CUMULATIVE COAL THICKNESS AND COALBED GAS POTENTIAL IN THE COMOX COAL BASIN; VANCOUVER ISLAND

Barry Ryan[1], Gwyneth-Cathyl Bickford[2] and Martin Niemann[3]

ABSTRACT

This paper presents desorption, isotherm and coal thickness data for the Comox Basin on Vancouver Island British Columbia. Cumulative coal thicknesses are presented as contours on a number of maps that together cover the Comox Basin. Cumulative coal thicknesses are greatest in the Cumberland to Tsable River areas. Based on coal rank and isotherms the potential gas capacity of the coal increases to the south. Carbon isotope data from the northern part of the basin indicates a biogeneic origin for the gas.

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[1]Resource Development and Geoscience Branch, BC Ministry of Energy and Mines, PO Box 9323, Victoria, BC, V8W 9N3
[2]Consultant, Westwater Mining Limited
[3]PhD candidate University of Victoria, BC

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INTRODUCTION

The eastern side of Vancouver Island is underlain by two major coal basins, which are subdivided into coalfields. These basins named from north to south are the Comox and Nanaimo basins. There is also an area referred to as the Suquash Coalfield to the north and a number of coal occurrences (Figure 1). The Suquash Coalfield has limited potential and the Nanaimo Basin has largely been mined out; however the Comox Basin has significant potential for coal mining and extraction of coalbed gas (CBG) also referred to as coalbed methane (CBM).

It should be noted that in previous literature there is no consistency in the use of the terms basins, coal basins or coalfields however, in this paper it is convenient to use the term Comox Basin, for the total area and then subdivide it into a number of coalfields.

The coal measures on Vancouver Island are contained in the Late Cretaceous Nanaimo Group and in the Comox Basin are largely restricted to the Comox Formation, which is divided into three members. The lowest Benson Member tends to be coarse grained and devoid of coal. The overlying Cumberland Member contains at least 2 coal seams and the uppermost Dunsmuir Member, which is sandier that the Cumberland Member also sometimes contains a single seam. Bickford and Kenyon (1988) describe the coal geology of the Comox Basin and Cathyl-Bickford and Hoffman (1998) mapped the Comox and Nanaimo basins on a scale of 1 to 2000.

This paper utilizes a drillhole database developed by Cathyl-Bickford to contour cumulative coal thickness in the Comox Formation within the Comox Basin. This is a preliminary study and depth and rank data are not contoured so that a detailed CBM resource estimate is not included. The paper also includes some new data that will aid in an assessment of the CBM potential of the basin. Desorption, carbon isotope and gas composition data were collected from samples obtained during 2004 exploration in the Quinsam area. Isotherm data were collected from core samples from exploration holes drilled in the summer 2004 in the Quinsam area and from samples collected from drilling in the Comox area in 2001.

COAL RANK IN THE COMOX BASIN

In literature, rank data is quoted as mean maximum (Rmax%) or mean random (Rran%) reflectance of vitrinite. Recently, literature generally uses mean random reflectance, which is quicker to measure in terms of microscope time than mean maximum reflectance. Older literature sometimes used mean maximum reflectance. The relationship between the two measurements is empirical but most equations indicate that mean maximum reflectance is about 5% greater than random reflectance for ranks in the Comox Basin (Table 1). Data in this paper is all corrected to mean random reflectance of vitrinite.

It is important to have an over view of coal rank variation in the Comox Basin. Most of the coal in the basin is high-volatile A bituminous with ranks in the 0.65% to 0.9% range. Kenyon and Bickford (1989) provide mean maximum reflectance measurements for many locations within the basin. Rank tends to increase from north to south with some areas of high rank adjacent to Tertiary intrusions. Rank in the north at the Quinsam Mine ranges from 0.61% to 0.64% Rran (0.64% to 0.67% Rmax) (Ryan and Dawson, 1993) and in the area, averages 0.66% with a range of 0.50% to 0.80% (recalculated to Rran from Matheson *et al.*, 1994). The

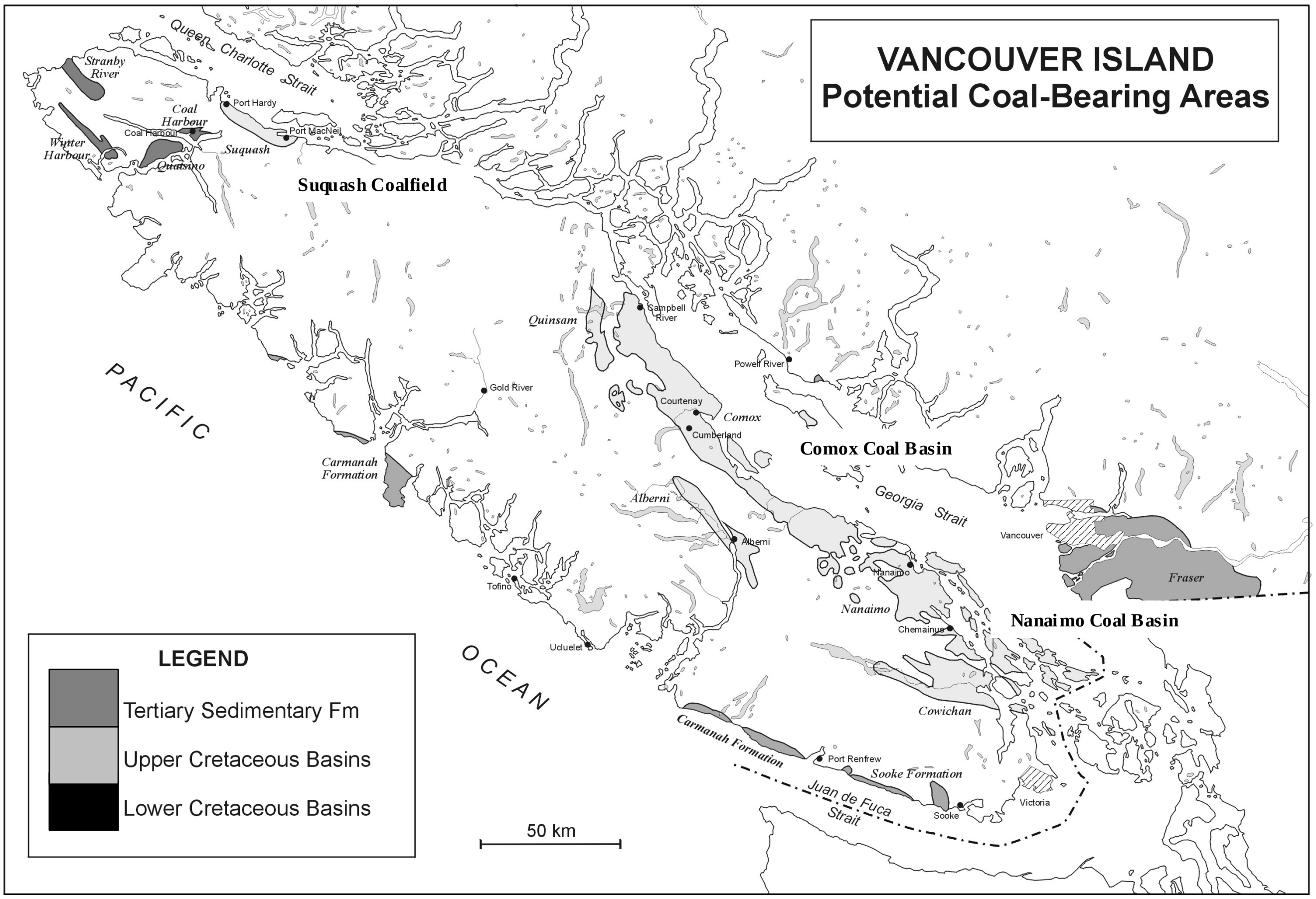


Figure 1. Regional map of coalfields on Vancouver Island.

coal contains about 80% vitrinite (mmfb) and high vitrinite contents are generally characteristic of Comox coals. In the Cumberland area rank is variable increasing to 1.7% in the vicinity of Tertiary intrusions in the Browns River area (Kenyon and Bickford, 1989) but is generally in the range 0.75% to 0.85% (Kenyon and Bickford, 1989 and Ryan, 2002). In the southern part of the Comox Basin in the Tsable River area rank is 0.80% Rran (Ryan, 1997) to 0.83% (Kenyon and Bickford, 1989).

GAS DESORPTION DATA ON VANCOUVER ISLAND

There are very limited desorption data for coals on Vancouver Island. Novacorp obtained some of the earliest data when the company drilled 8 holes in 1985. Geophysical logs and hole locations are in reports filed with the Ministry of Energy and Mines in Victoria. Desorption data from this program have been referenced by a number of authors (Cathyl-Bickford, 1992) but little detail is published. Ryan (1997, 2002) has published limited desorption data for coal from Tsable River and Cumberland areas and Ryan and Dawson (1993) have published data for coals from the Quinsam Mine. Samples from the last study came from depths ranging from 100.9 to 145.7 metres and gas contents (dry ash-free basis dafb) ranged from 1 to 1.6 cc/g.

In this study advantage was taken of a four-hole exploration program conducted by the Quinsam Mine personnel, west of the present Quinsam mine. Eight samples were collected from Hole 2004-4 from depths ranging from 134.25 to 156.4 metres (Table 2). The samples generally consisted of inter-layered bright coal and mudstone with high ash contents (Photo 1). Gas contents on an air-dried basis range from 0.2 cc/g to 1.3

TABLE 1. CONVERSION OF MEAN RANDOM REFLECTANCE TO MEAN MAXIMUM REFLECTANCE OF VITRINITE.125

Empirical linear equations in the literature for converting Rrand to Rmax			
		Slope	intercept
Grieve (1991)		1.0809	-0.0306
Deissel (1992)		1.0700	-0.0100
Weiss(1985)		1.12	-0.05
Marchioni and Kalkreuth (1992)		1.06	0.01
Average results			
	Rand	Rmax	% dif
	0.6	0.63	4.8
	0.65	0.68	5.07
	0.7	0.74	5.29
	0.75	0.79	5.49
	0.8	0.86	5.66
	0.85	0.9	5.82

TABLE 2. DESORPTION DATA FROM HOLE 2004-4 QUINSAM AREA.

Hole location Elevation 260, Easting 322796, Northing 5536095 metres										
sample	wt g adb	Seam	from metres	to metres	ash% adb	adm	gas cc/g adb	gas cc/g dmmfb	slope lost gas line	tau Hours
5	2829	2	134.25	134.65	39.39	1.56	0.585	1.10	0.065	35
6	2544	1R	138.11	138.5	21.32	1.44	1.332	1.80	0.106	150
8	3877	1	143.9	144.31	66.87	0.96	0.227	1.23	0.046	12
9	3331	1	144.45	144.85	67.70	0.87	0.450	2.11	0.050	125
7	3220	1	144.85	145.24	54.91	0.93	0.531	1.48	0.066	30
10	3109	1	146.43	146.84	60.92	1.05	0.533	1.84	0.061	120
11	3216	1	148.51	148.89	68.38	0.96	0.292	1.43	0.039	20
12	3646	1L	155.98	156.4	68.89	1.13	0.237	1.21	0.028	70

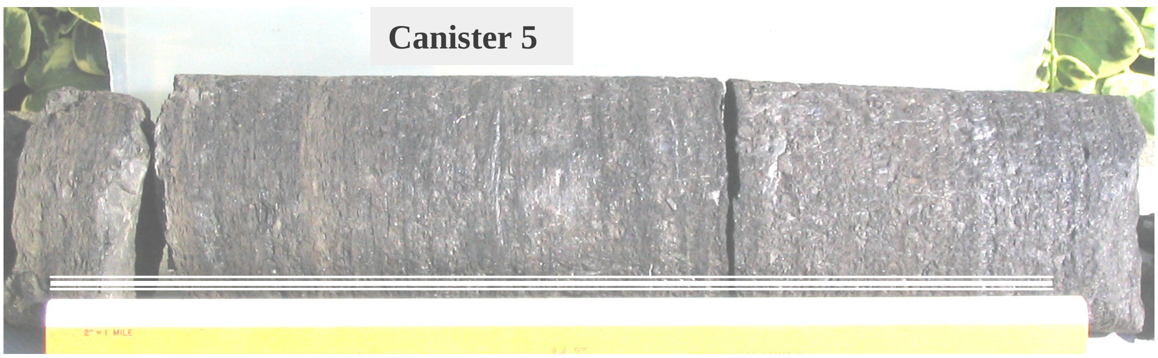


Photo 1. Core sample canister 5.

cc/g and on a dry mineral-matter free basis range from 1.1 to 2.1 cc/g. The mmfb calculation was made using a mineral matter to ash ratio of 1.15 as supported by the specific gravity data discussed in the "correction to mmfb" section that follows. A plot of gas content mmfb *versus* ash does not reveal any trend indicating that there is no obvious bias in the correction to mmf basis. Based on an isotherm for the sample from seam 1R (Figure 2, Table 3) seams are under saturated at the shallow depth of about 150 metres. The degree of under saturation may reflect a low and fluctuating water table. If the effective long-term water table is 50 metres below surface, then on average the samples appear to be saturated.

The ash content of the samples is variable and high and some samples are mainly mudstone with coal stringers. There is no apparent correlation of gas content (dry mineral matter-free basis, dmmfb) with ash content. However sorption time Tau (time to 0.632 total desorbed gas) correlates weakly with gas content mmfb possibly indicating that high mmfb gas contents correlate with larger particle sizes, which control diffusion. However, there is no correlation of coal particle size with the total ash content in samples. Whatever is influencing coal grain size is not related to the amount of mudstone in samples and is variable with depth.

Diffusivity is related to the slope of the lost gas plot (gas *versus* t^1/2) (Smith and Williams, 1984) and to the sorption time Tau (Gas Research Institute**,** 1995). However the later determination assumes that the calculation uses the shape factor and the first that the actual radius of particles is the radius controlling spherical diffusion. The values of diffusivity calculated by the two methods differ but the difference is minimized if spherical diffusion, with a shape factor of $15/r^2$, is used (Figure 3). It appears that even for in fairly solid core, it is broken into particles approaching spherical shape rather than cylindrical shape. This is also suggested by the fairly short Tau times, because long Tau times probably correlate with cylindrical diffusion. Sample 8 (Table 1), which has high ash content and is mainly mudstone with stringers, appears not to confirm with spherical diffusion; however the Tau time constant is short.

TABLE 3. ISOTHERM DATA CANISTER 6 SEAM 1R; DEPTH CALCULATED ASSUMING NORMAL HYDROSTATIC GRADIENT.

temperature	20ºC
ash %	20.37
EQ moisture%	4.82
SG	1.472
wtlos	1.15
Rran	0.68
Lang vol AR cc/g	34.09
Lang P Mpa	4.6

depth m	MPa	AR	DAF	mmfb
37	0.366	0.39	0.52	0.54
72	0.709	0.91	1.21	1.26
118	1.155	1.45	1.94	2.02
170	1.668	1.92	2.57	2.68
221	2.164	2.33	3.12	3.25
273	2.682	2.62	3.5	3.65
386	3.787	3.27	4.37	4.56
522	5.122	3.79	5.06	5.28
671	6.577	4.08	5.45	5.68
821	8.05	4.34	5.8	6.05
938	9.196	4.69	6.27	6.54
1111	10.9	4.92	6.57	6.85
1214	11.906	5.08	6.79	7.08

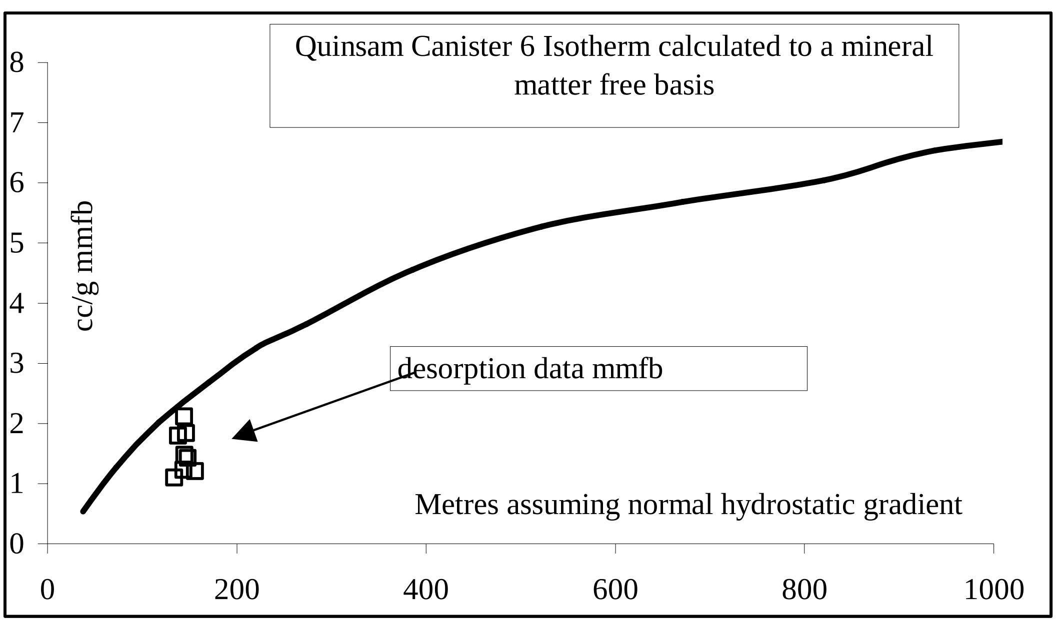


Figure 2. Isotherm plot Canister 6 seam 1R Quinsam area with desorption data all calculated to a mineral matter free basis using a mineral matter to ash ratio of 1.15..

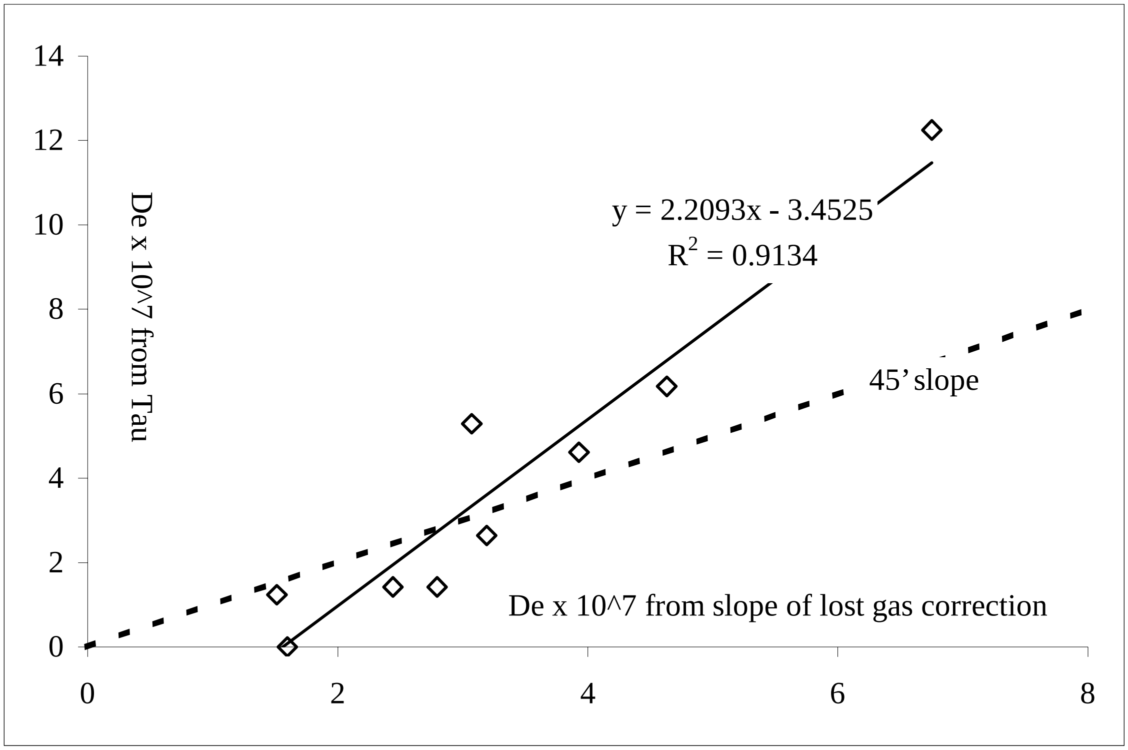


Figure 3. Diffusivity calculated from lost gas plots and from the time to 63.2% desorbed gas for each sample.

CARBON ISOTOPE RATIOS AND GAS COMPOSITION DATA FOR QUINSAM GAS SAMPLES

Gas samples from canisters 5 to 12 (Table 2) were taken during desorption and analyzed for chemical, composition and isotopic composition. Analyzes were performed at the Biogeochemistry Facility of the University of Victoria using a gas chromatography – isotope ratio mass spectrometer (GC-IRMS).

Concentrations of hydrocarbons and carbon dioxide were measured over a period of time from each canister. Prior to collecting gas samples the sampling line was purged with argon. Consequently samples contained a mixture of desorbed gas and argon (Table 4). If it is assumed that samples contain only CH_4, C_2H_6, CO_2 and argon, then the average composition of the gas desorbed from the canisters is about 97% methane, 2% CO_2 and less than 0.2% C_2H_6.

Carbon isotope values ($\delta^{13}C$-C_1 methane) for the samples change over time during desorption (Table 5), as does the gas composition of the samples. The isotope values (Table 5) are given in the delta (δ) notation with reference to the PDB-standard. A modified Bernard Plot (Figure 4, gas wetness vs. $\delta^{13}C$-C_1 plot) is commonly used to differentiate between biogenic and thermogenic gases. Biogenic gases are generally characterized by "light" methane isotope compositions, with $\delta^{13}C$ values more negative than -55‰, where as thermogenic gases generally have $\delta^{13}C$ values less negative than -55‰ (Schoell, 1980). Compared to biogenic gases, thermogenic gases are also characterized by higher concentrations of heavier hydrocarbons (wet gas). Biogenic activity does not generally generate heavier hydrocarbons and heavier hydrocarbons are adsorbed more strongly onto coal than methane.

Almost all $\delta^{13}C$ values for the samples are "lighter" than -55‰ (Figure 4) and in terms of gas composition are considered to be dry, indicating biogenic gas generation. The data are divided into two sets; one representing initial samples and a second representing samples collected latter during desorption. The wetness increases with desorption (Figure 4) but there is little change in $\delta^{13}C$ values. The increase in wetness is due to stronger adsorption of higher hydrocarbons and not due to mixing of biogenic gas with thermogenic gas, which would create $\delta^{13}C$ values in the range –50‰ to –30‰ (Figure 4).

CORRECTION TO MINERAL MATTER FREE BASIS

It is important to reduce all data to a common basis when comparing gas content results. This is often done by reducing data to a dry ash-free basis (dafb), which is a simple correction using the measured moisture contents (or a constant equilibrium moisture content) and ash contents. Alternatively a mineral matter free correction is used that requires ash and sulphur contents and generally uses the Parr Equation. Both approaches have problems derived from the fact that the ratio of mineral matter/ash is not 1, varies, and is not always adequately accounted for using the Parr equation. An alternative approach uses Apparent Specific Gravity (ASG) analyses performed on air-dried samples.

TABLE 4. ISOTOPIC COMPOSITION AND VARIATION OVER TIME OF METHANE RELEASED FROM CANISTERS DURING DESORPTION.

	actual concentations				calculated to 100%		
Canister No.	**[CH_4] [%]**	**[C_2H_6] [%]**	**[CO_2] [%]**	**A %**	**[CH_4] [%]**	**[C_2H_6] [%]**	**[CO_2] [%]**
5	14.7	0.1	0.3	84.9	97.4	0.7	2.0
6	14.9	< 0.02	0.2	84.9	98.5	0.1	1.3
7	13.1	< 0.04	0.3	99.7	97.5	0.3	2.2
8	10.9	< 0.007	0.2	88.9	98.1	0.1	1.8
9	10.5	< 0.01	0.2	89.3	98.0	0.1	1.9
10	5.8	0	0.1	94.1	98.3	0.0	1.7
11	2.7	0	0.1	97.2	96.4	0.0	3.6
12	3.1	0	0.1	96.8	96.9	0.0	3.1

TABLE 5. AVERAGE CONCENTRATIONS OF METHANE, ETHANE AND CARBON DIOXIDE RELEASED FROM CANISTERS DURING DESORPTION.

Time Steps	**$\delta^{13}C$-CH_4 Can. 5 [‰]**	**$\delta^{13}C$-CH_4 Can. 6 [‰]**	**$\delta^{13}C$-CH_4 Can. 7 [‰]**	**$\delta^{13}C$-CH_4 Can. 8 [‰]**	**$\delta^{13}C$-CH_4 Can. 9 [‰]**	**$\delta^{13}C$-CH_4 Can. 10 [‰]**	**$\delta^{13}C$-CH_4 Can. 11 [‰]**	**$\delta^{13}C$-CH_4 Can. 12 [‰]**
1	-75.9	-81.1	-65.3	-74.7	-79.3	-69.0	-77.6	-66.4
2	-73.0	-77.2	-61.4	-67.7	-65.9	-65.5	-76.9	-64.5
3	-67.2	-68.2	-60.7	-63.9	-66.4	-65.0	-72.9	-64.6
4	-67.5	-64.1	-63.3	-66.5	-64.6	-68.5	-71.6	-71.3
5	-70.3	-63.6	-65.6	-66.1	-66.3	-68.4	-69.8	-72.1
6	-70.6	-69.7	-67.5	-67.6	-66.5	-68.8	-70.4	-72.3
7	-72.6	-70.7	-67.7	-67.6	-66.9	-69.8	-70.7	-73.5
8	-72.3	-70.8	-67.4	-67.5	-66.5	-69.2	-70.5	-72.7
9	-72.2	-70.2	-66.9	-66.9	-66.1	-70.3	-71.8	
10	-73.4	-71.1	-67.7	-68.1	-66.7	-71.1	-70.6	
11	-72.9	-71.6	-67.9	-65.8	-67.4	-70.9		

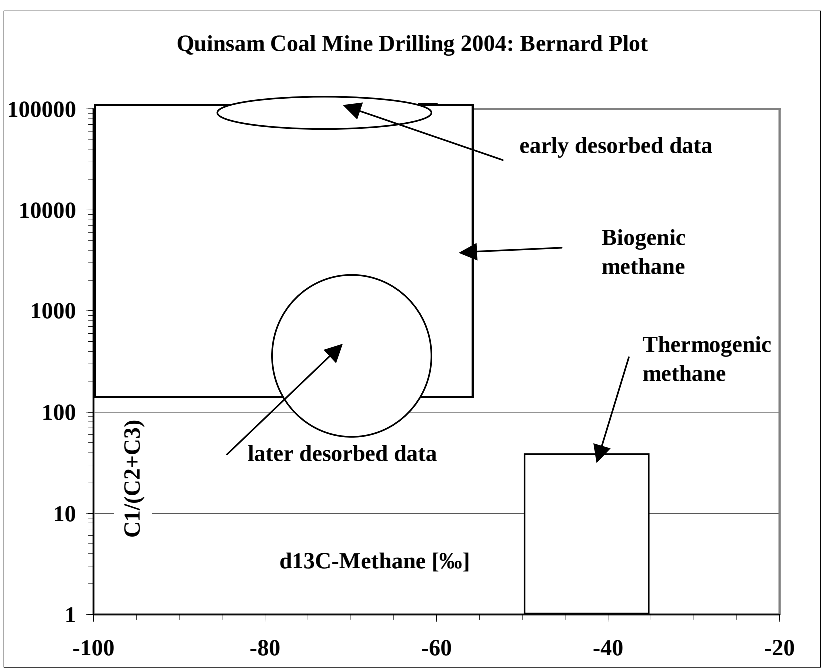


Figure 4. Simplified Bernard Plot showing gas wetness (C1/C2+C3) on the y-axis vs. the carbon isotope composition of methane on the x-axis. Separate fields indicate biogenic and thermogenic gas generation (modified from Whiticar, 1986)

The relationship of ASG to ash has the form

SG=1/(A-B*ash) (1) (Ryan, 1993)

Which can also be expressed as:

1/ASG=A-B*ash (2)

The constant A= 1/(density for zero ash coal) (DC) and the constant B incorporates the density of rock (DMM) and the ratio mineral matter/ash (WTLOS). Plotting ash *versus* ASG data using Equation 2 allows for solution of DC and for generation of a table of possible pairs of DMM and WTLOS values. Correction of data to a mmf basis is easy using Gas mmfb= gas/(1-ash*WTLOS) once a value of WTLOS is determined. The Quinsam data set is plotted in Figure 5 and illustrates how to obtain a solution for WTLOS.

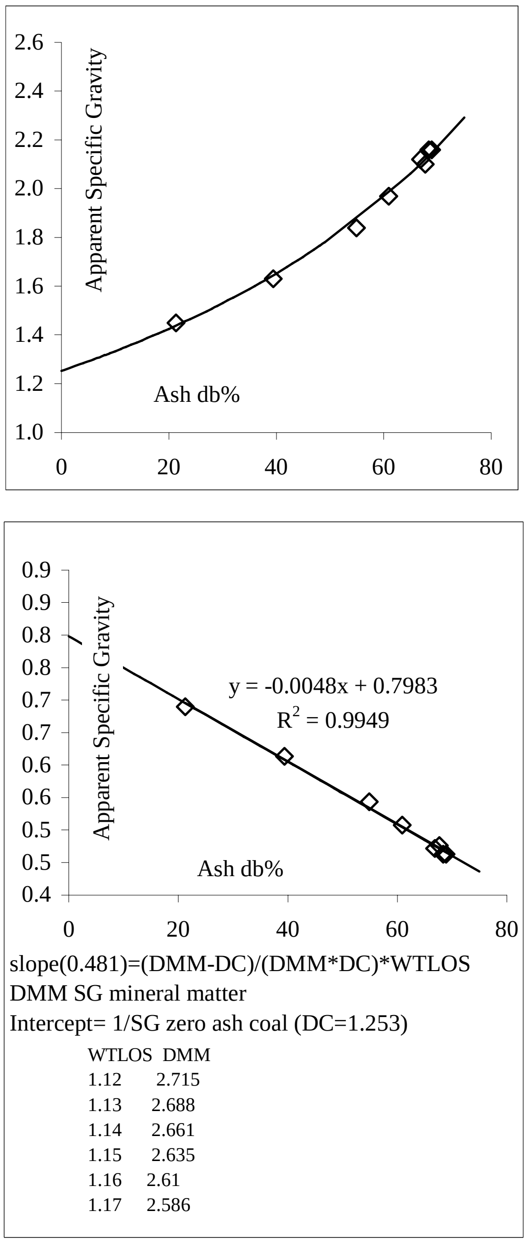


Figure 5. Quinsam desorption data; measured apparent specific gravity values (ASG) *versus* ash content and calculation of mineral matter to ash ratio (WTLOS).

A plot of gas content *versus* ash content (dry basis) (for saturated samples) should provide a straight line, which intersects the Y axis at the gas content mmfb and have a slope of gas content mmfb x WTLOS (Figure 6). The imaginary data in Figure 6 are calculated assuming a gas content of 10cc/g mmfb. Unfortunately many data sets do not plot on a straight line in part because coal petrographic composition varies with ash content. Correcting data, with varying ash contents, back to dafb gas contents produces considerable errors when there is a range of ash contents (Figure 6). In fact for the data set used in Figure 6, with ash contents ranging from 20% to 70%, calculated gas values dafb range from 6.7 to 9 cc/g when the actual gas mmfb is 10 cc/g.

It is apparent that when there is a wide range of ash contents corrections using daf basis produce errors that will make it difficult to compare data and to determine whether samples are saturated. Use of ASG data and a linear plot to determine the WTLOS factor allows calculation of the mmfb gas content in a simple and cost effective way.

ISOTHERM DATA PETROGRAPHY AND RANK OF CANISTER 6

A number of isotherms exist for the Comox Basin. This paper presents new isotherms for the Quinsam and Dove Creek areas (Figure 2, Table 3). An isotherm was measured for the sample Canister 6 seam 1R, which has a rank of 0.65% Rrand. The sample is vitrinite rich and contains about 13% by volume % mineral matter (Figure 7). Two isotherms, previously unpublished, were obtained from samples collected during the drilling at Dove Creek in 2001. The rank of these samples is somewhat higher but they also contain a high percentage of vitrinite on a mineral matter free basis (Figure 7).

Isotherm data all ready exists for coals at Tsable River (Bustin, personal communication 2003) and Quinsam (Ryan and Dawson, 1993). All isotherm data are plotted in Figure 8. The isotherms reflect the decreasing rank from north to south and at 500 metres saturated gas contents are predicted to range from 6.6cc/g daf to 10.9 cc/g daf. Ranks are highest in the Dove Creek area though this may be the result of local Tertiary intrusions. The composition of gas desorbed from the 3 holes at Dove creek (Ryan, 2002) contained a moderate amount of nitrogen that might originate from Tertiary intrusive activity.

COAL THICKNESS ISOPACKS

A database containing formation and coal picks from approximately 1300 holes was generated by Cathyl-Bickford and made available for this study. The database includes depth and thicknesses of net coal in seams and thickness of seams in the Comox Formation. An estimate of the cumulative thickness of seams including in-seam splits in each hole provides a starting point for estimating the potential CBM resource in the Comox Basin. Because it does not consider individual seam thicknesses, seam depth or exclude splits, it does not provide an estimate of

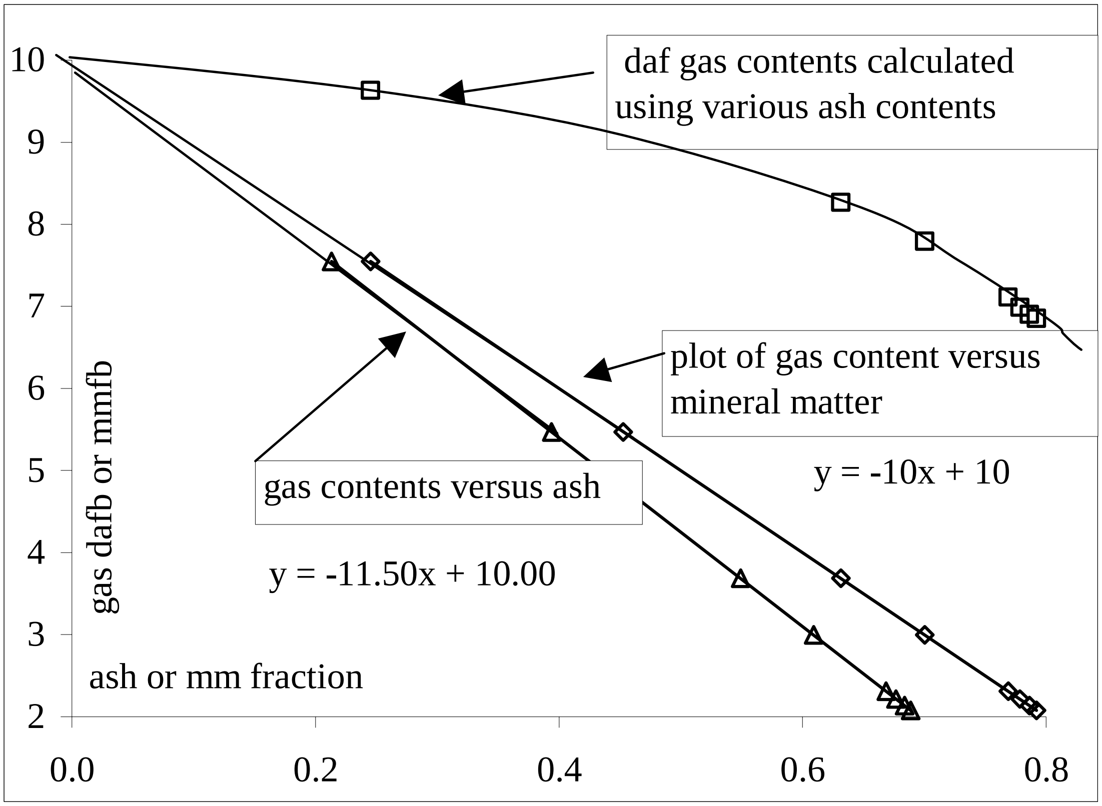


Figure 6. Plot of ash or mineral matter *versus* gas content. The slope of the ash db *versus* gas content plot is the WTLOS factor.

that part of the coal resource that might be available for underground or surface mining.

The cumulative coal thickness data for holes was contoured to provide isopachs. Contouring was limited by the subcrop of the Comox Formation and by the coastline to the east. In addition contours were not extended into areas where holes did not contain coal irrespective of whether this was because there was not coal in the section or because the hole was not drilled deep enough. The gridded file used to produce the contours was also used to calculate the tonnage represented by the contour values and area covered by the contours. Tonnage calculations are made assuming an average specific gravity of 1.5. The value derived is an estimate of coal resource including splits and seams too thin to be of interest for mining. It is therefore an estimate of the resource available for CBM exploration.

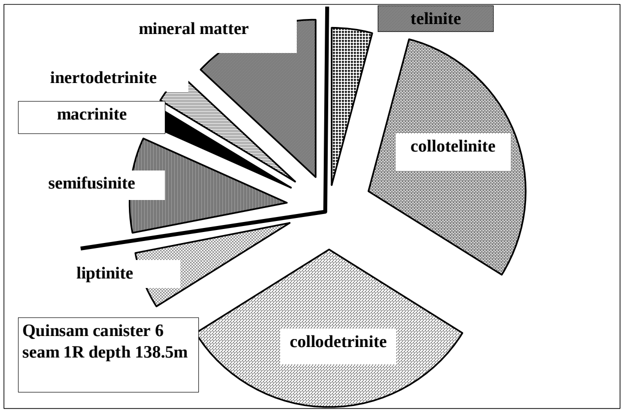
The Comox Basin is subdivided into 8 areas (Figure 9). These areas tend to outline local areas of more intense drilling (Figure 10) and therefore in a loose way tend also to outline areas previously described as coalfields. The area referred to as Ash River (Figure 9) is actually in the Alberni Coalfield but is included here for completeness. It should be noted that there are no accepted outlines to coalfields or standardized name usage. Maps for each of the sub areas outlined in Figure 9 provide contours of cumulative coal thickness and plots of drill holes indicating which holes intersected coal and which did not.

Data in each area are krieged using 250 x 250 metres cell sizes. Search areas were set as circles with 2.5 kilometres radii. No attempt is made in this preliminary study to tailor the krieging to recognize anisotropy in the geology. Seam development is probably most consistent in a northwest southeast direction with a shoreline to the west-southwest and a hinterland to the northeast.

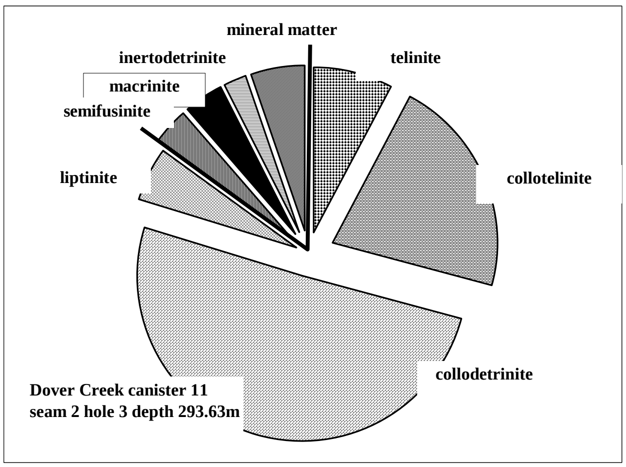
In the south (Figure 11), a number of holes were drilled in the Ash River area (Alberni Coalfield) but none intersected coal.

The southern-most area of interest in the Comox Basin is Cowie River, where 47 holes were drilled (circles Figure 12a) with 33 intersecting coal (circles filled with a cross Figure 12a). Some of this area overlaps with the Tsable River area to the north. The drilling was not successful in extending the coal measures south of Wilfred Creek. The Comox Formation subcrops along the western margin of the area and dips at between 5° and 20° to the northeast. Coal is restricted to the northern part of the area where cumulative thicknesses range from less than 3 metres to over 10 metres (Figure 12b). An area of about 30 square kilometers is underlain by about 250 mt of resource (Table 6).

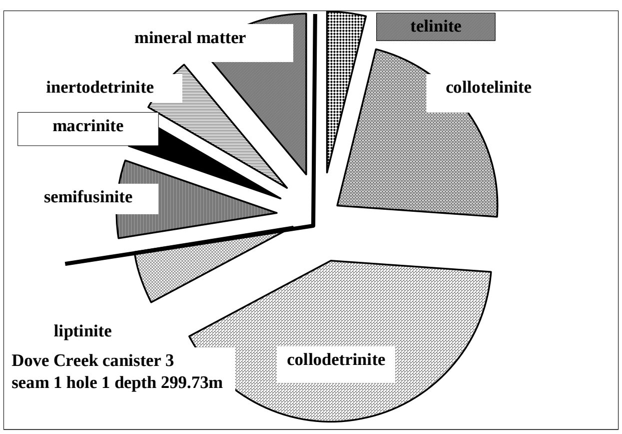
Over the years there has been a lot of interest in the Tsable River area. A small underground mine operated from 1945 to 1966 and in the 1990's Hillsbourgh explored the area hoping to develop an underground coalmine. Exploration outlined a potentially underground mineable resource of about 100mt (Gardner, 1999). There is a large area underlain by more than 6 metres of cumulative coal and data indicate that coal probably extends under Georgia Strait though ash content of the



Rrand = 0.65% (SD=0.005). Calculated RmeanMax 0.68%.



Rrand = 0.85 Rmean Max= 0.89 equilibrium moisture 2.77%



Rrand = 0.77% Rmean Max 0.81 equilibrium moisture 2.96%

Figure 7. Petrography and rank for isotherm samples Quinsam canister 3, Dove Creek canister 3 and Dove Creek canister 11.

seams may increase to the east (Cathyl-Bickford, 1992). More recently there has been interest in the CBM potential of the area.

The southern part of the Tsable River area overlaps with the Cowie River area and this is accounted for when calculating the tonnage attributed to the Tsable River area. There are 151 holes in the area of which 126 intersect coal (Figure 13a). The contoured area (Figure 13b), which is about 71 square kilometers is underlain by 454 mt of resource. Some CBM desorption data were collected in 1996 (Ryan, 1997). Generally samples appeared to be under saturated and as received gas contents ranged from 1.6 to 5.5 cc/g for samples collected over a depth range of 127 to 376 metres. Ash content of samples ranged from 14% to 55%.

In the Cumberland area, there is a long history of mining, which lasted from 1869 to 1947. During this period 14.5 million tonnes (mt) of high-volatile A bituminous coal were extracted. The mines in the area were gassy and over the years at least 300 people were killed. Based on emission rates (Cathyl-Bickford, 1992) gas contents vary from 7 to 14 cc/g on an as received basis. In 2001 Priority Ventures drilled three holes in the Dove Creek area (Figure 14a) north of the Cumberland mines. Hole D3 (Table 7) is about 2 kilometers from the underground workings and the other two holes further away to the north. Some desorption work was performed on the core from these holes (Ryan, 2002). Gas contents of the samples range from 3.5 to 11.5 on a daf basis. Ash contents are high but some of the samples appeared to be gas saturated.

A report on the exploration at Dove Creek was submitted to the government (Cathyl Bickford, 2001). Data in coal exploration reports is confidential for three years following the exploration program so that data in this report are now public and Table 7 provides information on the cumulative coal in the three holes. Net coal data is extracted from the report and gross coal thicknesses are estimated from geophysical logs in the report. There is considerable difference between net coal thickness and seam width (Table 7). The three holes have cumulative coal thicknesses of 12, 11, and 5 metres and net coal thicknesses of 4.9, 6.1, and 2.3 metres. Ash contents generally appear to be high and in the range 35% to 50%.

A total of 245 holes were drilled in the Cumberland area with 174 holes intersecting coal (Figure 14a). A lot of these holes were shallow and drilled in the area of the underground mines, which are located on Figure 14a. These areas were excluded from resource calculations. The area contoured (Figure 14b) is 125 square kilomtres and it contains 1820 mt. Much of this resource underlies existing communities and may not be available for CBM exploration. Cumulative coal thicknesses in much of the area are over 10 metres though in the east the contours are not supported by much drill data (Figure 14a). Gardner (1999) estimates that there might be a potential coal resource of about 70 mt available for underground mining in the area.

The Trent River area, also referred to as the Hamilton Lakes area, (Figure 15) consists of 2 outliers and an ill-defined area of coal bearing rocks to the east that dipping off to the northeast. Within these areas there are 35 holes of which 16 intersect coal (Figure 15 in which cumulative thickness data are posted next to hole location). The northeastern outcrop area, which is about 4.5 square kilometres, contains a resource of about 32 mt (Figure 15). No resource is assigned to the southern area. Gardner (1999) calculates a coal resource in these areas of

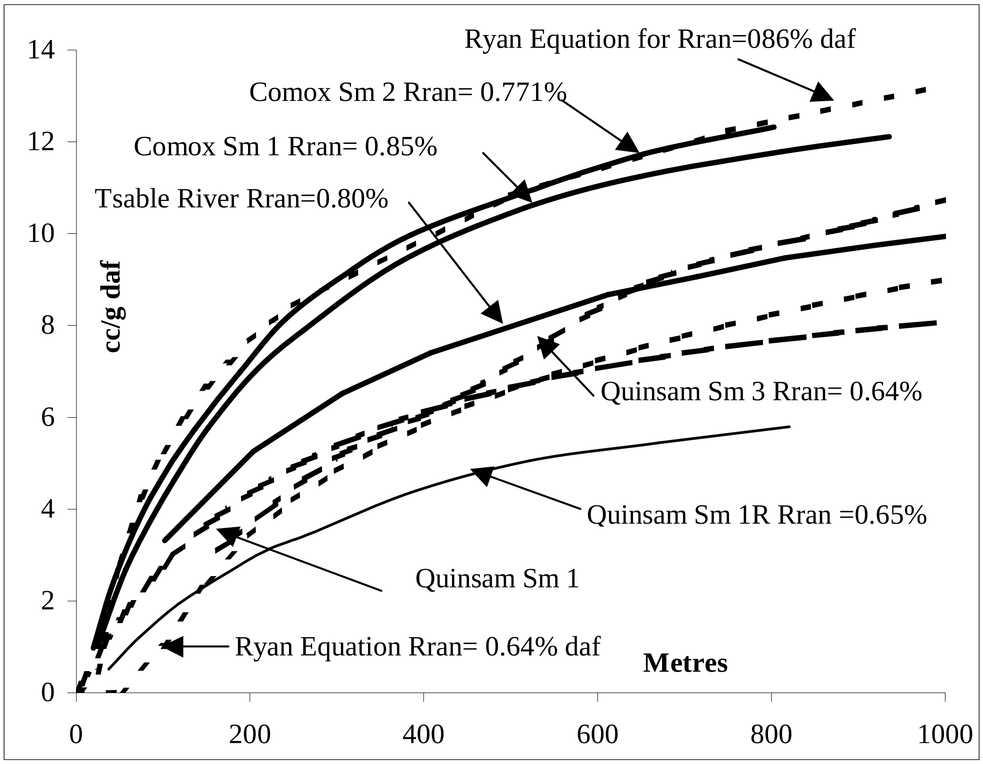


Figure 8. Isotherms for seams from the Comox Basin.

6.4 mt in the north and 2.6 in the south. The amount of data east of the main subcrop line (Figure 15) is limited and the tonnage estimate is restricted to two areas where holes intersected coal (outlined by small circles in Figure 15) these two areas cover about 6.5 square kilometers and represent a potential resource of about 100 mt.

There are 30 holes in the Tsolum River area and only 7 intersect coal (Figure16). The cumulative coal is posted next to the holes. There are only 3 holes in the south with cumulative coal thicknesses between 6 and 14 metres. Tonnage calculation restricted to the area where holes intersected coal resulted in a potential resource of 130 mt. in an area of 16.5 square kilometers. A number of companies have drilled in the area and intersected thin seams 1 to 1.5 metres thick with limited mining potential however the rank in the area is high in some places reaching semi anthracite (Gardner, 1999).

The coal potential of the Oyster River area, which is east and south of the Quinsam mine, is discussed by Bickford *et al.* (1990) and by Gardner (1999) who refers to it as the Quinsam East area and outlined a surface mineable resource of 8.2 mt.. There are 87 holes in the area and 49 intersect coal (Figure 17a). The potential resource in the area contoured (Figure 17b) is 360 mt, which underlies an area of 41.5 square kilometers.

The Quinsam area represents an outlier isolated from the Comox Basin by faults that bring to surface an area of basement. The area has been explored extensively by a number of companies over the years **(**Kenyon *et al*., 1991) and 768 holes are represented in the database, of which 77 intersected coal (Figure 18a). Many holes were drilled to outline shallowly buried coal and did not reach the coal seams. Figure 18a only plots holes that intersected coal. The estimated resource in the area contoured (Figure 18b), which is 26 km^2, is 112 mt. Gardner (1999) estimates a potential resource of 77 mt available for underground mining. Chute Creek is a small deposit south of the Quinsam mine that was explored in the 1980's when a number of holes were drilled and an addit constructed. At least three holes intersected thin seams in the area (Figure 18a) and a resource of about 5 mt is documented of which Gardner (1999) considers about 2 mt to be surface mineable.

The Comox Basin extends for some distance north to the town of Campbell River but there has been very little exploration in the area. In the Campbell River area 45 holes were drilled and 27 intersect coal (Figure 19a). The area contoured (Figure 19b) is area 46 square kilometers and is underlain by an estimated 245 mt of resource. The area south of Campbell River is referred to as the Airport area as it underlies the local airport. In this area and to the north Gardner (1999) outlines a potential underground mineable resource of about 45 mt.

The total coal resource in the Comox Basin is in the range of 3 billion tonnes (Table 6) and this resource underlies an area of about 400 square kilometers. Based on the isotherms in Figure 8 approximate gas contents at an average depth of 300 metres are assigned to each area (Table 6) and an estimate of the insitu gas resource of about 0.65 tcf is calculated. There have been numerous estimates of the gas resource on Vancouver island and most are in the range of 0.5 to 1 .5 tcf. These are only

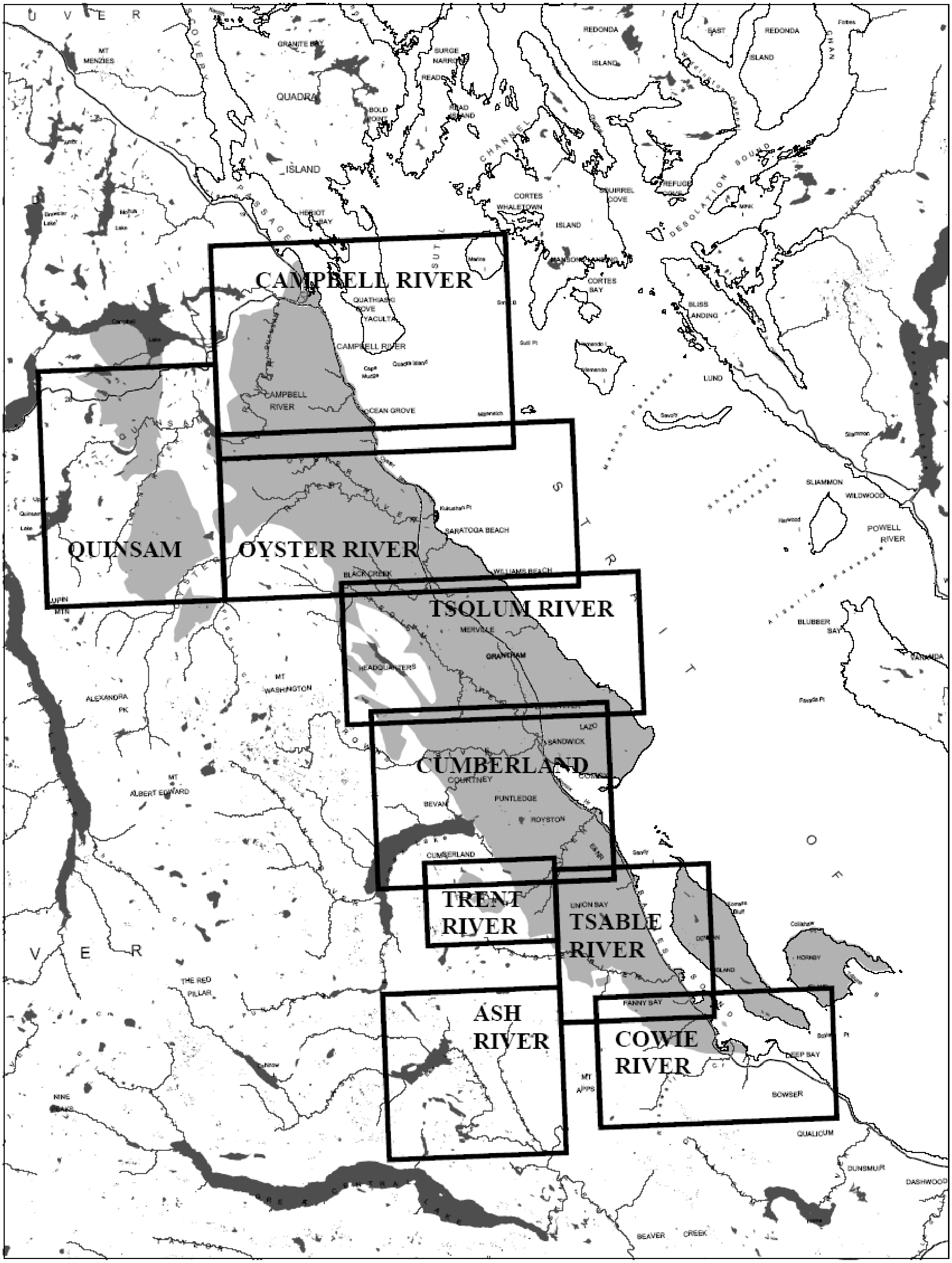


Figure 9. location of sub areas of the Comox Basin in which cumulative coal thickness is contoured.

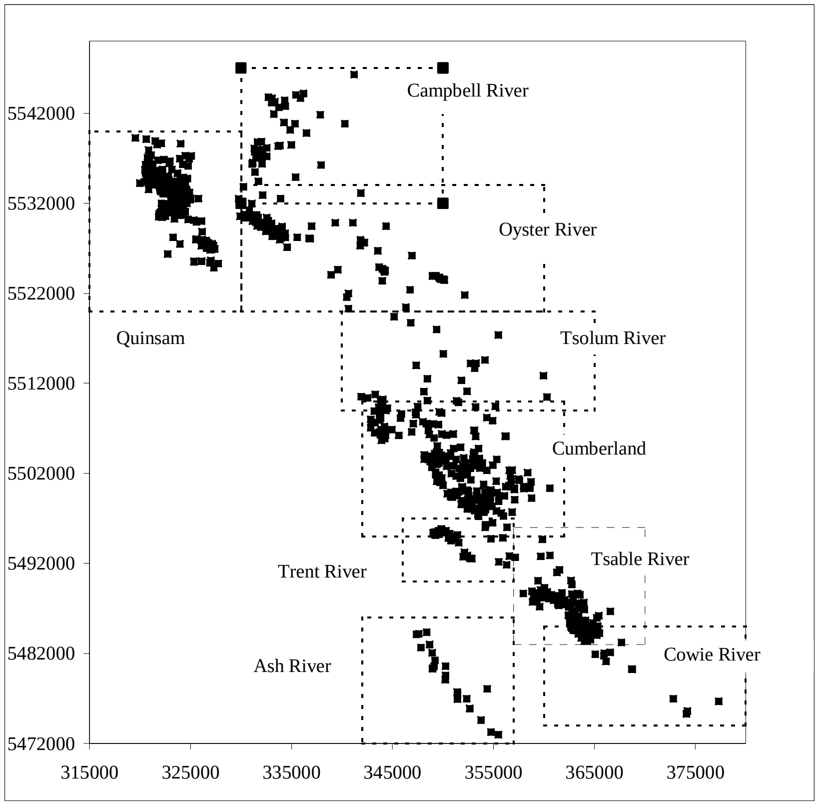


Figure 10. Drill distribution in the Comox Basin.

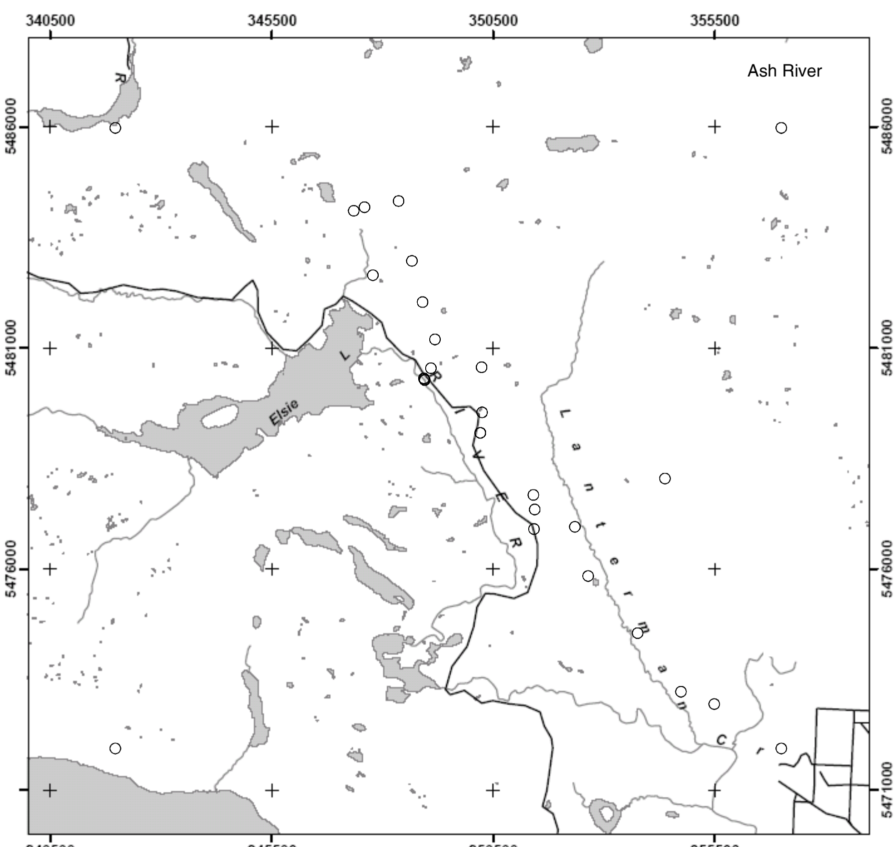


Figure 11. Drill holes Ash River area, Alberni Coalfield

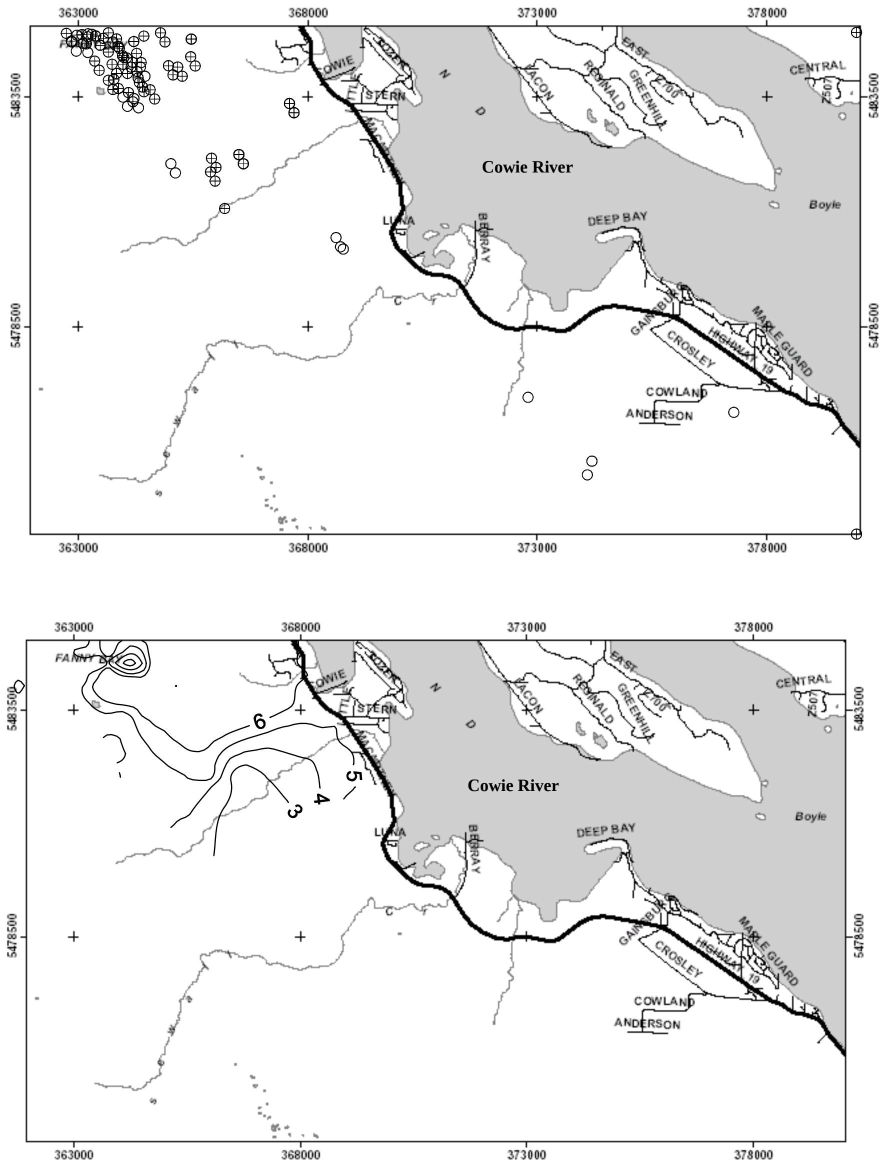


Figure 12. Cowie River area; (a) All holes drilled and holes intersecting coal and (b) Cumulative coal thickness contours.

TABLE 6: COMOX BASIN; COAL BEARING AREAS AND ESTIMATED COAL RESOURCE BY AREA.

Area from Figure 9	mil tonnes	area Km^2	av thick	gas cc/g	resource bcf
Campbell River	**245**	**46.2**	**3.5**	**4.0**	**31.3**
Quinsam	**112**	**26.1**	**2.9**	**4.0**	**14.4**
Oyster River	**332**	**49.1**	**4.5**	**4.0**	**42.5**
Tsolum River	**87**	**16.6**	**3.5**	**8.5**	**23.7**
Cumberland	**1287.2**	**124.2**	**6.9**	**8.5**	**350.5**
Trent River N area	**32**	**4.4**	**4.9**	**6.0**	**6.1**
Trent River NE area	**83**	**5.3**	**10.6**	**6.0**	**16.0**
Trent River SE area	**15**	**1.3**	**7.6**	**6.0**	**2.9**
Tsable River	**587**	**84.5**	**4.6**	**6.0**	**112.9**
Cowie River	**246**	**29.3**	**5.6**	**6.0**	**47.3**
totals	**3026.9**	**386.8**			**647.8**

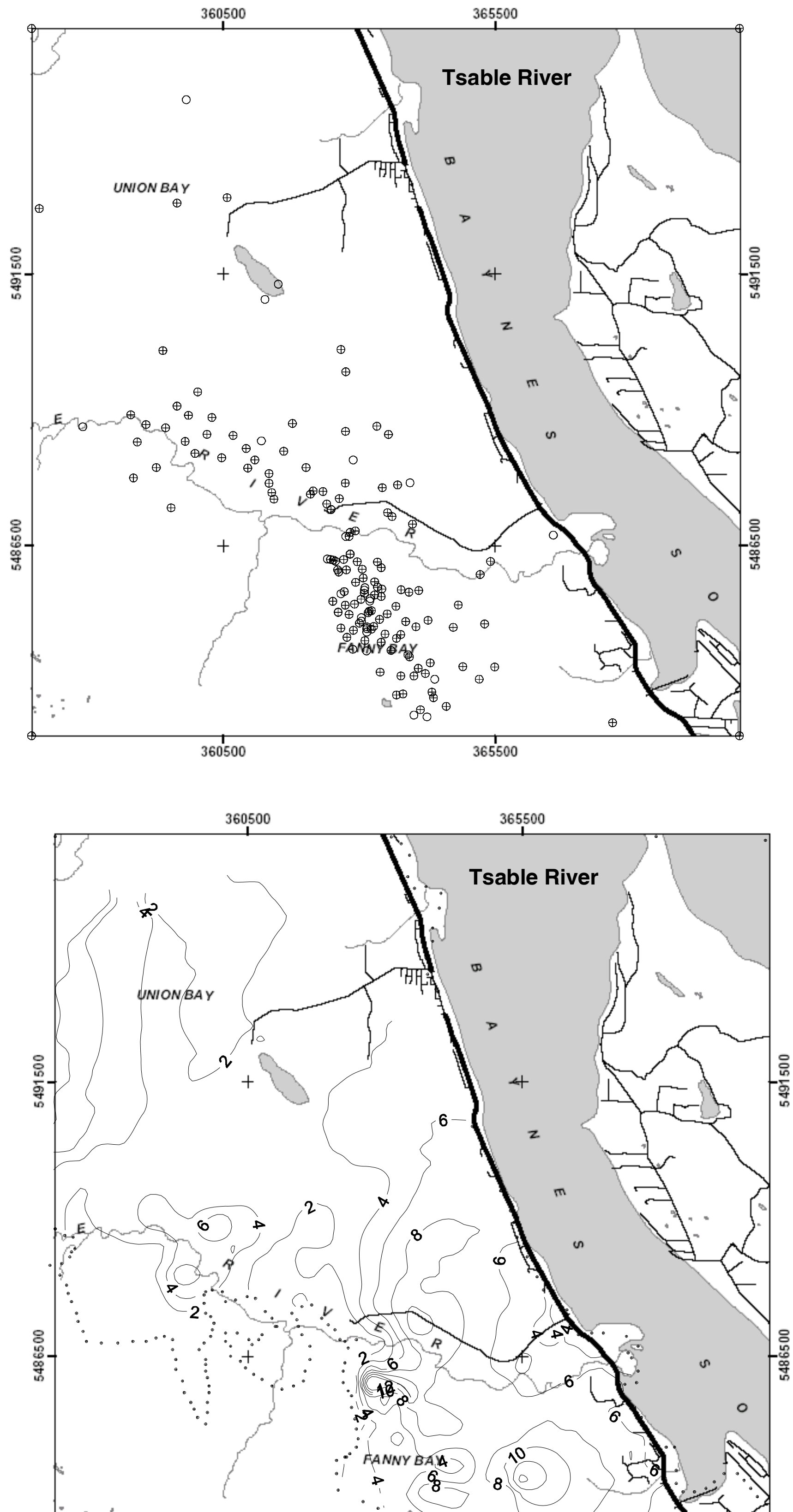


Figure 13. Tsable River area; (a) All holes drilled and holes intersecting coal and (b) Cumulative coal thickness contours.

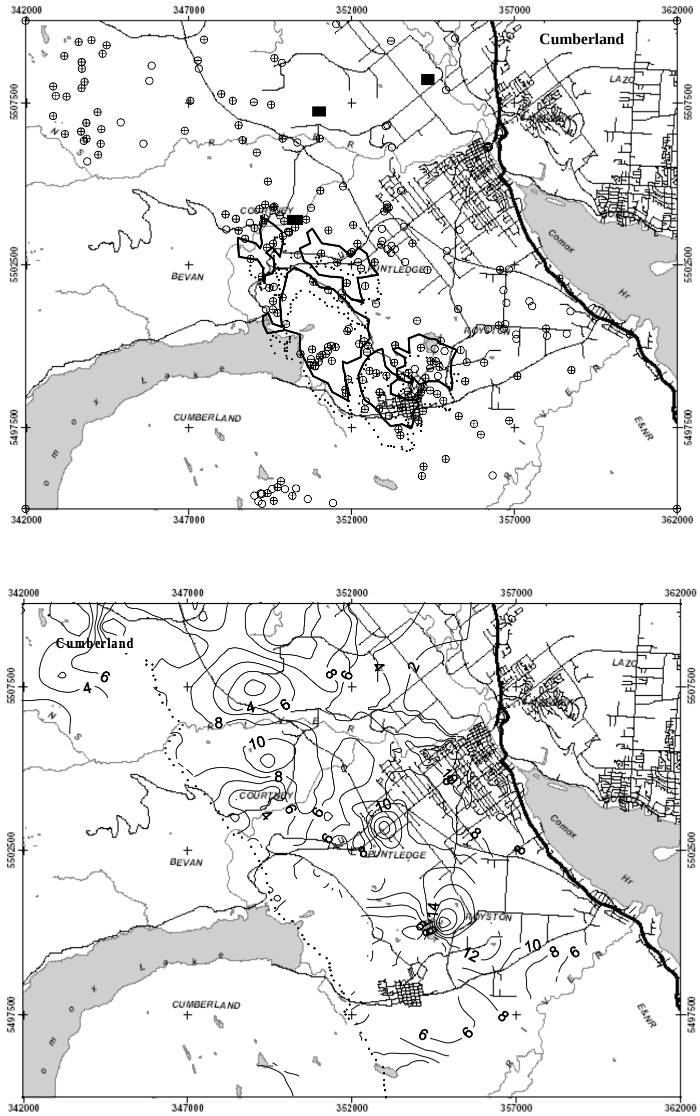


Figure 14. Cumberland area (a) Drill holes with outline of underground mining and location of the three Priority Ventures holes; (b) Contours of cumulative coal thickness.

TABLE 7. COAL THICKNESSES BY SEAM IN THE DOVE CREEK AREA

seam	hole D1				hole D2A				hole D3		
	depth metres	coal net	coal gross	ash	depth metres	coal net	coal gross	ash	depth metres	coal net	coal gross
X	206.0	0.01			416.4	0.48	1.6		236.1	0.52	1.4
XL	211.6	0.03	0.8		424.8	0.55	0.8				
Y	230.6	0.305	1		443.0	0.53	0.6		255.5	0.12	0.4
YL	235.6	0.33	0.7		448.3	0.03	0.5		260.0	0.27	0.4
Z	254.1	1.09	1.8	45.85	460.4	0.98	2.2	46.5	271.5	0.15	0.3
1R	274.1	0.54	1.2		477.1	1.08	1.4		296.0	0.6	1.2
1	276.2	0.22	0.6		484.7	1.19	2		297.5	0.51	0.9
1L					490.7	0.47	0.5		298.9	0.35	0.9
2R	291.0	0.35	0.4		504.0	0.55	0.6		309.4	0	
2	298.9	0.9	1.8	35.14	512.4	0.28	0.6		314.5	0.315	1.1
2A	325.3	0.51	1.8								
3	347.5	0.6	2.2								
cumulative coal		4.885	12.3			6.14	10.8			2.315	5.2

Data from Cathyl Bickford (2001).

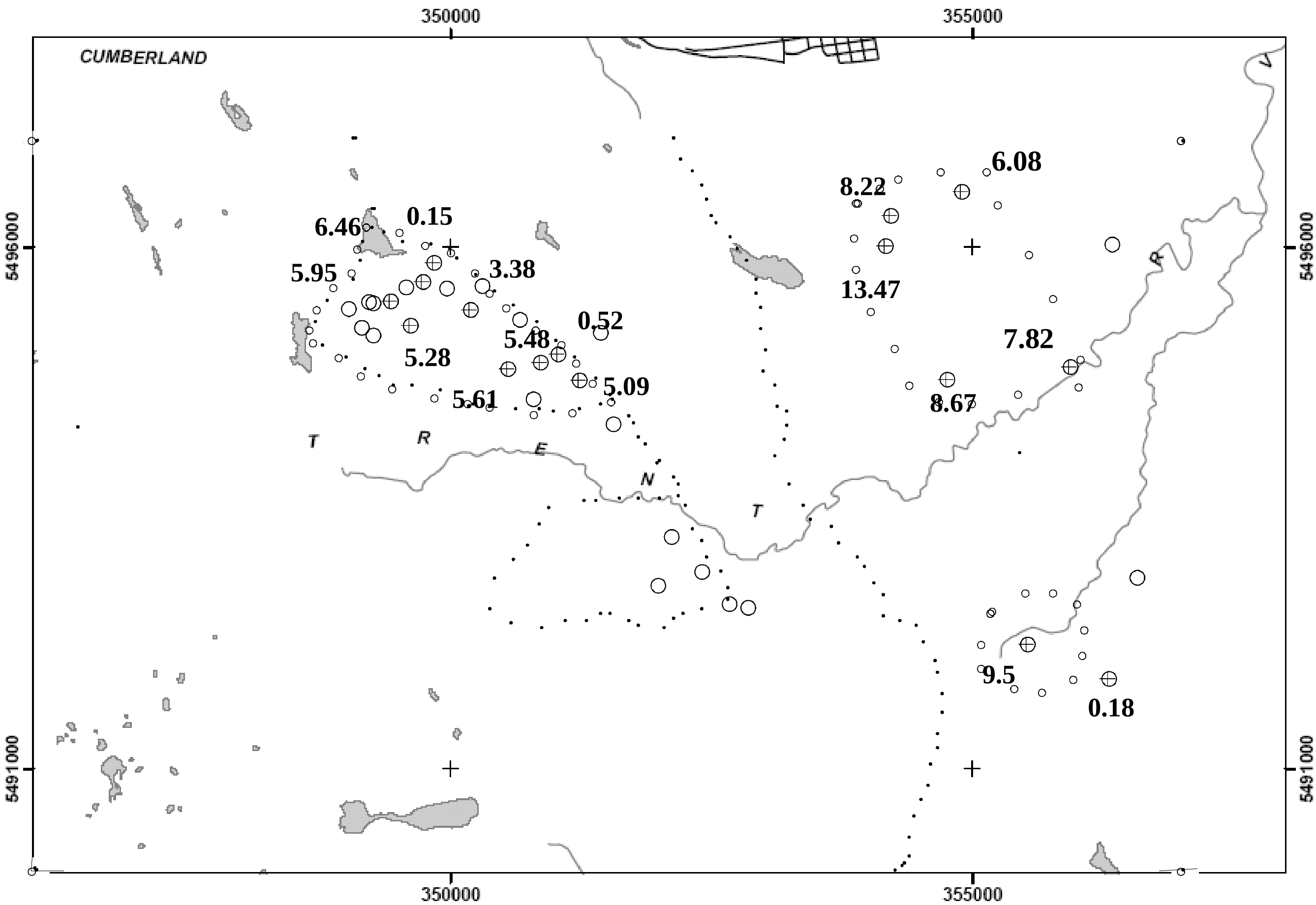


Figure 15. Trent River area; (a) All holes drilled and holes intersecting coal; (b) Contours of cumulative coal thickness.

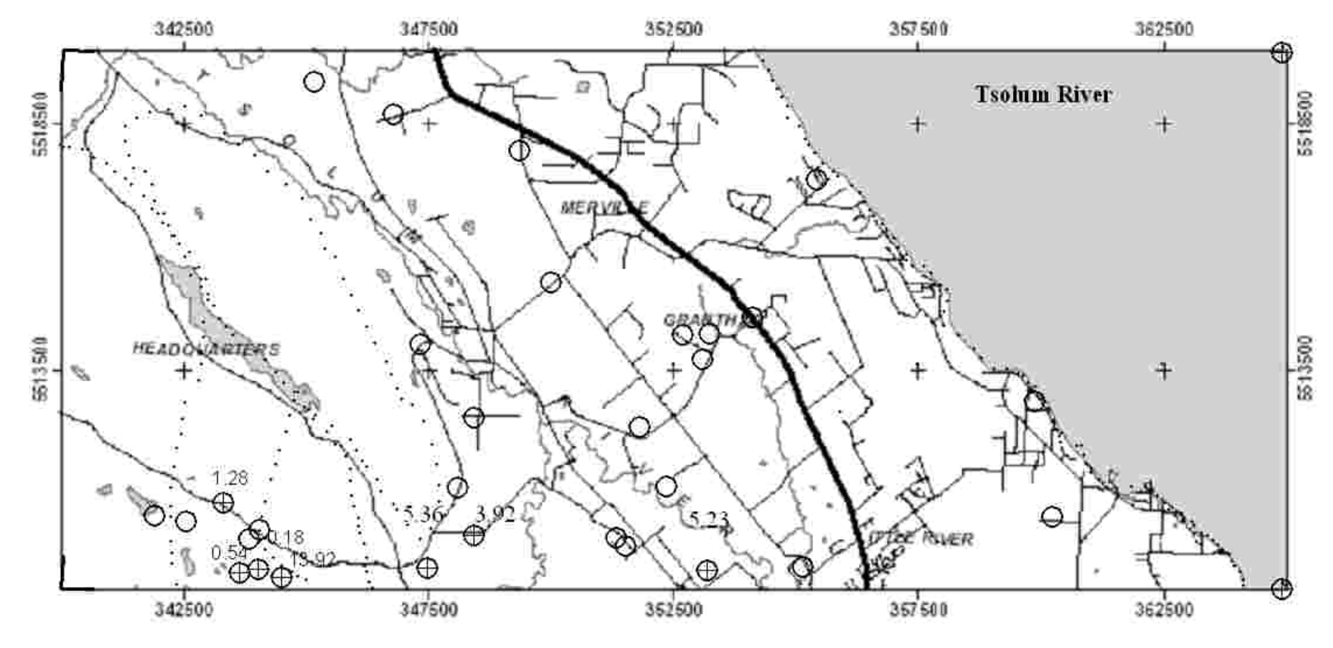


Figure 16. Tsolum River area; plot of drill holes and posted cumulative coal thickness contours.

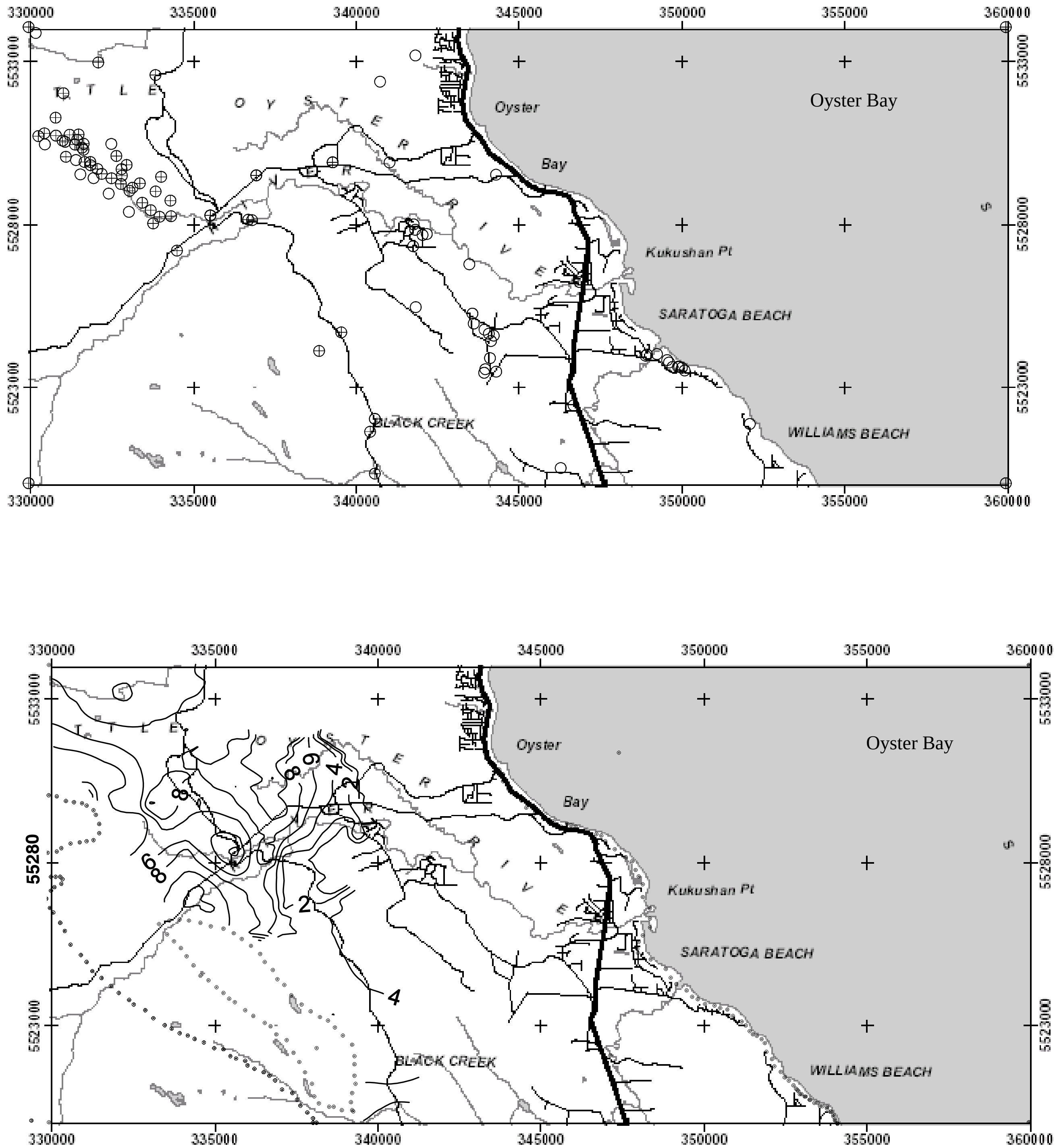


Figure 17. Oyster River area; (a) All holes drilled and holes intersecting coal. (b) Cumulative coal thickness contours.

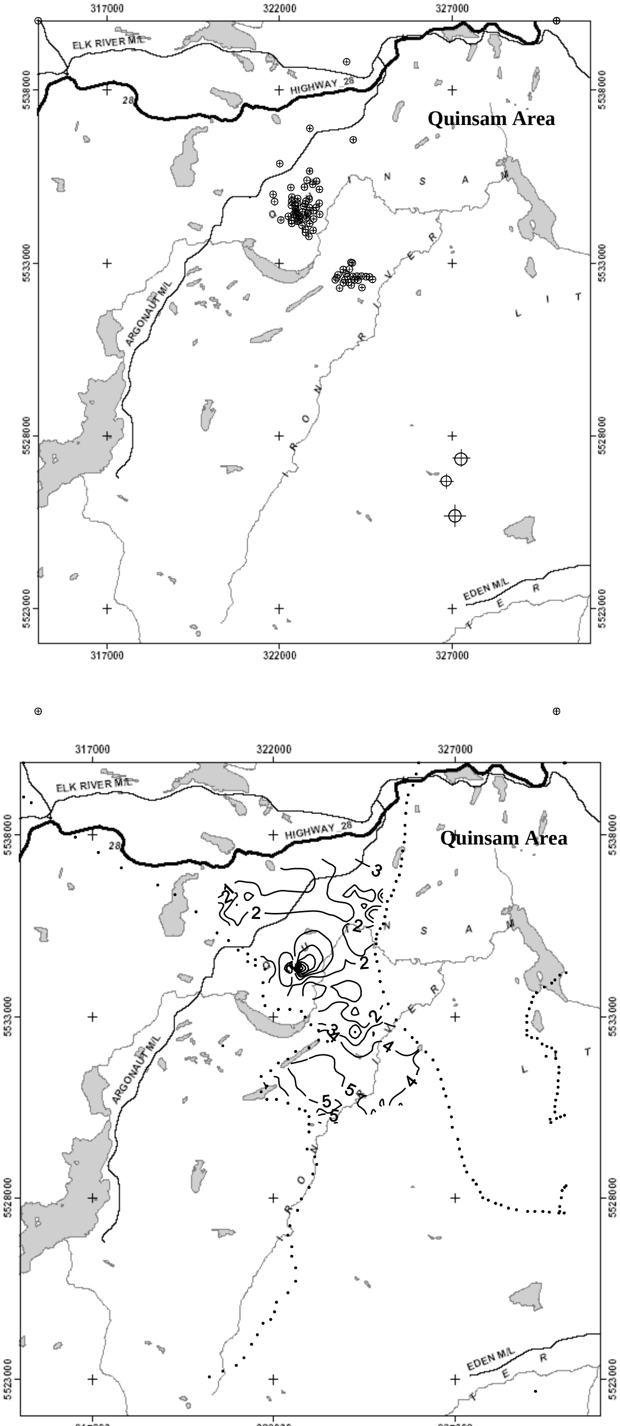


Figure 18. Quinsam River area; (a) All holes drilled and holes intersecting coal; (b) Cumulative coal thickness contours.

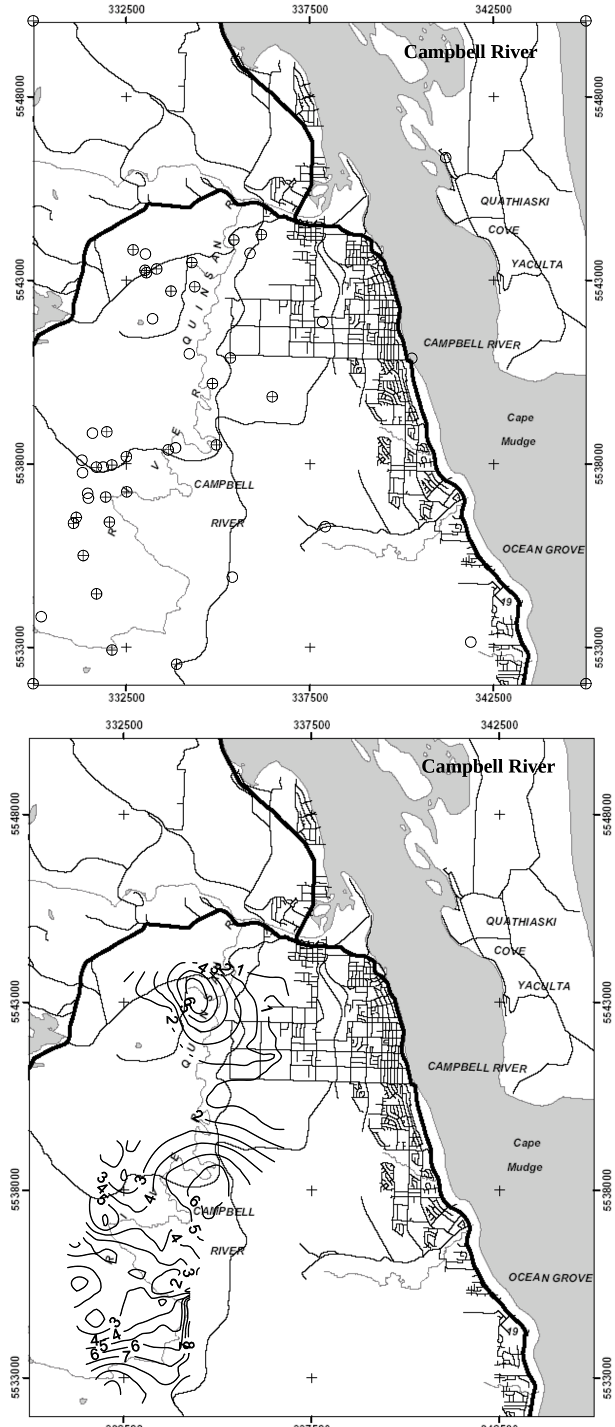


Figure 19. Campbell River area; (a) All holes drilled and holes intersecting coal; (b) Cumulative coal thickness contours.

estimates of what might be in the ground and are in no way estimates of what might be produced in the future.

CONCLUSIONS

There is very little desorption data available for coals in the Comox Basin and that which does exist is generally from shallow coals so it is not surprising that results often indicate under saturation. In the north where ranks are in the range of high-volatile B bituminous, the gas has a biogenic carbon isotope imprint and contains less than 3% carbon dioxide. The isotopic composition of the gas in the Dove Creek area was not checked but composition data indicate a moderate amount of nitrogen in some of the samples.

Isotherms now exist for samples from Quinsam, Dove Creek and Tsable River providing information about the potential saturated gas contents for Comox Formation coals.

The Comox Formation contains a number of coal seams with 1 or 2 of mineable thickness in some areas. The over all impression is that there is not a lot of coal in the formation. Initial CBM resource assessments should use hanging wall to footwall estimates of seam thicknesses even when this includes splits, because splits are often carbonaceous and may generate and retain CBM. In this study the cumulative gross coal seam thicknesses are contoured. The thickness values and tonnages calculated are not appropriate for assessing coal mining potential but do provide the basis for a CBM resource assessment.

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