Distribution of Minor Elements in Coals of the Appalachian Region

GEOLOGICAL SURVEY BULLETIN 1117-C

Distribution of Minor Elements in Coals of the Appalachian Region

By PETER ZUBOVIC, TAISIA STADNICHENKO, *and* NOLA B. SHEFFEY

MINOR ELEMENTS IN AMERICAN COALS

GEOLOGICAL SURVEY BULLETIN 1117-C

A study of 15 minor elements in some coals in Ohio, Pennsylvania, Maryland, Kentucky, Tennessee, Alabama, and Georgia

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1966

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

William T. Pecora, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price 20 cents (paper cover)

CONTENTS

	Page
Abstract	C1
Introduction	1
Acknowledgments	2
Stratigraphy	2
Sampling and sample preparation	3
Methods of analysis	15
Analytical data	16
Evaluation and summary of the data	16
Distribution of elements among coal components	16
Comparison of float fractions and whole coal samples	16
Comparison of vitrains, fusains, and kettle-bottom coal with blocks of whole coal	31
Comparison of blocks of coal with included pyrite	32
Comparison of coal samples from the three principal areas of the Appalachian region	34
Comparison of coals from various regions of the United States	35
Summary and conclusions	36
References	37

ILLUSTRATION

	Page
Figure 1.—Map showing distribution of coal samples in the Appalachian region	C4

TABLES

	Page
Table 1. Location and description of the coal samples	C5
2. Data on flotation of samples	12
3. Spectrochemical analyses of the ash of coal samples of the Appalachian region	17
4. Average minor-element content of the ash of the columnar samples of coal	27
5. Average minor-element content of the columnar samples of coal	29
6. Average minor-element content of the floated and whole coals	31
7. Average minor-element content of the columnar coal samples and ash fractions	31
8. Analyses of fusains, vitrains, and blocks of whole coal	33
9. Analyses of coal samples and included pyrite	34
10. Average minor-element contents of coal from 3 areas of the Appalachian region	35
11. Average minor-element contents of coals from various regions of the United States	35

MINOR ELEMENTS IN AMERICAN COALS

DISTRIBUTION OF MINOR ELEMENTS IN COALS OF THE APPALACHIAN REGION

By Peter Zubovic, Taisia Stadnichenko, and Nola B. Sheffey

ABSTRACT

Spectrochemical analyses were made for beryllium, boron, titanium, vanadium, chromium, cobalt, nickel, copper, zinc, gallium, germanium, molybdenum, tin, yttrium, and lanthanum in 73 columnar samples of coal beds of the Appalachian region. The analyses indicate that coals of the northern area, Ohio, Pennsylvania, and Maryland, contain larger quantities of boron, titanium, chromium, nickel, zinc, gallium, germanium, and yttrium than the central or southern areas. The coals of the central area, Kentucky and northern Tennessee, contain the largest amounts of beryllium, tin, and lanthanum. The coals of the southern area, Alabama, Georgia, and southern Tennessee, are highest in vanadium, cobalt, copper, and molybdenum. No definite reason for the differences can be ascribed; however, the fact that these coals vary considerably in stratigraphic position may be a factor. Another factor may be differences in source rocks, as the samples cover a large geographic area.

Analyses of 12 samples of pyrite taken from the coals do not indicate any relation between the minor-element content of the pyrite and coal.

Investigation of vitrain and fusain fractions supports, in general, an organic-affinity series of the elements established in earlier work. Coals of the Appalachian region contain much less zinc, boron, and tin than do those of the Northern Great Plains coal province or the Eastern Interior coal region.

INTRODUCTION

Coals of Pennsylvanian age in the Appalachian region of the eastern United States have been an important factor in the economic development of the country and are well known. Aside from their use as an energy source, they have come to be important to the chemical industry, and are known, from previous geochemical studies, to contain high concentrations of some of the minor elements (Headlee and Hunter, 1955; Stadnichenko and others, 1953; Zubovic and others, 1961a).

The distribution of these elements in several important coal beds of Pennsylvanian age that occur over broad parts of the Appalachian region is the subject of this report. Investigation was also made of the distribution of the elements among various organic and inorganic components. The elements of interest are beryllium, boron, titanium, vanadium, chromium, cobalt, nickel, copper, zinc, gallium, germanium, molybdenum, tin, yttrium, and lanthanum. It is doubtful whether the concentrations of any of these elements in the coals can be regarded as economically important at present. This study, however, has been of reconnaissance nature and intended only to search for broad areas that may be of interest in further investigations.

ACKNOWLEDGMENTS

The authors wish to thank the mine operators and the miners who generously gave their time and the use of their equipment, thus easing the many problems of sampling the coals in the mines. Thanks are also due the personnel of the State Geological Surveys of Ohio, Kentucky, and Alabama for their help in acquainting the authors with the coals of their States. J. W. Huddle, of the U.S. Geological Survey, and his coworkers were particularly helpful in sampling the coals of eastern Kentucky and Tennessee.

In the preparation of the samples, the assistance of J. H. Townsend and H. M. Cohen proved to be invaluable. Elizabeth L. Hufschmidt and H. J. Rose, Jr., made some spectrographic analyses of the coal ash before Nola B. Sheffey became associated with the project as a full-time spectrographer.

Many other members of the U.S. Geological Survey extended their help in the interpretation of the geochemical data and in the preparation of this report.

STRATIGRAPHY

In the northern part of the Appalachian region the rocks of Pennsylvanian age are divided into four formations which have been named, from oldest to youngest, Pottsville, Allegheny, Conemaugh, and Monongahela. All four of the formations are present in parts of Pennsylvania, Ohio, and West Virginia; rocks of Allegheny age or younger are absent south of Kentucky, and those of Monongahela age do not occur south of West Virginia.

In Kentucky, the rocks of Pottsville age are divided into two units: the lower is the Lee Formation and the upper is the Breathitt Formation (Wanless, 1946, p. 10, 63–64; McFarlan, 1943). The Breathitt is equivalent to the Briceville, Jellico of Glenn (1925), Scott, and Anderson Formations in Tennessee, and the Kanawha Formation of southwestern West Virginia. The Pottsville equivalents in southern Tennessee and Georgia are described by Wanless (1946). The many equivalents of the Pottsville rocks in Alabama are discussed by Adams and others (1926, p. 208–230). In addition, coals of the Warrior Basin of Alabama are described by McCalley (1900), those of Georgia by McCallie (1904), and those of northern Tennessee by Glenn (1925). Shotts (1954) reviews the correlation of the coals and some of the other strata of Alabama, Georgia, and southern Tennessee.

The rock sequences of the southern part of the region are generally much thicker than equivalent ones to the north. Although only a part of the Pottsville is present in Alabama, it is as much as 9,000 feet thick, whereas in the anthracite region of Pennsylvania it is only 1,200 feet thick. In southeastern Kentucky it is about 4,000 feet thick. There is also a rapid thinning of the formations northwestward. In Boyd County, Ky., the Pottsville is about 400 feet thick compared to the 4,000 feet in the southeastern part of the State. Similarly, the unit thins from 1,200 feet in the anthracite region of Pennsylvania to about 250 feet in Ohio. In a similar manner, a considerable thinning takes place in the Pottsville of Alabama and also in younger Pennsylvanian strata where present.

The coal beds, as well as Pennsylvanian strata in general, are intensely folded along their southeastern outcrops, and the intensity of folding decreases northwestward. Folding is especially intense in the anthracite region of Pennsylvania and in the Coosa and Cahaba fields of Alabama. The Paleozoic strata in the northern part of the Appalachians are generally intensely folded, whereas in the southern part the folds are ruptured, resulting in faults and thrust blocks. The rank of the coal increases in a southeasterly direction. This is related directly to the thickening of the formations, and thus the depth of burial, and to an increase in intensity of deformation.

SAMPLING AND SAMPLE PREPARATION

A group of 73 columnar samples of coal were collected, as tabulated in table 1. The geographic distribution of sampling localities is shown in figure 1. The localities fall within three general groups—those in the northern, central, and southern parts of the Appalachian region. The stratigraphic distribution of the sampling localities within each of these areas (table 1) is not entirely representative of the coal beds present; the best stratigraphic coverage is in Kentucky and Alabama.

All the samples were collected from operating underground mines or from operating or recently abandoned strip mines. The beds were sampled by cutting out a series of blocks of the coal across the entire thickness of the beds. The size of such blocks was determined by changes in the macroscopic character of the coal. Where a large part of the bed appeared to be uniform, the coal was broken into blocks which were easier to wrap, pack, and ship. Later, in the laboratory, such uniform series of blocks were composited into a single sample. A series of blocks of coal that represent the entire thickness of the bed at the sampled locality is called a columnar sample of the bed.

A total of 466 blocks of coal, representing 73 columnar samples, were collected and analyzed. Because many of the individual blocks were combined, the 466 blocks are represented by 376 analyses. In addition, 3 samples of vitrain, 4 of fusain, 1 of kettle-bottom coal, and 12 samples of included pyrite were analyzed.

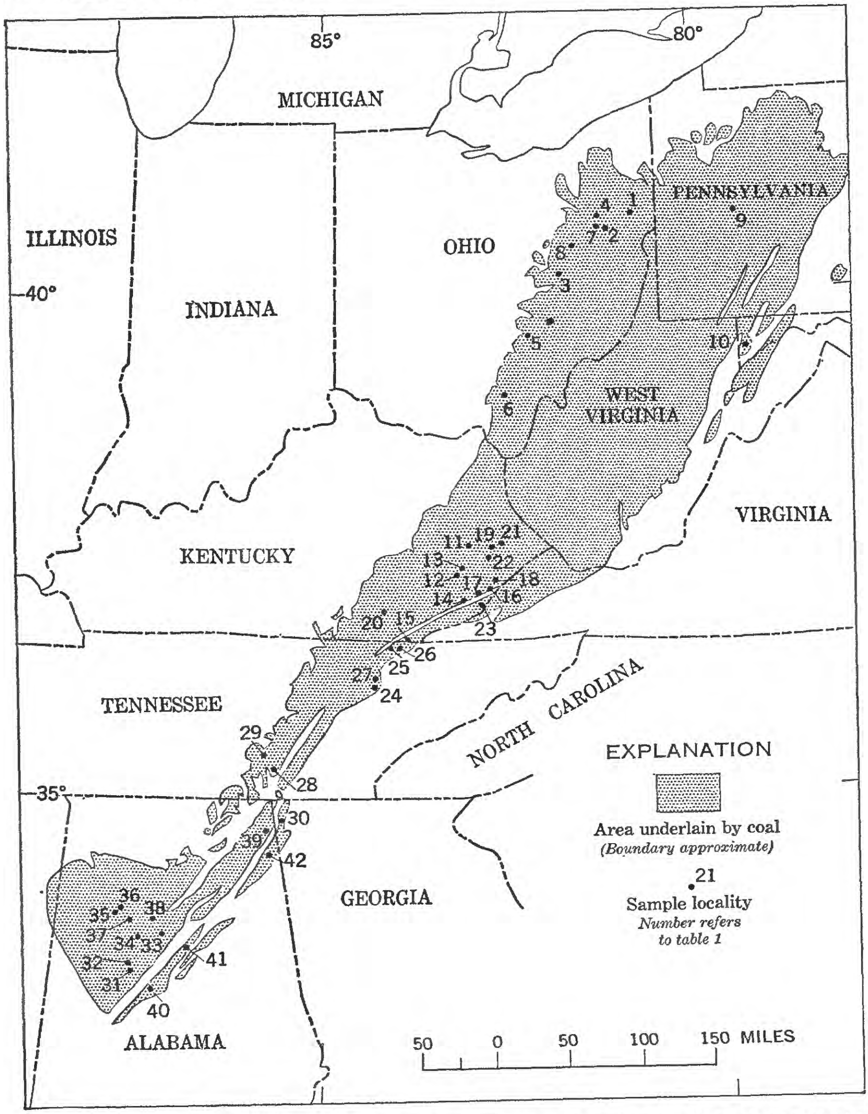

FIGURE 1.—Map showing distribution of coal samples in the Appalachian region. Modified from Averitt, 1942.

TABLE 1.—*Location and description of the coal samples*

[Leaders indicate no measurement made]

Locality (fig. 1)	Coal column	County	Mine and location	Coal bed and geologic formation	Thickness of bed (feet)	Number of blocks	Percent of bed analyzed	Remarks
			Ohio					
1	O-L-MK	Columbiana	J. and R. Coal Co. mine, near Guilford Lake, Lisbon.	Middle Kittanning (Allegheny Formation).	4.17	8	100	Strip mine.
2	O-Mal-MK	Carroll	Stark Ceramics Co. mine, on Cameron farm, near Malvern.	do	2.80	6	100	Do.
3	O-SB-MK	Coshocton	Abandoned mine, on Harris farm, near Sunnybrook.	do	------	4	75	Do.
4	$O-SC_{14}-MK$	Stark	Stark Ceramics Co., pit 14, East Canton.	do	3.03	9	98	Do.
5	O-SH-MK	Perry	Sunnyhill Coal Co., Sunnyhill No. 8 mine, New Lexington.	do	------	17	90	Do.
6	O-W-MK	Jackson	Exposure, near R. and W. Coal Co. mine, about 2 miles east-northeast of Wellston, on route 349.	do	2.49	11	39	Do.
7	O-M-LK	Stark	Billman Coal Co. mine, on Miller farm, near Waynesburg.	Lower Kittanning (Allegheny Formation).	3.95	11	100	Do.
7	O-Mag-LK	do	Magnolia Mining Co., Magnolia mine, on McCall farm, near Waynesburg.	do	1.81	7	100	Do.
2	O-Mal-LK	Carroll	Stark Ceramics Co. mine, on Cameron farm, near Malvern.	do	1.90	7	100	Do.

TABLE 1.—*Location and description of the coal samples*—Continued

Locality (fig. 1)	Coal column	County	Mine and location	Coal bed and geologic formation	Thickness of bed (feet)	Number of blocks	Percent of bed analyzed	Remarks
			Ohio—Continued					
4	O-Me-LK	Stark	Metropolitan Clay Co. mine, southeast of East Canton.	Lower Kittanning (Allegheny Formation).	2. 12	7	100	Strip mine.
5	O-P-LK	Perry	Floyd Angle Coal Co. mine, near Junction City.	do	3. 41	8	100	Do.
4	O-SC_{13}-LK	Stark	Stark Ceramics Co., pit 13, East Canton.	do	2. 18	5	100	Do.
4	O-SC_{14}-LK	do	Stark Ceramics Co., pit 14, East Canton.	do	1. 87	4	100	Do.
4	O-SC_{20}-LK	do	Stark Ceramics Co., pit 20, East Canton.	do	2. 23	7	90	Do.
5	O-SH-LK	Perry	Sunnyhill Coal Co., Sunnyhill No. 8 mine, New Lexington.	do		6	100	Do.
8	O-T-LK	Tuscarawas	Copperhead Coal Co., Inc., Copperhead mine, near Sugar Creek.	do	3. 14	7	100	Do.
			Pennsylvania					
9	Pa-Pi-LK	Armstrong	Freebrook Corp., Pittshaw No. 15 mine, Kittanning.	Lower Kittanning (Allegheny Formation.)	3. 24	4	73	Do.
			Maryland					
10	Md-Up-LK	Garrett	Upperman mine, near Deer Park.	Lower Kittanning (Allegheny Formation.)	4. 00	7	90	Drift mine.

Kentucky

11	Ky-UE-SL	Breathitt	United Electric Coal Co., Skyline mine, Evanston.	Skyline (Breathitt Formation).	10. 74	37	97	Strip mine.
12	Ky-Dia-H_9	Perry	Fourseam Coal Corp. No. 3 mine, Diablock.	Hazard No. 9 (Breathitt Formation).	4. 34	15	100	Drift mine.
13	Ky-Har-H_6	do	Harvey Coal Corp. mine, Harveyton.	Hazard No. 6 (Breathitt Formation).	3. 60	13	100	Do.
14	Ky-BD-Le	do	Blue Diamond Coal Co., Leatherwood No. 1 mine, Leatherwood.	Hazard No. 6 (Leatherwood) (Breathitt Formation).	3. 81	7	100	Do.
15	Ky-Pu-Hi	Bell	Pruden Coal & Coke Co., Black Creek mine, north of Pruden, Tennessee.	Hignite (Breathitt Formation).	3. 59	6	56	Do.
12	Ky-Al-H_4	Perry	Algoma Block Coal Co., Algoma mine, Lothair.	Hazard No. 4 (Fireclay) (Breathitt Formation).	3. 15	12	71	Do.
13	Ky-Col_1-H_4	do	Columbus Mining Co., Columbus No. 4 mine, Allais.	do	2. 23	8	100	Do.
13	Ky-Col_2-H_4	do	Columbus Mining Co., Columbus No. 6 mine, Allais.	do	2. 95	8	100	Do.
16	Ky-Sx-H_4	Letcher	Ed Sexton Coal Co. No. 1 mine, near Whitesburg.	do	4. 75	15	31	Do.
16	Ky-SL-Wh	do	Sandlick Coal Co., Sandlick mine, Whitesburg.	Whitesburg (Breathitt Formation).	3. 64	13	100	Do.
17	Ky-PC-Am	do	Premium Coal Corp., Amburgy mine, Amburgy.	Amburgy (Breathitt Formation).	4. 21	11	100	Do.

TABLE 1.—*Location and description of the coal samples*—Continued

Locality (fig. 1)	Coal column	County	Mine and location	Coal bed and geologic formation	Thickness of bed (feet)	Number of blocks	Percent of bed analyzed	Remarks
Kentucky—Continued								
16	Ky-EJ-E_3	Letcher	Elkhorn & Jellico Coal Co. mine, near Whitesburg.	Elkhorn No. 3 (Breathitt Formation).	5. 20	15	100	Drift mine.
18	Ky-Hx-E_3	do	Consolidation Coal Corp., Hendrix No. 2 mine, Deane.	do	4. 34	10	93	Do.
19	Ky-W-E_3	Floyd	Stevens Elkhorn Fuel Co., Wilson Creek mine, Manton.	do	2. 81	8	29	Do.
21	Ky-B&S-E_2	do	Burchatt and Stambo mine, Emma.	Elkhorn No. 2 (Breathitt Formation).	2. 92	6	100	Do.
19	Ky-Hop-E_2	do	Hopkins Coal Co. No. 5 mine, Hunter.	do	3. 31	7	100	Do.
22	Ky-GV_1-E_1	do	Glo Valley Coal Corp. mine, Glo.	Elkhorn No. 1 (Breathitt Formation).	6. 34	11	92	Drift mine. First sample.
22	Ky-GV_2-E_1	do	do	do	4. 53	9	91	Drift mine. Second sample.
20	Ky-Wo-J	Whitley	Abandoned mine, near Woodbine.	Jellico (Breathitt Formation).	2. 96	9	100	Strip mine.
23	Ky-IH-Ha	Harlan	International Harvester Corp., Wisconsin Steel No. 2 mine, Benham.	Harlan (Breathitt Formation).	4. 81	7	97	Drift mine.

			Tennessee					
24	Tenn-R&P-D	Campbell	Rochester & Pittsburgh Coal Co. mine, Briceville.	Dean (Breathitt Formation).	3. 49	12	35	Drift mine.
25	Tenn-A-J	do	New Jellico Coal Co., Inc., Blue Rose mine, Morley.	Jellico (Breathitt Formation).	6. 19	12	50	Do.
26	Tenn-D-J	Claiborne	Dippel & Dippel Coal Co. mine, Clairfield.	Jellico (Mason) (Breathitt Formation).	2. 62	9	42	Strip mine.
26	Tenn-E-J	do	Blue Diamond Coal Co., Eagan mine, Eagan.	Jellico (Breathitt Formation).	2. 55	6	42	Drift mine.
27	Tenn-V-K	Campbell	Block Coal & Coke Corp., Anthras mine, Vasper.	Kent (Coal Creek) (Breathitt Formation).	3. 58	12	42	Slope mine.
28	Tenn-Re-S	Marion	Tennessee Products & Chemical Corp., Reel's Cove mine, Whitwell.	Sewannee (Lee Formation).	3. 77	10	7	Drift mine.
29	Tenn-Va-S	Grundy	Tennesssee Consolidated Coal Co., Palmer mine, Palmer.	do	3. 59	9	48	Shaft mine.
			Georgia					
30	Ga-B-5	Walker	Boulevard Coal Co. mine, near Rising Fawn.	Tatum No. 5 (Lee Formation).	1. 64	4	9	Strip mine.
30	Ga-Bl-5	do	W. T. Blebens mine, near Rising Fawn.	do	1. 46	4	100	Drift mine.
30	Ga-W-4	do	Lee Waldin mine, near Rising Fawn.	Tatum No. 4 (Lee Formation).	1. 63	3	78	Do.

TABLE 1.—*Location and description of the coal samples*—Continued

Locality (fig. 1)	Coal column	County	Mine and location	Coal bed and geologic formation	Thickness of bed (feet)	Number of blocks	Percent of bed analyzed	Remarks
			Alabama					
31	Ala-Mi-B(R)	Tuscaloosa	Mitchell Bros. Construction Co. mine, 2 miles north of Brookwood.	Rider (above Brookwood bed). (Pottsville Formation).	1. 24	5	100	Strip mine.
31	Ala-Mi-B	do	do	Brookwood (Pottsville Formation).	2. 95	11	41	Do.
32	Ala-T-B	do	Twin Seam Mining Co., Kellerman mine, Searles.	do	2. 91	9	38	Drift mine.
31	Ala-TH-B	do	Toxey and Hosmer Coal Co. mine, near Brookwood.	do	2. 89	9	86	Strip mine.
31	Ala-Mi-Mi	do	Mitchell Bros. Construction Co. mine, near Brookwood.	Milldale (Pottsville Formation).	2. 27	7	59	Do.
32	Ala-T-Mi	do	Twin Seam Mining Co., Kellerman mine, Searles.	do	2. 08	6	69	Drift mine.
31	Ala-TH-Mi	do	Toxey and Hosmer Coal Co. mine, near Brookwood.	do	2. 51	6	47	Strip mine.
33	Ala-Da-P	Jefferson	Davidson Coal Co., Davidson No. 9 mine, near Adamsville, on route 1.	Pratt (Pottsville Formation).	2. 55	6	47	Drift mine.
34	Ala-G-P	Walker	Alabama Power Co., Gorgas mine, Gorgas.	do	------	2	------	Near mine entrance. Top and bottom of bed.
34	Ala-G-NP	do	do	Nickel Plate (Pottsville Formation).	1. 35	6	100	Exposure near mine.

34	Ala-G-A	do	do	American (Pottsville Formation).	4.29	9	48	Drift mine.
35	Ala-M-N	do	Monarch Coal Co. mine, near Carbon Hill.	Newcastle (Pottsville Formation).	.44	2	100	Strip mine.
36	Ala-Ga-ML	do	Galloway Coal Mining Co., Inc., No. 29 mine, near Carbon Hill.	Mary Lee (Pottsville Formation).	2.89	9	100	Do.
37	Ala-Ma-J	do	Marigold Coal Mining Co., Inc., Marigold mine, near Jasper.	Black Creek (Jefferson) (Pottsville Formation).	1.90	9	62	Strip mine. Shovel pit.
37	Ala-Ma$_1$-J	do	do	do	1.86	8	100	Strip mine. Dragline pit.
38	Ala-De-BC	do	DeBardeleben Coal Corp., New Empire No. 3 mine, Empire.	Black Creek (Pottsville Formation).	1.82	8	74	Strip mine.
36	Ala-Ga-BC	Walker	Galloway Coal Mining Co., Inc., Hawk's No. 4 mine, Carbon Hill.	Black Creek (Pottsville Formation).	2.45	8	100	Drift mine. First sample.
36	Ala-H-BC	do	do	do	2.88	8	55	Drift mine. Second sample.
40	Ala-BD-W	Bibb	Black Diamond Coal Mining Co., Blocton No. 9 mine, near West Blocton.	Woodstock (Pottsville Formation).	2.89	10	36	Slope mine.
41	Ala-Z-M	St. Clair	Ziegler Bros. Construction Co., Ziegler mine, near Leeds.	Mammoth (Pottsville Formation).	12.51	36	25	Strip mine. Coal is in 3 benches; in tables 3–5, each bench is reported separately.
42	Ala-FtP-UC	De Kalb	Hill's mine, 6 miles east of Fort Payne.	Upper Cliff (Pottsville Formation).	2.03	10	5	Drift mine.
42	Ala-FtP$_1$-UC	do	Exposure, on Yellow Creek, 300 yds east of Hill's mine.	do	------	3	------	Top and bottom of bed.
39	Ala-E-BC	do	J. A. Erwin, operator, Sand Mountain Coal Co. mine.	Unknown (Pottsville Formation).	1.31	6	30	Strip mine.

In the laboratory, the blocks were either broken or cut in half; one-half was rewrapped and put into storage. The other half was broken into pieces small enough that the visible noncoaly matter, such as lenses or fracture fillings of pyrite, calcite, or shale, could be removed from the sample. Twelve samples of pyrite were analyzed for minor elements. In the latter stages of the project, many of the high-ash coals were floated to remove mineral matter.

The samples were crushed to pass through a 100-mesh sieve. Ten grams of this −100-mesh coal from each of the block samples were placed in a cold muffle furnace. The temperature was then gradually raised to 450°C and held there until all the organic matter was oxidized. Ash derived from coal at this temperature may differ somewhat from that derived from combustion at higher temperatures. At higher temperatures larger amounts of volatile inorganic constituents may be lost.

In the flotation process a −100-mesh-size fraction was centrifuged in ethyl alcohol and carbon tetrachloride (specific gravity ranging from 1.32 to 1.36), for 20 minutes. The float fraction was decanted into a Büchner funnel, dried, ashed, and analyzed spectrographically. The percentages of float material recovered and the ash contents of the material are given in table 2.

The lighter fractions of the coal separated by the flotation process are of interest for two reasons: (1) a large part of their minor-element content is chemically bound to organic constituents rather than mineral matter, and (2) the lighter fraction is roughly comparable to coals cleaned by mechanical means before shipping (Averitt, 1961, p. 25), and hence, more comparable to coal from which commercial separation of minor elements might be attempted. Horton and Aubrey (1950) found that germanium and other elements tend to be associated with lighter float fractions.

TABLE 2.—*Data on flotation of samples*

[Location of samples shown in table 1]

Coal block No.	Specific gravity of floating medium	Float fraction (percent)	Ash (percent of float fraction)
Ky—UE-SL			
1–2	1. 32	60. 16	2. 06
9–12	1. 32	47. 54	2. 29
14–18	1. 32	16. 64	2. 94
19–23	1. 32	25. 87	2. 47
24–31	1. 32	57. 74	1. 85
33–35	1. 32	22. 37	2. 43
36–37	1. 32	18. 00	3. 08

Table 2.—*Data on flotation of samples*—Continued

Coal block No.	Specific gravity of floating medium	Float fraction (percent)	Ash (percent of float fraction)
Ky—Har-H_6			
8	1.36	12.62	5.38
10–12	1.34	47.33	3.74
Ky—BD-Le			
2–4	1.32	68.02	1.63
5–7	1.32	66.02	2.93
Ky—Al-H_4			
2–3	1.32	21.80	4.07
4–7	1.32	77.12	2.06
12	1.32	21.80	4.07
Ky—Col_2-H_4			
5–6	1.32	39.23	2.84
Ky—SL-Wh			
2–3	1.32	73.09	1.63
4–6	1.32	53.34	1.71
11–13	1.34	28.12	3.54
Ky—PC-Am			
2–3	1.34	34.26	3.30
4–6	1.32	80.86	1.86
7–9	1.32	84.03	2.31
10–11	1.34	62.50	2.72
Ky—EJ-E_3			
7–11	1.32	61.94	1.77
12–14	1.34	15.19	2.47
Ky—Hx-E_3			
8c	1.36	23.75	5.35
Ky—Wo-J			
1–2a	1.32	46.69	2.42
3–5	1.32	78.56	1.20
Ky—B&S-E_2			
1a	1.32	98.04	1.11

213-790—66——3

TABLE 2.—*Data on flotation of samples*—Continued

Coal block No.	Specific gravity of floating medium	Float fraction (percent)	Ash (percent of float fraction)
Ky—GV_2–E_1			
2–4	1. 32	75. 09	2. 15
8–9	1. 32	82. 84	1. 94
Ky–IH–Ha			
1a	1. 32	83. 86	1. 00
1b	1. 32	78. 43	1. 02
Ala–Mi-B(R)			
1	1. 36	23. 79	4. 06
2–3	1. 32	21. 62	2. 39
4	1. 32	53. 46	2. 21
Ala–TH–B			
1	1. 32	62. 68	2. 76
3–4	1. 34	48. 01	4. 25
5–6	1. 34	61. 41	3. 54
Ra	1. 36	12. 79	4. 97
Ala–G–P			
T	1. 32	45. 66	3. 67
Ala–G–NP			
1	1. 36	43. 42	7. 10
2–3	1. 36	42. 52	9. 82
5–6	1. 36	76. 99	6. 90
Ala–Ga–ML			
1	1. 32	28. 21	4. 13
2–3	1. 34	38. 51	2. 95
4–6	1. 34	38. 39	6. 12
7–8	1. 34	42. 60	5. 18
9	1. 34	35. 63	2. 70
Ala–Ma–J			
2	1. 30	59. 52	2. 51
3	1. 30	38. 24	1. 71
4–5	1. 32	26. 43	1. 00
9	1. 32	38. 98	3. 02
Ala–Ma_1–J			
4–6	1. 32	58. 74	2. 69
7–8	1. 32	67. 24	2. 35

METHODS OF ANALYSIS

Blocks of coal were selected for spectrographic analysis on the basis of preliminary determinations of germanium and molybdenum. Blocks having low concentrations of these elements, particularly germanium, were combined into composite samples, and many of these were floated because of their high ash content. The preliminary germanium and molybdenum determinations were made by rapid methods (Zubovic and others, 1961a). The final germanium and molybdenum determinations, as well as the determinations for 13 other elements, were done by a quantitative spectrographic procedure.

The quantitative spectrographic procedure used has been described by Zubovic and others (1961a, p. 18–20); therefore, only a brief outline of the method is given here.

The total energy method, employing d-c arc excitation of samples and synthetic standard, was used. The spectra of samples and standards are recorded on photographic plates that cover the wavelength region 2300–4700 A with a dispersion of 5 A per millimeter. The transmittances of the analytical lines were measured with a microphotometer, and the photographic plates were calibrated by using a set of homologous iron lines for which relative intensities are known (Dieke and Crosswhite, 1943). By the use of synthetic standards, analytical curves were constructed which relate the logarithm of intensity of analytical lines to the logarithm of concentration. Concentrations of the various elements were determined from these curves.

The spectral lines used and the corresponding detection limits are listed below:

Spectral lines and corresponding detection limits

Element	Wavelength (angstrom units)	Limit of detection (weight percent of ash)	Element	Wavelength (angstrom units)	Limit of detection (weight percent of ash)
B	2497.733	0.001	La	4333.734	0.003
Be	2348.610	.0001		3337.488	.01
	3131.072	.001	Mo	3170.346	.0005
Cd	3261.057	.005	Ni	3414.765	.0005
Co	3453.505	.0005		3050.819	.001
	3449.170	.001	Sn	3175.019	.001
	3449.411	.002	Ti	3261.605	.005
Cr	4254.346	.0001		3152.251	.05
	3021.558	.001	V	3185.396	.001
	3024.350	.005		3183.406	.001
Cu	3273.962	.0001	Y	4374.935	.001
	2824.369	.05		3327.875	.002
Ga	2943.637	.0005	Zn	3345.020	.01
Ge	2651.178	.001			
	3039.064	.002			

The final analytical results are, in general, averages of two determinations made on separate plates. The overall coefficient of variation for the mean of such duplicates for all the elements is ±15 percent.

ANALYTICAL DATA

The minor-element content of the ash of each of the individual and composite block samples comprising the 73 columnar coal samples is given in table 3.

Table 4 shows the average minor-element content of ash in weight percent for each of the columnar samples. Table 5 shows the average content of the elements on the basis of parts per million in coal for each of the columnar samples. The averages for columnar samples in which more than 75 percent of the bed was analyzed were computed on a weighted basis using the thickness of the analyzed blocks making up the columnar sample. The other averages are unweighted.

EVALUATION AND SUMMARY OF THE DATA

The analytical data in table 3 and the columnar-sample averages in tables 4 and 5 may not be representative of the minor-element content of the sampled beds. This study was reconnaissance in nature and in most places too few samples were obtained from any one bed. However, this study does provide a groundwork for further geochemical investigations that may be undertaken.

In the computation of some averages given in this report, analyses of float fractions of the coals were used along with analyses of coals not separated in this manner. Where this was done, the resulting averages for particular elements are somewhat different from those that would have been obtained if the float fractions were not included. However, the averages given in table 6 for floated and unfloated samples from the same general areas demonstrate that the effects of this procedure are not great for most elements.

The estimated average minor-element contents of coals of the Appalachian region and their ash fractions are given in table 7. These figures were derived from the averages for the columnar samples given in tables 4 and 5.

DISTRIBUTION OF ELEMENTS AMONG COAL COMPONENTS

COMPARISON OF FLOAT FRACTIONS AND WHOLE COAL SAMPLES

Average minor-element contents of coals, with averages for float fractions of coals from the same areas, have been given in table 6. The elements found to be more highly concentrated in the float frac-

TABLE 3.—*Spectrochemical analyses of the ash of coal samples of the Appalachian region*

[Figures indicate percent by weight: *, visual estimate; O, below limit of detection; leaders indicate no analysis made; f, floated sample; F, fusain; V, vitrain; a, b, c, subdivision of a block collected as a unit. Location of samples shown in table 1]

Sample	Block No.	Thickness (feet)	Ash	Be	B	Ti	V	Cr	Co	Ni	Cu	Zn	Ga	Ge	Mo	Sn	Y	La
O-L-MK	1	0.44	12.24	0.001	--------	0.2	0.01	0.003	0.003	0.005	0.003	0.03	0.006	0.01	0.005	0	0.02	0.01
	2	.27	8.34	.0001	--------	.2	.008	.003	.002	.005	.01	.03	.003	0	.004	0	.02	.007
	3	.55	11.76	.001	--------	.2	.01	.003	.002	.008	.009	.03	.003	0	.005	0	.01	.006
	4	.18	9.70	.0003	--------	.3	.01	.02	.002	.008	.02	0	.003	0	.004	0	.03	.02
	5	.30	13.00	.0003	--------	.3	.009	.005	.001	.005	.008	0	.003	0	.003	0	.01	.01
	6	.75	9.24	.0009	--------	.4	.02	.02	.002	.01	.02	0	.004	0	.004	0	.05	.03
	7	.88	8.78	.003	--------	.7	.04	.04	.01	.06	.03	0	.009	.009	.006	0	.04	.02
	8	.80	12.54	.0025	0.021	.86	.03	.033	.025	.09	.033	.03	.014	.014	.006	0	0	.018
O-Mal-MK	1	.37	6.34	.002	.04*	--------	.009	.005	.002	.05	.008	0	.01	.03	.002	0	.02	0
	2	.20	11.64	.001	.03*	--------	.009	.005	.002	.02	.005	0	.008	.008	.002	0	.02	0
	3	.83	9.24	.003	.04*	--------	.02	.01	.002	.005	.01	0	.007	--------	.001	0	.01	.01
	4	.53	6.56	.001	.03*	--------	.02	.01	.002	.01	.02	0	.007	--------	.001	0	.03	.008
	5	.50	5.56	.001	.05*	--------	.01	.01	.002	.005	.01	0	.008	.002	.002	0	.04	0
	6	.37	7.48	.005	--------	--------	.04	.03	.005	.04	.07	.3	.01	.03	.003	0	.05	0
	4F	--------	13.04	.0004	.006	--------	.008	.009	.002	.0007	.02	0	0	.002	0	0	0	.008
	4V	--------	3.50	.001	.05*	--------	.03	.02	.003	.008	.02	0	.007	.002	.008	0	.04	.007
O-SB-MK	1	--------	2.10	.01	.09*	--------	.01	.02	.004	.01	.01	.05	.005	.003	.006	0	--------	--------
	2	--------	2.80	.01	.09*	--------	.009	.02	.003	.01	.01	.06	.005	.004	.006	0	--------	--------
	3	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
	4	--------	2.70	.002	.2*	--------	.01	.009	.003	.008	.02	.2	.005	.004	.003	0	--------	--------
	1V	--------	1.50	.04	.07*	--------	.02	.03	.004	.01	.02	0	.008	.002	.007	0	--------	--------
	5V	--------	6.00	.007	.03*	--------	.03	.02	.006	.01	.02	.05	.03	.02	.006	0	--------	--------
O-SC14-MK	1	.25	6.94	.006	--------	--------	.01	.004	.002	.02	.009	0	.004	.03	.005	0	.02	0
	2	.30	10.22	.001	--------	--------	0	.002	.001	.003	.004	0	.003	.004	.002	0	.009	0
	3	.60	5.66	.001	--------	--------	.01	.009	.002	.004	.04	0	.003	0	.003	0	.03	.008
	4	.40	17.50	.0008	--------	--------	.04	.01	.002	.003	.01	0	.006	0	0	0	.02	.01
	5	.16	4.68	.002	--------	--------	.02	.02	.003	.008	.02	0	.006	0	.006	0	.04	.008
	6	.30	6.54	.003	--------	--------	.03	.02	.003	.009	.02	0	.005	0	.003	0	.08	.01
	7	.84	6.72	.002	--------	--------	.02	.01	.002	.006	.01	0	.009	.004	0	0	.08	.01
	8	.06	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
	9	.12	11.22	.002	--------	--------	.04	.007	.02	.04	.02	0	.01	.02	0	0	.2	.02
	3F	--------	18.10	.0001	--------	--------	0	.0008	0	.003	.007	0	0	0	.001	0	0	.01
	4F	--------	13.60	.0004	--------	--------	.006	.005	.002	.003	.03	0	.003	0	.001	0	0	0
O-SH-MK	1	--------	41.72	.0003	--------	.5	.03	.02	.002	.01	.006	0	.003	0	.002	0	.01	.03
	2	--------	43.76	.001	--------	.3	.007	.003	.002	.01	.006	.03	.003	.004	.002	0	.02	.01
	3	--------	23.68	.002	--------	.6	.01	.009	.0009	.003	.005	0	.003	.003	0	0	.01	.01
	4	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
	5	--------	31.14	.0004	--------	.6	.01	.006	.001	.003	.008	0	.002	0	0	0	.01	.01
	6	--------	26.24	.0003	--------	.5	.02	.02	.001	.002	.003	0	.005	0	0	0	.008	.01
	7	--------	32.24	.0004	--------	.6	.02	.01	.001	.003	.006	0	.002	0	0	0	.009	.009
	8	--------	20.48	.002	--------	.6	.02	.006	.001	.003	.008	0	.003	0	0	0	.01	.02

See footnotes at end of table.

TABLE 3.—*Spectrochemical analyses of the ash of coal samples of the Appalachian region*—Continued

Sample	Block No.	Thick-ness (feet)	Ash	Be	B	Ti	V	Cr	Co	Ni	Cu	Zn	Ga	Ge	Mo	Sn	Y	La
O-SH-MK	9	--------	5.22	.001	--------	0.1	0.02	0.01	0.003	0.006	0.005	0	0.005	0	0	0	0.02	0.04
	10	--------	7.78	.0004	--------	.08	.005	.003	.002	.003	.003	0	.003	0	0	0	.01	0
	11	--------	8.82	.0008	--------	.3	.03	.02	.002	.005	.008	0	.006	0	0	0	.01	.01
	12	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
	13	--------	9.98	.002	--------	.3	.03	.009	.005	.003	.006	0	.004	0	0	0	.01	.02
	14	--------	7.66	.002	--------	.08	.006	.003	.002	.002	.008	0	.002	0	0	0	.01	0
	15	--------	4.44	.006	--------	.1	.008	.003	.002	.003	.008	.03	.003	0	0	0	.05	0
	16	--------	8.32	.003	--------	.06	.006	.002	0	.002	.006	.03	.003	0	0	0	.01	0
	17	--------	11.50	.009	--------	.08	.01	.003	0	.003	.006	.04	.01	.03	.002	0	.01	0
O-W-MK	1	0.13	20.54	.003	0.04	.6	.033	.034	.0044	.022	.018	0	.007	.06	.002	0	.01	.01
	2	.10	20.30	.001	.03	.3	.02	.02	.003	.01	.005	0	.005	.02	0	0	.01	.007
	3	.29	11.84	.003	.05*	.3	.02	.04	.002	.03	.01	0	.02	.01	.004	0	.02	.01
	4-10	1.53	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
	11	.44	4.06	.01	.8	.4	.078	.055	.03	.06	.054	0	.03	.052	.004	0	.06	.02
O-M-LK	1	.05	4.70	.01	--------	--------	.3	.09	.004	.06	.5	.1	.02	.06	.01	0	.02	.02
	2	.20	4.00	.003	--------	--------	.06	.03	.002	.03	.04	0	.009	.03	.009	0	.008	0
	3	.65	26.62	.003	--------	--------	.004	.006	.001	.005	.002	.02	.005	.004	0	0	.001	0
	4	.20	13.28	.0007	--------	--------	.01	.01	.001	.002	.03	.05	.003	0	.001	0	.005	.02
	5	.64	6.30	.003	--------	--------	.01	.02	.003	.002	.004	0	.004	0	.001	0	.005	0
	[1]5	--------	6.88	.002	--------	--------	.007	.008	.002	.01	.003	0	.004	0	0	0	.002	0
	6	.09	7.24	.0003	--------	--------	.001	.001	.0009	.001	.02	.04	.0005	.002	.001	0	.002	0
	7	.37	21.90	.0001	--------	--------	0	.0003	.0003	.0006	.01	.05	.0007	.003	.002	0	0	0
	8	.38	5.48	.0005	--------	--------	.001	.001	.0008	.001	.01	.03	.0003	.004	.001	0	.003	0
	9	.50	10.36	.0007	--------	--------	.004	.002	.002	.003	.05	0	.003	.006	.003	0	.01	0
	10	.62	7.02	.004	--------	--------	.02	.04	.004	.008	.01	0	.006	.005	.006	0	.06	.01
	11	.25	5.98	.002	--------	--------	.08	.03	.005	.02	.07	.04	.02	.01	.008	0	.06	.01
O-Mag-LK	1	.04	20.48	.003	--------	--------	.03	.006	.006	.04	.009	0	.006	.03	.02	0	.02	.008
	2	.37	18.30	.003	--------	--------	.03	.02	.003	.02	.006	0	.007	.01	.01	0	.02	.008
	3	.10	6.16	.004	--------	--------	.02	.03	.006	.01	.02	0	.008	.003	.02	0	.04	0
	4	.50	16.92	.0009	--------	--------	.005	.003	.003	.01	.007	0	.006	0	.02	0	0	.001
	5	.15	4.38	.004	--------	--------	.05	.03	.006	.01	.008	0	.01	.003	.02	0	.05	.008
	6	.30	3.84	.004	--------	--------	.05	.03	.006	.01	.008	0	.009	.004	.02	0	.07	.008
	7	.35	6.39	.003	--------	.2	.03	.03	.01	.06	.03	.05	.03	.08	.01	.006	.03	0
O-Mal-LK	1	.07	27.88	.0005	--------	--------	.02	.02	.002	.007	.009	0	.006	.003	.02	0	.008	0
	2	.12	26.14	.0005	--------	--------	.02	.02	.002	.007	.01	0	.006	.004	.02	0	.008	0
	3	.67	3.56	.002	--------	--------	.04	.03	.01	.02	.04	0	.009	0	.01	0	.04	0
	4	.29	3.00	.002	--------	--------	.02	.009	.01	.05	.03	0	.008	.003	.01	0	.05	0
	5	.20	3.34	.001	--------	--------	.01	.005	.006	.02	.02	0	.004	.002	.005	0	.03	0
	6	.25	4.50	.001	--------	--------	.04	.002	.007	.05	.01	0	.01	.01	.003	0	.02	0
	7	.30	3.54	.002	--------	--------	.05	.03	.03	.2	.1	.1	.07	.2	.01	0	.05	0
	[2]7	--------	6.86	.004	--------	--------	.03	.009	.02	.12	.03	.05	.02	.2	.004	.009	.02	0
	7V	--------	4.60	.001	--------	.1	.009	.02	.02	.1	0	.5	.03	.22	.004	0	.02	.02
O-Me-LK	1	.12	24.42	.001	--------	--------	.03	.02	.002	.09	.03	0	.003	.008	.01	0	.01	.01
	2	.15	29.66	.001	--------	--------	.01	.01	.002	.003	.009	0	.005	.004	.001	0	.01	.01
	3	.20	32.60	.0008	--------	--------	.001	.007	.002	.02	.02	0	.004	.002	0	0	.02	.01

	4	.25	31.14	.0008			.001	.006	.003	.05	.009	0	.005	0	.001	0	.02	.01
	5	.30	8.03	.002			.02	.03	.007	.02	.07	0	.007	.005	.008	0	.02	0
	6	.50	4.34	.005			.002	.002	.003	.03	.01	.02	.002	.001	.004	0	.01	0
	7	.60	11.02	.008			.006	.005	.002	.01	.004	0	.006	.008	0	0	.01	0
O-P-LK	1	.15	19.74	.003		0.6	.01	.02	.003	.007	.008	0	.006	.008	0	0	.04	0
	2	.25	29.24	.001		.4	.01	.02	.003	.006	.01	0	.005	.006	0	0	.009	0
	3	.20	17.10	.003		.8	.02	.03	.003	.006	.01	0	.005	0	0	0	.04	.02
	4	.72	14.12	.0006		.2	.008	.003	.003	.005	.008	0	.003	0	0	0	.01	.03
	5	.38	13.14	.0008		.04	0	.002	.002	.005	.003	0	.002	0	0	0	.005	0
	6	.68	7.78	.003		0	.003	.002	.005	.01	.02	0	.001	0	.002	0	.008	0
	7	.75	4.48	.005		0	.004	.003	.006	.01	.02	0	.002	.001	.003	0	.02	0
	8	.28	19.98	.0025	.028	.47	.021	.015	.027	.044	.015	.093	.016	.072	.0036	0	0	.0078
O-SC$_{13}$-LK	1	.45	10.06	.001			.03	.01	.001	.02	.01	0	.005	.005	.01	0	.01	0
	2	.60	9.38	.001			.02	.01	.002	.01	.02	0	.003	0	.006	0	.02	0
	3	.43	3.00	.002			.03	.01	.003	.03	.03	0	.006	.004	.01	0	.08	0
	4	.15	4.50	.002			.02	.008	.002	.02	.02	0	.003	.002	.006	0	.04	0
	5	.55	5.67	.005		.2	.02	.02	.007	.1	.05	.04	.03	.03	.006	0	.08	0
	3F	.03	7.54	.001			0	.038	.082	.002	.02	0	0	0	.007	0	.002	0
O-SC$_{14}$-LK	1	.85	7.20	.003			.05	.03	.002	.01	.02	0	.007	.004	.006	0	.02	0
	2	.27	6.66	.003			.008	.004	.002	.01	.02	0	.004	0	.003	0	.02	0
	3	.30	3.74	.004			.01	.02	.005	.09	.05	0	.009	.005	.006	0	.05	.01
	4	.45	5.08	.007			.05	.03	.01	.08	.04	0	.02	.04	.005	.008	.1	.01
O-SC$_{20}$-LK	1	.16	12.04	.002			.09	.01	.005	.04	.01	0	.02	.02	.02	0	.02	0
	2	.14	15.14	.001			.05	.01	.004	.02	.009	0	.01	.02	.007	0	.01	0
	3	.16	12.00	.001			.02	.001	.003	.009	.02	0	.001	.004	.002	0	.02	0
	4	.22																
	5	.35	17.78	.004			.07	.03	.006	.01	.006	0	.007	.002	.003	0	.01	0
	6	.55	12.78	.001			.001	.005	.008	.02	.007	0	.006	.002	.003	0	.02	0
	7	.65	6.56	.006			.02	.02	.01	.07	.05	.01	.02	.04	.004	0	.03	.01
O-SH-LK	1		16.24	.002		.3	.009	.005	.009	.02	.003	.01	.005	.006	.002	0	.02	0
	2		17.56	.0006		.5	.01	.005	.002	.002	.005	.01	.003	0	0	0	.01	.01
	3		10.68	.001		.2	.008	.003	.002	.003	.003	.01	.003	0	.001	0	.01	.01
	4		7.08	.006		.06	0	.001	.001	.002	.003	.01	.002	0	.002	0	.02	0
	5		6.54	.006		.08	0	.002	.003	.006	.009	.01	.005	0	.002	0	.03	0
	6		12.30	.005		.2	.02	.005	.008	.003	.009	.02	.008	.02	.003	0	.03	0
	V		9.10	.0005			.03	.02	.03	.008	.02	.04	.006	0	.001	0	.02	.01
O-T-LK	1	.18	9.88	.002			.03	.03	.003	.08	.02	0	.008	.03	.008	0	.01	0
	2	.45	22.68	.0009			.02	.01	.001	.02	.01	0	.002	0	.003	0	.008	0
	3	.38	5.90	.002			.02	.02	.002	.009	.01	0	.004	0	.005	0	.01	0
	4	.55	2.64	.001			.002	.002	.002	.008	.004	0	.0005	0	.004	0	.007	0
	5	.45	7.32	.002			.003	.002	.002	.02	.02	0	.001	0	.006	0	.01	0
	6	.48	4.80	.004			.01	.006	.007	.04	.02	0	.002	.001	.005	0	.04	0
	7	.65	8.40	.004			.04	.02	.01	.1	.02	0	.01	.03	.006	0	.04	0
Pa-Pi-LK	1	.80	11.10	.004			.04	.02	.003	.008	.01	0	.007	.01	.002	0	.02	.02
	2	.85																
	3	1.10	14.38	.004			.009	.006	.003	.009	.02	0	.004	0	0	0	.02	.01
	4	.50	10.02	.001			.004	.005	.002	.002	.01	.02	.0007	0	.0005	0	.004	0
Md-Up-LK	1	.55	9.60	.004			.003	.02	.01	.02	.01	0	.006	.008	.002	0	.02	.01
	2a	.09	17.32	.0001			.003	.005	.003	.003	.004	0	.0005	0	0	0	.001	0
	2b	.09	11.24	.002			.03	.02	.009	.02	.01	0	.004	0	.001	0	.02	.05
	3	1.2	8.64	.002			.04	.05	.03	.06	.02	.1	.007	0	0	0	.01	.06

See footnotes at end of table.

TABLE 3.—*Spectrochemical analyses of the ash of coal samples of the Appalachian region*—Continued

Sample	Block No.	Thickness (feet)	Ash	Be	B	Ti	V	Cr	Co	Ni	Cu	Zn	Ga	Ge	Mo	Sn	Y	La
Md-Up-LK	4	0.82	16.36	0.0001	------	------	0.007	0.006	0.002	0.005	0.01	0.02	0.0007	0	0.0007	0	0.003	0.01
	5	.85	24.40	.002	------	------	.03	.02	.002	.009	.007	0	.005	.009	.001	0	.06	0
	6	.40																
Ky-UE-SL	1–2f	.52	2.06	.003	.2*	.98	.14	.068	.026	.06	.02*	0	.038	.003	.006	.007	.021	.06
	3	.21	4.94	.0001	.02	.2	.03	.02	.007	.02	.009	0	.007	0	.002	0	.008	0
	4	.53	4.26	.0005	.02*	.8	.02	.02	.006	.02	.007	0	.005	0	.002	0	.009	.008
	5	.13	2.96	.0008	.02*	.3	.02	.02	.009	.02	.007	0	.004	0	.002	0	.01	.009
	6	.13	3.80	.0007	.04	.3	.03	.02	.007	.02	.007	0	.006	0	.004	.008	.01	.02
	7	.30																
	8	.12	5.02	.001	.02*	.4	.03	.03	.01	.02	.007	0	.008	0	.007	0	.01	.007
	9–12f	.72	2.29	.004	.2*	1.6	.14	.084	.03	.054	.03*	0	.029	.002	.009	.009	.038	.03
	13	.30	4.86	.002	.02*	.4	.03	.02	.01	.02	.02*	0	.007	0	.003	0	.02	.007
	14–18f	.99	2.94	.005	.1*	2	.12	.086	.023	.035	.04	0	.026	.002	.009	.004	.045	.03
	19–23f	2.09	2.47	.003	.3*	1.5	.074	.05	.01	.057	.04	0	.018	.002	.01	.004	.026	.04
	24–31f	2.42	1.85	.002	.2*	1	.04	.032	.014	.068	.03*	0	.012	0	.006	.003	.012	.02
	33–35f	1.57	2.43	.006	.1*	1.8	.12	.08	.045	.076	.07	0	.021	.003	.007	.005	.034	.03
	36–37f	.71	3.08	.02	.2*	1.6	.15	.09	.045	.13	.09	0	.053	.024	.01	.005	.042	.02
Ky-Dia-H_9	1	.18	1.92	.01	.05	.3	.01	.009	.006	.009	.07	0	.009	0	.007	.002	.03	.03
	2	.16	2.70	.01	.03	.2	.02	.01	.005	.01	.03	.07	.01	.03	.01	.003	.04	.02
	3	.25	2.50	.005	.04	.4	.02	.01	.007	.01	.03	.02	.006	0	.006	.003	.02	.02
	4	.24	2.16	.0003	.04	.9	.02	.02	.006	.01	.05	0	.004	0	.005	.005	.01	.03
	5	.27	3.20	.0001	.04	.6	.02	.02	.006	.01	.03	0	.006	0	.004	.003	.02	.04
	6	.15	4.38	.0001	.04	.3	.02	.02	.006	.01	.03	0	.01	0	.003	.002	.02	.03
	7	.45	12.92	.00003	.02	.9	.03	.02	.002	.006	.03	0	.005	0	.001	.002	.01	.01
	8	.35	18.68	.00002	.01	.9	.02	.02	.002	.008	.03	0	.002	0	.0008	.002	.02	.01
	9	.30	6.32	.0001	.02	.5	.02	.02	.004	.009	.03	0	.005	0	.002	.002	.01	.06
	10	.31	9.92	.00003	.02	.9	.02	.02	.003	.007	.03	0	.005	0	.001	.002	.01	.009
	11	.21	6.82	.00004	.03	.8	.03	.02	.004	.008	.03	0	.004	0	.001	.002	.01	.01
	12	.53	5.28	.00003	.04	.7	.03	.02	.006	.01	.03	0	.005	0	.001	.002	.01	.02
	13	.24	6.22	.0001	.03	.5	.02	.02	.005	.009	.02	0	.005	0	.001	.002	.01	.02
	14	.25	13.04	.0001	.02	.3	.01	.02	.005	.01	.01	0	.004	0	0	.003	.007	.01
	15	.45	19.38	.005	.006	.7	.02	.01	.01	.03	.01	.07	.01	.003	0	.002	.01	0
Ky-Har-H_6	1	.42	3.14	.004	.03*	1.6	0.51	.046	.025	.053	.04	0	.018	.12	.003	0	.02	.02
	2	.25	3.52	.0009	.3*	.9	.03	.02	.02	.02	.03*	0	.009	0	.002	0	.02	.03
	3	.37	4.56	.002	.05*	1	.03	.02	.006	.01	.03*	0	.003	0	.002	0	.02	.03
	4	.15	2.28	.001	.3*	.6	.03	.02	.02	.03	.03*	0	.007	0	.004	0	.01	.03
	5a	.31	2.12	.001	.05*	.7	.04	.02	.02	.03	.03*	0	.007	0	.004	0	.01	.03
	5b	.37	2.62	.0006	.05*	.7	.04	.03	.01	.03	.08*	0	.006	0	.003	0	.01	.04
	6	.32	5.44	.0004	.02*	.9	.03	.02	.005	.02	.02*	0	.01	0	.002	0	.009	.03
	7	.18	6.96	.0002	.01*	1	.03	.02	.004	.01	.02*	0	.01	0	.002	0	.01	.03
	8f	.14	5.38	.002	.03	2.4	.16	.076	.003	.015	.02	0	.012	0	.002	.005	.01	.02
	9	.40	10.92	.0002	.009*	1	.04	.02	.004	.01	.02*	0	.009	0	.001	0	.01	.03
	10–12f	.69	3.74	.005	.09	2.6	.11	.06	.009	.018	.07	0	.016	.005	.003	.006	.048	.04

Ky-BD-Le	1	.25	13.68	.004	.006	1	.03	.03	.03	.03	.007*	0	.01	.008	.002	0	.03	.02
	2-4f	1.35	1.63	.003	.1*	3.2	.058	.06	.004	.03	.04*	0	.014	0	.005	.007	.034	.03
	5-7f	2.21	2.93	.003	.05*	.6	.04	.02	.005	.01	.03*	0	.005	0	.008	0	.02	.03
Ky-Pu-Hi	1	.39	4.69	.025	.05	1.4	.27	.076	.004	.06	.1	0	.037	.035	.01	.004	.07	.02
	2-3	1.21	1.78	.008	.07*	.7	.09	.04	.004	.03	.03*	0	.009	.003	.006	.003	.03	.02
	4	.41	4.02	.0002	.01	.3	.03	.02	.005	.02	.007	0	.005	0	.001	.005	.01	.01
	5-6	1.58																
Ky-Al-H4	1	.34																
	2-3f	.40	4.07	.007	.03*	2	.2	.07	.006	.02	.03*	0	.02	0	.002	.005	.02	.03
	4-7f	.98	2.06	.02	.1	1.4	.074	.045	.031	.054	.04	0	.034	.009	.004	.004	.048	.04
	8-10	.74	3.45	.003	.05*	.8	.05	.02	.01	.03	.03*	0	.01	.002	.002	0	.02	.03
	9	.36																
	11	.21																
	12f	.12	4.07	.01	.02	1.4	.078	.054	.029	.046	.04	0	.022	.005	.002	0	.045	.02
Ky-Col1-H4	1a	.63	2.42	.01	.048	.58	.075	.04	.062	.056	.077	.02	.037	.061	.008	0	.088	.02
	1b	.10	1.96	.006	.05*	1	.02	.03	.007*	.03	.03*	.02	.007	0	.001	0	.03	.06
	1c	.15	1.96	.002	.05*	.5	.03	.02	.007*	.03	.1*	.02	.007	0	.002	0	.02	.04
	2	.18	3.00	.0002	.01	1	.03	.02	.004	.02	.02	0	.003	0	0	0	.01	.02
	3	.29	3.52	.0002	.02*	.8	.03	.02	.008	.02	.03*	.02	.007	0	.001	0	.01	.02
	4	.32	2.32	.0005	.02*	.5	.02	.03	.02	.04	.02*	0	.008	0	.002	0	.01	.03
	5	.23	2.34	.002	.05*	.8	.02	.02	.04*	.04	.02*	0	.007	0	.002	0	.02	.02
	6	.33	2.42	.001	.03*	.4	.02	.01	.02	.02	.02*	0	.006	0	.001	0	.02	.02
Ky-Col2-H4	1a	.24	2.10	.03	.05	.5	.10	.04	.06	.08	.07	.06	.05	.2	.006	.005	.1	.02
	1b	.38	2.30	.02	.05*	.9	.04	.02	.03	.03	.08*	0	.02	.004	.004	0	.04	.03
	1c	.38	1.26	.0006	.06	.7	.02	.02	.01	.03	.06	0	.005	0	.004	.009	.03	.04
	2	.18	1.90	.0002	.06	.5	.02	.01	.007	.02	.04	0	.007	0	.002	.003	.02	.03
	3-4	.79	2.70	.002	.05*	1	.04	.02	.004	.02	.03*	0	.004	0	.002	0	.02	.03
	5-6f	.98	2.84	.007	.09	1.4	.10	.054	.022	.057	.07	0	.035	.021	.005	.005	.04	.03
Ky-Sx-H4	1a	.31	5.20	.05	.009*	1	.034	.02	.024	.018	.032	0	.032	.014	0	0	.04	.02
	2-5	2.12																
	6	.18	20.70	.0018	.003	.5	.01	.01	.005	.003	.005	0	.006	0	0	.003	.02	.03
	7-9	.88																
	10	.41	2.72	.0036	.02	.4	.01	.02	.004	.01	.008	.02	.007	.002	0	.004	.04	.09
	11	.27																
	12	.20	1.70	.18	.02*	.5	.023	.036	.052	.048	.07	0	.06	.02	.004	.004	.088	.07
	13	.38	1.98	.17	.02*	.4	.024	.023	.069	.044	.06	.04	.096	.02	.003	0	.097	.04
Ky-SL-Wh	1	.18	13.90	.002	.006	.7	.02	.02	.008	.006	.02*	0	.004	.004	.001	.004	.01	.02
	2-3f	.41	1.63	.004	.2*	2.4	.062	.052	.004	.01	.05*	0	.018	.004	.003	.009	.076	.04
	4-6f	.66	1.71	.003	.2*	1.6	.05	.044	.005	.02	.04*	0	.013	.002	.003	.02	.029	.04
	7-10	1.41	3.61	.0004	.07*	.34	.016	.012	.0015	.006	.02*	0	.003	0	.001	.005	.013	.026
	11-13f	.98	3.54	.006	.06	2.4	.10	.05	.003	.02	.08	0	.012	.003	.003	.004	.056	.04
Ky-PC-Am	1	.40	3.72	.004	.036	.3	.058	.064	.006	.001	.08*	0	.022	.074	.004	.004	.02	.03
	2-3f	.90	3.30	.003	.08	1.4	.038	.026	.003	.01	.03	0	.018	0	.003	.01	.044	.06
	4-6f	.94	1.86	.002	.1*	.86	.044	.033	.003	.009	.03	0	.013	0	.005	.003	.024	.02
	7-9f	1.16	2.31	.002	.1*	.86	.044	.04	.003	.008	.03	0	.0088	0	.006	.008	.031	.02
	10-11f	.81	2.72	.005	.2*	.82	.09	.048	.005	.022	.04*	0	.016	.002	.007	.01	.048	.02
Ky-EJ-E3	1	.55	9.34	.004	.02	.2	.01	.003	.003	.008	.008	.03	.004	0	.004	0	.02	0
	2a-5	1.73	2.25	.006	.1*	.2	.02	.01	.007	.03	.03*	0	.004	.003	.002	.005	.02	.008
	2b	.27	1.14	.011	.05*	.4	.02	.03	.01	.02	.007	.03	.002	0	.006	0	.03	.02
	6	.12	5.10	.009	.07*	.5	.056	.032	.007	.07	.02*	.03	.019	0	.013	.02	.04	0
	7-11f	1.17	1.77	.006	.07*	1.9	.1	.05	.01	.033	.04*	0	.014	.002	.005	.007	.032	.04
	8	.42	2.14	.008	.03*	.3	.03	.02	.009	.02	.007	.03	.007	0	.007	0	.02	.01
	12-14f	.94	2.47	.016	.04*	1	.044	.03	.015	.033	.04*	0	.023	.03	.002	.003	.055	.02

See footnotes at end of table.

TABLE 3.—*Spectrochemical analyses of the ash of coal samples of the Appalachian region*—Continued

Sample	Block No.	Thickness (feet)	Ash	Be	B	Ti	V	Cr	Co	Ni	Cu	Zn	Ga	Ge	Mo	Sn	Y	La
Ky-Hx-E$_3$	1–2	1.09	1.23	0.008	0.1*	0.4	0.02	0.01	0.004	0.008	0.02*	0	0.007	0.002	0.007	0	0.04	0.02
	3–5	1.66	1.43	.0004	.2*	.4	.02	.01	.003	.008	.03*	0	.002	0	.006	.004	.007	.02
	6	.21	3.78	.0005	.03*	1.2	.022	.025	.002	.013	.03*	0	.0065	0	.024	0	.016	.02
	7	.31																
	8a	.51	3.69	.008	.01	.7	.02	.02	.001	.004	.02*	0	.004	0	.001	0	.01	.03
	8b	.38	4.90	.008	.01	1	.02	.026	.002	.016	.03	0	.022	.038	.001	0	.03	.03
	8cf	.18	5.35	.021	.02	3.8	.05	.058	.001	.007	.04	0	.012	.017	.001	.005	.065	.02
Ky-W-E$_3$	1	.41	8.16	.007	.03*	.7	.05	.02	.01	.02	.02*	.04	.01	.02	.002	0	.02	.02
	2–5	1.71																
	6a	.41	3.26	.007	.08	.3	.042	.02	.02	.041	.08*	0	.04	.02	.003	0	.02	.02
	7	.28																
Ky-B&S-E$_2$	1af	.38	1.11	.03	.4*	.71	.07	.035	.02	.048	.04*	0	.039	.003	.01	.003	.08	.03
	1b	.53	17.40	.004	.005	.8	.02	.02	.006	.01	.008	0	.006	.002	0	0	.01	.02
	2	.58	3.00	.0007	.1*	.2	.02	.004	.002	.009	.03*	0	0	0	.003	.005	.005	.008
	3	.38	1.24	.003	.03*	.8	.064	.022	.01	.032	.07*	2	.008	.002	.024	.004	.022	.03
	4–5	1.05	1.81	.003	.3*	.69	.038	.03	.006	.028	.08	0	.026	.006	.005	0	.027	.02
Ky-Hop-E$_2$	1a	.23	1.88	.02	.13	.36	.14	.03	.017	.036	.022	0	.058	.12	.006	.005	.10	.01
	1b	.58	3.68	.02	.05*	.9	.03	.02	.004	.02	.02*	0	.02	.003	.004	.007	.03	.02
	2	.78	13.26	.0003	.02	1	.03	.02	.002	.007	.02*	0	.008	0	0	0	.01	.02
	3	.54	1.18	.002	.02*	.5	.02	.02	.02	.04	.04*	0	.005	0	.004	0	.02	.05
	4	.30	.92	.008	.2*	.8	.03	.03	.08	.06	.2*	0	.008	0	.006	0	.08	.05
	5	.50	.98	.01	.2*	.6	.03	.03	.08	.08	.2*	0	.007	.003	.005	.007	.1	.05
	6	.38	1.88	.02	.10	.41	.06	.04	.082	.08	.3*	0	.034	.031	.004	0	.11	.007
Ky-GV$_1$-E$_1$	1	.86	5.56	.02	.02	.6	.03	.02	.02	.02	.1	0	.02	.005	.002	.003	.04	.02
	2	.70	3.86	.002	.04	.7	.03	.02	.008	.02	.03	0	.007	0	.003	.004	.02	.04
	3	.41	2.14	.0004	.07	.3	.03	.01	.009	.02	.04	0	.005	0	.005	.003	.03	.03
	4	.70	2.66	.0002	.06	.4	.03	.01	.008	.02	.08	0	.004	0	.004	.002	.02	.03
	5	.80	4.06	.0002	.05	.8	.04	.02	.007	.02	.04	0	.006	0	.005	.003	.02	.04
	6	.37	1.86	.0003	.09	.6	.04	.02	.01	.03	.1	.02	.004	0	.007	.003	.04	.04
	7	.32	2.06	.0007	.1	.6	.03	.02	.01	.03	.1	.02	.003	0	.006	.002	.04	.05
	8	.53																
	9	.75	4.02	.0002	.05	.4	.02	.01	.008	.02	.08	0	.002	0	.003	.002	.03	.03
	10	.62	3.86	.0003	.06	.6	.03	.02	.01	.02	.09	0	.003	0	.002	.002	.05	.06
	11	.28	7.28	.0007	.03	.6	.05	.03	.008	.02	.02	.02	.02	.03	.002	.002	.03	.03
Ky-GV$_2$-E$_1$	1	.41																
	2–4f	1.74	2.15	.003	.2*	1	.14	.05	.005	.021	.05*	0	.014	0	.009	.003	.042	.04
	5–7	1.38	2.51	.002	.2*	.3	.038	.02	.01	.035	.04*	0	.007	0	.01	0	.025	.03
	8–9f	1.00	1.94	.006	.3*	1.2	.081	.046	.01	.042	.05*	0	.013	.003	.007	.003	.056	.05
Ky-Wo-J	1–2af	.36	2.42	.022	.1*	1.3	.07	.036	.0035	.014	.05*	0	.026	.02	.0029	.006	.08	.023
	2b–2c	.89	1.34	.0045	.1	.39	.028	.021	.0046	.022	.04*	0	.0034	0	.0057	0	.03	.025
	3–5f	.87	1.20	.0031	.1*	1.3	.21	.072	.018	.068	.05*	0	.0044	0	.005	.007	.042	.026
	6–7	.84	1.39	.034	.1*	.28	.076	.032	.081	.12	.083	0	.04	.014	.0058	0	.04	.024
Ky-IH-Ha	1af	.88	1.00	.24	.075	2	.12	.056	.13	.24	.065	0	.23	.64	.001	.006	.14	.02
	1bf	.43	1.02	.15	.078	2.3	.088	.051	.075	.22	.06*	0	.078	.29	.004	.008	.062	.03

	1c	.12																
	2	.77	1.90	.0007	.01	.9	.02	.02	.005	.03	.02	0	.003	0	.002	0	.01	.05
	3–4	1.85	3.16	.006	.02	1.4	.033	.026	.022	.036	.06	0	.004	.002	.002	.003	.019	.02
	5	.76	7.48	.035	.005*	.91	.028	.018	.017	.034	.05	0	.009	.023	0	0	.022	.02
Tenn-R&P-D	1	.50	3.78	.0007	.2	.86	.27	.026	.003	.01	.07*	0	.006	0	.004	0	.01	.03
	2–4	.71																
	5	.31	2.14	.0003	.2*	.6	.02	.01	.003	.01	.02*	0	.008	0	.003	0	.008	.03
	6	.20	2.02	.0004	.2*	.8	.02	.01	.003	.02	.02*	0	.002	0	.007	.02	.009	.02
	7–11	1.55																
	12	.22	6.14	.003	.07*	.3	.04	.02	.009	.02	.02*	0	.009	0	.007	0	.02	.04
Tenn-A-J	1	.65	2.68	.0002	.05*	.3	.07	.005	.004	.01	.01	.03	.003	0	.003	.01	.005	.007
	2–4	1.00																
	5	.58	1.78	.0005	.2*	.6	.02	.03	.009	.02	.02*	.02	.007	0	.007	.002	.02	.04
	6–8	1.73																
	9	1.00	2.72	.0004	.2*	.4	.03	.01	.006	.01	.04*	0	.006	0	.009	.007	.01	.02
	10a	.36																
	10b	.44	2.86	.0005	.05*	.3	.051	.02	.02	.024	.03*	0	.0065	0	.012	0	.01	.02
	10c	.43	2.60	.001	.07*	.3	.12	.037	.048	.042	.03*	0	.018	0	.028	.02	.01	.02
Tenn-D-J	1	.11	8.74	.006	.04	.63	.056	.026	.005	.031	.07*	0	.01	.004	.01	0	.021	.02
	2–5	1.30																
	6	.31	1.60	.003	.2*	.2	.03	.02	.01	.03	.04*	.05	.003	0	.01	0	.02	.03
	7	.23																
	8	.18	1.10	.004	.2*	.3	.04	.02	.03	.05	.2*	.1	.004	0	.02	0	.03	.02
	9	.49	1.08	.004	.082	.5	.072	.03	.023	.052	.03*	.05	.012	.005	.01	.004	.03	.03
Tenn-E-J	1	.12	21.74	.0007	.01	.5	.036	.03	.007	.022	.03	.02	.0072	.008	.005	0	.01	.02
	2	.54	4.56	.003	.03*	.2	.06	.004	.003	.02	.02*	.02	.003	0	.01	0	.009	0
	3–5	1.47																
	6	.42	4.36	.009	.028	1	.028	.021	.02	.022	.03	.04	.018	.054	.003	0	.04	.05
Tenn-V-K	1	.14	31.22	.02	.005*	1.0	.03	.02		.005	.02*	.02	.002		.001	0	.02	.05
	2	.19	10.78	.002	.005*	1.2	.068	.024	.001	.008	.02	.02	.008	.028	.001	0	.031	.04
	3	.44	3.38	.0005	.02*	.5	.02	.03	.01	.02	.007	.02	.005	.01	.003	0	.007	.02
	4	.14																
	5	.33	2.14	.0005	.07*	.5	.02	.01	.004	.01	.02*	0	.005	0	.004	.005	.01	.01
	6	.13																
	7	.16	1.36	.002	.2*	.5	.01	.01	.003	.01	.02*	0	.003	0	.003	0	.007	.02
	8–11	1.80																
	12	.25	4.56	.003	.1*	1	.03	.02	.008	.02	.02*	0	.006	0	.003	0	.02	.03
Tenn-Re-S	1–9	3.50																
	10	.27	7.58	.003	.006	.4	.03	.02	.004	.008	.007	0	.005	.004	0	0	.02	.02
Tenn-Va-S	1	.21																
	2	.42	8.56	.0003	.01	.4	.02	.03	.003	.01	.008	0	.008	0	.002	0	.01	.02
	3	3.0	6.80	.0007	.01	.4	.02	.03	.003	.01	.006	0	.005	0	0	0	.01	.02
	4	.64	3.18	.0007	.01	.5	.02	.02	.002	.007	.006	0	.005	0	0	0	.008	.02
	5–8	1.67																
	9	.35	7.68	.0003	.01	.4	.03	.03	.007	.01	.008	0	.008	0	.002	0	.01	.02
	[3] KB	--------	5.18	.011	.005	1.9	.9	.38	.022	.26	.008	0	.016	.18	0	0	.02	0
Ga-B-5	1	.16	3.12	.007	.02	.045	.033	.018	.0043	.021	.1	0	.007	.004	.014	0	.042	.01
	2–4	1.48																
Ga-Bl-5	1	.38	2.84	.004	.025	.36	.032	.029	.012	.024	.03*	.04	.0065	.003	.012	0	.031	.03
	2	.25	2.14	.0015	.04*	.29	.052	.026	.016	.025	.07	0	.0037	0	.022	.006	.023	.042
	3	.48	2.74	.0015	.028	.41	.054	.028	.023	.038	.02*	0	.0033	0	.028	0	.016	.038
	4	.35	3.42	.004	.024	.59	.05	.046	.014	.035	.03*	.04	.0084	.003	.012	0	.04	.03
	[4] R	--------	4.92	.006	.01	.3	.027	.006	.01	.025	.02*	.08	.008	.004	.018	.01	.028	0

See footnotes at end of table.

TABLE 3.—*Spectrochemical analyses of the ash of coal samples of the Appalachian region*—Continued

Sample	Block No.	Thickness (feet)	Ash	Be	B	Ti	V	Cr	Co	Ni	Cu	Zn	Ga	Ge	Mo	Sn	Y	La
Ga-W-4	1	.35																
	2	.88	1.18	0.002	0.03	0.32	0.023	0.02	0.016	0.048	0.1	0	0.0076	0	0.017	0	0.027	0.03
	3	.40	1.76	.005	.02	.56	.07	.062	.082	.07	.09	.02	.014	.004	.004	0	.056	.04
Ala-Mi-B(R)	1f	.12	4.06	.018	.02	1.6	.14	.05	.056	.014	.6	0	.016	0	.0052	0	.22	.054
	2–3f	.70	2.39	.0082	.03	1.9	.16	.074	.056	.088	.05*	0	.018	0	.03	0	.081	.028
	4f	.25	2.21	.011	.012	1.4	.10	.054	.064	.072	.07*	0	.032	0	.044	.004	.094	.031
	5	.17	9.06	.004	.0031	.5	.035	.019	.055	.04	.03	.18	.01	.003	.02	0	.03	.04
Ala-Mi-B	1–3	.94																
	4	.33	8.82	.002	.01	.4	.03	.02	.009	.02	.02*	.04	.005	0	.004	0	.01	.02
	5–8	.80																
	9	.60	3.74	.003	.018	.3	.037	.034	.065	.06	.03	.03	.008	0	.0088	0	.01	.03
	10a	.28	5.28	.011	.002*	.4	.05	.03	.077	.14	.02*	.09	.01	.084	.002	0	.04	.02
	10b		13.88	.007	.0028	.4	.05	.04	.015	.028	.02*	.08	.006	.0098	.003	0	.02	.009
Ala-T-B	1	.32	1.98	.016	.01	.35	.022	.015	.018	.02	.09	.1	.0082	.002	.0095	.004	.044	.03
	2	.19	6.28	.003	.025	1.0	.026	.02	.005	.016	.02	0	.006	0	.017	.004	.012	.02
	3–5	1.03																
	6	.60	3.42	.002	.03	.4	.044	.03	.011	.015	.02	0	.0072	0	.012	0	.01	.03
	7–9	.77																
Ala-TH-B	1f	.26	2.76	.01	.032	2.0	.07	.04	.02	.04	.03	0	.019	.006	.009	0	.05	.03
	2	.42																
	3–4f	.56	4.25	.0019	.02	1.4	.10	.054	.022	.054	.027	0	.013	0	.009	0	.032	.041
	5–6f	.71	3.54	.0022	.019	1.6	.10	.056	.014	.039	.026	0	.017	0	.0096	.004	.032	.028
	7	.27	4.02	.002	.02	.2	.035	.029	.017	.021	.05	.03	.007	0	.015	0	.01	.03
	8	.42	5.70	.002	.02*	.5	.04	.02	.01	.02	.2	.05	.007	0	.02	0	.02	.03
	9	.25	9.40	.005	.012	.46	.051	.031	.01	.072	.03*	.02	.012	.004	.012	0	.044	.02
	[5]Raf		4.97	.009	.034	4.0	.26	.10	.014	.086	.1	0	.023	.017	.004	.02	.032	.01
Ala-Mi-Mi	1	.45																
	2	.23	4.20	.003	.01*	.4	.02	.02	.008	.02	.02*	0	.004	0	.003	0	.008	.01
	3–4	.86	2.80	.0004	.0096	.33	.022	.014	.0052	.015	.02*	0	.003	0	.005	0	.012	.02
	5–6	.49																
	7	.24	2.90	.017	.02	.41	.043	.03	.009	.048	.1*	0	.016	.002	.01	0	.091	.02
Ala-T-Mi	1	.12																
	2	.55	5.98	.003	.02*	.6	.039	.028	.02	.03	.03*	.2	.014	0	.012	0	.033	.03
	3	.63	3.50	.0007	.009	.41	.028	.027	.0062	.022	.02*	0	.0046	0	.012	0	.01	.03
	4	.48																
	5a	.25	3.94	.01	.02	.48	.054	.036	.024	.076	.1	0	.026	.028	.014	.005	.078	.01
	6	.05																
Ala-TH-Mi	1	.35	5.38	.01	.006	2.0	.029	.028	.0041	.015	.02	.17	.012	.02	.009	.004	.057	.02
	2	.49	3.38	.002	.012	.86	.031	.032	.0072	.015	.03	.04	.0062	0	.0066	0	.01	.03
	3–4	1.21	2.23	.0027	.02*	.45	.029	.022	.0068	.018	.02*	0	.0041	0	.0099	0	.014	.024
	5	.24	2.28	.008	.02	.5	.039	.034	.02	.025	.02*	.23	.008	.003	.0082	0	.02	.03
	6	.22	3.54	.03	.002*	.6	.088	.04	.058	.13	.05*	.06	.02	.094	.002	.007	.12	.02

Ala-Da-P	1-3	1.45																
	4	.25	1.58	.002	.03*	.7	.04	.02	.01	.02	.03*	0	.005	0	.007	0	.02	.03
	5	.45	3.98	.002	.02*	.2	.02	.005	.009	.01	.02*	0	.009	0	.007	0	.01	.01
	6	.40	5.18	.005	.01	.3	.10	.052	.011	.022	.08	0	.034	.024	.007	0	.06	0
Ala-G-P [6]	Tf	--------	3.67	.005	.07*	1	.06	.03	.001	.008	.005	0	.008	.01	.004	.005	.02	.03
	B	--------	3.58	.004	.1	.81	.05	.038	.014	.025	.03*	0	.012	.003	.0082	0	.036	.03
Ala-G-NP	1f	.16	7.10	.002	.008	.18	.01	.006	.0055	.043	.007	0	.002	0	0	0	.19	.015
	2-3f	.36	9.82	.0004	.01	.41	.021	.013	.004	.022	.01*	0	.002	0	.001	0	.02	.024
	4	.26	6.02	.003	.02	.2	.01	.008	.005	.01	.007	0	.002	0	.002	0	.01	.01
	5-6f	.57	6.90	.0025	.02*	.32	.027	.016	.0082	.028	.02*	0	.003	0	.0045	0	.012	.017
Ala-G-A	1	.57	3.62	.004	.05*	.8	.035	.022	.0065	.012	.02*	0	.01	.022	.0052	0	.024	.02
	2	.63	4.48	.0007	.1*	.65	.023	.017	.004	.008	.02*	0	.0055	0	.013	0	.018	.02
	3-7	2.25																
	8	.29	6.58	.003	.082	.48	.072	.034	.008	.038	.05*	0	.005	0	.02	0	.044	.03
	9	.55	8.42	.004	.052	.68	.072	.029	.009	.033	.07*	.03	.006	.002	.014	0	.056	.03
Ala-M-N	1	.44	12.02	.003	.03*	.61	.031	.014	.0042	.020	.01*	0	.0062	.008	.001	0	.012	.007
	2		15.52	.0018	.02*	.42	.024	.02	.0028	.012	.007*	0	.0041	.004	.0014	0	.008	.006
Ala-Ga-ML	1f	.25	4.13	.0043	.1*	1.6	.066	.046	.0022	.0074	.012	0	.012	.019	.0024	0	.026	.009
	2-3f	.46	2.95	.002	.2*	1.9	.07	.05	.0033	.011	.015	0	.0086	0	.0018	0	.016	.019
	4-6f	.78	6.12	.0022	.2*	2.3	.10	.056	.0036	.023	.026	0	.02	.002	.002	0	.026	.009
	7-8f	1.11	5.48	.0022	.1*	1.7	.066	.046	.012	.024	.024	0	.0073	0	.0022	0	.026	.017
	9f	.29	2.70	.009	.2*	1.9	.19	.078	.021	.076	.028	0	.03	.0078	.016	0	.042	.018
	[4] R	--------	15.34	.002	.02*	.93	.027	.022	.002	.0095	.0073	0	.011	.041	.011	0	.007	0
Ala-Ma-J	1	.04	17.640	.007	.05*	.28	.031	.016	.003	.014	.0075	0	.006	.2	.0022	0	.011	0
	2f	.33	2.51	.012	.2*	.38	.016	.03	.0039	.011	.009*	0	.0074	.0046	.012	0	.032	.023
	3f	.14	1.71	.0038	.09*	.55	.043	.025	.0076	.018	.01*	0	.006	0	.04	.005	.03	.022
	4-5f	.52	1.00	.0021	.1*	.35	.039	.026	.0039	.012	.02*	0	.002	0	.0096	0	.021	.022
	6	.30																
	7	.08	3.32	.0018	.02*	.2	.02	.03	.03	.03	.009	0	.004	0	.006	0	.03	.02
	8	.43																
	9f	.06	3.02	.02	.1*	1	.2	.04	.01	.07	.07	0	.01	.01	.006	0	.07	.03
Ala-Ma1-J	1	.06	5.02	.0065	.1*	.28	.03	.043	.0036	.03	.012	0	.027	.049	.001	0	.06	.009
	2	.48	3.68	.002	.2*	.1	.009	.003	.005	.01	.1	0	.002	0	.009	.007	.006	0
	3	.16	3.66	.002	.4*	.3	.02	.003	.007	.03	.03*	0	.003	0	.01	0	.01	0
	4-6f	.68	2.69	.0024	.1*	.72	.18	.054	.012	.04	.05*	0	.0033	0	.012	0	.04	.035
	7-8f	.48	2.35	.0046	.2*	.64	.066	.05	.021	.05	.04*	0	.0063	0	.0092	0	.092	.024
Ala-De-BC	1	.51	1.78	.007	.07*	.57	.019	.022	.0078	.026	.09	0	.093	.031	.0078	0	.034	.03
	2	.25	1.52	.003	.2*	.59	.042	.028	.03	.048	.08	0	.004	0	.007	0	.04	.05
	3-4	.47																
	5	.18	1.20	.009	.2	.42	.035	.024	.09	.085	.1	0	.004	.034	.007	0	.034	.05
	6	.15	1.18	.03	.099	.5	.049	.02	.2	.088	.16	0	.015	.067	1.5	.007	.05	.04
	7	.20	1.64	.02	.1	.53	.054	.024	.12	.043	.08	0	.012	.071	.004	0	.053	.04
	8	.06	2.94	.02	.064	.82	.44	.08	.12	.17	.09	.04	.048	.23	.24	.005	.072	.05
Ala-Ga-BC	1	.36	3.14	.014	.02	.47	.024	.029	.0078	.018	.02*	0	.013	.022	.0095	0	.037	.03
	2	.18	1.96	.002	.03	.45	.024	.018	.011	.019	.09	0	.0065	0	.014	0	.017	.03
	3	.28	2.98	.0008	.018	.72	.036	.025	.007	.017	.03*	0	.0052	0	.01	0	.019	.025
	4	.38	6.00	.003	.014	1.7	.03	.022	.004	.01	.07*	0	.004	0	.005	0	.023	.02
	5	.36	5.00	.004	.017	1.9	.054	.036	.006	.01	.07*	0	.011	0	.01	0	.028	.02
	6	.34	5.08	.004	.016	1.8	.064	.036	.01	.024	.2*	.02	.008	0	.014	.004	.028	.02
	7	.37	3.32	.007	.025	.68	.054	.034	.01	.048	.07*	0	.015	0	.03	0	.036	.02
	8	.18	3.22	.02	.02	.6	.082	.043	.024	.046	.1	0	.032	.02	.034	0	.05	.02

See footnotes at end of table.

TABLE 3.—*Spectrochemical analyses of the ash of coal samples of the Appalachian region*—Continued

Sample	Block No.	Thickness (feet)	Ash	Be	B	Ti	V	Cr	Co	Ni	Cu	Zn	Ga	Ge	Mo	Sn	Y	La
Ala-H-BC	1	0.44	3.98	0.004	0.2*	0.3	0.02	0.004	0.003	0.01	0.02*	0	0.005	0.003	0.005	0	0.01	0
	2	.35																
	3	.50	4.62	.002	.2*	.4	.02	.02	.01	.02	.03*	0	.002	0	.005	0	.01	.03
	4	.40	1.94	.002	.2*	.42	.038	.032	.017	.042	.09	0	.0048	0	.014	0	.02	.02
	5–6	.72																
	7	.25	2.06	.008	.2*	.51	.082	.045	.032	.052	.08	0	.004	.002	.006	.004	.047	.03
	8	.22																
Ala-BD-W	1–5	.92																
	6	.74	2.86	.0003	.02*	.6	.02	.02	.004	.01	.02*	0	.003	0	.01	0	.01	.02
	7–9	.93																
	10	.30	6.92	.003	.019	.54	.023	.026	.006	.023	.03*	.03	.003	.002	.012	0	.032	.01
Ala-Z-M1	1–2	.37																
	3	.16	3.64	.0003	.08	.65	.025	.02	.012	.035	.02*	0	.0065	0	.01	0	.015	.02
	4–7	.97																
	8	.42	5.20	.003	.04	.76	.13	.049	.023	.028	.02*	0	.019	.029	.002	0	.02	.03
Ala-Z-M2	1	.27																
	2	.32	4.80	.0005	.09*	.7	.02	.02	.02	.02	.02*	.04	.005	0	.01	0	.007	.02
	3–7	1.59																
	8	.54	4.52	.0003	.07*	2	.03	.02	.003	.01	.02*	0	.005	0	.004	0	.01	.03
	9–10	.58																
	11	.29	4.18	.0007	.2*	1	.03	.02	.005	.02	.02*	0	.004	0	.004	0	.02	.03
	12	.46																
	13	.31	3.72	.003	.2*	.6	.02	.02	.01	.03	.02*	0	.002	0	.01	0	.02	.03
	14	.20																
	15	.23	5.34	.008	.064	2.0	.23	.084	.013	.062	.03	0	.024	.003	.014	0	.032	.007
Ala-Z-M3	1–8	4.63																
	9	.28	6.16	.0004	.07*	.8	.03	.02	.01	.02	.02*	0	.004	0	.006	0	.01	.02
	10–11	.38																
	12	.33	5.08	.005	.07*	.4	.1	.03	.03	.02	.03*	0	.006	0	.02	0	.04	.03
	13	.18																
Ala-FtP-UC	1	.10	5.86	.007	.002	.3	.03	.04	.009	.02	.007	0	.005	.02	.002	0	.04	.02
	2–10	1.93																
Ala-FtP1-UC	1	------	2.86	.007	.006	.3	.02	.04	.01	.02	.008	.04	.005	.004	.005	0	.02	.02
	2–3																	
Ala-E-BC	1	.08	4.90	.007	.009	.3	.02	.01	.006	.02	.01*	0	.006	.003	.003	0	.02	.008
	2–5	.92																
	6	.31	6.48	.004	.03	1	.03	.02	.01	.02	.02*	0	.004	.003	.002	.004	.02	.03

[1] Bone coal from block 5.
[2] Extra sample taken 6 ft from block 7.
[3] Kettle-bottom coal.
[4] Rider coal.
[5] Rash coal.
[6] Only top and bottom parts of bed were sampled.

TABLE 4.—*Average minor-element content of the ash of the columnar samples of coal*

[O, below limit of detection; leaders indicate no data for element; *, not used in computing regional averages. Locations of samples shown in table 1]

Sample	Percent of bed analyzed	Average ash percent	Averages (percent in ash by weight)														
			Be	B	Ti	V	Cr	Co	Ni	Cu	Zn	Ga	Ge	Mo	Sn	Y	La
O-L-MK	100	11.07	0.0016	0.021	0.48	0.022	0.021	0.0081	0.034	0.02	0.015	0.0069	0.0056	0.005	0	0.024	0.017
O-Mal-MK	100	7.62	.0023	.039	--------	.019	.012	.0024	.016	.019	.04	.008	.0088	.0016	0	.026	.0045
O-SB-MK	75	3.40	.0073	.10	--------	.015	.017	.004	.0095	.015	.09	.011	.0073	.0063	0	--------	--------
O-SC$_{11}$-MK	98	8.39	.002	--------	--------	.022	.01	.0028	.0078	.017	0	.0058	.0049	.0019	0	.052	.008
O-SH-MK	90	19.20	.002	--------	.32	.015	.0085	.0017	.0043	.0061	.0087	.0038	.0025	.0004	0	.014	.011
O-W-MK	39	14.19	.0043	.23	.4	.038	.037	.01	.031	.022	0	.016	.036	.0025	0	.025	.012
O-M-LK	100	11.46	.0021	--------	--------	.018	.015	.0021	.0073	.026	.018	.005	.0059	.0029	0	.016	.0035
O-Mag-LK	100	11.43	.0027	--------	.2	.028	.02	.0053	.022	.012	.01	.012	.019	.016	.0012	.028	0
O-Mal-LK	100	5.89	.0016	--------	--------	.033	.019	.012	.056	.039	.016	.018	.034	.0095	0	.036	0
O-Me-LK	100	15.52	.004	--------	--------	.0076	.0094	.0031	.026	.015	.005	.0047	.0041	.0028	0	.013	.003
O-P-LK	100	12.62	.0025	.028	.19	.0072	.0073	.0059	.011	.013	.0076	.0037	.007	.0014	0	.013	.0082
O-SC$_{13}$-LK	100	6.98	.0023	--------	.2	.024	.012	.0032	.039	.027	.01	.011	.0095	.0076	0	.046	0
O-SC$_{14}$-LK	100	6.06	.0041	--------	--------	.038	.025	.0044	.04	.03	0	.01	.012	.0054	.002	.014	.001
O-SC$_{20}$-LK	90	11.70	.0023	--------	--------	.031	.013	.0074	.035	.022	.0032	.012	.017	.0049	0	.021	.0032
O-SH-LK	100	11.73	.0034	--------	.22	.0078	.0035	.0042	.006	.0053	.012	.0043	.0043	.0017	0	.02	.0033
O-T-LK	100	8.50	.0024	--------	--------	.018	.011	.0043	.04	.015	0	.0038	.0081	.0051	0	.02	.0033
Pa-Pi-LK	73	11.83	.003	--------	--------	.0057	.01	.0027	.0063	.013	.0067	.0039	.0033	.0008	0	.015	.01
Md-Up-LK	90	14.55	.0018	--------	--------	.023	.026	.013	.027	.012	.038	.0047	.0033	.0007	0	.022	.025
Ky-UE-SL	97	2.63	.0043	.17	1.3	.084	.056	.022	.053	.04	0	.02	.003	.0073	.004	.025	.027
Ky-Dia-H$_9$	100	8.88	.0016	.027	.65	.022	.018	.005	.011	.029	.011	.0058	.0014	.0022	.0024	.014	.02
Ky-Har-H$_6$	100	4.60	.002	.078	1.3	.056	.034	.011	.023	.041	0	.01	.015	.0038	.0013	.02	.031
Ky-BD-Le	100	3.18	.0031	.065	1.5	.046	.035	.0063	.018	.032	0	.0085	.0005	.0065	.0025	.026	.035
Ky-Pu-Hi	56	3.50	.011	.043	.8	.13	.045	.0043	.037	.046	0	.017	.013	.0057	.004	.037	.017
Ky-Al-H$_4$	71	3.41	.01	.05	1.4	.1	.047	.019	.038	.035	0	.022	.004	.0025	.0023	.033	.03
Ky-Col$_1$-H$_4$	100	2.54	.0037	.035	.57	.038	.026	.03	.036	.043	.011	.015	.017	.0045	0	.036	.025
Ky-Col$_2$-H$_4$	100	2.41	.008	.065	1.0	.061	.032	.019	.04	.057	.0049	.02	.024	.0038	.0034	.037	.03
Ky-Sx-H$_4$	31	6.46	.081	.014	.56	.02	.022	.031	.025	.035	.012	.04	.011	.0014	.0022	.057	.05
Ky-SL-Wh	100	3.52	.0029	.1	1.4	.05	.033	.0031	.013	.043	0	.009	.0018	.0021	.0078	.034	.034
Ky-PC-Am	100	2.63	.003	.11	.92	.053	.039	.0037	.011	.037	0	.014	.0074	.0051	.0073	.034	.03
Ky-EJ-E$_3$	100	2.92	.008	.065	.75	.043	.024	.009	.028	.028	.0078	.01	.007	.0037	.0042	.03	.017
Ky-Hx-E$_3$	93	2.29	.0051	.11	.69	.021	.016	.0028	.0085	.026	0	.0062	.0049	.0059	.0019	.022	.022
Ky-W-E$_3$*	29	5.71	.007	.055	.5	.046	.02	.015	.031	.05	.02	.025	.02	.0025	0	.02	.02
Ky-B&S-E$_2$	100	4.72	.0062	.18	.63	.039	.023	.0076	.024	.051	.26	.017	.0032	.0068	.0019	.026	.02
Ky-Hop-E$_2$	100	4.54	.0098	.1	.73	.078	.026	.035	.042	.1	0	.015	.0047	.0038	.0024	.051	.024
Ky-GV$_1$-E$_1$	92	3.83	.0034	.052	.57	.032	.017	.011	.021	.068	.003	.0074	.0022	.0037	.0027	.031	.036
Ky-GV$_2$-E$_1$	91	2.22	.0034	.22	.81	.091	.039	.008	.031	.047	0	.011	.0007	.009	.002	.04	.039
Ky-Wo-J	100	1.45	.015	.1	.74	.1	.04	.03	.062	.056	0	.017	.0064	.0052	.0028	.042	.025
Ky-IH-Ha	97	3.05	.067	.032	1.4	.051	.032	.044	.09	.053	0	.054	.15	.0017	.003	.045	.026
Tenn-R&P-D	35	3.52	.0011	.17	.64	.027	.017	.0045	.015	.033	0	.0063	0	.0053	.005	.012	.03
Tenn-A-J	50	2.53	.0005	.11	.38	.058	.02	.017	.021	.026	.01	.0081	0	.012	.0078	.011	.021
Tenn-D-J	42	3.13	.0043	.13	.41	.05	.024	.017	.041	.085	.05	.0073	.0023	.013	.001	.025	.025
Tenn-E-J	42	10.22	.0042	.023	.57	.041	.018	.01	.021	.027	.027	.0094	.021	.006	0	.02	.023

TABLE 4.—*Average minor-element content of the ash of the columnar samples of coal*—Continued

Sample	Percent of bed analyzed	Average ash percent	Averages (percent in ash by weight)													
			Be	B	Ti	V	Cr	Co	Ni	Cu	Zn	Ga	Ge	Mo	Sn	Y	La
Tenn-V-K	42	8.91	0.0047	0.067	0.78	0.03	0.019	0.0043	0.012	0.018	0.01	0.0048	0.0063	0.0025	0.001	0.016	0.028
Tenn-Re-S*	7	7.58	.003	.006	.4	.03	.02	.004	.008	.007	0	.005	.004	0	0	.02	.02
Tenn-Va-S	48	6.56	.0005	.01	.43	.023	.028	.0038	.0093	.007	0	.0065	0	.001	0	.0095	.02
Ga-B-5*	9	3.12	.007	.02	.45	.033	.018	.0043	.021	.1	0	.007	.004	.014	0	.042	.01
Ga-B1-5	100	2.83	.0028	.028	.42	.047	.032	.017	.031	.034	.02	.0054	.0015	.019	.001	.027	.035
Ga-W-4	78	1.47	.0035	.025	.44	.047	.041	.049	.059	.095	.01	.011	.002	.011	0	.042	.035
Ala-Mi-B(R)	100	3.43	.0091	.022	1.6	.13	.06	.058	.083	.1	.025	.02	.0004	.029	.0008	.09	.033
Ala-Mi-B	41	7.93	.0058	.0082	.38	.042	.031	.042	.062	.023	.06	.0073	.023	.0045	0	.02	.02
Ala-T-B	38	3.89	.007	.022	.58	.031	.022	.011	.017	.043	.033	.0071	.0007	.013	.0027	.022	.027
Ala-TH-B	86	4.95	.0046	.022	1.5	.094	.047	.015	.047	.066	.014	.014	.004	.011	.0034	.031	.027
Ala-Mi-Mi	59	3.30	.0068	.013	.38	.028	.021	.0074	.028	.047	0	.0077	.007	.006	0	.037	.017
Ala-T-Mi	69	4.47	.0046	.016	.36	.04	.03	.017	.043	.05	.07	.015	.009	.013	.0017	.04	.023
Ala-TH-Mi	100	3.01	.0064	.015	.76	.036	.028	.012	.028	.025	.059	.0074	.011	.0083	.0012	.029	.025
Ala-Da-P	47	3.58	.003	.02	.04	.053	.026	.01	.017	.043	0	.016	.008	.007	0	.03	.013
Ala-G-P*		3.63	.0045	.085	.91	.055	.034	.008	.017	.018	0	.01	.0065	.006	.0025	.028	.03
Ala-G-NP	100	7.54	.002	.016	.3	.02	.012	.006	.0025	.013	0	.0024	0	.0026	0	.015	.017
Ala-G-A	48	5.78	.0029	.071	.65	.051	.026	.007	.023	.04	.0075	.0066	.006	.013	0	.036	.016
Ala-M-N	100	13.77	.0024	.025	.52	.028	.017	.0035	.016	.0085	0	.0052	.006	.0012	0	.01	.0065
Ala-Ga-ML	100	4.85	.003	.15	1.9	.088	.053	.0084	.025	.022	0	.014	.003	.0035	0	.026	.015
Ala-Ma-J	62	4.87	.0078	.093	.46	.058	.028	.0097	.026	.021	0	.0059	.036	.013	.0008	.032	.02
Ala-Ma1-J	100	3.02	.003	.18	.5	.088	.035	.012	.034	.057	0	.0045	.0016	.01	.0018	.043	.019
Ala-De-BC	74	1.71	.015	.12	.57	.11	.033	.095	.076	.1	.007	.015	.072	.29	.002	.047	.043
Ala-Ga-BC	100	4.05	.0064	.019	1.1	.045	.03	.009	.023	.08	.0028	.011	.0047	.015	.0006	.03	.022
Ala-H-BC	55	3.15	.004	.2	.41	.04	.025	.016	.031	.055	0	.004	.0013	.0075	.001	.022	.02
Ala-BD-W	36	4.89	.0017	.02	.57	.022	.023	.005	.017	.025	.015	.003	.001	.011	0	.021	.015
Ala-Z-M1	45	4.42	.0017	.06	.71	.078	.035	.018	.032	.02	0	.013	.015	.006	0	.018	.025
Ala-Z-M2	35	4.51	.0025	.12	1.3	.066	.033	.01	.028	.022	.008	.008	.006	.008	0	.018	.023
Ala-Z-M3*	10	5.62	.0027	.07	.6	.065	.025	.02	.02	.025	0	.005	0	.013	0	.025	.025
Ala-FtP-UC	5	5.86	.007	.002	.3	.03	.04	.009	.02	.007	0	.005	.02	.002	0	.04	.02
Ala-FtP1-UC		2.86	.007	.006	.3	.02	.04	.01	.02	.008	.04	.005	.004	.005	0	.02	.02
Ala-E-BC*	30	5.69	.0055	.02	.65	.025	.015	.008	.02	.015	0	.005	.003	.0025	.002	.02	.019

TABLE 5.—*Average minor-element content of the columnar samples of coal*

[O, below limit of detection; leaders indicate no data for element; *, not used in computing regional averages. Location of samples shown in table 1]

Sample	Percent of bed analyzed	Average ash percent	Averages (parts per million in coal)														
			Be	B	Ti	V	Cr	Co	Ni	Cu	Zn	Ga	Ge	Mo	Sn	Y	La
O-L-MK	100	11.07	1.6	26	510	23	21	9.2	37	21	17	7.5	6.3	5.3	0	23	17
O-Mal-MK	100	7.62	1.8	29	-------	14	8.8	1.8	13	11	30	6.1	6.3	1.2	0	19	4.0
O-SB-MK	75	3.40	1.8	33	-------	2.4	4.1	.8	2.4	3.4	27	1.3	1.0	1.3	0	-------	-------
O-SC$_{14}$-MK	98	8.39	1.5	-------	-------	21	7.9	2.5	6.4	13	0	4.9	3.8	1.2	0	41	6.9
O-SH-MK	90	19.20	2.6	-------	830	31	19	2.9	9.9	12	14	6.5	4.0	1.3	0	23	25
O-W-MK	39	14.19	4.0	132	590	41	45	7.4	31	20	0	15	49	2.6	0	22	14
O-M-LK	100	11.46	2.4	-------	-------	12	12	1.9	6.2	20	27	5.1	5.3	2.2	0	12	3.0
O-Mag-LK	100	11.43	2.6	-------	130	24	17	4.8	23	11	6.2	11	15	18	.7	20	4.6
O-Mal-LK	100	5.89	.7	-------	-------	17	12	4.6	22	16	5.6	7.7	13	8.0	0	14	0
O-Me-LK	100	15.52	4.1	-------	-------	11	14	4.1	46	26	2.1	7.4	5.7	3.5	0	23	10
O-P-LK	100	12.62	2.4	56	360	12	13	8.1	15	14	15	6.2	14	1.2	0	16	12
O-SC$_{13}$-LK	100	6.98	1.3	-------	110	17	8.4	2.0	23	17	5.7	6.5	5.6	5.3	0	25	0
O-SC$_{14}$-LK	100	6.06	2.4	-------	-------	24	15	2.4	19	16	0	5.7	6.5	3.2	1.0	24	1.8
O-SC$_{20}$-LK	90	11.70	3.2	-------	-------	42	17	8.0	32	19	2.1	12	14	5.7	0	21	2.1
O-SH-LK	100	11.73	3.3	-------	320	11	4.7	5.5	8.0	6.0	14	5.2	5.7	1.8	0	22	4.7
O-T-LK	100	8.50	1.8	-------	-------	18	11	3.2	34	12	0	3.4	7.0	4.0	0	15	0
Pa-Pi-LK	73	11.83	3.7	-------	-------	20	12	3.2	7.9	17	6.7	4.8	3.7	.9	0	18	12
Md-Up-LK	90	14.55	2.4	-------	-------	33	32	12	28	15	36	6.2	6.4	1.2	0	42	24
Ky-UE-SL	97	2.63	1.2	41	330	21	14	5.5	15	10	0	5.2	0.8	1.8	1.0	6.7	6.7
Ky-Dia-H$_9$	100	8.88	1.3	17	630	19	15	4.5	12	21	15	5.1	.6	1.0	1.9	11	12
Ky-Har-H$_6$	100	4.60	.8	25	600	25	14	4.1	8.7	16	0	4.7	4.8	1.0	.5	8.4	14
Ky-BD-Le	100	3.18	1.1	15	380	13	9.6	3.8	6.1	8.0	0	2.6	.7	1.8	.4	8.1	8.6
Ky-Pu-Hi	56	3.50	4.4	13	300	52	17	1.5	14	18	0	7.0	5.6	2.1	1.5	14	5.7
Ky-Al-H$_4$	71	3.41	3.0	15	490	36	17	6.0	12	12	0	6.9	1.2	.8	.7	11	9.7
Ky-Col$_1$-H$_4$	100	2.54	.9	8.5	170	9.7	6.5	7.2	8.9	11	2.7	3.8	4.2	.8	0	8.8	6.0
Ky-Col$_2$-H$_4$	100	2.41	1.9	16	260	16	8.2	4.5	9.8	14	1.0	5.2	5.5	.9	.7	8.8	7.2
Ky-Sx-H$_4$	31	6.46	19.1	4.7	370	10	9.4	9.3	7.0	11	2.7	12	3.0	.3	1.6	21	23
Ky-SL-Wh	100	3.52	.9	26	420	16	10	1.3	4.0	14	0	2.6	.7	.7	2.1	10	11
Ky-PC-Am	100	2.63	.8	28	240	14	11	1.0	2.8	10	0	4.0	2.7	1.3	2.0	9.3	8.4
Ky-EJ-E$_3$	100	2.92	2.1	16	170	9.7	5.3	2.2	7.2	6.9	4.0	2.6	1.7	1.1	1.0	8.2	3.4
Ky-Hx-E$_3$	93	2.29	1.6	17	230	5.4	4.9	.5	21	6.3	0	2.0	2.2	1.2	.4	5.5	4.9
Ky-W-E$_3$*	29	5.71	4.0	25	350	27	11	7.4	15	21	16	11	11	1.3	0	11	11
Ky-B&S-E$_2$	100	4.72	2.0	33	330	12	9.4	2.9	6.7	11	32	4.3	1.1	1.0	.4	6.7	9.0
Ky-Hop-E$_2$	100	4.54	2.3	18	410	16	9.9	5.1	8.1	20	0	5.6	2.5	.6	.6	11	10
Ky-GV$_1$E$_1$	92	3.83	1.8	18	230	12	7.0	4.1	7.9	26	1.2	3.5	1.5	1.3	1.0	12	13
Ky-GV$_2$E$_1$	91	2.22	.7	49	170	20	8.4	1.8	6.8	10	0	2.5	.1	2.0	.4	8.6	8.5
Ky-Wo-J	100	1.45	2.3	15	110	14	5.7	4.1	8.4	8.1	0	2.7	1.1	.7	.4	6.6	3.6
Ky-IH-Ha	97	3.05	11	5.5	370	11	7.6	8.1	16	16	0	6.8	18	.4	.6	8.6	7.1
Tenn-R&P-D	35	3.52	.6	50	200	11	6.6	2.0	5.6	12	0	2.5	0	2.0	1.0	4.9	10
Tenn-A-J	50	2.53	.1	27	92	15	5.0	4.5	5.3	6.7	2.3	2.0	0	3.0	2.0	2.6	5.1
Tenn-D-J	42	3.13	1.6	25	170	17	7.8	3.7	11	23	6.1	2.7	1.0	3.2	.1	7.0	6.9
Tenn-E-J	42	10.22	2.3	16	540	39	25	8.4	22	29	23	8.3	14	5.6	0	14	22

TABLE 5.—*Average minor-element content of the columnar samples of coal*—Continued

Sample	Percent of bed analyzed	Average ash percent	Averages (parts per million in coal)														
			Be	B	Ti	V	Cr	Co	Ni	Cu	Zn	Ga	Ge	Mo	Sn	Y	La
Tenn-V-K	42	8.91	11	19	870	32	19	1.6	7.3	17	15	3.5	5.6	1.3	0.2	18	37
Tenn-Re-S*	7	7.58	2.3	4.6	300	23	15	3.0	6.1	5.3	0	3.8	3.0	0	0	15	15
Tenn-Va-S	48	6.56	.3	6.6	270	15	19	2.7	6.3	4.7	0	4.5	0	.8	0	6.4	13
Ga-B-5*	9	3.12	2.2	6.2	140	10	5.6	1.3	6.6	31	0	2.2	1.2	4.4	0	13	3.1
Ga-Bl-5	100	2.83	.6	3.5	68	7.5	6.7	8.2	9.0	14	1.8	1.7	.4	1.4	0	6.6	5.3
Ga-W-4	78	1.47	.8	7.8	120	13	9.4	4.7	9.0	9.1	6.3	1.6	.5	5.2	.2	7.9	9.6
Ala-Mi-B(R)	100	3.43	2.8	5.8	440	36	17	19	26	37	22	5.7	.4	8.7	.2	28	12
Ala-Mi-B	41	7.93	4.6	5.1	310	34	25	23	38	17	51	5.3	15	3.0	0	15	13
Ala-T-B	38	3.89	1.9	9.3	280	12	6.4	3.5	6.4	12	6.6	2.6	.1	5.6	1.1	6.6	9.6
Ala-TH-B	86	4.95	2.2	10	640	44	22	7.0	25	34	8.5	6.6	2.0	5.8	1.6	16	13
Ala-Mi-Mi	59	3.30	2.1	4.2	130	9.0	7.0	2.5	8.8	14	0	2.4	.2	1.9	0	11	5.2
Ala-T-Mi	69	4.47	2.0	7.7	230	18	14	7.9	19	21	39	6.7	3.7	5.5	.7	18	11
Ala-TH-Mi	100	3.01	2.3	3.9	280	11	8.6	3.8	8.6	7.6	22	2.5	4.5	2.4	.5	11	7.3
Ala-Da-P	47	3.58	1.2	6.0	120	22	11	3.6	6.2	18	0	7.3	4.1	2.5	0	13	2.9
Ala-G-P*	----------	3.63	1.6	31	330	20	12	2.7	5.9	6.3	0	3.6	2.4	2.2	.9	10	11
Ala-G-NP	100	7.54	1.4	11	240	15	9.5	4.5	19	9.9	0	1.8	0	1.8	0	12	14
Ala-G-A	48	5.78	1.8	40	370	33	16	4.2	15	27	6.3	3.6	2.4	8.2	0	23	14
Ala-M-N	100	13.77	3.2	34	690	37	24	4.7	21	11	0	6.9	7.9	1.7	0	13	8.9
Ala-Ga-ML	100	4.85	1.3	72	940	41	25	3.9	12	11	0	6.5	1.2	1.4	0	13	6.8
Ala-Ma-J	62	4.87	3.8	33	180	23	11	3.5	11	7.2	0	3.0	60.0	3.1	0.1	11	4.6
Ala-Ma_1-J	100	3.02	.9	55	130	24	9.4	3.2	9.3	18	0	1.4	.8	2.9	.7	11	5.0
Ala-De-BC	74	1.71	2.6	19	110	26	6.8	16	15	16	2.0	3.4	16	42	.4	8.7	7.5
Ala-Ga-BC	100	4.05	2.4	7.4	530	19	12	3.3	8.5	35	1.4	4.1	1.5	5.5	.3	12	8.9
Ala-H-BC	55	3.15	1.1	63	120	10	6.6	3.9	8.0	14	0	1.2	.4	2.1	.2	5.5	6.0
Ala-BD-W	36	4.89	1.1	9.4	270	11	12	2.6	9.4	13	10	1.5	.7	5.6	0	13	6.3
Ala-Z-M_1	45	4.42	.8	25	320	38	16	8.2	14	8.8	0	6.1	7.5	2.4	0	7.9	11
Ala-Z-M_2	35	4.51	1.2	53	590	33	16	4.7	13	10	3.8	4.0	.3	3.9	0	8.2	10
Ala-Z-M_3*	10	5.62	1.4	39	350	35	14	11	11	14	0	2.8	0	6.9	0	13	14
Ala-FtP-UC*	5	5.86	4.1	1.2	180	18	23	5.3	12	4.1	0	2.9	12	1.2	0	23	12
Ala-FtP_1-UC*	----------	2.86	2.0	1.7	86	5.7	11	2.9	5.7	2.3	11	1.4	1.1	1.4	0	5.7	5.7
Ala-E-BC*	30	5.69	3.0	12	400	15	8.9	4.7	11	8.9	0	2.8	1.7	1.4	1.3	11	12

TABLE 6.—*Average minor-element content in parts per million, of the floated and whole coals*

Element	Kentucky and northern Tennessee		Alabama		Element	Kentucky and northern Tennessee		Alabama	
	Samples					Samples			
	Unfloated 118	Floated 32	Unfloated 68	Floated 22		Unfloated 118	Floated 32	Unfloated 68	Floated 22
Be	2.9	3.2	2.3	2.1	Zn	6.4	0	12	0
B	18	28	24	28	Ga	4.4	5.8	4.4	4.3
Ti	334	440	330	510	Ge	3.3	4.4	10.7	1.3
V	16	24.5	23	34	Mo	1.5	1.2	7.7	2.8
Cr	10	14	13	16	Sn	.84	1.4	.3	.7
Co	4.5	3.9	7.6	5.5	Y	9.7	10.7	13	16
Ni	9.0	9.9	14.5	16.5	La	11.5	7.8	9	9
Cu	14.7	11.3	19	21.6					

TABLE 7.—*Average minor-element content, in parts per million, of the columnar coal samples and ash fractions*

Element	Coal	Ash	Element	Coal	Ash
Be	2.5	65	Zn	7.6	160
B	25	730	Ga	4.9	110
Ti	340	7,100	Ge	5.8	110
V	21	460	Mo	3.5	110
Cr	13	260	Sn	.4	14
Co	5.1	140	Y	14	290
Ni	14	320	La	9.4	200
Cu	15	370			

tions than in the whole coal samples are, for the most part, those found to have an affinity for organic matter in previous work (Zubovic and others, 1961b).

Tin is a notable exception and appears to be about twice as highly concentrated in the float fractions as in the whole coal samples. Germanium, the element having the highest organic affinity, of those considered, is notably lower in floated fractions of coals from Alabama than in whole coal samples from the same State. This can be attributed to the fact that in the initial screening process samples high in germanium were analyzed without any separation of the inorganic matter.

COMPARISON OF VITRAINS, FUSAINS, AND KETTLE-BOTTOM COAL WITH BLOCKS OF WHOLE COAL

The analyses of three vitrain samples, four fusain samples, and one kettle-bottom coal sample and the data on the blocks of coals from which these samples were extracted are given in table 8. The data on the kettle-bottom coal are compared with those from the top block from the columnar sample. It would be expected that because vitrain is relatively purer coal compared to the blocks of whole coal, the vitrains should contain larger amounts of those elements with a high-organic affinity and lesser amounts of those with a low-organic affinity. This expectation is not supported by the data and may be due to the large vertical variability of the minor-element content of the coals.

Many elements having a high affinity for organic matter in coals are present in lower concentrations in fusains than in the block coal samples (table 8). These elements include vanadium, gallium, yttrium, boron, and to a lesser extent, beryllium and nickel. As fusains are considered to have undergone a high degree of degradation of the organic molecular species, which originally made up the tissues of the material from which the fusains were derived, it may be expected that fewer organic ligands would be available for complex formation. This may, at least partially, account for their low minor-element contents of elements with a high organic affinity.

Chromium and cobalt occur in lesser amounts in two of the four fusains than in the corresponding block samples (table 8). Their position is thus intermediate as it is in the organic-affinity series (Zubovic and others, 1961b). Copper, molybdenum, and lanthanum, which are at the lower end of the series, are generally equally or more highly concentrated in the fusains than in the block samples. Thus, the relation shown by these elements in their distribution between fusain and the whole blocks of coal follows the general pattern to be expected from the organic-affinity series.

The kettle-bottom coal and the nearest block of coal from the bed underlying it also show relationships supporting the organic-affinity series. The kettle-bottom coal is purer than that from the block. Germanium, vanadium, nickel, and chromium are considerably more highly concentrated in the kettle-bottom coal; beryllium, titanium, cobalt, gallium, and yttrium are somewhat more highly concentrated; whereas copper, molybdenum, and lanthanum are less highly concentrated in the kettle-bottom coal than in the block sample. Boron, which, on the basis of the organic-affinity series, might be expected to be more highly concentrated in the purer kettle-bottom coal, is actually present in a much lower concentration.

COMPARISON OF BLOCKS OF COAL WITH INCLUDED PYRITE

Twelve samples of the handpicked pyrite from blocks of lower and middle Kittanning coal of Ohio and Maryland were also analyzed (table 9). Beryllium, vanadium, boron, chromium, gallium, germanium, molybdenum, tin, and lanthanum were not detected in any of the samples. Yttrium was found in one sample (O-SC_{14}-MK-9 py). Zinc was found in 3 samples, cobalt in 4 samples, nickel in 9 samples,

TABLE 8.—*Analyses of fusains, vitrains, and blocks of whole coal*

[Data are in parts per million in coal. 0, element below limit of detection. Leaders indicate element not looked for. Location of samples shown in table 1]

Element	O-Mal-MK-4		O-SB-MK-1		O-Mal-LK-7		O-Mal-MK-4		O-SC14-MK-3		O-SC14-MK-4		O-SC13-LK-3		Tenn-Va-S	
	Block	Vitrain	Block	Vitrain	Block	Vitrain	Block	Fusain	Block	Fusain	Block	Fusain	Block	Fusain	Block	Kettle-bottom
Be	0.7	0.35	2.1	6.0	1.7	0.5	0.7	0.5	0.6	0.2	1.4	0.5	0.6	0.8	0.26	5.7
B	20	18	19	11	------	------	20	7.8	------	------	------	------	------	------	8.6	2.6
Ti	------	------	------	------	------	------	------	------	------	------	------	------	------	------	340	980
V	13	11	2.1	3.0	19	4.1	13	10	5.7	<1.8	70	8.2	9	<.8	17	470
Cr	6.6	7	4.2	4.5	8.4	9.2	6.6	12	5.1	1.4	18	6.8	3	29	26	197
Co	1.3	1.1	.8	.6	12.2	9.2	1.3	2.6	1.1	<.9	3.5	2.7	.9	6.8	2.6	11
Ni	6.6	2.8	2.1	1.5	77	46	6.6	.9	2.3	5.4	5.3	4.1	9.0	1.5	8.6	135
Cu	13	7	2.1	3.0	28	<.1	13	26	23	13	18	41	9.0	15	6.9	4.1
Zn	0	0	11	<1.5	35	230	0	0	0	0	0	0	0	0	0	0
Ga	4.6	2.5	1.1	1.2	19	14	4.6	<.7	1.7	<.9	11	4.1	1.8	<.4	6.9	8.3
Ge	<.7	.7	.6	.3	104	101	<.7	2.6	0	0	0	0	1.2	<.8	<.8	93
Mo	.7	2.8	1.3	1.1	3.1	1.8	.7	<.7	1.7	1.8	<.9	1.4	3.0	5.3	1.7	<.3
Sn	0	0	0	0	3.1	<.5	0	0	0	0	0	0	0	0	0	0
Y	20	14	------	------	16	9.2	20	<1.3	17	<1.8	35	<1.4	24	1.5	8.6	10
La	5.2	2.5	------	------	<.5	9.2	5.2	10	4.5	18	18	<4.2	0	0	17.1	<1.5

and copper in 11 samples (table 9). The large quantity of zinc in two of the samples suggest that some sphalerite may be present.

The amounts of cobalt, nickel, copper, and zinc in the coal from which the pyrite samples were separated are also given in table 9. No pronounced correlations between the amounts of these elements in the coal and the included pyrite are apparent.

TABLE 9.—*Analyses of coal samples and included pyrite*

[Upper value refers to coal sample, lower value refers to included pyrite; values in parts per million. Location of samples shown in table 1]

Sample	Cobalt	Nickel	Copper	Zinc	Ash (weight percent)
Md-Up-Lk-4	3.2	8.2	16	33	16.36
4py	<30	50	100	<300	
O-P-LK-4	4.2	7.1	11	<14	14.12
4py	50	90	30	<300	
O-M-LK-6	.7	.7	15	29	7.24
6py	<30	<30	20	<300	
O-M-LK-11	3.0	12	42	24	5.98
11py	<30	90	30	<300	
O-T-LK-6	3.4	19.2	9.6	<4.8	4.80
6py	50	200	30	<300	
O-Mag-LK-2	5.5	37	11	<18	18.30
2py	<30	100	30	<300	
O-Mal-LK-7	11	71	35	35	3.54
7py	70	200	90	5,000	
O-SH-LK-6	9.8	3.7	11	25	12.30
6py	<30	50	200	2,000	
O-SC$_{14}$-LK-3	1.9	34	19	<3.7	3.74
3py	<30	100	50	<300	
O-SC$_{14}$-MK-9	22	45	22	<11	11.22
9py	50	200	200	<300	
O-SH-MK-10	1.6	2.3	2.3	7.8	7.78
10py	<30	<30	<10	<300	
O-L-MK-3	2.4	9.4	11	35	11.76
3py	<30	<30	20	500	

COMPARISON OF COAL SAMPLES FROM THE THREE PRINCIPAL AREAS OF THE APPALACHIAN REGION

Within each of the three principal areas of the Appalachian region (fig. 1) the coals vary in minor-element content. The variation appears to be related to both their stratigraphic and geographic position. Variation among the three principal areas—the northern, central, and southern parts of the region—appears to be significant for some elements, and it is possible to draw some very general, though preliminary, conclusions about the relative minor-element contents of coals in the three areas (table 10).

Coals from the northern area appear to contain more boron, and perhaps more yttrium, than those from the central and southern areas. They are also lower in tin content. Coals from the central area are richer in tin and apparently lower in zinc, germanium, and molybdenum. Coals from the southern area are, in large part, intermediate between those from the two areas to the north, but they appear to contain more molybdenum and zinc than coals from the central region (table 10).

TABLE 10.—*Average minor-element contents, in parts per million, of coal from 3 areas of the Appalachian region*

Area	Be	B	Ti	V	Cr	Co	Ni	Cu	Zn	Ga	Ge	Mo	Sn	Y	La
Northern (Ohio, Md., Pa.)	2.4	55	407	21	15	4.7	20	15	12	6.8	9.6	3.8	0.1	22	8.3
Central (Ky., Northern Tenn.)	3.1	22	340	19	11	4.1	9.7	14	4.4	4.5	3.3	1.5	.9	9.6	11
Southern (Ala.)	2.0	24	350	25	14	6.7	15	17	8.6	4.1	6.4	5.8	.3	13	8.8

Some of the differences in minor-element content of coals among the three areas may be due to stratigraphic variation. This may be especially true for comparisons involving the northern area; all the samples from this area are from two coal beds in the Alleghany Formation (table 1). Samples from the central and southern areas, however, represent beds widely distributed throughout the Pottsville Formation, and the differences between these two areas, where significant, are thought to indicate principally geographic variation.

COMPARISON OF COALS FROM VARIOUS REGIONS OF THE UNITED STATES

The average minor-element contents of coals from the Northern Great Plains province and the Eastern Interior region, from Zubovic and others (1960), are given in table 11 where they may be compared with those of coals from the Appalachian region.

TABLE 11.—*Average minor-element contents, in parts per million, of coals from various regions of the United States*

Element	Northern Great Plains province	Eastern Interior region	Appalachian region	Element	Northern Great Plains province	Eastern Interior region	Appalachian region
Be	1.5	2.5	2.5	Ga	5.5	4.1	4.9
B	116	96	25	Ge	1.6	13	5.8
Ti	590	450	340	Mo	1.7	4.3	3.5
V	16	35	21	Sn	.9	1.5	.4
Cr	7	20	13	Y	13	7.7	14
Co	2.7	3.8	5.1	La	9.5	5.1	9.4
Ni	7.2	15	14	Ash average (in weight percent)	13.42	6.16	6.11
Cu	15	11	15				
Zn	59	44	7.6				

The concentrations of most of the elements in coals of the Appalachian region do not appear to be significantly different from those in coals from the Northern Great Plains and the Eastern Interior region. Zinc and boron are exceptions and appear to be present at lower concentrations in coals of the Appalachian region. Few of the coal samples collected in the Appalachian region contain as much zinc and boron as the average amounts present in coals from the other regions. The average concentration of tin in coals from the Appalachian region also appears to be lower than tin in coals from the other regions.

SUMMARY AND CONCLUSIONS

Several hundred block samples of coal, representing 73 columnar samples of coal beds, were collected and analyzed for beryllium, boron, titanium, vanadium, chromium, cobalt, nickel, copper, zinc, gallium, germanium, molybdenum, tin, yttrium, and lanthanum. The samples are all from three general areas in the Appalachian region. Selected specimens were separated by a flotation process, and vitrain, fusain, and pyrite fractions were separated from a few others.

Generally, coals from the northern part of the region, Ohio, Pennsylvania, and Maryland, contain more boron, titanium, chromium, nickel, zinc, gallium, germanium, and yttrium than do the coals from the central and southern parts of the region. Coals from the Kentucky central area and Tennessee are highest in beryllium, tin, and lanthanum. The southern part of the region, Alabama, Georgia, and southern Tennessee, are highest in vanadium, cobalt, copper and molybdenum.

Floated fractions of 54 samples tend to contain more boron, titanium, vanadium, chromium, nickel, yttrium, and tin than whole coal samples from the same areas. This suite of elements, excepting tin, is relatively high in an organic-affinity series established in earlier work (Zubovic and others, 1961b, p. D346). Germanium, the highest element in the organic-affinity series, was not consistently high in the floated fractions; however, since these samples were initially low in germanium, this is to be expected.

Analyses of vitrain do not show generally higher concentrations of minor elements than the less pure blocks of coal from which the vitrain was separated.

Analyses of fusain show, in general, lower concentrations of vanadium, gallium, yttrium, boron, beryllium, and nickel than the coal blocks from which they were separated. These elements are relatively high in the organic-affinity series, and their presence in lower concentrations in the fusains is expectable.

Most of the elements high in the organic-affinity series are more highly concentrated in kettle-bottom coal than in a less pure block of coal collected just beneath it. Boron is an exception.

Coals of the Apalachian region appear to contain less zinc, boron, and tin than coals of the Northern Great Plains or Eastern Interior region. No other significant differences were found in comparing the coals of these three regions.

REFERENCES

Adams, G. I., Butts, Charles, Stephenson, L. W., and Cooke, Wythe, 1926, Geology of Alabama: Alabama Geol. Survey Spec. Rept. 14, 312 p.

Averitt, Paul, 1942, Coal fields of the United States, U.S. Geol. Survey map, scale 1:2,500,000.

——— 1961, Coal reserves of the United States—A progress report, January 1, 1960: U.S. Geol. Survey Bull. 1136, 116 p.

Dieke, G. H., and Crosswhite, H. M., 1943, The use of iron lines as intensity standards: Optical Soc. America Jour., v. 33, p. 425–434.

Glenn, L. C., 1925, The northern Tennessee coal field: Tennessee State Geol. Survey Bull. 33–B, 478 p.

Headlee, A. J. W., and Hunter, R. G., 1955, Characteristics of minable coals of West Virginia, pt. 5, The inorganic elements in the coals: West Virginia Geol. Survey Bull., v. 13A, p. 1–131.

Horton, L., and Aubrey, K. V., 1950, Distribution of minor elements in three vitrains from the Barnsley seam: Soc. Chem. Industry Jour. [London], v. 69, supp. no. 1, p. s41–s48.

McCalley, Henry, 1900, Report on the Warrior Coal basin: Alabama Geol. Survey Spec. Rept. 10, 327 p.

McCallie, S. W., 1904, A preliminary report on the coal deposits of Georgia: Georgia Geol. Survey Bull. 12, 121 p.

McFarlan, A. C., 1943, Geology of Kentucky: Lexington, Ky., University of Kentucky, 531 p.

Shotts, R. Q., 1954, The identity and equivalency of persistent coal zones, sandstone beds and conglomerates of southern Tennessee and the plateau region of Alabama, based upon a study of the literature: Alabama Acad. Sci. Jour., v. 26, p. 37–46.

Stadnichenko, Taisia, Murata, K. J., Zubovic, Peter, and Hufschmidt, E. L., 1953, Concentration of germanium in the ash of American coals, a progress report: U.S. Geol. Survey Circ. 272, 34 p.

Wanless, H. R., 1946, Pennsylvanian geology of a part of the southern Appalachian coal field: Geol. Soc. America Mem. 13, 162 p.

Zubovic, Peter, Stadnichenko, Taisia, and Sheffey, N. B., 1960, Comparative abundance of the minor elements in coals from different parts of the United States, *in* Short papers in the geological sciences, U.S. Geol. Survey Prof. Paper 400–B: p. B87–B88.

——— 1961a, Geochemistry of minor elements in coals of the Northern Great Plains coal province: U.S. Geol. Survey Bull. 1117–A, 58 p.

——— 1961b, Chemical basis of minor-element associations in coal and other carbonaceous sediments, *in* Short papers in the geologic and hydrologic sciences, U.S. Geol. Survey Prof. Paper 424–D: p. D345–D348.

○