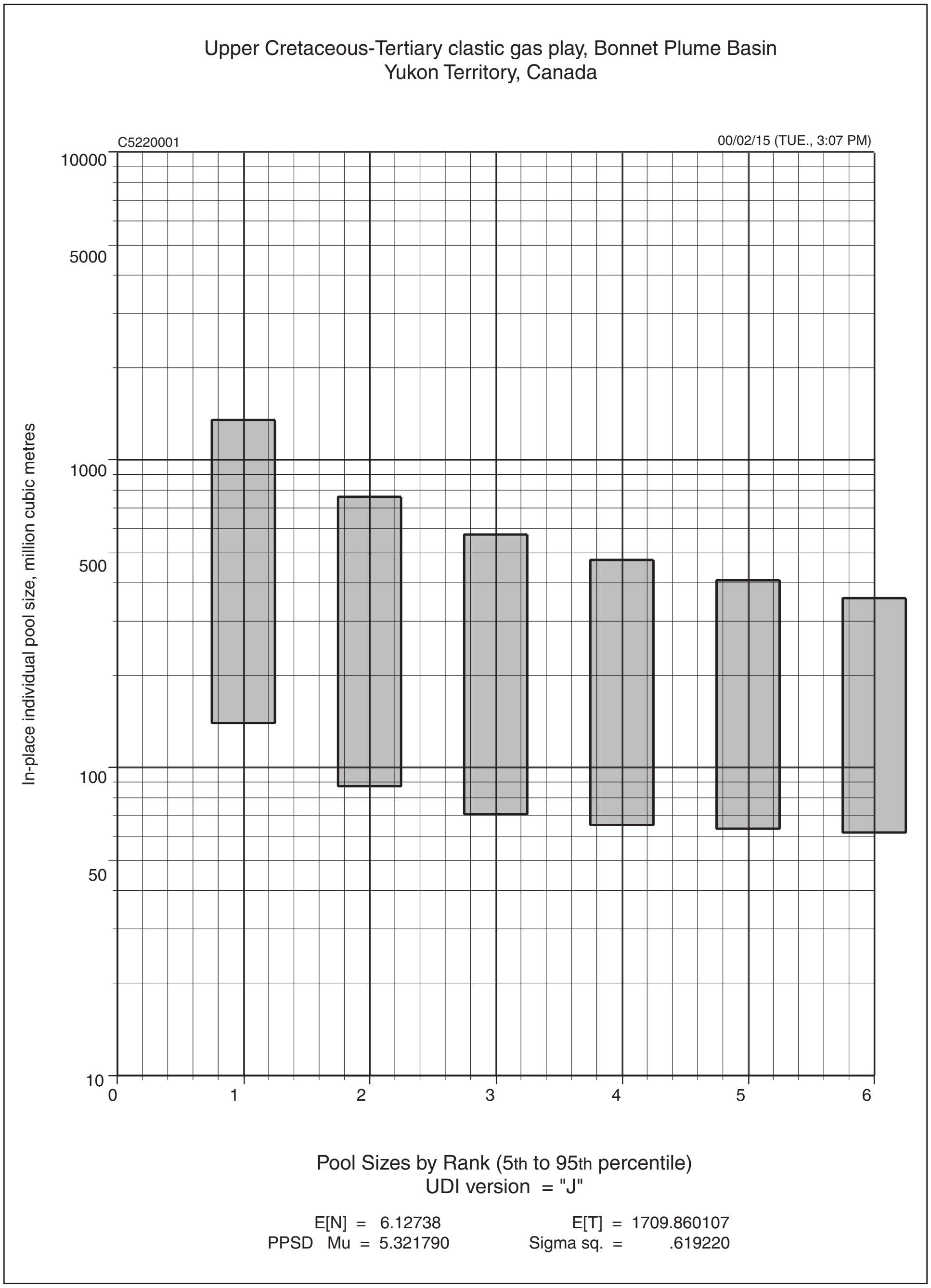


Figure 11. *Field-size-by-rank plot of the Upper Cretaceous-Tertiary clastic gas play. Median value of the largest predicted field size is 503 million m*^{3} *of in-place gas.*

UPPER CRETACEOUS CLASTIC SUBTHRUST GAS PLAY

CONCEPTUAL HYDROCARBON PLAY

Play definition

The subthrust play includes all Cretaceous gas prospects interpreted to occur beneath Proterozoic and Paleozoic thrust sheets in southern and western Bonnet Plume Basin along the northern fringe of the Wernecke Mountains (Figure 22; Norris and Hopkins, 1977; Norris, 1982).

Geology

Conglomerate and sandstone horizons within the lower member of the Bonnet Plume Formation are prospective targets in this play. There are no indications that Tertiary Bonnet Plume strata are present within the play area (Norris, 1982). The reservoir strata are present in subthrust areas beneath overriding thrust sheets consisting of

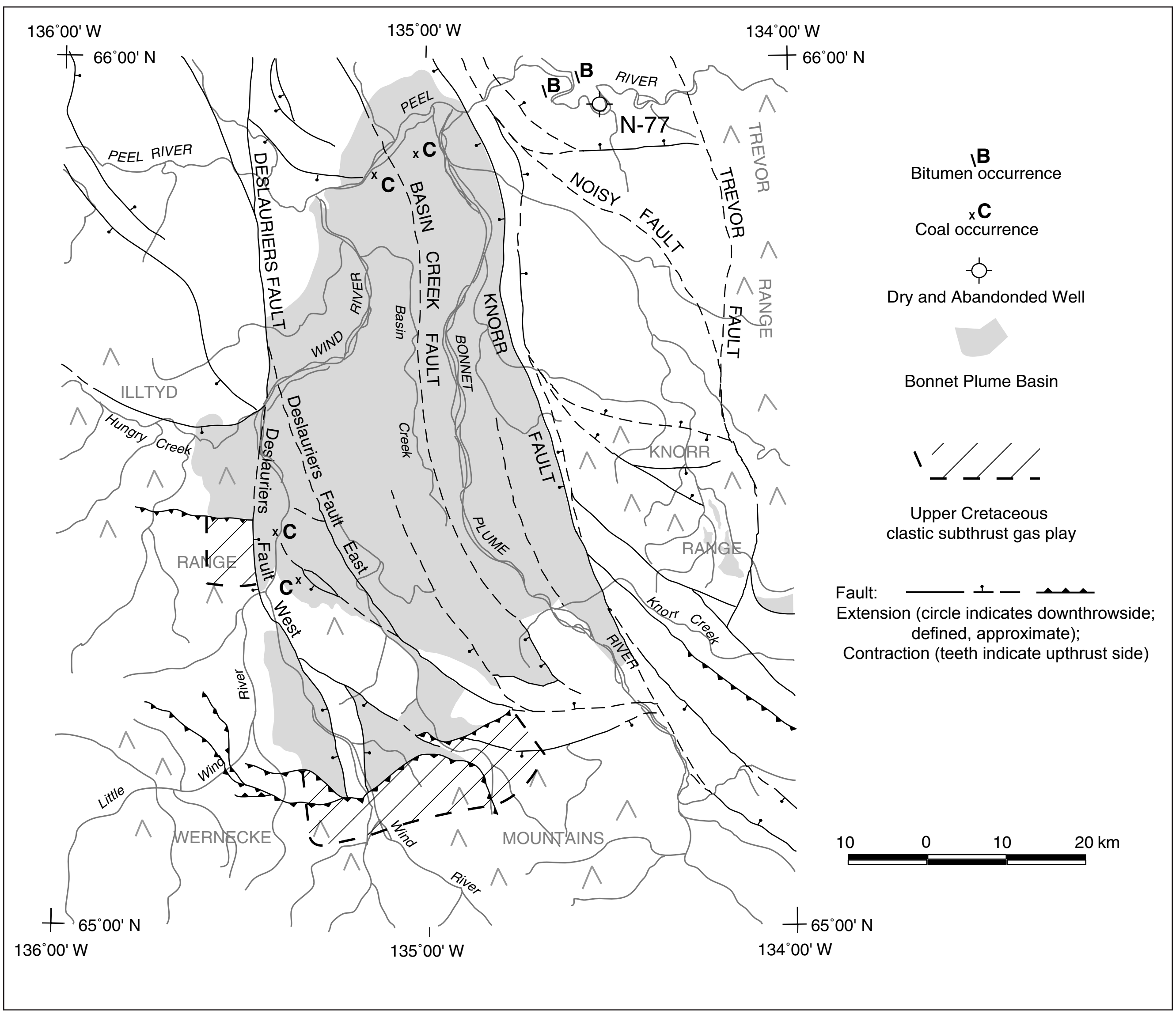


Figure 12. *Upper Cretaceous clastic subthrust gas play.*

older Paleozoic and Proterozoic rocks. Thrusting episodes in the Wernecke Mountains coincide with Laramide-related dextral strike-slip movements in the Richardson Fault Array and the development of curvilinear folds in the Bonnet Plume Basin in early Tertiary time. Traps associated with this compressional Laramide deformation are interpreted to occur in Cretaceous rocks beneath these overthrust sheets. Cretaceous source rocks are generally immature and any primary hydrocarbons produced from these rocks are minor and most likely gas. The tectonic burial of Cretaceous strata beneath overthrust sheets may produce secondary hydrocarbon generation from newly mature Cretaceous source material. Additionally, thermally-generated gas from Paleozoic source material may have migrated vertically into Cretaceous reservoirs beneath the overthrust sheets. The overthrust sheets and intraformational shales provide good vertical seal. In Paleozoic time, oil was generated from oil-prone Paleozoic rocks but these rocks are now overmature and gas is solely generated. Previous oil accumulations may be represented today by sporadic bitumen intrusions.

Again, the Kandik Tertiary/Upper Cretaceous non-marine structural play from the Kandik assessment was used as a play analogue in deriving reservoir parameter probability distributions (Appendix 1).

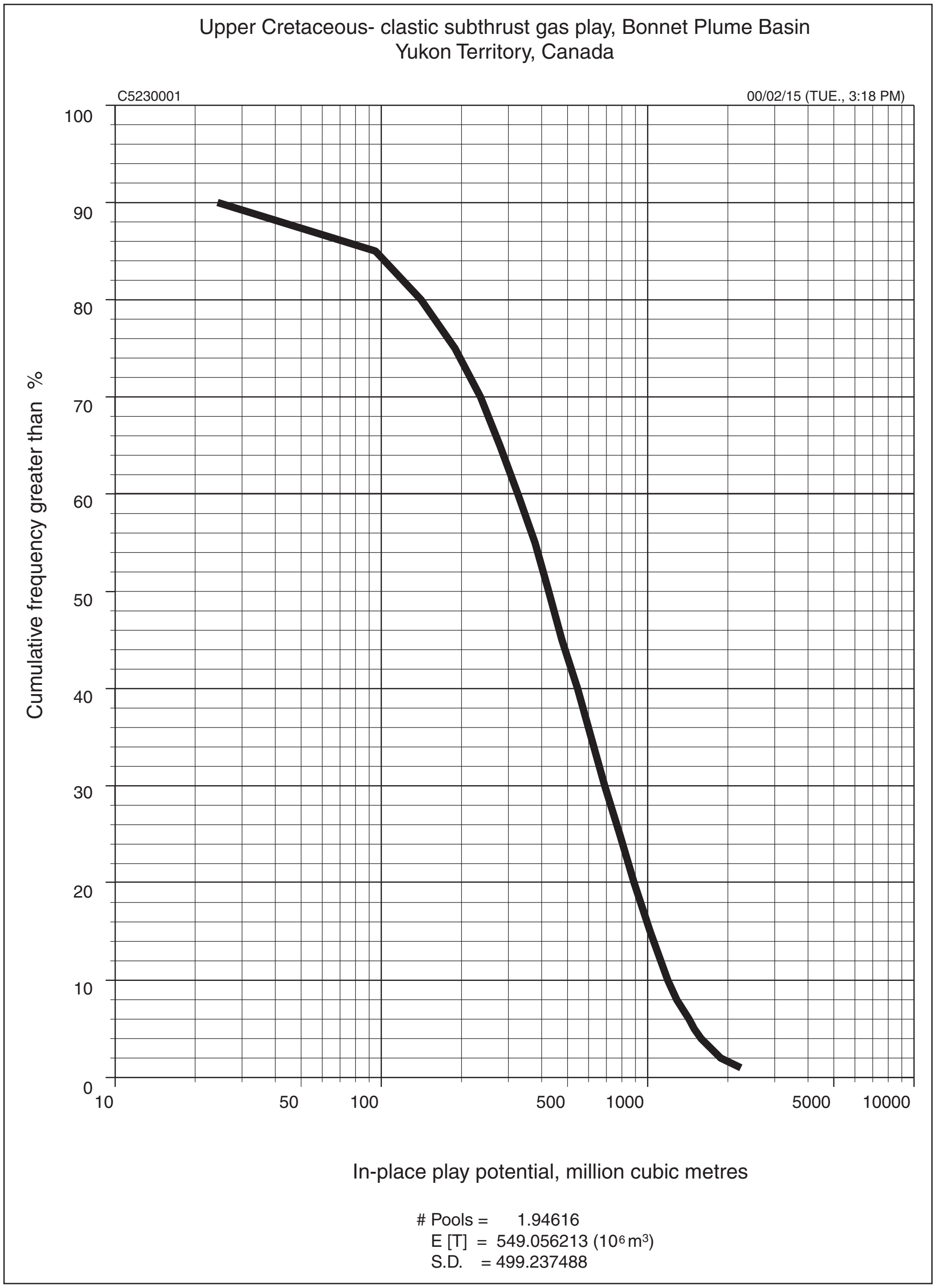
Exploration risks

Significant risk factors associated with the subthrust play are adequate timing and presence of reservoir facies. Similar to the previous play, Bonnet Plume conglomerates and sandstones are often porous or poorly cemented, so the existence of reservoir in individual closures is considered to be certain, thus the risk factor is 1.0. On the other hand, the primary hydrocarbon generation episode occurred well before the Early Tertiary thrusting event so a significant risk factor of 0.75 was assigned to adequate timing. Secondary generation of gas associated with tectonic burial by overriding thrust sheets may have occurred and this gas may be trapped in underlying Laramide-related structures.

Play potential

Estimates of potential for the Upper Cretaceous clastic subthrust play indicate a median in-place volume of 0.425 billion m^3 distributed in 2 fields (mean value) (Figures 13, 14; Table 1). The largest undiscovered gas field is predicted to contain 0.312 billion m^3 (median value) (Figure 14). No fields greater in size than 3 billion m^3 of in-place gas is predicted to occur in this play.

__Figure 13.__ Estimate of in-place gas potential of the Upper Cretaceous clastic subthrust gas play. Median value of probabilistic assessment is 425 million m³ of in-place gas distributed in 2 fields.



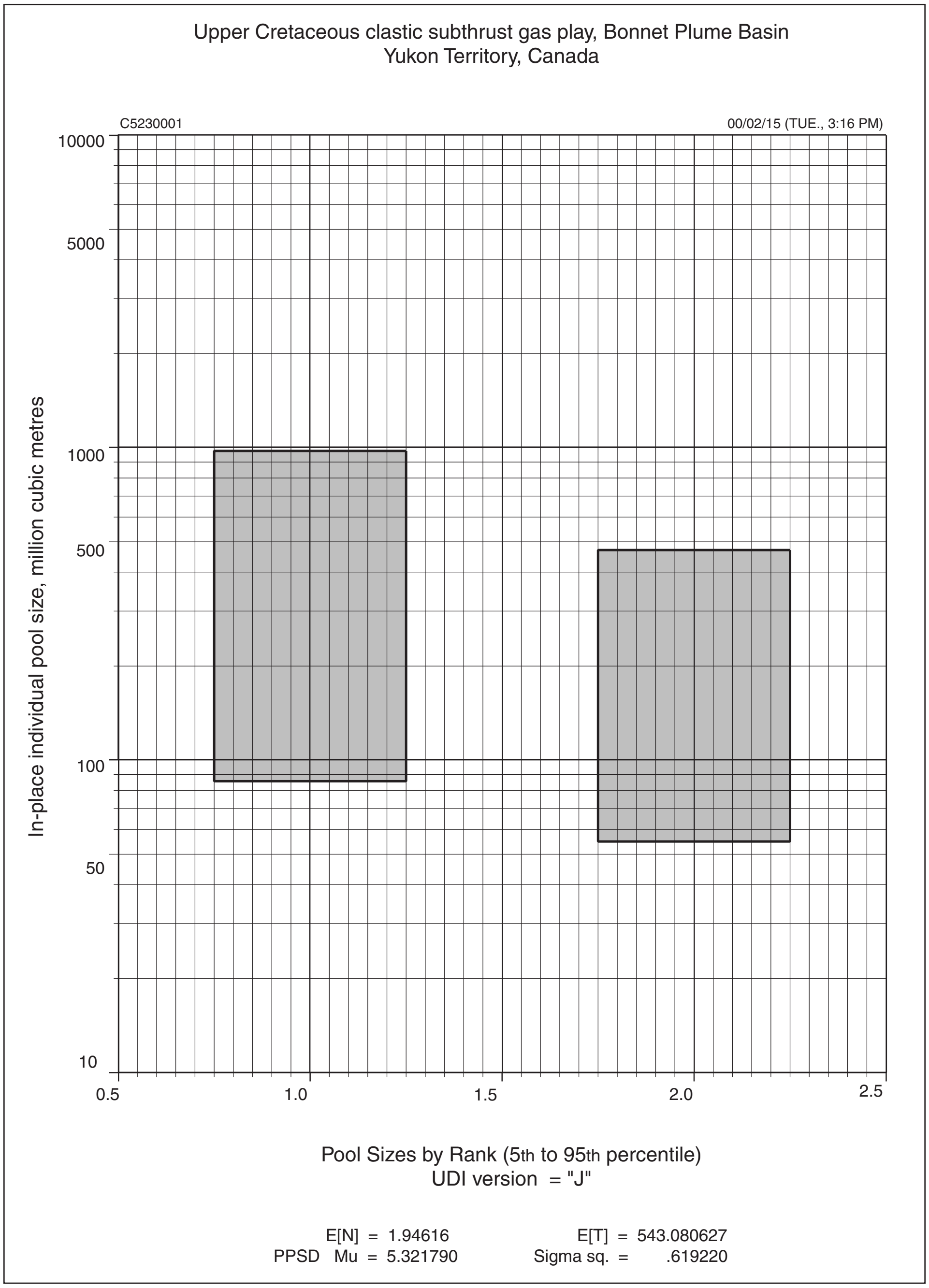


Figure 14. *Field-size-by-rank plot of the Upper Cretaceous clastic subthrust gas play. Median value of the largest predicted field size is 312 million m*^{3} *of in-place gas.*

SPECULATIVE HYDROCARBON PLAYS

There are three exploration plays that may be present in the Bonnet Plume Basin area but insufficient information is available to properly determine whether these plays actually exist.

Two of the plays are expected to occur in the Cambrian succession. It is possible hydrocarbons may have accumulated in Cambrian rocks such as Illtyd limestones and Slats Creek clastics deformed by Laramide-related tectonics into structural traps. These fault block and curvilinear fold structures may be present throughout the area beneath Cretaceous cover in the Bonnet Plume Basin as well as along the flanks of the basin in Paleozoic outcrop areas. Lack of reservoir quality strata and overmaturity are significant geological risk factors associated with these rocks. Secondary fracture porosity may have developed in this strata.

Numerous surveys have indicated significant coal seams occur in the Upper Cretaceous to Eocene terrestrial Bonnet Plume Formation (Norris and Hopkins, 1977; Long, 1978, 1987; Norris, 1982; Smith, 1989). Norris and Hopkins, 1977 estimate that more than 12 m of lignitic coal in 1.5 m thick seams are found within the upper member of the Bonnet Plume Formation. Long (1978, 1987) surmised that coal seams are present in the lower member as well – generally higher rank coals (lignite to high volatile C bituminous). He measured at least six seams, two of which average 7 m thick. Smith (1989) indicated that inferred coal resource for the basin is about 200 megatonnes. Thus, there is a significant volume of coal in the basin. Coal bed methane potential for the basin has previously been doubted because of the low rank of the coal. Recent studies, however, have indicated that coal bed methane may occur in low-rank coals; specifically coal bed methane was found within low-rank coals in the Powder River Basin of Wyoming. There have been no measurements of gas content of the Bonnet Plume coal seams, so there is insufficient information for predicting coal bed methane potential of the area.

DISCUSSION OF ASSESSMENT RESULTS

RESOURCE POTENTIAL

The median estimate of total hydrocarbon potential for the Bonnet Plume region (including all conceptual plays) is 25 billion m^3 (0.9 TCF) of in-place gas (Table 1; Figure 15). (Note that the total median estimate for the Bonnet Plume Basin is not arithmetically derived by summing the hydrocarbon potentials of individual plays. This number is derived using statistical techniques). High confidence (95% probability) and speculative (5% probability) estimates of total gas potential are 9 and 59 million m^3 (0.3 and 2.1 TCF), respectively (Figure 15). Individual field-size estimates in each play 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 greatest gas potential or volume occurs in the Lower Paleozoic carbonate/shale facies transition play (Table 1). The largest individual gas field is expected to occur in the same play, having a median-size estimate of 6.7 billion m^3 (236 BCF) of in-place gas.

The assessment results indicate the Lower Paleozoic carbonate/shale facies transition play is expected to contain about 67% of the basin's total gas resource volume and 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 volumes of hydrocarbons accumulating in pre-Laramide traps derived from the main episode of hydrocarbon generation. In contrast, gas resource distributions in younger Cretaceous/Tertiary clastic rocks, where small fields are predicted, indicate minor volumes of gas may occur as a result of less significant secondary hydrocarbon generation.

ASSESSMENT RESULTS AND EXPLORATION HISTORY

The exploration risks estimated in the assessment suggest success rates for exploratory drilling in the Bonnet Plume area should average about 1 in 2. This predicted success rate seems high, and this is most likely affected by the underestimation of the number

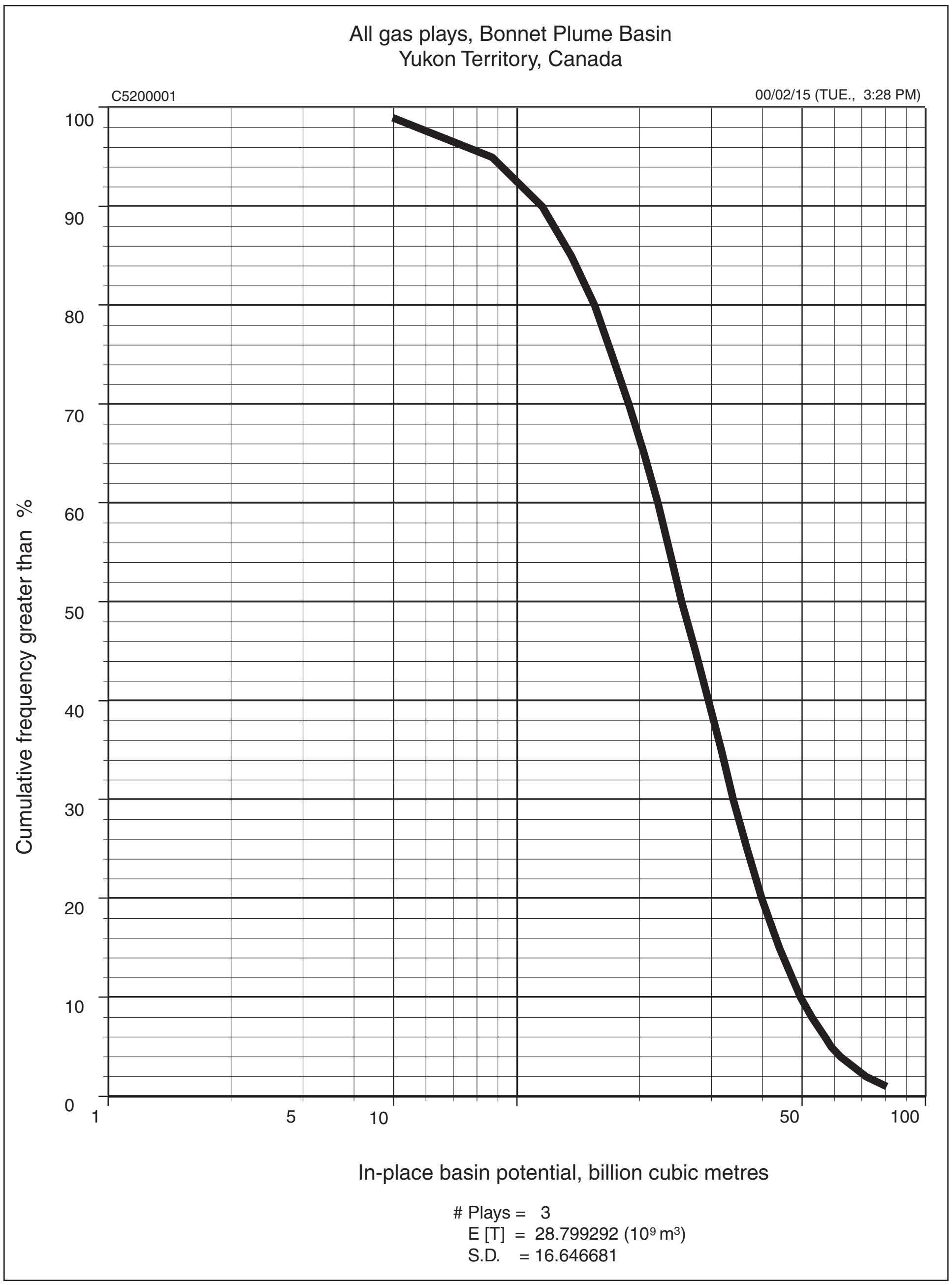


Figure 15. *Estimate of total gas potential for the Bonnet Plume Basin area. Median value of probabilistic assessment is 25,374 million m³ of in-place gas.*

of prospects in the basin. The absence of seismic data, along with the inherent difficulty in estimating numbers of prospects in association with stratigraphic traps, makes the presumption of the number of prospects quite arbitrary. The use of probability distributions from analogue plays with appropriate adjustments for differences in play area was the only method available for approximating the probability distribution of the number of prospects. By incorporating relevant future exploration data, greater confidence in hydrocarbon potential estimates is attainable.

CONCLUSIONS

The hydrocarbon resource potential of the Bonnet Plume Basin 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 3 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 the ground', not the volumes that are economically producible. Individual field-size determinations are important in identifying which plays are attractive for future exploration programs.

The median estimate for total gas potential for all Bonnet Plume plays is 25 billion m^3 of in-place gas (Figure 15; Table 1). Two fields with median sizes greater than 3 billion m^3 of in-place gas are expected in one play: the Lower Paleozoic exploration play.

The potential for significant hydrocarbon accumulations in the Bonnet Plume assessment region is achieved with 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 succession. However, significant risks associated with lack of porosity development in Paleozoic strata, freshwater flushing of Mesozoic and Tertiary reservoirs, and thermal maturity considerations reduces overall hydrocarbon potential. Thermal maturity studies indicate that insignificant oil potential is expected in the area. Significant gas potential is predicted for Lower Paleozoic carbonate margins in carbonate/shale transition zones in the Illtyd Range west of the Bonnet Plume Basin. The complex geology and anticipated high exploration risks associated with all exploration plays suggest that considerable seismic survey work and exploration drilling are required to properly evaluate the region's hydrocarbon potential.

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APPENDIX 1

INPUT DATA FOR BONNET PLUME 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. 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	10	15	33

2. UPPER CRETACEOUS-TERTIARY CLASTIC GAS PLAY

Table 1.2a: 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	0.5	7	21	40
Reservoir thickness	m	1	6	10	20
Porosity	decimal fraction	0.05	0.12	0.22	0.25
Trap fill	decimal fraction	0.05	0.25	0.9	1
Gas saturation	decimal fraction	0.5	0.65	0.75	0.8
Formation volume factor	decimal fraction	0.002	0.004	0.009	0.01

Table 1.2b. Marginal probabilities of geological risk factors

Geological factors	Marginal probability	Play level	Prospect level
Presence of closure	0.8		x
Presence of reservoir facies	1.00		x
Adequate seal	0.7		x
Adequate timing	0.75		x
Adequate source	0.9		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	3	10	40

3. UPPER CRETACEOUS CLASTIC SUBTHRUST 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	0.5	7	21	40
Reservoir thickness	m	1	6	10	20
Porosity	decimal fraction	0.05	0.12	0.22	0.25
Trap fill	decimal fraction	0.05	0.25	0.9	1
Gas saturation	decimal fraction	0.5	0.65	0.75	0.8
Formation volume factor	decimal fraction	0.002	0.004	0.009	0.01

Table 1.3b. Marginal probabilities of geological risk factors

Geological factors	Marginal probability	Play level	Prospect level
Presence of closure	0.8		x
Presence of reservoir facies	1		x
Adequate seal	0.85		x
Adequate timing	0.75		x
Adequate preservation	0.9		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	3	7

APPENDIX 2

OUTPUT FOR BONNET PLUME 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). A PSUM module for total gas potential on a basin-scale is also presented.

PETRIMES MODULE MPRO

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

UAI        C5210001
PLAY       Lower Paleozoic carbonate/shale facies transition gas play
Assessor   Peter Hannigan
Geologist  Peter Hannigan
Remarks    Yukon Hydrocarbon Assessment Project
Run date   TUE, JAN 25, 2000,  4:06 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 Closure          ( 1)       .85
                  Presence of Reservoir Facies ( 2)       .60
                  Adequate Seal                ( 4)       .70
                  Adequate Timing              ( 5)       .90
                  ---------------------------------------------------
                  Overall Prospect Level Risk    =        .32

   EXPLORATION RISK:                             =        .32


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

   Minimum       =    10                  Minimum       =     0
   Maximum       =    33                  Maximum       =    22
   Mean          =   18.72                Mean          =    6.01
   S.D.          =    6.92                S.D.          =    3.01

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

     99.00          10                      99.59          0      Note: The no. of pools
       95           11                        99           1      distribution is saved in the
       90           11                        95           2      database with UDI= 6201GB4
       80           12                        90           3
       75           13                        80           3
       60           14                        75           4
       50           15                        60           5
       40           19                        50           6
       25           24                        40           6
       20           26                        25           8
       10           30                        20           9
        5           32                        10          10
        1           33                         5          12
        0           33                         1          14
                                               0          22
```

PETRIMES MODULE PSRK

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

UAI        C5210001
PLAY       Lower Paleozoic carbonate/shale facies transition gas play
Assessor   Peter Hannigan
Geologist  Peter Hannigan
Remarks    Yukon Hydrocarbon Assessment Project
Run date   TUE, JAN 25, 2000,  4:07 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    12
   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     =  22
   Expectation       =   6.01
   Standard Deviation=   3.01

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

   Pool Rank                      Distribution

        1     MEAN   = 8761.2     S.D.   = 7898.7     P(N>=r)= .99594
              99%    = 921.42     75%    = 4101.3     10%    = 16909.
              95%    = 1864.1     50%    = 6673.3      5%    = 22386.
              90%    = 2554.8     25%    = 10795.      1%    = 38950.

        2     MEAN   = 4313.9     S.D.   = 3036.9     P(N>=r)= .97211
              99%    = 435.97     75%    = 2241.2     10%    = 8032.4
              95%    = 942.20     50%    = 3631.0      5%    = 9961.5
              90%    = 1343.7     25%    = 5576.9      1%    = 14951.
```

```
  3     MEAN   = 2840.6     S.D.   = 1920.3     P(N>=r)= .90619
        99%    = 280.95     75%    = 1464.9     10%    = 5304.8
        95%    = 588.81     50%    = 2436.4      5%    = 6459.3
        90%    = 849.45     25%    = 3749.8      1%    = 9247.4

  4     MEAN   = 2111.9     S.D.   = 1411.1     P(N>=r)= .79099
        99%    = 216.85     75%    = 1076.6     10%    = 3962.9
        95%    = 435.36     50%    = 1818.0      5%    = 4788.2
        90%    = 621.70     25%    = 2816.5      1%    = 6705.5

  5     MEAN   = 1694.7     S.D.   = 1112.9     P(N>=r)= .64596
        99%    = 185.24     75%    = 869.09     10%    = 3171.3
        95%    = 360.41     50%    = 1464.9      5%    = 3811.4
        90%    = 507.78     25%    = 2266.2      1%    = 5264.1

  6     MEAN   = 1426.6     S.D.   = 913.13     P(N>=r)= .50181
        99%    = 167.43     75%    = 746.90     10%    = 2644.6
        95%    = 318.76     50%    = 1242.2      5%    = 3163.4
        90%    = 443.85     25%    = 1903.8      1%    = 4324.3

  7     MEAN   = 1231.6     S.D.   = 767.00     P(N>=r)= .37850
        99%    = 155.16     75%    = 661.06     10%    = 2256.9
        95%    = 290.39     50%    = 1080.3      5%    = 2689.3
        90%    = 400.10     25%    = 1636.4      1%    = 3648.5

  8     MEAN   = 1075.1     S.D.   = 654.53     P(N>=r)= .27969
        99%    = 144.38     75%    = 589.28     10%    = 1950.9
        95%    = 265.98     50%    = 947.79      5%    = 2318.7
        90%    = 362.86     25%    = 1421.9      1%    = 3130.3

  9     MEAN   = 944.92     S.D.   = 565.67     P(N>=r)= .20108
        99%    = 134.03     75%    = 525.98     10%    = 1702.2
        95%    = 243.17     50%    = 835.41      5%    = 2020.1
        90%    = 328.73     25%    = 1244.6      1%    = 2719.2

 10     MEAN   = 837.12     S.D.   = 494.44     P(N>=r)= .13851
        99%    = 124.50     75%    = 471.72     10%    = 1499.1
        95%    = 222.71     50%    = 741.50      5%    = 1777.4
        90%    = 298.63     25%    = 1098.7      1%    = 2388.1

 11     MEAN   = 748.90     S.D.   = 436.76     P(N>=r)= .90048E-01
        99%    = 116.21     75%    = 426.79     10%    = 1333.6
        95%    = 205.28     50%    = 664.62      5%    = 1579.8
        90%    = 273.27     25%    = 979.68      1%    = 2119.3

 12     MEAN   = 677.01     S.D.   = 389.69     P(N>=r)= .54635E-01
        99%    = 109.21     75%    = 390.16     10%    = 1198.5
        95%    = 190.78     50%    = 602.21      5%    = 1418.2
        90%    = 252.37     25%    = 882.83      1%    = 1899.3
```

E) The mean of the potential = 20152.

PETRIMES MODULE PSUM

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

UAI        C5210001
PLAY       Lower Paleozoic carbonate/shale facies transition gas play
Assessor   Peter Hannigan
Geologist  Peter Hannigan
Remarks    Yukon Hydrocarbon Assessment Project
Run date   TUE, JAN 25, 2000,  4:08 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     =   22
   Expectation       =      6.01474
   Standard Deviation=      3.00511
```

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

   Play Resource:    (  B cu m    )
   ------------------------------
     Minimum     = .0000000E+00  Maximum           = 148.1077
     Expectation = 20.38312      Standard Deviation= 14.84371

   EMPERICAL DISTRIBUTION:
   ----------------------
     Greater than    Play
     Percentage      Potential
     ------------    -----------
        100.00          .00000E+00
         99.00          .90951
         95.00          3.1865
         90.00          5.1528
         85.00          6.7625
         80.00          8.2517
         75.00          9.7548
         70.00          11.097
         65.00          12.582
         60.00          13.969
         55.00          15.415
         50.00          17.027
         45.00          18.675
         40.00          20.551
         35.00          22.369
         30.00          24.828
         25.00          27.199
         20.00          30.253
         15.00          34.395
         10.00          40.141
          8.00          42.993
          6.00          46.457
          5.00          49.432
          4.00          52.350
          2.00          59.118
          1.00          67.725
           .01          132.73
           .00          146.57
```

PETRIMES MODULE MPRO

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

UAI        C5220001
PLAY       Upper Cretaceous-Tertiary clastic gas play
Assessor   Peter Hannigan
Geologist  Peter Hannigan
Remarks    Yukon Hydrocarbon Assessment Project
Run date   TUE, JAN 25, 2000,  3:18 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 Closure          ( 1)       .80
                  Adequate Seal                ( 4)       .70
                  Adequate Timing              ( 5)       .75
                  Adequate Source              ( 6)       .90
                  ----------------------------------------------------
                  Overall Prospect Level Risk    =        .38

   EXPLORATION RISK:                             =        .38


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

   Minimum       =     3                 Minimum       =     0
   Maximum       =    40                 Maximum       =    28
   Mean          =   16.21               Mean          =    6.13
   S.D.          =   11.22               S.D.          =    4.67

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

     99.00          3                      97.06          0     Note: The no. of pools
       95           4                        95           1     distribution is saved in the
       90           5                        90           1     database with UDI= 6201GB4
       80           6                        80           2
       75           7                        75           2
       60           9                        60           4
       50          10                        50           5
       40          16                        40           6
       25          25                        25           9
       20          28                        20          11
       10          34                        10          13
        5          37                         5          15
        1          40                         1          18
        0          40                         0          28
```

PETRIMES MODULE PSRK

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

UAI        C5220001
PLAY       Upper Cretaceous-Tertiary clastic gas play
Assessor   Peter Hannigan
Geologist  Peter Hannigan
Remarks    Yukon Hydrocarbon Assessment Project
Run date   THU, JAN 27, 2000,  4:18 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    15
   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     = 5.3218     MEAN   = 279.05
   Statistics   sig. sq= .61922     S.D.   = 258.40

   Upper        99.99% = 10.971     60.00% = 167.74     15.00% = 462.83
   Percentiles  99.00% = 32.824     55.00% = 185.47     10.00% = 561.30
                95.00% = 56.117     50.00% = 204.75      8.00% = 618.59
                90.00% = 74.689     45.00% = 226.03      6.00% = 695.93
                85.00% = 90.578     40.00% = 249.92      5.00% = 747.05
                80.00% = 105.58     35.00% = 277.27      4.00% = 811.93
                75.00% = 120.43     30.00% = 309.34      2.00% = 1030.6
                70.00% = 135.52     25.00% = 348.12      1.00% = 1277.2
                65.00% = 151.20     20.00% = 397.05       .01% = 3821.1

C) No. of Pools Distribution
   -------------------------
   Lower Support     =   0
   Upper Support     =  28
   Expectation       =   6.13
   Standard Deviation=   4.67

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

   Pool Rank                       Distribution

        1     MEAN   = 594.56     S.D.   = 417.48     P(N>=r)= .97064
              99%    = 71.454     75%    = 316.93     10%    = 1085.2
              95%    = 140.04     50%    = 503.42      5%    = 1353.0
              90%    = 194.17     25%    = 757.44      1%    = 2084.3

        2     MEAN   = 361.61     S.D.   = 216.91     P(N>=r)= .87700
              99%    = 47.084     75%    = 200.26     10%    = 643.01
              95%    = 87.281     50%    = 325.77      5%    = 761.12
              90%    = 120.46     25%    = 478.13      1%    = 1040.9
```

```
 3     MEAN   = 283.11     S.D.   = 159.67     P(N>=r)= .73911
       99%    = 39.608     75%    = 160.19     10%    = 494.77
       95%    = 70.844     50%    = 261.43      5%    = 574.13
       90%    = 96.617     25%    = 377.75      1%    = 750.90

 4     MEAN   = 243.82     S.D.   = 128.43     P(N>=r)= .60663
       99%    = 37.028     75%    = 145.05     10%    = 414.22
       95%    = 65.278     50%    = 230.01      5%    = 474.68
       90%    = 88.460     25%    = 323.00      1%    = 605.36

 5     MEAN   = 217.22     S.D.   = 106.85     P(N>=r)= .50515
       99%    = 36.264     75%    = 136.56     10%    = 358.60
       95%    = 63.507     50%    = 207.47      5%    = 407.63
       90%    = 85.491     25%    = 283.87      1%    = 511.76

 6     MEAN   = 194.67     S.D.   = 91.037     P(N>=r)= .43282
       99%    = 35.619     75%    = 126.90     10%    = 315.14
       95%    = 61.727     50%    = 186.71      5%    = 356.54
       90%    = 82.103     25%    = 251.59      1%    = 443.44

 7     MEAN   = 174.30     S.D.   = 79.275     P(N>=r)= .37822
       99%    = 34.167     75%    = 115.53     10%    = 279.47
       95%    = 58.294     50%    = 167.24      5%    = 315.46
       90%    = 76.554     25%    = 223.93      1%    = 390.26

 8     MEAN   = 156.33     S.D.   = 70.195     P(N>=r)= .33141
       99%    = 32.128     75%    = 104.27     10%    = 249.75
       95%    = 53.929     50%    = 149.82      5%    = 281.66
       90%    = 70.109     25%    = 200.28      1%    = 347.49

 9     MEAN   = 140.87     S.D.   = 62.849     P(N>=r)= .28722
       99%    = 30.031     75%    = 94.197     10%    = 224.77
       95%    = 49.651     50%    = 134.76      5%    = 253.47
       90%    = 64.013     25%    = 180.17      1%    = 312.33

10     MEAN   = 127.67     S.D.   = 56.713     P(N>=r)= .24411
       99%    = 28.104     75%    = 85.505     10%    = 203.58
       95%    = 45.825     50%    = 121.87      5%    = 229.65
       90%    = 58.647     25%    = 163.02      1%    = 282.89

11     MEAN   = 116.35     S.D.   = 51.489     P(N>=r)= .20225
       99%    = 26.381     75%    = 78.057     10%    = 185.43
       95%    = 42.479     50%    = 110.83      5%    = 209.28
       90%    = 54.002     25%    = 148.30      1%    = 257.88

12     MEAN   = 106.61     S.D.   = 46.990     P(N>=r)= .16243
       99%    = 24.855     75%    = 71.681     10%    = 169.77
       95%    = 39.567     50%    = 101.37      5%    = 191.72
       90%    = 49.995     25%    = 135.63      1%    = 236.39

13     MEAN   = 98.227     S.D.   = 43.084     P(N>=r)= .12572
       99%    = 23.511     75%    = 66.230     10%    = 156.20
       95%    = 37.044     50%    = 93.251      5%    = 176.50
       90%    = 46.548     25%    = 124.69      1%    = 217.78

14     MEAN   = 91.001     S.D.   = 39.678     P(N>=r)= .93212E-01
       99%    = 22.334     75%    = 61.575     10%    = 144.43
       95%    = 34.866     50%    = 86.295      5%    = 163.27
       90%    = 43.591     25%    = 115.25      1%    = 201.58

15     MEAN   = 84.772     S.D.   = 36.698     P(N>=r)= .65819E-01
       99%    = 21.307     75%    = 57.604     10%    = 134.19
       95%    = 32.990     50%    = 80.338      5%    = 151.73
       90%    = 41.056     25%    = 107.09      1%    = 187.43

E) The mean of the potential =  1702.0
```

PETRIMES MODULE PSUM

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

UAI        C5220001
PLAY       Upper Cretaceous-Tertiary clastic gas play
Assessor   Peter Hannigan
Geologist  Peter Hannigan
Remarks    Yukon Hydrocarbon Assessment Project
Run date   THU, JAN 27, 2000,  4:20 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     = 5.3218     MEAN   = 279.05
   Statistics   sig. sq= .61922     S.D.   = 258.40

   Upper        99.99% = 10.971     60.00% = 167.74     15.00% = 462.83
   Percentiles  99.00% = 32.824     55.00% = 185.47     10.00% = 561.30
                95.00% = 56.117     50.00% = 204.75      8.00% = 618.59
                90.00% = 74.689     45.00% = 226.03      6.00% = 695.93
                85.00% = 90.578     40.00% = 249.92      5.00% = 747.05
                80.00% = 105.58     35.00% = 277.27      4.00% = 811.93
                75.00% = 120.43     30.00% = 309.34      2.00% = 1030.6
                70.00% = 135.52     25.00% = 348.12      1.00% = 1277.2
                65.00% = 151.20     20.00% = 397.05       .01% = 3821.1

C) NO. OF POOLS DISTRIBUTION
   ------------------------------
   Lower Support     =    0
   Upper Support     =   28
   Expectation       =      6.12738
   Standard Deviation=      4.66876
```

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

   Play Resource:    (    M cu m  )
   ------------------------------
     Minimum     = .0000000E+00  Maximum           = 8708.855
     Expectation = 1732.209      Standard Deviation= 1459.054

   EMPERICAL DISTRIBUTION:
   ----------------------
     Greater than    Play
     Percentage      Potential
     ------------    -----------
        100.00         .00000E+00
         95.00         102.21
         90.00         251.69
         85.00         359.09
         80.00         472.58
         75.00         568.24
         70.00         697.81
         65.00         826.59
         60.00         966.94
         55.00         1135.5
         50.00         1305.2
         45.00         1505.4
         40.00         1718.0
         35.00         2001.3
         30.00         2271.7
         25.00         2568.0
         20.00         2923.1
         15.00         3348.3
         10.00         3886.0
          8.00         4146.6
          6.00         4403.3
          5.00         4528.5
          4.00         4793.7
          2.00         5490.6
          1.00         6068.4
           .01         8698.6
           .00         8707.8
```

PETRIMES MODULE MPRO

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

UAI        C5230001
PLAY       Upper Cretaceous clastic subthrust gas play
Assessor   Peter Hannigan
Geologist  Peter Hannigan
Remarks    Yukon Hydrocarbon Assessment Project
Run date   TUE, JAN 25, 2000,  3:42 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 Closure          ( 1)       .80
                  Adequate Seal                ( 4)       .85
                  Adequate Timing              ( 5)       .75
                  Adequate Source              ( 6)       .90
                  ----------------------------------------------------
                  Overall Prospect Level Risk    =        .46

   EXPLORATION RISK:                             =        .46


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

   Minimum       =     2                  Minimum       =     0
   Maximum       =     7                  Maximum       =     7
   Mean          =    4.24                Mean          =    1.95
   S.D.          =    1.49                S.D.          =    1.23

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

     99.00          2                       89.82          0        Note: The no. of pools
       95           3                         80           1        distribution is saved in the
       90           3                         75           1        database with UDI= 6201GB4
       80           3                         60           2
       75           3                         50           2
       60           3                         40           2
       50           3                         25           3
       40           4                         20           3
       25           5                         10           4
       20           6                          5           4
       10           7                          1           5
        5           7                          0           7
        1           7
        0           7
```

PETRIMES MODULE PSRK

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

UAI        C5230001
PLAY       Upper Cretaceous clastic subthrust gas play
Assessor   Peter Hannigan
Geologist  Peter Hannigan
Remarks    Yukon Hydrocarbon Assessment Project
Run date   THU, JAN 27, 2000,  4:12 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     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     = 5.3218     MEAN   = 279.05
   Statistics   sig. sq= .61922     S.D.   = 258.40

   Upper        99.99% = 10.971     60.00% = 167.74     15.00% = 462.83
   Percentiles  99.00% = 32.824     55.00% = 185.47     10.00% = 561.30
                95.00% = 56.117     50.00% = 204.75      8.00% = 618.59
                90.00% = 74.689     45.00% = 226.03      6.00% = 695.93
                85.00% = 90.578     40.00% = 249.92      5.00% = 747.05
                80.00% = 105.58     35.00% = 277.27      4.00% = 811.93
                75.00% = 120.43     30.00% = 309.34      2.00% = 1030.6
                70.00% = 135.52     25.00% = 348.12      1.00% = 1277.2
                65.00% = 151.20     20.00% = 397.05       .01% = 3821.1

C) No. of Pools Distribution
   -------------------------
   Lower Support     =   0
   Upper Support     =   7
   Expectation       =   1.95
   Standard Deviation=   1.23
```

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

   Pool Rank                      Distribution

        1     MEAN   = 394.88     S.D.   = 319.34     P(N>=r)= .89816
              99%    = 46.625     75%    = 190.46     10%    = 758.14
              95%    = 85.616     50%    = 312.36      5%    = 976.66
              90%    = 117.01     25%    = 499.06      1%    = 1586.6

        2     MEAN   = 209.14     S.D.   = 138.15     P(N>=r)= .60877
              99%    = 32.399     75%    = 112.47     10%    = 383.39
              95%    = 54.901     50%    = 177.34      5%    = 470.50
              90%    = 72.292     25%    = 269.36      1%    = 686.17

        3     MEAN   = 150.90     S.D.   = 90.269     P(N>=r)= .29170
              99%    = 27.414     75%    = 86.436     10%    = 267.84
              95%    = 44.741     50%    = 131.59      5%    = 322.41
              90%    = 57.617     25%    = 193.74      1%    = 451.26

        4     MEAN   = 121.73     S.D.   = 67.567     P(N>=r)= .10826
              99%    = 24.679     75%    = 73.147     10%    = 210.15
              95%    = 39.383     50%    = 108.26      5%    = 249.77
              90%    = 50.012     25%    = 155.33      1%    = 341.07

E) The mean of the potential =  539.18
```

PETRIMES MODULE PSUM

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

UAI        C5230001
PLAY       Upper Cretaceous clastic subthrust gas play
Assessor   Peter Hannigan
Geologist  Peter Hannigan
Remarks    Yukon Hydrocarbon Assessment Project
Run date   THU, JAN 27, 2000,  4:13 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     = 5.3218     MEAN   = 279.05
   Statistics   sig. sq= .61922     S.D.   = 258.40

   Upper        99.99% = 10.971     60.00% = 167.74     15.00% = 462.83
   Percentiles  99.00% = 32.824     55.00% = 185.47     10.00% = 561.30
                95.00% = 56.117     50.00% = 204.75      8.00% = 618.59
                90.00% = 74.689     45.00% = 226.03      6.00% = 695.93
                85.00% = 90.578     40.00% = 249.92      5.00% = 747.05
                80.00% = 105.58     35.00% = 277.27      4.00% = 811.93
                75.00% = 120.43     30.00% = 309.34      2.00% = 1030.6
                70.00% = 135.52     25.00% = 348.12      1.00% = 1277.2
                65.00% = 151.20     20.00% = 397.05       .01% = 3821.1

C) NO. OF POOLS DISTRIBUTION
   ------------------------------
   Lower Support     =    0
   Upper Support     =    7
   Expectation       =      1.94616
   Standard Deviation=      1.23332
```

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

   Play Resource:    (    M cu m  )
   ------------------------------
     Minimum     = .0000000E+00  Maximum           = 5491.401
     Expectation = 549.0562      Standard Deviation= 499.2375

   EMPERICAL DISTRIBUTION:
   ----------------------
     Greater than    Play
     Percentage      Potential
     ------------    -----------
        100.00          .00000E+00
         90.00          24.272
         85.00          95.069
         80.00          140.99
         75.00          189.00
         70.00          235.67
         65.00          278.78
         60.00          325.79
         55.00          377.67
         50.00          425.00
         45.00          476.56
         40.00          545.55
         35.00          613.20
         30.00          689.65
         25.00          786.13
         20.00          889.83
         15.00          1022.5
         10.00          1190.1
          8.00          1285.6
          6.00          1431.1
          5.00          1495.8
          4.00          1587.3
          2.00          1880.6
          1.00          2237.9
           .01          4969.6
           .00          5439.2
```

PETRIMES MODULE PSUM

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

UAI        C5200001
PLAY       All gas plays
Assessor   Peter Hannigan
Geologist  Peter Hannigan
Remarks    Yukon Hydrocarbon Assessment Project
Run date   THU, JAN 27, 2000,  4:24 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 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   = 20.383     S.D.   = 14.844
   Statistics   B cu m

   Upper       100.00% = .00000E+00 55.00% = 15.415      8.00% = 42.993
   Percentiles  99.00% = .90951     50.00% = 17.027      6.00% = 46.457
                95.00% = 3.1865     45.00% = 18.675      5.00% = 49.432
                90.00% = 5.1528     40.00% = 20.551      4.00% = 52.350
                85.00% = 6.7625     35.00% = 22.369      2.00% = 59.118
                80.00% = 8.2517     30.00% = 24.828      1.00% = 67.725
                75.00% = 9.7548     25.00% = 27.199       .01% = 132.73
                70.00% = 11.097     20.00% = 30.253       .00% = 146.57
                65.00% = 12.582     15.00% = 34.395
                60.00% = 13.969     10.00% = 40.141

   Summary      MEAN   = 6.4232     S.D.   = 5.2488
   Statistics   B cu m

   Upper       100.00% = .00000E+00 55.00% = 4.2243     10.00% = 14.353
   Percentiles  95.00% = .44817     50.00% = 4.9094      8.00% = 15.103
                90.00% = 1.0253     45.00% = 5.6253      6.00% = 16.118
                85.00% = 1.4384     40.00% = 6.4374      5.00% = 16.556
                80.00% = 1.8427     35.00% = 7.3868      4.00% = 17.202
                75.00% = 2.2130     30.00% = 8.5499      2.00% = 19.619
                70.00% = 2.6847     25.00% = 9.5963      1.00% = 21.549
                65.00% = 3.1742     20.00% = 10.882       .01% = 29.118
                60.00% = 3.6670     15.00% = 12.474       .00% = 29.523
```

```
   Summary      MEAN   = 1.5325     S.D.   = 1.2863
   Statistics   B cu m

   Upper       100.00% = .00000E+00 50.00% = 1.2451      8.00% = 3.4908
   Percentiles  90.00% = .95295E-01 45.00% = 1.3941      6.00% = 3.7969
                85.00% = .31501     40.00% = 1.5794      5.00% = 3.9794
                80.00% = .44822     35.00% = 1.7538      4.00% = 4.1873
                75.00% = .58191     30.00% = 1.9604      2.00% = 4.9974
                70.00% = .71175     25.00% = 2.2041      1.00% = 5.6047
                65.00% = .83947     20.00% = 2.4559       .01% = 11.312
                60.00% = .97170     15.00% = 2.8071       .00% = 12.204
                55.00% = 1.1044     10.00% = 3.2596

C) NO. OF PLAYS DISTRIBUTION
   ------------------------------
   Lower Support     =    3
   Upper Support     =    3
   Expectation       =      3.00000
   Standard Deviation=       .00000



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

   Basin Resource:   (  B cu m    )
   ------------------------------
     Minimum     = .7453876    Maximum           = 132.9766
     Expectation = 28.79929    Standard Deviation= 16.64668

   EMPERICAL DISTRIBUTION:
   ----------------------
     Greater than    Basin
     Percentage      Potential
     ------------    -----------
        100.00          .74539
         99.00          4.9737
         95.00          8.7162
         90.00          11.568
         85.00          13.619
         80.00          15.537
         75.00          17.121
         70.00          18.830
         65.00          20.527
         60.00          22.191
         55.00          23.742
         50.00          25.374
         45.00          27.428
         40.00          29.511
         35.00          31.735
         30.00          33.936
         25.00          36.700
         20.00          39.857
         15.00          44.021
         10.00          49.606
          8.00          52.856
          6.00          56.941
          5.00          58.968
          4.00          62.114
          2.00          71.720
          1.00          80.570
           .01          132.88
           .00          132.97
```