Chapter A

Executive Summary

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

Chapter A *of*

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

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Executive Summary

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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 depth (feet)	Springfield Coal				Herrin Coal				Danville-Baker Coals				Coal depth (feet)
Mining area or State		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	
Northern Illinois	0-150	0	0	37	37	77	140	170	390	290	340	190	810	0–150
	>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 Illinois	0–150	380	450	1,200	2,000	15	470	2,000	2,500	430	200	0	630	0–150
	>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 Illinois	0–150	0	0	1,100	1,100	98	600	300	990	0	0	0	0	0–150
	>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 Illinois	0–150	17	9	13	39	81	56	470	610	57	350	450	850	0–150
	>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 Illinois	0–150	12	98	250	360	2	17	2,400	2,500	NC	NC	NC	NC	0–150
	>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 Illinois	0–150	0	4	370	370	3	47	580	630	120	4	0	120	0–150
	>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 Kentucky total	0–150	1	17	960	980	47	74	430	550	310	360	260	930	0–150
	>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 Basin total	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
	>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

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,

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.

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.

References Cited

Allgaier, G.J., and Hopkins, M.E., 1975, Reserves of the Herrin (No. 6) Coal in the Fairfield Basin in southeastern Illinois: Illinois State Geological Survey Circular 489, 31 p.

Ashley, G.H., 1899, The coal deposits of Indiana: Indiana Department of Geology and Natural Resources Annual Report 23, p. 1–1573.

Bement, A., 1910, The Illinois coal field: Illinois State Geological Survey Bulletin 16, p. 182–202.

Bohor, B.F., and Gluskoter, H.J., 1973, Boron in illite as a paleosalinity indicator of Illinois coals: Journal of Sedimentary Petrology, v. 43, no. 4, p. 945–956.

Buschbach, T.C., and Kolata, D.R., 1991, Regional setting of Illinois Basin, *in* Leighton, M.W., Kolata, D.R., Oltz, D.F., and Eidel, J.J., eds., Interior cratonic basins: American Association of Petroleum Geologists Memoir 51, p. 29–55.

Cady, G.H., 1935, Classification and selection of Illinois coals: Illinois State Geological Survey Bulletin 62, 354 p.

Cady, G.H., 1948, Analysis of Illinois coals: Supplement to Illinois State Geological Survey Bulletin 62, 77 p.

Cady, G.H., 1952, Mineable coal reserves of Illinois: Illinois State Geological Survey Bulletin 78, 138 p.

Campbell, M.R., and Leverett, F., 1913, Coal reserves of the United States, *in* Coal resources of the World: Toronto, Canada, Morang and Co., v. 2, p. 525–540.

Carey, D.I., and Hiett, J.K., 2000, Kentucky Coal Production, 1790–1999. Accessed January 2, 2001at URL http://www.uky.edu/KGS/coal/webcoal/pages/kycoaltitle.html

Carter, M.D., and Gardner, N.K., 1989, An assessment of coal resources available for development, central Appalachian region: U.S. Geological Survey Open-File Report 89–362, 52 p.

Carter, M.D., Rohrbacher, T.J., Weisenfluh, G.A., Fedorko, N., Axon, A.G., Treworgy, C.G., Cetin, H., Teeters, D.D., Geroyan, R.I., Sites, R.S., and Gardner, N.K., 1995, Federal and State coal availability/recoverability studies in Eastern United States—A new approach to coal resource assessment, *in* Carter, L.M.H., ed., Energy and the environment—Application of geosciences to decision-making: U.S. Geological Survey Circular 1108, p. 48–50.

Chesnut, D.R., Jr., Weisenfluh, G.A., Greb, S.F., Eble, C.F., and Andrews, R.E., 2000, Coal geology of Kentucky, *in* 2000 Keystone Coal Industry Manual: Chicago, Ill., Primedia Intertec, p. 587–603.

Cobb, J.C., Brant, R.A., Currens, J.C., and Williamson, A.D., 1985, Kentucky coal: Kentucky Geological Survey Series XI, Reprint 20, 17 p.

Cobb, J.C., Masters, J.M., Treworgy, C.G., and Helfinstine, R.J., 1979, Abundance and recovery of sphalerite and fine coal from mine wastes in Illinois: Illinois State Geological Survey Illinois Mineral Notes 71, 11 p.

Currens, J.C., 1986, Coal-quality data for the western Kentucky coal field: Kentucky Geological Survey Open-File Report, Series XI, 40 p.

Damberger, H.H., 1971, Coalification pattern of the Illinois Basin: Economic Geology, v. 66, no. 3, p. 488–495.

Damberger, H.H., 2000, Coal geology of Illinois, *in* 2000 Keystone Coal Industry Manual: Chicago, Ill., Primedia Intertec, p. 562–573.

DeWolf, F.W., 1908, Coal resources of Illinois: American Institute of Mining and Metallurgical Engineers Bulletin, v. 24, p. 1103–1112.

Eggleston, J.R., Carter, M.D., and Cobb, J.C., 1990, Coal resources available for development—A methodology and pilot study: U.S. Geological Survey Circular 1055, 15 p.

Gluskoter, H.J., 1965, Electric low temperature ashing of bituminous coal: Fuel, v. 44, no. 4, p. 285–291.

Gluskoter, H.J., 1967, Clay minerals in Illinois coals: Journal of Sedimentary Petrology, v. 37, no. 1, p. 205–214.

Gluskoter, H.J., 1975, Mineral matter and trace elements in coal, *in* Babu, S.P., ed., Trace elements in fuel: American Chemical Society Advances in Chemistry Series, no. 141, p. 1–22.

Gluskoter, H.J., Flores, R.M., Hatch, J.R., Kirschbaum, M.A., Ruppert, L.F., and Warwick, P.D., 1996, Assessing the coal resources of the United States: U.S. Geological Survey Fact Sheet 157–96, 8 p.

Gluskoter, H.J., and Lindahl, P.C., 1973, Cadmium—Mode of occurrence in Illinois coals: Science, v. 181, no. 4096, p. 264–266.

Gluskoter, H.J., and Rees, O.W., 1964, Chlorine in Illinois coal: Illinois Geological Survey Circular 372, 23 p.

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.

Gluskoter, H.J., and Simon, J.A., 1968, Sulfur in Illinois coals: Illinois State Geological Survey Circular 432, 28 p.

Greb, S.F., Williams, D.A., and Williamson, A.D., 1992, Geology and stratigraphy of the western Kentucky coal field: Kentucky Geological Survey Bulletin 1, Series XI, 77 p.

Harvey, R.D., Cahill, R.A., Chou, C.L., and Steele, J.D., 1983, Mineral matter and trace elements in the Herrin and Springfield Coals—Illinois Basin coal field: Illinois State Geological Survey Contract/Grant Report 1983–4, 162 p.

Hasenmueller, W.A., 1994, The quality of Indiana's coal resources: Indiana Geological Survey Occasional Paper 63, 45 p.

Hasenmueller, W.A., and Miller, L.V., 1992, The Indiana coal analysis database: Indiana Geological Survey Computer Database 1, 13 p., 3 data diskettes.

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

Hopkins, M.E., 1968, Harrisburg (No. 5) Coal reserves of southeastern Illinois: Illinois State Geological Survey Circular 431, 25 p.

Hopkins, M.E., and Simon, J.A., 1974, Coal resources of Illinois: Illinois State Geological Survey Illinois Minerals Note 53, 24 p.

Hopkins, M.E., and Simon, J.A., 1975, Pennsylvanian System, *in* Handbook of Illinois Stratigraphy: Illinois State Geological Survey Bulletin 95, p. 163–210

Illinois Department of Mines and Minerals, 1994, 1993, Annual statistical report: Springfield, Ill., Illinois Department of Natural Resources, Office of Mines and Minerals, 29 p.

Jacobson, R.J., Trask, C.B., Ault, C.H., Carr, D.D., Gray, H.H., Hasenmeuller, W.A., Williams, D., and Williamson, A.D., 1985, Unifying nomenclature in the Pennsylvanian System of the Illinois Basin: Transactions of the Illinois Academy of Science, v. 78, number 1–2, p. 1–11.

Mastalerz, Maria, and Harper, Denver, 1998, Coal in Indiana—A geologic overview: Indiana Geological Survey Special Report 60, 45 p.

Mastalerz, Maria, and Shaffer, K.R., 2000, Coal geology of Indiana, in 2000 Keystone Coal Industry Manual: Chicago, Ill., Primedia Intertec, p. 574–579.

Nelson, W.J., 1983, Geologic disturbances in coal seams: Illinois State Geological Survey Circular 530, 47 p.

Oman, C.L., Hassenmueller, W.H., and Bragg, L.J., 1992, Indiana coal and associated rock samples collected from 1975 to 1977: U.S. Geological Survey Open-file Report 93–0111, 133 p.

Plis, M.N., Rohrbacher, T.J., and Teeters, D.D., 1993, COALVAL—A prefeasibility software package for evaluating coal properties using Lotus 1-2-3, release 2.2: U.S. Bureau of Mines Information Circular 9348, 93 p.

Rao, C.P., and Gluskoter, H.J., 1973, Occurrences and distribution of minerals in Illinois coals: Illinois State Geological Survey Circular 476, 56 p.

Rohrbacher, T.J., Teeters, D.D., Sullivan, G.L., and Osmonson, L.M., 1993, Coal resource recoverability—A methodology: U.S. Bureau of Mines Information Circular 9368, 48 p.

Rowan, E.L., Goldhaber, M.G., and Hatch, J.R., in press, The role of regional fluid flow in the Illinois Basin's thermal history— Constraints from fluid inclusions and the maturity of Pennsylvanian coals: American Association of Petroleum Geologists Bulletin, 35 p.

Smith, G.E., and Brant, R.A., 1980, Western Kentucky coal resources: Lexington, Ky., University of Kentucky Institute for Mining and Minerals Research, Energy Resource Series, 148 p.

Spencer, F.D., 1953, Coal resources of Indiana: United States Geological Survey Circular 266, 42 p.

Suffredini, C.D., Plis, M.N., Rohrbacher, T.J., and Teeters, D.D., 1994, COALVAL 2.0—A prefeasibility software package for evaluating coal properties using Lotus 1-2-3, release 3.1: U.S. Bureau of Mines Open File Report 35–94, 198 p.

Treworgy, C.G., and Bargh, M.H., 1982, Deep-minable coal resources of Illinois: Illinois State Geological Survey Circular 527, 62 p.

Treworgy, C.G., Bengal, L.E., and Dingwell, A.G., 1978, Reserves and resources of surface-minable coal in Illinois: Illinois State Geological Survey Circular 504, 44 p.

Treworgy, C.G., Prussen, E.I., Justice, M.A., Chenoweth, C.A., Bargh, M.H., Jacobson, R.J., and Damberger, H.H., 1997, Illinois coal resource assessment and database development—Final report: Illinois State Geological Survey Open File Series 1997–4, 105 p.

Trumbull, James, 1960, Coal fields of the United States, exclusive of Alaska—Sheet 1: U.S. Geological Survey Map, scale 1:5,000,000.

U.S. Bureau of Mines, Intermountain Field Operations Center, 1995, Coal recoverability and coal reserve analysis, Appalachian and Illinois Basins, 1994: U.S. Bureau of Mines Open File Report 02–95, 41 p.

U.S. Energy Information Administration, 1998, Coal Industry Annual, 1997 Executive Summary: Accessed January 26, 1999 at URL http://www.eia.doe.gov

U.S. Energy Information Administration, 2000, U.S. coal production by State, 1989, 1994–1998: Accessed September 20, 2000 at URL http://www.eia.doe.gov

Weisenfluh, G.A., Andrews, W.A., and Hiett, K.K., 1998, Availability of coal resources for the development of coal—Western Kentucky summary report: Kentucky Geological Survey Interim Report for U.S. Department of Interior Grant 14–08–001–A0896, 32 p.

Whelan, J.F., Cobb, J.C., and Rye, R.O., 1988, Stable isotope geochemistry of sphalerite and other mineral matter in coal beds of the Illinois and Forest City basins: Economic Geology, v. 83, p. 990–1007.