EUB/AGS Geo-Note 2004-01

Desorption and Adsorption of Coal in the Coal Valley Area, Alberta Foothills

Alberta Energy and Utilities Board
Alberta Geological Survey

EUB/AGS Geo-Note 2004-01

Desorption and Adsorption of Coal in the Coal Valley Area, Alberta Foothills

C. Willem Langenberg[1] and Ron Ronaghan[2]

[1] Alberta Geological Survey
[2] RJ Ronaghan Consulting

September 2004

ISBN 0-7785-3820-6

Langenberg, C.W. and Ronaghan, R. (2004): Desorption and adsorption of coal in the Coal Valley area, Alberta Foothills; Alberta Energy and Utilities Board, EUB/AGS Geo-Note 2004-01.

Author address:
RJ Ronaghan Consulting
Box 5102
Hinton, Alberta
T7V 1X3

Published September 2004 by:
Alberta Energy and Utilities Board
Alberta Geological Survey
4th Floor, Twin Atria Building
4999 – 98th Avenue
Edmonton, Alberta
T6B 2X3
Canada

Tel: (780) 422-3767 (Information Sales)
Fax: (780) 422-1918
E-mail: EUB.AGS-Infosales@gov.ab.ca

Web site: www.ags.gov.ab.ca

Contents

Figures

Tables

Acknowledgments

Dave Marchioni, Marc Bustin, Wolfgang Kalkreuth and Andrzej Skupinski are thanked for supplying reports on components of the work. Andrew Beaton is thanked for reviewing the report.

Abstract

Coal quality data were obtained for coal from the Val d'Or seam, which was cored from a hole drilled at location 10-25-47-21W5. Desorption of 16 samples from the Val d'Or coal seam of the Coalspur Formation revealed an average dry-ash-free gas content of 5.59 cc/g. Proximate analysis and vitrinite reflectance measurements indicate a high-volatile bituminous C rank for these coals. High-pressure methane adsorption analysis indicates a storage capacity of 3.94 cc/g (dry-ash-free) of one of the samples. About 80% of the cleats are open and not filled with calcite, indicating the potential for permeability. These data indicate that the coalbed methane reservoir might be over-saturated in methane, that free gas may be present in the cleat system and that the reservoir might be producible.

1 Introduction

The Alberta Geological Survey (AGS) obtained desorption and adsorption data from coal cored from a drillhole located at 10-25-47-21W5, at UTM location 504,500 m East; 5881,685 m North (Zone 11; NAD27) in the Coal Valley area. This coalhole was drilled into the Val d'Or seam of the Coalspur Coal Zone (Coalspur Formation) of Tertiary age. The core includes Val d'Or subseams AA, A, B, C, D, E, F, G and H (Table 1). The core was collected to characterize coal of the Entrance Syncline of the Coal Valley map area (Langenberg and LeDrew, 2001). The location of this hole enabled the possibility to verify predictions on gas content by Langenberg et al. (2002). The core was obtained according to coal exploration standards.

Drilling took place July 22 to 23, 2002 and desorption continued into December 2002. The coal was cored by a track-mounted rotary rig using wireline retrieval of a 3-metre long core barrel. Recovery of the 5-centimetre diameter core was very good. The core description and location of samples (canisters 1 to 16) are given in Table 1. Some additional samples collected for petrography are also indicated in Table 1.

Sixteen coal samples, each about 40 centimetres in length, were desorbed at 19 degrees Celsius. All samples were subjected to proximate and density analyses after desorption was complete. The percentage of vitrinite reflectance was determined on four of the samples. The desorbed gas of two of the samples was analyzed to determine its components. One of the samples (canister 3) was selected for high-pressure methane adsorption analysis.

2 Coal Quality

Proximate and density analysis were performed on all 16 samples. The results are listed in Table 2. Ash content is generally lower than 15%, but 3 samples are above 30% (canisters 1, 4 and 14). The average ash (as received) is 14.3% (Table 3). The core description of these high-ash samples indicates that the three samples include some shaley horizons. Mineral matter can occur in shaley layers, as grains within the coal and as mineral filling along cleats or bedding parallel fracture.

Rank can be determined chemically or optically. Dry-ash-free volatile matter ranges from 40.7% to 47.1% with an average of 43.5% (Table 3). The average reflectance of four samples of which mean vitrinite reflectance in oil was measured is 0.54%. These data indicate a high-volatile bituminous C rank (Bustin et al., 1989). Equilibrium moisture was determined of one sample (canister 3) to be 12.5%, also indicating this rank.

3 Cleats

The core description reveals cleats at 1 mm spacing in bright coal layers and 5 mm spacing in banded-bright and banded layers. Dull coal layers contain fewer cleats. Cleats crosscutting the bedding commonly form irregular networks. Mineral filling of cleats varies. In most of the core, about 10% of cleats are filled with calcite. Locally, 50% of the total volume of cleats is filled with calcite. Some bedding parallel fractures are also filled with calcite (Figure 1, C and D).

Three coal samples were studied in thin section: two banded bright lithotypes and one banded lithotype. From these thin sections, an estimate of aperture width and percentage of mineral filling of the cleats could be made. In addition, observations on cavities were made.

Table 1. Core description and location of samples

Core/sample	Depth top interval m	Thickness m	
Run 1	282.00	0.2	Banded Coal - AA
		0.45	Siltstone with Coaly stringers
		0.025	Bentonite light grey-green soft wet- sample 10-25-Min2
		0.035	Banded coal, good cleating
		0.015	Bentonite light grey green soft wet
Canister 1	282.73	0.05	Banded Coal - looked gassy - cleating: 5 mm; in bright: 1 mm. Rank sample 6-25-R1
Canister 1		0.01	Dull Coal
Canister 1		0.11	Banded coal, very little cleating
Canister 1		0.09	Banded Dull Coal, some calcite veining
Canister 1		0.03	Shale (Siltstone)
	283.02	0.13	Shaley Coal
		0.16	Silty Sandstone grey, massive, lower contact bentonitic
		0.34	Banded dull to dull coal, clay blebs, some calcite fractures at approx. 2 cm spacing, some visible gas
		1.09	Siltstone, grey to grey, banded, locally carbonaceous, bottom dirty coal, some slicks on shear planes at top.
		0.03	Banded, bright coal, good cleating - top 'A'
Run 2	284.77	0.29	Banded bright. Some 5 mm cleats are calcite filled. Parallel bedding calcite present. Sample 10-25-Min4
		0.02	Dull
Canister 2	285.08	0.31	Banded bright
Canister 3	285.39	0.31	Banded bright, minor calcite, bright layers micro cleating (1 mm)
Canister 4	285.70	0.23	Banded bright, minor calcite, bright layers micro cleating (1 mm spacing), 1 cm cleating in duller bands
Canister 4		0.08	Dull coal, lower contact shaley
		0.1	Bentonitic mudstone, dull brown, medium hard
		0.1	Banded bright - top 'B'
Canister 5	286.21	0.31	Banded bright, minor calcite veining parallel to bedding, 5 mm cleating, 1 mm in bright, some cleats have calcite
Canister 6	286.52	0.31	Banded bright, minor calcite veining, top 2 cm: rank sample 6-25-R2
		0.18	Banded bright, minor calcite, minor amber, sample 10-25-Min1 at 286.46m (old depth designation)
		0.72	Sandstone (between B and C) light grey, upper carbonaceous zone, weakly banded, coaly stringers, fine to med grained
Run 3	287.73	0.3	Sandstone light grey, upper carbonaceous zone, weakly banded, coaly stringers, fine to medium-grained
		0.08	Banded dull, blebs of sandstone - top 'C'
		0.12	Interbanded dull coal and shale
		0.06	Dull banded, some amber, 2 cm cleating
Canister 7	288.29	0.07	Dull banded
Canister 7		0.04	Banded bright, bedding parallel calcite, silty blebs
Canister 7		0.2	Banded bright, very minor calcite, micro cleating in bright layers, cm cleating in dull layers
		0.09	Banded bright, some calcite veining bedding parallel
		0.03	Silty mudstone
		0.18	Banded coal, brighter bands micro cleating, fairly well cleated - some calcite on face cleats
		0.19	Siltstone, good bedding, rooted (picture)
Canister 8	289.09	0.04	Dull coal - top 'D'
Canister 8		0.24	Banded bright, bottom: rank sample 6-25-R3
		0.2	Banded bright
		0.11	Siltstone, Bentonitic, brown
		0.04	Dull coal
		0.16	Carbonaceous shale, dull black - calcite vein at 45 degrees
		0.12	Bright banded, well cleated, some calcite parallel bedding and some parallel to face cleats, visible gas bubbling - top 'E'
Run 4	290.00		
Canister 9	290.00	0.48	Banded bright, broken - milled, well cleated
Canister 10	290.48	0.33	Banded bright, some calcite parallel face cleats, blocky, from canister 10: rank sample 6-25-R4
Canister 11	290.81	0.46	Banded bright, some calcite parallel bedding, broken and milled
Canister 12	291.27	0.25	Banded coal
		0.06	Banded bright, minor calcite parallel to bedding, very good cleating, 5 mm cleating in dull bands, 1 mm in bright bands
		0.12	Banded bright
		0.06	Shaley Coal
		0.13	Silty mudstone, bentonitic, dull brown
		0.1	Banded Coal
		0.045	Carbonaceous shale, dull black
		0.16	Banded coal, calcite parallel bedding, weakly cleated, top 'F', visible gas, minor calcite parallel face cleat
Canister 13	292.19	0.32	Banded bright, shale bleb, calcite parallel bedding
		0.36	Banded bright- well cleated, some calcite parallel bedding, minor calcite parallel face cleats, visible gas
Run 5	292.87		
Canister 14	292.87	0.26	Banded, well cleated, some amber, minor calcitic veining
Canister 14		0.05	Dull Coal
		0.05	Dull Coal
		0.03	Shale with carbonaceous streaks
		0.03	Dull Coal
		0.05	Coaly shale, calcite stringers mainly parallel bedding (veins) at the bottom
		0.05	Banded coal - top 'G' - Sample 10-25-Min3
Canister 15	293.39	0.22	Banded bright, some calcite veining parallel bedding, face cleats 5 mm spacing, in bright layers 1 mm
Canister 15		0.08	Banded dull
		0.23	Banded coal, well cleated, minor calcite
		0.15	Carbonaceous shale with small bands of bentonite
Canister 16	294.07	0.15	Banded dull, calcite parallel bedding - top 'H'
Canister 16		0.13	Banded bright, some amber
		1.26	Sandstone, grey, well bedded, with cross-bedding
Bottom core	295.61		
Length core		13.61	

Table 2. Proximate and ultimate analyses of 16 canister samples.

Canister ID	SAMPLE wt, g		ADM%	MOIST%	ASH%	VOL%	F.C.%	SG	BASIS
	WET	DRY							
	1672	1573	5.92	2.31	34.14	29.07	34.48	1.60	adb
1				8.09	32.12	27.35	32.44		arb
					34.95	29.76	35.30		db
	1660	1587	4.40	3.35	7.26	38.19	51.20	1.36	adb
2				7.60	6.94	36.51	48.95		arb
					7.51	39.51	52.97		db
	1295	1258	2.86	2.82	9.85	38.32	49.01	1.38	adb
3				5.60	9.57	37.23	47.61		arb
					10.14	39.43	50.43		db
	1966	1900	3.36	3.10	31.87	29.28	35.75	1.56	adb
4				6.35	30.80	28.30	34.55		arb
					32.89	30.22	36.89		db
	1753	1691	3.54	4.10	6.87	38.10	50.93	1.37	adb
5				7.49	6.63	36.75	49.13		arb
					7.16	39.73	53.11		db
	1715	1657	3.38	3.62	8.82	37.56	50.00	1.39	adb
6				6.88	8.52	36.29	48.31		arb
					9.15	38.97	51.88		db
	1771	1704	3.78	4.10	22.16	32.80	40.94	1.49	adb
7				7.73	21.32	31.56	39.39		arb
					23.11	34.20	42.69		db
	1520	1464	3.68	3.71	14.32	35.81	46.16	1.42	adb
8				7.26	13.79	34.49	44.46		arb
					14.87	37.19	47.94		db
	1588	1480	6.80	3.55	7.51	36.21	52.73	1.38	adb
9				10.11	7.00	33.75	49.14		arb
					7.79	37.54	54.67		db
	1607	1549	3.61	3.99	6.98	38.13	50.90	1.37	adb
10				7.46	6.73	36.75	49.06		arb
					7.27	39.71	53.02		db
	1726	1592	7.76	3.42	6.28	37.56	52.74	1.35	adb
11				10.92	5.79	34.64	48.65		arb
					6.50	38.89	54.61		db
	1771	1703	3.84	3.49	12.43	36.70	47.38	1.41	adb
12				7.20	11.95	35.29	45.56		arb
					12.88	38.03	49.09		db
	1783	1710	4.09	3.81	9.25	36.75	50.19	1.39	adb
13				7.75	8.87	35.25	48.14		arb
					9.62	38.21	52.18		db
	1948	1861	4.47	2.81	30.34	31.49	35.36	1.54	adb
14				7.15	28.99	30.08	33.78		arb
					31.22	32.40	36.38		db
	1500	1427	4.87	2.94	12.56	35.26	49.24	1.40	adb
15				7.66	11.95	33.54	46.84		arb
					12.94	36.33	50.73		db
	1258	1200	4.61	3.16	18.51	34.88	43.45	1.44	adb
16				7.62	17.66	33.27	41.45		arb
					19.11	36.02	44.87		db

Table 3. Gas content of coal core.

Canister	Depth (m)	Lost Gas (scf/t)	Desorbed Gas (scf/t)	Residual Gas (scf/t)	Total Gas (as received)		Gas (dry) (cc/g)	Gas (daf) (cc/g)	Reflect. Ro (mean)	Vol. Mat. daf	Moisture (as received)	Ash % (as received)	Ash % (dry)
					(scf/t)	(cc/g)							
1	282.7	11.29	96.28	6.94	114.51	3.57	3.89	5.98	0.59	45.74	8.09	32.12	34.95
2	285.1	4.69	125.91	1.73	132.33	4.13	4.47	4.83		42.72	7.60	6.94	7.51
3	285.4	4.10	156.79	24.21	185.1	5.78	6.12	6.81		43.88	5.60	9.57	10.14
4	285.7	2.23	87.01	14.39	103.63	3.23	3.45	5.15		45.03	6.35	30.80	32.89
5	286.2	4.13	127.13	3.30	134.56	4.20	4.54	4.89		42.79	7.49	6.63	7.17
6	286.5	3.05	128.86	15.64	147.55	4.61	4.95	5.44	0.55	42.90	6.88	8.52	9.15
7	288.3	2.78	110.72	14.58	128.08	4.00	4.33	5.63		44.38	7.73	21.32	23.11
8	289.1	3.82	133.41	15.39	152.62	4.76	5.14	6.03	0.51	43.69	7.26	13.79	14.87
9	290.0	4.84	135.75	9.75	150.34	4.69	5.22	5.66		40.71	10.11	7.00	7.79
10	290.5	2.78	128.86	28.54	160.18	5.00	5.40	5.83	0.51	42.83	7.46	6.73	7.27
11	290.8	3.77	128.13	15.47	147.37	4.60	5.16	5.52		41.59	10.92	5.79	6.50
12	291.3	3.63	131.71	9.29	144.63	4.51	4.86	5.58		43.65	7.20	11.95	12.88
13	292.2	5.37	124.36	29.44	159.17	4.97	5.39	5.96		42.27	7.75	8.87	9.62
14	292.9	2.58	84.76	24.24	111.58	3.48	3.75	5.45		47.11	7.15	28.98	31.21
15	293.4	5.20	131.04	13.96	150.2	4.69	5.08	5.83		41.73	7.66	11.95	12.94
16	294.1	4.91	103.38	7.92	116.21	3.63	3.93	4.85		44.53	7.62	17.66	19.12
	MEAN	4.32	120.88	14.67	139.88	4.37	4.73	5.59	0.54	43.47	7.68	14.29	15.44

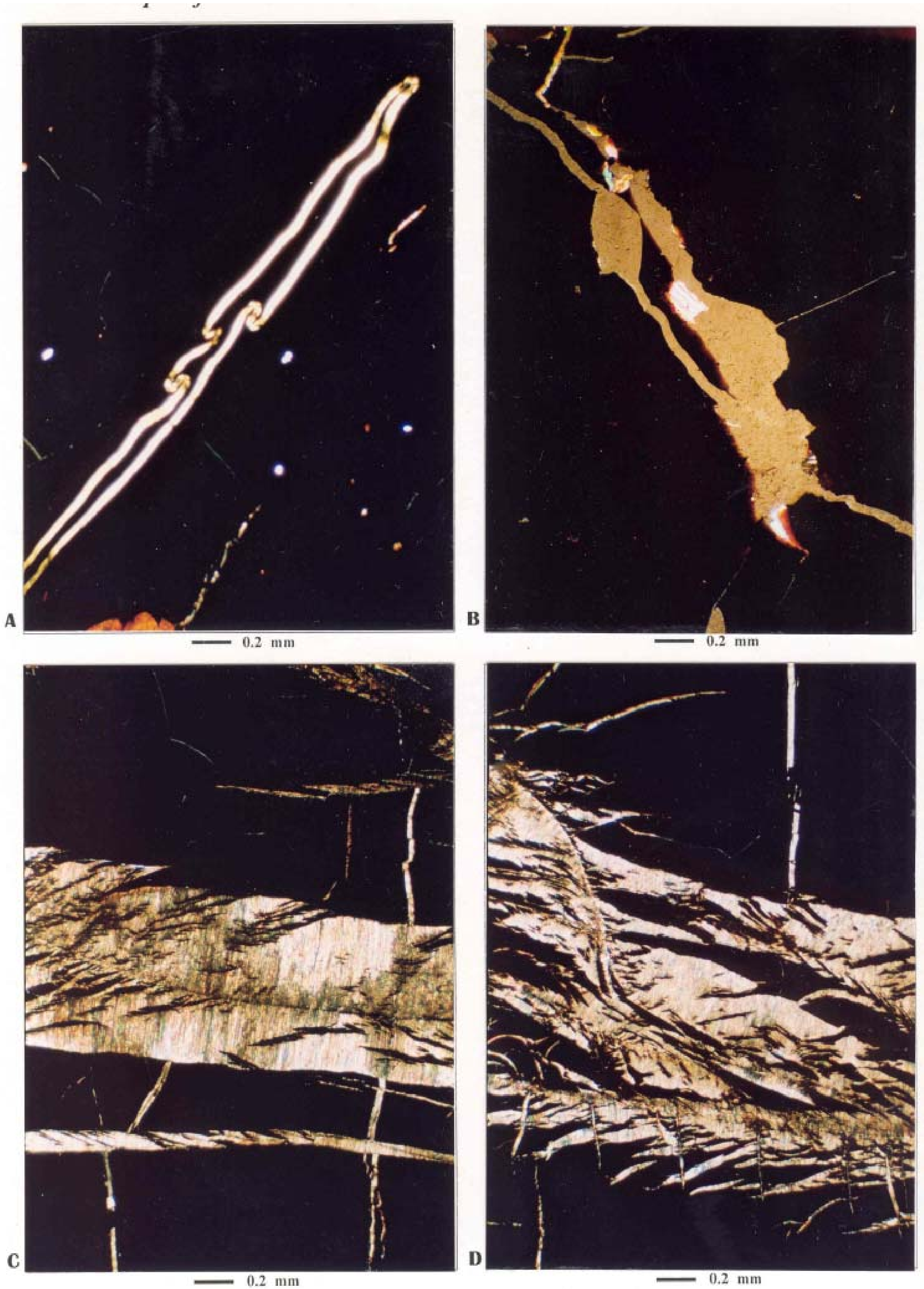


Figure 1. Photomicrographs of thin sections of coal. A) Enigmatic liptinite (?) maceral included in vitrinite. B) Cavities with small calcite crystals. C) Cluster of calcite veins and cleats. D) Cluster of calcite veins and cleats.

The aperture of cleats varies in width from 0.01 mm to about 0.02 mm; occasionally the aperture is up to 0.3 mm in width. Infrequently, cleats are connected with small cavities, which are about 0.2 mm in width and 0.5 mm in length. The cavities are open, except about 5% of the space that is filled with calcite. Cavities parallel to bedding are also present.

In banded coal, cleats show spacing of up to 12 mm and cavities are frequently developed along them. Both cavities and cleats are usually empty. Less than 5% of their volume is filled with calcite.

In places, cleats occur that are oriented diagonally to bedding. These cleats are shorter and thinner than cleats of the perpendicular system. Their aperture is about 0.02 mm in width. Very frequently, they are connected with calcite veins that are parallel to bedding. They are filled with calcite in more than 70% of the cases. Very rare infillings of quartz also occur.

4 Gas Content

In-situ gas content was measured by placing 16 coal samples in sealed vessels (canisters) and recording the volume of desorbed gas over an extended period. This procedure was terminated when gas ceased to desorb. The samples were maintained at reservoir temperature (19^{o} Celsius) for 77 days to facilitate an accurate assessment of gas lost during the trip up-hole. After 77 days (1850 hours), the temperature was increased to 38^{o} Celsius to quickly drive-off the remaining gas from the coal. The final desorption data are given in Table 3.

Total gas content of a sample comprises desorbed gas, lost gas and residual gas (Table 3). Lost gas was estimated using the U.S. Bureau of Mines "direct method." The residual gas volume could be estimated from the desorbed gas data because of a linear relationship near the end of the desorption period. These gas volumes are also listed in Table 3.

After sealing the coal core in pressure canisters and placing them in a heat box maintained at reservoir temperature, desorbed gas was released at the volume measured at regular intervals, until desorption ceased. In the early stages, desorbed gas volumes were measured frequently, every 5 to 10 minutes, to clearly define the steepest part of the desorption curve and to facilitate an accurate estimate of the lost gas component. As desorption rates declined, the measurement interval was increased to hours and eventually to days. Complete desorption required a period of several weeks. Desorption was allowed to continue until the gas desorbed between measurements made no significant impact on the total desorbed gas volume. In practice, desorption is usually discontinued when the volume falls below 10cc/day from a canister. Cumulative desorbed gas volume was plotted versus total desorption time to provide a desorption curve for each sample (Figure 2).

Total gas content ranges from 3.48 to 5.78 cc/g (average 4.37) when measured on an as-received basis and from 4.85 to 6.81 cc/g (average 5.59 cc/g) on a dry-ash-free basis (Table 3). Residual and lost gas components are estimates only and perhaps subject to error, but represent only small parts of the total values. These gas contents are higher than the ones reported for the Silkstone and Mynheer seams of the Coal Valley mine, which showed an average gas content of 2.6 cc/g from samples collected between 200 and 300 m depth (Das et al., 1982). The measured gas contents are also higher than gas contents reported for Ardley coal of equivalent rank to the east, where the coal is 500 to 600 m deep (Dawson et al., 2000).

As can be expected for samples with little rank variation (as discussed above), there is a scattered linear relationship between gas and ash content (on an as-received basis), as shown in Figure 3.

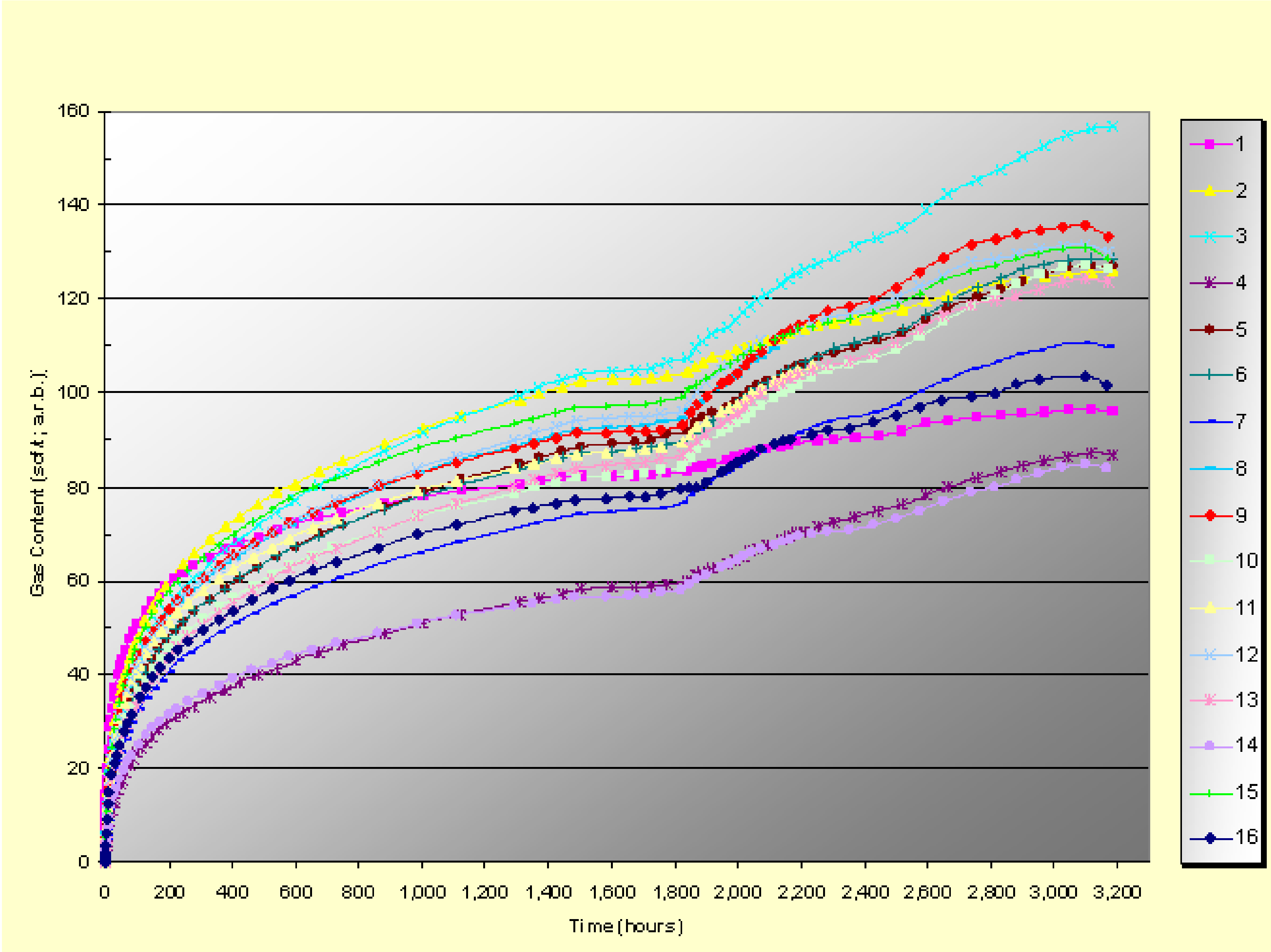


Figure 2. Desorption curves for all 16 samples.

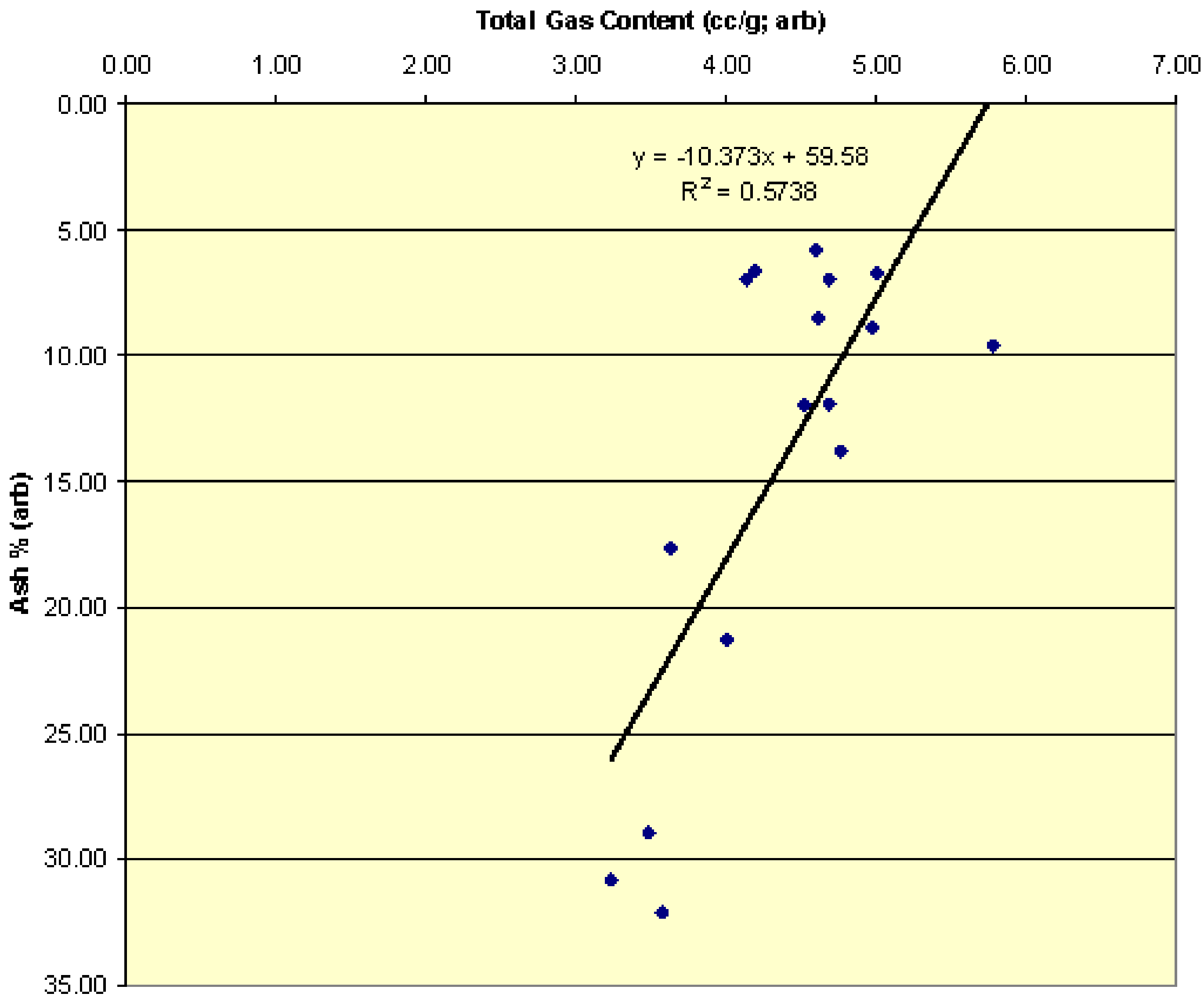


Figure 3. Relationship between total gas and ash (as received).

Analysis of desorbed gas indicates that about 99% of the gas is methane and no CO_2 is present (Table 4).

5 Methane Adsorption

High-pressure methane adsorption was carried out on the sample from canister 3, which is from 285 m depth. This sample was selected after 77 days, in which it seemed to behave representatively for all 16 samples. The relatively large and anomalous increase in gas release after the sample was heated to 38^o Celsius (Figure 2) was unexpected. This anomalous behaviour might be explained by possible biogenic action of the water in the canister (Dave Marchioni, pers. comm., 2003). The sample was weighed, crushed and placed in an equilibrium moisture bath for two weeks. A temperature of 19^o Celsius was maintained for analysis. The results of this analysis are listed in Table 5.

The amount of adsorbed gas can be predicted using the Langmuir Equation (Langmuir, 1916). A plot of the ratio of gas pressure and adsorbed gas volume versus gas pressure should yield a straight line (Figure 4). The difference between the measured amount of adsorbed gas and that predicted by the Langmuir Equation is a measure of error. The goodness of fit of the measured adsorbed gas contents to the Langmuir Equation can be expressed by the correlation coefficient between the measured and predicted values. The sample obtained a correlation coefficient of $r^2=0.98$, which is a good fit (Figure 4).

No information on reservoir pressure is available for this area. The closest drill-stem test data point is from well 00/05-36-47-22W5, where a shut-in reservoir pressure of 22.4 MPa was measured at 2593 m depth. This pressure implies a pressure gradient of 8.6 kPa/m, which is similar to a normal water pressure gradient of 9.8 kPa/m. Using a pressure gradient of 9.8 kPa/m, a reservoir pressure of 2.8 MPa can be assumed. The equilibrium pressure plot for the sample (Table 5) indicates a storage capacity of 3.94 cc/g (dry-ash-free) at 2.8 MPa pressure. The measured, dry-ash-free gas content for this sample is 6.81 cc/g (Table 3), which might indicate the reservoir is over-saturated at present. A much higher reservoir pressure during burial is indicated by erosion of 3 km of overburden since maximum burial, which is generally accepted (Kalkreuth and McMechan, 1996). Over-saturation of this coalbed methane (CBM) reservoir indicates free gas may have been present in the cleat system, which was measured during desorption and added to the total (Marc Bustin, pers. comm., 2003). About 80% of the cleats are open and not filled with calcite, indicating the potential for permeability.

6 Petrography in Thin Section

Three coal samples were examined in thin section: two banded-bright samples and one banded. In addition, a contact zone between coal and bentonite was studied.

Sample MIN 1

Sample MIN 1 was collected at a depth of 286.85 m and is banded bright. The texture shows a groundmass consisting mostly of vitrinite group macerals. Along the bedding plane, wedge-like, cellular-textured macerals, up to 1 mm in width, occasionally occur. Their cellular voids are carbonatized and filled with unidentified clay.

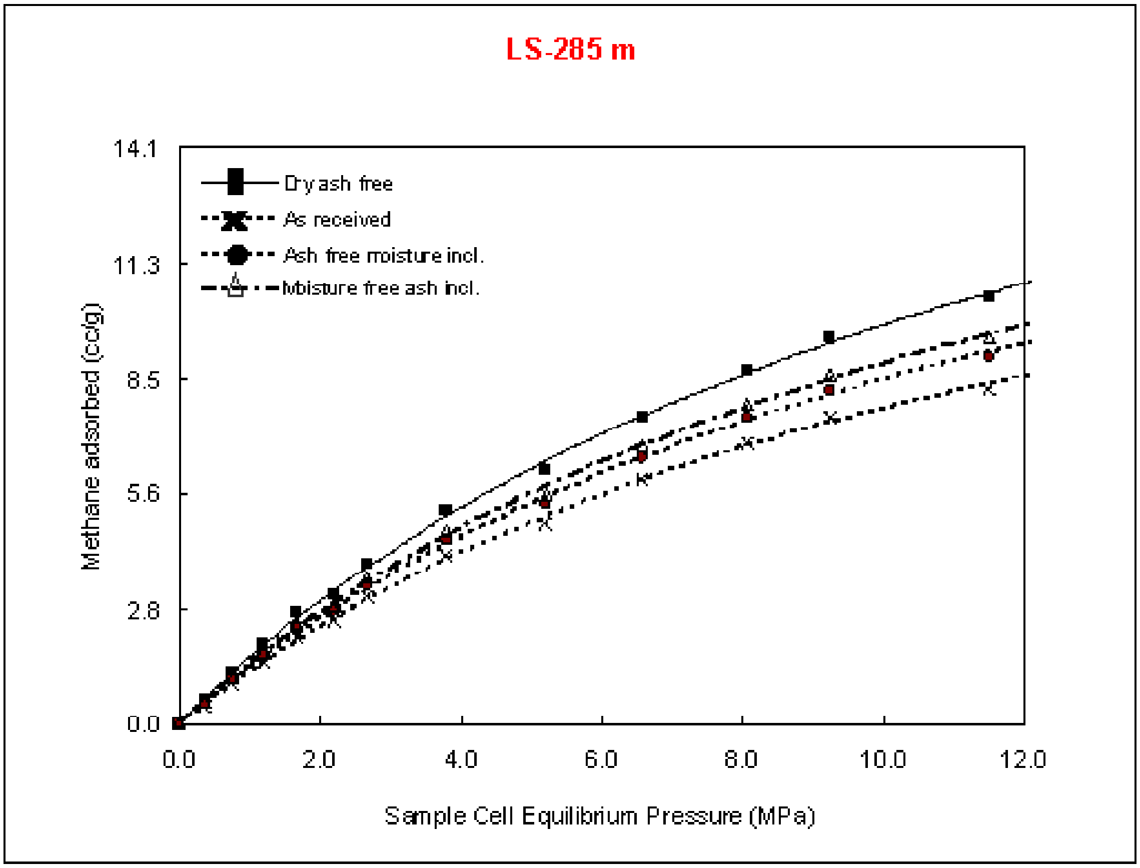
Stringy macerals of unknown origin (liptinite?) are occasionally included in vitrinite (Figure 1A). They are frequently folded and yellow. In double polarized light, they show biaxial (negative) optical character. Clusters of calcite and quartz veins are occasionally present along the bedding plane.

Table 4. Desorbed gas composition of 2 canisters.

Canister	Canister 2 (285.7 m)			Canister 12 (296.6 m)				
Lab	Lab. 1	Lab. 1	Lab. 1	Lab. 1	Lab. 1	Lab. 2	Lab. 2	Lab. 2
Hrs Desorbed	39.6	246.1	601.0	71.0	228.3	583.2	1294.3	2190.4
Proportion of Gas Desorbed	29.6%	52.3%	65.1%	30.1%	44.3%	56.7%	70.0%	87.5%
H_2	NR	NR	NR	NR	NR	0.00%	0.00%	Tr
He	NR	NR	NR	NR	NR	0.00%	0.04%	Tr
N_2	0.00%	0.00%	0.00%	0.00%	0.00%	10.89%	0.71%	1.18%
CO_2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
H_2S	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
methane	99.35%	99.62%	99.37%	100.00%	100.00%	89.10%	99.25%	98.79%
ethane	0.60%	0.33%	0.63%	0.00%	0.00%	0.01%	0.00%	0.03%
butane	0.04%	0.05%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
TOTAL	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Liquids (mL/cub m)	0.7	1.5	1.8	0	0	0	0	0

Note: Analyses by Lab. 1 (all of canister 2 and samples at 71 and 228.3 hours in canister 12) do not report H_2 or He.Lab. 1 analyses have been recalculated to a nitrogen and air-free basis. As they do not measure oxygen they are unable to assign a proportional volume of nitrogen to air contamination. The Lab. 2 data are recalculated to an air-free basis.

Table 5. Summary of adsorption analysis.



Pressure (MPa)	Adsorbed gas (cc/g)			
	As Received	**Moisture-free ash incl.**	**Ash-free moisture incl**	**Dry-Ash-Free**
0.366	0.46	0.52	0.50	0.58
0.750	0.98	1.12	1.07	1.24
1.209	1.53	1.75	1.67	1.94
1.686	2.14	2.44	2.33	2.70
2.206	2.51	2.87	2.74	3.18
2.677	3.12	3.56	3.40	3.94
3.806	4.13	4.72	4.51	5.23
5.211	4.91	5.61	5.36	6.20
6.573	5.94	6.79	6.49	7.52
8.068	6.85	7.83	7.48	8.66
9.245	7.49	8.56	8.18	9.47
11.500	8.25	9.42	9.01	10.43
Langmuir Parameters				
	As Received	**Moisture-free ash incl.**	**Ash-free moisture incl**	**Dry-Ash-Free**
Vol. (cc/g)	17.74	20.27	19.37	22.43
Pressure (MPa)	12.97	12.97	12.97	12.97
SUMMARY OF ADSORPTION ANALYSES SI UNITS Isotherm Temperature: 19.0 ºC Goodness of fit of Langmuir regression: 0.98% Ash= 8.43% Moisture =12.49 Density = 1.380				

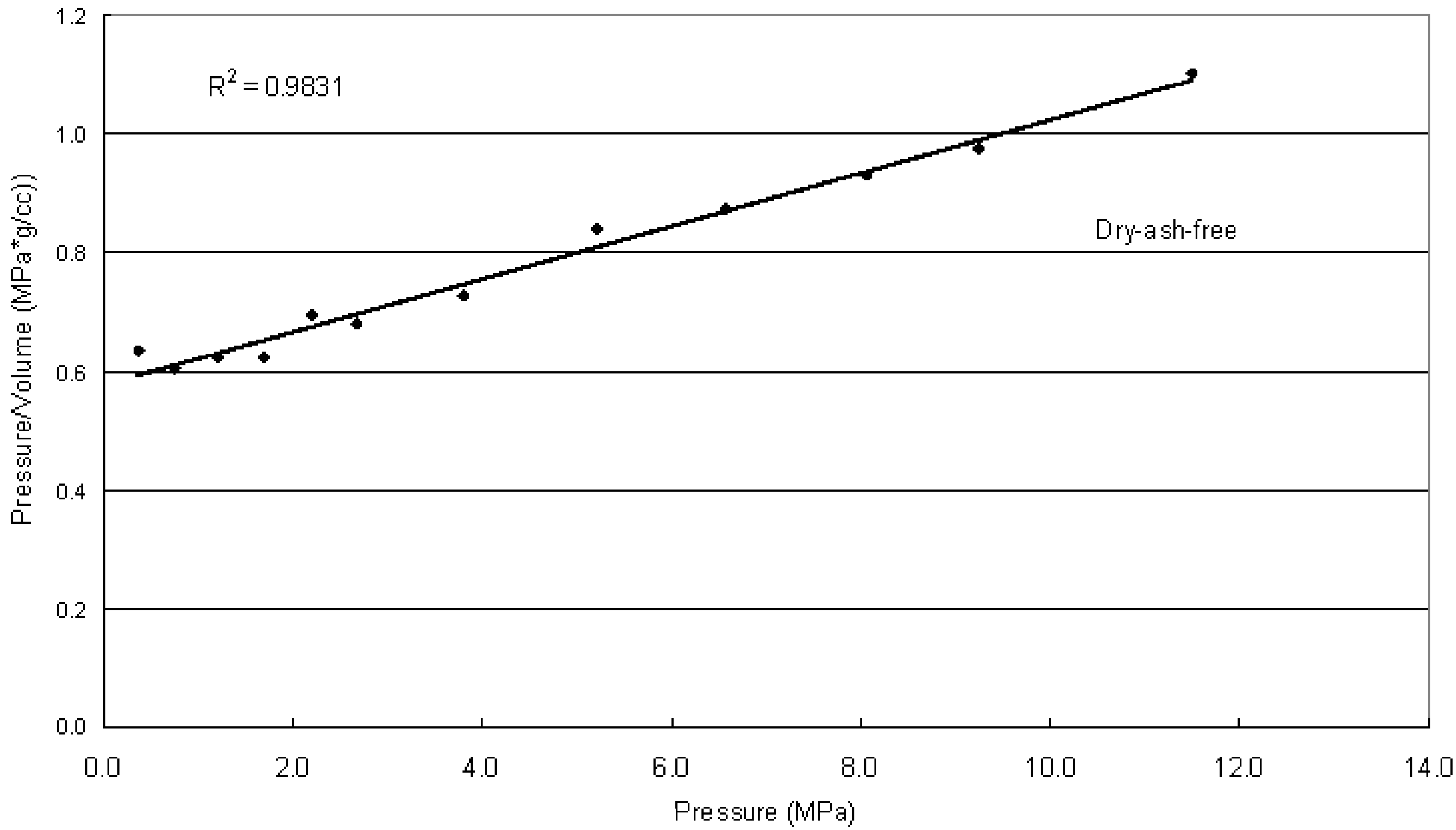


Figure 4. Adsorption Langmuir Plot for canister 3 sample.

Many quartz detrital grains, mostly up to 0.02 mm in size, are randomly distributed in the vitrinite groundmass. Particles of quartz are mostly subangular to angular. No sorting, lamination or banding can be observed in the detrital quartz distribution. Due to the small sizes, their provenance is not possible to determine.

The cleats form networks. They usually crosscut the bedding plane at angles between 45 and 90 degrees. Thickness of cleats varies from 0.01 mm to about 0.02 mm. Cavities are sometimes present along the cleats, which are about 0.2 mm in width and 0.5 mm in length (Figure 1B). Besides cleats crosscutting the bedding, fractures oriented parallel to bedding also occur.

Up to 10% of cleats and less than 5% of the cavities, are totally or partially cemented by calcite.

Sample MIN 2

Sample MIN 2 was collected at a depth of 282.7 m and includes the base of a 2-centimetre thick bentonite layer. Three zones showing diverse mineralogical content, adjacent to each other, can be roughly distinguished from bottom to top:

1. Bottom zone: Brecciated coal (mainly vitrinite) with irregular-shaped, elongated vugs filled with smectite group phyllosilicates and minor kaolinite. Some broken vitrinite particles, up to 5 mm in size, are cemented by bentonite. Some of these show cellular textures from incorporated wood particles. In vitrinite, occasionally clastic grains of mosaic-textured quartz occur, up to 1.5 mm in size. Rare vugs are partly cemented by authigenic, euhedral quartz crystals, about 0.05 mm in diameter. Nodular inclusions of phosphate occasionally occur in vitrinite as well. The cleats, due to tectonic deformation of vitrinite, are very irregular in shape and cannot be classified by size or orientation. They are mostly filled with quartz and clay.
2. Middle zone: Immediately adjacent to the coal, is a comb- and radial-textured carbonate (ankerite or dolomite?) zone. The carbonate occurs as elongated, partly vermicular aggregates, which are cemented by mixed smectite/kaolinite phyllosilicates. The external part of this zone is enriched in fine-grained bentonite with randomly included clastic grains of quartz and feldspar (plagioclase and microcline), up to 0.05 mm in size. In addition, crystals of kaolinite, up to 0.1 mm in size, uncommonly occur in the fine-grained bentonite groundmass.
3. Top zone: Comprised largely of very fine-grained, textured bentonite with included kaolinite crystals (optically negative), up to 0.2 mm in size. The zone gradually becomes richer in kaolinite toward the top. Clastic grains are very rare in this zone; however, one K-feldspar grain has been found.

Sample MIN 3

Sample MIN 3, collected at a depth of 293.3 m, is banded and consists mostly of vitrinite. Locally vitrinite is intergrown with clusters of calcite and quartz veins oriented approximately parallel to bedding. On the sample border, vitrinite is intergrown with quartz-rich shale, which detrital particles are cemented by coal maceral. The detrital grains vary in size from coarse silt to fine sand (~0.2 mm). They are angular to very angular. Elongated grains show a marked arrangement parallel to bedding. The most of detrital grains are quartz and muscovite. Less abundant mineral constituents are cherts and plagioclase (albite/oligoclase). Infrequently, angular grains of vitrinite are incorporated in shale as well.

Disseminated quartz grains are common in vitrinite and are up to 0.1 mm in size. Occasionally, quartz grains are subhedral in shape. In addition, detrital grains occur as small-scale bands parallel to bedding planes. Fibrous anisotropic macerals (liptinite?), described in sample MIN 1, are also occasionally present.

Cleats crosscutting the bedding can be roughly divided into two systems:

1. System perpendicularly bedding

   This system is very regular with thickness variable from 0.04 mm to 0.2 mm. The cleats are distant to each other, up to 12 mm. Along the perpendicular system of cleats, frequently cavities are developed. Both cavities and cleats are usually empty. Less than 5% of their volume is infilled with calcite.

2. System diagonal to bedding

   The cleats are shorter and thinner than cleats of the above system. Their thickness is about 0.02 mm in width. Very frequently, they are connected with the veins parallel to bedding. They are infilled with calcite in more than 70%. Very rare infillings of quartz also occur.

Sample MIN 4

Sample MIN 4 was collected at a depth of 284.8 m depth and is banded bright. The sample consists almost entirely of vitrinite, with only minor interbedded inclusions of other macerals (liptinite and inertinite). A few detrital grains (mostly quartz) are unevenly distributed in vitrinite. The quartz grains are angular, and up to 0.05 mm in size. Elongated pyrite grains are randomly distributed in vitrinite. The pyrite grains are frequently intergrown with fine-grained clay (illite?) and show framboidal textures. Inertinite macerals included in vitrinite are mostly lensoidal in shape (Figure 5 C). Detrital grains, about 0.01 mm in size, are usually included in them. Fibrous, birefringent macerals, as described in sample MIN 1, occasionally occur as well. In thinner parts of the vitrinite section, diverse textures from uniform, glass-like to woody cellular tissue are recognized (Figure 5 A).

The vitrinite groundmass is cut by fractures and wedge-like clusters of calcite veins (up to 2 mm in width), which are mainly oriented parallel to the bedding plane (Figure 1, C and D). However, diagonal veins are also present (Figure 5 D). Very regular systems of cleats, varying in width from 0.01 mm to about 0.3 mm, cut the bedding plane at angles of about 80 to 90 degrees (Figure 1, C and D; Figure 5B). The fractures, which are oriented parallel to the bedding plane, are mostly empty. About 50% of cleats that cut the bedding plane at high angles are cemented by calcite. After calcite cementation, the tensional strain in coal was probably continually in progress, as many of the cleats are open between cemented matter and their walls.

Calcite is the only cementing matter, as quartz infillings have not been found. Except for cleats and fractures, cavities of different shape frequently occur in both directions parallel and perpendicular to the bedding plane. Most commonly, the cavities are not cemented by calcite and are open.

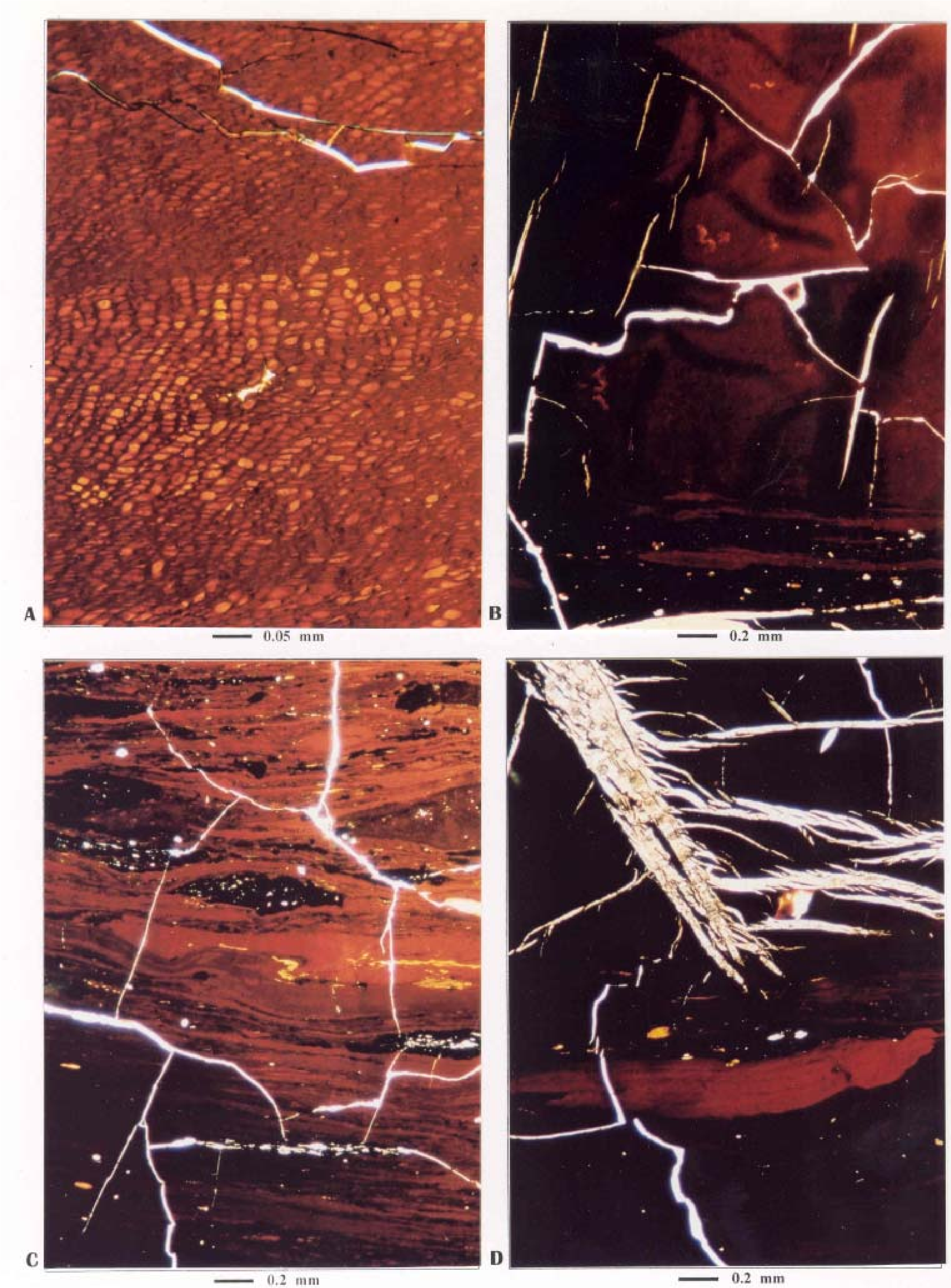


Figure 5. Photomicrographs of thin sections of coal. A) Cellular textured vitrinite. B) Vitrinite with open cleats (white) and calcite-filled cleats (yellow, mainly vertical). C.) Vitrinite with lensoidal inclusions of possible inertinite (black and enriched in white detrital matter). D) Clusters of calcite veinlets with lateral openings in vitrinite.

7 Conclusions

Desorption of 16 samples from the Val d'Or coal seam of the Coalspur Formation obtained an average dry-ash-free gas content of 5.59 cc/g. Proximate analysis and vitrinite reflectance measurements indicate a high-volatile bituminous C rank for these coals. High-pressure methane adsorption analysis indicates a storage capacity of 3.94 cc/g (dry-ash-free) of one of the samples. About 80% of the cleats are open and not filled with calcite, indicating the potential for permeability. These data indicate the CBM reservoir might be over-saturated in methane and free gas may be present in the open cleat system.

Additional drilling and production testing will be necessary to answer questions about the permeability and producibility of this reservoir.

8 References

Bustin, R., Cameron, A., Grieve, D. and Kalkreuth, W. (1989): Coal petrology – its principles, methods and application; Geological Association of Canada, Short Course Notes, Volume 3, 276 p. (3rd edition).

Das, B., LaRoque, G., Tajcnar, L. and Chiang, B. (1982): Methane desorption study on borehole coal samples at Coal Valley, Alberta; Energy, Mines and Resources Canada, CANMET, Division Report ERP/MRL 82-06(TR), 32 p.

Dawson, F.M., Marchioni, D.L., Anderson, T.C. and McDougall, W.J. (2000): An assessment of coalbed methane exploration projects in Canada; Geological Survey of Canada, Bulletin 549, 217 p.

Kalkreuth, W. and McMechan, M. (1996): Coal rank and burial history of Cretaceous-Tertiary strata in the Grande Cache and Hinton areas, Alberta, Canada: implications for fossil fuel exploration; Canadian Journal of Earth Sciences, v. 33, p. 938–957.

Langenberg, C.W. and LeDrew J. (2001): Geological map: Foothills (Coal Valley), NTS mapsheet 83F/2; Alberta Energy and Utilities Board, EUB/AGS Map 237, 1:50 000 scale map and accompanying cross-sections.

Langenberg, C.W., Beaton, A. and Berhane, H. (2002): Regional evaluation of the coalbed-methane potential of the Foothills/Mountains of Alberta (second edition); Alberta Energy and Utilities Board, EUB/AGS Earth Sciences Report 2002-05, 74 p.

Langmuir, I. (1916): The constitution and fundamental properties of solids and liquids; Journal of the American Chemical Society, v. 38, p. 2221-2295.