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National Coal Resource Assessment

Resource Assessment of the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin

Edited by **J.R. Hatch** *and* **R.H. Affolter**

Professional Paper 1625–D

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Illinois Basin

U.S. Department of the Interior
U.S. Geological Survey

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Prepared in cooperation with the Illinois State Geological Survey,
Indiana Geological Survey, and Kentucky Geological Survey

U.S. Department of the Interior
U.S. Geological Survey

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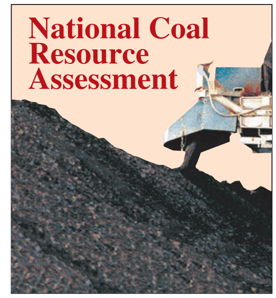

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Chapter A *of*

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Executive Summary

By J. R. Hatch[1] *and* R. H. Affolter[1]

Introduction

The goal of this resource assessment of Illinois Basin coals is to provide an overview of the geologic setting, distribution, resources, and quality of Pennsylvanian-age coals in the basin as part of the U.S. Geological Survey's National Coal Resource Assessment Project (NCRA). The area of coal-bearing rocks in the Illinois Basin (fig. 1) comprises 36,800 square miles in Illinois, 6,500 square miles in southwestern Indiana, and 6,400 square miles in western Kentucky. This area is also referred to as the "Eastern Region of the Interior Coal Province" (Trumbull, 1960). This assessment differs from previous coal assessments in that (1) the major emphasis is placed on coals that are most likely to be mined over the next few decades, and (2) data are being collected and stored in digital formats that can be updated as new information becomes available (Gluskoter and others, 1996). Most past, current, and expected future coal production in the Illinois Basin is from the Springfield, Herrin, Danville, and Baker Coals.

The main products of this assessment are digital databases that contain all publicly available point-source data on thickness, depth, and coal quality for the Springfield, Herrin, Danville, and Baker Coals. Regional and statewide maps have been prepared from these databases that depict coal extent, thickness, elevation (structure), mined-out areas, areas where the coal may potentially be mined at the surface or underground, and geographic distribution of ash, sulfur, and major, minor, and trace-element contents. Also prepared from these databases are summaries of proximate, ultimate, and major, minor, and trace-element analyses, and estimates of the uncertainty in calculations of the remaining coal resources. These databases and other proprietary databases managed by the State geological surveys of Illinois, Indiana, and Kentucky were used to calculate the remaining resources for the Springfield, Herrin, Danville, and Baker Coals.

This Illinois Basin coal assessment was completed in cooperation with multidisciplinary groups of scientists, technicians, and computer specialists from the U.S. Geological Survey, Illinois State Geological Survey, Indiana Geological Survey, and Kentucky Geological Survey. These three State surveys make up the Illinois Basin Consortium (IBC).

Geologic Framework

Stratigraphy

The coal-bearing rocks in the Illinois Basin are of Pennsylvanian age and were deposited between about 325 and 290 million years before the present. The Pennsylvanian rocks are divided into the Raccoon Creek Group, Carbondale Group or Formation, and the McLeansboro Group (fig. 2). The Pennsylvanian rocks reach a maximum thickness of nearly 2,500 ft in southeastern Illinois and generally thin toward the north, northwest, and northeast (fig. 3). The lower stratigraphic units pinch out to the north and northwest, and in much of western and northern Illinois the lower most formations are thin or absent (Hopkins and Simon, 1975). Typically, 90–95 percent of the Pennsylvanian section consists of clastic rocks. In the lower part of the section, quartzose, pebbly sandstones commonly make up 60 percent of the total thickness, with most of the remainder made up of siltstone and shale containing less than 1 percent limestone. Sandstone makes up 25 percent of the total thickness in the middle and upper parts of the section, and shale and claystone form 65–70 percent of the upper parts of the section. In general, 5–10 percent of the upper two-thirds of the section is limestone (Hopkins and Simon, 1975).

In Illinois and western Kentucky, the Raccoon Creek Group is divided into the Caseyville and Tradewater Formations (fig. 2). In southern Illinois and western Kentucky, the Caseyville Formation contains several thin, lenticular coals. Tradewater Formation coals in Illinois and western Kentucky are thicker and more continuous than coals in the underlying Caseyville Formation. In western Kentucky, the Tradewater Formation contains more than 20 mined coals. In Indiana, the Raccoon Creek Group consists of the Mansfield, Brazil, and Staunton Formations. As many as 12 coals are present in the Mansfield Formation. Thicknesses of these coals are highly variable over short distances. Generally, the Brazil Formation includes four named coals, and the Staunton Formation, as many as eight coals. The Seelyville Coal Member, at the top of the Staunton Formation in Indiana, is the only coal that has been traced regionally (Mastalerz and Shaffer, 2000).

The Carbondale Formation (Illinois and Kentucky) or Group (Indiana) consists of numerous named members, many of which possess remarkable lateral persistence in thickness and lithologic character. The Carbondale Formation or Group contains the principal economic coals in the Illinois Basin, including the Davis, Dekoven, Colchester, Survant, Springfield, and Herrin Coals (Hopkins and Simon, 1975; Greb and others, 1992; Mastalerz and Shaffer, 2000). In Indiana, the Dugger Formation of the Carbondale Group contains the Hymera and Danville Coal Members (fig. 2).

In Illinois, the Danville Coal Member is the only economically important coal in the McLeansboro Group. McLeansboro Group coals above the Danville in Illinois and Indiana are not as thick nor as extensive as the coals in the underlying Carbondale Formation or Group (Hopkins and Simon, 1975; Mastalerz and Shaffer, 2000). In western Kentucky, the McLeansboro Group contains three important commercial coals, the Paradise, Baker, and Coiltown coals (Greb and others, 1992) (fig. 2).

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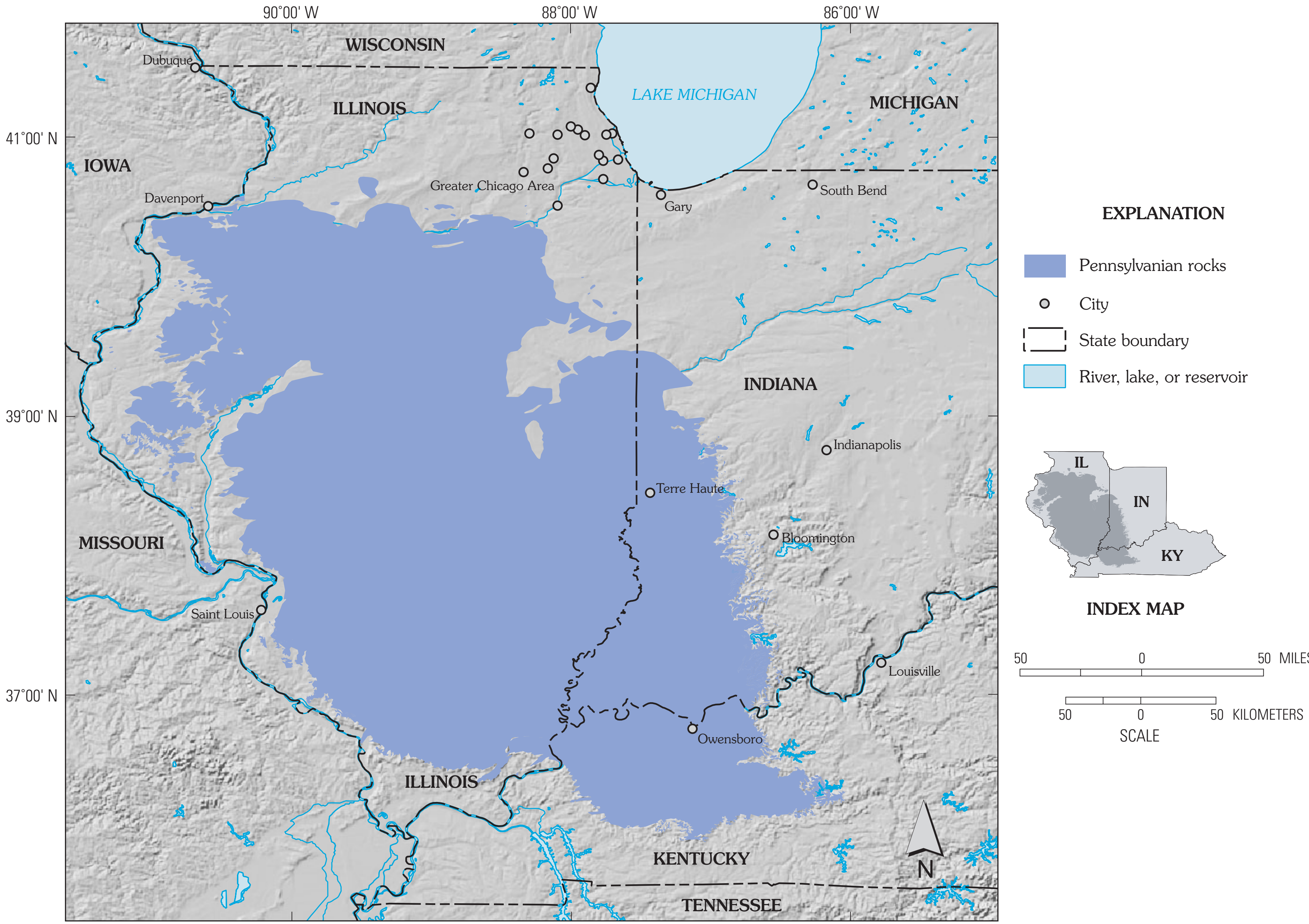

Figure 1. Map showing extent of the Illinois Basin as defined by the outcrop or subcrop of the Pennsylvanian rocks in Illinois, Indiana, and Kentucky. This illustration was produced from regional shapefiles contained in the Illinois Basin ArcView project (Gunther and others, this publication).

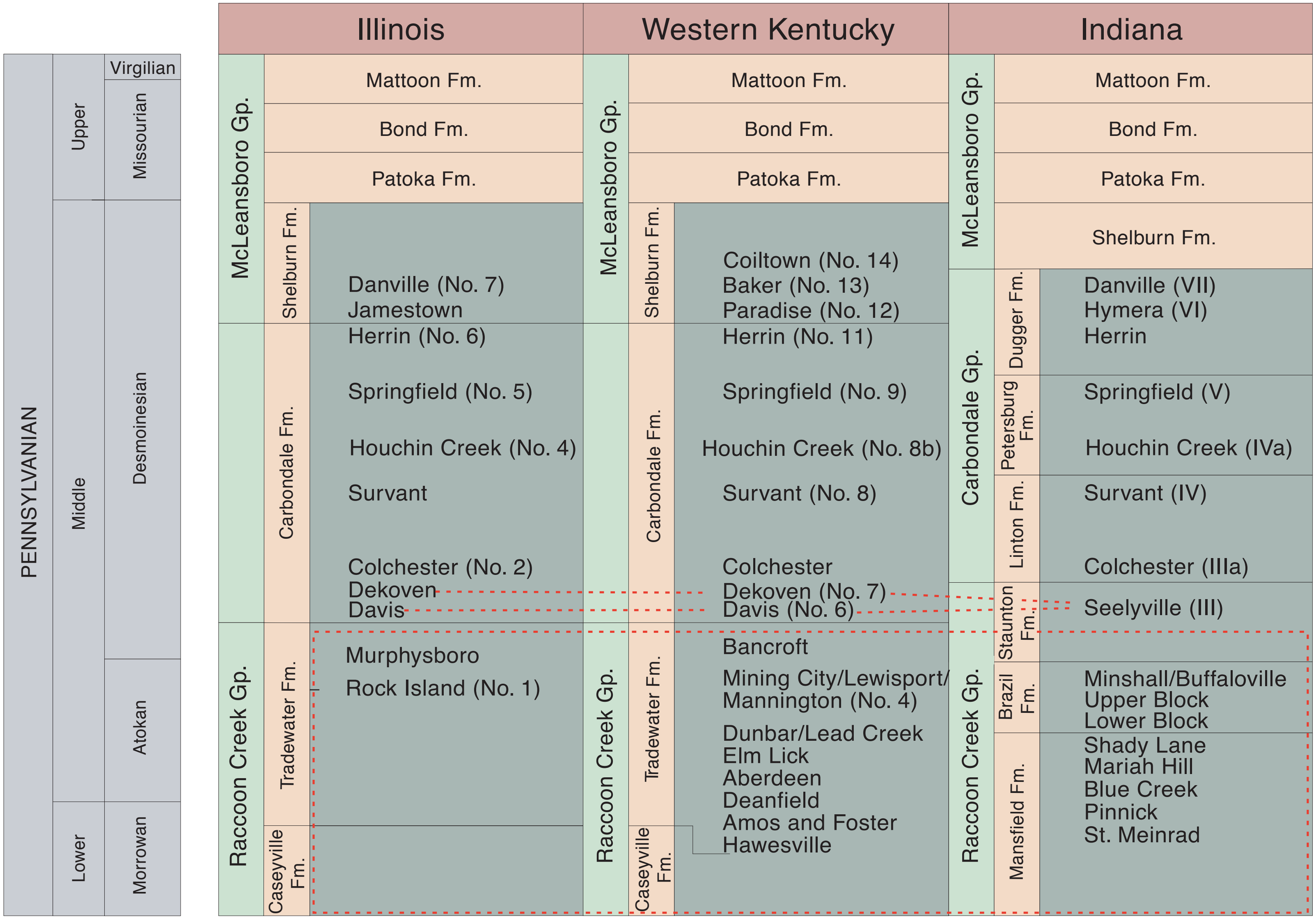

Figure 2. Stratigraphic chart of the Pennsylvanian System in the Illinois Basin, showing major coal members. Modified from Mastalerz and Harper (1998, fig. 2) and Greb and others (1992, fig. 22). Fm., Formation; Gp., Group; ---, problematic coal correlations.

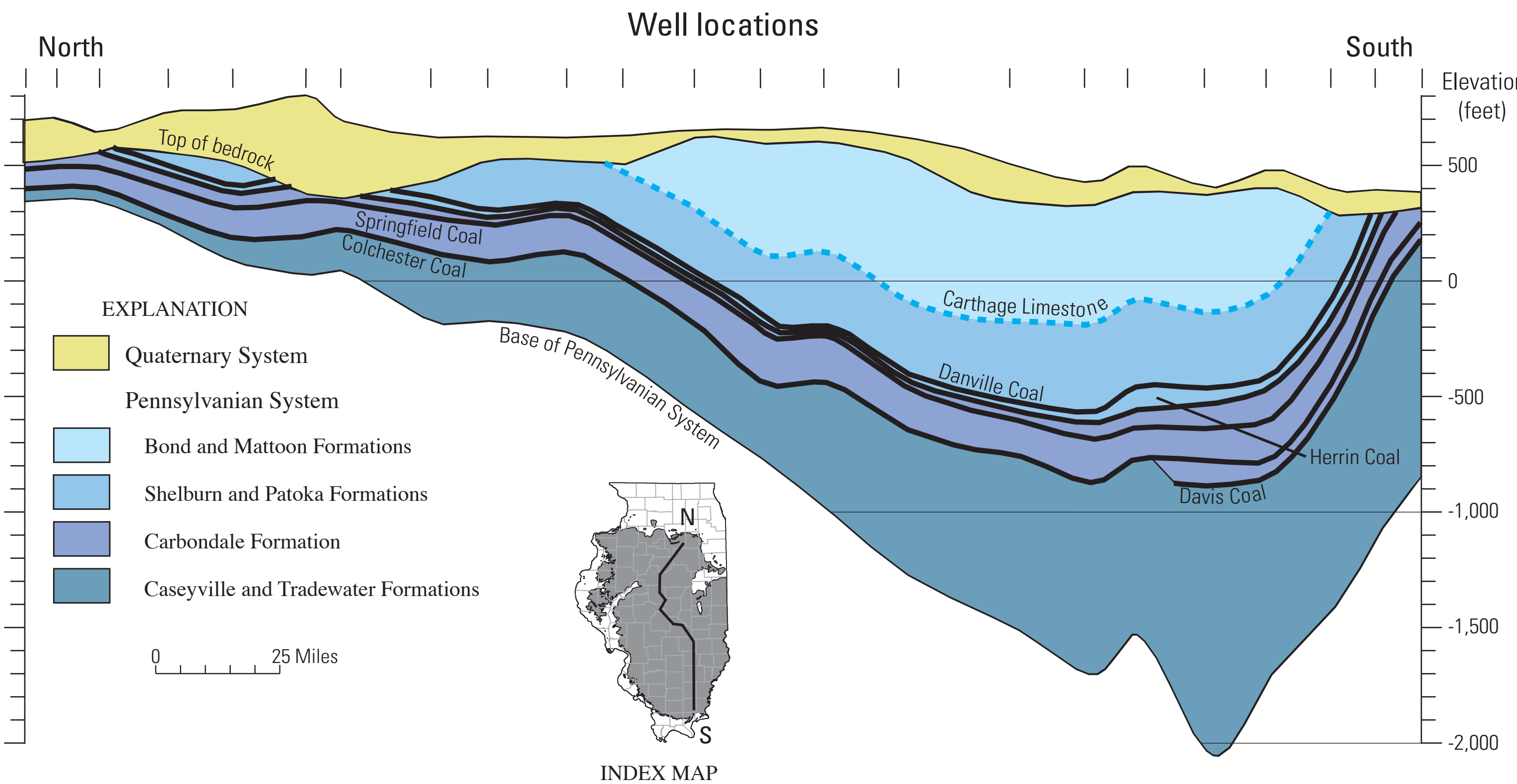

Figure 3. Generalized north-south cross section of the Pennsylvanian System in Illinois. This section illustrates the thickening of the Pennsylvanian strata southward across the basin (provided by C.P. Korose and C.G. Treworgy, Illinois State Geological Survey).

Structure

The major structural features within the Illinois Basin are the La Salle anticlinal belt, the DuQuoin monocline, and the Cottage Grove–Rough Creek fault system; these structures bound the Fairfield Basin in southeastern Illinois (fig. 4) (Buschbach and Kolata, 1991). In Illinois and Indiana, the major coal beds crop out along the margins of the basin and generally dip to depths of more than 1,000 ft at the center of the Fairfield Basin, as shown for the Springfield Coal in figure 4. In western Kentucky, structures affecting the coal bearing rocks are different on either side of the east-west trending Rough Creek fault system (figs. 5 and 6). North of the Rough Creek fault system, the rocks dip gently to the west at about 15–20 ft/mi, in general conformity with the broad north-south, asymmetrical syncline that generally characterizes the structure of the Illinois Basin. South of the Rough Creek fault system the structure is characterized by east-west oriented synclines (Webster and Moorman synclines) that have much steeper dips. Along the axes of these southern synclinal structures, and within some graben structures, depths to the coals lower in the Carbondale Formation can exceed 1,500 ft.

Descriptions of the Springfield, Herrin, Danville, and Baker Coals

Springfield Coal (Ill. No. 5, Ind. V, W. Ky. No. 9)

The Springfield Coal is the most extensively mined coal in the Illinois Basin. In Illinois, this coal has a usual thickness of between 4.5 and 6 ft in most areas where it has been mined (fig. 7) (Damberger, 2000). In Indiana, the Springfield generally averages about 5 ft thick, but coal thicknesses of as much as 13 ft have been reported. Mined coal thickness is between 3 and 7.4 ft (Mastalerz and Shaffer, 2000). Within the Moorman syncline of western Kentucky, the Springfield Coal is 5–6 ft in thickness, but thins to less than 4 ft toward the east and northeast of the Rough Creek fault system (Greb and others, 1992; Chesnut and others, 2000).

The types of roof rocks over the Springfield Coal are variable. Over much of its extent, the Springfield is normally overlain by black, fissile shale that is 6–24 in. thick. However, in a 4- to 10-mi-wide area extending across southwestern Indiana and southeastern Illinois a delta distributary system (the Galatia channel system, see fig. 4) was contemporaneous with the swamps depositing the peat that formed the coal. Within this belt, the coal is absent or irregularly developed and is overlain by the gray, silty Dykersburg Shale Member of the Carbondale Formation (Illinois and Kentucky) or the Dugger Formation (Indiana) (Hopkins, 1968; Hopkins and Simon, 1975). Adjacent to the channel system, the coal is relatively thick (from 5 to 10 ft) and is more commonly split by shale partings. Where the Dykersburg Shale Member is greater than about 20 ft thick, the coal commonly is relatively low in sulfur (1.5–3 percent; Cady, 1935; Damberger, 2000).

Herrin Coal (Ill. No. 6, W. Ky. No. 11)

In Illinois, the Herrin Coal averages more than 6 ft thick over extensive areas and locally reaches 15 ft thick (Hopkins and Simon, 1975) (fig. 8). It is thinner and irregular in thickness in much of central and southeastern Illinois. The Herrin Coal is neither well developed nor mined in Indiana (fig. 8). In the southwestern-most Indiana counties, the Herrin varies from about 2 to 5 ft thick. To the north and east in Indiana, the Herrin is thin or absent (Mastalerz and Shaffer, 2000). In western Kentucky, the Herrin Coal occurs in two geographically distinct bodies (fig. 8). The thickest of these bodies is in a narrow belt along the southern edge of the coal field, where the Herrin Coal is as much as 10 ft thick. The second body of coal is north of the Rough Creek fault system (fault location shown in fig. 6). Here, the Herrin coal is thin (<2.4 ft) or absent (Greb and others, 1992; Weisenfluh and others, 1998; Chesnut and others, 2000).

The types of roof rocks overlying the Herrin Coal are also variable. Over much of its extent in Illinois, the Herrin Coal is normally overlain by as much as 4 ft of black, fissile shale of the Anna Shale or the Brereton Limestone Members of the Carbondale Formation. However, in parts of southern and central Illinois a delta distributary system (the Walshville channel system) was contemporaneous with the swamps depositing the peat that formed the coal. Within this belt, the coal is cut out by a channel sandstone as much as 1 mi wide and 60–80 ft thick or it is irregularly developed and overlain by the silty gray Energy Shale Member of the Carbondale Formation, which is as much as 100 ft thick (Allgaier and Hopkins, 1975; Nelson, 1983). Adjacent to this distributary channel system, the coal is relatively thick (from 5 to 10 ft) and is more commonly split by shale partings. Where the Energy Shale Member is thick, the coal often has a relatively low sulfur content (0.5–2.5 percent; Cady, 1935; Damberger, 2000).

The lower part of the Herrin Coal contains a prominent claystone parting (the "blue band") that normally is 1–3 in. thick (Hopkins and Simon, 1975). The blue band may have been deposited by a basin-wide flooding event (Nelson, 1983). The blue band and other partings and splits thicken along a trend associated with the contemporaneous Walshville channel.

Danville Coal (Ill. No. 7, Ind. VII) and Baker Coal (W. Ky. No. 13)

In east-central Illinois, the Danville Coal is as much as 6 ft thick and has been extensively mined (fig. 9). Recent exploration of the Danville has reportedly identified resources of relatively low-sulfur coal in east-central Illinois, to the west of the mined area, that is mineable underground (Damberger, 2000). In most of the rest of the state, the Danville Coal is thin, generally from a few inches to less than 3 ft thick (Hopkins and Simon, 1975). In Indiana, the Danville Coal ranges from 0.2 to 6.5 ft thick, averaging 4.3 ft in the northern Indiana counties and 2.1 ft in the south (fig. 9) (Mastalerz and Shaffer, 2000)

In western Kentucky, the Baker coal is a complex, multiple-bench zone in which mineable coals are separated by rock partings (Weisenfluh and others, 1998). The Danville in southern Indiana is correlative with an upper bench of the Baker coal in western Kentucky. The lower benches of the Baker coal in Kentucky are the mined benches near the Indiana border, but the mineable Baker coal as mapped elsewhere in western Kentucky may include this upper bench (Danville) in some places (W. A. Andrews, written commun., 1999). Development of thick coal bodies in the Baker coal is typically found in areas where the

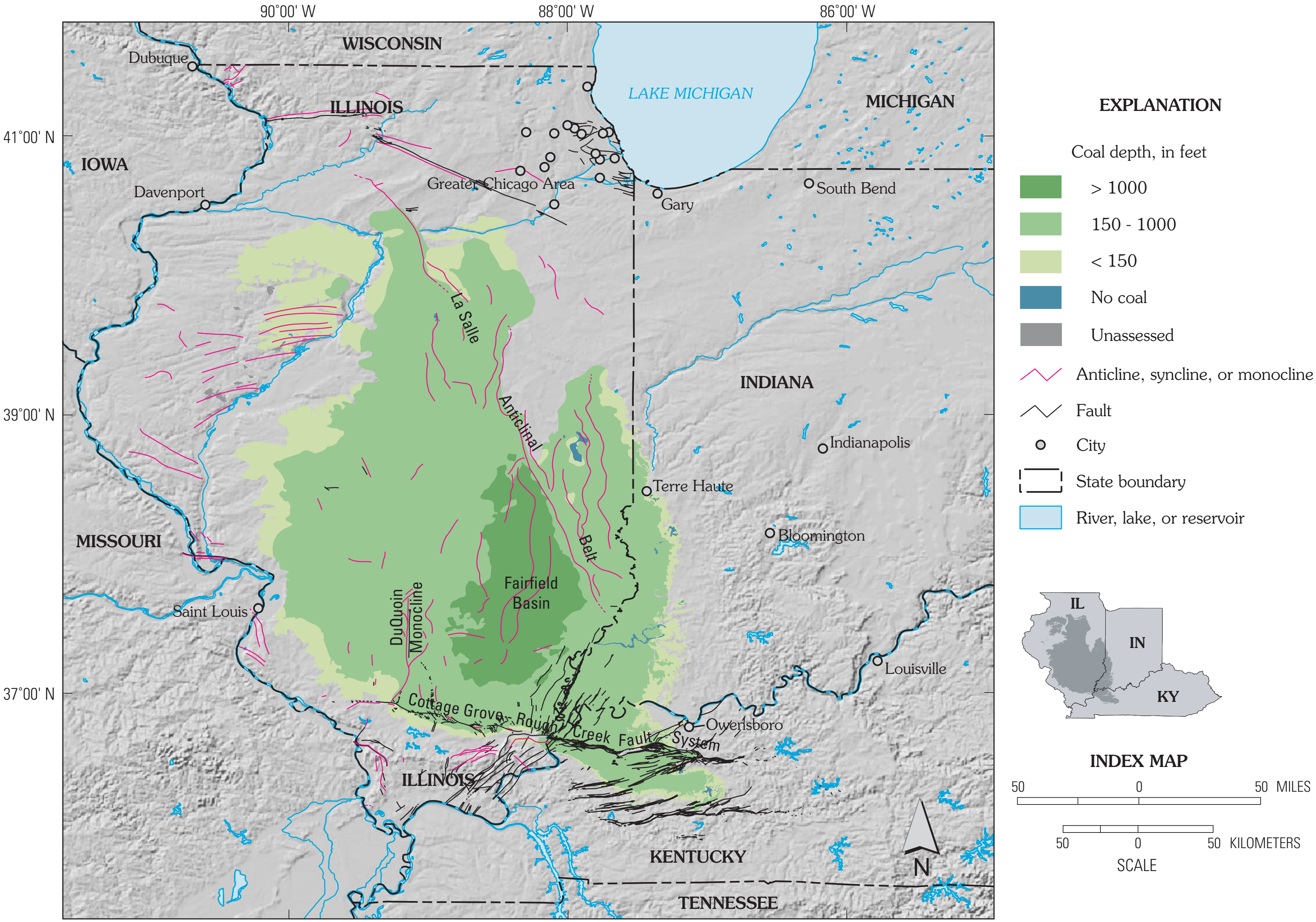

Figure 4. Map showing locations of the major structural features in the Illinois Basin and depth to the Springfield Coal. Structure locations are from Buschbach and Kolata (1991). The Springfield Coal reaches depths of 1,000 ft or greater in the Fairfield Basin, in southeastern Illinois, and in the Webster and Moorman synclines, in western Kentucky (locations shown in fig. 5).This illustration was modified from regional shapefiles contained in the Illinois Basin ArcView project (Gunther and others, this publication).

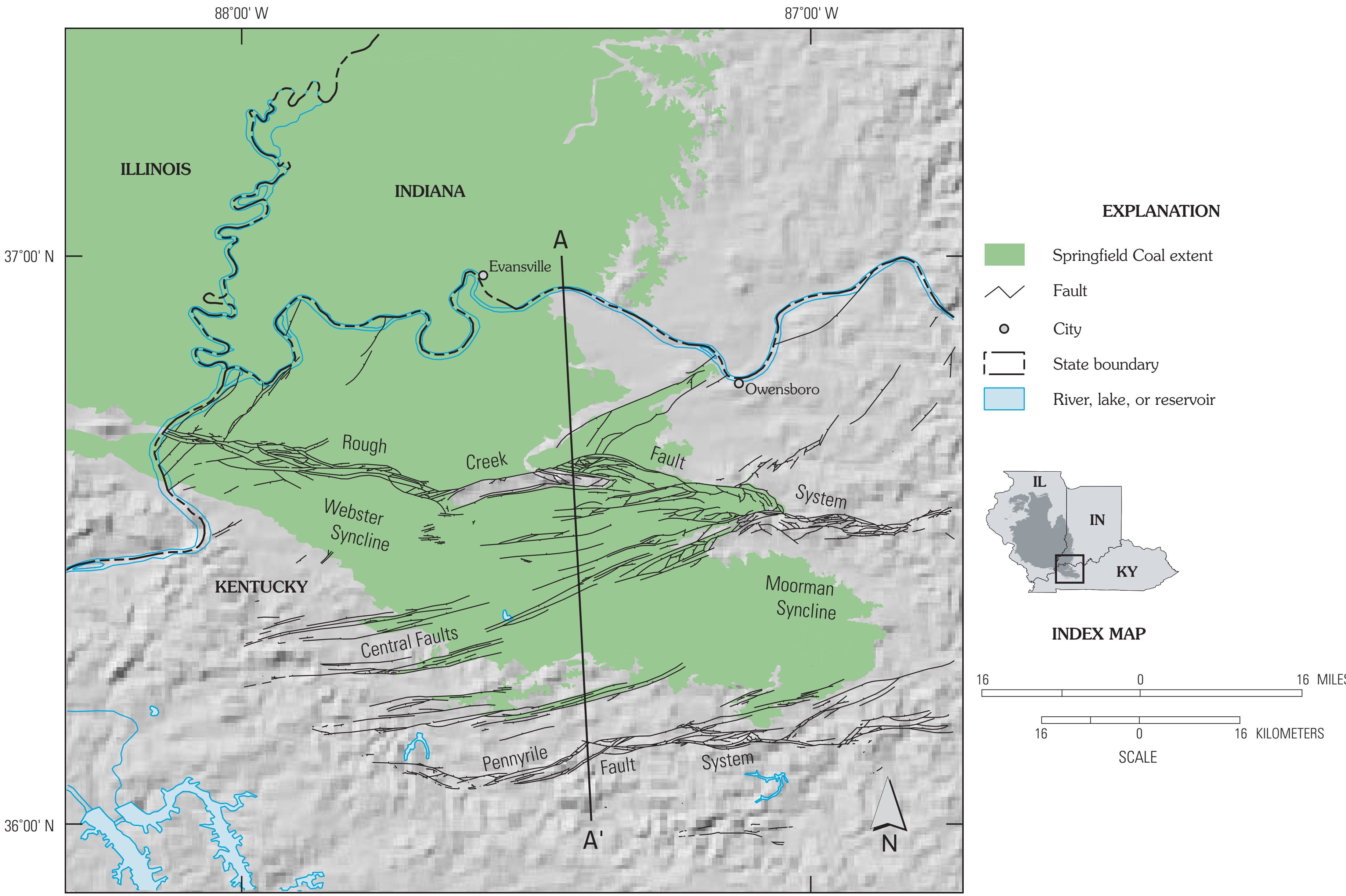

Figure 5. Map showing major structural features of the western Kentucky coal field. Modified from Cobb and others (1985) and Greb and others (1992). Section A–A′ is the approximate location of the cross section shown in figure 6.

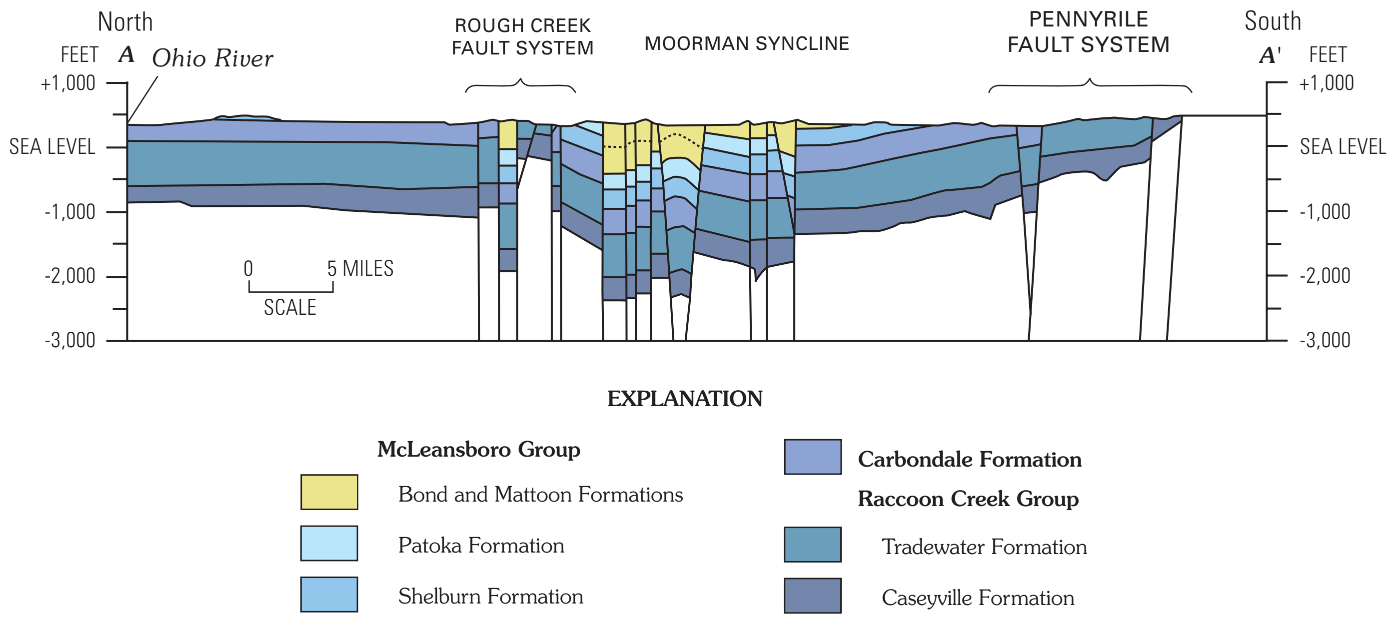

Figure 6. Generalized north-south cross section (*A–A′*) through western Kentucky. The approximate location of cross section *A–A′* is shown in figure 5. Figure provided by S.F. Greb.

underlying Herrin and Paradise Coals are thin or absent (Greb and others, 1992; Weisenfluh and others, 1998). Two distinct bodies of thicker Baker coal are well documented, one south of the Rough Creek fault system and one north (fig. 9). Because of the close stratigraphic relationship between the Danville and Baker Coals, resources and quality for these coals are summarized together.

Coal Resource Assessment

Coal Production

Coal was first reported in what is now Illinois by French-Canadian explorers who noted an outcrop along the Illinois River on a map made in the 1670's. Coal production began in Illinois in the early 1800's. In Indiana, coal was first discovered along the Wabash River in 1736; by 1832 coal was being advertised for sale, and in 1837 the first coal company was officially incorporated. The first recorded coal production in western Kentucky was in 1820.

Annual coal production from Illinois, Indiana, and western Kentucky between 1890 and 1998 is shown in figure 10. Coal production from the basin through time, in general, was related to the overall increasing demand for power generation. At the same time, specific events have had both short- and long-term effects on coal development. These include industrial development and railroad expansion between 1890 and the late 1920's, the Depression of the 1930's, World War II, competition from expanded oil and gas usage, the conversion of railroad locomotives from coal to diesel-electric power following World War II, and an increased demand for electrical utility coal in the 1960's and 1970's. A maximum of about 148 million tons was produced from the Illinois Basin in 1984. Since about 1990 production has dropped. This decrease in the demand for Illinois Basin coal has primarily been a result of the enactment and implementation of Phase I restrictions of the 1990 Amendments to the Clean Air Act and increasing price competition from western low-sulfur coals (U.S. Energy Information Administration, 1998). During 1998, coal production from the Illinois Basin was about 112 million short tons (U.S. Energy Information Administration, 2000).

Previous Coal Resource Assessments

Since 1899, a number of assessments of the original and remaining coal resources, coal compositions, and recoverable coal reserves in the Illinois Basin have been completed. The early assessments in Illinois include those of DeWolf (1908) and Bement (1910), and for Indiana, Ashley (1899) and Campbell and Leverett (1913). For Illinois, comprehensive coal resource assessments include those of Cady (1952), Hopkins and Simon (1974), Treworgy and others (1978), Treworgy and Bargh (1982), Treworgy and others (1997), and Damberger (2000). For Indiana, they include Spencer (1953) and for western Kentucky, Smith and Brant (1980) and Weisenfluh and others (1998).

As listed in table 1, these previous coal resource estimates all show that the Springfield, Herrin, Danville, and Baker Coals contain most of the remaining coal resources in the Illinois Basin. Cady (1952) estimated that the combined remaining resources for the Springfield, Herrin, and Danville Coals in Illinois were about 79 percent of the total for the state. Hopkins and Simon (1974) estimated that 78 percent of the total was from these coals; Treworgy and others (1978) estimated 60 percent of Illinois surface-mineable resources were from these coals; Treworgy and Bargh (1982) estimated 82 percent of Illinois deep-mineable coals were from these coals; and Damberger (2000) showed that 80 percent of the total was from these coals. For Spencer's (1953) Indiana assessment, the combined resources estimated for the Springfield and Danville Coals were 49 percent of the total resources estimated for the state, and for the Smith and Brant (1980) assessment for western Kentucky, the remaining resources estimated for the Springfield, Herrin, and Baker Coals were 43 percent of

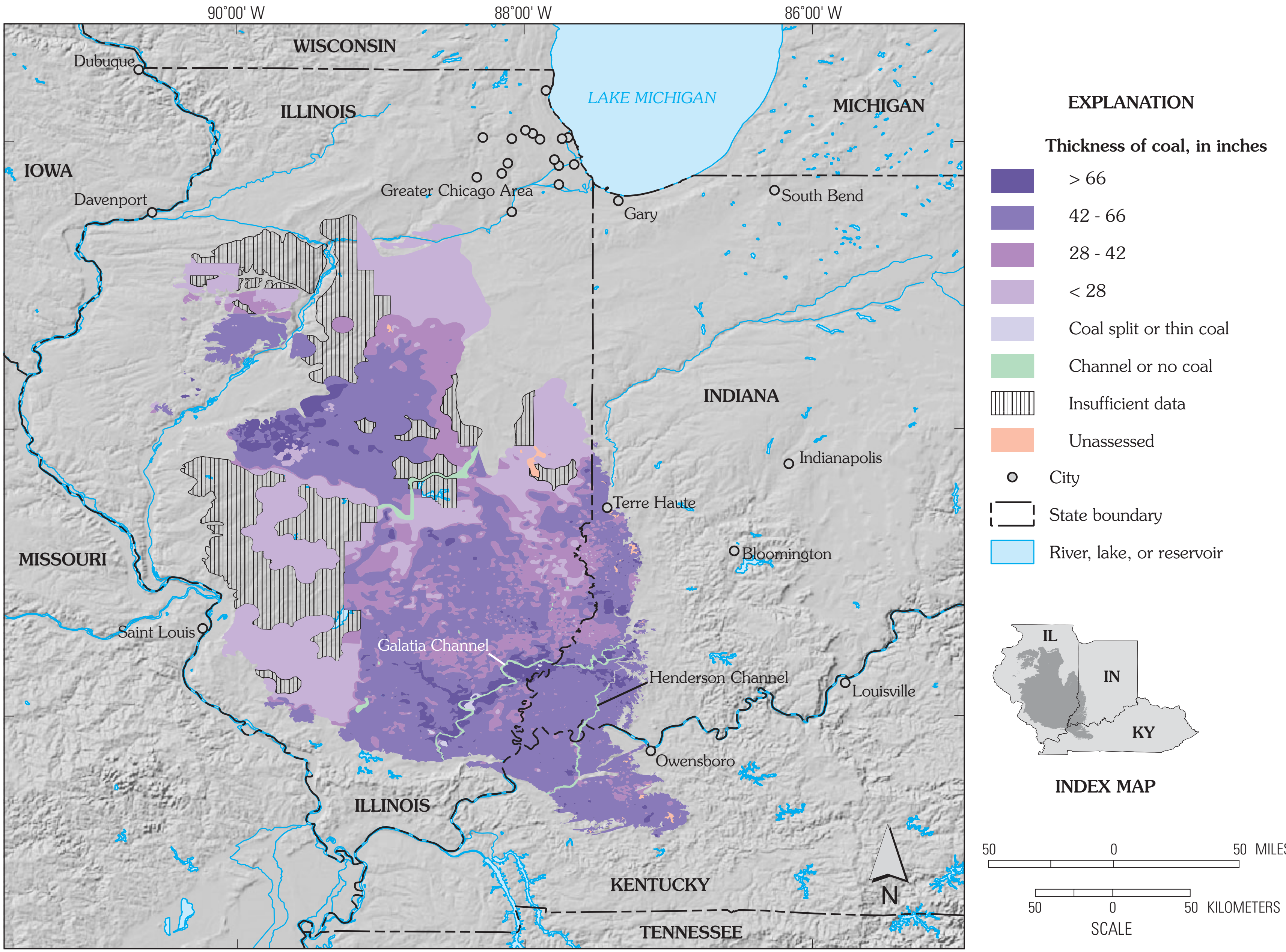

Figure 7. Map showing thickness of the Springfield Coal in Illinois, Indiana, and western Kentucky. This illustration was modified from regional shapefiles contained in the Illinois Basin ArcView project (Gunther and others, this publication).

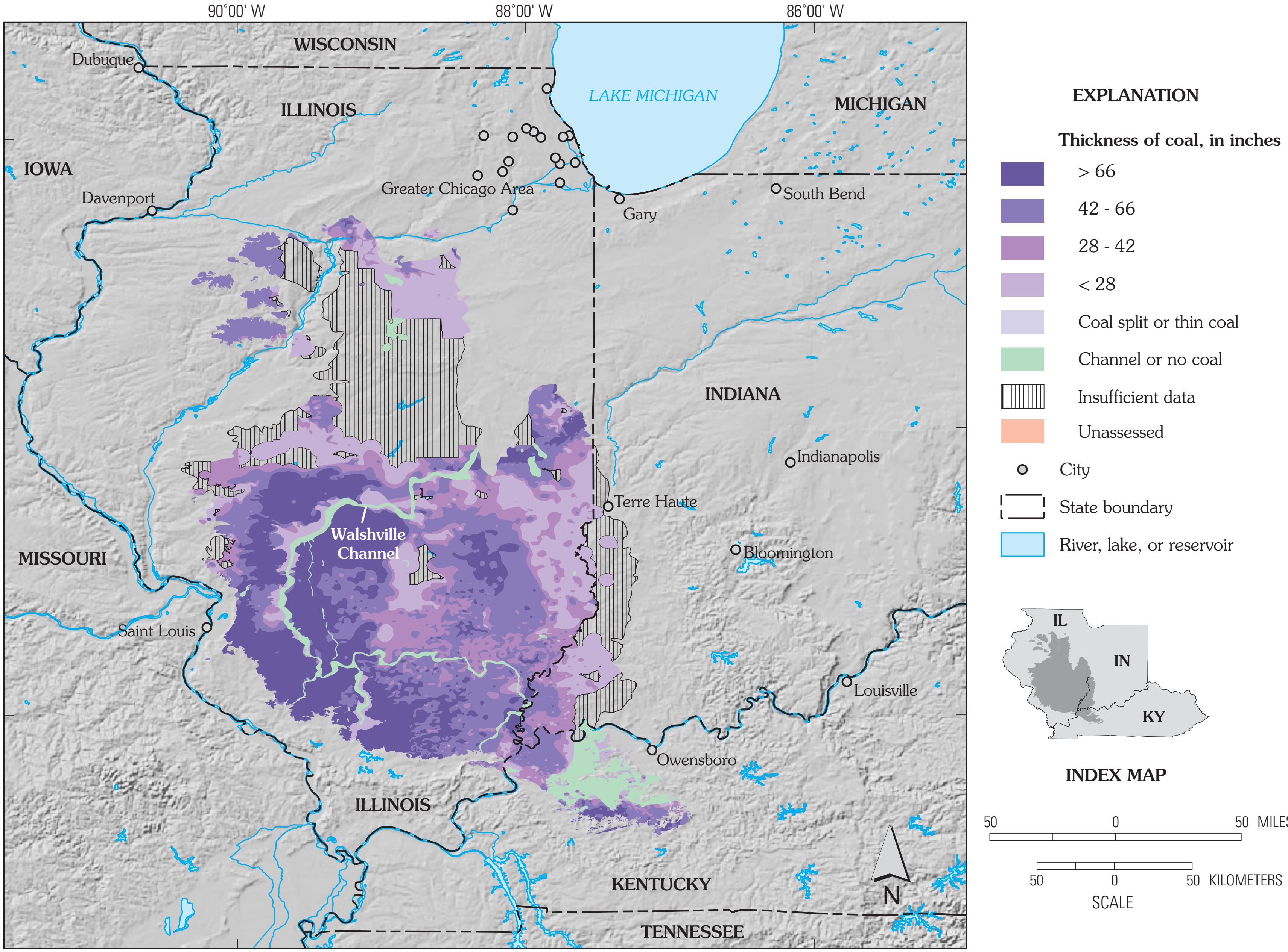

Figure 8. Map showing thickness of the Herrin Coal in Illinois, Indiana, and western Kentucky. This illustration was modified from regional shapefiles contained in the Illinois Basin ArcView project (Gunther and others, this publication).

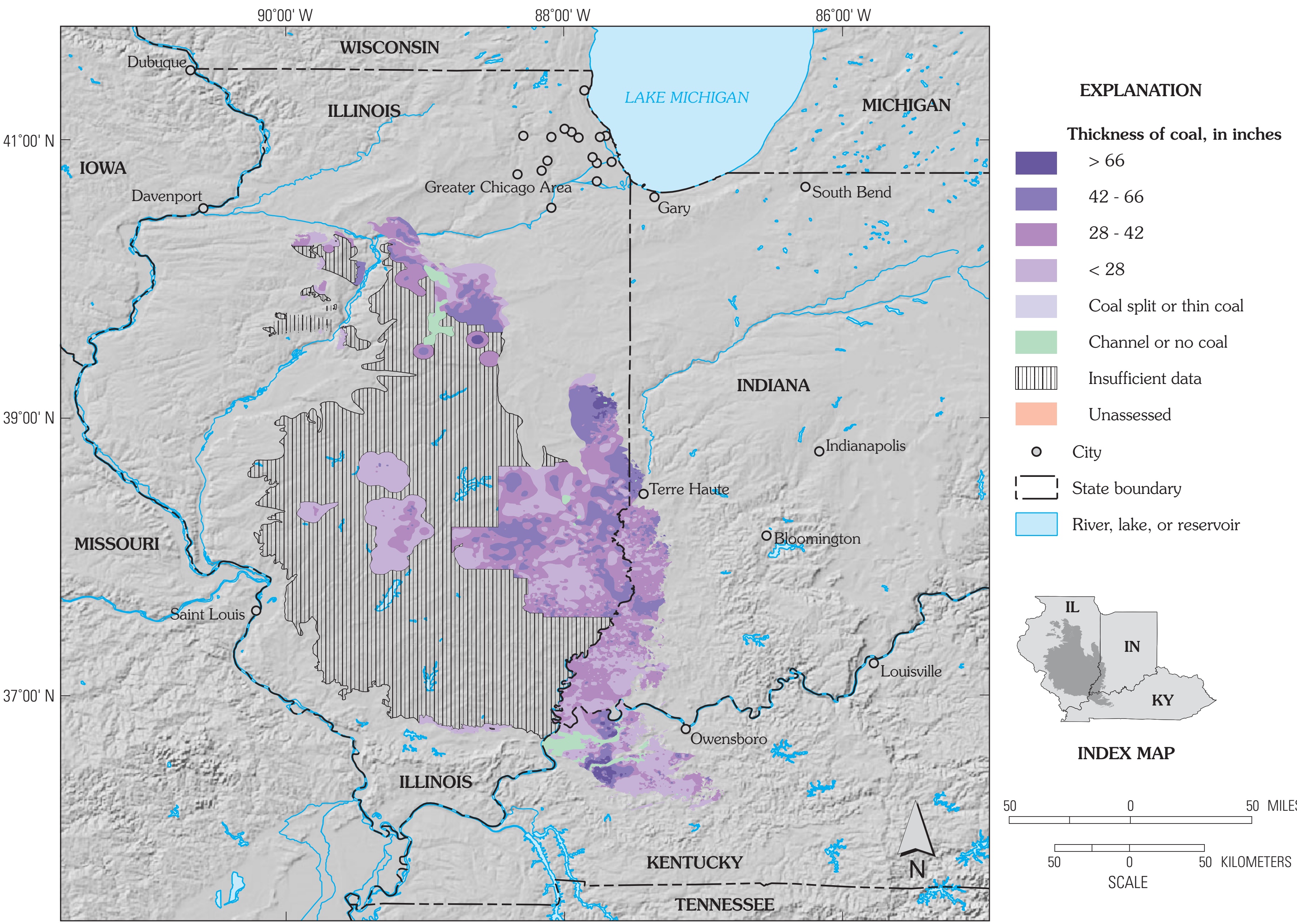

Figure 9. Map showing thickness of the Danville Coal in Illinois and Indiana, and the Baker coal in western Kentucky. This illustration was modified from regional shapefiles contained in the Illinois Basin ArcView project (Gunther and others, this publication).

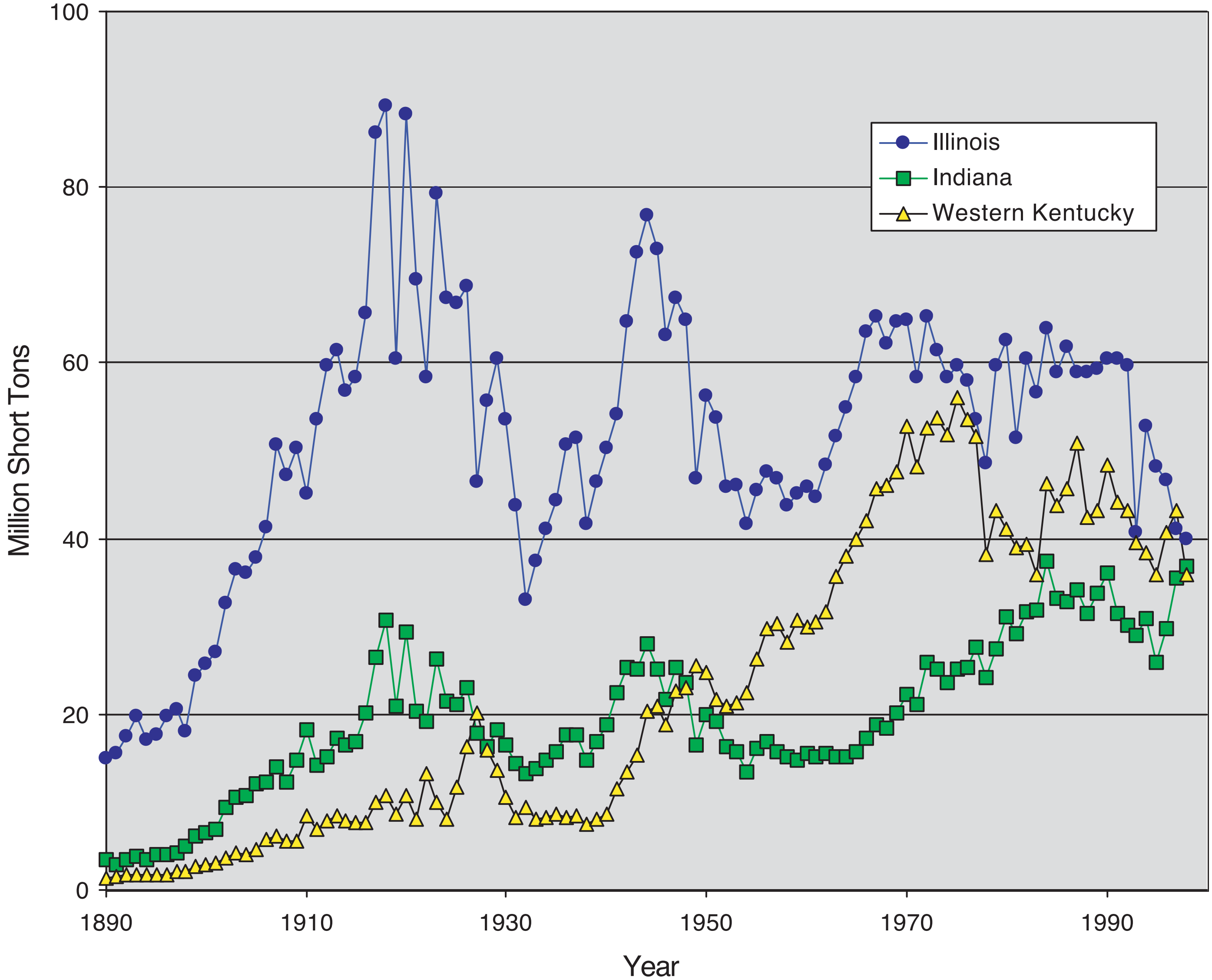

Figure 10. Graph showing annual coal production (million short tons) in Illinois, Indiana, and western Kentucky between 1890 and 1998. Data are from Carey and Hiett (2000), U.S. Energy Information Administration (2000), and Illinois Department of Mines and Minerals (1994).

the total. This Kentucky estimate assumes that half the combined estimate for the Herrin and Paradise coals (8.4 billion short tons) is from the Herrin coal.

Remaining Coal Resources

For this assessment, estimated remaining coal resources are categorized by coal bed, state, mining area, county, overburden thickness (0–150 ft and >150 ft), coal thickness (>14–28 in., >28–42 in., and >42 in.), and reliability of estimate. For Illinois and Indiana, reliability categories are I–A (0–0.5 mi from a data point), I–B (>0.5–2 mi), and II–A (>2–4 mi). For western Kentucky, the categories are measured (0–0.25 mi), indicated (>0.25–0.75 mi), inferred (>0.75–3.0 mi), and hypothetical (>3 mi).

For this assessment, Schuenemeyer and others (as reported in "Confidence Limits for Resource Estimates of Illinois Basin Coals" in chapter D of this publication) determined the uncertainties of coal resource estimates for the Springfield, Herrin, Danville, and Baker Coals. Figure 11 shows that in Illinois and Indiana, estimated percent error (±) ranges from <1 to 2 percent for category I–A and from 2 to 6 percent for category I–B. For category II–A in Illinois, percent error ranges from 4 to 9 percent, whereas for category II–A in Indiana, percent error is much higher, 40 percent for the Danville and 37 percent for the Springfield. For western Kentucky, estimated percent error for measured resources ranges from <1 to 2 percent; indicated, from 2 to 5 percent; inferred, from 5 to 16 percent: and hypothetical, from 34 to 77 percent. For Illinois and Indiana, estimated percent errors for the combined reliability categories I–A, I–B, and II–A range from 3 to 6 percent. For western Kentucky, estimated percent errors for the combined reliability categories measured, indicated, inferred, and hypothetical range from 5 to 15 percent.

Detailed listings of the remaining identified resources are in appendixes 1–3 of chapter D of this publication. These listings are summarized here in table 2, this chapter. For the Springfield and Herrin resource data summarized in table 2, a large majority

Table 1. Previous estimates of remaining coal resources (billion short tons) for the Springfield, Herrin, and Danville-Baker Coals in Illinois, Indiana, and western Kentucky.

[The Danville Coal is recognized in Illinois and Indiana; the Baker coal is recognized in western Kentucky. Smith and Brant's (1980) resource estimate for the Herrin coal in western Kentucky includes resource estimates for the Paradise coal. This table is derived from tables 1–7, chapter D, this publication. ND, not determined.]

Reference	Remaining resources (billion short tons)			
	Springfield Coal	Herrin Coal	Danville-Baker Coals	Total coal resource
Illinois				
Cady (1952)	38.5	62.6	7.8	137
Hopkins and Simon (1974)	42.6	65.8	7.6	148
Treworgy and others (1978) and Treworgy and Bargh (1982)	56.0	70.1	10.5	167
Damberger (2000)	61.7	78.9	17.8	199
Indiana				
Spencer (1953)	13.8	ND	3.7	36
Western Kentucky				
Smith and Brant (1980)	9.4	8.4	3.1	39
Weisenfluh and others (1998)	8.0	2.6	3.6	ND

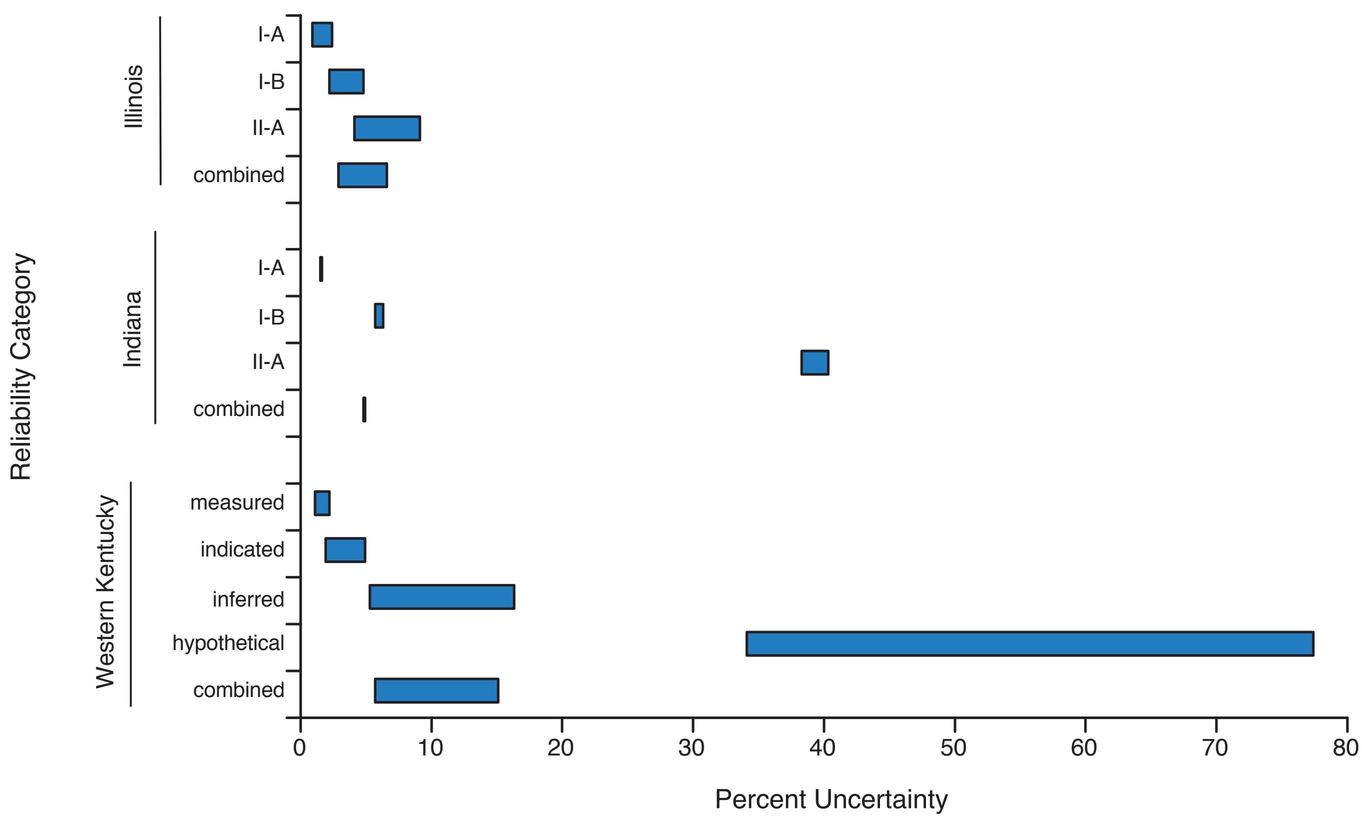

Figure 11. Graph showing range in percent uncertainty (at the 90 percent confidence level) for coal resource reliability categories for Illinois (range for three coals), Indiana (range for two coals), and western Kentucky (range for three coals). I–A resources are within 0.5 mi of a data point; I–B resources, >0.5–2 mi; and II–A resources, >2–4 mi. Measured resources are within 0.25 mi of a data point; indicated resources, >0.25–0.75 mi; inferred resources, >0.75–3 mi; and hypothetical resources, >3 mi.

Table 2. Estimated remaining identified resources (million short tons) of the Springfield, Herrin, and Danville-Baker Coals in Illinois, Indiana, and western Kentucky.

[The Danville Coal is recognized in Illinois and Indiana; the Baker coal is recognized in western Kentucky. Identified resources include reliability categories I–A, I–B, and II–A for Illinois and Indiana, and measured, indicated, and inferred for Kentucky. Resources are listed by mining area in Illinois and by state and are categorized by overburden thickness (coal depth) and coal thickness. Resource values are rounded to two significant figures, or to the nearest one hundred million tons for values greater than ten billion short tons. Columns may not sum exactly due to rounding. This table is derived from tables 8–10, chapter D, this publication. NC, resources not calculated because coal was generally not greater than 14 in. thick.]

		Remaining, identified resources (million short tons)												
	Coal	Springfield Coal				Herrin Coal				Danville-Baker Coals				Coal
Mining area	depth	Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				depth
or State	(feet)	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	(feet)
Northern	0-150	0	0	37	37	77	140	170	390	290	340	190	810	0–150
Illinois	>150	0	2,200	2,500	4,700	0	330	62	390	570	950	1,300	2,800	>150
	Subtotal	0	2,200	2,500	4,700	77	470	230	780	850	1,300	1,500	3,600	Subtotal
Western	0–150	380	450	1,200	2,000	15	470	2,000	2,500	430	200	0	630	0–150
Illinois	>150	0	68	480	550	0	130	320	450	0	150	37	190	>150
	Subtotal	380	520	1,700	2,600	15	600	2,300	2,900	430	350	37	820	Subtotal
West-central	0–150	0	0	1,100	1,100	98	600	300	990	0	0	0	0	0–150
Illinois	>150	0	2,400	15,600	18,000	0	2,800	23,400	26,100	18	1,300	450	1,800	>150
	Subtotal	0	2,400	16,700	19,100	98	3,400	23,700	27,200	18	1,300	450	1,800	Subtotal
East-central	0–150	17	9	13	39	81	56	470	610	57	350	450	850	0–150
Illinois	>150	0	1,700	3,700	5,400	0	2,200	5,200	7,400	0	2,500	3,900	6,400	>150
	Subtotal	17	1,700	3,700	5,500	81	2,300	5,700	8,000	57	2,800	4,400	7,300	Subtotal
Southwestern	0–150	12	98	250	360	2	17	2,400	2,500	NC	NC	NC	NC	0–150
Illinois	>150	0	89	300	380	0	150	11,200	11,300	NC	NC	NC	NC	>150
	Subtotal	12	190	550	740	2	170	13,600	13,800	NC	NC	NC	NC	Subtotal
Southeastern	0–150	0	4	370	370	3	47	580	630	120	4	0	120	0–150
Illinois	>150	0	5,400	23,200	28,600	0	4,900	20,800	25,700	0	2,700	1,500	4,200	> 150
	Subtotal	0	5,400	23,600	29,000	3	4,900	21,400	26,300	120	2,700	1,500	4,300	Subtotal
Illinois total	0–150	410	560	3,000	4,000	280	1,300	5,900	7,600	910	880	630	2,400	0–150
	>150	0	11,900	45,800	57,700	0	10,500	60,900	71,400	590	7,600	7,300	15,500	>150
	Subtotal	410	12,500	48,800	61,700	280	11,800	66,800	78,900	1,500	8,500	8,000	17,900	Subtotal
Indiana total	0–150	25	280	1,800	2,100	NC	NC	NC	NC	210	840	500	1,600	0–150
	>150	150	1,500	8,400	10,100	NC	NC	NC	NC	1,200	2,900	670	4,700	>150
	Subtotal	180	1,800	10,200	12,100	NC	NC	NC	NC	1,400	3,700	1,200	6,300	Subtotal
Western	0–150	1	17	960	980	47	74	430	550	310	360	260	930	0–150
Kentucky total	>150	9	180	5,800	6,000	140	460	1,500	2,100	580	500	1,300	2,400	>150
	Subtotal	10	200	6,800	7,000	180	530	1,900	2,600	890	870	1,600	3,400	Subtotal
Illinois	0–150	430	860	5,700	7,000	320	1,400	6,300	8,100	1,400	2,100	1,400	4,900	0–150
Basin total	>150	160	13,500	60,000	73,700	140	11,000	62,400	73,500	2,300	11,000	9,200	22,500	>150
	Total	590	14,400	65,700	80,700	460	12,400	68,700	81,600	3,700	13,100	10,600	27,400	Total

(81 and 84 percent, respectively) of the identified (reliability categories I–A + I–B + II–A or measured + indicated + inferred) coal resources are in relatively thick coals (>42 in.) (fig. 12). Coals greater than 42 in. thick are the coals that are most likely to be mined. For the combined Danville and Baker Coals, only 39 percent of the identified resources are in relatively thick coal.

The quantities of identified resources in coals greater than 42 in. thick, and at depths of less than 150 ft (potentially mineable at the surface) are summarized by coal and by mining area in table 2. These data are illustrated in figure 13. For the Springfield Coal, the mining areas having the largest identified resources of coal in these categories are western Illinois (1.2 billion short tons), west-central Illinois (1.1 billion short tons), and southwestern Indiana (1.8 billion short tons). For the Herrin Coal, such mining areas are western Illinois (2.0 billion short tons) and southwestern Illinois (2.4 billion short tons), and for the Danville and Baker Coals, east-central Illinois (450 million short tons) and southwestern Indiana (500 million short tons). For the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin, identified coal resources in beds greater than 42 in. thick and at depths less than 150 ft are about 13.4 billion short tons.

The quantities of identified resources in coals greater than 42 in. thick and at depths of greater than 150 ft (potentially mineable underground) are also listed by coal and by mining area in table 2. These data are shown in figure 14. For the Springfield Coal, the mining areas having the largest identified coal resources in these categories are west-central Illinois (15.6 billion short tons), southeastern Illinois (23.2 billion short tons), southwestern Indiana (8.4 billion short tons), and western Kentucky (5.8 billion short tons). For the Herrin Coal, such mining areas are west-central Illinois (23.4 billion short tons), southwestern Illinois (11.2 billion short tons), and southeastern Illinois (20.8 billion short tons). For the Danville and Baker Coals, such mining areas are on the east side of the basin in east-central Illinois (3.9 billion short tons), southeastern Illinois (1.5 billion short tons), southwestern Indiana (670 million short tons), and western Kentucky (1.3 billion short tons). For the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin, identified coal resources in beds greater than 42 in. thick and at depths greater than 150 ft are about 132 billion short tons.

Coal Availability and Recoverability

Coal resources available for mining are significantly less than estimates of coal in the ground because some resources are unavailable due to surface or subsurface land-use and technological restrictions (Carter and Gardner, 1989; Eggleston and others, 1990; Carter and others, 1995). Estimates of recoverable resources are based on the available coal resources, the current state of mining technology, present and near-future market conditions, and the impact of Phase I restrictions of the 1990 Amendments to the Clean Air Act (Plis and others, 1993; Rohrbacher and others, 1993; Suffredini and others, 1994; U.S. Bureau of Mines, Intermountain Field Operations Center, 1995). Coal resources actually recoverable during mining are less than the available coal resources.

Results from the availability and recoverability studies in the Illinois Basin have shown that only part of the original coal resources within the quadrangles studied is available for development. For 19 representative quadrangles in Illinois, 46 percent (4.6 billion short tons) of the original coal resource is still

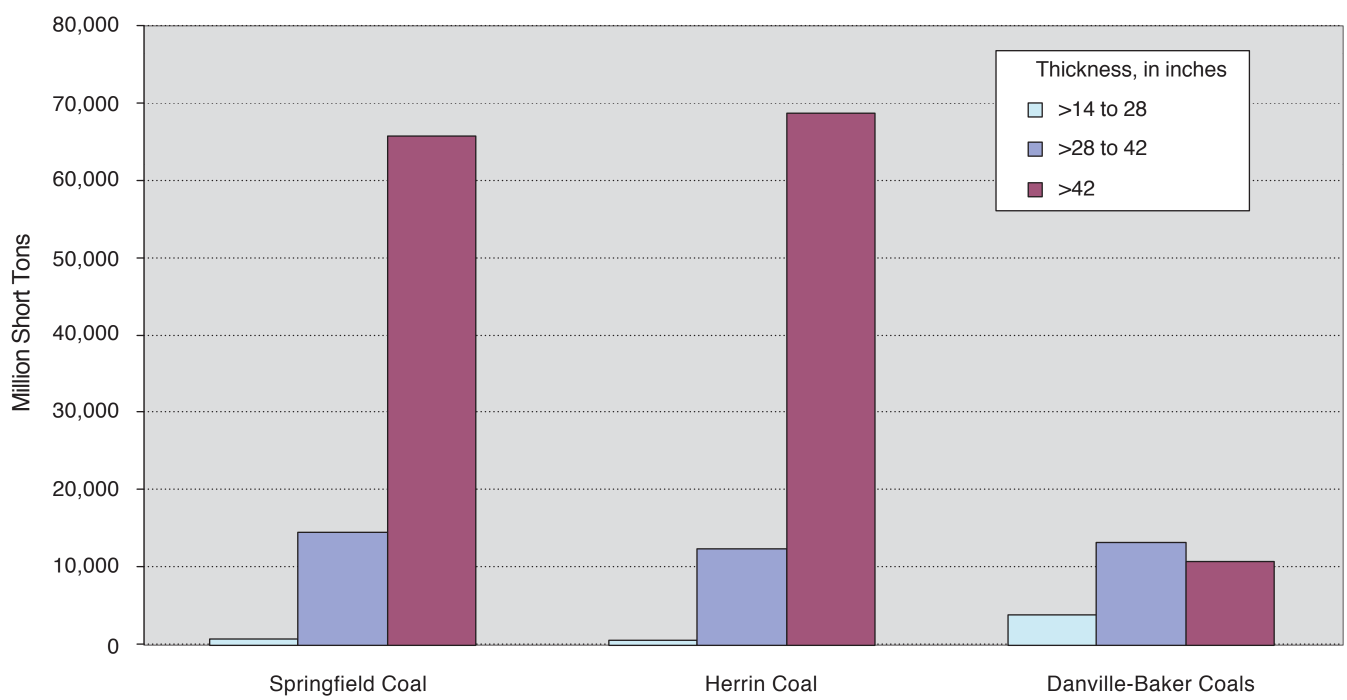

Figure 12. Histogram showing remaining, identified coal resources (million short tons) of the Springfield, Herrin, and Danville-Baker Coals in Illinois, Indiana, and western Kentucky, summarized by thickness. Identified resources include reliability categories IA, IB, and IIA in Illinois and Indiana, and measured, indicated, and inferred in western Kentucky. Data are from table 1, this chapter, and tables 8–10, chapter D, this publication.

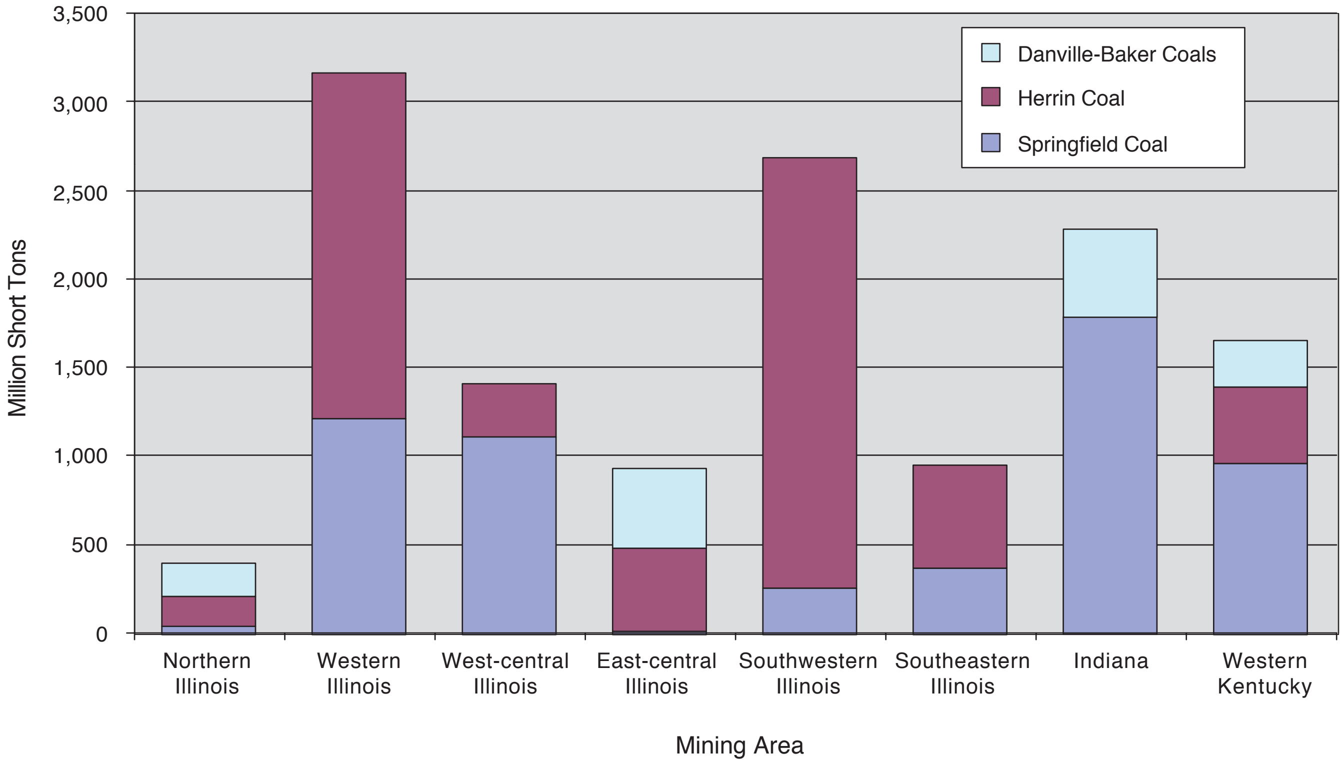

Figure 13. Histogram showing remaining, identified coal resources (>42 in. thick, million short tons) of the Springfield, Herrin, and Danville-Baker Coals in Illinois, Indiana, and western Kentucky at depths of less than 150 ft. Identified resources include reliability categories IA, IB, and IIA in Illinois and Indiana and measured, indicated, and inferred in western Kentucky. Data are from table 1, this chapter, and tables 8–10, chapter D, this publication.

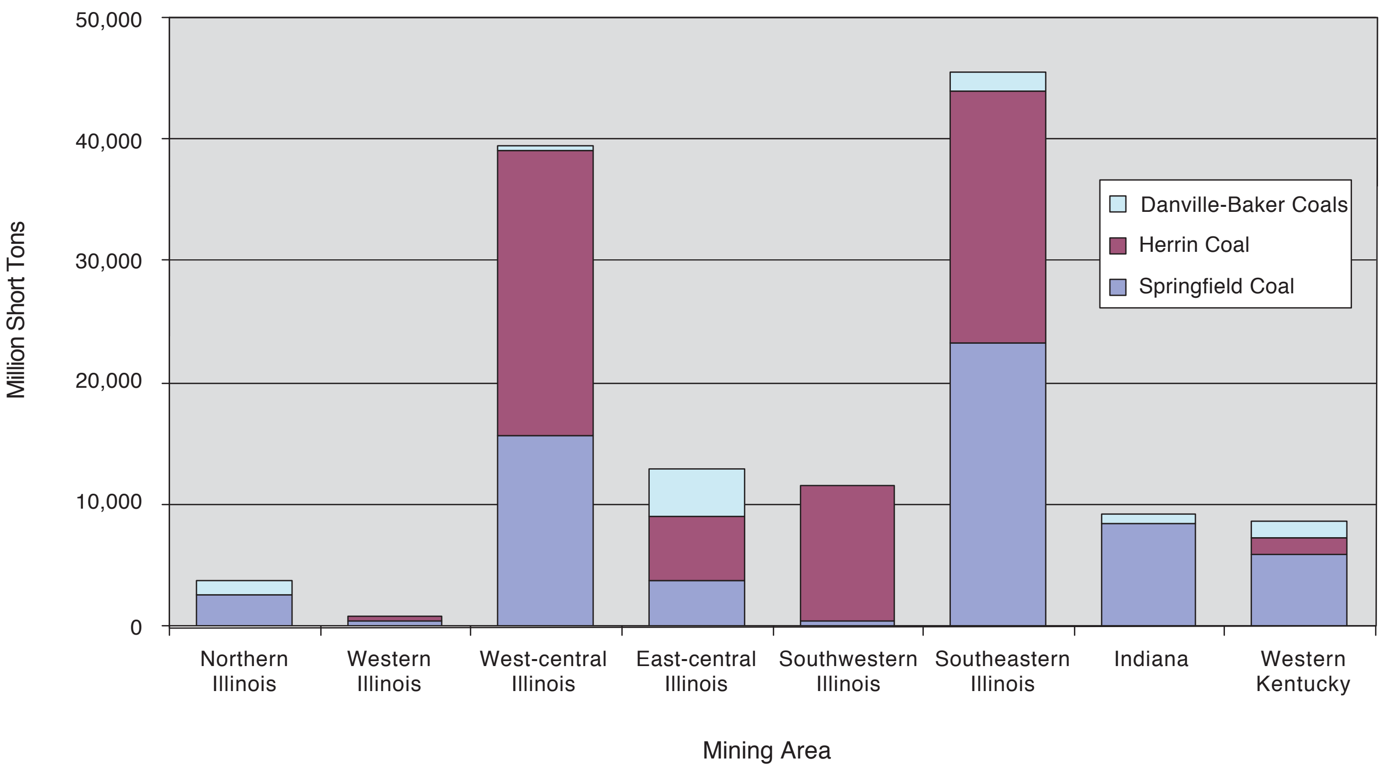

Figure 14. Histogram showing remaining, identified coal resources (>42 in. thick, million short tons) of the Springfield, Herrin, and Danville-Baker Coals in Illinois, Indiana, and western Kentucky at depths of greater than 150 ft. Identified resources include reliability categories IA, IB, and IIA in Illinois and Indiana and measured, indicated, and inferred in western Kentucky. Data are from table 1, this chapter, and tables 8–10, chapter D, this publication.

available; for 10 quadrangles in southwestern Indiana, 57 percent (3.3 billion short tons) is available; and for 12 quadrangles in western Kentucky, 53 percent (2.7 billion short tons) is available (table 3). For all 41 Illinois Basin quadrangles studied for coal availability (fig. 15), about 51 percent of the coal is still available. Studies of coal recoverability show that even less of the original resource is actually recoverable and only a small percentage of the original coal resources is economically recoverable (table 4). For eight representative quadrangles in Illinois, 13 percent (900 million short tons) of the original coal resource is currently economically recoverable; for three quadrangles in southwestern Indiana, 7 percent (170 million short tons) is economically recoverable, and for five quadrangles in western Kentucky, less than 0.01 percent (7 million short tons) is economically recoverable. For all 16 Illinois Basin quadrangles studied for coal recoverability (fig. 16), only about 9 percent of the coal is economically recoverable in today's market. See "Availability and Recoverability of Illinois Basin Coals," chapter D of this publication, for details of, and references for, studies of Illinois Basin coal availability and coal recoverability.

Coal Quality

A primary purpose of this assessment of coals in the Illinois Basin was to tabulate, summarize, and graphically display the available coal-quality information and to show geographic distributions of the analytical chemistry results. The assembled data sets were summarized for the entire basin and by state for the Springfield, Herrin, Danville, and Baker Coals, and for other coals from the Raccoon Creek Group, Carbondale Formation or Group, and the McLeansboro Group (see chapter E, of this publication, including appendixes 1–8).

Most chemical analyses of Illinois Basin coals that were compiled and summarized for this assessment have been previously published. The most significant of the previously published reports on coal quality in Illinois are those by Cady (1935 and 1948, proximate and ultimate analyses, Btu/lb), Gluskoter and Simon (1968, sulfur analyses), and Gluskoter and others (1977, proximate and ultimate analyses, Btu/lb, and major, minor, and trace-element analyses). For Indiana coals, published reports are those by Hasenmueller and Miller (1992, proximate and ultimate analyses, Btu/lb), Oman and others (1992, proximate and ultimate analyses, Btu/lb, and major, minor, and trace-element analyses), Hassenmueller (1994, proximate and ultimate analyses, Btu/lb), and Mastalerz and Harper (1998, proximate analyses, Btu/lb, and sulfur content). For western Kentucky coal, published reports are those by Cobb and others (1985, proximate analyses, Btu/lb, and sulfur content) and Currens (1986, proximate analyses, Btu/lb, and sulfur content).

Summaries of ash yield, calorific value, sulfur, arsenic, mercury, and lead contents for the Springfield, Herrin, and Danville-

Table 3. Summary of coal availability (billion short tons) for 19 representative 7.5-minute quadrangles in Illinois, 10 quadrangles in Indiana, and 12 quadrangles in western Kentucky.

[Resource values are rounded to two significant figures. Columns may not sum exactly due to rounding.]

	Coal resources (billion short tons)			
	Illinois	**Indiana**	**W. Kentucky**	**Total**
Original resource	10.0	5.8	5.1	20.9
Mined-out resources	0.7	0.7	1.0	2.4
Land-use restrictions	0.8	0.3	0.2	1.3
Technological restrictions	3.9	1.5	1.3	6.7
Available resources	4.6	3.3	2.7	10.6

Table 4. Summary of coal recoverability (billion short tons) for eight representative 7.5-minute quadrangles in Illinois, three quadrangles in Indiana, and five quadrangles in western Kentucky.

[Resource values are rounded to two significant figures. Columns may not sum exactly due to rounding.]

	Coal resources (billion short tons)			
	Illinois	**Indiana**	**W. Kentucky**	**Total**
Original resource	7.1	2.4	2.8	12.2
Mined-out resources	0.7	0.3	0.5	1.5
Restrictions to mining	2.3	0.8	0.6	3.7
Losses in mining	1.4	0.5	0.6	2.5
Uneconomic resources	1.7	0.6	1.0	3.3
Economic resources	0.9	0.2	<0.1	1.1

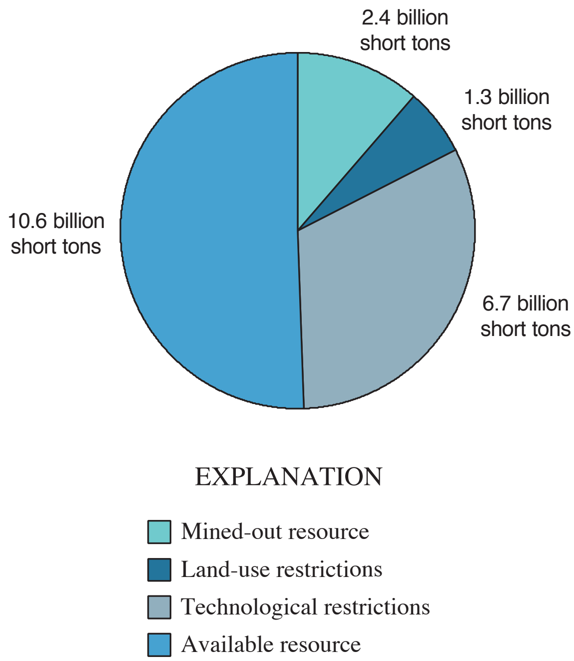

Figure 15. Chart summarizing coal availability for 41 representative 7.5-minute quadrangles in Illinois (19 quadrangles), Indiana (10 quadrangles), and western Kentucky (12 quadrangles). Total original resource for the 40 quadrangles was 20.9 billion short tons. See table 3, this chapter, for data.

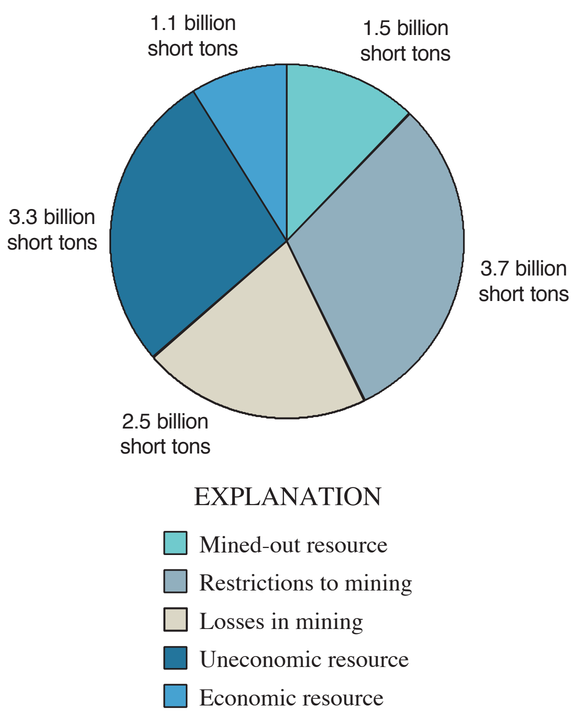

Figure 16. Chart summarizing coal recoverability for 16 representative 7.5-minute quadrangles in Illinois (8 quadrangles), Indiana (3 quadrangles), and western Kentucky (5 quadrangles). Total original resource for the 16 quadrangles was 12.2 billion short tons. See table 4, this chapter, for data.

Baker Coals are listed in tables 5 and 6, respectively (data are from chapter E, this publication, including appendixes 1–8). Mean ash yields are similar for the Springfield Coal (11.2 percent), Herrin Coal (10.9 percent) and Danville-Baker Coals (11.9 percent) (table 5). Ash yields vary both vertically and laterally within the coals and result from changes in the mineral matter composition. Studies of mineral matter in Illinois Basin coals (Gluskoter, 1965, 1967, 1975; Rao and Gluskoter, 1973; and Harvey and others, 1983), show that the distributions and compositions of minerals within the coals are dependent on many geologic and geochemical factors, including the chemical composition of original plants in the peat swamp, amounts and compositions of the various detrital, diagenetic, and epigenetic minerals, and the temperature and pressures during burial.

Mean calorific values are similar for the Springfield Coal (11,280 Btu/lb), Herrin Coal (11,170 Btu/lb), and Danville-Baker Coals (10,920 Btu/lb) (table 5). Calorific value of coal generally increases from the northwestern part of the Illinois Basin toward the southeast (Damberger, 1971). In western Kentucky, calorific value increases from east to west (Greb and others, 1992, fig. 7). The coal rank in much of the northern part of the basin in Illinois and Indiana is high-volatile-C bituminous coal (Cady, 1935, 1948; Damberger, 1971). In a small area in southeastern Illinois and western Kentucky, coal rank reaches high-volatile-A bituminous coal. These differences in rank were most likely caused by increased depths of burial. However, it has been suggested (Damberger, 1971) that the increased rank in the southeastern part of the basin may, in part, result from an increased heat flow related to possible plutonic intrusions.

Mean sulfur contents are similar for the Springfield Coal (3.5 percent), Herrin Coal (3.0 percent), and Danville-Baker Coals (2.9 percent) (table 5). Sulfur content of coal in the Illinois Basin has been related to the type of roof rocks that directly overlie the coal. The coal that is overlain by marine rocks (for example, black shale or limestone) tends to contain greater than 2.5 percent sulfur. The marine water is the proposed primary source for the sulfur incorporated in the coal. Coal near the Galatia sandstone channel in the Springfield Coal in Illinois and Indiana (see fig. 7) and the Walshville sandstone channel in the Herrin Coal in Illinois (see fig. 8) is, in many places, overlain by nonmarine gray shale more than 20 ft thick. These gray shale units may represent river splay deposits. Where overlain by these thick gray shales, the coal commonly is relatively low in sulfur (less than 2.5 percent). The thick gray shale presumably isolates the precursor peat from the later incursions of marine waters (Gluskoter and Simon, 1968).

Mean contents for many trace elements in the Springfield, Herrin, and Danville-Baker Coals are also similar (table 6). Mean content of arsenic for these coals ranges from 5.8 to 19 ppm; mercury, from 0.11 to 0.12 ppm; and lead, from 13 to 18 ppm. The distributions and chemical forms of the major, minor, and trace elements in the coals are, like the mineral distributions, dependent on many geologic and geochemical factors. For example, most zinc and cadmium in Illinois Basin coals are found in sphalerite (ZnS). This sphalerite was introduced into the coals millions of years after peat deposition by hydrothermal fluid-flow systems in operation at the end of the Permian (Hatch and others, 1976; Whelan and others, 1988; Rowan and others, in press). Other investigations of the distributions and chemical form of elements in Illinois Basin coals are those by Gluskoter and Rees (1964,

Table 5. Means and ranges of ash yields (percent), calorific value (Btu/lb), and total sulfur contents (percent) for the Springfield, Herrin, and Danville-Baker Coals in the Illinois Basin.

[Summary data are from tables 4–6, appendix 1, chapter E, this publication, and are on a whole-coal, as-received basis; *n*, number of analyses.]

Coal	Ash yield (percent)		Calorific value (Btu/pound)		Total sulfur (percent)	
	Mean	Range	Mean	Range	Mean	Range
Danville-Baker Coals	11.9	4.4–44.2 (*n* = 334)	10,920	5,800–12,990 (*n* = 295)	2.9	0.3–9.7 (*n* = 335)
Herrin Coal	10.9	2.4–43.6 (*n* = 2,542)	11,170	5,770–13,420 (*n* = 2,390)	3.0	0.3–14.5 (*n* = 2,517)
Springfield Coal	11.2	2.8–49.7 (*n* = 1,832)	11,280	4,810–13,910 (*n* = 1,770)	3.5	0.5–19.5 (*n* = 1,830)

Table 6. Means and ranges of arsenic, mercury, and lead contents (parts per million) for the Springfield, Herrin, and Danville-Baker Coals in the Illinois Basin.

[Summary data are from tables 4–6, appendix 3, chapter E, this publication, and are on a whole-coal, as-received basis; *n*, number of analyses.]

Coal	Arsenic (ppm)		Mercury (ppm)		Lead (ppm)	
	Mean	Range	Mean	Range	Mean	Range
Danville-Baker Coals	19	0.50–70 (*n* = 39)	0.11	<0.01–0.32 (*n* = 39)	18	<1.5–70 (*n* = 39)
Herrin Coal	6	<0.2–140 (*n* = 216)	0.12	<0.01–0.70 (*n* = 206)	18	<0.02–350 (*n* = 226)
Springfield Coal	12	0.27–130 (*n* = 145)	0.12	<0.01–1.2 (*n* = 123)	13	<0.49–110 (*n* = 124)

chlorine), Bohor and Gluskoter (1973, boron in illite), Gluskoter and Lindahl (1973, cadmium), Cobb and others (1979, zinc), and Harvey and others (1983, spatial distributions of selected elements and mineral matter for the Herrin and Springfield Coals).

Conclusions

This assessment of the remaining coal resources in the Illinois Basin and availability and recoverability of these resources shows that

1. Identified remaining resources for the Springfield Coal in coal greater than 42 in. thick and at depths less than 150 ft (potentially mineable at the surface), are about 5.7 billion short tons; for the Herrin Coal, 6.3 billion short tons; and for the Danville-Baker Coals, 1.4 billion short tons.
2. Identified remaining resources for the Springfield Coal in coal greater than 42 in. thick and at depths greater than 150 ft (potentially mineable underground) are about 60 billion short tons; for the Herrin Coal, 62.4 billion short tons; and for the Danville-Baker Coals, 9.2 billion short tons.
3. Coal resources available for mining are significantly less than estimates of coal in the ground because resources are unavailable due to surface or subsurface land-use and technological restrictions. Even less of the original resource is actually recoverable, and only a small percentage of the original coal resources is economically recoverable. Summaries of studies of 16 Illinois Basin quadrangles show that only about 9 percent of the coal in the ground is economically recoverable in today's market.

Summaries of coal quality for the Springfield, Herrin, and Danville-Baker Coals in the Illinois Basin show many similarities:

1. Mean ash yields are similar (Springfield Coal, 11.2 percent; Herrin Coal, 10.9 percent; and Danville-Baker Coals, 11.9 percent.
2. Mean calorific values are similar (Springfield Coal, 11,280 Btu/lb; Herrin Coal, 11,170 Btu/lb; and Danville-Baker Coals, 10,920 Btu/lb). Calorific value of coal generally increases from the northwestern part of the Illinois Basin toward the southeast. In western Kentucky, calorific value increases from east to west.
3. Mean sulfur contents are similar (Springfield Coal, 3.5 percent; Herrin Coal 3.0 percent; and Danville-Baker Coals, 2.9 percent). Where coal is overlain by nonmarine gray shale more than 20 ft thick, the coal commonly contains <2.5 percent sulfur.

4. Mean contents of trace elements of environmental concern are similar. Mean contents of arsenic for the Springfield, Herrin, and Danville-Baker Coals range from 5.8 to 19 ppm; mercury, from 0.11 to 0.12 ppm; and lead, from 13 to 18 ppm.

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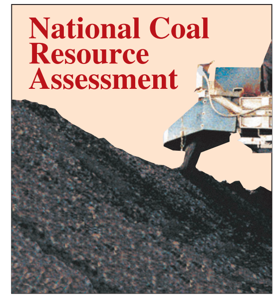
Chapter B

Introduction

By J.R. Hatch *and* R.H. Affolter



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Chapter B *of*

Resource Assessment of the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin

Edited by J.R. Hatch *and* R.H. Affolter

U.S. Geological Survey Professional Paper 1625–D

U.S. Department of the Interior
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Introduction

By J. R. Hatch[1] *and* R. H. Affolter[1]

In the Illinois Basin, coal-bearing rocks of Pennsylvanian age underlie most of Illinois (36,800 mi^2), and parts of southwestern Indiana (6,500 mi^2) and northwestern Kentucky (6,400 mi^2) (fig. 1). Rocks of Pennsylvanian age were formed between about 325 and 290 million years before present.

Coal was first reported in what is now Illinois by French-Canadian explorers who noted an outcrop along the Illinois River on a map they made in the 1670's. In Illinois, coal production began in the early 1800's (U.S. Energy Information Administration, 1998). In Indiana, coal was first discovered along the Wabash River in 1736. In 1832, coal was being advertised for sale; in 1837, the first coal company was officially incorporated, and by 1840, coal was being shipped on flatboats on the Wabash and other rivers. The first recorded coal production in western Kentucky was in 1820 in Henderson and Muhlenburg Counties, and W. W. Mather (1839) mentioned several surface mines and local openings in western Kentucky in his "Report on the Geological Reconnaissance of Kentucky."

From these early beginnings, coal mining in the Illinois Basin has made a significant contribution to the Nation's economy. From 1890 to 1998, about 5.6 billion short tons of coal were produced from Illinois, about 2.5 billion short tons from western Kentucky, and about 2.1 billion short tons from Indiana (U.S. Energy Information Administration, 1998; Carey and Hiett, 2000; U.S. Energy Information Administration, 2000; Weisenfluh and others, 1998). During 2000, coal production from the Illinois Basin was about 88 million short tons (Freme, 2001).

During the last 100 years, a number of assessments of the original and remaining coal resources, coal compositions, and recoverable coal reserves in the Illinois Basin have been completed. For Illinois, the most significant of the coal-quantity assessments include those of DeWolf (1908), Cady (1952), Hopkins and Simon (1974), Treworgy and others (1978), Treworgy and Bargh (1982), and Treworgy and others (1997). For Indiana, significant coal quantity assessments are those of Ashley (1899), Campbell (1913), and Spencer (1953). For western Kentucky, they include Smith and Brant (1980) and Weisenfluh and others (1998). Assessments of coal quality for Illinois include Cady (1935, 1948), Gluskoter and Simon (1968), and Gluskoter and others (1977); for Indiana, Hasenmueller and Miller (1992), Hassenmueller (1994), Oman and others (1992), and Mastalerz and Harper (1998); and for western Kentucky, Cobb and others (1985) and Currens (1986).

The goal of the current coal assessment in the Illinois Basin is to provide an overview of the geologic setting, coal distribution, and estimates of the quantity, quality, and recoverability of the remaining coal resources. These estimates are important to

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(1) utilities and other major users of coal who need to determine what quantity and quality of coal is mineable at current prices,
(2) state and county governments who must plan for the infrastructure necessary to support coal mining (for example, roads, housing, and schools),
(3) companies that provide services to the mining industry (for example, railroads),
(4) federal and state regulators concerned with the environmental impacts of coal mining and utilization (for example, reclamation, atmospheric emissions, and coal combustion waste disposal) (Treworgy and Bargh, 1982).

This assessment is part of the U.S. Geological Survey's National Coal Resource Assessment Program (NCRA). Other areas studied as part of this program include the Colorado Plateau, Northern Rocky Mountains and Great Plains, Northern and Central Appalachian Basin, and Gulf Coast Coal Regions of the United States (fig. 2). This assessment is different from previous coal assessments in that the major emphasis is placed on coals that are most likely to provide energy over the next few decades (Gluskoter and others, 1996).

The objectives of this coal resource assessment in the Illinois Basin are to

(1) Compile the information needed to assess the coals that are most likely to be mined in the next 10–20 years. For the Illinois Basin, most past, current, and expected future coal production will be from the Springfield, Herrin, Danville, and Baker Coals.
(2) Create publicly available digital databases for the assessed coals that can be rapidly accessed and analyzed to provide information for decision-making by government, industry, and the public. These digital databases will contain all publicly available point-source data on thickness, depth, and coal-quality for the basin. These databases can be updated as new information becomes available.
(3) Produce digital state- and basin-wide maps for the Springfield, Herrin, Danville, and Baker Coals, depicting thickness, elevation (structure), mined-out areas, and areas where the coals potentially may be stripped or recovered from underground mines. These maps can be used as a basis to show where coal mining may be restricted because of land use, industrial, social, or environmental factors.
(4) Provide (a) reviews of Illinois Basin coal production history and previous coal assessments, (b) descriptions of coal assessment methodologies, and (c) an update of estimates of the remaining coal resources for the Springfield, Herrin, Danville, and Baker Coals in the basin.

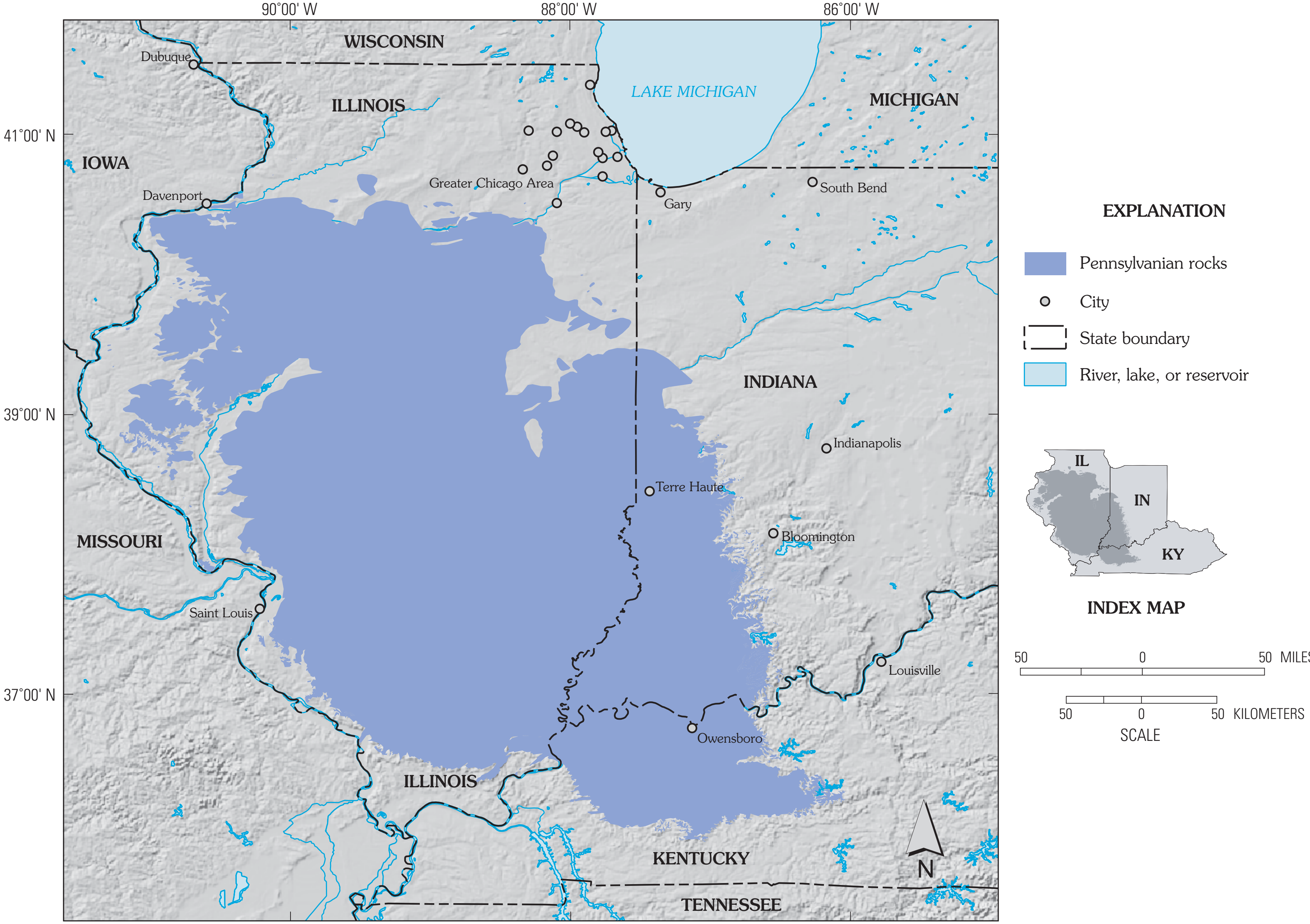

Figure 1. Map showing extent of the Illinois Basin as defined by the outcrop or subcrop of the Pennsylvanian rocks in Illinois, Indiana, and Kentucky. This illustration was produced from regional shapefiles contained in the Illinois Basin ArcView project (Gunther and others, this publication).

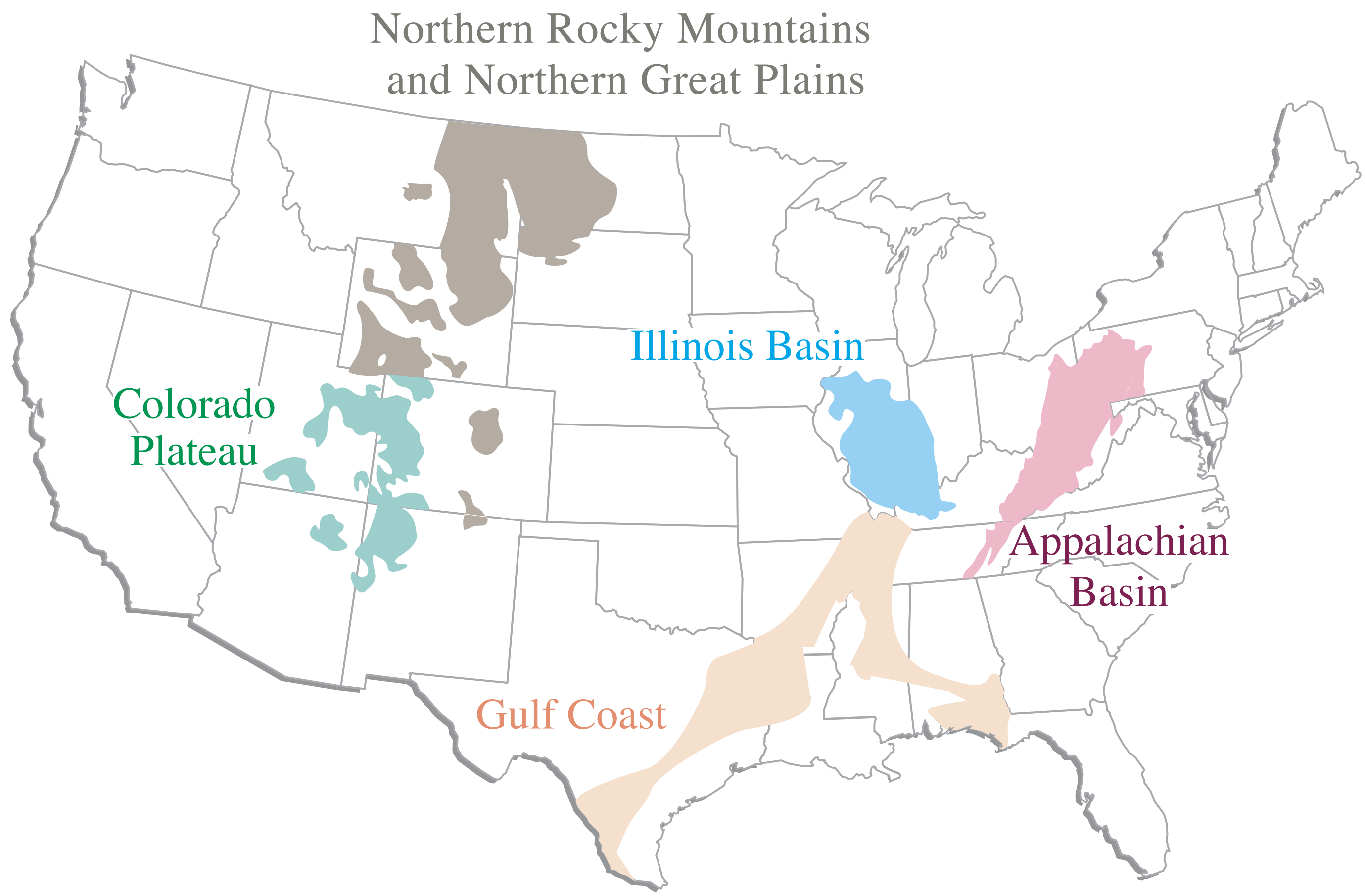

Figure 2. Map showing location of the Illinois Basin study area in the United States in relation to other areas assessed during the National Coal Resource Assessment Project.

Acknowledgments

The Illinois Basin assessment was completed in cooperation with groups of multidisciplinary scientists, technicians, and computer specialists from the U.S. Geological Survey, Illinois State Geological Survey, Indiana Geological Survey, and Kentucky Geological Survey. These three state surveys make up the Illinois Basin Consortium (IBC), which was created to coordinate and complement geologic studies within the basin. Trade and company names used in this report are for descriptive purposes only and do not imply endorsement by the U.S. Geological Survey.

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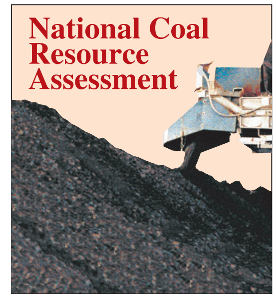
Chapter C

Geologic Overview

By J.R. Hatch *and* R.H. Affolter



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Chapter C *of*

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Geologic Overview

By J. R. Hatch[1] *and* R. H. Affolter[1]

This overview of the geology of the coal-bearing rocks in the Illinois Basin is made up of five parts:

(1) brief summary of the processes of coal formation,
(2) discussion of the stratigraphic framework of the Pennsylvanian rocks,
(3) characterization of the Illinois Basin structural setting,
(4) descriptions of the mining history, geology, and quality of the Springfield, Herrin, Danville, and Baker Coals, and
(5) brief descriptions of other economic coals in the Illinois Basin.

Coal Formation

Coal is a readily combustible rock containing more than 50 percent by weight and more than 70 percent by volume of carbonaceous material, formed from compaction of variously altered plant remains similar to those of peaty deposits (Schopf, 1956). The original plant materials that became coal accumulated in mires. Mires are an ecosystem where the groundwater table is near (wetland) or slightly above (bogs, fens, swamps) the mineral soil, and the vegetation present produces organic matter (peat) at a rate faster than degradation processes can decompose it (Flores, 1993). The layers of organic matter that accumulated in mires were subsequently buried beneath other sediments. These layers were gradually compressed and chemically transformed by microbial action, heat, and pressure to form lignite and coal (Schopf, 1956).

Plant Material

Many factors control plant growth, accumulation, and preservation in peat-forming environments. These include nutrients, topography, subsidence rates, hydrology, and climate. Climatic factors, in particular, influence rates of plant growth and decomposition, swamp types, and formation of peat. In modern settings, tropical and subtropical climates are more favorable than temperate-zone climates for growth of forest swamps having densities of large trees (Mastalerz and Harper, 1998).

In the tropical Pennsylvanian forest swamps, the flora was dominated by tree forms and herbaceous plants of five major groups—lycopods, ferns, pteridosperms, cordaites and sphenopsids—of lower vascular plants (Francis, 1954; Van Krevelen, 1961; Phillips and others, 1976). Lycopod trees were the predominant form of vegetation. Sphenopsids (horse-tails) such as Calamities and pteridosperms (primitive conifers) were also abundant. The tree forms were mostly composed of periderm (barklike tissue), which became the major constituents of most coals. The plant materials contributing to the peats also included foliage, spores, pollen, stems, and rootlets.

Phases of Coal Formation

There are two main phases in the formation of coals: peatification and coalification. Microbial activity is the main process that alters organic matter during the peatification and early coalification, whereas increased temperatures and pressures are the main factors later in coalification. The change in organic matter with increasing temperature and burial is called maturation. For coal, the term "rank" is used to describe various levels of maturation. In order of increasing rank, the main stages of humic coal formation are: peat, lignite, subbituminous coal, bituminous coal, and anthracite (Parr, 1928; Francis, 1954; Van Krevelen, 1961).

Stratigraphic Framework of the Illinois Basin Coals

In the Illinois Basin, coal-bearing rocks are of Pennsylvanian age and were formed between about 325 and 290 million years before present. Rocks representing all series in the Pennsylvanian system (Morrowan, Atokan, Desmoinesian, Missourian, and Virgilian) are present in the Illinois Basin. Stratigraphic correlations of the Pennsylvanian rocks and coals in Illinois, Indiana, and western Kentucky are shown in figure 1. Each coal shown in figure 1 is referred to by a geographic place name, which is usually that of a locality close to the area where the coal was first described. Until recently, the important coals were also commonly referred to by number: the lower the number, the older the coal. The Pennsylvanian rocks reach a maximum thickness of nearly 2,500 ft in southeastern Illinois and generally thin toward the north, northwest, and northeast (fig. 2). This thinning primarily occurs in the lower stratigraphic units (formations in the Raccoon Creek Group) and in much of western and northern Illinois, these lowermost formations are thin or absent (Hopkins and Simon, 1975).

Typically, 90–95 percent of the Pennsylvanian section consists of clastic sedimentary rocks. For the Morrowan rocks (Caseyville Formation in Illinois and western Kentucky and lower part of the Mansfield Formation in Indiana), quartzose, pebbly sandstone commonly makes up 50–75 percent of the total thickness, with most of the remainder made up of siltstone and silty shale. The Morrowan rocks contain less than 1 percent limestone and thin, lenticular coals (Hopkins and Simon, 1975; Nelson and others, 1991). The Atokan rocks (lower and middle parts of the Tradewater Formation in Illinois and western Kentucky, and the upper part of the Mansfield Formation and Brazil Formation in Indiana) consist largely of lenticular sandstone intertonguing with

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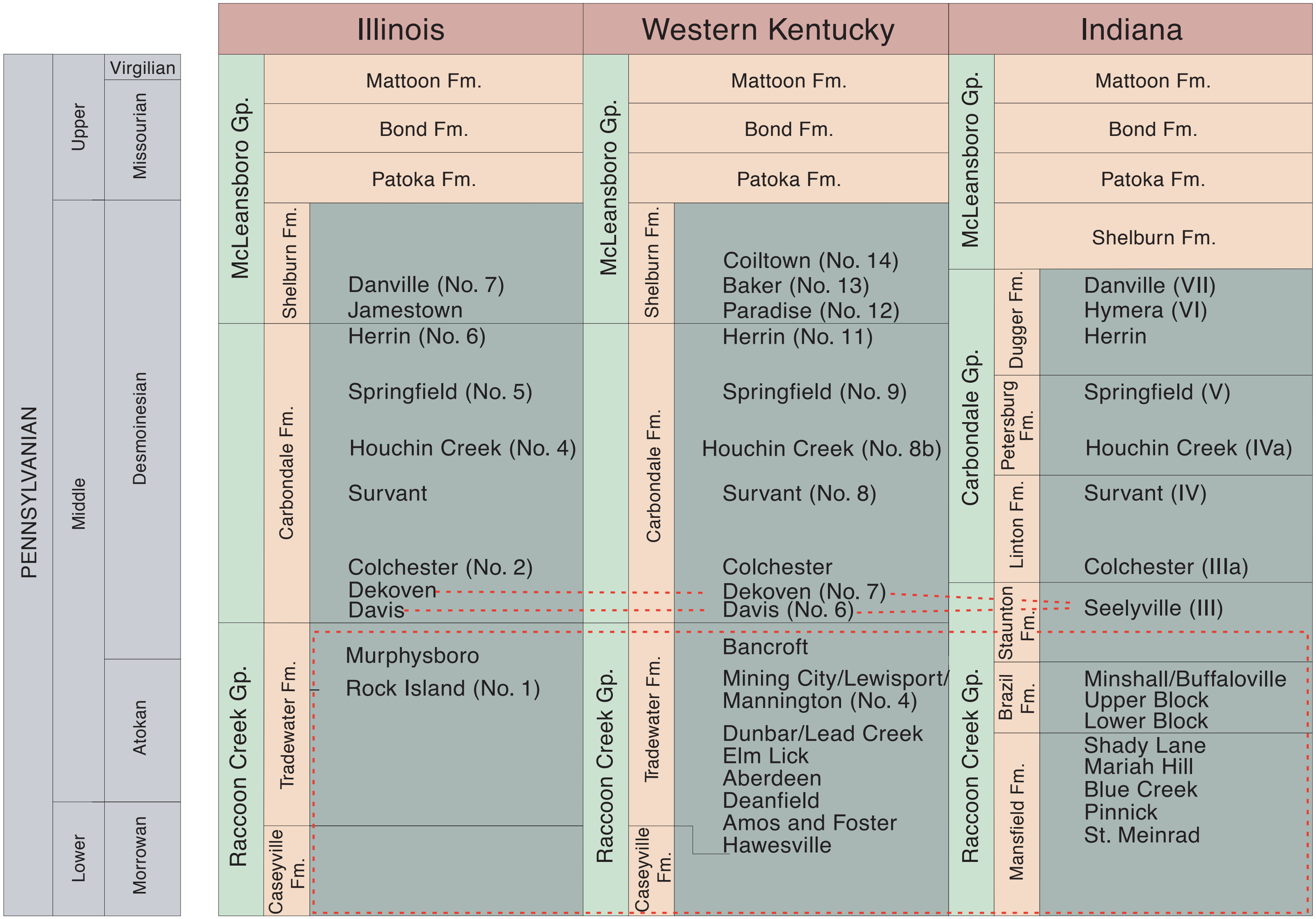

Figure 1. Stratigraphic chart of the Pennsylvanian System in the Illinois Basin, showing major coal members. Modified from Mastalerz and Harper (1998, fig. 2) and Greb and others (1992, fig. 22). Fm., Formation; Gp., Group; ---, problematic coal correlations.

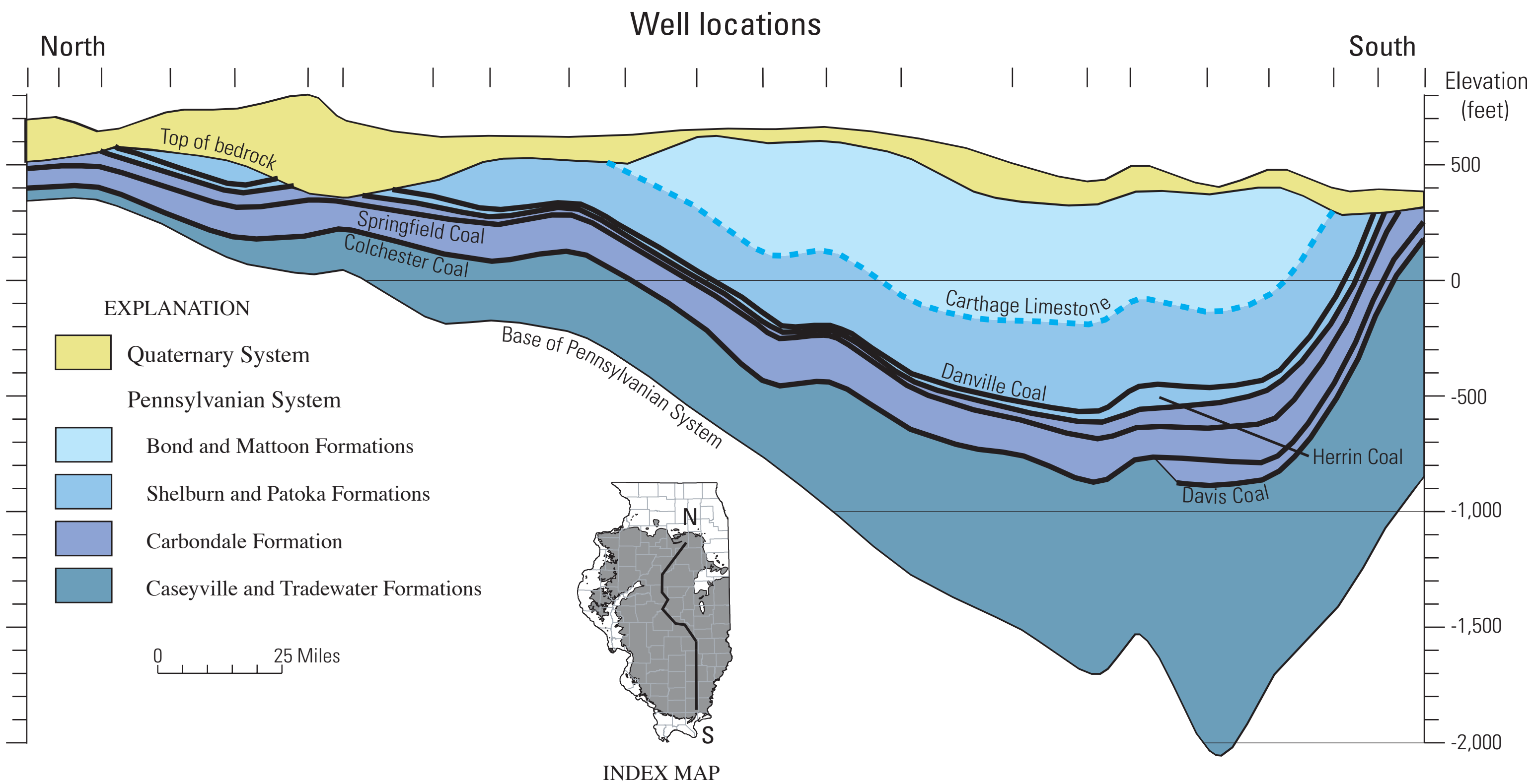

Figure 2. Generalized north-south cross section of the Pennsylvanian System in Illinois. This section illustrates the thickening of the Pennsylvanian strata southward across the basin (provided by C.P. Korose and C.G. Treworgy, Illinois State Geological Survey).

gray shale and siltstone, sandstone being a less predominant lithology than in the underlying Morrowan rocks. Atokan coals in the Illinois Basin are generally thicker and more continuous compared to coals lower in the section (Hopkins and Simon, 1975; Nelson and others, 1991).

Desmoinesian strata consist principally of medium- to dark-gray shale and siltstone, along with lesser quantities of subgraywacke. Numerous highly persistent beds of mineable coal, limestone, and marine black shale are present, particularly in the Carbondale Formation or Group (Nelson and others, 1991). The Desmoinesian rocks contain greater than 96 percent of the remaining coal resources in Illinois (Cady, 1952; Hopkins and Simon, 1974; Treworgy and others, 1978; Treworgy and Bargh, 1982), 98 percent in Indiana (Spencer, 1953), and about 80 percent in western Kentucky (Smith and Brant, 1980).

Rock types in the Missourian and Virgilian strata are similar to those in the Desmoinesian, except that they contain a greater proportion of limestone and less coal. Coals in this part of the section are not as thick (most less than 1 ft thick), nor as extensive as those coals lower in the section (Hopkins and Simon, 1975; Nelson and others, 1991, Mastalerz and Shaffer, 2000).

In the Illinois Basin, the Pennsylvanian rocks are divided into the Raccoon Creek Group, the Carbondale Group or Formation, and the McLeansboro Group. The Raccoon Creek Group, Carbondale Formation, and McLeansboro Group are defined the same in Illinois and western Kentucky (Jacobson and others, 1985). However, stratigraphic definitions accepted in these two states differ from those in Indiana (see fig. 1). The main differences are that

(1) The Raccoon Creek Group in Illinois and western Kentucky is divided into the Caseyville and Tradewater Formations. The Raccoon Creek Group in Indiana consists of the Mansfield, Brazil, and Staunton Formations.

(2) The Carbondale Formation is recognized in Illinois and Kentucky; the Carbondale Group is recognized in Indiana. In Indiana, the Carbondale Group is divided into the Linton, Petersburg, and Dugger Formations.

(3) In Indiana, the Seelyville Coal Member is at the top of the Staunton Formation of the Raccoon Creek Group. In Illinois and western Kentucky, the Seelyville Coal and equivalents are in the Carbondale Formation.

(4) The base of the McLeansboro Group and the base of the Shelburn Formation in Illinois and Kentucky are at the top of the Herrin Coal. In Indiana, the base of the Shelburn Formation is located at the top of the Danville Coal Member.

(5) In Illinois and western Kentucky, the Springfield Coal is in the Carbondale Formation; in Indiana, it is in the Petersburg Formation. In Illinois and western Kentucky, the Herrin Coal is in the Carbondale Formation; in Indiana, it is in the Dugger Formation. In Illinois, the Danville Coal Member is in the Shelburn Formation of the McLeansboro Group; in Indiana, it is in the Dugger Formation of the Carbondale Group. In western Kentucky, the Baker coal is in the Shelburn Formation of the McLeansboro Group.

(6) In Illinois (Hopkins and Simon, 1975) and Indiana (Mastalerz and Harper, 1998), the Springfield, Herrin, and Danville Coal Members, as well as most other coals, are formally recognized stratigraphic members. In western Kentucky, coals are not given that same status (for example, Baker coal) (Greb and others, 1992). For this assessment report, when discussing coals in a given state, we will follow the stratigraphic nomenclature previously established for that state. When referring to a coal, or coals, in an area that includes parts of states with different stratigraphic nomenclatures, we will list the coal name as the "Springfield Coal" or "Herrin Coal."

Figure 3 shows the mining areas of the Illinois basin and the extent of coal-bearing rocks in Illinois, Indiana, and western Kentucky. The mining areas in Illinois are from Damberger (2000, fig. 1) and, in general, are based on historic mining districts.

Raccoon Creek Group

In Illinois and western Kentucky, the Raccoon Creek Group is divided into the Caseyville and Tradewater Formations. In southern Illinois and western Kentucky, the Caseyville Formation is between 100 and 600 ft thick and contains several thin, lenticular coals, the most persistent of which is the Nolin coal in Grayson and Edmonson Counties, Ky. The Tradewater Formation has a maximum thickness of 650–700 ft in southern Illinois, but in western Illinois, it is generally less than 100 ft thick (Hopkins and Simon, 1975). In western Kentucky, the Tradewater Formation is 400–600 ft thick (Greb and others, 1992). Tradewater Formation coals in Illinois and western Kentucky are thicker and more continuous compared to coals in the Caseyville Formation. In Illinois, coals mined from the Tradewater Formation include the Rock Island and Murphysboro Coal Members. In western Kentucky, the Tradewater Formation contains more than 20 mined coals (Greb and others, 1992). The most extensive of these mined coals are the Mannington, Mining City, and Lewisport coals, near the top of the formation. These three coals are thought to be continuous. Likewise, the Dunbar and Lead Creek coals lower in the section are thought to be continuous. Other, more localized, Tradewater Formation coals in western Kentucky include the Bancroft coal, in the western half of the coal field; Amos, Foster, and Aberdeen coals, in the southeastern part of the coal field; and Hawesville, Deanfield, and Elm Lick coals, in the northeastern part of the coal field (Greb and others, 1992, fig. 22).

In Indiana, the Raccoon Creek Group consists of three formations. In ascending order, these are the Mansfield Formation (50–400 ft thick), the Brazil Formation (40–90 ft thick), and the Staunton Formation (75–125 ft thick.). As many as twelve coals are present in the Mansfield Formation, and at least five coals have been given formal stratigraphic names (St. Meinrad, Pinnick, Blue Creek, Mariah Hill, and Shady Lane Coal Members) (fig. 1). Thicknesses of coals in the Mansfield Formation are highly variable over short distances, and only two or three of these coals may be present at any one location (Mastalerz and Shaffer, 2000). Generally, the Brazil Formation includes four named coals, the Lower Block, Upper Block, Minshall, and Buffaloville Coal Members. The last two named coals are thought to be lateral equivalents. Raccoon Creek Group coals in Indiana that have been mined in the last decade include the St. Meinrad, Blue Creek, and Mariah Hill Coal Members of the Mansfield Formation, and the Lower Block, Upper Block, and Minshall or Buffaloville Coal Members of the Brazil Formation. As many as eight coals occur within the Staunton Formation. The Seelyville Coal Member, at the top of the formation, is the only coal that has been traced

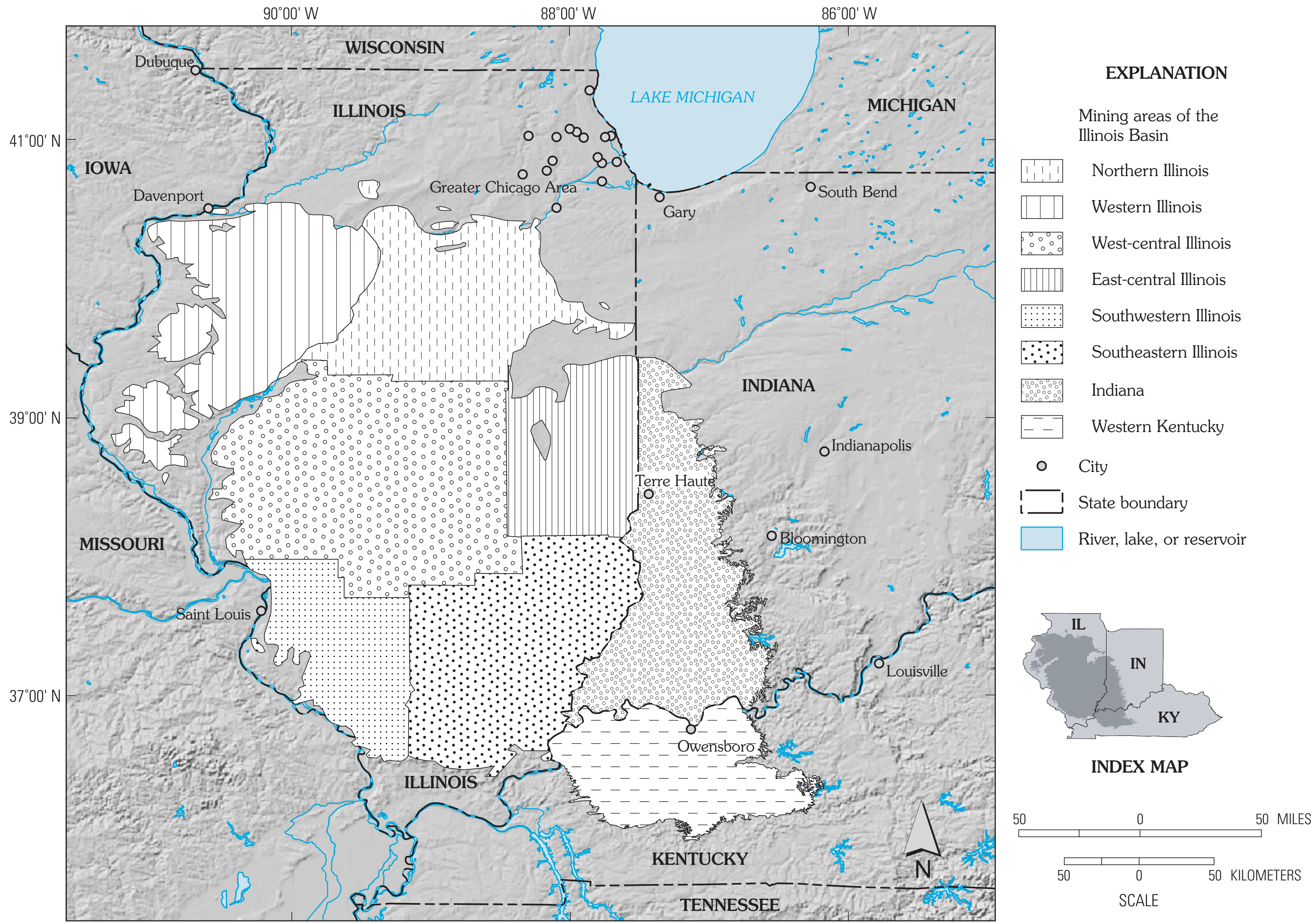

Figure 3. Map showing mining areas of the Illinois Basin and extent of coal-bearing rocks in Illinois, Indiana, and western Kentucky. The mining areas in Illinois are from Damberger (2000, fig. 1). This illustration was modified from regional shapefiles contained in the Illinois Basin ArcView project (Gunther and others, this publication).

regionally (Mastalerz and Shaffer, 2000). The Seelyville Coal Member in Indiana is correlative with the Davis and Dekoven Coal Members (Carbondale Formation) in southern Illinois, the Seelyville Coal Member (Carbondale Formation) in east-central Illinois, and the Davis and Dekoven coals (Carbondale Formation) in western Kentucky.

Carbondale Formation or Group

The Carbondale Formation varies from more than 400 ft thick in southern Illinois to less than 150 ft in western and northeastern Illinois (Hopkins and Simon, 1975). In western Kentucky, the Carbondale Formation is more than 400 ft thick in the western part of the coal field, maintains a fairly consistent thickness over most of the area, then thins rapidly on the eastern flanks of the basin to a minimum thickness of 195 ft (Gildersleeve, 1975). In Indiana, the Carbondale Group consists of the Linton Formation (43–162 ft thick), the Petersburg Formation (70–190 ft thick), and the Dugger Formation (73–185 ft thick) (Mastalerz and Shaffer, 2000).

The Carbondale Formation or Group consists of a large number of named members, many of which possess remarkable lateral persistence in thickness and lithologic character. In the sandstone and gray silty shale units, however, rapid lateral changes are common. Gray shale is the most abundant rock type; with most of the thick gray shale units being either delta front or pro-delta deposits (Hopkins and Simon, 1975). The Carbondale Formation or Group contains the principal economic coals in the Illinois Basin, including the Davis, Dekoven, Colchester, Survant, Springfield, and Herrin Coals (Hopkins and Simon, 1975; Greb and others, 1992; Mastalerz and Shaffer, 2000).

The Hymera and Danville Coal Members of the Dugger Formation (Carbondale Group) in Indiana are correlative with the Jamestown and Danville Coal Members of the McLeansboro Group in Illinois and with the Paradise and Baker coals of the McLeansboro Group in western Kentucky.

McLeansboro Group

The McLeansboro Group in the Illinois Basin is divided into the Shelburn, Patoka, Bond, and Mattoon Formations. The Shelburn and Patoka Formations together vary from more than 450 ft thick in southern Illinois to less than 125 ft thick along the LaSalle Anticlinal Belt in east-central Illinois (fig. 4), and they average about 350 ft thick. The Bond Formation varies from more than 300 ft thick in southern Illinois to less than 150 ft thick in eastern Illinois; the average is about 250 ft thick. A maximum of slightly more than 600 ft of the Mattoon Formation is preserved in southeastern Illinois. In Illinois, the top of the Mattoon Formation is an erosional surface (Hopkins and Simon, 1975). In Indiana, the Shelburn Formation is 50–250 ft thick, the Patoka Formation is 100–310 ft thick, and the Bond Formation is 150–250 ft thick. In Indiana, about 150 ft of the lowest part of the Mattoon Formation is preserved (Mastalerz and Shaffer, 2000). In western Kentucky, the Shelburn Formation is 155–245 ft thick, the Patoka Formation is 235–325 ft thick, the Bond Formation is 310–390 ft thick, and the Mattoon Formation is 1,100 ft thick (Greb and others, 1992).

Economically important McLeansboro Group coals include the Danville Coal Member in east-central Illinois and the Paradise, Baker, and Coiltown coals (Shelburn Formation) in western Kentucky. Above the Danville in Illinois and Indiana, coals in the McLeansboro Group are not as thick, nor as extensive as the coals in the underlying Carbondale Formation or Group (Hopkins and Simon, 1975; Mastalerz and Shaffer, 2000). Most McLeansboro Group coals are less than 1 foot thick, although some coals locally are as much as 4 ft thick (Hopkins and Simon, 1975; Mastalerz and Harper, 1998). In western Kentucky, coal has also been produced from the No. 15 coal (Patoka Formation) and from the Lisman coal (Bond Formation) (Greb and others, 1992).

Structural Setting

The major structural features within the Illinois and Indiana parts of the Illinois Basin are the La Salle anticlinal belt, the DuQuoin monocline, and the Cottage Grove fault system. In Illinois, these structures bound the Fairfield Basin (fig. 4) (Buschbach and Kolata, 1991). In Illinois and Indiana, the major coal beds crop out along the margins of the basin and generally dip basinward to depths of more than 1,000 ft subsurface at the center of the Fairfield Basin in southeastern Illinois as shown for the Springfield Coal in figure 4. The La Salle anticlinal belt flanks the Fairfield Basin to the northeast and consists of sub-parallel north-south-trending anticlines that extend north-northwestward from Lawrence County, Ill., for a distance of about 180 mi. For much of its length, the western side of the La Salle anticlinal belt is bounded by a pronounced monoclinal fold that rises above the basin floor as much as 2,000 ft. The DuQuoin monocline trends north-south along the western edge of the Fairfield Basin. The steep side of the monocline dips to the east. Its western flank forms the relatively shallow Sparta shelf, which is the southern part of the larger Western shelf. The Cottage Grove and Rough Creek fault systems mark the southern margin of the Fairfield Basin. The Rough Creek fault system consists of multiple high-angle, normal faults that form a series of narrow horsts and grabens, trending roughly east to west. At its western end in southern Illinois, the Rough Creek fault system turns abruptly southwestward. The Cottage Grove fault system is a right-lateral wrench fault (Nelson and Lumm, 1984) that extends westward across much of southern Illinois, from Gallatin to Jackson Counties, a distance of about 70 mi. This complex structure is as much as 10 mi wide (Buschbach and Kolata, 1991).

In western Kentucky, the structure of the coal fields is distinctly different on either side of the east-west trending Rough Creek fault system (figs. 5 and 6). North of the Rough Creek fault system, the rocks dip gently to the west at about 15–20 ft/mi, in general conformity with the broad north-south, asymmetrical syncline that generally characterizes the structure of the Illinois Basin. South of the Rough Creek fault system, the structure is characterized by east-west-oriented synclines having much steeper dips. Within the Moorman syncline, southeast of the Central fault system (fig. 5), dips range between 50 and 65 ft/mi. Northwest of the Central fault system, in the Webster syncline and the Eagle Valley syncline in southern Gallatin County, in southeastern Illinois, dips are as great as 250 ft/mi. Along the axis of these southern synclinal structures and within some graben structures, depth to the lower Carbondale Formation coals can exceed 1,500 ft. Both the northern and southern structural areas are modified by a number of northeast-trending graben structures, many having considerable displacement (Greb and others, 1992).

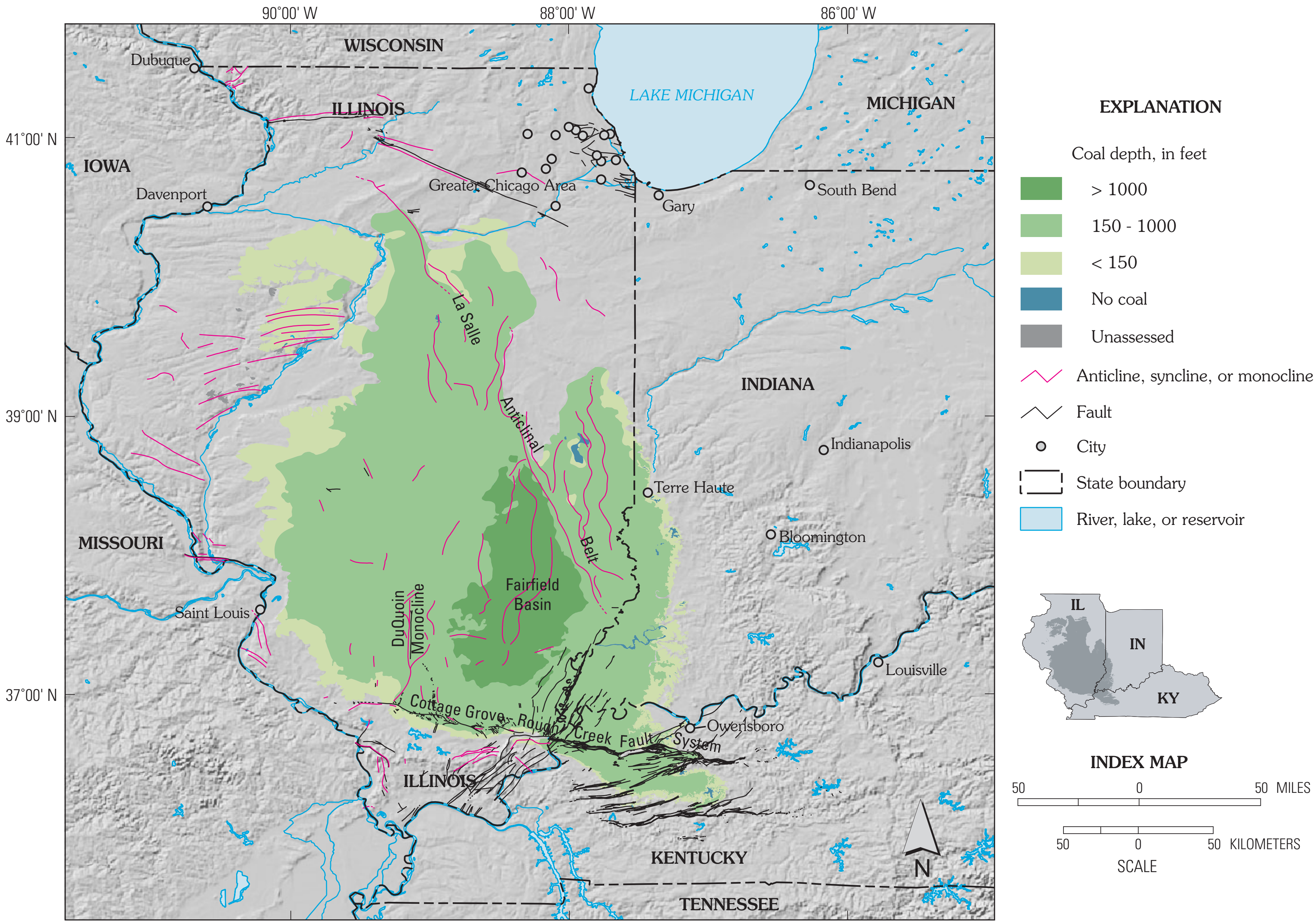

Figure 4. Map showing locations of the major structural features in the Illinois Basin and depth to the Springfield Coal. Structure locations are from Buschbach and Kolata (1991). The Springfield Coal reaches depths of 1,000 ft or greater in the Fairfield Basin, in southeastern Illinois, and in the Webster and Moorman synclines, in western Kentucky (locations shown in fig. 5). This illustration was modified from regional shapefiles contained in the Illinois Basin ArcView project (Gunther and others, this publication).

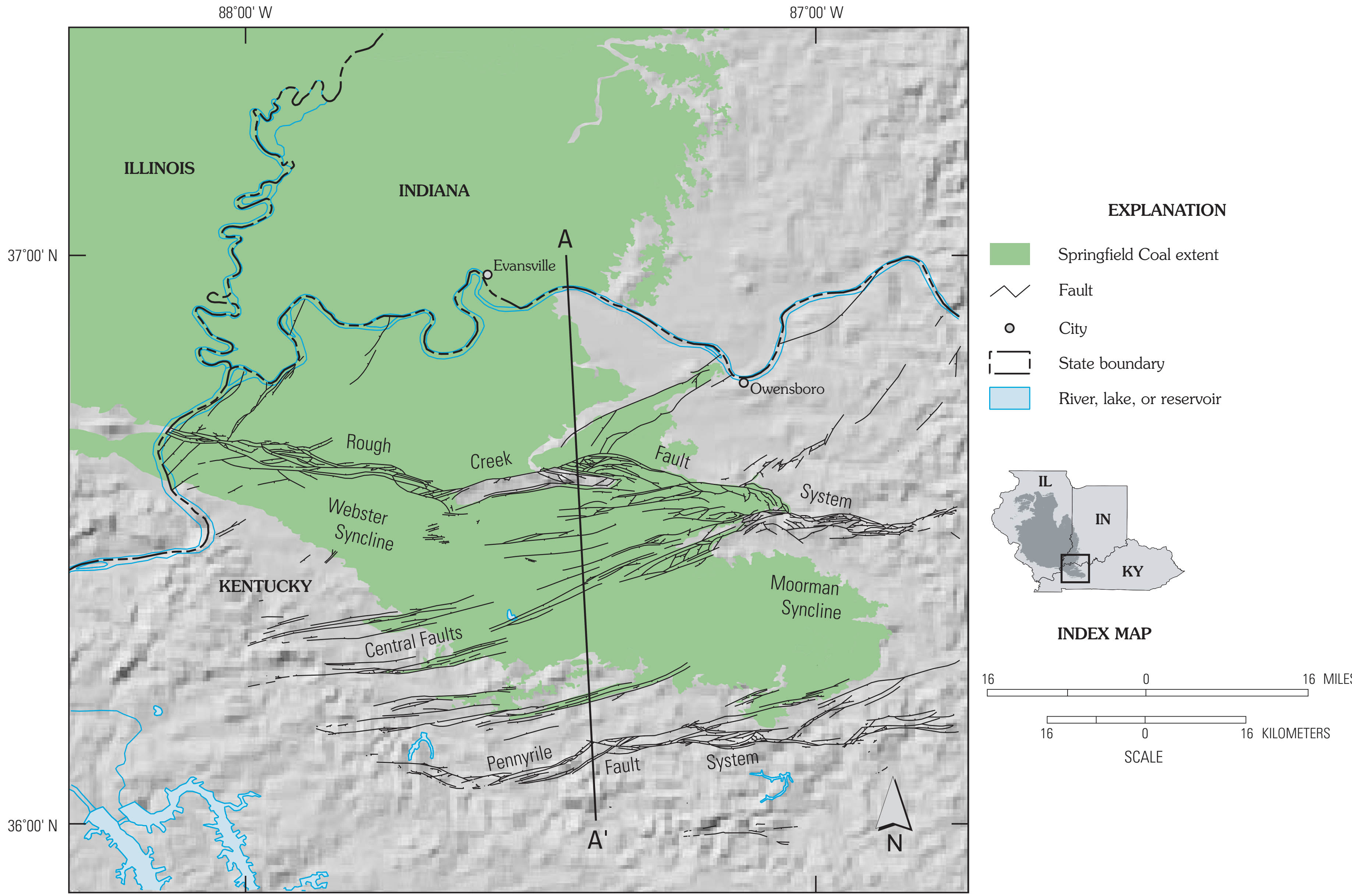

Figure 5. Map showing the major structural features of the western Kentucky coal field. Modified from Cobb and others (1985) and Greb and others (1992). Section A–A′ is the approximate location of the cross section shown in figure 6.

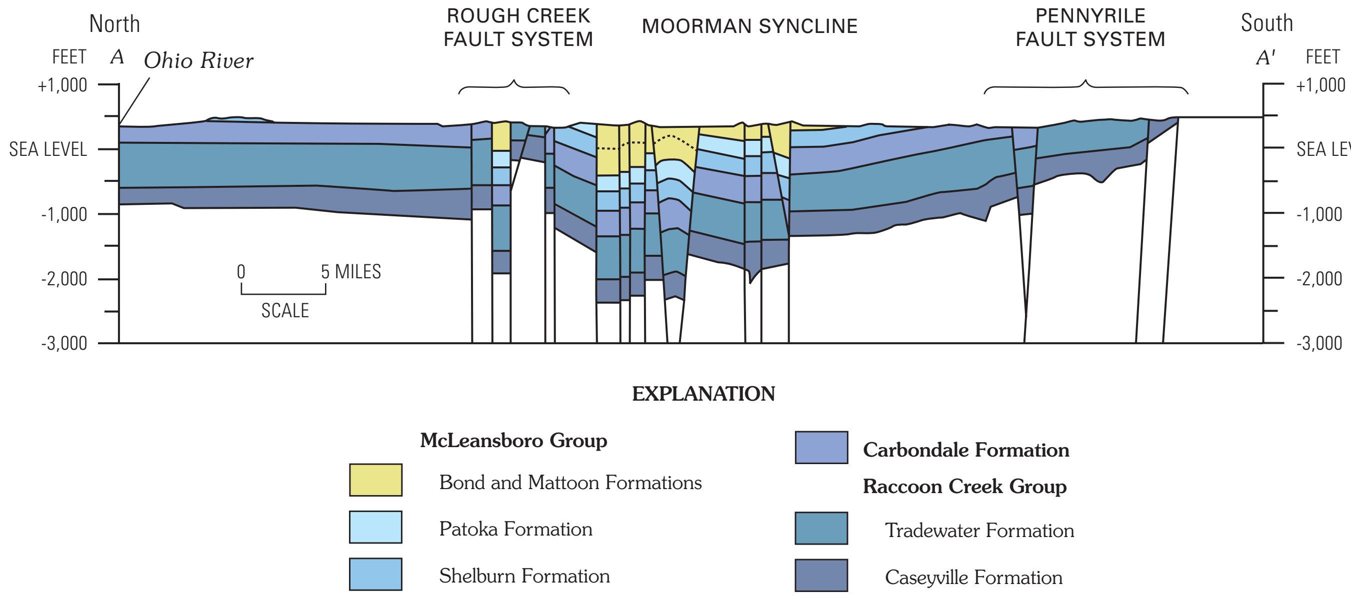

Figure 6. Generalized north-south cross section through western Kentucky. The approximate location of cross section A–A′ is shown on figure 5. Figure provided by S.F. Greb.

Descriptions of the Springfield, Herrin, Danville, and Baker Coals

The Springfield, Herrin, Danville, and Baker Coals are the primary focus of this assessment of Illinois Basin coal resources because most past, current, and expected future coal production has been and will be from these coals.

Springfield Coal (Ill. No. 5; Ind. V; W. Ky. No. 9)

In Illinois, the Springfield Coal Member has a usual thickness of between 4.5 and 6 ft in most areas where it has been mined (Damberger, 2000) (fig. 7). In Indiana, the Springfield Coal Member generally averages about 5 ft thick, but coal thicknesses as much as 13 ft have been reported. Mined coal thickness averages between 3.0 and 7.4 ft (Mastalerz and Shaffer, 2000). Within the Moorman syncline of western Kentucky, the Springfield coal ranges from 5 to 6 ft in thickness, but thins to less than 4 ft toward the east and northeast of the Rough Creek fault system (Greb and others, 1992; Chesnut and others, 2000).

The lithologies of roof rocks overlying the Springfield Coal are variable. Over much of its extent, the Springfield is normally overlain by black, fissile shale that is 6–24 in. thick. However, in a 4- to 10-mi-wide area extending from Gibson County, Ind., to Saline County, Ill., a delta distributary system (Galatia channel system, see fig. 7) was contemporaneous with the swamps depositing the peat that formed the coal. Within this belt, the coal is absent or irregularly developed and is overlain by the gray, silty Dykersburg Shale Member of the Carbondale Formation (Illinois and Kentucky) or Dugger Formation (Indiana) (Hopkins, 1968; Hopkins and Simon, 1975). Adjacent to the channel system, the coal is relatively thick (from 5 to 10 ft) and is more commonly split by shale partings. Where the Dykersburg Shale Member is greater than about 20 ft in thickness, the coal commonly is relatively low in sulfur (1.5–3 percent, fig. 8, Cady, 1935; and Damberger, 2000). In Henderson and Webster Counties, in western Kentucky, the interval of the Springfield coal is replaced by the Henderson channel, a south-southwest-oriented feature less than 1.5 mi wide (fig. 7). This channel appears to be a result of contemporaneous sedimentation, but evidence of post-depositional erosion has been found (Beard and Williamson, 1979).

One of the characteristics of the Springfield in western and west-central Illinois is the occurrence of fairly numerous claystone dikes ("horsebacks"), which may cut through the coal seam from top to bottom as well as through its roof strata. These irregularities may seriously influence the purity of the coal and strength of the roof strata (Damberger, 2000).

Cady (1952) estimated remaining resources for the Springfield Coal Member in Illinois at 38.5 billion short tons; Hopkins and Simon (1974) estimated 42.6 billion short tons, whereas Damberger (2000) listed 61.7 billion short tons. For the Springfield Coal Member in Indiana, Spencer (1953) estimated 13.7 billion short tons, and for the Springfield coal in western Kentucky, Smith and Brant (1980) estimated 9.4 billion short tons.

Calorific value (as-received basis) for the Springfield Coal Member in northern, western, and west-central Illinois ranges from 10,100 to 11,100 Btu/lb, in east-central and southwestern Illinois, from 11,000 to 11,800 Btu/lb, and in southeastern Illinois, from 11,900 to 12,700 Btu/lb. Ash content of the Springfield in Illinois generally ranges from 8 to 12 percent and sulfur content from 3 to 5 percent (Damberger, 2000). Average calorific value (as-received basis) for the Springfield in Indiana is about 11,300 Btu/lb, ash content 10.4 percent, and sulfur content 3.3 percent (modified from Mastalerz and Harper, 1998, table 3). Average calorific value (as-received basis) for the Springfield coal in western Kentucky is 11,700 Btu/lb, ash content 10.5 percent, and sulfur content 3.3 percent (Cobb and others, 1985, table 5; Greb and others, 1992, table 1).

Herrin Coal (Ill. No. 6, W. Ky. No. 11)

In Illinois, the Herrin Coal Member averages more than 6 ft thick over extensive areas and locally reaches 15 ft thick (Hopkins

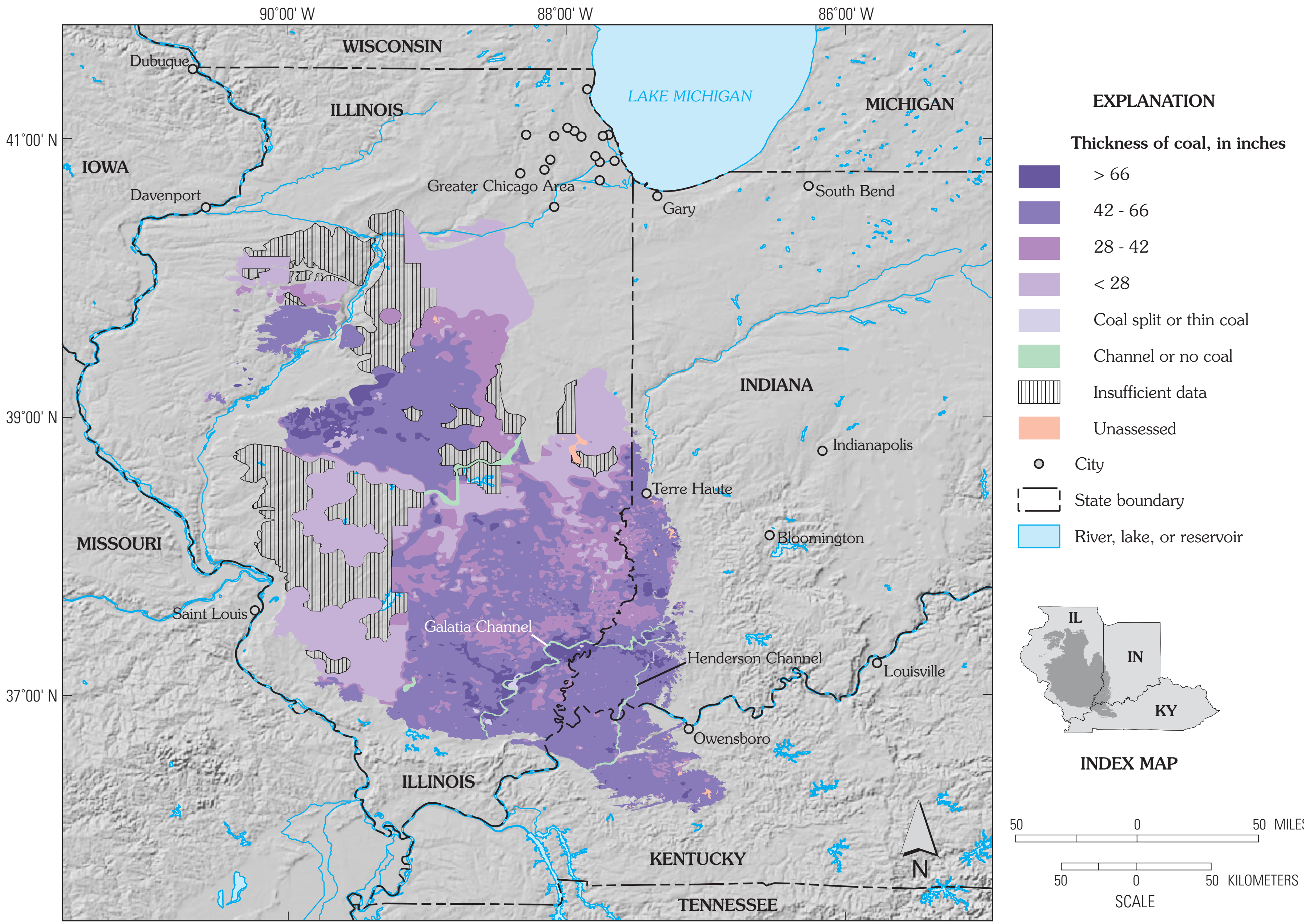

Figure 7. Map showing thickness of the Springfield Coal in Illinois, Indiana, and western Kentucky. This illustration was modified from regional shapefiles contained in the Illinois Basin ArcView project (Gunther and others, this publication).

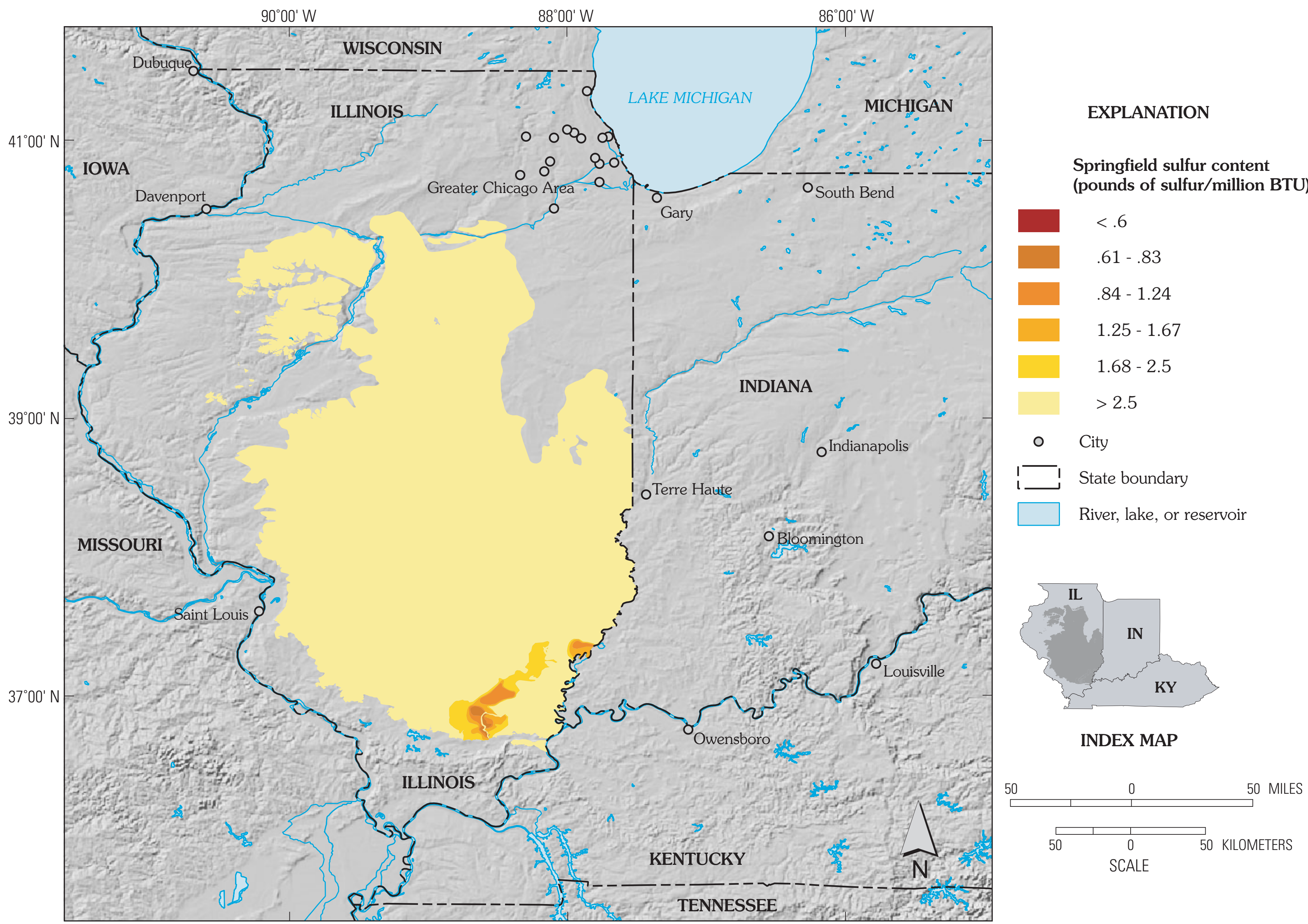

Figure 8. Map showing sulfur contents of the Springfield Coal in Illinois. This figure illustrates the areas of lower sulfur coal associated with the Galatia channel in southern Illinois (see fig. 7 for location of Galatia channel). Figure provided by C.P. Korose and C.G. Treworgy, Illinois State Geological Survey.

and Simon, 1975) (fig. 9). It is thinner and more irregular in thickness in much of central Illinois and in southeastern Illinois, in Saline and Gallatin Counties. The Herrin Coal is not well developed in Indiana. There, the Herrin coal varies from about 2 to 5 ft in thickness in Posy County, southwestern Gibson County, and western Vanderburgh County and is present as a thin coal at shallow depths in Warrick County. To the north and east in Indiana, the coal is thin or absent (Mastalerz and Shaffer, 2000). In western Kentucky, the Herrin coal occurs in two geographically distinct bodies (fig. 9). The thickest of these bodies is in a narrow belt along the southern edge of the coal field in Union, Webster, Hopkins, and Muhlenburg Counties, where the Herrin is as much as 10 ft thick. The second body of coal is north of the Rough Creek fault system (see fig. 6). Here, the Herrin coal is thin (<2.4 ft) or absent (Greb and others, 1992; Weisenfluh and others, 1998; Chesnut and others, 2000).

The roof rocks overlying the Herrin Coal are also lithologically variable. Over much of its extent in Illinois, the coal is normally overlain by the Anna Shale Member or the Brereton Limestone Member of the Carbondale Formation. However, in parts of southern and central Illinois, a delta distributary system (Walshville channel system) was contemporaneous with the swamps depositing the peat that formed the Herrin. Within this belt, the coal is cut out by a channel sandstone as much as a 1 mi wide and 60–80 ft thick, or is irregularly developed and overlain by the silty, gray Energy Shale Member of the Carbondale Formation, which is as much as 100 ft thick (Allgaier and Hopkins, 1975; Nelson, 1983). Adjacent to this distributary system, the coal is relatively thick (from 5 to 10 ft) and is more commonly split by shale partings. Where the Energy Shale Member is thick, the sulfur content of the coal is relatively low in many places (0.5–2.5 percent) (fig. 10). The Energy Shale overlies the coal in four areas: (1) the Franklin-Williamson-Jefferson County area of southeastern Illinois (known as the "Quality Circle" area); (2) northern St. Clair County and adjacent Madison and Clinton Counties, in southwestern Illinois; (3) eastern Macoupin County and adjacent Montgomery and Christian Counties, in west-central Illinois; and 4) southern Vermillion County, in east-central Illinois. The “Quality Circle” area of relatively low sulfur and thick coal in the Franklin-Williamson-Jefferson County area extends for approximately 250 square miles; however, most of the "Quality Circle" has been mined out (Hopkins and Simon, 1975; Damberger, 2000).

The lower part of the Herrin Coal contains a prominent claystone parting (the “blue band”) that normally is 1–3 in. thick (Hopkins and Simon, 1975). The blue band may have been deposited by basin-wide flooding (Nelson, 1983). The blue band and other partings and splits thicken along a trend associated with the contemporaneous Walshville channel (fig. 9).

Cady (1952) estimated remaining resources for the Herrin Coal Member in Illinois at 62.2 billion short tons, Hopkins and Simon (1974) estimated 65.8 billion short tons, whereas Damberger (2000) listed 78.9 billion short tons. For western Kentucky, Smith and Brant (1980) estimated remaining combined resources for the Herrin coal and overlying Paradise coal at 8.4 billion short tons.

In western and west-central Illinois, calorific value (as-received basis) for the Herrin Coal Member ranges from 9,700 to 10,900 Btu/lb, in east-central and southwestern Illinois, from 10,000 to 11,300 Btu/lb, and in northern Illinois, from 10,500 to 11,400 Btu/lb. Ash content of the Herrin in Illinois generally ranges from 7 to 13 percent. For most of northern, western, and west-central Illinois, sulfur contents range from 3 to 5 percent, whereas in southwestern and east-central Illinois, sulfur contents range from 1 to 4 percent (Damberger, 2000). In western Kentucky, calorific value (as-received basis) for the Herrin coal averages 12,100 Btu/lb, ash content is 9.7 percent, and sulfur content is 4.0 percent (Cobb and others, 1985, table 5; Greb and others, 1992, table 1).

Danville Coal (Ill. No. 7, Ind. VII) and Baker Coal (W. Ky. No. 13)

In east-central Illinois, the Danville Coal Member is as much as 6 ft thick in parts of Vermilion County (fig. 11). In most of the rest of the state, the Danville is thin, generally from a few inches to less than 3 ft thick (Hopkins and Simon, 1975). In Indiana, the Danville ranges from 0.2 to 6.5 ft in thickness, averaging 4.3 ft in the northern Indiana counties and 2.1 ft in the south (fig. 11) (Mastalerz and Shaffer, 2000).

In western Kentucky, the Baker coal is a complex, multiple-bench zone consisting of mineable coals separated by rock partings (Weisenfluh and others, 1998). The Danville Coal Member in southern Indiana is correlative with an upper bench of the Baker coal in western Kentucky. The lower benches of the Baker coal in Kentucky are the mined benches near the Indiana border, but the mineable Baker coal as mapped elsewhere in western Kentucky may include this upper bench (Danville) in some places (W. A. Andrews, written commun., 1999). Development of thick coal bodies in the Baker coal is typically found in areas where the underlying Herrin and Paradise coals are thin or absent (Greb and others, 1992; Weisenfluh and others, 1998). Two distinct bodies of thicker Baker coal are well documented; one south of the Rough Creek fault system and one north (fig. 11). Each coal body is either bisected or bounded by contemporaneous or post-depositional paleo-channels that split or entirely replace the coal (Weisenfluh and others, 1998).

Cady (1952) estimated remaining resources for the Danville Coal Member in Illinois at 7.8 billion short tons; Hopkins and Simon estimated 7.6 billion short tons, and Damberger (2000) listed 17.8 billion short tons. For the Danville Coal Member in Indiana, Spencer (1953) estimated 13.7 billion short tons, and for the Baker coal in western Kentucky, Smith and Brant (1980) estimated 3.1 billion short tons.

Calorific value (as-received basis) of the Danville Coal Member in northern Illinois ranges from 9,600 to 10, 300 Btu/lb, ash content from 12 to 15 percent and sulfur content from 3 to 4 percent. In east-central Illinois, calorific value (as-received basis) ranges from 10,500 to 11, 300 Btu/lb, ash content from 9 to 11 percent, and sulfur content is about 3 percent (Damberger, 2000). Average calorific value (as-received basis) of the Danville in Indiana is 11,000 Btu/lb, ash content 11.1 percent, and sulfur content 2.5 percent (modified from Mastalerz and Harper, 1998, table 3). Limited analyses of the Baker coal in western Kentucky indicate an average calorific value (as received basis) of 10,970 Btu/lb, an ash content of 15.3 percent, and a sulfur content of 3.5 percent (Cobb and others, 1985; Greb and others, 1992).

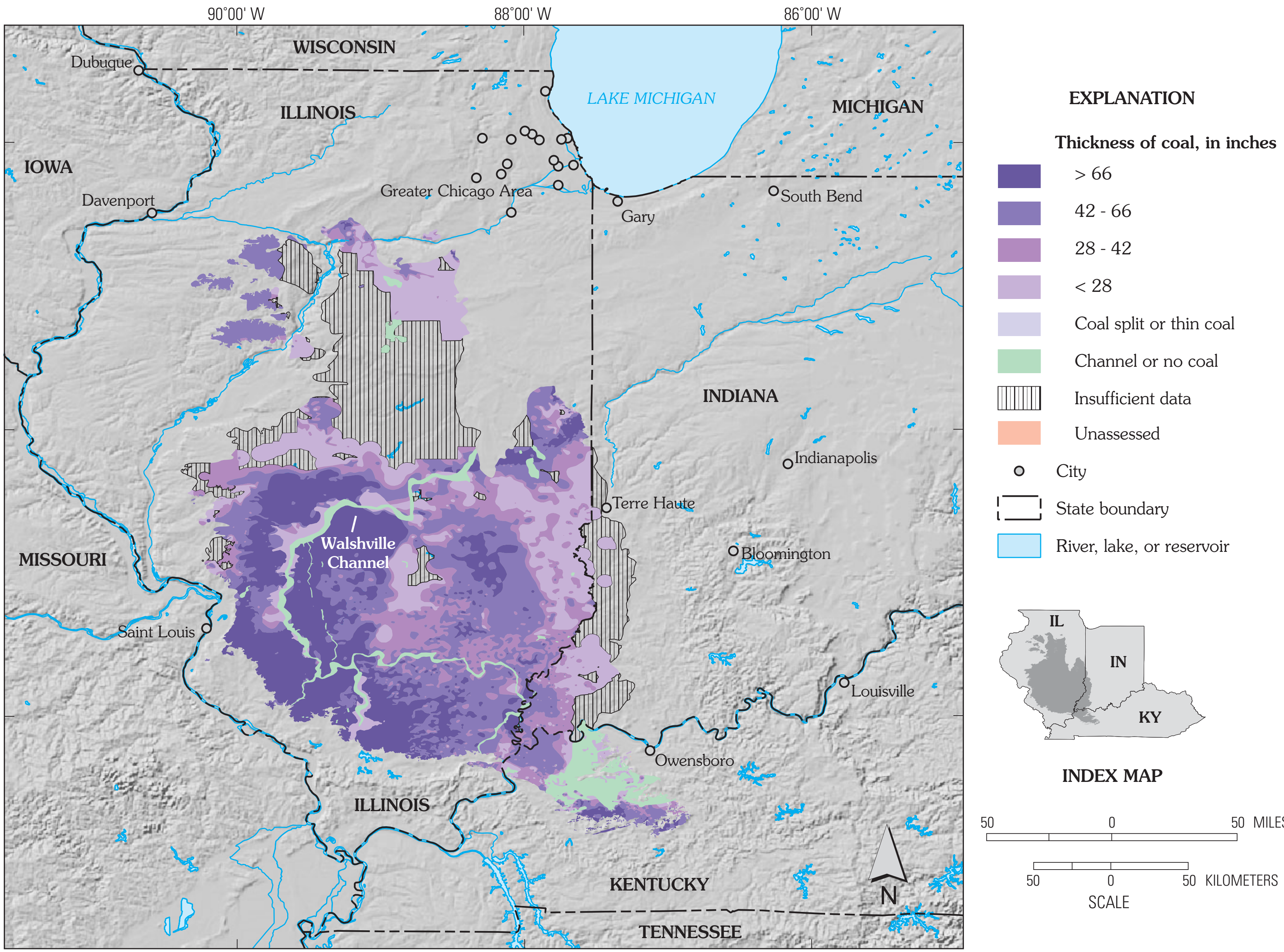

Figure 9. Map showing thickness of the Herrin Coal in Illinois, Indiana, and western Kentucky. This illustration was modified from regional shapefiles contained in the Illinois Basin ArcView project (Gunther and others, this publication).

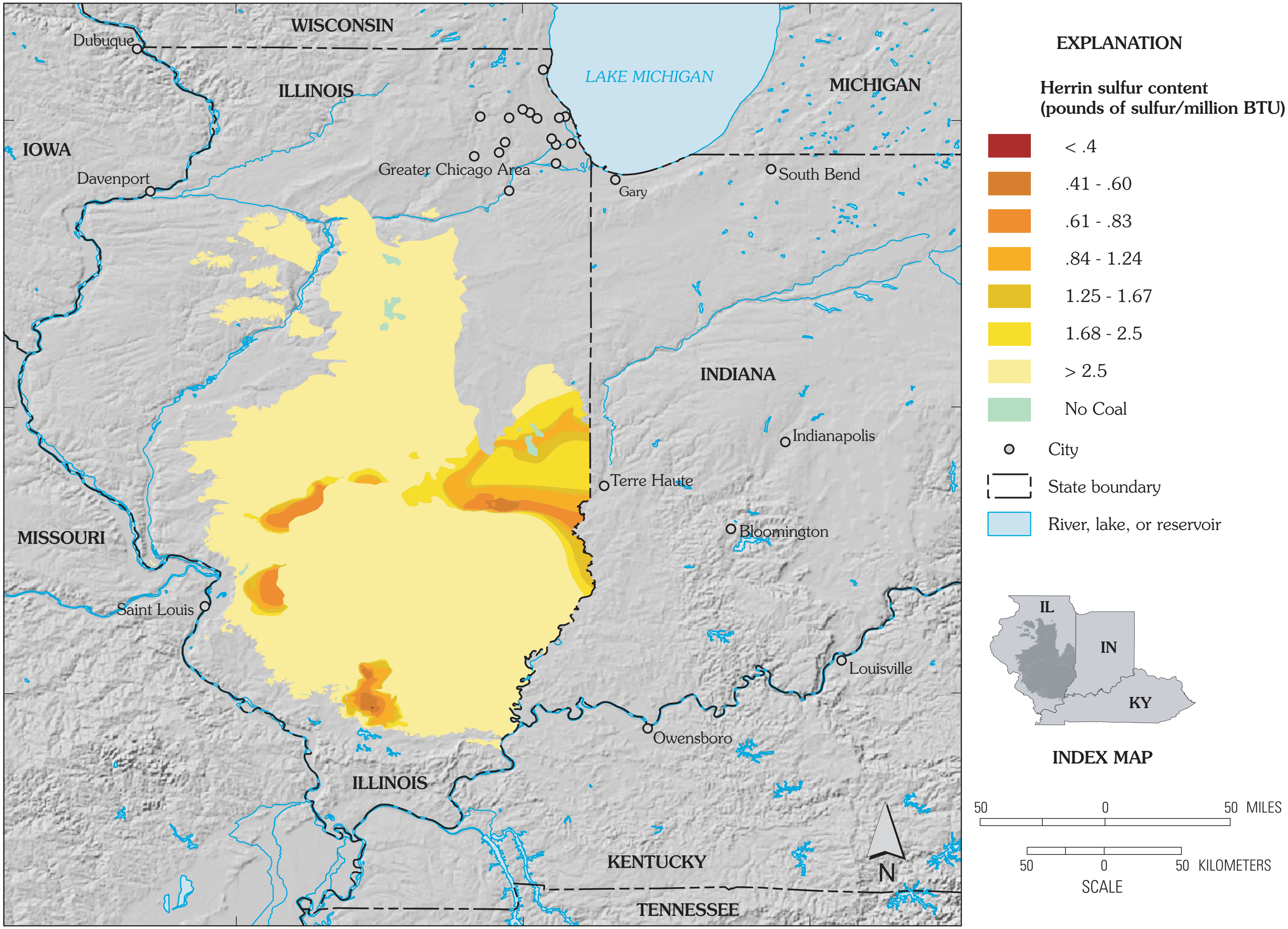

Figure 10. Map showing sulfur contents of the Herrin Coal in Illinois. This figure illustrates the areas of lower sulfur coal associated with the Walshville channel in central and southern Illinois (see fig. 9 for location of Walshville channel). Figure provided by C.P. Korose and C.G. Treworgy, Illinois State Geological Survey.

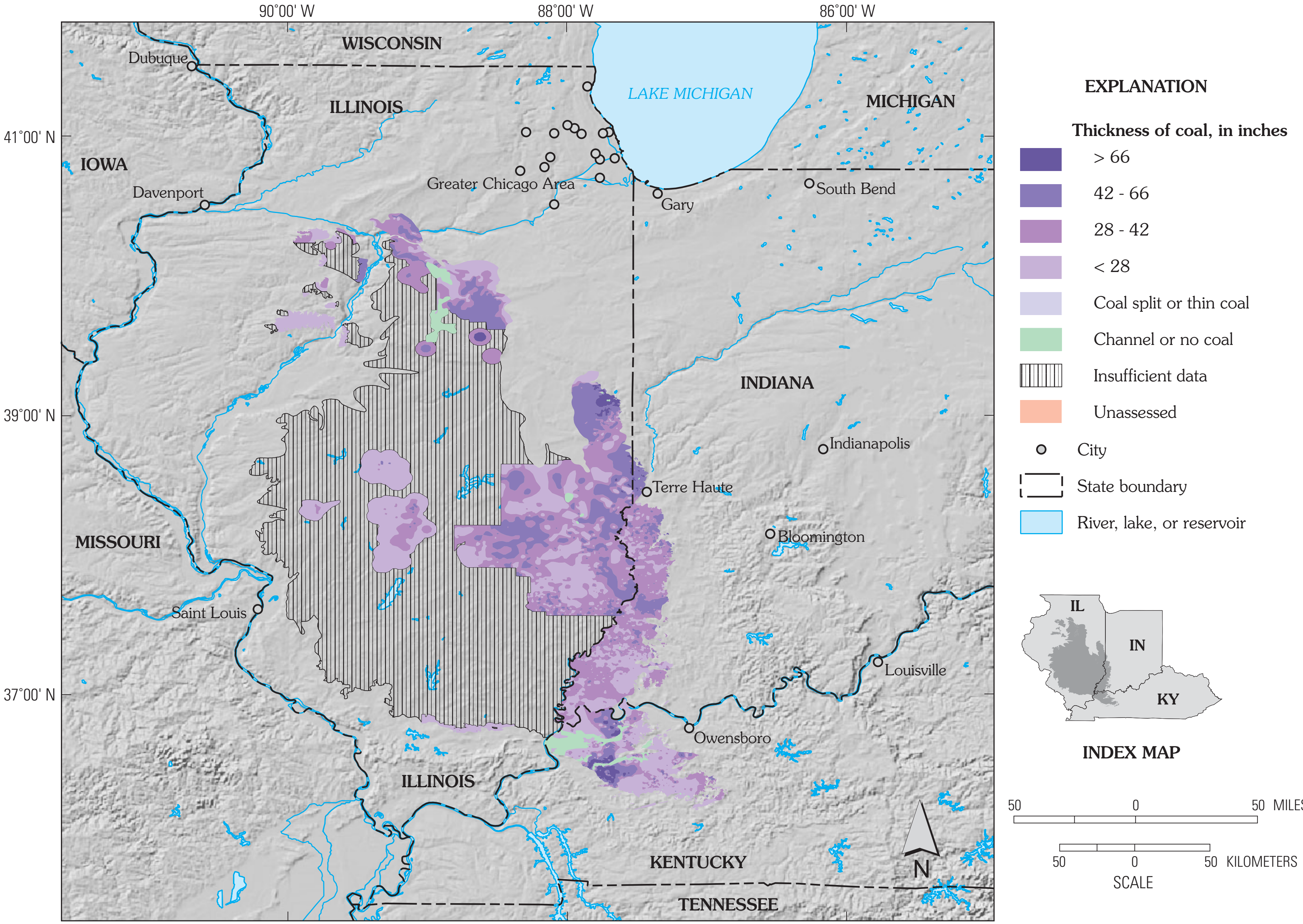

Figure 11. Map showing thickness of the Danville Coal in Illinois and Indiana and the Baker coal in western Kentucky. This illustration was modified from regional shapefiles contained in the Illinois Basin ArcView project (Gunther and others, this publication).

Other Illinois Basin Coals

In addition to the Springfield, Herrin, Danville, and Baker Coals, many other coals in the Raccoon Creek Group, Carbondale Group or Formation, and McLeansboro Group have been previously mined. Cumulative production from these other coals, however, has been much less than production from the four principal coals that are the focus of this assessment. Brief descriptions of these other coals are included here for completeness.

Raccoon Creek Group

Tradewater Formation—Illinois

Rock Island Coal Member (Ill. No. 1)

Production from this coal has come from western Illinois. In each mined location, this coal has been found to lie in narrow troughs, where coal thickness commonly ranges from 4 to 5 ft. It is correlated with the Litchfield and Assumption Coal Members of the Tradewater Formation in west-central Illinois (Montgomery and Christian Counties, respectively) (Damberger, 2000). Cady (1952) estimated remaining resources at 262 million short tons for the Rock Island Coal Member and 1.3 billion short tons for the Litchfield and Assumption Coal Members. Damberger (2000) listed a combined estimate of 1.55 billion short tons for the three coals. For the Rock Island in western Illinois, typical calorific value (as-received basis) ranges from 10,400 to 11,200 Btu/lb, ash content from 7 to 10 percent; and sulfur content from 3 to 6 percent (Damberger, 2000).

Murphysboro Coal Member

This coal is found only in Jackson and Perry Counties and in western Williamson County, in southwestern Illinois, where the coal ranges from about 1 to 7 ft in thickness. Near the town of Murphysboro, the coal, which was reported to have very low ash and sulfur contents, was used for making coke. Here, the coal occurs beneath thick, nonmarine, silty, gray shales that are related to a channel now filled with sandstone. Although the thicker coal near Murphysboro is largely mined out, additional areas of thick coal, ranging in thickness from 1.5 to 7.5 ft, have been found in north-central Jackson County and in Perry County (Damberger, 2000). Cady (1952) estimated remaining resources for the Murphysboro Coal Member at 392 million short tons. For the Murphysboro in southwestern Illinois, calorific value (as-received basis) ranges from 12,200 to 12,700 Btu/lb and ash contents from 5 to 11 percent. Sulfur contents range from 0.6 to 2.0 percent west of the DuQuoin monocline and from 3 to 5 percent east of the DuQuoin monocline (Damberger, 2000).

Tradewater Formation—Kentucky

Hawesville Coal

This coal is distributed in lenticular patches that reach thicknesses of 5 ft in Hancock County, Ky., although thicknesses of 3 ft or less are more common. Where the coal is thick, it commonly contains a 6-in.-thick pyritic parting and may be cut out by sandstone. The Hawesville coal was one of the most heavily mined coals in western Kentucky before the Civil War (Greb and others, 1992). Smith and Brant (1980) estimated the remaining resources for the Hawesville coal to be 72 million short tons.

Amos and Foster Coals

In the southeastern part of the western Kentucky coal field, this coal zone may contain as many as four coals in an interval 40 ft thick. The coals are cut out in many places by 10- to 40-ft-thick, cross-bedded sandstone units. The Foster coal has been reported to be as much as 4 ft thick in Butler County, Ky., where it is extensively mined. The Amos coal is a low-sulfur (1.2 percent), low-ash (3.9 percent) coal and is the most persistent of the four coals. The Foster coal has higher average sulfur content (2.7 percent) and ash content (7.7 percent) (Williams and others, 1990; Greb and others, 1992). Smith and Brant (1980) estimated the remaining resources for the combined Amos and Foster coals to be 23 million short tons.

Deanfield Coal

This coal is about 50 ft above the Hawesville coal. In Hancock County, Ky., it is as thick as 4 ft (Greb and others, 1992). Smith and Brant (1980) estimated the remaining resources for the Deanfield coal to be 290 million short tons.

Aberdeen Coal

In Butler County, Ky., this coal occurs 90–100 ft above the Foster coal. Here, the Aberdeen coal is 0–2.5 ft thick and overlain (and in some areas cut out) by the Aberdeen Sandstone Member of the Tradewater Formation. Smith and Brant (1980) estimated the remaining resources for the Aberdeen coal to be 39 million short tons.

Elm Lick Coal

This coal is probably limited geographically to Ohio and Butler Counties, Ky., where the coal generally ranges from 0 to 3.5 ft in thickness. This coal may contain partings as much as 1.5 ft thick, and is commonly truncated or cut out by a thick sandstone (Johnson, 1971a,b). Thick Elm Lick coal (greater than 3.5 ft) occurs in a thin belt that extends from Hartford in Ohio County, southeast to the Ohio-Butler-Grayson County line (Greb and others, 1992). Smith and Brant (1980) estimated the remaining resources for the Elm Lick coal to be 69 million short tons.

Dunbar and Lead Creek Coals

Unpublished studies correlate the Lead Creek coal with the Dunbar coal (Greb and others, 1992). In Hancock County, Ky., the Lead Creek coal is generally thin but may be thicker than 4 ft. Farther south, in Butler and Warren Counties, Ky., the Dunbar coal is as thick as 3.7 ft (Shawe, 1968). The Lead Creek and Dunbar coals commonly contain 5–8 percent sulfur and 11–18 percent ash. However, in northwestern Butler County and southeastern Daviess County, the Dunbar coal locally is a low-ash (3.5–4.3 percent) and low-sulfur (0.8–1.8 percent) coal (Hower and others, 1982). Smith and Brant (1980) estimated the remaining resources for the Lead Creek coal to be 223 short million tons but did not estimate resources for the Dunbar coal.

Mannington, Mining City, and Lewisport Coals (W. Ky. No. 4)

These three coals were correlated by Williams and others (1982). In the northeastern part of the western Kentucky coal field, the Lewisport coal ranges from 0 to 4.5 ft in thickness and may be split by as much as 5 ft of shale. In the southeastern part of the coal field (Butler County), the Mining City coal is as thick as 4.5 ft. In the western part of the coal field, the Mannington coal is generally between 3 and 4 ft thick. Although these coals can be correlated across the western Kentucky coal field, the thickness of the coal is quite variable (Shepard, 1980; Baynard and Hower, 1984). Mean calorific value (as-received) for the Mannington, Mining City, and Lewisport coals is 11,900 Btu/lb, ash content is 10 percent, and sulfur content is 3.0 percent (Cobb and others, 1985). Smith and Brant (1980) estimated the remaining resources for the combined Mannington, Mining City, and Lewisport coals to be 6.8 billion short tons. Between 1980 and 1990, combined average annual production from the Mannington, Mining City, and Lewisport coals was about 1,500,000 short tons.

Bancroft Coal

This coal occurs about 100 ft above the western Kentucky No. 4 coal in Muhlenburg County, in the south-central part of the coal field. Smith and Brant (1980) estimated the remaining resources for the Bancroft coal to be 113 million short tons.

Mansfield Formation—Indiana

Spencer (1953) estimated remaining resources of 340 million short tons for all coals in the Mansfield Formation in southwestern Indiana

St. Meinrad Coal Member

This coal is semi-blocky and contains numerous thin partings throughout much of its extent. It is highly variable in thickness, ranging from 0.1 to 5.0 ft. Mined thickness averages about 3.5 ft (Mastalerz and Shaffer, 2000).

Blue Creek Coal Member

This coal is extremely variable in thickness and quality. It splits into two benches in some localities. The coal is replaced by black, fissile shale throughout much of its extent. Mined thickness averages about 2.5 ft (Mastalerz and Shaffer, 2000). For the Blue Creek, calorific value (as-received basis) averages 11,300 Btu/lb, ash content 6.6 percent, and sulfur content 1.5 percent (modified from Mastalerz and Harper, 1998, table 3).

Mariah Hill Coal Member

This coal is moderately bright and semi-blocky, and it ranges from 2 to 4 ft thick where it is best developed. Mined thickness averages about 3.0 ft (Mastalerz and Shaffer, 2000). For the Mariah Hill, calorific value (as-received basis) averages 11,100 Btu/lb, ash content 9.7 percent, and sulfur content 1.5 percent (modified from Mastalerz and Harper, 1998, table 3).

Brazil Formation—Indiana

Lower Block Coal Member

The Lower Block Coal Member typically consists of a moderately dull banded, slabby coal having two conspicuous sets of cleats that cause it to break out in large blocks. The bed is absent or unidentifiable north of southern Park County, Ind. The Lower Block Coal Member, and its probable equivalent south of Green County, Ind., has been mined mostly from small surface mines during the last decade. The Lower Block Coal Member ranges from 0.7 to 5.8 ft in thickness, having a maximum thickness near the centers of small basins. Mined thickness averages about 3.5 ft in the northern counties. South of Green County, the Lower Block averages about 3 ft thick where mined. Spencer (1953) estimated remaining resources for the Lower Block Coal Member at 74 million short tons (Mastalerz and Shaffer, 2000). For the Lower Block, calorific value (as-received basis) averages 10,900 Btu/lb, ash content 9.5 percent, and sulfur content 1.5 percent (modified from Mastalerz and Harper, 1998, table 3).

Upper Block Coal Member

This coal is typically a moderately dull banded, semi-splint coal having two sets of cleats that cause it to break out in blocks. A band of fusain, usually about 1.5 ft above the base, divides the coal into two benches. The Upper Block Coal Member and its probable equivalent south of Green County, Ind., have been mined mostly in small surface mines during the last decade. In the northern counties, mined thickness of the coal varies from 1.4 to 5 ft, averaging about 4 ft. South of Greene County, the coal in the Upper Block position averages about 3 ft where mined, with a range of 2 to 4 ft (Mastalerz and Shaffer, 2000). Spencer (1953) estimated remaining resources for the Upper Block Coal Member at 81 million short tons. For the Upper Block, calorific value (as-received basis) averages 10,800 Btu/lb, ash content 8.1 percent, and sulfur content 1.4 percent (modified from Mastalerz and Harper, 1998, table 3).

Minshall and Buffaloville Coal Members

These coal members are thought to be a single continuous bed. The name "Minshall Coal Member" is applied in Clay, Fountain, Greene, Owen, and Parke Counties, Ind., whereas "Buffaloville Coal Member" is applied farther south, in Daviess, Dubois, Spencer, and Warrick Counties, Ind. In Clay County, the Minshall is typically a bright- to dull-banded pyritiferous coal with a pyritiferous shale or limestone roof and gray, carbonaceous plastic underclay. The Buffaloville is a blocky coal with a black shale, calcareous black shale, or argillaceous limestone roof and an underclay as much as 3 ft thick. During the past decade, the Minshall and Buffaloville have been mined mostly at small surface mines, where they range from less than 1 ft to more than 6 ft in thickness. Mined thicknesses average from slightly more than 2 ft in the southern counties to almost 4.5 ft in some northern counties (Mastalerz and Shaffer, 2000). Spencer (1953) estimated remaining resources for the Minshall Coal Member at 158 million short tons. For the Minshall and Buffaloville Coal Members, calorific value (as-received basis) averages 11,100 Btu/lb, ash content 10.7 percent, and sulfur content 3.3 percent (modified from Mastalerz and Harper, 1998, table 3).

Carbondale Formation or Group

Davis, Dekoven, and Seelyville Coals (Ind. III; W. Ky. No. 6 and No. 7)

The Davis, Dekoven, and Seelyville Coals occur within the same coal zone. In Illinois and western Kentucky, the Davis and Dekoven Coals are near the base of the Carbondale Formation. In Indiana, the Seelyville Coal Member is near the top of the Staunton Formation. In Illinois, the Davis and Dekoven are commonly 10–25 ft apart and the beds are usually co-produced in surface mines. Resources, most too deep for strip mining, are known to occur in Franklin, Williamson, Saline, and Gallatin Counties, in southern Illinois. These beds have been extensively mined at the surface in parts of southern Saline County, eastern Williamson County, and Gallatin County. Where mined, the Davis Coal Member has an average thickness of 3.5–4 ft, whereas the Dekoven Coal Member has an average thickness of 3–3.5 ft (Damberger, 2000). The Davis and Dekoven have been correlated with the Seelyville Coal Member in east-central Illinois (Jacobson, 1987). In an area of approximately 1,900 square miles in 10 counties of east-central Illinois the Seelyville may be 3.5–9 ft thick (Treworgy, 1981). Very little is known about coal structure and coal quality in this area. One or more shale partings can be inferred in many places from the geophysical logs.

In Indiana, the Seelyville Coal Member has been mined in surface operations in Clay, Davies, Greene, Pike, Sullivan, and Warrick Counties during the last 15 years. Mined thickness in Indiana averages about 6 ft in the northern counties and about 3 ft in the southern counties (Mastalerz and Shaffer, 2000).

Although the Davis coal is widespread in western Kentucky, it has been intensively mined only in the southern part of Union County. An interval of relatively thick coal extends across the northern part of Union and Henderson Counties and into the western edge of Daviess County (Greb and others, 1992). The Dekoven coal is 3 ft thick in western Union County but thins southeastward along the outcrop.

Cady (1952) estimated remaining resources for the Davis Coal Member in Illinois at 3.4 billion short tons, Hopkins and Simon (1974) estimated 3.4 billion short tons, and Damberger (2000) listed 3.6 billion short tons. For the Dekoven Coal Member, Cady (1952) estimated 2.5 billion short tons, Hopkins and Simon (1974) estimated 2.5 billion short tons, and Damberger (2000) listed 2.7 billion short tons. Damberger (2000) listed remaining resources for the Seelyville Coal Member in Illinois at 10 billion short tons. Spencer (1953) estimated remaining resources for the Seelyville in Indiana at 5.9 billion short tons. Smith and Brant (1980) estimated the remaining resources for the Davis coal in western Kentucky to be 7.5 billion short tons, and for the Dekoven coal they estimated 290 million short tons. A combined total resource estimate for the Davis, Dekoven, and Seelyville Coals from the three states would be about 30 billion short tons.

For the Davis Coal Member in southern Illinois, calorific value ranges from 12,500 to 12,800 Btu/lb (moist, mineral-matter-free basis), ash content from 8 to 11 percent (as-received basis), and sulfur contents from 3 to 4 percent (as-received basis). For the Dekoven Coal Member, calorific value (as-received basis) ranges from 11,900 to 12,700 Btu/lb, ash content from 8 to 13 percent, and sulfur content from 3 to 5 percent (Damberger, 2000).). For the Seelyville Coal Member in Indiana, calorific value (as-received basis) averages 11,200 Btu/lb, ash content 13.1 percent, and sulfur content 4.5 percent (modified from Mastalerz and Harper, 1998, table 3). For the Davis coal in western Kentucky, calorific value (as-received basis) averages 12,300 Btu/lb, ash content 8.2 percent, and sulfur content 2.9 percent (Greb and others, 1992).

Colchester Coal (Ill. No. 2, Ind. IIIa)

In Illinois, the Colchester Coal Member is in the Carbondale Formation; in Indiana, it is part of the Linton Formation. In Illinois, the Colchester has been mined principally in northern and western Illinois. The coal is 2.5–3.5 ft thick in northern Illinois; 2.5 to 3.3 ft in Henry County in the northern part of western Illinois and 1.5–2.5 ft in the southern part of western Illinois. Throughout most of the rest of Illinois, where present, it appears to range from a few inches to less than 2 ft thick. Currently, the Colchester is being mined only in western Illinois (Damberger, 2000). In Indiana, the Colchester is generally thin, varying from 0.1 ft to more than 4 ft in thickness. There, it has been mined only in a few small surface mines. In Indiana, the roof of the coal is typically black, fissile shale, 1–7 ft thick (Mastalerz and Shaffer, 2000).

Cady (1952) estimated remaining resources for the Colchester Coal Member in Illinois at 17.5 billion short tons, Hopkins and Simon (1974) estimated 20.9 billion short tons, and Damberger (2000) listed 16.6 billion short tons. No coal resource estimates have been made for the Colchester in Indiana. For the Colchester Coal Member in northern and western Illinois, calorific value (as-received basis) ranges from 10,500 to 11,700 Btu/lb, ash content from 3 to 11 percent, and sulfur content from 1 to 5 percent (Damberger, 2000). For the Colchester in Indiana, calorific value (as-received basis) averages about 10,800 Btu/lb, ash content 11.6 percent, and sulfur content 3.7 percent (modified from Mastalerz and Harper, 1998, table 3).

Survant Coal (Ind. IV; W. Ky. No. 8)

In Indiana, the Survant Coal Member is in the Linton Formation; in western Kentucky, the Survant coal is in the Carbondale Formation. In Indiana, it is best developed in Greene and Vigo Counties, where it generally carries a medial parting as much as a few feet thick. The upper part of the coal is variously black fissile shale, a canneloid coal, or a banded coal. The roof is typically gray shale or sandstone. Thickness of the coal in Indiana varies from 0.2 to 8 ft; mined thicknesses vary from 2 to 6.5 ft. In the last 10 years, the coal has been mined in Pike, Greene, Warrick, and Clay Counties, Ind. (Mastalerz and Shaffer, 2000). In western Kentucky, the Survant coal is one of the least persistent Carbondale Formation coals and is usually less than 3 ft thick. It is cut out in many places by overlying channel sandstones. In western Kentucky, the coal commonly occurs in two benches separated by as much as 10 ft of shale and siltstone (Greb and others, 1992).

Spencer (1953) estimated remaining resources for the Survant Coal Member in Indiana at 3.9 billion short tons. For western

Kentucky, Smith and Brant (1980) estimated the remaining resources for the Survant coal to be 116 million short tons. For the Survant in Indiana, calorific value (as-received basis) averages about 11,200 Btu/lb, ash content 9.9 percent, and sulfur content 2.7 percent (modified from Mastalerz and Harper, 1998, table 3).

Houchin Creek Coal (Summum, Ill. No. 4, Ind. IVa, W. Ky. No.8b)

The Houchin Creek Coal is one of the most widely traceable coal horizons in Illinois, Indiana, and western Kentucky (Hopkins and Simon, 1975). In Illinois, the Houchin Creek Coal Member is in the Carbondale Formation, whereas in Indiana it is in the Petersburg Formation. It is normally overlain by the black, fissile Excello Shale Member of the Carbondale Formation (Illinois and Kentucky) or Petersburg Formation (Indiana). Where present, the Houchin Creek is usually within 25 ft of the base of the Springfield Coal. The coal, however, is usually not of mineable thickness (Damberger, 2000). In western Kentucky, the Houchin Creek coal consists of less than 2 ft of impure coal overlain by black shale that ranges from 2 to 6 ft in thickness. The Houchin Creek has been mined in western Illinois (Knox and Fulton Counties), west-central Illinois (Greene and Jersey Counties), southeastern Illinois (Saline County), and, most recently, in northern Illinois (Kankakee and Grundy Counties), where it was mined in conjunction with the Colchester Coal Member. In Indiana, the Houchin Creek Coal Member has been mined in small surface operations in Pike, Clay, Vigo, and Spencer Counties (Mastalerz and Shaffer, 2000).

Cady (1952) estimated resources for the Houchin Creek Coal Member in Illinois at 182 million short tons; Hopkins and Simon (1974) estimated 260 million short tons. Damberger (2000) did not list resource estimates for this coal. Spencer (1953) estimated remaining resources for the Houchin Creek Coal Member in Indiana at 108 million short tons. Smith and Brant (1980) did not estimate resources for the Houchin Creek coal in western Kentucky. For the Houchin Creek in western Illinois, calorific value (as-received basis) ranges from 10,800 to 11,300 Btu/lb, ash content from 7 to 9 percent, and sulfur content from 3 to 4 percent (Damberger, 2000).

McLeansboro Group

Jamestown and Hymera Coal Members and Paradise Coal (Ind. VI; W. Ky. No. 12)

The Jamestown Coal Member in Illinois, Hymera Coal Member in Indiana, and Paradise coal in western Kentucky are equivalent (Hopkins and Simon, 1975; Greb and others, 1992). In Illinois and western Kentucky, the Jamestown Coal Member and the Paradise coal are within the Shelburn Formation. In Indiana, the Hymera Coal Member is in the Dugger Formation of the Carbondale Group. The Jamestown is a widespread but thin coal in southern Illinois.

For Illinois, Cady (1952) estimated resources for the Jamestown Coal Member at 600 million short tons; Damberger (2000) listed 3.6 billion short tons. For the Hymera Coal Member in Indiana, Spencer (1953) estimated 3.7 billion short tons. For western Kentucky, Smith and Brant (1980) estimated remaining combined resources for the Paradise coal and the underlying Herrin coal at 8.4 billion short tons. Average calorific value (as-received basis) for the Hymera in Indiana is about 10,800 Btu/lb, ash content is 12.7 percent, and sulfur content is 2.9 percent (modified from Mastalerz and Harper, 1998, table 3). Analyses of the Paradise coal in western Kentucky indicate an average calorific value (as-received basis) of 11,900 Btu/lb, ash content of 9.7 percent, and sulfur content of 2.0 percent (Cobb and others, 1985; Greb and others, 1992).

Coiltown Coal (W. Ky. No.14)

The Coiltown coal is not persistent in western Kentucky, but where present this coal tends to be one of the thickest beds. In eastern Hopkins County, a coal thickness as much as 151 in. was reported, making the Coiltown coal the thickest coal in western Kentucky. Where the Coiltown coal is thick, it often contains abundant partings (as much as 12 in. thick) and may be cut out by thick sandstone units (Palmer, 1972; Greb and others, 1992). Smith and Brant (1980) estimated remaining resources for the Coiltown coal at 1.2 billion short tons. Analyses of the Coiltown coal indicate an average calorific value (as received basis) of about 11,860 Btu/lb, ash content of 8.7 percent, and sulfur content of 3.2 percent (Cobb and others, 1985; Greb and others, 1992).

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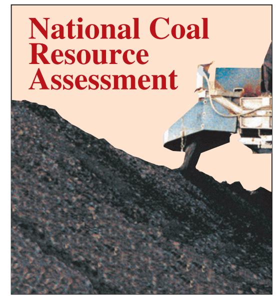
Chapter D

Resource Assessment

Edited by J.R. Hatch *and* R.H. Affolter



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Chapter D *of*

Resource Assessment of the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin

Edited by J.R. Hatch *and* R.H. Affolter

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U.S. Department of the Interior
U.S. Geological Survey

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Resource Assessment

Edited by J.R. Hatch[1] *and* R.H. Affolter[1]

Introduction

By J.R. Hatch[1] *and* R.H. Affolter[1]

A primary goal of the current coal assessment in the Illinois Basin is to provide an update of estimates of the quantity and recoverability of the remaining coal resources. To accomplish this goal, in this chapter we

(1) review the history of coal production in the basin,
(2) summarize the results of the previous Illinois Basin coal assessments efforts,
(3) detail the methodologies used to calculate the remaining resources,
(4) present the resource calculations for the Springfield, Herrin, Danville, and Baker Coals categorized by coal, state, mining area, county, coal depth, coal thickness, and geologic reliability category,
(5) apply a recently developed methodology for determining the uncertainty of the resource calculations for the assessed coals, and
(6) briefly discuss the results of the many coal availability and coal recoverability assessment studies completed for areas within the basin.

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Illinois Basin Coal Production

By J.R. Hatch[1] *and* R.H. Affolter[1]

Coal production began in Illinois in the early 1800's. In Indiana, coal was being advertised for sale by 1832, and the first coal company was officially incorporated in 1837. The first recorded coal production in western Kentucky was in 1820, in Henderson and Muhlenburg Counties. Since these early beginnings, coal production from the basin, in general, was related to the overall increasing demand for power generation. At the same time, specific events have had both short- and long-term effects on coal development, and these include socio-political, technological, and market factors.

The annual coal production from Illinois, Indiana, and western Kentucky between 1890 and 1998 is shown in figure 1. Between 1890 and the late 1920's, coal production in all three states rose significantly, spurred by industrial development and railroad expansion. Coal production reached 89 million short tons in Illinois in 1918, 31 million short tons in Indiana, also in 1918, and 20 million short tons in western Kentucky in 1927. Production then declined markedly during the Great Depression of the 1930's (fig. 1). Production increased to meet the demands of World War II, but later decreased due to competition from oil and gas and the conversion of railroad locomotives from coal to diesel-electric power. In the 1960's and early 1970's, increased production resulted from an increased demand to meet the needs of a growing number of coal-fired power plants. A maximum of about 148 million tons was produced from the Illinois Basin in 1984.

Since about 1990, coal production from the Illinois Basin has dropped, primarily a result of the enactment and implementation of Phase I restrictions of the 1990 Amendment to the Clean Air Act and increasing price competition from western low-sulfur coals (U.S. Energy Information Administration, 1998; Carey and Hiett, 2000). Average coal production from the Illinois Basin was about 138 million short tons between 1988 and 1992, about 116 million short tons between 1993 and 1997, and about 112 million short tons in 1998. From 1890 to 1998, about 5.6 billion short tons of coal were produced in Illinois, about 2.5 billion short tons in western Kentucky, and about 2.1 billion short tons in Indiana. (U.S. Energy Information Administration, 1998, 2000; Carey and Hiett, 2000).

Springfield, Herrin, Danville, and Baker Coals

The Springfield Coal has been the most extensively mined coal in the Illinois Basin. The Springfield was mined at the surface in western Illinois and is the only coal mined in west-central Illinois. It is the most important coal in southeastern Illinois and has been mined in southwestern Illinois (Damberger, 2000). The Springfield has been mined in both surface and underground mines in nine counties in Indiana and eight counties in western Kentucky (fig. 2).

The Herrin Coal Member has been the most extensively mined coal in Illinois and has been mined in western, west-central, southern, east-central, and northern Illinois (Damberger, 2000). The Herrin is neither well developed nor mined in Indiana. Mining activity in the Herrin coal in western Kentucky is centered along the southern edge of the field (fig. 3).

The Danville Coal Member has been mined in east-central Illinois and in the adjacent counties in Indiana. Most of the historical mining of the Baker coal has been by surface methods along the southern and eastern margins of the coal field (Weisenfluh and others, 1998) (fig. 4).

The annual coal production (million short tons) from the Springfield, Herrin, and Danville Coals in Illinois between 1890 and 1997 is shown in figure 5. The data shown in figure 5 were compiled by C.G. Treworgy and C.A. Chenoweth from coal production data from the Illinois Department of Mines and Minerals (written commun., 1998). Figure 5 shows that most of the historical Illinois coal production has been from the Herrin Coal and that most of the decrease in coal production in Illinois during the last five years has been primarily a result of decreased Herrin Coal production.

Coal Production from Surface and Underground Mines

Data comparing coal production from surface mines with production from underground mines in western Kentucky are shown in figure 6. Surface mining methods were introduced in this area in 1922, and production from surface mines exceeded underground production in 1957. From 1957 to 1985, production from surface mining was greater than that from underground mining, a maximum of about 33 million tons being produced by surface mining in 1972 (Weisenfluh and others, 1997; Carey and Hiett, 2000). Since 1972, coal production from surface mining has consistently diminished; in 1998, only about 8.0 million short tons (22 percent of total) was produced by this method. In 1998, 27.9 million short tons (78 percent of total) was produced from underground mines in western Kentucky (U.S. Energy Information Administration, 2000; Carey and Hiett, 2000).

The history of coal production from surface mines as compared to production from underground mines is similar in Illinois. Annual production from underground mines in Illinois reached a peak of 47 million short tons in 1992, and surface-mine production peaked at almost 35 million tons in 1969 (Illinois Department of Mines and Minerals, 1994). In 1998, nearly 89 percent (35.2 million tons) of Illinois coal production was from underground mines, whereas only about 11 percent (4.7 million tons) was produced from surface mines). Reasons for the significant decline in production from surface mines in Illinois and western Kentucky include stricter reclamation requirements and the depletion of low-cost reserves, as well as the 1990 Amendment to the Clean Air Act and increased price competition from western low-sulfur coals (Treworgy and others, 1997; Weisenfluh and others, 1997).

In Indiana, in contrast to decreases in production from surface mines in Illinois and western Kentucky, nearly 33.4 million short tons (91 percent of total) was produced from surface mines in 1998, compared to only 3.4 million short tons (9.3 percent of total) produced from underground mines (U.S. Energy Information Administration, 2000; Sanda, 2000a). Coal production in Indiana has actually increased since 1995, with production of 36.8 million tons being produced in 1998 (fig. 1) (U.S. Energy Information

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Administration, 2000).This increase in production has primarily been from coals that are relatively low in sulfur (Danville, Upper and Lower Block, Minshall and Buffaloville Coal Members (Blunck and Carpenter, 1997; Sanda, 2000b).

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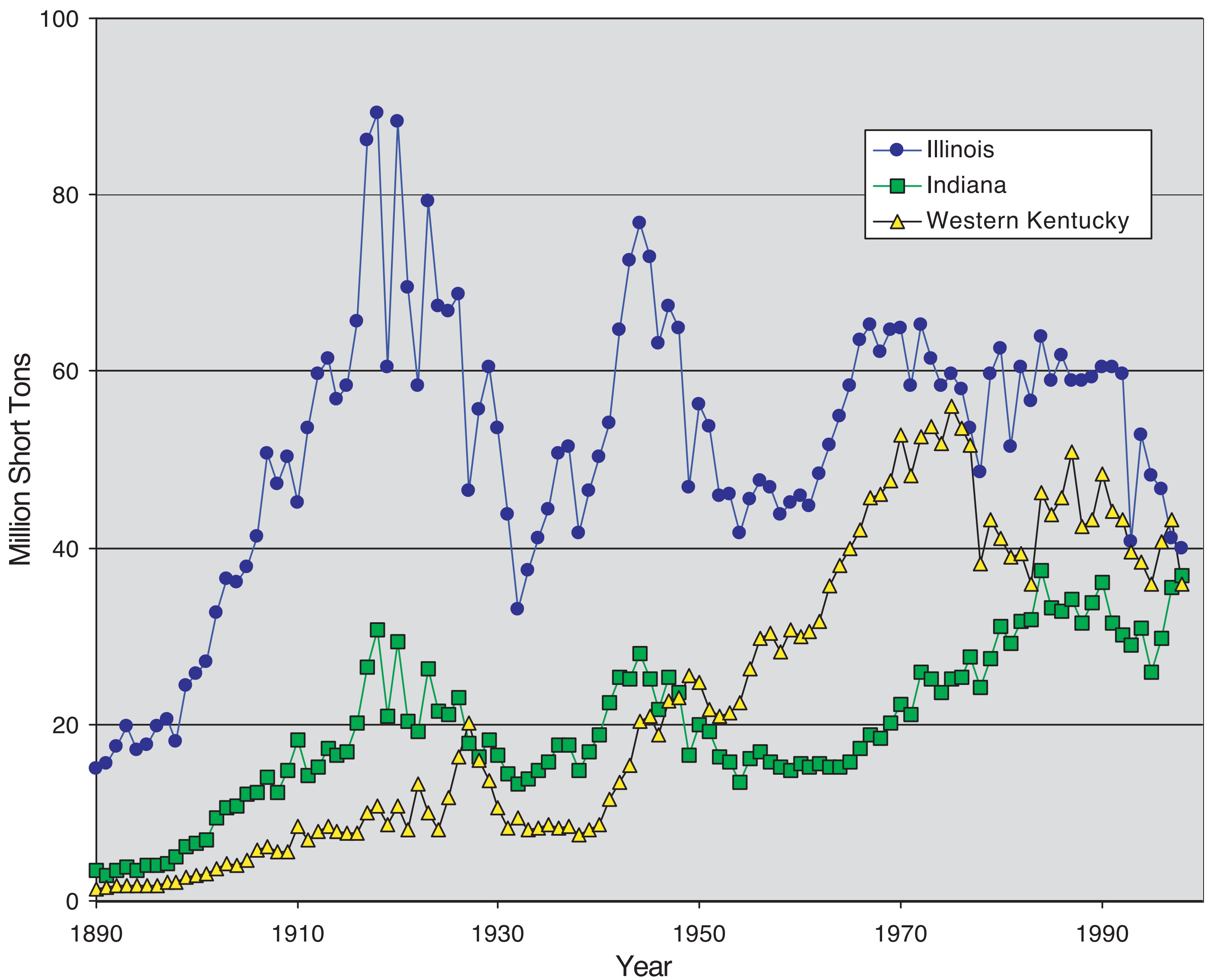

Figure 1. Graph showing annual coal production (million short tons) in Illinois, Indiana, and western Kentucky between 1890 and 1998. Data are from Carey and Hiett (2000), U.S. Energy Information Administration (2000), and Illinois Department of Mines and Minerals (1994).

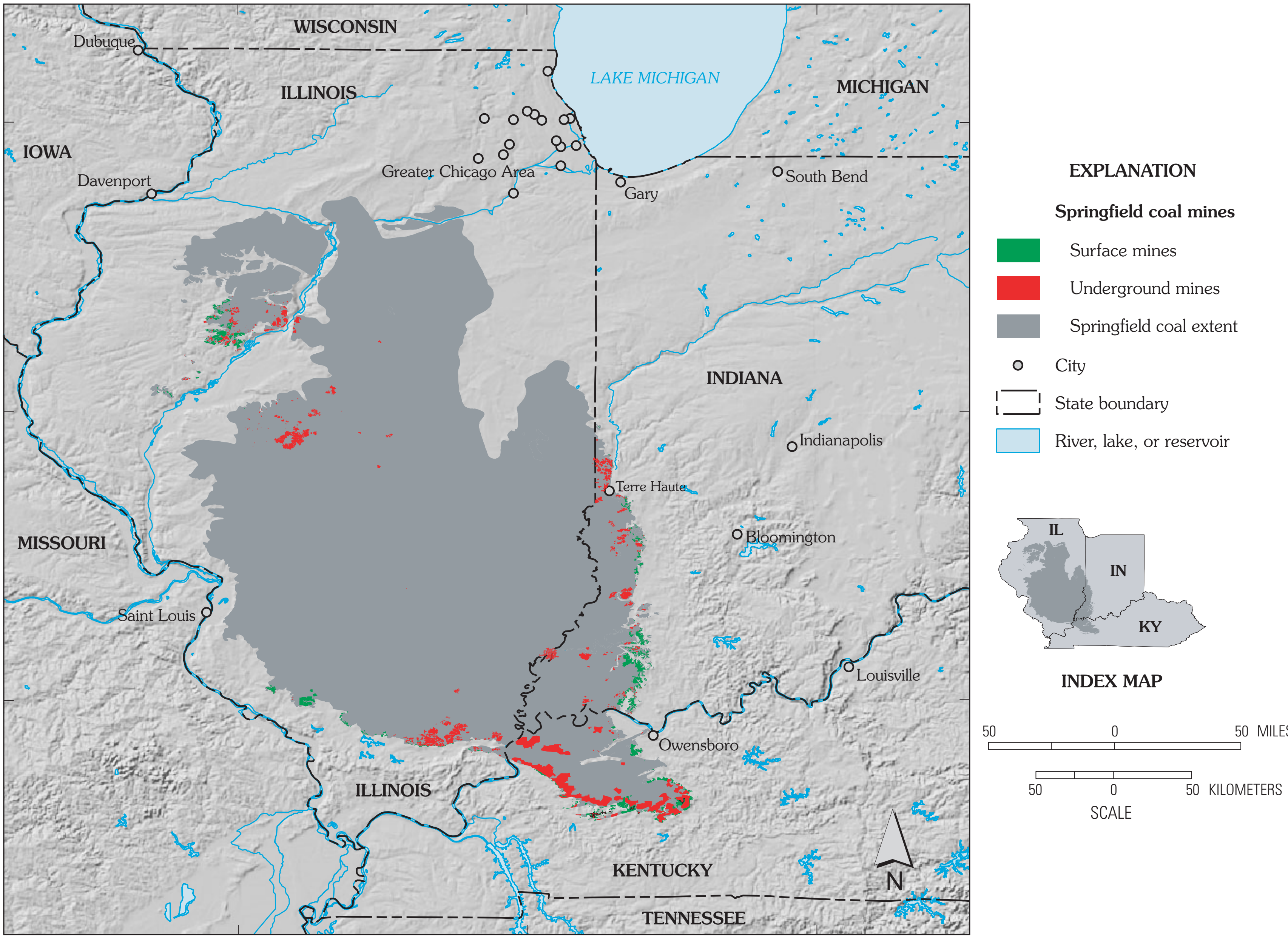

Figure 2. Map showing mined-out areas of the Springfield Coal in Illinois, Indiana, and Kentucky. This illustration was modified from regional shapefiles contained in the Illinois Basin ArcView project (Gunther and others, this publication).

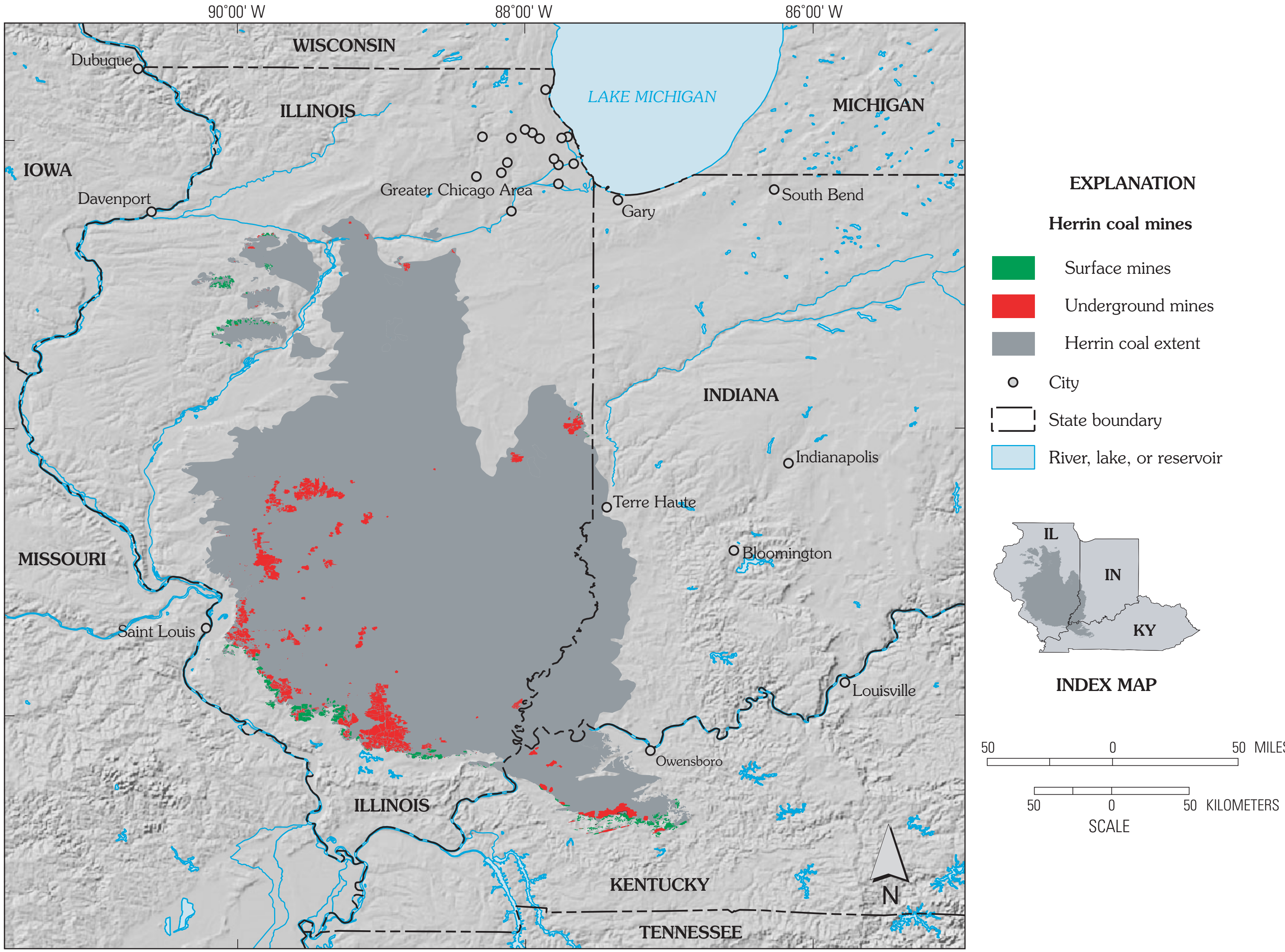

Figure 3. Map showing mined-out areas of the Herrin Coal in Illinois, Indiana, and Kentucky. This illustration was modified from regional shapefiles contained in the Illinois Basin ArcView project (Gunther and others, this publication).

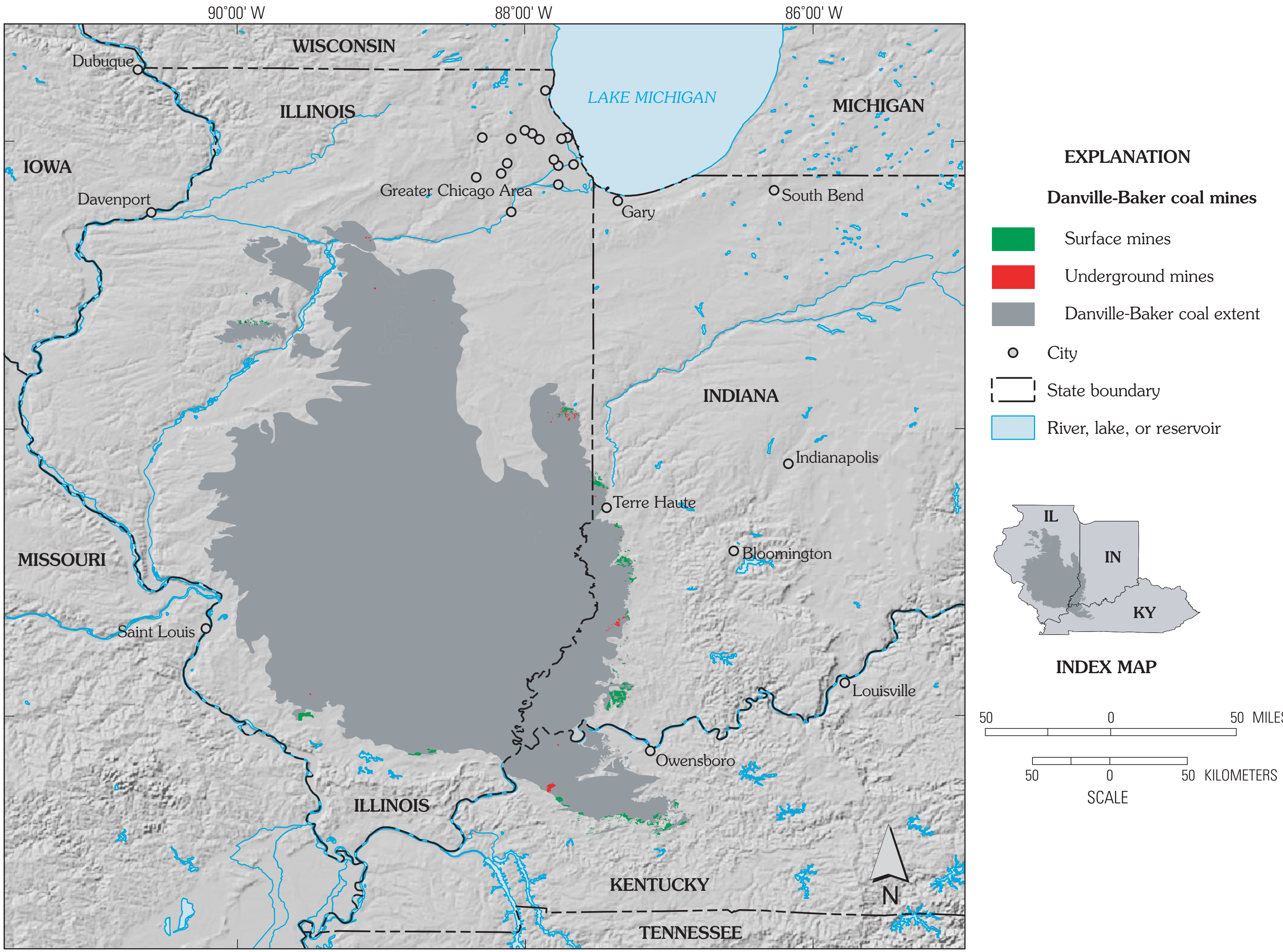

Figure 4. Map showing mined-out areas of the Danville Coal Member in Illinois and Indiana, and the Baker coal in Kentucky. This illustration was modified from regional shapefiles contained in the Illinois Basin ArcView project (Gunther and others, this publication).

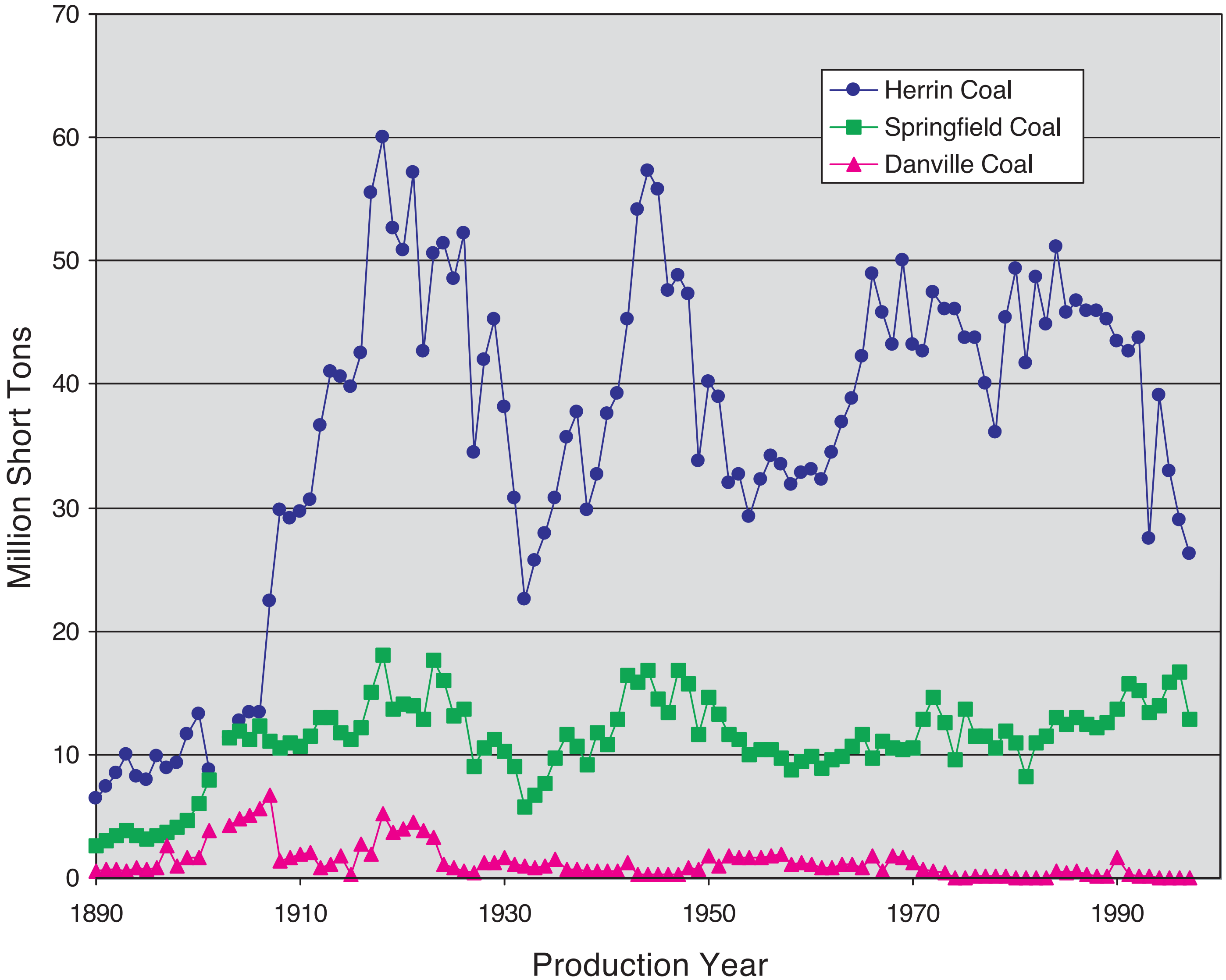

Figure 5. Graph showing annual coal production (million short tons) from the Springfield, Herrin, and Danville Coal Members in Illinois between 1890 and 1997. No data were available for 1902. These data were compiled by C.G. Treworgy and C.A. Chenoweth (written commun., 1998) from coal production data from the Illinois Department of Mines and Minerals .

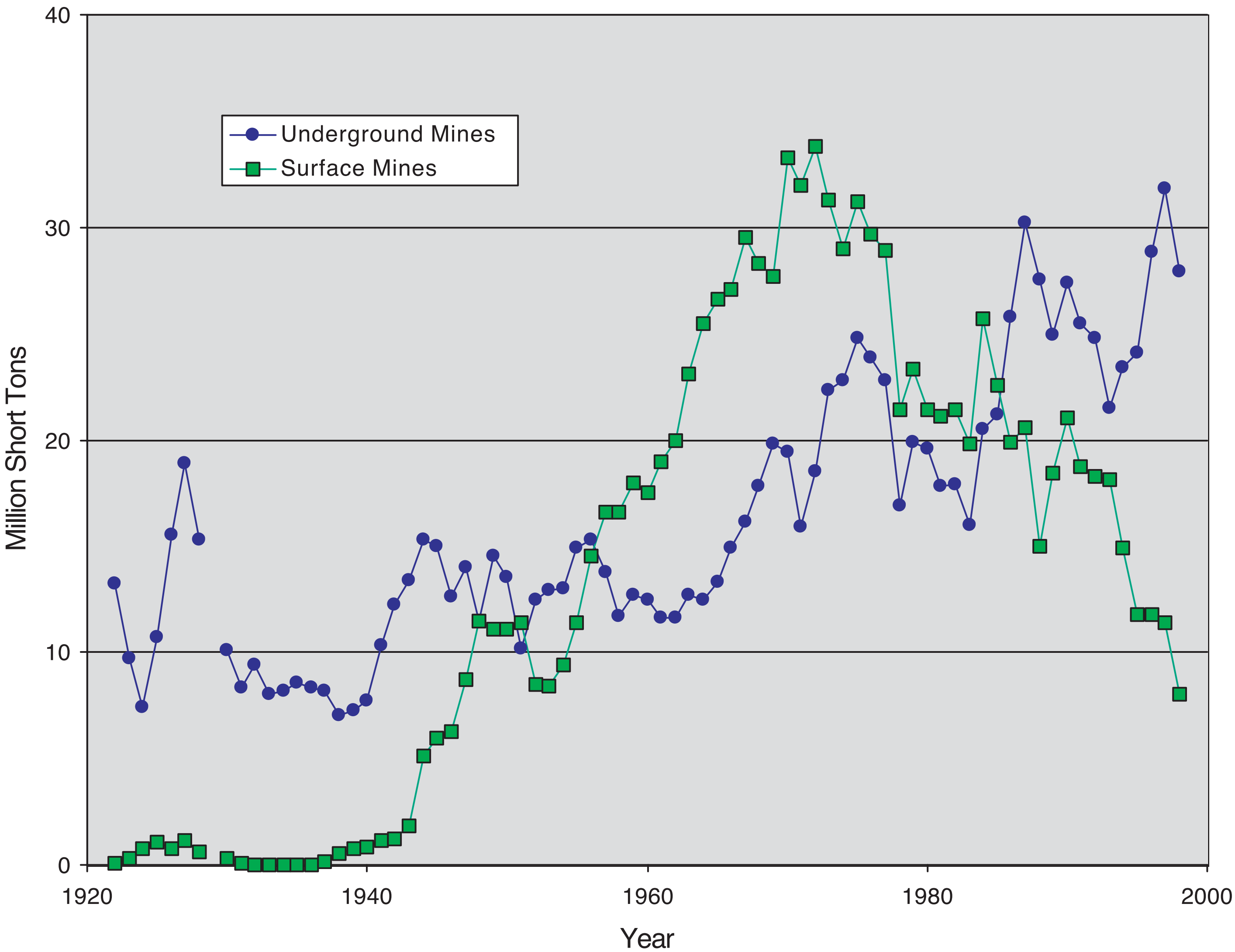

Figure 6. Graph showing annual coal production (million short tons) from underground and surface mines in western Kentucky between 1922 and 1998. Data are from Carey and Hiett (2000). No data were available for 1929.

Previous Resource Assessments of Illinois Basin Coals

By J.R. Hatch[1] *and* R.H. Affolter[1]

Since 1899, a number of assessments of the original, remaining, and recoverable coal resources in the Illinois Basin have been completed. For Illinois, the assessments are those of DeWolf (1908), Bement, 1910, Cady (1952), Hopkins and Simon (1974), Treworgy and others (1978), Treworgy and Bargh (1982), and Treworgy and others (1997). For Indiana, they are those of Ashley (1899), Campbell and Leverett (1913), Spencer (1953), and Wier (1973). For western Kentucky they are those of Smith and Brant (1980) and Weisenfluh and others (1998). For the 1974 U.S. Geological Survey national coal resource assessment, Averitt (1975) reported the resource estimates of Hopkins and Simon (1974) for Illinois, Wier (1973) for Indiana, and Huddle and others (1963, p. 177) for western Kentucky.

Illinois

For Illinois, DeWolf (1908) estimated that there was about 137 billion short tons (both surface and deep mineable) in deposits greater than 24 in. thick. Bement (1910) estimated about 201 billion short tons by measuring the extent of the coal-bearing areas on a map at a scale of one inch equals two miles (1:63,360), then combining these measurements with the known or estimated thickness of the coals. Cady (1952) provided the first comprehensive assessment of the coal reserves in Illinois, estimating about 137.3 billion short tons of remaining coal in 20 different coals. Cady's (1952) estimate was categorized by county, coal bed, thickness (≥28 in.) and by reliability category (I–A: proved, 0–0.5 mi from a data point; I–B: probable, >0.5–2 mi; II–A: strongly indicated, >2–4 mi; and II–B: weakly indicated, >4 mi). About 74 percent of Cady's (1952) estimated 137.3 billion short tons was associated with two coals, the Herrin and Harrisburg-Springfield Coal Members; 98 percent was associated with seven coals (see table 1).

Hopkins and Simon (1974) updated the assessment of the coal resources of Illinois. They estimated about 148.2 billion short tons of remaining coal in eight identified coals and a miscellaneous coals category. Their estimate includes coal 28 in. thick or greater in all classes of reliability. About 73 percent of this total is associated with two coals, the Springfield–Harrisburg and the Herrin Coal Members; 96 percent of the resource is in six coals (table 2). Hopkins and Simon (1974) also estimated the percentage of each resource category that was strippable (> 28 in. thick and < 150 ft of overburden) for each county and the amounts of relatively low sulfur (<2.5 percent) coal for the Springfield-Harrisburg and Herrin. For the Springfield-Harrisburg Coal Member, low-sulfur reserves were estimated at about 2.7 billion short tons, and for the Herrin Coal Member, about 2.1 billion tons.

Treworgy and others (1978) estimated surface-mineable coal resources of 20.4 billion short tons for 14 different coals in Illinois. Treworgy and Bargh (1982) estimated deep-mineable resources of 161 billion short tons for 13 different coals. Surface-mineable coal is that which is less than 150 ft in depth and equal to or greater than 28 in. thick (Treworgy and others, 1978). Deep-mineable coal is that which is greater than 150 ft in depth and equal to or greater than 28 in. thick (Treworgy and Bargh, 1982). Estimated resources of surface-mineable and deep-mineable coal for the six principal coals in Illinois (from Treworgy and others, 1978; and Treworgy and Bargh, 1982) are listed in table 3.

Damberger (2000) listed remaining resources (as of January 1996) in Illinois by county and for nine different coals. He estimated the total remaining identified resource at about 199 billion short tons. About 71 percent of this total is associated with two coals, the Herrin and Springfield Coal Members, and 91 percent with six coals (table 4). Of the 199 billion short tons of coal estimated for Illinois, 22.4 billion short tons are identified as surface-mineable (Damberger, 2000). The resource numbers for the Springfield, Herrin, and Danville Coal Members listed by Damberger (2000) are the same numbers used for the current assessment.

In addition to the above listed state-wide coal resource assessments for Illinois, many additional reports provide coal occurrence maps and summaries of coal resources on a quad- rangle, county, mining district, or regional scale. Information in these reports was

Table 1. Estimated remaining resources of the principal coals in Illinois (Cady, 1952).

[Columns may not sum exactly due to independent rounding.]

Coal	Billion short tons	Percent of total
Danville (Sparland) Coal	7.8	5.7
Herrin Coal	62.6	45.6
Harrisburg (Springfield) Coal	38.5	28.0
LaSalle (Colchester) Coal	17.5	12.7
Dekoven Coal	2.5	1.8
Indiana III Coal	1.8	1.3
Davis-Wiley Coal	3.4	2.5
Other coals	3.2	2.3
Total	137.3	100.0

Table 2. Estimated remaining resources of the principal coals in Illinois (Hopkins and Simon, 1974).

[Columns may not sum exactly due to independent rounding.]

Coal	Billion short tons	Percent of total
Danville Coal	7.6	5.1
Herrin Coal	65.8	44.4
Springfield-Harrisburg Coal	42.6	28.7
Colchester Coal	20.8	14.0
Dekoven Coal	2.5	1.7
Davis Coal	3.4	2.3
Other coals	5.5	3.7
Total	148.2	100.0

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Table 3. Estimated resources of surface-mineable and deep-mineable coal for the principal coals in Illinois (Treworgy and others, 1978; Treworgy and Bargh, 1982).

[Columns may not sum exactly due to independent rounding.]

Coal	Surface mineable		Deep mineable	
	Billion short tons	Percent of total	Billion short tons	Percent of total
Danville Coal	1.4	6.9	10.2	6.3
Herrin Coal	6.9	33.8	67.0	41.6
Springfield Coal	4.0	19.6	54.8	34.0
Colchester Coal	7.2	35.3	9.0	5.6
Dekoven Coal	<0.1	<0.5	2.3	1.4
Davis Coal	<0.1	<0.5	2.6	1.6
Other coals	0.8	3.9	15.0	9.3
Total	20.4	100.0	160.9	99.8

used to compile the above-listed statewide assessments and summaries. The following is a partial listing of these reports (in chronological order):

Cady, 1915, District 1 (Longwall District), northern Illinois
Kay, 1915, District VII, southwestern Illinois
Kay and White, 1915, District VIII, Vermilion and Edgar Counties
Cady, 1916, District VI, Jefferson, Franklin, and Williamson Counties
Cady, 1917, District II, Jackson County
Cady, 1919a, District V, Saline and Gallatin Counties
Cady, 1919b, Hennepin and LaSalle quadrangles, LaSalle and Bureau Counties
Cady, 1921, District IV, west-central Illinois
Culver, 1925, District III, western Illinois
Willman and Payne, 1942, Marseilles, Ottawa, and Streator quadrangles, LaSalle, Livingston, and Grundy Counties
Cady and others, 1951, Clay, Edwards, Gallatin, Hamilton, and Richland Counties
DuBois, 1951, Shelby and Moultrie Counties and parts of Effingham and Fayette Counties
Harrison, 1951, White County
Cady and others, 1955, Wabash County
Williams and Rolley, 1955, Jasper County
Potter, 1956, Crawford and Lawrence Counties
Smith, 1957, Part 1—Gallatin, Hardin, Johnson, Pope, Saline, and Williamson Counties
Wanless, 1957, Beardstown, Glasford, Havanna, and Vermont quadrangles, Brown, Cass, Fulton, and Peoria Counties
Smith, 1958, Part 2—Jackson, Monroe, Perry, Randolph and St. Clair Counties
Clegg, 1959, Douglas, Coles, and Cumberland Counties
Clegg, 1961, Sangamon, Macon, and Menard Counties and parts of Christian and Logan Counties
Smith, 1961, Part 3—Madison, Macoupin, Jersey, Greene, Scott, Morgan, and Cass Counties
Smith and Berggren, 1963, Part 5A—Fulton, Henry, Knox, Peoria, Stark, and Tazewell Counties and parts of Bureau, Marshall, Mercer, and Warren Counties
Reinertsen, 1964, Part 4—Adams, Brown, Calhoun, Hancock, McDonough, Pike, and Schuyler Counties and southern parts of Henderson and Warren Counties
Clegg, 1965, Clark and Edgar Counties
Smith, 1968, Part 6—LaSalle, Livingston, Kankakee, Will, and Putnam Counties and parts of Bureau and Marshall Counties
Searight and Smith, 1969, Part 5B—Mercer, Rock Island, and Warren Counties and parts of Henderson and Henry Counties
Clegg, 1972, DeWitt, McLean, and Piatt Counties
Allgaier and Hopkins, 1975, Fairfield basin in southeastern Illinois
Jacobson and Bengal, 1981, Part 7—Vermilion and Edgar Counties
Nance and Treworgy, 1981, Part 8—Central and southern counties
Jacobson, 1983, Jackson and Perry Counties
Treworgy and Bargh, 1984, statewide coal maps
Jacobson, 1985, Grundy, LaSalle, and Livingston Counties
Nelson, 1987, Christian, Macoupin, Montgomery, and Sangamon Counties
Jacobson, 1993, Gallatin and Saline Counties

Indiana

Ashley (1899) estimated coal resources of Indiana to be about 47 billion short tons. Campbell and Leverett (1913), assuming a larger tonnage per acre-foot of coal, revised that

Table 4. Estimated remaining resources of the principal coals in Illinois (Damberger, 2000).

[Columns may not sum exactly due to independent rounding.]

Coal	Billion short tons	Percent of total
Danville Coal	17.8	8.9
Herrin Coal	78.9	39.6
Springfield Coal	61.7	31.0
Colchester Coal	16.6	8.3
Dekoven Coal	2.7	1.4
Davis Coal	3.5	1.8
Other coals	17.8	8.9
Total	199.0	100.0

Table 5. Estimated remaining resources of the principal coals in Indiana as of January 1, 1951 (Spencer, 1953).

[Columns may not sum exactly due to independent rounding.]

Coal	Billion short tons	Percent of total
Danville Coal	3.7	10.4
Hymera Coal	3.7	10.3
Springfield Coal	13.8	38.5
Survant Coal	3.9	10.9
Seelyville Coal	5.9	16.4
Other coals	4.8	13.4
Total	35.8	100.0

estimate to about 53 billion short tons. The first comprehensive coal resource assessment for Indiana is that of Spencer (1953), who estimated remaining resources (as of January 1, 1951) at 35.8 billion short tons for 17 different coals. About 31 billion short tons (86 percent) of this total was associated with five beds (table 5). Wier (1973), updating Spencer (1953), estimated remaining resources as of January 1, 1965, at 33.2 billion tons.

In addition to the above-listed state-wide coal resource assessments for Indiana, other reports summarize coal resources on a quadrangle, county, mining district, or regional scale. Information in many of these reports was used to compile later, state-wide summaries. The following is a partial listing of these reports in chronological order:

Indiana Geological Survey, 1950, Jasonville quadrangle, Greene and Sullivan Counties
Indiana Geological Survey, 1951, Linton quadrangle, Greene and Sullivan Counties
Wier, 1952, Vigo County
Wier and Stanley, 1953, Pike County
Friedman, 1954a, Gibson County
Friedman, 1954b, Vanderburgh County
Indiana Geological Survey, 1954a, Dugger quadrangle, Sullivan County
Indiana Geological Survey, 1954b, Hymera quadrangle, Sullivan County
Indiana Geological Survey, 1954c, Coal City quadrangle, Greene, Clay, and Owen Counties
Hutchison and Hamilton, 1956, Clay County
Indiana Geological Survey, 1958, Seelyville quadrangle, Vigo County
Hutchison, 1958, Warrick County
Indiana Geological Survey, 1959, Coal City quadrangle, Greene, Clay, and Owen Counties
Indiana Geological Survey, 1960, Switz City quadrangle, Greene County
Indiana Geological Survey, 1961, Terre Haute and Dennison quadrangles, Vigo County
Hutchison, 1961, Fountain and Warren Counties and the northernmost part of Vermillion County
Hutchison, 1964, Dubois County
Hutchison, 1967, Martin County
Powell and Wier, 1967, Knox County
Powell. 1968, Parke County and southern Vermillion County
Hutchison, 1971a, Perry County
Hutchison, 1971b, Daviess County
Hutchison, 1976, Parke and Putnam Counties
Hill, 1980, Putnam County
Tanner, and others, 1981a, southwestern Gibson County
Tanner and others, 1981b, northern Posey County
Tanner and others, 1981c, southern Posey County
Hutchison and Hasenmueller, 1988, Greene County
Friedman, 1989, Clinton area, west-central Indiana
Hasenmueller, 1993, Owen County
Callis, 1994, Spencer County
Callis and Rupp, 1994, Daviess County
Eggert, 1994, Gibson County
Harper and Eggert, 1995, Knox County
Ault, 1997, Posey County
Conolly and Buciak, 1997, Pike County

Western Kentucky

For western Kentucky, a comprehensive coal resource estimate was provided by Smith and Brant (1980), who estimated remaining coal resource at about 38.6 billion short tons for 33 different coals. About 36.4 billion short tons (94 percent) of the total was associated with seven coals (table 6).

As part of a discussion of the availability of coal resources in western Kentucky, Weisenfluh and others (1998) estimated the remaining resources for the Springfield, Herrin, and Baker coals (table 7). They did not estimate resources for the Man-

Table 6. Estimated remaining resources of the principal coals in western Kentucky as of January 1, 1976 (Smith and Brant, 1980).

[Smith and Brant (1980) reported results for the Herrin and Paradise coals together; the Mannington, Mining City, and Lewisport coals are thought to be continuous and are reported as one coal. Columns may not sum exactly due to independent rounding.]

Coal	Billion short tons	Percent of total
Coiltown coal	1.2	3.2
Baker coal	3.1	8.1
Herrin and Paradise coals	8.4	21.7
Springfield coal	9.4	24.3
Davis coal	7.5	19.3
Mannington, Mining City, and Lewisport coals	6.5	16.9
Other coals	2.5	6.5
Total	38.6	100.0

Table 7. Estimated remaining resources of the Springfield, Herrin, and Baker coals in western Kentucky as of August 15, 1998 (Weisenfluh and others, 1998).

Coal	Billion short tons
Baker coal	3.6
Herrin coal	2.6
Springfield coal	8.0

nington—Mining City—Lewisport, Davis, Paradise, or Coiltown coals in western Kentucky.

In addition to the coal resource assessments of Smith and Brant (1980) and Weisenfluh and others (1998), there are additional reports providing coal occurrence maps and summaries of coal resources on a quadrangle, county, or regional scale. The following is a partial listing of these reports in chronological order:

Walker and others, 1951, Henderson quadrangle, Henderson County
Cathey, 1955, Newburgh quadrangle, Henderson County
Mullins and others, 1963, parts of Butler, Edmonson, Grayson, Muhlenberg and Warren Counties
Hodgson, 1963, upper Tradewater River area, western Kentucky
Mullins and others, 1965, northwestern Kentucky (primarily Union, Henderson, and Webster Counties)

As part of a cooperative program between the U.S. Geological Survey and the Kentucky Geological Survey, geologic quadrangle maps were produced for all of western Kentucky. This quadrangle mapping program, completed in 1978, served as a basis for producing coal distribution maps and for calculating coal resources. The following 34 geologic quadrangle maps show the outcrops for the Springfield, Herrin and (or) Baker coals in western Kentucky:

Amos, 1970, Blackford quadrangle, Crittenden, Webster, and Union Counties
Fairer and Norris, 1972, Curdsville quadrangle, Henderson, Daviess, and McLean Counties
Franklin, 1967, Coiltown quadrangle, Hopkins County
Franklin, 1969, Nebo quadrangle, Webster and Hopkins Counties
Franklin, 1973, Millport quadrangle, Muhlenberg and Hopkins Counties
Gildersleeve, 1975, Cromwell quadrangle, Butler and Ohio Counties
Goudarzi, 1968, Hartford quadrangle, Ohio County
Goudarzi, 1969, Equality quadrangle, Ohio, McLean, and Muhlenberg Counties
Goudarzi, 1971, Panther quadrangle, Daviess County
Goudarzi and Smith, 1971, part of the Owensboro West quadrangle, Daviess County
Hansen, 1972, Drakesboro quadrangle, Muhlenberg County
Hansen, 1974, Rochester quadrangle, Muhlenberg, Ohio, and Butler Counties
Hansen and Smith, 1978, Livermore quadrangle, McLean, and Muhlenberg Counties
Johnson, 1971, Horton quadrangle, Ohio County
Johnson, 1972, Reed quadrangle, Henderson and Daviess Counties
Johnson, 1973a, Evansville South quadrangle, Henderson County
Johnson, 1973b, Spottsville quadrangle, Henderson County
Johnson and Smith, 1972a, Utica quadrangle, Daviess, McLean, and Ohio Counties
Johnson and Smith, 1972b, Glenville quadrangle, McLean and Daviess Counties
Johnson and Smith, 1975, Calhoun quadrangle, Daviess, McLean, and Webster Counties
Kehn, 1963, Madisonville East quadrangle, Hopkins and Muhlenberg Counties
Kehn, 1964, Madisonville West quadrangle, Hopkins County
Kehn, 1966a, Providence quadrangle, Webster, Crittenden, and Hopkins Counties
Kehn, 1966b, Dawson Springs quadrangle, Hopkins, Caldwel,l and Christian Counties
Kehn, 1968, Graham quadrangle, Muhlenberg, Hopkins, and Christian Counties
Kehn, 1971, Greenville quadrangle, Muhlenberg County
Kehn, 1974a, Dekoven and Saline Mines quadrangles, Crittenden, and Union Counties
Kehn, 1974b, Paradise quadrangle, Muhlenberg and Ohio Counties
Kehn, 1975, Sturgis quadrangle, Union and Crittenden Counties
Palmer, 1966, Dalton quadrangle, Caldwell, Hopkins, Crittenden and Webster Counties
Palmer, 1967, Saint Charles quadrangle, Hopkins and Christian Counties
Palmer, 1968, Nortonville quadrangle, Hopkins and Christian Counties
Palmer, 1969, Central City West quadrangle, Muhlenberg and Ohio Counties
Palmer, 1972, Central City East quadrangle, Muhlenberg and Ohio Counties

Summary

These earlier coal resource estimates all show that the Springfield, Herrin, Danville, and Baker Coals contain most of the remaining coal resources in the Illinois Basin. The combined remaining resources estimated by Cady (1952) for the Springfield, Herrin, and Danville Coal Members were about 79 percent of the total estimated for all of Illinois. The combined remaining resources estimated by Hopkins and Simon (1974) were about 78 percent of the total coal resource; the estimates by Treworgy and others (1978) and Treworgy and Bargh (1982) were 82 percent of the total coal resource; and the estimates by Damberger (2000) were 80 percent of the total coal resources of Illinois. For Indiana, the combined resource estimate for the Springfield and Danville Coal Members by Spencer (1953) represents 49 percent of the total resource estimate, and for western Kentucky the combined resource estimate for the Springfield, Herrin, and Baker coals by Smith and Brant (1980) represents 54 percent of the total coal resources estimated.

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Remaining Resources of the Springfield, Herrin, Danville, and Baker Coals

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Methodology

A Geographic Information System (GIS) was used to estimate volumes of coal resources from information on coal distribution and coal thickness. This approach allows for the digital storage of information obtained from drill hole cores and logs, coal outcrop maps, and maps showing areas where coal has been mined out, and it permits comparisons of calculations made from one map with those made from others (Weisenfluh and others, 1998). Data from descriptions of exploration drill holes, geophysical logs, outcrop measurements, and mine maps included stratigraphic position, coal bed thickness, thickness of rock partings if present, and elevation. Outcrop data were digitized from 1:24,000-scale geologic quadrangle maps. Maps showing mined-out areas in Illinois were preserved through a cooperative effort between the U.S. Bureau of Mines, the Illinois Office of Mines and Minerals, and the Illinois State Geological Survey. These include maps from more than 2,100 underground and 400 surface mines. Maps showing mined-out areas for western Kentucky were obtained from the Kentucky Department of Mines and Minerals; for Indiana, maps were provided by the Indiana Bureau of Mines and Mining Safety.

Resource Categories

Thickness

Wood and others (1983) defined the standard USGS procedures for estimating coal resources as including coal thickness greater than 14 in.; and categorized thickness in multiples of 14 in. between 14 and 42 in., and in multiples of 42 in. between 42 and 168 in. For this assessment of coal resources in Illinois, Indiana, and western Kentucky, only three categories were used: >14 to 28 in., >28 to 42 in., and >42 in. This categorization is based on historical mining practices in the Illinois Basin and on the assumptions that coal less than 28 in. thick is generally not mineable by underground methods and that coal less than 42 in. thick is not economically mineable by underground methods at this time.

Overburden

Resources and reserves are divided into categories based on the coal mining method (surface or underground) most likely to be used. Given current mining practices, an overburden of less than150 ft was used to estimate resources amenable to surface mining, and overburden between 150 and 1,500 ft was used to estimate resources amenable to underground mining. It should be noted that, in practice, maximum overburden thickness for surface mining is generally determined by a ratio of overburden to coal thickness. The footage limits stated above were used to provide estimates of surface-mineable and deep-mineable areas for purposes of the present study.

Reliability

The USGS standard reliability categories are "measured," "indicated," "inferred," and "hypothetical." Measured resources are within 0.25 mi of a data point; indicated resources, between 0.25 and 0.75 mi; inferred resources, between 0.75 and 3.0 mi; and hypothetical resources, greater than 3 mi (Wood and others, 1983). These categories were used for the coal resources from western Kentucky. Because of the considerable lateral continuity of the Springfield, Herrin, and Danville Coals, coal resources in Illinois and Indiana were categorized according to the I–A, I–B, II–A and II–B class system originally defined by Cady (1952) and modified by Treworgy and Bargh (1982) to include oil test geophysical logs as accepted data points for class II–A. In this system, I–A (proved) resources are within 0.5 mi of a data point, I–B (probable) resources between 0.5 and 2 mi, II–A (strongly indicated) resources between 2 and 4 mi, and II–B (weakly indicated) resources beyond 4 mi from a data point. The I–A category is approximately equivalent to the USGS "measured" category, I–B to the USGS "indicated" category, and II–A to the USGS "inferred" category (Treworgy and others, 1997).

Data Analysis

Illinois

The following steps were taken to calculate coal resources in Illinois (Treworgy and others, 1997):

1. Thickness, depth, and elevation contours for each bed were created from the selected data points by using Earthvision, version 3 (Dynamic Graphics Inc., Alameda, CA).
2. These computer-generated contour maps were converted from the grid format of the contouring software to a format used by GIS software (ArcInfo version 7.04 by Environmental Systems Research Institute, Redlands, CA).
3. The GIS software was used to create reliability zones, which were then merged with maps of bed thickness, depth, and mined areas.
4. Tonnages were calculated from the merged layers by assuming 1 acre-foot of bituminous coal = 1,800 short tons of coal.

Indiana

The following steps were taken to calculate coal resources in Indiana (C. L. Connolly, written commun., 2000):

1. ArcInfo was used to create a 200-m resolution floating-point grid of coal thickness in inches.

[1]U.S. Geological Survey, Mail Stop 939, Box 25046, Denver, CO 80225–0046
[2]Indiana Geological Survey, Indiana University, 611 N. Walnut Grove, Bloomington, IN 47405–2208
[3]Illinois State Geological Survey, Natural Resources Building, 615 E. Peabody Drive, Champaign, IL 61820
[4]Kentucky Geological Survey, 228 Mining and Minerals Bldg., University of Kentucky, Lexington, KY 40506–0107

2. The floating-point grid was reclassified to create a grid in which the coal thickness values correspond to 7-in. contour intervals.
3. The reclassified grid was converted to a polygon coverage.
4. The 7-in. contour interval coal thickness coverage was combined with coverages for surface mines, underground mines, reliability circles (I–A, II–A, and I–B), and coal depth (0–150 ft and >150 ft).
5. The tonnage in each polygon was calculated by using the conversion constants of 1,800 short tons of coal/(acre–feet of coal), and 4,046.9 m^2/acre.

Western Kentucky

The GIS software utilized for resource calculations was GRASS (Geographic Resources Analysis Support System), a U.S. Government software package developed primarily by the U.S. Army Corps of Engineers, the U.S. Soil Conservation Service, and the USGS. GRASS is a raster-based GIS, which means that map data are rendered as matrices of equal-sized cells. Maps stored in a GRASS database must be oriented to a particular coordinate system. In order to utilize map information for calculations, the original vector data (points, lines, areas) must be converted to raster (gridded) data files. Following map and file preparation, the USGS program "resources" used GRASS commands to calculate areas (in square meters) for all resource categories (original, mined-out, and remaining). These data were then converted to acres, and coal tonnages were calculated by using the conversions constants of 1,800 short tons of coal /(acre-feet of coal), and 4,047 m^2/acre (Weisenfluh and others, 1998).

Coal Resource Assessment Results

Estimated remaining coal resources (million short tons) for the Springfield, Herrin, Danville, and Baker Coals are listed in appendixes 1–3 (at the end of chapter D). Resources are categorized on the basis of coal bed, state, mining area (in Illinois), county, overburden thickness (0–150 ft and >150 ft), coal thickness (>14–28 in., >28-42 in., and >42 in.), and reliability of estimate (Illinois and Indiana: I–A, 0–0.5 mi from a data point; I–B, >0.5–2 mi; II–A, >2–4 mi. Western Kentucky: measured, 0–0.25 mi; indicated, >0.25–0.75 mi; inferred, >0.75–3.0 mi; and hypothetical, >3 mi). Figure 7 shows the mining areas of the Illinois Basin. The mining areas in Illinois are from Damberger (2000, fig. 1) and, in general, are based on historic mining districts. Each of these areas in Illinois is comparable in size to the coal-producing areas of Indiana and western Kentucky.

Identified coal resources are those resources in categories I–A + I–B + II–A, or measured + indicated + inferred. Summaries of the remaining identified coal resources estimates (million short tons) for the Springfield, Herrin, Danville, and Baker Coals as listed in appendixes 1–3 are listed in tables 8–10 by mining area, coal thickness interval (>14–28 in., >28–42 in., and >42 in.), and overburden thickness (0–150 ft and >150 ft). Histograms in figure 8 show the distribution of remaining identified coal resources by coal and by thickness interval. Histograms in figures 9–11 show the remaining identified coal resources in beds greater than 42 in. thick, summarized by mining area and by coal depth (0–150 ft and >150 ft).

Figure 8 shows that the large majority (81 and 84 percent, respectively) of the identified coal resources for the Springfield and Herrin Coals are in relatively thick (>42 in.) coal, whereas, for the Danville and Baker Coals, only 39 percent of the identified resources are in coals >42 in. thick. For the Springfield Coal (fig. 9), the mining areas having the largest amount of remaining identified resources include west-central Illinois (19 billion short tons), southeastern Illinois (29 billion short tons), and Indiana (12 billion short tons). In these areas, the Springfield Coal is generally greater than 42 in. thick (fig. 10). For the Herrin Coal (fig. 11), the mining areas having the greatest amount of remaining identified resources include west-central Illinois (27 billion short tons), southwestern Illinois (14 billion short tons), and southeastern Illinois (26 billion short tons). In these areas, the Herrin Coal is also generally greater than 42 in. thick (fig. 12). For the Danville and Baker Coals (fig. 13), the mining areas having the largest remaining identified resources are on the east side of the Illinois basin in east-central Illinois (7.3 billion short tons), southeastern Illinois (4.4 short billion tons), and Indiana (6.3 billion short tons). As shown in figure 14, these mining areas are where Danville and Baker Coals reach their greatest thickness.

For the Springfield Coal, the mining areas having the largest remaining identified resources in coals >42 in. thick and at depths 0—150 ft (table 8 and fig. 9) include western Illinois (1.2 billion short tons), west-central Illinois (1.1 billion short tons), and Indiana (1.8 billion short tons). For the Herrin Coal (table 9 and fig. 10), areas having such resources are western Illinois (1.9 billion short tons) and southwestern Illinois (2.4 billion short tons), and for the Danville and Baker Coals (table 10 and fig. 11), such areas are in east-central Illinois (450 million short tons) and Indiana (500 million short tons).

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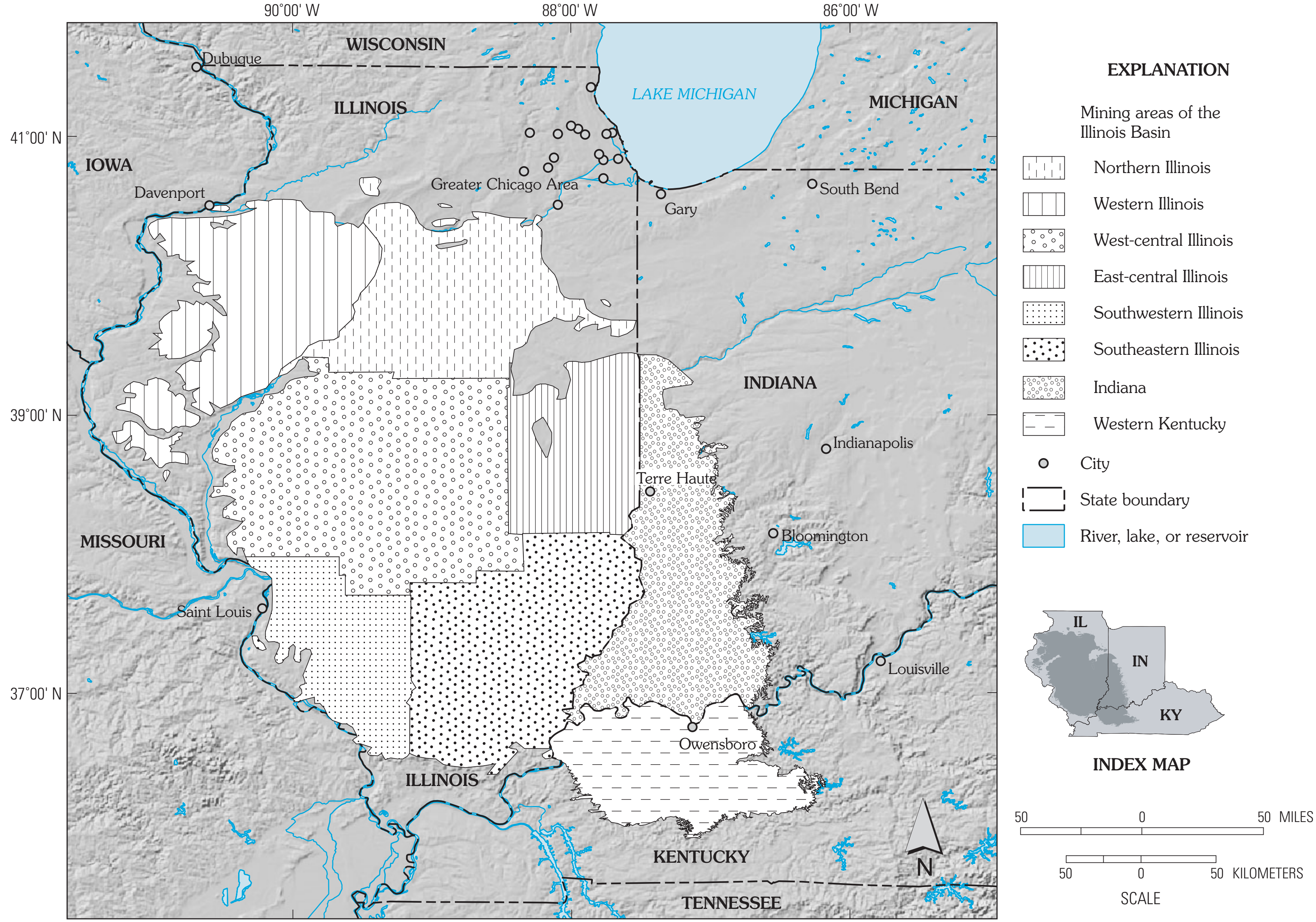

Figure 7. Map showing mining areas of the Illinois Basin and the extent of coal-bearing rocks in Illinois, Indiana, and western Kentucky. The six mining areas in Illinois are from Damberger (2000, fig. 1). This illustration was modified from regional shapefiles contained in the Illinois Basin ArcView project (Gunther and others, this publication).

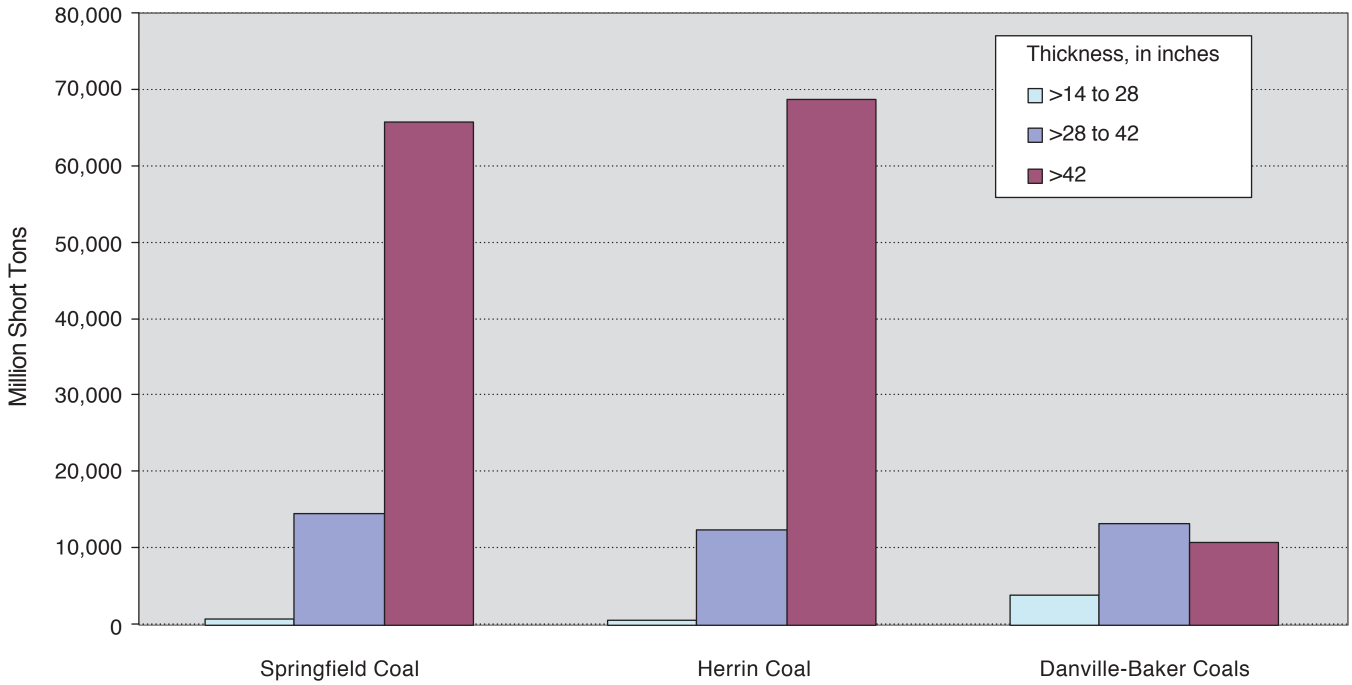

Figure 8. Histogram showing remaining, identified coal resources (million short tons) of the Springfield, Herrin, and Danville-Baker Coals in Illinois, Indiana, and western Kentucky, summarized by thickness. Identified resources include categories I–A, I–B, and II–A in Illinois and Indiana, and measured, indicated, and inferred in western Kentucky.

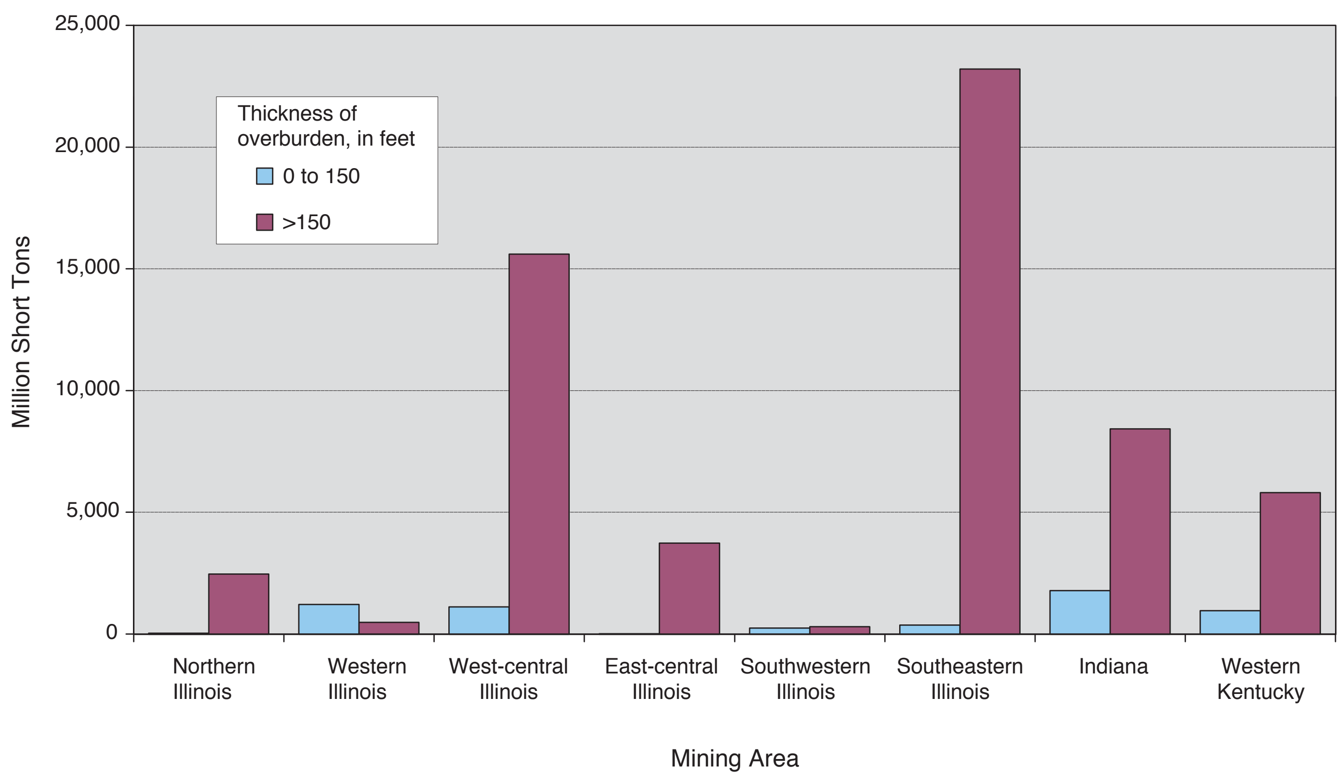

Figure 9. Histogram showing remaining, identified coal resources (>42 in. thick, million short tons) of the Springfield Coal in Illinois, Indiana, and western Kentucky, summarized by mining area and by overburden thickness (coal depth). Data are from table 8. Identified resources include categories I–A, I–B, and II–A in Illinois and Indiana, and measured, indicated, and inferred in western Kentucky.

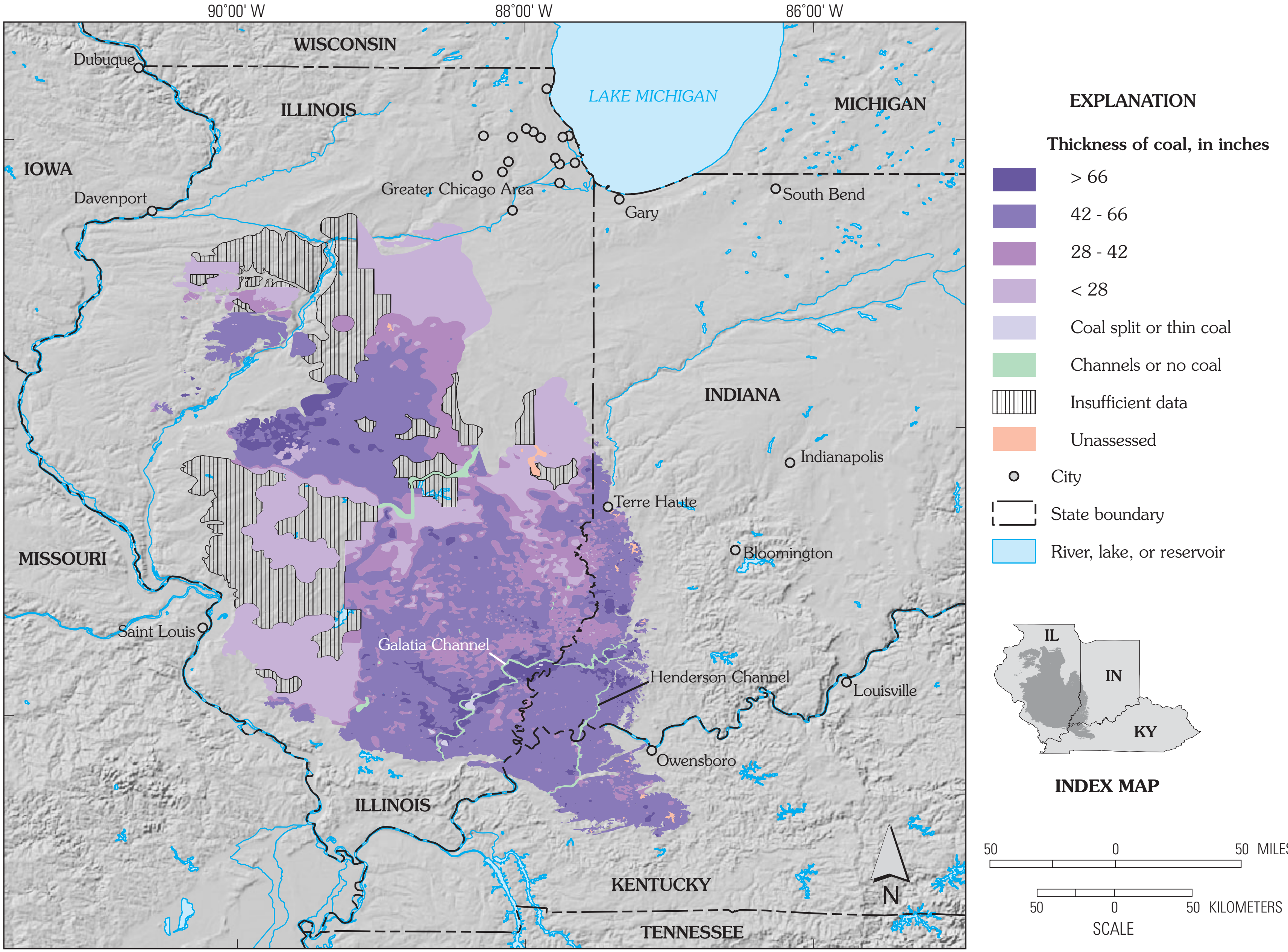

Figure 10. Map showing thickness of the Springfield Coal in Illinois, Indiana, and western Kentucky. This illustration was modified from regional shapefiles contained in the Illinois Basin ArcView project (Gunther and others, this publication).

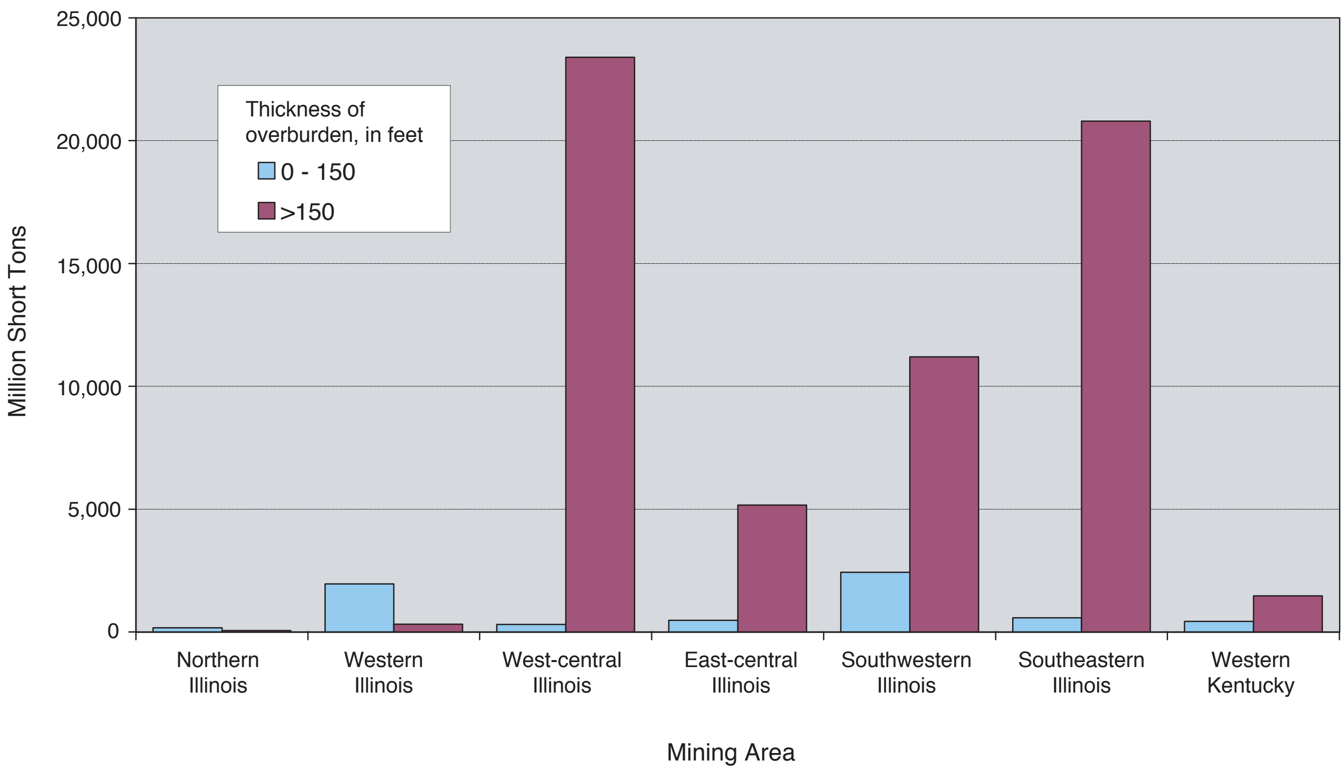

Figure 11. Histogram showing remaining, identified coal resources (>42 in. thick, million short tons) of the Herrin Coal in Illinois and western Kentucky, summarized by mining area and by overburden thickness (coal depth). Data are from table 9. Identified resources include categories I–A, I–B, and II–A in Illinois and Indiana, and measured, indicated, and inferred in western Kentucky.

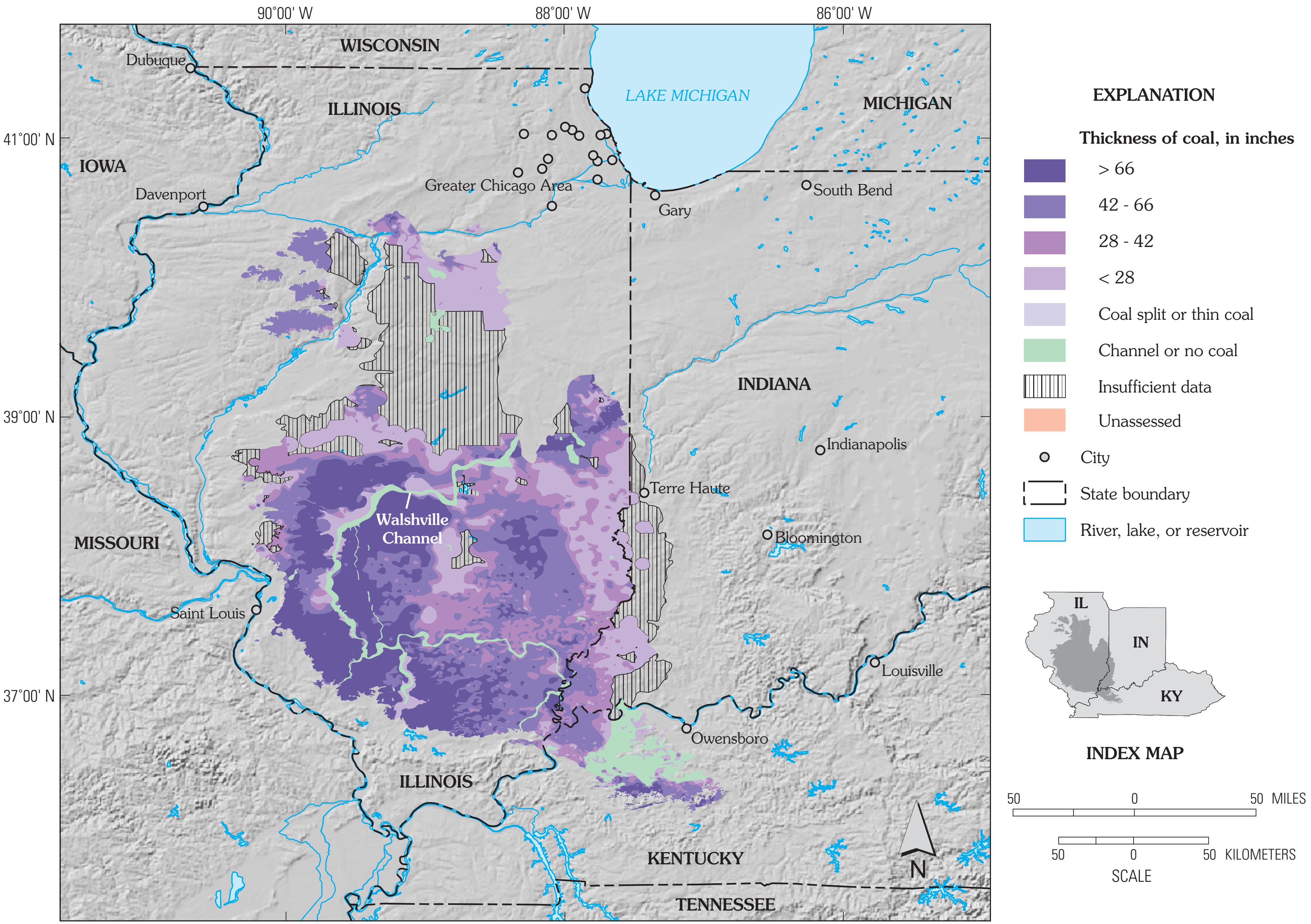

Figure 12. Map showing thickness of the Herrin Coal in Illinois, Indiana, and western Kentucky. This illustration was modified from regional shapefiles contained in the Illinois Basin ArcView project (Gunther and others, this publication).

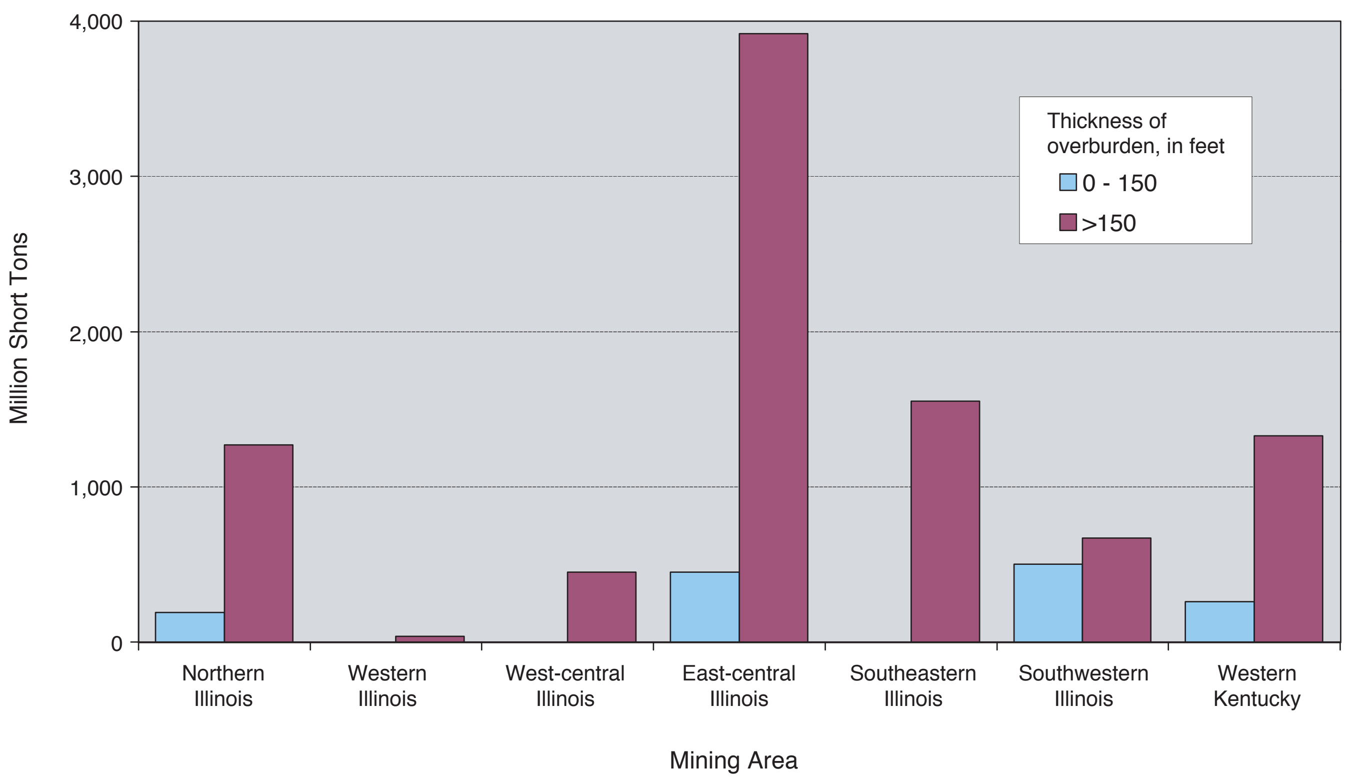

Figure 13. Histogram showing remaining, identified coal resources (>42 in. thick, million short tons) of the Danville Coal Member in Illinois and Indiana, and the Baker coal in western Kentucky, summarized by mining area and by overburden thickness (coal depth). Data are from table 10. Identified resources include categories I–A, I–B, and II–A in Illinois and Indiana, and measured, indicated, and inferred in western Kentucky.

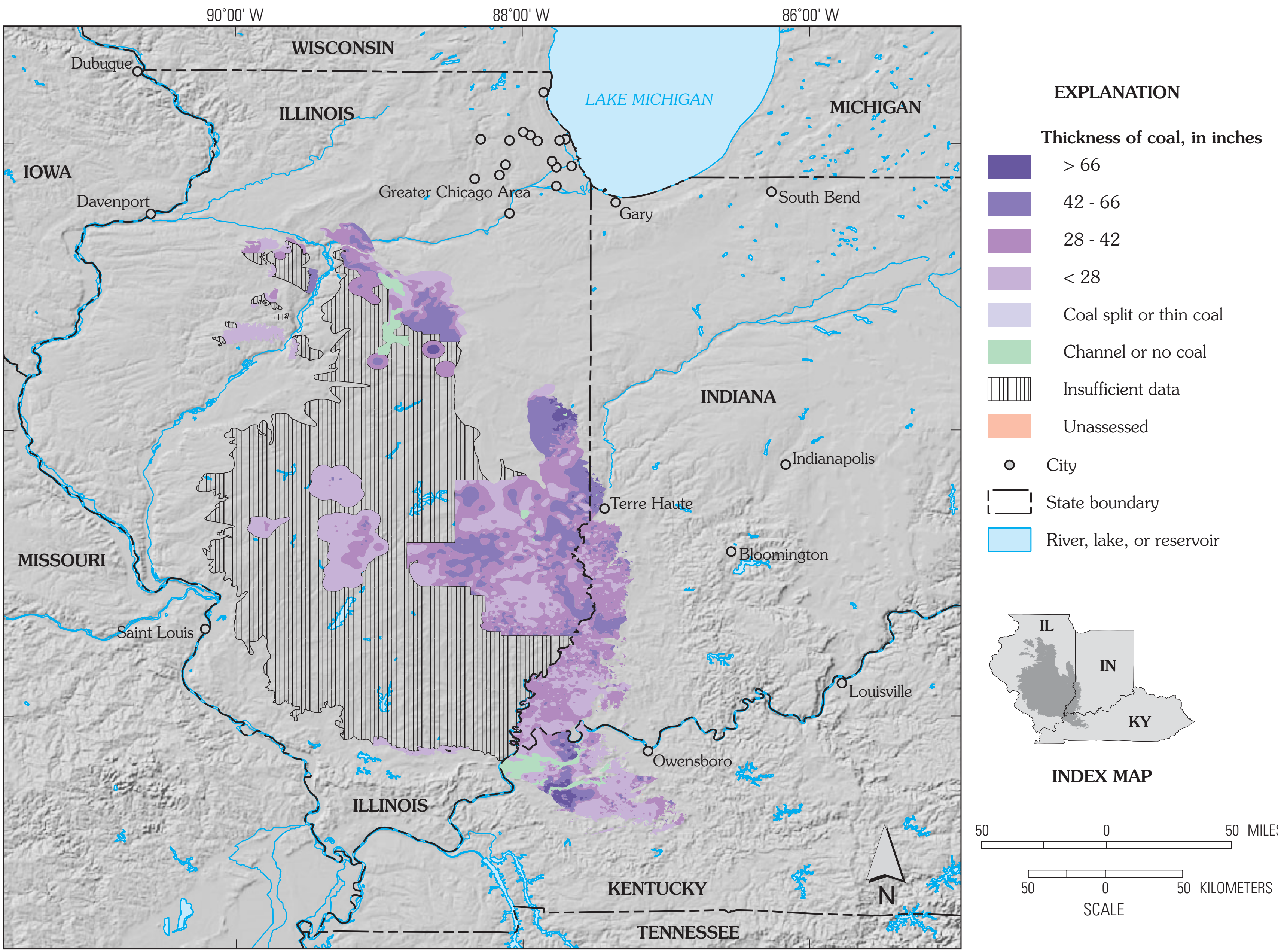

Figure 14. Map showing thickness of the Danville Coal Member in Illinois and Indiana, and the Baker coal in western Kentucky. This illustration was modified from regional shapefiles contained in the Illinois Basin ArcView project (Gunther and others, this publication).

Table 8. Summary of estimated remaining, identified resources of the Springfield Coal in Illinois, Indiana, and western Kentucky.

[Data are from appendix 1. Identified resources include geologic reliability categories I–A, I–B, and II–A for Illinois and Indiana, and measured, indicated, and inferred for Kentucky. Resources are listed by mining area and are categorized by overburden thickness (coal depth) and coal thickness. Resource numbers are rounded to two significant figures, or to the nearest one hundred million short tons for resources greater than ten billion short tons. Columns may not sum exactly due to rounding.]

Mining area	Coal depth (feet)	Remaining, identified resources (million short tons)			
		Coal thickness (inches)			
		>14-28	>28-42	>42	All
Northern Illinois	0 – 150	0	0	37	37
	> 150	0	2,200	2,500	4,700
	Subtotal	0	2,200	2,500	4,700
Western Illinois	0 – 150	380	450	1,200	2,000
	> 150	0	68	480	550
	Subtotal	380	520	1,700	2,600
West-central Illinois	0 – 150	0	0	1,100	1,100
	> 150	0	2,400	15,600	18,000
	Subtotal	0	2,400	16,700	19,100
East-central Illinois	0 – 150	17	9	13	39
	> 150	0	1,700	3,700	5,400
	Subtotal	17	1,700	3,700	5,500
Southwestern Illinois	0 – 150	12	98	250	370
	> 150	0	89	300	380
	Subtotal	12	190	550	740
Southeastern Illinois	0 – 150	0	4	370	370
	> 150	0	5,400	23,200	28,600
	Subtotal	0	5,400	23,600	29,000
Illinois	0 – 150	410	560	3,000	4,000
	> 150	0	11,900	45,800	57,700
	Subtotal	410	12,400	48,800	61,700
Indiana	0 – 150	25	280	1,800	2,100
	> 150	150	1,500	8,400	10,100
	Subtotal	180	1,700	10,200	12,100
Western Kentucky	0 – 150	1	17	960	990
	> 150	9	180	5,800	6,000
	Subtotal	10	200	6,800	7,000
Illinois Basin	0 – 150	430	860	5,700	7,000
	> 150	160	13,500	60,000	73,700
	Total	590	14,400	65,700	80,700

Table 9. Summary of estimated remaining, identified resources of the Herrin Coal in Illinois and western Kentucky.

[Data are from appendix 2. Identified resources include geologic reliability categories I–A, I–B, and II–A for Illinois and measured, indicated, and inferred for western Kentucky. Resources are listed by mining area and are categorized by overburden thickness (coal depth) and coal thickness. Resource numbers are rounded to two significant figures, or to the nearest one hundred million short tons for resources greater than ten billion short tons. Columns may not sum exactly due to rounding.]

Mining area	Coal depth (feet)	Remaining, identified resources (million short tons)			
		Coal thickness (inches)			
		>14-28	>28-42	>42	All
Northern Illinois	0 – 150	77	140	170	390
	> 150	0	330	62	390
	Subtotal	77	470	230	780
Western Illinois	0 – 150	15	470	2,000	2,500
	> 150	0	130	320	450
	Subtotal	15	600	2,300	2,900
West-central Illinois	0 – 150	98	600	300	990
	> 150	0	2,800	23,400	26,100
	Subtotal	98	3,400	23,700	27,100
East-central Illinois	0 – 150	81	56	470	610
	> 150	0	2,200	5,200	7,400
	Subtotal	81	2,300	5,700	8,000
Southwestern Illinois	0 – 150	2	17	2,400	2,400
	> 150	0	150	11,200	11,300
	Subtotal	2	170	13,600	13,800
Southeastern Illinois	0 – 150	3	47	580	630
	> 150	0	4,900	20,800	25,700
	Subtotal	3	4,900	21,400	26,300
Illinois	0 – 150	280	1,300	5,900	7,600
	> 150	0	10,500	60,900	71,400
	Subtotal	280	11,800	66,800	78,900
Western Kentucky	0 – 150	47	74	430	550
	> 150	140	460	1,500	2,100
	Subtotal	180	530	1,900	2,600
Illinois Basin	0 – 150	320	1,400	6,300	8,100
	> 150	140	11,000	62,400	73,500
	Total	460	12,400	68,700	81,600

Table 10. Summary of estimated remaining, identified resources of the Danville Coal in Illinois and Indiana, and the Baker coal in western Kentucky.

[Data are from appendix 3. Identified resources include geologic reliability categories I–A, I–B, and II–A for Illinois and Indiana, and measured, indicated, and inferred for Kentucky. Resources are listed by mining area and are categorized by overburden thickness (coal depth) and coal thickness. Resource numbers are rounded to two significant figures, or to the nearest one hundred million short tons for resources greater than ten billion short tons. Columns may not sum exactly due to rounding.]

Mining area	Coal depth (feet)	Remaining, identified resources (million short tons)			
		Coal thickness (inches)			
		>14-28	>28-42	>42	All
Northern Illinois	0 – 150	290	340	190	810
	> 150	570	950	1,300	2,800
	Subtotal	850	1,300	1,500	3,600
Western Illinois	0 – 150	430	200	0	630
	> 150	0	150	37	190
	Subtotal	430	350	37	820
West-central Illinois	0 – 150	0	0	0	0
	> 150	18	1,300	450	1,800
	Subtotal	18	1,300	450	1,800
East-central Illinois	0 – 150	57	350	450	850
	> 150	0	2,500	3,900	6,400
	Subtotal	57	2,800	4,400	7,300
Southeastern Illinois	0 – 150	120	4	0	120
	> 150	0	2,700	1,500	4,200
	Subtotal	120	2,700	1,500	4,300
Illinois	0 – 150	900	880	630	2,400
	> 150	590	7,600	7,300	15,500
	Subtotal	1,500	8,500	8,000	17,900
Indiana	0 – 150	210	840	500	1,600
	> 150	1,200	2,900	670	4,700
	Subtotal	1,400	3,700	1,200	6,300
Western Kentucky	0 – 150	310	360	260	930
	> 150	580	500	1,300	2,400
	Subtotal	890	870	1,600	3,400
Illinois Basin	0 – 150	1,400	2,100	1,400	4,900
	> 150	2,300	11,000	9,200	22,500
	Total	3,700	13,100	10,600	27,400

Confidence Limits for Resource Estimates of Illinois Basin Coals

By J.H. Schuenemeyer,[1] H.C. Power,[2] *and* J.R. Hatch[1]

Methodology

As part of the current USGS coal resource assessment, a geostatistical procedure has been developed (Schuenemeyer and Power, 2000) to estimate the uncertainty of coal resource calculations for the geological reliability categories used in the Illinois Basin The procedure of Schuenemeyer and Power (2000) involves trend removal, an examination of spatial correlation, computation of a sample variogram, and fitting a semi-variogram model. In the Illinois Basin, the data consist of spatially clustered coal-thickness measurements from coal beds that cover areas from 853 to 14,050 mi^2. The number of drill holes is generally proportional to areal extent. This model provides standard deviations for the uncertainty estimates. The minimum number of sample points for each reliability category was estimated (called a pseudo n) by dividing the area measured by the area determined by the maximum distance for a category (as examples, 0.5 mi for I–A, 0.25 mi for indicated). Measurement errors in coal bed thickness were then obtained from the fitted model. From this information, approximate estimates of uncertainty (confidence interval) for each reliability category were computed. A complete explanation of this procedure (with examples) is in Schuenemeyer and Powers (2000).

Results

Based on the above outlined procedure, volumes of the Springfield, Herrin, Danville, and Baker Coals were calculated at a 90-percent confidence interval on the volume (total resource in million short tons) of coal with measurement error for each geological reliability category used in the Illinois Basin. For Illinois and Indiana, resources are reported by categories of I–A (0–0.5 mi from a data point), I–B (>0.5–2 mi), and II–A (>2–4 mi). Resources in western Kentucky are reported by categories of measured (0–0.25 mi from a data point), indicated (0.25–0.75 mi), inferred (0.75–3.0 mi), and hypothetical (>3.0 mi). Although the state resource estimates listed in appendixes 1–3 and summarized in tables 8–10 were computed by using both the available public and proprietary data, only the publicly available data from each state were used to make the uncertainty calculations. The number of publicly available data points ranged from 16,325 for the Herrin Coal Member in Illinois to 653 for the Herrin coal in western Kentucky. If both the public and proprietary data points were to be used for the calculations, the estimates of uncertainty would most likely be less.

Summaries of the calculations of confidence intervals for geological reliability categories for the Springfield, Herrin, and Danville Coal Members in Illinois are shown in tables 11—13; for the Springfield and Danville Coal Members in Indiana, tables 14 and 15; and for the Springfield, Herrin, and Baker coals in western Kentucky, tables 16—18. Because of the generally low variability in coal thickness for the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin, estimates of uncertainty are also low. Ranges of the estimated percent errors for the various reliability categories from tables 11—18 are shown in figure 15.

Discussion

For the Springfield, Herrin, and Danville Coal Members in Illinois and the Springfield and Danville Coal Members in Indiana, estimated percent error for reliability category I–A ranges from <1 to 2 percent; for reliability category I–B it ranges from 2 to 6 percent (fig. 15). For category II–A in Illinois, estimated percent error ranges from 4 to 9 percent, whereas for category II–A in Indiana, percent error is much higher, 37 percent for the Springfield and 40 percent for the Danville. For the Springfield, Herrin, and Baker coals in western Kentucky, estimated percent error for the measured resources ranges from <1 to 2 percent; for indicated resources, 2 to 5 percent; for inferred resources, 5 to 16 percent; and for hypothetical resources, 34 to 77 percent. For the combined categories I–A, I–B, and II–A for Illinois and Indiana, estimated percent error ranges from 3 to 6 percent. For the combined measured, indicated, inferred, and hypothetical resources in western Kentucky, estimated percent error ranges from 5 to 15 percent.

As shown in figure 15, the uncertainty (<1 to 2 percent) for category I–A resources as used in Illinois and Indiana is comparable to the uncertainty (<1 to 2 percent) for measured resources as used in western Kentucky. Similarly, the uncertainty (2 to 6 percent) for I–B resources in Illinois and Indiana is comparable to the uncertainty (2 to 5 percent) for indicated resources in western Kentucky, and the uncertainty (4 to 9 percent) for II–A resources in Illinois is similar to, although not as high as, the uncertainty (5 to 16 percent) for inferred resources in western Kentucky. In contrast, the uncertainty (37 to 40 percent) for II–A resources in Indiana is similar to the range of uncertainty (34 to 77 percent) for hypothetical resources in western Kentucky.

These studies show that in addition to "distance from a data point," other geologic characteristics (for example, variability in coal thickness) of the coal have to be understood if resource reliability categories for a coal are to be comparable to those assigned to other coals in the basin or in other basins.

Reference Cited—Confidence Limits

Schuenemeyer, J.H., and Power, H.C., 2000, Uncertainty estimation for resource assessment—An application to coal: Mathematical Geology, v. 32, p. 521–541.

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Table 11. Estimates of uncertainty (calculated with measurement error) of coal resource estimates for the Springfield Coal Member in Illinois.

[To show detail, resources are reported in million short tons to three significant figures. Resources will not sum due to independent rounding. I–A resources are within 0.5 mi of a data point; I–B resources, >0.5–2 mi; and II–A resources, >2–4 mi. Number of publicly available data points = 10,630. NA, not applicable.]

Parameter	Reliability Category			
	I-A	I-B	II-A	Entire area
Area (acres)	705,000	2,501,000	5,255,000	8,462,000
Percent of area	8	30	62	100
Pseudo n^* = minimum number of points in area	1403	311	163	NA
Half interval width (90% confidence interval)	48	419	1,337	1,805
Percent error (half interval width / volume) x 100	<1	2	4	3
Lower 90% confidence bound (million short tons)	5,960	19,100	34,500	59,600
Volume (million short tons)	6,000	19,600	35,800	61,400
Upper 90% confidence bound (million short tons)	6,050	20,000	37,200	63,200

Table 12. Estimates of uncertainty (calculated with measurement error) of coal resource estimates for the Herrin Coal Member in Illinois.

[To show detail, resources are reported in million short tons to three significant figures. Resources will not sum due to independent rounding. I–A resources are within 0.5 mi of a data point; I–B resources, >0.5–2 mi; and II–A resources, >2–4 mi. Number of publicly available data points = 16,325. NA, not applicable.]

Parameter	Reliability Category			
	I-A	I-B	II-A	Entire area
Area (acres)	1,749,000	3,637,000	3,604,000	8,989,000
Percent of area	19	41	40	100
Pseudo n^* = minimum number of points in area	3,479	452	112	NA
Half interval width (90% confidence interval)	100	610	1,290	2,000
Percent error (half interval width / volume) x 100	<1	2	5	3
Lower 90% confidence bound (million short tons)	19,100	33,800	24,100	76,900
Volume (million short tons)	19,200	34,400	25,400	78,900
Upper 90% confidence bound (million short tons)	19,300	35,000	26,700	80,900

Table 13. Estimates of uncertainty (calculated with measurement error) of coal resource estimates for the Danville Coal Member in Illinois.

[To show detail, resources are reported in million short tons to three significant figures. Resources will not sum due to independent rounding. I–A resources are within 0.5 mi of a data point; I–B resources, >0.5–2 mi; and II–A resources, >2–4 mi. Number of publicly available data points = 6,465. NA, not applicable.]

Parameter	Reliability Category			
	I-A	I-B	II-A	Entire area
Area (acres)	254,000	1,247,000	1,520,000	3,021,000
Percent of area	8	41	50	100
Pseudo n^* = minimum number of points in area	505	155	47	NA
Half interval width (90% confidence interval)	37	332	732	1,100
Percent error (half interval width / volume) x 100	2	4	9	6
Lower 90% confidence bound (million short tons)	1,810	7,180	7,720	16,700
Volume (million short tons)	1,850	7,510	8,450	17,800
Upper 90% confidence bound (million short tons)	1,890	7,840	9,180	18,900

Table 14. Estimates of uncertainty (calculated with measurement error) of coal resource estimates for the Springfield Coal Member in Indiana.

[To show detail, resources are reported in million short tons to three significant figures. Resources will not sum due to independent rounding. I–A resources are within 0.5 mi of a data point; I–B resources, >0.5–2 mi; and II–A resources, >2–4 mi. Number of publicly available data points = 4,842. NA, not applicable.]

Parameter	Reliability Category			
	I-A	I-B	II-A	Entire area
Area (acres)	1,031,000	705,000	68,600	1,805,000
Percent of area	57	39	4	100
Pseudo n^* = minimum number of points in area	2051	88	2	NA
Half interval width (90% confidence interval)	74	280	177	531
Percent error (half interval width / volume) x 100	1	6	37	5
Lower 90% confidence bound (million short tons)	6,610	4,460	296	11,400
Volume (million short tons)	6,680	4,740	473	11,900
Upper 90% confidence bound (million short tons)	6,750	5,020	649	12,400

Table 15. Estimates of uncertainty (calculated with measurement error) of coal resource estimates for the Danville Coal Member in Indiana.

[To show detail, resources are reported in million short tons to three significant figures. Resources will not sum due to independent rounding. I–A resources are within 0.5 mi of a data point; I–B resources, >0.5–2 mi; and II–A resources, >2–4 mi. Number of publicly available data points = 3,088. NA, not applicable.]

Parameter	Reliability Category			
	I-A	I-B	II-A	Entire area
Area (acres)	707,000	571,000	55,900	1,334,000
Percent of area	53	43	4	100
Pseudo n^* = minimum number of points in area	1407	71	2	NA
Half interval width (90% confidence interval)	35	142	96	273
Percent error (half interval width / volume) x 100	1	5	40	4
Lower 90% confidence bound (million short tons)	3,280	2,550	145	5,980
Volume (million short tons)	3,320	2,690	241	6,250
Upper 90% confidence bound (million short tons)	3,350	2,830	337	6,520

Table 16. Estimates of uncertainty (calculated with measurement error) of coal resource estimates for the Springfield coal in western Kentucky.

[To show detail, resources are reported in million short tons to three significant figures. Resources will not sum due to independent rounding. Measured resources are within 0.25 mi of a data point; indicated resources, >0.25–0.75 mi; inferred resources, >0.75–3 mi; and hypothetical resources, >3 mi. Number of publicly available data points = 984. NA = not applicable.]

Parameter	Reliability Category				
	Measured	Indicated	Inferred	Hypo-thetical	Entire area
Area (acres)	198,000	379,000	566,000	73,800	1,218,000
Percent of area	16	31	47	6	100
Pseudo n^* = minimum number of points in area	1576	335	31	1	NA
Half interval width (90% confidence interval)	8	33	181	176	399
Percent error (half interval width / volume) x 100	<1	2	5	34	5
Lower 90% confidence bound (million short tons)	1,050	2,200	3,520	347	7,110
Volume (million short tons)	1,060	2,230	3,700	524	7,510
Upper 90% confidence bound (million short tons)	1,070	2,270	3,880	700	7,910

Table 17. Estimates of uncertainty (calculated with measurement error) of coal resource estimates for the Herrin coal in western Kentucky.

[To show detail, resources are reported in million short tons to three significant figures. Resources will not sum due to independent rounding. Measured resources are within 0.25 mi of a data point; indicated resources, >0.25–0.75 mi; inferred resources, >0.75–3 mi; and hypothetical resources, >3 mi. Number of publicly available data points = 650. NA, not applicable.]

Parameter	Reliability Category				
	Measured	Indicated	Inferred	Hypo-thetical	Entire area
Area (acres)	104,000	167,000	231,000	43,900	546,000
Percent of area	19	31	42	8	100
Pseudo n^* = minimum number of points in area	829	148	13	1	NA
Half interval width (90% confidence interval)	8	37	193	132	371
Percent error (half interval width / volume) x 100	2	4	15	45	13
Lower 90% confidence bound (million short tons)	463	799	1,110	160	2,540
Volume (million short tons)	471	836	1,310	293	2,910
Upper 90% confidence bound (million short tons)	480	873	1,500	425	3,280

Table 18. Estimates of uncertainty (calculated with measurement error) of coal resource estimates for the Baker coal in western Kentucky.

[To show detail, resources are reported in million short tons to three significant figures. Resources will not sum due to independent rounding. Measured resources are within 0.25 mi of a data point; indicated resources, >0.25–0.75 mi; inferred resources, >0.75–3 mi; and hypothetical resources, >3 mi. Number of publicly available data points = 2,343. NA, not applicable.]

Parameter	Reliability Category				
	Measured	Indicated	Inferred	Hypo-thetical	Entire area
Area (acres)	120,000	212,000	334,000	66,100	733,000
Percent of area	16	29	46	9	100
Pseudo n^* = minimum number of points in area	956	188	18	1	NA
Half interval width (90% confidence interval)	10	49.0	256	218	533
Percent error (half interval width / volume) x 100	2	5	16	77	15
Lower 90% confidence bound (million short tons)	621	1,060	1,360	64	3,100
Volume (million short tons)	631	1,110	1,610	282	3,640
Upper 90% confidence bound (million short tons)	642	1,160	1,870	500	4,170

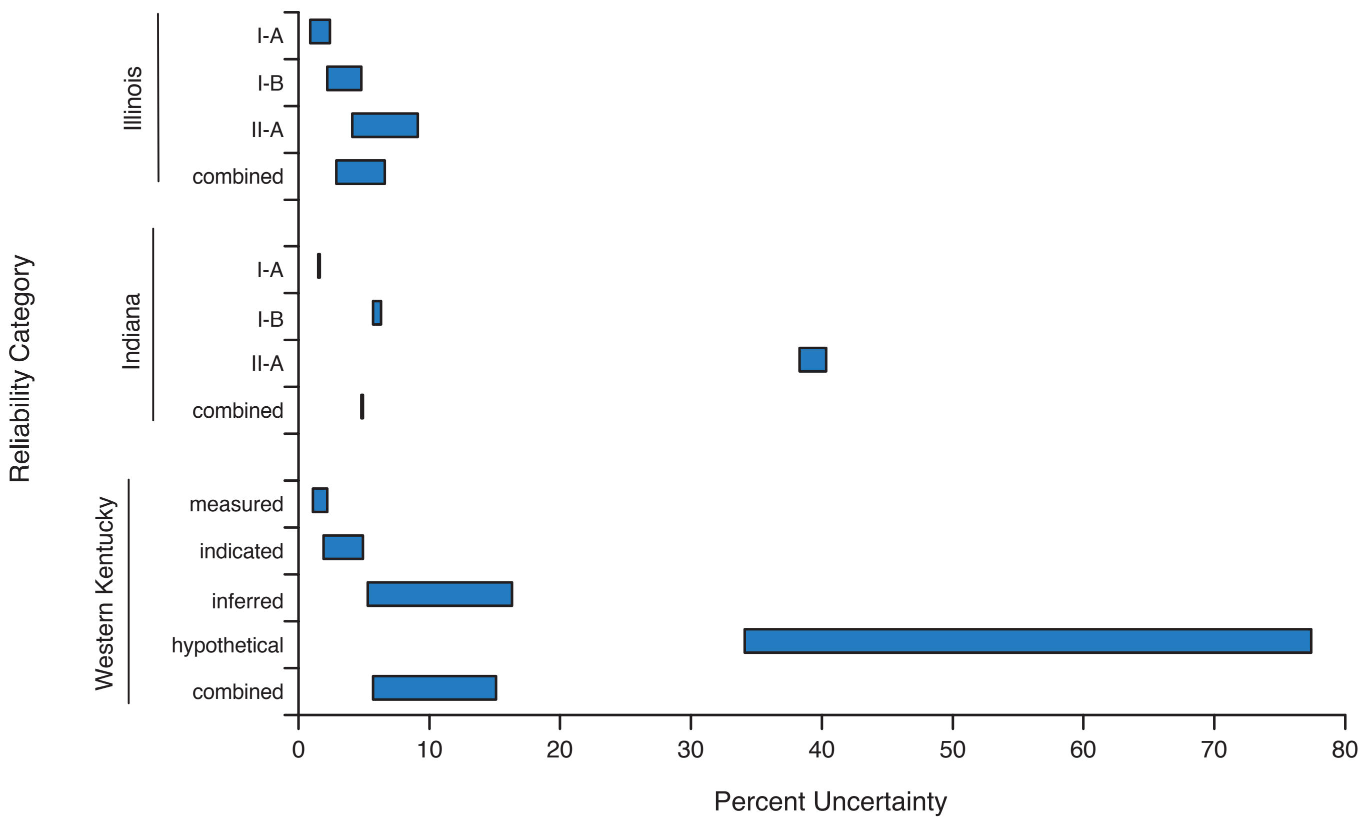

Figure 15. Graph showing range in percent uncertainty (at the 90 percent confidence level) for coal resource reliability categories from Illinois (range for three coals), Indiana (range for two coals), and western Kentucky (range for three coals). I–A resources are within 0.5 mi of a data point; I–B resources, >0.5–2 mi; and II–A resources, >2–4 mi. Measured resources are within 0.25 mi of a data point; indicated resources, >0.25–0.75 mi; inferred resources, >0.75–3 mi; and hypothetical resources, >3 mi.

Availability and Recoverability of Illinois Basin Coals

By L.M. Osmonson,[1] C.G. Treworgy,[2] C.L. Connolly,[3]
W.A. Andrews,[4] G.A. Weisenfluh,[4] M.D. Carter,[1] *and* J. R. Hatch[1]

Introduction

Coal Availability, a cooperative program between the USGS and various State geological surveys, has been assessing coal resources within various coal regions to determine how much is potentially available for mining (Carter and Gardner, 1989; Eggleston and others, 1990; Carter and others, 1995). The coal resource available for mining is significantly less than estimates of coal in the ground because resources are unavailable due to land-use and technological restrictions. The Coal Recoverability Program of the USGS and the former U.S. Bureau of Mines addresses the technological, economic, and environmental restrictions that may affect the extractability of coal. Coal recoverability considerations modify the available coal resource estimates to reflect the current state of mining technology, present and near-future market conditions, and the impact of 1990 Amendment to the Clean Air Act (Plis and others, 1993; Rohrbacher and others, 1993; Suffredini and others, 1994; Staff, U.S. Bureau of Mines, Intermountain Field Operations Center, 1995).

Coal Availability

Availability of coal resources for an area is determined by calculating the original, in-place resource and then subtracting (a) the coal resources that have already been mined, (b) coal resources that are restricted by land-use considerations, and (c) coal resources that are restricted by technological considerations. Land-use restrictions apply to areas through which, or under which, mining is prohibited, either by law, or because of potential legal liabilities. Such restrictions to coal mining include

(1) Cities, towns, rural dwellings and buildings, cemeteries
(2) Rivers, lakes, reservoirs, major streams
(3) Major highways and rail lines, airports
(4) Power lines, pipelines, oil and gas wells
(5) National or State forests, parks, protected wildlife areas, recreation sites

An example of how land-use restrictions can limit coal mining on a quadrangle scale is shown in figure 16 for the Seelyville 7.5-minute quadrangle, Indiana (modified from Connolly and Krueger, 1997a).

Technological restrictions are mainly due to a geologic setting of the coal that affects the ability to physically extract the coal. Some of the restrictions affect only surface mining operations, some affect only underground mining operations, and some apply to both. Technological restrictions to coal mining include

(1) Coal depth and thickness (too deep or too thin)
(2) Mine barriers (needed between separate mines)
(3) Adjacent coal beds (overlie or underlie too closely)
(4) Structural problems (faulting or areas of weak rock)
(5) Overburden (unstable or too thin)
(6) Oil and gas wells (nonmineable buffers required around active wells)

A diagram illustrating some of the technological restrictions to coal mining is shown in figure 17 (modified from Axon, 1996).

In the Illinois Basin, coal availability studies have been completed for forty-one 7.5-minute quadrangles (nineteen in Illinois, ten in Indiana, and twelve in western Kentucky; fig. 18). Coal recoverability studies have been completed for 16 of the 41 quadrangles (eight in Illinois, three in Indiana, and five in western Kentucky). The quadrangles studied were selected on the basis of likely differences in both land use and technological restrictions and the availability of data, which permitted a variety of coal resource scenarios to be analyzed. For example, each quadrangle has its own unique combination of in-place coal resource size, current and (or) previous mining activity, geologic structure, cultural development, and land-management regulations. These 41 quadrangles also represent an average sampling of the potential coal resource development within each state, as well as throughout the Illinois Basin.

Results

Illinois

Coal availability studies for 19 representative 7.5-minute quadrangles in Illinois have been completed (Treworgy, Chenoweth, and Bargh, 1995; Jacobson and others, 1996; Treworgy, Chenoweth, and Jacobson, 1996; Treworgy, Chenoweth, and Justice, 1996; Treworgy and others, 1994, 1995, 1997, and 1998). Results of these studies are summarized in figures 19 and 20. Figure 19 shows that the original coal resources for all coals studied in the 19 quadrangles was about 10 billion short tons and that the remaining available coal is about 4.6 billion short tons (46 percent of the original coal resource). Figure 20 illustrates the amount of original resource, how much of the resource has been mined-out, or is not available because of land-use and technological restrictions, and the amounts of available coal for the Danville, Davis, Herrin, Seelyville, and Springfield Coal Members, the coals that have the largest estimated original resources in these 19 quadrangles. Figure 20 shows that

(1) Mining has been mainly from the Springfield and Herrin; production from the other three coals has been minimal.
(2) For all five coals, technological restrictions are the primary factors affecting the amounts of available coal.
(3) Technological and land-use restrictions leave little of the Danville available for future mining.

Indiana

Coal availability studies for 10 representative 7.5-minute quadrangles in Indiana have been completed (Cetin and others,

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1994, 1995; Conolly and Cetin, 1995, 1996; Cetin and Conolly, 1996a,b; Conolly and others, 1996; and Conolly and Krueger, 1997a,b, 1998). Results of these studies are summarized in figures 21 and 22. Figure 21 shows that the original coal resource for all coals studied in the 10 quadrangles was about 5.8 billion short tons and that the remaining available coal is about 3.3 billion short tons (57 percent of the original coal resource). Figure 22 illustrates the amount of original resource, how much of the resource has been mined out or is not available because of land-use and technological restrictions, and the amounts of available coal for the Danville, Hymera, Seelyville, Springfield, and Survant Coal Members, the coals that have the largest estimated original resources in these 10 quadrangles. Figure 22 shows that

(1) Mining has been primarily from the Springfield and Hymera, with lesser production from the Danville, Seelyville, and Survant Coal Members.
(2) For the Springfield, previous mining is the primary factor affecting coal availability; for the other four coals, technological restrictions are the primary factors.

Western Kentucky

Coal availability studies for 12 representative 7.5-minute quadrangles have been completed in western Kentucky (Weisenfluh and others, 1998). Results of this study are summarized in figures 23 and 24. Figure 23 shows that the original coal resource for all coals studied was about 5.1 billion short tons and that the remaining available coal is about 2.7 billion short tons (53 percent of the original coal resource). Figure 24 illustrates the amounts of original resource, how much of the resource has been mined-out, or is not available because of land-use and technological restrictions, and the amounts of available coal for the Baker, Davis, Herrin, Paradise, and Springfield coals, the coals that have the largest estimated original resources in these 12 quadrangles. Figure 24 shows that

(1) Mining has been primarily from the Springfield coal, with lesser production from the Baker, Herrin and Paradise coals, and minimal production from the Davis coal.
(2) For the Springfield coal, mined-out coal is the largest factor affecting coal availability, but for the other four coals, technological restrictions are the primary factors.

Coal Recoverability

Recoverability of coal resources for an area is determined by subtracting from the available coal resource the resources that cannot be removed during mining because of mine barriers, areas having an unstable mine roof or floor, areas where the mining slope would be too steep, and the resources that are lost during the cleaning process. The definition of available coal resources in calculating coal recoverability is a bit different than the definition as discussed in the above paragraphs. For coal recoverability, available coal includes partings within the coal because the partings cannot be removed during the mining process. The economically recoverable coal is the recoverable coal resource minus the recoverable resource that cannot be mined at a profit. The economics of coal mining vary and depend upon the mine location, characteristics of the coal, mined coal quality, mining method, shipping costs, and taxes.

In the Illinois Basin, coal recoverability studies have been completed for sixteen of the forty-one 7.5-minute quadrangles where coal availability studies have been completed. Eight of these are in Illinois, three are in Indiana, and five are in western Kentucky; quadrangle locations are shown in figure 18. These coal recoverability studies demonstrate that only a small percentage (from less than 1 percent to about 13 percent) of the original coal resource is economically mineable in today's coal market.

Results

Illinois

Coal recoverability studies for eight quadrangles in Illinois have been completed (Sullivan, 1995; DST and Associates unpublished contract studies, 1998a–c, 1999a–d). Results of these studies (illustrated in fig. 25) show that of the 7.1 billion short tons of original coal resource in place, only about 900 million short tons of coal can potentially be mined at a profit. This 900 million short tons is about 13 percent of the original coal resource.

Indiana

Coal recoverability studies for three quadrangles in Indiana have been completed (DST and Associates, 1998d,e, and 1999e). Results of these studies (illustrated in fig. 26) show that of the 2.4 billion short tons of original coal resource in place, only about 170 million short tons of coal can potentially be mined at a profit. This 170 million short tons is about 7 percent of the original coal resource.

Western Kentucky

Coal recoverability studies for five quadrangles in western Kentucky have been completed (Scott, 1997). Results of these studies (illustrated in figure 27) show that of the 2.8 billion short tons of original coal resource in place, only about 7 million short tons of coal can potentially be mined at a profit. This 7 million short tons is less than 1 percent of the original coal resource.

Summary

In summary, coal availability and coal recoverability studies in the Illinois Basin show that only a part of the original coal resources within the 7.5-minute quadrangles studied is available for development (46 percent of the resources for 19 quadrangles in Illinois, 57 percent for 10 quadrangles in Indiana, and 53 percent for 12 quadrangles in western Kentucky). Even less of the original resource is actually recoverable, and only a small percentage of the original coal resource is economically recoverable (13 percent of the resource for eight Illinois quadrangles, 7 percent for three Indiana quadrangles, and less than 1 percent for five quadrangles in western Kentucky).

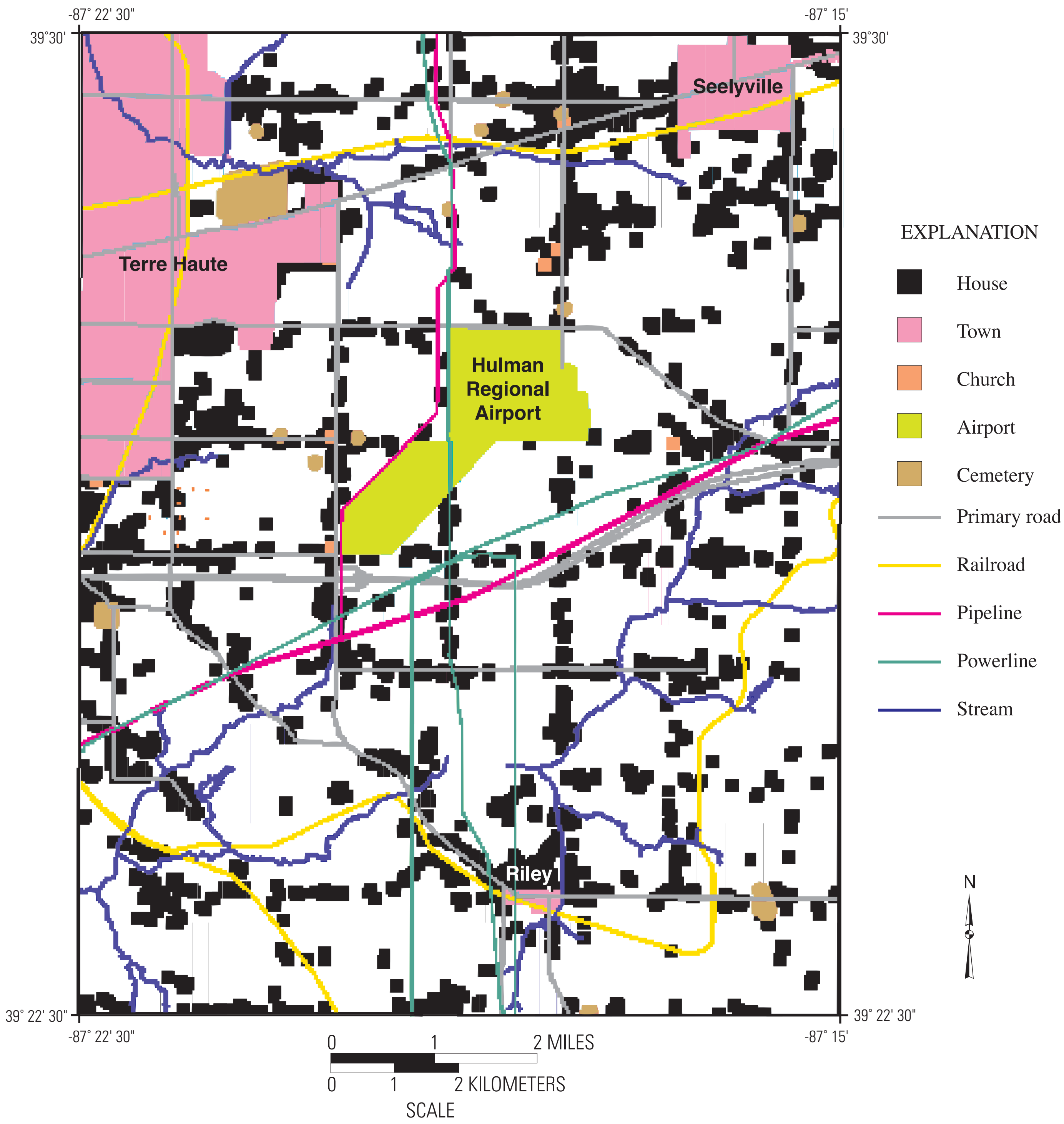

Figure 16. Map showing land use that can limit coal mining in the Seelyville 7.5-minute quadrangle, Indiana (modified from Conolly and Krueger, 1997a).

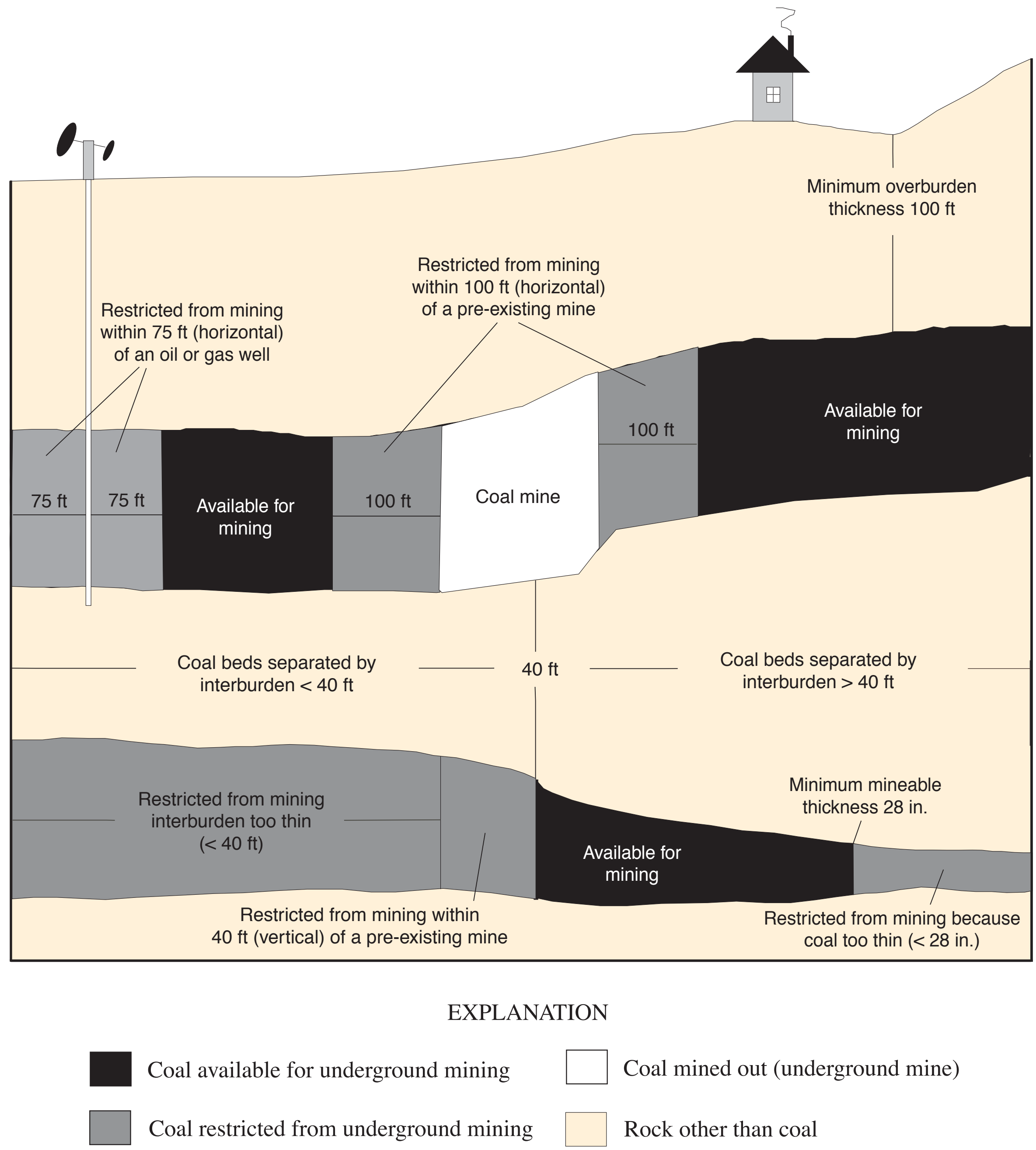

Figure 17. Diagram illustrating some of the technological restrictions on mining (modified from Axon, 1996).

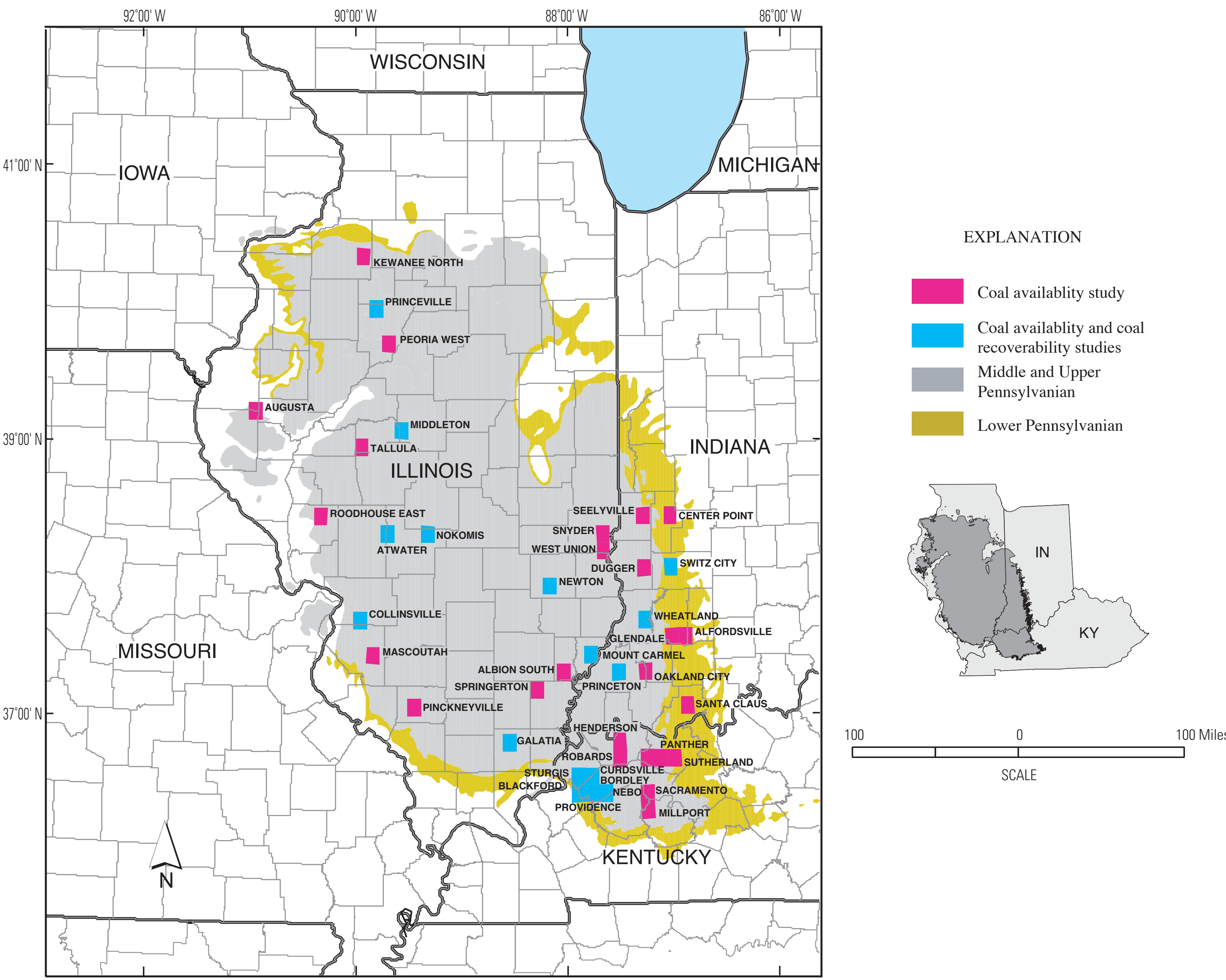

Figure 18. Map of the Illinois Basin showing county boundaries and locations of the 7.5-minute quadrangles studied for coal availability and coal recoverability.

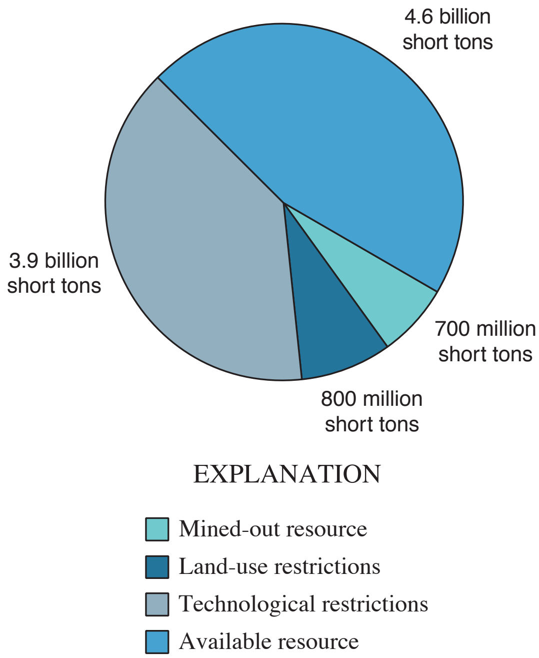

Figure 19. Chart showing results from coal availability studies for 19 representative 7.5-minute quadrangles in Illinois.

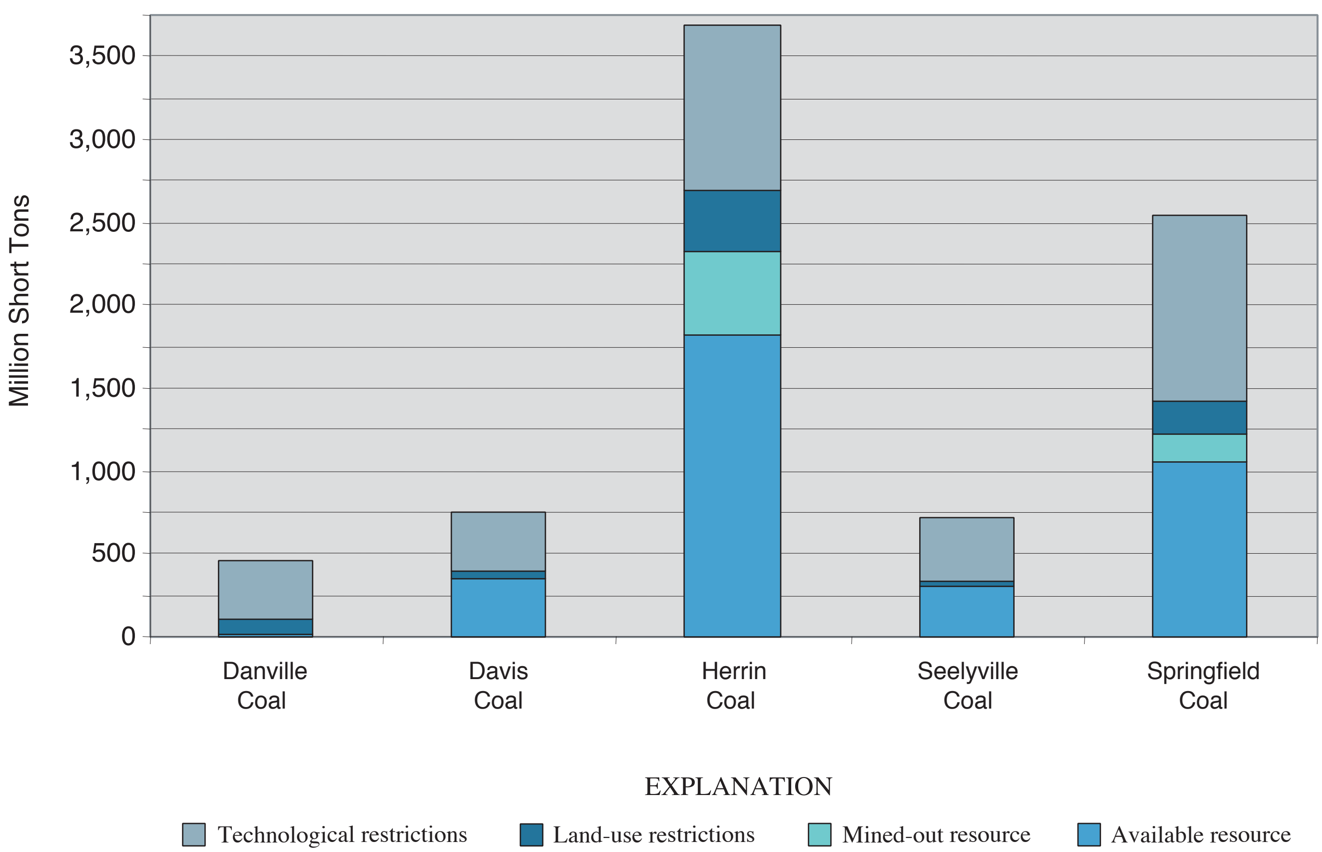

Figure 20. Chart comparing effects of restrictions on available coal resources for the Danville, Davis, Herrin, Seelyville, and Springfield Coal Members in 19 representative 7.5-minute quadrangles in Illinois.

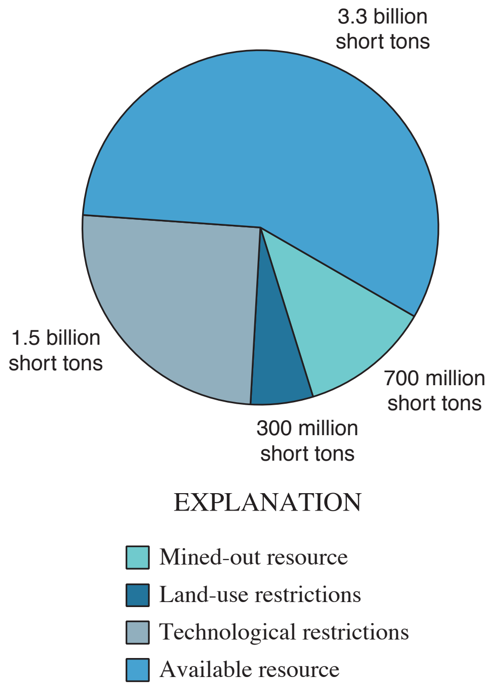

Figure 21. Chart showing results from coal availability studies for 10 representative 7.5-minute quadrangles in Indiana.

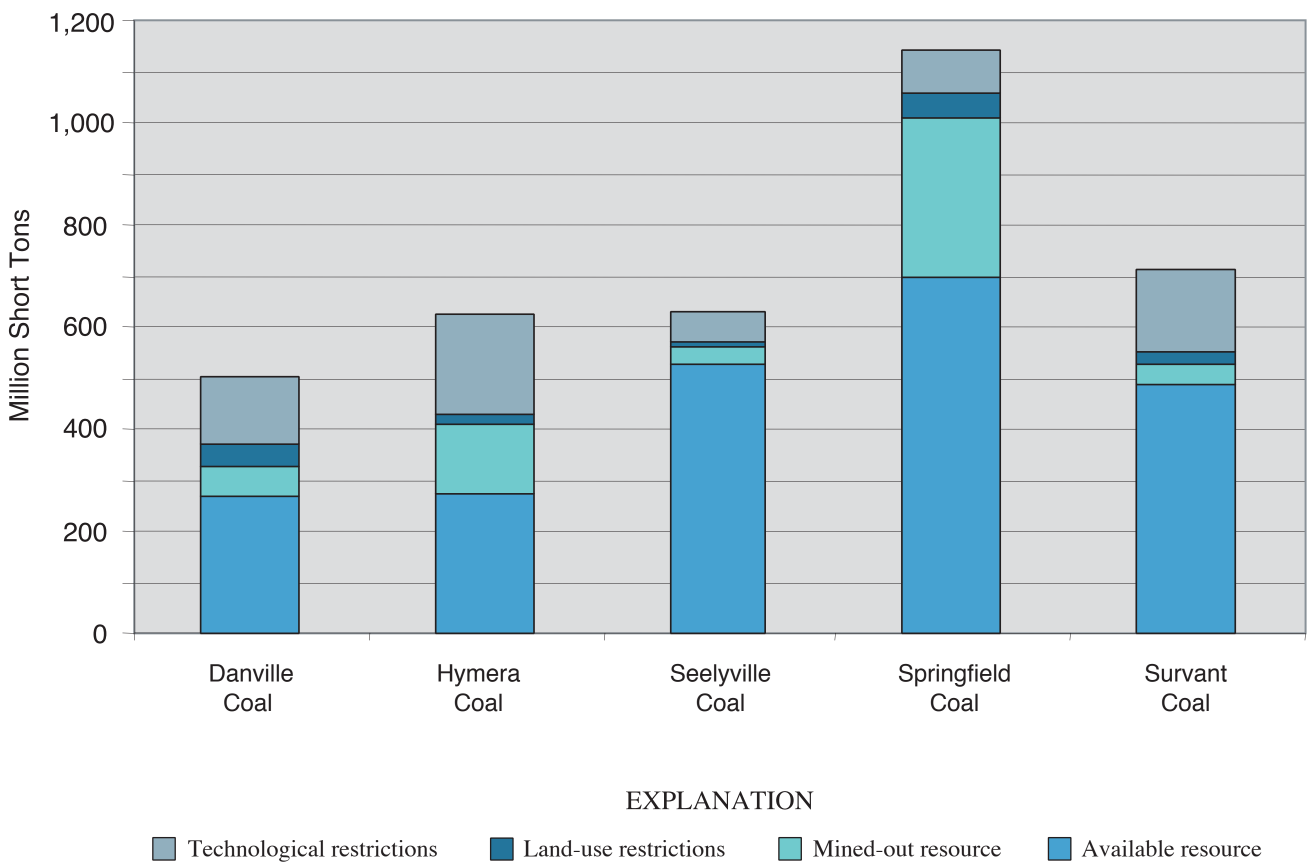

Figure 22. Chart comparing effects of restrictions on available coal resources for the Danville, Hymera, Seelyville, Springfield, and Survant Coal Members in 10 representative 7.5-minute quadrangles in Indiana.

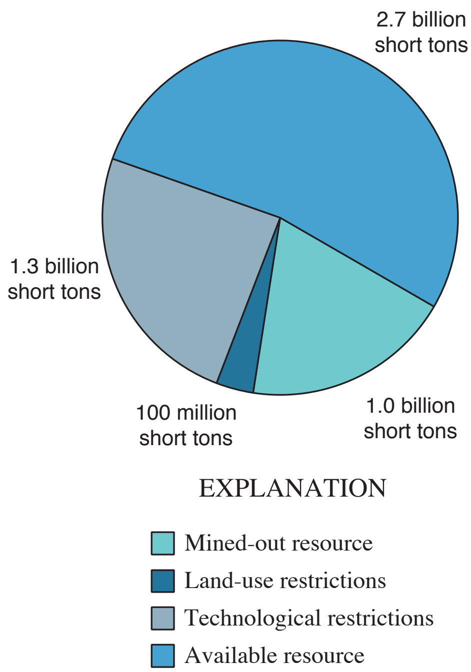

Figure 23. Chart showing results from coal availability studies for 12 representative 7.5-minute quadrangles in western Kentucky.

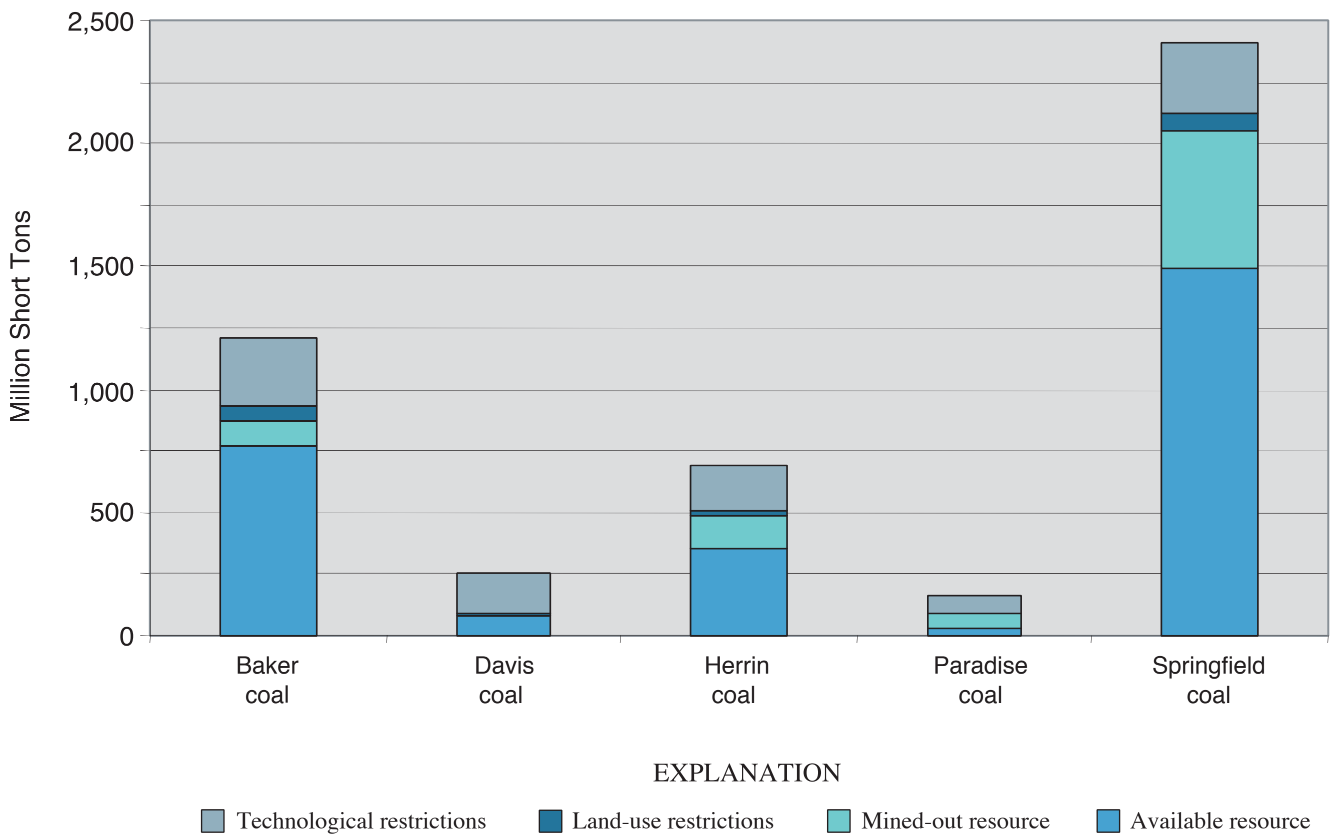

Figure 24. Chart comparing effects of restrictions on available coal resources for the Baker, Davis, Herrin, Paradise, and Springfield coals in 12 representative 7.5-minute quadrangles in western Kentucky.

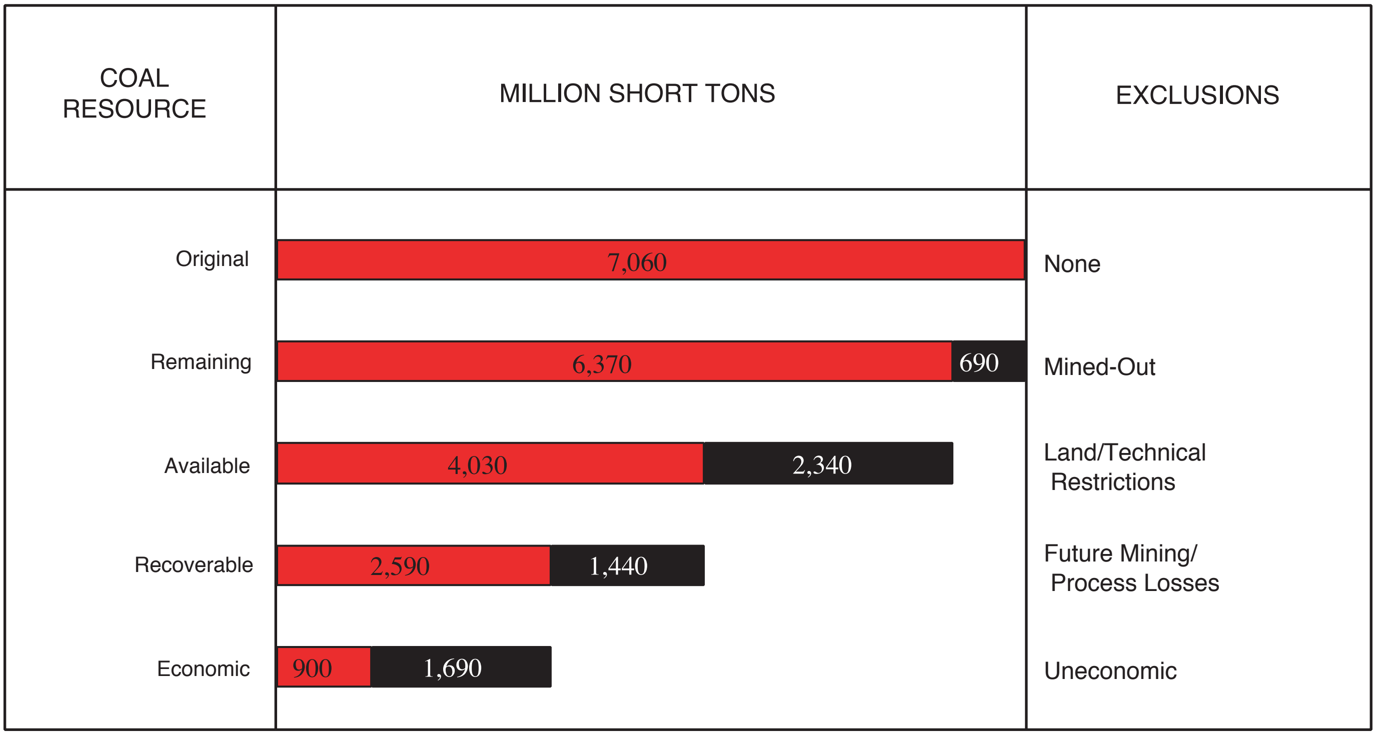

Figure 25. Chart showing results from coal availability and coal recoverability studies for eight 7.5-minute quadrangles in Illinois.

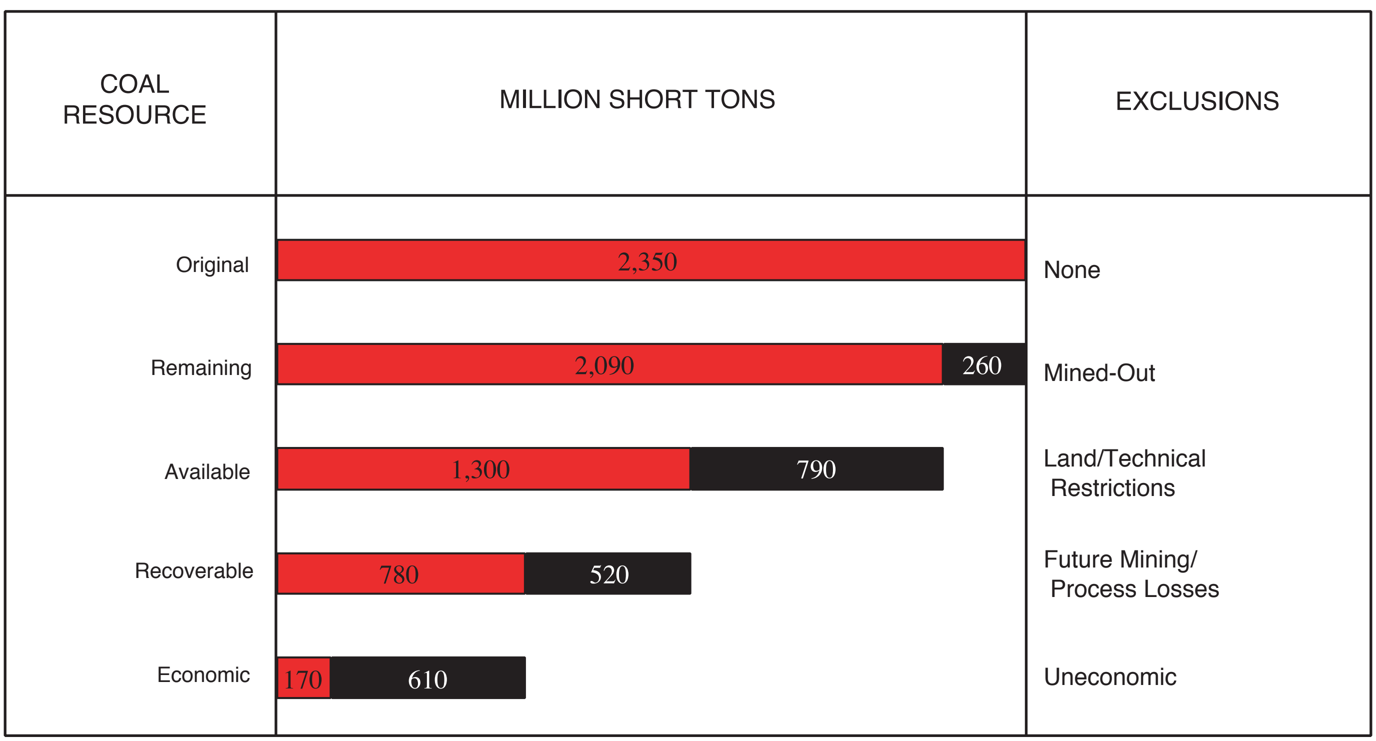

Figure 26. Chart showing results from coal availability and coal recoverability studies for three 7.5-minute quadrangles in Indiana.

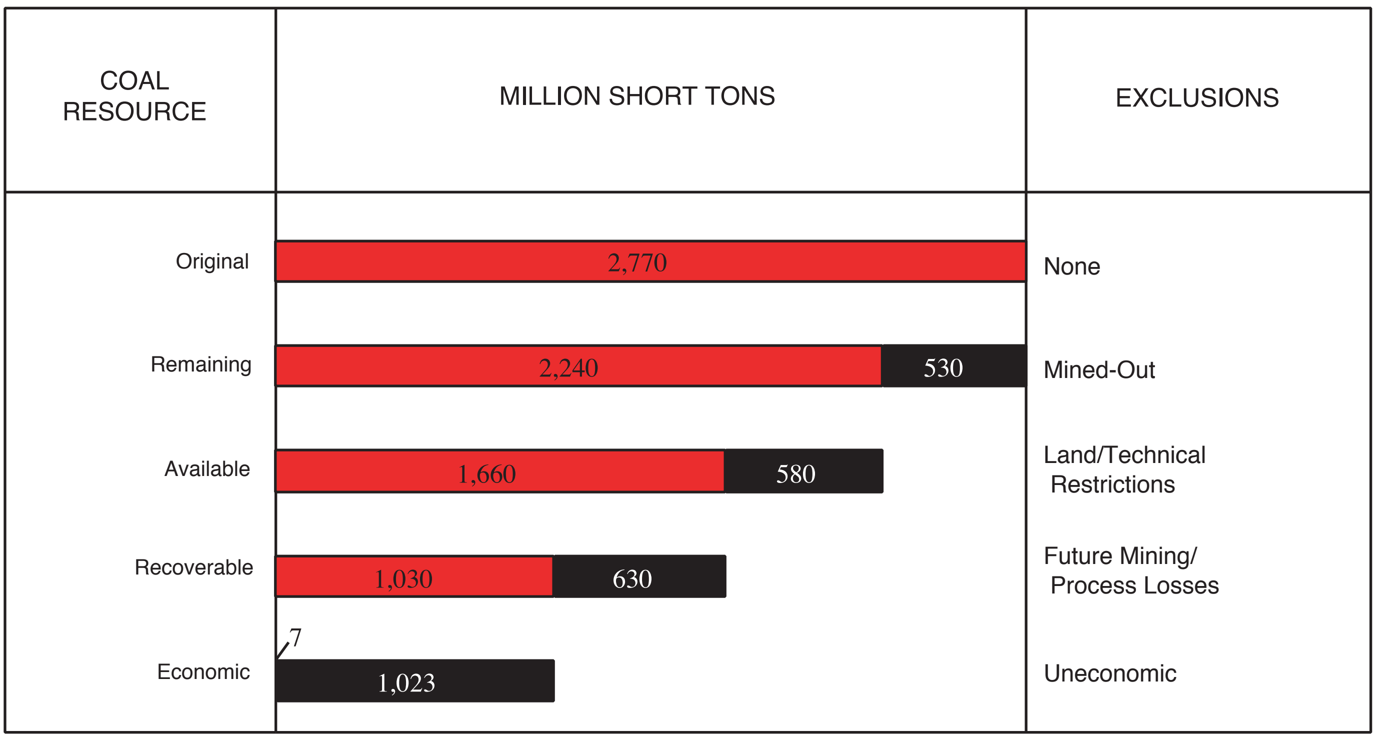

Figure 27. Chart showing results from coal availability and coal recoverability studies for five 7.5-minute quadrangles in western Kentucky.

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Appendixes 1–3

Appendix 1. Estimated remaining resources of the Springfield Coal in Illinois, Indiana, and western Kentucky.

[Resources are listed by mining area and county and are categorized by geologic reliability (I–A, 0–0.5 mi from a data point; I–B, >0.5–2 mi; II–A, >2–4 mi; measured, 0–0.25 mi; indicated, >0.25–0.75 mi; inferred, >0.75–3.0 mi; and hypothetical, >3 mi), coal thickness, and overburden thickness (coal depth). Resource numbers are rounded to two significant figures, or to the nearest one hundred million short tons for numbers greater than ten billion short tons. Columns may not sum exactly due to rounding.]

		Remaining resources (million short tons)																
County	**Coal depth (feet)**	**I-A**				**I-B**				**II-A**				**Total**				**Coal depth (feet)**
		Coal thickness (inches)				**Coal thickness (inches)**				**Coal thickness (inches)**				**Coal thickness (inches)**				
		>14-28	**>28-42**	**>42**	**All**	**>14-28**	**>28-42**	**>42**	**All**	**>14-28**	**>28-42**	**>42**	**All**	**>14-28**	**>28-42**	**>42**	**All**	
Northern Illinois																		
McLean	>150	0	6	13	19	0	75	90	170	0	1,800	1,900	3,700	0	1,900	2,000	4,000	>150
Tazewell	0–150	0	0	0	0	0	0	30	30	0	0	8	8	0	0	37	37	0–150
	>150	0	1	50	51	0	0	150	150	0	0	220	220	0	1	420	420	>150
	Subtotal	0	1	50	51	0	0	180	180	0	0	230	230	0	1	460	460	Subtotal
Woodford	>150	0	0	0	0	0	46	0	46	0	210	0	210	0	260	0	260	>150
Northern Illinois	0–150	0	0	63	0	0	0	30	30	0	0	8	8	0	0	37	37	0–150
	>150	0	7	0	70	0	120	240	360	0	2,000	2,200	4,200	0	2,200	2,500	4,700	>150
	Total	0	7	63	70	0	120	270	390	0	2,000	2,200	4,200	0	2,200	2,500	4,700	Total
Western Illinois																		
Fulton	0–150	0	0	0	0	0	0	580	580	0	0	0	0	0	0	580	580	0–150
	>150	0	0	0	0	0	0	80	80	0	0	0	0	0	0	80	80	>150
	Subtotal	0	0	0	0	0	0	660	660	0	0	0	0	0	0	660	660	Subtotal
Knox	0-150	0	0	0	0	190	170	99	460	150	12	0	160	340	180	99	620	0-150
Peoria	0–150	0	0	0	0	0	140	440	590	31	120	0	150	31	260	440	740	0-150
	>150	0	0	0	0	0	0	400	400	0	68	0	68	0	68	400	460	>150
	Subtotal	0	0	0	0	0	140	840	980	31	190	0	220	31	330	840	1,200	Subtotal
Schuyler	0-150	0	0	0	0	1	10	86	96	9	0	0	9	9	10	86	100	0-150
Warren	0-150	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	1	0-150
Western Illinois	0–150	0	0	0	0	190	330	1,200	1,700	190	130	0	320	380	450	1,200	2,000	0–150
	>150	0	0	0	0	0	0	480	480	0	68	0	68	0	68	480	550	>150
	Total	0	0	0	0	190	330	1,700	2,200	190	200	0	390	380	520	1,700	2,600	Total

Appendix 1. Estimated remaining resources of the Springfield Coal in Illinois, Indiana, and western Kentucky—Continued.

County	Coal depth (feet)	Remaining resources (million short tons)																Coal depth (feet)
		I-A				I-B				II-A				Total				
		Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				
		>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	
West-central Illinois																		
Christian	>150	0	3	61	64	0	38	510	550	0	15	610	620	0	56	1,200	1,200	>150
DeWitt	>150	0	0	0	0	0	0	0	0	0	32	1,500	1,500	0	32	1,500	1,500	>150
Effingham	>150	0	3	46	49	0	3	380	390	0	310	1,400	1,800	0	310	1,900	2,200	>150
Fayette	>150	0	1	4	6	0	39	81	120	0	1,100	1,100	2,200	0	1,200	1,100	2,300	>150
Logan	>150	0	0	170	170	0	0	1,300	1,300	0	0	1,100	1,100	0	0	2,600	2,600	>150
Macon	>150	0	3	87	91	0	19	460	480	0	120	870	990	0	140	1,400	1,500	>150
Mason	>150	0	0	0	0	0	0	0	0	0	0	8	8	0	0	8	8	>150
Menard	0–150	0	0	0	0	0	0	510	510	0	0	180	180	0	0	680	680	0–150
	>150	0	0	170	170	0	0	560	560	0	0	78	78	0	0	810	810	>150
	Subtotal	0	0	170	170	0	0	1,200	1,200	0	0	250	250	0	0	1,500	1,500	Subtotal
Piatt	>150	0	0	0	0	0	0	0	0	0	240	1,100	1,300	0	240	1,100	1,300	>150
Sangamon	0–150	0	0	0	0	0	0	280	280	0	0	160	160	0	0	430	430	0–150
	>150	0	2	620	620	0	31	1,300	1,300	0	46	640	680	0	80	2,600	2,700	>150
	Subtotal	0	2	620	620	0	31	1,600	1,600	0	46	790	840	0	80	3,000	3,100	Subtotal
Shelby	>150	0	0	13	13	0	1	79	79	0	410	1,500	1,900	0	410	1,600	2,000	>150
West-central Illinois	0–150	0	0	0	0	0	0	790	790	0	0	340	340	0	0	1,100	1,100	0–150
	>150	0	12	1,200	1,200	0	130	4,600	4,700	0	2,300	9,800	12,100	0	2,400	15,600	18,000	>150
	Total	0	12	1,200	1,200	0	130	5,400	5,500	0	2,300	10,100	12,400	0	2,400	16,700	19,100	Total

Appendix 1. Estimated remaining resources of the Springfield Coal in Illinois, Indiana, and western Kentucky—Continued.

County	Coal depth (feet)	Remaining resources (million short tons)																Coal depth (feet)
		I-A				I-B				II-A				Total				
		Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				
		>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	
East-central Illinois																		
Clark	0–150	0	0	0	0	0	0	0	0	4	5	0	10	4	5	0	10	0–150
	>150	0	38	210	250	0	110	510	620	0	420	360	780	0	570	1,100	1,700	>150
	Subtotal	0	38	210	250	0	110	510	620	4	430	360	790	4	570	1,100	1,700	Subtotal
Coles	0–150	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	1	0–150
	>150	0	0	25	25	0	33	200	230	0	440	380	820	0	480	600	1,100	>150
	Subtotal	0	0	25	25	1	33	200	230	0	440	380	820	1	480	600	1,100	Subtotal
Cumberland	>150	0	11	230	240	0	52	540	600	0	110	550	660	0	170	1,300	1,500	>150
Douglas	0–150	2	0	0	2	5	0	0	5	0	0	0	0	8	0	0	8	0–150
	>150	0	10	3	13	0	66	34	100	0	99	250	350	0	170	290	470	>150
	Subtotal	2	10	3	15	5	66	34	110	0	99	250	350	8	170	290	470	Subtotal
Edgar	0–150	1	2	6	10	2	1	7	10	0	0	0	0	4	3	13	20	0–150
	>150	0	22	95	120	0	130	190	320	0	180	130	320	0	330	420	750	>150
	Subtotal	1	24	100	130	2	130	200	330	0	180	130	320	4	340	430	770	Subtotal
East-central Illinois	0–150	3	2	6	12	8	1	7	16	5	5	0	11	17	9	13	39	0–150
	>150	0	81	560	650	0	390	1,500	1,900	0	1,200	1,700	2,900	0	1,700	3,700	5,400	>150
	Total	3	83	570	660	8	390	1,500	1,900	5	1,300	1,700	2,900	17	1,700	3,700	5,500	Total
Southwestern Illinois																		
Jackson	0–150	0	0	0	0	0	0	96	97	0	0	0	0	0	0	96	97	0–150
	>150	0	0	56	56	0	0	85	85	0	0	6	6	0	0	150	150	>150
	Subtotal	0	0	56	56	0	0	180	180	0	0	6	6	0	0	240	240	Subtotal
Perry	0–150	0	0	0	0	0	25	64	89	0	0	19	19	0	25	83	110	0–150
	>150	0	0	19	19	0	4	130	130	0	62	0	62	0	66	150	210	>150
	Subtotal	0	0	19	19	0	29	190	220	0	62	19	81	0	90	230	320	Subtotal
Randolph	0–150	0	0	0	0	12	57	70	140	0	15	0	15	12	73	70	160	0–150
	>150	0	0	0	0	0	23	1	24	0	0	0	0	0	23	1	24	>150
	Subtotal	0	0	0	0	12	80	71	160	0	15	0	15	12	96	71	180	Subtotal
Southwestern Illinois	0–150	0	0	0	0	12	82	230	330	0	15	19	34	12	98	250	370	0–150
	>150	0	0	70	70	0	27	220	240	0	62	6	68	0	89	300	380	>150
	Total	0	0	70	70	12	110	450	570	0	77	25	100	12	190	550	740	Total

Appendix 1. Estimated remaining resources of the Springfield Coal in Illinois, Indiana, and western Kentucky—Continued.

County	Coal depth (feet)	Remaining resources (million short tons) I-A Coal thickness (inches)				I-B Coal thickness (inches)				II-A Coal thickness (inches)				Total Coal thickness (inches)				Coal depth (feet)
		>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	
Southeastern Illinois																		
Clay	>150	0	0	0	0	0	0	0	0	0	340	1,700	2,000	0	340	1,700	2,000	>150
Crawford	>150	0	33	10	43	0	350	21	380	0	600	260	860	0	990	290	1,300	>150
Edwards	>150	0	1	28	29	0	10	140	150	0	270	670	940	0	280	840	1,100	>150
Franklin	>150	0	38	640	680	0	62	1,300	1,300	0	2	54	56	0	100	2,000	2,100	>150
Gallatin	0–150	0	0	1	1	0	3	99	100	0	0	0	0	0	3	100	100	0–150
	>150	0	2	520	520	0	7	570	580	0	2	66	68	0	11	1,150	1,160	>150
	Subtotal	0	2	520	520	0	10	670	680	0	2	66	68	0	14	1,300	1,300	Subtotal
Hamilton	>150	0	3	680	680	0	22	1,100	1,100	0	3	640	640	0	28	2,400	2,400	>150
Jasper	>150	0	27	250	280	0	150	980	1,100	0	410	320	730	0	580	1,600	2,100	>150
Jefferson	>150	0	16	300	320	0	28	880	900	0	75	1,600	1,700	0	120	2,800	2,900	>150
Lawrence	>150	0	25	97	120	0	150	280	430	0	430	520	950	0	610	890	1,500	>150
Marion	>150	0	0	24	24	0	6	220	220	0	410	1,800	2,200	0	420	2,100	2,500	>150
Richland	>150	0	0	20	20	0	5	150	160	0	190	1,300	1,500	0	200	1,500	1,700	>150
Saline	0–150	0	0	0	0	0	0	90	90	0	0	0	0	0	0	90	90	0–150
	>150	0	8	500	510	0	4	220	230	0	0	0	0	0	12	720	730	>150
	Subtotal	0	8	500	510	0	4	310	320	0	0	0	0	0	12	810	820	Subtotal
Wabash	>150	0	0	100	100	0	27	320	350	0	190	450	640	0	220	880	1,100	>150
Wayne	>150	0	0	40	40	0	48	170	210	0	1,000	1,700	2,700	0	1,100	1,900	3,000	>150
White	>150	0	3	270	270	0	61	1,100	1,100	0	310	700	1,000	0	370	2,000	2,400	>150
Williamson	0–150	0	0	1	1	0	1	180	180	0	0	0	0	0	1	180	180	0–150
	>150	0	6	380	390	0	42	280	320	0	0	0	0	0	49	660	710	>150
	Subtotal	0	6	380	390	0	43	460	500	0	0	0	0	0	50	840	890	Subtotal
Southeastern	0–150	0	0	2	2	0	4	370	370	0	0	0	0	0	4	370	370	0–150
Illinois	>150	0	160	3,900	4,000	0	970	7,600	8,600	0	4,300	11,700	16,000	0	5,400	23,200	28,600	>150
	Total	0	160	3,900	4,000	0	980	8,000	9,000	0	4,300	11,700	16,000	0	5,400	23,600	29,000	Total

Appendix 1. Estimated remaining resources of the Springfield Coal in Illinois, Indiana, and western Kentucky—Continued.

County	Coal depth (feet)	Remaining resources (million short tons)																Coal depth (feet)
		I-A				I-B				II-A				Total				
		Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				
		>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	
Indiana																		
Clay	0–150	0	0	11	11	0	0	9	9	0	0	0	0	0	0	20	20	0–150
	>150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	>150
	Subtotal	0	0	11	11	0	0	9	9	0	0	0	0	0	0	20	20	Subtotal
Daviess	0–150	2	10	56	68	3	6	20	28	0	0	0	0	5	16	76	96	0–150
	>150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	>150
	Subtotal	2	10	56	68	3	6	20	28	0	0	0	0	5	16	76	96	Subtotal
Gibson	0–150	0	1	110	110	0	0	18	18	0	0	0	0	0	1	130	130	0–150
	>150	3	60	1,700	1,800	0	24	520	550	0	0	0	0	3	83	2,200	2,300	>150
	Subtotal	3	60	1,800	1,900	0	24	540	570	0	0	0	0	3	73	2,400	2,400	Subtotal
Greene	0–150	3	8	58	69	1	2	38	41	0	0	0	0	4	10	96	110	0–150
	>150	0	0	0	0	0	0	2	2	0	0	0	0	0	0	2	2	>150
	Subtotal	3	8	58	69	1	2	40	43	0	0	0	0	4	10	98	110	Subtotal
Knox	0–150	1	27	97	120	0	17	40	57	0	0	0	0	1	44	140	180	0–150
	>150	27	280	710	1,000	6	210	560	780	0	7	17	24	33	500	1,300	1,800	>150
	Subtotal	28	310	810	1,100	6	230	600	840	0	7	17	24	34	540	1,400	2,000	Subtotal
Pike	0–150	2	17	240	260	0	21	110	130	0	2	0	2	2	40	350	400	0–150
	>150	0	7	80	87	0	6	150	160	0	0	5	5	0	13	240	250	>150
	Subtotal	2	24	320	350	0	27	270	290	0	2	5	7	2	53	590	350	Subtotal
Posey	0–150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0–150
	>150	0	85	800	890	0	19	990	1,000	0	0	110	110	0	100	1,900	2,000	>150
	Subtotal	0	85	800	890	0	19	990	1,000	0	0	110	110	0	100	1,900	2,000	Total

Appendix 1. Estimated remaining resources of the Springfield Coal in Illinois, Indiana, and western Kentucky—Continued.

County	Coal depth (feet)	Remaining resources (million short tons)																Coal depth (feet)
		I-A				I-B				II-A				Total				
		Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				
		>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	
Indiana – continued																		
Sullivan	0–150	5	15	75	95	3	43	63	110	0	4	3	7	8	62	140	210	0–150
	>150	74	260	510	840	35	230	390	650	0	2	5	7	110	490	890	1,500	>150
	Subtotal	80	270	580	930	38	280	450	760	0	6	8	14	120	560	1,000	1,700	Subtotal
Vanderburgh	0–150	0	0	0	0	0	0	16	16	0	0	22	22	0	0	37	38	0–150
	>150	0	15	230	50	0	33	400	430	0	3	290	290	0	50	920	970	>150
	Subtotal	0	15	230	250	0	33	420	450	0	3	310	310	0	50	960	1,000	Subtotal
Vermillion	0–150	1	1	45	46	1	5	54	60	0	1	3	4	1	7	100	110	0–150
	>150	0	7	53	60	0	6	88	94	0	0	0	0	0	12	140	150	>150
	Subtotal	1	7	98	110	1	11	140	150	0	1	3	4	1	19	240	260	Subtotal
Vigo	0–150	2	41	71	110	1	31	85	120	0	4	1	4	3	75	160	230	0–150
	>150	7	110	260	370	0	110	190	310	0	0	0	0	7	220	450	380	>150
	Subtotal	9	150	330	490	1	140	280	420	0	4	1	4	10	290	610	910	Subtotal
Warrick	0–150	1	17	390	410	0	7	140	150	0	0	0	0	1	25	530	560	0–150
	>150	1	3	190	200	0	2	170	170	0	0	1	1	2	5	370	370	>150
	Subtotal	3	20	590	610	0	10	310	320	0	0	1	1	3	30	900	930	Subtotal
Indiana	0–150	17	140	1,200	1,300	8	130	590	740	0	11	28	39	25	280	1,800	2,100	0–150
	>150	110	830	4,500	5,500	41	640	3,500	4,200	0	11	430	440	155	1,500	8,400	10,100	>150
	Total	130	960	5,700	6,800	49	770	4,100	4,900	0	22	460	480	180	1,700	10,200	12,100	Total

Appendix 1. Estimated remaining resources of the Springfield Coal in Illinois, Indiana, and western Kentucky—Continued.

County	Coal depth (feet)	Remaining resources (million short tons)																				Coal depth (feet)
		Measured				Indicated				Inferred				Hypothetical				Total				
		Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				
		>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	
Western Kentucky																						
Daviess	0–150	0	2	38	39	0	2	50	52	0	0	23	23	0	0	21	21	0	3	130	140	0–150
	>150	0	1	39	40	0	1	39	40	0	0	27	27	0	0	0	0	0	3	100	110	>150
	Subtotal	0	3	76	80	0	3	89	92	0	0	50	50	0	0	21	21	0	6	240	240	Subtotal
Henderson	0–150	0	1	40	40	0	2	100	100	0	0	190	190	0	0	9	9	0	3	340	340	0–150
	>150	0	2	170	170	1	5	380	390	1	14	680	700	0	0	230	230	2	21	1,500	1,500	>150
	Subtotal	0	3	210	210	1	7	480	490	1	14	870	880	0	0	240	240	2	24	1,800	1,800	Subtotal
Hopkins	0–150	0	0	32	32	0	0	57	57	0	0	78	78	0	0	1	1	0	0	170	170	0–150
	>150	0	1	97	99	0	3	310	310	0	7	560	570	0	0	92	92	0	12	1,100	1,100	>150
	Subtotal	0	1	130	130	0	3	370	370	0	7	640	640	0	0	93	93	0	12	1,200	1,200	Subtotal
McLean	0–150	0	1	17	18	0	0	33	34	1	6	60	66	0	1	11	12	1	9	120	130	0–150
	>150	1	31	140	170	0	37	240	280	0	20	320	340	0	3	5	8	1	90	700	800	>150
	Subtotal	1	32	150	190	1	37	270	310	1	26	380	410	0	4	16	20	3	99	820	930	Subtotal
Muhlenberg	0–150	0	0	19	19	0	0	28	28	0	0	66	66	0	0	1	1	0	0	110	110	0–150
	>150	0	2	73	75	0	2	180	180	0	0	190	190	0	0	3	3	0	4	450	450	>150
	Subtotal	0	2	92	94	0	2	200	210	0	0	260	260	0	0	4	4	0	4	560	560	Subtotal
Ohio	0–150	0	0	12	12	0	1	28	28	0	2	57	60	0	0	0	0	0	3	97	100	0–150
	>150	0	1	3	4	0	3	18	21	0	3	160	160	0	0	3	3	0	6	180	190	>150
	Subtotal	0	1	15	16	0	4	50	50	0	5	210	220	0	0	3	3	0	10	280	290	Subtotal
Union	0–150	0	0	3	3	0	0	3	3	0	0	4	4	0	0	0	0	0	0	9	9	0–150
	>150	0	2	140	140	1	4	370	370	0	2	710	720	0	0	120	120	1	8	1,300	1,300	>150
	Subtotal	0	2	140	140	1	4	370	380	0	2	720	720	0	0	120	120	1	8	1,400	1,400	Subtotal
Webster	0–150	0	0	1	1	0	0	6	6	0	0	23	23	0	0	0	0	0	0	29	29	0–150
	>150	1	7	190	200	2	14	320	340	0	22	470	490	0	0	24	24	3	42	1,000	1,000	>150
	Subtotal	1	7	190	200	2	14	330	340	0	22	490	510	0	0	24	24	3	42	1,000	1,100	Subtotal
Western Kentucky	0–150	0	3	160	170	0	5	300	310	1	9	500	510	0	1	43	44	1	18	1,000	1,000	0–150
	>150	3	47	840	890	4	68	1,900	1,900	1	67	3,100	3,200	0	3	480	480	8	190	6,300	6,500	>150
	Total	3	51	1,000	1,100	5	73	2,200	2,200	2	76	3,600	3,700	0	4	520	520	10	200	7,300	7,500	Total

Appendix 2. Estimated remaining resources of the Herrin Coal in Illinois and western Kentucky.

[Resources are listed by mining area and county and are categorized by geologic reliability (I–A, 0–0.5 mi from a data point; I–B, >0.5–2 mi; II–A, >2–4 mi; measured, 0–0.25 mi; indicated, >0.25–0.75 mi; inferred, >0.75–3.0 mi; and hypothetical, >3 mi), coal thickness, and overburden thickness (coal depth). Resource numbers are rounded to two significant figures, or to the nearest one hundred million short tons for numbers greater than ten billion short tons. Columns may not sum exactly due to rounding.]

County	Coal depth (feet)	Remaining resources (million short tons)																Coal depth (feet)
		I-A				I-B				II-A				Total				
		Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				
		>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	
Northern Illinois																		
Grundy	0-150	0	0	0	0	4	6	33	43	2	0	0	2	5	6	33	45	0-150
LaSalle	0–150	0	2	50	52	29	30	24	82	16	1	0	17	46	33	74	150	0–150
	>150	0	0	0	0	0	99	30	130	0	3	0	3	0	100	30	130	>150
	Subtotal	0	2	50	52	29	130	53	210	16	4	0	20	46	130	100	280	Subtotal
Livingston	0–150	0	1	28	29	16	31	27	74	10	4	6	20	26	35	61	120	0–150
	>150	0	0	0	0	0	0	0	0	0	35	4	40	0	35	4	40	>150
	Subtotal	0	1	28	29	16	31	27	74	10	39	11	60	26	70	66	160	Subtotal
Putnam	>150	0	11	8	19	0	39	20	59	0	0	0	0	0	50	27	78	>150
Tazewell	0–150	0	0	0	0	0	60	4	63	0	10	0	10	0	69	4	73	0–150
	>150	0	6	0	6	0	48	0	48	0	89	0	90	0	143	0	140	>150
	Subtotal	0	6	0	6	0	110	4	110	0	99	0	99	0	210	4	220	Subtotal
Northern Illinois	0–150	0	3	78	81	49	130	86	260	28	15	6	49	77	140	170	390	0–150
	>150	0	18	8	25	0	150	50	200	0	130	5	130	0	330	62	390	>150
	Total	0	21	85	110	49	270	140	460	28	140	11	180	77	470	230	780	Total

Appendix 2. Estimated remaining resources of the Herrin Coal in Illinois and western Kentucky—Continued.

County	Coal depth (feet)	Remaining resources (million short tons) — I-A Coal thickness (inches)				I-B Coal thickness (inches)				II-A Coal thickness (inches)				Total Coal thickness (inches)				Coal depth (feet)
		>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	
Western Illinois																		
Bureau	0–150	0	0	0	0	0	0	170	170	0	0	100	100	0	0	270	270	0–150
	>150	0	28	130	160	0	87	150	230	0	7	9	17	0	120	290	410	>150
	Subtotal	0	28	130	160	0	87	320	410	0	7	110	120	0	120	560	680	Subtotal
Fulton	0–150	0	0	0	0	0	5	240	240	0	0	0	0	0	5	240	240	0–150
	>150	0	0	0	0	0	0	4	4	0	0	0	0	0	0	4	4	>150
	Subtotal	0	0	0	0	0	5	240	250	0	0	0	0	0	5	240	250	Subtotal
Henry	0-150	0	0	0	0	0	61	130	190	0	0	59	59	0	61	190	250	0-150
Knox	0-150	0	0	0	0	0	190	27	210	0	0	0	0	0	190	27	210	0-150
Marshall	>150	0	0	0	0	0	7	0	7	0	0	0	0	0	7	0	7	>150
Peoria	0-150	0	0	0	0	5	180	670	850	6	43	130	180	11	220	800	1,000	0-150
Stark	0–150	0	0	0	0	0	6	220	230	4	0	210	210	4	6	430	440	0–150
	>150	0	0	0	0	0	0	0	0	0	0	27	27	0	0	28	28	>150
	Subtotal	0	0	0	0	0	6	220	230	4	0	240	240	4	6	460	470	Subtotal
Western Illinois	0–150	0	0	0	0	5	430	1,500	1,900	10	43	500	550	15	470	2,000	2,500	0–150
	>150	0	28	130	160	0	94	150	240	0	7	37	44	0	130	320	450	>150
	Total	0	28	130	160	5	524	1,600	2,100	10	50	540	590	15	600	2,300	2,900	Total

Appendix 2. Estimated remaining resources of the Herrin Coal in Illinois and western Kentucky—Continued.

County	Coal depth (feet)	Remaining resources (million short tons): I-A, Coal thickness (inches) >14-28	>28-42	>42	All	I-B, Coal thickness (inches) >14-28	>28-42	>42	All	II-A, Coal thickness (inches) >14-28	>28-42	>42	All	Total, Coal thickness (inches) >14-28	>28-42	>42	All	Coal depth (feet)
West-central Illinois																		
Bond	>150	0	3	880	890	0	7	1,400	1,400	0	0	210	210	0	10	2,500	2,500	>150
Christian	>150	0	3	1,100	1,100	0	22	1,700	1,700	0	110	510	620	0	130	3,300	3,400	>150
Effingham	>150	0	0	60	60	0	0	450	450	0	260	740	1,000	0	260	1,200	1,500	>150
Fayette	>150	0	0	230	230	0	9	1,600	1,600	0	110	1,700	1,800	0	110	3,500	3,600	>150
Greene	0-150	0	0	0	0	2	54	20	75	6	14	0	21	8	68	20	96	0-150
Jersey	0-150	0	0	0	0	10	22	20	53	7	0	0	702	18	22	20	60	0-150
Logan	>150	0	94	200	300	0	94	270	360	0	5	60	66	0	190	530	720	>150
Macon	>150	0	4	2	6	0	43	40	83	0	220	72	290	0	260	110	380	>150
Macoupin	0–150	6	3	75	84	23	24	130	180	34	0	43	77	63	27	250	340	0–150
	>150	0	16	1,300	1,300	0	100	1,800	1,900	0	180	16	200	0	300	3,200	3,500	>150
	Subtotal	6	19	1,400	1,400	23	130	2,000	2,100	34	180	60	280	63	330	3,400	3,800	Subtotal
Montgomery	>150	0	41	2,200	2,200	0	9	1,600	1,600	0	0	23	23	0	49	3,800	3,800	>150
Morgan	0–150	0	0	0	0	3	85	7	96	0	390	0	390	3	480	7	490	0–150
	>150	0	0	4	4	0	30	32	62	0	180	51	230	0	210	87	290	>150
	Subtotal	0	0	4	4	3	110	39	160	0	570	51	620	3	680	94	780	Subtotal
Moultrie	>150	0	0	19	19	0	50	190	240	0	440	370	800	0	490	580	1,100	>150
Sangamon	>150	0	18	940	960	0	94	710	810	0	150	59	210	0	270	1,700	2,000	>150
Scott	0-150	0	0	0	0	6	0	0	6	0	0	0	0	6	0	0	6	0-150
Shelby	> 150	0	1	400	400	0	12	1,300	1,300	0	480	1,100	1,600	0	490	2,800	3,300	> 150
West-central	0–150	6	3	75	84	45	180	180	410	47	410	43	500	98	600	300	990	0–150
Illinois	>150	0	180	7,300	7,500	0	470	11,000	11,500	0	2,100	5,000	7,100	0	2,800	23,400	26,100	>150
	Total	6	180	7,400	7,600	45	650	11,200	11,900	47	2,500	5,000	7,600	98	3,400	23,700	27,100	Total

Appendix 2. Estimated remaining resources of the Herrin Coal in Illinois and western Kentucky—Continued.

County	Coal depth (feet)	Remaining resources (million short tons)																Coal depth (feet)
		I-A				I-B				II-A				Total				
		Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				
		>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	
East-central Illinois																		
Champaign	>150	0	0	21	21	0	0	130	130	0	4	43	47	0	4	200	200	>150
Clark	0–150	0	0	0	0	1	5	2	9	8	6	0	13	9	11	2	23	0–150
	>150	0	43	6	49	0	140	17	160	0	180	7	190	0	370	31	400	>150
	Subtotal	0	43	7	49	1	150	19	170	8	190	7	200	9	380	33	420	Subtotal
Coles	0–150	0	0	4	4	1	0	0	2	1	0	0	1	3	0	4	7	0–150
	>150	0	21	60	81	0	150	94	250	0	560	170	730	0	730	330	1,100	>150
	Subtotal	0	21	64	85	1	150	94	250	1	560	170	740	3	730	330	1,100	Subtotal
Cumberland	>150	0	5	290	300	0	46	800	850	0	81	560	640	0	130	1,700	1,800	>150
Douglas	0–150	0	0	77	77	4	4	88	96	1	0	4	6	5	4	170	180	0–150
	>150	0	11	360	380	0	31	390	420	0	110	160	270	0	150	910	1,100	>150
	Subtotal	0	11	440	450	4	35	470	510	1	110	170	270	5	150	1,100	1,200	Subtotal
Edgar	0–150	4	2	53	60	12	15	57	83	3	1	0	4	18	17	110	150	0–150
	>150	0	41	160	200	0	230	300	530	0	370	210	580	0	640	680	1,300	>150
	Subtotal	4	43	210	260	12	240	360	620	3	370	210	580	18	650	790	1,500	Subtotal
Vermilion	0–150	0	0	0	0	27	13	180	230	19	10	0	29	46	23	180	250	0–150
	>150	0	62	580	640	0	150	600	750	0	22	190	210	0	230	1,400	1,600	>150
	Subtotal	0	62	580	640	27	160	790	980	19	32	190	240	46	250	1,600	1,900	Subtotal
East-central	0–150	4	2	140	140	46	37	330	410	31	17	4	52	81	56	470	610	0–150
Illinois	>150	0	180	1,500	1,700	0	750	2,300	3,100	0	1,300	1,400	2,700	0	2,200	5,200	7,400	>150
	Total	4	190	1,600	1,800	46	790	2,700	3,500	31	1,300	1,400	2,700	81	2,300	5,700	8,000	Total

Appendix 2. Estimated remaining resources of the Herrin Coal in Illinois and western Kentucky—Continued.

County	Coal depth (feet)	Remaining resources (million short tons)																Coal depth (feet)
		I-A				I-B				II-A				Total				
		Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				
		>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	
Southwestern Illinois																		
Clinton	>150	0	1	890	890	0	5	2,000	2,000	0	5	300	310	0	11	3,200	3,200	>150
Jackson	0-150	0	0	0	0	0	0	80	79	0	0	0	0	0	0	80	79	0-150
Madison	0–150	0	0	0	0	0	16	391	410	2	0	56	58	2	16	450	470	0–150
	>150	0	10	420	430	0	36	390	970	0	48	310	350	0	94	1,700	1,800	>150
	Subtotal	0	10	420	430	0	52	1,300	1,400	2	48	360	410	2	110	2,100	2,200	Subtotal
Monroe	0-150	0	0	0	0	0	0	7	7	0	0	0	0	0	0	7	7	0-150
Perry	0–150	0	0	0	0	0	0	600	600	0	0	0	0	0	0	610	610	0–150
	>150	0	0	1,200	1,200	0	0	42	42	0	0	0	0	0	0	1,300	1,300	>150
	Subtotal	0	0	1,200	1,200	0	0	660	660	0	0	0	0	0	0	1,900	1,900	Subtotal
Randolph	0–150	0	0	0	0	0	0	180	180	0	0	0	0	0	0	180	180	0–150
	>150	0	0	82	82	0	0	0	0	0	0	0	0	0	0	82	82	>150
	Subtotal	0	0	82	82	0	0	180	180	0	0	0	0	0	0	260	260	Subtotal
St. Clair	0–150	0	0	0	0	0	1	1,100	1,100	0	0	0	0	0	1	1,100	1,100	0–150
	>150	0	2	200	200	0	23	950	970	0	16	16	32	0	41	1,200	1,200	>150
	Subtotal	0	2	200	200	0	24	2,000	2,100	0	16	16	32	0	42	260	2,300	Subtotal
Washington	0–150	0	0	0	0	0	0	9	9	0	0	0	0	0	0	9	9	0–150
	>150	0	4	2,200	2,200	0	1	1,400	1,400	0	0	130	130	0	4	3,800	3,800	>150
	Subtotal	0	4	2,200	2,200	0	1	1,400	1,400	0	0	130	130	0	4	3,800	3,800	Subtotal
Southwestern	0–150	0	0	0	0	0	17	2,400	2,400	2	0	56	58	2	17	2,400	2,400	0–150
Illinois	>150	0	17	5,100	5,100	0	64	5,400	5,400	0	69	750	820	0	150	11,200	11,300	>150
	Total	0	17	5,100	5,100	0	81	7,700	7,800	2	69	810	880	2	170	13,600	13,800	Total

Appendix 2. Estimated remaining resources of the Herrin Coal in Illinois and western Kentucky—Continued.

County	Coal depth (feet)	Remaining resources (million short tons) I-A Coal thickness (inches)				I-B Coal thickness (inches)				II-A Coal thickness (inches)				Total Coal thickness (inches)				Coal depth (feet)
		>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	
Southeastern Illinois																		
Clay	>150	0	0	0	0	0	0	0	0	0	590	1,500	2,100	0	590	170	2,100	>150
Crawford	>150	0	1	2	3	0	36	1	37	0	230	93	330	0	270	96	370	>150
Edwards	>150	0	5	30	35	0	47	130	170	0	250	460	720	0	310	620	930	>150
Franklin	>150	0	0	990	990	0	0	410	410	0	0	0	0	0	0	1,400	1,400	>150
Gallatin	0–150	2	13	18	33	1	25	120	140	0	0	0	0	3	38	140	180	0–150
	>150	0	79	190	270	0	98	310	410	0	10	75	85	0	190	580	760	>150
	Subtotal	2	92	210	300	1	120	430	550	0	10	75	85	3	220	710	940	Subtotal
Hamilton	>150	0	5	680	690	0	22	1,300	1,400	0	33	520	550	0	60	2,500	2,600	>150
Jasper	>150	0	0	400	400	0	1	1,500	1,500	0	62	890	960	0	63	2,800	2,900	>150
Jefferson	>150	0	6	630	640	0	13	960	970	0	210	810	1,000	0	230	2,400	2,600	>150
Lawrence	>150	0	8	15	23	0	140	140	280	0	380	130	510	0	530	290	820	>150
Marion	>150	0	1	91	93	0	18	200	210	0	960	600	1,500	0	980	890	1,900	>150
Richland	>150	0	0	24	24	0	0	180	180	0	77	1,500	1,600	0	77	1,800	1,900	>150
Saline	0–150	0	0	0	0	0	8	210	210	0	0	0	0	0	8	210	210	0–150
	>150	0	7	590	590	0	21	390	410	0	0	0	0	0	28	980	1,000	>150
	Subtotal	0	7	590	590	0	30	600	620	0	0	0	0	0	37	1,200	1,200	Subtotal
Wabash	>150	0	23	81	100	0	130	180	310	0	300	180	480	0	460	440	900	>150
Wayne	>150	0	0	38	38	0	32	130	130	0	910	1,800	2,700	0	940	1,900	2,900	>150
White	>150	0	13	180	190	0	85	1,300	1,400	0	38	740	780	0	140	2,300	2,400	>150
Williamson	0–150	0	0	0	0	0	0	240	240	0	0	0	0	0	0	240	240	0–150
	>150	0	1	330	330	0	0	1	1	0	0	0	0	0	1	330	330	>150
	Subtotal	0	1	330	330	0	0	240	240	0	0	0	0	0	1	560	560	Subtotal
Southeastern Illinois	0–150	2	13	18	33	1	34	560	600	0	0	0	0	3	47	580	630	0–150
	>150	0	150	4,300	4,400	0	640	7,300	7,900	0	4,080	9,300	13,400	0	4,900	20,800	25,700	>150
	Total	2	160	4,300	4,400	1	680	7,800	8,500	0	4,080	9,300	13,400	3	4,900	21,400	26,300	Total

Appendix 2. Estimated remaining resources of the Herrin Coal in Illinois and western Kentucky—Continued.

County	Coal depth (feet)	Remaining resources (million short tons) — Measured: Coal thickness (inches)				Indicated: Coal thickness (inches)				Inferred: Coal thickness (inches)				Hypothetical: Coal thickness (inches)				Total: Coal thickness (inches)				Coal depth (feet)
		>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	
Western Kentucky																						
Daviess	0–150	3	1	0	3	5	0	0	6	4	1	0	5	0	0	0	0	12	2	0	14	0–150
	>150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	>150
	Subtotal	3	1	0	3	5	0	0	5	5	1	0	5	0	0	0	0	12	2	0	14	Subtotal
Henderson	0–150	5	1	0	5	11	1	0	12	9	1	0	10	0	0	0	0	25	2	0	27	0–150
	>150	1	3	3	7	5	11	10	27	28	100	130	250	14	6	140	160	49	120	280	450	>150
	Subtotal	6	3	3	13	17	12	10	39	37	100	130	260	15	6	140	160	75	120	280	470	Subtotal
Hopkins	0–150	1	1	23	25	1	2	31	34	0	1	19	20	0	0	0	0	3	4	72	79	0–150
	>150	3	4	60	67	8	21	120	150	6	18	140	160	0	0	0	0	17	42	320	380	>150
	Subtotal	4	5	82	92	10	23	150	180	6	18	160	180	0	0	0	0	20	47	390	460	Subtotal
McLean	0–150	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0–150
	>150	11	1	9	27	14	9	10	32	11	9	2	22	0	0	0	0	36	26	20	82	>150
	Subtotal	11	8	9	28	14	9	10	32	11	9	2	22	0	0	0	0	36	26	20	83	Subtotal
Muhlenberg	0–150	0	3	42	46	0	7	53	60	0	2	65	97	0	6	16	22	0	19	210	220	0–150
	>150	0	9	27	36	0	18	45	63	0	14	48	62	0	0	4	5	1	41	120	170	>150
	Subtotal	0	13	70	82	0	25	98	120	0	17	140	160	0	6	20	27	1	61	330	390	Subtotal
Ohio	0–150	1	3	1	5	2	7	7	15	3	28	110	140	2	5	13	20	7	42	130	180	0–150
	>150	0	0	0	0	0	0	0	0	2	10	10	22	1	0	0	1	3	10	10	24	>150
	Subtotal	1	3	1	5	2	7	7	15	5	38	120	160	3	5	13	21	11	52	140	210	Subtotal
Union	0–150	0	2	17	19	1	7	22	30	0	4	5	9	0	0	0	0	1	14	44	59	0–150
	>150	6	35	160	210	10	100	270	380	11	71	410	490	2	4	81	87	30	210	930	1,200	>150
	Subtotal	6	38	180	230	11	110	290	410	11	75	420	500	2	4	81	87	30	220	970	1,200	Subtotal
Webster	0–150	0	1	4	5	0	1	3	4	0	0	0	0	0	0	0	0	0	2	7	9	0–150
	>150	6	5	8	19	8	9	10	27	4	4	0	8	0	0	0	0	19	19	17	54	>150
	Subtotal	6	6	11	24	8	10	13	31	4	4	0	9	0	0	0	0	19	20	24	64	Subtotal
Western Kentucky	0–150	9	13	87	110	20	25	120	160	17	37	230	280	3	11	28	42	49	85	460	600	0–150
	>150	29	64	270	360	46	170	460	680	63	230	740	1,000	17	11	220	250	150	470	1,700	2,300	>150
	Total	38	77	360	470	66	190	580	840	80	260	960	1,300	20	22	250	290	200	550	2,200	2,900	Total

Appendix 3. Estimated remaining resources of the Danville Coal in Illinois and Indiana, and the Baker coal in western Kentucky.

[Resources are listed by mining area and county and are categorized by geologic reliability (I–A, 0–0.5 mi from a data point; I–B, >0.5–2 mi; II–A, >2–4 mi; measured, 0–0.25 mi; indicated, >0.25–0.75 mi; inferred, >0.75–3.0 mi; and hypothetical, >3 mi), coal thickness, and overburden thickness (coal depth). Resource numbers are rounded to two significant figures, or to the nearest one hundred million short tons for numbers greater than ten billion short tons. Columns may not sum exactly due to rounding.]

County	Coal depth (feet)	Remaining resources (million short tons)																Coal depth (feet)
		I-A				I-B				II-A				Total				
		Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				
		>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	
Northern Illinois																		
LaSalle	0–150	0	1	10	12	0	12	13	26	21	38	16	76	21	52	40	110	0–150
	>150	0	5	19	24	1	180	170	350	0	45	19	64	1	230	210	440	>150
	Subtotal	0	6	29	35	2	190	180	370	21	83	35	140	23	280	250	550	Subtotal
Livingston	0–150	0	0	0	0	32	28	33	93	230	200	70	500	260	220	100	590	0–150
	>150	0	0	0	0	0	36	180	220	0	350	680	1,000	0	390	850	1,200	>150
	Subtotal	0	0	0	0	32	64	210	310	230	550	750	1,500	260	610	950	1,800	Subtotal
Marshall	0–150	0	0	0	0	0	69	47	120	0	0	0	0	0	69	47	110	0–150
	>150	2	14	0	15	16	65	0	81	150	0	0	150	170	79	0	250	>150
	Subtotal	2	14	0	15	16	130	47	200	150	0	0	150	170	150	47	360	Subtotal
McLean	>150	0	9	13	22	0	110	93	200	360	0	0	360	360	120	110	590	>150
Putnam	>150	0	40	27	67	0	87	53	140	0	0	12	12	0	130	92	220	>150
Tazewell	0-150	0	0	0	0	5	0	0	5	0	0	0	0	5	0	0	5	0-150
Woodford	>150	0	3	0	3	27	0	0	27	9	0	0	9	37	3	0	39	>150
Northern Illinois	0–150	0	1	10	12	37	110	93	240	250	240	86	570	290	340	190	810	0–150
	>150	2	70	59	130	44	480	500	1,000	510	390	710	1,600	570	950	1,300	2,800	>150
	Total	2	71	69	140	81	590	590	1,300	760	630	800	2,200	850	1,300	1,500	3,600	Total

Appendix 3. Estimated remaining resources of the Danville Coal in Illinois and Indiana, and the Baker coal in western Kentucky—Continued.

County	Coal depth (feet)	Remaining resources (million short tons)																Coal depth (feet)
		I-A				I-B				II-A				Total				
		Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				
		>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	
Western Illinois																		
Bureau	0–150	0	0	0	0	12	62	0	73	100	7	0	110	110	70	0	180	0–150
	>150	0	42	4	46	0	110	33	150	0	0	0	0	0	150	37	190	>150
	Subtotal	0	42	4	46	12	170	33	220	100	7	0	110	110	220	37	380	Subtotal
Fulton	0-150	0	0	0	0	42	0	0	42	15	0	0	15	57	0	0	57	0-150
Henry	0-150	0	0	0	0	0	57	0	57	0	0	0	0	0	57	0	57	0-150
Knox	0-150	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	1	0-150
Peoria	0-150	0	0	0	0	190	40	0	230	43	0	0	43	240	40	0	280	0-150
Stark	0-150	0	0	0	0	0	0	0	0	26	30	0	56	26	30	0	56	0-150
Western	0–150	0	0	0	0	250	160	0	400	180	37	0	220	430	200	0	630	0–150
Illinois	>150	0	42	4	46	0	110	33	150	0	0	0	0	0	150	37	190	>150
	Total	0	42	4	46	250	270	33	550	180	37	0	220	430	350	37	810	Subtotal
West-central Illinois																		
Christian	>150	0	21	9	30	0	31	0	31	0	0	0	0	0	53	9	62	>150
Effingham	>150	0	6	4	10	0	140	190	330	0	620	240	860	0	770	430	1,200	>150
Fayette	>150	0	31	0	31	0	280	0	280	0	0	0	0	0	310	0	310	>150
Macoupin	>150	1	4	0	5	9	0	0	9	0	0	0	0	11	4	0	14	>150
Montgomery	>150	2	10	0	12	5	35	0	40	0	0	0	0	7	44	0	52	>150
Shelby	>150	0	18	4	22	0	110	0	110	0	0	0	0	0	130	4	130	>150
West-central	0–150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0–150
Illinois	>150	3	89	17	110	15	600	190	800	0	620	240	860	18	1,300	450	1,800	>150
	Total	3	89	17	110	15	600	190	800	0	620	240	860	18	1,300	450	1,800	Total

Appendix 3. Estimated remaining resources of the Danville Coal in Illinois and Indiana, and the Baker coal in western Kentucky—Continued.

County	Coal depth (feet)	Remaining resources (million short tons)																Coal depth (feet)
		I-A				I-B				II-A				Total				
		Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				
		>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	
East-central Illinois																		
Champaign	>150	0	1	10	11	0	7	19	26	0	0	67	67	0	8	96	100	>150
Clark	0–150	0	1	4	5	1	2	5	8	23	51	32	110	25	54	41	120	0–150
	>150	0	62	90	150	0	190	480	670	0	350	310	670	0	600	890	1,500	>150
	Subtotal	0	64	93	160	1	190	490	680	23	400	350	770	25	660	930	1,600	Subtotal
Coles	0–150	0	0	0	0	5	2	0	7	15	120	0	130	20	120	0	140	0–150
	>150	0	2	0	2	0	130	110	240	0	520	240	770	0	650	350	1,000	>150
	Subtotal	0	2	0	2	5	130	110	250	15	640	240	900	20	770	350	1,100	Subtotal
Cumberland	0–150	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	1	0–150
	>150	0	11	17	28	0	220	240	450	0	240	170	410	0	470	420	890	>150
	Subtotal	0	11	17	28	0	220	240	450	1	240	170	410	1	470	420	890	Subtotal
Edgar	0–150	0	1	23	24	4	43	65	110	1	46	7	54	5	90	95	190	0–150
	>150	0	52	120	170	0	230	440	680	0	370	200	570	0	660	760	1,400	>150
	Subtotal	0	53	140	200	4	280	510	790	1	420	210	630	5	750	860	1,600	Subtotal
Vermilion	0–150	6	64	300	370	0	0	7	7	0	18	0	18	6	82	310	400	0–150
	>150	0	77	590	660	0	27	780	800	0	6	48	54	0	110	1,400	1,500	>150
	Subtotal	6	140	890	1,000	0	27	780	810	0	24	48	72	6	190	1,700	1,900	Subtotal
East-central Illinois	0–150	6	66	330	400	10	48	77	130	39	230	39	310	57	350	450	850	0–150
	>150	0	210	820	1,000	0	800	2,100	2,900	0	1,500	1,000	2,500	0	2,500	3,900	6,400	>150
	Total	6	270	1,100	1,400	10	850	2,200	3,000	39	1,700	1,100	2,800	57	2,800	4,400	7,300	Total
Southeastern Illinois																		
Crawford	>150	0	31	8	38	0	260	140	400	0	480	290	770	0	780	440	1,200	>150
Jasper	>150	0	23	32	55	0	540	400	940	0	210	29	240	0	780	460	1,200	>150
Lawrence	>150	0	28	6	34	0	180	270	450	0	410	240	650	0	610	520	1,100	>150
Richland	>150	0	0	0	0	0	0	0	0	0	520	130	650	0	520	130	650	>150
Saline	0-150	0	0	0	0	68	1	0	69	0	0	0	0	68	1	0	69	0-150
Williamson	0-150	0	0	0	0	53	3	0	56	0	0	0	0	53	3	0	56	0-150
Southeastern Illinois	0–150	0	0	0	0	120	4	0	120	0	0	0	0	120	4	0	120	0–150
	>150	0	82	46	130	0	980	810	1,800	0	1,600	690	2,300	0	2,700	1,500	4,200	>150
	Total	0	82	46	130	120	980	810	1,900	0	1,600	690	2,300	120	2,700	1,500	4,300	Total

Appendix 3. Estimated remaining resources of the Danville Coal in Illinois and Indiana, and the Baker coal in western Kentucky—Continued.

County	Coal depth (feet)	Remaining resources (million short tons)																Coal depth (feet)
		I-A				I-B				II-A				Total				
		Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				
		>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	
Indiana																		
Gibson	0–150	49	82	17	150	13	33	4	49	0	0	0	0	61	110	21	200	0–150
	>150	230	360	70	660	130	210	22	360	0	0	0	0	360	580	92	1,000	>150
	Subtotal	280	440	87	810	140	240	25	410	0	0	0	0	420	690	110	1,200	Subtotal
Knox	0–150	15	80	60	150	8	92	28	130	0	16	0	16	23	190	88	300	0–150
	>150	73	380	190	640	32	300	120	440	0	8	0	9	110	680	300	1,100	>150
	Subtotal	88	460	250	790	40	390	150	570	0	24	0	24	130	870	390	1,400	Subtotal
Pike	0–150	4	6	0	10	4	36	6	46	3	30	5	38	10	72	12	94	0–150
	>150	1	5	0	6	2	19	0	21	0	0	0	0	2	25	0	27	>150
	Subtotal	5	12	0	17	5	55	6	67	3	30	5	38	12	97	12	120	Subtotal
Posey	0–150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0–150
	>150	92	450	11	550	220	380	1	600	40	18	0	57	350	850	12	1,200	>150
	Subtotal	92	450	11	550	220	380	1	600	40	18	0	57	350	850	12	1,200	Subtotal
Sullivan	0–150	22	130	86	230	19	87	25	130	0	0	0	0	41	210	110	360	0–150
	>150	87	230	120	440	75	270	30	370	0	2	0	2	160	500	150	820	>150
	Subtotal	110	360	210	670	94	350	55	500	0	2	0	2	200	710	260	1,200	Subtotal
Vanderburgh	0–150	4	1	1	6	11	8	1	19	13	27	0	40	27	36	1	65	0–150
	>150	42	16	0	58	77	60	0	140	32	44	0	76	150	120	0	270	>150
	Subtotal	46	17	1	63	88	69	1	160	45	71	0	120	180	160	1	340	Subtotal
Vermillion	0–150	0	1	27	27	0	0	9	9	0	0	1	1	0	1	37	38	0–150
	>150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	>150
	Subtotal	0	1	27	27	0	0	9	9	0	0	1	1	0	1	37	38	Subtotal
Vigo	0–150	5	77	130	210	2	82	110	190	0	0	0	0	6	160	230	400	0–150
	>150	10	21	53	83	10	86	65	160	0	1	0	1	20	110	120	240	>150
	Subtotal	14	98	180	290	11	170	170	350	0	1	0	1	26	270	350	640	Subtotal
Warrick	0–150	24	49	4	77	13	10	1	24	1	0	0	1	38	60	4	100	0–150
	>150	2	4	0	6	0	1	0	1	0	0	0	0	2	4	0	6	>150
	Subtotal	26	53	4	83	13	11	1	25	1	0	0	1	40	64	4	110	Subtotal
Indiana	0–150	120	430	320	870	70	350	180	600	16	73	7	96	210	840	500	1,600	0–150
	>150	540	1,500	440	2,400	540	1,300	230	2,100	72	73	0	140	1,200	2,900	670	4,700	>150
	Total	660	1,900	760	3,300	610	1,700	410	2,700	88	150	7	240	1,400	3,700	1,200	6,300	Total

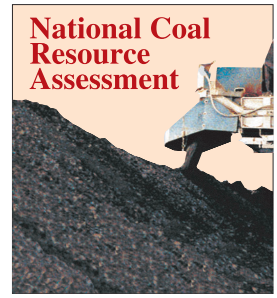
Appendix 3. Estimated remaining resources of the Danville Coal in Illinois and Indiana, and the Baker coal in western Kentucky—Continued.

County	Coal depth (feet)	Remaining resources (million short tons) Measured Coal thickness (inches)				Indicated Coal thickness (inches)				Inferred Coal thickness (inches)				Hypothetical Coal thickness (inches)				Total Coal thickness (inches)				Coal depth (feet)
		>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	
Western Kentucky																						
Daviess	0–150	3	0	0	3	4	0	0	4	3	6	1	10	1	0	0	1	10	6	1	18	0–150
	>150	0	0	0	0	1	1	1	3	0	3	4	7	0	0	0	0	1	4	5	10	>150
	Subtotal	3	0	0	3	5	1	1	7	3	10	5	17	1	0	0	1	11	10	7	28	Subtotal
Henderson	0–150	14	19	29	62	44	47	71	160	67	82	80	230	27	8	8	43	150	160	190	500	0–150
	>150	1	4	17	22	3	15	70	89	19	82	210	310	35	41	28	110	58	140	320	520	>150
	Subtotal	15	22	46	84	47	62	140	250	86	160	290	540	63	49	36	150	210	300	510	1,000	Subtotal
Hopkins	0–150	18	5	15	38	21	7	9	37	11	1	1	12	0	0	0	0	50	13	24	88	0–150
	>150	22	25	50	97	43	35	120	190	110	55	77	240	22	21	0	43	190	140	240	570	>150
	Subtotal	40	30	65	130	64	43	130	230	120	55	78	250	22	21	0	43	240	150	270	660	Subtotal
McLean	0–150	5	5	2	12	9	11	2	22	15	20	1	36	1	0	0	1	30	37	4	71	0–150
	>150	27	25	17	60	44	38	19	100	71	39	21	130	0	0	0	0	140	92	57	290	>150
	Subtotal	32	21	19	72	53	49	21	120	86	59	22	170	1	0	0	1	170	130	61	360	Subtotal
Muhlenberg	0–150	7	3	3	13	15	6	0	22	33	26	0	59	2	13	0	15	57	49	3	110	0–150
	>150	15	5	1	21	30	6	3	39	27	6	0	33	0	0	0	0	72	17	4	94	>150
	Subtotal	22	8	4	34	44	12	3	60	60	32	0	93	2	13	0	15	130	66	8	200	Subtotal
Ohio	0–150	0	3	2	5	1	8	3	12	20	74	7	100	1	25	2	28	22	110	15	150	0–150
	>150	0	0	0	0	0	0	0	0	4	13	5	22	0	6	0	7	4	19	5	28	>150
	Subtotal	0	3	2	5	1	9	3	12	24	87	12	120	1	31	3	35	26	130	20	180	Subtotal
Union	0–150	1	2	1	4	3	2	0	5	4	2	0	6	0	0	0	0	9	5	1	15	0–150
	>150	25	22	5	52	54	22	5	80	45	10	1	56	19	0	0	19	140	54	11	210	>150
	Subtotal	27	24	6	56	57	24	5	86	49	12	1	61	19	0	0	19	150	59	12	220	Subtotal
Webster	0–150	1	2	14	16	1	3	23	26	6	26	3	36	2	1	0	2	9	32	39	80	0–150
	>150	10	25	190	230	18	36	260	310	20	51	260	330	3	7	6	17	52	120	720	890	>150
	Subtotal	10	27	200	240	18	39	280	340	26	77	260	370	5	8	6	19	60	150	760	970	Subtotal
Western Kentucky	0–150	50	40	65	150	97	85	110	290	160	240	92	490	34	47	10	91	340	410	270	1,000	0–150
	>150	100	96	280	480	190	150	470	820	290	260	580	1,100	80	77	35	190	660	580	1,400	2,600	>150
	Total	150	130	350	630	290	240	580	1,100	450	500	670	1,600	110	120	45	280	1,000	990	1,600	3,600	Total

Chapter E

Characterization of the Quality of Coals from the Illinois Basin

By R.H. Affolter *and* J.R. Hatch



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Chapter E *of*

Resource Assessment of the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin

Edited by J.R. Hatch *and* R.H. Affolter

U.S. Geological Survey Professional Paper 1625–D

U.S. Department of the Interior
U.S. Geological Survey

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Characterization of the Quality of Coals from the Illinois Basin

By R.H. Affolter[1] *and* J.R. Hatch[1]

Introduction

The goal of the Illinois Basin Coal Assessment Project is to provide an overview of the geologic setting, distribution, resources, and quality of Pennsylvanian coal in the Illinois Basin. This assessment is part of the U.S. Geological Survey's National Coal Resource Assessment Program (NCRA), which includes, along with the Illinois Basin, the Colorado Plateau, the Northern Rocky Mountains and Northern Great Plains region, the Appalachian Basin, and the Gulf Coast region of the United States (fig. 1). Such studies are of considerable significance because environmental mandates and concerns relating to coal development have become increasingly important to the National interest.

This assessment is different from previous U.S. Geological Survey coal assessments in that the major emphasis is placed on coals that are most likely to be major sources of energy over the next few decades (Gluskoter and others, 1996). Another major difference is that data are being collected and stored in a digital format that can be updated as new information becomes available. In the future, environmental considerations may eventually control which coals will be mined and will determine what preventative procedures will be implemented in order to reduce sulfur and possibly trace element emissions from coal-burning power plants. It is also expected that in the future, emphasis will be placed on coal combustion products and the challenges of disposal and utilization of these products. Therefore, this coal-quality assessment includes not only information on ash, sulfur, and calorific content, but also information on the major-, minor-, and trace-element content of these coals. Characterization of coal quality is an important aspect of the assessment program in that it provides a synthesis and analysis of data that will influence future utilization of this valuable resource.

Acknowledgments and Products

The Illinois Basin coal assessment was completed in cooperation with multidisciplinary groups of scientists, technicians, and computer specialists from the U.S. Geological Survey (USGS), the Indiana Geological Survey (IGS), the Kentucky Geological Survey (KGS), and the Illinois State Geological Survey (ISGS). Together, these three state surveys make up the Illinois Basin Consortium (IBC). The main products of this assessment are digital databases that contain all publicly available point-source data on thickness, depth, and coal quality for the Springfield, Herrin, Danville, and Baker Coals, which are the major mined coals in the basin. From this database, statewide maps have been prepared that depict thickness, elevation (structure), mined-out areas, and extents of the principal areas where the coals may potentially be mined at the surface or recovered from underground. This information is available as digital products accessible in a variety of interpretive and interactive forms (see the ArcView section of this publication).

Geologic Framework

The Illinois Basin coal assessment area includes parts of Illinois, southwestern Indiana, and western Kentucky, containing the largest reserve base of bituminous coal of any basin in the United States. Coal production in 2000 was about 88.4 million short tons (Freme, 2001). However, this production level is declining (down from 104 million short tons in 1999) and is expected to decline further as electric utilities switch from high-sulfur Illinois Basin coal to low-sulfur western coal. Assessments of the original and remaining coal resources, coal compositions, and recoverable coal reserves in the Illinois Basin have at least a 100-year history. The last major coal assessment by the U.S. Geological Survey was done in 1974 (Averitt, 1975).

Coal-bearing rocks in the Illinois Basin are part of the Eastern Region of the Interior Coal Province (Trumball, 1960). These rocks are of Pennsylvanian age and were formed between about 325 and 290 million years ago. In the Illinois Basin, the Pennsylvanian rocks are divided into the Raccoon Creek Group, the Carbondale Group or Formation, and the McLeansboro Group. Correlations of these strata across Illinois, southwestern Indiana, and western Kentucky are shown in figure 2.

Stratigraphic Nomenclature

The Raccoon Creek Group, Carbondale Formation, and McLeansboro Group are defined the same in Illinois and western Kentucky (Jacobson and others, 1985), but are defined differently in Indiana (see fig. 2). The main differences are

(1) The Raccoon Creek Group in Illinois and western Kentucky is divided into the Caseyville and Tradewater Formations. The Raccoon Creek Group in Indiana consists of the Mansfield, Brazil, and Staunton Formations.

(2) The Carbondale Formation is recognized in Illinois and Kentucky. The Carbondale Group is recognized in Indiana, where it is divided into the Linton, Petersburg, and Dugger Formations.

(3) In Indiana, the Seelyville Coal Member is at the top of the Staunton Formation of the Raccoon Group, whereas in Illinois and western Kentucky the Seelyville Coal and equivalents are in the Carbondale Formation.

[1]U.S. Geological Survey, Mail Stop 939, Box 25046, Denver, CO 80225

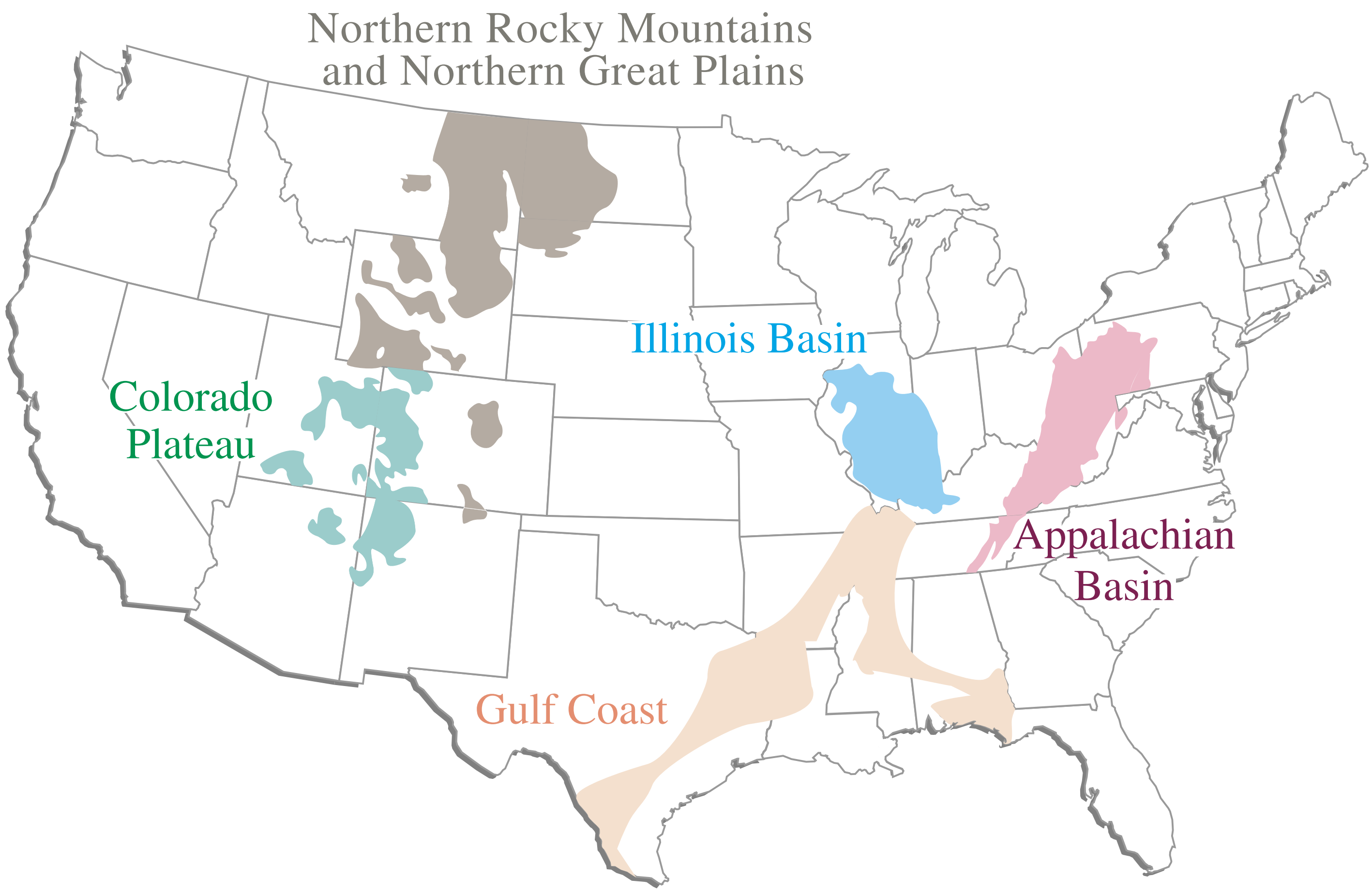

Figure 1. Map showing location of the Illinois Basin study area in the United States in relation to other areas assessed during the National Coal Resource Assessment Project.

(4) The base of the McLeansboro Group and the base of the Shelburn Formation in Illinois and Kentucky are at the top of the Herrin Coal. The base of the Shelburn Formation is at the top of the Danville Coal Member in Indiana.

(5) The Springfield Coal is in the Carbondale Formation in Illinois and western Kentucky and in the Petersburg Formation in Indiana. The Herrin Coal is in the Carbondale Formation in Illinois and western Kentucky and in the Dugger Formation in Indiana; however, the Herrin Coal Member is neither well developed nor mined in Indiana. The Danville Coal Member is in the Shelburn Formation of the McLeansboro Group in Illinois and in the Dugger Formation of the Carbondale Group in Indiana. The Baker coal is in the Shelburn Formation of the McLeansboro Group in western Kentucky.

(6) In Illinois (Hopkins and Simon, 1975) and Indiana (Mastalerz and Harper, 1998), the Springfield, Herrin, and Danville Coal Members, as well as most other coals, are formally recognized stratigraphic members. In western Kentucky, coals are not given that same status (for example, the Baker coal) (Greb and others, 1992). For this assessment report, when discussing coals in a given State we will follow the stratigraphic nomenclature previously established for that State. When referring to a coal, or coals, in an area that includes parts of States having different stratigraphic nomenclatures, we will list the coal name as the Springfield Coal, Herrin Coal, Danville Coal, or Baker Coal. When summarizing and comparing the chemistry of the coals, we have chosen to combine the Danville and Baker Coals (Danville-Baker) as stratigraphically equivalent units and also to list them as separate coals for each State.

The primary focus of this chapter is the chemical composition of coals from the Springfield Coal (Illinois No. 5, western Kentucky No. 9, Indiana V), the Herrin Coal (Illinois No. 6, western Kentucky No. 11), the Danville Coal (Illinois No. 7, Indiana VII), and the Baker coal (western Kentucky No. 13). The Springfield and Herrin Coals are in the Carbondale Formation or Group in all three States. The Danville-Baker Coals are within the McLeansboro Group in Illinois and western Kentucky but within the Carbondale Group in southwestern Indiana. The chemical

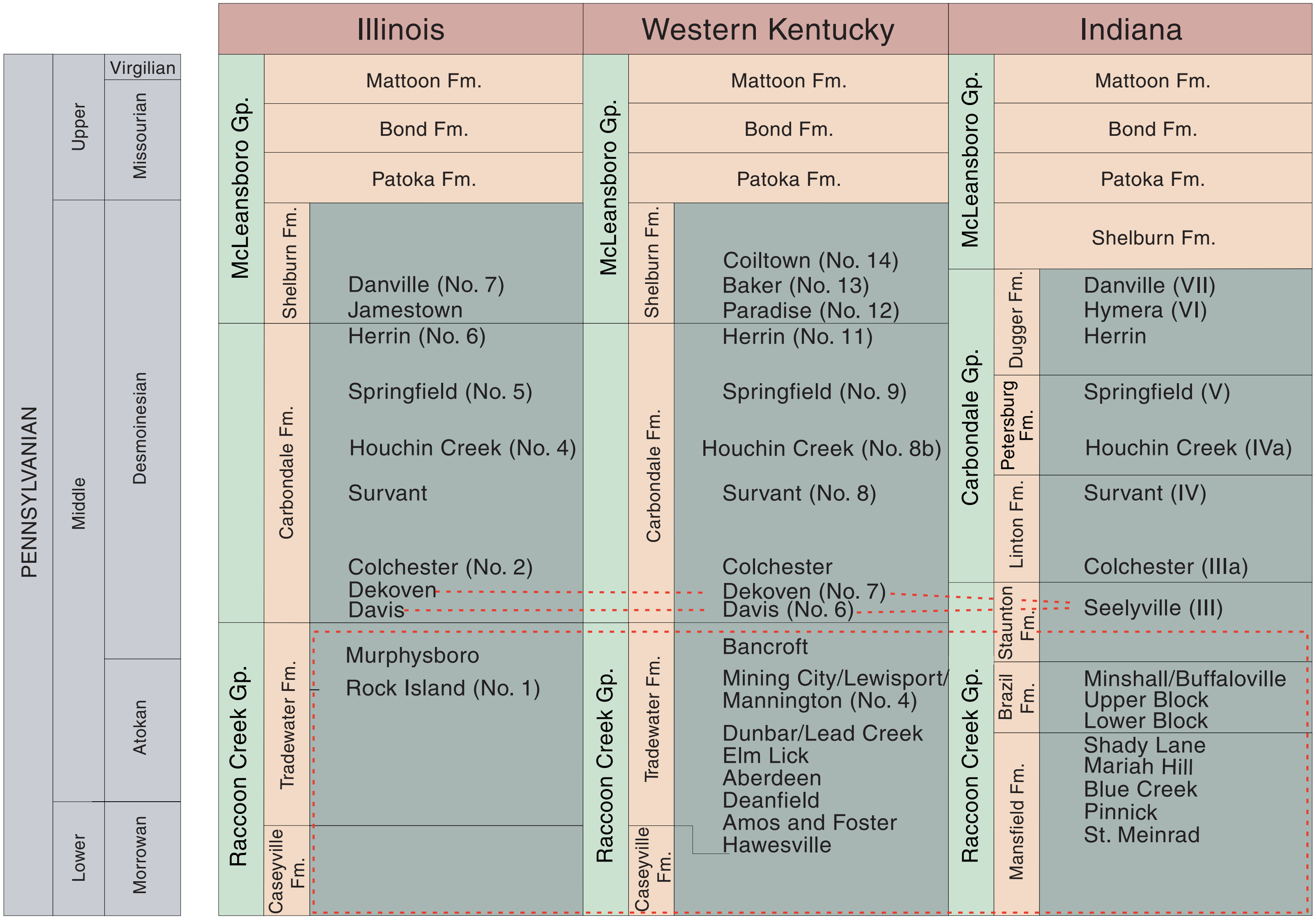

Figure 2. Stratigraphic chart of the Pennsylvanian system in the Illinois Basin, showing major coal members. Modified from Mastalerz and Harper (1998, fig. 2) and Greb and others (1992, fig. 22). Fm., Formation; Gp, Group; - - -, problematic coal correlations.

compositions of nonassessed coals from the McLeansboro Group, Carbondale Group or Formation, and Raccoon Creek Group from southwestern Indiana and western Kentucky have also been summarized. These additional analyses are included in summary charts or tables in the appendixes to provide an overall view of the quality and characterization of all coal (assessed and nonassessed) from the Illinois Basin.

Methods

Proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for this study were provided by the USGS, ISGS, IGS, and KGS. Major-, minor-, and trace-element analyses were supplied by the USGS, ISGS, and only selected elements by the KGS. For assessed coals, table 1 summarizes the data by State, coal-bearing stratigraphic unit, coal name of assessed coals, number of samples, data source, and name of ASCII file used to create the ArcView State views for the Springfield, Herrin, Danville, and Baker Coals. Table 2 summarizes the same information for nonassessed beds from the Raccoon Creek Group, Carbondale Group or Formation, and McLeansboro Group. Table 3 shows the data source, number of samples analyzed, name of ASCII file containing chemical data, State, coal-bearing stratigraphic unit, and coal names used to create the ArcView regional views for the Springfield, Herrin, Danville, and Baker Coals.

Because the data for this study were received from multiple sources, it is important to document the individual techniques and methods as well as what the data represent. Following is a brief summary of the methods used by the various sources.

U.S. Geological Survey

Since 1971 the USGS has maintained a program to evaluate the chemical composition of coal in the United States. This has been accomplished through a cooperative effort in the collection of coal samples by many different workers from State and Federal agencies, the coal mining industry, and various colleges and universities. The goals were to (1) provide baseline chemical and geologic data through the evaluation of site-specific, proposed or future surface and underground mining and future reclamation areas, and (2) store this information in digital form (Affolter and Hatch, 1995).

The USGS USCHEM coal-quality database is a geologic database in that it represents the quality of the coal as it is found in the ground, and it represents only single coals. Information on coal-mine products or washed coals that are directly utilized by utilities was not available. A complete description of the USCHEM database, along with a discussion of its weaknesses and strengths, was given by Finkelman and others (1994, table 7). Despite its limitations, the USCHEM database is one of the few comprehensive and publicly available sources of proximate and ultimate analyses, forms of sulfur, calorific values, and major-, minor-, and trace-element content of United States coals. Documentation and chemical analyses for coal samples processed during the USGS's collection program are available to the public in more than 40 published reports (Finkelman and others, 1991).

Ash yields were determined and major-, minor-, and trace-element contents were analyzed by USGS laboratories in Denver, Colo., and Reston, Va. Detailed descriptions of analytical methods are given by Swanson and Huffman (1976), Baedecker (1987), and Golightly and Simon (1989); figure 3 is a flow diagram of procedures used for the analysis of Illinois Basin coal samples (modified from Finkelman and others, 1994). Proximate and ultimate analyses, calorific value, and forms of sulfur were determined by commercial and government laboratories according to ASTM standards (American Society for Testing and Materials, 1999a). The raw analytical data are stored digitally in the USGS USCHEM Coal Quality Database. All chemical data are either on an as-received or whole-coal basis. The samples, primarily face-channel or bench mine samples, are representative of the coals in general and were carefully selected to provide an accurate view of the overall coal quality throughout the basin.

Some analytical data for the Illinois Basin were previously published by Swanson and others (1976), Zubovic and others (1979, 1980), and Oman and others (1992). Some of the data are also available digitally on the USGS COALQUAL database (Bragg and others, 1998) and the National Geochemical database: PLUTO Geochemical database for the United States (Baedecker and others, 1998).

Samples selected from the USCHEM database for the purpose of the present study were of Pennsylvanian age, with less than 50 percent ash yield, and were all within the Illinois Basin study area in Illinois, southwestern Indiana, and western Kentucky. All samples were edited for geographical and chemical information and were updated to reflect any changes. The resulting data therefore represent a modified subset of the USCHEM database. These data sets are listed in tables 1–3 and are stored on disc 2 of this CD-ROM as ASCII text files ilhechmu.txt, indachmu.txt, inspchmu.txt, incgchmu.txt, inrgchmu.txt, kyspchmu.txt, kydachmu.txt, kyhechmu.txt, kymgchmu.txt, kyrgchmu.txt, kycgchmu.txt, and uschmu.txt. In ArcView these text files were added as tables, the tables were added as event themes, and the themes were converted into shapefiles. A data dictionary explaining all the fields within this database is included in appendix 8 of this chapter and as uschmtm.pdf on disc 2 in the ArcView regional views. In the ArcView project, the data dictionary is linked to the individual ArcView geochemical shapefiles.

Illinois State Geological Survey

Chemical data from Illinois coals are primarily from face-channel samples collected in active or abandoned mines. Files for the Springfield, Herrin, and Danville Coals (il_loc.dif, il_prox.dif, il_ult.dif, il_misc.dif, il_rem.dif, and il_trace.dif) were supplied by Colin Treworgy of the ISGS, merged into one file and edited for content. Each analysis in the Illinois coal database has a unique 12-character identifier called LABNO (laboratory number). The first character in the item LABNO is a letter assigned by the ISGS indicating the laboratory that analyzed the sample. All chemical data are either on a dry basis or dry, whole-coal basis. Publications by Cady (1935, 1948), Rees (1966),

Table 1. State, coal-bearing stratigraphic unit, coal name of assessed coals, number of samples, data source, and name of ASCII file containing chemical data from coal samples for the Illinois Basin coal assessment.

State	Stratigraphic unit	Coal name	No. of samples	Data source	File name
Illinois	Shelburn Formation	Danville (No. 7)	170	ISGS[1]	Ildachms.txt
	Carbondale Formation	Herrin (No. 6)	77	USGS[2]	Ilhechmu.txt
			2,330	ISGS	Ilhechms.txt
		Springfield (No. 5)	1,171	ISGS	Ilspchms.txt
Indiana	Dugger Formation	Danville (VII)	115	IGS[3]	Indachms.txt
			19	USGS	Indachmu.txt
	Petersburg Formation	Springfield (V)	336	IGS	Inspchms.txt
			49	USGS	Inspchmu.txt
Kentucky	Shelburn Formation	Baker	19	KGS[4]	Kydachms.txt
		Baker (No. 13)	15	USGS	Kydachmu.txt
	Carbondale Formation	Herrin	121	KGS	Kyhechms.txt
		Herrin (No. 11)	20	USGS	Kyhechmu.txt
		Springfield	259	KGS	Kyspchms.txt
		Springfield (No. 9)	31	USGS	Kyspchmu.txt

[1]Illinois State Geological Survey
[2]U.S. Geological Survey
[3]Indiana Geological Survey
[4]Kentucky Geological Survey

Gluskoter and others (1977), and Harvey and others (1983, 1985) document and list in detail the analytical procedures used by the Illinois State Geological Survey for most coal samples.

Samples from this ISGS file were retrieved if they contained less than 50 percent ash yield and were within the Illinois part of the Illinois Basin study area. All samples were edited for geographical and chemical information and were updated to reflect any changes. The resulting data set is therefore a modified subset of the ISGS chemical database. These data sets are listed in tables 1 and 3 and stored on disc 2 of on this CD-ROM as ASCII text files ildachms.txt, ilhechms.txt, ilspchems.txt, and ilchms.txt. In ArcView the text files were added as tables, the tables were added as event themes, and the themes were converted into shapefiles. A data dictionary explaining all the fields within this database is included in appendix 8 and as ilchmtm.pdf on disc 2 in the ArcView regional views. This data dictionary is linked to the individual ArcView geochemical shapefiles.

Indiana Geological Survey

Samples from Indiana were collected by the IGS, primarily from face-channels in mines, with some mine tipple and grab samples where no other samples were available. These data were selected from "The Indiana Coal Analysis Database; Computer database 1" by Hasenmueller and Miller (1992). Some of these data were also published by Hasenmueller (1994) and Mastalerz and Harper (1998). All analyses were done according to ASTM standards (American Society for Testing and Materials, 1999a). Some of these analyses were performed on sample splits received from the USGS that were analyzed by several different laboratories, therefore resulting in slightly different analytical results. Also, some location descriptions have been updated.

Text files from Hasenmueller and Miller's 1992 report (igschm1l, igschm1c, igschm1r, igschm2l, igschm2c, igschm2r, igschm3l, igschm3c, igschm3r) were merged and modified. Samples from this merged file were retrieved if they contained less than 50 percent ash yield and were collected within the southwestern Indiana part of the Illinois Basin study area. All samples were edited for geological and chemical information and were updated to reflect any changes. This resulting data set is therefore a modified subset of the coal analysis database published by Hasenmueller and Miller (1992). The data are listed in tables 1–3 and stored as ASCII text files indachms.txt, inspchms.txt, incgchms.txt, inrgchms.txt, and inchms.txt on disc 2 of this CD-ROM. In ArcView, the text files were added as tables, the tables were added as event themes, and the themes were converted into shapefiles. All chemical data are on an as-received basis and contain no major-, minor-, or trace-element data. A data dictionary explaining all the fields within this database is included in appendix 8 and as inchmtm.pdf on disc 2 in the ArcView regional views. In the ArcView project the data dictionary is linked to the individual ArcView geochemical shapefiles.

Kentucky Geological Survey

Samples from Kentucky are primarily from face channels in mines and were collected either by the KGS or by the USGS. Files (wky1.xls, wky2.xls, wky3.xls, and wky4.xls) were supplied by Cortland Eble of the KGS, merged into one file, and then edited for content. Samples from this merged file were retrieved

Table 2. State, coal-bearing stratigraphic unit, coal names of nonassessed coals, number of samples, data source, and name of ASCII file containing chemical data from coal samples for the Illinois Basin coal assessment.

State	Stratigraphic unit	Coal names	No. of samples	Data source	File name
Indiana	Carbondale Group	Bucktown, Colchester, Houchin Creek, Hymera, Survant, unnamed Dugger, and unnamed Linton.	313	IGS[1]	Incgchms.txt
		Bucktown V-B, Colchester, Houchin Creek IV-A, Hymera VI, Survant IV.	44	USGS[2]	Incgchmu.txt
	Raccoon Creek Group	Blue Creek, Buffaloville, French Lick, Lower Block, Mariah Hill, Minshall, Pinnick, Seelyville, St. Meinrad, unnamed Brazil, unnamed Mansfield, unnamed Staunton, Upper Block	586	IGS	Inrgchms.txt
		Blue Creek, Buffaloville, Lower Block, Mariah Hill, Seelyville III, St. Meinrad, unnamed Brazil, unnamed Mansfield, unnamed Staunton, Upper Block	106	USGS	Inrgchmu.txt
Kentucky	Carbondale Formation	Briar Hill, Dekoven, No. 6, No. 7, No. 8, No. 8B, Schultztown	42	KGS[3]	Kycgchms.txt
		No. 6, No. 7, No. 8, No. 8B	42	USGS	Kycgchmu.txt
	Raccoon Creek Group	Aberdeen, Amos, Amos Rider, Bancroft, Bell, Deanfield, Dunbar, Elm Lick B, Elm Lick C, Foster, Main Nolin, No. 4A, No. 5	87	KGS	Kyrgchms.txt
		Amos, Deanfield, Dunbar, Elm Lick, Elm Lick Zone, Empire, Foster, Hawesville, Lead Creek, No. 1B, No. 4, No. 4A, No. 5, Nolin	43	USGS	Kyrgchmu.txt
	McLeansboro Group	Coiltown, No. 12, No. 13B split	57	KGS	Kymgchms.txt
		No. 12, No. 14	25	USGS	Kymgchmu.txt

[1]Indiana Geological Survey
[2]U.S. Geological Survey
[3]Kentucky Geological Survey

if they contained less than 50 percent ash yield and were collected within the western Kentucky part of the Illinois Basin study area. All samples were edited for geographical and chemical information and were updated to reflect any changes. The resulting data set is therefore a modified subset of the KGS's chemical database. All chemical data are on a dry basis or a dry, whole-coal basis and contain proximate and ultimate analyses, calorific values, and only selected major-, minor-, and trace element data; forms of sulfur or ash-fusion temperature data are not included. All proximate and ultimate analyses were done according to ASTM standards (American Society for Testing and Materials, 1999a). Some of the data may consist of duplicate analyses from the USGS that were analyzed by different methods. There is limited published information on the specific analytical methods that were used to determine KGS coal quality data. Some data were published by Currens (1986), and additional information about the samples may be obtained from the KGS.

Data acquired on Kentucky coals are listed in tables 1–3 and stored as ASCII text files kyspchms.txt, kyhechms.txt, kydachms.txt, kycgchms.txt, kyrgchms.txt, kymgchms.txt, and kychms.txt on disc 2 of this CD-ROM. In ArcView, the text files were added as tables, the tables were added as event themes, and the themes were converted into shapefiles. A data dictionary explaining all the fields within this database is included in appendix 8 and as kychmtm.pdf on disc 2 in the ArcView regional views. In the ArcView project, the data dictionary is linked to the individual ArcView geochemical shapefiles.

Explanation of Data Selected for the Illinois Basin Assessment

The chemical information on the Illinois Basin coals presented in this report is a compilation of data that were collected during the last 30–50 years by the USGS, ISGS, IGS, and KGS. The coal-quality data are primarily from samples of the Springfield, Herrin, Danville, and Baker Coals (assessed coals), with additional samples of coals (nonassessed) from the Raccoon Creek Group, the Carbondale Group or Formation, and the McLeansboro Group. Figure 4 shows the sample localities for

Table 3. Data source, number of samples analyzed, name of ASCII file containing chemical data, State, coal-bearing stratigraphic unit, and coal names of assessed coals for the regional summaries from the Illinois Basin coal assessment.

Data source	No. of samples	File name	State	Stratigraphic unit	Coal name
ISGS[1]	3,671	Ilchms.txt	Illinois	Shelburn Formation	Danville (No. 7)
				Carbondale Formation	Herrin (No. 6) Springfield (No. 5)
IGS[2]	451	Inchms.txt	Indiana	Dugger Formation Petersburg Formation	Danville (VII) Springfield (V)
KGS[3]	399	Kychms.txt	Kentucky	Shelburn Formation	Baker
				Carbondale Formation	Herrin Springfield
USGS[4]	211	Uschmu.txt	Indiana Kentucky Illinois Kentucky Indiana Kentucky	Dugger Formation Shelburn Formation Carbondale Formation Carbondale Formation Petersburg Formation Carbondale Formation	Danville (VII) Baker (No. 13) Herrin (No. 6) Herrin (No. 11) Springfield (V) Springfield (No. 9)

[1] Illinois State Geological Survey
[2] Indiana Geological Survey
[3] Kentucky Geological Survey
[4] U.S. Geological Survey

the assessed coals in the Illinois Basin, and figure 5 shows the sample localities for nonassessed coals in the Illinois Basin that have been chemically analyzed.

Chemical data for this study were derived from many different sources; hence, they may reflect variations in the quality of analytical results. Analytical procedures have changed through time, with improved detection limits being made possible by new and more precise analytical methods. Because of differences in the precision of various analytical techniques and for consistency, the analytical values in the trace-element summary tables are reported to only two significant figures for most elements. Mercury and cadmium are reported to no more than two decimal places, and antimony and selenium to only one decimal place. Proximate and ultimate analyses and total sulfur are reported to one decimal place. Calorific values are reported to the nearest 10 Btu, ash-fusion temperatures to the nearest 5° F., and forms of sulfur to two decimal places. Also for consistency and meaningful comparison of the chemical composition of these coals, all proximate and ultimate analyses, calorific value, forms of sulfur, and ash-fusion temperatures were calculated to an as-received basis by formula ASTM D3180 (American Society for Testing and Materials, 1999b) (see appendixes 1 and 2). All elements were calculated to an as-received, whole-coal basis and are presented in percent or as parts per million (see appendixes 3 and 4). Because some of these coals show a wide range in values, the mean is not always the best estimate of the average value. Therefore, we have also included the median, which is a better measure of the central tendency when values have large ranges and (or) nonnormal data distributions.

A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of censored data for the summary statistics in this report (tables in appendixes 1–4), we adopted the protocol of reducing all " less than" values by 50 percent before summary statistics were generated. For example, a reported value of 4.0L was changed to 2.0L, which was then used to calculate basic statistics.

The uneven geographic distribution of sample localities precludes a thorough and detailed analysis of all coals within the Illinois Basin assessment area. For comparison across the basin, representative coal samples were carefully selected and restricted to samples containing less than 50 percent ash yield (Wood and others, 1983). Samples were also carefully selected in order to provide a regional and State view of the quality for each coal. In order to adequately characterize these coals, some chemical comparisons were made among individual Illinois Basin coals and also among these coals and other major coals of Pennsylvanian, Cretaceous, and Tertiary ages that make up most of the marketable coal in the United States. Comparison with these other coals allowed us to evaluate and contrast the quality of Illinois Basin coal with other coal mined in the United States.

Appendix 1 consists of 11 tables that show the number of samples and summary statistics for the proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for all coals in the Illinois Basin, presented on a regional basis; appendix 2 consists of 24 tables that show similar data for all coals in the Illinois Basin on a statewide basis. Appendix 3 consists of 11 tables that show the number of samples and summary statistics for ash yield and 38 elements in all coals in the Illinois Basin, on a regional basis; appendix 4 consists of 20 tables that show similar data for all coals in the Illinois Basin,

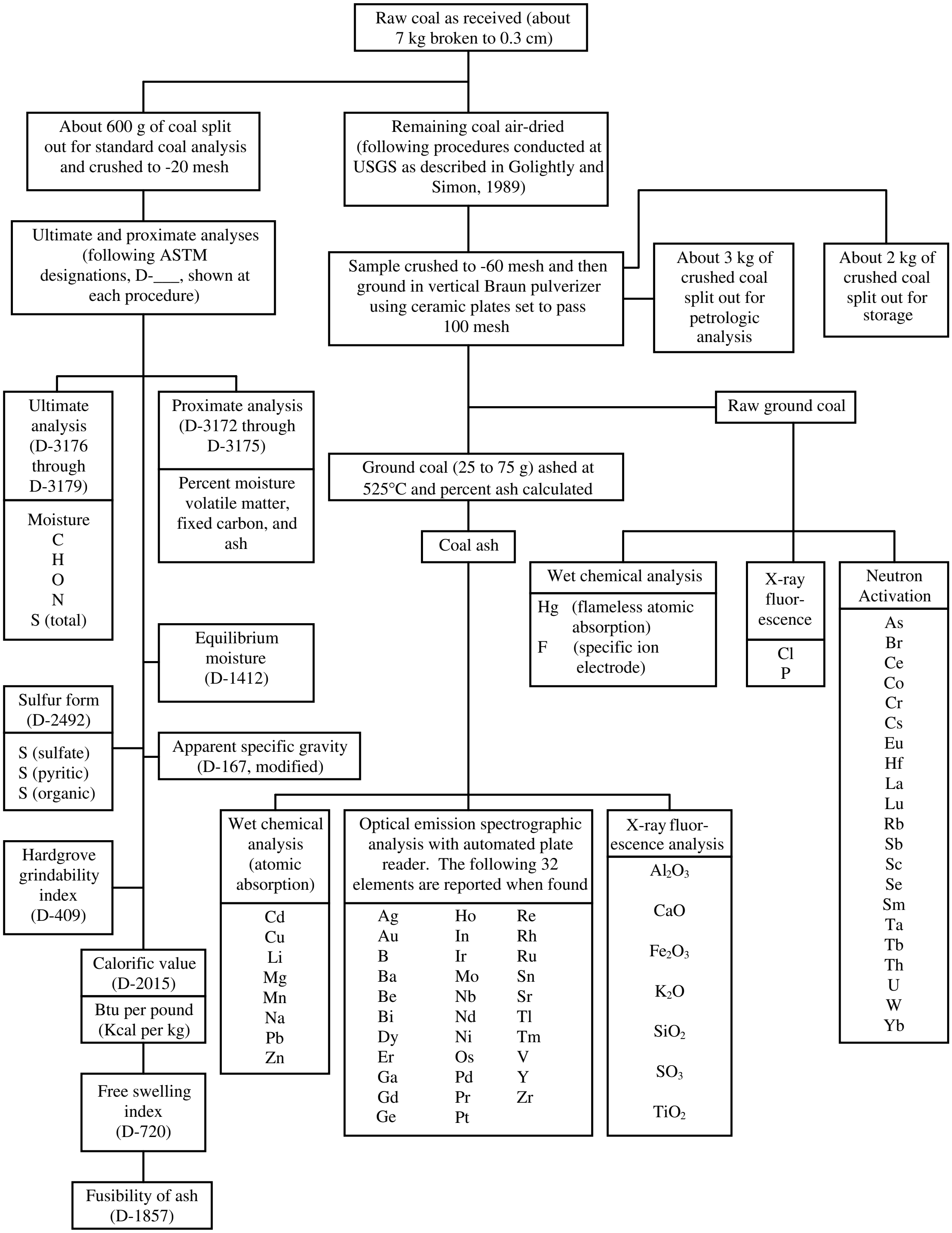

Figure 3. Flow diagram of analytical procedures used through September 1990 for the analysis of coal samples from the Illinois Basin assessment. Modified from Finkelman and others (1994). ASTM, American Society for Testing and Materials, 1999; USGS, United States Geological Survey.

presented on a statewide basis. Tables 1–3 list all ASCII text database file names for all coal samples that were used in this study. These files contain all the original (as received from the individual States) compositional data reported on the basis in which they were received and contains correct significant figures. Qualified data in these files are indicated by L (less than), B (not determined), N (not detected), or G (greater than).

Importance of Coal Quality

Hatch and Swanson (1977) suggested four general reasons why coal-quality data are necessary for the proper assessment and utilization of coal:

(1) Evaluation of environmental impacts of mining of coal

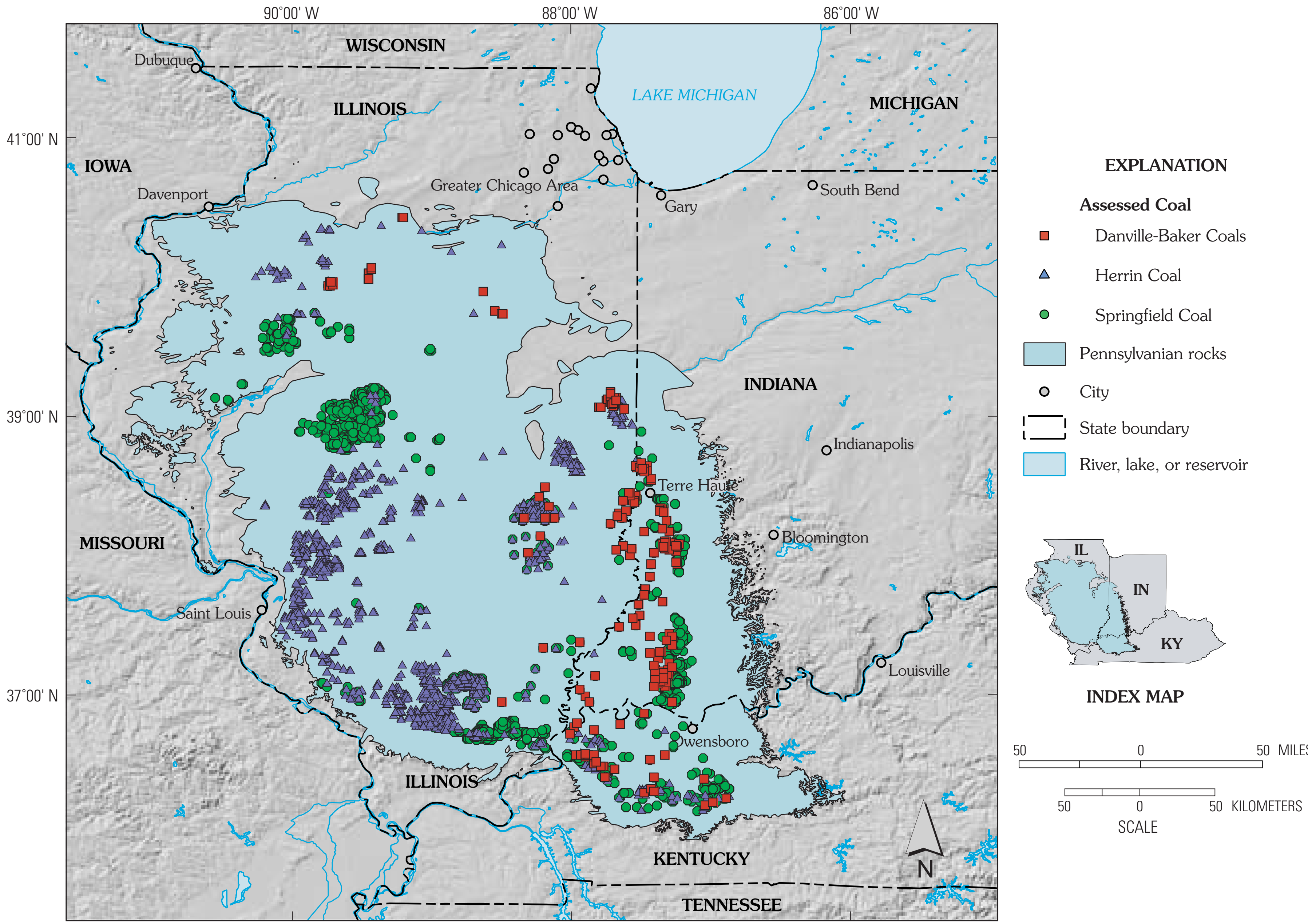

Figure 4. Localities of Pennsylvanian samples from assessed coals in the Illinois Basin for which chemical data are available.

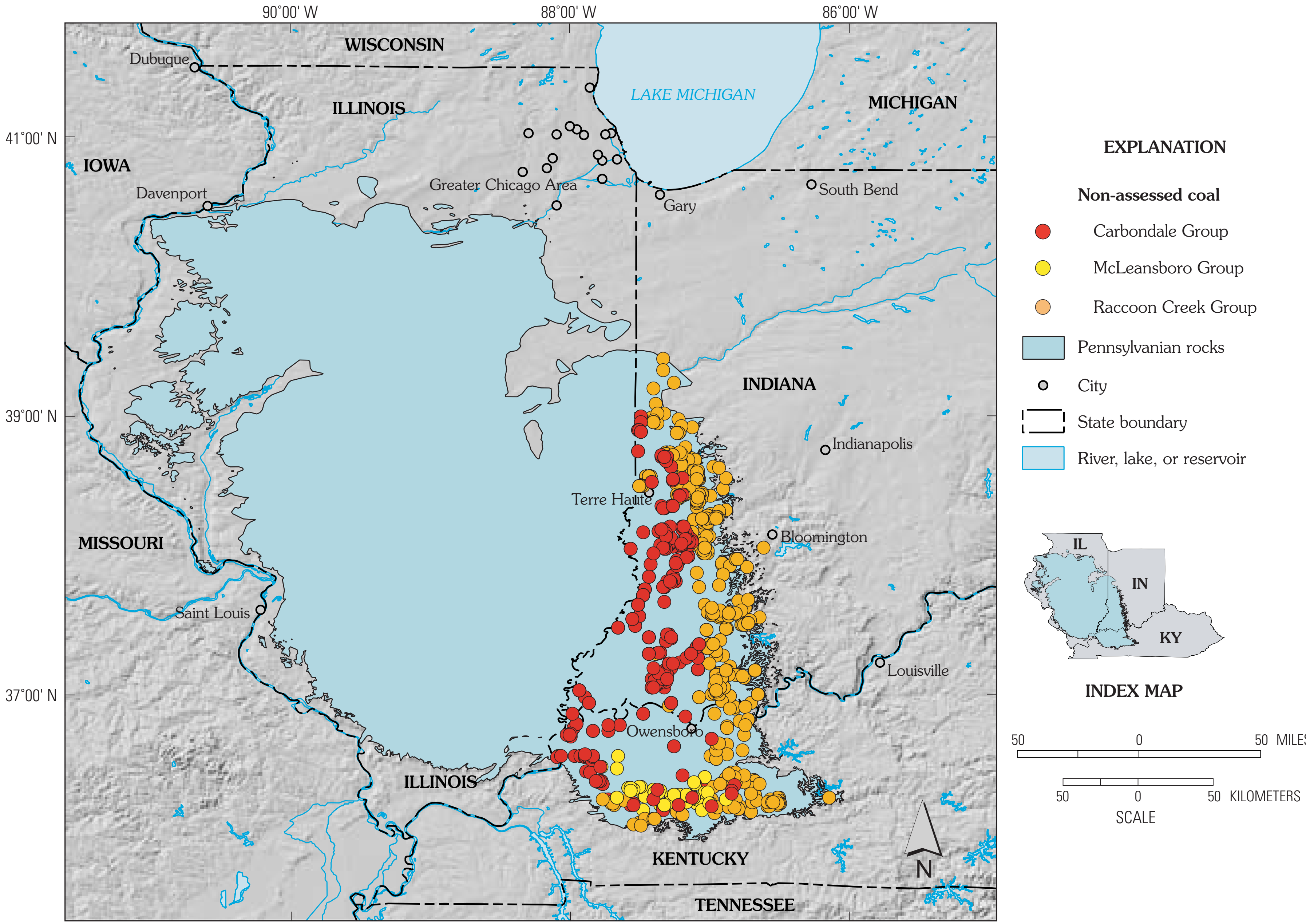

Figure 5. Localities of Pennsylvanian samples from nonassessed coals in the Illinois Basin for which chemical data are available.

(2) Evaluation of the best and most effective technological use of coal (for example, combustion, liquefaction, gasification)
(3) Determination of the potential economic benefits of the extraction of elements such as germanium, selenium, uranium, vanadium, and zinc from the coal
(4) Development of geologic and geochemical models for the interpretation and prediction of coal quality and for relating these factors to the stratigraphic and sedimentological framework

Health issues related to increased utilization of coal, either as a result of mining or combustion, are also important factors. Current coal-quality issues related to coal combustion are now focusing on the release of particulate matter, sulfur, and trace elements, as well as acid-rain and greenhouse-gas effects. The quality of the coal mined and burned impacts air and water quality. It also affects disposal of the solid waste (fly ash desulfurization sludge, washing plant sludge, and bottom ash), recovery of economic coal combustion products (CCP's), and power plant efficiency.

With emphasis on elements of environmental concern as indicated in the 1990 Clean Air Act Amendment (U.S. Statutes at Large, 1990, Public Law 101–549), there has been concern about the possible health effects of increased coal utilization. This Clean Air Act Amendment has identified several potentially hazardous air pollutants, including antimony, arsenic, beryllium, cadmium, cobalt, lead, manganese, mercury, nickel, selenium, and uranium. Because coal-quality data are an essential component of the USGS resource classification system (Wood and others, 1983), and because utilization of coal may be regulated by its possible effect on the environment, any evaluation of future coal resource potential must and should consider quality as well as quantity.

Coal Quality in the Illinois Basin

The main purpose of this coal-quality study is to list and summarize coal chemical information from the Illinois Basin, illustrating regional trends, and to graphically display the information. Summary tables of regional data (Illinois Basin) and individual State data were compiled. These tables are supplemented with range plots and histograms that compare ash, sulfur, calorific values, and contents of potentially hazardous air pollutants (antimony, arsenic, beryllium, cadmium, chromium, cobalt, lead, manganese, mercury, nickel, selenium, thorium, and uranium). Most of the chemical data listed and summarized for this coal assessment have been previously published and discussed by various authors over the last 30 years.

Appendix 5 consists of diagrams showing minimum, maximum, and median values for ash yield, sulfur content, and calorific value for the Danville-Baker, Herrin, and Springfield Coals. Also included for comparison are the McLeansboro Group, Carbondale Group or Formation, and Raccoon Creek Group Coals. In summarizing and comparing coals on a regional basis, we have chosen to treat the combined Danville and Baker Coals as stratigraphically equivalent coals; they are therefore summarized together as the Danville-Baker Coals. Appendix 6 consists of frequency histograms for ash yield, sulfur content, calorific value, and elements of environmental concern for the Danville-Baker, Herrin, and Springfield Coals from the Illinois Basin. Appendix 7 consists of graduated-symbol maps for ash yield, sulfur, calorific value, and elements of environmental concern for samples of assessed coal from the Illinois Basin.

Ash Yield

On a regional basis, the assessed coals can be characterized by mean ash yield of 11.9 percent for the Danville-Baker Coals (range 4.2–44.2 percent, fig. 6), 10.9 percent for the Herrin Coal (range 2.4–43.6 percent, fig. 7), and 11.2 percent for the Springfield Coal (range 2.8–49.7 percent, fig. 8). The mean for these assessed coals is 11.1 percent. Nonassessed coals can be characterized regionally by mean ash yields of 10 percent for coal in the Raccoon Creek Group (range 1.5–48.7 percent), 12.8 percent for coal from the nonassessed Carbondale Group or Formation (range 3.6–48.5 percent), and 14.1 percent for coal from the McLeansboro Group (range 6.0–28.7 percent). The mean for these nonassessed coals is 11.2 percent, which is essentially the same as the ash yield for the assessed coals.

Ash yield is variable within individual coals, both vertically and laterally, and the variability is probably the result of changes in the amounts and composition of the mineral matter in the coals. The mineralogical composition of Illinois Basin coal has been extensively studied by Gluskoter (1965,1967b, 1975), Rao and Gluskoter (1973), and Ward (1977). Based on low-temperature ash techniques on selected coals, the mineralogical composition (Damberger, 1999) of these coals is characterized by clay minerals (Herrin 9.4 percent, Springfield 7.0 percent), quartz (Herrin 2.4 percent, Springfield 2.4 percent), pyrite (Herrin 3.4 percent, Springfield 3.9 percent), and calcite (Herrin 1.3 percent, Springfield 1.6 percent).

Studies of other minerals and elements present in Illinois Basin coals have been reported by Gluskoter and Rees (1964) (chlorine), Gluskoter (1967a) (chlorine), Gluskoter and Ruch (1971) (chlorine and sodium), Bohor and Gluskoter (1973) (boron in illite), and Harvey and others (1983) (detailed studies on the spatial distribution of selected trace-element and mineral-matter associations within the Herrin and Springfield Coals in the Illinois Basin). Most zinc and cadmium in Illinois Basin coals are found in sphalerite (ZnS) and have been reported by Gluskoter and Lindahl (1973) (cadmium), Gluskoter and others (1973) (zinc), Hatch and others (1976) (zinc in sphalerite), Cobb and others (1979) (zinc in sphalerite), and Cobb and others (1980) (zinc and cadmium in sphalerite).

These studies show that the distributions and compositions of minerals within Illinois coals are dependent on many geologic and geochemical factors, including the chemical composition of original plants in the peat swamp, amounts and compositions of the various detrital, diagenetic, and epigenetic minerals, and the temperature and pressures during burial. For example, most zinc and cadmium in Illinois Basin coals are found in sphalerite (ZnS). This sphalerite was introduced into the coals millions of years after peat deposition by hydrothermal fluid-flow systems that were in operation at the end of the Permian (Hatch and others, 1976; Whelan and others, 1988).

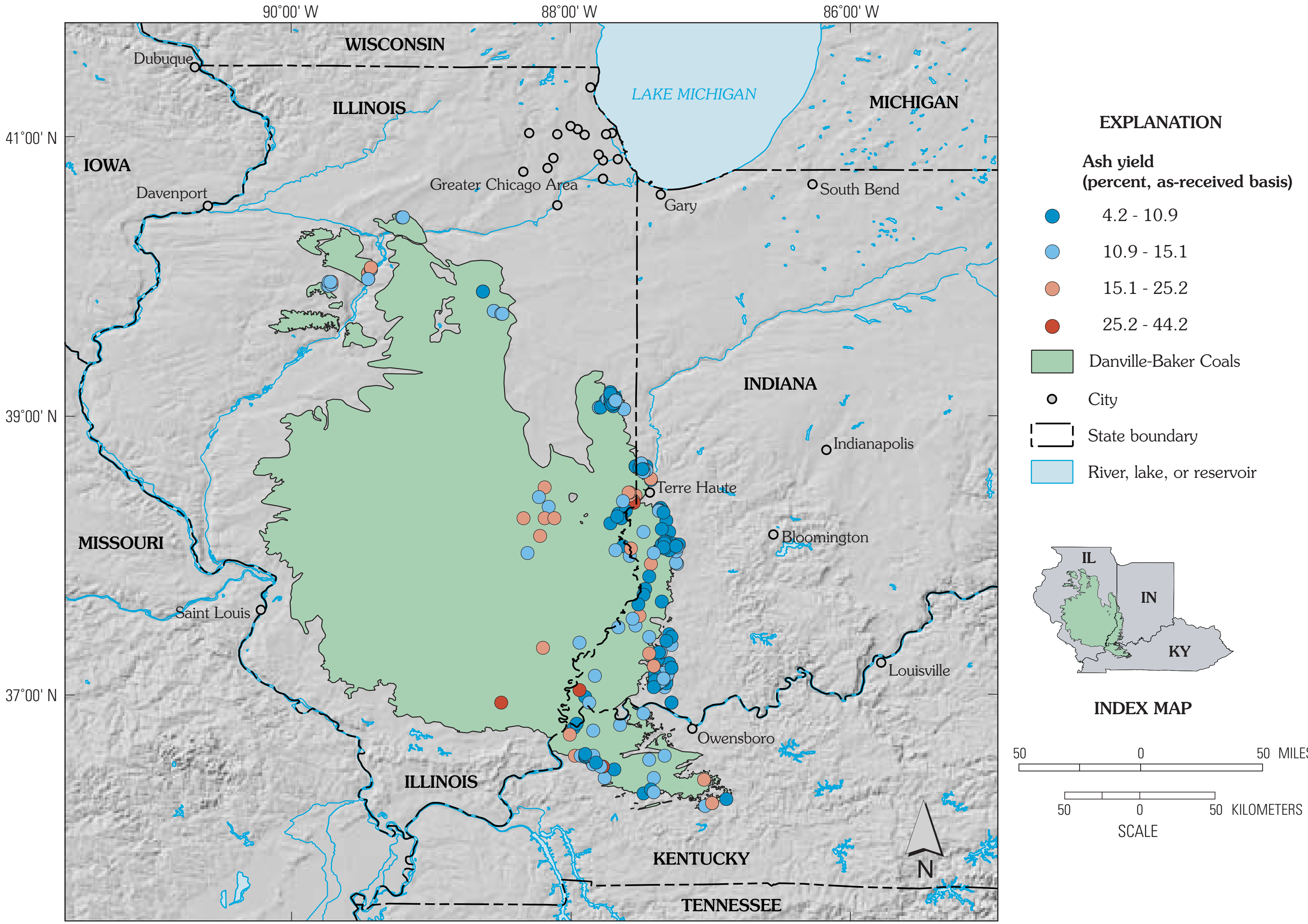

Figure 6. Graduated-symbol map for ash yield (percent, as-received basis) of the Danville-Baker Coals in the Illinois Basin.

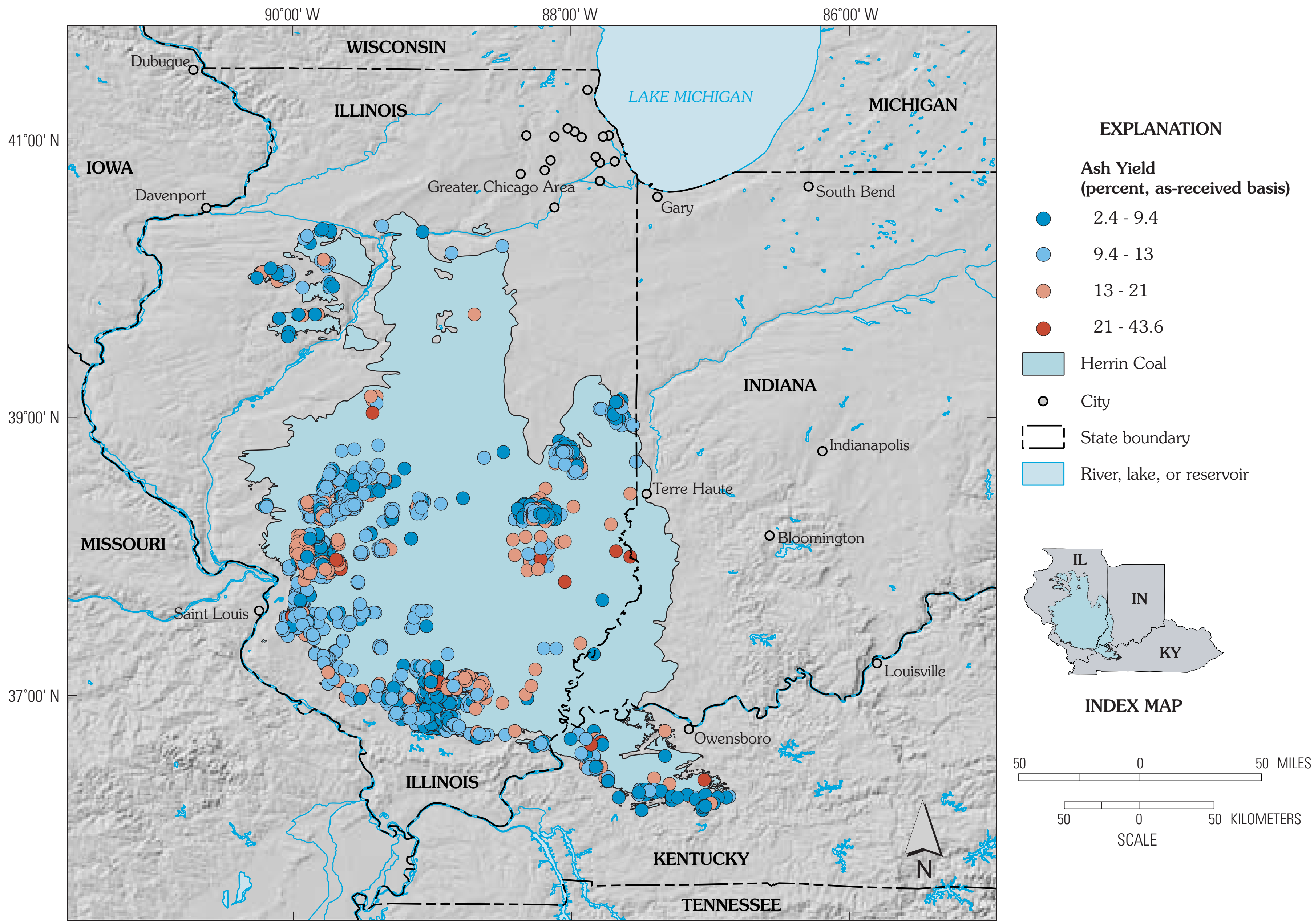

Figure 7. Graduated-symbol map for ash yield (percent, as-received basis) of the Herrin Coal in the Illinois Basin.

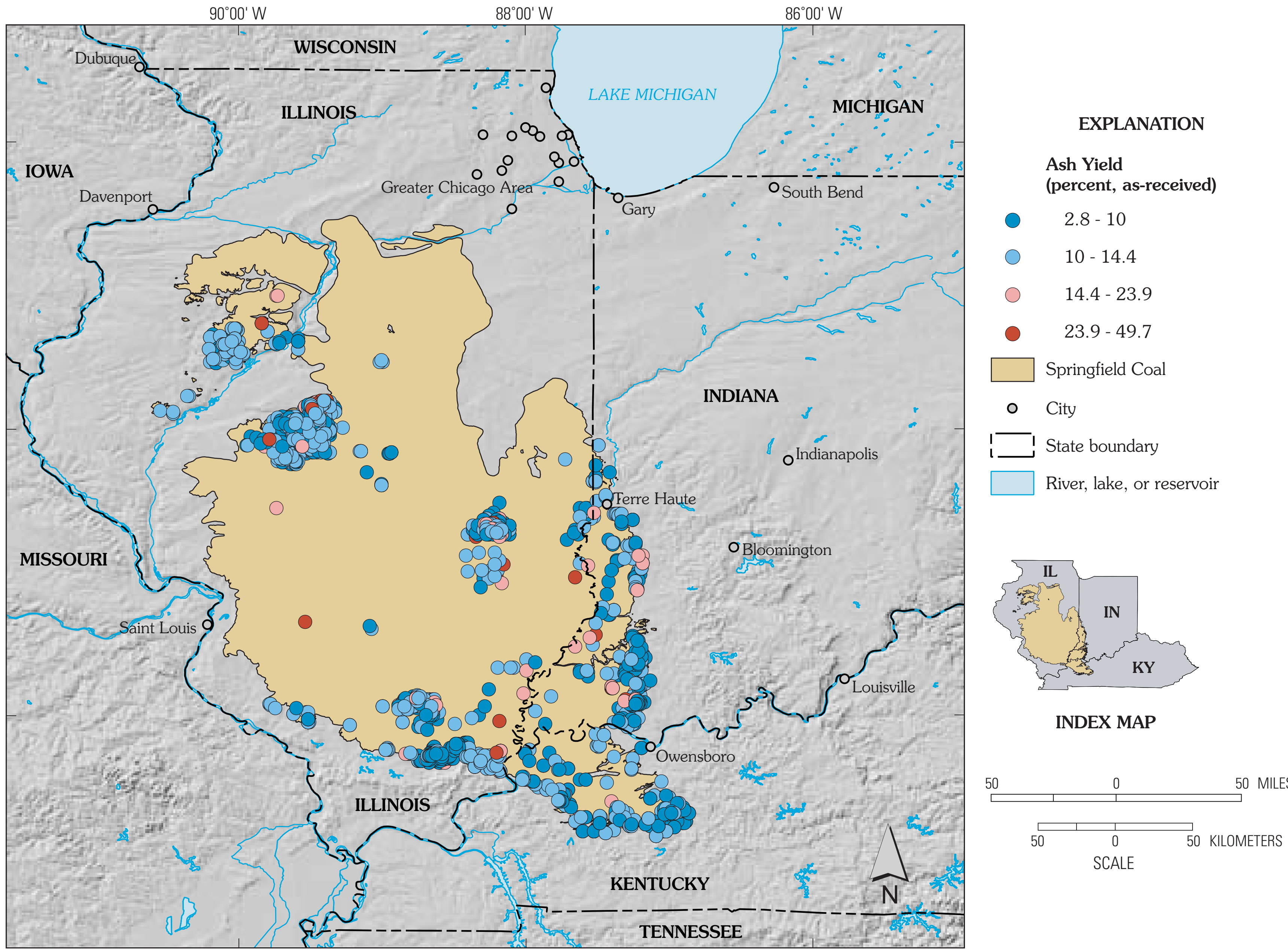

Figure 8. Graduated-symbol map for ash yield (percent, as-received basis) of the Springfield Coal in the Illinois Basin.

One of the characteristics of the Springfield in western Illinois and in the Springfield area (Sangamon, Logan, and Menard Counties of west-central Illinois) is the occurrence of a relatively high number of claystone dikes (“horsebacks”). These dikes cut through the coal seam from top to bottom as well as its roof strata and therefore may seriously influence the ash and sulfur content of the coal and strength of the roof strata.

Sulfur

On a regional basis, the assessed coals can be characterized by mean sulfur content of 2.9 percent for the Danville-Baker Coals (range 0.3–9.7 percent, fig. 9), 3.0 percent for the Herrin Coal (range 0.3–14.5 percent, fig. 10), and 3.5 percent for the Springfield Coal (range 0.5–19.5 percent, fig. 11). The mean is 3.2 percent. Nonassessed coals are characterized regionally by mean sulfur content of 2.9 percent for coal from the Raccoon Creek Group (range 0.1–30.1 percent), 3.2 percent for coal from the nonassessed Carbondale Group or Formation (range 0.3–28.1 percent), and 3.7 for coal from the McLeansboro Group (range 1.7–8.0 percent). The mean is 3.0 percent, which is similar to the sulfur content of the assessed coals.

Sulfur content has been related to the type of roof rocks that directly overlie the coal. Most of the coals that are overlain by marine rocks, such as black shales or limestone, tend to have higher sulfur content, greater than 2.5 percent. Coals that are overlain by nonmarine gray shales more than 20 ft thick usually contain less than 2.5 percent sulfur (Gluskoter and Simon, 1968). Lower sulfur content in the Herrin and Springfield Coals has been reported for samples located near various sandstone channels (for example, the Walshville channel in the Herrin and the Galatia channel in the Springfield) that may be related to fluvial splay deposits (Harvey and others, 1983).

In the Illinois Basin, the Springfield Coal is normally overlain by a 6- to 24-in.-thick, black, fissile shale. However, in a 4- to 10-mi-wide area extending from Gibson County, Ind., to Saline County, Ill., a delta distributary system was active during deposition of peats that formed the Springfield Coal. Within this belt, the coal is absent or irregularly developed and is overlain by the gray, silty Dykersburg Shale Member of the Carbondale Formation (Illinois and Kentucky) or by the Dugger Formation (Indiana) (Hopkins, 1968). In this area, the Springfield Coal is from 5 to 10 ft thick and commonly split by shale partings. Where the Dykersburg Shale Member is thicker than about 20 ft, the coal typically is relatively low in sulfur (1.5–3 percent) (Cady, 1935; Damberger, 1999).

The Herrin Coal of the Dugger Formation (Indiana) or the Carbondale Formation (Illinois and western Kentucky) is normally overlain by as much as 4 ft of black, fissile shale (Anna Shale Member, Dugger Formation in Indiana, Carbondale Formation in Illinois and western Kentucky) or limestone (Brereton Limestone Member of the Dugger Formation in Indiana, Carbondale Formation in Illinois and western Kentucky). However, in parts of southern and central Illinois a delta distributary system (Walshville channel system) was active during deposition of peats that formed the Herrin Coal. Within this belt, the coal is eroded by a channel sandstone as much as 1 mi wide and 60–80 ft thick, or was irregularly developed and overlain by the silty, gray Energy Shale Member of the Carbondale Formation, which is as much as 100 ft thick (Allgaier and Hopkins, 1975; Nelson, 1983). Where the Energy Shale Member is thick, the coal commonly is relatively low in sulfur. The thick Energy Shale Member overlies the Herrin Coal in four areas: (1) the Franklin-Williamson-Jefferson County area of southeastern Illinois (known as the “Quality Circle” area); (2) northern St. Clair County and adjacent Madison and Clinton Counties, in southwestern Illinois; (3) eastern Macoupin County and adjacent Montgomery and Christian Counties, in west-central Illinois; and (4) southern Vermillion County, in east-central Illinois.

The sulfur content of the assessed Illinois Basin coals, which is mostly in the form of pyrite or organic sulfur (fig. 12 and appendixes 1 and 2), is relatively high as compared to other United States coals. The sulfur content of most United States coals was primarily dependent on pH-controlled levels of bacterial activity in the ancestral peat swamps (Cecil and others, 1982). This bacterial activity, along with the general presence of marine shales and carbonates overlying the coal, probably accounts for the high sulfur content of many of the Illinois Basin coals. Sulfur content might also be controlled by the location of the peat swamp. Affolter and Stricker (1989) suggested that the activity of sulfate-reducing bacteria in peat is related to temperature, as indicated by the paleolatitude of the peat swamp, and could affect the sulfur content. A comparison of paleolatitudes as calculated from paleomagnetic poles and sulfur contents of United States coals, indicates that the higher the latitude in which a peat swamp developed, the lower the mean sulfur content of the resulting coal deposit. For example, low-sulfur coals such as those in Cretaceous rocks of the Colorado Plateau formed at higher paleolatitudes (lat >35°), whereas higher sulfur coals such as those in the Pennsylvanian of the Illinois Basin formed at low paleolatitudes (lat 0°–15°).

Calorific Value

On a regional basis, the assessed coals of the Illinois Basin can be characterized by mean calorific values of 10,920 Btu/lb for the Danville-Baker Coals (range 5,800–12,990 Btu/lb, fig. 13), 11,170 Btu/lb for the Herrin Coal (range 5,770–13,420 Btu/lb, fig. 14), and 11,280 Btu/lb for the Springfield Coal (range 4,810–3,910 Btu/lb, fig. 15). The mean is 11,200 Btu/lb for these assessed coals. The nonassessed coals are characterized regionally by mean calorific values of 10,920 Btu/lb for coals from the nonassessed Carbondale Group or Formation (range 5,440–13,200 Btu/lb), 11,190 Btu/lb for coals from the Raccoon Creek Group (range 4,540–13,620 Btu/lb), and 11,260 Btu/lb for coals from the McLeansboro Group (range 9,080–12,660 Btu/lb). The mean is 11,110 Btu/lb for these nonassessed coals.

Calorific values generally increase from the northwestern part of the coal basin to the southeastern part (Cady, 1935, 1948; Damberger, 1971). In western Kentucky, calorific value increases from east to west (Greb and others, 1992). The coal rank in much of the northern part of the basin in Illinois and Indiana is high-volatile-C bituminous coal (Cady, 1935, 1948; Damberger, 1971). In a small area in southeastern Illinois and western Kentucky, coal rank reaches high-volatile-A bituminous coal. These differences in rank were most likely caused by

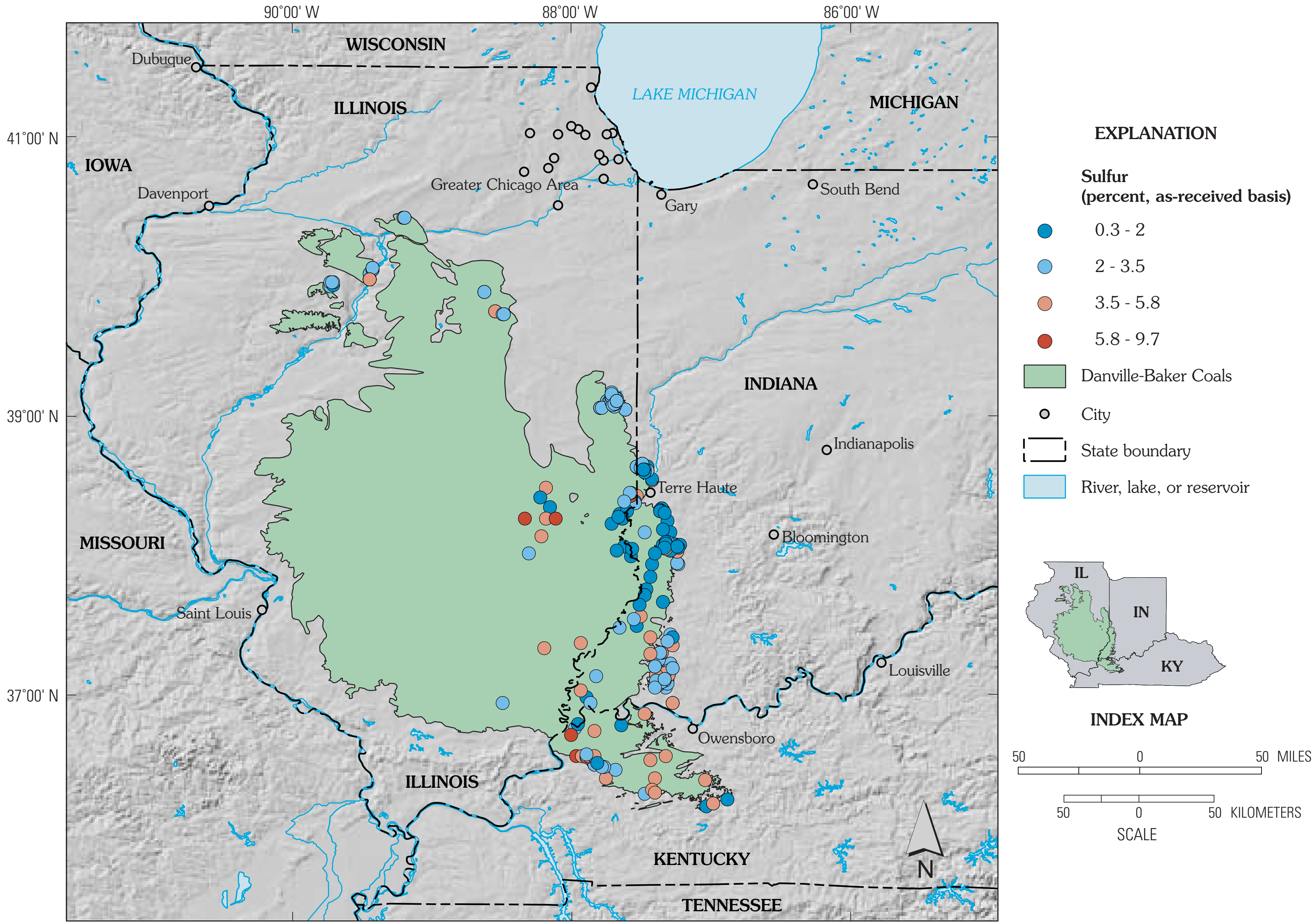

Figure 9. Graduated-symbol map for sulfur content (percent, as-received basis) of the Danville-Baker Coals in the Illinois Basin.

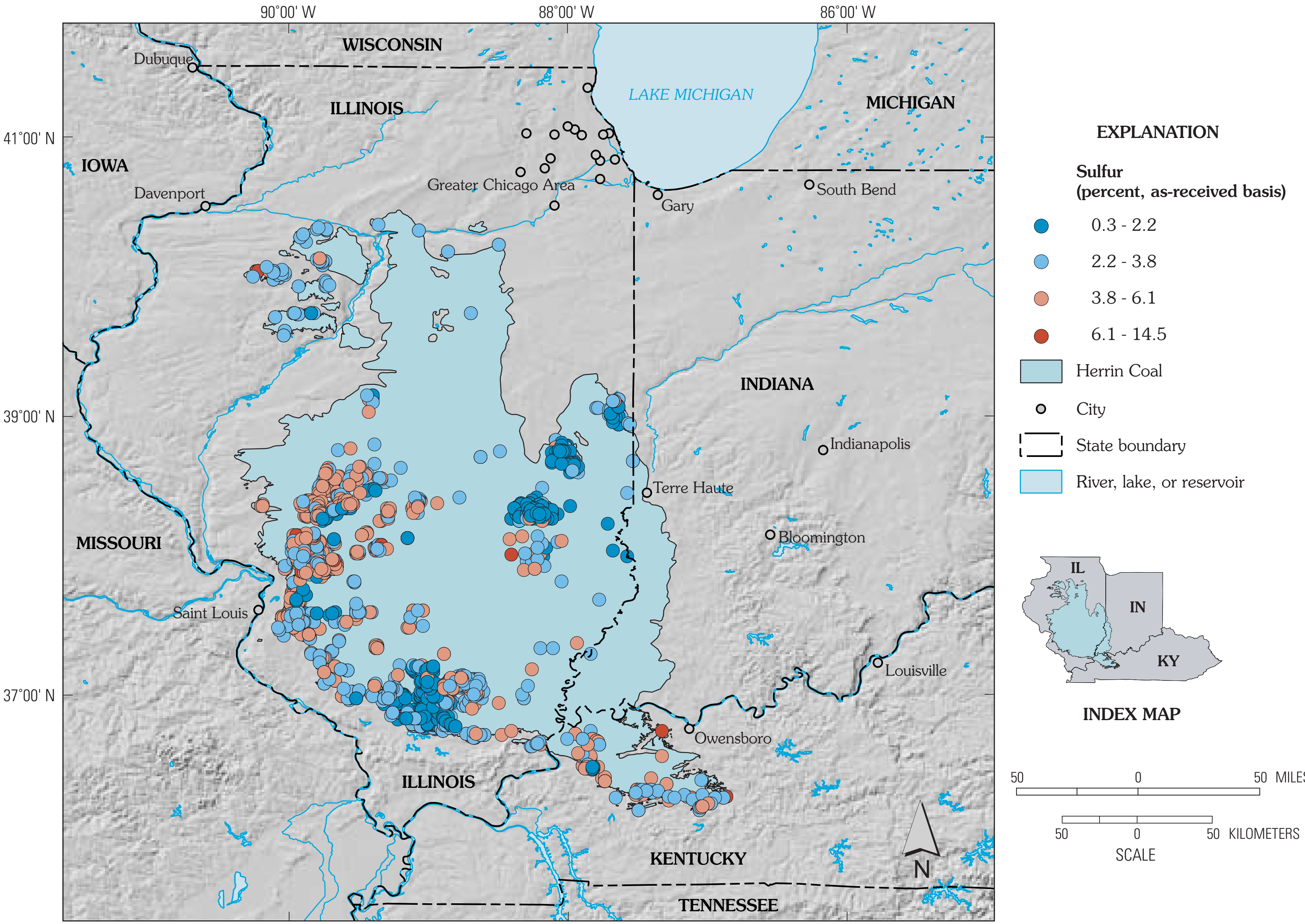

Figure 10. Graduated-symbol map for sulfur content (percent, as-received basis) of the Herrin Coal in the Illinois Basin.

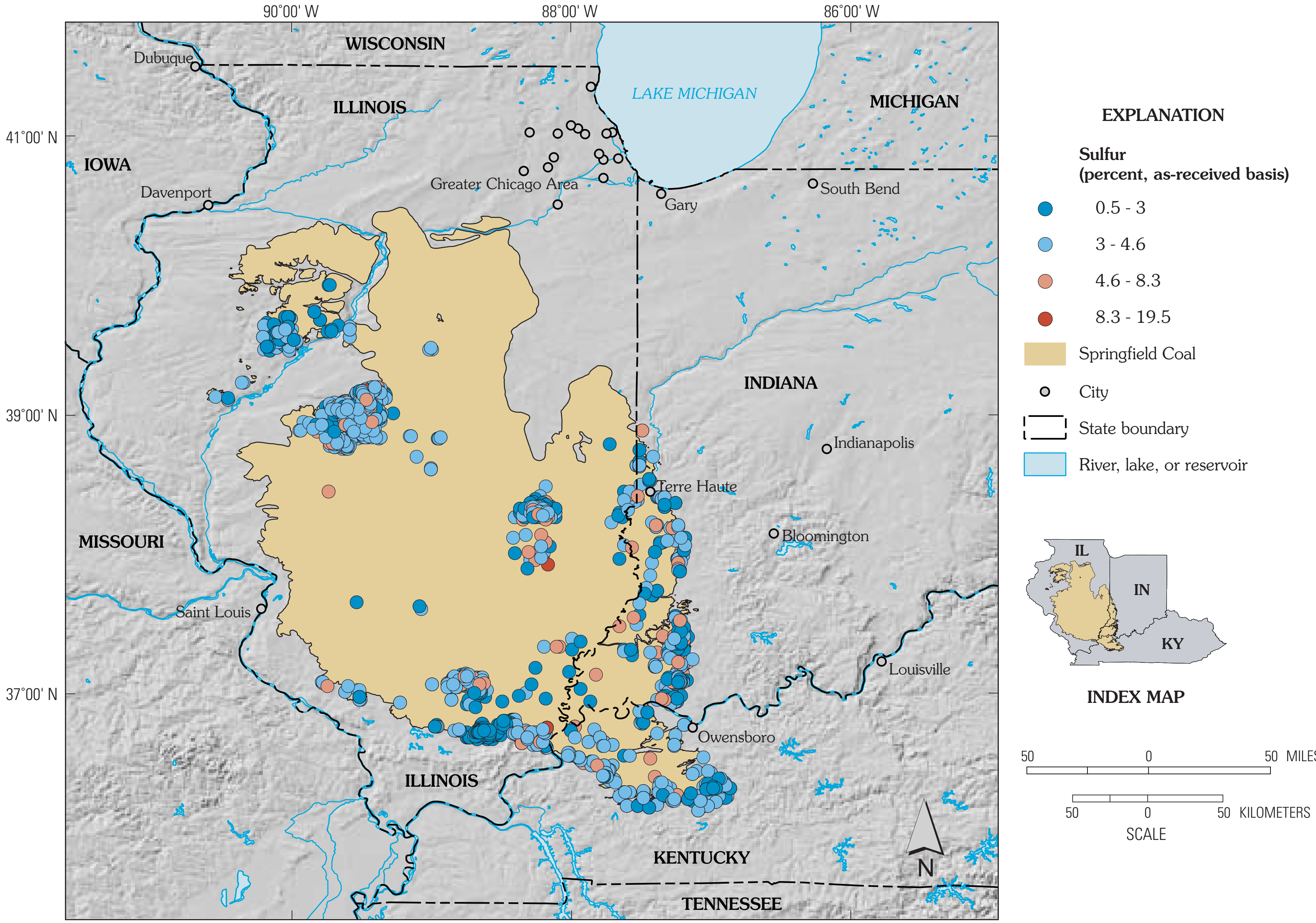

Figure 11. Graduated-symbol map for sulfur content (percent, as-received basis) of the Springfield Coal in the Illinois Basin.

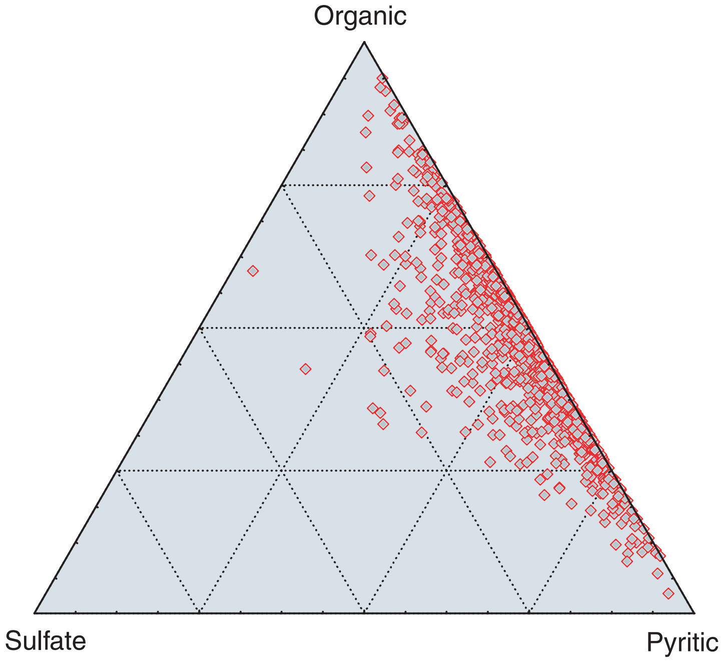

Figure 12. Diagram showing distribution of sulfate, organic, and pyritic sulfur from the assessed Pennsylvanian Springfield, Herrin, and Danville-Baker Coals in the Illinois Basin.

increased depths of burial. The southward increase was caused by increasing depth of burial during the coalification process. However, in the southeastern part of the Illinois Basin, many of the coals are relatively shallow and it has been suggested by Damberger (1971) that the increase in calorific value in that area may be attributed to increased heat flow related to possible plutonic intrusions.

Element Composition

Table 4 lists the mean content of elements of environmental concern (1990 Clean Air Act Amendment) for assessed and nonassessed coals from the Illinois Basin. Table 5 compares the mean content of these elements of environmental concern from the Illinois Basin with selected summaries of coal from the Appalachian Basin, Colorado Plateau, Gulf Coast, and Tertiary regions of the Western United States. Appendix 7 consists of graduated-symbol maps for each element of environmental concern in the assessed coals of the Illinois Basin. Appendix 5 consists of range plots of minimum, maximum, and mean contents of elements of environmental concern for all of the assessed and nonassessed coals. Comparison of elements of environmental concern in the Illinois Basin coals with other coal regions within the United States shows that (1) contents of antimony, arsenic, cadmium, chromium, lead, nickel, selenium, and uranium are generally higher in Illinois Basin coals when compared to either Colorado Plateau Cretaceous coals or western Tertiary coals; (2) contents of antimony, cadmium, chromium, nickel, and uranium in Illinois Basin coals are similar to Appalachian Basin Pennsylvanian age coals; and (3) contents of beryllium, chromium, cobalt, lead, manganese, mercury, selenium, and uranium are generally lower in Illinois Basin coals as compared to Gulf Coast coals.

Conclusion

Differences in the quality of coal result from variations in the total and relative amounts of detrital and authigenic minerals, the elemental composition of these minerals, and the total and relative amounts of any organically bound elements. The chemical form and distribution of a given element are dependent on the geological history of the coal. A partial listing of the factors that might influence element distributions includes (1) chemical composition of the original plant community in the peat swamp; (2) amounts and compositions of the various detrital, diagenetic, and epigenetic minerals; (3) chemical characteristics of the ground waters that come in contact with the coal bed; (4) temperature and pressures during burial; and (5) extent of chemical weathering. As yet, many of these factors have not been fully evaluated in detail for many of the Illinois Basin assessed coals. Thus, the currently available databases are considered inadequate to provide a complete characterization of coal quality throughout the basin.

Currently, the databases represent only a generalized view of Illinois Basin coal quality, based on a limited number of samples. Many of the samples are more than 30 years old and represent coal that has already been mined.

In order to better predict potential environmental impacts resulting from the increased utilization of coal from the region, it will be necessary to identify the modes of occurrence of the various elements within the coal and the nature of the coal combustion products. Accomplishing this would involve collecting additional samples from mines, power plants, and many other localities to obtain essential mineralogical and related data.

More than 92 percent of the United States' yearly production of coal is consumed in the production of electricity by utilities (U.S. Energy Information Administration, 2001).

Coal quality, composition of stack emissions, and coal combustion byproducts have become major environmental concerns as the rate of coal utilization increases, especially with regard to meeting the requirements of the 1990 Clean Air Act Amendment. With increasing emphasis on environmental issues, information on the quality of coal (which includes ash yield, sulfur content, calorific value, and major-, minor-, and trace-element content) has become almost as important as information on the quantity of the resource.

The future of coal utilization in the Illinois Basin therefore depends on a careful evaluation of coal distribution, resources, coal quality, mining methods, beneficiation costs, transportation, coal combustion byproducts, and waste disposal. Almost 84 percent of low-sulfur coal and 61 percent of medium-sulfur coal is found in coal fields in the Western United States. Seventy-one percent of the high-sulfur coal in the United States is from the Interior region (U.S. Energy Information Administration, 1999). Since 1990, production in the Illinois Basin has dropped. This decrease in the demand has primarily been a result of the enactment and implementation of the 1990 Clean Air Act Amendment and increasing price competition from Western United States coal. Because Illinois Basin assessment coals are high in sulfur, and high in many of the elements of environmental concern, these coals may play a much smaller role in supplying future United States energy needs unless technological advances can

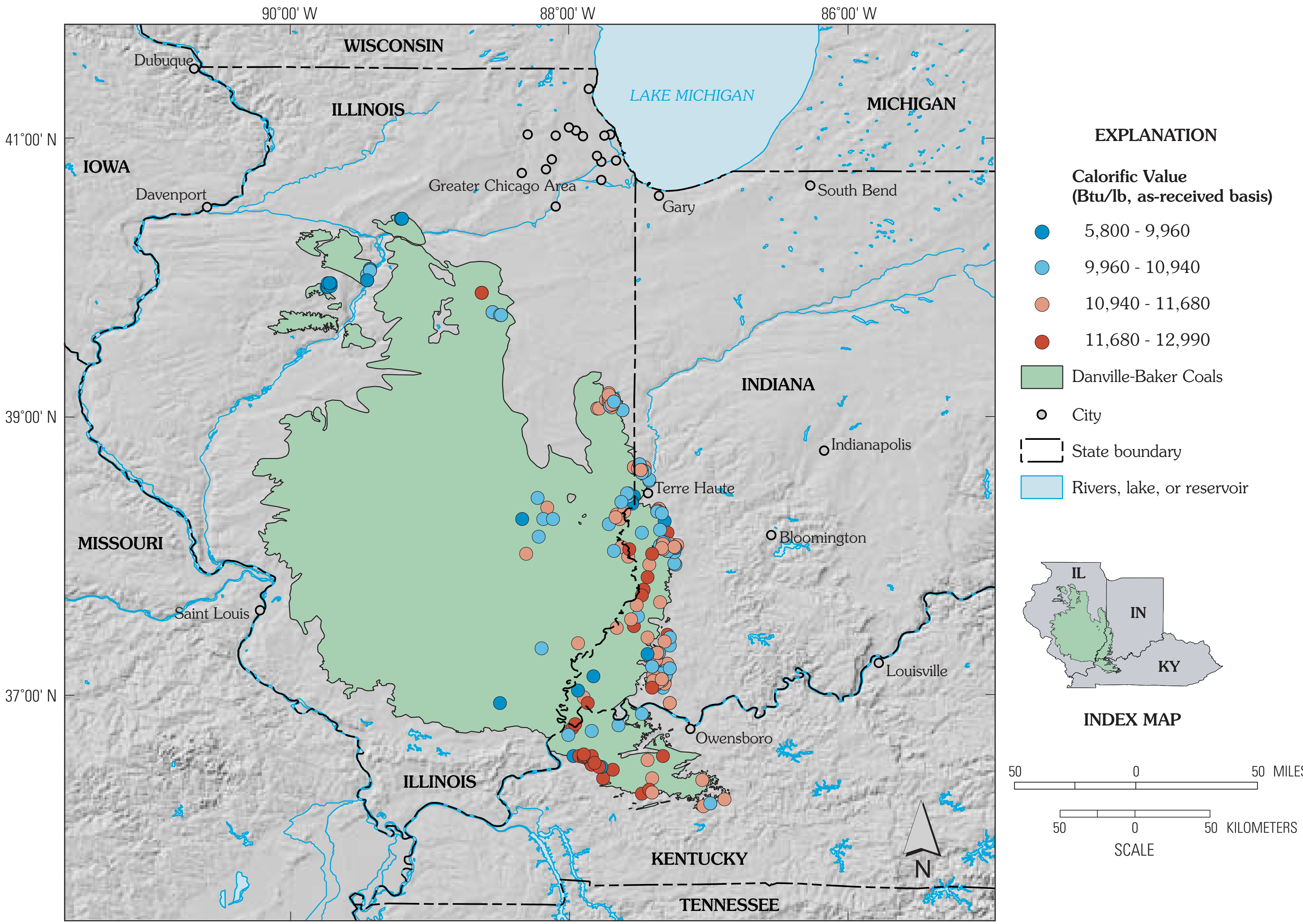

Figure 13. Graduated-symbol map for calorific values (Btu/lb, as-received basis) of the Danville-Baker Coals in the Illinois Basin.

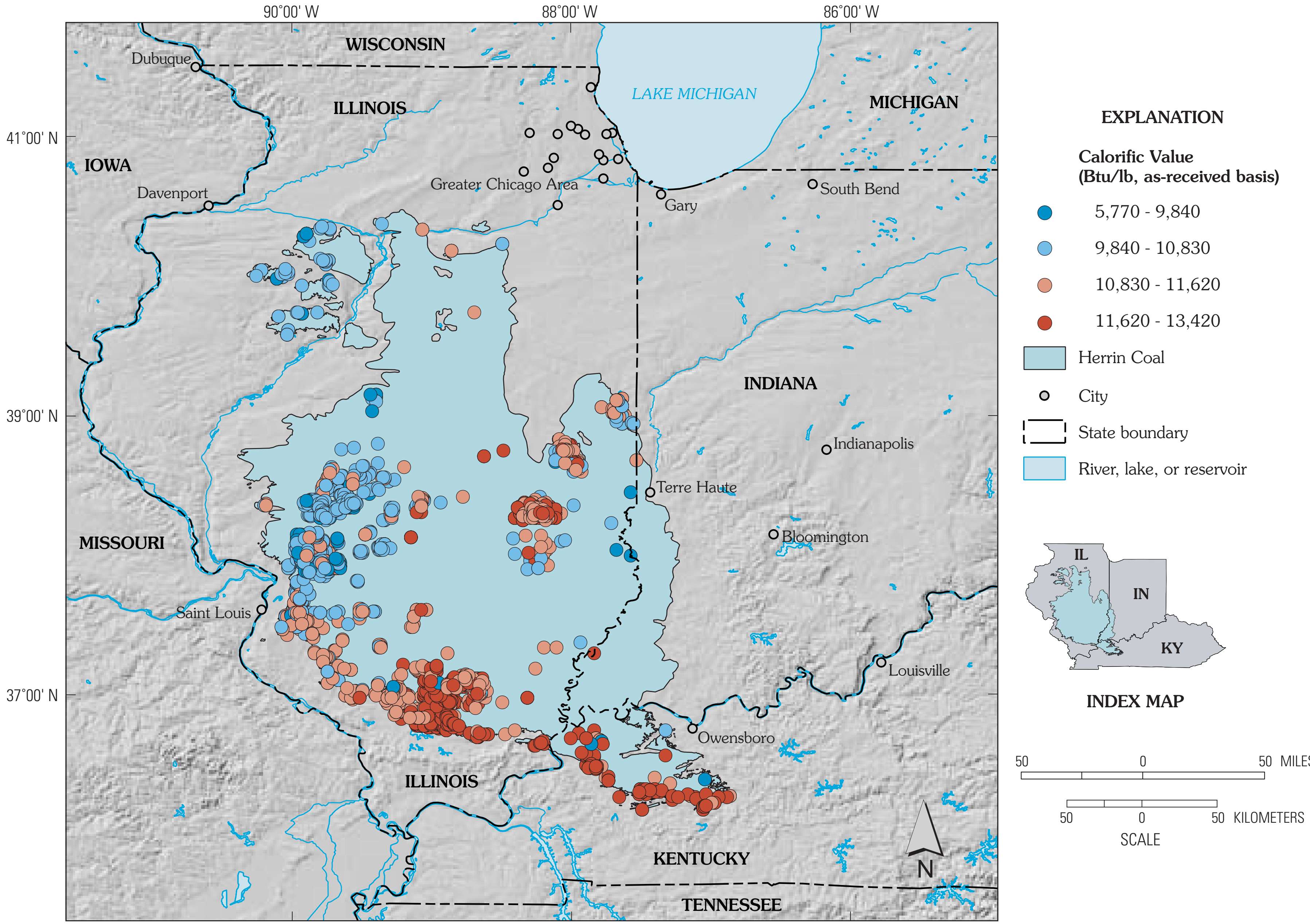

Figure 14. Graduated-symbol map for calorific values (Btu/lb, as-received basis) of the Herrin Coal in the Illinois Basin.

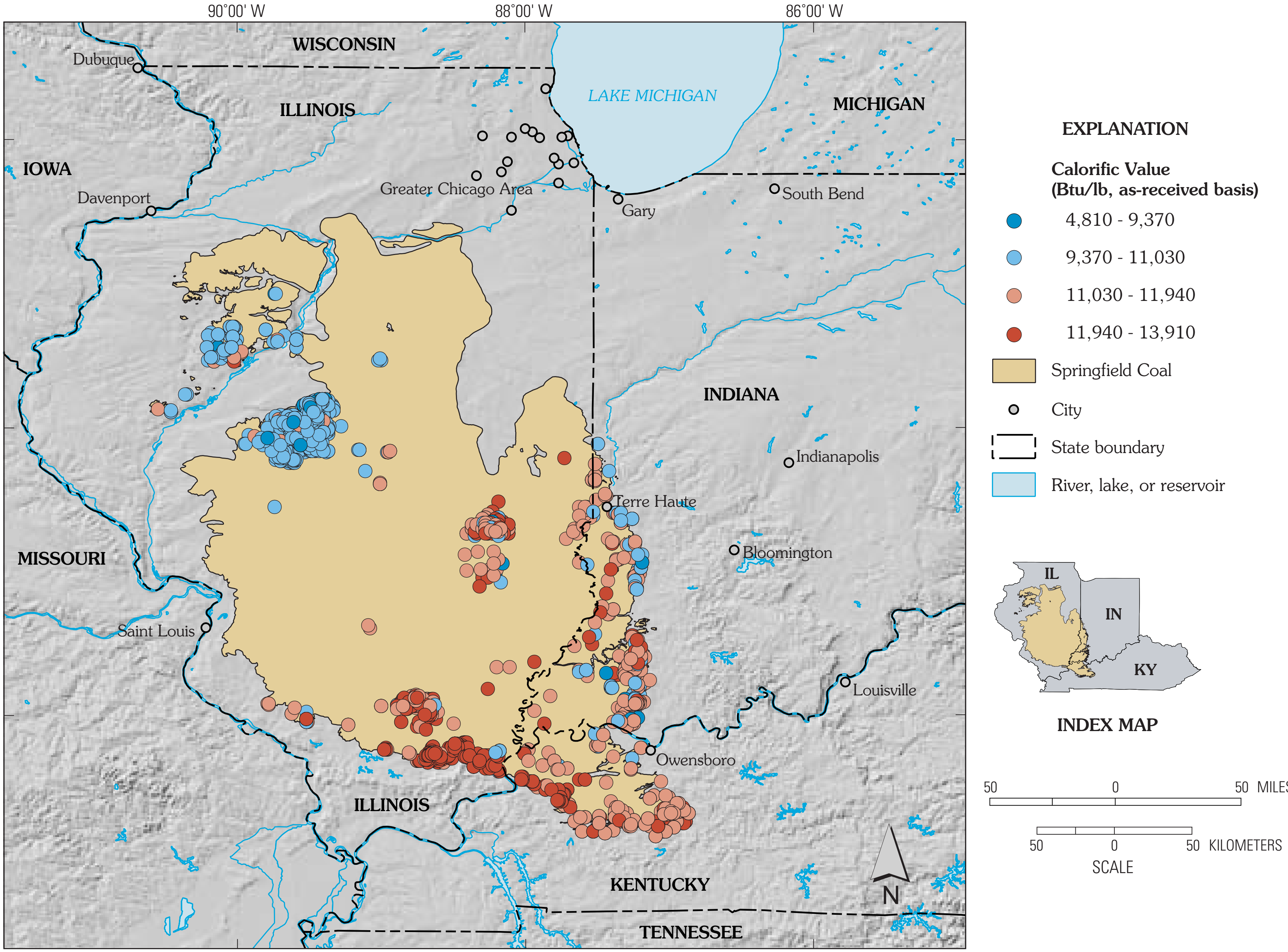

Figure 15. Graduated-symbol map for calorific values (Btu/lb, as-received basis) of the Springfield Coal in the Illinois Basin.

Table 4. Mean content of elements of environmental concern (1990 Clean Air Act Amendment) for coals from the Illinois Basin coal assessment.

[All elements are in parts per million (ppm), on a whole-coal basis. Element contents are reported to two significant figures for most elements. However, mercury and cadmium are reported to two decimal places and antimony and selenium are reported to one decimal place. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated.]

Coal name or coal-bearing unit	As	Be	Cd	Co	Cr	Hg	Mn	Ni	Pb	Sb	Se	Th	U
Danville	12	3.2	0.40	6.3	19	0.10	55	24	17	2.3	1.3	2.5	1.3
Baker	27	2.2	0.19	5.2	19	0.13	62	36	20	1.5	1.8	2.0	2.5
Danville and Baker	19	2.7	0.30	5.6	19	0.11	59	31	18	1.9	1.5	2.2	1.9
Herrin	5.8	1.6	1.3	4.0	19	0.12	58	17	18	0.8	2.1	2.1	2.0
Springfield	12	1.9	0.60	3.6	16	0.12	43	12	13	1.1	2.5	1.7	2.6
Carbondale Group or Formation	34	3.5	0.45	7.1	20	0.14	51	28	27	1.5	3.3	2.1	3.3
Raccoon Creek Group	20	3.7	0.35	9.2	15	0.12	17	38	24	1.6	3.7	2.2	1.8
McLeansboro Group	9.5	2.2	0.14	5.3	20	0.08	56	20	7.7	0.7	2.1	2.1	1.6
Assessed coals	9.5	1.8	0.99	4.0	18	0.12	52	16	16	1.0	2.2	2.0	2.2
Non-assessed coals	23	3.4	0.35	7.9	17	0.12	35	31	23	1.4	3.4	2.2	2.2
All coals in Illinois Basin	15	2.5	0.70	5.6	17	0.12	45	22	19	1.2	2.7	2.1	2.2

Table 5. Comparison of the mean content of elements of environmental concern (1990 Clean Air Act Amendment) for the Illinois Basin assessed coals (Danville, Baker, Herrin, and Springfield Coals only) with coals from the Appalachian Basin, Colorado Plateau coal assessment area, Gulf Coast, and Western United States Tertiary coal.

[All elements are in parts per million (ppm), on a whole-coal basis.]

Element	Illinois Basin Assessment (Danville, Baker, Herrin, and Springfield Coals) Mean (n=580)	Appalachian Basin Pennsylvanian Mean[1] (n=4,700)	Colorado Plateau Coal Assessment Area Cretaceous Mean[2] (n=1,265)	Gulf Coast Tertiary Mean[1] (n=200)	Western United States Tertiary Mean[3] (n=520)
Antimony	1.0	1.4	0.5	1.0	0.6
Arsenic	9.4	35	1.6	10	7.4
Beryllium	1.8	2.5	1.2	2.4	1.1
Cadmium	0.99	0.10	0.10	0.55	0.10
Chromium	18	17	4.5	24	10
Cobalt	4.0	7.2	1.5	7.2	3.5
Lead	16	8.4	6.5	21	4.2
Manganese	52	29	22	150	60
Mercury	0.12	0.21	0.06	0.22	0.12
Nickel	16	17	3.7	13	4.6
Selenium	2.2	3.5	1.2	5.7	0.7
Uranium	2.2	1.7	1.3	23	1.7

[1]Finkelman and others, 1994
[2]Affolter, 2000
[3]Summarized from Affolter and Hatch, 1993

make them more economically and environmentally competitive with low-sulfur western coal.

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Appendix 1. Summary descriptive statistics of proximate and ultimate analyses, calorific values, forms-of-sulfur analyses, and ash-fusion temperatures for all assessed and nonassessed coals in the Illinois Basin.

Table 1. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for all assessed coals (Danville, Baker, Herrin, and Springfield) in the Illinois Basin.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). G, greater than value shown.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	4,711	10.5	10.4	0.5	34.7	3.7
Volatile matter	4,392	35.1	35.1	17.7	56.7	2.9
Fixed carbon	4,392	43.4	42.9	14.0	62.7	4.8
Ash	4,708	11.1	10.4	2.4	49.7	4.0
Hydrogen	2,062	4.6	4.4	2.7	7.1	0.7
Carbon	2,070	61.8	62.1	28.0	77.8	5.3
Nitrogen	2,055	1.2	1.2	0.3	2.7	0.2
Oxygen	2,054	9.6	7.7	0.2	42.2	4.7
Sulfur	4,682	3.2	3.3	0.3	19.5	1.5
Calorific value						
Btu/lb	4,455	11,200	11,250	4,810	13,910	910
Forms of sulfur						
Sulfate	1,548	0.09	0.04	0.01	2.02	0.17
Pyritic	1,888	1.74	1.67	0.02	18.28	1.16
Organic	1,891	1.49	1.56	0.16	5.11	0.60
Ash-fusion temperatures (˚F)						
Initial deformation	1,214	2,055	2,015	1,680	2,800G	165
Softening temperature	1,290	2,135	2,095	1,820	2,995G	173
Fluid temperature	1,213	2,245	2,230	1,845	2,910G	181

Table 2. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for the Danville Coal in the Illinois Basin.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). G, greater than value shown.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	300	12.2	12.7	1.9	28.2	3.5
Volatile matter	291	35.6	35.8	25.2	56.7	3.5
Fixed carbon	291	40.4	39.7	20.4	52.3	3.9
Ash	300	11.8	10.7	4.2	44.2	4.5
Hydrogen	136	5.3	5.5	3.3	6.3	0.7
Carbon	139	60.5	61.2	36.9	69.5	4.7
Nitrogen	134	1.3	1.3	0.7	1.9	0.2
Oxygen	134	15.4	17.3	4.0	24.4	5.6
Sulfur	301	2.9	3.0	0.3	9.7	1.3
Calorific value						
Btu/lb	261	10,820	11,020	5,800	12,630	840
Forms of sulfur						
Sulfate	65	0.16	0.08	0.01	1.68	0.25
Pyritic	74	1.51	1.36	0.03	6.01	1.06
Organic	74	1.13	1.17	0.22	2.17	0.43
Ash-fusion temperatures (˚F)						
Initial deformation	118	2,100	2,045	1,822	2,745	183
Softening temperature	135	2,230	2,200	1,905	2,800G	200
Fluid temperature	118	2,350	2,335	1,935	2,800G	206

Table 3. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for the Baker coal in the Illinois Basin.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F).]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	34	6.7	6.6	3.4	10.8	1.4
Volatile matter	34	34.8	35.4	25.7	40.8	3.2
Fixed carbon	34	45.9	46.2	34.5	54.7	4.2
Ash	34	12.7	11.7	6.5	27.6	4.4
Hydrogen	34	4.7	4.7	3.1	5.6	0.6
Carbon	34	64.8	65.9	52.7	72.7	4.8
Nitrogen	34	1.4	1.4	0.9	1.7	0.2
Oxygen	34	9.1	7.7	3.1	18.1	4.4
Sulfur	34	3.7	3.8	1.5	7.7	1.5
Calorific value						
Btu/lb	34	11,670	12,070	9,300	12,990	880
Forms of sulfur						
Sulfate	15	0.15	0.13	0.01	0.45	0.12
Pyritic	15	2.25	2.67	0.69	3.72	0.94
Organic	15	1.36	1.24	0.57	2.04	0.46
Ash-fusion temperatures (˚F)						
Initial deformation	15	2,080	2,030	1,930	2,610	169
Softening temperature	15	2,140	2,080	2,030	2,710	176
Fluid temperature	15	2,310	2,260	2,080	2,800	194

Table 4. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for the Danville-Baker Coals in the Illinois Basin.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). G, greater than value shown.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	334	11.7	12.3	1.9	28.2	3.8
Volatile matter	325	35.6	35.8	25.2	56.7	3.5
Fixed carbon	325	40.9	40.0	20.4	54.7	4.3
Ash	334	11.9	10.8	4.2	44.2	4.5
Hydrogen	170	5.2	5.3	3.1	6.3	0.7
Carbon	173	61.4	61.9	36.9	72.7	5.0
Nitrogen	168	1.3	1.3	0.7	1.9	0.2
Oxygen	168	14.1	15.8	3.1	24.4	5.9
Sulfur	335	2.9	3.0	0.3	9.7	1.4
Calorific value						
Btu/lb	295	10,920	11,060	5,800	12,990	880
Forms of sulfur						
Sulfate	80	0.16	0.09	0.01	1.68	0.23
Pyritic	89	1.63	1.49	0.03	6.01	1.07
Organic	89	1.17	1.24	0.22	2.17	0.44
Ash-fusion temperatures (˚F)						
Initial deformation	133	2,095	2,040	1,820	2,745	181
Softening temperature	150	2,220	2,175	1,905	2,800G	199
Fluid temperature	133	2,340	2,330	1,935	2,800G	204

Table 5. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for the Herrin Coal in the Illinois Basin.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). G, greater than value shown.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	2,545	10.7	10.6	1.2	22.2	3.4
Volatile matter	2,375	34.8	34.8	19.5	45.2	2.8
Fixed carbon	2,375	43.7	43.2	25.3	58.5	4.6
Ash	2,542	10.9	10.3	2.4	43.6	3.6
Hydrogen	939	4.3	4.3	2.9	5.9	0.4
Carbon	939	61.5	61.4	41.4	73.6	5.4
Nitrogen	935	1.2	1.2	0.3	2.7	0.2
Oxygen	935	8.2	7.6	2.3	20.5	2.6
Sulfur	2,517	3.0	3.2	0.3	14.5	1.5
Calorific value						
Btu/lb	2,390	11,170	11,170	5,770	13,420	830
Forms of sulfur						
Sulfate	860	0.09	0.04	0.01	2.02	0.17
Pyritic	1,108	1.62	1.61	0.02	8.48	1.08
Organic	1,110	1.46	1.52	0.16	5.08	0.64
Ash-fusion temperatures (˚F)						
Initial deformation	531	2,100	2,060	1,680	2,800G	170
Softening temperature	534	2,160	2,140	1,820	2,995G	163
Fluid temperature	530	2,280	2,270	1,860	2,910G	160

Table 6. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for the Springfield Coal in the Illinois Basin.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). G, greater than value shown.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	1,832	10.0	9.3	0.5	34.7	4.0
Volatile matter	1,692	35.5	35.5	17.7	55.0	2.9
Fixed carbon	1,692	43.3	43.2	14.0	62.7	5.0
Ash	1,832	11.2	10.4	2.8	49.7	4.4
Hydrogen	953	4.7	4.5	2.7	7.1	0.7
Carbon	958	62.2	62.9	28.0	77.8	5.3
Nitrogen	952	1.2	1.2	0.3	2.2	0.2
Oxygen	951	10.2	7.6	0.2	42.2	5.4
Sulfur	1,830	3.5	3.4	0.5	19.5	1.4
Calorific value						
Btu/lb	1,770	11,280	11,430	4,810	13,910	990
Forms of sulfur						
Sulfate	608	0.09	0.04	0.01	1.28	0.15
Pyritic	691	1.96	1.77	0.06	18.28	1.25
Organic	692	1.58	1.65	0.29	5.11	0.52
Ash-fusion temperatures (˚F)						
Initial deformation	550	2,000	1,970	1,795	2,800G	139
Softening temperature	606	2,090	2,050	1,835	2,910G	162
Fluid temperature	550	2,185	2,150	1,845	2,910G	176

Table 7. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for all nonassessed coals in the Illinois Basin.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). G, greater than value shown.]

	Number of samples	Mean	Median	Range Minimum	Range Maximum	Standard deviation
Proximate and ultimate analyses						
Moisture	1,285	10.5	10.2	0.7	52.8	5.1
Volatile matter	1,278	35.5	35.7	16.5	54.0	3.6
Fixed carbon	1,278	42.8	43.1	7.9	59.8	5.7
Ash	1,285	11.2	9.8	1.5	48.7	6.4
Hydrogen	1,012	5.2	5.4	1.7	8.2	0.8
Carbon	1,042	62.1	62.8	24.0	82.9	6.6
Nitrogen	1,006	1.3	1.3	0.4	2.5	0.2
Oxygen	1,001	15.7	16.1	2.0	51.2	6.1
Sulfur	1,315	3.0	2.8	0.1	30.1	2.1
Calorific value						
Btu/lb	1,282	11,110	11,310	4,540	13,620	1,220
Forms of sulfur						
Sulfate	270	0.25	0.15	0.01	2.31	0.28
Pyritic	270	1.85	1.52	0.03	12.10	1.54
Organic	271	1.28	1.17	0.05	5.78	0.77
Ash-fusion temperatures (˚F)						
Initial deformation	846	2,120	2,025	1,760	2,860G	252
Softening temperature	951	2,240	2,160	1,810	2,910G	239
Fluid temperature	846	2,340	2,315	1,900	2,910G	223

Table 8. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for all nonassessed coals from the McLeansboro Group in the Illinois Basin.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F).]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	82	7.3	7.5	3.8	12.6	1.1
Volatile matter	82	35.0	34.7	29.7	38.5	2.2
Fixed carbon	82	43.7	43.2	34.0	50.6	3.8
Ash	82	14.1	13.7	6.0	28.7	4.4
Hydrogen	82	4.4	4.3	3.0	5.5	0.6
Carbon	82	62.5	62.7	50.6	70.1	3.9
Nitrogen	82	1.3	1.3	0.7	1.6	0.2
Oxygen	82	8.9	7.8	2.1	20.5	3.8
Sulfur	82	3.7	3.5	1.7	8.0	1.2
Calorific value						
Btu/lb	82	11,260	11,320	9,080	12,660	710
Forms of sulfur						
Sulfate	24	0.13	0.08	0.01	0.70	0.17
Pyritic	24	1.83	1.69	0.84	4.04	0.89
Organic	24	1.42	1.51	0.50	1.92	0.43
Ash-fusion temperatures (˚F)						
Initial deformation	25	2,145	2,115	1,905	2,615	153
Softening temperature	25	2,240	2,190	2,015	2,710	153
Fluid temperature	25	2,380	2,340	2,130	2,800	172

Table 9. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for all nonassessed coals from the Carbondale Group or Formation in the Illinois Basin.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). G, greater than value shown.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	425	9.9	10.1	0.8	37.1	4.7
Volatile matter	420	35.9	36.2	19.7	44.3	3.4
Fixed carbon	420	41.4	41.7	8.5	59.8	5.0
Ash	425	12.8	10.9	3.6	48.5	6.5
Hydrogen	348	5.2	5.3	1.7	6.8	0.7
Carbon	355	60.6	61.7	24.0	73.6	6.3
Nitrogen	342	1.3	1.3	0.4	2.1	0.2
Oxygen	340	15.6	16.6	2.0	32.0	5.3
Sulfur	432	3.2	2.9	0.3	28.1	2.2
Calorific value						
Btu/lb	425	10,920	11,170	5,440	13,200	1,150
Forms of sulfur						
Sulfate	91	0.28	0.18	0.01	1.08	0.28
Pyritic	91	2.17	1.79	0.30	12.10	1.65
Organic	91	1.45	1.33	0.26	5.78	0.82
Ash-fusion temperatures (˚F)						
Initial deformation	280	2,050	2,000	1,780	2,800G	183
Softening temperature	322	2,175	2,115	1,900	2,800G	185
Fluid temperature	280	2,285	2,250	1,930	2,805G	187

Table 10. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for all nonassessed coals from the Raccoon Creek Group in the Illinois Basin.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). G, greater than value shown.]

	Number of samples	Mean	Median	Range Minimum	Range Maximum	Standard deviation
Proximate and ultimate analyses						
Moisture	778	11.3	11.0	0.7	52.8	5.4
Volatile matter	776	35.4	35.5	16.5	54.0	3.9
Fixed carbon	776	43.4	44.1	7.9	58.7	6.2
Ash	778	10.0	8.4	1.5	48.7	6.2
Hydrogen	582	5.4	5.5	2.4	8.2	0.7
Carbon	605	63.0	63.6	27.7	82.9	6.9
Nitrogen	582	1.3	1.3	0.6	2.5	0.2
Oxygen	579	16.6	16.6	4.3	51.2	6.2
Sulfur	801	2.9	2.5	0.1	30.1	2.2
Calorific value						
Btu/lb	775	11,190	11,400	4,540	13,620	1,290
Forms of sulfur						
Sulfate	155	0.26	0.15	0.01	2.31	0.29
Pyritic	155	1.66	1.26	0.03	7.46	1.53
Organic	156	1.16	0.90	0.05	5.43	0.76
Ash-fusion temperatures (˚F)						
Initial deformation	541	2,150	2,040	1,760	2,860G	278
Softening temperature	604	2,275	2,200	1,810	2,910G	260
Fluid temperature	541	2,370	2,360	1,900	2,910G	237

Table 11. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for all coals (assessed and nonassessed) in the Illinois Basin.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). G, greater than value shown.]

	Number of samples	Mean	Median	Range Minimum	Range Maximum	Standard deviation
Proximate and ultimate analyses						
Moisture	5,996	10.5	10.4	0.5	52.8	4.0
Volatile matter	5,670	35.2	35.2	16.5	56.7	3.1
Fixed carbon	5,670	43.2	43.0	7.9	62.7	5.0
Ash	5,993	11.1	10.3	1.5	49.7	4.6
Hydrogen	3,074	4.8	4.6	1.7	8.2	0.8
Carbon	3,112	61.9	62.5	24.0	82.9	5.8
Nitrogen	3,061	1.2	1.3	0.3	2.7	0.2
Oxygen	3,055	11.6	8.6	0.2	51.2	5.9
Sulfur	5,997	3.1	3.2	0.1	30.1	1.6
Calorific value						
Btu/lb	5,737	11,180	11,270	4,540	13,910	990
Forms of sulfur						
Sulfate	1,818	0.12	0.04	0.01	2.31	0.19
Pyritic	2,158	1.76	1.66	0.02	18.28	1.21
Organic	2,162	1.46	1.53	0.05	5.78	0.63
Ash-fusion temperatures (˚F)						
Initial deformation	2,060	2,080	2,020	1,680	2,860G	207
Softening temperature	2,241	2,180	2,120	1,810	2,995G	210
Fluid temperature	2,059	2,285	2,260	1,845	2,910G	205

Appendix 2. Summary descriptive statistics of proximate and ultimate analyses, calorific values, forms-of-sulfur analyses, and ash-fusion temperatures for all assessed and nonassessed coals in the Illinois Basin as analyzed by the Illinois State Geological Survey, Indiana Geological Survey, Kentucky Geological Survey, and U.S. Geological Survey

Table 1. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for the Danville Coal Member in Illinois as analyzed by the Illinois State Geological Survey.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F).]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	170	13.4	13.4	5.3	25.0	2.7
Volatile matter	162	35.9	36.7	25.2	44.5	3.4
Fixed carbon	162	38.6	38.8	26.5	48.4	2.8
Ash	170	12.2	11.0	4.3	44.2	4.4
Hydrogen	31	4.5	4.3	3.6	5.9	0.6
Carbon	31	60.2	61.3	52.7	67.6	4.0
Nitrogen	31	1.1	1.1	0.7	1.4	0.2
Oxygen	31	6.6	6.8	4.0	8.6	1.1
Sulfur	168	3.1	3.1	0.3	9.7	1.2
Calorific value						
Btu/lb	131	10,670	11,030	5,800	12,190	870
Forms of sulfur						
Sulfate	40	0.07	0.04	0.01	0.26	0.07
Pyritic	49	1.63	1.50	0.03	6.01	1.14
Organic	49	1.19	1.25	0.26	2.17	0.40
Ash-fusion temperatures (˚F)						
Initial deformation	20	2,075	2,010	1,920	2,330	120
Softening temperature	20	2,185	2,080	1,935	2,570	197
Fluid temperature	20	2,400	2,360	2,005	2,770	231

Table 2. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for the Danville Coal Member in Indiana as analyzed by the Indiana Geological Survey.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). G, greater than value shown.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	115	10.9	10.9	1.9	28.2	4.2
Volatile matter	114	35.5	35.6	26.0	56.7	3.8
Fixed carbon	114	42.2	42.1	20.4	51.1	3.9
Ash	115	11.3	10.3	4.2	39.7	4.6
Hydrogen	90	5.5	5.6	3.3	6.3	0.5
Carbon	90	60.9	61.2	41.3	69.5	4.0
Nitrogen	88	1.4	1.3	1.1	1.9	0.1
Oxygen	88	18.1	18.7	9.4	24.4	3.5
Sulfur	115	2.5	2.6	0.4	6.7	1.3
Calorific value						
Btu/lb	115	10,970	10,970	7,400	12,630	790
Forms of sulfur						
Sulfate	10	0.27	0.09	0.05	1.68	0.50
Pyritic	10	1.35	1.15	0.61	2.74	0.70
Organic	10	0.99	0.84	0.39	1.82	0.44
Ash-fusion temperatures (˚F)						
Initial deformation	84	2,095	2,045	1,820	2,600	192
Softening temperature	101	2,240	2,230	1,905	2,710G	200
Fluid temperature	84	2,340	2,340	1,935	2,720G	198

Table 3. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for the Danville Coal Member in Indiana as analyzed by the U.S. Geological Survey.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). G, greater than value shown.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	15	10.1	9.5	6.2	15.0	2.2
Volatile matter	15	33.8	33.1	28.4	37.2	2.5
Fixed carbon	15	44.7	44.8	35.0	52.3	4.9
Ash	15	11.5	10.8	6.4	21.5	4.4
Hydrogen	15	5.5	5.5	5.1	6.1	0.3
Carbon	18	59.0	61.8	36.9	68.1	7.9
Nitrogen	15	1.2	1.1	0.8	1.5	0.2
Oxygen	15	17.6	17.2	13.6	21.5	1.9
Sulfur	18	2.7	2.6	0.3	7.6	1.8
Calorific value						
Btu/lb	15	11,020	11,140	9,350	11,990	730
Forms of sulfur						
Sulfate	15	0.31	0.40	0.01	0.62	0.22
Pyritic	15	1.21	0.85	0.09	3.14	0.95
Organic	15	1.05	1.11	0.22	1.80	0.49
Ash-fusion temperatures (˚F)						
Initial deformation	14	2,135	2,115	1,900	2,745	207
Softening temperature	14	2,225	2,155	1,960	2,800G	215
Fluid temperature	14	2,325	2,315	1,995	2,800G	218

Table 4. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for the Baker coal in Kentucky as analyzed by the Kentucky Geological Survey.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). G, greater than value shown.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	19	6.6	6.6	5.2	8.0	0.5
Volatile matter	19	33.8	34.1	25.7	37.3	3.0
Fixed carbon	19	46.5	46.7	34.5	54.7	4.8
Ash	19	13.2	11.6	6.5	27.6	5.4
Hydrogen	19	4.3	4.5	3.1	4.7	0.4
Carbon	19	65.3	66.7	52.7	72.7	5.7
Nitrogen	19	1.4	1.4	0.9	1.7	0.2
Oxygen	19	5.7	5.5	3.1	8.4	1.6
Sulfur	19	3.6	3.6	1.5	7.7	1.6
Calorific value						
Btu/lb	19	11,740	12,150	9,300	12,990	1,050
Forms of sulfur						
Sulfate	---	---	---	---	---	---
Pyritic	---	---	---	---	---	---
Organic	---	---	---	---	---	---
Ash-fusion temperatures (˚F)						
Initial deformation	---	---	---	---	---	---
Softening temperature	---	---	---	---	---	---
Fluid temperature	---	---	---	---	---	---

Table 5. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for the Baker coal in Kentucky as analyzed by the U.S. Geological Survey.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). G, greater than value shown.]

	Number of samples	Mean	Median	Range Minimum	Range Maximum	Standard deviation
Proximate and ultimate analyses						
Moisture	15	6.9	6.7	3.4	10.8	2.1
Volatile matter	15	36.0	35.8	31.3	40.8	3.0
Fixed carbon	15	45.1	44.1	40.0	50.5	3.1
Ash	15	12.0	11.7	7.9	17.9	2.7
Hydrogen	15	5.2	5.2	4.8	5.6	0.2
Carbon	15	64.2	64.8	58.6	70.3	3.4
Nitrogen	15	1.4	1.4	1.2	1.7	0.1
Oxygen	15	13.5	13.0	10.2	18.1	2.3
Sulfur	15	3.7	4.2	1.6	5.8	1.2
Calorific value						
Btu/lb	15	11,590	11,510	10,410	12,660	640
Forms of sulfur						
Sulfate	15	0.15	0.13	0.01	0.45	0.12
Pyritic	15	2.25	2.67	0.69	3.72	0.94
Organic	15	1.36	1.24	0.57	2.04	0.46
Ash-fusion temperatures (˚F)						
Initial deformation	15	2,080	2,030	1,930	2,610	169
Softening temperature	15	2,140	2,080	2,030	2,710	176
Fluid temperature	15	2,310	2,260	2,080	2,800	194

Table 6. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for the Herrin Coal Member in Illinois as analyzed by the Illinois State Geological Survey.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F).]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	2,330	11.1	11.0	1.2	22.2	3.2
Volatile matter	2,160	34.6	34.6	19.5	45.2	2.8
Fixed carbon	2,160	43.4	42.6	25.3	58.2	4.6
Ash	2,327	10.9	10.4	2.7	43.6	3.6
Hydrogen	780	4.2	4.2	3.0	5.5	0.3
Carbon	780	60.8	60.5	41.4	73.6	5.2
Nitrogen	776	1.2	1.1	0.3	2.7	0.2
Oxygen	776	7.5	7.5	3.5	12.2	1.0
Sulfur	2,302	2.9	3.2	0.3	14.5	1.5
Calorific value						
Btu/lb	2,176	11,100	11,120	5,770	13,420	800
Forms of sulfur						
Sulfate	776	0.07	0.03	0.01	2.02	0.12
Pyritic	1,014	1.63	1.64	0.04	8.48	1.07
Organic	1,016	1.43	1.48	0.16	3.35	0.62
Ash-fusion temperatures (˚F)						
Initial deformation	437	2,110	2,080	1,680	2,700	168
Softening temperature	440	2,165	2,150	1,820	2,995	161
Fluid temperature	436	2,290	2,290	1,880	2,700	151

Table 7. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for the Herrin Coal Member in Illinois as analyzed by the U.S. Geological Survey.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). G, greater than value shown.]

	Number of samples	Mean	Median	Range Minimum	Range Maximum	Standard deviation
Proximate and ultimate analyses						
Moisture	74	6.4	5.8	3.1	12.1	2.5
Volatile matter	74	34.8	34.9	27.3	40.9	2.6
Fixed carbon	74	48.1	48.3	40.1	58.5	3.9
Ash	74	10.7	10.2	2.4	24.3	4.1
Hydrogen	74	5.1	5.2	4.2	5.9	0.3
Carbon	74	64.6	65.2	55.1	73.6	4.9
Nitrogen	74	1.2	1.2	0.5	1.6	0.2
Oxygen	74	14.9	14.5	10.0	20.5	2.7
Sulfur	74	3.4	3.1	0.5	8.7	1.6
Calorific value						
Btu/lb	73	11,500	11,500	9,780	13,090	870
Forms of sulfur						
Sulfate	64	0.33	0.20	0.01	1.71	0.37
Pyritic	74	1.39	1.09	0.02	7.51	1.24
Organic	74	1.76	1.81	0.34	5.08	0.81
Ash-fusion temperatures (˚F)						
Initial deformation	74	2,060	2,035	1,780	2,800G	168
Softening temperature	74	2,130	2,125	1,820	2,910G	174
Fluid temperature	74	2,210	2,175	1,860	2,910G	191

Table 8. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for the Herrin coal in Kentucky as analyzed by the Kentucky Geological Survey.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). Leaders (---) indicate no data.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	121	6.5	6.5	3.8	9.4	0.9
Volatile matter	121	37.4	37.4	32.2	42.5	2.1
Fixed carbon	121	45.7	45.7	35.8	52.9	3.4
Ash	121	10.5	9.8	5.3	24.1	3.6
Hydrogen	65	4.3	4.3	2.9	5.0	0.5
Carbon	65	65.0	65.8	47.8	71.0	4.4
Nitrogen	65	1.2	1.3	0.7	1.7	0.2
Oxygen	65	7.3	7.8	2.3	16.7	2.4
Sulfur	121	3.8	3.8	1.0	7.0	1.1
Calorific value						
Btu/lb	121	11,990	12,070	9,540	13,100	690
Forms of sulfur						
Sulfate	---	---	---	---	---	---
Pyritic	---	---	---	---	---	---
Organic	---	---	---	---	---	---
Ash-fusion temperatures (˚F)						
Initial deformation	---	---	---	---	---	---
Softening temperature	---	---	---	---	---	---
Fluid temperature	---	---	---	---	---	---

Table 9. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for the Herrin coal in Kentucky as analyzed by the U.S. Geological Survey.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). G, greater than value shown.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	20	6.0	6.2	2.3	9.7	2.0
Volatile matter	20	37.9	37.7	30.4	42.7	2.9
Fixed carbon	20	47.0	47.3	40.7	51.3	3.3
Ash	20	9.0	7.5	5.3	24.8	4.9
Hydrogen	20	5.4	5.5	4.3	5.8	0.3
Carbon	20	67.3	68.6	53.5	73.3	4.7
Nitrogen	20	1.4	1.4	1.2	1.5	0.1
Oxygen	20	13.3	13.5	8.7	16.8	2.2
Sulfur	20	3.6	3.6	2.9	5.0	0.6
Calorific value						
Btu/lb	20	12,240	12,540	9,710	13,390	850
Forms of sulfur						
Sulfate	20	0.09	0.07	0.01	0.26	0.09
Pyritic	20	1.83	1.65	0.77	3.56	0.77
Organic	20	1.69	1.85	0.51	2.40	0.48
Ash-fusion temperatures (˚F)						
Initial deformation	20	2,040	2,015	1,925	2,770	175
Softening temperature	20	2,125	2,085	2,030	2,800G	163
Fluid temperature	20	2,250	2,225	2,125	2,800G	139

Table 10. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for the Springfield Coal Member in Illinois as analyzed by the Illinois State Geological Survey.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F).]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	1,171	10.7	10.5	0.9	24.2	4.2
Volatile matter	1,032	34.7	34.8	22.4	41.1	2.4
Fixed carbon	1,032	43.0	41.8	25.0	60.7	5.4
Ash	1,171	11.7	10.7	2.8	43.5	4.6
Hydrogen	472	4.3	4.2	2.7	5.5	0.4
Carbon	472	61.2	60.0	38.3	77.8	5.4
Nitrogen	472	1.2	1.2	0.3	2.2	0.2
Oxygen	472	6.5	6.7	0.2	12.8	1.3
Sulfur	1,163	3.5	3.4	0.6	17.7	1.5
Calorific value						
Btu/lb	1,109	11,140	10,980	4,810	13,910	1,070
Forms of sulfur						
Sulfate	505	0.06	0.03	0.01	1.18	0.09
Pyritic	584	2.01	1.79	0.11	18.28	1.29
Organic	585	1.57	1.65	0.29	5.11	0.50
Ash-fusion temperatures (˚F)						
Initial deformation	257	1,990	1,970	1,800	2,500	96
Softening temperature	257	2,030	2,010	1,835	2,550	102
Fluid temperature	257	2,130	2,105	1,845	2,700	139

Table 11. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for the Springfield Coal Member in Indiana as analyzed by the Indiana Geological Survey.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). G, greater than value shown.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	336	9.9	10.2	0.5	34.7	4.0
Volatile matter	335	37.0	37.3	17.7	55.0	3.9
Fixed carbon	335	42.1	42.2	14.0	62.7	4.9
Ash	336	10.9	9.7	4.3	49.7	5.3
Hydrogen	274	5.5	5.6	3.1	7.1	0.5
Carbon	273	62.0	62.9	34.7	72.5	5.3
Nitrogen	273	1.3	1.3	0.7	1.9	0.2
Oxygen	272	16.9	16.9	2.9	42.2	3.9
Sulfur	336	3.3	3.3	0.6	7.4	1.3
Calorific value						
Btu/lb	336	11,210	11,400	6,020	13,400	920
Forms of sulfur						
Sulfate	37	0.20	0.12	0.01	1.19	0.24
Pyritic	41	1.51	1.25	0.20	4.66	1.07
Organic	41	1.55	1.46	0.50	3.92	0.74
Ash-fusion temperatures (˚F)						
Initial deformation	237	2,001	1,959	1,795	2,700G	167
Softening temperature	293	2,130	2,080	1,860	2,810G	186
Fluid temperature	237	2,234	2,200	1,924	2,720G	194

Table 12. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for the Springfield Coal Member in Indiana as analyzed by the U.S. Geological Survey.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). G, greater than value shown.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	35	8.8	8.9	4.6	15.3	2.2
Volatile matter	35	36.1	35.8	22.8	42.8	4.1
Fixed carbon	35	46.1	46.6	38.7	57.7	3.7
Ash	35	9.0	8.9	4.2	12.5	1.9
Hydrogen	35	5.5	5.5	5.1	5.9	0.2
Carbon	41	62.0	64.2	28.0	68.6	7.9
Nitrogen	35	1.2	1.2	0.9	1.6	0.2
Oxygen	35	16.3	16.5	12.0	22.9	2.4
Sulfur	41	4.2	3.4	0.5	19.5	3.3
Calorific value						
Btu/lb	35	11,603	11,590	10,800	12,460	377
Forms of sulfur						
Sulfate	35	0.29	0.15	0.01	1.28	0.34
Pyritic	35	1.51	1.42	0.06	3.41	0.83
Organic	35	1.68	1.73	0.42	2.65	0.50
Ash-fusion temperatures (˚F)						
Initial deformation	25	2,105	2,035	1,865	2,800	236
Softening temperature	25	2,205	2,145	1,935	2,910G	238
Fluid temperature	25	2,280	2,255	1,985	2,910G	235

Table 13. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for the Springfield coal in Kentucky as analyzed by the Kentucky Geological Survey.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). Leaders (---) indicate no data.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	259	7.9	7.9	1.8	12.2	1.7
Volatile matter	259	36.2	36.4	31.6	41.4	1.5
Fixed carbon	259	45.7	45.5	40.0	52.1	2.3
Ash	259	10.2	10.1	5.0	16.4	1.6
Hydrogen	141	4.2	4.3	3.2	4.8	0.4
Carbon	141	65.2	65.4	50.5	72.6	2.4
Nitrogen	141	1.3	1.3	0.8	1.7	0.2
Oxygen	141	7.1	7.2	2.6	19.9	2.0
Sulfur	259	3.5	3.5	2.1	6.2	0.7
Calorific value						
Btu/lb	259	11,870	11,820	10,820	13,250	480
Forms of sulfur						
Sulfate	---	---	---	---	---	---
Pyritic	---	---	---	---	---	---
Organic	---	---	---	---	---	---
Ash-fusion temperatures (˚F)						
Initial deformation	---	---	---	---	---	---
Softening temperature	---	---	---	---	---	---
Fluid temperature	---	---	---	---	---	---

Table 14. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for the Springfield coal in Kentucky as analyzed by the U.S. Geological Survey.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F).]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	31	7.2	7.0	2.5	12.4	2.2
Volatile matter	31	36.9	36.9	34.7	39.8	1.3
Fixed carbon	31	45.3	45.2	40.8	49.9	2.5
Ash	31	10.5	10.7	6.7	15.2	2.4
Hydrogen	31	5.3	5.3	4.8	5.7	0.2
Carbon	31	65.2	65.4	59.8	70.2	2.8
Nitrogen	31	1.4	1.4	1.0	1.6	0.1
Oxygen	31	13.6	13.5	7.6	20.3	2.7
Sulfur	31	3.9	3.7	2.5	8.0	1.1
Calorific value						
Btu/lb	31	11,840	11,930	10,820	12,770	530
Forms of sulfur						
Sulfate	31	0.12	0.06	0.01	0.53	0.13
Pyritic	31	2.09	1.90	0.71	4.10	0.85
Organic	31	1.74	1.67	1.08	3.94	0.52
Ash-fusion temperatures (˚F)						
Initial deformation	31	2,015	2,015	1,910	2,220	69
Softening temperature	31	2,100	2,105	1,950	2,250	77
Fluid temperature	31	2,205	2,205	2,050	2,360	78

Table 15. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for nonassessed coals from the McLeansboro Group in Kentucky as analyzed by the Kentucky Geological Survey.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). Leaders (---) indicate no data.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	57	7.5	7.5	7.5	7.5	0.0
Volatile matter	57	34.6	34.4	29.8	38.2	2.1
Fixed carbon	57	43.2	43.0	34.0	50.6	4.0
Ash	57	14.7	14.6	6.0	28.7	4.4
Hydrogen	57	4.0	4.1	3.0	4.7	0.4
Carbon	57	62.0	62.2	51.8	69.9	3.9
Nitrogen	57	1.3	1.3	0.7	1.6	0.2
Oxygen	57	6.7	7.0	2.1	12.5	2.0
Sulfur	57	3.8	3.6	1.7	8.0	1.3
Calorific value						
Btu/lb	57	11,150	11,200	9,300	12,620	710
Forms of sulfur						
Sulfate	---	---	---	---	---	---
Pyritic	---	---	---	---	---	---
Organic	---	---	---	---	---	---
Ash-fusion temperatures (˚F)						
Initial deformation	---	---	---	---	---	---
Softening temperature	---	---	---	---	---	---
Fluid temperature	---	---	---	---	---	---

Table 16. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for nonassessed coals from the McLeansboro Group in Kentucky as analyzed by the U.S. Geological Survey.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F).]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	25	6.7	7.0	3.8	12.6	1.9
Volatile matter	25	35.8	36.6	29.7	38.5	2.3
Fixed carbon	25	44.9	45.3	38.7	50.1	3.0
Ash	25	12.5	12.8	6.0	24.4	3.8
Hydrogen	25	5.2	5.2	4.6	5.5	0.2
Carbon	25	63.7	64.3	50.6	70.1	3.6
Nitrogen	25	1.4	1.4	1.2	1.6	0.1
Oxygen	25	13.8	13.4	11.1	20.5	2.0
Sulfur	25	3.4	3.2	1.8	5.7	1.0
Calorific value						
Btu/lb	25	11,530	11,530	9,080	12,660	660
Forms of sulfur						
Sulfate	24	0.13	0.08	0.01	0.70	0.17
Pyritic	24	1.83	1.69	0.84	4.04	0.89
Organic	24	1.42	1.51	0.50	1.92	0.43
Ash-fusion temperatures (˚F)						
Initial deformation	25	2,145	2,115	1,905	2,615	153
Softening temperature	25	2,240	2,190	2,015	2,710	153
Fluid temperature	25	2,380	2,340	2,130	2,800	172

Table 17. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for nonassessed coals from the Carbondale Group in Indiana as analyzed by the Indiana Geological Survey.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). G, greater than value shown.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	312	10.8	11.3	0.8	37.1	5.0
Volatile matter	307	35.8	36.2	19.7	43.4	3.5
Fixed carbon	307	40.9	41.4	8.5	59.8	5.0
Ash	312	12.5	10.5	4.7	48.5	6.6
Hydrogen	235	5.4	5.5	3.1	6.8	0.6
Carbon	235	60.2	61.4	32.2	73.6	5.7
Nitrogen	229	1.3	1.3	0.9	2.1	0.2
Oxygen	228	17.6	18.1	6.2	32.0	4.5
Sulfur	312	2.8	2.5	0.3	11.1	1.6
Calorific value						
Btu/lb	312	10,800	11,100	5,440	13,200	1,170
Forms of sulfur						
Sulfate	20	0.28	0.21	0.02	1.02	0.28
Pyritic	20	1.77	1.61	0.59	3.80	0.92
Organic	20	1.55	1.24	0.68	5.78	1.21
Ash-fusion temperatures (˚F)						
Initial deformation	212	2,045	1,980	1,800	2,700G	191
Softening temperature	254	2,180	2,120	1,900	2,770G	193
Fluid temperature	212	2,295	2,260	1,930	2,805G	193

Table 18. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for nonassessed coals from the Carbondale Group in Indiana as analyzed by the U.S. Geological Survey.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). G, greater than value shown.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	29	9.0	9.1	2.8	15.6	2.6
Volatile matter	29	34.6	34.8	25.0	40.7	3.2
Fixed carbon	29	44.4	44.7	27.3	52.7	4.5
Ash	29	12.0	10.5	6.3	44.9	7.1
Hydrogen	29	5.4	5.4	3.5	6.1	0.5
Carbon	36	59.4	61.5	24.0	69.6	9.1
Nitrogen	29	1.2	1.3	0.5	1.5	0.2
Oxygen	29	16.6	17.1	9.8	21.6	2.5
Sulfur	36	4.1	3.2	1.2	28.1	4.4
Calorific value						
Btu/lb	29	11,070	11,090	6,930	12,330	960
Forms of sulfur						
Sulfate	29	0.46	0.49	0.02	1.08	0.32
Pyritic	29	1.62	1.48	0.34	3.34	0.78
Organic	29	1.06	1.09	0.26	1.92	0.46
Ash-fusion temperatures (˚F)						
Initial deformation	26	2,090	2,030	1,885	2,800G	214
Softening temperature	26	2,180	2,120	1,985	2,800G	201
Fluid temperature	26	2,255	2,195	2,020	2,800G	199

Table 19. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for nonassessed coals from the Carbondale Formation in Kentucky as analyzed by the Kentucky Geological Survey.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). Leaders (---) indicate no data.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	42	7.5	7.5	7.5	7.5	0.0
Volatile matter	42	36.0	36.0	26.2	42.5	3.2
Fixed carbon	42	41.5	41.1	30.4	53.1	4.9
Ash	42	15.0	13.8	3.6	30.9	6.4
Hydrogen	42	4.1	4.2	1.7	4.8	0.6
Carbon	42	60.9	62.1	47.0	69.7	5.8
Nitrogen	42	1.2	1.3	0.4	1.5	0.2
Oxygen	41	7.6	7.2	2.0	17.7	3.3
Sulfur	42	3.9	3.9	1.8	8.2	1.4
Calorific value						
Btu/lb	42	11,070	11,270	8,410	12,570	1,010
Forms of sulfur						
Sulfate	---	---	---	---	---	---
Pyritic	---	---	---	---	---	---
Organic	---	---	---	---	---	---
Ash-fusion temperatures (˚F)						
Initial deformation	---	---	---	---	---	---
Softening temperature	---	---	---	---	---	---
Fluid temperature	---	---	---	---	---	---

Table 20. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for nonassessed coals from the Carbondale Formation in Kentucky as analyzed by the U.S. Geological Survey.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F).]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	42	6.1	6.3	2.4	16.3	2.4
Volatile matter	42	37.6	37.4	32.1	44.3	2.8
Fixed carbon	42	42.9	42.9	33.2	52.2	4.1
Ash	42	13.4	12.3	6.1	27.1	5.1
Hydrogen	42	5.2	5.3	4.0	5.8	0.4
Carbon	42	63.3	63.7	45.5	73.6	6.2
Nitrogen	42	1.4	1.4	1.0	1.6	0.2
Oxygen	42	12.2	12.1	6.5	25.3	2.8
Sulfur	42	4.6	4.0	1.4	15.9	2.6
Calorific value						
Btu/lb	42	11,590	11,630	8,950	13,200	1,010
Forms of sulfur						
Sulfate	42	0.16	0.11	0.01	0.64	0.15
Pyritic	42	2.74	2.24	0.30	12.10	2.13
Organic	42	1.66	1.58	0.64	4.37	0.70
Ash-fusion temperatures (˚F)						
Initial deformation	42	2,065	2,035	1,930	2,440	101
Softening temperature	42	2,130	2,105	2,000	2,530	113
Fluid temperature	42	2,255	2,225	2,070	2,650	139

Table 21. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for nonassessed coals from the Raccoon Creek Group in Indiana as analyzed by the Indiana Geological Survey.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). G, greater than value shown.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	586	12.0	12.1	0.7	52.8	5.8
Volatile Matter	584	35.3	35.2	16.5	54.0	3.9
Fixed carbon	584	42.2	42.9	7.9	58.7	6.1
Ash	586	10.5	8.7	1.7	48.7	6.4
Hydrogen	390	5.6	5.7	2.4	8.2	0.6
Carbon	390	61.8	62.8	30.2	75.7	6.3
Nitrogen	390	1.3	1.3	0.7	1.8	0.2
Oxygen	387	18.3	17.8	5.7	51.2	5.8
Sulfur	586	2.9	2.6	0.1	14.1	2.0
Calorific value						
Btu/lb	583	10,980	11,290	4,540	13,540	1,300
Forms of sulfur						
Sulfate	50	0.34	0.27	0.02	2.31	0.37
Pyritic	50	1.76	1.13	0.15	7.46	1.79
Organic	51	1.43	1.32	0.05	5.43	1.00
Ash-fusion temperatures (˚F)						
Initial deformation	444	2,135	2,020	1,760	2,860G	275
Softening temperature	507	2,265	2,200	1,810	2,895G	256
Fluid temperature	444	2,360	2,360	1,900	2,895G	231

Table 22. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for nonassessed coals from the Raccoon Creek Group in Indiana as analyzed by the U.S. Geological Survey.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). G, greater than value shown.]

	Number of samples	Mean	Median	Range: Minimum	Range: Maximum	Standard deviation
Proximate and ultimate analyses						
Moisture	62	10.9	11.0	2.1	21.4	3.8
Volatile matter	62	33.9	34.3	22.4	43.5	4.2
Fixed carbon	62	46.7	47.3	39.2	57.8	4.0
Ash	62	8.5	8.1	2.0	15.0	3.1
Hydrogen	62	5.6	5.6	4.8	6.3	0.3
Carbon	85	62.2	63.3	27.7	82.9	8.0
Nitrogen	62	1.1	1.2	0.6	1.6	0.2
Oxygen	62	18.4	18.2	7.9	31.3	4.0
Sulfur	85	3.1	2.5	0.4	30.1	3.5
Calorific value						
Btu/lb	62	11,360	11,405	9,020	13,010	730
Forms of sulfur						
Sulfate	62	0.29	0.26	0.01	0.92	0.26
Pyritic	62	1.70	1.24	0.06	6.10	1.50
Organic	62	1.09	0.93	0.15	2.15	0.53
Ash-fusion temperatures (˚F)						
Initial deformation	54	2,215	2,065	1,895	2,800G	289
Softening temperature	54	2,305	2,205	1,960	2,910G	291
Fluid temperature	54	2,390	2,340	2,000	2,910G	276

Table 23. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for nonassessed coals from the Raccoon Creek Group in Kentucky as analyzed by the Kentucky Geological Survey.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). Leaders (---) indicate no data.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	87	7.5	7.5	7.5	7.5	0.0
Volatile matter	87	36.5	36.1	24.2	44.9	3.5
Fixed carbon	87	46.9	47.0	24.4	55.9	5.5
Ash	87	9.1	7.6	1.5	43.9	6.9
Hydrogen	87	4.2	4.2	2.4	5.1	0.5
Carbon	87	67.1	68.6	35.9	75.7	7.2
Nitrogen	87	1.3	1.4	0.6	1.8	0.3
Oxygen	87	8.3	8.1	4.3	12.8	1.7
Sulfur	87	2.6	2.4	0.6	7.3	1.6
Calorific value						
Btu/lb	87	11,960	12,310	6,180	13,620	1,270
Forms of sulfur						
Sulfate	---	---	---	---	---	---
Pyritic	---	---	---	---	---	---
Organic	---	---	---	---	---	---
Ash-fusion temperatures (˚F)						
Initial deformation	---	---	---	---	---	---
Softening temperature	---	---	---	---	---	---
Fluid temperature	---	---	---	---	---	---

Table 24. Number of samples, mean, median, range, and standard deviation of proximate and ultimate analyses, calorific value, forms-of-sulfur analyses, and ash-fusion temperatures for nonassessed coals from the Raccoon Creek Group in Kentucky as analyzed by the U.S. Geological Survey.

[All values are reported on an as-received basis and are in percent, except calorific value (Btu/lb) and ash-fusion temperatures (°F). G, greater than value shown.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Proximate and ultimate analyses						
Moisture	43	8.9	8.7	4.1	15.2	2.5
Volatile matter	43	36.5	36.3	30.7	42.6	2.6
Fixed carbon	43	47.7	47.4	40.4	53.5	3.3
Ash	43	6.8	6.4	1.5	13.9	3.4
Hydrogen	43	5.6	5.7	4.7	6.1	0.3
Carbon	43	67.9	69.0	60.6	74.4	3.5
Nitrogen	43	1.5	1.4	1.1	2.5	0.2
Oxygen	43	15.6	15.5	10.4	21.4	2.8
Sulfur	43	2.5	2.2	0.5	8.1	1.8
Calorific value						
Btu/lb	43	12,220	12,340	10,970	13,330	570
Forms of sulfur						
Sulfate	43	0.11	0.05	0.01	0.45	0.13
Pyritic	43	1.49	1.40	0.03	4.57	1.23
Organic	43	0.95	0.72	0.34	3.13	0.63
Ash-fusion temperatures (˚F)						
Initial deformation	43	2,240	2,120	1,915	2,800G	270
Softening temperature	43	2,325	2,205	2,030	2,800G	262
Fluid temperature	43	2,430	2,350	2,080	2,800G	239

Appendix 3. Summary descriptive statistics of ash yields and contents of selected elements for all assessed and nonassessed coals in the Illinois Basin.

Table 1. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for all assessed coals (Springfield, Herrin, Danville, and Baker Coals) in the Illinois Basin.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
			Percent			
Ash	211	12.4	11.0	2.8	47.0	6.7
Si	574	2.2	1.9	0.018	13	1.2
Al	574	1.1	0.93	0.17	5.8	0.57
Ca	574	0.52	0.40	0.015	11	0.62
Mg	575	0.054	0.043	0.0044L	0.47	0.043
Na	587	0.053	0.038	0.0018	0.42	0.049
K	592	0.18	0.15	0.003L	1.4	0.13
Fe	574	2.0	1.7	0.096	27	1.5
Ti	574	0.058	0.051	0.004L	0.37	0.03
			Parts per million			
As	400	9.4	4.4	0.20L	140	15
B	352	99	89	5.7L	390	48
Ba	332	100	35	5.5	2,500	280
Be	389	1.8	1.5	0.36L	8.5	1.1
Cd	370	0.99	0.16	0.01L	54	4.2
Co	566	4.0	3.3	0.78	17	2.3
Cr	568	18	14	2.8L	190	16
Cu	355	11	8.6	2.7	77	8.3
F	345	71	52	10L	600	75
Ge	338	7.8	5.8	0.045L	63	8.1
Hg	368	0.12	0.09	0.01L	1.2	0.11
La	316	5.8	5.0	0.84L	31	4.2
Li	284	11	7.3	0.94L	89	13
Mn	558	52	36	0.58	1,200	64
Mo	335	7.6	5.0	0.16L	190	12
Nb	210	1.8	1.6	0.26L	12	1.4
Ni	580	16	12	1.0	190	15
P	399	90	45	2.8L	2,200	160
Pb	389	16	6.3	0.019L	350	30
Sb	399	0.9	0.6	0.1	15	1.4
Sc	313	2.7	2.3	0.38	16	1.5
Se	380	2.2	1.8	0.4L	13	1.6
Sr	332	33	23	2.7L	980	60
Th	334	2.0	1.5	0.3L	17	1.7
U	351	2.2	1.2	0.15L	26	3.1
V	358	24	19	1.2	130	19
Y	211	5.6	4.9	1.1	27	3.3
Yb	299	0.55	0.5	0.065L	3.2	0.33
Zn	373	170	36	3.7	4,500	510
Zr	346	26	20	0.51L	270	24

Table 2. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for the Danville Coal Member in Illinois and Indiana.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. L, less than value shown. G, greater than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated. Leaders (---) indicate statistics could not be calculated owing to no data or to an insufficient number of analyses above the lower detection limit.]

	Number of samples	Mean	Median	Range Minimum	Range Maximum	Standard deviation
			Percent			
Ash	19	16.2	13.0	6.7	47.0	11
Si	22	3.3	2.2	1.4	13	2.7
Al	22	1.6	1.1	0.55	5.8	1.2
Ca	22	0.37	0.33	0.029	1.2	0.34
Mg	22	0.12	0.079	0.029	0.47	0.10
Na	22	0.075	0.058	0.013	0.24	0.061
K	22	0.35	0.23	0.11	1.4	0.33
Fe	22	2.0	1.7	0.2.0	7.5	1.5
Ti	22	0.089	0.062	0.044	0.37	0.073
			Parts per million			
As	22	12	10	0.50	43	10
B	22	110	110	31	190G	40
Ba	21	67	46	20	290	62
Be	22	3.2	3.2	1.2	6.0	1.2
Cd	22	0.40	0.12	0.01L	4.5	0.98
Co	22	6.3	6.2	2.5	12	2.5
Cr	22	19	17	9.5	46	9.5
Cu	22	10	9.9	5.5	24	4.0
F	22	110	66	22	450	120
Ge	22	12	14	1.1L	19	5.5
Hg	22	0.10	0.09	0.01	0.32	0.07
La	21	8.7	6.5	3.0	26	5.8
Li	21	19	10	5.5	89	20
Mn	22	55	48	10	230	48
Mo	21	2.6	2.3	0.16L	10	2.1
Nb	19	2.9	2.1	0.61L	12	2.5
Ni	22	24	27	5.5	48	15
P	---	---	---	---	---	---
Pb	22	17	13	1.5L	48	15
Sb	22	2.3	1.5	0.2	15	3.2
Sc	21	3.9	3.2	1.9	8.9	1.8
Se	22	1.3	1.2	0.7	2.1	0.4
Sr	21	35	31	13	130	26
Th	20	2.5	1.8	1.0	8.3	1.7
U	21	1.3	1.4	0.35L	3.5	0.73
V	22	25	20	10	85	17
Y	19	6.8	6.4	3.3	18	3.5
Yb	21	0.70	0.60	0.27	1.6	0.39
Zn	22	250	36	8.2	3,300	710
Zr	21	49	29	13	270	61

Table 3. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for the Baker coal in western Kentucky.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
			Percent			
Ash	15	13.1	13.0	7.7	20.0	3.2
Si	34	2.2	1.9	1.3	6.6	1.0
Al	34	1.3	1.1	0.63	4.4	0.7
Ca	34	0.47	0.27	0.044	1.6	0.45
Mg	34	0.063	0.049	0.019	0.19	0.04
Na	33	0.041	0.039	0.0047	0.12	0.025
K	34	0.21	0.17	0.065	0.87	0.16
Fe	34	2.6	2.5	0.65	5.7	1.3
Ti	34	0.061	0.051	0.033	0.18	0.03
			Parts per million			
As	17	27	22	4.6	70	19
B	15	77	75	52	110	15
Ba	15	87	43	17	400	120
Be	17	2.2	2.1	1.6	3.7	0.52
Cd	17	0.19	0.12	0.02	0.55	0.16
Co	33	5.2	4.0	2.0	17	3.3
Cr	33	19	17	9.5	50	7.4
Cu	15	16	14	8.8	46	9.2
F	15	94	60	10L	300	86
Ge	15	18	14	4.6	52	13
Hg	17	0.13	0.07	0.02L	0.32	0.11
La	15	7.4	6.3	2.0	22	5.4
Li	15	12	11	2.9	24	7.1
Mn	33	62	36	5.8	240	53
Mo	7	4.6	3.6	1.8	10	2.8
Nb	15	2.0	2.0	0.77	3.6	0.77
Ni	33	36	31	4.6	120	25
P	31	170	100	22L	740	180
Pb	17	20	15	4.7	70	18
Sb	17	1.5	1.4	0.2	3.7	1.0
Sc	15	4.4	4.2	2.7	7.1	1.0
Se	17	1.8	1.9	0.8	3.0	0.8
Sr	15	65	38	15	200	57
Th	17	2.0	1.9	1.0	3.3	0.72
U	17	2.5	2.1	0.94	7.0	1.5
V	15	26	25	14	70	13
Y	15	7.9	6.5	3.5	18	4.3
Yb	15	0.99	0.8	0.58	2.8	0.57
Zn	15	56	39	13	130	39
Zr	15	25	24	7.7	39	8.4

Table 4. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for the Danville-Baker Coals in the Illinois Basin.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. L, less than value shown. G, greater than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated.]

	Number of samples	Mean	Median	Range Minimum	Range Maximum	Standard deviation
Percent						
Ash	34	14.8	13.0	6.7	47.0	8.3
Si	56	2.7	2.1	1.3	13	1.9
Al	56	1.4	1.1	0.55	5.8	0.95
Ca	56	0.43	0.27	0.029	1.6	0.41
Mg	56	0.083	0.061	0.019	0.47	0.076
Na	55	0.055	0.044	0.0047	0.24	0.046
K	56	0.27	0.19	0.065	1.4	0.25
Fe	56	2.4	2.2	0.2.0	7.5	1.4
Ti	56	0.072	0.055	0.033	0.37	0.053
Parts per million						
As	39	19	14	0.50	70	16
B	37	97	93	31	190G	36
Ba	36	75	45	17	400	90
Be	39	2.7	2.4	1.2	6.0	1.1
Cd	39	0.31	0.12	0.01L	4.5	0.74
Co	55	5.6	5.3	2.0	17	3.0
Cr	55	19	17	9.5	50	8.2
Cu	37	12	11	5.5	46	7.1
F	37	100	60	10L	450	110
Ge	37	14	14	1.1L	52	9.7
Hg	39	0.11	0.09	0.01L	0.32	0.09
La	36	8.2	6.4	2.0	26	5.6
Li	36	16	11	2.9	89	16
Mn	55	59	39	5.8	240	51
Mo	28	3.1	2.5	0.16L	10	2.4
Nb	34	2.5	2.0	0.61L	12	2.0
Ni	55	31	30	4.6	120	22
P	34	160	96	15L	740	180
Pb	39	18	14	1.5L	70	16
Sb	39	1.9	1.4	0.2	15	2.5
Sc	36	4.1	3.8	1.9	8.9	1.6
Se	39	1.5	1.3	0.7	3.0	0.7
Sr	36	48	33	13	200	44
Th	37	2.2	1.8	1.0	8.3	1.4
U	38	1.9	1.4	0.35L	7.0	1.3
V	37	25	21	10	85	16
Y	34	7.3	6.5	3.3	18	3.8
Yb	36	0.82	0.7	0.27	2.8	0.49
Zn	37	170	37	8.2	3,300	550
Zr	36	39	28	7.7	270	48

Table 5. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for the Herrin Coal in the Illinois Basin.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated.]

	Number of samples	Mean	Median	Range: Minimum	Range: Maximum	Standard deviation
Percent						
Ash	97	11.7	11.0	2.8	46.0	5.9
Si	269	2.3	1.9	0.46	9.3	1.2
Al	269	1.1	1.0	0.29	4.2	0.54
Ca	269	0.55	0.42	0.02	11	0.77
Mg	270	0.055	0.045	0.0044L	0.31	0.04
Na	270	0.071	0.054	0.0019	0.42	0.059
K	269	0.17	0.15	0.003L	0.75	0.098
Fe	269	1.8	1.6	0.096	11	1.2
Ti	269	0.06	0.054	0.004L	0.20	0.029
Parts per million						
As	216	5.8	3.0	0.2L	140	12
B	207	110	97	22	390	54
Ba	201	120	36	5.5	2,000	300
Be	226	1.6	1.3	0.36	8.5	1.1
Cd	209	1.3	0.14	0.02L	54	5.5
Co	267	4.0	3.2	0.78	17	2.4
Cr	268	19	15	2.8	190	21
Cu	209	10	9.0	2.7	58	6.7
F	199	66	51	10L	570	65
Ge	196	6.4	3.3	0.045L	63	8.5
Hg	206	0.12	0.10	0.01L	0.70	0.09
La	176	5.3	4.5	0.84L	28	3.8
Li	158	12	7.6	0.94L	80	13
Mn	256	58	39	1.6	1,200	85
Mo	206	8.4	5.2	0.42L	190	15
Nb	97	1.7	1.4	0.28L	10	1.4
Ni	275	17	13	1.0	190	17
P	182	110	46	2.8L	2,200	210
Pb	226	18	5.4	0.019L	350	36
Sb	216	0.8	0.4	0.1	7.6	1.0
Sc	190	2.5	2.3	0.38	16	1.4
Se	214	2.1	1.7	0.4L	13	1.5
Sr	201	33	24	2.7L	980	73
Th	196	2.1	1.6	0.35L	17	1.8
U	203	2.0	0.92	0.15L	26	3.5
V	213	22	18	1.2	110	15
Y	97	5.2	4.5	1.1	27	3.7
Yb	178	0.5	0.45	0.065L	3.2	0.28
Zn	209	200	39	3.7	4,500	600
Zr	203	25	19	0.51L	110	19

Table 6. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for the Springfield Coal in the Illinois Basin.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
			Percent			
Ash	80	12.1	10.0	5.5	46.0	6.7
Si	249	1.9	1.9	0.018	9.0	0.73
Al	249	0.94	0.88	0.17	5.8	0.45
Ca	249	0.5	0.4.0	0.015	3.9	0.46
Mg	249	0.047	0.04	0.0047L	0.31	0.03
Na	262	0.033	0.027	0.0018	0.2	0.026
K	267	0.16	0.15	0.004	1.3	0.11
Fe	249	2.0	1.8	0.25	27	1.9
Ti	249	0.052	0.049	0.022	0.26	0.021
			Parts per million			
As	145	12	5.9	0.27	130	18
B	108	85	81.5	5.7L	210	35
Ba	95	73	26	8.3	2,500	280
Be	124	1.9	1.7	0.44	6.0	0.9.0
Cd	122	0.61	0.20	0.02L	9.0	1.1
Co	244	3.6	3.3	0.90	12	1.7
Cr	245	16	13	3.1	86	9.8
Cu	109	10	7.4	3.5	77	11
F	109	71	50	10L	600	77
Ge	105	8.0	7.2	0.43L	38	5.1
Hg	123	0.12	0.09	0.01L	1.2	0.13
La	104	5.9	5.0	1.8	31	4.0
Li	90	8.9	5.8	2.3L	89	11
Mn	247	43	34	0.58	210	34
Mo	101	7.3	5.4	0.76L	46	7.1
Nb	79	1.8	1.6	0.26L	4.6	0.94
Ni	250	12	10	1.8	41	6.6
P	183	54	39	4.2L	740	75
Pb	124	13	5.7	0.49L	110	20
Sb	144	1.1	0.8	0.1	13	1.2
Sc	87	2.4	2.1	0.47	12	1.5
Se	127	2.5	2.0	0.9L	13	1.8
Sr	95	26	18	3.4	160	25
Th	101	1.7	1.3	0.30	10	1.3
U	110	2.6	1.6	0.17L	15	2.7
V	108	28	19	3.2	130	24
Y	80	5.3	4.8	1.2	13	2.2
Yb	85	0.53	0.48	0.19L	1.9	0.27
Zn	127	110	33	6.5	3,300	310
Zr	107	23	17	1.8L	130	18

Table 7. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for all nonassessed coals in the Illinois Basin.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
			Percent			
Ash	260	12.4	10.0	1.5	48.0	8.5
Si	437	2.3	1.8	0.019	13	2.0
Al	437	1.3	1.0	0.11	7.8	1.1
Ca	435	0.23	0.065	0.0093	3.5	0.39
Mg	446	0.065	0.04	0.002L	4.6	0.22
Na	417	0.034	0.019	0.001L	0.28	0.042
K	436	0.21	0.14	0.007	1.3	0.21
Fe	437	2.2	1.9	0.0093	25	2.1
Ti	437	0.068	0.054	0.002	0.46	0.058
			Parts per million			
As	298	23	11	0.30L	950	60
B	259	81	77	12	210	38
Ba	260	44	24	1.9	560	60
Be	302	3.4	3.3	0.25	9.2	1.4
Cd	298	0.35	0.11	0.01L	6.2	0.81
Co	402	7.8	5.5	0.20	110	9.4
Cr	411	17	15	3.0L	86	12
Cu	260	17	13	2.1L	140	16
F	260	82	56	10L	780	84
Ge	258	13	12	0.31L	59	9.3
Hg	290	0.12	0.07	0.01L	2.4	0.18
La	253	9.6	6.7	0.97	72	10
Li	260	17	8.9	0.67L	210	25
Mn	403	35	22	1.0	360	42
Mo	234	3.5	1.9	0.16L	56	6.0
Nb	256	2.3	1.7	0.051L	14	2.1
Ni	411	31	25	3.3	190	25
P	236	140	69	5.6L	6,700	450
Pb	298	23	16	0.37L	230	26
Sb	298	1.4	1.0	0.1L	13	1.6
Sc	260	3.9	3.3	0.39	18	2.6
Se	298	3.4	2.8	0.5L	14	2.2
Sr	260	54	26	1.3	490	72
Th	290	2.2	1.6	0.15L	18	2.1
U	302	2.2	1.3	0.055L	17	2.3
V	260	23	17	0.60	98	20
Y	255	8.4	6.7	0.96L	64	6.9
Yb	249	0.91	0.7	0.15L	8.1	0.77
Zn	260	80	30	1.8	2,600	230
Zr	260	25	16	0.83L	210	26

Table 8. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for all nonassessed coals from the McLeansboro Group in the Illinois Basin.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Percent						
Ash	25	13.6	14.0	8.1	26.0	3.9
Si	82	2.9	3.0	0.028	5.9	1.2
Al	82	1.5	1.5	0.67	2.8	0.45
Ca	82	0.27	0.15	0.037	2.4	0.34
Mg	82	0.073	0.07	0.015	0.29	0.042
Na	74	0.038	0.022	0.006	0.17	0.035
K	82	0.29	0.29	0.065	0.81	0.13
Fe	82	2.3	2.1	0.0093	6.4	1.2
Ti	82	0.081	0.082	0.031	0.14	0.025
Parts per million						
As	44	9.5	3.5	0.30L	65	13
B	25	86	84	55	130	18
Ba	25	40	35	8.9	98	22
Be	48	2.2	2.0	1.1	5.5	0.96
Cd	44	0.14	0.09	0.03	0.65	0.13
Co	76	5.3	4.2	1.6	19	3.2
Cr	81	20	18	7.8	40	7.2
Cu	25	14	10	6.7	50	9.6
F	25	97	86	33	260	49
Ge	25	4.8	4.0	1.7	14	3.1
Hg	43	0.09	0.05	0.01L	0.33	0.09
La	25	8.1	7.0	2.8	21	4.8
Li	25	14	11	6.6	39	7.5
Mn	81	56	41	7.5	360	64
Mo	25	3.1	2.0	0.42	14	3.2
Nb	25	1.8	1.7	0.52	5.4	1.1
Ni	81	20	15	3.6	75	14
P	64	160	110	10L	1,300	180
Pb	44	7.7	5.2	2.2	49	7.6
Sb	44	0.7	0.3	0.1	3.6	1.0
Sc	25	3.3	3.0	1.9	7.9	1.1
Se	44	2.1	2.1	0.7	3.5	0.6
Sr	25	44	33	14	150	33
Th	44	2.1	2.0	1.0	5.1	0.76
U	48	1.6	0.98	0.35	7.4	1.3
V	25	21	17	9.8	57	10
Y	25	6.0	5.8	2.0	20	3.8
Yb	25	0.70	0.64	0.32	1.4	0.28
Zn	25	39	32	13	140	30
Zr	25	16	14	5.5	41	9.3

Table 9. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for all nonassessed coals from the Carbondale Group or Formation in the Illinois Basin.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. L, less than value shown. G, greater than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Percent						
Ash	86	14.3	12.0	5.4	48.0	7.6
Si	128	2.6	2.2	0.34	12	1.7
Al	128	1.4	1.2	0.15	6.4	0.88
Ca	127	0.4	0.18	0.023	3.5	0.56
Mg	128	0.11	0.055	0.009	4.6	0.40
Na	124	0.043	0.033	0.0028	0.22	0.035
K	128	0.25	0.19	0.027	1.2	0.20
Fe	128	2.8	2.5	0.32	25	2.6
Ti	128	0.071	0.063	0.005	0.33	0.045
Parts per million						
As	90	34	14	0.50L	950	100
B	86	89	88	13	190G	36
Ba	86	41	30	7.5	170	33
Be	90	3.5	3.3	1.2	7.3	1.3
Cd	90	0.45	0.11	0.01L	6.2	1.0
Co	121	7.1	5.4	1.1	110	11
Cr	121	20	17	4.1	86	12
Cu	86	16	14	4.4	96	12
F	86	98	60	10L	780	110
Ge	86	14	13	0.31L	59	11
Hg	90	0.14	0.08	0.01L	2.4	0.26
La	84	7.5	5.4	1.0	55	7.1
Li	86	16	9.4	0.76	210	24
Mn	120	51	37	1.1	220	42
Mo	67	6.2	3.0	0.46L	56	9.7
Nb	86	2.6	2.4	0.39L	8.6	1.5
Ni	121	28	24	3.3	190	23
P	74	210	83	20L	6,700	770
Pb	90	27	17	0.46L	230	35
Sb	90	1.5	1.0	0.1L	7.1	1.6
Sc	86	4.2	3.5	0.70	18	2.6
Se	90	3.3	2.7	0.5L	12	2.1
Sr	86	43	25	8.4	300	45
Th	88	2.1	1.7	0.20L	15	1.8
U	90	3.3	2.1	0.44L	13	2.9
V	86	26	23	3.8	84	17
Y	86	8.9	7.0	0.96L	64	7.7
Yb	83	1.1	0.80	0.20L	8.1	1.1
Zn	86	69	25	1.8	1,100	150
Zr	86	28	24	3.9	140	21

Table 10. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for all nonassessed coals from the Raccoon Creek Group in the Illinois Basin.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated.]

	Number of samples	Mean	Median	Range: Minimum	Range: Maximum	Standard deviation
Percent						
Ash	149	11.2	8.1	1.5	48.0	9.3
Si	227	2.0	1.2	0.019	13	2.3
Al	227	1.2	0.75	0.11	7.8	1.3
Ca	226	0.11	0.046	0.0093	1.2	0.20
Mg	236	0.04	0.023	0.002L	0.35	0.049
Na	219	0.028	0.011	0.001L	0.28	0.047
K	226	0.16	0.081	0.007	1.3	0.22
Fe	227	1.9	1.5	0.068	24	2.0
Ti	227	0.061	0.04	0.002	0.46	0.071
Parts per million						
As	164	20	11	0.40	180	28
B	148	75	70	12	210	41
Ba	149	46	16	1.9	560	74
Be	164	3.7	3.5	0.25	9.2	1.4
Cd	164	0.35	0.12	0.01L	4.7	0.79
Co	205	9.2	7.0	0.20	110	10
Cr	209	15	11	3.0L	65	13
Cu	149	19	14	2.1L	140	19
F	149	70	49	10L	420	71
Ge	147	14	13	0.82L	39	8.5
Hg	157	0.12	0.07	0.01L	1.2	0.14
La	144	11	7.9	0.97	72	12
Li	149	18	8.0	0.67L	140	27
Mn	202	17	11	1.0	94	16
Mo	142	2.4	1.6	0.16L	25	3.0
Nb	145	2.2	1.4	0.051L	14	2.4
Ni	209	38	30	4.4	170	27
P	98	79	42	5.6L	520	97
Pb	164	24	19	0.37L	190	22
Sb	164	1.5	1.1	0.1L	13	1.7
Sc	149	3.8	3.1	0.39	13	2.7
Se	164	3.7	3.3	0.6L	14	2.4
Sr	149	61	27	1.3	490	87
Th	158	2.2	1.4	0.15L	18	2.5
U	164	1.8	1.2	0.055L	17	2.0
V	149	22	14	0.60	98	22
Y	144	8.6	6.6	1.5	41	6.7
Yb	141	0.84	0.70	0.15L	4.1	0.60
Zn	149	94	31	5.5	2,600	280
Zr	149	24	13	0.83	210	30

Table 11. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for all coals (assessed and nonassessed) in the Illinois Basin.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Percent						
Ash	471	12.4	10.0	1.5	48.0	7.7
Si	1011	2.2	1.9	0.018	13	1.6
Al	1011	1.2	0.96	0.11	7.8	0.85
Ca	1009	0.39	0.24	0.0093	11	0.55
Mg	1021	0.059	0.042	0.002L	4.6	0.15
Na	1004	0.045	0.03	0.001L	0.42	0.047
K	1028	0.19	0.15	0.003L	1.4	0.17
Fe	1011	2.1	1.8	0.0093L	27	1.8
Ti	1011	0.062	0.052	0.002L	0.46	0.044
Parts per million						
As	698	15	5.9	0.20L	950	41
B	611	91	84	5.7L	390	45
Ba	592	76	31	1.9	2,500	220
Be	691	2.5	2.2	0.25L	9.2	1.5
Cd	668	0.71	0.13	0.01L	54	3.2
Co	968	5.6	3.9	0.20	110	6.6
Cr	979	17	14	2.8L	190	14
Cu	615	14	10	2.1L	140	13
F	605	76	54	10L	780	79
Ge	596	10	7.5	0.045L	63	9.0
Hg	658	0.12	0.08	0.01L	2.4	0.15
La	569	7.5	5.2	0.84L	72	7.7
Li	544	14	8.1	0.67L	210	20
Mn	961	45	29	0.58	1,200	57
Mo	569	5.9	3.3	0.16L	190	10
Nb	466	2.1	1.7	0.051L	14	1.8
Ni	991	22	15	1.0	190	21
P	635	110	49	2.8L	6,700	300
Pb	687	19	9.8	0.019L	350	29
Sb	697	1.2	0.7	0.1L	15	1.5
Sc	573	3.2	2.6	0.38	18	2.2
Se	678	2.7	2.1	0.4L	14	2.0
Sr	592	42	24	1.3L	980	66
Th	624	2.1	1.5	0.15L	18	1.9
U	653	2.2	1.3	0.055L	26	2.8
V	618	24	18	0.60	130	19
Y	466	7.1	5.8	0.96L	64	5.7
Yb	548	0.71	0.58	0.065L	8.1	0.6
Zn	633	130	33	1.8	4,500	420
Zr	606	25	18	0.51L	270	25

Appendix 4. Summary descriptive statistics of ash yields and contents of selected elements for all assessed and non-assessed coals in the Illinois Basin as analyzed by the Illinois State Geological Survey, Indiana Geological Survey, Kentucky Geological Survey, and U.S. Geological Survey.

Table 1. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for the Danville Coal Member in Illinois as analyzed by the Illinois State Geological Survey.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. Leaders (---) indicate statistics could not be calculated owing to no data or to an insufficient number of analyses above the lower detection limit.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Percent						
Ash	170	12.2	11.0	4.3	44.2	4.4
Si	3	1.9	1.9	1.7	2.0	0.15
Al	3	0.82	0.91	0.55	1.0	0.24
Ca	3	0.78	0.73	0.72	0.88	0.09
Mg	3	0.10	0.10	0.044	0.16	0.058
Na	3	0.073	0.072	0.072	0.075	0.0017
K	3	0.16	0.16	0.15	0.18	0.015
Fe	3	1.7	1.7	1.3	2.0	0.35
Ti	3	0.047	0.046	0.044	0.052	0.0042
Parts per million						
As	3	4.6	5.1	2.8	6.0	1.7
B	3	110	95	90	130	22
Ba	---	---	---	---	---	---
Be	3	1.3	1.3	1.2	1.5	0.15
Cd	---	---	---	---	---	---
Co	3	3.6	3.5	2.5	4.8	1.2
Cr	3	12	10	10	16	3.5
Cu	3	6.8	7.0	5.5	7.8	1.2
F	3	39	39	36	41	2.5
Ge	3	6.7	6.6	4.8	8.7	2.0
Hg	3	0.09	0.09	0.07	0.11	0.02
La	---	---	---	---	---	---
Li	---	---	---	---	---	---
Mn	3	73	73	67	80	6.5
Mo	3	6.1	4.4	3.9	10	3.4
Nb	---	---	---	---	---	---
Ni	3	7.9	6.1	5.5	12	3.6
P	---	---	---	---	---	---
Pb	---	---	---	---	---	---
Sb	3	1.1	1.4	0.4	1.5	0.6
Sc	---	---	---	---	---	---
Se	3	1.3	1.0	0.8	2.1	0.7
Sr	---	---	---	---	---	---
Th	---	---	---	---	---	---
U	---	---	---	---	---	---
V	3	14	11	10	22	6.7
Y	---	---	---	---	---	---
Yb	---	---	---	---	---	---
Zn	3	17	8.7	8.2	33	14
Zr	---	---	---	---	---	---

Table 2. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for the Danville Coal Member in Indiana as analyzed by the U.S. Geological Survey.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. L, less than value shown. G, greater than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated. Leaders (---) indicate statistics could not be calculated owing to no data or to an insufficient number of analyses above the lower detection limit.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Percent						
Ash	19	16.2	13.0	6.7	47.0	11
Si	19	3.5	2.5	1.4	13	2.8
Al	19	1.7	1.1	0.68	5.8	1.3
Ca	19	0.3	0.21	0.029	1.2	0.32
Mg	19	0.12	0.072	0.029	0.47	0.11
Na	19	0.075	0.051	0.013	0.24	0.066
K	19	0.38	0.23	0.11	1.4	0.35
Fe	19	2.0	1.7	0.20	7.5	1.6
Ti	19	0.096	0.064	0.044	0.37	0.077
Parts per million						
As	19	13	12	0.50	43	11
B	19	110	110	31	190G	43
Ba	19	67	44	20	290	65
Be	19	3.5	3.2	2.0	6.0	1.1
Cd	19	0.44	0.12	0.01L	4.5	1.1
Co	19	6.7	6.7	3.0	12	2.4
Cr	19	20	17	9.5	46	9.7
Cu	19	11	10	6.6	24	4.0
F	19	120	72	22	450	120
Ge	19	13	15	1.1L	19	5.5
Hg	19	0.10	0.09	0.01	0.32	0.08
La	19	8.9	6.5	3.0	26	6.0
Li	19	20	12	5.5	89	21
Mn	19	52	36	10	230	51
Mo	18	2.0	2.2	0.16L	4.5	1.2
Nb	19	2.9	2.1	0.61L	12	2.5
Ni	19	26	30	5.6	48	14
P	---	---	---	---	---	---
Pb	19	19	14	1.5	48	15
Sb	19	2.4	1.5	0.2	15	3.5
Sc	19	4.0	3.3	2.1	8.9	1.9
Se	19	1.3	1.2	0.7	2.0	0.4
Sr	19	36	31	13	130	27
Th	18	2.6	1.8	1.0	8.3	1.8
U	19	1.4	1.4	0.35	3.5	0.73
V	19	26	21	11	85	18
Y	19	6.8	6.4	3.3	18	3.5
Yb	19	0.73	0.6	0.30	1.6	0.39
Zn	19	280	44	9.2	3,300	760
Zr	19	52	30	13	270	63

Table 3. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for the Baker coal in Kentucky as analyzed by the Kentucky Geological Survey.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. Leaders (---) indicate statistics could not be calculated owing to no data or to an insufficient number of analyses above the lower detection limit.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Percent						
Ash	19	13.2	11.6	6.5	27.6	5.4
Si	19	2.3	1.9	1.3	6.6	1.3
Al	19	1.4	1.1	0.70	4.4	0.88
Ca	19	0.39	0.21	0.075	1.4	0.38
Mg	19	0.062	0.04	0.019	0.19	0.049
Na	18	0.041	0.037	0.0047	0.12	0.026
K	19	0.22	0.15	0.065	0.87	0.20
Fe	19	2.5	2.4	0.68	5.7	1.4
Ti	19	0.062	0.049	0.034	0.18	0.036
Parts per million						
As	---	---	---	---	---	---
B	---	---	---	---	---	---
Ba	---	---	---	---	---	---
Be	---	---	---	---	---	---
Cd	---	---	---	---	---	---
Co	18	3.8	3.3	2.0	7.7	1.7
Cr	18	21	20	11	50	8.7
Cu	---	---	---	---	---	---
F	---	---	---	---	---	---
Ge	---	---	---	---	---	---
Hg	---	---	---	---	---	---
La	---	---	---	---	---	---
Li	---	---	---	---	---	---
Mn	18	56	34	5.8	140	45
Mo	---	---	---	---	---	---
Nb	---	---	---	---	---	---
Ni	18	44	43	4.6	120	29
P	19	210	130	27	740	210
Pb	---	---	---	---	---	---
Sb	---	---	---	---	---	---
Sc	---	---	---	---	---	---
Se	---	---	---	---	---	---
Sr	---	---	---	---	---	---
Th	---	---	---	---	---	---
U	---	---	---	---	---	---
V	---	---	---	---	---	---
Y	---	---	---	---	---	---
Yb	---	---	---	---	---	---
Zn	---	---	---	---	---	---
Zr	---	---	---	---	---	---

Table 4. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for the Baker coal in Kentucky as analyzed by the U.S. Geological Survey.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated.]

	Number of Samples	Mean	Median	Range Minimum	Range Maximum	Standard deviation
			Percent			
Ash	15	13.1	13.0	7.7	20.0	3.2
Si	15	2.1	2.1	1.3	4.1	0.68
Al	15	1.2	1.1	0.63	2.2	0.40
Ca	15	0.56	0.33	0.044	1.6	0.53
Mg	15	0.064	0.053	0.03	0.11	0.026
Na	15	0.042	0.044	0.008	0.11	0.026
K	15	0.20	0.18	0.082	0.45	0.085
Fe	15	2.8	2.9	0.65	5.4	1.3
Ti	15	0.059	0.057	0.033	0.12	0.022
			Parts per million			
As	15	28	22	4.6	70	19
B	15	77	75	52	110	15
Ba	15	87	43	17	400	120
Be	15	2.2	2.1	1.7	3.7	0.53
Cd	15	0.19	0.12	0.02	0.55	0.17
Co	15	6.9	5.6	2.1	17	3.9
Cr	15	16	16	9.5	26	4.4
Cu	15	16	14	8.8	46	9.2
F	15	94	60	10L	300	86
Ge	15	18	14	4.6	52	13
Hg	15	0.14	0.10	0.02L	0.32	0.11
La	15	7.4	6.3	2.0	22	5.4
Li	15	12	11	2.9	24	7.1
Mn	15	69	48	12	240	61
Mo	7	4.6	3.6	1.8	10	2.8
Nb	15	2.0	2.0	0.77	3.6	0.77
Ni	15	26	25	5.1	58	15
P	12	110	81	22L	320	95
Pb	15	21	15	4.7	70	18
Sb	15	1.5	1.4	0.2	3.7	1.1
Sc	15	4.4	4.2	2.7	7.1	1.0
Se	15	1.8	1.9	0.8	3.0	0.8
Sr	15	65	38	15	200	57
Th	15	2.0	1.9	1.0	3.3	0.71
U	15	2.6	2.1	0.94	7.0	1.6
V	15	26	25	14	70	13
Y	15	7.9	6.5	3.5	18	4.3
Yb	15	0.99	0.80	0.58	2.8	0.57
Zn	15	56	39	13	130	39
Zr	15	25	24	7.7	39	8.4

Table 5. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for the Herrin Coal Member in Illinois as analyzed by the Illinois State Geological Survey.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated. Leaders (---) indicate statistics could not be calculated owing to no data or to an insufficient number of analyses above the lower detection limit.]

	Number of samples	Mean	Median	Range Minimum	Range Maximum	Standard deviation
			Percent			
Ash	2,327	10.9	10.4	2.7	43.6	3.6
Si	108	2.4	2.2	0.46	9.3	1.3
Al	108	1.2	1.1	0.33	3.1	0.50
Ca	108	0.7	0.61	0.045	2.5	0.47
Mg	108	0.063	0.052	0.0044L	0.31	0.05
Na	114	0.083	0.081	0.009	0.42	0.069
K	108	0.17	0.15	0.017	0.75	0.11
Fe	108	1.6	1.5	0.28	3.8	0.70
Ti	108	0.06	0.054	0.0089	0.18	0.028
			Parts per million			
As	107	5.7	3.4	0.36	140	14
B	110	110	99	33	280	47
Ba	104	90	47	5.5	1,300	160
Be	116	1.3	1.2	0.36L	3.3	0.55
Cd	100	1.6	0.17	0.04L	54	6.7
Co	107	4.7	4.0	1.0	17	2.9
Cr	107	18	15	5.5	54	9.0
Cu	112	11	10	3.3	58	6.3
F	102	64	49	13	570	71
Ge	114	4.4	2.5	0.045L	23	4.4
Hg	100	0.15	0.12	0.03	0.47	0.09
La	93	5.3	4.5	0.84	28	3.4
Li	61	16	13	1.7	80	15
Mn	100	78	61	11	270	56
Mo	116	8.5	6.5	0.42L	45	7.5
Nb	---	---	---	---	---	---
Ni	114	16	14	1.8	84	10
P	108	73	44	4.1L	740	100
Pb	116	21	11	0.32L	170	28
Sb	107	0.7	0.5	0.1	3.5	0.7
Sc	93	2.4	2.3	0.89	5.8	0.92
Se	107	2.1	1.8	0.8	6.6	1.0
Sr	104	29	25	4.2L	220	25
Th	95	1.9	1.6	0.46	5.7	0.95
U	93	1.7	0.98	0.20L	26	3.1
V	116	23	20	3.0	110	15
Y	---	---	---	---	---	---
Yb	93	0.48	0.45	0.065L	1.4	0.19
Zn	112	260	51	4.2	4,500	720
Zr	106	28	21	2.8	110	20

Table 6. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for the Herrin Coal Member in Illinois as analyzed by the U.S. Geological Survey.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated. Leaders (---) indicate statistics could not be calculated owing to no data or to an insufficient number of analyses above the lower detection limit.]

	Number of Samples	Mean	Median	Range Minimum	Range Maximum	Standard deviation
Percent						
Ash	77	12.2	11.0	2.8	46.0	6.0
Si	76	2.2	1.9	0.46	7.0	1.3
Al	76	1.0	0.90	0.29	3.4	0.6
Ca	76	0.63	0.38	0.02	11	1.3
Mg	77	0.057	0.047	0.012	0.18	0.037
Na	77	0.094	0.088	0.029	0.36	0.049
K	76	0.17	0.14	0.003L	0.59	0.11
Fe	76	1.7	1.3	0.096	11	1.6
Ti	76	0.06	0.05	0.004L	0.19	0.034
Parts per million						
As	77	5.3	2.8	0.20L	44	7.6
B	77	120	110	22	390	62
Ba	77	180	33	6.2	2,000	440
Be	77	1.8	1.3	0.40	8.5	1.5
Cd	77	1.5	0.14	0.02L	30	4.9
Co	77	3.2	2.4	0.78	11	2.2
Cr	77	18	12	2.8L	190	27
Cu	77	9.9	8.2	2.7	30	6.0
F	77	69	60	10L	420	59
Ge	62	9.4	5.1	0.085L	47	11
Hg	77	0.09	0.07	0.03	0.39	0.06
La	63	5.1	4.2	1.0L	26	3.8
Li	77	9.7	6.7	0.94	69	12
Mn	77	62	43	8.4	1,200	140
Mo	77	6.4	3.3	0.56	43	8.0
Nb	77	1.7	1.4	0.28L	10	1.5
Ni	77	14	9.4	1.0	67	13
P	---	---	---	---	---	---
Pb	77	19	4.3	0.64L	350	49
Sb	77	0.9	0.3	0.1	7.6	1.4
Sc	77	2.5	2.1	0.38	6.2	1.2
Se	77	2.2	1.7	0.4L	13	1.8
Sr	77	30	25	8.3	290	32
Th	69	2.8	2.1	0.35L	17	2.6
U	77	1.9	0.75	0.15L	20	3.8
V	77	20	17	1.2	86	16
Y	77	5.5	5.0	1.1	27	3.6
Yb	65	0.50	0.50	0.20L	1.3	0.22
Zn	77	160	26	3.7	2,600	460
Zr	77	23	17	0.51L	110	18

Table 7. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for the Herrin coal in Kentucky as analyzed by the Kentucky Geological Survey.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. Leaders (---) indicate statistics could not be calculated owing to no data or to an insufficient number of analyses above the lower detection limit.]

	Number of samples	Mean	Median	Range Minimum	Range Maximum	Standard deviation
			Percent			
Ash	121	10.5	9.8	5.3	24.1	3.6
Si	65	2.2	2.0	0.95	4.9	0.89
Al	65	1.1	1.1	0.51	2.2	0.39
Ca	65	0.30	0.21	0.028	1.2	0.27
Mg	65	0.044	0.039	0.019	0.12	0.021
Na	59	0.033	0.026	0.0019	0.10	0.022
K	65	0.18	0.16	0.094	0.38	0.066
Fe	65	2.3	2.1	0.40	5.1	1.0
Ti	65	0.061	0.056	0.032	0.14	0.022
			Parts per million			
As	12	6.2	2.0	0.92	52	14
B	---	---	---	---	---	---
Ba	---	---	---	---	---	---
Be	13	1.7	1.7	0.46	2.5	0.59
Cd	12	0.24	0.10	0.04	1.2	0.35
Co	63	4.0	3.6	1.4	9.2	1.7
Cr	64	19	18	9.9	61	7.9
Cu	---	---	---	---	---	---
F	---	---	---	---	---	---
Ge	---	---	---	---	---	---
Hg	9	0.02	0.01	0.01	0.12	0.04
La	---	---	---	---	---	---
Li	---	---	---	---	---	---
Mn	59	30	27	1.6	100	20
Mo	---	---	---	---	---	---
Nb	---	---	---	---	---	---
Ni	64	21	17	2.9	80	16
P	65	180	94	2.8	2,200	310
Pb	13	3.1	2.0	0.019	9.3	2.5
Sb	12	0.2	0.1	0.1	0.8	0.2
Sc	---	---	---	---	---	---
Se	10	1.3	1.3	1.0	2.0	0.3
Sr	---	---	---	---	---	---
Th	12	1.2	1.2	0.95	1.5	0.18
U	13	1.9	1.8	0.83	3.8	1.0
V	---	---	---	---	---	---
Y	---	---	---	---	---	---
Yb	---	---	---	---	---	---
Zn	---	---	---	---	---	---
Zr	---	---	---	---	---	---

Table 8. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for the Herrin coal in Kentucky as analyzed by the U.S. Geological Survey.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. L, less than value shown. G, greater than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
			Percent			
Ash	20	10.0	7.9	5.9	26.0	5.2
Si	20	1.9	1.5	1.0	6.2	1.3
Al	20	0.97	0.75	0.56	4.2	0.79
Ca	20	0.22	0.17	0.025	0.84	0.22
Mg	20	0.036	0.03	0.02	0.11	0.021
Na	20	0.025	0.023	0.005	0.055	0.017
K	20	0.15	0.13	0.10	0.29	0.052
Fe	20	1.8	1.5	0.43	4.2	1.0
Ti	20	0.058	0.046	0.032	0.20	0.037
			Parts per million			
As	20	8.6	3.0	1.3	55	13
B	20	60	57	38	94	17
Ba	20	33	18	7.5	190	43
Be	20	2.0	1.5	0.39	7.9	1.7
Cd	20	0.20	0.08	0.03	1.2	0.30
Co	20	3.6	3.0	2.1	8.8	1.7
Cr	20	29	14	10	190	47
Cu	20	9.5	7.0	3.5	53	10
F	20	62	48	10L	290	58
Ge	20	8.9	5.0	0.60	63	14
Hg	20	0.14	0.08	0.03L	0.70	0.15
La	20	5.4	3.6	1.7	27	5.6
Li	20	6.8	4.7	2.6	42	8.6
Mn	20	26	21	9.4	95	21
Mo	13	19	4.4	0.55	190G	51
Nb	20	1.5	1.4	0.31	4.5	1.1
Ni	20	20	7.7	2.4	190	43
P	9	97	22	22L	440	140
Pb	20	6.1	3.3	0.84	36	8.0
Sb	20	0.6	0.2	0.1	5.7	1.2
Sc	20	3.3	2.4	2.1	16	3.0
Se	20	2.6	1.7	0.8L	11	2.7
Sr	20	68	14	2.7	980	220
Th	20	1.8	1.2	1.1	10	2.0
U	20	3.3	1.7	0.37	22	5.4
V	20	20	13	5.1	82	19
Y	20	4.3	3.4	1.1	19	3.8
Yb	20	0.61	0.43	0.35	3.2	0.62
Zn	20	31	23	8.8	170	36
Zr	20	17	12	3.7	67	15

Table 9. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for the Springfield Coal Member in Illinois as analyzed by the Illinois State Geological Survey.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated. Leaders (---) indicate statistics could not be calculated owing to no data or to an insufficient number of analyses above the lower detection limit.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
			Percent			
Ash	1,171	11.7	10.7	2.8	43.5	4.6
Si	28	2.2	2.1	1.6	3.6	0.45
Al	28	1.0	0.95	0.59	2.5	0.41
Ca	28	0.77	0.69	0.22	2.1	0.47
Mg	28	0.04	0.036	0.0047L	0.16	0.031
Na	50	0.048	0.04	0.011	0.20	0.041
K	46	0.15	0.14	0.03	0.46	0.069
Fe	28	1.8	1.8	0.65	3.9	0.64
Ti	28	0.055	0.056	0.028	0.094	0.013
			Parts per million			
As	50	20	8.8	0.27	130	26
B	28	90	82	14	180	40
Ba	15	230	46	22	2,500	630
Be	28	1.2	1.1	0.58	2.5	0.38
Cd	27	0.96	0.26	0.05L	6.9	1.4
Co	32	5.1	4.7	1.7	12	2.6
Cr	32	12	11	6.9	28	5.2
Cu	29	9.6	8.5	4.1	30	4.9
F	29	55	48	28	130	23
Ge	28	5.2	4.8	0.43L	15	3.5
Hg	28	0.13	0.11	0.03	0.47	0.10
La	33	5.4	5.3	1.8	11	2.4
Li	10	9.7	7.8	4.4	27	6.8
Mn	32	62	56	18	150	39
Mo	28	7.8	6.5	1.4L	22	5.1
Nb	---	---	---	---	---	---
Ni	29	15	15	1.8	28	7.2
P	28	62	46	4.2L	290	60
Pb	29	34	27	3.6	110	30
Sb	49	1.2	0.8	0.1	13	1.9
Sc	15	2.2	2.4	1.3	3.4	0.62
Se	32	2.1	1.8	0.9	5.5	1.0
Sr	15	29	23	13	59	13
Th	15	1.5	1.3	1.1	2.9	0.50
U	15	0.95	0.94	0.46L	1.6	0.40
V	28	29	28	7.0	75	17
Y	---	---	---	---	---	---
Yb	15	0.41	0.38	0.19	0.57	0.094
Zn	47	210	58	9.0	3,300	500
Zr	27	30	22	6.5	130	25

Table 10. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for the Springfield Coal Member in Indiana as analyzed by the U.S. Geological Survey.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated. Leaders (---) indicate statistics could not be calculated owing to no data or to an insufficient number of analyses above the lower detection limit.]

	Number of samples	Mean	Median	Range Minimum	Range Maximum	Standard deviation
			Percent			
Ash	49	12.8	9.8	5.5	46.0	8.3
Si	49	2.1	1.7	1.0	9.0	1.4
Al	49	1.1	0.92	0.17	5.8	0.90
Ca	49	0.37	0.24	0.015	3.9	0.58
Mg	49	0.059	0.044	0.016	0.31	0.051
Na	49	0.033	0.028	0.006	0.1	0.02
K	49	0.22	0.15	0.004	1.3	0.22
Fe	49	2.5	1.7	0.25	27	3.9
Ti	49	0.061	0.052	0.027	0.26	0.042
			Parts per million			
As	49	9.7	5.0	1.4	50	11
B	49	87	85	5.7L	210	38
Ba	49	35	26	8.3	160	28
Be	49	2.4	2.4	0.83	6.0	0.93
Cd	49	0.75	0.26	0.02L	9.0	1.4
Co	41	4.4	3.6	0.90	12	2.6
Cr	41	18	12	3.1	75	16
Cu	49	14	7.7	4.1	77	15
F	49	88	56	10L	600	110
Ge	46	8.9	8.5	1.5L	38	6.2
Hg	49	0.14	0.1	0.02	1.2	0.17
La	40	7.4	6.0	2.0	31	5.6
Li	49	10	5.7	2.3L	89	14
Mn	49	35	26	5.1	180	31
Mo	48	8.0	5.3	0.76	46	9.3
Nb	48	1.9	1.8	0.61L	4.6	1.0
Ni	49	14	12	5,0	40	8.6
P	---	---	---	---	---	---
Pb	49	7.3	3.9	0.49L	60	9.8
Sb	49	1.0	0.9	0.2	3.0	0.6
Sc	41	2.8	2.1	0.47	12	2.1
Se	49	3.1	2.2	0.9L	13	2.5
Sr	49	28	17	3.4	160	32
Th	40	2.2	1.6	0.30	10	1.9
U	49	3.1	1.7	0.17	15	3.2
V	49	27	17	3.2	120	24
Y	49	6.2	6.0	1.8	13	2.2
Yb	39	0.63	0.55	0.20L	1.9	0.35
Zn	49	51	28	6.5	300	63
Zr	49	23	19	1.8L	69	15

Table 11. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for the Springfield coal in Kentucky as analyzed by the Kentucky Geological Survey.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. Leaders (---) indicate statistics could not be calculated owing to no data or to an insufficient number of analyses above the lower detection limit.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
			Percent			
Ash	259	10.2	10.1	5.0	16.4	1.6
Si	141	1.9	1.9	0.018	3.1	0.37
Al	141	0.88	0.87	0.38	1.4	0.16
Ca	141	0.47	0.41	0.028	2.0	0.33
Mg	141	0.044	0.041	0.017	0.10	0.014
Na	132	0.028	0.025	0.0018	0.11	0.019
K	141	0.15	0.15	0.064	0.26	0.037
Fe	141	1.9	1.9	0.69	3.7	0.62
Ti	141	0.048	0.047	0.022	0.11	0.0097
			Parts per million			
As	15	4.8	4.7	1.8	11	2.5
B	---	---	---	---	---	---
Ba	---	---	---	---	---	---
Be	16	1.8	1.5	0.44	4.7	0.96
Cd	15	0.27	0.17	0.04	0.97	0.27
Co	140	3.2	3.3	1.5	5.2	0.80
Cr	141	16	14	4.1	86	8.8
Cu	---	---	---	---	---	---
F	---	---	---	---	---	---
Ge	---	---	---	---	---	---
Hg	15	0.02	0.02	0.01	0.03	0.01
La	---	---	---	---	---	---
Li	---	---	---	---	---	---
Mn	135	39	35	0.58	160	24
Mo	---	---	---	---	---	---
Nb	---	---	---	---	---	---
Ni	141	10	9.6	2.2	41	5.5
P	141	52	37	4.6	740	80
Pb	15	3.8	2.6	1.0	9.0	2.5
Sb	15	1.0	0.8	0.2	2.4	0.7
Sc	---	---	---	---	---	---
Se	15	2.0	1.9	1.2	3.6	0.7
Sr	---	---	---	---	---	---
Th	15	1.3	1.2	0.95	2.4	0.45
U	15	2.5	1.6	0.52	9.1	2.3
V	---	---	---	---	---	---
Y	---	---	---	---	---	---
Yb	---	---	---	---	---	---
Zn	---	---	---	---	---	---
Zr	---	---	---	---	---	---

Table 12. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for the Springfield coal in Kentucky as analyzed by the U.S. Geological Survey.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. L, less than value shown. G, greater than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated. Leaders (---) indicate statistics could not be calculated owing to no data or to an insufficient number of analyses above the lower detection limit.]

	Number of Samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Percent						
Ash	31	11.1	11.0	7.3	17.0	2.8
Si	31	1.8	1.8	1.4	2.3	0.23
Al	31	0.83	0.80	0.65	1.1	0.13
Ca	31	0.63	0.35	0.038	2.3	0.63
Mg	31	0.044	0.037	0.018	0.23	0.036
Na	31	0.027	0.018	0.007	0.072	0.02
K	31	0.14	0.14	0.10	0.22	0.029
Fe	31	2.2	2.0	0.75	5.8	1.0
Ti	31	0.051	0.049	0.04	0.069	0.0071
Parts per million						
As	31	7.9	4.9	1.8	37	7.6
B	31	76	71	42	130G	24
Ba	31	58	18	9.6	1,100	190
Be	31	1.8	1.7	0.56	3.8	0.69
Cd	31	0.26	0.14	0.04	1.4	0.31
Co	31	2.5	2.4	1.5	4.2	0.67
Cr	31	13	11	7.7	35	6.6
Cu	31	5.9	5.8	3.5	10	1.5
F	31	59	47	10L	260	44
Ge	31	9.2	8.4	3.9	16	3.3
Hg	31	0.14	0.13	0.01L	0.39	0.1
La	31	4.4	4.0	2.8	6.8	0.93
Li	31	6.4	5.8	2.6	16	2.7
Mn	31	54	31	2.7	210	55
Mo	25	5.5	5.2	1.9	13	2.5
Nb	31	1.5	1.5	0.26L	3.8	0.78
Ni	31	8.8	9.1	2.4	18	4.3
P	14	63	59	22L	180	44
Pb	31	5.7	4.2	0.77	17	4.3
Sb	31	1.0	0.8	0.2	2.4	0.7
Sc	31	2.0	1.9	1.5	3.1	0.4
Se	31	2.4	2.1	1.1	6.3	1.2
Sr	31	21	18	3.9	81	16
Th	31	1.3	1.2	0.98	2.5	0.29
U	31	2.7	1.9	0.51	9.8	2.2
V	31	30	13	5.8	130	31
Y	31	4.0	3.9	1.2	7.8	1.5
Yb	31	0.45	0.41	0.25	0.71	0.10
Zn	31	45	27	6.9	390	69
Zr	31	16	15	5.1	45	8.1

Table 13. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for nonassessed coals from the McLeansboro Group in Kentucky as analyzed by the Kentucky Geological Survey.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. Leaders (---) indicate statistics could not be calculated owing to no data or to an insufficient number of analyses above the lower detection limit.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
			Percent			
Ash	57	14.7	14.6	6.0	28.7	4.4
Si	57	3.0	3.0	0.028	5.9	1.3
Al	57	1.5	1.5	0.67	2.7	0.45
Ca	57	0.27	0.13	0.037	2.4	0.36
Mg	57	0.077	0.071	0.015	0.29	0.047
Na	49	0.041	0.031	0.0065	0.17	0.037
K	57	0.30	0.29	0.065	0.81	0.14
Fe	57	2.4	2.1	0.0093	6.4	1.2
Ti	57	0.081	0.081	0.031	0.14	0.025
			Parts per million			
As	19	9.0	3.7	0.43	37	10
B	---	---	---	---	---	---
Ba	---	---	---	---	---	---
Be	23	2.1	1.9	1.1	5.3	0.83
Cd	19	0.14	0.09	0.03	0.65	0.16
Co	51	5.3	4.7	1.6	15	2.6
Cr	56	21	20	7.8	40	7.7
Cu	---	---	---	---	---	---
F	---	---	---	---	---	---
Ge	---	---	---	---	---	---
Hg	18	0.02	0.01	0.01	0.04	0.01
La	---	---	---	---	---	---
Li	---	---	---	---	---	---
Mn	56	60	37	7.5	360	75
Mo	---	---	---	---	---	---
Nb	---	---	---	---	---	---
Ni	56	22	18	3.6	51	14
P	57	170	110	10	1,300	190
Pb	19	6.9	4.8	2.2	20	4.8
Sb	19	0.8	0.3	0.1	3.3	1.0
Sc	---	---	---	---	---	---
Se	19	2.0	2.0	0.7	3.1	0.6
Sr	---	---	---	---	---	---
Th	19	2.0	2.0	1.0	3.6	0.70
U	23	1.6	0.88	0.35	7.4	1.6
V	---	---	---	---	---	---
Y	---	---	---	---	---	---
Yb	---	---	---	---	---	---
Zn	---	---	---	---	---	---
Zr	---	---	---	---	---	---

Table 14. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for nonassessed coals from the McLeansboro Group in Kentucky as analyzed by the U.S. Geological Survey.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Percent						
Ash	25	13.6	14.0	8.1	26.0	3.9
Si	25	2.8	3.0	0.94	4.9	1.1
Al	25	1.4	1.5	0.73	2.8	0.44
Ca	25	0.27	0.18	0.054	1.4	0.29
Mg	25	0.064	0.069	0.016	0.14	0.027
Na	25	0.03	0.019	0.006	0.15	0.032
K	25	0.28	0.29	0.072	0.59	0.12
Fe	25	2.1	1.8	0.87	4.6	1.0
Ti	25	0.08	0.084	0.035	0.14	0.026
Parts per million						
As	25	9.9	3.2	0.30L	65	15
B	25	86	84	55	130	18
Ba	25	40	35	8.9	98	22
Be	25	2.3	2.1	1.1	5.5	1.1
Cd	25	0.14	0.10	0.03	0.49	0.12
Co	25	5.3	3.7	2.5	19	4.2
Cr	25	16	16	9.2	31	4.5
Cu	25	14	10	6.7	50	9.6
F	25	97	86	33	260	49
Ge	25	4.8	4.0	1.7	14	3.1
Hg	25	0.13	0.11	0.03L	0.33	0.09
La	25	8.1	7.0	2.8	21	4.8
Li	25	14	11	6.6	39	7.5
Mn	25	48	44	18	140	27
Mo	25	3.1	2.0	0.42	14	3.2
Nb	25	1.8	1.7	0.52	5.4	1.1
Ni	25	16	12	5.5	75	14
P	7	91	79	22L	260	81
Pb	25	8.2	5.2	3.5	49	9.2
Sb	25	0.7	0.3	0.1	3.6	1.0
Sc	25	3.3	3.0	1.9	7.9	1.1
Se	25	2.2	2.1	1.2	3.5	0.6
Sr	25	44	33	14	150	33
Th	25	2.1	2.0	1.2	5.1	0.81
U	25	1.5	0.99	0.49	4.8	1.1
V	25	21	17	9.8	57	10
Y	25	6.0	5.8	2.0	20	3.8
Yb	25	0.70	0.64	0.32	1.4	0.28
Zn	25	39	32	13	140	30
Zr	25	16	14	5.5	41	9.3

Table 15. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for the nonassessed coals from the Carbondale Group in Indiana as analyzed by the U.S. Geological Survey.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. L, less than value shown. G, greater than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated. Leaders (---) indicate statistics could not be calculated owing to no data or to an insufficient number of analyses above the lower detection limit.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
			Percent			
Ash	44	14.0	12.0	5.4	48.0	9.2
Si	44	2.4	2.0	0.34	12	2.1
Al	44	1.2	0.95	0.15	6.4	1.1
Ca	43	0.41	0.18	0.023	3.5	0.7
Mg	44	0.071	0.053	0.009	0.35	0.063
Na	44	0.04	0.032	0.006	0.22	0.039
K	44	0.23	0.15	0.027	1.2	0.24
Fe	44	2.7	2.2	0.32	25	3.6
Ti	44	0.069	0.054	0.019	0.33	0.058
			Parts per million			
As	44	43	14	2.4	950	140
B	44	100	100	27	190G	41
Ba	44	41	27	11	170	37
Be	44	3.3	3.1	1.4	7.0	1.2
Cd	44	0.46	0.11	0.01L	5.7	1.0
Co	44	6.5	5.3	1.4	26	4.4
Cr	44	16	12	4.1	72	11
Cu	44	16	12	4.4	96	15
F	44	100	58	10L	780	120
Ge	44	12	9.9	0.31L	59	11
Hg	44	0.19	0.11	0.02	2.4	0.36
La	42	7.6	4.3	1.0	55	8.9
Li	44	17	8.5	0.76	210	33
Mn	44	48	30	7.6	150	40
Mo	44	4.7	2.6	0.46L	45	8.2
Nb	44	2.4	1.9	0.39L	8.6	1.7
Ni	44	23	21	3.3	81	16
P	---	---	---	---	---	---
Pb	44	30	15	0.46L	230	44
Sb	44	1.9	1.2	0.3	7.1	1.8
Sc	44	3.8	3.2	0.70	18	2.8
Se	44	2.7	2.2	0.5L	11	2.1
Sr	44	42	23	8.4	190	45
Th	42	2.2	1.5	0.2L	15	2.5
U	44	2.1	1.7	0.44L	7.6	1.8
V	44	22	18	3.8	84	16
Y	44	7.5	6.4	0.96L	64	9.2
Yb	41	0.98	0.6	0.20L	8.1	1.3
Zn	44	67	23	4.3	1,100	170
Zr	44	28	24	3.9	140	23

Table 16. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for nonassessed coals from the Carbondale Formation in Kentucky as analyzed by the Kentucky Geological Survey.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. Leaders (---) indicate statistics could not be calculated owing to no data or to an insufficient number of analyses above the lower detection limit.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Percent						
Ash	42	15.0	13.8	3.6	30.9	6.4
Si	42	2.9	2.5	0.75	8.6	1.7
Al	42	1.6	1.5	0.41	4.5	0.88
Ca	42	0.29	0.12	0.037	1.9	0.38
Mg	42	0.19	0.081	0.019	4.6	0.70
Na	38	0.054	0.043	0.0028	0.15	0.038
K	42	0.32	0.29	0.065	0.97	0.20
Fe	42	2.6	2.6	0.46	6.3	1.3
Ti	42	0.079	0.075	0.021	0.23	0.043
Parts per million						
As	4	16	10	3.8	38	15
B	---	---	---	---	---	---
Ba	---	---	---	---	---	---
Be	4	2.9	2.1	1.5	5.9	2.1
Cd	4	0.33	0.26	0.08	0.71	0.28
Co	35	4.8	4.6	1.3	11	2.2
Cr	35	24	22	5.3	55	12
Cu	---	---	---	---	---	---
F	---	---	---	---	---	---
Ge	---	---	---	---	---	---
Hg	4	0.02	0.02	0.01	0.05	0.02
La	---	---	---	---	---	---
Li	---	---	---	---	---	---
Mn	34	45	32	1.1	140	34
Mo	---	---	---	---	---	---
Nb	---	---	---	---	---	---
Ni	35	26	24	7.4	64	14
P	42	280	96	20	6,700	1000
Pb	4	20	18	11	35	10
Sb	4	0.9	0.4	0.3	2.4	1.0
Sc	---	---	---	---	---	---
Se	4	3.1	2.6	2.0	5.1	1.4
Sr	---	---	---	---	---	---
Th	4	2.2	2.4	1.1	2.9	0.81
U	4	2.9	2.0	1.2	6.3	2.3
V	---	---	---	---	---	---
Y	---	---	---	---	---	---
Yb	---	---	---	---	---	---
Zn	---	---	---	---	---	---
Zr	---	---	---	---	---	---

Table 17. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for nonassessed coals from the Carbondale Formation in Kentucky as analyzed by the U.S. Geological Survey.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. L, less than value shown. G, greater than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
			Percent			
Ash	42	14.7	14.0	6.2	28.0	5.6
Si	42	2.4	2.2	0.87	5.9	1.1
Al	42	1.3	1.2	0.51	3.1	0.58
Ca	42	0.5	0.34	0.037	2.4	0.56
Mg	42	0.058	0.046	0.015	0.15	0.034
Na	42	0.036	0.029	0.009	0.11	0.025
K	42	0.21	0.18	0.051	0.52	0.11
Fe	42	3.2	2.6	0.67	12	2.2
Ti	42	0.065	0.063	0.005	0.17	0.03
			Parts per million			
As	42	27	15	0.50L	130	30
B	42	78	74	13	140G	25
Ba	42	40	31	7.5	130	28
Be	42	3.7	3.7	1.2	7.3	1.3
Cd	42	0.45	0.11	0.02L	6.2	1.1
Co	42	9.6	5.8	1.1	110	17
Cr	42	20	17	9.7	86	13
Cu	42	16	15	6.6	33	7.1
F	42	97	65	10L	460	88
Ge	42	16	15	1.8	41	10
Hg	42	0.10	0.08	0.02L	0.45	0.09
La	42	7.3	6.0	2.0	28	4.7
Li	42	15	11	2.7	46	11
Mn	42	59	50	8.1	220	47
Mo	23	8.9	5.3	0.96	56	12
Nb	42	2.8	2.6	0.74	6.3	1.4
Ni	42	34	28	3.7	190	33
P	32	110	74	22L	810	140
Pb	42	25	20	2.2	120	24
Sb	42	1.2	1.0	0.1L	7.1	1.2
Sc	42	4.7	4.2	2.0	12	2.2
Se	42	3.9	3.3	1.7	12	2.0
Sr	42	44	33	9.5	300	46
Th	42	2.1	1.9	0.71	6.4	0.99
U	42	4.6	3.7	0.59	13	3.4
V	42	31	28	7.8	82	17
Y	42	10	9.2	5.1	34	5.5
Yb	42	1.2	1.0	0.57	4.4	0.67
Zn	42	71	29	1.8	670	130
Zr	42	28	24	9.9	110	18

Table 18. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for nonassessed coals in the Raccoon Creek Group in Indiana as analyzed by the U.S. Geological Survey.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. L, less than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated. Leaders (---) indicate statistics could not be calculated owing to no data or to an insufficient number of analyses above the lower detection limit.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
Percent						
Ash	106	12.7	8.9	1.7	48.0	10
Si	105	2.5	1.5	0.40	13	2.8
Al	105	1.5	0.89	0.14	7.8	1.7
Ca	105	0.084	0.046	0.018	1.0	0.16
Mg	106	0.05	0.029	0.002L	0.25	0.055
Na	106	0.036	0.012	0.002	0.28	0.06
K	104	0.20	0.085	0.007	1.3	0.28
Fe	105	1.9	1.4	0.11	24	2.5
Ti	105	0.081	0.047	0.002	0.46	0.092
Parts per million						
As	106	16	9.0	0.40	95	17
B	105	83	77	12	210	45
Ba	106	59	23	1.9	560	85
Be	106	3.7	3.5	0.25	9.2	1.5
Cd	106	0.30	0.12	0.01L	3.5	0.57
Co	106	12	8.8	1.0	110	12
Cr	106	19	13	3.1L	65	15
Cu	106	22	16	2.1L	140	21
F	106	79	55	10L	420	80
Ge	104	12	13	0.82L	37	8.3
Hg	106	0.13	0.08	0.01L	1.2	0.16
La	101	13	9.0	1.0	72	13
Li	106	22	8.8	0.67L	140	31
Mn	106	18	13	2.2	94	17
Mo	106	2.4	1.6	0.16L	25	3.1
Nb	102	2.5	1.5	0.051L	14	2.8
Ni	106	39	31	4.4	170	30
P	---	---	---	---	---	---
Pb	106	23	19	0.37L	190	24
Sb	106	1.3	1.1	0.1	7.4	1.2
Sc	106	4.4	3.5	0.47	13	3.0
Se	106	4.2	3.6	0.6L	14	2.6
Sr	106	75	33	2.0	490	99
Th	100	2.7	1.5	0.15L	18	3.0
U	106	1.9	1.2	0.055L	17	2.2
V	106	26	15	0.60	98	25
Y	101	9.3	6.7	1.5	41	7.8
Yb	98	0.92	0.70	0.15L	4.1	0.69
Zn	106	88	33	5.5	1,600	210
Zr	106	30	14	0.83L	210	34

Table 19. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for nonassessed coals from the Raccoon Creek Group in Kentucky as analyzed by the Kentucky Geological Survey.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. Leaders (---) indicate statistics could not be calculated owing to no data or to an insufficient number of analyses above the lower detection limit.]

	Number of samples	Mean	Median	Range: Minimum	Range: Maximum	Standard deviation
Percent						
Ash	87	9.1	7.6	1.5	43.9	6.9
Si	83	1.7	1.1	0.019	12	1.8
Al	83	1.0	0.71	0.11	5.9	0.92
Ca	82	0.13	0.037	0.0093	1.1	0.21
Mg	87	0.036	0.019	0.0028	0.35	0.049
Na	70	0.024	0.011	0.0019	0.17	0.028
K	83	0.13	0.065	0.0093	1.2	0.18
Fe	83	1.8	1.6	0.093	5.4	1.3
Ti	83	0.047	0.034	0.0037	0.29	0.044
Parts per million						
As	15	26	11	2.0	180	44
B	---	---	---	---	---	---
Ba	---	---	---	---	---	---
Be	15	3.8	3.5	2.4	7.3	1.2
Cd	15	0.72	0.15	0.01	4.4	1.4
Co	56	5.3	3.7	0.20	18	4.9
Cr	60	13	11	3.2	56	9.0
Cu	---	---	---	---	---	---
F	---	---	---	---	---	---
Ge	---	---	---	---	---	---
Hg	8	0.01	0.01	0.01	0.03	0.01
La	---	---	---	---	---	---
Li	---	---	---	---	---	---
Mn	53	14	9.4	1	81	15
Mo	---	---	---	---	---	---
Nb	---	---	---	---	---	---
Ni	60	43	40	5.3	120	25
P	83	79	42	5.6	520	99
Pb	15	22	17	6.2	65	16
Sb	15	2.4	1.4	0.2	13	3.2
Sc	---	---	---	---	---	---
Se	15	2.6	2.0	1.1	5.1	1.3
Sr	---	---	---	---	---	---
Th	15	1.2	1.0	0.48	2.7	0.70
U	15	2.0	1.2	0.76	7.8	1.9
V	---	---	---	---	---	---
Y	---	---	---	---	---	---
Yb	---	---	---	---	---	---
Zn	---	---	---	---	---	---
Zr	---	---	---	---	---	---

Table 20. Number of samples, mean, median, range, and standard deviation of ash yield and contents of elements for nonassessed coals from the Raccoon Creek Group in Kentucky as analyzed by the U.S. Geological Survey.

[All analyses are in percent or parts per million and are reported on an as-received, whole-coal basis. L, less than value shown. G, greater than value shown. A common problem in statistical summaries of trace-element data arises when element values are below the limits of analytical detection. This results in a censored distribution. To compute unbiased estimates of the means for censored data, we adopted the protocol of reducing all "less than" values by 50 percent before summary statistics were generated.]

	Number of samples	Mean	Median	Range		Standard deviation
				Minimum	Maximum	
			Percent			
Ash	43	7.2	6.8	1.5	15.0	3.7
Si	39	1.2	0.98	0.41	2.8	0.61
Al	39	0.73	0.65	0.14	2.3	0.42
Ca	39	0.16	0.051	0.013	1.2	0.28
Mg	43	0.022	0.021	0.006	0.052	0.01
Na	43	0.015	0.008	0.001	0.16	0.026
K	39	0.088	0.083	0.013	0.21	0.048
Fe	39	1.8	1.5	0.068	6.4	1.6
Ti	39	0.038	0.033	0.011	0.088	0.021
			Parts per million			
As	43	29	17	1.3	170	39
B	43	56	58	15	100G	24
Ba	43	15	13	3.8	59	9.9
Be	43	3.7	3.6	1.9	8.0	0.99
Cd	43	0.34	0.11	0.01L	4.7	0.92
Co	43	8.4	7.3	1.2	30	6.0
Cr	43	8.7	7.5	3.0L	18	4.0
Cu	43	12	12	4.8	27	5.1
F	43	49	41	10L	160	35
Ge	43	17	16	3.4	39	8.2
Hg	43	0.12	0.08	0.01	0.44	0.11
La	43	5.8	4.4	0.97	20	4.6
Li	43	7.4	4.3	1.1	30	6.9
Mn	43	16	9.8	1.4	74	17
Mo	36	2.2	1.5	0.37	17	2.9
Nb	43	1.4	1.1	0.24	3.2	0.79
Ni	43	26	22	6.4	65	15
P	15	76	22	22L	300	91
Pb	43	26	20	1.5	90	22
Sb	43	1.7	1.2	0.1L	13	2.1
Sc	43	2.5	2.2	0.4	5.0	1.2
Se	43	2.9	2.5	0.9L	8.5	1.7
Sr	43	28	17	1.3	170	31
Th	43	1.3	1.1	0.36L	2.7	0.65
U	43	1.7	1.2	0.17L	7.7	1.5
V	43	12	11	3.2	30	6.4
Y	43	6.8	6.5	3.4	14	2.6
Yb	43	0.67	0.6	0.30	1.3	0.26
Zn	43	110	28	5.8	2,600	390
Zr	43	11	8.4	3.2	28	7.0

Appendix 5. Minimum, maximum, percentile, and median values of ash yield, sulfur content, calorific value, and elements of environmental concern for assessed and nonassessed coals, grouped by assessed coal or stratigraphic unit in the Illinois Basin.

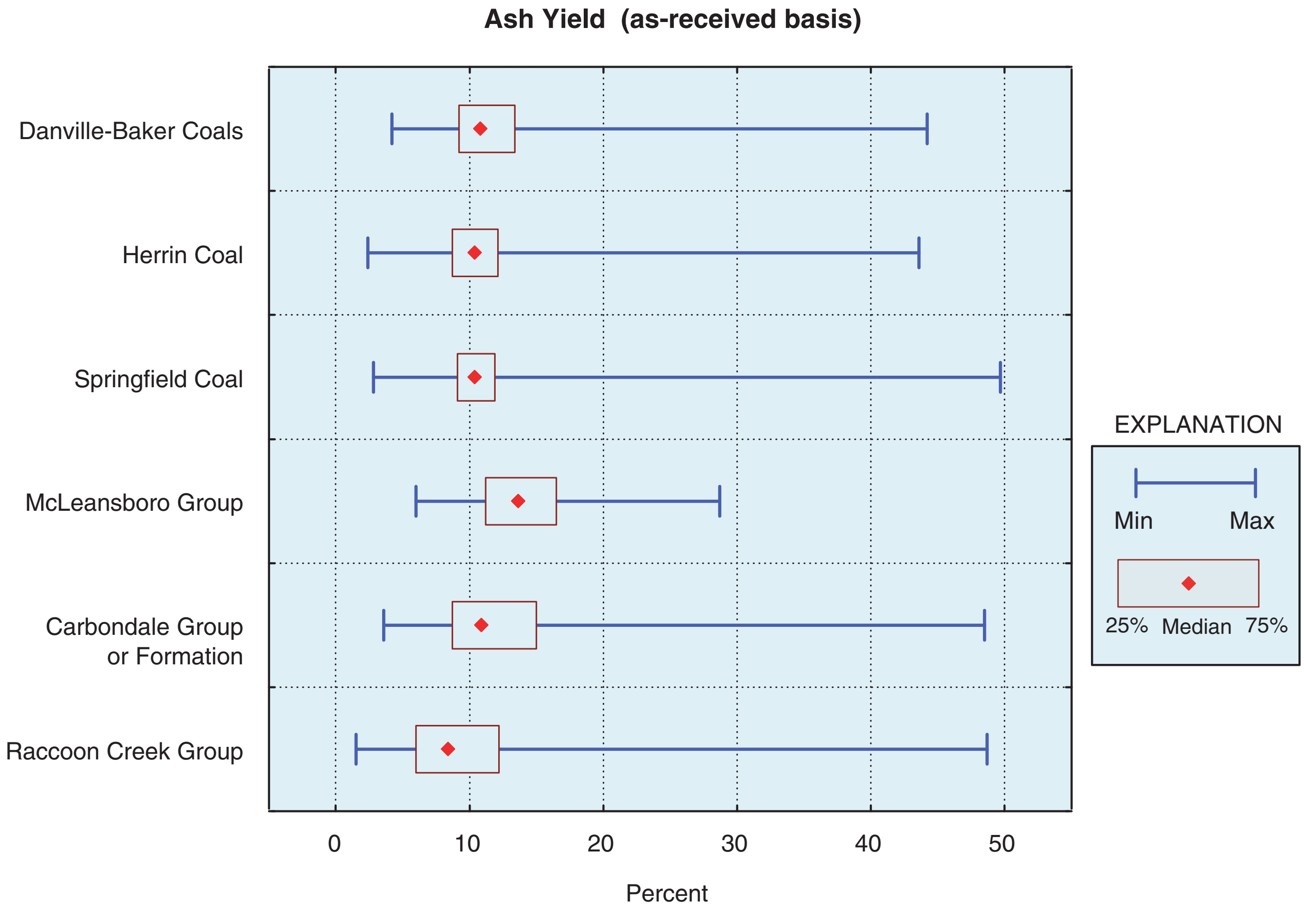

Figure 1. Minimum, maximum, percentile, and median values for ash yield (percent, as-received basis) of coals, grouped by assessed coal or stratigraphic unit in the Illinois Basin.

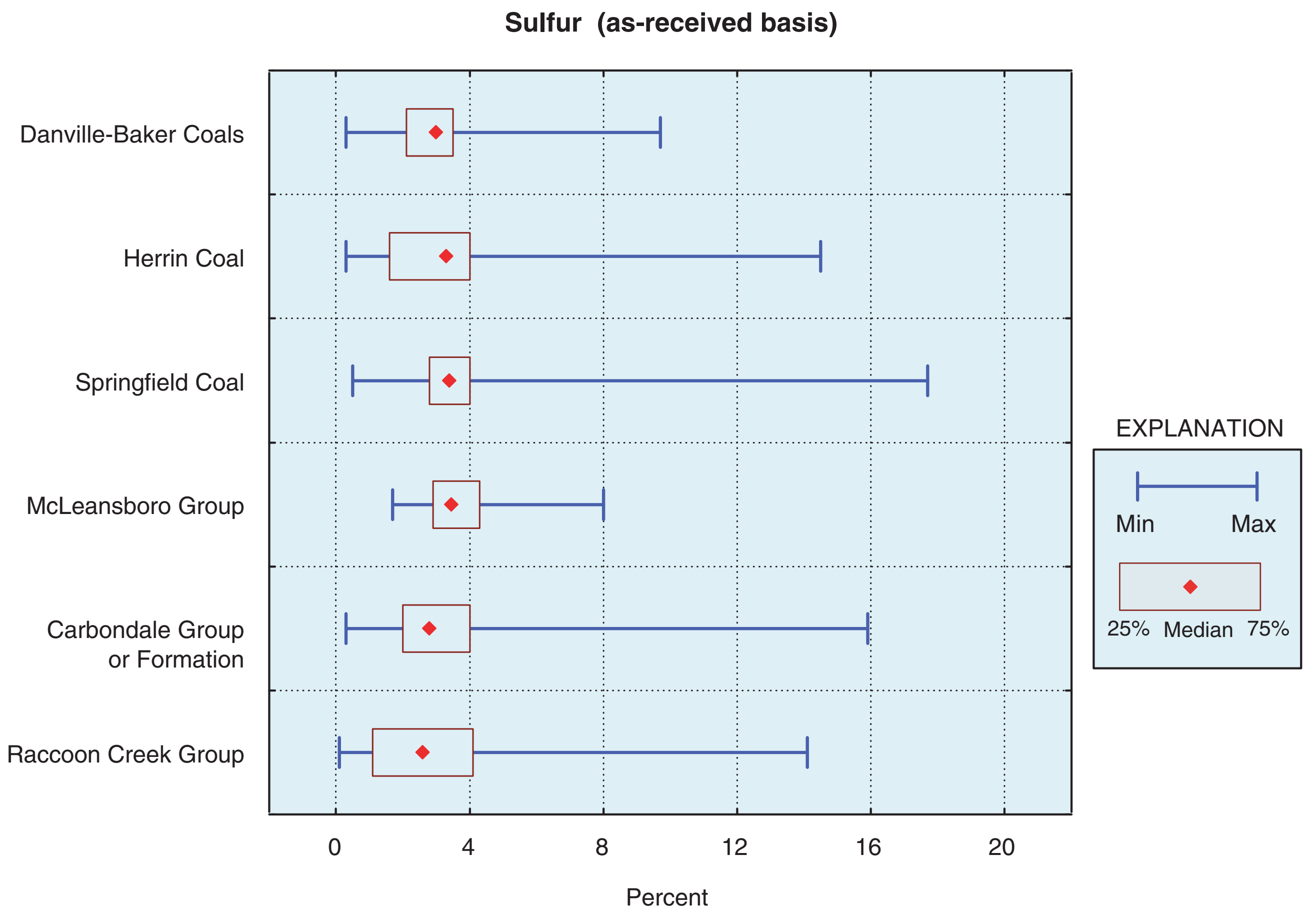

Figure 2. Minimum, maximum, percentile, and median values for sulfur content (percent, as-received basis) of coals, grouped by assessed coal or stratigraphic unit in the Illinois Basin.

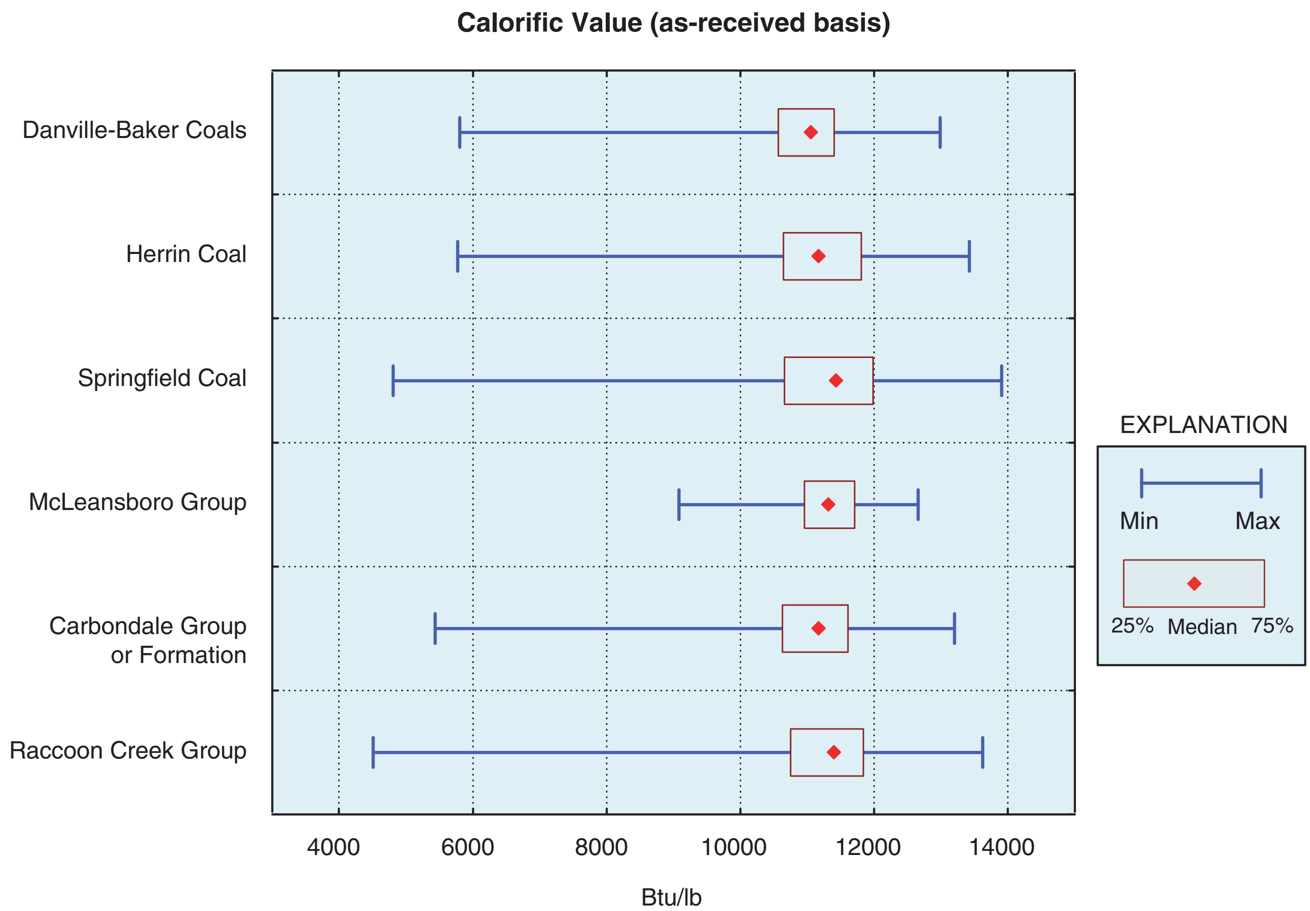

Figure 3. Minimum, maximum, percentile, and median values for calorific value (Btu/lb, as-received basis) of coals, grouped by assessed coal or stratigraphic unit in the Illinois Basin.

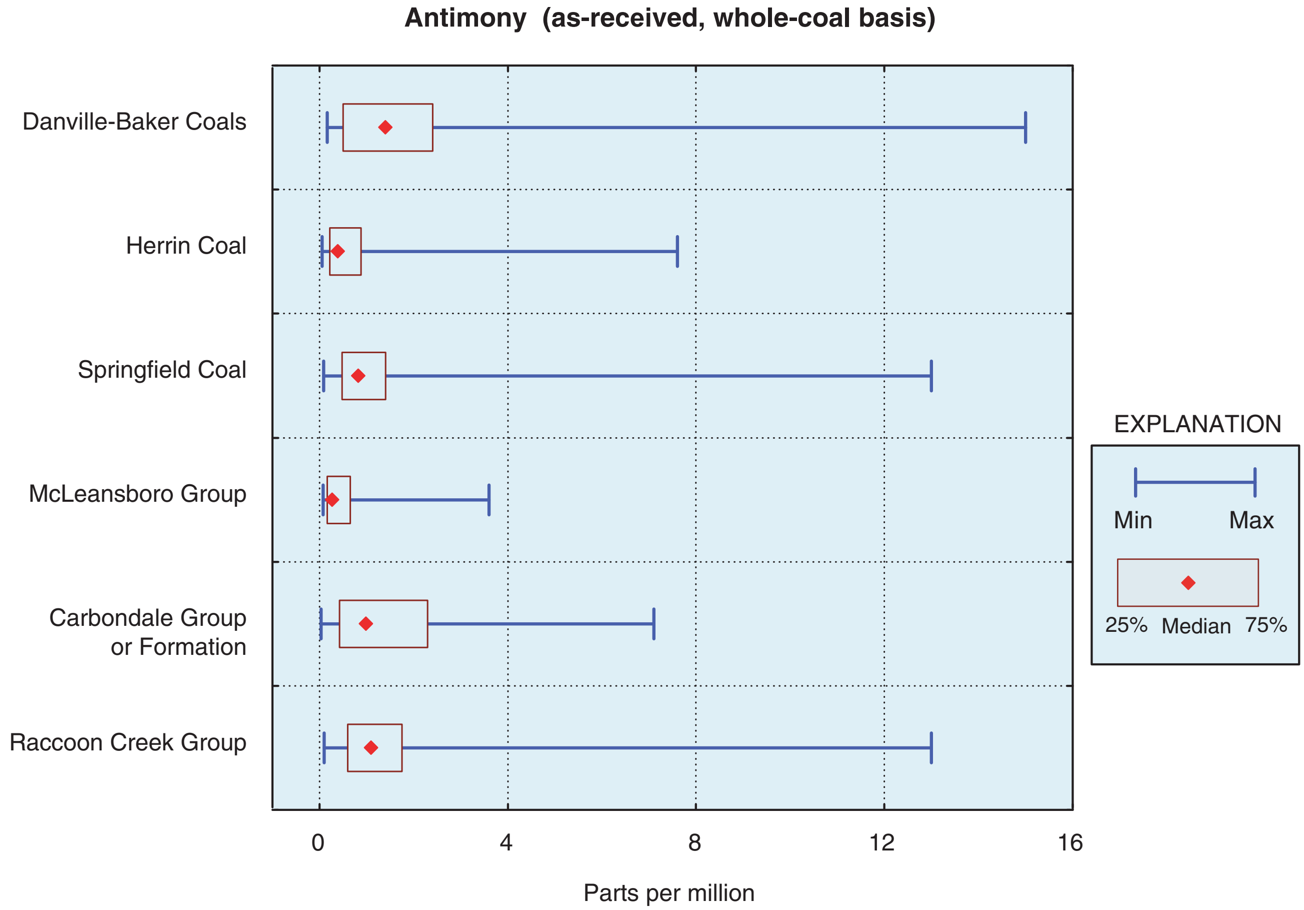

Figure 4. Minimum, maximum, percentile, and median values for antimony content (parts per million, as-received, whole-coal basis) of coals, grouped by assessed coal or stratigraphic unit in the Illinois Basin.

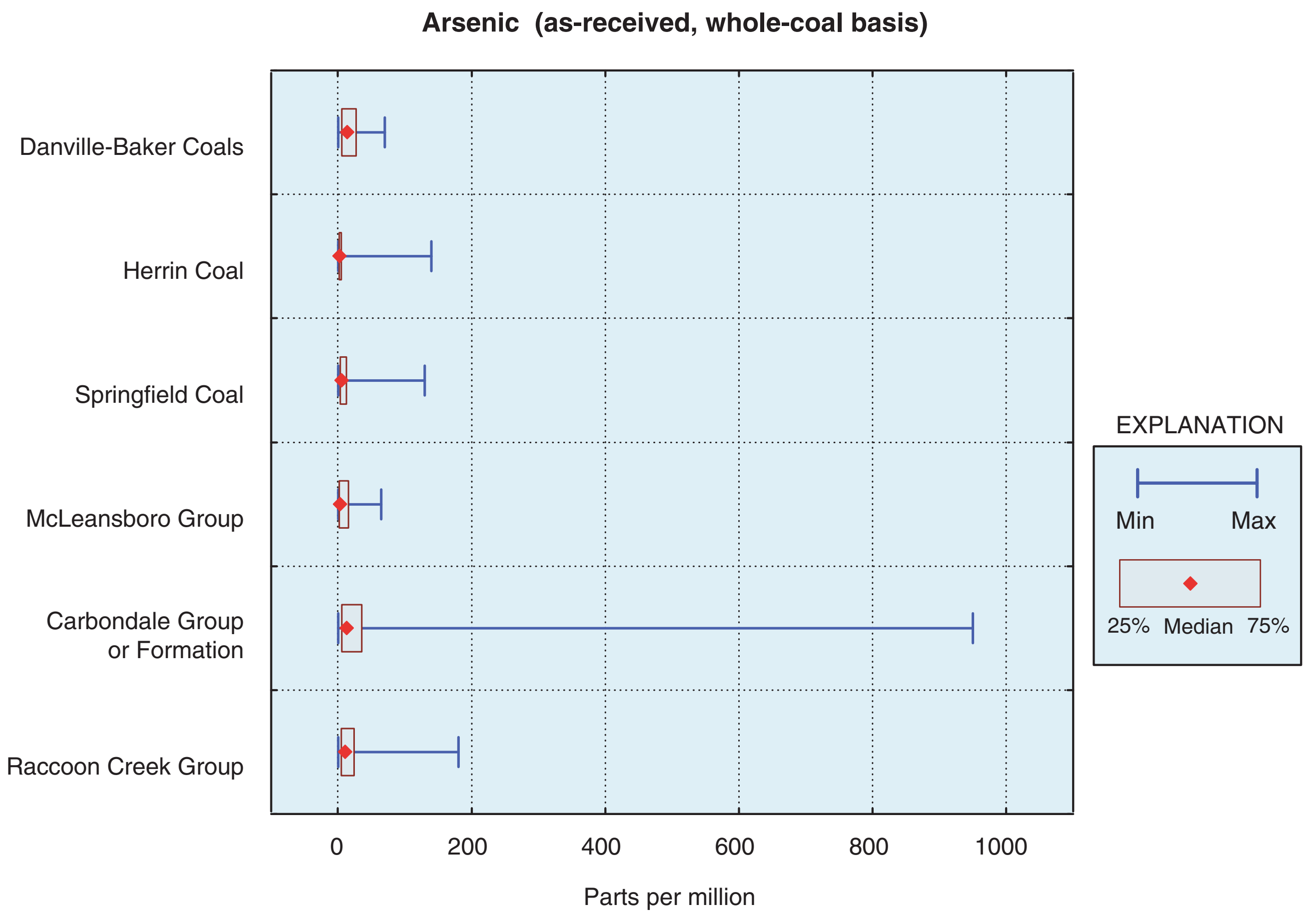

Figure 5. Minimum, maximum, percentile, and median values for arsenic content (parts per million, as-received, whole-coal basis) of coals, grouped by assessed coal or stratigraphic unit in the Illinois Basin.

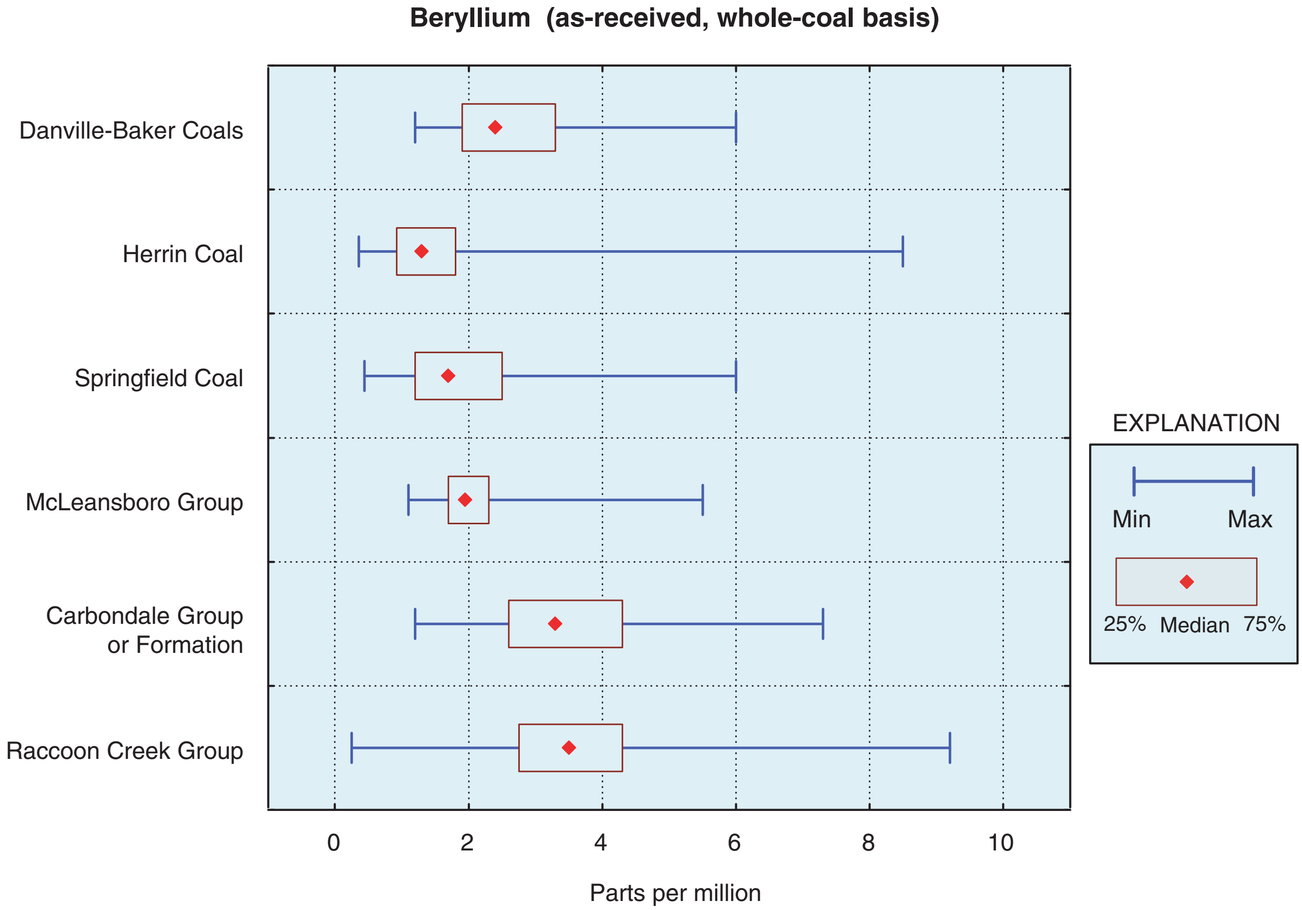

Figure 6. Minimum, maximum, percentile, and median values for beryllium content (parts per million, as-received, whole-coal basis) of coals, grouped by assessed coal or stratigraphic unit in the Illinois Basin.

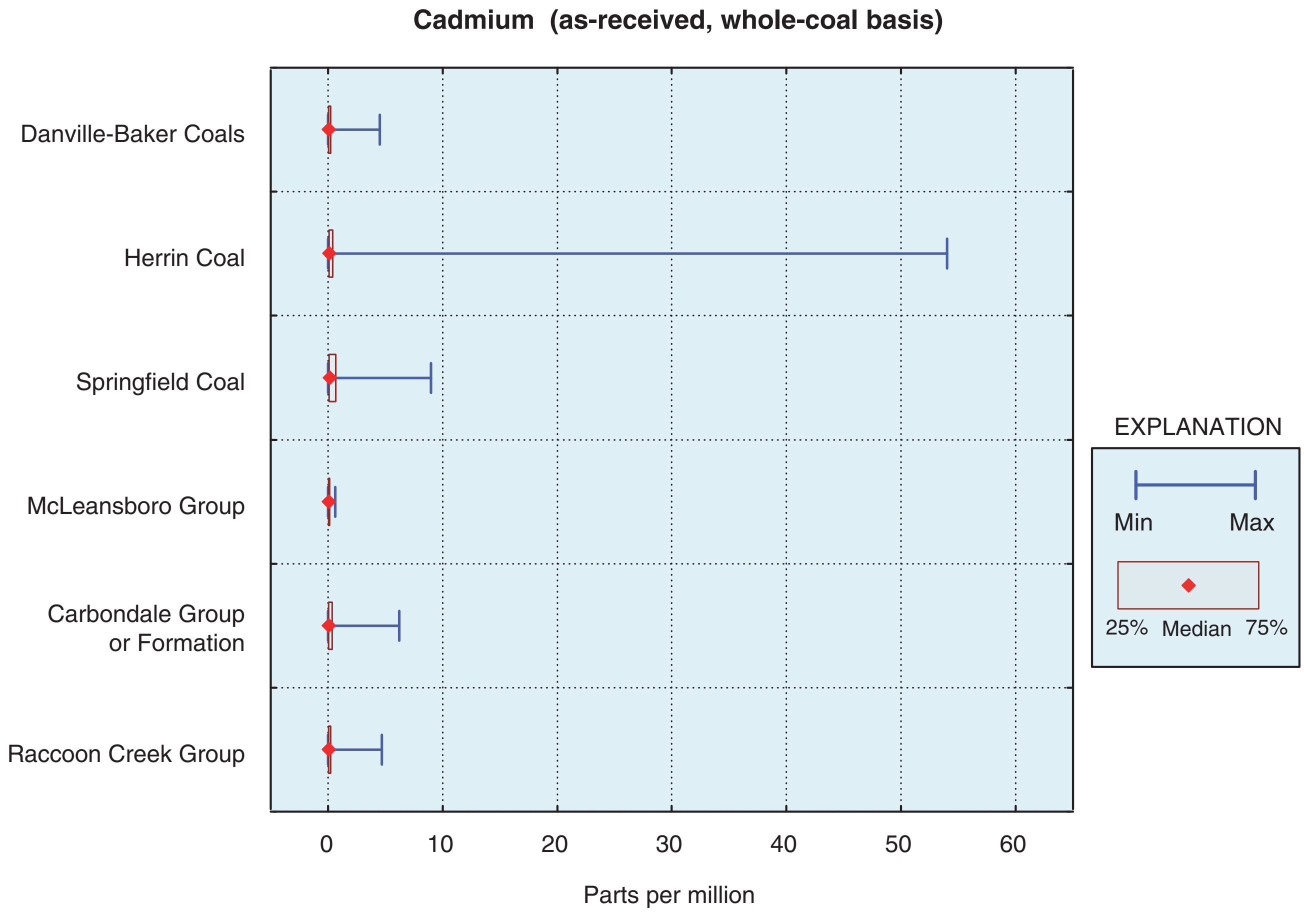

Figure 7. Minimum, maximum, percentile, and median values for cadmium content (parts per million, as-received, whole-coal basis) of coals, grouped by assessed coal or stratigraphic unit in the Illinois Basin.

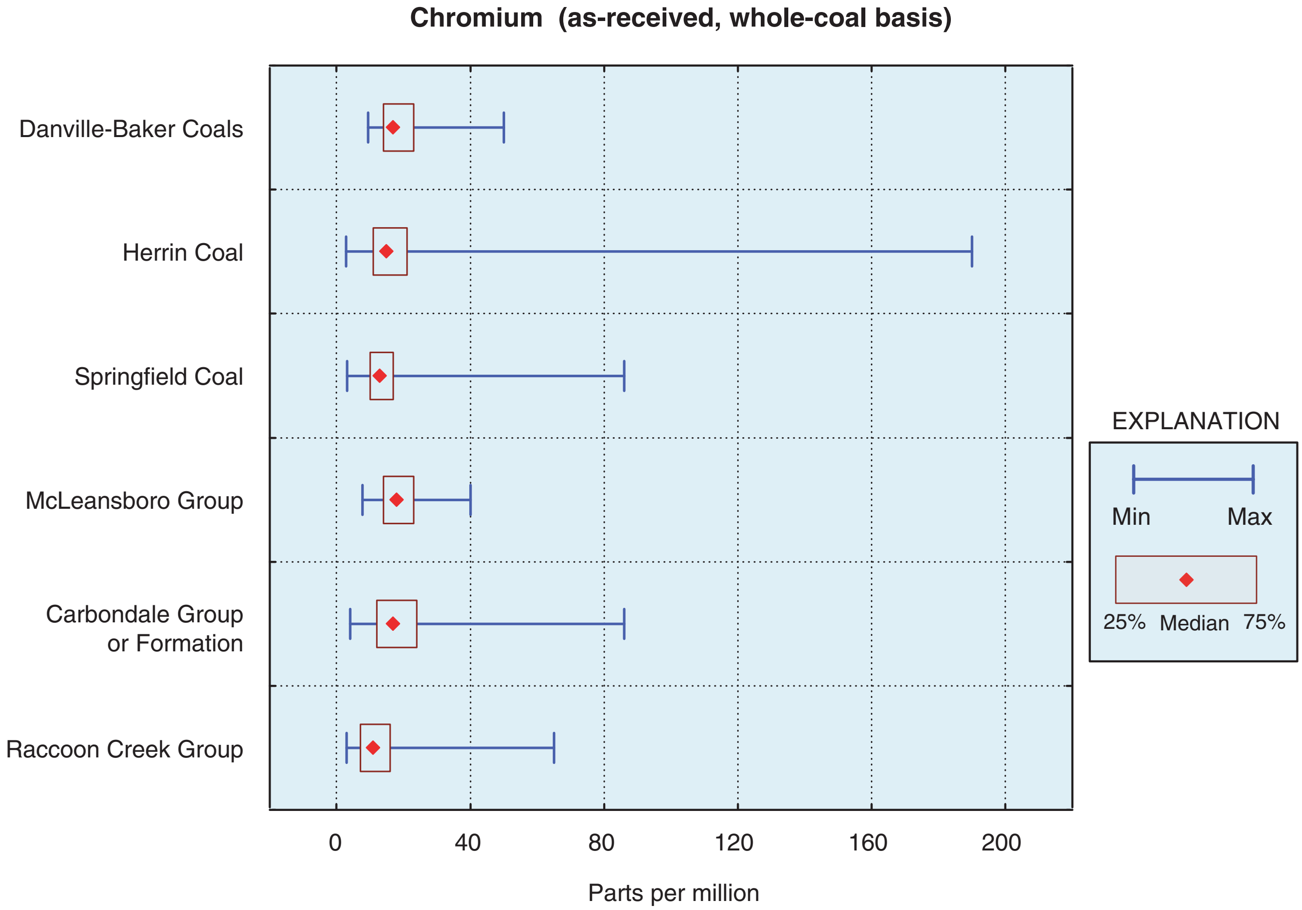

Figure 8. Minimum, maximum, percentile, and median values for chromium content (parts per million, as-received, whole-coal basis) of coals, grouped by assessed coal or stratigraphic unit in the Illinois Basin.

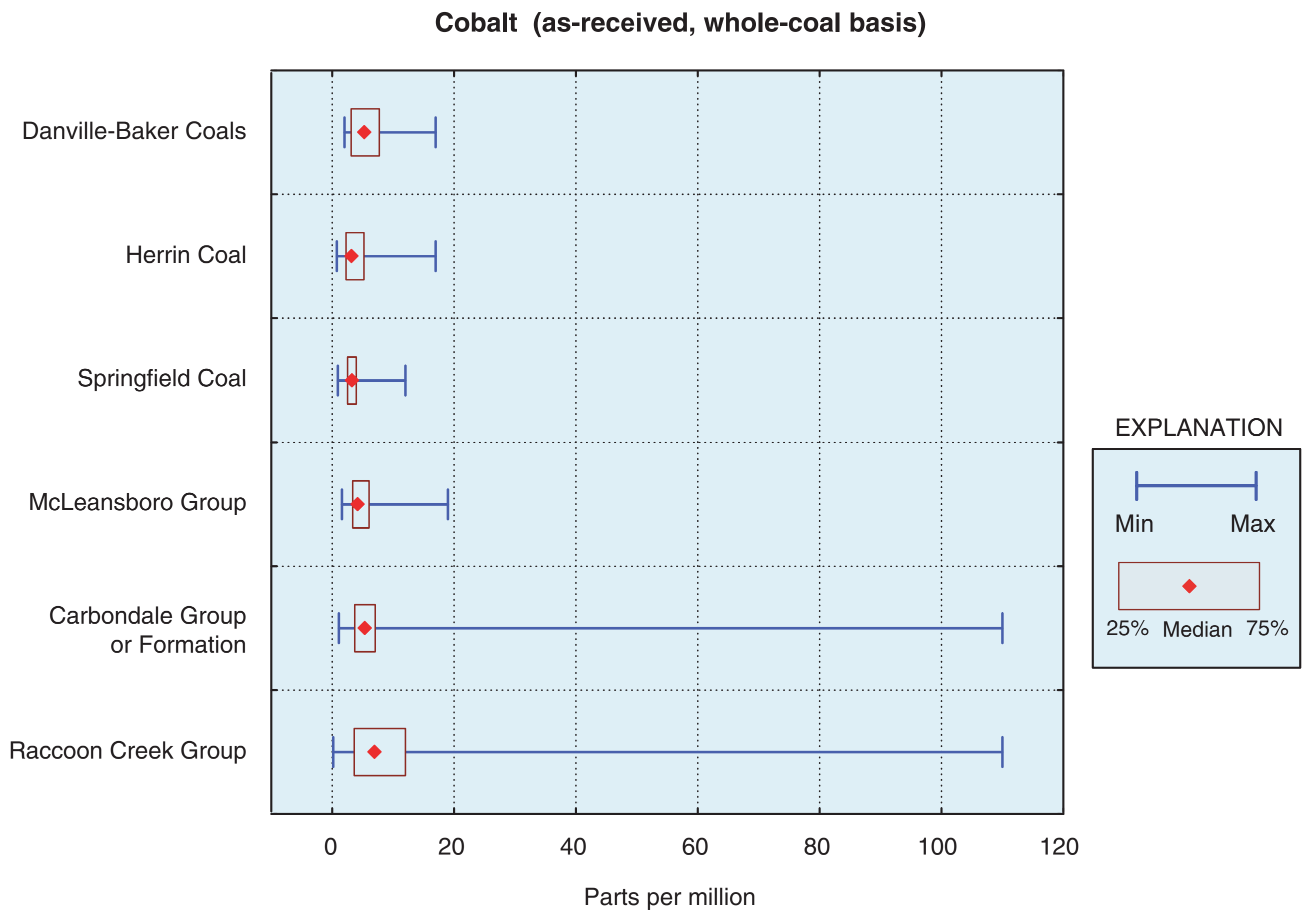

Figure 9. Minimum, maximum, percentile, and median values for cobalt content (parts per million, as-received, whole-coal basis) of coals, grouped by assessed coal or stratigraphic unit in the Illinois Basin.

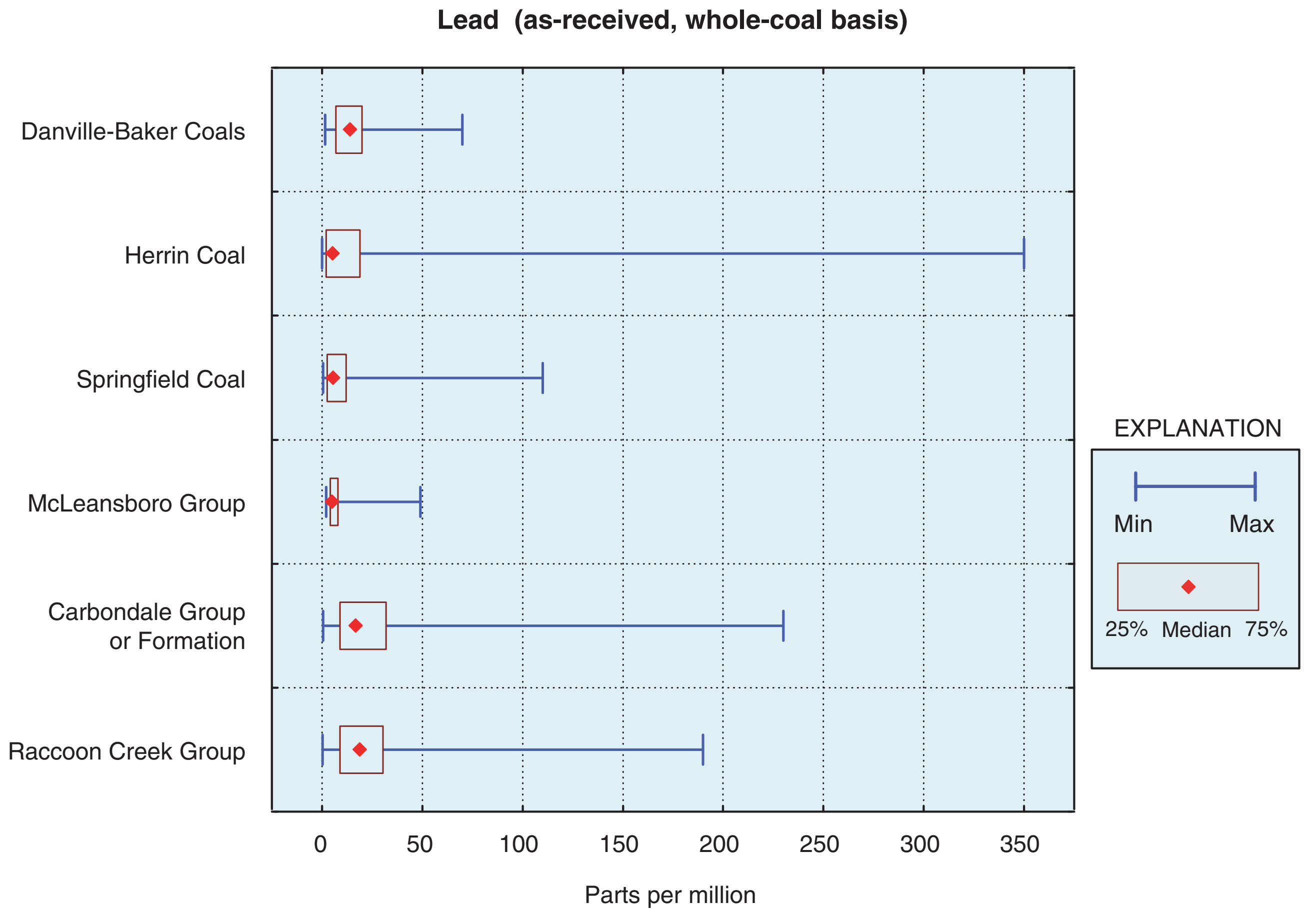

Figure 10. Minimum, maximum, percentile, and median values for lead content (parts per million, as-received, whole-coal basis) of coals, grouped by assessed coal or stratigraphic unit in the Illinois Basin.

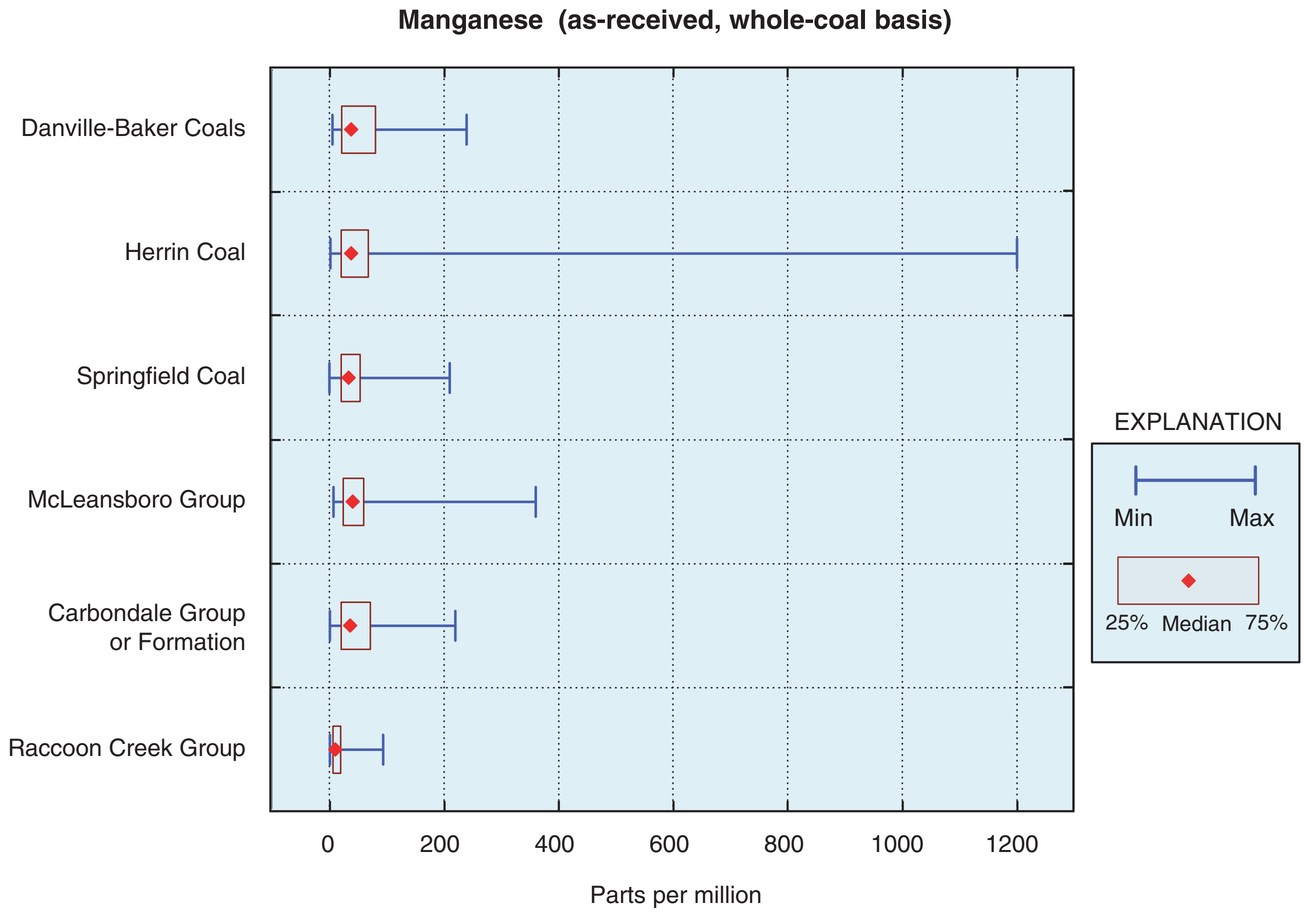

Figure 11. Minimum, maximum, percentile, and median values for manganese content (parts per million, as-received, whole-coal basis) of coals, grouped by assessed coal or stratigraphic unit in the Illinois Basin.

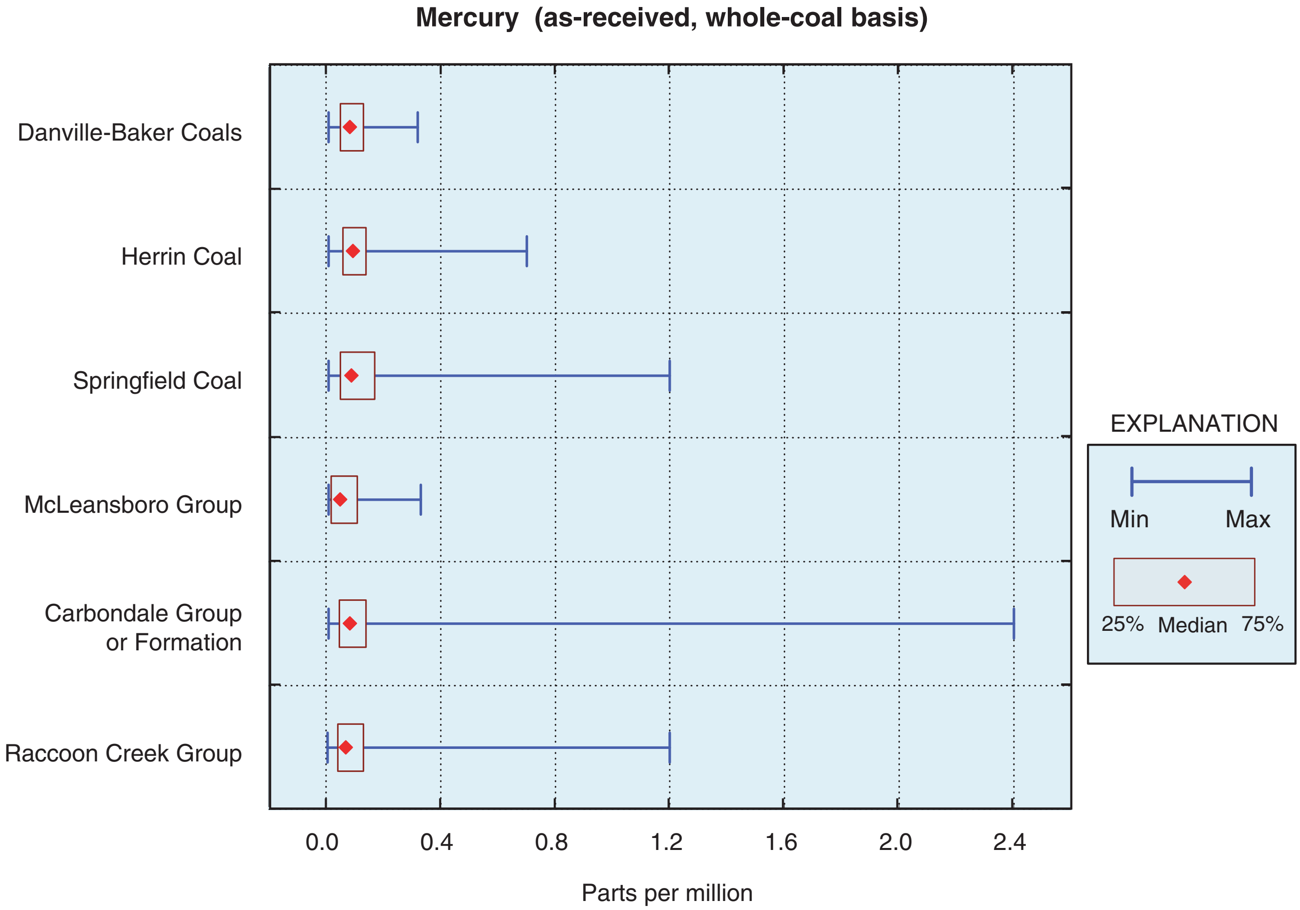

Figure 12. Minimum, maximum, percentile, and median values for mercury content (parts per million, as-received, whole-coal basis) of coals, grouped by assessed coal or stratigraphic unit in the Illinois Basin.

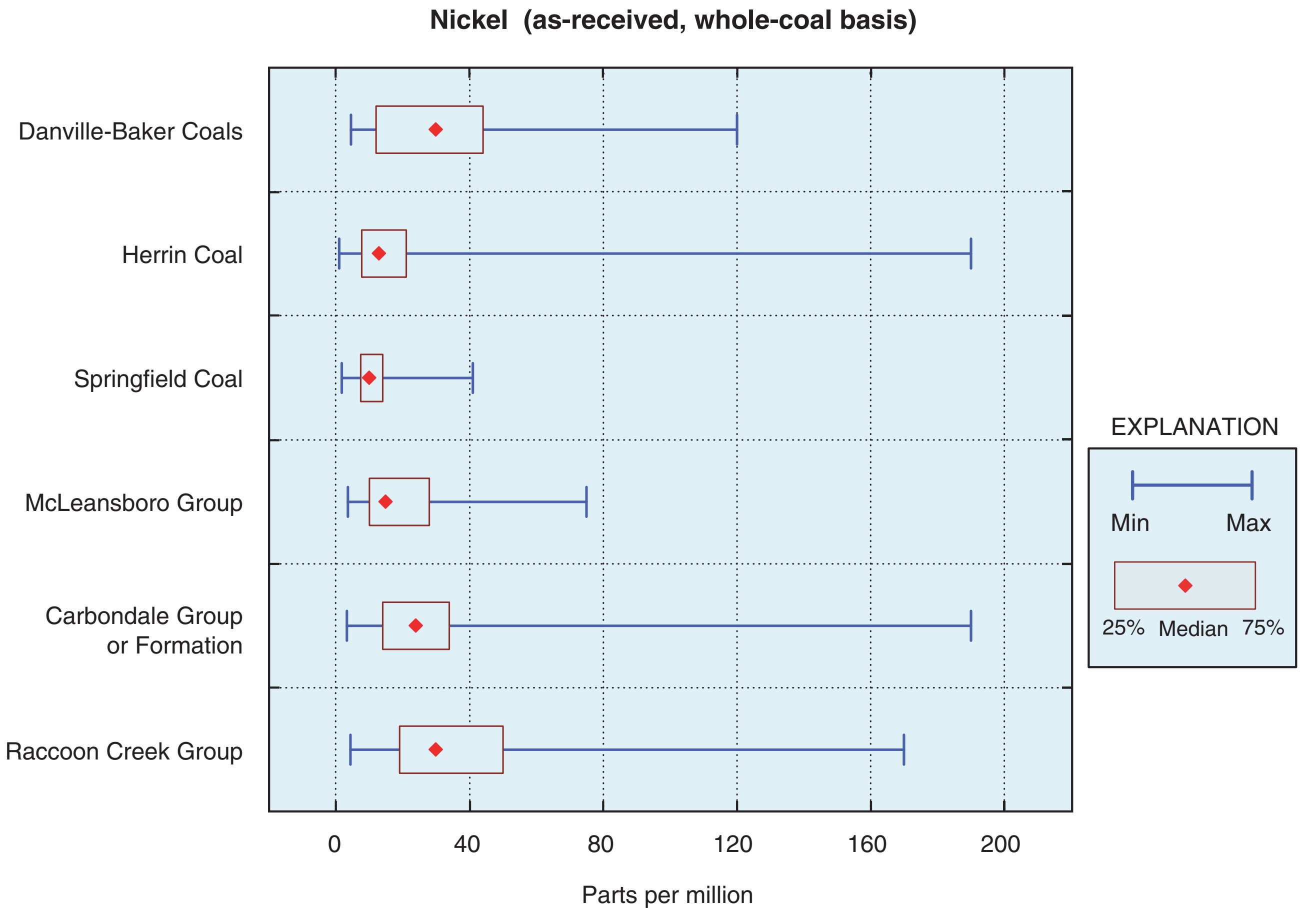

Figure 13. Minimum, maximum, percentile, and median values for nickel content (parts per million, as-received, whole-coal basis) of coals, grouped by assessed coal or stratigraphic unit in the Illinois Basin.

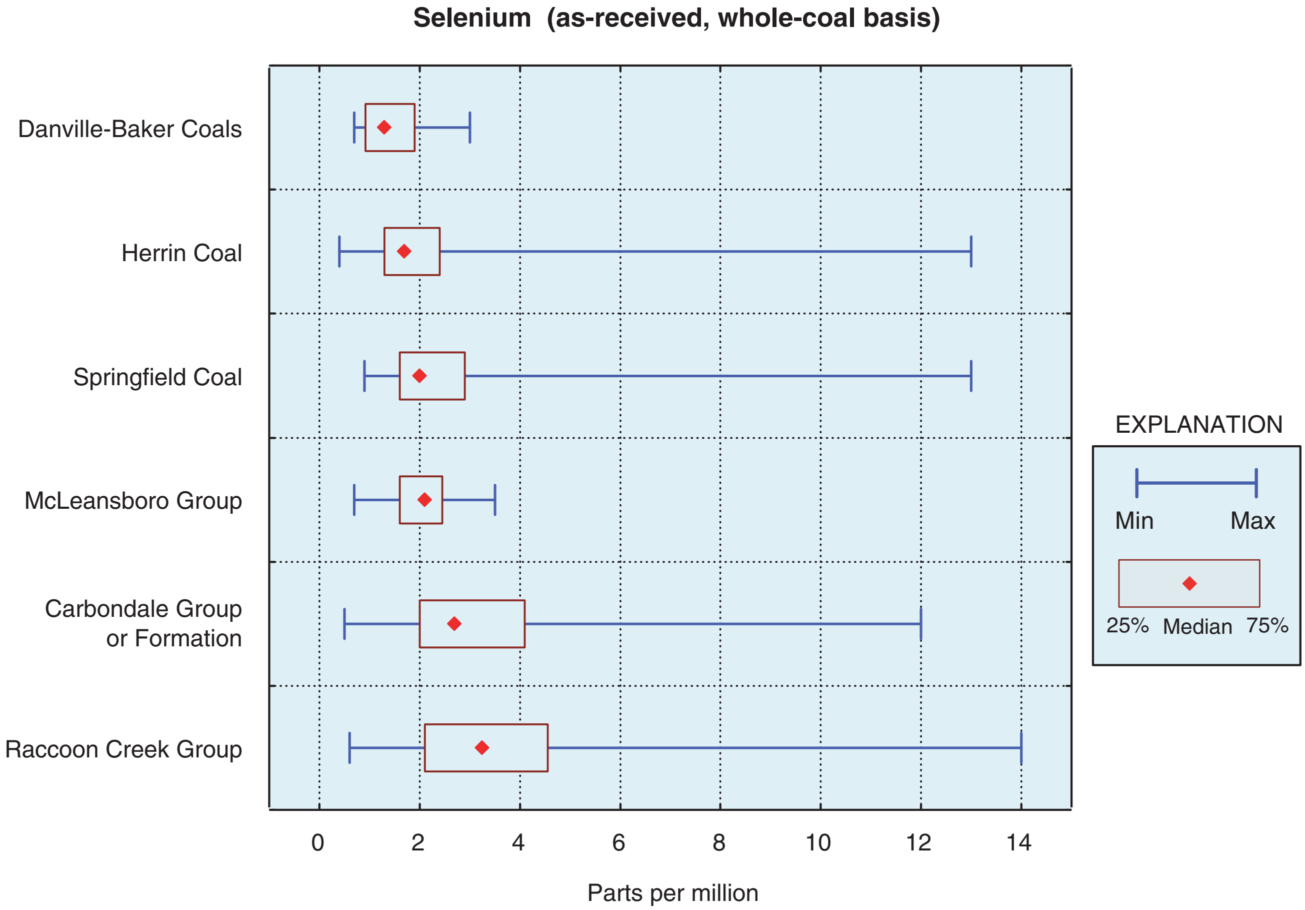

Figure 14. Minimum, maximum, percentile, and median values for selenium content (parts per million, as-received, whole-coal basis) of coals, grouped by assessed coal or stratigraphic unit in the Illinois Basin.

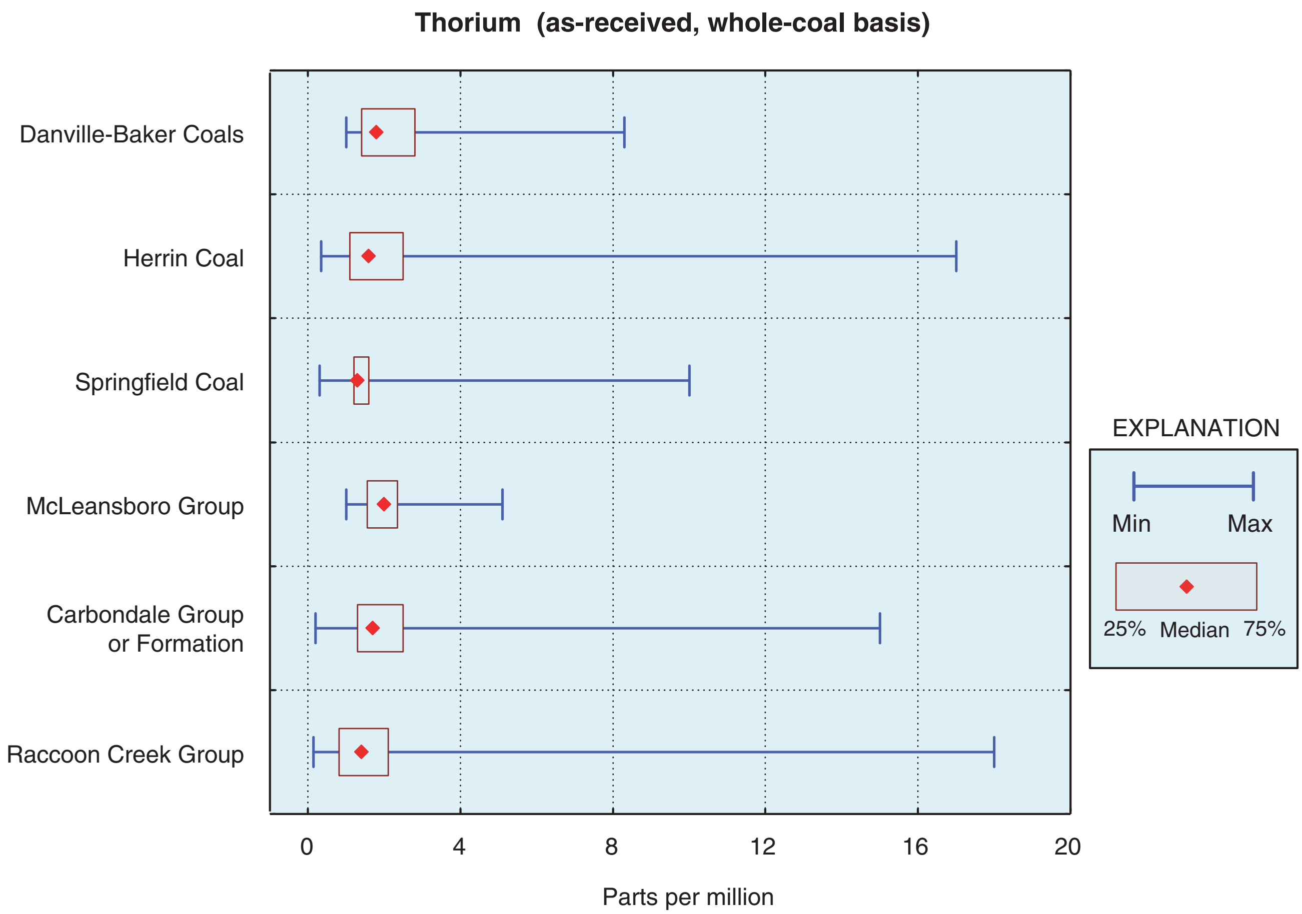

Figure 15. Minimum, maximum, percentile, and median values for thorium content (parts per million, as-received, whole-coal basis) of coals, grouped by assessed coal or stratigraphic unit in the Illinois Basin.

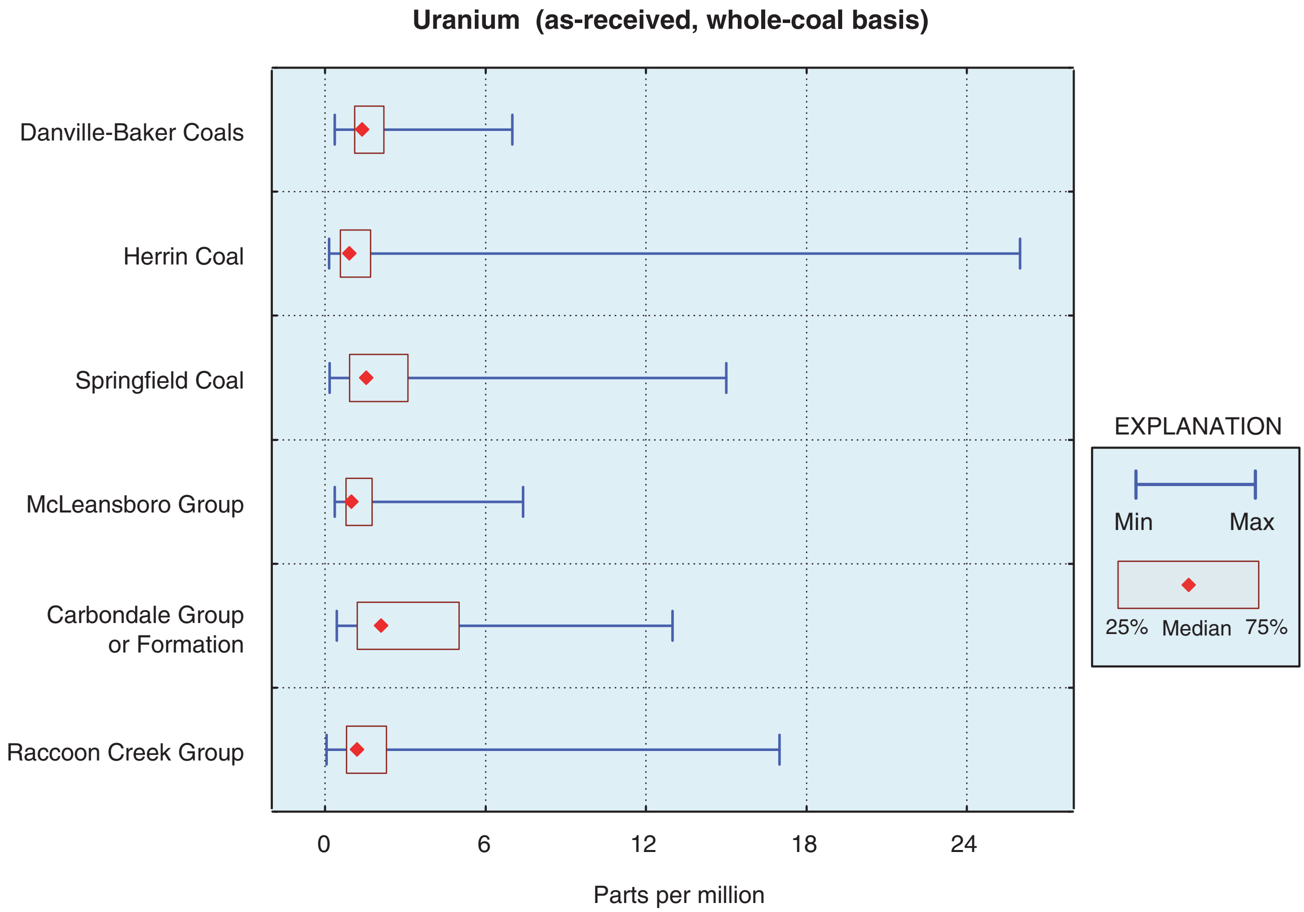

Figure 16. Minimum, maximum, percentile, and median values for uranium content (parts per million, as-received, whole-coal basis) of coals, grouped by assessed coal or stratigraphic unit in the Illinois Basin.

Appendix 6. Histograms of ash yield, sulfur content, calorific value, and elements of environmental concern for the Springfield, Herrin, and Danville-Baker Coals in the Illinois Basin.

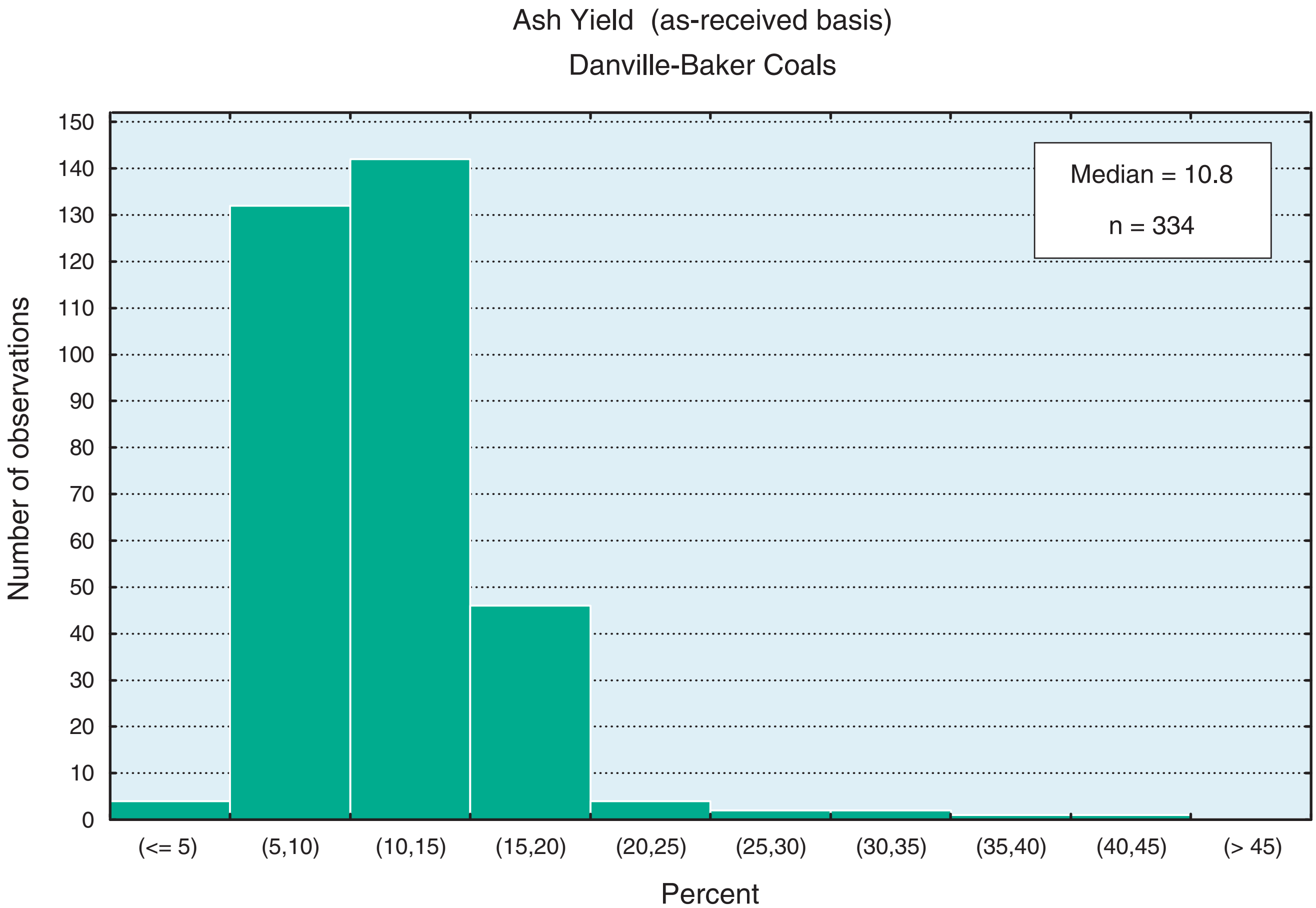

Figure 1. Histogram of ash yield (percent, as-received basis) of the Danville-Baker Coals in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

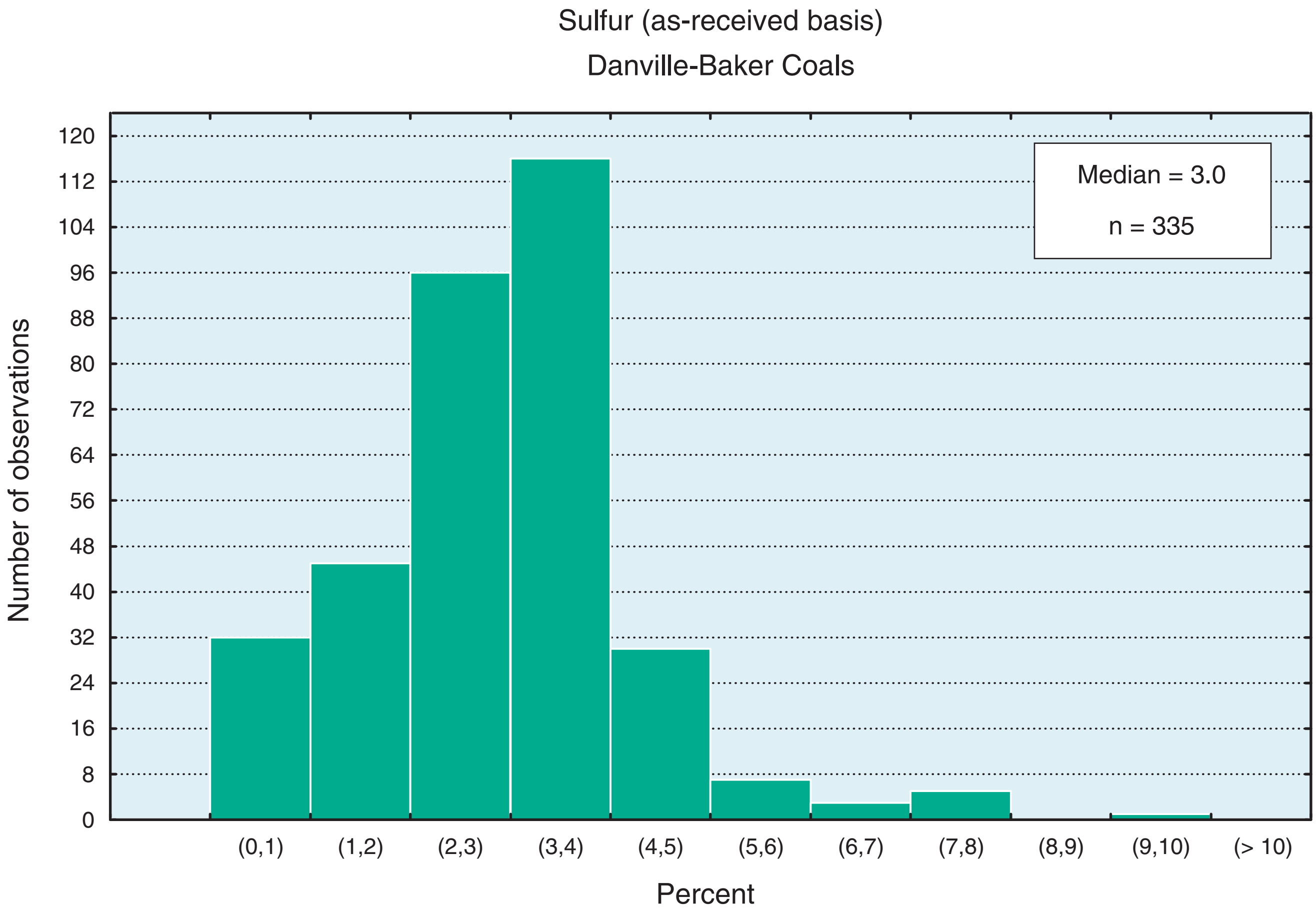

Figure 2. Histogram of sulfur content (percent, as-received basis) of the Danville-Baker Coals in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

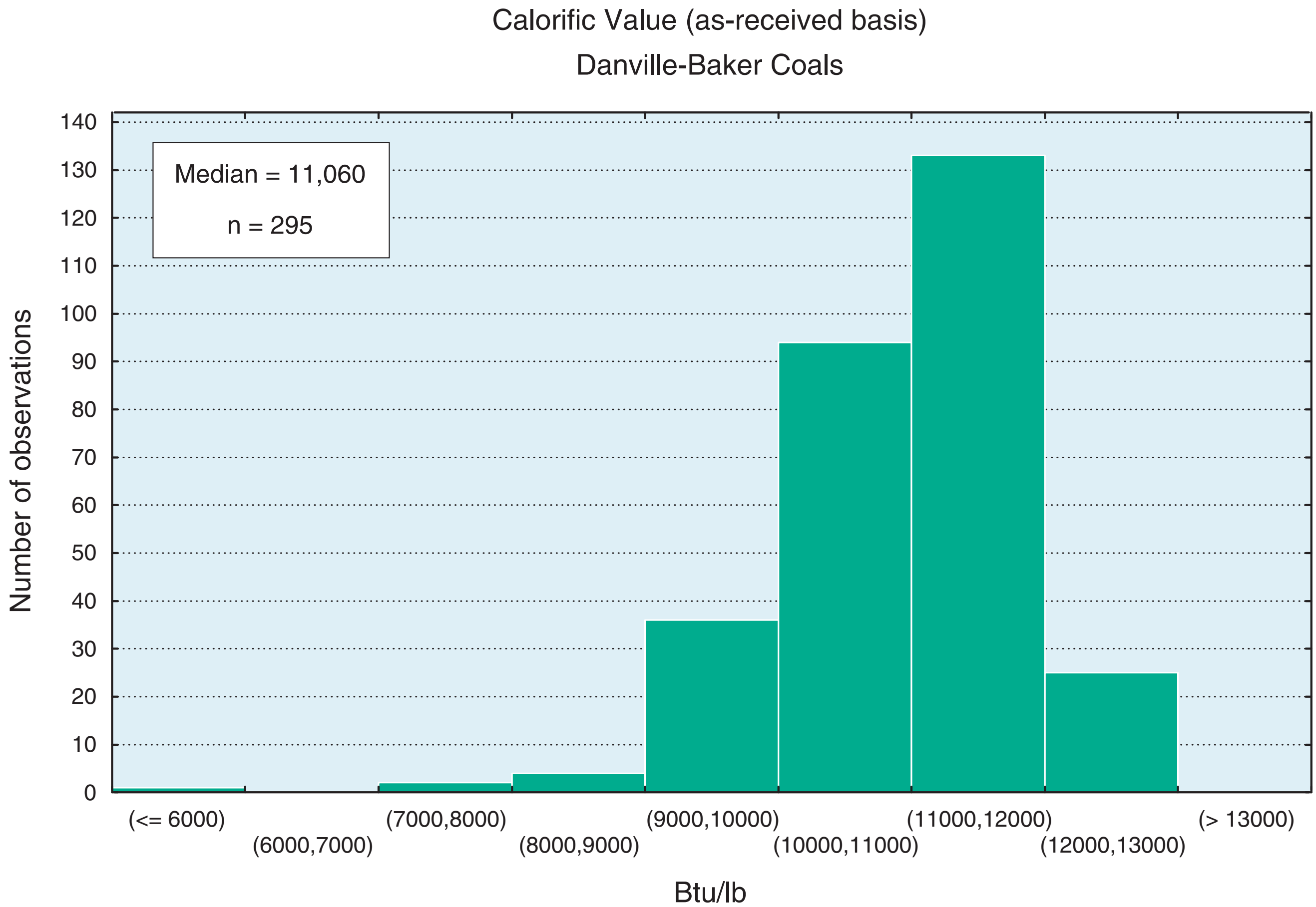

Figure 3. Histogram of calorific values (Btu/lb, as-received basis) of the Danville-Baker Coals in the Illinois Basin. Intervals on the x-axis are shown in parentheses

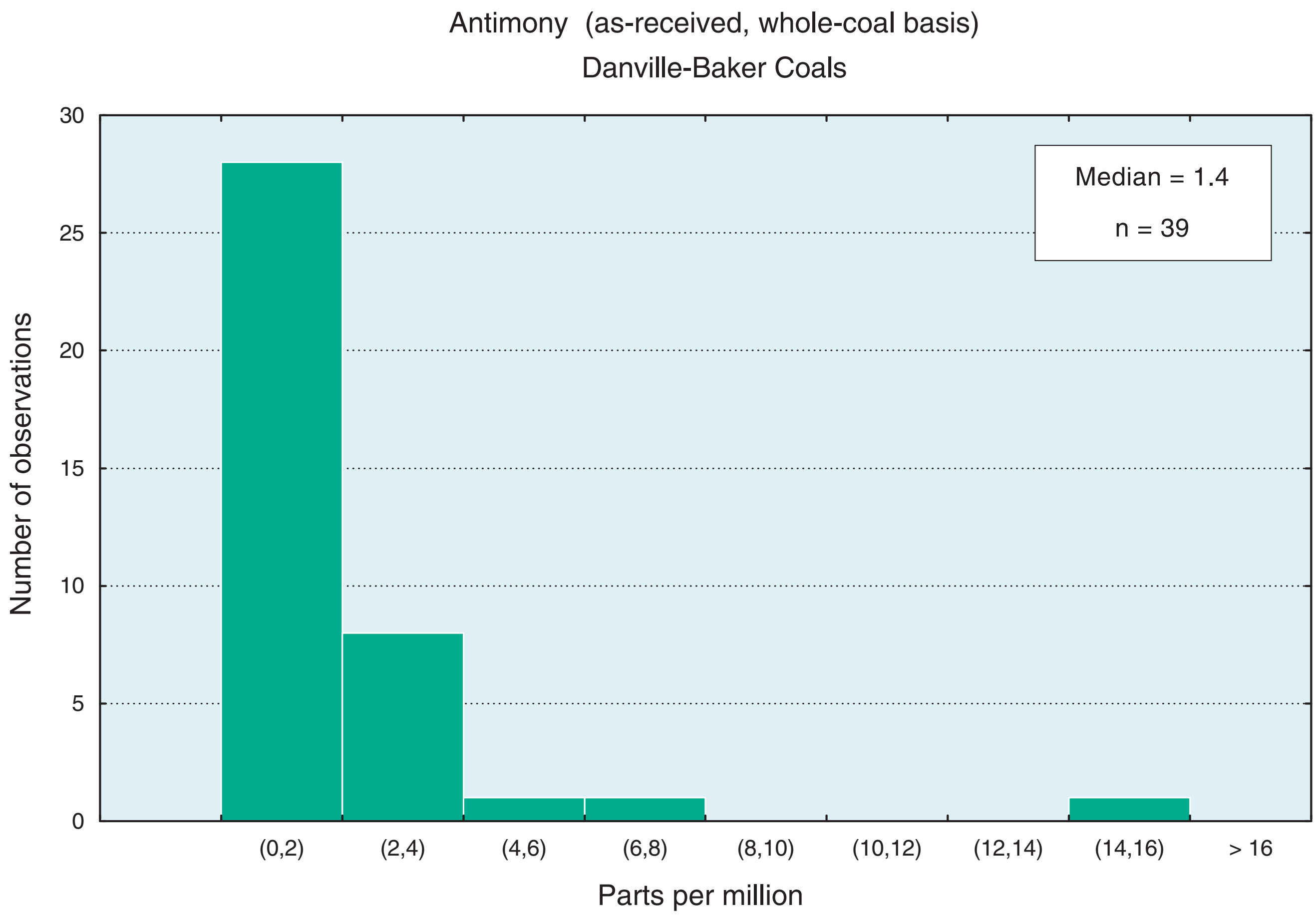

Figure 4. Histogram of antimony content (parts per million, as-received, whole-coal basis) of the Danville-Baker Coals in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

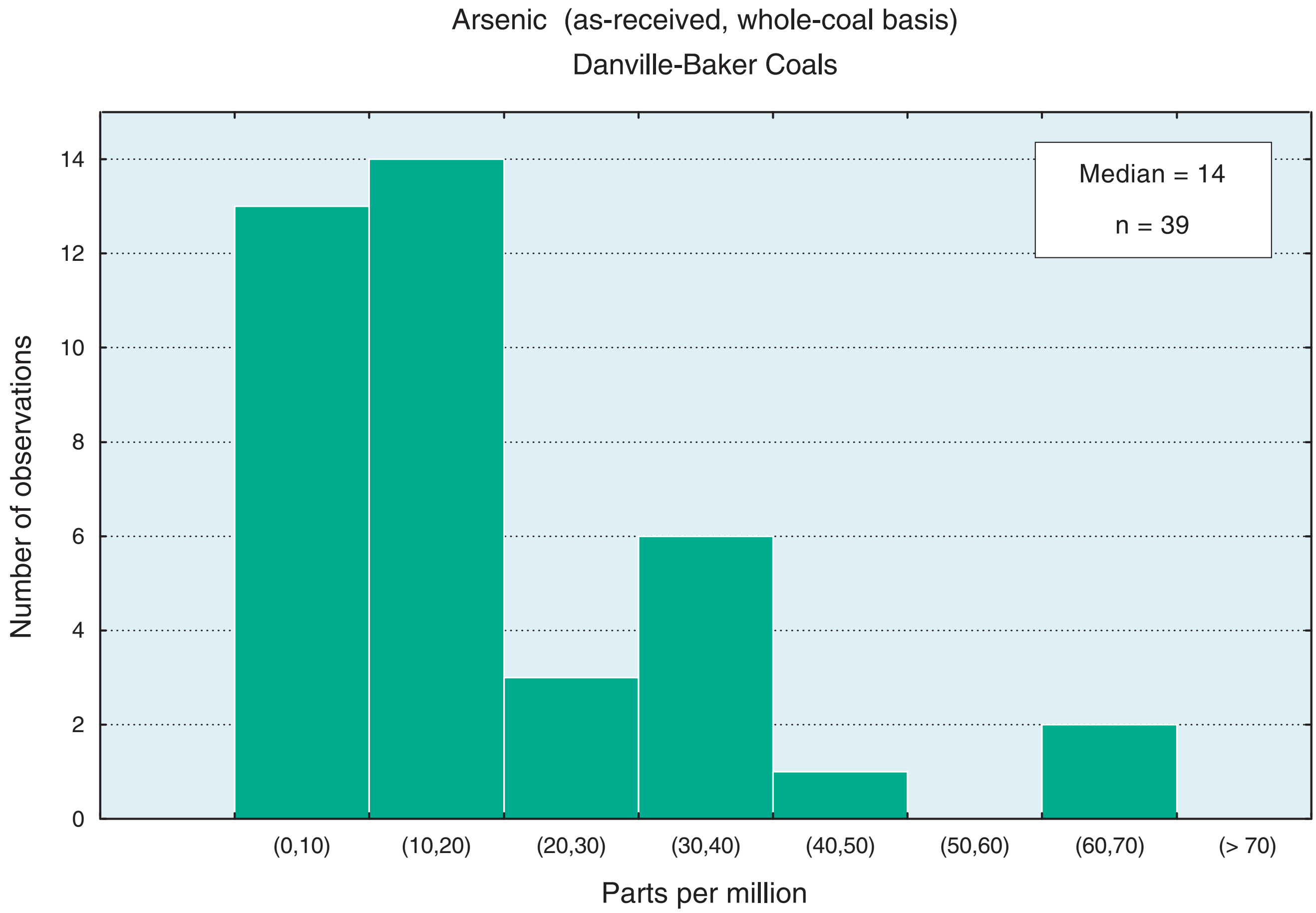

Figure 5. Histogram of arsenic content (parts per million, as-received, whole-coal basis) of the Danville-Baker Coals in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

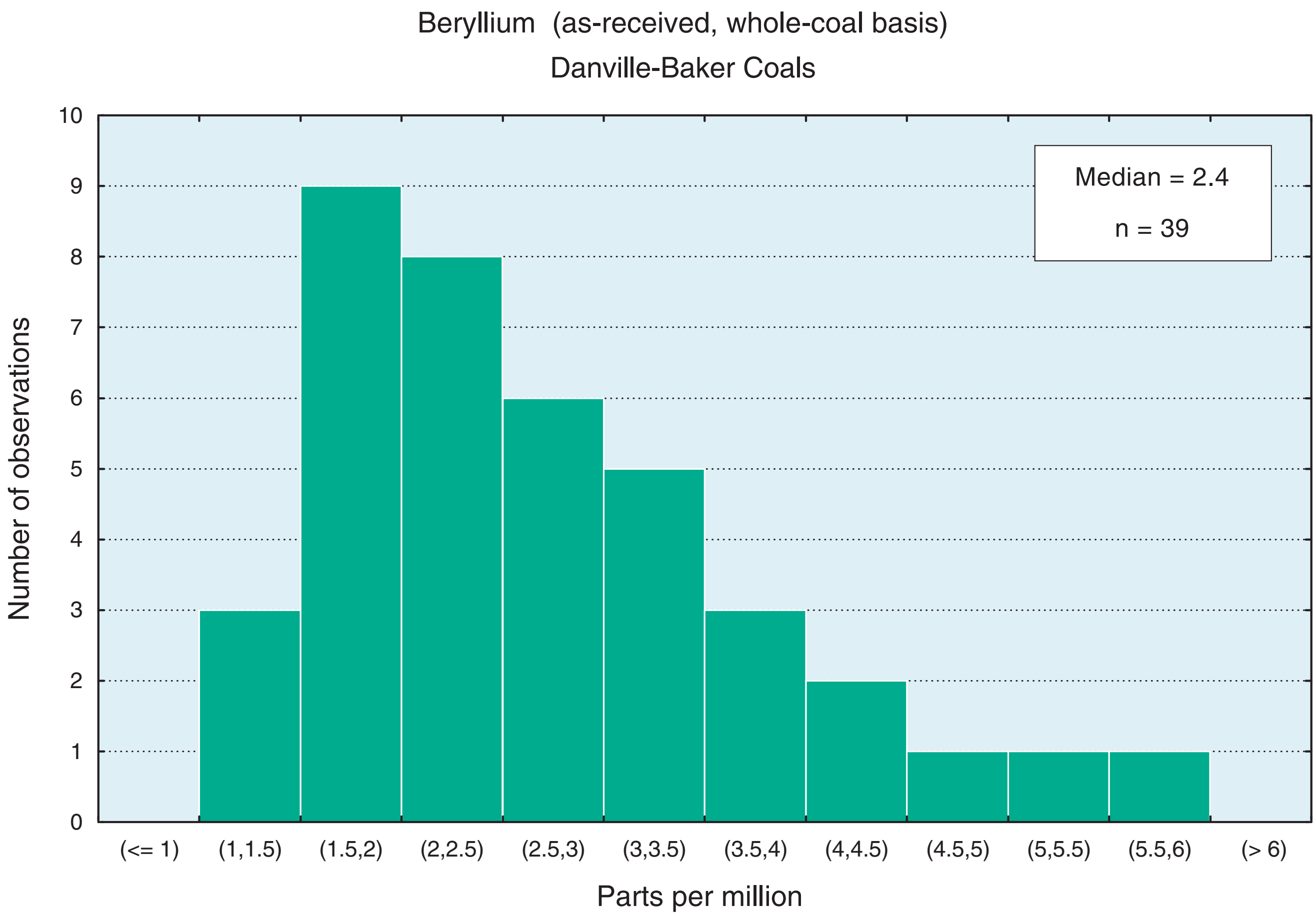

Figure 6. Histogram of beryllium content (parts per million, as-received, whole-coal basis) of the Danville-Baker Coals in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

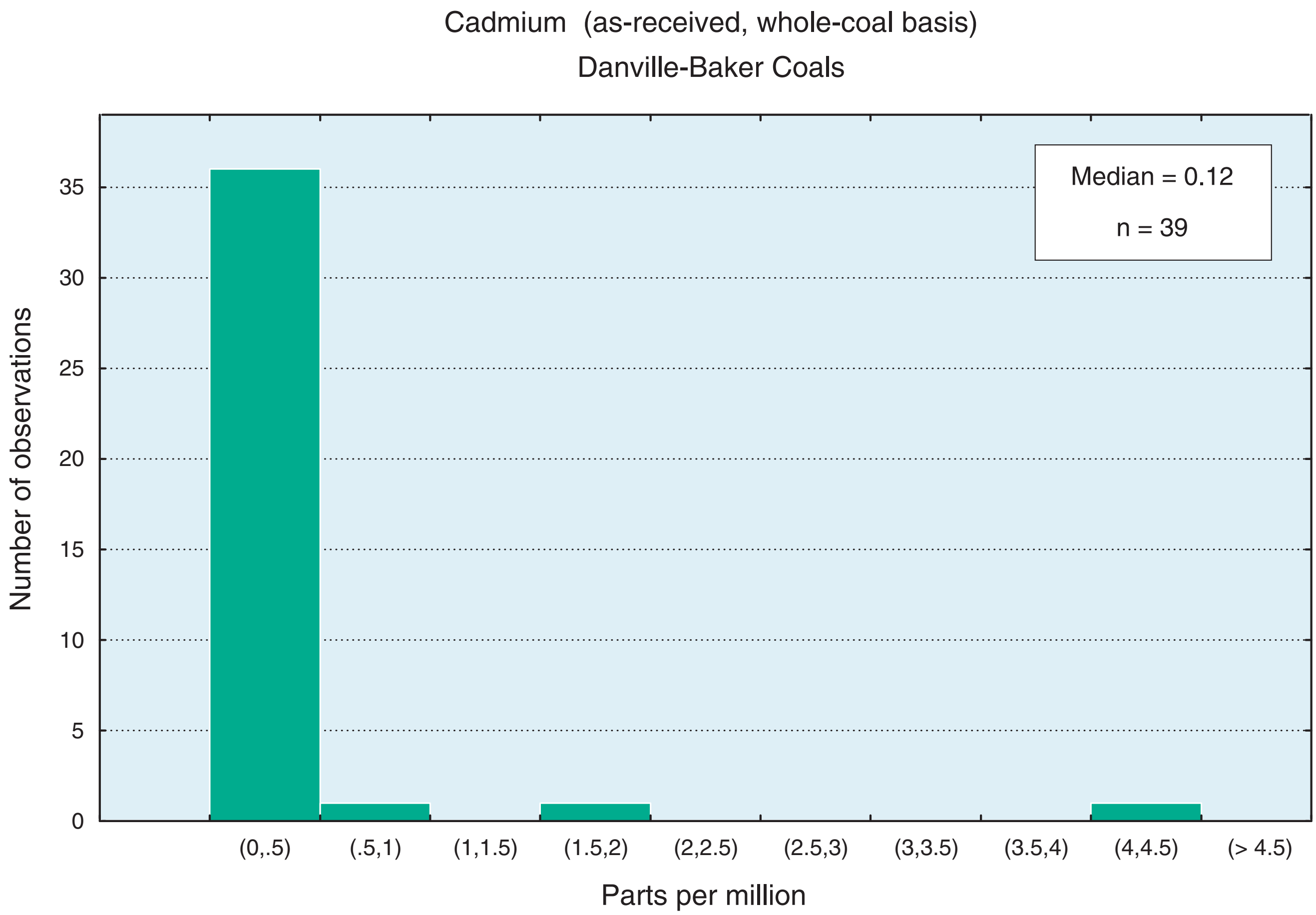

Figure 7. Histogram of cadmium content (parts per million, as-received, whole-coal basis) of the Danville-Baker Coals in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

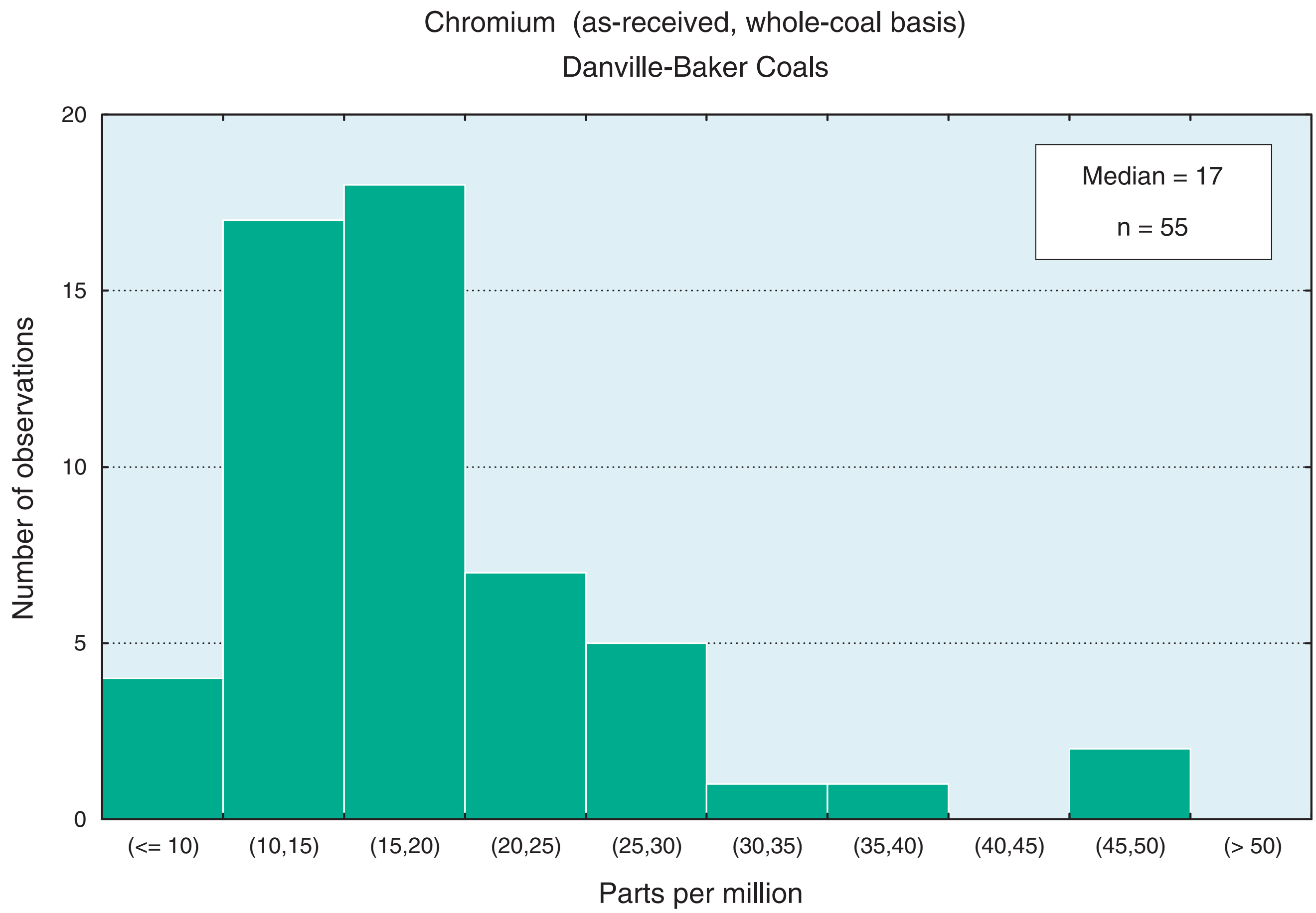

Figure 8. Histogram of chromium content (parts per million, as-received, whole-coal basis) of the Danville-Baker Coals in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

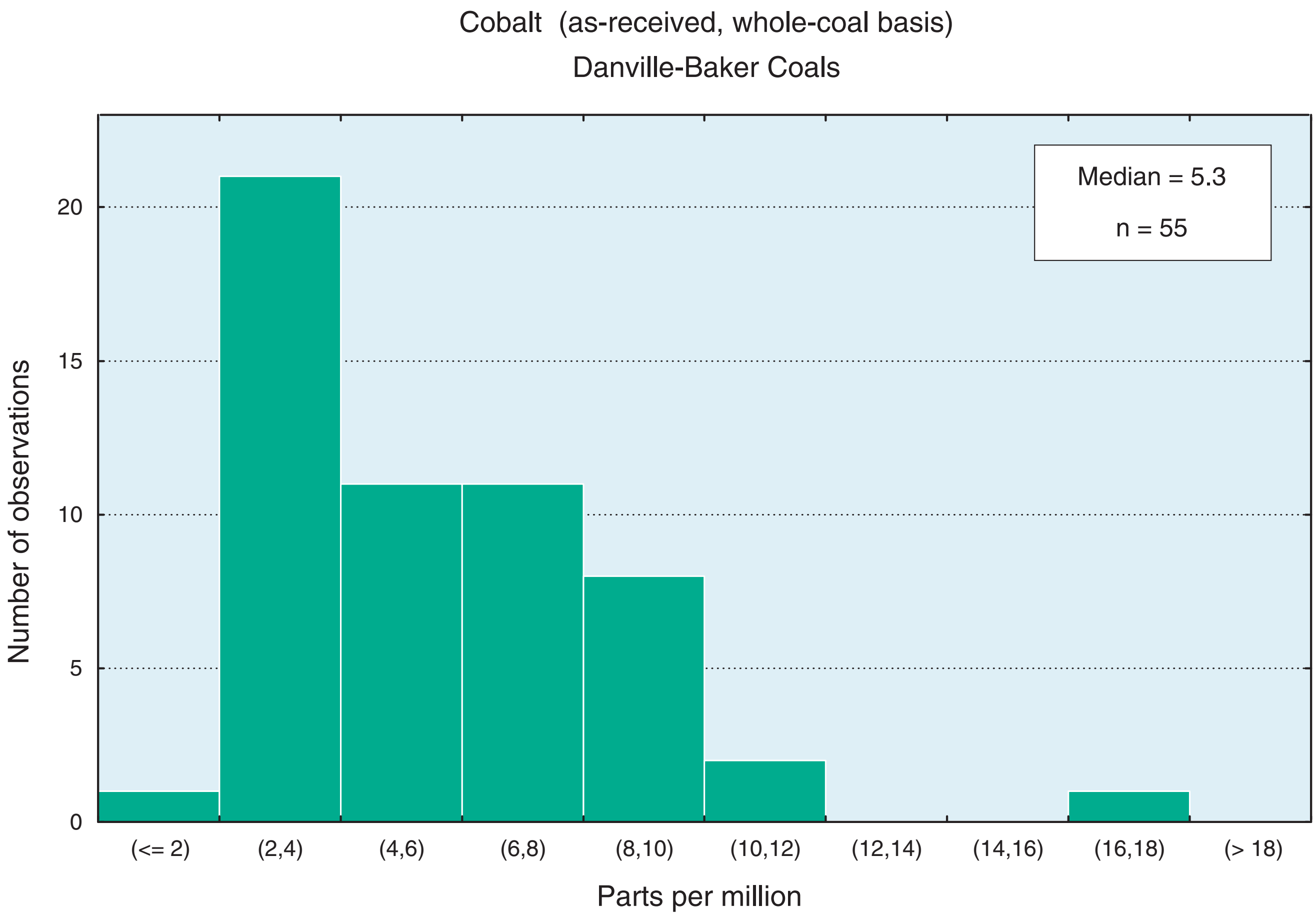

Figure 9. Histogram of cobalt content (parts per million, as-received, whole-coal basis) of the Danville-Baker Coals in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

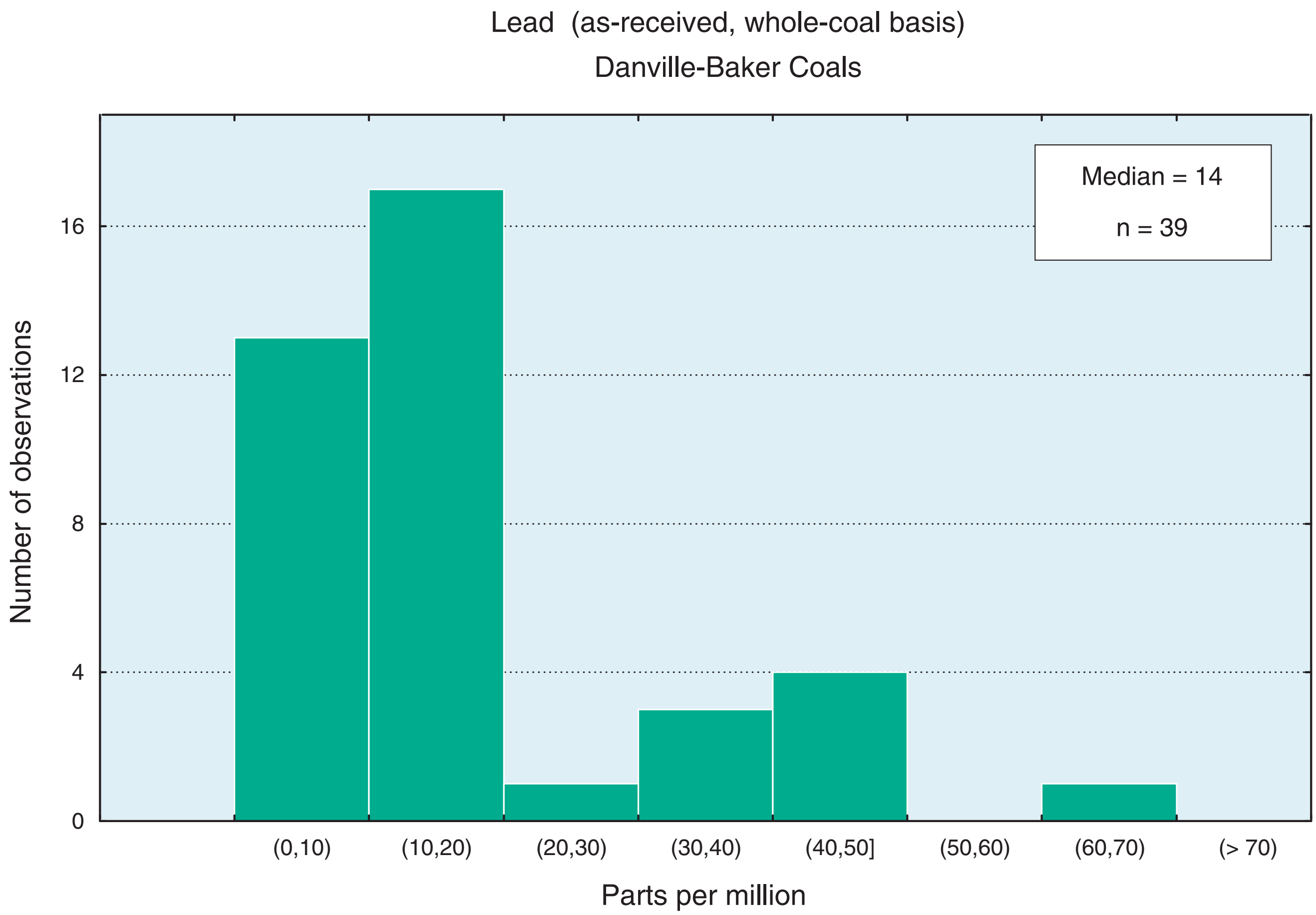

Figure 10. Histogram of lead content (parts per million, as-received, whole-coal basis) of the Danville-Baker Coals in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

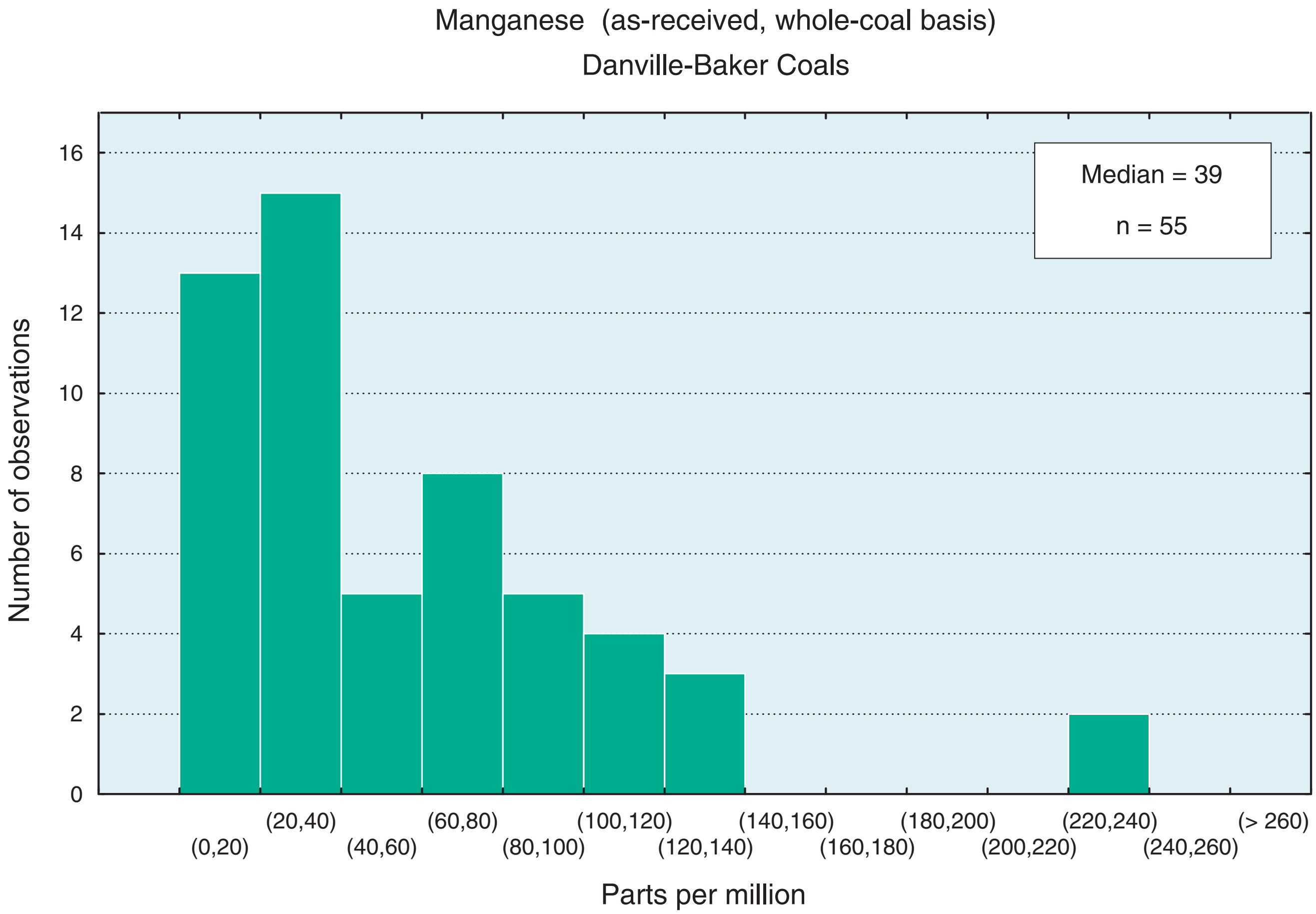

Figure 11. Histogram of manganese content (parts per million, as-received, whole-coal basis) of the Danville-Baker Coals in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

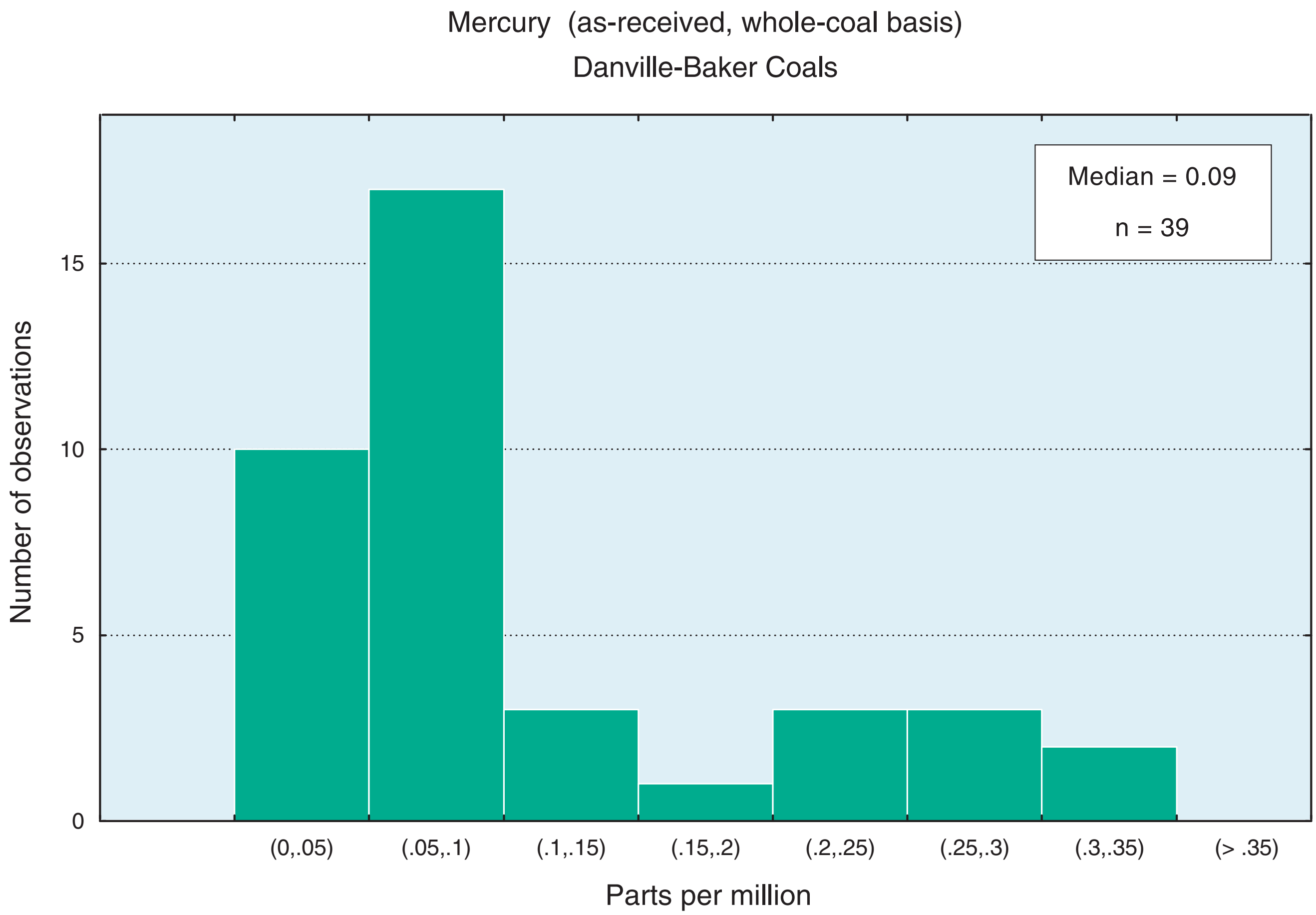

Figure 12. Histogram of mercury content (parts per million, as-received, whole-coal basis) of the Danville-Baker Coals in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

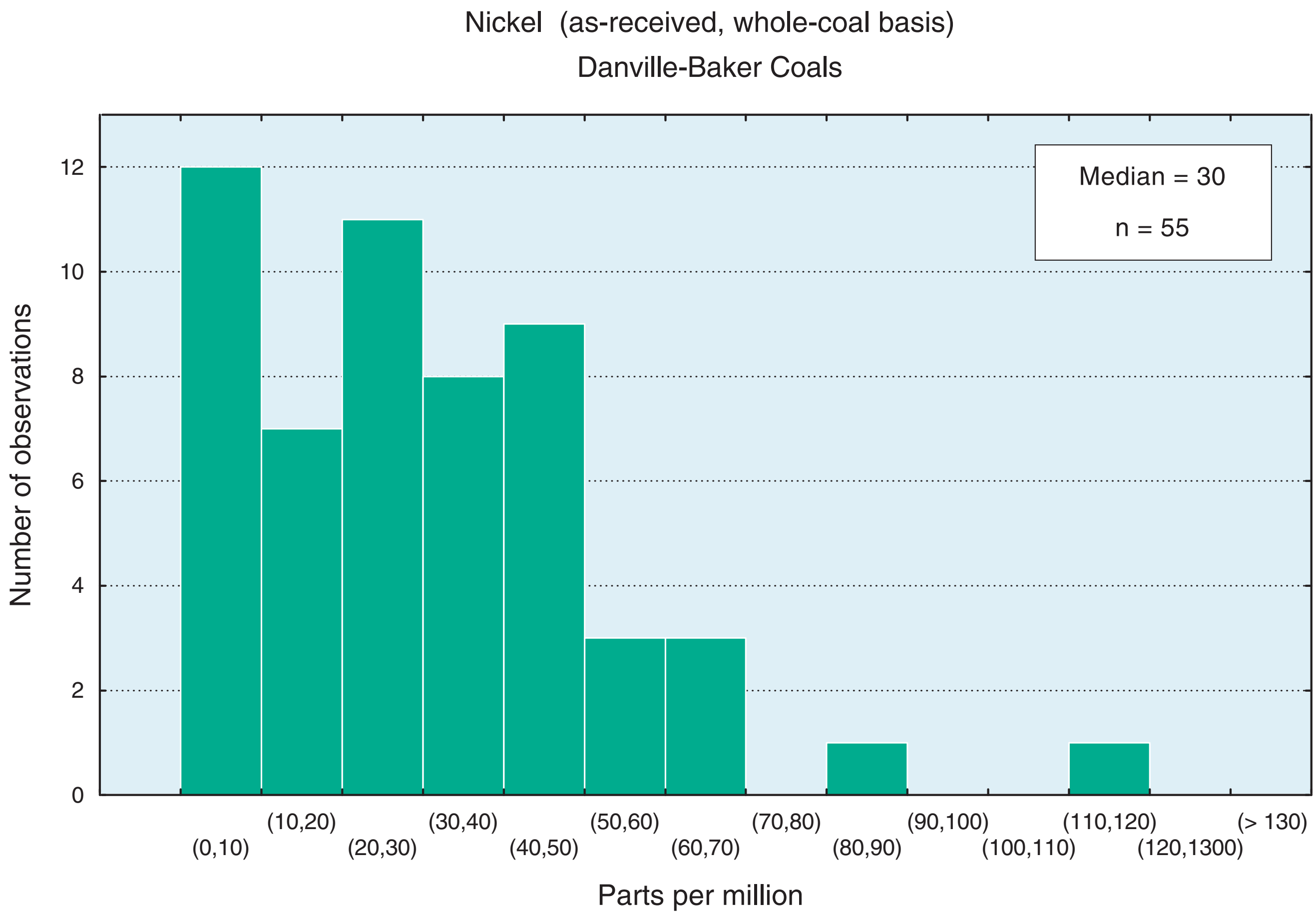

Figure 13. Histogram of nickel content (parts per million, as-received, whole-coal basis) of the Danville-Baker Coals in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

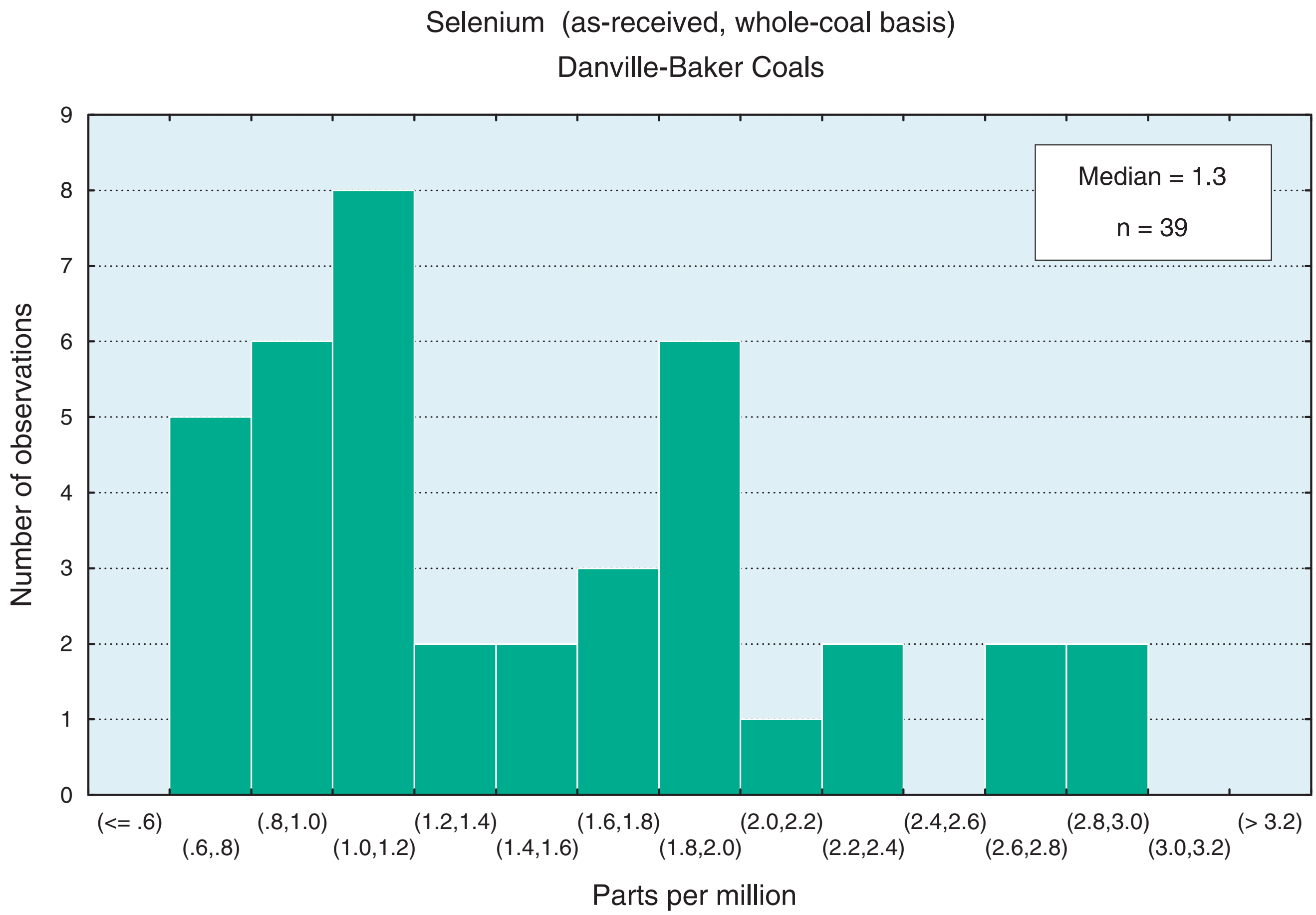

Figure 14. Histogram of selenium content (parts per million, as-received, whole-coal basis) of the Danville-Baker Coals in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

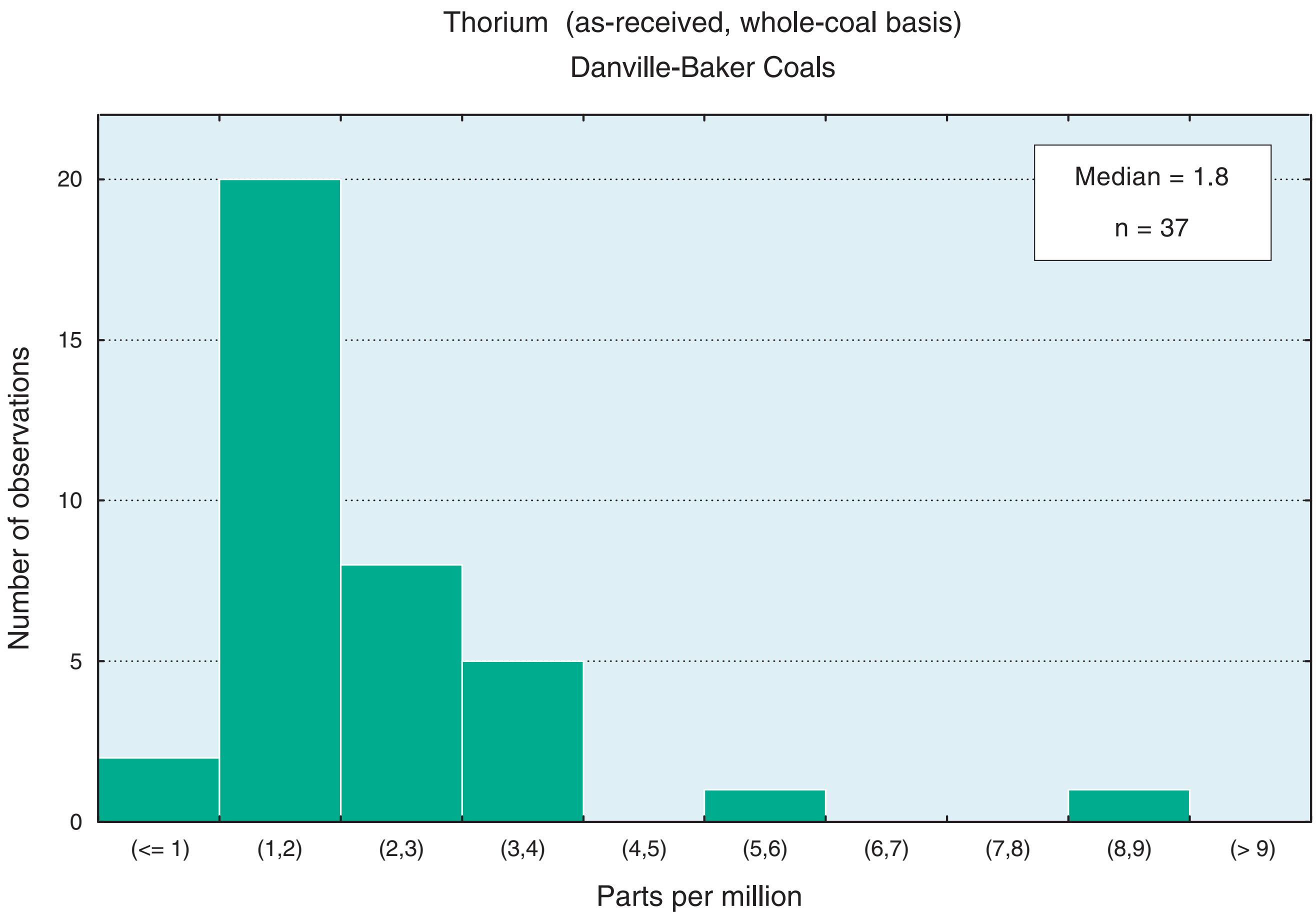

Figure 15. Histogram of thorium content (parts per million, as-received, whole-coal basis) of the Danville-Baker Coals in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

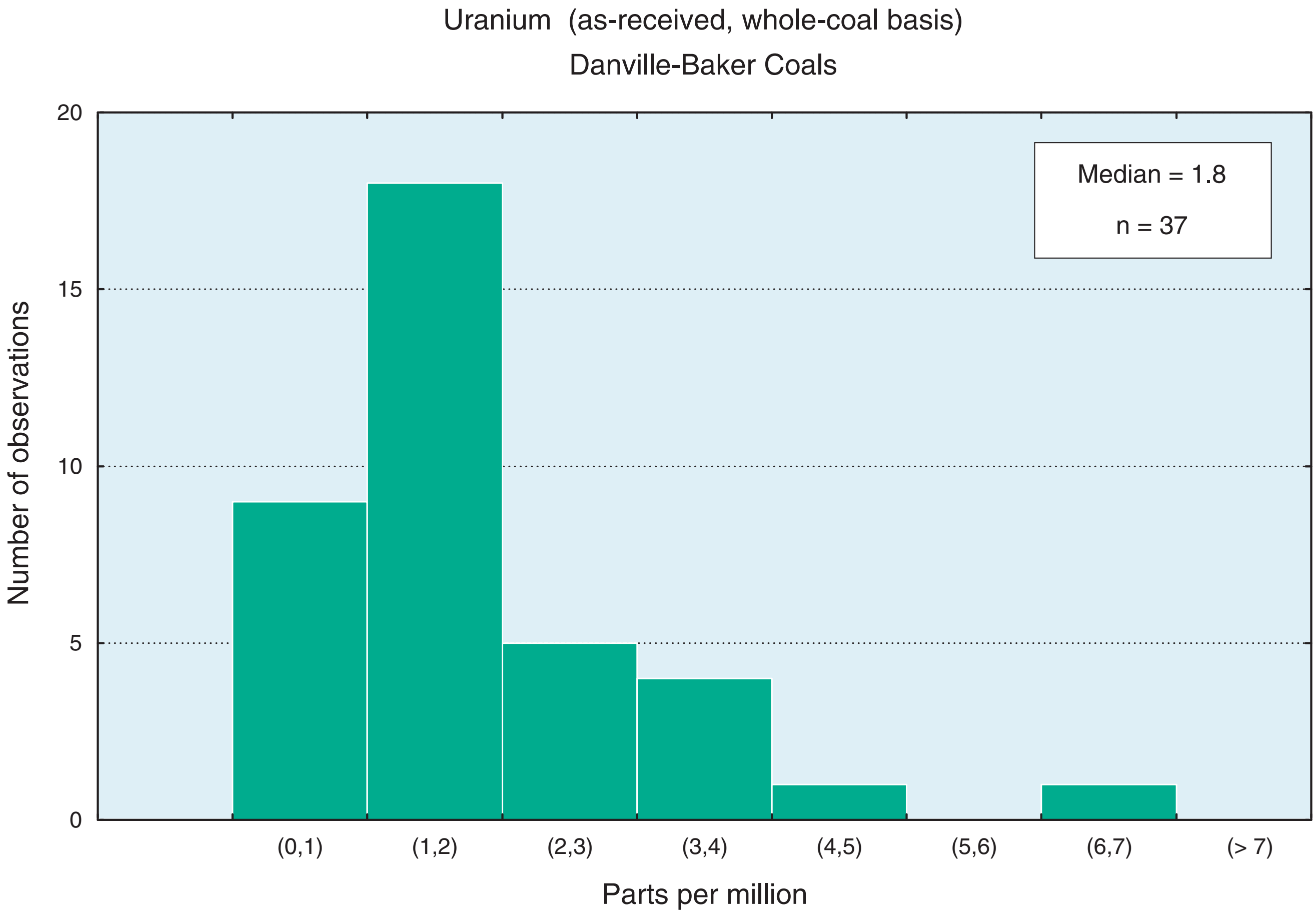

Figure 16. Histogram of uranium content (parts per million, as-received, whole-coal basis) of the Danville-Baker Coals in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

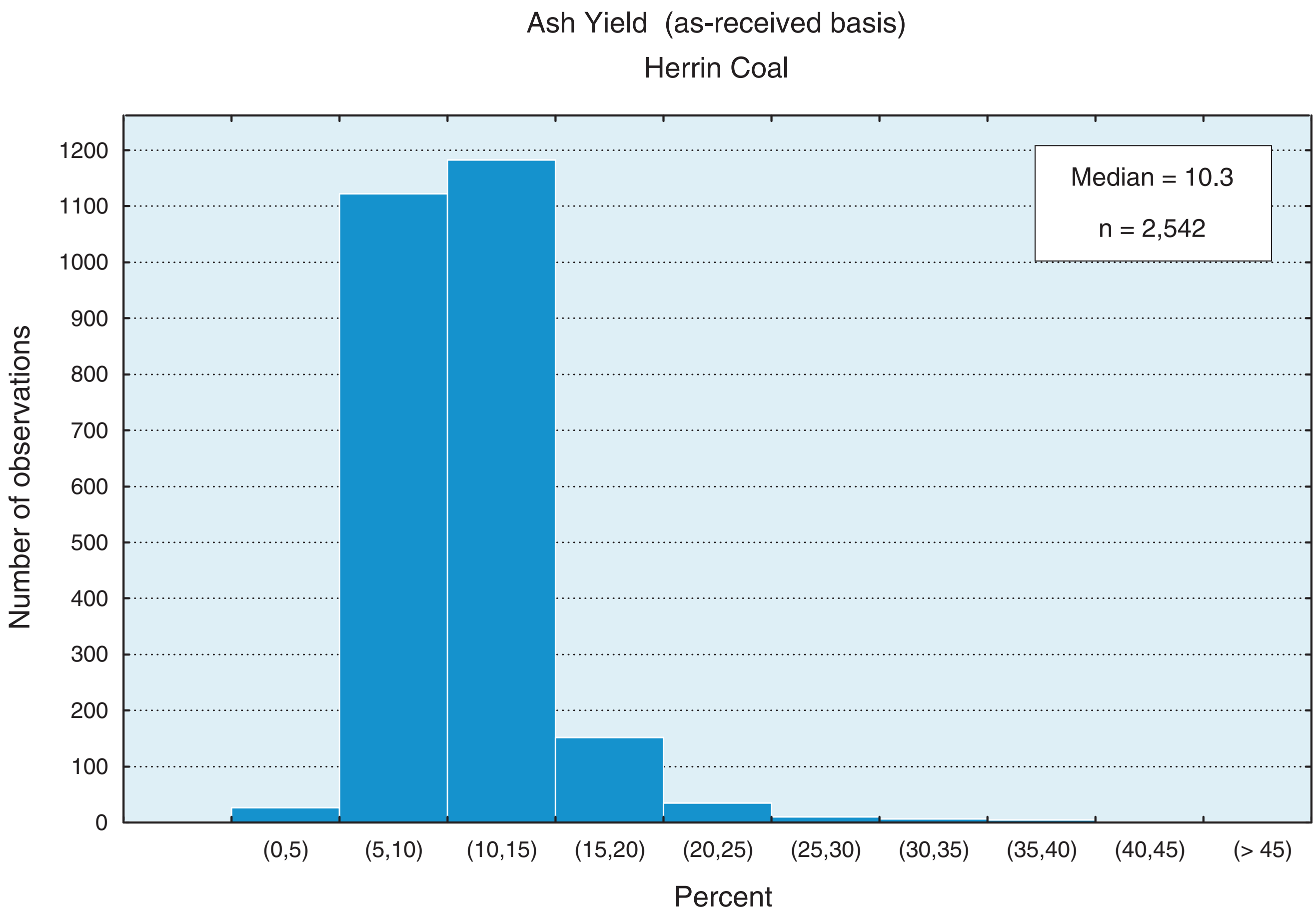

Figure 17. Histogram of ash yield (percent, as-received basis) of the Herrin Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

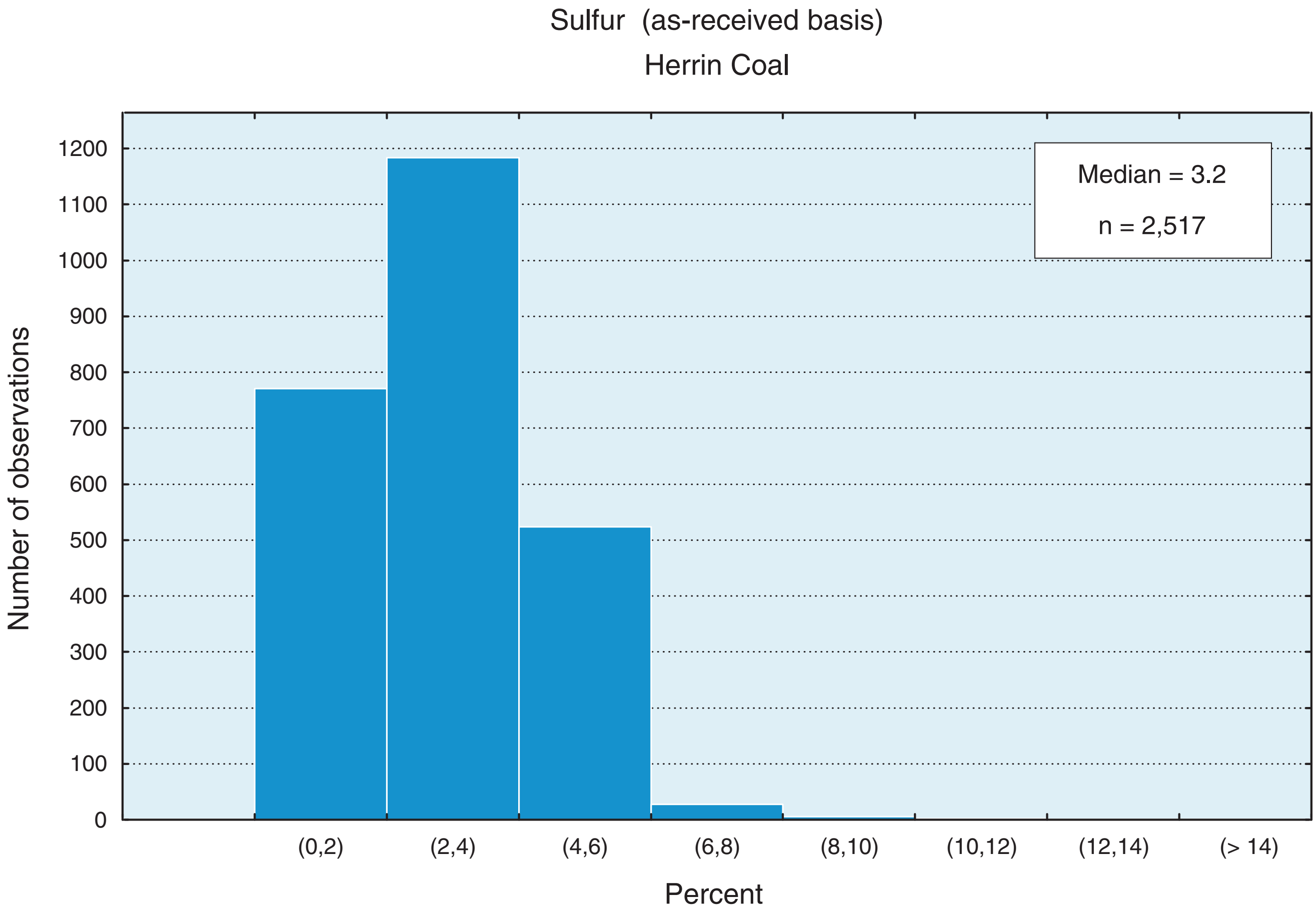

Figure 18. Histogram of sulfur content (percent, as-received basis) of the Herrin Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

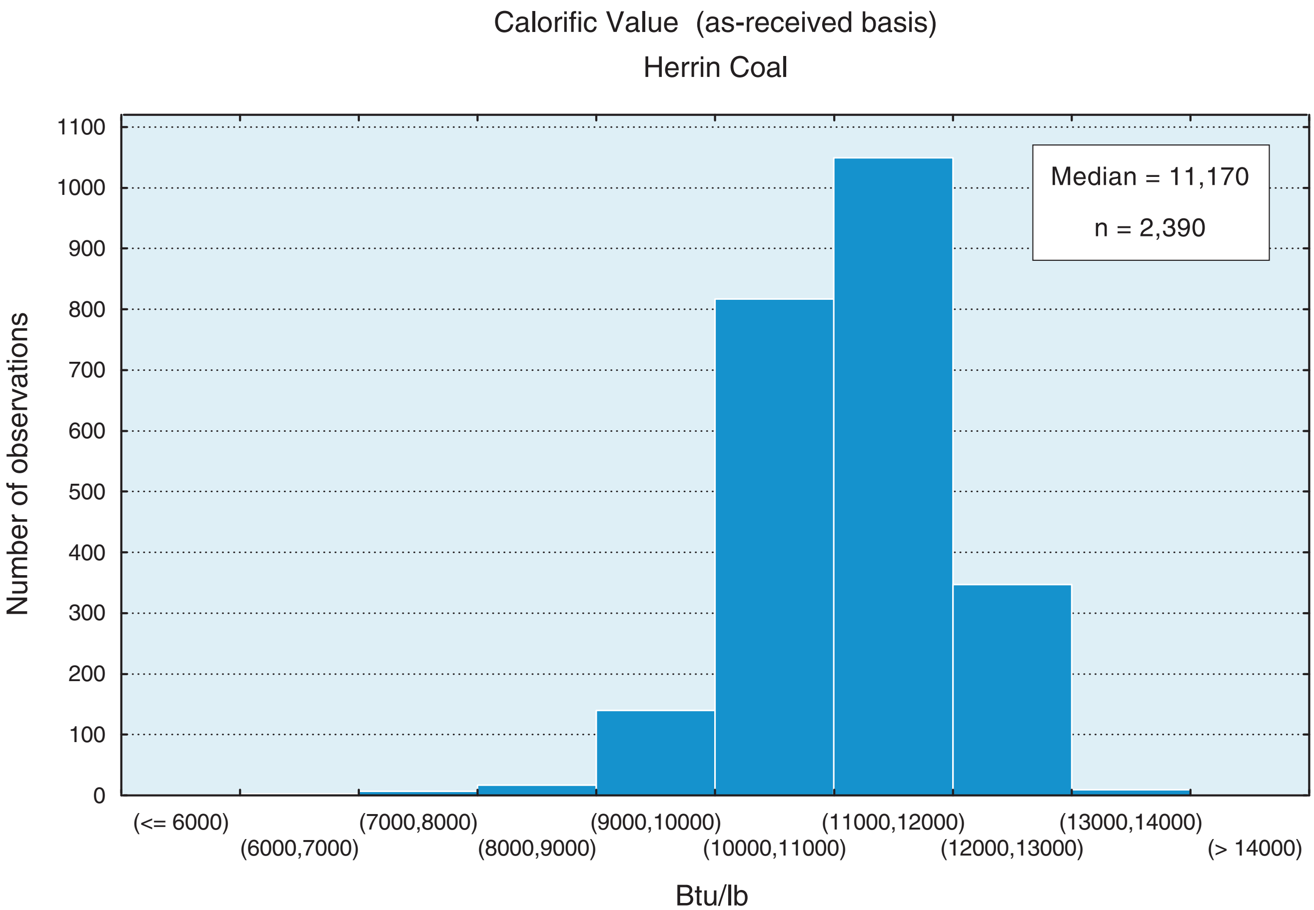

Figure 19. Histogram of calorific values (Btu/lb, as-received basis) of the Herrin Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

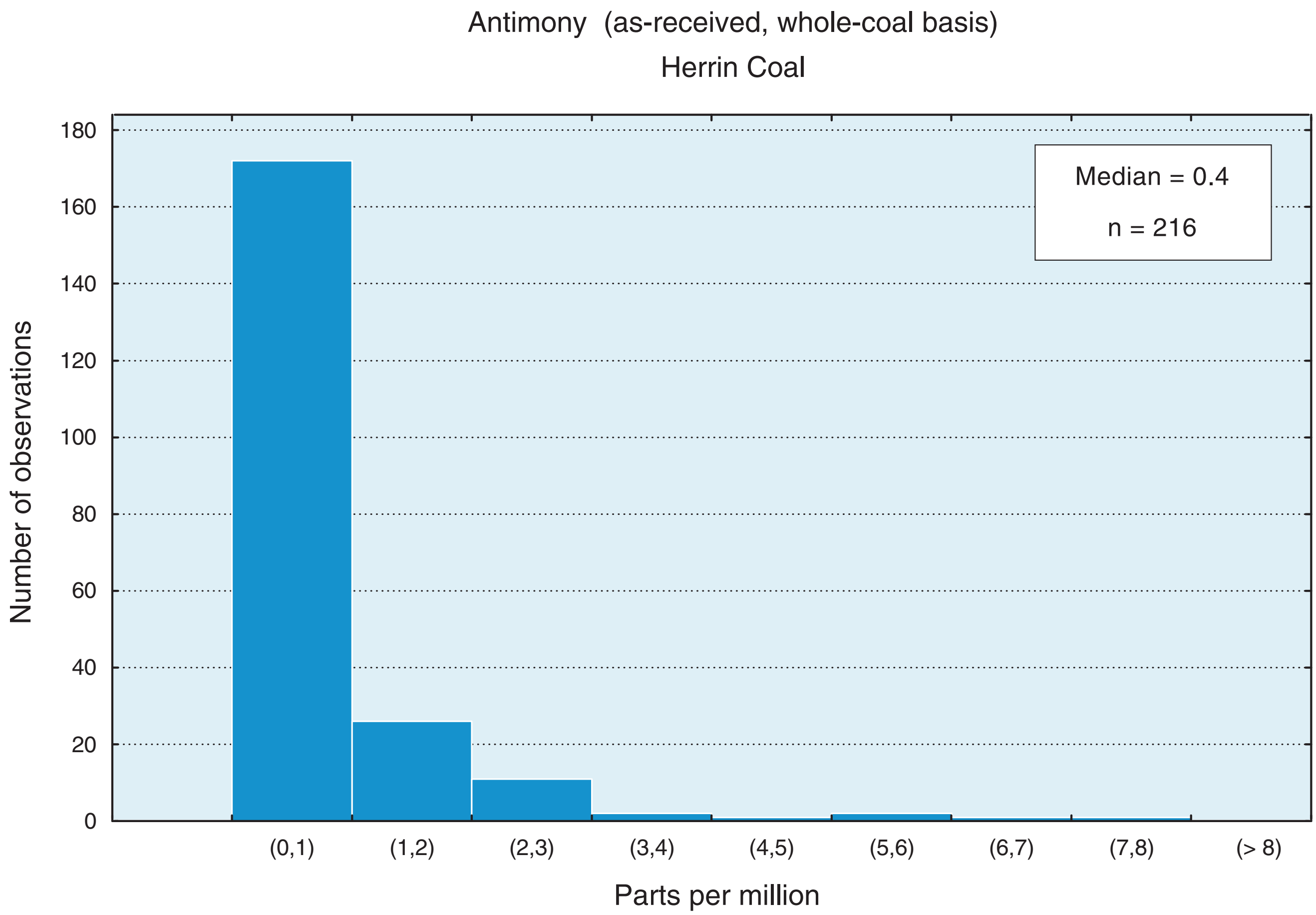

Figure 20. Histogram of antimony content (parts per million, as-received, whole-coal basis) of the Herrin Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

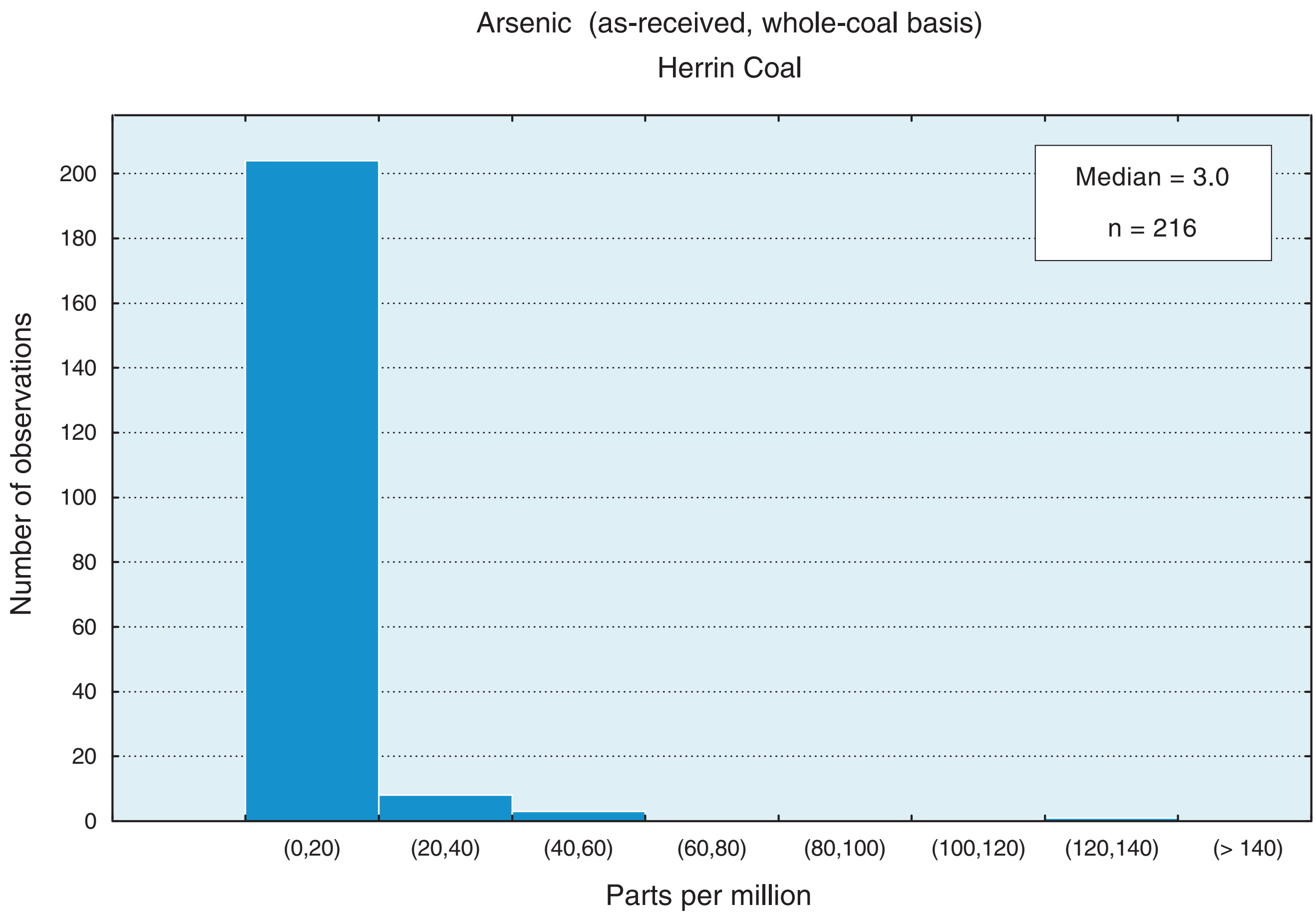

Figure 21. Histogram of arsenic content (parts per million, as-received, whole-coal basis) of the Herrin Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

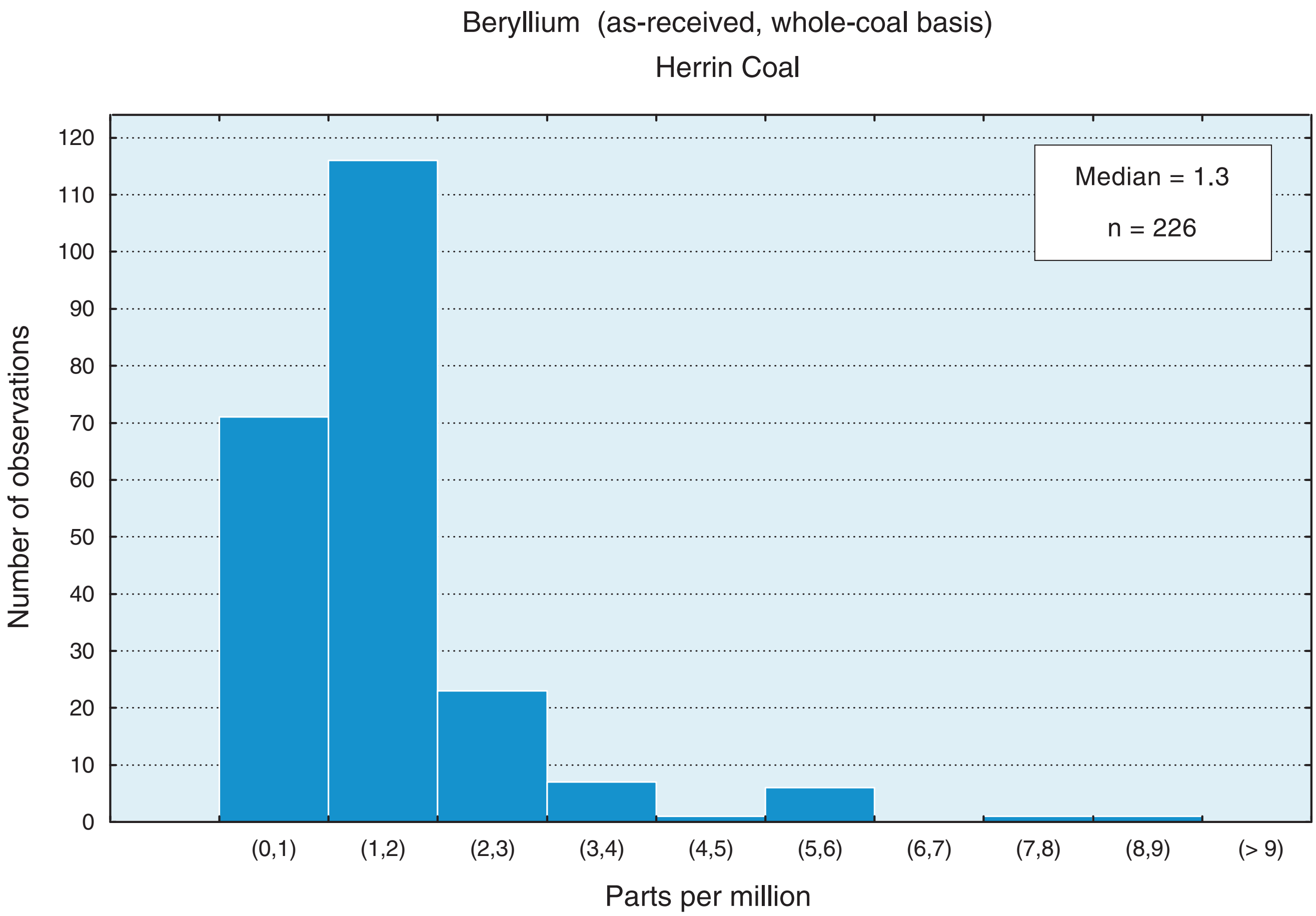

Figure 22. Histogram of beryllium content (parts per million, as-received, whole-coal basis) of the Herrin Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

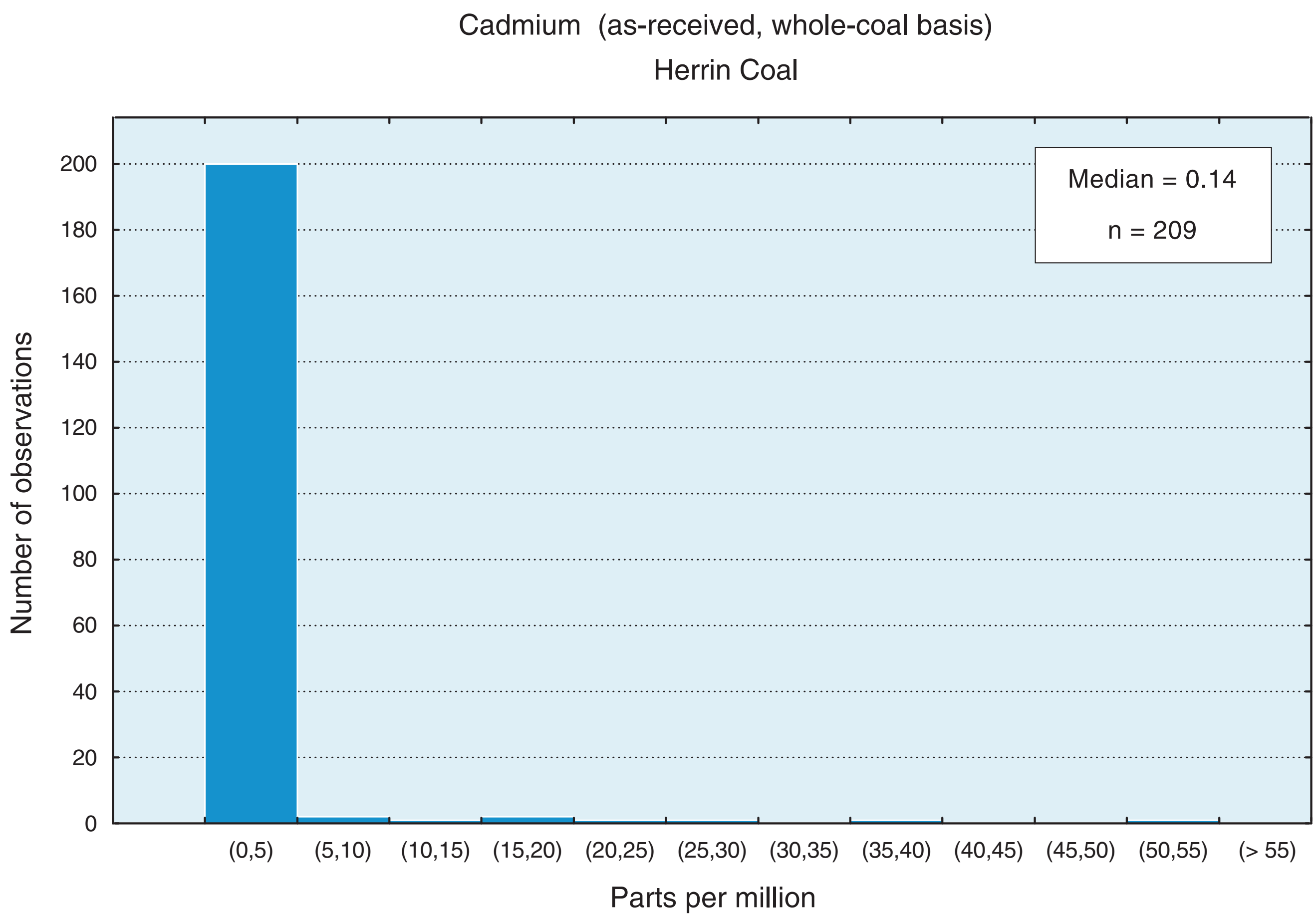

Figure 23. Histogram of cadmium content (parts per million, as-received, whole-coal basis) of the Herrin Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

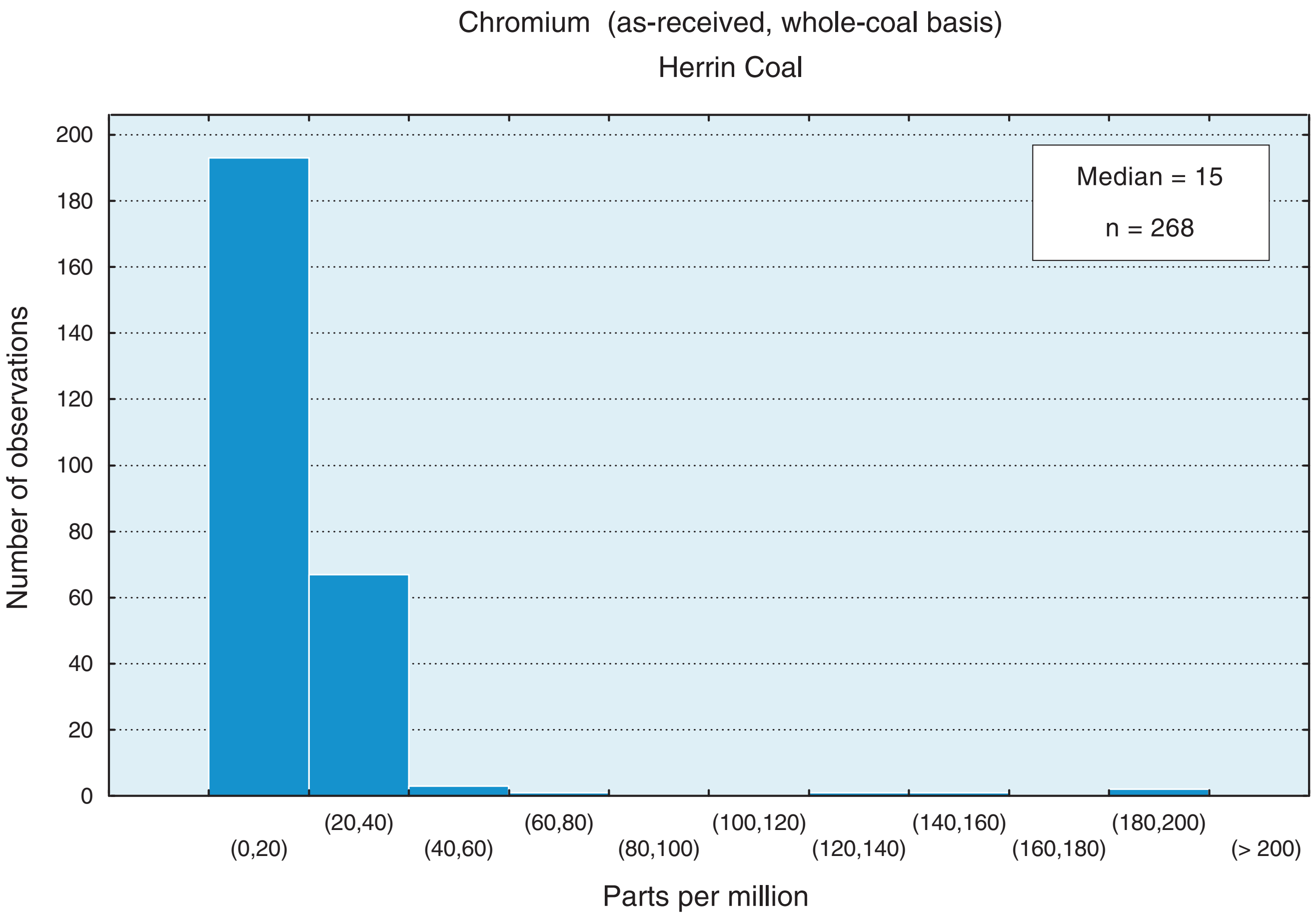

Figure 24. Histogram of chromium content (parts per million, as-received, whole-coal basis) of the Herrin Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

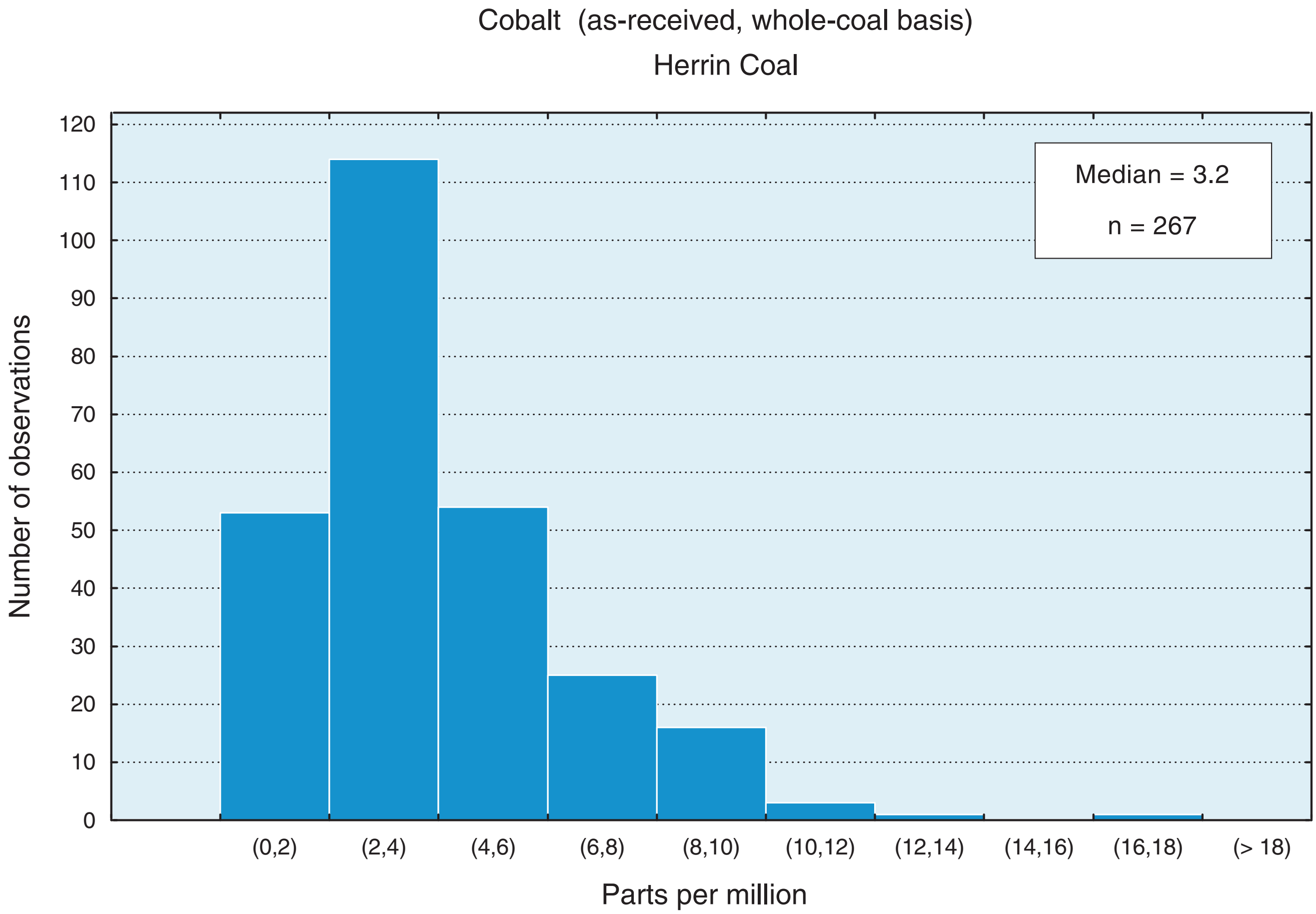

Figure 25. Histogram of cobalt content (parts per million, as-received, whole-coal basis) of the Herrin Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

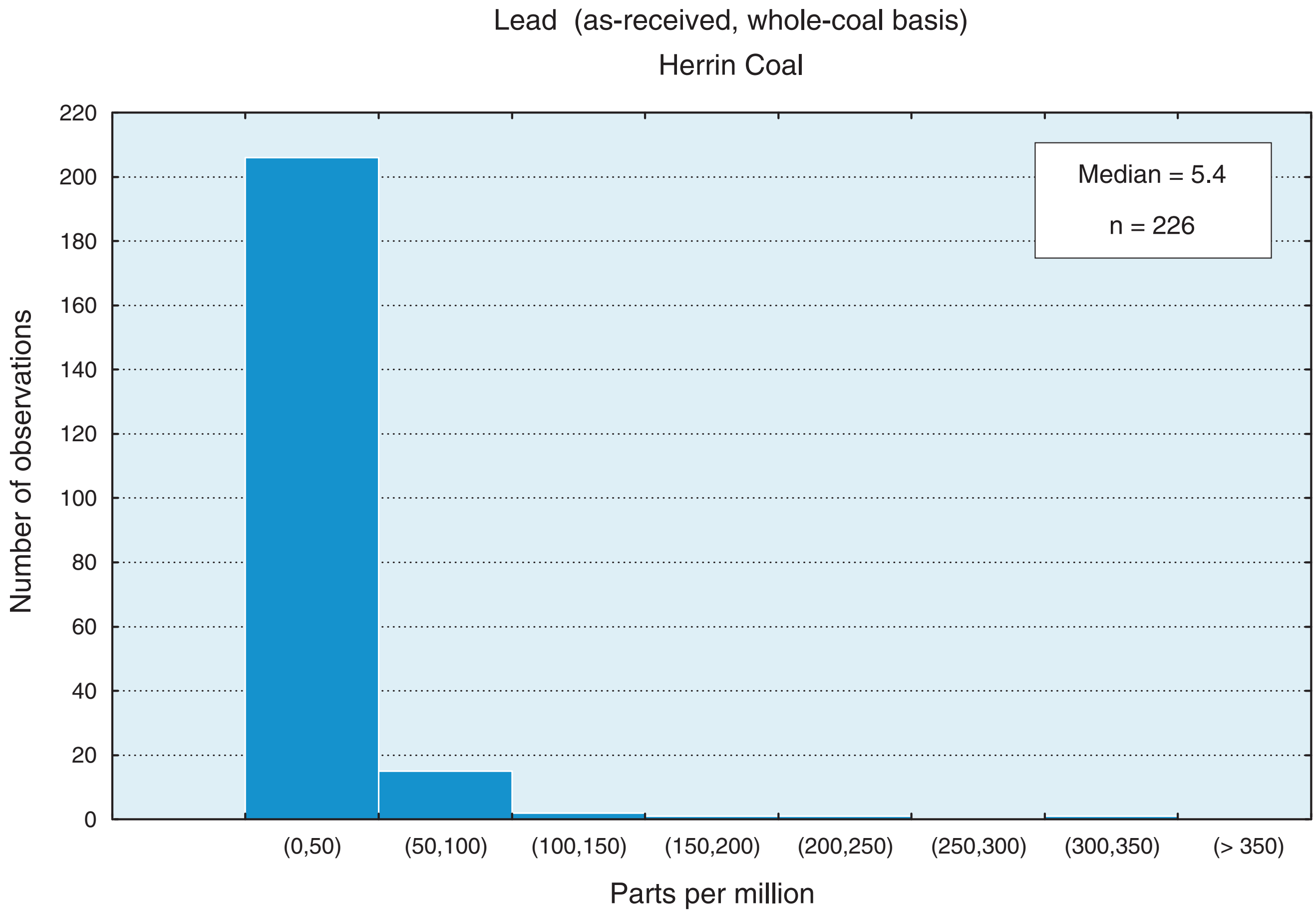

Figure 26. Histogram of lead content (parts per million, as-received, whole-coal basis) of the Herrin Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

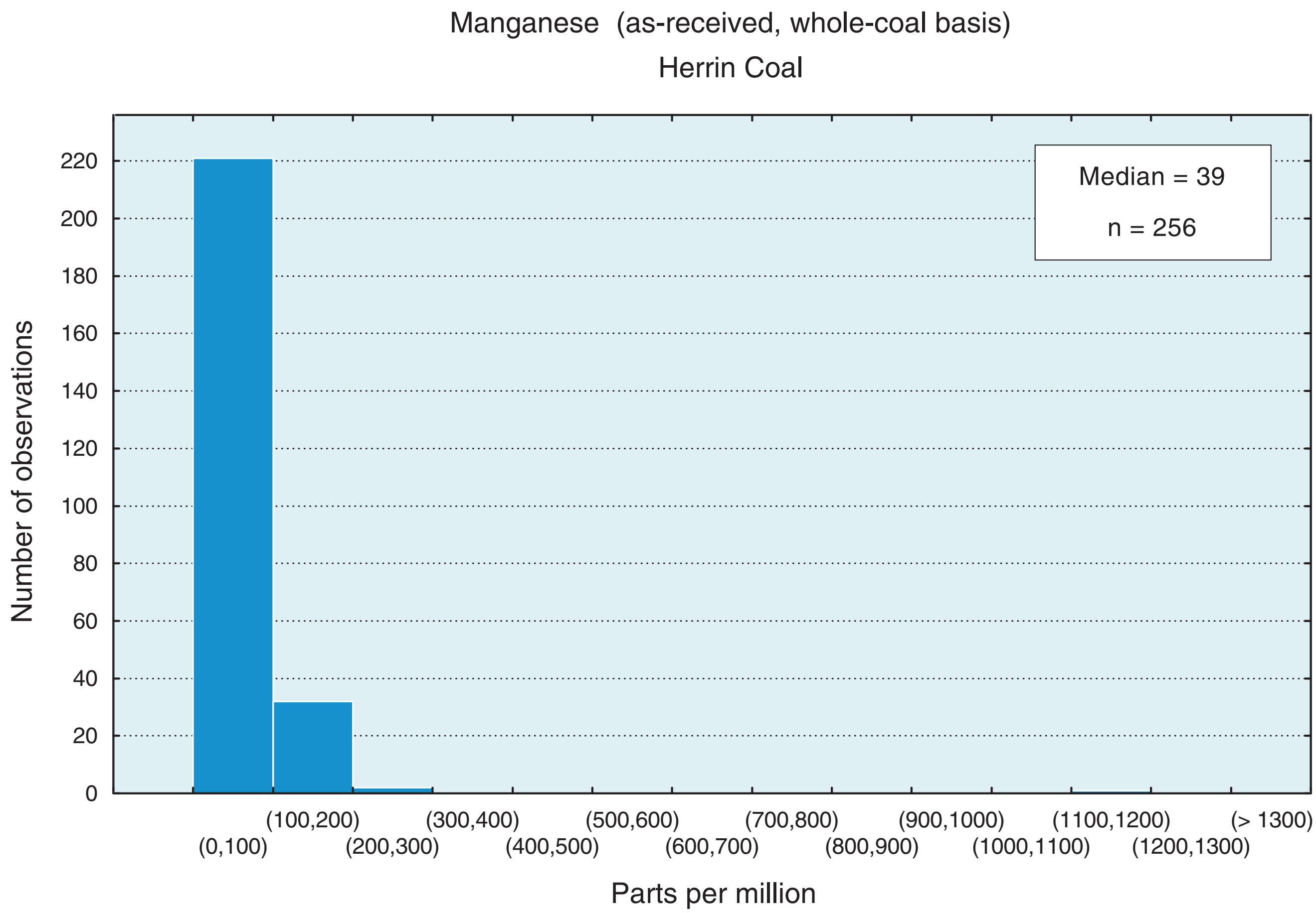

Figure 27. Histogram of manganese content (parts per million, as-received, whole-coal basis) of the Herrin Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

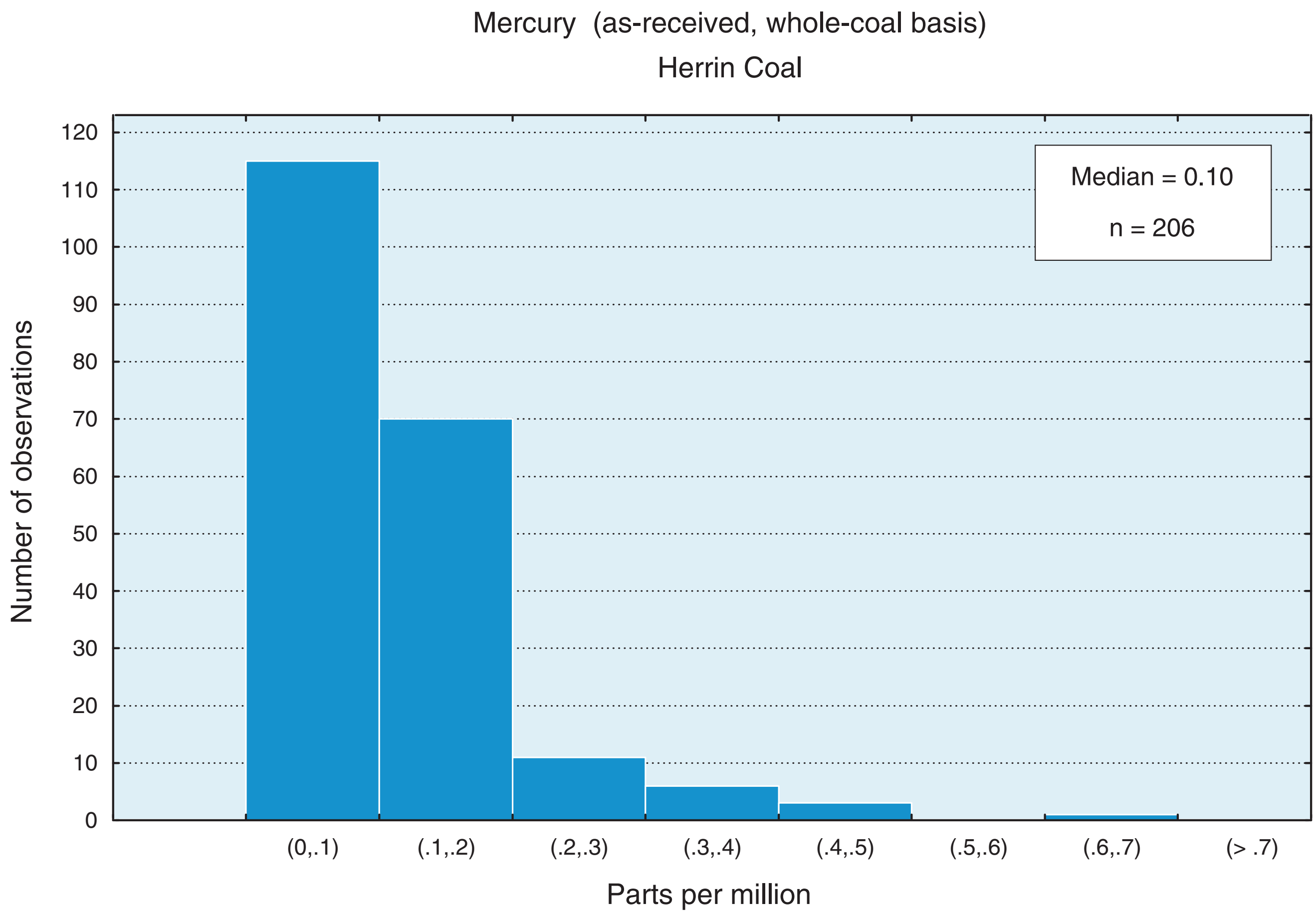

Figure 28. Histogram of mercury content (parts per million, as-received, whole-coal basis) of the Herrin Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

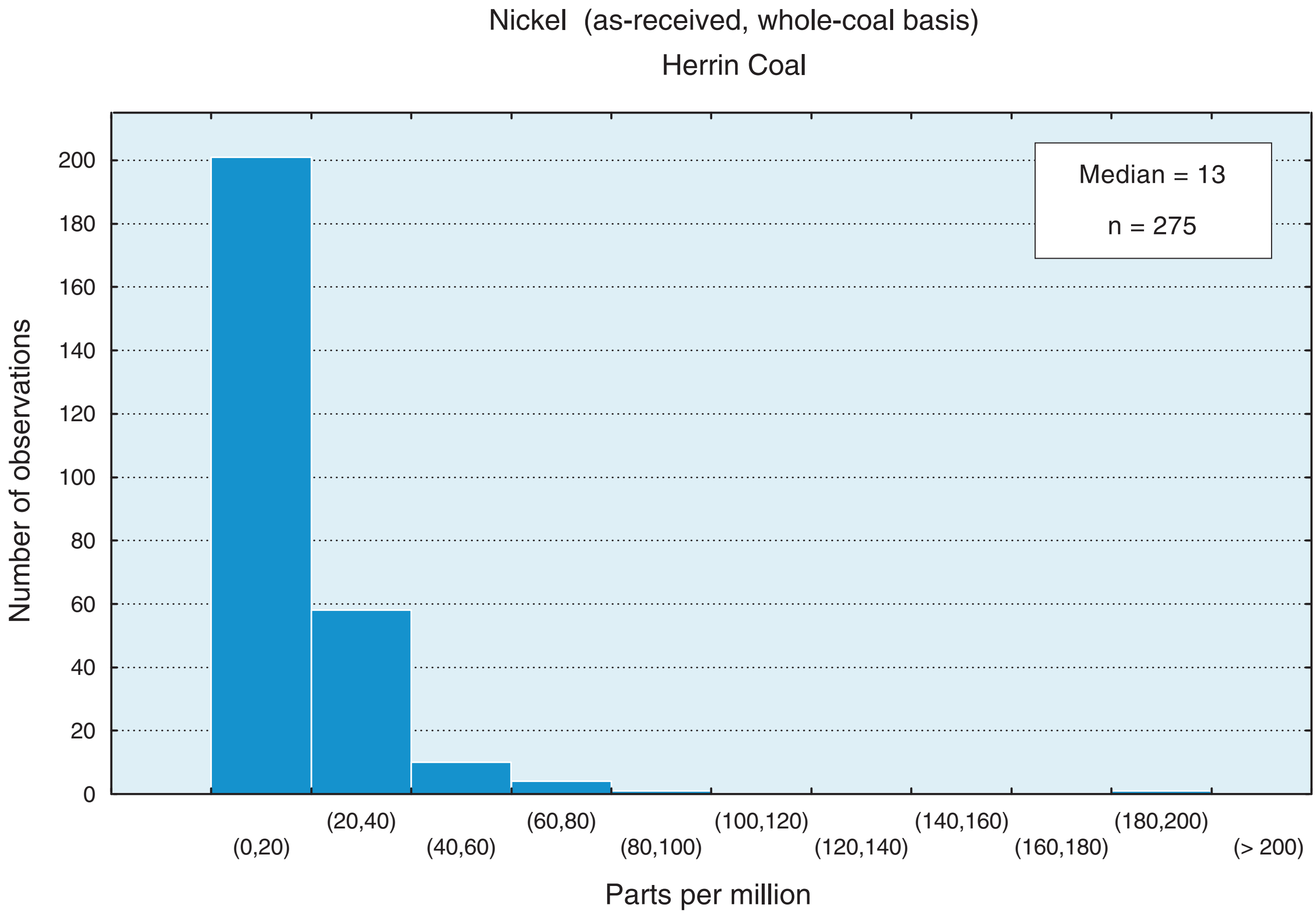

Figure 29. Histogram of nickel content (parts per million, as-received, whole-coal basis) of the Herrin Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

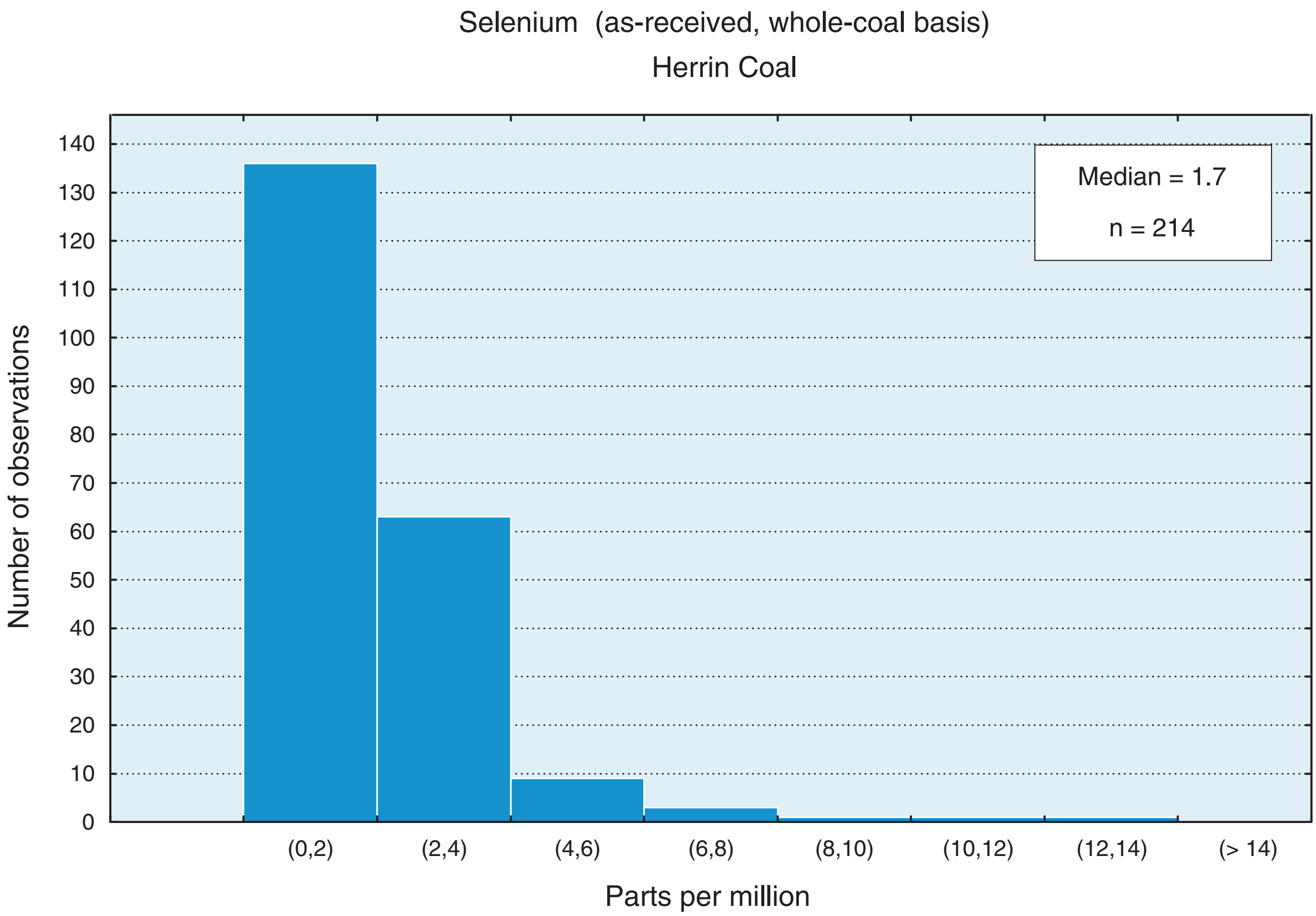

Figure 30. Histogram of selenium content (parts per million, as-received, whole-coal basis) of the Herrin Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

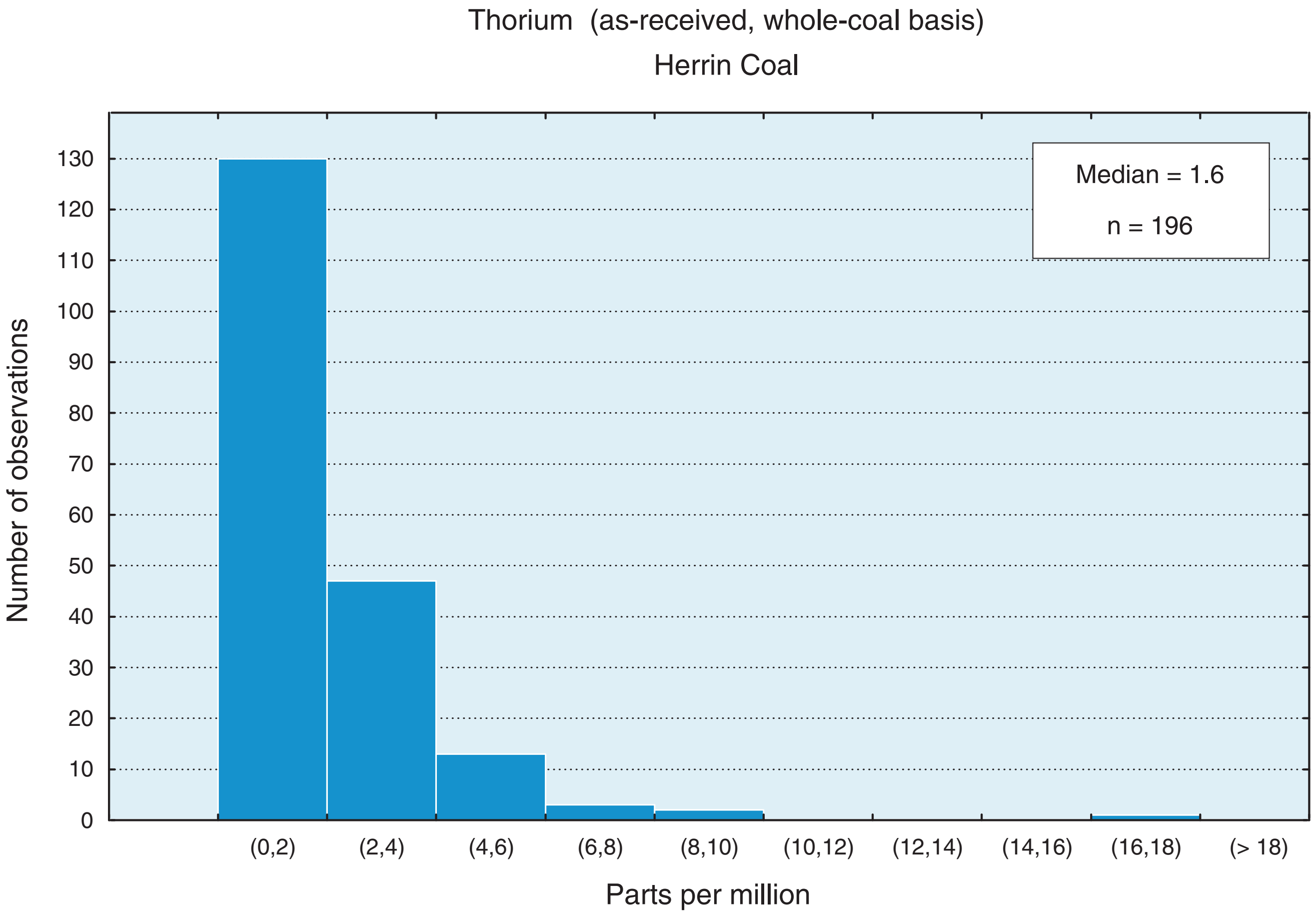

Figure 31. Histogram of thorium content (parts per million, as-received, whole-coal basis) of the Herrin Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

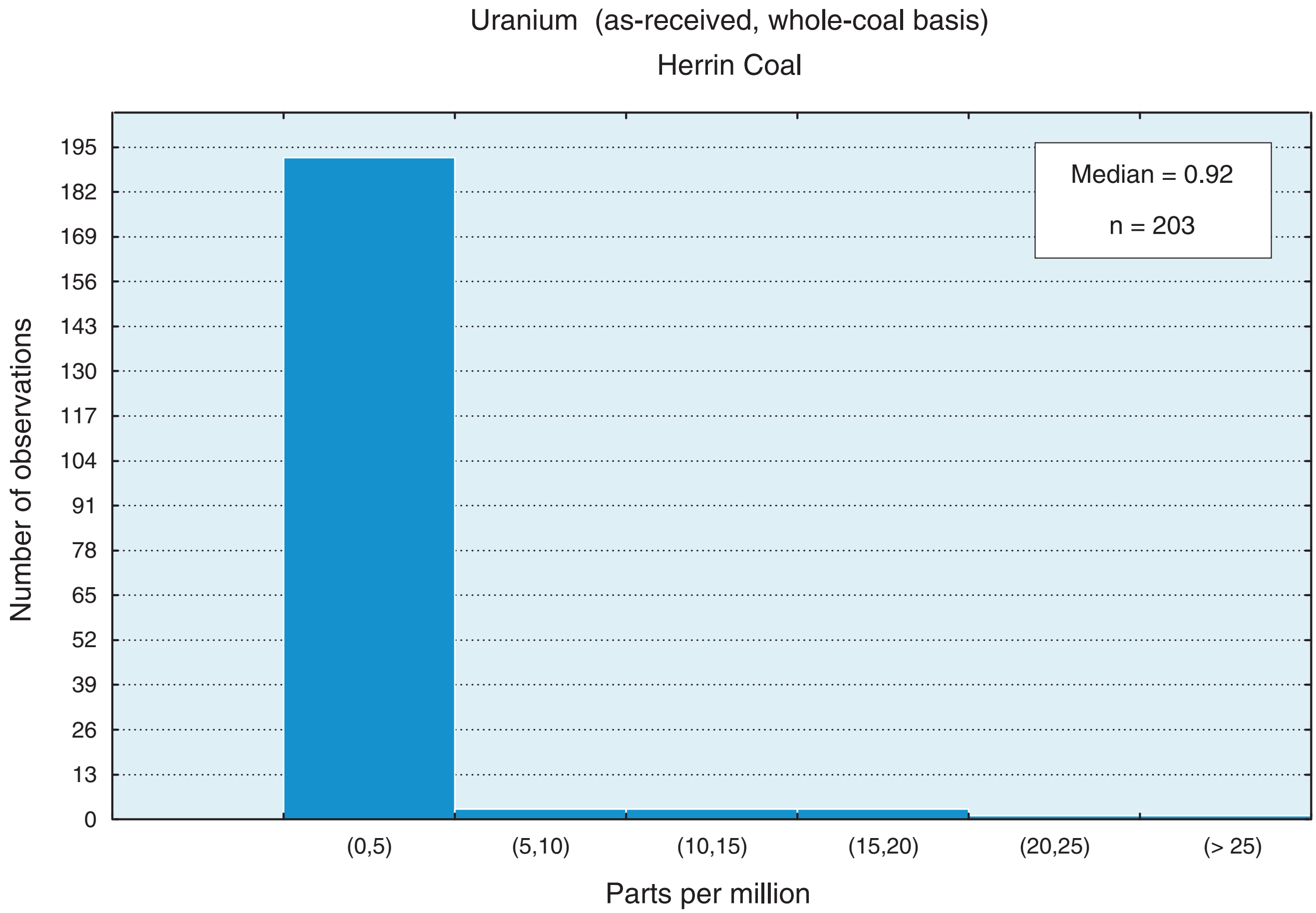

Figure 32. Histogram of uranium content (parts per million, as-received, whole-coal basis) of the Herrin Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

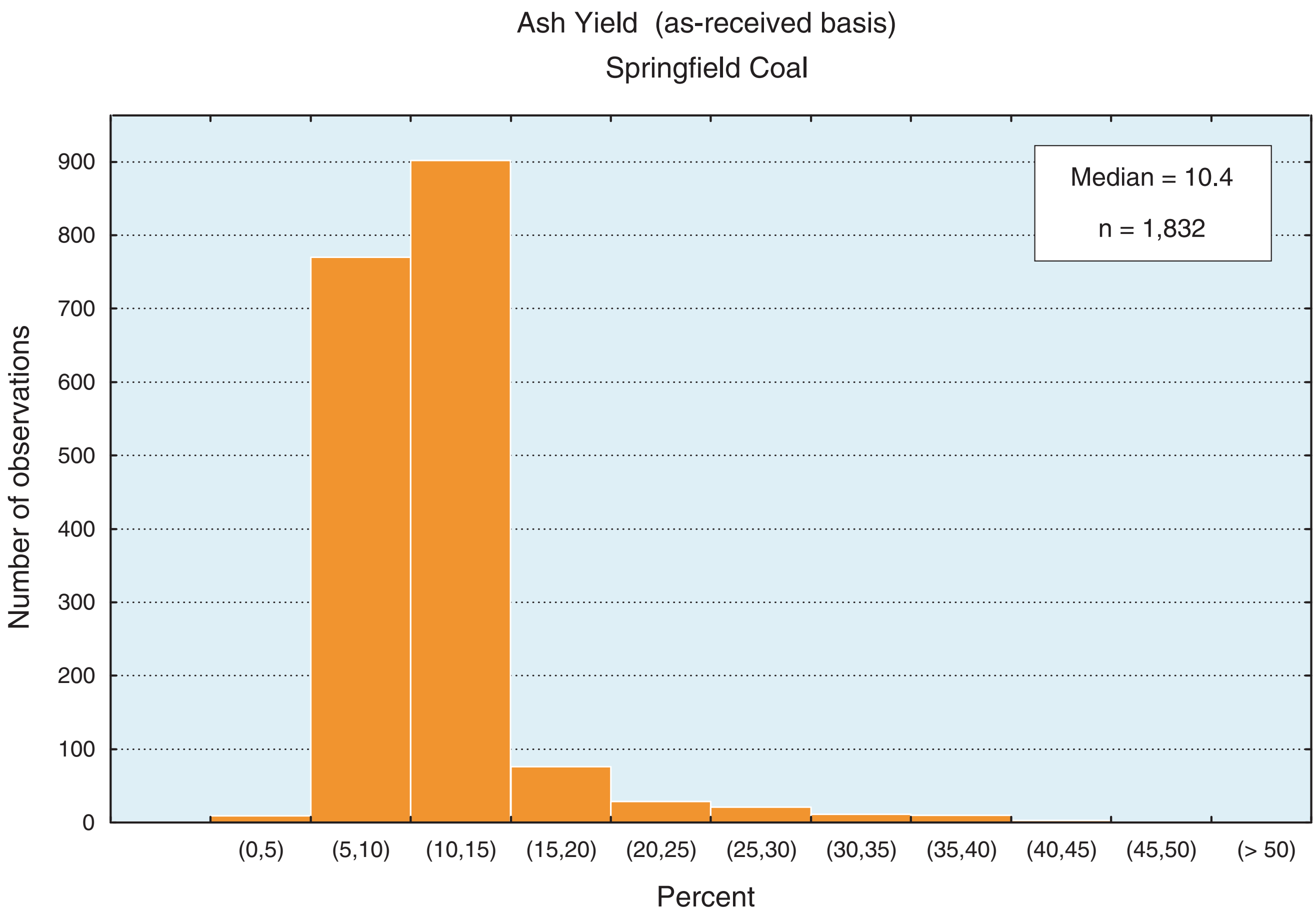

Figure 33. Histogram of ash yield (percent, as-received basis) of the Springfield Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

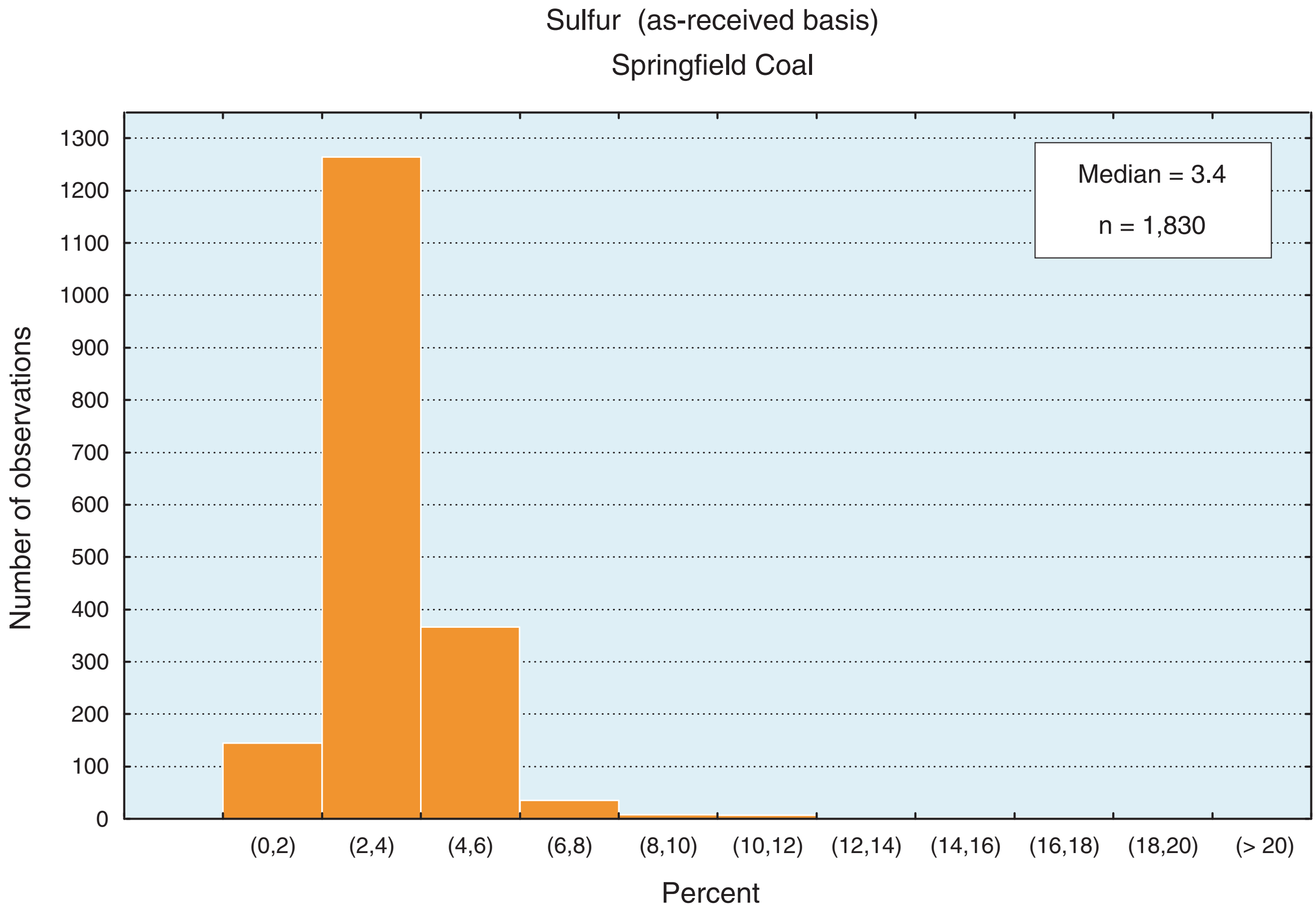

Figure 34. Histogram of sulfur content (percent, as-received basis) of the Springfield Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

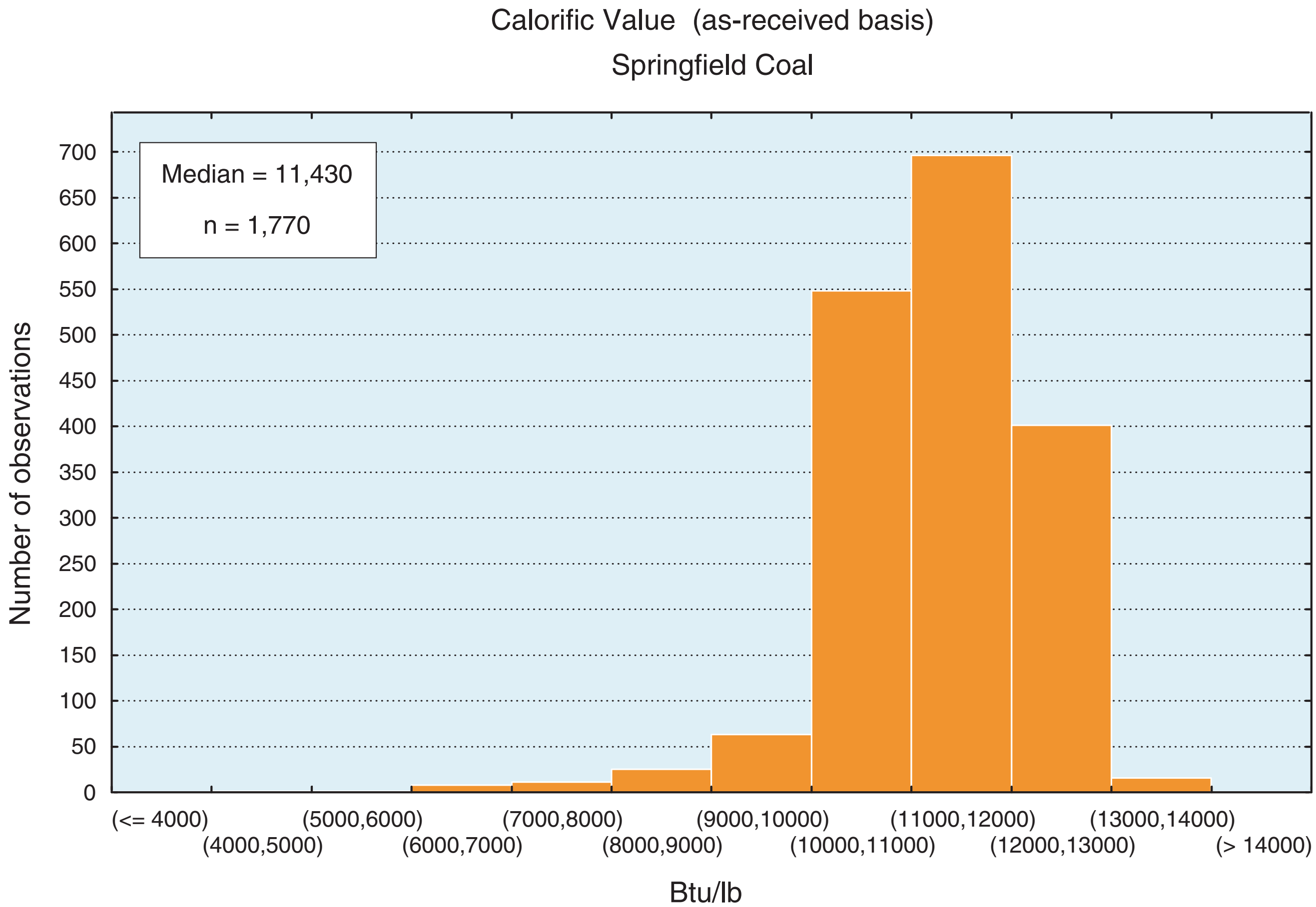

Figure 35. Histogram of calorific values (Btu/lb, as-received basis) of the Springfield Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

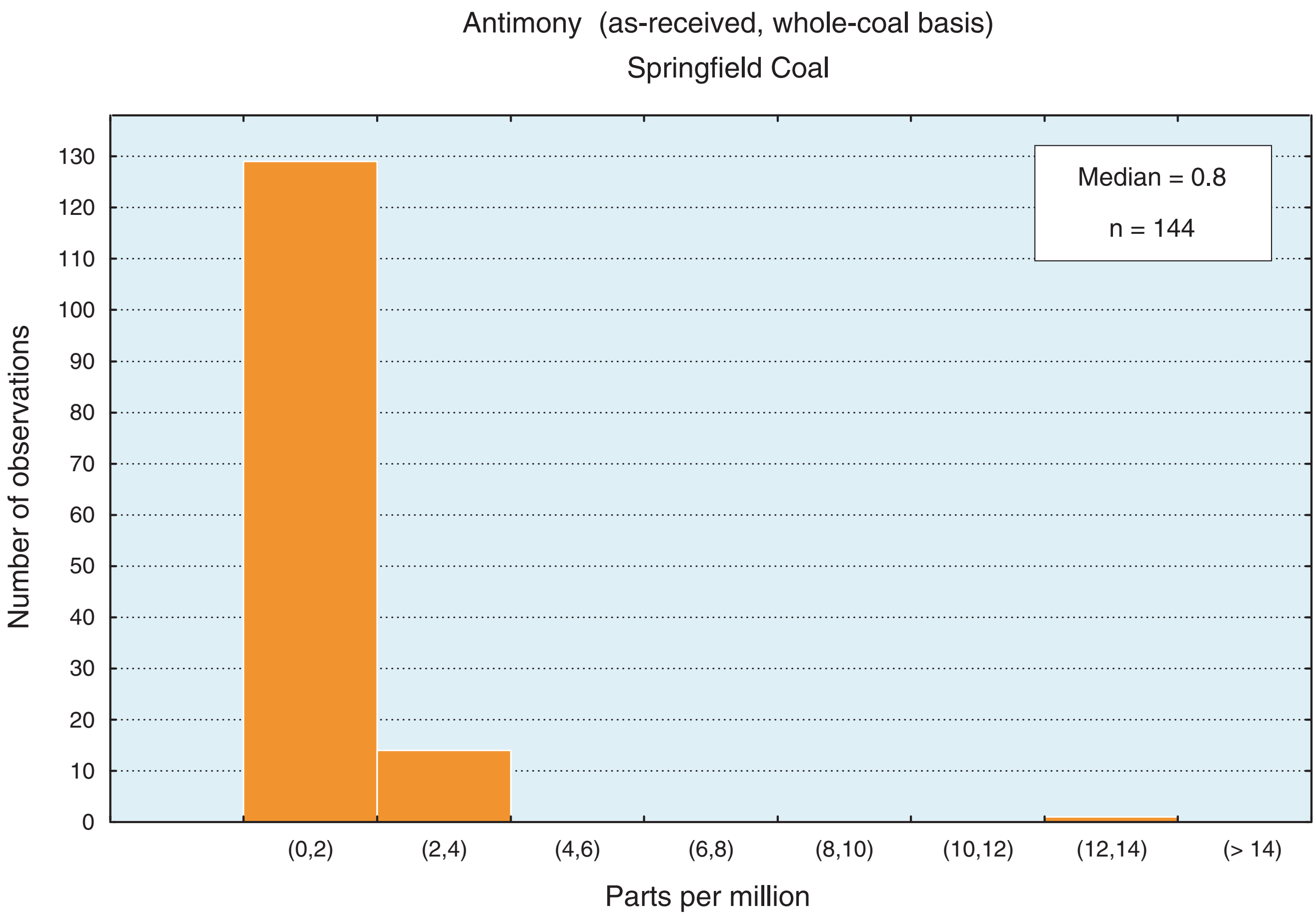

Figure 36. Histogram of antimony content (parts per million, as-received, whole-coal basis) of the Springfield Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

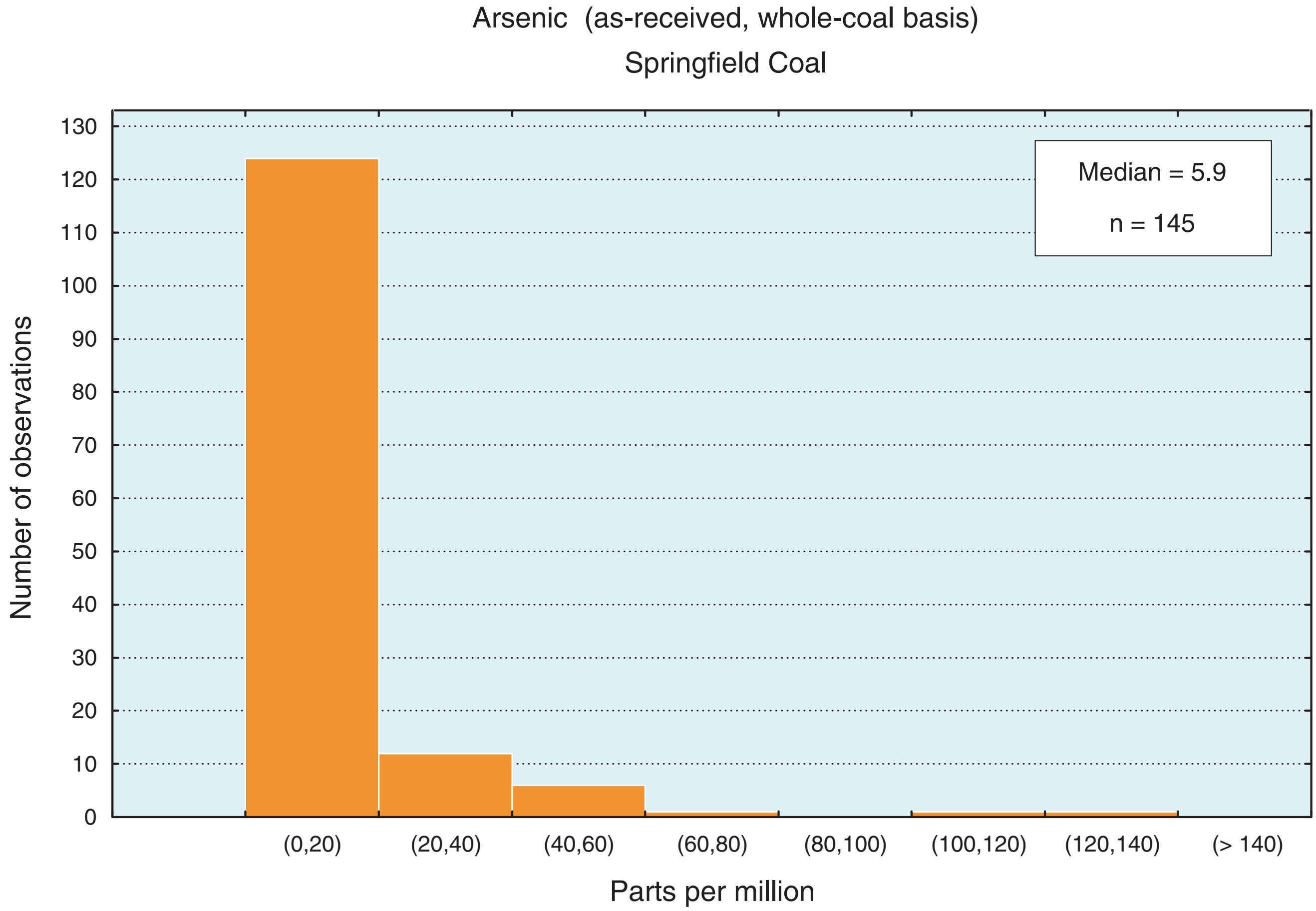

Figure 37. Histogram of arsenic content (parts per million, as-received, whole-coal basis) of the Springfield Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

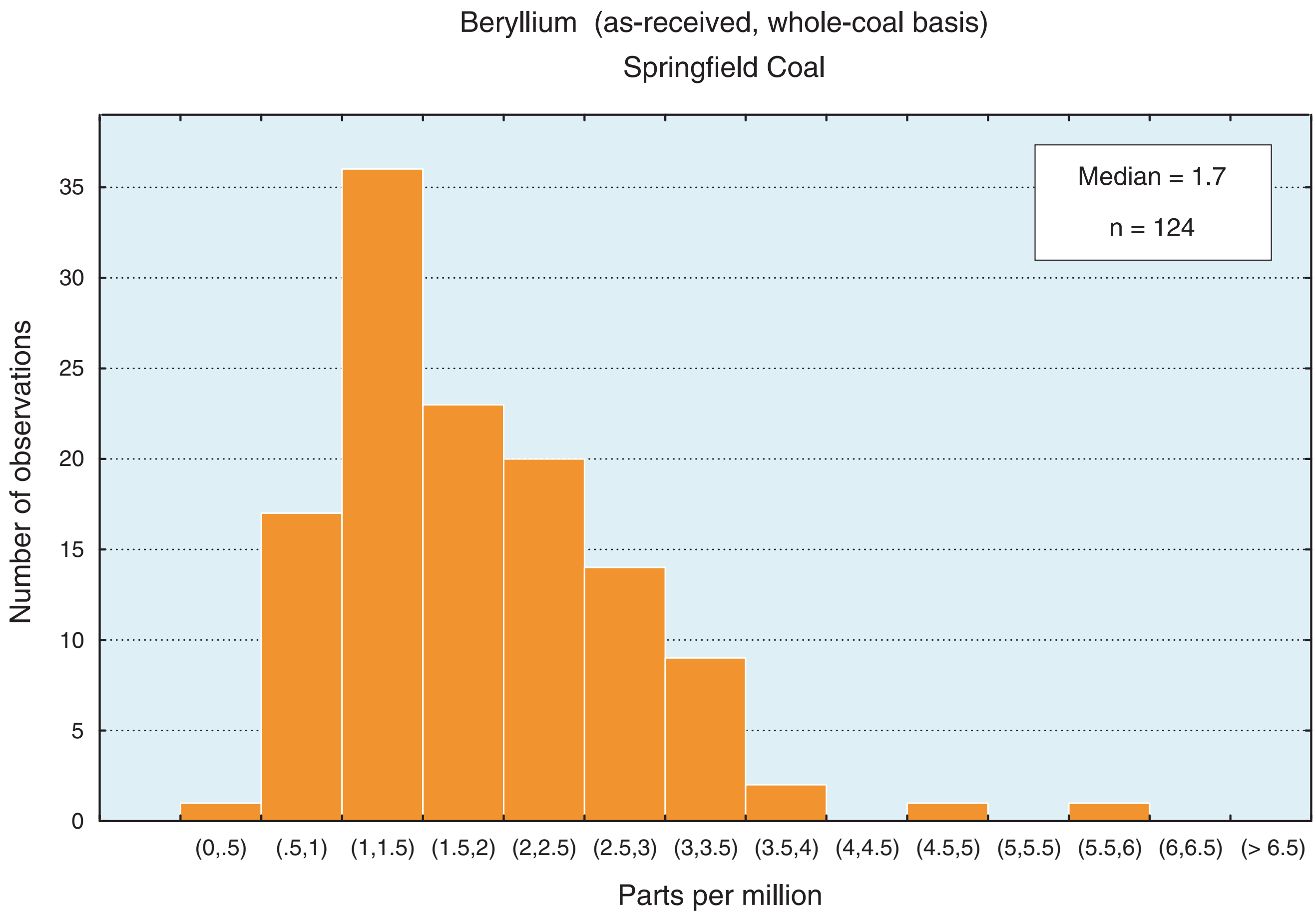

Figure 38. Histogram of beryllium content (parts per million, as-received, whole-coal basis) of the Springfield Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

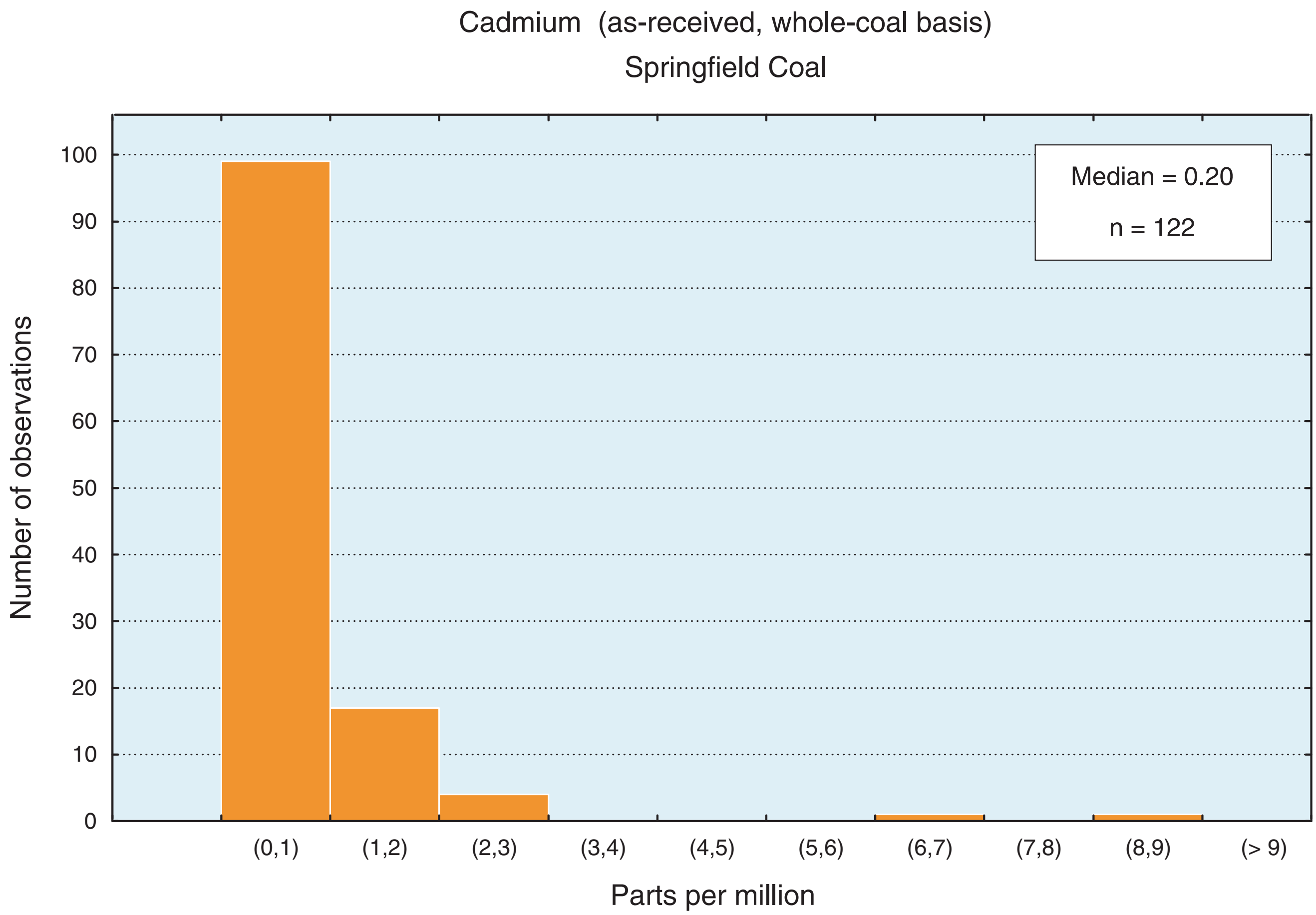

Figure 39. Histogram of cadmium content (parts per million, as-received, whole-coal basis) of the Springfield Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

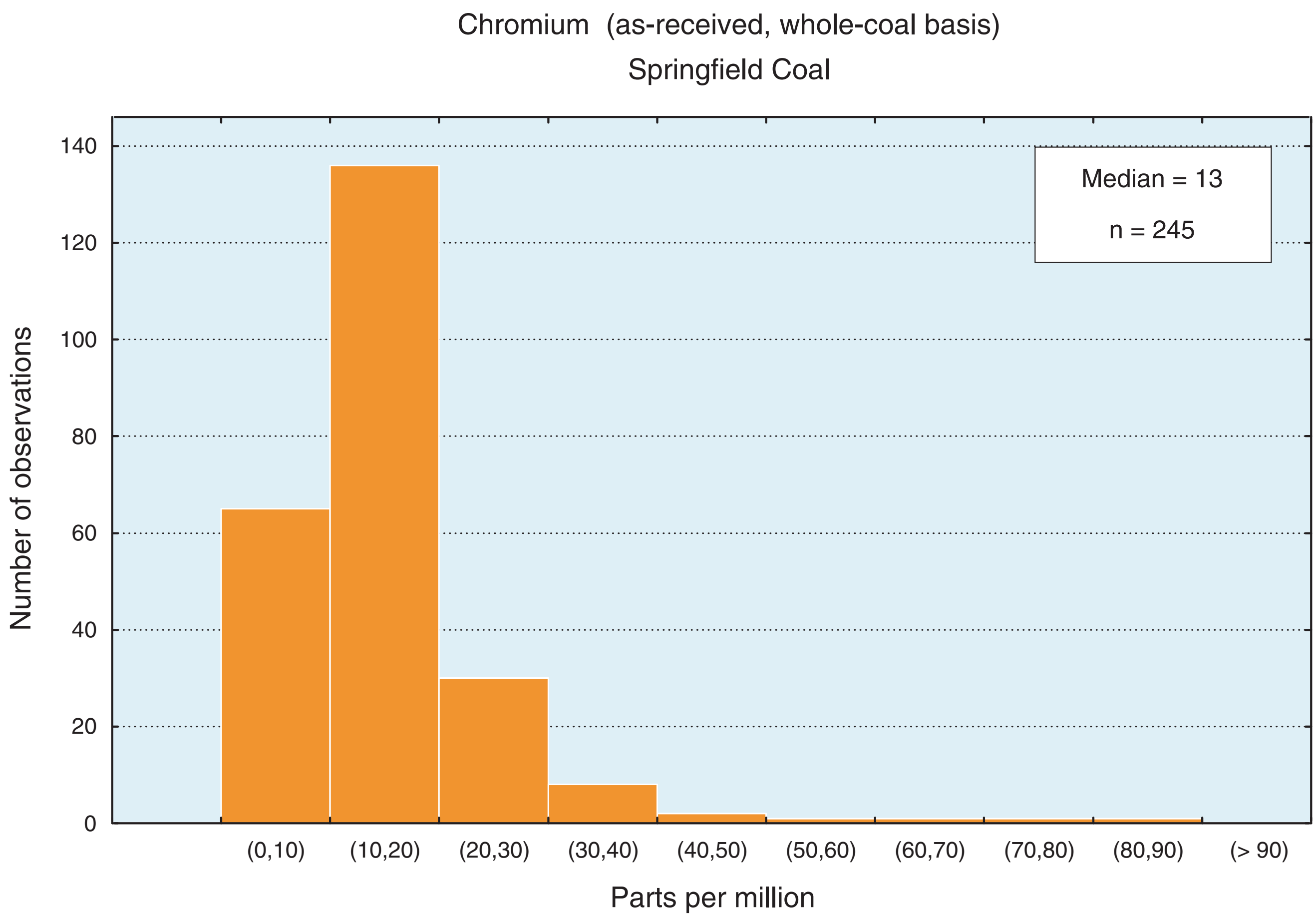

Figure 40. Histogram of chromium content (parts per million, as-received, whole-coal basis) of the Springfield Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

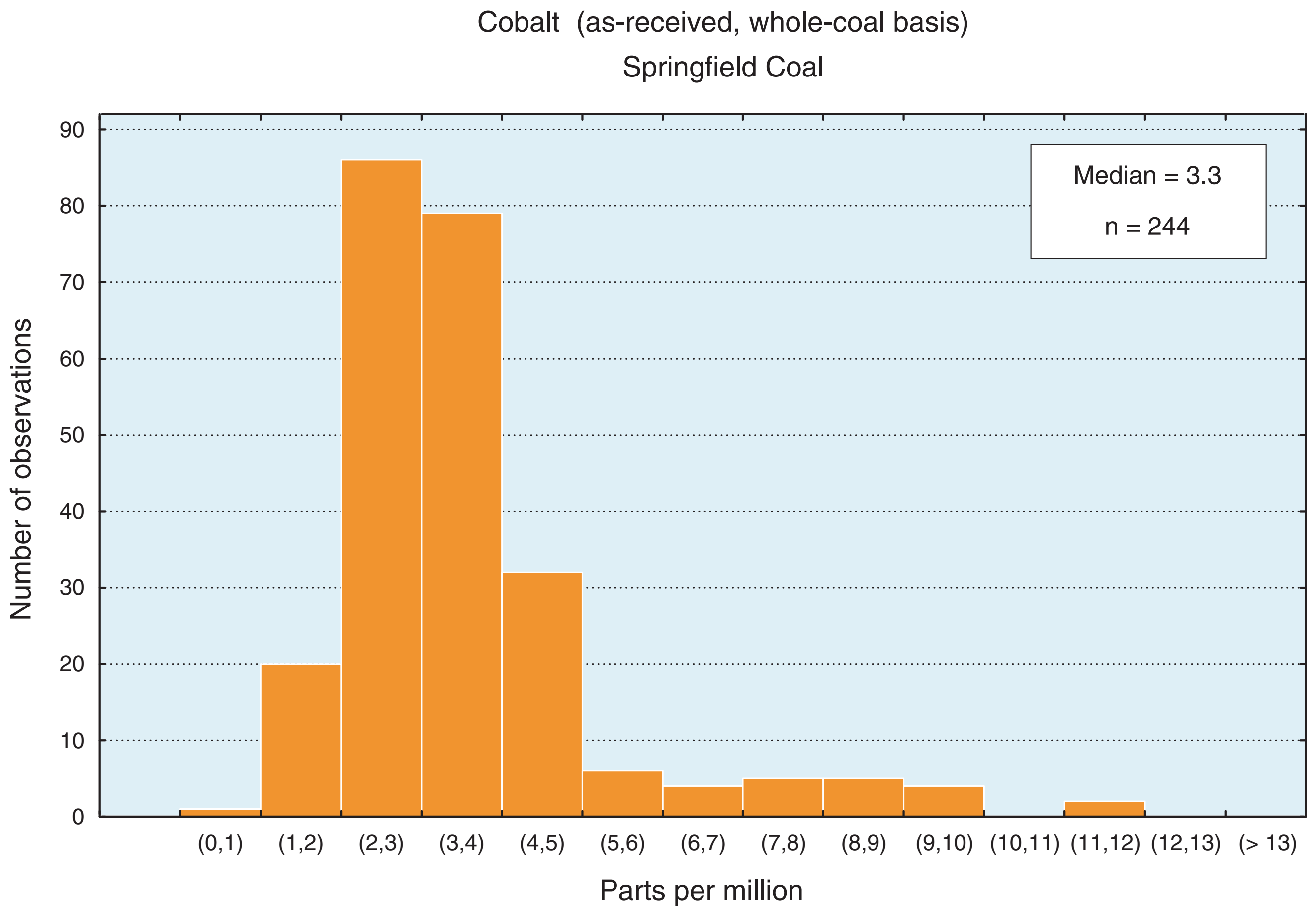

Figure 41. Histogram of cobalt content (parts per million, as-received, whole-coal basis) of the Springfield Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

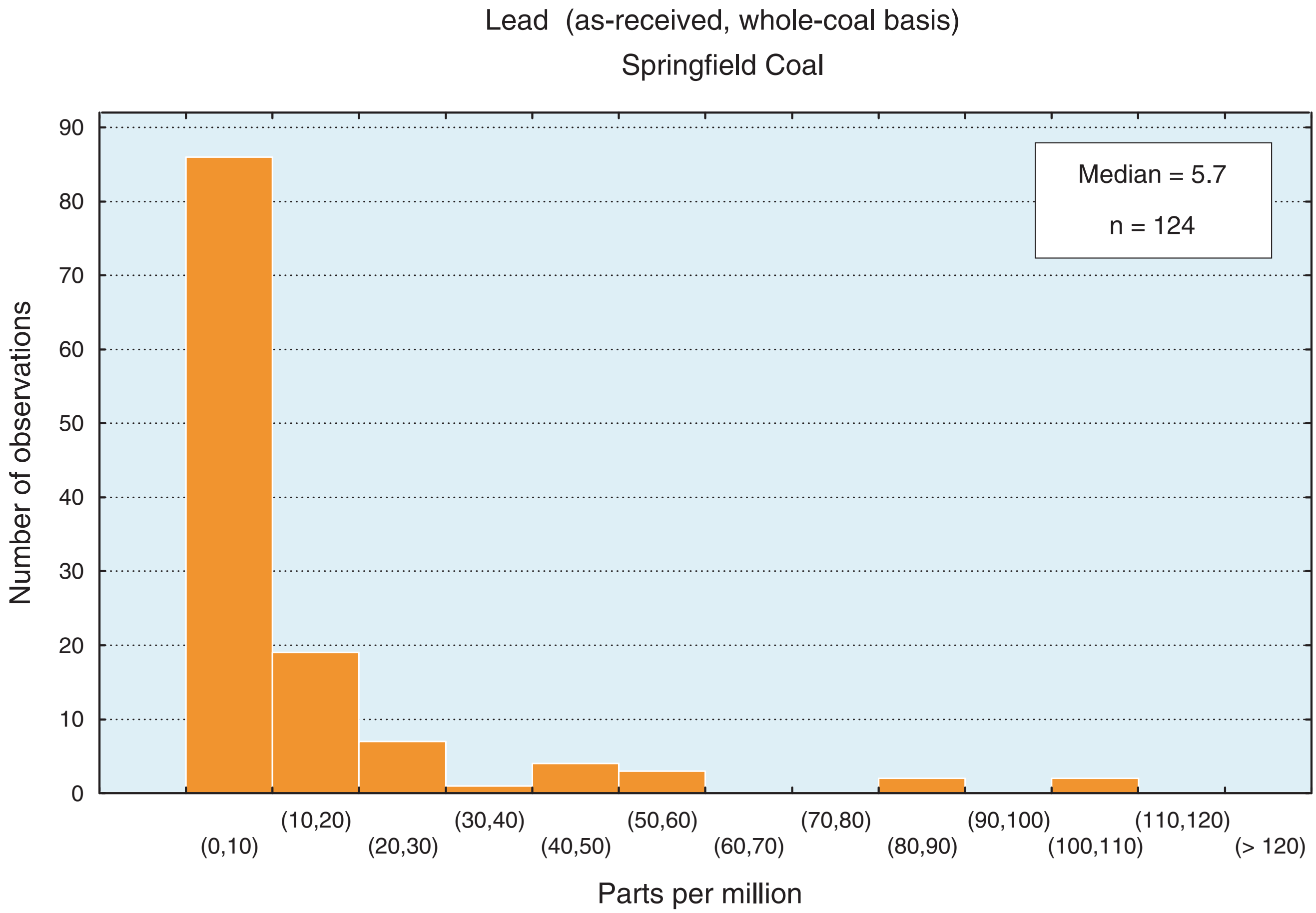

Figure 42. Histogram of lead content (parts per million, as-received, whole-coal basis) of the Springfield Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

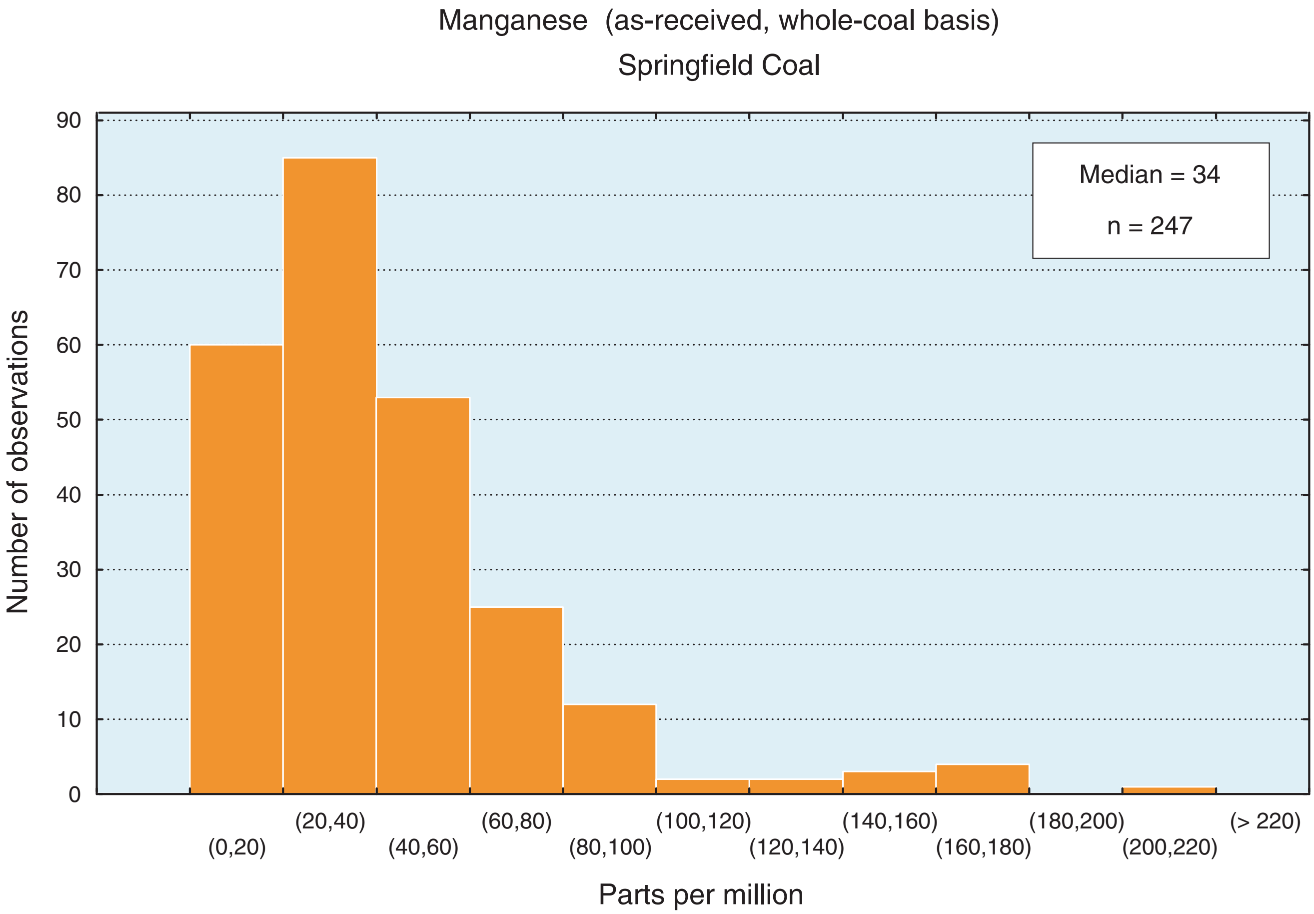

Figure 43. Histogram of manganese content (parts per million, as-received, whole-coal basis) of the Springfield Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

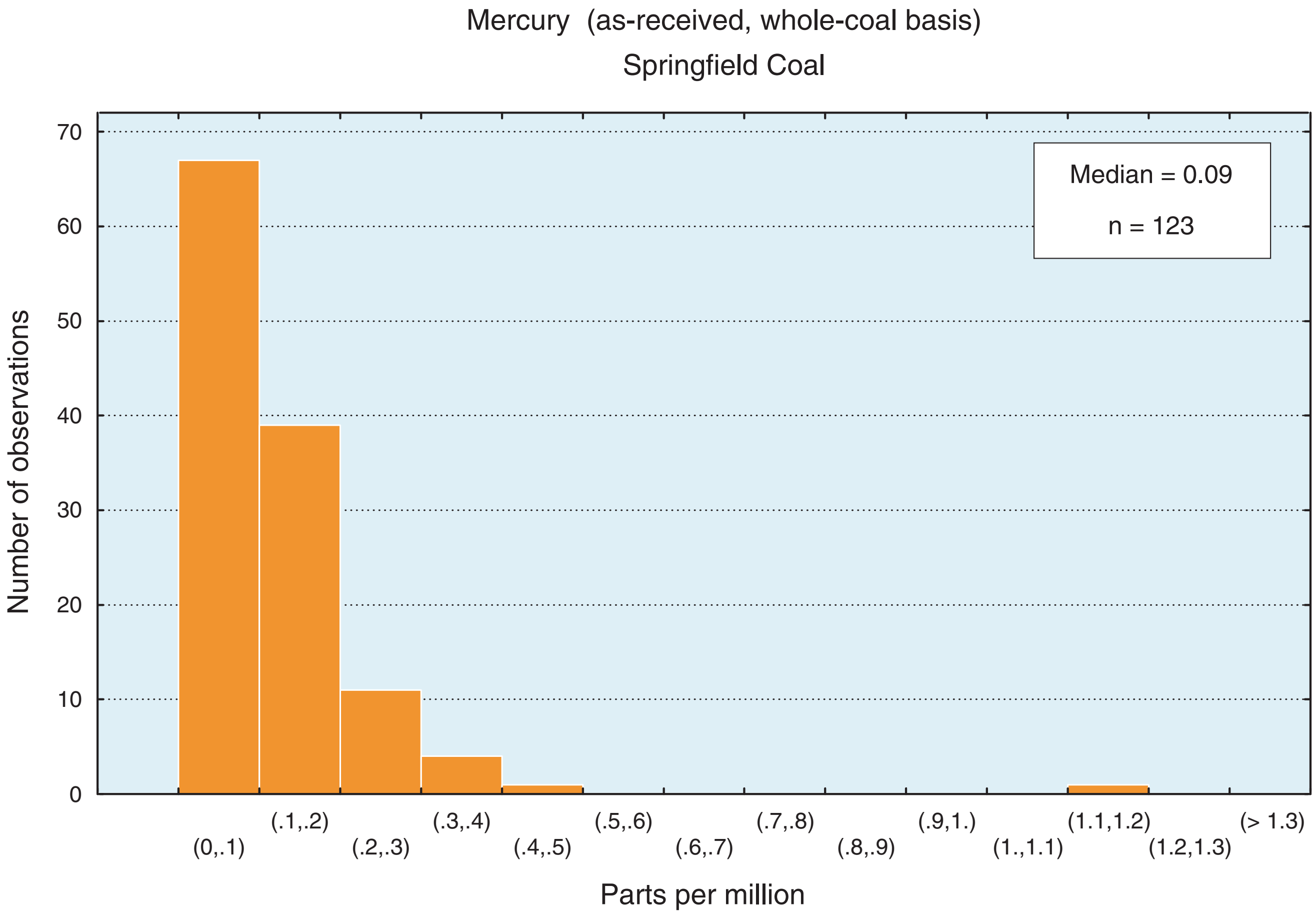

Figure 44. Histogram of mercury content (parts per million, as-received, whole-coal basis) of the Springfield Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

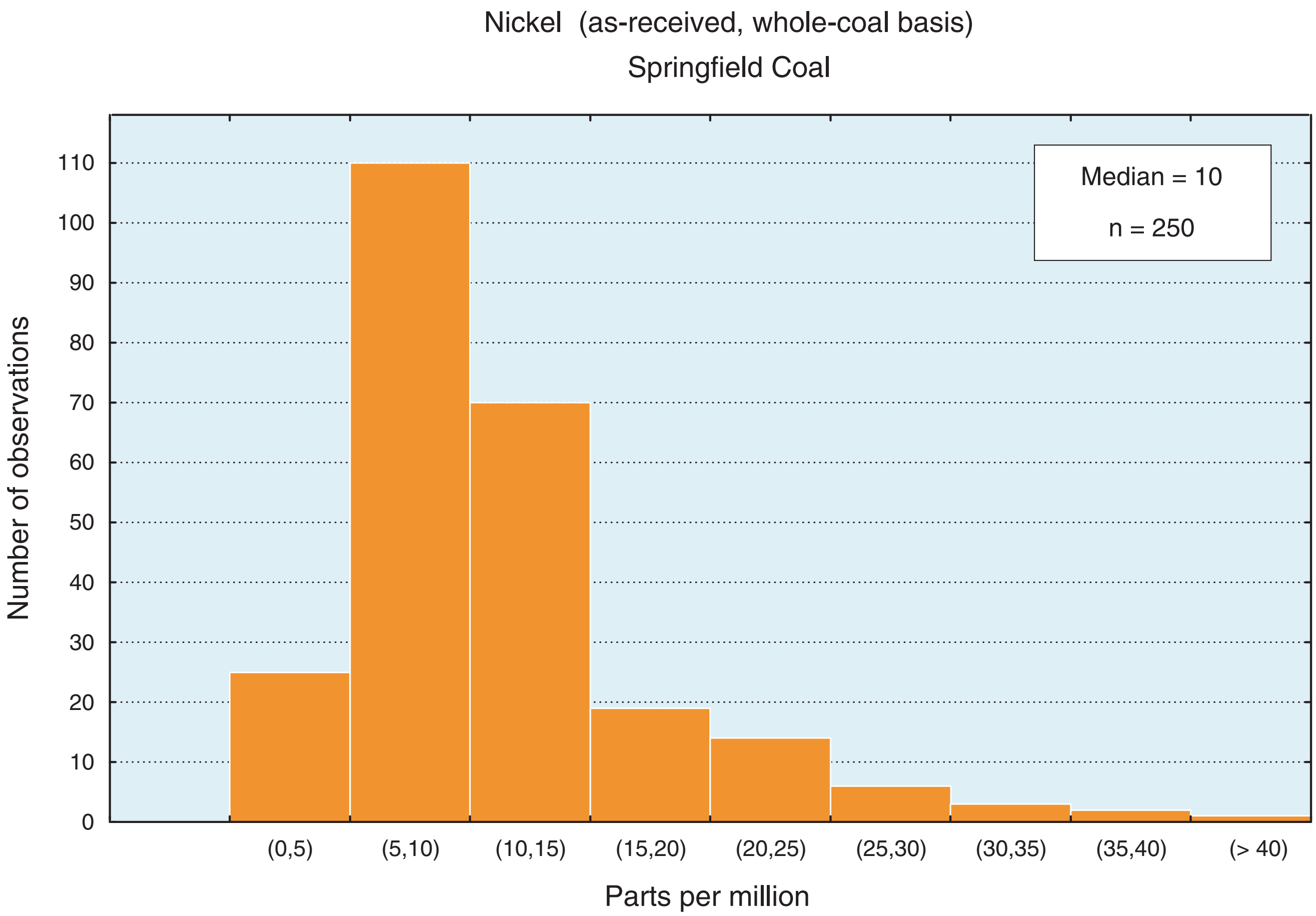

Figure 45. Histogram of nickel content (parts per million, as-received, whole-coal basis) of the Springfield Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

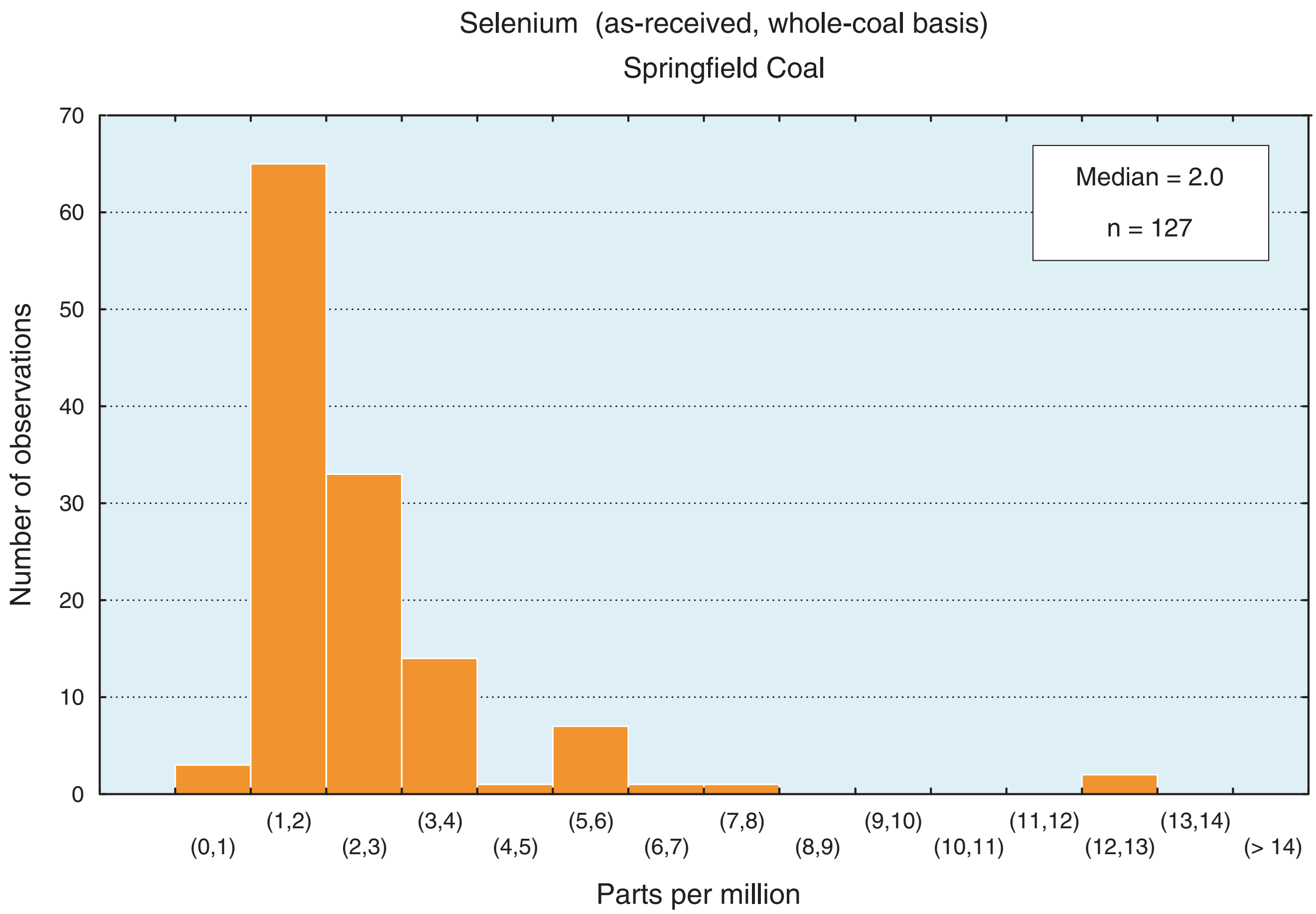

Figure 46. Histogram of selenium content (parts per million, as-received, whole-coal basis) of the Springfield Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

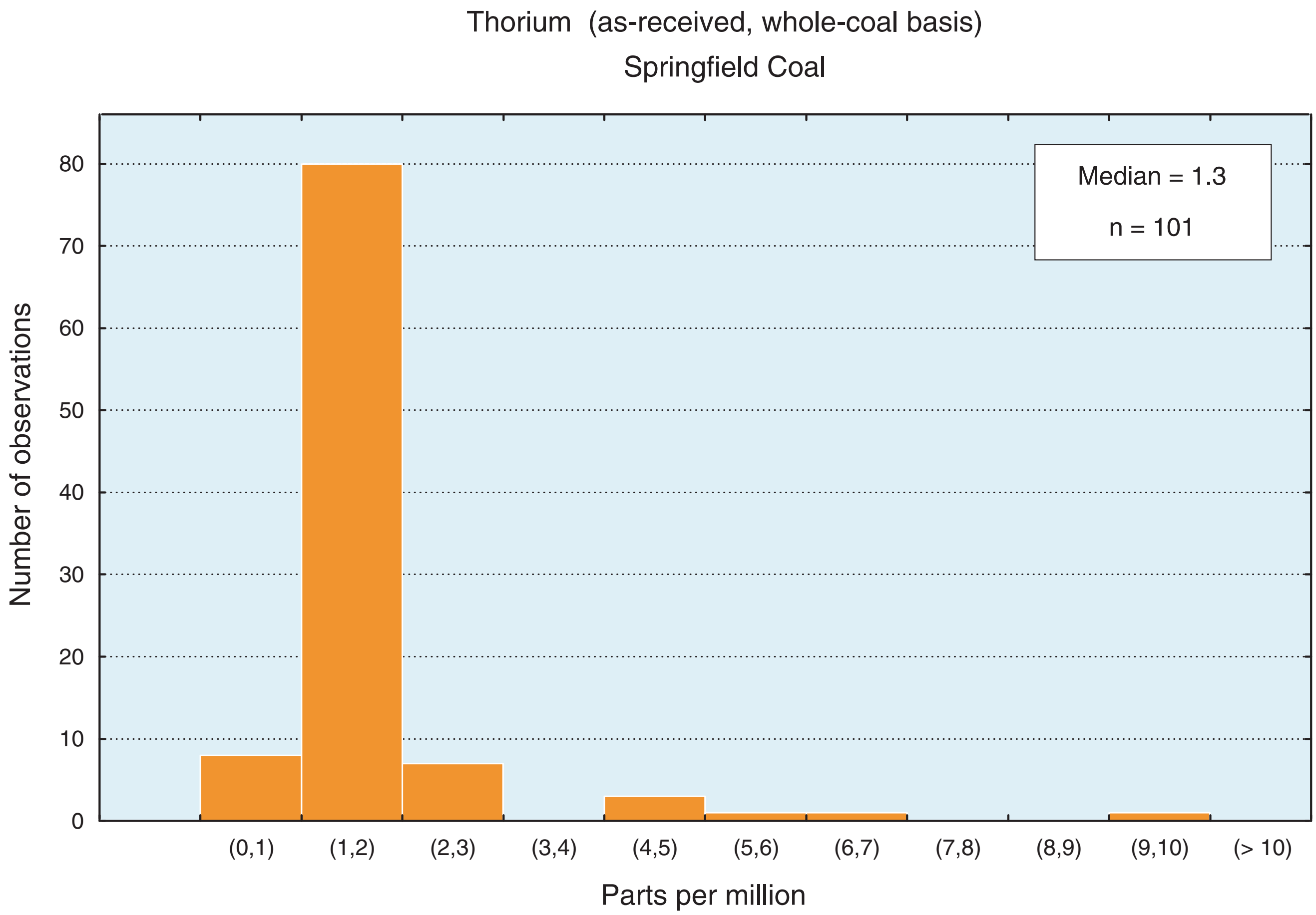

Figure 47. Histogram of thorium content (parts per million, as-received, whole-coal basis) of the Springfield Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

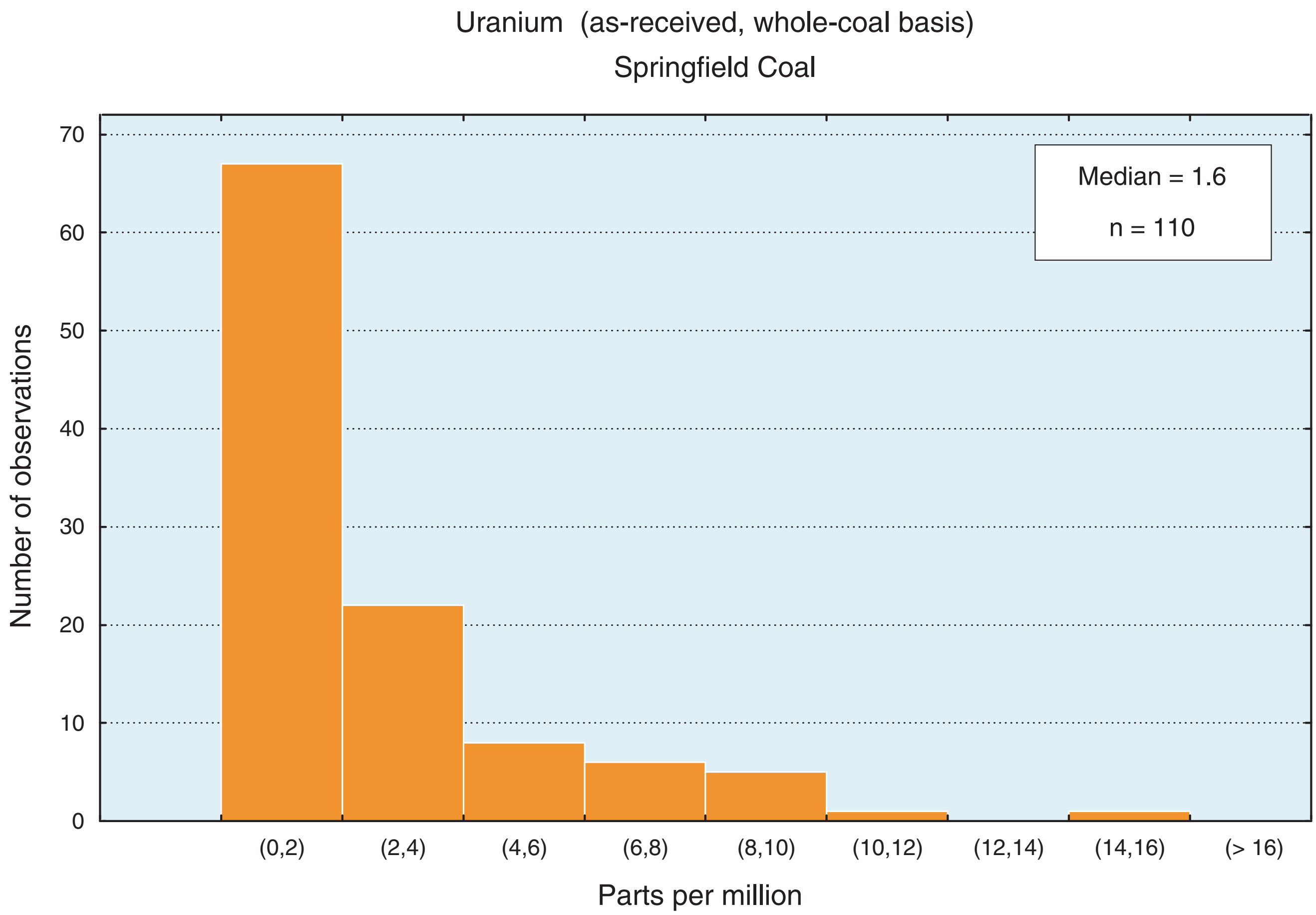

Figure 48. Histogram of uranium content (parts per million, as-received, whole-coal basis) of the Springfield Coal in the Illinois Basin. Intervals on the x-axis are shown in parentheses.

Appendix 7. Graduated-symbol maps for ash yield, sulfur content, calorific value, and elements of environmental concern for the Springfield, Herrin, and Danville-Baker Coals in the Illinois Basin.

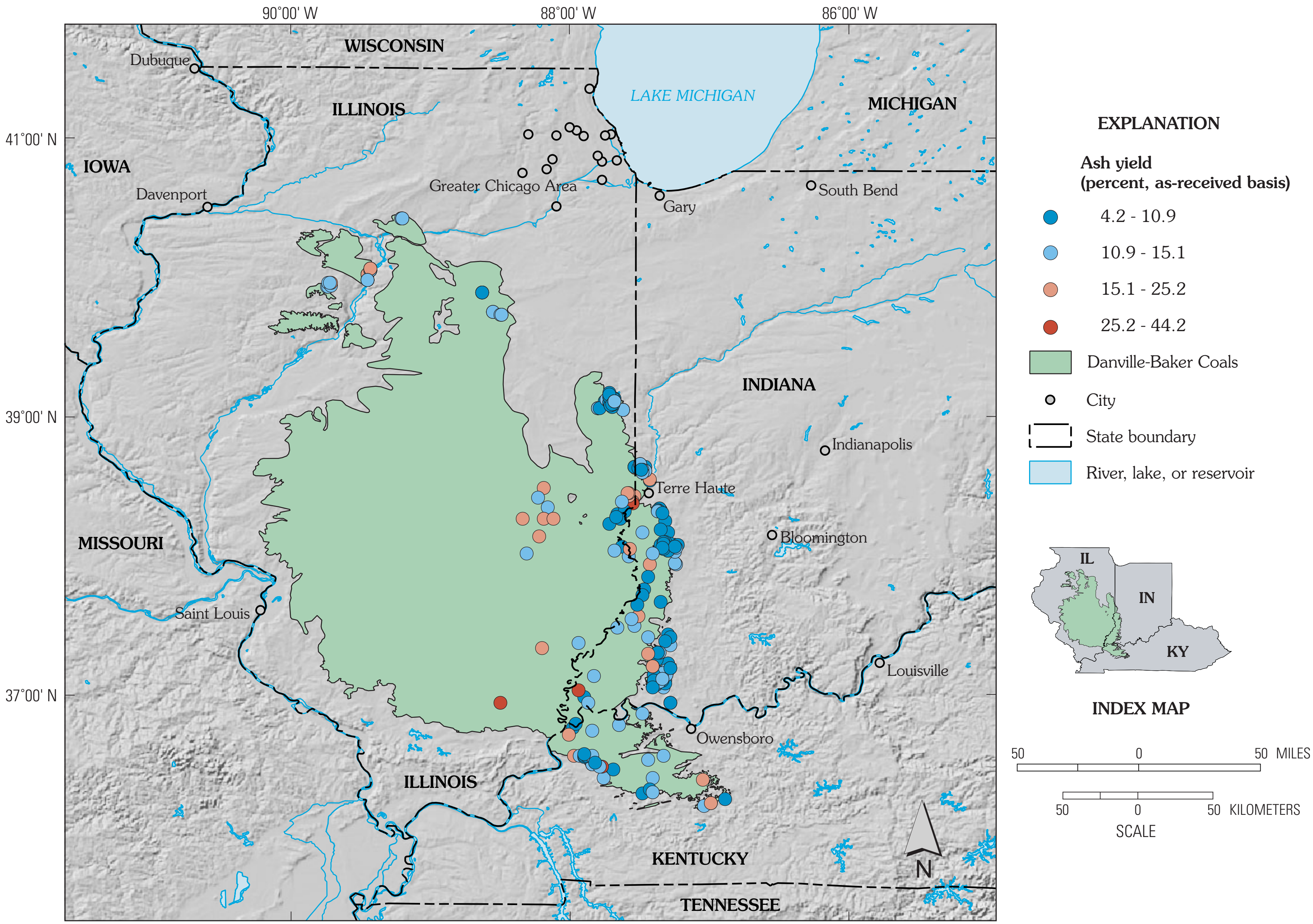

Figure 1. Graduated-symbol map for ash yield (percent, as-received basis) of the Danville-Baker Coals in the Illinois Basin.

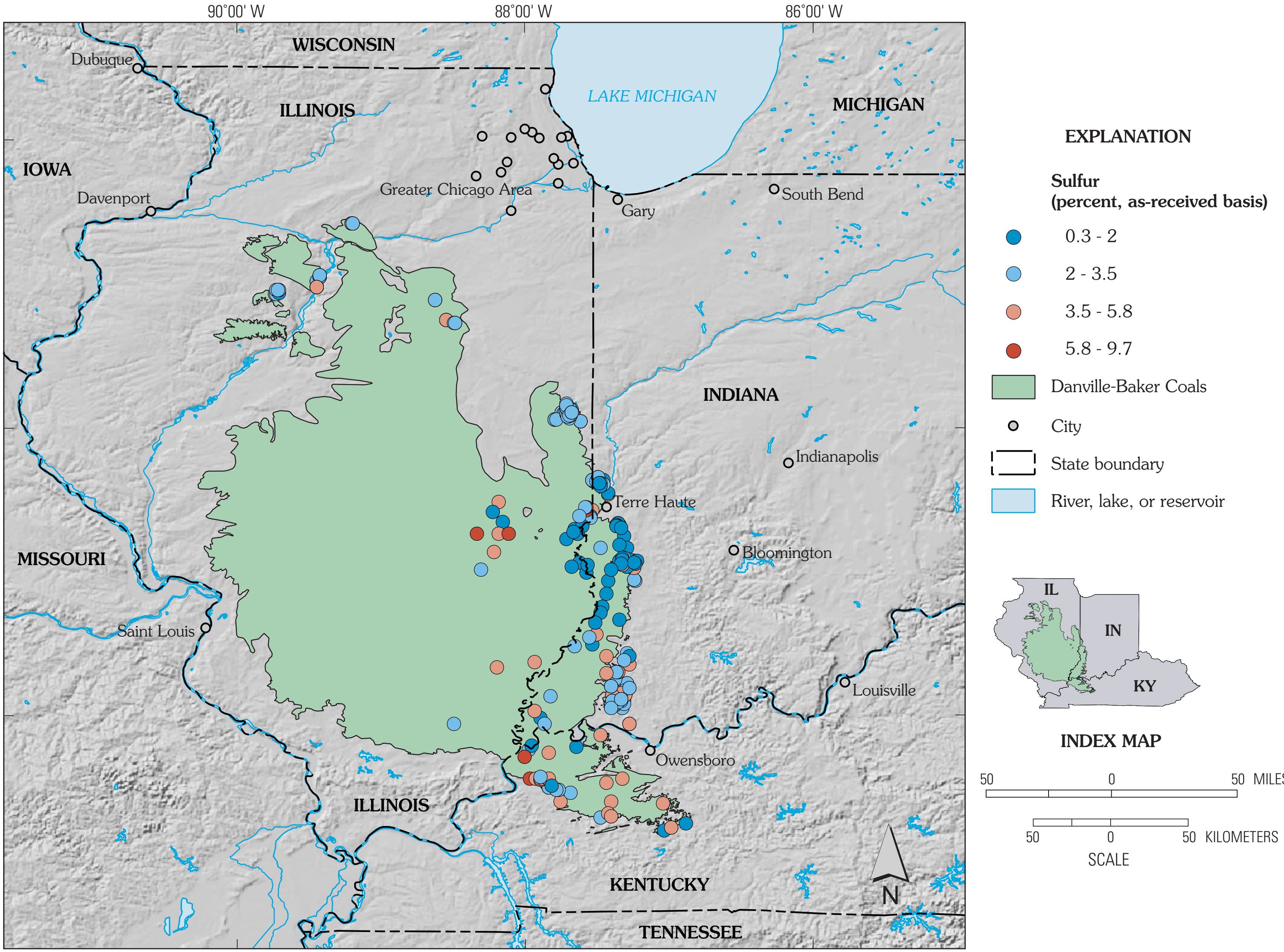

Figure 2. Graduated-symbol map for sulfur content (percent, as-received basis) of the Danville-Baker Coals in the Illinois Basin.

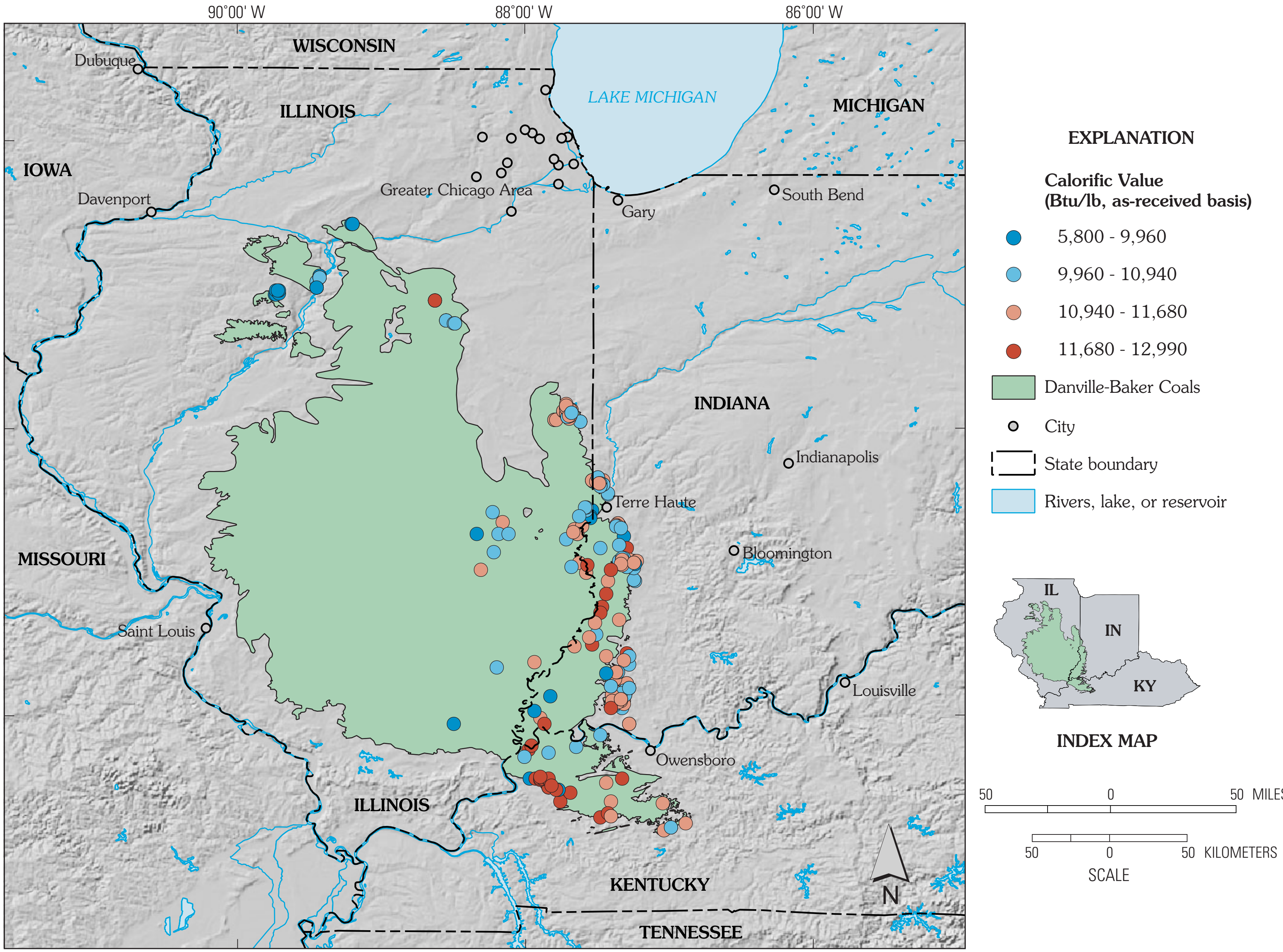

Figure 3. Graduated-symbol map for calorific values (Btu/lb, as-received basis) of the Danville-Baker Coals in the Illinois Basin.

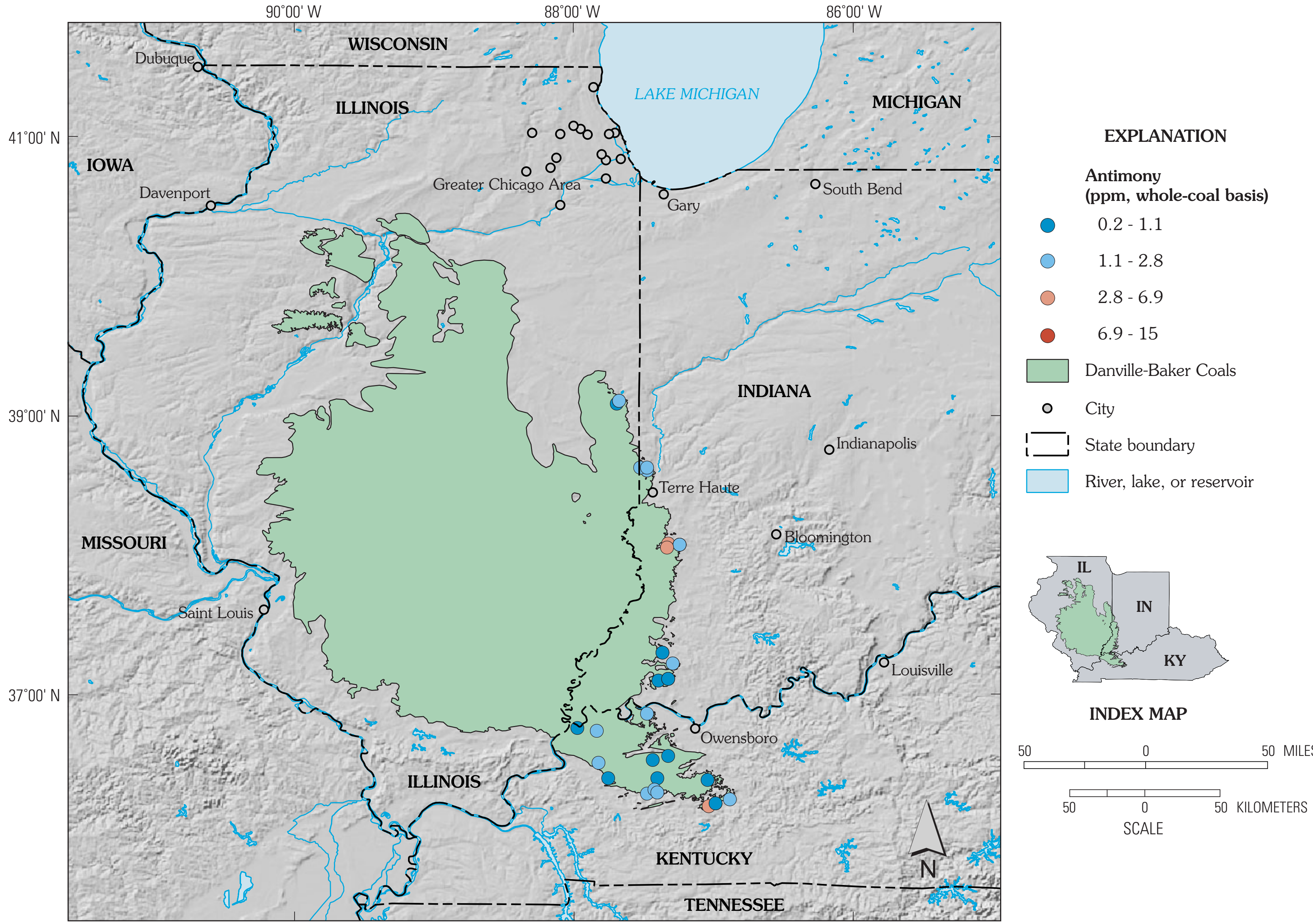

Figure 4. Graduated-symbol map for antimony content (parts per million, as-received, whole-coal basis) of the Danville-Baker Coals in the Illinois Basin.

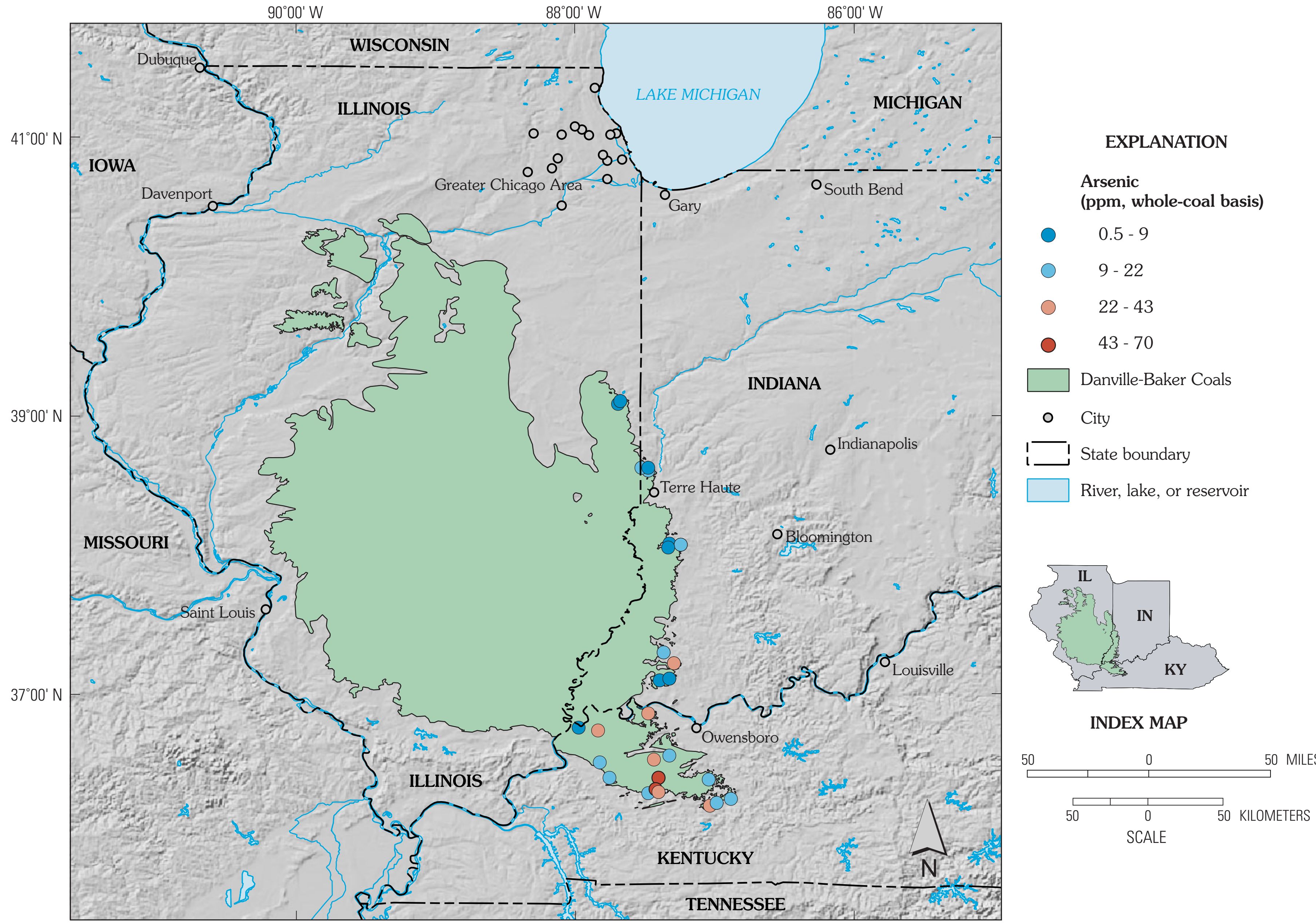

Figure 5. Graduated-symbol map for arsenic content (parts per million, as-received, whole-coal basis) of the Danville-Baker Coals in the Illinois Basin.

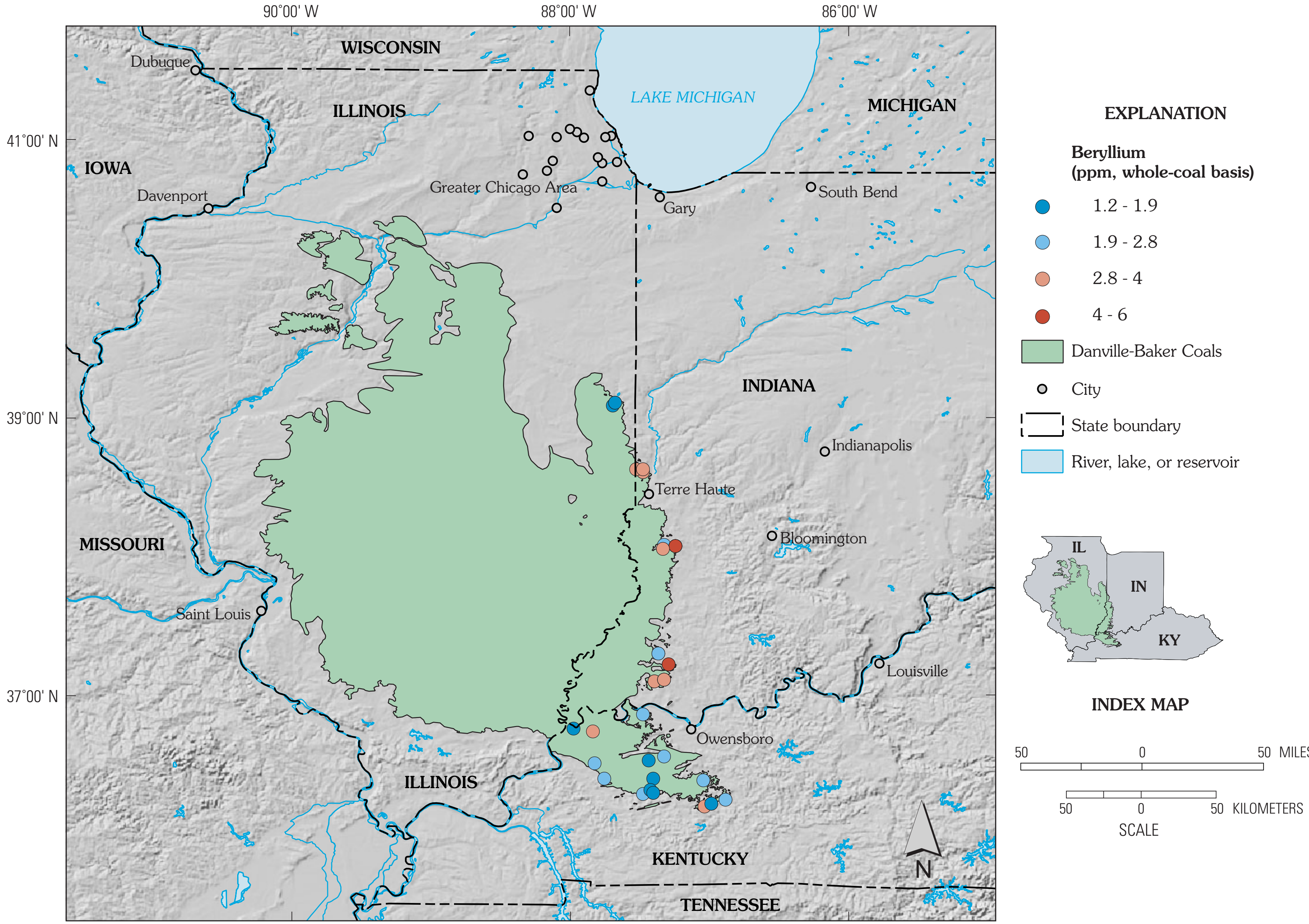

Figure 6. Graduated-symbol map for beryllium content (parts per million, as-received, whole-coal basis) of the Danville-Baker Coals in the Illinois Basin.

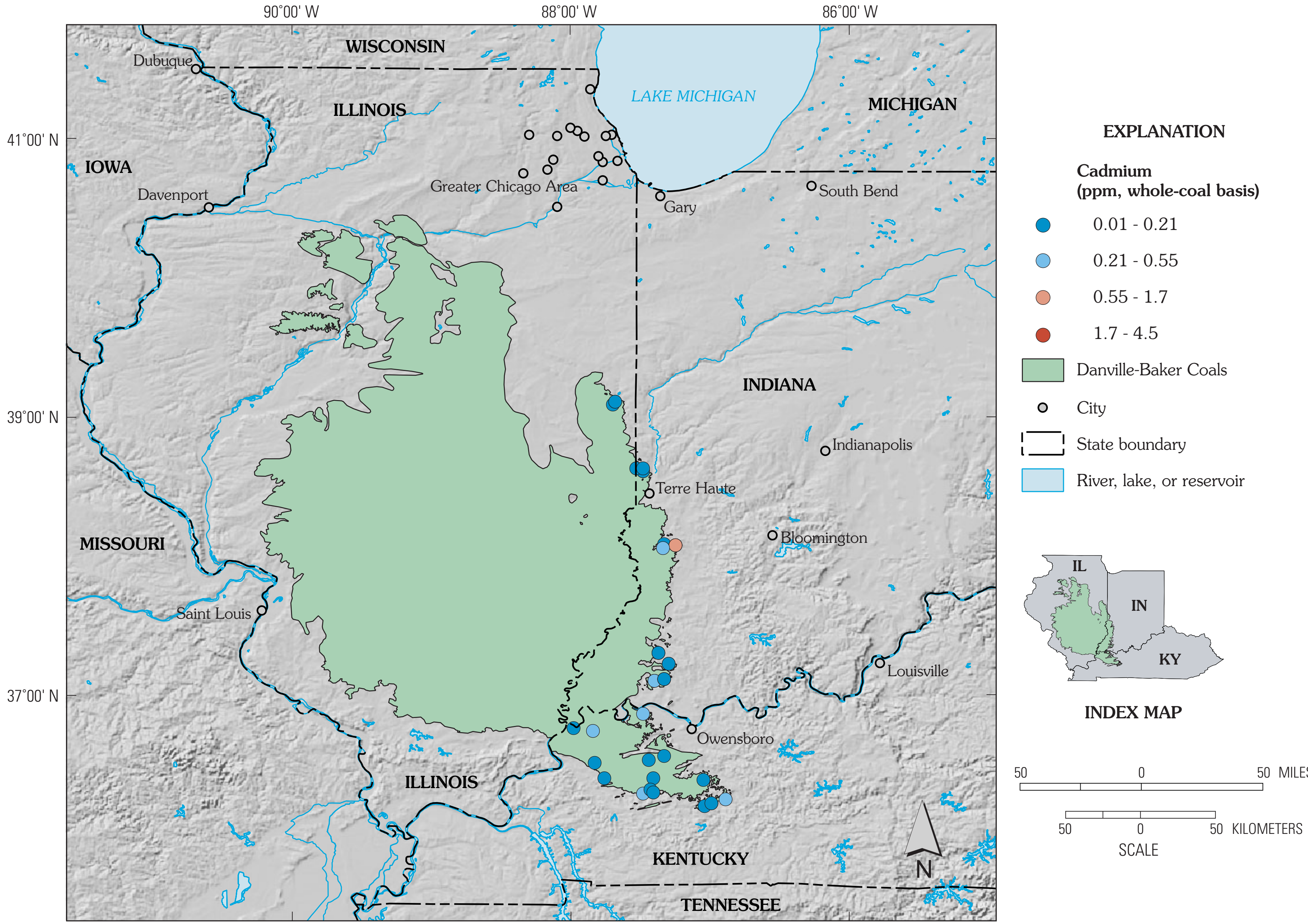

Figure 7. Graduated-symbol map for cadmium content (parts per million, as-received, whole-coal basis) of the Danville-Baker Coals in the Illinois Basin.

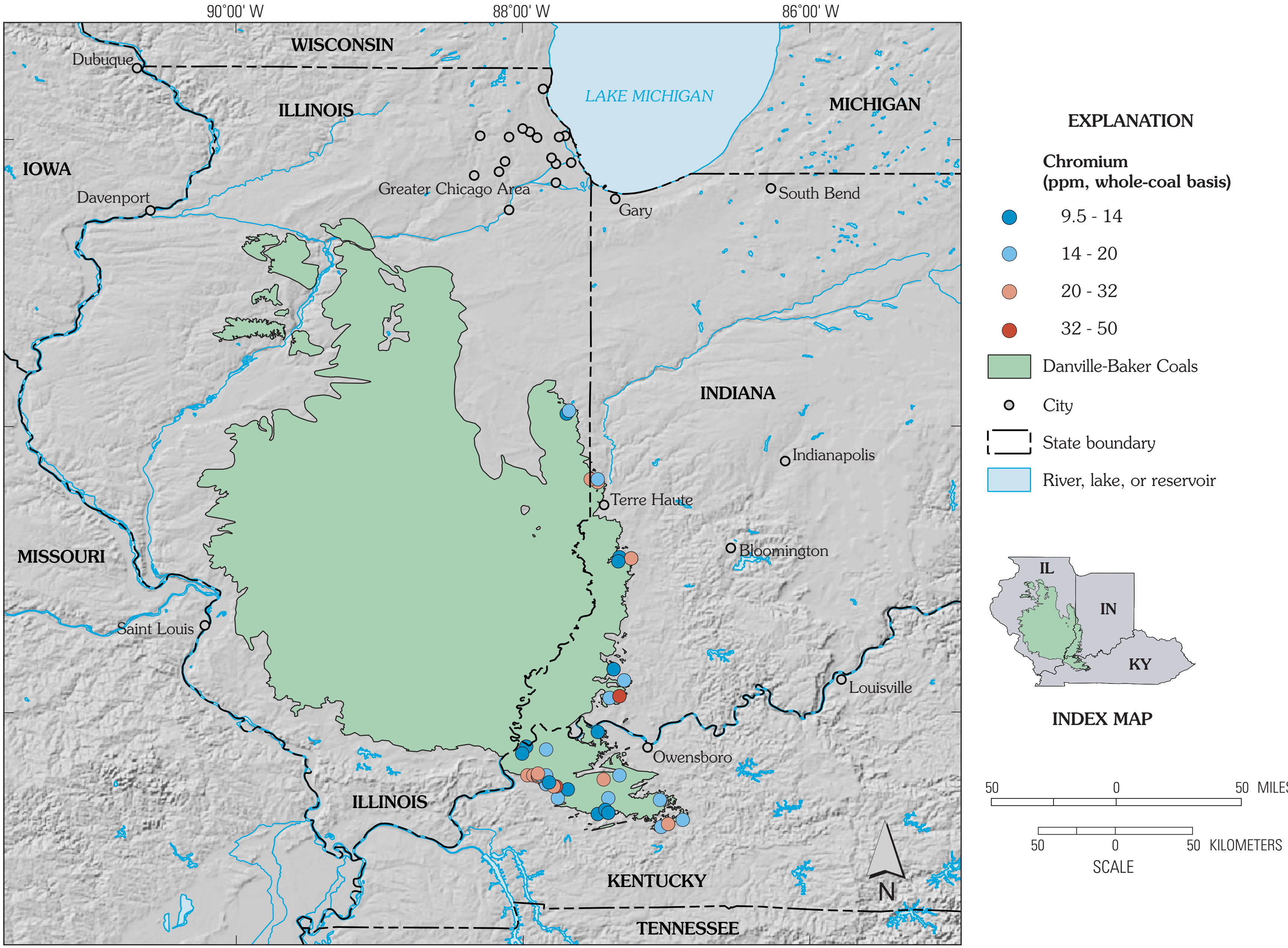

Figure 8. Graduated-symbol map for chromium content (parts per million, as-received, whole-coal basis) of the Danville-Baker Coals in the Illinois Basin.

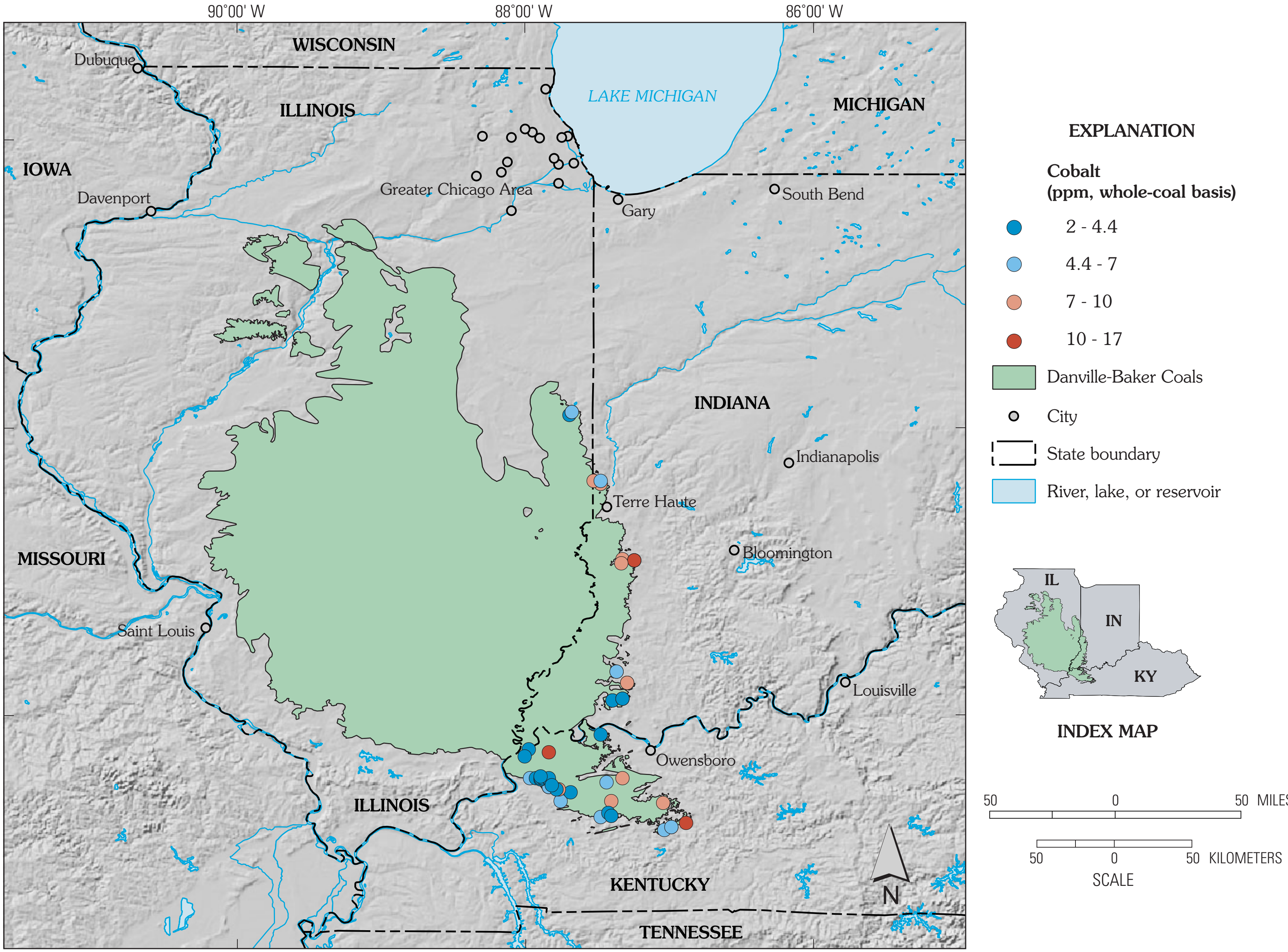

Figure 9. Graduated-symbol map for cobalt content (parts per million, as-received, whole-coal basis) of the Danville-Baker Coals in the Illinois Basin.

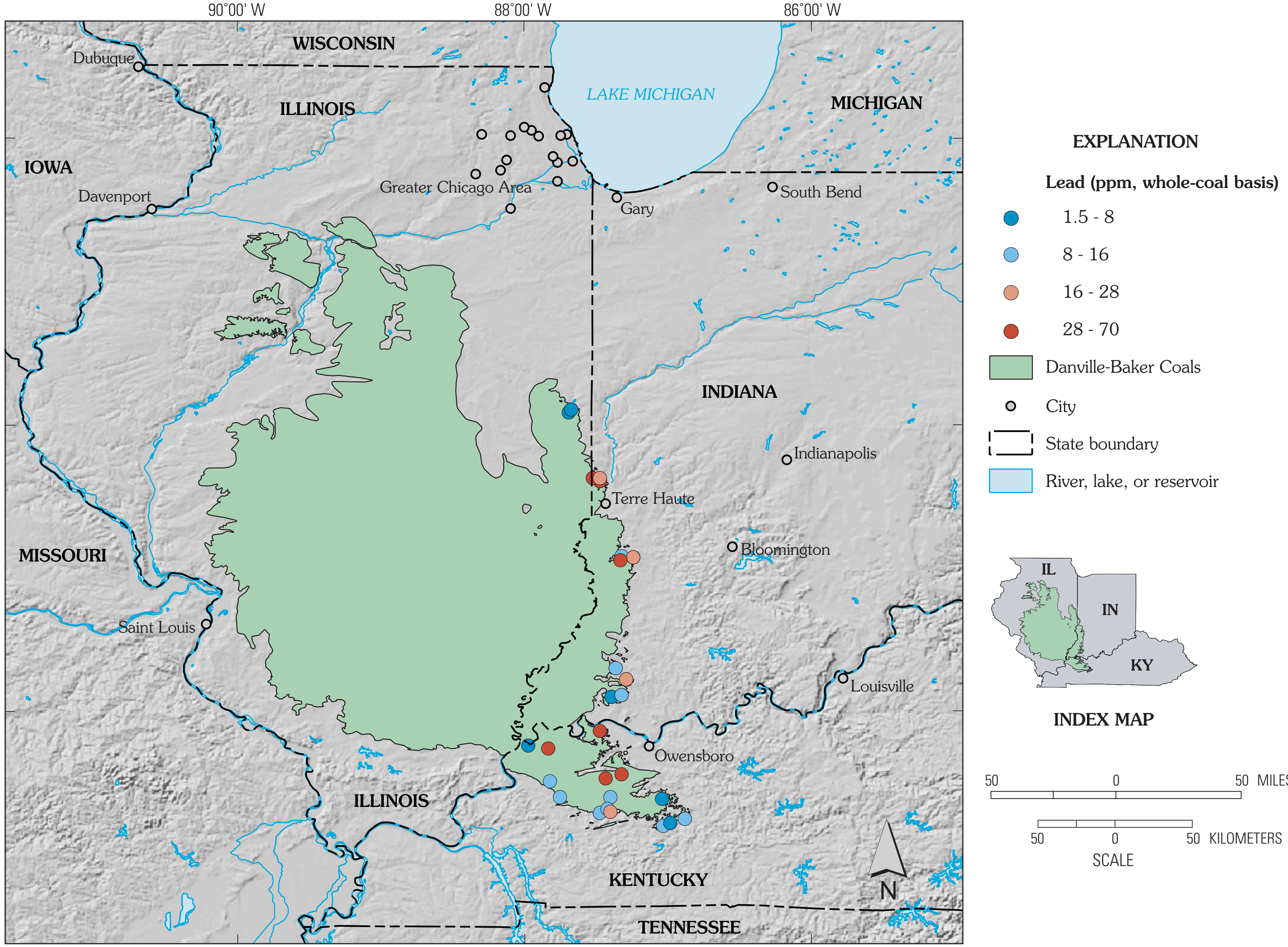

Figure 10. Graduated-symbol map for lead content (parts per million, as-received, whole-coal basis) of the Danville-Baker Coals in the Illinois Basin.

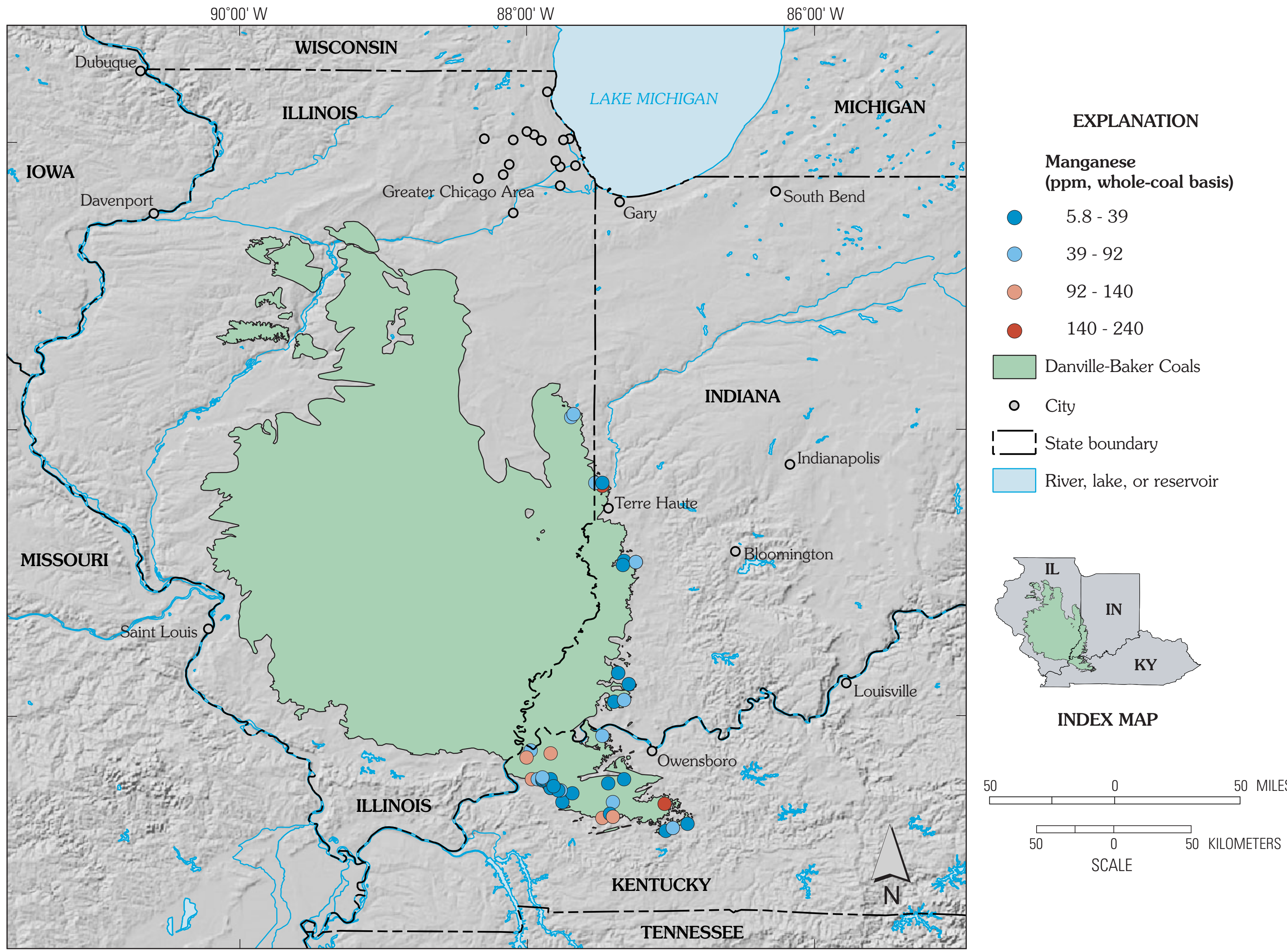

Figure 11. Graduated-symbol map for manganese content (parts per million, as-received, whole-coal basis) of the Danville-Baker Coals in the Illinois Basin.

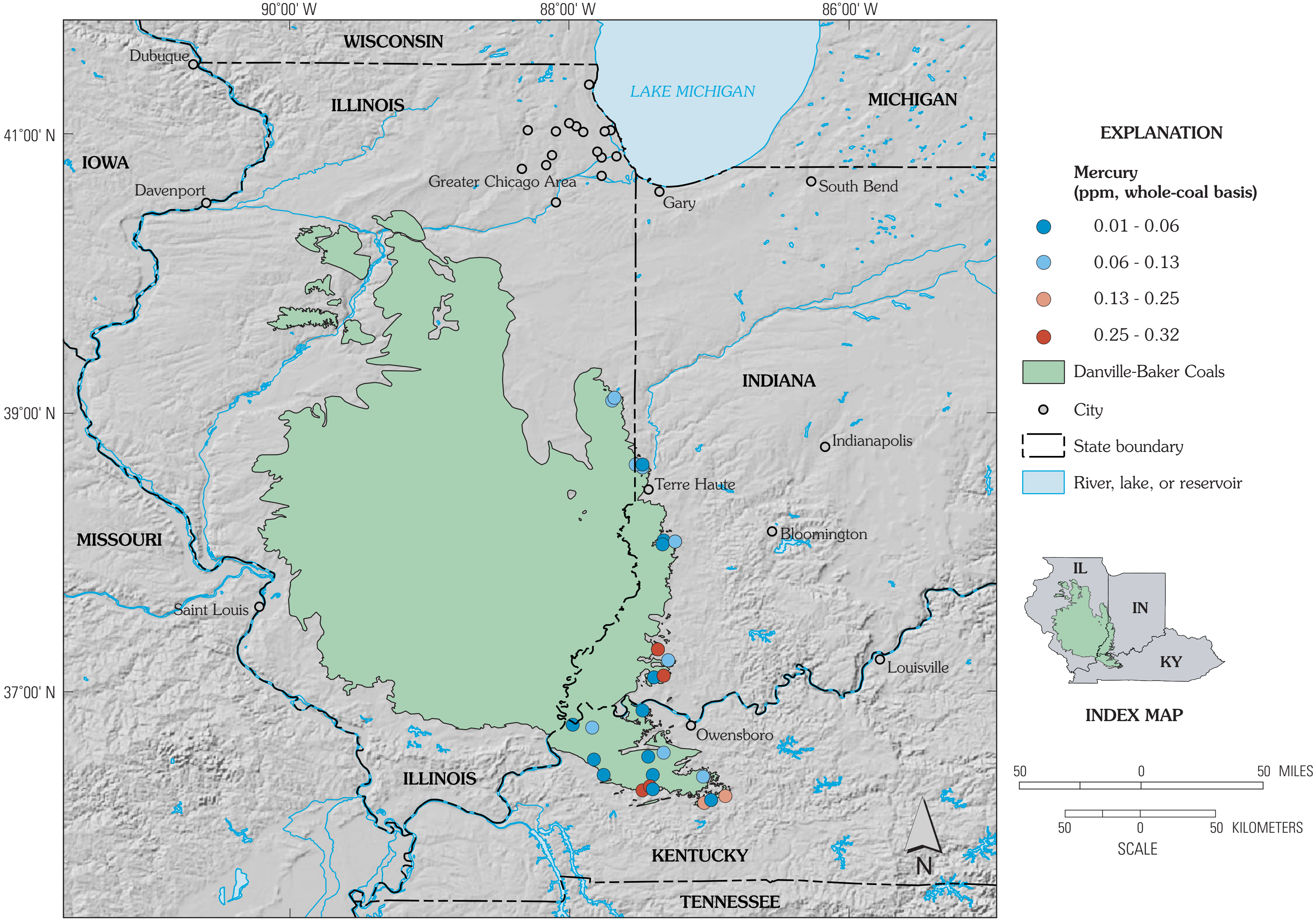

Figure 12. Graduated-symbol map for mercury content (parts per million, as-received, whole-coal basis) of the Danville-Baker Coals in the Illinois Basin.

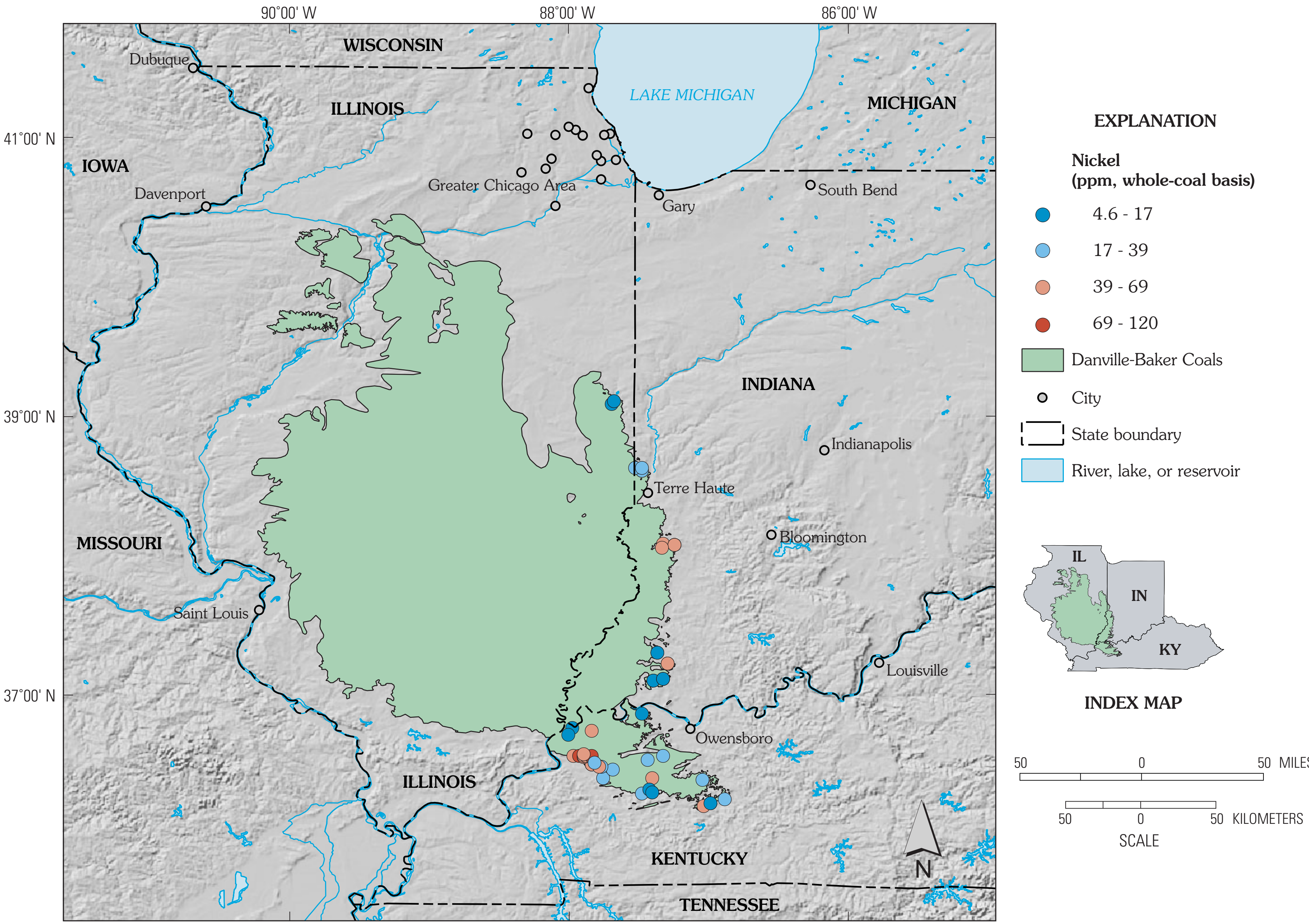

Figure 13. Graduated-symbol map for nickel content (parts per million, as-received, whole-coal basis) of the Danville-Baker Coals in the Illinois Basin.

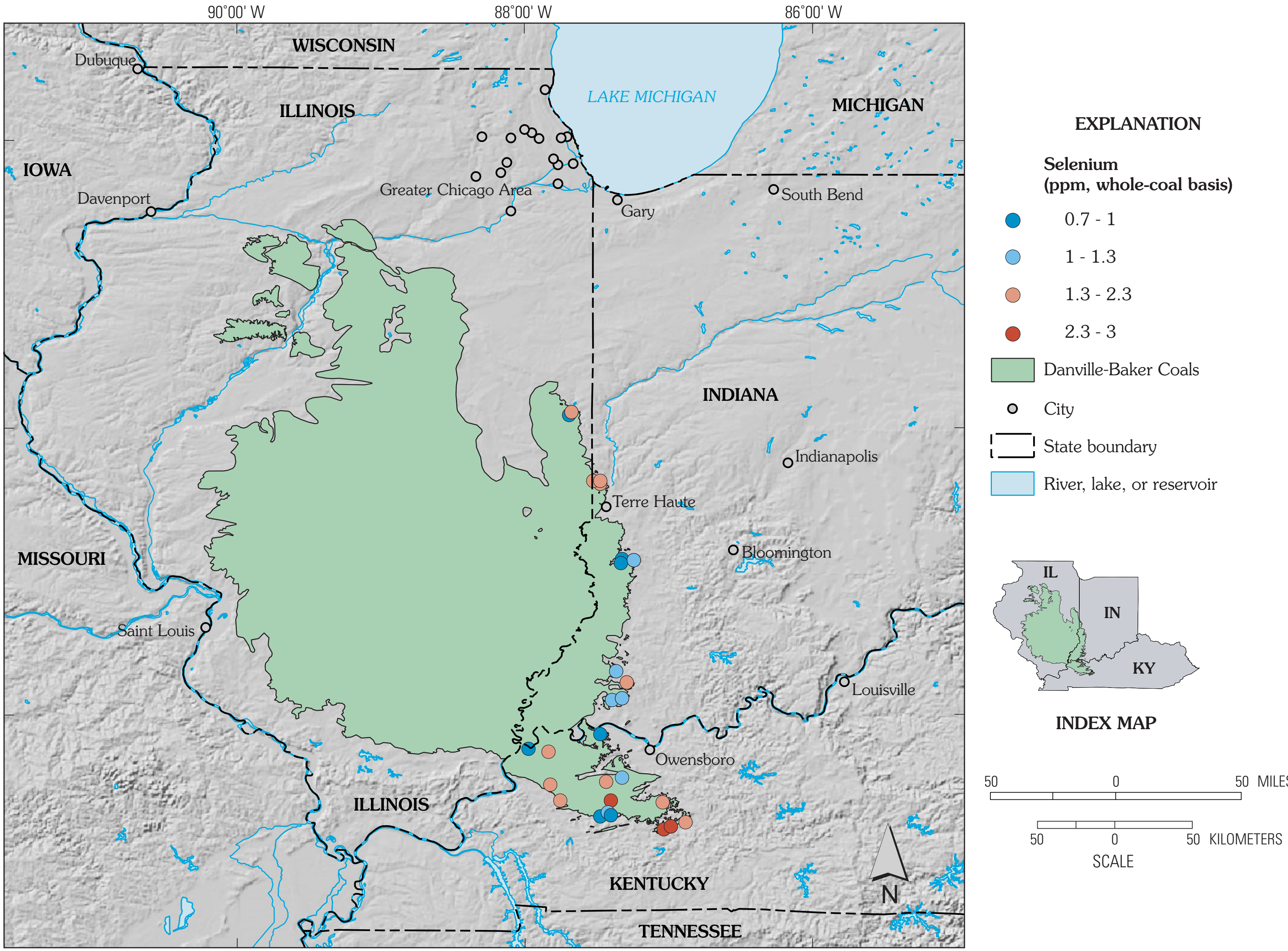

Figure 14. Graduated-symbol map for selenium content (parts per million, as-received, whole-coal basis) of the Danville-Baker Coals in the Illinois Basin.

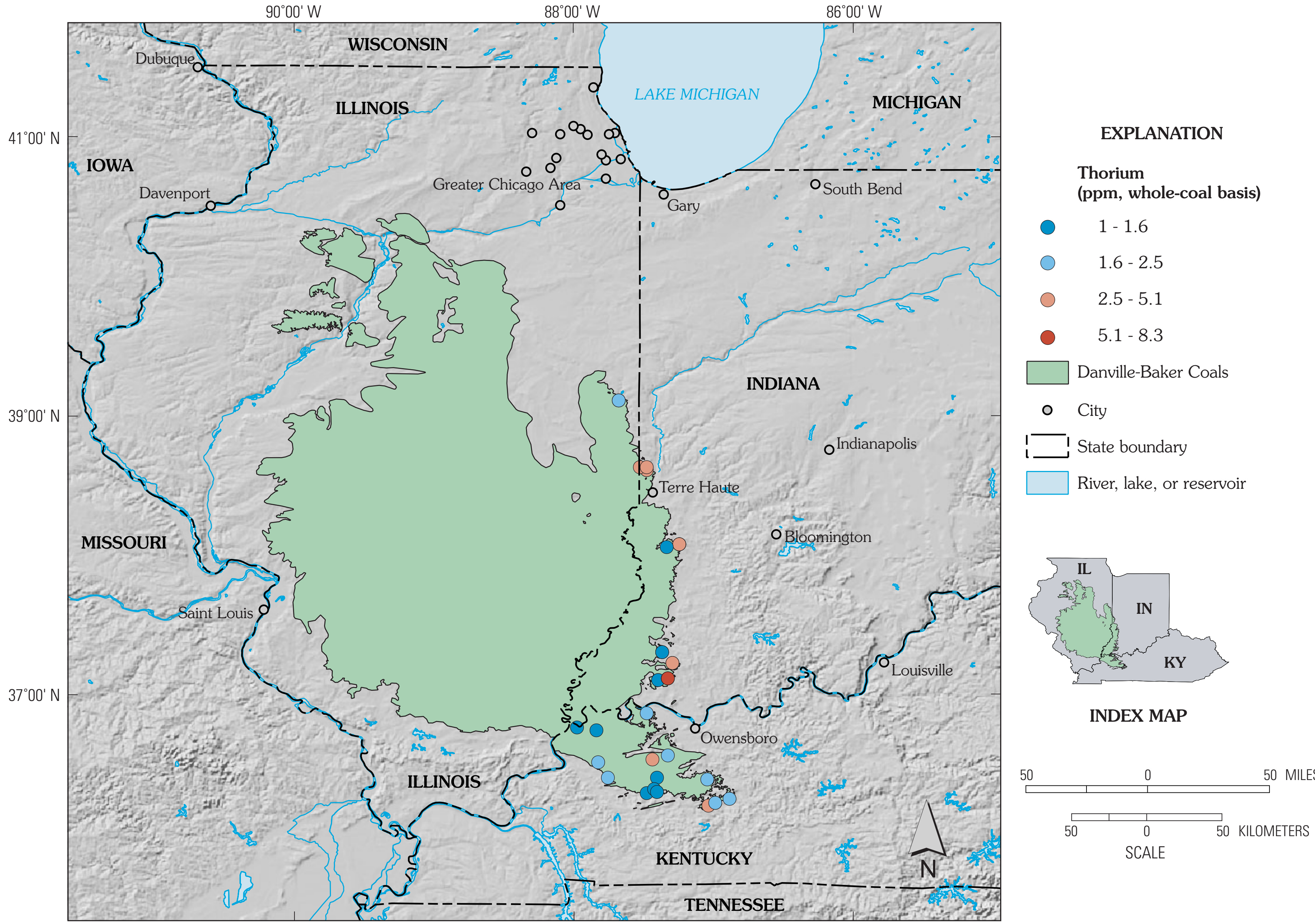

Figure 15. Graduated-symbol map for thorium content (parts per million, as-received, whole-coal basis) of the Danville-Baker Coals in the Illinois Basin.

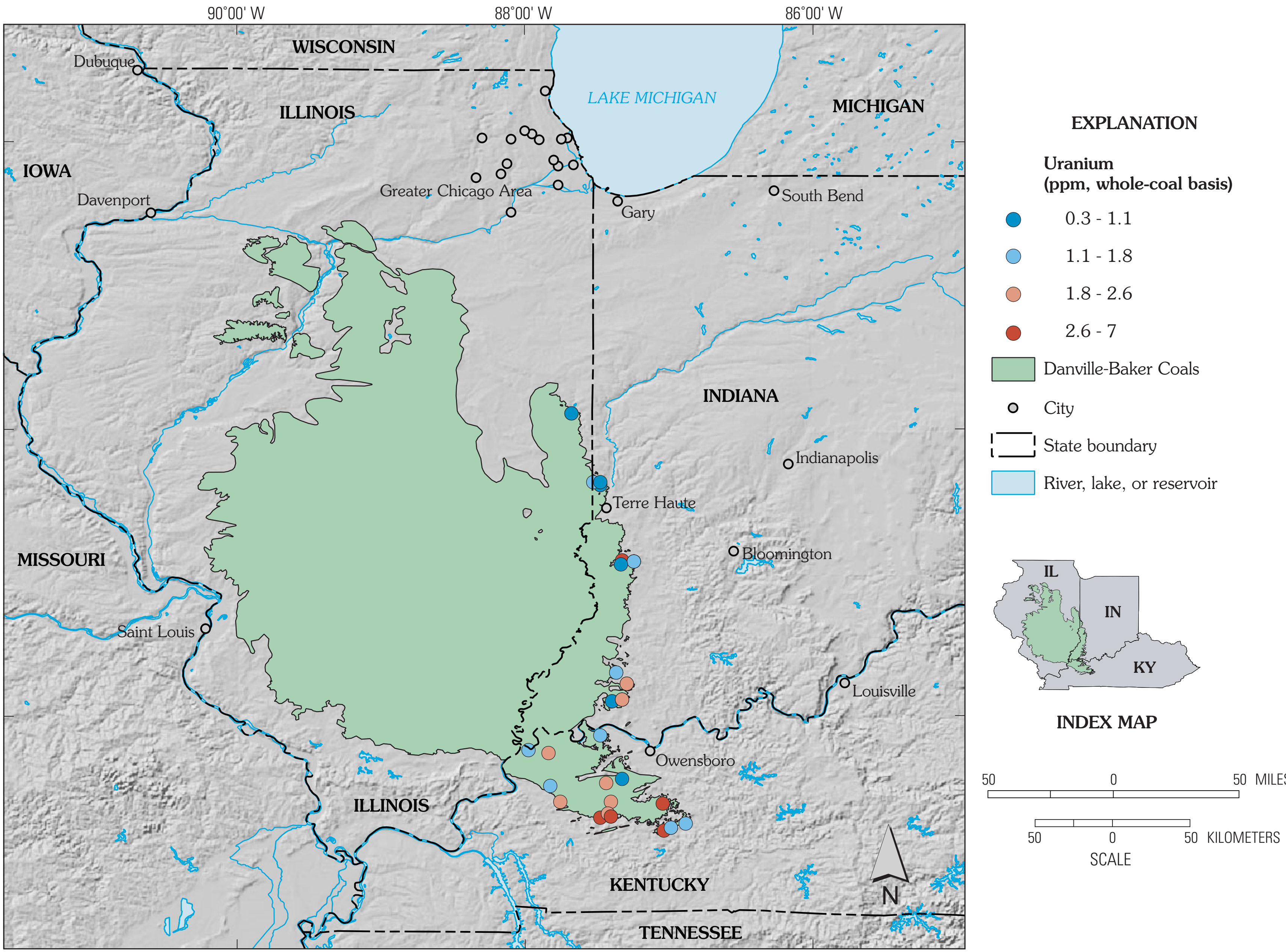

Figure 16. Graduated-symbol map for uranium content (parts per million, as-received, whole-coal basis) of the Danville-Baker Coals in the Illinois Basin.

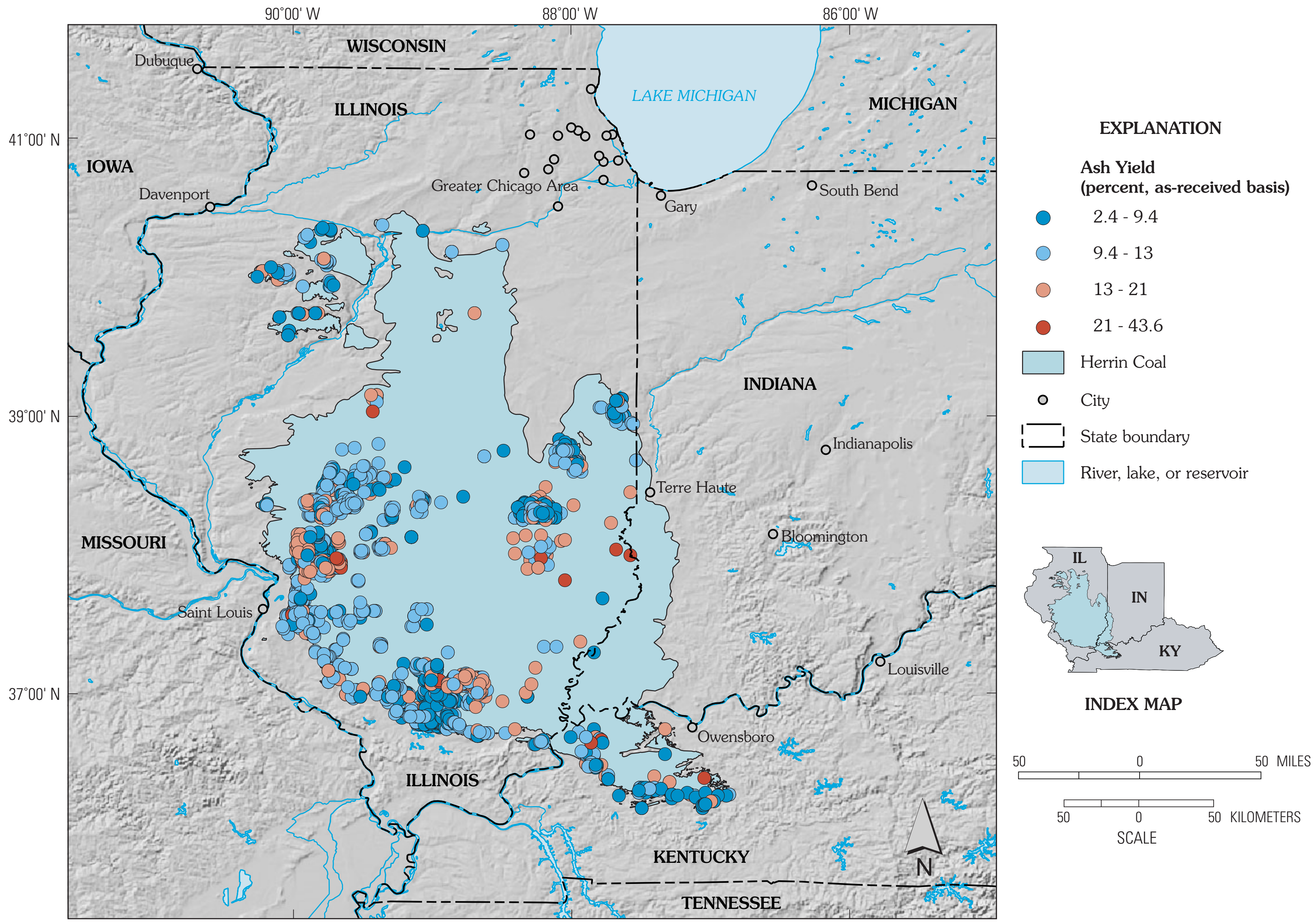

Figure 17. Graduated-symbol map for ash yield (percent, as-received basis) of the Herrin Coal in the Illinois Basin.

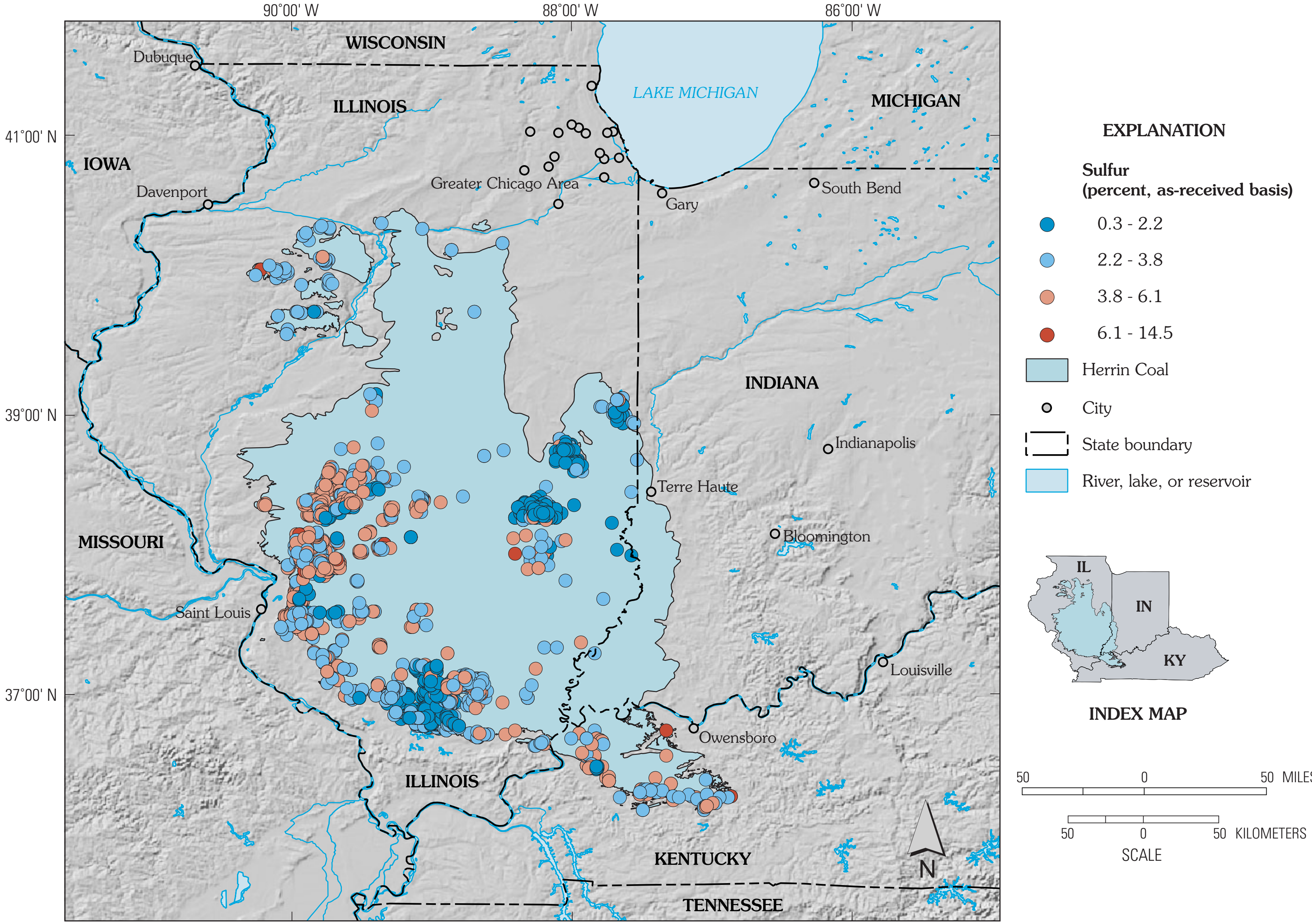

Figure 18. Graduated-symbol map for sulfur content (percent, as-received basis) of the Herrin Coal in the Illinois Basin.

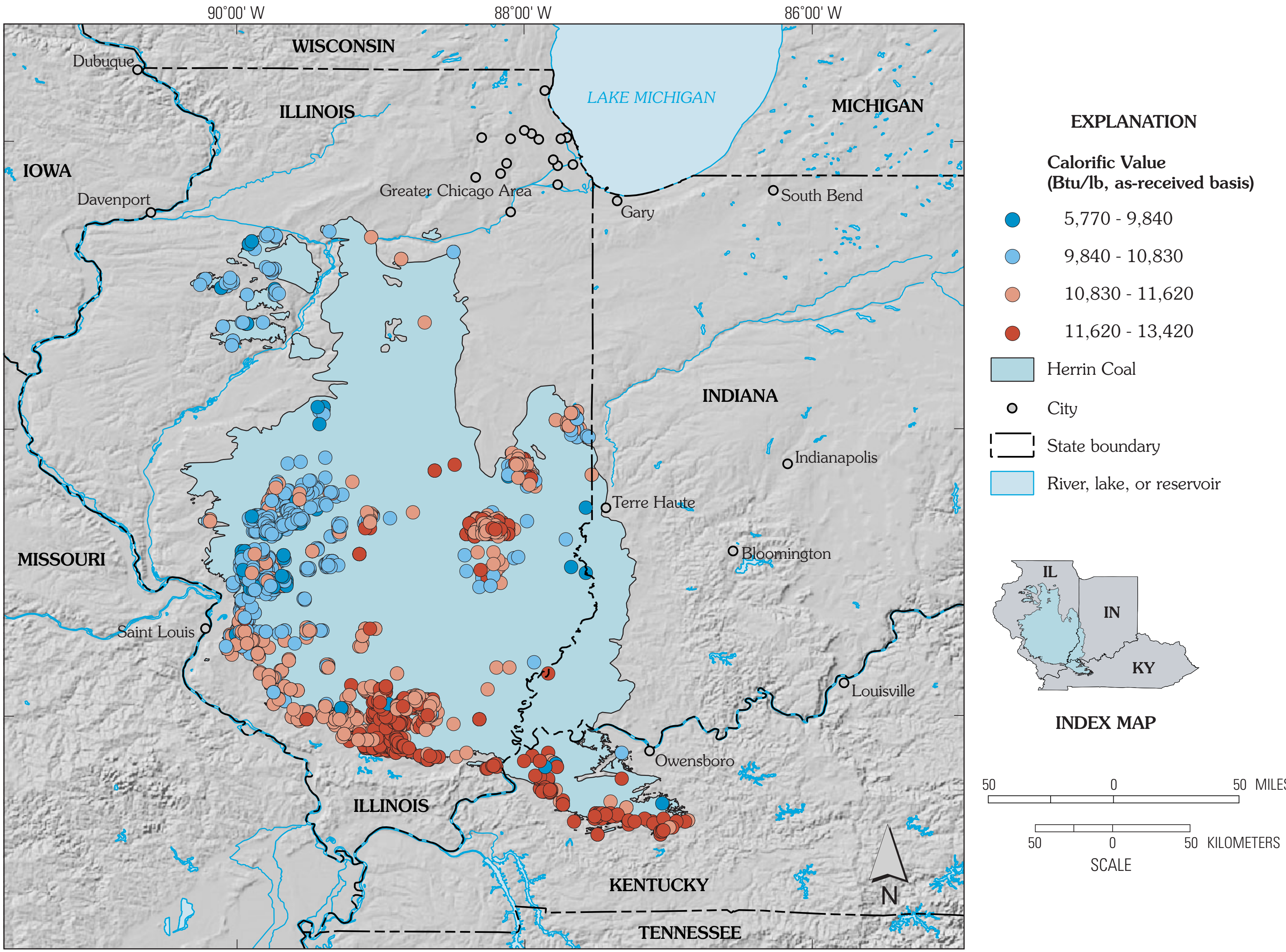

Figure 19. Graduated-symbol map for calorific values (Btu/lb, as-received basis) of the Herrin Coal in the Illinois Basin.

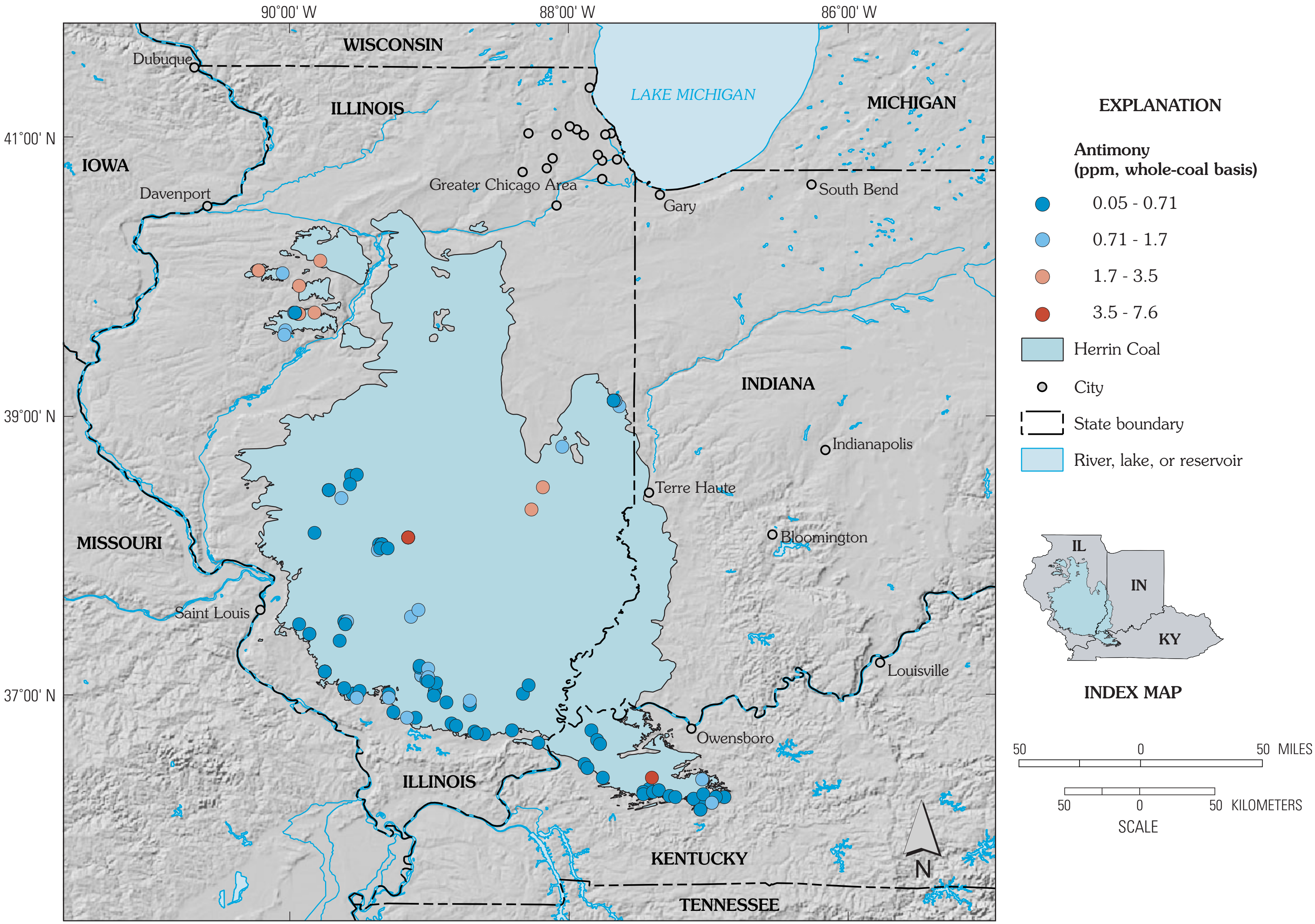

Figure 20. Graduated-symbol map for antimony content (parts per million, as-received, whole-coal basis) of the Herrin Coal in the Illinois Basin.

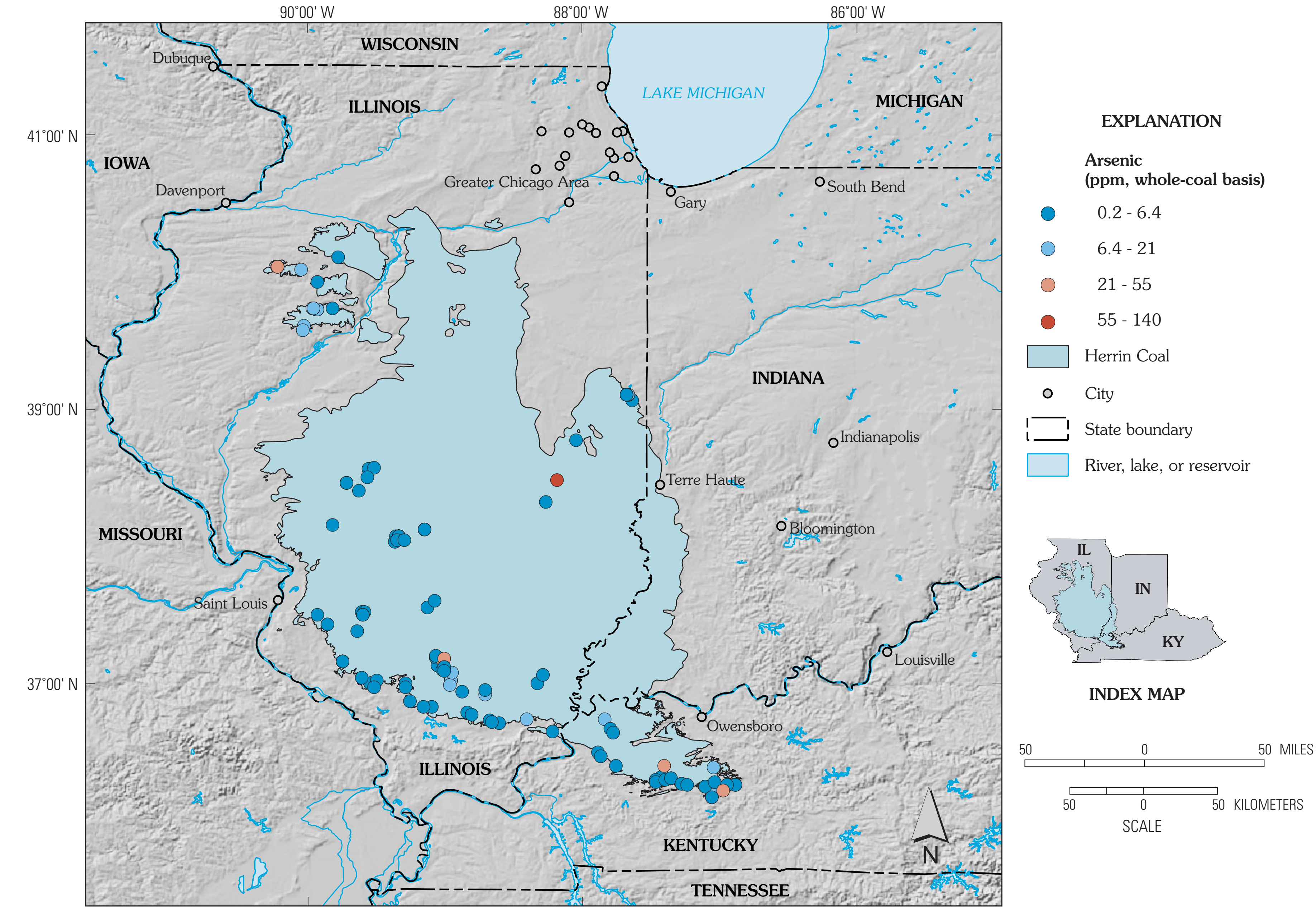

Figure 21. Graduated-symbol map for arsenic content (parts per million, as-received, whole-coal basis) of the Herrin Coal in the Illinois Basin.

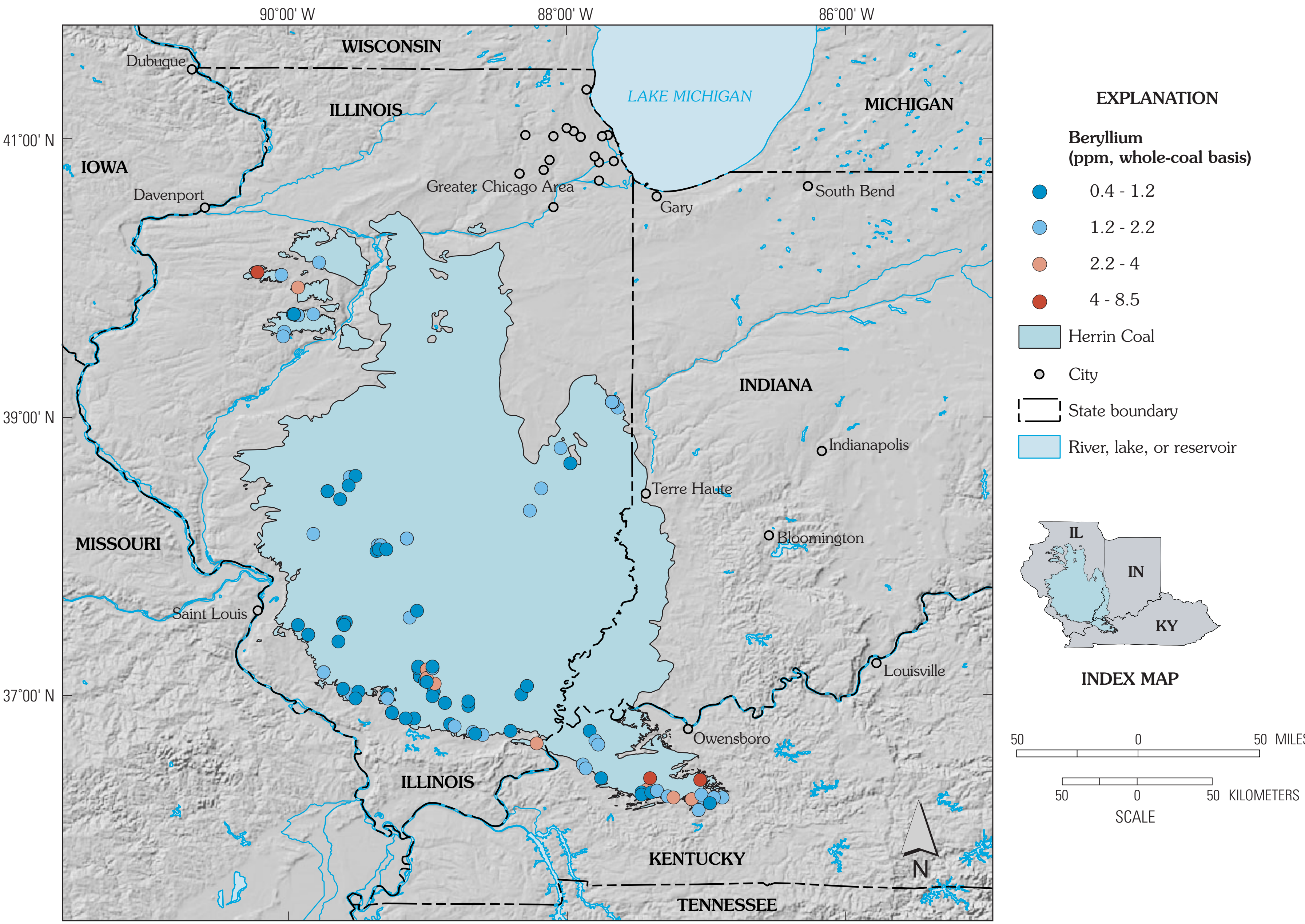

Figure 22. Graduated-symbol map for beryllium content (parts per million, as-received, whole-coal basis) of the Herrin Coal in the Illinois Basin.

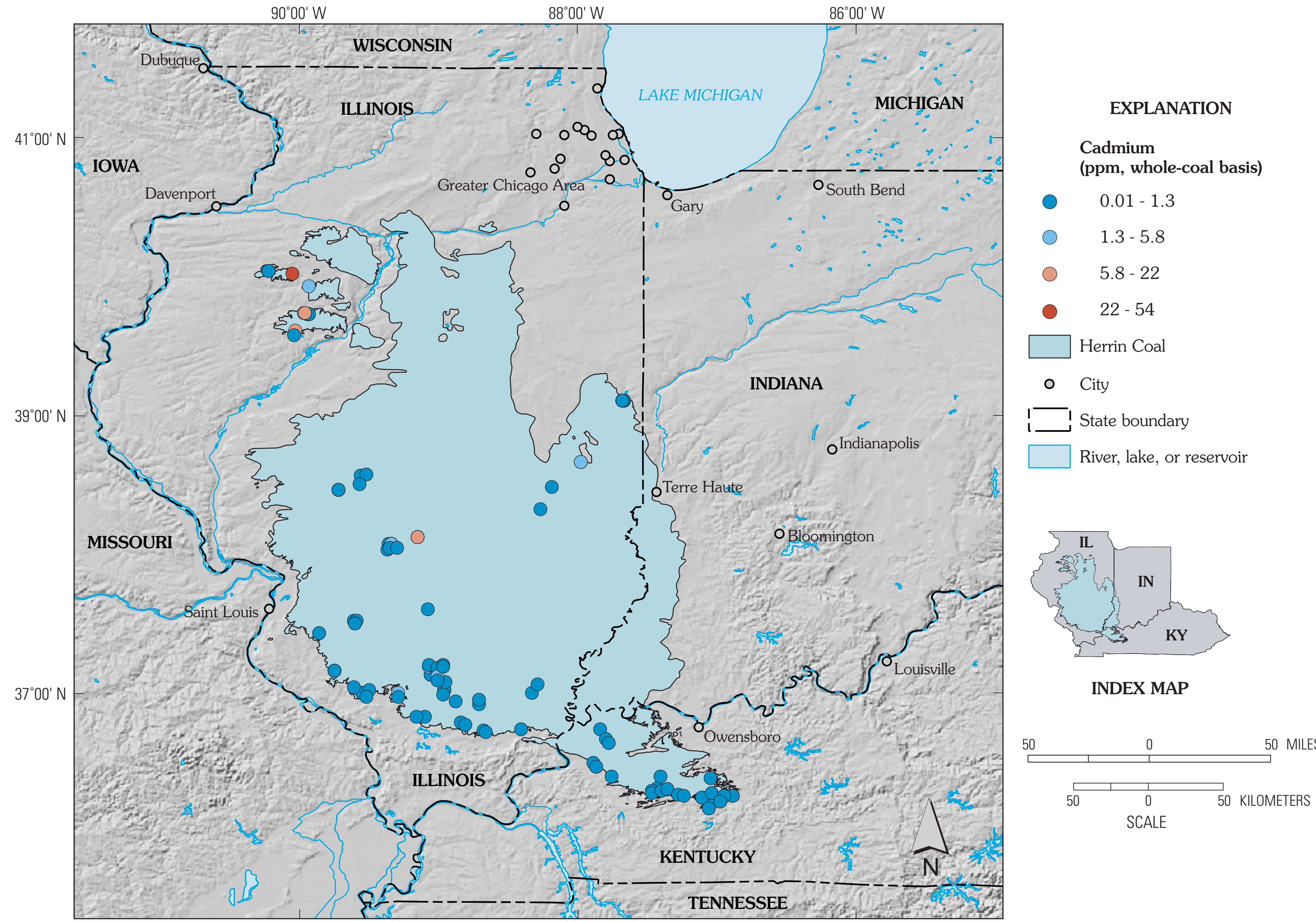

Figure 23. Graduated-symbol map for cadmium content (parts per million, as-received, whole-coal basis) of the Herrin Coal in the Illinois Basin.

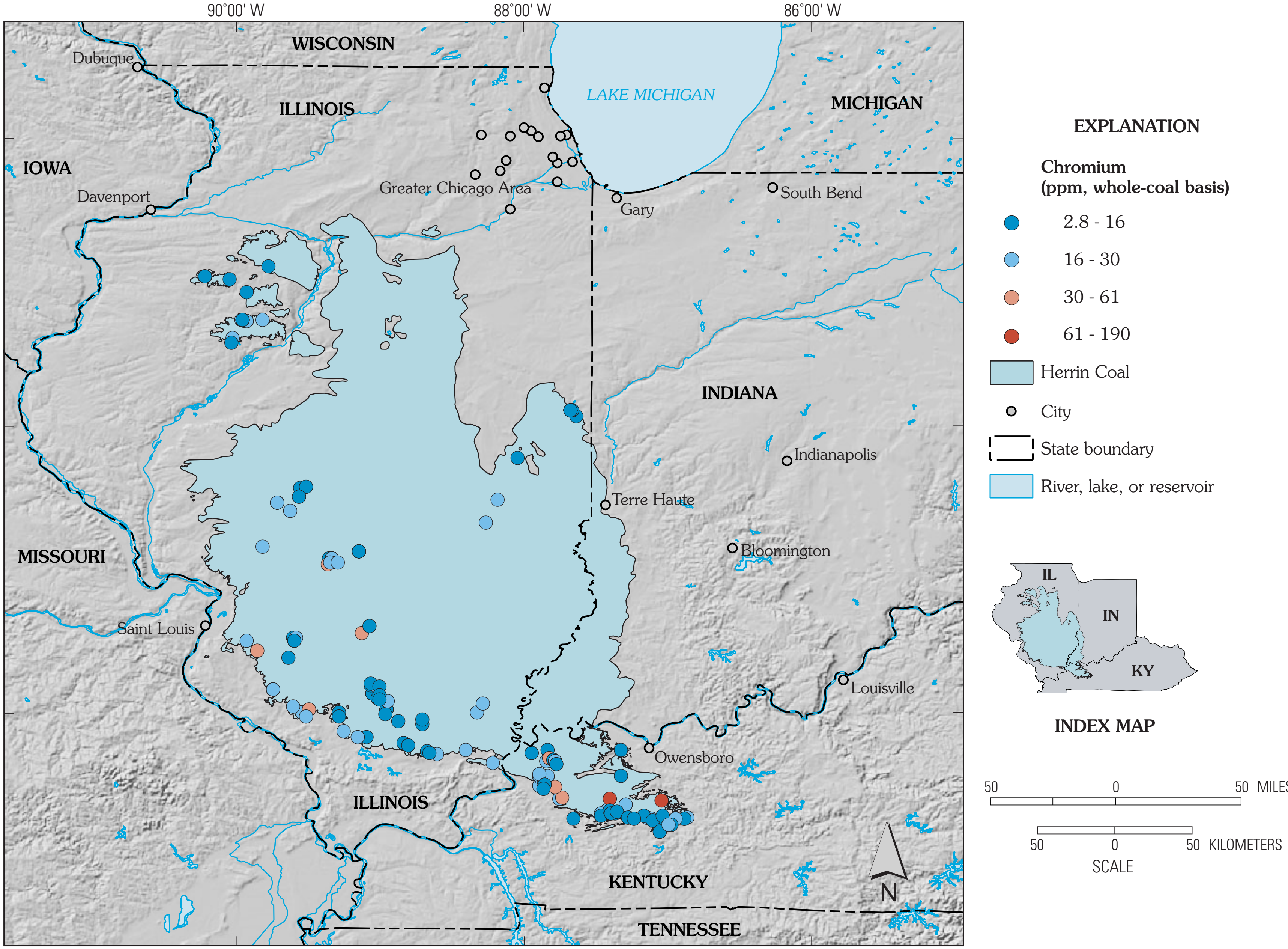

Figure 24. Graduated-symbol map for chromium content (parts per million, as-received, whole-coal basis) of the Herrin Coal in the Illinois Basin.

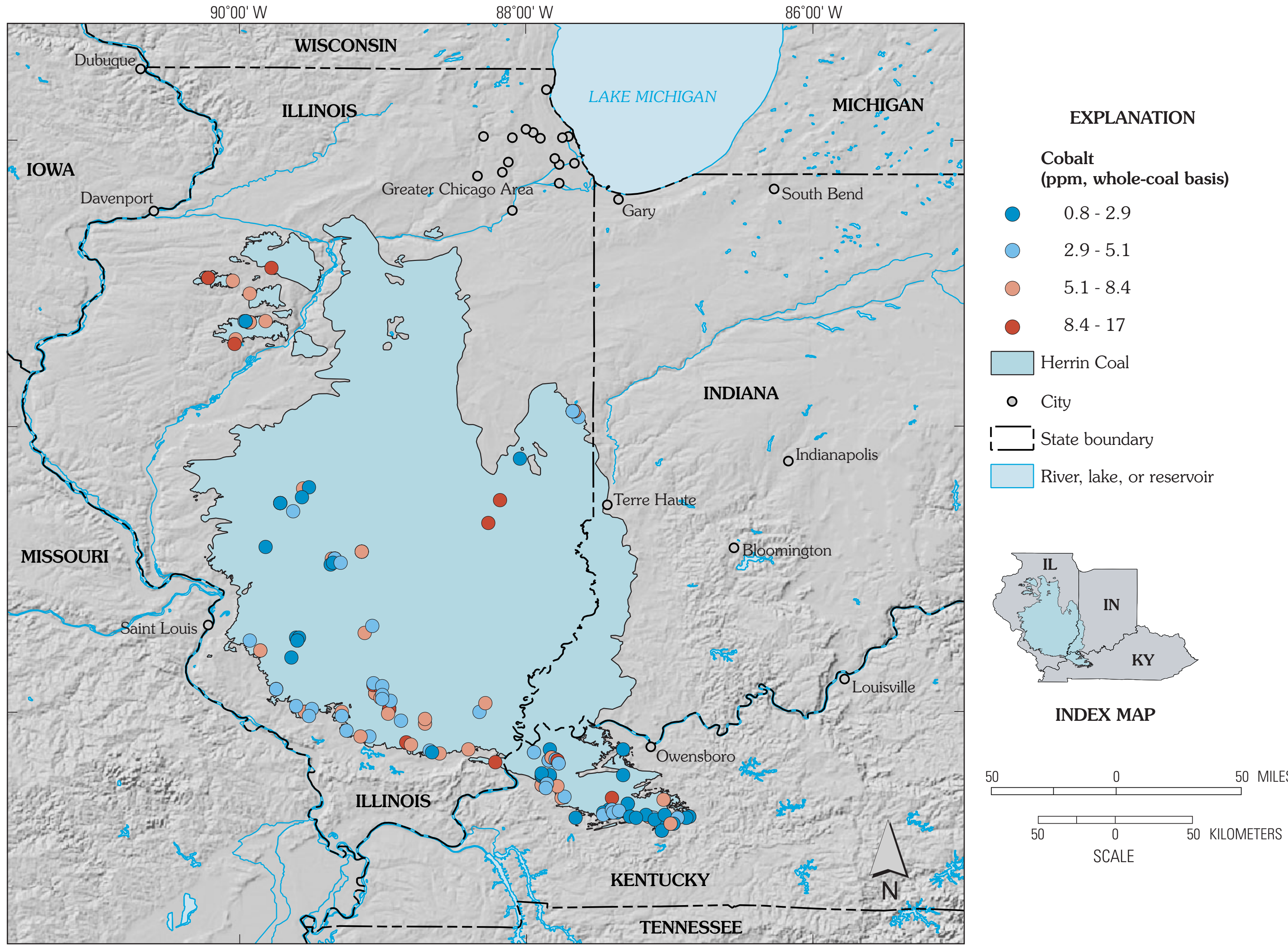

Figure 25. Graduated-symbol map for cobalt content (parts per million, as-received, whole-coal basis) of the Herrin Coal in the Illinois Basin.

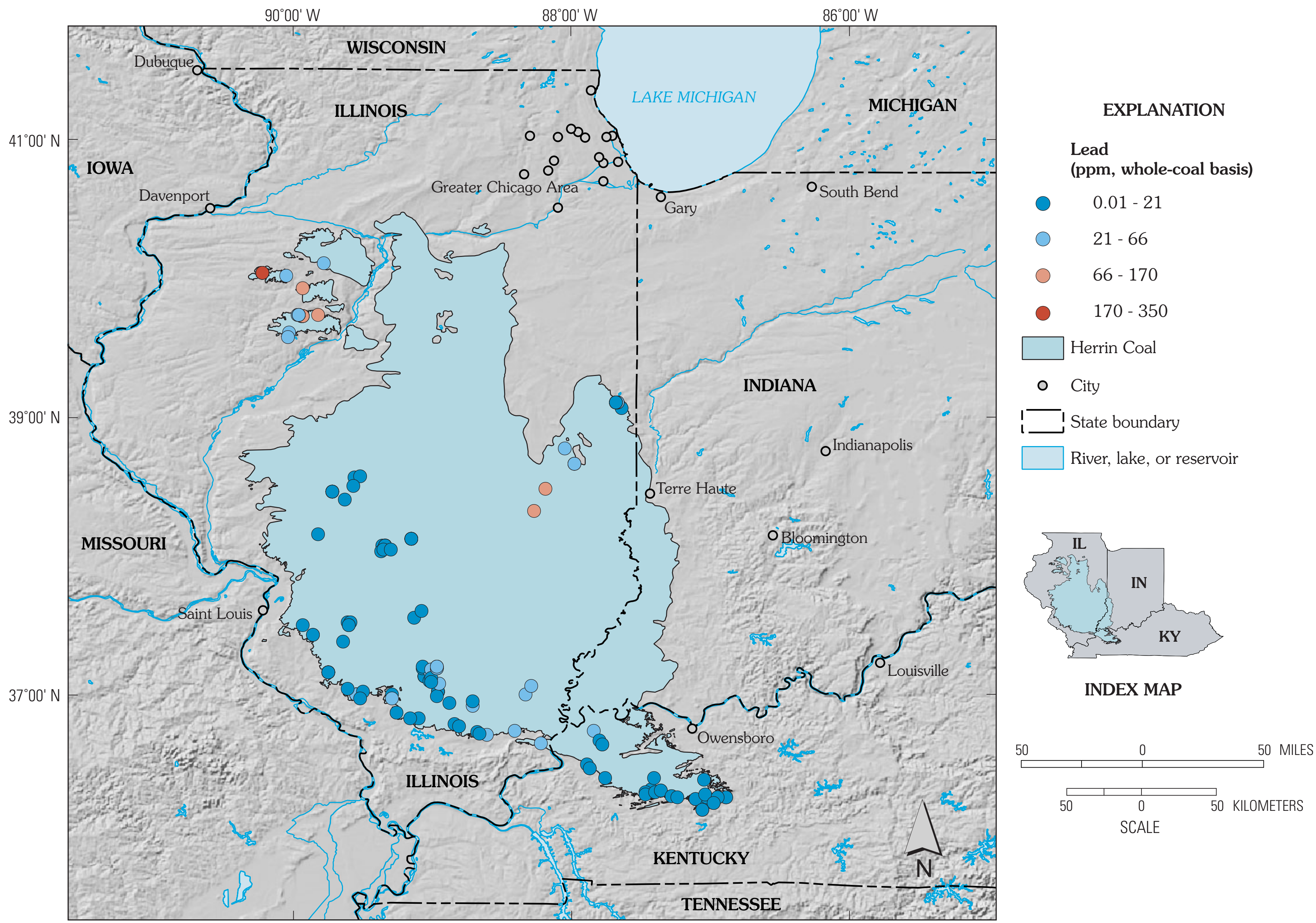

Figure 26. Graduated-symbol map for lead content (parts per million, as-received, whole-coal basis) of the Herrin Coal in the Illinois Basin.

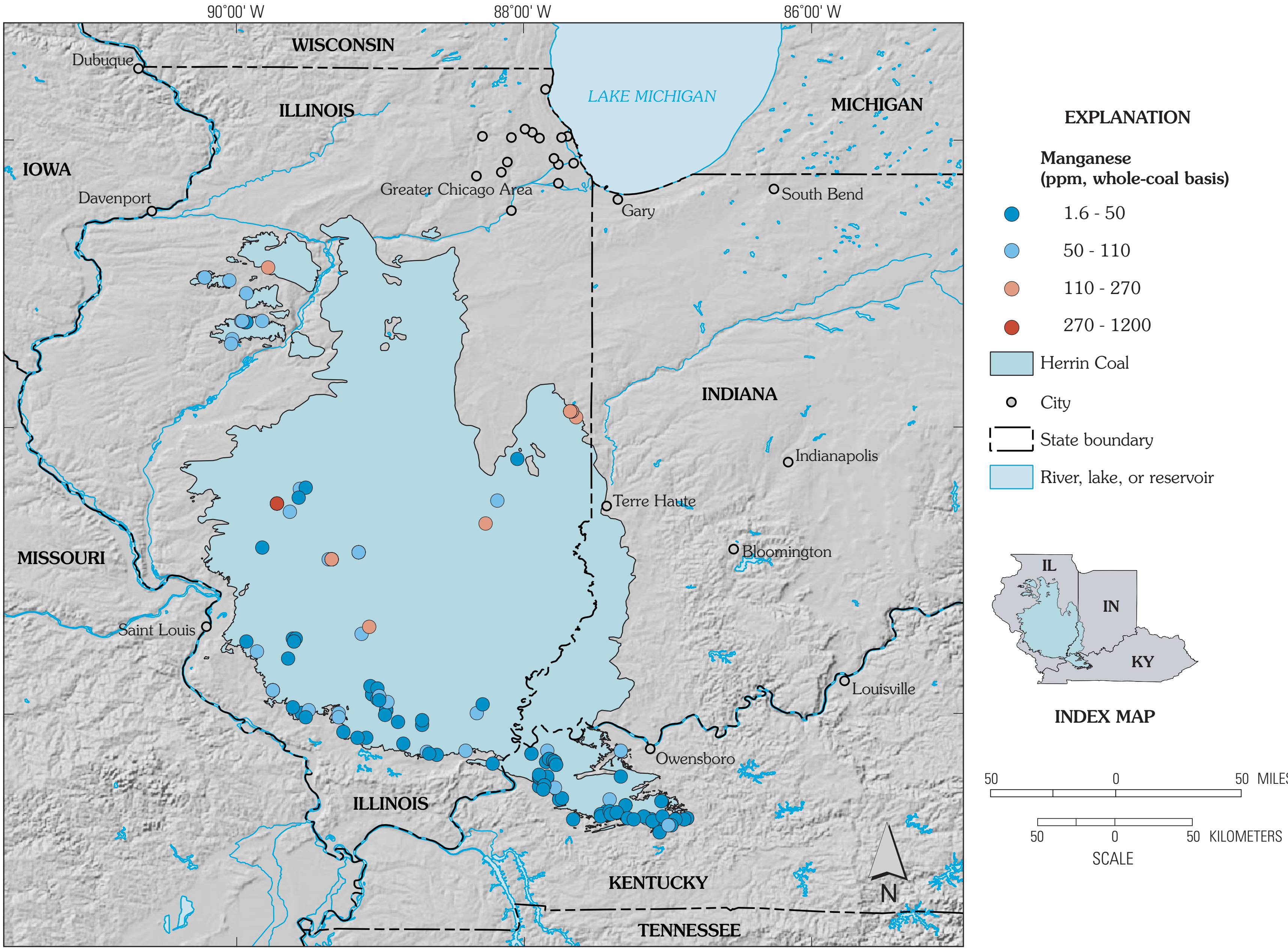

Figure 27. Graduated-symbol map for manganese content (parts per million, as-received, whole-coal basis) of the Herrin Coal in the Illinois Basin.

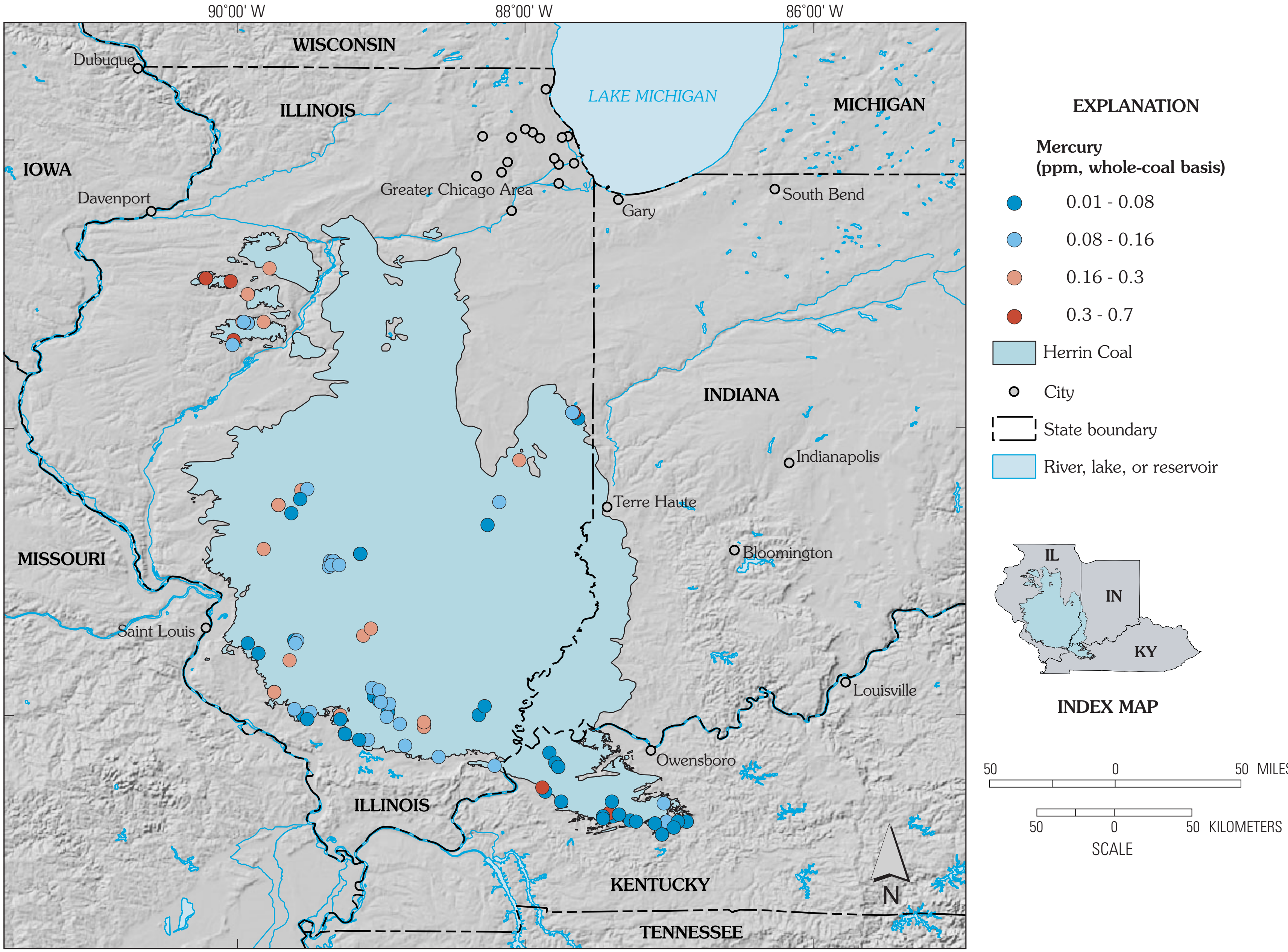

Figure 28. Graduated-symbol map for mercury content (parts per million, as-received, whole-coal basis) of the Herrin Coal in the Illinois Basin.

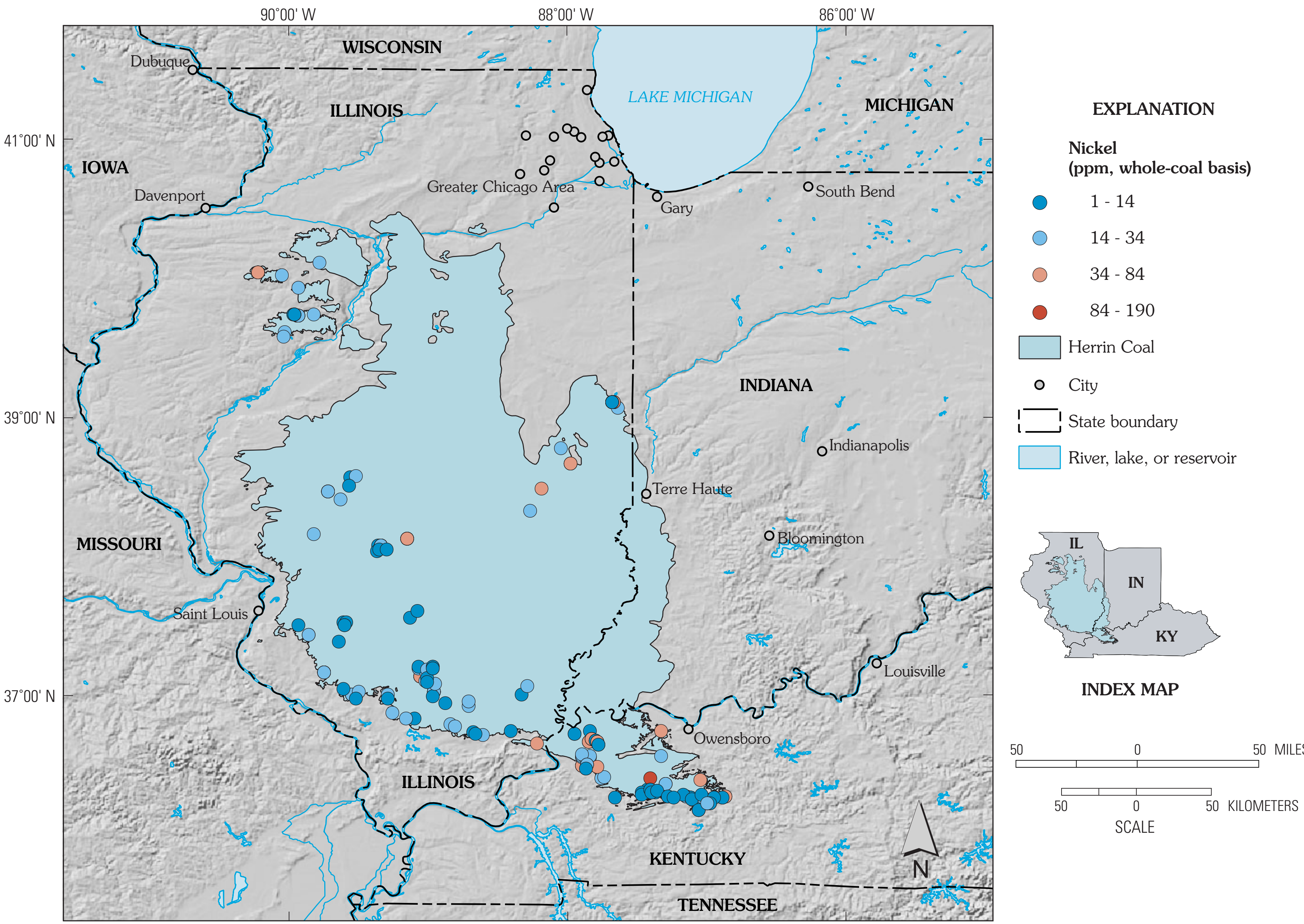

Figure 29. Graduated-symbol map for nickel content (parts per million, as-received, whole-coal basis) of the Herrin Coal in the Illinois Basin.

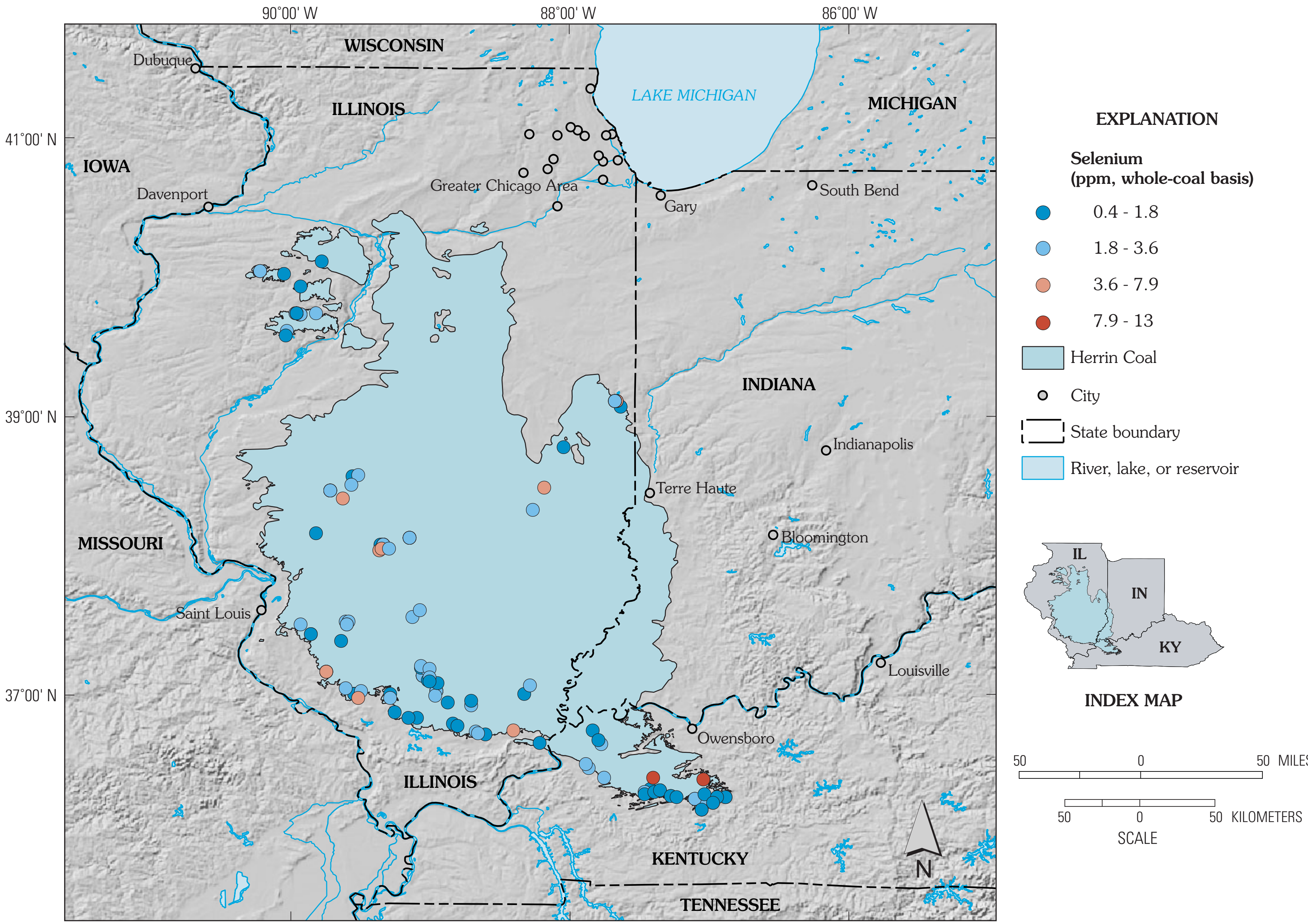

Figure 30. Graduated-symbol map for selenium content (parts per million, as-received, whole-coal basis) of the Herrin Coal in the Illinois Basin.

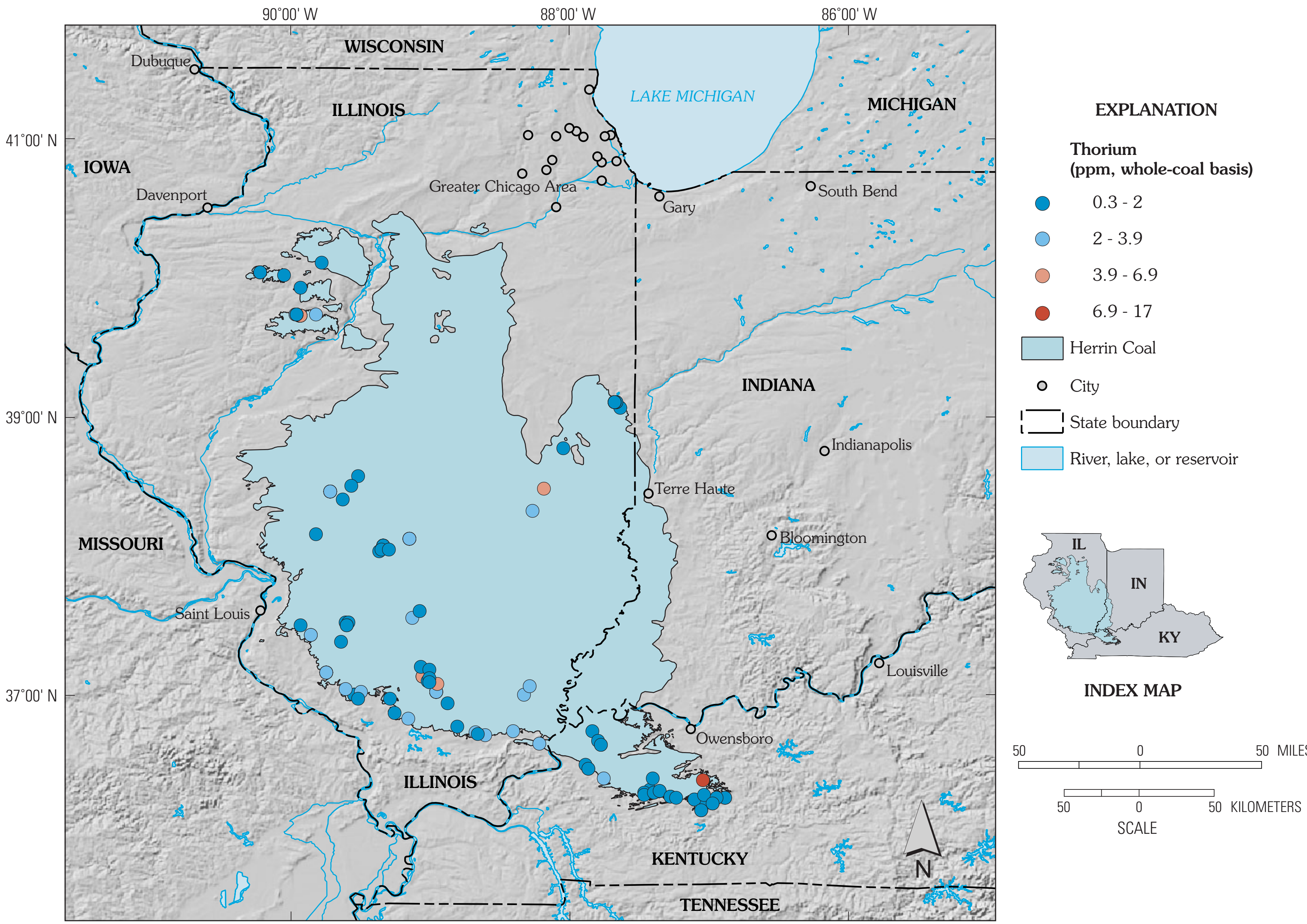

Figure 31. Graduated-symbol map for thorium content (parts per million, as-received, whole-coal basis) of the Herrin Coal in the Illinois Basin.

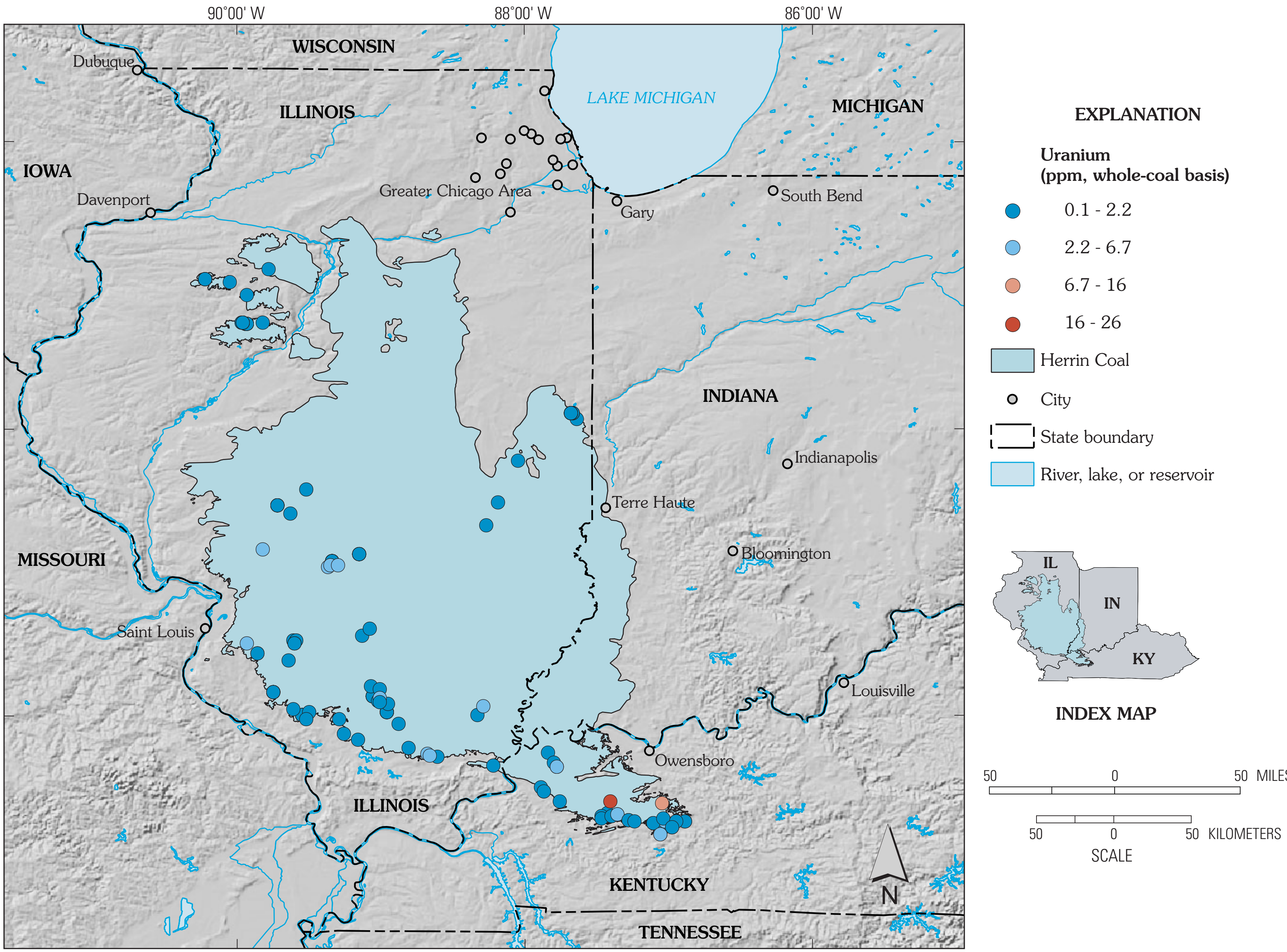

Figure 32. Graduated-symbol map for uranium content (parts per million, as-received, whole-coal basis) of the Herrin Coal in the Illinois Basin.

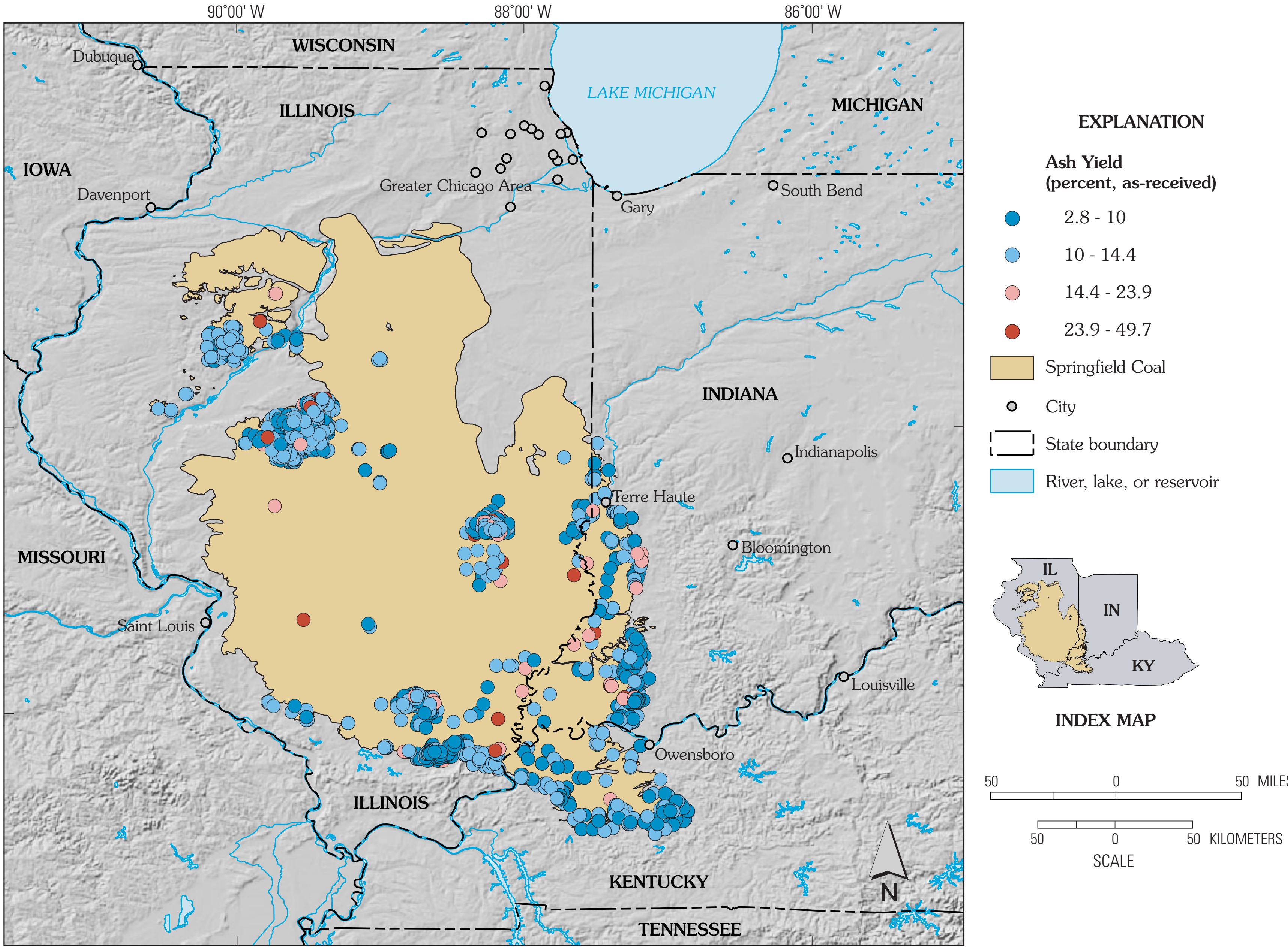

Figure 33. Graduated-symbol map for ash yield (percent, as-received basis) of the Springfield Coal in the Illinois Basin.

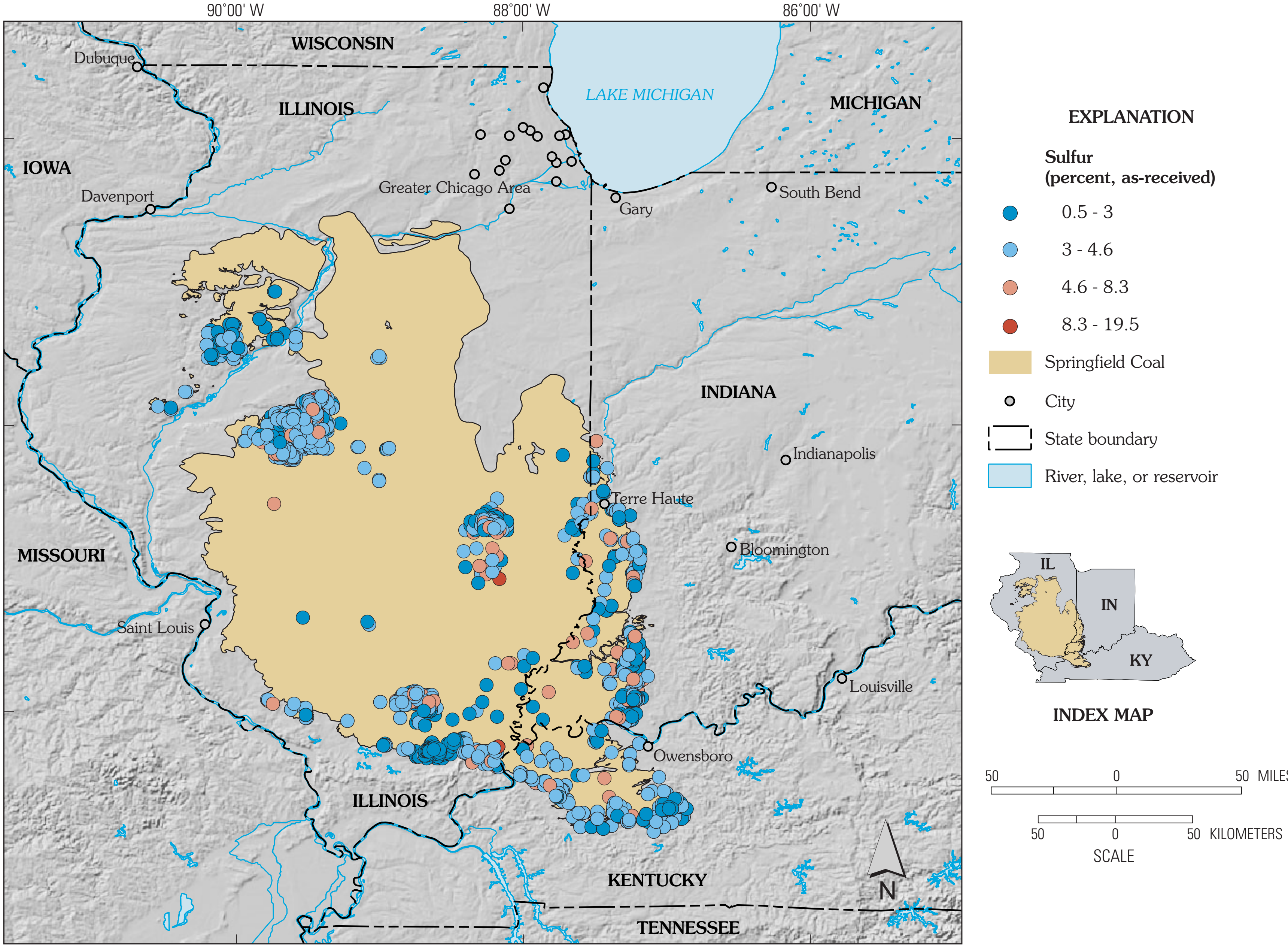

Figure 34. Graduated-symbol map for sulfur content (percent, as-received basis) of the Springfield Coal in the Illinois Basin.

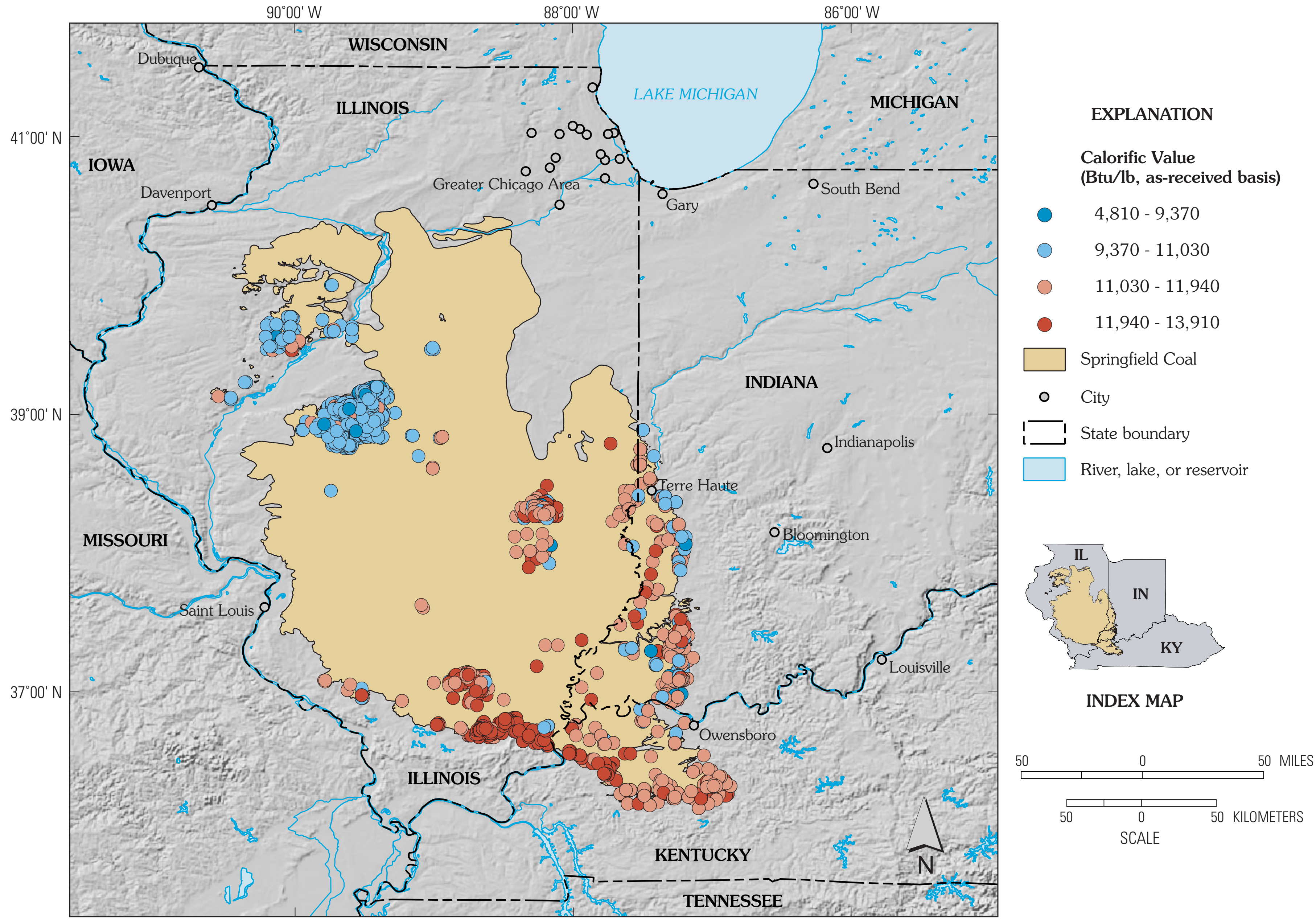

Figure 35. Graduated-symbol map for calorific values (Btu/lb, as-received basis) of the Springfield Coal in the Illinois Basin.

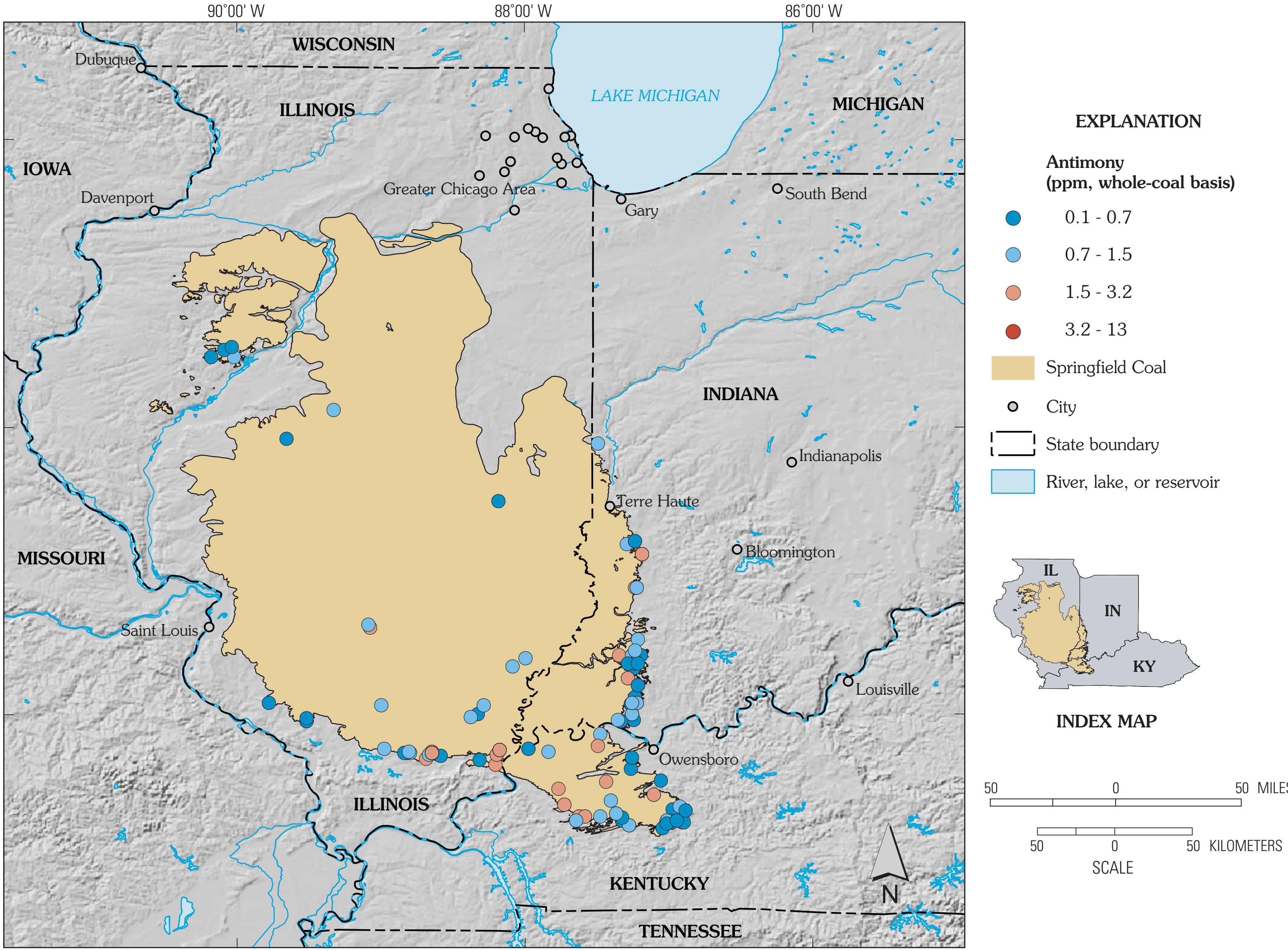

Figure 36. Graduated-symbol map for antimony content (parts per million, as-received, whole-coal basis) of the Springfield Coal in the Illinois Basin.

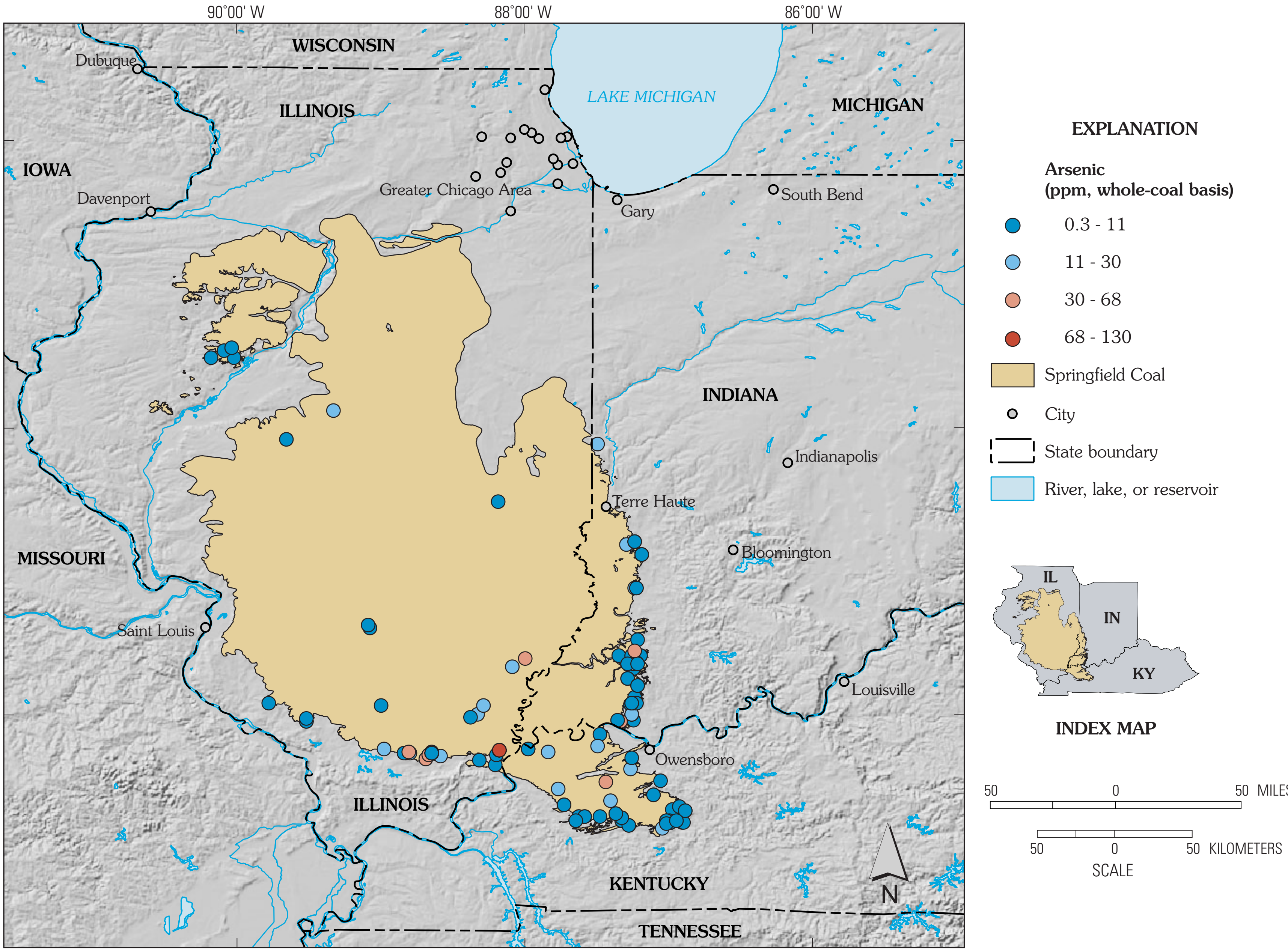

Figure 37. Graduated-symbol map for arsenic content (parts per million, as-received, whole-coal basis) of the Springfield Coal in the Illinois Basin.

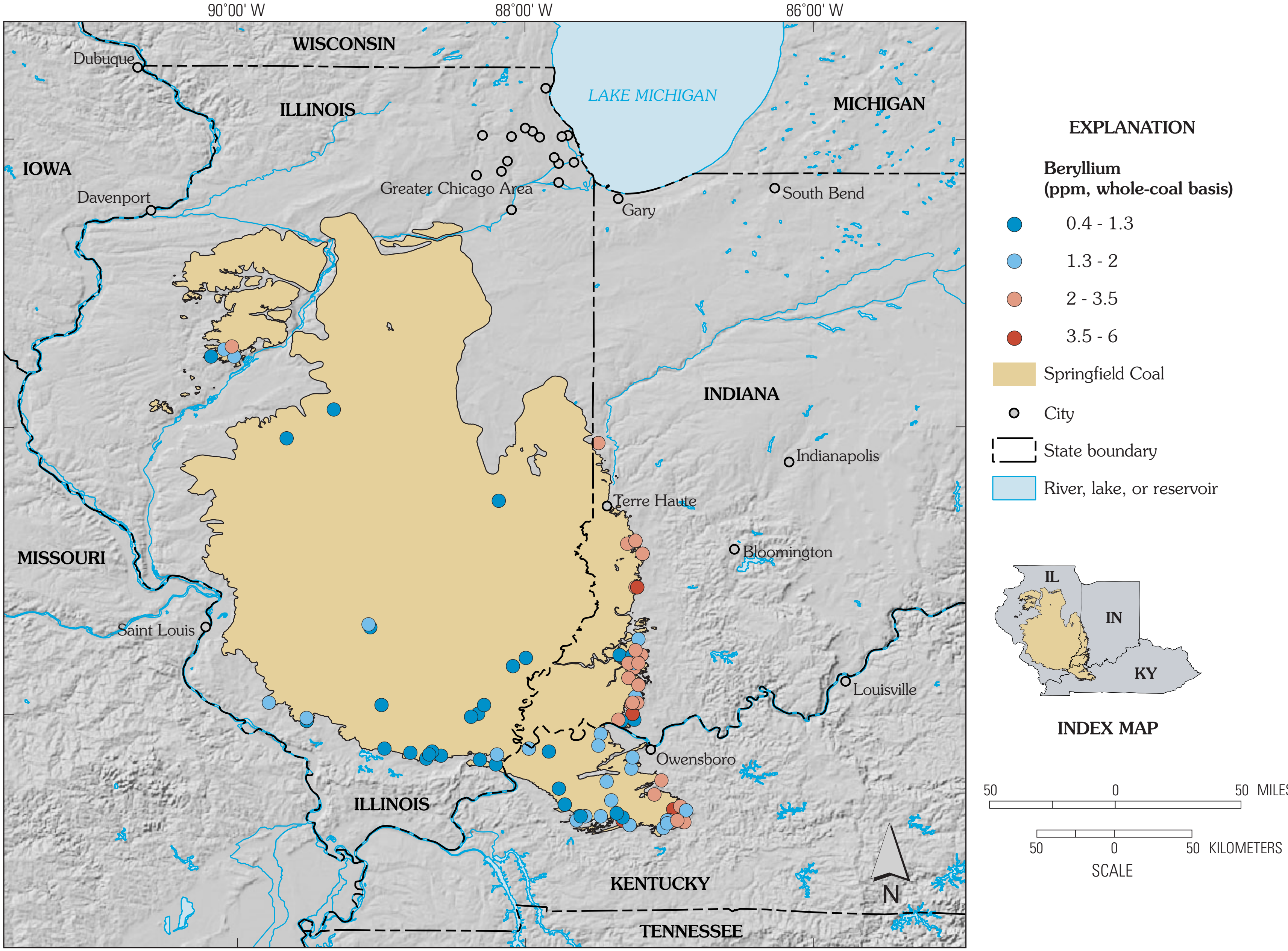

Figure 38. Graduated-symbol map for beryllium content (parts per million, as-received, whole-coal basis) of the Springfield Coal in the Illinois Basin.

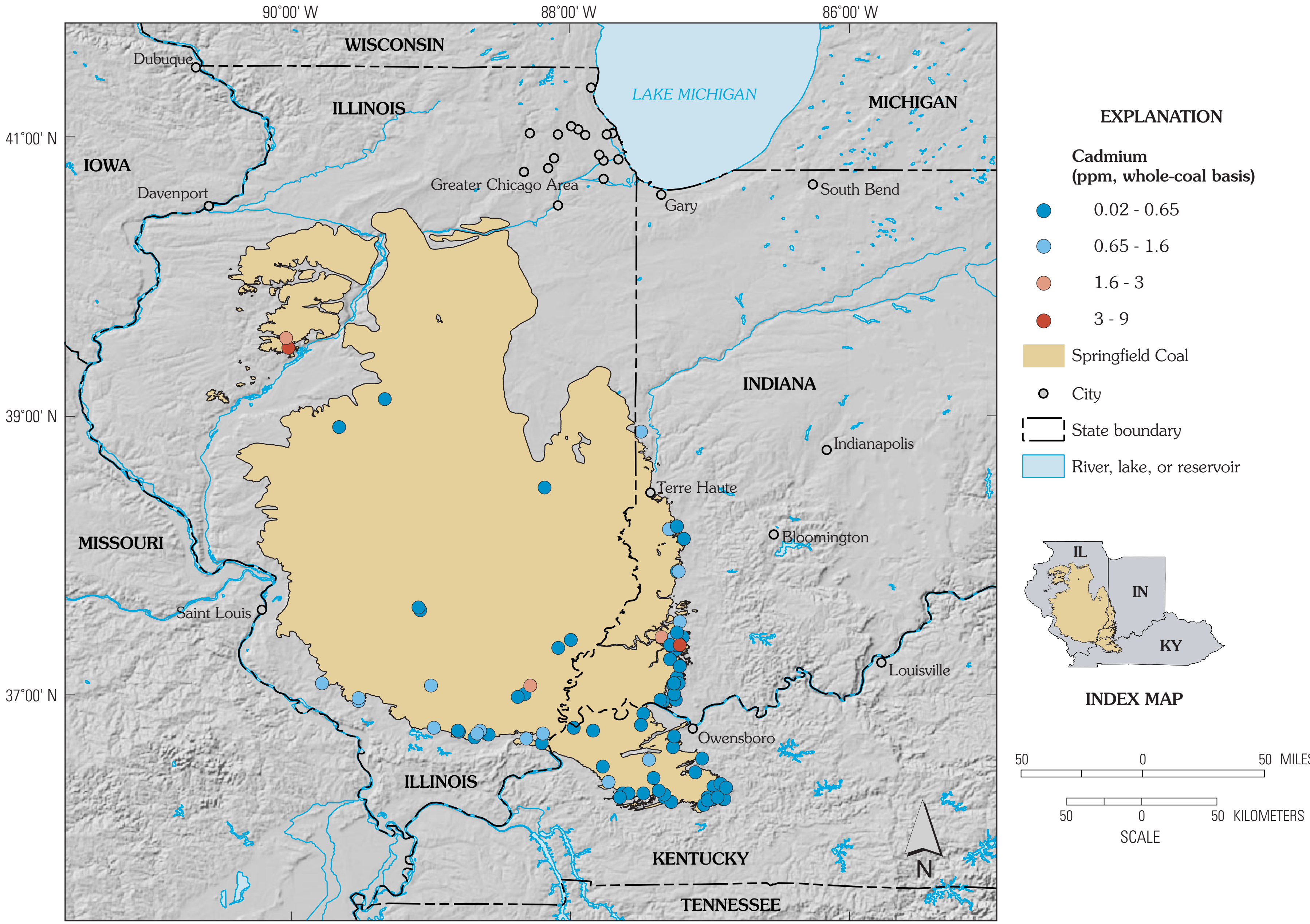

Figure 39. Graduated-symbol map for cadmium content (parts per million, as-received, whole-coal basis) of the Springfield Coal in the Illinois Basin.

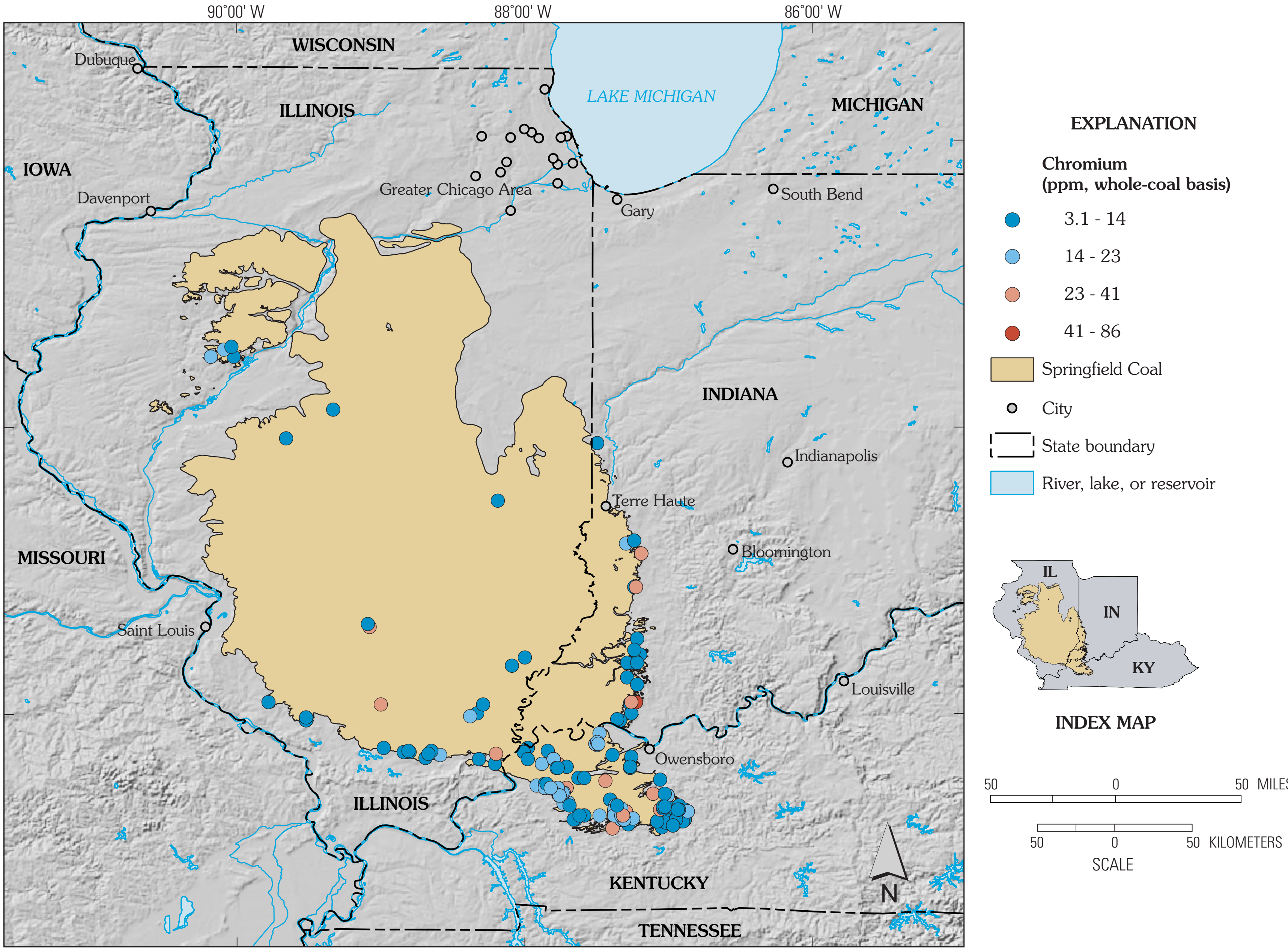

Figure 40. Graduated-symbol map for chromium content (parts per million, as-received, whole-coal basis) of the Springfield Coal in the Illinois Basin.

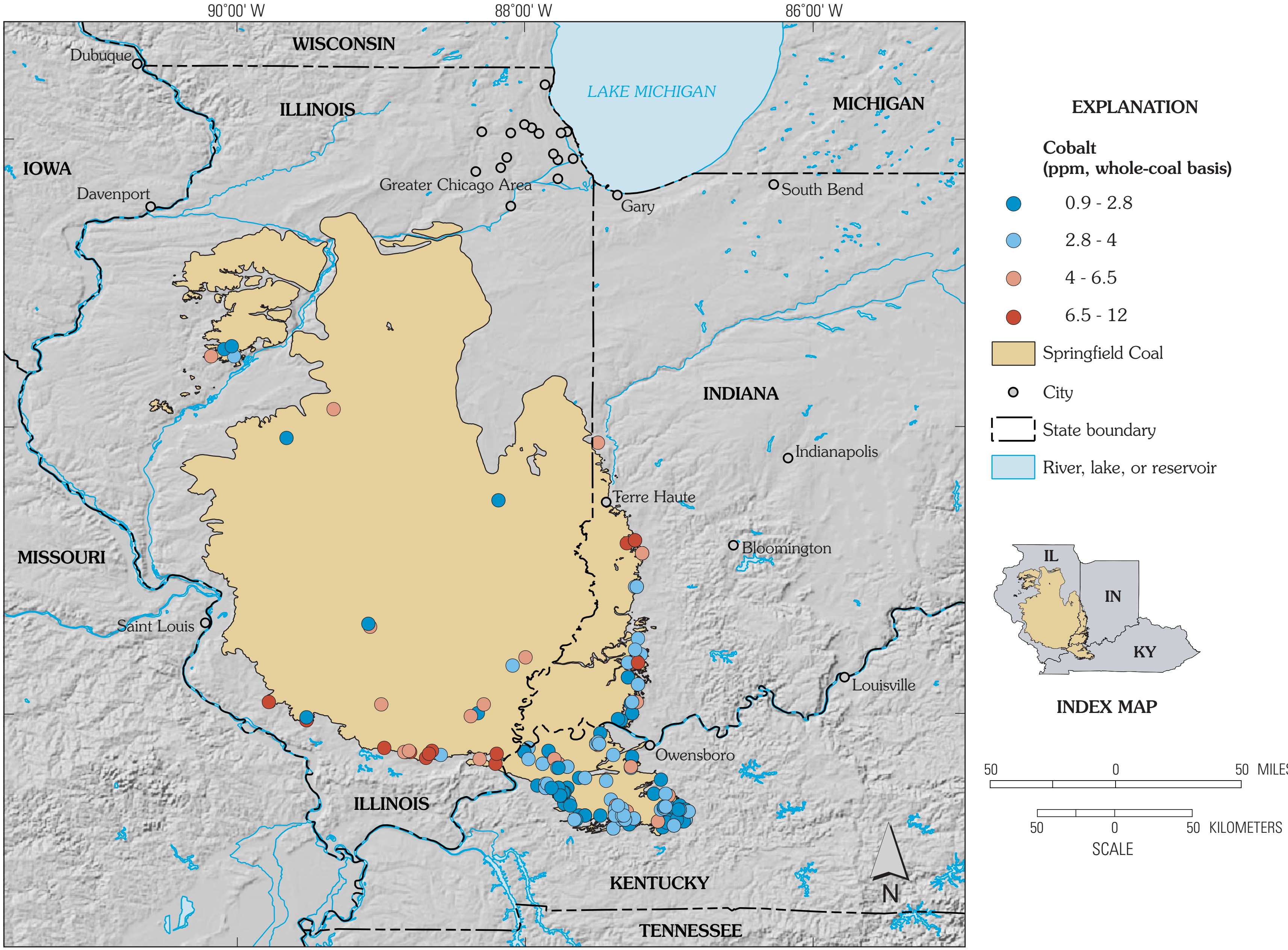

Figure 41. Graduated-symbol map for cobalt content (parts per million, as-received, whole-coal basis) of the Springfield Coal in the Illinois Basin.

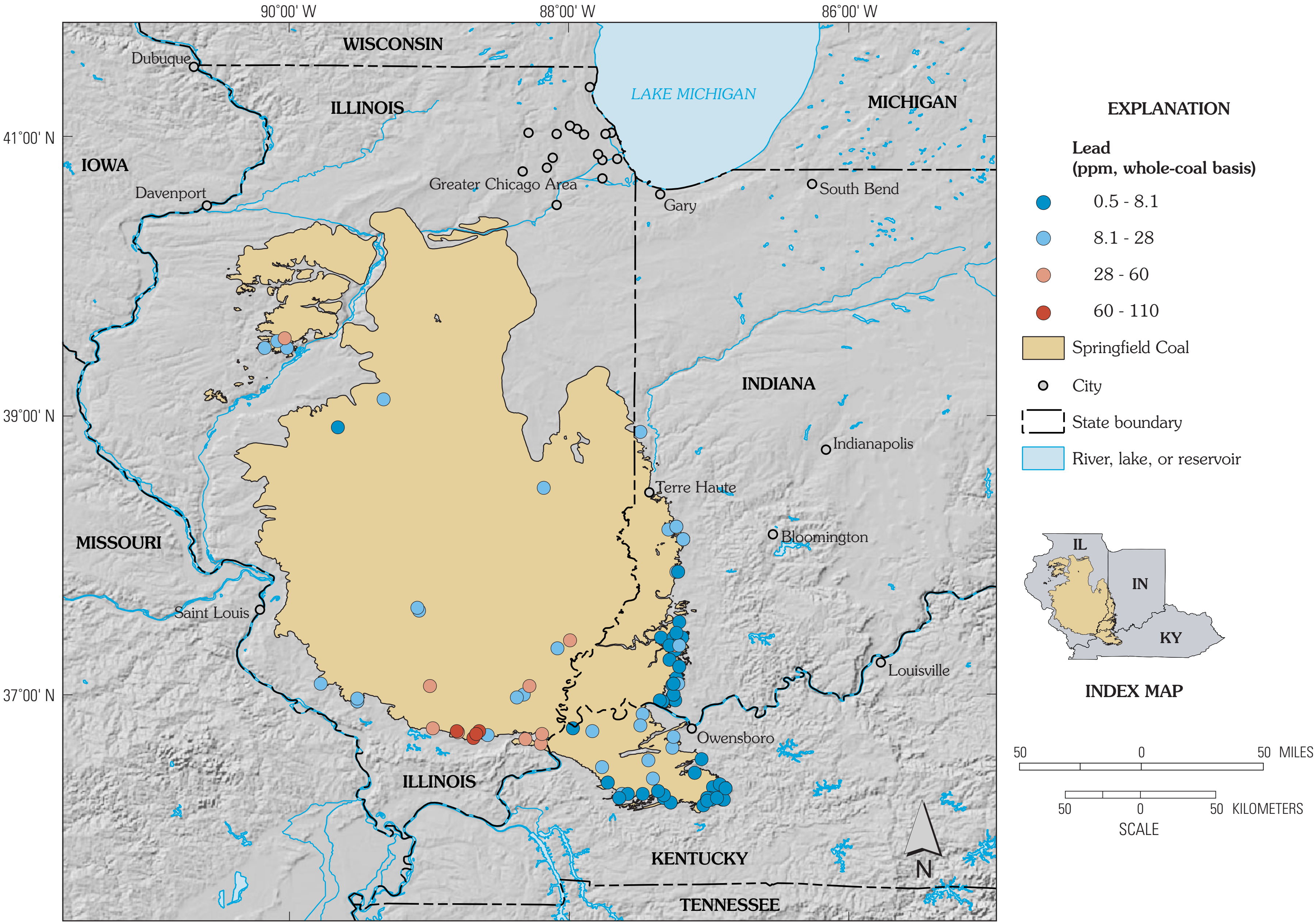

Figure 42. Graduated-symbol map for lead content (parts per million, as-received, whole-coal basis) of the Springfield Coal in the Illinois Basin.

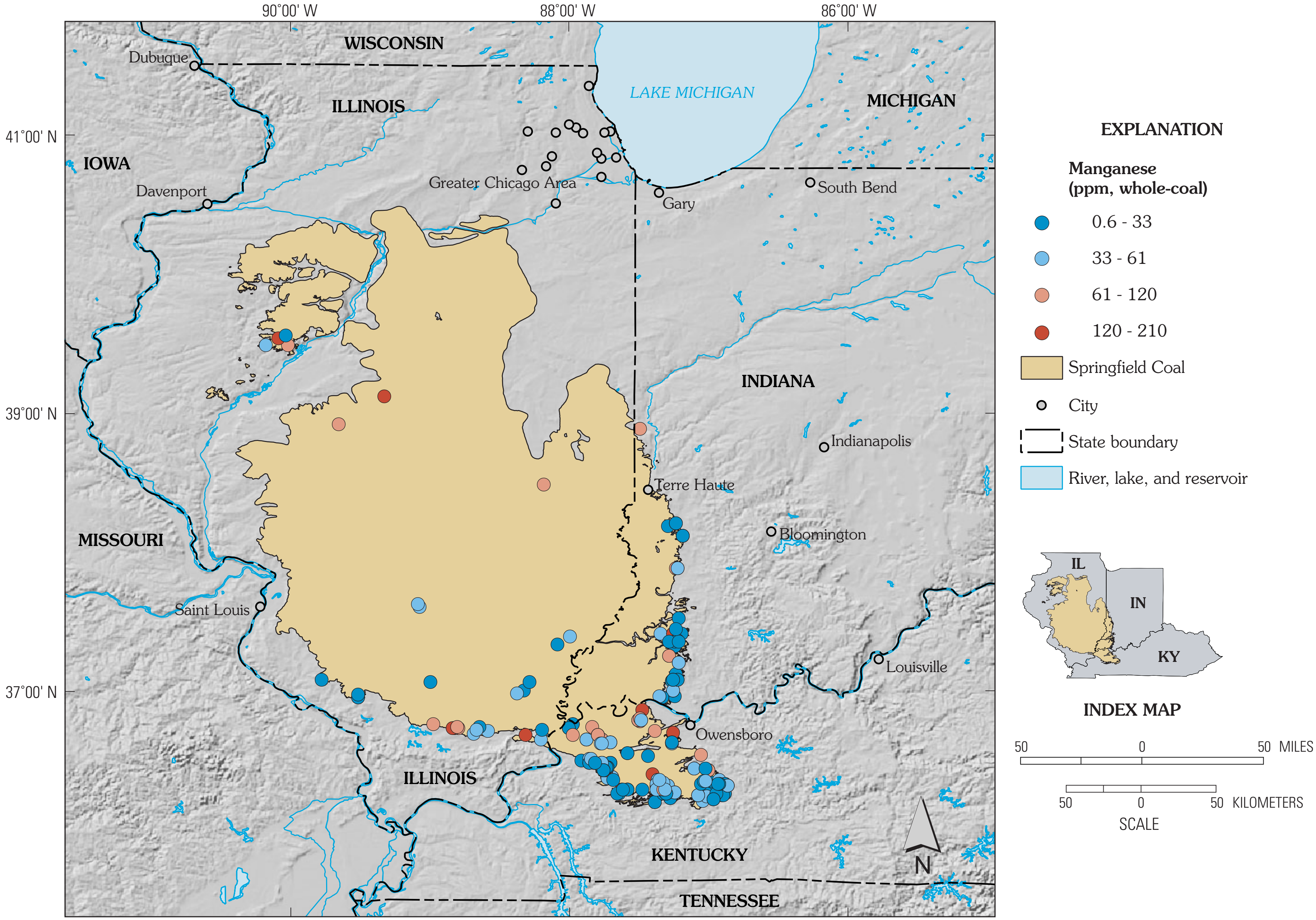

Figure 43. Graduated-symbol map for manganese content (parts per million, as-received, whole-coal basis) of the Springfield Coal in the Illinois Basin.

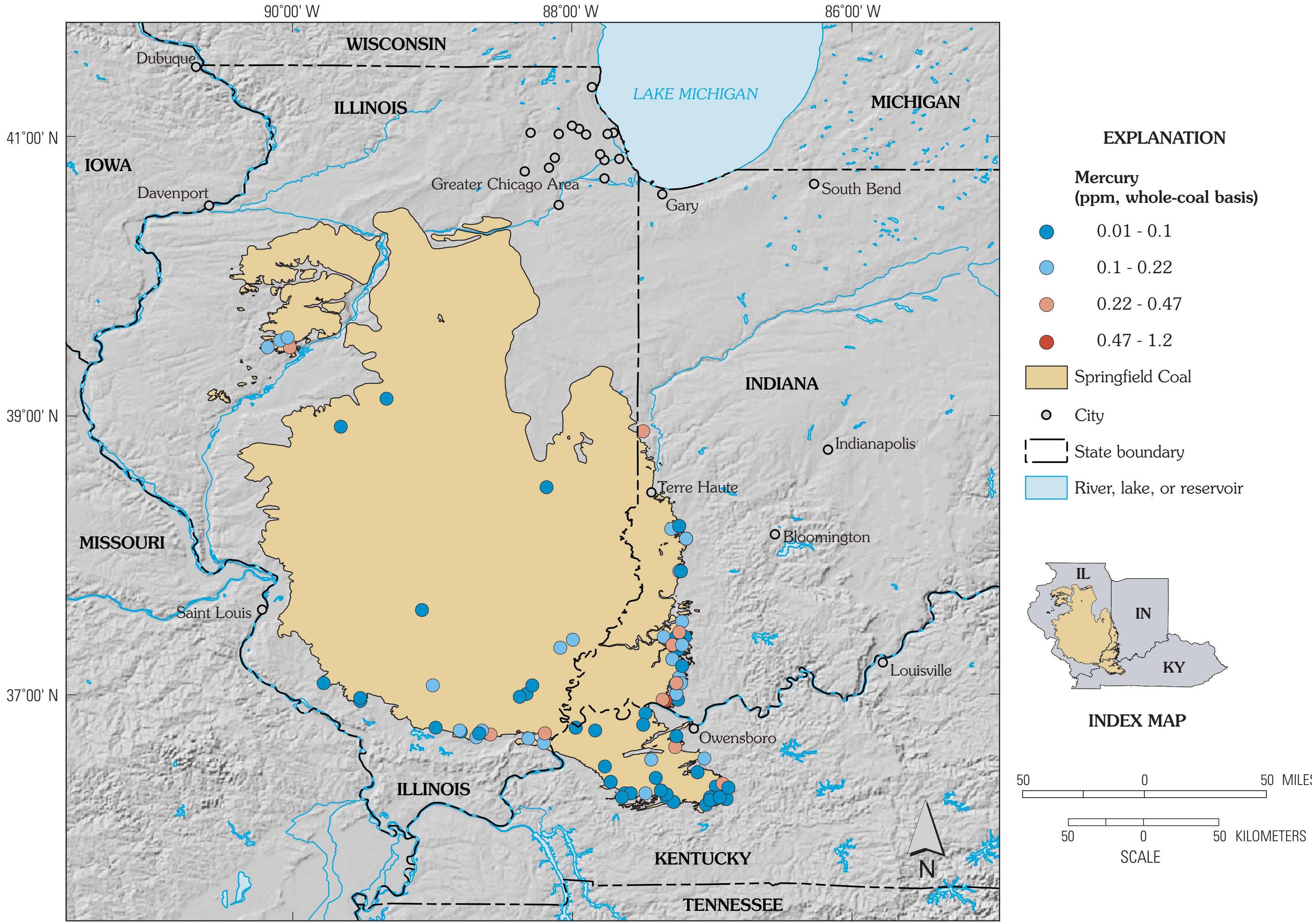

Figure 44. Graduated-symbol map for mercury content (parts per million, as-received, whole-coal basis) of the Springfield Coal in the Illinois Basin.

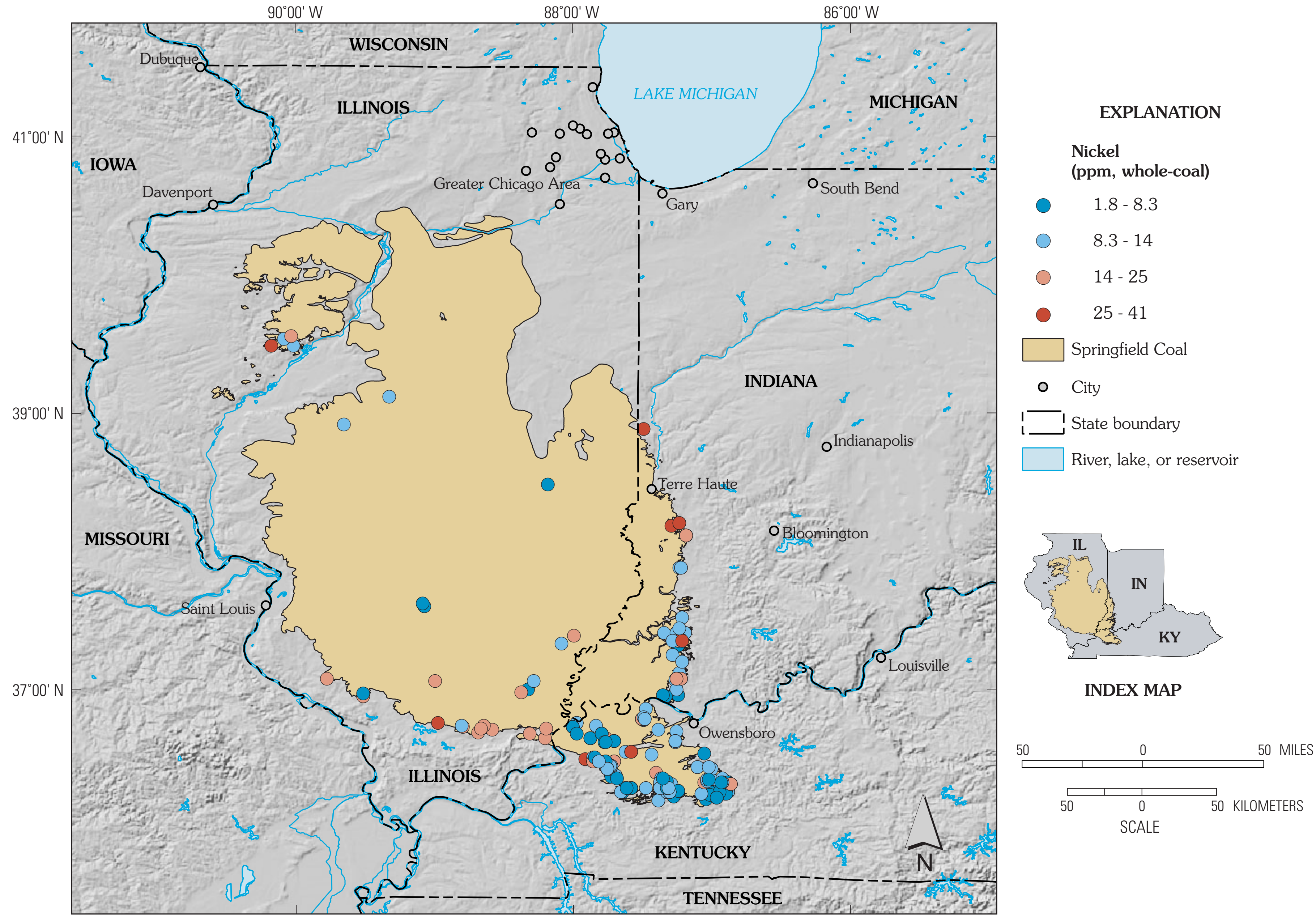

Figure 45. Graduated-symbol map for nickel content (parts per million, as-received, whole-coal basis) of the Springfield Coal in the Illinois Basin.

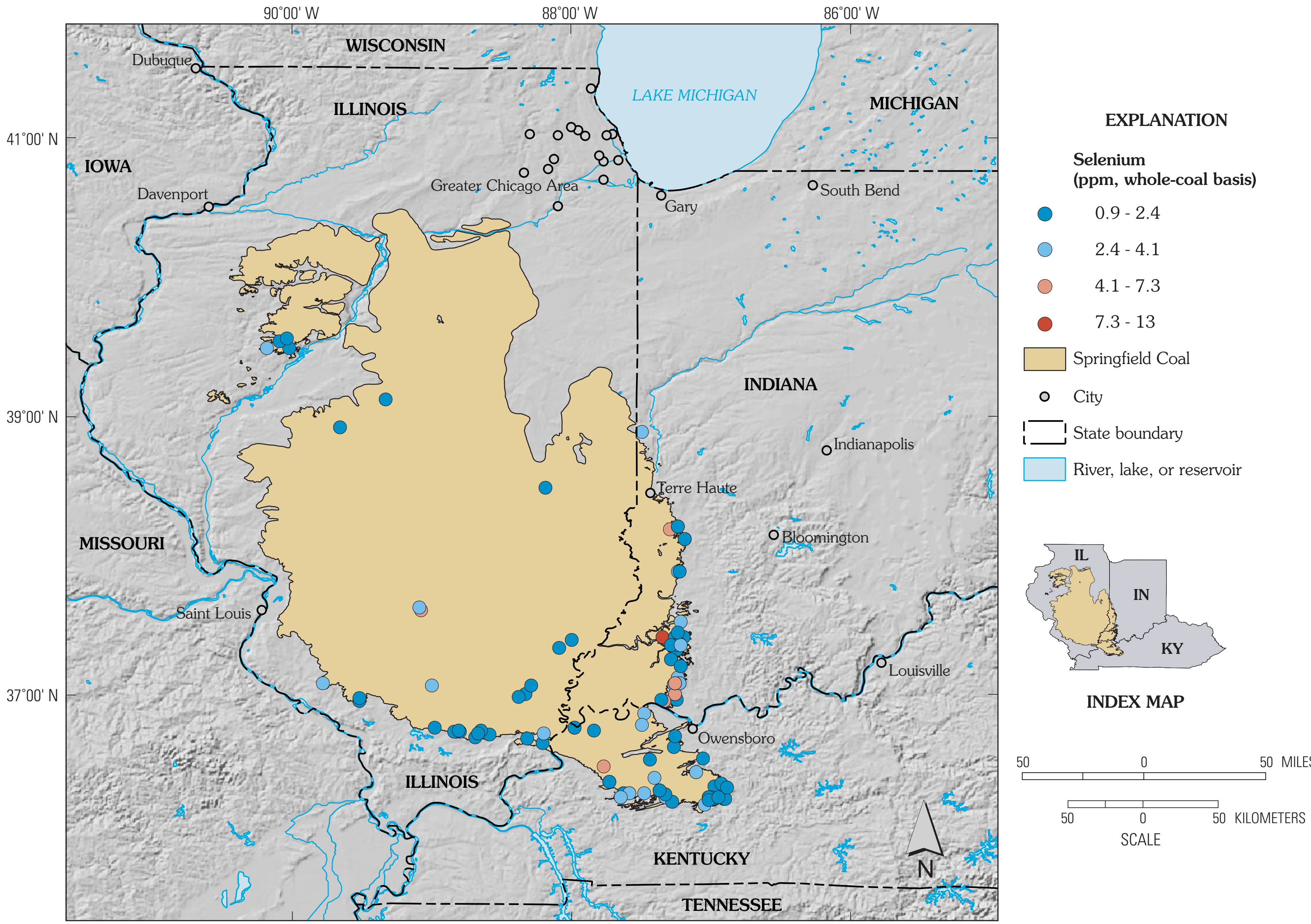

Figure 46. Graduated-symbol map for selenium content (parts per million, as-received, whole-coal basis) of the Springfield Coal in the Illinois Basin.

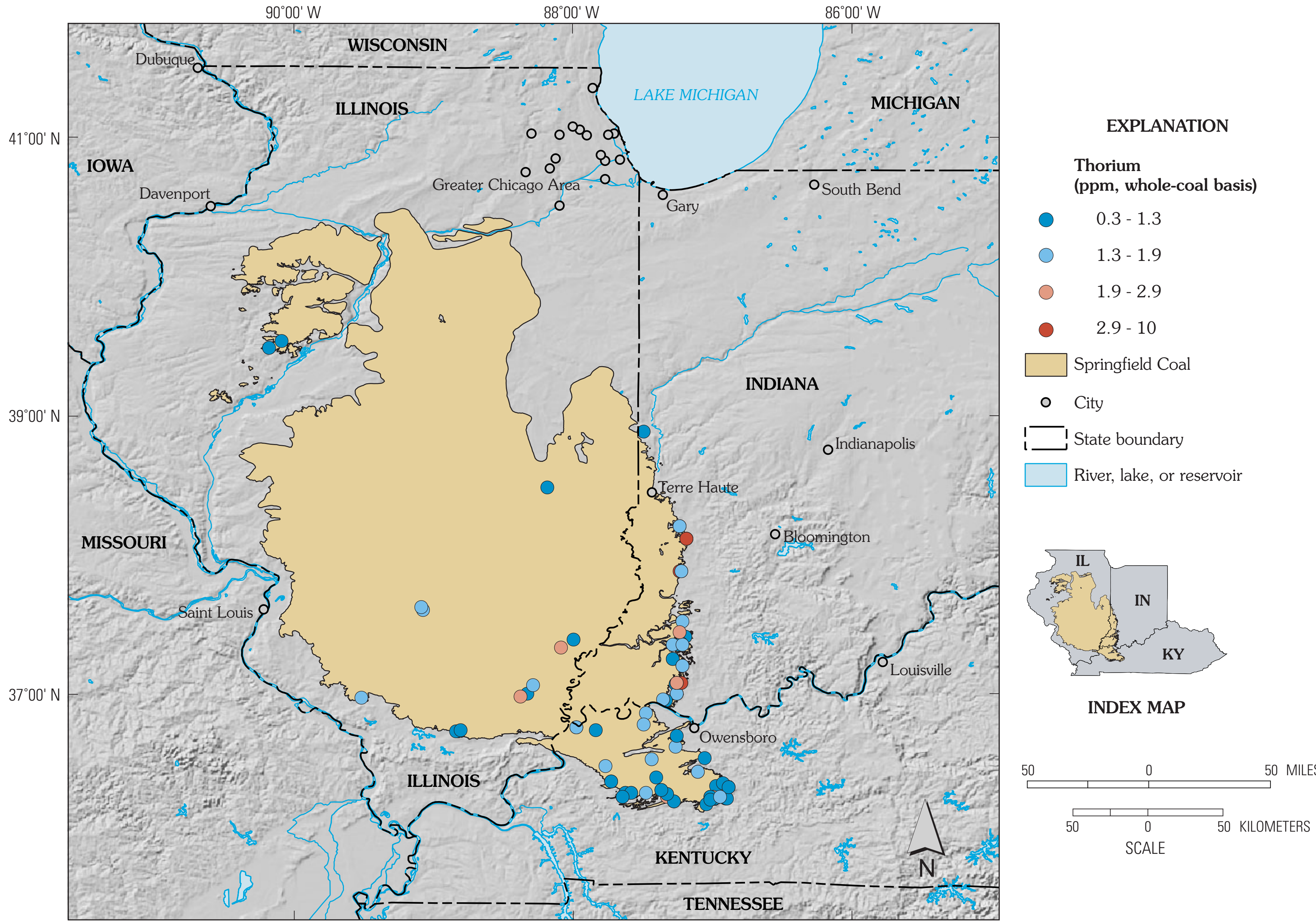

Figure 47. Graduated-symbol map for thorium content (parts per million, as-received, whole-coal basis) of the Springfield Coal in the Illinois Basin.

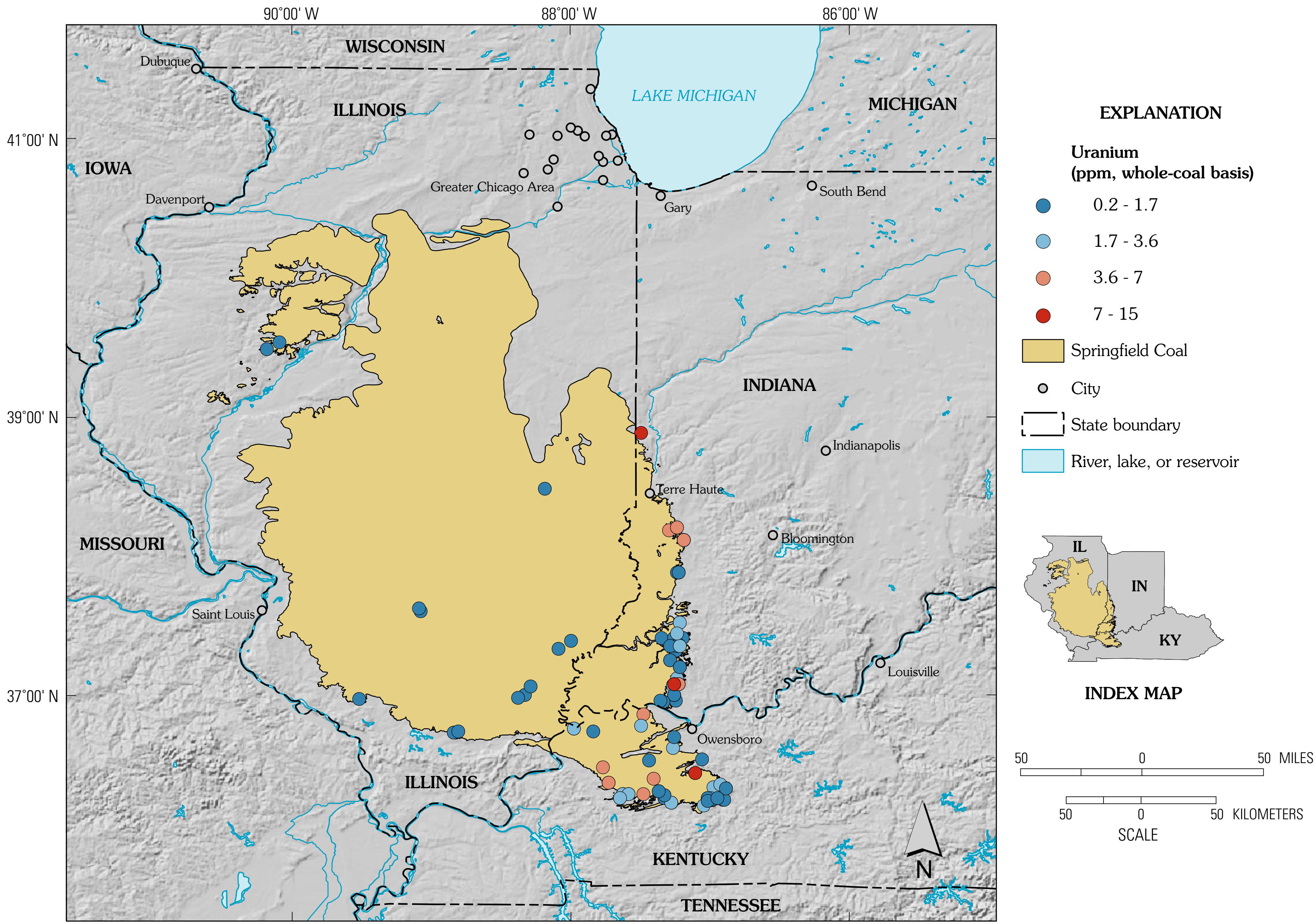

Figure 48. Graduated-symbol map for uranium content (parts per million, as-received, whole-coal basis) of the Springfield Coal in the Illinois Basin.

Appendix 8. Explanation of chemical data columns in the U.S. Geological Survey, Indiana Geological Survey, Kentucky Geological Survey, and Illinois State Geological Survey coal database files created for the resource assessment of the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin.

Table 1. Explanation of chemical data columns in the U.S. Geological Survey's chemical files created for the resource assessment of the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin.

[This is a simplified data dictionary showing Field Name, Type, and Description for all the columns in the ASCII files ilhechmu.txt, indachmu.txt, inspchmu.txt, incgchmu.txt, inrgchmu.txt, kyspchmu.txt, kydachmu.txt, kyhechmu.txt, kyrgchmu.txt, kycgchmu.txt, and uschmu.txt. These text files and this file were created by R.H. Affolter (affolter@usgs.gov) of the U.S. Geological Survey from the USGS USCHEM database and were used to create the ArcView chemical data shapefiles for the assessed Springfield, Herrin, Danville, and Baker Coals, and the nonassessed Carbondale Group or Formation, Raccoon Creek Group, and McLeansboro Group coals in the Illinois Basin. Column definitions were modified from Bragg and others, 1998. All columns_Q in these files are used for the qualified data values and are indicated by L (less than), B (not determined), N (not detected), or G (greater than). For detailed descriptions of U.S. Geological Survey analytical methods, see Swanson and Huffman (1976), Baedecker (1987), and Golightly and Simon (1989), or see the related metadata files for USGS chemical data. For limitations of the coal quality, data see Finkelman and others (1994). All columns except DLAT and DLONG are in text to preserve significant figures.]

Field Name	Type	Description
SAMPID	TEXT	Analysis Identification Number.
STATE	TEXT	Name of State where sample was collected.
COUNTY	TEXT	Name of county in State where sample was collected.
DLAT	REAL	Decimal Latitude coordinate for point source location of coal sample.
DLONG	REAL	Decimal Longitude coordinate for point source location of coal sample.
CFORMATN	TEXT	Formation Name—Stratigraphic formation name specified by the collector of the sample.
CGROUP	TEXT	Group Name—Stratigraphic group name specified by the collector of the sample.
CBED	TEXT	Bed Name—Stratigraphic bed name specified by the collector of the sample.
DEPTH	TEXT	Depth from the surface of the earth to the top of the sample if the sample is part of a drill core. If samples are not drill cores, but samples are benched, then depth is a measure from the top of the uppermost bench to the top of the next sample in the benched series. (Depth is measured in inches).
SAMPTHK	TEXT	Thickness of the sample, measured in inches.
COMMENTS	TEXT	Used as a comment field to describe the mine name, the drill hole identified, or other miscellaneous information about the sample.
SYSTEM	TEXT	System designates a fundamental unit of the sample's geologic age.
POINTID	TEXT	The field number assigned by the collector or submitter of the sample.
MOISTR	TEXT	(as-received basis) Moisture content in percent as determined by ASTM method D-3173.

Table 1. Explanation of chemical data columns in the U.S. Geological Survey's chemical files created for the resource assessment of the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin—Continued.

Field Name	Type	Description
VOLMAT	TEXT	(as-received basis) Volatile matter content in percent as determined by ASTM method D-3175.
FIXEDC	TEXT	(as-received basis) Fixed Carbon content in percent as determined by ASTM method D-3172.
STDASH	TEXT	(as-received basis) Ash yield in percent as determined by ASTM method D-3174 (ash obtained at 750 degrees Centigrade).
HYDRGN	TEXT	(as-received basis) Hydrogen content in percent as determined by ASTM method D-3178.
CARBON	TEXT	(as-received basis) Carbon content in percent as determined by ASTM method D-3178.
NITRGN	TEXT	(as-received basis) Nitrogen content in percent as determined by ASTM method D-3179.
OXYGEN	TEXT	(as-received basis) Oxygen content in percent as determined by ASTM method D-3176.
SULFUR	TEXT	(as-received basis) Sulfur content in percent as determined by ASTM method D-3177.
BTU	TEXT	(as-received basis) Gross calorific value of the coal sample expressed in British Thermal Units (BTU/lb) as determined by ASTM method D-2015.
SLFATE	TEXT	(as-received basis) Sulfate content in percent as determined by ASTM method D-2492.
SLFPYR	TEXT	(as-received basis) Pyritic Sulfur content in percent as determined by ASTM method D-2492.
SLFORG	TEXT	(as-received basis) Organic Sulfur content in percent as determined by ASTM method D-2492.
ASHDEF	TEXT	(as-received basis) Ash Deformation temperature in degrees Fahrenheit as determined by ASTM method D1857 in reducing atmosphere.
ASHSOF	TEXT	(as-received basis) Ash Softening temperature in degrees Fahrenheit as determined by ASTM method D1857 in reducing atmosphere.
ASHFLD	TEXT	(as-received basis) Ash Fluid temperature in degrees Fahrenheit as determined by ASTM method D1857 in reducing atmosphere.
FRESWL	TEXT	(as-received basis) Free-Swelling index as determined by ASTM method D-720.
ADLOSS	TEXT	(as-received basis) Air-Dried loss content in percent as determined by ASTM method D-2013.
GSASH	TEXT	Ash yield in percent as determined by USGS laboratories (ash obtained at 525 degrees Centigrade).

Table 1. Explanation of chemical data columns in the U.S. Geological Survey's chemical files created for the resource assessment of the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin—Continued.

Field Name	Type	Description
SI_E	TEXT	(as-received, whole-coal basis) Silicon (Si) content in percent converted from content as determined on coal ash by USGS laboratories using X-ray fluorescence analysis (ash obtained at 525 degrees Centigrade)—May be converted from SiO_2 content in percent which was determined by the same method.
AL_E	TEXT	(as-received, whole-coal basis) Aluminum (Al) content in percent converted from content as determined on coal ash by USGS laboratories using X-ray fluorescence analysis (ash obtained at 525 degrees Centigrade)—May be converted from Al_2O_3 content in percent which was determined by the same method.
CA_E	TEXT	(as-received, whole-coal basis) Calcium (Ca) content in percent converted from content as determined on coal ash by USGS laboratories using X-ray fluorescence analysis (ash obtained at 525 degrees Centigrade)—May be converted from CaO content in percent which was determined by the same method.
MG_E	TEXT	(as-received, whole-coal basis) Magnesium (Mg) content in percent converted from content as determined on coal ash by USGS laboratories using wet chemistry analysis (atomic absorption: ash obtained at 525 degrees Centigrade)—May be converted from MgO content in percent which was determined by the same method.
NA_E	TEXT	(as-received, whole-coal basis) Sodium (Na) content in percent converted from content as determined on coal ash by USGS laboratories using wet chemistry analysis (atomic absorption: ash obtained at 525 degrees Centigrade)—May be converted from Na_2O content in percent which was determined by the same method.
K_E	TEXT	(as-received, whole-coal basis) Potassium (K) content in percent converted from content as determined on coal ash by USGS laboratories using X-ray fluorescence analysis (ash obtained at 525 degrees Centigrade)—May be converted from K_2O content in percent which was determined by the same method.
FE_E	TEXT	(as-received, whole-coal basis) Iron (Fe) content in percent converted from content as determined on coal ash by USGS laboratories using X-ray fluorescence analysis (ash obtained at 525 degrees Centigrade)—May be converted from Fe_2O_3 content in percent which was determined by the same method.
TI_E	TEXT	(as-received, whole-coal basis) Titanium (Ti) content in percent converted from content as determined on coal ash by USGS laboratories using X-ray fluorescence analysis (ash obtained at 525 degrees Centigrade)—May be converted from TiO_2 content in percent which was determined by the same method.
AS_E	TEXT	(as-received, whole-coal basis) Arsenic (As) content in parts per million as determined on whole-coal by USGS laboratories using either wet chemistry analysis or Instrumental Neutron Activation Analysis (INAA).
B_E	TEXT	(as-received, whole-coal basis) Boron (B) content in parts per million converted from content determined on coal ash by USGS laboratories using either 6-Step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525 degrees Centigrade).

Table 1. Explanation of chemical data columns in the U.S. Geological Survey's chemical files created for the resource assessment of the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin—Continued.

Field Name	Type	Description
BA_E	TEXT	(as-received, whole-coal basis) Barium (Ba) content in parts per million converted from content determined on coal ash by USGS laboratories using either 6-Step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525 degrees Centigrade).
BE_E	TEXT	(as-received, whole-coal basis) Beryllium (Be) content in parts per million converted from content determined on coal ash by USGS laboratories using either 6-Step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525 degrees Centigrade).
CD_E	TEXT	(as-received, whole-coal basis) Cadmium (Cd) content in parts per million converted from content determined on coal ash by USGS laboratories using wet chemistry analysis (atomic absorption—ash obtained at 525 degrees Centigrade).
CO_E	TEXT	(as-received, whole-coal basis) Cobalt (Co) content in parts per million converted from content determined on coal ash by USGS laboratories using either semi-quantitative 6-Step emission spectrographic analysis or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525 degrees Centigrade) or on a whole-coal basis using Instrumental Neutron Activation Analysis (INAA).
CR_E	TEXT	(as-received, whole-coal basis) Chromium (Cr) content in parts per million converted from content determined on coal ash by USGS laboratories using either semi-quantitative 6-Step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525 degrees Centigrade) or on a whole-coal basis using Instrumental Neutron Activation Analysis.
CU_E	TEXT	(as-received, whole-coal basis) Copper (Cu) content in parts per million converted from content determined on coal ash by USGS laboratories using wet chemistry analysis (atomic absorption—ash obtained at 525 degrees Centigrade).
F_E	TEXT	(as-received, whole-coal basis) Fluorine (F) content in parts per million as determined on whole-coal by USGS laboratories using wet chemistry analysis (ion-selective electrode).
GA_E	TEXT	(as-received, whole-coal basis) Gallium (Ga) content in parts per million converted from content determined on coal ash by USGS laboratories using either 6-Step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525 degrees Centigrade).
GE_E	TEXT	(as-received, whole-coal basis) Germanium (Ge) content in parts per million converted from content determined on coal ash by USGS laboratories using either 6-Step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525 degrees Centigrade).

Table 1. Explanation of chemical data columns in the U.S. Geological Survey's chemical files created for the resource assessment of the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin—Continued.

Field Name	Type	Description
HG_E	TEXT	(as-received, whole-coal basis) Mercury (Hg) content in parts per million as determined on whole-coal by USGS laboratories using wet chemistry analysis (cold-vapor atomic absorption).
LA_E	TEXT	(as-received, whole-coal basis) Lanthanum (La) content in parts per million converted from content determined on coal ash by USGS laboratories using either 6-Step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525 degrees Centigrade) or on a whole-coal basis using Instrumental Neutron Activation Analysis (INAA).
LI_E	TEXT	(as-received, whole-coal basis) Lithium (Li) content in parts per million converted from content determined on coal ash by USGS laboratories using wet chemistry analysis (atomic absorption—ash obtained at 525 degrees Centigrade).
MN_E	TEXT	(as-received, whole-coal basis) Manganese (Mn) content in parts per million converted from content determined on coal ash by USGS laboratories using either 6-Step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525 degrees Centigrade) and later using wet chemistry analysis (atomic absorption on the ash).
MO_E	TEXT	(as-received, whole-coal basis) Molybdenum (Mo) content in parts per million converted from content determined on coal ash by USGS laboratories using either 6-Step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525 degrees Centrigrade).
NB_E	TEXT	(as-received, whole-coal basis) Niobium (Nb) content in parts per million converted from content determined on coal ash by USGS laboratories using either 6-Step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525 degrees Centrigrade).
NI_E	TEXT	(as-received, whole-coal basis) Nickel (Ni) content in parts per million converted from content determined on coal ash by USGS laboratories using either 6-Step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525 degrees Centrigrade).
P_E	TEXT	(as-received, whole-coal basis) Phosphorus (P) content in parts per million as determined on the coal ash or whole-coal by USGS laboratories using X-ray fluorescence analysis (ash obtained at 525 degrees Centigrade)—May be converted from P_2O_5 content in percent which was determined by the same method.
PB_E	TEXT	(as-received, whole-coal basis) Lead (Pb) content in parts per million converted from content determined on coal ash by USGS laboratories using wet chemistry analysis (atomic absorption—ash obtained at 525 degrees Centigrade).
SB_E	TEXT	(as-received, whole-coal basis) Antimony (Sb) content in parts per million as determined on whole-coal by USGS laboratories using wet chemistry analysis (Rhodamine B) or on Instrumental Neutron Activation Analysis (INAA).

Table 1. Explanation of chemical data columns in the U.S. Geological Survey's chemical files created for the resource assessment of the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin—Continued.

Field Name	Type	Description
SC_E	TEXT	(as-received, whole-coal basis) Scandium (Sc) content in parts per million converted from content determined on coal ash by USGS laboratories using either 6-Step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525 degrees Centigrade) or on a whole-coal basis using Instrumental Neutron Activation Analysis (INAA).
SE_E	TEXT	(as-received, whole-coal basis) Selenium (Se) content in parts per million as determined on whole-coal basis by USGS laboratories using Xray-fluorescence or on a whole-coal basis using Instrumental Neutron Activation Analysis (INAA).
SR_E	TEXT	(as-received, whole-coal basis) Strontium (Sr) content in parts per million converted from content determined on coal ash by USGS laboratories using either 6-Step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525 degrees Centigrade).
TH_E	TEXT	(as-received, whole-coal basis) Thorium (Th) content in parts per million as determined on whole-coal basis by USGS laboratories using Delayed Neutron Analysis (DNA) for older samples and Instrumental Neutron Activation analysis (INAA).
U_E	TEXT	(as-received, whole-coal basis) Uranium (U) content in parts per million as determined on whole-coal basis by USGS laboratories using Delayed Neutron Analysis (DNA).
V_E	TEXT	(as-received, whole-coal basis) Vanadium (V) content in parts per million converted from content determined on coal ash by USGS laboratories using either 6-Step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525 degrees Centigrade).
Y_E	TEXT	(as-received, whole-coal basis) Yttrium (Y) content in parts per million converted from content determined on coal ash by USGS laboratories using either 6-Step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525 degrees Centigrade).
YB_E	TEXT	(as-received, whole-coal basis) Ytterbium (Yb) content in parts per million converted from content determined on coal ash by USGS laboratories using either 6-Step emission spectrographic analysis for older samples or automatic plate reading computer-assisted emission spectrographic analysis (ash obtained at 525 degrees Centigrade) or on a whole-coal basis using Instrumental Neutron Activation Analysis (INAA).
ZN_E	TEXT	(as-received, whole-coal basis) Zinc (Zn) content in parts per million converted from content determined on coal ash by USGS laboratories using wet chemistry analysis (atomic absorption ash obtained at 525 degrees Centigrade).
ZR_E	TEXT	(as-received, whole-coal basis) Zirconium (Zr) content in parts per million converted from content determined on coal ash by USGS laboratories using either 6-Step emission spectrographic analysis for older samples or automatic plate reading omputer-assisted emission spectrographic analysis (ash obtained at 525 degrees Centigrade).

Table 2. Explanation of chemical data columns in the Indiana coal analysis database files created for the resource assessment of the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin.

[This is a simplified data dictionary showing Field Name, Value, and Description for all the columns in the ASCII files indachms.txt, inspchms.txt, incgchms.txt, inrgchms.txt, and inchms.txt. These text files and this file were created by R.H. Affolter (affolter@usgs.gov) of the U.S. Geological Survey from "The Indiana coal analysis database; Computer database I," 1992, by Walter A. Hasenmueller and Louis V. Miller, and were used to create the ArcView chemical data shape files of the Springfield, Danville, Carbondale Group, and Raccoon Creek Group coals for the Illinois Basin resource assessment. The purpose of this file is to briefly explain the abbreviations used in the Indiana coal analysis database published by the Indiana Geological Survey (IGS). Each record in this file represents a coal sample and comprises the variables defined below in the order they appear in the database. For detailed information on field names, values, and descriptions see Hasenmueller (whasenmu@indiana.edu) and Miller (1992). For additional information see the related metadata files for the Indiana chemical data. All columns except Lat-dd and Long-dd are in text to preserve the original numbers.]

Field Name	Type	Description
Smpnme	**Text**	Coal sample number
Cnty	**Text**	County name
Cvltwp	**Text**	Civil township name
Clctr	**Text**	Collector(s) of coal and associated samples and the recorder(s) of sample-site description including the sample-site stratigraphic section.
Smpsrc	**Text**	Source of the sample.
Smptyp	**Text**	Sample type
Moist	**Text**	Visual estimate of the moisture condition of the sample made when the sample was collected.
Cond	**Text**	Weathering condition of the sampled coal. Sample can be assumed to be freshly exposed coal when this field is blank. "Weathered" indicates that the coal had a weathered appearance.
Strnme	**Text**	Stratigraphic name for the sampled coal bed.
Altnme	**Text**	Alternate names for the sampled coal bed, or commonly used unofficial names for a coal bed.
Date	**Text**	Date sample was collected and recorded in the form MM/DD/YY where MM = month, DD = day, and YY last two digits of year.
Wdth	**Text**	Width of channel cut or diameter of drill core in decimal feet.
Dpth	**Text**	Depth of channel cut in decimal feet.
Twp	**Text**	Township number followed by "N" for north and "S" for south of Buckingham's Base Line.

Table 2. Explanation of chemical data columns in the Indiana coal analysis database files created for the resource assessment of the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin—Continued.

Field Name	Type	Description
Rng	**Text**	Range number followed by "W" or "E" to designate west or east of the Second Principal Meridian.
Sec	**Text**	Section number or equivalent. Three alpha characters followed by a "." indicate the type of land subdivision, which is followed by the two- or three-digit integer number of that subdivision.
Qtr	**Text**	Subdivisions of sections. Abbreviations for quarter, half, and center are separated by commas and listed in the normal order, i.e., smallest to the largest quarter.
Lat-dd	**Real**	Latitude in decimal degrees.
Long-dd	**Real**	Longitude in decimal degrees.
Spe	**Text**	State plane easting coordinate.
Spn	**Text**	State plane northing coordinate.
Utme	**Text**	Universal transverse Mercator easting coordinate.
Utmn	**Text**	Universal transverse Mercator northing coordinate.
Quad	**Text**	U.S. Geological Survey 71/2-minute quadrangle map name.
Comp	**Text**	Name of the company operating the mine from which a sample was collected or the name of the company operating the drill rig that cut the core from which the sample was collected.
Mine	**Text**	Name of the mine or drill hole from which a sample was collected.
Cmnt	**Text**	Comment field.
Analdate	**Text**	Date analysis was completed and recorded in the form MM/DD/YY, where MM = month, DD = date, and YY = last two digits of year.
Analyst	**Text**	Chemist who analyzed the coal sample.
Adl	**Text**	Air dried loss.
Moar	**Text**	Moisture on the as-received basis.
Ashar	**Text**	Ash on the as-received basis.
Volar	**Text**	Volatile matter on the as-received basis.
Fixar	**Text**	Fixed carbon on the as-received basis.
Car	**Text**	Ultimate carbon on the as-received basis.

Table 2. Explanation of chemical data columns in the Indiana coal analysis database files created for the resource assessment of the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin—Continued.

Field Name	Type	Description
Har	**Text**	Ultimate hydrogen on the as-received basis.
Nar	**Text**	Ultimate nitrogen on the as-received basis.
Oar	**Text**	Ultimate oxygen on the as-received basis.
Sar	**Text**	Ultimate sulfur on the as-received basis.
Btuar	**Text**	Heating value on the as-received basis (Btu/Ib).
S04ar	**Text**	Sulfate sulfur on the as-received basis.
Pyrar	**Text**	Pyritic sulfur on the as-received basis.
Orgar	**Text**	Organic sulfur on the as-received basis.
Ashmf	**Text**	Ash on the moisture-free basis.
Volmf	**Text**	Volatile matter on the moisture-free basis.
Fixmf	**Text**	Fixed carbon on the moisture-free basis.
Cmf	**Text**	Ultimate carbon on the moisture-free basis.
Hmf	**Text**	Ultimate hydrogen on the moisture-free basis.
Nmf	**Text**	Ultimate nitrogen on the moisture-free basis.
Omf	**Text**	Ultimate oxygen on the moisture-free basis.
Smf	**Text**	Ultimate sulfur on the moisture-free basis.
Btumf	**Text**	Heating value on the moisture-free basis (Btu/Ib).
S04mf	**Text**	Sulfate sulfur on the moisture-free basis.
Pyrmf	**Text**	Pyritic sulfur on the moisture-free basis.
Orgmf	**Text**	Organic sulfur on the moisture-free basis.
Volmaf	**Text**	Volatile matter on the moisture and ash-free basis.
Fixmaf	**Text**	Fixed carbon on the moisture and ash-free basis.
Cmaf	**Text**	Ultimate carbon on the moisture and ash-free basis.
Hmaf	**Text**	Ultimate hydrogen on the moisture and ash-free basis.
Nmaf	**Text**	Ultimate nitrogen on the moisture and ash-free basis.
Omaf	**Text**	Ultimate oxygen on the moisture and ash-free basis.
Smaf	**Text**	Ultimate sulfur on the moisture and ash-free basis.

Table 2. Explanation of chemical data columns in the Indiana coal analysis database files created for the resource assessment of the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin—Continued.

Field Name	Type	Description
Btumaf	**Text**	Heating value on the moisture and ash-free basis (Btu/Ib).
S04maf	**Text**	Sulfate sulfur on the moisture and ash-free basis.
Pyrmaf	**Text**	Pyritic sulfur on the moisture and ash-free basis.
Orgmaf	**Text**	Organic sulfur on the moisture and ash-free basis.
Agi	**Text**	Agglomerating index.
Id	**Text**	Initial deformation temperature in the fusibility of coal ash test. The temperature in degrees Fahrenheit at which the first rounding of the apex of the ash cone occurs in a reducing atmosphere.
Id +	**Text**	A plus sign in this field indicates that the sample had not yet undergone initial deformation at the temperature recorded in the Id field. This field is blank when the Id temperature represents a precise measurement.
Heqw	**Text**	Height-equals-width temperature in the fusibility of coal-ash test. The temperature in degrees Fahrenheit at which the height of the ash cone equals its width in a reducing atmosphere.
Heqw +	**Text**	A plus sign in this field indicates that the sample had not yet reached the height-equals-width condition at the temperature recorded in the Heqw field. This field is blank when the Heqw temperature represents a precise measurement.
Heqhw	**Text**	Height equals one-half width temperature in the fusibility of coal-ash test. Temperature in degrees Fahrenheit at which height of ash cone equals one-half the width in a reducing atmosphere.
Heqhw+	**Text**	A plus sign in the field indicates that the sample had not yet reached the height-equals-half width condition at the temperature recorded in the Heqhw field. This field is blank when the Heqhw temperature represents a precise measurement.
Fluid	**Text**	Fluid temperature in the fusibility of coal-ash test. Temperature in degrees Fahrenheit at which ash becomes fluid in a reducing atmosphere.
Fluid+	**Text**	A plus sign in this field indicates that the sample had not yet reached a fluid condition at the temperature recorded in the Fluid field. This field is blank when the Fluid temperature represents a precise measurement.

Table 3. Explanation of chemical data columns in the Kentucky coal chemistry database files created for the resource assessment of the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin.

[This is a simplified data dictionary showing Field Name, Type, and Description for all the columns in the ASCII files kyspchms.txt, kyhechms.txt, kydachms.txt, kycgchms.txt, kyrgchms.txt, kymgchms.txt, and kychms.txt. These text files and this file were created by R.H. Affolter (affolter@usgs.gov) of the U.S. Geological Survey from selected parts of several files that were received from Cortland Eble (eble@kgs.mm.uky.edu) of the Kentucky Geological Survey and were used to create the ArcView chemical data shapefiles of the Springfield, Baker, Herrin, Carbondale Formation, Raccoon Creek Group, and the McLeansboro Group coals for the Illinois Basin resource assessment. For additional information, see the related metadata files for the Kentucky chemical data. Currently, there is no information on published reports detailing the analytical method used for this Kentucky data. For additional information about analytical methodology, contact Cortland Eble (KGS) or see the related metadata files for Kentucky chemical data. All columns except NORTH_LATITUDE and WEST_LONGITUDE are in text to preserve the original numbers.]

Field Name	Type	Description
FOREIGN_LAB_ID	TEXT	Laboratory ID
ANALYZING_LAB	TEXT	Name of laboratory
ANALYSIS_NAME	TEXT	Type of analysis
ANALYSIS_TYPE	TEXT	Portion of bed analyzed
ANALYSIS_NUMBER	TEXT	Analysis number
COAL_NUMBER	TEXT	Coal number—Kentucky coals are arranged by group with the first 3 numbers representing the group and the last 3 digits reflecting the named coal that was collected. Any code with an XXX199 or XXX999 means the coal zone was identified, but not the individual coal name.
COAL_NAME	TEXT	Coal name
NORTH_LATITUDE	TEXT	Decimal degrees north latitude
WEST_LONGITUDE	TEXT	Decimal degrees west longitude
RESERVE_DISTRICT	TEXT	Reserve district
COUNTY_NAME	TEXT	County name
QUADRANGLE_NAME	TEXT	7.5 minute quadrangle name
TOTAL_COAL	TEXT	Total coal thickness in inches
TOTAL_PARTING	TEXT	Total parting thickness in inches
COAL_ELEVATION	TEXT	Elevation of coal in feet
Si_wc	TEXT	(dry, whole-coal basis) silicon content in percent converted from SiO_2 content in percent.
Al_wc	TEXT	(dry, whole-coal basis) aluminum content in percent converted from Al_2O_3 content in percent.

Table 3. Explanation of chemical data columns in the Kentucky coal chemistry database files created for the resource assessment of the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin—Continued.

Field Name	Type	Description
Ca_wc	TEXT	(dry, whole-coal basis) calcium content in percent converted from CaO content in percent.
Na_wc	TEXT	(dry, whole-coal basis) sodium content in percent converted from Na_2O content in percent.
Mg_wc	TEXT	(dry, whole-coal basis) magnesium content in percent converted from MgO content in percent.
Fe_wc	TEXT	(dry, whole-coal basis) iron content in percent converted from Fe_2O_3 content in percent.
K_wc	TEXT	(dry, whole-coal basis) potassium content in percent converted from K_2O content in percent.
Ti_wc	TEXT	(dry, whole-coal basis) titanium content in percent converted from TiO_2 content in percent.
P_wc	TEXT	(dry, whole-coal basis) phosphorous content in parts per million converted from P_2O_5 content in percent.
As_wc	TEXT	(dry, whole-coal basis) arsenic content in parts per million
Be_wc	TEXT	(dry, whole-coal basis) beryllium content in parts per million
Cd_wc	TEXT	(dry, whole-coal basis) cadmium content in parts per million
Co_wc	TEXT	(dry, whole-coal basis) cobalt content in parts per million
Cr_wc	TEXT	(dry, whole-coal basis) chromium content in parts per million
Hg_wc	TEXT	(dry, whole-coal basis) mercury content in parts per million
Mn_wc	TEXT	(dry, whole-coal basis) manganese content in parts per million
Ni_wc	TEXT	(dry, whole-coal basis) nickel content in parts per million
Pb_wc	TEXT	(dry, whole-coal basis) lead content in parts per million
Sb_wc	TEXT	(dry, whole-coal basis) antimony content in parts per million

Table 3. Explanation of chemical data columns in the Kentucky coal chemistry database files created for the resource assessment of the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin—Continued.

Field Name	Type	Description
Se_wc	TEXT	(dry, whole-coal basis) selenium content in parts per million
Th_wc	TEXT	(dry, whole-coal basis) thorium content in parts per million
U_wc	TEXT	(dry, whole-coal basis) uranium content in parts per million
TOTAL_MOISTURE	TEXT	(as-received basis) total moisture in percent
DRY_ASH	TEXT	(dry basis) ash yield in percent
DRY_VOLATILE_MATTER	TEXT	(dry basis) volatile matter content in percent
DRY_FIXED_CARBON	TEXT	(dry basis) fixed carbon content in percent
DRY_TOTAL_SULFUR	TEXT	(dry basis) total sulfur content in percent
DRY_COMPLIANCE	TEXT	Compliance sulfur is calculated by the following formula: (% total S *19,500) / Calorific Value in BTU/lb. The resulting number is in lbs $S0_2$ / MM
DRY_BTU	TEXT	(dry basis) Gross calorific value of the coal sample expressed in British Thermal Units (BTU/lb)
DRY_CARBON	TEXT	(dry basis) carbon content in percent
DRY_HYDROGEN	TEXT	(dry basis) hydrogen content in percent
DRY_NITROGEN	TEXT	(dry basis) nitrogen content in percent
DRY_OXYGEN	TEXT	(dry basis) oxygen content in percent

Table 4. Explanation of chemical data columns in the Illinois State Geological Survey's coal database files created for the resource assessment of the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin.

[This is a simplified data dictionary showing Field Name, Value, and Description for all the columns in the ASCII files ildachms.txt, ilhechms.txt, ilspchms.txt, and ilchms.txt. These text files, as well as this file, were created by R.H. Affolter (affolter@usgs.gov) of the U.S. Geological Survey from several files received from Colin Treworgy (colin@isgs.uiuc.edu) of the Illinois State Geological Survey and were used to create the ArcView chemical data shapefiles of the Springfield, Danville, and Herrin coals for the Illinois Basin resource assessment. All columns that are labeled column_Q were generated by R.H. Affolter and indicate the qualified values (indicated by L = less than) for selected elements. All columns except DLONG and DLAT are in text to preserve original numbers. For additional information see the related metadata files for Illinois chemical data.]

Field Name	Type	Description
LABNO	TEXT	Laboratory sample number
STATE	TEXT	FIPS state code
COUNTY	TEXT	FIPS county code
STRATCODE	TEXT	ISGS stratigraphic code
DLONG	REAL	Decimal Longitude
DLAT	REAL	Decimal Latitude
THICK	TEXT	Thickness of sample
DEPTH	TEXT	Depth of sample
ELEV	TEXT	Elevation
SAMPLEDATE	TEXT	Sample date
ANALDATE	TEXT	Analysis date
SAMPLETYPE	TEXT	Sample type
ADL	TEXT	Air dried loss
MOISTURE	TEXT	(as received) Moisture content in percent.
VOLATILE	TEXT	(dry basis) Volatile matter content in percent.
FIXEDC	TEXT	(dry basis) Fixed carbon content in percent.
ASH	TEXT	(dry basis) Ash yield in percent.
TOTAL-SUL	TEXT	(dry basis) Total sulfur content in percent.
BTU	TEXT	(dry basis) Btu/lb

Table 4. Explanation of chemical data columns in the Illinois State Geological Survey's coal database files created for the resource assessment of the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin—Continued.

Field Name	Type	Description
CARBON	TEXT	(dry basis) Carbon content in percent.
HYDROGEN	TEXT	(dry basis) Hydrogen content in percent.
NITROGEN	TEXT	(dry basis) Nitrogen content in percent.
OXYGEN	TEXT	(dry basis) Oxygen content in percent.
ORGANIC-SUL	TEXT	(dry basis) Organic sulfur content in percent.
PYRITIC-SUL	TEXT	(dry basis) Pyritic sulfur content in percent.
SULFATE-SUL	TEXT	(dry basis) Sulfate sulfur content in percent.
FSI	TEXT	Free swelling index
TOT-CHLOR	TEXT	(dry basis) Total chlorine content in percent.
AFUSION-INIT	TEXT	(dry basis) Initial ash fusion temperature in degrees Fahrenheit.
AFUSION-SOFT	TEXT	(dry basis) softening temperature in degrees Fahrenheit.
AFUSION-HEMI	TEXT	(dry basis) Hemi ash fusion temperature in degrees Fahrenheit.
AFUSION-FLUID	TEXT	(dry basis) Fluid ash fusion temperature in degrees Fahrenheit.
EQM	TEXT	Equilibrium moisture
COMMENT	TEXT	Comments
TYPE	TEXT	Type of sample
MINE	TEXT	Mine name
SI	TEXT	(dry, whole-coal basis) Silicon content in percent converted from Silicon content in parts per million.
AL	TEXT	(dry, whole-coal basis) Aluminum content in percent. converted from Aluminum content in parts per million.
FE	TEXT	(dry, whole-coal basis) Iron content in percent converted from Iron content in parts per million.
MG	TEXT	(dry, whole-coal basis) Magnesium content in percent converted from Magnesium content in parts per million.
CA	TEXT	(dry, whole-coal basis) Calcium content in percent converted from Calcium content in parts per million.
NA	TEXT	(dry, whole-coal basis) Sodium content in percent converted from Sodium content in parts per million.

Table 4. Explanation of chemical data columns in the Illinois State Geological Survey's coal database files created for the resource assessment of the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin—Continued.

Field Name	Type	Description
K	TEXT	(dry, whole-coal basis) Potassium content in percent converted from Potassium content in parts per million.
TI	TEXT	(dry, whole-coal basis) Titanium content in percent converted from Titanium content in parts per million.
P	TEXT	(dry, whole-coal basis) Phosphorus content in parts per million.
AS	TEXT	(dry, whole-coal basis) Arsenic content in parts per million.
B	TEXT	(dry, whole-coal basis) Boron content in parts per million.
BA	TEXT	(dry, whole-coal basis) Barium content in parts per million.
BE	TEXT	(dry, whole-coal basis) Beryllium content in parts per million.
CD	TEXT	(dry, whole-coal basis) Cadmium content in parts per million.
CO	TEXT	(dry, whole-coal basis) Cobalt content in parts per million.
CR	TEXT	(dry, whole-coal basis) Chromium content in parts per million.
CU	TEXT	(dry, whole-coal basis) Copper content in parts per million.
F	TEXT	(dry, whole-coal basis) Fluorine content in parts per million.
GA	TEXT	(dry, whole-coal basis) Gallium content in parts per million.
GE	TEXT	(dry, whole-coal basis) Germanium content in parts per million.
HG	TEXT	(dry, whole-coal basis) Mercury content in parts per million.
LA	TEXT	(dry, whole-coal basis) Lanthanum content in parts per million.
LI	TEXT	(dry, whole-coal basis) Lithium content in parts per million.
MN	TEXT	(dry, whole-coal basis) Manganese content in parts per million.
MO	TEXT	(dry, whole-coal basis) Molybdenum content in parts per million.
NI	TEXT	(dry, whole-coal basis) Nickel content in parts per million.
PB	TEXT	(dry, whole-coal basis) Lead content in parts per million.
SB	TEXT	(dry, whole-coal basis) Antimony content in parts per million.
SC	TEXT	(dry, whole-coal basis) Scandium content in parts per million.
SE	TEXT	(dry, whole-coal basis) Selenium content in parts per million.

Table 4. Explanation of chemical data columns in the Illinois State Geological Survey's coal database files created for the resource assessment of the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin—Continued.

Field Name	Type	Description
SR	TEXT	(dry, whole-coal basis) Strontium content in parts per million.
TH	TEXT	(dry, whole-coal basis) Thorium content in parts per million.
U	TEXT	(dry, whole-coal basis) Uranium content in parts per million.
V	TEXT	(dry, whole-coal basis) Vanadium content in parts per million.
YB	TEXT	(dry, whole-coal basis) Ytterbium content in parts per million.
ZN	TEXT	(dry, whole-coal basis) Zinc content in parts per million.
ZR	TEXT	(dry, whole-coal basis) Zirconium content in parts per million.

GENERAL COMMENTS

The following information was received from Colin Treworgy (ISGS) and helps to clarify the Illinois State Geological Survey chemical data descriptions.

Each analysis in the Illinois coal quality database has a unique 12-character identifier called LABNO (laboratory number). The first character in the item LABNO is a letter assigned by the ISGS indicating the laboratory that analyzed the sample. The 11 characters following the letter are, in most cases, the identifier assigned by the original laboratory. If the laboratory number is unknown, the company drill hole number is used.

Letter	Laboratory
A	USBM analyses, prior to ISGS "C" lab numbers, old ASTM methods
B	ISGS analyses of oil field brines
C	ISGS analyses of coal or coal-related material
D	ISGS isotopic analyses (e.g. carbon-14)
E	AMAX MIDWEST AREA LAB analyses of coal or coal-related material
G	ISGS analyses of gas
L	COALFIELD RESEARCH, INC. analyses of coal or coal-related material
M	CDM-Acculabs analyses of coal or coal-related material
O	ISGS analyses of oil or oil-related samples
R	ISGS analyses of rocks, soil, and other non-coal sediments
S	ISGS analyses of Devonian black shales
T	COMMERCIAL TESTING & ENGINEERING analyses of coal or coal-related material
U	Unknown laboratory
V	SUNNYVALE MINERALS analyses of coal or coal-related material
W	ISGS analyses of water
X	BLOOMINGTON EXPLORATION analyses of coal or coal-related material

Selected Stratigraphic Codes

2490	Danville Coal
2660	Herrin Coal
2790	Springfield Coal

Table 4. Explanation of chemical data columns in the Illinois State Geological Survey's coal database files created for the resource assessment of the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin—Continued.

	Sampletype Codes
B	Bench sample undifferentiated
C	Column
W	Washed sample undifferentiated
B	Bench sample undifferentiated
C	Column
CB	Composite of bench or block samples; details in remarks
CC	Composite of column samples
FC	Channel of seam; impurities > 3/8" present, but excluded
IC	Channel of seam; impurities > 3/8" present in sample
PC	Channel of seam; impurities > 3/8" not present
W	Washed sample undifferentiated
B	Bench sample undifferentiated
B1	Bench sample of the first bench of the seam
B2	Bench sample of the second bench of the seam
B3	Bench sample of the third bench of the seam
B4	Bench sample of the fourth bench of the seam
B5	Bench sample of the fifth bench of the seam
B6	Bench sample of the sixth bench of the seam
B7	Bench sample of the seventh bench of the seam
B8	Bench sample of the eighth bench of the seam
BD1	Bench sample of core - first bench of seam
BD2	Bench sample of core- second bench of seam
BD3	Bench sample of core- third bench of seam
BD4	Bench sample of core- fourth bench of seam
BD5	Bench sample of core- fifth bench of seam
BF	Channel of bench; impurities > 3/8" present but excluded
BF1	Channel of bench 1; impurities > 3/8" present but excluded.
BF2	Channel of bench 2; impurities > 3/8" present but excluded.
BF3	Channel of bench 3; impurities > 3/8" present but excluded.
BF4	Channel of bench 4; impurities > 3/8" present but excluded.
BF5	Channel of bench 5; impurities > 3/8" present but excluded.
BF6	Channel of bench 6; impurities > 3/8" present but excluded
BF7	Channel of bench 7; impurities > 3/8" present but excluded
BI	Channel of bench; impurities > 3/8" present in sample
BI1	Channel of bench 1; impurities > 3/8" present in sample
BI2	Channel of bench 2; impurities > 3/8" present in sample
BI3	Channel of bench 3; impurities > 3/8" present in sample
BI4	Channel of bench 4; impurities > 3/8" present in sample
BI5	Channel of bench 5; impurities > 3/8" present in sample
BL	Blend of 2 or more different coals, details in remarks
BP	Channel of bench; impurities > 3/8" not present
BP1	Channel of bench 1; impurities > 3/8" not present
BP2	Channel of bench 2; impurities > 3/8" not present
BP3	Channel of bench 3; impurities > 3/8" not present
BP4	Channel of bench 4; impurities > 3/8" not present
BP5	Channel of bench 5; impurities > 3/8" not present
BP6	Channel of bench 6; impurities > 3/8" not present
BP7	Channel of bench 7; impurities > 3/8" not present
BP8	Channel of bench 8; impurities > 3/8" not present
BP9	Channel of bench 9; impurities > 3/8" not present

Table 4. Explanation of chemical data columns in the Illinois State Geological Survey's coal database files created for the resource assessment of the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin—Continued.

Sampletype Codes

C	Column
CB	Composite of bench or block samples
CC	Composite of column samples
CDC	Composite of drill core samples
CFC	Composite channel samples; impurities > 3/8" present but excluded
CGD	Composite of composited samples collected on grids
CIC	Composite of channel samples; impurities > 3/8" present in sample
CPC	Composite of channel samples; impurities > 3/8" not present
D C	Drill core
DC	Drill core
DF	Drill core of bench; impurities > 3/8" present, but excluded
DFC	Drill core of seam
DI	Drill core of bench; impurities > 3/8" present in sample
DIC	Drill core of seam
DP	Drill core of bench; impurities > 3/8" not present
DP1	Drill core of bench 1; impurities > 3/8" not present
DP2	Drill core of bench 2; impurities > 3/8" not present
DP3	Drill core of bench 3; impurities > 3/8" not present
DPC	Drill core of seam
FC	Channel of seam; impurities > 3/8" present, but excluded
GB	Grab sample, details in remarks
Bn	Grab sample of strata 1..n (1 = top)
GD	Grid sample, composite of individual samples collected on a grid
IC	Channel of seam; impurities > 3/8" present in sample
LAB	Laboratory generated sample, details in remarks
PC	Channel of seam; impurities > 3/8" not present
RM	Run of mine, details in remarks
RP	Run of preparation plant, details in remarks
SP	Special sample, details in remarks
SZ	A particle size fraction; feed sample noted elsewhere.
UNN	Unknown type of sample, details in remarks
W	Washed sample undifferentiated
W1	Washed sample- first bench of seam
W2	Washed sample- second bench of seam
W3	Washed sample- third bench of seam
CDS	Calculated composite of sized core samples

The following publications document the analytical procedures used for most Illinois State samples.

Rees, O. W., 1966, Chemistry, Uses and Limitations of Coal Analyses: Illinois State Geological Survey Report of Investigations 220, 55 p. (This publication documents the proximate, ultimate, etc. analysis methodology)

Gluskoter, H. J., Ruch, R. R., Miller, W. G., Cahill, R. A., Dreher, G. B., and Kuhn, J. K., 1977, Trace Elements in Coal: Occurrences and Distribution: Illinois State Geological Survey Circular 499, 154 p. (The appendix at the end of this publication details element analyses methodology).