COALBED METHANE IN THE COMOX FORMATION

TSABLE RIVER AREA, VANCOUVER ISLAND

Barry D. Ryan

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INTRODUCTION

There are two major coal basins on the east side of Vancouver Island, British Columbia (Figure 1). The Nanaimo basin is centered on the town of Nanaimo; between 1849 to about 1950 over 50 million tonnes of coal were extracted from seams in this basin. This basin is now considered to be largely mined out. At present companies are interested in the Comox coal basin, which 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 Comox basin. Quinsam mine, the only operating coal mine on Vancouver Island, is located in the basin. The Comox basin coal resource, which is estimated to be over 300 million tonnes, is contained in the Late Cretaceous Comox Formation of the Nanaimo Group.

Virtually all mining on Vancouver Island has been underground, usually room and pillar, or an early form of long wall mining. Underground explosions caused by gassy coals were a problem and over the years killed many of the more than 930 people who lost their lives in the mines. The Quinsam coal mine is an underground room and pillar operation mining high-volatile bituminous coal. The maximum depth of mining is planned not to exceed 300 metres and this with the low rank of the coal limits the potential methane content of the coal. In fact measured coalbed methane (CBM) contents from depths ranging from 100 to 150 metresare up to 1.6 cubic metres/tonne on an ash-free basis (Ryan and Dawson, 1994a). These concentrations are low and are consistent with gas flows encountered at the mine. At Tsable River the rank of the coal is higher and coal resources are at depths exceeding 400 metres. Therefore CBM concentrations in the coal will be higher and preliminary tests of gas content will provide valuable data for any underground coal mining or CBM extraction plans.

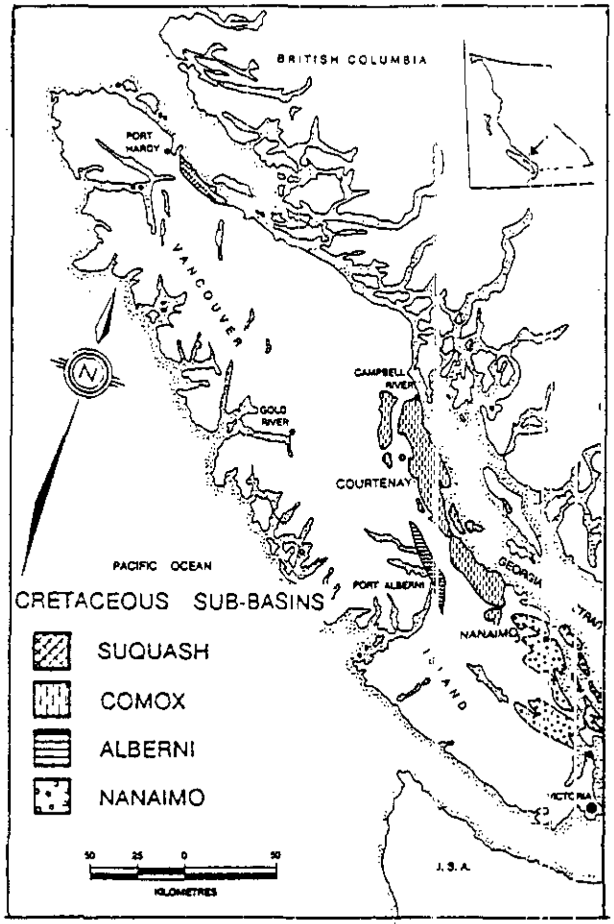

Figure 1: Major coal basins on Vancouver Island.

PREVIOUS WORK

The existence of coal on Vancouver Island was probably brought to the attention of the Hudson Bay fur traders in 1833. An Indian on seeing coal being used in a Hudson Bay Fort told Dr. Tolmie of its existence on Vancouver Island. The next year its presence was confirmed by Mr. Finlayson (Newsome, 1989). One of the earliest scientific reports of coal on Vancouver Island was by Hector (1861) who discussed the coal geology of some of the early mines of the Hudson Bay Company near Nanaimo. The earliest regional mapping of the coalfields of Vancouver Island was conducted by James Richardson in the period 1872 to 1878 (Richardson, 1878). He recognized the three main areas of coal deposition as the Nanaimo, Comox and Cowichan basins. MacKenzie, in the summers of 1921 and 1922, studied the stratigraphy of the Comox Formation (MacKenzie, 1922). Muller and Atchison (1970) published a summary of the geology of the coal basins on the Island. Gardner (1996) produced a report summarizing the history of coal exploration and mining activity on Vancouver Island and an appraising the coal resources.

REGIONAL GEOLOGY

The Nanaimo Group, which contains the coal measures of Vancouver Island, is Upper 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. The 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 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 Nanaimo 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.

There are at least three coal bearing formations within the Nanaimo Group (Table 1). The lower Comox Formation outcrops extensively in the Comox coal basin. It is overlain by marine sediments of the Haslam Formation in the Nanaimo basin or the Trent River Formation in the Comox. 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).

TABLE 1

STRATIGRAPHIC UNITS COMOX BASIN*

STAGE	FORMATION	MEMBER	CYCLOTHERM
MAESTRICHTIAN	HORNBY		5
MAESTRICHTIAN	SPRAY		4
L CAMPANIAN	GEOFFREY		4
L CAMPANIAN	LAMBERT		4
L CAMPANIAN	DENMAN	Norman Point	3
		Graham	3
		Madigan	3
L CAMPANIAN	CEDAR DISTRICT		2
E CAMPANIAN	PROTECTION		2
E CAMPANIAN	TRENT RIVER	Willow Point	2
		Baynes Sound	2
		Royston	2
		Tsable	2
		Browns	2
		Puntledge	2
		Cowie	2
		Cougarsmith	2
SANTONIAN	COMOX	Dunsmuir	1
		Cumberland	1
		Benson	1

L late, E early. *After Muller and Jeletsky (1970), Cathyl-Bickford (1992) and Bickford *et al.* (1990)

The Comox Formation is divided into three members in the Comox basin. The lowest is the Benson member, which is overlain by the Cumberland and Dunsmuir members. In the Tsable River area, which marks the southern end of the Comox basin, the Benson member ranges in thickness from 0 to 220 metres and consists of conglomerate, minor red shale and siltstone (Cathyl-Bickford, 1992). It is overlain by the Cumberland member, which is composed of 30 to 90 metres of siltstone, shale, minor sandstone and coal. The uppermost Dunsmuir member is composed of 120 to 190 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 contains two other seams, including the No. 2 seam which is significant and ranges in thickness from 0.8 to 2.2 metres. The No. 1 seam is about 25 metres above the base of the Dunsmuir member and ranges in thickness from 0.9 to 2.4 metres. Figure 2, which is adapted from Bickford *et al.* (1990), is a schematic diagram illustrating seam stratigraphy in the Comox Formation. Recent exploration reports tend to number seams starting at 1 at the base of the succession as at Quinsam and Tsable River.

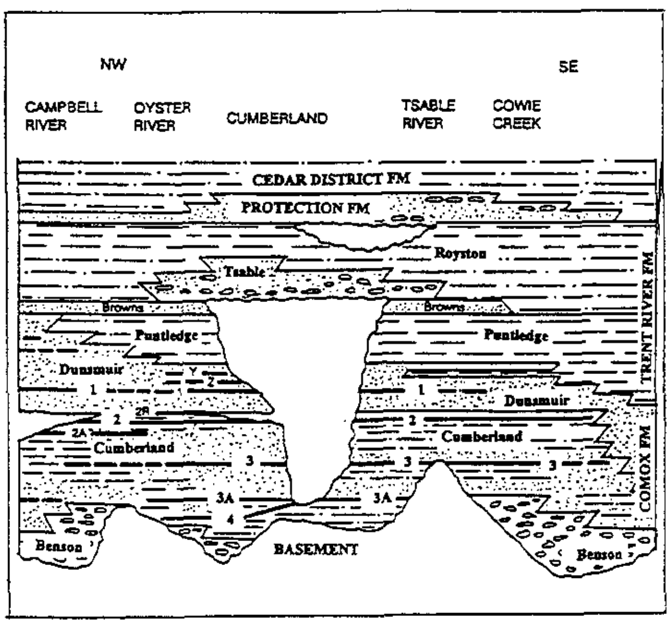

Figure 2: Seam stratigraphy in the Comox Coal Basin, modified from Bickford *et al.* (1990).

The Comox Formation in the Tsable River area is broken by three sets of faults (Cathyl-Bickford, 1992). The earliest set trends northwest with extensional or dextral strike slip movement. They are cut by near vertical, east or northeast-striking faults with sinstral offsets of up to 1000 metres. The third set of faults are of indeterminate relative age and consist of bedding plane shear zones. The coal seams often contain shear zones and low angle extension faults (Bickford *et al.*, 1990).

COAL MINING IN THE TSABLE RIVER AND CUMBERLAND AREAS

Coal development work started in the Tsable River area in 1869 when the Baynes Sound Colliery tried unsuccessfully to develop a mine. A short time later, in the Cumberland area, the Union Collieries opened the Number 3 tunnel, which was driven into the No. 1 seam. This was followed by construction of the Number 1 slope to develop the No 4 seam (slope is a coal term used to describe a tunnel that is constructed down the full dip of the coal seam). In 1888 the Union Collieries was bought by Robert Dunsmuir, who expanded the operations considerably and built a rail line connecting the mines to the wharf at Union Bay. The period 1890 to 1896 saw the construction of the Number 4 slope mine (1890), which accessed the No. 4 seam and the Number 5 shaft mine (1895), which penetrated the No. 1 seam.

A coking plant with 100 beehive coke ovens was built at Union Bay in 1896. The coke, which was made using fine washed coal, was shipped to metal smelters on Vancouver Island and south to the west coast of the United States. The ovens operated up until 1922. By 1900 the Cumberland mines were producing between 200 000 and 250 000 tonnes annually and production continued up to 1947 when the last mine, the Number 5 mine, closed. By this time 14.5 million tonnes had been extracted from the Cumberland mines. Most of the coal was extracted from the No. 1 seam although seams 2 and 4 were also mined. The mines were gassy and a number of explosions with loss of life occurred (Table 2). There were fewer fatalities in the Cumberland area than in mines in the Nanaimo basin possibly because the mines were smaller or not as deep.

Despite the fact that coal was prospected in the Tsable River area in 1869, it was not until 1945 that the Tsable River mine opened. It is located 20 kilometres south of Courtenay on Tsable River west of the area covered by Figure 3. Annual production in the later years was very low averaging about 50 000 tonnes and in the last year (1966) only 15 000 tonnes were mined. Over its life the mine produced 1.8 million tonnes. Slopes were driven north of the Tsable River; water from the roof, thick overburden of sand and gravel and faulting all caused problems. The coal was extracted from a seam 1.2 metres to 4.2 metres thick near the top of the Cumberland member, possibly the Comox No. 2 Seam (Cathyl-Bickford, 1992). This 2 Seam dips at about 15° to 20° to the northeast and ash content

TABLE 2

VANCOUVER ISLAND COAL MINE DISASTERS RELATED TO GAS EXPLOSIONS COMOX COAL BASIN

DATE	COLLIERY/MINE	FATALITIES	CAUSE
Feb15, 1901	COMOX NO. 6 SHAFT	64	EXPLOSION
Jul 15, 1903	COMOX NO. 6 MINE	16	EXPLOSION
Jun 3, 1917	COMOX NO. 6 MINE	4	EXPLOSION
Aug 30, 1922	COMOX NO. 4 MINE	18	EXPLOSION
Feb 8, 1925	COMOX NO. 4 MINE	33	EXPLOSION

SUMMARY TOTAL FATALIES (ALL CAUSES) IN THE COAL BASINS

CUMBERLAND = 305 NANAIMO= 686 TOTAL= 991

increases in areas where the thickness of the Benson member decreases. The coal is susceptible to spontaneous combustion because of its moderate to high sulphur content and rank (high-volatile A bituminous); fires were reported in two of the mining panels. The seam roof is composed of mudstone, which is often sheared and was difficult to support in the Tsable River mine (Bickford *et al.*, 1990).

LOCAL GEOLOGY TSABLE RIVER AREA

The most recent regional mapping of the Tsable River area was completed by Cathyl-Bickford (1992, Figure 3). In the 1990's there were exploration programs in the area, which outlined two seams of economic interest. The lower seam in the Cumberland member averages 1.92 metres thickness south of the Tsable River and 2.6 metres north of the river (Gardner, 1996). In the Dunsmuir member, about 50 metres above the lower seam, a second thinner seam outcrops, which averages 1.18 metres south of the river and 1.05 metres north of the river. Based on exploration in 1991 a potential resource of 26.2 million tonnes exists south of the river and 61.7 million tonnes to the north (Gardner, 1996). Prior to the 1996 exploration program only 11 million tonnes of this resource south of the river was considered to be well defined. These reserve and resource calculations consider only the lower seam. The 1996 exploration program was planned to better define faults and the reserves south of the river and prove up more reserves north of the river. Preliminary assessment of the 1996 exploration data indicates that there is an inplace proven reserve of over 35 million tonnes in an area that extends north and south of the Tsable River (personal communication, S. Gardner, 1996).

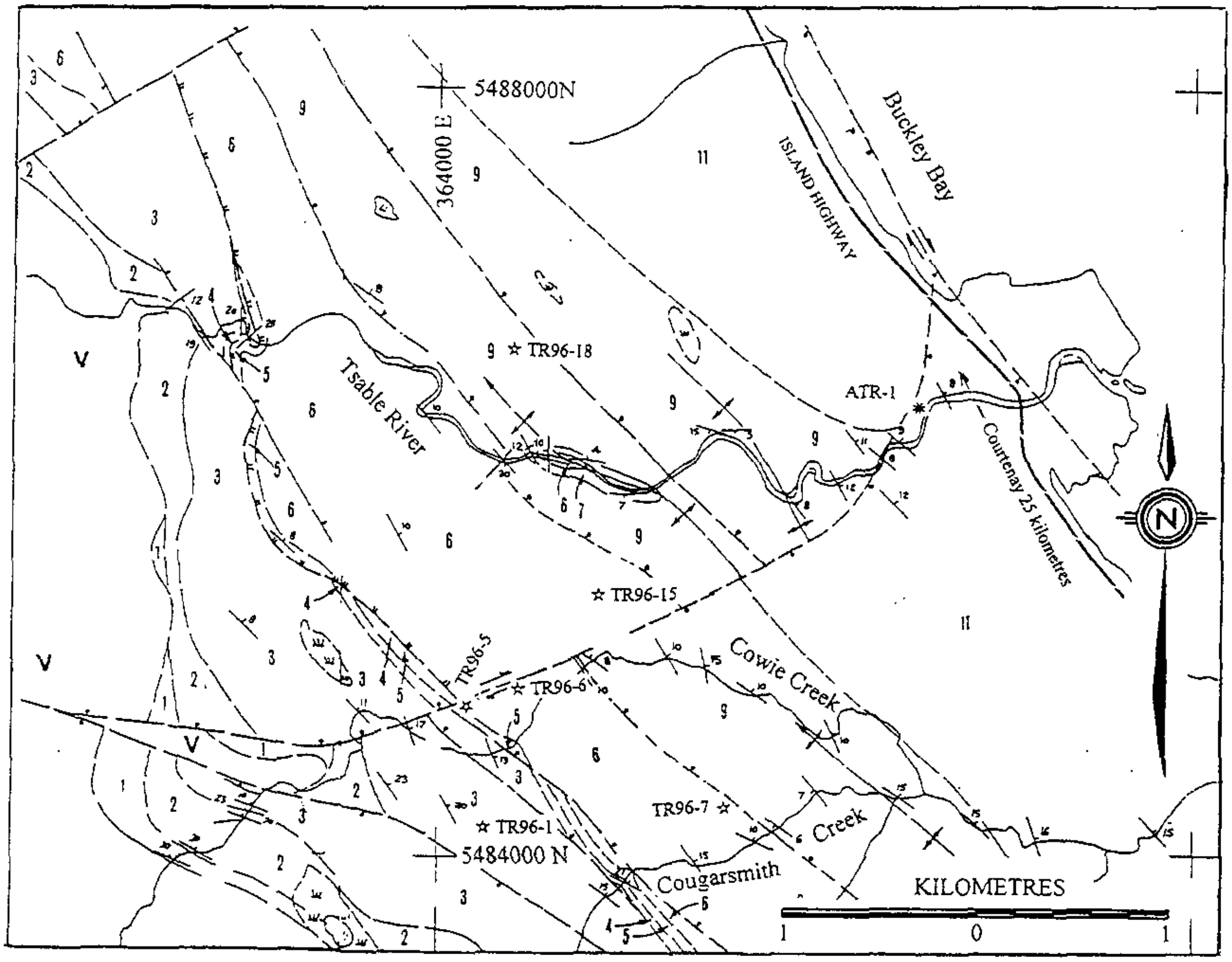

Figure 3: Regional geology Tsable River area from Cathyl-Bickford, (1992) showing location of selected drillholes.

LEGEND FOR FIGURE 3

FORMATION		MEMBER
TRENT RIVER	11	Willow Point
	10	Baynes Sound
	9	Royston
	8	Tsable
	7	Browns
	6	Puntledge
	5	Cowie
	4	Cougarsmith
COMOX	3	Dunsmuir
	2	Cumberland
	1	Benson
	V	Karmutsen

Contact
Fault
with down dropped side
☆ TR96-18 Drillhole 1996
✱ ATR-1 Pre 1996 drillhole

COALBED METHANE DATA FROM VANCOUVER ISLAND

Coalbed methane was a major factor contributing to the many mine disasters in the Nanaimo and Comox coal basins. Despite this there is very little data, other than anecdotal, about methane contents of the coal. More recently interest in CBM as an energy resource has increased and Vancouver Island is seen as an interesting target because of its large resource of high-volatile bituminous coal occurring in a regional, moderately-deformed basin.

In the Nanaimo basin, as the mining got deeper, mines experienced difficulty with ventilation because of high gas contents and this is one reason for the closure of the last mines in the period 1947 to 1952 (Cathyl-Bickford, 1991). The mines worked the Douglas and Newcastle seams in the Pender Formation and the Wellington seam in the Extension Formation. Most of the coal was extracted from the Douglas seam, which averages 2.5 metres in thickness and is generally soft and sheared. The Newcastle seam is thin averaging only 1.2 metres thick and the underlying Wellington seam is 1.2

to 2.7 metres thick. Both these seams are hard, blocky and cleated, but they are not extensive. The Wellington seam does not extend eastwards of the outcrop of the Douglas seam.

The Douglas coal zone consists of four coal beds and includes the Newcastle seam. The total thickness of coal in the zone is about 6 metres. The petrography of the seams varies and the lowest seam has the highest inertinite content, though the zone as a whole is considered to be vitrinite rich ((Cathyl-Bickford, 1991). Generally, vitrinite is considered to adsorb more gas than inertinite but to desorb it more slowly. Desorption tests on coal from the Douglas seam collected from bore holes averaging 250 metres in depth and drilled near the Morden Colliery, south of Nanaimo, range from 6 to 12 cubic metres per tonne on an uncorrected basis (Cathyl-Bickford, 1991). The gas contains over 95% methane; the data probably comes from holes drilled by Novacorp in 1984. The gas contents indicate saturation or over saturation of the coal, based on the rank and depth of samples. This could be because the Douglas seam is within impermeable mudstones, which may tend to keep the gas in the seam (Cathyl-Bickford, 1991). Also shearing of the coal limits in-seam permeability and may have contributed to gas outbursts in the mines. The depth at which gas outbursts became prevalent decreased from 550 metres under Nanaimo Harbour to 240 metres at Cassidy, probably because of increased shearing in the Douglas seam to the south (Cathyl-Bickford *et al.*, 1991).

An equation for predicting CBM contents based on depth and reflectance (Ryan, 1989) has been used successfully to reproduce desorption results in Alberta (Dawson, 1994) and in this case it predicts a gas content of 3 to 3.5 cubic metres/tonne at a depth of 250 metres for 10% to 20% ash coal with a Rmmax of 0.68%.

Gas emission rates from mines can be used to estimate the gas content of the coal. The emission rates per tonne of coal mined are between 6 and 9 times greater than the desorption values per tonne of coal(Kissel *et al.*, 1973). Based on the data in Cathyl-Bickford (1991) the Douglas seam at 250 metres could contain up to 4 cubic metres per tonne, which is in agreement with the predicted capacities (Table 3), but lower than the desorption data.

The average mean maximum reflectance (Rmmax%) of coal from the Pender and Extension formations in the Nanaimo area of the Nanaimo basin is 0.68% (Kenyon and Bickford, 1989). They suggest that, because the Rmmax% values do not vary much from seam to seam and are not sensitive to the position of the seams in the stratigraphy, that coalification in this part of the basin post-dates deformation. Regionally the rank increases to the southwest and decreases to the northeast and over the whole basin England and Calon (1991) suggest that the rank was fixed during Late Eocene regional contraction, which defines the Cowichan fold and thrust belt. The Tsable River area is at the northern end of the Cowichan fold and thrust belt and in this area Kenyon and Bickford (1989) suggest that coalification predated deformation. This is important because, if correct, it means that rank does not increase to the northeast where Comox seams are more deeply buried and consequently their CBM content is influenced only by changes in depth. In the Comox basin the rank of the Comox Formation, as defined by Rmmax% values, increases to the south. It averages 0.73% in the Quinsam area but increases to 0.88% in the Tsable River area (Kenyon and Bickford, 1989).

There is some CBM emission data for mines from the Cumberland area (Cathyl-Bickford, 1991). Mine depths range from 200 to 300 metres and predicted gas contents range from 3 to 21 cubic metres/tonne (Table 3). The average values range from 7.8 to 11.7 cubic metre per tonne at depths that average 250 metres. The higher gas contents from coals of the Comox basin are in part supported by the higher Rmmax% values, which in the Cumberland/Tsable River area average 0.88% (Kenyon and Bickford, 1988). The higher gas content did not translate into more mine disasters in the Comox basin than in the Nanaimo basin. This is attributed to the mining method (generally longwall rather than the room and pillar method used in the Nanaimo basin Bickford, 1991) and the better permeability in the seams and roof rocks.

Gas has been reported in a few deep holes in the Tsable River area (Cathyl-Bickford, 1991). One hole drilled in 1914 intersected gassy coal at 350 metres and drilling was stopped because of excessive gas pressure. The hole is located about 4 kilometres northeast from the present drilling near the mouth of the Tsable River (ATR-1, Figure 3). The hole was capped and supplied gas to a local forestry camp until 1984 when the casing was sheared off by a landslide. Another hole drilled in 1945 in the Royston area, 12 kilometres north of Tsable River, intersected gas at 418 metres. After a fire was extinguished it was used as an unlicensed gas well by a local farmer.

TABLE 3

Existing coalbed methane desorption and emission data for the Nanaimo and Comox basins.

MINE	COAL FIELD	YEAR	SEAM	depth metres	emission m3/t	content m3/t
Reserve	Nanaimo	1918	Douglas Main	300	8.8	0.98
Morden	Nanaimo	1918	Douglas Main	250	23.8	2.64
Morden	Nanaimo	1990?	Douglas Main	?		12.00
No. 5	Comox	1918	Comox No. 1	200	17.2	1.91
No. 5	Comox	1935	Comox No. 2	300	128.1	14.23
No. 4	Comox	1918	Comox No. 4	250	64.5	7.17

COAL QUALITY

A limited amount of coal quality data was obtained as part of this study. Though it is not necessarily representative of the coal which may be mined, it does add to the small database of coal quality information available for the Tsable River. Some samples used for desorption were recombined with the rest of the seam after the desorption measurements and the seam analyzed as a whole. In these cases there is only an estimate of the raw ash available. For all the samples raw ash varies

TABLE 4

Coal quality data for four Tsable River samples.

type	yield	ADM%	Ash%	V.M%	F.C%	S%	MJ/Kg	F.S.I
			TRCBM10					
raw	100	0.92	34.46	28.4	37.14	0.4	20.99	3
1.6 float	58.8	0.75	14.86	32.58	52.55	0.53	29.8	7
			TRCBM11					
raw	100	1	29.96	28.62	41.42	0.67	24.1	5
1.6 float	66.6	0.58	16.79	32.65	50.56	0.71	29.22	7.5
			TRCBM12					
raw	100	0.86	23.27	31.87	44.86	0.8	26.81	6.5
1.6 float	87.2	0.66	18.79	34.61	46.6	0.75	28.57	7
			TRCBM13					
raw	100	1.11	14.64	32.58	52.78	0.73	30.04	7
1.6 float	91.8	0.72	11.26	35.75	52.99	0.68	31.35	7.5

TABLE 5

Vitrinite reflectance measurements.

Sample	depth m	rmmax%	Rmmin%	SD	Rmax%
TRCBM10	278.8	0.82	0.73	0.01	0.9
TRCBM11	296.8	0.83	0.77	0.01	0.89
TRCBM12	300.9	0.84	0.78	0.01	0.9
TRCBM13	376.2	0.84	0.79	0.01	0.88

from 15% to 55%. In four cases the desorption samples were analyzed separately and more extensive coal quality information is available. Based on the data in Table 4, Tsable River coal is a high calorific coal with excellent F.S.I values. Sulphur concentrations are moderate and it appears that it will be difficult to wash the below 0.6%. The coal washes with moderate ease and obviously contains some middlings material. Vitrinite reflectance values were also obtained for the four samples (Table 5). The Rmmax% values range from 0.82% to 0.84% and are therefore somewhat lower than previous measurements, which average 0.88%.

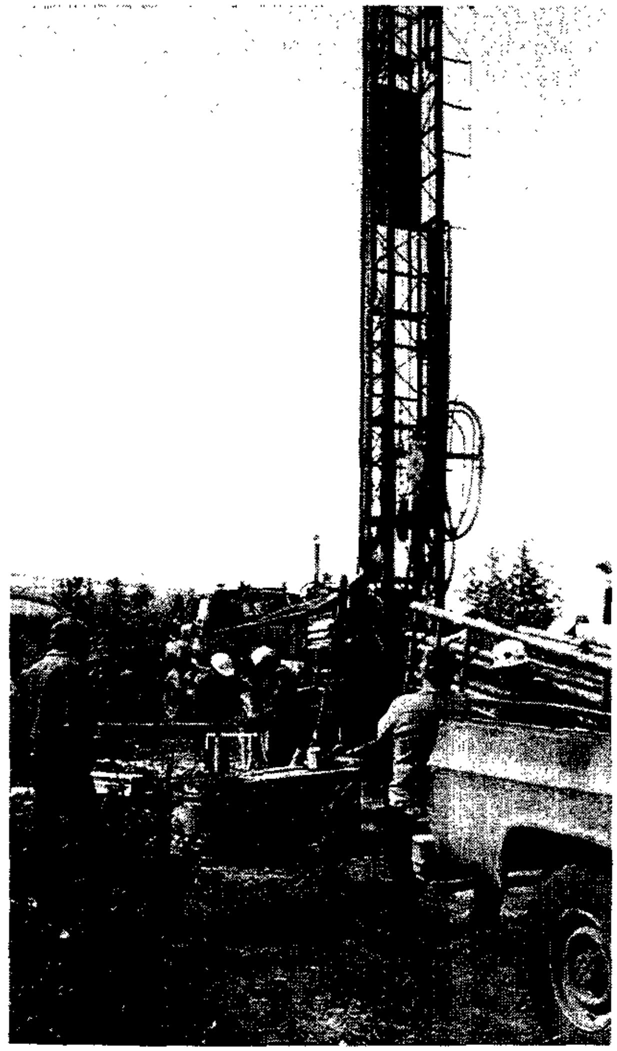

Photo 1: Drilling on the Tsable River property during the summer of 1996.

COALBED METHANE DESORPTION RESULTS

The 1996 drilling program employed a truck mounted rig (Photograph 1) to drill to the coal stratigraphy at which point a coring bit was attached and 8 cm core recovered through the coal section. Coring continued into the top of the Benson member to ensure that all the seams were penetrated. Sample collection techniques are similar to those described in Ryan and Dawson, (1994b). Samples for CBM desorption samples were collected from seams not being analyzed by the company to represent the largest possible range of depths. Generally thinner seams or single samples from larger seams were collected. The CBM canisters hold about 40 centimetres of core and were filled if possible. The diameter of the canisters is greater than 8 cm and coal was placed in a section of PVC pipe that acted as a sleeve for the sample and made it easier to insert the core sample into the canister, remembering that it is important not to get the O ring seals or valves of the canisters dirty. Most samples consisted of a number of lengths of core with some sheared coal (Photograph 2). A few of the samples were single lengths of core. Every effort was made to get the coal sealed into the canisters as quickly as possible, so as to minimize the lost time and the amount of gas escaping prior to the start of measurements. The time from starting to bring the core barrel to surface and sealing the coal in the canisters was less than 12 minutes. Once in the canister, as many desorption measurements as possible were made over the first few hours to provide good definition of the desorption curve and a good estimate of the lost gas component. Measurements are made by releasing the gas into a manometer and measuring the volume at existing atmospheric conditions.

Various ways of making lost gas corrections are discussed in Ryan and Dawson, (1994b) and in this study the method of Diamond and Levine (1981) is used. Lost gas corrections range up to 10% of the total gas content of the samples. A number of corrections, which are

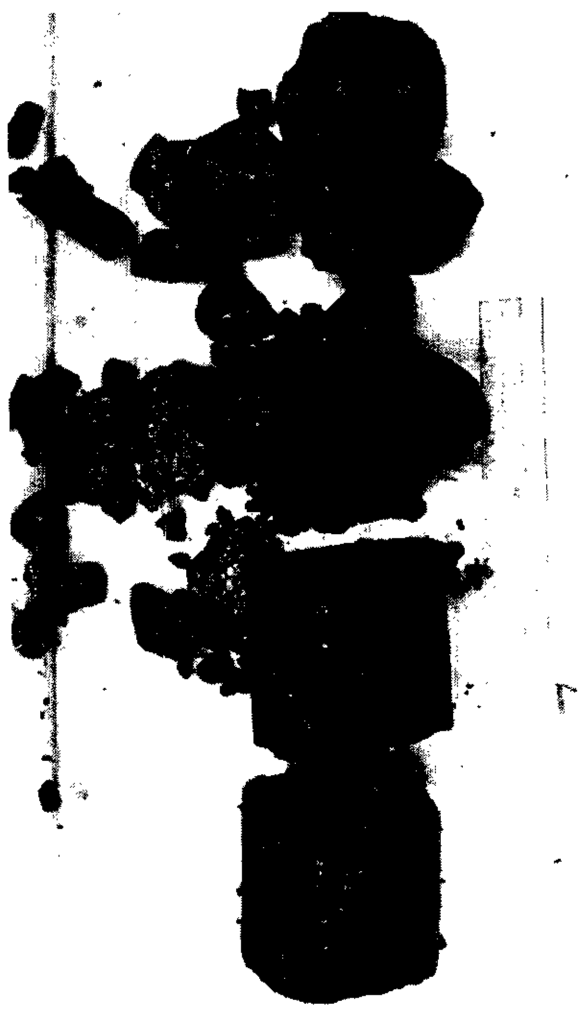

Photo 2: Typical coal sample used for desorption (sample TR96-11, scale is 15 centimetres long).

described in Ryan and Dawson (1994b) are made to the desorption data before a cumulative total desorbed gas amount can be calculated. During this study the pressure in the canister was calculated using the volume of gas desorbed at atmospheric conditions and the dead space in the canister. This is interesting because if the dead space is small and the desorption rate high then it is possible to build up a high pressure in the canister prior to releasing the gas into the manometer. Canisters were pressure checked to over two times atmospheric pressure and the measurement schedule was adjusted to ensure that pressure in the canisters did not exceed this value. Obviously for very gassy coal it is preferable to leave some dead space in the canister to safeguard against the build up of high pressures in the canister. It is therefore important to be able to make accurate dead space corrections.

A total of 13 samples were desorbed covering depths from 126 to 376 metres (Table 6) and obtained from 6 drill holes (Figure 3). Gas contents on an as-received basis range from 1.6 to 5.5 cubic metres per tonne.

GAS CONTENTS OF VANCOUVER ISLAND COALS

The gas content of the Tsable River samples (stars, Figure 4) increase consistently with depth but are less than would be predicted using either Ryan's equation (Ryan, 1992) or Kim's equation (Kim, 1977). In doing the calculations it was assumed that there was a normal geothermal gradient, a water table at 25 metres below surface and coal with 20% ash and a constant rank of Rmmax=0.83%. All available gas content data from the Nanaimo and Comox coal basin are plotted in Figure 4. The Quinsam samples (open diamonds) have lower rank (Rmmax=0.66%) and were collected from shallow depths. Their gas contents average less than 1 cubic metre per tonne. Two samples from the Comox basin (solid triangles) have higher gas contents than the two samples from the Nanaimo basin (solid diamonds).

A straight line fitted to the Tsable River desorption data (stars, Figure 4) predicts gas contents of 2.6 cubic metres per tonne at 200 metres increasing to 7.5 cubic metres per tonne at 600 metres on an as-received basis. This relationship is probably the best one to use to estimate the CBM resource potential of the southern part of the Comox basin and ventilation requirements of possible underground mines in the area. Diamond and Levine (1981) use the relationship:

$$Y = 220 \times X.$$

where Y is gas emission rates in cubic feet per ton and X is desorbed gas content in cubic metres per tonne to estimate the gas emission rates from coal in mature underground coal mines.

The shape of the desorption curve has been studied by Airey (1968) who developed an empirical equation, that predicts the shape of most desorption curves. Ryan and Dawson (1994b) illustrate a simple way of calculating Airey's constants which he designates as N

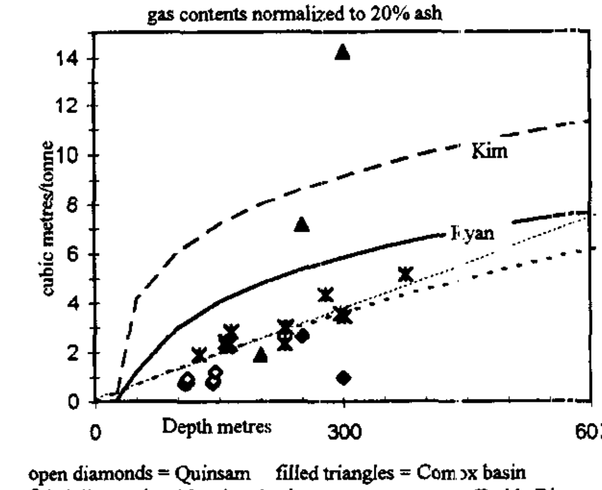

Figure 4: Gas *versus* Depth content for samples from the Tsable River area, Quinsam coal mine and Nanaimo and Comox basins. Curves illustrate predicted variation of gas content with depth using equations from Ryan (1992) and Kim (1977).

TABLE 6
Desorption data for Tsable River samples.

										m^3/tonne						
SAMPLE	CANISTER	SEAM	HOLE	FROM metres	TO metres	ASH	LENGTH cm	WEIGHT grams	DEAD SPACE cc	LOST GAS	DESORBED GAS	REMAINING GAS	TOTAL GAS	GAS ash free	HALF LIFE days	COMMENTS
TRCBM1	2	1	TR96-01	166.50	166.88	23.00	38.0	2156.5	1297	0.08	1.95	0.21	2.24	2.91	3.6	
TRCBM2	4	1	TR96-01	168.25	168.54	55.00	29.0	1965.0	1200	0.03	1.42	0.14	1.59	3.53	3	footwall coal
TRCBM3	1	2	TR96-05	127.40	127.80	20.00	35.0	2401.7	1002	0.06	1.59	0.25	1.90	2.38	1.6	
TRCBM4	5	1	TR96-05	158.60	159.00	23.40	37.0	2437.9	1149	0.07	1.95	0.30	2.32	3.03	1.4	hangingwall
TRCBM5	7	1	TR96-05	159.30	159.70	23.40	34.0	2131.0	1294	0.07	1.90	0.34	2.31	3.02	1.2	
TRCBM6	6	1	TR96-05	159.90	160.30	23.40	36.0	2174.6	1108	0.08	1.79	0.27	2.14	2.79	0.9	
TRCBM7	8	1	TR96-06	227.30	227.70	16.50	40.0	2598.3	1161	0.21	2.43	0.51	3.15	3.77	0.5	
TRCBM8	9	1	TR96-06	228.20	228.45	16.50	22.5	1521.9	1776	0.11	1.75	0.57	2.43	2.91	1.6	
TRCBM9	3	1	TR96-06	228.60	229.00	16.50	26.0	1696.0	1368	0.14	2.38	0.58	3.10	3.71	1.1	
TRCBM10	2	3	TR96-07	278.90	280.00	34.46	10.0	1100.1	2187	0.33	3.21	0.01	3.55	5.42	0.27	
TRCBM11	7	3	TR96-15	296.80	297.00	29.96	20.0	1688.5	1847.3	0.14	2.70	0.29	3.13	4.47	1.26	
TRCBM12	1	3	TR96-15	300.90	301.10	23.27	20.0	945.5	1939.7	0.12	2.85	0.34	3.31	4.31	2	
TRCBM13	2	4	TR96-18	376.20	376.54	14.64	32.0	1782.0	1789.9	0.33	5.14	0.04	5.51	6.46	0.6	full seam

and To. The value N was found not to correlate with any of the coal properties measured by him, but the constant To was found to be influenced by initial gas pressure in the sample and particle size. In this study To values from Tsable River data are inversely proportional to depth and gas content. It is difficult to separate the effects of depth and gas content, but in either case one can expect faster desorption of gas at greater depths. This is important and is not considered in the calculations by Diamond and Levine (1981). The To values for the Quinsam data do not correlate with gas content or depth and are therefore probably influenced by varying particle size. The half life of the desorption curve, which is the time taken for the first half of the gas to desorb, is easier to calculate than the value To. Half lives have a similar relationship to depth and gas content as To.

COALBED METHANE RESOURCES OF THE TSABLE RIVER AREA

In recent years a lot of attention has been paid to CBM as a resource, rather than a hazard in underground mining. There are published CBM resource assessments available for southeast British Columbia [Johnson and Smith (1991) over 300 billion cubic metres] and northwest British Columbia [Ryan and Dawson (1993) over 200 billion cubic metres]. The author estimates a resource of over 2900 billion cubic metres for northeast B.C, whereas on Vancouver Island the resource is estimated to be 17.1 billion cubic metres. To put these number is perspective it is interesting to note that at present about 21 billion cubic metres of natural gas are produced in British Columbia each year. The CBM resource numbers are large but as yet none of this resource has been recovered.

Technology for the extraction of CBM is improving but generally it is considered that there will be insufficient regional permeability to permit CBM extraction at depths greater than 1000 metres. As a first attempt at estimating the potential CBM resource to 1000 metres in the an area underlain by the Comox Formation in the Cumberland, Tsable River, Denman Island area, a potential resource area was outlined on Figure 5 which is modified from Bickford and Kenyon (1988). Coal extends at least to the western shore of Baynes Sound (Figure 3), where the coal is approximately 550 metres deep and the cover increases to 675 to 950 metres under Denman Island further to the east (Bickford, 1992).

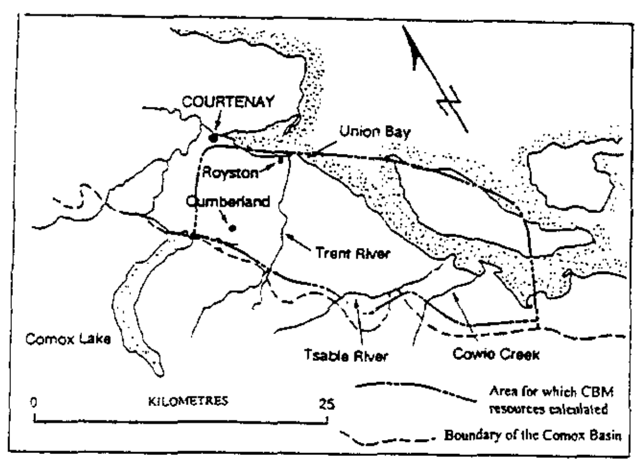

Figure 5: Regional map of the area underlain by the Comox Formation modified from Bickford and Kenyon (1988).

TABLE 7

Coalbed methane resource calculations for the southern end of the Comox basin (area outlined in Figure 5)

Resource calculation assuming linear or negative exponential increase in gas content with depth

ie curves A and B in Figure 4

Depth in metres $D=d1+(d2-d1)/L*X$ Where L is surface expression of downdip length in metres extending northeast in Figure 6

d1 and d2 are the updip and down dip depths of the coal

X is the horizontal increment of L

(A) Gas content m^3/t $G=I+sl*D$ Where D is depth in metres and I and sl are intercept and slope of line

(B) Gas content m3/t $G=C*(1-e^{(-lamda*D)})$ Where C and lamda are constants defined in the input table

At depth d resource increment dr is given by

$dr=G*W*SG*T*dx$ Where W is width of area, T is thickness of coal and SG is specific gravity

The variable G is replaced by D using equation A or B and the result integrated for values of X from 0 to L

the result is the total resource avialable

	Input parameters		
L length in metres	10000	12500	2500
W width in kilometres	30		
T coal thickness metres	4		
SG specific gravity	1.2		
slope of gas content v D	0.012		
intercept of gas v depth line	0.12		
depth1 start depth d1	200		
depth2 finish depth d2	1000		
X length	10000	12500	
lamda	0.0012		
exp constant (C)	12		

	Output data			
	linear		exponential	
Gas m^3/t at 1000m	12.12		9.32	
X_1 to X_2	0,10000	2500-12500	0-12500	2500-12500
tonnes coal x 10^9	1.44	1.44	1.80	0.36
average m3/tonne	7.32	5.93	6.26	0.33
resource m^3 x 10^9	**10.54**	**8.54**	9.02	0.48

Seams 2 and 3 (Figure 2) range in thickness from 1.2 to 4.2 metres and 1 to 4.1 metres in the Tsable River, Cumberland areas (Cathyl-Bickford, 1992) indicating that an average of 4 metres of coal probably exists in the Cumberland member. It is assumed that the area outlined in Figure 5, which is about 300 square kilometres, is underlain by coal seams with a cumulative vertical thickness of 4 metres and that the resource is evenly distributed between depths of 200 and 1000 metres. Gas contents are predicted using the depth relationship derived from the desorption data (Figure 4). Two functions are fitted through the desorption data. The first, which is derived by fitting a line though the desorption data (curve A, Figure 4), probably over-estimates the gas content at a given depth so a second model (curve B, Figure 4) fits an exponential curve to the data. This curve probably under estimates gas contents. These curves are combined with a linear equation that relates depth of coal to horizontal projection of the down dip location and the result integrated to give the total CBM resource (Table 7). This was done using a computer spread sheet so that all parameters can be varied to illustrate the sensitivities of the resource estimate to the various parameters. The more conservative exponential model provides a resource estimate of 8.5 billion cubic metres billion cubic metres. This resource estimate cannot be converted easily into an estimate of recoverable reserves because there is no history of CBM extraction on Vancouver Island. Unlike natural gas, the percentage of a CBM resource that is economically recoverable is probably small.

CONCLUSIONS

Gas contents of coal from the Tsable River area vary from 1.6 to 5.5 cubic metres/tonne over a depth range of 127 to 376 metres. There is a consistent increase in gas content with depth and a linear extrapolation of the data indicates that gas contents at 600 and 1000 metres may be 6.2 and 8.4 cubic metres/tonne for 20% ash coal. These concentrations are high enough to make the area attractive for its CBM resource. A resource calculation for part of the southern end of the Comox basin outlines a potential resource of at least 8.5 billion cubic metres. The moderate gas contents indicate that care will have to be taken when mining the coal underground.

The Tsable River coal has a rank of high-volatile A bituminous based on four Rmmax% values that average 0.83%. A limited amount of coal quality data indicates that the coal is coking with F.S.I values that range from 7.0 to 7.5 at ash concentrations in the range of 10% to 20%. The washed coal has low to moderate concentrations of sulphur (0.5% to 0.8%) and excellent calorific value.

The Tsable River area has attractive CBM potential and may also be the site of the next coal mine on Vancouver Island. There is a strong international market for the type of thermal coal found at Tsable River. There is also an expanding market for soft coking coal which may be available from a Tsable River coal mine. There is continuing CBM exploration in Canada. The present natural gas prices may not be maintained and any increase in price will stimulate interest in potential CBM resources.

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Thanks are extended to the Quinsam Coal Corporation for letting me collect samples for this project. Collecting core samples for CBM desorption tests can be a time consuming and frustrating process, that requires a lot of waiting at the drill site for the seam to be intersected and the core to be recovered. The best one can hope for is good communication between the people involved in the program so that the waiting on site is kept to a minimum. In this case Steve Gardner, the consultant in charge of the program, was very helpful and provided all assistance possible. In the field Ron Swaren, the on-site geologist, remained remarkably sane through a long and far from smooth program. Finally the High-Rate Drilling Limited drilling crew helped in many ways and were rewarded with a certain amount of amusement as I tried to seal the maximum amount of coal in the minimum amount of time into various containers.

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