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COKING COALS OF WESTERN CANADA

by

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INTRODUCTION

The history of the development of the coking coal industry of western Canada has been somewhat of a Cinderalla story[(1)]. Traditionally the producing mines had supplied coal mainly to the railway and domestic markets. With the loss of these outlets because of dieselization of the railways and the discovery of oil and gas in this region of Canada and with the problem aggravated by the great distance separating the mines from markets in Central Canada, the coal producers during the 1950's were virtually faced with shut-down. The potential market for coking coal for the Japanese steel industry provided the stimulus for revival. Although not without difficulties progress in the expansion of the industry has been phenomenal during the intervening years and, indeed, with the present international shortage of this commodity a worldwide interest has been directed towards this potential source of coking coals.

The principal coking coal deposits are confined to the Inner Foothills belt which parallels the eastern front of the Rocky Mountains. The long narrow belt stretches 650 miles from the international boundary in Alberta and British Columbia through to the Peace River in north-eastern British Columbia. The nature of the coal seams has been affected by the extreme forces exerted by tectonic movements during the periods of mountain formation. The seams are

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normally steeply inclined, thickened or thinned, truncated by faults and the coals so crushed as to make the coal extremely friable. The number of seams laid down stratigraphically varies along the belt. For example, in the Fernie-Michel area of the Crowsnest Pass in British Columbia the coal-bearing formation is about 3700 ft. thick and contains 23 seams. The thickest of these is 50 ft. and 18 are over 3 ft.

The Kootenay formation extends from the southern end of the belt to approximately a latitude of 52 degrees. The seams are Late Jurassic to Early Cretaceous in geological age and mainly low and medium volatile bituminous in rank. High volatile and semi-anthracite coals also occur in this region. The sulphur content of the coals is usually low and the ash content is moderately high.

From the 52 degree latitude to the 57 degree latitude the coal seams occur in the Luscar formation. The coking coals in this formation are Lower Cretaceous in age and fall into the low and medium volatile bituminous rank classification. The sulphur content is also low with less mineral matter than the coals of the Kootenay formation.

Figure 1 gives the general distribution of the coking coals in western Canada and the location of principal coking coal mines.

Table 1 presents a preliminary estimate of coal resources as obtained from a joint study by the Mineral Resources Branch and the Geological Survey of Canada during 1969 and 1970 for the Federal Energy Policy Study[2, 3]. Since that study was prepared, coal companies have done additional exploration, indicating that the resources may be larger than shown.

The production of coking coal from western Canada has increased nine-fold since 1969. The tonnage of cleaned coal produced from these mines alone in 1973 was 12 million tons and it is anticipated that 13 million tons will be reached in 1975.

The coals of western Canada are adversely located with respect to the domestic and export market areas. The integrated steel industry of Canada is mainly situated in Ontario a distance of approximately 2500 land miles (1500 miles from the Lakehead). For this reason and the close proximity of the eastern U.S. Appalachian coalfields to Ontario, Canadian market has been precluded. The average distance from the mines to tidewater on the west coast is some 700 miles of rugged mountain terrain. Transportation costs have been reduced to a large extent by the use of 10,000 ton capacity unit train system. Two railway companies, namely the Canadian Pacific and the Canadian National transport the coal from mine site to port. The Canadian National also built the Alberta Resources Railway and operates it on behalf of its owner, the province of Alberta. The British Columbia Railway is also making plans to transport coal to the west coast. The movement of coking coal by pipeline in slurry form from mine to tidewater has been considered by the major railway companies. Extensive studies were carried out by CANMET to investigate the feasibility of this mode of transport.

The coal produced from the six producing mines is carried by the two railway lines to three bulk loading terminal facilities in the Vancouver area. The three port facilities are West Shore Terminals Limited, Neptune Terminals Limited and Pacific Coast Bulk Terminals Limited with dead weight ship capacities of 120,000, 100,000 and 65,000 tons, respectively. The total coal capacity of the terminals is 13 million tons annually.

The quality specifications of coking coals currently being exported to Japan are given in Table 2.

QUALITY SPECIFICATIONS OF COKING COALS

A preamble on the subject of cokemaking and associated ironmaking is necessary for a cursory understanding of the quality of coking coals.

Primary iron is produced almost exclusively by the reduction of iron-bearing oxides in the high shaft blast furnace. Carbon, in the form of coke, is used as the source of heat and reduction. Blast furnace coke accounts for about 90 per cent of the world coke production[(4)]. The world coking demand will rise an estimated 14 per cent from 1969 to 1975 (from 465 million to 530 million tons, coal equivalent)[(5)].

Coke for blast furnace use is manufactured from coking coals mainly in conventional slot-type coke ovens. Coke is rarely produced from a single coal. Coking coals of various types and properties are usually blended and carbonized in order to produce coke of optimum quality and to remain within the operating limitations of the coke oven. In Japan, as an example, a steel plant may carbonize a blend of coals from as many as twenty-three different sources.

The coke rate, which is the amount of coke required to produce a ton of hot metal (lb/NTHM), is the absolute unit of coke quality. The average coke rate in Canada in 1970 was 1080 lb/NTHM and it has been estimated that the rate will drop to 900 lb/NTHM by 1980. The projected rate is predicated on the production of good quality coke[(6)].

Good quality coke must be high in carbon content, low in extraneous elements and with high strength properties to withstand the mechanical handling from the coke oven to the blast furnace as well as the weight of the blast furnace burden and to provide smooth furnace operation.

In order to explain coal and coke quality within the confines of this report, significant properties are grouped under the following headings:

1. Grade - The inherent extraneous material contained in coal, such as sulphur and mineral matter, appear in the coke product and have a deleterious effect on blast furnace performance and production. Some elements contained in the mineral matter such as phosphorus, sodium and potassium may have a particularly adverse effect in furnace operation.

2. Caking Properties - A coking coal must become plastic or fluid during its thermal decomposition. The fluidity is indicative of its cementing ability, a prerequisite for strong coke structure. Standard impirical tests are used to measure the thermal rheological properties of coal (7, 8, 9). FSI, Dil, Gieseler (Plast.) are abreviations used in Figures 2 to 5 inclusive for the free swelling, dilatation and plasticity parameters, respectively.

3. Coking Properties - Although caking propensity is essential in cokemaking, a proper balance between caking components and non-reactive carbon is essential for optimum coke strength. Cokemaking is not unlike the making of concrete whereby the strength of the concrete is related to a proper balance of cement and aggregate. From the petrographic analysis of coal the percentage of reactive constituents (those components which provide fluidity to the coal) and the percentage of inert constituents (those components which have no fluid properties) can be determined. This information along with the mean reflectance in oil (R_o), which is directly related to the coal rank, permits the calculation of the predicted Stability Factor - an ASTM index of coke strength and used exclusively in ironmaking produce on this continent[14]. In Figures 2 to 5 inclusive Stab. (Pred.) refers to the predicted Stability Factor calculation from the petrographic analysis and Stab. (actual) refers to the actual value obtained from testing coke produced from pilot plant coking tests.

4. Operational Properties - Conventional slot-type coke ovens are long narrow chambers of refractory brick construction. This type of design restricts the use of coals to those coals which exhibit wall pressures less than 2 psi. Movable-wall type test ovens are usually used to determine the wall or carbonization pressures during the coking cycle[15,16,17]. In addition, the coke must have certain shrinkage characteristics after coking to permit ease of discharge from the oven. The shrinkage characteristics of a coal are indicated from the expansion/contraction values obtained from the sole-heated oven test method[6]. These properties are abbreviated in Figures 2 to 5 inclusive as Press. and E/C, respectively.

With the aforegiven remarks on coal and coke properties in mind, the specification for a good blast furnace coke are given in Table 3. Typical properties of a coal blend which should produce coke of good quality are given in Table 4. Coals from different sources are blended to approximate these specifications.

An indication of the importance of coke quality on blast furnace performance may be gleaned from the following credits or demerits applicable to one particular steel plant operation[18].

> Grade - Each one per cent increase in coke ash content requires an additional 30 lb of dry coke per NTHM produced.
> - Each 0.1 per cent increase in coke sulphur requires an additional 8 lb of dry coke per NTHM.
> - Excessive amounts of phosphorus and alkalis in the coke ash can have detrimental effects in the furnace operation.
>
> Coke Strength - Coke strength is related to the caking and coking properties of the coal. For each decrease of one stability unit below 55, the dry coke rate increases by approximately 15 lb/NTHM.

As the coke strength is sensitive to the variabilities associated with the coking properties of the coal and coke oven operation, the Stability Factor of the coke can vary over a wide range. For this reason the changes in coke strength, in most cases, contribute the most to changes in coke rates.

QUALITY OF WESTERN CANADIAN COKING COALS

Since 1961 the Ottawa laboratories of the Department of Energy, Mines and Resources (EMR) have received and evaluated approximately 1400 samples of coal from western Canada and about 600 of these coals have been carbonized in the 12-inch movable-wall coke oven. Selected data to indicate some of the basic properties of cleaned coking coals from producing areas are given in Figure 2. Since our work has dealt mainly with establishing the quality of a product, these results represent specific samples and are not necessarily indicative of current production specifications. Selected data pertaining to exploration adit samples from non-producing areas in the Kootenay and Luscar formations are given in Figure 3.

The coals from the producing mines and those presently under exploration are low and medium volatile coals. Coals of this rank are normally used as blending coals and have recently commanded a premium price. Their properties are, in general, compatible with the high volatile coals (usually with excessive caking propensity) to produce a blend suitable for cokemaking (Table 4). EMR test results have indicated that some of the western Canadian coals are potentially capable of producing excellent coke when carbonized alone (Figures 2 and 3).

In general, the cleaned coals from western Canada presently under production, are higher in ash levels than their counterparts in the United States (USA). If future beneficiation methods permit the economic reduction of the ash of western Canadian coals to lower levels, their caking and coking properties can be expected to be similar to coals of the same rank in the Appalachian coalfield in the USA. To illustrate the effect of ash content on the caking properties a western Canadian low volatile coal was prepared to different ash levels. The results obtained are given in Figure 4. There is a progressive improvement in the caking properties as the ash level is reduced particularly the expansion/contraction properties, fluidity and the free swelling index.

The effect of coal depth on coalification as pertaining to the western Canadian coals has been treated in a paper by the Geological Survey of Canada[8]. Studies of coal bearing formations along the Cordillera from the Crowsnest coalfield in the south to the Peace River canyon in the north showed that the rank increases regularly with stratigraphic depth but not with geological age, depth mining or degree of tectonic disturbance.

EMR has carbonized adit samples taken from various seams stratigraphically positioned in the coal formation. In one particular investigation seams ranging in volatile matter content from 19.9 to 34.2 (dry mineral matter free basis) were studied. Figure 5 gives the analyses and coking characteristics of a selection of seams to show the rank spread through one particular coal formation.

From Figures 4 and 5 it can be inferred that the full gamut of good coking coals are potentially available in western Canada.

CONCLUDING REMARKS

In summation, western Canada is established as a potential source of coking coals. Recent exploration work indicates that the estimated resources are much greater than already reported. The coals which are in the coking category are, in the main, low and medium volatile bituminous in rank classification. Stratigraphically the coals increase in rank with depth of cover, with high volatile coking coals occurring in the upper horizons. Limited information is available on these seams as recent demands have been for the low and low-medium volatile coals.

The rugged mountainous terrain and the disturbed seam conditions present, in many cases, severe problems regarding strip and underground mining. Their remote and adverse location in relation to market areas adds to the transportation costs and have compounded the difficulties of commercial exploitation.

The coals of the Luscar and Kootenay formations of the Inner Foothills Belt are generally abnormally low in sulphur contents. The ash levels occurring in coals of the Luscar formation are generally lower in content and more amenable to cleaning than those of the Kootenay formation. Adit samples tested from seams in the northern regions of the Luscar formation have analysed four per cent ash in the raw state, and indications are that low ash levels are economically feasible from this area of western Canada. The caking and coking properties of samples from both formations has varied over a wide range. Cokes with extremely high strength values have been obtained from specific samples carbonized individually and in standard blends.

The low volatile coals from the Crowsnest Area do not exhibit excessive expanding pressures when carbonized individually indicating that higher proportions can be tolerated in coal blends than their Appalachian counterparts with accruing higher fixed carbon yields and possibly higher coke strength properties. Reduction of the ash contents to levels below their present export specifications will however increase their expanding properties.

Crushing certain Canadian coals to sizes smaller than normal practise and thereby distributing the coal caking constituents and mineral inerts more evenly in the blend matrix has improved the coke quality as demonstrated in coal slurry studies on pipeline transportation.

Intended research investigations on innovations to the conventional method of cokemaking and studies on formed coke may expand their potentials in the field of carbonization.

The low and medium volatile coals currently being exported to Japan under contract, have demonstrated their successful use for cokemaking in proportions up to 45 per cent in blends with other coals. With the recent economic changes in coal availability, market expansions are foreseeable. For example the Canadian steel industry which has used Appalachian coals almost exclusively for the manufacture of blast furnace coke, has expressed an interest in the use of western Canadian coals at their respective coke plants. Trial shipments have been carbonized in blends composed of their traditional coal sources with reported satisfactory results. Coal shipments to countries other than Japan have been made on a modest scale and it is anticipated that these new market areas will expand.

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TABLE 1

BITUMINOUS COAL RESOURCES OF WESTERN CANADA BY RANK

(THOUSANDS OF SHORT TONS)

	MEASURED	INDICATED	INFERRED	TOTAL
LOW AND MEDIUM VOLATILE BITUMINOUS				
ALBERTA	982,100	19,620,200	7,366,500	27,968,800
BRITISH COLUMBIA	6,943,000	10,775,000	40,480,100	58,198,100
RANK TOTAL	7,925,100	30,395,200	47,846,600	86,166,900
HIGH VOLATILE BITUMINOUS				
ALBERTA	NA*	6,278,600	3,043,700	9,322,300
BRITISH COLUMBIA	45,600	100,400	172,900	318,900
RANK TOTAL	45,600	6,379,000	3,216,600	9,641,200

*NA - NIL OR NOT AVAILABLE

TABLE 2

EXPORT CONTRACTS*-WESTERN CANADIAN COALS

Company	Annual Shipments (millions of long tons)	Term	Coal Quality Specifications					
			Total Moist (%)	Ash (%)	Vol. Matter (%)	Total Sulphur (%)	FSI	Size (in)
McIntyre Porcupine Mines Ltd.	2.0	1970-84	6.0	7.0	17.5	0.5	7/9	1 1/2" max
Cardinal River Coals Ltd.	1.0	1970-84	6.0	8.5	24/26	0.37	5/7	1 1/2" max
The Canmore Mines Ltd.	0.15	1968-77	6.0	9.0	16/17	0.6	6/8	
Coleman Collieries Ltd.	1.5	1967-82	5.0	9.5	20/23	0.6	6	2" max
Fording Coal Ltd.	3.0	1972-86	6.0	8.0	21/24	0.45	5/7	1 1/2" max
Kaiser Resources Ltd.	4.4	1970-84	6.0	9.5	19/22	0.4	6/8	90% -1/2"

*As of February 15, 1973

TABLE 3
SPECIFICATIONS FOR GOOD BLAST FURNACE COKE

ANALYSIS	LIMITS
Ash, %	$\leq$ 8.0
Volatile Matter, %	$\leq$ 1.0
Sulphur, %	$\leq$ 0.70
Alkali Oxide in Coke, %	$\leq$ 0.20
Phosphorous Pentoxide in Coke, %	$\leq$ 0.27
Stability Factor (ASTM)	$\geq$ 55

TABLE 4
TYPICAL PROPERTIES OF COAL BLEND
TO PRODUCE GOOD QUALITY
COKE

		LIMITS
GRADE		
Ash	%	< 6.0
Volatile Matter	%	28-31
Sulphur	%	≤ 0.8
Phosphorus	%	≤ 0.09
Alkalis	%	≤ 0.19
Mean Reflectance	R_o	1.10 to 1.25
CAKING PROPERTIES		
Free Swelling Index	FSI	> 6
Plasticity (Gieseler)	DD/M	60 to 1000
Dilatation (Ruhr)	%	50 to 140
COKING PROPERTIES		
Stability Factor (ASTM)		≥ 55
OPERATIONAL PROPERTIES		
Max. Wall Pressure	PSI	< 2.0
Expansion/Contration	%	-6

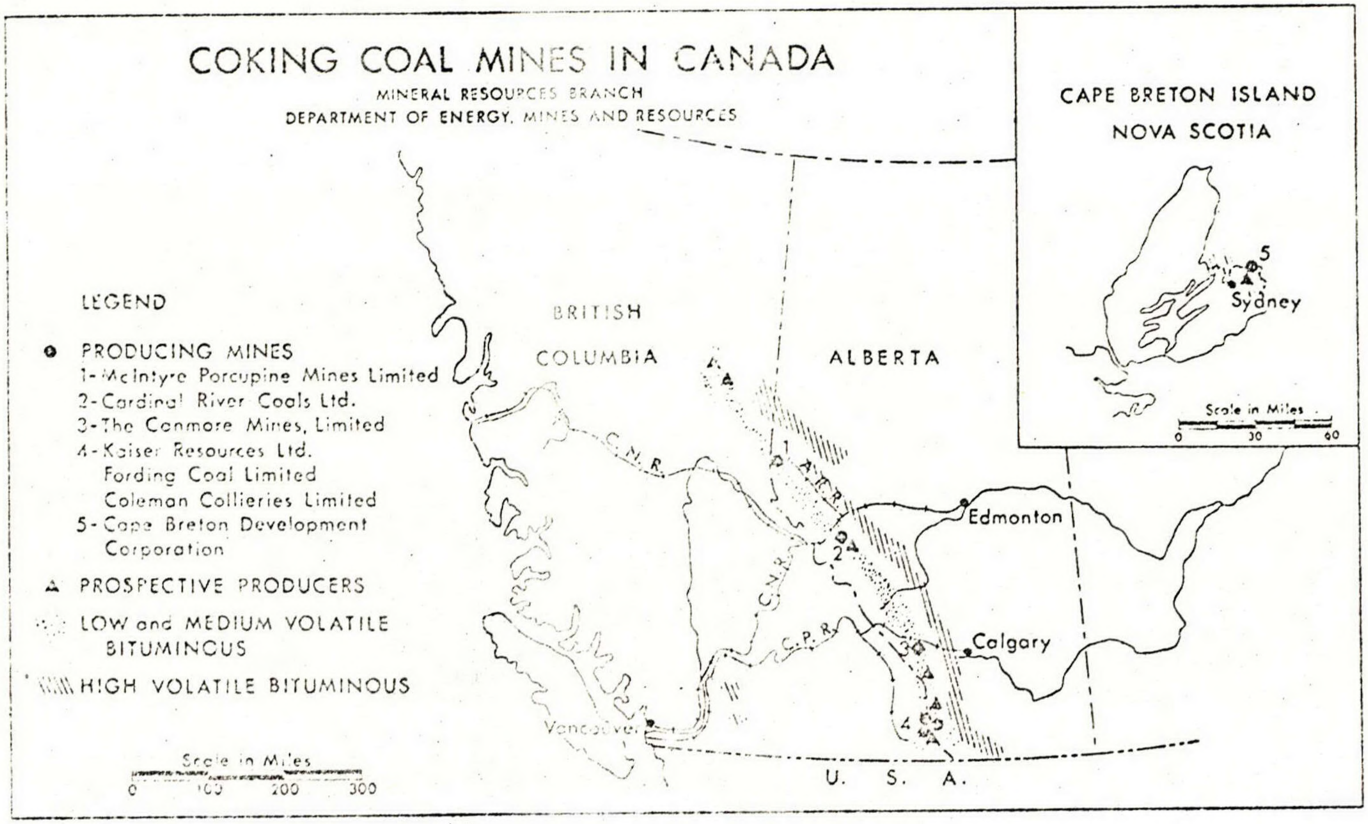

Figure 1. Coking Coal Mines in Canada

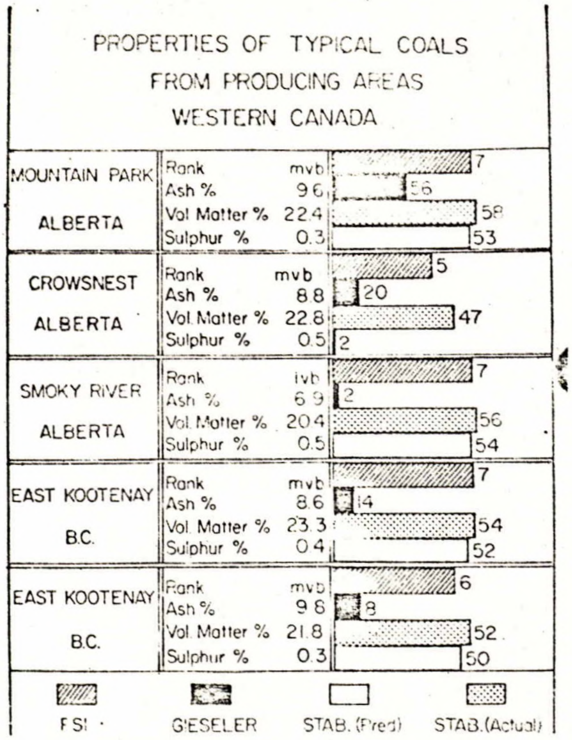

Figure 2

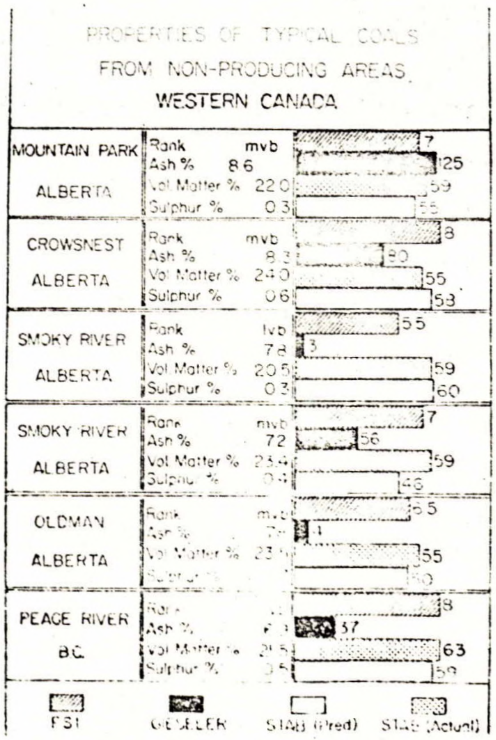

Figure 3