



# COALBED METHANE DESORPTION RESULTS FROM THE QUINSAM COAL MINE AND COALBED METHANE RESOURCE OF THE QUINSAM COALFIELD, BRITISH COLUMBIA.

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**KEYWORDS:** Quinsam mine, coalbed methane, desorption, mine ventilation, coal quality, coalbed-methane resources, Comox Formation.

## INTRODUCTION

Coalbed methane is potentially a valuable resource in British Columbia. Resource development is in its early stages and it is important for government agencies to acquire the data now that companies will need in the future when they plan exploration programs. Gathering coalbed methane (CBM) desorption data from drill-core samples is an important first step in assessing the resource potential of an area. Companies undertaking coal exploration may not at present incorporate a CBM component, to the program but are willing to provide samples to government agencies for CBM desorption tests. The provincial and federal geological surveys are cooperating to ensure that desorption data are obtained wherever possible and the results used in an assessment of the CBM resource of the province.

This paper discusses the results of desorption tests on drill-core samples from the Quinsam coal mine. A separate paper (Ryan and Dawson, 1994) discusses the method of desorption data collection in detail and the background to the corrections applied to the data.

## QUINSAM COAL MINE

The Quinsam coal mine is located 20 kilometres west of the town of Campbell River on Vancouver Island.

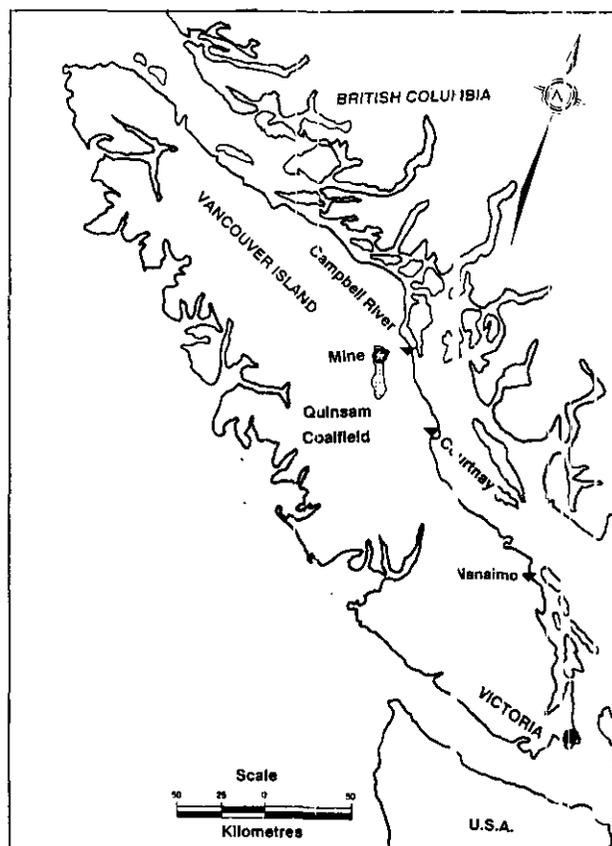


Figure 1. Location map, Vancouver Island and the Quinsam coal mine.

Access is by an all-weather gravel road that joins Highway 28 at kilometre 20 west of Campbell River (Figure 1). The mine opened in 1987, initially as a small surface mine and now as a combined surface and underground operation. Present annual raw-coal production is 500 000 tonnes; this is planned to increase to 1 000 000 tonnes by 1995.

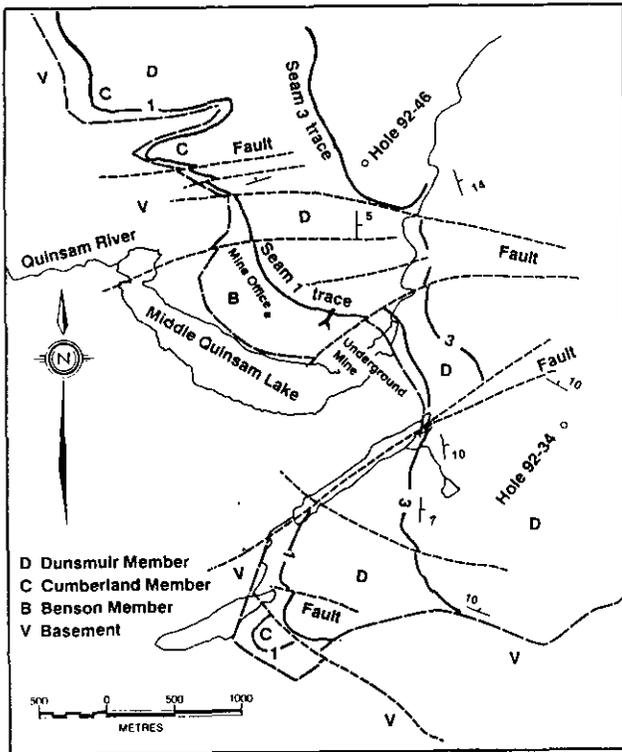


Figure 2. Simplified geology of the Quinsam mine area from Kenyon *et al.* (1991).

The coal seams at Quinsam are in the Comox Formation of the Upper Cretaceous Nanaimo Group (Kenyon *et al.*, 1991). The Comox Formation is divided into the basal conglomeratic Benson Member, which is overlain by the Cumberland and Dunsmuir members. Two seams outcrop in the Cumberland Member and two seams in the Dunsmuir Member. Most of the reserves are in the lowermost seam 1 in the Cumberland Member. Seam 1 averages 2.3 metres in thickness and is sometimes accompanied by a rider which averages 0.40 metre. Seam 1 is mined underground and in surface pits. The overlying seam 2 ranges from 0.30 to 0.55 metre in thickness and is mined at surface in some pits. Seam 3 in the Dunsmuir Member ranges from 2.4 to 3.4 metres thick and is mined in surface pits. Seam 4 is thin and is not mined. The stratigraphic separation of seams 1 and 3 is 30 to 60 metres.

Quinsam management elected to drill two holes for CBM testing because of the expansion in the underground mining activity and the renewed interest in using CBM as an energy resource to support the mining activity. The locations of the two holes with reference to the present mine operations are indicated in Figure 2. Five samples from seam 3 and four samples from seam 1 were desorbed initially at the mine site and then in Victoria.

## CANISTER DESORPTION TECHNIQUES

The techniques used to collect and correct the methane desorption data are described in detail in Ryan and Dawson (1994, this volume).

The samples in this study were recovered from shallow depth where the rock temperature is probably less than 25°C. For this reason the canisters were not put in a temperature controlled box. The lost-gas corrections applied in this study were calculated using the U.S. Bureau of Mines method (Diamond and Levine, 1981) applied to cumulative gas volumes corrected to standard temperature and pressure (STP). The U.S. Bureau of Mines method was used because the down-hole lost-time component was so small that a more complicated method of correcting for lost gas was not justified. The drilling times used to calculate the lost-time are reported in Table 1. Two estimates of lost time for each sample are recorded in the table. In the first case it was assumed that the hole was dry and the gas started to desorb as soon as the seam was drilled, and in the second case it was assumed that the hole was filled with water and that gas started to desorb when the core sample was half-way up the hole.

Hole 92-34 was not making water when drilled and it was assumed to be dry to the sampling depth, whereas hole 92-46 was making some water and was assumed to be filled with water to the collar. The lost-gas calculations for samples from hole 92-34 were made using both dry and wet lost-time estimates. The longer, dry lost-time estimates increased the lost-gas calculation by about 15% (excluding sample 92-34-6). The lost-gas estimate for sample 92-34-6 was made using a modified plot described in Ryan and Dawson (1993, this volume) and appears to be about 641 cubic centimetres. The other samples from hole 92-34 have dry lost-gas estimates ranging from 126 to 132 cubic centimetres.

All samples with the exception of 92-34-6 produced reasonable cumulative gas (STP) *versus* square-root time linear plots.

Dead space corrections are necessary because of the effect of changing pressure and temperature on the empty space in the canister. This correction is referred to as the canister dead space correction and is described in Ryan and Dawson (1994, this volume). Obviously it is important to minimize the dead space in the canister and to be able to measure it. The canisters used in this study have spacer rings to fill in space if the core diameter is much less than the inside diameter of the canister.

The dead space in the canister was measured in the following way: after making a measurement the manometer is used to pressure the canister with the methane just expelled or with air. This is done by raising the water reservoir bulb above the water level in the burette while the manometer is still attached to the

canister. Measure the difference in water levels (h in cm). This value represents the pressure above atmosphere forcing methane or air back into the canister. Measure the volume of gas (M) returned to the manometer at atmospheric pressure (PA). Calculate the dead space (DS) using

$$DS \times (Pa + Ph) = (DS + M) \times Pa$$

$$DS = M \times Pa / Ph$$

Ph (millibars) = 980.62 x 0.998 x h / 1000 where 0.998 corrects for the density of water at room temperature.

TABLE 1  
QUINSAM SAMPLE COLLECTION DATA

HOLE	DATE	SEAM	METRES		ELEVATION
			EASTING	NORTHING	
H92-34	1/10/92	3	324284	5532297	336
H92-46	16/10/92	1	322854	5534322	317

METRES FROM-TO	CUT	TIMES		LOST TIME		T <sub>25%</sub>
		TRIP	SURFACE	SEAL	DRY WET	
<b>HOLE 92-34 SEAM 3 SAMPLES 92-34-2 (TOP) TO 92-34-6 (BOTTOM)</b>						
141.5-141.9	14.46	14.50	14.51	14.56	10	6
141.9-142.3	14.46	14.50	14.51	14.57	11	6
142.3-142.7	14.46	14.50	14.51	14.58	12	7
142.7-143.1	14.46	14.50	14.51	14.59	13	8
143.1-143.5	14.46	14.50	14.51	14.00	14	9
145.3-145.7	15.02	14.09	14.11	14.15	13	6
<b>HOLE 92-46 SEAM 1 SAMPLES 92-46-1 (TOP) TO 92-46-4 (BOTTOM)</b>						
108.5-108.9	14.57	15.01	15.02	15.10	13	9
109.4-109.8	14.57	15.01	15.02	15.08	11	7
111.5-111.9	14.09	15.14	15.15	15.19	10	5
111.9-112.3	14.09	15.14	15.15	15.20	11	6

LOST TIME DRY = Lost-time minutes assuming dry hole.  
 LOST TIME WET = Lost time minutes assuming water-filled hole.  
 CUT TIME = Time (hours.minutes) drill cuts coal.  
 TRIP TIME = Time (hours.minutes) core starts to surface.  
 SURFACE TIME = Time (hours.minutes) coal reaches surface.  
 SEAL TIME = Time (hours.minutes) sealed in canister

SMITH AND WILLIAMS TERMS

T<sub>s</sub> = Cut time to seal time.  
 T<sub>d</sub> = Cut time to surface time.  
 T<sub>25%</sub> = Time from cut time to time for 25% desorption into canister  
 Note this is not time for 25% total desorption loss because it does not consider the lost gas component  
 SURFACE-TIME RATIO = (T<sub>s</sub> - T<sub>d</sub>)/T<sub>s</sub>  
 LOST-TIME RATIO = T<sub>s</sub>/T<sub>25%</sub>

This method of calculating the dead space has a number of advantages. Calculations can be made after each desorbed gas measurement and a number of measurements averaged. The method requires no additional equipment and is direct. Lastly, it measures the same volume as the desorbing gas occupies, not a liquid filled volume or a theoretical volume.

The desorption data were corrected for the effect of water vapour in the canister. The vapour pressure of water is temperature dependent and ranges from 0.5 to 7.5 Kilopascals (5 to 75 millibars) in the temperature range of 0 to 40°C. The desorbed gas volumes were calculated using atmospheric pressure minus partial pressure of water. Applying a water vapour correction reduces the measured gas volume at STP by about 2.5%. The resultant gas volume is dry gas at STP.

Finally the desorbed gas volumes were converted to the equivalent volume at STP using the general relationship for ideal gases:

$$P_1 \times V_1 / T_1 = P_2 \times V_2 / T_2$$

## DESORPTION AND COAL QUALITY DATA

Samples from two holes were desorbed at room temperature which is assumed to be similar to *in situ* rock temperature. Canister sample data, coal quality and desorption results are recorded in Tables 2 and 3. Samples were analyzed for as-received moisture, air-dried moisture, volatile matter (VM), ash and fixed carbon content (FC). Some samples were also analyzed for equilibrium moisture and Hardgrove Index (HGI). The mean maximum reflectance values (R<sub>max</sub>) of all samples were measured.

TABLE 2  
SUMMARY CANISTER AND SAMPLE ANALYTICAL DATA

SAMPLE No	CANISTER VOLUME	CANISTER DATA IN cm <sup>3</sup>			SPECIFIC GRAVITY
		DEAD SPACE	SAMPLE VOLUME	SAMPLI WEIGH gram	
<b>SEAM 3</b>					
92-34-2	2975	990	1985	2854	1.4
92-34-3	2936	876	2060	2560	1.4
92-34-4	3002	986	2016	2398	1.39
92-34-5	2874	1050	1824	2241	1.3
92-34-6	2947	1100	1847	2179	1.8
<b>SEAM 1</b>					
92-46-1	2975	1248	1727	2192	1.37
92-46-2	2936	1220	1716	2204	1.38
92-46-3	3002	1645	1357	1642	1.3
92-46-4	2874	1313	1561	2194	1.3

SAMPLE	R <sub>max</sub>	COAL QUALITY DATA				EQUIL H <sub>2</sub> O	HGI
		% H <sub>2</sub> O ar	% VM	% ASH	% FC		
<b>SEAM 3</b>							
92-34-1		2.83	38.63	11.85	46.69		
92-34-2	0.64	1.87	22.15	54.61	21.37	3.8	61
92-34-3	0.67	3.25	33.92	15.24	47.59	4.7	
92-34-4	0.67	3.13	35.83	11.92	49.12		
92-34-5	0.66	3.28	36.91	5.97	53.84		
92-34-6	0.64	5.38	31.07	27.59	35.96	4.3	63
<b>SEAM 1</b>							
92-46-1	0.70	6.28	36.03	8.12	49.57		
92-46-2	0.65	6.62	35.5	7.99	49.88	5.3	53
92-46-3	0.63	7.96	36.03	9.51	46.50		
92-46-4	0.66	8.69	30.99	19.05	41.27		

data reported on an as-received basis  
 R<sub>max</sub> = Mean maximum reflectance  
 ar = As-received VM = Volatile matter  
 FC = Fixed carbon EQUIL H<sub>2</sub>O = Equilibrium moisture  
 HGI = Hardgrove Index

Hole 92-34 intersected seam 3 at 141.5 metres where it has a vertical thickness of 4.3 metres. Six samples, each being 40 centimetres of core, were collected and sealed into canisters. The ash contents of the samples range from 5.97 to 54.61% (arb). The samples spanned the seam from hangingwall to footwall and Figure 3 presents the density and gamma geophysical log traces of the seam. Unfortunately the hangingwall canister

(sample 92-34-1) leaked. The samples of seam 3 were desorbed at room temperature for 15 days, at which time the canisters were re-used for the seam 1 samples. At this time only one sample had finished desorbing and the last increment of desorbed gas from the other seam 3 samples was estimated by projecting the cumulative desorption curves. In all cases the correction was less than 250 cubic centimetres.

TABLE 3  
SUMMARY DESORPTION DATA CORRECTED FOR CANISTER DEAD SPACE  
AND CONVERTED TO STP DRY GAS

SAMPLE	L GAS cm <sup>3</sup> /g	D GAS cm <sup>3</sup> /g	S GAS cm <sup>3</sup> /g	T GAS cm <sup>3</sup> /g	T GAS daf/g
<b>HOLE 34 SEAM 3</b>					
92-34-2	0.0441	0.3919	0.0053	0.441	1.014
92-34-3	0.0516	0.7127	0.0332	0.797	0.978
92-34-4	0.0551	0.7239	0.0676	0.847	0.997
92-34-5	0.0562	0.8694	0.0919	1.018	1.121
92-34-6	0.1482	0.9456	0.0000	1.094	1.632
<b>HOLE 46 SEAM 1</b>					
92-46-1	0.0402	0.7906	0.0000	0.8308	0.971
92-46-2	0.0436	0.8685	0.0000	0.9121	1.068
92-46-3	0.0633	0.8091	0.0000	0.8724	1.057
92-46-4	0.0574	0.9046	0.0000	0.9620	1.331

ABBREVIATIONS

- L GAS = Gas lost prior to sealing sample in canister.
- D GAS = Gas desorbed into canister.
- S GAS = Estimate of gas desorbed after samples removed from canister.
- T GAS = Total estimated gas desorbed from samples.
- T GAS daf = Total gas on a dry, ash-free basis per dry gram.

Hole 92-46 intersected seam 1 at 108.5 metres where it has a vertical thickness of 3.80 metres. Four samples 40 centimetres long, including hangingwall and footwall were sealed into canisters (Figure 3). The ash contents of the samples range from 7.99 to 19.05% (arb). Samples were desorbed at room temperature for periods ranging from 44 to 54 days. At this time the gas being desorbed (after correcting for variations of pressure and temperature between readings) was less than 5.0 cubic centimetres per day.

ADSORPTION DATA

An adsorption isotherm (Table 4 and Figure 4) was measured for sample 92-34-3 at a temperature of 22°C per 1000 metres and an equilibrium moisture of 4.72%. At a geothermal gradient of 18°C per 1000 metres a temperature of 22°C is equivalent to a depth of about 500 metres. Above 500 metres the adsorption data probably predict an unrealistically low gas capacity and below 500 metres they probably predict an unrealistically high gas capacity.

The results fit the Langmuir equation well (Langmuir, 1918). The data plotted on a linearized Langmuir plot scatters about a straight line with an R<sup>2</sup> value of 0.994. The Langmuir volume (V<sub>L</sub>) which is the predicted gas content of the sample at infinite pressure, is

18.6 cubic centimetres per gram and the Langmuir pressure (P<sub>L</sub>) is 1335.6 psia or 947 metres based on hydrostatic pressure. The V<sub>L</sub> value is similar to the values obtained for coals of similar rank by Olszewski and Schraufnagel (1992), who fitted Langmuir curves to U.S. Bureau of Mines desorption data reported by Kim (1977).

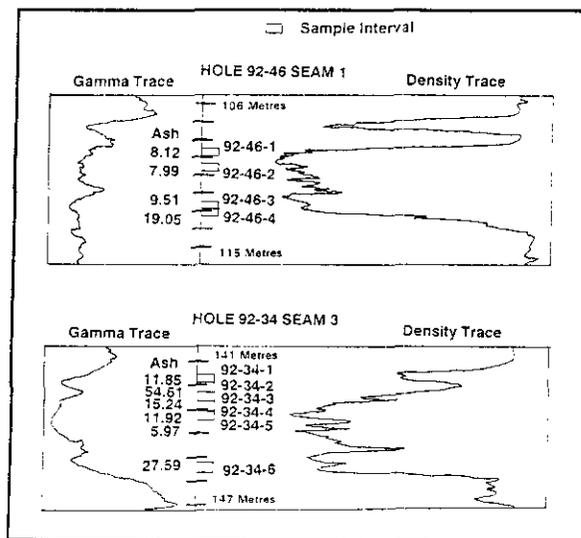


Figure 3. Geophysical logs for Quinsam coal mine holes 92-34 and 92-46.

The Langmuir pressure for the Quinsam sample (1335.6 psia or 947 metres hydrostatic) is approximately seven times greater than P<sub>L</sub> values obtained by Olszewski and Schraufnagel on coals of similar rank. They modelled data obtained from air-dried samples. The Quinsam isotherm was measured on a sample with equilibrium moisture of 4.72%. Olszewski and Schraufnagel mention the effect of moisture but do not quantify its effect in the Langmuir rank equation that they derive. Moisture decreases the adsorption ability of coal (Joubert *et al.*, 1973) up to a critical content above which increase in moisture content has no effect on adsorption ability. The critical moisture for a particular coal is similar to its equilibrium moisture. Data from Joubert *et al.* indicate that, decrease in moisture content below the critical moisture value increases V<sub>L</sub> but has a much more pronounced effect on P<sub>L</sub>, increasing it markedly. This means that the adsorption curve is flattened and adsorption contents at low pressures are decreased.

The retention ability of high-volatile bituminous and sub-bituminous coals at low pressures may vary below predicted values, based on changes in the high and variable equilibrium moisture contents.

A number of curves predicting adsorption capacity are plotted on Figure 4. These curves are derived from the work of Kim (1977), Eddy *et al.* (1982) and Olszewski and Schraufnagel (1992; Langmuir rank equation). The equations used to derive these curves used data from desorbed samples which, for the low-rank coals may not have been saturated, consequently the curves for low-rank coals may not match experimental adsorption curves measured on saturated low-rank coals. It is therefore not surprising that two of these curves plot below the adsorption curve (Figure 4).

TABLE 4  
ADSORPTION DATA FOR SAMPLE 92-34-3

Coal quality					
Equilibrium moisture = 4.72 %					
Ash db = 15.75 %					
Volatile matter db = 35.06 %					
R <sub>max</sub> = 0.67 %					
Adsorption data run at 22 °C					
Pressure psia	Depth metres	scf/ ton	cm <sup>3</sup> / gram	psia/ (scf/ton)	kPa/ (cm <sup>3</sup> /g)
232	164.5	83.6	2.61	2.78	597.7
423	300.0	137.7	4.30	3.07	510.9
633	448.9	174.8	5.46	3.623	799.5
937	664.4	241.3	7.53	3.882	858.0
1270	900.6	274.3	8.56	4.631	1023
1553	1101.2	302.1	9.43	5.141	1135
1919	1360.8	333.0	10.4	5.763	1272
Adsorption data dry ash free basis					
Pressure psia	Depth metres	scf/ ton	cm <sup>3</sup> / gram	psia/ (scf/ton)	kPa/ (cm <sup>3</sup> /g)
232	164.5	99.2	3.10	2.342	503.2
423	300.0	163.4	5.10	2.587	430.8
633	448.9	207.5	6.48	3.052	673.6
937	664.4	286.4	8.94	3.270	722.7
1270	900.6	325.5	10.16	3.902	861.9
1553	1101.2	358.6	11.19	4.332	956.9
1919	1360.8	395.3	12.34	4.855	1072.3
Langmuir Constants					
As-received			Dry ash-free basis		
V <sub>L</sub>	P <sub>i</sub>		V <sub>L</sub>	P <sub>i</sub>	
scf/ton	cm <sup>3</sup> /g	psia	kPa	scf/ton	cm <sup>3</sup> /g
564.8	17.6	1335.6	9209	670.3	20.9
				1335.6	9209

1335.6 psia = 947 metres hydrostatic pressure

There is some evidence that the adsorption capacity of high-volatile B rank coals may actually be higher than that for high-volatile bituminous A rank coals. The Langmuir volume for the Quinsam coal with a reflectance of about 0.65% is 20.9 cubic centimetres per gram (daf basis) whereas the Langmuir volumes of three samples from the Telkwa coalfield with reflectances ranging from 0.9 to 0.99% are 14.6, 12.3 and 11.1 cubic centimetres per gram daf basis (Ryan and Dawson, this volume).

## RESULTS AND INTERPRETATION

The gas contents of the five samples from seam 3 in hole 92-34 range from 0.44 cubic centimetres per gram at the hangingwall of the seam to 1.09 cubic centimetres per gram at the footwall of the seam. On a dry, ash-free basis the values range from 1.014 to 1.632 cubic centimetres per gram (Table 3). The R<sub>max</sub> values of the samples vary from 0.64 to 0.67% (Table 2) which is characteristic of high-volatile bituminous coal.

The gas contents of the four samples from seam 1 in hole 92-46 range from 0.97 cubic centimetres per gram at the top of the seam to 1.331 cubic centimetres per gram at the bottom and from 0.97 to 1.33 on a dry, ash-free basis (Table 3). The R<sub>max</sub> values of the samples range from 0.63 to 0.70% (Table 2).

The rank of the Quinsam coal is low and its adsorption capacity is probably greater than the cumulative gas it has generated. Karweil (in Meissener, 1984) suggests that methane generation starts after the coal has achieved a rank equivalent to a volatile matter (VM) (daf) content of about 37.8%. Dow (1977) indicates that wet gas generation starts after the rank of the samples exceeds an R<sub>max</sub> of 0.8%. Models of other workers indicate initiation of methane generation at VM (daf) values ranging from 35 to 46% (Meissener, 1984). Some data (Snowden and Powell, 1982) indicate that methane generation may start at ranks below a R<sub>max</sub> value of 0.6%.

The R<sub>max</sub> of Quinsam coal is below Dow's threshold for methane generation. Before using the Karweil equation the VM (daf) value for the coal must be determined. The Quinsam coal contains calcite which dissociates to CaO and CO<sub>2</sub> during VM determinations; consequently the determinations are influenced by a variable addition of CO<sub>2</sub>, depending on the amount of ash. An estimate of the true VM (daf) can be obtained by plotting individual VM (daf) determinations (Y axis) versus the individual ash contents dry-basis (X axis). The Y intercept is then VM (daf) at zero ash, and without addition of CO<sub>2</sub> from the ash. A plot of this type for the nine Quinsam samples provided an average VM (daf) at zero ash of 40.33%. Obviously the various methane generation models would indicate very little or no methane generation by the coal.

There is another result of the higher than normal concentration of carbonate in the coal. Generally it is more useful to report gas contents on a mineral-free basis rather than an ash-free basis. The weight of mineral matter is usually approximated from the weight of ash using the Parr equation (Parr, 1932). This equation does not take variations in ash chemistry into account. The line of VM (daf) versus ash (db) has a negative slope of 0.19%. If this is caused by release of volatile components, including CO<sub>2</sub>, from the ash then the

original mineral-matter weighed 1.19 times the weight of ash.

The gas contents of the coal on a mineral matter free (mmf) basis will be higher than the concentrations on a dry ash-free basis. For low ash contents the increase is probably about 2.5% and at high ash contents it is about 23%. For most of the samples the effect is not significant, but the gas contents (mmf basis) for samples 92-34-2 (55% ash) and 92-34-6 (29% ash) would increase significantly.

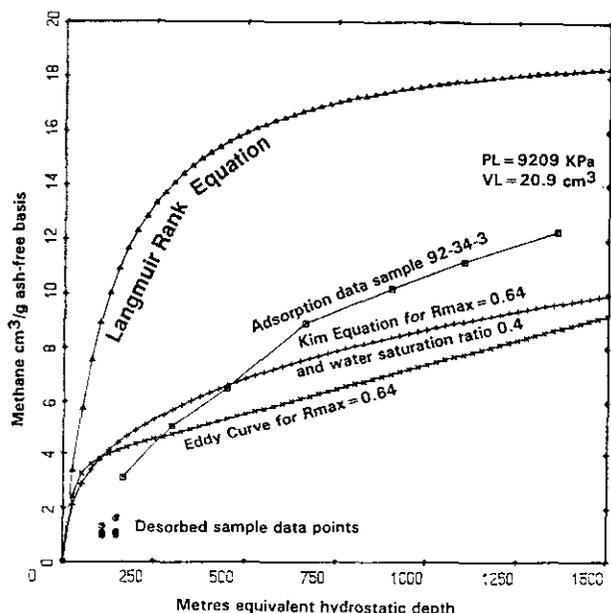


Figure 4. Desorption data, adsorption curve for sample 92-34-3 and theoretical adsorption curves predicting the adsorption capacity of low-rank coals.

The only way of doing the mineral matter correction accurately is to weigh a low-temperature ash sample (true mineral matter sample). The mineral matter can then be subjected to a standard ash analysis to provide a mineral matter to ash weight ratio to correct the ash content measurements of other samples to equivalent mineral matter contents.

The Quinsam samples are under saturated with respect to their adsorption capacities and much of the gas adsorbed on the samples may have been scavenged from elsewhere. The scavenged gas could be methane generated by, and released from higher rank coals, carbon dioxide generated by low-rank coal or biogenic methane. Carbon dioxide is strongly adsorbed by coal.

The seam 3 samples were intersected at about 140 metres. If the hydrostatic head was also 140 metres then the adsorption capacity of these samples should be about 2.7 cubic centimetres per gram (daf basis). The hydrostatic head is probably less than 140 metres. For example, if the water table is 20 metres below surface

then the adsorption capacity is 2.2 cubic centimetres per gram (daf) basis. The actual desorbed gas contents range from 1.0 to 1.6 cubic centimetres per gram and the samples are therefore undersaturated, containing between 40 and 70% of the maximum possible adsorbed gas.

The seam 1 samples were intersected at about 110 metres. If the hydrostatic head is 110 metres, then the coal can adsorb 2.2 cubic centimetres per gram, or if the hydrostatic head is only 90 metres, the adsorption capacity drops to 1.8 cubic centimetres per gram. Consequently seam 1 samples contain between 50 and 70% of the maximum possible adsorbed gas.

Under ideal conditions, if the coal is saturated, the gas contents on a dry, ash-free basis of samples from throughout the seam should be similar, assuming that the petrography of the samples is similar. Seam 3 sample 92-34-6, which contains the most gas on a dry ash-free basis, is also the most crushed seam 3 sample. It probably contains the most gas because its smaller size range allowed it to scavenge gas more easily. It is also the sample that desorbed the quickest because of its finer size range. The situation is the same for the seam 1 samples; the footwall sample (92-46-4) which was the most crushed also contained the most gas and desorbed the quickest.

The samples from holes 92-34 and 92-46 were collected from similar depths and one would expect the gas contents on a dry ash-free basis to be similar. Ignoring the two footwall samples, which definitely contain higher than average gas contents (Figure 5) there is still a considerable spread of gas contents on a daf basis (Table 3). This spread may indicate that the method of correcting to an ash free or mineral matter free basis is incorrect. It is suggested in some literature that finely dispersed ash can damage the adsorption capacity of coal by blocking the microporosity (Gamson *et al.*, 1993). If this is the case then the ash content of a sample may have two components. One may act as a dilutant and be composed of easily removed rock splits and the other may consist of more difficult to remove inherent ash which has a more damaging effect on adsorption capacity. The finely dispersed inherent ash which makes up the last component to be removed by washing may cause a large decrease in gas capacity per 1% ash whereas ash additions above a critical value act as a dilutant to the gas capacity. In Figure 5 the gas contents on an as-received basis are plotted against the ash content. A correction line is plotted that, above 10% ash, has a dilution-effect slope and below 10% ash the slope is increased by a factor of 3 implying that a 1% increase in ash will decrease gas content by 3%.

There is some suggestion that the data may plot on a steeper line at lower ash contents. There are indications of this in other data sets (Dawson 1993; Faiz and Cook, 1991). If this is the case it has a number of important implications for predicting gas contents. Generally gas

contents on a dry ash-free basis will be underestimated. The relationship between depth and gas content on a dry ash-free basis will be obscured. Predictions of gas contents at different ash contents from samples with measured gas contents will be in error.

The specific gravity (S.G.) of the samples was calculated using the sample weight, canister volume and the dead-space volume. This approach is interesting because it comes close to estimating *in situ* bulk density which is an elusive property to measure. Sample 92-34-2 has a high ash content and S.G. whereas the other four samples average 14% ash on a dry basis and a S.G. of 1.25. This value could be useful for calculating *in situ* tonnages from coal seam volumes.

The HGI values for samples from holes 92-34-2, 92-34-6 and 92-46-2 average 59. Sample 92-46-2, which has the lowest ash content has the lowest HGI and is therefore the hardest sample. The sample with the highest HGI is visibly the most crushed sample and has the highest gas content on a daf basis.

The HGI values correlate with the rate of desorption. The time required for half the gas to desorb is inversely correlated to HGI, thus the sample with an HGI of 63 required only 7 hours to lose half its gas, whereas the sample with an HGI of 53 required 90 hours. This relationship, which is related to the degree of crushing of the coal, may be useful in rating the coals for their safety when mined underground. In a situation where coal pillars start to crush there could be an increase in the rate of methane desorption.

The equilibrium moisture increases as the ash content decreases. The data indicate that the equilibrium moisture of the pure coal is greater than 6.0%.

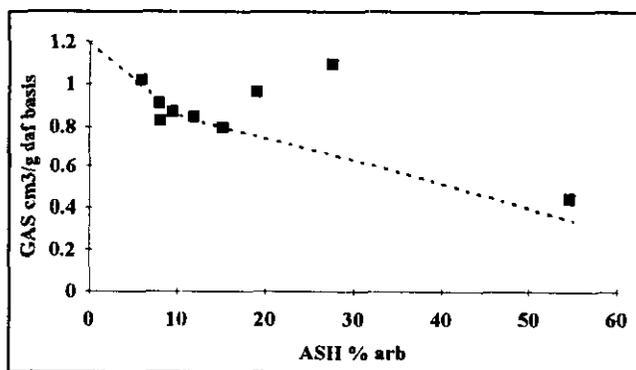


Figure 5: Gas contents on an as-received basis versus ash contents

## RESOURCE POTENTIAL

The potential coalbed methane resource of the Quinsam coalfield is limited by the low rank, shallow depth of burial and apparent under saturation of the coal.

A number of estimates of the resource have been made. Kenyon *et al.* (1991) estimate a resource of 90 billion cubic feet or 2.55 billion cubic metres (BCM) using a methane content of about 4.7 cubic centimetres per gram in the coal. This study uses a lower gas content of 1.5 cubic centimetres per gram based on a somewhat lower estimate of the average  $R_{max}$  value for the coalfield. The mine reports total coal reserves of about 50 million tonnes. If this coal has an average gas content of 1.5 cubic centimetres per gram (or 1.5 cubic metres per tonne) then a minimum resource of 0.075 BCM exists at the mine. The area of the Quinsam coalfield is about 200 square kilometres and the cumulative coal thickness in the Comox Formation in the mine area is estimated at 7.5 metres (Bickford and Kenyon, 1988). It is unlikely that this thickness of coal exists over all the coalfield. If it is present over half the coalfield and the average gas content is 1.5 cubic metres per tonne then the resource of the coalfield is 1.4 BCM.

Over fifty  $R_{max}$  measurements have been made from 24 sites in the Quinsam coalfield (Kenyon *et al.* 1991; A. Matheson, personal communication, 1993) and this study. A variogram of the data indicates that there is no coherent contour pattern and consequently the data are not contoured. Regressions of  $R_{max}$  versus easting or  $R_{max}$  versus northing provided very low  $R^2$  values, confirming the lack of any systematic regional trends in the data. A numeric average for the data is  $0.70 \pm 0.07\%$ ; the highest and lowest values recorded are 0.85 and 0.52%. There is no evidence that seam 1 is of higher rank than seam 3. It appears that the samples desorbed had ranks similar to but slightly lower than the average for the coalfield.

The Langmuir rank equation (Olszewski and Schraufnagel, 1992) can be used to predict the adsorption capacity of Quinsam coal at different ranks and depths. Based on Figure 4, the equation seems to predict values that are high for Quinsam coal but probably the increments between samples of different rank are more accurate. At 150 metres and a temperature of 22 °C the adsorption capacity increases 0.34 cubic centimetres per gram over a rank increase of 0.52 to 0.85%  $R_{max}$ .

There is the possibility of using methane to meet some of the on-site energy requirements of the mine. The Quinsam mine does not have a coal drier so the main opportunities for using CBM are for heating buildings or fueling light trucks. As an example, a hypothetical well is considered which utilizes 60% of the gas in 1 square kilometre times 5 metres of coal. The coal has a methane content of 1.0 cubic metres per tonne. If the well has a life of 5 years then it will provide 2000 cubic metres of methane per day (order of magnitude estimate). One litre of gasoline has the same calorific value as about 1 cubic metre of gas. The well therefore could provide the equivalent of over 2000 litres of gasoline per day. This would meet the daily fuel

requirements for several light vehicles if they were adapted to burn natural gas. A small office complex using 300 kilowatt hours per day of electricity for heating, if converted to natural gas, would use about 30 cubic metres of gas. Even at low productivity rates, a single well can provide sufficient methane to fuel light vehicles and heat mine buildings. The cost of converting to natural gas and drilling the well has to be compared to the cost savings in gasoline and electricity over the life of the well.

The value of natural gas on a Btu basis is about \$1 to \$2 dollars per million Btu. The cost of gasoline on the same basis is \$10 to \$20, about the same as electricity. The replacement value of natural gas can therefore be surprisingly high and the imaginary well has a gasoline replacement reserve value of \$2 to \$4 million undiscounted. These numbers are order of magnitude, but it is apparent from the discussion that if coalbed methane can be used as a replacement for on-site gasoline or electricity, then the feasibility of drilling single wells should be carefully investigated.

The cost of on-site coal, if the mining costs are \$25 per tonne, is about \$1 per million Btu. The general advantages of replacing on-site coal use with gas are not obvious, and if there are advantages, they would derive from the specific details of a mining operation.

## IMPLICATIONS FOR METHANE IN UNDERGROUND MINES

Some general comments can be made about methane released from low-rank coals in underground mines. The data cannot be used to draw specific conclusions about methane in the Quinsam underground mine.

Methane is an explosive hazard underground if the concentration in the mine air is between 5 and 15%. Mine safety regulations in British Columbia require that the concentration be maintained below 1.0% for normal mine operation. In order to maintain sufficient ventilation it is important to know the rate of methane release per tonne of coal mined. It is also important to know if this value is going to fluctuate over short periods of time, or, as the mining face geometry changes. McCulloch *et al.* (1975) provide a plot for estimating the methane released per ton of coal mined based on the desorbed methane content of fresh coal. They indicate that the methane released is usually between 6 and 9 times the amount desorbed per ton.

Based on the present desorption data, coal from the Quinsam underground mine probably contains between 0.5 and 2.0 cubic metres per tonne, depending on rank, depth and ash content. Using the relationship of McCulloch *et al.* (1975), the methane released into the underground workings would be between 3 and 18 cubic

centimetres per gram (100 to 575 standard cubic feet) per ton of coal mined. McCulloch *et al.* indicate that the relationship only provides an estimate for mature mines that have constant production. An estimate of ventilation requirements can be obtained by multiplying daily coal production recalculated to an average of tons produced per minute by a methane release per ton value by 100. The 100 is to reduce the methane concentration to 1.0%. A million tonnes per year raw coal production averages out at about 2 tonnes per minute for 24-hour shifts. At this production rate ventilation requirements for methane extraction would range from 550 to 3250 cubic metres (20 000 to 115 000 cubic feet) per minute if the desorbed gas content is between 0.5 and 2.0 cubic centimetres per gram.

These ventilation requirements are calculated using data from low-rank samples that are undersaturated based on their predicted adsorption capacity (Figure 4). If coal is encountered that is of higher rank or is saturated, then the gas content could increase significantly and so would ventilation requirements.

The rate of desorption increases as the grain size of the coal decreases. If coal pillars are subjected to high strain-rates causing crushing, then this might cause an increase in the rate of methane desorption. Ongoing desorption tests, as the mine progresses, could help track any changes in rank or the degree of methane saturation of the coal. The rapid desorption of the footwall samples indicates that gas concentrations may be higher at the base of the seams. An increase in the amount of crushed coal in the lower part of the seam may signal increased gas desorption.

Methane desorbed from coal may collect in porous sandstones adjacent to the coal seams. A coal desorbing 1.0 cubic centimetre per gram at surface effectively has as much gas as a sandstone with 13.0% porosity at 100 metres, but the sandstone may expel its gas into the mine workings faster. The hangingwall of the seam 1 is a mudstone overlain by the seam 1 rider which is about 0.35 metre thick. The footwall is a soft, light grey mudstone seat earth. Undisturbed the hangingwall and footwall lithologies of seam 1 are probably relatively impermeable and will tend to contain the methane in the seam so that it will migrate up dip. Seam 3 often has a sandstone roof and a moderately strong mudstone or siltstone floor.

Specific comments on the methane ventilation requirements, or the need for methane drainage holes cannot be made based on this limited database.

## CONCLUSIONS

- Coal from the Quinsam coal mine does not contain high concentrations of methane. This is partly because of the low rank but also because the coal at depths of 100 and 150 metres is at least 30% under-saturated.
- When coals with low gas contents are desorbed it is important to accurately correct the data to standard temperature and pressure conditions, otherwise large percentage errors are introduced into the data.
- The methane resource potential of the Quinsam coalfield is low, but a single well could be an economic alternative to electricity for heating and gasoline for light vehicles.
- The desorbable methane content is higher in footwall coal than for the rest of the seam. This may be because footwall coal is more crushed and has scavenged methane. The broken nature of the footwall coal and its resulting high HGI correlate with faster methane release.

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