ELEMENT GEOCHEMISTRY OF CHEROKEE GROUP COALS (MIDDLE PENNSYLVANIAN) FROM SOUTH-CENTRAL AND SOUTHEASTERN IOWA

Technical Paper No.5

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1984

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ABSTRACT

Middle Pennsylvanian Cherokee Group coals from south-central and southeastern Iowa are typical high-sulfur, high-ash coals. These coals have an arithmetic mean sulfur content of 5.8 percent and a mean ash content of 15.9 percent. Apparent rank for most samples is high-volatile C bituminous coal. The relatively high contents of sulfur and 23 other elements in Iowa Cherokee Group coals are related to near neutral pH conditions (6-8) in the depositional and early diagenetic environments, and to post-depositional epigenetic sphalerite/calcite/pyrite/kaolinite/barite mineralization. Changes from an aluminosilicate- to a sulfide-element association for U, Mo, Cr, and V, and an increase in element content for U, Mo, Cr, V, Na, Mg, and K in stratigraphically higher coals are thought to be related to differences in depositional environments of the coal-associated rocks, which change from predominantly terrestrial in the Lower Cherokee Group, to predominantly marine in the upper part of the Upper Cherokee Group. Coals overlain by marine, phosphatic, black shale lithologies have the highest content of U, Mo, Ag, Sb, Se, and V.

INTRODUCTION

Pennsylvanian coal-bearing rocks underlie all or parts of 44 counties in southern and western Iowa, an area of approximately 20,000 square miles (Landis and Van Eck, 1965). Identified coal resources, in beds at least 14 inches thick, total about 6.5 billion tons (Landis and Van Eck, 1965). Estimated hypothetical coal resources are an additional 14 billion tons for a total of 20.5 billion tons of identified and hypothetical coal resources (Averitt, 1975).

An essential part of any complete coal-resource evaluation is a chemical characterization of the coal by proximate, ultimate, and minor and trace element analyses. In order to chemically characterize Iowa's coal resources, a cooperative program was initiated in 1973 between the Iowa Geological Survey and the U.S. Geological Survey. From 1973 to 1978, 106 coal samples were collected by the Iowa Geological Survey from drill cores and surface and underground coal mines in 11 south-central and southeastern Iowa counties (figure 1), which incorporates the area of present-day mining. One hundred and five of the 106 coal samples represent beds from the Cherokee Group, (Landis and Van Eck, 1965), (figure 2). One sample (D192373) is from the Marmaton Group. Sample numbers, locations, and descriptive information for the 106 coal samples are listed in table 1. This report lists, statistically summarizes, and briefly discusses the proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, and ash-fusion-temperature determinations, and minor- and trace-element composition of these 106 Iowa coal samples.

Analyses of samples D176169-D176200 have been published in Swanson and others (1976, tables 19A-19E). Ash percent and zinc and cadmium contents in both ash and whole coal for 68 samples (D166027-D166043, D176169-D176200, and D179838-D179856) from this report are also listed and discussed in Hatch, Avcin, and others (1976). Other reports listing elemental analyses of Iowa coals include Zubovic and others (1967, 23 bench samples, 2 locations) and Abernethy and others (1969a and 1969b, 3 samples, 3 locations).

ANALYTICAL METHODS AND RESULTS

Proximate and ultimate analyses, heat-of-combustion, air-dried-loss, forms-of-sulfur, free-swelling-index, and ash-fusion-temperature determinations for 90 coal samples were provided by the U.S. Bureau of Mines (now a part of the U.S. Department of Energy), Pittsburgh, Pennsylvania. Analytical procedures for these analyses are described in U.S. Office of Coal Research (1967). Analyses of 106 Iowa coal samples for ash content, 34 to 36 major and minor oxides and trace elements in the laboratory ash (ashed at 525°C), and 7 trace elements in whole coal were provided by the U.S. Geological Survey, Denver, Colorado. Analytical procedures used by the U.S. Geological Survey are described in Swanson and Huffman (1976). Chemical analyses and physical tests performed by the two laboratories are listed in table 2. The sequence of sample preparation and chemical analyses is shown in figure 3. Table 3 lists the results of the U.S. Bureau of Mines analyses; table 4 the results of the U.S. Geological Survey analyses of coal ash; and table 5 the results of the U.S. Geological Survey analyses of 42 elements in whole coal. Whole-coal data in table 5 for all elements except As, F, Hg, Sb, Se, Th, and U were calculated from analyses of coal ash.

Analytical results from the six-step emission spectrographic technique are identified with geometric brackets whose boundaries are (in ppm) 12, 8.3,

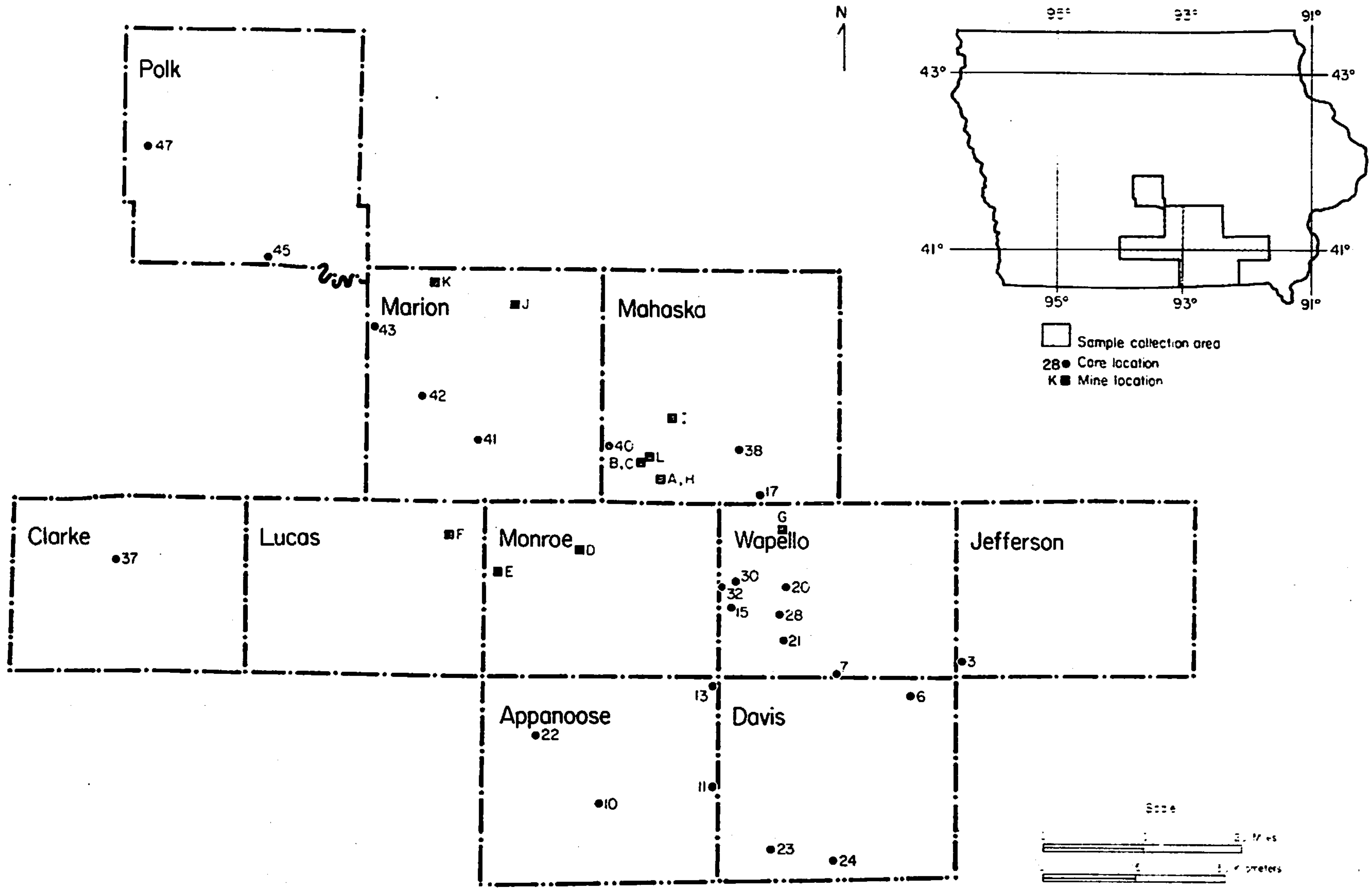

Figure 1. Index map of south-central and southeastern Iowa showing coal sample collection sites.

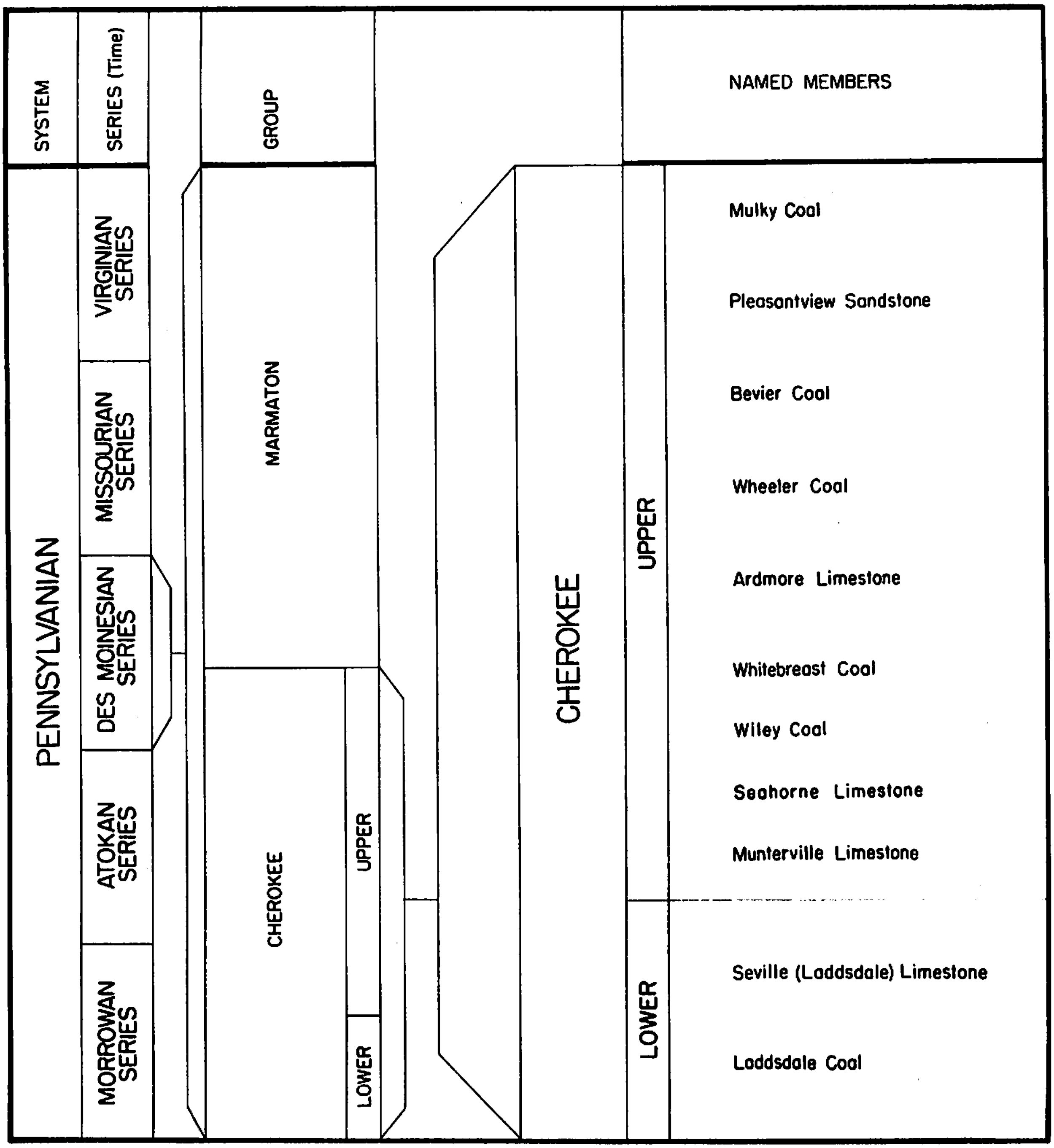

Figure 2. Stratigraphic nomenclature, after Landis and Van Eck (1965).

Table 1. Identification numbers, locations, and brief descriptions of 106 Middle Pennsylvanian coal samples from south-central and southeastern Iowa

[Sample D192373 is from the Marmaton Group; all other samples are from the Cherokee Group. Coal-zone designations are from unpublished Iowa Geological Survey data. -- = not applicable. One foot = 0.305 meters]

U.S. Geological Survey laboratory number	Iowa Geological Survey sample number	U.S. Bureau of Mines laboratory number	Location	Index map key	Sample type	Iowa Geological Survey core-hole number	Depth interval or bed thickness sampled (feet)	Coal zone	Notes
D166027	1-A-73	--	T.74N., R.16W., Mahaska County	A	channel	--	4	4	
D166028	1-B-73	--	---------------do---------------	A	---do--	--	4	4	
D166029	1-D-73	K34084	---------------do---------------	A	run-of-mine	--	4	4	
D166030	2-A-73	--	T.74N., R.17W., Mahaska County	B	channel	--	5	4	
D166031	2-B-73	K34085	---------------do---------------	B	---do--	--	5	4	
D166032	3-A-73	--	---------------do---------------	C	---do--	--	4	4	
D166033	3-B-73	--	---------------do---------------	C	---do--	--	4	4	
D166034	3-D-73	K34086	---------------do---------------	C	run-of-mine	--	4	4	
D166035	4-A-73	--	T.73N., R.18W., Monroe County	D	channel	--	4	4	
D166036	4-B-73	K34087	---------------do---------------	D	---do--	--	4	4	
D166037	5-A-73	K34088	T.72N., R.19W., Monroe County	E	run-of-mine	--	4.5	4	
D166038	5-B-73	--	---------------do---------------	E	---do--	--	4.5	4	
D166039	6-A-73	K34089	T.73N., R.20W., Lucas County	F	---do--	--	4	4	
D166040	6-B-73	--	---------------do---------------	F	---do--	--	4	4	
D166041	7-A-73	--	T.73N., R.15W., Wapello County	G	channel	--	3	3	

Table 1. Identification numbers, locations, and brief descriptions of 106 Middle Pennsylvanian coal samples from south-central and southeastern Iowa--continued

U.S. Geological Survey laboratory number	Iowa Geological Survey sample number	U.S. Bureau of Mines laboratory number	Location	Index map key	Sample type	Iowa Geological Survey core-hole number	Depth interval or bed thickness sampled (feet)	Coal zone	Notes
D166042	7-B-73	--	------------do--------------	G	---do--	--	3	3	
D166043	7-D-73	K34090	------------do--------------	G	run-of-mine	--	3	3	
D176169	CP7-5	K57858	SE,SE,SE, sec. 36, T.71N., R.14W., Wapello County	7	core	CP-7	109.1-110.2	7	
D176170	CP7-15	K57859	------------do--------------	7	-do-	-do-	149.4-150.1	5	
D176171	CP7-22	K57860	------------do--------------	7	-do-	-do-	165.3-165.9	4	
D176172	CP7-26	K57861	------------do--------------	7	-do-	-do-	193.2-194.5	4	
D176173	CP7-30	K57862	------------do--------------	7	-do-	-do-	206.2-207.7	4	
D176174	CP7-35	K57863	------------do--------------	7	-do-	-do-	229.1-234.2	4	
D176175	CP7-37	K57864	------------do--------------	7	-do-	-do-	252.2-253.8	3	
D176176	CP7-46	K57865	------------do--------------	7	-do-	-do-	288.1-289.5	2	
D176177	CP7-50	K57866	------------do--------------	7	-do-	-do-	323.8-324.7	1	
D176178	CP10-26	K61200	SE,SW,SW,SW, sec. 6, T.68N., R.17W., Appanoose County	10	-do-	CP-10	240.1-241.0	9	0.25-foot-thick parting 0.5 foot from top
D176179	CP10-28	K61201	------------do--------------	10	-do-	--do-	253.1-254.3	8	
D176180	CP10-31	K61202	------------do--------------	10	-do-	--do-	279.0-280.2	7	
D176181	CP10-34	K61203	------------do--------------	10	-do-	--do-	306.9-308.7	6	
D176182	CP10-40	K61204	------------do--------------	10	-do-	--do-	361.5-362.3	4	
D176183	CP-10-46	K61205	------------do--------------	10	-do-	--do-	387.7-389.1	4	

Table 1. Identification numbers, locations, and brief descriptions of 106 Middle Pennsylvanian coal samples from south-central and southeastern Iowa--continued

U.S. Geological Survey laboratory number	Iowa Geological Survey sample number	U.S. Bureau of Mines laboratory number	Location	Index map key	Sample type	Iowa Geological Survey core-hole number	Depth interval or bed thickness sampled (feet)	Coal zone	Notes
D176184	CP10-50	K61206	------------do-------------	10	-do-	--do-	406.7-407.4	4	
D176185	CP10-58	K61207	------------do-------------	10	-do-	--do-	425.2-426.0	3	
D176186	CP-10-67	K61208	------------do-------------	10	-do-	--do-	465.9-466.8	1	
D176187	CP17-9	K61209	NE,NE,NW,NW, sec. 34, T.74N. R.25W. Mahaska County	17	-do-	CP-17	138.1-142.8	2	
D176188	CP20-13	K57867	SE,SE,NW, sec. 18, T.72N., R.14W., Wapello County	20	-do-	CP-20	128.6-133.6	2	
D176189	CP21-2	K58854	NW,NW,NW, sec. 18, T.71N., R.14W., Wapello County	21	-do-	CP-21	76.7-79.6	8	0.5-foot-thick parting, 0.3 foot from base; clay dike in upper portion
D176190	CP21-8	K58855	------------do-------------	21	-do-	--do-	131.9-133.3	7	0.5-foot-thick parting 0.25 foot from base
D176191	CP21-14	K58856	-------------do------------	21	-do-	--do-	167.1-167.9	6	
D176192	CP21-18	K58857	-------------do------------	21	-do-	--do-	183.8-186.4	5	
D176193	CP21-20	K58858	-------------do------------	21	-do-	--do-	191.7-195.3	5	0.5-foot-thick parting, 0.9 foot from top; boney below parting
D176194	CP21-22	K58859	-------------do------------	21	-do-	--do-	197.9-199.0	5	0.2-foot-thick parting 0.3 foot from base
D176195	CP21-26	K58860	-------------do------------	21	-do-	--do-	215.7-217.1	4	
D176196	CP21-29	K58861	-------------do------------	21	-do-	--do-	243.8-246.2	4	
D176197	CP21-31	K58862	-------------do------------	21	-do-	--do-	263.0-264.2	4	
D176198	CP21-34	K58863	-------------do------------	21	-do-	--do-	316.0-319.5	3	boney in lower two-thirds

Table 1. Identification numbers, locations, and brief descriptions of 106 Middle Pennsylvanian coal samples from south-central and southeastern Iowa--continued

U.S. Geological Survey laboratory number	Iowa Geological Survey sample number	U.S. Bureau of Mines laboratory number	Location	Index map key	Sample type	Iowa Geological Survey core-hole number	Depth interval or bed thickness sampled (feet)	Coal zone	Notes
D176199	CP21-36	K58864	-----------do-------------	21	-do-	--do-	322.0-326.1	2	
D176200	CP21-40	--	-----------do-------------	21	-do-	--do-	357.9-358.4	1	
D179838	CP24-3	Z-598	NW,NE,SE, sec. 1, T.67N., R.14W., Davis County	24	-do-	CP-24	174.1-176.2	8	
D179839	CP24-5U	--	-----------do-------------	24	-do-	--do-	179.2-179.6	8	
D179840	CP24-5L	Z-599	-----------do-------------	24	-do-	--do-	179.9-181.0	8	
D179841	CP24-17	Z-600	-----------do-------------	24	-do-	--do-	238.6-241.3	6	
D179842	CP24-9	--	-----------do-------------	24	-do-	--do-	210.4-211.0	7	severely disturbed by clay dike
D179843	CP30-7	Z-601	NE,NE,NW, sec. 17, T.72N., R.15W., Wapello County	30	-do-	CP-30	65.7-66.6	4	
D179844	CP30-9	Z-602	-----------do-------------	30	-do-	--do-	78.7-79.5	4	
D179845	CP30-17	--	-----------do-------------	30	-do-	--do-	111.9-112.5	3	
D179846	CP30-20	Z-603	-----------do-------------	30	-do-	--do-	123.7-124.9	2	
D179847	CP32-2	Z-604	SW,SW,SW, sec. 18, T.72N., R.15W., Wapello County	32	-do-	CP-32	24.6-25.7	7	core loss at base, bed may be thicker.
D179848	CP32-6	Z-605	-----------do-------------	32	-do-	--do-	59.2-60.2	6	
D179849	CP32-20	--	-----------do-------------	32	-do-	--do-	117.0-117.4	4	boney
D179850	CP32-28	Z-606	-----------do-------------	32	-do-	--do-	177.5-180.7	2	
D179851	CP28-4	Z-607	NW,SE,NE, sec. 36, T.72N., R.15W., Wapello County	28	-do-	CP-28	55.8-56.9	7	

Table 1. Identification numbers, locations, and brief descriptions of 106 Middle Pennsylvanian coal samples from south-central and southeastern Iowa--continued

U.S. Geological Survey laboratory number	Iowa Geological Survey sample number	U.S. Bureau of Mines laboratory number	Location	Index map key	Sample type	Iowa Geological Survey core-hole number	Depth interval or bed thickness sampled (feet)	Coal zone	Notes
D179852	CP28-11	--	----------do-----------	28	-do-	--do-	96.7-97.5	6	
D179853	CP28-24	Z-608	----------do-----------	28	-do-	--do-	153.7-154.7	4	
D179854	CP28-31	Z-609	----------do-----------	28	-do-	--do-	181.2-184.4	4	two partings 0.1 and 0.3 feet thick in lower half of bed
D179855	CP28-35	Z-610	----------do-----------	28	-do-	--do-	211.4-217.7	3	
D179856	CP28-38	Z-611	----------do-----------	28	-do-	--do-	229.4-231.2	2	0.4-foot-thick parting 0.4 foot from top
D185601	C-AN	K-69871	sec. 24, T.74N., R.17W., Mahaska County	H	channel	--	4.0	4	
D185602	C-AA	K-69872	----------do-----------	H	---do--	--	4.0	4	
D185603	H-B1	K-69873	sec. 19, T.75N., R.16W., Mahaska County	I	---do--	--	2.7	4	
D185604	H-B2	K-69874	----------do-----------	I	---do--	--	2.7	4	
D185605	H-B3	K-69875	----------do-----------	I	---do--	--	2.7	4	
D185606	E-A	K-69876	sec. 21, T.77N., R.19W., Marion County	J	---do--	--	2.2	4	
D185609	E1-A	K-69877	----------do-----------	J	---do--	--	4.0	4	
D185610	E1-B	K-69878	----------do-----------	J	---do--	--	4.0	4	
D185611	D-A	K-69879	sec. 7, T.77N., R.20W., Marion County	K	---do--	--	2.0	4	
D185612	D-B	K-69880	----------do-----------	K	---do--	--	3.5	4	

Table 1. Identification numbers, locations, and brief descriptions of 106 Middle Pennsylvanian coal samples from south-central and southeastern Iowa--continued

U.S. Geological Survey laboratory number	Iowa Geological Survey sample number	U.S. Bureau of Mines laboratory number	Location	Index map key	Sample type	Iowa Geological Survey core-hole number	Depth interval or bed thickness sampled (feet)	Coal zone	Notes
D185613	D-BB	K-69881	------------do-------------	K	---do--	--	3.5	4	
D186062	I-B	K-69959	sec. 21, T.73N., R.20W., Lucas County	F	---do--	--	4.5	4	
D186063	I-C	K-69960	------------do-------------	F	---do--	--	4.5	4	
D186064	I-D	K-69961	------------do-------------	F	---do--	--	4.5	4	
D186065	ST-1	K-69962	sec. 10, T.74N., R.17W., Mahaska County	B	---do--	--	3.7	4	
D186066	EM-1	K-69963	sec. 11, T.74N., R.17W., Mahaska County	L	---do--	--	3.2	3	
D186067	CP3-18	K-69964	SW,SW,SW, sec. 30, T.71N., R.11W., Jefferson County	3	core	CP-3	145.5-147.5	3a	rider coal associated with but not equivalent to coal zone 3
D186068	CP3-21	K-69965	------------do-------------	3	-do-	-do-	162.0-165.0	2	
D186069	CP6-18	K-69966	NW,SW,NW, sec. 8, T.70N., R.12W., Davis County	6	-do-	CP-6	97.5-101.0	4	lower 0.3 foot boney
D186070	CP11-7	K-69967	NW,NW,NE,NE sec. 1, T.68N., R.16W., Appanoose County	11	-do-	CP-11	347.2-351.7	2	1.5-foot-thick coal ball 1.3 feet from top
D186071	CP13-5	K-69968	SE,NE,SE, sec. 1, T.70N., R.16W., Appanoose County	13	-do-	CP-13	264.0-266.7	3	
D186072	CP15-7	K-69969	NE,SE,SE, sec. 30, T.72N., R.15W., Wapello County	15	-do-	CP-15	142.8-146.3	2	upper 0.7 foot boney
D186073	CP20-11	K-69970	SW,SE,NW, sec. 18, T.72N., R.14W., Wapello County	20	-do-	CP-20	115.1-117.3	3	
D186074	CP38-2	K-69971	SW,NW,NE, sec. 5, T.74N., R.15W., Mahaska County	38	-do-	CP-38	82.6-85.0	3	minor sphalerite in cleats

Table 1. Identification numbers, locations, and brief descriptions of 106 Middle Pennsylvanian coal samples from south-central and southeastern Iowa--continued

U.S. Geological Survey laboratory number	Iowa Geological Survey sample number	U.S. Bureau of Mines laboratory number	Location	Index map key	Sample type	Iowa Geological Survey core-hole number	Depth interval or bed thickness sampled (feet)	Coal zone	Notes
D186075	L2-1	K-69972	sec. 8, T.72N., R.19W., Monroe County	E	channel	--	6.2	4	
D186076	L2-3	K-69973	------------do--------------	E	---do--	--	5.8	4	
D192368	CP23-8	K-81517	SE,NE,SE, sec. 36, T.68N., R.15W., Davis County	23	core	CP-23	252.3-254.6	5	contains 0.2 foot thick calcareous pyrite concretion
D192369	CP41-48	K-81518	NE,NE,SE,SW, sec. 36, T.75N. R.20W., Marion County	41	-do-	CP-41	277.5-281.7	3	
D192370	CP41-51	K-81519	------------do--------------	41	-do-	--do-	297.0-299.2	3	
D192371	CP42-19	K-81520	SE,SE,SE, sec. 1, T.75N., R.21W., Marion County	42	-do-	CP-42	105.1-107.2	4	minor sphalerite in cleats
D192372	CP43-18	K-81521	NE,SW,NE, sec. 6, T.76N., R.21W., Marion County	43	-do-	CP-43	203.8-206.8	2	
D192373	CP22-7	K-81522	SE,SW,SE, sec. 36, T.70N., R.19W., Appanoose County	22	-do-	CP-22	138.6-141.0	-	no zone assigned; Mystic Coal, Marmaton Group
D192374	CP22-48	K-81523	------------do--------------	22	-do-	--do-	419.8-422.3	2	large pyrite blebs
D192375	CP37-57	K-81524	NE,SE,NE, sec. 2, T.72N., R.26W., Clarke County	37	-do-	CP-37	436.8-439.8	4	0.3-foot-thick clay parting 1.5 feet below top
D192376	CP37-66	K-81525	------------do--------------	37	-do-	--do-	483.4-486.1	2	minor sphalerite in cleats
D192377	CP45-2	K-81526	NE,NE,NW, sec. 32, T.78N., R.23W., Polk County	45	-do-	CP-45	57.4-59.8	3	0.8-foot-thick boney zone near middle
D192378	CP47-38	K-81527	SE,NE,NE, sec. 4, T.79N., R.25W., Polk County	47	-do-	CP-47	265.5-269.3	2	sphalerite in cleats near bottom
D192379	CP40-8	K-81528	SW,NW,NE, sec. 6, T.74N., R.17W., Mahaska County	40	-do-	CP-40	78.3-81.6	2	lower 0.4 foot boney

Table 2. Analyses and physical tests performed by various laboratories

U.S. Geological Survey	U.S. Bureau of Mines and U.S. Department of Energy
Major and minor elements (percent)[1]	Proximate analysis (percent)
Silicon (Si)	Moisture
Aluminum (Al)	Volatile matter
Calcium (Ca)	Fixed carbon
Magnesium (Mg)	Ash
Sodium (Na)	
Potassium (K)	Ultimate analysis (percent)
Iron (Fe)	
Titanium (Ti)	Hydrogen (H)
Phosphorous (P)	Carbon (C)
Sulfur (S)	Nitrogen (N)
	Oxygen (O)-by difference
Trace elements (ppm)[2]	Sulfur (S)
	Ash
Antimony (Sb)	
Arsenic (As)	Heat of combusion (Btu/lb;cal/kg)
Barium (Ba)	
Beryllium (Be)	Forms of sulfur (percent)
Boron (B)	
Cadmium (Cd)	Sulfate
Cerium (Ce)	Pyritic
Chromium (Cr)	Organic
Cobalt (Co)	
Copper (Cu)	Fusibility of ash (temperature °C)
Fluorine (F)	
Gallium (Ga)	Initial deformation
Germanium (Ge)	Softening
Lanthanum (La)	Fluid
Lead (Pb)	
Lithium (Li)	Free-swelling index
Manganese (Mn)	
Mercury (Hg)	
Molybdenum (Mo)	
Nickel (Ni)	
Niobium (Nb)	
Neodymium (Nd)	
Scandium (Sc)	
Selenium (Se)	
Silver (Ag)	
Strontium (Sr)	
Thorium (Th)	
Uranium (U)	
Vanadium (V)	
Ytterbium (Yb)	
Yttrium (Y)	
Zinc (Zn)	
Zirconium (Zr)	

[1]Reported as oxides in 525°C laboratory ash as well as on a whole-coal basis.
[2]Reported as parts per million in 525°C laboratory ash and (or) on a whole-coal basis.

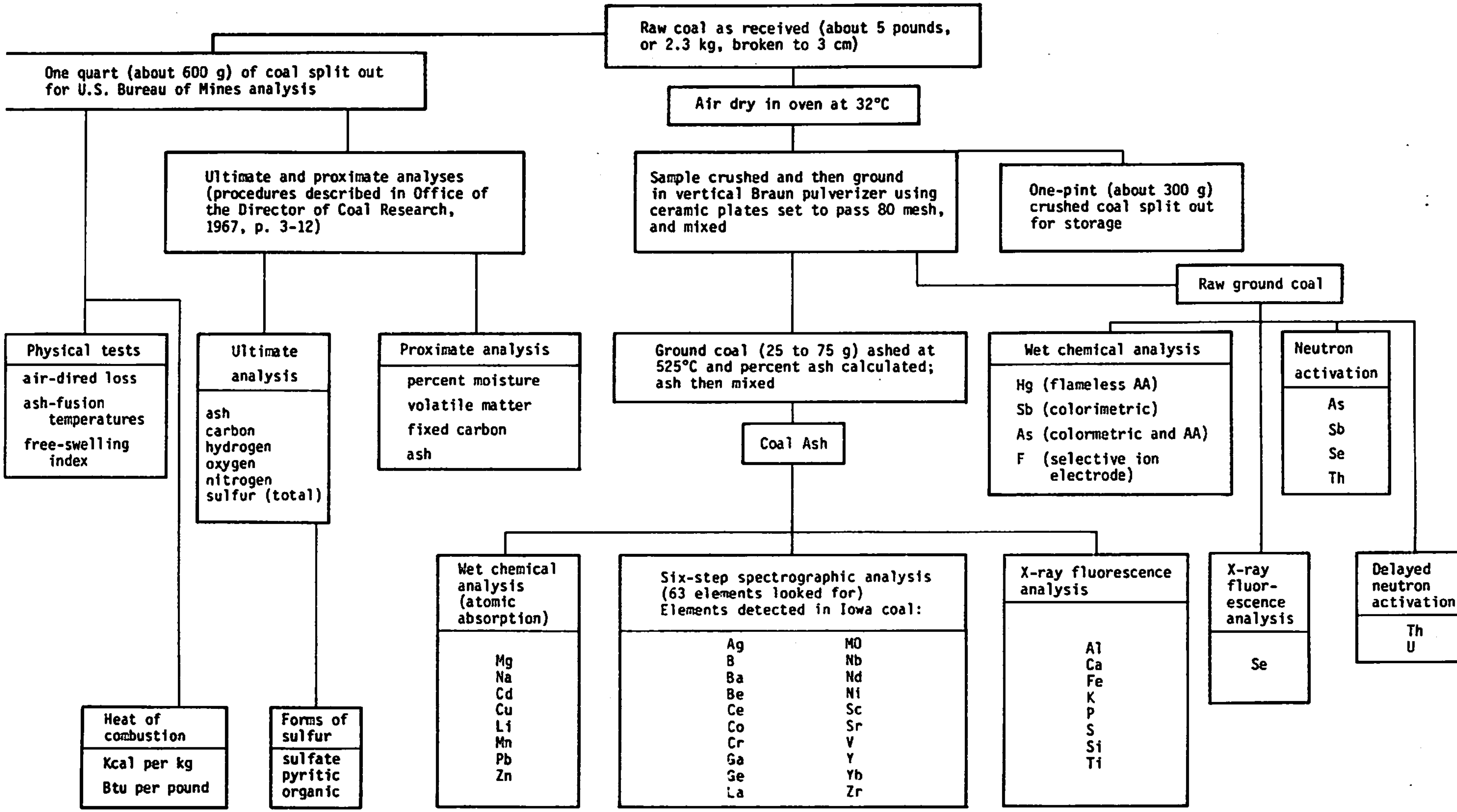

Figure 3. Flow chart showing sequence of sample preparation and chemical analysis. Modified from Swanson and Huttman (1976, figure 1).

5.6, 3.8, 2.6, 1.8, 1.2, etc., but are reported arbitrarily as midpoints of these brackets, i.e. 10, 7, 5, 3, 2, 1.5, 1, etc. The precision of a reported value is approximately plus or minus one bracket at 68 percent confidence, or two brackets at 95 percent confidence.

Twenty-two additional elements not listed in tables 4 and 5 were not found during emission spectrographic analysis. These elements and their lower limits of determination in ppm are: palladium (5); bismuth, indium, and tin (20); gold, holmium, and thulium (50); lutetium (70); dysprosium, erbium, gadolinium, platinum, rhenium, and thallium (100); europium, hafnium, praseodymium, samarium, and tungsten (200); terbium (700); tantalum (1,000); and tellurium (5,000).

Changes in the analytical procedures outlined in figure 3 for phosphorus content in ash, and thorium and arsenic contents in whole coal, result in variable lower-detection limits. Modifications in the analytical technique for determining phosphorus content in ash, as determined by X-ray fluorescence spectroscopy, resulted in a lower-detection limit of 0.04 percent phosphorus (0.1 percent P_2O_5) for samples D166027-D166043 and 0.4 percent phosphorus (1.0 percent P_2O_5) for all other samples. Thorium contents of samples D166027-D166043, D176169-D176200, D179838-D179841, D179844-D179847, D179849, D179850, and D179852-D179856 were determined by delayed-neutron activation analysis with a lower-detection limit of 3.0 ppm; the remaining 42 samples were analyzed by instrumental neutron-activation analysis with a lower-detection limit of 0.1 ppm. Arsenic contents of samples listed in this report were determined by three different analytical methods: samples D166027-D166043 and D176169-D176200 were analyzed spectro-photometrically (lower-detection limit of 1.0 ppm); samples D179838-D179856 were analyzed by the graphite-furnace atomic absorption method (lower-detection limit of 0.5 ppm); and the other 38 samples were analyzed by instrumental neutron activation analysis (lower-detection limit of 0.1 ppm).

Summary Tables

To aid in the statistical comparison of the data, the coal samples were divided into five groups based upon nine palynologically-determined stratigraphically-positioned coal zones (Ravn, 1980, personal communication; Ravn, in press). The first group of samples (15 samples) is from coal-zone 2; the second group (15 samples) is from coal-zone 3; the third group (49 samples) is from coal-zone 4; the fourth group (5 samples) is from coal-zone 5; and the fifth group (16 samples) is from coal-zones 6, 7, 8, and 9. Only five coal zones are equivalent with currently recognized named memebers. Coal-zones 1, 2, and 3 occur stratigraphically below the Laddsdale coal. Coal-zone 4 is equivalent to most historical references to the Laddsdale Coal (Howes, 1981, personal communication). Coal-zone 5 occurs above the Laddsdale Coal and below the Wiley Coal. Coal-zones 6, 7, 8, and 9 are equivalent, respectively, to the currently named coal beds: the Wiley Coal, the Whitebreast Coal, the Wheeler Coal, and the Bevier Coal (Ravn, 1980, personal communication). Statistical summaries were not made for the Mystic Coal, in the Marmaton Group, the coal associated with coal-zone 3, sample D186067, and coal-zone 1 because of the limited number of samples (one, one, and three respectively) available. Sample D179842 (zone 7) was not included in the summaries because it contained 68.8 percent ash and is a coaly shale.

Unweighted statistical summaries for coal-zone-2 samples are listed in tables 6 and 7; coal-zone-3 samples, tables 8 and 9; coal-zone-4 samples, tables 10 and 11; coal-zone-5 samples, tables 12 and 13; coal-zones 6, 7, 8, and 9, tables 14 and 15; and for 105 Cherokee Group coal samples from Iowa, tables 16 and 17. The number of U.S. Bureau of Mines analyses summarized for each coal zone is less than the number of U.S. Geological Survey analyses, because not every sample was sent to the U.S Bureau of Mines and because of sampling problems discussed later in the section on Apparent Rank.

For comparison with the Iowa Cherokee Group coals, statistical summaries of analyses for 114 Pennsylvanian coal samples from the Eastern Interior coal region (Illinois Basin) from Gluskoter and others (1977), and summaries of analyses of 63 Upper Cretaceous Williams Fork Formation coal samples from the Yampa field, Routt and Moffat Counties, Colorado from Hildebrand and others (1981) are listed in tables 18-19 and 20-21 respectively. These analyses are from coals of about the same rank as the Iowa coals. Similar rank coals were selected for comparison because element composition of coal, particularly for lower rank coals, varies with rank (Hildebrand and Hatch, 1977). Illinois Basin coal data summarized in tables 18 and 19 primarily represent samples of the Harrisburg (No. 5) coal (32 samples) and Herrin (No. 6) coal (49 samples) that were collected almost exclusively from operating coal mines (105 of 114 samples). Consequently, the statistics for the Illinois Basin samples are biased toward the thicker, better quality (lower ash and lower sulfur contents) coals of the Illinois Basin and are not strictly comparable to the statistics for the Cherokee Group sample set. A more serious source of disparity between the Iowa Cherokee Group and Illinois Basin sample sets results from the exclusion of all mineral bands, partings, and nodules more than one centimeter (3/8 inch) thick during collection of the Illinois Basin samples. This sampling procedure results in an underestimation of ash and sulfur contents and an overestimation of the heat of combustion (Btu/lb) of the samples relative to the in-place coal.

Statistical Methods

In tables 6-21, the geometric mean (GM) is used as the estimate of the most probable element content (mode); the geometric mean is calculated by taking the logarithm of each analytical value, summing the logarithms, dividing the sum by the total number of values, and obtaining the antilogarithm of the result. The measure of scatter about the mode used in this report is the geometric deviation (GD), which is the antilog of the standard deviation of the logarithms of the analytical values. These statistics are used because the quantities of trace elements in natural materials commonly exhibit positively skewed frequency distributions; such distributions are normalized by analyzing and summarizing trace-element data on a logarithmic basis.

If the frequency distributions are lognormal, the geometric mean is the best estimate of the mode, and the estimated range of the central two-thirds of the observed distribution has a lower limit equal to GM/GD and an upper limit equal to GMxGD. The estimated range of the central 95 percent of the observed distribution has a lower limit equal to $GM/(GD)^2$ and an upper limit equal to $GM \times (GD)^2$ (Connor and others, 1976).

Although the geometric mean is, in general, an adequate estimate of the most common analytical value, it is, nevertheless, a biased estimate of the arithmetic mean. The estimates of the arithmetic means as listed in the summary tables are Sichel's <u>t</u> statistic (Miesch, 1967).

A common problem in statistical summaries of trace-element data arises when the element content of one or more of the samples is below the limit of analytical determination. This circumstance, which occurs for 14 elements listed in the summary tables, is called a "censored" distribution. Procedures developed by Cohen (1959) were used to compute unbiased estimates of the geometric mean, geometric deviation, and arithmetic mean when the data are "censored."

To be consistent with the precision of the semiquantitative emission spectrographic technique, arithmetic and geometric means of elements determined by this method were reported as the midpoint of the enclosing six-step brackets.

Data summaries for phosphorus and cerium contents were not included in any of the summary tables because these elements were detected in too few samples to calculate meaningful statistics. For the same reason, summaries of silver and niobium contents in tables 7, 9, 11, and 13, neodymium content in tables 9, 11, 13, 15, and 17, lanthanum content in tables 11, 13, and 15, and ytterbium content in tables 7, 9, 11, 13, and 17 were also omitted.

DISCUSSION OF RESULTS

Apparent Rank

The apparent rank of each of the 90 coal samples from south-central and southeastern Iowa was calculated using the data in table 3, and the approximation to the Parr formula and classifications in ASTM designation D-388-77 (American Society for Testing and Materials, 1978). The ASTM classification scheme is reproduced in table 22. The apparent ranks range from subbituminous B coal (1 sample) through subbituminous A coal (5 samples), high-volatile C bituminous coal (68 samples), high-volatile B bituminous coal (15 samples), to high-volatile A bituminous coal (1 sample).

The single sample of subbituminous B rank (D185606) was from a shallow surface mine; the coal at that location has probably been slightly weathered. At the other end of the distribution, the high-volatile-A-bituminous-coal sample (D186069), 12 of 14 high-volatile-B-bituminous-coal samples, and 11 samples from the higher end of high-volatile-C-bituminous-coal range are from core holes CP3, CP6, CP7, CP10, CP11, CP13, and CP15. These 24 samples were collected early in the project and were apparently allowed to dry out before bagging, resulting in low moisture contents and erroneously high apparent ranks. This conclusion is based on data from Neely H. Bostick (written communication, 1982) who found no significant difference in average vitrinite reflectance (R_0), a second measure of coal rank, in samples from these seven core holes when compared to samples collected later in the study. The relationship between moist, mineral-matter-free (mmmf) Btu/lb and apparent rank for the remaining 65 Iowa coal samples is shown in figure 4.

Average Btu/lb (mmmf) for coal-zones 2, 3, 4, 5, and 6-9 are very similar (table 23), ranging from 11,820 Btu/lb for coal zone 5 to 12,110 Btu/lb for coal-zone 4. Average heat of combustion for 65 Iowa Cherokee Group coal samples is 12,040 Btu/lb (mmmf), and is similar to the heat of combustion of samples from the Yampa Field (11,910 Btu/lb, mmmf). Both sets have an average apparent rank of high-volatile C bituminous coal. Average heat of combustion for the Illinois Basin samples is higher (12,990 Btu/lb) reflecting a slightly higher average apparent rank (high-volatile C to high-volatile B bituminous coal).

Proximate, Ultimate, and Related Analyses

Arithmetic means and ranges (as-received basis) of the proximate and ultimate analyses, heat-of-combustion,

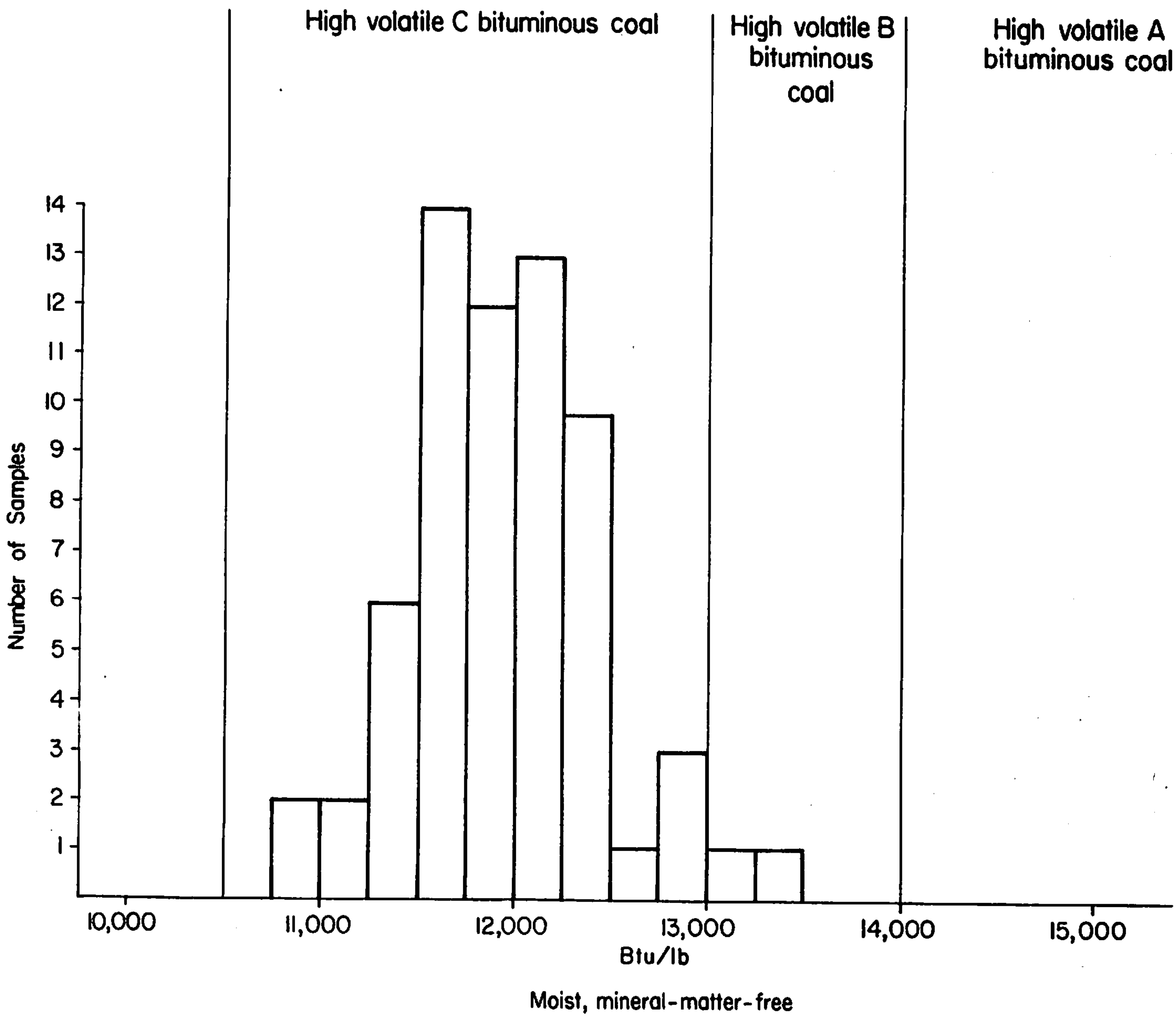

Figure 4. Distribution of moist, mineral-matter-free Btu/lb in coal samples from south-central and southeastern Iowa.

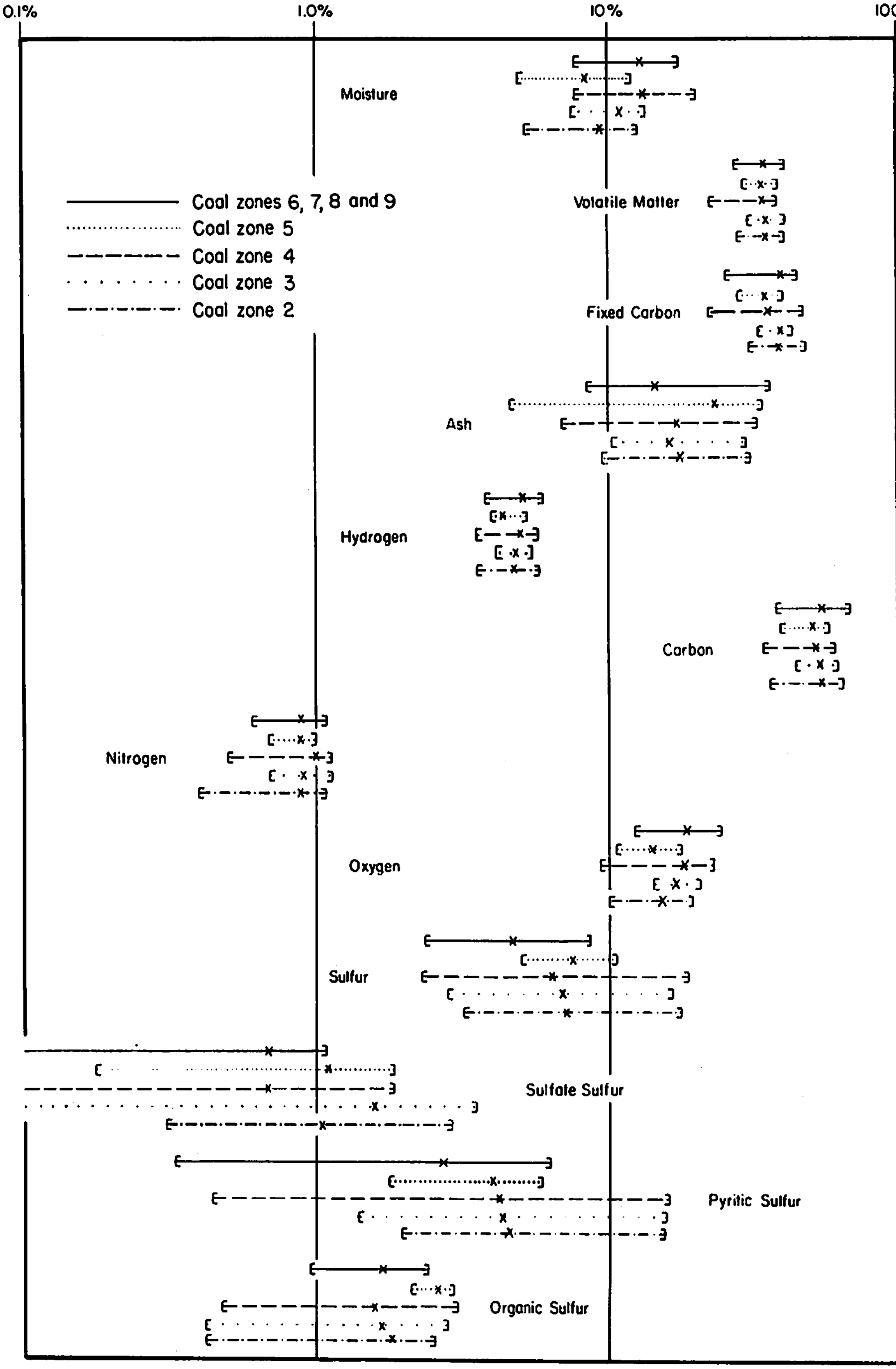

Figure 5. Arithmetic means (*) and ranges [---] of proximate and ultimate analyses and forms of sulfur (as-received basis) for Iowa Cherokee Group coal samples from coal-zones 2, 3, 4, 5, and 6-9.

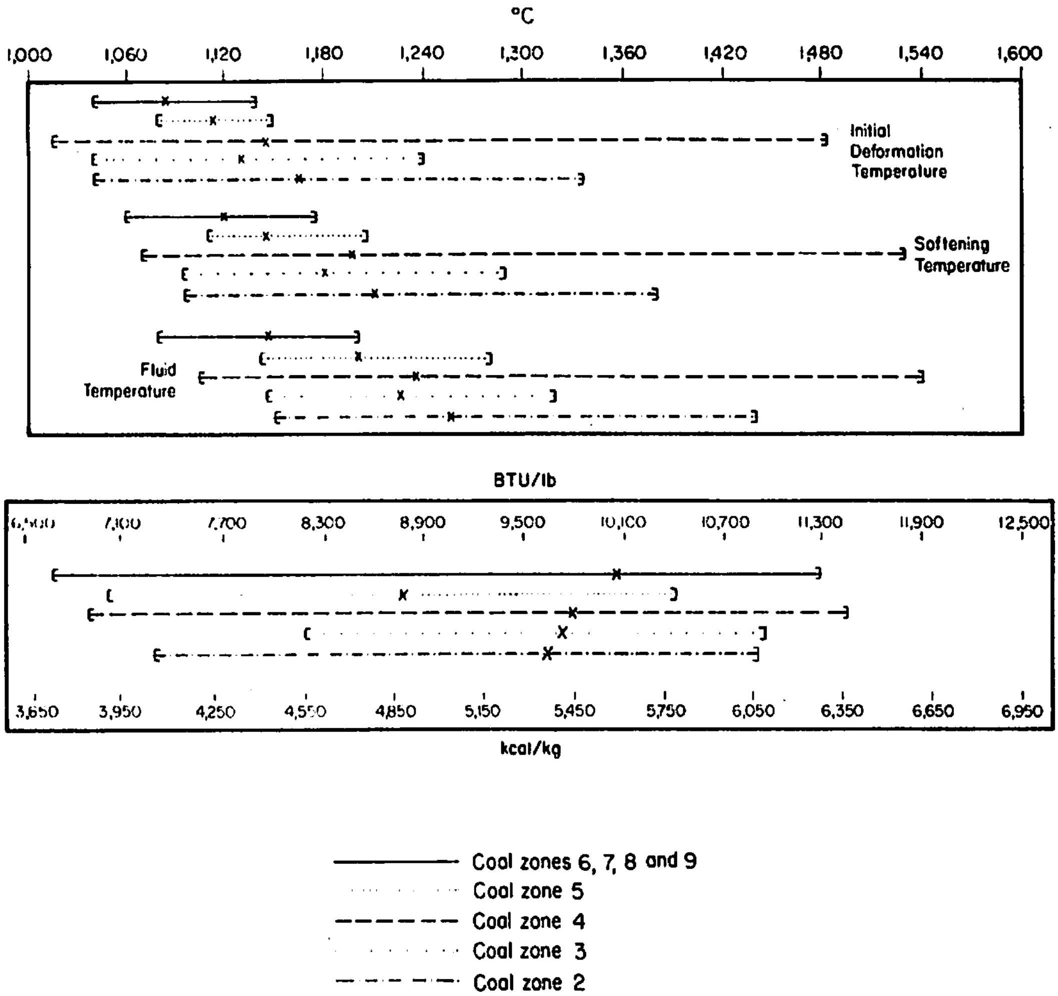

Figure 6. Arithmetic means (*) and ranges [---] of ash-fusion temperature and heats of combustion (as-received basis) for Iowa Cherokee Group coal samples from coal-zones 2, 3, 4, 5, and 6-9.

forms-of-sulfur, and ash-fusion-temperature data for samples from coal-zones 2, 3, 4, 5, and 6-9 are shown in figures 5 and 6. Statistical comparisons (Student's t test, 95 percent confidence level) of the means from the different Cherokee Group coal zones show two significant differences: a) zone 5 coals have the highest ash and organic-sulfur contents and the lowest heats of combustion, and b) ash-fusion temperatures decrease significantly from zone 2 through zones 6-9. For the other analyses, average composition of coals from one zone may be significantly higher or lower than those from a second zone, but may be similar to the analyses of a third zone. For example, mean sulfur content of zones 6-9 is significantly lower than mean sulfur contents of zones 2 and 5, but is statistically similar to the mean sulfur contents of zones 3 and 4.

Arithmetic means and ranges of the proximate and ultimate analyses, heat-of-combustion, and forms-of-sulfur data for the Iowa Cherokee Group, Illinois Basin, and Yampa field sample sets are shown in figures 7 and 8. A strict statistical comparison of these three data sets is not possible because of a lack of standard deviations for the Iowa Cherokee Group and Yampa field

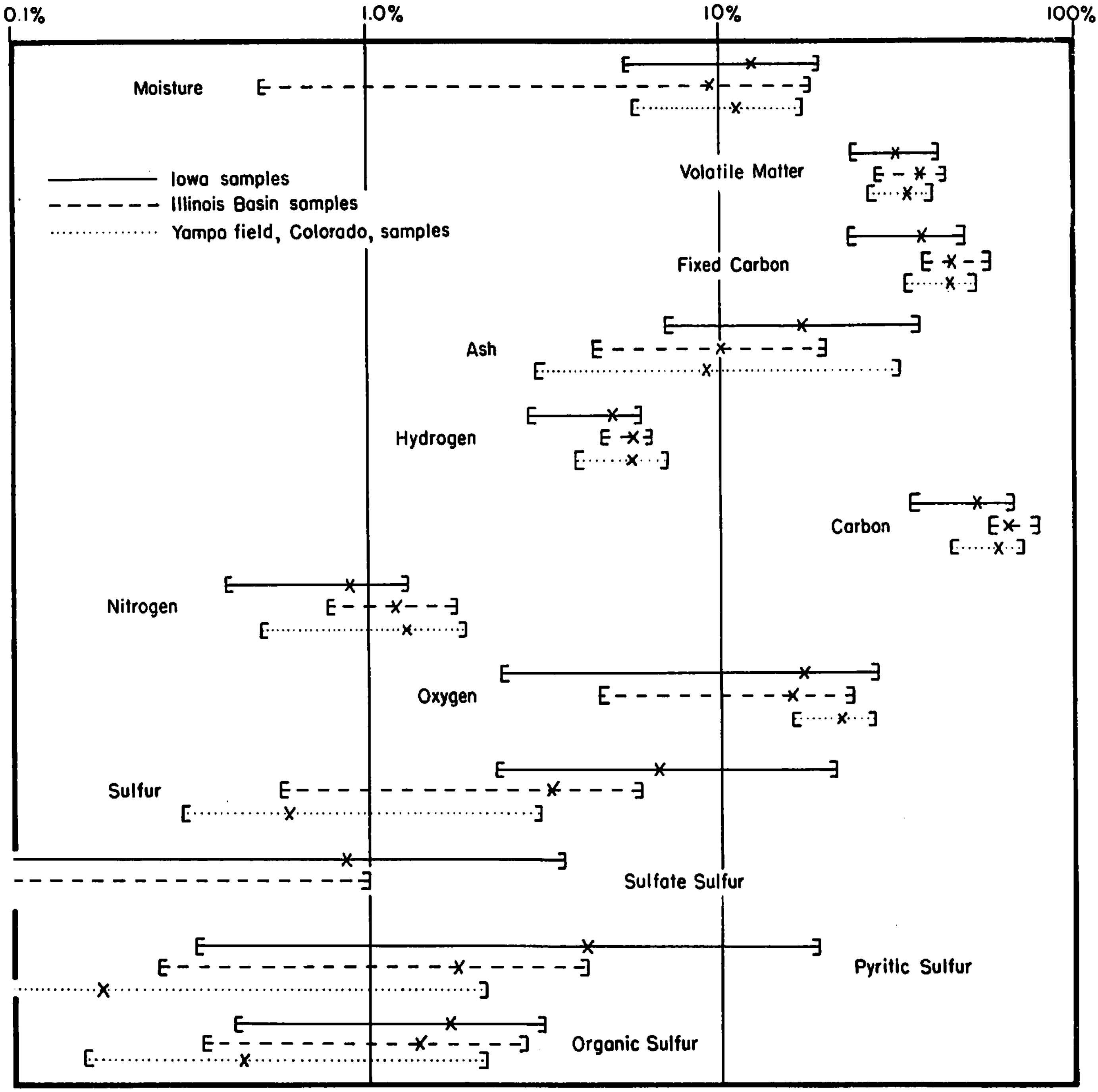

Figure 7. Arithmetic means (*) and ranges [---] of proximate and ultimate analyses and forms of sulfur (as-received basis) for 65 Iowa Cherokee Group coal samples, 114 Illinois Basin coal samples, and 44 Yampa field, Colorado coal samples. [Illinois Basin data are from Gluskoter and others (1977, table 8). Yampa Field data are from Hildebrand and others (1981, table 7a).]

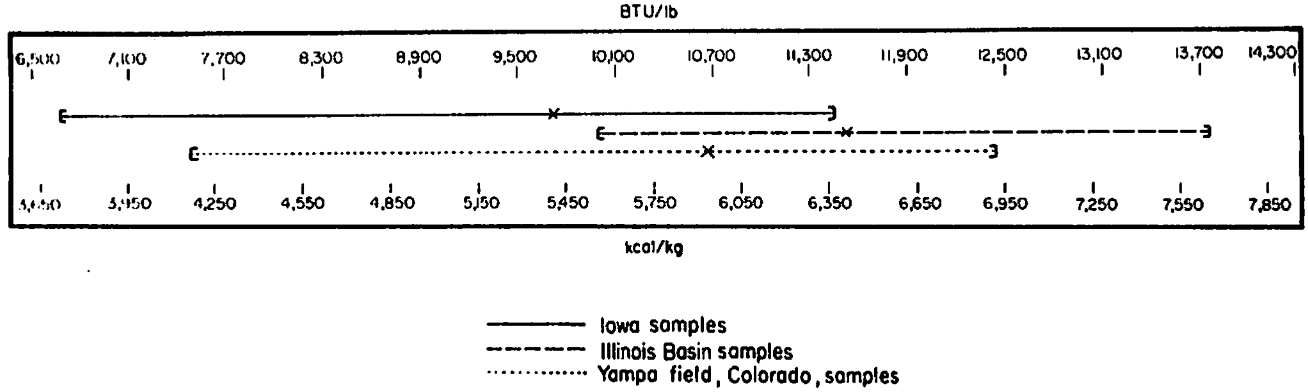

Figure 8. Arithmetic means (*) and ranges [---] of heats of combustion (as-received basis) for 65 Iowa Cherokee Group coal samples, 114 Illinois Basin coal samples, and 44 Yampa field, Colorado, coal samples. [Illinois Basin data are from Gluskoter and others (1977, table 8); Yampa field data are from Hildebrand and others (1981, table 7a).]

sets and sampling biases previously discussed. However, the information listed in tables 16, 18, and 20 and illustrated in figures 7 and 8 shows that Iowa Cherokee Group coals probably have lower nitrogen, fixed-carbon, carbon, and hydrogen contents; higher ash, and total-, sulfate-, and pyritic-sulfur contents, and a lower heat of combustion. Illinois Basin coals have lower moisture contents, higher volatile matter and carbon contents, and a higher heat of combustion. The Yampa field samples have higher oxygen and oxygen/carbon mole ratios (moisture-free basis, table 23) and much lower total-, sulfate-, pyritic-, and organic-sulfur contents. Hydrogen/carbon mole ratios (moisture-free basis, table 23) for the Iowa Cherokee Group, Illinois Basin, and Yampa field sample sets are similar.

The lower oxygen/carbon mole ratios for the high-sulfur coals probably resulted from greater bacterial activity in the peat swamps that produced the high-sulfur coals. Because bacteria utilize oxygen-rich organic components (for example, cellulose or lignin) more easily than more hydrogen-rich components (for example, cuticles, spore and pollen exines, waxes and resins) (Waksman and Stevens, 1928), increased bacterial activity would result in a depletion of oxygen-rich organic matter and decreased oxygen/carbon mole ratios.

Differences in ash and total-, sulfate, and pyritic-sulfur contents between Iowa Cherokee Group and Illinois Basin coals result in part from the sampling biases discussed earlier (core and mine samples of Iowa coal versus mine samples for Illinois coal). Differences between Iowa Cherokee Group, Illinois, and Yampa field coals in moisture and carbon contents and heat of combustion are probably due to the minor differences in thermal maturity.

Element Analyses

Geometric means and ranges for the contents of 35 elements in coal samples from coal-zones 2, 3, 4, 5, and 6-9 are shown in figure 9. Statistical comparisons (Student's _t_ test, 95 percent confidence) of the summary data from the different coal zones show few significant differences. One significant difference, however, is that the contents of nine elements (Na, Mg, K, As, Mn, Mo, Sb, U, and V) increase from coal-zone 2 through coal-zones 6-9.

Geometric means and ranges for the contents of 34 elements in the Iowa, Cherokee Group, Illinois Basin, and Yampa field sample sets are shown in

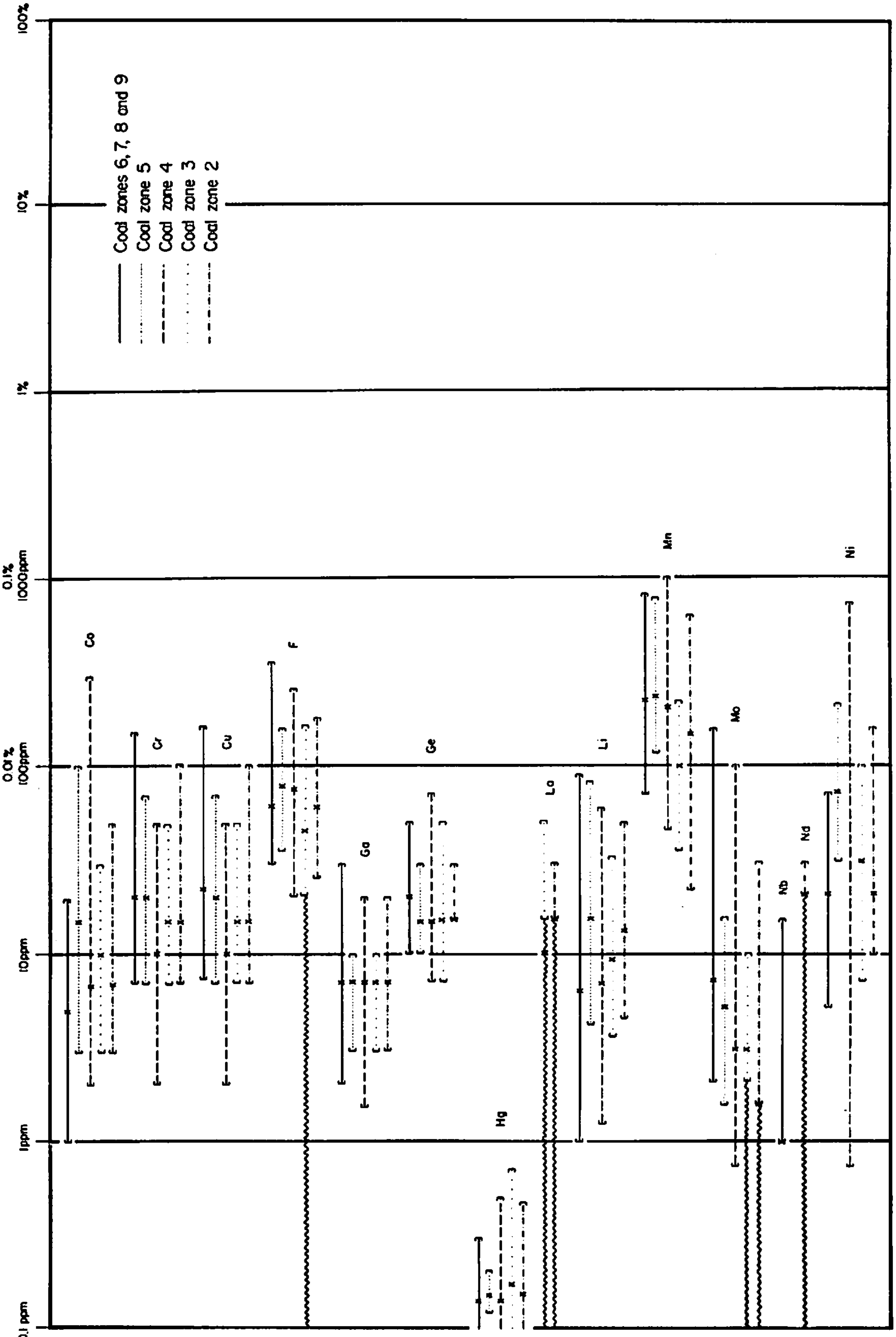

Figure 9. Geometric means (*) and ranges [---] for contents of 40 elements (air-dried, whole-coal basis) in Iowa Cherokee Group coal samples from coal-zones 2, 3, 4, 5, and 6-9. Wavy lines to the left of the range brackets for Cd, F, La, Mo, Nd, Sb, Se, Th, and U indicate data that are less than the lower-detection limit.

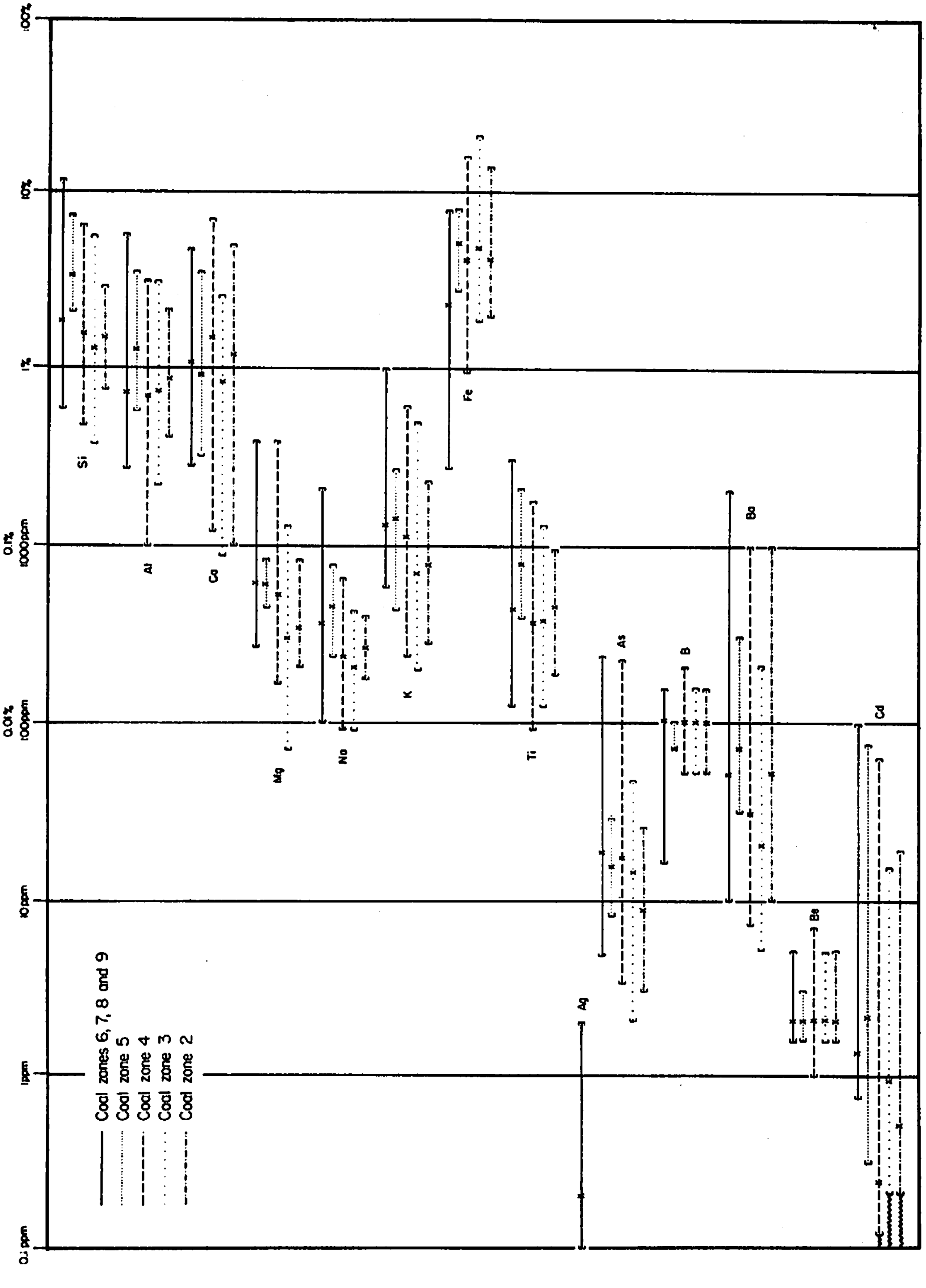

Figure 9. Geometric means (*) and ranges [---] for contents of 40 elements (air-dried, whole-coal basis) in Iowa Cherokee Group coal samples from coal-zones 2, 3, 4, 5, and 6-9--continued.

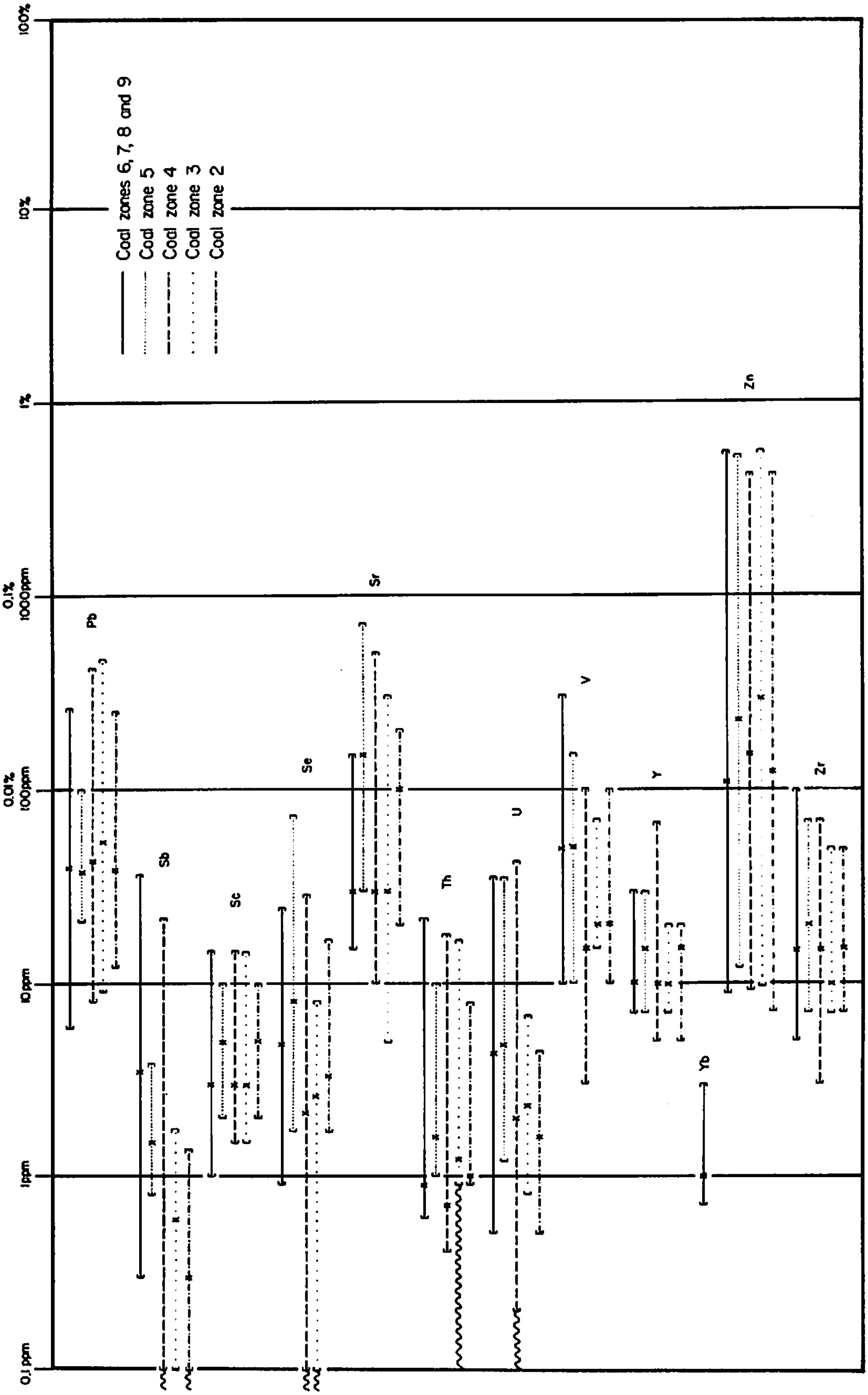

Figure 9. Geometric means (*) and ranges [---] for contents of 40 elements (air-dried, whole-coal basis) in Iowa Cherokee Group coal samples from coal-zones 2, 3, 4, 5, and 6-9--continued.

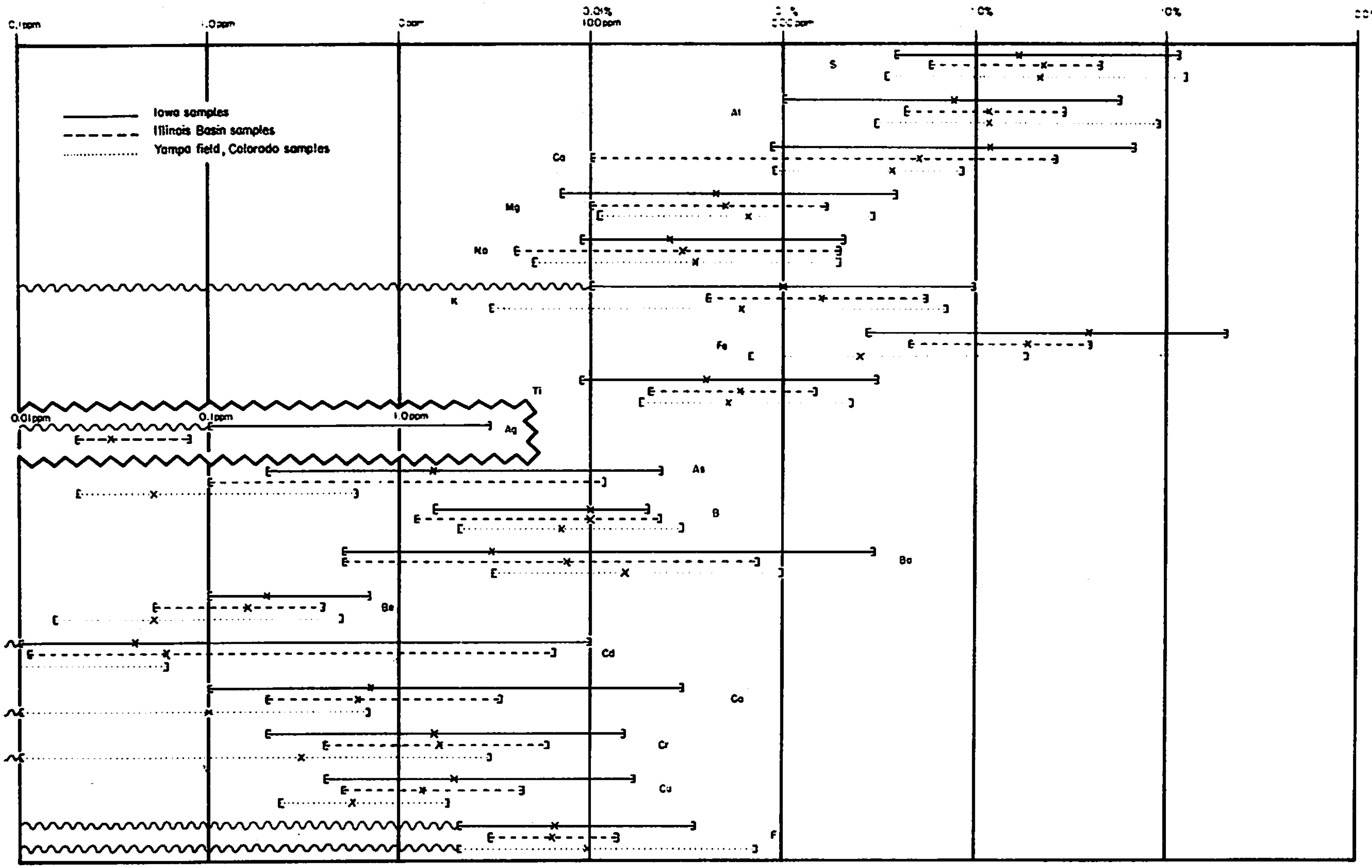

Figure 10. Geometric means (*) and ranges [---] for contents of 38 elements (whole-coal basis) in 105 Iowa Cherokee Group coal samples, 114 Illinois Basin coal samples, and 63 Yampa field coal samples. Iowa and Yampa field data are on an air-dried basis, Illinois Basin data are on a moisture-free basis. Illinois Basin data are from Gluskoter and others (1977, table 8); Yampa field data are from Hildebrand and others (1981, table 9a). Wavy lines to the left of the range brackets for K, Ag, Cd, Co, Cr, F, La, Mo, Nb, Pb, Sb, Sc, Se, Sr, Th, and U indicate data that are less than the lower-detection limit. Illinois Basin data summaries for La, Li, Nb, and Y are not available; Yampa field data summaries for Ag, Ge, and La are not available.

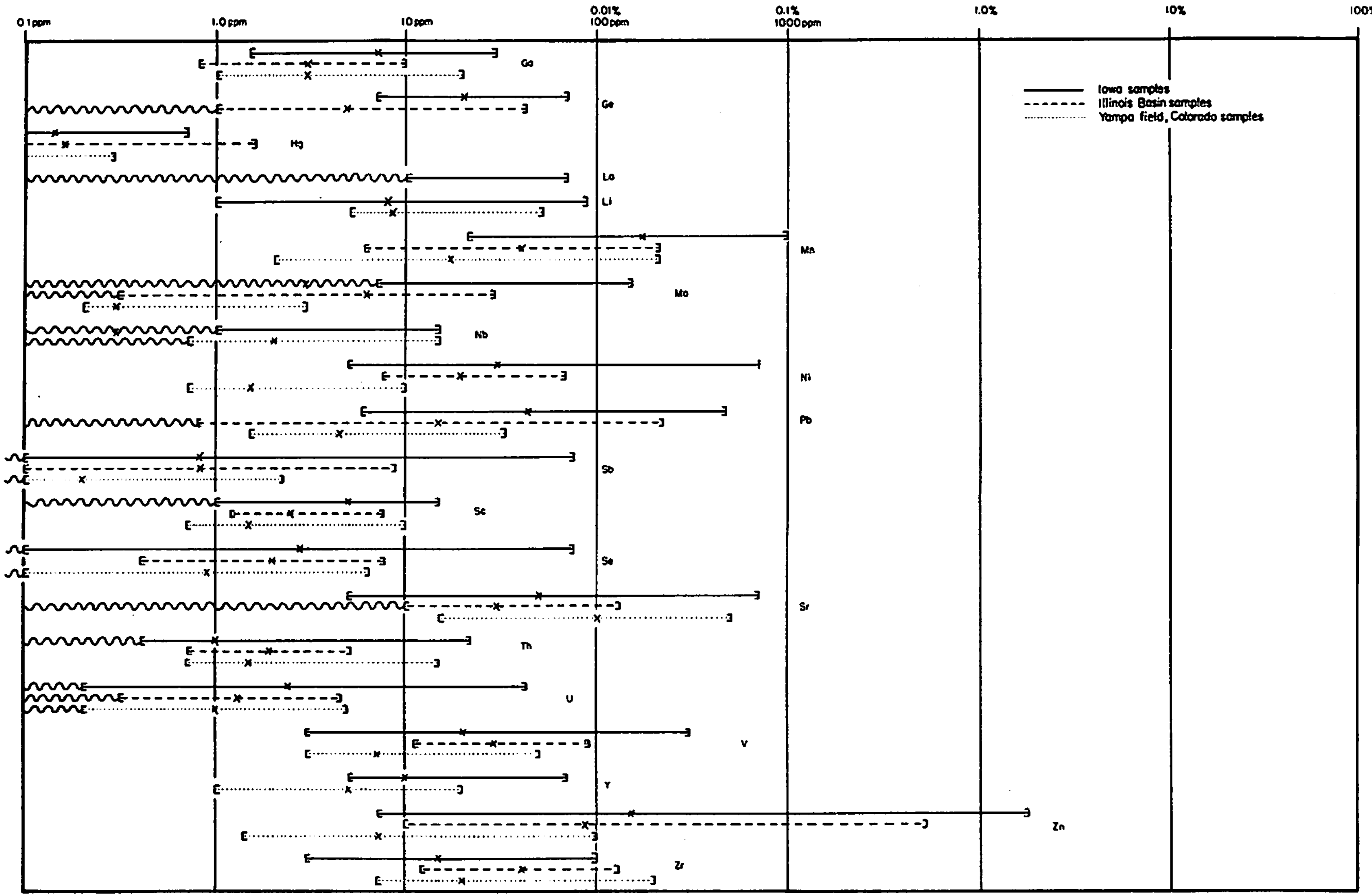

Figure 10. Geometric means (*) and ranges [---] for contents of 38 elements (whole-coal basis) in 105 Iowa Cherokee Group coal samples, 114 Illinois Basin coal samples, and 63 Yampa field coal samples--continued.

figure 10. The information listed in tables 17, 19, and 21 and illustrated in figure 10 shows that the contents of at least 16 elements are directly related to sulfur content of the coals. Of the three sample sets, Iowa Cherokee Group coals have the highest mean sulfur content (5.8 percent), Illinois Basin coals an intermediate content (3.1 percent), and Yampa field coals the lowest sulfur content (0.6 percent). Iowa Cherokee Group coal has the highest content of Ca, Fe, Ag, As, Be, Co, Cu, Ge, Mn, Ni, Pb, Sc, Se, U, Y, and Zn; Illinos coal has an intermediate content of these elements; and Yampa field coal has the lowest content of these elements. The low-sulfur Yampa field coal also has significantly lower mean contents of K, Cd, Cr, Hg, Mo, Sb, and V than the relatively high-sulfur Iowa Cherokee Group and Illinois Basin coals.

Element distributions in coals are controlled by many factors, including provenance, geochemical conditions (pH, Eh, salinity) of the depositional and early diagenetic environments, thermal maturity (rank), groundwater composition, and nature and intensity of any epigenetic mineralization (Hatch, A, in press). According to Cecil and others (1982) the most important geochemical parameter during deposition and early diagenesis is the pH of waters in the peat swamp. Under low-pH conditions (3-4.5), solution of most metal ions is favored and the activity of sulfate-reducing bacteria is minimal; the resulting peat has low sulfur and metal contents. The activity of sulfate-reducing bacteria reaches a maximum when pH conditions are near neutral (6-8) (Baas Becking and others, 1960).

A strong relationship exists between sulfur content in coals and $CaCO_3$ content of associated rocks (Cecil and others, 1982). Lack of carbonate rocks would indicate minimal carbonate buffering of depositional and early diagenetic connate waters, resulting in relatively low-pH conditions (3-4.5); presence of carbonates and calcareous shales would indicate relatively high-pH conditions (6-8). Iowa Cherokee Group and Illinois Basin coals are associated with carbonates and have high sulfur contents. In contrast, Yampa field coals have low sulfur contents and are associated with noncalcareous rocks.

Elements whose contents are significantly higher in the high-sulfur sample sets may be fixed by a variety of processes: (1) they form highly insoluble sulfides (Fe, Ag, As, Cd, Co, Cu, Hg, Ni, Sb, and Zn); (2) they are included in minerals that form at (or are less readily leached at) near-neutral pH's (Ca and Mn carbonates, Sc and Th phosphates, and K and Ca in illite or smectite clays); or (3) they have multiple valence states (Fe, S, U, Se, Mo, Ge, Cr, V, and Be), and may be fixed in the coal during the peat stage or subsequent stages of coalification through reduction of the element by reaction with H_2S or other reactive sulfur species, and may subsequently be incorporated into stable organic or mineral phases. Except for chromium, the elements listed in (3) are also the same elements enriched in roll-type uranium deposits (Harshman, 1974), suggesting that similar geochemical processes are operating in both environments (Hatch, B, in press).

Correlation Analyses

Correlation coefficients relating the variability of each parameter with the variability of every other parameter were calculated from the element data for coal-zones 2, 3, 4, 5, and 6-9. Geochemical associations of some elements are apparent from these correlation coefficients.

(1) In all five coal groups there are strong positive correlation coefficients ($\geq$0.89) between zinc and

cadmium. In Iowa coals, zinc occurs as sphalerite (ZnS) that is found along cleats and fractures in the coal, and is associated with pyrite, calcite, kaolinite, and barite (Hatch, Avcin, and others, 1976). In similar occurrences in Illinois Basin coals, cadmium is found in solid solution with zinc in the sphalerite (Gluskoter and Lindahl, 1973, and Hatch, Gluskoter and Lindahl, 1976). The strong positive correlation coefficients for Iowa Cherokee Group coals suggest a similar relationship. Similar high zinc:cadmium correlation coefficients were found for Missouri coals by Wedge and Hatch (1980). These occurrences of sphalerite and associated minerals have been interpreted by Hatch, Gluskoter, and Lindahl (1976) to represent post-depositional, epigenetic mineralization of the coals.

The zinc and cadmium contents of Iowa Cherokee Group coal samples are as much as 18,000 and 100 ppm, respectively, and have arithmetic means of 1,100 and 18 ppm, respectively. Most zinc and cadmium could be removed and recovered from the coals by conventional washing techniques (Hatch, Gluskoter, and Lindahl, 1976).

An apparent zoning of zinc/cadmium molecular ratios was noted in five cores (CP-7, CP-10, CP-21, CP-28, and CP-32) from Wapello and Appanoose Counties by Hatch, Avcin, and others (1976). The data listed in table 24 and illustrated in figure 11 show that cadmium is enriched relative to zinc in the stratigraphically higher coals, indicating a chemical differentiation of the solutions from which the sphalerite and associated minerals were precipitated.

(2) In all five coal groups, calcium and manganese have high positive correlation coefficients (0.6 to 0.9); manganese does not correlate well with any other element. Because manganese commonly substitutes for calcium in calcite ($CaCO_3$), it is presumed to occur in calcite in Iowa Cherokee Group coals. Similar associations were found in Illinois Basin coals by Gluskoter and others (1977) and in Missouri coals by Wedge and Hatch (1980). Abundant calcite occurs in cleats and fractures in Iowa Cherokee Group coals and is thought to have been deposited during the sphalerite mineralization process.

(3) In all five coal groups, elements that generally occur in sedimentary rocks as aluminosilicate minerals (Al, Si, Mg, K, Li, and Zr) or as resistant oxides or phosphates (Ti, Th, Sc, and La) have mutually positive correlation coefficients (0.6 to 0.9) suggesting a detrital origin (water or wind transported). In coal-zones 2, 3, and 4, Cr, Mo, U, and V are positively correlated (0.5 to 0.7) to this element assemblage as are Na and Y (correlation coefficients 0.7 to 0.9) in coal-zones 5 and 6-9.

(4) In all five coal groups, Fe, As, Hg, and Sb have mutually high positive correlation coefficients (0.6 to 0.9). Most of the iron is probably present in the coals as pyrite (FeS_2). The other three elements are commonly found in nature as sulfides and are presumably associated with the pyrites. In coal-zones 2, 3, and 4, Cu, Pb, Co, and Ni are positively correlated (0.5 to 0.9) with the Fe, As, Hg, and Sb assemblage of elements; in coal-zones 5 and 6-9, U, Se, Mo, Cr, and V are positively correlated (0.6 to 0.9) with this assemblage.

The changes in element association of U, Mo, Cr, and V from an aluminosilicate assemblage in the lower part of the section (coal-zones 2, 3, and 4) to a sulfide assemblage in the upper part of the section (coal-zones 5 and 6-9), are related to the increases in mean element content with higher stratigraphic position (illustrated in figure 9). With higher stratigraphic position Na, Mg, and K also have higher mean contents. Avcin and Koch (1979)

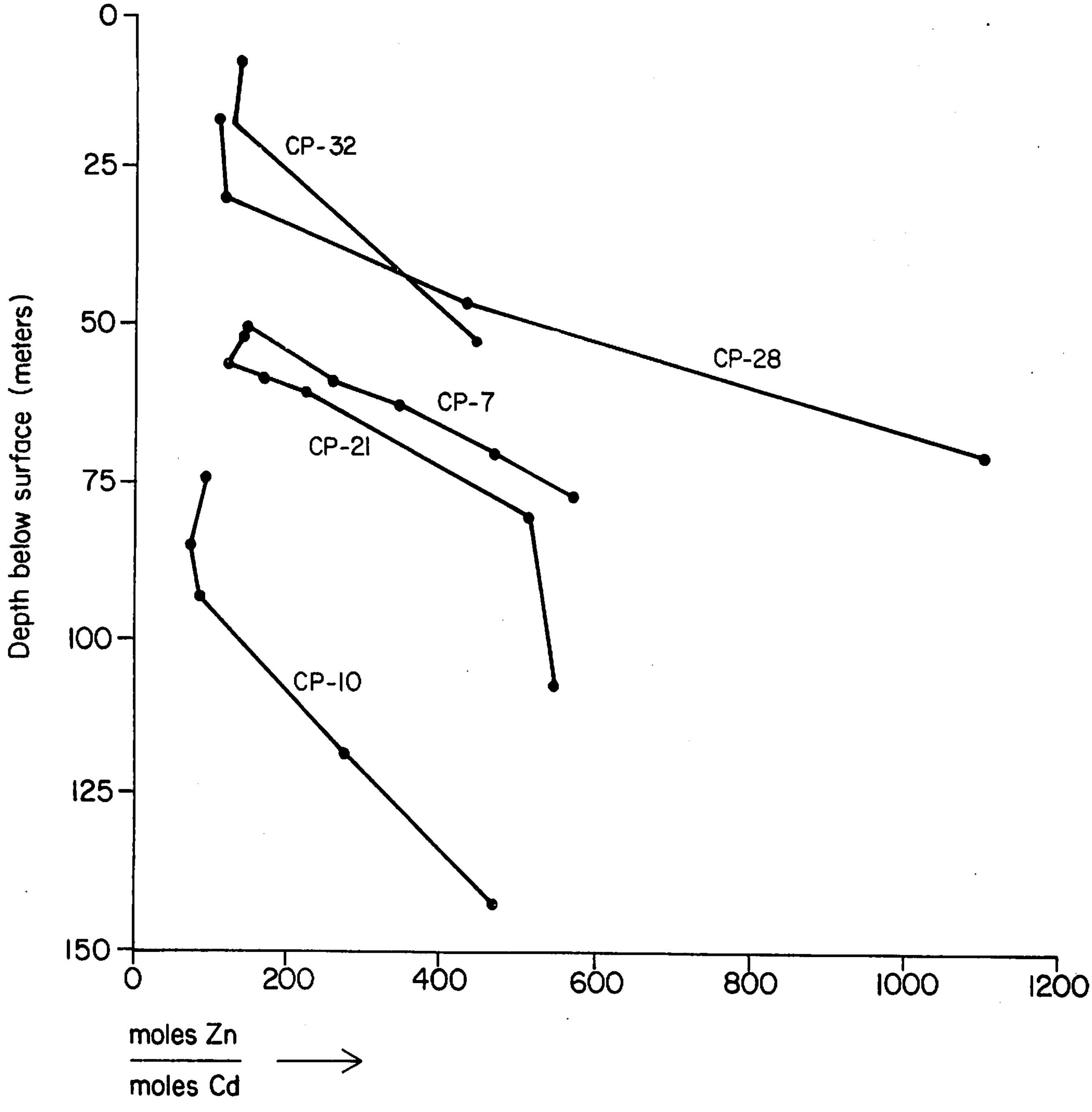

Figure 11. Relationship of the zinc/cadmium mole ratio in coal to depth in five core holes from Wapello and Appanoose Counties, Iowa.

indicated that depositional environments for the Cherokee and Marmaton Groups changed from predominantly terrestrial in the lower part of the Cherokee Group to predominantly marine higher in the stratigraphic section.

Presumably Na, Mg, K, Cr, V, U, Mo, Sb, Se, and Ag were more readily available in the more marine-influenced environments in which upper Cherokee and Marmaton rocks were deposited. Changes in contents of Na, Mg, and K apparently affect the ash-fusion temperatures which drop significantly from coal-zone 2 to coal-zones 6-9 (figure 6).

All six coal samples from coal-zone 7 and three samples from coal-zone 4 (D176171, D176183, and D179843) have much higher contents of U, Mo, Sb, Se, V, and Ag. The coals at these sample sites are overlain by black, sometimes phosphatic, shale; shales that were deposited under anoxic marine conditions (Heckel, 1977).

SUMMARY

1. Middle Pennsylvanian Cherokee Group coals from south-central and southeastern Iowa are typical high-sulfur, high-ash coals, with a mean total sulfur content of 5.8 percent; and a mean ash content of 15.9 percent. Mean, as-received heat of combustion is 9,640 Btu/lb. Mean, moist, mineral-matter-free heat of combustion is 12,040 Btu/lb, which is equivalent to an apparent rank of high-volatile C bituminous coal.

2. In a comparison with equivalent-rank Illinois Basin and Yampa field coals, Iowa coals have the highest mean contents of 16 elements (S, Ca, Fe, Ag, As, Be, Co, Cu, Ge, Mn, Ni, Pb, Sc, Se, U, and Zn).

3. Low sulfur Yampa field coals have significantly lower mean contents of K, Cd, Cr, Hg, Mo, Sb, and V than high-sulfur, Iowa Cherokee Group and Illinois Basin coals.

4. Iowa Cherokee Group coals have been subject to post-depositional, epigenetic sphalerite/calcite/pyrite/kaolinite/barite mineralization. Zinc and cadmium contents of Iowa coal samples are as much as 18,000 ppm and 100 ppm respectively. Most zinc and cadmium can be removed and recovered from the coals by conventional washing techniques.

5. Iowa coal samples also have as much as 300 ppm Co, 150 ppm Cr, 70 ppm Ge, 150 ppm Mo, 700 ppm Ni, and 300 ppm V. As conventional world supplies of these metals and zinc and cadmium are depleted, Iowa Cherokee Group coal should be considered as a possible source.

6. Element associations of U, Mo, Cr, and V change from an aluminosilicate assemblage in the lower part of the section (coal-zones 2, 3, and 4) to a sulfide assemblage higher in the section (coal-zones 5 and 6-9). This change is related to increased element content with higher stratigraphic position. These increases are thought to be related to differences in depositional environments of the coal-associated rocks which change from predominantly terrestrial lower in the stratigraphic section to predominantly marine higher in the section. The decrease in ash-fusion temperatures with higher stratigraphic position is probably related to increased contents of Na, Mg, and K.

7. Coals, in particular, samples from coal-zone 7, which are overlain by marine, phosphatic, black-shale

lithologies, have the highest contents of U, Mo, Ag, Sb, Se, and V.

ACKNOWLEDGMENTS

The authors are indebted to Vernon E. Swanson, Orville J Van Eck, and Samuel J. Tuthill for their initiation of this project and for their direction and encouragement. Of fundamental importance to this paper was the contribution of the team of chemical laboratory personnel in the U.S. Geological Survey under the direction of Claude Huffman, Jr. and Joseph H. Christie: James W. Baker, Ardith J. Bartel, Leon A. Bradley, Elaine L. Brandt, George T. Burrow, Nancy M. Conklin, James G. Crock, Celeste M. Ellis, Edward J. Fennelly, Johnnie M. Gardner, William D. Goss, Patricia G. Guest, John C. Hamilton, Raymond G. Havens, Adolph W. Haubert, Jay P. Hemming, Jessie O. Johnson, Roy J. Knight, Lorraine Lee, Robert E. McGregor, Violet M. Merritt, Hugh T. Millard, Jr., Harriet G. Nieman, Ralph L. Nelms, Jeffry O'Kelly, Charles A. Ramsey, George O. Riddle, Caryl L. Shields, Gaylord D. Shipley, Vertie C. Smith, James A. Thomas, Michele L. Tuttle, Richard E. Van Loenen, Robin J. Vinnola, James S. Wahlberg, William J. Walz, Ralph J. White, Robert J. Young, and Robert A. Zielinski. In connection with the acknowledgment to the above staff of chemical analysts, the invaluable contribution of the chemists in the Coal Analysis Section (Forrest E. Walker, Chemist in Charge), U.S. Bureau of Mines, Pittsburgh, Pa., is also gratefully acknowledged. The assistance of James Dockal, Logan Kuiper, Mary Howes, and Edwin R. Landis in collecting mine samples; the contributions of the drillers and driller's assistants, Randy Bentzinger, Kevin Bentzinger, Whitey Woods, Ora Robinson, and Jan Watson; and the contributions of Robert Ravn, John Swade, and numerous other student assistants are gratefully acknowledged.

We also appreciate the cooperation of the many mine owners and operators in allowing access to the mines for sample collection.

We would also like to acknowledge the efforts of Survey Staff member Laurie Comstock, who prepared this manuscript, and graphic artists Donna McGuire and Kay Irelan who prepared the illustrations.

REFERENCES

Abernethy, R. F., Peterson, M. J., and Gibson, F. H., 1969a, Major ash constituents in U.S. Coals: U.S. Bureau of Mines Report of Investigations 7240, 9 p.

_____ 1969b, Spectrochemical analysis of coal ash for trace elements: U.S. Bureau of Mines Report of Investigations 7281, 30 p.

American Society for Testing and Materials, 1978, Standard specifications for classification of coals by rank (ASTM designation D-388-77): 1978 Annual book of ASTM standards, pt. 26, p. 200-224.

Avcin, M. J., and Koch, D. L., 1979, The Mississippian and Pennsylvanian (Carboniferous) Systems in the United States -Iowa: U.S. Geological Survey Professional Paper 1110-M, M1-M13.

Averitt, Paul, 1975, Coal Resources of the United States, January 1, 1974; U.S. Geological Survey Bulletin 1412, 131 p.

Baas Becking, L. G. M., Kaplan, I. R., and Moore, Derek, 1960, Limits of the natural environment in terms of pH and oxidation-reduction potentials: Journal of Geology, v. 68, p. 243-284.

Cecil, C. B., Stanton, R. W., Dulong, F. T., and Renton, J. J., 1982, Geologic factors that control mineral matter in coal: Proceedings of ANS/ACS Symposium on Atomic and Nuclear Methods in Fossil Energy Research, p. 323-336, Plenum Press.

Cohen, A. C., 1959, Simplified estimators for the normal distribution when samples are singly censored or truncated: Technometrics, v. 1, no. 3, p. 217-237.

Connor, J. J., Keith, J. R., and Anderson, B. M., 1976, Trace-metal variations in soils and sagebrush in the Powder River basin, Wyoming and Montana: U.S. Geological Survey Journal of Research, v. 4, no. 1, p. 49-59.

Given, P. H., and Yarzab, R. F., 1978, Analysis of the organic substances of coals: Problems posed by the presence of mineral matter: Analytical Methods for Coal and Coal Products, Volume II, Chapter 20, p. 3-41.

Gluskoter, H. J., and Lindahl, P. C., 1973, Cadmium-mode of occurrence in Illinois coals: Science, v. 188, p. 264-266.

Gluskoter, H. J., Ruch, R. R., Miller, W. G., Cahill, R. A., Dreher, G. B., and Kuhn, J. K., 1977, Trace elements in coal-occurrence and distribution: Illinois Geological Survey Circular 499, 154 p.

Harshman, E. N., 1974, Distribution of elements in some roll-type uranium deposits, *in*: Formation of uranium ore deposits: International Atomic Energy Agency Proceedings, Series no. STI/pub/374, p. 169-183.

Hatch, J. R., A in press, Geochemical processes that control minor and trace element composition of U.S. coals: Chapter 8 *in* Cameron Volume on Unconventional Mineral Resources, American Institute of Mining Engineers Special Publication No.

Hatch, J. R., B in press, Element geochemistry, *in* Geological Investigations of the Vermillion Creek coal bed in the Eocene Niland Tongue of the Wasatch Formation, Sweetwater County, Wyoming: U.S. Geological Survey Professional Paper No.

Hatch, J. R. Avcin, M. J., Wedge, W. K., and Brady, L. L., 1976, Sphalerite in coals from southeastern Iowa, Missouri, and southeastern Kansas: U.S. Geological Survey Open-File Report 76-796, 26 p.

Hatch, J. R., Gluskoter, H. J., and Lindahl, P. C., 1976, Sphalerite in coals from the Illinois Basin: Economic Geology, v. 71, no. 3, p. 613-624.

Heckel, P. H., 1977, Origin of phosphatic black shale facies in Pennsylvanian cyclothems of mid-continent North America: American Association of Petroleum Geologists Bulletin, v. 61, no. 7, p. 1045-1068.

Hildebrand, R. T., Garrigues, R. S., Meyers, R. F., and Reheis, M. C., 1981, Geology and chemical analyses of coal and coal-associated rock samples, Williams Fork Formation (Upper Cretaceous), northwestern Colorado: U.S. Geol. Survey Open-File Report 81-1348, 103 p.

Hildebrand, R. T., and Hatch, J. R., 1977, The distribution of sodium and alkaline-earth elements in coal of the Rocky Mountain and northern Great Plains provinces: Geological Society of America Abstracts with Programs, v. 9, no. 7, p. 1015-1016.

King, J. G., Maries, M. B., and Crossley, A. E. J., 1936, Formulas for the calculation of coal analyses to a basis of coal substance free of mineral matter: Journal of the Society of Chemical Industry v. 55, p. 277-281.

Landis, E. R., and Van Eck, O. J, 1965, Coal Resources of Iowa: Iowa Geological Survey Technical Paper No. 4, 141 p.

Leighton, L. H., and Tomlinson, R. C., 1960, Estimation of the volatile matter of pure coal substance: Fuel, v. 39, p. 133-140.

Miesch, A. T., 1967, Methods of computation for estimating geochemical abundances: U.S. Geological Survey Professional Paper 574-B, 15 p.

Ravn, R. L., in press, Palynostratigraphy of the Lower and Middle Pennsylvanian coals of Iowa: Iowa Geological Survey Technical Paper No. 7.

Swade, J. W., Ravn, R. L., Howes, M. R., Fitzgerald, D. J., and Van Dorpe, P. E., 1981, Formational Subdivision of the Cherokee Group and proposed revisions in Pennsylvanian stratigraphic nomenclature in Iowa: Geol. Soc. Am. Abstracts with Programs, v. 13, no. 6, p. 318.

Swanson, V. E., and Huffman, C., Jr., 1976, Guidelines for sample collecting and analytical methods used in the U.S. Geological Survey for determining chemical composition of coal: U.S. Geological Survey Circular 735, 11 p.

Swanson, V. E., Medlin, J. H., Hatch, J. R., Coleman, S. L., Wood, G. H., Jr., Woodruff, S. D., and Hildebrand, R. T., 1976, Collection, chemical analysis, and evaluation of coal samples in 1975: U.S. Geological Survey Open-File Report 76-468, 503 p.

U.S. Office of Coal Research, 1967, Methods of analyzing and testing coal and coke: U.S. Bureau of Mines Bulletin 638, 85 p.

Waksman, S. A., and Stevens, K. R., 1928, Contribution to the chemical composition of peat II. Chemical composition of various peat profiles: Soil Science, v. 26, p. 239-251.

Wedge, W. K., and Hatch, J. R., 1980, Chemical composition of Missouri coals: Missouri Department of Natural Resources, Geological Survey Report of Investigations 63, 102 p.

Zubovic, P., Sheffey, N. B., and Stadnichenko, T., 1967, Distribution of minor elements in some coals in the western and southwestern regions of the Interior coal province: U.S. Geological Survey Bulletin 1117-D, 33 p.

Table 3. Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 90 Iowa coal samples

{All analyses except heat of combustion, free-swelling index, and ash-fusion temperatures in percent. For each sample, the analyses are reported three ways: first, as received; second, moisture free; and third, moisture and ash free. Kcal/kg = 0.556 (Btu/lb); °F = (°C x 1.8) + 32; L, less than the value shown; B not determined}

Sample number	Proximate analysis				Ultimate analysis					Air-dried loss
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	
D166029	14.5	32.7	40.2	12.6	5.4	56.0	1.0	19.7	5.3	B
	---	38.2	47.0	14.7	4.4	65.5	1.2	8.0	6.2	---
	---	44.9	55.1	---	5.2	76.8	1.4	9.3	7.3	---
D166031	11.9	33.9	37.5	16.7	5.1	54.3	.9	15.4	7.6	B
	---	38.5	42.6	19.0	4.3	61.6	1.0	5.5	8.6	---
	---	47.5	52.5	---	5.3	76.1	1.3	6.8	10.6	---
D166034	11.5	35.1	34.7	18.7	4.8	52.1	.8	11.9	11.7	B
	---	39.7	39.2	21.1	4.0	58.9	.9	1.9	13.2	---
	---	50.3	49.7	---	5.0	74.6	1.1	2.4	16.8	---
D166035	13.1	37.6	35.8	13.5	5.4	56.4	1.1	19.8	3.8	B
	---	43.3	41.2	15.5	4.5	64.9	1.3	9.4	4.4	---
	---	51.2	48.8	---	5.4	76.8	1.5	11.1	5.2	---
D166037	11.9	37.0	37.6	13.5	5.5	57.5	1.2	18.7	3.6	B
	---	42.0	42.7	15.3	4.7	65.3	1.4	9.2	4.1	---
	---	49.6	50.4	---	5.6	77.1	1.6	10.9	4.8	---
D166039	12.1	33.4	38.5	16.0	5.2	56.0	1.2	19.3	2.3	B
	---	38.0	43.8	18.2	4.4	63.7	1.4	9.7	2.6	---
	---	46.5	53.5	---	5.4	77.9	1.7	11.9	3.2	---
D166043	9.8	38.7	41.2	10.3	5.5	62.7	1.0	14.8	5.7	B
	---	42.9	45.7	11.4	4.9	69.5	1.1	6.8	6.3	---
	---	48.4	51.6	---	5.5	78.5	1.3	7.6	7.1	---

Table 3. Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 90 Iowa coal samples--continued

Sample number	Heat of combustion		Forms of sulfur			Free Swelling	Ash fusion temperature, C°		
	Kcal/kg	Btu/lb	Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D166029	5,650	10,170	0.01L	3.24	2.05	B	B	B	B
	6,610	11,890	.01L	3.79	2.40				
	7,750	13,950	.01L	4.44	2.81				
D166031	5,560	10,000	.06	5.25	2.29	B	B	B	B
	6,310	11,350	.07	5.96	2.60				
	7,780	14,010	.08	7.35	3.21				
D166034	5,320	9,570	.14	9.35	2.16	B	B	B	B
	6,010	10,810	.16	10.56	2.44				
	7,620	13,710	.20	13.40	3.09				
D166035	5,550	9,990	.04	2.78	1.03	B	B	B	B
	6,390	11,500	.05	3.20	1.19				
	7,560	13,610	.05	3.79	1.40				
D166037	5,790	10,420	.01L	2.82	.77	B	B	B	B
	6,570	11,830	.01L	3.20	.87				
	7,760	13,970	.01L	3.78	1.03				
D166039	5,510	9,920	.06	1.64	.61	B	B	B	B
	6,270	11,290	.07	1.87	.69				
	7,660	13,800	.08	2.28	.85				
D166043	6,360	11,450	.01	4.34	1.31	B	B	B	B
	7,050	12,690	.01	4.81	1.45				
	7,960	14,330	.01	5.43	1.64				

Table 3. Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 90 Iowa coal samples--continued

Sample number	Proximate analysis				Ultimate analysis					Air-dried loss
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	
D176169	5.7	40.4	41.7	12.2	4.9	64.5	1.0	13.7	3.7	1.9
	---	42.8	44.2	12.9	4.5	68.4	1.1	9.2	3.9	---
	---	49.2	50.8	---	5.2	78.6	1.2	10.5	4.5	---
D176170	6.3	36.4	40.1	17.2	4.4	56.1	1.0	13.4	7.9	1.8
	---	38.8	42.8	18.4	3.9	59.9	1.1	8.3	8.4	---
	---	47.6	52.4	---	4.8	73.3	1.3	10.2	10.3	---
D176171	4.3	28.3	40.0	27.4	3.7	51.7	1.0	11.3	4.9	.8
	---	29.6	41.8	28.6	3.4	54.0	1.0	7.8	5.1	---
	---	41.4	58.6	---	4.7	75.7	1.5	10.9	7.2	---
D176172	3.4	37.1	33.7	25.8	3.5	49.7	.9	6.6	13.5	.8
	---	38.4	34.9	26.7	3.2	51.4	.9	3.7	14.0	---
	---	52.4	47.6	---	4.4	70.2	1.3	5.1	19.1	---
D176173	4.7	38.8	34.2	22.3	4.3	55.1	1.0	12.2	5.1	2.0
	---	40.7	35.9	23.4	4.0	57.8	1.0	8.4	5.4	---
	---	53.2	46.8	---	5.2	75.5	1.4	11.0	7.0	---
D176174	4.3	36.5	40.5	18.7	4.7	60.4	1.1	11.7	3.4	1.2
	---	38.1	42.3	19.5	4.4	63.1	1.1	8.2	3.6	---
	---	47.4	52.6	---	5.5	78.4	1.4	10.2	4.4	---
D176175	5.1	40.7	38.8	15.4	5.0	62.0	1.1	12.9	3.6	1.7
	---	42.9	40.9	16.2	4.7	65.3	1.2	8.8	3.8	---
	---	51.2	48.8	---	5.6	78.0	1.4	10.5	4.5	---
D176176	4.5	35.0	37.7	22.8	4.2	52.5	.9	7.7	11.9	.6
	---	36.6	39.5	23.9	3.9	55.0	.9	3.9	12.5	---
	---	48.1	51.9	---	5.1	72.2	1.2	5.1	16.4	---

Table 3. Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 90 Iowa coal samples--continued

Sample number	Heat of combustion		Forms of sulfur			Free Swelling	Ash fusion temperature, C°		
	Kcal/kg	Btu/lb	Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D176169	6,230	11,220	0.25	2.00	1.46	1.0	1,140	1,165	1,200
	6,610	11,900	.27	2.12	1.55				
	7,590	13,670	.30	2.44	1.78				
D176170	5,640	10,160	1.20	4.51	2.17	1.0	1,110	1,140	1,170
	6,020	10,840	1.28	4.81	2.32				
	7,380	13,280	1.57	5.90	2.84				
D176171	4,970	8,950	.90	1.86	2.14	.5	1,110	1,140	1,200
	5,200	9,350	.94	1.94	2.24				
	7,280	13,100	1.32	2.72	3.13				
D176172	5,160	9,280	.80	11.85	.80	1.0	1,145	1,170	1,200
	5,340	9,610	.83	12.27	.83				
	7,280	13,110	1.13	16.74	1.13				
D176173	5,420	9,750	.23	3.15	1.76	1.5	1,145	1,170	1,200
	5,680	10,230	.24	3.31	1.85				
	7,420	13,360	.32	4.32	2.41				
D176174	5,990	10,790	.21	1.38	1.83	1.5	1,290	1,315	1,345
	6,260	11,270	.22	1.44	1.91				
	7,780	14,010	.27	1.79	2.38				
D176175	6,150	11,070	.15	1.43	2.00	3.5	1,080	1,110	1,145
	6,480	11,660	.16	1.51	2.11				
	7,740	13,920	.19	1.80	2.52				
D176176	5,260	9,470	1.60	8.90	1.38	.5	1,260	1,290	1,320
	5,510	9,920	1.68	9.32	1.45				
	7,240	13,030	2.20	12.24	1.90				

Table 3. Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 90 Iowa coal samples--continued

	Proximate analysis				Ultimate analysis					
Sample number	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Air-dried loss
D176177	4.0	41.5	38.3	16.2	4.7	57.9	1.0	10.3	9.9	0.8
	---	43.2	39.9	16.9	4.4	60.3	1.0	7.0	10.3	---
	---	42.0	48.0	---	5.3	72.6	1.3	8.5	12.4	---
D176178	4.7	30.7	35.3	29.3	3.8	46.0	.9	11.7	8.3	.7
	---	32.2	37.0	30.7	3.4	48.3	.9	7.9	8.7	---
	---	46.5	53.5	---	5.0	69.7	1.4	11.4	12.6	---
D176179	4.1	36.6	41.4	17.9	4.2	57.5	.6	12.4	7.4	1.0
	---	38.2	43.2	18.7	3.9	60.0	.6	9.1	7.7	---
	---	46.9	53.1	---	4.8	73.7	.8	11.2	9.5	---
D176180	4.9	41.2	45.0	8.9	5.1	67.2	1.2	14.0	3.6	1.8
	---	43.3	47.3	9.4	4.8	70.7	1.3	10.1	3.8	---
	---	47.8	52.2	---	5.3	78.0	1.4	11.2	4.2	---
D176181	5.4	35.5	44.3	14.8	4.6	59.1	1.1	15.6	4.8	1.4
	---	37.5	46.8	15.6	4.2	62.5	1.2	11.4	5.1	---
	---	44.5	55.5	---	5.0	74.1	1.4	13.5	6.0	---
D176182	3.4	33.4	31.4	31.8	3.3	41.7	.8	7.0	15.4	1.4
	---	34.6	32.5	32.9	3.0	43.2	.8	4.1	15.9	---
	---	51.5	48.5	---	4.5	64.4	1.2	6.1	23.8	---
D176183	4.4	34.5	35.9	25.2	4.0	49.5	.9	9.9	10.5	1.2
	---	36.1	37.6	26.4	3.7	51.8	.9	6.3	11.0	---
	---	49.0	51.0	---	5.0	70.3	1.3	8.5	14.9	---
D176184	5.7	33.9	40.6	19.8	4.3	53.5	1.2	12.4	8.8	2.0
	---	35.9	43.1	21.0	3.9	56.7	1.3	7.8	9.3	---
	---	45.5	54.5	---	4.9	71.8	1.6	9.8	11.8	---

Table 3. Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 90 Iowa coal samples--continued

Sample number	Heat of combustion		Forms of sulfur			Free Swelling	Ash fusion temperature, C°		
	Kcal/kg	Btu/lb	Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D176177	6,010	10,810	0.96	6.38	2.60	2.5	1,180	1,210	1,240
	6,260	11,260	1.00	6.65	2.71				
	7,530	13,550	1.20	7.99	3.26				
D176178	4,710	8,470	1.05	5.94	1.31	.5	1,110	1,140	1,170
	4,940	8,890	1.10	6.23	1.37				
	7,130	12,830	1.59	9.00	1.98				
D176179	5,730	10,310	1.09	4.33	1.95	1.5	1,040	1,060	1,080
	5,970	10,750	1.14	4.52	2.03				
	7,340	13,220	1.40	5.55	2.50				
D176180	6,680	12,030	.21	1.18	2.27	3.0	1,040	1,060	1,080
	7,030	12,650	.22	1.24	2.39				
	7,750	13,960	.24	1.37	2.63				
D176181	5,910	10,630	.78	1.83	2.18	1.5	1,040	1,060	1,080
	6,240	11,240	.82	1.93	2.30				
	7,400	13,320	.98	2.29	2.73				
D176182	4,430	7,970	.70	13.60	1.05	1.5	1,225	1,260	1,290
	4,580	8,250	.72	14.08	1.09				
	6,830	12,300	1.08	20.99	1.62				
D176183	5,090	9,160	.90	9.08	.48	1.0	1,170	1,215	1,260
	5,320	9,580	.94	9.50	.50				
	7,230	13,010	1.28	12.90	.68				
D176184	5,320	9,570	1.54	5.85	1.45	.5	1,050	1,075	1,200
	5,640	10,150	1.63	6.20	1.54				
	7,140	12,850	2.07	7.85	1.85				

Table 3. Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 90 Iowa coal samples--continued

Sample number	Proximate analysis: Moisture	Proximate analysis: Volatile matter	Proximate analysis: Fixed carbon	Proximate analysis: Ash	Ultimate analysis: Hydrogen	Ultimate analysis: Carbon	Ultimate analysis: Nitrogen	Ultimate analysis: Oxygen	Ultimate analysis: Sulfur	Air-dried loss
D176185	2.7	31.5	35.2	30.6	3.3	45.3	0.8	2.7	17.3	1.0
	---	32.4	36.2	31.4	3.1	46.6	.8	.3	17.8	---
	---	47.2	52.8	---	4.5	67.9	1.2	.4	25.9	---
D176186	2.3	30.4	31.7	35.6	2.9	37.4	.7	2.5	20.9	.8
	---	31.1	32.4	36.4	2.7	38.3	.7	.5	21.4	---
	---	49.0	51.0	---	4.3	60.2	1.1	.7	33.7	---
D176187	11.1	38.3	40.9	9.7	5.9	60.2	1.0	17.6	5.6	8.4
	---	43.1	46.0	10.9	5.2	67.7	1.1	8.7	6.3	---
	---	48.4	51.6	---	5.9	76.0	1.3	9.8	7.1	---
D176188	9.9	32.4	35.5	22.2	4.7	50.4	.8	13.8	8.1	6.3
	---	36.0	39.4	24.6	4.0	55.9	.9	5.5	9.0	---
	---	47.7	52.3	---	5.3	74.2	1.2	7.4	11.9	---
D176189	14.0	27.3	36.3	22.4	4.7	45.7	.9	17.4	8.9	10.2
	---	31.7	42.2	26.0	3.7	53.1	1.0	5.8	10.3	---
	---	42.9	57.1	---	4.9	71.9	1.4	7.8	14.0	---
D176190	9.6	28.2	25.5	36.7	3.9	38.4	.6	15.7	4.7	7.3
	---	31.2	28.2	40.6	3.1	42.5	.7	7.9	5.2	---
	---	52.5	47.5	---	5.3	71.5	1.1	13.3	8.8	---
D176191	15.8	35.0	39.5	9.7	5.7	57.9	1.0	22.0	3.7	13.8
	---	41.6	46.9	11.5	4.7	68.8	1.2	9.4	4.4	---
	---	47.0	53.0	---	5.3	77.7	1.3	10.7	5.0	---
D176192	12.3	34.1	39.0	14.6	5.3	55.8	1.0	18.2	5.1	8.7
	---	38.9	44.5	16.6	4.5	63.6	1.1	8.3	5.8	---
	---	46.6	53.4	---	5.4	76.3	1.4	9.9	7.0	---

Table 3. Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 90 Iowa coal samples--continued

Sample number	Heat of combustion		Forms of sulfur			Free Swelling	Ash fusion temperature, C°		
	Kcal/kg	Btu/lb	Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D176185	4,770	8,590	0.70	16.16	0.42	1.5	1,155	1,175	1,200
	4,900	8,830	.72	16.61	.43				
	7,150	12,880	1.05	24.23	.63				
D176186	4,330	7,790	.79	18.75	1.35	1.0	1,065	1,095	1,120
	4,430	7,970	.81	19.19	1.38				
	6,970	12,540	1.27	30.19	2.17				
D176187	6,060	10,900	.87	2.52	2.24	1.5	1,110	1,140	1,170
	6,810	12,260	.98	2.82	2.52				
	7,650	13,760	1.10	3.18	2.83				
D176188	5,130	9,240	.49	5.37	2.24	.5	1,145	1,170	1,205
	5,700	10,260	.54	5.96	2.49				
	7,560	13,610	.72	7.91	3.30				
D176189	4,540	8,170	.99	6.40	1.52	.0	1,080	1,110	1,140
	5,280	9,500	1.15	7.44	1.77				
	7,140	12,850	1.56	10.06	2.39				
D176190	3,710	6,670	.72	2.77	1.22	.0	1,080	1,110	1,140
	4,100	7,380	.80	3.06	1.35				
	6,900	12,420	1.34	5.16	2.27				
D176191	5,700	10,260	.01	1.33	2.41	5.0	1,080	1,110	1,140
	6,770	12,190	.01	1.58	2.86				
	7,650	13,770	.01	1.79	3.23				
D176192	5,580	10,040	.27	1.82	2.99	.5	1,095	1,120	1,150
	6,360	11,450	.31	2.08	3.41				
	7,630	13,730	.37	2.49	4.09				

Table 3. Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 90 Iowa coal samples--continued

Sample number	Proximate analysis				Ultimate analysis					Air-dried loss
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	
D176193	8.9	29.3	28.1	33.7	4.1	39.6	0.7	13.3	8.6	6.4
	---	32.2	30.8	37.0	3.4	43.5	.8	5.9	9.4	---
	---	51.0	49.0	---	5.4	69.0	1.2	9.4	15.0	---
D176194	7.7	31.1	31.2	30.0	4.0	41.0	.7	13.5	10.8	2.7
	---	33.7	33.8	32.5	3.4	44.4	.8	7.2	11.7	---
	---	49.9	50.1	---	5.0	65.8	1.1	10.7	17.3	---
D176195	13.3	36.3	39.8	10.6	5.7	56.9	1.0	19.5	6.3	10.4
	---	41.9	45.9	12.2	4.9	65.6	1.2	8.9	7.3	---
	---	47.7	52.3	---	5.5	74.8	1.3	10.1	8.3	---
D176196	13.2	37.1	31.8	17.9	5.2	52.3	.9	20.0	3.7	10.8
	---	42.7	36.6	20.6	4.3	60.3	1.0	9.5	4.3	---
	---	53.8	46.2	---	5.4	75.9	1.3	12.0	5.4	---
D176197	11.6	37.5	39.6	11.3	5.7	58.6	1.0	16.8	6.6	8.9
	---	42.4	44.8	12.8	5.0	66.3	1.1	7.3	7.5	---
	---	48.6	51.4	---	5.7	76.0	1.3	8.4	8.6	---
D176198	12.7	30.4	33.0	23.9	4.9	46.2	.8	18.5	5.7	9.3
	---	34.8	37.8	27.4	4.0	52.9	.9	8.3	6.5	---
	---	47.9	52.1	---	5.5	72.9	1.3	11.4	9.0	---
D176199	12.0	40.6	35.5	11.9	5.6	58.3	.9	18.1	5.2	10.1
	---	46.1	40.3	13.5	4.8	66.2	1.0	8.4	5.9	---
	---	53.4	46.6	---	5.6	76.6	1.2	9.8	6.8	---
D179838	12.2	34.0	43.2	10.6	5.4	58.8	.7	20.0	4.5	2.3
	---	38.7	49.2	12.1	4.6	67.0	.8	10.4	5.1	---
	---	44.0	56.0	---	5.2	76.2	.9	11.9	5.8	---

Table 3. Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 90 Iowa coal samples--continued

Sample number	Heat of combustion		Forms of sulfur			Free Swelling	Ash fusion temperature, C°		
	Kcal/kg	Btu/lb	Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D176193	3,900	7,020	1.15	5.16	2.27	0.5	1,130	1,160	1,280
	4,280	7,710	1.26	5.66	2.49				
	6,790	12,230	2.00	8.00	3.95				
D176194	4,210	7,580	1.89	6.03	2.84	.5	1,080	1,110	1,140
	4,560	8,210	2.05	6.53	3.08				
	6,760	12,170	3.03	9.68	4.56				
D176195	5,800	10,440	.65	3.49	2.11	1.0	1,105	1,130	1,160
	6,690	12,040	.75	4.03	2.43				
	7,620	13,720	.85	4.59	2.77				
D176196	5,070	9,130	.37	1.66	1.68	1.0	1,140	1,170	1,200
	5,840	10,520	.43	1.91	1.94				
	7,360	13,250	.54	2.41	2.44				
D176197	5,930	10,670	.71	3.97	1.93	.5	1,275	1,305	1,330
	6,710	12,070	.80	4.49	2.18				
	7,690	13,840	.92	5.15	2.50				
D176198	4,690	8,450	.62	3.12	1.94	.5	1,175	1,205	1,230
	5,380	9,680	.71	3.57	2.22				
	7,400	13,330	.98	4.92	3.06				
D176199	5,910	10,630	.31	2.27	2.61	4.0	1,230	1,260	1,290
	6,710	12,080	.35	2.58	2.97				
	7,760	13,970	.41	2.98	3.43				
D179838	5,910	10,630	.82	2.25	1.40	1.0	1,095	1,155	1,180
	6,730	12,110	.93	2.56	1.59				
	7,650	13,770	1.06	2.91	1.82				

Table 3. Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 90 Iowa coal samples--continued

Sample number	Proximate analysis: Moisture	Volatile matter	Fixed carbon	Ash	Ultimate analysis: Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Air-dried loss
D179840	13.5	31.6	45.2	9.7	5.9	60.3	0.8	20.1	3.2	4.7
	---	36.5	52.3	11.2	5.1	69.7	.9	9.4	3.7	---
	---	41.1	58.9	---	5.7	78.5	1.0	10.5	4.2	---
D179841	7.9	35.6	39.4	17.1	4.8	58.2	1.0	12.5	6.4	2.0
	---	38.7	42.8	18.6	4.3	63.2	1.1	5.9	6.9	---
	---	47.5	52.5	---	5.2	77.6	1.3	7.3	8.5	---
D179843	9.1	28.2	29.9	32.8	3.5	34.4	.5	9.6	19.2	3.1
	---	31.0	32.9	36.1	2.7	37.8	.6	1.7	21.1	---
	---	48.5	51.5	---	4.3	59.2	.9	2.6	33.0	---
D179844	13.1	29.5	30.2	27.2	4.6	42.3	.8	15.9	9.2	5.0
	---	33.9	34.8	31.3	3.6	48.7	.9	4.9	10.7	---
	---	49.4	50.6	---	5.3	70.9	1.3	7.1	15.4	---
D179846	9.4	27.9	31.6	31.1	3.6	36.6	.4	10.0	18.3	3.7
	---	30.8	34.9	34.3	2.8	40.4	.4	1.8	20.2	---
	---	46.9	53.1	---	4.3	61.5	.7	2.8	30.8	---
D179847	13.6	37.9	39.2	9.3	5.8	61.0	.9	19.4	3.6	7.0
	---	43.9	45.4	10.8	5.0	70.6	1.0	8.5	4.2	---
	---	49.2	50.8	---	5.6	79.1	1.2	9.5	4.7	---
D179848	18.7	32.1	40.0	9.2	6.0	56.9	.7	24.8	2.4	12.1
	---	39.5	49.2	11.3	4.8	70.0	.9	10.1	3.0	---
	---	44.5	55.5	---	5.4	78.9	1.0	11.3	3.3	---
D179850	13.0	31.7	38.1	17.2	5.2	51.9	.7	19.5	5.5	3.4
	---	36.4	43.8	19.8	4.3	59.7	.8	9.1	6.3	---
	---	45.4	54.6	---	5.4	74.4	1.0	11.4	7.9	---

Table 3. Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 90 Iowa coal samples--continued

Sample number	Heat of combustion		Forms of sulfur			Free Swelling	Ash fusion temperature, C°		
	Kcal/kg	Btu/lb	Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D179840	6,010	10,810	0.34	1.92	0.97	1.0	1,100	1,140	1,160
	6,940	12,500	.39	2.22	1.12				
	7,820	14,080	.44	2.50	1.26				
D179841	5,910	10,640	.36	3.42	2.45	3.5	1,105	1,140	1,165
	6,420	11,550	.39	3.71	2.66				
	7,880	14,190	.48	4.57	3.27				
D179843	3,840	6,910	1.34	16.56	1.30	.0	1,180	1,225	1,235
	4,220	7,600	1.47	18.22	1.43				
	6,610	11,890	2.31	28.50	2.24				
D179844	4,410	7,940	.84	6.78	.64	.0	1,050	1,105	1,125
	5,080	9,410	.97	7.80	.74				
	7,390	13,300	1.41	11.36	1.07				
D179846	4,040	7,280	.72	15.47	2.09	.0	1,195	1,240	1,260
	4,460	8,040	.79	17.08	2.31				
	6,800	12,240	1.21	26.00	3.51				
D179847	6,090	10,970	.22	1.66	1.71	1.5	1,120	1,155	1,175
	7,050	12,700	.25	1.92	1.98				
	7,900	14,230	.29	2.15	2.22				
D179848	5,600	10,080	.04	.33	2.05	2.0	1,125	1,175	1,195
	6,890	12,400	.05	.41	2.52				
	7,770	13,980	.06	.46	2.84				
D179850	5,280	9,500	.62	3.21	1.71	.0	1,100	1,155	1,185
	6,070	10,920	.71	3.69	1.97				
	7,560	13,610	.89	4.60	2.45				

Table 3. Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 90 Iowa coal samples--continued

Sample number	Proximate analysis: Moisture	Volatile matter	Fixed carbon	Ash	Ultimate analysis: Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Air-dried loss
D179851	12.5	39.0	40.1	8.4	6.0	62.5	0.8	18.8	3.5	4.9
	---	44.6	45.8	9.6	5.3	71.4	.9	8.8	4.0	---
	---	49.3	50.7	---	5.8	79.0	1.0	9.7	4.4	---
D179853	12.0	34.5	22.8	30.7	4.5	44.7	.8	11.9	7.4	4.6
	---	39.2	25.9	34.9	3.6	50.8	.9	1.4	8.4	---
	---	60.2	39.8	---	5.5	78.0	1.4	2.2	12.9	---
D179854	9.5	33.4	35.0	22.1	4.8	49.7	.7	16.0	6.7	2.2
	---	36.9	38.7	24.4	4.1	54.9	.8	8.3	7.4	---
	---	48.8	51.2	---	5.5	72.7	1.0	11.0	9.8	---
D179855	12.2	34.4	42.8	10.6	5.5	59.6	.7	18.6	5.0	2.7
	---	39.2	48.7	12.1	4.7	67.9	.8	8.8	5.7	---
	---	44.6	55.4	---	5.4	77.2	.9	10.0	6.5	---
D179856	8.8	28.4	34.1	28.7	4.0	40.1	.7	13.4	13.1	2.4
	---	31.1	37.4	31.5	3.3	44.0	.8	6.1	14.4	---
	---	45.4	54.6	---	4.8	64.2	1.1	8.9	21.0	---
D185601	13.9	33.4	39.3	13.4	5.3	53.4	.8	18.3	8.9	10.1
	---	38.8	45.6	15.6	4.4	62.0	.9	6.9	10.3	---
	---	45.9	54.1	---	5.2	73.5	1.1	8.2	12.2	---
D185602	15.4	33.5	38.0	13.1	5.5	54.2	.8	19.3	7.1	12.4
	---	39.6	44.9	15.5	4.5	64.1	.9	6.6	8.4	---
	---	46.9	53.1	---	5.3	75.8	1.1	7.8	9.9	---
D185603	15.6	35.6	38.3	10.5	5.7	57.7	1.0	21.3	3.8	12.8
	---	42.2	45.4	12.4	4.7	68.4	1.2	8.8	4.5	---
	---	48.2	51.8	---	5.4	78.1	1.4	10.1	5.1	---

Table 3. Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 90 Iowa coal samples--continued

Sample number	Heat of combustion		Forms of sulfur			Free Swelling	Ash fusion temperature, C°		
	Kcal/kg	Btu/lb	Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D179851	6,270	11,280	0.20	1.73	1.60	1.5	1,045	1,070	1,095
	7,160	12,890	.23	1.98	1.83				
	7,920	14,260	.25	2.19	2.02				
D179853	4,420	7,950	.44	5.85	1.07	1.0	1,235	1,270	1,285
	5,020	9,030	.50	6.65	1.22				
	7,710	13,870	.77	10.21	1.87				
D179854	5,050	9,090	.66	3.69	2.28	1.0	1,100	1,150	1,175
	5,580	10,040	.73	4.08	2.52				
	7,380	13,290	.96	5.39	3.33				
D179855	5,960	10,720	1.37	3.13	.51	1.0	1,240	1,290	1,320
	6,780	12,210	1.56	3.56	.58				
	7,710	13,890	1.77	4.05	.66				
D179856	4,340	7,810	2.98	11.70	.69	.0	1,245	1,290	1,325
	4,760	8,560	3.27	12.83	.76				
	6,940	12,500	4.77	18.72	1.10				
D185601	5,500	9,900	1.21	4.77	2.92	1.0	1,180	1,235	1,295
	6,390	11,490	1.41	5.54	3.39				
	7,560	13,610	1.66	6.56	4.02				
D185602	5,530	9,950	.96	3.37	2.76	1.0	1,095	1,155	1,220
	6,530	11,760	1.13	3.98	3.26				
	7,730	13,910	1.34	4.71	3.86				
D185603	5,780	10,410	.52	2.30	.97	1.0	1,165	1,205	1,255
	6,850	12,340	.62	2.73	1.15				
	7,830	14,090	.70	3.11	1.31				

Table 3. Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 90 Iowa coal samples--continued

Sample number	Proximate analysis				Ultimate analysis					Air-dried loss
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	
D185604	14.8	35.6	39.0	10.6	5.6	58.8	1.2	20.9	2.9	11.9
	---	41.8	45.8	12.6	4.6	69.0	1.4	9.1	3.4	---
	---	47.7	52.3	---	5.3	78.8	1.6	10.4	3.9	---
D185605	13.3	34.2	43.5	9.0	5.6	61.0	1.3	20.3	2.8	10.0
	---	39.4	50.2	10.4	4.8	70.4	1.5	9.8	3.2	---
	---	44.0	56.0	---	5.3	78.5	1.7	10.9	3.6	---
D185606	21.1	31.6	36.1	11.2	5.7	51.1	.9	27.9	3.2	16.5
	---	40.1	45.8	14.2	4.3	64.8	1.1	11.6	4.1	---
	---	46.7	53.3	---	5.0	75.5	1.3	13.5	4.7	---
D185609	16.5	34.8	30.3	18.4	5.4	50.7	1.0	19.7	4.8	13.4
	---	41.7	36.3	22.0	4.3	60.7	1.2	6.0	5.7	---
	---	53.5	46.5	---	5.5	77.9	1.5	7.7	7.4	---
D185610	11.9	34.9	38.6	14.6	5.1	54.2	1.1	17.9	7.1	4.5
	---	39.6	43.8	16.6	4.3	61.5	1.2	8.3	8.1	---
	---	47.5	52.5	---	5.1	73.7	1.5	10.0	9.7	---
D185611	14.5	35.8	34.5	15.2	5.3	54.1	.9	22.0	2.5	11.9
	---	41.9	40.4	17.8	4.3	63.3	1.1	10.7	2.9	---
	---	50.9	49.1	---	5.2	77.0	1.3	13.0	3.6	---
D185612	14.9	33.2	41.2	10.7	5.4	55.8	1.0	21.2	5.8	9.8
	---	39.0	48.4	12.6	4.4	65.6	1.2	9.3	6.8	---
	---	44.6	55.4	---	5.0	75.0	1.3	10.7	7.8	---
D185613	16.6	34.3	42.1	7.0	5.9	59.9	1.1	23.0	3.1	12.6
	---	41.1	50.5	8.4	4.9	71.8	1.3	9.9	3.7	---
	---	44.9	55.1	---	5.3	78.4	1.4	10.8	4.1	---

Table 3. Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 90 Iowa coal samples--continued

Sample number	Heat of combustion		Forms of sulfur			Free Swelling	Ash fusion temperature, C°		
	Kcal/kg	Btu/lb	Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D185604	5,850	10,530	0.19	1.66	1.05	1.5	1,040	1,090	1,140
	6,860	12,350	.22	1.95	1.23				
	7,840	14,110	.25	2.23	1.41				
D185605	6,100	10,980	.37	1.68	.73	1.0	1,055	1,115	1,155
	7,030	12,660	.43	1.94	.84				
	7,850	14,130	.48	2.16	.94				
D185606	5,030	9,050	.47	.99	1.70	.0	1,100	1,150	1,215
	6,370	11,470	.60	1.25	2.15				
	7,430	13,370	.69	1.46	2.51				
D185609	5,090	9,160	.54	3.43	.85	1.0	1,215	1,265	1,325
	6,100	10,980	.65	4.11	1.02				
	7,820	14,080	.83	5.27	1.31				
D185610	5,490	9,880	.08	4.18	2.83	.0	1,150	1,205	1,255
	6,230	11,220	.09	4.74	3.21				
	7,470	13,440	.11	5.69	3.85				
D185611	5,220	9,390	.76	.45	1.27	1.5	1,485	1,530	1,540
	6,100	10,980	.89	.53	1.49				
	7,420	13,360	1.08	.64	1.81				
D185612	5,670	10,210	.51	3.36	1.94	1.0	1,050	1,115	1,165
	6,670	12,000	.60	3.95	2.28				
	7,630	13,730	.69	4.52	2.61				
D185613	5,990	10,780	.20	1.01	1.87	1.5	1,120	1,170	1,230
	7,180	12,920	.24	1.21	2.24				
	7,840	14,110	.26	1.32	2.45				

Table 3. Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 90 Iowa coal samples--continued

Sample number	Proximate analysis				Ultimate analysis					Air-dried loss
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	
D186062	17.0	32.1	40.0	10.9	5.5	56.7	1.2	20.6	5.1	10.3
	---	38.7	48.2	13.1	4.4	68.3	1.4	6.6	6.1	---
	---	44.5	55.5	---	5.0	78.6	1.7	7.6	7.1	---
D186063	16.8	33.7	36.5	13.0	5.5	55.0	1.2	20.3	4.9	11.8
	---	40.5	43.9	15.6	4.4	66.1	1.4	6.5	5.9	---
	---	48.0	52.0	---	5.2	78.3	1.7	7.6	7.0	---
D186064	17.7	33.2	40.3	8.8	5.8	57.9	1.3	22.4	3.8	13.2
	---	40.3	49.0	10.7	4.7	70.4	1.6	8.1	4.6	---
	---	45.2	54.8	---	5.2	78.8	1.8	9.1	5.2	---
D186065	13.1	34.6	37.1	15.2	5.3	53.7	.9	18.0	6.9	7.2
	---	39.8	42.7	17.5	4.4	61.8	1.0	7.3	7.9	---
	---	48.3	51.7	---	5.4	74.9	1.3	8.9	9.6	---
D186066	13.0	37.8	38.4	10.8	5.7	59.8	.8	18.2	4.7	9.1
	---	43.4	44.1	12.4	4.9	68.7	.9	7.6	5.4	---
	---	49.6	50.4	---	5.6	78.5	1.0	8.7	6.2	---
D186067	4.3	35.2	36.7	23.8	4.3	49.5	1.1	11.8	9.5	.7
	---	36.8	38.3	24.9	4.0	51.7	1.1	8.3	9.9	---
	---	49.0	51.0	---	5.3	68.8	1.5	11.1	13.2	---
D186068	3.1	38.5	44.9	13.5	4.6	65.5	1.1	11.5	3.8	.7
	---	39.7	46.3	13.9	4.4	67.6	1.1	9.0	3.9	---
	---	46.2	53.8	---	5.1	78.5	1.3	10.5	4.6	---
D186069	2.7	23.3	48.1	25.9	4.5	53.6	.9	10.4	4.7	.3
	---	23.9	49.4	26.6	4.3	55.1	.9	8.2	4.8	---
	---	32.6	67.4	---	5.9	75.1	1.3	11.2	6.6	---

Table 3. Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 90 Iowa coal samples--continued

Sample number	Heat of combustion		Forms of sulfur			Free Swelling	Ash fusion temperature, C°		
	Kcal/kg	Btu/lb	Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D186062	5,690	10,240	0.26	3.52	1.30	1.0	1,145	1,205	1,260
	6,850	12,330	.31	4.24	1.57				
	7,890	14,200	.36	4.88	1.80				
D186063	5,530	9,960	.51	2.85	1.57	1.0	1,125	1,180	1,245
	6,650	11,970	.61	3.43	1.89				
	7,880	14,190	.73	4.06	2.24				
D186064	5,820	10,480	.36	2.39	1.02	1.0	1,085	1,135	1,185
	7,080	12,740	.44	2.90	1.24				
	7,920	14,260	.49	3.25	1.39				
D186065	5,460	9,830	1.38	3.34	2.14	1.0	1,095	1,155	1,215
	6,290	11,310	1.59	3.84	2.46				
	7,620	13,710	1.92	4.66	2.98				
D186066	6,080	10,940	.45	1.81	2.44	1.0	1,175	1,235	1,290
	6,990	12,570	.52	2.08	2.80				
	7,980	14,360	.59	2.38	3.20				
D186067	5,150	9,260	1.85	7.21	.45	.0	1,050	1,100	1,150
	5,380	9,680	1.93	7.53	.47				
	7,160	12,880	2.57	10.03	.63				
D186068	6,440	11,590	.60	2.35	.85	1.0	1,180	1,235	1,290
	6,650	11,960	.62	2.43	.88				
	7,720	13,900	.72	2.82	1.02				
D186069	5,570	10,020	.72	2.28	1.74	1.0	1,240	1,300	1,365
	5,720	10,300	.74	2.34	1.79				
	7,790	14,030	1.01	3.19	2.44				

Table 3. Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 90 Iowa coal samples--continued

Sample number	Proximate analysis				Ultimate analysis					Air-dried loss
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	
D186070	3.3	38.2	45.5	13.0	4.8	64.4	1.2	11.1	5.4	0.5
	---	39.5	47.1	13.4	4.6	66.6	1.2	8.4	5.6	---
	---	45.6	54.4	---	5.3	76.9	1.4	9.8	6.5	---
D186071	2.8	38.5	43.2	15.5	4.6	62.0	1.1	8.9	7.9	.4
	---	39.6	44.4	15.9	4.4	63.8	1.1	6.6	8.1	---
	---	47.1	52.9	---	5.2	75.9	1.3	7.8	9.7	---
D186072	7.0	39.7	30.6	22.7	4.6	53.7	.9	12.8	5.3	2.1
	---	42.7	32.9	24.4	4.1	57.7	1.0	7.1	5.7	---
	---	56.5	43.5	---	5.4	76.4	1.3	9.4	7.5	---
D186073	9.4	35.1	38.2	17.3	4.7	57.4	.9	14.5	5.3	3.1
	---	38.7	42.2	19.1	4.0	63.4	1.0	6.8	5.8	---
	---	47.9	52.1	---	5.0	78.3	1.2	8.4	7.2	---
D186074	12.2	35.1	35.4	17.3	5.0	53.5	.9	17.2	6.0	7.0
	---	40.0	40.3	19.7	4.2	60.9	1.0	7.2	6.8	---
	---	49.8	50.2	---	5.2	75.9	1.3	9.0	8.5	---
D186075	16.2	33.8	37.1	12.9	5.4	56.4	1.2	20.8	3.2	11.3
	---	40.3	44.3	15.4	4.3	67.3	1.4	7.6	3.8	---
	---	47.7	52.3	---	5.1	79.5	1.7	9.0	4.5	---
D186076	15.1	34.1	35.6	15.2	5.5	55.4	1.1	19.6	3.1	9.3
	---	40.2	41.9	17.9	4.5	65.3	1.3	7.3	3.7	---
	---	48.9	51.1	---	5.5	79.5	1.6	8.9	4.4	---
D192368	5.0	39.0	36.3	19.7	4.3	58.4	1.0	10.9	5.7	2.5
	---	41.1	38.2	20.7	3.9	61.5	1.1	6.8	6.0	---
	---	51.8	48.2	---	5.0	77.6	1.3	8.6	7.6	---

Table 3. Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 90 Iowa coal samples--continued

Sample number	Heat of combustion		Forms of sulfur			Free Swelling	Ash fusion temperature, C°		
	Kcal/kg	Btu/lb	Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D186070	6,390	11,510	0.73	2.88	1.81	1.0	1,100	1,155	1,205
	6,610	11,900	.75	2.98	1.87				
	7,640	13,750	.87	3.44	2.16				
D186071	6,350	11,430	.51	6.02	1.36	1.0	1,125	1,175	1,240
	6,530	11,760	.52	6.19	1.40				
	7,770	13,990	.62	7.37	1.66				
D186072	5,290	9,520	.83	1.97	2.51	1.0	1,335	1,380	1,430
	5,680	10,230	.89	2.12	2.70				
	7,520	13,540	1.18	2.80	3.57				
D176073	5,680	10,230	.98	2.58	1.78	1.0	1,105	1,175	1,230
	6,270	11,290	1.08	2.85	1.96				
	7,750	13,950	1.34	3.52	2.43				
D186074	5,410	9,740	.97	3.64	1.44	1.0	1,095	1,155	1,225
	6,160	11,090	1.10	4.15	1.64				
	7,680	13,820	1.38	5.16	2.04				
D186075	5,640	10,150	.24	2.37	.63	1.0	1,105	1,155	1,220
	6,730	12,110	.29	2.83	.75				
	7,950	14,310	.34	3.34	.89				
D186076	5,480	9,870	.21	2.05	.82	1.0	1,125	1,180	1,235
	6,460	11,630	.25	2.41	.97				
	7,870	14,160	.30	2.94	1.18				
D192368	5,790	10,410	.18	2.49	3.01	1.5	1,150	1,205	1,265
	6,090	10,960	.19	2.62	3.17				
	7,680	13,830	.24	3.31	4.00				

Table 3. Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 90 Iowa coal samples--continued

Sample number	Proximate analysis: Moisture	Proximate analysis: Volatile matter	Proximate analysis: Fixed carbon	Proximate analysis: Ash	Ultimate analysis: Hydrogen	Ultimate analysis: Carbon	Ultimate analysis: Nitrogen	Ultimate analysis: Oxygen	Ultimate analysis: Sulfur	Air-dried loss
D192369	13.8	32.2	43.1	10.9	5.4	58.5	1.3	21.1	2.8	10.5
	---	37.4	50.0	12.6	4.5	67.9	1.5	10.2	3.2	---
	---	42.8	57.2	---	5.1	77.7	1.7	11.7	3.7	---
D192370	8.1	33.5	36.6	21.8	4.2	44.1	.8	16.4	12.8	3.2
	---	36.5	39.8	23.7	3.6	48.0	.9	10.0	13.9	---
	---	47.8	52.2	---	4.7	62.9	1.1	13.1	18.3	---
D192371	11.1	29.8	39.2	19.9	4.5	46.7	.8	17.6	10.6	6.7
	---	33.5	44.1	22.4	3.7	52.5	.9	8.7	11.9	---
	---	44.5	56.8	---	4.7	67.7	1.2	11.2	15.4	---
D192372	10.0	35.0	43.7	11.3	5.3	59.0	1.0	17.9	5.5	6.4
	---	38.9	48.6	12.6	4.7	65.6	1.1	10.0	6.1	---
	---	44.5	55.5	---	5.3	75.0	1.3	11.4	7.0	---
D192373	8.6	33.1	47.3	11.0	5.0	59.3	1.0	18.9	4.8	4.8
	---	36.2	51.8	12.0	4.4	64.9	1.1	12.3	5.3	---
	---	41.2	58.8	---	5.0	73.8	1.2	14.0	6.0	---
D192374	5.3	32.7	48.5	13.5	4.7	60.1	1.2	13.6	6.9	2.3
	---	34.5	51.2	14.3	4.3	63.5	1.3	9.4	7.3	---
	---	40.3	59.7	---	5.1	74.0	1.5	10.9	8.5	---
D192375	7.9	31.7	39.6	20.8	4.4	48.6	.8	14.9	10.5	3.7
	---	34.4	43.0	22.6	3.8	52.8	.9	8.6	11.4	---
	---	44.5	55.5	---	4.9	68.2	1.1	11.0	14.7	---
D192376	9.0	33.6	39.7	17.7	4.9	55.3	1.0	15.4	5.7	5.3
	---	36.9	43.6	19.5	4.3	60.8	1.1	8.1	6.3	---
	---	45.8	54.2	---	5.3	75.4	1.4	10.1	7.8	---

Table 3. Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 90 Iowa coal samples--continued

Sample number	Heat of combustion		Forms of sulfur			Free Swelling	Ash fusion temperature, C°		
	Kcal/kg	Btu/lb	Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D192369	5,760	10,380	0.45	1.41	0.90	1.0	1,040	1,095	1,150
	6,690	12,040	.52	1.64	1.04				
	7,660	13,780	.60	1.87	1.20				
D192370	4,540	8,170	3.57	6.30	2.89	.5	1,180	1,235	1,290
	4,940	8,890	3.88	6.86	3.14				
	6,480	11,660	5.09	8.99	4.12				
D192371	4,790	8,620	1.87	5.57	3.13	.5	1,180	1,230	1,295
	5,380	9,690	2.10	6.27	3.52				
	6,940	12,490	2.71	8.07	4.54				
D192372	5,900	10,630	1.04	2.11	2.39	1.0	1,040	1,100	1,150
	6,560	11,810	1.16	2.34	2.66				
	7,500	13,500	1.32	2.68	3.04				
D192373	5,840	10,510	1.04	1.59	2.15	1.0	985	1,040	1,095
	6,390	11,500	1.14	1.74	2.35				
	7,270	13,080	1.29	1.98	2.67				
D192374	6,040	10,870	1.12	3.89	1.85	1.0	1,040	1,095	1,155
	6,380	11,480	1.18	4.11	1.95				
	7,440	13,390	1.38	4.79	2.28				
D192375	4,990	8,990	1.88	5.84	2.73	1.0	1,015	1,070	1,125
	5,420	9,760	2.04	6.34	2.96				
	7,000	12,610	2.64	8.19	3.83				
D192376	5,460	9,820	1.29	2.47	1.99	1.0	1,235	1,290	1,345
	6,000	10,800	1.42	2.71	2.19				
	7,450	13,400	1.76	3.37	2.71				

Table 3. Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 90 Iowa coal samples--continued

Sample number	Proximate analysis: Moisture	Proximate analysis: Volatile matter	Proximate analysis: Fixed carbon	Proximate analysis: Ash	Ultimate analysis: Hydrogen	Ultimate analysis: Carbon	Ultimate analysis: Nitrogen	Ultimate analysis: Oxygen	Ultimate analysis: Sulfur	Air-dried loss
D192377	7.7	32.2	41.6	18.4	4.4	49.6	1.0	18.1	8.6	3.4
	---	34.9	45.1	19.9	3.8	53.7	1.1	12.2	9.3	---
	---	43.6	56.3	---	4.8	67.1	1.4	15.2	11.6	---
D192378	10.6	34.5	39.2	15.7	4.8	53.2	.9	18.4	7.0	6.4
	---	38.6	43.8	17.6	4.1	59.5	1.0	10.0	7.8	---
	---	46.8	53.2	---	4.9	72.2	1.2	12.2	9.5	---
D192379	6.5	34.2	38.5	20.8	4.6	55.7	1.2	14.4	3.2	3.5
	---	36.6	41.2	22.2	4.1	59.6	1.3	9.2	3.4	---
	---	47.0	53.0	---	5.3	76.6	1.7	11.9	4.4	---

Table 3. Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 90 Iowa coal samples--continued

Sample number	Heat of combustion		Forms of sulfur			Free Swelling	Ash fusion temperature, C°		
	Kcal/kg	Btu/lb	Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D192377	5,110	9,210	2.74	3.41	2.42	0.5	1,070	1,125	1,180
	5,540	9,970	2.97	3.69	2.62				
	6,920	12,460	3.71	4.61	3.27				
D192378	5,280	9,500	2.07	3.03	1.87	.5	1,180	1,235	1,290
	5,900	10,620	2.32	3.39	2.09				
	7,160	12,890	2.81	4.11	2.54				
D192379	5,450	9,810	.52	2.25	.42	1.0	1,095	1,150	1,200
	5,830	10,490	.56	2.41	.45				
	7,500	13,500	.72	3.09	.58				

Table 4. Major- and minor-oxide and trace element composition of the laboratory ash of 106 Iowa coal samples

{Coal ashed at 525°C. L, less than the values shown; N, not detected; B, not determined. S after element title indicates determinations by semiquantitative emission spectrography}

Sample number	Ash (percent)	SiO_2 (percent)	Al_2O_3 (percent)	CaO (percent)	MgO (percent)	Na_2O (percent)	K_2O (percent)	Fe_2O_3 (percent)	TiO_2 (percent)
D166027	23.7	16	8.0	16	0.38	0.07	0.61	35	0.20
D166028	25.5	27	14	15	.70	.12	1.4	22	.50
D166029	15.5	21	11	17	.51	.08	.78	28	.50
D166030	15.1	28	13	4.5	.46	.15	.95	37	.50
D166031	20.0	22	12	.84	.56	.12	.85	42	.30
D166032	20.9	21	7.2	19	.46	.11	.56	31	.20
D166033	17.9	24	9.3	13	.45	.15	.87	32	.50
D166034	21.9	15	5.5	8.1	.27	.09	.35	46	.15
D166035	21.0	14	5.8	28	.38	.09	.36	22	.20
D166036	12.8	16	7.3	19	.40	.11	.43	30	.30
D166037	14.2	28	9.6	18	.46	.30	.69	22	.20
D166038	15.3	29	9.7	15	.46	.30	.73	25	.30
D166039	18.3	44	18	9.3	.88	.26	1.7	15	.50
D166040	29.3	49	21	5.2	2.21	.30	2.5	13	1.0
D166041	17.2	18	10	.71	.22	.11	.34	46	.30
D166042	16.2	31	11	9.3	.33	.11	.72	30	.50
D166043	11.2	23	11	2.4	.25	.12	.40	44	.50
D176169	16.2	12	4.1	30	.51	.14	.57	18	.25
D176170	18.5	28	9.6	4.5	.50	.30	1.0	42	.64
D176171	29.5	48	16	6.2	.38	.24	1.2	15	.90
D176172	25.6	12	9.4	7.1	.17	.15	.21	53	.19
D176173	27.9	24	8.5	19	1.36	.20	.71	22	.44
D176174	20.1	46	23	4.6	.51	.32	1.2	14	1.2
D176175	16.6	31	17	15	.61	.31	1.2	16	.52
D176176	22.2	11	6.5	7.0	.22	.14	.34	56	.30

Table 4. Major- and minor-oxide and trace element composition of the laboratory ash of 106 Iowa coal samples--continued

Sample number	P_2O_5 (percent)	SO_3 (percent)	Ag-S (ppm)	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Ce-S (ppm)	Co-S (ppm)	Cr-S (ppm)
D166027	0.13	8.7	N	300	3,000	7	2.0	N	30	70
D166028	.42	6.7	N	300	2,000	7	6.0	N	30	70
D166029	.18	8.6	N	700	3,000	15	13.0	N	30	70
D166030	.13	3.2	N	1,000	150	15	4.0	N	30	70
D166031	.16	2.6	N	700	100	7	1.0L	N	70	70
D166032	.17	12	N	700	100	7	1.0L	N	15	100
D166033	.070	6.1	N	700	150	7	8.0	N	20	70
D166034	.060	6.0	N	500	70	7	1.0L	N	15	30
D166035	.51	14	N	700	70	7	1.0L	N	15	50
D166036	.72	6.5	N	1,500	100	15	1.0L	N	15	50
D166037	.98	8.4	N	1,500	500	7	2.0	N	30	50
D166038	.87	11	N	1,500	300	10	2.0	N	30	50
D166039	.56	6.0	N	1,000	200	15	1.0L	500L	30	70
D166040	.30	3.4	N	700	300	7	1.0L	500L	30	100
D166041	.060	3.4	N	700	150	15	85.0	N	70	50
D166042	.11	6.1	N	700	150	15	33.0	N	30	70
D166043	.10	2.7	1.5	1,000	50	20	28.0	N	70	70
D176169	1.0L	15	5	700	100	10	1.0L	N	20	100
D176170	1.0L	4.8	N	500	150	15	1.0L	N	30	70
D176171	1.0L	5.7	3	200	200	15	165	N	150	150
D176172	1.0L	6.1	3	300	150	7	58.0	500L	200	30
D176173	1.0L	10	N	300	150	10	1.0	N	30	70
D176174	1.0L	2.7	N	500	500	15	64.0	500L	30	150
D176175	1.0L	5.1	N	1,000	1,000	15	18.0	N	30	100
D176176	1.0L	6.3	N	300	300	10	1.0L	500L	70	50

Table 4. Major- and minor-oxide and trace element composition of the laboratory ash of 106 Iowa coal samples--continued

Sample number	Cu (ppm)	Ga-S (ppm)	Ge-S (ppm)	La-S (ppm)	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Nd-S (ppm)	Ni-S (ppm)
D166027	62	B	150	N	40	700	15	20L	B	150
D166028	58	B	100	100L	91	1,000	15	20L	N	150
D166029	84	B	200	N	43	1,000	30	20L	B	150
D166030	160	B	100	100L	76	700	15	20L	N	150
D166031	204	B	50	100L	76	3,000	15	20L	150	200
D166032	98	B	70	N	22	1,000	15	20L	B	70
D166033	98	B	100	N	46	700	15	20L	B	70
D166034	100	B	30	N	17	500	15	20L	B	50
D166035	56	B	100	N	26	2,000	7	20L	B	100
D166036	86	B	150	N	32	1,500	7	20L	B	150
D166037	60	B	70	N	48	1,000	7	20L	B	150
D166038	60	B	70	N	57	700	7	20L	B	150
D166039	94	20	70	100L	91	700	7	20L	150L	150
D166040	80	B	70	100L	114	700	10	20L	150L	200
D166041	148	B	100	N	93	300	30	20L	B	150
D166042	104	B	150	N	138	700	70	20L	B	200
D166043	142	B	150	100L	75	300	30	20L	150L	70
D176169	82	15	150	N	10	2,340	100	20L	B	100
D176170	116	B	200	N	35	585	7	20L	B	150
D176171	162	15	30	N	143	485	150	20L	B	300
D176172	180	B	150	100	53	440	30	20L	150	700
D176173	70	B	70	100L	38	1,530	50	20L	N	150
D176174	120	50	30	100	179	255	15	30	150	100
D176175	120	30	100	100	99	705	20	20L	150	150
D176176	70	B	70	100L	40	350	N	20L	150L	200

Table 4. Major- and minor-oxide and trace element composition of the laboratory ash of 106 Iowa coal samples--continued

Sample number	Pb (ppm)	Sc-S (ppm)	Sr-S (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)
D166027	400	15	150	70	30	B	1,480	70
D166028	110	30	100	150	50	B	3,000	70
D166029	250	30	100	150	30	B	7,800	70
D166030	70	30	150	150	30	B	1,500	70
D166031	75	20	150	150	70	B	1,080	70
D166032	70	15	70	100	30	B	292	70
D166033	45	20	70	100	30	B	2,400	70
D166034	90	10	50	70	30	B	52	50
D166035	360	15	150	70	30	B	188	70
D166036	450	15	150	70	30	B	364	70
D166037	305	15	200	70	30	B	2,240	50
D166038	345	15	200	70	30	3	1,740	70
D166039	150	20	150	150	30	3	740	100
D166040	120	20	150	150	30	B	260	150
D166041	500	20	30	100	70	B	32,000	70
D166042	270	30	70	150	50	B	11,000	150
D166043	630	15	150	150	70	B	7,800	70
D176169	110	15	100	300	50	5	64	50
D176170	560	30	150	70	50	B	64	100
D176171	200	30	300	300	30	7	14,200	200
D176172	220	30	2,000	150	30	B	8,840	50
D176173	90	30	100	100	70	B	200	100
D176174	75	50	150	150	70	5	17,500	200
D176175	120	30	300	150	100	7	6,000	70
D176176	300	20	300	70	30	B	60	70

Table 4. Major- and minor-oxide and trace element composition of the laboratory ash of 106 Iowa coal samples--continued

Sample number	Ash (percent)	SiO_2 (percent)	Al_2O_3 (percent)	CaO (percent)	MgO (percent)	Na_2O (percent)	K_2O (percent)	Fe_2O_3 (percent)	TiO_2 (percent)
D176177	16.6	15	9.6	5.7	.30	0.16	.62	52	.48
D176178	30.4	31	17	1.3	.76	.40	1.6	35	.73
D176179	18.4	24	8.4	8.0	.58	.45	1.0	39	.58
D176180	10.3	23	7.5	20	.76	.50	1.1	20	.42
D176181	18.1	29	9.2	15	.70	.40	1.1	22	.48
D176182	41.6	5.6	1.9	13	.23	.09	.14	51	.17
D176183	29.4	12	5.7	11	.27	.19	.43	46	.23
D176184	22.5	18	10	3.9	.32	.26	.62	50	.45
D176185	32.0	3.5	1.4	8.1	.13	.11	.070	64	.14
D176186	34.2	8.0	4.3	3.8	.10L	.09L	.11	66	.15
D176187	12.6	13	7.3	12	.32	.18	.51	42	.37
D176188	25.3	24	16	7.2	.55	.18	1.1	32	.63
D176189	24.9	26	10	3.0	.76	.35	1.1	45	.57
D176190	45.9	42	6.6	14	.88	.61	1.2	14	.64
D176191	12.8	25	7.1	19	.42	.36	.60	21	.33
D176192	17.0	35	12	7.5	.53	.32	1.2	23	.52
D176193	37.8	43	18	1.2	.37	.28	.87	28	.91
D176194	31.5	28	12	4.5	.37	.26	.72	36	.50
D176195	10.7	13	5.1	6.9	.25	.40	.36	52	.36
D176196	23.7	20	7.4	24	.56	.26	.57	16	.36
D176197	16.4	6.4	4.8	6.4	.17	.19	.17	60	.16
D176198	29.2	42	21	1.7	.73	.20	2.1	21	.74
D176199	16.2	12	6.1	25	.32	.22	.34	25	.29
D176200	30.1	13	6.0	5.0	.27	.14	.48	50	.73
D179838	11.6	17	8.6	9.2	.43	.18	.67	36	.37
D179389	49.8	52	23	.84	1.29	.39	2.4	8.0	1.0
D379840	11.8	32	15	5.9	.51	.27	1.1	23	.63
D179841	20.6	18	4.9	17	.45	.18	.39	26	.23
D179842	68.8	39	9.4	2.5	1.08	.53	1.9	26	.43
D179843	38.6	11	3.7	8.7	.13	.05	.25	58	.28

Table 4. Major- and minor-oxide and trace element composition of the laboratory ash of 106 Iowa coal samples--continued

Sample number	P_2O_5 (percent)	SO_3 (percent)	Ag-S (ppm)	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Ce-S (ppm)	Co-S (ppm)	Cr-S (ppm)
D176177	1.0L	2.8	N	700	700	15	1.0L	N	100	70
D176178	1.0L	5.0	2	500	200	15	328	500L	70	100
D176179	1.0L	4.4	N	700	150	15	1.0L	N	30	70
D176180	1.0L	6.9	5	1,500	150	30	22.0	N	30	150
D176181	1.0L	4.6	1	700	150	15	4.0	N	50	70
D176182	1.0L	16	1	150	70	3L	1.0	N	30	20
D176183	1.0L	11	5	300	100	7	68.0	500L	100	50
D176184	1.0L	3.3	1	500	150	10	1.0L	N	300	70
D176185	1.0L	7.6	N	200	20	7	1.0L	N	50	30
D176186	1.0L	2.8	N	150	50	7	5.0	500L	50	30
D176187	1.0L	8.0	N	500	150	15	6.0	N	50	70
D176188	1.0L	4.9	N	500	300	7	1.0	500L	30	150
D176189	1.0L	3.4	N	500	200	10	1.0L	N	30	70
D176190	1.0L	9.9	3	200	5,000	N	1.0L	N	30	70
D176191	1.0L	7.8	N	100	300	20	73.0	N	15	50
D176192	1.0L	6.3	2	700	200	15	437	N	50	150
D176193	1.0L	2.0	N	200	150	7	35.0	500L	100	150
D176194	1.0L	6.0	N	200	200	7	1.0	500L	300	100
D176195	1.0L	4.1	N	1,500	100	30	1.0L	N	100	70
D176196	1.0L	11	N	500	100	10	1.0L	N	20	70
D176197	1.0L	4.8	3	1,000	50	15	9.0	N	30	70
D176198	1.0L	1.5	N	500	700	7	1.0L	500L	30	150
D176199	1.0L	8.3	N	700	700	15	1.0L	500L	30	50
D176200	1.0L	10	N	300	10,000	7	188	N	70	70
D179838	1.0L	6.2	1	700	150	30	1.0L	N	70	150
D179389	1.0L	.74	N	300	700	10	1.0L	200	50	300
D379840	1.0L	3.1	2	700	300	30	9.0	200	150	300
D179841	1.0L	14	N	300	100	15	26.0	N	15	30
D179842	1.0L	4.5	7	70	500	N	1.0L	N	30	150
D179843	1.0L	9.9	7	150	3,000	15	1.0L	N	700	30

Table 4. Major- and minor-oxide and trace element composition of the laboratory ash of 106 Iowa coal samples--continued

Sample number	Cu (ppm)	Ga-S (ppm)	Ge-S (ppm)	La-S (ppm)	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Nd-S (ppm)	Ni-S (ppm)
D176177	80	B	300	100L	70	335	7	20L	150L	200
D176178	520	B	100	100	242	220	20	20L	150L	200
D176179	172	B	100	N	92	1,250	20	20L	B	150
D176180	142	B	300	N	20	2,270	150	20L	B	150
D176181	150	B	200	N	50	2,040	30	20	B	200
D176182	220	B	100	N	10	1,130	30	20L	B	100
D176183	240	B	150	150	30	785	70	20L	150	700
D176184	170	B	70	N	65	375	30	20L	B	300
D176185	118	B	70	N	11	635	N	20L	B	150
D176186	84	B	70	100	30	240	N	20L	200	150
D176187	72	B	150	150	54	925	15	20L	150	70
D176188	70	30	70	150	192	390	N	20L	150	70
D176189	170	B	100	100L	88	590	15	20L	N	150
D176190	62	10	20	N	22	1,710	30	20L	B	70
D176191	120	30	300	N	22	2,580	20	20L	B	150
D176192	128	20	70	N	78	960	100	20L	B	300
D176193	120	20	N	150	212	280	20	20L	150	300
D176194	112	30	30	150	78	2,340	15	20L	150	700
D176195	100	B	300	N	28	1,180	30	20L	B	200
D176196	64	30	70	N	46	2,310	10	20L	B	100
D176197	264	B	300	N	71	670	30	20L	B	200
D176198	156	30	30	150	110	275	15	20	150	150
D176199	44	20	100	150	35	1,760	N	20L	150	70
D176200	82	B	200	N	55	395	15	20L	B	150
D179838	228	70	200	N	25	1,130	70	20	B	150
D179389	147	70	20	100	177	270	N	30	200	150
D379840	197	70	200	150	100	895	70	30	200	300
D179841	36	30	100	N	17	1,470	30	N	B	70
D179842	157	50	N	N	26	460	70	20	B	150
D179843	440	20	150	N	11	790	300	20	B	1,500

Table 4. Major- and minor-oxide and trace element composition of the laboratory ash of 106 Iowa coal samples--continued

Sample number	Pb (ppm)	Sc-S (ppm)	Sr-S (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)
D176177	390	70	150	150	100	B	60	70
D176178	350	50	150	500	70	B	17,600	150
D176179	630	15	150	100	70	B	97	100
D176180	130	15	150	700	70	7	960	70
D176181	485	30	200	150	70	B	210	150
D176182	530	20	150	50	50	B	476	30
D176183	520	15	700	150	200	B	11,000	70
D176184	320	30	150	200	50	B	182	100
D176185	155	30	30	70	30	B	42	30
D176186	190	15	50	50	150	B	1,360	30
D176187	160	20	300	150	100	B	2,800	70
D176188	130	30	1,000	150	70	B	176	100
D176189	1,020	20	150	100	70	B	58	150
D176190	130	15	150	200	20	3	46	150
D176191	190	30	150	70	70	7	6,120	70
D176192	130	15	3,000	1,000	70	7	30,000	150
D176193	75	30	1,500	150	70	B	3,480	200
D176194	100	30	300	200	100	B	130	150
D176195	335	50	300	150	100	B	95	150
D176196	155	20	150	100	70	3	66	70
D176197	535	30	100	150	50	B	2,720	70
D176198	110	50	200	200	70	7	54	150
D176199	85	15	700	100	100	B	44	50
D176200	285	30	700	150	30	B	60,000	100
D179838	850	30	300	300	100	7	76	70
D179389	60	30	300	700	70	7	11	200
D379840	100	50	300	700	100	15	1,450	150
D179841	300	7	500	70	70	7	4,540	50
D179842	300	15	150	300	30	7	40	70
D179843	1,100	10	150	70	70	7	120	70

Table 4. Major- and minor-oxide and trace element composition of the laboratory ash of 106 Iowa coal samples--continued

Sample number	Ash (percent)	SiO_2 (percent)	Al_2O_3 (percent)	CaO (percent)	MgO (percent)	Na_2O (percent)	K_2O (percent)	Fe_2O_3 (percent)	TiO_2 (percent)
D179844	32.9	21	8.7	7.9	0.46	0.11	0.68	33	0.38
D179845	38.7	2.1	2.2	3.6	.03	.03	.030L	79	.10
D179846	35.6	13	8.9	6.4	.18	.11	.35	58	.30
D179847	12.7	15	5.9	19	.60	.11	.77	22	.27
D179848	7.9	39	10	17	.55	.31	.87	4.9	.48
D179849	21.8	11	4.8	17	1.48	.14	.32	30	.23
D179850	13.0	40	21	1.1	.65	.42	1.3	21	.81
D179851	5.7	22	9.0	16	.83	.32	1.2	17	.36
D179852	10.6	27	7.6	18	.51	.32	.76	14	.36
D179853	32.8	9.3	4.3	22	1.58	.12	.27	23	.18
D179854	24.6	32	18	4.8	.53	.32	1.3	23	.63
D179855	13.4	14	13	11	.22	.26	.48	46	.37
D179856	32.0	14	9.8	2.6	.17	.12	.28	49	.48
D185601	13.9	7.7	3.7	13	.31	.10	1.1	60	.15
D185602	14.3	13	5.3	17	.45	.11	1.1	48	.31
D185603	12.3	15	1.6	17	.45	.18	.84	47	.12
D185604	11.8	20	5.0	23	.52	.20	1.0	32	.36
D185605	10.6	18	4.7	18	.55	.22	1.1	42	.29
D185606	13.1	34	11	11	1.37	.16	1.3	24	1.0
D185609	21.8	12	3.0	25	.39	.10	.93	35	.24
D185610	17.0	9.4	2.7	16	.24	.11	1.0	54	.18
D185611	23.0	15	2.8	43	.41	.10	.49	5.8	.27
D185612	12.1	28	12	2.2	.57	.13	1.6	42	.54
D185613	8.4	32	12	12	.73	.19	1.6	25	.70
D186062	11.6	15	5.0	19	.38	.35	.81	44	.16
D186063	14.9	10	4.1	24	.31	.26	.67	41	.12
D186064	8.9	21	8.1	13	.46	.44	.98	42	.26
D186065	16.6	17	8.1	14	.40	.14	1.1	46	.32
D186066	12.1	31	17	14	.35	.16	1.1	28	.63
D186067	24.7	25	12	6.4	.47	.20	1.6	47	.27

Table 4. Major- and minor-oxide and trace element composition of the laboratory ash of 106 Iowa coal samples--continued

Sample number	P_2O_5 (percent)	SO_3 (percent)	Ag-S (ppm)	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Ce-S (ppm)	Co-S (ppm)	Cr-S (ppm)
D179844	1.0L	8.8	1.5	200	500	10	22.0	N	70	150
D179845	1.0L	5.3	1.5	100	70	7	23.0	N	70	30
D179846	1.0L	5.6	1.5	150	70	10	3.0	N	30	70
D179847	1.0L	13	15	700	150	30 1	20	N	70	150
D179848	1.0L	5.3	N	700	700	30	14.0	N	15	100
D179849	1.0L	10	1.5	200	150	15	1.0L	200	150	150
D179850	1.0L	1.2	N	500	300	30	4.0	N	70	300
D179851	1.4	11	10	1,000	200	30	35.0	N	20	500
D179852	1.0L	8.2	1.5	300	2,000	20	93.0	N	30	150
D179853	1.0L	17	1.5	150	70	7	5.0	N	20	50
D179854	1.0L	2.9	2	300	300	20	1.0L	300	50	200
D179855	1.0L	8.5	N	700	150	30	1.0L	N	30	150
D179856	1.0L	3.4	3	150	3,000	15	4.0	N	150	300
D185601	1.0L	11	N	300	70	15	1.0L	N	50	20
D185602	1.0L	14	N	300	70	15	1.0L	N	50	30
D185603	1.0L	9.2	N	1,000	50	15	1.0	N	50	15
D185604	1.0L	8.3	N	1,500	100	15	1.0	500L	50	30
D185605	1.0L	10	N	1,500	100	15	1.0L	500L	50	30
D185606	1.0L	15	N	700	2,000	15	4.0	700	50	100
D185609	1.0L	11	N	300	70	5	2.0	N	30	20
D185610	1.0L	8.9	N	500	70	7	1.0L	N	70	20
D185611	1.0L	11	N	300	50	5	1.0L	N	10	20
D185612	1.0L	5.4	10	1,000	150	15 5	10	N	50	50
D185613	1.0L	7.1	5	500	300	20 3	70	N	30	70
D186062	1.0L	10	1.5	700	70	15	1.0L	N	30	30
D186063	1.0L	12	1.5	700	100	10	1.0	N	30	30
D186064	1.0L	7.7	1.5	1,500	100	20	12.0	N	50	70
D186065	1.0L	12	N	500	700	7	1.0L	N	15	70
D186066	1.0L	6.4	N	700	150	15	1.5	500L	30	100
D186067	1.0L	5.3	1.5	300	150	7	1.0L	N	100	70

Table 4. Major- and minor-oxide and trace element composition of the laboratory ash of 106 Iowa coal samples--continued

Sample number	Cu (ppm)	Ga-S (ppm)	Ge-S (ppm)	La-S (ppm)	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Nd-S (ppm)	Ni-S (ppm)
D179844	145	70	100	N	44	780	70	20	B	200
D179845	179	30	100	N	10L	230	30	N	B	300
D179846	157	70	100	N	44	380	100	20	B	200
D179847	146	70	300	N	12	2,780	1,000	20	B	300
D179848	100	70	500	N	63	2,060	50	20	B	70
D179849	192	30	150	150	33	2,780	30	20	N	300
D179850	112	70	100	N	250	160	30	20	B	200
D179851	149	50	300	N	17	1,710	300	20	B	200
D179852	149	50	300	N	25	2,060	30	20	B	150
D179853	109	50	100	N	17	2,060	50	N	B	150
D179854	137	100	70	200	222	530	50	20	300	300
D179855	69	70	100	150	45	820	15	20	N	200
D179856	171	50	70	N	72	560	15	20	B	500
D185601	29	B	70	N	10	1,160	7	20L	B	50
D185602	34	30	100	N	16	1,240	7	20L	B	50
D185603	99	B	150	N	10	1,840	7	20L	B	200
D185604	77	30	150	100	16	1,660	10	20L	150	150
D185605	96	30	150	100	18	1,880	7	20L	150	150
D185606	125	30	150	200	109	1,600	10	20	300	100
D185609	67	15	30	N	14	1,920	N	20L	B	100
D185610	109	B	50	N	11	1,330	N	20L	B	200
D185611	22	15	70	N	13	4,260	15	N	B	30
D185612	157	B	150	N	97	365	70	20	B	500
D185613	98	20	150	N	68	1,260	70	20	B	300
D186062	157	B	70	N	13	1,490	15	20L	B	300
D186063	150	B	70	N	10L	1,800	15	N	B	300
D186064	175	B	150	N	25	970	15	20	B	300
D186065	153	B	70	100L	29	915	15	20L	300	100
D186066	88	30	150	150	94	610	15	20	150	70
D186067	153	B	70	100L	37	370	7	20L	300	300

Table 4. Major- and minor-oxide and trace element composition of the laboratory ash of 106 Iowa coal samples--continued

Sample number	Pb (ppm)	Sc-S (ppm)	Sr-S (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)
D179844	400	30	150	300	70	7	7,400	150
D179845	800	15	150	150	30	10	7,350	N
D179846	700	15	150	70	50	7	1,370	70
D179847	500	20	500	1,500	70	10	9,300	70
D179848	75	30	300	150	150	15	1,000	70
D179849	500	30	300	200	100	7	320	70
D179850	170	30	300	300	100	10	1,030	150
D179851	190	15	500	3,000	100	15	2,200	70
D179852	525	30	300	200	100	15	6,250	70
D179853	260	30	300	100	70	7	1,000	50
D179854	190	50	1,500	300	70	10	370	100
D179855	150	30	2,000	200	70	7	970	70
D179856	225	30	150	300	70	10	2,560	150
D185601	360	10L	70	30	50	B	76	30
D185602	400	10L	70	50	50	B	82	50
D185603	200	15	300	30	50	B	83	30
D185604	105	15	700	70	70	B	80	70
D185605	160	15	700	50	70	B	87	70
D185606	230	30	1,000	200	150	B	1,050	150
D185609	170	10L	150	15	50	B	847	30
D185610	245	10L	150	20	50	B	54	30
D185611	45	10L	200	30	70	7	76	30
D185612	515	15	150	70	70	B	31,600	100
D185613	130	20	150	150	70	B	13,000	100
D186062	650	15	150	70	70	B	501	50
D186063	795	15	150	70	70	B	402	30
D186064	665	20	150	150	70	B	3,120	70
D186065	80	30	150	100	70	B	77	70
D186066	75	30	150	150	150	B	1,010	70
D186067	595	15	100	150	70	B	60	70

Table 4. Major- and minor-oxide and trace element composition of the laboratory ash of 106 Iowa coal samples--continued

Sample number	Ash (percent)	SiO_2 (percent)	Al_2O_3 (percent)	CaO (percent)	MgO (percent)	Na_2O (percent)	K_2O (percent)	Fe_2O_3 (percent)	TiO_2 (percent)
D186068	13.8	14	7.3	27	0.24	0.20	0.62	31	0.22
D186069	26.0	46	23	3.1	.85	.19	2.1	16	.88
D186070	11.1	29	18	10	.47	.23	1.4	28	.63
D186071	14.5	11	7.5	14	.25	.17	.90	51	.28
D186072	22.2	15	8.1	32	.44	.19	.82	20	.45
D186073	15.2	22	9.4	18	.44	.18	1.2	32	.54
D186074	19.9	18	6.4	18	.50	.13	1.0	37	.40
D186075	13.2	23	7.5	25	.58	.40	.90	22	.43
D186076	15.1	18	4.7	21	.60	.31	.86	33	.29
D192368	24.2	19	4.5	21	.30	.13	.21	22	.26
D192369	11.4	31	9.6	12	.55	.38	.71	22	.49
D192370	25.9	5.1	1.8	5.9	.09	.13	.030L	59	.080
D192371	20.6	14	5.6	8.6	.31	.26	.29	46	.24
D192372	13.5	24	12	9.5	.36	.31	.47	31	.46
D192373	14.1	29	9.4	11	.51	.35	.77	27	.40
D192374	13.4	15	5.8	8.4	.25	.26	.24	46	.30
D192375	22.9	28	12	3.4	.32	.21	.76	40	.55
D192376	16.4	15	4.9	13	.22	.22	.23	35	.50
D192377	19.9	26	10	3.2	.35	.16	.51	41	.44
D192378	18.0	13	8.0	13	.24	.21	.27	38	.27
D192379	20.9	31	12	15	.57	.15	1.1	16	.55

Table 4. Major- and minor-oxide and trace element composition of the laboratory ash of 106 Iowa coal samples--continued

Sample number	P_2O_5 (percent)	SO_3 (percent)	Ag-S (ppm)	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Ce-S (ppm)	Co-S (ppm)	Cr-S (ppm)
D186068	1.0L	14	N	700	200	15	1.0L	500	50	70
D186069	1.0L	2.3	N	300	150	15	5.0	500L	50	150
D186070	1.3	5.7	N	1,000	500	20	1.0L	500	50	150
D186071	1.0L	9.1	1.5	700	150	15	74.0	500L	70	70
D186072	1.0L	16	N	500	150	10	2.0	N	15	70
D186073	1.0L	12	N	500	100	15	23.0	N	70	150
D186074	1.0L	13	N	500	100	10	62.0	N	70	70
D186075	1.0L	9.9	N	1,000	150	15	1.5	N	50	70
D186076	1.0L	10	N	1,000	150	15	24.0	N	30	50
D192368	1.0L	19	N	300	1,000	7	9.0	N	15	30
D192369	1.0L	9.7	N	1,500	200	15	2.5	N	100	70
D192370	1.0L	13	N	300	20	10	1.0L	N	15	30
D192371	1.0L	13	N	700	70	15	82.0	N	200	70
D192372	1.0L	7.7	N	700	300	15	5.0	N	50	100
D192373	1.0L	5.1	N	1,500	100	15	1.0L	N	30	70
D192374	1.0L	6.1	N	1,000	70	15	3.0	N	100	70
D192375	1.0L	7.6	N	300	150	15	31.0	N	50	50
D192376	1.0L	16	N	500	5,000	20	115	N	30	50
D192377	1.0L	6.5	N	500	150	15	2.0	N	70	70
D192378	1.0L	12	N	700	150	15	17.0	N	20	50
D192379	1.0L	8.3	N	700	200	15	3.0	N	30	70

Table 4. Major- and minor-oxide and trace element composition of the laboratory ash of 106 Iowa coal samples--continued

Sample number	Cu (ppm)	Ga-S (ppm)	Ge-S (ppm)	La-S (ppm)	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Nd-S (ppm)	Ni-S (ppm)
D186068	55	B	100	150	40	1,570	N	20L	150	150
D186069	112	30	70	150	225	240	15	20	N	150
D186070	75	50	150	150	162	430	15	20	300	100
D186071	131	30	150	150	31	575	15	20	150	300
D186072	77	20	100	100L	79	2,740	15	20L	N	50
D186073	77	50	100	N	85	785	50	20L	B	150
D186074	112	30	100	100L	35	1,070	15	20	150L	300
D186075	47	30	150	100L	31	1,890	7	20	150L	300
D186076	59	30	150	100L	20	3,520	7	20L	150L	300
D192368	37	20	100	N	17	1,550	7	N	B	150
D192369	103	50	70	N	43	1,180	N	N	B	300
D192370	60	30	50	N	20	600	N	N	B	100
D192371	125	70	150	100L	35	1,370	7	N	N	500
D192372	112	70	100	N	134	1,010	15	N	B	150
D192373	89	30	300	N	21	1,240	30	N	B	100
D192374	129	70	150	100	33	670	N	N	N	300
D192375	57	30	100	N	88	400	N	20L	B	200
D192376	82	50	150	100	45	750	N	20L	150	200
D192377	232	50	150	N	99	800	30	20L	B	300
D192378	73	30	100	100L	69	1,370	15	N	N	100
D192379	66	30	70	N	69	1,950	N	N	B	150

Table 4. Major- and minor-oxide and trace element composition of the laboratory ash of 106 Iowa coal samples--continued

Sample number	Pb (ppm)	Sc-S (ppm)	Sr-S (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)
D186068	220	30	1,500	150	150	B	196	70
D186069	300	30	150	200	70	B	1,880	150
D186070	110	30	2,000	300	150	B	488	150
D186071	260	30	1,000	100	70	B	14,000	70
D186072	155	20	700	150	70	B	462	70
D186073	150	30	150	200	70	B	4,820	100
D186074	405	30	150	150	70	B	18,700	70
D186075	170	20	700	100	70	B	1,240	70
D186076	230	15	700	70	70	B	6,790	70
D192368	150	10	150	50	30	B	700	30
D192369	270	30	500	150	70	B	1,500	70
D192370	1,800	20	70	70	30	B	37	30
D192371	440	30	150	150	100	15	12,400	70
D192372	95	30	150	150	70	B	2,250	150
D192373	365	15	150	100	30	B	68	70
D192374	615	15	300	100	30	B	517	50
D192375	750	15	300	70	30	B	3,000	70
D192376	490	20	1,000	70	50	B	25,700	70
D192377	1,000	20	200	150	50	B	58	70
D192378	620	15	1,000	100	30	B	3,000	50
D192379	135	20	300	100	70	B	200	70

Table 5. Element composition of 106 Iowa coal samples

[As, F, Hg, Sb, Se, Th, and U values are from direct determinations on air-dried (32°C) coal; all other values calculated from analyses of coal ash. S means analysis by emission spectrography; L, less than the value shown; N, not detected; B, not determined]

Sample number	Si (percent)	Al (percent)	Ca (percent)	Mg (percent)	Na (percent)	K (percent)	Fe (percent)	Ti (percent)	Ag-S (ppm)	As (ppm)
D166027	1.8	1.0	2.6	0.054	0.012	0.12	5.7	0.028	N	15
D166028	3.3	1.9	2.7	.11	.023	.29	3.9	.076	N	10
D166029	1.5	.91	1.9	.048	.009	.10	3.0	.046	N	5.0
D166030	2.0	1.0	.49	.042	.017	.12	3.9	.045	N	12
D166031	2.0	1.2	.12	.067	.018	.14	5.9	.036	N	20
D166032	2.0	.80	2.8	.058	.017	.097	4.5	.025	N	5.0
D166033	2.0	.88	1.7	.048	.020	.13	4.0	.054	N	8.0
D166034	1.5	.63	1.3	.036	.015	.064	7.0	.020	N	10
D166035	1.3	.64	4.2	.048	.014	.063	3.2	.025	N	30
D166036	.98	.50	1.7	.031	.010	.046	2.7	.023	N	30
D166037	1.9	.72	1.9	.039	.032	.082	2.2	.017	N	20
D166038	2.1	.79	1.7	.042	.034	.093	2.6	.027	N	30
D166039	3.8	1.7	1.2	.097	.035	.27	1.9	.055	N	20
D166040	6.6	3.2	1.1	.39	.065	.61	2.7	.18	N	25
D166041	1.5	.95	.087	.023	.014	.049	5.6	.031	N	20
D166042	2.3	.98	1.1	.032	.013	.097	3.4	.049	N	20
D166043	1.2	.64	.19	.017	.010	.037	3.4	.034	.15	15
D176169	.94	.35	3.5	.050	.017	.077	2.1	.024	.7	5.0
D176170	2.4	.94	.59	.056	.041	.16	5.4	.071	N	20
D176171	6.7	2.5	1.3	.067	.052	.29	3.1	.16	1	30
D176172	1.4	1.3	1.3	.026	.028	.045	9.5	.029	.7	160
D176173	3.1	1.2	3.8	.23	.041	.17	4.3	.074	N	10
D176174	4.3	2.5	.66	.062	.048	.20	2.0	.15	N	3.0
D176175	2.4	1.5	1.8	.061	.038	.16	1.9	.052	N	3.0
D176176	1.2	.76	1.1	.029	.023	.063	8.6	.040	N	25

Table 5. Element composition of 106 Iowa coal samples--continued

Sample number	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Ce-S (ppm)	Co-S (ppm)	Cr-S (ppm)	Cu (ppm)	F (ppm)	Ga-S (ppm)	Ge-S (ppm)
D166027	70	700	1.5	0.47	N	7	15	15	75	B	30
D166028	70	500	2	1.5	N	7	20	15	145	B	20
D166029	100	500	2	2.0	N	5	10	13	75	B	30
D166030	150	20	2	.60	N	5	10	24	85	B	15
D166031	150	20	1.5	.20L	N	15	15	41	150	B	10
D166032	150	20	1.5	.21L	N	3	20	20	90	B	15
D166033	150	30	1.5	1.4	N	3	15	18	115	B	20
D166034	100	15	1.5	.22L	N	3	7	22	60	B	7
D166035	150	15	1.5	.21L	N	3	10	12	80	B	20
D166036	200	15	2	.13L	N	2	7	11	60	B	20
D166037	200	70	1	.28	N	5	7	8.5	100	B	10
D166038	200	50	1.5	.31	N	5	7	9.2	80	B	10
D166039	200	30	3	.18L	100L	5	15	17	115	3	15
D166040	200	100	2	.29L	150L	10	30	23	185	B	20
D166041	100	20	2	15	N	10	10	25	40	B	15
D166042	100	20	2	5.3	N	5	10	17	40	B	20
D166043	100	5	2	3.1	N	7	7	16	30	B	15
D176169	100	15	1.5	.16L	N	3	15	13	40	2	20
D176170	100	30	3	.19L	N	5	15	21	45	B	30
D176171	70	70	5	49	N	50	50	48	85	5	10
D176172	70	50	2	15	150L	50	7	46	40	B	50
D176173	100	50	3	.28	N	10	20	20	70	B	20
D176174	100	100	3	13	100L	7	30	24	65	10	7
D176175	150	150	2	3.0	N	5	15	20	80	5	15
D176176	70	70	2	.22L	100L	15	10	16	25	B	15

Table 5. Element composition of 106 Iowa coal samples--continued

Sample number	Hg (ppm)	La-S (ppm)	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Nd-S (ppm)	Ni-S (ppm)	P (ppm)	Pb (ppm)
D166027	0.12	N	9.5	170	3	5L	B	30	130	95
D166028	.09	20L	23	250	3	5L	N	30	470	28
D166029	.09	N	6.7	150	5	3L	B	20	120	39
D166030	.07	15L	11	110	2	3L	N	20	86	11
D166031	.07	20L	15	600	3	5L	30	50	140	15
D166032	.08	N	4.6	210	3	5L	B	15	160	15
D166033	.08	N	8.2	130	3	3L	B	15	55	8.1
D166034	.10	N	3.7	110	3	5L	B	10	57	20
D166035	.18	N	5.5	420	1.5	5L	B	20	470	76
D166036	.12	N	4.1	190	1	2L	B	20	400	58
D166037	.11	N	6.8	140	1	3L	B	20	610	43
D166038	.16	N	8.7	110	1	3L	B	20	580	53
D166039	.08	20L	17	130	1.5	3L	30L	30	450	27
D166040	.09	30L	33	210	3	7L	50L	70	380	35
D166041	.22	N	16	52	5	3L	B	20	45	86
D166042	.14	N	22	110	10	3L	B	30	78	44
D166043	.19	10L	8.4	34	3	2L	15L	7	49	71
D176169	.14	N	1.6	380	15	3L	B	15	710L	18
D176170	.14	N	6.5	110	1.5	3L	B	30	810L	100
D176171	.27	N	42	140	50	7L	B	100	1,300L	59
D176172	.17	20	14	110	7	5L	50	200	1,100L	56
D176173	.09	30L	11	430	15	5L	N	50	1,200L	25
D176174	.17	20	36	51	3	7	30	20	880L	15
D176175	.11	15	16	120	3	3L	20	20	730L	20
D176176	.11	20L	8.9	78	N	5L	30L	50	970L	67

Table 5. Element composition of 106 Iowa coal samples--continued

Sample number	Sb (ppm)	Sc-S (ppm)	Se (ppm)	Sr-S (ppm)	Th (ppm)	U (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)
D166027	0.5	3	1.1	30	3.0L	1.2	15	7	B	350	15
D166028	.6	7	1.3	20	6.2	1.2	30	15	B	760	20
D166029	.4	5	.9	15	3.0L	2.1	20	5	B	1,200	10
D166030	.4	5	1.7	20	3.0L	2.8	20	5	B	230	10
D166031	.8	5	2.0	30	3.0L	4.2	30	15	B	220	15
D166032	.4	3	2.6	15	3.0L	2.7	20	7	B	61	15
D166033	.4	3	1.3	15	3.9	1.4	20	5	B	430	15
D166034	.6	2	1.7	10	3.0L	1.4	15	7	B	11	10
D166035	.5	3	1.4	30	3.0L	.5	15	7	B	39	15
D166036	.4	2	1.0	20	3.0L	.7	10	5	B	47	10
D166037	.6	2	.5	30	3.0L	.6	10	5	B	320	7
D166038	.5	2	1.2	30	3.0L	.6	10	5	.5	270	10
D166039	1.8	3	1.0	30	3.0L	1.4	30	5	.5	140	20
D166040	2.2	7	1.3	50	4.2	1.7	50	10	B	76	50
D166041	1.0	3	3.0	5	3.0L	1.6	15	10	B	5,500	10
D166042	.9	5	2.6	10	3.0L	1.8	20	7	B	1,800	20
D166043	.8	1.5	3.1	15	3.8	1.6	15	7	B	870	7
D176169	15.7	2	11	15	B	30	50	7	.7	10	7
D176170	1.0	5	3.2	30	3.0L	2.2	15	10	B	12	20
D176171	7.6	10	29	100	B	43	100	10	2	4,200	70
D176172	1.9	7	3.3	500	9.7	4.9	50	7	B	2,300	15
D176173	.7	10	3.4	30	18.0	9.3	30	20	B	56	30
D176174	.2	10	6.5	30	11.0	2.4	30	15	1	3,500	50
D176175	.3	5	4.7	50	8.7	4.6	20	15	1	1,000	10
D176176	.5	5	3.7	70	3.0L	1.6	15	7	B	13	15

Table 5. Element composition of 106 Iowa coal samples--continued

Sample number	Si (percent)	Al (percent)	Ca (percent)	Mg (percent)	Na (percent)	K (percent)	Fe (percent)	Ti (percent)	Ag-S (ppm)	As (ppm)
D176177	1.2	.84	.68	0.030	0.020	0.086	6.0	0.048	N	12
D176178	4.4	2.7	.28	.14	.090	.41	7.4	.13	.7	50
D176179	2.1	.82	1.1	.064	.061	.15	5.0	.064	N	30
D176180	1.1	.41	1.5	.047	.038	.097	1.5	.026	.5	5.0
D176181	2.4	.88	1.9	.076	.054	.16	2.8	.052	.2	20
D176182	1.1	.41	3.9	.058	.028	.049	15	.042	.5	90
D176183	1.6	.89	2.3	.048	.041	.11	9.4	.041	1.5	60
D176184	1.9	1.2	.63	.043	.043	.12	7.9	.061	.2	60
D176185	.52	.24	1.9	.025	.026	.019	14	.027	N	40
D176186	1.3	.77	.93	.021L	.023L	.031	16	.031	N	25
D176187	.76	.49	1.1	.024	.017	.054	3.7	.028	N	8.0
D176188	2.9	2.2	1.3	.084	.034	.23	5.7	.095	N	4.0
D176189	3.1	1.4	.53	.11	.065	.24	7.8	.085	N	240
D176190	9.0	1.6	4.6	.24	.21	.47	4.6	.18	1.5	40
D176191	1.5	.48	1.7	.032	.034	.064	1.9	.025	N	15
D176192	2.8	1.0	.91	.054	.040	.16	2.7	.053	.3	8.0
D176193	7.6	3.6	.32	.084	.078	.27	7.4	.21	N	30
D176194	4.1	2.0	1.0	.070	.061	.19	8.0	.094	N	12
D176195	.66	.29	.53	.016	.032	.032	3.9	.023	N	20
D176196	2.2	.92	4.1	.080	.046	.11	2.6	.051	N	5.0
D176197	.49	.42	.75	.017	.023	.023	6.8	.016	.5	30
D176198	5.8	3.2	.35	.13	.043	.50	4.4	.13	N	12
D176199	.90	.52	2.9	.031	.026	.046	2.9	.028	N	5.0
D176200	1.8	.96	1.1	.049	.031	.12	10	.13	N	50
D179838	.91	.53	.76	.030	.015	.065	3.0	.026	.1	18
D179839	12	5.9	.30	.39	.14	1.0	2.8	.31	N	33
D179840	1.8	.97	.50	.036	.024	.11	1.9	.045	.2	22
D179841	1.7	.53	2.4	.056	.027	.067	3.8	.028	N	5.5
D179842	12	3.4	1.2	.45	.27	1.1	13	.18	5	250
D179843	2.0	.76	2.4	.030	.014	.080	16	.065	3	230

Table 5. Element composition of 106 Iowa coal samples--continued

Sample number	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Ce-S (ppm)	Co-S (ppm)	Cr-S (ppm)	Cu (ppm)	F (ppm)	Ga-S (ppm)	Ge-S (ppm)
D176177	100	100	2	0.17L	N	15	10	13	70	B	50
D176178	150	70	5	100	150L	20	30	160	100	B	30
D176179	150	30	3	.18L	N	5	15	32	50	B	20
D176180	150	15	3	2.3	N	3	15	15	50	B	30
D176181	150	30	3	.72	N	10	15	27	110	B	30
D176182	70	30	1.5L	.42	N	15	10	92	45	B	50
D176183	100	30	2	20	150L	30	15	71	45	B	50
D176184	100	30	2	.23L	N	70	15	38	65	B	15
D176185	70	7	2	.32L	N	15	10	38	20	B	20
D176186	50	15	2	1.7	150L	15	10	29	25	B	20
D176187	70	20	2	.76	N	7	10	9.1	30	B	20
D176188	150	70	1.5	.25	150L	7	30	18	140	7	15
D176189	150	50	2	.25L	N	7	15	42	50	B	20
D176190	100	2,000	N	.46L	N	15	30	28	140	5	10
D176191	15	50	2	9.3	N	2	7	15	30	5	50
D176192	100	30	2	74	N	10	20	22	120	3	10
D176193	70	70	3	13	200L	30	70	45	155	7	N
D176194	70	70	2	.32	150L	100	30	35	100	10	10
D176195	150	10	3	.11L	N	10	7	11	30	B	30
D176196	100	20	2	.24L	N	5	15	15	55	7	15
D176197	150	7	2	1.5	N	5	10	43	40	B	50
D176198	150	200	2	.29L	150L	10	50	46	160	10	10
D176199	100	100	2	.16L	70L	5	7	7.1	110	3	15
D176200	100	3,000	2	57	N	20	20	25	80	B	70
D179838	70	15	3	.12L	N	7	15	26	40	7	20
D179839	150	300	5	.50L	100	20	150	73	350	30	10
D179840	100	30	3	1.1	20	15	30	23	40	10	20
D179841	70	20	3	5.4	N	3	7	7.4	50	7	20
D179842	50	300	N	.69L	N	20	100	110	370	30	N
D179843	70	1,000	7	.39L	N	300	10	170	20	7	70

Table 5. Element composition of 106 Iowa coal samples--continued

Sample number	Hg (ppm)	La-S (ppm)	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Nd-S (ppm)	Ni-S (ppm)	P (ppm)	Pb (ppm)
D176177	0.07	15L	12	56	1	3L	20L	30	730L	65
D176178	.25	30	74	67	7	7L	50L	70	1,300L	110
D176179	.23	N	17	230	3	3L	B	30	800L	120
D176180	.09	N	2.1	230	15	2L	B	15	450L	13
D176181	.15	N	9.1	370	5	3	B	30	790L	88
D176182	.37	N	4.2	470	15	10L	B	50	1,800L	220
D176183	.44	50	8.8	230	20	7L	50	200	1,300L	150
D176184	.20	N	15	84	7	5L	B	70	980L	72
D176185	.12	N	3.5	200	N	7L	B	50	1,400L	50
D176186	.08	30	10	82	N	7L	70	50	1,500L	65
D176187	.08	20	6.8	120	2	2L	20	10	500L	20
D176188	.10	30	49	99	N	5L	30	15	1,100L	33
D176189	.17	20L	22	150	3	5L	N	30	1,100L	260
D176190	.20	N	10	780	15	10L	B	30	2,000L	60
D176191	.08	N	2.8	330	2	2L	B	20	560L	24
D176192	.14	N	13	160	15	3L	B	50	740L	22
D176193	.20	70	80	110	7	7L	70	100	1,700L	28
D176194	.12	50	25	740	5	7L	50	200	1,400L	32
D176195	.08	N	3.0	130	3	2L	B	20	470L	36
D176196	.08	N	11	550	2	5L	B	20	1,000L	37
D176197	.34	N	12	110	5	3L	B	30	720L	88
D176198	.10	50	32	80	5	7	50	50	1,300L	32
D176199	.09	20	5.7	290	N	3L	20	10	710L	14
D176200	.21	N	17	120	5	7L	B	50	1,300L	86
D179838	.25	N	2.9	130	7	2	B	15	510L	99
D179839	.14	50	88	130	N	15	100	70	2,200L	30
D179840	.07	15	12	110	10	3	20	30	520L	12
D179841	.13	N	3.5	300	7	N	B	15	900L	62
D179842	.41	N	18	320	50	15	B	100	3,000	210
D179843	.49	N	4.2	300	100	7	B	700	1,700L	420

Table 5. Element composition of 106 Iowa coal samples--continued

Sample number	Sb (ppm)	Sc-S (ppm)	Se (ppm)	Sr-S (ppm)	Th (ppm)	U (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)
D176177	0.5	10	5.4	20	9.3	1.8	20	15	B	10	10
D176178	10.0	15	7.1	50	22.0	9.3	150	20	B	5,400	50
D176179	.9	3	3.6	30	3.0L	1.1	20	15	B	18	20
D176180	1.5	1.5	12	15	3.0L	12	70	7	.7	99	7
D176181	2.5	5	3.6	30	6.6	1.7	30	15	B	38	30
D176182	4.0	10	2.4	70	6.8	3.5	20	20	B	200	15
D176183	6.4	5	18	200	3.0L	18	50	70	B	3,200	20
D176184	1.3	7	7.5	30	14.0	4.9	50	10	B	41	20
D176185	.5	10	2.5	10	3.0L	3.7	20	10	B	13	10
D176186	.4	5	3.5	15	3.0L	6.8	15	50	B	470	10
D176187	.3	2	6.4	30	3.0L	1.3	20	15	B	350	10
D176188	.3	7	3.2	200	8.1	2.0	30	15	B	45	20
D176189	10.5	5	4.2	30	3.0L	5.3	20	15	B	14	30
D176190	16.0	7	21	70	B	19	100	10	1.5	21	70
D176191	1.3	5	2.1	20	3.0L	1.6	10	10	1	780	10
D176192	3.9	2	75	500	B	35	150	10	1	5,200	20
D176193	1.7	10	17	700	3.0L	8.4	70	30	B	1,300	70
D176194	1.3	10	4.9	100	10.0	3.3	70	30	B	41	50
D176195	.3	5	1.8	30	3.0L	2.2	15	10	B	10	15
D176196	.3	5	2.3	30	3.0L	3.6	20	15	.7	16	15
D176197	2.6	5	11	15	3.0L	8.3	20	7	B	450	10
D176198	.5	15	8.2	70	17.0	5.3	70	20	2	16	50
D176199	.3	2	2.3	100	3.0L	.9	15	15	B	7.1	7
D176200	.8	10	2.6	200	3.0L	2.7	50	10	B	18,000	30
D179838	.6	3	4.0	30	4.4	2.6	30	10	.7	8.8	7
D179839	1.2	15	3.5	150	11.0	3.8	300	30	3	55	100
D179840	2.1	7	3.0	30	3.0L	.7	100	10	1.5	170	15
D179841	.3	1.5	2.2	100	3.0L	.5	15	15	1.5	940	10
D179842	39.0	10	53	100	4.3	6.0	200	20	5	28	50
D179843	22.0	5	4.0	70	1.0	41	30	30	3	46	30

Table 5. Element composition of 106 Iowa coal samples--continued

Sample number	Si (percent)	Al (percent)	Ca (percent)	Mg (percent)	Na (percent)	K (percent)	Fe (percent)	Ti (percent)	Ag-S (ppm)	As (ppm)
D179844	3.2	1.5	1.8	0.091	0.027	0.19	7.6	0.075	0.5	28
D179845	.38	.45	.99	.007	.009	.010L	21	.023	.7	49
D179846	2.2	1.7	1.6	.039	.029	.10	14	.064	.5	13
D179847	.86	.40	1.8	.046	.010	.081	1.9	.021	2	28
D179848	1.4	.43	.98	.026	.018	.057	.27	.023	N	4.5
D179849	1.1	.56	2.6	.19	.023	.058	4.6	.030	.3	24
D179850	2.4	1.4	.10	.051	.040	.14	1.9	.063	N	11
D179851	.59	.27	.64	.028	.014	.058	.68	.012	.7	10
D179852	1.3	.42	1.4	.033	.025	.067	1.1	.023	.15	16
D179853	1.4	.75	5.1	.31	.029	.074	5.2	.035	.5	26
D179854	3.6	2.4	.84	.078	.058	.26	3.9	.093	.5	7.5
D179855	.88	.92	1.1	.018	.026	.054	4.3	.030	N	13
D179856	2.1	1.7	.60	.033	.028	.075	11	.092	1	16
D185601	.50	.27	1.3	.026	.010	.13	5.8	.012	N	4.9
D185602	.87	.40	1.7	.039	.012	.13	4.8	.027	N	6.4
D185603	.86	.10	1.5	.033	.016	.086	4.0	.009	N	11
D185604	1.1	.31	1.9	.037	.017	.098	2.6	.025	N	6.9
D185605	.89	.26	1.4	.035	.017	.097	3.1	.018	N	9.8
D185606	2.1	.76	1.0	.11	.016	.14	2.2	.078	N	6.6
D185609	1.2	.35	3.9	.051	.016	.17	5.3	.031	N	19
D185610	.75	.24	1.9	.025	.014	.14	6.4	.018	N	20
D185611	1.6	.34	7.1	.057	.017	.094	.93	.037	N	4.3
D185612	1.6	.77	.19	.042	.012	.16	3.6	.039	1	13
D185613	1.3	.53	.72	.037	.012	.11	1.5	.035	.5	3.7
D186062	.81	.31	1.6	.027	.030	.078	3.6	.011	.15	47
D185063	.70	.32	2.6	.028	.029	.083	4.3	.011	.2	62
D185064	.87	.38	.83	.025	.029	.073	2.6	.014	.15	43
D185065	1.3	.71	1.7	.040	.017	.15	5.3	.032	N	3.9
D185066	1.8	1.1	1.2	.025	.014	.11	2.4	.046	N	2.0
D185067	2.9	1.6	1.1	.070	.037	.33	8.1	.040	.3	75

Table 5. Element composition of 106 Iowa coal samples--continued

Sample number	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Ce-S (ppm)	Co-S (ppm)	Cr-S (ppm)	Cu (ppm)	F (ppm)	Ga-S (ppm)	Ge-S (ppm)
D179844	70	150	3	7.2	N	20	50	48	105	20	30
D179845	50	30	3	8.9	N	30	10	69	20L	10	50
D179846	50	20	3	1.1	N	10	20	56	30	20	30
D179847	100	20	3	15	N	10	20	19	30	10	30
D179848	50	50	2	1.1	N	1	7	7.9	40	5	50
D179849	50	30	3	.22L	50	30	30	42	45	7	30
D179850	70	50	5	.52	N	10	50	15	175	10	15
D179851	70	10	1.5	2.0	N	1	30	8.5	135	3	15
D179852	30	200	2	9.9	N	3	15	16	50	5	30
D179853	50	20	2	1.6	N	7	15	36	85	15	30
D179854	70	70	5	.25L	70	15	50	34	100	20	15
D179855	100	20	5	.13L	N	5	20	9.2	60	10	15
D179856	50	1,000	5	1.3	N	50	100	55	30	15	20
D185601	50	10	2	.14L	N	7	3	4.0	90	B	10
D185602	50	10	2	.14L	N	7	5	4.9	100	5	15
D185603	150	7	2	.12	N	7	2	12	85	B	20
D185604	150	10	1.5	.12	70L	7	3	9.1	75	3	15
D185605	150	10	1.5	.11L	50L	5	3	10	75	3	15
D185606	100	300	2	.52	100	7	15	16	95	5	20
D185609	70	15	1	.44	N	7	5	15	75	3	7
D185610	100	10	1	.17L	N	10	3	45	45	B	10
D185611	70	10	1	.23L	N	2	5	70	70	3	15
D185612	100	20	2	62	N	7	7	250	250	B	20
D185613	50	20	1.5	31	N	2	7	70	70	1.5	15
D186062	70	7	1.5	.12L	N	3	3	70	70	B	7
D185063	100	15	1.5	.15	N	5	5	22	75	B	10
D185064	150	10	2	1.1	N	5	7	16	80	B	15
D185065	100	100	1	.17L	N	2	10	25	65	B	10
D185066	100	20	2	.18	70L	3	10	11	60	3	20
D185067	70	30	1.5	.25L	N	20	15	38	65	B	15

Table 5. Element composition of 106 Iowa coal samples--continued

Sample number	Hg (ppm)	La-S (ppm)	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Nd-S (ppm)	Ni-S (ppm)	P (ppm)	Pb (ppm)
D179844	0.25	N	14	260	20	7	B	70	1,400L	130
D179845	.42	N	3.9L	89	10	N	B	100	1,700L	310
D179846	.46	N	16	140	30	7	B	70	1,600L	250
D179847	.22	N	1.5	350	150	2	B	30	550L	64
D179848	.07	N	5.0	160	5	1.5	B	5	350L	5.9
D179849	.40	30	7.2	610	7	5	N	70	950L	110
D179850	.15	N	33	21	5	2	B	20	570L	22
D179851	.30	N	1.0	98	15	1	B	10	340	11
D179852	.12	N	2.7	220	3	2	B	15	460L	56
D179853	.24	N	5.6	680	15	N	B	50	1,400L	85
D179854	.24	50	55	130	15	5	70	70	1,100L	47
D179855	.22	20	6.0	110	2	3	N	30	590L	20
D179856	.41	N	23	180	5	7	B	150	1,400L	72
D185601	.13	N	1.4	160	1	3L	B	7	610L	50
D185602	.14	N	2.3	180	1	3L	B	7	620L	57
D185603	.12	N	1.2	230	1	2L	B	20	540L	25
D185604	.08	10	1.9	200	1	2L	15	15	520L	12
D185605	.08	10	1.9	200	.7	2L	15	15	460L	17
D185606	.16	30	14	210	1.5	3	50	15	570L	30
D185609	.09	N	3.1	420	N	5L	B	20	950L	37
D185610	.12	N	1.9	230	N	3L	B	30	740L	42
D185611	.07	N	3.0	980	3	N	B	7	1,000L	10
D185612	.40	N	12	44	10	2	B	70	530L	62
D185613	.14	N	5.7	110	7	1.5	B	20	370L	11
D186062	.13	N	1.5	170	1.5	2L	B	30	510L	75
D185063	.18	N	1.5L	270	2	N	B	50	650L	120
D185064	.10	N	2.2	86	1.5	2	B	30	390L	59
D185065	.07	15L	4.8	150	2	3L	50	15	730L	13
D185066	.08	20	11	74	2	2	20	10	530L	9.1
D185067	.13	20L	9.1	91	1.5	5L	70	70	1,100L	150

Table 5. Element composition of 106 Iowa coal samples--continued

Sample number	Sb (ppm)	Sc-S (ppm)	Se (ppm)	Sr-S (ppm)	Th (ppm)	U (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)
D179844	2.2	10	5.1	50	3.0L	13	100	20	2	2,400	50
D179845	1.2	7	2.0	70	3.0L	4.3	70	10	5	2,800	N
D179846	1.4	5	3.3	50	3.0L	3.8	20	20	2	490	20
D179847	37.0	2	25	70	.7	26	200	10	1.5	1,200	10
D179848	4.4	2	.9	20	1.4	2.5	10	10	1	79	5
D179849	1.8	7	3.2	70	3.0L	4.6	50	20	1.5	70	15
D179850	.3	5	3.2	50	3.0L	3.0	50	15	1.5	130	20
D179851	29.0	1	15	30	.6	36	150	7	1	130	5
D179852	2.0	3	1.8	30	3.0L	1.9	20	10	1.5	660	7
D179853	1.0	10	2.6	100	3.0L	6.5	30	20	2	410	15
D179854	.6	15	5.5	300	5.8	5.8	70	15	2	91	20
D179855	.3	5	2.8	300	3.0L	.8	30	10	1	130	10
D179856	.6	10	17	50	3.0L	2.7	100	20	3	820	50
D185601	.1L	1.5L	1.0	10	.5	.2L	5	7	B	11	5
D185602	.1L	1.5L	1.1	10	.9	.6	7	7	B	12	7
D185603	.3	2	1.7	30	.4	.5	3	7	B	10	3
D185604	.2	1.5	1.1	100	.7	.2L	10	10	B	9.4	10
D185605	.1	1.5	1.2	70	.6	.4	5	7	B	9.2	7
D185606	.2	5	4.2	150	3.8	2.5	30	20	B	140	20
D185609	.3	2L	1.4	30	1.0	.5	3	10	B	180	7
D185610	.5	1.5L	1.6	20	.6	.4	3	10	B	9.2	5
D185611	.6	2L	.8	50	.9	3.2	7	15	1.5	17	7
D185612	12.5	2	13	20	.1L	1.8	10	10	B	3,800	10
D185613	11.1	1.5	6.0	15	1.2	2.3	15	7	B	1,100	10
D186062	1.0	1.5	1.6	15	1.1	1.7	7	7	B	58	7
D185063	1.2	2	1.5	20	1.1	1.7	10	10	B	60	5
D185064	1.4	2	1.5	15	1.1	1.9	15	7	B	280	7
D185065	.1	5	1.7	20	1.9	2.0	15	10	B	13	10
D185066	.1	3	3.1	20	1.8	1.7	20	20	B	120	10
D185067	3.2	3	.1L	20	3.1	2.6	30	15	B	15	15

Table 5. Element composition of 106 Iowa coal samples--continued

Sample number	Si (percent)	Al (percent)	Ca (percent)	Mg (percent)	Na (percent)	K (percent)	Fe (percent)	Ti (percent)	Ag-S (ppm)	As (ppm)
D186068	0.90	0.53	2.7	0.020	0.020	0.071	3.0	0.018	N	13
D186069	5.6	3.2	.58	.13	.037	.45	2.9	.14	N	7.4
D186070	1.5	1.1	.79	.031	.019	.13	2.2	.042	N	7.0
D186071	.74	.58	1.4	.022	.018	.11	5.2	.024	.2	33
D186072	1.6	.95	5.1	.059	.031	.15	3.1	.060	N	3.2
D186073	1.6	.76	2.0	.040	.020	.15	3.4	.049	N	6.3
D186074	1.7	.67	2.6	.060	.019	.17	5.1	.048	N	14
D186075	1.4	.52	2.4	.046	.039	.099	2.0	.034	N	12
D186076	1.3	.38	2.3	.055	.035	.11	3.5	.026	N	22
D192368	2.1	.58	3.6	.044	.023	.042	3.7	.038	N	15
D192369	1.7	.58	.98	.038	.032	.067	1.8	.033	N	29
D192370	.62	.25	1.1	.014	.025	.006L	11	.012	N	15
D192371	1.3	.61	1.3	.038	.040	.050	6.6	.030	N	19
D192372	1.5	.86	.92	.029	.031	.053	2.9	.037	N	2.8
D192373	1.9	.70	1.1	.043	.037	.090	2.7	.034	N	11
D192374	.94	.41	.80	.020	.026	.027	4.3	.024	N	13
D192375	3.0	1.5	.56	.044	.036	.14	6.4	.075	N	27
D192376	1.1	.43	1.5	.022	.027	.031	4.0	.049	N	16
D192377	2.4	1.1	.45	.042	.024	.085	5.7	.052	N	17
D192378	1.1	.76	1.7	.026	.028	.040	4.8	.029	N	4.6
D192379	3.0	1.3	2.2	.072	.023	.19	2.3	.069	N	18

Table 5. Element composition of 106 Iowa coal samples--continued

Sample number	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Ce-S (ppm)	Co-S (ppm)	Cr-S (ppm)	Cu (ppm)	F (ppm)	Ga-S (ppm)	Ge-S (ppm)
D186068	100	30	2	0.14L	70	7	10	7.6	135	B	15
D186069	70	50	5	1.3	150L	15	50	29	180	7	20
D186070	100	50	2	.11L	50	5	15	8.3	160	5	15
D186071	100	20	2	11	70L	10	10	19	40	5	20
D186072	100	20	2	.44	N	3	15	17	95	5	20
D186073	70	15	2	3.5	N	10	20	12	85	7	15
D186074	100	20	2	12	N	15	15	22	75	7	20
D186075	150	20	2	.20	N	7	10	6.2	95	5	20
D186076	150	20	2	3.6	N	5	7	8.9	125	5	20
D192368	70	200	1.5	2.2	N	3	7	9.0	35	5	20
D192369	150	20	1.5	.29	N	10	7	12	60	7	7
D192370	70	5	2	.26L	N	5	7	16	20L	7	15
D192371	150	15	3	17	N	50	15	26	25	15	30
D192372	100	50	2	.68	N	7	15	15	35	10	15
D192373	200	15	2	.14L	N	5	10	13	45	5	50
D192374	150	10	2	.40	N	15	10	17	25	10	20
D192375	70	30	3	7.1	N	10	10	13	55	7	20
D192376	70	700	3	19	N	5	7	13	30	7	20
D192377	100	30	3	.40	N	15	15	46	40	10	30
D192378	150	30	3	3.1	N	3	10	13	60	5	20
D192379	150	50	3	.63	N	7	15	14	90	7	15

Table 5. Element composition of 106 Iowa coal samples--continued

Sample number	Hg (ppm)	La-S (ppm)	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Nd-S (ppm)	Ni-S (ppm)	P (ppm)	Pb (ppm)
D186068	0.09	20	5.5	220	N	3L	20	20	600L	30
D186069	.14	50	59	62	5	5	N	50	1,100L	78
D186070	.08	15	18	48	1.5	2	30	10	630	12
D186071	.17	20	4.5	83	2	3	20	50	630L	38
D186072	.13	20L	18	610	3	5L	N	10	970L	34
D186073	.14	N	13	120	7	3L	B	20	660L	23
D186074	.15	20L	7.0	210	3	5	30L	70	870L	81
D186075	.08	15L	4.1	250	1	3	20L	50	580L	22
D186076	.10	15L	3.0	530	1	3L	20L	50	660L	35
D192368	.14	N	4.1	380	1.5	N	B	30	1,100L	36
D192369	.07	N	4.9	130	N	N	B	30	500L	31
D192370	.70	N	5.2	160	N	N	B	20	1,100L	470
D192371	.17	20L	7.2	280	1.5	N	N	100	900L	91
D192372	.09	N	18	140	2	N	B	20	590L	13
D192373	.12	N	3.0	170	5	N	B	15	620L	51
D192374	.28	15	4.4	90	N	N	N	50	590L	82
D192375	.28	N	20	92	N	5L	B	50	1,000L	170
D192376	.29	15	7.4	120	N	3L	20	30	720L	80
D192377	.25	N	20	160	7	5L	B	70	870L	200
D192378	.23	20L	12	250	3	N	N	20	790L	110
D192379	.10	N	14	410	N	N	B	30	910L	28

Table 5. Element composition of 106 Iowa coal samples--continued

Sample number	Sb (ppm)	Sc-S (ppm)	Se (ppm)	Sr-S (ppm)	Th (ppm)	U (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)
D186068	0.3	5	3.3	200	1.2	0.5	20	20	B	27	10
D186069	.3	7	.1L	50	6.0	5.6	50	20	B	490	50
D186070	.1	3	2.6	200	1.9	1.1	30	15	B	54	15
D186071	1.2	5	3.2	150	1.2	.8	15	10	B	2,000	10
D186072	.1	5	1.9	150	2.2	4.5	30	15	B	100	15
D186073	.4	5	.1L	20	1.5	6.5	30	10	B	730	15
D186074	.5	7	.1L	30	1.3	1.8	30	15	B	3,700	15
D186075	.7	3	.1L	100	1.1	.6	15	10	B	160	10
D186076	.8	2	B	100	.8	.4	10	10	B	1,000	10
D192368	.8	2	1.7	30	1.0	1.2	10	7	B	170	7
D192369	1.2	3	1.5	70	1.0	1.1	15	7	B	170	7
D192370	.2	5	2.5	20	.9	1.8	20	7	B	9.6	7
D192371	.7	7	1.3	30	1.0	2.5	30	20	3	2,600	15
D192372	.1L	5	2.8	20	1.5	2.4	20	10	B	300	20
D192373	5.4	2	2.5	20	1.1	5.2	15	5	B	9.6	10
D192374	.5	2	3.4	50	.9	1.1	15	5	B	69	7
D192375	.6	3	3.5	70	2.6	2.2	15	7	B	690	15
D192376	.4	3	2.9	150	1.0	1.8	10	7	B	4,200	10
D192377	1.8	5	3.4	50	1.7	6.9	30	10	B	12	15
D192378	.1L	3	2.9	200	1.4	1.0	20	5	B	540	10
D192379	.7	5	1.7	70	2.1	1.2	20	15	B	42	15

Table 6. Arithmetic mean, observed range, geometric mean, and geometric deviation of proximate and ultimate analyses, heat of combustion, forms of sulfur, and ash-fusion temperatures for 11 Middle Pennsylvanian-age coal samples from coal-zone 2, Cherokee Group, south-central and southeastern Iowa

[All values are in percent except kcal/kg, Btu/lb, ash-fusion temperatures and geometric deviations and are reported on an as-received basis. Kcal/kg = 0.556 (Btu/lb). °F = (°C x 1.8) + 32]

	Arithmetic mean	Observed range		Geometric mean	Geometric deviation
		Minimum	Maximum		
Proximate and ultimate analysis					
Moisture	9.6	5.3	13.0	9.3	1.3
Volatile matter	34.4	27.9	40.6	33.9	1.1
Fixed carbon	38.6	30.6	48.5	37.9	1.1
Ash	18.0	9.7	31.1	16.8	1.4
Hydrogen	4.9	3.6	5.9	4.8	1.1
Carbon	54.0	36.6	65.5	53.0	1.2
Nitrogen	.9	.4	1.2	.9	1.3
Oxygen	15.3	10.0	19.5	15.1	1.3
Sulfur	7.2	3.2	18.3	6.5	1.6
Heat of combustion					
Kcal/kg	5,360	4,050	6,060	5,315	1.1
Btu/lb	9,630	7,280	10,900	9,560	1.1
Forms of sulfur					
Sulfate	1.04	0.31	2.98	0.87	1.8
Pyritic	4.51	1.97	15.47	3.59	1.9
Organic	1.82	.42	2.61	1.57	1.7
Ash-fusion temperatures (°C)					
Initial deformation	1,165	1,040	1,335	1,165	1.1
Softening	1,210	1,095	1,380	1,210	1.1
Fluid	1,255	1,150	1,430	1,255	1.1

Table 7. Arithmetic mean, observed range, geometric mean, and geometric deviation of 37 elements in 15 Middle Pennsylvanian age coal samples from coal-zone 2, Cherokee Group, southcentral and southeastern Iowa

[All analyses except geometric deviations are in percent or parts per million and are reported on a whole-coal basis. L, less than the value shown]

Element	Arithmetic mean	Observed range		Geometric mean	Geometric deviation
		Minimum	Maximum		
		Percent			
Si	1.6	0.76	3.0	1.5	1.6
Al	1.0	.41	2.2	.88	1.7
Ca	1.8	.10	5.1	1.2	2.4
Mg	.038	.020	.084	.034	1.6
Na	.027	.017	.040	.026	1.3
K	.096	.027	.23	.077	1.9
Fe	4.9	1.9	14	4.1	1.8
Ti	.050	.018	.095	.044	1.6
		Parts per million			
As	11	2.8	25	8.7	2.0
B	100	50	150	100	1.5
Ba	100	10	1,000	50	3.5
Be	3	1.5	5	2	1.4
Cd	1.4	.2L	19	.5	4.4
Co	10	3	50	7	2.0
Cr	20	7	100	15	2.1
Cu	18	7.1	56	15	1.8
F	80	25	175	60	2.1
Ga	10	3	20	7	1.7
Ge	15	15	30	15	1.2
Hg	.18	.08	.46	.15	1.8
La	15	15L	30	15	1.4
Li	16	4.4	49	13	2.0
Mn	190	21	610	140	2.3
Mo	3	1.5L	30	1.5	3.7
Nd	20	20L	30	20	1.3
Ni	30	10	150	20	2.2
Pb	58	12	250	39	2.4
Sb	.4	.1L	1.4	.3	2.5
Sc	5	2	10	5	1.6
Se	3.9	1.7	17	3.3	1.7
Sr	100	20	200	100	2.1
Th	1.5	.9	8.1	1.0	2.4
U	2.0	.5	4.5	1.6	1.8
V	30	10	100	20	1.7
Y	15	5	20	15	1.6
Zn	470	7.1	4,200	120	5.5
Zr	15	7	50	15	1.7

Table 8. Arithmetic mean, observed range, geometric mean, and geometric deviation of proximate and ultimate analyses, heat of combustion, forms of sulfur, and ash-fusion temperatures for 9 Middle Pennsylvanian-age coal samples from coal-zone 3, Cherokee Group, south-central and southeastern Iowa

[All values are in percent except kcal/kg, Btu/lb, ash-fusion temperatures and geometric deviations, and are reported on an as-received basis. Kcal/kg = 0.556 (Btu/lb). °F = (°C x 1.8) + 32]

	Arithmetic mean	Observed range		Geometric mean	Geometric deviation
		Minimum	Maximum		
Proximate and ultimate analyses					
Moisture	11.1	7.7	13.8	10.9	1.3
Volatile matter	34.5	30.4	40.7	33.9	1.1
Fixed carbon	38.4	33.0	43.2	38.2	1.1
Ash	16.7	10.3	30.6	15.6	1.4
Hydrogen	5.0	4.2	5.5	5.0	1.2
Carbon	54.2	44.1	62.7	53.1	1.1
Nitrogen	.9	.7	1.3	.9	1.2
Oxygen	17.1	14.5	21.1	15.7	1.3
Sulfur	7.0	2.8	17.3	6.1	1.7
Heat of combustion					
Kcal/kg	5,410	4,545	6,080	5,380	1.1
Btu/lb	9,730	8,170	10,940	9,680	1.1
Forms of sulfur					
Sulfate	1.59	0.01	3.57	0.54	4.6
Pyritic	4.31	1.41	16.2	3.36	2.0
Organic	1.66	.42	2.89	1.36	1.8
Ash-fusion temperatures (°C)					
Initial deformation	1,130	1,040	1,240	1,130	1.1
Softening	1,180	1,095	1,290	1,180	1.1
Fluid	1,225	1,145	1,320	1,225	1.0

Table 9. Arithmetic mean, observed range, geometric mean, and geometric deviation of 36 elements in 15 Middle Pennsylvanian-age coal samples from coal-zone 3, Cherokee Group, south-central and southeastern Iowa

[All Analyses except geometric deviations are in percent or parts per million and are reported on a whole-coal basis. L, less than the value shown]

Element	Arithmetic mean	Observed range		Geometric mean	Geometric deviation
		Minimum	Maximum		
		Percent			
Si	1.7	0.38	5.8	1.3	2.0
Al	.92	.24	3.2	.75	1.9
Ca	1.3	.087	2.6	.85	2.6
Mg	.037	.007	.13	.029	2.0
Na	.022	.009	.043	.020	1.6
K	.12	.019	.50	.068	2.9
Fe	6.1	1.8	21	4.8	2.0
Ti	.043	.012	.13	.037	1.7
		Parts per million			
As	21	2	49	14	2.4
B	100	50	150	100	1.4
Ba	30	5	200	20	2.8
Be	2	1.5	5	2	1.3
Cd	9.2	.2L	15	.9	10
Co	10	3	30	10	1.8
Cr	15	7	50	15	1.7
Cu	25	9.2	69	21	1.8
F	56	20L	160	45	2.0
Ga	7	3	10	7	1.5
Ge	20	7	50	15	1.6
Hg	.10	.07	.7	.17	1.8
La	15	15L	50	10	2.1
Li	12	3.5	32	9.0	2.1
Mn	120	34	210	100	1.6
Mo	5	2L	10	3	2.1
Ni	50	7	100	30	2.1
Pb	95	9.1	470	54	3.0
Sb	.8	.1	1.8	.6	2.2
Sc	7	1.5	15	5	1.7
Se	3.0	.1L	8.2	2.6	1.7
Sr	70	5	300	30	3.0
Th	2.5	.9L	17	1.2	3.4
U	3.0	.8	6.9	2.3	2.1
V	30	15	70	20	1.7
Y	10	7	20	10	1.4
Zn	2,800	9.6	5,500	290	9.8
Zr	15	7	50	10	1.7

Table 10. Arithmetic mean, observed range, geometric mean, and geometric deviation of proximate and ultimate analyses, heat of combustion, forms of sulfur, and ash-fusion temperatures for 32 Middle Pennsylvanian-age coal samples from coal-zone 4, Cherokee Group, south-central and southeastern Iowa

[All values are in percent except kcal/kg, Btu/lb, ash-fusion temperatures and geometric deviations and are reported on an as-received basis. L, less than the value shown. Kcal/kg = 0.556 (Btu/lb). °F = (°C x 1.8) + 32]

	Arithmetic mean	Observed range		Geometric mean	Geometric deviation
		Minimum	Maximum		
Proximate and ultimate analyses					
Moisture	13.4	7.9	17.7	13.2	1.2
Volatile matter	33.4	23.3	38.8	32.8	1.1
Fixed carbon	36.7	22.8	48.1	35.8	1.1
Ash	17.1	7.0	32.8	15.7	1.5
Hydrogen	5.1	3.5	5.8	5.1	1.2
Carbon	52.6	34.4	61.0	51.5	1.1
Nitrogen	1.0	.5	1.3	1.0	1.2
Oxygen	18.1	9.6	23.0	18.1	1.2
Sulfur	6.4	2.3	19.2	5.5	1.7
Heat of combustion					
Kcal/kg	5,440	3,840	6,365	5,410	1.1
Btu/lb	9,780	6,910	11,450	9,730	1.1
Forms of sulfur					
Sulfate	0.68	0.01L	1.88	0.43	2.6
Pyritic	4.26	.45	16.6	3.20	2.1
Organic	1.58	.48	3.13	1.36	1.7
Ash-fusion temperatures (°C)					
Initial deformation	1,145	1,015	1,485	1,145	1.1
Softening	1,195	1,070	1,530	1,190	1.1
Fluid	1,235	1,105	1,540	1,235	1.1

Table 11. Arithmetic mean, observed range, geometric mean, and geometric deviation of 35 elements in 49 Middle Pennsylvanian-age coal samples from coal-zone 4, Cherokee Group, south-central and southeastern Iowa

[All analyses except geometric deviations are in percent or parts per million and are reported on a whole-coal basis. L, less than the value shown]

Element	Arithmetic mean	Observed range		Geometric mean	Geometric deviation
		Minimum	Maximum		
Percent					
Si	2.0	0.48	6.7	1.6	1.8
Al	.94	.10	3.2	.71	2.1
Ca	2.0	.12	7.1	1.5	2.2
Mg	.065	.016	.39	.052	2.0
Na	.027	.009	.065	.023	1.7
K	.13	.023	.61	.11	1.9
Fe	4.7	.93	16	4.1	1.7
Ti	.046	.009	.18	.036	2.0
Parts per million					
As	26	3	230	17	2.7
B	100	50	200	100	1.5
Ba	70	7	1,000	30	3.5
Be	2	1	7	2	1.6
Cd	12	.12L	62	.24	19
Co	15	2	300	7	2.8
Cr	15	2	50	10	2.2
Cu	25	4.0	170	19	2.1
F	84	20	250	75	1.6
Ga	7	1.5	20	7	2.0
Ge	20	7	70	15	1.7
Hg	.16	.07	.49	.14	1.7
Li	11	1.2	58	6.8	2.8
Mn	240	44	980	190	2.0
Mo	7	.7	100	3	3.4
Ni	50	.7	700	30	2.5
Pb	63	8.1	420	43	2.4
Sb	1.7	.1L	22	.7	3.6
Sc	5	1.5	15	3	2.1
Se	3.3	.1L	29	2.1	2.5
Sr	50	10	500	30	2.4
Th	2.8	.4	18	.7	6.3
U	4.2	.2L	43	2.0	3.3
V	20	3	100	15	2.3
Y	10	5	70	10	1.7
Zn	850	9.2	4,200	150	6.7
Zr	15	3	70	15	1.9

Table 12. Arithmetic mean, observed range, geometric mean, and geometric deviation of proximate and ultimate analyses, heat of combustion, forms of sulfur, and ash-fusion temperatures for four Middle Pennsylvanian-age coal samples from coal-zone 5, Cherokee Group, south-central and southeastern Iowa

[All values are in percent except kcal/kg, Btu/lb, ash-fusion temperatures and geometric deviations, and are reported on an as-received basis. Kcal/kg = 0.556 (Btu/lb). °F = (°C x 1.8) + 32]

	Arithmetic mean	Observed range		Geometric mean	Geometric deviation
		Minimum	Maximum		
Proximate and ultimate analyses					
Moisture	8.5	5.0	12.3	8.1	1.5
Volatile matter	33.9	29.3	39.0	33.7	1.1
Fixed carbon	34.9	28.1	40.1	34.5	1.2
Ash	23.2	14.6	33.7	21.8	1.4
Hydrogen	4.4	4.0	5.3	4.4	1.1
Carbon	50.2	39.6	58.4	49.3	1.2
Nitrogen	.9	.7	1.0	.9	1.2
Oxygen	14.2	10.9	18.2	14.0	1.2
Sulfur	7.7	5.1	10.8	7.3	1.4
Heat of combustion					
Kcal/kg	4,870	3,905	5,790	4,800	1.2
Btu/lb	8,760	7,020	10,410	8,640	1.2
Forms of sulfur					
Sulfate	1.07	0.18	1.89	0.66	2.8
Pyritic	4.11	1.82	6.03	3.62	1.7
Organic	2.65	2.17	3.01	2.62	1.2
Ash-fusion temperatures (°C)					
Initial deformation	1,115	1,080	1,150	1,115	1.0
Softening	1,145	1,110	1,205	1,145	1.0
Fluid	1,200	1,140	1,280	1,200	1.1

Table 13. Arithmetic mean, observed range, geometric mean, and geometric deviation of 35 elements in five Middle Pennsylvanian-age coal samples from coal-zone 5, Cherokee Group, south-central and southeastern Iowa

[All analyses except geometric deviations are in percent or parts per million and are reported on a whole-coal basis]

Element	Arithmetic mean	Observed range		Geometric mean	Geometric deviation
		Minimum	Maximum		
Percent					
Si	3.9	2.1	7.6	3.4	1.7
Al	1.7	.58	3.6	1.3	2.1
Ca	1.3	.32	3.6	.92	2.4
Mg	.062	.044	.084	.060	1.3
Na	.050	.023	.078	.045	1.6
K	.18	.042	.27	.14	2.0
Fe	5.6	2.7	8.0	5.1	1.6
Ti	.095	.038	.21	.077	1.9
Parts per million					
As	17	8	30	15	1.6
B	70	70	100	70	1.2
Ba	70	30	300	70	2.2
Be	2	1.5	3	2	1.3
Cd	29	.3	74	2.1	17
Co	30	3	100	15	4.1
Cr	30	7	70	20	2.3
Cu	28	9.0	45	23	1.9
F	96	35	155	78	1.9
Ga	7	3	10	7	1.7
Ge	15	10	30	15	1.8
Hg	.15	.12	.20	.15	1.2
Li	27	4.1	80	15	3.2
Mn	310	110	740	220	2.3
Mo	7	1.5	15	5	2.7
Ni	100	30	200	70	2.3
Pb	45	22	100	38	1.8
Sb	1.8	.8	3.9	1.5	1.8
Sc	7	2	10	5	2.2
Se	21	1.7	75	8.1	4.5
Sr	300	30	700	150	4.5
Th	3.5	1.0	10	1.6	2.8
U	10	1.2	35	4.8	3.7
V	70	10	150	50	3.1
Y	20	7	30	15	2.0
Zn	2,100	12	5,200	220	12
Zr	30	7	70	20	2.5

Table 14. Arithmetic mean, observed range, geometric mean, and geometric deviation of proximte and ultimate analyses, heat of combustion, forms of sulfur, and ash-fusion temperatures for 9 Middle Pennsylvanian-age coal samples from coal-zones 6, 7, 8, and 9, Cherokee Group, south-central and southeastern Iowa.

[All values are in percent except kcal/kg, Btu/lb, ash-fusion temperatures, and geometric deviations, and are reported on an as-received basis. Kcal/kg = 0.556 (Btu/lb). °F = (°C x 1.8) + 32]

	Arithmetic mean	Observed range		Geometric mean	Geometric deviation
		Minimum	Maximum		
Proximate and ultimate analyses					
Moisture	13.1	7.9	18.7	12.7	1.3
Volatile matter	33.8	27.3	41.2	33.2	1.1
Fixed carbon	38.8	25.5	45.2	38.0	1.2
Ash	14.9	8.4	36.7	13.2	1.6
Hydrogen	5.3	3.9	6.0	5.2	1.2
Carbon	55.3	38.4	67.2	54.1	1.2
Nitrogen	.9	.6	1.2	.9	1.2
Oxygen	18.8	12.5	24.8	16.9	1.3
Sulfur	4.8	2.4	8.9	4.4	1.5
Heat of combustion					
Kcal/kg	5,530	3,710	6,270	5,560	1.2
Btu/lb	9,940	6,670	11,280	9,820	1.2
Forms of sulfur					
Sulfate	0.70	0.01	1.09	0.29	3.8
Pyritic	2.72	.33	6.40	2.04	2.1
Organic	1.71	.97	2.45	1.62	1.3
Ash-fusion temperatures (°C)					
Initial deformation	1,085	1,040	1,140	1,085	1.0
Softening	1,120	1,060	1,175	1,115	1.0
Fluid	1,145	1,080	1,200	1,140	1.0

Table 15. Arithmetic mean, observed range, geometric mean, and geometric deviation of 38 elements in 16 Middle Pennsylvanian-age coal samples from coal-zones 6, 7, 8 and 9, Cherokee Group, south-central and southeastern Iowa

[All analyses except geometric deviations are in percent or parts per million and are reported on a whole-coal basis]

Element	Arithmetic mean	Observed range: Minimum	Observed range: Maximum	Geometric mean	Geometric deviation
		Percent			
Si	2.7	0.59	12	1.9	2.3
Al	1.1	.27	5.9	.74	2.3
Ca	1.5	.28	4.9	1.1	2.3
Mg	.083	.026	.39	.061	2.2
Na	.052	.010	.21	.036	2.4
K	.18	.057	1.0	.13	2.4
Fe	3.3	.27	7.8	2.3	2.4
Ti	.064	.012	.31	.043	2.4
		Parts per million			
Ag	0.5	0.1	2	0.2	4.8
As	31	4.5	230	18	2.8
B	100	15	150	100	1.9
Ba	100	10	2,000	50	3.9
Be	3	1.5	5	2	1.5
Cd	8.9	.71	100	1.3	8.5
Co	10	1	20	5	2.7
Cr	20	7	150	20	2.1
Cu	31	7.4	160	22	2.3
F	78	30	350	62	2.0
Ga	7	2	30	7	2.0
Ge	20	10	50	20	1.6
Hg	.17	.07	.30	.14	1.6
Li	15	1.0	88	6.2	3.9
Mn	250	67	780	210	1.9
Mo	15	2	150	7	3.1
Nb	2	1	15	1	3.5
Ni	30	5	70	20	2.0
Pb	69	5.9	260	40	2.9
Sb	9.4	.3	37	3.5	4.3
Sc	5	1	15	3	2.2
Se	7.7	.9	25	4.9	2.6
Sr	50	15	150	30	1.9
Th	8.4	.6	22	.9	2.8
U	11	.5	36	4.3	4.0
V	100	10	300	50	3.0
Y	15	7	30	10	1.5
Yb	1.5	.7	3	1	1.5
Zn	620	8.8	5,400	110	7.0
Zr	20	5	100	15	2.6

Table 16. Arithmetic mean, observed range, geometric mean, and geometric deviation of proximate and ultimate analyses, heat of combustion, forms of sulfur, and ash-fusion temperatures for 65 Middle Pennsylvanian-age coal samples from the Cherokee and Marmaton Groups, south-central and southeastern Iowa

[All values are in percent except kcal/kg, Btu/lb, ash-fusion temperatures and geometric deviations, and are reported on an as-received basis. L, less than the value shown. Kcal/kg = 0.556 (Btu/lb). °F = (°C x 1.8) + 32]

	Arithmetic mean	Observed range		Geometric mean	Geometric deviation
		Minimum	Maximum		
Proximte and ultimate analyses					
Moisture	12.1	5.3	18.7	11.7	1.3
Volatile matter	33.1	23.3	41.5	33.4	1.1
Fixed carbon	37.3	22.8	48.5	37.0	1.1
Ash	17.2	7.0	36.7	15.9	1.5
Hydrogen	5.0	2.9	6.0	5.0	1.2
Carbon	52.9	34.4	67.2	52.5	1.1
Nitrogen	.9	.4	1.3	.9	1.2
Oxygen	17.2	2.5	27.9	17.1	1.3
Sulfur	6.6	2.3	20.9	5.8	1.7
Heat of combustion					
Kcal/kg	5,400	3,710	6,370	5,360	1.1
Btu/lb	9,710	6,670	11,450	9,640	1.1
Forms of sulfur					
Sulfate	0.92	0.01L	3.57	0.50	3.0
Pyritic	4.19	.33	18.8	3.20	2.1
Organic	1.70	.42	3.13	1.50	1.7
Ash-fusion temperatures (°C)					
Initial deformation	1,130	985	1,485	1,130	1.1
Softening	1,175	1,040	1,530	1,175	1.1
Fluid	1,215	1,080	1,540	1,215	1.1

Table 17. Arithmetic mean, observed range, geometric mean, and geometric deviation of 38 elements in 105 Middle Pennsylvanian-age coal samples from the Cherokee and Marmaton Groups, south-central and southeastern Iowa

[All analyses except geometric deviations are in percent or parts per million and are reported on a whole-coal basis. L, less than the value shown]

Element	Arithmetic mean	Observed range		Geometric mean	Geometric deviation
		Minimum	Maximum		
Percent					
Si	2.0	0.38	12	1.7	1.9
Al	1.0	.10	5.9	.78	2.0
Ca	1.7	.087	7.1	1.2	2.3
Mg	.058	.007	.39	.045	2.0
Na	.030	.009	.21	.026	1.8
K	.13	.010L	1.0	.10	2.1
Fe	5.0	.27	21	4.0	2.0
Ti	.051	.009	.31	.040	2.0
Parts per million					
Ag	0.3	0.1L	3	0.05	8.1
As	24	2.0	240	15	2.5
B	100	15	200	100	1.6
Ba	100	5	3,000	30	3.6
Be	2	1	7	2	1.5
Cd	18	.1L	100	.4	17
Co	15	1	300	7	2.5
Cr	15	2	150	15	2.1
Cu	25	4.0	170	19	2.0
F	78	20L	350	65	1.8
Ga	7	1.5	30	7	1.8
Ge	20	7	70	20	1.7
Hg	.17	.07	.70	.14	1.7
La	10	10L	70	5	4.0
Li	13	1.0	88	7.9	2.8
Mn	210	21	980	170	2.0
Mo	7	7L	150	3	3.7
Nb	1.5	1L	15	.3	5.8
Ni	50	5	700	30	2.3
Pb	67	5.9	470	44	2.5
Sb	2.1	.1L	37	.8	4.0
Sc	5	1L	15	5	2.1
Se	4.5	.1L	75	2.8	2.7
Sr	70	5	700	50	2.6
Th	3.6	.4L	22	1.0	4.0
U	4.5	.2L	43	2.4	3.1
V	30	3	300	20	2.4
Y	15	5	70	10	1.7
Zn	1,100	7.1	18,000	150	7.5
Zr	15	3	100	15	2.0

Table 18. Arithmetic mean, observed range, and geometric mean of proximate and ultimate analyses, heat of combustion, and forms of sulfur for 114 Pennsylvanian-age coal samples from the Illinois Basin

[Data are calculated from Gluskoter and others (1977, Table 8). All values are in percent except kcal/kg and Btu/lb and are reported on an as-received basis. Kcal/kg = 0.556 (Btu/lb)]

Element	Arithmetic mean	Observed range		Geometric mean
		Minimum	Maximum	
Proximate and ultimate analyses				
Moisture	9.4	0.5	18	8.1
Volatile matter	37	27	43	37
Fixed carbon	45	37	57	45
Ash	10	4.4	20	10
Hydrogen	5.6	4.6	6.4	5.5
Carbon	64	57	77	64
Nitrogen	1.2	.77	1.8	1.2
Oxygen	16	4.6	24	15
Sulfur	3.3	.56	5.9	3.1
Heat of combustion				
Kcal/kg	6,410	5,550	7,650	6,490
Btu/lb	11,520	9,985	13,760	11,670
Forms of sulfur				
Sulfate	0.09	0.01	1.0	0.05
Pyritic	1.8	.26	4.2	1.7
Organic	1.4	.34	2.8	1.3

Table 19. Arithmetic mean, observed range, and geometric mean of 35 elements in 114 Pennsylvanian-age coal samples from the Illinois Basin

[Data are from Gluskoter and others (1977, table 8). All analyses are in percent or parts per million and are reported on moisture-free basis. L = less than the value shown]

Element	Arithmetic mean	Observed range		Geometric mean
		Minimum	Maximum	
Percent				
Si	2.4	0.58	4.7	2.3
Al	1.2	.43	3.0	1.2
Ca	.67	.01	2.7	.51
Mg	.05	.01	.17	.05
Na	.05	.004	.2	.03
K	.17	.04	.56	.16
Fe	2.0	.45	4.1	1.9
Ti	.06	.02	.15	.06
Parts per million				
Ag	0.03	0.02	0.08	0.03
As	14	1.0	120	7.4
B	110	12	230	98
Ba	100	5.0	750	75
Be	1.7	.5	4.0	1.6
Cd	2.2	.11	65	.59
Co	7.3	2.0	34	6.0
Cr	18	4	60	16
Cu	14	5	44	13
F	67	29	140	63
Ga	3.2	.8	10	3.0
Ge	6.9	1.0L	43	4.8
Hg	.2	.03	1.6	.16
Mn	53	6.0	210	40
Mo	8.1	.3L	29	6.2
Ni	21	7.6	68	19
Pb	32	.8L	220	15
Sb	1.3	.1	8.9	.81
Sc	2.7	1.2	7.7	2.5
Se	2.2	.4	7.7	2.0
Sr	35	10L	130	30
Th	2.1	.71	5.1	1.9
U	1.5	.31L	4.6	1.3
V	32	11	90	29
Yb	.56	.27	1.5	.53
Zn	250	10	5,300	87
Zr	47	12	130	41

Table 20. Arithmetic mean, observed range, geometric mean, and geometric deviation of proximate and ultimate analyses, and heat of combustion, forms of sulfur, and ash-fusion temperatures of 44 coal samples from the Upper Cretaceous Williams Fork Formation, Yampa coal field, northwestern Colorado

[From Hildebrand and others (1981, table 7a). All values are in percent except kcal/kg, Btu/lb, and ash-fusion temperatures, and are reported on an as-received basis. Kcal/kg = 0.556 x (Btu/lb) F = (°C x 1.8) + 32. L, less than the value shown]

Element	Arithmetic mean	Observed range		Geometric mean	Geometric deviation
		Minimum	Maximum		
		Proximate and ultimate analyses			
Moisture	11.1	5.7	17.1	10.6	1.3
Volatile matter	34.9	26.1	40.3	34.8	1.1
Fixed carbon	44.4	33.2	52.3	44.2	1.1
Ash	9.6	3.0	32.7	8.4	1.7
Hydrogen	5.6	3.9	7.1	5.6	1.1
Carbon	60.9	44.0	71.0	60.7	1.1
Nitrogen	1.3	.5	1.9	1.2	1.4
Oxygen	22.0	16.0	27.2	21.8	1.2
Sulfur	.6	.3	3.1	.6	1.5
		Heat of combustion			
Kcal/kg	5,930	4,170	6,920	5,910	1.1
Btu/lb	10,670	7,500	12,440	10,630	1.1
		Forms of sulfur			
Sulfate	0.01	0.01L	0.04	0.01	1.4
Pyritic	.18	.01	2.18	.10	2.9
Organic	.45	.16	2.27	.40	1.6
		Ash-fusion temperatures (C°)			
Initial deformation	1,315	1,070	1,600+	1,310	1.1
Softening	1,360	1,095	1,600+	1,350	1.1
Fluid	1,390	1,115	1,600+	1,385	1.1

Table 21. Arithmetic mean, observed range, geometric mean, and geometric deviation of 37 elements in 63 coal samples from the Williams Fork Formation, Yampa coal field, northwestern Colorado

[From Hildebrand and others (1981, table 9a). All analyses are in percent or parts per million and are reported on a whole-coal basis. L, less than the value shown]

Element	Arithmetic mean	Observed range		Geometric mean	Geometric deviation
		Minimum	Maximum		
		Percent			
Si	3.1	0.34	13	2.2	2.3
Al	1.4	.30	9.3	1.2	1.8
Ca	.41	.088	.89	.37	1.5
Mg	.079	.011	.31	.066	1.8
Na	.055	.005	.20	.035	2.6
K	.11	.003	.72	.061	2.9
Fe	.33	.067	1.9	.25	2.1
Ti	.059	.018	.23	.052	1.6
		Parts per million			
As	1.0	0.2	6.0	0.5	3.3
B	100	20	300	70	1.7
Ba	200	30	1,000	150	1.9
Be	.7	.15	5	.5	2.9
Cd	.12	.04L	.60	.06	3.3
Co	1.5	.1L	7	1	2.1
Cr	5	.1L	30	3	2.4
Cu	6.4	2.3	18	5.6	1.7
F	125	20L	740	95	2.1
Ga	5	1	20	3	1.8
Hg	.06	.01	.29	.04	2.3
Li	10	1.5	52	8.4	1.9
Mn	29	2.0	210	17	2.8
Mo	.7	.2	3	.3	2.9
Nb	3	.7L	15	2	2.2
Ni	2	.7	10	1.5	2.0
P	520	45L	2,000	120	5.6
Pb	6.0	1.5	33	4.4	2.2
Sb	.3	.1L	2.3	.2	1.9
Sc	1.5	.7	10	1.5	1.8
Se	1.0	.1L	6.4	.9	1.6
Sr	100	15	500	100	2.0
Th	3.2	.7	15	1.5	3.6
U	1.2	.2L	4.9	1.0	1.8
V	10	3	50	7	1.9
Y	7	1	20	5	2.0
Yb	.7	.1	2	.5	2.0
Zn	11	1.4	100	7.3	2.5
Zr	30	7	200	20	1.9

Table 22. Classification of coals by rank[1]

[from American Society for Testing Materials, 1978, Table 1]

Class	Group	Fixed carbon limits, per cent (Dry, mineral-matter-free basis)		Volatile matter limits, per cent (Dry, mineral-matter-free basis)		Calorific value limits Btu per pound (Moist,[2] mineral-matter-free basis)		Agglomerating character
		Equal or greater than	Less than	Equal or greater than	Less than	Equal or greater than	Less than	
I. Anthracitic	1. Meta-anthracite	98	....	....	2	....	....	....
	2. Anthracite	92	98	2	8	....	....	....
	3. Semianthracite	86	92	8	14	....	....	nonagglomerating[3]
II. Bituminous	1. Low-volatile bituminous coal	78	86	14	22	....	....	
	2. Medium-volatile bituminous coal	69	78	22	31	....	....	
	3. High-volatile A bituminous coal	....	69	31	....	14,000[4]		commonly agglomerating[5]
	4. High-volatile B bituminous coal	....	....	....	....	13,000[4]		
	5. High-volatile C bituminous coal	....	....	....	....	11,500	13,000	
						10,500	11,500	agglomerating
III. Subbituminous	1. Subbituminous A coal	....	....	....	....	10,500	11,500	nonagglomerating
	2. Subbituminous B coal	....	....	....	....	9,500	10,500	
	3. Subbituminous C coal	....	....	....	....	8,300	9,500	....
IV. Lignitic	1. Lignite A	....	....	....	....	6,300	8,300	....
	2. Lignite B	....	....	....	....	....	6,300	....

[1]This classification does not include a few coals, principally nonbanded varieties, which have unusual physical and chemical properties and which come within the limits of fixed carbon or calorific value of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less than 48 per cent dry, mineral-matter-free fixed carbon or have more than 15,500 moist, mineral-matter-free British thermal units per pound.

[2]Moist refers to coal containing its natural inherent moisture but not including visible water on the surface of the coal.

[3]If agglomerating, classify in low-volatile group of the bituminous class.

[4]Coals having 69 percent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of calorific value.

[5]It is recognized that nonagglomerating varieties may occur in these groups of the bituminous class, and notable exceptions exist in high-volatile C bituminous group.

Table 23. Calculated Btu/lb, hydrogen/carbon and oxygen/carbon molecular ratios (moisture-free basis) for Iowa Cherokee Group coal zones 2, 3, 4, 5, and 6-9, Iowa coal, Illinois Basin coal, and Yampa field, Colorado coal

	Btu/lb[1] (mmmf)	Carbon[2]	Hydrogen[3]	Mineral[4] matter	Oxygen[5]	Hc/Cc	Oc/Cc	S_{pyrite} + $S_{organic}$
Coal zones 6-9	11,930	63.0	4.3	22.6	7.2	0.81	0.086	5.1
Coal zone 5	11,820	54.6	3.6	32.6	5.3	.79	.073	7.4
Coal zone 4	12,110	60.1	4.0	26.3	6.6	.80	.082	6.7
Coal zone 3	11,990	60.6	4.1	27.4	5.1	.82	.063	6.7
Coal zone 2	12,080	59.1	4.1	27.5	6.3	.83	.081	6.6
Iowa Coal	12,040	59.8	4.0	26.5	6.7	.81	.083	6.7
Illinois Coal[6] (114 samples)	12,990	70.6	4.9	13.1	8.5	.84	.090	3.5
Yampa Field, Colo.[7] (44 samples)	11,910	68.5	4.8	11.8	12.9	.83	.14	.71

[1] Parr formula; moist, mineral-matter-free Btu = [(as-received Btu - 50S)/100 - (1.08 Ash + 0.55S)] x 100.

[2] Carbon content of organic matter corrected for carbonate carbon content by $C_{calculated} = C_{analytical}$ - 12/40 Ca, where (12/40 calcium) replaces the (12/44 CO_2) in the British Standard Formula (see Given and Yarzab, 1978, equation 2). Ca is the amount of calcium assumed present as carbonate above a 0.5% non-carbonate calcium base level.

[3] Hydrogen content of organic matter corrected for water of clays by $H_{calculated} = H_{analytical}$ -0.014 Ash + 0.02 $S_{pyritic}$ x 0.02 (44/40 Ca) + 0.014 SO_3 (modified from Leighton and Tomlinson, 1960), where 44/40 Ca replaces CO_2; calcium is defined as in [2], and SO_3 is SO_3 in coal ash reported on a whole-coal basis.

[4] Mineral matter = 1.13 ash + 0.8 (44/40 Ca) + 0.5 $S_{pyritic}$ - 2.8 (S_{ash} - S_{so4}) (modified from King, Maries and Crossley (1936)). Calcium is defined as in [2]; S_{ash} and S_{so4} represents sulfur as sulfate in the ash and in the coal respectively.

[5] Oxygen content calculated by difference; $O_{calculated}$ = 100 - (mineral matter + $C_{calculated}$ + $H_{calculated}$ + $N_{analytical}$ + $S_{organic}$).

[6] Data from Gluskoter and others (1977, table 8).

[7] Data from Hildebrand and others (1981, table 7a).

Table 24. Depths from the surface (in meters) and the zinc/cadmium mole ratios for 40 Cherokee Group coal samples from five core holes in Wapello and Appanoose Counties, Iowa.

[Data from table 6, core hole number CP-10 is in Appanoose County; the other four core holes are in Wapello County. Because of data uncertainties, qualified cadmium values (L) and real cadmium values of 1.0 ppm or less were not used to calculate the Zn/Cd mole ratio. Table modified from Hatch and others (1976, table 5)]

Table modified from Hatch and others (1976, table 5)

Hole No.	Sample No.	Depth (meters)	moles Zn / moles Cd
CP-7	D176169	33.3	---
	D176170	45.5	---
	D176171	50.4	148
	D176172	58.9	261
	D176173	62.8	345
	D176174	69.8	469
	D176175	76.9	572
	D176176	87.8	---
	D176177	98.7	---
CP-10	D176178	74.0	93
	D176179	79.6	---
	D176180	85.1	76
	D176181	93.6	91
	D176182	109.9	---
	D176183	118.5	278
	D176184	123.8	---
	D176185	129.5	---
	D176186	142.2	468
CP-21	D176189	23.4	---
	D176190	40.2	---
CP-21 (cont.)	D176191	50.9	144
	D176192	56.0	120
	D176193	58.3	170
	D176194	60.3	223
	D176195	65.7	---
	D176196	73.5	---
	D176197	80.1	515
	D176198	95.2	---
	D176199	96.9	---
	D176200	107.8	548
CP-32	D179847	7.5	134
	D179848	18.0	123
	D179849	35.7	---
	D179850	54.1	445
CP-28	D179851	17.0	108
	D179852	29.5	115
	D179853	46.9	430
	D179854	55.2	---
	D179855	64.4	---
	D179856	69.5	1100