OIL AND GAS RESOURCE POTENTIAL OF THE NECHAKO-CHILCOTIN AREA OF BRITISH COLUMBIA

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September, 1994

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SUMMARY

There are fifteen exploration hydrocarbon plays identified in the Nechako-Chilcotin area of central and south-central British Columbia. The plays are:

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2. Nechako Tertiary Structural Oil Play,
3. Nechako Upper Cretaceous Structural Gas Play,
4. Nechako Upper Cretaceous Structural Oil Play,
5. Nechako Skeena Structural Gas Play,
6. Nechako Skeena Structural Oil Play,
7. Nechako Jurassic Structural Gas Play,
8. Tyaughton-Methow Upper Cretaceous Structural Gas Play,
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12. Tyaughton-Methow Relay Mountain/Ladner Structural Gas Play,
13. Quesnel Tertiary/Cretaceous Structural Gas Play,
14. Quesnel Tertiary/Cretaceous Structural Oil Play, and
15. Quesnel Jura-Triassic Structural Gas Play.

The Nechako Tertiary, Nechako Upper Cretaceous, Nechako Skeena, Tyaughton-Methow Skeena, and Quesnel Tertiary/Cretaceous Structural Oil and Gas Plays have no established reserves or production and are, therefore, conceptual. The remaining five plays are classified as speculative, meaning insufficient petroleum geological information was available to properly assess potential hydrocarbon reserves. In addition, increased levels of metamorphism with accompanying decreases in porosity in these speculative plays preclude any significant hydrocarbon accumulation. The conceptual plays were assessed using current practices employed at the Petroleum Resources Subdivision of the Geological Survey of Canada.

The most favourable and important play recognized in the Nechako-Cariboo assessment is the Nechako Skeena Structural Oil and Gas Play. Ninety oil and ten gas shows were reported from well cuttings in these rocks. Very good to fair oil and gas-generating capabilities were recognized in numerous interbedded bituminous and carbonaceous shales. A mean value of 2.47×10^{11} m^3 (8.74 TCF) discloses the gas potential of the play while the expected oil resource is determined to be 7.74×10^{8} m^3 (4870.6 million barrels).

Tertiary sediment fill in extensional grabens and a thin veneer-like deposit underneath the Eocene volcanic cover constitute the rocks incorporated into the Nechako Tertiary Structural Oil and Gas Play. The ultimate mean play potential is 1.42×10^{10} m^3 (502 BCF) for gas and 2.17×10^{7} m^3 (136.4 million barrels) of oil.

Oil and gas prospects in the Nechako Upper Cretaceous Structural Plays are present in open to transitional marine and terrestrial easterly-derived clastic sediments. Mean play potential for gas is $6.49x10^8$ m^3 (23 BCF) and the oil resource is $2.0x10^6$ m^3 (12.8 million barrels). Negligible hydrocarbon potential is predicted for this play.

The Skeena Assemblage is also represented in the Tyaughton-Methow Basin in the south and southwest portion of the study area. Although no wells have been drilled and no shows or seeps have been reported in the basin, it was concluded that oil and gas potential is present in the play due to similarity with Skeena Group sedimentation to the north. The mean oil potential for the Tyaughton-Methow Skeena Structural Play is $1.0x10^5$ m^3 (0.8 million barrels). The total mean gas potential has been determined to be $4.2x10^7$ m^3 (1 BCF). Negligible hydrocarbon potential prevails in the play.

The petroleum potential in the youngest group of sediments found in the Quesnel Trough located to the east of the previous basins, is represented by the conceptual Quesnel Tertiary/Cretaceous Structural Oil and Gas Plays. Terrestrial fluvial and lacustrine sedimentation prevailed. Gas shows have been reported from drill reports. The total mean gas potential is statistically determined to be $8.37x10^9$ m^3 (296 BCF). Oil potential is $1.21x10^7$ m^3 (76.3 million barrels).

The total oil and gas potential for the entire Nechako-Chilcotin area is $8.10x10^8$ m^3 (5096.6 million barrels) and $2.71x10^{11}$ m^3 (9.56 TCF), respectively.

Good hydrocarbon potential is recognized in Skeena sediments deposited in the central and southern portions of the Nechako Basin. Grabens with Tertiary fill in southern Quesnel Trough and along the Fraser River are favourable areas for hydrocarbon accumulation.

INTRODUCTION

In October, 1992, John MacRae, Director of the Petroleum Geology Branch of British Columbia's Ministry of Energy, Mines and Petroleum Resources requested that the Institute of Sedimentary and Petroleum Geology of the Geological Survey of Canada assess the hydrocarbon potential of certain sedimentary basins in British Columbia. Consequently, an assessment of the sedimentary basins surrounding Vancouver Island was completed and submitted to the Ministry in January 1993. This work constituted Phase I of the information requested by the Ministry. Phase II, which involved the oil and gas potential of the Kootenay area of southeastern British Columbia, was submitted in April of 1993. This particular report deals with Phase III, which describes the results obtained from an oil and gas assessment of the Nechako-Chilcotin region of west-central British Columbia. Results from these assessments are to be employed by British Columbia's Commission on Resources and Environment, which is currently performing a detailed land-use planning study of selected areas in the Province.

G. S. C. hydrocarbon resource assessments are computer-generated by an internally formulated statistical program known as PETRIMES (Lee and Wang, 1990). These assessments can be applied to mature, immature and conceptual hydrocarbon plays. A play is defined as a family of hydrocarbon pools or prospects with similar histories of hydrocarbon generation and migration as well as similar trapping mechanisms and reservoir configurations. A mature play has sufficient discoveries and pool definitions for analysis by the "discovery process model" while an immature play has too few discoveries to allow analysis by this method. A conceptual play has no defined pools, just prospects.

All of the plays analyzed statistically in this assessment were defined as conceptual and the pool-size distributions were generated using probability distributions of geological variables substituted into the standard pool-size equation. Prospect-level and play-level risks were assigned to each play prior to analysis. Speculative plays were also defined in this assessment. These plays are ones where little or no pertinent petroleum geological information is available. In addition, it was deemed that sufficient negative conditions are present that significant accumulations of hydrocarbons are not likely to occur. These speculative plays were not statistically analyzed but were included in this report for the sake of completeness.

Following compilation of pertinent geological information in the Nechako-Chilcotin area of British Columbia as well as adjacent Washington State (see reference list), fifteen geological hydrocarbon plays were recognized. Six of these plays have oil potential while the remainder are gas prospects. However, five of these plays are speculative and consequently were not assessed. The play boundaries are illustrated in Maps 1 to 3.

Basins included in the study are the Nechako Basin, Tyaughton Trough, Methow Basin and the Quesnel Trough. Immediately apparent on the tectonic map of the Cordillera is the cover of Tertiary volcanics overlying a major part of the study area (Wheeler and McFeely, 1991). This volcanic cover as well as limited well control and complex tectonic and structural histories complicate the definition of the physical boundaries of the basins. Before defining any petroleum plays, it was necessary to compile and analyze the numerous tectonic and orogenic episodes and depositional events in the Intermontane Belt of the Cordillera. The affiliation of basins with exotic terrane as well as the timing of accretion onto the continent were important criteria used to determine the tectonic histories of each basin. Transgressive and regressive cycles were significant sequences in the formulation of depositional histories. Thicknesses of sedimentary and volcanic successions and identification of major unconformities were important geological criteria required to properly establish petroleum exploration plays.

At the beginning of the Mesozoic Era off the west coast of ancestral North America, there were widely scattered volcanic arcs associated with oceanic plateaus separated from the continent by back-arc basins. In the study area, the arc is represented by the Nicola calc-alkaline assemblage of volcanics while the Cache Creek assemblage constitutes the oceanic platform in the fore-arc (Souther,1991). In Late Triassic, the terrane known as Quesnellia is represented by a continuous west-facing arc west of the craton while the Cache Creek Terrane is subducting under the arc. The oceanic Slide Mountain Terrane to the east represents back-arc basin material (Gabrielse and Yorath, 1991c). Stikinia Terrane where both Bowser and Nechako Basins later developed, lay west of the arc in Panthalassa. Amalgamation of Stikinia, Cache Creek and Quesnellia terranes commenced during the Late Triassic to form the Intermontane Superterrane. The amalgamation was encouraged by the Cache Creek subduction (Gabrielse and Yorath, 1991c).

The Early Jurassic embraces a fundamental shift from terrane-specific geological processes of plutonism, volcanism and sedimentation, to the development of overlap assemblages starting in the Middle Jurassic.

Lower to Middle Jurassic volcanic and volcaniclastic Hazelton Group rocks represent a complex of island arcs surrounding Bowser and Nechako Basins (Gabrielse and Yorath, 1991c). The Skeena and Stikine Arches developed at this time in Stikinia. These arches separated and delineated the proto-Bowser and Nechako Basins. Accretion of the Intermontane Superterrane onto North America most likely terminated in the mid-Jurassic. Meanwhile, deposition of the Early to mid-Jurassic Ladner Group sediments was occurring in the Methow Terrane on extra-continental Wrangellia. The Methow Terrane encompasses both the Methow Basin and the Tyaughton Trough. The deposition of non-marine coarse clastics of the Relay Mountain Group in the Tyaughton Trough represents the sedimentation caused by and resulting from accretion of the Insular Superterrane onto North America in the Late Jurassic. Uplift in western Quesnellia due to this accretionary event provided the sedimentary material for the easterly-derived Relay Mountain and Ashcroft package in the Tyaughton-Methow Basin. This accretionary episode also contracted the back-arc oceanic basin and uplifted the Slide Mountain oceanic rocks onto the miogeocline. Cordillera-wide erosion and the development of a major unconformity occurred in the Early Cretaceous before another episode of uplift in the Cordillera facilitated the deposition of the Aptian to Cenomanian Skeena Group sedimentary assemblage in the Cordillera and equivalent Blairmore Group sedimentary succession in the Rocky Mountain foredeep. Thick clastic marine and non-marine sediments were shed eastward from the Omineca Belt into the Sustut, Skeena and Tyaughton-Methow basins (Gabrielse and Yorath, 1991c). The Skeena Assemblage is an accretionary response assemblage (see Map 4 for interpreted Cretaceous sediment distribution). Post-accretionary deposition of Late Cretaceous to

Paleocene marine and non-marine sediments are represented by Upper Cretaceous westerly-derived rocks in the Sustut and Nechako Basins and the Brazeau Assemblage in the foredeep of the Rocky Mountain Foreland Belt. During Early to mid-Eocene time, extensional tectonics prevailed and Early Eocene deposition of sediments in extensional basins took place before the major episode of mid-Eocene extrusion of volcanic piles. Extensional tectonics has continued until Recent time with concomitant block-faulting producing fault-bounded valleys where non-marine sediments have accumulated.

The Nechako Basin, located in the Cariboo-Chilcotin area of south-central British Columbia, contains seven oil and gas geological plays defined in Tertiary to Jurassic-aged sediments. (Maps 1-3).

The Tyaughton Trough and Methow Basin have been combined in this study and five oil and gas plays have been recognized (Maps 1-3).

Three oil and gas plays in the Quesnel Trough area in Tertiary to Jurassic sediments have been proposed (Maps 1-3).

Fifteen plays have been defined in the area. They are the:

1) Conceptual Nechako Tertiary Structural Gas Play,
2) Conceptual Nechako Tertiary Structural Oil Play,
3) Conceptual Nechako Upper Cretaceous Structural Gas Play,
4) Conceptual Nechako Upper Cretaceous Structural Oil Play,
5) Conceptual Nechako Skeena Structural Gas Play,
6) Conceptual Nechako Skeena Structural Oil Play,
7) Speculative Nechako Jurassic Structural Gas Play,
8) Speculative Tyaughton-Methow Upper Cretaceous Structural Gas Play,
9) Speculative Tyaughton-Methow Upper Cretaceous Structural Oil Play,
10) Conceptual Tyaughton-Methow Skeena Structural Gas Play,
11) Conceptual Tyaughton-Methow Skeena Structural Oil Play,
12) Speculative Tyaughton-Methow Relay Mountain/Ladner Structural Gas Play,
13) Conceptual Quesnel Tertiary/Cretaceous Structural Gas Play,
14) Conceptual Quesnel Tertiary/Cretaceous Structural Oil Play, and the
15) Speculative Quesnel Jura-Triassic Structural Gas Play.

GEOLOGICAL SETTING AND PLAY PARAMETERS

Nechako Tertiary Structural Gas Play

This play is located in the Nechako Basin within the Intermontane Belt of south-central British Columbia. It is bounded to the north and northwest by the Skeena Arch, to the east by the dextral strike-slip Fraser Fault, and to the south and southwest by the Yalakom-Hungry Valley fault system (Map 1). The stratigraphic interval of interest encompasses sediments of Early Eocene to Pliocene age (Hunt, 1992; Mathews and Rouse,1984; Rouse and Mathews, 1988,1989).

The Nechako Tertiary Structural Gas Play covers an area of about 23,300 square kilometres exclusively located in British Columbia (Map 1). Four exploratory wells have penetrated the Tertiary sediments in this play. No shows were encountered in the wells although two surface asphalt (?) shows have been recorded (Koch, 1973; Tipper, 1963). The Tertiary sediments vary greatly in thickness throughout the play area. In the Nechako River area, Rouse and Mathews, 1989, state that Tertiary sediments are 250 metres thick in two diamond drillholes. Eocene sediments are 160 metres thick in the Chilcotin b-22-K well in the Nazko area (Hunt, 1992, Figure 1, this report), while in the Churn Creek area to the southeast, the Tertiary volcanic and sedimentary sequence varies from 1600 to 2000 metres with sediments occupying about 400 to 900 metres of the succession (Mathews and Rouse, 1984). Estimates of reservoir thickness vary from 0 to 2% of the total succession. Porous sands and conglomerates are thin and usually stacked. Porosity in sands range from 7 to 14% with an average value of 8%. Secondary porosity occurs below +800 metres subsea in open fractures. The majority of fractures, however, are plugged with cementing material.

Prospects can be found in traps formed by small-scale antithetic and synthetic normal and reverse faults within extensional grabens. Sandstone and conglomerate pinchouts and facies changes may produce stratigraphic traps as well. Due to the lack of seismic information, the inference of the area of closure as well as vertical relief of the traps are poorly constrained. The largest estimated closure is 90 square kilometres while the smallest is 1.0 square kilometre (see Appendix 1). There are estimated to be about 175 prospects throughout the play.

Fair to very good source rock potential for gas is present in Tertiary carbonaceous and bituminous shales and claystones in the Nechako Basin. Type III kerogens are the dominant organic matter in the basin with minor amounts of Type I and II. Vitrinite reflectance on surface outcrops vary from 0.41 to 1.43 (Hunt, 1992; Mathews and Rouse, 1984). Thermal alteration values in Tertiary sediments in well cuttings range from 0.25 to 4.0 (Hunt, 1992) which rank the samples as unmetamorphosed to subgreenschist facies metamorphic grade material. In outcrop, TOC varies from 0.00 to 55.13. One very good value (TOC>2.0) occurs in outcrop in the southeastern part of the basin. One very good TOC value was also encountered in the Chilcotin well at 147.5 metre depth (+1244 metres subsea). Three out of 12 samples in outcrop show fair to good gas potential in the southeast part of the basin near the Gang Ranch. Two out of 45 samples in the well are fair to very good potential gas sources (+1244 and +1181 metres subsea).

Block faulting occurred in the mid-Eocene when extensional tectonics commenced. Tertiary sediments have been tilted after deposition. Antithetic and synthetic faults were formed subsequent to extensional faulting. Therefore, structures developed previous to, contemporaneous with, and subsequent to deposition. The presence of numerous faults and fractures, some of which are open, provide opportunity for the migration of fluids. Numerous interbedded and overlying shales as well as a cap of Eocene volcanics over large areas may provide seal.

Nechako Tertiary Structural Oil Play

This oil play pertains to the same rock succession as the gas component. The play parameters described for the Nechako Tertiary gas play would also apply to the oil play, for the most part.

Two surface asphalt shows indicate oil potential in these rocks. One well sample, out of 45, has sufficient TOC and Type II kerogen to indicate moderate oil and gas source material. Trap formation, migration and seal are all present.

Nechako Upper Cretaceous Structural Gas Play

This conceptual petroleum play consists of the Santonian (or older?) to Maastrichtian assemblage of open and transitional marine to terrestrial easterly-derived sediments in the Nechako Basin. This sedimentary package is defined by a palynological study completed in the Chilcotin b-22-K well (Hunt, 1992)(see Figure 1, this report). These sediments are dominated by volcanic detritus. Sediments of this age are not known to outcrop in the basin. However, similar-aged sediments are exposed north of the region in the Sustut Basin, as well as to the south in the Methow Basin (Wheeler and McFeeley, 1991). It was noted that the Chilcotin well was drilled on an anomaly of low gravity (Canadian Hunter, 1981). This gravity low may represent the preservation of these rocks under the volcanic cover. The Redstone gravity low was thus interpreted as representing the same assemblage of sediments underlying volcanic flows (Canadian Hunter, 1981; Maps 2 and 4, this report).

The play occupies an area of 3700 square kilometres and varies from 850 to 1700 metres thick (Hunt, 1992). Two wells were drilled into this succession and no hydrocarbon shows were reported.

Structures encountered in this play are simple compressional folds, drag folds over thrust faults and normal block fault traps. Simple and drag folds formed as a result of compressional tectonics were developed during, and subsequent to deposition. In the Late to Middle Eocene, extensional tectonics prevailed, and normal block fault traps were formed in the Upper Cretaceous rocks.

Structural mapping of the equivalent succession is published in a paper describing the Sustut Basin to the north (Eisbacher, 1974). Structural characteristics of this basin were used as an analogue for the play. Area of closures vary from 10 to 90 square kilometres on the Sustut Basin map. Presumably, smaller structures are also present and would not be represented on a map of this scale (1:250,000). It was thus, estimated that the minimum structural closure area for this play is one square kilometre. The range of vertical closure was interpreted to range from 20 to 300 metres. Five prospects were counted in the Sustut Basin. Ten major prospects were interpreted to occur in the Nechako Basin. However, there are many more smaller potential traps, possibly 100.

Very little primary porosity was recognized from well logs in these rocks. However, secondary fracture porosity does occur. Thin stacked reservoir sands are present in the succession.

Thermal alteration values in the two wells vary from 1.5 to 3.0. These alteration values indicate unmetamorphosed to zeolite-grade metamorphosed rocks. Two out of 82 samples from the two wells penetrating these sediments show fair to good gas-generating potential. Type III kerogens dominate; there are minor amounts of Type I and II. Carbonaceous and bituminous shales and sandstones and minor coal are the source rock-types in the play.

The presence of numerous faults and fractures, some of which are open, would provide opportunities for migration. Abundant overlying and interbedded shales as well as a volcanic cap would provide seal in some instances.

Nechako Upper Cretaceous Structural Oil Play

One dead oil show was encountered in the wells intersecting the Upper Cretaceous assemblage. However, all 82 geochemical samples in these wells indicate poor oil potential. As noted above, Type III kerogens dominate while there are minor amounts of Type I and II organic material. Other reservoir parameters are similar to the gas play.

Nechako Skeena Structural Gas Play

The most significant petroleum plays in this assessment are the ones evaluating the oil and gas potential found in the Skeena Assemblage of sediments. Mid-Cretaceous uplift of the Omineca Belt resulting from the collision of Stikinia with the Cache Creek Terrane provided the source material for westerly-directed deposition of the Skeena Group in the Sustut Basin to the north and Nechako and Tyaughton-Methow Basins to the south (Gabrielse et al, 1991d). Skeena Group sedimentation is thus characterized as an accretionary response assemblage. Transgression of a sea in the Early Cretaceous provided marine to nearshore depositional sites for Skeena Group rocks. This Group ranges in age from Hauterivian to Cenomanian. The interpreted extent of the Skeena sedimentary assemblage is illustrated on Map 4. Map 4 incorporates outcrop information gathered from many published reports and subsurface data from well reports. Skeena deposition under Eocene volcanics and younger sediments are interpreted where there is no well control. The boundaries for the play are delineated on Map 2.

The play encompasses an area of 17,600 square kilometres. Five wells penetrate the sediments and ten gas shows in three of the wells have been reported. Prospects are present throughout the Skeena assemblage so the thickness of the prospect succession corresponds with the thickness of the total succession. Thicknesses varies from 400 to 3000 metres (Hunt, 1992; Gabrielse et al, 1991d; Hickson et al, 1991; Mahoney et al, 1992; Diakow and Koyanagi, 1988).

If one compares Map 3 with Map 2 and studies the structural cross-section in Figure 1 through the Nazko structure, the major Skeena preservation area shows no underlying Jurassic-aged material while on either side of the preservation area, Jurassic rock directly underlies the Tertiary and/or Upper Cretaceous sequence. This represents an inverted feature in this part of the Nechako Basin. After widespread deposition of Skeena sediments in the Albian-Aptian sea, faulting preserved the Skeena rocks in a large north-south trending graben structure. Erosion then removed the Skeena sediments on either side of the graben. Extensive deposition of younger sediments then occurred preceding uplift of Skeena sediments within the graben. Later erosion removed the younger sediments overlying the uplifted Skeena succession. Thus, the preseved Skeena succession is an inverted structure.

Petroleum traps that developed within the play reflect the compressional tectonic regime that commenced in the mid-Jurassic and continued to mid-Eocene, succeeded then by extension until Recent time. Structure trap-types encountered in the Skeena play are simple compressional anticlinal folds, folds associated with thrust faults, and normal block fault traps. Compressional tectonics form the anticlinal and thrust fault traps while block fault structures formed during extension. The Sustut Basin located to the northeast of the Bowser Basin was used as an analogue in identifying and limiting trap sizes and estimating number of prospects. An anticlinal trap tested by two wells near the village of Nazko has been identified as the largest structure with an area of closure of 175 square kilometres and a vertical closure of 1000 metres. Average estimated areas of closure vary from 10 to 90 square kilometres as measured from the structural map of the Sustut Basin (Eisbacher, 1974). Block fault traps have a minimum area of closure of one square kilometre. The estimated mean amplitude for the numerous folds identified in the Sustut Basin varies from 100 to 300 metres (Eisbacher, 1974). The minimum vertical closure is interpreted to be one metre. Eleven major structures were identified in the Skeena assemblage in the Nechako Basin according to the Canhunter geophysical study of the region. If one determines the number of structures encountered in the Sustut Basin and apply it proportionately to the Nechako area, 1000 possible hydrocarbon-bearing traps are estimated. The approximate maximum number of structures in the area is inferred to be 2000.

Thin reservoir sands within the marine to non-marine shale and sandstone succession are characteristic of this play. Estimated proportion of reservoirs compared to total thickness varies from 0 to 7%. Porosity ranges from 5 to 15% in the porous sands with a 10% average. The development of numerous fractures, the majority of which are plugged with cementing material, occurs below about +800 metres subsea in drillholes. A few fractures, however, remain open and produce secondary porosity in parts.

Vitrinite reflectance on surface outcrops of Skeena Group rocks vary from 0.41 to 2.71% (Hunt, 1992). Most samples are mature to overmature with respect to hydrocarbon generation and preservation. Thermal alteration values in well cuttings vary from 0.5 to 3.75 which indicate a range of metamorphism from unmetamorphosed material to zeolite-grade (Hunt, 1992). Previous published material had proposed that subgreenschist to greenschist metamorphic grades prevail in Lower Cretaceous sediments in the Nechako Basin (Read, 1988). These grades imply that these rocks are overmature with respect to hydrocarbon generation and have no potential. The measured thermal alteration values by Hunt, 1992, however, show lower-grade metamorphism of the Skeena Group in the Nechako Basin and hydrocarbon potential consequently could be significant. The fact that both oil and gas shows have been observed in well cuttings further implies that these sediments are not overmature. Heat flows may have been somewhat lower in the Nechako Basin due to a lack of plutonism in the immediate area (Hunt, 1992). In outcrop, TOC varies from 0.00 to 49.67.

Thirteen out of 136 samples exhibit very good TOC values ranging from 2.24 to 49.67. These anomalous values are found in the Ootsa Lake area in the northern part of the basin, in the centrally-located Nazko region, and in the Redstone and Churn Creek areas to the south. These 13 samples are categorized as moderate to good gas generators. In wells, TOC ranges from 0.00 to 9.12 with good to very good values occurring throughout the vertical succession. Thirty-six of 324 geochemical samples were identified as fair to good potential gas sources. These 36 samples, principally carbonaceous and bituminous shales with minor coal partings, are found in three wells, the same three wells containing gas shows. Subsea elevations of gas source beds range from +1307.9 to -1602.4. Organic matter is dominantly classified as Type III material, with lesser amounts of Type I and II.

Structures were developed during mid-Jurassic to Recent time in this play. Structures, thus, evolved previous to, contemporaneously and subsequent to deposition and hydrocarbon generation. The presence of numerous faults and fractures identified in wells, some of which are open, would produce opportunities for migration of fluids in these sediments. Geochemical maturity factors in numerous individual samples indicate that migration has taken place. In these samples, Tmax values of greater than 435^{o}C. are indicative of mature source rocks while production index (S1/S1+S2) values of <0.1 disclose immature source material. Low production index values imply that migration of earlier formed S1 hydrocarbon out of the source strata has occurred. Low risk has been assigned to seal because of the presence of numerous overlying and interbedded shales and the cap of Eocene volcanics. A greater risk has been assigned to adequate preservation of hydrocarbons reflecting the possibility of breaching of structures (Appendix 1).

Nechako Skeena Structural Oil Play

This play occupies the same play area and incorporates the same package of sediments as the Nechako Skeena Gas reservoir. Among the five wells that penetrate the succession, 26 live oil, 49 dead oil, and 15 possible dead oil occurrences were encountered during drilling. One surface asphalt show was noted in these rocks. Reservoir parameters are similar to the previous play.

In outcrop, Hydrogen Index values range from 0.00 to 400 (Hunt, 1992). Oil potential (HI>150), occurs in five out of 136 samples. Three of these samples have sufficient TOC in order to be considered good oil-source rocks.

The Hydrogen Index varies from 0.00 to 700 in the well samples. Type I or II oil-generating organic matter occur in 16 out of 191 samples. However, only 8 of these samples have sufficient TOC to be considered good source material. These samples are found in two wells at relatively shallow depths.

Nechako Jurassic Structural Gas Play

The Nechako Jurassic Gas Play is classified as a speculative play because the rocks are generally too metamorphosed and overmature to be considered as a significant hydrocarbon-bearing package of sediments. For completeness, this play has been included, but statistical analysis was not performed due to little or no hydrocarbon potential.

As illustrated on Map 3, the Nechako Jurassic Structural Play, consisting of the Hazelton Group of intermixed volcanic and volcanogenic sedimentary rock, covers a large area of the Nechako Basin; about 54,200 square kilometres.

The Lower to Middle Jurassic Hazelton Group can be divided into four formations. The Sinemurian Telkwa Formation is the oldest and most widespread volcanic unit in the Skeena Arch area. One thousand metres of interbedded clastic sediments and tuffs comprise the overlying Pliensbachian to Toarcian Nilkitkwa Formation. Above the Nilkitkwa succession is a 500 to 800 metre thick sedimentary and volcanogenic assemblage called the Smithers Formation of Toarcian to Bajocian age. The Whitesail Formation is of Aalenian to Bajocian age and consists of 600 metres of intermixed marine volcanics and sediments (Monger et al, 1991). These sediments and volcanics were deposited in fore-arc basins previous to accretion of the Intermontane Superterrane onto North America. During deposition of the Hazelton Group, both the Skeena and Stikine Arch were uplifted (during the Bajocian in Stikinia), separating the Bowser and Nechako Basins (Tipper and Richards, 1976). Subsequent to deposition of the Hazelton Group, a hiatus occurred over most of the basin before the Skeena Group was deposited. However, there was Ashman deposition in the northwest and Relay Mountain Group sedimentation in the southeast of the basin during the hiatus.

One well intersected the Jurassic succession in the Nechako Basin (Punchaw c-38-J). No oil or gas shows were encountered in the well.

Thicknesses of Jurassic clastic and volcanogenic sediments vary from 250 to 2400 metres throughout the basin. Like the Skeena play, structural-type traps are represented by simple compressional folds, drag folds over thrust faults, and minor block fault traps. The deformation of rocks underlying Skeena Group follow the tectonic history that characterizes that play. It was discussed above.

Recent mapping in the northeast quadrant of the Taseko Lakes map-sheet indicate the presence of numerous stacked folded thrust slices that incorporate the Jurassic rocks (Mahoney et al, 1992; Read, 1992, 1993)(Figure 2, this report). Repetition of sequences in the Punchaw well also implies thrust faulting in the area. Figure 2 is a cartoon of an interpreted structural cross-section in the northeast quadrant of the Taseko Lakes map-sheet. A major unconformity where the Middle Jurassic succession is directly overlain by mid-Eocene rocks is shown in the diagram. Compressional thrusting and folding occured subsequent to Middle Jurassic deposition. Fraser Fault movement occurred post-mid-Eocene. West of Fraser Fault, pre-Late Permian rocks are well-foliated and veined while younger rocks are not. This foliation represents another earlier deformation episode. Area of closures defined by recent mapping range from a maximum of 60 square kilometres (Wineglass Slice, Read, 1993) down to 1 square kilometre. Two major structures were noted in half of the northeast Taseko map-sheet. There are probably at least 20 major structures throughout the basin and many more smaller structures. The range of vertical closure in the various structures is unknown.

A major play-level risk is the lack of primary porosity. Very little primary porosity has been reported in these rocks although fracture porosity may occur. Most fractures are cemented with clay minerals derived from the volcanic material intermixed in the sedimentary succession. Sandstones and conglomerates that may be reservoir quality with regard to porosity are very thin. Proportional representation of reservoir material compared to total thickness of the Jurassic assemblage would be minor.

In the well, TOC varies from 0.59 to 12.39. Potewntial gas-generating sources with a Hydrogen Index of less than 300 occur in all shale samples in this well. Only one sample at 1290 metre depth (-585.3 subsea) has sufficient TOC and hydrocarbon potential to be considered a good gas generator. Almost all samples consist of Type III kerogens, with minor amounts of Type I and II. All samples and rocks are metamorphosed to at least a subgreenschist facies. Carbonaceous and bituminous shales are present within the sequence and could possibly serve as source material.

Tyaughton-Methow Upper Cretaceous Structural Gas Play

The Tyaughton Trough and Methow Basin constitute a large proportion of the relatively small Methow Terrane which had already accreted to North America by Upper Cretaceous time. The Tyaughton-Methow Upper Cretaceous Structural speculative play is equivalent to the Nechako Upper Cretaceous succession described above as a post-accretionary assemblage.

The play area is only 680 square kilometres (Map 2). No wells and gas shows have been reported in these rocks. The thickness of the total succession has been estimated to vary from 600 metres in British Columbia to 7400 metres in Washington (Trexler, 1985). Maxson, (1992) reports a sequence of Late Cretaceous sedimentary rocks in the Taseko River area with a thickness of over 1000 metres.

Structure trap-types found in this play vary from simple compressional folds to drag folds over thrust faults and normal block fault traps. Simple compressional folding and thrusting occurred previous to Upper Cretaceous sedimentation. Transpressional deformation occurred in Late Cretaceous time and produced both sinistral strike-slip faults and compressive structures (Schiarizza et al, 1990). Dextral strike-slip faults and normal faults were developed during extensional episodes in the post-mid-Eocene. Folds are reported to be large-scale both in the Tyaughton and Methow Basins (McLaren, 1986; Tennyson and Cole, 1978) with wavelengths up to 10 kilometres. Vertical relief is not known, however. Many small-scale anticlinal and fault-trap structures are probably present.

There have been no descriptions of any porosity in these rocks and no geochemical samples taken. The rocks are dominantly non-marine and are derived from uplift of the Hozameen and Bridge River successions to the west and Spences Bridge volcanics to the east (Woodsworth and Monger, 1991). The volcanic-rich nature of these sediments imply little or no primary porosity. Secondary fracture porosity may be present in parts. Disseminated organic debris is present in parts within these sediments (Trexler, 1985). Structures were developed previous to, contemporaneous with, and subsequent to hydrocarbon generation.

This play is highly speculative due to no shows reported and no porosity described. No assessment was completed on this play because of its speculative nature.

Tyaughton-Methow Upper Cretaceous Structural Oil Play

Play parameters are basically the same as the previous one. No oil shows are reported in the play and it was deemed to be another highly speculative play. Again, no assessment was performed on these rocks.

Tyaughton-Methow Skeena Structural Gas Play

The Tyaughton-Methow Skeena Group of rocks cover a substantially larger area than that of the Upper Cretaceous sediments. It encompasses an area of 6950 square kilometres. Barremian to Albian sediments of the Jackass Mountain and Taylor Creek Group represent the Skeena Assemblage in the Tyaughton-Methow Basin. No wells and no gas shows have been reported in the area. The total succession ranges up to 5700 metres thick (Woodsworth and Monger, 1991).

Reservoir and play parameters derived from the study of the Skeena assemblage in the Nechako Basin were also applied to this play. Area of closures, vertical relief, porosity limits and trap fill parameters were obtained from the Nechako Skeena Play. We speculated that one hundred possible traps are present in the Tyaughton-Methow Play.

Forty-one outcrop samples were collected for geochemical analysis from Skeena Group rocks in the basin. TOC values range from 0.00 to 0.63 which shows that these samples are poor potential hydrocarbon generators. None of the 41 samples were identified as fair to good gas generators. The organic matter encountered was dominantly Type III. Carbonaceous and bituminous shales and organic partings in sandstones may represent source rock material.

Timing of structure with respect to hydrocarbon generation, the presence of migration and seal all have been assigned relatively low prospect-level risk factors. Adequate source and preservation have somewhat higher levels of risk (Appendix 1).

Tyaughton-Methow Skeena Structural Oil Play

No oil shows have been reported in this play and no geochemical samples have been recognized as fair to good oil generators. All samples are immature and dominantly Type III. Reservoir and play parameters are similar to the gas play.

Tyaughton-Methow Relay Mountain/Ladner Structural Gas Play

This speculative play illustrated on Map 3 includes sediments of the Early to Middle Jurassic Ladner Group combined with the Late Jurassic to Early Cretaceous Relay Mountain Group. The Ladner Group varies in thickness from 1800 to 3600 metres (Woodsworth and Monger, 1991). The

Relay Mountain Group, which consists of shale and siltstone in the centre of the basin and grades to sandstone and conglomerate on the margins, range in thickness from 1500 to 2700 metres in the Tyaughton Trough in British Columbia (Jeletzky and Tipper, 1968) and up to 9800 metres in the Methow Graben of Washington State (Trexler, 1985). Therefore, total thickness varies from 3300 to 11,100 metres throughout the basin. The play area encompasses 5850 square kilometres. Marine conditions prevailed throughout deposition of the sediments (O'Brien, 1986; Mahoney, 1993; Garver et al, 1988; Woodsworth and Monger, 1991).

Structure-types reveal the complicated structural history in the Tyaughton-Methow Basin. Compressional folding occurred in the Albian and continued into the Cenomanian. In Late Cretaceous time, transpressional deformation commenced which produced sinistral strike-slip faulting and compressional folding. Dextral strike-slip faulting and normal faults reveal extensional episodes of deformation that were activated in the mid-Eocene (Schiarizza et al, 1990). Simple compressional anticlines, fault-propagation and fault bend folds associated with thrust faults, and normal fault traps are derived from the above structural history. The structures developed subsequent to any hydrocarbon generation that may have been involved with primary burial metamorphism.

Closure area is likely comparable to Nechako Cretaceous prospect areas, that is, ranging from 90 to 1 square kilometre. Vertical relief varies from 1000 metres to 1 metre. The play area is approximately one half of the Tyaughton-Methow Skeena area, so prospect numbers are halved to a maximum of 50.

Reservoir sands are probably very thin and sparse due to little or no primary porosity (0-3% range, average- 0.5%). Numerous fractures are present throughout the succession. However, most fractures, if not all, are plugged with cementing material.

Vitrinite reflectance on surface outcrops in the Tyaughton area of the basin reveal a range of 1.48 to 1.73%. These values indicate that the organic matter is overmature with respect to oil generation but gas generation is possible. In outcrop, TOC varies from 0.00 to 1.13. One good TOC value (>1.0) was found at Tatlayoko Lake. Three out of 11 samples show geochemical characteristics that indicate fair to good gas generation. However, these sediments have been metamorphosed to at least a subgreenschist facies and oil or gas potential is reduced. Organic matter is dominantly Type III. Carbonaceous shales are the source rocks in the play.

This play has been classified as speculative because of lack of porosity, metamorphic effects and the lack of any hydrocarbon shows. No assessment was performed on these rocks.

Quesnel Tertiary/Cretaceous Structural Gas Play

The Quesnel Tertiary/Cretaceous Structural Gas Play involve sedimentary rocks located in the Quesnel Trough and environs that were deposited in basins on Quesnellia subsequent to accretion of the Intermontane Superterrane onto the continent. Within the Omineca Belt scattered fault-controlled basins containing Upper Cretaceous to Paleogene sediments occur (Gabrielse, 1991a).

Examples are the Quesnel, Princeton and Hat Creek basins. Neogene sediments are also present in places along the Fraser Valley (Souther and Yorath, 1991). Map 1 illustrates the extent of the play area, about 8650 square kilometres. Four wells have been drilled into these rocks. Five gas shows in one well were encountered. Total succession thickness varies from a few centimetres to in excess of 2300 metres.

Potential petroleum accumulations in this play may be located in the crests of anticlines or in stratigraphic traps of sandstone and conglomerate pinchouts. In addition, traps associated with block faulting may be present as the result of formation of grabens, into which a great proportion of the sediments have accumulated. Folds developed from mid-Jurassic to early Late Cretaceous while block faulting and dextral strike-slip faulting occurred post-mid-Eocene. Areas of closure vary from 10 to 0.5 square kilometres while vertical relief ranges from 10 to 1500 metres. There are at least 6 major structures that would be prospective and probably about 100 lesser structures that are yet to be identified.

Fluvial and lacustrine sedimentary rocks are prevalent in the play area. Sandstones, conglomerates and minor shales along with coal seams and a diatomite sequence are present. Reservoir sands and conglomerates are thin and lenticular in nature. It was estimated that reservoir thickness compared to total succession thickness varies from 0 to 5%. The porosity range was estimated to be 7 to 14% in reservoir material, with an 8% average. The diatomite near the top of the succession was described to be very porous (Cockfield, 1932).

Abundant coal seams are present mostly in the lower part of the succession. The coal is generally high in ash and water content and low in calorific value. Rank is sub-bituminous B to C (Graham, 1978). The seams are lenticular in nature. Aggregate thicknesses of coal vary from nine metres at Merritt to 370 metres at Hat Creek. Carbonaceous and bituminous shales provide additional potential source material for the play.

Compressional structures developed previous to some of the sedimentary deposition, but extensional tectonic processes took over and continue to the present day. Therefore, hydrocarbon generation occurred both subsequent and contemporaneously with deformation and trap formation. The opportunity for migration is possible in these rocks due to the presence of open fracturing. However, the lenticular nature of the porous sandstone beds may produce barriers to migration. Seal may at times be risky because the sediments frequently outcrop and leakage may consequently occur. A prospect-level risk of 0.25 was assigned to adequate prospect conditions to reflect possible seal, closure and migration problems.

Quesnel Tertiary/Cretaceous Structural Oil Play

Oil potential in Tertiary and Cretaceous rocks in the Quesnel Trough is probable due to the presence of oil shows in a well (Australian No. 1). The fact that lacustrine sequences are now recognized as important petroleum hosts as well as potential source material for oil and gas (Powell, 1986), gives this play significant oil potential. Depositional environments obtained from spore and pollen studies (Rouse and Mathews, 1979), range from humid flood-plain deposits to rift valley lakes in humid environments. Lacustrine sequences deposited in similar environments contain significant oil reserves in other basins around the world (eg. Daqing Oil Field in Songliao Basin of northeastern China)(Powell, 1986). Sufficient maturation levels have been attained in these rocks so that significant hydrocarbon generation could occur.

Quesnel Jura-Triassic Structural Gas Play

This highly speculative play includes sediments of Upper Triassic (Carnian) to Middle Jurassic (Callovian) age. Map 3 illustrates the play covering an area of 11,275 square kilometres. The thickness of the total succession ranges from 1200 to 3500 metres (Travers, 1982). Volcanogenic sediments of the Nicola Group as well as marine sedimentary rocks of the overlying Ashcroft Formation are represented. No wells or gas shows have been reported in the play.

Compressional tectonics produce simple folds and thrust fault traps in these rocks (Travers, 1982). Normal fault traps related to extensional block faulting also affect the succession.

Travers, 1982 argues that potential reservoir sandstones and conglomerates of the Lower Jurassic Ashcroft Formation have been deformed by low-angle thrusting and are capped by impermeable marine shales. Thus, a potential trap for petroleum was created. No porosity measurements have been recorded for the Ashcroft but organic matter does exist in these rocks. Interpreted burial depths of these reservoir rocks are sufficient for oil and gas generation. Koch (1973) states, however, that these rocks have been metamorphosed to a higher degree compared to contemporaneous rocks in the adjacent Nechako Basin. This metamorphism would have been sufficient to heat and degrade any petroleum that may have been present.

The lack of porosity, oil and gas shows, as well as the metamorphic effects categorizes this play as speculative and, consequently, no assessment was run.

ASSESSMENT TECHNIQUE

After compiling relevant material for each hydrocarbon play, an assessment committee assigned objective and subjective probabilities and risk factors for ten of the hydrocarbon plays (see Appendix 1 for probabilities and risk factors and Appendix 2 for the statistical data retrieved). The risk factors were defined by analyzing the geological characteristics of various play parameters, comparing them to analogous settings, and then deciding upon reasonable limits for these parameters. Once the probabilities and risk factors were compiled, Monte Carlo and lognormal approximation options in PETRIMES were used to model the conceptual plays (Lee and Wang, 1990).

RESOURCE APPRAISAL

Following is a discussion of statistical results obtained for each play (see Appendix 2 for output data).

Nechako Tertiary Structural Gas Play

Overall, the play-level risk is 0.90, which signifies the high probability that this hydrocarbon play exists. At the prospect-level, relatively high risk factors were assigned to the presence of reservoir-type rock, adequate seal and especially adequate preservation. The overall prospect-level risk was determined to be 0.03 (see Appendix 1). Preservation was considered risky because of the scarce information concerning the actual distribution of Tertiary sediments underlying the Eocene volcanic flows in the Nechako Basin. Widespread, but sparse, drillhole and subordinate Tertiary outcrop data were used in interpreting the distribution of Tertiary sediment cover illustrated on Map 1 and Figure 1.

Complicated tectonic histories with numerous depositional histories prevail in the Nechako assessment area of south-central British Columbia. Structural deformation is inferred to have occurred previous to, contemporaneous with, and subsequent to hydrocarbon generation and accumulation depending on location. Some hydrocarbon accumulations may have been affected by these deformation episodes. Such accumulations may have been cut by many faults and subsequently remigrated. Fields, rather than pools, are interpreted as representing these composite structurally-complex hydrocarbon accumulations. Thus, the largest undiscovered hydrocarbon accumulation in this assessment is considered to be a field, rather than a pool. We emphasize that readers consider the range of possible sizes for the largest recoverable field size (90% confidence interval) rather than simply quoting the median of the largest field size. This range more accurately describes the largest field size.

In this assessment, the mean of the expected number of fields present in the play is recorded. In addition, values representing the probability of one or more fields existing in a play and the number of fields at 1% are presented. The number of fields at 1% indicate the probable maximum of expected number of fields in a play and it would be 99% certain that no greater number of fields would be found.

The total mean play potential of in-place resources in the Nechako Tertiary Structural Gas Play is $1.42\text{x}10^{10}$ m^3 (502 BCF) of gas (Appendix 2). The in-place resource estimate for the largest field size varies from $3.48\text{x}10^{8}$ to $2.93\text{x}10^{10}$ m^3 (12.3 to 1033.9 BCF)(Figure 3). The median of the largest in-place field size is $4.60\text{x}10^{9}$ m^3 (162.3 BCF)(Figure 3). Using standard recovery factors (0.70), we suggest a largest field size of $2.44\text{x}10^{8}$ to $2.05\text{x}10^{10}$ m^3 (8.6 to 723.7 BCF)(recoverable) occurs in the play. The probability of one or more fields existing in the play is 0.80. A mean of seven gas fields are expected to occur in the play. It is 99% certain that no more than 23 fields are expected.

All plays in the Nechako Basin and Quesnel Trough are entirely within British Columbia.

All values in this section associated with the two basins are applicable exclusively to British Columbia. Sixty percent of the area of the Tyaughton-Methow plays is located in British Columbia while the remainder is found in Washington State. Resource figures quoted for B.C. are reduced by 40%.

Nechako Tertiary Structural Oil Play

Adequate play conditions are present so that a play-level risk of 0.90 can be assigned to the oil component of the Nechako Tertiary geological play. A risk factor of 0.02 has been applied to prospect conditions. The Nechako Tertiary Oil Play has a mean in-place oil potential of $2.17x10^7$ m^3 (136.4 million barrels). In-place oil resources show the largest undiscovered field size limits ranging from $8.0x10^5$ to $4.99x10^7$ m^3 (4.8 to 313.7 million barrels)(see Fig. 4). The median of the largest undiscovered field is $8.40x10^6$ m^3 (52.8 million barrels). The range of the largest undiscovered recoverable oil field varies from $2.5x10^5$ to $1.65x10^7$ m^3 or 1.6 to 103.5 million barrels. There is a 75% chance that one or more oil fields would be found in the play. The mean number of fields expected to occur is 4. No more than sixteen oil fields are expected in the play.

Nechako Upper Cretaceous Structural Gas Play

A risk factor of 0.90 assigned to adequate play conditions signifies the highly probable consideration that the play actually exists. Prospect-level risks, however, are much lower (0.02) principally due to presence of closure, presence of a reservoir-type rock, adequate seal, and adequate preservation. The play area is rather limited and interpreted boundaries only are shown (Map 2).

The mean in-place gas potential is $6.49x10^8$ m^3 or 23 BCF. The range of the largest undiscovered in-place gas field varies from $5.30x10^7$ to $3.56x10^9$ m^3 (1.9 to 125.8 BCF)(recoverable - $3.7x10^7$ to $2.49x10^9$ m^3 (1.3-88.10 BCF)). The median of the largest field is $4.87x10^8$ m^3 (17.2 BCF)(see Fig. 5). The chance of one or more gas fields existing in the play is calculated to be 50%. If gas fields are present, the analysis suggests that only a single field is expected to be found and it is very unlikely that more than 4 fields would be found in the play.

Nechako Upper Cretaceous Structural Oil Play

Play parameters are similar to the gas component and play-level and prospect-level risks are identical. The mean number of expected fields, probability of one or more fields existing, and the number of fields at 1% are identical with the oil play. The Nechako Upper Cretaceous Oil Play has a mean in-place potential of $2.0x10^6$ m^3 or 12.8 million barrels of oil. The largest in-place undiscovered oil field from the field-size-by-rank diagram (Fig. 6) ranges from $3.0x10^5$ to $9.90x10^6$ m^3 (1.6 to 62.4 million barrels). The median of this range is $1.8x10^6$ m^3 (11.1 million barrels). The range for the largest recoverable oil field in the play is $8.0x10^4$ m^3 to $3.28x10^6$ m^3 (0.5 - 20.6 BCF).

Nechako Skeena Structural Gas Play

Adequate preservation of hydrocarbons is assigned the greatest risk in the play because of the extensive outcrop exposure of Skeena Group sediments which may provide opportunities for leakage of hydrocarbons. Timing of hydrocarbon generation with respect to trap formation has been interpreted to be unfavourable in some cases, and in such instances the play is appropriately risked. Risk has also been assigned to the presence of closure in some prospects. All of the above risks are applied at the prospect level. An overall prospect risk of 0.06 has been calculated for the Nechako Skeena Structural Gas Play. However, a play-level risk of 1.00 has been assigned which implies total confidence in the existence of the play.

The total mean in-place gas potential of the play is 2.47×10^{11} m^3 or 8.7 TCF. The median of the largest undiscovered field (in-place resources) is statistically determined to be 3.26×10^{10} m^3 (1150.3 BCF). The median has been extracted from a range of 8.88×10^{9} to 1.07×10^{11} m^3 (313.5-3771.9 BCF) for the largest undiscovered field (Fig. 7). The recoverable limits of largest field size are 6.21×10^{9} to 7.48×10^{10} m^3 (219.4-2640.4 BCF). The probability of one or more gas fields existing in the play is greater than 99%. If gas fields do exist, the expected mean number of fields is 58. It is extremely unlikely that more than 122 gas fields are present.

Nechako Skeena Structural Oil Play

Play parameters are similar for the oil component in the Nechako Skeena group of rocks. Therefore, play-level and prospect-level risks are identical. The mean in-place play potential is 7.74×10^{8} m^3 (4870.6 million barrels). The in-place range of the largest undiscovered field is 2.78×10^{7} to 2.40×10^{8} m^3 (174.8 to 1512.0 million barrels). The median would be 8.58×10^{7} m^3 (539.8 million barrels)(Fig. 8). The range of the largest undiscovered field (recoverable) varies from 9.17×10^{6} to 7.93×10^{7} m^3 (57.7 to 499.0 million barrels).

Tyaughton-Methow Skeena Structural Gas Play

A play-level risk of 0.60 has been assigned. The fact that no hydrocarbon shows have been recorded in the play is a major contributing factor to the elevated play risk. At the prospect-level, relatively high risk factors have been assigned to the presence of closure, adequate source material, and adequate preservation. The overall prospect risk factor is 0.05. There is only a 40% chance that one or more gas fields exist in this play. If any fields do exist, the mean expected number is 1, and it is extremely unlikely that more than seven gas fields are present.

The mean play potential is 4.2×10^{7} m^3 (1 BCF)(in-place). The largest undiscovered gas field according to the field-size-by-rank diagram (Fig. 9) ranges from 8.0×10^{6} to 1.63×10^{8} m^3 (0.3 to 5.8 BCF). The median of the largest field size is 4.1×10^{7} m^3 (1.5 BCF). Recoverable largest undiscovered field size varies from 5.0×10^{6} to 1.14×10^{8} m^3 (0.2 to 4.0 BCF).

This particular play extends into Washington in the United States. Sixty percent of the play is located in British Columbia. If resources are evenly distributed throughout, then the mean play potential for B. C. would be 2.5×10^{7} m^3 (0.6 BCF).

Tyaughton-Methow Skeena Structural Oil Play

Play conditions are similar to the gas component in the oil play. The mean in-place play potential is 1.0×10^5 m^3 (0.8 million barrels). The range of the largest undiscovered field (in-place) according to the field-size-by-rank diagram within a 90% interval varies from 3.9×10^4 to 4.0×10^5 m^3 (0.2 to 2.4 million barrels) (Figure 10). The median of the largest field size is calculated to be 1.0×10^5 m^3 (0.8 million barrels). Recoverable largest undiscovered field size range is 1.0×10^4 to 1.2×10^5 m^3 (0.1 to 0.8 million barrels).

Even distribution of resources indicates that 60% of the mean potential would occur in British Columbia. Therefore, the mean play potential in B.C. is 6.0×10^4 m^3 (0.5 million barrels).

Quesnel Tertiary/Cretaceous Structural Gas Play

The Tertiary and Cretaceous sedimentary succession in the Quesnel Trough is extensively deformed by extensional block faults that often produce grabens which may be potential sites for hydrocarbon accumulation. Five gas shows have been reported from a well drilled in the succession so an appropriate risk factor is 0.90. Migration, seal and closure is problematic on certain prospects and consequently a prospect-level risk of 0.25 was assigned to the gas portion of the play.

The expected mean number of gas fields (N) is statistically determined to be 25. It is 99% certain that no more than 56 fields would be found in the play. It is also 80-90% certain that one or more fields are present. The mean play potential for gas is 8.37×10^9 m^3 (296 BCF). According to the field-size-by-rank diagram (Fig. 11), the median of the largest undiscovered field size (in-place) is 1.90×10^9 m^3 (67.1 BCF). The median is derived from a range of 5.87×10^8 to 7.42×10^9 m^3 (20.7 to 262.0 BCF). The largest recoverable field size varies from 4.11×10^8 m^3 to 5.19×10^9 m^3 (14.5 - 183.4 BCF).

Quesnel Tertiary/Cretaceous Structural Oil Play

Play parameters are similar to the gas portion of the play. However, since no oil shows have been reported, a greater prospect risk was assigned to adequate prospect conditions (0.15 versus 0.25 for gas). A mean of fifteen oil fields can be expected in the play. There is a probable maximum of 36 fields present. The mean play potential is 1.21×10^7 m^3 (76.3 million barrels)(in-place). The field-size-by-rank diagram (Fig. 12) indicates the range of the largest in-place field size (1.0×10^6 to 1.14×10^7 m^3 (6.0 to 71.9 million barrels)). The median of the largest field size (in-place) is 3.1×10^6 m^3 (19.7 million barrels). Recoverable largest oil field size ranges from 3.10×10^5 m^3 to 3.77×10^6 m^3 or 2.0 to 23.7 million barrels.

HYDROCARBON POTENTIAL DISTRIBUTION

Map 5 illustrates a qualitative interpretation of the distribution of potential for hydrocarbon accumulation in the Nechako-Chilcotin assessment area. Good potential is indicative of favourable locations for hydrocarbon accumulations and should be the major focus for any future exploration activities. Medium potential signifies secondary and less important areas for oil and gas prospects but significant resources may occur. Fair and poor potential mark areas where little or no hydrocarbon reserves are expected and would likely not be of interest to oil companies.

The dominant depositional expanse of Skeena sedimentation in the central and southern part of the Nechako Basin is included in the area of good hydrocarbon potential (Maps 2 & 5). The outliers of Skeena rocks in the northwest of the basin have a reduced potential. In addition, good hydrocarbon potential is recognized in Tertiary sediments deposited along the Fraser River from Quesnel to Big Bar Creek (Maps 1 & 5). Extensive coal deposits and oil and gas shows along the Fraser River are major factors in determining the area of good hydrocarbon potential. Good potential is also interpreted in the numerous, often coal-bearing grabens in the southern portion of the Quesnel Trough; namely Hat Creek, Merritt, and Princeton basins.

Medium potential areas include the Skeena outliers in the northwest of the Nechako Basin as well as the Fraser Tertiary sediments to the north of Quesnel.

Areas of fair to poor potential include the Nechako Tertiary Veneer region, the Nechako and Quesnel Jurassic as well as the Tyaughton-Methow play areas.

SUMMARY AND CONCLUSIONS

The Nechako Tertiary Structural Gas Play consists of Tertiary sediment fill in extensional grabens and a thin veneer-like deposit immediately underlying the Eocene volcanic cover. A general lack of available geological information needed to accurately map out the distribution of these sediments was reflected in the high risk factor attributed to adequate preservation at the prospect level. The mean potential of this conceptual play is computed to be $1.42\text{x}10^{10}$ m^3 (502 BCF). These figures represent in-place petroleum resource potential. Similar geological and reservoir parameters can be applied to the Nechako Tertiary Structural Oil Play. The total mean play potential is $2.17\text{x}10^7$ m^3 (136.4 million barrels).

In the conceptual Nechako Upper Cretaceous Structural Gas Play, potential gas prospects are found in open to transitional marine and terrestrial easterly-derived clastic sediments containing abundant volcanic detritus. Primary porosity is generally low, but secondary fracture porosity can occur. This play has a total mean potential of $6.49\text{x}10^8$ m^3 (23 BCF) of gas. The Nechako Upper Cretaceous Structural Oil Play within the same package of rocks has a mean potential of $2.0\text{x}10^6$ m^3 (12.8 million barrels).

The most widespread and favourable petroleum play recognized in the assessment incorporates the oil and gas components of the Nechako Skeena Structural Play. Marine to nearshore deposition of Skeena Assemblage rocks occurred in the Early Cretaceous period. Ten gas shows were reported in well cuttings. The total mean play potential for gas is $2.47\text{x}10^{11}$ m^3 (8.74 TCF). The mean potential of the Nechako Skeena Structural Oil Play is $7.74\text{x}10^8$ m^3 (4870.6 million barrels).

The Nechako Jurassic Structural Gas Play is considered to be speculative rather than a conceptual petroleum play. Metamorphism to at least subgreenschist facies and the inherent loss of porosity resulted in the probable expulsion of any volatiles from these rocks.

The Tyaughton-Methow group of petroleum plays occupy the Tyaughton Trough located to the southwest of the Nechako Basin and the Methow Basin found along the Fraser Fault in south-central British Columbia and continuing to the south into Washington State. About 60% of the play area is found in British Columbia. Upper Cretaceous to Jurassic sediments were studied in the basin.

The youngest group of sediments considered as a possible petroleum play is the Upper Cretaceous succession. The Tyaughton-Methow Upper Cretaceous Structural Oil and Gas Play is classified as a speculative play. The lack of sufficient petroleum geological information and the fact that no oil or gas seeps or shows are reported indicates little or no confidence for hydrocarbon potential. Thus, no statistical computations were performed for these sediments.

The Skeena Assemblage is also present in the Tyaughton-Methow Basin. Although no wells have been drilled and no shows or seeps are known, it was surmised that there are sufficient similarities to the important Nechako Skeena Play to the north to justify classifying the play as conceptual. Statistical analysis was thus performed on the Skeena Group of rocks. The total mean play potential for gas is 4.2×10^7 m^3 or 1 BCF. The Tyaughton-Methow Skeena Structural Oil Play has a total mean play potential of 1.0×10^5 m^3 (0.8 million barrels).

The Jurassic Ladner Group and Jura-Cretaceous Relay Mountain Group is a significant sedimentary succession in the Tyaughton-Methow Basin. The structural gas play is classified as speculative in this assessment due to lack of porosity, significant metamorphism and the lack of any hydrocarbon show. Marine conditions prevailed during deposition of these sediments.

The conceptual Quesnel Tertiary/Cretaceous Structural Oil and Gas Play represents the youngest group of sediments containing petroleum plays in the Quesnel Trough. Fault-controlled basins that developed during extensional tectonics provided sites for deposition. Fluvial and lacustrine terrestrial sedimenatation prevails. Gas shows have been encountered during drilling. The ultimate mean play potential for gas in the play is 8.37×10^9 m^3 or 296 BCF. For oil, the potential is determined to be 1.21×10^7 m^3 (76.3 million barrels).

The highly speculative Quesnel Jura-Triassic Structural Gas Play includes volcanogenic sediments within the Nicola Group and the overlying marine sedimentary rocks of the Ashcroft Formation. Lack of porosity and heating due to metamorphism signifies the speculative nature of the play.

The total gas potential for all plays in this assessment is 2.71×10^{11} m^3 (9.56 TCF).

Total oil potential for all plays is 8.10×10^8 m^3 or 5096.9 million barrels.

Good hydrocarbon potential is recognized in the principal area of Skeena deposition in the Nechako Basin. Tertiary and Cretaceous sediments along the Fraser River south of Quesnel and in graben features in south Quesnel Trough are also considered to be good sites for potential hydrocarbon accumulations.

Secondary or medium potential is interpreted in Skeena outliers in northwestern Nechako Basin and in Tertiary sediments along the Fraser River to the north of Quesnel.

Poor and fair potential is applied to the remainder of the assessment area.

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APPENDIX 1: PROBABILITY DISTRIBUTIONS AND RISK FACTORS

(INPUT DATA)

APPENDIX 2: STATISTICAL OUTPUT

FIGURE CAPTIONS

Map 1: Nechako Oil & Gas Assessment - Tertiary Plays (Nechako Tertiary Structural (Oil & Gas), and Quesnel Tertiary/Cretaceous Structural (Oil & Gas))
Map 2: Nechako Oil & Gas Assessment - Cretaceous Plays (Nechako Upper Cretaceous Structural (Oil & Gas), Nechako Skeena Structural (Oil & Gas), Tyaughton-Methow Upper Cretaceous Structural (Oil & Gas), and Tyaughton-Methow Skeena Structural (Oil & Gas))
Map 3: Nechako Oil & Gas Assessment - Jurassic Plays (Nechako Jurassic Structural (Gas), Tyaughton-Methow Relay Mountain/Ladner Structural (Gas), and Quesnel Jura-Triassic Structural (Gas))
Map 4: Cretaceous Sedimentation in Intermontane Basins
Map 5: Nechako Oil & Gas Assessment - Hydrocarbon Potential Map

Figure 1: Structural cross-section in the Nazko area
Figure 2: Structural cross-section in the Alkali Lake/Riske Creek area
Figure 3: Field size by rank diagram of Nechako Tertiary Structural Gas Play
Figure 4: Field size by rank diagram of Nechako Tertiary Structural Oil Play
Figure 5: Field size by rank diagram of Nechako Upper Cretaceous Structural Gas Play
Figure 6: Field size by rank diagram of Nechako Upper Cretaceous Structural Oil Play
Figure 7: Field size by rank diagram of Nechako Skeena Structural Gas Play
Figure 8: Field size by rank diagram of Nechako Skeena Structural Oil Play
Figure 9: Field size by rank diagram of Tyaughton-Methow Skeena Structural Gas Play
Figure 10: Field size by rank diagram of Tyaughton-Methow Skeena Structural Oil Play
Figure 11: Field size by rank diagram of Quesnel Tertiary/Cretaceous Structural Gas Play
Figure 12: Field size by rank diagram of Quesnel Tertiary/Cretaceous Structural Oil Play