AR-5

CHARACTERIZATION OF ALASKA'S COALS

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Coal characterization is a systematic determination of those properties of coal, or of its constituents, that affect its behavior when used. It will help in planning for recovery and use of the extensive Alaskan coal deposits, which have proven reserves of 130 billion tons. This estimate is of necessity based on widely scattered outcrops and meager drill hole data, and the potential reserves in the Cook Inlet region and the Northern Alaska field are considered to be several fold this figure.

Coal petrography

Coal is a very complex material. An examination of a piece of coal with the naked eye shows different bands with varying luster, the first indication of its inhomogenity. A further examination of a polished specimen under the microscope will show that the bands, although consisting predominently of one or two constituents, are mixtures of several components called macerals. The macerals are distinguishable by their morphological characteristics and reflectance. An increase in rank results in an increase in reflectance. Although, during the past two decades, substantial advances have been made in correlating coal petrographic components and reflectance rank of vitrinoids to their behavior during carbonization, prediction of reaction of coal during conversion processes such as gasification, liquification and solvent refining, is still a subject of intensive research.

Rank of coal

Coalification stage is expressed as rank which is determined from proximate analysis of the coal sample, based on its volatile matter and/or heating value. The rank of a coal can also be expressed in percent carbon, carbon content increasing with an increase in rank. The rank determined by these methods is an average of coal components and cannot distinguish the spread in rank of various macerals of the sample. By far the most scientific way of expressing the rank of coal is by reflectance. Alaska's large coal deposits range in rank from lignite to anthracite; lignites and subbituminous coals are found in the Kenai, Beluga, Susitna, Nenana and Northern Alaska fields. High volatile bituminous coals are found in Matanuska and the western parts of northern

Alaska fields. Low volatile and medium volatile bituminous coal and anthracites are found in the Matanuska and Bering River fields. Although much of the known reserves of Alaska's coals are of subbituminous rank, there are coking quality high volatile bituminous coals in the northwestern arctic which are of considerable interest. Due to their proximity to the Chukchi coast these coals have the potential of being mined, as the availability of valuable coking coals of the other parts of the world diminishes.

Rank determination of outcrop samples

U.S. Geological Survey has been investigating the coal deposits of Northwestern Alaska since 1966. The author has received samples from them on a cooperative agreement. Initial samples collected during the 1969 and 1970 field seasons were surface samples. Due to severe oxidation and weathering the ASTM rank of these coals as determined by proximate analyses appeared to be subbituminous in rank. It was therefore decided to rank these samples on the basis of reflectance. To serve as a basis for rank determination, coals from Bering River, Matanuska and Kukpowruk were analyzed. Tables 1, 2 and 3 show analyses and reflectance values of these coals. Additional information on sample locations, preparation and trace element distribution for these coals have been presented elsewhere (1). Table 4 shows the relationship between reflectance vs. rank for Alaskan coals. The reflectance determination of Northern Alaska coals, tables 5, 6, & 7, showed that these coals are of high volatile B or C rank. The sample numbers assigned in these tables are those of U.S. Geological Survey. Tables 5 and 6 show surface samples collected during the 1969 and 70 field seasons respectively. Table 7 gives data on samples collected by an auger in 1973 field season. Although oxidation and weathering is known to affect reflectance, the use of this method for rank is justified since the interest is for classifying into broad categories of ASTM rank.

Drill hole samples

During the 1972 field season, the U.S. Bureau of Mines obtained fresh samples of coal from Cape Beaufort by drilling and, an analysis of these coals proved that these coals are in fact of coking quality (2). Even some of these drill samples showed signs of oxidation, such as cracks, in reflected light under the microscope (see Fig. 1). These preliminary studies also showed that the free swelling index of these coals is low due to a high concentration of pseudovitrinite (figure 2) and semifusinite (figures 3, 4) which are inert for coking purposes. Also the pseudovitrinite grades into vitrinite, which could result in higher average reflectance values.

Hardness of coal macerals

Comminution behavior of coals, normally expressed as hardgrove grindability index, is representative only of the size fraction used for the test. Differential comminution of monomaceral bands could yield a grindability index that is not truly representative of the whole coal sample. Moisture content of the coal used for testing can influence the grindability index. This is of particular significance in low rank coals such as subbituminous 'C' where moisture in coal can vary from 25% as mined to about 16% when allowed to dry in air, and is a function of humidity of the ambient air.

Measurements of microhardness of coal macerals would fully define the comminution behavior of coal during pulverization. Table 8 shows Vicker's microhardness of vitrinites from various Alaskan coal fields, on dry and wet polished sections. Please note that wet sections show lower microhardness than dry sections. This difference in hardness is greatest for low rank coals. This aspect, however, needs further evaluation. Data therefore need to be developed to correlate reflectance of vitrinite with microhardness, and the effect of moisture on microhardness. Microhardness data are particularly needed for the other macerals, pseudovitrinite and semifusinite, which are abundant in northern Alaska coals.

Crushing of coal tends to break monomaceral bands of vitrain and fusain more than the multimaceral bands of clarin and durain. Therefore, vitrinite and fusinite tend to be concentrated in the finer size fraction. This property can be used for concentration and seggregation of macerals by simple crushing and screening.

Inorganic constituents of coal

Apart from macerals (the organic constituents of coal), coal also has inorganic substances. Although much of this inorganic material is present as discrete mineral particles such as quartz, carbonates, sulfides, and clay minerals and other silicates; certain trace and minor elements are associated with the organic phase of coal. This is of particular significance because many elements (e.g. Ti) tend to be carried with the dissolved coal substance in solvent refining or similar solution techniques. In certain conversion processes Mo in coal can act as a catalyst. Ash composition determines the behavior of ash during combustion, affecting ash fusion temperatures, and fluidity of molten ash at high temperatures. Also, the physical association of ash forming minerals with the organic components of coal determines washability characteristics of the coal. The finer the size that coal needs to be crushed for beneficiation, the more expensive the processing cost will be.

Form and association of sulfur are quite important if coal processing is required to reduce the sulphur content of the clean coal. Sulphur associated with coal substance, i.e. organic sulfur, cannot be eliminated by any physical processes. Likewise very finely disseminated pyritic sulfur associated with coal macerals cannot be removed. Fortunately, Alaskan coals are exceptionally low in sulfur and thus are not plagued by this problem.

M.I.R.L. Report No. 15 (1) gives the distribution of certain minor and trace elements. In a more recent study (M.I.R.L. Report No. 35) of inorganic constituents of coals from Cape Beaufort, the scope of analysis was extended to major elements (2).

The knowledge of Alaskan coals available is quite meager and it will take an enormous effort to fully characterize them for prudent utilization.

Acknowledgement

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References of Author's work

1. Rao, P. Dharma, "Distribution of certain minor elements in Alaskan coals: Mineral Industry Research Laboratory Report No. 15, June, 1966.
2. Rao, P. Dharma, "Distribution and significance of major, minor and trace elements in arctic Alaskan coals": Mineral Industry Research Laboratory Report No. 35 (in publication).

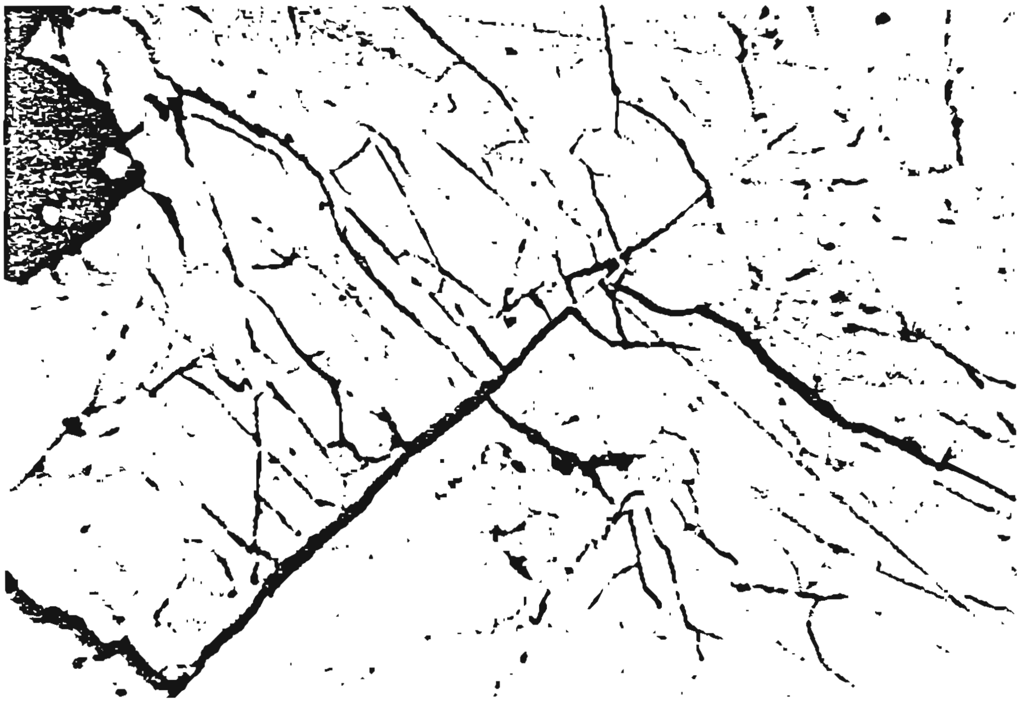

Figure 1: Cracks due to oxidation in a Cape Beaufort core sample (UA-44) - reflected light (R.L.) oil immersion (520X)

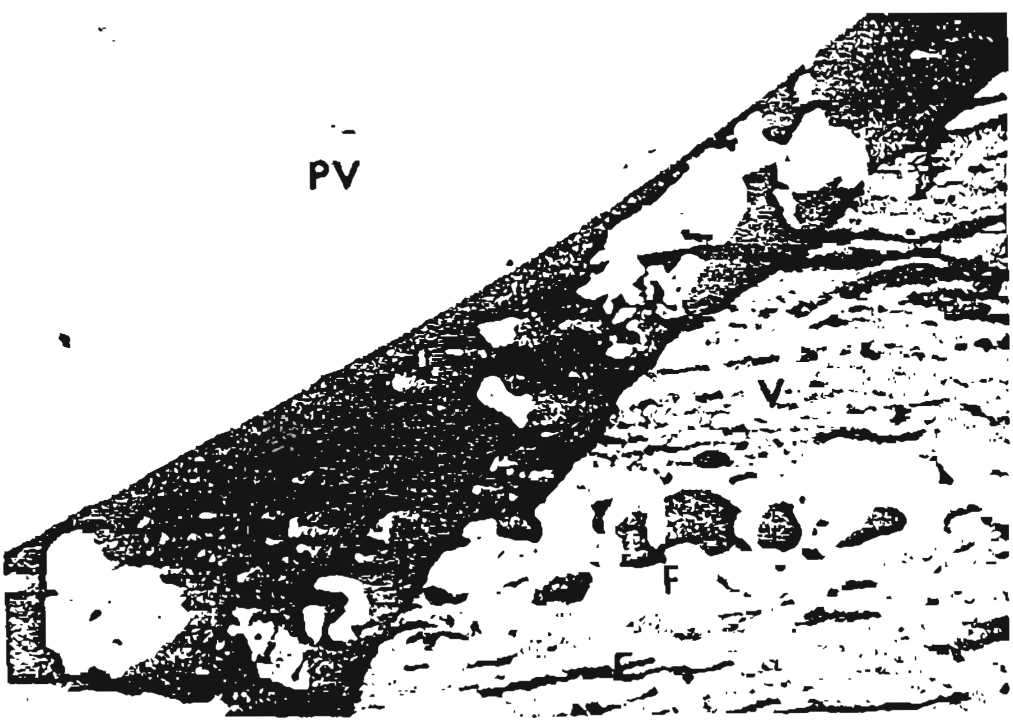

Figure 2: Pseudovitrinite (PV) showing reflectance higher than vitrinite (V) (UA-2) - exinite (E) and fusinite (F) are only associated with vitrinite R.L. oil immersion (520X)

Figure 3: Semifusinite (SF) with varying reflectance values (UA-2) - vitrinite (V) has exinite (E) and bright spots of micrinite R. L. oil immersion (520X)

Figure 4: Larger concentration of exinite (E) associated with vitrinite (V) and semi-fusinite (SF) showing varying textures (UA-44) R. L. oil immersion (520X)

Table I

Petrographic and Analytical Data for Coals from Matanuska Field

Sample No.	Seam No.	Reflectance Class %					Reflectance $\bar{R}_o$, %	Mois. & Ash Free Basis		Eqilibrated Bed Moisture Basis			F.S.I.	S, %
		V_4	V_5	V_6	V_7	V_8		Vol. Mat. %	Heating value Btu/lb	Moist. %	Ash, %	Moist ash-free Btu		
37	Ev. J., 5L		26	54	20		0.667	45.2	14,253	6.34	9.73	13,349	2	.31
38	" 5UI		46	54			0.604	46.1	14,258	5.87	9.01	13,421	2	.27
39	" 5UII		20	64	16		0.634	46.3	14,354	5.49	8.83	13,566	1/2	0.31
40	" 6L		12	66	22		0.660	45.4	14,366	5.97	7.89	13,506	1 1/2	0.26
41	" 6U	2	26	50	22		0.664	45.4	14,402	6.10	9.22	13,523	1 1/2	0.28
42	" 7 L		8	72	20		0.656	43.5	14,531	6.18	7.85	13,633	2	0.31
43	" 7U		22	76	2		0.632	46.2	14,511	6.42	8.35	13,579	2	0.33
44	" 7AL			74	26		0.662	42.4	14,332	6.30	3.08	13,429	2	0.32
45	" 7AU		28	66	6		0.612	44.8	14,410	5.98	9.18	13,548	1 1/2	0.41
46	" 7BL		2	72	26		0.655	44.0	14,466	6.97	4.72	13,458	2	0.43
47	" 7BU		18	78	4		0.636	43.8	14,377	6.09	3.19	13,501	2	0.34
48	" 7C		28	64	8		0.608	45.2	14,494	6.39	5.80	13,568	2	0.31
49	" 8		14	74	12		0.642	43.4	14,372	6.93	5.98	13,376	2	0.38
50	" Bogus		4	56	36	4	0.695	41.6	14,236	7.89	7.57	13,113	2	0.39

Table I (Contd)

Petrographic and Analytical Data for Coals from Matanuska Field

Sample No.	Seam No.	Reflectance Class %						Reflectance $\bar{R}_o$,%	Mois. & Ash Free Basis		Eqilibrated Bed Moisture Basis			F.S.I.	S,%
		V_9	V_{10}	V_{11}	V_{12}	V_{13}	V_{14}		Vol.Mat. %	Heating value Btu/lb	Moist. %	Ash, %	Moist ash-free Btu		
51	CM 1	4	40	54	2			1.10	33.7	15,474	1.80	9.10	15,195	8	0.39
52	CM 2		42	20	16	12	10	1.17	24.5	15,236	3.31	7.46	14,099	2	0.53
		V_4	V_5	V_6	V_7	V_8	V_9								
53	PM 1		8	64	28			0.674	44.6	14,231	5.33	7.47	13,472	$1\frac{1}{2}$	0.29
54	PM 2		14	72	14			0.654	44.8	14,416	4.95	3.80	13,762	2	0.35
55	PM 3		2	60	38			0.682	44.0	14,312	5.34	5.63	13,506	2	0.56
56	PM 4			48	50	2		0.704	41.7	14,369	5.76	1.72	13,541	2	0.78
57	PM 5		16	70	14			0.664	44.5	14,333	5.05	4.77	13,541	2	0.29
58	PM 6		22	76	2			0.630	46.1	14,319	5.19	6.74	13,576	$1\frac{1}{2}$	0.50

Table 2

Petrographic and Analytical Data for Coals from Bering River Field

Sample No.	Seam No.	Reflectance Class % V_{17}	V_{18}	V_{19}	V_{20}	V_{21}	Reflectance $\bar{R}_o$, %	Mois. & Ash Free Basis: Vol. Mat. %	Heating value Btu/lb	Equilibrated Bed Moisture Basis: Moist. %	Ash, %	Moist ash-free Btu	F.S.I.	S, %
59	32 C	14	46	34	6		1.84	18.1	15,528	2.62	2.67	15,121	$\frac{1}{2}$	0.60
60	55 C		8	49	38	14	2.00	17.0	15,119	4.29	3.54	14,470	0	1.00
61	51 C	4	34	44	18		1.92	16.2	15,707	1.99	1.24	15,534	$1\frac{1}{2}$	0.78
62	61 C		8	58	28	6	1.97	16.1	15,738	1.95	1.67	15,490	$1\frac{1}{2}$	0.76
63	63 C	10	32	42	16		1.91	16.1	15,528	2.46	1.15	15,146	$\frac{1}{2}$	0.76

Table 3

Petrographic and Analytical Data for Coals from Kukpowruk, Northern Alaska Field

Sample No.	Seam No.	Reflectance Class %						Reflectance $\bar{R}_o$, %	Mois. & Ash Free Basis		Equilibrated Bed Moisture Basis			F.S.I.	S,%
		V_5	V_6	V_7	V_8	V_9	V_{10}		Vol. Mat. %	Heating value Btu/lb	Moist. %	Ash, %	Moist ash-free Btu		
64	1C		4	64	26	6		0.787	40.5	14,743	3.77	2.48	14,187	6	0.18
65	2C		2	28	56	14		0.837	38.0	14,363	3.88	6.39	13,806	2½	0.14
66	3C							0.946	32.1	14.578	4.76	4.61	13,884	1½	0.15
67	4C	6	14	30	44	6		0.792	39.8	14,839	3.00	5.84	14,275	1½	0.31
68	5C		6	28	40	26		0.835	36.6	14,458	4.81	4.55	13,762	½	0.46
69	6C		4	28	54	14		0.810	36.7	14,266	5.11	8.24	13,537	½	0.30
70	7C		10	62	24	4		0.775	34.0	14,579	5.54	8.35	13,771	½	0.37
71	8C		2	24	66	4	4	0.795	39.0	14,612	4.29	5.15	13,985	2	0.36
72	9C		6	60	28	6		0.780	38.1	14,330	5.65	3.13	13,520	2	.25
73	10C		12	74	14			0.745	40.4	14,228	5.45	5.93	13,452	2	0.30
74	11C			46	54			0.710	37.5	13,994	6.70	4.70	13,056	0	0.34
75	12C			20	66	14		0.730	37.6	13,928	8.00	6.94	12,813	0	0.23

Table 4

Relationship between ASTM Rank and Vitrinite Reflectance

ASTM Ranks	Reflectance R_o, %
Subbituminous	.3 - .4
High Volatile C	.4 - .6
High Volatile B	.6 - .8
High Volatile A	0.8 - 1.1
Medium Volatile	1.1 - 1.5
Low Volatile Bituminous	1.5 - 2.0

Table 5

Reflectance Rank Distribution of Vitrinites In Cape Beaufort Coals

Sample No.	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}	V_{11}	V_{12}	V_{13}	V_{14}	V_{15}	Average reflectance $\bar{R}_o$,%	V.M.
1-U				6	6	4	10	18	16	22	16	2	1.194	27.0
1-M		6	58	38									.687	38.6
1-L		22	56	22									.646	36.7
2-U			12	60	28								.756	29.1
2-L			22	62	16								.742	35.8
3		6	50	42	2								.682	36.2
4	6	38	40	16									.616	41.3
5		4	38	54	4								.705	38.0
6		50	26	24									.622	38.7
7					2	6	10	16	14	28	6	18	1.270	26.0
8			10	66	24								.766	34.4
9			2	62	36								.778	33.1
10		2	48	50									.684	35.8
11		28	64	8									.616	40.6
12	4	34	40	22									.624	40.7
13		66	26	8									.594	40.6
17-U		12	68	20									.660	38.3
17-L		26	64	10									.634	39.4
18		10	68	22									.662	37.4
19			12	68	18	2							.755	36.0
20		10	44	38	6	2							.690	40.9
21		4	26	64	6								.705	37.8
22			46	46	8								.708	38.2
23-U		2	8	50	36	4							.787	34.5
23-L		2	76	20	2								.666	37.4
24		20	54	26									.660	35.0
25-U			44	42	14								.722	35.0
25-M		44	24	32									.685	38.1
25-L		10	56	30	4								.674	38.0
26		4	64	32									.670	39.9
27		28	66	6									.624	43.4
28-U		10	70	20									.646	40.2
28-L													.532	43.3
29		10	50	38	2								.686	39.8
30			18	46	26	4	6						.786	33.5
31			34	62	4								.708	43.6
32		6	60	34									.676	37.7
LAG.A													.590	43.6
LAG.B-U	36	60	4										.512	41.2
LAG.B-L		20	72	8									.64	43.2
LAG.C	2	26	54	16	2								.634	41.7
LAG.E		16	64	20									.655	37.8
LAG.F													.454	46.0
LAG.G	4	52	38	6									.600	44.1
LAG.H													.528	47.0
LAG.I	4	76	20										.572	40.4
LAG.J		50	50										.596	42.3
LAG.K													.588	42.6
LAG.L	12	64	24										.566	43.2
LAG.M	2	52	44	2									.598	44.2
LAG.N													.626	42.4

Table 6

Reflectance Rank Distribution of Vitrinites in Cape Beaufort Coals

U.S.G.S. No.	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}	Average Reflectance R_o, %
11				20	54	16	10		.730
17			14	74	12				.646
19				50	50				.790
27			8	80	12				.648
28*		2	18	80					.626
29		18	64	18					.542
30A			38	58	4				.602
30B			70	30					.572
30C		4	76	20					.566
30D*			36	62	2				.610
30E*		4	56	40					.574
31A*			48	52					.596
31B*		20	60	18	2				.548
32A			10	76	14				.644
32B*		2	38	58	2				.606
32C			60	40					.580
33 upper			12	60	28				.652
33 middle			58	42					.590
33 lower			44	54	2				.602
73		2	30	62	6				.624
74*			26	68	6				.618
80		2	60	38					.578
82		12	74	14					.546
83*		16	72	12					.548
88*			46	52	2				.592

*The polished sections had high relief due to oxidation.

Table 7

Reflectance rank distribution of vitrinites in Arctic coals.

Sample No.	Reflectance Class, %						Mean Max. Reflectance* $\bar{R}_o$,%
	V_3	V_4	V_5	V_6	V_7	V_8	
AH-73-1A			12	48	40		0.687
AH-73-1B			4	48	42	6	0.696
AH-73-1C			22	56	22		0.650
AH-73-1D		4	24	52	20		0.637
AH-73-2			32	62	6		0.626
AH-73-3		2	22	68	8		0.634
AH-73-4		2	62	34			0.590
AH-73-5				40	56	4	0.713
AH-73-6			2	74	24		0.665
AH-73-8		2	38	52	6	2	0.611
AH-73-10A			12	46	34	8	0.685
AH-73-10B			10	76	10	4	0.671
AH-73-10C			16	60	24		0.654
AH-73-23A			6	58	36		0.680
AH-73-23B		8	58	34			0.574
AH-73-24			14	54	32		0.670
AH-73-25A			34	60	6		0.617
AH-73-25B			56	38	6		0.603
AH-73-25C		12	56	32			0.572
AH-73-27				78	22		0.674
AH-73-29			2	30	58	10	0.718
AH-73-31A		4	36	54	6		0.611
AH-73-31B			58	42			0.598
AH-73-32			24	56	20		0.648
AH-73-34			6	48	44	2	0.695
AH-73-36			22	58	20		0.637

* Based on 50 measurements

Table 8

Vicker's Micro Hardners as a Function of Rank and Condition

Locality	Rank	Sample No.	R_o	HV Dry	HV Wet
Bering River	LVB	62	1.97	35.2	
Chickaloon	HVA	51	1.1	34.4	
Kukpowruk I C	HVA	64	0.787	40.5	33.3
Evans Jones 7AL	HVB	44	0.662	42.7	30.7
" " 5U2	HVB	38	0.634	43.5	35.4
" " 7C	HVB	48	0.608	43.9	35.5
" " 5U1	HVB	39	0.604		35.5
Cape Beaufort	HVC	J	0.596	53.9	
Jarvis Creek	Sub.bit C	34	0.32	60.2	30.2