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COAL RANK VARIATIONS IN THE CABINET CREEK AREA, TELKWA COALFIELD, CENTRAL BRITISH COLUMBIA (93L/11)

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KEYWORDS: Coal, Telkwa coalfield, coal rank, semi-anthracite, reflectance indicating surface, biaxial negative coals.

INTRODUCTION

The Telkwa coalfield is in central British Columbia, centered on the town of Smithers. It extends from north of Smithers to south of Telkwa along the Bulkley River for about 50 kilometres (Figure 1) and contains a potential coal resource of approximately 850 million tonnes (Ryan and Dawson, 1994). The Telkwa coal property, which occupies less than 10 percent of the whole field, is 15 kilometres south of Smithers and is centered on the confluence of the Telkwa River and Goathorn Creek. Coal on the property is generally high-volatile A bituminous and is considered to be an excellent thermal coal, however there is one area where the rank appears to be semi-anthracite. This report confirms the existence of this area of elevated coal rank in the Cabinet Creek area of the Telkwa coalfield and discusses some possible causes.

The geology of the Telkwa Coalfield is discussed in a number of papers (Koo, 1984, Palsgrove and Bustin, 1990) and is shown on regional geology maps of Tipper (1976), MacIntyre *et al.* (1989) and Ryan (1993). Coal-bearing rocks belong to the Skeena Group of Lower Cretaceous age and are assigned to the Red Rose Formation of Albian age and possibly also to the older Kitsun Creek Formation of Hauterivian age. Coal-bearing rocks outcrop north of Smithers, south of Smithers in the Bulkley River, north of the Telkwa River in the vicinity of Pine Creek, east and west of Goathorn Creek and at the headwaters of Tenas and Cabinet Creeks (Figure 1). Cretaceous rocks of Hauterivian age outcrop along the north east edge of the coalfield and contain only traces of coal.

EXPLORATION HISTORY

There is a long history of exploration and mining in the southern part of the Telkwa coalfield. In the Telkwa area coal seams were stripped in 1903 on Goathorn Creek, previously called Goat Creek (Dowling, 1915). In the Cabinet Creek area (previously Cabin Creek) from 1913 to 1915 the Transcontinental Exploration syndicate constructed 2 tunnels which intersected five seams of semi-anthracite (Dowling , 1915) and sank a shaft. Despite this intermittent activity there has been no mining in the area

In the period 1930 to 1970 six small underground mines and one surface mine operated in the Telkwa River-Goathorn Creek area and about 480 000 tonnes of coal were mined. A small tonnage of coal was mined in the Goathorn Creek area by Lloyd Gething during the 1970's and early 1980's.

Exploration activity at Telkwa is recorded in a number of geological assessment reports submitted to the B.C. Ministry of Energy Mines and Petroleum Resources (now part of the Ministry of Employment and Investment) and on file in Victoria (Handy and Cameron, 1982, 1983, 1984; McKinstry, 1990 and Ledda, 1992). The property was intensively explored in the period 1978 to 1989 by Crowsnest Resources Limited, when over 350 exploration holes were drilled and a large test pit excavated in the area east of Goathorn Creek. In 1989 Manalta Coal Limited acquired the property and since then has carried out a number of major programs which concentrated on the areas north of the Telkwa River, east of Goathorn Creek and east of Tenas Creek. Mineable coal reserves have now been outlined in all three areas. In 1996 as part of a major exploration program, a test pit was dug in the Tenas Creek area, which is now considered to contain the best mining potential on the property. The company is considering the possibility of developing an open pit thermal coal mine on the property. Drilling in 1995 intersected coal in the Cabinet Creek area but it appears that there are no mineable reserves in the area because coal intersections are thin and the structure appears to be complex.

STRATIGRAPHY

The Cretaceous stratigraphy on the Telkwa Coal property was divided into four units by Palsgrove and Bustin (1990). The lowest unit, which is 20 to 100 metres thick, rests unconformably on Lower Jurassic volcanic rocks of the Telkwa Formation, Hazelton Group. It is non-marine and is distinguished by an abundance of coarse clastics. It contains a single coal zone composed of up to six component seams, together referred to as Seam 1, which has a cumulative coal thickness averaging 7 metres in the Tenas Creek area (Figure 1).

Unit 2 is composed of from 60 to 170 metres of shallow marine mudstones and siltstones.

The major coal-bearing zone, comprising seams 2 to 10, is within unit 3 which averages 90 metres in thickness. The unit is composed of siltstones, mudstones and sandstones, which often overlie the seams with higher sulphur contents. The cumulative coal thickness in unit 3 ranges from 6 to 14 metres in areas considered

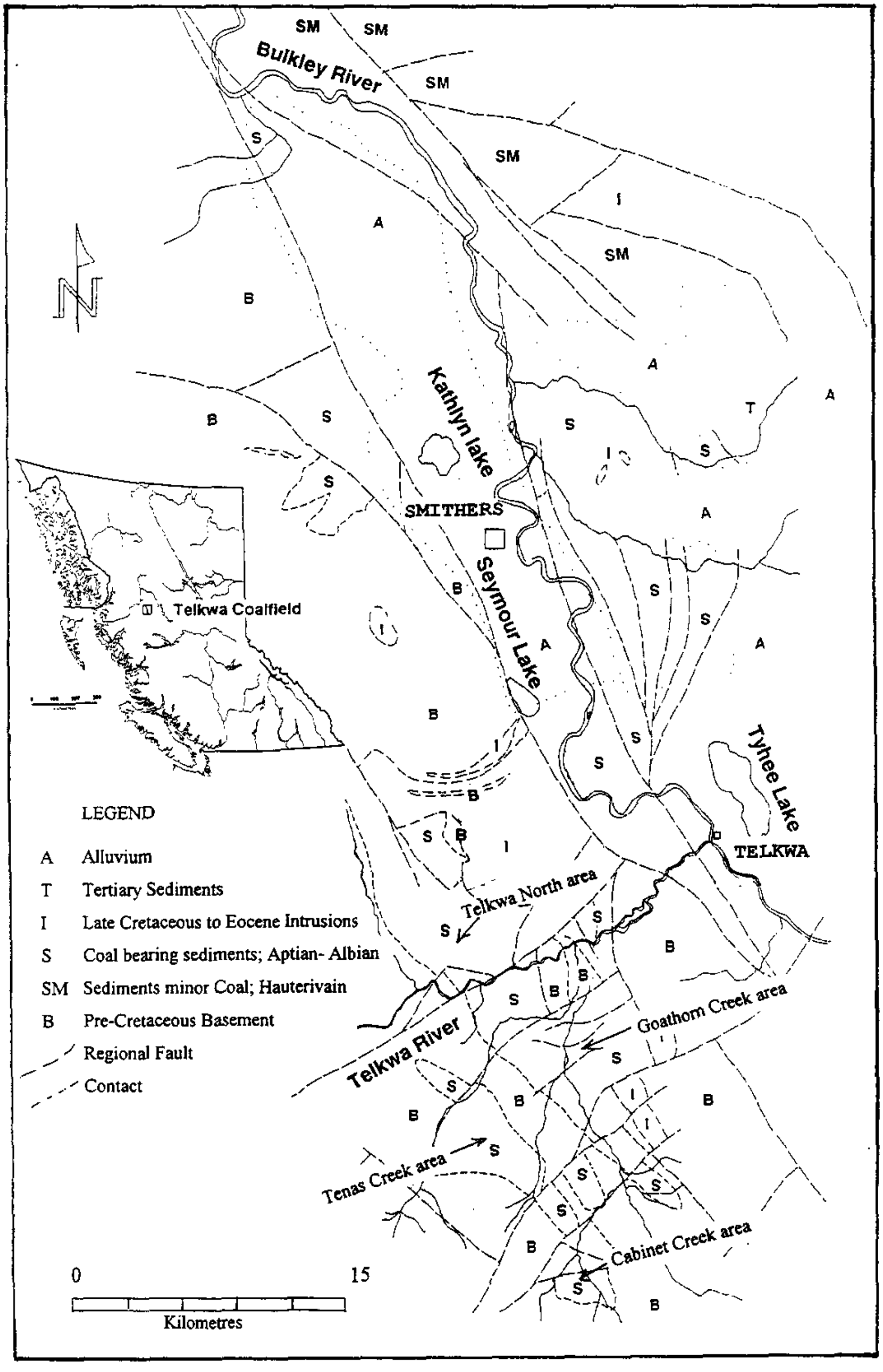

Figure 1: Geology of the Telkwa coalfield showing locations of Cabinet Creek, Telkwa North, Goathorn Creek and Tenas Creek areas.

for development. Unit 3 is overlain by the sandstone-rich unit 4 which is over 100 metres thick.

Outcrop on the Telkwa coal property is sparse. An understanding of the structural geology of the property has evolved as information from drilling and a number of geophysical surveys has became available. Bedding generally dips shallowly southeast or east and is disrupted by at least two generations of faulting. Early faults are east-dipping thrusts that offset the east dip of the sediments east of Goathorn Creek. Late steep-dipping faults trend northwest or northeast. Folding has produced open folds that trend northwest with shallow plunges.

TABLE 1

LOCATION OF REFLECTANCE DATA FROM CABINET CREEK

hole OC	Northing m	Easting m	Elev m	Dpth m	Rmax %	Rmmax %	Rint %	Rmin %
OC90-46	6047480	620980	900	0	2.2	2.2	2.04	1.74
OC90-47	6047480	620980	900	0	2.3	2.3	2.27	1.87
OC90-51	6047240	620960	920	0	2.33	2.32	2.28	1.83
OC90-52	6047160	620980	920	0	2.36	2.36	2.31	2.08
OC90-53	6047160	620980	920	0	2.44	2.44	2.34	2.04
T95R-52	6048400	620330	1005	117	1.72	1.6	1.57	1.43
T95R-56	6047210	620840	925	77	2.27	2.2	2.15	1.85
T95R-56	6047210	620840	925	119	2.3	2.21	2.15	1.9
T95R-56	6047210	620840	925	130	2.35	2.29	2.25	1.85
T95R-58	6046420	621170	990	24.5	2.75	2.61	2.55	2.15
T95R-59	6046470	620740	1005	103	2.75	2.58	2.5	2
T95D-1-1	6045540	621150	1105	61	3.3	3.03	3	2.4
T95D-1-2	6045330	621480	1115	61.2	3.35	3.1	3	2.55
T95D-1-3	6045007	621440	1125	52.1	3.3	3.32	3.2	2.7
R205*	6048353	620667	960	136		1.7		
R206*	6048779	620279	970	190		1.6		
R207*	6049330	620137	960	138		1.5		

* estimated from volatile matter

CABINET CREEK GEOLOGY

An outlier of the Telkwa coalfield outcrops in the Cabinet Creek area (Figure 1). A number of seams outcrop in the creeks and over the years there has been some prospecting and a number of holes have intersected coal.. Semi-anthracite is mentioned in the area by Dowling (1915), who describes an adit, probably located near Cabinet Creek, which intersected anthracite. Mean maximum reflectance measurements on vitrinite (Rmmax%) from drillhole and outcrop samples confirm a rank of low-volatile bituminous to anthracite (Ryan, 1992) (Table 1). The volatile content data from samples from three 3 rotary drill holes indicates a rank of at least low-volatile bituminous based on the relationship of volatile matter on a dry ash-free basis to Rmax% (Stach *et al.*, 1982). Two of these holes intersected 6 and 11 metres respectively of fine grained igneous rock in the sedimentary section (assessment report 1980). Two of the holes, 205 and 207 (Figure 2), intersected volcanic basement at depths of 167 and 173 metres giving some indication of the thickness of the sedimentary succession at Cabinet Creek. No intrusive rocks have been seen in outcrop in Cabinet or Webster Creeks, nor are any Tertiary plutons mapped in the area. They have not been encountered in any of the recent drilling in unit 1 in the Tenas Creek area and their presence in the Cabinet Creek area is unusual

The regional map (Ryan, 1993) shows a number of possible faults cutting the Cretaceous rocks in the Cabinet Creek area, which based in large part on air photo interpretation. They are shown on Figure 2 and appear to divide the reflectance data into a number of groups.

It is possible that the Cabinet Creek area represents a preserved block of the older Kitsun Creek sediments, Hauterivian to Albian in age, separated from younger middle Albian sediments to the north by a major fault. Generally the Kitsun Creek sediments outcrop near Smithers and are more sandy than the Albian sediments that host the coal in the Telkwa area (Tipper, 1976). Only traces of coal have been found in the Kitsun Creek sediments in the Smithers area by the author so this explanation is not considered likely and is not clearly supported by the palynological data. A single sample was analyzed for palynomorphs, but in part because of the high rank, the age determination was not very specific. The sample contained a Late Jurassic to Early Cretaceous assemblage of long-ranging gymnospermous taxa and a paralic to non-marine environment is suggested (Davies, 1991). This contrasts with 2 samples from Unit 1 in the Goathorn Creek area which provided ages ranging from Barremian to Albian and came from restricted marine environments.

Coal quality data (Table 2) from three 1982 rotary holes and outcrops indicate that the coal is characterized by moderate to low sulphur suggesting that it is probably not from the upper unit, which contains coal seams with higher sulphur contents. Seam thicknesses in outcrop range from 0.3 to 1.9 metres. There are over 7 metres cumulative coal outcropping in a section of a few hundred metres, which is located on Webster Creek above the confluence with Cabinet Creek (Figure 2).

TABLE 2

COAL QUALITY OUTCROP SAMPLES CABINET CREEK AREA

Sample	Type	Yield	ADM	VM%	Ash%	FC%	S%	Su%	Py%	Or%
OC90-5	raw	100	1.02	7.88	13.97	77.13	0.7	0.1	0	0.7
OC90-5	1.6 flt	91.2	1.01	9.01	9.79	80.19	0.5			
OC90-4	raw	100	0.82	10.08	11.7	77.4	1.3			
OC90-4	raw	100	0.77	9.23	22.64	67.36	0.7			
OC90-5	raw	100	1.5	10.58	25.93	61.99				
OC90-5	raw	100	1.34	8.29	17.15	73.22				
R205	raw	100	0.66	13.89	53.67	31.78				
R205	1.6 flt	15	0.61	13.7	19.26	66.43				
R206	raw	100	0.68	13.58	43.9	41.84				
R206	1.6 flt	35	0.72	14.44	23.57	61.27				
R207	raw	100	0.66	14	65.04	20.3				
R207	1.6 flt	9	0.48	19.76	11.3	68.46				

oxide analysis 90-52 1.6 float

SiO_2	Al_2O_3	TiO2	Fe_2O_3	CaO	MgO	Na_2O	K_2O	P_2O_5	SO_3	B/A
56.51	29	1.33	5.63	2.14	0.65	0.6	0.9	1.3	0.6	0.1

ADM = air dried moisture Py = pyritic sulphur B/A = base acid ratio

Su = Sulphate sulphur Or = organic sulphur

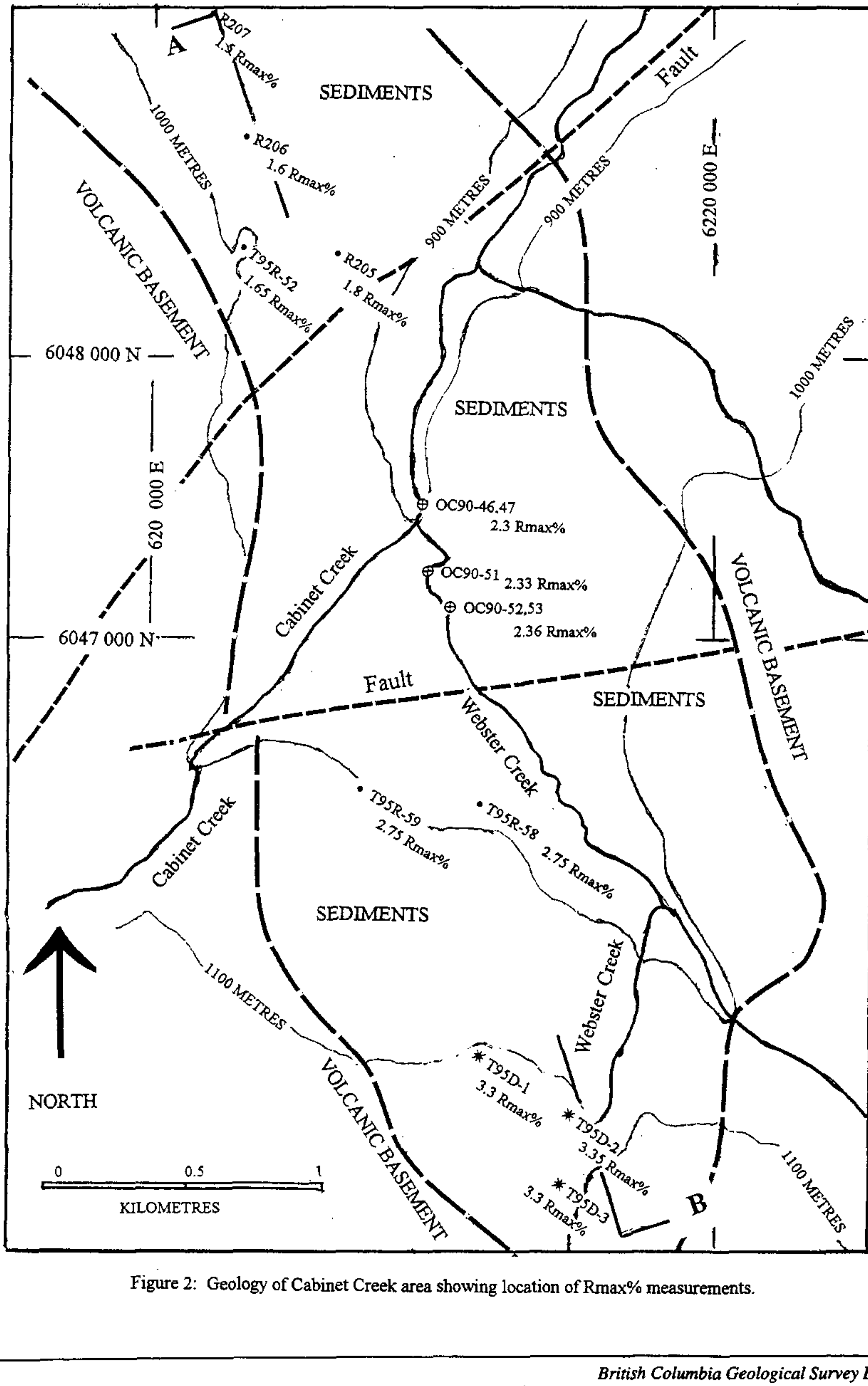

Figure 2: Geology of Cabinet Creek area showing location of Rmax% measurements.

VITRINITE REFLECTANCE MEASUREMENTS

Nine drill hole and 5 outcrop samples were analyzed. On each sample the reflectance of 50 vitrinite grains was measured using a procedure similar to that discussed by Kilby (1988), which allows the shape of the reflectance indicating surface to be described using samples composed of randomly oriented grains. The method allows the optical properties of the samples to be classified as uniaxial or biaxial positive or negative. Until recently it was assumed that most coal samples were uniaxial negative, in which case the maximum reflectance (Rmax%) of the reflectance indicating surface is equal to the intermediate reflectance (Rint%) and the value, mean maximum reflectance (Rmmax%), is a good measure of the actual maximum reflectance. When coal is biaxial negative most of the 50 maximum reflectance measurements will be less than the actual maximum of the indicatrix and only by using the technique discussed by Kilby (1988) can the actual Rmax% value be derived.

In this study each 10 reflectance measurements were bracketed by the measurements of 2 standards. Unfortunately neither standard has a reflectance higher than that of the Cabinet Creek samples. The data were corrected for drift and scale factors before being plotted into a reflectance *versus* bireflectance diagram and a histogram of vitrinite reflectance *versus* count (Figure 3). The shape of the reflectance indicating surface was illustrated using the R_{st} versus R_{am} plot introduced by Kilby (1988, Figure 4).

IMPLICATIONS OF THE DIFFERENCE BETWEEN RMMAX% AND RMAX%

The value Rmax% is greater than Rmmax% for biaxial coals and the relationship for Mist Mountain coals (Grieve, 1991) is given by:

Rmax%=Rmmax%*1.044.

Grieve suggests that the biaxiality is caused by a differential stress factor imposed upon the hydrostatic stress, which is responsible for the uniaxial component of the reflectance indicating surface. If this is the case then coals that experienced a simple burial history will have uniaxial reflectance indicating surfaces, Rmmax% will equal Rmax% and Rmmax% will be a true measure of rank. However for coals whose rank was established during folding, Rmmax% will be an underestimate of rank and the true rank will be indicated by Rmax%.

The maturity of vitrinite strongly influences the rheological properties of the coal. This is because reflectance correlates very well with the hydrogen content above a reflectance of about 1.0%. Coal with a reflectance of 0.6% to 1.0% is in the "oil window", meaning that the liptinites and vitrinites are generating oil, which may leave the coal or become trapped in the microporosity of the virtinite, which increases its reflectance and vastly improves its rheological properties. Above a reflectance of 1.0% the coal is in "the gas window" and the bitumen is broken down to gas, initially wet gas, and at a reflectance above about 1.3% to dry gas. The gas is partially adsorbed in the micro-porosity, which at this reflectance is becoming open again, and in part is lost by the coal to migrate and possibly become a natural gas resource. The evolution of coal maturity as a source for oil or natural gas is the mirror image of its evolution as a coking coal; one's loss is the others gain.

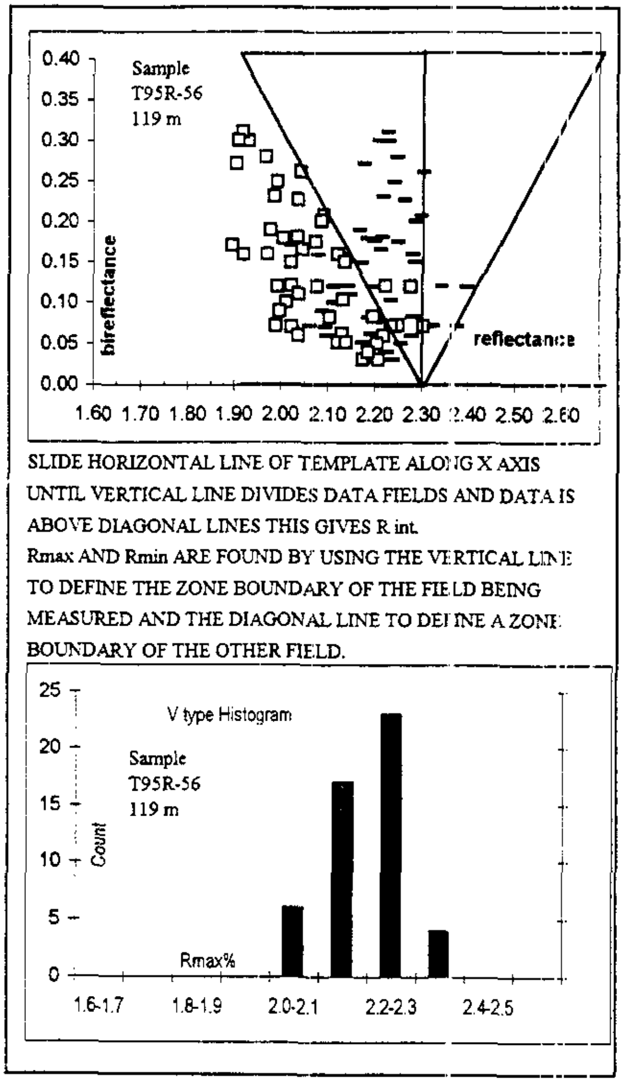

Figure 3: Example data from a Cabinet Creek sample. The bireflectance *versus* reflectance plot with template for determining Rmax% and histogram plot of V types

The possible under estimation of the rank of coals with biaxial negative reflectance indicating surfaces and the difference in internal structure for medium-volatile coals with biaxial or uniaxial optical properties have implications for the coking properties of coal.

It is possible that the rank of the Carboniferous high-vitrinite coals such as those from the Eastern U.S. was imposed during a simple burial history and they are uniaxial negative, whereas the more complicated maturation history of western Canadian coals ensured that they are predominantly biaxial negative. Bustin *et al.* (1986) heated and deformed samples of anthracite and was able to increase the reflectance as well as the biaxial

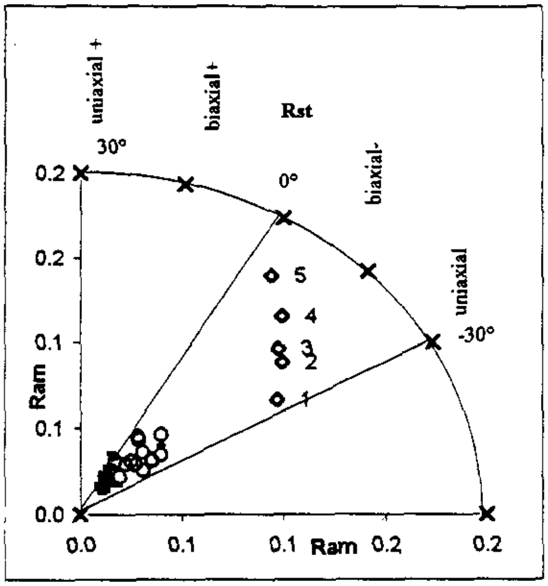

Figure 4: A R_{am} *versus* R_{st} plot illustrating the shape of the reflecting indicating surfaces for Cabinet Creek samples. Circles are Cabinet Creek data, diamonds are data from Bustin *et al.* (1986) and dashes are Seam 2 data from the rest of the Telkwa property.

negative component of the reflectance indicating surface (Figure 4). Clearly deformation does change a uniaxial negative reflectance indicating surfaces into a biaxial negative one possibly with higher Rmax% values.

Gransden *et al.* (1991) compare the chemical properties of vitrinites of identical Rmax% values from Western Canadian and Appalachian coals. Western Canadian vitrinites have approximately 2% less volatile matter and 0.1% less hydrogen than their Appalachian counterparts. But because of the probably biaxial negative nature of the western Canadian vitrinites their reflectances could have been under estimated by about 0.05%, which based on the hydrogen *versus* Rmmax% relationship in Stach *et al.* (1982) would account for about 0.06% hydrogen. If the true rank of the western Canadian vitrinites were used, then they would not appear to have a low hydrogen content.

It is difficult to relate coal molecular structure to its optical properties in the medium-volatile range because the material is still composed of large and somewhat disorganized molecules. It is possible that for two medium-volatile rank vitrinites with identical Rmax% values that the uniaxial negative vitrinite probably has a more uniform and ordered micro-porosity than the biaxial negative vitrinite. If Rmax% values are strongly correlated to hydrogen content, then both vitrinites will have the same amount of hydrogen (probably as bitumen) locked in the microporosity. One difference may well be that the biaxial negative vitrinite will soften at a higher temperature during coking making. It may be important to consider this when estimating the amount of fluidity in a coal blend required to make good coke.

The reflecting indicating surfaces of coals deformed during heating tend to be biaxial negative (Bustin, *et al.*, 1986). Compared to uniaxial negative surfaces, there is an increased spread of individual Rmax% values and the values may tend to be a bit higher. The spread in vitrinite reflectances is an important parameter in predicting Coke Stability Index in the method proposed by Schapiro and Gray (1964), which is still widely used. The method uses a number of graphs to derive constants from the maceral composition and vitrinite measurements of a coal sample. These constants are then used to provide a predicted Coke Stability Index called Coke Stability Factor. The method of Schapiro and Gray was examined in an attempt to see what the effect on Stability Factor would be of changing from a uniaxial negative to biaxial negative indicating reflecting surface. Results indicate that for coals with moderate to high inertinite contents there is little apparent increase or decrease in predicted stability index.

VITRINITE REFLECTANCES IN THE CABINET CREEK AREA

Fourteen Rmax% measurements exist for the Cabinet Creek area and in addition three Rmax% values are estimated using volatile measurements corrected to a dry ash free basis for samples from the three pre 1990 rotary holes (R205, R206 and R207, Figure 2). The data (Table 1) indicate a consistent trend of increasing rank to the south and along strike (based on a limited number of bedding measurements). There are no large intrusive bodies within 4 kilometres of the Cabinet Creek area and experience north of the Telkwa River indicates that the Late Cretaceous to Eocene quartz feldspar porphyries mapped in the area (MacIntyre *et al.*, 1989) have had little effect on coal rank. It appears that the pattern of Rmax% values is not caused by a local intrusion.

It is unlikely that the pattern of Rmax% values is caused by faults uplifting successively deeper sections of the sedimentary sequence to the south. The fault traces on Figure 2, which are copied from Ryan (1993) divide the data into three blocks and a third fault is hypothesized to separate the high reflectance measurements in the south. If the average Rmax% values in each block differ because of vertical fault displacement then if the Rmax%/100 metres gradient is known it is possible to estimate the displacement. The reflectance gradients for units 3 and 1 measured to the north (Ryan, 1992) are respectively 0.114% and 0.3 % per 100 metres. If the lower gradient is used then the average vertical displacement on the faults is approximately 490 metres and if the higher gradient is used the average displacement drops to about 185 metres. Even at a 185 metre displacement there would be considerable offset of the sedimentary/basement contact (assuming the contact is not vertical) across the faults. Except in one location there does not appear to be major offsets in the sediment/basement contact, except in one location, and consequently it seems to be unlikely that the pattern of Rmax% values is caused by faults.

If the Rmax% values are plotted against distance along traverse line A:B (Figure 2) there is a remarkably consistent trend apparent (Figure 5). The apparent

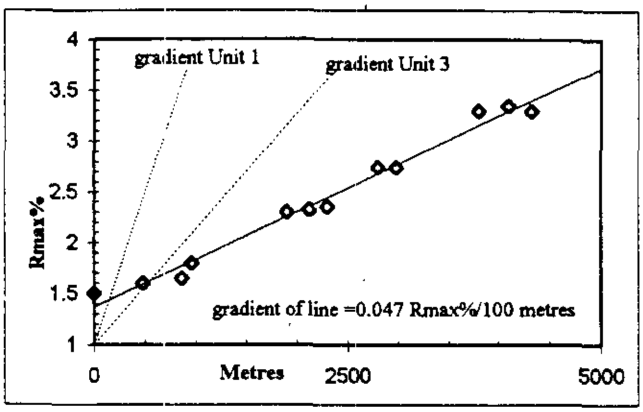

Figure 5: Plot of Rmax% data (Table 1) *versus* distance along or close to traverse line A:B (Figure 2).

gradient of Rmax%/100 metres is low and if the data represent a reflectance *versus* depth gradient then the present topographic surface intersects the iso-reflectance surfaces at a small angle. In the Cabinet Creek area the apparent reflectance gradient along A:B is 0.0471%/100 metres and if true gradients of 0.114% or 0.3% per 100 metres (Ryan, 1992)are used then this implies a dip to the north of the iso-reflectance surfaces of between 23° and 8°. Because the volcanic basement is within 200 metres of the surface to the north, it is unlikely that the iso reflectance surfaces parallel it. Therefore the high Rmax% values indicate that either the paleo heat flow from the basement was substantially greater to the south or there was substantial cover over the Cabinet Creek sediments to the south. Without any indication of the gradient no estimates of the post mid Cretaceous cover can be made.

The reflectance indicating surfaces for samples from the Cabinet Creek area are distinctly less biaxial and closer to being uniaxial negative than samples from the rest of the Telkwa property (Figure 4). Bustin *et al.* (1986) was able to increase the biaxiality of samples from uniaxial negative by straining them at high temperatures, as indicated in Figure 4 where his data are numbered in order of increasing applied strain and temperature. This suggests that coal rank at Cabinet Creek was established after the deformation whereas the coal rank of high-volatile bituminous in the rest of the Telkwa area was established prior to or during deformation.

CONCLUSIONS

The Cabinet Creek area has unusually high and variable rank compared to the rest of the Telkwa property. Indications are that the high rank relates to regional heat flow from the basement and thicker cover rather than local dikes or sills or nearby large intrusions. There is some evidence to suggest that the high rank was imposed on the coal in the Cabinet Creek area after the main deformation, which in the Telkwa area is considered to be mid Cretaceous (D. MacIntyre, personal communication 1996).

There is no clear evidence to suggest that the Cabinet creek sediments are older or different from the rest of the Skeena Group sediments in the Telkwa River area.

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