Distribution of Minor Elements in Coal Beds of the Eastern Interior Region

GEOLOGICAL SURVEY BULLETIN 1117-B

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

MINOR ELEMENTS IN AMERICAN COALS

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A study of 15 minor elements in coal beds of Illinois, Indiana, and western Kentucky

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DISTRIBUTION OF MINOR ELEMENTS IN COAL BEDS OF THE EASTERN INTERIOR REGION

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

ABSTRACT

Columnar samples of coal were collected from 12 coal beds at 53 localities in Illinois, Indiana, and Kentucky. The ash of 475 block samples of these coal beds was analyzed spectrochemically for 16 minor elements. The average minor-element content of 47 coal-bed columns considered to be representative of the region is listed below.

Element	Average amount in ash (percent)	Average amount in coal (parts per million)	Element	Average amount in ash (percent)	Average amount in coal (parts per million)
Beryllium	0. 0056	2. 5	Lanthanum	0. 0087	5. 1
Boron	. 22	96	Molybdenum	. 0087	4. 3
Cadmium	<. 005	---------	Nickel	. 032	15
Chromium	. 035	20	Tin	. 0027	1. 5
Cobalt	. 0069	3. 8	Titanium	. 85	450
Copper	. 02	11	Vanadium	. 054	35
Gallium	. 0081	4. 1	Yttrium	. 015	7. 7
Germanium	. 025	13	Zinc	. 059	44

A study of special types of coal showed that germanium tends to be concentrated in vitrain but not in kettle-bottom coal samples, several of which contain titanium as a major element. When the distribution of the elements is plotted in vertical profiles, the patterns for different elements in the same beds are similar for several localities in Kentucky and southern Illinois. The areal distribution patterns vary for each element studied, and no distribution pattern is consistent enough to contour. Coal beds from this region contain nearly twice as much germanium, molybdenum, chromium, vanadium, and nickel as beds from the northern Great Plains province. Germanium is about 10 times more abundant in the coal beds studied than in common igneous rocks.

We believe that the accumulation of these elements was, for the most part, syngenetic with the deposition of the coal. The enriched amounts of some of the elements frequently found at the top of some beds may be due to postburial accumulation.

INTRODUCTION

PURPOSE AND SCOPE

This report is one of a series intended to document a study of minor elements in American coals. This study began as a search for coal that might be used as a source for germanium and, possibly, other rare or valuable elements. A study of the geochemistry of minor elements in coal was a secondary consideration. Coal beds from all the major coal-producing areas of the conterminous United States were sampled and analyzed. Sixteen elements were looked for in the samples of 12 different coal beds discussed here; they are beryllium, boron, titanium, vanadium, chromium, cobalt, nickel, copper, zinc, gallium, germanium, molybdenum, tin, yttrium, lanthanum, and cadmium. The last element was not found in any of the samples. The history of the project is outlined in a previous report (Zubovic and others, 1961a, p. A3–A5).

LOCATION AND FIELDWORK

The Eastern Interior coal region (Averitt, 1942) encompasses a large part of Illinois, the southwestern part of Indiana, and a part of western Kentucky. Most of the samples were collected by Zubovic and Stadnichenko in 1952 and 1953. Jack Simon, chief of the Coal Section of the Illinois Geological Survey, supplied samples from two beds at locality 28, and the Black Star Coal Corp. supplied samples from localities 45 and 48 in Kentucky.

ACKNOWLEDGMENTS

We are indebted to many individuals, especially the mine operators and miners who gave generously of their time and use of their equipment to make the sampling program possible. We also wish to thank the members of the State Geological Surveys of Illinois, Indiana, and Kentucky for their cooperation. We especially wish to thank the members of the Illinois Geological Survey who accompanied us in the field and supplied samples from two beds.

James H. Townsend and Howard Cohen assisted in the preparation of samples. Elizabeth L. Hufschmidt and Harry J. Rose, Jr., are among those in the U.S. Geological Survey spectrographic laboratory who helped make some of the analyses of coal ash. We wish to thank Sarah M. Berthold for help given in the calculation of the data and Dorothy Dudley for the maintenance of an orderly card file of the data.

GEOLOGIC SETTING AND SAMPLE LOCATION

The Eastern Interior coal region is underlain by Paleozoic sedimentary rocks ranging from Cambrian through Pennsylvanian age. These rocks are overlain in extreme western Kentucky and the southern tip of Illinois by Cretaceous and Tertiary strata, but these younger rocks are not present within the area of the coal region. The northern part of the region is mantled with Pleistocene glacial drift. Coal beds occur in the strata of Pennsylvanian age, and the outline of the Eastern Interior coal region is defined by the base of the Pennsylvanian strata. As shown on the tectonic map of the United States (Cohee and others, 1962), the base of the Pennsylvanian strata also coincides generally with the outline of the Illinois basin, a broad structural depression, which has its center in southern Illinois. This depression is nearly surrounded by a series of structural highs, including the Kankakee arch, the Cincinnati arch, the Nashville dome, the Pascola arch, the Ozark uplift, and the Mississippi River arch. The Illinois basin is interrupted on its northeast flank by the north-northwest-trending La Salle anticlinal belt and on the south side by the west-trending Rough Creek fault zone and a series of smaller faults. Figure 1 shows these major features and also the localities from which samples were collected.

The Pennsylvanian strata and their contained coal beds have been the subjects of many detailed reports, but only the coal-bed correlations pertinent to this report are summarized here. Further stratigraphic details are available in McFarlan (1946) for Kentucky, Spencer (1953) for Indiana, and Cady (1952) for Illinois. Wanless (1955) described the Pennsylvanian rocks of the Eastern Interior region in considerable detail and compiled a convenient summary of the stratigraphy (Wanless, 1956).

In general, sandstone, shale, limestone, underclay, and coal of nonmarine origin are interstratified with marine limestone, black shale, and gray shale throughout the Pennsylvanian strata, which attain a maximum thickness of about 2,500 feet in southern Illinois. The cyclic nature of the strata in Illinois was recognized as early as 1930 by Weller (1930), and the cyclothem has become the basic unit of stratigraphy in this area (Wanless and Weller, 1932). According to Wanless (1956, p. 8), as many as 39 cyclothems have been identified in some parts of Illinois. However, because this report is concerned only with the coal beds and their correlation from one part of the area to another, the complicated formal stratigraphic nomenclature is not discussed. Table 1 lists the coal beds that were sampled and shows their proper stratigraphic position, as indicated by Siever (*in* Wanless, 1956, pl. 1).

The Herrin (No. 6) and the Harrisburg (No. 5) coal beds of Illinois and their correlatives in Indiana and Kentucky are the most important commercial beds in the region and have the largest number of operating mines. Because our sampling was dependent upon accessibility of

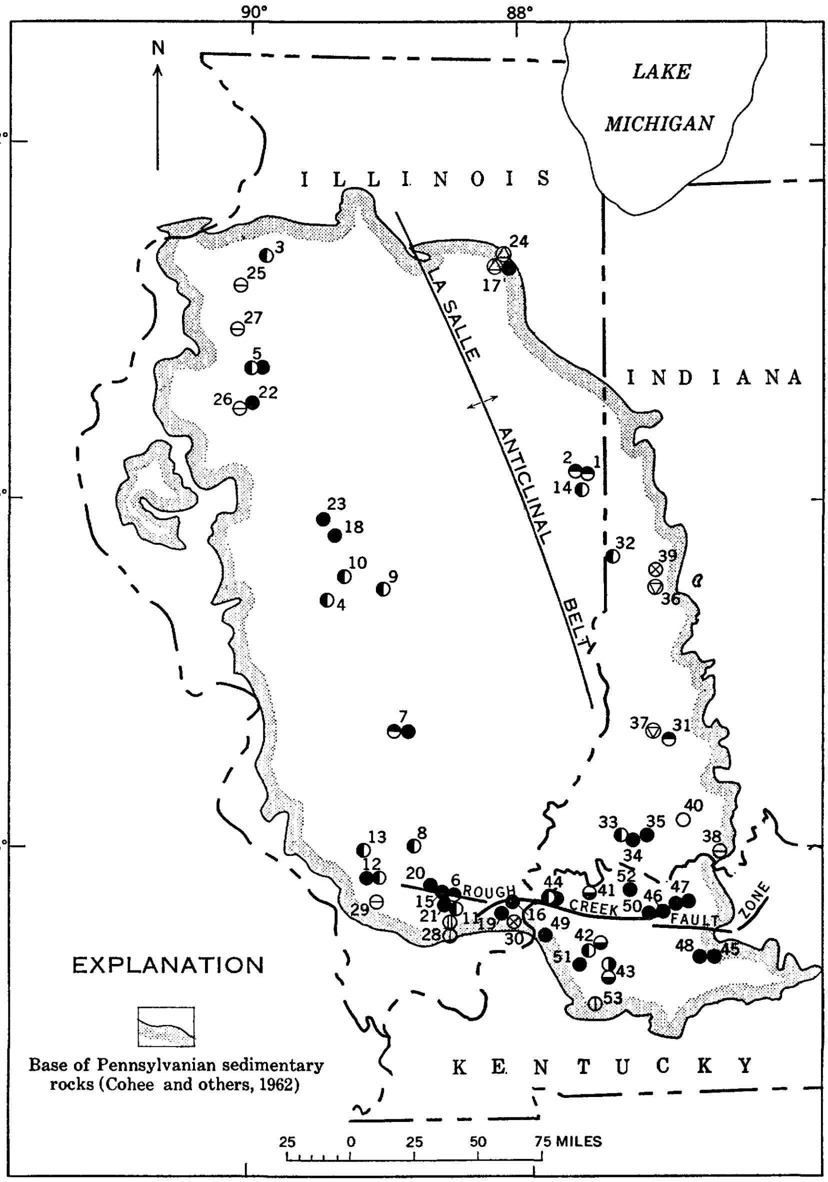

FIGURE 1.—Map of Eastern Interior coal region showing location of coal samples. Coal bed and locality symbol are as follows (see also table 2):

Illinois	*Indiana*	*Kentucky*	*Map symbol*
No. 7	No. VII	----------	◓
----------	----------	No. 14	◒
----------	----------	No. 12	◑
Herrin (No. 6)	No. VI	No. 11	◐
Harrisburg (No. 5)	No. V	No. 9	●
No. 2	----------	----------	△⃝
----------	No. III	----------	▽⃝
DeKoven	----------	----------	⦷
Davis	----------	Davis (No. 6)	⦶
Murphysboro (No. 1)	Minshall	----------	⊖
Willis	Lower Block	----------	⊗
----------	Unnamed	----------	○

TABLE 1.—*Coal beds and samples collected, by states*

[Correlations according to Siever (in Wanless, 1956, pl. 1)]

Illinois		Indiana		Kentucky		Total
Coal bed	Samples	Coal bed	Samples	Coal bed	Samples	
No. 7	2	No. VII	1			3
				No. 14	2	2
				No. 12	1	1
Herrin (No. 6)	12	No. VI(?)[1]	2	No. 11	3	17
Harrisburg (No. 5)[2]	12	No. V	2	No. 9	10	24
No. 2[3]	2					2
		No. III	2			2
DeKoven	1					1
Davis	1			Davis (No. 6)	1	2
Murphysboro (No. 1)	4	Minshall	1			5
Willis	1	Lower Block	1			2
		Unnamed	1			1
Total	35		10		17	62

[1] Also called No. Vb coal.
[2] Also called Springfield (No. 5) coal, and No. 5 coal.
[3] Also called LaSalle (No. 2) coal, and Colchester (No. 2) coal.

operating mines, almost twice as many samples were collected from these two beds as from all the others combined.

Table 2 gives the sample localities and the manner in which each locality was sampled.

TABLE 2.—*Location and description of the coal samples*

[Mines underground, unless indicated as a strip mine]

Locality (fig. 1)	Coal column	County	Mine and location	Coal bed No. or name	Thickness (feet)	Coal block samples	Percentage of bed analyzed
			Illinois				
1	Ill-D-7	Vermilion	Two Rivers Coal Co., strip mine near Danville, NE¼ NE¼ sec. 17, T. 19 N., R. 11 W.	7	5.49	23	94.2
2	Ill-Ha-7	do	Fairview Collieries Corp., Harmattan strip mine, NE¼ SW¼ sec. 3, T. 19 N., R. 12 W.	7	5.54	23	100
3	Ill-A-6	Henry	Midland Electric Coal Corp., Mecca No. 1 strip mine, near Atkinson.	6	4.62	18	100
4	Ill-C-6	Montgomery	Freeman Coal Mining Corp., Crown mine, 1 mile northeast of Farmersville.	6	7.06	17	100
5A	Ill-F-6	Fulton and Knox.	Midland Electric Coal Corp., Middle Grove No. 2 strip mine, Farmington.	6	4.13	19	90.6
5B	Ill-R-5	do	Midland Electric Coal Corp., Middle Grove No. 3 strip mine, near Rapatee.	5	2.85	13	100
6	Ill-M-6	Saline	Peabody Coal Co., Majestic No. 14 mine, near Duquoin.	6	8.42	27	12.6
7A	Ill-Ma-6	Marion	Marion County Coal Mining Corp., Inc., Glenridge mine, Centralia.	6	6.53	19	11.2
7B	Ill-Ma-5	do	Marion County Coal Mining Corp., Glenridge strip mine, Centralia.	5		1	
8	Ill-OB-6	Franklin	Old Ben Coal Corp., Old Ben No. 22 mine, Valier.	6	7.90	19	100

See footnote at end of table.

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TABLE 2.—*Location and description of the coal samples*—Continued

Locality (fig. 1)	Coal column	County	Mine and location	Coal bed No. or name	Thickness (feet)	Coal block samples	Percentage of bed analyzed
			Illinois—Continued				
9	Ill-Pa-6	Christian	Peabody Coal Co., No. 17 mine, Pana.	6	7.44	25	30
10	Ill-Pw-6	do	Peabody Coal Co., Pawnee No. 10 mine, Pawnee.	6	8.04	21	83.1
11	Ill-S-6	Saline	Sahara Coal Co., No. 6 mine, 11 miles west of Harrisburg.	6	4.29	19	12.1
12A	Ill-TrB-6	Jackson	Truax Traer Coal Co., Burning Star mine, near Elkville.	6	7.03	26	100
12B	Ill-TrB-5	do	do	5	3.04	21	25
13	Ill-TrP-6	Perry	Truax Traer Coal Co., Pyramid strip mine, near Pinkneyville.	6	5.68	20	4.5
14	Ill-V-6	Vermilion	V-Day Coal Co., V-Day miue, near Danville, sec. 30, T. 19 N., R. 11 W.	6	5.58	23	29.6
15	Ill-BB-5	Saline	Blue Bird Coal Co., Blue Bird mine, 15 miles west of Harrisburg.	5	3.94	13	24.1
16	Ill-B&W-5	Gallatin	B. and W. Coal Co., ½ mile west of Junction.	5	5.14	14	32.5
17A	Ill-E-5	Will	Northern Illinois Coal Corp., Essex strip mine, sec. 5, T. 31 N., R. 9 E.	5	3.45	15	100
17B	Ill-E-2	do	Northern Illinois Coal Corp., Essex strip mine, near Braidwood, sec. 5, T. 31 N., R. 9 E.	2	2.60	11	100
18	Ill-F-5	Sangamon	Farrand Coal Co., near Riverton, sec. 12, T. 16 N., R. 4 W.	5	4.99	16	100
19	Ill-G-5	Gallatin	Oak Hill Coal Co. mine, near Gibsonia, sec. 24, T. 10 S., R. 8 E., 3d principal meridian.	5	5.10	13	94.7
20	Ill-H-5	Saline	Peabody Coal Co., No. 43 mine, Harco.	5	4.93	15	100
21	Ill-S-5	do	Sahara Coal Co., No. 7 mine, 13 miles west of Harrisburg.	5	6.68	20	25.3
22	Ill-Tr-5	Fulton	Truax Traer Coal Co., Red Ember strip mine, near Fiatt.	5	4.15	21	57.1
23	Ill-W-5	Sangamon	Wenneborg Coal Co. mine, near Sherman.	5	5.86	16	100
24	Ill-B-2	Will and Grundy.	Wilmington Coal Mining Corp., Braidwood strip mine, sec. 29, T. 32 N., R. 9 E.	2	2.95	16	100
25	Ill-A-1	Henry	Bugos-White Coal Co., Alpha mine, Alpha.	1	4.92	14	94.3
26	Ill-P-1	Fulton	Putt Creek Coal Co. mine, 2 miles north of Cuba.	1	3.32	12	100
27	Ill-T-1	Knox	Knoxville Mining Co., Thermal No. 1 mine, Knoxville.	1	4.63	14	94.6
28A	Ill-S-DeK	Saline	Saxton Coal Corp., Saxton No. 2 strip mine, near Carrier Mills NE¼ sec. 20, T. 10 S., R. 5 E.	DeKoven.	3.13	13	62.3
28B	Ill-S-Da	do	do	Davis	3.18	17	96.5
29	Ill-P-Mu	Jackson	Phillips Coal Co., Phillips mine, near Carbondale.	Murphysboro(?).	7.70	25	100
30	Ill-PH-LW	Gallatin	Blue Blaze Coal Co., Blue Blaze mine, near Pounds Hollow Lake.	Willis	3.42	13	100
			Indiana				
31	Ind-L-VII	Pike	Landrey Mining Co., Inc., Landrey No. 1 strip mine, 6 miles northwest of Winslow.	VII	2.75	15	100
32	Ind-S-VI	Vermilion	Ayreshire Collieries Corp., Sunspot strip mine, 5 miles southwest of Clinton.	VI	7.09	22	80.1
33	Ind-D-VI	Warrick	Ingle Coal Corp., Ditney Hill mine, 2 miles south of Elberfeld.	VI	8.32	18	58.1
34	Ind-P-V	do	Shaw Mining Co., 2½ miles north of Boonville, SW¼NW¼ sec. 14, T. 5 S., R. 8 W.	V	7.98	17	26.9

See footnote at end of table.

TABLE 2.—*Location and description of the coal samples*—Continued

Locality (fig. 1)	Coal column	County	Mine and location	Coal bed No. or name	Thickness (feet)	Coal block samples	Percentage of bed analyzed
			Indiana—Continued				
35	Ind-S-V	Warwick	Sunlight Coal Co., Sunlight No. 11 strip mine, Boonville, NW¼SE¼ sec. 15, T. 5 S., R. 8 W.	V	7.51	29	92.7
36	Ind-C-III	Clay	Ayreshire Collieries Corp., Chinook mine, 2 miles south of Staunton, sec. 28, T. 12 N., R. 7 W.	III	6.67	21	20.5
37	Ind-H-III	Daviess	Hicks Coal Co., Hicks mine, 4.3 miles south of Cannelsburg, NE¼ sec. 17, T. 2 N., R. 5 E.	III	2.73	10	100
38	Ind-M-M	Spencer	Mulzer Brothers Coal Co. strip mine, 1½ miles northeast of Buffaloville, NW¼ sec. 4, T. 5 S., R. 5 W.	Minshall	3.30	12	100
39	Ind-Hi-LB	Clay	G. and F. Coal Corp., Old Hickory No. 1 strip mine, 3 miles west of Carbon.	Lower Block.	3.54	13	50
40	Ind-Ge	Spencer	Coal in road cut along Rte. 45, 1½ miles south of Gentryville.	Unnamed.	.75	3	100
			Kentucky				
41	Ky-Co-14	Henderson	Community Coal Co. mine, Smith Mills.	14	6.09	14	100
42A	Ky-H-14	Webster	Hart and Hart Coal Co., Precision strip mine, Providence.	14	6.34	22	42.4
42B	Ky-H-11	do	do	11	3.67	14	32.7
43A	Ky-Ho-12	Hopkins	Homestead Coal Co., Homestead strip mine, Earlington.	12	4.24	17	21.7
43B	Ky-Ho-11	do	do	11	7.20	4	14.7
44A	Ky-U-11	Union	Uniontown Coal Co., Uniontown mine, Uniontown.	11	4.59	14	91.9
44B	Ky-U-9	do	do	9	4.31	11	44.1
45	Ky-BD-9	Ohio	Black Star Coal Corp., Ken strip mine, Bixby.	9	------	[1] 1	------
46	Ky-F-9	Daviess	Fowler Coal Co., Lick Branch mine, 16 miles SSW. of Owensboro.	9	3.62	11	47.2
47A	Ky-G_1-9	do	Green Coal Co., Panther strip mine, near Panther.	9	3.49	15	58.5
47B	Ky-G_2-9	do	do	9	3.77	14	36.9
48	Ky-OH-9	Ohio	Black Star Coal Corp., Kentucky Winner strip mine, Winner.	9	------	[1] 1	------
49	Ky-PR-9	Union	Poplar Ridge Coal Co., Poplar Ridge mine, 2 miles southeast of Sturgis.	9	3.98	13	100
50	Ky-Sch-9	Daviess	Schaber Coal Co. mine, 2 miles northeast of West Louisville.	9	3.15	11	34.6
51	Ky-SP-9	Hopkins	Stony Point Coal Co., Stony Point mine, near Providence.	9	6.01	13	100
52	Ky-Wi-9	Henderson	Wilson Risley Coal Co. mine, Hebbardsville (near Zion).	9	3.62	7	100
53	Ky-D-6	Hopkins	Dawson Daylight Coal Co., Daylight No. 6 mine, Dawson Springs.	6	4.67	13	100

[1] Channel sample; thickness not known.

SAMPLE PREPARATION AND ANALYSIS

Most of the coal beds were sampled by cutting out a column of coal from the bed in a manner similar to that described by Stadnichenko and others (1953, p. 2–4) and by Zubovic and others (1961a, p. A13–A18). Each column was then split parallel with the bedding to form blocks of convenient size that were numbered consecutively, beginning with 1 at the top of the bed. Thereafter, each block was treated as a separate sample, although some were later combined to make composite samples. Most of the blocks ranged from about 0.1 to 0.5 foot thick.

In the laboratory, a split of each block sample was ground to pass through a 100–mesh sieve, and 10 g of this ground sample was placed in a cold muffle furnace. The temperature was gradually raised to 450° C and held there until all the organic matter was oxidized. Because the primary objective was to investigate germanium, a rapid spectrophotometric method was used to determine the approximate amount of germanium in the ash of each sample. The approximate amount of molybdenum was also estimated by the thiocyanate method. Individual block samples that contained relatively large amounts of germanium and molybdenum were then analyzed spectrographically for 16 minor elements. Block samples that contained relatively small amounts of germanium and molybdenum, however, were generally combined to form composite samples before further spectrographic analysis. Only block samples in sequence that had a fairly uniform ash content were combined to make composite samples, and the essential lithologic characteristics of the beds were thus preserved. During the early part of the work, each block sample was analyzed individually for some of the coal beds, but later it became necessary to limit the number of samples analyzed by making composite samples. The 475 analyses of ash represent 669 blocks of coal.

Most of the composite samples were cleaned and beneficiated by flotation to remove extraneous mineral matter and produce a sample with less ash. This procedure was employed in order to make easier the detection of small quantities of those minor elements that are organically combined. The minor elements that are organically bonded would be found in larger concentrations in the smaller amount of ash from the treated coal, but, on a parts-per-million-in-coal basis, the amount in the floated coal and whole coal should be quite similar. The amounts of the elements inorganically bonded would be considerably less when calculated to a parts per million of the floated coal. For most of the elements, this procedure does not unduly prejudice the averages calculated on a parts-per-million-in-coal basis. Because more than half the coal mined in the United States is cleaned by some mechanical means (U.S. Bureau of Mines, 1959, p. 71), these beneficiated samples are comparable to commercially available coals. Table 3 lists the block samples that were floated and the percentage of the original block that floated. Although no analyses were made of the corresponding fractions that sank, a separate study was made of light and heavy coal fractions of selected blocks (Zubovic and others, 1961b).

TABLE 3.—*List of beneficiated block samples and composites*

Locality (fig. 1)	Coal column	Coal block sample	Specific gravity of floating medium	Ash (percent)	Float fraction (percent)	Remarks
1	Ill-D-7	3-5	1.32	2.08	91.26	
		9-13	1.36	5.45	52.39	
		15-17	1.34	4.55	54.20	
		18-21	1.32	2.36	81.98	
		23	1.32	2.49	60.57	
2	Ill-Ha-7	8-11	1.32	4.04	59.74	
		12-17	1.36	5.55	58.06	
		18-22	1.32	3.19	62.83	
3	Ill-A-6	5	1.32	3.42	67.03	
		8	1.36	7.32	69.11	
		10b, 11	1.34	3.80	57.66	
		14	1.32	2.50	62.63	
4	Ill-C-6	6-10	1.32	2.23	40.48	
		11, 13	1.34	6.00	66.51	Composite (2 blocks; block 12 not included).
5A	Ill-F-6	5-7	1.30	2.16	50.62	
		11	1.32	3.06	------	
		13-15	1.32	4.58	69.55	
5B	Ill-R-5	1	1.32	4.03	34.55	
		3	1.32	4.07	31.03	
		5-9	1.36	8.36	60.70	
		11	1.36	7.37	34.76	
8	Ill-OB-6	3-10	1.32	2.32	80.24	
		11-16	1.34	4.09	55.95	
		17, 18	1.32	2.92	63.86	
10	Ill-Pw-6	1	1.32	3.33	72.70	
		8-13	1.34	4.58	45.56	
		15, 16	1.32	2.92	50.28	
		17, 18	1.34	4.16	63.11	
12A	Ill-TrB-6	2-6	1.32	2.92	81.86	
		7-12	1.32	2.92	63.20	
		13-17	1.32	3.10	47.94	
		18-23	1.32	4.52	49.16	Composite (5 blocks; block 20 not included).
17A	Ill-E-5	9	1.32	3.19	72.99	
		13	1.32	4.33	43.14	
18	Ill-F-5	2-3b	1.32	2.92	41.33	
		5-6b	1.32	3.17	66.71	
		8-11	1.32	5.00	54.60	
		12	1.36	8.08	66.85	
19	Ill-G-5	2, 3	1.30	1.70	50.40	
		7-10	1.32	2.85	52.32	
		12	1.34	3.14	46.95	
20	Ill-H-5	2, 3	1.32	2.41	40.44	
		4-9	1.30	1.68	61.51	
		10-13	1.32	3.10	60.34	
23	Ill-W-5	2	1.32	3.65	43.84	
		6, 7	1.34	2.30	76.14	
		11	1.32	2.15	56.07	
		14, 15	1.32	4.99	58.93	
24	Ill-B-2	14	1.36	4.69	55.58	
25	Ill-A-1	1	1.32	3.84	41.44	
		4-6	1.32	3.00	55.71	
		8-9	1.32	2.98	53.12	
		10, 11	1.36	10.15	53.12	
26	Ill-P-1	1	1.32	4.75	60.04	
27	Ill-T-1	2-4	1.34	4.21	69.71	
		5b	1.36	5.90	54.81	
		10	1.36	4.03	63.13	
28A	Ill-S-DeK	4	1.32	2.89	43.41	
		8-10	1.40	6.73	31.58	
		11, 12	1.32	3.50	52.65	
28B	Ill-S-Da	2	1.36	4.60	18.39	
		5-8	1.32	3.41	72.62	
		9-15	1.32	3.07	51.99	
29	Ill-P-Mu	1-5	1.32	3.85	62.45	
		6-10	1.34	3.94	52.51	
		11-13	1.32	3.00	72.45	
		15-21	1.32	4.20	44.09	
		22-25	1.36	5.54	25.49	
31	Ind-L-VII	5	1.30	.86	54.73	
32	Ind-S-VI	14, 16	1.32	2.41	75.35	
		17-19	1.32	3.25	46.52	

TABLE 3.—*List of beneficiated block samples and composites*—Continued

Locality (fig. 1)	Coal column	Coal block sample	Specific gravity of floating medium	Ash (percent)	Float fraction (percent)	Remarks
35	Ind-S-V	1	1.32	3.40	42.50	
		4-6	1.32	2.89	60.19	
		8-12	1.32	2.75	77.71	Composite (4 blocks; block 10 not included).
		14-21	1.32	3.45	64.83	Composite (7 blocks; block 15 not included).
		24-29	1.40	7.37	30.49	
37	Ind-H-III	3	1.34	2.76		
		8	1.32	2.68	66.57	
38	Ind-M-M	4	1.30	1.73		
		5-8	1.32	1.87		
		9	1.30	1.46	60.01	
40	Ind-Ge	1	1.36	5.48	55.04	
		3	1.36	5.82	58.54	
41	Ky-Co-14	2-5	1.32	2.25	64.80	
		6-8	1.32	2.00	31.88	
		9-13	1.32	3.45	56.37	
44A	Ky-U-11	8	1.32	3.54		
		9	1.32	4.05		
		10	1.32	2.72		
		11	1.32	2.49		
		12	1.32	3.42		
		13	1.32	2.74		
		14	1.32	3.72		
44B	Ky-U-9	2	1.32	2.64	42.58	
		11	1.28	1.57	9.23	
47B	Ky-G_2-9	2	1.32	3.87	41.87	
		3	1.32	3.55	57.20	
48	Ky-PR-9	1	1.30	2.98	53.54	
		3	1.30	2.10	45.51	
		9-12	1.30	2.10	34.79	
51	Ky-SP-9	4-6	1.32	3.07	84.73	
52	Ky-Wi-9	2	1.32	2.28	38.29	
		4	1.32	2.54	64.42	
53	Ky-D-6	1	1.32	2.47	68.84	

The ash of the coal block samples was then analyzed for 16 minor elements by the quantitative spectrographic method described by Zubovic and others (1961a, p. A18–A20). In brief, this method involves the use of a microphotometer to measure the spectral line density as recorded on a photographic plate. The values are then compared with analytical curves constructed from synthetic standards. However, because of interference, many of the boron and copper analyses were determined by visual comparison with the standard plates. A comparison of the spectrochemical and chemical determinations for molybdenum and germanium indicate a probable error for the spectrochemical determinations of about ±30 percent. No check was made on the accuracy for the other elements, although the overall coefficient of variations for the mean of duplicate spectral plates is ±15 percent with a range of about 10 to 20 percent. The lower limit of detection for each element is:

Element	*Limit of detection (percent)*	*Element*	*Limit of detection (percent)*
B	0.001	La	0.003
Be	.0001	Mo	.0005
Cd	.005	Ni	.0005
Co	.0005	Sn	.001
Cr	.0001	Ti	.005
Cu	.0001	V	.001
Ga	.0005	Y	.001
Ge	.001	Zn	.01

The results of the spectrochemical analyses are listed in table 4, which lists the analyses of 15 elements in the ash of 475 block or composite samples, 12 vitrain samples, and 3 kettle-bottom coal samples. Cadmium is not listed because it was not found in any of the samples. Whenever an element is below the limit of detection, it is reported as a zero. The list includes data for 62 coal columnar samples. All the block samples from 24 of the columns were analyzed, whereas only part of the block samples from the other 38 columns were analyzed. The thickness of each block sample or composite sample is listed, including those which were not analyzed. The percentage of each bed that was analyzed is listed in table 2.

TABLE 4.—*Spectrochemical analyses of 15 minor elements in the ash of coal samples from the Eastern Interior coal region*

[Figures indicate percent by weight; *, visual estimate; 0, below limit of detection; leaders indicate sample not analyzed; a, b, separates of a single block; v, vitrain; KB, kettle-bottom coal; pa, sample of shaly parting; B, bone coal]

Locality (fig. 1)	Coal column	Coal block sample	Thickness (feet)	Ash in coal (percent)	Be	B	Ti	V	Cr	Co	Ni	Cu	Zn	Ga	Ge	Mo	Sn	Y	La
1	Ill-D-7	1	0.34	3.46	0.01	0.9*	0.3	0.013	0.0088	0.0088	0.044	0.012	0.048	0.01	0.08	0.007	0	0.02	0
		2	.28	3.60	.02	.5*	.2	.01	.006	.003	.02	.005	0	.002	.02	.002	0	.01	0
		3-5 [1]	.65	2.08	.01	.9*	.7	.02	.03	.003	.02	.007*	0	.003	.02	.004	.005	.02	.007
		6	.20	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
		7	.41	3.92	.003	.9*	.32	.02	.028	.0034	.008	.02*	.02	.006	.005	.002	0	.01	0
		8	.43	5.92	.0004	.05*	.5	.02	.02	.002	.007	.006	0	.006	.003	0	0	.007	.005
		9-13 [1]	1.13	5.45	.006	.2*	1	.03	.02	.002	.01	.007*	0	.003	0	.001	0	.008	0
		14	.12	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
		15-17 [1]	.79	4.55	.008	.3*	2	.04	.04	.004	.02	.02*	0	.009	.004	.002	.005	.01	.007
		18-21 [1]	.76	2.36	.02	1*	.6	.05	.04	.01	.03	.007*	0	.01	.02	.003	0	.02	0
		22	.32	6.76	.004	.4*	.2	.02	.007	.01	.02	.006	0	.005	.01	.001	0	.02	0
		23 [1]	.06	2.49	.02	.9*	.8	.1	.1	.01	.05	.007*	0	.01	.03	.006	.006	.02	0
		21v	----	4.34	.005	.7*	.09	.04	.01	.01	.02	.02*	0	.01	.02	.002	0	.02	0
2	Ill-Ha-7	1-3	.74	2.28	.01	.4*	.66	.094	.044	.003	.014	.014	0	.007	.12	.018	0	.02	.01
		4	.50	3.34	.004	.5*	.4	.02	.13	.004	.11	.018	0	.006	.07	.004	0	.02	.006
		5-6	.42	2.91	.005	.5*	.7	.03	.03	.002	.007	.007*	0	.01	.04	.007	0	.01	.009
		7	.12	6.86	.0007	.5*	.2	.01	.01	.002	.05	.02	0	.004	.02	.004	0	.01	0
		8-11 [1]	.95	4.04	.005	.2*	.8	.01	.01	.001	.004	.004	0	.001	.008	.001	0	.007	0
		12-17 [1]	1.77	5.55	.004	.2*	1.2	.058	.04	.003	.011	.014	0	.006	.01	.002	0	.009	.009
		18-22 [1]	.77	3.19	.006	.4*	1.2	.082	.065	.018	.037	.026	0	.02	.062	.004	.006	.01	0
		23	.27	10.46	.0004	.4*	.2	.07	.05	.002	.017	.018	0	.006	.04	.0008	0	.01	0
3	Ill-A-6	1a	.22	37.76	.0002	.04*	.05	.003	.0004	0	.01	.01	.08	0	.004	.01	0	0	0
		1b	.19	9.64	.005	.13	.26	.013	.03	.0023	.022	.011	7.6	.005	.011	.02	0	.005	0
		2	.40	5.66	.004	.03*	.43	.020	.026	.0023	.017	.015	4.8	.008	.036	.02	0	.007	0
		3	.09	12.82	.001	.05*	.1	.004	.003	.003	.02	.01	.72	.001	.006	.02	0	0	0
		4	.45	9.70	.001	.09*	.4	.01	.03	.002	.02	.02*	.3	.003	.007	.01	0	.008	0
		5 [1]	.12	3.42	.007	.2*	2.2	.085	.055	.004	.022	.02	0	.011	.016	.02	.006	.01	0
		6	.25	3.54	.006	1.2*	.27	.030	.026	.004	.02	.01*	0	.01	.018	.02	0	.01	0
		7	.60	2.92	.006	1.2*	.20	.048	.037	.004	.02	.04*	0	.01	.026	.02	0	.01	0
		8 [1]	.10	7.32	.004	.05*	2.4	.19	.14	.004	.016	.05	0	.0074	.003	.014	.005	.01	.02
		9	.26	5.44	.004	.5*	.4	.06	.06	.02	.02	.008*	0	.008	.01	.01	0	.01	0
		10a	.23	3.88	.006	.6*	.48	.042	.046	.0044	.022	.014	0	.009	.026	.01	0	.008	0
		10b-11 [1]	.55	3.80	.006	.2*	2.0	.10	.09	.019	.039	.03	0	.0094	.021	.0094	.005	.008	0
		12	.28	8.10	.002	.09*	.4	.02	.02	.008	.03	.01	0	.01	.01	.006	0	0	0
		13	.14	4.96	.006	.5*	.24	.026	.04	.0038	.022	.01	0	.005	.029	.003	0	.005	0
		14 [1]	.21	2.50	.008	.2*	1.4	.060	.050	.0060	.043	.02	0	.012	.048	.0092	0	.007	0
		15	.34	5.12	.004	.5*	.38	.021	.034	.005	.02	.013	0	.01	.066	.004	0	.009	0
		16a	.19	11.66	.001	.1*	.34	.017	.029	.003	.02	.014	0	.003	.020	.003	.04	.007	0
		4v	----	3.34	.004	1.2*	.28	.023	.023	.002	.02	.02*	.048	.009	.023	.01	0	.009	0

--------	Ill-C-6	1	.46	9.58	.003	.26	.52	.092	.072	.009	.20	.036	.32	.007	.078	.08	0	.005	0
		2	.37	7.38	.002	.3	--------	.02	--------	.01	.01	--------	.02	--------	.007	.02	0	.002	0
		3	.38	5.48	.002	.5*	.27	.01	.021	.002	.008	.03*	0	.005	.004	.01	0	.007	0
		4	.25	4.30	.002	.5	--------	.009	--------	.01	.007	--------	0	--------	.004	.008	0	.005	0
		5	.40	5.08	.002	.4	--------	.06	--------	.002	.02	--------	.02	--------	.005	.02	0	.01	0
		6-10 [1]	1.78	2.23	.009	.2*	1.9	.098	.036	.0032	.012	.0092	0	.006	.019	.0050	0	.009	0
		11-13 [1]	1.62	6.00	.002	.3*	.6	.03	.02	.003	.007	.01*	0	.005	0	.002	0	.007	.009
		14	.68	7.30	.003	.4*	--------	.02	--------	.003	.009	--------	.04	--------	.004	.002	0	.008	0
		15	.30	7.74	.0005	.4	--------	.02	--------	.003	.01	--------	.03	--------	.009	.005	0	.008	0
		16	.32	9.00	.003	.4	--------	.02	--------	.003	.01	--------	.02	--------	.008	.004	0	.005	0
		17	.50	10.06	.003	.38	.80	.026	.018	.004	.024	.024	.38	.009	.046	.005	0	.01	0
5A	Ill-F-6	1	.10	5.10	.004	.09*	.6	.066	.05	.005	.12	.018	1.8	.004	.099	.032	0	.01	.01
		2	.24	4.92	.004	.4*	.6	.058	.04	.006	.15	.016	0	.009	.15	.024	0	.01	.01
		3	.15	5.90	.003	.1*	.5	.057	.04	.004	.10	.016	.38	.006	.07	.03	0	.01	.01
		4	.16	6.54	.002	.05*	.5	.028	.024	.001	.049	.02*	.03	.002	.027	.014	0	.009	.007
		5-7 [1]	.66	2.16	.0049	.5*	1.8	.080	.065	.003	.11	.02	0	.010	.059	.021	0	.01	.005
		8	.34	2.42	.01	.9*	.3	.064	.06	.007	.078	.037	.16	.02	.10	.02	.01	02	.009
		9	.32	1.76	.007	.5*	.7	.14	.10	.01	.084	.04	0	.01	.12	.01	.009	.02	0
		10	.23	10.40	.001	.05*	.28	.010	.031	.014	.038	.01*	0	.0055	.022	.002	0	.01	.03
		11 [1]	.13	3.08	.01	.2*	1.6	.33	.12	.008	.045	.03	0	.014	.026	.009	.004	.01	.009
		12	.07																
		13-15 [1]	.86	4.58	.002	.05*	1.2	.072	.070	.006	.041	.03	0	.0075	.031	.0050	0	.006	0
		16	.15	8.32	.001	.03*	.44	.039	.034	.015	.027	.04*	.03	.0008	.024	.003	0	.007	.007
		17	.20	2.96	.007	.2*	1.5	.052	.060	.008	.035	.02	.02	.014	.10	.0085	.004	.01	0
		17a	.20	6.40	.002	.5*	.75	.026	.028	.008	.021	.02	.02	.0062	.036	.004	0	.009	0
		18	.32																
		17v	--------	2.56	.004	.4*	.6	.08	.061	.02	.088	.05	.02	.01	.26	.009	.01	.01	0
		18v	--------	12.32	.001	.05*	.9	.06	.05	.01	.04	.02*	0	.004	.02	.002	0	.008	0
5B	Ill-R-5	1 [1]	.13	4.03	.008	.2*	1.7	.42	.15	.002	.030	.03	0	.0067	.031	.035	.007	.008	0
		2	.12	12.40	.002*	.005*	.6	.071	.04	.002	.004	.02*	0	.001	.005	.007	0	.004	0
		3 [1]	.40	4.07	.006	.05*	.78	.042	.050	.003	.01	.016	0	.0084	.073	.015	.01	.007	0
		4	.14	12.72	.0007*	.007*	.4	.009	.02	.002	.005	.02*	0	.002	.01	.003	0	.004	0
		5-9 [1]	1.11	8.36	.002	.05*	.34	.01	.016	.001	.005	.0058	0	.004	.017	.002	0	.005	0
		10	.13	16.06	.0007*	.005*	.3	.01	.01	.002	.009	.007*	.06	.002	.009	.001	0	.008	.007
		11 [1]	.34	7.37	.009	.05*	.7	.02	.02	.002	.006	.005	0	.002	.01	.001	.008	.006	0
		12	.27	12.04	.0005*	.05*	.3	.014	.02	.001	.005	.007*	0	.0008	.035	.002	0	.008	0
		13	.21	16.90	.0007*	.005*	.3	.02	.016	.002	.005	.02*	.69	.002	.028	.001	0	.008	0
6	Ill-M-6	1	.40	4.94	.0025	.05*	.4	.037	.02	.0045	.032	.02*	.04	0	.07	.0046	0	.01	.007
		2-8	1.54																
		9	.13	5.52	.002	.05*	.53	.035	.035	.001	.013	.05*	.04	0	.006	.0051	0	.01	.006
		10-22	4.53																
		23-26	1.29																
		27	.53	16.68	.001	.5*	.3	.02	.02	.008	.04	.01	.14	.004	.02	.004	0	.01	.006
		22v	--------	4.82	.002	.05*	.34	.09	.043	.01	.072	.08*	.05	.014	.01	.0034	.005	.02	.007
7A	Ill-Ma-6	1t [2]	.04	29.70	.0001	.05*	.1	.01	.007	0	.002	.005	0	0	.006	.005	0	.01	0
		1	.47	7.20	.0004	.4*	.3	.40	.20	.001	.034	.0072	.09	.004	.02	.04	0	.01	.004
		2-17	5.80																
		18	.22	12.64	.0007	.05*	.3	.03	.02	.005	.04	.02	.05	.004	.02	.01	0	.009	.01

See footnotes at end of table.

TABLE 4.—*Spectrochemical analyses of 15 minor elements in the ash of coal samples from the Eastern Interior coal region*—Continued

Locality (fig. 1)	Coal column	Coal block sample	Thickness (feet)	Ash in coal (percent)	Be	B	Ti	V	Cr	Co	Ni	Cu	Zn	Ga	Ge	Mo	Sn	Y	La
7B	Ill-Ma-5	1	0.2	6.10	0.002	0.048	0.22	2.1	1.0	0.004	0.17	0.003	0.02	0.002	0.049	0.12	0	0.008	0
8	Ill-OB-6	1	.10	6.18	.005	.3*	.40	.38	.082	.011	.12	.015	0	.008	.12	0	0	.01	.004
		2	.36	8.16	.004	.02*	.26	.024	.030	.0045	.040	.022	0	.004	.046	.002	0	.008	0
		3–10 [1]	4.07	2.32	.005	.4*	.88	.044	.042	.0065	.016	.02	0	.007	.003	.002	.003	.01	.03
		11–16 [1]	2.10	4.09	.003	.4*	1.4	.1	.051	.005	.044	.014	0	.007	0	.002	.005	.01	.03
		17–18 [1]	.96	2.97	.009	.4*	1.7	.13	.11	.018	.084	.03	0	.011	.008	.01	.006	.02	.01
		19	.31	9.74	.003	.2*	.24	.014	.019	.005	.041	.014	.17	.003	.015	.006	0	.006	.005
9	Ill-Pa-6	1t [2]	.24	7.02	.003	.39	.60	.082	.082	.002	.01	.050	0	.01	.074	.02	0	.02	0
		2t–3t [2]	.29																
		4t [2]	.33	7.76	.001	.05*	.2	.01	.02	.001	.004	.01	0	.005	.006	.005	0	.009	0
		1a	.42																
		1	.38	5.38	.002	.07*	.3	.02	.02	.002	.008	.008	0	.006	0	.01	0	.007	0
		2–6	1.81																
		7	.48	7.70	.0007	.5*	.4	.01	.01	.0009	.008	.12*	.02	.003	0	.003	0	.005	.007
		8–11	1.40																
		11a	.25	8.84	.002	.02*	.4	.03	.02	.002	.006	.02	0	.007	.005	.002	0	.008	.003
		12	.24	9.60	.002	.5*	.68	.034	.01	.001	.005	.12*	0	.004	.004	.001	0	.009	.01
		13–17	1.29																
		18	.13	12.34	.002	.18	.30	.026	.005	.0066	.019	.016	0	.016	.089	0	0	.02	0
		19	.18	17.72	.002	.080	.52	.058	.040	.0076	.022	.022	1.2	.006	.056	0	0	.007	0
10	Ill-Pw-6	1 [1]	.48	3.33	.005	.48	.56	.070	.088	.002	.028	.025	.05	.0076	.15	.053	0	.008	0
		2	.16	8.26	.0002	.05*	.3	.02	.03	.002	.009	.006	0	.005	.005	.03	0	.01	.01
		3	.46	6.80	.0002	.05*	.3	.02	.03	.002	.008	.01	0	.005	.003	.01	0	.008	.01
		3a–3b	.73																
		4	.40	3.62	.002	.2	.2	.02	.02	.003	.009	.006	0	.01	0	.009	0	.02	0
		5–6	.63																
		7	.54	8.26	.0002	.05*	.3	.02	.03	.002	.009	.01	0	.003	.002	.003	0	.008	.02
		8–13 [1]	2.54	4.58	.003	.3*	.9	.058	.044	.004	.014	.012	0	.006	0	.006	.004	.008	.008
		14	.22	7.48	.002	.05*	.4	.06	.04	.004	.02	.01	0	.007	.003	.006	0	.01	.02
		15–16 [1]	1.15	2.92	.006	.6*	1.0	.08	.03	.005	.03	.02*	0	.01	.03	.02	.005	.02	0
		17–18 [1]	.59	4.16	.005	.6	1.2	.052	.041	.0062	.066	.03	0	.006	.056	.028	.006	.03	.007
		19	.14	3.65	.01	.35	.60	.096	.048	.016	.15	.055	.05	.010	.24	.11	.10	.034	0
11	Ill-S-6	1–2	.45																
		3	.30	3.26	.003	.5*	.6	.04	.032	.01	.022	.05*	.09	.006	.006	.038	.005	.02	.009
		4–17	3.27																
		18	.22	13.84	.003	.002*	.6	.038	.032	.03	.046	.02	.54	.0037	.022	.0047	0	.01	.04
		19	.05																

12A	Ill-TrB-6	1	.30	5.92	.001	.5*	.88	.82	.49	.004	.47	.015	.06	.004	.049	.020	0	.008	0
		2-6 [1]	.98	2.92	.005	.3*	.4	.03	.02	.003	.01	.007*	0	.003	0	.03	0	.009	.01
		7-12 [1]	2.15	2.92	.004	.3*	1.0	.042	.03	.003	.01	.02*	0	.004	0	.01	0	.01	.03
		13-17 [1]	1.10	3.10	.004	.4*	2.0	.078	.06	.005	.023	.018	0	.007	0	.006	0	.02	.03
		18-23 [1]	1.68	4.52	.005	.1*	2.0	.2	.04	.005	.02	.02*	0	.005	0	.006	0	.02	.02
		24	.43	9.82	.004	.09*	.22	.026	.007	.005	.020	.011	.48	.001	.013	.004	0	.008	.01
		25	.24	17.74	.002	.045	.25	.020	.041	.005	.028	.02*	.03	.003	.024	.003	0	.04	.006
		26	.15	35.38	.0002	.04*	.1	.01	.004	.004	.02	.02*	.02	0	.02	.001	0	.007	.006
12B	Ill-TrB-5	1	.19	10.20	.002	.005*	.5	.02	.02	.002	.006	.007*	.04	.003	.01	.002	0	.01	0
		2-3	.42																
		4	.11	3.50	.003	.03*	.4	.02	.02	.03	.01	.02*	.06	.003	.004	.003	0	.02	0
		5-16	1.86																
		17	.12	11.80	.002	.05*	.4	.01	.01	.004	.007	.007*	.02	.002	.004	0	0	.009	.02
		18	.20	9.42	.004	.005*	.7	.02	.020	.011	.031	.02*	.03	.004	.076	.01	0	.01	.02
		19	.07	16.66	.0009	.05*	.4	.01	.01	.004	.01	.02*	.02	.004	.011	0	0	.008	.02
		20	.07	10.04	.002	.06*	.8	.10	.038	.008	.039	.02*	.02	.0084	.04	.001	0	.01	.04
13	Ill-TrP-6	1-18	5.33																
		19	.12	20.04	.002	.05*	.06	.004	.002	.004	.02	.002	.03	0	.007	0	0	0	0
		20	.13	19.80	.002	.05*	.15	.012	.015	.002	.025	.011	5.6	.001	.034	.001	0	.004	.01
14	Ill-V-6	1	.16	10.70	.002	.10	.4	.22	1.2	.002	.03	.0040	.08	.006	.046	.02	0	.008	.006
		2-15	3.55																
		16	.20	6.32	.002	.09*	.4	.03	.04	.16	.02	.02*	.02	.006	.01	.005	0	.009	.006
		17	.32	10.38	.002	.05*	.4	.02	.02	.003	.01	.02*	.02	.004	.01	.006	0	.006	0
		18	.11	7.60	.001	.05*	.5	.02	.02	.004	.01	.02	.02	.006	.02	.005	0	.007	0
		19	.30	4.66	.004	.09*	.5	.03	.04	.008	.02	.0092	0	.009	.026	.006	0	.01	.006
		20	.26	8.20	.0007	.12	.3	.02	.03	.003	.01	.0066	2.5	.008	.037	.009	0	.006	0
		21	.21	8.58	.001	.05*	.4	.02	.03	.004	.01	.02*	.08	.008	.02	.009	0	.007	0
		22	.38																
		22b	.09	4.36	.001	.5*	.4	.02	.04	.004	.02	.02*	.02	.008	.004	.05	.01	.007	.006
15	Ill-BB-5	1	.2	12.38	.004	.05*	.40	.064	.060	.0060	.068	.018	.03	.0092	.061	.005	0	.008	0
		2-11	3.09																
		12	.25	11.44	.001	.02*	.5	.01	.03	.007	.02	.03	.90	.003	.007	0	0	.01	.01
		13	.40	11.78	.001	.037	.3	.026	.02	.01	.043	.02*	.19	.003	.024	.002	0	.01	.02
		KB		4.32	.0036	.048	.6	4.2	.7	.02	.37	.2*	0	.004	.054	.01	.006	.073	0
16	Ill-B&W-5	1	.25	10.66	.001	.05*	.49	1.5	.20	.002	.042	.010	0	.003	.034	.056	0	0	.006
		2-9	2.60																
		10	.79	12.48	.001	.04*	.2	.006	.01	.002	.007	.006	0	.002	.005	.003	0	.004	0
		11-12	.87																
		13	.32	14.54	.002	.05*	.2	.004	.003	.002	.007	.002	0	.001	.008	.001	0	.005	.007
		14	.31	17.06	.001	.04*	.2	.009	.01	.002	.01	.012	0	.002	.009	.001	0	.004	.007
17A	Ill-E-5	1	.11	6.42	.003	.09*	.3	.068	.036	.001	.032	.01*	.36	.002	.050	.003	0	.01	0
		2	.18	2.64	.007	.5*	.2	.018	.02	.001	.02	.1*	.05	.013	.11	.005	.004	.02	0
		3	.15	3.12	.004	.2*	.44	.032	.026	.001	.016	.01*	.15	.003	.036	.002	0	.02	0
		4	.23	6.12	.004	.5*	.2	.009	.007	.002	.01	.02*	.02	.003	.027	0	0	.01	0
		5	.14	4.04	.005	.5*	.24	.02	.0098	.0052	.037	.02*	.02	.006	.046	0	0	.02	0
		6	.28	3.16	.007	.5*	.3	.016	.02	.001	.01	.02*	0	.005	.065	.001	0	.02	0

See footnotes at end of table.

TABLE 4.—*Spectrochemical analyses of 15 minor elements in the ash of coal samples from the Eastern Interior coal region*—Continued

Locality (fig. 1)	Coal column	Coal block sample	Thickness (feet)	Ash in coal (percent)	Be	B	Ti	V	Cr	Co	Ni	Cu	Zn	Ga	Ge	Mo	Sn	Y	La
17A	Ill-E-5	7	0.47	7.64	0.003	0.4*	0.3	0.02	0.02	0.002	0.017	0.02*	0.02	0.004	0.035	0.001	0	0.02	0
		8	.33	7.64	.002	.5*	.46	.016	.02	.002	.01	.03	.02	.004	.012	0	0	.01	.004
		9[1]	.21	3.19	.013	.2*	.90	.042	.037	.002	.012	.01	0	.014	.025	.001	.008	.031	0
		10	.23	8.06	.003	.2*	.3	.02	.02	.002	.01	.041	4.4	.004	.007	.001	0	.02	0
		11	.26	8.12	.003	.2*	.38	.02	.01	.002	.01	.022	2.6	.004	.006	0	0	.01	0
		12	.15	7.98	.005*	.02*	.7	.02	.02	.003	.01	.03*	.06	.006	.009	.001	0	.02	0
		13[1]	.38	4.33	.0090	.2*	1.4	.042	.032	.002	.025	.02	0	.015	.030	.001	.008	.021	0
		14	.15	9.06	.002*	.01*	.6	.03	.02	.002	.02	.03*	.04	.008	.025	.001	0	.02	0
		15	.18	8.50	.005*	.009*	.8	.08	.036	.02	.045	.03*	.05	.008	.034	.003	.008	.02	0
17B	Ill-E-2	1	.22	4.52	.0036	.5*	.2	.009	.02	.02	.11	.08*	0	.004	.084	.003	0	.01	0
		2	.33	11.08	.002	.05**	.2	.004	.003	.0078	.048	.02*	.02	.002	.024	0	0	.008	0
		3	.36	4.22	.008	.5*	.32	.02	.01	.013	.078	.02*	.02	.006	.045	.002	0	.02	0
		4	.14	10.30	.003	.05	.1	.006	.002	.01	.02	.02*	.02	.001	.004	.003	0	.008	0
		5	.19	6.08	.003	.5*	.47	.013	.01	.030	.086	.03*	.04	.002	.024	.001	0	.01	0
		6	.15	3.02	.0072	.5*	.2	.012	.02	.02	.090	.02*	0	.004	.052	.002	0	.01	0
		7	.21	3.78	.0036	.9*	.45	.046	.035	.041	.19	.04*	.03	.005	.064	.003	0	.02	0
		8	.25	3.68	.0036	.5*	.3	.016	.02	.03	.12	.05*	.06	.006	.070	.004	0	.02	0
		9	.22	3.56	.0072	.5*	.4	.02	.03	.04	.12	.08*	.24	.01	.062	.007	0	.02	0
		10	.35	3.66	.0072	.5*	.4	.02	.03	.02	.10	.1*	.12	.01	.11	.006	0	.02	0
		11	.18	4.22	.0072	.5*	.3	.12	.066	.03	.18	.08*	.42	.008	.13	.007	0	.01	0
18	Ill-F-5	1	.30	10.74	.0007*	.009	.6	.02	.013	.002	.008	.007*	0	.003	.013	.004	.005	.004	0
		1a	.14	17.76	.0007*	.005*	.5	.050	.03	.002	.0090	.007*	0	.001	.018	.006	0	.005	0
		2–3b[1]	.73	2.92	.001	.5*	2.0	.09	.065	.003	.019	.02	0	.011	.002	.0085	0	.01	.005
		4	.43	8.14	.002*	.02*	.5	.009	.02	.002	.005	.007*	.03	.001	.004	.004	0	.008	0
		5–6b[1]	1.43	3.17	.002	.5	1.2	.037	.041	.002	.009	.010	0	.0055	.008	.006	0	.008	0
		7	.55	7.76	.003	.05*	.5	.02	.02	.002	.004	.004	0	.002	.002	.002	0	.006	0
		8–11[1]	.94	5.00	.002	.5*	1.2	.032	.028	.003	.015	.012	0	.0065	.020	.003	0	.01	0
		12[1]	.22	8.08	.001	.2*	1.1	.024	.022	.003	.029	.02	0	.005	.016	.002	0	.008	0
		13	.25	14.08	.002*	.005*	.5	.048	.03	.005	.032	.007*	.2	.002	.014	.004	0	.02	0
19	Ill-G-5	1	.27																
		2–3[1]	.78	1.70	.006	.05*	1.8	.82	.058	.003	.014	.0092	.02	.013	.042	.047	0	.008	0
		4–6	1.06	4.34	.0005	.02*	.6	.02	.01	.002	.006	.005	.03	.002	0	.007	0	.006	0
		7–10[1]	2.14	2.85	.003	.02*	1.7	.043	.042	.002	.0082	.0085	.02	.0078	.006	.0045	.008	.008	.007
		11	.28	14.30	.0007	.05*	.3	.01	.02	.004	.008	.007*	.02	.002	.005	.001	0	.008	.01
		12[1]	.37	3.14	.005	.005*	1.5	.039	.031	.005	.032	.01	.02	.0078	.044	.002	.009	.01	.009
		13	.20	14.74	.0007	.05*	.42	.025	.026	.01	.042	.08*	.05	.001	.020	.002	0	.009	.007
20	Ill-H-5	1	.33	11.38	.002	.005*	.8	.025	.028	.0048	.024	.02*	.04	.005	.023	.002	0	.01	.007
		2–3[1]	.53	2.41	.002	.2*	1.2	.058	.052	.002	.0095	.02	.03	.01	.026	.002	0	.008	.01
		4–9[1]	2.02	1.68	.001	.2*	1.8	.06	.055	.002	.013	.02	.02	.012	.028	0	0	.008	.006

		10–13 [1]	1.82	3.10	.002	.2*	2.0	.055	.052	.007	.041	.013	0	.0070	.028	.002	0	.01	.01
		14	.16	7.72	.002	.05	.7	.022	.023	.002	.064	.02*	3.1	.0045	.034	0	0	.02	.02
		15	.07	8.70	.002	.05*	.55	.067	.036	.02	.08	.08*	.42	.002	.029	.001	0	.01	.02
21	Ill-S-5	1	.46	10.88	.002	.04*	.4	.04	.01	.005	.02	.02*	0	.004	.01	0	0	.005	.005
		2	.28	10.84	.0009	.05*	.5	.02	.03	.002	.006	.02*	0	0	.003	0	0	.01	.02
		3–10	2.77																
		11	.30	8.24	.0005	.04*	.4	.02	.03	.003	.008	.03*	0	.004	.004	0	0	.003	.006
		12	.35																
		13	.30	8.12	.001	.02*	.4	.02	.02	.002	.009	.02*	0	.004	.005	0	0	.005	.006
		14–19	1.87																
		20	.35	3.86	.0025	.066	5.4	.34	.074	.016	.22	.040	0	.0039	.028	.016	.023	.006	.005
22	Ill-Tr-5	1	.32																
		2	.15	4.98	.008	.005*	.6	.02	.02	.002	.01	.02*	.04	.002	.026	.005	0	.01	0
		3	.15	6.30	.002	.2*	.3	.02	.02	.002	.007	.02*	0	.003	.009	.004	0	.004	0
		4	.17	7.66	.002	.2*	.3	.02	.02	.002	.006	.02*	.01	.002	.01	.003	0	.004	0
		5	.17	5.62	.005	.005*	.6	.01	.02	.002	.006	.006*	.03	.002	.008	.003	0	.008	0
		6	.28	8.04	.002	.2*	.3	.02	.034	.003	.008	.02*	.02	.003	.022	.003	.01	.004	0
		7	.27	6.30	.003	.005*	.5	.021	.024	.003	.010	.007*	.25	.002	.021	.0036	0	.01	0
		8	.22	7.70	.002	.5*	.60	.021	.028	.003	.0088	.005	.03	.0052	.018	.003	0	.004	0
		9–10	.39																
		11	.21	10.44	.0005	.2*	.3	.01	.025	.002	.007	.01*	0	.003	.015	.002	0	.003	0
		12–13	.43																
		14	.20	7.22	.002	.005*	.7	.031	.028	.003	.009	.007*	.03	.0054	.032	0	0	.008	0
		15	.12	9.78	.003	.05*	.3	.004	.009	.0008	.003	.003	.01	.002	.009	0	0	.005	0
		16	.13																
		17	.20	8.12	.002	.5*	.3	.02	.02	.002	.008	.02*	0	.003	.01	0	0	.004	0
		18	.23	8.68	.002	.02*	.6	.02	.02	.002	.008	.02*	0	.002	.02	.01	0	.01	0
		19–21	.51																
23	Ill-W-5	1	.10	18.40	.0004	.046*	.44	.052	.05	.002	.0098	.02*	0	.004	.018	.009	0	.002	0
		2 [1]	.29	3.65	.006	.2*	2.0	.065	.048	.003	.016	.010	0	.0072	.048	.018	.005	.004	0
		3	.20	9.44	.002	.02*	.4	.01	.01	.001	.005	.02*	0	.002	.007	.004	0	.006	0
		4	.24	6.46	.002	.3*	.3	.028	.01	.002	.005	.05*	0	.003	.043	.007	0	.005	0
		5	.28	6.88	.002	.5*	.4	.01	.01	.002	.005	.02*	0	.002	.006	.004	0	.006	0
		6–7 [1]	.50	2.30	.01	.2*	1.2	.039	.038	.002	.011	.01	0	.0085	.032	.012	.009	.008	.007
		8	.23	4.28	.004	.5*	.4	.02	.02	.003	.006	.05*	0	.004	.01	.008	0	.01	0
		9	.26	3.94	.008	.09*	.4	.03	.02	.002	.005	.02*	0	.007	.02	.008	0	.01	0
		10	.25	5.68	.005	.04*	.3	.02	.01	.002	.004	.01*	0	.005	.01	.008	0	.01	0
		11 [1]	.40	2.15	.006	.5*	1.7	.048	.042	.002	.010	.01	0	.0085	.023	.016	.007	.009	0
		12	.75	7.90	.002	.5*	.4	.02	.02	.002	.006	.03*	0	.003	.02	.007	0	.006	0
		13	.39	9.40	.0009	.04*	.3	.01	.01	.001	.004	.02*	0	.002	.004	.001	0	.008	.004
		14–15 [1]	1.25	4.99	.003	.2*	.9	.048	.042	.002	.0095	.0095	.02	.0072	.021	.002	.01	.006	0
		16	.72	17.84	.0001	.05*	.2	.02	.009	.001	.008	.01	0	.003	.007	0	0	.008	0
24	Ill-B-2	1	.14	3.24	.01	.6*	.42	.060	.027	.020	.13	.02	0	.008	.15	0	0	.01	0
		2	.18	6.00	.009	.2*	.2	.006	.004	.01	.03	.04*	0	.003	.02	0	0	.008	0
		3	.08	6.80	.01	.1*	.24	.029	.0076	.007	.044	.02	0	.003	.028	0	0	.01	0
		4–5	.31	5.12	.008	.2*	.46	.012	.006	.0081	.058	.02	.02	.013	.038	.002	0	.03	0
		6	.17	3.76	.020	1.0*	.48	.024	.040	.0036	.036	.04*	0	.02	.048	0	0	.03	.006
		7	.12	5.26	.004	.5*	.55	.015	.037	.0034	.045	.021	.02	.0075	.033	0	0	.025	0

See footnotes at end of table.

TABLE 4.—*Spectrochemical analyses of 15 minor elements in the ash of coal samples from the Eastern Interior coal region*—Continued

Locality (fig. 1)	Coal column	Coal block sample	Thickness (feet)	Ash in coal (percent)	Be	B	Ti	V	Cr	Co	Ni	Cu	Zn	Ga	Ge	Mo	Sn	Y	La
24	Ill-B-2	8	0.23	05.34	0.01	0.2*	0.2	0.01	0.006	0.003	0.02	0.03*	0	0.004	0.02	0.001	0	0.006	0
		9	.22	6.36	.008	.4*	.2	.005	.008	.002	.01	.02*	0	.002	.02	0	0	.01	0
		10	.18	3.50	.009	.6*	.42	.03	.019	.003	.011	.026	0	.008	.084	0	0	.024	.003
		11	.25	3.42	.01	.9*	.40	.02	.019	.003	.013	.031	0	.004	.10	0	0	.03	0
		12	.28	5.30	.008	.3*	.2	.009	.006	.002	.009	.04	0	.007	.044	0	0	.02	0
		13	.26	5.66	.006	.2	.2	.02	.006	.002	.01	.058	0	.007	.064	0	0	.01	0
		14 [1]	.28	4.69	.009	.2*	1.2	.15	.050	.003	.020	.09	0	.012	.079	.009	.006	.03	0
		15	.14	11.74	.004	.06*	.1	.04	.006	.03	.03	.04	0	.002	.01	0	0	.006	0
		16	.11	13.50	.002	.06*	.2	.09	.009	.005	.04	.08	0	.003	.01	0	0	.006	0
25	Ill-A-1	1 [1]	.32	3.84	.002	.2*	.50	.09	.044	.002	.031	.01	0	.0042	.011	.090	0	.005	0
		2–3	.48	2.84	.002	.5*	.4	.02	.02	.003	.01	.008	0	.002	.006	.03	0	.01	.005
		4–6 [1]	1.33	3.00	.002	.3*	.52	.068	.034	.004	.010	.02	0	.0060	.009	.011	0	.01	.008
		7	.48	8.30	.002*	.005*	.2	.009	.02	.003	.007	.007*	.04	0	.007	0	.007	.02	0
		8–9 [1]	.93	2.98	.004	.3*	.90	.052	.040	.003	.0065	.02	0	.0060	.018	.006	0	.03	.008
		10–11 [1]	.75	10.15	.002	.05*	.40	.008	.003	.001	.006	.005	0	.001	.003	.003	0	.007	0
		12	.35	19.70	.002*	.004*	.2	.01	.02	.003	.01	.007*	.03	.002	.009	.001	0	.008	0
		13–14	.23																
		13v	.05	27.78	.0007*	.005*	.4	.033	.031	.003	.001	.02*	.04	.002	.014	0	0	.006	0
26	Ill-P-1	1 [1]	.09	4.75	.005	.05*	1.5	.52	.12	.02	.16	.02	.02	.0090	.16	.094	.01	.006	.01
		2	.16	5.90	.004	.14	.49	.070	.044	.002	.062	.011	0	.006	.040	.05	0	.01	.004
		3–4	.41	3.83	.006	.2*	.55	.021	.031	.01	.060	.02	0	.012	.044	.021	0	.008	0
		5	.29	3.12	.008	.6*	.1	.006	.005	.007	.02	.03*	0	.003	.02	0	0	.005	0
		6	.50	2.28	.01	.6*	.23	.017	.010	.011	.040	.02	0	.005	.050	.009	0	.01	.004
		7a	.18	6.22	.004	.05*	.12	.010	.0052	.008	.020	.008	0	.002	.016	.002	0	.007	0
		7pa	.07	31.80	.0002	.008	.01	.001	.0005	.004	.01	.02*	0	0	.005	.002	0	0	0
		8	.26	4.60	.005	.05*	.2	.01	.031	.0088	.026	.026	1.2	.003	.033	.002	0	.01	0
		9	.25	5.26	.005	.01	.64	.028	.040	.011	.020	.018	2.1	.006	.046	.004	0	.01	.009
		9a	.18	2.02	.03	.29	.46	.034	.069	.02	.041	.035	.2	.01	.092	.009	0	.04	.005
		10	.50	7.30	.005	.06*	.52	.030	.028	.010	.020	.01	0	.008	.038	.004	0	.01	.005
		11	.43	15.72	.003	.05*	.5	.06	.03	.005	.02	.02*	0	.009	.01	.002	0	.01	0
27	Ill-T-1	1	.45	8.68	.001	.05*	.4	.02	.04	.002	.008	.007	0	.003	.01	.003	0	.008	.02
		2–4 [1]	1.05	4.21	.005	.09*	.46	.030	.026	.0065	.016	.02	0	.006	.019	.0052	0	.01	.05
		5B [1]	.21	5.90	.003	.05*	.17	.065	.047	.012	.038	.02	0	.0044	.008	.0058	0	.01	.15
		5v	.15	3.66	.004	.3*	.2	.08	.06	.02	.04	.018	.02	.004	.029	.003	0	.02	.009
		6	.38	4.94	.003	.5*	.2	.042	.068	.031	.060	.024	.01	.0042	.042	0	0	.02	0
		7	.48	5.10	.003	.5*	.4	.024	.038	.023	.035	.020	.01	.002	.024	0	0	.02	.01
		8	.20	7.76	.002	.5*	.4	.020	.044	.026	.028	.021	.01	.002	.017	0	0	.025	0
		9	.27	6.44	.003	1.0*	.4	.02	.05	.02	.04	.02*	.02	.009	.024	.004	0	.02	.01
		10 [1]	.42	4.03	.005	.2*	2.1	.043	.044	.036	.090	.04	0	.011	.084	.008	0	.02	.03
		11	.32	8.94	.004	.09*	.5	.04	.04	.02	.042	.02*	.02	.004	.026	.004	0	.02	.06

		12	.45	17.26	.001	.05*	.5	.04	.04	.01	.04	.007*	0	.004	.02	.003	0	.01	.04
		13	.25																
28A	Ill-S-DeK.	1	.19	14.76	.002	.01	.4	.02	.02	.003	.009	.003	.02	.004	.02	.008	0	.01	0
		2	.41	12.38	.002	.02	.4	.01	.02	.003	.008	.004	.02	.003	.008	.003	0	.01	0
		3	.30																
		4 [1]	.20	2.89	.0044	.2*	1.2	.086	.030	.0016	.01	.03*	.07	.0032	.004	.0052	.009	.026	.012
		5	.55																
		6	.20	5.76	.001	.07*	.2	.02	.04	.003	.008	.006	.02	.004	0	.002	0	.03	.02
		7	.20																
		8–10 [1]	.46	6.73	.004	.07*	.7	.1	.04	.003	.01	.02*	0	.005	0	.002	0	.01	.008
		11–12 [1]	.49	3.50	.01	.2*	.7	.094	.056	.005	.017	.03	0	.012	.039	.006	.006	.03	.01
		13	.13																
		4v		17.00	.0006	.014	.31	.013	.0093	.0012	.0021	.01*	0	0	0	.0008	0	.005	0
28B	Ill-S-Da.	1	.11																
		2 [1]	.16	4.60	.01	.03	.9	.6	.1	.001	.01	.008*	0	.002	.02	.01	.004	.007	0
		3	.33	5.32	.003	.03	.5	.02	.03	.002	.009	.005	.03	.004	.02	.006	0	.01	0
		4	.23	4.74	.002	.04	.4	.02	.02	.003	.01	.005	.04	.004	.006	.005	0	.02	.01
		5–8 [1]	.62	3.41	.008	.1*	.9	.03	.03	.003	.01	.007*	0	.006	.006	.003	0	.02	.02
		9–15 [1]	1.44	3.07	.03	.07*	1.0	.03	.02	.004	.04	.01*	0	.005	.01	.002	0	.03	.04
		16	.21	10.80	.004	.027	.4	.015	.016	.03	.080	.02	.88	.009	.022	.002	0	.062	.060
		17	.08	12.50	.003	.018	.4	.10	.027	.02	.11	.02	.14	.005	.012	.002	0	.030	.23
29	Ill-P-Mu.	1–5 [1]	1.76	3.85	.004	.2*	.8	.06	.02	.004	.02	.02*	.02	.003	0	.007	0	.02	.02
		6–10 [1]	1.40	3.94	.004	.07*	.8	.06	.03	.008	.03	.02*	0	.007	0	.009	0	.03	.03
		11–13 [1]	.92	3.00	.003	.2*	.9	.04	.01	.003	.02	.02*	0	.002	0	.003	0	.03	.03
		14	.30	5.62	.0002	.02*	.5	.02	.03	.003	.02	.009	.02	.005	0	.002	0	.01	.009
		15–21 [1]	2.81	4.20	.004	.07*	.8	.03	.02	.002	.008	.007*	0	.005	0	.002	0	.008	.008
		22–25 [1]	.51	5.54	.006	.07*	1.0	.05	.02	.002	.01	.02*	0	.005	.01	.004	0	.01	0
30	Ill-PH-LW.	1	.26	4.88	.007	.009	.9	.070	.036	.007	.03	.009	.02	.004	.002	.008	0	.01	.02
		2	.12	3.14	.007	.01	.6	.048	.044	.01	.04	.01	.03	.01	.007	.005	0	.02	.02
		3	.25	2.66	.004	.02*	.8	.05	.03	.02	.06	.02*	.03	.01	.02	.003	.008	.02	.01
		4–9	2.07	4.22	.006	.05*	.93	.054	.035	.011	.055	.02	.02	.010	.016	.002	0	.02	.02
		10	.11	2.92	.004	.05*	1.0	.06	.04	.02	.07	.07*	.05	.01	.034	.002	0	.02	.01
		11	.14	3.34	.011	.01	.4	.05	.03	.01	.04	.01	.04	.005	.01	0	0	.02	.03
		12–13	.47	3.64	.011	.05*	.58	.062	.041	.0076	.078	.02	.05	.018	.087	.004	0	.03	.02
31	Ind-L-VII.	1	.40	14.26	.0007	.12	1.7	.14	.052	.008	.065	.018	0	.012	.016	.011	0	.007	.008
		2	.24	8.26	.001	.065	1.8	.021	.042	.005	.059	.018	.01	.012	.027	.010	0	.008	.007
		3	.18	8.78	.007	.02	.4	.008	.03	.009	.03	.01	.02	.003	.009	.007	.01	.007	0
		4	.20	4.54	.017	.02*	.2	.014	.01	.012	.040	.02	.05	.0053	.051	.004	.003	.01	0
		5 [1]	.18	.86	.10	.5*	.68	.049	.037	.019	.12	.026	0	.030	.28	.016	.03	.046	0
		6	.20	5.86	.014	.02*	.26	.017	.01	.011	.028	.03	.46	.0085	.042	.004	.005	.008	0
		7	.17	5.90	.012	.02*	.51	.014	.03	.0075	.015	.02	.02	.0068	.028	.003	0	.01	.008
		8	.26	6.08	.007	.03	.5	.02	.03	.009	.02	.006	.03	.012	.024	.004	0	.02	0
		9	.29	6.36	.013	.02*	.42	.016	.030	.012	.024	.02	.03	.014	.044	.004	0	.01	0
		10	.28	11.38	.004	.02	.6	.02	.03	.0072	.02	.008	.02	.008	.025	.004	.01	.01	0
		11	.12	7.98	.013	.02*	.60	.028	.026	.0098	.024	.04	.02	.0094	.058	.003	0	.007	.006
		12	.11	10.90	.003	.02	.3	.02	.03	.01	.019	.01	.02	.008	.019	.004	0	.007	0
		13	.12	8.86	.0005	.08	2.6	.09	.04	.009	.03	.03	.01	.01	.04	.004	0	.01	.01

See footnotes at end of table.

TABLE 4.—*Spectrochemical analyses of 15 minor elements in the ash of coal samples from the Eastern Interior coal region*—Continued

Locality (fig. 1)	Coal column	Coal block sample	Thickness (feet)	Ash in coal (percent)	Be	B	Ti	V	Cr	Co	Ni	Cu	Zn	Ga	Ge	Mo	Sn	Y	La
32	Ind-S-VI	1	0.43	20.12	0.0002	0.05	1.5	0.04	0.03	0.003	0.01	0.008	0	0.004	0.01	0.003	0	0.009	0
		2	.35	24.02	.0006	.05*	.4*	.02	.02	.002	.006	.02*	0	.006	.007	0	0	.006	.008
		3-4	.96																
		5	.28	3.26	.0002	.04	.5	.02	.01	.002	.004	.007	.02	.003	0	.0008	0	.006	.007
		6	.45																
		7	.21	4.44	.022	.05*	.23	.02	.012	.005	.013	.006	0	.0044	.029	.002	.008	.01	.06
		8	.30	4.54	.004	.05*	.22	.016	.020	.0095	.018	.01	.03	.0062	.031	.002	.005	.01	.005
		9	.35	2.26	.024	.2*	.46	.031	.025	.013	.031	.02	.03	.0094	.076	.002	.002	.03	0
		10 & 12	.49	2.84	.02	1.0*	.67	.034	.034	.0053	.021	.04	0	.006	.035	.004	.004	.026	.006
		11	.20	3.70	.024	.05*	.72	.01	.018	.0033	.0082	.004	0	.0041	.018	.001	.006	.02	0
		13	.45	2.76	.029	.05*	.72	.031	.026	.015	.038	.01	.02	.010	.078	.0008	0	.02	.005
		14 & 16 [1]	.65	2.41	.01	1.0*	1.2	.044	.041	.014	.11	.013	0	.014	.076	.002	.003	.034	.02
		15	.35	4.72	.024	.05*	.62	.021	.025	.012	.071	.014	.03	.01	.051	.001	.01	.01	0
		17-19 [1]	1.02	3.25	.01	.4*	2.4	.058	.055	.015	.16	.017	0	.014	.05	.002	.006	.034	.008
		20	.20	15.38	.0005	.08	2.0	.02	.02	.006	.04	.02	.04	.008	.01	0	0	.02	.008
		21	.21	17.70	.0004	.05	1.6	.01	.02	.006	.03	.009	0	.008	.01	0	0	.02	.01
		22	.19	22.06	.0012	.066	2.1	.055	.044	.01	.065	.018	.01	.013	.016	0	0	.01	.009
		3v		4.56	.014	.09*	.74	.05	.039	.012	.026	.021	0	.01	.096	.002	.007	.01	.06
33	Ind-D-VI	1	.27	6.10	.001	.09*	.3*	.02	.01	.002	.008	.03*	0	.004	0	.004	0	.01	.02
		2	.17																
		3	.14	5.76	.002	.4*	.3*	.02	.008	.003	.01	.04*	0	.004	0	.002	0	.01	.02
		4-6	.74																
		7	.40	7.16	.007	.02*	.7	.04	.02	.001	.009	.004	0	.002	0	.001	0	.008	0
		8	.30	2.62	.004	.2*	.7	.04	.04	.005	.02	.011	.01	.008	.001	.002	0	.02	.02
		9-10	.90																
		11	.33	3.70	.007	.05*	.6	.02	.05	.004	.02	.006	.03	.003	0	.003	0	.01	.02
		12	1.07																
		13	.57	1.98	.004	.2*	.5	.04	.04	.008	.03	.009	.02	.006	0	.003	.006	.02	.01
		14	.70	3.06	.007	.2*	.7	.03	.04	.003	.02	.006	0	.004	0	.003	0	.01	.008
		15	.61																
		16b	1.00	4.86	.0004	.05*	.6	.02	.02	.002	.01	.01	0	.005	0	.005	0	.008	.009
		17	.50	4.64	.0006	.1*	.4*	.03	.02	.005	.02	.04	0	.006	0	.01	0	.01	.01
		18	.62	5.28	.0005	.2*	.4*	.03	.02	.004	.02	.06*	0	.003	0	.01	0	.009	.02
34	Ind-P-V	1	.48	10.92	.01	.07	2.0	.03	.01	.002	.007	.03	0	.004	.02	0	.005	.009	.009
		2	.30	16.04	.0005	.02	.4*	.02	.02	.002	.006	.02*	0	.004	0	.004	0	.008	0
		3-13	5.50																
		14	.63	9.20	.003	.04*	.6	.05	.04	.006	.02	.008	.02	.005	.01	.01	.009	.01	0
		15	.33																
		16	.53	9.74	.002	.05	.4*	.03	.02	.003	.009	.007*	.4	.005	.004	.004	0	.01	0
		17	.21	6.72	.002	.05*	.4*	.02	.02	.003	.01	.007*	0	.005	0	.003	0	.01	0

35	Ind-S-V	1[1]	.31	3.40	.004	.5*	2.3	.14	.051	.003	.028	.04	0	.0089	.10	.066	.004	.01	0
		2	.22																
		3	.47	3.12	.003	.1*	1	.03	.03	.003	.05	.007	0	.007	.002	.008	.008	.01	.02
		4-6[1]	.68	2.89	.003	.4*	1.0	.04	.03	.003	.02	.02*	0	.006	.01	.01	.003	.01	.008
		7	.19	6.30	.0007	.2*	.3	.02	.01	.002	.008	.01*	0	.002	0	.003	0	.009	0
		8, 9, 11, 12[1]	1.09	2.75	.002	.6*	.6	.03	.03	.003	.02	.007	0	.004	0	.005	.004	.009	.01
		10	.10	5.22	.0003	.3*	.37	.016	.023	.0027	.012	.01	0	.005	0	.003	0	.009	.01
		13	.45	6.88	.0002	.2*	.3	.014	.007	.0027	.011	.0077	0	.0055	0	.002	0	.008	0
		14, 16-21[1]	2.36	3.45	.004	.6*	1.0	.04	.03	.003	.02	.02*	0	.005	.006	.01	.003	.01	.009
		15	.33																
		22	.18	7.20	.006	.07*	.4	.02	.02	.005	.01	.03*	0	.004	.02	.02	0	.01	.005
		23	.15	9.18	.004	.07*	.4	.04	.009	.004	.02	.03*	.02	.003	.02	.02	0	.01	.006
		24-29[1]	.98	7.37	.004	.3*	2.2	.18	.056	.0047	.033	.08	0	.01	.021	.038	.006	.027	.01
		25v	------	14.72	.0026	.068	.60	.21	.029	.0032	.029	.03*	0	.0055	.006	.018	0	.0046	.008
		26v	------	9.10	.007	.02*	.5	1.0	.054	.005	.050	.02*	.04	.006	.017	.014	0	.01	0
36	Ind-C-III	1	.22	15.82	.01	.09*	.2*	.04	.01	.05	.05	.009*	.2	.005	.009	.004	0	.02	0
		2	.22	17.42	.002	.05*	.4*	.02	.006	.02	.02	.007*	0	.005	.003	.002	0	.02	0
		3	.26	12.74	.003	.05*	.2*	.02	.006	.002	.006	.007*	0	.005	.004	.002	0	.02	0
		4-18	5.30																
		19	.27	15.90	.001	.05*	.4*	.02	.02	.002	.008	.01	0	.009	0	.002	0	.02	0
		20	.28	12.04	.01	.07	2.0	.03	.03	.002	.006	.03	0	.009	.01	.002	0	.02	0
		21	.12	9.04	.003	.05*	.4	.22	.1	.003	.02	.01*	0	.009	.005	.006	0	.02	0
37	Ind-H-III.	1	.22	4.04	.006	.18	2.2	.052	.055	.007	.05	.021	0	.026	.120	.006	0	.01	.007
		2	.20	5.04	.0055	.29	.60	.006	.0025	.0085	.030	.085	0	.021	.067	0	0	.009	0
		3[1]	.40	2.76	.02	.5*	.8	.078	.055	.01	.045	.02	.04	.019	.046	.006	0	.01	.01
		4	.20	5.46	.032	.05*	.61	.014	.008	.033	.080	.016	.075	.0041	.030	.004	0	.01	0
		5	.32	2.88	.033	.2	.61	.015	.02	.03	.07	.009	.098	.0073	.040	.004	0	.01	0
		6	.28	3.48	.027	.2*	.58	.015	.009	.048	.10	.010	.12	.0076	.047	.006	.009	.01	0
		7	.32	4.24	.02	.05*	.51	.011	.009	.065	.17	.0067	.098	.005	.036	.002	.02	.01	0
		8[1]	.35	2.68	.02	.5*	1.7	.10	.036	.036	.18	.010	.04	.012	.032	.001	.006	.021	.01
		9	.25	6.36	.006	.24	2.0	.024	.012	.008	.10	.022	.03	.026	.050	0	0	.001	.006
		10	.19	15.56	.002	.03*	.4*	.08	.06	.004	03	.02	0	.006	.006	0	0	.01	.06
38	Ind-M-M.	1	.32	19.94	.0007	.074	1.1	.019	.0072	.0028	.0072	.017	0	.0066	.022	0	0	.01	.007
		2	.20	30.00	.0006	.02*	.1*	.006	.005	.002	.003	.007*	0	.002	.004	.003	0	.003	0
		3	.40	9.08	.011	.02	.06	.001	.003	.002	.006	.002	.03	.002	.009	.002	.02	.008	0
		4[1]	.43	1.73	.02	.5*	.2	.02	.005	.0095	.020	.010	.03	.044	.002	.002	0	.027	0
		5-8[1]	.74	1.87	.02	.5*	.5	.078	.072	.031	.030	.02	0	.0036	.012	.004	0	.036	.01
		9[1]	.27	1.46	.02	.5*	.5	.078	.062	.035	.036	.06*	0	.016	.034	.008	0	.060	.03
		10	.19	4.36	.02	.05*	.3	.02	.05	.02	.03	.01	.04	.005	.02	.003	0	.03	.03
		11	.52	4.10	.003	.23	1.5	.022	.039	.020	.037	.031	0	.021	.050	0	0	.03	.04
		12	.23	8.88	.001	.17	1.1	.022	.011	.014	.066	.029	0	.019	.057	0	0	.02	.01
39	Ind-Hi-LB.	1	.22	5.48	.011	.26	3.6	.039	.012	.019	.22	.037	.04	.021	.055	0	0	.02	.007
		2	.25	7.56	.006	.24	3.8	.020	.030	.023	.14	.026	.06	.012	.028	0	0	.02	.007
		3	.28	13.96	.002	.04*	.7*	.02	.02	.01	.02	.007*	.03	.002	.003	0	0	.01	.05
		4-7	1.04																
		8	.42	7.96	.007	.09	.6	.02	.03	.03	.075	.01	.04	.005	.01	.002	0	.01	.009
		9-10	.73																

See footnotes at end of table.

TABLE 4.—*Spectrochemical analyses of 15 minor elements in the ash of coal samples from the Eastern Interior coal region*—Continued

Locality (fig. 1)	Coal column	Coal block sample	Thickness (feet)	Ash in coal (percent)	Be	B	Ti	V	Cr	Co	Ni	Cu	Zn	Ga	Ge	Mo	Sn	Y	La
39	Ind-Hi-LB.	11	0.28	6.20	0.018	0.086	2.7	0.030	0.050	0.060	0.26	0.090	0.10	0.018	0.038	0	0	0.02	0.10
		12	.15	7.58	.0002	.05*	.1*	.02	.01	.003	.007	.02	0	0	0	.006	0	.005	0
		13	.17	13.10	.002	.04*	.5*	.09	.05	.02	.08	.007*	.05	.004	.008	0	0	.01	.08
40	Ind-Ge	1[1]	.20	5.48	.01	.02*	1.0	.058	.036	.0034	.060	.02	0	.040	.045	.026	.004	.065	.01
		2	.25	16.26	.007	.01	.6	.04	.04	.001	.01	.008	0	.01	.02	.01	0	.02	0
		3[1]	.30	5.82	.01	.05*	2.6	.16	.058	.002	.028	.031	0	.027	.086	.016	.006	.054	.01
41	Ky-Co-14	1	.38	12.10	.002	.06	.3	.02	.07	.005	.02	.02	.02	.01	.01	0	0	.01	0
		2–5[1]	1.43	2.25	.008	1.0*	1.0	.04	.04	.003	.03	.02*	0	.009	.008	.009	.008	.02	.01
		6–8[1]	.96	2.00	.009	1.0*	2.2	.19	.08	.006	.06	.08	0	.013	.003	.01	.01	.044	.02
		9–13[1]	3.11	3.45	.008	.4*	1.2	.086	.07	.019	.094	.04	0	.01	.006	.011	.12	.055	.02
		14	.21	17.72	.001	.04	.3	.03	.06	.01	.06	.02	.07	.005	.01	.004	0	.009	.005
		KB-1		4.94	.002	.06	8.5	.9	.4	.2	.2	.1	1.0	.01	.01	.004	.009	.05	.004
		KB-2		2.26	.003	.1	>10	2.9	.8	.004	.2	.1	.2	.01	.04	.004	.020	.1	0
42A	Ky-H-14	1	.11	15.26	.002	.003*	.7	.2	.04	.007	.04	.02	.03	.008	.009	.01	.009	.01	0
		2	.14	6.76	.0013	.096	.70	.020	.021	.007	.01	.005	0	.022	.11	.017	0	.01	0
		3	.10																
		4	.30	7.32	.01	.02*	.6	.02	.04	.004	.01	.007	.03	.004	.01	.02	0	.01	.01
		5	.30																
		6	.65	5.74	.0078	.05*	.36	.011	.028	.011	.013	.002	.03	.006	.004	.012	0	.01	0
		7–8	.62																
		9	.50	18.84	.001	.05	.6	.02	.02	.004	.01	.02*	.02	.007	0	.004	0	.02	0
		10	.26	10.46	.003	.05*	.5	.06	.02	.02	.03	.007	.03	.006	.006	.004	0	.03	0
		11	.24	7.72	.006	.02*	.6	.02	.03	.003	.01	.005	.03	.002	.006	.002	0	.01	.01
		12–20	2.63																
		21	.34	8.80	.0013	.053	.44	.022	.033	.014	.023	.008	.04	.009	.02	.01	0	.02	.01
		22	.15	17.32	.001	.01	.5	.05	.03	.02	.03	.009	.03	.009	.01	.007	0	.01	.008
42B	Ky-H-11	1	.26	20.08	.0005	.01*	2	.06	.06	.003	.04	.02	0	.004	0	.06	0	.01	0
		2	.29	21.98	.0002	.03*	.7	.03	.03	.01	.04	.007*	.03	.003	0	.04	0	.01	0
		3–12	2.47																
		13	.46	9.78	.0009	.02	.4	.02	.02	.002	.01	.008	0	.005	.01	.002	0	.009	0
		14	.19	8.56	.002	.019	1.4	.14	.1	.003	.04	.020	.02	.007	.054	.004	0	.01	.008
43A	Ky-Ho-12	1	.36	12.54	.0005	.02*	.6	.02	.03	.002	.004	.02*	.02	.006	0	.005	0	.01	.007
		2–15	3.32																
		16	.28	13.20	.0002	.02*	.6	.02	.03	.004	.01	.007	.03	.006	.005	0	0	.008	.007
		17	.28	13.40	.0005	.05*	.5	.04	.03	.03	.04	.02	.2	.007	.005	.01	0	.008	.007
43B	Ky-Ho-11	1	.30	3.44	.002	.38	.92	.02	.03	.004	.02	.01	.03	.01	.01	.094	0	.01	.007
		2	.22	2.56	.003	.2*	.5	.02	.02	.003	.01	.02	.02	.008	.004	.1	0	.01	0

		3-5	6.14															
		6	.27	9.22	.002	.14	.96	.02	.03	.006	.02	.017	0	.01	.02	.004	0	.02	.01
		7	.27	18.54	.0016	.033	.18	.054	.018	.0054	.019	.016	0	.005	.028	.001	0	.008	0
44A	Ky-U-11	1	.14	6.88	.003	.36	.35	.1	.049	.008	.055	.072	0	.011	.034	.22	0	.004	0
		2	.32	5.68	.003	.42	.78	.030	.02	.006	.017	.047	0	.011	.005	.12	0	.005	0
		3	.26	5.20	.002	.2*	.51	.032	.02	.005	.010	.03	0	.0071	.003	.07	0	.006	0
		4	.47	6.02	.003	.26	.23	.027	.02	.004	.009	.044	0	.010	0	.049	0	.005	0
		5	.37																
		6	.20	2.96	.002	.5*	.5	.01	.032	.003	.008	.02*	.03	.002	0	.018	0	.01	.008
		7	.35	3.68	.003	.3*	.6	.02	.02	.003	.008	.01*	0	.003	0	.02	0	.009	0
		8 [1]	.42	3.54	.005	.5*	1.0	.044	.037	.0034	.026	.014	0	.0085	0	.017	0	.017	.02
		9 [1]	.19	4.05	.004	.4*	1.8	.06	.05	.0029	.014	.018	0	.01	0	.007	0	.018	.007
		10 [1]	.52	2.72	.005	.5*	1.0	.072	.054	.005	.014	.024	.03	.014	.003	.009	.005	.022	.008
		11 [1]	.46	2.49	.006	.4*	.84	.17	.078	.008	.036	.027	0	.029	.016	.007	.004	.032	.01
		12 [1]	.14	3.42	.008	.4*	2.4	.54	.22	.014	.054	.027	0	.014	.003	.003	.005	.032	.01
		13 [1]	.61	2.74	.009	.4*	.9	.07	.052	.014	.14	.02*	0	.017	.058	.004	.004	.034	.01
		14 [1]	.14	3.72	.01	.2*	2.7	.2	.096	.014	.16	.04	0	.012	.088	.004	.004	.029	.008
44B	Ky-U-9	1	.30	2.73	.0048	.3*	2.0	.077	.056	.0045	.016	.038	0	.013	.028	.094	.013	.008	.005
		2 [1]	.42	2.64	.0052	.4*	1.8	.082	.056	.0039	.014	.030	0	.0063	.024	.094	.015	.008	0
		3	.30	8.60	.003	.2	.65	.014	.020	.002	.006	.03*	0	.003	.002	.016	0	.006	0
		4-8	.241																
		9	.40	2.64	.0033	.3*	1.5	.072	.044	.0063	.076	.06*	0	.014	.10	.018	.013	.038	.009
		10	.28	14.62	.0001	.05*	.4	.01	.02	.003	.008	.002*	0	.003	.005	0	0	.007	0
		11 [1]	.20	1.57	.009	.2*	2.2	.32	.067	.0084	.24	.025	0	.030	.20	.016	.0078	.038	.008
45	Ky-BD-9	1-3																	
		4		6.70	.003	.2*	.2	.003	.006	.0009	.004	.005	.02	.001	0	.01	.004	.003	0
46	KY-F-9	1	.15	19.44	.0008	.05*	.5	.49	.075	.001	.024	.007	0	.003	.016	.006	0	.004	0
		2	.34	12.68	.0026	.002*	.4	.088	.02	.002	.007	.007	0	.005	.02	.005	0	.007	0
		3-4	.46																
		5	.42	8.40	.0019	.03*	.22	.0078	.012	.001	.0058	.0056	0	0	.002	.0038	0	.0033	0
		6-7	.83																
		8	.45	7.52	.002	.07*	.5	.02	.01	.004	.09	.02*	0	.004	.01	.004	0	.01	.006
		9	.35	10.56	.002	.05*	.4	.02	.04	.003	.03	.02*	0	.004	.02	.002	0	.006	.008
		10-11	.62																
47A	Ky-G_1-9	1	.24	9.22	.003	.075	3.2	.03	.02	.003	.005	.01	0	.008	.01	.02	0	.008	.007
		2	.29	10.42	.002	.005*	.8	.03	.020	.002	.009	.03*	.02	.007	.003	.007	0	.006	0
		3-4	.44																
		5	.19	5.10	.007	.05*	.5	.02	.02	.003	.02	.003	0	.004	.003	.008	0	.009	.009
		6-8	.79																
		9	.11	6.04	.007	.05	.5	.02	.02	.004	.01	.005	.02	.005	.01	.005	0	.009	.006
		10	.37	7.54	.007	.02*	.5	.01	.02	.003	.005	.005	0	.003	.008	.002	.002	.008	.008
		11	.18	9.60	.007	.02*	.5	.02	.02	.003	.007	.005	.02	.004	.008	.002	0	.009	.01
		12	.27	8.82	.007	.03*	.52	.017	.02	.004	.012	.010	.02	.005	.019	.002	0	.01	.01
		13	.22																
		14	.31	10.78	.0005	.08	2.1	.03	.04	.01	.04	.01	.04	.007	.04	.003	0	.01	.009
		15	.08	13.04	.0005	.08	3.6	.17	.2	.02	.056	.01	.04	.007	.02	0	0	.001	.009

See footnotes at end of table.

TABLE 4.—*Spectrochemical analyses of 15 minor elements in the ash of coal samples from the Eastern Interior coal region*—Continued

Locality (fig. 1)	Coal column	Coal block sample	Thickness (feet)	Ash in coal (percent)	Be	B	Ti	V	Cr	Co	Ni	Cu	Zn	Ga	Ge	Mo	Sn	Y	La
47B	Ky-G$_3$-9	1	0.20																
		2 [1]	.35	3.87	0.0048	0.06*	2.0	0.068	0.041	0.0027	0.052	0.07*	0	0.016	0.11	0.022	0.005	0.0063	0.007
		3 [1]	.21	3.55	.0075	.2*	1.5	.068	.038	.0027	.068	.07*	0	.015	.052	.018	.004	.010	.007
		4–7	1.37																
		8	.28	5.08	.002	.5*	.3	.02	.03	.007	.009	.02*	.03	.003	.006	.004	0	.01	.02
		9	.26																
		10	.21	7.00	.002	.5*	.5	.02	.02	.004	.01	.006	0	.004	.004	.001	0	.01	0
		11–12	.55																
		13	.12	8.48	.004	.02*	.6	.026	.03	.007	.056	.009	.06	.006	.10	.002	.005	.01	.02
		14	.22	10.98	.003	.3*	.5	.030	.03	.003	.055	.007	0	.004	.075	0	.001	.009	.03
		7v		3.20	.0065	.4*	.65	.028	.025	.0033	.014	.03*	0	.008	.009	.0055	.017	.01	.01
48	Ky-OH-9	1		2.26	.011	.02	.3	.02	.034	.004	.029	.01	.04	.050	.052	.012	.020	.06	.02
49	Ky-PR-9	1 [1]	.20	2.98	.01	.09*	1.9	1.9	.12	.009	.12	.013	0	.012	.12	.21	0	.02	0
		2	.32	10.24	.002	.03	.4	.02	.02	.001	.005	.008	0	.005	.01	.03	0	.008	0
		3 [1]	.25	2.10	.007	.2*	2.0	.044	.046	.003	.01	.010	.02	.011	.002	.075	0	.02	0
		4–8	1.52	4.20	.003	.09*	.30	.011	.023	.003	.01	.0099	.07	.006	0	.0096	0	.01	.01
		9–12 [1]	1.36	2.10	.009	.09*	3.2	.062	.060	.003	.01	.013	.02	.012	.004	.005	0	.02	.007
		13	.33	13.62	.003	.01	.3	.02	.04	.003	.01	.008	.05	.006	.02	0	0	.02	.01
50	Ky-Sch-9	1–6	1.77																
		7	.38	8.22	.007	.06	.5	.01	.02	.004	.009	.008	0	.006	.01	0	0	.01	.008
		8	.29																
		9	.21	10.12	.005	.05	.7	.01	.02	.002	.009	.008	0	.006	.02	.001	0	.01	.02
		10	.25	8.98	.002	.05*	.5	.029	.023	.004	.024	.02*	.28	.002	.042	.002	0	.01	.008
		11	.25	15.80	.003	.03	.7	.04	.04	.008	.03	.01	0	.005	.02	0	0	.01	.008
51	Ky-SP-9	1	.28	10.40	.0005	.05	2.1	2.0	.3	.003	.040	.01	0	.007	.04	.09	0	0	.005
		2	.21	11.56	.0005	.05	1.7	1.8	.4	.003	.04	.02	0	.006	.04	.1	0	0	.005
		3	.13	5.22	.007	.03*	.42	.016	.020	.0035	.012	.006	.02	.0047	.024	.046	.002	.005	0
		4–6 [1]	1.78	3.07	.004	.09*	.92	.028	.022	.0027	.013	.016	.03	.0047	.008	.018	.02	.01	.01
		7	.37	5.08	.007	.02*	.7	.01	.03	.003	.01	.005	.02	.004	.005	.004	.006	.006	.008
		8–9	.97	5.41	.002	.05*	.5	.01	.02	.002	.006	.005	.02	.003	.003	.002	.005	.006	.01
		10	.65	7.44	.007	.02*	.6	.01	.02	.002	.006	.004	0	.003	.002	.002	.006	.006	.008
		11	.40	11.88	.007	.02*	1	.02	.02	.03	.007	.005	0	.004	.002	.002	0	.007	.007
		12	.93	13.56	.002	.003*	1.6	.02	.04	.004	.008	.007*	.03	.007	.008	0	.01	.008	.007
		13	.29	14.62	.0005	.030	.56	.018	.088	.0056	.022	.014	.096	.0096	.036	.0064	0	.02	.02
52	Ky-Wi-9	1	.50	20.56	.002	.028	.50	.28	.038	.002	.01	.006	0	.005	.02	.006	0	.005	.007
		2 [1]	.84	2.28	.008	1.0*	1.4	.056	.04	.0044	.016	.02	0	.012	.01	.014	.007	.024	.01
		3	.34	12.56	.0002	.05*	.3	.01	.009	.002	.005	.005	.04	.003	.004	.003	0	.004	0
		4 [1]	1.10	2.54	.005	.6*	1.4	.043	.046	.0065	.02	.02	0	.008	.02	.0036	.005	.022	.02

		5	.40	16.64	.002	.03	.4	.02	.006	.003	.01	.007	0	.002	.02	0	0	.01	.01
		6	.23	11.76	.002	.04	.6	.02	.03	.006	.03	.01	0	.005	.03	0	0	.02	.01
		7	.21	18.24	.003	.03	.7	.04	.02	.005	.03	.042	0	.005	.02	.03	0	.01	.03
53	Ky-D-6	1[1]	.28	2.47	.012	.6*	.2	.098	.058	.012	.12	.1	0	.019	.14	.007	.006	.03	0
		2	.44	2.50	.0026	.19	.15	.0072	.048	.12	.034	.028	.01	.012	.082	0	0	.18	0
		3	.28	2.28	.011	.05*	.3	.0095	.002	.007	.030	.02	.06	.003	.044	.005	.01	.02	0
		4	.30	1.98	.007	.04*	.3	.006	.003	.005	.03	.008	.05	.002	.02	.005	.02	.02	0
		5	.26	1.88	.007	.05*	.3	.008	.003	.005	.03	.008	.05	.002	.01	.006	0	.02	0
		6	.53	3.88	.007	.08*	.2	.005	.004	.003	.01	.009	.03	.001	.007	.005	.02	.01	0
		7	.48	.84	.008	.2*	.2*	.01	.02	.004	.02	.005	.03	.002	.008	.007	.008	.01	0
		8	.25	1.06	.007	.07*	.4	.039	.02	.003	.022	.01	.05	.0076	.038	.01	0	.04	.01
		9	.30	4.38	.004	.02*	.4	.04	.02	.007	.03	.02	.04	.002	.007	.008	0	.01	0
		10–11	.77	1.91	.007	.2*	.5	.02	.02	.002	.01	.006	0	.002	.007	.006	0	.01	0
		12	.63	3.50	.006	.3*	.7	.03	.02	.003	.01	.02*	.02	.007	.004	.01	0	.01	.007
		13	.15	32.16	.0005	.005	.10	.03	.004	.02	.04	.03*	.02	.003	.003	0	0	.008	0

[1] Samples which were floated; see table 3.
[2] Blocks 1t to 4t are top of bed collected about 100 feet from main columnar sample.

EVALUATION AND SUMMARY OF THE ANALYSES

In order to evaluate further the significance of the analytical results, a weighted average was calculated on the basis of the thickness of only those block samples that were analyzed, for each element in the 34 coal-bed columns that were more than 75 percent analyzed. Arithmetic averages were calculated for the other 28 columnar samples. A value of zero was arbitrarily assigned if an element was reported to be below the limit of detection. For elements such as zinc, tin, and yttrium that are reported to be below the limit of detection in a large proportion of the block samples, this procedure tends to lower the average value. The averages of the coal-bed columns, calculated on the basis of the ash, are listed in table 5, and the corresponding averages calculated on the basis of the coal are listed in table 6. Because only the top and bottom block samples were analyzed for some of the coal-bed columns, the averages calculated therefrom are not sufficiently representative to be included in any interpretation of the overall average for coal. These nonrepresentative averages are marked with an asterisk in tables 5 and 6. The other 47 coal-bed column averages are probably more representative, even though 23 of them were not completely analyzed, because they included block samples from various parts of the columns.

From the average content of minor elements in the ash of the 47 representative coal-bed columns listed in table 5, we have calculated the arithmetic average percentage in the ash for each element. Likewise, the arithmetic average calculated in parts per million in the coal was determined from the data in table 6. These overall averages are given in table 7, along with the arithmetic average of the 475 block samples for comparison. For most of the elements, the difference between the block and coal-bed column averages is not great, but for zinc the average is significantly higher in the block samples. Table 8 gives the range between the maximum and minimum values for the 475 block samples and 12 vitrain samples and compares these ranges with the ranges for the average of the 47 representative coal-bed columns. For eight of the elements, the minimum for individual samples is the limit of detection (p. B11); hence the corresponding ratio of the maximum to the minimum has little meaning for these elements. In calculating the ranges for the 47 coal-bed columns, no minimums could be evaluated for zinc, tin, and lanthanum because detectable amounts of these elements were not found in any of the blocks of several coal-bed columns. Germanium was not detected in the coal from locality 48, and the data for this element were calculated by using the lower limit of detection as the minimum.

DISTRIBUTION OF MINOR ELEMENTS IN VITRAIN AND SPECIAL SAMPLES

When the coal samples were being prepared for grinding, several bands of vitrain, as much as 1 cm thick, and a bony parting were separated from the blocks in which they were contained. These samples were analyzed separately, and the analyses are given in table 9, along with the analyses of the enclosing of adjacent whole blocks for comparison. Table 9 also gives the analyses of three samples of kettle-bottom coal and the adjacent block samples from the top of the bedded coal with which they were associated. The samples of vitrain and kettle-bottom coal have less ash than the adjacent blocks with which they are compared. The bony parting contains more ash than the adjacent block sample. These samples are useful, therefore, in providing evidence of those elements that are associated with the organic and mineral matter of coal.

When compared with the block samples, the germanium content is slightly higher in three of the four vitrain samples; beryllium, boron, titanium, vanadium, cobalt, and gallium contents are slightly higher in two. Nickel, copper, and yttrium contents are lower in three of the vitrain samples. Chromium, zinc, molybdenum, and lanthanum are considerably more concentrated in the coal block samples. The sample of a bony parting differs somewhat from the vitrain samples in that gallium and germanium are somewhat more concentrated in the parting than in the adjacent, more nearly pure coal.

The samples of kettle-bottom coal contain unusually high concentrations of vanadium, chromium, nickel, copper, and yttrium. Kettle-bottom coal samples from the northern Great Plains province were previously found to have similar concentrations of minor elements (Zubovic and others, 1961a, p. A46–A52). The germanium concentration, however, which is especially high in kettle bottoms from the northern Great Plains, is low in kettle bottoms from the Eastern Interior region. Titanium is a major constituent in two of the samples of kettle-bottom coal but is a relatively minor one in the third. Because beryllium, boron, gallium, and germanium are known to be associated predominantly with the organic matter in coal (Zubovic and others, 1961b), we thought they might be concentrated in the kettle-bottom coal samples, but the analyses indicate they are more concentrated in the adjacent coal blocks.

VERTICAL DISTRIBUTION OF MINOR ELEMENTS IN SELECTED COAL BEDS

The distribution profiles of the minor-element contents were plotted in the form of bar diagrams on plate 1 for selected coal beds from eight

TABLE 5.—*Average content of 15 minor elements in ash of individual coal-bed columns from the Eastern Interior coal region*

[O, below limit of detection; *, average of column not used in compiling averages, table 7]

Locality (fig. 1)	Coal column	Percentage of bed analyzed	Average ash (percent)	Average (percent in ash)														
				Be	B	Ti	V	Cr	Co	Ni	Cu	Zn	Ga	Ge	Mo	Sn	Y	La
1	Ill-D-7	94.2	3.92	0.0087	0.51	0.77	0.028	0.025	0.0045	0.018	0.0095	0.0045	0.0057	0.013	0.0022	0.0014	0.013	0.0022
2	Ill-Ha-7	100	4.40	.005	.32	.88	.052	.046	.005	.024	.014	0	.0074	.041	.0048	.0001	.011	.0054
3	Ill-A-6	100	7.27	.0043	.4	.66	.042	.042	.0064	.023	.02	.78	.0077	.023	.012	.0025	.0073	.0004
4	Ill-C-6	100	5.83	.004	.32	.82	.048	.033	.004	.023	.022	.056	.0064	.015	.011	0	.0075	.0021
5A	Ill-F-6	90.6	4.35	.0043	.31	.99	.075	.06	.0067	.07	.026	.083	.009	.064	.013	.002	.011	.0057
5B	Ill-R-5	100	9.16	.0033	.048	.51	.038	.029	.0017	.0073	.011	.054	.0038	.025	.0053	.0027	.0061	.0003
6	Ill-M-6*	12.6	9.05	.0018	.2	.41	.031	.025	.0045	.028	.027	.073	.01	.032	.0046	0	.01	.0063
7A	Ill-Ma-6*	11.2	16.51	.0004	.17	.23	.15	.076	.002	.025	.011	.047	.0027	.015	.018	0	.0097	.005
7B	Ill-Ma-5*		6.10	.002	.048	.22	2.1	1.0	.004	.17	.003	.02	.002	.049	.12	0	.008	0
8	Ill-OB-6	100	3.47	.0049	.37	1.06	.072	.052	.0074	.035	.019	.0066	.0072	.0068	.0031	.0036	.011	.025
9	Ill-Pa-6	30	9.57	.0018	.22	.43	.034	.026	.0029	.010	.046	.15	.007	.029	.005	0	.011	.0023
10	Ill-Pw-6	83.1	4.73	.0034	.33	.75	.054	.041	.0041	.024	.016	.0046	.0068	.027	.017	.005	.013	.007
11	Ill-S-6*	12.1	8.55	.003	.25	.6	.039	.032	.02	.034	.035	.32	.005	.014	.021	.0025	.015	.025
12A	Ill-TrB-6	100	5.06	.0041	.25	.93	.11	.054	.004	.017	.017	.033	.0043	.0041	.011	0	.015	.021
12B	Ill-TrB-5*	25	10.27	.0023	.033	.53	.03	.02	.01	.017	.016	.032	.0041	.024	.0027	0	.011	.017
13	Ill-TrP-6*	4.5	19.92	.002	.05	.11	.008	.009	.003	.023	.007	2.8	.0005	.02	.0005	0	.002	.005
14	Ill-V-6*	29.6	7.6	.0017	.13	.41	.048	.18	.024	.016	.015	.34	.0069	.022	.014	.0013	.0075	.003
15	Ill-BB-5*	24.1	11.87	.002	.036	.4	.033	.037	.0077	.044	.023	.37	.005	.031	.0023	0	.009	.01
16	Ill-B&W-5*	32.5	13.69	.0013	.045	.27	.38	.056	.002	.017	.0075	0	.002	.014	.015	0	.0033	.005
17A	Ill-E-5	100	6.08	.0051	.3	.53	.028	.022	.0029	.018	.027	.52	.0067	.033	.012	.002	.018	.0004
17B	Ill-E-2	100	5.30	.0052	.45	.31	.024	.022	.023	.1	.05	.083	.0056	.062	.0034	0	.016	0
18	Ill-F-5	100	6.03	.0018	.33	1.1	.039	.035	.0025	.013	.011	.013	.0035	.014	.0048	.0003	.0087	.0007
19	Ill-G-5	94.7	4.17	.0029	.027	1.3	.042	.035	.0029	.012	.011	.024	.0068	.014	.012	.0042	.008	.0047
20	Ill-H-5	100	3.22	.0016	.18	1.7	.054	.05	.0043	.026	.018	.12	.0091	.028	.0013	0	.006	.0053
21	Ill-S-5	25.3	8.39	.0014	.043	1.4	.088	.033	.0056	.053	.026	0	.0032	.01	.0032	.0046	.0058	.0084
22	Ill-Tr-5	57.1	7.57	.0028	.16	.45	.018	.022	.0022	.0076	.013	.035	.0029	.017	.0031	.001	.0062	0
23	Ill-W-5	100	7.23	.0035	.23	.7	.031	.026	.0019	.008	.018	.0043	.005	.019	.0062	.004	.0071	.0009
24	Ill-B-2	100	5.57	.0086	.37	.39	.034	.019	.006	.03	.042	.0029	.0074	.052	.0012	.0006	.019	.0005
25	Ill-A-1	95.3	5.99	.0021	.22	.51	.041	.027	.0029	.0098	.013	.0064	.0037	.0095	.014	.0007	.014	.0044
26	Ill-P-1	100	5.96	.0072	.22	.42	.042	.029	.0095	.036	.019	.27	.0069	.037	.011	.0003	.011	.0029
27	Ill-T-1	94.6	6.88	.0033	.25	.56	.035	.041	.017	.037	.02	.0058	.0051	.028	.0036	0	.015	.035
28A	Ill-S-DeK	62.3	7.67	.0039	.095	.6	.055	.034	.0031	.01	.016	.022	.0052	.012	.0044	.0025	.019	.0083
28B	Ill-S-Da	96.5	4.35	.017	.063	.82	.059	.027	.0055	.031	.0093	.07	.0051	.011	.0033	.0002	.026	.034
29	Ill-P-Mu	100	4.07	.0039	.11	.81	.044	.021	.0037	.017	.015	.0054	.0046	.0007	.0047	0	.018	.017
30	Ill-PH-LW	100	3.96	.0068	.042	.84	.056	.036	.011	.056	.02	.027	.01	.025	.0028	.0006	.021	.019

31	Ind-L-VII	100	8.12	.013	.073	.84	.041	.032	.0096	.033	.018	.050	.014	.047	.0064	.0042	.012	.003
32	Ind-S-VI	80.1	7.40	.012	.3	1.2	.034	.032	.0095	.06	.016	.0096	.0091	.04	.0017	.0033	.021	.0089
33	Ind-D-VI	58.1	4.52	.0034	.15	.53	.029	.027	.0035	.017	.022	.006	.0045	.0001	.0043	.0006	.012	.014
34	Ind-P-V*	26.9	10.52	.0035	.045	.76	.03	.022	.0032	.01	.014	.084	.0046	.0068	.0042	.0028	.0094	.002
35	Ind-S-V	92.7	4.37	.0032	.43	1.1	.059	.032	.0033	.023	.026	.0004	.0059	.012	.015	.0035	.012	.0086
36	Ind-C-III*	20.5	13.83	.0048	.06	.6	.058	.029	.013	.018	.012	.033	.007	.0052	.003	0	.02	0
37	Ind-H-III	100	4.71	.018	.25	1.0	.042	.028	.027	.091	.02	.055	.013	.046	.0031	.004	.011	.0081
38	Ind-M-M	100	7.15	.012	.28	.63	.035	.033	.017	.026	.021	.011	.0086	.028	.0024	.0002	.026	.014
39	Ind-Hi-LB	50	8.83	.0066	.12	1.7	.034	.029	.024	.11	.028	.046	.0089	.02	.0011	0	.014	.036
40	Ind-Ge	100	9.21	.009	.029	1.5	.093	.046	.002	.031	.02	0	.025	.053	.017	.0035	.046	.0067
41	Ky-Co-14	100	3.96	.0075	.6	1.2	.086	.064	.012	.068	.04	.0036	.01	.0064	.0095	.014	.041	.016
42A	Ky-H-14	42.4	10.91	.0037	.039	.56	.047	.029	.01	.02	.0092	.027	.0081	.019	.0096	.001	.014	.0042
42B	Ky-H-11*	32.7	15.10	.0009	.02	1.1	.063	.053	.0045	.033	.014	.013	.0048	.016	.027	0	.0098	.002
43A	Ky-Ho-12*	21.7	13.05	.0004	.03	.57	.027	.03	.012	.018	.016	.083	.0063	.0033	.005	0	.0087	.007
43B	Ky-Ho-11*	14.7	8.44	.0022	.19	.64	.029	.025	.0046	.017	.016	.013	.0083	.016	.05	0	.012	.0043
44A	Ky-U-11	91.9	3.87	.005	.38	.9	.083	.049	.0068	.042	.028	.0051	.013	.015	.033	.0019	.018	.0068
44B	Ky-U-9	44.1	5.47	.0042	.24	1.4	.096	.044	.0047	.06	.031	0	.012	.06	.04	.0081	.018	.0037
45	Ky-BD-9		6.70	.003	.2	.2	.003	.006	.0009	.004	.005	.02	.001	0	.01	.004	.003	0
46	Ky-F-9	47.2	11.72	.0019	.04	.4	.13	.031	.0022	.031	.012	0	.0032	.014	.0042	0	.0061	.0028
47A	Ky-G1-9	58.5	8.95	.0056	.046	1.4	.039	.042	.0058	.018	.0098	.018	.0056	.013	.0054	.0002	.0078	.0008
47B	Ky-G2-9	36.9	6.49	.0039	.26	.9	.039	.032	.0044	.042	.03	.015	.008	.058	.0078	.0025	.0092	.014
48	Ky-OH-9		2.26	.011	.02	.3	.02	.034	.004	.029	.01	.04	.05	.052	.012	.02	.06	.02
49	Ky-PR-9	100	4.55	.0056	.085	1.5	.13	.042	.0032	.015	.011	.039	.0086	.01	.023	0	.015	.007
50	Ky-Sch-9*	34.6	10.78	.0043	.048	.6	.022	.026	.0045	.018	.012	.07	.0048	.023	.0008	0	.01	.011
51	Ky-SP-9	100	7.51	.0037	.046	.97	.17	.054	.0048	.012	.0097	.023	.0049	.01	.015	.0093	.0077	.0089
52	Ky-Wi-9	100	8.96	.0042	.43	.97	.071	.033	.0045	.016	.016	.0038	.007	.017	.0072	.0031	.016	.013
53	Ky-D-6	100	3.43	.0067	.17	.35	.023	.019	.016	.026	.019	.025	.0049	.027	.0061	.0053	.031	.0015

TABLE 6.—*Average content of 15 minor elements in coal of individual coal-bed columns from the Eastern Interior coal region*

[0, below limit of detection; * average of column not used in compiling averages, table 7]

Locality (fig. 1)	Coal column	Percentage of bed analyzed	Average ash (percent)	Average (parts per million)														
				Be	B	Ti	V	Cr	Co	Ni	Cu	Zn	Ga	Ge	Mo	Sn	Y	La
1	Ill-D-7	94.2	3.92	3.2	183	354	11.9	10.1	1.9	6.0	3.1	1.7	2.4	4.5	0.8	0.5	5.1	0.9
2	Ill-Ha-7	100	4.40	1.9	133	382	22.5	19.3	1.8	6.2	9.0	0	3.0	14.1	1.5	.3	4.6	2.3
3	Ill-A-6	100	7.27	2.0	165	333	20.1	21.7	3.2	14	11.7	597	3.8	12	8.2	2.3	3.8	.32
4	Ill-C-6	100	5.83	1.8	198	447	23.0	23.7	2.5	18.5	16.6	53.0	4.5	10.7	8.1	0	4.2	1.2
5A	Ill-F-6	90.6	4.35	1.4	96	364	26.2	23.2	3.4	23.7	10.6	39.8	3.2	23.6	4.9	.54	4.3	3.5
5B	Ill-R-5	100	9.16	2.3	35	398	24.3	21.0	1.5	5.7	9.8	90.7	2.7	20.2	3.2	1.4	5.7	.5
6	Ill-M-6*	12.6	9.05	1.2	228	289	28.6	20.8	5.2	31.1	23.2	74.9	3.4	26.5	3.4	.6	9.2	12.5
7A	Ill-Ma-6*	11.2	16.51	.5	167	297	119	63.4	2.3	27.0	15.1	42.7	2.7	19.2	18.7	0	16.1	5.2
7B	Ill-Ma-5*		6.10	1.2	29	134	1,281	610	2.4	104	1.8	12.2	1.2	30.0	73.2	0	4.9	0
8	Ill-OB-6	100	3.47	1.6	116	348	25.5	17.0	2.4	13.7	6.4	2.7	2.3	3.9	1.1	1.1	3.6	7.4
9	Ill-Pa-6	30	9.57	1.8	200	418	34.7	24.5	3.5	10.9	41.4	268	7.1	34.2	3.5	0	17.7	2.0
10	Ill-Pw-6	83.1	4.73	1.4	131	278	23.0	18.6	1.8	10.0	6.9	1.6	2.9	9.4	6.8	1.9	5.8	4.2
11	Ill-S-6*	12.1	8.55	2.6	83	513	32.8	27.4	22.4	35.5	22.0	388	3.6	16.2	9.5	.8	10.2	29.2
12A	Ill-TrB-6	100	5.06	1.7	93	476	54.7	26.4	2.2	10.1	8.8	33.6	1.7	5.0	4.1	0	8.0	8.1
12B	Ill-TrB-5*	25	10.27	2.1	37	542	29.2	18.8	7.1	17.2	15.8	27.8	4.2	24.4	2.2	0	8.6	19.3
13	Ill-TrP-6*	4.5	19.92	4.0	100	209	15.9	16.9	6.0	44.8	12.9	5,570	.1	40.7	1.0	0	4.0	9.9
14	Ill-V-6*	29.6	7.6	1.3	82	309	43.3	179	15.1	12.2	11.1	283	5.7	18.0	9.3	.6	5.0	2.0
15	Ill-BB-5*	24.1	11.87	2.2	37	420	484	109	9.0	79.4	41.7	323	5.0	33.8	3.2	.7	16.2	8.8
16	Ill-B&W-5*	32.5	13.69	1.7	46	351	407	61.8	2.7	20.2	10.4	0	2.6	17.4	16.7	0	4.8	7.1
17A	Ill-E-5	100	6.08	2.6	169	306	17.0	17.5	2.0	10.6	15.9	415	3.6	14.5	.6	0	1.0	0
17B	Ill-E-2	100	5.30	2.3	189	149	10.2	8.8	10.2	46.0	22.5	35.3	2.4	27.0	1.4	0	6.9	0
18	Ill-F-5	100	6.03	1.1	128	523	20.5	17.5	1.6	8.0	5.7	16.2	2.4	6.5	2.6	.3	4.1	.2
19	Ill-G-5	94.7	4.17	.8	13	409	33.7	11.9	1.6	6.0	7.5	11.1	2.0	4.9	2.8	1.2	3.3	2.4
20	Ill-H-5	100	3.22	.6	44	469	15.2	14.2	1.7	10.2	6.4	18.0	2.4	8.8	.6	0	3.3	3.1
21	Ill-S-5	25.3	8.39	1.1	35	743	45.8	22.6	3.6	25.4	20.0	0	2.5	6.5	1.2	1.8	5.0	7.8
22	Ill-Tr-5	57.1	7.57	1.9	126	329	13.3	16.8	1.7	5.6	9.8	10.9	2.2	12.4	2.2	.7	4.5	0
23	Ill-W-5	100	7.23	1.5	138	352	19.1	14.7	1.2	5.3	12.7	2.1	2.9	10.7	3.0	1.4	5.0	.4
24	Ill-B-2	100	5.57	4.3	168	193	19.9	8.0	4.0	16.2	24.7	2.9	3.6	23.8	.6	.3	9.0	.2
25	Ill-A-1	95.3	5.99	1.3	73	236	15.5	12.2	1.5	5.4	5.9	7.9	2.5	4.7	5.2	.6	7.1	1.3
26	Ill-P-1	100	5.96	3.1	76	276	28.8	17.9	4.8	18.1	10.7	130	4.4	18.7	5.3	.1	5.9	1.4
27	Ill-T-1	94.6	6.88	1.9	149	354	23.7	27.3	10.3	24.4	11.2	3.7	3.2	16.6	2.3	0	9.8	24.3
28A	Ill-S-DeK	62.3	7.67	2.2	43	377	29.7	22.1	2.4	7.2	7.6	14.3	3.4	9.0	3.6	.8	11.5	4.0
28B	Ill-S-Da	96.5	4.35	5.7	23	313	26.9	11.8	3.9	17.0	4.7	72	2.3	5.7	1.5	.1	12.7	19.4
29	Ill-P-Mu	100	4.07	1.6	44	330	17.9	8.7	1.5	6.7	5.9	2.2	1.9	.4	1.8	0	6.8	6.4
30	Ill-PH-LW	100	3.96	2.7	17	336	22.2	14.2	4.2	21.8	7.7	10.2	4.1	9.4	1.1	.2	8.0	7.7

31	Ind-L-VII	100	8.12	5.1	46	805	43	28.5	7.1	31.1	14	31.5	8	23.5	5.3	2.2	7.7	3.1
32	Ind-S-VI	80.1	7.40	4.0	112	814	23.2	21.1	4.8	28.3	10.9	5.6	5.7	15.6	.9	1.2	10.9	5.4
33	Ind-D-VI	58.1	4.52	1.4	65	228	12.7	10.4	1.4	6.7	10.8	1.8	1.9	.03	2.0	.12	4.7	6.0
34	Ind-P-V*	26.9	10.52	3.5	46	870	30.7	22.5	3.2	10.2	16.8	81.7	4.7	7	4.3	2.8	9.6	2.0
35	Ind-S-V	92.7	4.37	1.4	166	493	30.9	14.1	1.5	10.0	14.0	.4	2.7	5.5	7.8	1.5	6.0	3.5
36	Ind-C-III*	20.5	13.83	6.6	84	780	65	32	20.8	26.6	16.1	52.7	9.4	6.8	3.9	0	27.7	0
37	Ind-H-III	100	4.71	6.8	90	436	20.7	14.4	10.4	37.4	10.1	20.2	5.9	19.0	1.1	1.5	4.9	7.9
38	Ind-M-M	100	7.15	3.7	85	442	12.8	11.0	5.7	12.0	10.6	5	5	13.8	1.2	2.2	10.1	6.1
39	Ind-Hi-LB	50	8.83	4.7	85	1,240	33.2	26.5	18.8	8.4	19.7	38.4	6.3	13.9	.9	0	11.1	36.2
40	Ind-Ge	100	9.21	7.6	20	1,080	67.4	40.4	1.5	20.8	14.5	0	17.6	37.5	13.0	2.0	32.9	3.8
41	Ky-Co-14	100	3.96	2.4	167	379	26.6	25.9	4.7	25.2	13.3	5.7	3.8	3.0	3.0	21.9	13.4	5.0
42A	Ky-H-14	42.4	10.91	3.1	31	617	62.4	31.5	11.4	23.6	12.4	29.7	8.7	15.9	9.2	1.5	16.3	4.2
42B	Ky-H-11*	32.7	15.10	1.0	31	1,790	81.5	73	8.2	53.1	20.1	20.8	6.4	14	53.5	0	14.9	1.7
43A	Ky-Ho-12*	21.7	13.05	.5	40	738	35	39	16	23.9	20.4	110	8.3	4.4	6.6	0	11.3	9.1
43B	Ky-Ho-11*	14.7	8.44	1.6	93	416	32.5	19.1	4.4	15.8	13.5	3.9	6.0	18.7	15.9	0	9.8	2.9
44A	Ky-U-11	91.9	3.87	1.7	142	320	28.2	16.9	2.5	14	12.1	1.4	4.5	5.0	18	.6	5.8	2.1
44B	Ky-U-9	44.1	5.47	1.3	91	484	23.1	16.4	1.9	13.8	11.1	0	3.4	13.5	11.9	2.0	6.0	.9
45	Ky-BD-9	-------	6.70	2.0	134	134	2.0	4.0	.6	2.7	3.4	13.4	.7	0	6.7	2.7	2.0	0
46	Ky-F-9	47.2	11.72	2.0	46	490	222	46.2	2.3	32	12.7	0	3.9	17.4	5.3	0	6.7	2.6
47A	Ky-G1-9	58.5	8.95	3.6	42	1,400	41.9	46.4	6.0	18.6	9.6	18.3	5.2	13.3	4.6	.2	6.8	6.7
47B	Ky-G2-9	36.9	6.49	2.3	174	478	21.6	19.5	2.9	27.3	13.6	11	4.2	39	3.2	1.4	6.1	10.9
48	Ky-OH-9	-------	2.26	2.5	4.5	68	4.5	7.7	.9	6.6	2.3	9.0	11.3	11.8	2.7	4.5	13.6	4.5
49	Ky-PR-9	100	4.55	1.9	28.5	400	39	16.6	1.3	5.8	4.4	18.6	3.2	5.2	8.5	0	9.2	3.2
50	Ky-Sch-9*	34.6	10.78	4.4	48	670	27	30	5.4	21.4	12.1	62.8	5.2	24.4	.7	0	10.8	11.7
51	Ky-SP-9	100	7.51	2.5	24	830	182	53.5	4.6	10	6.6	18.3	4.1	9.6	11.7	5.0	5.8	6.6
-------	Ky-Wi-9	100	8.96	2.2	125	552	96.4	23	3.1	13.1	11.4	4.7	4.3	16.3	6.2	.8	9.3	9.8
-------	Ky-D-6	100	3.43	1.6	42	101	8.7	5.1	5.9	10.2	7.9	8.1	1.5	6.5	1.5	1.4	8.1	.4

TABLE 7.—*Average content of 15 minor elements in coal and coal ash from the Eastern Interior coal region*

Element	Analytical detections (percent of 475 block samples)	Arithmetic average of 475 block samples (percent in ash)	Arithmetic average of 47 coal-bed columns (percent in ash)	Arithmetic average of 47 coal-bed columns (parts per million in coal)
Beryllium	100	0.0051	0.0056	2.5
Boron	100	.20	.22	96
Chromium	100	.04	.035	20
Cobalt	99.8	.0077	.0069	3.8
Copper	100	.02	.02	11
Gallium	97.7	.0067	.0081	4.1
Germanium	90.1	.027	.025	13
Lanthanum	50.1	.0075	.0087	5.1
Molybdenum	85.5	.01	.0087	4.3
Nickel	100	.033	.032	15
Tin	22.1	.0022	.0027	1.5
Titanium	100	.73	.85	450
Vanadium	100	.069	.054	35
Yttrium	98.3	.013	.015	7.7
Zinc	47.6	.11	.059	44

localities in order to show graphically the vertical distribution in typical beds and facilitate comparisons with different beds and different localities on the same bed. The first two profiles show vertical distribution in the No. 2 coal bed, from localities 17 and 24, about 10 miles apart, near the northern margin of the Eastern Interior coal region in Illinois. The third and fourth distribution profiles show the Herrin (No. 6) coal at locality 3 in northern Illinois and its correlative, the No. 11 coal from locality 44 in Kentucky. The fifth, sixth, and seventh distribution profiles show the Harrisburg (No. 5) coal from localities 17 and 23 in Illinois and its correlative, the No. 9 coal from locality 51 in Kentucky. The last distribution profile shows the Davis (No. 6) coal from locality 53, the southernmost locality in Kentucky. The profiles have an irregular pattern that cannot be simply explained.

The distribution profile for the No. 2 coal bed from locality 24, shows little similarity among different elements except for cobalt and nickel. The distribution profile for the No. 2 coal bed from locality 17 shows no similarity between any two elements. In the next profile, the Herrin (No. 6) coal has an irregular distribution of elements similar to the distribution for the No. 2 coal bed, except that the profiles for titanium, vanadium, chromium, cobalt, and nickel are somewhat similar. The correlative to the Herrin (No. 6) coal, the No. 11 coal from locality 44 in Kentucky, shows a much greater degree of similarity of distribution for the elements titanium, vanadium, chromium, cobalt, and nickel. In addition, the copper and germanium profiles are somewhat similar to the profiles of those elements, and the profiles for beryllium and gallium are similar to each other. The three distribution profiles for the Harrisburg (No. 5)

TABLE 8.—*Range of 15 minor elements in coal from the Eastern Interior coal region*

Element	Range of 475 block samples and 12 vitrain samples (table 4; percent in ash)			Range of 47 coal-bed columns (table 5; percent in ash)			Range of 47 coal-bed columns (table 6; parts per million in coal)		
	Maximum	Minimum	Maximum/Minimum	Maximum	Minimum	Maximum/Minimum	Maximum	Minimum	Maximum/Minimum
Beryllium	0.1	0.0001	1,000	0.018	0.0014	12.9	7.6	0.6	12.7
Boron	1.2	.002	600	.6	.02	30	200	4.5	44
Chromium	1.2	.0004	3,000	.076	.006	12.7	54	4.0	13.5
Cobalt	.16	<.0005	>320	.027	.0009	30	19	.6	31.7
Copper	.12	.002	60	.05	.005	10	41	2.3	18
Gallium	.05	<.0005	>100	.05	.001	50	18	.7	26
Germanium	.28	<.001	>280	.064	<.001	764	39	<.7	>56
Lanthanum	.23	<.003	>77	.036	(1)	----------	36	(1)	----------
Molybdenum	.22	<.0005	>440	.04	.0011	36.4	18	.6	30
Nickel	.26	.002	130	.11	.004	27.5	46	2.7	17
Tin	.12	<.001	>120	.02	(1)	----------	22	(1)	----------
Titanium	5.4	.01	540	1.7	.2	8.5	1,400	68	20.6
Vanadium	2.1	.001	2,100	.17	.003	57	220	2.6	110
Yttrium	.18	<.001	>180	.06	.003	20	33	1.0	33
Zinc	7.6	<.01	>760	.78	(1)	----------	600	(1)	----------

1 Element not detected in any block of columnar sample.

TABLE 9.—*Spectrochemical analyses of 15 minor elements in vitrain and kettle-bottom coal*

[Elements calculated to nearest two digits from percentage of ash and percentage of each element in the ash; 0, element below limit of detection; a, b, separates of a single block; v, vitrain; KB, kettle-bottom coal; pa, sample of shaly parting]

Locality (fig. 1)	Coal column and block	Ash (percent)	Minor elements (parts per million in coal)														
			Be	B	Ti	V	Cr	Co	Ni	Cu	Zn	Ga	Ge	Mo	Sn	Y	La
3	Ill-A-6-4v	3.34	1.3	400	94	7.7	7.7	0.7	6.7	6.7	16	3	7.7	3.3	0	3	0
	4	9.70	1	87	390	9.7	29	1.9	19	19	290	2.9	6.8	9.7	0	7.8	0
5A	Ill-F-6-17v	2.56	1	100	150	21	16	5.1	23	13	5.1	2.6	67	2.3	2.6	2.6	0
	17	2.96	2.1	59	440	15	30	3	25	12	0	3	36	3	2.7	5.9	0
	17a	6.40	1.3	320	490	17	18	5.2	14	12	12	4	23	2.6	0	5.8	0
15	Ill-BB-5-KB-1	4.32	1.6	21	260	1,800	300	8.6	160	86	0	1.7	23	4.3	2.6	32	0
	1	12.38	5	62	500	79	74	7.4	84	22	37	11	76	6.2	0	9.9	0
26	Ill-P-1-7a	6.22	2.5	31	75	6.2	3.2	5	12	5	0	1.2	10	1.2	0	4.4	0
	7pa	31.80	.6	25	32	3.2	1.6	13	32	64	0	0	16	6.4	0	0	0
27	Ill-T-1-5v	3.66	1.5	110	73	29	22	7.3	15	6.6	7.3	1.5	11	1.1	0	7.3	3.3
	5b	5.90	1.8	30	100	38	28	7.1	22	12	0	2.6	5	3.4	0	5.9	89
41	Ky-Co-14-KB-1	4.94	1	30	4,200	450	200	99	99	49	490	4.9	4.9	2	4.4	25	2
	KB-2	2.26	.7	23	>2,200	660	180	.9	45	23	45	2.3	9	.9	4.5	23	0
	1	12.10	2.4	73	360	24	85	6.1	24	24	24	12	12	0	0	12	0
47B	Ky-G_2-9-7v	3.20	2.1	130	210	9	8	1.1	4.5	9.6	0	2.6	2.9	1.9	5.4	3.2	3.2
	8	5.08	1	250	150	10	15	3.6	4.6	10	15	1.5	3	2	0	5.1	10

coal from Illinois and its correlative from Kentucky show a similarity in the profiles for different elements only in the sample from Kentucky. In the profile for the sample from locality 51 in Kentucky, only beryllium, tin and yttrium have distribution profiles that differ from other elements. The distribution profile of the sample from locality 53 from the southern part of the region, like the others from Kentucky, shows a large degree of similarity in the distribution of most of the elements except for beryllium, tin, and yttrium. In general, most of the distribution profiles for localities in northern Illinois and Indiana are irregular and show no similarity in the pattern for different elements in the same bed, whereas the profiles from localities in Kentucky and some from southern Illinois show some degree of regularity for different elements in the same profile.

Many of the distribution profiles indicate a tendency for some of the elements to be concentrated at the top and bottom of coal beds. Likewise, there is a tendency for total ash to increase toward the top and bottom of the coal beds. Both relationships probably reflect the greater availability of mineral matter and mineral-rich solutions toward the beginning and end of the interval of accumulation of the plant debris that eventually becomes coal.

We believe that the position of a coal bed relative to the margin or center of the basin of deposition may be a factor in the regularity or lack of regularity in the distribution profile of the different minor elements. Coal near the margin of the basin of deposition may have a heterogeneous vertical distribution of the elements because of the variable conditions of weathering and erosion in the borderland. The environment in the interior of the coal basin is more uniform, and this uniformity is reflected in the similarity of the distribution profiles for different elements. Presumably, northern Illinois was near the margin, and southern Illinois and Kentucky were near the center of the original basin of deposition.

AREAL DISTRIBUTION OF THE MINOR ELEMENTS IN COAL BEDS

In the following discussion of areal distribution, emphasis is placed on the average minor-element content of coal at the 47 more representative localities. The localities of the samples in which each of the 15 minor elements are most concentrated are noted below and in table 10. However, because of insufficient sample density, the areal distribution for individual beds is not evaluated.

TABLE 10.—*List of localities and coal beds with corresponding minor element concentrations*

Locality	Coal bed	Elements concentrated
	Illinois	
1	No. 7	B
3	Herrin (No. 6)	B, Zn
4	do	B
9	do	B, Cu, Ge, Zn, Y
17A	Harrisburg (No. 5)	B, Zn
17B	No. 2	B, Co, Ni, Cu
21	Harrisburg (No. 5)	Cu
24	No. 2	Cu
27	Murphysboro (No. 1)	Co, La, B
28A	DeKoven	Y
28B	Davis	Be, Y, La
	Indiana	
31	No. VII	Be, Ni
32	No. VI	Y
35	No. V	B
37	No. III	Be, Co, Ni
38	Minshall	Y
39	Lower Block	Ti, Co, Y, La, Cu
40	Unnamed	Be, Ti, Ga, Ge, Mo, Y
	Kentucky	
41	No. 14	Sn, Y, B
42A	do	Co, Y
44A	No. 11	Mo
44B	No. 9	Mo
46	do	V, Cr, Ni
47A	do	Ti, Cr
47B	do	Ge, La, B
48	do	Sn, Y, Ga
51	do	V, Mo, Cr, Sn

BERYLLIUM

Individual coal beds containing from 5.1 to 7.6 ppm (parts per million) beryllium occur at localities 28B, 31, 37, and 40, scattered throughout the eastern and southern parts of the region. The ash of these beds contains from 0.009 to 0.018 percent beryllium. An earlier paper (Stadnichenko and others, 1961) discussed the possible source of the beryllium and compared the beryllium content of this region with other regions that were also sampled.

BORON

Concentrations of boron in coal ranging from 149 to 228 ppm were found at localities 1, 3, 4, 9, 17A, 17B, 27, 35, 41, and 47B. The samples from these localities show that boron has a more uniform distribution throughout the region than any other element. Individual beds contain as much as 0.5 percent boron in the ash.

TITANIUM

As much as 1,000 ppm titanium occurs in individual beds of coal at localities 39, 40, and 47A in the eastern and southern part of the region. A concentration of more than 1 percent titanium occurs in the ash of coal beds from a number of other localities, especially in the southeastern part of the region.

VANADIUM

Unusually high concentrations of vanadium occur in coal bed 9 at localities 46 and 51 in Kentucky; here the averages for the bed are 222 and 182 ppm in the coal, respectively. The greatest enrichment occurs at the top of the bed; for example, the upper sample block at locality 46 contains nearly 0.5 percent vanadium in the ash. The same bed also shows an enrichment of vanadium at the top of the bed at localities 7A, 16, 52, and 49 in the southern part of the region.

CHROMIUM

Coal beds containing more than 45 ppm chromium occur at localities 46, 47A, and 51. The highest concentration is at locality 51, with 53.5 ppm chromium in the coal and 0.054 percent in the ash.

COBALT

Coal beds that contain from 10 to 20 ppm cobalt occur at localities 17B, 27, 37, 39, and 42A, widely scattered throughout the region. The ash of these beds contains from about 0.01 to 0.024 percent cobalt.

NICKEL

Coal beds containing more than 30 ppm nickel occur at localities 17B, 31, 37, and 46. At locality 17B, in northern Illinois, the No. 2 coal contains 46 ppm nickel in the coal and 0.1 percent nickel in the ash; the other localities are in Indiana and Kentucky.

COPPER

Coal beds containing about 20 ppm copper or more occur at localities 9, 17B, 21, 24, and 39. At locality 9, in central Illinois, the No. 6 coal contains 41 ppm copper in the coal and 0.05 percent copper in the ash. The next highest average copper content is at locality 24, where the No. 2 coal bed contains less than 25 ppm copper.

ZINC

The highest concentrations of zinc in coal occur at localities 3, 9, and 17A, where the beds contain 597, 268, and 415 ppm zinc respectively. The coal at locality 3 contains 0.78 percent zinc in the ash, about one-tenth the amount contained in an individual block sample from the same locality, which also includes a number of blocks in which zinc is reported to be below the limit of detection.

GALLIUM

The unnamed coal bed at locality 40 in Indiana contains 17.6 ppm gallium in the coal and 0.025 percent gallium in the ash. The next highest concentration is at locality 48, where the coal contains 11.3 ppm gallium. Samples from all other localities contain less than 10 ppm gallium.

GERMANIUM

A concentration of as much as 30 ppm germanium in coal beds occurs only at localities 9, 40, and 47B. The ash of these beds ranges from 0.029 to 0.058 percent germanium. Elsewhere a number of beds contain concentrations of germanium in only the upper or lower block samples, which may have as much as 0.1 percent germanium in the ash.

MOLYBDENUM

Concentrations of more than 10 ppm molybdenum occur at localities 40, 44A, 44B, and 51. The highest concentration is in the No. 11 coal bed at locality 44A, which contains 18 ppm molybdenum in the coal and 0.033 percent molybdenum in the ash. Other localities contain as much as 0.1 percent molybdenum in the ash of individual block samples, especially near the top and bottom of the beds.

TIN

Kentucky localities 41, 48, and 51 contain the highest concentrations of tin, 21.9, 4.5, and 5 ppm tin, respectively. The ash of these same beds contains 0.014, 0.02, and 0.0093 percent tin, respectively.

YTTRIUM

Coal beds with an average of 10 ppm yttrium, or more, occur at localities 9, 28A, 28B, 32, 38, 39, 40, 41, 42A, and 48, of which all but locality 9 are in the southern or eastern part of the region. Locality 40 has the highest concentration: 32.9 ppm in the coal and 0.046 percent in the ash.

LANTHANUM

Samples from localities 27, 28B, 39, and 47B, from widely scattered parts of the region, all contain as much as 10 ppm lanthanum in the coal. The highest concentration is at locality 39, which has 36.2 ppm lanthanum in the coal and 0.036 percent in the ash.

ABUNDANCE OF MINOR ELEMENTS IN COAL FROM THE EASTERN INTERIOR COAL REGION COMPARED WITH OTHER ROCKS

A comparison of the abundance of 15 minor elements in coal from the Eastern Interior coal region with other coal and other rocks is useful in evaluating the significance of the data. For this purpose, we compared the average-abundance data with similar data previously reported from the coal beds of the Northern Great Plains coal province (Zubovic and others, 1961a, p. A31) and with data for other rocks compiled by Turekian and Wedepohl (1961), as shown in table 11. Germanium, molybdenum, chromium, vanadium, and

TABLE 11.—*Comparison of the average abundance of 15 minor elements in coal from the Eastern Interior coal region with other rocks*

[In parts per million]

Element	Average in coal		Other rocks (Turekian and Wedepohl, 1961)	
	Eastern Interior coal region	Northern Great Plains coal province (Zubovic and others, 1961a, p. A31)	Basalt and granite	Shale
Beryllium	2.5	1.5	1-3	3
Boron	96	116	5-10	100
Titanium	450	591	1,200-13,800	4,600
Vanadium	35	16	44-250	130
Chromium	20	7	4.1-170	90
Cobalt	3.8	2.7	1-48	19
Nickel	15	7.2	45-130	68
Copper	11	15	10-87	45
Zinc	44	59	39-105	95
Gallium	4.1	5.5	17	19
Germanium	13	1.6	1.3	1.6
Molybdenum	4.3	1.7	1-1.5	2.6
Tin	1.5	.9	1.5-3	6
Yttrium	7.7	13	21-40	26
Lanthanum	5.1	9.5	15-55	92

nickel are more than twice as abundant in coal from the Eastern Interior coal region as in coal from the Northern Great Plains coal province. Of these, germanium and molybdenum are both more abundant in coal from the Eastern Interior coal region than in shale or the common igneous rocks. Germanium especially appears to be concentrated to a significant degree in the coal, being about 10 times more abundant than in igneous rocks.

MODE OF ORIGIN OF MINOR ELEMENTS IN COAL

Many investigators have studied the occurrence of rare and minor elements in the ash of coal, and many references to the literature are cited in the summary report by Gibson and Selvig (1944). Most of the investigators have commented on the probable mode of origin of various elements, especially the elements that occur in unusually high concentration. Three principal methods of concentration were proposed by Goldschmidt (1950, p. 240), who was one of the pioneers of this work: (1) concentration during the life of the plants, (2) concentration during decay of the organic substances, and (3) concentration by reaction with aqueous solutions after burial under younger sediment. Others have elaborated on these ideas and suggested specific ways of concentration for specific elements. For example, Headlee and Hunter (1951, p. 11–12) suggested that the unusually high concentrations of germanium in certain coal beds probably resulted from introduction after burial.

Our observations on the distribution of minor elements in coal support in general most of the ideas expressed by other investigators. We believe that a certain amount of the elements present in the organic matter of coal were accumulated during growth of the plants. This method was the predominant means of accumulation during the initial phases of the formation of the swamp when plants had their roots in the subsoil. Part of the minor-element content of a large portion of the subsoil could have thus been concentrated in the bottom layers of the coal beds, and the large amounts of the elements generally found in these coal-bed layers could be thus explained.

During the main sequence of organic-matter deposition, the elements brought in solution into the swamps from the borderland probably combine with the decaying organic matter in the swamp to form complexes that are the principal means of accumulation of the elements. The large amounts of some of the elements found at the top of coal beds can be attributed to postburial formation of complexes of the elements with the underlying organic matter. The source of the elements can be either the overlying strata or the eroding borderland. If the borderland was the source the elements could have been carried easily by percolating solutions through the overlying unconsolidated strata into the coal bed.

Accumulation of elements in the major portion of the coal beds excluding the enriched top parts is probably syngenetic with the accumulation of the organic matter.

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