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Sambaa K'e Candidate Protected Area Hydrocarbon Assessment Summary Report

D.W. Morrow

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ABSTRACT

The Sambaa K'e candidate protected area lies within the Great Slave Plain physiographic region southwest of Great Slave Lake and is centered on the community of Trout Lake. Gently southwest-dipping Devonian carbonate and siliciclastic strata that underlie this region contain numerous gas shows and several significant gas discoveries, one of which is within the Sambaa K'e area. Quantitative estimates indicate that the ultimate potential for additional undiscovered petroleum within the outer boundary of the Sambaa K'e candidate protected area is about 13.3 billion cubic meters, or 470 billion cubic feet of gas, and about 1.18 million cubic meters, or 7.4 million barrels of oil. Most of this gas potential lies within the Upper Devonian Jean Marie Formation and within the Middle Devonian Slave and Sulphur Point formations along the subsurface Devonian Presqu'ile barrier reef complex. Most of the undiscovered oil potential resides within the Mississippian subcrop play.

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 the Sambaa K'e candidate protected area. Sambaa K'e occupies a large region of about 10,680 km^2 surrounding Trout Lake and the smaller Trainor, Tetcho and Cormack lakes and includes the community of Trout Lake on the southeast side of Trout Lake (Fig. 1-3). Sambaa K'e extends between 60.0^o and 61.2^o N latitude and between 119.5^o and 122.5^o W longitude and falls entirely within the Dehcho region of the Northwest Territory near its southern boundary. Sambaa K'e occupies parts of the low relief Great Slave Plain and Alberta Plateau physiographic regions (Bostock, 1970). Sambaa K'e is an area rich in wildlife and it is a particularly important habitat for boreal Woodland caribou.

Geological setting

Exposed bedrock across most of the Sambaa K'e area consists of a gently southwestward-dipping succession of Upper Devonian strata composed of limestone or silty and sandy shales that is unconformably overlain by a much younger Cretaceous succession (Fig. 4; Table 1). Upper Devonian limestone of the Kakisa Formation (uDKA) is the oldest unit exposed and outcrops only in the extreme northeast corner of Sambaa K'e. Younger Devonian units, such as the Trout River (uDTR) sandy limestone, the Tetcho (uDTe) limestone and Kotcho (uDKop, uDKoc) calcareous shale and shaly limestone formations, are exposed southward across the northeast part of the Sambaa K'e area.

A conformable succession of Lower, Middle and Upper Devonian carbonate, siliciclastic and evaporate-bearing strata underlie the Upper Devonian units that are exposed across northernmost Sambaa K'e. These underlying strata include, in descending stratigraphic order; the Redknife Formation and the Jean Marie Member, the Fort Simpson Formation, the Muskwa, Slave Point, Watt Mountain, Sulphur Point, Keg River, Horn Plateau, Lonely Bay, Nahanni, and Headless formations, the Chinchaga Formation and the Ebbutt Member, the Mirage Point and La Loche formations and the Horn River Group (Table 1). The thickness of the entire preserved Devonian System in the Sambaa K'e area ranges from a minimum of about 750 metres in the northeast part of to a maximum of about 1500 metres in the southwest (Meijer-Drees, 1993; Gal, 2007). The Devonian System unconformably overlies non-porous Precambrian metasedimentary and igneous rocks (Table 1) along a contact that dips uniformly southwestward across the Sambaa K'e area except in the vicinity of Celibeta High (Fig. 5; Williams, 1977), a broadly domal feature of elevated Precambrian and Phanerozoic strata.

Cretaceous strata cover all of the central and southern portions of Sambaa K'e. Cretaceous strata are subhorizontal and overly Devonian strata with a profoundly erosional, subhorizontal angular unconconformity. This may be inferred from the map relationship between the basal Cretaceous contact and its intersections of Devonian formational contacts across Sambaa K'e and surrounding areas (Fig. 4).

Cretaceous strata, ranging from 200 to more than 500 metres thick (Dixon, 1997), occupy a broad very shallow syncline, the northwest trending Trout Lake Syncline southwest of Trout Lake and form a hilly upland plateau in south-central Sambaa K'e (cf. Fig. 3-5). The Lower Cretaceous Fort St. John Group overlying the 'basal Cretaceous' unconformity forms most of the Cretacous succession. The Garbutt Formation (KGr) shales at the base of the Fort St. John Group pass upward to the Scatter Formation (Ksc) sandstones, the Lepine Formation (KL) silty shales, and the Sully Formation (KSU) silty sandstones. Resistant hard sandstone caprock of the Upper Cretaceous Dunvegan Formation (KD) unconformably overlies the Fort St. John Group (Dixon, 1997; Table 1) across several small higher elevation areas in southern Sambaa K'e.

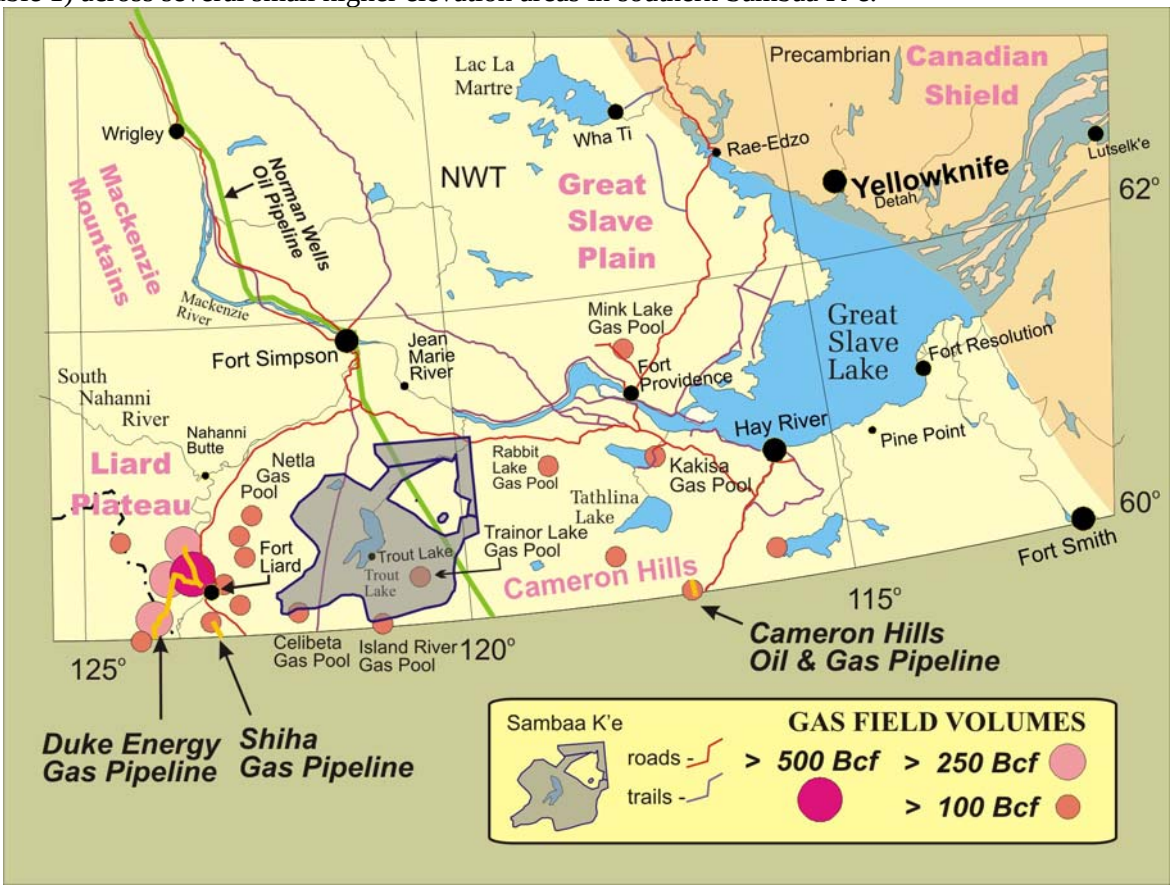

Figure 1. Map of Sambaa K'e candidate protected area and discovered gas resources of the southern Northwest Territories (after Morrow et al., 2006a)

Unconsolidated glacial drift, ranging in thickness from a few metres to several hundred metres, covers almost the entire Sambaa K'e area

The basal clastics unit (La Loche and Tsetso sandstone) forms the base of the Devonian succession, which, in turn, rests unconformably on Precambrian bedrock (Table 1). Precambrian bedrock was exposed in pre-Devonian time across Tathlina Uplift (Meijer-Drees, 1993; Fig. 5), a large emergent land mass that extended approximately east-west across the southern Northwest Territories. Sandstones of the La Loche and Tsetso formations and the Mirage Point, Fort Norman, Arnica and Landry dolomites, limestones and evaporites progressively onlapped the flanks of this arch on either side of Trout Lake in Early Devonian time. The uplift was entirely submerged during deposition of the platform carbonates of the upper Chinchaga, the lower part of the Keg River, and the Lonely Bay and Nahanni formations (Fig. 6).

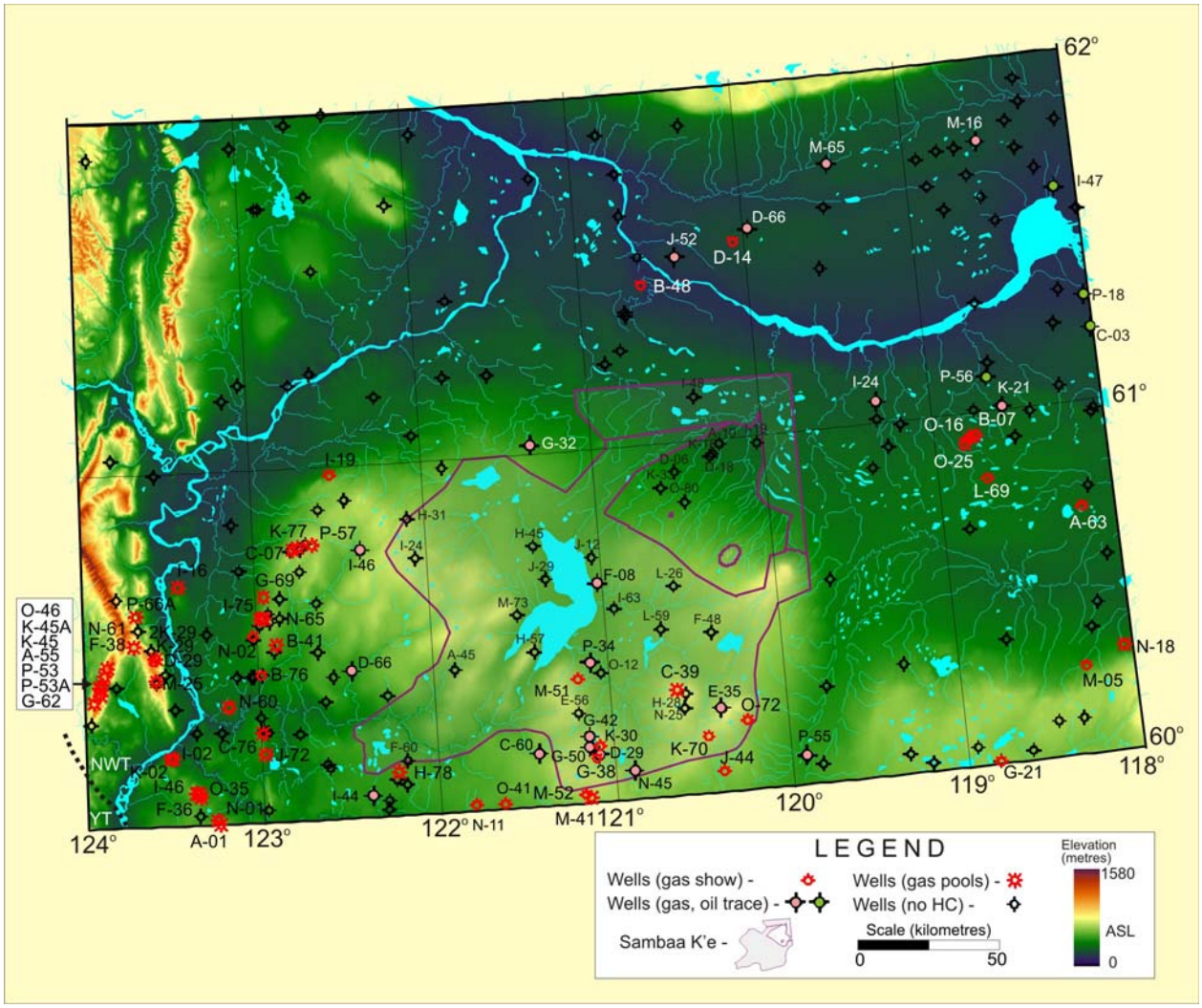

Figure 2. Topography across the southwest Northwest Territories and the Sambaa K'e candidate protected area. Exploration wells and oil and gas pools, shows and traces are shown.

The Presqu'ile Barrier (Fig. 6-7), a subsurface reefal buildup is an extremely important feature that developed along the axis of the former Tathlina Uplift (Fig. 5) during deposition of the upper part of the Keg River Formation and the Sulphur Point Formation of the upper Elk Point Group (Fig. 7). This depositional barrier reef complex separated the Elk Point evaporite basin to the south from open marine shelf to the north (Morrow and Geldsetzer, 1988). Reefal and biostromal buildups of the Sulphur Point and the overlying Slave Point formations preferentially occur along a ribbon defining the northern edge of the Barrier (see Slave/Sulphur Reef Edge play in Fig. 7). The eastern part of the Presqu'ile Barrier is separated from the western part of the barrier, the Arrowhead Salient, by the Cordova Embayment (Meijer-Drees, 1993; Fig. 7) in which dark, open marine, lower Keg River platform dolostones are overlain by organic-rich shales of the Horn River Group.

Open marine platform carbonates of the Lonely Bay and Nahanni formations and organic-rich shales of the Horn River Group accumulated along with the reef mounds of the Horn Plateau Formation encased in Horn River shales north of the Presqu'ile Barrier in the northwestern part of the Sambaa K'e area (see Keg River Horn Plateau play in Fig. 6; Table 1).

An important petroleum reservoir facies, the Presqu'ile Dolomite (Table 1; Meijer-Drees, 1993; Janicki, 2006), is developed within large parts of the Slave Point and Sulphur Point limestones, which have been recrystallized to coarsely crystalline porous and permeable white 'hydrothermal' dolomite.

A strongly developed set of northeast-trending and subvertical faults, or fault zones cross the Sambaa K'e area (Fig. 5). The Rabbit Lake and Trout River fault zones appear to be basement faults that have transected, or offset, the entire overlying Devonian stratigraphy (Maclean, 2006; Morrow et al., 2006b). Although the Presqu'ile Dolomite extends variably within strata forming the Presqu'ile Barrier across the southern Northwest Territories (Meijer-Drees, 1993), the Presqu'ile dolomite is particularly thick along and adjacent to these northeast-trending fault zones (Janicki, 2006) and along the Presqu'ile Barrier edge and, locally, within the area of the Celibeta High (Meijer-Drees, 1993).

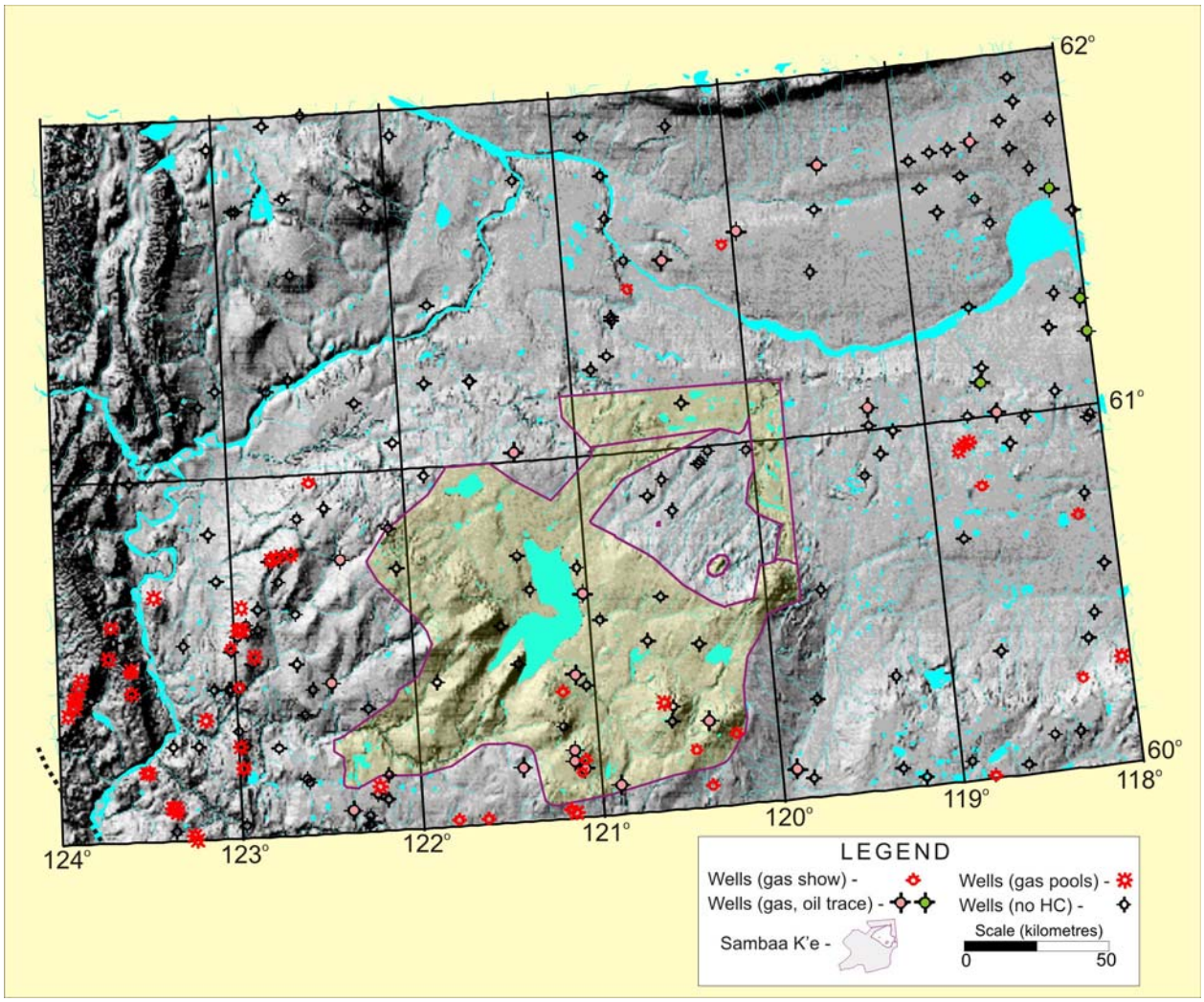

Figure 3. Shaded relief map across the southwestern Northwest Territories and the Sambaa K'e candidate protected area.

The overlying Upper Devonian succession of westward prograding depositional wedges of marine slope-deposited siliclastics buried the Presqu'ile Barrier. Slope-deposited, silty and sandy shales, such as the Fort Simpson, Redknife and Trout River formations are punctuated with platform carbonates, such as the Jean Marie Member, the Kakisa, and the Techo and Kotcho formations which extend variable distances westward across the southern Northwest Territories and northward where they are truncated beneath the 'sub-Cretaceous' unconformity (Fig. 8). Most of these platform carbonates occupy the upper parts of depositional wedges that thicken westward across the southern Northwest Territories. Organic-rich black shales of the lower part of the Exshaw Formation mark the top of the Devonian succession.

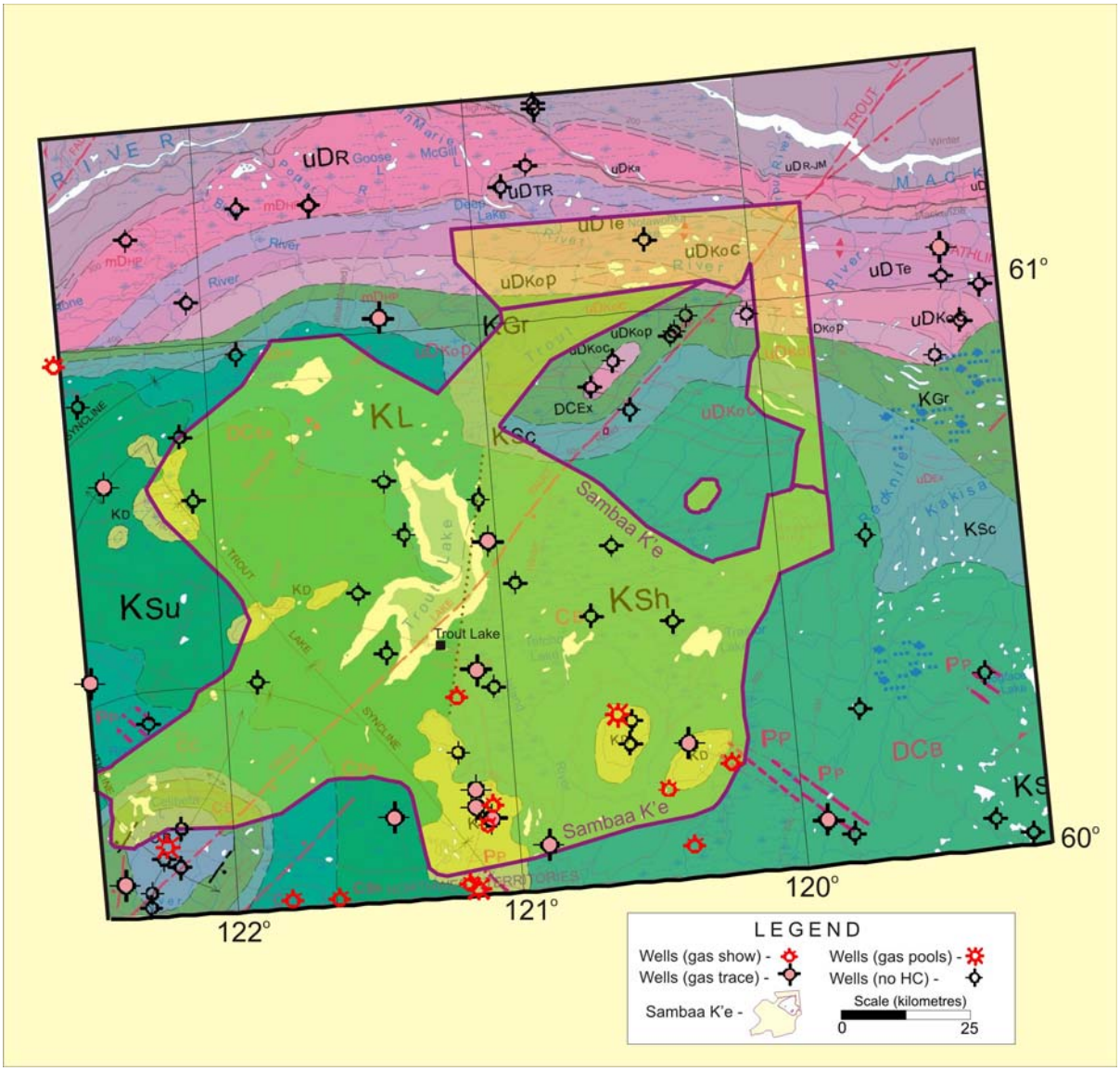

Figure 4. Bedrock geology map of Sambaa K'e candidate protected area (Okulitch, 2006; in prep). See Table 1 for map unit designations.

Early Carboniferous-aged, or Mississippian, units, which overlie Devonian strata, extend across the southern Northwest Territories and the southern half of the Sambaa K'e area (Fig. 9). Like the underlying Devonian succession, Mississippian strata are truncated progressively northward by the 'sub-Cretaceous' unconformity to an east-west zero edge trending across the middle of Sambaa K'e (Fig. 9). The Mississipian succession is comprised of black shale of the upper Exshaw Formation, calcareous shale of the Banff Formation, limestone of the Pekisko Formation, shaly and cherty limestone of the Prophet and Shunda formations, and dolomitic and cherty limestone of the Flett Formation (Table 1). This succession thickens uniformly southward in the southern part of the Sambaa K'e area and are successively truncated northward beneath the 'basal-Cretaceous' unconformity. Mississippian units are exposed only at Celibeta High (Williams, 1977) in southwestern Sambaa K'e where calcareous shales of the Banff Formation are exposed in the central part of this domal uplift (Fig. 4).

Hydrocarbon Occurrences

Table 2 provides summary information concerning the discovered volumes and occurrences of natural gas that falls within the Sambaa K'e area. Three known gas pools, Trainor Lake (Trainor Lake C-39 well), Celibeta (Celibeta H-78) and Island River (South Island M-41), occur within or very close to the Sambaa K'e area (Fig. 1). Trainor Lake and Island River gas pools are both contained within reefal Slave Point and Sulphur Point strata along the Presqu'ile Barrier edge facing Cordova Embayment. The Island River reservoir with 6 metres of gas pay is developed within the porous Presqu'ile Dolomite, whereas Trainor Lake gas with 22.9 metres of

gas pay occurs in fractured limestones (Gal, 2007). The Celibeta H-78 pool is developed within porous uppermost Slave Point limestones within Arrowhead Salient inboard of the Presqu'ile Barrier edge with a gas pay zone of about 6 metres (Gal, 2007). The combined total volume of recoverable gas in these three pools is 324 million cubic metres, or 11.3 billion cubic feet (Bcf) (Gal, 2007).

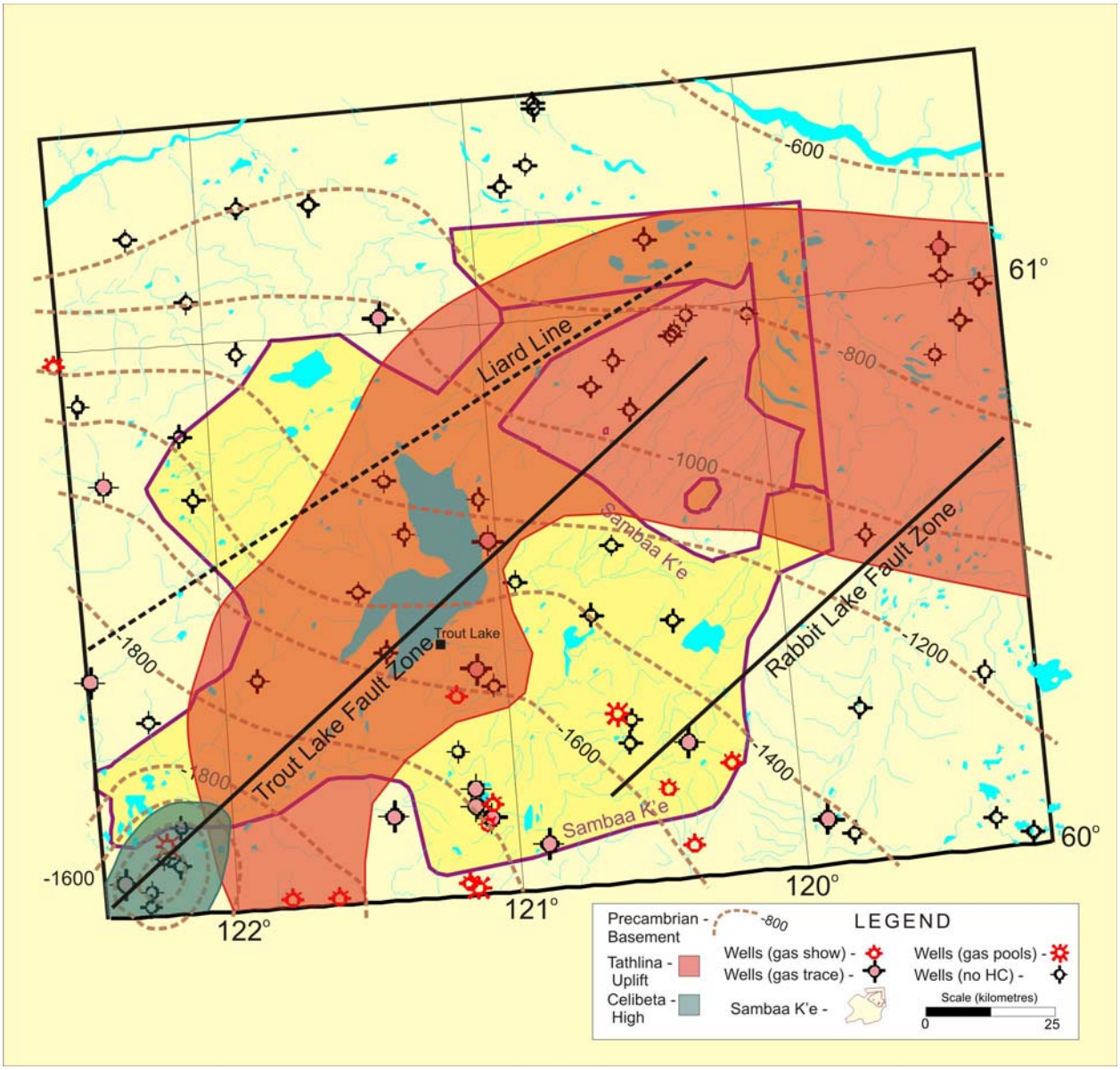

Figure 5. Tectonic, structural elements and Precambrian basement map across the Sambaa K'e candidate protected area. Liard Line is a tectono-stratigraphic, and possibly a structural, discontinuity of uncertain character that influenced the distribution and thickness of lower Paleozoic strata in a profound manner (Cecile et al. 1997).

Measured gas flows in Slave Point, Sulphur Point and Keg River strata have also been recorded for nine wells in and around Sambaa K'e as well as gas shows from Slave Point, Sulphur Point, Keg River, Lonely Bay, Jean Marie and Flett strata in an additional thirteen wells (Table 2). About 25 to 30 kilometres west of Sambaa K'e, is a north-trending, but slightly arcuate fairway of many gas pools and shows, such as at Netla C-07 (Fig. 2) that occur mainly in Slave Point limestone reservoirs developed along the western reefal edge of the Arrowhead Salient of the Presqu'ile Barrier (Fig. 7).

Farther west are the large producing gas fields hosted in reservoirs formed of the Devonian Manetoe Dolomite in the Liard, Pointed Mountain and Liard gas fields of the Liard Plateau region (Fig. 1). These vertically extensive hydrothermal dolomite reservoirs are similar to the Presqu'ile Dolomite gas reservoir of the South Island River M-41 gas pool just south of Sambaa K'e albeit with a much higher gas column. Kotaneelee Field, a typical Manetoe gas field under Liard Plateau has a gas column of over 600 metres high partly because

of its great thickness of dolomitized reservoir strata and its large structural closure (Columbia Gas Development of Canada Ltd., 1979). In contrast, gas fields in the plains east of Liard Plateau, such as the South Island River M-41 Field with a net pay interval of only six metres tend to have gas pays less than a few tens of metres (Gal, 2007).

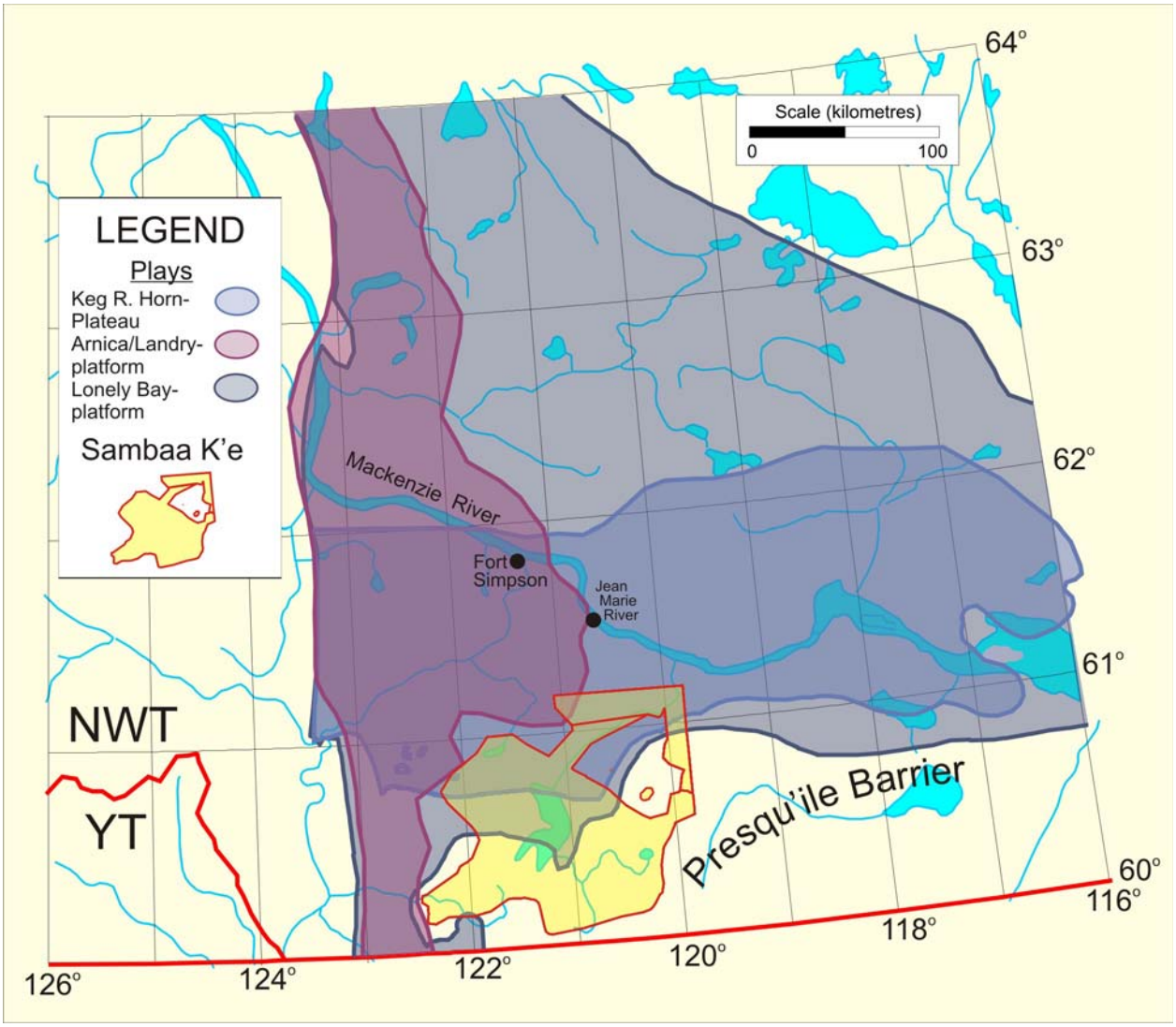

Figure 6. Map showing areas of the Arnica/Landry platform, the Lonely Bay/Nahanni platform and the Keg River - Horn Plateau plays across southern Northwest Territories.

It is worth noting, however, that at the South Island River M-41 well the thin gas pay zone is at the top of about 100 metres of hydrothermally dolomitized Slave Point and Sulphur Point strata. The thin pay zone may be the result of a lack of effective reservoir seals below the zone of gas pay. This facies style of petroleum trap depends on lateral stratigraphic seals as well as an upward confining shale seal. The relatively low amplitudes of structures developed in the subsurface across the southern Interior Plains (MacLean and Morrow, 2001) also may limit the size of gas pools in the Sambaa K'e area.

North of Sambaa K'e, gas shows and pools are developed within the Devonian Horn Plateau limestone reef mound reservoirs lying north of the Presqu'ile Barrier, such as at Trout River D-14 (Fig. 1-2).

Hydrocarbon Prospectivity

The Sambaa K'e candidate protected area is, as discussed previously, underlain by Devonian to Carboniferous and Cretaceous rocks that are prospective for oil and gas. The Canadian Gas Potential Committee (2001, 2005; see also Gal, 2007 and Gal and Jones, 2003) have previously defined hydrocarbon plays in the central Mackenzie Valley area that could potentially host oil and/or natural gas. These plays have formed the basis for a set of revised plays (Hannigan et al., 2006) and a set of previously unpublished boundaries for these revised

plays are used here to outline the petroleum potential of the Sambaa K'e candidate protected area. Twelve of these revised plays occupy portions of the Sambaa K'e candidate protected area. These plays include the 'Arnica/Landry platform', the 'Lonely Bay/Nahanni/Hume platform', the 'Keg River offshore isolated reef – Horn Plateau', the 'Keg River platform - Cordova Embayment', the 'upper Elk Point – Presqu'ile Barrier', the 'Slave Point/Sulphur Point Barrier Reef edge', the 'Slave Point back barrier shelf', the 'Slave Point platform', the 'Jean Marie shelf & shelf margin' , the 'Kakisa platform', the 'Mississippian subcrop', and the 'Lower Cretaceous' plays (Fig. 6-9). A more complete discussion of the petroleum geology of these plays within the Sambaa K'e candidate protected area is given in Gal (2007).

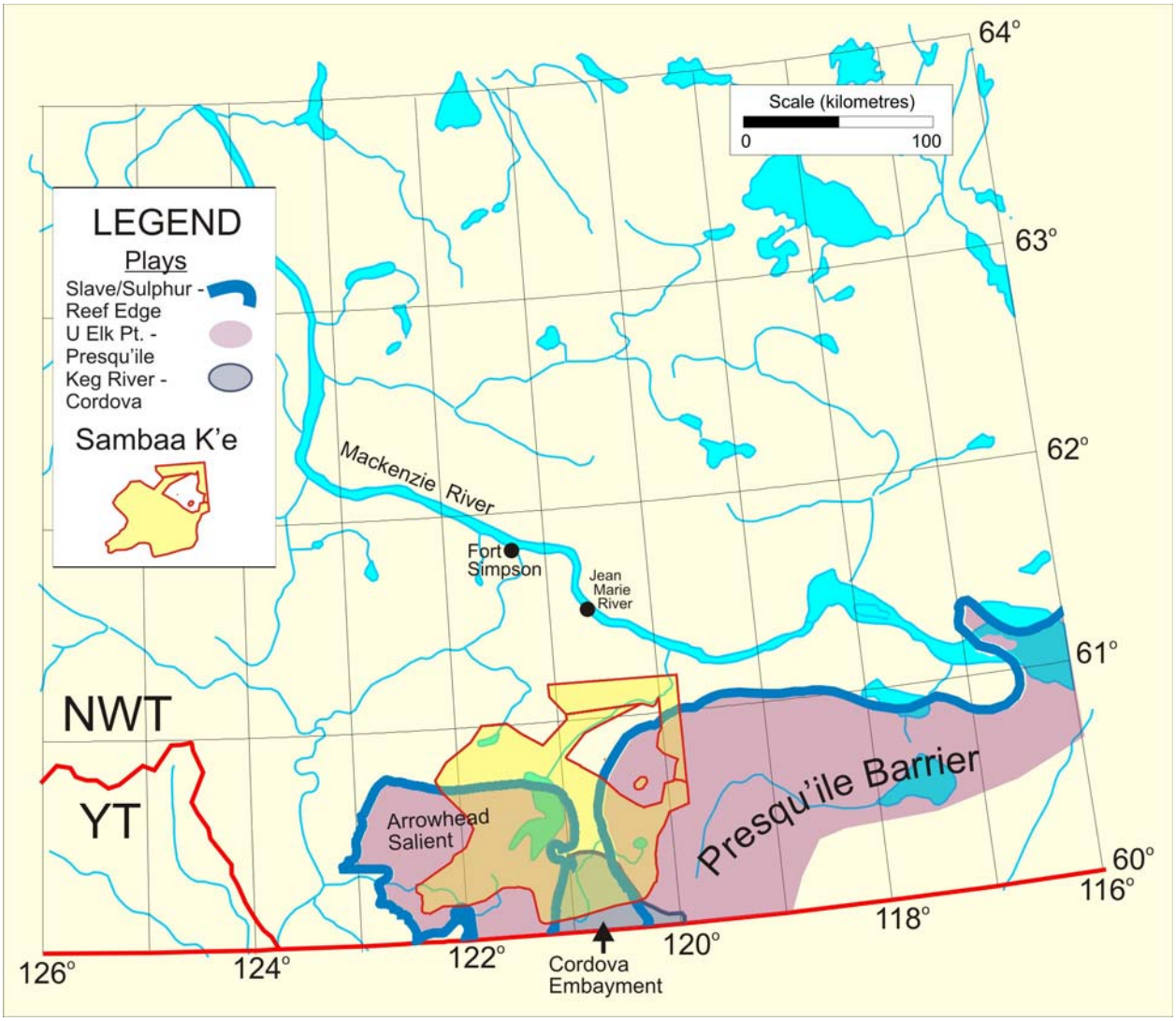

Figure 7. Play areas of the Slave/Sulphur Point reef edge, the Presqu'ile-Keg River and the Keg River platform - Cordova Embayment plays across southern Northwest Territories.

The most organic-rich petroleum-generating source rocks in the Sambaa K'e candidate protected area include the Middle Devonian Horn River Group shales and bituminous limestones (Evie member), the Upper Devonian Muskwa and Fort Simpson Formation shales and siltstones, the uppermost Devonian to Mississippian Exshaw Formation shale, and the Lower Cretaceous Garbutt shale (Table 1). In this area Horn River shales are considerably overmature with respect to oil generation and are well down in the zone of gas generation (Stasiuk and Fowler, 2002). The stratigraphically higher Muskwa and Fort Simpson formations are also overmature and in the gas generation zone, but the very prolific petroleum source rock of the Exshaw formation at the top of the Devonian succession in the 'oil window' for petroleum generation across the entire Sambaa K'e area (Stasiuk and Fowler, 2002). The other significant source rock, the Cretaceous Garbutt Formation overlying the sub-Cretaceous angular unconformity is only immature to barely mature with respect to the oil window (Stasiuk et al. 2002).

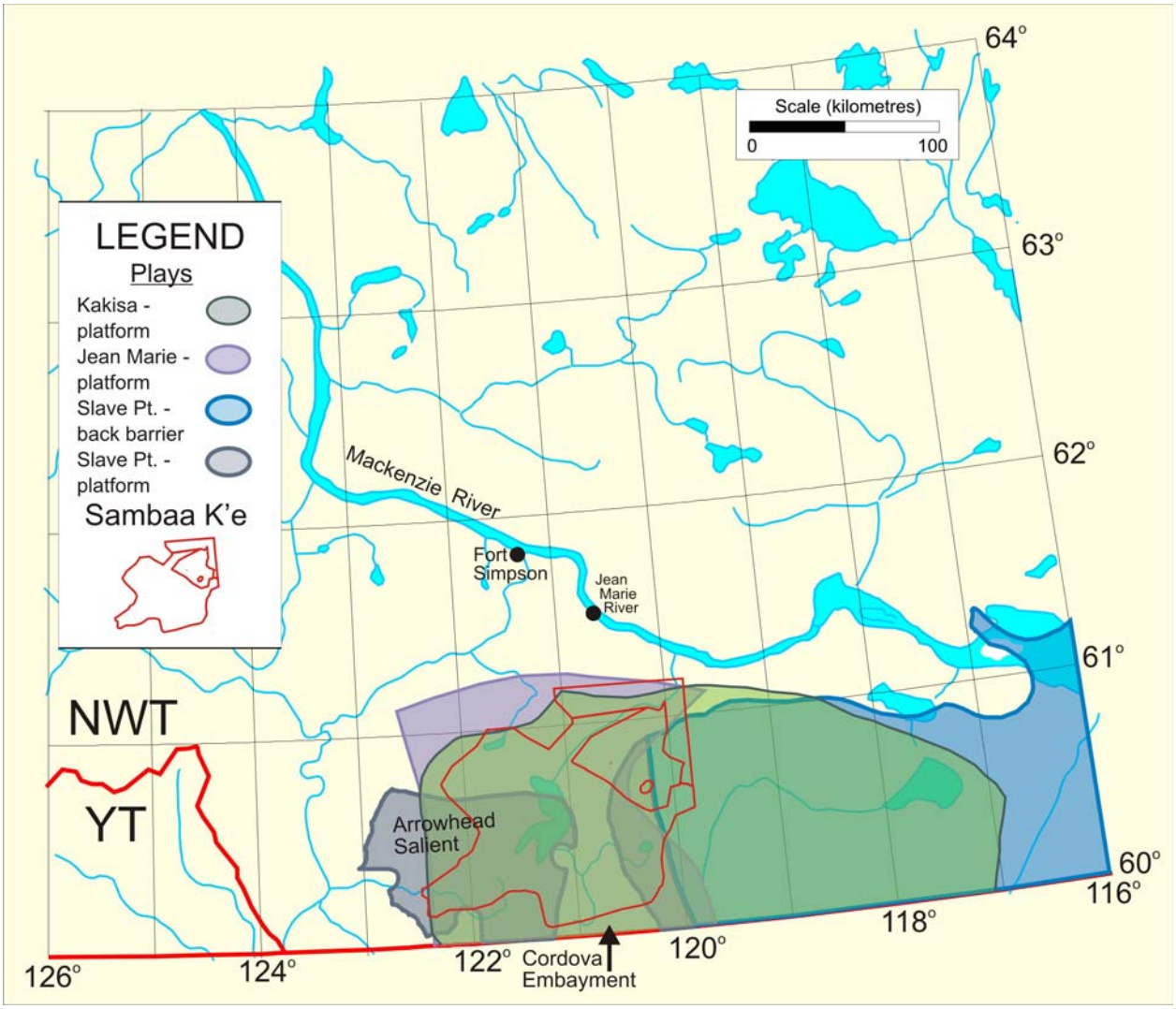

Figure 8. Areas of Kakisa platform, Jean Marie Platform, Slave Point back barrier and Slave Point Platform plays across southern Northwest Territories.

Arnica/Landry platform and Lonely Bay/Nahanni/Hume platform plays (conceptual)[1]

Vuggy dolostone of the Arnica Formation and solution breccia of the Bear Rock Formation are potential oil and gas bearing horizons. This stratigraphic interval yielded both oil and gas at the Summit Creek B-44 well in a recent discovery approximately 70 km south of Tulita (Unocal Corporation, 2005: Fig. 1). Although few details concerning this discovery have been published, it is likely that the Bear Rock and Arnica to Hume succession forms the petroleum reservoir and that the overlying Horn River or 'Canol' dark shales act as the reservoir seal and as the organic source rock for hydrocarbons.

However very little, if any, of the Arnica/Landry platform play falls within Sambaa K'e (Fig. 6) as the Arnica to Landry stratigraphic interval is represented by facies-equivalent, evaporite-dominated strata of the Fort Norman Formation (Table 1) that is not of reservoir quality. Consequently, little, if any, petroleum potential can be assigned to this play in the Samba K'e area

The Lonely Bay/Nahanni/Hume platform play above the Arnica/Landry platform play, occupies roughly the northern half of Sambaa K'e. In this area, the Lonely Bay/Nahanni/Hume platform play is represented by strata of the Lonely Bay Formation. Here, the Lonely Bay Formation is comprised of a lower slightly porous and gas-

[1] A conceptual play does not yet have discoveries or reserves, but may exist according to geological analysis. An established play has been demonstrated to exist by the discovery of hydrocarbon pools. Established plays may be further characterized as mature, or immature plays. Mature established plays are those for which the number of discoveries permit a statistical derivation of the play resource endowment based solely on the statistics of petroleum discoveries. Immature plays have an insufficient number of discoveries to allow a statistical derivation of the play resource endowment (Reinson et al. 1993).

prone dolostone member overlain by a non-porous upper limestone member (Meijer-Drees, 1993; also see Gal and Jones, 2003) which may act as a seal for gas for reservoirs in the underlying dolostone member, particularly in the vicinity of the Trout Lake and Rabbit Lake fault zones (Fig. 4-5).

The Manetoe Dolomite, developed within the Lonely Bay Formation in the Sambaa K'e area is another possible reservoir type in this play. However, the absence of Manetoe Dolomite in wells east of 122˚ west longitude (Meijer-Drees, 1993) restricts the possible occurrence of Manetoe reservoirs to the small part of the Sambaa K'e area that lies west of 122˚ west longitude and north of the northern limit of the Presqu'ile Barrier. A key feature of the Liard gas fields is that massive dolomitization of the entire Nahanni to Arnica stratigraphic interval (i.e. the Manetoe Dolomite) extends vertically upwards to the top of the Middle Devonian Nahanni Formation to its contact with the overlying Horn River Group shale hydrocarbon source rock. The increase in permeability and porosity associated with this dolomitization event allowed downward movement of petroleum generated from overlying organic-rich black shales of the Horn River Group into the entire underlying Nahanni to Arnica stratigraphic interval occupied by Manetoe Dolomite reservoirs (Morrow et al., 1990). However, the occurrence of similarly prospective Manetoe Dolomite reservoirs in the Sambaa K'e area must be considered to be high risk. This is because Manetoe Dolomite has not been observed above the base of the Hume, or Lonely Bay formations in any wells more than a few kilometers east of the mountain front.

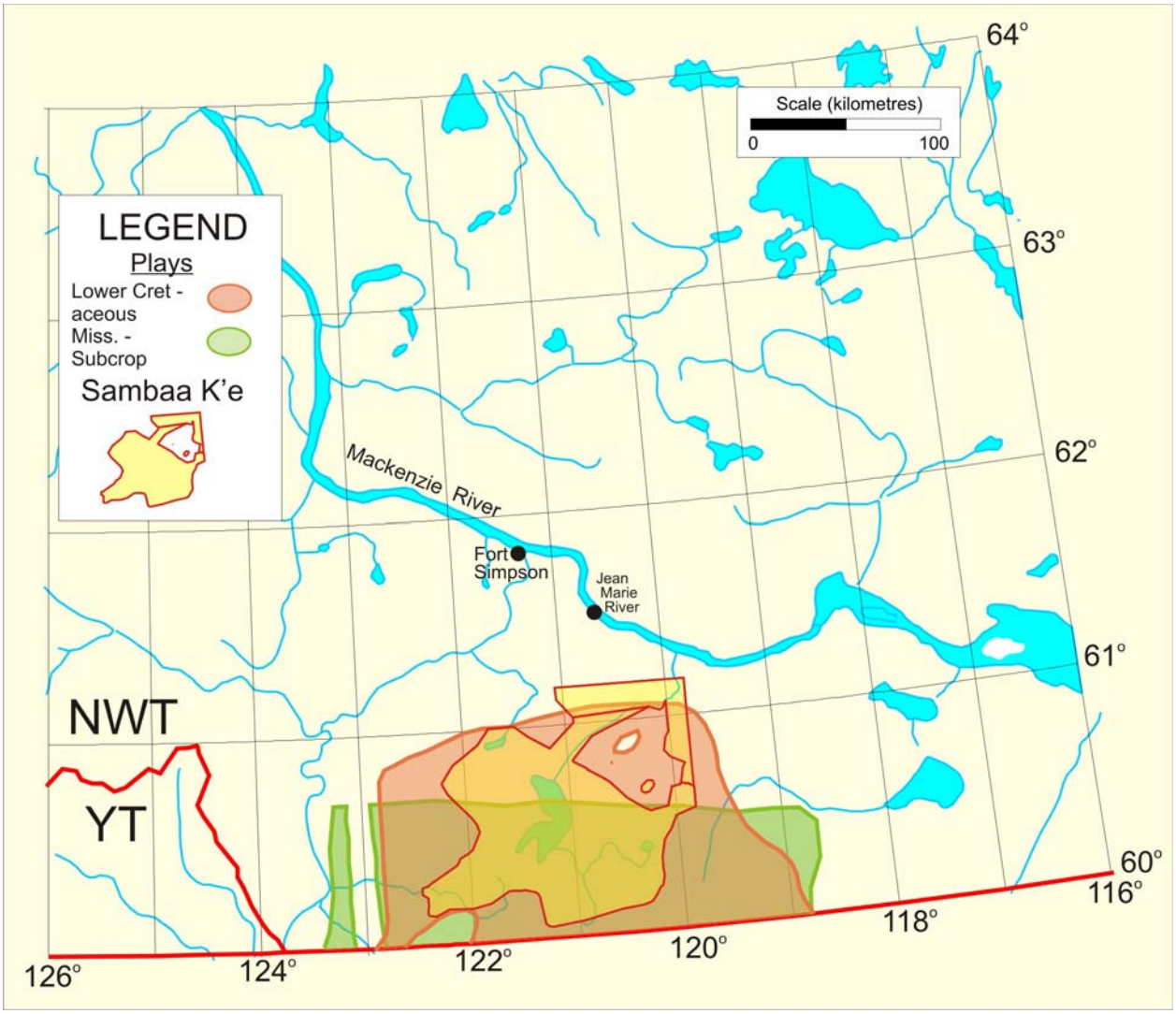

Figure 9. Areas of the Mississippian subcrop and Lower Cretaceous plays across southern Northwest Territories.

PERIOD (Epoch)		FORMATION / GROUP (map symbol – location, thickness)		LITHOLOGY
Quaternary		Unnamed Quaternary		Glacial drift
		Unconformity		
Creta-ceous	Upper	Dunvegan (KD- scattered plateaus, 60 m)		Sandstone
		Unconformity		
	Lower	Fort St. John Group	Sully (KSU- in Trout Lake Syncline, 250 m)	Siltstone, sandstone
			Lepine (KL- in Trout Lake Syncline, 450 m)	Siltstone, shale
			Scatter (KSC- around Trout Lake Syncline, 90 m)	Sandstone, siltstone
			Garbutt (KGr- around Trout Lake Syncline, 180 m)	Shale, siltstone
		Unconformity		
Carbon-iferous (Mississ-ippian)	Lower	Flett, Debolt (southern Sambaa K'e; subsurface only, 100 m)		Cherty limestone (dolomite)
		Prophet, Shunda (southern Sambaa K'e; subsurface only, 100m)		Shale, cherty limestone
		Clausen (southern Sambaa K'e; subsurface only, 10 m)		Grey shale
		Pekisko (southwestern Sambaa K'e; subsurface only, 20 m)		Crinoidal limestone
		Banff (CB –near Celibeta Lake; mainly subsurface, 500 m)		Shale; silty limestone
		Exshaw (DCEX – small area enclosed by, but not in Sambaa K'e; mainly subsurface, 20 m)		Black shale
Devonian	Upper	Kotcho (UDKOC- carbonate facies and UDKOP- shale facies, small area north of Trout River; mainly subsurface, 400 m)		Green shale, siltstone, sandstone, limestone
		Tetcho (UDTe- small area north of Trout River; subsurface, 90 m)		Limestone (pelletal)
		Trout River (UDTR- north of Trout River; subsurface, 60 m)		Limestone, sandstone
		Kakisa (UDKA- north of Trout River; subsurface, 50 m)		Limestone; silty, bioclastic
		Redknife (UDR- subsurface only, 100 m)		Shale; calcareous and silty
		Jean Marie Member-Redknife (UDR-JM- subsurface only, 40 m)		Limestone; silty, bioclastic
		Fort Simpson (UDFS- subsurface only, 550 m)		Shale; greenish-grey, calcareous, silty
	Middle	Horn River Group (subsurface north of Presqu'ile Barrier-black shale, 50 m)	Muskwa (subsurface only, 10 m)	Shale
			Slave Point (subsurface- Presqu'ile Barrier, 70 m)	Limestone; bioclastic
			Watt Mountain (subsurface-Presqu'ile Barrier, 2m)	Shale; greenish-grey to green
			Unconformity	
			Sulphur Point (subsurface-Presqu'ile Barrier, 50m)	Limestone; pelletal
			Presqu'ile Dolomite (Pp- subsurface; dolomitized Sulphur Point to Slave Point, 0-50 m)	White, coarse crystalline diagenetic dolomite (significant reservoir facies)
		Horn Plateau (subsurface north of Presqu'ile Barrier-limestone reefs, 60 m)	Keg River (subsurface-Presqu'ile Barrier, 50 m)	Dolostone, limestone (dark crinoidal to biostromal)
		Nahanni, Lonely Bay and upper Chinchaga (subsurface, 75 m)		Dolostone, limestone
		Headless and Ebbut Member (subsurface near Tathlina, 5 m)		Shaly limestone, siltstone
		Unconformity		
	Lower	Lower Chinchaga, Fort Norman, Landry? (subsurface near Tathlina, 30m)		Anhydrite, tan dolostone
		Mirage Point (subsurface around Tathlina, 30 m)		Anhydrite, dolostone, evap.
		Unnamed basal clastics, La Loche and Tsetso (subsurface near Tathlina, 10 m)		Dolomitic sandstone
		Unconformity		
Precambrian		Fort Simpson and Nahanni domains (subsurface only)		Metasedimentary

Table 1. Main rock formations in the Sambaa K'e area (see Figure 4 for formational bedrock map designations such as 'uDFS' for exposed bedrock, see Gal, 2007).

Rank of Discovery	Well name	Location	Gas – volumes, flow rates and indications	Formation
Significant Discoveries	Celibeta H-78	south of Sambaa K'e	154x10^6 m^3 (5.4 Bcf)	Slave Point
	Trainor Lake C-39	Sambaa K'e - southeast	108x10^6 m^3 (3.8 Bcf)	Slave Point/Sulphur Point
	South Island M-41	south of Sambaa K'e	62 x10^6 m^3 (2.1 Bcf)	Slave Point
Gas Show flow rates from DST	Trainor K-70	Sambaa K'e - southeast	8.3-14.6 x10^3 m^3 per day (293-516 Mcf/d)	Sulphur Point/Slave Point
	South Island River M-52	south of Sambaa K'e	8.45 x10^3 m^3 per day (298 Mcf/d)	Slave Point
	Trout Lake O-41	south of Sambaa K'e	8.45 x10^3 m^3 per day (298 Mcf/d)	Keg River
	Island River J-44	southeast of Sambaa K'e	5.8-7.3 x10^3 m^3 per day (205-256 Mcf/d)	Sulphur Point/Slave Point
	Trout Lake M-51	Sambaa K'e - central	3.04 x10^3 m^3 per day (107 Mcf/d)	Keg River
	Little Growl N-11	south of Sambaa K'e	2.82 x10^3 m^3 per day (100 Mcf/d)	Keg River
	Trainor Lake O-72	Sambaa K'e - southeast	1.69 x10^3 m^3 per day (60 Mcf/d)	Slave Point
	Island River G-38	Sambaa K'e – south	0.64 x10^3 m^3 per day (22 Mcf/d)	Sulphur Point/Slave Point
	Trainor K-30	Sambaa K'e – south	<1.24 x10^3 m^3 per day (<44 Mcf/d)	Sulphur Point/Slave Point
Gas traces from DST	Trainor Lake P-55	southeast of Sambaa K'e	gas to surface, 0.6 m flare	Slave Point
	Island Lake N-45	Sambaa K'e – south	gas cut mud gas cut mud and water	Jean Marie Flett (?)
	Island River D-29	Sambaa K'e – south	gas cut mud, gas to surface gas cut mud	Keg River/Chinchaga Slave Point (?)
	Island River G-50	Sambaa K'e – south	gas cut salt water	Keg River/Lonely Bay
	Petitot C-60	south of Sambaa K'e	gas to surface, 1 m flare, gas cut mud	Keg River
	Celibeta I-44	southwest of Sambaa K'e	gas cut mud	Keg River
	Trainor E-35	Sambaa K'e - southeast	gas cut mud and water gas cut mud and water	Sulphur Point Keg River
	Island River G-42	Sambaa K'e – south	gas to surface gas cut mud and water	Slave Point Sulphur Point/Keg River
	Celibeta D-66	west of Sambaa K'e	gas to surface, 0.6 m flare	Keg River
	Trout Lake P-34	Sambaa K'e - central	gas to surface	Slave Point
	Trout Lake F-08	Sambaa K'e – north	gas cut mud	Lonely Bay
	Arrowhead I-46	northwest of Sambaa K'e	gas cut mud	Lonely Bay
	Poplar River G-32	north of Sambaa K'e	gas cut mud	Slave Point (?)

Table 2. Gas discoveries, shows and traces in wells drilled within and near the Sambaa K'e candidate protected area (modified from Table 3 in Gal (2007); Bcf= billion cubic feet, Mcf/d= thousand cubic feet per day).

Drummond (2004) assigned less than 450 million cubic metres (less than 16 Bcf) of undiscovered recoverable gas to the Lonely Bay/Nahanni/Hume platform play within the Sambaa K'e area north of the Presqu'ile Barrier (Fig. 6).

Keg River – offshore isolated reef – Horn Plateau play (conceptual)

Keg River – offshore isolated reef – Horn Plateau play occupies the northern third of the Sambaa K'e candidate protected area (Fig. 6). The play includes all pools and prospects in isolated reefs and bioherms located basinward (outboard) from the northern limit of the Presqu'ile Barrier (Fig. 6). The southern play boundary is the northern edge of the Middle Devonian carbonate Presqu'ile Barrier. The eastern boundary is the subcrop/outcrop edge at the boundary with the Canadian Shield. Reefs of the Horn Plateau Formation are developed above and overlie the Lonely Bay Formation platform carbonate and are overlain and surrounded by organic-rich black shale petroleum source rocks of the gas-prone (Stasiuk and Fowler, 2002) Horn River Formation. These surrounding shales act both as source rocks and as reservoir 'seals'. The Horn Plateau reefs contain abundant fauna dominated by stromatoporoids and corals with good interfossil and interfragment porosity. Gas was found in subsurface Horn plateau reef masses at two nearby wells, Trout River D-14 and Jean Marie B-48 wells about 30 kilometers north of the Sambaa K'e area (Fig. 2). Horn Plateau reefs have not been found in Sambaa K'e. The low density of drilling in northern Sambaa K'e in itself indicates that Horn Plateau reefs could be present. This perception though must be tempered by the realization that these reef mounds are very well imaged seismically and Sambaa K'e has a dense coverage of industry seismic lines (Gal, 2007).

Drummond (2004) estimated a relatively small potential for undiscovered recoverable gas of about 250 million cubic metres (9 Bcf) for this play within the Sambaa K'e area.

Upper Elk Point-Presqu'ile barrier play (established gas and conceptual oil play)

The established (immature) Upper Elk Point-Presqu'ile barrier play includes all pools and prospects in stratigraphic traps hosted in Devonian reefal and dolomitized Keg River and Sulphur Point carbonate reservoirs (particularly the Presqu'ile Dolomite) in the interval between the tight Chinchaga Formation anhydrite and Slave Point Formation lime mudstones (Hannigan et al., 2006). The play is limited to the north by the edge of the Presqu'ile Barrier and its southern limit is defined by the edge of the Keg River and Sulphur Point back barrier shelf plays. The Upper Elk Point-Presqu'ile barrier play underlies about half of Sambaa K'e (Fig. 7).

This play is represented by one gas pool in Alberta and by the Rabbit Lake O-16 gas pool in a Sulphur Point reservoir north of 60˚ latitude east of Sambaa K'e (Fig. 2). Within the Sambaa K'e area, this play includes the Trout Lake M-51 Keg River gas show and the trace of Keg River gas at the Trainor E-35 well (Fig. 2; Table 2). Hydrocarbon source rocks for this play include the Horn River Group and the Muskwa Formation shales both of which are gas prone. This play has not previously been recognized as a separate play but has been incorporated with other plays in previous assessments (e.g. as part of the 'Slave Point Back Barrier/NE Fault Structures play of Drummond, 2004; also see below the "Slave Point back barrier shelf" gas play; see also Gal, 2007).

Slave Point back barrier shelf play (established)

The established and mature Slave Point back barrier shelf gas and oil play includes all pools and prospects within shelf facies carbonate rocks of the Slave Point Formation east of Cordova Embayment (Fig. 8; Gal and Jones, 2003; Hannigan et al., 2006). Most of this play is in Alberta, but extends northward into the Northwest Territories up to the northern limit of the Presqu'ile Barrier and westward towards its junction with the Slave Point/Sulphur Point barrier edge play (Fig. 8). The Slave Point back barrier shelf play extends across only the easternmost part of the Sambaa K'e candidate protected area where it joins with the Slave Point platform play east of Cordova Embayment (Fig. 8).

This play includes the prolific Cameron Hills gas fields along the Alberta-Northwest Territories border (Fig. 1). Structural traps are dominant within this play, as fractured reservoir rocks form traps in anticlinal closures associated with reactivated northeast-trending faults. The faults also act as conduits for hydrocarbons, such as at the Rabbit Lake O-16 gas pool (Fig. 1) developed along the Rabbit Lake fault zone (Fig. 5; Gal and Jones, 2003). Presqu'ile Dolomite, a hydrothermal dolomite and potential petroleum reservoir rock, is known to occur in this play region near the southeast corner of Sambaa K'e (Meijer-Drees, 1993; Gal, 2007) and, as mentioned previously, could be expected to occur along fault zones (Fig. 5). Hydrocarbon source rocks include overmature Horn River and Muskwa strata and consequently this play is mainly a non-associated gas play with low prospectivity for oil but with light oil generation (Stasiuk and Fowler, 2002) east of Cordova Embayment (Fig. 8). Drummond (2004) assigned an aggregate potential of almost one billion cubic metres (about 35 Bcf) for undiscovered recoverable gas in a play that comprises the Slave Point back barrier shelf, the Upper Elk Point-Presqu'ile barrier, and the Slave Point platform plays of this in the Sambaa K'e area.

Slave Point platform play (established)

The established and mature Slave Point platform gas play includes all pools and prospects within shelf facies carbonate rocks of the Slave Point Formation west of the Slave Point back barrier shelf play (Gal and Jones, 2003; Hannigan et al., 2006). Most of this play is in British Columbia, but it also extends northward into the Northwest Territories close to the northern limit of the Presqu'ile Barrier (Fig. 8). The Slave Point platform play extends across large portions of the southern and central parts of the Sambaa K'e candidate protected area (Fig. 8).

As with the Slave Point back barrier shelf play, structural traps may occur within this play, as fractured reservoir rocks form antiformal closures associated with reactivated northeast-trending faults such as the Trout River fault zone (Fig. 4-5). The Celibeta H-78 gas pool near the crest of the Celibeta High close to the southwest edge of the Sambaa K'e area (compare Fig. 2, 4, 5) may be located on the edge of a local graben associated with the Trout River fault zone (Fig. 5). This has been imaged on seismic across Celibeta High and shown in Figure 22 of Gal (2007). Other pool reservoir types may include dolomitized and porous

stratigraphic lenses within the shelf platform, such as the Adsett Field in northeast British Columbia (Reinson et al., 1993). Hydrocarbon source rocks include mature to overmature Horn River and Muskwa strata; consequently this play is mainly a non-associated gas play with some prospectivity for light oil east of Cordova Embayment (Stasiuk and Fowler, 2002; Fig. 8). Lack of porosity development is a major exploration risk for this play.

Drummond (2004) estimated a potential for undiscovered recoverable gas of about 650 million cubic metres (about 23 Bcf) for this play within the Sambaa K'e area. He assigned a potential for undiscovered recoverable oil for the combined Slave Point platform and Slave Point back barrier shelf plays of about 375 thousand cubic metres (about 2.4 million barrels) within the Sambaa K'e area.

Keg River platform- Cordova embayment play (established)

The established and mature Keg River platform- Cordova embayment play includes all pools and prospects within the Keg River 'platform', or lower Keg River shelf dolostones that underlie Horn River basinal shales and shaly slope-deposited limestones within the Cordova Embayment which is bordered by the basinward edge of the Presqu'ile Barrier reef complex (Fig. 7: Reinson et al., 1993; Gal and Jones, 2003; Hannigan et al., 2006). Only a small portion of the Keg River platform- Cordova embayment play falls within the Sambaa K'e candidate protected area (Fig. 7). Primary source rocks for the dolomitized (Presqu'ile Dolomite-type) stratiform Keg River reservoirs are the shales of the Horn Group (Klua and Otter Park shales) which are entirely in the gas generation zone of organic maturity across this play (Gal and Jones, 2003).

Most of this play lies in British Columbia where numerous, but relatively small, gas pools (all less than 550 million cubic metres, or 20 Bcf of gas) have been discovered (Reinson et al., 1993; Gal and Jones, 2003; Hannigan et al., 2006). No gas has been found to date in the Northwest Territories portion of this play. Drummond (2004) assigned less than 250 million cubic metres (9 Bcf) of undiscovered recoverable gas potential to this play within the Sambaa K'e area. This is mainly a non-associated gas play with low prospectivity for oil.

Slave Point/Sulphur Point barrier edge play (established)

The established and mature Slave Point/Sulphur Point barrier edge play sour gas and oil play includes all pools and prospects within a narrow ribbon a few kilometers wide of porous reefal limetones and dolomitized limestones comprised of undivided Slave Point and Sulphur Point formations (Gal and Jones, 2003; Hannigan et al., 2006). The Watt Mountain Formation shales that normally separate the Slave Point and Sulphur Point formations are very thin or absent within this play area. The well known Clarke Lake gas field of northeast British Columbia, developed in Presqu'ile Dolomite that has dolomitized porous reefal Slave Point limestone, is a typical example of the large gas fields found within this play (e.g. Reinson et al., 1993). Approximately 250 kilometres of this reefal ribbon-shaped play extends across south-central Sambaa K'e bordering the Presqu'ile Barrier and Cordova Embayment (Fig. 7). Source rocks include Horn River and Muskwa shales which are primarily gas-prone in the Sambaa K'e area (Stasiuk and Fowler, 2002).

The Trainor Lake C-39 gas pool within Sambaa K'e, and the South Island River M-41 gas pool immediately south of Sambaa K'e, are significant discoveries (Fig. 2; Table 2), which indicate significant potential for future gas discoveries. The large Netla C-07 gas field, developed within porous reefal limestone west of the Sambaa K'e area, is another nearby discovery. This play is highly prospective for non-associated gas. Drummond (2004) assigned nearly 3.0 billion cubic metres (or about 106 Bcf) of undiscovered recoverable gas potential to this play within the Sambaa K'e area. Oil potential is very low to negligible.

Jean Marie shelf & shelf margin play (established)

The Jean Marie shelf & shelf margin play is an established and mature gas play that occupies a large region in northeast British Columbia and Alberta, and extends northward into the Northwest Territories (Gal and Jones, 2003; Hannigan et al., 2006). The Sambaa K'e candidate protected area occupies almost the entire portion of the play area that lies north of 60˚ latitude (Fig. 8). The Jean Marie Member of the Redknife Formation is a southwestward-dipping partly dolomitized limestone depositional ramp containing numerous low amplitude biostromes (Gal, 2007). Numerous gas pools (approximately 30) have been discovered in this play in British Columbia and Alberta, and one oil pool in Alberta. No discoveries have been made north of 60˚ latitude but at least one well (Island Lake N-45 in Table 2) in the Sambaa K'e area recorded a trace of gas from the Jean Marie interval. Dolomitized and fractured intervals are commonly potential gas reservoirs

in this play. Petroleum source rocks include the Fort Simpson, Redknife and Horn River shales, which are gas-prone in this area (Stasiuk and Fowler, 2002).

This play has good prospectivity for gas, but has low to negligible oil prospectivity in the Sambaa K'e area. Drummond (2004) assigned more than 4.5 billion cubic metres (more than 160 Bcf) to the potential for undiscovered recoverable gas for Jean Marie shelf & shelf margin play in the Sambaa K'e candidate protected area.

Kakisa platform play (established)

Kakisa platform is an established, but immature gas play that occupies almost the entire Sambaa K'e candidate protected area (Fig. 8). Some gas production occurs from pools in northeast British Columbia, but no discoveries have been made in this play north of 60˚ latitude (Gal and Jones, 2003). Petroleum source rocks for this play include the Fort Simpson and Redknife shales, which in the Sambaa K'e area are almost entirely in the gas generation zone of organic maturity (Stasiuk and Fowler, 2002).

The Kakisa Formation is generally a tight platform limestone; prospects for gas reservoirs occur where dolomitization has enhanced porosity and permeability (Gal and Jones, 2003; Hannigan et al., 2006). This play is fairly high risk with low prospectivity because the infrequent presence of dolomitization. Drummond (2004) assigned less than 800 million cubic metres (less than 28 Bcf) to the potential for undiscovered recoverable gas for this play in the Sambaa K'e area. Oil potential is very low to negligible.

Mississippian subcrop play (established)

The Mississippian subcrop play is an established play for both oil and gas with hundreds of discovered oil and gas pools south of 60˚ latitude (Podruski et al., 1988; Gal and Jones, 2003; Hannigan et al., 2006). In the Northwest Territories this play extends across the southern half of the Sambaa K'e candidate protected area (Fig. 9). No discoveries have been made north of 60˚ latitude, but one well in the Sambaa K'e area may have recorded a trace of gas from the Mississippian Flett Formation at the Island Lake N-45 well (Table 2). Porous carbonates in the Banff, Pekisko, Prophet, Shunda, Debolt, and Flett formations are the main reservoir units. Petroleum reservoirs in this play occur in updip unconformity traps involving the entrapement of buoyant oil and gas along the eastern, or northeastern, subcrop edges of these strata where they are truncated by the "basal Cretaceous" unconformity, and overlain and sealed by impermeable shales of the Lower Cretaceous Fort St. John Group (Table 2). Primary petroleum source rocks include the organic-rich Devono-Mississippian Exshaw Formation beneath the Banff Formation, and the organic-rich basal Cretaceous Garbutt Formation (Table 1) shales immediately above the "basal Cretaceous" unconformity. These shale source rocks also serve as reservoir seals.

North of 60˚ latitude, major exploration risks for this play include the relatively low porosities and thicknesses of potential reservoir units (Gal and Jones, 2003; Hannigan et al., 2006). Drummond (2004) assigned less than 0.3 billion cubic metres (less than 10.6 Bcf) to the potential for undiscovered recoverable gas, and about 850 thousand cubic metres (about 5.4 million barrels) to the potential for undiscovered recoverable oil, for this play in the Sambaa K'e area.

Lower Cretaceous play (established)

The Lower Cretaceous play is an established and mature oil and gas play with hundreds of discovered oil and gas pools south of 60˚ latitude (Gal and Jones, 2003; Hannigan et al., 2006). North of 60˚ latitude this play covers all but the extreme northern portion of the Sambaa K'e candidate protected area (Fig. 9). Only one significant petroleum discovery has been made in this play in the southern Northwest Territories; gas has been found at the Arrowhead B-41 well (Dixon, 1997; Hannigan et al., 2006), west of Trout Lake and the Sambaa K'e area (Fig. 2). In the Sambaa K'e candidate protected area, lower Cretaceous potential reservoir rocks include sandstones of the Scatter and Sikanni formations. The main reservoir rock of this play, the Chinkeh Formation basal Cretaceous sandstone is not present within Sambaa K'e (see Dixon, 1997). Potential petroleum source rocks are the Cretaceous shales within the Fort St. John Group that are intercalated with the potential reservoir sandstones units within the Fort St. John Group (Table 1). However the low level of organic maturity of Cretaceous source rocks in the Sambaa K'e area indicates that in-situ generation of petroleum was as heavy oil or bitumen and migration of generated oil from source to reservoir may not have occurred in large quantities. Small volumes of associated biogenic gas may have also been generated and updip lateral migration of thermogenic gas from more deeply buried, more mature Cretaceous strata farther west may also have occurred to charge Cretaceous Sambaa K'e reservoirs.

Drummond (2004) assigned about 1.2 billion cubic metres (about 42.6 Bcf) to the potential for undiscovered recoverable gas, and about 200 thousand cubic metres (about 1.3 million barrels) to the potential for undiscovered recoverable oil for this play in the Sambaa K'e area.

Qualitative and Quantitative estimates of Hydrocarbon Potential

In the Sambaa K'e candidate protected area, the most prospective gas plays, in order of decreasing potential, are the 'Jean Marie shelf & shelf margin', the 'Slave Point/Sulphur Point Barrier Reef edge', the 'Lower Cretaceous', and the 'Slave Point back barrier shelf' plays. However, several other plays (e.g. the 'Lower Cretaceous', 'Mississippian subcrop', and 'Keg River – offshore isolated reef – Horn Plateau' plays) also contain significant additional potential gas resources.

Oil potential is dominated by the 'Mississippian subcrop' play, but additional oil potential occurs in the 'Lower Cretaceous' play and in the combined 'Slave Point platform' and 'Slave Point back barrier shelf' plays.

Gal and Jones (2003) presented a qualitative ranking for the undiscovered petroleum potential across the entire Dehcho region. Most of the Sambaa K'e candidate protected area has been assigned a very high petroleum potential (Fig. 10) largely because of the contribution of a cumulative weighting factor that is proportional to the number of overlapping plays across a given area, even though individually many plays may provide little real additional petroleum potential. This is a reasonable procedure in the absence of quantitative estimates of petroleum potential for individual plays.

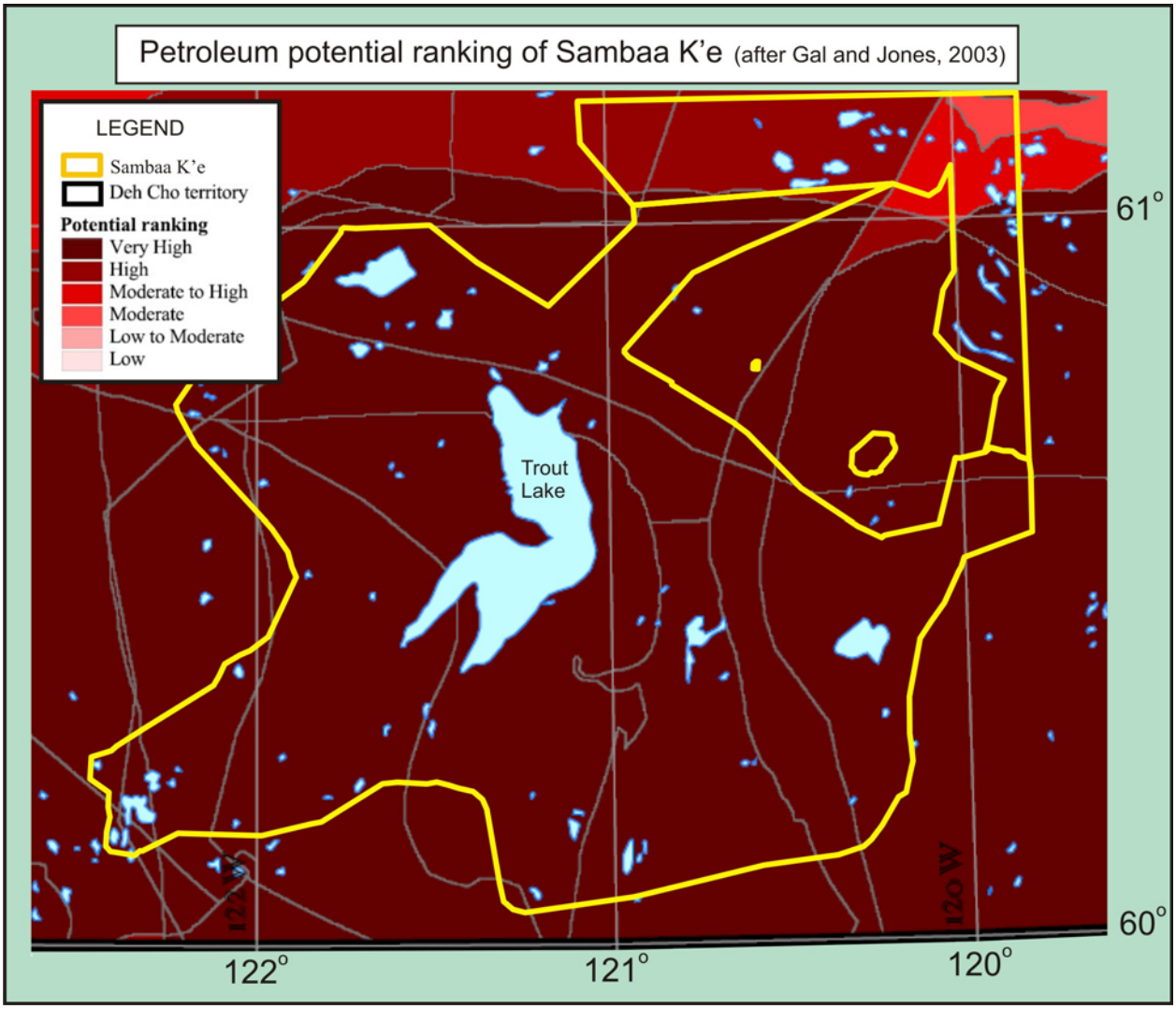

Figure 10. Qualitative ranking of petroleum potential across the Sambaa K'e candidate protected area from Gal and Jones (2003). Most of Sammba K'e is ranked "very high" for petroleum potential because of the numerous overlapping petroleum plays in this area.

However, Drummond (2004) recently derived an independent estimate of the remaining undiscovered recoverable gas potential of the Dehcho region based on the estimation of undiscovered petroleum potential for 20 individual plays that are approximately equivalent to those described in Hannigan et al. (2006) and used in this report (see also Canadian Gas Potential Committee, 2001, 2005). Drummond's (2004) regional map showing total undiscovered potential by quarter degree grid (Figure 9 in Drummond, 2004) across the Dehcho region can be utilized to define the undiscovered potential in the Sambaa K'e candidate protected area (Fig. 11). This gives an estimate of 13.3 billion cubic meters, or 470 billion cubic feet of potentially recoverable, undiscovered gas within the outer boundary of the Sambaa K'e area.

Similarly, Drummond's (2004) regional map of undiscovered recoverable oil potential (Figure 12 in Drummond, 2004) indicates that about 1.18 million cubic meters, or 7.4 million barrels of oil are likely to be found within the outer boundary of the Sambaa K'e area. These estimates for oil and gas potential are reduced slightly if non-Sambaa K'e lands within the outer boundary are excluded from consideration (Fig. 11, 12).

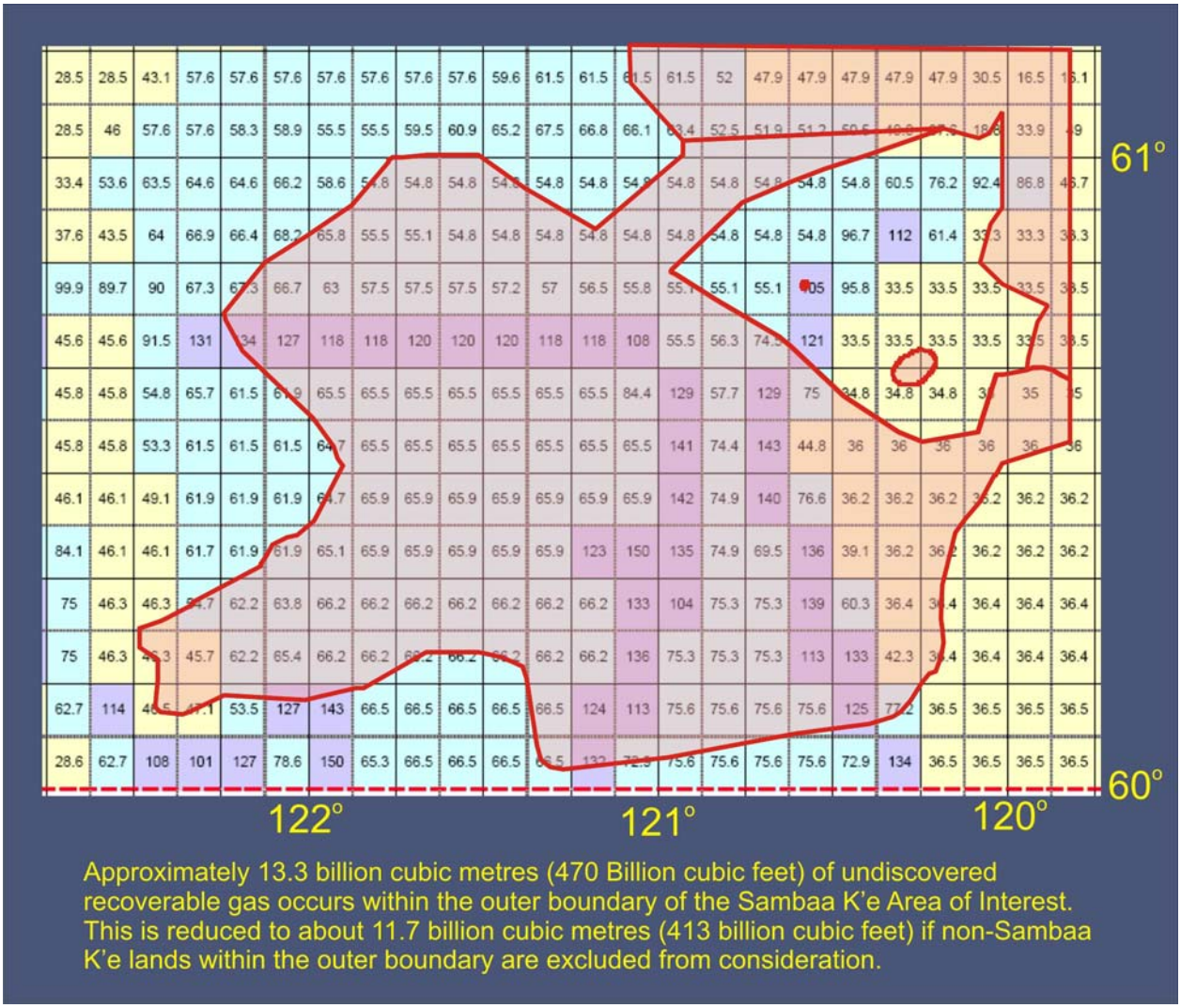

Figure 11. Quantitative estimate of potential for undiscovered recoverable gas across Sambaa K'e is from Drummond (2004). Each quarter grid area shows undiscovered gas potential in millions of cubic metres.

Conclusions

In summary, the potential for undiscovered recoverable gas in the Sambaa K'e candidate protected area is about 0.5 trillion cubic feet; the potential for undiscovered recoverable oil is about 7.4 million barrels. Additional gas field discoveries will likely be made, but most will be small and most will be a few tens of billion cubic feet in volume. This is almost all non-associated gas that has migrated eastward updip during

Paleozoic to Cenozoic maturation of primarily Devonian-aged, organic-rich, source rock shales. Oil prospectivity is moderate, and is based primarily on oil generated locally from the Exshaw Formation source rock shale that is in the oil window in the Sambaa K'e candidate protected area. The estimate of 7.4 million barrels of undiscovered recoverable oil may be somewhat overestimated because of uncertainty regarding the possibility of suitably porous reservoir development within the Mississippian subcrop play in the Sambaa K'e candidate protected area.

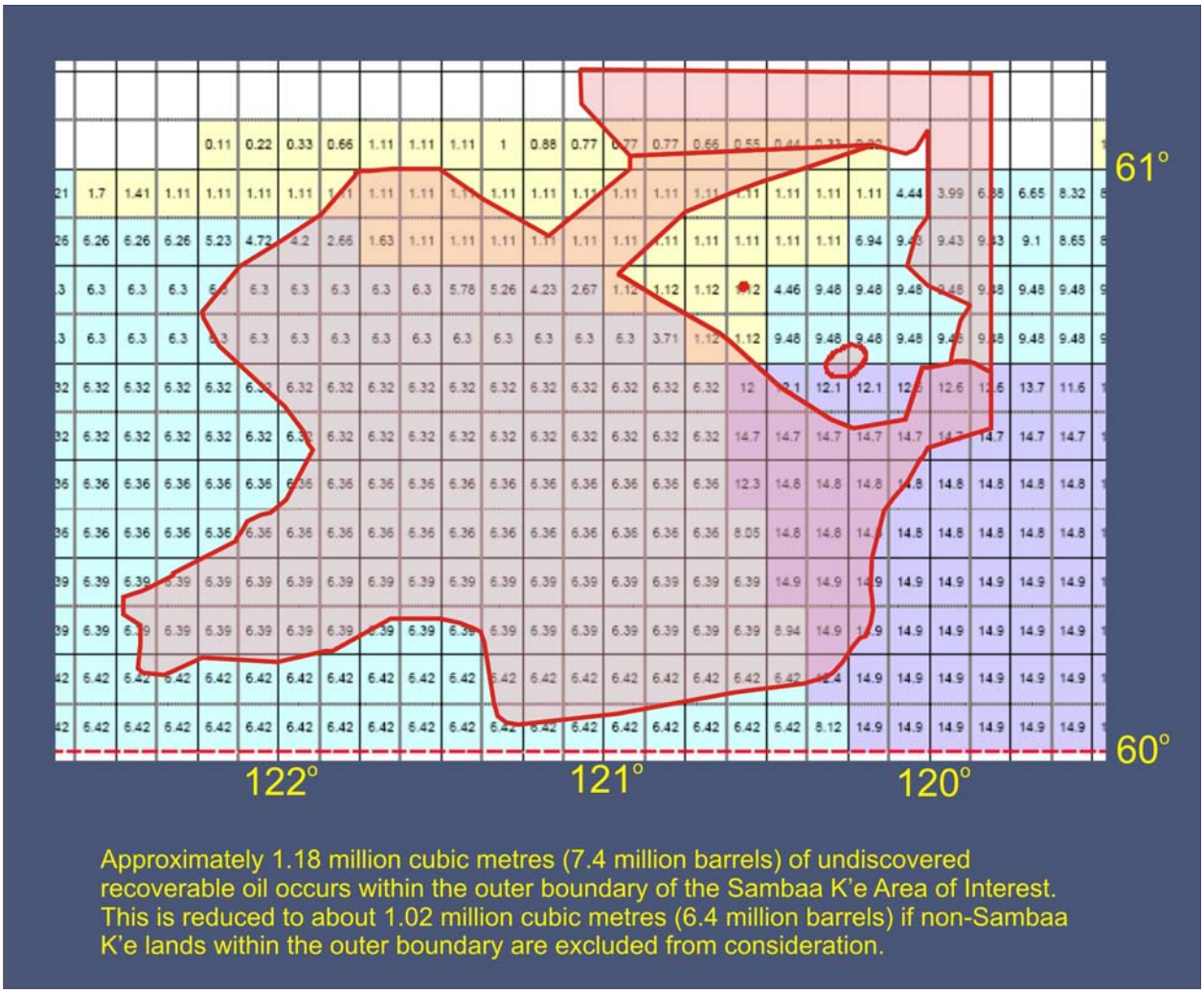

Figure 12. Quantitative estimate of potential for undiscovered recoverable oil across Sambaa K'e is from Drummond (2004). Each quarter grid area shows undiscovered oil potential in thousands of cubic metres.

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