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GEOLOGY AND POTENTIAL COAL AND COALBED METHANE RESOURCE OF THE TUYA RIVER COAL BASIN (104J/2, 7)

By Barry Ryan

KEYWORDS: Coal geology, Tuya River, coal basin, coalbed methane.

INTRODUCTION

This article forms part of an ongoing study of the coal and coalbed methane resource potential of northwestern British Columbia. Other areas under study include the Bowser basin coalfield, Telkwa coalfield and Tertiary coalfields of the Bulkley Valley.

Tertiary sediments survive in many major watersheds in British Columbia. The sediments are generally not well consolidated, poorly exposed and their subcrop extent is arbitrarily delineated by adjacent high ground underlain by pre-Tertiary rocks. Many of these Tertiary basins contain coal, varying in rank from lignite to medium-volatile bituminous and seam thickness varies from a few centimetres to many metres.

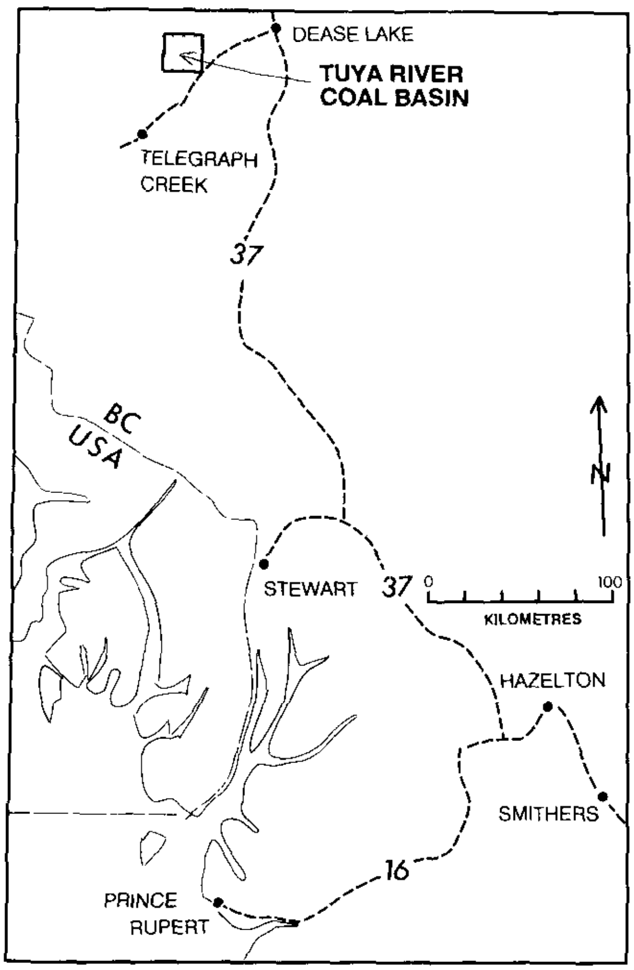

Figure 5-9-1. Tuya River coal basin location map; northwestern British Columbia.

The Tuya River Tertiary coal basin is located between the communities of Dease Lake and Telegraph Creek in northwestern British Columbia (Figure 5-9-1). The basin straddles the drainage of Tuya River and its tributaries Little Tuya River and Mansfield Creek. Tuya River flows south, joining the Stikine River 60 kilometres southwest of Dease Lake. Access is via the Dease Lake to Telegraph Creek gravel road, which at 52 kilometres is 5 kilometres south of the coal basin, or by a 15-minute helicopter flight from Dease Lake.

The Tuya River basin is potentially quite large, yet it has escaped detailed study. Limits of the basin are poorly defined and in places it is overlain by Recent volcanic rocks. However, it is estimated that the basin covers approximately 150 square kilometres and contains over 600 million tonnes of high-volatile B bituminous coal; a sizeable coalbed methane resource up to 0.04 Tcf (trillion cubic feet) may also exist.

Five field days were spent in the area. All known coal outcrops were sampled and the major drainages mapped.

PREVIOUS WORK

The earliest recorded description of coal in the Tuya River area is by R.D. Featherstonhaugh in 1904 (Dowling, 1915). He describes large seams in Tuya River (11.6 metres and 7.9 metres) and a 12.2-metre seam probably in and near the mouth of Little Tuya River. Dowling notes the existence of 13 coal leases and provides a single coal analysis which, based on analyses of ash and heating value, indicates a high-volatile bituminous C rank. 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 where he located Tertiary lignite coal zones ranging up to 4 metres in thickness. The Tahltan River coal occurrences are about 20 kilometres southwest of the Tuya River coal basin and may be part of an outlier to it.

The Tuya River coal basin was drilled and mapped in detail in the period 1979 to 1980 when interest in coal was high. PetroCanada mapped and drilled the western half of the basin (Reid, 1980; De Nys, 1980) and Esso Minerals Canada (Vincent, 1979) mapped the eastern half. Ten cored holes were drilled and a number of hand trenches dug. Analytical results indicate a coal rank of sub-bituminous B to high-volatile bituminous C. A potential of 200 million tonnes of surface-mineable coal was outlined in the western half of the basin to a depth of 500 metres. Data were insufficient to define measured reserves. The low rank of the coal, geographic isolation and general down-turn in coal utilization made the property unattractive to coal companies, and all coal licences in the area were allowed to lapse.

REGIONAL GEOLOGY

The Tuya River coal basin is within the Intermontane Belt of the Cordillera. Basement is composed of deformed Paleozoic and Mesozoic strata. Palynology (Vincent, 1979; De Nys, 1980) dates the coal-bearing rocks as not younger than early Eocene and not older than Paleocene. They may be equivalent to the Tango Formation of the Sustut Group (Eisbacher, 1974).

The basin is bounded on the north by basic rocks, possibly part of the Recent Level Mountain Complex. The eastern and western boundaries are probably fault-controlled, with pre-Tertiary rocks to the east and younger volcanic rock to the west. The southern boundary is arbitrarily defined by thick postglacial drift and absence of outcrop. The basin is covered by the regional map of Gabrielse and Souther (1962) and is mentioned briefly in a number of coal compilation articles, the most recent of which is by Smith (1989).

The basin lies within the Stikine Plateau physiographic division. The topography in the Tuya River area is subdued with an average elevation of 800 metres. The area is lightly treed with patches of swamp. The Tuya and Little Tuya rivers and Mansfield Creek have incised meandering canyons up to 200 metres deep. Outcrop is restricted to the canyon floors.

LOCAL GEOLOGY

Sediments within the basin are generally coarse grained and poorly consolidated. In order of decreasing abundance, rock types are: sandstone, conglomerate and mudstone. The sandstones are medium to coarse grained, orange weathering and greyish when fresh. They contain numerous pebble

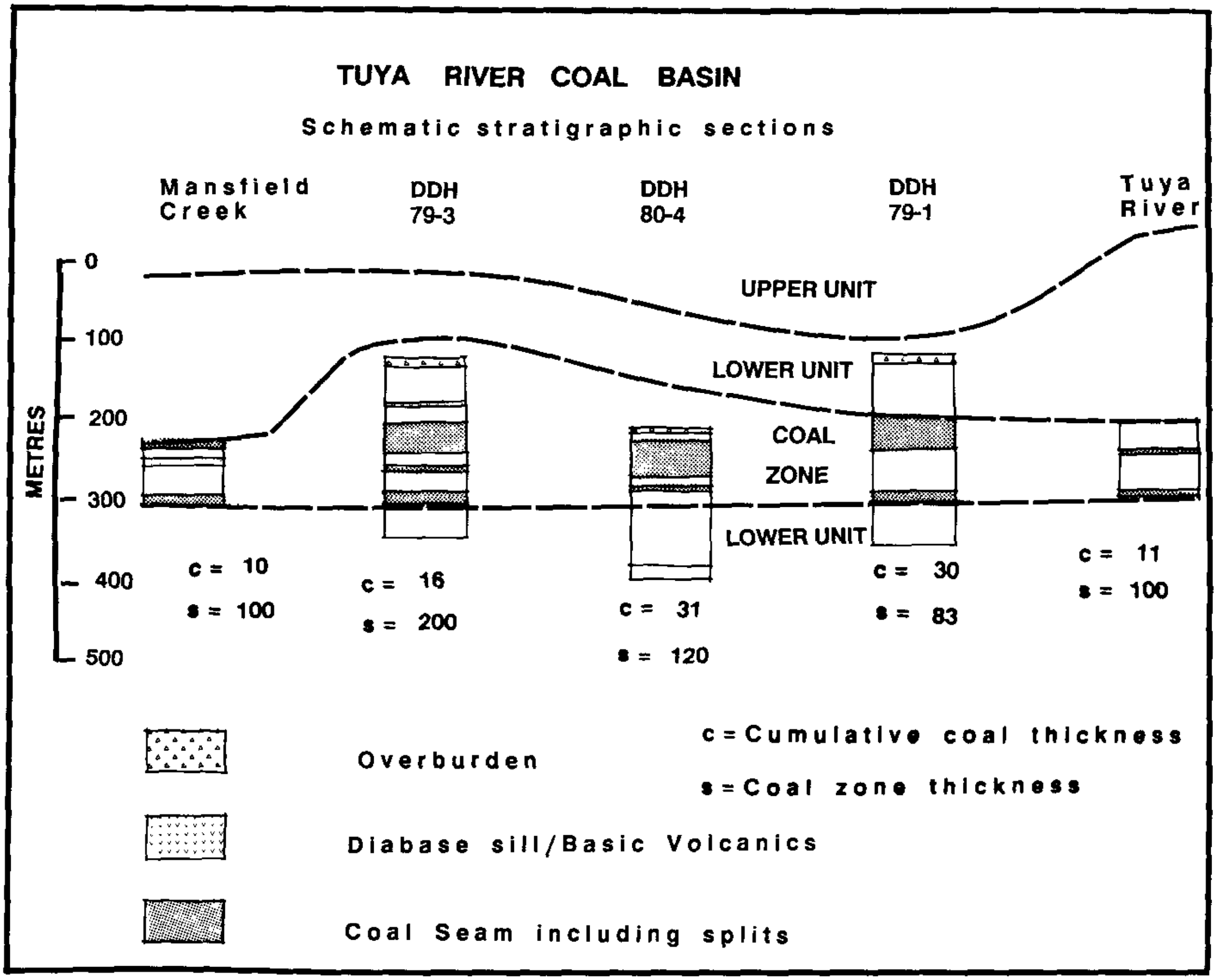

Figure 5-9-2. Stratigraphic sections of coal-bearing zone.

and grit bands and coal fragments; clasts are usually quartz or chert in a grey clay matrix; some lithic fragments have weathered to limonite. Conglomerates contain rounded volcanic and chert clasts ranging in size from granules to boulders, with pebbles predominating. They are yellow to orange weathering and form cliffs along the banks of the Little Tuya River. The mudstones are brown, sideritic and soft, and generally contain fine silty laminations. Vesicular basalts and diabases crop out in the basin.

It is difficult to establish a detailed stratigraphy in the area because of the lack of outcrop. Rocks structurally low in the succession in Mansfield Creek are mudstones, sandstones and a diabase sill, whereas rocks low in the succession in Tuya River are sandstones. Generally rocks high in the succession are conglomerates with volcanic clasts or basalt flows. Coal seams appear restricted to a zone fairly low in the succession.

A tentative stratigraphic succession is outlined in Figure 5-9-2. A lower unit, 200 to 300 metres thick, is composed of mudstones and sandstones in the west and sandstones and chert-pebble conglomerates in the east; it contains a single coal zone. The coal zone, described in detail later, is about 100 metres thick and contains from 5 to 30 metres of coal. The lower unit is overlain by an upper unit at least 300 metres thick which is composed of volcanic-pebble conglomerate, sandstones and volcanics.

Structural Geology

There are insufficient data to adequately describe regional faults or folds. The simplest interpretation, presented here, represents the basin as an open, northerly plunging syncline, complicated by smaller scale faults and folds. Beds in Little Tuya River and Mansfield Creek dip to the east; beds in Tuya River dip to the north or west (Figure 5-9-3).

All available bedding orientation data are plotted on Figure 5-9-4; the eigen values/eigen vector technique was then used to calculate a best-fit cylindrical fold axis of 019°/13° (trend/plunge) for the data. Local, open, low-amplitude folds are outlined by bedding in Mansfield Creek, and isolated outcrops with steep bedding in Tuya River are probably evidence of faulting. Generally, interpretation of structures is complicated by extensive block-slumping off the valley walls and toward the rivers, causing detachment and rotation of some outcrops.

Coal Geology and Quality

No detailed depositional model is postulated for coal in the Tuya River coal basin; certainly it would not be the same as that for Cretaceous coals. Depositional models for Cretaceous coals in British Columbia postulate large coastal swamps and cyclic deposition leading to fining-upwards sequences topped with coal. At Tuya River the surrounding rocks are sandier and contain evidence of rapid deposition in high-energy environments. Long (1981) suggests that the boundaries of Tertiary intermontane coal basins in the Cordillera and the type of sedimentation found in them were controlled by penecontemporaneous faulting. The abundant coarse detritus and apparent lateral and/or temporal variability of depositional environment lend support to this suggestion.

In outcrop the coal is blocky, well banded and usually clean. It is often harder than the enclosing poorly consolidated sandstones. A burn zone was noted above one coal seam in Mansfield Creek, but in general the coal does not appear susceptible to rapid oxidation or spontaneous combustion. Seams vary in thickness up to 20 metres. Mudstone bands are common in the coal seams; bentonite layers are also conspicuous but are not radioactive on geophysical logs. The coal seams do not form part of fining-upwards sequences, and hanging and footwall contacts are sharp, with no particular enclosing rock type predominating. The coal is vitrain rich and contains an unusually high percentage of resin; some bands contain up to 5 per cent resin blebs ranging up to 5 millimetres in diameter. In places, the vitrain bands have a waxy lustre and conchoidal fracture which forms a distinctive eyed pattern on the fracture surfaces (Plate 5-9-1).

Coal seams were trenched and were intersected by three drill holes (Figures 5-9-2 and 3) in the Little Tuya and Tuya rivers and Mansfield Creek areas. Correlation of coal seams is made difficult by the sparsity of drill and surface data and by the lateral variability of the coal stratigraphy. A conservative approach is adopted in this report and most of the coal is assigned to a single coal-bearing zone. Stratigraphic sections (*see* Figure 5-9-2) measured in outcrop, represent approximate thickness, except for coal-seams. All coal-seam thicknesses include minor rock bands; where possible rock bands thicker than 50 centimetres are noted separately.

Coal seams forming part of the coal-bearing zone are exposed in Mansfield Creek. A thick seam outcropping below a 5-metre-thick diabase sill was trenched in three locations, providing: 3.89 metres of coal (hanging and footwalls not exposed); 6.6 metres of coal in a 7.7-metre zone; and a 2.7-metre zone of coal and mudstone below a burn zone. Above the diabase sill a 4.22-metre coal seam was trenched without exposing the hangingwall. The total coal-bearing section is about 100 metres thick and contains about 9.5 metres of coal.

The lower part of the coal-bearing zone is intersected by holes 79-3 and 80-4 (Figure 5-9-2). It is assumed that both holes are collared below the 4.22-metre seam, which is above the diabase sill in Mansfield Creek. In this case, the total coal-bearing zone at location 79-3 should be 200 metres thick with 16 metres of coal and, at location 80-4, 120 metres with 31 metres of coal. Hole 79-1 (Figure 5-9-3) is collared near an outcrop in Little Tuya River which has 6.1 metres of coal over 7.1 metres. The hole intersects this seam, and others lower in the section, for a cumulative coal thickness of 31 metres over an 83-metre section, which is assumed to be the full width of the coal-bearing zone.

The coal-bearing zone extends across the syncline to Tuya River where a zone 100 to 150 metres thick contains three coal seams with a cumulative coal thickness of 11 metres (Figures 5-9-2 and 3). A second coal zone, down

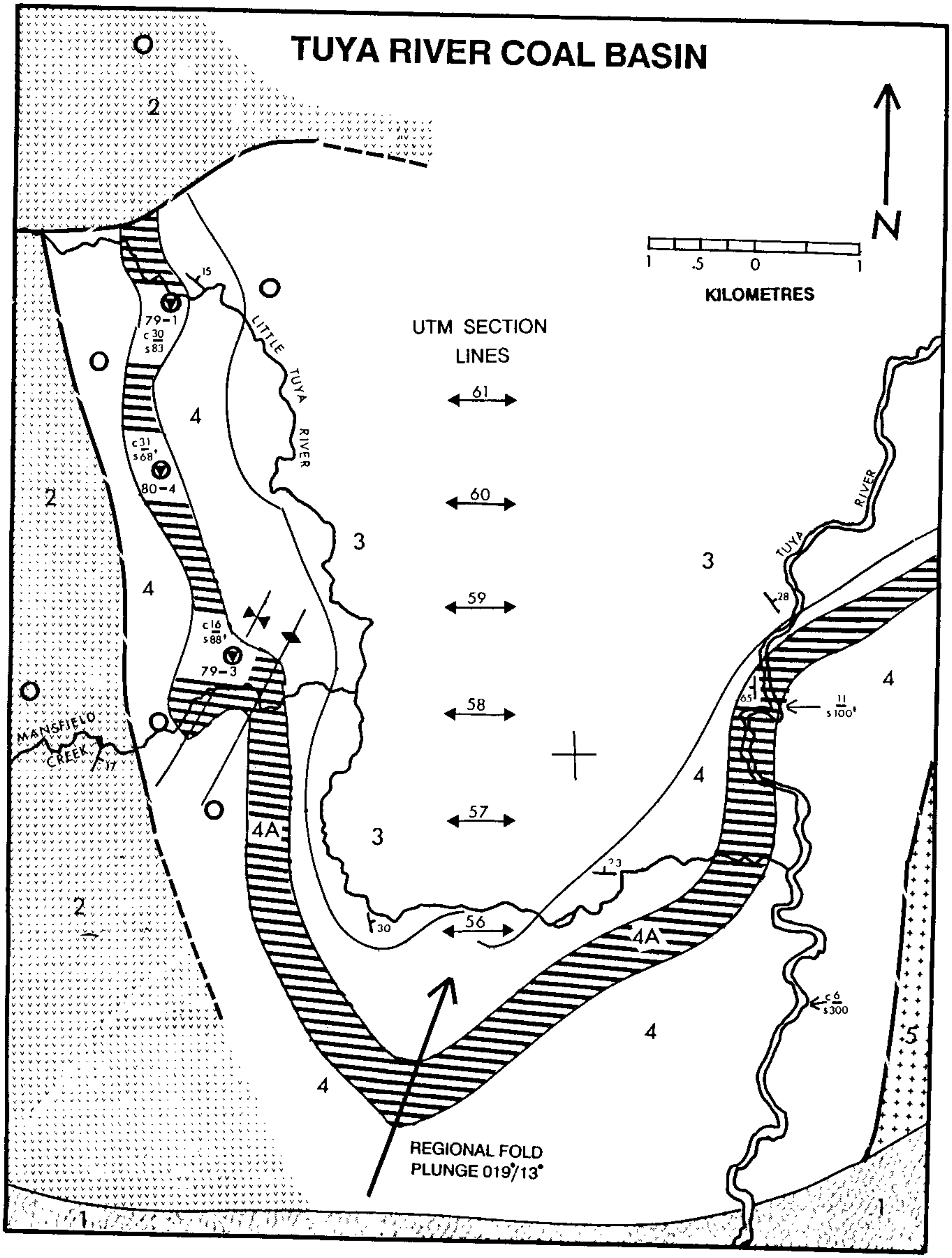

Figure 5-9-3. Regional map of Tuya River coal basin.

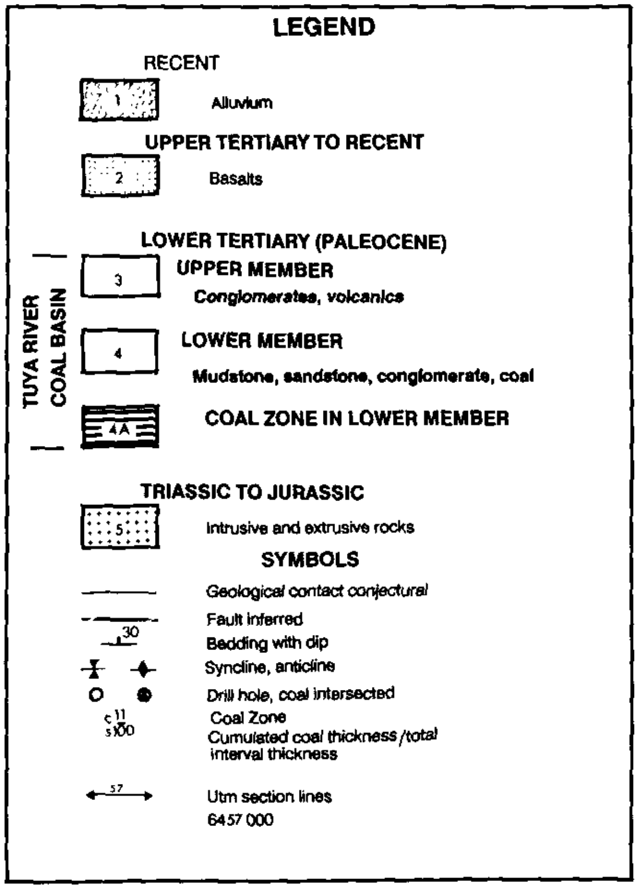

Figure 5-9-3A. Legend for Tuya River map.

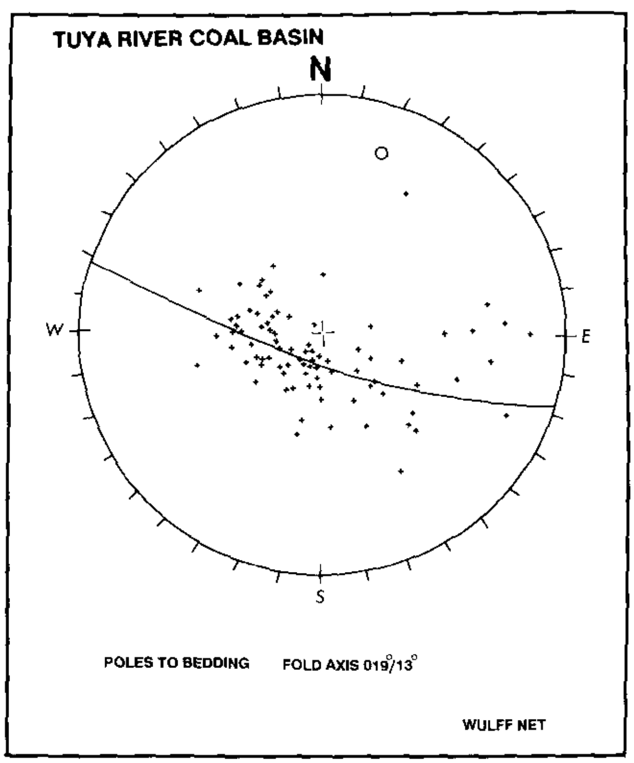

Figure 5-9-4. Stereonet of poles to Tuya River bedding data and best-fit great circle.

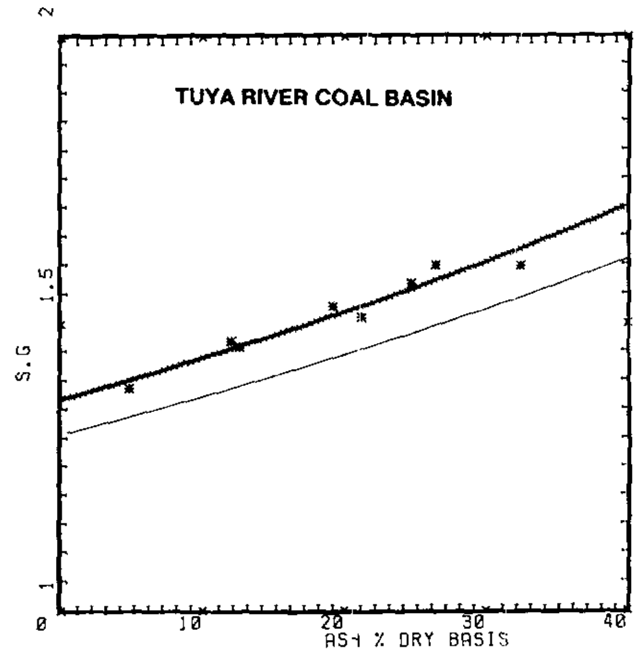

Figure 5-9-5. Plot of specific gravity versus ash data from drill holes; Tuya River.

TABLE 5-9-1
EQUATIONS USED IN TEXT

EQUATION 1 Derived by author for estimating specific gravity (S.G.)

S.G	=	100×K/(K+(TM+VP)+MM×(DC−DMM)+DMM ×(100−TM))
DC	=	Specific gravity dry zero-ash coal
DMM	=	Specific gravity dry rock
VP	=	Void porosity
TM	=	total moisture
MM	=	weight dry mineral matter
K	=	DC×DMM
MM	=	WTLOS×Ash
Ash	=	per cent dry ash
WTLOS	=	ratio mineral matter/ash; 1.17 used in Figure 3-9-5.
S.G.	=	Specific gravity of coal ash-mixture at TM moisture

EQUATION 2 Empirical fit to Figure 3-9-7 (derived by author)

CBM	=	(log(H×(R^2.5−.2))−1.095)/.003913
CBM	=	coalbed methane in cubic feet per short ton
H	=	depth in metres
R	=	Ro Max
		Note equation limits Ro Max>.6

EQUATION 3 From Kim (1977)
For estimating adsorption capacity of coal

MA	=	(1−M−A)×Vw/Vd×(K×(.096×H)^N −B×(1.8×H/100+11))
MA	=	methane: cubic centimetres/gram
M	=	moisture per cent/100
A	=	Ash per cent/100
K	=	.8×FC/VM+.56
N	=	.315−.01×FC/VM
B	=	.14 cubic centimetres/gram/°C
H	=	depth in metres
FC	=	fixed carbon per cent
VM	=	volatile matter per cent
Vw/Vd	=	ratio of adsorption capacity wet coal: adsorption capacity dry coal
Vw/Vd	=	1/(1.067+.24337×M ARB)
M ARB	=	Moisture on an as-recieved basis or equilibrium moisture

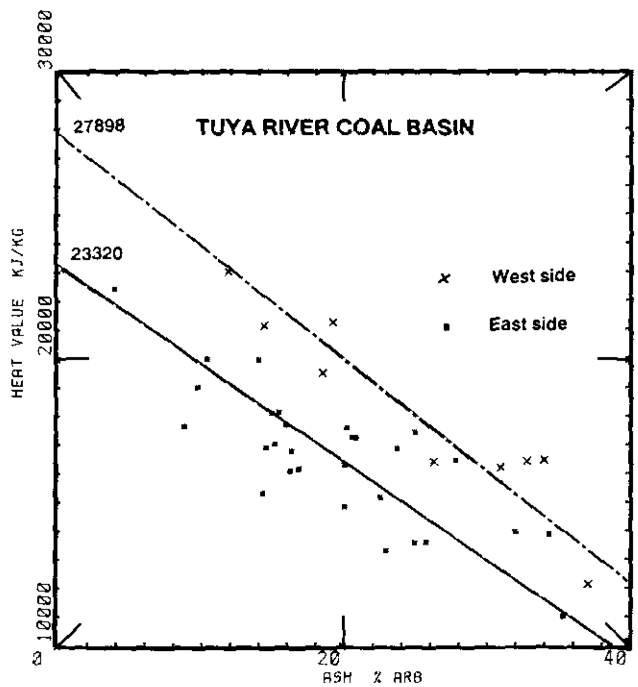

Figure 5-9-6. Plot of heat value versus ash; surface and drill-hole data.

Plate 5-9-1. Eyed coal from Tuya River.

river, contains approximately 6 metres of coal and carbonaceous shale over 300 metres of section; it is not correlated with any other outcrop.

Existing coal-quality data are available from Dowling (1915), Vincent (1979) and De Nys (1980). Data from the western side of the basin were obtained from NQ diamond-drill core and on the eastern side from hand trenches. Samples were analyzed for per cent moisture (as received basis, ARB and air dried basis, ADB), ash, volatile matter, fixed carbon, sulphur and heat value. Data from the drill holes provide average, as received values of 12.4 per cent moisture, 19.1 per cent ash, 30.7 per cent volatile matter, 37.8 per cent fixed carbon and 0.5 per cent sulphur. Some specific gravity (S.G.) and Hardgrove index (HGI) data are also available from some drill-core samples. Eight petrographic analyses will be carried out during the present study and will be described in detail in a later report.

Eight S.G determinations on air-dried core samples are reported by De Nys (1980); data are plotted in Figure 5-9-5 and a curve derived from a theoretical density equation (Equation 1, Table 5-9-1) is fitted to the data. A dry, clean coal specific gravity of 1.37 is calculated from the curve, based on the eight data points. This dry ash-free specific gravity is high for low-rank coals which usually have values in the range 1.2 to 1.3. The S.G. data were measured on air-dried core with a moisture content averaging 8 per cent; the thin line (Figure 5-9-5) illustrates the ash (DB) versus S.G. relationship at an *in situ* moisture of 12.5 per cent and provides an S.G. of 1.48, for an ash of 22.5 per cent ADB and 8 per cent moisture. This value is used as an average for deriving tonnages from *in situ* volumes in the resource calculation (next section).

Hardgrove index values are a measure of the friability of coal; small numbers indicate hard or non-friable coal, large numbers indicate soft or friable coal. Two HGI values from drill core (De Nys, 1980) average 52.5, indicating a moderately hard coal in agreement with outcrop observations.

Rank can be estimated from the projected moist, ash-free heat value of the coal. The western and eastern surface data sets were treated separately and lines fitted to each using the method of York (1969) (Figure 5-9-6). The western data predict a moist, ash-free heat value of 27 898 kilojoules per kilogram and the eastern data 23 322 kilojoules per kilogram. These values are compatible with ranks of high-volatile bituminous C on the west and sub-bituminous B on the east. Oxidation of surface samples may have lowered the heat content of coal for the eastern side of the basin.

Seven samples from the coal basin were analyzed for per cent mean maximum reflectance of vitrinite in oil (referred to in the text as reflectance). Reflectances of the samples from Tuya River and Mansfield Creek range from 0.60 to 0.79 and average 0.68 per cent, indicating a rank of high-volatile bituminous B. The reflectance value of a single sample of float from the mouth of the Tahltan River, 20 kilometres southwest of Tuya River, is 0.71; previous references to coal in the area postulate a rank of lignite to sub-bituminous. If the sample is representative of coal from the Tahltan River then there is a possibility that the high-volatile coal of the Tuya River coal basin extends to the southwest. The preliminary petrographic data indicate a rank of high-volatile B extending to high-volatile A based on rank versus reflectance relationships provided by Ward (1984). This rank is higher than previously expected and increases the potential for a coalbed methane resource. The preliminary data indicate reflectances of 0.61 from Tuya River above Little Tuya River, 0.72 from the Tuya River south of Little Tuya River and 0.79 from Mansfield Creek.

POTENTIAL COAL AND COALBED METHANE RESOURCE

Coalbed Methane in Coal

It is unlikely that the Tuya River coal basin will be of interest as a source for surface-mineable coal for a long time; however, the deposit could be a source of coalbed methane. Natural gas is 74 per cent methane, while the gas desorbed from coal is 98 per cent methane and is invariably low in SO_2 (despite varying sulphur contents in the coal) and has a heat value similar to natural gas. Coalbed methane is a safety hazard in underground mining. Its presence has long been monitored and steps taken to vent it safely. More recently, especially in the U.S.A., coalbed methane is collected as a viable replacement for natural gas. Wells drilled into deeply buried coal seams decrease the overburden pressure on the coal and allow methane to desorb from the coal and rise to the surface. The process has similarities to natural gas exploration; the technology, depth of holes and gas composition, are all similar; differences exist in the process of recovering the methane.

Coalbed methane is released slowly after water is pumped out of the seam and the overburden pressure reduced. The amount of methane trapped by coal is in part proportional to the surface area of the coal structure. To use an analogy, coal is like a book in which the amount of methane retained is proportional to the cumulative surface area of all the pages, while a sandstone reservoir is like a block of styrofoam in which the amount of natural gas retained is proportional to the cumulative volume of voids in the styrofoam. It is easy to imagine how, on a volume to volume comparison, coal can retain up to five times more gas than a sandstone reservoir.

Coalbed methane occupies three general sites in the coal seam: (1) fractures and large pores in the coal; (2) adsorbed onto the coal structure; and (3) absorbed into the coal structure. When coalbed-methane measurements are made on core, Type 1 methane is lost prior to the desorption measurement and is referred to as "lost gas"; Type 2 methane, which usually accounts for most of the reservoir potential, is referred to as the desorbed component, and Type 3 methane is the residual component which is generally not measured. Theoretical estimates of coalbed methane attempt to estimate the content of Type 2 and some of the Type 3 methane and refer to this as the "adsorbed component".

Coal rank and depth of burial are important controls on the amount of gas coal can retain. Figure 5-9-7, adapted from Hunt (1979), tracks cumulative and incremental meth-

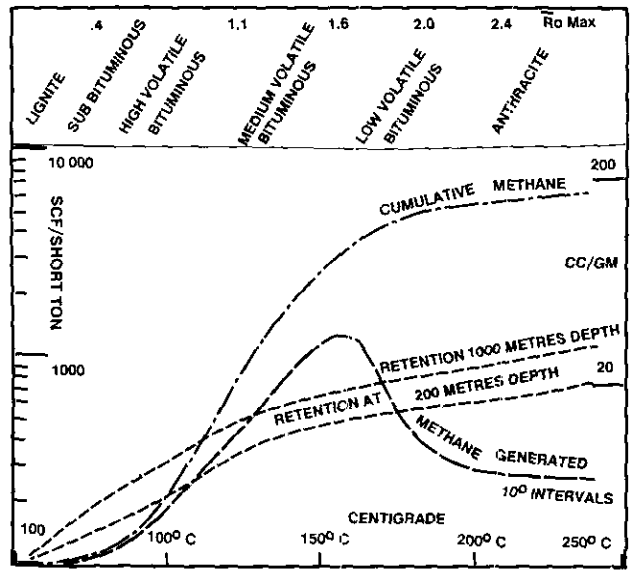

Figure 5-9-7. Methane generation and retention by temperature, modified from Hunt (1979).

ane generated by coals from lignite to anthracite rank. It illustrates the limited proportion of methane that is retained; the rest being available to charge sandstone reservoirs. A cubic metre of coal can charge up to 60 cubic metres of sandstone reservoir with expelled coalbed methane. The figure shows that for low-rank coals, methane generated is close to or less than retention capability. This means that the coal will not have charged the surrounding rocks by expelling methane. The coalbed gas expelled at greater depths from coals of higher rank can migrate upwards and actually be adsorbed by lower rank coals with a retention capacity exceeding their cumulative methane generation value. Figure 5-9-8, derived from Eddy *et al.* (1982) with minor extrapolation of some lines by the author, plots lost and desorbed gas contents of fresh drill-core coal samples of different ranks against depth. The lost gas component is lost before the desorption test but its value can be determined by extrapolation. The methane retention curves in Figure 5-9-3 can be approximated by a single equation developed by the author, which has reflectance and depth as variables (Equation 2, Table 5-9-1). The equation provides approximate values of coalbed methane for any combination of reflectance and depth (reflectance >0.6) and therefore offers more flexibility than the six curves in Figure 5-9-8. Kim (1977) developed a theoretical equation (Equation 3 in Table 5-9-1) which predicts methane adsorption capacity by rank and depth.

The experimental approach of Eddy *et al.* (1982) and the theoretical approach of Kim (1977) measure different combinations of the types of methane in coal. Figure 5-9-8 provides information on the amount of lost and desorbed gas; residual gas is assumed to remain in the core. Eddy *et al.* indicate that residual gas can vary from 5 to 32 per cent of the total with low-rank coals having more than higher rank coals. McCulloch *et al.* (1975) estimate residual

METHANE RETENTION AS A FUNCTION OF RANK AND DEPTH

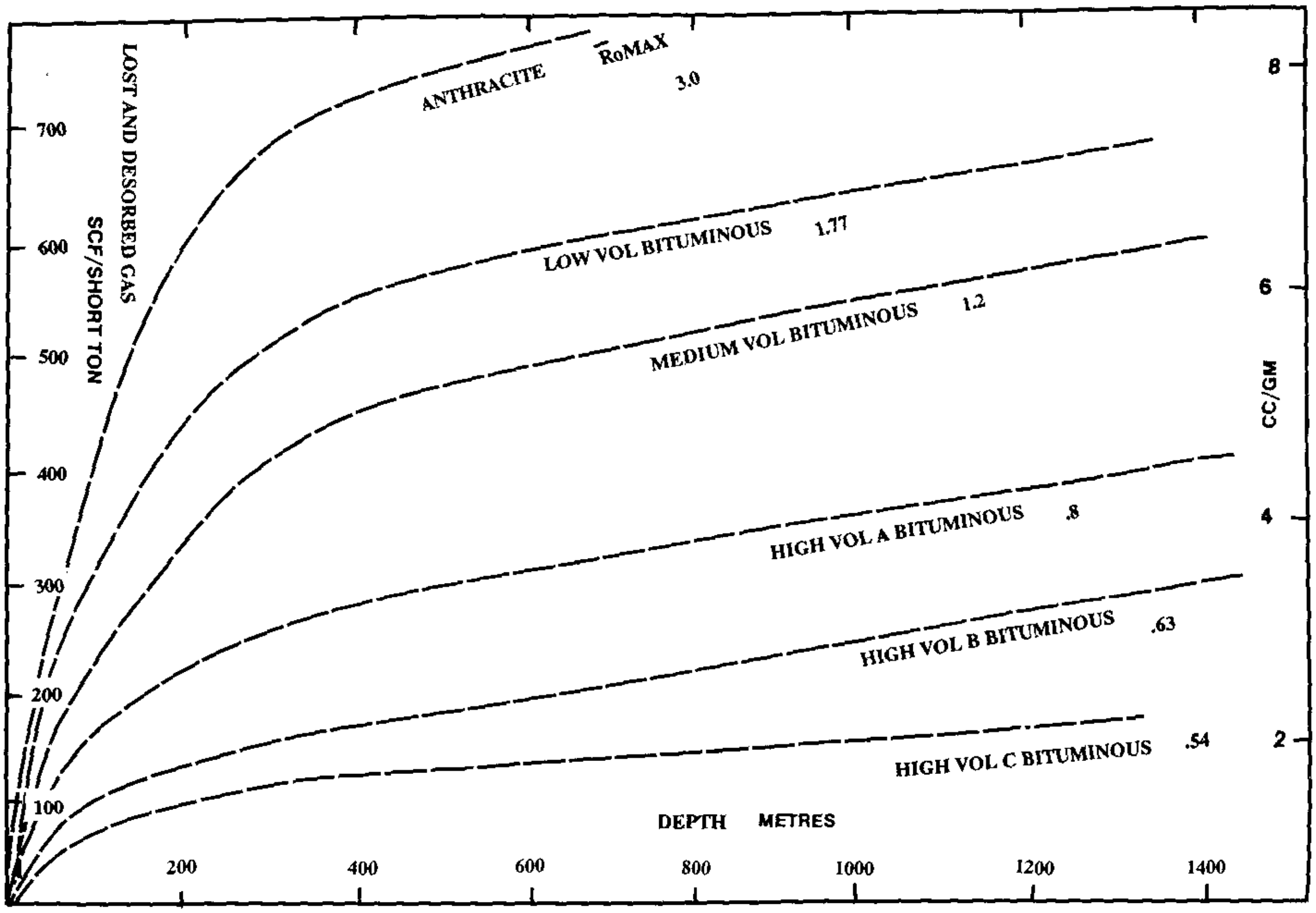

Figure 5-9-8. Methane retention by rank and depth, modified from Eddy *et al.* (1982).

gas using HGI values. A value of 52.5 defines the coal as blocky, which represents a potential residual gas content of 39 per cent. Diamond *et al.* (1981) found a less reliable relationship between HGI and residual gas. McCulloch *et al.* note that the lost gas component for blocky coals is smaller than for friable coals. Eddy *et al.* indicate that lost gas ranges from 5 to 17 per cent of the total gas. Equation 3 (Table 5-9-1) from Kim (1977) does not predict lost gas components. It is a theoretical estimate of the adsorptive capacity of coal and corresponds with the desorption component measured by Eddy *et al.*, and some of the residual gas component which is not incorporated in Figure 5-9-8. If residual gas is greater than lost gas for Tuya River coals then Equation 3 may tend to overestimate recoverable methane.

Calculation of Coal and Coalbed Methane Resource

The amount of methane retained by Tuya River coals is limited by the low rank (though the rank is higher than previously reported). However, the large tonnage of coal and permeable interburden lithologies, all point to the possibility of a sizeable coalbed methane resource. Volcanic flows and sills in the succession may have raised the rank and helped contain the methane.

An estimate of the potential resource requires first a coal tonnage calculation and then information on how gas retention varies with depth. The coal resource at Tuya River was estimated using six 1:10 000-scale sections (Figure 5-9-3). The coal-bearing zone was drawn on the sections using the sparse surface and drill data and assuming fold plunge orientation 019°/13°(trend/plunge). The numerical average, vertical coal-thickness in the coal-bearing zone is 19.6 metres; this was converted to an estimated true thickness of 17 metres assuming an average dip of 30°. The true thickness was reduced by 20 per cent to account for rock splits. Coal volumes were calculated for each 1000-metre section-strip using 200-metre vertical slices; volumes were converted to tonnages using an S.G. of 1.48. Table 5-9-2 tabulates the results: there is a total potential coal resource of over 600 million tonnes, of which 416 million tonnes are within 1600 metres of surface (Table 5-9-2).

Variation of methane retention with depth has been investigated in a number of ways. Coals of sub-bituminous to

TABLE 5-9-2
TUYA RIVER COAL BASIN
POTENTIAL COAL AND COALBED METHANE RESOURCE

Section		Depth in Metres										
6400	FROM	0	200	400	600	800	1000	1200	1400	0	+	TOTAL
x1000	TO	200	400	600	800	1000	1200	1400	1600	1600	1600	
		Million Tonnes										
61		9.5	6.8	10.8	19	12.2	13.6	13.6	13.6			
60		9.5	12.2	17.6	10.8	13.6	13.6					
59		16.3	10.8	12.2	13.6	17.6						
58		27.1	8.1	10.8	16.3							
57		21.7	8.1	12.2								
56		65										
TOTAL TONNES		149.1	46	63.6	59.7	43.4	27.2	13.6	13.6	416	232	648
(A) Methane cft/ton		25	25	25	25	25	25	25	25	25	0	.01Tcf
(B) Methane cft/ton		72	108	117	125	133	150	150	150		0	.039Tcf
(C) Methane cft/ton		89	98	114	126	132	141	146	151		0	.038Tcf

(A) uses constant 25 cubic feet per short ton
(B) values derived from Figure 3-9-8
(C) values derived from Equation 3, Table 3-9-1

Note 1 sections located in Figure 3-9-3
Note 2 half of 491.1 million tonnes used to calculate CBM

high-volatile bituminous rank do not generate or retain much methane. Meissner (1984) states that catagenic methane generation starts when the volatile matter (dry, ash-free basis) is less than 37.8 per cent, equivalent to a rank of high-volatile A. The dry, ash-free volatile matter of Tuya River coals is about 45 per cent though the rank may be as high as high-volatile bituminous A. Figure 5-9-8 indicates that high-volatile bituminous C coals can retain up to 150 cubic feet of methane per short ton (4 cubic centimetres per gram) at depths of 1500 metres. Equation 2 provides ranges of 0 to 250 cubic feet per short ton (reflectance=0.6) and 0 to 350 cubic feet per short ton (reflectance=0.7) for depths 0 to 1500 metres. These values assume that the rank of coal at 1500 metres is not higher than that at surface. In the case of Tuya River, if folding predates coalification, then the rank in the core of the syncline could be as high as medium-volatile bituminous and the coal at depth capable of retaining two to three times more methane. A high-volatile bituminous C rank is assumed for the purpose of estimating the coalbed methane resource at Tuya River.

The resource has been estimated for other low-rank coal basins. Choate *et al.* (1989) estimate an average gas content of 25 cubic feet per short ton for coals in the Powder River basin where rank is sub-bituminous to high volatile C. Recently, desorption tests from the Powder River basin have provided values of 56 and 74 cubic feet per short ton (McBane, 1990) McCord (1989) uses a range of 0 to 100 cubic feet per short ton for sub-bituminous coal when estimating the methane resource of the Greater Green River coal region. Equation 3 (Table 5-9-1) from Kim (1977) is described later, but it predicts a range of gas contents of 69 to 151 cubic feet per short ton from 100 metres to 1500 metres depth. Obviously there is a wide range of uncertainty in trying to predict the methane contents for low-rank coals.

The coalbed methane resource was calculated in this study in three ways. A minimum estimate was obtained by multiplying the total tonnage to a depth of 1600 metres by 25 cubic feet per short ton derived from Choate *et al.* (1989), to give a resource value of 0.01 trillion cubic feet. The second and third approaches involved multiplying the coal tonnages, distributed by depth of burial, by methane-retention values derived from the data of Eddy *et al.* (1982; Figure 5-9-8 high volatile bituminous C line) and from Equation 3 (Table 5-9-1) from Kim (1977).

Application of Equation 3 to Tuya River coals predicts a methane resource of 0.038 trillion cubic feet, with retention values ranging from 67 to 151 cubic feet per short ton. Equation 3 requires coal-quality data and estimates of the pressure and temperature acting on the coal as well as an estimate of the ratio of gas-adsorption capacity for wet coal divided by gas-adsorption capacity for dry coal (Vw/Vd, Table 5-9-1). The coal-quality data were averaged from coal

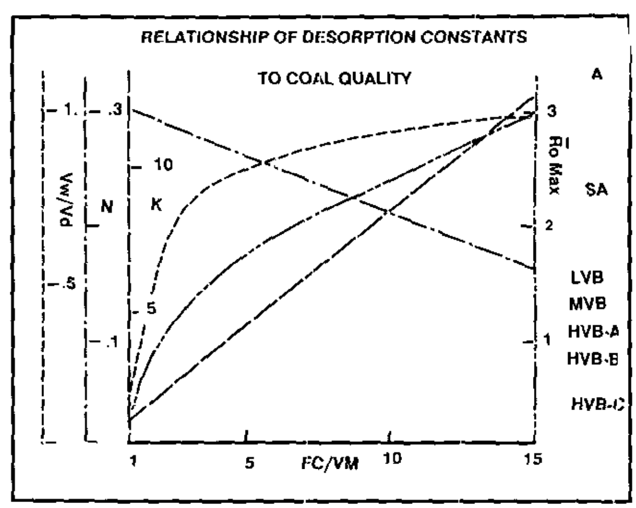

Figure 5-9-9. Plot of fixed carbon/volatile matter ratio versus reflectance and desorption constants from Kim (1977).

intersections in the drill holes which provided values of 12.4 per cent moisture, 19.1 per cent ash, 30.7 per cent volatile matter, 37.8 per cent fixed carbon (all AR). These data are incorporated into Equation 3 (Table 5-9-1) using constants K and N which are derived from the ratio of fixed carbon divided by volatile matter. This ratio is related to rank and reflectance measurements in Figure 5-9-9 (data from Stach, 1982) which also illustrates the relationship of K and N to reflectance.

The pressure acting on the coal seam is an important constraint on methane retention. Usually pressure will equal hydrostatic pressure, but drill results indicate cases where pressures are less than hydrostatic or more than hydrostatic and approach lithostatic pressure (over-pressure situations). For this study hydrostatic pressure is assumed.

Methane retention decreases as the moisture content of the coal increases. High moisture contents are an important limiting factor on methane retention by low-rank coals. The effect of moisture content on methane retention is accounted for in Equation 3 by the ratio Vw/Vd which was derived for Tuya River coals by curve fitting and extrapolation using data in Table B-1 of Kim (1977); a value of 0.25 was determined. Methane retention decreases with temperature, which increases with depth. The factor B (Table 5-9-1) takes into account temperature and the term following B in the equation assumes a geothermal gradient of 18° C per 1000 metres.

Coalbed methane retention values from Figure 5-9-8 (high-volatile bituminous C line) range from 72 cubic feet per short ton at 100 metres depth to 150 cubic feet per short ton at 1500 metres; the upper value was fixed at 150 cubic feet per short ton because the original diagram by Eddy *et al.* (1982) does not extrapolate beyond this point. Using these values a coalbed methane resource of 0.039 trillion cubic feet is calculated (Table 5-9-2). The resource calculated using Equation 2 would be even larger because reflectance values, on average, indicate a rank up to high-volatile A. A resource of 0.062 trillion cubic feet is predicted using Equation 2 and an average reflectance of 0.68.

DISCUSSION

The three methods of estimating coalbed methane resources to a depth of 1600 metres produce values of 0.01, 0.038 and 0.039 trillion cubic feet. These values are based on minimal data and are at the low end of the scale for methane retention. This approach was taken because at the moment no desorption data are available for Tuya River coals. The same approach is being applied more usefully to the Telkwa deposit where coal rank for the lowest seam is favorable for methane retention.

It is useful to make some order of magnitude comparisons between coal and coalbed methane as fuels. A tonne of coal mined and burned will provide about sixty times more energy than the methane extracted from one tonne of coal. This means that extracting methane decreases the energy content of the coal by about 2 per cent and represents about 1 per cent of the volatile matter in the coal. Therefore its extraction has little if any effect on the quality of the coal because the gas would probably also be lost during conventional mining.

A single house using electricity derived from coal for all its energy needs requires from 1 to 5 tonnes of coal per year; in contrast, if the house were using coalbed methane, the coal requirement would be from 40 to 200 tonnes. The increased requirement of coal may be offset as the end-use efficiency for natural gas or coalbed methane can be much higher than for coal. A resource of 400 million tonnes or 0.04 trillion cubic feet is sufficient to service up to 5000 houses for 100 years.

The environmental impact of burning coal is greater than the impact of burning the same energy-equivalent of coalbed methane. Burning methane provides two times more energy than coal per unit CO_2 generated (Fulkerson, 1990). Although using coal only as a source of gas requires a larger coal resource, and may be considered an inefficient use of the resource, it is environmentally much cleaner. Recovering the methane does not detract from the value of the coal for future use when coal-burning technologies have improved. Also, on a molecule for molecule basis, methane is twenty times more potent as a greenhouse gas than CO_2 (although its residence time in the atmosphere is one-tenth that of CO_2). Collecting and burning methane that might otherwise escape into the atmosphere should help to reduce the overall impact of greenhouse gases.

SUMMARY

A review of existing data, with the addition of some 1990 fieldwork, indicates that the Tuya River coal basin is large with a potential resource of 650 million tonnes of high-volatile B bituminous coal and a possible coalbed-methane resource of up to 0.04 trillion cubic feet. A resource of this magnitude could make a significant contribution to the energy requirements of the region, as it develops, while minimizing impact on the environment.

In the long term, the isolation of the basin might be a positive factor in its development; it might be more economic and environmentally sound to sustain development in northwestern British Columbia using a local energy source than to continue to use high-priced petroleum products and build expensive transmission systems. The methane could be distributed by truck as pressurized gas and used for local industry as well as to run motor vehicles and heat houses.

Petrographic and coal-quality analyses of the 1990 samples are ongoing and will be discussed in depth in a later report. The next stage in clarifying the potential for a coalbed-methane resource should be a drilling program to provide fresh samples for methane desorption tests, petrography and coal quality analyses. Some existing drill sites could be used and new ones cleared in Tuya River. The program would have to be helicopter supported from Dease Lake which is 15 minutes flying time away.

There are numerous poorly explored Tertiary coal-bearing sedimentary basins in British Columbia. It is intriguing to speculate that some may, in the future, provide local, environmentally sound sources of energy to help in the development of the province.

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