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Hydrocarbon Assessment Summary Report of Buffalo Lake Area of Interest

Y. Lemieux

2007

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Available from
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Lemieux, Y.
2007: Hydrocarbon Assessment Summary Report of Buffalo Lake Area of Interest, Geological Survey of Canada, Open File 5575, 13 p.

ABSTRACT

The purpose of this report is to present a hydrocarbon resource potential assessment of Buffalo Lake area of interest. The area of interest examined here is located in the southern Great Slave Plain region and covers an area in excess of 2100 km^2. The region is almost entirely covered by a thick mantle of glacial deposits; it is underlain by a gently southwest-dipping, relatively undisturbed succession dominated by Paleozoic carbonate rocks and Cretaceous clastic rocks. Six exploration wells have been drilled within, or near the outer limit of Buffalo Lake area of interest. Although suitable source and reservoir rocks are present within Buffalo Lake area of interest, the potential of significant petroleum discoveries is probably very low. Most of the prospective intervals are either shallow or exposed at surface. Other exploration risks, such as discontinuous distribution and isolation from source rocks, are also anticipated for some of the plays.

INTRODUCTION

The NWT Protected Areas Strategy (PAS) is a partnership process to establish protected areas in the Northwest Territories. The PAS process requires that as areas are identified, the known cultural, ecological and economic values are studied, documented and discussed. As part of this work, Non-Renewable Resource Assessments of mineral and hydrocarbon potential are conducted on areas of interest. The purpose of this report is to present a hydrocarbon resource potential assessment of Buffalo Lake area of interest. The area of interest examined here is located in the southern Great Slave Plain region and covers an area in excess of 2100 km^2 (Fig. 1); it covers parts of NTS map sheets 085 B and C.

Buffalo Lake area of interest is located south and east of Hay River and Enterprise, respectively, in the vicinity of Buffalo Lake; it falls entirely within the Deh Cho territory (Fig. 2). It lies in the southern Great Slave Plain physiographic region, where elevation rarely exceeds more than 300 m above sea level. Buffalo Lake area of interest is limited to the south by the 60^{th} parallel and extends north to Great Slave Lake. The eastern boundary of the area is defined by the southeastern limit of the Deh Cho territory. West of Buffalo Lake, the area of interest extends to $116^{o}13'$W longitude.

GEOLOGICAL SETTING

Great Slave Plain physiographic region is almost entirely covered by a thick mantle of glacial deposits; it is underlain by a gently southwest-dipping, relatively undisturbed succession dominated by Paleozoic carbonate rocks and Cretaceous clastic rocks (Table 1; Fig. 3). Paleozoic sedimentation beneath Great Slave Plain commenced with deposition of regionally discontinuous Devonian sandstone beds (basal clastics, or La Loche Formation of Norris (1963); see also Meijer-Drees, 1993) on the flanks of the Tathlina Arch (Fig. 4), a paleotopographic feature that persisted until Late Devonian time and influenced sedimentation. Basal Paleozoic strata rest unconformably on Precambrian igneous and metamorphic basement rocks. The La Loche Formation is conformably overlain by interbedded anhydrite, dolostone, evaporites and red beds of the Mirage Point and Lower Chinchaga formations, which onlap the Tathlina Arch.

The Middle Devonian succession is marked by the development of a great carbonate barrier complex, the Presqu'ile Barrier reef complex across Tathlina Arch (Meijer-Drees, 1993). Buffalo Lake area of interest lies on the south flank of this barrier reef complex and on the northernmost limit of the Elk Point Basin. The Presqu'ile Barrier includes carbonate rocks of the Keg River, Sulphur Point, and Slave Point formations, and shale of the Watt Mountain Formation. Anhydrite of the Muskeg Formation was deposited beneath the Sulphur Point carbonates along the northern edge of the Elk Point Basin across Buffalo Lake area of interest.

PERIOD (Epoch, stage)		FORMATION / GROUP	LITHOLOGY
Cretaceous	Lower	Fort St. John	Shale
Unconformity			
Devonian	Upper	Kotcho	Shale, limestone, sandstone
		Tetcho	Limestone (bioclastic)
		Trout River	Limestone
		Kakisa	Limestone (sandy, silty)
		Redknife	Shale (calcareous, silty)
		Jean-Marie Member of Redknife	Limestone (silty, bioclastic)
		Tathlina	Siltstone (calcareous)
		Twin Falls	Limestone (bioclastic)
		Alexandra Member of Twin Falls	Limestone (reefal, bioclastic)
		Hay River	Shale (calcareous, bioclastic)
		Muskwa (Horn River Group)	Shale, evaporite
	Middle	Slave Point	Limestone (bioclastic)
		Watt Mountain	Shale
		Sulphur Point	Limestone
		Muskeg	Anhydrite, dolostone
		Keg River, Nahanni (Lonely Bay)	Dolostone (biostromal)
		Upper Chinchaga and Ebbut Member	Dolostone, minor anhydrite
	Unconformity		
	Lower	Lower Chinchaga	Anhydrite, dolostone
		Mirage Point (Ernestina Lake)	Anhydrite, dolostone, evaporite
		Basal clastics (La Loche)	Sandstone
Unconformity			
Precambrian		Slave, Buffalo Head, and Great Bear domains	Metasedimentary, gneiss, granite

Table 1. Main rock formations of the southern Great Slave Plain.

The Middle Devonian Presqu'ile dolostone, which is developed within the Presqu'ile Barrier carbonates, is a diagenetic, coarse crystalline dolostone that occurs south and west of Great Slave Lake (Meijer-Drees, 1993). It resulted from episodic karstification and dolomitization of Middle Devonian reefal carbonate units. The Presqu'ile facies includes important reservoir rocks, such as the Sulphur Point and Slave Point formations, and hosts the Pine Point lead-zinc deposit. The Upper Devonian succession comprises carbonate platform and shelf limestone units including the Twin Falls (Alexandra Member), Redknife (Jean Marie Member), Kakisa, Tetcho, and Kotcho formations, which alternate with variably shaly siliciclastic intervals including the Muskwa, Hay River, Tathlina, Trout River formations. In the southern Great Slave Plain area, Early Cretaceous strata unconformably rest on the Devonian succession and include marine shale and minor sandstone of the Fort St. John Group.

Much of Buffalo Lake area of interest is mantled by Quaternary-aged glacial deposits; exposed bedrock consists of limited outcrops of shale of the Hay River Formation on the west side of Buffalo Lake and limestone of the Slave Point Formation along Buffalo River.

The southern Great Slave Plain area is marked by an array of surface and subsurface northeast-trending faults and fault zones (Fig. 3), which have likely played a role in migration of hydrocarbons. The Great Slave Shear Zone (Hoffman, 1987) has been interpreted as a major Precambrian transform structure. Numerous smaller northeast-trending faults (not shown on Fig. 3) occur northwest of the Great Slave Shear Zone and offset the lower Paleozoic succession (Morrow et al., 2002). The influence of faults on Paleozoic strata southeast of the shear zone

appears less pronounced. Other major regional faults include the Tathlina Fault, and the Hay River and McDonald fault zones (Fig. 3; Williams, 1990; Burwash et al., 1994).

HYDROCARBON OCCURRENCES

Six exploration wells have been drilled within, or near the outer limit of Buffalo Lake area of interest, and are summarized in Table 2. No drill stem tests (DSTs) for oil and gas were reported for Shell H.B. Grumbler I-72 well. DSTs were performed within Devonian carbonate units, and mud and (or) water was recovered from Shell H.B. Grumbler L-05, J-72, and I-16, and Mobil Alex Falls B-07 wells; a gas show was found at Shell H.B. Grumbler G-63 well.

A significant oil and gas field, the Cameron Hills Field, is located approximately 50 km southwest of Buffalo Lake area of interest (Fig. 3). Production commenced in 2002. At the end of 2005, it had a cumulative production of 125.4 x 10^3 m^3 of oil, and 347.8 x 10^6 m^3 of gas (Indian and Northern Affairs Canada, 2005).

Well name and Grid number	Location of well	Completion Date	Total Depth (m)	Lowest Formation Reached	Status of well
Shell H.B. Grumbler L-05 6020-11600	West of Buffalo Lake	1969/03/13	753.5	Precambrian	Dry and abandoned
Shell H.B. Grumbler G-63 6020-11545	West of Buffalo Lake	1969/03/11	753.2	Basal clastics	Gas show, abandoned
Shell H.B. Grumbler I-72 6030-11530	North of Buffalo Lake	1969/04/02	771.1	Precambrian	Dry and abandoned
Shell H.B. Grumbler J-72 6030-11530	North of Buffalo Lake	1969/02/09	730.3	Precambrian	Dry and abandoned
Shell H.B. Grumbler I-16 6030-11545	North of Buffalo Lake	1969/01/17	708.4	Precambrian	Dry and abandoned
Mobil Alex Falls B-07 6040-11545	North of Buffalo Lake	1969/02/21	638.3	Precambrian	Dry and abandoned

Table 2. Summary of wells drilled within (or near) Buffalo Lake area of interest.

HYDROCARBON PROSPECTIVITY

The southern Great Slave Plain area is underlain by Paleozoic rocks that are prospective for oil and gas. Hannigan and others (2006; P.K. Hannigan, pers. comm.; see also Canadian Gas Potential Committee, 2001; Gal and Jones, 2003; Canadian Gas Potential Committee, 2005; Gal and Udell, 2005) defined several hydrocarbon plays in the southern Mackenzie Valley area that could potentially host oil and (or) natural gas. Six of these exploration plays partly or entirely underlie Buffalo Lake area of interest (Figs. 4, 5) and are discussed below.

Early Devonian play

(Basal clastics)

This play includes all prospects in structural and stratigraphic traps where transgressive basal Devonian clastic strata unconformably onlap Precambrian basement highs, such as the Tathlina Arch (Gal and Jones, 2003; Hannigan et al., 2006). Although a conceptual[1] play here, it is a prolific oil producer in northern Alberta, where Middle Devonian sandstone beds (also known

[1] A conceptual play does not yet have discoveries or reserves, but may exist according to geological analysis

as “Granite Wash”) mantle the flank of the Peace River Arch (e.g., Podruski et al., 1988). In the subsurface, basal Devonian clastic rocks are regionally discontinuous; the play extends north and south of the Tathlina Arch and a small portion of it underlies the area of interest (Fig. 4). Potential reservoir intervals are generally less than 1.5 m thick, but reach a thickness of 21 m in places (Meijer-Drees, 1993). Porosity of the reservoir is generally poor to fair, although zones of porosity over 9% have been locally documented (Gal and Jones, 2003). Source rocks include organic-rich beds of the Lower Chinchaga Formation or Middle Devonian shale. Evaporitic strata of the Mirage Point and Lower Chinchaga formations could provide reasonable seal.

Middle Devonian plays

(Lonely Bay/Nahanni/Hume platform, Keg River back barrier shelf, Upper Elk Point-Presqu’ile barrier, Sulphur Point back barrier shelf, and Slave Point back barrier shelf)

The conceptual Lonely Bay/Nahanni/Hume platform play includes all pools and prospects in stratigraphic and structural traps hosted in leached or dolomitized Devonian platform carbonate rocks, such as the Lonely Bay, Nahanni, or Hume formations (Gal and Jones, 2003; Hannigan et al., 2006). The play mostly extends outboard (i.e., north) of the Middle Devonian carbonate barrier and underlies the northern portion of Buffalo Lake area of interest (Fig. 4). The Middle Devonian Lonely Bay/Nahanni/Hume platformal succession is regionally widespread and of uniform thickness (Gal and Jones, 2003). Potential reservoir consists of dolomitized and (or) fractured carbonate rocks, the result of reactivated basement faults.

The established[2] Keg River back barrier shelf play includes all pools and prospects in dolomitized platformal carbonate rocks of the Keg River Formation resting south of the Middle Devonian carbonate barrier (Gal and Jones, 2003). Much of this play is located in northwestern Alberta, but extends north of the 60th parallel into the Buffalo and Tathlina lakes area (Fig. 4). Approximately 200 km southwest of Buffalo Lake area of interest, in northern Alberta, Keg River age-equivalent strata are host to the prolific Zama, Rainbow and Shekilie oil fields (Podruski et al., 1988).

The established (immature) Upper Elk Point-Presqu’ile barrier play includes all pools and prospects in stratigraphic traps hosted in Devonian reefal and dolomitized carbonate rocks in the interval including the Keg River, Sulphur Point, and Slave Point formations (Hannigan et al., 2006). The play is limited to the north by the carbonate barrier edge; its southern limit is defined by the edge of the Keg River and Sulphur Point back barrier shelf plays (Fig. 5). The Upper Elk Point-Presqu’ile barrier play underlies the northern portion of Buffalo Lake area of interest.

The established Sulphur Point back barrier shelf and Slave Point back barrier shelf plays include all pools and prospects comprising shelf facies carbonate rocks of the Sulphur Point and Slave Point formations (Gal and Jones, 2003; Hannigan et al., 2006). Much of these plays are located in northern Alberta, but their northern extent reaches the Tathlina and Buffalo lakes area (Figs. 4, 5). The Sulphur Point back barrier shelf plays rest south of the Presqu’ile barrier and extends northward up to the northern limit of the Muskeg Formation anhydrite, which acts as an underlying impermeable play seal. The Slave Point back barrier shelf play extends north to the Slave Point barrier edge. Structural traps within these plays play are dominant, as fractured reservoir rocks form traps in antiformal closures associated with reactivated northeast-trending faults, which act as conduits for hydrocarbons (Gal and Jones, 2003).

In the southeastern Great Slave Plain area, organic-rich facies of the Muskwa and Horn River formations lie within the oil window and are potential source rocks for the Middle Devonian plays (Stasiuk and Fowler, 2002). Evaporite of the Muskeg Formation and shale of the Watt Formation provide reservoir seals.

[2] An established play has been demonstrated to exist by the discovery of hydrocarbon pools

Summary of hydrocarbon potential

Drummond (2004) recently published estimates of potential hydrocarbon resources in the Deh Cho region; his report indicates an undiscovered potential of 220 billion cubic feet (Bcf) of gas within the basal clastics play. Interpretation of the data suggests approximately 4 Bcf of gas within Buffalo Lake area of interest.

The most prospective plays within the study area are the Sulphur Point and Slave Point back barrier shelf plays, and the Upper Elk Point – Presqu'ile barrier play. The Canadian Gas Potential Committee (2001, 2005) published resource estimates for Middle Devonian play in the Western Canadian Sedimentary Basin, which extends into the southern Northwest Territories. Interpretation of the data for the Middle Devonian Keg River/Pine Point reservoirs play and the Slave Point/Sulphur Point bank margin and interior reservoirs play suggest an undiscovered potential of approximately 50 Bcf of gas in the Buffalo Lake area of interest. These estimates reflect the area's low potential for undiscovered hydrocarbon resources.

The hydrocarbon potential map of mainland Northwest Territories compiled by Gal and Udell (2005) provides a comparative and qualitative assessment based on a number of geological factors, such as the number of overlapping petroleum plays, the presence of established plays and (or) known hydrocarbon for any given area. The map suggests that much of the southern Great Slave Plain area has a "Very High" hydrocarbon potential (Fig. 6), most likely a consequence, among other things, of the number of overlapping plays.

Although suitable source and reservoir rocks are present within Buffalo Lake area of interest, the potential of significant petroleum discoveries is probably very low. Most of the prospective intervals are either shallow or exposed at surface, increasing the risk of reservoir breaching, and (or) flushing and degradation of hydrocarbons by meteoritic or ground water. Also, the absence of dolomitization or fracturing may have produced insufficient porosity in the generally tight Middle Devonian carbonate reservoirs. Finally, several exploration risks, such as discontinuous distribution and isolation from source rocks, are anticipated for the basal clastics play (Gal and Jones, 2003).

FUTURE WORK

Oil and gas potential of the Mackenzie Valley and surrounding areas is the focus of a Northern Energy project under the Secure Canadian Energy Supply program of the Geological Survey of Canada. The main objective of this multidisciplinary project is to assess the hydrocarbon resource potential of the Mackenzie Valley using quantitative and qualitative geoscience data. Key outputs will be a series of Open File reports that outline the petroleum potential across the Mackenzie Valley. Resource estimates will be available by 2009.

ACKNOWLEDGEMENTS

Dave Morrow critically reviewed this report. Northwest Territories Geoscience Office Contribution #0032.

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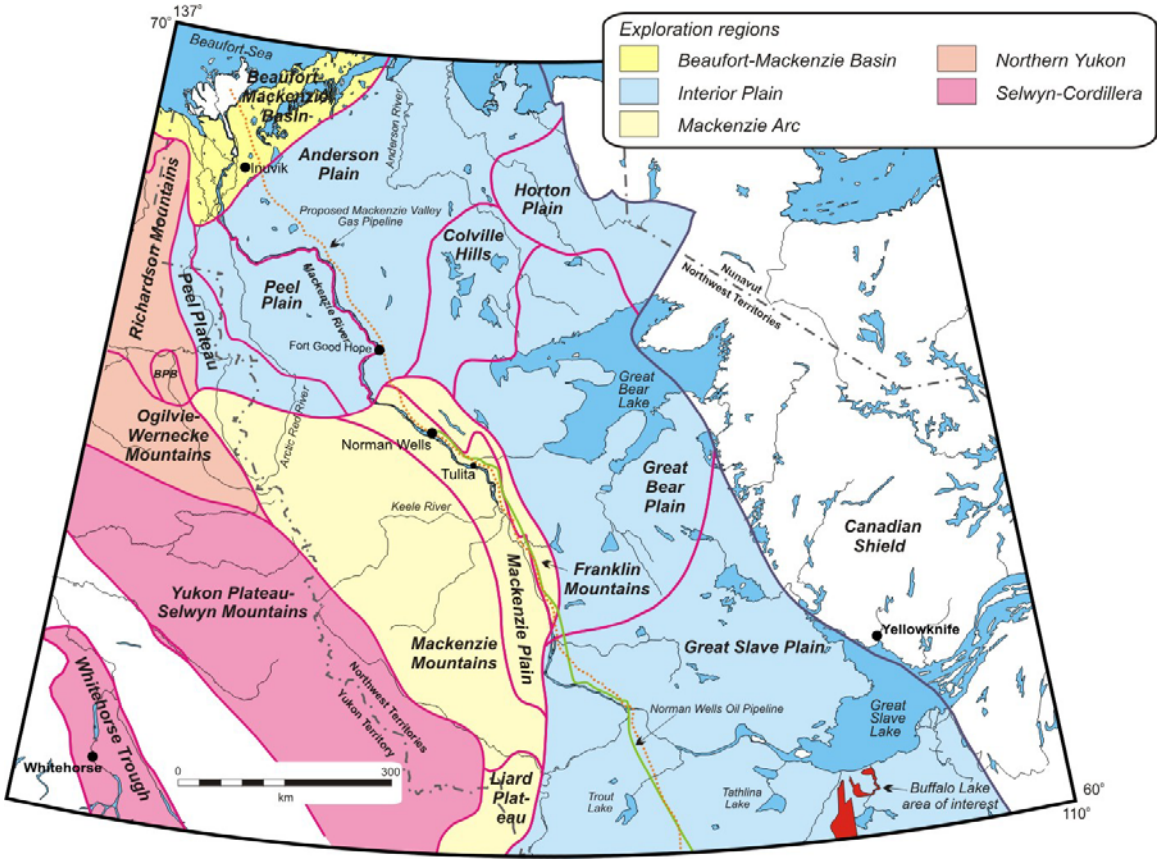

Figure 1. Main exploration regions of the Mackenzie Valley. Exploration regions are subdivided into exploration areas (e.g., Great Slave and Great Bear plains) on the basis of physiographic and/or geologic features. Figure shows the location of Buffalo Lake area of interest. BPB, Bonnet Plume Basin. Modified from Morrow et al. (2006).

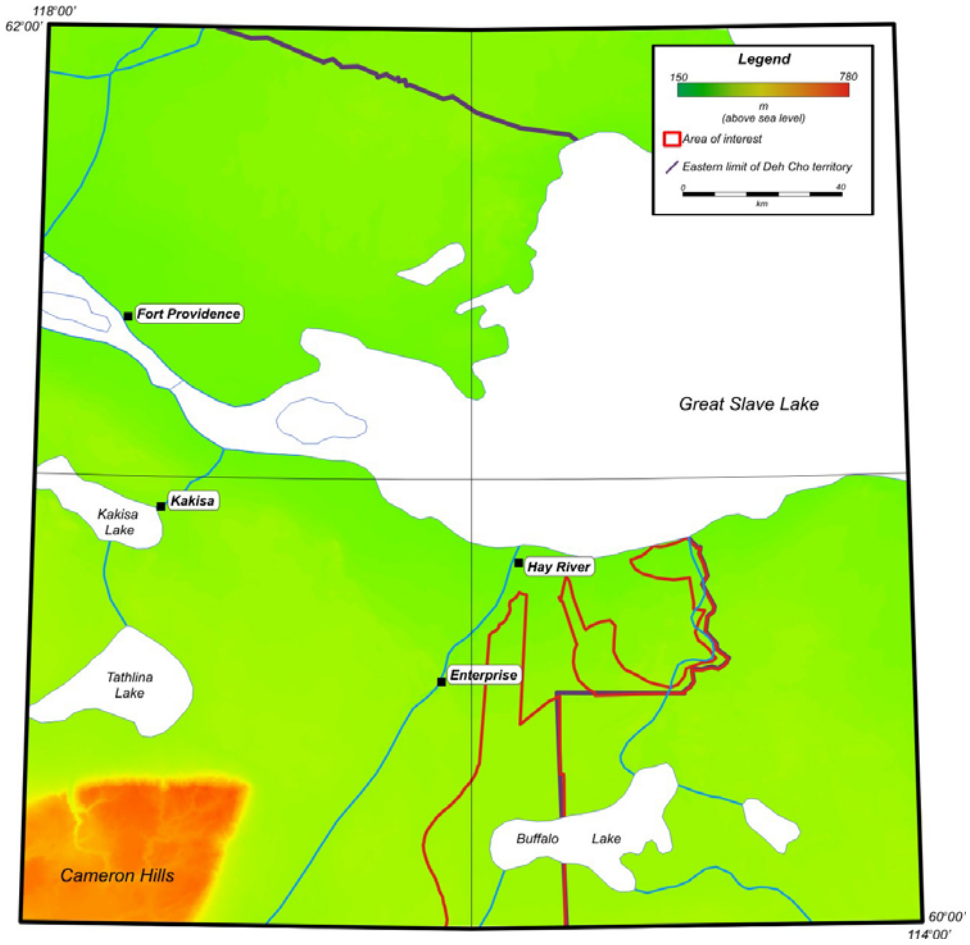

Figure 2. Elevation map of the southern Great Slave region including Buffalo Lake area of interest. The map shows the eastern boundary of the Deh Cho territory. Except for the Cameron Hills, elevation in this region rarely exceeds more than 300 m above sea level.

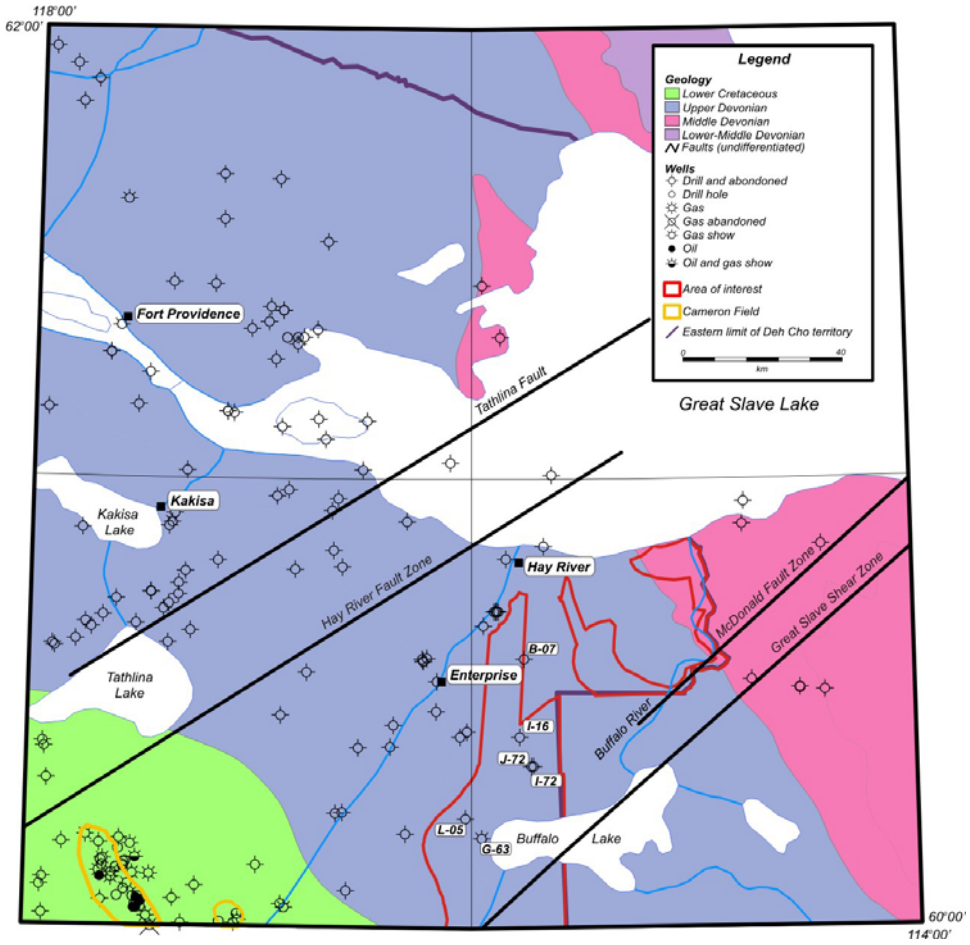

Figure 3. General geology map of Buffalo Lake area of interest. The area is underlain by a gently southwest-dipping, relatively undisturbed succession dominated by Paleozoic carbonate rocks and Cretaceous clastic rocks. The map shows the location of wells mentioned in the text. Location of Cameron Hills Field is also shown. Geology modified after Wheeler and McFeely (1991).

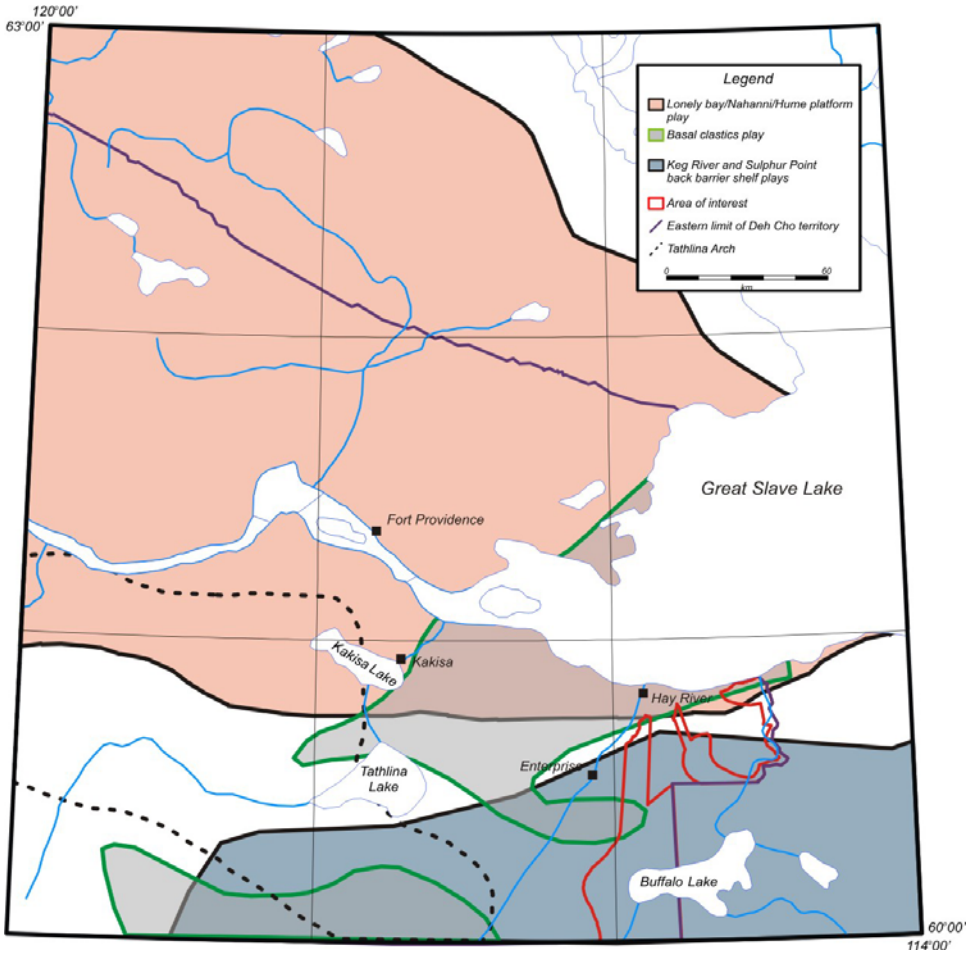

Figure 4. Map of the Lonely Bay/Nahanni/Hume platform, Keg River back barrier shelf, Sulphur Point back barrier shelf, and Basal clastics plays underlying Buffalo Lake area of interest. Within the map area, the Keg River back barrier shelf play and Sulphur Point back barrier shelf play have the same extent. The figure shows the extent of the Tathlina Arch.

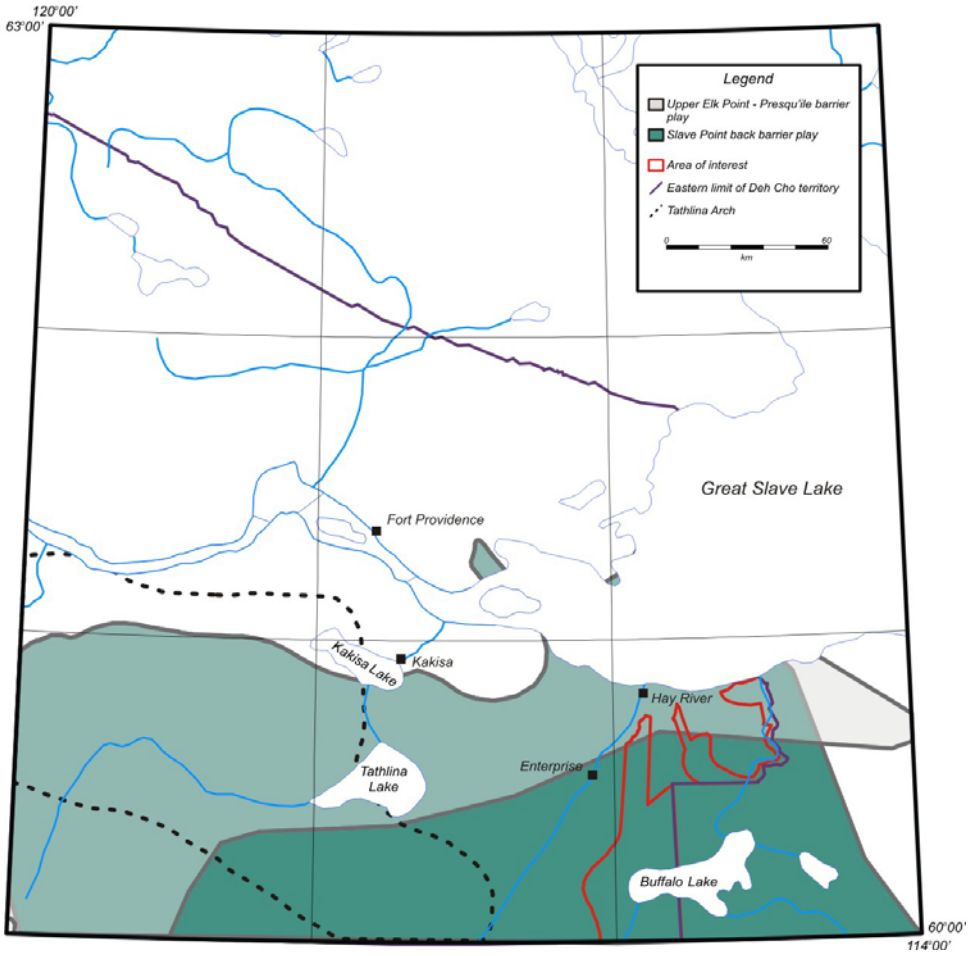

Figure 5. Map of the Upper Elk Point-Presqu'ile barrier and Slave Point back barrier plays underlying Buffalo Lake area of interest. The figure shows the extent of the Tathlina Arch.

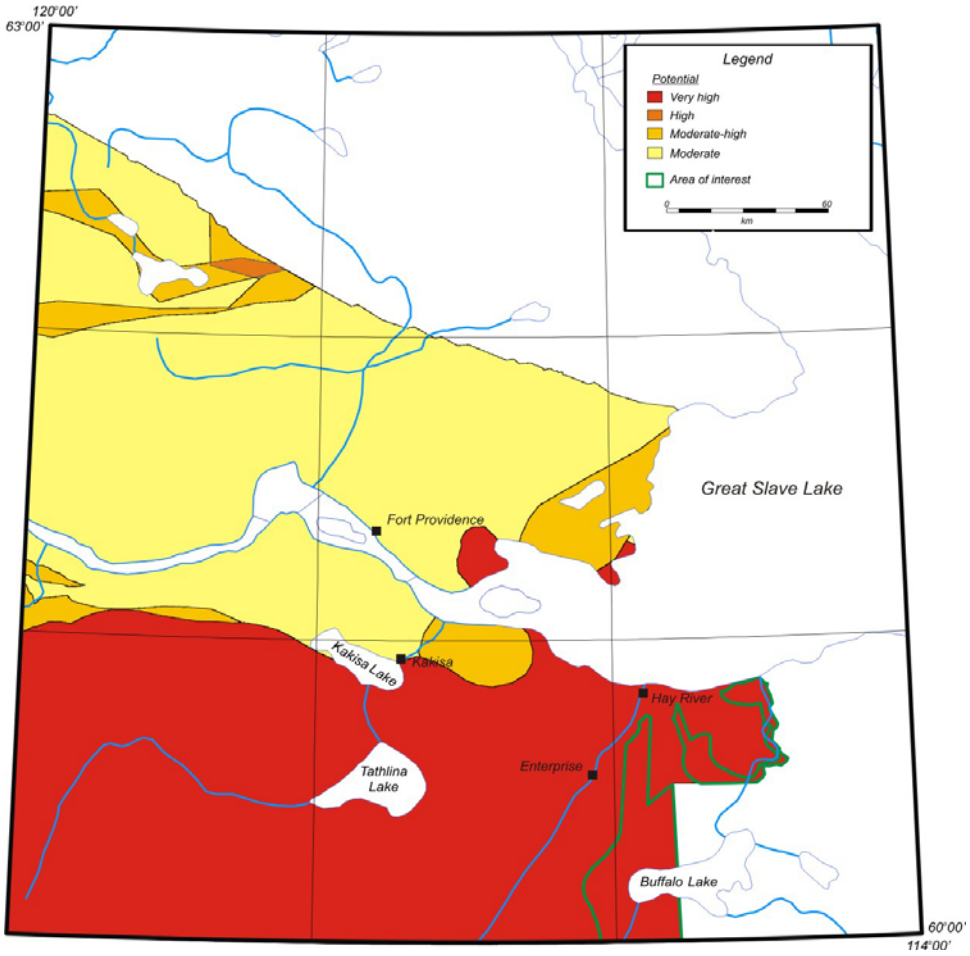

Figure 6. Hydrocarbon potential map of Buffalo Lake area of interest. The area of interest is shown to have a "Very High" petroleum potential (Gal and Udell, 2005). Subsequent work suggests that the overall petroleum potential of Buffalo Lake area of interest would be better characterized as very low. See text for discussion. Note that the potential polygons are limited to the Deh Cho territory. Modified from Gal and Udell (2005).