604H - M21
Box 16092

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PETROGRAPHIC STUDIES OF HAT CREEK COALS

B.N. NANDI AND T.D. BROWN

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AN INTERIM REPORT

PETROGRAPHIC STUDIES OF HAT CREEK COALS FOR COMBUSTION

by

B.N. Nandi* and T.D. Brown**

ABSTRACT

Petrographic analysis of Hat Creek coal and the fly-ash from pilot-scale combustion studies have shown that one of the coals (designated Sample A) is significantly different from the other two in its maceral composition. This coal (A), which contains an extremely high ash content (75%) contains also a preponderance of the reactive vitrinite maceral. The vitrinite maceral in the other two coals, which had lower ash contents, consisted of almost equal proportions of the reactive vitrinite maceral and the unreactive oxidized vitrinite maceral.

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* *Research Scientist, Coal Resource and Processing Laboratory, and ** Research Scientist, Canadian Combustion Research Laboratory, Energy Research Laboratories, Canada Centre for Mineral and Energy Technology, Department of Energy, Mines and Resources, Ottawa, Canada.*

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INTRODUCTION

The petrographic studies described in this interim report were undertaken in support of the combustion trials being carried out by the Canadian Combustion Research Laboratory (CCRL). These combustion trials had the objective of providing research data which could be used in defining some of the fuel handling and combustion system parameters to be incorporated in the design of the projected 5000 MWe power station using the Hat Creek coal resource.

Analytical and petrographic studies were carried out on three samples of Hat Creek coal designated A, B and C (this identification nomenclature followed that adopted by CCRL), and this report is the first of two petrographic reports. A few microphotographs of macerals have been included in this first report; more detailed microphotographs will be incorporated in the final report which will be available later in 1977.

Classification of Hat Creek Coals

The proximate, ultimate and calorific analyses of the three coals is given in Table 1. This data was used, according to ASTM Specification D388, to classify the coals. Samples, A, B and C were classed as sub-bituminous C, B and C, respectively.

Owing to the complex character of the structure of the sub-bituminous coal macerals, these three samples were forwarded to Dr. M.Th. Mackowsky (President, International Committee for Coal Petrology) of Bergbau-Forschung, Essen, West Germany, for her comments on the nomenclature of the macerals present in these coals. A preliminary report on these three coals was obtained from her. Dr. Mackowsky suggested that a system of the nomenclature of sub-bituminous coal would be discussed at the next ICCP meeting at Liege April 27-30, 1977.

Maceral Composition of the Hat Creek Coals

Maceral analyses were carried out according to ASTM Specification D2696 for bituminous coals. It must be emphasized that the use of the nomenclature represents an extension of terminology from the well documented field of bituminous coals into the relatively uninvestigated petrography of western Canadian sub-bituminous coals. The maceral counts recorded in two different laboratories are presented in Table 2.

It is clear that all the coals contained massive quantities of mineral matter; a more realistic comparison of the maceral counts is achieved when they are calculated on a mineral matter free basis as in Table 3.

The material classified as vitrinite by both laboratories was not homogeneous in any of the coal samples; it contained a multiplicity of differently structured components showing remnants of the parent plant materials (Figure 1). These materials were identified (tentatively) as "Tellinite-like" (Fig. 2). Many of these macerals consisted of resinite structure (a low-medium reflectance material)(Figure 3), interspersed between lamellations of a high reflectance vitrinite. All the coals were characterised by the absence of significant amounts of well developed inert macerals, fusinite and semi-fusinite. The maceral count shows unusually low exinite macerals (Figure 4) for this rank of coal where typical values lie in the range of 6-10%.

Behaviour of Coals on Heating

Vitrinite, on heating to 550°C in a Ruhr dilatometer at a rate of 3°C/min, normally undergoes a major structural and compositional change. The changes are evidenced in the dilatometer as an initial contraction as the vitrinite becomes plastic and in subsequent expansion as the bulk of the sample devolatilises to produce the semi-coke. This expansion may restore the sample volume to its original (or a higher) level. The results of the dilatation test is given in Table 6 .

This characteristic contraction due to the plasticity of vitrinite was totally absent in all of the Hat Creek coals. No dilatation was recorded.

Changes did occur however. The structures which were visible in the vitrinite of all three coals disappeared and all samples retained this structurally modified vitrinite with small amounts of fusinite and semi-fusinite (Figures 5 and 6). The bituminous coal maceral which exhibits this type of behaviour is oxidized vitrinite and is known to be an unreactive coal component in combustion systems.

Maceral analyses on the samples of the heat treated coals were carried out and the results of the maceral count were used in conjunction with the results of the raw coal maceral counts to calculate the extent of the oxidized vitrinite in each of the raw coal samples. The results of this calculation are shown in Table 5. It can be seen that the vitrinite macerals identified in the A coal consisted dominantly of the reactive vitrinite component with less than 25% in the unreactive oxidized vitrinite component. This disposition of the vitrinite maceral progressively reversed with the B and C coals. The C coal contained the highest proportion of the unreactive vitrinite component as well as being the only sample in which other unreactive components (fusinite and semi-fusinite) were identified.

Examination of the Combustion Residue

Samples of the fly-ash produced during combustion trials of the Hat Creek coals at the Canadian Combustion Research Laboratory were also examined.

The fly ash from the A coal was dominated by the mineral matter which was observed to exist largely in a series of hollow spheres (Fig. 7). The chief carbonaceous remnants were partially reacted vitrinite with a sparse population of oxidized vitrinite (Figure 8).

The fly ash from the B and C coals was significantly different in that (a) the mineral matter was dominant but did not appear to exist in such well defined spheres (Figure 9) and (b) the chief carbonacous remnants was a filamented structure that was reminiscent of the lamellations of high reflectance material identified in the raw coals (Figure 10).

It appeared that the resinous material interspersed between these structures had partially disappeared during combustion leaving the high reflectance lamellae as a residue which had not burnt out (Figure 11). The large size of the filamented structures observed in the fly ashes from the

B and C coals was attributed to the known increase in particle size that had occurred in the pulverised coal combustion trials.

Retrospect

The low exinite content of the coal, the thermal behaviour of the macerals identified as vitrinite, the behaviour of the resinitic material and the presence of some high reflectance vitrinite together indicate that the coal has been subjected to significant thermal action during formation. This opinion should be consolidated by further experimental investigation.

It appears that the A sample is significantly different to the B and C samples in its maceral composition in that it consists largely of the reactive vitrinite maceral, whereas the B and C coals contain almost equal quantities of both reactive and oxidized vitrinite. The implication is that, despite its high ash content, this coal should give a stable flame with a satisfactory burn-out. The extent of burn-out will be modified because of the massive thermal load imposed by the high ash content of the coal.

The beneficial effects of coal washing on the combustion performance of this coal will be marked provided that the ash is to some extent discrete rather than occluded in the coal substance.

The B and C coals do not contain the same amount of reactive vitrinite, equally they do not contain the same high ash content and these two factors, which would have opposed effects on flame stability and burn-out, may cancel each other. It is unlikely that the effect of coal washing on the combustion characteristics of these two coals will be as dramatic as that anticipated for the A coal.

ACKNOWLEDGEMENT

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TABLE 1

Proximate and Ultimate Analyses of Three Hat Creek Coal Samples

		Sample A	Sample B	Sample C
Proximate Analysis				
Air-dried Moisture	%	15.64	13.53	18.99
Ash	%	44.51	29.94	20.57
Volatile Matter	%	22.16	30.55	31.34
Fixed Carbon	%	17.69	25.98	29.10
Ultimate Analysis				
Carbon		35.88	39.02	42.35
Hydrogen		2.23	3.07	3.20
Sulphur		0.80	1.04	0.58
Nitrogen		0.54	0.82	0.93
Ash		44.51	29.94	20.57
Oxygen		10.51	12.58	13.38
Calorific Value (Gross)				
Cal/gm		2355	3601	4006
Btu/lb		4239	6482	7211
Classification		Sub-bituminous C	Sub-bituminous B	Sub-bituminous C

TABLE 2

Maceral Composition of the Hat Creek Coal Samples

Maceral, vol %	Laboratory A	Laboratory B
	Sample A	
Vitrinite	36.0	38
Structured vitrinite		17
Exinite	0.8	3
Resinite & telinite		3
Micrinite	1.2	
Semi-fusinite	0.4	
Pyrite	0.4	
Fusinite		
Mineral matter	61.2	39
Mean max reflectance, Ro	0.38	0.46
	Sample B	
Vitrinite	27.6	27
Structured vitrinite		23
Exinite		2
Resinite & telinite		3
Micrinite		3
Semi-fusinite	0.4	2
Pyrite		
Fusinite		
Mineral matter	72.0	43
Mean max reflectance, Ro	0.34	0.41
	Sample C	
Vitrinite	55.6	40
Structured vitrinite		33
Exinite	1.2	2
Resinite & telinite		1
Micrinite	1.8	
Semi-fusinite	5.6	1
Pyrite	0.2	
Fusinite	2.2	
Mineral matter	33.4	23
Mean max reflectance, Ro	0.34	0.43

Laboratory A, Energy Research Labs.; Laboratory B, Bergbau-Forschung

TABLE 3

Maceral Composition of Hat Creek Coals
(on a mineral matter free basis)

Maceral, vol %	Laboratory A	Laboratory B	
Sample A			
Vitrinite	93	62	90 (62 + 28)
Structured vitrinite		28	
Exinite	2	5	
Resinite & Telinite		5	
Micrinite	3		
Semi-fusinite	1		
Pyrite	1		
Fusinite	–		
Sample B			
Vitrinite	99	47	87 (47 + 40)
Structured vitrinite		40	
Exinite		5	
Micrinite		4	
Semi-fusinite	1	4	
Pyrite			
Fusinite			
Sample C			
Vitrinite	83	52	95 (52 + 43)
Structured vitrinite		43	
Exinite	2	3	
Resinite & Telinite		1	
Micrinite	3		
Semi-fusinite	8	1	
Pyrite	<1		
Fusinite	3		

TABLE 4

Maceral Composition of Semi-coke
Produced at 550°C in the Ruhr-dilatometer

	Sample A	Sample B	Sample C*
1. On a dry basis			
Vitrinite	4.4	21.2	24.0
Fusinite / Semi-fusinite	24.4	21.6	18.4
Mineral matter	71.2	57.2	57.6
2. On a mineral matter free basis			
Vitrinite	15	49	57
Fusinite / Semi-fusinite	85	51	43

* A slight coke formation (0.8%) was observed in Sample C.

TABLE 5

Nature of the Vitrinite Component in the Hat Creek Coal Samples (Mineral Matter Free Basis)

		Sample A	Sample B	Sample C
Total vitrinite	*vol %	90-93	87-99	83-95
Reactive vitrinite	vol %	76-80	38-56	29-48
Oxidized vitrinite	vol %	13-14	43-49	47-54

* The data is presented as a range by considering the vitrinite analysis from the two different laboratories.

TABLE 6

Dilatation Tests

		Sample A	Sample B	Sample C
Softening temperature	$^{o}C\ \Theta_S$	no S.T	no S.T	$380^{o}C$
Contraction	% C	nil	nil	2
Max. temperature of contraction	$^{o}C\ \Theta_S$	nil	nil	
Dilatation	%	nil	nil	nil
Max. temperature of dilatation	^{o}C	nil	nil	nil
Plasticity index	$\frac{C}{\Theta_C - \Theta_S}$	nil	nil	nil

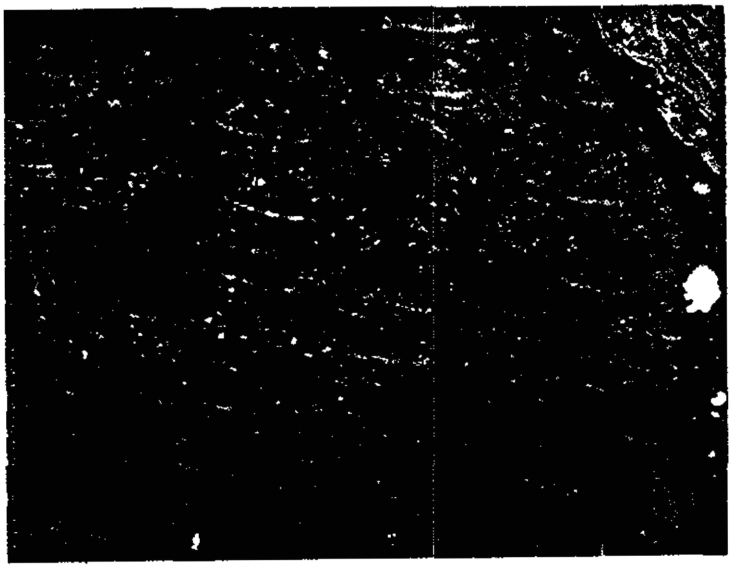

FIGURE 1 - Vitrinite showing remnants of parent plant materials

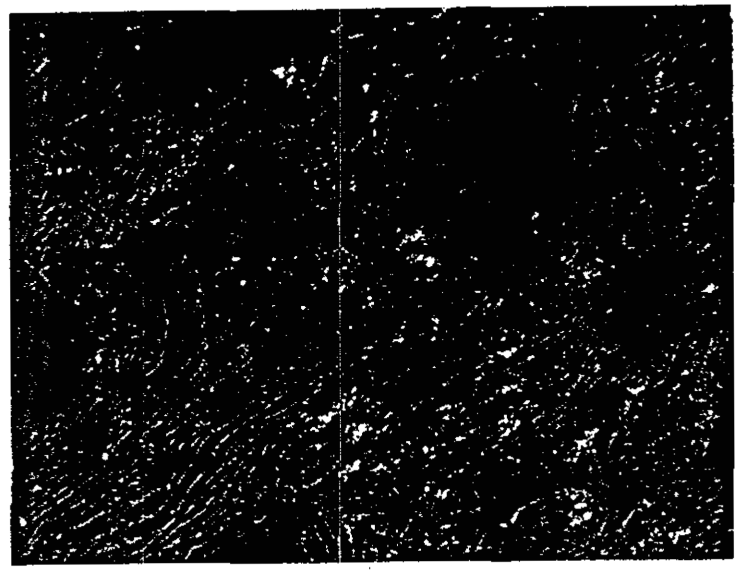

FIGURE 2 - Tellinite-like structure

FIGURE 3 - Resinite (oxidized) structure

FIGURE 4 - Exinite and vitrinite with structure

FIGURE 5 - Semi-coke on heating to 550°C Vitrinite and semi-fusinite structure

FIGURE 6 - Semi-coke on heating to 550°C Low reflectance fusinite and oxidized resinitic structure

FIGURE 7 - Mineral matter in fly ash showing series of hollow spheres

FIGURE 8 - Partially reactive vitrinite and fusinite in fly ash
F - fusinite,
PV - partially oxidized vitrinite

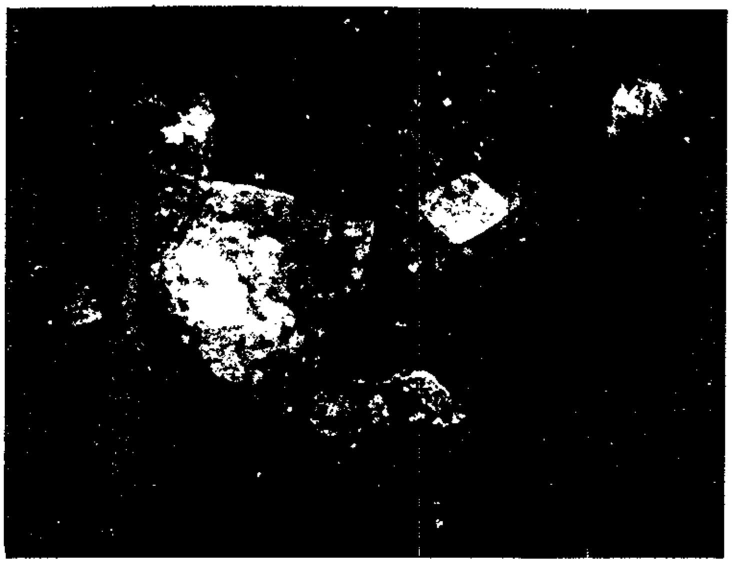

FIGURE 9 - Mineral matter in fly ash from coal B. Well defined sphere is not observed

FIGURE 10 - Carbonaceous reminiscent in fly ash from coal B

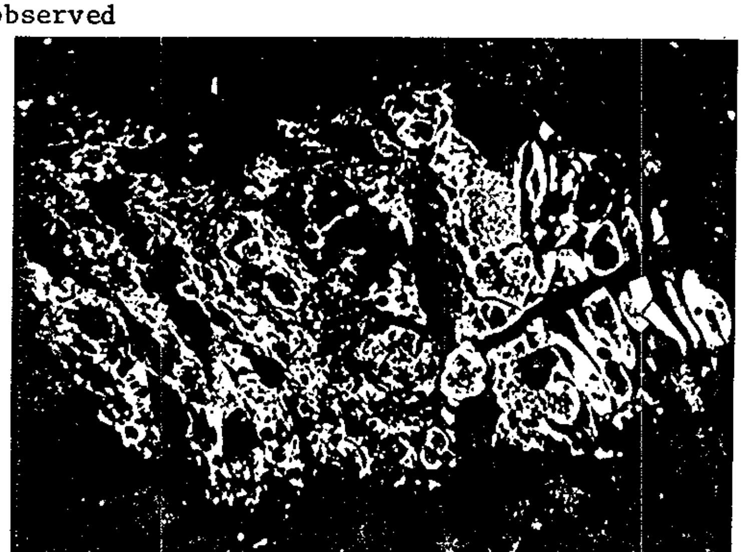

FIGURE 11 - High reflectance carbonaceous lamellae in the unburnt residue fly ash