M.M. Papic, I.H. Warren, R.M. Woodley

HAT CREEK COAL UTILIZATION

ABSTRACT

The location and extent of the Hat Creek coal deposits are outlined. The presently mineable amounts of coal are estimated and the potential economic significance of the deposits indicated.

The properties of the coal are described and its suitability for various alternate uses discussed. The possible uses of the coal for direct combustion in electricity generation and in alternate uses such as gasification are reviewed.

The economics and markets for the products of possible alternate use processes which have been examined are outlined.

INTRODUCTION

This paper discusses the prospects for utilization of coal from the unique Hat Creek deposits in British Columbia. The deposits have been under intensive studies by the licensor of the property, British Columbia Hydro and Power Authority (B.C. Hydro), since 1974. The aim of the studies has been to establish the geology and magnitude of the deposits, to investigate the mining potential of the coal, to determine the coal properties, and to identify the optimal use of the resource from the social, economic and ecological points of view. The geology, magnitude and mining potential of the deposits will be briefly outlined first. The properties and potential alternate uses of the coal will then be discussed.

GEOGRAPHY OF THE HAT CREEK COAL DEPOSITS

The coal deposits are located in the Upper Hat Creek Valley in south central British Columbia 200 km (120 mi) northeast of Vancouver, $50^{\circ}45'$N, $121^{\circ}35'$W (Figure 1). The Valley has a north-south orientation and lies between the Trachyte and Cornwall Hills with peaks of 1500-1800 m (5000-6000 ft) on the east and the Clear Range with peaks of 1800-2100 m (6000-7000 ft) on the west (Figure 2). It is approximately 25 km (15 mi) long and 5-6 km (3-4 mi) wide. The floor of the Valley has an elevation of about 850 m (2800 ft) at the north end and about 1220 m (4000 ft) at the south end (1).

The climate in Upper Hat Creek Valley is moderate with mean daily temperatures of 29°C in summer and -12°C in winter. The period from May to September is usually frost-free. Precipitation averages about 380 mm per year, including about 120 cm of snow.

The Upper Hat Creek Valley is close to the road and railway transportation routes, electrical transmission network, and oil and gas pipelines. Potential water supply exists either from the Thompson or from the Fraser River (2).

GEOLOGY AND MAGNITUDE OF THE DEPOSITS

Information to date indicates the presence of two coal deposits of similar magnitude having similar geological and geotechnical environment.

In terms of geological age the Hat Creek coal deposits are relatively young (40-60 million years) occurring within folded and faulted Tertiary (Eocene) strata of the Coldwater ~~Group~~ Beds (3). The coal is covered with overburden consisting of till and glacial outwash deposits containing much clay material ranging up to 120 m (400 ft) in depth.

The coal layer ranges in true thickness from 300 to 550 m (1000-1800 ft) of which approximately 30 percent is made up of interbedded waste rock. The cross section of the coal layer at the north end of the Valley is shown in Figure 3 which indicates four zones of coal. The longitudinal section of the layer is shown in Figure 4 (3).

The preliminary coal quantity estimates for the Upper Hat Creek deposits are (Table 1):

Table 1

Resources and Reserves of the Hat Creek Coal Deposits

	Resources: Based on Geological Evidence 10^6 tons	Reserves: Proven-Probable 10^6 tons	Reserves: Possible 10^6 tons	Waste/Coal @ 25° Slopes
No. 1 Deposit	3,000	925	100	2.6
No. 2 Deposit	7,000	1,000	1,000	3-4
TOTAL	10,000	1,925	1,100	

The Upper Hat Creek coal deposits thus represent the largest coal resources in such a small area, about 65 km^2 (25 sq mi), in the world. The main coal layer is also the thickest known in the world (3).

The amount of coal mineable from the No. 1 pit has been estimated at two levels depending on the depth of pit considered. With a 182 m (600 ft) pit it is considered that 450 million tons of coal (in-situ) (proved, probable and possible) will be available. With an extension of the pit depth to 457 m (1500 ft) the total mineable reserves would become 910 million tons of coal.

The extent of coal reserves that would be available in Openpit No. 2 has been conjectured to be 664 million tons with development to the 182 m (600 ft) level. It has been estimated that a 457 m (1500 ft) pit would provide 3,397 million tons run of mine coal (4).

In both pits, but particularly Openpit No. 2, it can be seen that considerable coal reserves exist beyond the 182 m (600 ft) level proposed for initial exploitation. Present indications are that these reserves may not be economically mineable by surface mines, however, and that underground mining would be extremely difficult and also uneconomic at current price levels.

The potential of the Hat Creek coal deposits can be illustrated by assuming the consumption of about 12 million tons of coal per year by a 2000 MW power station or by an SNG plant of 7 x 10^6 Nm^3/d (250 x 10^6 scf/d) capacity. Such depletion rate would exhaust the No. 1 deposit mined to 182 m (600 ft) pit in about 35 years and No. 2 deposit in about 55 years.

PROPERTIES OF HAT CREEK COAL

Hat Creek coal is a low rank, low grade coal with highly variable physical and chemical properties. Nonetheless, it is possible to obtain mean analysis values of sufficient accuracy for process applications, Table 2 (5).

Equilibrium moisture content is about 23 percent and this is believed to approximate that of the coal in-situ. The moisture content is typical of sub-bituminous coals and is less than that of North American lignites (30-40 percent) and European brown coal (50-70 percent) (5). Hat Creek coal air dries to 10-12 percent moisture content accompanied by some break-up.

The ash content of the raw Hat Creek coal is high and varies widely. The mean ash content is about 32 percent which brings the total inerts content to about 55 percent.

The observed ash contents are less than the mineral matter actually present principally because of carbonates and a high content of water of hydration in the associated clay minerals (6). The ratio of mineral matter to ash determined from graphs of coal heating value vs. ash content is 1.218, considerably higher than the 1.08 assumed in the Parr formulae, Table 2.

Table 2

Proximate and Ultimate Analysis of Hat Creek Coal

Basis		AR	Dry	DAF	DMMF	MMMF
Proximate:						
Moisture	%	22.5 (M)				22.5
Ash	%	32.5 (A)	41.9			
Volatile Matter	%	23.8 (V)	30.7	52.9	49.9(V')	39.6
Fixed Carbon	%	21.2 (F)	27.4	47.1	50.1(F')	37.9
		100.0	100.0	100.0	100.0	100.0
HHV	kJ/kg	11570	14920		23000	17820
	Btu/lb	4970 (Q)	6410		9880	7655(Q')
Ultimate:						
Carbon		30.8	39.8	68.6		
Hydrogen		2.4	3.1	5.3		
Oxygen		10.6	13.7	23.6		
Nitrogen		0.8	1.0	1.7		
Sulphur		0.4 (S)	0.5	0.8		
Chlorine		0.1				

Table 2 (Cont'd)

Parr Formulae:

$$F' = \frac{100(F - 0.15S)}{100 - (M+1.08A+0.55S)}$$

$$V' = 100 - F'$$

$$Q' = \frac{100\ (Q - 50S)}{100 - (1.08A+0.55S)}$$

AR = as received
DAF = dry, ash free
DMMF = dry, mineral matter free
MMMF = moist, mineral matter free

Volatile matter and fixed carbon were determined as 23.8 percent and 21.2 percent respectively, giving a low fuel ratio (F.C./V.M.) at 0.89. It has been suggested that total volatile matter as determined in the laboratory contains also the water of hydration of the associated clay minerals, thus giving too high values for volatile matter and too low fuel ratio (6). If a mineral matter/ash ratio of 1.218 is applied in a Parr formula, the corrected fuel ratio has a value of 1.29 in which the noncombustible volatile matter accounts for 24 percent of the total volatile matter (6).

The observed discrepancies indicate difficulties in obtaining consistent proximate analyses which may result either from the nature of the associated minerals or from the variability of the coal substance itself. The latter observation points out the borderline lignite/sub-bituminous character of the coal (5).

The reported heating value of as received coal is 11570 kJ/kg (4970 Btu/lb) which gives the heating value on a moist, mineral matter free basis of 17820 kJ/kg (7655 Btu/lb).

The relationship between heating value and the ash content is given by the linear equation:

$$Q = 30459 - 370.96A \text{ kJ/kg}$$
$$Q = 13085 - 159.36A \text{ Btu/lb)}$$

where Q and A are heating value and ash content on the dry basis respectively (6). For Q = 0 (100% inert) A = 82.11% of the mineral matter present in coal, giving the mineral matter/ash ratio 1.218. From the above relationship the heating value on dry, mineral matter free basis is 30459 kJ/kg (13085 Btu/lb) and on moist, mineral matter free basis 23612 kJ/kg (10143 Btu/lb). Parr formula with mineral matter/ash ratio of 1.218 on the other hand gives heating value on moist, mineral matter free basis of 19141 kJ/kg (8223 Btu/lb).

Ultimate analysis shown in Table 2 shows carbon content of DAF coal 69 percent, which is less than that generally reported for lignites and sub-bituminous coals (73-83 percent). The carbon deficiency is attributed to the effect of the high oxygen content (5).

The hydrogen content appears to be normal at about 5 percent of DAF coal.

The oxygen content of about 24 percent on DAF basis is very high. It is determined as a "difference" and may be the result of cumulative errors in other determinations.

The nitrogen content of about 2 percent on DAF basis is normal.

The sulphur content of Hat Creek coal is less than 1 percent on DAF basis. Taking the heating value of dry coal 14920 kJ/kg (6410 Btu/lb) and assuming that all sulphur is converted to SO_2, the corresponding weight of sulphur dioxide is approximately 0.67 kg/GJ (1.56 lb. per million Btu). The analytical data indicate that about 70 percent of sulphur in coal is organic in nature, about 25 percent is pyritic and about 5 percent sulphate sulphur.

The chlorine content of Hat Creek coal is generally less than 0.1 percent and is expected to cause no fouling or corrosion problems.

Petrographic analysis of one sample of Hat Creek coal is shown in Table 3 (5).

Table 3

Petrographic Analysis of Hat Creek Coal

Maceral Group & Mineral Composition	Maceral Sub-Group	% Volume
Huminite	Humotelinite/ Humocollinite	83.0
Exinite	Sporinite	0.4
	Resinite	2.4
Inertinite	Mainly Sclerotinite	0.6
Clays		13.4
Pyrites		0.2

Mean maximum reflectance of Huminite at 546 nm in oil of r.i. 1.518 is 0.34 which is low when compared with values for sub-bituminous coals ranging between 0.5-0.8, and points toward low rank, lignite composition.

The clays present consist of about two-thirds strongly swelling and gelling minerals montmorillonite ($\sim$ 10%) and kaolinite ($\sim$55%). The stickiness of these impurities may cause difficulties in coal handling and beneficiation.

The ash composition and fusion temperatures are given in Table 4.

Table 4

Hat Creek Coal Ash Composition and Fusion Temperature

SiO_2	48-55%
Al_2O_3	27-33%
Fe_2O_3	5-8%
MgO	~1%
CaO	2-5%
Na_2O	~1%
K_2O	~0.5%
TiO_2	~1%
P_2O_5	~0.2%
SO_3	1-3%

Ash fusion (Oxidizing Atmosphere): 1400-1500°C

The ash is high in silica and alumina, low in alkali oxides with consequent low basicity ratio and high fusion temperatures.

The results of Fischer carbonization assay and various coking tests are shown in Table 5.

Table 5

Fischer Carbonization Assay and Coking Properties of Hat Creek Coal

	AR	Dry	DAF	MMMF
Gas Liquor %	25.0	3.2	5.6	26.8
Tar %	3.1	3.9	6.8	5.3
Gas %	4.5	5.8	9.9	7.7
Char %	67.4	87.1	77.7	60.2

Gieseler Plastometer	non-fluid
Free Swelling Index	0
Gray-King Coke Type	A
Ruhr Dilatometer	
max. expansion	Nil
contraction at 500°C	10%

Hat Creek coal possesses no caking or coking properties and has very low tar yield. The ash content of char is almost 50 percent which makes it unsuitable for briquetting and formed coke process.

The information on the yield and composition of gas produced by devolatilization of the coal under pressure and on the reactivity of the resulting char towards carbon dioxide is provided by the Pressure Reick Degasification test and Pressure CO_2 - reactivity test (Boudouard Reaction) presented in Table 6 (7).

Table 6

Pressure Reick Degassing and
CO_2 - Reactivity of Hat Creek Coal

Pressure Degassing:

Gas yield	0.119 Nm^3/kg	@	690°C
Residue	64.6%		
Moisture input	10.0%		
Gas Composition (N_2-free)			
CO_2	33.7%V		
CO	5.5%V		
H_2	17.1%V		
CH_4	39.5%V		
CnHm	4.2%V		
Density	1.102 kg/Nm^3		
HHV	22050 kJ/Nm^3		($\sim$ 600 Btu/scf)
LHV	19850 kJ/Nm^3		($\sim$ 530 Btu/scf)

Pressure Reactivity:

Input char	18.05 g		
CO_2 - conversion	6.67%V		
CO yield	12.5%V		
Reactivity	0.044 Nml CO/g sec	@	800°C

Interpretation of the results in respect to the coal gasification is empirical and dependent on previous experience. In Lurgi's opinion, Hat Creek coal is suitable for gasification.

A combustion profile of Hat Creek coal determined by the differential thermo-gravimetric analysis is illustrated in Figure 5 together with that for Pennsylvania anthracite. The analysis indiates: complete drying before onset of decomposition with ignition; low temperatures of ignition; and lower rates of burnout than generally measured for bituminous coals and anthracites.

Pilot combustion tests with pulverized fuel indicate good burning characteristics (8).

The type or rank of Hat Creek coal is determined by its heating value on moist, mineral-matter free basis (17800 kJ/kg, 7670 Btu/lb) moisture content on ash-free basis (33%), tar yield on dry, ash-free basis (7%), volatile matter on dry, mineral-matter free basis (50%) and caking properties (nonaglomerating).

By the International Classification System Hat Creek coal can be classified as soft or brown coal ($\angle$ 23800 kJ/kg), class 12 (30-40 percent moisture), group 00 ($\angle$ 10 percent tar), i.e. code number 1200.

By the ASTM Classification System it could be ranked as lignite A (6300-8300 Btu/lb, 14620-19260 kJ/kg) with nonaglomerating properties, i.e. lignite A (50-770).

The lignitic character of the Hat Creek coal is also supported by the low mean reflectance value of 0.34 (5).

POTENTIAL UTILIZATION OF HAT CREEK COAL

Comments have been made about the low rank and grade of Hat Creek coal and its possible utilization. In support of the utilization of Hat Creek coal two observations are of significance: the cost of Hat Creek coal at which it can be made available for use in energy form is about 50¢/GJ, and coals of even lower rank and grade have found economic use in other parts of the world, Figure 6 (9).

B.C. Hydro commissioned a study to identify and evaluate major uses of Hat Creek coal. The study has been performed by Stone & Webster (Canada) Ltd. and has considered the technical feasibility, economics and marketing of the following products for the period 1980-2010:

(a) Principally solid products

for direct sales
for combustion for process heat generation
for combustion for thermal-electric generation
from carbonization and recovery of coal chemicals
from delayed coking of coal tar pitch
from form coking
from solvent refining
from carbon activation
from direct conversion (fertilizers)

(b) Principally liquid products

from pyrolysis
from solution and hydrogenation of coal and tar
from synthesis gas

(c) Principally gaseous products

from coal gasification

Preliminary results of the present studies indicate that the potential for sale of Hat Creek coal is low due to high transportation costs ($\sim$ 1¢/t km) (10), high ash content, and availability of better quality thermal coal.

Combustion for process heat generation is technically and economically feasible but there is no suitable market in the area.

The production of upgraded solid products from Hat Creek coal, such as char and activated carbon, is not technically feasible because of the very high inherent ash content. The high ash content and the complete absence of coking properties also render production of metallurgical coke or formed coke technically infeasible. Again, high ash plus high oxygen content makes solvent refining technically infeasible. Direct conversion of Hat Creek coal to nitrogenated and ammoniated product is technically impractical and economically unattractive.

High ash, moisture and oxygen content, and low tar yield make production of coal liquids from Hat Creek coal by pyrolysis and solution/hydrogenation technically impractical and economically unattractive.

The production of synthesis gas and liquid hydrocarbons from it is technically feasible and a range of products is capable of being fully marketed. The economics seem unattractive at present and depend upon the future price of naturally derived products.

Methanol from synthesis gas while technically feasible and economically acceptable (~ $3.50/GJ) faces an uncertain market situation. Currently, the annual world demand for methanol is about 8 million tons (5) but any alteration in present usages, such as gasoline additive, would vastly increase world demand. On the other hand, the open market would be greatly reduced should Middle East flare gas be converted in large quantities to methanol. Thus, for methanol there is a large potential but no assured market (5).

The use of Hat Creek coal as a chemical feedstock for production of benzenes and phenols as major products (~ 400,000 tons/year) would encounter very difficult market situation. Only as a by-product, (~ 45,000 tons), e.g. from an SNG plant, could these chemicals find a market.

The production of ammonia and nitrogen fertilizers while technically feasible and economically attractive, faces a very unsatisfactory world market situation in which ample capacity into the 1990's seems a certainty (5). Production of a million tons per year of ammonia, for example, from 3 million tons of Hat Creek coal would double current Canadian production of ammonia and surpass Canadian total consumption of 600,000 tons per year by 1980.

SNG could not successfully compete with natural sources on the market today but in the future the production of SNG (7×10^6 Nm^3/d, 250×10^6 scf/d) from Hat Creek coal seems technically and economically feasible, and market for the product and by-products seems good. The economic estimates based on selling price of SNG of $3/GJ would allow the price of feedstock coal to be about $10/ton, which compares favourably with the estimated mining cost of Hat Creek coal of about $8/ton in 1981.

The generation of electricity (2000 MW) using Hat Creek coal in conventional pulverized fuel boilers seems technically feasible and economically attractive. The economic analysis based on a selling price of electricity of 2.9¢/kWh ($8/GWS) in 1981 (2¢/kWh in 1976) would allow the price of feedstock coal to be about $19/ton. This compares favourably with the mining cost of Hat Creek coal of $8/ton and opportunity cost of coal in SNG production of $10/ton in 1981. It is thus evident that electricity generation from the Hat Creek coal is economically attractive and a viable alternative to the other uses considered, including gasification.

Figure 7 illustrates the products obtainable from coal and mutual relationship between various processes. It should be noted that the uses indicated above are not necessarily mutually exclusive and the construction of a thermal generating plant - far from excluding alternate uses - could well provide the catalyst for their development should the economic climate become favourable.

REFERENCES

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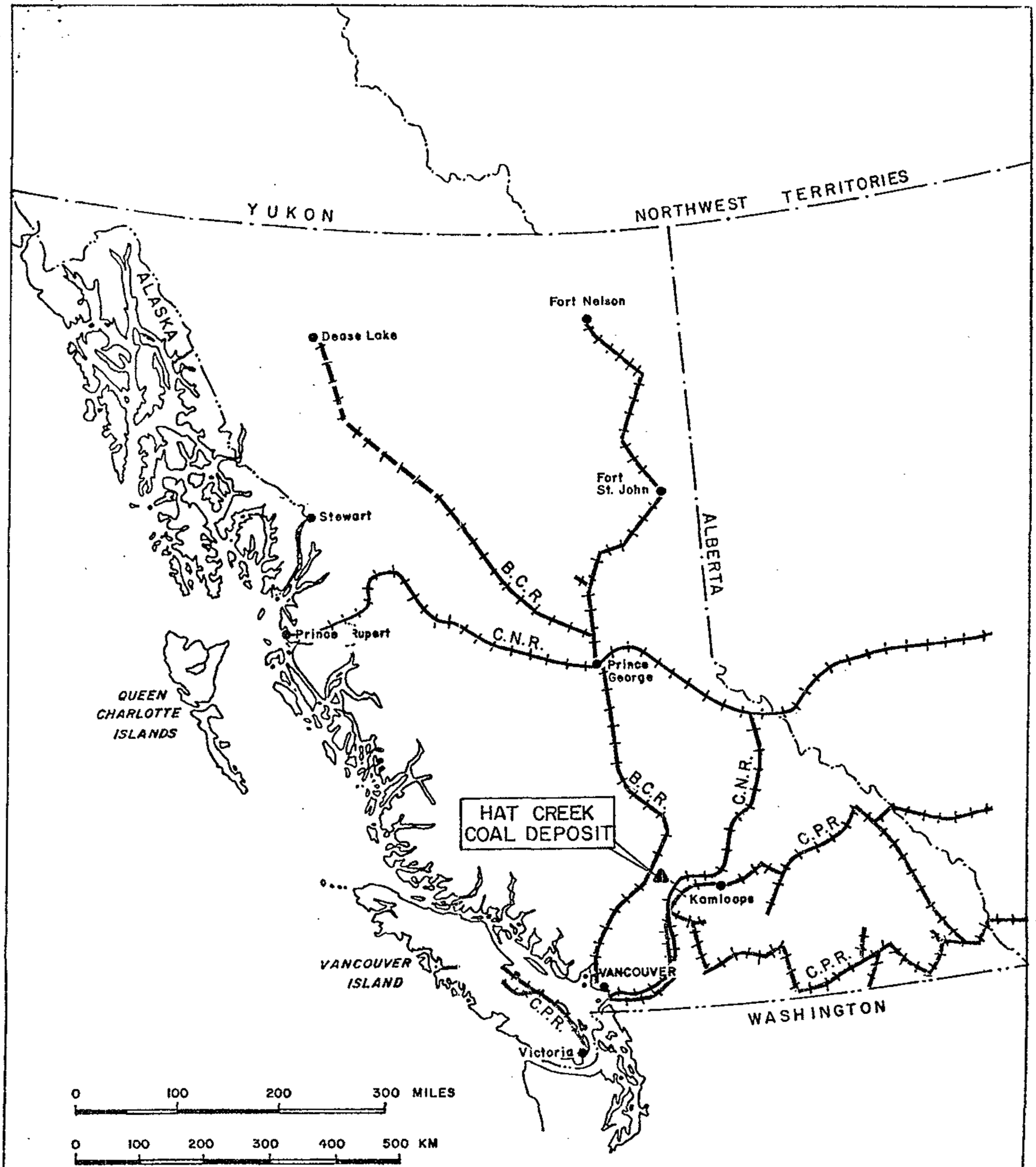

FIGURE I

LOCATION OF HAT CREEK COAL DEPOSIT

FIGURE 2

THOMPSON PLATEAU WITH UPPER HAT CREEK VALLEY

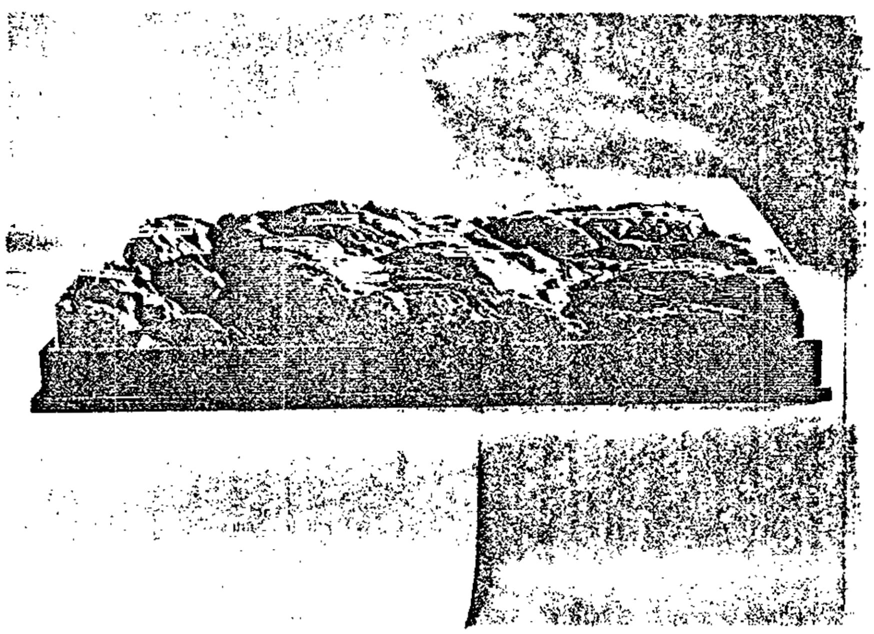

FIGURE 3

HAT CREEK COAL
No. 1 DEPOSIT
CROSS-SECTION 78,000 N

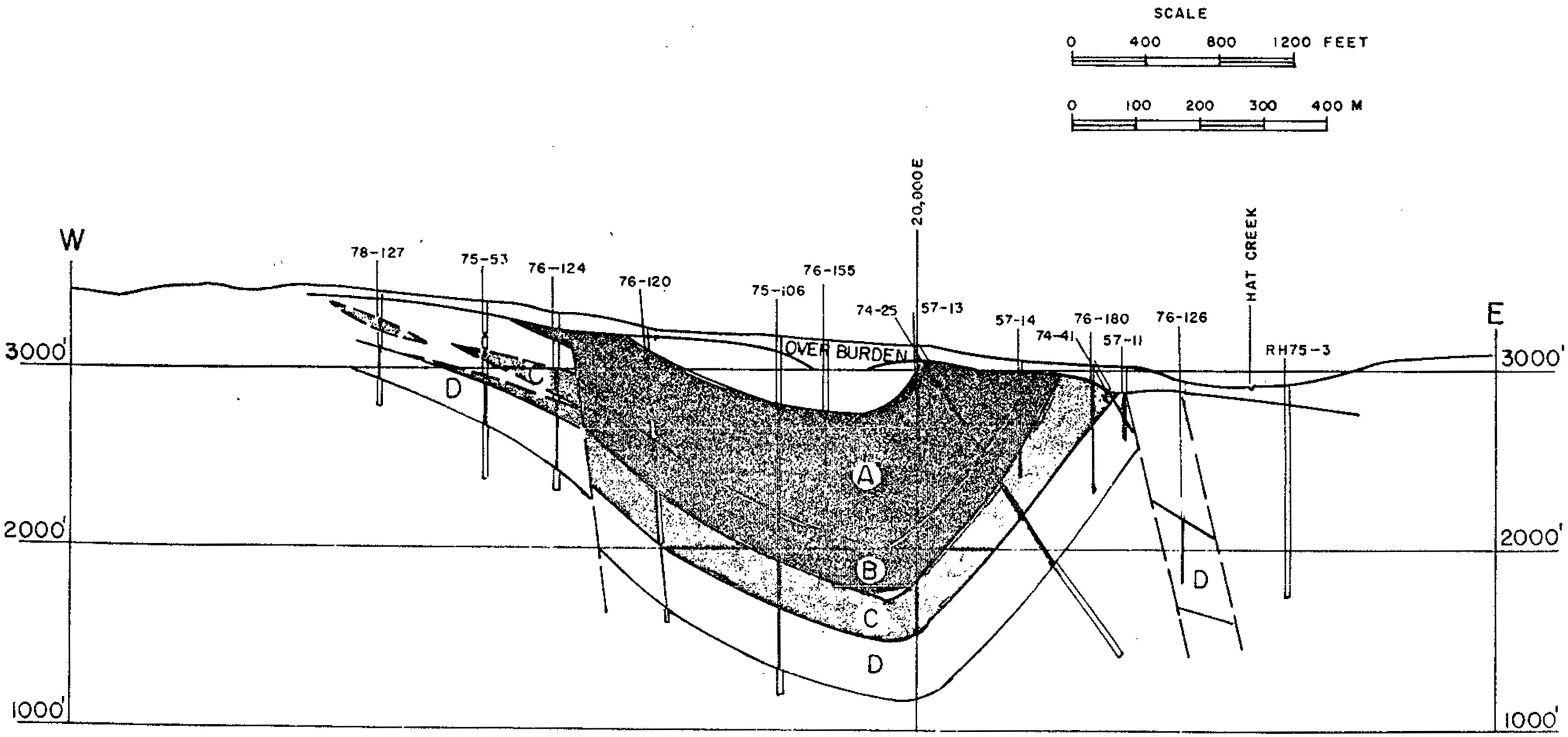

FIGURE 4

HAT CREEK COAL

No. 1 DEPOSIT

LONGITUDINAL (N-S) SECTION

19,500 E

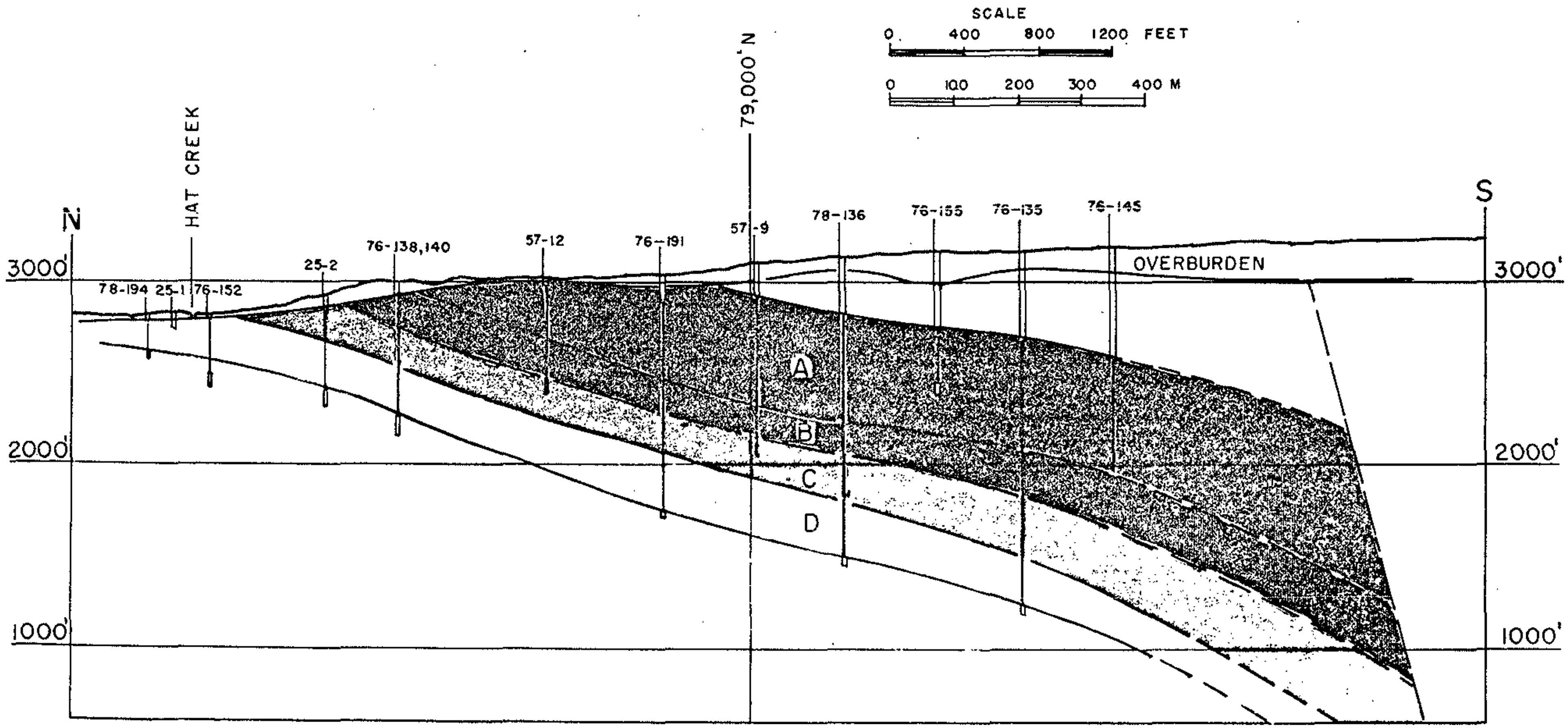

FIGURE 5

BURNING PROFILES OF HAT CREEK RAW COAL COMPARED WITH A PENNSYLVANIA ANTHRACITE

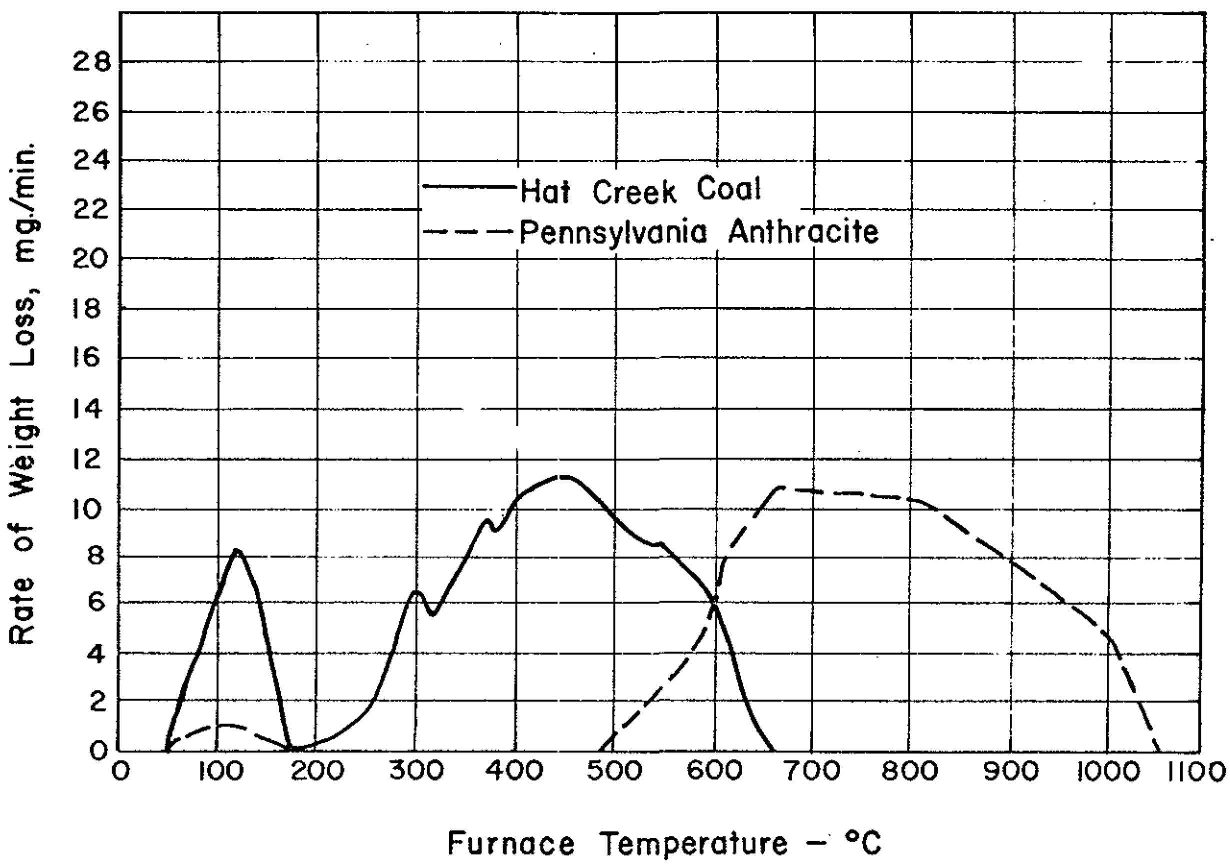

FIGURE 6

RANGE OF PROPERTIES OF LOW RANK, LOW GRADE COALS USED IN THE WORLD WITH HAT CREEK VALUES SUPERIMPOSED