

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

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## INTRODUCTION

There has been increasing interest in the coalbed methane (CBM) potential in the coalfields of British Columbia and some of this interest has been directed at the Comox Basin on Vancouver Island. The CBM resource of the basin has been estimated by a number of authors using published coal data. Most recently by Ryan (2001) quotes a potential resource of 0.8 tcf. These estimates are indeed estimates of the potential resource. Any estimate that is of use for an economic evaluation requires detailed information on gas contents and gas permeability of coal seams. This paper documents some new gas content data for coals from the Comox Basin.

A CBM resource assessment requires drilling, collection of coal samples and a battery of tests. Some of these tests are fairly simple and could, in fact, be included in an exploration program designed to prove reserves for surface or underground coal mining. Other tests are obviously specifically part of a CBM exploration program. Canister tests, which provide estimates of the amount and composition of the gas adsorbed by coal samples, may be part of a coal exploration program, because results impact considerations of mining safety, ventilation and greenhouse gas emissions. On the other hand the results provide the starting point for a realistic CBM resource assessment.

Priority Ventures Ltd. undertook a coal exploration program in the Courtenay area permitted under the mines act and coal regulations. The approval to drill was granted in part on the understanding that the program would not exceed the bounds of what could be expected to be part of a coal exploration program. Data collected by the company have to be submitted to the British Columbia government, but remains confidential for 3 years as specified by the Coal Act Regulations. After three years the data becomes public, with the exception of coal quality information obtained from washed coal samples. The canister tests discussed in this paper were performed at no cost to the company by the author on behalf of the British Columbia Ministry of Energy Mines. 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 in a timely fashion. Obviously this applies only to data collected by

the government and not other aspects of the exploration program.

The paper presents the gas content and composition data collected from 12 canister tests of samples collected from the three holes drilled by Priority Ventures. Sample depths range from 254 to 486 metres. Gas contents on an as-received basis range from 2.1 to 7.4 cc/g and from 3.6 to 12 cc/g on a dry ash-free basis (daf).

## REGIONAL GEOLOGY

The Nanaimo Group, which contains the coal measures of Vancouver Island, is Late Cretaceous (Turonian to Maastrichtian) in age. It was deposited in the Late Mesozoic to Cenozoic sedimentary Georgia basin, which overlaps the Coast and Insular belts of the Cordillera. Deposition of the Nanaimo Group correlates with a period of rapid subsidence, which led to the accumulation of over 5 kilometres of sediments by the close of the Cretaceous (England and Bustin, 1995). Much of the Nanaimo Group in the Mount Washington area near Courtenay is in tectonic contact with the Triassic basement (Muller, 1989), which is often represented by the Karmutsen Volcanics. In places the basement surface is intensely weathered and the resulting lateritic deposits are zones of localized shearing. The group was deformed by the Cowichan fold and thrust system, which is composed of a number of northwest-trending, southwest-verging thrusts, that account for a 20% to 30% shortening of the Nanaimo Group cover over the Wrangellian basement (England and Calon, 1991). This contraction is indirectly dated as Late Eocene.

The Nanaimo Group outcrops in two coal basins on the east side of Vancouver Island (Figure 1). The Nanaimo basin is centered on the town of Nanaimo and covers an area of approximately 780 square kilometres. Between 1849 to about 1950 over 50 million tonnes of coal were extracted from seams in the basin, which is now considered to be largely mined out. The Comox Basin extends from 20 kilometres north of Nanaimo to Campbell River and covers about 1230 square kilometres. Over 15 million tonnes have been mined from the basin in the period 1888 to 1955 (Gardner, 1999) and since then over 6 million tonnes have been extracted from the Quinsam Mine near Campbell River.

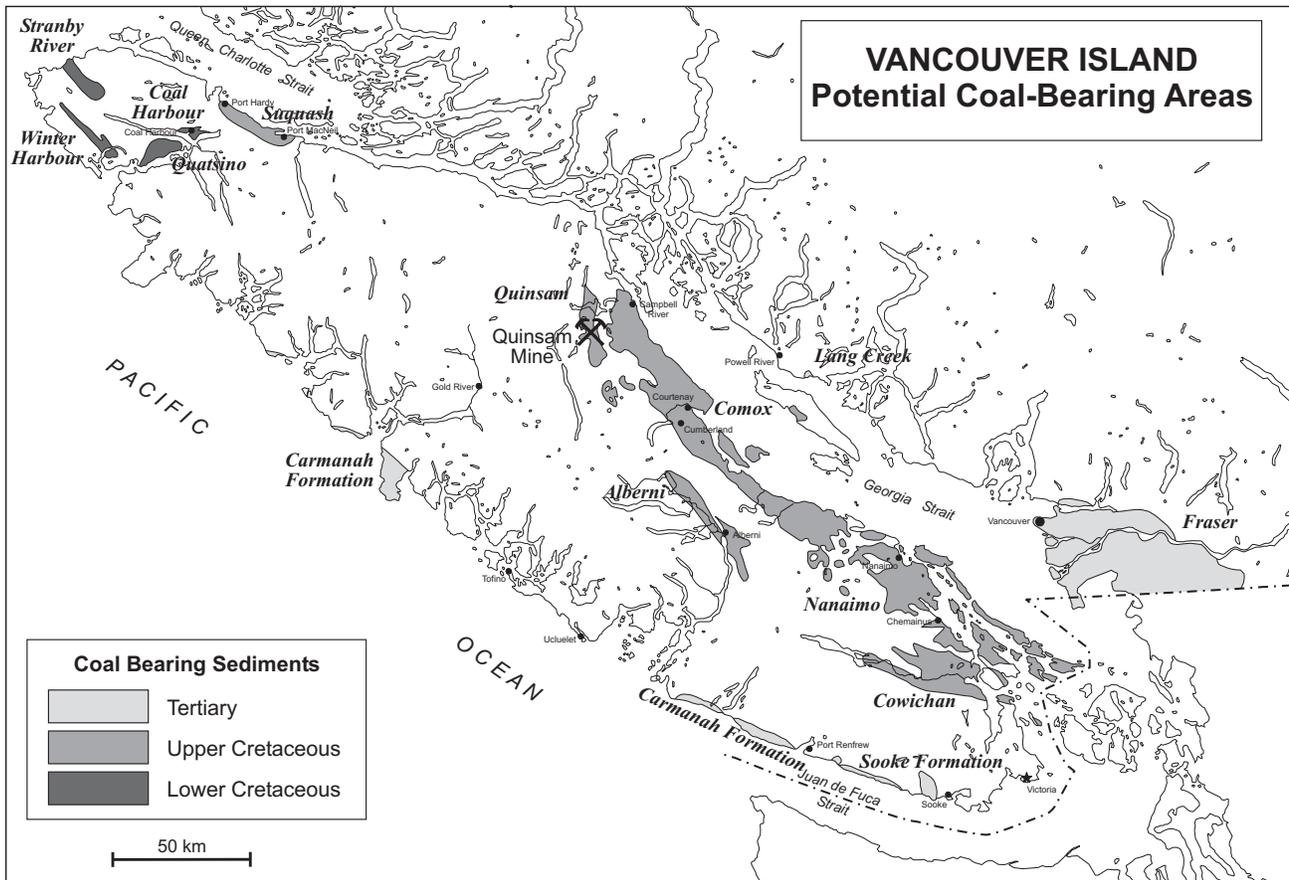


Figure 1. Coal basins of Vancouver Island.

There are at least three coal-bearing formations within the Nanaimo Group (Table 1). The lower Comox Formation outcrops extensively in the Comox Basin, where it is overlain by the Trent River Formation. It occurs at depth in the Nanaimo Basin where it is overlain by marine sediments of the Haslam Formation. The second coal-bearing cyclotherm is marked by the deposition of the Extension and Protection formations, which host the coal seams and mines in the Nanaimo Basin. Coal is reported in the Spray River Formation higher in the Nanaimo Group, but there are no significant deposits (Ward, 1978).

The Comox Formation in the Comox Basin is divided into three members. The lowest Benson Member, which is not always present, underlies or inter fingers with the overlying Cumberland Member, which in turn is disconformably overlain by the Dunsmuir Member. The Benson Member ranges in thickness from 0 to 220 metres and consists of conglomerate, minor red shale and siltstone (Cathyl-Bickford, 1992). The Cumberland Member is composed of 0 to 160 metres of siltstone, shale, minor sandstone and coal. The Dunsmuir Member is composed of 11 to 356 metres of sandstone, minor siltstone and coal.

There are four, economically important seams in the Comox Formation. The lowermost No. 4 seam, which

ranges in thickness from 1.2 to 4.5 metres (Cathyl-Bickford, 1991), is in the Cumberland Member near its contact with the underlying Benson member. Near basement highs, where the Benson Member thins, it grades into stony coal or coaly mudstone. The Cumberland Member also contains the Number 3 and the Number 2 seam, which ranges in thickness from 0.8 to 2.2 metres. The Number 1 seam is about 25 metres above the base of the Dunsmuir Member and ranges in thickness from 0.9 to 2.4 metres.

The rank of coals in the Nanaimo and Comox basins is generally high-volatile A bituminous though vitrinite reflectance ( $R_{max}$  values range from 0.6% to over 2% near intrusions. In the Quinsam area (Figure 1) rank averages 0.7% (Ryan 1993) with values ranging from 0.53% to 0.85%. Further south in the Comox Basin along Browns River (Figure 2), 8 samples provided an average  $R_{max}$  of 1.69% (Kenyon and Bickford, 1989). This location is about 4 kilometres south of the three Priority Ventures drill sites and north and adjacent to an area of Tertiary intrusives. Further south along the Trent River values average 0.84% and between Trent River and Comox Lake values range from 0.84% to 0.99%. In the Tsable River area at the southern end of the Comox Basin Ryan (1996) reports an average of 0.82% and previous values in the area average 0.88%.

**TABLE 1**  
**STRATIGRAPHY OF THE NANAIMO GROUP**

	Nanaimo Basin Formations		Comox Basin Formations	
	late Cretaceous	Campanian		
Gabriola			Gabriola	
Northumberland			Spray River Coal?	
Northumberland			Geoffrey	
Northumberland			Lambert	
De Courcy				
Cedar District				
Protection		Coal	Denam	
Pender				
Extension		Coal		
Haslam			Trent River	
Santonian				
Comox		Coal	Comox	Coal

The three holes were drilled approximately 5 kilometres northwest of Courtenay between the Tsolum and Puntledge rivers (Figure 2). The holes were collared in the Trent River Formation and drilled to a cumulative depth of 1200 metres. In the area a number of members of the Trent River outcrop as well as the Dunsmuir and Cumberland members of the Comox Formation. A Tertiary intrusion is mapped (Cathyl-Bickford and Hoffman, 1998) approximately 4 kilometres southwest of holes 1 and 3 (Figure 2) and it has increased the rank of coal along the Browns River from 0.79% to 1.69% Rmax (Kenyon and Bickford, 1988). No other reflectance values are published for the area covered by Figure 2. The stratigraphy of the Comox and Trent River formations in the area is discussed by Cathyl-Bickford (2001).

**PREVIOUS CBM DATA**

There is very little CBM information available for coals on Vancouver Island. Data for the Nanaimo Basin are discussed by Cathyl-Bickford *et al.* (1991), who quote previous references, which provide a range of 5 to 12 cc/g for gas contents in the Douglas Seam. It is not specified if the data is on an as-received or ash-free basis. Gas emission rates range from 8.8 to 128.1 cubic metres/tonne mined. Kissel *et al.* (1973) suggest that for mature mines emission rates divided by 9 provide a rough estimate of gas contents, in which case gas contents range from 1 to 14.2 cc/g. In 1984 Novacorp drilled 14 holes and five intersected the Douglas seam. It has been re-

**LOCAL GEOLOGY**

The area explored by Priority Ventures Ltd. is within the Cumberland sub basin of the Comox Basin. An area with a long history of coal mining (MacKenzie, 1922).

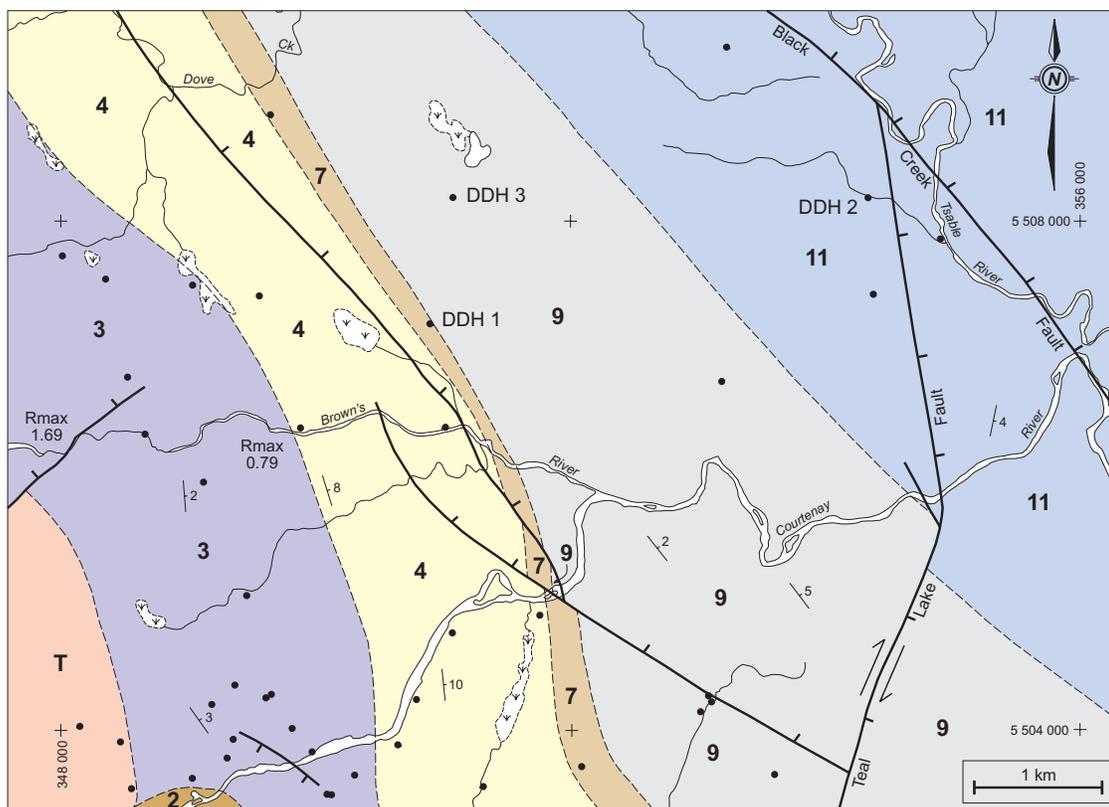


Figure 2. Map of the Comox Basin Courtenay area.

ported by a number of authors that samples were desorbed but the results have never been published. There are a number of reports of drillers intersecting gassy coals in the Nanaimo and Comox basins (Cathyl-Bickford, 1991) but the reports are not accompanied by desorption data.

There are some desorption data for coals from the Comox Basin. In 1996 Ryan (1997) collected samples from the Tsable River area. Thirteen samples from depths ranging from 127 to 377 metres were desorbed. Gas contents ranged from 2.4 to 6.5 cc/g on a dry-ash free basis. No gas composition analyses were performed. Samples collected from 2 drill holes near the Quinsam Coal Mine in the northern part of the Comox Basin were desorbed in 1993 (Ryan, 1994a). The holes intersected the Number 1 seam at 106 metres and the Number 3 seam at 142 metres. Gas contents were approximately 1 cc/g (dry as-free basis) for 1 seam and from 1 to 1.6 cc/g (dry as-free basis) for the number 3 seam. Based on an adsorption isotherm the seams were under saturated at the shallow depth intersected. The data were collected to provide information for the underground coal mine and not to provide a test for the potential CBM resource of coal in the area.

## PROGRAM RESULTS

### PROCEDURES

Techniques for desorbing coal in canisters have evolved from those outlined by Kissel *et al.* (1973) to those discussed in McLennan *et al.* (1995). In this study, an excel spread sheet was designed to handle, data input, the multiple corrections to raw data, and curve fitting algorithms (Figure 3). Samples were sealed into canisters capable of holding up to 40 cm of core. Canisters were maintained at about 23°C and measurements were corrected for the effects of changing temperature and pressure and the effects of water vapour. Data were then corrected to standard temperature and pressure. The spreadsheet calculates cumulative gas contents, gas desorption rates and canister pressure.

Free gas (the gas compressed into the porosity in coal seams) cannot be estimated by canister tests, but there are a number of ways of estimating the amount of gas lost by desorption prior to sealing the samples in canisters. In this study the USBM direct method (McCulloch *et al.*, 1975) was used, which plots desorbed gas measurements against the square root of time. Lost times, measured as the time from when the coal was half way up the hole to when it was sealed in a canister, ranged from 10 minutes to 38 minutes and averaged 20 minutes. The amount of lost gas averaged 7.2% of the total gas.

Once the coal was sealed in the canister desorbed gas measurements were made at increasing intervals for periods ranging from 31 to 49 days. After this time, most of the gas had desorbed from the samples and desorption rates were about 0.01 c/g/day. McCulloch *et al.* (1975) suggest that samples should be desorbed in the canisters until the rate is less than 0.05 cc/g/day. The canisters were opened and samples sent for analysis. The remaining

desorbable gas was estimated by fitting a desorption curve to the data and projecting to infinite time. The amount of remaining gas averaged 8.3%. The curve used was developed by Airey (1968) and is based on experimental data. The equation:

$$V_t = A * (1 - e^{-(t/t_0)^n})$$

predicts the cumulative gas desorbed ( $V_t$ ) up to a time  $t$  in terms of total desorbable gas ( $A$ ) and two constants.

$t_0$  is the time when 63.21% of the total gas ( $A$ ) has desorbed i.e. when  $t=t_0$   $V_t/A=(1-1/e)$ . This is in fact the sorption time used in some reservoir simulators for predicting gas production. The term varies based on grain size or degree of fracturing of the coal. By plotting the predicted sorption point on the desorption curve, it is possible to check the agreement of the Airey Curve based on values of  $A$  and " $t_0$ " with the curve defined by the data.

The constant " $n$ " generally does not vary much and is usually in the range 0.3 to 0.4. It does not correspond to the power term discussed by Williams and Smith (1984). The power term they report which is usually approximately 0.5 controls initial desorption ( $V_t = D * t^{Nw}$ ). The value of  $Nw$  can be found by plotting  $\ln(V_t)$  versus  $\ln(t)$  where the slope is  $Nw$ . For the data presented here the term  $Nw$  is approximately 0.5 for all samples ranging from 0.5 to 0.57. Changes in the power term ( $Nw$ ) can be caused by oxidation of the coal or adsorption of oxygen onto the coal, both effects will tend to decrease the value of  $Nw$ .

The Airey Curve was fitted to the data by adjusting values of " $n$ " to fit data points close to the origin and " $t_0$ " and " $A$ " to fit curve to data points further from the origin. The best fit by eye can be found quickly by setting up the constants to actively change the curve in the gas versus time plot in an excel file (Figure 3). Attempts to use a direct mathematical solution for solving for " $n$ " and " $t_0$ " were not as effective. The fitted curve provided estimates of the total desorbable gas ( $A$ ) in each sample and the amount of gas left to desorb after the canisters were opened. An additional useful plot is  $\ln(\text{gas desorption rate})$  versus time (Figure 3). Any problems in the data are immediately apparent as points plot off the trend. Usually this flags minor errors in data entry.

Canisters were purged with argon to eliminate as much air as possible. Spacer pipes were used to decrease the void space (dead space) in the canisters. This helps minimize air contamination, but also increases the risk of producing a saw tooth pressure profile as the pressure increases before each desorption measurement. Smaller dead spaces and larger desorbed gas volumes may cause excessive increase in pressure just prior to a measurement. The excel spread sheet calculates the pressure using an estimated dead space or a calculated value. It is generally not possible to measure the dead space until after the canisters are opened. However the manometer used for measuring gas volumes can be used to measure dead space. By lifting the reserve liquid container argon can be pressured by a known amount into the canister. When the argon is released at atmospheric pressure back

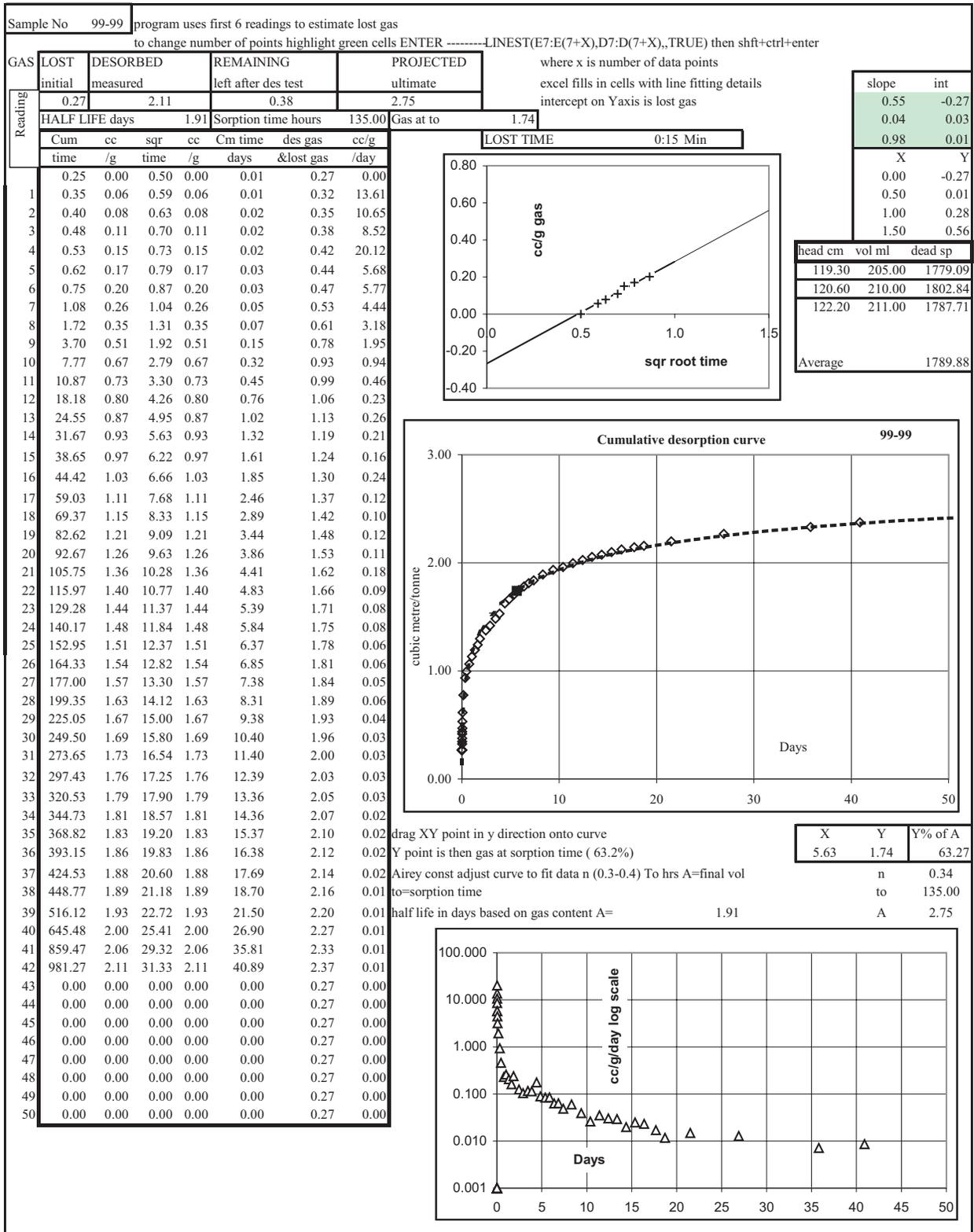


Figure 3. Excel Spread sheet for charting desorption data.

**TABLE 2**  
**STRATIGRAPHY OF THE COMOX AND TRENT RIVER FORMATIONS, COURTENAY AREA**

<b>Eocene to Oligocene</b>	
<b>Mount Washington Intrusive Suite</b>	
<b>T</b>	sills and dikes of dacite and quartz diorite
<b>Upper Cretaceous</b>	
<b>Nanaimo Group</b>	
Campanian	
TRENT RIVER FORMATION	
<b>11</b>	<b>Willow Point Member:</b> shale and siltstone; minor sandstone
<b>9</b>	<b>Royston Member:</b> shale and siltstone
<b>8</b>	<b>Tsable Member:</b> shale and siltstone
<b>7</b>	<b>Browns Member:</b> sandstone and siltstone; locally glauconitic
<b>4</b>	<b>Puntledge Member:</b> siltstone and shale; minor sandstone
COMOX FORMATION	
<b>3</b>	<b>Dunsmuir Member:</b> sandstone; siltstone, shale and coal; minor conglomerate
Santonian	
<b>2</b>	<b>Cumberland Member:</b> siltstone and sandstone; coal and shale
Santonian ?	
<b>1</b>	<b>Benson Member:</b> conglomerate and sandstone; red shale and siltstone
<b>Upper Triassic</b>	
<b>Vancouver Group</b>	
<b>V</b>	<b>Karmutsen Formation:</b> massive and pillowed basaltic flows; basaltic breccia

Notes: Units 5 and 6 are not recognized within the map area. Units 10a and 10b are probably not present within the map area.

-  Bedding orientation
-  Geology contact - approximate
-  Extension fault (ornament on down thrown side)
-  Strike-slip fault (arrows indicate offset)
-  Diamond drill hole

into the manometer the volume measured and the pressure used to force argon into the canister provide sufficient information to calculate the dead space (Ryan and Dawson, 1994b).

## DATA

Approximately 40 cm of core were collected for each canister. To minimize lost time corrections, samples were placed in canisters after minimal description by the project geologist, and as is usual, most of the coal was intersected at night. This in part may explain the variable and sometimes high ash contents of the twelve samples, which range from 8% to 64% (Table 2). The gas contents on an as-received basis range from 2.1 cc/g to 7.4 cc/g and on a dry ash-free basis 3.6 cc/g to 12 cc/g.

The Airey Equation models desorption curves well and values of  $n$ , sorption time ( $t_0$ ) and total desorbable gas (A) are well defined. The sorption times are short to mod-

**TABLE 3**  
**GAS CONTENT DATA FOR BLOW-OUT-PREVENTOR SAMPLES AND CANISTER SAMPLES**

canister	depth top metres	wt ar grams	ar moist	ash% db	mineral matter	lost gas cc/g	desorbed gas cc/g	remaining gas cc/g	total gas cc/g	total gas daf	total gas mmfb
Hole 1											
1	255.2	861	5.8	39.3	42.5	0.62	4.90	0.68	6.20	10.2	10.5
2	298.7	1347	3.0	35.1	37.9	0.25	5.01	0.54	5.80	8.9	9.2
3	299.7	1129	2.7	12.1	13.1	0.24	6.29	0.82	7.35	8.4	8.4
4	325.1	843	3.5	48.0	51.9	0.33	5.43	0.24	6.00	11.5	12.0
5	254.8	1292	6.0	52.5	56.7	0.22	3.10	0.08	3.40	7.2	7.5
Hole 2											
6	485.2	1513	2.3	61.9	66.8	0.32	3.09	0.09	3.50	9.2	9.6
7	486.1	1199	3.6	55.8	60.3	0.33	3.93	0.39	4.65	10.5	11.0
8	512.6	750	4.1	64.4	69.6	0.80	3.10	0.14	4.05	11.4	12.0
Hole 3											
9	237.9	1245	3.0	26.1	28.1	0.11	2.31	0.18	2.60	3.5	3.6
10	237.6	1427	2.7	50.4	54.4	0.11	1.58	0.37	2.05	4.1	4.3
11	297.6	1218	3.6	7.9	8.6	0.23	3.93	0.58	4.75	5.2	5.2
12	298.9	1312	3.2	28.9	31.2	0.19	2.31	0.30	2.80	3.9	4.0

Average Cumberland S%=1.45% from Dolmage and Campbell (1975)  
ar = as received moisture daf = dry ash free

dmmf = dry mineral matter free BOP = Blow-out -preventor

erate and correlate inversely with ash content. It appears that coal in thin bands in carbonaceous mudstone tends to be more fractured than thicker low ash coal bands.

A number of samples were collected for gas composition analyses and analyzed on a HP 5710 gas chromatograph. Samples were extracted, using a 50cc syringe, from the manometer feed line adjacent to where it attaches to the canister. The syringe samples were injected into 1 litre Tedlar sample bags and sent to B.C. Research Inc. for analysis. Two samples were collected from blow-out-preventors (BOP) on holes 1 and 2. In these cases large plastic exploration sample bags were held over the outlet and allowed to fill. Gas samples were extracted by injecting into the filled bags. Gas composition data (Table 3) indicate that either not all the air was purged out of the canisters or air got into the samples via the manometer or the sampling process. The amounts of gas analyzed are less than 100% because the analysis procedure is not able to measure the argon used to purge the canisters. On average the samples contained 34% air. After correcting the samples for air by removing all the oxygen and air-associated nitrogen based on a volumetric ratio of oxygen/nitrogen= 0.2682, the samples appear to have excess nitrogen. The individual gas composition analyses do not reflect the average gas composition for all the gas desorbed from each canister because the composition of the desorbed gas changes over time as discussed in the

next section. However, based on analyses amounts of CO<sub>2</sub> are generally low and less than 10% by volume and average 3%. Methane concentrations range from 9% to 93%. It appears that hole 3 has high nitrogen concentrations. Data from holes 1 to 3 provide averages of 14.1%, 17.7% and 70.3 % nitrogen.

## DISCUSSION

Dolmage and Campbell (1975) estimate a coal resource of approximately 300 million tonnes to a depth of 1000 metres in the Cumberland sub basin. Based on coal quality data they published for the sub basin, coal has an average Volatile matter daf value of 39% indicating a rank of high-volatile bituminous. In the plot of gas content dmmf basis *versus* depth (Figure 4) a vitrinite reflectance value (R<sub>max</sub>) of 0.9% is used. Samples from holes 1 and 2 appear to be close to saturated based on a predicted gas content using the Ryan Equation (Ryan, 1992). Based on these two holes a gas content of about 8 to 9 c/g (250 to 300 scf/ton) can be assumed for 20% ash coal at about 500 metres. This provides a conservative potential resource of about 0.08 to 0.1 tcf based on a coal resource of 300 million tonnes.

There is evidence that the stratigraphy may be pressured with free gas. This has important implications for the gas content of coal. If the phase in contact with the coal is a CH<sub>4</sub> rich gas rather than water, then it is probable that the coal will be saturated in terms of its ability to adsorb CH<sub>4</sub> and this appears to be the case for coals from the two holes that were over pressured. Coal seams that are in gas pressured stratigraphy will not produce much water during the early stages of production, which will improve the economics of the CBM development. In addition if the porosity in the coal seams is gas filled rather than water filled then there is an additional increment to the total gas that can be produced from the seam. In coal seams the amount of free gas, at any depth, can be calculated using assumed values of porosity, density and a normal hydrostatic gradient. The higher gas content curve (Figure 4) is

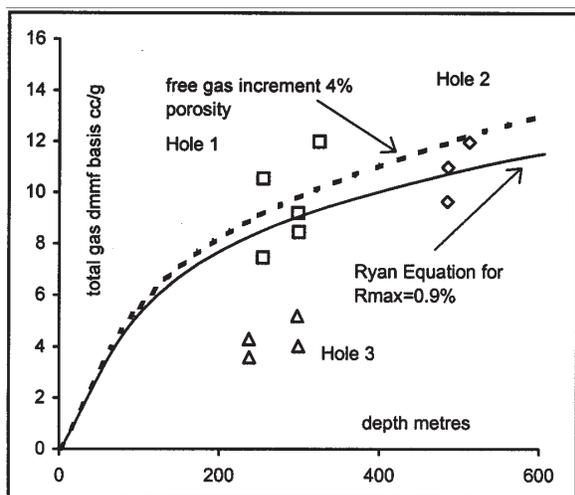


Figure 4. Gas contents (mineral matter free basis) *versus* depth for data from the three holes.

constructed assuming an additional increment of free gas based on a gas filled porosity of 4%. This might be high for coal, but on the other hand the pressure might be higher than assumed, because there is evidence of over pressuring in holes 1 and 2. It is apparent that at depths greater than 200 metres there could be a significant increment of free gas in the coal seams. The over pressuring could also increase the adsorbed gas content of the seams. Most depth *versus* gas plots assume a normal hydrostatic gradient. An increased gradient would have the effect of producing apparently over saturated samples. The amount of over saturation depends on the constants defining the adsorption curve (V<sub>i</sub> and P<sub>i</sub> Langmuir constants) or desorption curve (Ryan Equation and R<sub>max</sub>) and the percent increase in the hydrostatic gradient. The amount of over saturation does not change much with depth whatever the curve used. For example in this case an over pressuring of 25% would increase the adsorption capacity at most depths by about 1 cc/g. This increase would be reflected in the desorption results. Adsorption capacity at any rank is very sensitive to moisture content of coal and it is generally assumed that coals at depth are at equilibrium moisture. However in a situation where there is over pressured free gas in the stratigraphy this might have the effect of reducing the moisture content of the coal and increasing its adsorption capacity.

The ash contents of the samples collected are variable and high, possibly because seams in the Comox Formation sometimes grade laterally into coaly zones. This does not necessarily decrease the CBM resource as long as the amount of carbon in the zone is the same as that in a thinner cleaner seam. In fact a lot of interest is developing in the resource potential of organic rich shales. A 30 metre thick shale bed with total organic carbon of 10% can contain as much gas as a 3.75 metre coal seam.

Samples from hole 3 have unusually high nitrogen contents, which may be an artifact of the sampling process. However there is certainly nitrogen in the stratigraphy as indicated by the composition of the 2 BOP samples and high nitrogen contents may reflect gas compositions in the coal samples. Nitrogen can originate from the sampling process when the oxygen in excess air in the canister is either adsorbed, or chemically bound to the coal by oxidation. This removes oxygen from the gas leaving nitrogen. After correcting for air, using an air oxygen/nitrogen ratio of 0.2682 and the remaining oxygen, there appears to be excess nitrogen in the gas. Oxygen can be adsorbed or can oxidize coal, in which case to some extent CO<sub>2</sub> replaces oxygen in the gas. The samples from hole 3 do not have excessively high CO<sub>2</sub> contents. If the excess nitrogen in samples from hole 3 is caused by adsorption of oxygen in the canisters, then one would expect this to impact the desorption curves. In fact there is no decrease in the power term  $Nw$  ( $Vt=Dt^{Nw}$ ) compared to data from the other holes. On balance it is felt that most of the excess nitrogen probably originates from the coal and surrounding stratigraphy and is not an artifact caused by uptake of oxygen in the canisters. If all the excess nitrogen results from oxidation in the canister, then the percentage of adsorbed oxygen is 19% based on an average

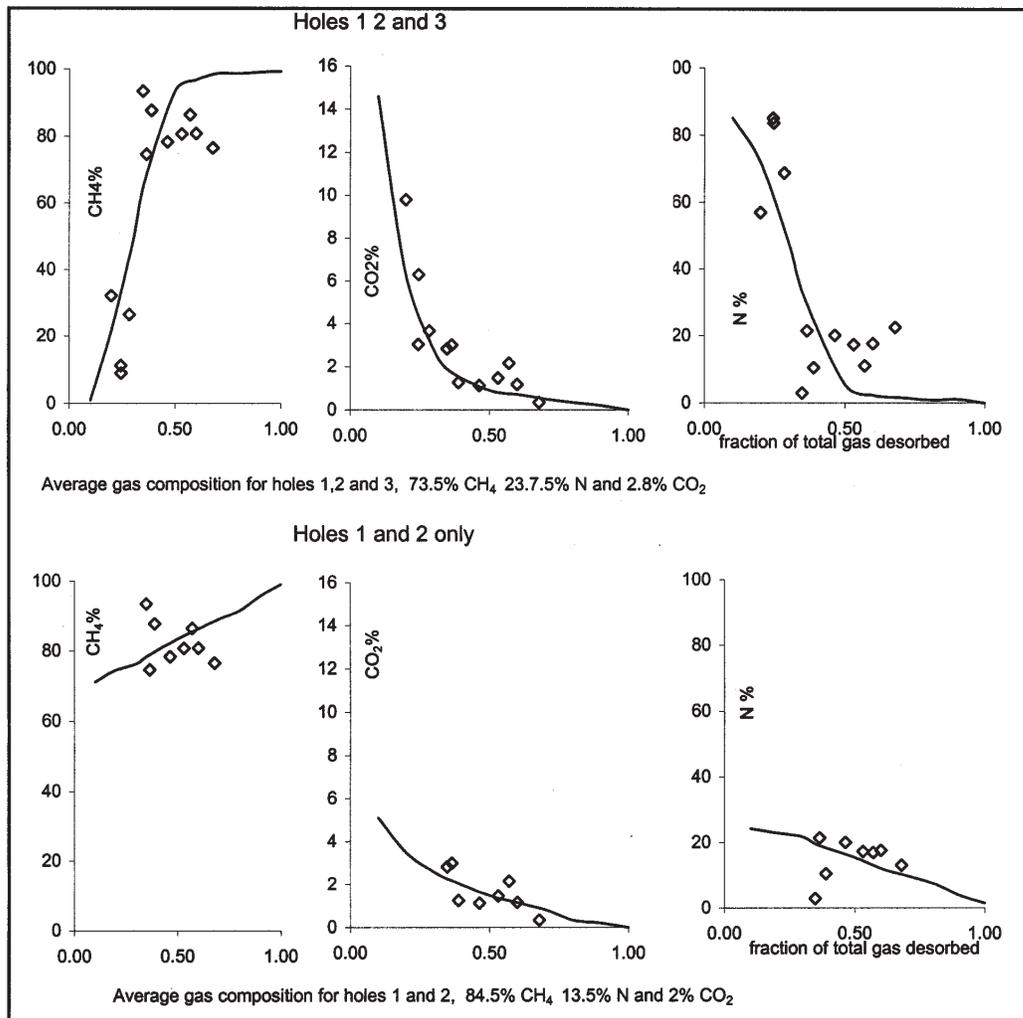


Figure 5. Plots of gas contents versus fraction of total gas desorbed. Data for all three holes and for holes 1 and 2.

of 73% nitrogen in samples from hole 3 and this volume should be added back to the desorption totals. Even a 20% correction to samples from hole 3 is not enough to raise them to the saturation curve in Figure 4.

The high nitrogen contents of the desorbed gases are unusual. Nitrogen is generated as part of the coalification process. Kneuper and Huckel (1972) estimate that 320 scf/ton are released from Carboniferous coals over the rank range of sub-bituminous to anthracite. Scott (1993) estimates from 250 to 500 scf/ton (8 to 15.5 cc/g) are generated during coalification. Coal gas with the highest nitrogen content is found associated with the wet gas generation stage, which occurs in the R<sub>max</sub> range 0.5% to 0.8%. Nitrogen contents in coal gas generally peak at 12% at R<sub>max</sub> 0.7%, with another maximum of 4% nitrogen at R<sub>max</sub> 1.7% (Scott, 1993).

Hole 3 has low total gas contents and high nitrogen contents. If the nitrogen was adsorbed on the coal this would explain the low gas contents because coal has a

lower adsorption capacity for nitrogen than CH<sub>4</sub> or CO<sub>2</sub>. Nitrogen can originate from the coalification process or from igneous activity. There were indications in Hole 3 that it might be close to an intrusion but there is no discernible difference in the rank of the coals from the 3 holes. There is igneous activity in the vicinity and there is excess nitrogen in the stratigraphy as indicated by the composition of the gas from the two BOP samples; 93% for hole 1 and 30% from hole 2. An alternative explanation is that the nitrogen comes from gob gas in abandoned underground coal mines. These mines were originally filled with air, from which oxygen would be removed over time leaving nitrogen that could then penetrate the surrounding stratigraphy.

It is difficult to draw detailed conclusions about the overall gas composition of the desorbed gas from each canister, because the composition changes over time and only 1 or 2 samples were collected from each canister. If however it is assumed that the composition of gases is

similar from canister to canister, and the mix changes in a similar way over time, then it is possible to normalize the data to indicate the composition of an average sample over time using all 3 holes (Table 4, Figure 5). This provides an average gas composition of 73.4% CH<sub>4</sub>, 23.8% N<sub>2</sub> and 2.8%CO<sub>2</sub>. In this case it is probable that the assumptions are not valid, but in many situations the approach might be a poor mans way of producing an average gas composition curve. Data from hole 3 are not representative of the gas compositions in the other two holes and if these data are removed from the analysis, then the average gas composition for holes 1 and 2 becomes approximately 83% CH<sub>4</sub>, 15% N and 2% CO<sub>2</sub>. The nitrogen is somewhat high but this can be explained easily by some adsorption of oxygen from air contamination in the canisters. The CO<sub>2</sub> contents are low, which makes the gas more attractive as a commercial product.

Nitrogen and carbon dioxide are predicted to come off the coal faster than methane (Figure 6). This has been documented by other authors and is the reverse of what happens during production. Desorption occurs at atmospheric pressure where as production occurs at incremental pressures less than hydrostatic pressure. Under atmospheric conditions, the rate at which different gases enter the canister free space is dependent on diffusion rates through the coal. This is evident in the Airy equation, in which sorption time (t<sub>0</sub>) is dependent on coal fragment size (Airey, 1968). There is no correlation of sorption

time to concentrations of nitrogen or carbon dioxide in this study.

## CONCLUSIONS

Twelve samples were collected from a drill program in the Courtenay area British Columbia. The samples were desorbed in canisters maintained at about 23°C until the desorption rate was less than 0.01 cc/day, at which time samples were removed weighed and sent for ash analysis. The equipment used was inexpensive and in part constructed by the author and in part by contractors. Results indicate that the coals in two of the holes are close to saturated with methane and contain moderate concentrations of nitrogen and low concentrations of carbon dioxide. Samples from the third hole are under saturated and appear to contain a lot of nitrogen. One sample of gas from the BOP on hole 1 indicated that there is nitrogen over pressuring of the stratigraphy. A sample of gas from the BOP on hole 2 indicated over pressuring of the stratigraphy by a methane (70%) nitrogen (30%) gas.

**TABLE 4**  
**GAS COMPOSITION DATA GAS COMPOSITION DATA**  
**FOR BLOW-OUT-PREVENTOR SAMPLES AND**  
**CANISTER SAMPLES**

Hole	Sample	depth metres	% air	GP%	percent mole fraction air free					
					CH <sub>4</sub>	CO <sub>2</sub>	C <sub>2</sub> H <sub>6</sub>	H <sub>2</sub>	CO	N <sub>2</sub>
1	D1-1	BOP	14.7		6.6	0.2	0.1	0.1	0.1	93.0
2	D2-1	BOP	61.59		69.5	0.3	0.3	0.1	0.2	29.6
1	2-1	298.7	42.2	0.35	93.5	2.8	0.5	0.1	0.2	2.9
1	4-1	325.11	37.5	0.37	74.6	3.0	0.5	0.1	0.2	21.5
1	5-1	254.8	33.1	0.57	86.4	2.2	0.2	0.1	0.2	11.0
1	6-1	485.17	47.2	0.53	80.7	1.5	0.2	0.1	0.2	17.4
1	6-2	485.17	31.3	0.60	80.8	1.2	0.1	0.1	0.1	17.6
2	7-1	486.11	35.6	0.39	87.7	1.3	0.2	0.1	0.2	10.5
2	7-2	486.11	22.7	0.46	78.4	1.1	0.2	0.1	0.2	20.1
2	8-1	512.64	31.5	0.68	76.6	0.3	0.2	0.1	0.2	22.5
3	9-1	237.94	40.2	0.20	32.2	9.8	0.1	0.3	0.7	56.9
3	9-2	237.94	31.6	0.28	26.5	3.7	0.5	0.2	0.4	68.8
3	11-1	297.63	21.8	0.24	11.2	3.0	0.2	0.1	0.2	85.1
3	12-1	298.9	31.2	0.25	9.0	6.3	0.4	0.2	0.4	83.7

Sample notation first number=canister

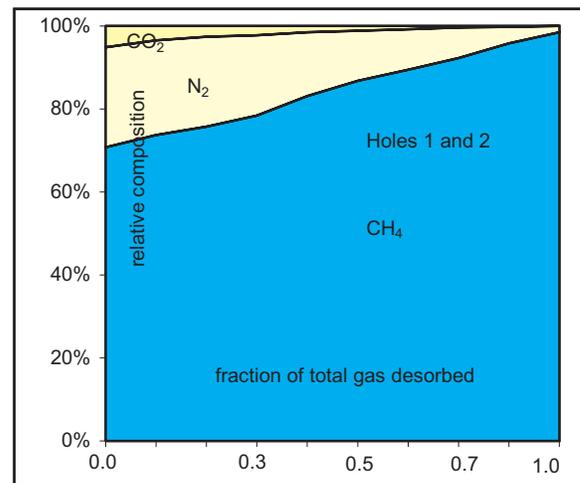
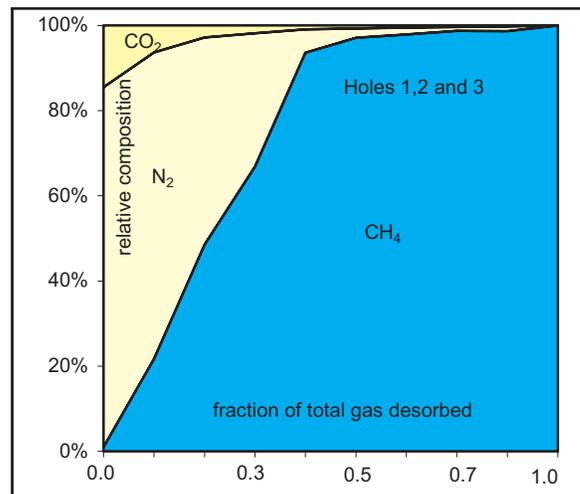


Figure 6. Composite plots of changes of gas composition versus amount of gas desorbed for all 3 holes and holes 1 and 2.

**TABLE 5**  
**CALCULATIONS OF AVERAGE GAS CONTENTS FOR DATA FROM ALL**  
**THREE HOLES COMBINED AND HOLES 1 AND 2**

Holes 1, 2 and 3														
sample gas data					curve fitting data									
hole	GI%	N <sub>2</sub>	CH <sub>4</sub>	CO <sub>2</sub>	GI%	CH <sub>4</sub>	int	GI%	N <sub>2</sub>	int	GI%	CO <sub>2</sub>	int	sum
1	0.35	2.9	93.5	2.8	0.0	actual	curve	0.0	actual	curve	0.0	actual	curve	
1	0.37	21.5	74.6	3.0	0.1	1.0	0.1	0.1	85.2	8.5	0.1	14.6	1.5	100.8
1	0.57	11.0	86.4	2.2	0.2	21.7	2.2	0.2	72.0	7.2	0.2	6.3	0.6	100.0
1	0.53	17.4	80.7	1.5	0.3	48.0	4.8	0.3	48.0	4.8	0.3	2.8	0.3	98.8
1	0.60	17.6	80.8	1.2	0.4	66.8	3.8	0.4	31.3	1.8	0.4	1.8	0.1	99.9
2	0.39	10.5	87.7	1.3	0.5	93.6	13.4	0.5	5.5	0.8	0.5	0.9	0.1	100.0
2	0.46	20.1	78.4	1.1	0.6	96.8	9.7	0.6	2.2	0.2	0.6	0.7	0.1	99.7
2	0.68	22.5	76.6	0.3	0.7	98.7	9.9	0.7	1.6	0.2	0.7	0.5	0.0	100.8
3	0.20	56.9	32.2	9.8	0.8	98.7	9.9	0.8	0.9	0.1	0.8	0.4	0.0	100.0
3	0.28	68.8	26.5	3.7	0.9	99.1	9.9	0.9	1.1	0.1	0.9	0.2	0.0	100.4
3	0.24	85.1	11.2	3.0	1.0	99.4	9.9	1.0	0.0	0.0	1.0	0.0	0.0	99.4
3	0.25	83.7	9.0	6.3	average%	CH <sub>4</sub>	73.5	average%	N	23.7	average%	CO <sub>2</sub>	2.8	

Holes 1 and 2 only												
GI%	CH <sub>4</sub>	int	GI%	N <sub>2</sub>	int	GI%	CO <sub>2</sub>	int	sum			
0.0	actual	curve	0.0	actual	curve	0.0	actual	curve				
0.1	71.1	7.1	0.1	24.3	2.4	0.1	5.1	0.5	100.5			
0.2	74.4	7.1	0.2	23.0	2.3	0.2	3.5	0.4	100.9			
0.3	76.3	8.0	0.3	21.8	2.2	0.3	2.6	0.3	100.7			
0.4	78.7	4.5	0.4	19.4	1.1	0.4	2.2	0.1	100.3			
0.5	83.4	11.9	0.5	15.5	2.2	0.5	1.5	0.2	100.4			
0.6	86.3	8.6	0.6	12.0	1.3	0.6	1.1	0.1	99.4			
0.7	89.1	8.9	0.7	9.7	1.0	0.7	0.8	0.1	99.6			
0.8	91.5	9.2	0.8	7.3	0.8	0.8	0.4	0.0	99.2			
0.9	95.7	9.6	0.9	4.0	0.4	0.9	0.2	0.0	99.9			
1.0	99.1	9.9	1.0	1.5	0.2	1.0	0.0	0.0	100.6			
average%	CH <sub>4</sub>	84.8	average%	N	13.7	average%	CO <sub>2</sub>	1.7				

Int curve = area under curve for change in GI%

GI%=percent of total gas desorbed

This paper documents a cooperative effort between industry and government, in which a balance is struck between timely release of new information, cost saving for the company and recognition of some level of confidentiality for the company.

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