Overview of the Coalbed Methane Potential of Tertiary Coal Basins in the Interior of British Columbia

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INTRODUCTION

The interior of British Columbia contains a number of fault bounded Tertiary basins that contain coal (Figure 1). This paper brings together existing data that aids in assessing the coalbed methane (CBM) potential of the basins and presents new data on some of the basins. The CBM potential of the basins ranges from up to 1 tcf at Hat Creek to a few bcf at Coal River. In all cases the resources of the basins are poorly defined leaving open the possibility that aggressive and imaginative exploration will be successful in increasing resource estimates. The size and location of the basins may mean that they cannot be developed as conventional CBM fields. Markets may be local communities or industries and distribution may avoid compression costs.

The overall geometry of most of the basins is controlled by Tertiary faults that trend north or northwest. The faults influence fold trends within the basins and probably also the original drainage patterns that fed sediments into the basins (Long, 1981). Most of the basins are of Eocene age (45 to 53 my) (Table 1), though ages range from Miocene to Paleocene. They generally formed as grabens, when the pacific tectonic plate was moving north relative to British Columbia producing right lateral shear on transcurrent faults, some of which also have extensional offset. The basins are filled with sediments ranging from mudstones to conglomerates and coal. Often there is a lot of associated volcanic material present as flows, ash, or bentonite layers. Coal formation reflects the climate through the Eocene, which tended to be tropical to sub tropical.

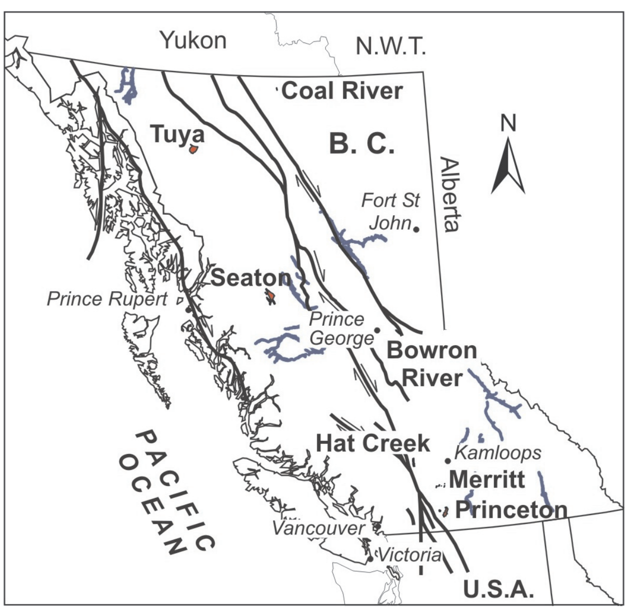


Figure 1. Location of Tertiary coal basins in British Columbia with major fault systems.

There is confusion in the literature about the names of some of the basins. Names change and sometimes they are referred to as sub basins or coalfields. Usually the name will indicate the area and it is immaterial whether the author uses the designation basin, sub basin or coalfield, the important question is what are the potential coal and CBM resources of the basins.

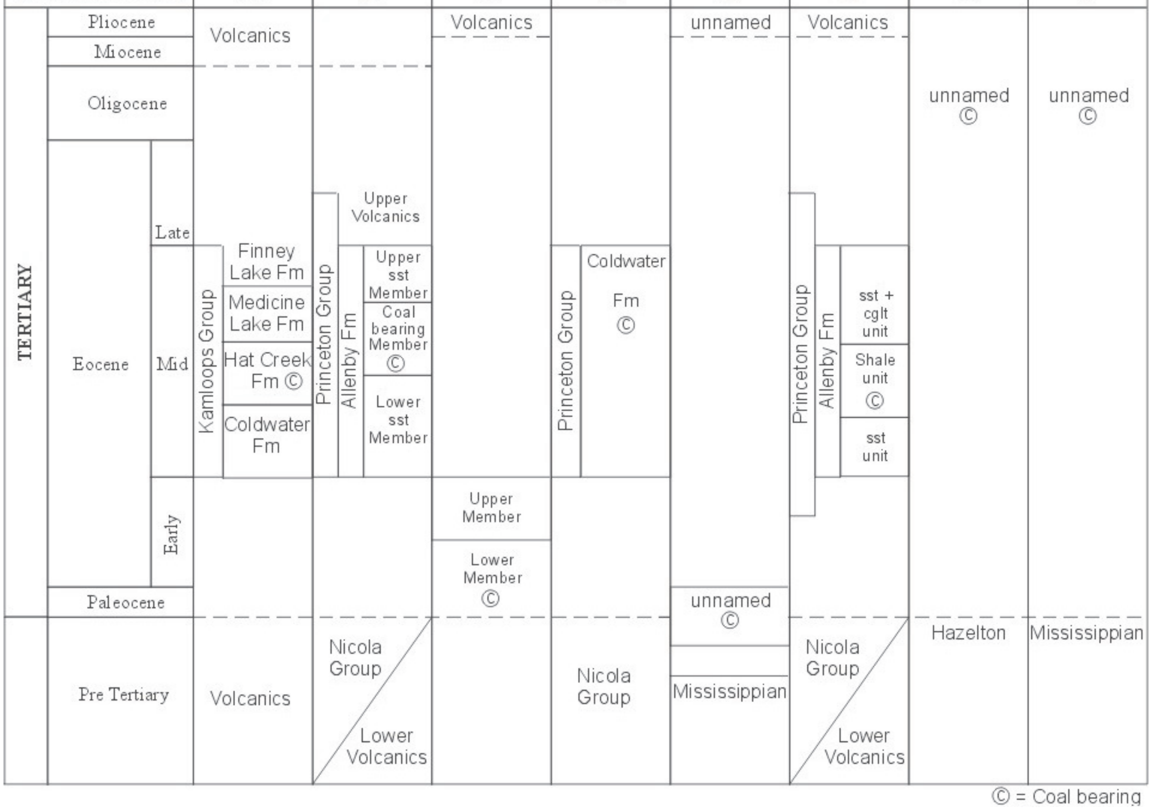
UNIQUE CHARACTERISTICS OF TERTIARY BASINS

Tertiary deposits are characterized by rapidly subsiding basins often fault bounded. The depositional environment generally ensures a lot of lateral variation in the character of the coal zones. The coals often have high inherent ash and vary in thickness and ash content along strike. The enclosing sediments are also very variable, making stratigraphic correlations difficult. Local facies changes may control the shape and permeability of productive areas within the basins. Development of thick coal zones requires the correct balance between the rates of subsidence and of vegetation accumulation and the absence of sediment influx during accumulation of vegetation. Often the pulsing of subsidence in Tertiary times caused rhythmic deposition of fining upwards sequences capped by coal. Sometimes thick carbonaceous zones formed composed of coal interspersed with sediments and bentonite. Strike-slip motion on faults may have been responsible for disrupting drainage patterns and producing basins starved of sediment influx (Long, 1981).

Folding may be hinged to the faults and monoclinal or related to differential strike-slip motion along faults. It is less likely to be related to regional compression. The tectonic environment is therefore favourable for extension on cleat surfaces. Folding probably occurred soon after deposition and before the temperature in the sedimentary pile could equilibrate with that in surrounding basement rocks,

TABLE 1
STRATIGRAPHY OF TERTIARY BASINS IN BRITISH COLUMBIA THAT CONTAIN COAL

	Hat Creek	Princeton	Tuya	Merritt	Bowron	Tulameen	Seaton	Coal River
rank	Lig - Sub B	Lig - HVBB	HVCB-HVBB	HVBB-HVAB	HVBB	HVBB-HVAB	MVB	Lig
Rmax range %	0.35 - 0.45	0.52 - ?	0.68 -0.76	0.64 - 0.86	0.65	0.62 - 0.86	1.34	0.2
CBM resource bcf	500	80	48	52	48	42	25	3



which because of Eocene volcanism may have been high. Coal rank is therefore dependent on depth and not position in folds. The high heat flow in some basins probably resulted in a coalification gradient characterized by high temperature and low pressure, very different from that experienced by Cretaceous coals in the Rocky Mountains.

One could speculate that coals that attain their rank in an environment dominated more by temperature and less by pressure may have a more micro porous structure than coals that attain the same rank in an environment dominated more by pressure. The result may be that Tertiary coals, on an equivalent rank basis, may have higher adsorption abilities than other coals. To some extent this might be a circular argument because the higher adsorption would be reflected in a lower moisture content, which in turn would give the appearance of a higher rank. Also rank is estimated using different parameters and one persons rank estimated using calorific value or carbon content (dry ash-free basis) may not be the same as another person's rank estimated using vitrinite reflectance.

Tertiary coals are generally of low rank often well cleated (Ryan, 2002) and are contained in immature sediments, consequently in some situations the coals will be harder than the surrounding lithologies. They should have and maintain good permeability even at considerable depth. Thicker coal seams should respond well to fracing as long as they are deep enough. If the surrounding sediments are poorly consolidated or bentonite rich they may not propagate fractures and remain as aquatards. Some coal zones may respond well to cavitation as long as enclosing sediments are consolidated.

Generally Tertiary basins influenced by Eocene volcanic activity have high geothermal gradients. Coal rank in some basins may increase rapidly with depth and vary along strike because of high and variable geothermal gradients in the basins. The general low rank of Tertiary coals will limit adsorption capacity. Also the present geothermal gradient may be high and this will have the effect of decreasing the adsorptive capacity of coals at depth as temperatures increase.

Sediments in most Tertiary basins are non-marine (Graham, 1980) with no marine association one can expect formation water to be non-saline. Basin shapes, combined with impermeable sediment layers such as bentonite bands, may be ideal to restrict water movement through the sediments allowing accumulation of biogenic methane. Some of the basins are in the form of major synclines with limbs tending to outcrop on the sides of valleys making for ideal artesian over pressured environments in the cores of the basins. Bentonite layers may respond to dewatering by swelling and therefore help to inhibit water movement across the stratigraphy.

The presence of basement volcanic rocks may effect the gas composition, providing sources for thermogenic carbon dioxide (CO_2) and nitrogen (N_2). Carbon dioxide is generated at low rank during coal maturation and may still be present in the stratigraphic section. The low rank and poor compaction of the sediment pile may allow easy migration of gases from the basement.

Coals of sub-bituminous to high-volatile bituminous rank have not generated much thermogenic methane. Meissner (1984) states that thermogenic methane generation starts when the volatile matter (dry, ash-free basis) is less than 37.8 %, equivalent to a rank of high-volatile A bituminous or a mean maximum reflectance of vitrinite (Rmax% value) of 0.73%. Dow (1977) suggests that thermogenic methane generation starts at a Rmax value of 1.0% however Snowden and Powell (1982) suggest that oil and condensates can be generated from coals rich in resinite at Rmax% values in the range 0.4% to 0.6%. Some of the Tertiary basins such as Hat Creek, Tuya and Bowron contain significant amounts of amber a form of resinite.

Tertiary coals in British Columbia generally have higher vitrinite contents than Cretaceous coals in the province. This probably indicates an absence of paleofires that characterized the Early Cretaceous (Lamberson, 1991). Also in part because of low rank, they contain more liptinite. Based upon these petrographic characteristics Tertiary coals should generate thermogenic methane at lower temperatures and have better adsorption characteristics at equivalent ranks compared to Cretaceous coals in British Columbia.

COAL RANK DETERMINATIONS

For some of the basins, rank determinations in the form of vitrinite reflectances either as mean maximum (Rmax) or as mean random (Rrand) are available. For low rank coals the difference between Rmax and Rrand is minimal but for higher rank coals Rmax is distinctly higher than Rrand and an empirical correction should be applied before comparing data sets. Grieve (1993) uses Rmax= 1.0809*Rrand - 0.0306 and Diessel (1998) uses Rmax=1.07*Rrand - 0.01. In some basins the only data available are old proximate analyses. It is possible to estimate rank from volatile matter corrected to an ash-free basis (VM daf). Meissner (1984) uses a series of equations to cover the range of VM daf and Rmax data. Before using this approach to estimate rank it is important to remove the effects of ash from the VM daf value and to consider the effect of petrography on the VM daf value. A true VM daf value is obtained by plotting VM daf values *versus* ash and projecting to zero ash to obtain VM daf(zero ash). This removes the contribution of volatile matter by ash to the VM daf value. Vitrinite contains more volatile matter than inert macerals and this has to be considered when using VM daf data to estimate Rmax values. A limited data set of VM daf and petrography data was used to derive the equation

$$Rmax=-1.2124*\ln(VM\ daf)+0.0073*R\%+4.4851:$$

Where R is percent vitrinite on a mineral matter free basis and VM daf is volatile matter dry ash-free derived from a plot of data and projected to zero ash.

Using this approach it is possible to derive approximate rank determinations for a lot of the basins and to determine if rank increases with depth. In the future an extended database will be used to improve the equation.

FRACTURE POROSITY

Low rank coals have limited ability to adsorb gas so that the free gas may be a major percent of the total gas recovered. It is difficult to estimate fracture porosity in coals but it is possible to estimate it using bulk washability data (Ryan and Takkinen, 1999). Washability data may be available if there has been active mining in an area and the data can be useful for CBM studies. It is possible to derive some information on fracture porosity by careful inspection of the different sizes washed and the average ash in each SG split of the wash matrix. For larger size consists the ash concentration of material in each SG split is higher than for smaller size consists. This is because there is greater fracture porosity associated with the larger coal fragments. The porosity is estimated by converting ash concentration to average density. The density equation in Ryan and Takkinen (1999) can then be used to predict the porosity in the larger size consist.

HAT CREEK

GENERAL

The Hat Creek area is about 20 kilometers west of Cache Creek. G.M. Dawson of the Geological Survey of Canada first reported coal in the area in 1877. There was some drilling and development of coal outcrops along Hat Creek in the early 1900,s and from 1933 to 1945 a few hundred tonnes of coal were mined. In 1959 the property was purchased for 2 million dollars by the for-runner of BC Hydro as a potential source of coal for a coal fired power plant. There was not much exploration on the property till 1974, when BC Hydro initiated a series of major exploration and engineering projects.

GEOLOGY

Middle Eocene rocks of the Coldwater Group are preserved between 2 north trending faults that define a graben about 6 kilometres wide and 25 kilometres long (Figure 2). The Group is subdivided into three members a lower member 1400 metres thick is composed of coarse-grained sediments and is overlain by a member composed of fine-grained sediments and coal. This member, which is 1200 metres thick, contains up to 550 metres of intermixed coal (70%) and rock partings (30%). An upper unit 600 metres thick is composed of fine-grained sediments and contains no coal. Two coal deposits referred to as the Number 1 and Number 2 deposits have been explored within the graben. A major negative gravity anomaly (Figure 2) over-

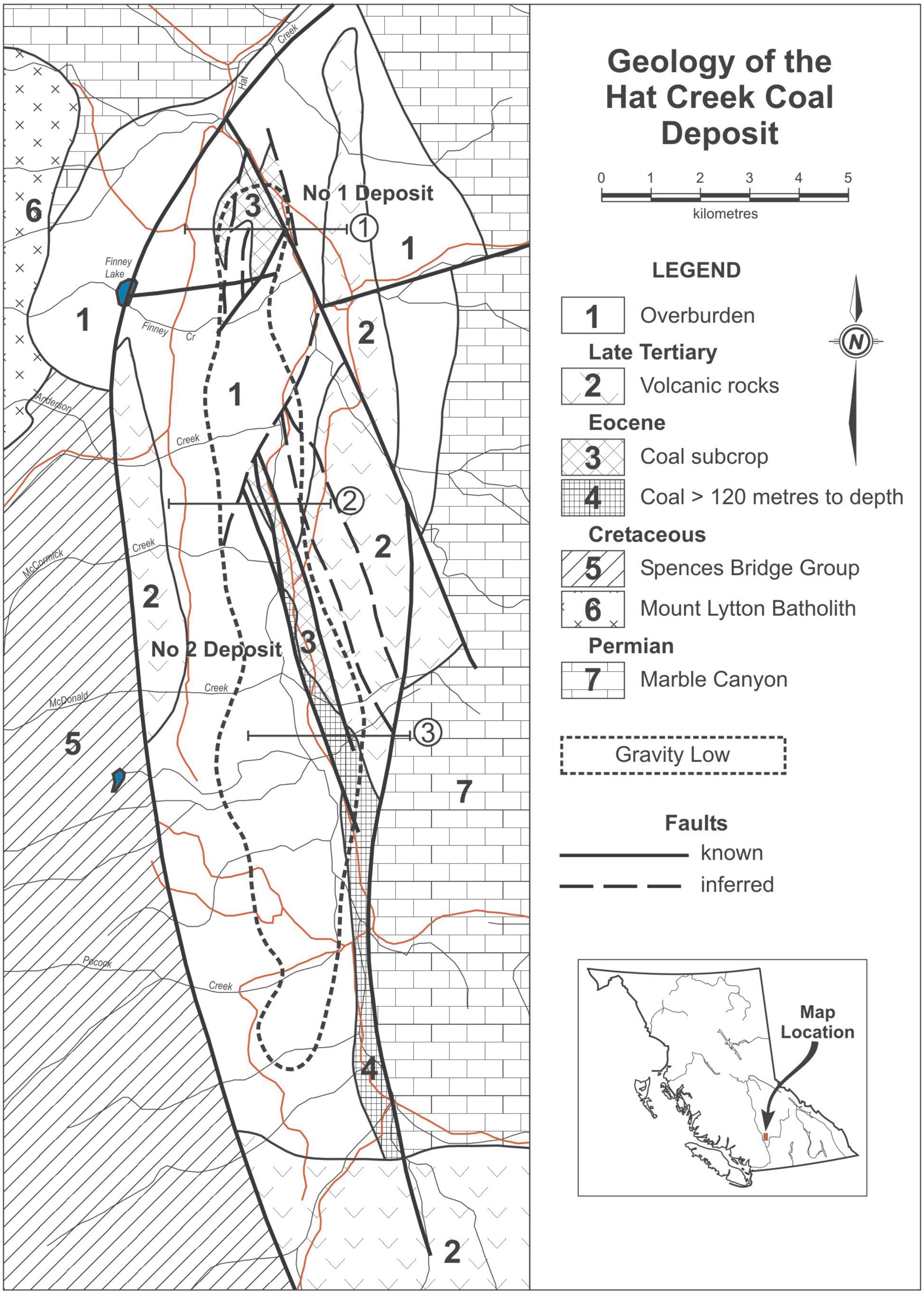


Figure 2. General Geology of the Hat Creek deposit adapted from Church (1975).

lies both deposits and extends south of the Number 2 deposit (Church, 1975).

The northern Number 1 deposit was extensively explored because of its low strip ratio and potential as an open pit mine. 474 holes were drilled into the deposit, which contains lignite A to sub bituminous C coal. The deposit comprises two synclines plunging 15° - 17° south-southwest separated by an anticline. The synclines are truncated on the southeast end by northeast trending gravity faults (Graham 1989) (Figure 3). The folds are truncated in the south by a fault and in places beds are steepened or overturned by reverse faults.

The second and potentially larger Number 2 deposit is 10 kilometres south of the Number 1 deposit. It has experienced less exploration and only 64 holes have been drilled to date. Most of these holes failed to penetrate the full thickness of the deposit. The deposit occurs within a graben bounded on the east and west by north-trending normal faults. Displacements on the western faults appear to be more than on the eastern faults causing a rotation and a 25^{o} western dip of the sediments. The deposit appears to be folded into a broad anticline, which trends north and is dis-

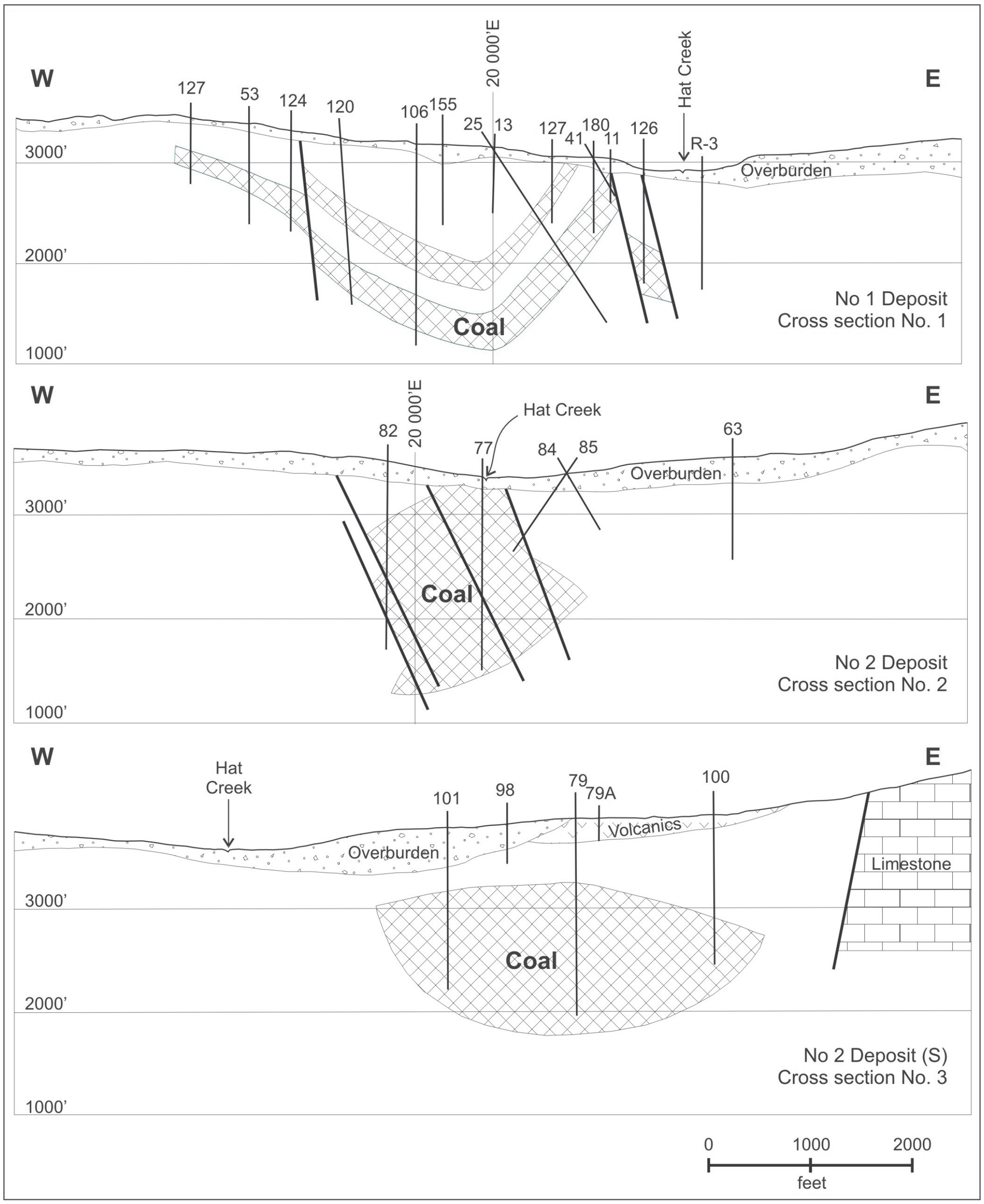


Figure 3. Schematic cross sections of the Number 1 and 2 deposits, Hat Creek; from Campbell *et. al.* (1977).

rupted by faulting on its eastern edge. The deposit is divided into 4 coal units numbered from A at the top to D at the bottom; thicknesses are respectively 185, 100, 150 and 80 metres (Goodarzi and Gentzis, 1987) though they may well be minimum as it is not clear if any holes drilled the complete coal section. Coal unit D is described as consisting almost entirely of coal.

COAL RANK

Coal at Hat Creek is composed of almost 100% vitrinite macerals (Goodarzi and Gentzis, 1987). Rank of the Number 1 deposit varies from a random reflectance (Rrand%) of 0.38% to 0.5% over a depth of 600 metres (Goodarzi, 1985), which indicates a rank gradient of about 0.06%/100 metres. At these ranks the difference between random reflectance and mean maximum reflectance is minimal. This gradient is similar to those in southeast BC (Hacquebard and Cameron 1989) and at Seaton and is not noticeably compressed. The rank of the larger Number 2 deposit (Figures 4 and 5) is slightly lower than that of the number 1 deposit and varies from 0.35% to 0.45% over a depth of 500 metres (Goodarzi and Gentzis, 1987). There is no clear trend of increasing rank with depth.

COAL RESOURCE

Estimates of the mineable reserves in the Number 1 deposit range from 200 to 750 million tonnes (mt). Kim (1979) estimates a reserve of 740 million tonnes. Of this total, over 500 mt are within of 200 metres of the surface. The resource of the No 2 deposit to a depth of 460 metres is estimated to be over 2 billion tonnes (Papic, *et. al.,* 1977).

The potential resource in the whole graben is estimated at over 10 billion tonnes by Campbell *et al.,* (1977) and in the two known pit areas to be 10 billion tonnes (7 in pit 2 and 3 in pit 1, Papic, *et al*., 1977). Church (1975) refers to gravity data that indicates that 3000 hectares (30 square kilometers or 11.6 square miles) of the central part of the graben may be underlain by coal. Depending on the thickness of coal assumed, the potential resource could easily exceed 10 billion tonnes

CBM RESOURCE

CBM in Hat Creek coals will be of biogenic origin because of the low rank. Based on experience in the Powder River Basin where coal ranks and ash contents are lower, it is unlikely that adsorbed gas contents will exceed 2 cc/g even at depth. Gas contents in the Powder River Basin range from 0.1 to 1 cc/g (Larsen, 1989) for coal with ranks ranging from 0.28% to 0.4%, which are a little lower than those at Hat Creek. Adsorption characteristics are very variable for low rank coals and appear to increase rapidly with small increases in rank as seen in Figure 6, which includes an isotherm from a coal of rank 0.67%. Figure 6 also illustrates the effect of a 5% gas filled porosity on the total gas available for production. The adsorption of Hat Creek coal should be somewhat better than that of Powder River on an ash free basis though generally Hat Creek coal contains more ash than Powder River coals. In the absence of any adsorption or desorption data, estimates of the CBM resource are made using 1 cc/g and 2 cc/g (30-70 scf/ton) applied to the resource estimate of pit 2 which is 7 billion tonnes. This provides a potential resource in the range of 0.2 tcf to 0.65 tcf.

The possible anticline structure of the Number 2 deposit in conjunction with the many bentonite layers may form ideal traps for adsorbed or free gas. The bentonite layers may make it possible to produce CBM from different stratigraphies in the deposit at different times. If this is the case, water extracted from one layer could be injected into a layer, which had already been depleted of CBM by production. This would mean that after an initial period of production, produced water could be re injected with minimal disruption of production. It is also conceivable that if a surface power plant were constructed that CBM produced water could be used as cooling water in the plant. Final costs of water disposal would be shared by both developments.

There are some data on ground water composition from the Number 1 deposit. BC Hydro conducted an Environmental Impact Study in 1978 (Beak Consultants, 1978) in which there are some analyses of water from holes drilled into the Number 1 deposit (Table 2). The drill hole water meets the standards for toxic chemicals required by Canadian standards for drinking water and for cations only exceeds the limits for sodium. It is apparent that the water would need very little treatment before surface discharge.

COMPARISON OF HAT CREEK TO POWDER RIVER BASIN

Ranks of coals in the Powder River range from 0.28% to 0.4% (Pratt *et al*, 1997) and are similar to, though slightly lower than ranks at Hat Creek. Desorbed gas contents are 0.6 to 0.7 cc/g (20-25 scf/ton) at depths of 175-200 metres. Both Hat Creek and Powder River coals are vitrinite rich

TABLE 2
PERMEABILITY DATA HAT CREEK NUMBER 1 DEPOSIT

Lith Unit	No of tests	milli Darcies	
		low	high
Upper Siltstone	13	0.0001	3
A zone siltstone and coal	6	0.001	0.03
B zone coal	3	20	50
C zone siltstone and coal	13	0.003	3
D zone coal	12	0.6	100
Lower Siltstone sandstone	15	0.0002	0.5
Conglomerate	4	0.0095	0.3
Limestone	7	0.12	10 000

The B and D coal zones may have reasonable permeability

Data from Hat Creek Mining report, Volume 1, 1979 BC Hydro

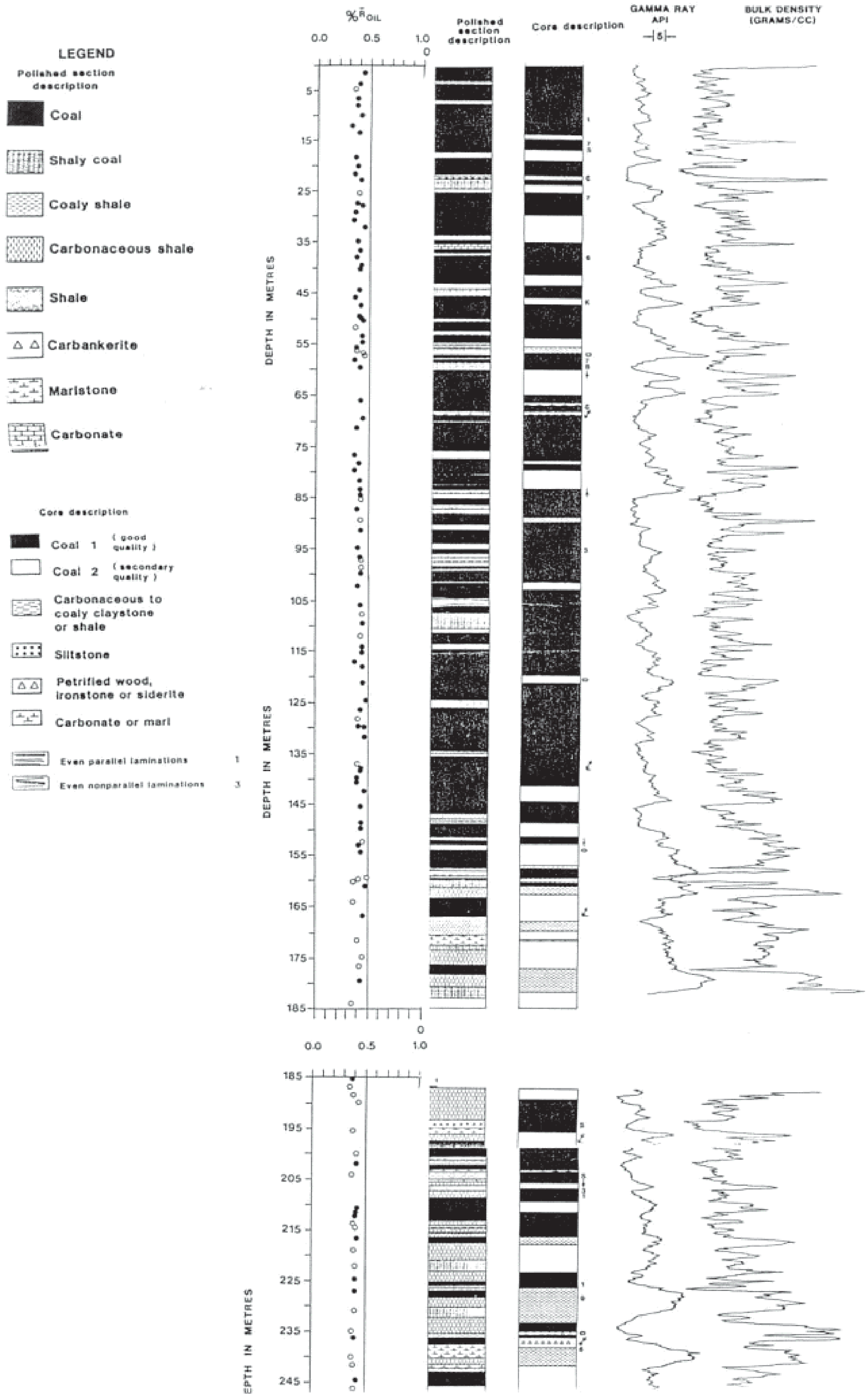


Figure 4. Rank and geophysical logs from the Number 2 deposit; data from Goodarzi and Gentzis (1987).

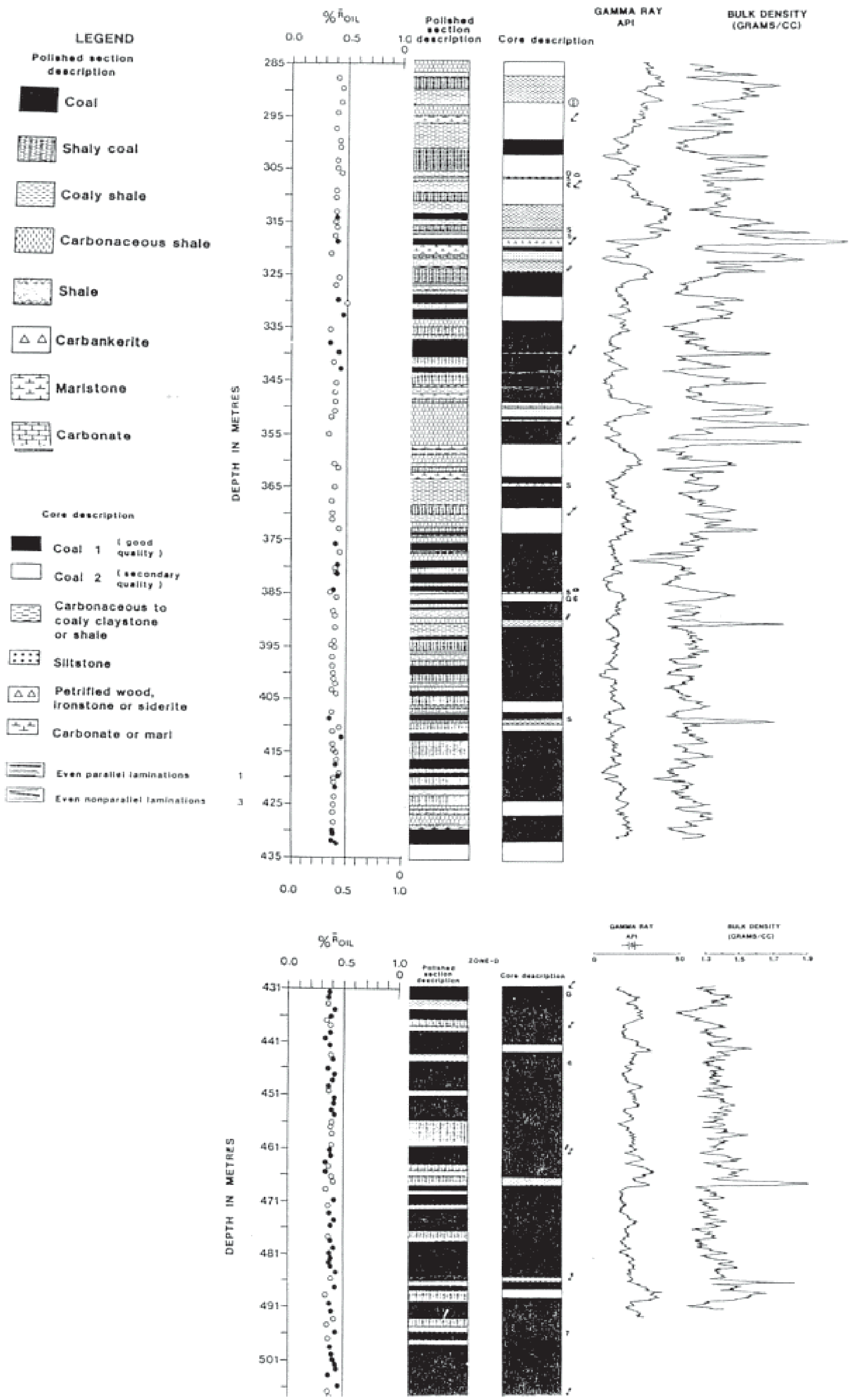


Figure 5. Rank and geophysical logs from the Number 2 deposit; data from Goodarzi and Gentzis (1987).

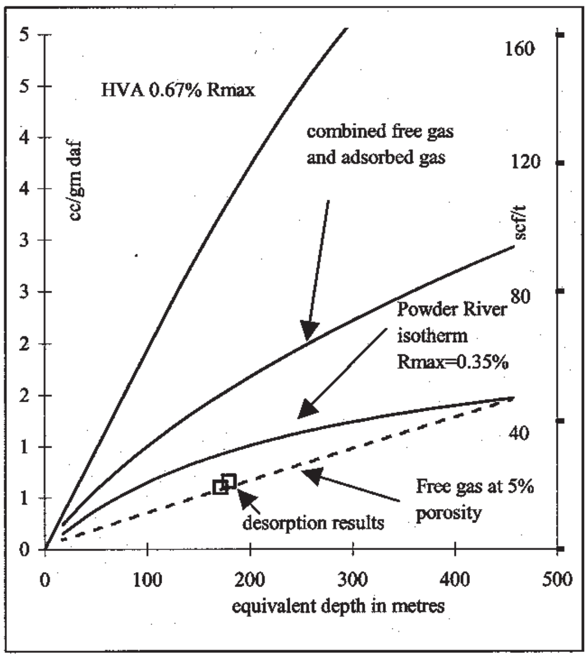


Figure 6. Adsorption isotherms for the Powder River Basin data from Mavor *et. al*. (1999).

with the Powder River coals containing more inertinite (15% to 25% mmfb) compared to Hat Creek coals that contain almost no inertinite (Goodarzi and Gentzis, 1987). Hat Creek coals generally contain a lot of rock splits and the intervening coal probably averages about 30% ash. In comparison the Powder River coals generally have low ash contents of less than 10% % (Pratt *et al*, 1997).

Permeability is high in the Powder River coals and values range from the milli Darcies to Darcies. Some conductivity data, available for the Number 1 deposit at Hat Creek is converted to milli Darcies (Table 3). The upper coal zone A has low permeability but the two lower zones B and D appear to have good permeabilities (averaging 40 and 50 milli Darcies) though not as good as Powder River.

One of the reasons that the Powder River Basin is successful is that the desorbed gas content appears to account for less than half of the recoverable gas per tonne of coal. It has been suggested (Bustin and Clarkson, 1999) that in low rank coals a significant amount of the gas in a volume of coal (up to 70%) may be stored as free gas in the matrix porosity. There is no information on the fracture porosity of Hat Creek coal but it may be possible to extract some useful information from washability data that exists for the property. It may also be possible to use moisture analyses to indicate if the coal is gas saturated. If equilibrium moisture values are greater than as –received moisture values obtained from core samples, then this might indicate that cores were partially gas saturated. This assumes that the core samples were sealed and not allowed to dry out prior to as-received moisture analyses.

TABLE 3
PETROGRAPHY OF TULAMEEN AND TUYA RIVER SAMPLES

	telinite	collotelinite	collodetrinite	vitrodetrinite	liptinite	gelovitrinite	total reactives	semifusinite	fusinite	macrinite	micrinite	inertodetrinite	total inerts
A	15	34	45	1	4	1	99	1	0	0	0	0	1
B	7	41	43	3	2	3	100	0	0	0	0	0	0
C	6	33	50	3	8	0	100	0	0	0	0	0	0
D	57	10	15				97						3

A Tulameen HW B Tulameen FW
C Tuya River D Hat Creek

Hat Creek data from Goodarzi (1985)

MERRITT

GENERAL

The Merritt Coal Basin (also referred to as the Nicola Basin) comprises several isolated Eocene (Coldwater Formation) sedimentary areas (Figure 7) (Read, 1988) that outcrop within a radius of 15 kilometres. The main area, which covers about 80 square kilometers is centered on the town of Merritt and includes the mining areas of Coal Gully, Coldwater Hill and Diamond Vale. A second area 15 kilometres to the east overlies Quilchena Creek and covers about 25 square kilometers. It hosts the Diamond Valle prospect. The Tertiary rocks in the area unconformably overly the Triassic Nicola Group and Coast Range intrusive rocks.

The limits of the Merritt Basin to the southwest follow the Coldwater Creek and to the northeast the Nicola River and in both areas are obscured by valley fill. The basin is filled with sediments belonging to the Coldwater Formation that are in part overlain by Miocene-Pliocene basalts in the east. The coal measures are up to 300 metres thick on the western edge of the basin where seams tend to be thicker and more continuous (Matheson, 1992). Structure is dominated by a series of northwest trending normal faults and folds (Figure 8). The folds are described as plunging to the southeast (Dolmage and Campbell, 1975) but the map of Swaren (1979) implies a northwest plunge. Dips steepen and the structure becomes more complicated to the west near the contact with the basement. The northeastern part of the basin is overlain by Pliocene basalt flows that separate the Normandale mine from the rest of the basin. Overall the basin has not been extensively explored; much of it is overlain by alluvium with potential coal seams at depth and therefore not of interest as resources for surface or shallow underground mining.

In the past mining occurred in three areas in the Merritt Basin. Most occurred in the Coal Gulch area (Figure 7), which produced about 2.5 mt of high-volatile C to A bituminous coal in the period 1906 to 1963. In this area Swaren (1977) identified seven coal zones (not numbered in strati-

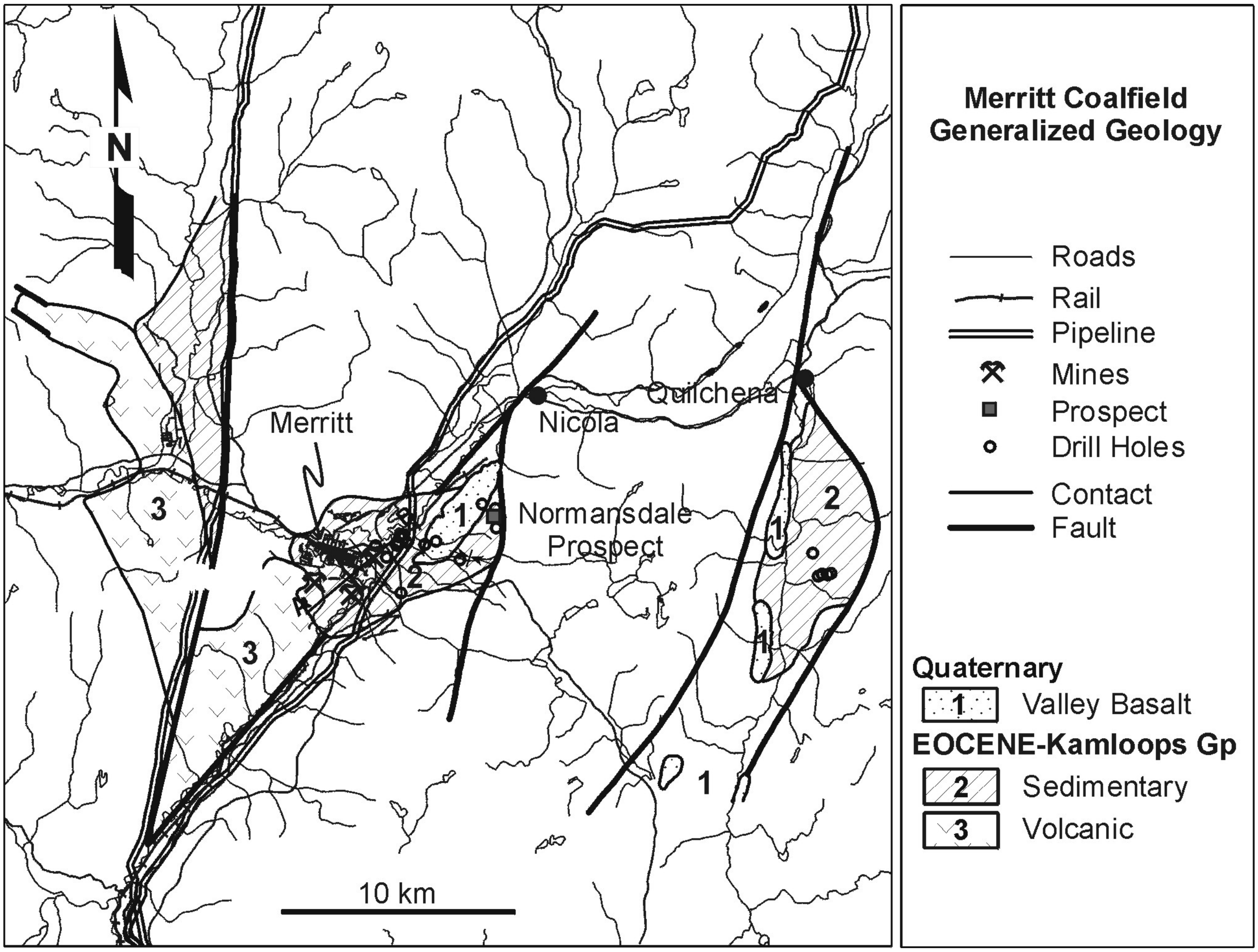


Figure 7. General geology of the Merritt Basin from Read (1988) and Matheson (1992).

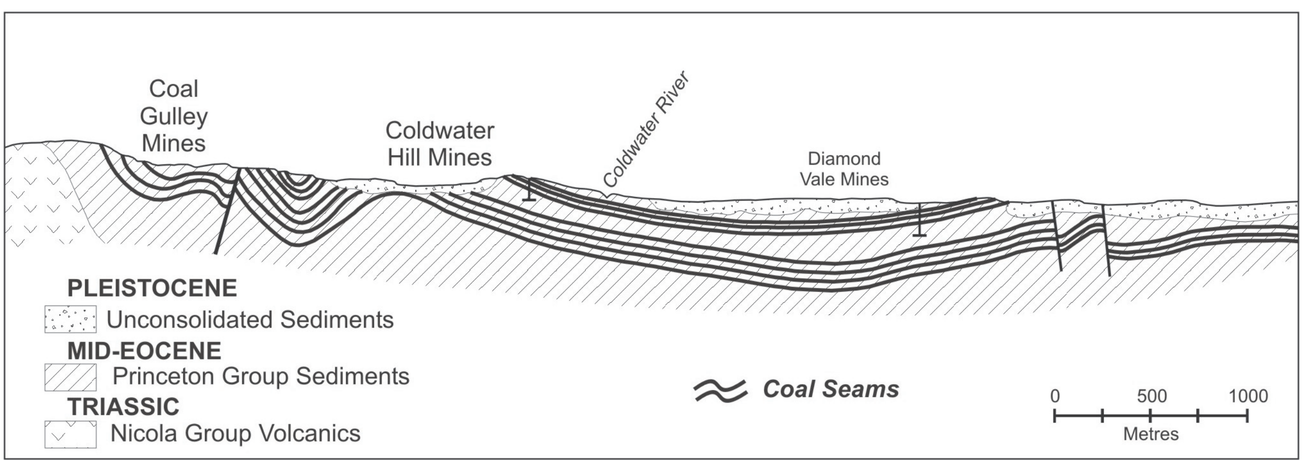


Figure 8. Generalized cross section through the Merritt Basin from Matheson (1992).

graphic order) in the 300 metres coal section. The lowest No 1 is 7.9 metres, No 5 is 1.5 metres, No 4 is 7.6 metres, No 8 is 2.44 metres, No 6 is 1.8 metres, No 3 is 0.76 and the top seam (No 2) is 1.8 metres thick for a cumulative thickness of 23.76 metres. On Coldwater Hill one kilometer northeast of the Coal Gully mines, ten seams with cumulative coal thickness of 6.4 metres occur in a 140 metre section.

In the Diamond Vale Mine, which is 2 kilometers east of the Coldwater Mines, seams 2, 3 and 6 were mined; seams lower in the section were not mined because of depth. Five seams are described with a cumulative thickness of 5.3 metres over a stratigraphic interval of 95 metres. Seams dip to the southwest outlining a northwest trending syncline between the Diamond Vale and Coal Gully mines. The fold projects the coal seams under the town of Merritt and the Nicola River. The depth to the top of the coal measures in the core of the syncline is projected to be greater than 450 metres (Swaren, 1977). A single seam 1.5 metre thick was explored and mined briefly at the Normandale Mine, which is on the eastern edge of the Merritt Basin. Beds in the area dip to the southeast and it is not clear how this relates to the westerly dips at the Dips at the Diamond Vale mine.

In the Quilchena area, where the Diamond Valle prospect is described, coal seams rarely exceed of 1.5 metres (Ells, 1905). Thicker seams 2 to 4.5 metres thick were apparently found in the northern part of the sub basin (Ells, 1905). Drilling in 1981did not intersect additional seams and it appears that either there is much less coal in the section than in the Merritt area or the drill holes missed the coals seams because of faulting .

COAL QUALITY

Coal rank in the Merritt area spans the range high-volatile C to A bituminous with random reflectances ranging from 0.62% to 0.82% (Rmax 0.64% to 0.86%). There does not appear to be any relationship to depth but rank may be increasing in a northeasterly direction (Matheson *et al*, 1994). Reflectance values of 0.745% and 1.44% were obtained from Coal Gully (Kilby, personal communication 1987). Proximate data (Matheson *et. al*. 1994) predict a rank of 0.75% based on the equation discussed in the introduction. The volatile matter data is used to predict the Volatile matter dry ash-free value at zero ash and this with an assumption of vitrinite content is used to predict Rmax% values (Figure 9).

COAL AND CBM RESOURCE

In the western part of the Merritt Basin, Swaren (1977) estimates the speculative underground mining resource of 180 million tonnes. The area considered does not extend north under the town of Merritt or northeast along the Nicola valley. Including these areas in a potential resource calculation increases the tonnage to about 300 million tonnes. The calculation used 20 metres of accumulated coal in the western part of the basin progressively thinning to 5 metres in the northeast and no tonnage was assigned to the Normandale Prospects area where only one 1.5 metre thick seam has been mapped.

Coal rank averages about 0.75% Rmax. Isotherms for coals of rank 0.8% and 0.67% as well as the predicted gas content for Rmax 0.75% (Ryan Equation, Ryan 1992) bracket the possible gas content for Merritt coal (Figure 10). The isotherms were obtained from coals with close to 100 % vitrinite on a mineral-matter free basis and in conjunction with the calculated isotherm have been recalculated to a 25% ash basis. The coal resource of 300 million tonnes is assumed to be evenly distributed from 0 to 800 metres and appropriate gas contents assigned to each block of coal. The potential CBM resource of the coal is then estimated to be about 52 bcf. The best potential is west and under the town of Merritt. Areas that have untested potential include the Nicola Valley to the northeast and under the Miocene-Pliocene valley basalts on the eastern side of the Merritt Basin.

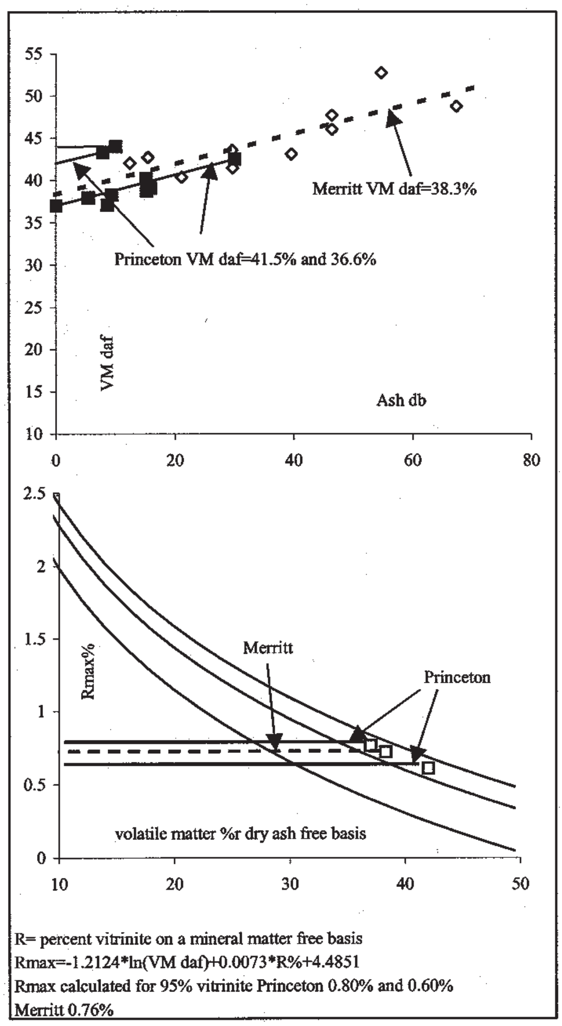


Figure 9. Rank determination for the Merritt and Princeton basins.

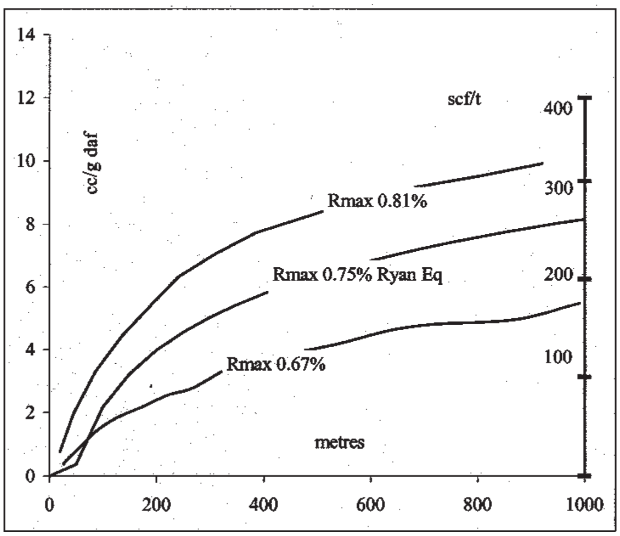


Figure 10. Possible adsorption isotherms for Merritt coals.

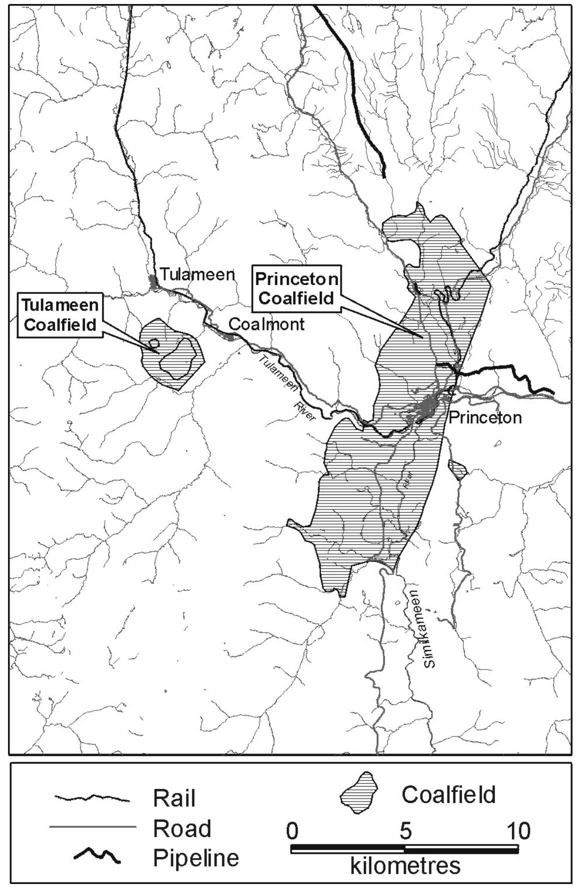


Figure 11. Similkameen coalfields and location of the Tulameen and Princeton Basins.

PRINCETON BASIN

GENERAL

The Similkameen Coalfield (Figure 11) contains a number of basins. The two most important are the Princeton and Tulameen. The Princeton Basin is a northerly elongated basin approximately 4 to 7 kilometres wide and 24 kilometres long, covering a total area of about 170 square kilometers and centered on the town of Princeton (Figure 12). The basin is a half graben bounded on the east by a north-northeasterly trending west dipping extension fault that has a minimum separation of 1400 metres (McMechan, 1983). The basin is filled with mid Eocene strata of the Princeton Group, which rest unconformably on volcanic rocks of the Upper Triassic Nicola Group. The Princeton Group is divided into 2 formations. The Lower Volcanic Formation, which is 1370 metres thick (Cedar Formation, Read, 1987) is overlain by the coal-bearing Allenby Formation, which is 1700 metres thick (Shaw, 1952). This formation is divided into 3 members, a lower member containing volcanic tuffs and flows, a middle member containing non-marine sediments and tuffs and an upper member containing non-marine sediments and coal. Four coal zones occur in the basal 530 metres of the coal-bearing member, other coal zones occur higher in the member. Sediments in the northern part of the basin north of the town of Princeton coarsen and coal zones may not be present possibly because paleocurrent direction was from the north or northeast (McMechan, 1983).

The basin is divided east-west by the Similkameen River and a northwest trending open anticline. The southern part of the basin, which contains most of the potential coal resource, forms an east plunging syncline truncated by the boundary fault to the east. A maximum thickness of about 1500 metres of Allenby Formation is preserved. The basin is shallower in the north and consists of a homocline dipping east at 15° to 25°, truncated by the boundary fault. A gravity survey (Ager, 1975) confirmed that the thickness of sediments in the northern part of the basin is much less than the in the south where the survey indicated a maximum thickness of 1200 to 1500 metres. The survey did not indicate a major gravity low that might be associated with a deposit similar to Hat Creek.

COAL RESOURCES

Coal mining started in the basin in 1909 and over the next 52 years, 13 small underground and one surface mine operated in the central part of the basin. Mining activity finished in the basin in 1961, by which time 1.9 million tonnes of sub bituminous coal had been mined. From 1971 to 1982 there was renewed exploration and 26 short holes were drilled mainly in the northern part of the basin but no major coal seams were intersected and the coal licenses were subsequently dropped.

In the southern part of the basin, coal seams are difficult to correlate and lense-out over fairly short distances. Four major coal zones, numbered from 1 at the top to 4 at the base of the section (Dolmage and Campbell, 1975), have been recognized in a 530 metres section. The lowest zone (Number 4) is represented by the Blue Flame, Black

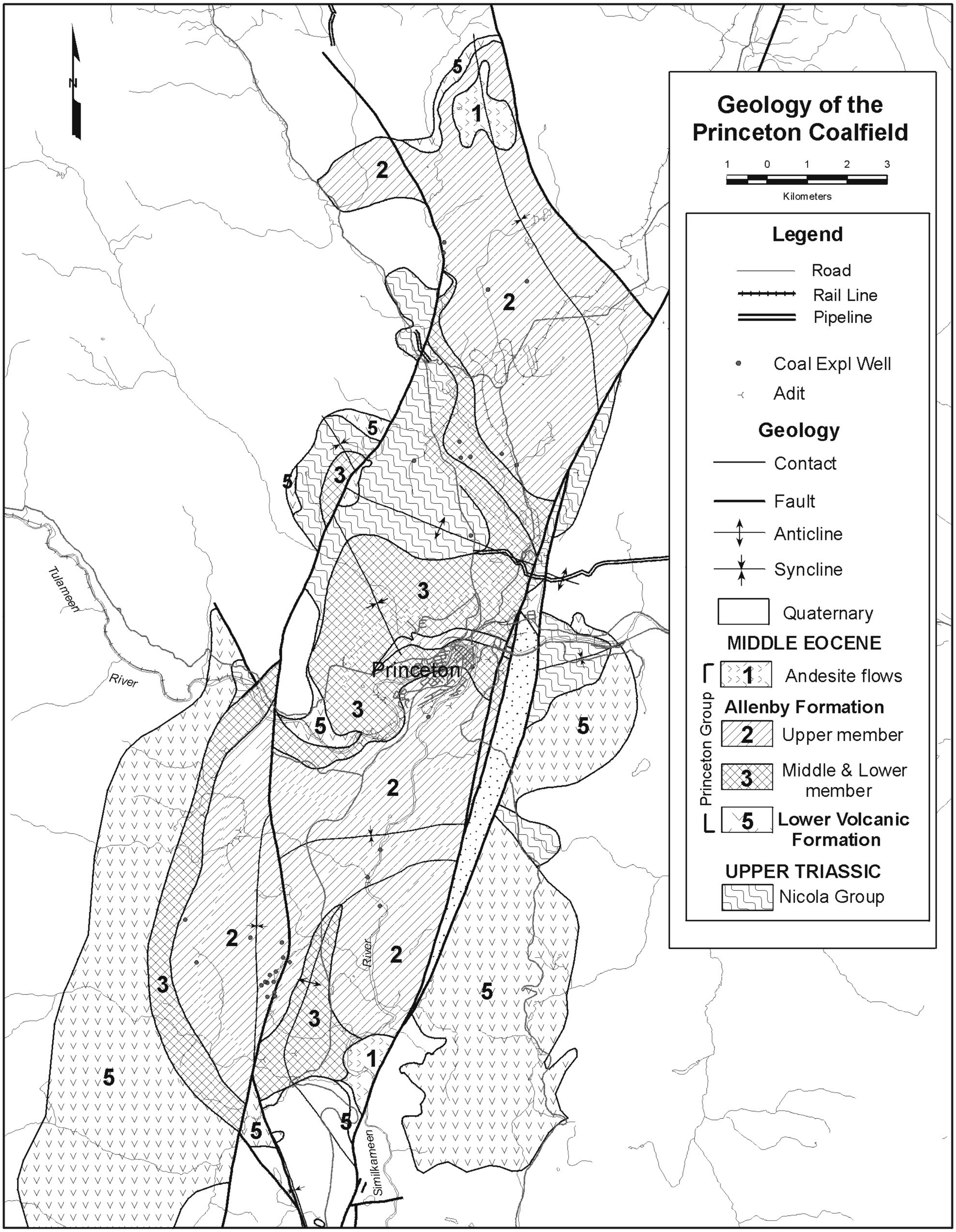


Figure 12. General geology of the Princeton Basin from McMechan (1983) and Read (1987).

Jack or Princeton seams. It ranges in thickness from 10 to 50 metres and is described as mainly dirty coal with a clean coal seam up to 2 metres thick near the top. Sections through the zone (McMechan, 1983) provide an average thickness of coal with splits removed of 6 metres. In 1947 a sample of the number 4 zone collected by Granby Consolidated was over 28.5 metres thick and averaged 37.6% ash (arb). Coal and carbonaceous mudstone continued below the sample for another 18 metres. The next (number 3 zone) is 140 metres higher in the section and contains the Jackson or Pleasant Valley seams and is about 30 metres thick. It is reported to contain up to 2 workable seams. The Number 2 zone, which hosts the Bromley Vale and Gem seams contains 7.5 metres of coal in a 26 metres section and is 200 metres above the number 3 zone. The number 1 zone contains the Golden Glow and Blakemore seams. This zone is 100 metres above the number 2 zone and contains from 2 to 3 metres of coal.

COAL QUALITY

A single Rmax value of 0.54% for the Number 1 seam (Blue Flame Seam, Lamont Creek, personal communication Kilby 1987) indicates a sub bituminous rank. Volatile matter dry-ash-free basis data (VM daf) for seams in the southern half of the basin appear to form two clusters, one indicates a rank of 0.8% and the other from 0.6% to 0.65% (Figure 9). There is not a lot of data and it is difficult locate the data stratigraphically however there does seem to be an indication that in general rank is higher than the single reflectance value of 0.54%. If folding predated coal maturation then higher ranks can be expected in the core of the syncline in the southern part of the basin.

COAL AND CBM RESOURCE

Seam characteristics are very variable laterally and the recognized zones are separated vertically by many metres of sediments. It is therefore difficult to derive cumulative coal thicknesses at any one location through the Allenby Formation. Drill holes have intersected from 7 to 15 metres of coal but generally did not drill the whole coal section. The cumulative coal thickness for the 4 zones appears to be about 20 metres, however seams are very discontinuous. Dolmage and Campbell (1975) estimate a potential resource of over 800 mt in the southern part of the basin, which covers about 65 square kilometers. They are therefore assuming a cumulative coal thickness of about 10 metres over the whole area. They outline a coal bearing section of 520 metres that contains 4 coal zones with a cumulative thickness of 77 metres. Unfortunately they do not indicate the percentage of coal in the zones. If a third of the zones are coal, then this would indicate a cumulative coal section of about 26 metres compared to a single drill hole that intersected 17 metres. The best estimate of coal in the section is therefore probably between 17 and 26 metres and the assumption of an average of 10 meters over the whole southern basin seems reasonable.

The gas contents depend in part on the ability of low rank coal to retain gas but more on the availability of gas, because coal of rank less than 0.7% have not generated much thermogenic methane. The presence of amber in the coal may indicate that thermogenic methane generation has started at lower ranks and temperatures. However any gas present will probably be biogenic.

The adsorption capacity of Princeton coals is probably better than that of Powder River coals, for which there is a lot of data. These coals, which have ranks ranging up to 0.4% Rmax, hold about 35 scf/t at 200 metres. Coals of a slightly higher rank in the Alberta hold between 50 to 100 scf/t at 200 metres. Based on these data an average gas content of 100 scf/t is assumed for Princeton coals at 200 metres depth. Some coal will be deeper and some shallower than this reference depth. A tonnage of 800 mt and a gas content of 100 scf/t therefore indicates a potential CBM resource of 80 bcf.

Most of the mines in the Princeton Basin were shallow underground operations of short duration. There is no mention in the literature of gas problems in the mines. Most problems originated from spontaneous combustion of the low rank coal and swelling of bentonite, producing pressure in roofs floors and pillars.

TUYA RIVER

GENERAL

The Tuya River Basin was mapped and the CBM resource appraised in 1991(Ryan, 1991). The basin is located between the communities of Dease Lake and Telegraph Creek in northwestern British Columbia and straddles the drainage of Tuya River and its tributaries Little Tuya River and Mansfield Creek (Figure 13). The Tuya and Little Tuya Rivers and Mansfield Creek have incised meandering canyons up to 200 metres deep into the topography, which in the area, is subdued with an average elevation of 800 metres. Outcrop is restricted to valley floors. The basin is potentially quite large and covers approximately 150 square kilometers, potentially containing over 600 million tonnes of high-volatile bituminous coal. Basin boundaries are poorly defined and in places recent volcanic rocks cover Tertiary sediments. The eastern and western boundaries are probably fault-controlled, with pre-Tertiary rocks to the east and younger volcanic rocks to the west. The southern boundary is arbitrarily defined by thick post-glacial drift and absence of outcrop.

The earliest recorded description of coal in the Tuya River area was in 1904 (Dowling, 1915) when seams 12.2, 11.6 and 7.9 metres thick were described adjacent to Tuya River. Smitheringale (1953) mapped Tuya River and had only partial success in locating the coal outcrops described by Dowling. He also mapped the Tahltan River Canyon, which is about 20 kilometres southwest of the Tuya River Basin, where he located Tertiary coal zones ranging up to 4 metres in thickness. The Basin was explored in detail in the period 1979 to 1980, when 10 cored-holes were drilled and a number of hand trenches dug. Sediments in the basin were dated using Palynology (Vincent, 1979) as not younger than early Eocene, and not older than Paleocene.

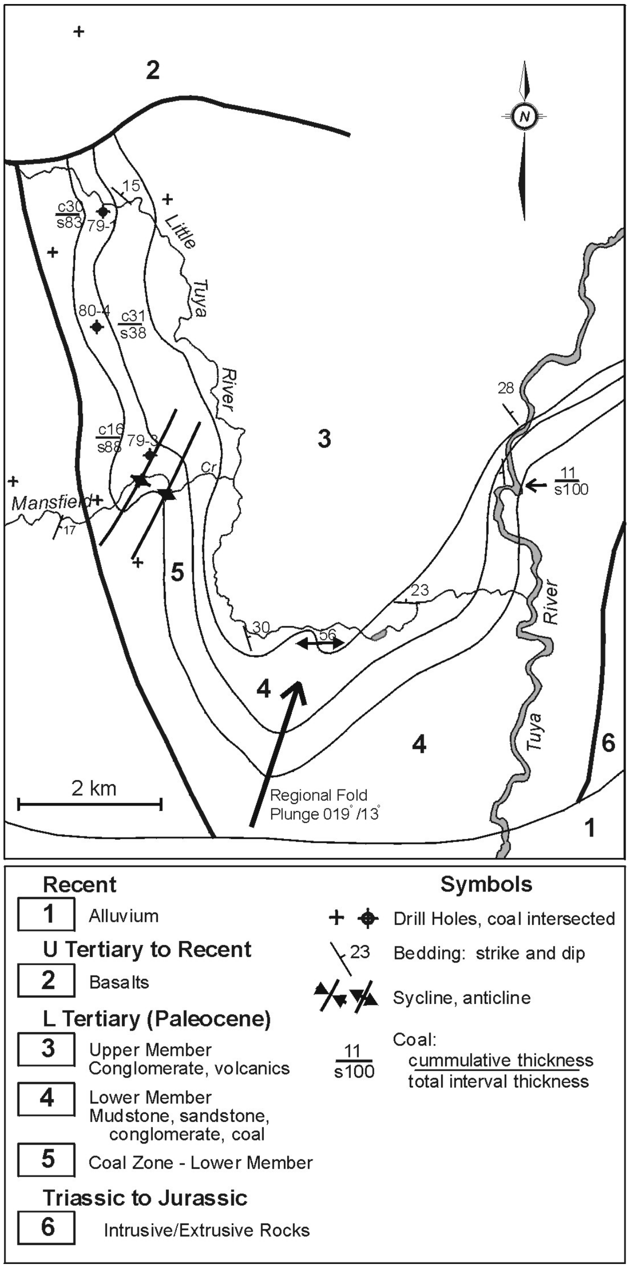


Figure 13. Generalized geology of the Tuya River Basin.

COAL GEOLOGY

A tentative stratigraphic succession divides the Paleocene rocks into two members. The upper member is at least 300 metres thick and is composed of volcanic-pebble conglomerate, sandstones and volcanics. The lower member, which is 200 metres to 300 metres thick, contains a single coal zone and is composed mainly of mudstones and sandstones in the west and sandstones and chert-pebble conglomerates in the east. The coal zone is about 100 metres thick and contains from 5 to 30 metres of coal.

The simplest interpretation the basin structure is that of an open, northerly plunging syncline (fold axis 019°/13° trend/plunge), complicated by smaller scale faults and folds. Isolated outcrops with steep bedding in Tuya River are probably evidence of faulting. Also interpretation of geology is complicated by the presence of extensive block slumping off the valley walls toward the rivers, causing detachment and rotation of some outcrops.

In outcrop coal is blocky, well banded and usually clean with well-developed cleats. It is often harder than the enclosing poorly consolidated sandstones. Seams vary in thickness up to 20 metres. Mudstone and bentonite bands are common in seams. The coal is vitrain rich and contains an unusually high percentage of resin; some bands contain up to 5 % occurring as blebs ranging up to 5 millimetres, in diameter. In places, the vitrain bands have a waxy luster and conchoidal fracture, which forms a distinctive eyed pattern on the fracture surfaces.

COAL QUALITY

Coal rank is sub-bituminous B to high-volatile bituminous C. Average quality of the coal on an as-received basis is 12.4% moisture, 19.1% ash, 30.7% volatile matter, 37.8 % fixed carbon and 0.5 % sulphur. Some Hardgrove Index (HGI) data, which are a measure of coal friability, average 52.5, indicating a moderately hard coal. Rmax values from Mansfield Creek and Little Tuya River on the west side of the syncline average 0.76% (7 values) and samples from Tuya River on the east side of the syncline average 0.68% (9 values). A single sample collected from near a burn zone in Mansfield Creek had an Rmax% value of 0.97%. Rank appears to be higher (high-volatile B bituminous) on the west limb of the syncline than on the east side (high-volatile bituminous C). If maturation postdates folding, then rank will increase at deeper levels towards the core of the syncline. A single petrographic analysis indicates that the coal is composed mainly of vitrinite with minor liptinite and trace inertinite (Table 4). There is a moderate amount of finely dispersed mineral matter. The volatile matter (daf) of the coals is about 45%, which predicts a rank lower than the 0.68%-0.76% Rmax values measured. The coals may be unusually volatile rich because of the presence of resin.

A subsidiary basin or extension of the Tuya River Basin outcrops 20, kilometres southwest of Tuya River in the lower reaches of the Tahltan River. Seams are generally thin with the exception of a single seam, which is in excess of 2 metres thick. Rmax% values of four samples from the Thaltan area, average 0.5%.

COAL AND CBM RESOURCE

The coal resource within 1600 metres of surface is 460 mt calculated assuming a simple syncline structure and an average true thickness of cumulated coal in the coal zone of 17 metres (Ryan, 1991). The true thickness was reduced by 20 % to account for rock splits. Coal areas were calculated on sections 1000 metres apart and broken down into 200 metre depth increments. Volumes were converted to tonnages using a specific gravity of 1.48. The potential CBM resource is calculated using the incremental coal tonnages

TABLE 4
BOWRON RIVER CBM RESOURCES

depth	coal	adsorption gas		resource
metres	mt	scf/ton	cc/g	bcf
0	30.8	0.0	0.0	0.0
100	30.8	8.8	0.3	0.3
200	30.8	58.8	1.8	1.8
300	30.8	88.1	2.7	2.7
400	30.8	108.8	3.4	3.3
500	30.8	124.9	3.9	3.8
600	30.8	138.1	4.3	4.2
700	30.8	149.2	4.7	4.6
800	30.8	158.8	5.0	4.9
900	30.8	167.3	5.2	5.1
1000	30.8	174.9	5.5	5.4
1100	30.8	181.8	5.7	5.6
1200	30.8	188.1	5.9	5.8
TOTAL	400.0			47.6

at various depths to 1600 metres and gas contents predicted using an isotherm from a Quinsam coal (Rmax 0.67%) or using the Ryan Equation Rmax 0.72% and 25% ash. The two methods produce the same potential resource of about 66 bcf.

The basin is very isolated but could provide energy to the local communities of Dease Lake or Telegraph Creek. It could also provide energy for any other resource development in the area.

TULAMEEN BASIN

GENERAL

The Tulameen basin, which is about 20 kilometres northwest of Princeton, forms an elliptical sedimentary basin 5.4 by 3.6 kilometres that contains two well-developed thick coal seams (Figure 14). The area underlain by coal is about 10 square kilometers.

Gold was discovered in Granite Creek in 1885 adjacent to coal outcrops. However, the first references to the coal potential of the area is found in the GSC Summary Reports for 1908 and 1909 by W.F. Robertson describing in part a 1901 observation. Coal analyses are reported in the Geo-

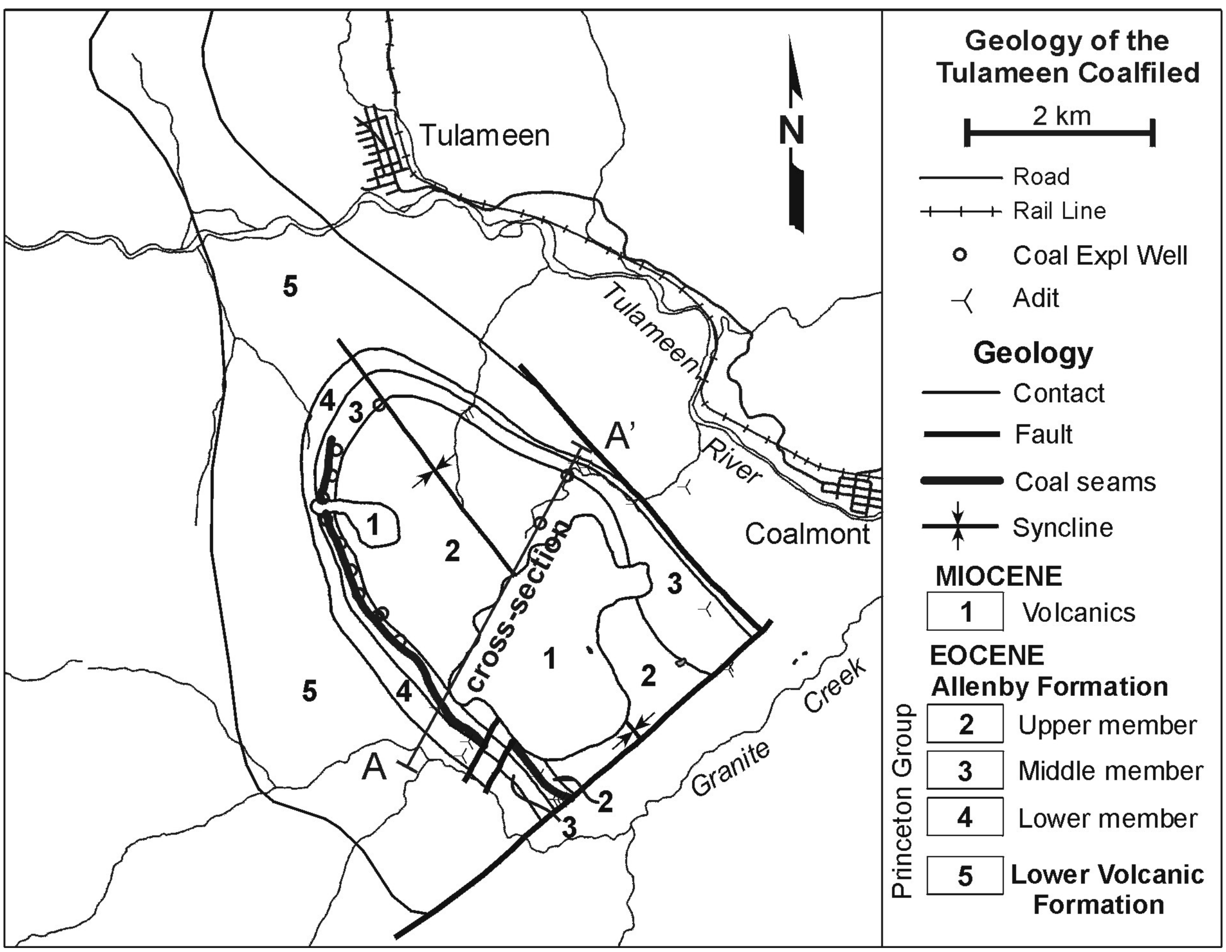


Figure 14. Generalized geology of the Tulameen Basin.

logical Survey Report for 1899. Mining started in 1904 in the Blakeburn Creek area with the development over the next 30 years of 5 underground mines. In 1913 Coalmont Collieries developed the No 1 and No 2 mines. The No 3 and No 4 mines were developed in mid 1920's, but closed in the mid 1930's because of fires and flooding. In fact the No 4 mine closed after a disastrous explosion on August 13, 1930, which killed 45 men. Up until that time the mines had been described as gas free with almost no mention of methane by the fire bosses. The cause of the explosion was not clear, but it was suggested that gas built up as a result of spontaneous combustion in an area closed off from active mining. The gas broke out into the active mine area because of low atmospheric pressure associated with a violent thunderstorm. Once mixed with air the gas became explosive and was probably ignited by the reactivated spontaneous combustion. The explanation indicates that desorbing methane was not a major contributing factor. The No 5 mine opened in 1931 and operated for 9 years.

In the period 1900 to 1940 about 2.2 million tonnes were produced from the basin. A small strip mine operated in 1954 to 1957 and produced about 240 000 tonnes. The basin has seen sporadic exploration since 1960 and at present Compliance Coal Mining is planning to develop a small mine. The main limitation on underground mining was the increase in crushing of the coal with depth. Possibly caused by movement within the bentonite bands. Also, in some mines, deterioration in coal quality caused mining to stop.

In 2000 a small test was excavated into the upper coal zone and coal shipped for test washing. The coal is hard and well cleated in outcrop with numerous bentonite or clay partings (Ryan, 2002).

GEOLOGY

The stratigraphy in the basin is subdivided into 5 units (Anderson, 1978) that consist of a lower conformable volcanic unit, three sedimentary units and an uppermost non conformable volcanic unit. The lower 4 units are probably contemporaneous with the Princeton Group to the southeast and the 3 sedimentary units with the Allenby Formation, though stratigraphic nomenclature has not been established. The lower sedimentary unit is composed of sandstones and is 100 to 150 metres thick. The middle unit contains shales and 2 major coal seams and is about 130 metres thick (Anderson, 1978). The upper sedimentary unit consists of conglomerates sandstones and is at least 400 metres thick. The depositional environment for the sediments is described as a slowly subsiding valley influenced by intermittent volcanic activity but distant from salt water.

The Tertiary sediments of the Princeton group rest unconformably on volcanic and sedimentary rocks of the Upper Triassic Nicola group. Beds appear to be folded into a southeast trending syncline with beds on the southwest limb dipping shallowly to the northeast (20°-25°) and beds on the northeast limb dipping steeply southwest (40°-65°) (Figure 15). The maximum thickness of sediments in the basin is about 850 metres and the maximum depth to the top of the coal-bearing unit is about 700 metres based on sections by Evans (1978). The plunge of the syncline was estimated by Evans (1978) to be 15° in a direction 138°. A gravity survey (Church and Basnett, 1983) did not find evidence of a south plunging syncline and Anderson (1978) describes the structure as an asymmetric northwest trending syncline and does not assign a plunge.

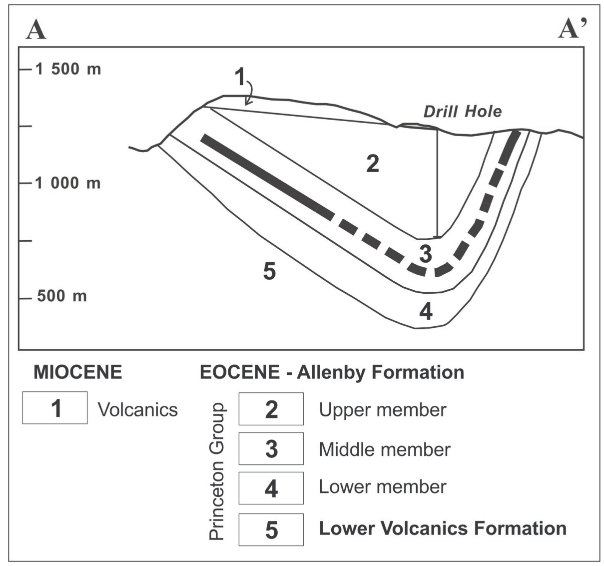


Figure 15. Cross section through the Tulameen Basin.

The area is cut by a number of vertical faults that trend north to northeast (Anderson, 1978). One fault mapped by Shaw (1952) had a down drop on the west of about 150 metres and another of 40 metres both faults trended northeast. Other faults are mapped that generally trend northeast with down drop to the east or west.

COAL QUALITY

Two coal zones are present in the basin; the lower, which is generally less well developed, is 120 metres above the volcanic unit. It is 7 to 7.6 metres thick and averages 52% ash (Anderson, 1978). There is not a lot of coal quality or rank information available for the lower seam because most exploration concentrated on the upper coal zone. This zone, which is 25 to 40 metres above the lower coal zone, is better developed and attains thicknesses ranging from 15 to 21 metres. Bentonite rich partings make up from 10% to 60% of the seam generally increasing in percentage to the northeast. The coal bands are vitrinite rich and well cleated with face and butt cleats. Ankerite sometimes coats butt cleats.

The rank of Tulameen coal is high-volatile B bituminous and it contains over 90% vitrinite on an ash free basis. The low rank means that any rank variation may have a significant impact on the potential CBM resource. Rank increases from 0.62% in the north to 0.86% in the south but there does not seem to be any relationship to depth (Williams and Ross, 1979). Other authors have found that rank varies from 0.69% to 0.81% over 19 metres in the upper part of the main seam, but below this depth remains constant at about 0.8% (Donaldson, 1972). No rank determinations exist for coal in the central part of the basin. If rank was superimposed after folding then it should be higher at depth in the center of the basin.

COAL AND CBM RESOURCE POTENTIAL

The area of the basin is about 6 square kilometres and based on average thicknesses for the two coal zones and the percent of coal in the zones the potential coal resource is in the range of 300 million tonnes

Two adsorption isotherms are available for the upper coal zone (Figure 16). They are typical of low rank coals in that isotherm slopes are flat at low pressures and only at high pressures or depth does the adsorptive capacity increase markedly, reaching 8 to 10 cc/g daf basis at about 1000 metres. There is no obvious reason for the better adsorption of the footwall sample. Both samples have similar petrography and rank (Table 4).

The CBM potential resource is estimated by distributing the coal resource evenly between 0 and 800 metres and assigning gas contents for each depth increment, based on the adsorption isotherms. The estimated total potential CBM resource is 42 bcf. A zero gas content is assigned to coal less than 100 metres. This is conservative but is meant to take into account the fact that the Tulameen Basin occupies relatively high ground between the drainages of Blackburn Creek and the Tulameen River. Probably the height of the old mines above Blakeburn Creek explains the apparent absence of gas in them.

BOWRON BASIN

GENERAL

The Bowron River graben, which is 50 kilometres east of Prince George, is 2.5 kilometres wide and 19 kilometres long (Figure 17). Coal was discovered in the area in 1871 by G.M. Dawson and has been intermittently explored from period 1914 to 1981. The lower 85 meters of the late Cretaceous to Paleocene sedimentary section (Graham, 1980), which is over 700 metres thick (Klein, 1978), is coal-bearing. The area of the basin could be up to 47.5 square kilometers based on aero-magnetic maps (Verzosa, 1981) so that there is potential for a moderately large CBM resource. The underground mineable resource calculated, based on an area of 3.6 square kilometres, is reported as 81 mt.

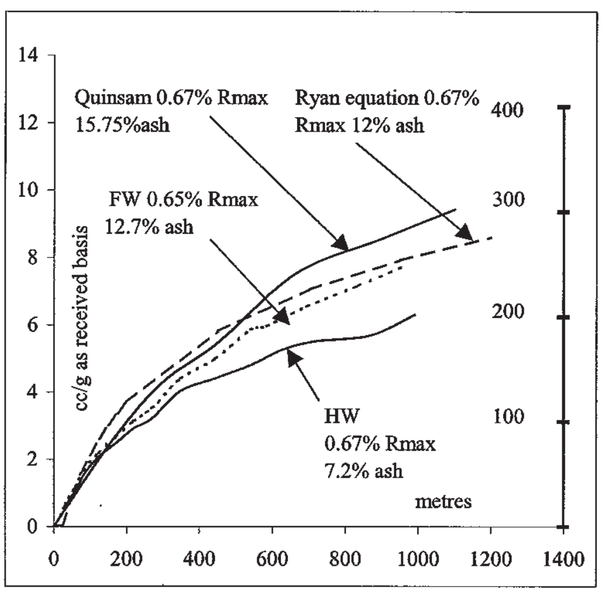


Figure 16. For hanging wall and footwall upper coal zone, Tulameen Basin.

Outcrop is sparse and most is found in an 11 kilometre stretch along the west bank of the Bowron River. Ninety-five holes were drilled From 1967 to 1981. The description of the stratigraphy, which is characterized by rapid changes in lithology, is based mainly on drill hole data. The coal measures are interpreted to rest unconformably on the Antler Formation and to be folded into a southeast plunging syncline, which intersects the northwest trending fault that defines the eastern edge of the basin (Verzosa, 1981). Information in the northern half of the basin is sparse and there is no structural interpretation.

There are a number of coal zones in the section but only the lowest appears to be persistent. It is between 50 and 100 metres above the Antler Formation and is up to 35 metres thick (Graham, 1980) of which up to 6.7 metres is coal. In places there may be a single seam up to 5 metres thick in others multiple thinner seams. There is a coal zone that occurs about 50 metres above the lower coal zone that is less persistent and averages 4.75 metres of coal and rock partings.

COAL QUALITY

The coal is high-volatile B bituminous in rank and is characterized by a high (8%) resin content. The average rank of the lower seam is 0.65% (Campbell 1973). The raw ash content of a number of proximate analyses of drill core averages 35.7% (Verzosa, 1981).

CBM RESOURCE

Any CBM potential will depend on presence of biogenic methane though the presence of amber may help initiate generation of thermogenic methane at a lower rank. The synclinal structure in the southern part of the basin indicates that the coal intersects the eastern fault at depths ranging from less than 100 metres to over 1500 metes. Matheson and Sadre (1991) estimate a potential resource of 400 mt down to a depth of 1200 metres considering only the lower seam. There is some indication in the volatile matter analyses that the rank increases over the depth covered by the drilling (0 to 350 metres). Using a rank of 0.65%, an ash content of 35% and distributing the resource over 1200 metres produces a potential CBM resource of 47.6 bcf (Table 5).

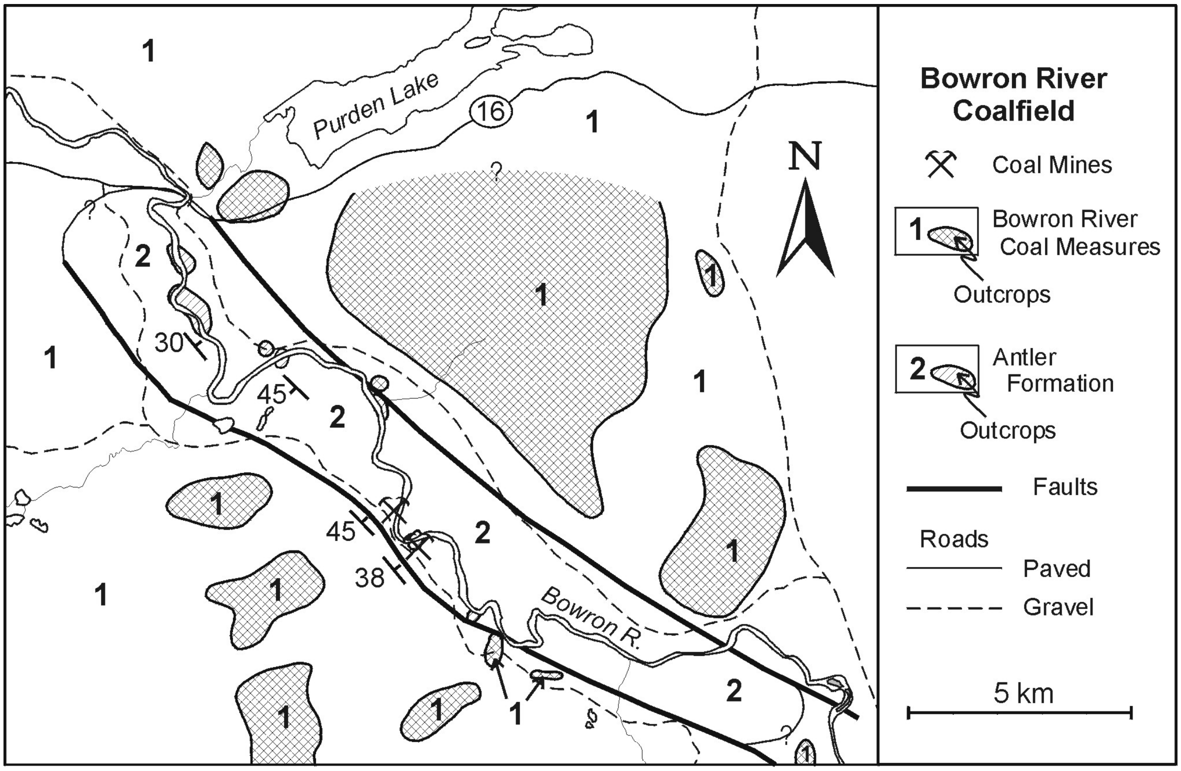


Figure 17. Generalized geology of the Bowron Basin.

SEATON COAL BASIN

GENERAL

The Grand Trunk British Columbia Rail Line (now the CN line) was constructed in the Bulkley Valley in 1910. This stimulated exploration for coal and a number of small coal basins were found including the Tertiary Seaton Basin 42 kilometres north of Smithers, others older than Tertiary include one in the Zymoetz River and Denys Creek in the Smithers area. Only the Lower Cretaceous Telkwa Basin sustained commercial mining and by 1930 most of the other basins including Seaton had been abandoned. Exploration activity briefly resumed in the Seaton Basin in the period 1986 to 1988.

The Bulkley Valley is a graben in the vicinity of the Seaton Basin defined by faults trending north or northwest with throws of over 1000 metres on each side of the valley (Figure 18). The valley, which is flat and generally filled with alluvium, is about 5 kilometres wide. Surrounding mountains rise to 1000 to 1500 metres above the valley and are comprised of Cretaceous rocks of the Skeena Group and Jurassic rocks of the Bowser Lake Group. The valley-fill al-

TABLE 5
SUMMARY OF INFORMATION ON THE TERTIARY BASINS

Basin	Area Km^2	Rank Rmax %	Coal million tonnes	CBM bcf total	CBM scf/t ton	CBM bcf section
Hat Creek	35	0.35-0.45	10000	500	50	37.0
Merritt	105	0.64-0.86	312	52	167	1.3
Princeton	170	0.52	800	80	100	1.2
Tulameen	19.4	0.62-0.86	300	42	140	5.6
Bowron	47.5	0.65	400	48	120	2.6
Tuya	150	0.68-0.76	460	66	143	1.1
Seaton	25	1.34	100	25	250	2.6
Coal River	35	0.20	200	3	15	0.2

luvium is interspersed with scattered outcrops as young as Paleocene.

The first reference to coal in the Seaton Coal Basin was by Dawson (1881). Dowling (1915) summarized work in the area up to 1915. Activity was in three areas. A 3.4 metre thick section of carbonaceous shale and coal was trenched and tunneled in one area. Elsewhere eleven thin coal seams were found in a 150 metres section. Ash contents were high but the coal was reported to produce a firm coke. In another area six seams varying in thickness up to 1 metre thick were described. Analyses indicate that seams are medium-volatile bituminous rank with moderate ash contents. Further exploration in 1916 and 1927 describes exploration in three widely dispersed areas that located three seams; Number 1, 1.4 metres thick, Number 2, 0.43 metres and Number 3, 1.0 metre thick. Two diamond core holes were drilled in 1987 and three in 1988 for a total length of 794 metres. A geological report (Perry 1986) was prepared for the company and a single petrographic analysis was made (Pearson 1987).

GEOLOGY

There appears to be at least 400 metres of Tertiary sediments in the basin. Sediments consist of a number of fining upward cycles, which are from 5 to 30 metres thick. Cycles start with chert-pebble conglomerate, grit or coarse sandstone deposited on an erosional surface and are overlain in succession by sandstone, siltstone, mudstone and sometimes carbonaceous mudstone with coal. Coal seams are usually less than 1 metre thick. Sediments generally dip shallowly to the east with variable strike. Paleonology on mudstone samples indicate a Late Eocene to Early Oligocene age (Sweet; personal communication 1991). The unexpectedly high coal rank of the samples made extraction of spores and pollen difficult. Some of the samples appear to contain material reworked from a Campanian aged source.

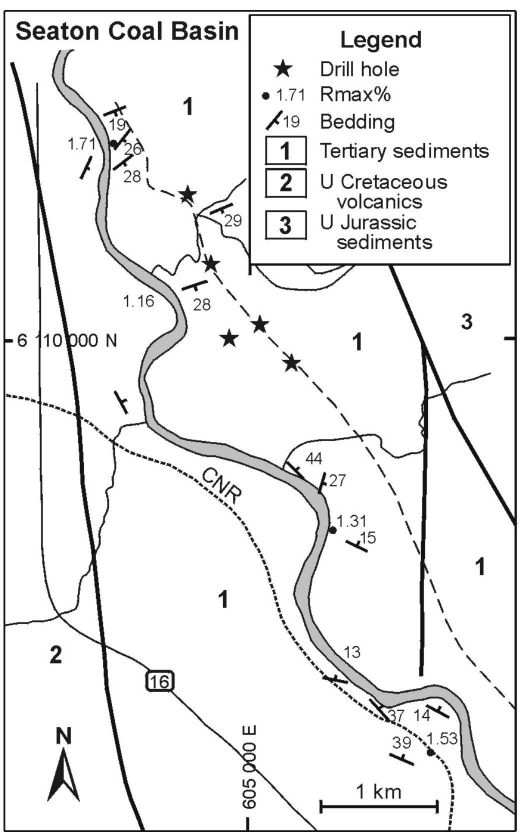


Figure 18. Geology of the Seaton Basin.

COAL QUALITY

The average raw ash of the coal is 30.5%. Thirteen Rmax values average 1.34% indicating a rank of medium-volatile bituminous that extends for 9 kilometres along the Bulkley River. This represents a large area of unusually high rank for Tertiary coal. This could indicate a combination of high geothermal gradient and/or removal of a lot of overlying sediment. Reflectance values for samples from a 1988 drill hole indicate a vertical reflectance gradient of 0.38%/100 metres, which is high. A single Rmax measurement (0.65%) on Tertiary rocks 40 kilometres to the south indicates a rank of high volatile bituminous B, considerably lower than the rank at Seaton and similar to the rank in other Tertiary coal basins.

COAL AND CBM RESOURCE

Seams are generally thin the thickest located was 1.4 metres and only about 3.5 metres of cumulative coal was located in a 100 metres section of nearly continuous outcrop. Thicker seams could exist in the basin much of which remains untested, especially the lower parts of the section. Potential resource in basin is about 100 million tones, based on an area of 25 square kilometers and a cumulative coal thickness of about 3 metres. Sediments accompanying the coal are at least 50 per cent sandstones and conglomerates with good permeability and porosity. The cycles of coarse to fine sediments probably produces permeability barriers between the sediments of each cycle.

The high rank gradient and Rmax values indicate that considerable cover must have been removed from the basin. Rapid uplift may help coals to maintain gas saturation. The cyclical nature of the sediments may trap gas generated during coalification, so that it can be re-adsorbed by the coal during uplift, as temperatures decrease. A medium-volatile coal generates enough gas during coalification to saturate between 20 and 40 times its volume of sediments with free gas. If sediment packages including coal are isolated from overlying and under lying packages by impermeable mudstone layers, then gas may remain adjacent to seams and be available to be re-adsorbed when the adsorption capacity of coal increases as temperature decreases during uplift.

Raw coal analyses average 30.5% and the rank averages 1.34%. Based on these values and a depth of 200 metres a potential gas content of 8.25 cc/g is predicted. This provides a potential CBM resource of about 25 bcf. Because of the steep reflectance gradient any coal deep in the

Tertiary section could be very gassy, especially considering its high vitrinite content.

COAL RIVER

GENERAL

The Coal River area was mapped in 1991 (Ryan, 1996) (Figure 19). The river flows south joining the Liard River approximately 150 kilometres east of Watson Lake and 40 kilometres south of the Yukon border. The river crosses the Alaska Highway at kilometre 858. The area is marked by subdued topography and elevations range from about 550 to 600 metres. McConnel (1891) was the first to reported coal in the area. He located lignite boulders, at the mouth of Coal River, which he describes as being of inferior quality. The source of the lignite was located by Williams and DeLeen prior to 1944 (Williams, 1944) about 10 kilometres as the crow flies up river from the Alaska Highway. At about the same time crews building the Alaska Highway were using lignite boulders, washed down from the outcrop, for heating in an army camp. Williams found an outcrop of 4.6 metres of lignite dipping to the southwest at about 25 degrees on the west bank of the river. He did not expose the footwall and part of the seam was on fire. Williams describes foul smelling gases and the presence of tar at the surface. A partial map of the area was produced in 1950 by McLearn and Kindle (1950) who outlined an area of about 50 square kilometres possibly underlain by Tertiary lignite-bearing sediments. The area was mapped in 1958 and 1960 by Gabrielse (1962) who mapped a small area of Tertiary lignite bearing sediments on Coal River but found no other occurrences in the vicinity.

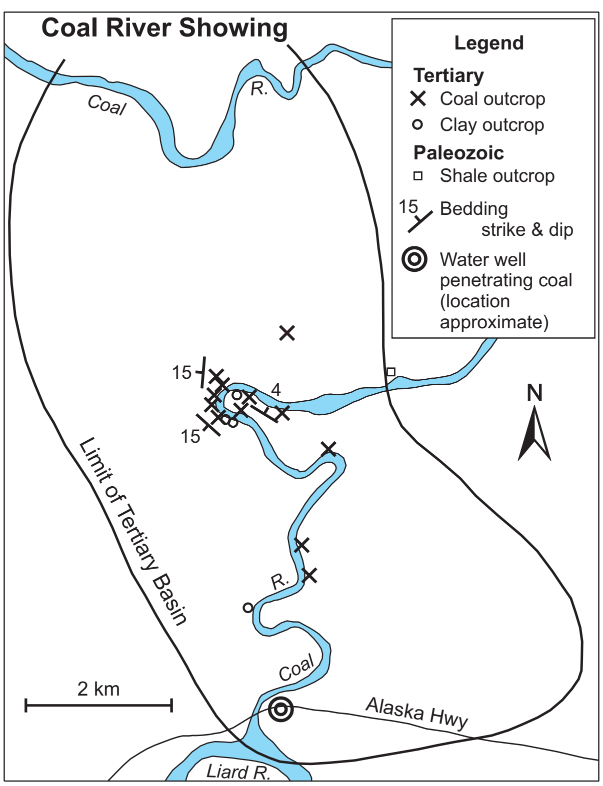


Figure 19. Geology of the Coal River Basin.

Generally Tertiary outcrops are restricted to the bank of Coal River, trees, swamp and a burn zone cover the rest of the area. The area around the river is marked by large crescent shaped slumps, presumably where younger sediments have slid on a prominent clay layer. A number of lignite outcrops were located along Coal River. The lignite is well cleated with two sets developed. The full thickness of the seam is not observed in any of the outcrops found and where exposed thicknesses range up to over 8 metres. Generally 3 to 4 metres of lignite are exposed in outcrops on the west side of the river, where lignite is overlain by about 10 metres of white to light grey clay. The clay contains occasional iron stained surfaces but otherwise appears to be quite pure.

On the east side of the river, the topography is flatter, outcrops less well developed and no thickness estimates were obtained. Here the lignite is underlain by grey clay. It is assumed that the lignite outcrops on the west and east sides of the river are of the same seam. The clay will make a very good seal above the lignite to contain any biogenic methane formed in the seam. A water-well drilled near where the river crosses the Alaska Highway, intersected 15 metres of coal at a depth of 15 metres. This may or may not be the same seam that outcrops 10 kilometres up Coal River.

COAL QUALITY

Lignite samples were analyzed by Williams (1944) and Ryan (1996). Rmax% measurements are difficult to make because of the very low rank. In fact the average of five values is 0.2%, which classifies the material as a peat rather than lignite. This is supported by the average volatile matter on a dry ash free basis, which is 75% but is not supported by the heat value or the as-received moisture measurements, both of which are characteristic of a coal with a higher rank. Ash is generally less than 10% and sulphur averages 0.3% both on a dry basis.

COAL AND CBM RESOURCE

The basin has a possible area of about 35 square kilometers and appears to be underlain by at least 5 metres of lignite, which provides a potential resource of about 200 mt at shallow depth.

The rank is too low for the lignite to have generated thermogenic methane. However the lignite could contain reasonable quantities of biogenic methane in part as free gas. The overlying clay would act as a perfect trap to contain the methane. There are no data on gas contents of lignite coals but a value of 0.5 cc/g or 16 scf/t for adsorbed and free gas should be conservative. This would predict a potential resource of about 3 bcf. A resource of this size is of no interest to a major company but might be very useful in supporting local development on the Alaska Highway.

SUMMARY

The potential CBM resources of Tertiary basins in British Columbia range from over 0.5 tcf to less than 10 bcf (Table 6). In all cases these estimates are based on minimal data and there is a lot of room for re interpretation that may indicate the possibility of a greatly increased CBM resource in some of the basins. The rank of the coal in the basins is moderately well defined at least at surface. Information about rank at depth is generally not available but can be estimated from coal quality data. There is very little CBM data available.

There is no published desorption data and not much anecdotal data from old underground mines in the basins. It is feasible to collect samples for adsorption isotherms and this paper presents two for the Tulameen Basin. However for low rank coals adsorption isotherms may give a miss-leading estimate of the potential of the basin because of the importance of free gas, as is the case in the Powder River Basin.

Tertiary coal basins in British Columbia have unique characteristics compared to older coal basins in the province. They are generally fault bounded and more likely to have experienced extensional tectonics combined with rapid subsidence. Geothermal gradients may have been and may still be high as indicated by the evidence of volcanism contemporaneous with deposition of the coal zones. This is a plus in terms of increasing rank with depth but could be a negative in terms of a high present temperature gradient that could limit adsorption capacity at depth.

The basins are filled with lacustrine sediments and therefore the ground water is probably fresh.

The low rank and simple tectonic history ensures that in most cases the coals are hard, well cleated and will not generate fines. They should be amenable to fracing or cavitation depending on the cohesion of the surrounding sediments. The cyclic deposition of fining upwards units may ensure good permeability and sealing of each unit. Bentonite layers, which represent time lines in the stratigraphy may be the perfect seals for ensuring no inflow of water from hanging walls and foot walls of seams during dewatering.

The coal seams are often in coal zones containing a lot of carbonaceous material and the whole zone should be considered for its ability to adsorb methane and not just the low ash components.

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