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PETROGRAPHIC, MINERALOGICAL AND CHEMICAL CHARACTERIZATION OF CERTAIN ARCTIC ALASKAN COALS FROM THE CAPE BEAUFORT REGION

by

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NOTICE

The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies or recommendations of the Interior Department's Bureau of Mines or of the U.S. Government.

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ABSTRACT

Coal seams for the Cape Beaufort region of Arctic Northwestern Alaska were sampled by drilling by the U.S. Bureau of Mines, Juneau and the U.S. Geological Survey, Anchorage). Samples from the drill holes were supplied to the Mineral Industry Research Laboratory. These are Cretaceous coals ranging in rank from high volatile bituminous A to B. A total of 48 samples from 18 drill holes intersecting 14 seams were studied. Float-sink separations were made at 1.50 specific gravity for ten of these samples. Raw coals and float-sink products were characterized for proximate analysis, ultimate analysis, ash fusibility, vitrinite reflectance, coal petrology in reflected light, quantitative determination of mineral matter by x-ray diffraction and infrared spectrophotometry of low temperature ash, major minor and trace elements by atomic absorption and emission spectrochemical analysis. Influence of beneficiation and geological significance of these characteristics, and organic affinity of trace elements are discussed. A generalized scheme for analysis of coal ash by atomic absorption and emission spectrochemical methods is presented.

ACKNOWLEDGMENTS

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INTRODUCTION

Alaska's coal resources, estimated at several trillion tons, form one of the nation's largest energy resources. The bulk of these resources are located in Alaska's Arctic north slope. Coal fields of the Cape Beaufort region are closest to the west coast and are accessible to ocean shipment. These coal seams are found in the Corwin formation of Cretaceous age (Figure 1). The U.S. Department of the Interior has undertaken a program to systematically sample and evaluate these seams. Since the bulk of the earlier seams sampled were outcrop samples subject to oxidation and weathering, the U.S. Bureau of Mines, in 1972, under the direction of Mr. Robert S. Warfield, Alaska Field Operation Center, undertook a drilling program to obtain fresh coal. Figure 2 shows the location of drill holes. Geological investigations in the region were done by Mr. James Callahan, U.S. Geological Survey, Anchorage.

Figure 3 shows sections along Tulugak and Kahkatak Creeks and other correlated seams along with coal bed numbers, drill hole numbers, and University of Alaska (UA) sample numbers. Correlations of various coal seams from the drill hole data were made by the U.S. Geological Survey, Anchorage (Callahan and Sloan, 1978). Complete up-to-date analytical data for the region were reported by Martin and Callahan (1978). Bed 10 and older beds are high volatile 'A' bituminous rank, whereas bed 8 and younger beds are high volatile 'B' rank (Figure 3).

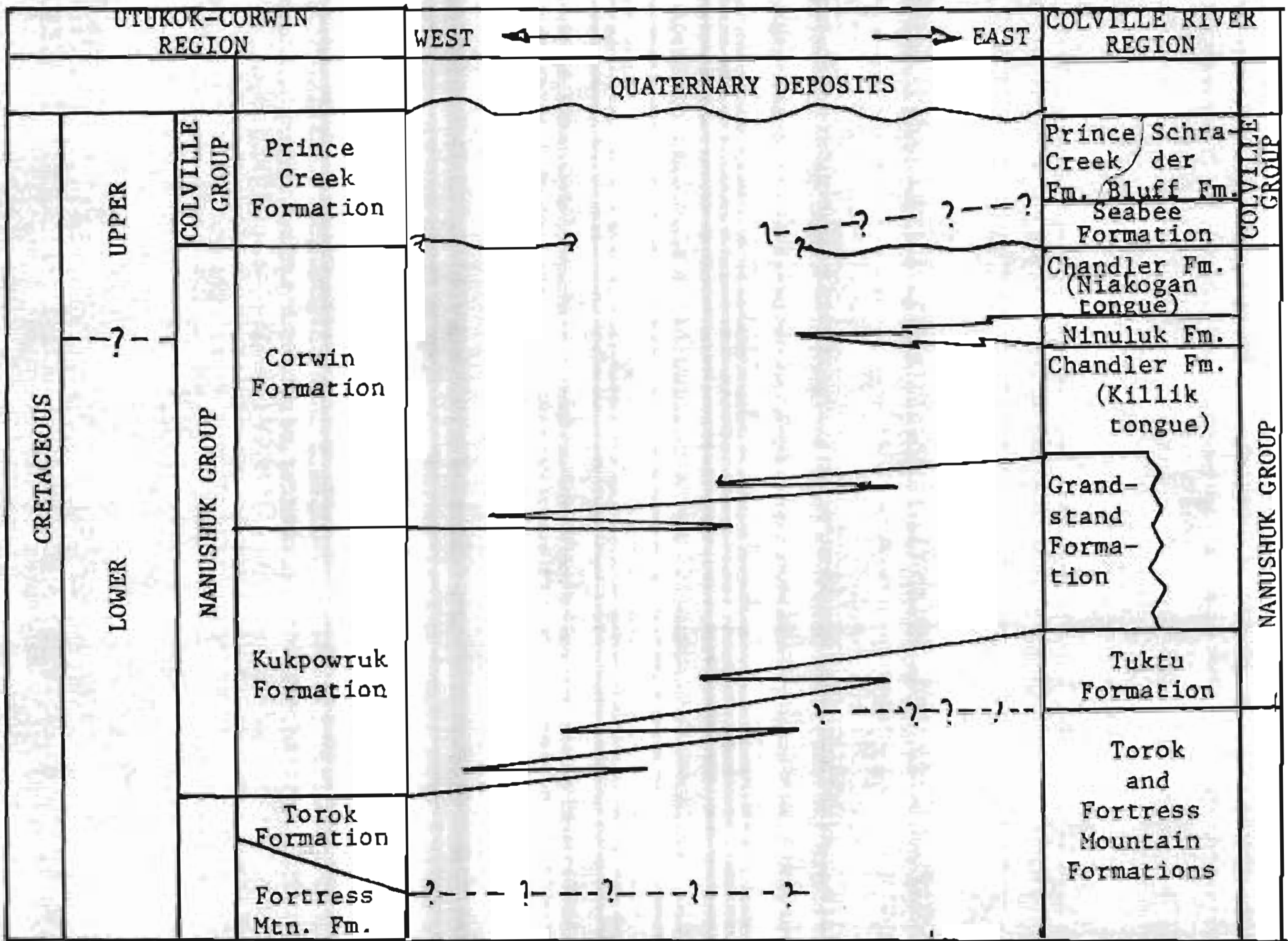


Figure 1: Generalized stratigraphic correlations of Cretaceous rocks of northwestern Alaska. Wavy lines represent unconformities. Chapman and Sable (1960, p.70).

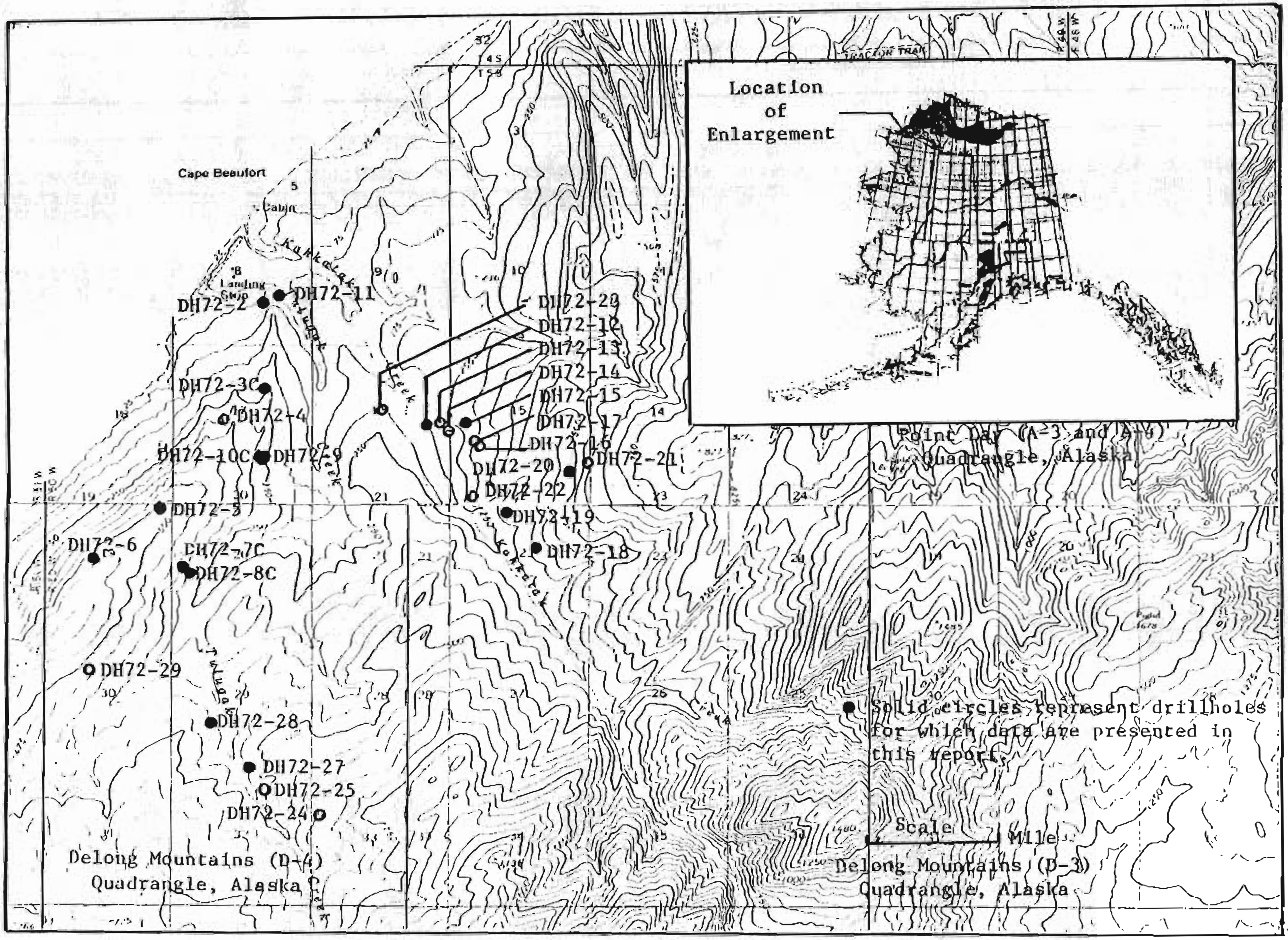
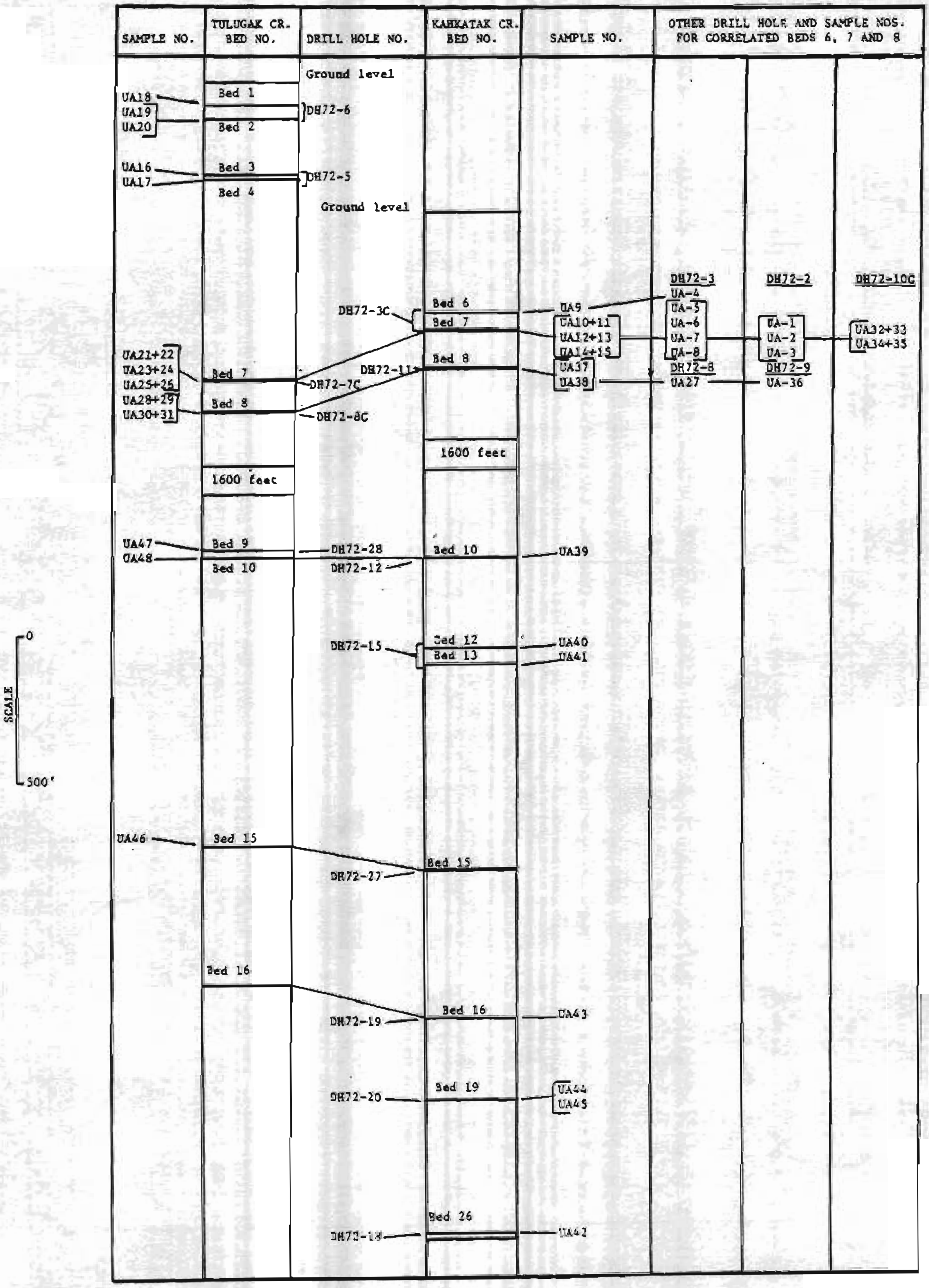


Figure 2. Location of drill holes in the Cape Beaufort region.

Figure 3

Stratigraphic sections of the Corwin formation showing mineable coal beds

(Source: Simplified from: Callahan and Sloan, 1978)



Samples were collected either as drill cuttings or cores. A total of 13 holes were drilled. Of these, coal samples from four holes were obtained as cores, the rest as cuttings. Drill hole numbers of these cores are suffixed with C(3C, 7C, 8C, 10C). The samples were shipped to the Grand Forks Energy Research Laboratory where they were processed under the direction of Mr. Charles C. Boley. Since the drill cuttings were generally 85 to 90% minus 8 mesh, sample splits were taken without further crushing. The cored samples were crushed to 8 mesh and sink-floated at 1.50 specific gravity. Approximately 250 grams of each of the samples were supplied to the author for the present investigation. Proximate and ultimate analyses of the samples were conducted by the U.S. Bureau of Mines, Pittsburgh Analytical Laboratory (now U.S. Dept. of Energy). Table 1 shows sample designations and the analyses converted to equilibrium bed moisture basis along with the author's determinations of equilibrium bed moisture, low temperature ash (L.T.A.) at 150°C, medium temperature ash (M.T.A.) at 450°C and high temperature ash (H.T.A.) at 750°C. The data are presented by drill hole number along with the seam number designation assigned by Callahan and Sloan (1978). No. 7 seam has been intersected by five drill holes, No. 8 seam by four drill holes and No. 10 seam by 2 drill holes. All other seams were only intersected once. Figure 2 is a geological section showing various coal seams studied. Details of drilling, geological and other analytical information are available in an open-file report by Callahan and Sloan (1978).

TABLE 1

IDENTIFICATION AND ANALYSES OF COAL SAMPLES

DRILL HOLE NO.	SEAM NO.	DEPTH INTERVAL FEET	SAMPLE NO.	PRODUCT (WT %)	BASIS[a]	MOIST.[b] %	V.M.[c] %	F.C.[d] %	ASH %	HEATING VALUE BTU/LB	H %	C %	N %	O %	S %	F.S.I.[e]	HTA[f] 750°C %	MTA[g] 450°C %	LTA[h] 150°C %
2	7	80-86	UA-1	Raw	1	6.13	24.26	32.34	37.27	7885	3.69	45.39	0.76	12.69	0.20	0.5	38.9	39.8	42.6
				coal	2		42.85	57.15		13930	5.30	80.19	1.34	12.81	0.36				
		86.4-90	UA-2	Raw	1	5.81	23.21	32.56	38.32	7753	3.64	45.14	0.71	12.00	0.18	0.5	38.3	38.6	42.4
				coal	2		41.72	58.28		13870	5.34	80.80	1.27	12.26	0.20				
		90-95	UA-3	Raw	1	5.47	25.88	29.30	39.35	7656	3.82	43.41	0.76	12.44	0.23	1.0	40.7	41.1	45.4
				coal	2		46.91	53.09		13880	5.82	78.66	1.38	13.72	0.42				
3	6	70-73	UA-4	Raw	1	5.32	24.69	45.79	24.16	9476	3.79	56.45	0.84	14.58	0.14	0.0	24.6	26.1	28.5
				coal	2		35.03	64.97		13450	4.54	20.10	1.19	13.98	0.19				
	7	135.5-141	UA-5	Raw	1	5.05	27.61	52.87	14.51	11197	4.33	65.94	1.00	14.07	0.18	0.5	12.1	12.5	13.6
				coal	2		34.31	65.69		13910	4.67	81.95	1.24	11.92	0.22				
		141-146	UA-6	Raw	1	6.66	28.38	35.68	29.30	8937	4.15	51.33	0.86	14.20	0.18	1.8	45.1	47.0	50.8
				coal	2		44.30	55.70		13960	5.32	80.12	1.34	12.95	0.27				
		146-151	UA-7	Raw	1	5.44	26.77	34.75	33.03	8622	3.92	49.35				2.0	24.2	25.4	26.4
				coal	2		43.50	56.50		14020	5.40	80.23	1.32	12.78	0.27				
		151-153.5	UA-8	Raw	1	4.14	33.20	40.14	22.57	10408	4.72	58.66	1.00	12.83	0.27	2.3	19.5	19.9	22.8
				coal	2		45.27	54.73		14200	5.79	79.98	1.37	12.50	0.36				
3C	6	69-72.7	UA-9	Raw	1	4.41	23.89	47.18	24.54	9530	3.67	57.19	0.80	13.60	0.20	0.0	24.0	23.1	29.6
				coal	2		33.61	66.39		13410	4.47	80.48	1.13	13.64	0.28				
	7	135.3-143.3	UA-10	Float	1	5.03	30.97	56.51	7.53	12388	4.92	72.12	1.11	14.22	0.23		7.5	8.0	9.7
				74.2	2		35.40	64.60		14170	4.88	82.44	1.27	11.15	0.26				
		-do-	UA-11	Sink	1	4.14	20.85	41.27	33.74	7860	3.13	48.63	0.66	13.68	0.16		36.1	38.1	42.3
				25.8	2		33.57	66.43		12650	4.30	78.28	1.06	16.11	0.25				
		143.3-151.3	UA-12	Float	1	4.31	34.83	51.04	9.82	12380	5.26	71.49	1.11	12.10	0.22	2.8	10.0	10.3	11.3
				77.3	2		40.56	59.44		14424	5.27	83.26	1.29	9.63	0.25				
		-do-	UA-13	Sink	1	4.01	22.39	31.69	41.93	7025	3.17	43.54	0.50	10.75	0.13		42.4	45.9	48.0
				22.7	2		41.40	58.60		12980	5.04	80.50	0.93	13.29	0.24				
		151.3-152.9	UA-14	Float	1	4.40	38.62	52.48	4.46	13057	5.62	74.09	1.22	14.34	0.28		4.7	5.0	6.0
				89.9	2		42.39	57.61		14330	5.91	81.01	1.34	11.44	0.30				

[a] Basis 1 - bed moisture, Basis 2 - dry ash-free; [b] Equilibrium bed moisture, authors' sample; [c] Volatile matter; [d] Fixed carbon; [e] Free swelling index; [f] High temperature ash, authors' sample; [g] Medium temperature ash, authors' sample, [h] Low temperature ash, authors' sample.

TABLE 1 Continued

IDENTIFICATION AND ANALYSES OF COAL SAMPLES

DRILL HOLE NO.	SEAM NO.	DEPTH INTERVAL FEET	SAMPLE NO.	PRODUCT (WT %)	BASIS[a]	MOIST.[b] %	V.M.[c] %	F.C.[d] %	ASH %	HEATING VALUE BTU/LB	H %	C %	N %	O %	S %	F.S.I.[e]	HTA[f] 750°C %	MTA[g] 450°C %	LTA[h] 150°C %
3C	7	-do-	UA-15	Sink	1	3.95	23.82	23.57	48.71	5512	2.91	34.01	0.47	13.78	0.14		57.7	60.9	67.7
				10.1	2		50.27	49.73		11640	5.20	71.76	1.00	21.75	0.29				
5	3	85-86.8	UA-16	Raw	1	4.54	37.96	45.46	12.08	11888	5.21	67.15	1.31	14.02	0.26	1.9	12.1	13.0	17.3
				coal	2		45.51	54.49		14260	5.63	80.50	1.57	11.99	0.31				
	4	90-94.1	UA-17	Raw	1	4.77	25.47	27.82	41.93	6913	3.32	41.17	0.81	12.61	0.15	0.0	43.4	44.8	51.1
				coal	2		47.78	52.22		12970	5.22	77.26	1.52	15.73	0.27				
6	1	75-77	UA-18	Raw	1	5.85	30.45	39.99	23.71	9740	4.49	55.50	1.31	14.73	0.26	1.0	25.0	25.9	30.4
				coal	2		43.24	56.76		9662	5.46	78.80	1.86	13.52	0.36				
	2	122.7-127.7	UA-19	Raw	1	5.33	33.84	45.60	15.24	11043	4.80	63.80	1.41	14.58	0.18	1.9	15.3	16.3	19.1
				coal	2		42.59	57.41		13900	5.30	80.32	1.78	12.38	0.22				
		128.3-129	UA-20	Raw	1	4.44	36.01	39.60	19.96	10625	4.91	59.98	1.20	13.68	0.28		20.6	21.1	29.4
				coal	2		47.62	52.38		14050	5.83	79.32	1.59	12.90	0.36				
7C	7	43-49.7	UA-21	Float	1	4.79	33.23	54.66	7.29	12527	4.63	71.92	1.06	14.82	0.25		7.1	7.9	10.0
				88.5	2		37.81	62.19		14260	4.67	81.83	1.21	12.01	0.28				
		-do-	UA-22	Sink	1	3.96	27.86	32.85	35.36	7250	2.96	45.02	0.56	15.96	0.17		36.7	44.4	47.6
				11.5	2		45.89	54.11		11930	4.17	74.15	0.92	20.48	0.28				
		49.7-57.9	UA-23	Float	1	4.51	34.93	49.94	10.58	12190	5.08	69.14	1.01	13.92	0.23		11.0	11.6	12.6
				82.3	2		41.16	58.84		14370	5.40	81.46	1.19	11.68	0.27				
		-do-	UA-24	Sink	1	4.91	22.30	29.63	43.19	6943	3.19	41.19	0.54	11.75	0.17		42.2	44.5	48.4
				17.7	2		42.95	57.05		13360	5.08	79.31	10.04	14.25	0.32				
		57.9-59.9	UA-25	Float	1	4.24	39.18	52.20	4.37	14340	5.58	74.25	1.15	14.27	0.37		4.8	5.2	7.6
				89.9	2		42.88	57.12		13680	5.59	81.25	1.26	11.50	0.40				
		-do-	UA-26	Sink	1	3.58	19.82	14.85	61.74	3234	2.59	22.52	0.38	12.62	0.16		63.6	66.2	74.0
				10.1	2		57.15	42.82		9314	6.31	64.86	1.09	27.18	0.46				
8	8	97-110	UA-27	Raw	1	4.26	33.33	48.23	14.17	11582	4.80	66.37	1.05	13.41	0.19	2.1	13.9	15.4	17.8
				coal	2		40.86	59.14		14200	5.29	81.37	1.29	11.82	0.23				
8C	8	96.9-103.4	UA-28	Float	1	4.32	33.58	54.23	7.87	12470	4.88	72.10	1.09	12.51	0.33		8.2	8.8	9.9
				77.3	2		38.24	61.76		12283	4.97	82.11	1.07	13.66	0.33				

TABLE 1 Continued

IDENTIFICATION AND ANALYSES OF COAL SAMPLES

DRILL HOLE NO.	SEAM NO.	DEPTH INTERVAL FEET	SAMPLE NO.	PRODUCT (WT %)	BASIS[a]	MOIST.[b] %	V.M.[c] %	F.C.[d] %	ASH %	HEATING VALUE BTU/LB	H %	C %	N %	O %	S %	F.S.I.[e]	HTA[f] 750°C %	MTA[g] 450°C %	LTA[h] 150°C %
8C	8	-do-	UA-29	Sink	1	3.48	27.03	36.37	33.11	7699	3.13	47.69	0.57	15.29	0.20		33.8	39.5	44.4
				22.7	2		42.64	57.36		12140	4.33	75.22	0.90	19.24	0.31				
		103.4-109.8	UA-30	Float	1	4.06	36.74	52.88	6.36	12887	5.29	73.16	1.17	13.88	0.19	2.3	6.2	6.7	8.0
				88.1	2		41.00	59.00		14380	5.40	81.63	1.30	11.46	0.21				
		-do-	UA-31	Sink	1	3.48	27.15	31.37	37.97	7129	3.23	45.01	0.58	13.02	0.16		38.6	44.7	48.3
				11.9	2		46.40	53.60		12180	4.85	76.92	0.99	16.97	0.27				
10C	7	52.2-57.85	UA-32	Float	1	4.24	33.82	54.64	7.26	12555	4.99	72.04	1.06	14.35	0.25		6.9	7.4	8.3
				86.4	2		38.23	61.77		14190	5.11	81.44	1.19	11.98	0.28				
		-do-	UA-33	Sink	1	4.52	22.77	36.11	36.60	7442	3.22	45.53	0.55	13.95	0.15		39.7	42.8	46.5
				13.6	2		38.67	61.33		12640	4.61	77.32	0.94	16.88	0.25				
		57.85-61.05	UA-34	Float	1	4.32	35.14	52.21	8.33	12424	5.19	70.90	1.08	14.22	0.27	2.2	8.9	9.2	10.3
				86.6	2		40.23	59.77		14230	5.40	81.17	1.24	11.89	0.28				
		-do-	UA-35	Sink	1	4.83	20.91	29.55	44.74	6573	3.15	39.35	0.51	12.17	0.13		43.3	45.5	48.7
				13.4	2		41.44	58.56		13020	5.17	77.98	1.01	15.59	0.25				
9	8	84-96.3	UA-36	Raw	1	4.51	31.14	44.72	19.61	10697	4.50	61.51	0.97	13.24	0.14	2.1	21.0	22.6	24.6
				coal	2		41.05	58.95		14100	5.27	81.08	1.28	12.19	0.18				
11	8	84.5-91.7	UA-37	Raw	1	4.92	29.65	44.39	21.06	10230	4.49	59.82	0.93	13.53	0.19	1.9	16.5	18.0	19.3
				coal	2		40.05	59.95		13810	5.33	80.79	1.26	12.37	0.25				
		91.7-96.34	UA-38	Raw	1	4.75	35.61	45.42	14.25	11622	5.30	66.41	1.17	12.68	0.23	3.0	13.8	14.9	15.9
				coal	2		43.95	56.05		14350	5.88	81.75	1.44	10.45	0.28				
12	10	111-119	UA-39	Raw	1	3.22	34.90	46.56	15.34	11870	4.99	66.77	1.35	11.29	0.27	3.5	17.3	18.0	21.0
				coal	2		42.85	57.15		11882	5.70	81.97	1.66	10.34	0.27				
15	12	43-46.1	UA-40	Raw	1	3.64	32.96	50.94	12.51	12312	4.93	69.31	1.32	11.61	0.33	3.2	17.3	17.4	20.0
				coal	2		39.29	60.71		14670	5.44	82.61	1.57	9.99	0.39				
	13	104-107.5	UA-41	Raw	1	3.42	31.51	51.87	13.24	12184	4.81	69.32	1.23	11.16	0.29	2.7	17.6	18.4	19.6
				coal	2		37.79	62.21		14610	5.32	83.13	1.48	9.72	0.35				

TABLE I Continued

IDENTIFICATION AND ANALYSES OF COAL SAMPLES

DRILL HOLE NO.	SEAM NO.	DEPTH INTERVAL FEET	SAMPLE NO.	PRODUCT (WT %)	BASIS[a]	MOIST.[b] %	V.M.[c] %	F.C.[d] %	ASH %	HEATING VALUE BTU/LB	H %	C %	N %	O %	S %	F.S.I.[e]	HTA[f] 750°C %	MTA[g] 450°C %	LTA[h] 150°C %
18	26	60.9-65	UA-42	Raw	1	2.72	30.48	44.91	21.87	11237	4.60	63.03	1.56	8.57	0.36	6.1	19.7	20.4	23.0
				coal	2		40.43	59.57		14910	5.71	83.61	2.07	8.12	0.49				
19	16	48.2-55.3	UA-43	Raw	1	2.91	34.14	54.90	8.08	13204	5.18	74.94	1.59	10.04	0.19	5.6	8.9	9.3	10.7
				coal	2		38.34	61.66		14830	5.46	84.18	1.78	8.37	0.21				
20	19	72.5-77.1	UA-44	Raw	1	3.03	25.16	30.85	41.00	8004	3.76	45.33	1.18	8.57	0.20	3.8	39.8	41.7	43.8
				coal	2		44.92	55.08		14300	6.11	80.93	2.11	10.50	0.35				
		77.5-81.0	UA-45	Raw	1	3.80	21.22	23.86	51.17	6279	3.16	35.53	1.01	8.96	0.20	2.9	50.2	50.7	57.8
				coal	2		47.06	52.94		13930	6.05	78.83	1.24	12.44	0.44				
27	15	22-30.2	UA-46	Raw	1	3.78	31.35	54.87	9.98	12456	4.85	71.35	1.39	12.17	0.24	2.0	6.4	6.8	7.7
				coal	2		36.35	63.65		14440	5.15	82.75	1.62	10.21	0.27				
28	9	25.5-29.7	UA-47	Raw	1	3.86	33.80	44.28	18.05	11331	4.88	64.10	1.21	11.50	0.25	2.5	18.8	19.2	20.8
				coal	2		43.29	56.71		14510	5.70	82.09	1.54	10.36	0.31				
	10	54-60.8	UA-48	Raw	1	3.99	32.80	44.66	18.53	10986	4.77	62.73	1.19	12.48	0.27	1.9	20.5	20.6	22.7
				coal	2		42.34	57.66		14180	5.56	80.99	1.54	11.55	0.36				

OBJECTIVES OF THE INVESTIGATION

Coal is a complex substance; the nature of its organic and inorganic constituents is determined by depositional and post depositional environments as well as parent plant material. Organic constituents are present as microscopically recognizable components called macerals. The macerals reflect the depositional environments. Reflectance of vitrinite shows the degree of coalification or the rank of the coal. Maceral composition also permits evaluation of coal for coking and coal conversion process.

If the mineral matter is intimately associated with the coal substance, it defies beneficiation processes. Many of these minerals are authigenic. The pH and chemical environment of the swamp determines the mineral suite, and conversely the mineral suite can furnish clues as to the depositional environments. The mineral composition affects ash fusion temperature, an important characteristic in coal combustion, whereas certain minerals are suspected of having catalytic properties in coal conversion.

This investigation involves the most comprehensive characterization so far undertaken for Alaskan coals. Although interpretations are brief, much of the data will have significance in the interpretation of the environments of deposition of Cape Beaufort coals, as well as their utilization potential.

SAMPLE PREPARATION

Coal samples as received were minus 8 mesh in size. They were first crushed in a disc pulverizer, using coal plates, so as to pass a 20 mesh sieve for petrographic analysis. A sample split was further ground to 60 mesh in a hammermill pulverizer.

Medium Temperature Ash (MTA)

Twenty (20) grams of the pulverized sample was weighed into a quartz combustion boat and oxidized in a tube furnace at 450°C while maintaining a positive flow of air using an aspirator for suction. A 24-hour ashing time was allowed for all samples. After completion of ashing, the combustion boat was weighed and the ash was stored in air-tight plastic bags for atomic absorption and emission spectrochemical analysis.

No problems were encountered in ashing two samples at a time in the combustion tube. A total of 48 samples were ashed for analysis. Table 1 gives weight percent ash at 450°C. This value is different from high temperature ash since it has more undecomposed mineral matter, particularly carbonates, and the sulfur was retained as sulfate.

Low Temperature Ash (LTA)

One gram of 60 mesh sample was ashed in the LTA-302 low temperature asher (LFE Corporation) using plasma excited oxygen at a temperature of less than 150°C. The sample was stirred several times during a 48 hour ashing period. This sample was used for x-ray diffraction and infrared studies.

COAL PETROLOGY

Analytical Procedure

Procedures outlined by ASTM (D2797-72, D2798-72, D2799-72), were followed. Fifty grams of minus 20 mesh coal was kneaded with epoxy resin with enough added to wet the grains, and briquetted in 1 inch diameter moulds with a hydraulic press at 4000 to 5000 PSI. The briquets were polished using a Buehler Automet in the following sequence, 320, 400 and 600 grit silicon carbide paper followed by Linde A (0.3 micron) and Linde B (0.05 micron) aluminum oxide suspensions.

Reflectance Measurements

The polished pellets were dried in a vacuum dessicator prior to reflectance measurements. The reflectance apparatus consists of a Leitz Ortholux microscope with a trinocular body. The vertical tube is attached to a photo multiplier, Model 520 B, manufactured by the Photovolt Corporation, with a 60x objective and an 8x ocular. The ocular is fitted with a laser perforated platinum disc with a 100 micron diameter diaphram opening to measure an area on the specimen of 3.2 microns. An interference filter is fitted over the disc to give a peak transmittance at 546 mμ wave length. Bausch and Lomb Co. optical glasses were used as reflectance standards. Mean maximum reflectance of vitrinite was measured in oil along equally spaced traverses. A total of 100 measurements per sample were made, 50 on each of two pellets.

Determination of Macerals

A Swift point counter was used to count macerals. Five hundred counts were made on each of the two pellets in a 0.3 x 0.4 mm grid to make a total of 1000 counts. The macerals counted were: vitrinite, pseudovitrinite, exinite, resinite, fusinite, semifusinite, macrinite (globular), macrinite inertodetrinite, sclerotinite, pyrite and other inerts with varying reflectances. The other inerts are those that could not be classed under any other inert macerals and are closest to semifusinite in characteristics. The macerals are reported as volume percent, on a mineral matter free basis. The maceral concentrations were also calculated including mineral matter on a volume percent basis. Low temperature ash residue was taken as mineral matter. Densities used in calculating temperature ash were 2.8 gms/cm^3 for mineral matter and 1.35 gms/cm^3 for macerals.

Table 2 shows mean maximum reflectance of vitrinites, ranging from 0.65 to 0.74%.

Table 3 shows petrology of the raw coals. The petrology varies quite widely from seam to seam and also within a seam. For example, No. 7 seam showed lowest inert macerals at the bottom of the seam and increased in concentration towards the top. This trend was consistent with all five locations that No. 7 seam was intersected, showing a gradual change to a drier environment during the formation of the seam. A similar trend is evident for No. 8 seam.

TABLE 2

VITRINITE REFLECTANCE

Drill Hole No.	Seam No.	Sample No.	Vitrinite Types % V_5	V_6	V_7	V_8	V_9	Mean Maximum Reflectance $\bar{R}_{om}$%
2	7	UA-1	2	30	53	15		.73
		UA-2		33	58	9		.72
		UA-3		47	51	2		.70
3	6	UA-4		51	41	8		.71
	7	UA-5		48	51	1		.70
		UA-6		82	15	3		.67
		UA-7		64	36			.68
		UA-8		31	61	8		.73
3C	6	UA-9		33	57	10		.72
	7	UA-10		53	39	8		.71
		UA-12		51	45	4		.70
		UA-14		57	42	1		.69
5	3	UA-16	2	75	23			.67
	4	UA-17	3	87	10			.65
6	1	UA-18		33	63	4		.72
	2	UA-19		46	50	4		.70
		UA-20		34	61	5		.72
7C	7	UA-21	13	53	24	8	2	.68
		UA-23		27	69	4		.73
		UA-25		38	58	4		.72
8		UA-27		33	60	7		.73
8C	8	UA-28		25	66	9		.74
		UA-30		33	61	8		.73
10C	7	UA-32		32	61	7		.73
		UA-34		28	59	13		.73
9	8	UA-36		21	69	10		.74
11	8	UA-37		18	67	15		.74
		UA-38		16	68	16		.74
12	10	UA-39		13	80	7		.74
15	12	UA-40		19	74	7		.74
	13	UA-41		12	77	11		.74
18	26	UA-42		42	51	7		.72
19	16	UA-43	1	36	47	14	2	.73
20	19	UA-44		16	73	11		.74
		UA-45		14	75	11		.74
27	15	UA-46		12	80	8		.74
28	9	UA-47		19	70	11		.74
	10	UA-48		15	76	9		.74

TABLE 3

DISTRIBUTION OF MACERALS IN RAW COALS

Drill Hole No.	Seam No.	Sample No.	Vitrinite	Pseudo-Vitrinite	Exinite	Resinite	Fusinite	Semi-Fusinite	Macrinite (Globular)	Macrinite	Inerto-detrinite	Sclerotinite	Pyrite	Other Inerts	Mineral* Matter
2	7	UA-1	63.9	----	5.4	----	12.4	12.7	----	3.6	1.7	----	0.2	0.1	----
			47.1	----	4.0	----	9.1	9.4	----	2.7	1.2	----	----	0.1	26.4
		UA-2	40.6	22.5	1.3	----	9.0	19.0	2.0	4.7	0.9	----	----	----	----
			30.0	16.6	1.0	----	6.6	14.0	1.5	3.4	0.7	----	----	----	26.2
		UA-3	74.8	2.1	10.3	----	3.5	4.4	----	2.0	2.2	----	0.2	0.5	----
			53.4	1.5	7.4	----	2.5	3.2	----	1.4	1.6	----	----	0.4	28.6
3	6	UA-4	51.2	1.5	9.0	----	5.7	19.9	0.1	5.7	6.6	----	----	0.3	----
			43.0	1.3	7.5	----	4.8	16.7	0.1	4.8	5.5	----	----	0.2	16.1
	7	UA-5	72.2	0.5	2.7	----	8.9	9.9	0.1	2.4	2.6	----	0.1	0.7	----
			67.1	0.5	2.5	----	8.3	9.2	0.1	2.2	2.4	----	----	0.7	7.0
		UA-6	66.9	0.3	10.4	----	9.9	8.2	----	0.7	3.0	----	0.1	0.5	----
			44.7	0.2	7.0	----	6.6	5.5	----	0.5	2.0	----	----	0.3	33.2
		UA-7	75.0	0.4	4.1	----	10.3	6.7	0.1	0.9	2.0	----	----	0.5	----
			63.9	0.3	3.5	----	8.8	5.7	0.1	0.8	1.7	----	----	0.5	14.7
		UA-8	86.9	1.1	4.8	----	3.4	2.9	----	0.3	0.5	----	0.1	----	----
			76.1	1.0	4.2	----	3.0	2.5	----	0.3	0.4	----	----	----	12.5
3C	6	UA-9	14.9	2.0	4.0	0.1	2.9	38.0	----	19.8	18.1	0.2	----	----	----
			12.4	1.7	3.3	0.1	2.4	31.6	----	16.5	15.0	0.2	----	----	16.8
	7	UA-10+11	40.3	7.6	4.8	0.2	6.5	19.3	----	18.3	3.0	----	----	Tr	----
			36.5	6.9	4.2	0.2	5.9	17.5	----	16.6	2.7	----	----	Tr	9.5
		UA-12+13	49.6	11.8	3.0	1.3	13.6	11.6	Tr	5.8	2.5	0.4	----	0.4	----
			44.4	10.6	2.7	1.2	12.2	10.4	Tr	5.2	2.2	0.3	----	0.3	10.5
		UA-14+15	59.6	25.2	3.7	0.2	2.8	6.3	----	1.1	1.1	----	----	Tr	----
			55.8	23.7	3.5	0.2	2.6	5.9	----	1.0	1.0	----	----	Tr	6.3
5	3	UA-16	59.8	17.8	3.0	0.2	7.1	5.2	----	5.3	1.6	----	----	----	----
			54.3	16.2	2.7	0.2	6.4	4.7	----	4.8	1.5	----	----	----	9.2
	4	UA-17	60.1	7.5	2.0	0.6	4.0	14.1	----	9.9	1.7	0.1	----	----	----
			40.0	4.9	1.3	0.4	2.7	9.4	----	6.6	1.1	0.1	----	----	33.5
6	1	UA-18	70.2	7.3	3.7	0.1	1.5	12.2	----	2.4	2.2	0.4	----	----	----
			58.0	6.0	3.1	0.1	1.2	10.1	----	2.0	1.8	0.3	----	----	17.4
	2	UA-19	75.6	0.4	2.6	0.1	3.4	12.1	----	1.6	2.7	0.1	0.1	1.3	----
			67.9	0.4	2.3	0.1	3.0	10.9	----	1.4	2.4	0.1	----	1.3	10.2
	2	UA-20	65.4	4.6	4.2	0.3	8.7	5.2	----	5.6	5.9	0.1	----	----	----
			54.5	3.8	3.5	0.2	7.3	4.3	----	4.7	4.9	0.1	----	----	16.7
7C	7	UA-21+22	62.6	0.7	6.0	----	9.9	13.0	----	2.5	4.3	Tr	----	1.0	----
			57.9	0.6	5.6	----	9.2	12.0	----	2.3	4.0	Tr	----	0.9	7.5
		UA-23+24	73.3	1.6	4.4	0.4	9.2	5.0	0.4	2.3	3.3	----	----	0.1	----
			65.9	1.4	4.0	0.3	8.3	4.5	0.4	2.1	2.9	----	----	0.1	10.1
		UA-25+26	84.3	1.7	5.8	0.2	1.0	4.3	Tr	0.3	2.4	----	----	Tr	----
			77.9	1.6	5.3	0.2	1.0	4.0	Tr	0.3	2.2	----	----	Tr	7.5
8	8	UA-27	68.9	0.7	4.1	0.1	7.7	13.3	0.2	1.0	3.8	0.1	----	0.1	----
			62.4	0.6	3.7	0.1	7.0	12.1	0.2	0.9	3.4	0.1	----	0.1	9.4

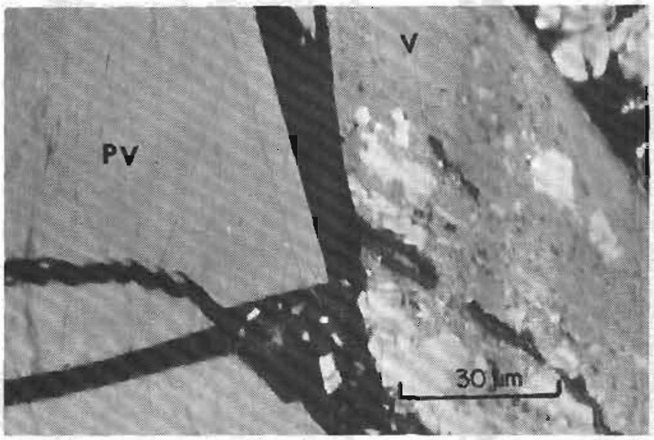
TABLE 3 (Continued)

DISTRIBUTION OF MACERALS IN RAW COALS

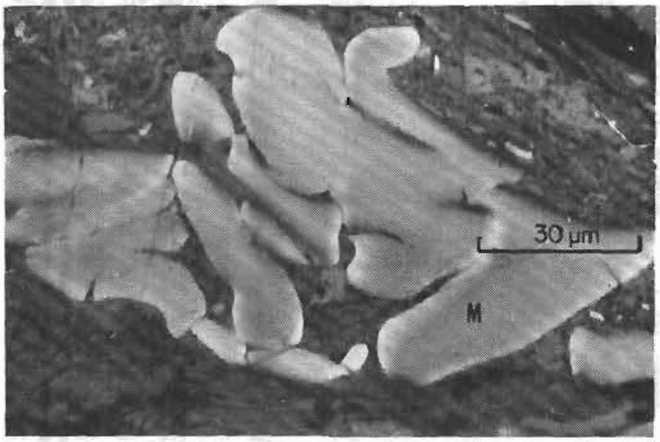
Drill Hole No.	Seam No.	Sample No.	Vitrinite	Pseudo-Vitrinite	Exinite	Resinite	Fusinite	Semi-Fusinite	Macrinite (Globular)	Macrinite	Inerto-detrinite	Sclerotinite	Pyrite	Other Inerts	Mineral* Matter
8C	8	UA-28+29	59.9	0.8	4.4	----	10.5	16.1	0.6	2.6	4.8	Tr	----	0.3	----
			54.3	0.7	4.0	----	9.5	14.6	0.5	2.4	4.3	Tr	----	0.3	9.4
		UA-30+31	78.5	1.0	3.5	----	6.2	5.8	0.2	1.1	1.6	0.1	----	0.1	----
			73.2	0.9	3.3	----	5.9	4.0	0.2	1.0	1.5	0.1	----	0.1	6.7
10C	7	UA-32+33	61.9	1.7	3.9	0.3	10.5	13.8	1.3	2.2	3.4	----	----	1.0	----
			57.6	1.6	3.6	0.3	9.8	12.8	1.2	2.0	3.1	----	----	1.0	7.0
		UA-34+35	74.8	0.3	2.3	0.1	7.0	10.2	0.5	1.3	3.4	----	----	----	----
			68.7	0.3	2.1	0.1	6.4	9.5	0.5	1.2	3.1	----	----	----	8.1
9	8	UA-36	73.9	0.9	3.7	0.4	5.6	10.2	0.1	2.0	1.8	0.1	----	1.3	----
			63.8	0.8	3.2	0.4	4.8	8.8	0.1	1.7	1.5	0.1	----	1.2	13.6
11	8	UA-37	68.0	1.2	1.8	0.3	8.5	12.1	0.3	2.9	3.5	----	----	1.4	----
			61.0	1.1	1.6	0.3	7.6	10.8	0.3	2.6	3.1	----	----	1.3	10.3
		UA-38	90.0	0.8	2.3	----	1.7	2.2	----	1.3	1.3	----	0.1	0.3	----
			82.5	0.7	2.1	----	1.6	2.0	----	1.2	1.2	----	----	0.3	8.4
12	10	UA-39	82.7	0.6	3.6	----	4.8	5.0	----	0.9	1.8	----	----	0.6	----
			73.3	0.5	3.2	----	4.3	4.4	----	0.8	1.6	----	----	0.5	11.4
15	12	UA-40	79.5	0.2	2.6	0.4	4.9	7.6	0.3	1.2	2.2	----	----	0.9	----
			71.0	0.2	2.3	0.4	4.4	6.8	0.3	1.0	2.0	----	----	0.8	10.8
	13	UA-41	76.6	1.2	3.1	----	4.8	9.5	0.3	1.5	2.2	----	----	0.8	----
			68.5	1.1	2.8	----	4.3	8.5	0.3	1.3	2.0	----	----	0.7	10.5
18	26	UA-42	78.6	0.5	8.7	0.1	4.7	2.7	----	0.8	3.6	----	0.3	----	----
			68.9	0.4	7.6	0.1	4.1	2.4	----	0.7	3.2	----	----	----	12.6
19	16	UA-43	77.3	0.6	5.5	----	4.7	8.4	----	1.1	2.1	0.1	----	0.2	----
			73.1	0.6	5.2	----	4.4	7.9	----	1.0	2.0	0.1	----	0.2	5.5
20	19	UA-44	88.2	0.1	2.9	----	3.6	2.9	----	0.5	1.2	----	0.2	0.4	----
			64.2	0.1	2.1	----	2.6	2.1	----	0.4	0.9	----	----	0.3	27.3
		UA-45	95.8	0.2	0.7	----	0.6	1.1	----	0.2	1.0	----	0.4	----	----
			57.9	0.1	0.4	----	0.4	0.7	----	0.1	0.6	----	----	----	39.8
27	15	UA-46	89.1	0.4	1.5	----	1.8	4.7	----	0.5	1.5	----	0.1	0.4	----
			85.8	0.4	1.4	----	1.7	4.5	----	0.5	1.4	----	----	0.4	3.9
28	9	UA-47	79.1	0.2	3.4	0.2	2.9	7.9	----	3.3	2.3	----	----	0.7	----
			70.2	0.2	3.0	0.2	2.6	7.0	----	2.9	2.0	----	----	0.7	11.2
	10	UA-48	83.1	0.3	4.7	----	4.7	3.7	----	1.1	1.7	----	----	0.7	----
			72.8	0.3	4.1	----	4.1	3.2	----	1.0	1.5	----	----	0.6	12.4

Tr - Trace
* - Includes Pyrite

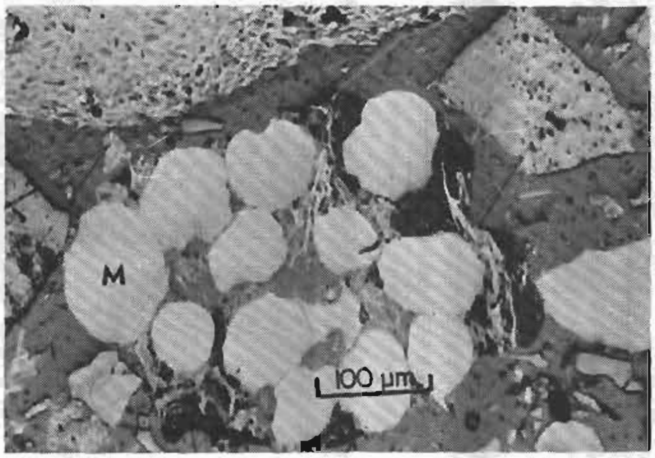
Figures 4 and 5 are photomicrographs showing the nature and association of various macerals. The coals in general did not have true micrinite as defined by Stach (1976). Many seams were high in pseudovitrinite, fusinite, semifusinite and other non-coking inerts, and this explains the low freeswelling indexes of these coals tested. Samples that gave a freeswelling index of 3 or more had in excess of 80% reactive macerals (vitrinite + exnite + resinite). Another interesting feature is the presence of macrinite, in globules, generally 40-120 microns in diameter (Figure 4C) (80 microns average diameter). Globular macrinite has been found only in seam Nos. 7, 8, 12 and 13, indicative of specific environments conducive to its formation. Although spherical shape is the most common, in a few cases it is found as irregular shapes but always with rounded edges (Figure 4B). It has high relief and generally has a variable reflectance which approaches that of fusinite. Because of its unique characteristics it is counted as a separate maceral and is tabulated as macrinite, globular. It is likely that this maceral could be used in correlating coal seams. Petrology of sink-float fractions, presented in Table 4, shows a higher concentration of fusinite in sinks than in floats due to the higher density of fusinite and the filling of cell cavities with carbonates and clay minerals (Figure 5 C, D, E and F).



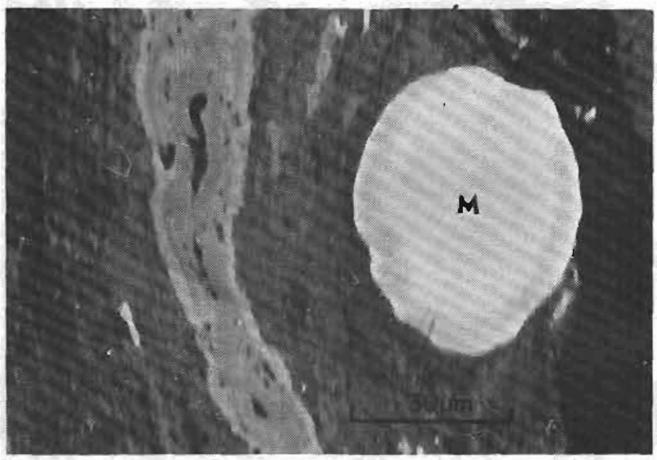
A. Pseudovitrinite (PV) showing higher reflectance than vitrinite (V) (UA-12)



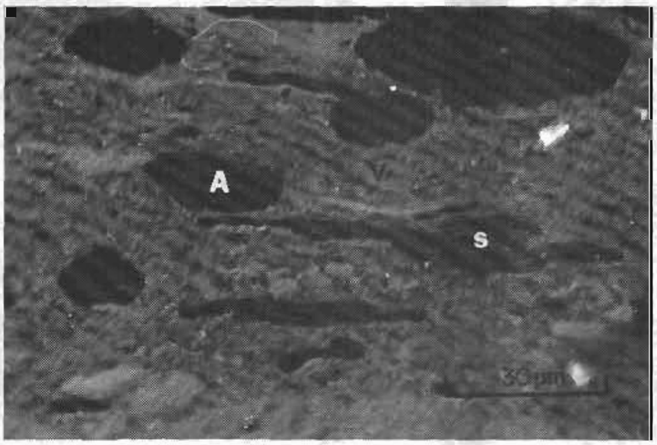
B. Macrinite (M) showing irregular shape and sharp edges (UA-12)



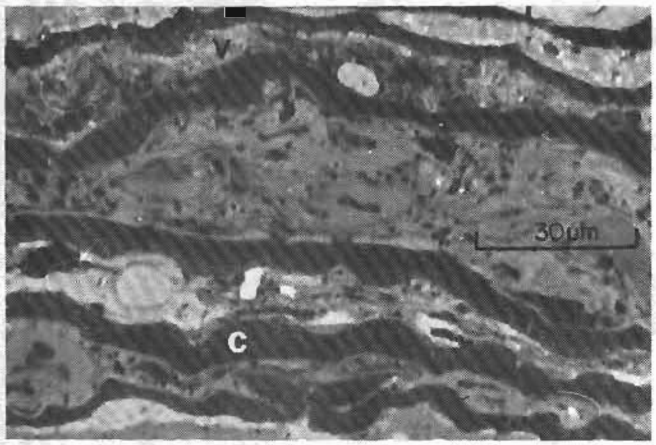
C. Typical aggregate of macrinite (M) globules with transition to fusinite (UA-33)



D. An isolated macrinite (M) globule showing oxidation rim and differential compaction (UA-2)

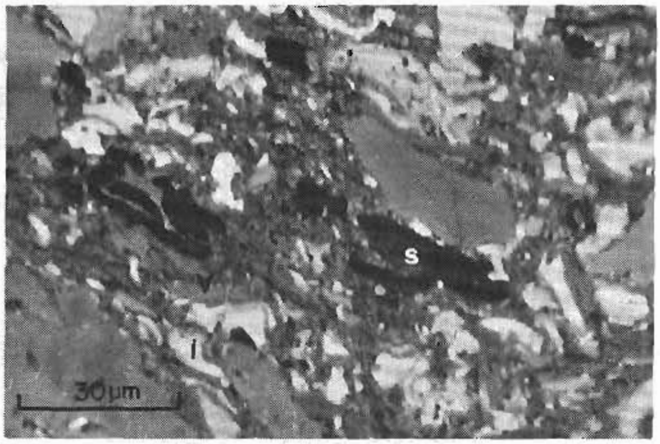


E. Alginite (A) and sporinite (S) embedded in vitrinite (V) (UA-10)

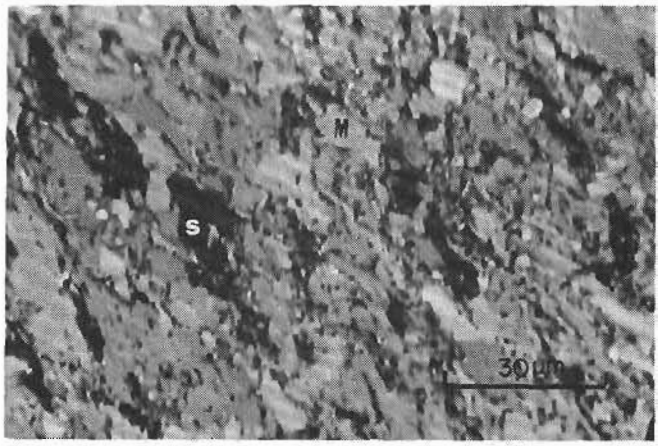


F. Cutinite (C) embedded in vitrinite (V) (UA-2)

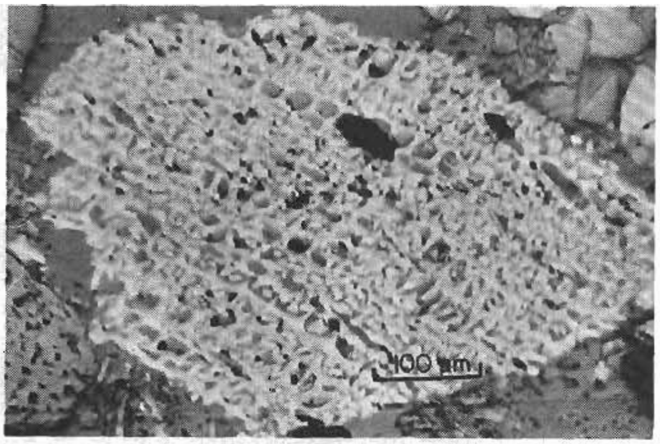
Figure 4. Photomicrographs of Cape Beaufort coals showing various macerals, reflected light, C--air, and all others oil immersion.



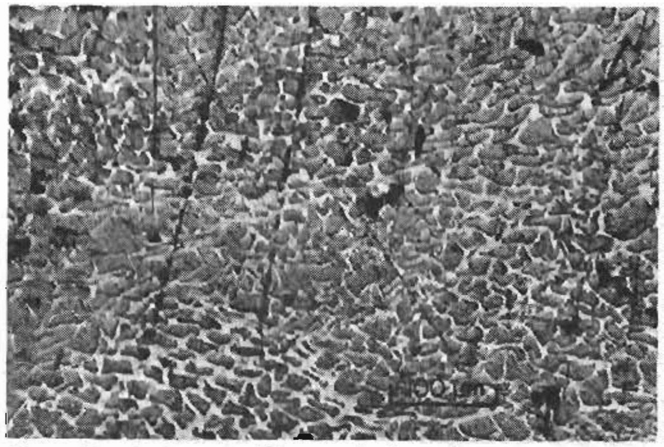
A. Trimacerite showing Inertodetrinite(I) Vitrinite (V) and sporinite (S) (UA-2)



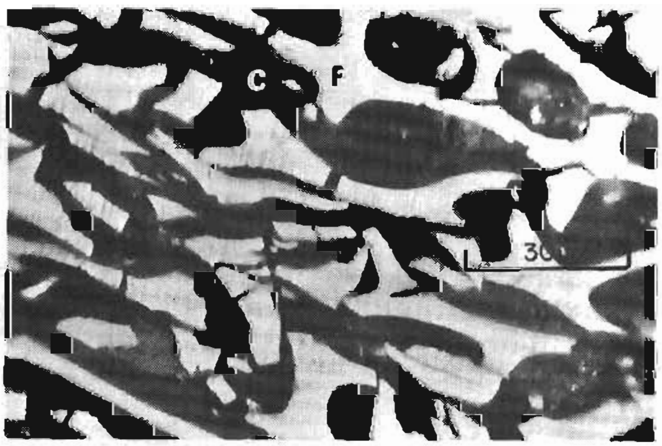
B. Inertodetrinite, essentially fine-grained macrinite (M) with varying reflectance and embedded spores (S) (UA-2)



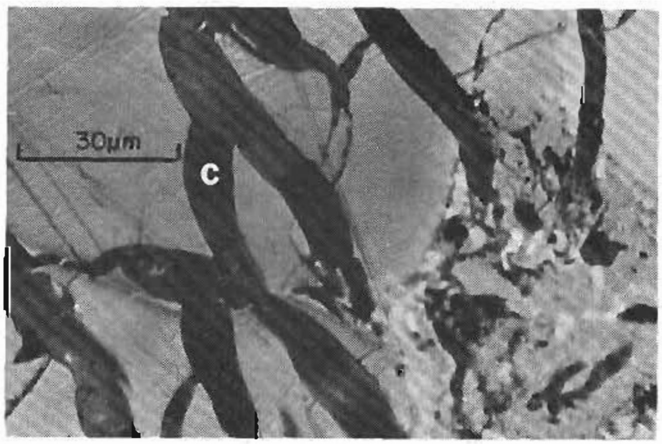
C. Fusinite cell cavities filled with carbonate (UA-33)



D. Fusinite cell cavities impregnated with clay minerals (UA-33)



E. Fusinite (F) with bogen structure impregnated with carbonate (C) (UA-29)



F. Carbonate (C) filling fissures (UA-29)

Figure 5. Photomicrographs of Cape Beaufort coals showing various macerals and associated minerals, reflected light, C and D air, all others oil immersion.

TABLE 4

DISTRIBUTION OF MACERALS IN SINK-FLOAT FRACTIONS

Drill Hole No.	Seam No.	Sample No.	Product	Vitrinite	Pseudo-Vitrinite	Exinite	Resinite	Fusinite	Semi-Fusinite	Macrinite (Globular)	Macrinite	Inerto-detrinite	Sclerotinite	Pyrite	Other Inerts	Mineral* Matter
3C	7	UA-10	Float	37.8	9.0	3.0	0.2	6.4	19.0	----	21.8	2.8	----	----	----	----
				35.9	8.6	2.8	0.2	6.1	18.1	----	20.7	2.7	----	----	----	4.9
		UA-11	Sink	51.5	1.4	12.9	----	7.0	20.6	----	2.5	3.9	----	----	0.2	----
				38.1	1.0	9.5	----	5.2	15.2	----	1.8	2.9	----	----	0.2	26.1
		UA-10+11	Recomb.	40.3	7.6	4.8	0.2	6.5	19.3	----	18.3	3.0	----	----	Tr	----
				36.5	6.9	4.2	0.2	5.9	17.5	----	16.6	2.7	----	----	Tr	9.5
		UA-12	Float	50.2	13.6	2.5	1.5	10.6	11.9	----	6.5	2.7	0.5	----	----	----
				47.3	12.8	2.4	1.4	10.0	11.2	----	6.1	2.5	0.5	----	----	5.8
		UA-13	Sink	46.3	1.1	6.0	----	30.8	9.7	0.3	1.6	1.7	0.1	0.1	2.3	----
				32.0	0.8	4.2	----	21.3	6.7	0.2	1.1	1.2	0.1	----	1.6	30.8
		UA-12+13	Recomb.	49.6	11.8	3.0	1.3	13.6	11.6	Tr	5.8	2.5	0.4	----	0.4	----
				44.4	10.6	2.7	1.2	12.2	10.4	Tr	5.2	2.2	0.3	----	0.3	10.5
		UA-14	Float	59.5	26.1	3.4	0.2	2.2	6.4	----	1.1	1.1	----	----	----	----
				57.7	25.3	3.3	0.2	2.1	6.2	----	1.1	1.1	----	----	----	3.0
		UA-15	Sink	61.0	0.6	12.5	----	19.4	3.5	----	1.3	1.4	----	0.2	0.1	----
				30.3	0.3	6.2	----	9.6	1.7	----	0.7	0.8	----	----	0.1	50.3
		UA-14+15	Recomb.	59.6	25.2	3.7	0.2	2.8	6.3	----	1.1	1.1	----	----	Tr	----
				55.8	23.7	3.5	0.2	2.6	5.9	----	1.0	1.0	----	----	Tr	6.3
7C	7	UA-21	Float	63.2	0.6	5.8	----	8.9	13.4	----	2.6	4.5	----	----	1.0	----
				59.9	0.6	5.5	----	8.4	12.7	----	2.5	4.3	----	----	1.0	5.1
		UA-22	Sink	54.9	1.5	8.1	----	23.4	8.1	----	0.9	2.2	0.1	----	0.8	----
				38.2	1.0	5.6	----	16.3	5.6	----	0.6	1.5	0.1	----	0.6	30.5
		UA-21+22	Recomb.	62.6	0.7	6.0	----	9.9	13.0	----	2.5	4.3	Tr	----	1.0	----
				57.9	0.6	5.6	----	9.2	12.0	----	2.3	4.0	Tr	----	0.9	7.5
		UA-23	Float	75.2	1.5	4.4	0.4	7.5	4.8	0.4	2.4	3.3	----	0.1	----	----
				70.4	1.4	4.1	0.4	7.0	4.5	0.4	2.2	3.1	----	----	----	6.5
		UA-24	Sink	56.4	1.8	4.7	0.3	22.5	7.2	0.8	1.6	3.5	----	0.3	0.9	----
				39.0	1.2	3.3	0.2	15.5	5.0	0.6	1.1	2.4	----	----	0.6	31.1
		UA-23+24	Recomb.	73.3	1.6	4.4	0.4	9.2	5.0	0.4	2.3	3.3	----	----	----	----
				65.9	1.4	4.0	0.3	8.3	4.5	0.4	2.1	2.9	----	----	0.1	10.1
		UA-25	Float	84.7	1.7	5.7	0.2	0.8	4.2	----	0.3	2.4	----	----	----	----
				81.5	1.6	5.5	0.2	0.8	4.0	----	0.3	2.3	----	----	----	3.8
		UA-26	Sink	71.4	0.2	7.5	0.1	8.5	9.1	0.1	0.9	1.3	----	0.7	0.2	----
				----	----	----	----	----	----	----	----	----	----	----	----	----
		UA-25+26	Recomb.	84.3	1.7	5.8	0.2	1.0	4.3	Tr	0.3	2.4	----	----	Tr	----
				77.9	1.6	5.3	0.2	1.0	4.0	Tr	0.3	2.2	----	----	Tr	7.5
8C	8	UA-28	Float	62.4	0.6	4.7	0.1	8.6	15.2	0.7	2.7	4.9	----	----	0.1	----
				59.3	0.6	4.5	0.1	8.2	14.4	0.7	2.6	4.6	----	----	0.1	5.0
		UA-29	Sink	46.1	1.7	2.3	----	21.2	20.7	0.3	2.3	4.2	0.1	----	1.1	----
				33.3	1.2	1.7	----	15.3	15.0	0.2	1.7	3.0	0.1	----	0.7	27.8
		UA-28+29	Recomb.	59.9	0.8	4.4	----	10.5	16.1	0.6	2.6	4.8	Tr	----	0.8	----
				54.3	0.7	4.0	----	9.5	14.6	0.5	2.4	4.3	Tr	----	0.3	9.4
		UA-30	Float	79.3	1.1	3.6	0.3	5.5	7.7	0.2	0.9	1.2	0.1	----	0.1	----
				76.1	1.0	3.4	0.3	5.3	7.4	0.2	0.9	1.2	0.1	----	0.1	4.0
		UA-31	Sink	66.7	0.2	1.5	----	16.0	5.8	0.2	3.2	6.2	0.1	----	----	----
				45.9	0.2	1.0	----	11.0	4.0	0.2	2.2	4.3	0.1	----	----	31.1
		UA-30+31	Recomb.	78.5	1.0	3.5	----	6.2	5.8	0.2	1.1	1.6	0.1	----	0.1	----
				73.2	0.9	3.3	----	5.9	4.0	0.2	1.0	1.5	0.1	----	0.1	6.7

TABLE 4 (Continued)

DISTRIBUTION OF MACERALS IN SINK-FLOAT FRACTIONS

Drill Hole No.	Seam No.	Sample No.	Product	Vitrinite	Pseudo-Vitrinite	Exinite	Resinite	Fusinite	Semi-Fusinite	Macrinite (Globular)	Macrinite	Inerto-detrinite	Sclerotinite	Pyrite	Other Inerts	Mineral* Matter
10C	7	UA-32	Float	63.8	1.6	4.0	0.3	9.4	13.5	1.2	2.3	3.4	----	----	0.5	----
				61.1	1.5	3.8	0.3	9.0	12.9	1.2	2.2	3.3	----	----	0.5	4.2
		UA-33	Sink	41.3	3.2	2.7	0.1	21.9	17.0	2.0	1.7	3.4	----	1.0	6.6	----
				29.1	2.3	1.9	0.1	15.4	12.0	1.4	1.2	2.4	----	----	4.7	29.5
		UA-32+33	Recomb.	61.9	1.7	3.9	0.3	10.5	13.8	1.3	2.2	3.4	----	----	1.0	----
				57.6	1.6	3.6	0.3	9.8	12.8	1.2	2.0	3.1	----	----	1.0	7.0
		UA-34	Float	76.9	0.2	2.0	0.1	5.8	10.2	0.5	1.2	3.1	----	----	----	----
				72.9	0.2	1.9	0.1	5.5	9.7	0.5	1.1	2.9	----	----	----	5.2
		UA-35	Sink	44.7	2.0	6.9	0.5	24.3	10.9	0.3	2.9	7.0	----	----	0.5	----
				30.7	1.4	4.7	0.3	16.7	7.5	0.2	2.0	4.8	----	----	0.3	31.4
		UA-34+35	Recomb.	74.8	0.3	2.3	0.1	7.0	10.2	0.5	1.3	3.4	----	----	----	----
				68.7	0.3	2.1	0.1	6.4	9.5	0.5	1.2	3.1	----	----	----	8.1

Tr - Trace
* - Includes Pyrite

MINERALOGY OF THE COALS

X-Ray Diffraction Analyses of Low Temperature Ash

An internal standard method recommended by Rao and Gluskoter (1973) was used for the quantitative analysis of minerals in low temperature ash. A Phillips Norelco X-ray diffraction system with CuKα Ni-filtered radiation at 40 Kv, 15 ma was used.

Mineral matter residue obtained from low-temperature ashing was first ground in an agate mortar to minus 200 mesh. As an internal standard, 0.02 grams of finely powdered pure fluorite was added to 0.1 gram of sample, and mixed with a spatula on a weighing paper, followed by mechanical mixing in a stainless vial with a stainless ball, using a Spec mixer for 1 minute.

The back-packed cavity mount technique described by Rao and Gluskoter (1973) was used in order to avoid orientation of powdered grains along the preferred cleavage faces of minerals.

A preliminary scan of the 48 samples from 2° to 60° (2θ) revealed that the minerals in the samples were quartz, calcite, dolomite, plagioclase, siderite, analcime, kaolinite, illite, and montmorillonite. Two series of standard mixes were prepared. The first set (Standard QCD) of standards consisted of quartz, calcite and dolomite, and the second set (Standard PSA), of plagioclase, siderite and analcime.

An internal standard of 0.2 grams of fluorite powder, and a clay mixture diluent containing equal amounts of kaolinite, montmorillonite, and illite were added to the series of standard mixes (Tables 5 and 6). The standard mixes were pulverized in a stainless steel vial in a spec mixer for 20 minutes to obtain optimum grain size. The mounted standards were x-rayed from 14° to 34° 2θ with a scanning speed of 1/2 degree per minute and a chart speed of 1/4 inch per minute for accurate peak-height. Peak-height intensities of each mineral were measured in recorded chart units with 500 counts full scale. The reflections of minerals used for peak-height measurements were quartz (101) calcite (104), dolomite (104), siderite (104) analcime (400), plagioclase (002;040), and fluorite (111). Three mounts were prepared for each standard mix and each mount was x-rayed twice. The average value from the six patterns were used for the calibration curves.

The calibration curves of quartz, calcite, dolomite, plagioclase, siderite, and analcime are constructed by plotting the respective peak-height intensity ratios of these minerals with fluorite as the ordinate and grams of the respective minerals per 0.2 grams of fluorite as the abscissa (Figures 6, 7, 8, 9, 10 and 11).

Identical settings of x-ray diffractometer and recorder are used for samples and standards. Percentages of the minerals are obtained by referring directly to their respective calibration curves using internal standard sample peak-height ratios.

TABLE 5

PREPARATION OF STANDARDS AND CALIBRATION CURVES FOR PLAGIOCLASE, SIDERITE AND ANALCIME FOR ANALYSIS BY X-RAY DIFFRACTION

	Weight of Minerals In Standard Mixture, gms.					Weight Percent of Minerals in Standard Mixture			Peak Height Ratio		
Mixture Number	Plagioclase P	Siderite S	Analcime A	Fluorite F	Clay Mineral Mixture	Plagioclase	Siderite	Analcime	H_P/H_F	H_S/H_F	H_A/H_F
PSA-1	0	0.40	0.40	0.20	0.80	0	40	40	0	1.96	0.97
PSA-2	0.04	0.36	0.36	0.20	0.76	4	36	36	0.08	1.77	0.87
PSA-3	0.08	0.32	0.32	0.20	0.72	8	32	32	0.17	1.57	0.77
PSA-4	0.12	0.28	0.28	0.20	0.68	12	28	28	0.25	1.37	0.68
PSA-5	0.16	0.24	0.24	0.20	0.64	16	24	24	0.34	1.18	0.58
PSA-6	0.20	0.20	0.20	0.20	0.60	20	20	20	0.42	0.98	0.48
PSA-7	0.24	0.16	0.16	0.20	0.56	24	16	16	0.51	0.79	0.38
PSA-8	0.28	0.12	0.12	0.20	0.52	28	12	12	0.59	0.58	0.29
PSA-9	0.32	0.08	0.08	0.20	0.48	32	8	8	0.67	0.38	0.19
PSA-10	0.36	0.04	0.04	0.20	0.44	36	4	4	0.76	0.20	0.97
PSA-11	0.40	0	0	0.20	0.40	40	0	0	0.84	0	0

* Diluent - A mixture of Montmorillonite, Kaolinite and Illite in equal parts.

TABLE 6

PREPARATION OF STANDARDS AND CALIBRATION CURVES FOR QUARTZ, CALCITE AND DOLOMITE FOR ANALYSIS BY X-RAY DIFFRACTION

	Weight of Minerals in Standard Mixture gms.					Weight Percent of Minerals in Standard Mixture			Peak Height Ratio		
Mixture Number	Quartz Q	Calcite C	Dolomite D	Fluorite F	Clay Mineral Mixture*	Quartz	Calcite	Dolomite	H_Q/H_F	H_C/H_F	H_D/H_F
QCD-1	0.40	0	0.40	0.20	0.80	40	0	40	3.50	0	1.71
QCD-2	0.36	0.04	0.36	0.20	0.76	36	4	36	2.74	0.17	1.54
QCD-3	0.32	0.08	0.32	0.20	0.72	32	8	32	2.44	0.34	1.37
QCD-4	0.28	0.12	0.28	0.20	0.68	28	12	28	2.14	0.50	1.20
QCD-5	0.24	0.16	0.24	0.20	0.64	24	16	24	1.84	0.67	1.03
QCD-6	0.20	0.20	0.20	0.20	0.60	20	20	20	1.53	0.84	0.86
QCD-7	0.16	0.24	0.16	0.20	0.56	16	24	16	1.23	1.00	0.69
QCD-8	0.12	0.28	0.12	0.20	0.52	12	28	12	0.93	1.17	0.52
QCD-9	0.08	0.32	0.08	0.20	0.48	8	32	8	0.62	1.34	0.34
QCD-10	0.04	0.36	0.04	0.20	0.44	4	36	4	0.31	1.51	0.17
QCD-11	0	0.40	0	0.20	0.40	0	40	0	0	1.68	0

* Diluent - A mixture of montmorillonite, kaolinite and illite in equal parts.

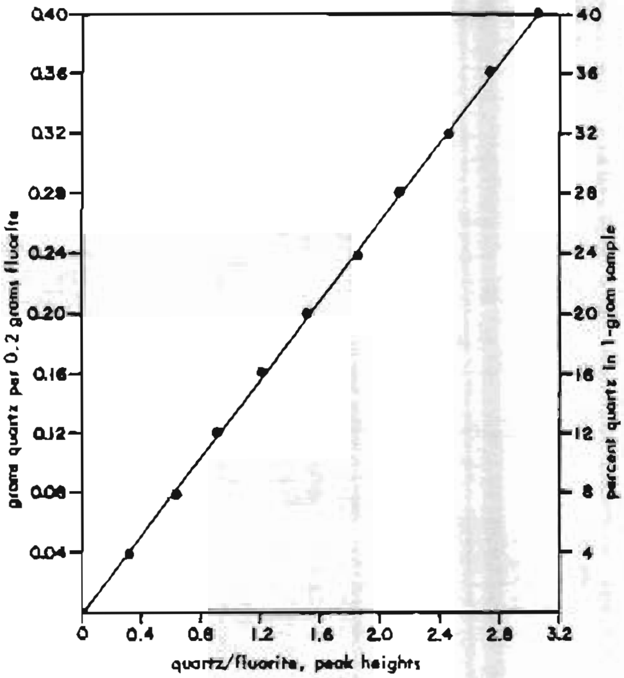


Figure 6 Quartz-fluorite calibration curve

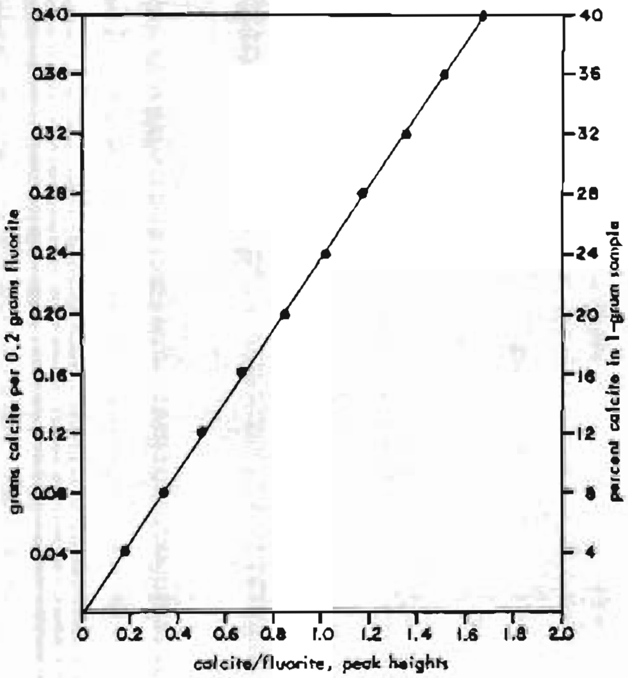


Figure 7 Calcite-fluorite calibration curve

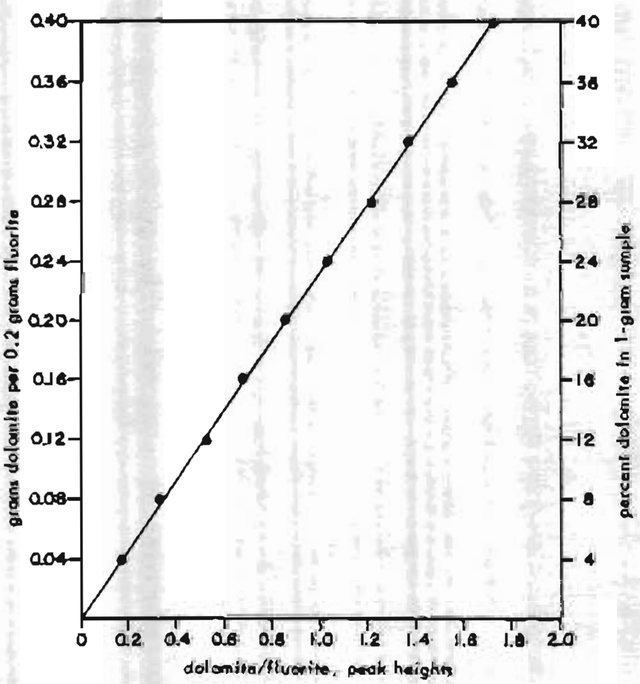


Figure 8 Dolomite-fluorite calibration curve

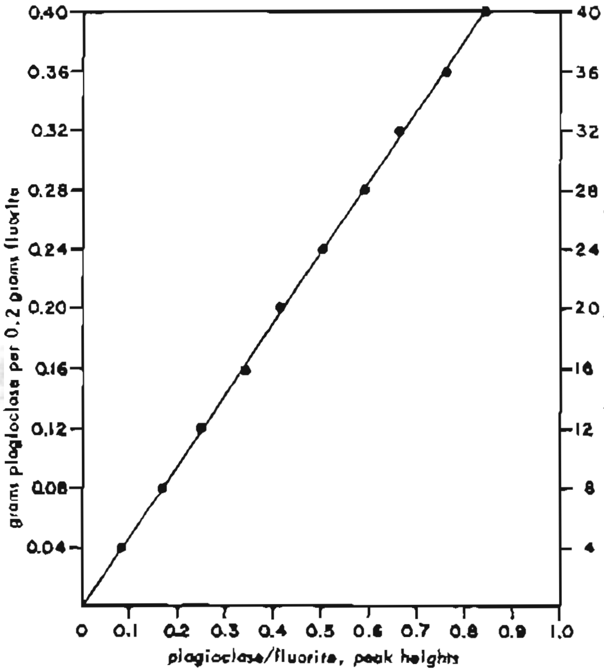


Figure 9 Plagioclase-fluorite calibration curve

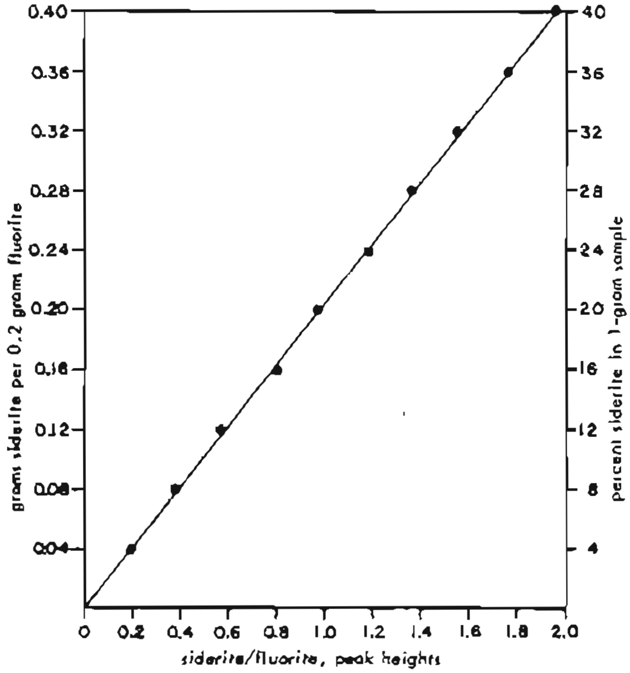


Figure 10 Siderite-fluorite calibration curve

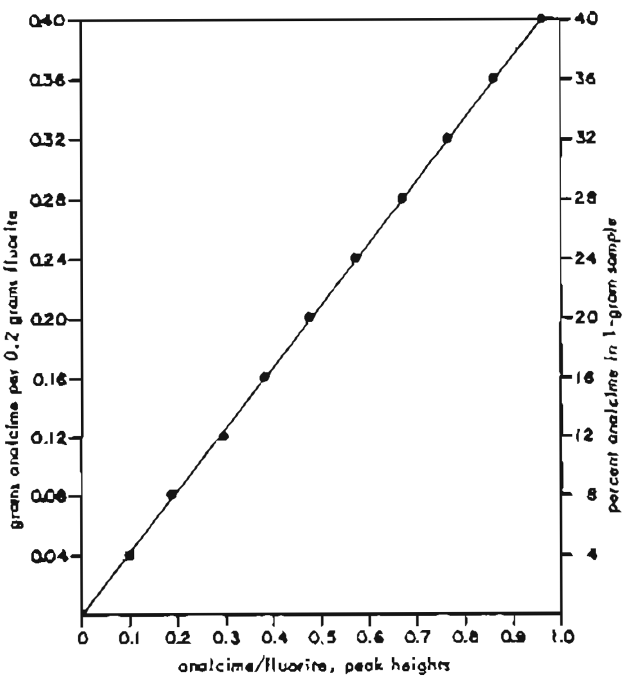


Figure 11 Analcime-fluorite calibration curve

Infrared spectrographic determination of kaolinite

Procedures described by O'Gorman and Walker (1972) and Gong and Suhr (personal comm.) were used. Kaolinite used for the preparation of standards was pulverized wet in an agate mortor and the minus 2 μ fraction separated by sedimentation. LTA samples were pulverized in an agate mortor wetted with ethanol. 1 mg sample or standard was mixed with 200 mg of KBr and pelletized in an evacuated die with pressure maintained at 10 tons/sq. inch for 10 seconds. The pellets were scanned using a Perkin-Elmer model 467 double beam grating infrared spectrophotometer. Kaolinite is determined using the 910 cm -1 peak. Standard curves were drawn of absorbance vs concentration of kaolinite, and these gave an excellent straight line relationship. The baseline method (O'Gorman and Walker, 1972) was used. The baseline is obtained by connecting the background lows on either side of the peak by a straight line. Absorbance A is calculated as follows from the transmittance spectram:

$$A = -\log t = -\log \frac{\text{reading at peak}}{\text{reading at baseline at same wavelength as peak}}$$

"The total other clays" (i.e. montmorillonite and illite and mixed layer clays) is calculated from mineralogical and chemical analysis (Gong and Suhr, per. comm.) as 2 times the remaining SiO_2, calculated as follows:

$$SiO_2 \text{ remaining} = SiO_2 \text{ in LTA} - \left[(\text{Kaolinite} \times 0.465) + (\text{Analcime} \times 0.546) + (\text{plagioclase} \times 0.687) + \text{quartz}\right]$$

$$\text{Total other clays} = SiO_2 \text{ remaining} \times 2.$$

The mineralogy of the coals is shown in Table 7. Clay minerals are by far the most abundant in the samples. All samples contained kaolinite. As can be seen in the section (Figure 3) the coal seams 1 through 8 are separated by more than 1600 feet from seams 9 through 20. Analcine was found only in the top portion; in particular, seams 7 and 8, and none in the bottom portions. Mineral assemblage is determined by the chemical environment of the original peat bog. Phase equilibrium studies by Kurt Linn (Blatt et al '72) showed that at room temperature and atmospheric pressure the formation of albite-analcime-montmorillonite and kaolinite are determined by the concentration of silicic acid and sodium and hydrogenions. For example, the formation of analcime is favored by a high sodium ion concentration, an alkaline pH, and an intermediate concentration of silicic acid. A decrease in pH favors the formation of sodium montmorillonite and finally kaolinite. An increase in silicic acid concentration favors formation of albite. Further lowering of the silicic acid concentration favors the formation of gibbsite. From the fact that analcime is limited to seams in the top section it appears that the environment favored its formation. Mineralogy could give clues to the depositional environment of the swamp as do the macerals themselves. Of the carbonates, dolomite is the most abundant followed by calcite and siderite. Distribution of minerals in the sink-float fractions (Table 8) shows no preferential association of calcite and dolomite with sinks or floats. Siderite however shows a

TABLE 7

DISTRIBUTION OF MINERALS IN THE LOW TEMPERATURE ASH OF RAW COALS

Drill Hole No.	Seam No.	Sample No.	Quartz	Calcite	Dolomite	Siderite	Plagioclase	Analcime	Kaolinite	Other Clays	Fusibility of Ash Temperature, °F Initial Deformation	Softening	Fluid
2	7	UA-1	26	1	3	0	6	7	8	50			
	7	UA-2	25	2	3	0	7	6	5	54	2300	2350	2550
	7	UA-3	17	1	1	0	5	0	16	60	2430	2480	2580
3	6	UA-4	4	3	4	0	0	0	51	32			
	7	UA-5	4	9	8	2	0	2	7	50			
	7	UA-6	12	0	4	0	11	4	7	60			
	7	UA-7	18	3	3	1	5	5	8	66			
	7	UA-8	18	4	3	0	0	0	19	58			
3C	6	UA-9	3	3	3	1	0	0	38	34			
	7	UA-10+11	4	2	6	1	2	2	31	41			
	7	UA-12+13	21	4	4	1	2	9	10	47			
	7	UA-14+15	4	6	6	1	2	0	20	38			
5	3	UA-16	8	4	6	0	0	0	10	31	2250	2300	2350
	4	UA-17	17	0	4	5	0	0	11	57	2180	2240	2350
6	1	UA-18	3	1	1	0	5	0	22	49			
	2	UA-19	21	5	8	6	0	0	10	29			
	2	UA-20	8	0	1	0	0	0	24	34	2680	2760	2840
7C	7	UA-21+22	8	7	8	1	0	3	19	27			
	7	UA-23+24	21	4	3	1	2	5	11	28			
	7	UA-25+26	5	5	3	1	2	0	21	58			
8	8	UA-27	1	7	11	1	2	5	23	30			
8C	8	UA-28+29	2	4	18	2	0	5	20	47			
	8	UA-30+31	1	3	12	1	0	5	9	46			
10C	7	UA-32+33	6	3	6	1	0	3	21	46			
	7	UA-34+35	16	4	3	2	0	6	14	52			
9	8	UA-36	5	3	9	1	4	7	30	33			
11	8	UA-37	7	4	11	0	0	10	18	46			
	8	UA-38	16	3	3	2	0	7	18	27			
12	10	UA-39	2	3	4	0	0	0	19	56	2320	2370	2430
15	12	UA-40	13	2	3	0	4	0	18	43	2300	2360	2420
	13	UA-41	25	1	3	0	10	0	20	27	2230	2280	2380
18	26	UA-42	10	2	4	0	5	0	15	47	2680	2730	2790

0 - Not Detected

TABLE 7 (Continued)

DISTRIBUTION OF MINERALS IN THE LOW TEMPERATURE ASH OF RAW COALS

Drill Hole No.	Seam No.	Sample No.	Quartz	Calcite	Dolomite	Siderite	Plagioclase	Analcime	Kaolinite	Other Clays	Fusibility of Ash Temperature, °F Initial Deformation	Softening	Fluid
19	16	UA-43	8	7	12	2	0	0	11	33	2090	2140	2190
20	19	UA-44	18	0	0	0	0	0	14	61	2910+		
	19	UA-45	14	0	0	0	0	0	15	63	2910+		
27	15	UA-46	36	8	28	4	12	0	4	0	2100	2150	2250
28	9	UA-47	14	4	10	0	9	0	28	25	2720	2780	2910+
	10	UA-48	22	6	9	1	14	0	22	2	2420	2470	2520

0 - Not Detected

TABLE 8

DISTRIBUTION OF MINERALS IN THE LOW TEMPERATURE ASH OF SINK-FLOAT FRACTIONS

Drill Hole No.	Seam No.	Sample No.	Product	Quartz	Calcite	Dolomite	Siderite	Plagioclase	Analcime	Kaolinite	Other Clays	Fusibility of Ash Temperature, °F Initial Deformation	Softening	Fluid
3C	7	UA-10	Float	3	3	8	2	4	5	21	34	2340	2390	2440
		UA-11	Sink	4	2	5	1	0	0	38	45	2770	2820	2870
		UA-10+11	Recomb.	4	2	6	1	2	2	31	41			
		UA-12	Float	15	2	3	2	0	8	13	51	2320	2420	2680
		UA-13	Sink	26	5	5	1	3	9	7	43	2240	2310	2570
		UA-12+13	Recomb.	21	4	4	1	2	9	10	47			
		UA-14	Float	2	7	9	2	0	0	8	30	2200	2260	2360
		UA-15	Sink	5	6	4	0	4	0	30	45	2660	2710	2760
		UA-14+15	Recomb.	4	6	6	1	2	0	20	38			
7C	7	UA-21	Float	5	4	7	2	0	4	23	24			
		UA-22	Sink	12	13	9	0	0	0	13	32			
		UA-21+22	Recomb.	8	7	8	1	0	3	19	27			
		UA-23	Float	17	4	3	1	0	5	13	44			
		UA-24	Sink	28	4	4	0	4	5	9	9			
		UA-23+24	Recomb.	21	4	3	1	2	5	11	28			
		UA-25	Float	2	6	6	2	0	0	10	71			
		UA-26	Sink	7	4	1	0	3	0	31	47			
		UA-25+26	Recomb.	5	5	3	1	2	0	21	58			
8C	8	UA-28	Float	1	3	12	0	0	6	23	46	2410	2460	2510
		UA-29	Sink	3	5	22	Tr	0	5	17	49	2250	2300	2350
		UA-28+29	Recomb.	2	4	18	Tr	0	5	20	47			
		UA-30	Float	1	2	9	2	0	4	11	42	2380	2430	2480
		UA-31	Sink	2	6	15	1	0	7	6	51	2200	2250	2350
		UA-30+31	Recomb.	1	3	12	2	0	5	9	46			
10C	7	UA-32	Float	3	2	6	2	0	4	24	40			
		UA-33	Sink	10	4	7	0	0	2	18	53			
		UA-32+33	Recomb.	6	3	6	1	0	3	21	46			
		UA-34	Float	13	2	3	2	0	5	15	56			
		UA-35	Sink	19	6	4	1	0	9	12	48			
		UA-34+35	Recomb.	16	4	3	2	0	6	14	52			

Tr - Trace
0 - Not Detected

consistently higher concentration in floats than sinks. Concentration of quartz is higher in sink ash than in float ash. Plagioclase is quite common in the ashes and has been detected in half the samples. Of the five samples containing plagioclase four showed preferential association with the sinks.

Fusibility of Ash

It is generally recognized that ash fusion temperature is a function of ash composition. The ash fusion temperature is lowered by the presence of the oxides of iron, calcium and magnesium, sodium and potassium. Iron oxide has the highest influence on the ash fusion temperatures. The coals under study, as is the case with all Alaskan coals, are low in total sulfur, and only have traces of pyrite. The ash therefore has a low iron content. The ash fusion temperature of these coals is primarily dictated by the lime and magnesia content of the coal ash, contributed by calcite and dolomite in the coal. As can be seen from Table 7, the maximum initial deformation temperature of 2910°F is obtained from the samples UA-44 and 45, that have no carbonates. Sample No. UA-43 with 21% carbonates gave the lowest initial deformation temperature of 2090°F. Table 8 shows ash fusion temperatures for sink-float fractions. The difference in ash fusion temperatures of sink and float products can be readily attributed to the carbonate content. For example, UA-10, the float product with 13% carbonates has a lower ash fusion temperature compared to UA-11, the sink product, which contains 8% carbonates. On the other hand UA-28, a float product with 15% carbonates, has a higher ash fusion temperature compared to UA-29 which has 27% carbonates. An understanding of the mineralogy of coals, in contrast to major oxide composition alone, plays a significant role in interpreting the ash fusion temperatures for Alaskan coals.

DETERMINATION OF CHEMICAL COMPOSITION OF ASH

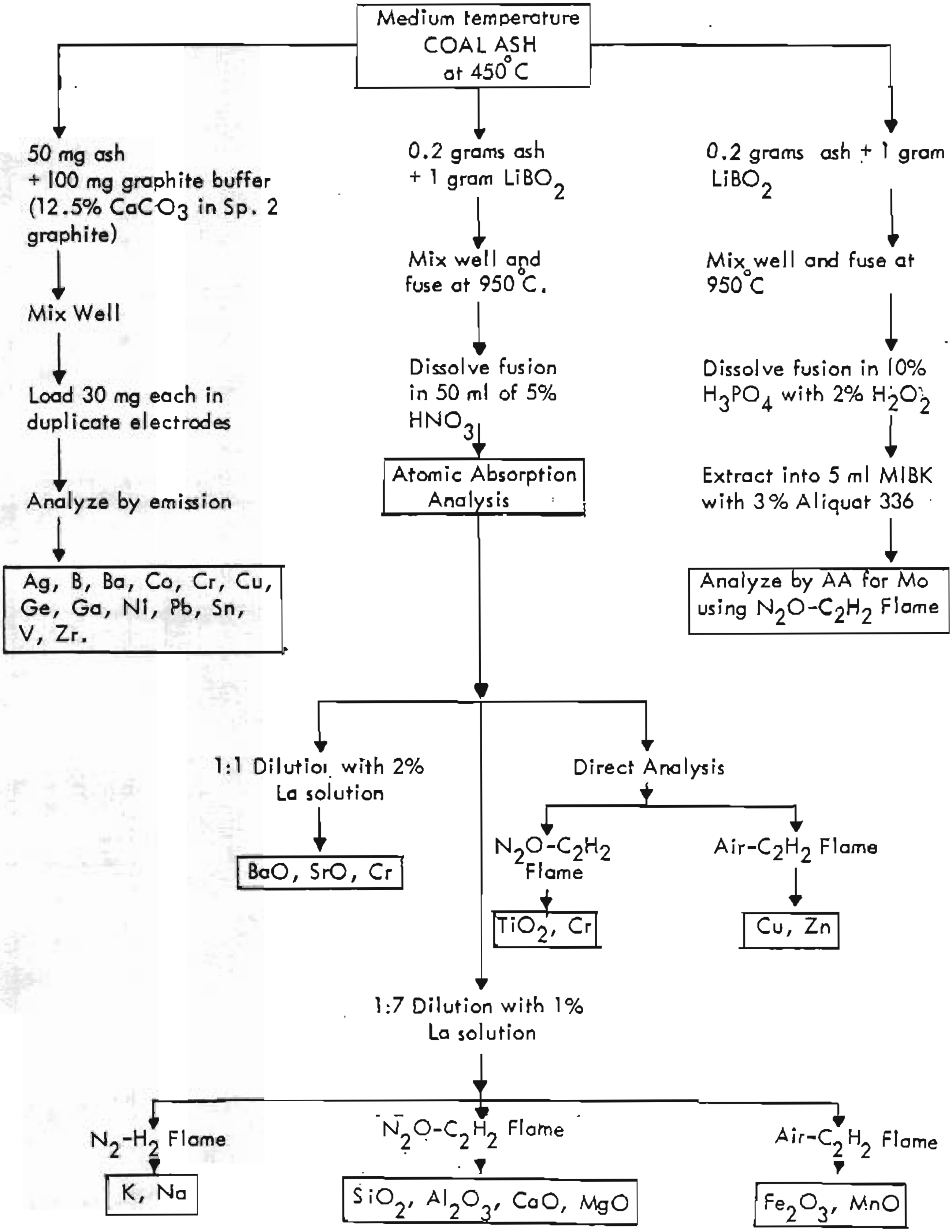
Atomic absorption and emission spectrochemical procedures were used for the analysis. The analytical scheme is shown in Table 9. For Ba, Cu, Mo and Ni, both methods were used. For atomic absorption analysis, sample digestions were made by both lithium metaborate fusions and hydroflouric acid digestions, the latter to permit determination of trace elements.

Atomic Absorption Analysis

In the lithium metaborate fusion procedure (Ingamells, 1970, Meldin, Suhr and Bodkin, 1969) 0.2 g. of coal is mixed with 1 g. of lithium metaborate in a plastic vial in a wig-L-bug mixer. The mixed product is fused for 10 minutes in a graphite crucible at 950°C. The fusion is dissolved in 50 ml. of 5% HNO_3 solution in a screw cap test tube while stirring over a magnetic stirrer hot plate. Rapid dissolution will prevent precipitation of silica. The solutions are transferred to polyethylene bottles and capped tightly.

TABLE 9

ANALYTICAL SCHEME FOR COAL ASH



Solvent Extraction Procedure for the Determination of Molybdenum (Rao, 1971)

Lithium metaborate fusions prepared as described above are dissolved in 40 ml. of 10% H_3PO_4 solution containing 2% H_2O_2 in a 50 ml. screw cap test tube. The molybdenum, now present as phosphomolybdate, is extracted into 5 ml. of methyl iso-butyl ketone containing 3% aliquot 336 and analyzed by the atomic absorption method. This method allows determination of molybdenum at levels as low as 1 ppm, whereas the lower limit of detection by emission spectrochemical analysis is 6 ppm.

Digestion with Hydroflouric Acid

0.5 gms. of coal ash is weighed and transferred to a 3" diameter Teflon evaporation dish. The sample is moistened with 2 ml. distilled water. After an addition of 4 ml. perchloric acid, the dish is heated on a hot plate until nearly dry. The dish is cooled and 1 ml. perchloric acid and 10 ml. HF are added and evaporated to near dryness. The dish is cooled and 1 ml. $HClO_3$ and 5 ml. HF are added, again evaporated to dryness. The dish is again cooled and 1 ml. $HClO_3$ and 5 ml. 5% boric acid solution are added and swirled to make sure that all the sample is loosened from the bottom of the dish. Any sticking residue is loosened with a polyethylene covered rod. The dish is now heated until dense fumes evolve, without allowing the residue to dry. The dish is cooled and the residue is taken into solution with 20 ml. 25% HCl and made up to 25 ml.

EMISSION SPECTROCHEMICAL ANALYSIS

A Jarrel-Ash, Model 78-090, 1.5 meter Wadsworth grating spectrograph with a reciprocal linear dispersion of 5.4 A^{o}/mm in the second order was used. Details of excitation conditions are given in Table 10. The exposures were recorded in the second order between 2100 A^{o} and 4850 A^{o} using spectrum analysis No. 1 emulsion 35 mm film. The exposed films were processed for 3 minutes at 68^{o} F in D-19 developer using a Jarrel-Ash photo-processor. The emulsion was calibrated and attenuated using a 7-step rotating sector having a transmission ratio of 1.585 between steps.

All samples were analyzed in duplicate on separate films. Standards were burned in triplicate, spaced in between samples. Standard analyzed rocks were analyzed to check the accuracy of the procedure. Percent transmission of the lines was measured with a Jarrel-Ash microphotometer using a 12.5 micron slit. Background corrections were made for Ge, Pb, Ga, Mo, Sn, V, Ag, Ni, and Co. No corrections were made for the background for Ba, B, Cu, or Cr since the background level for these elements was very low at the step measured.

Preparation of Standards

Spectrographically pure chemicals were used for the preparation of standards. The procedure described by the author was used (Rao, 1968). A synthetic matrix approaching the average composition of ash of Alaskan coals was used for dilution of

TABLE 10

EXCITATION CONDITIONS FOR SPECTROCHEMICAL ANALYSIS

Spectrograph: Jarrel-Ash, Model 78-090, 1.5 Meter, Wadsworth mounting with reciprocal linear dispersion of 5.4 A°/mm in the second order.

Filtration: 7 step rotating sector with a ratio of 1.585. Steps 5, 6 and 7 having 25.1, 39.8 and 63.1 percent transmission respectively were recorded for each exposure.

Spectral Region: 2100 A° to 4850 A°

Emulsion: SA-1 35mm film, 5 exposure per film strip.

Slit height: 4 mm

Slit width: 25 microns

Total Exposure time = 180 sec. (10 sec. at 3 amps, 10 sec. at 4 amps, 10 sec. at 50 amps and 150 sec. at 9 amps).

Analytical gap: 4 mm

Sample Electrode: Ultracarbon 7075

Counter Electrode: Ultracarbon 52202

Atmosphere: Air

standards. A standard mix was prepared by combining oxides of various elements in the ratio normally encountered in coal ashes. By successive dilutions 7 sets of standards were prepared in such a way that there were standards for each element covering the range occurring in coal ashes. Standard curves were constructed for all the 14 trace elements from the 7 standards. Table 11 gives the concentrations of the elements in each of the standards.

Analytical Procedure

The total energy method was used in which only one exposure is needed for the determination of all elements. 50 mg. of coal ash was mixed with 100 mg of graphic buffer mix (SP-2 graphite containing 12.5% $CaCO_3$) in a wig-L-bug mixer. 30 mg. of the arc mix was loaded into electrodes and packed. Duplicate exposures are made for each sample.

DISCUSSION OF ANALYTICAL PROCEDURES

Atomic Absorption

Of the two digestion methods used, the lithium metaborate fusion technique is preferred due to the rapidity with which the samples can be brought into solution, and the fact that all elements, including Si could be analyzed. For atomic absorption analysis HF digestions were needed for only two elements, Cu and Ni. Nickel needed deuterium arc background correction for high nonatomic absorption in the flame. The two elements could, however, be determined by emission spectrochemical analysis.

TABLE 11

STANDARDS FOR EMISSION SPECTROCHEMICAL ANALYSIS

Element	Compound Used	Concentration of Element, PPM						
		STD. A_2	STD. A_1	STD. A	STD. B	STD. C	STD. D	STD. E
Ag	Ag_2O	250	125	62.5	31.3	15.6	7.8	3.9
B	H_3BO_3	2000	1000	500	250	125	62.5	313
Ba	$BaCO_3$	15000	7500	3750	1875	938	469	234
Co	Co_3O_4	500	250	125	62.5	31.3	15.6	7.8
Cr	Cr_2O_3	1000	500	250	125	62.5	31.3	15.6
Cu	CuO	2000	1000	500	250	125	62.5	31.3
Ga	Ga_2O_3	500	250	125	62.5	31.3	15.6	7.8
Ge	GeO_2	1000	500	250	125	62.5	31.3	15.6
Mo	MoO_3	500	250	125	62.5	31.3	15.6	7.8
Ni	NiO	1000	500	250	125	62.5	31.3	15.6
Pb	PbO	2000	1000	500	250	125	62.5	31.3
Sn	SnO_2	500	250	125	62.5	31.3	15.6	7.8
V	V_2O_5	2500	1250	625	313	156	78	39
Zr	ZrO_2	1000	500	250	125	62.5	31.3	15.6

Although Sr has been determined from HF digestions for the results reported in this research, the concentration of strontium is high enough to be determined from lithium metaborate fusions. The elements for which $LiBO_2$ fusions can be used for analysis by atomic absorption are, expressed as oxides, SiO_2, Al_2O_3, CaO, Na_2O, K_2O, Fe_2O_3, TiO_2, MnO, and Zn, and possibly BaO and SrO. Cu and Cr in the Cape Beaufort samples were too low in concentration to be determined from these solutions, although their concentrations can be determined for samples high in these elements. In HF digestions, barium precipitated out of solutions made from floats and low ash samples as the sulfate. It appears that since sulfur is retained in the ash as sulfate, low ash samples concentrate more sulfur in the ash. Sink fractions gave barium concentrations comparable to those obtained with emission spectrochemical analysis, showing that barium is present in coal samples in a form other than as sulfate.

The concentrations of Pb, Mo, Ag, and Co in HF digestions were in most cases too low to be determined by atomic absorption. Even by emission methods, Mo in 80% of the samples was at or near detection limits. The solvent extraction procedure proved to be very effective for the determination of molybdenum.

<u>Standards for Atomic Absorption</u>

Analyzed rocks were used as standards for all major and minor elements. Aqueous standards with matched matrix were used for trace elements.

Emission Spectrochemical Analysis

At low concentrations Cu, Ni, Cr, and Pb could be best determined by the emission method. The elements B, Ge, Ga, Sn, V, Ag, Co, and Zr have to be determined by emission methods due to low concentration of these elements in coal ashes. Germanium concentration was at or below the detection limit.

Table 9 shows a recommended analytical scheme for coal ashes, using atomic absorption analysis with lithium metaborate fusions and emission spectrochemical analysis. The scheme covers the determination of major and trace elements. Table 12 shows the comparative detection limits that can be achieved with various methods described in this report. HF digestion followed by atomic absorption analysis gave lower detection limits for Cu and Ni than the emission method. Since the detection limits that could be reached with emission are quite adequate for the analysis of coal ashes, HF digestion is not used in the recommended analytical scheme.

DISCUSSION OF RESULTS

The analysis of major, minor and trace elements of medium temperature ashes of coal samples are shown in Tables 13 and 15, and analyses of ashes of sink and float products are given in Tables 14 and 16. Tables 17 and 19 show the distribution of major and trace elements in whole coals on as received basis and Tables 18 and 20 show distribution in float and sink fractions.

TABLE 12

DETECTION LIMITS FOR TRACE ELEMENTS

Element	Analytical Line λ, E.S.	Detection Limit, PPM Coal Ash		
		E.S.	A.A. $LiBO_2$ Fusion	H.F. Digestion
Ag	3280	1		
B	2496	15		
Ba	2335	200	125	N. Rc
Co	3453	10		
Cr	4254	30		N. Rc
Cu	3274	10		2
Ga	2493	10		
Ge	2651	15		
Mo	3170	6	1*	
Ni	3414	10		5
Pb	2833	60		
Sn	3175	15		N. Rc
Sr			20	7
Ti			450	
V	3185	15		
Zn			10	
Zr	3392	30		

* After extraction into 5 ml. MIBK.
N.Rc = Not recommended.

Table 21 shows mean analysis and standard deviation of whole coals and reconstituted head analyses from sink-float fractions. Table 22 shows mean analysis of sink and float fractions and ashes of these products.

Major Elements

The concentrations of silica, alumina, magnesia, sodium, and potassium concentrations are generally within the range of other U.S. coals. Of particular interest is that iron in the sample is low partly due to low pyrite concentration in the samples. Polished sections showed only sporadic pyrite grains of a few microns in diameter. Manganese concentration was also low. No correlation has been found between manganese and calcium concentration. Carbonates (calcite and dolomite) have been identified in polished sections and low temperature ashes, and account for the high calcium content. In general, sodium concentration was higher than potassium. Of particular interest are barium and strontium, which have been found to be highly concentrated in coal ashes.

Organic Affinity of Major and Minor Elements

The coal ashes of sink float fractions showed that the concentrations of Fe_2O_3, MgO, Na_2O, TiO_2, MnO, BaO, and SrO were significantly higher in float ash than sink ash, signifying the organic affinity of these elements. K_2O and Al_2O_3 did not show any consistently high values either in floats or sinks, whereas SiO_2 and CaO were generally higher in the sinks.

Trace Elements

The concentrations of trace elements is generally low in most samples, except for a few abnormal values. The elements Pb, Cu, Co, Ga, Mo, Ni, Cr, and Ge were all quite low compared to other U.S. coals. B, Zn, and Zr concentrations were within the range of other U.S. coals. The concentration of Ag was less than 2 ppm in the majority of coal ashes.

Certain samples showed high concentrations of trace elements. These samples generally were high in Co, Cr, Cu, Ni, Pb, and Sn. Samples of drill holes 3C, 7C, 8C, and 10C showed abnormally high concentrations of Sn. No investigation was made to determine the mode of occurrence of Sn in these samples.

Organic Affinity of Trace Elements

In general, the trace elements that are highly concentrated in float ash compared to sink ash are Ag, B, Co, Cr, Mo, Ni, Sn, V, and Zr. The elements Ga, Pb, Zn, and Cu did not show any preferential concentration in either floats or sinks. The relatively high concentrations of trace elements in some float fractions would indicate association with the organic phase in the coal rather than as separate mineral species. This is of significance as these elements tend to influence conversion reactions. Of particular interest is molybdenum, which is concentrated in float ash threefold or more, compared to sink ash. Further work on distribution of trace elements in various density fractions of Alaskan coal would be of benefit for future evaluation of the potential of these coals for coal conversion processes.

TABLE 13

ANALYSIS OF MAJOR AND MINOR ELEMENTS IN COAL ASHES (PERCENT)

Drill Hole No.	Sample No.	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	BaO	SrO
2	UA-1	67.4	18.2	2.40	1.55	2.15	3.26	1.32	0.72	0.028	0.18	0.028
	UA-2	69.0	18.2	1.92	1.31	3.08	3.05	1.27	0.72	0.030	0.13	0.025
	UA-3	63.4	21.6	2.26	1.78	2.06	2.13	2.48	1.22	0.015	0.14	0.031
3	UA-4	48.1	33.1	2.26	1.65	4.30	0.84	0.54	1.17	0.011	0.19	0.033
	UA-5	35.7	20.9	4.29	2.98	16.2	2.31	0.75	0.90	0.021	0.75	0.20
	UA-6	59.2	25.6	2.22	1.74	2.74	3.62	1.04	1.04	0.011	0.31	0.030
	UA-7	63.6	19.7	2.13	1.41	3.83	3.16	2.07	0.78	0.031	0.28	0.036
	UA-8	64.0	20.7	2.02	1.54	3.23	1.95	1.25	0.97	0.025	0.40	0.077
3C	UA-9	48.8	22.3	7.89	5.39	5.26	0.90	0.47	0.87	0.020	0.15	0.041
	UA-10+11	46.9	31.3	2.90	2.75	6.10	1.75	0.36	1.19	0.029	0.36	0.057
	UA-12+13	58.6	18.6	2.17	1.63	7.84	2.99	0.98	0.72	0.052	0.30	0.054
	UA-14+15	39.0	29.5	3.44	3.14	9.41	2.25	0.49	1.01	0.023	0.52	0.063
5	UA-16	37.2	24.3	4.07	4.15	11.4	1.93	0.56	1.18	0.017	0.92	0.094
	UA-17	57.5	22.6	6.95	2.78	3.13	1.42	1.08	1.18	0.052	0.19	0.020
6	UA-18	48.4	32.3	1.34	1.44	3.17	1.87	0.74	1.15	0.007	0.70	0.12
	UA-19	50.7	15.4	8.19	3.36	5.91	1.69	0.86	0.62	0.068	0.41	0.073
	UA-20	50.5	28.7	1.86	1.77	5.43	1.76	1.02	1.34	0.027	0.37	0.12
7C	UA-21+22	37.2	22.4	3.13	3.08	15.30	2.08	0.46	0.73	0.039	0.64	0.097
	UA-23+24	49.2	23.5	2.43	1.91	7.28	1.72	1.79	0.99	0.051	0.31	0.029
	UA-25+26	51.1	30.4	3.41	3.00	3.44	1.33	2.13	1.28	0.017	0.37	0.070
8	UA-27	35.8	25.5	3.05	3.44	11.8	2.76	2.48	1.63	0.013	0.59	0.098
8C	UA-28+29	37.7	23.5	3.24	5.20	10.3	2.47	0.62	1.10	0.018	0.50	0.066
	UA-30+31	36.1	26.6	4.06	3.99	11.0	3.73	0.80	1.36	0.018	0.70	0.093
10C	UA-32+33	45.0	25.1	2.89	3.04	6.57	2.33	0.71	1.08	0.035	0.74	0.070
	UA-34+35	56.5	23.5	2.69	1.66	4.80	2.88	1.01	0.74	0.070	0.25	0.027

TABLE 13 (CONTINUED)

ANALYSIS OF MAJOR AND MINOR ELEMENTS IN COAL ASHES (PERCENT)

Drill Hole No.	Sample No.	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	BaO	SrO
9	UA-36	45.9	31.8	2.57	3.65	4.52	2.90	0.62	1.53	0.018	0.50	0.057
11	UA-37	47.1	24.5	2.36	2.53	6.29	3.21	0.71	1.22	0.020	0.66	0.075
	UA-38	44.5	28.1	2.76	3.86	5.39	3.26	0.81	1.27	0.011	0.87	0.10
12	UA-39	45.7	33.7	2.07	2.82	5.51	2.09	1.42	1.89	0.007	0.68	0.079
15	UA-40	52.2	29.9	2.29	1.68	3.40	2.17	1.02	1.37	0.007	0.77	0.089
	UA-41	58.3	23.6	2.63	1.69	2.92	2.35	1.45	1.39	0.010	0.60	0.052
18	UA-42	49.7	27.6	3.33	2.45	4.44	2.17	1.72	1.14	0.025	0.78	0.52
19	UA-43	34.2	23.0	3.15	4.27	11.8	3.59	1.54	1.01	0.024	0.82	0.62
20	UA-44	58.0	28.3	2.29	1.49	0.94	1.00	3.42	1.35	0.008	0.16	0.10
	UA-45	60.2	28.8	2.44	1.62	0.58	0.94	3.97	1.35	0.007	0.13	0.055
27	UA-46	38.8	15.3	7.53	6.47	13.4	3.06	0.80	0.75	0.050	1.1	0.43
28	UA-47	49.4	29.2	2.14	2.16	4.87	1.66	1.04	1.73	0.015	0.64	0.064
	UA-48	47.0	26.5	2.30	2.27	4.54	2.61	1.53	1.61	0.014	0.74	0.070

TABLE 14

ANALYSIS OF MAJOR AND MINOR ELEMENTS IN ASHES OF SINK-FLOAT PRODUCTS (PERCENT)

Drill Hole No.	Sample No.	Product	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	BaO	SrO
3C	UA-10	Float	43.0	27.3	4.93	4.06	6.00	2.48	0.58	1.13	0.041	0.63	0.085
	UA-11	Sink	49.3	33.7	1.67	1.95	6.17	1.31	0.54	1.23	0.021	0.20	0.040
	UA-10+11	Recomb.	46.9	31.3	2.90	2.75	6.10	1.75	0.56	1.19	0.029	0.36	0.057
	UA-12	Float	56.2	22.7	2.49	1.61	4.62	3.15	1.03	1.01	0.064	0.42	0.052
	UA-13	Sink	60.4	15.5	1.93	1.65	10.32	2.87	0.94	0.50	0.042	0.21	0.055
	UA-12+13	Recomb.	58.6	18.6	2.17	1.63	7.84	2.99	0.98	0.72	0.052	0.30	0.054
	UA-14	Float	24.8	26.1	6.43	5.39	13.9	2.58	0.54	1.38	0.038	1.12	0.11
	UA-15	Sink	49.3	32.0	1.26	1.50	6.15	2.01	0.45	0.74	0.012	0.08	0.029
	UA-14+15	Recomb.	39.0	29.5	3.44	3.14	9.41	2.25	0.49	1.01	0.023	0.52	0.063
7C	UA-21	Float	37.7	26.0	3.93	3.19	18.7	2.38	0.41	0.90	0.045	0.73	0.11
	UA-22	Sink	36.4	17.5	2.03	2.94	10.7	1.69	0.54	0.50	0.031	0.52	0.079
	UA-21+22	Recomb.	37.2	22.4	3.13	3.08	15.3	2.08	0.46	0.73	0.039	0.64	0.097
	UA-23	Float	52.0	23.5	2.86	2.16	4.44	2.46	0.83	1.14	0.065	0.33	0.029
	UA-24	Sink	45.8	23.5	1.93	1.61	10.7	0.83	0.68	0.80	0.035	0.23	0.029
	UA-23+24	Recomb.	49.2	23.5	2.43	1.91	7.28	1.72	0.76	0.99	0.051	0.31	0.029
	UA-25	Float	48.6	28.6	6.79	6.13	2.99	1.42	0.74	2.09	0.033	0.79	0.15
	UA-26	Sink	52.8	31.7	1.07	0.83	3.75	1.27	3.09	0.72	0.006	0.08	0.015
	UA-25+26	Recomb.	51.1	30.4	3.41	3.00	3.44	1.33	2.13	1.28	0.017	0.37	0.070
8C	UA-28	Float	42.8	26.3	3.83	4.10	4.32	2.90	0.69	1.79	0.016	0.92	0.069
	UA-29	Sink	33.8	21.4	2.80	6.05	14.8	2.14	0.57	0.57	0.020	0.18	0.064
	UA-28+29	Recomb.	37.7	23.5	3.24	5.20	10.3	2.47	0.62	1.10	0.018	0.50	0.066
	UA-30	Float	35.2	27.8	5.22	4.10	8.34	4.17	0.64	1.48	0.017	0.92	0.087
	UA-31	Sink	37.2	25.2	2.77	3.86	13.9	3.24	0.98	1.23	0.019	0.46	0.10
	UA-30+31	Recomb.	36.1	26.6	4.06	3.99	11.0	3.73	0.80	1.36	0.018	0.70	0.093

TABLE 14 (CONTINUED)

ANALYSIS OF MAJOR AND MINOR ELEMENTS IN ASHES OF SINK-FLOAT PRODUCTS (PERCENT)

Drill Hole No.	Sample No.	Product	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	BaO	SrO
10C	UA-32	Float	40.4	27.3	3.72	3.40	6.58	2.33	0.66	1.45	0.048	1.13	0.10
	UA-33	Sink	50.0	22.7	1.97	2.65	6.56	2.32	0.76	0.67	0.020	0.31	0.038
	UA-32+33	Recomb.	45.0	25.1	2.89	3.04	6.57	2.33	0.71	1.08	0.035	0.74	0.070
	UA-34	Float	56.0	22.8	3.15	1.66	4.55	2.88	1.04	0.86	0.090	0.33	0.026
	UA-35	Sink	57.2	24.5	2.10	1.66	5.12	2.87	0.99	0.58	0.044	0.16	0.029
	UA-34+35	Recomb.	56.5	23.5	2.69	1.66	4.80	2.88	1.01	0.74	0.070	0.25	0.027

TABLE 15

ANALYSIS OF TRACE ELEMENTS IN COAL ASHES (PARTS PER MILLION)

Drill Hole No.	Sample No.	Ag	B	Co	Cr	Cu		Ga	Mo		Ni		Pb	Sn	V	Zn	Zr
						A.A.	E.S.		A.A.	E.S.	E.S.	A.A.					
2	UA-1	<2	109	18	<30	22	18	16	7.0	<6	18	12	25	<10	55	118	202
	UA-2	<2	117	15	<30	24	19	19	4.9	<6	19	18	36	<10	76	128	257
	UA-3	7	161	18	96	42	32	20	4.9	<6	34	35	39	<10	250	111	310
3	UA-4	<2	96	14	30	30	27	42	7.0	6	27	37	55	<10	110	104	620
	UA-5	<2	445	30	33	57	46	19	7.0	6	27	25	21	<10	203	76	335
	UA-6	<2	106	<10	<30	36	38	30	5.2	<6	18	10	38	<10	51	79	302
	UA-7	7	240	<10	31	33	38	24	6.1	<6	29	27	40	<10	84	89	280
	UA-8	<2	302	55	61	47	48	27	7.0	<6	47	50	41	<10	113	137	402
3C	UA-9	<2	110	<10	<30	25	31	39	5.7	<6	27	37	50	<10	70	72	610
	UA-10+11	<2	285	16	<30	44	52	37	8.0		19	30	253	45	75	79	506
	UA-12+13	<2	406	<10	<30	42	41	21	6.7	<6	34		66	158	132	290	591
	UA-14+15	<2	743	81	56	72	90	40	9.7		65	62	59	794	126	70	931
5	UA-16	<2	470	150	157	72	80	42	9.0	10	106	97	55	23	245	201	180
	UA-17	<2	200	16	114	40	43	34	4.6	<6	48	38	<20	<10	228	119	250
6	UA-18	<2	210	27	<30	27	23	42	7.0	<6	33	30	56	<10	55	107	755
	UA-19	<2	545	20	<30	20	26	27	4.1	6	44	30	<20	<10	54	80	375
	UA-20	<2	210	89	57	42	34	25	7.5	6	73	75	57	12	130	86	1170
7C	UA-21+22	<2	367	12	<30	46	42	25	6.0		20		48	145	65	47	395
	UA-23+24	<2	393	22	<30	49	44	21	6.9		42		48	47	112	86	683
	UA-25+26	<2	500	115	88	88	98	38	9.8		71	71	46	119	141	145	818
8	UA-27	6	265	14	62	42	34	34	4.7	6	25	27	48	17	92	58	505
8C	UA-28+29	<2	231	18	41	40	37	18	6.5		28	21	48	580	100	89	780
	UA-30+31	9	498	417+	36	41	36	32	9.0		43	55	58	1990	128	90	47
10C	UA-32+33	9	464	18	<30	51	59	30	7.4		23		57	4600	118	64	329
	UA-34-35	17	503	19	<30	36	36	23	7.2		30		51	2200	93	59	511
9	UA-36	<2	225	24	36	47	39	36	5.9	<6	38	20	52	<10	130	107	420

TABLE 15 (CONTINUED)

ANALYSIS OF TRACE ELEMENTS IN COAL ASHES (PARTS PER MILLION)

Drill Hole No.	Sample No.	Ag	B	Co	Cr	Cu		Ga	Mo		Ni		Pb	Sn	V	Zn	Zr
						A.A.	E.S.		A.A.	E.S.	E.S.	A.A.					
11	UA-37	< 2	315	11	31	32	29	31	5.0	6	29	20	51	22	118	133	465
	UA-38	< 2	425	34	28	53	48	29	7.4	8	36	35	49	<10	135	114	422
12	UA-39	< 2	545	26	28	44	38	46	3.6	<6	39	37	75	<10	176	155	615
15	UA-40	< 2	985	19	72	48	44	32	2.5	<6	40	58	45	<10	180	88	680
	UA-41	< 2	540	26	86	51	43	29	4.0	<6	57	55	52	<10	155	76	670
18	UA-42	< 2	575	35	53	37	41	32	4.7	7	62	55	98	98	140	163	865
19	UA-43	< 2	930	46	65	46	43	33	5.1	6	54	55	80	<10	152	233	500
20	UA-44	5	243	12	141	45	36	35	2.0	<6	39	37	79	<10	240	81	335
	UA-45	15	260	8	153	47	41	28	2.6	<6	46	40	39	<10	257	111	308
27	UA-46	2	2500	48	57	42	45	17	4.9	6	93	87	<20	200	100	153	322
28	UA-47	< 2	580	16	38	48	44	53	4.3	<6	43	40	56	<10	167	105	895
	UA-48	7	865	17	44	41	39	38	2.8	<6	41	40	60	10	147	86	655

A.A. - Atomic absorption Analysis
E.S. - Emission Spectrochemical Analysis

TABLE 16

ANALYSIS OF TRACE ELEMENTS IN ASHES OF SINK-FLOAT FRACTIONS (PARTS PER MILLION)

Drill Hole No.	Sample No.	Product	Ag	B	Co	Cr	Cu		Ga	Mo		Ni		Pb	Sn	V	Zn	Zr
							A.A.	E.S.		A.A.	E.S.	E.S.	A.A.					
3C	UA-10	Float	< 2	590	27	30	86	96	30	13.5	12	34	37	250	77	118	108	590
	UA-11	Sink	< 2	99	<10	<30	27	26	42	4.6	< 6	<10	25	255	26	49	61	455
	UA-10+11	Recomb.	< 2	285	16	<30	49	52	37	8.0		19	30	253	45	75	79	506
	UA-12	Float	< 2	760	27	<30	64	63	26	10.5	< 6	54	42	92	350	250	296	1070
	UA-13	Sink	< 2	134	<10	<30	25	25	17	3.7	< 6	18	<10	46	< 10	41	286	224
	UA-12+13	Recomb.	< 2	406	<10	<30	42	41	21	6.7	< 6	34		66	158	132	290	591
	UA-14	Float	<2	1600	178	93	129	176	39	19.7	25	141	125	93	1060	242	104	2020
	UA-15	Sink	<2	120	<10	<30	31	28	40	2.5	< 6	<10	17	35	600	41	45	139
	UA-14+15	Recomb.	< 2	743	81	56	72	90	40	9.7		65	62	59	794	126	70	931
7C	UA-21	Float	< 2	540	13	<30	62	45	26	9.0	8	27	27	46	240	81	58	535
	UA-22	Sink	< 2	130	< 10	<30	25	37	23	2.0	< 6	11	<10	50	15	84	31	202
	UA-21+22	Recomb.	< 2	367	12	<30	46	42	25	6.0		20		48	145	65	47	395
	UA-23	Float	< 2	615	31	<30	56	45	23	9.0	9	61	52	45	78	175	83	975
	UA-24	Sink	< 2	125	<10	<30	41	43	19	4.3	<6	20	<10	51	<10	38	89	332
	UA-23+24	Recomb.	< 2	393	22	<30	49	44	21	6.9		42		48	47	112	86	683
	UA-25	Float	< 2	1080	267	172	156	197	41	21.5	19	145	138	72	275	267	140	1820
	UA-26	Sink	< 2	97	<10	30	40	30	36	1.6	<6	19	27	28	<10	53	148	123
	UA-25+26	Recomb.	< 2	500	113	88	88	98	38	9.8		71	71	46	119	141	145	818
8C	UA-28	Float	2	425	28	56	58	54	24	10.6	14	43	28	63	1300	163	70	1600
	UA-29	Sink	<2	83	<10	<30	27	24	14	3.4	<6	16	15	36	34	53	103	155
	UA-28+29	Recomb.	<2	231	18	41	40	37	18	6.5		28	21	48	580	100	89	780
	UA-30	Float	10	800	780	41	49	49	25	13.6	12	67	85	61	3000	194	123	785
	UA-31	Sink	8	160	<10	<30	33	22	39	3.9	<6	16	22	54	11	53	52	112
	UA-30+31	Recomb.	9	498	417	36	41	36	32	9.0		43	55	58	1990	128	90	468

TABLE 16 (CONTINUED)

ANALYSIS OF TRACE ELEMENTS IN ASHES OF SINK-FLOAT FRACTIONS (PARTS PER MILLION)

Drill Hole No.	Sample No.	Product	Ag	B	Co	Cr	Cu		Ga	Mo		Ni		Pb	Sn	V	Zn	Zr
							A.A.	E.S.		A.A.	E.S.	E.S.	A.A.					
10C	UA-32	Float	15	765	25	32	60	78	32	11.4	10	31	32	62	8900	194	64	495
	UA-33	Sink	3	134	<10	<30	42	38	28	3.0	<6	14	<10	52	<10	35	64	146
	UA-32+33	Recomb.	9	464	18	31	51	59	30	7.4		23		57	4600	118	64	329
	UA-34	Float	28	780	24	<30	43	46	27	10.5	11	44	45	68	4500	145	60	790
	UA-35	Sink	<2	145	<10	<30	26	23	18	3.0	<6	14	<10	30	<10	26	58	151
	UA-34+35	Recomb.	17	503	19	30	36	36	23	7.2		30		51	2200	93	59	511

TABLE 17

ANALYSIS OF MAJOR AND MINOR ELEMENTS IN RAW COALS

Drill Hole No.	Sample No.	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	MnO ppm	BaO ppm	SrO ppm
2	UA-1	28.0	7.57	1.00	0.64	0.89	1.36	0.55	0.30	116	750	116
	UA-2	27.7	7.32	0.77	0.53	1.24	1.23	0.51	0.29	120	522	100
	UA-3	27.2	9.27	0.97	0.76	0.88	0.91	1.06	0.52	64	600	133
3	UA-4	13.0	8.97	0.61	0.45	1.17	0.23	0.15	0.32	29	510	89
	UA-5	4.6	2.72	0.56	0.39	2.11	0.30	0.10	0.12	27	975	260
	UA-6	14.6	6.32	0.55	0.43	0.68	0.89	0.26	0.26	27	766	74
	UA-7	16.8	5.20	0.56	0.37	1.01	0.83	0.55	0.21	82	740	95
	UA-8	13.1	4.22	0.41	0.31	0.66	0.40	0.26	0.20	51	816	157
3C	UA-9	11.7	5.33	1.89	1.23	1.29	0.22	0.11	0.21	48	358	98
	UA-10+11	7.6	5.10	0.47	0.45	0.99	0.29	0.09	0.19	47	587	93
	UA-12+13	11.1	3.52	0.41	0.31	1.48	0.57	0.19	0.14	98	567	102
	UA-14+15	4.3	3.22	0.37	0.34	1.02	0.25	0.05	0.11	25	567	69
5	UA-16	5.0	3.26	0.55	0.56	1.52	0.26	0.08	0.16	23	1232	126
	UA-17	26.6	10.4	3.21	1.28	1.44	0.66	0.50	0.55	240	877	92
6	UA-18	12.9	8.62	0.36	0.38	0.85	0.50	0.20	0.31	19	1870	320
	UA-19	8.5	2.58	1.38	0.56	0.99	0.28	0.14	0.10	114	690	122
	UA-20	10.9	6.20	0.40	0.38	1.17	0.38	0.22	0.29	58	800	260
7C	UA-21+22	4.61	2.78	0.39	0.38	1.90	0.26	0.06	0.09	48	790	120
	UA-23+24	8.8	4.21	0.43	0.34	1.30	0.31	0.32	0.18	91	550	52
	UA-25+26	5.9	3.53	0.40	0.35	0.40	0.15	0.25	0.15	20	430	81
8	UA-27	5.7	4.03	0.48	0.54	1.86	0.44	0.39	0.26	21	930	155
8C	UA-28+29	6.1	3.78	0.52	0.84	1.65	0.40	0.10	0.18	29	800	106
	UA-30+31	4.2	3.06	0.47	0.46	1.27	0.42	0.09	0.16	21	800	107

TABLE 17 (CONTINUED)

ANALYSIS OF MAJOR AND MINOR ELEMENTS IN RAW COALS

Drill Hole No.	Sample No.	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	MnO ppm	BaO ppm	SrO ppm
10C	UA-32+33	5.6	3.14	0.36	0.38	0.82	0.29	0.09	0.14	44	920	88
	UA-34+35	8.1	3.38	0.39	0.24	0.69	0.42	0.15	0.11	100	360	39
9	UA-36	10.6	7.38	0.60	0.85	1.05	0.67	0.14	0.35	42	1160	132
11	UA-37	8.7	4.53	0.44	0.47	1.16	0.59	0.13	0.23	37	1220	139
	UA-38	6.8	4.27	0.42	0.59	0.82	0.50	0.12	0.19	17	1320	152
12	UA-39	8.4	6.16	0.38	0.52	1.01	0.38	0.26	0.35	13	1240	145
15	UA-40	9.29	5.32	0.41	0.30	0.61	0.39	0.18	0.24	12	1370	158
	UA-41	11.0	4.44	0.49	0.32	0.55	0.44	0.27	0.26	19	1130	98
18	UA-42	10.3	5.59	0.69	0.51	0.92	0.45	0.36	0.24	52	1600	1080
19	UA-43	3.2	2.22	0.30	0.40	1.11	0.34	0.14	0.095	23	770	580
20	UA-44	24.5	12.0	0.97	0.63	0.40	0.42	1.45	0.57	34	680	420
	UA-45	31.2	14.9	1.26	0.84	0.30	0.49	1.79	0.70	36	670	280
27	UA-46	2.7	1.07	0.53	0.45	0.94	0.21	0.056	0.053	35	770	300
28	UA-47	9.7	5.72	0.42	0.42	0.95	0.33	0.20	0.34	29	1250	125
	UA-48	9.9	5.57	0.48	0.48	0.95	0.55	0.32	0.34	29	1550	147

TABLE 18

ANALYSIS OF MAJOR AND MINOR ELEMENTS IN SINK-FLOAT FRACTIONS

Drill Hole No.	Sample No.	Product	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	MnO ppm	BaO ppm	SrO ppm
3C	UA-10	Float	3.3	2.27	0.41	0.34	0.50	0.21	0.05	0.09	34	520	70
	UA-11	Sink	19.3	13.2	0.65	0.76	2.40	0.51	0.21	0.48	82	780	157
	UA-10+11	Recomb.	7.6	5.10	0.47	0.45	0.99	0.29	0.09	0.19	47	587	93
	UA-12	Float	6.0	2.41	0.26	0.17	0.49	0.33	0.11	0.11	68	445	55
	UA-13	Sink	28.4	15.0	0.91	0.78	4.85	1.34	0.44	0.23	200	990	260
	UA-12+13	Recomb.	11.1	3.52	0.41	0.31	1.48	0.57	0.19	0.14	98	567	102
	UA-14	Float	1.3	1.33	0.33	0.27	0.71	0.13	0.03	0.07	19	570	56
	UA-15	Sink	30.8	20.0	0.79	0.94	3.84	1.26	0.28	0.46	75	500	180
	UA-14+15	Recomb.	4.3	3.22	0.37	0.34	1.02	0.25	0.05	0.11	25	567	69
7C	UA-21	Float	3.1	2.11	0.32	0.25	1.51	0.19	0.03	0.07	36	590	89
	UA-22	Sink	16.5	7.95	0.92	1.33	4.86	0.77	0.25	0.23	141	2360	360
	UA-21+22	Recomb.	4.6	2.78	0.39	0.38	1.90	0.26	0.06	0.09	48	790	120
	UA-23	Float	6.2	2.80	0.34	0.26	0.53	0.29	0.10	0.14	77	390	35
	UA-24	Sink	21.1	10.8	0.89	0.74	4.92	0.38	0.31	0.37	160	1290	133
	UA-23+24	Recomb.	8.8	4.2	0.43	0.34	1.30	0.31	0.14	0.18	91	550	52
	UA-25	Float	2.6	1.52	0.36	0.32	0.16	0.08	0.04	0.11	17	420	80
	UA-26	Sink	35.9	21.6	0.73	0.36	2.55	0.86	2.10	0.49	41	540	102
	UA-25+26	Recomb.	5.9	3.53	0.40	0.35	0.40	0.15	0.25	0.15	20	430	81
8C	UA-28	Float	3.9	2.37	0.34	0.37	0.39	0.26	0.06	0.16	14	830	62
	UA-29	Sink	13.6	8.62	1.13	2.44	5.96	0.86	0.23	0.23	81	730	260
	UA-28+29	Recomb.	6.1	3.78	0.52	0.84	1.65	0.40	0.10	0.18	29	800	106
	UA-30	Float	2.4	1.92	0.36	0.28	0.58	0.29	0.04	0.10	12	630	60
	UA-31	Sink	17.0	11.5	1.26	1.76	6.34	1.48	0.45	0.56	87	2100	460
	UA-30-31	Recomb.	4.2	3.06	0.47	0.46	1.27	0.43	0.09	0.16	21	800	107

TABLE 18 (CONTINUED)

ANALYSIS OF MAJOR AND MINOR ELEMENTS IN SINK-FLOAT FRACTIONS

Drill Hole No.	Sample No.	Product	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	MnO ppm	BaO ppm	SrO ppm
10C	UA-32	Float	3.1	2.07	0.28	0.26	0.50	0.18	0.05	0.11	36	860	76
	UA-33	Sink	22.0	9.97	0.86	1.16	2.88	1.02	0.33	0.29	92	1360	167
	UA-32+33	Recomb.	5.6	3.13	0.36	0.38	0.82	0.29	0.09	0.14	44	930	88
	UA-34	Float	5.3	2.14	0.30	0.16	0.43	0.27	0.10	0.08	85	310	24
	UA-35	Sink	26.8	11.5	0.98	0.78	2.40	1.35	0.46	0.27	206	750	136
	UA-34+35	Recomb.	8.1	3.38	0.39	0.24	0.69	0.41	0.15	0.11	100	360	39

TABLE 19

ANALYSIS OF TRACE ELEMENTS IN RAW COALS (PARTS PER MILLION)

Drill Hole No.	Sample No.	Ag	B	Co	Cr	Cu A.A.	Ga	Mo A.A.	Ni E.S.	Pb	Sn	V	Zn	Zr
2	UA-1	< 1	45	7.5	< 15	9.2	6.7	2.9	7.5	10	< 5	23	49	84
	UA-2	< 1	47	6.0	< 15	9.6	7.6	2.0	7.6	14	< 5	31	51	103
	UA-3	3	69	7.7	41	18.0	8.6	2.1	15	17	< 5	107	48	133
3	UA-4	< 1	26	3.8	8	8.1	11.4	1.9	7.3	15	< 5	30	28	168
	UA-5	< 1	58	3.9	4	7.4	2.5	0.9	3.5	2.7	< 5	26	10	44
	UA-6	< 1	26	< 3	< 10	8.9	7.4	1.3	4.4	9.4	< 5	13	20	75
	UA-7	1.8	63	< 3	8	8.7	6.3	1.6	7.7	11	< 5	22	23	74
	UA-8	< 1	61	11	12	9.6	5.5	1.4	9.6	8.4	< 5	23	28	82
3C	UA-9	< 1	26	< 3	< 10	6.0	7.4	1.4	6.5	12	< 5	17	17	146
	UA-10+11	< 1	46	2.6	< 5	8.0	6.0	1.3	3.1	41	7.3	12	13	82
	UA-12+13	< 1	77	3.2	< 5	7.9	4.0	1.3	6.4	13	30	25	55	112
	UA-14+15	< 1	81	8.8	< 5	7.8	4.4	1.1	7.1	6.4	87	14	7.6	101
5	UA-16	< 1	63	20	21	9.6	5.6	1.2	14	7.4	3.1	33	27	21
	UA-17	< 1	92	7.4	53	18	10	2.1	22	< 10	< 5	105	55	115
6	UA-18	< 1	56	7.2	< 10	7.2	11	1.9	8.8	15	< 5	15	29	202
	UA-19	< 1	92	3.4	< 10	3.4	4.5	0.7	7.4	< 5	< 5	9	13	63
	UA-20	< 1	45	19	12	9.1	5.4	1.6	16	12	2.6	28	19	253
7C	UA-21+22	< 1	46	< 2	< 15	5.7	3.1	0.74	2.5	6.0	18	8.1	5.8	49
	UA-23+24	< 1	70	< 4	< 15	8.8	3.8	1.2	7.5	8.6	< 10	20	15	122
	UA-25+26	< 1	58	< 13	10	10	4.4	1.1	3.6	5.3	< 14	16	17	95
8	UA-27	0.95	42	2.2	9.8	6.6	5.4	0.74	4.0	7.6	2.7	15	9.2	80
8C	UA-28+29	< 1	37	< 5	< 10	6.4	2.9	1.1	4.5	7.7	93	16	14	126
	UA-30+31	1.6	57	48	< 5	4.7	3.7	1.0	5.0	6.7	230	15	10	54

TABLE 19 (CONTINUED)

ANALYSIS OF TRACE ELEMENTS IN RAW COALS (PARTS PER MILLION)

Drill Hole No.	Sample No.	Ag	B	Co	Cr	Cu A.A	Ga	Mo A.A.	Ni E.S.	Pb	Sn	V	Zn	Zr
10C	UA-32+33	1.1	58	< 3	< 5	6.4	3.8	0.93	2.9	7.1	570	15	8	41
	UA-34+35	2.5	72	< 3	< 15	5.2	3.3	1.0	4.3	7.3	317	13	8.5	74
9	UA-36	< 1	52	5.6	8.4	11	8.4	1.4	8.8	12	< 5	30	25	97
11	UA-37	< 1	58	2.0	5.7	5.9	5.7	0.9	5.4	9.4	4.1	22	25	86
	UA-38	< 1	64	5.2	4.3	8.1	4.4	1.1	5.5	7.4	< 5	21	17	64
12	UA-39	< 1	100	4.8	4.8	8.1	8.4	0.7	7.1	14	< 5	32	28	112
15	UA-40	< 1	175	3.4	13	8.5	5.7	0.4	7.1	8	< 5	32	16	121
	UA-41	< 1	101	4.9	16	9.6	5.5	0.8	11	9.8	< 5	29	14	126
18	UA-42	< 1	119	7.2	11	9.1	9.5	0.7	8.1	16	< 5	36	32	127
19	UA-43	< 1	87	4.3	6	4.3	3.1	0.5	5.1	7.5	< 5	14	22	47
20	UA-44	2.1	102	51	60	19	15	0.8	16	33	< 5	101	34	142
	UA-45	7.8	135	4.1	79	24	15	1.3	23	20	< 5	133	57	160
27	UA-46	< 1	175	3.4	4.0	2.9	1.2	0.3	6.5	< 2	14	7	107	23
28	UA-47	< 1	114	3.1	7.4	9.4	10	0.8	8.4	11	< 5	33	21	175
	UA-48	1.5	181	3.6	9.2	8.6	8	0.6	8.6	13	< 5	31	18	138

TABLE 20

ANALYSIS OF TRACE ELEMENTS IN SINK-FLOAT FRACTIONS (PARTS PER MILLION)

Drill Hole No.	Sample No.	Product	Ag	B	Co	Cr	Cu A.A.	Ga	Mo A.A.	Ni E.S.	Pb	Sn	V	Zn	Zr
3C	UA-10	Float	< 1	49	2.2	2.5	7.1	2.5	1.1	2.8	21	6.4	9.8	9.0	49
	UA-11	Sink	< 1	38	< 5	< 15	10.6	16	1.8	2.5	100	10	19	24	178
	UA-10+11	Recomb.	< 1	46	2.6	< 5	8.0	6.0	1.3	3.1	41	7.3	12	13	82
	UA-12	Float	< 1	81	2.9	< 3	6.8	2.8	1.1	5.7	9.8	37	27	31	113
	UA-13	Sink	< 1	63	< 5	< 15	12	8.0	1.7	8.5	22	< 5	19	134	105
	UA-12+13	Recomb.	< 1	77	3.2	< 5	7.9	4.0	1.3	6.4	13	30	25	55	112
	UA-14	Float	< 1	82	9.1	4.7	6.6	2.0	1.0	7.2	4.7	54	12	5.3	103
	UA-15	Sink	< 1	75	< 5	< 15	19	25	1.6	< 5	22	375	26	28	87
	UA-14+15	Recomb.	< 1	81	8.8	< 5	7.8	4.4	1.1	7.1	6.4	87	14	7.6	101
7C	UA-21	Float	< 1	44	1.1	< 5	5.0	2.1	0.73	2.2	3.7	19	6.6	4.7	43
	UA-22	Sink	< 1	59	< 5	< 15	11	10	0.91	5.0	23	6.8	20	14	92
	UA-21+22	Recomb.	< 1	46	< 2	< 15	5.7	3.1	0.74	2.5	6.0	18.0	8.1	5.8	49
	UA-23	Float	< 1	73	3.7	< 5	6.7	2.7	1.1	7.3	5.4	9.3	21	9.9	116
	UA-24	Sink	< 1	58	< 5	< 15	19	8.7	2.0	9.2	23	< 5	17	41	153
	UA-23+24	Recomb.	< 1	70	< 4	< 15	8.8	3.8	1.2	7.5	8.6	< 10	20	15	122
	UA-25	Float	< 1	57	14	9.1	8.3	2.2	1.1	2.6	3.8	14.6	14.2	7.4	96
	UA-26	Sink	< 1	66	< 5	20	27	24	1.1	13	19	< 5	36	100	84
	UA-25+26	Recomb.	< 1	58	< 13	10	10	4.4	1.1	3.6	5.3	< 14	16	17	95
8C	UA-28	Float	0.2	38	2.5	5.0	5.2	2.2	1.0	3.9	5.7	117	15	6.3	144
	UA-29	Sink	< 1	33	< 5	< 15	10.9	5.6	1.4	6.4	15	14	21	42	62
	UA-28+29	Recomb.	< 1	37	< 5	< 10	6.4	2.9	1.1	4.5	7.7	93	16	14	126
	UA-30	Float	0.7	55	53	2.8	3.4	1.7	0.94	4.6	4.2	207	13	8.5	54
	UA-31	Sink	3.6	73	< 5	< 15	15	18	1.8	7.3	25	5.0	24	24	51
	UA-30+31	Recomb.	1.0	57	48	< 5	4.7	3.7	1.0	5.0	6.7	230	15	10	54

TABLE 20 (CONTINUED)

ANALYSIS OF TRACE ELEMENTS IN SINK-FLOAT FRACTIONS (PARTS PER MILLION)

Drill Hole No.	Sample No.	Product	Ag	B	Co	Cr	Cu A.A.	Ga	Mo A.A.	Ni E.S.	Pb	Sn	V	Zn	Zr
10C	UA-32	Float	1.1	58	1.9	2.4	4.6	2.4	0.87	2.4	4.7	676	15	4.9	38
	UA-33	Sink	1.3	59	< 5	< 15	18	12	1.3	6.1	23	< 5	15	28	64
	UA-32+33	Recomb.	1.1	58	< 3	< 5	6.4	3.8	0.93	2.9	7.1	570	15	8	41
	UA-34	Float	2.6	73	2.3	< 3	4.0	2.5	0.99	4.1	6.4	423	14	5.6	74
	UA-35	Sink	< 1	68	< 5	< 15	12	8.4	1.4	6.6	14	< 5	12	27	71
	UA-34+35	Recomb.	2.5	72	< 3	< 15	5.2	3.3	1.0	4.3	7.3	317	13	8.5	74

TABLE 21

MEAN ANALYSIS OF WHOLE COALS AND ASHES

Constituent	No. of Samples	Whole Coal Basis Mean	S.D.	C.V. %	Ash Basis Mean	S.D.	C.V. %
SiO_2, %	39	11.0	7.75	70	48.7	10.3	21
Al_2O_3, %	41	5.23	2.89	55	25.0	4.76	19
Fe_2O_3, %	41	0.64	0.52	81	3.27	1.82	56
MgO, %	41	0.50	0.23	46	2.70	1.22	45
CaO, %	41	1.03	0.41	40	6.29	4.00	64
Na_2O, %	41	0.46	0.26	57	2.39	0.96	40
K_2O, %	41	0.30	0.36	120	1.25	0.79	63
TiO_2, %	41	0.24	0.14	58	1.14	0.30	26
MnO, ppm	41	49	43	88	250	170	68
BaO, ppm	41	925	398	43	5900	4500	76
SrO, ppm	41	178	178	100	1200	1600	133
B, ppm	41	74	39	53	465	416	89
Cu, ppm	41	8.6	4.2	49	45	18	40
Ga, ppm	41	6.3	3.6	57	31	8.6	28
Mo, ppm	41	1.2	0.54	45	6.3	2.9	
Ni, ppm	41	8.0	4.7	59	45	25	56
Pb, ppm	37	11.6	7.2	62	53	15	28
V, ppm	41	30	29	97	135	59	44
Zn, ppm	41	22	15	68	106	49	46
Zr, ppm	41	101	51	50	510	238	47

S.D. - Standard Deviation
C.V. - Coefficient of Variation

TABLE 22

MEAN ANALYSIS OF FLOAT AND SINK FRACTION AND THEIR ASHES

Constituent	% or ppm	No. of Samples	Whole Product Basis				Ash Basis			
			Floats		Sinks		Floats		Sinks	
			Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
SiO_2	%	10	3.7	1.6	23.1	7.1	43.7	9.8	47.2	8.9
Al_2O_3	%	10	2.09	0.43	13.0	4.6	25.8	2.1	24.8	6.1
Fe_2O_3	%	10	0.33	0.043	0.91	0.18	4.34	1.45	1.95	0.55
MgO	%	10	0.27	0.067	1.13	0.58	3.58	1.50	2.47	1.53
CaO	%	10	0.58	0.36	4.10	1.49	7.4	5.0	8.8	3.8
Na_2O	%	10	0.22	0.079	0.98	0.37	2.68	0.70	2.06	0.79
K_2O	%	10	0.080	0.033	0.51	0.57	0.72	2.0	0.95	0.78
TiO_2	%	10	.10	0.029	0.36	0.13	1.32	0.40	0.75	0.27
MnO	ppm	10	40	27	117	57	460	230	250	130
BaO	ppm	10	557	181	1140	643	7300	3000	2500	1500
SrO	ppm	10	61	20	221	114	0.082	0.039	0.048	0.027
B	ppm	10	61	15.5	58	14.6	800	330	120	25
Co	ppm	10	9.3	16	<5		140	240	<10	
Cr	ppm	10	4.4	2.6	<15		54	46	<30	
Cu	ppm	10	5.8	1.6	15.5	5.3	76	37	31	6.9
Ga	ppm	10	2.3	0.33	13.6	6.9	29	6.3	28	11
Mo	ppm	10	0.99	0.12	1.5	0.34	12.9	4.4	3.2	0.97
Ni	ppm	10	4.3	1.9	7.2	2.5	65	43	15	3.6
Pb	ppm	10	6.9	5.3	29	25	85	60	61	68
Sn	ppm	9	160	230	=5		2000	2800	15	8.8
V	ppm	10	15	5.7	21	6.7	180	59	43	9
Zn	ppm	10	9.3	7.9	46	39	111	71	94	76
Zr	ppm	10	83	36	95	41	1070	550	200	110

S.D. - Standard Deviation

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