NOTE ON DESORPTION RESULTS OF COMOX FORMATION COALS FROM THE QUINSAM AREA, VANCOUVER ISLAND, BRITISH COLUMBIA

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ABSTRACT

This paper presents desorption and gas chemistry data from a small-scale study of gas content of coals from the Quinsam area, Vancouver Island, British Columbia. Seven coal samples from two holes in the Comox Formation were taken from depths ranging from 245 to 333 m. Desorption data are compared to pre-existing isotherms and indicate near-saturated conditions. Gas contents range from 2.61 to 4.80 cm^3/g on a mineral-matter-free basis. Gas chemistry data display a high proportion of methane gas.

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INTRODUCTION

In the summer of 2008, Hillsborough Resources Limited undertook a drilling program to further delineate the coal resource available for underground mining on the Quinsam North property on Vancouver Island. As part of this program, two holes were chosen to provide coalbed methane (CBM; also referred to as coalbed gas or CBG) data on the coals of this area. Canister tests, which provide estimates of the amount and composition of gas adsorbed in coal, may be a part of a coal exploration program because results affect considerations of mining safety, ventilation, and greenhouse gas emissions. These data are also a starting point for a realistic CBM resource estimate.

The canister tests discussed in this paper were performed by the authors on behalf of the British Columbia Ministry of Energy, Mines and Petroleum Resources and at no cost to the company. In this situation, the company gets data at no cost but loses the right to keep it confidential for an extended period, because the government is obliged to make the information public. This applies to data collected by the authors and not to other aspects of the exploration program.

This paper presents gas content and composition data collected from seven canister tests of samples from two holes drilled by Hillsborough. Sample depths range from 245.9 to 333.5 m, and gas contents range from 2.61 to 4.80 cm^3/g on a mineral-matter-free basis (mmfb).

REGIONAL GEOLOGY

The Cretaceous Nanaimo Group sediments were deposited during a period of subsidence in the Georgia Basin east of current Vancouver Island. Over 5 km of sediment accumulated by the close of the Cretaceous (England and Bustin 1995). These sediments overlie Triassic weathered crystalline volcanic basement known as the Karmutsen Volcanics. The Nanaimo Group is cut by northwest-trending, southwest-verging thrusts that are indirectly dated as Eocene. These thrusts shorten the basin by up to 30% (England and Calon 1991). Six subbasins are contained within the Georgia Basin: from north to south, they are Quatsino Sound, Suquash, Comox, Alberni, Nanaimo, and Cowichan. The Comox and Nanaimo subbasins are the largest and contain the Comox and the Nanaimo Coalfields, respectively. In the literature, the use of the terms "basin", "subbasin", "coalfield", and "deposit" is inconsistent. In this paper, it is convenient to refer to the Quinsam area within the Comox Coalfield of the Comox subbasin. The Comox subbasin lies within the Georgia Basin.

LOCAL GEOLOGY

The Quinsam area is located in the northwestern corner of the Comox Coalfield (Figure 1). The coal measures are contained in the Comox Formation of the Nanaimo Group. These coal measures correlate with coals that occur further south in the Cumberland and Tsable River areas of the Comox Coalfield. Only the basal half of the coal-bearing section has been preserved at Quinsam. The Quinsam area is a discrete body separated from the rest of the Comox

Coalfields by a basement rock topographic high. The Karmutsen Formation underlies the coalfield and consists of basalt, gabbro, volcanic breccia, skarn, and granodiorite. These rocks are folded and faulted and display an erosional contact with the overlying sediments. Paleotopography of the basement rocks strongly influences the distribution of the coal measures. The Comox Formation is divided into three members (Benson, Cumberland, and Dunsmuir; Table 1) in the Quinsam area. The Benson, which is largely conglomeratic, forms the base of the section. It is conformably overlain by and interfingers with the Cumberland. The Dunsmuir overlies the Cumberland. The Cumberland Member contains sandstones, mudstones, and two coal zones of mineable thickness in the Quinsam area. The Dunsmuir Member contains conglomerates to mudstones and multiple thin coal seams.

The structure of the Comox Formation in the Quinsam area consists of a generally northeast dipping (8° to 12°) monocline over the basement. Smaller-scale, asymmetric synclines verging southwest and displaying steeper dips (up to 60°) occur in the northeastern portion of the Quinsam area. Other minor folds and buckles are common throughout. The Quinsam area has undergone brittle, thick-skinned deformation characterized by moderate to steep faults. Three major sets of faults are mapped in the area. Bedding plane shear is common in the coal zones of the Comox Formation producing both slickensided and pulverized coals. A more detailed description of local geology is available in Kenyon et al. (1991) and Gardner (1999).

Seven coal zones occur at Quinsam: from shallowest to deepest, they are the No. 5, No. 4, No. 4B, No. 3 (Dunsmuir Member), No. 2, No. 1 Rider, and No. 1 (Cumberland Member). Some of the zones split into individual plies within a varied spatial distribution. The No. 1 zone ranges from 2.5 to 4.5 m thick in the area and is at a depth of approximately 330 m at drill location B (Figure 1). The No. 2 zone averages approximately 1 m thick and is at an approximate depth of 320 m at drill location B. The No. 3 zone was not intersected in either hole A or B. The No. 4 zone is at a depth of 245 m in drill hole A and at 290 m in drill hole B and is less than 1 m thick.

PREVIOUS CBM DATA

CBM information on the coals of Vancouver Island is limited. Before this study, Ryan and Dawson (1994a) collected samples from two drill holes in the Quinsam Coalfield to provide information for underground coal mining. The holes intersected the No. 1 seam at 106 m and the No. 3 seam at 142 m. Gas contents were 1.0 cm^3/g on a dry ash-free basis (dafb) for No. 1 seam and 1.0 to 1.6 cm^3/g (dafb) for No. 3 seam. An adsorption isotherm suggests the seams were undersaturated at this depth. In 2004, eight samples were collected from four holes drilled as part of a coal
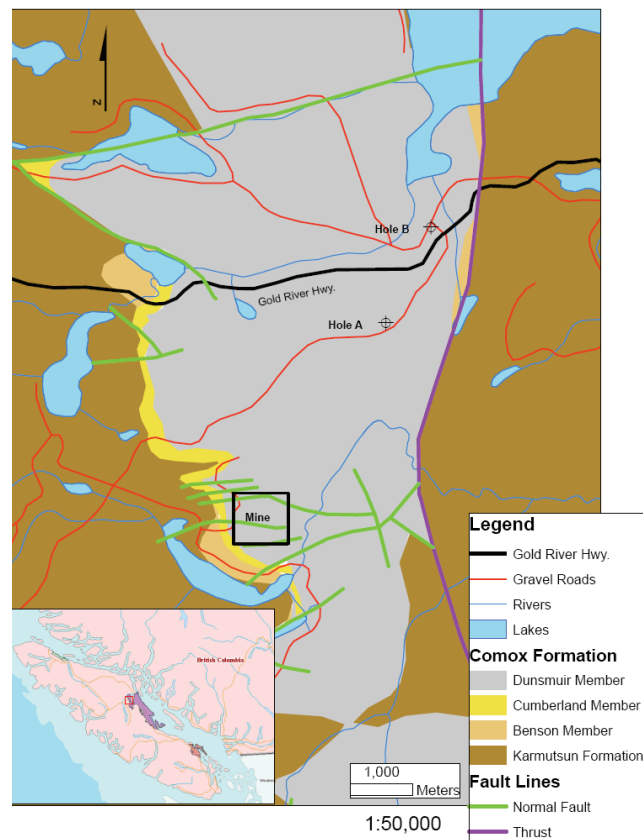
Figure 1. Geological map of the Quinsam area, showing drill locations in this study. *Geological layers modified from Cathyl-Bickford (1991).*

TABLE 1. GEOLOGICAL FORMATIONS OF THE QUINSAM AREA. (MODIFIED FROM CATHYL-BICKFORD 1991).

Quaternary	Pliestocene and Recent	Drift	Till, Gravel, Sand, Silt, Clay
	Unconformity		
Cretaceous	Santonian	Nanaimo Group Comox Formation	
		Dunsmuir Member	Sandstone; Minor conglomerate; Shale and Coal
		Cumberland Member	Siltstone; Shale and Coal
		Benson Member	Conglomerate; Minor red shale
	Unconformity		
Triassic	Ladinian to Carnian	Vancouver Group Karmutsen Formation	Fine-Grained basalt and Basalt breccia

exploration program west of Quinsam Mine (Ryan et al. 2005). The samples ranged from 134 to 156 m in depth and consisted of high ash content coal with interlayered mudstone. Gas contents ranged from 1.1 to 2.1 cm^3/g (mmfb). Ryan (unpublished, 2006) desorbed three samples from the Quinsam area. The samples were collected between 192 m and 205 m depth, and gas contents ranged from 2.83 to 2.86 cm^3/g (mmfb). The adsorption isotherms produced in 1994

and desorption data from 2004 and 2006 (Figure 4) are discussed in this study.

Some data are available from other areas of the Comox Coalfield. Ryan (1997) collected and desorbed 13 samples from the Tsable River area. Sample collection depths ranged from 127 to 377 m, and gas contents ranged from 2.4 to 6.5 cm^3/g (dafb). No gas composition analysis was performed. Ryan (2002) collected 12 samples from three holes in Comox Formation coals in the Courtenay area as part of Priority Ventures' appraisal of CBM potential in the area. Samples were collected from depths of 237 to 513 m and range in gas content from 3.5 to 11.5 cm^3/g (dafb). The methane concentrations ranged from 9% to 93%.

Very little data are available prior to these studies. In 1984, Novacorp drilled 14 holes, five of which intersected the Douglas coal seam. A number of authors reported that samples were desorbed, but the information was never published. Cathyl-Bickford et al. (1991) cite a number of references that indicate a range of 5 to 12 cm^3/g (basis unknown) in the Douglas coal seam.

PROCEDURES

Methods used to acquire desorption data in this report were developed by Ryan and Dawson (1994b). These methods evolved from those outlined by Kissel et al. (1973). A spreadsheet designed by Ryan (2002) was used in this study to handle data input and manipulation. Manipulations included all necessary corrections, such as changes in temperature and atmospheric pressure, and curve fitting. Gas contents are reported on a dry, ash-free basis (dafb) and on a mineral-matter-free basis (mmfb). The conversion from dafb to mmfb can be performed in a number of ways. This study uses a normative calculation known as the Parr formula, widely used in North America. The Parr formula requires both ash and sulphur content:

mineral matter % = 1.08(ash %) + 0.55(sulphur %)

Samples were collected directly from wireline core upon reaching the surface after drilling. Samples were quickly placed in air-tight canisters capable of holding up to 40 cm of core (Figure 2); any space not filled with sample was filled with inert argon gas to inhibit sample oxidation. Canisters were maintained at approximately 23 °C, and any deviation from this was recorded and corrected for. Gas was bled off the canisters and into a manometer to measure volumes of gas lost over time. As gas comes out of the canisters, it displaces fluid in a tube of known volume. Both the manometer and the canisters were constructed by Barry Ryan. These data were entered into a spreadsheet that calculates cumulative gas, desorption rates, and canister pressure. Data were corrected to both standard temperature and pressure.

Desorbed gas is lost from a sample before it is sealed in a canister. There are a number of ways to estimate the amount of lost gas. In this study, the USBM direct method was used (McCulloch et al. 1975). The amount of desorbed gas was plotted against the square root of time for the first initial measurements. Cumulative gas as a function of time was plotted about a straight line that was projected back to the time when the sample was halfway up the hole during wireline haul-up. Lost times (time from sample halfway up the hole to being sealed in a canister) ranged from 6 to 12 minutes and average about 8 minutes in this study. Lost gas over this time averaged 6.7% of the total gas desorbed. This method does not account for free gas (gas compressed in the pores of the coal), only lost desorbed gas. Free gas is not estimated by canister tests—it is released in unknown quantities from the samples before they are sealed in canisters (Ryan 2002).

The measurements were made with the manometer over a period averaging 60 days in this study. When the amount of cumulative gas levelled off and less than 0.05 cm^3/g/day was bled off the canisters, the measurements were considered insignificant and the process was stopped. The remaining gas was estimated by fitting a desorption curve and projecting the data to infinite time. The curve used was developed and discussed by Airey (1968) and is based on experimental data. The curve is manually fitted to the data by adjusting variables. This has proved to be the most efficient way of curve fitting (Ryan 2002). The amount of remaining gas averaged 0.27 cm^3/g and comprised an average of 11.7% of the total gas desorbed.

The natural logarithm of the gas desorption rate was also plotted as a function of time. This plot acts as a check of errors in the data. Any errors are immediately apparent because an invalid data point lies well outside the trend.

When the process of measuring cumulative gas is finished, the volume of dead space in the canisters (the amount of space in the canister not occupied by sample) must be measured. This is accomplished by a method developed by Ryan and Dawson (1994b) using the same manometer used to measure cumulative gas. By raising the reserve liquid container in the manometer, a hydraulic head is created, which forces gas back into the canister. The manometer is then used to measure this pressure from the canister. Using the volume of gas as read on the manometer and the height of the hydraulic head, the volume of dead space is calculated.

One sample was subjected to gas analysis to provide information on gas composition. Four gas samples were taken from sample #7 (depth of 333 m) of hole B. The gas samples were extracted from the canister via the manometer during cumulative gas measurements. A 50 cc syringe was used to gather gas from the system; the gas was injected into nonreactive bags to be sent to Loring Labs for analysis using a Shimadzu 9A gas chromatograph. One sample was

taken early in the first hour of desorption, another sample was taken the 20th hour, a third sample was taken after five days, and the last sample was taken on the 25th day of desorption. This allows gas compositions to be compared over the duration of the desorption process.

DATA

Figure 2. Example of typical core sample.

TABLE 2. COAL CHEMISTRY AND GAS RESULTS.

Hole	Canister	Depth to Top	Seam	Wieght	Moisture	Ash	Mineral Matter	Lost Gas	Desorbed Gas	Remaining Gas	Total Gas	Total Gas	Total Gas
				arb	arb	db	db				arb	dafb	mmfb
		metres		grams	%	%	%	cm^3/g	cm^3/g	cm^3/g	cm^3/g	cm^3/g	cm^3/g
A	1	245.9	No. 4	2312	4.38	27.49	32.47	0.05	2.05	0.36	2.46	3.61	3.90
A	2	246.3	No. 4	2459	4.70	15.82	19.95	0.07	2.10	0.40	2.57	3.23	3.41
B	3	290.7	No. 4	2107	6.18	16.05	18.75	0.30	2.51	0.11	2.92	3.75	3.89
B	4	291.3	No. 4	2190	9.35	28.91	32.68	0.29	1.21	0.02	1.52	2.45	2.61
B	5	319.2	No. 2	3246	5.84	49.96	56.34	0.10	1.42	0.24	1.75	3.96	4.63
B	6	332.2	No. 1	2583	6.53	29.57	32.15	0.19	2.28	0.48	2.94	4.60	4.80
B	7	333.5	No. 1	2755	6.61	33.05	35.84	0.12	1.96	0.34	2.41	3.99	4.19

arb   As received basis
db   Dry basis
dafb Dry ash free basis
mmfb Mineral matter free basis

TABLE 3. GAS COMPOSITION RESULTS.

Hole: B
Canister: 7
Depth: 333 metres

Sample	A	B	C	D
% Total Gas Desorbed	10.0	40.7	62.7	78.0
% Air	82	80	74	72
Mole Fraction (Air Free Basis)				
N_2	0.0000	0.0000	0.0000	0.0000
CO_2	0.0015	0.0013	0.0009	0.0009
H_2S	0.0000	0.0000	0.0000	0.0000
CH_4	0.9884	0.9874	0.9860	0.9845
C2	0.0097	0.0104	0.0120	0.0139
C3	0.0004	0.0005	0.0006	0.0007
iC4	trace	0.0004	0.0005	trace

Sample No	7		hole	B	top		333.50	

Lost gas cm^3/g	Des gas cm^3/g	Remaining gas cm^3/g		Total gas cm^3/g	
0.115	1.959	0.336		2.410	

program uses first 6 readings to estimate lost gas
to change number of points change values in slope and intercept

HALF LIFE days	1.78	Sorb time hrs	145.0	Gas at To	1.52

intercept on Yaxis is lost gas

slope	0.37
intercpt	-0.12

	Cum time days	cm^3 /g	sqr time	Cm time days	des gas &lost gas	cm^3/g /day
	0.10	0.00	0.32	0.00	0.12	0.00
1	0.15	0.03	0.39	0.01	0.14	12.23
2	0.23	0.06	0.48	0.01	0.18	10.62
3	0.35	0.10	0.59	0.01	0.22	7.75
4	0.47	0.13	0.68	0.02	0.24	5.70
5	0.63	0.14	0.80	0.03	0.26	2.31
6	0.85	0.17	0.92	0.04	0.29	3.07
7	1.02	0.20	1.01	0.04	0.31	3.45
8	1.28	0.23	1.13	0.05	0.34	2.97
9	1.83	0.29	1.35	0.08	0.40	2.53
10	2.65	0.35	1.63	0.11	0.46	1.77
11	4.87	0.48	2.21	0.20	0.60	1.44
12	6.55	0.56	2.56	0.27	0.68	1.19
13	13.40	0.76	3.66	0.56	0.88	0.71
14	18.73	0.86	4.33	0.78	0.98	0.43
15	21.32	0.90	4.62	0.89	1.01	0.34
16	25.98	0.95	5.10	1.08	1.07	0.29
17	41.40	1.04	6.43	1.73	1.16	0.14
18	48.23	1.09	6.95	2.01	1.21	0.18
19	63.72	1.18	7.98	2.65	1.29	0.13
20	71.67	1.22	8.47	2.99	1.33	0.12
21	89.00	1.28	9.43	3.71	1.39	0.08
22	112.43	1.35	10.60	4.68	1.46	0.07
23	137.87	1.40	11.74	5.74	1.51	0.04
24	159.02	1.43	12.61	6.63	1.55	0.04
25	208.02	1.49	14.42	8.67	1.61	0.03
26	233.42	1.52	15.28	9.73	1.64	0.03
27	282.35	1.57	16.80	11.76	1.69	0.02
28	309.68	1.60	17.60	12.90	1.71	0.02
29	353.68	1.64	18.81	14.74	1.75	0.02
30	376.25	1.65	19.40	15.68	1.77	0.02
31	474.18	1.71	21.78	19.76	1.83	0.01
32	597.53	1.77	24.44	24.90	1.88	0.01
33	736.73	1.82	27.14	30.70	1.93	0.01
34	880.35	1.86	29.67	36.68	1.98	0.01
35	1054.63	1.90	32.48	43.94	2.02	0.01
36	1216.82	1.93	34.88	50.70	2.04	0.01
37	1384.87	1.96	37.21	57.70	2.07	0.00
38	0.00	0.00	0.00	0.00	0.12	0.00
39	0.00	0.00	0.00	0.00	0.12	0.00
40	0.00	0.00	0.00	0.00	0.12	0.00
41	0.00	0.00	0.00	0.00	0.12	0.00
42	0.00	0.00	0.00	0.00	0.12	0.00
43	0.00	0.00	0.00	0.00	0.12	0.00
44	0.00	0.00	0.00	0.00	0.12	0.00
45	0.00	0.00	0.00	0.00	0.12	0.00
46	0.00	0.00	0.00	0.00	0.12	0.00
47	0.00	0.00	0.00	0.00	0.12	0.00
48	0.00	0.00	0.00	0.00	0.12	0.00
49	0.00	0.00	0.00	0.00	0.12	0.00
50	0.00	0.00	0.00	0.00	0.12	0.00

LOST TIME 0:06 Min

	X	Y
	0.00	-0.12
	0.50	0.07
	1.00	0.25
	1.50	0.43

head cm	vol ml	head space
63.50	69.00	1125.02
63.00	70.00	1150.38
63.00	68.00	1117.52
Average		1130.97

Cumulative desorption curve

Days

X=sorption time at Y=63.2% total gas desorbed
Airey Constants To in days gas at 63.2% total
adjust curve to fit data n (0.25-0.45) To hrs A=final vol
To=sorption time hours
half life in days based on total gas content A= 1.78

X	Y	Y% of A
6.04	1.52	63.20
	n	0.30
	To	145.00
total gas L+D+R		2.410

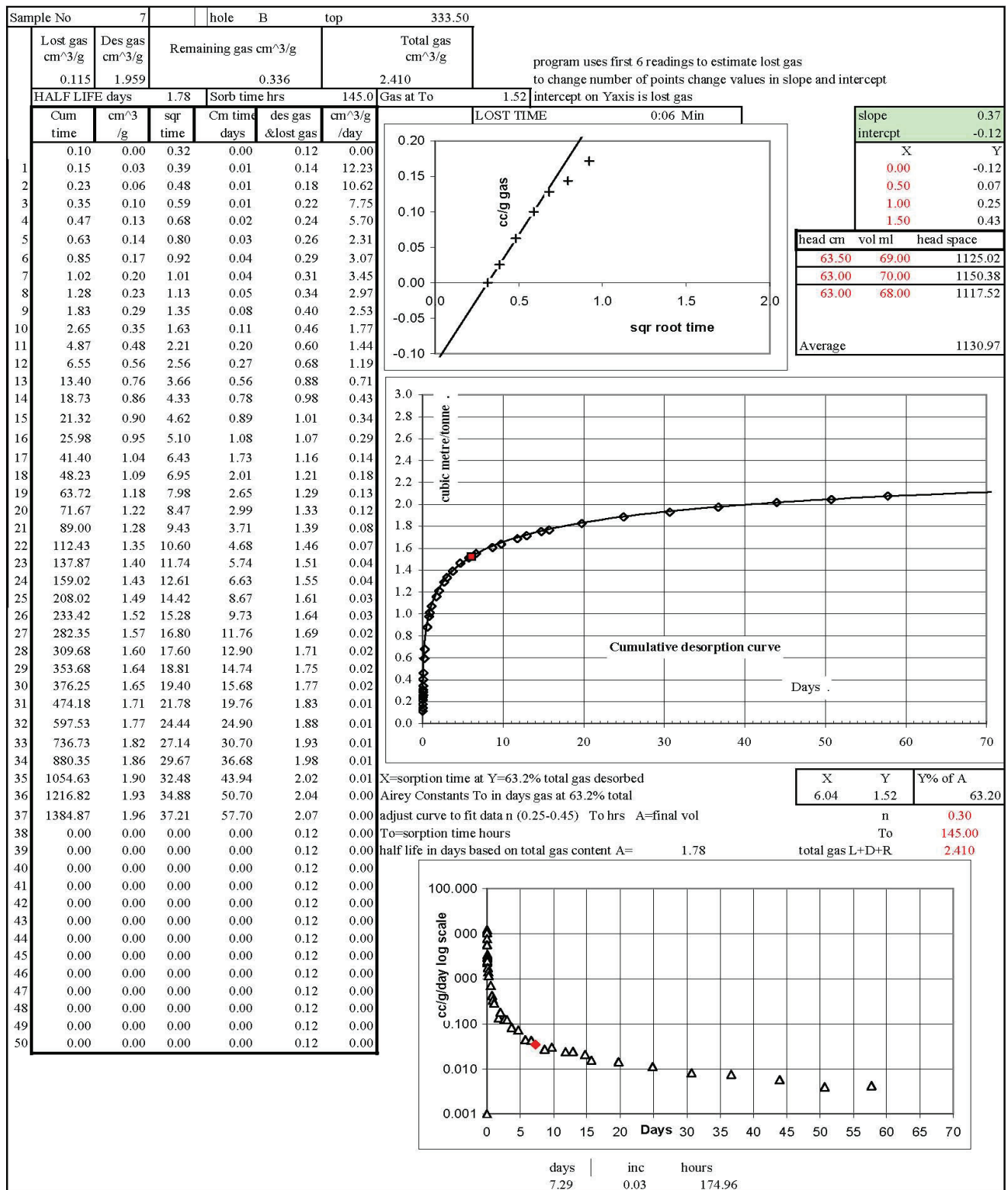| days	inc	hours
7.29	0.03	174.96

Figure 3. Example of data sheet used in calculating gas contents.

DISCUSSION

Gas contents of the samples ranged from 2.61 to 4.80 cm³/g (mmfb); the average was 3.92 cm³/g (mmfb). Collection depths of samples range from 245.9 to 333.5 m; 294 m is the average depth.

Ryan et al. (2005) report a gas resource of 14.4 billion cubic feet for the Quinsam area of the Comox Coalfield. This estimate is based on a coal resource estimate of 112 million tonnes and an average gas content of 4 cm³/g (mmfb). Given the average depth to the coal seams in the Quinsam area, new data support the estimate of average gas content and therefore also the resource estimate from Ryan et al. (2005).

Gas contents are plotted as a function of depth in Figure 4. Desorption data from previous studies performed in the Quinsam area are also shown (Ryan et al. 2005, Ryan unpublished 2006). Desorption data are compared to two isotherms (from Ryan and Dawson 1994a) that are based on adsorption data from two samples from the Quinsam area. The data follow the same general trend of the isotherms, though at a slightly lower gas content. The two isotherms displayed show the theoretical maximum adsorbed gas content for Quinsam coals at two different pressure gradients: 0.009805 and 0.007000 MPa/m.

Our estimate of whether or not the coals are gas saturated depends on our estimate of the pressure in the coal at depth. The two isotherms shown are based on two different estimates of pressure gradients. This shows that with a lower, subhydrostatic pressure gradient of 0.007000 MPa/m, the coals are nearly saturated. With a hydrostatic pressure gradient (due to an interconnected water column) of 0.009805 MPa/m, the coals are undersaturated. Subhydrostatic pressures are common in sedimentary formation waters and can be the result of several different hydrogeological phenomena. One possible phenomena is explained in the steady-state model of Toth (1972). This model explains general characteristics of regional groundwater flow and states that in areas of groundwater recharge, subhydrostatic pressures generally occur. Given the shallow regional dip of the Comox Formation towards the Georgia Strait and the shallow depth to the seams, it is possible that the seams experience a subhydrostatic pressure.

When considering pressure gradients at shallow depths (maximum sample depth 333 m), the depth of the water table plays a significant role. Hydrostatic pressure will change with water table depth. One must consider the water table depth over the time since the coals started developing gas.

When coals are saturated, it means that gas occupies all available adsorption surfaces. When this occurs, there is the potential for free gas development. Any gas that develops in the coals past the adsorption capacity of the coal has the potential to fill pore spaces. For gas to fill the pore space it must overcome hydrostatic and capillary pressures to force water out of the pore space. Free gas is not measurable via desorption; however, it is often noticed during drilling when an overpressured seam is encountered. The two holes drilled in this study did not encounter any significantly overpressured seams.

Excluding canister 5, ash contents range from 15.82% to 33.05%; the average is 25.15%. Ash content of Canister 5 is 49.96%, increasing the average ash content to 28.69%. These are ash contents of only the 40 cm sample taken for desorption tests and are not the ash content of the whole seam from which the samples were collected. These data were used for a correction to estimate the amount of gas per unit of clean coal in each canister. The 40 cm samples might not be representative of the entire seam, because they might have higher proportions of rock splits.

Four gas samples were taken from canister 7 to provide estimates of methane content. These data are not sufficient to provide a reliable estimate of the composition of all the gas in the Quinsam area. All samples contained high levels of nitrogen and (probable) oxygen contamination. Gas released from coal often contains some nitrogen, which tends to preferentially release before methane. When the coal is brought to surface and placed in a canister, air (oxygen and nitrogen) contamination is introduced. Proportions of oxygen to nitrogen will change in the canister over time because of oxidation. An effort was made to minimize the amount of air (head space) in the canisters. This was accomplished both by flooding the canisters with inert argon gas as well as by physically minimizing air space with a PVC pipe sleeve. This sleeve fits tightly into the canister and is placed around the coal before inserting the coal in the canister. Despite these efforts, minor air contamination is expected. When taking samples for gas composition analysis, there is another risk of air contamination from space in hoses of the manometer and from potential minor air space in both the end of the syringe and the gas sample bag nozzle.

The percentage of air in the samples decreased from 82% to 72% over the desorption process. The remaining 18% to 28% of the gas that came off the samples was made up of approximately 99% methane (Table 3). The lesser fraction of the gas consisted of ethane, propane, and CO_2. There was no H_2S in any sample.
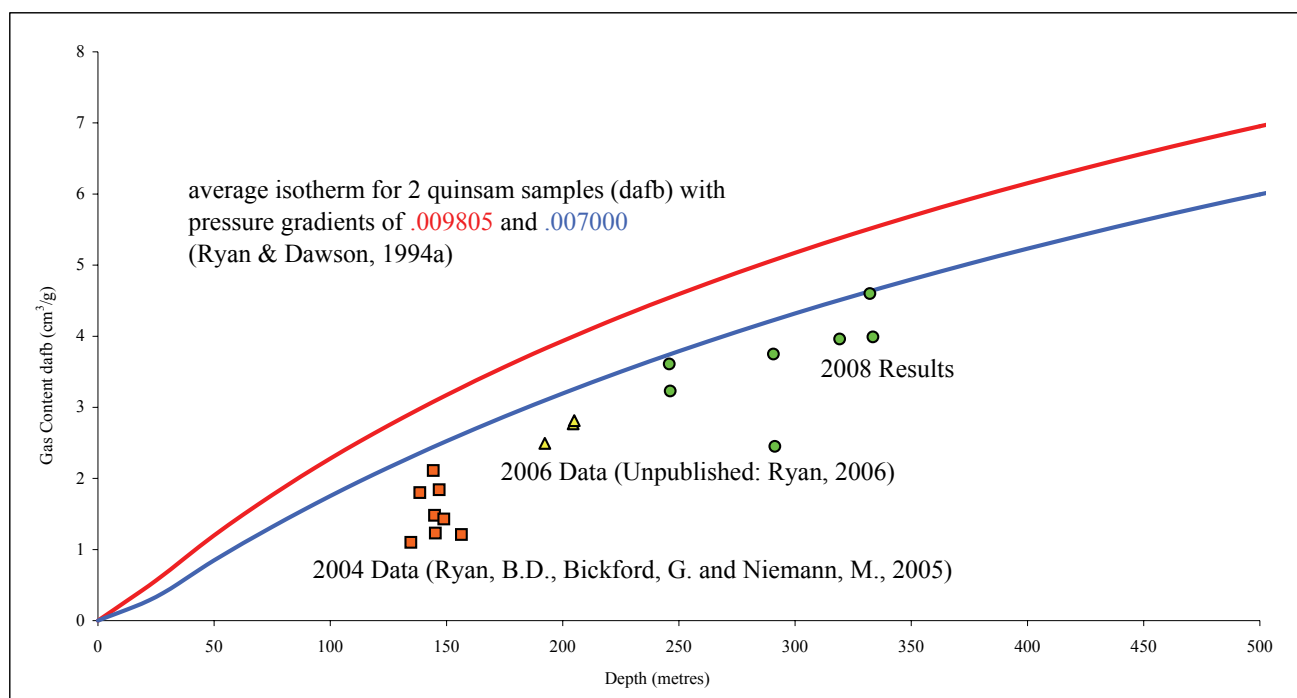
Figure 4. Coal adsorption isotherms and desorption results as a function of depth.

CONCLUSIONS

Results from this study support estimates of gas content in the Quinsam area made by previous studies and agree with a resource estimate of 14.4 billion cubic feet. Coals are nearly saturated at a depth averaging 294 m using a subhydrostatic gradient of 0.00700 MPa/m, and gas contents are 3.92 cm³/g (mmfb) on average. Maximum gas content observed was 4.80 cm³/g (mmfb) at a depth of 332 m. Likely due in part to contamination, the percentage of air in the gas samples was high; however, on an air-free basis, the gas was 99% methane.

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