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DISTRIBUTION OF CERTAIN MINOR ELEMENTS IN ALASKAN COALS

by

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ABSTRACT

Seventy-five samples of coal from Northern Alaska, Jarvis Creek, Nenana, Matanuska, Kenai and Bering River Coal Fields were analyzed by quantitative spectrochemical procedures for lead, gallium, copper, barium, beryllium, nickel, titanium, vanadium, zirconium, cobalt, chromium, germanium, and tin. Other elements, of significance, identified from the spectrograms were, gold and silver identified in certain Nenana coals and silver in coals from Chickaloon in the Matanuska field, in concentrations up to several parts per million of coal ash.

Forty-one of the above samples were sink-floated to study the distribution of minor elements between the organic and inorganic phases of the coals. Relative affinities of the minor elements to the organic matter in the coal is discussed.

INTRODUCTION

The Mineral Industry Research Laboratory at the University of Alaska, has sponsored a research project for a study of potential uses of Alaskan coals. As a part of this overall project samples from coal fields of Northern Alaska (Kukpowruk), Nenana, Jarvis Creek, Matanuska, Kenai, and the Bering River were studied for distribution of minor elements in coal ash. The primary objective in analyzing the ashes for minor elements was to determine if any of the elements are present in appreiable concentration for commercial exploitation, to develop additional criteria for correlation of seams and determine the distribution of minor elements between organic and inorganic phases of coal. Coal has a property of absorbing metallic ions from solutions that comes in contact, during coalification process. However, only germanium has received widespread interest in recovering commerical quantities from coal and its product. Actual commercial recovery of germanium from flue dust has been done by a gas producer plant in England.

Quantitative spectrographic procedures were used in analyzing for the elements. The results reported herein include the distribution of lead, gallium, copper, barium, beryllium, nickel, titanium, vanadium, zirconium, cobalt, chromium, germanium, and tin. Other elements of significance that were identified from the spectra of the various samples were gold and silver in coals from Nenana coal field. One sample form No. 2 seam in this area, had a concentration of four parts per million gold in ash. Certain coals from Chickaloon area of Matanuska coal field had up to several parts per million silver. A detailed study of distribution of these two elements in Alaskan coals is under investigation.

PREVIOUS WORK

Considerable work has been done by almost every major coal producing country in the world on the distribution of minor elements in coals since Goldschmidt (1954) first reported the discovery of high concentrations of germanium in coals and is well summarized by Lowry (1963). U. S. Geological Survey (Zubovic and others, 1960, 1961, 1964, 1967) has done extensive work on the distribution of minor elements in coals from all the major coal fields of lower 48 States. No data is available till the date of publication of this report on Alaskan coals.

Horton and Aubrey (1950) first attempted to explain the relative affinities of minor elements to the organic matter in coal and Zubovic and others (1961) made a new approach to explain the relative affinities on the basis of percent minor element associated with organic matter, ionic radius, ionic potential, and ionic potential x bond strength.

SAMPLING AND SAMPLE PREPARATION

Samples of coal were collected from freshly exposed sections of coal beds in operating mines, abandoned mines, or beds exposed by natural erosion. Thick beds of coal were divided into several sections and separate samples were collected for each section, in order to have a better understanding of the variation of any trace elements within a seam. The sections within a seam are identified numerically from top to bottom.

Sample preparation: All samples were crushed in a jaw crusher followed by a roll crusher to minus 20 mesh size. A portion of the sample was ground to minus 60 mesh in a disc pulverizer. Samples containing more than 10% ash were separated, in a heavy liquid at 1.5 or 1.6 Sp. G. at minus 20 mesh, prior to pulverizing. However, all samples from Matanuska and Bering River fields were sink-floated. Ash was prepared by heating the pulverized samples in flat porcelain dishes in a muffle furnace, with the temperature gradually raised to and kept at, 450^{o}C until all organic matter is oxidized. The resulting ash was thoroughly mixed in an agate mortor prior to storing in plastic vials. Bed moisture in the smaples was determined after equilibration as per procedure outlined under ASTM, designition D1412-56T. Details of sample location, sink-float results and analytical data are given in Table 6, in the Appendix.

SPECTROGRAPHIC EQUIPMENT AND EXCITATION CONDITIONS

A Jarrel-Ash, Model 78-090, 1.5 meter Wadsworth grating spectrograph with reciprocal linear dispersion of 5.4 A^{o}/mm in the second order was used. The sample was excited in direct current arc at 8.5 amperes, using a 25 micron slit width and a step filter. The exposure was recorded in the second order from 2100A^{o} and 4850A^{o} using Eastman Spectrum Analysis No. 1 emulsion 35mm 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 filter.

All samples were analyzed in duplicate, the duplicates being exposed on separate films. Standards were burned in triplicate initially to establish the analytical curve and additionally one standard was burned for each five exposures made for samples. G-1 and W-1 were burned to check the accuracy of the procedure. Additionally five samples of coal ash were analyzed by atomic absorption as an additional check for analytical precision. The percent transmission of the lines were measured with Jarrel-Ash Microphotometer using 12.5 micron slit opening. Background correction was made only for elements where transmission for background was less than 90%. Percent transmission values were converted to log relative intensities or relative intensity rations using Jarrel-Ash calculating board.

ANALYTICAL PROCEDURE

Indium was used as an internal standard for Pb, Ge, Ga, and Sn, and total energy method (Zubovic and others, 1966) was adopted for Be, Cr, Co, Ti, Zr, V, Ni, Ba, and Cu. Arc mix was prepared by mixing 100 mg. of the sample with 100 mg. of SP-2 graphite containing 0.0267% In_2O_3, in a small plastic vial in a Wig-L-Bug mixer, with one 1/8" Plexiglas ball Pestle. 25 mg. of arc mix was loaded into the electrodes and packed thoroughly with a tight fitting steel rod. Steps 5, 6, and 7 of the filter having 17.7%, 11.6%, and 7.7% transmissions respectively were recorded. The details of excitations conditions are given in Table 1.

Table 1
EXCITATION CONDITIONS

	Total Energy Method	Selective Volatilization
Current	8.5 Amps	8.5 Amps
Analytical gap	3 mm	4.5 mm
Exposure time	120 Seconds	50 Seconds
Electrodes, dia.	5/32"	1/4"
Electrode cavity, dia.	1/8"	3/16"
Electrode cavity, depth	3/16"	1/4"
Counter electrode, dia.	5/32"	1/4"
Atmosphere	Air	Air

Since certain elements sought, particularly tin and germanium, were too low in concentration to be detected by the procedure outlined above, a more sensitive technique used by O'Neil and others (1960) was adopted. This technique uses a large quantity of sample in a pellet form. Since the elements sought are volatile, the exposure period is limited to the early period of excitation until a substantial portion of the elements are volatized. Moving plate studies indicated that volatization of indium, lead, tin, germanium, and gallium was substantially complete within the first 60 seconds, although copper persisted even after the first 60 second period. Selective volatization was facilitated by using low current of 8.5 amperes, deep electrode cavity, and compression of the sample to a pellet form. The pellet technique was found to improve the sensitivity substantially, although at a cost of possible loss of precision. Indium was used as internal standard with the In 3039 as internal standard line. Internal standard mix was prepared by mixing 0.01% In_2O_3 with 1:1 mixture of SP-1 graphite and Johnson-Matthey spectrographic flux (60% lithium tetraborate, 30% strontium tetraborate, 10% cobalt oxide). Arc mix was prepared by mixing five parts of sample or standard with one part of internal standard mix.

Charges of 40 mg. of arc mix were weighed and compressed into a pellet using a metallographic mounting press and a pellet moulding assembly. Addition of a drop of ethyl alcohol with the sample helped to obtain a coherent pellet.

The resulting pellet had a diameter of 11/64" and snugly fits in the electrode cavity. The loaded electrodes were heated in a muffle furnace at 450°C for about 20 minutes prior to arcing to drive off any moisture contained in the pellet. Steps 1 and 7 having transmissions of 100% and 7.7% were recorded. The excitation period was for 50 seconds.

PREPARATION OF STANDARDS

Synthetic base was prepared using spectrographically pure chemicals to yield an average composition of ash of coals from Nenana and Matanuska fields, ash shown in Table 2.

Table 2
COMPOSITION OF SYNTHETIC BASE MIX

Constituent	Weight Per Cent
SiO_2	46.0
Al_2O_3	25.0
Fe_2O_3	8.0
$CaCO_3$	26.4
MgO	4.0
KCl	1.6
NaCl	1.9
	100.0

After thoroughly mixing, the synthetic base was heated in a muffle furnace at 1000°C for 3 hours. The synthetic base was further ground for use in the preparation of synthetic standards. Separate standards were prepared for volatile and involatile groups of elements. All standards were prepared using spectrographically pure chemicals. The details of preparation of standard mix for volatile elements is given in Table 3.

Table 3
PREPARATION OF STANDARD MIX FOR VOLATILE GROUP OF ELEMENTS

Element	Compound Used	Gravimetric Factor	Weight Used
Ga	Ga_2O_3	1.3442	0.0672
Pb	PbO	1.0772	0.0539
Ag	Ag_2O	1.0742	0.0537
Au	$HAuCl4H_2O$	1.9921	0.0996
Cu	CuO	1.2518	0.0626
Ge	Ge_2O	1.4408	0.0720
Sn	SnO_2	1.2696	0.0635
Zn	ZnO	1.2448	0.0622
		TOTAL	0.5347

The standard mix has 9.352% of each of the elements sought. This was further diluted step by step with appropriate amounts of synthetic base to obtain standards with element concentrations of 10,000, 2,000, 400, 80, 16, and 3.2 part per million.

For involatile group of elements the standards were prepared to contain only the range of concentration of the elements encountered in the ashes of coals studied. This was designed to avoid preparation of excessive number of standards required for the wide range of concentration encounted between the elements. Details of preparation of standards are given in Table 4. Table 5 gives the range of concentrations for which the methods are applicable. The ranges shown, however, extend a little beyond the useful range for quantitative analysis. A synthetic base was used for dilution of base mix 2 and subsequent dilutions to obtain standards A, B, C, D, and E.

RESULTS AND DISCUSSION

The analytical results are tabulated according to sample numbers. The sample location seam identification, ash content, and moisture content of the samples can be obtained by reference to Table No. 1. Table No. 7, in the Appendix, shows the distribution of minor elements in Alaskan coals, and represents analysis of whole coals on bed moisture basis. The concentrations for whole coals of sink-floated fractions was obtained by calculation from the analytical results of float and sink fractions, and bed moisture in whole coal. Distribution of minor elements in coal ash is given in Table No. 9 in the Appendix and represent analysis of ash from whole coals.

The minor element concentrations in coal ashes, Table 9, from any particular coal field do not vary appreciably

Table 4
PREPARATION OF STANDARDS FOR INVOLATILE GROUP OF ELEMENTS

Element	Compound Used	Gravi-metric Factor	Weight Used for Base Mix 1	Weight Used for Base Mix 2	Concentration of Elements, PPM					
					Mix 2	Std. A	Std. B	Std. C	Std. D	Std. E
Zr	ZrO_2	1.3408	0.0675		5000	250	125	62.5	31.3	15.6
V	V_2O_5	1.7852	0.2233		12500	625	312.5	156.3	78.1	39.0
Ni	NiO_2	1.2725	0.0636	.0475	5000	250	125	62.5	31.3	15.6
Co	Co_2O_3	1.3620	0.0341		2500	125	62.5	31.3	15.6	7.8
Cr	Cr_2O_3	1.4616	0.0731		5000	250	125	62.5	31.3	15.6
Be	BeO	2.7754	0.0139		500	25	12.5	6.3	3.1	1.6
Ti	TiO_2	1.6681		0.4170	250000	12500	6250	3125	1563	781
Ba	$BaCO_3$	1.4370		0.1078	75000	3750	1875	938	469	234
Synthetic	Coal Ash			0.4277						
		TOTAL	.4755	1.0000						

Table 5

ANALYTICAL RANGE FOR VARIOUS ELEMENTS

Element, A°		Selective Volatalization PPM	Total Energy Method, PPM
Pb	2833.07	10 to 1000	30 to 400
Ga	2943.64	0.5 to 400	10 to 200
Cu	3273.96	0.2 to 100	10 to 200
Ba	2335.27	- - -	200 to 150,000
Be	2348.61	- - -	1.5 to 100
Ni	3414.77	- - -	10 to 500
Ti	3106.23	- - -	250 to 100,000
V	3183.25	- - -	5 to 1,000
Zr	3391.98	- - -	5 to 1,000
Co	3453.51	- - -	10 to 500
Cr	4254.35	- - -	6 to 250
Ge	2651.18	6 to 2000	30 to 300
Sn	2839.99	2 to 3000	- - -
Sn	3175.02	- - -	15 to 400

although the variation is greater when the values are expressed as concentration in raw coal (Table 7). The block-wise sampling of Nenana coals do not show any systematic variation of concentration of minor elements across the thickness. The No. 1 seam of Nenana coal field was sampled at two locations and the profile of minor element concentrations for the two locations are not identical. The observed small variations in the distribution of minor elements within a seam or seams in the coal field cannot be explained at this time except to attribute the variation to the availability of the elements. A comparision of the distribution of minor elements in various coal fields of Alaska and of the major U. S. coal fields in the lower 48 States is given in Table No. 8 in the Appendix.

It can be observed from Table No. 9 that the concentration of minor elements is lower in the ash of low rank coals from Nenana, Kenai and Jarvis Creek field compared to higher rank coals from Matanuska, Northern Alaska and Bering River fields. Table No. 10, in the Appendix, gives the average minor element concentrations in coal ash for Alaskan coals and major coal fields of lower 48 States. The concentration in Alaskan coal ashes fall within the range of three major coal fields of the lower 48 States. With a few minor exceptions the concentration of trace elements is less in the ash of low rank coals (Nenana, Jarvis Creek and Kenai) compared to high rank coals (Matanuska, Northern Alaska and Bering River). The same is true for the three major fields of the lower 48 presented in Table No. 10. The low rank Northern Great Plains province coals show lower concentration compared to higher rank coals from the Interior or the Appalachian regions.

The concentration of minor elements in coals from Bering River field (Table 9) are low compared to other high rank coals but the concentration in coal ash compares favorably.

Table No. 11 in the Appendix shows the concentration of minor elements in the ash of float and sink fractions, and percent recovery of each element varies very widely from sample to sample. This would suggest that percent recovery of the elemtns in float fractions cannot by itself be a satisfactory criterion for determining the relative organic affinities of the elements quantitatively. The variation in recovering in float fractions was in greater part due to the varying weight percent sinks in the samples. The recoveries of any single element for various samples cannot be averaged for this reason for ranking the elements in terms of organic affinity.

The elements were therefore ranked for each sample in the order of decreasing organic affinity, the highest recovery being for the element with the greatest organic affinity. The rank frequency distribution was tabulated for each element. The final rank for each element was assigned to the rank where the highest frequency occurs. Germanium was determined only in low rank coals and had the highest recovery in all the samples analyzed and hence was assigned to the position of highest organic affinity. Ranking of the elements based on all samples sink-floated (Table 11) gave the order of decreasing organic affinity Ge, V, Be, Co, Ni, Zr, Ba, Cr, Ti, Cu, Ga, and Pb. However, using high ranking coals from sample No. 37-75 the order was the same except that the positions of Cu and Ba were reversed, giving Ge, V, Be, Co, Ni, Zr, Ba, Cr, Ti, Ga, Cu, and Pb.

The concentration of the elements in the ash of float fractions compared to the ash of sink fractions could possibly be utilized for determining the relative organic affinities of the elements. Table No. 12, in the Appendix, gives the average concentration of the elements in the float and sink fractions. Based on the ratio of average concentrations of float to sink fractions the elements were arranged as to organic affinity. The order obtained was Ge, Co, V, Be, Ni, Zr, Cr, Ba, Ti, Ga, Cu, and Pb. Although there are some reversals, the order of organic affinity obtained by the two methods are in general agreement. To satisfy both results, we can bracket some elements and obtain a new order of organic affinity series as follows: Ge (V, Be, Co), Ni (Cr, Ba, Zr), Ti (Ga, Cu), and Pb. Compared to the order of organic affinities reported by Zubovic and others (1961) i.e., Ge, Be, Ga, Ti, V, Ni, Cr, Co, and Cu, the results obtained are only in partial agreement. The positions of Ga and Ti are far removed. A reason could be the possible presence of gallium in clay minerals and detrital titanium minerals which would report in the sink fractions.

Another interesting observation that could be made from Table No. 12 is that the concentration of minor elements in the ash of float and sink fractions of a sample are not very different for low rank coals of Nenana, Jarvis Creek and Kenai coals. The higher rank coals of Matanuska, Bering River and Northern Alaska show much higher concentration of minor elements in float ash compared to sink ash.

It appears a quantitative evaluation of relative organic affinities of the elements based on concentration in float and sink fractions can only give a generalized picture. All the minor elements studied are too low in concentration to be of economic value at this time. Preliminary analysis showed that the coals of Nenana and Chickaloon areas merit further investigation on the distribution of gold and silver.

SUMMARY AND CONCLUSIONS

Summary

Seventy-five coal samples were collected from various coal fields in Alaska and the ash was analyzed for lead, gallium, copper, barium, beryllium, nickel, titanium, vanadium, zirconium, cobalt, chromium, germanium, and tin. Quantitative spectrochemical methods were used for the analysis. Other elements of significance that were identified from the spectrograms of the various samples were, gold and silver, detected in No. 2 seam from Nenana field and silver in coals from Chickaloon area in the Matanuska field. Forty-one samples were sink-floated to obtain a lower density organic (coal) fraction and a higher density inorganic (shale) fraction. The two fractions were ashed and analyzed to study the distribution of the elements between organic and inorganic phases of the coals. Analytical results are presented as concentrations of raw coal, raw coal ash, and ash of float and sink fractions. Recovery of the elements in float fractions were calculated.

Conclusions

Although none of the elements analyzed were in a high enough concentration to be of economic significance by present day standards, ever increasing demands for there elements will necessitate search for alternate sources. It is therefore necessary to have such data available to meet the future needs. However, a detailed study of the distribution of gold and silver in Nenana and Chickaloon coals merit further detailed study.

The concentration of trace elements in Alaskan coals fall in ranges found for coals in the lower 48

States. The organic affinity series obtained from percent element associated with floats and also from the ratio of concentration in float and sink ash was Ge, (V, Be, Co), Ni, (Cr, Ba, Zr), Ti, (Ga, Cu), and Pb. The concentration of minor elements is higher in the ash of float fractions compared to sink ash in high rank coals. The low rank coals showed only minor increase in concentration in float ash.

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APPENDIX

TABLE 6 LOCATION AND SINK-FLOAT RESULTS OF COAL SAMPLES

COAL FIELD	SEAM NO.	LOCATION	BLOCK NO.	THICKNESS SAMPLES FT.	SAMPLE NO.	RAW COAL		FLOATS		SINKS	
						BED MOISTURE %	ASH %	WEIGHT %	ASH %	WEIGHT %	ASH %
Nenana	1	Usibelli Coal Mine	1	8	1	21.83	6.00				
do	1	do	2	4	2	18.69	17.87	85.05	13.30	14.95	71.35
do	1	do	3	12	3	19.90	10.12				
do	1	do	4	8	4	20.31	3.80				
do	1	do	5	8	5	18.99	6.05				
do	1	do	6	12	6	20.49	7.12				
do	2	do	1	14	7	21.24	18.75	74.98	12.86	25.02	56.64
do	2	do	2	14	8	20.53	24.45	65.39	17.24	34.61	56.33
do	2	do	3	14	9	23.34	7.24				
do	2	do	4	8	10	22.93	11.43	93.60	12.66	6.40	46.72
do	3	do	1	5	11	27.79	5.06				
do	3	do	2	5	12	21.96	3.85				
do	3	do	3	5	13	21.13	3.82				
do	3	do	4	2	14	20.94	4.81				

do	1	Vitro Minerals Corp.	1	7	15	20.11	7.07				
do	1	do	2	7	16	18.69	3.26				
do	1	do	3	7	17	21.87	7.85				
do	1	do	4	7	18	20.75	4.65				
do	1	do	5	5	19	19.55	10.02				
do	1	do	6	2	20	15.52	33.34	52.71	18.45	47.29	62.91
do	1	do	7	2.5	21	16.45	9.77				
do	1	do	8	7	22	15.11	17.16	89.48	14.36	10.52	70.06
do	1	do	9	7	23	14.75	17.50	84.46	13.82	15.54	57.00
do	1	do	10	7	24	15.89	13.80	90.14	12.34	9.86	53.63
do	1	do	11	3	25	17.60	17.95	93.55	19.84	6.45	50.08
Kenai		Gist Property	1	2.2	26	17.75	9.73				
do		do	2	0.5	27	17.37	15.78	84.00	13.18	16.00	50.21
do	1	Augastino Property	Whole Seam	1.2	28	20.71	8.00				
do	2	do	do	1.8	29	20.25	7.73				
do	3	do	do	6.8	30	18.22	13.76	89.60	11.49	10.40	62.86
do	5	do	do	2.2	31	19.37	7.99				

TABLE 6 LOCATION AND SINK-FLOAT RESULTS OF COAL SAMPLES (Continued)

COAL FIELD	SEAM NO.	LOCATION	BLOCK NO.	THICKNESS SAMPLED FT.	SAMPLE NO.	RAW COAL BED MOISTURE %	RAW COAL ASH %	FLOATS WEIGHT %	FLOATS ASH %	SINKS WEIGHT %	SINKS ASH %
Kenai	1	Happy Valley	Part Seam Sample	0.5	32	24.28	9.51				
do	2	do	do	0.5	33	20.78	7.31				
Jarvis Creek	1	Ober Creek Reed Property	1	5	34	21.85	8.38				
do	2	do	1	1	35	22.06	10.40	95.40	10.52	4.60	72.03
do	3	do	Whole Seam	1	36	19.41	10.73				
Mata-nuska	5L	Evans Jones		2.8	37	5.08	27.85	53.42	10.38	46.58	51.10
do	5U I	do	1 (Bottom)	8.5	38	5.09	20.36	71.02	8.51	28.98	53.20
do	5U II	do	2 (Top)	6.3	39	4.44	26.48	59.60	9.32	40.40	54.85
do	6L	do	Whole Seam	4.0	40	5.20	19.93	77.61	8.39	22.39	64.85
do	6U	do	do	1.9	41	5.78	14.28	87.82	9.82	12.18	53.66
do	7L	do	do	3	42	5.67	15.40	84.50	8.18	15.50	60.77

do	7U	do	do	2.2	43		5.56	20.93	67.29	8.84	32.71	49.58
do	7AL	do	do	2.6	44		6.24	4.15	97.86	3.29	2.14	56.49
do	7AU	do	do	2.1	45		6.25	20.39	75.72	9.86	24.28	59.18
do	7BL	do	do	2.3	46		6.80	7.14	94.71	5.07	5.29	54.13
do	7BU	do	do	3.4	47		6.07	3.74	98.85	3.39	1.15	55.13
do	7C	do	do	3.2	48		5.87	13.62	86.78	6.21	13.22	68.76
do	8	do	do	3.5	49		6.41	13.31	87.02	6.42	12.98	66.54
do	Bogus	do	do	4.8	50		5.97	30.03	53.13	8.21	46.87	59.53
do	Upper Seam	Chicka-loom Castle Mountain Mine	do	5.0	51		1.72	13.03	92.21	9.26	7.79	60.71
do	Lower Seam	do	do	4.3	52		3.13	12.16	92.00	7.72	8.00	68.22
do	3	Premier Mine	do	7.7	53		4.53	21.75	74.86	7.94	25.14	67.00
do	3A	do	do	3.5	54		4.75	7.81	92.59	4.00	7.41	60.98
do	2¼	do	do	2.5	55		5.04	11.13	89.01	5.95	10.99	58.54
do	2½	do	do	2.2	56		5.40	7.93	88.75	1.83	11.25	60.15
do	1	do	do	5.8	57		4.78	10.03	89.51	5.03	10.49	57.55
do	1	do	do	2.5	58		3.93	29.51	61.08	7.11	38.92	67.79

TABLE 6 LOCATION AND SINK-FLOAT RESULTS OF COAL SAMPLES (Continued)

COAL FIELD	SEAM NO.	LOCATION	BLOCK NO.	THICKNESS SAMPLES FT.	SAMPLE NO.	RAW COAL		FLOATS		SINKS	
						BED MOISTURE %	ASH %	WEIGHT %	ASH %	WEIGHT %	ASH %
Bering River		Trout Creek Out-Crop 42-C Sample 32-C	do	16	59	2.62	3.02	99.29	2.74	0.71	53.89
do		Carbon Creek Out-Crop 56 Sample 55-C	do	6.5	60	4.23	5.09	96.30	3.70	3.34	56.86
do		Newada Creek Out-Crop 69 Sample 51C	do	8	61	1.97	2.04	98.64	1.27	1.36	61.08
do		Carbon Creek Out-Crop 89 Sample 61-C	do	5.5	62	1.93	2.55	98.54	1.71	1.46	63.21

do		Carbon Creek Out-Crop 92 Sample 63-C	do	5.5	63	2.45	1.65	99.20	1.18	0.80	65.53
Northern Alaska	1C	Kukpow-ruk River	-	-	64	3.77	2.48				
do	2C	do	-	-	65	3.88	6.39				
do	3C	do	-	-	66	4.76	4.60				
do	4C	do	-	-	67	3.80	13.48	85.25	6.07	14.75	59.96
do	5C	do	-	-	68	4.45	12.89	86.54	4.78	13.46	69.54
do	6C	do	-	-	69	5.11	21.43	76.02	8.68	23.98	66.67
do	7C	do	-	-	70	5.54	13.61	89.03	8.84	10.97	59.69
do	8C	do	-	-	71	4.29	13.41	86.36	5.38	13.64	68.67
do	9C	do	-	-	72	5.65	3.13				
do	10C	do	-	-	73	5.45	5.92				
do	11C	do	-	-	74	6.70	4.70				
do	12C	do	-	-	75	8.00	18.65	78.58	7.54	21.42	67.00

Seam Desiqnition: U = Upper; L = Lower
Ash % of Raw Coal: Bed Moisture Basis
Weight % and Ash % of Float and Sink: Moisture Free Basis
Sample Nos: 37,38,39,43 and 50 were separated at 1.5 Sp.G. All other Samples at 1.60 Sp.G.

TABLE 7 CONCENTRATION OF MINOR ELEMENTS IN ALASKAN COALS

COAL FIELD	SAMPLE NO.	PARTS PER MILLION												
		Pb	Ga	Cu	Ba	Be	Ni	Ti	V	Zr	Co	Cr	Ge	Sn
Nenana	1	12.5	1.1	4.2	136	<0.1	2.5	48	1.6	1.4	0.7	1.9	0.4	0.6
do	2	46.2	8.7	30.0	223	0.4	4.4	497	12.8	9.0	2.3	12.4	1.8	2.8
do	3	9.0	5.0	7.2	175	0.2	3.3	229	5.2	4.5	1.5	5.7	< .6	0.9
do	4	8.9	0.5	3.0	119	< .1	2.4	57	0.8	1.7	0.6	0.8	< .2	2.5
do	5	8.0	3.2	3.9	82	< .1	2.8	41	1.8	1.3	< .6	2.9	0.6	0.9
do	6	8.0	4.5	5.4	205	0.2	3.6	272	4.6	3.3	0.9	4.2	0.8	0.8
do	7	16.7	7.5	17.6	348	0.6	8.0	708	15.7	10.3	2.6	14.8	0.6	3.2
do	8	13.4	8.3	31.8	447	1.0	10.4	815	27.5	16.1	3.8	26.1	1.5	2.5
do	9	7.8	2.0	3.1	83	0.2	1.8	35	1.2	1.4	0.9	2.1	1.2	2.3
do	10	7.6	4.6	8.1	267	< .1	5.3	355	5.9	6.4	1.8	9.4	0.8	0.9
do	11	4.9	0.03	5.5	162	< .1	5.3	42	2.4	1.9	0.9	2.1	< .3	0.1
do	12	2.4	0.08	3.7	195	< .1	3.4	30	2.2	1.5	0.8	1.6	< .2	0.6
do	13	3.5	0.26	4.1	143	0.1	3.4	34	1.2	1.3	0.7	1.6	<0.2	1.1
do	14	3.8	0.7	1.6	45	<0.1	1.3	31	0.3	1.2	0.7	1.1	0.3	2.9
do	15	7.8	3.1	3.9	116	<0.1	1.8	43	1.4	1.3	< .7	1.8	1.0	6.9
do	16	4.6	0.7	3.7	168	<0.1	3.4	154	2.1	3.6	0.6	1.3	<0.2	3.1
do	17	5.6	2.8	9.7	220	<0.1	3.5	216	10.7	6.6	1.2	8.4	0.7	3.7

do	18	4.6	2.2	2.4	76	<0.1	1.6	37	1.1	1.1	0.6	1.8	0.6	3.7
do	19	16.6	5.6	12.0	251	0.4	6.5	323	14.8	5.7	1.8	19.1	1.6	1.4
do	20	22.0	13.9	23.1	487	0.7	7.6	1169	28.7	24.1	4.0	39.6	2.8	3.5
do	21	12.4	2.7	10.9	567	< .1	7.0	929	14.3	26.7	2.7	15.4	1.7	3.2
do	22	17.4	6.8	15.3	488	0.6	8.7	581	12.7	13.8	3.0	21.8	1.7	2.4
do	23	28.3	8.0	13.4	503	0.6	6.5	749	20.3	13.8	2.6	27.0	2.6	3.1
do	24	18.0	8.5	15.2	502	0.5	8.6	678	22.5	13.3	3.0	23.4	2.7	3.2
do	25	12.2	11.8	17.5	370	0.6	7.4	443	15.9	8.7	3.5	30.2	4.5	3.5
Kenai	26	4.7	2.1	12.7	414	< .1	7.4	162	8.0	12.2	3.0	11.4	0.9	0.3
do	27	7.7	4.4	15.2	315	0.5	20.1	261	11.4	7.4	9.0	15.3	0.5	0.4
do	28	12.9	1.1	13.7	346	< .1	6.0	121	4.9	2.7	3.3	3.5	0.2	0.2
do	29	1.5	0.2	3.5	302	< .1	6.0	84	4.9	8.9	3.5	11.8	1.5	0.1
do	30	16.8	3.7	15.2	311	0.3	5.8	273	10.0	8.0	2.2	9.1	1.8	0.4
do	31	10.0	1.0	5.7	200	4.1	4.7	102	5.4	4.2	3.0	2.9	1.7	0.3
do	32	10.0	2.0	16.0	286	1.7	6.7	172	7.3	5.2	5.7	5.4	2.1	4.2
do	33	5.8	2.0	2.9	85	< .1	2.0	60	1.7	1.3	1.6	0.9	0.6	0.5
Jarvis Creek	34	1.8	1.4	3.4	696	< .1	2.3	201	2.9	8.4	<0.8	1.1	0.8	1.2
do	35	5.9	3.2	7.2	721	< .1	3.2	221	4.9	6.3	<1.0	4.8	2.7	1.2

TABLE 7 CONCENTRATION OF MINOR ELEMENTS IN ALASKAN COALS (Continued)

COAL FIELD	SAMPLE NO.	PARTS PER MILLION *												
		Pb	Ga	Cu	Ba	Be	Ni	Ti	V	Zr	Co	Cr	Ge	Sn
Jarvis Creek	36	8.4	4.1	4.9	311	0.5	2.3	108	6.5	2.3	<1.0	6.8	2.7	1.1
Matanuska	37	15.4	9.8	47.1	237	0.6	19.2	1220	27.6	34.8	7.5	31.8		
do	38	9.6	7.8	29.1	458	0.5	14.0	904	28.3	20.7	5.0	25.0		
do	39	18.6	9.9	28.1	946	0.8	19.0	1310	49.1	49.8	6.5	26.5		
do	40	10.5	8.5	30.4	273	0.8	16.5	1560	47.9	42.7	10.0	18.1		
do	41	13.8	8.2	17.9	824	0.7	14.7	1150	20.1	31.8	11.7	10.2		
do	42	9.0	7.4	19.4	1060	0.5	29.2	1280	28.1	33.3	10.6	10.4		
do	43	14.4	11.6	28.4	1510	1.0	35.7	1910	93.6	58.6	16.2	25.2		
do	44	11.0	1.3	7.6	494	0.2	17.8	178	5.6	8.8	7.8	2.8		
do	45	21.9	8.1	21.5	264	1.2	20.0	1380	44.6	75.6	9.0	17.6		
do	46	11.0	3.8	14.6	415	0.5	25.1	593	33.0	19.3	17.0	10.4		
do	47	4.3	2.0	4.6	531	0.3	12.6	200	6.8	6.4	8.3	4.1		
do	48	29.5	6.8	22.8	557	0.8	33.4	1570	45.0	61.1	22.1	7.2		
do	49	20.2	8.6	34.5	374	1.3	32.4	1160	16.6	143.2	16.8	3.8		
do	50	14.3	11.5	35.8	722	0.9	30.0	1450	75.5	45.1	8.9	49.1		
do	51	12.2	4.9	11.5	518	0.8	16.9	688	17.0	42.0	4.6	6.2		

do	52	19.8	4.6	21.5	371	0.7	12.0	724	13.6	36.3	4.2	6.1		
do	53	18.0	11.8	47.1	891	0.8	19.8	1480	16.2	40.0	6.9	10.8		
do	54	6.8	5.5	7.8	1000	0.4	18.2	401	14.1	14.7	7.9	3.6		
do	55	7.8	5.7	11.8	691	0.8	32.6	974	21.5	37.6	17.9	6.5		
do	56	7.0	1.1	5.4	171	0.5	21.1	98	1.9	10.8	8.8	1.2		
do	57	7.6	4.1	10.5	508	0.4	16.9	604	5.8	18.5	8.2	7.7		
do	58	17.1	10.8	27.9	897	1.5	44.3	2150	72.7	69.9	14.8	19.3		
Bering River	59	7.4	1.3	7.5	250	< 0.1	4.3	236	1.7	20.1	0.8	1.0		
do	60	6.1	1.6	4.7	54	< 0.1	1.9	305	1.8	18.3	1.0	1.9		
do	61	7.8	0.9	5.2	120	Int.	4.9	120	2.5	3.1	1.6	2.4		
do	62	4.9	1.0	2.5	76	Int.	3.2	320	1.3	9.5	1.2	1.1		
do	63	6.6	1.3	10.0	53	0.2	1.8	84	2.9	2.6	1.0	1.4		
Northern Alaska	64	8.1	0.2	15.6	165	< .1	1.4	37	0.5	1.8	< .2	0.7		
do	65	9.0	1.2	4.6	384	< .1	1.0	252	2.4	9.9	< .6	0.9		
do	66	6.5	1.8	4.6	330	0.5	7.1	106	1.3	5.7	4.2	2.3		
do	67	24.2	6.0	18.9	690	2.1	16.6	1990	16.6	37.7	9.2	10.8		
do	68	14.4	4.3	17.8	590	0.8	5.4	586	13.5	27.4	3.3	16.4		

TABLE 7 CONCENTRATION OF MINOR ELEMENTS IN ALASKAN COALS (Continued)

COAL FIELD	SAMPLE NO.	PARTS PER MILLION*												
		Pb	Ga	Cu	Ba	Be	Ni	Ti	V	Zr	Co	Cr	Ge	Sn
Northern Alaska	69	17.3	9.1	16.1	411	0.8	15.4	1230	28.8	60.7	6.7	1.8		
do	70	31.1	7.7	16.3	266	2.3	13.1	1050	5.8	67.0	7.3	4.5		
do	71	11.3	5.4	7.9	1730	0.6	5.6	413	5.2	17.2	2.6	2.0		
do	72	6.3	0.6	5.4	257	< .1	3.7	66	0.6	2.6	0.8	0.8		
do	73	5.5	0.9	7.1	599	< .1	5.7	174	1.7	8.1	2.1	2.2		
do	74	4.6	0.6	3.8	277	< .1	4.6	137	2.0	3.0	1.2	3.5		
do	75	28.9	8.8	28.9	2340	1.5	8.2	2330	31.2	52.0	4.5	2.0		

*Bed moisture Basis.
Int - Could not be determined due to interference.

Table 8
RELATIVE ABUNDANCE OF MINOR ELEMENTS IN COALS FROM VARIOUS REGIONS OF THE UNITED STATES

ELEMENT	PARTS PER MILLION COAL										
								INTERIOR REGION*			
								WESTERN			
	Nenana	Jarvis Creek	Kenai	Matanuska	Northern Alaska	Bering River	Northern Great Plains Province*	Okla. Ark. Basin	Iowa, Mo., North Okla.	EASTERN	Appalachian*
Pb	9.7	5.4	8.7	13.6	13.9	6.6	-	-	-	-	-
Ga	3.4	2.9	2.1	6.5	3.9	1.2	5.5	1.4	3.7	4.1	4.9
Cu	8.7	5.2	10.6	22.1	12.3	6.0	15	11	13	11	15
Ba	228	576	282	623	670	111	-	-	-	-	-
Be	0.25	0.2	0.9	0.7	0.8	.1	1.5	0.64	2.3	2.5	2.5
Ni	4.8	2.6	7.3	22.8	7.3	3.2	7.2	11	24	15	14
Ti	214	177	154	1040	698	213	590	250	250	450	340
V	6.5	4.8	6.7	31.1	9.1	2.0	16	17	22	35	21
Zr	5.2	5.6	6.2	39.2	19.4	10.7	-	-	-	-	-
Co	1.5	1.0	3.9	10.5	3.6	1.1	2.7	4.4	5.4	3.8	5.1
Cr	7.1	4.2	7.5	13.8	4.0	1.6	7	12	17	20	13
Ge	0.90	2.1	1.2	-	-	-	1.6	1.0	22	13	5.8
Sn	2.12	1.2	0.8	-	-	-	0.9	1.6	0.6	1.5	.4

*Zubovic and others (1961, 1964, 1966, 1967)
-Not Determined

TABLE 9 CONCENTRATION OF MINOR ELEMENTS IN COAL ASH

COAL FIELD	SAMPLE NO.	PARTS PER MILLION												
		Pb	Ga	Cu	Ba	Be	Ni	Ti	V	Zr	Co	Cr	Ge	Sn
Nenana	1	208	18	70	2270	< 1.5	41	800	27	23	12	32	7.5	10.9
do	2	259	49	168	1250	2.3	24	2780	72	51	13	69	10.1	15.7
do	3	89	49	71	1730	1.7	33	2270	51	44	15	56	<6	9.1
do	4	233	12	79	3130	< 1.5	63	1510	22	44	15	22	<6	67.0
do	5	133	53	64	1350	< 1.5	46	680	29	22	<10	48	10.6	15.0
do	6	112	63	76	2880	3.3	50	3830	64	47	12	59	11.5	11.2
do	7	89	40	94	1850	3.0	43	3780	83	55	14	79	3.0	6.9
do	8	55	34	130	1830	3.9	43	3330	113	66	16	107	6.2	10.3
do	9	108	28	43	1150	2.6	25	490	16	19	12	29	16.9	32.0
do	10	67	41	71	2340	1.7	47	3110	52	56	16	83	7.2	8.0
do	11	97	.5	109	3200	< 1.5	105	835	48	38	18	42	6.0	2.8
do	12	64	2	96	5050	< 1.5	89	775	56	39	21	42	<6	16
do	13	92	7	108	3740	2.5	89	875	31	33	18	43	<6	30
do	14	80	15	33	935	< 1.5	27	640	7	25	15	22	6.8	60
do	15	110	44	55	1640	< 1.5	25	605	20	18	<10	25	13.8	98
do	16	142	22	112	5150	< 1.5	106	4720	64	111	17	39	<6	97
do	17	71	36	123	2800	< 1.5	45	2750	136	84	15	107	8.9	48

do	18	101	47	52	1630	< 1.5	34	790	24	24	13	38	13.6	80.0
do	19	166	56	120	2500	4.0	65	3220	148	57	18	191	16.1	14.0
do	20	66	42	69	1460	2.3	23	3510	86	72	12	119	8.5	10.3
do	21	127	28	111	5800	6.0	72	9500	147	273	28	158	17.7	33.0
do	22	102	39	89	2840	3.2	51	3390	74	81	18	127	10.2	14.0
do	23	161	46	77	2880	3.1	37	4280	116	79	15	154	14.9	17.5
do	24	130	62	110	3640	3.5	62	4920	163	96	22	169	19.9	23.1
do	25	68	66	98	2060	3.3	41	2470	88	48	19	168	25.0	10.6
Kenai	26	48	22	130	4250	< 1.5	76	1660	83	125	31	117	9.6	3.5
do	27	49	28	96	2000	3.1	127	1650	72	47	57	97	3.4	2.7
do	28	162	14	171	4320	< 1.5	75	1510	61	34	41	44	3.0	2.2
do	29	20	2	45	3900	< 1.5	78	1090	63	115	45	152	20.0	1.2
do	30	122	27	110	2270	2.1	42	1980	73	58	16	66	12.7	2.9
do	31	125	12	71	2500	5.1	59	1270	68	52	37	36	20.7	3.4
do	32	105	21	168	3000	1.8	70	1810	77	55	60	57	22.0	44.0
do	33	79	28	39	1160	< 1.5	27	815	23	18	22	13	8.6	7.5
Jarvis Creek	34	22	17	41	8300	< 1.5	28	2400	34	100	<10	13	9.5	14.7
do	35	56	30	69	6930	< 1.5	30	2130	47	61	11	46	25.8	12.0

TABLE 9 CONCENTRATION OF MINOR ELEMENTS IN COAL ASH (Continued)

COAL FIELD	SAMPLE NO.	PARTS PER MILLION												
		Pb	Ga	Cu	Ba	Be	Ni	Ti	V	Zr	Co	Cr	Ge	Sn
Jarvis Creek	36	78	39	46	2900	4.7	21	1010	61	21	<10	63	25	10.2
Mata-nuska	37	55	35	169	850	2.0	69	4380	99	125	27	114		
do	38	47	38	143	2250	2.6	69	4440	139	101	25	123		
do	39	76	37	106	3570	2.9	72	4960	185	188	25	100		
do	40	53	43	153	1370	3.8	83	7810	241	214	50	91		
do	41	97	58	125	5770	4.8	103	8040	141	223	82	71		
do	42	59	48	126	6850	3.2	189	8340	183	216	69	67		
do	43	69	55	136	7220	4.6	171	9110	447	280	78	120		
do	44	265	32	183	11900	5.2	430	4290	135	212	190	68		
do	45	107	40	106	1300	6.1	98	6750	219	370	44	87		
do	46	155	54	205	5810	7.6	351	8300	462	270	238	146		
do	47	116	53	123	1420	8.8	336	5310	182	172	221	110		
do	48	216	50	167	4090	6.2	245	11500	330	450	163	53		
do	49	152	64	259	2810	9.9	244	8700	125	1080	126	29		
do	50	47	38	118	2380	2.9	99	4790	249	149	29	162		
do	51	94	38	89	3980	6.0	130	5280	130	322	35	47		

Mata-nuska	52	163	38	177	3050	5.4	99	5960	112	300	34	50			
do	53	83	54	217	4100	3.5	91	6800	75	184	32	50			
do	54	86	71	100	12800	4.9	234	5130	180	188	102	46			
do	55	70	51	106	6210	6.9	293	8750	193	338	160	59			
do	56	89	14	73	2160	6.1	266	1240	24	137	110	15			
do	57	76	41	105	5070	4.4	169	6020	58	185	82	76			
do	58	58	37	95	3040	4.9	150	7300	247	237	50	66			
Bering River	59	244	43	247	8280	< 1.5	142	7810	56	665	25	33			
do	60	119	32	93	1070	< 1.5	37	5990	35	359	20	37			
do	61	382	44	256	5860	< 1.5	238	5900	124	153	78	116			
do	62	194	40	97	3000	< 1.5	126	12600	49	374	49	45			
do	63	402	81	606	3230	12.6	112	5100	177	154	59	86			
Northern Alaska	64	325	6.6	630	6660	< 1.5	57	1490	22	72	<10	30			
do	65	141	19	72	6000	< 1.5	15	3950	37	155	<10	14			
do	66	140	39	99	7150	11.2	155	2300	28	123	91	49			
do	67	179	45	140	5120	16.1	123	14700	123	280	68	63			
do	68	112	33	138	4580	6.6	42	4550	105	212	25	84			

TABLE 9 CONCENTRATION OF MINOR ELEMENTS IN COAL ASH (Continued)

COAL FIELD	SAMPLE NO.	PARTS PER MILLION												
		Pb	Ga	Cu	Ba		Ni	Ti	V	Zr	Co	Cr	Ge	Sn
Northern Alaska	69	81	42	75	1920	3.8	72	5740	134	283	31	77		
do	70	229	57	120	1950	16.7	96	7750	42	492	53	13		
do	71	84	40	59	12900	4.4	42	3080	39	129	20	34		
do	72	202	20	171	8200	< 1.5	118	2110	18	82	26	27		
do	73	92	15	120	10100	< 1.5	96	2930	29	137	36	37		
do	74	97	12	80	5900	< 1.5	97	2910	42	64	25	75		
do	75	155	47	155	12500	7.8	44	12500	167	279	24	10		

Table 10
RELATIVE ABUNDANCE OF MINOR ELEMENTS IN COAL ASH
FROM VARIOUS REGIONS IN THE UNITED STATES

ELEMENT	PART PER MILLION, COAL ASH										
								INTERIOR REGION*			
								WESTERN			
	Nenana	Jarvis Creek	Kenai	Mata-nuska	Northern Alaska	Bering River	Northern Great Plains Province*	Okla. Ark.	Iowa, Mo., North Okla.	EASTERN	Appa-lachian*
Pb	100	52	89	101	153	268	-	-	-	-	-
Ga	29	29	19	45	31	48	47	30	71	81	110
Cu	88	52	104	140	154	259	130	230	230	200	370
Ba	2650	6040	2930	4450	6920	4290	-	-	-	-	-
Be	2.3	2.6	2.3	5.1	6.2	3.7	18	11	52	56	65
Ni	58	28	69	181	80	131	64	240	330	320	320
Ti	2050	1850	1470	6510	5330	7480	6500	5300	4400	8500	7100
V	59	47	65	189	65	88	150	400	310	540	460
Zr	47	61	63	270	192	341	-	-	-	-	-
Co	16	10	39	88	35	46	21	115	105	69	140
Cr	64	41	73	80	43	63	70	330	240	350	260
Ge	8.5	20.1	12.5	-	-	-	22	19	500	250	110
Sn	21.7	12.3	8.4	-	-	-	16			27	14

*Zubovic and others (1961, 1964, 1966, 1967)
-Not Determined

TABLE 11 DISTRIBUTION OF MINOR ELEMENTS IN THE ASH OF FLOAT AND SINK PRODUCTS

COAL FIELD	SAMPLE NO.	PRODUCT	PARTS PER MILLION, MOISTURE FREE BASIS												
			Pb	Ga	Cu	Ba	Be	Ni	Ti	V	Zr	Co	Cr	Ge	Sn
Nenana	2	Float	152	57	275	1600	3.0	28	2080	76	38	16	82	17.7	11.7
		Sink	372	40	54	880	<1.5	21	3530	67	64	<10	56	2.2	20
		Rec. %	30.2	60.2	84.4	65.8	-	58.6	38.4	54.6	38.6	-	60.8	89.5	38.3
do	7	Float	82	43	119	2130	3.5	56	4400	77	38	19	71	6.0	10.8
		Sink	94	38	77	1670	2.6	34	3350	88	66	<10	84	<1	21.0
		Rec. %	37.2	43.5	51.3	46.4	47.8	52.8	47.2	37.3	28.1	-	36.5	-	25.9
do	8	Float	56	48	114	2230	5.0	56	3300	138	52	20	137	13.7	11.8
		Sink	54	26	139	1600	3.3	35	3350	98	74	13	89	1.9	9.5
		Rec. %	37.5	51.6	32.2	44.6	46.7	48.1	36.3	44.9	28.9	47.1	47.1	80.7	41.8
do	10	Float	42	40	53	2440	<1.5	31	2840	40	48	17	70	8.7	7.3
		Sink	165	43	142	1950	2.7	108	4180	97	88	12	132	1.0	10.9
		Rec. %	50.2	78.7	59.7	83.2	-	53.2	72.9	62.0	68.4	84.9	67.8	97.2	72.6
do	20	Float	85	81	92	1930	3.1	28	2300	120	40	19	253	31.5	22.0
		Sink	60	29	62	1310	2.0	21	3900	75	83	<10	75	<1	6.6
		Rec. %	31.7	47.7	32.7	32.5	33.6	30.4	16.2	34.3	13.6	-	52.4	-	52.1

TABLE 11 DISTRIBUTION OF MINOR ELEMENTS IN THE ASH OF FLOAT AND SINK PRODUCTS (Continued)

COAL FIELD	SAMPLE NO.	PRODUCT	PARTS PER MILLION, MOISTURE FREE BASIS												
			Pb	Ga	Cu	Ba	Be	Ni	Ti	V	Zr	Co	Cr	Ge	Sn
Nenana	22	Float	106	54	100	3800	4.2	60	3780	101	90	22	138	15.5	18.0
		Sink	94	14	70	1700	<1.5	35	2700	27	64	<10	108	<1	7.1
		Rec. %	66.3	87.1	71.4	85.0	-	74.9	70.9	86.7	71.0	-	69.0	-	81.5
do	23	Float	73	56	96	3350	4.3	50	4150	139	70	19	191	25.5	19.0
		Sink	278	32	51	2250	1.6	20	4450	86	90	<10	106	<1	15.5
		Rec. %	25.7	69.8	71.3	66.2	78.0	76.7	55.1	68.0	50.6	-	70.4	-	61.8
do	24	Float	84	74	131	4500	4.3	81	4970	191	92	27	202	28.8	26.0
		Sink	228	36	67	1840	1.8	22	4800	104	105	<10	101	1.2	17.0
		Rec. %	43.7	81.2	80.4	83.7	83.4	88.6	68.5	79.4	64.8	-	80.8	98.1	76.3
do	25	Float	58	72	98	1900	3.4	44	2320	89	43	21	180	29.2	20.0
		Sink	124	31	95	3000	3.0	27	3330	86	78	<10	102	1.0	17.6
		Rec. %	72.9	93.0	85.6	78.4	86.7	90.4	80.0	85.6	76.0	-	91.0	99.4	86.7
Kenai	27	Float	38	28	90	2170	4.2	144	1350	59	36	60	91	5.2	2.5
		Sink	64	28	105	1760	<1.5	104	2070	91	62	53	106	<1	3.0
		Rec. %	45.0	57.9	54.2	62.9	-	65.6	47.4	47.2	44.5	60.9	54.2	-	53.5

TABLE 11 DISTRIBUTION OF MINOR ELEMENTS IN THE ASH OF FLOAT AND SINK PRODUCTS (Continued)

COAL FIELD	SAMPLE NO.	PRODUCT	PARTS PER MILLION, MOISTURE FREE BASIS												
			Pb	Ga	Cu	Ba	Be	Ni	Ti	V	Zr	Co	Cr	Ge	Sn
Kenai	30	Float	151	27	71	2210	2.5	48	1300	67	39	16	40	20.2	2.9
		Sink	76	26	192	2350	<1.5	32	3050	82	88	16	107	<1	3.0
		Rec. %	75.8	62.1	39.4	59.7	-	70.3	40.2	56.3	41.1	61.2	37.1	-	60.4
Jarvis Creek	35	Float	38	32	46	5800	<1.5	26	1890	23	62	<10	12	24.0	12.8
		Sink	113	27	140	10400	<1.5	44	2850	119	58	13	150	<1	9.6
		Rec. %	50.5	78.2	49.9	62.9	-	64.2	66.7	36.9	76.4	-	19.5	-	80.2
Matanuska	37	Float	95	63	135	1420	4.4	141	6200	242	206	48	303		
		Sink	46	29	177	720	<1.5	52	3950	66	106	22	70		
		Rec. %	32.5	33.6	15.1	31.5	-	38.7	26.8	46.1	31.2	33.7	50.2		
do	38	Float	62	65	163	3880	5.5	140	4800	297	100	52	286		
		Sink	41	28	135	1610	<1.5	41	4300	77	102	14	59		
		Rec. %	37.2	47.6	32.1	48.5	-	57.2	30.4	60.2	27.8	59.3	65.5		
do	39	Float	83	67	178	4250	8.7	219	12900	726	508	67	320		
		Sink	67	30	88	3400	<1.5	35	2970	50	108	14	45		
		Rec. %	23.7	35.9	33.6	23.9	-	61.1	52.1	78.4	54.1	54.5	64.1		

TABLE 11 DISTRIBUTION OF MINOR ELEMENTS IN THE ASH OF FLOAT AND SINK PRODUCTS (Continued)

COAL FIELD	SAMPLE NO.	PRODUCT	PARTS PER MILLION, MOISTURE FREE BASIS												
			Pb	Ga	Cu	Ba	Be	Ni	Ti	V	Zr	Co	Cr	Ge	Sn
Matanuska	40	Float	88	62	203	2730	8.9	190	17000	625	468	124	188		
		Sink	37	34	130	760	<1.5	35	3670	68	100	17	47		
		Rec. %	51.6	45.0	41.2	61.7	-	70.9	67.4	80.5	67.7	76.6	64.2		
do	41	Float	83	65	136	8700	5.9	150	8180	200	293	128	103		
		Sink	115	48	111	1900	3.3	40	7900	63	130	21	29		
		Rec. %	48.8	64.1	61.8	85.8	70.2	83.2	57.6	80.7	74.8	88.9	82.4		
do	42	Float	111	78	189	11400	5.6	393	13300	350	340	134	91		
		Sink	20	26	80	3550	<1.5	40	4700	60	125	21	50		
		Rec. %	80.3	68.8	63.4	70.11	-	87.8	67.5	81.1	66.6	82.4	57.2		
do	43	Float	85	102	235	12900	10.3	423	17600	1290	575	210	219		
		Sink	63	38	99	5150	2.5	78	6000	138	172	29	84		
		Rec. %	33.1	49.6	46.5	47.8	60.2	66.5	51.82	77.4	55.1	72.6	48.9		
do	44	Float	268	39	229	15200	6.6	575	5130	174	276	255	70		
		Sink	255	14	61	3130	<1.5	42	2040	31	42	11	61		
		Rec. %	73.7	88.1	90.9	92.8	-	97.3	87.0	93.7	94.6	98.4	75.3		

TABLE 11 DISTRIBUTION OF MINOR ELEMENTS IN THE ASH OF FLOAT AND SINK PRODUCTS (Continued)

COAL FIELD	SAMPLE NO.	PRODUCT	PARTS PER MILLION, MOISTURE FREE BASIS												
			Pb	Ga	Cu	Ba	Be	Ni	Ti	V	Zr	Co	Cr	Ge	Sn
Matanuska	45	Float	73	53	109	2500	13.8	225	12700	590	795	99	175		
		Sink	125	33	62	675	2.1	33	3680	28	152	16	41		
		Rec. %	23.1	45.2	61.2	65.6	77.2	77.8	64.0	91.6	72.9	76.1	68.7		
do	46	Float	135	66	245	8660	112	528	11000	710	365	365	206		
		Sink	188	33	139	1030	<1.5	54	3780	46	110	24	44		
		Rec. %	54.6	77.0	74.7	93.4	-	94.3	83.0	96.3	84.8	96.2	88.7		
do	47	Float	99	53	135	15700	102	395	5900	211	195	261	128		
		Sink	205	52	60	6250	<1.5	21	2180	30	49	11	17		
		Rec. %	71.9	84.3	92.2	93.0	-	99.0	93.5	97.4	95.5	99.2	97.5		
do	48	Float	345	65	370	6800	14.0	598	18500	850	1100	413	121		
		Sink	140	41	47	2480	<1.5	36	7400	22	62	14	12		
		Rec. %	59.4	48.5	82.4	61.9	-	90.8	59.7	95.8	91.3	94.6	85.7		
do	49	Float	252	102	220	6180	22.8	560	14500	285	2600	298	62		
		Sink	87	40	284	635	<1.5	39	4950	21	90	15	7		
		Rec. %	65.2	62.3	33.4	86.3	-	90.3	65.5	89.8	91.3	92.8	85.1		

TABLE 11 DISTRIBUTION OF MINOR ELEMENTS IN THE ASH OF FLOAT AND SINK PRODUCTS (Continued)

COAL FIELD	SAMPLE NO.	PRODUCT	PARTS PER MILLION, MOISTURE FREE BASIS												
			Pb	Ga	Cu	Ba	Be	Ni	Ti	V	Zr	Co	Cr	Ge	Sn
Matanuska	50	Float	105	83	247	6730	11.6	284	12900	1150	370	83	430		
		Sink	38	31	98	1700	<1.5	70	3520	108	114	21	120		
		Rec. %	30.2	29.5	28.3	38.2	-	38.8	36.4	62.5	33.7	38.2	35.9		
do	51	Float	80	40	111	5550	8.5	190	7400	190	465	48	67		
		Sink	119	33	48	1170	<1.5	21	1450	22	64	12	12		
		Rec. %	54.8	68.6	80.7	89.9	-	94.2	90.2	94.0	92.9	87.8	91.0		
do	52	Float	223	42	240	3780	8.4	164	8600	188	390	53	82		
		Sink	85	32	95	2100	<1.5	14	2510	12	180	<10	8		
		Rec. %	77.3	63.1	32.1	70.1	-	93.8	81.68	95.3	73.8	-	93.0		
do	53	Float	114	97	145	9500	9.2	244	11900	201	475	79	91		
		Sink	72	39	242	2190	<1.5	37	5000	30	81	15	35		
		Rec. %	35.8	46.7	17.5	60.5	-	69.9	45.6	70.3	67.4	65.0	47.8		
do	54	Float	87	127	132	22600	9.0	411	7450	340	314	201	62		
		Sink	86	25	73	4850	<1.5	88	3220	50	84	20	32		
		Rec. %	45.3	80.6	59.7	79.3	-	79.3	65.5	84.8	75.4	89.2	61.4		

TABLE 11 DISTRIBUTION OF MINOR ELEMENTS IN THE ASH OF FLOAT AND SINK PRODUCTS (Continued)

COAL FIELD	SAMPLE NO.	PRODUCT	PARTS PER MILLION, MOISTURE FREE BASIS												
			Pb	Ga	Cu	Ba	Be	Ni	Ti	V	Zr	Co	Cr	Ge	Sn
Matanuska	55	Float	73	70	166	12300	13.4	530	14600	384	630	326	95		
		Sink	67	36	56	1180	<1.5	97	3930	36	97	24	29		
		Rec. %	47.3	61.5	70.9	89.6	-	81.8	75.4	89.8	84.2	91.8	72.9		
do	56	Float	133	28	171	10200	25.0	1000	5200	86	435	478	51		
		Sink	78	11	50	230	<1.5	90	290	9	65	22	<6		
		Rec. %	29.0	37.9	45.1	91.4	-	72.7	81.1	69.6	61.6	83.9	-		
do	57	Float	71	73	161	10900	8.2	351	10400	85	341	176	141		
		Sink	79	17	63	710	<1.5	33	2750	38	68	12	28		
		Rec. %	40.12	76.2	65.6	91.96	-	88.8	73.8	62.5	78.9	91.6	79.0		
do	58	Float	106	96	201	9650	25.7	595	25000	1530	1160	228	275		
		Sink	50	27	77	1950	<1.5	77	4380	36	85	21	31		
		Rec. %	25.9	36.9	30.1	44.9	-	56.0	48.4	87.5	69.2	64.1	59.4		
Bering River	59	Float	227	44	270	9250	<1.5	159	8300	61	745	27	34		
		Sink	365	39	83	1350	<1.5	19	4300	20	97	11	23		
		Rec. %	81.6	88.9	95.9	98.0	-	98.3	93.2	95.6	98.2	94.6	91.3		

TABLE 11 DISTRIBUTION OF MINOR ELEMENTS IN THE ASH OF FLOAT AND SINK PRODUCTS (Continued)

COAL FIELD	SAMPLE NO.	PRODUCT	PARTS PER MILLION, MOISTURE FREE BASIS												
			Pb	Ga	Cu	Ba	Be	Ni	Ti	V	Zr	Co	Cr	Ge	Sn
Bering River	60	Float	82	36	122	1600	<1.5	54	9200	54	545	26	57		
		Sink	176	26	49	250	<1.5	10	1050	6	73	<10	<6		
		Rec. %	41.6	67.9	79.2	90.7	-	89.2	93.1	93.2	91.9	-	-		
do	61	Float	492	52	348	7850	Int.	372	5250	77	143	119	149		
		Sink	216	33	116	2850	<1.5	36	6850	194	167	15	67		
		Rec. %	77.5	70.4	81.9	80.6	-	94.0	53.6	37.4	56.4	92.3	77.0		
do	62	Float	170	56	124	3950	Int.	185	12200	67	507	68	60		
		Sink	235	<10	46	1230	<1.5	17	13100	17	127	13	16		
		Rec. %	56.9	-	83.1	85.4	-	95.2	63.0	87.8	87.9	90.5	87.3		
do	63	Float	350	112	630	4270	16.0	147	6850	243	206	78	117		
		Sink	518	<10	550	885	4.8	33	1160	28	39	17	17		
		Rec. %	60.1	-	71.9	91.5	88.2	90.9	93.0	95.1	92.2	91.1	93.9		
Northern Alaska	67	Float	185	53	141	9850	35.8	208	10700	213	378	112	93		
		Sink	176	40	140	2350	4.6	73	17100	70	222	43	46		
		Rec. %	38.1	43.7	37.1	71.0	82.0	62.5	26.8	64.0	49.9	60.4	54.2		

TABLE 11 DISTRIBUTION OF MINOR ELEMENTS IN THE ASH OF FLOAT AND SINK PRODUCTS (Continued)

COAL FIELD	SAMPLE NO.	PRODUCT	PARTS PER MILLION, MOISTURE FREE BASIS												
			Pb	Ga	Cu	Ba	Be	Ni	Ti	V	Zr	Co	Cr	Ge	Sn
Northern Alaska	68	Float	115	51	103	11100	18.0	78	5150	127	265	56	94		
		Sink	110	25	154	1690	<1.5	26	4280	95	189	12	79		
		Rec. %	31.6	47.4	22.8	74.4	-	57.0	34.7	37.1	38.3	67.3	34.5		
do	69	Float	105	63	88	3930	9.4	169	9950	229	635	73	124		
		Sink	71	34	70	1090	<1.5	32	4000	95	138	14	57		
		Rec. %	37.9	43.3	34.2	59.8	-	68.6	50.7	49.9	65.6	68.3	47.3		
do	70	Float	144	70	39	3050	28.0	160	11400	65	760	90	19		
		Sink	330	41	217	640	3.0	19	3350	15	169	<10	<6		
		Rec. %	34.4	67.2	17.6	85.1	91.8	91.0	80.4	83.9	84.4	-	-		
do	71	Float	91	46	80	11500	10.2	97	5100	61	281	40	60		
		Sink	80	37	48	13600	<1.5	14	2080	28	53	<10	21		
		Rec. %	36.1	38.1	45.3	29.5	-	77.5	54.9	51.9	72.5	-	58.6		
do	75	Float	130	60	143	11400	23.2	102	15300	420	675	58	22		
		Sink	165	42	160	13000	<1.5	20	11300	63	116	<10	<6		
		Rec. %	24.5	37.1	27.0	26.6	-	67.8	35.9	73.3	70.6	-	-		

Rec. % = Weight percent of the element recovered in Float Fraction.

Table 12

AVERAGE MINOR ELEMENT CONCENTRATION IN THE ASH OF FLOAT AND SINK FRACTIONS

ELEMENT	PARTS PER MILLION, IN ASH			
	Nenana, Jarvis Creek and Kenai Coals 12 Samples		Matanuska, Bering River and Northern Alaska Coals 12 Samples	
	Float	Sink	Float	SINK
Pb	80	143	147	137
Ga	49	31	66	31
Cu	107	98	191	118
Ba	2830	2510	8160	2610
Be	3.5	2.1	12.5	1.7
Ni	54	42	304	42
Ti	2890	3461	10600	4640
V	94	85	388	51
Zr	54	77	531	108
Co	22	15	148	17
Cr	122	101	133	36
Ge	19.7	1.2	-	-
Sn	13.7	10.9	-	-

-Not Determined