Petroleum Resource Assessment of the Whitehorse Trough, Yukon Territory, Canada

National Energy Board
for Energy Resources Branch

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Economic Development

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FOREWORD

The Government of Canada and the Government of Yukon have reached an agreement to transfer to Yukon the administrative legislative powers and responsibilities of managing onshore oil and gas resources. In the interim, officials of Canada involved in the administration of federal oil and gas legislation are cooperating and consulting with Yukon to facilitate implementing the Accord.

A study of the petroleum resources of the Yukon part of the Whitehorse Trough was undertaken by the National Energy Board (NEB) in response to a request from the Yukon Territorial Government. 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 report was undertaken by the National Energy Board (NEB) at the request of the Yukon Government's Energy Resources Branch, Department of Economic Development. The study is also important to the NEB's internal work in determining Canada's resource potential and for the NEB's current regulatory responsibilities with respect to Frontier Lands north of sixty degrees. The study's objectives were to assess the geology and petroleum resource potential of the Whitehorse Trough region within the Yukon Territory.

The study area is a triangular-shaped area with boundaries between longitudes 130° to 138°W and 60° to 62°30'N and covering an area of some 3.72 million hectares. Within the study area, no wells have been drilled nor any seismic shot.

The Whitehorse Trough is an immature, mainly gas-prone basin, containing variably preserved Mesozoic to Cenozoic strata in an intensely structured (folded, faulted and metamorphosed) intermontane setting. Potential for reservoir development exists within fractured Permian to Middle Triassic carbonates and Triassic reefs within Jurassic and Cretaceous fluvial, deltaic and marginal marine clastics, and within Quaternary clastics. Sealing potential is provided from shale, fine-grained volcanoclastics and tight carbonate. Source rocks have been identified within strata of Jurassic, Triassic and Cretaceous age. Anticlines defined on the surface pose the best primary drilling targets but the high density of faulting complicates sub-surface reservoir definition. Traps are also possible in Triassic reefs, fractured Permian carbonate and in the stratigraphic pinchout of clastic wedges of Jurassic, Cretaceous and Quaternary age. Maturity levels are variable throughout the study area from high (overmature for liquid hydrocarbons) within the axial portion of the basin, to just within the oil window on the western basin margin and in the shallower portions of the section.

This assessment has identified 8 separate plays within this gas-prone basin: 3 plays are gas with minor oil and 5 plays are solely gas; 2 of the plays are structural in nature while 6 of the plays are stratigraphic in nature. It must be emphasized that all of the plays identified within the study area are conceptual in nature and therefore highly risky. The analysis shows that there is a 52% chance that liquid hydrocarbons (oil) will exist in the basin and a 65% chance that natural gas will exist in the basin. Individual play level risk ranges from 3 to 21% while individual prospect level risk ranges from 10 to 33%. The mean recoverable oil estimate for the study area is 1.29 10^6m^3 (8.12 MMBbl) while the mean marketable gas estimate is 5,521 10^6m^3 (196 Bcf). Based on analogues, individual oil pool sizes are estimated to range from less than 0.16 to 1.59 10^6m^3 (1 up to 10 MMBbl) and gas pool sizes are estimated to range from less than 28 up to 1,416 10^6m^3 (1 up to 50 Bcf).

The 8 plays were analyzed using an evaluation model developed by staff of the NEB utilising @RISK® add-in templates for Excel spreadsheets. The @RISK® model produces estimates of the undiscovered potential resource for a play but cannot predict the remaining individual pool sizes. Since supply cost models require individual pool sizes in order to perform an analysis, no such analysis was undertaken for this study.

CONTENTS

INTRODUCTION

A study of the conventional petroleum resources of the Yukon Territorial portion of the Whitehorse Trough was undertaken in response to a request from the Yukon Territorial Government. Assessment of petroleum resource potential is important for the formation of regulatory policy with respect to these resources and to provide a basis for the planning for issuance of exploration rights. This work is also important to the NEB in fulfilling its ongoing activity of monitoring the Canadian oil and natural gas supply.

The objective of the study was to investigate the conventional petroleum resource potential in the Whitehorse region that is under the jurisdiction of the Yukon government. This report does not deal with the Coal Bed Methane (CBM) potential that may or may not exist within the study area. The study area is located in the south-central portion of the Yukon Territory between the Yukon and British Columbia border, latitudes 60˚N to 62˚30'N and longitudes 130° to 138°W (Figure3).

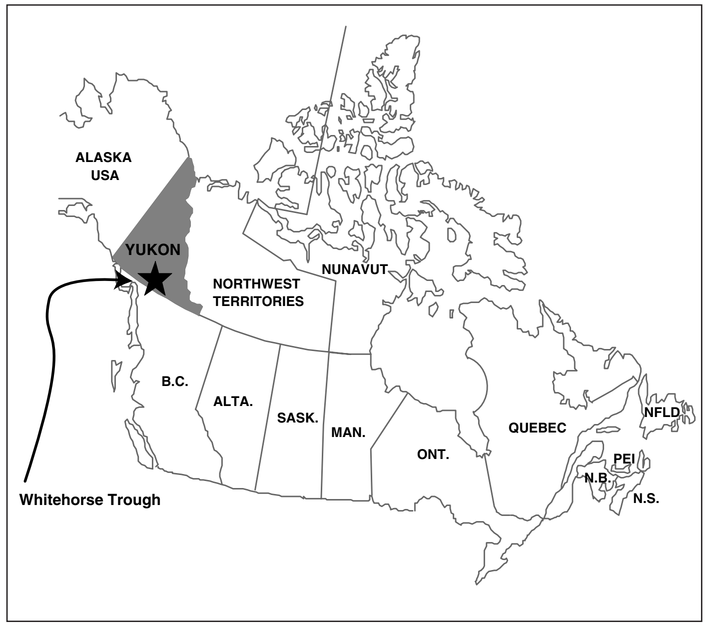


Figure 1. *Map of Canada showing study area location.*

ACKNOWLEDGEMENTS

The National Energy Board acknowledges the previous work and effort of the staff of the Geological Survey of Canada's Calgary and Vancouver offices. Their work laid the foundation for the concepts derived in this study. In particular the work of Drs. J.D. Aitken (retired) and D. Tempelman-Kluit (retired) were heavily drawn upon. Thanks are also expressed to Mr. T.D. Bird, Mr. P. Hannigan, Mr. K. Ozadetz and Drs. P.J. Lee (retired) and L. Snowdon for discussion and suggestions which led to an improvement in the original manuscript. The NEB also thanks Mr. David A. Downing of the Energy Resources Branch, Yukon Economic Development, Mr. Craig Hart of the Canada-Yukon Geoscience Office and to Gary G. Johannson for their assistance with respect to the content of this report. Finally, the NEB thanks the many members of the NEB staff for their suggestions, advice and assistance in the preparation of the play maps, schematic figures and the stratigraphic column.

METHODOLOGY

The analysis of the hydrocarbon endowment of the Whitehorse Trough study area began with the documentation and synthesis of the regional geological setting as it relates to the basin evolution, geometry, sedimentation history, geochemistry, structural history and hydrocarbon occurrence (shows and discoveries) within the study area. Documents relating to the geology and discovered resources of the study area are listed in the reference section of this report.

The initial phase of the study was supplemented with a comparative study of the geology in adjacent areas of British Columbia. This analysis was necessary in order to develop the assessment of the hydrocarbon potential of the study area. The results of this phase were then synthesized into hydrocarbon plays illustrated by schematic cross-sections and maps. These show the geologic settings of the discoveries, the parameters that control the discovered resources, and the potential for similar discoveries to those already made and for conceptual discoveries that may also be present. Within this framework, models for hydrocarbon entrapment in the study area were developed.

The geoscientific analysis was followed by a systematic statistical analysis of the undiscovered resource base, and its associated risk, utilizing a resource assessment methodology developed by NEB staff. In brief this resource assessment methodology utilizes a series of in-house developed templates created in a PC-based spreadsheet software package "Excel 5.0®" by Microsoft combined with Pallisade Corporation's "@RISK®" add-in probabilistic modelling functions. The @RISK® program "links" directly to Excel and adds risk analysis and modelling capabilities to the Excel spreadsheet models.

The probabilistic methodology utilized in the spreadsheet templates has been adapted from Roadifier (1979). A probabilistic estimate of the petroleum resources is achieved by independently multiplying randomly selected values from input distributions for hydrocarbon volume, hydrocarbon yield and risk using the following model:

Hydrocarbon Volume x Yield x Risk = Potential Resources

A full description of this methodology was included in the January 1994 NEB's *Natural Gas Resource Assessment, Northeast British Columbia*. This method has also been utilized by the NEB in the following resource assessment papers: *Petroleum Resources Assessment of the Liard Plateau Area, Yukon Territory, Canada* (November 1994), *Petroleum Resources Assessment of the Eagle Plain Basin, Yukon Territory, Canada* (November 1994), and the June 1996 *A Natural Gas Resource Assessment of Southeast Yukon and Northwest Territories, Canada*.

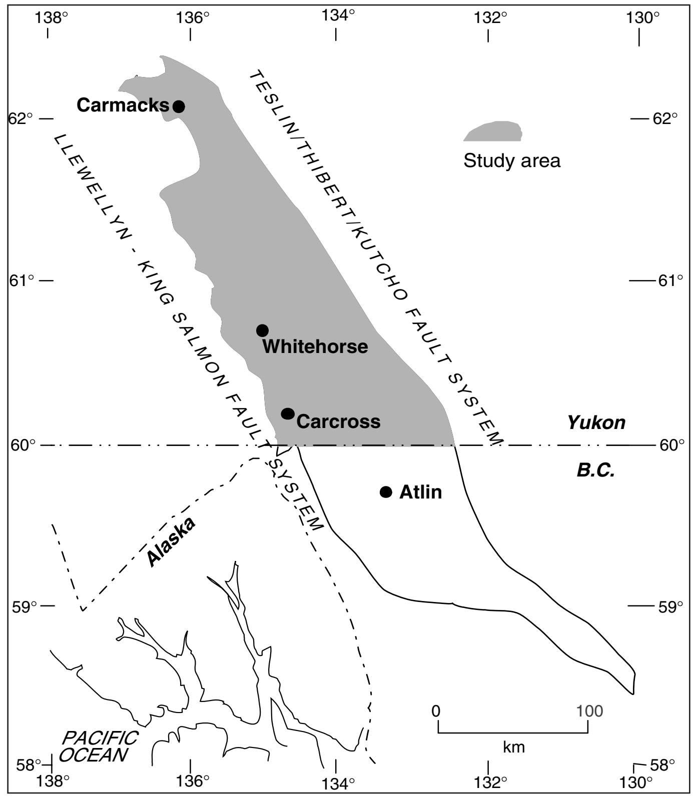
UNITS/ABBREVIATIONS

10^6m^3 - million cubic meters
ac-ft - acre feet
AOF - absolute open flow
Bbls - barrels
Bcf - billion cubic feet
BOE - barrels of oil equivalent
d - day
ft - feet
ft kb - feet below Kelly (the floor of the drill platform)
GIP - gas in place
GOR - gas/oil ratio
ha - hectares
IMG - marketable gas
km - kilometres
m - metres
md - millidarcies
mi - miles
mKb - metres below Kelly (the floor of the drill platform)
MMbbls - million barrels
MMcf - million cubic feet
psi - pounds per square inch
Tcf - trillion cubic feet

REGIONAL GEOLOGICAL SETTING

The 37,192 km^2 (13,426 miles^2) study area (Figure 2) is situated in the south-central portion of the Yukon Territory within the Canadian Cordillera. It forms a northwest-southeast finger bounded on the south by the boundary between the province of British Columbia and the Yukon Territory at latitude 60°N, on the north by latitude 62°30'N. It is bounded on the northeast by the Teslin River and on the southwest by a line running just west of Carmacks, Whitehorse and Carcross.

Figure 2. Whitehorse Trough study area.



The topography is moderately rugged with elevations ranging from 750 to 1375 m. The forested valley bottoms, containing numerous lakes and muskeg, are mantled by Quaternary glacial and recent alluvium deposits. Outcrop exposures occur at higher elevations and consist of Precambrian metamorphic strata, Paleozoic volcanics, Paleozoic and Mesozoic clastics and carbonates, Triassic, Cretaceous and Tertiary volcanics, volcanoclastics and terrigenous clastics and granitic intrusives of Jurassic, Cretaceous and Tertiary age.

Access to the area is via the Alaska Highway, the Klondike (Whitehorse to Dawson) Highway (which traverses the cental portion of the study area), by float-plane via Lake Laberge or Marsh Lake or by fixed-wing aircraft from the airstrips at Carmacks, Braeburn, Carcross and Whitehorse. The territorial capital, White-horse, has a commercial airport with scheduled flights from Calgary and Edmonton via Vancouver. Helicopter service is available from several companies located in Whitehorse and Carmacks in the Yukon Territory and from Atlin in British Columbia.

TECTONIC SETTING

In contrast to the relatively well ordered and continuous stratigraphy of the Western Canadian Sedimentary Basin, the regional stratigraphy of the study area records a complex and diverse geologic history of Early Mesozoic collisional convergence sedimentation (volcanoclastics, carbonates and clastics), Late Cretaceous to Early Tertiary convergent basin sedimentation (volcanoclastic and clastics) and Tertiary to Recent intermontane and glacial sedimentation. The lack of well control and the complex tectonic and structural histories within the study area complicate the stratigraphic picture.

For this area, the Geosynclinal Model envisioned an eastern miogeosynclinal belt of sedimentary rocks with minor volcanics and intrusives and a western eugeosynclinal belt of volcanic, intrusive and metamorphic rocks. Early assessments of the study area's petroleum resource potential used this model as the basis for their appraisals.

Detailed regional mapping within the framework of plate tectonics during the next 20 years, however, led to the construction of a model which identified 5 belts within

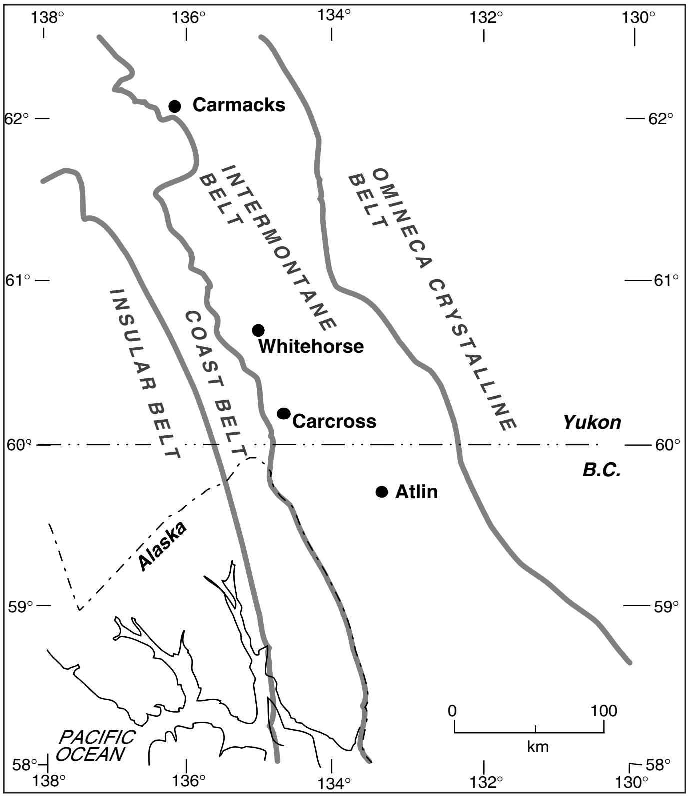


Figure 3. *Terrane map.*

the Canadian Cordillera consisting of combinations of a variety of tectonostratigraphic settings, such as volcanic arcs, oceanic crust, foredeeps, shelf and slope deposits, successor basins and plutonic and metamorphic complexes (Figure 5). From east to west the tectonostratigraphic belts are: the Foreland Belt (not shown on Figure 5), the Omineca Belt – pericratonic and displaced terrane strata, the Intermontane Belt, the Coast Belt – plutonic and metamorphic rocks, and the Insular Belt.

Refinement of Monger et al's model led to the development of the Tectonic Assemblage Model, a model that envisions a tectonic collage of terranes (distinct stratal associations) each characterized by a stratigraphy and geologic history that sets each terrane apart from the adjacent terrane and from the strata of the North American craton. Studies have shown that the rocks comprising these terranes were deposited at different locations from where they are currently located and that the terranes were subsequently moved into place through the action of plate motions.

Within the confines of the study area, the Intermontane Belt is represented by the following major tectonostratigraphic elements that reflect phases of interaction between the various terranes and between the terranes and the North American craton including: the Cache Creek (Atlin) Terrane, Stikine Terrane, the Upper Triassic to Upper Jurassic Whitehorse Trough and the Upper Jurassic to Lower Cretaceous Whitehorse Basin. The interactions can be summarized by the following phases:

Phase 1: A phase, during the pre-Mesozoic, that records a series of ocean basin formation and subduction cycles;

Phase 2: A phase, during the Upper Triassic to Middle Jurassic, of collisional convergence of the allochthonous Stikine and Cache Creek Terranes outboard of the margin of ancestral North America and of volcano-plutonic arc-related flysch sedimentation in the Whitehorse Trough;

Phase 3: A phase, during the Upper Jurassic to Lower Cretaceous, of convergent basinal sedimentation that resulted in the formation of the Whitehorse Basin when the terranes accreted to the North American craton;

Phase 4: A phase, during the Upper Cretaceous to Tertiary, of volcanoclastic-related tectonism and erosion;

Phase 5: A phase, during the Upper Pliocene to Quaternary, of intermontane glaciation and basin sedimentation.

STRATIGRAPHY

The stratigraphy of the study area is summarized in Figure 4 and can best be described using the tectonostratigraphic phases identified on the previous page.

PHASE 1: PRE-MESOZOIC OCEAN BASIN FORMATION AND SUBDUCTION

Along the margins of the study area, the effective basement is formed by strata of the Precambrian Yukon-Tanana Terrane (part of the Nisling Terrane and formerly called the Yukon Group) and the Lower Carboniferous to Triassic Cache Creek Terrane. The Cache Creek strata record a series of oceanic basin formation and subduction cycles.

Rocks of the Yukon-Tanana Terrane lie along the western and northern margin of the study area and are represented by a sequence of quartzites, and quartz-rich gneisses and schists that occur in discontinuous overturned fold belts trending northwest. These rocks are unconformably overlain by strata of the Triassic Lewes River Group, the Jurassic Laberge Group, the upper Jurassic Tantalus Formation, and Upper Cretaceous and Tertiary Skukum Group volcanics (Carmacks and Mt. Nansen).

In the southern and eastern portions of the study area, strata of the Cache Creek Terrane form the “effective” basement. Monger (1975; 1977) subdivided the Cache Creek Terrane into three distinct “facies” belts: the Nakina, Sentinel, and French Ridge Subterranes (Assemblages). The Lower Carboniferous to Middle Triassic Nakina Assemblage is composed of the Nakina Formation, a series of basic volcanic and flow breccia (amygdaloidal basalt, volcanic breccia, tuff) and small limestone pods containing Upper Visean to Upper Namurian foraminifers that overlie the Nahlin ultramafic rocks. Gradationally overlying the Nakina Formation is an unnamed massive crinoidal calcarenite and tuffa. Overlying this unnamed unit is the Horsefeed Formation, an Upper Namurian to Upper Permian grey to black and buff weathering, massive, poorly bedded, calcarenitic, fossiliferous limestone (crinoids, fusilinids, and foraminifers with local brachiopod coquinas). The Upper Horsefeed Formation is locally composed of a dolomitic algal oolite or laminite with occasional pillowed mafic volcanics and tuff. Sectioned fossils show carbonaceous (bitumen?) coatings (Aitken, 1959). This formation is restricted to the southwestern-most portion of the Whitehorse map sheet (NTS 105D) in the vicinity of Tagish Lake where it outcrops and has an estimated thickness of 2,000 m. The unit thins northward and north-westward. However, Campbell (1967) noted the presence of small lenses of cherty limestone similar to the Horsefeed Formation at the base of the lower Triassic volcanic sequence (Kutcho Formation) in the Glenlyon map sheet (NTS 105L). This may suggest the presence of Horsefeed Formation equivalents in the sub-surface of the northern portion of the study area. Disconformably overlying the Horsefeed Formation is an unnamed carbonate breccia containing Middle to Upper Permian clasts. This breccia is gradationally overlain by an unnamed Middle to Upper Triassic radiolarian chert.

The total Nakina assemblage was estimated by Aitken (1959) to have a thickness in excess of 6,100 m. The Nakina subterrane sediments record a transition from an oceanic platform volcanic setting to a shallow water setting where the algal carbonate of the Horsefeed Formation developed as atoll reefs on the marine basalt substrata of the Nakina Formation. A lowering of the Triassic sea level, recorded by the unnamed carbonate breccia, terminated the reef Permian growth and resulted in the deposition of the radiolarian chert, pelagic sediments (Monger et al, 1991; Gunning, 1993). To the east of the Nakina Assemblage lies the Upper Carboniferous to Permian Sentinel Assemblage which comprises deeper water facies of the Nakina Assemblage strata. East

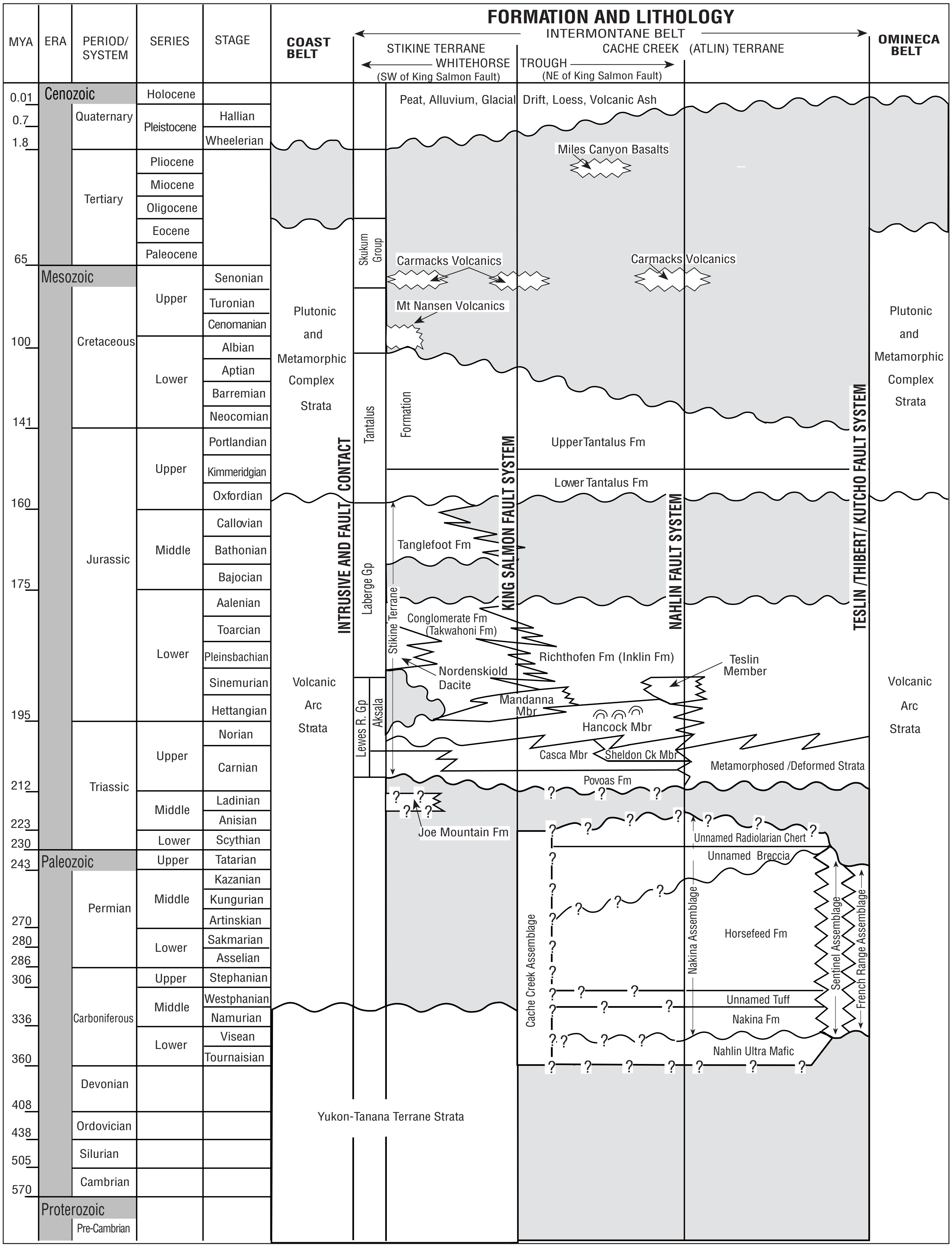


Figure 4. *The stratigraphy of the study area.*

of the Sentinel Assemblage lie the strata of the Lower Carboniferous French Range Assemblage which is composed of cherts, argillites and volcanoclastic material.

Along the eastern margin of the study area, the Cache Creek Terrane strata are in fault contact (King Salmon Fault system) with strata of the Stikine Terrane (Lewes River and Laberge Group strata). Contact relationships on the western margin are obscured by the intrusive plutonism, metamorphism, and faulting associated with the Coast Plutonic Belt.

PHASE 2: EARLY MESOZOIC COLLISIONAL CONVERGENCE AND THE FORMATION OF THE WHITEHORSE TROUGH

In the Early Mesozoic, a phase of collisional convergence of the allochthonous terranes (Stikinia and Cache Creek) occurred along the plate margin of ancestral North America. This convergence resulted in the formation of a syntectonic volcano-plutonic fore-arc related flysch basin, the Whitehorse Trough, in which more than 10,000 m of Upper Triassic to Middle Jurassic strata were deposited. The present outline of the Whitehorse Trough is confined to a narrow north-south trending belt 70 km wide and about 600 km long (from about Minto, Y.T. to Dease Lake, B.C.) whose depositional axis lies just east of the current position of Lake Laberge in the Yukon Territory.

Strata of the Lewes River Group comprise up to 7,000 m thick succession of basalts, andesites, flow breccia and tuff associated with carbonate, clastics and shale. Within the study area the Lewes River Group can be sub-divided into the Povoas and Aksala formations. The Povoas Formation, an Upper Triassic massive green to greenish-black epidotized andesitic basalt and tuff breccia, is found at the northern and southern ends of the study area (Carmacks, western Aishihik, Bennett, and Atlin map sheets). The Povoas Formation has a variable thickness with the greatest thickness lying just west of the current position of Lake Laberge (along the depositional axis of the Whitehorse Trough) where it is estimated to be 1,000 to 2,000 m thick (C.J.R. Hart per. comm). The Povoas Formation records a series of catastrophic volcanic events (both pyroclastic and autoclastic) separated by relative quiescence.

Unconformably capping the rocks of the Povoas Formation are strata of the Aksala Formation. The Alsaka Formation is composed of clastic and carbonate strata of the Casca, Hancock and Mandanna Members. These strata represent the products of competing deposition within the Whitehorse Trough: carbonate deposition during quiescent times, volcanoclastic beach development and tidal flat incursions in a shallow marine environment during more volcanically active times. Strata of the Aksala formation have been laid down on and around remnant highs of the Povoas Formation (Reid and Tempelman-Kluit, 1987). The lowermost unit, the Casca Member, is Carnian to Norian in age and consists of black to greenish-grey shale, greywacke and feldspathic, microcrystalline dense fossiliferous limestone (pelecypods, ammonites, and crinoid stems). Thickness estimates for the Casca range from 600 to 925 m. The Casca is equivalent to Tozer's (1957) Unit A of the Lewes River Group and possibly equivalent to the Norian Sinwa Formation, a massive fetid limestone up to 250 m thick that occurs south of the study area. The Sheldon Creek Formation is a recently defined lateral equivalent of the Casca Member.

Disconformably to conformably overlying the Casca member are the Carnian to Norian resistant weathering, massive to thick bedded, fossiliferous limestone with minor thin bedded argillaceous limestone of the Hancock Member. The unit is present in the

Whitehorse, Laberge and Carmacks map areas. The unit occurs as discontinuous lenticular asymmetric "reefal" bodies (semi-circular and elongate in shape) in a 30 km wide belt that approximately runs parallel to the Klondike Highway between Whitehorse and Carmacks. The best reefal development occurs in a 10 km belt within the wider area. Fringing, patch, bank reefs and algal mat buildups have been recorded. The sandy to muddy calcareous reefal mound complexes are composed of frame building "Tethyan" calcareous sponges, spongiomorphs and corals and nonskeletal pelloidal precipitate limestone (bacterial origin) with inter-mound bedded tabular limestone up to 30 m thick. Fauna within the reef communities are described in detail by Reid (1982, 1987) and Senowbari-Daryan and Reid (1987). An excellent exposure of one of these reef complexes occurs at Lime Peak (40 km northeast of Whitehorse) and has been documented by Reid (1985). These shallow water carbonate complexes have been shown by Reid to range from mounds over 100 m thick to tabular reefs 30 m thick. Outcrop of the carbonate reef complexes within the Laberge map area are locally bituminous, particularly in the back reef facies. Local detailed stratigraphy suggests that the fore-reef was to the north and east where reef talus debris aprons are often apparent (limestone boulders up to 5 m across encased in carbonate sand and mud) and that the back-reef and lagoonal facies was to the south and southwest. The reefs tailout gradually to the back-reef facies of thin bedded impure lime sands and muds, and further back into coarse mature quartzose sandstone. Detailed stratigraphic work by Reid at Lime Peak and Tozer near Casca Creek have shown that the reefal complexes involved multiple growth periods stacked one on top of another. The Hancock member is equivalent to Tozer's (1957) Units C, E, upper F and G. Estimates of the total thickness for the Hancock range from 450 to 700 m.

These reefal complexes are surrounded by volcanoclastics and clastics of the Mandanna and Teslin Members, Norian to Sinemurian sequences of red weathering grey, green and red greywacke and pebble conglomerate with minor red shale partings and interbeds of red shale and siltstone and associated volcanoclastics. The Mandanna Member is mainly restricted to the Laberge map area and is interpreted to be nearshore marine to beach deposits and is equivalent to Tozer's (1957) Units B, D and lower F. Estimates of the total thickness for the Mandanna range from 270 to 650 m.

During the Sinenurian, the sedimentation pattern changed from Lewes River Group carbonate production to fore-arc-basin, alluvial and marine clastic deposition of the Laberge Group. Laberge Group strata disconformably overly the Lewes River Group strata and form distinctive red-brown weathering northerly to northwesterly elongated outcrops that occupy most of the topographic highs in the study area. Total thickness of the Laberge Group is uncertain due to post-depositional erosion and structural complications. However, several estimates have been made: 1,200 m (Cairns, 1910); 1,400 to 1,700 m and up to 2,700 m west of Lake Laberge (Bostock and Lees, 1938); 2,130 m near Takhini Hot Springs (Wheeler, 1961), and 3,000 metres (Dickie and Hein, 1995). The Laberge Group can be subdivided into 4 formations: a proximal coarse clastic unit derived from Stikinia; the Conglomerate Formation, a distal basinal shale unit; the Richthofen Formation, an epiclastic and dacitic tuff and ash flow; the Nordenskiold dacite; and a deltaic to shallow marine clastic unit — the Tanglefoot Formation (Tempelman-Kluit; 1984).

These Lower Jurassic clastic units were derived from older volcanic and coastal sediment and record a transitional arc setting. Turbidity currents transported Upper Triassic mixed volcanoplutonic and sedimentary clastic material eastwardly into the Whitehorse Trough. Long shore drift dispersed these sediments north-northwesterly along the basin axis creating smeared submarine fan systems. Johannson (1994) suggests that this depositional cycle began, during the Lower Hettangian to Upper Sinemurian, with a period of stable tectonics and relatively quiescent volcanism. The Hettangian to Bajocian Conglomerate Formation represents this sediment cycle and disconformably overlies the Lewes River Group in the western portion of the Whitehorse Trough. It interfingers in the eastern and central portion of the study area with the Richthofen Formation. The Conglomerate represents a southwesterly derived proximal facies strata derived from, and deposited on, the Stikine Terrane. These strata are referred to south of the study area as the Takwahoni Formation (Souther; 1971) and previously as the Middle Laberge Formation. The formation consists of interbedded massive dark-grey to brown-grey conglomerate with minor amounts of greywacke, siltstone and shale. The conglomerate contains well rounded cobbles and boulders up to 3 m across (usually less than 1 m). The cobbles are usually of igneous origin but occasionally are limestone or sandstone. Wheeler (1961) suggests a possible origin as that of a talus at the base of a sea cliff. The thickness of the Takwahoni Formation varies over the study area but generally appears to thicken to the south and west. Published thicknesses range from 75 m at Mandanna Lake (30 km southeast of Carmacks) to 210 m just west of Coghlin Lake (about 75 km north of Whitehorse) to 450 m just north of Takhini Hot Springs to 1,600 m west of Whitehorse.

The Lower to Middle Jurassic (Hettangian to Bajocian) Richthofen Formation consists of Laberge Group strata in the eastern and central portions of the Whitehorse Trough that record a complex arc-basin evolution during the linkage of the Stikine and Cache Creek Terranes. The Richthofen Formation consists of easterly derived, proximal and southwesterly originating, distal facies composed of interbedded brown to dark-grey to black deep water shale, dark-grey to green-grey siltstone, maroon and grey-brown to tan fine-grained shaley proximal sandstone and occasional red weathering poorly sorted conglomerate of a turbidite origin. The maroon sandstone and the conglomerate are restricted to the northern part of the study area. In the area east of Takhini Hot Springs, the Richthofen Formation is represented by a few hundred feet of greenish-grey blocky shale and dark-grey calcareous silty sandstone. These sediments are defined to the south in British Columbia as the Inklin Formation or previously as the Lower Laberge Group. The total thickness can exceed 1,200 m.

Early Pliensbachian petrofacies indicate a change from the previous phase of arc dissection to one of rejuvenated arc volcanism with the deposition of the Nordenskiold dacite. The Nordenskiold dacite has a gradational to interfingering contact with the Takwahoni formation and consists of dark-grey, massive, reddish-brown weathering 30 to 50 m thick dacite with phenocrysts of quartz, feldspar, biotite and hornblende in a cryptocrystalline groundmass and a reworked tuffaceous sandstone up to 800 m thick. This unit is primarily located in the Whitehorse, Laberge and Carmacks map areas.

Early Pliensbachian paleocurrent studies (Johannson; 1994) indicate a period of bidirectional radial paleoflow. Late Pliensbachian petrofacies indicate a change in the sedimentation pattern to one of mixed volcanoplutonic material dominated by granitic constituents which record a new phase of arc evolution where active tectonics and high sedimentation rates resulted in a major progradational-aggradational northeastwardly pulse that subdued the previous outer margin topography. In the vicinity of Teslin Crossing, a localized Middle Jurassic (Bajocian to Bathonian) leucocratic monzonite, syenite and granite has been recognized and called the Teslin Crossing Stock. In dikes, it is composed of dacite and andesite porphyry. This occurrence seems to be limited to the Laberge map area.

Unconformably overlying the Conglomerate and Richthofen formations are deltaic to shallow marine clastics of the Tanglefoot Formation. These strata were previously referred to as the Upper Laberge Formation. The Tanglefoot Formation consists of 550 to over 600 m of coarse-grained, dark-green, dark-yellow and white arkosic and feldspathic sandstone with occasional dark shale and thin coal seams near the top of the succession. These strata appear to thicken to the south and west.

PHASE 3: CONVERGENT BASINAL SEDIMENTATION THAT PRODUCED THE SUCCESSOR COAL BASIN - WHITEHORSE BASIN

The Upper Jurassic represents a shift from terrane-specific sedimentation (volcanic and plutonic dominated) to sedimentation patterns reflecting the suture of the Intermontane super-terrane to the North American craton. The suturing of Intermontania to the craton together with the formation of the Stikine Arch to the south of the study area resulted in the formation of the Whitehorse (Tantalus) Basin — a depositional clastic basin with its basin axis approximately along Lake Laberge. Uplift and erosion of the sutured terranes produced a clastic overlap assemblage wedge, the Tantalus Formation which unconformably overlies the deformed Jurassic Laberge Group strata. In the northern part of the study area (especially in the vicinity of Carmacks) small preservational remnants (up to 1,200 m thick but averaging 650 m) of Tantalus Formation fluvial derived chert-rich conglomerate and paralic conglomeratic sandstone, medium- to fine-grained sandstone, shale and coal are found. The thickest occurrences of these sediments are believed to have been deposited in small sub-basins possibly related to Lower Cretaceous transcurrent faulting.

PHASE 4: A PHASE OF VOLCANOCLASTIC RELATED TECTONISM AND EROSION

In the southwestern corner of the Whitehorse map area, scattered small outcrops of Lower Aptian-aged ultramafic intrusives (peridotite, dunite, serpentinite and pyroxenite) are mapped as intruding Yukon-Tanana Terrane and Lewes River Group strata. In the same area, scattered outcrops of Paleocene to Eocene Skukum Group (Carmacks, Little Ridge and Mt. Nansen volcanics) remnant calderas (pyroclastics and subordinate lavas) unconformably overlie Yukon-Tanana Terrane and Tantalus strata. Miocene to Pliocene Miles Canyon basalts locally unconformably overlie the Triassic to the Cretaceous strata and range in thickness from 20 to 50 m but may reach up to 100 m.

PHASE 5: A PHASE OF INTERMONTANE GLACIATION AND BASIN SEDIMENTATION

Glacial drift, alluvium, loess and volcanic ash of Upper Pleistocene to Holocene extends over much of the area and is preserved mainly in the valley floors of the synclines. In the central and eastern portions of the study area, the thickness varies from less than 1 m to greater than 100 m. The thickest deposits are often found in the main river valleys and may reflect to some extent the pre-glacial and post-glacial drainage effects. Glaciation has also left a pronounced lineation pattern on the landscape, observable from the air, with a east-northeast to west-southwest trend of parallel drumlins and drumlinoids and northwest-southeast trending moraines.

STRUCTURAL GEOLOGY

REGIONAL STRUCTURAL STYLE

The style and geometry of structures in the study area vary with rock type and location. Broad folds prevail in thick volcanic sequences while tight folds, often associated with thrust faults, prevail in sedimentary strata. Some overturning of fold limbs is apparent in the central portion. The study area is further traversed by northwesterly trending basin bounding faults of Late Cretaceous and Tertiary age which show a dextral, normal strike-slip nature. These faults are at right angles to the principal Cretaceous and Tertiary compressional direction. Post-Cretaceous shear related faulting is evident and has resulted in a high density of subsidiary faulting and parasitic folding which complicates the original structural geometry. Intensity of the deformation appears to decrease in directions away from the current axis of the basin (approximately parallel to Lake Laberge) (Figure 5).

LOCAL STRUCTURES:

Numerous northwest trending anticlinal folds are present throughout the study area. The most significant are Belleview Mountain, Braeburn Mountain, Contact Mountain, Mistake Mountain, Surprise Mountain and the Takhini and Tower anticlines. The following details pertaining to each structure were excerpted from NEB Report No. 5-1-1-17.

The Belleview Mountain Anticline, located 14.5 km south-southwest of Braeburn Lodge at the north end of the Miners Range (at approximately 61°20'N and 135°54'W), is a northwesterly trending anticlinal feature (5.5 km long by 0.8 km wide) of exposed

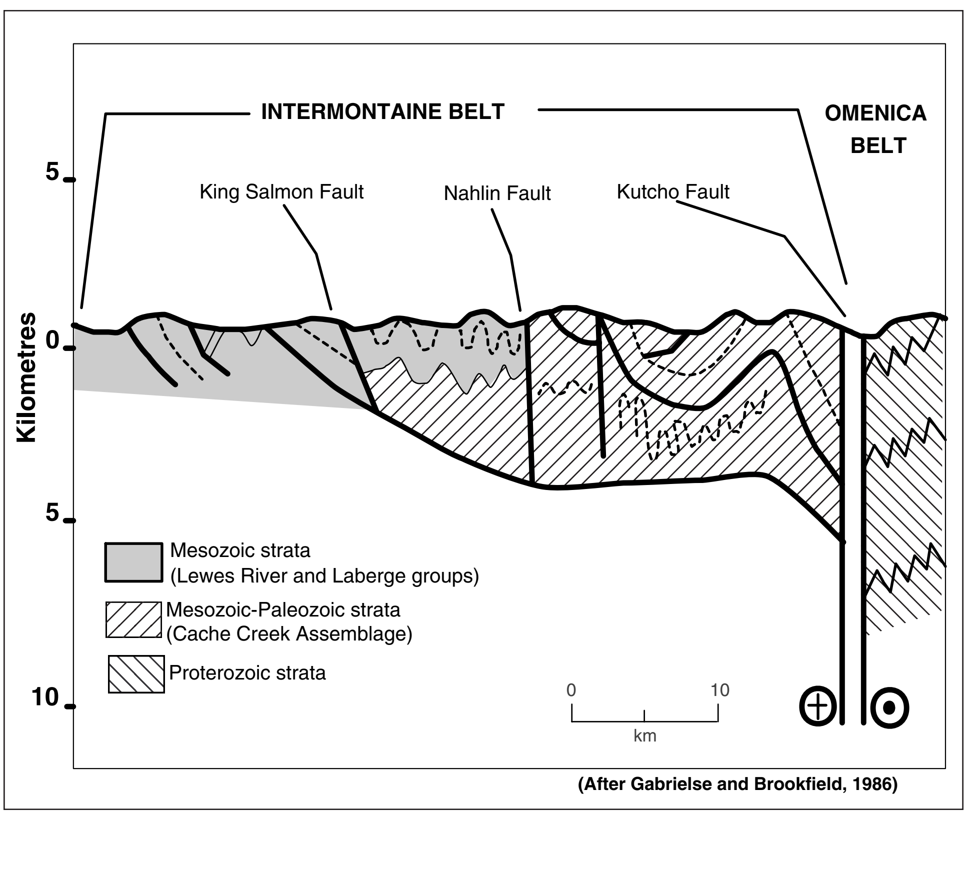


Figure 5. *Schematic cross-section.*

Takwahoni Formation strata with good closure and steeply dipping flanks that is cross cut by a northwest-southeast trending fault that is upthrown to the northwest. Therefore, there is a distinct possibility that Inklin Formation siltstone and shaley sandstone, and Lewes River Group Mandanna Member clastics and Hancock Member carbonate may be in a position to create a suitable trap for hydrocarbons.

The Braeburn Mountain Anticline, located 6.4 km south of Braeburn (at approximately 61°26'N and 135°41'W), is northwest-southeast trending, steeply dipping anticlinal feature with a bifurcated axis that has exposed uppermost Takwahoni Formation strata along its crest. Inklin Formation siltstone and shaley sandstone and Lewes River Group-Hancock Member carbonate are postulated to be in a structural position to create a suitable trap for hydrocarbons.

The Contact Mountain Antiform, located 9.6 km southwest of Braeburn Lodge (at approximately 61°26'N and 136°W), is a simple northwest trending structural antiform flanked by prominent synforms. Approximately 9 km long and 3.5 km wide, it is composed of exposed Takwahoni Formation and the uppermost part of the Inklin Formation strata. Two well-defined closed highs can be inferred from photogeologic evidence.

The Mistake Mountain Anticline, located at the north edge of Lake Laberge (at approximately 61°25'N and 135°25'W), is a complicated northwest trending antiform, 6.4 km long by 2.4 km wide, that is highly dissected by northeast to southwest trending faults. The structure has exposures of Takwahoni Formation on its southern flanks while Lewes River strata outcrop along the northern and western flanks.

The Surprise Mountain Anticline, located 10 km west and north-west of Lake Laberge (at approximately 61°24'N and 135°26'W), is a feature that has two closures separated by a saddle containing an overturned section of Inklin Formation strata and an east-west scissor fault. A fault at the northeast end of the structure juxtaposes Lewes River Hancock Member against Laberge clastics.

The Tower Anticline, located 8 km southwest of Lake Laberge and just northeast of Takhini Hotsprings (at approximately 60°56'N and 135°13'W), is a sharp asymmetrical fold trending west northwest of Inklin Formation strata. Targets in this structure would be Lewes River Group strata. Sulphur springs associated with a northeast trending fault are reported on the east side of the structure.

The Takhini Anticline, located directly northeast of Takhini Hotsprings at Flat Mountain (61°N and 135°21'W), is a Lewes River Group and Laberge Group structure with fault bounded closure, and may have potential for Lewes River Group hosted hydrocarbons.

REGIONAL GEOCHEMISTRY

Questionable reports of oil and natural gas seeps have been reported throughout the study area. None of the reports have been positively verified to date. Reports of marsh gas “fireballs,” ignited by passing automobiles and trucks, have also been reported in the area. A biogenic origin for this gas seems to be the most plausible explanation for the fireball phenomenon. An additional questionable gas seep is reported at Takhini Hot Springs (per comm. K. Osadetz, GSC Calgary). Sulphurous springs with hydrocarbon residues have been reported at numerous sites associated with cross cutting faults in the Laberge and Lewes River Group strata.

Oil seeps and slicks have been reported at Swan Lake (60°53'N 135°05'W), Crag Lake (60°13'N 134°33'W), Cowley Lake (60°31'N 134°54'W) and Flat Creek (60°54'N 135°30'W). In late 1986, the reported oil seeps and slicks were sampled by local residents with the assistance of Petro-Canada and were analyzed in early 1987 by the scientists at the GSC Calgary. Analysis of the samples indicates that the most likely origin is from spills of refined petroleum products rather than naturally occurring oil. Only the Crag Lake sample has the necessary attributes that may indicate the presence of a potential but highly questionable petroleum seep from Laberge Group strata (per. comm. L. Snowdon, GSC Calgary).

In conjunction with the 1986/87 seep study, Petro-Canada carried out a reconnaissance geochemical survey of the Whitehorse area (NEB Report No. 9137-P28-1E Part 2). Total Organic Carbon (TOC) within the Tantalus Formation suggest that the central portion of the study area (paralleling Lake Laberge and passing through Whitehorse) has little source potential (TOCs less than 1%) while areas to the north-east and southwest have reasonable to good source potential (TOCs over 1%). Hydrogen Index (HI) for this horizon show that the area around Carmacks is oil prone while the rest of the area is gas prone to inert. Maturity indicated Vitrinite reflectance (%VR_0) is highly variable but in general shows that the basin axis exceeds a 2.0%VR_0 (semi-anthracite coal rank) while the eastern and western flanks are less mature (1.5 to 1.75%VR_0) and in the vicinity of Carmacks maturity values are in the oil window.

Unaltered coal ranks within the Tantalus Formation are estimated to be medium to low volatile bituminous (Hunt and Hart, 1993). Locally, near volcanic sills, measured vitrinite reflectance on Tantalus coal samples (sub-bituminous to high volatile A bituminous and meta-anthracite) have been found. The background maturity is 1.73%VR_0, but this number approaches 3.81%VR_0 near a sill (Hunt and Hart; 1993). Additional vitrinite reflectance measurements adjacent to another sill indicate a wide range of values from nearly 5.00%VR_0 adjacent to the sill to 2.65%VR_0 at only 100 cm away from the sill (Goodarzi and Jerzykiewicz, 1989; Hunt and Hart, 1993). It is important to note that the local intrusive activity has obviously affected the maturity grade of the Tantalus Formation. Widespread regional conclusions concerning the overall maturity of the Tantalus strata away from the sampling location may be tenuous at best.

Within the Laberge Formation the organic richness appears, from the very limited data, to be richer in the west (greater than 1% TOC) than in the east (less than 1% TOC). Proneness data indicates that the Laberge strata are generally gas prone but that in the west central and central areas (area around the north end of Lake Laberge and in the Richthofen Valley and Miners Range) there may be some minor oil potential. Maturity indicators show that, as with the overlying Tantalus Formation, the basin axis and eastern flank from Whitehorse along Lake Laberge through to Carmacks is over mature (ie in the gas window). The western flank of the basin from the Miners Range to near Double Mountain is at the late stages of oil maturity.

Organic richness within the Hancock Member of the Aksala Formation appear, from the very limited data, to be richer in the west (between 0.5 and 1% TOC) than in the east (less than 0.5% TOC). Proneness data indicates that this section is entirely gas prone. Maturity indicators show that the area is within the dry gas zone.

No organic richness, proneness or maturity data is available for the Horsefeed Formation and the unnamed breccia of the Cache Creek Assemblage.

PETROLEUM GEOLOGY

EXPLORATION HISTORY

The first published report on the fossil fuel potential of the Whitehorse area was by McConnell (1901) where he documented the presence of a high ash anthracite seam. D.D. Cairns of the Geological Survey of Canada (1908 and 1910) published the results of a detailed examination of the coal geology of the study area and confirmed the area as a fossil fuel bearing region. Cairns' work was followed up by Bostock (1936, 1960) and Aitken (1959) who further outlined the stratigraphy and structural geology of the area. Exploration for coal continued in the area with the granting of coal exploration licenses to the US Army Core of Engineers in 1942, Luscar Ltd. in 1969, Savage in 1976 and the Whitehorse Coal Corporation from 1982 to present. Coal deposits are principally located in the Upper Jurassic to Lower Cretaceous Tantalus Formation. Coal rank ranges from anthracite at the Braeburn deposit to moderate to high volatility bituminous.

The first recorded evidence of active petroleum exploration in the area began in the 1950s with permitting of 18 grid blocks on four permits totalling 437,101 ha. The permits were held by Yukon Exploration and Development Ltd. and by George Pearly-Robertson as an agent for an unknown company. Work on the permits consisted of regional geological analysis for prospectivity. All the permits were surrendered by 1960. Prior to 1953, all petroleum permitting in this area was in the form of staked mineral claims. Unfortunately there is no record of which claims were staked solely for the purpose of petroleum exploration. Therefore, it is uncertain if any petroleum exploration activity was carried out prior to 1953.

From 1961 to 1970, 26 petroleum exploration permits covering 48 grid blocks (1,146,170 ha) were active in the study area. The permitting was undertaken by the following: a consortium of Ensign Oil Ltd., Gyer Oil Ltd., Ft. Reliance Exploration and Redstone Mines; by J. Francois Lemieux as an agent for an unknown company (possibly Dome Petroleum Ltd.); by Bruce W. Baker as an agent for an unknown company (possibly Yukon Exploration and Development Co. Ltd.); by Ken E. Shortt as an agent for an unknown company (possibly Yukon Exploration and Development Co. Ltd.); and by Richard V. Lindsay as an agent for an unknown company (possibly Ensign Oil Ltd.). All of these permits have since expired. Work on the permits consisted of regional geological analysis for prospectivity (NEB Reports No. 683-2-1-1 and 798-1-1-1).

From 1971 to 1980, 2 petroleum exploration permits covering 16 grid blocks (382,057 ha) were active in the study area. The permitting was undertaken by the following: a consortium of Ensign Oil Ltd., Gyer Oil Ltd., Ft. Reliance Exploration and Redstone Mines; and by J. Francois Lemieux as an agent for an unknown company (possibly Dome Petroleum Ltd.). All of these permits have since expired. Work on the permits consisted of regional geological analysis for prospectivity (NEB Reports No. 683-2-1-1 and 5-1-1-17).

From 1981 to the present, no permits were recorded in the study area. In 1985 Petro-Canada carried out field work in the Whitehorse area (NEB Reports No. 9137-P28-1E Parts 1 and 2) with the purpose of evaluating the section for petroleum prospectivity. Samples were collected for geochemical and reservoir analysis. This study identified areas of oil and gas potential in several separate zones within the study area.

It is important to note that in the early 1980s there was a radical change in the view of the geologic history and setting for the study area. When combined with the recently collected geochemical data, it suggests a much greater prospectivity for the area than was previously thought. Currently, there are no active petroleum permits or leases within the study area. No petroleum exploration or development wells have been drilled in the study area nor has any seismic been shot. It is doubtful that a deep reflection seismic acquisition program would prove effective due to the structural complexity and the amount of intrusive and extrusive material in the section.

DISCOVERED RESOURCES

No hydrocarbons have been discovered by drilling within the study area. However, there are abundant coal measures (bituminous to semi-anthracite grade) in the Tantalus Formation which may be capable of producing methane gas related to maturation of the coal seams. This report does not cover the potential associated with coal bed generated methane (CBM).

POTENTIAL RESOURCES

PREVIOUS ESTIMATES

Estimator	Date	Base Case Estimate	Median Estimate	High Case Estimate	Estimation Method/ Comments
Koch	1973	oil: na; gas: 25,000 10^6m^3 (0.9 Tcf)	oil: na; gas: 65,000 10^6m^3 (2.3 Tcf)	oil: na; gas: 116,000 10^6m^3 (4.1 Tcf)	Estimate based on Volumetric gas yield assumed at 270 mmcf/mi³; no oil yield or estimates given
Procter et al	1983	oil: na; gas: 40,000 10^6m^3	oil: 50 10^6m^3; gas: 270,000 10^6m^3	oil: 110 10^6m^3 gas: 760,000 10^6m^3	Estimates are for whole cordilleran basins (Whitehorse, Bowser, Nechako,...) not just for Whitehorse; no breakout or method of evaluation given.
McCrossan and Porter	1973	oil: na; gas: 60 MMcf/mi³	oil: na; gas: 150 MMcf/mi³	oil: na; gas: 270 MMcf/mi³	volumetric yields only given; qualitative comments: oil potential very poor; gas potential poor

Table 1. *Published estimates of the potential of the Whitehorse Trough.*

PETROLEUM PLAYS

For the purposes of this study, discovered hydrocarbon occurrences (pools) were grouped into plays. A **play** is defined as a family of pools (discovered occurrences of oil and/or gas) and/or prospects (an untested exploration target within a single stratigraphic interval; it may or may not contain hydrocarbons; it is not synonymous with an undiscovered pool) that share a common geological characteristics and history of hydrocarbon generation, migration, reservoir development and trap configuration (Energy, Mines and Resources Canada, 1977). Plays can be further subdivided into three types: an **established** play, one which is demonstrated to exist by virtue of discovered pools with established reserves and in which there is more than six discoveries; an **immature** play, one which by geological analysis, hydrocarbon shows and discoveries has been demonstrated to exist but for which there are less than six discoveries; and a **conceptual** play, one which by geological analysis is reasonably certain to exist, but for which there are no hydrocarbon discoveries or “shows.”

According to these definitions 8 conceptual petroleum plays were identified within the study area: 3 gas with minor oil potential and 5 with gas potential.

All the plays are based on analogies with established plays in other basins, on the current view of the structural and sedimentological setting, and on regional geochemical information. No attempt was made to quantify the Coal Bed Methane potential (CBM) of the area. The CBM potential has been evaluated at the Division Mountain coal field (Beaton, A.P., 1992). The CBM potential of northern coal basins is currently under review by geoscientists at the Geological Survey of Canada – Calgary.

PLAY SHEETS

As part of the potential resources a play sheet was prepared for each play. Each play sheet provides a description of the geology and a discussion of the area potential. Included on the play sheet is a map showing the area of potential, and a schematic cross-section showing the key elements of the play. On the page following the play sheet is the @RISK data input sheet and a results sheet.

Carboniferous Permian

CACHE CREEK–NAKINA CARBONATE

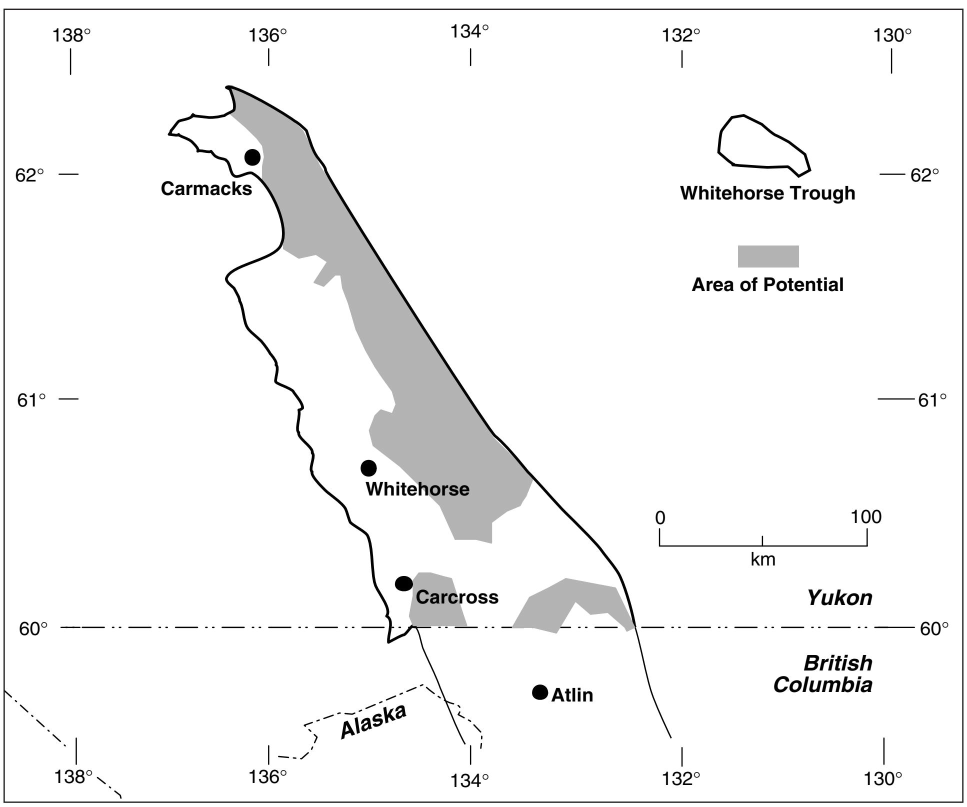
CONCEPTUAL GAS PLAY

Reservoir definition

This conceptual dry gas play is defined to include all pools and prospects within fractured cherty carbonate of the Nakina Assemblage of the Cache Creek Group (Upper Horsefeed Formation and the overlying unnamed brecciated carbonate). The play area considered in this study covers approximately 19,400 km^2 and is limited on the east by the Semenof-Teslin Fault System, on the north and west by the Carcross-Tagish Lake-Teslin Lake fault system and on the south by the study area boundary (border with British Columbia). The play extends into British Columbia where further potential probably lies (between the Llewellyn-King Salmon and Nahlin Fault Systems).

Hydrocarbon occurrence model

The reservoir for this play is composed of cherty carbonate of the Horsefeed Formation and the overlying unnamed breccia of the Nakina Assemblage where leaching and fracturing has developed porosity and permeability along the post-Permian unconformity and cross-cutting faults. Source for the gas is interpreted to be provided

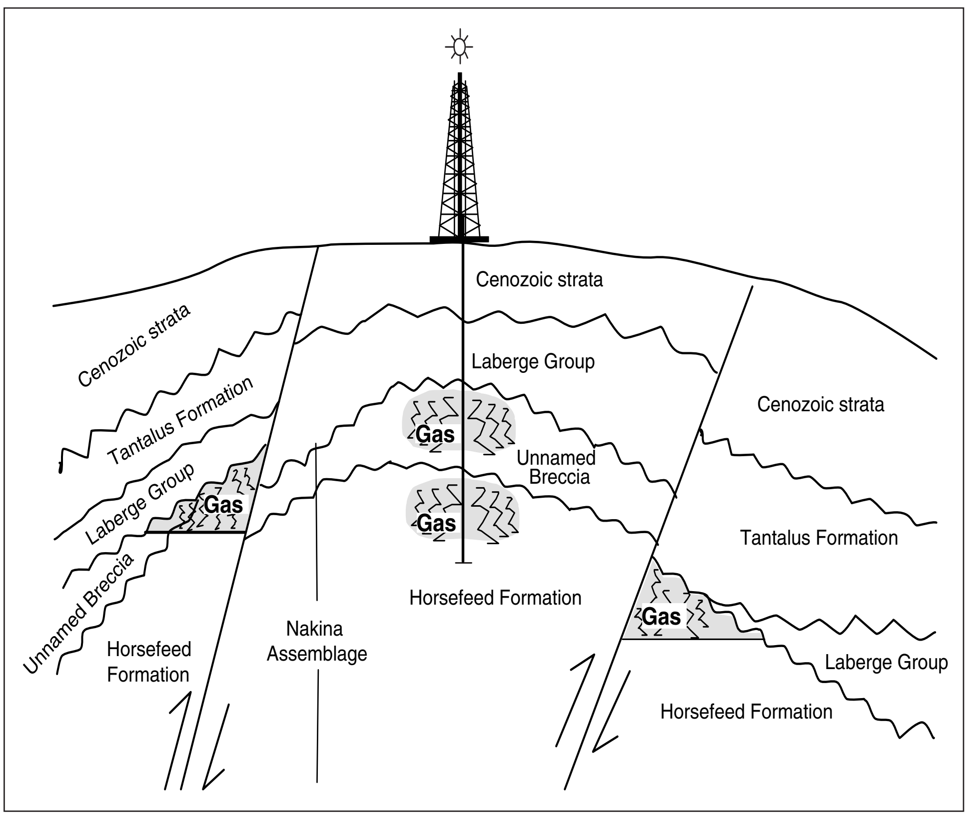


by shallow water back-reef algal laminite dolostone and dark argillaceous limestone which have a fetid odour when broken. Gas is expected to have migrated from the source horizons via the leached and fracture-enhanced porosity network, to be trapped in reservoirs associated with the post-Permian unconformity. Seal is probably provided by the unnamed Cache Creek radiolarian chert that overlies the breccia, by the Kutcho and Povoas/Sinwa formations and by fault juxtaposition with shale and tight carbonate within the Lewes River and Laberge groups and the Tantalus Formation. Individual pools in this play are expected to be very small.

This play carries an overall risk of existence of only 3% due to the risk of breach, lack of reservoir development (leaching and fracture related) and subsequent preservation (diagenetic occlusion) and degradation of the hydrocarbons due to bacterial action or water washing.

Potential resources

This work indicates that this play has a mean probability of occurrence of 3%, that prospects within this play have a mean level risk of 10% and that the mean potential for this play is 44 $10^6 m^3$ (1.56 Bcf).



Estimate of potential petroleum resources.

1) Risk Component **Mean**

Risk Component	Mean
Play Level Risk	0.03
Prospect Level Risk	0.10

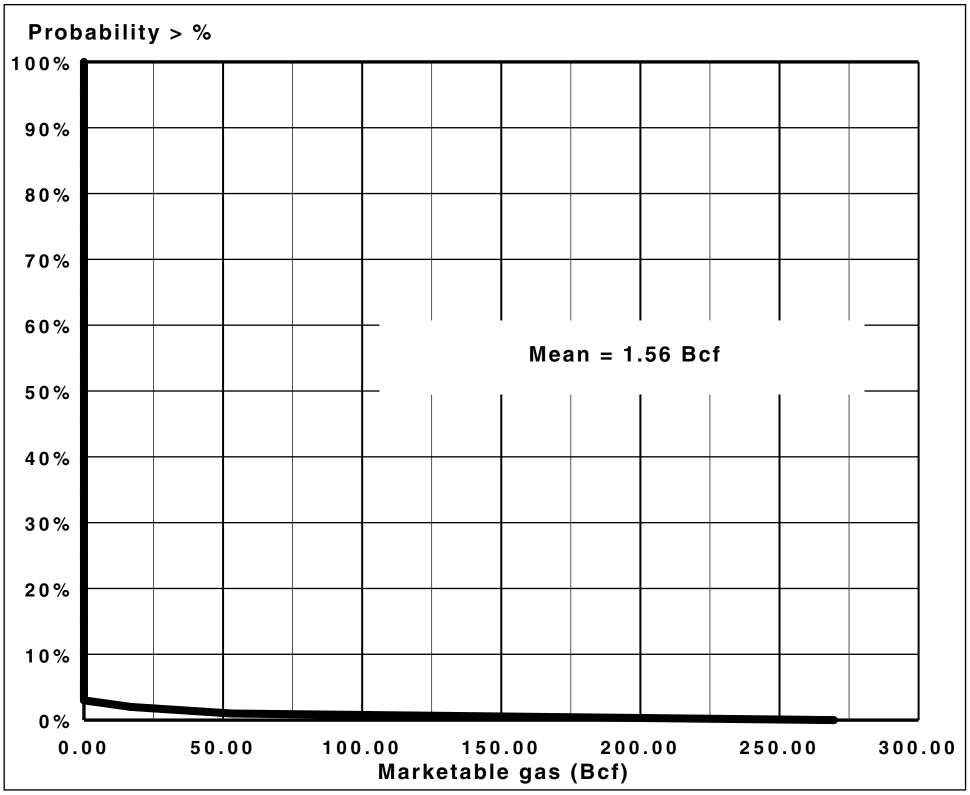
2) Hydrocarbon Volume Component

Average Surface Temperature (F°)	33.00	Temperature Gradient (F°/100 ft.)	2.00
Pressure Gradient (psi/ft.)	0.42	Raw Gas Gravity	0.41

Input Parameters	Minimum	Most Likely	Maximum	Mean
Gas Reservoir Depth (ft kb)	50.00	6,000.00	15,000.00	7,016.67
Oil Reservoir Depth (ft kb)	0.00	0.00	0.00	0.00
Reservoir Pressure (psi)	35.65	2,961.65	6,314.65	3,103.98
Reservoir Temperature (F°)	34.00	173.33	333.00	180.11
Methane Content	0.96	0.99	0.99	0.98
Ethane Content	0.00	0.01	0.01	0.01
Propane Content	0.00	0.00	0.01	0.00
H_2S Content	0.00	0.00	0.00	0.00
CO_2 Content	0.00	0.00	0.00	0.00
Total Play Area (MM acres)	1.00	1.50	2.50	1.67
Tested Play Area (MM acres)	0.00	0.00	0.00	0.00
Untested Play Area (MM acres)	***	***	***	1.67
Fraction of Total Play in Trap	0.08	0.10	0.15	0.11
Fraction of Untested Play Areally Filled	0.25	0.45	0.75	0.48
Potential Oil and Gas Area (MM acres)	***	***	***	0.09
Fraction of Pore Volume Oil Bearing	0.00	0.00	0.00	0.00
Potential Oil Area (MM acres)	***	***	***	0.00
Potential Gas Area (MM acres)	***	***	***	0.01
Average Net Pay (ft.)	10.00	40.00	120.00	56.67
Porosity	0.03	0.04	0.08	0.05
Hydrocarbon Saturation	0.50	0.60	0.75	0.62
Oil Recovery Factor	0.00	0.00	0.00	0.00
Gas Recovery Factor	0.45	0.55	0.65	0.55
GOR (MMcf/Bbl)	0.00	0.00	0.00	0.00
Oil Formation Volume Factor	1.00	1.00	1.00	1.00
Gas Compressibility Factor 'Z'	0.90	0.92	0.94	0.92
Gas Formation Volume Factor	***	***	***	0.19

3) Yield Component

Input Parameters	Minimum	Most Likely	Maximum	Mean
Yield - Oil In-place (Bbls/ac-ft.)	***	***	***	239.33
Yield - Recoverable Oil (Bbls/ac-ft.)	***	***	***	0.00
Yield - Gas In-place (MMcf/ac-ft.)	***	***	***	251.30
Yield - Raw Recoverable Gas (MMcf/ac-ft.)	***	***	***	138.21
Yield - Marketable Gas (MMcf/ac-ft.)	***	***	***	117.48
Liquids Yield (Bbls/MMcf)	0.00	0.00	0.00	0.00
Gas to BOE Conversion Factor (MMcf/BOE)	***	6.00	***	***
"Surface Loss (Fuel gas, etc)"	***	0.15	***	***
Marketable Gas (Fraction of Raw)	***	0.85	***	***



Percentile values

100%	0
95%	0
90%	0
85%	0
80%	0
75%	0
70%	0
65%	0
60%	0
55%	0
50%	0
45%	0
40%	0
35%	0
30%	0
25%	0
20%	0
15%	0
10%	0
5%	0
4%	0
3%	0
2%	16.98
1%	53.26
0%	269.6

Triassic

LEWES RIVER GROUP (HANCOCK MEMBER) STRATIGRAPHIC

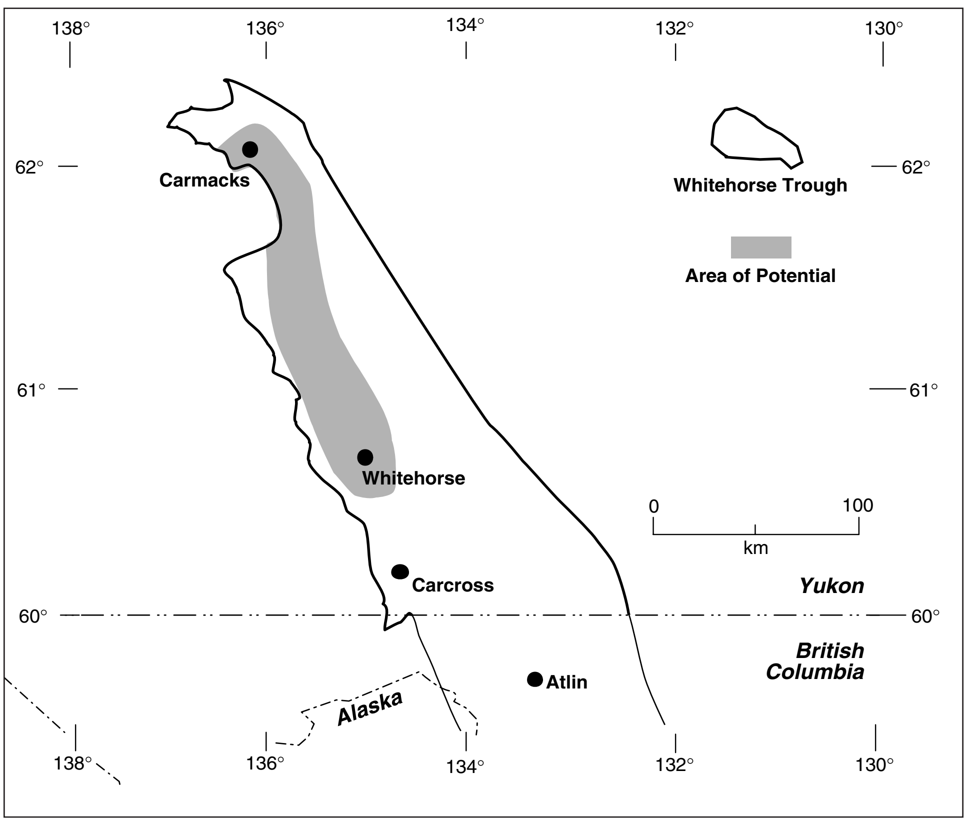
CONCEPTUAL GAS PLAY

Reservoir definition

This dry gas play is defined to include all pools and prospects within Lewes River Group Norian-aged "reefal" carbonate mud mound complexes within the Hancock Member of the Aksala Formation. The play covers 5,000 km^2 and is limited on the east, west, north (at approximately Carmacks) and south (just south of Whitehorse) by outcropping of the strata.

Hydrocarbon occurrence model

The reservoir for this play is composed of "reefal" carbonate mud mound complexes that generally lack effective porosity and permeability but which have been locally enhanced by leaching and brecciation. In outcrop, these reefal complexes have been measured in excess of 150 m thick with several successive reefs stacked on one another.

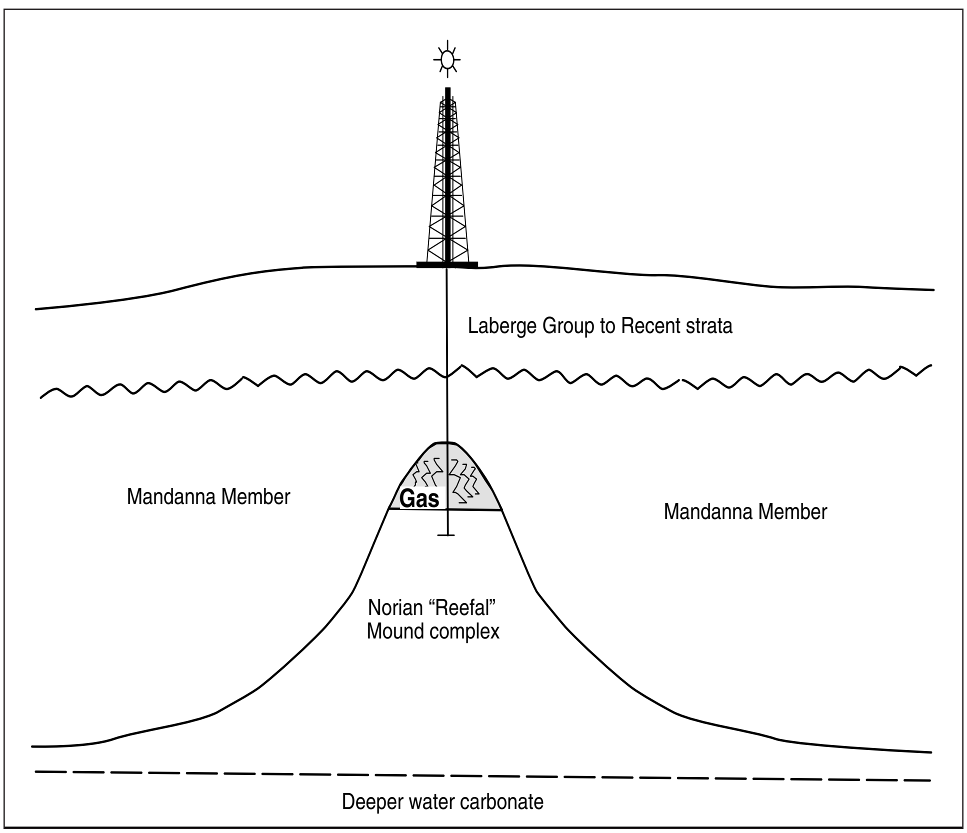


Source for the gas is interpreted to be provided by intra-formational dark (organic rich) shallow water back-reef argillaceous carbonates which have a fetid odour when broken. Gas is expected to have migrated from the source horizons via the leached, brecciated and fracture-enhanced porosity network and to be trapped in the reefal mound reservoirs. The seal is probably provided by the Mandanna Member and by shales within the overlying Inklin Formation of the Laberge Group. Individual pools in this play are expected to be very small.

This play carries an overall risk of existence of 11% due mainly to the risk of breach, lack of reservoir development (leaching and fracture-related reservoir) and subsequent preservation (diagenetic occlusion) and degradation of the hydrocarbons due to bacterial action or water washing.

Potential resources

No previous estimates of the potential gas resources attributable to this play could be located. This work indicates that this play has a mean probability of occurrence of 11%, that prospects within this play have a mean risk of 21% and that the mean potential for this play is 2,003 $10^6 m^3$ (70 Bcf).



Estimate of potential petroleum resources.

1) Risk Component **Mean**

Risk Component	Mean
Play Level Risk	0.11
Prospect Level Risk	0.21

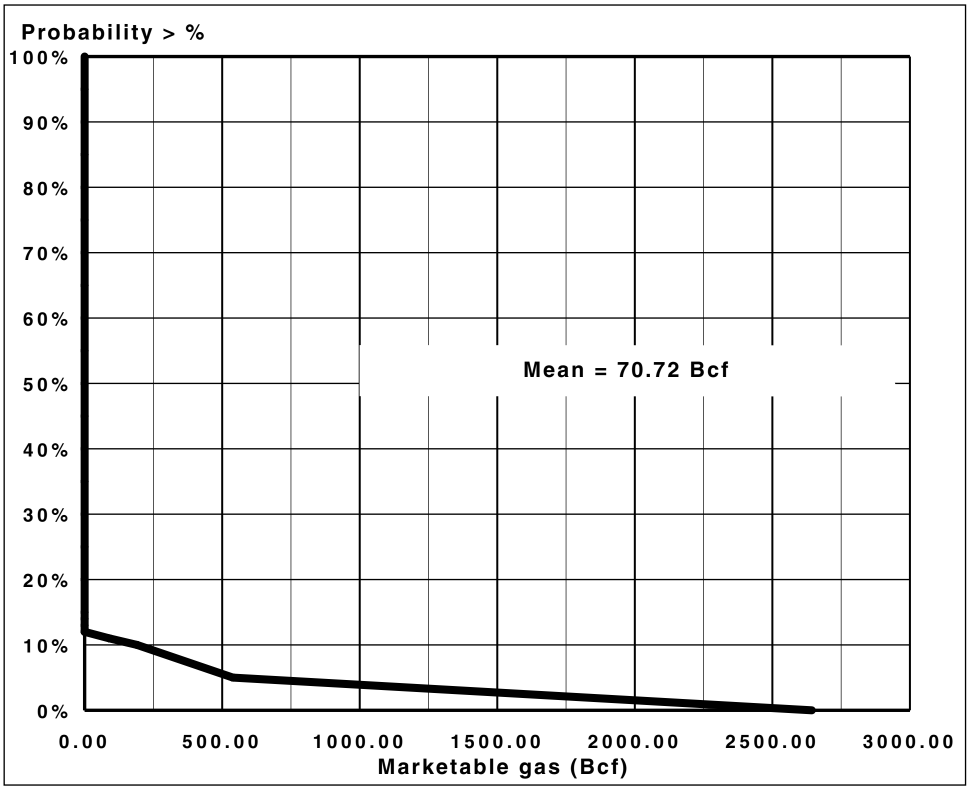
2) Hydrocarbon Volume Component

Average Surface Temperature (F°)	33.00	Temperature Gradient (F°/100 ft.)	2.00
Pressure Gradient (psi/ft.)	0.42	Raw Gas Gravity	0.42

Input Parameters	Minimum	Most Likely	Maximum	Mean
Gas Reservoir Depth (ft kb)	50.00	5,000.00	10,000.00	5,016.67
Oil Reservoir Depth (ft kb)	0.00	0.00	0.00	0.00
Reservoir Pressure (psi)	35.65	2,121.65	4,214.65	2,123.98
Reservoir Temperature (F°)	34.00	133.33	233.00	133.44
Methane Content	0.90	0.98	0.99	0.96
Ethane Content	0.01	0.02	0.05	0.03
Propane Content	0.00	0.01	0.05	0.02
H_2S Content	0.00	0.00	0.00	0.00
CO_2 Content	0.00	0.00	0.00	0.00
Total Play Area (MM acres)	1.00	1.25	1.50	1.25
Tested Play Area (MM acres)	0.00	0.00	0.00	0.00
Untested Play Area (MM acres)	***	***	***	1.25
Fraction of Total Play in Trap	0.10	0.20	0.25	0.18
Fraction of Untested Play Areally Filled	0.55	0.75	0.95	0.75
Potential Oil and Gas Area (MM acres)	***	***	***	0.17
Fraction of Pore Volume Oil Bearing	0.00	0.00	0.00	0.00
Potential Oil Area (MM acres)	***	***	***	0.00
Potential Gas Area (MM acres)	***	***	***	0.04
Average Net Pay (ft.)	35.00	75.00	150.00	8.67
Porosity	0.03	0.07	0.12	0.07
Hydrocarbon Saturation	0.65	0.75	0.85	0.75
Oil Recovery Factor	0.00	0.00	0.00	0.00
Gas Recovery Factor	0.60	0.65	0.85	0.70
GOR (MMcf/Bbl)	0.00	0.00	0.00	0.00
Oil Formation Volume Factor	1.00	1.00	1.00	1.00
Gas Compressibility Factor 'Z'	0.90	0.92	0.94	0.92
Gas Formation Volume Factor	***	***	***	0.14

3) Yield Component

Input Parameters	Minimum	Most Likely	Maximum	Mean
Yield - Oil In-place (Bbls/ac-ft.)	***	***	***	418.93
Yield - Recoverable Oil (Bbls/ac-ft.)	***	***	***	0.00
Yield - Gas In-place (MMcf/ac-ft.)	***	***	***	324.61
Yield - Raw Recoverable Gas (MMcf/ac-ft.)	***	***	***	227.23
Yield - Marketable Gas (MMcf/ac-ft.)	***	***	***	204.50
Liquids Yield (Bbls/MMcf)	0.00	0.00	0.00	0.00
Gas to BOE Conversion Factor (MMcf/BOE)	***	6.00	***	***
"Surface Loss (Fuel gas, etc)"	***	0.10	***	***
Marketable Gas (Fraction of Raw)	***	0.90	***	***



Percentile values

100%	0
95%	0
90%	0
85%	0
80%	0
75%	0
70%	0
65%	0
60%	0
55%	0
50%	0
45%	0
40%	0
35%	0
30%	0
25%	0
20%	0
15%	0
14%	0
13%	0
12%	0
11%	89.97
10%	190.55
5%	539.29
0%	2,643.30

Jurassic

CONGLOMERATE–RICHTHOFEN STRATIGRAPHIC

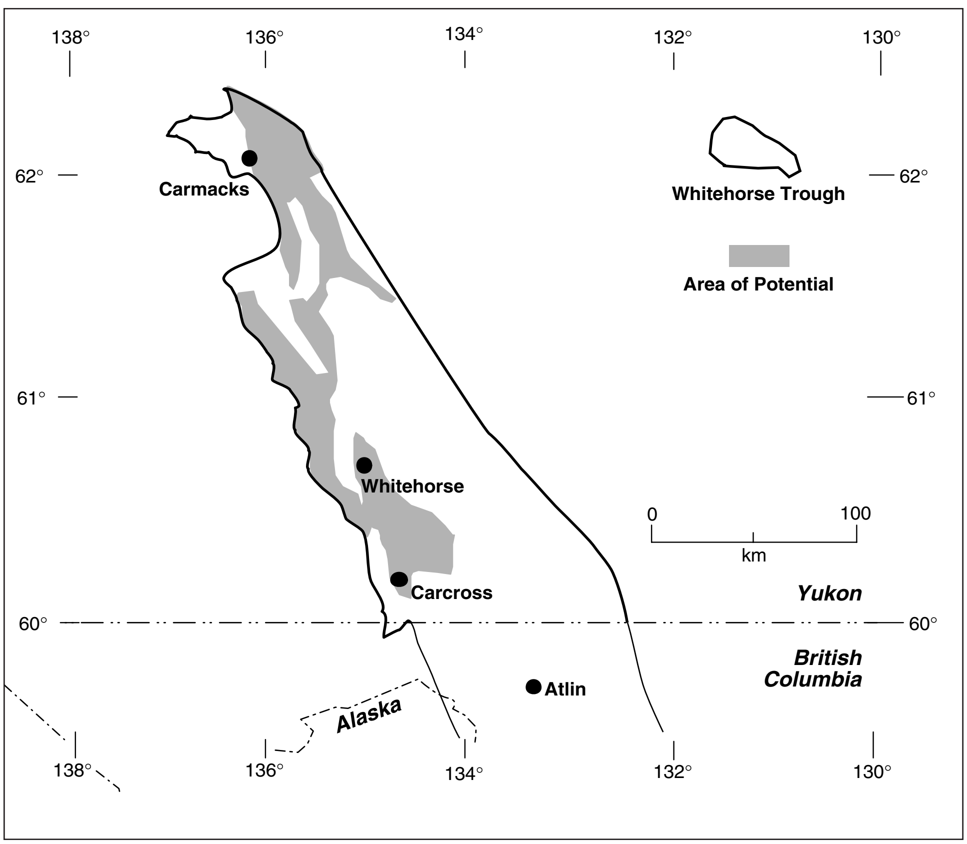
CONCEPTUAL GAS AND OIL PLAY

Reservoir definition

This gas and oil play is defined to include all pools and prospects within Laberge Group stratigraphic traps associated with the facies transition between the arkosic proximal Conglomerate Formation clastics and the more distal clastics of the Richthofen Formation. The play covers 6,000 km^2 and is limited on the east and north by the Llewellyn-King Salmon Fault System and outcrop occurrences, on the west by outcrop, subcrop traces and facies transition to the Richthofen Formation and on the south by the Bennett Lake-Marsh Lake-Crag Lake Fault System.

Hydrocarbon occurrence model

The reservoir for this play is composed of at least three distinct pulses of arkosic conglomerate and sandstone that was deposited in the Whitehorse Trough from the south and southwest and which interfinger with the more distal turbiditic greywacke,

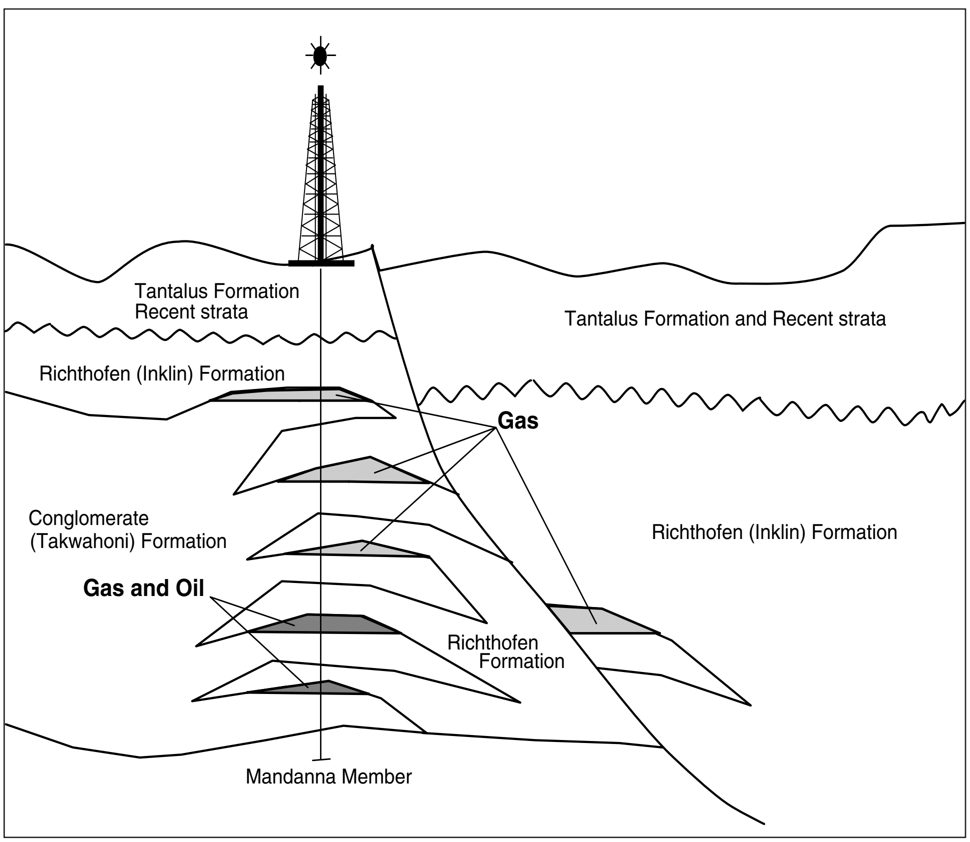


shale and siltstone of the Inklin Formation. Source for the gas is interpreted to be provided by the organic-rich horizons within the Hancock Member of the Lewes River Group and within the Richthofen Formation. Gas is expected to have migrated from the source horizons via fractures and faults from the Hancock Member and updip within the Richthofen via porous carrier beds. The seal is probably provided by the siltstone, tight sandstone and shale within the overlying Inklin Formation of the Laberge Group, the Tantalus Formation and Recent strata. Individual pools in this play are expected to be small and complex.

This play carries an overall risk of existence of 10% due mainly to the risk of breach, lack of reservoir development and subsequent reservoir (diagenetic occlusion) and degradation of the hydrocarbons due to bacterial action or water washing.

Potential resources

This work indicates that this play has a mean probability of occurrence of 10%, that prospects within this play have a mean risk of 24%. The mean gas potential for this play is 804 10^6m^3 (28.37 Bcf) while the mean oil potential is 0.20 10^6m^3 (1.27 MMBbls).



Estimate of potential petroleum resources.

1) Risk Component

Risk Component	Mean
Play Level Risk	0.10
Prospect Level Risk	0.24

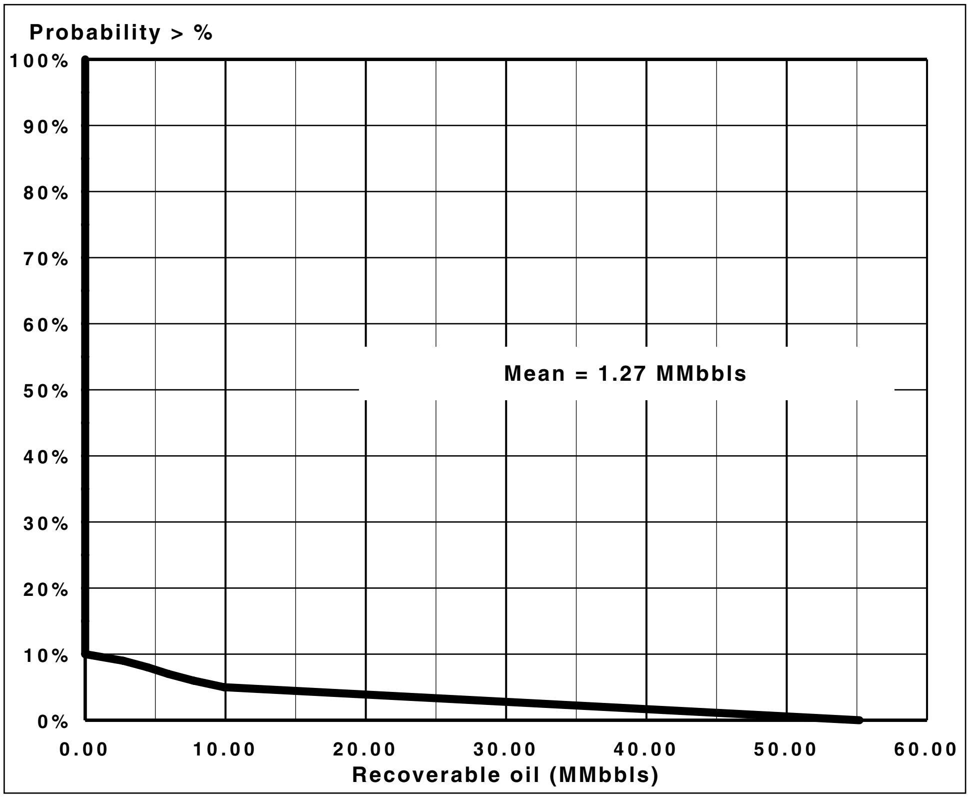
2) Hydrocarbon Volume Component

Average Surface Temperature (F°)	33.00	Temperature Gradient (F°/100 ft.)	2.00
Pressure Gradient (psi/ft.)	0.42	Raw Gas Gravity	0.43

Input Parameters	Minimum	Most Likely	Maximum	Mean
Gas Reservoir Depth (ft kb)	50.00	1,600.00	7,500.00	3,050.00
Oil Reservoir Depth (ft kb)	50.00	1,000.00	3,000.00	1,350.00
Reservoir Pressure (psi)	35.65	1,295.65	3,164.65	1,498.65
Reservoir Temperature (F°)	34.00	94.00	183.00	103.67
Methane Content	0.95	0.98	0.99	0.97
Ethane Content	0.01	0.02	0.05	0.03
Propane Content	0.01	0.02	0.05	0.03
H_2S Content	0.00	0.00	0.00	0.00
CO_2 Content	0.00	0.00	0.00	0.00
Total Play Area (MM acres)	0.50	1.25	2.50	1.42
Tested Play Area (MM acres)	0.00	0.00	0.00	0.00
Untested Play Area (MM acres)	***	***	***	1.42
Fraction of Total Play in Trap	0.05	0.15	0.20	0.13
Fraction of Untested Play Areally Filled	0.25	0.55	0.75	0.52
Potential Oil and Gas Area (MM acres)	***	***	***	0.10
Fraction of Pore Volume Oil Bearing	0.03	0.05	0.10	0.06
Potential Oil Area (MM acres)	***	***	***	0.00
Potential Gas Area (1MM acres)	***	***	***	0.02
Average Net Pay (ft.)	5.00	55.00	125.00	61.67
Porosity	0.06	0.12	0.22	0.13
Hydrocarbon Saturation	0.50	0.60	0.85	0.65
Oil Recovery Factor	0.10	0.15	0.45	0.23
Gas Recovery Factor	0.55	0.65	0.80	0.67
GOR (MMcf/Bbl)	0.04	0.04	0.04	0.04
Oil Formation Volume Factor	1.02	1.02	1.02	1.02
Gas Compressibility Factor 'Z'	0.90	0.92	0.94	0.92
Gas Formation Volume Factor	***	***	***	0.10

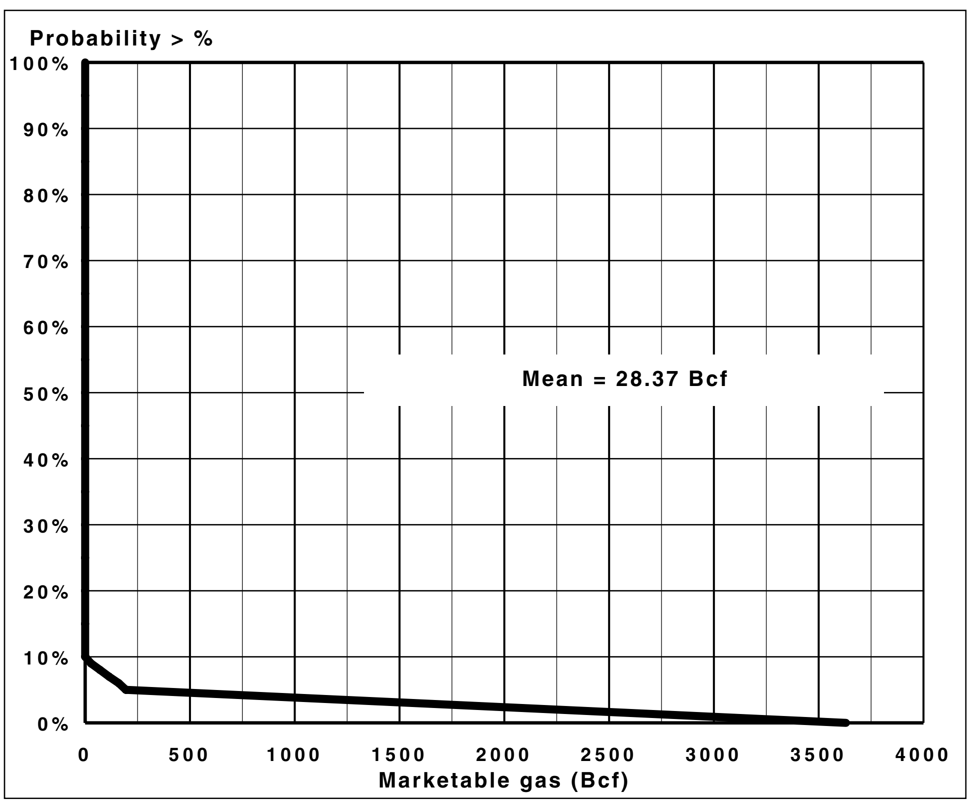
3) Yield Component

Input Parameters	Minimum	Most Likely	Maximum	Mean
Yield - Oil In-place (Bbls/ac-ft.)	***	***	***	655.60
Yield - Recoverable Oil (Bbls/ac-ft.)	***	***	***	152.75
Yield - Gas In-place (MMcf/ac-ft.)	***	***	***	387.87
Yield - Raw Recoverable Gas (MMcf/ac-ft.)	***	***	***	258.71
Yield - Marketable Gas (MMcf/ac-ft.)	***	***	***	232.84
Liquids Yield (Bbls/MMcf)	0.00	0.00	0.00	0.00
Gas to BOE conversion Factor (MMcf/BOE)	***	6.00	***	***
"Surface Loss (Fuel gas, etc)"	***	0.10	***	***
Marketable Gas (Fraction of Raw)	***	0.90	***	***



Percentile values

100% 0
95% 0
90% 0
85% 0
80% 0
75% 0
70% 0
65% 0
60% 0
55% 0
50% 0
45% 0
40% 0
35% 0
30% 0
25% 0
20% 0
15% 0
10% 0
9% 2.71
8% 4.46
7% 5.93
6% 7.70
5% 9.89
0% 55.18



Percentile values

100% 0
95% 0
90% 0
85% 0
80% 0
75% 0
70% 0
65% 0
60% 0
55% 0
50% 0
45% 0
40% 0
35% 0
30% 0
25% 0
20% 0
15% 0
10% 0
9% 28.1
8% 71.57
7% 114.05
6% 160.69
5% 194.42
0% 3,629.88

Jurassic

CONGLOMERATE–NORDENSKIOLD STRATIGRAPHIC

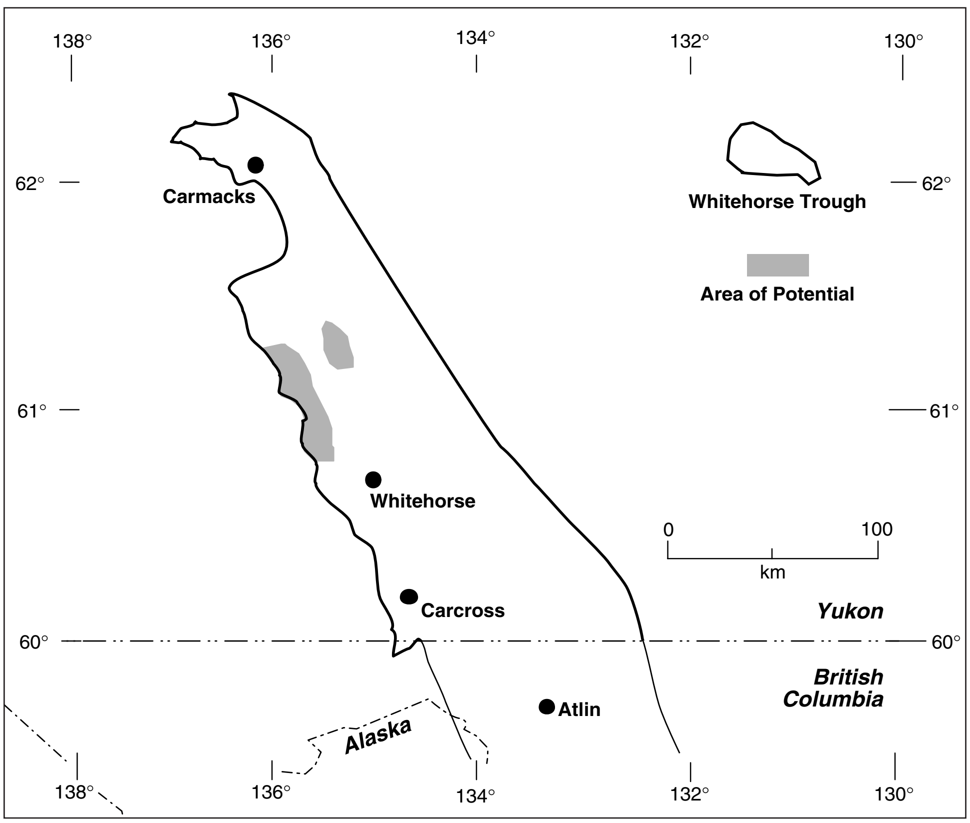
CONCEPTUAL GAS PLAY

Reservoir definition

This dry gas play was defined to include all pools and prospects within the uppermost clastic pulse of the arkosic Conglomerate Formation. The play area is restricted to two small areas north-northwest of Whitehorse covering approximately 648 km^2. The area is defined by outcrop, projected subcrop trends and estimated facies transitions between the Nordenskiold and Conglomerate formations.

Hydrocarbon occurrence model

The reservoir for this play is composed of a distinct pulse of arkosic conglomerate and sandstone that was deposited in the Whitehorse Trough from the south and southwest and that interfingered with, and on lapped onto the Nordenskiold Dacite and tuff.

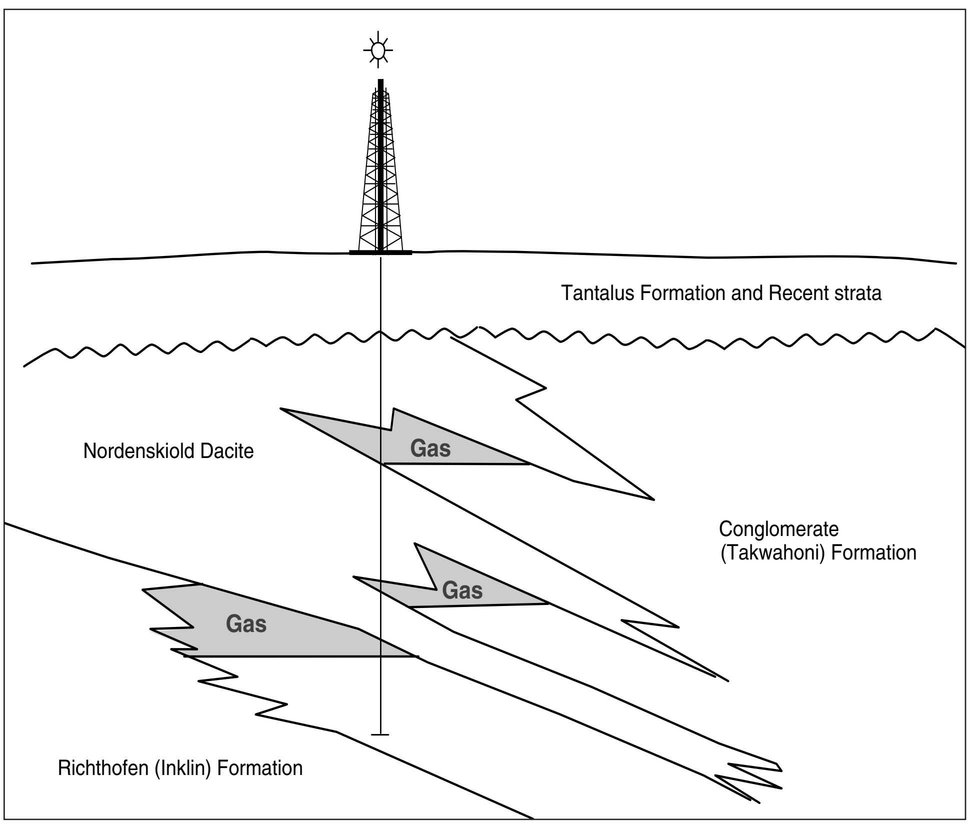


Source for the gas is interpreted to be provided by the organic-rich horizons within the Hancock Member of the Lewes River Group and within the Richthofen Formation. Gas is expected to have migrated from the source horizons via fractures and faults from the Hancock Member and updip within the Richthofen via porous carrier beds. The seal is provided by the siltstone, tight sandstone and shale of the Conglomerate Formation and by the Nordenskiold Dacite and tuff. Individual pools in this play are expected to be very small and complex.

This play carries an overall risk of existence of 5% due mainly to the risk of breach, lack of reservoir development and subsequent reservoir degradation (diagenetic occlusion and halo alteration near the dacite) and degradation of the hydrocarbons due to bacterial action, water washing, and over-heating near the dacite.

Potential resources

This work indicates that this play has a mean probability of occurrence of 5%, that prospects within this play have a mean risk of 10%. The mean gas potential for this play is 1.76 $10^6 m^3$ (0.062 Bcf).



Estimate of potential petroleum resources.

1) Risk Component **Mean**

Play Level Risk	0.05
Prospect Level Risk	0.10

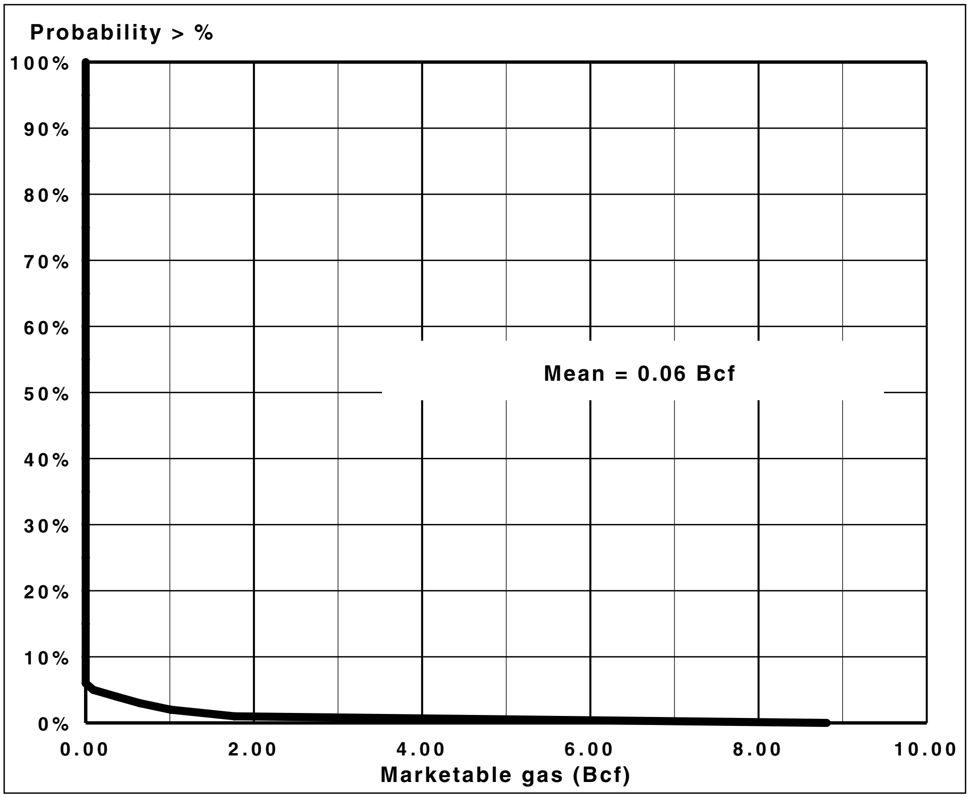
2) Hydrocarbon Volume Component

Average Surface Temperature (F°)	33.00	Temperature Gradient (F°/100 ft.)	2.00
Pressure Gradient (psi/ft.)	0.42	Raw Gas Gravity	0.42

Input Parameters	Minimum	Most Likely	Maximum	Mean
Gas Reservoir Depth (ft kb)	400.00	1,300.00	4,000.00	1,900.00
Oil Reservoir Depth (ft kb)	0.00	0.00	0.00	0.00
Reservoir Pressure (psi)	182.65	812.65	1,694.65	896.65
Reservoir Temperature (F°)	41.00	71.00	113.00	75.00
Methane Content	0.90	0.98	0.99	0.96
Ethane Content	0.01	0.01	0.02	0.01
Propane Content	0.01	0.01	0.05	0.02
H_2S Content	0.00	0.00	0.00	0.00
CO_2 Content	0.00	0.00	0.00	0.00
Total Play Area (MM acres)	0.05	0.18	0.25	0.16
Tested Play Area (MM acres)	0.00	0.00	0.00	0.00
Untested Play Area (MM acres)	***	***	***	0.16
Fraction of Total Play in Trap	0.03	0.05	0.15	0.08
Fraction of Untested Play Areally Filled	0.15	0.45	0.80	0.47
Potential Oil and Gas Area (MM acres)	***	***	***	0.01
Fraction of Pore Volume Oil Bearing	0.00	0.00	0.00	0.00
Potential Oil Area (MM acres)	***	***	***	0.00
Potential Gas Area (MM acres)	***	***	***	0.00
Average Net Pay (ft.)	5.00	25.00	75.00	35.00
Porosity	0.03	0.06	0.12	0.07
Hydrocarbon Saturation	0.55	0.65	0.75	0.65
Oil Recovery Factor	0.00	0.00	0.00	0.00
Gas Recovery Factor	0.30	0.50	0.85	0.55
GOR (MMcf/Bbl)	0.00	0.00	0.00	0.00
Oil Formation Volume Factor	1.00	1.00	1.00	1.00
Gas Compressibility Factor 'Z'	0.89	0.91	0.93	0.91
Gas Formation Volume Factor	***	***	***	0.07

3) Yield Component

Input Parameters	Minimum	Most Likely	Maximum	Mean
Yield - Oil In-place (Bbls/ac-ft.)	***	***	***	353.00
Yield - Recoverable Oil (Bbls/ac-ft.)	***	***	***	0.00
Yield - Gas In-place (MMcf/ac-ft.)	***	***	***	129.60
Yield - Raw Recoverable Gas (MMcf/ac-ft.)	***	***	***	71.30
Yield - Marketable Gas (MMcf/ac-ft.)	***	***	***	60.60
Liquids Yield (Bbls/MMcf)	0.00	0.00	0.00	0.00
Gas to BOE Conversion Factor (MMcf/BOE)	***	6.00	***	***
"Surface Loss (Fuel gas, etc)"	***	0.15	***	***
Marketable Gas (Fraction of Raw)	***	0.85	***	***



Percentile values

100%	0
95%	0
90%	0
85%	0
80%	0
75%	0
70%	0
65%	0
60%	0
55%	0
50%	0
45%	0
40%	0
35%	0
30%	0
25%	0
20%	0
15%	0
10%	0
6%	0
5%	0.09
4%	0.36
3%	0.64
2%	1.01
1%	1.77
0%	8.81

Jurassic–Cretaeous

TANTALUS STRATIGRAPHIC

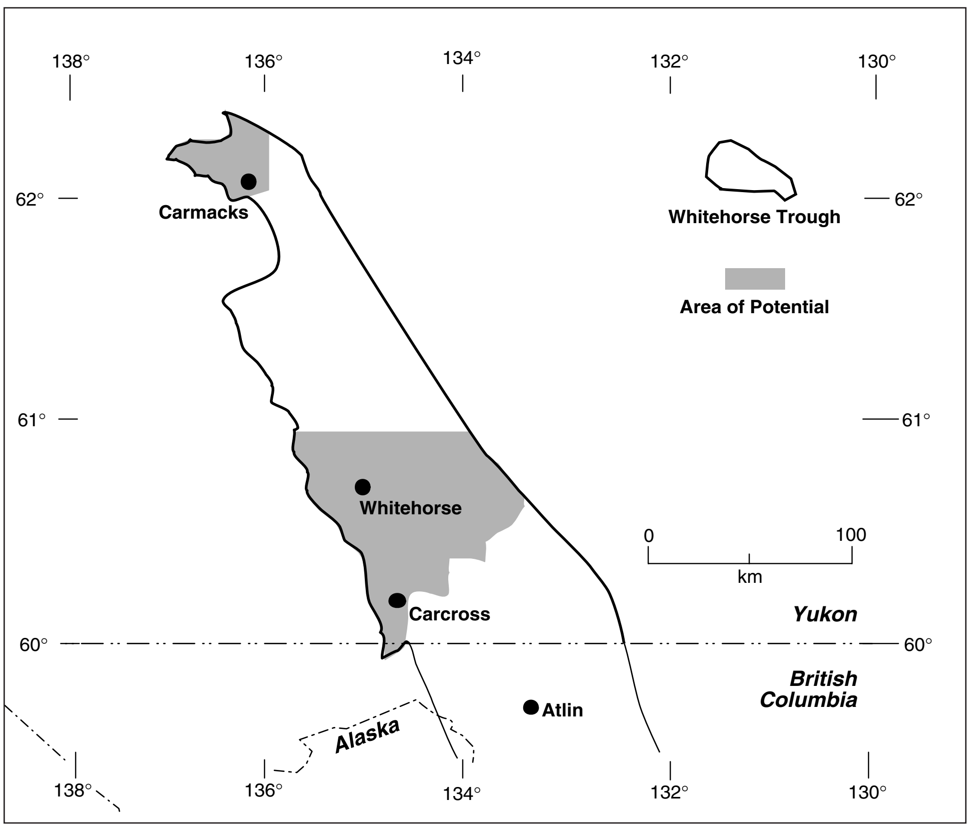
CONCEPTUAL OIL AND GAS PLAY

Reservoir definition

This gas and oil play is defined to include all pools and prospects within the Tantulus Formation. The play area covers approximately 12,800 km^2 and is limited by the occurrence of preservational remnants of non-marine fluvial to marine clastic sediments deposited in a series of small transcurrent faulted bounded basins.

Hydrocarbon occurrence model

The reservoir for this play is composed of non-marine to braided fluvial chert pebble conglomerate, cherty sandstone and siltstone, wave-dominated fan delta sediment and marine shoreface clastics. Source for the hydrocarbons within this play is interpreted to have been provided by the intraformational coals within the Tantalus from organic-rich

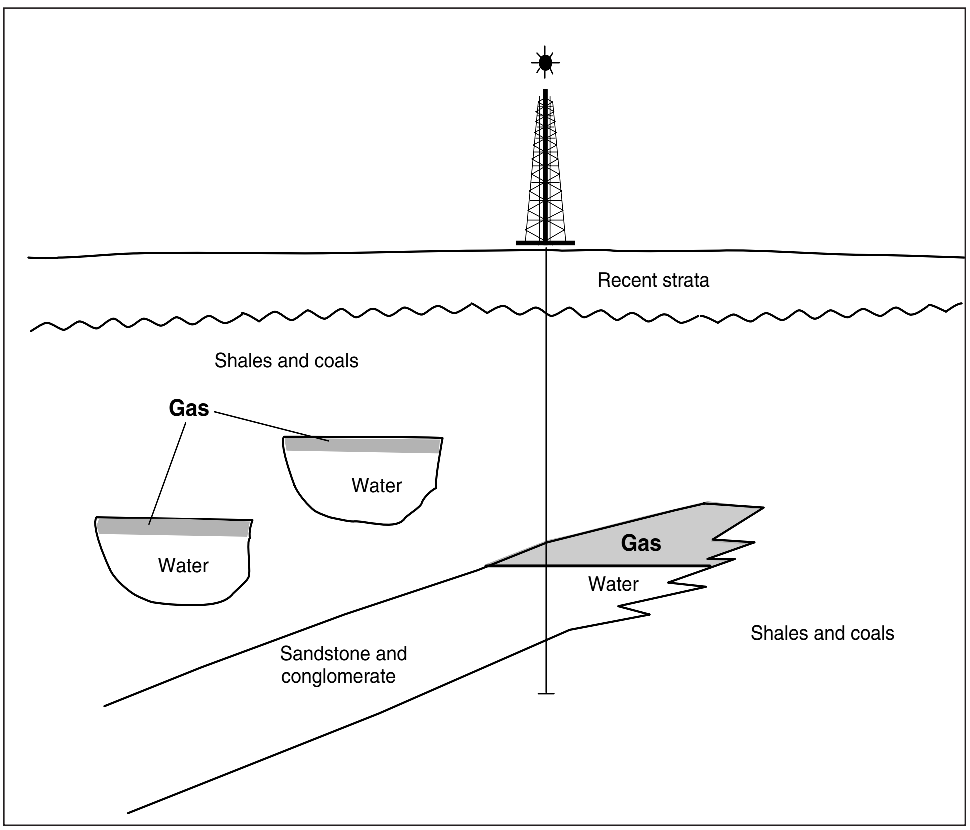


horizons within the Lewes River Group and the Richthofen Formation. Hydrocarbons are expected to have migrated from the source horizons via fractures and faults from the Hancock Member and Richthofen Formation and via porous carrier beds within the Tantalus Formation. The seal is provided by siltstone, tight sandstone and shale within the Tantalus Formation and from tight Recent strata and permafrost. Individual pools in this play are expected to be small and complex.

This play carries an overall risk of existence of 21% due mainly to the risk of breach, lack of reservoir development and subsequent reservoir degradation (diagenetic occlusion and halo alteration near the dacite) and degradation of the hydrocarbons due to bacterial action, water washing and over-heating near the dacite.

Potential resources

This work indicates that this play has a mean probability of occurrence of 21%, that prospects within this play have a mean risk of 33%. The mean gas potential for this play is 1,573 $10^6 m^3$ (55.53 Bcf) and the mean oil potential is 0.55 $10^6 m^3$ (3.44 MMBbls).



Estimate of potential petroleum resources.

1) Risk Component **Mean**

Play Level Risk	0.21
Prospect Level Risk	0.33

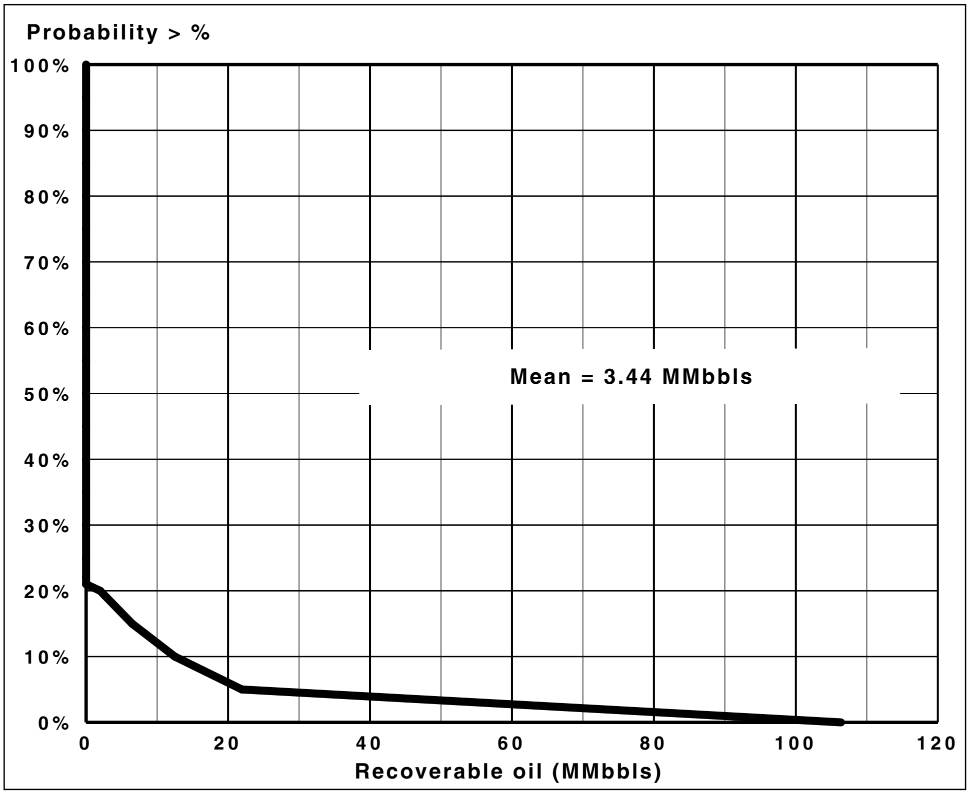
2) Hydrocarbon Volume Component

Average Surface Temperature (F°)	33.00	Temperature Gradient (F°/100 ft.)	2.00
Pressure Gradient (psi/ft.)	0.42	Raw Gas Gravity	0.43

Input Parameters	Minimum	Most Likely	Maximum	Mean
Gas Reservoir Depth (ft kb)	50.00	1,200.00	4,000.00	1,750.00
Oil Reservoir Depth (ft kb)	50.00	1,100.00	4,000.00	1,716.67
Reservoir Pressure (psi)	35.65	749.65	1,694.65	826.65
Reservoir Temperature (F°)	34.00	68.00	113.00	71.67
Methane Content	0.90	0.98	0.99	0.96
Ethane Content	0.01	0.02	0.05	0.03
Propane Content	0.00	0.01	0.05	0.02
H_2S Content	0.00	0.00	0.00	0.00
CO_2 Content	0.00	0.00	0.00	0.00
Total Play Area (MM acres)	2.00	3.00	4.50	3.17
Tested Play Area (MM acres)	0.00	0.00	0.00	0.00
Untested Play Area (MM acres)	***	***	***	3.17
Fraction of Total Play in Trap	0.05	0.10	0.20	0.12
Fraction of Untested Play Areally Filled	0.10	0.15	0.75	0.33
Potential Oil and Gas Area (MM acres)	***	***	***	0.12
Fraction of Pore Volume Oil Bearing	0.02	0.04	0.08	0.05
Potential Oil Area (MM acres)	***	***	***	0.00
Potential Gas Area (MM acres)	***	***	***	0.04
Average Net Pay (ft.)	5.00	50.00	130.00	61.67
Porosity	0.05	0.12	0.18	0.12
Hydrocarbon Saturation	0.50	0.65	0.85	0.67
Oil Recovery Factor	0.10	0.20	0.45	0.25
Gas Recovery Factor	0.50	0.65	0.85	0.67
GOR (MMcf/Bbl)	0.05	0.05	0.05	0.05
Oil Formation Volume Factor	1.03	1.03	1.03	1.03
Gas Compressibility Factor 'Z'	0.95	0.97	0.98	0.97
Gas Formation Volume Factor	***	***	***	0.06

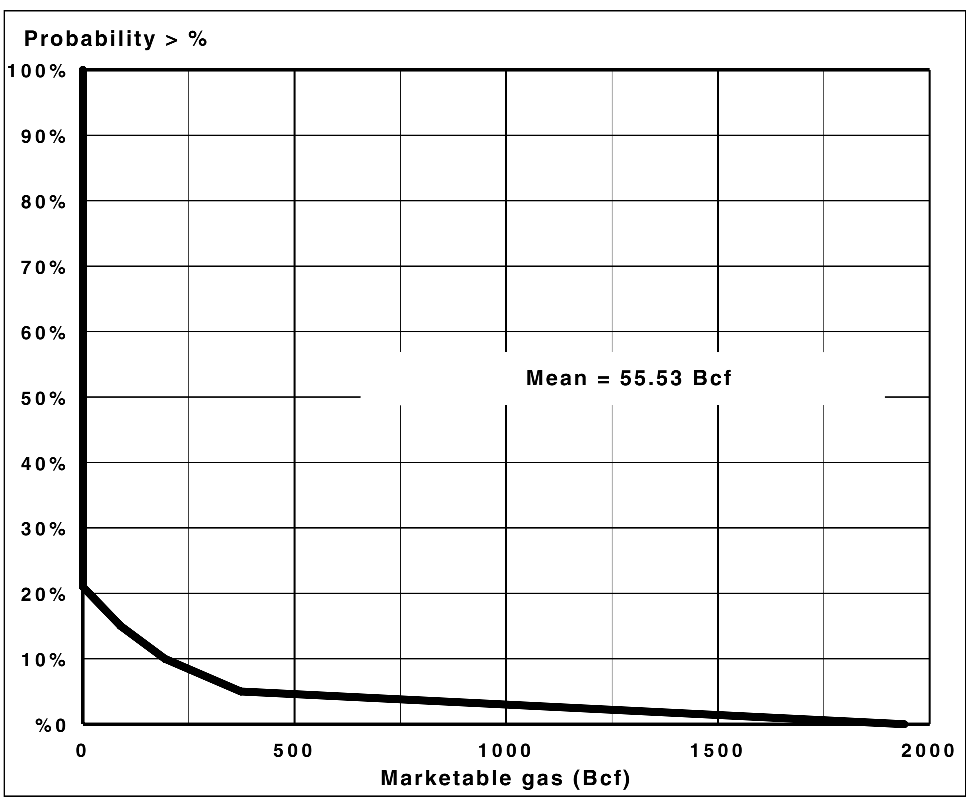
3) Yield Component

Input Parameters	Minimum	Most Likely	Maximum	Mean
Yield - Oil In-place (Bbls/ac-ft.)	***	***	***	587.79
Yield - Recoverable Oil (Bbls/ac-ft.)	***	***	***	146.95
Yield - Gas In-place (MMcf/ac-ft.)	***	***	***	194.41
Yield - Raw Recoverable Gas (MMcf/ac-ft.)	***	***	***	129.67
Yield - Marketable Gas (MMcf/ac-ft.)	***	***	***	116.70
Liquids Yield (Bbls/MMcf)	0.50	1.50	8.00	3.33
Gas to BOE Conversion Factor (MMcf/BOE)	***	6.00	***	***
"Surface Loss (Fuel gas, etc)"	***	0.10	***	***
Marketable Gas (Fraction of Raw)	***	0.90	***	***



Percentile values

100%	0
95%	0
90%	0
85%	0
80%	0
75%	0
70%	0
65%	0
60%	0
55%	0
50%	0
45%	0
40%	0
35%	0
30%	0
25%	0
22%	0
21%	0
20%	1.98
15%	6.49
10%	12.5
5%	21.95
0%	106.35



Percentile values

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90%	0
85%	0
80%	0
75%	0
70%	0
65%	0
60%	0
55%	0
50%	0
45%	0
40%	0
35%	0
30%	0
25%	0
22%	0
21%	0
21%	0
15%	89.41
10%	193.69
5%	373.08
0%	1,940.45

Jurassic

HANCOCK–CONGLOMERATE STRUCTURAL

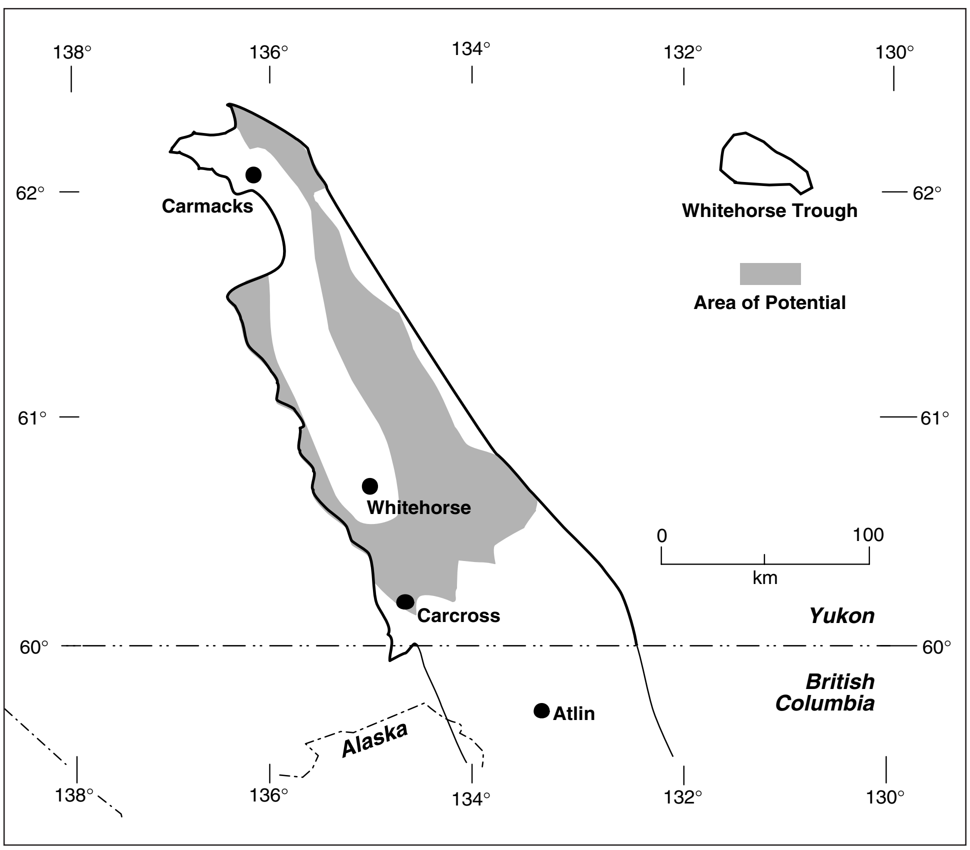
CONCEPTUAL GAS AND OIL PLAY

Reservoir definition

This gas and oil play is defined to include stacked pools and prospects within antiformal folds and fault-related traps containing strata of the Hancock, Conglomerate and possibly the Tanglefoot formations. The play area covers approximately 8,600 km^2 and is limited on the west and north by the Llewellyn-King Salmon Fault System and outcrop occurrences, on the west by outcrop, subcrop traces and the Teslin/Thibert/Kutcho Fault System and on the south by the Bennett Lake-Marsh Lake-Crag Lake Fault System.

Hydrocarbon occurrence model

The reservoir for this play is composed of stacked pools and prospects within antiformal folds and fault-related traps containing carbonate and clastic strata of the Hancock, Conglomerate and possibly the Tanglefoot formations. Source for the hydrocarbons

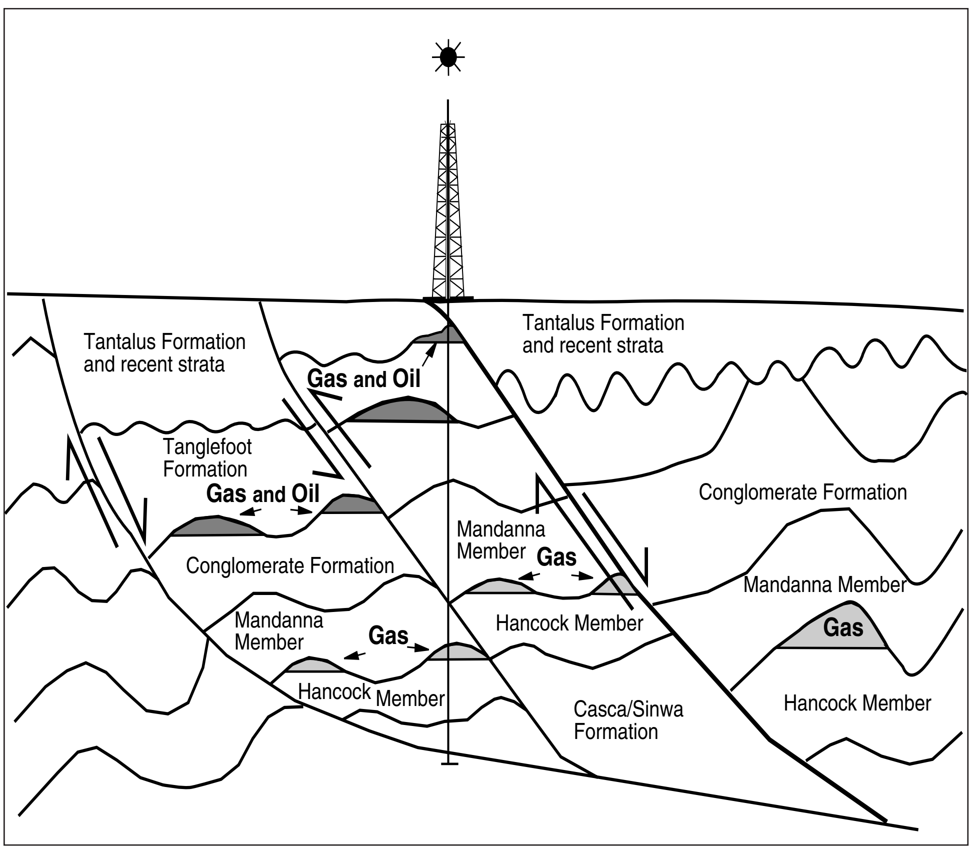


within this play is interpreted to have been provided by the organic-rich horizons within the Hancock, Tantalus and the Richthofen formations. Hydrocarbons are expected to have migrated from the source horizons via fractures and faults and within porous carrier beds within the various formations. The seal is provided by the siltstone, tight sandstone, shale, dacte and tuff that are fault juxtaposed against the reservoir beds. Individual pools in this play are expected to be complex.

This play carries an overall risk of existence of 16%. It is low due to the risk of breach, subsequent reservoir degradation (diagenetic occlusion and halo alteration near the intruding sills) and degradation of the hydrocarbons due to bacterial action, water washing and over-heating near the sills.

Potential resources

This work indicates that this play has a mean probability of occurrence of 16%, that prospects within this play have a mean risk of 26%. The mean gas potential for this play is 2,079 $10^6 m^3$ (73.39 Bcf) and 0.45 $10^6 m^3$ (2.81 MMBbls).



Estimate of potential petroleum resources.

1) Risk Component **Mean**

Play Level Risk	0.16
Prospect Level Risk	0.26

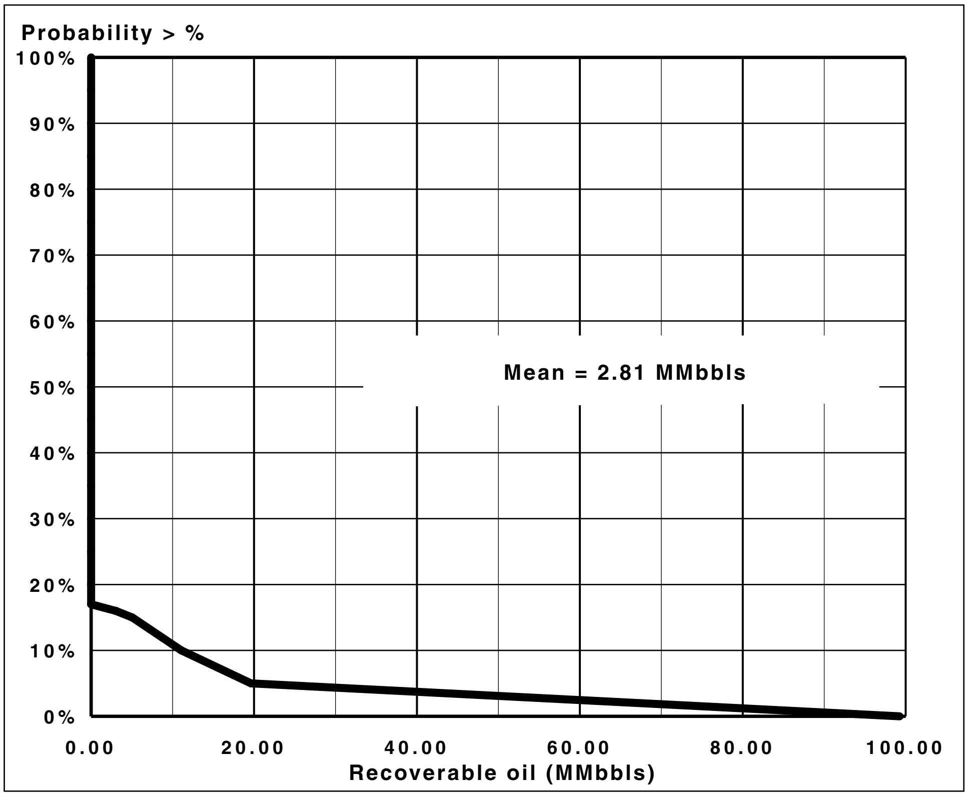
2) Hydrocarbon Volume Component

Average Surface Temperature (F°)	33.00	Temperature Gradient (F°/100 ft.)	2.00
Pressure Gradient (psi/ft.)	0.42	Raw Gas Gravity	0.43

Input Parameters	Minimum	Most Likely	Maximum	Mean
Gas Reservoir Depth (ft kb)	50.00	1,200.00	4,000.00	1,750.00
Oil Reservoir Depth (ft kb)	50.00	1,000.00	4,000.00	1,683.33
Reservoir Pressure (psi)	35.65	749.65	1,694.65	826.65
Reservoir Temperature (F°)	34.00	68.00	113.00	71.67
Methane Content	0.90	0.98	0.99	0.96
Ethane Content	0.01	0.02	0.05	0.03
Propane Content	0.00	0.01	0.05	0.02
H_2S Content	0.00	0.00	0.00	0.00
CO_2 Content	0.00	0.00	0.00	0.00
Total Play Area (MM acres)	1.75	2.10	2.50	2.12
Tested Play Area (MM acres)	0.00	0.00	0.00	0.00
Untested Play Area (MM acres)	***	***	***	2.12
Fraction of Total Play in Trap	0.05	0.15	0.25	0.15
Fraction of Untested Play Areally Filled	0.40	0.50	0.85	0.58
Potential HC Area (MM acres)	***	***	***	0.19
Fraction of Pore Volume Oil Bearing	0.01	0.03	0.08	0.04
Potential Oil Area (MM acres)	***	***	***	0.00
Potential Gas Area (MM acres)	***	***	***	0.05
Average Net Pay (ft.)	30.00	75.00	150.00	85.00
Porosity	0.06	0.12	0.22	0.13
Hydrocarbon Saturation	0.40	0.55	0.75	0.57
Oil Recovery Factor	0.10	0.15	0.30	0.18
Gas Recovery Factor	0.55	0.65	0.80	0.67
GOR (MMcf/Bbl)	0.05	0.05	0.05	0.05
Oil Formation Volume Factor	1.03	1.03	1.03	1.03
Gas Compressibility Factor ‘Z’	0.88	0.90	0.92	0.90
Gas Formation Volume Factor	***	***	***	0.06

3) Yield Component

Input Parameters	Minimum	Most Likely	Maximum	Mean
Yield - Oil In-place (Bbls/ac-ft.)	***	***	***	568.55
Yield - Recoverable Oil (Bbls/ac-ft.)	***	***	***	104.04
Yield - Gas In-place (MMcf/ac-ft.)	***	***	***	201.43
Yield - Raw Recoverable Gas (MMcf/ac-ft.)	***	***	***	134.35
Yield - Marketable Gas (MMcf/ac-ft.)	***	***	***	114.20
Liquids Yield (Bbls/MMcf)	0.50	1.50	8.00	3.33
Gas to BOE Conversion Factor (MMcf/BOE)	***	6.00	***	***
“Surface Loss (Fuel gas, etc)”	***	0.15	***	***
Marketable Gas (Fraction of Raw)	***	0.85	***	***



Percentile values

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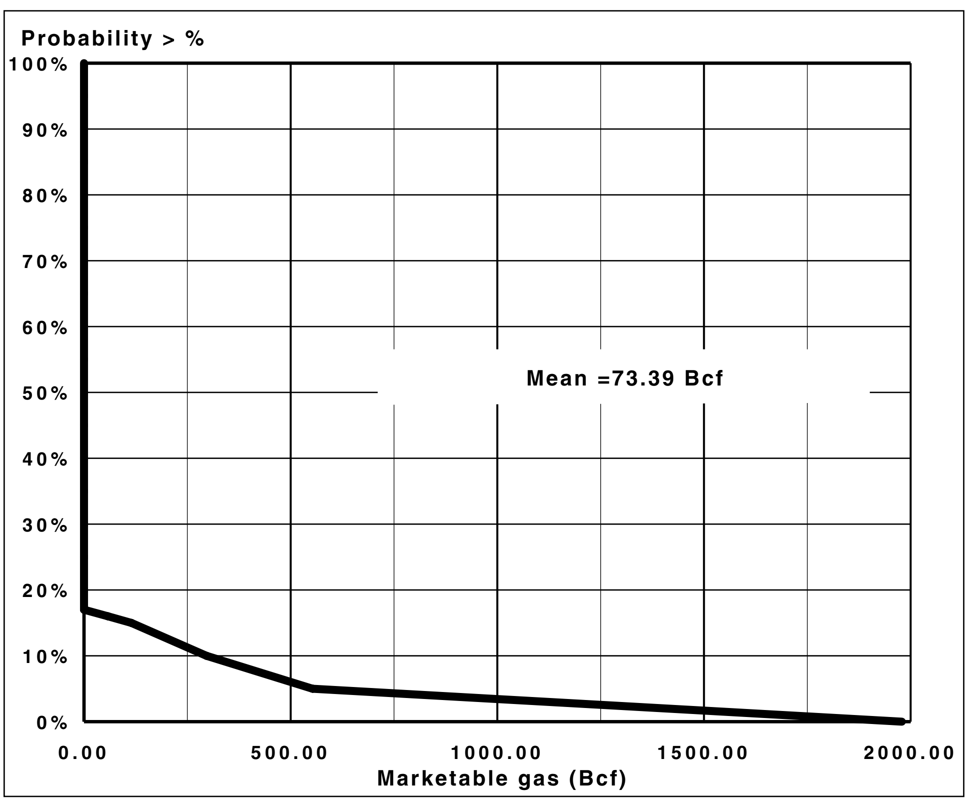
55%	0
50%	0
45%	0
40%	0
35%	0
30%	0
25%	0
20%	0
17%	0
16%	3.03
15%	5.05
10%	11.08
5%	19.63
0%	99.25



Percentile values

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50%	0
45%	0
40%	0
35%	0
30%	0
25%	0
20%	0
17%	0
16%	58.10
15%	114.55
10%	296.43
5%	552.95
0%	1,978.66

Cretaceous

TANTALUS STRUCTURAL

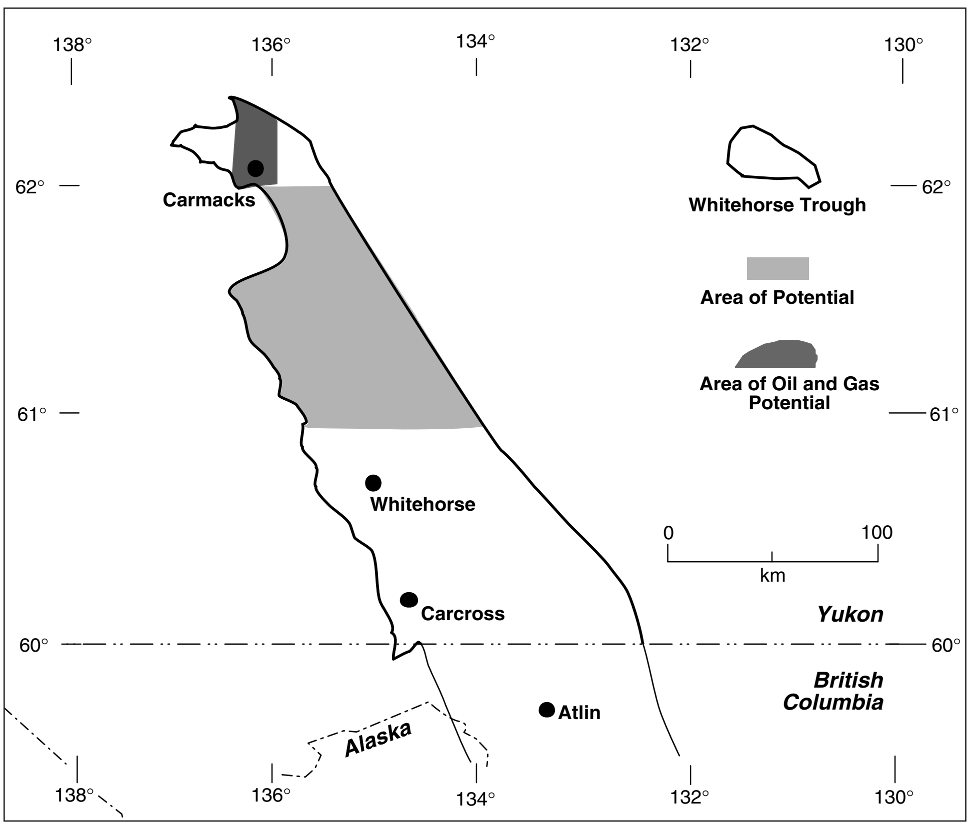
CONCEPTUAL GAS AND OIL PLAY

Reservoir definition

This gas and oil play is defined to include pools and prospects within antiformal folds and fault related traps containing strata of the Tantalus Formation. The play area covers approximately 4,400 km^2 and is limited on the west by the Llewellyn-King Salmon Fault System and outcrop occurrences, on the east by outcrop, subcrop traces and the Teslin/Thibert/Kutcho Fault System and on the south by outcrop exposures.

Hydrocarbon occurrence model

The reservoir for this play is composed of pools and prospects within antiformal folds and fault-related traps containing strata of the Tantalus Formation. Source for the hydrocarbons within this play is interpreted to have been provided by the organic-rich horizons within the Hancock, Tantalus (ie. the intraformational coals) and the

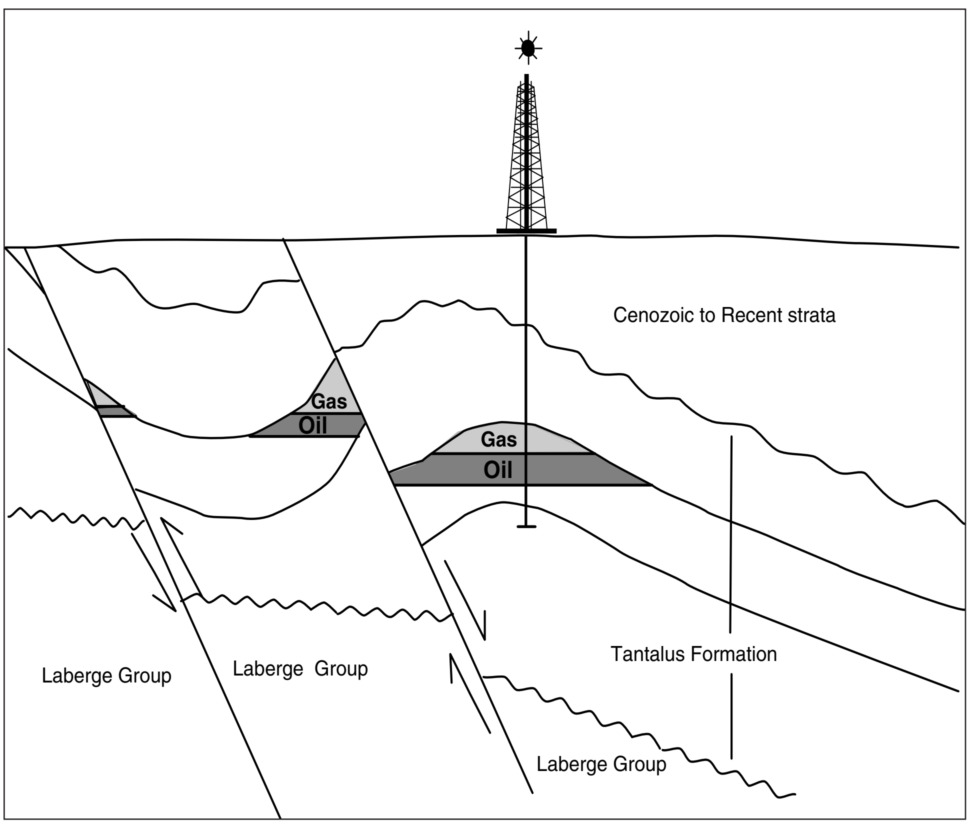


Richthofen formations. Hydrocarbons are expected to have migrated from the source horizons via fractures and faults and within porous carrier beds within the various formations. The seal is provided by the siltstones, tight sandstones and shales, dacties and tuffs that are fault juxtaposed against the reservoir beds and by interformational sills and shallow permafrost. Individual pools in this play are expected to be complex.

This play carries an overall risk of existence of 21% due mainly to the risk of breach, subsequent reservoir degradation (diagenetic occlusion and halo alteration near the intruding sills) and degradation of the hydrocarbons due to bacterial action, water washing and over-heating near the sills.

Potential resources

This work indicates that this play has a mean probability of occurrence of 21%, that prospects within this play have a mean risk of 33%. The mean gas potential for this play is 453 10^6m^3 (15.99 Bcf) and and the mean oil potential is 0.12 10^6m^3 (0.73 MMBbls).



Estimate of potential petroleum resources.

1) **Risk Component** — **Mean**

	Mean
Play Level Risk	0.21
Prospect Level Risk	0.33

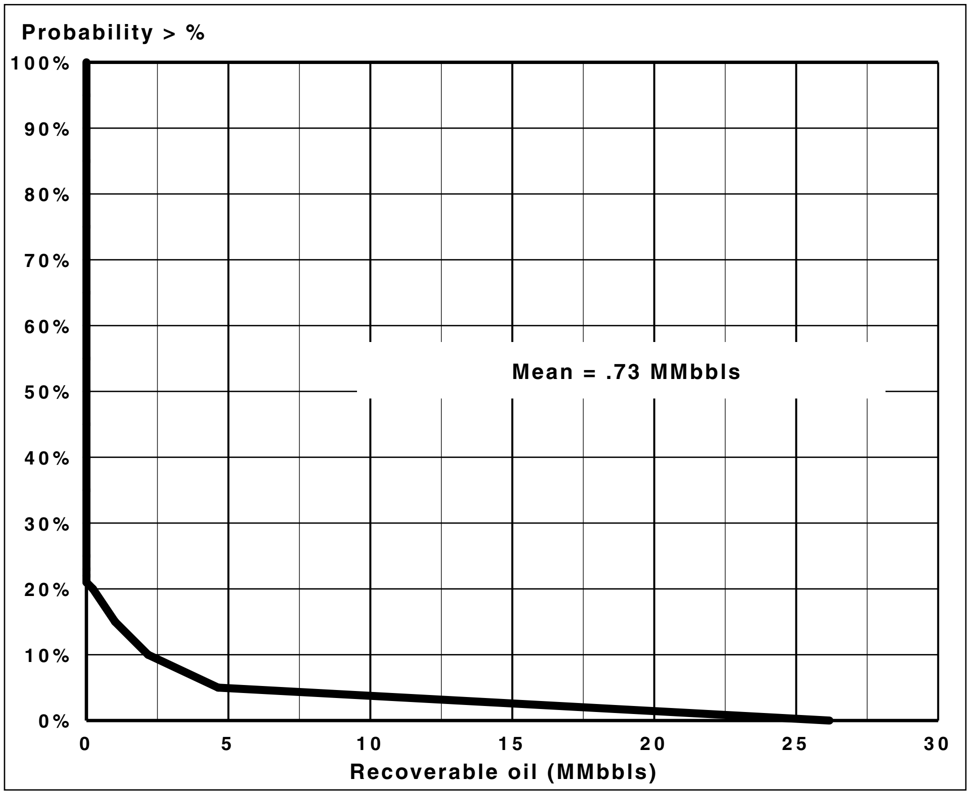
2) **Hydrocarbon Volume Component**

Average Surface Temperature (F°)	33.00	Temperature Gradient (F°/100 ft.)	2.00
Pressure Gradient (psi/ft.)	0.42	Raw Gas Gravity	0.43

Input Parameters	Minimum	Most Likely	Maximum	Mean
Gas Reservoir Depth (ft kb)	50.00	1,100.00	4,000.00	1,716.67
Oil Reservoir Depth (ft kb)	50.00	1,000.00	4,000.00	1,683.33
Reservoir Pressure (psi)	35.65	735.65	1,694.65	821.98
Reservoir Temperature (F°)	34.00	67.33	113.00	71.44
Methane Content	0.90	0.98	0.99	0.96
Ethane Content	0.01	0.02	0.05	0.03
Propane Content	0.00	0.01	0.05	0.02
H_2S Content	0.00	0.00	0.00	0.00
CO_2 Content	0.00	0.00	0.00	0.00
Total Play Area (MM acres)	0.50	0.80	2.00	1.10
Tested Play Area (MM acres	0.00	0.00	0.00	0.00
Untested Play Area (MM acres)	***	***	***	1.10
Fraction of Total Play in Trap	0.01	0.08	0.20	0.10
Fraction of Untested Play Areally Filled	0.01	0.10	0.75	0.29
Potential Oil and Gas Area (MM acres)	***	***	***	0.03
Fraction of Pore Volume Oil Bearing	0.01	0.05	0.09	0.05
Potential Oil Area (MM acres)	***	***	***	0.00
Potential Gas Area (MM acres)	***	***	***	0.01
Average Net Pay (ft.)	15.00	75.00	175.00	88.33
Porosity	0.04	0.12	0.18	0.11
Hydrocarbon Saturation	0.45	0.60	0.85	0.63
Oil Recovery Factor	0.05	0.15	0.25	0.15
Gas Recovery Factor	0.45	0.65	0.75	0.62
GOR (MMcf/Bbl)	0.05	0.05	0.05	0.05
Oil Formation Volume Factor	1.03	1.03	1.03	1.03
Gas Compressibility Factor 'Z'	0.95	0.97	0.98	0.97
Gas Formation Volume Factor	***	***	***	0.06

3) **Yield Component**

Input Parameters	Minimum	Most Likely	Maximum	Mean
Yield - Oil In-place (Bbls/ac-ft.)	***	***	***	539.28
Yield - Recoverable Oil (Bbls/ac-ft.)	***	***	***	80.89
Yield - Gas In-place (MMcf/ac-ft.)	***	***	***	177.26
Yield - Raw Recoverable Gas (MMcf/ac-ft.)	***	***	***	109.37
Yield - Marketable Gas (MMcf/ac-ft.)	***	***	***	98.43
Liquids Yield (Bbls/MMcf)	0.50	1.50	8.00	3.33
Gas to BOE Conversion Factor (MMcf/BOE)	***	6.00	***	***
"Surface Loss (Fuel gas, etc)"	***	0.10	***	***
Marketable Gas (Fraction of Raw)	***	0.90	***	***



Percentile values

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80%	0
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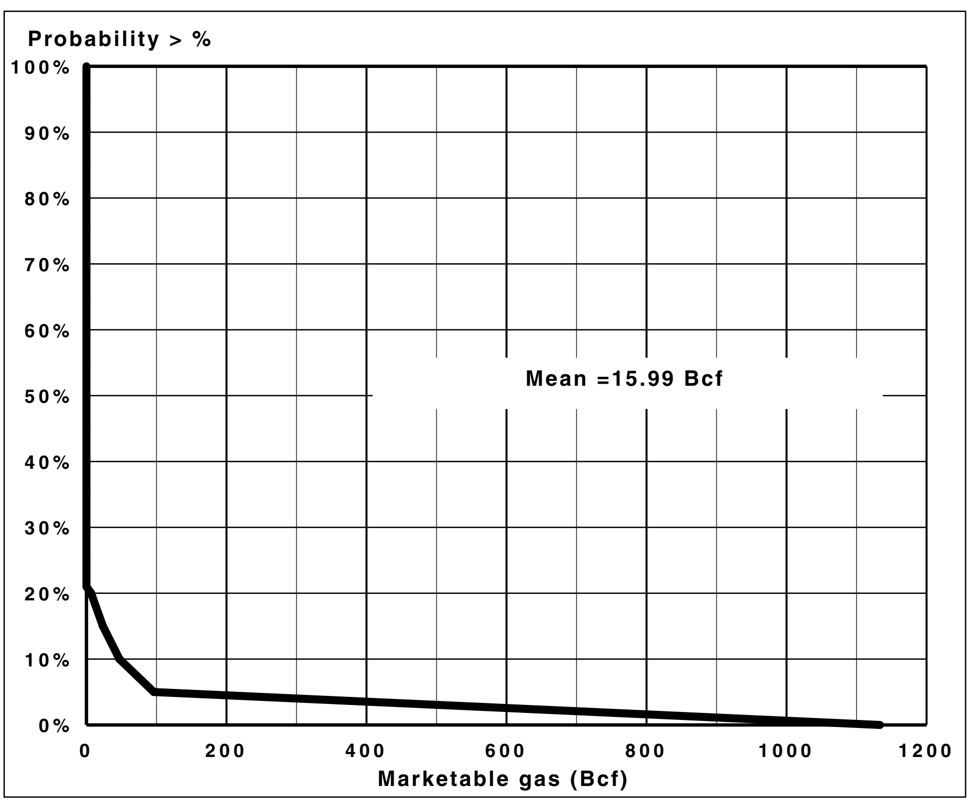
70%	0
65%	0
60%	0
55%	0
50%	0
45%	0
40%	0
35%	0
30%	0
25%	0
23%	0
22%	0
21%	0
20%	0.23
15%	1.01
10%	2.17
5%	4.64
0%	26.17



Percentile values

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60%	0
55%	0
50%	0
45%	0
40%	0
35%	0
30%	0
25%	0
23%	0
22%	0
21%	0
20%	6.65
15%	23.47
10%	47.12
5%	96.23
0%	1,133.46

Cenozoic

ALLUVIUM AND TILL STRATIGRAPHIC

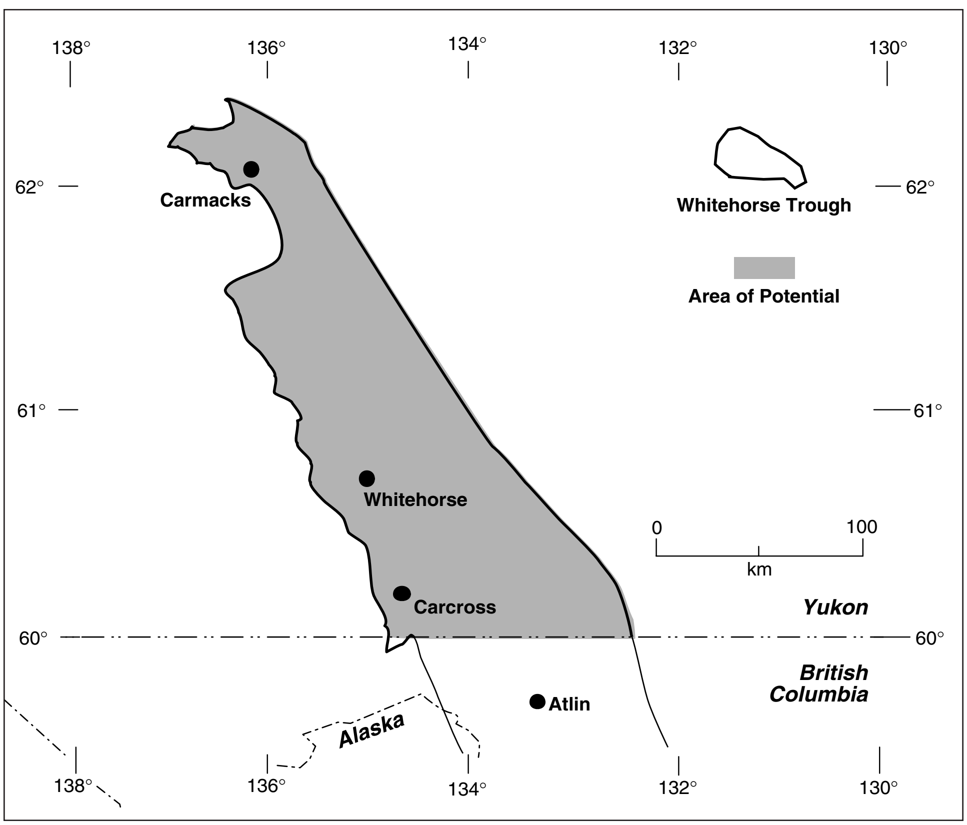
CONCEPTUAL GAS PLAY

Reservoir definition

This speculative low-pressure gas play was defined to include all pools and prospects within Quaternary to Recent unconsolidated alluvium and till. The play covers approximately 19,400 km^2 and is limited on the north and west by the Llewellyn-King Salmon Fault System and the outcrop exposures of older strata, on the east by Teslin-Thibert-Kutcho Fault System and the outcrop exposures of older strata and on the south by the study area boundary (border with British Columbia). The play extends into British Columbia.

Hydrocarbon occurrence model

The reservoir consists of coarser sand and gravel which may have thicknesses up to several hundred metres. The seal is provided by silt, shale and permafrost. The gas is biogenic in origin. Fractures and/or faults in the underlying bedrock may provide additional migration pathways for charging these reservoirs with thermogenic gas generated deeper in the section. Porous lenses within the Cenozoic section range in



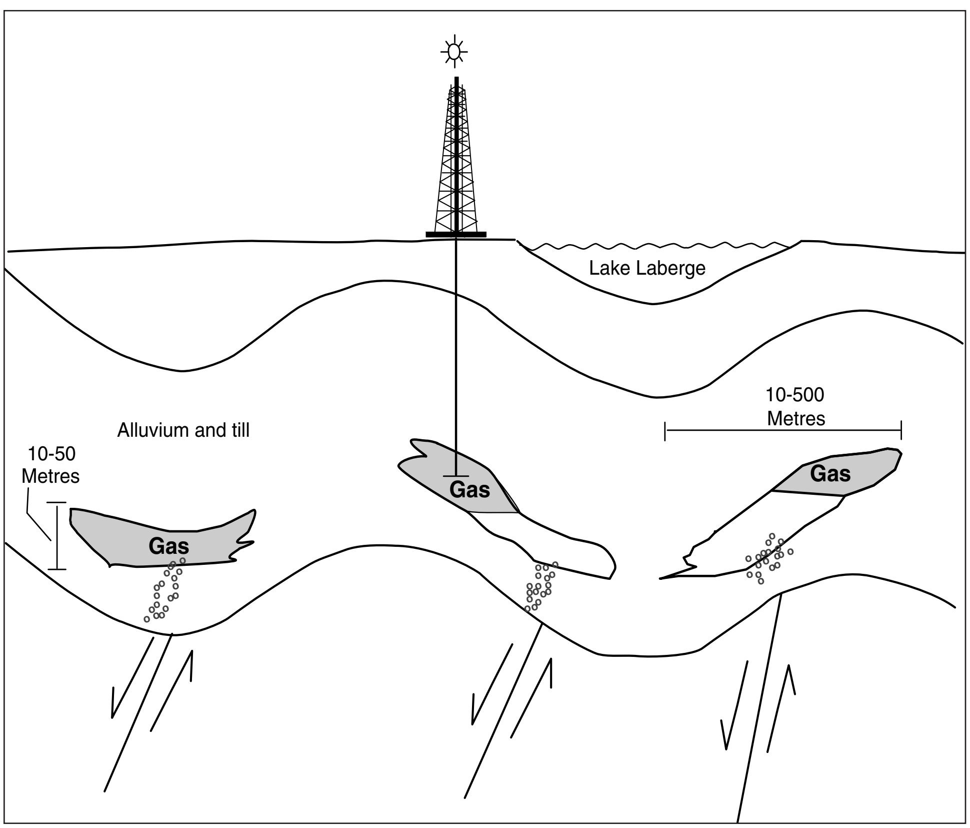
size from 10 to 500 m and 10 to 50 m in thickness. Gas accumulations are expected to be very small and represent more of a geotechnical hazard than a real resource; however, it may have some value in local residential heating.

No discoveries have been made in this play. However, Koch (1973) noted reports of vehicles to the north of Whitehorse igniting gaseous hydrocarbons as they drove along gravel roads.

This play carries an overall risk of existence of 10% due mainly to the risk of breach, subsequent reservoir degradation (diagenetic occlusion and halo alteration near the intruding sills) and degradation of the hydrocarbons due to bacterial action, water washing and over-heating near intrusive sills.

Potential resources

This work indicates that this play has a mean probability of occurrence of 10%, that prospects within this play have a mean risk of 16%. The mean gas potential for this play is 135 $10^6 m^3$ (4.7775 Bcf).



Estimate of potential petroleum resources.

1) Risk Component **Mean**

Play Level Risk	0.10
Prospect Level Risk	0.16

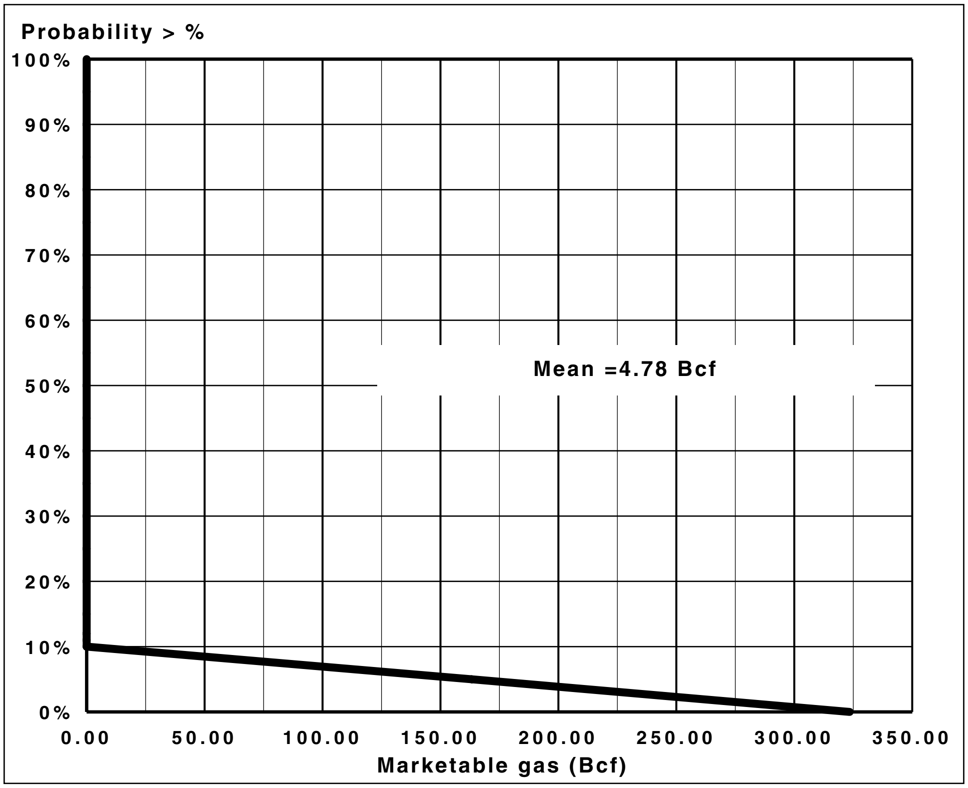
2) Hydrocarbon Volume Component

Average Surface Temperature (F°)	33.00	Temperature Gradient (F°/100 ft.)	2.00
Pressure Gradient (psi/ft.)	0.42	Raw Gas Gravity	0.42

Input Parameters	Minimum	Most Likely	Maximum	Mean
Gas Reservoir Depth (ft kb)	50.00	200.00	650.00	300.00
Oil Reservoir Depth (ft kb)	0.00	0.00	0.00	0.00
Reservoir Pressure (psi)	35.65	140.65	287.65	154.65
Reservoir Temperature (F°)	34.00	39.00	46.00	39.67
Methane Content	0.90	0.98	0.99	0.96
Ethane Content	0.01	0.02	0.05	0.03
Propane Content	0.00	0.01	0.05	-0.02
H_2S Content	0.00	0.00	0.00	0.00
CO_2 Content	0.00	0.00	0.00	0.00
Total Play Area (MM acres)	0.50	2.00	5.00	2.50
Tested Play Area (MM acres)	0.00	0.00	0.00	0.00
Untested Play Area (MM acres)	***	***	***	2.50
Fraction of Total Play in Trap	0.10	0.15	0.25	0.17
Fraction of Untested Play Areally Filled	0.35	0.60	0.80	0.58
Potential Oil and Gas Area (MM acres)	***	***	***	0.24
Fraction of Pore Volume Oil Bearing	0.00	0.00	0.00	0.00
Potential Oil Area (MM acres)	***	***	***	0.00
Potential Gas Area (MM acres)	***	***	***	0.04
Average Net Pay (ft.)	5.00	30.00	125.00	53.33
Porosity	0.06	0.15	0.28	0.16
Hydrocarbon Saturation	0.40	0.60	0.85	0.62
Oil Recovery Factor	0.00	0.00	0.00	0.00
Gas Recovery Factor	0.45	0.55	0.75	0.58
GOR (MMcf/Bbl)	0.00	0.00	0.00	0.00
Oil Formation Volume Factor	1.00	1.00	1.00	1.00
Gas Compressibility Factor 'Z'	0.88	0.90	0.92	0.90
Gas Formation Volume Factor	***	***	***	0.01

3) Yield Component

Input Parameters	Minimum	Most Likely	Maximum	Mean
Yield - Oil In-place (Bbls/ac-ft.)	***	***	***	780.23
Yield - Recoverable Oil (Bbls/ac-ft.)	***	***	***	0.00
Yield - Gas In-place (MMcf/ac-ft.)	***	***	***	53.48
Yield - Raw Recoverable Gas (MMcf/ac-ft.)	***	***	***	31.18
Yield - Marketable Gas (MMcf/ac-ft.)	***	***	***	26.50
Liquids Yield (Bbls/MMcf)	0.00	0.00	0.00	0.00
Gas to BOE conversion Factor (MMcf/BOE)	***	6.00	***	***
"Surface Loss (Fuel gas, etc)"	***	0.15	***	***
Marketable Gas (Fraction of Raw)	***	0.85	***	***



Percentile values

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95%	0
90%	0
85%	0
80%	0
75%	0
70%	0
65%	0
60%	0
55%	0
50%	0
45%	0
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35%	0
30%	0
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20%	0
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12%	0
11%	0
10%	0
5%	163.22
0%	323.48

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Geophysical Paper 7209G Glenlyon (NTS 105L).

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Map 372A Laberge (NTS 105E).

Map 1039A Whitehorse (NTS 105D).

Map 1082A Atlin (NTS 104N).

Map 1121A Glenlyon (NTS 105L).

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