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Availability of the Herrin Coal for Mining in Illinois

Colin G. Treworgy, Christopher P. Korose, and Christine L. Wiscombe

Illinois Minerals 120 2000

George H. Ryan, Governor

Department of Natural Resources
ILLINOIS STATE GEOLOGICAL SURVEY
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Cover photo: *Undercutting the Herrin Coal, Old Ben Mine No. 9, Franklin County, Illinois.*

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EXECUTIVE SUMMARY

Of the 88.5 billion tons of original resources of Herrin Coal in Illinois, 79 billion tons or 89% remain, the largest remaining coal resource in the state. The other 9.4 billion tons have been mined or lost during the almost 200 years of mining Illinois coal. The degree to which this remaining resource is utilized in the future depends on the availability of deposits that can be mined at a cost that is competitive with other coals and alternative fuels. This report identifies those resources that have the most favorable geologic and land-use characteristics for mining, shows the probable trend of future mining of these resources, and alerts mining companies to geologic conditions that have the potential to negatively impact mining costs.

Approximately 58% of the original Herrin Coal resources (51 billion tons) is available for mining (table 1). "Available" means that the surface land use and geologic conditions related to mining the deposit (e.g., thickness, depth, in-place tonnage, stability of bedrock overburden) are comparable with those of other coals currently being mined in the state. Of these resources, 21 billion tons are 42 to 66 inches thick, and 30 billion tons are greater than 66 inches thick. An additional 3 billion tons of the Herrin Coal resources are available but have geologic or land-use conditions that are potential restrictions making them less desirable for mining. Technological factors (geologic conditions and economic parameters such as size of reserve block) restrict mining of 24% of the resources, and land-use factors (e.g., towns, highways) restrict mining of 4% of the resources.

The available resources are primarily located in the central and southern portions of the state and are well suited for high-efficiency longwall mining. The resources are relatively flat-lying; have a consistent thickness over large areas; are relatively free of faults, channels, or other geological anomalies; are located predominantly in rural areas free from oil wells and other surface development; and are in minable blocks of hundreds of millions of tons. Whether or not the resources are ultimately mined is still dependent on a variety of other factors that have not been assessed, including the willingness of local landowners to lease the coal, demand for a particular quality of coal, accessibility of transportation infrastructure, proximity of the deposit to markets and cost, and availability of competing fuels.

About 74 billion tons of the remaining Herrin Coal resources have greater than 1.67 pounds of sulfur per million Btu and are therefore mostly suited for the high-sulfur coal market. Although only 9% of the original resources had a sulfur content of less than 1.67 pounds per million Btu, almost one-third of the past mining has been concentrated in these deposits. About 6 billion tons of this lower sulfur coal remain, and about half of this is classified as available or available with potential restrictions. For the most part, these lower sulfur resources are too deep for surface mining and will have to be mined by underground methods. Technological factors, particularly seam thickness and thickness of bedrock cover, are the primary restrictions on mining these lower sulfur deposits. About 5% of these resources are available but potentially restricted by land use because of eastward expansion of development in the St. Louis metropolitan area.

Table 1 Availability of the Herrin Coal for mining in Illinois (billions of tons).

		Potential mining method[1]		Sulfur[2]	
	Total	Surface	Underground	<1.67	>1.67
Original	88.5	14.9	86.5	8.4	80.1
Mined	9.4 (11)[3]	3.1 (21)	8.4 (10)	2.7 (32)	6.8 (8)
Remaining	79.0 (89)	11.8 (79)	78.1 (90)	5.7 (68)	73.6 (92)
Available	51.0 (58)	2.2 (15)	49.3 (57)	2.9 (34)	48.1 (60)
Available with conditions	3.1 (3)	0.2 (2)	3.3 (4)	0.3 (4)	2.7 (3)
Technological restrictions	21.1 (24)	6.8 (45)	21.4 (25)	2.3 (27)	19.1 (24)
Land-use restrictions	3.8 (4)	2.6 (17)	4.1 (5)	0.2 (3)	3.7 (5)

[1]Surface and underground resources do not add to the total because coal that lies between 40 and 200 feet deep is included in both categories.

[2]Pounds per million Btu.

[3]Numbers in parentheses are percent of original resources.

Most of the available Herrin Coal resources will have to be mined by underground methods. Of the 86 billion tons of original resources that are at least 40 feet deep (and therefore potentially minable by underground methods), 57% (49 billion tons) is available for underground mining. An additional 4% (3 billion tons) is available but with potential restrictions that make the resources less desirable. These potential restrictions include the presence of closely spaced oil wells, less stable roof strata, or close proximity to developing urban areas. The major technological factors that restrict underground mining are unfavorable thicknesses of bedrock and unconsolidated overburden (9% of original resources), coal less than 42 inches thick (8%), and thin interburden between the Herrin Coal and an overlying or underlying seam (4%). Land use restricts underground mining of 5% of the original resources, and 10% has already been mined or lost in mining.

Only about 15 billion tons of the original Herrin Coal resource lie at depths of less than 200 feet and are potentially minable by surface methods. Of these resources, 21% has already been mined (3 billion tons), and 15% (2 billion tons) is available for surface mining. Land-use factors, primarily towns, restrict 17% of the resources. Technological factors, primarily stripping ratio and thick unconsolidated material, restrict 45% of the surface-minable resources.

To avoid high mining costs resulting from unfavorable geologic conditions, companies seeking sites for underground mines should avoid areas with the following conditions: thick drift and thin bedrock cover, close proximity to the Walshville or Anvil Rock Channels or faults, areas of closely spaced oil wells and areas at the margins of the Energy Shale or closely overlain by Anvil Rock Sandstone. Areas with low-cost, surface-minable resources (areas with low stripping ratios that are free of conflicting land uses) are limited and will only support small, short-term operations.

This report is the second of a series that explains the availability of coal in Illinois for future mining. A previous report evaluated the availability of the Springfield Coal for mining (Treworgy et al. 1999a). These two statewide assessments are based on earlier reports that evaluated the availability of coal in 21 study areas. The study areas were 7.5-minute quadrangles that were representative of mining conditions found in various parts of the state. Coal resources and related geology were mapped in these study areas, and the factors that restricted the availability of coal in the quadrangles were identified through interviews with more than 40 mining engineers, geologists, and other mining specialists representing 17 mining companies, consulting firms, and government agencies active in the Illinois mining industry. The major restrictions identified in these individual study areas were used for the statewide assessments of the availability of the Herrin and Springfield Coals for mining.

INTRODUCTION

Accurate estimates of the amount of coal resources available for mining are needed for planning by federal and state agencies, local communities, utilities, mining companies, companies supplying goods and services to the mining industry, and other energy consumers and producers. Current inventories of coal resources in Illinois provide relatively accurate estimates of the total amount of coal in the ground (e.g., Treworgy et al. 1997b), but the actual percentage of the total having geologic and land-use conditions favorable for mining is not well defined. Environmental and regulatory restrictions, the presence of towns and other cultural features, current mining technology, geologic conditions such as unstable roof strata, and other factors significantly reduce the amount of coal available for mining.

The United States has enormous resources of coal.There is little concern that a shortage of coal could develop in the foreseeable future. The important issues for society are (1) where the greatest resources that are most favorable for mining are located and (2) how they will be extracted (McCabe 1998). Recognizing that a significant difference exists between the reported tonnage of total coal resources and the tonnage legally or practically restricted from mining by various land-use and geologic conditions, the United States Geological Survey (USGS) initiated a program in the late 1980s, in cooperation with state geological surveys, to assess the amount of available coal in the United States (Eggleston et al. 1990). As part of this ongoing effort, the Illinois State Geological Survey (ISGS) is assessing the availability of coal resources for future mining in Illinois. This report assesses the Herrin Coal resources in Illinois, identifies those resources that have geologic and land-use characteristics most favorable for mining, shows the probable trend of future mining of these resources, and alerts mining companies to geologic conditions that potentially can have a negative impact on mining costs.

Coal Resource Classification System

The ISGS follows the terms and definitions of the USGS coal resource classification system (Wood et al. 1983). With minor modifications to suit local conditions, these definitions provide a standardized basis for compilations and comparisons of nationwide coal resources and reserves.

The term "original resources" refers to the amount of coal originally in the ground prior to any mining. In past reports, the ISGS has defined "resources" as all coal in the ground that is 18 or more inches in thickness and lying less than 150 feet deep or all coal 28 or more inches thick lying at any depth. In this report, the ISGS defines "surface-minable coal" as all coal in the ground that is 18 or more inches thick and lying less than 200 feet deep and "underground-minable coal" as all coal 28 inches or more thick and lying 40 or more feet deep. The USGS and other states use 14 inches (not 18 or 28) as the minimum thickness for resources. This difference in definitions does not significantly affect the resource totals for the Herrin Coal, which is commonly thicker than 28 inches throughout the area of the state where it has been mapped.

Although not yet formally part of the resource classification system, in recent years, the USGS and many state surveys have made efforts to divide remaining resources into two categories: restricted and available (Eggleston et al. 1990). "Restricted resources" are those that have some land-use or technological restriction that makes it unlikely they will be mined in the foreseeable future. Land-use restrictions include manmade or natural features that are illegal to disturb by mining or that make mining impractical. Technological restrictions include geologic or mining-related factors that negatively impact the economics or safety of mining. "Available resources" are not necessarily economically minable at the present time but are expected to have mining conditions comparable with those currently being successfully mined. Determining the actual cost and profitability of these deposits requires further engineering and marketing assessments.

In this study, the ISGS uses an additional category called "available with potential restrictions." This term designates resources that are not restricted by the land-use or technological restrictions, but that have some known special condition that makes them less favorable for mining. Close proximity to rapidly developing urban areas, the presence of some but not too many oil wells, and potentially unstable roof conditions are examples of potential restrictions that have resulted in resources being placed in this category. In this study, therefore, remaining resources = resources restricted by land use + resources restricted by technology + resources available with potential restrictions + available resources.

The USGS classification system uses the terms "measured," "indicated," and "inferred" to indicate the reliability of resource estimates based on the type and density of data (Wood et al. 1983). The ISGS uses similar categories, which, in previous reports, have been called Class Ia, Class Ib, and Class IIa (Treworgy et al. 1997b). Because these earlier ISGS categories are essentially equivalent to the USGS categories, the USGS terminology is used in this report. Collectively, the resources in these three categories are termed "identified resources" to distinguish them from resources based on less reliable estimates. In this report, the term "resources" refers to identified resources as defined by Wood et al. (1983).

Figure 1 Extent of the Herrin Coal in the Illinois Basin.

Geology and Mining of the Herrin Coal

The Herrin Coal underlies about two-thirds of Illinois as well as portions of western Indiana and Kentucky (fig. 1). In some parts of Indiana the Herrin Coal is thin and has been considered to be a lower bench of the Hymera Coal (Treworgy et al. 1999b). The coal crops out along the margins of the Illinois Basin and reaches a maximum depth in Illinois of about 1,300 feet (figs. 2 and 3). No resources of the Herrin Coal have been mapped in Indiana. Remaining identified resources of Herrin Coal in Illinois and Kentucky are approximately 82 billion tons, of which 96% (79 billion tons) is in Illinois (fig. 4, Kentucky tonnage from William Andrews, personal communication, 1999). This represents about 40% and 29% of all the identified coal resources in Illinois and the Illinois Basin, respectively.

The Herrin Coal has been mined in Illinois for well over 100 years (fig. 5). Because of the vast resources of Herrin Coal, its production history reflects social and political events rather than the development and depletion cycle typical of non-renewable resources. From a beginning sometime in the 1800s production rose rapidly in the early 1900s with the discovery of thick deposits of Herrin Coal in southern Illinois. The all-time high production exceeded 60 million tons per year in 1918. Production declined after World War I and then dropped sharply during the depression to a low of 23 million tons. Production rose nearly to all-time highs again during World War II and fell back to the low 30 million tons after the war. Growing demand for electricity led to production growth again in the mid-1960s. Except for strike years, production hovered around 45 million tons per year until the early 1990s. Production has declined steadily since 1994 because of restrictions on the use of high-sulfur coal legislated by the Clean Air Act and competition from Powder River Basin coal. In 1999, twelve Illinois mines produced a total of 24 million tons from the Herrin Coal, approximately 60% of total state production (Illinois Office of Mines and Minerals, personal communication).

Thick resources of Herrin Coal in Illinois are found mostly in the southern half of the state; the largest area of thick coal is found in a wide arc stretching from just south of Springfield, through the southwestern part of the state, to Harrisburg (fig. 6). Smaller areas of thick coal are found in east-central Illinois in the vicinity of Danville and in central Illinois in the vicinity of Newton. Recent and historical mining of the coal has been concentrated around the margins of the coal field, particularly in southwestern Illinois and in shallow surface-minable deposits west of the Illinois River. The coal is thin or absent throughout much of the east-central and extreme northern portions of the coal field.

Quality of Coal

The Herrin Coal is a high-volatile, bituminous coal that ranges in rank from rank A in the southeastern corner of the state to rank C in the northwestern two-thirds of the state (fig. 7). Over the same area, heat content ranges from more than 25 million Btu per ton to less than 20 million Btu per ton (as received). Ash is commonly in the range of 9% to 12% (as received); slightly lower ash contents are reported in the southeastern part of the state.

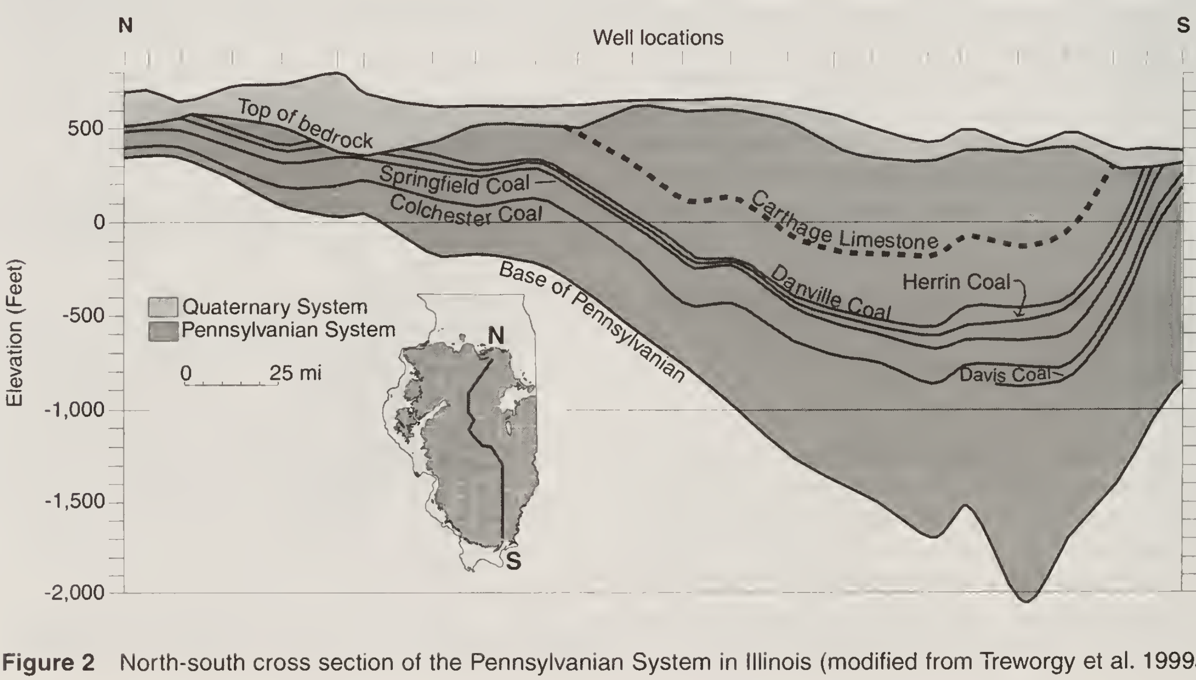


Figure 2 North-south cross section of the Pennsylvanian System in Illinois (modified from Treworgy et al. 1999a).

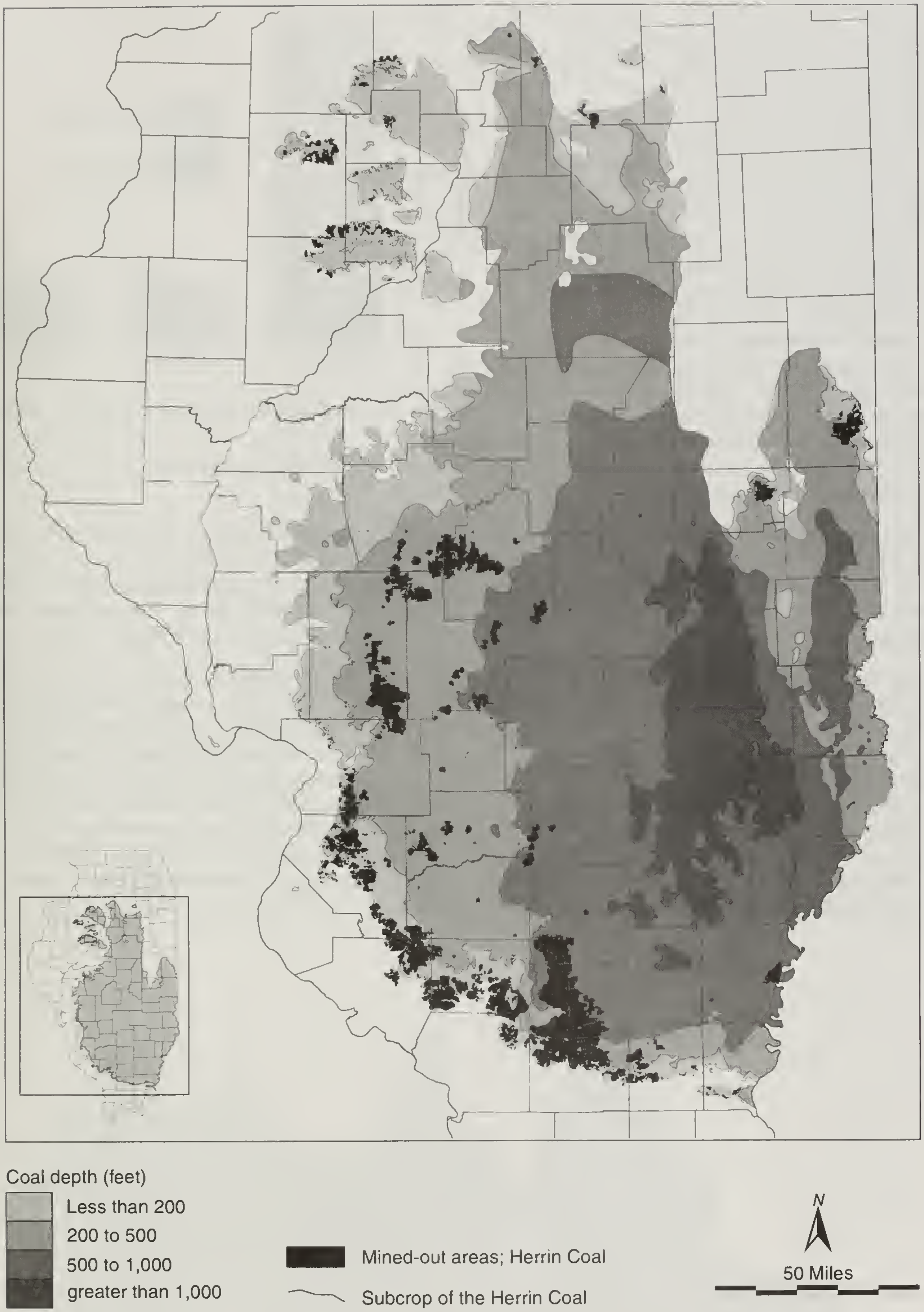


Figure 3 Depth of the Herrin Coal.

The sulfur content of the Herrin Coal is closely related to the coal's depositional history (Gluskoter and Simon 1968, Treworgy and Jacobson 1986). In areas where the Herrin peat swamp was inundated with marine waters, the sulfur content of the coal is commonly in the range of 3% to 5% (as-received basis, equivalent to 2.5 pounds to 5 pounds of sulfur per million Btu, fig. 8). In these areas, the coal typically is overlain by a sequence of marine rocks including black shale and limestones. In areas where the peat was buried by a thick (>20 feet) layer of clastic sediments before or shortly after the swamp was inundated by marine waters, the sulfur content of the coal is as low as about 0.5%. These lower sulfur areas are typically associated with the Walshville Channel, a river that was contemporaneous with the Herrin peat swamp. The clastic sediment that covered the peat, now lithified into a sequence of shale, siltstone, and sandstone, is called the Energy Shale.

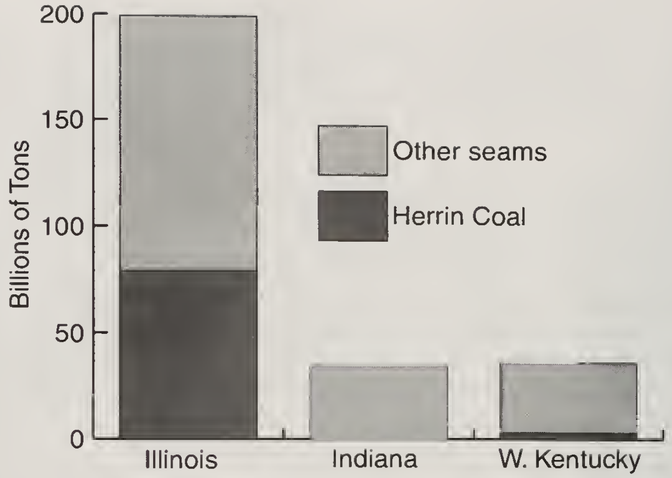


Figure 4 Remaining coal resources in the Illinois Basin.

Chlorine content of the coal is loosely correlated to depth and increases from <0.1% (as received) at shallow depths along the margins of the basin to >0.6% in the central part of the basin (fig. 9, Chou 1991). Chlorine content in British coals has been correlated with corrosion and fouling of high-temperature boilers, but no studies or field experiences have reported or confirmed such a correlation with respect to chlorine in coals from Illinois (Monroe and Clarkson 1994, Chou et al. 1998 and 1999).

The quality of coal was not considered in determining availability. Although coal quality is an extremely important factor in individual sales contracts and the magnitude of demand for coal, the availability for mining of a specific deposit of Herrin Coal cannot be ruled out based strictly on quality. Because most Herrin Coal resources have a relatively high-sulfur content, demand for them is currently limited. However, the market for high-sulfur coal, although reduced in size, is expected to continue and may even increase as power plants with new emission control technologies come on line. To identify what portion of the Herrin resources are available to meet that demand, available resources are classified by sulfur content. A logical continuation of this study would be to further characterize coal resources by other quality parameters important to the marketing of coal (e.g., ash, chlorine, trace elements). However, substantially more coal quality data are needed to make such a characterization feasible.

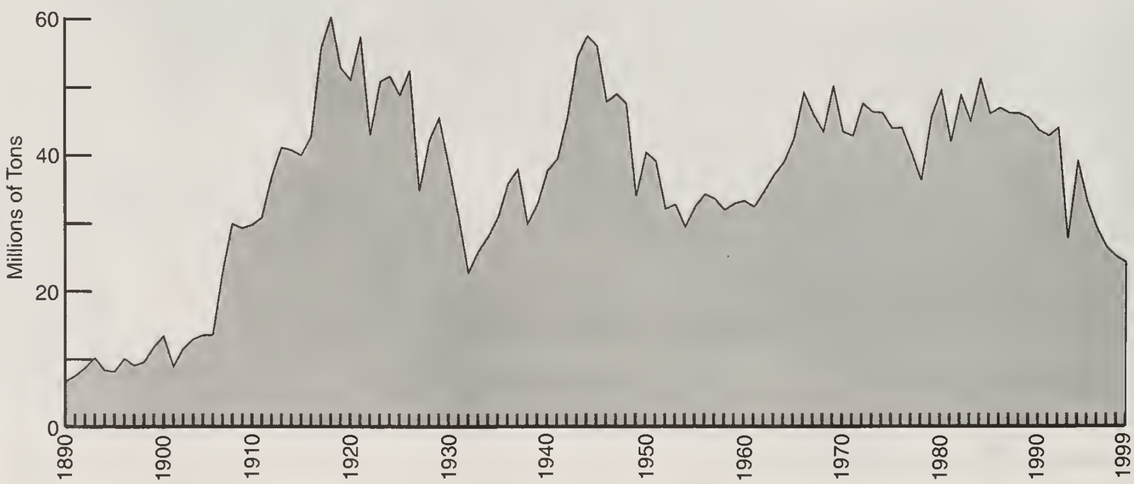


Figure 5 Annual production of the Herrin Coal in Illinois.

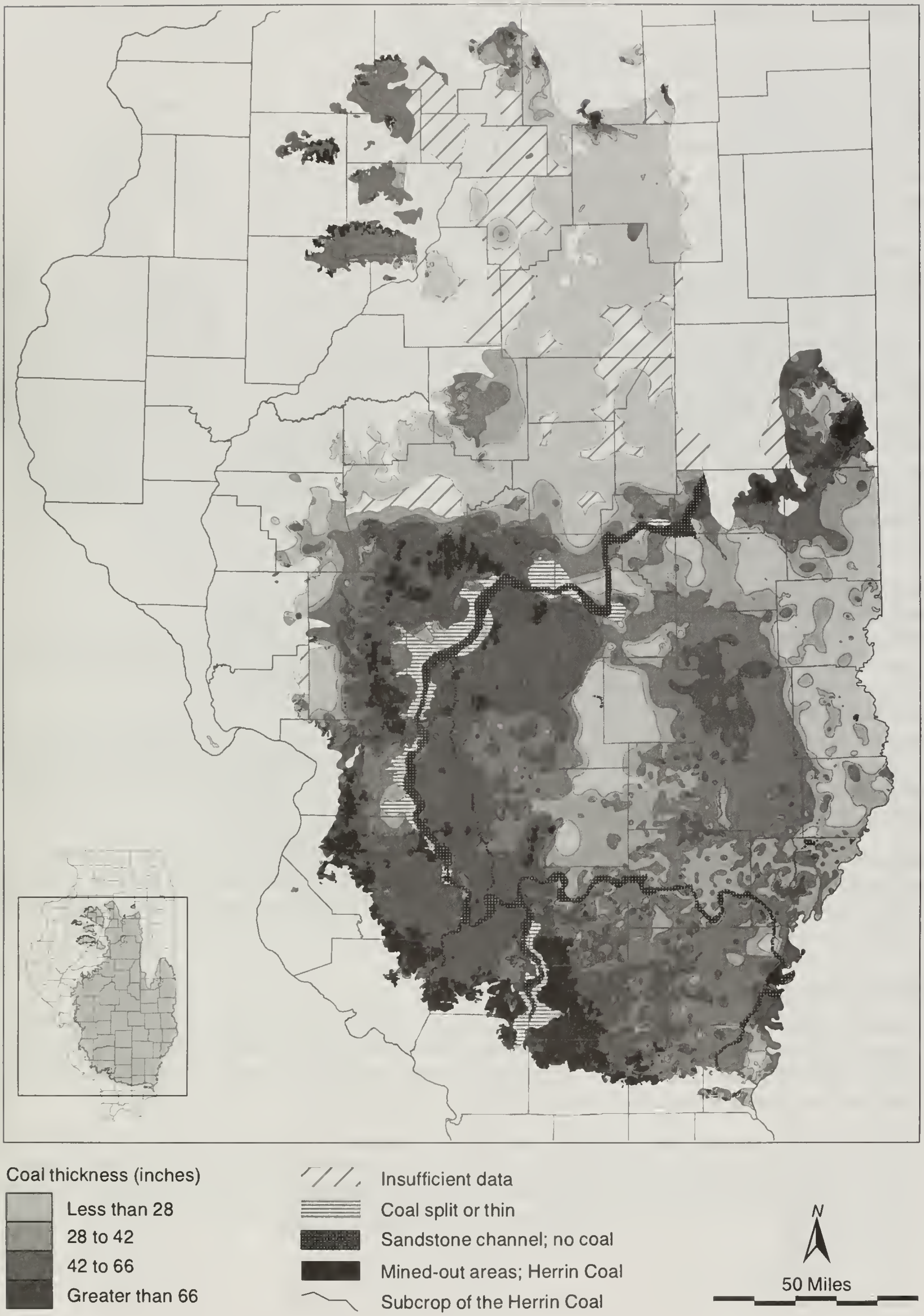


Figure 6 Thickness of the Herrin Coal.

Quadrangle Studies

The criteria defining available resources were developed through a series of 21 assessments of 7.5-minute quadrangles (fig. 10; Treworgy et al. 1994, 1995, 1996a,b, 1997a, 1998, 1999b; Jacobson et al. 1996; Treworgy 1999; Treworgy and North 1999). These assessments included interviews with more than 40 mining engineers, geologists, and other mining specialists representing 17 mining companies, consulting firms, and government agencies actively involved in the Illinois coal industry. Additional background of this program and a detailed description of the framework for the investigations in Illinois are provided in previous reports (e.g., Treworgy et al. 1994).

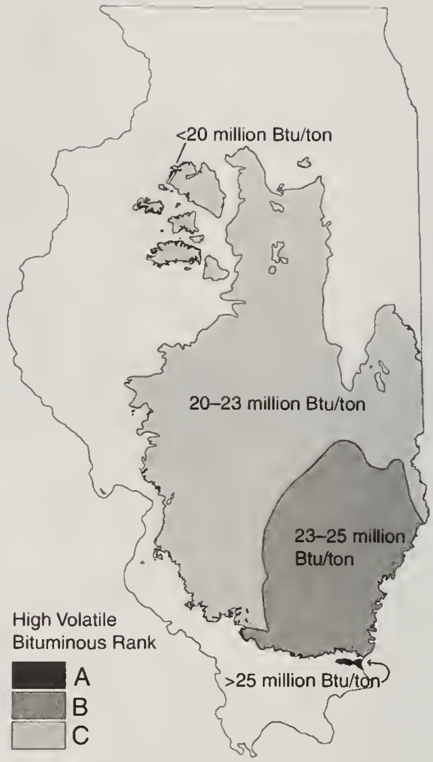


Figure 7 Rank and heat content of the Herrin Coal (modified from Treworgy et al. 1997b).

Quadrangles were selected to cover the range of physiographic and geologic conditions associated with mining the Herrin Coal. Quadrangle selection was not random, but rather focused on resources that have the highest potential for development (e.g., thick or lower sulfur content seams). This approach was taken to ensure that the most economically important deposits received sufficient study and that little time was spent on coal that is unlikely to become available for mining in the foreseeable future.

Maps at 1:24,000 scale showing the major coal seams, related geology, mines, and land use in each quadrangle were compiled based on previous regional investigations of mining conditions, resources, and geology. These maps provided the basis for detailed discussions with experts from mining companies, consulting firms, and government agencies active in the Illinois mining industry to identify the factors that affect the availability of coal in each quadrangle. Each quadrangle was discussed with three or more experts to develop a set of criteria for defining available coal. These criteria were then applied to each quadrangle to calculate the available resources and to identify the factors that restrict significant quantities of resources from being minable.

Of the 21 quadrangles studied, 17 included some resources of the Herrin Coal (fig. 10, table 2). The total Herrin Coal resource in these 17 quadrangles was more than 4 billion tons, or about 4% of the original Herrin resources in the state. Availability of the coal in the 17 quadrangles ranged from none to 95% and averaged 45%.

Sources of Data and Limitations of Maps

The maps used for this study were compiled from data obtained from a variety of public and private sources and have varying degrees of completeness and accuracy. The maps are designed for regional assessment and have a resolution of 1:500,000 or better. Features or details of features smaller than about one-half mile across may not be accurately portrayed or may be omitted altogether.

Resources of the Herrin Coal have been mapped by a number of previous studies. This assessment utilized the sources identified in appendix 1. Resources were revised in eight counties utilizing data acquired since the previous investigation. Minor corrections and revisions were made in a number of other counties. Mined areas were updated to about January 1, 2000, by using maps obtained from coal companies.

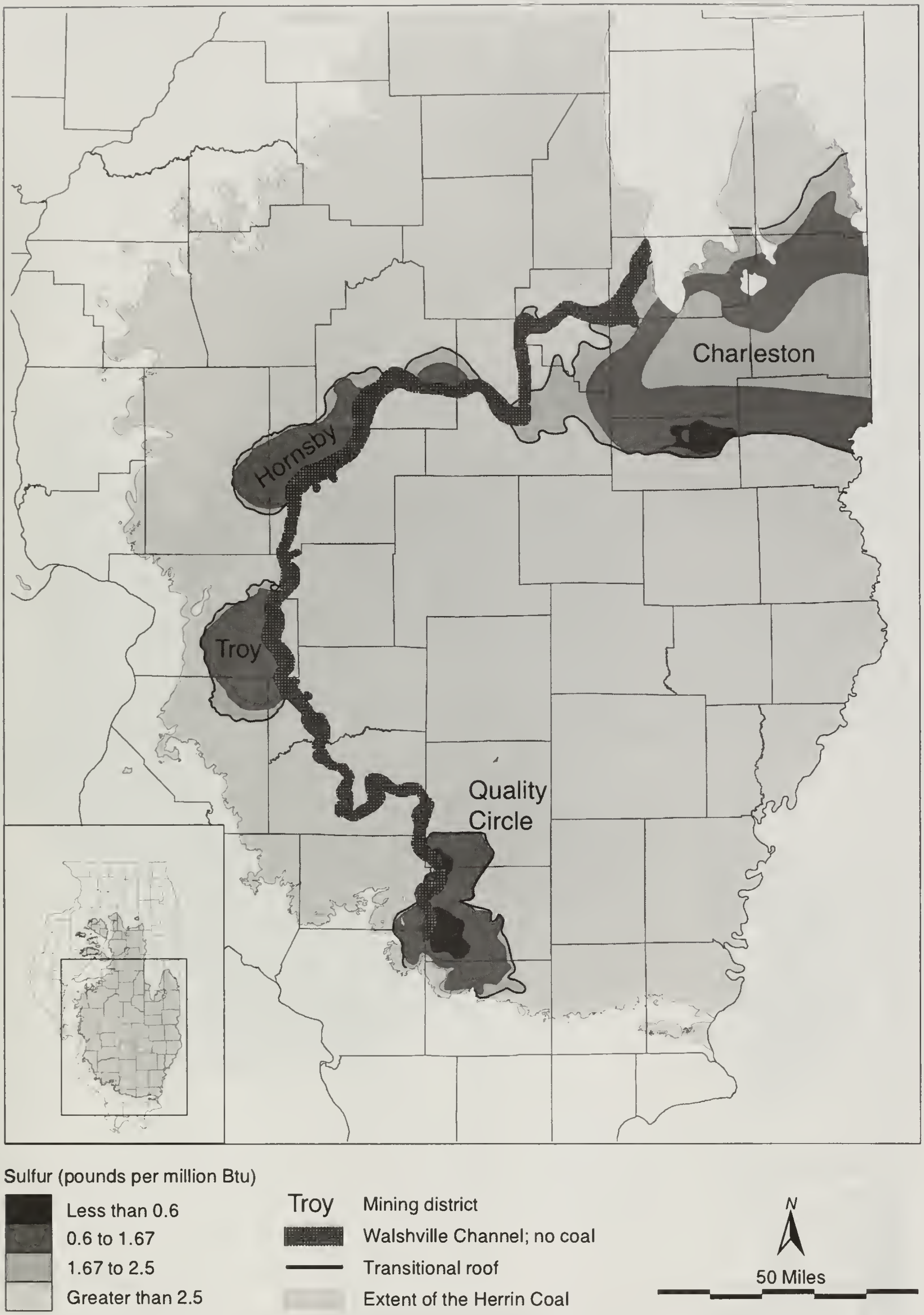


Figure 8 Sulfur content of the Herrin Coal.

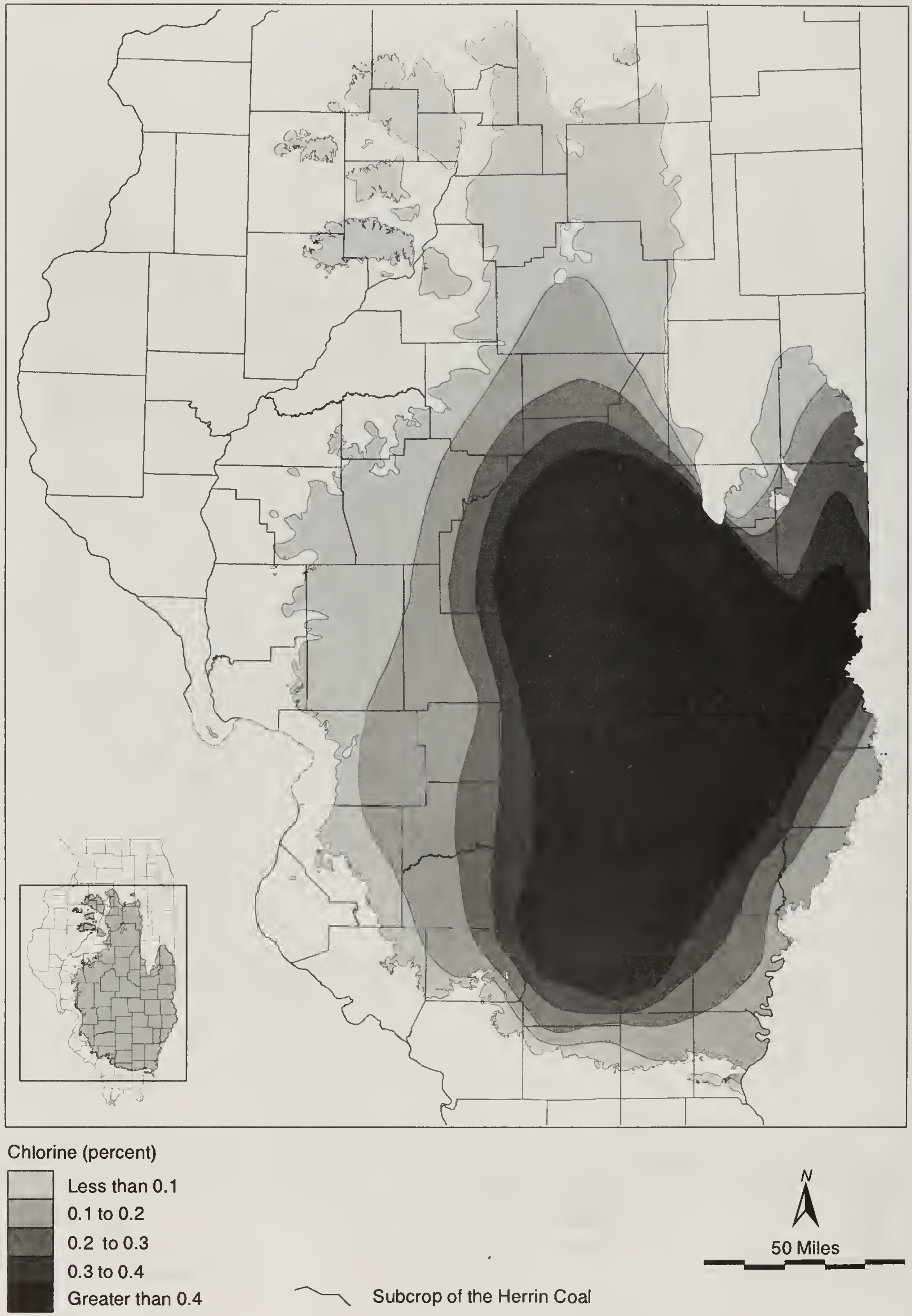


Figure 9 Chlorine content of the Herrin Coal (modified from Chou 1991).

TECHNOLOGICAL AND LAND-USE FACTORS THAT AFFECT THE AVAILABILITY OF COAL FOR MINING

Most technological or land-use factors that restrict mining are based on economic and social considerations and are not absolute restrictions on mining. Companies can choose to mine underground in areas of severe roof or floor conditions or thin seams if they are willing to bear the higher operating costs, interruptions and delays in production, and lower employee morale that result from operating in these conditions. It is possible to mine through most roads or under small towns if a company is willing to invest the time and expense necessary to gain approval from the appropriate governing units or individual landowners and to mitigate any damage. Previous economic and social conditions have, at times, enabled companies to mine in areas where factors are now restrictive. The current highly competitive price environment in the coal industry, which makes coal that is more expensive to mine uneconomic, is expected to prevail in the Illinois Basin indefinitely. Therefore, the criteria used to determine available coal for this report are likely to cover mining conditions for the foreseeable future.

The criteria used in this study to define available Herrin Coal are a composite set of rules based on our interviews with mining companies, observations of mining practice, and the assessments of the 21 quadrangles. Additional information can be found in the study reports on individual quadrangles where these conditions were encountered. In some cases it was necessary to modify or omit certain criteria used in the quadrangle studies to take advantage of existing statewide data or because the criteria were too complicated, costly, or impractical to apply in a statewide assessment. Modifications and omissions of criteria are noted in tables 3a and 3b and explained in the following sections. These changes had minimal effect on the overall results of the statewide assessment.

Some factors were modified during the course of the quadrangle studies as additional information was collected. For example, a different minimum block size for surface mining was used in several studies. The minimum was set at 15 million tons-in-place in the initial study. This minimum was based on the conditions in the Middletown Quadrangle and the practices of the companies interviewed (Treworgy et al. 1994). As additional quadrangles were studied and companies interviewed, the minimum size was changed to 10 million tons of clean coal and then modified further to as little as 150 thousand clean tons per mine pit with a cumulative pit total of 10 million tons of clean coal.

Table 2 Resources of the Herrin Coal in individual quadrangles studied (millions of tons).

Quadrangles	Original	Mined	Remaining	Available	Available with potential restrictions	Restrictions: Technological	Restrictions: Land use
Albion South	287		287 (100)[1]	68 (24)	5 (2)	208 (72)	6 (2)
Atwater	301		301 (100)	231 (77)		65 (22)	5 (2)
Collinsville	436	196 (45)	241 (55)	0 (0)	135 (31)	10 (2)	95 (22)
Galatia	330	19 (6)	311 (94)	232 (71)		61 (19)	18 (5)
Kewanee South	76	8 (10)	68 (90)	40 (53)		5 (7)	23 (31)
Mascoutah	462	60 (13)	402 (87)	182 (39)		177 (38)	43 (9)
Middletown	47		47 (100)	0 (0)		47 (100)	<1 (<1)
Mt. Carmel	229		229 (100)	0 (0)		209 (91)	20 (9)
Newton	380		380 (100)	359 (95)		0 (0)	20 (5)
Nokomis	413	110 (27)	303 (73)	183 (44)		89 (22)	47 (37)
Peoria West	127	2 (1)	126 (99)	3 (2)	55 (43)	21 (17)	47 (37)
Pinckneyville	380	107 (28)	273 (72)	233 (61)		12 (3)	27 (7)
Princeville	112	2 (1)	110 (99)	30 (27)		59 (53)	22 (20)
Shawneetown	82	5 (6)	77 (94)	7 (8)		64 (78)	7 (8)
Springerton	302		302 (100)	257 (85)	27 (9)	12 (4)	5 (2)
Tallula	46		46 (100)	0 (0)	12 (26)	24 (52)	10 (22)
Villa Grove	86		86 (100)	6 (7)	13 (15)	63 (73)	5 (5)
All combined	4,097	507 (12)	3,589 (88)	1,830 (45)	147 (6)	1,127 (28)	385 (9)

[1]Numbers in parentheses are percent of original resources.

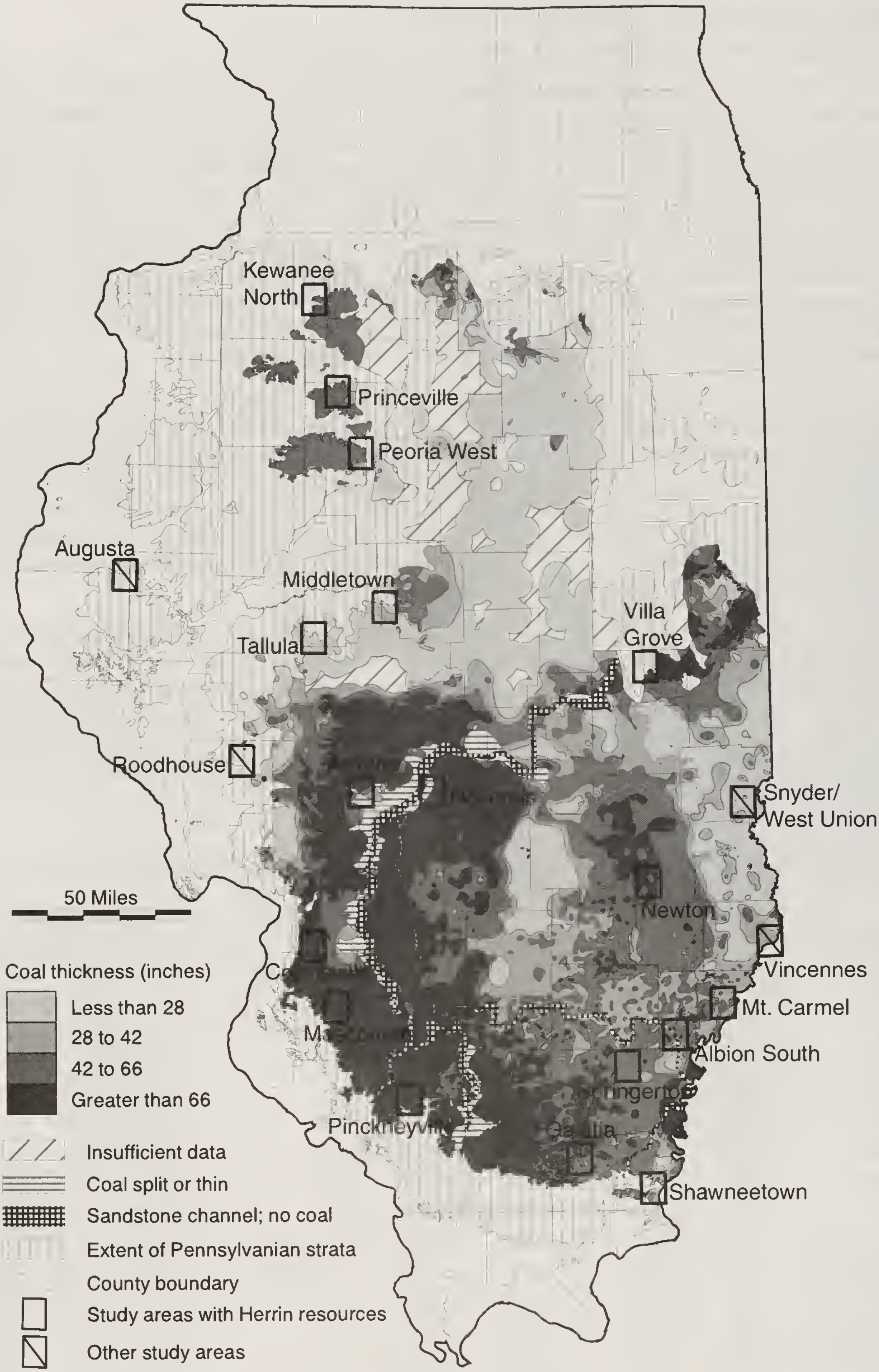


Figure 10 Quadrangle study areas used to identify criteria for coal available for mining.

Most factors used in this assessment could apply to any coal seam in Illinois. However, the specifics of certain criteria vary from seam to seam. For example, the minimum thickness of bedrock for underground mining of the Springfield Coal differs from that of the Herrin Coal because of the different competencies and lithologies of rock units overlying the two seams.

The restrictions are organized according to the relevant mining methods (surface or underground mining) as currently practiced in Illinois. Because surface mining can be used to mine coal lying as deep as 200 feet and underground mining can be used to extract coal lying as shallow as about 40 feet (if there is sufficient bedrock), resources that are 40 to 200 feet deep were evaluated for their availability for both surface and underground mining.

This study does not consider the availability of coal that could be mined using an auger or highwall miner. These techniques, which allow additional tonnages of coal to be recovered from the final cut of a

Table 3a Criteria used to define the Herrin Coal available for surface mining in this study and previous quadrangle studies.

Surface mining	Statewide study	Quadrangle studies
Technological restrictions		
Minimum seam thickness	18 inches	12 inches
Maximum depth	200 feet	200 feet
Maximum unconsolidated overburden	60 feet	various[1]
Stripping ratio[2]		
Maximum	25:1	25:1
Maximum average	20:1	20:1
Minimum size of mine reserve (clean coal)		
Cumulative tonnage needed to support a mine and preparation plant	10 million tons	various
Individual block size (thousands of tons)		
Less than 50 feet of overburden[3]	150	various
More than 50 feet of overburden[3]	500	various
Land-use restrictions (width of unminable coal around feature)		
Cemeteries	not used	100 feet
State parks and preserves	100 feet	100 feet
Railroads	100 feet	100 feet
Federal and state highways	100 feet	100 feet
Other paved roads (Peoria West only)	not used	100 feet
Major airports	100 feet	100 feet
High voltage transmission towers	not used	100 feet
Pipelines	100 feet	100 feet
Underground mines	200 feet	200 feet
Subdivisions	not used	500 feet
Towns	0.5 miles	0.5 miles
Available with potential restrictions		
Only if surface mined in combination with overlying or underlying seam	not identified	identified
Potential land-use conflicts		
All otherwise available surface minable coal in areas where land-use patterns are incompatible with mining	identified	identified

[1]Quadrangle studies used a sliding scale based on depth of coal.

[2]Cubic yards of overburden/ton of raw coal; volumes and weight not adjusted for swell factors or cleaning losses.

[3]Quadrangle studies used categories of less than 40 feet and more than 40 feet of overburden.

Table 3b Criteria used to define the Herrin Coal available for underground mining in this study and previous quadrangle studies.

Underground mining	Statewide study	Quadrangle studies
Technological restrictions		
Minimum seam thickness	42 inches	42 inches
Minimum bedrock cover	variable	40 feet
Minimum ratio of bedrock to unconsolidated overburden	1:1	not used
Floodplains[1]	. . .	. . .
Minimum interburden between minable seams	40 feet	40 feet
Minimum size of mining block (clean coal)	40 million tons	20 to 40 million tons
Faults (width of zone of no mining)		
Cottage Grove Fault System		
Master fault	500 to 1000 feet	variable
Subsidiary faults	100 feet	none
Rend Lake Fault System	200 feet	
Centralia Fault	300 feet	
Wabash Valley Fault System	800 feet	1,000 feet
Walshville Channel: no mining within	0.5 miles	0.5 miles
Anvil Rock Channel: no mining within	1,800 feet	1,800 feet
Energy Shale: no mining within	transition zone	transition zone
Anvil Rock Sandstone within 5 feet of coal	identified	identified
Partings:		
Minimum yield	not used	65% clean coal
Maximum thickness[2]	. . .	. . .
Land-use restrictions (width of unminable coal around feature)		
Surface and underground mines	200 feet	200 feet
Towns	0 feet	various
Subdivisions	not used	various
Churches and schools	not used	100 feet
Cemeteries	not used	100 feet
High-voltage transmission towers	not used	100 feet
Interstate highways	100 feet	100 feet
Major airports	100 feet	100 feet
Dams	100 feet	100 feet
Closely spaced oil wells	>7 wells per 40 acres	not used
Available with potential restrictions		
Closely spaced oil wells	4–7 wells per 40 acres	>4 wells per 20 acres
Potential land-use conflicts		
All otherwise available underground minable coal with areas where land-use patterns are incompatible with mining	identified	identified
Coal quality limitations	none	resources with chlorine contents >0.4%
Bedrock cover	>minimum but <100 feet	not used

[1]In the quadrangle studies, the tonnage of available coal within floodplains was reduced by 20%. In this statewide assessment, floodplains are considered a restriction only if bedrock is less than 100 feet thick.

[2]Areas where partings are likely to be too thick for mining were identified. Data were generally insufficient to isopach parting thickness.

surface mine, have been used on a limited basis in Illinois. In many cases this coal will be minable by underground methods. Most of the factors that restrict underground mining, with the exception of seam thickness, will also restrict auger or highwall mining. The amount of additional tonnage that is recoverable by these methods is probably not significant.

Surface-Minable Coal

Depth of Seam Although open-pit mining methods can remove hundreds of feet of overburden, surface mining of coal as practiced in Illinois currently has an economic limit of about 200 feet or less. Depending on their thickness, coals less than 200 feet deep can be mined by either surface methods or underground methods (provided there is sufficient bedrock cover). The selection of surface or underground methods depends on the comparative cost of extraction and the overall character of a company's reserves at a specific site. For example, if a company's reserve block is primarily deeper than 150 feet, or if the company does not own the rights to the land surface, it may elect to mine all of the coal by underground methods. Coals may be unavailable for surface mining because of their stripping ratio, a function of depth and thickness. Stripping ratio is discussed separately.

Thickness of Seam For this statewide assessment, the minimum thickness of coal for surface mining is 18 inches. In the quadrangle studies, a minimum thickness of 12 inches was used for the lowermost seam in an interval to be mined and 6 inches for overlying seams within the interval. Seams thinner than 18 inches have been mined in Illinois in small areas under certain conditions. No extensive areas of Herrin Coal less than 18 inches thick have ever been mined in the state, and existing resource maps do not include any coal thinner than 18 inches. Thinner seams are more costly to recover because the amount of out-of-seam dilution is a greater percentage of the material handled. Resources less than 18 inches thick could not be mapped within the time and budget constraints of this project, but the amount of unmapped resources is likely insignificant.

Stripping Ratio Stripping ratio is the number of cubic yards of overburden that must be removed to recover each ton of coal. Whereas the thickness and depth of coal that can be economically mined are controlled in part by technical factors such as mining equipment, the maximum stripping ratio is strictly an economic limit. Coals with high stripping ratios may be more economical to mine by underground methods or may remain unmined until the market price for coal increases relative to production costs.

Companies calculate stripping ratios on the basis of the anticipated tonnage of clean coal that will be produced. This calculation requires assumptions about the type and performance of mining and washing equipment to be used, as well as tests of the washability of the coal. For this study, the stripping ratios were calculated with the tonnage of in-place coal, excluding partings. In-place tonnage is 5% to 15% higher than the actual tonnage of clean coal after mining and cleaning losses.

Some companies use a "swell factor" to account for the increase in volume of overburden after it is blasted. Swell factors for lithologies typically encountered in Illinois mines range from 1 (no swell) for sand to 1.7 for shale (Allsman and Yopes 1973). Use of swell factors requires detailed site-specific knowledge about the quantities of different lithologies in the overburden (e.g., shale, limestone, sand, and clay), and we did not use them in our calculations. Cubic yards of overburden were calculated simply from the total thickness of consolidated and unconsolidated material overlying the coal.

For this study, the maximum stripping ratio adopted for available coal was 25 cubic yards of overburden per ton of in-place coal (25:1). The maximum average stripping ratio for any mining block was 20:1. Assuming a 10% loss of coal in mining and cleaning and an average overburden swell factor of 1.3, these ratios are equivalent to 36:1 and 29:1, respectively. These ratios are slightly higher than the limits currently used by companies actively involved in surface mining in Illinois. High stripping ratios are a factor mostly in the northern half of the state (fig. 11). Because the coal is relatively thick in the southern half of the state, overall depth, rather than stripping ratio, is a limiting factor.

Thickness of Bedrock and Unconsolidated Overburden Thick deposits of glacial drift or alluvial sediment can restrict surface mining because of their potential to slump into the pit, fail under the weight of large draglines, and allow excessive groundwater flow into the pit (fig. 12). A minimum amount of bedrock overburden is needed to ensure that the coal is not weathered and to provide stable material to hold the toe of the spoil pile. The maximum thickness of unconsolidated material that can be handled is

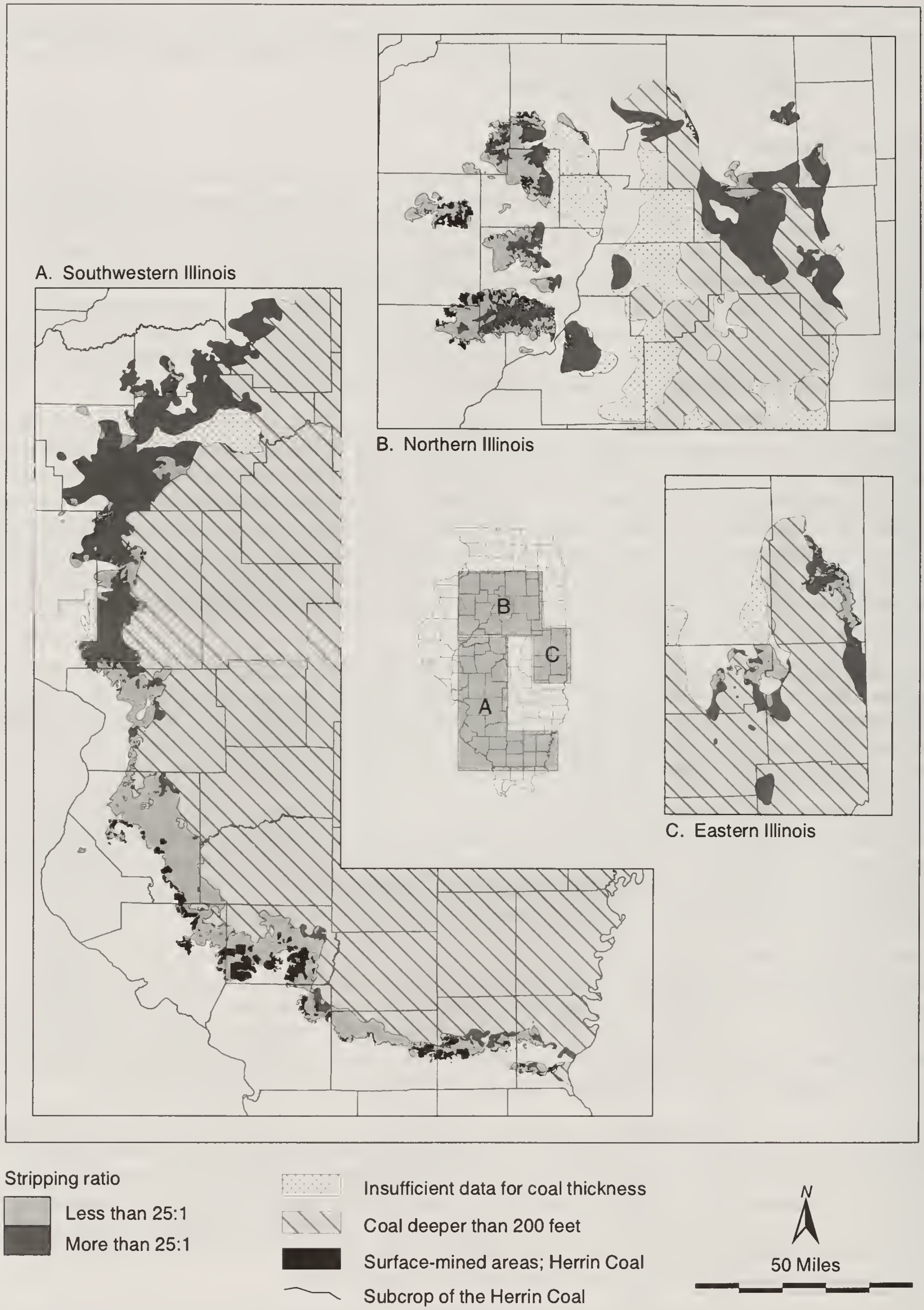


Figure 11 Stripping ratio of the Herrin Coal.

dependent on the lithology of the overburden, its physical properties (e.g., load-bearing capacity, permeability), and the presence or absence of groundwater. The minimum bedrock and maximum glacial drift thicknesses that were handled by the companies we interviewed also depended on the mining plan and the type of equipment they were using to remove overburden.

We did not compile sufficient information to assess the lithology and physical properties of the unconsolidated sediments in the quadrangles studied. The experience of the companies suggests that for an overburden thickness of 50 feet or less, a minimum of 10 feet of bedrock cover is needed. For overburden between 50 feet and 100 feet thick, one-third to one-half the material should be bedrock. The maximum thickness of unconsolidated overburden that can be handled over a large mining area is approximately 60 feet. Small areas of thicker unconsolidated overburden can be mined, but large areas of thick unconsolidated overburden generally will be avoided.

Because of the resolution of the bedrock cover and drift thickness maps used in this study, the only criterion we used for surface mining was a maximum of 60 feet of unconsolidated overburden. Thick, unconsolidated sediments limit surface mining in much of the state except for the southwestern and southern areas of the coal field (fig. 13).

Size and Configuration of Mining Block A mine reserve must contain sufficient tonnage to allow a company to recover the costs of developing a mine (e.g., exploratory drilling, land acquisition, equipment purchase, and construction of surface facilities and initial box cuts or shafts). Because of their lower development costs, greater equipment mobility, and flexibility in operating plans, surface mines can be developed with smaller reserves and mining blocks than can underground mines. Small surface mines can be developed using trucks and earth-moving equipment that can be readily transported to the site.

Most Illinois coals are cleaned to some degree before final shipment. The coal can be trucked from the mine pit over the existing road network to a central preparation plant. Companies currently consider the minimum recoverable tonnage for a surface mine to be 10 million saleable tons. For this study we assumed an 85% recovery rate, which makes the minimum tonnage equivalent to about 12 million tons of raw coal in place. The tonnage may be distributed among a number of adjacent blocks. Each mining block should contain at least 150 thousand tons of saleable coal (approximately 175 thousand tons of raw coal) if the coal is less than 50 feet deep or 500 thousand tons (590 thousand tons of raw coal) if the coal is greater than 50 feet deep. For a 48-inch thick coal, these minimum blocks would be about 25 acres and 80 acres, respectively.

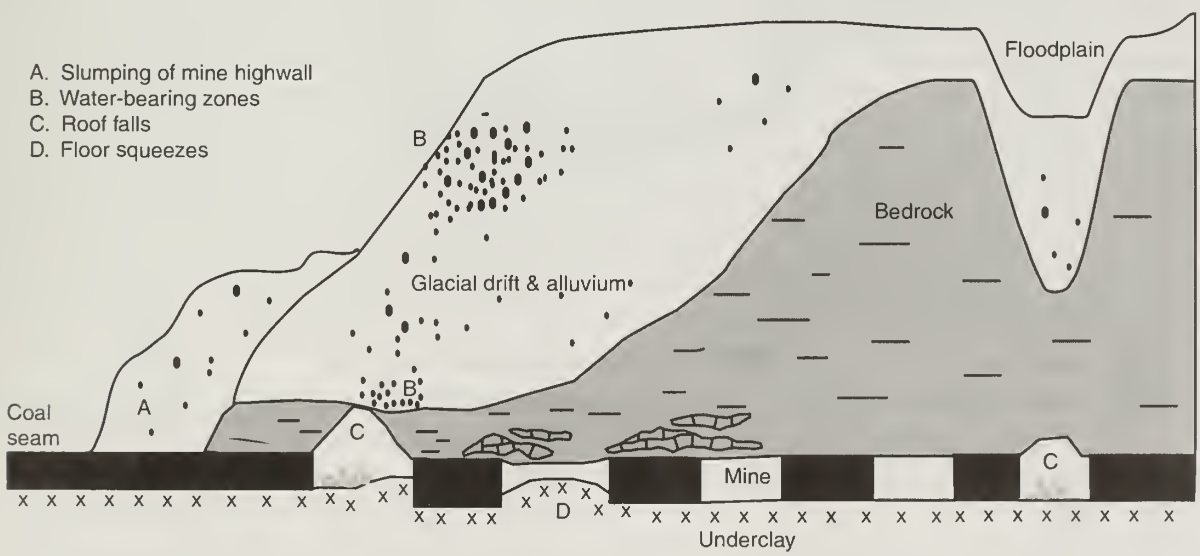


Figure 12 Problems encountered in surface and underground mines that have overburden consisting of thick unconsolidated sediments over thin bedrock (modified from Treworgy et al. 1998).

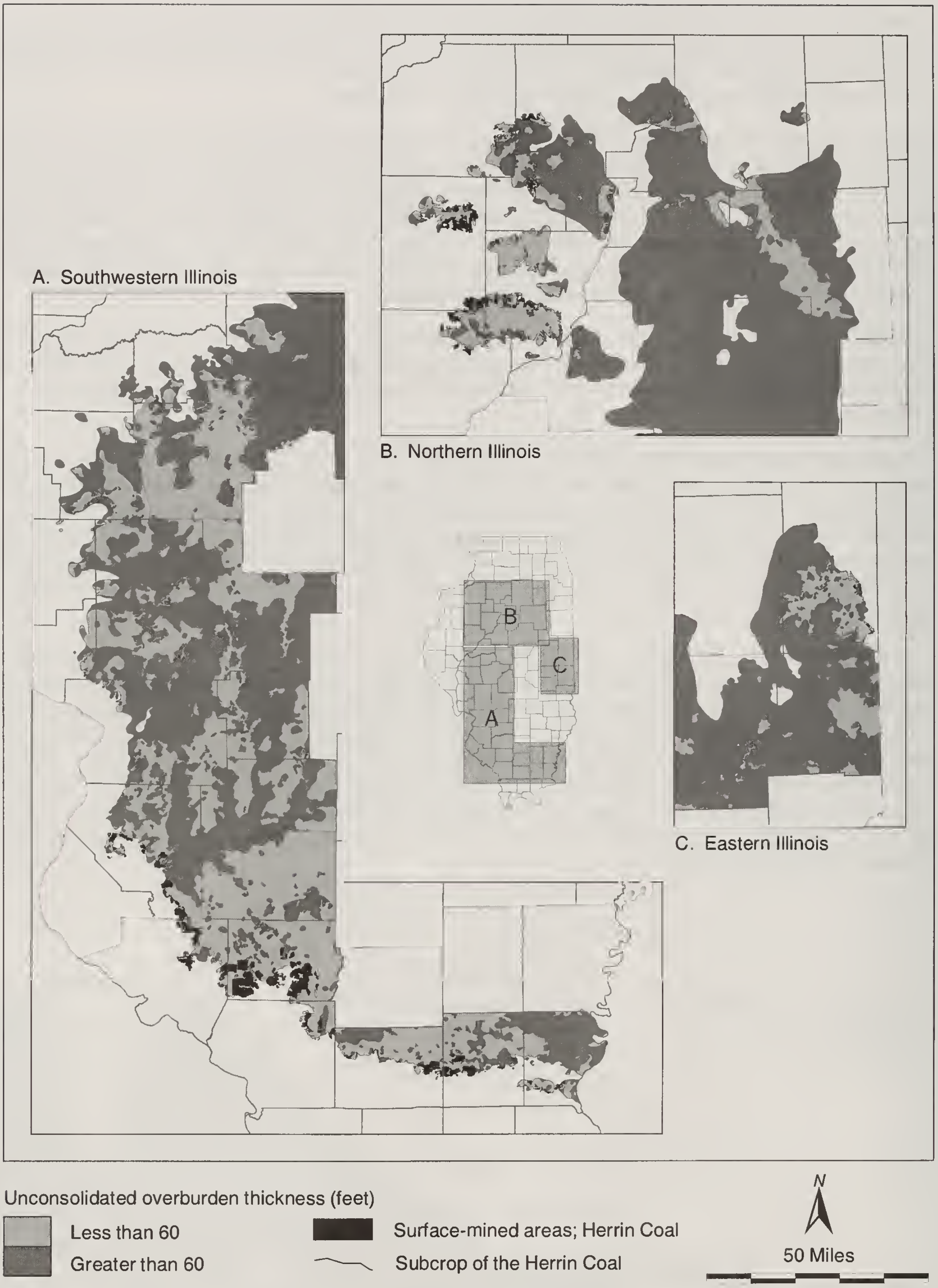


Figure 13 Thickness of unconsolidated overburden in counties with surface-minable resources of the Herrin Coal.

In this study, very few mining blocks were eliminated because they did not have the minimum tonnage to support surface mining. More commonly, blocks were considered unavailable because their geometry was unsuitable for mining. For example, narrow strips of land between roads and railroads; narrow, sinuous stream valleys; and irregularly shaped areas between abandoned mines are commonly unsuitable for mining.

Land Use Although almost any land use or surface feature can be undermined or mined through if a company obtains permission from the owner and agrees to repair damages, companies generally find it impractical to mine under or through certain features because of the expense of restoring the feature or the social and political hurdles required to obtain the necessary permission. A buffer of unmined coal must be left around any property or surface feature that the company does not own and is not permitted to disturb. State law requires that surface mines leave a 300-foot buffer around churches, schools, and other occupied dwellings. In practice, mining companies may purchase a few individual structures if doing so frees up a sufficient tonnage of resources for mining. A large buffer, although not required by law, is commonly left around towns because of the potential for disturbance by dust, vibrations from blasting, and disruption of water wells.

Our quadrangle studies considered all coal under towns, rural subdivisions, railroads, airports, high-voltage transmission towers, schools, churches, and cemeteries as unavailable for surface mining. For this statewide assessment, it was impractical to map small features such as transmission towers, rural subdivisions, schools, churches, and cemeteries. Since these features typically affected less than 1% of the resources in the quadrangles studied, their omission should not materially affect the results of this statewide assessment. In this assessment, we considered coal within a half mile of towns (as defined by their municipal boundaries) to be restricted from surface mining (fig. 14).

Roads can be a significant barrier to surface mining. Because of local opposition to mining and the relatively small value of the coal beneath roads (because of seam thickness), most paved roads in the western and northwestern parts of the state are considered a restriction to surface mining. In southern Illinois, the general acceptance of surface mining by the local population and the higher tonnage of coal per acre make it feasible for companies to surface mine through lightly used roads. For this statewide assessment, we considered state and federal highways to be restrictions to surface mining (fig. 15). An additional 1% to 2% of resources is probably restricted by other paved roads in the western part of the state. Other land-use features that restrict surface mining are railroads, pipelines, and public lands (figs. 16, 17, and 18). Although there have been situations where mining companies have arranged to move or mine through these features, commonly they are left unmined.

Abandoned Mine Workings Illinois law requires that surface mines have an unmined barrier of coal 500 feet wide around active or abandoned underground mine workings. This requirement may be waived under certain conditions, and surface mines have in many instances mined through all or portions of small abandoned underground mines. This may be done because the extent of the underground workings is not known or the area of the underground workings is so small that it is not worth the expense of diverting the surface operation around it. In most cases, these mines are less than about 4 acres in size. Larger underground mines are avoided by surface mining because the amount of recoverable coal is significantly reduced and there is a potential for large quantities of water to be present in the abandoned mine. Although in our quadrangle studies we assumed that surface mines would obtain waivers to mine through small abandoned underground mines, it was not practical to differentiate between small and large underground mines in this study. Instead, for this statewide assessment, we assumed that surface mines would be permitted to mine through any mine in an overlying seam and to mine within 200 feet of underground mines.

Surface Mining of Multiple Seams In a number of our quadrangle assessments we found that additional Herrin Coal was available for surface mining if mined in combination with the overlying Danville Coal or underlying Springfield Coal. In these cases, the additional tonnage of the underlying or overlying coals reduces the overall stripping ratio to less than 25:1.

Opportunities for multiseam mining were not evaluated in this statewide assessment of the Herrin Coal. Multiseam mining probably could increase the tonnage of available coal in parts of northwestern Illinois by a few percent, but the potential for multiseam surface mining in west-central and southwestern Illinois is

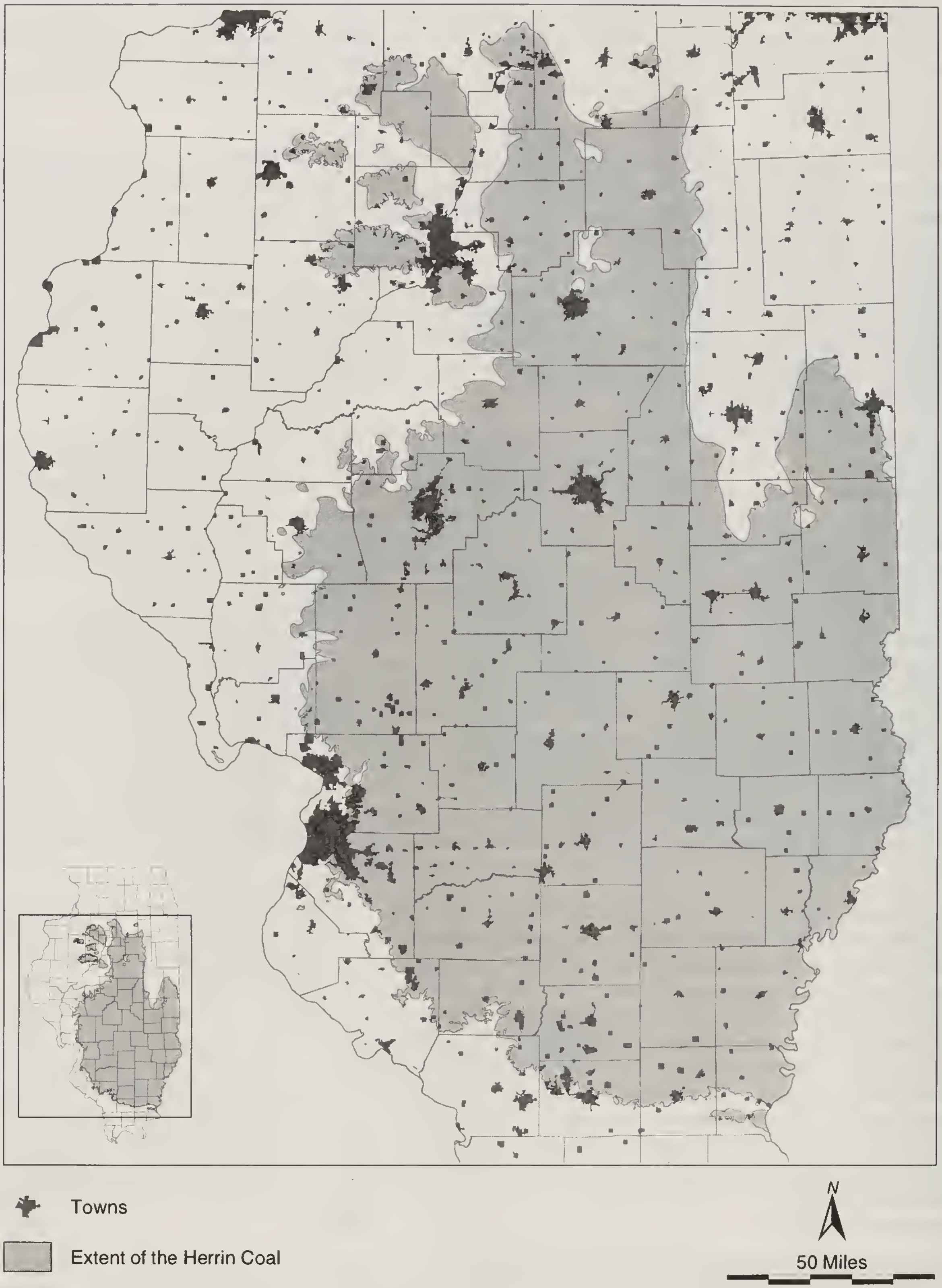


Figure 14 Towns in the vicinity of the Herrin Coal.

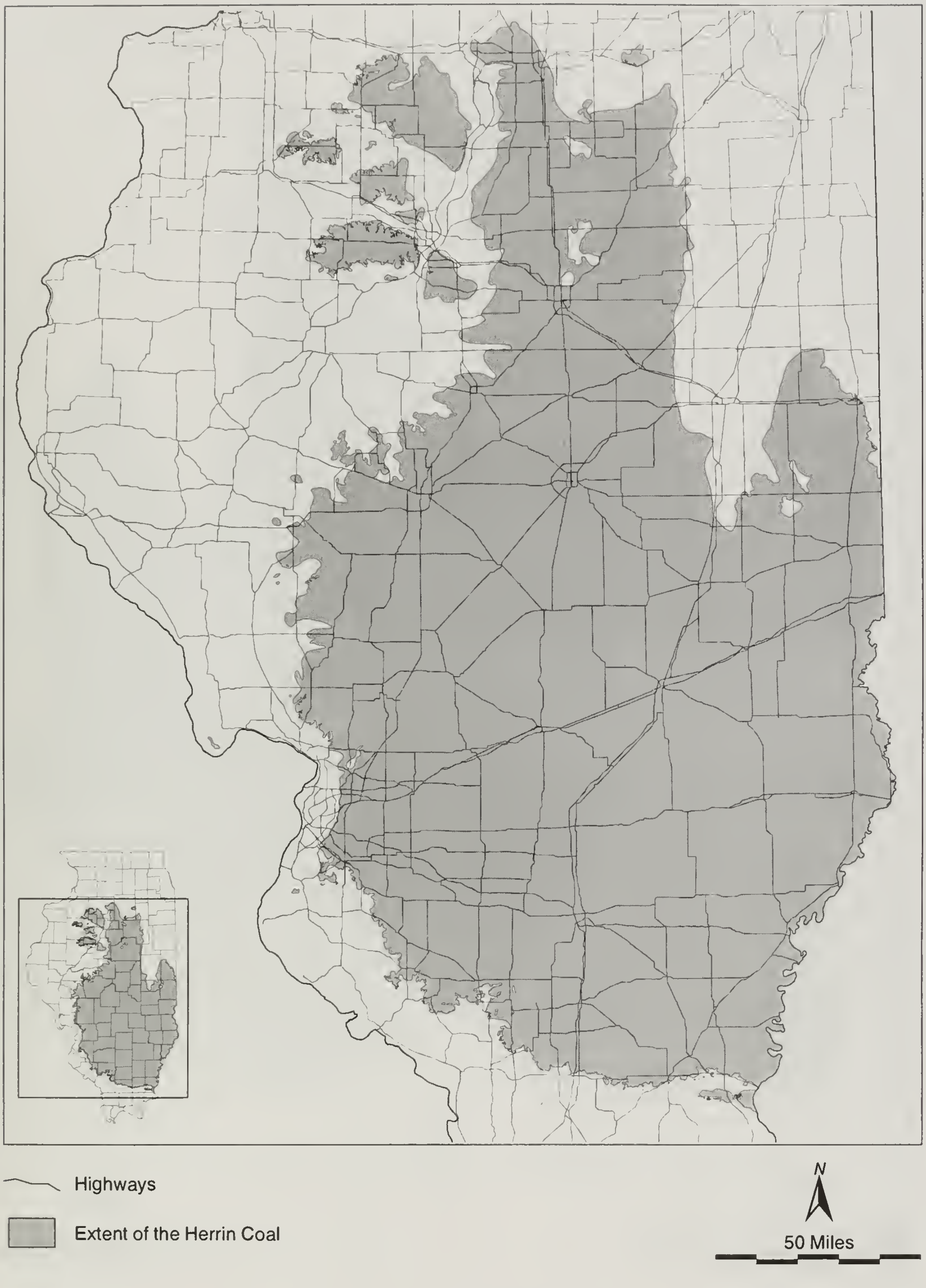


Figure 15 State and federal highways in the vicinity of the Herrin Coal.

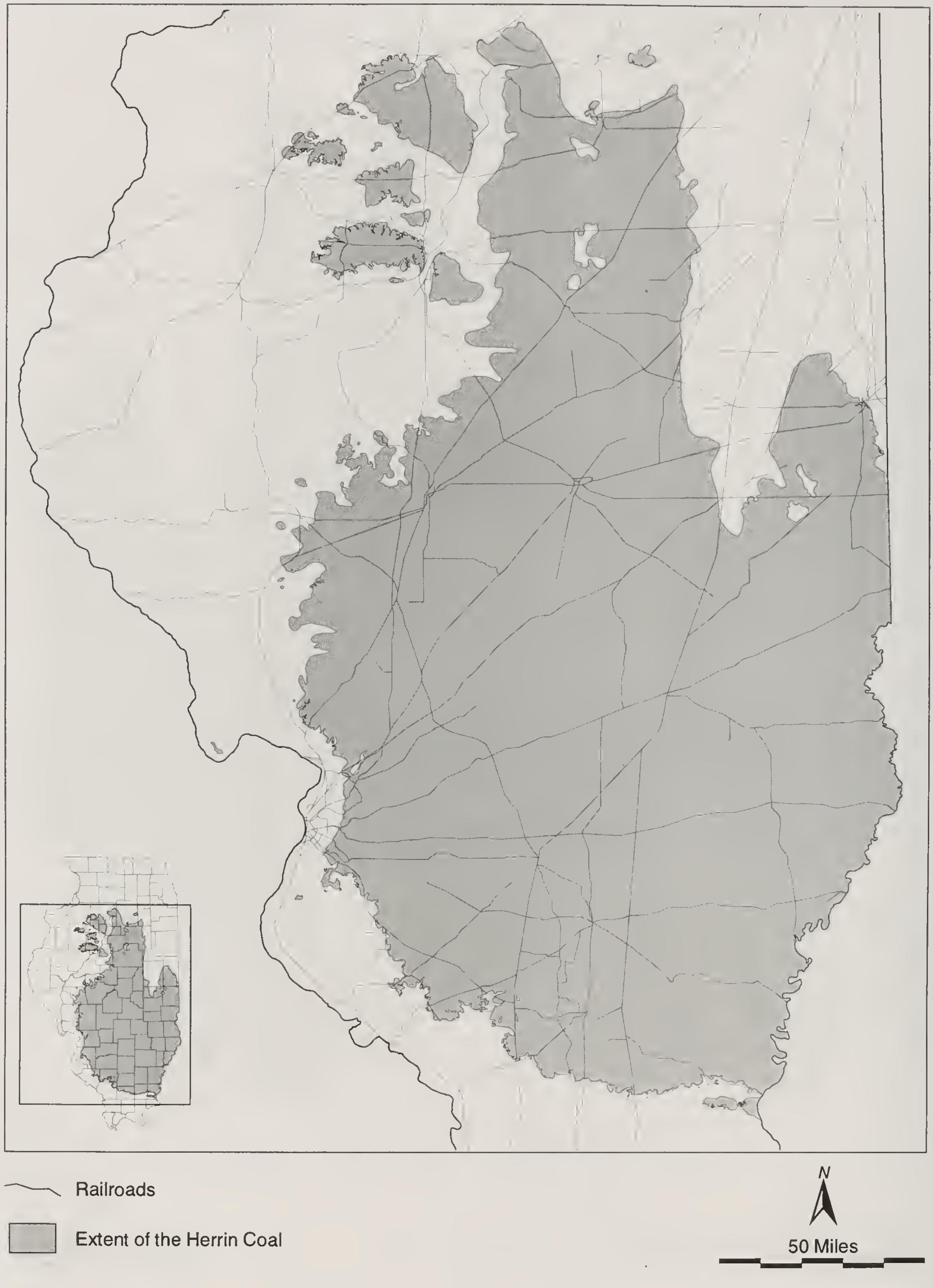


Figure 16 Railroads in the vicinity of the Herrin Coal.

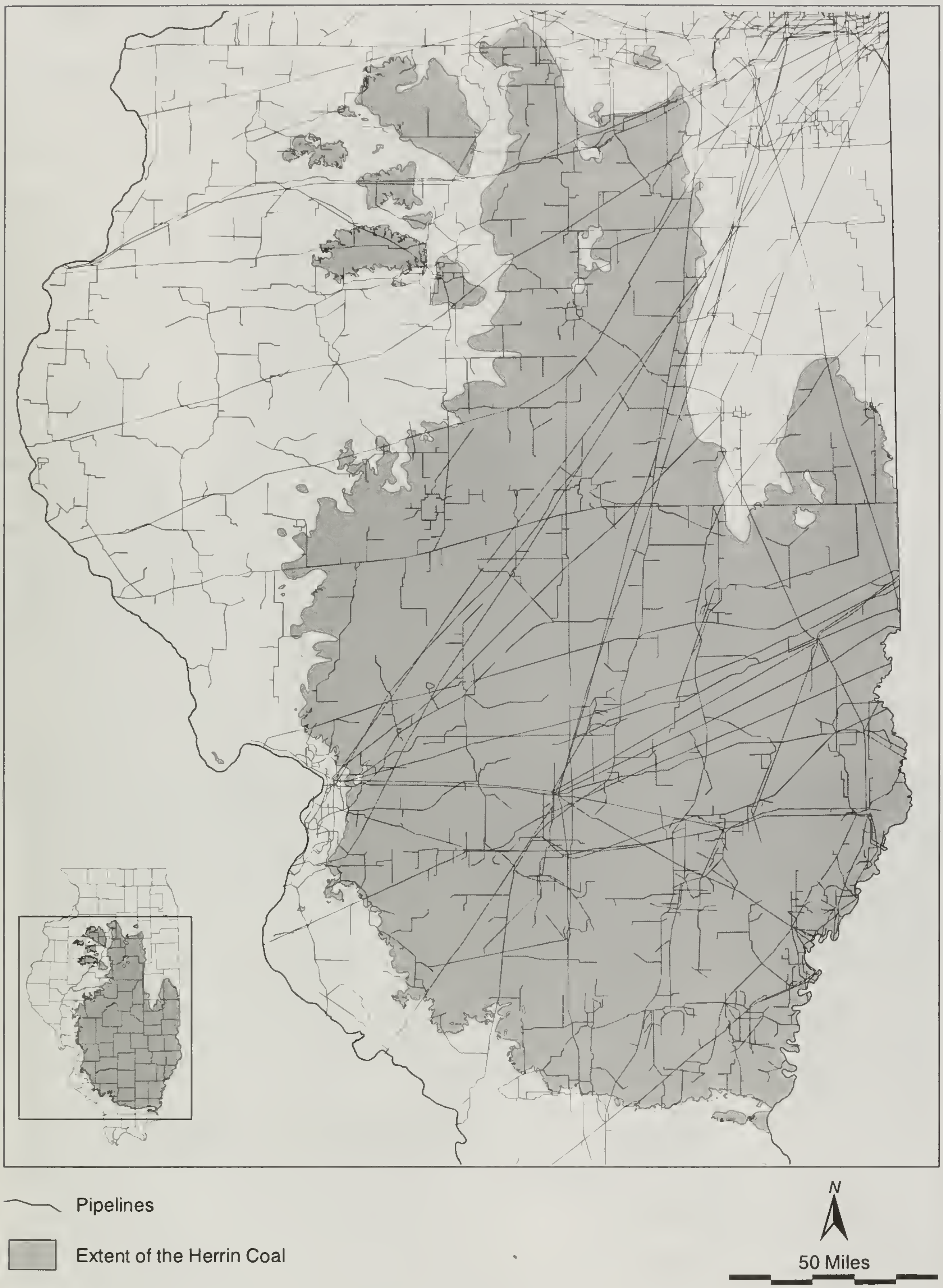


Figure 17 Pipelines in the vicinity of the Herrin Coal.

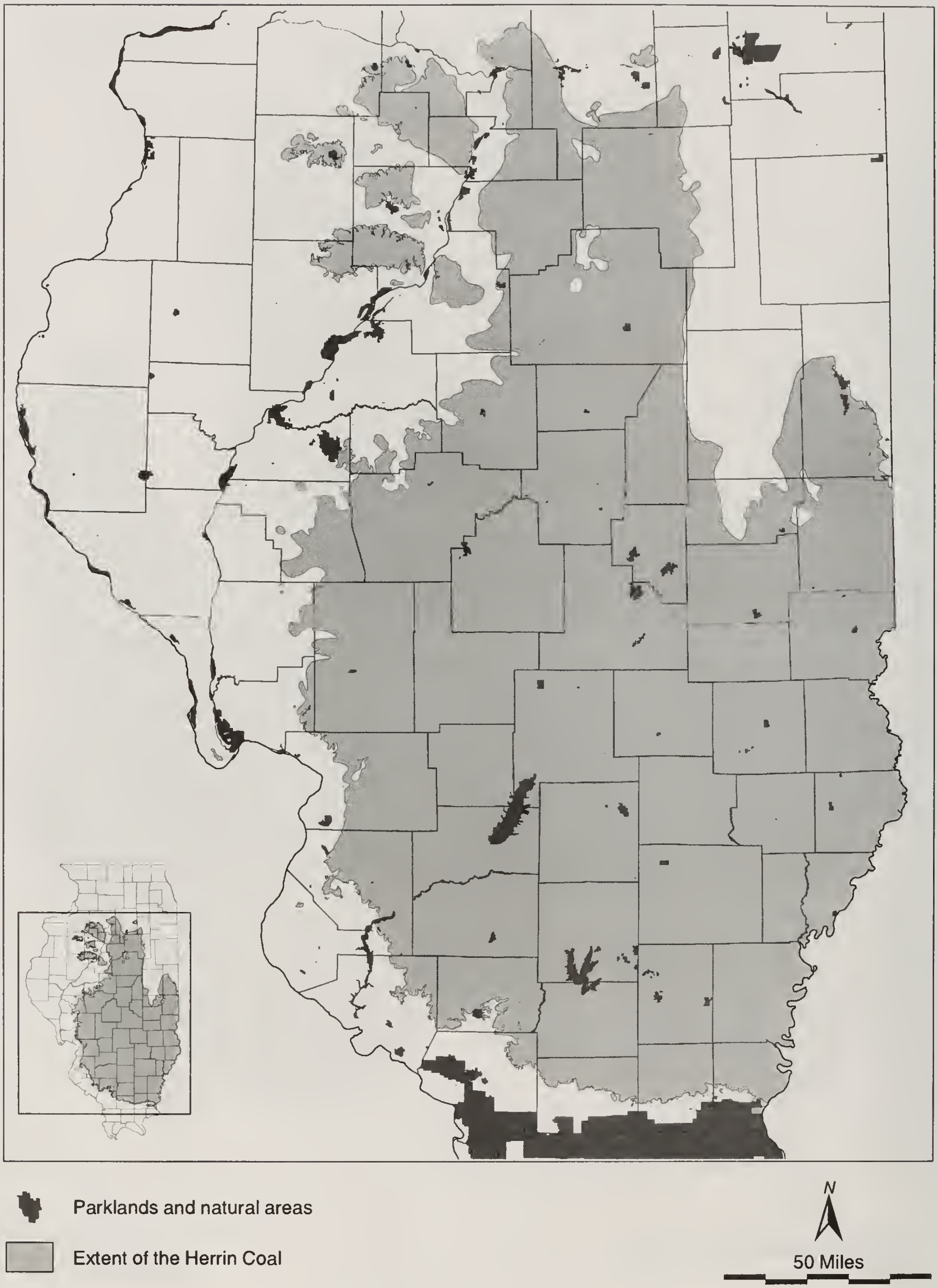


Figure 18 Parks and natural areas in the vicinity of the Herrin Coal.

limited. Also, the recent trend in southern Illinois is to mine the Herrin Coal underground, even where it is at a depth that would allow it to be surface mined in combination with the Springfield Coal.

Underground Minable Coal

Depth of Seam The Herrin Coal has a maximum depth in Illinois of about 1,300 feet (fig. 3). This depth is not by itself a technological restriction on mining in the state and was not used as a restriction in this study. Herrin Coal as deep as 1,000 feet is currently being mined.

Thickness of Seam For this study, 42 inches was the minimum thickness of coal considered available for underground mining. Mining thinner seams, although technologically possible and practiced in some mines in the Appalachian region, is considered for the most part to be economically unfeasible in Illinois. Because of the thick glacial cover in Illinois and the paucity of outcrops, most underground mines in the state must be developed from a slope or shaft rather than directly from an outcrop as is done in the Appalachians. The large initial capital investment required to sink a shaft or slope, combined with the higher operating costs associated with thin seams (movement of miners and equipment is more difficult, normal out-of-seam dilution from the roof and floor becomes a larger percentage of the material handled, and the tonnage produced per mining cycle is reduced), make mining of thin seams uneconomical at this time. A possible exception to this would be a small drift mine developed from an existing surface mine highwall. Given the limited amount of remaining surface-minable resources, the amount of additional coal available under such scenarios is not large.

Thickness of Bedrock and Unconsolidated Overburden Underground mining requires adequate bedrock overburden to support the mine roof and seal the mine against water seeping down from the surface (fig. 12). If the bedrock cover is incompetent and too thin (or is significantly weathered), the mine roof may not be strong enough to support the overburden. Weak underclay, which can block mine entries and make the roof unstable by squeezing out from under pillars, is commonly associated with areas where less than half of the overburden is bedrock (fig. 19).

In addition to the dangers and expense of roof failures and floor squeezes, fractures resulting from mine roof failure may extend to the bedrock surface where bedrock cover is very thin and allow water to enter

Figure 19 Floor squeeze in an underground mine in the Herrin Coal, Zeigler No. 5 Mine, Douglas County (Coal Section files, ISGS).

the mine if water-bearing units are present. At best, water seepage makes the movement of equipment more difficult and creates the additional expenses of pumping and disposing of the water. In the worst case, when the influx of water is rapid, equipment may be damaged, and the lives of miners may be threatened. In 1883, 69 miners drowned in the Diamond Mine near Braidwood (Illinois Department of Mines and Minerals 1954). Other less serious cases of mine flooding have occurred over the years (Dan Barkley, Illinois Office of Mines and Minerals, personal communication).

The amount of bedrock required for safe underground mining depends on local geologic conditions such as the depth of the seam, composition of the bedrock overburden, and thickness of the unconsolidated glacial overburden (drift). Bauer (1987) showed strength of bedrock is reduced below valleys.

The minimum thickness of bedrock cover needed for underground mining was estimated for this study based on interviews with mining experts and comparisons of maps of mines to the thickness and composition of overburden. Although some mines have operated under extremely thin bedrock, the minimum thickness required was judged to be that amount that best fits the observed limit of extraction of the majority of mines. The minimum bedrock thickness needed can also be influenced by non-geologic factors such as the size of rooms and the type and pattern of roof-bolting. Mine-dependent factors such as these probably account for cases where individual mines have had poorer or better conditions than would be expected based on our geologic criteria.

Based on our interviews and observations, three geologic factors appear to be important in determining the areas of Herrin Coal that may have difficult mining conditions caused by thin bedrock conditions: lithologic composition of the strata, ratio of bedrock cover thickness to drift cover thickness, and the presence of bedrock valleys. The limits used in this study for these criteria are listed in table 4. Rock strength tests along with various mine design parameters (e.g., pillar and room size) are needed to determine the minimum thickness bedrock needed for safe mining in specific areas.

The area where the Herrin Coal is present was divided into three zones based on the lithology and apparent competency of the strata making up the immediate roof sequence (fig. 20). Zone 1 includes areas where there generally are 5 feet or more of limestone in the first 40 feet of strata immediately above the coal. These limestone units are the Brereton, Conant, Bankston Fork, and Piasa Limestones (fig. 21). In some parts of zone 1, the cumulative thickness of these limestones may exceed 20 feet. Zone 2 includes areas where the immediate strata above the coal generally contain less than 5 feet of limestone. Zone 3 covers areas where the Herrin Coal is overlain by a thick sequence of shale and interlaminated shale and siltstone under which mines have encountered weak roof conditions. The minimum thickness of bedrock needed for the coal to be available for mining was approximately 40 feet in zones 1 and 2 and 75 feet in zone 3. Areas in all zones underlying valleys in the bedrock surface needed at least 100 feet of bedrock cover. The minimum bedrock thickness to unconsolidated thickness ratio was 0.5:1 in Zone 1 and 1:1 in Zones 2 and 3 to be available for mining. All zones underlying valleys needed at least a 1:1 bedrock/drift ratio.

To identify areas where bedrock may be weakened because of the effect of valleys, we used the boundaries of 100-year floodplains. Although there are cases in Illinois where buried bedrock valleys have no correspondence to surface drainage, the use of floodplains instead of actual valleys is not believed to have materially affected the results of this study.

Areas of thin bedrock overburden are found all along the crop of the Herrin Coal, but are most restrictive to underground mining where they coincide with thick resources of Herrin Coal in southwestern Illinois (fig. 22).

Table 4 Minimum bedrock overburden (feet) and minimum bedrock thickness to drift thickness ratio for underground mining of the Herrin Coal.

Zone	Minimum bedrock	Minimum bedrock below valleys	Minimum bedrock/ drift ratio	Minimum bedrock/drift ratio below valleys
1	40	100	0.5:1	1:1
2	40	100	1:1	1:1
3	75	100	1:1	1:1

For areas farther from the outcrop with excessively thick unconsolidated sediments (100 to 300 feet thick), mine experience suggests a minimum 1:1 ratio of bedrock to unconsolidated overburden thickness is needed to reduce the incidence of roof falls and floor squeezes. This observation is based on mining at depths of up to 350 feet (e.g., a minimum of 175 feet of bedrock is needed at these depths). Since there have been no attempts to mine resources deeper than 350 feet that have a bedrock to unconsolidated overburden ratio of less than 1:1, it is not known if this criterion is applicable or whether a certain minimum bedrock thickness may be a sufficient criterion.

Areas where the ratio of bedrock to unconsolidated overburden thickness is less than 1:1 are especially widespread in the northern part of the state because of the presence of deep bedrock valleys filled with unconsolidated sediment (fig. 23). The deepest resources in these areas have less than 300 feet of bedrock and more than 300 feet of unconsolidated overburden, but most resources restricted by this criterion have less than 200 feet of bedrock and more than 200 feet of unconsolidated overburden.

Thickness of Interburden Between Seams The interburden between two coal seams must contain competent strata of sufficient thickness so that the mining of one seam will not disrupt the stability of the roof or the floor of the other seam (Chekan et al. 1986). The minimum thickness of interburden required between two seams depends on several geotechnical variables, including the lithology of the interburden, the thickness and depth of the coals, and the method and sequence of mining the two seams (Hsiung and Peng 1987a,b). The mining experts interviewed commonly cited 40 feet as the mini-

Figure 20 Zones used to assign minimum thickness of bedrock overburden for underground mining of the Herrin Coal.

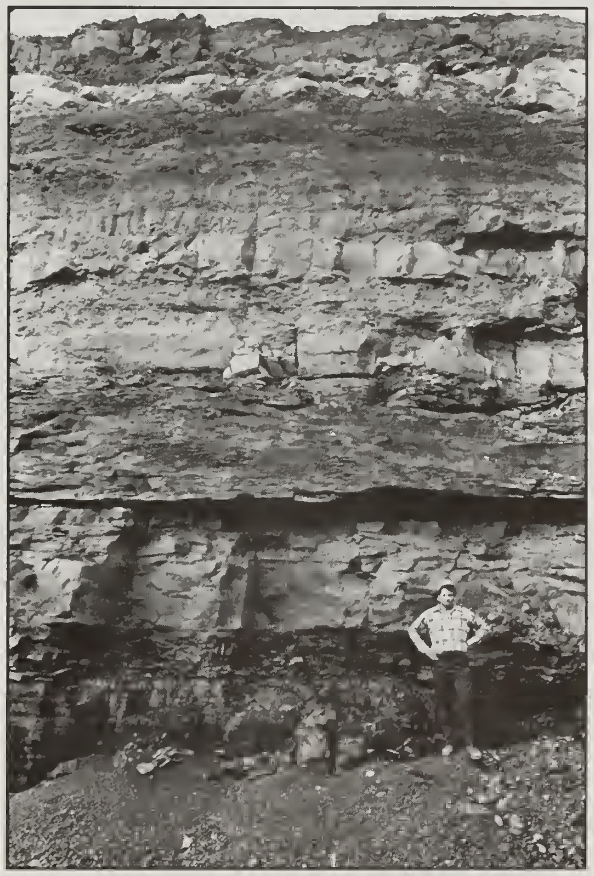


Figure 21 Thick limestone sequence above the Herrin Coal, River King Pit No. 3, St. Clair County (Coal Section files, ISGS).

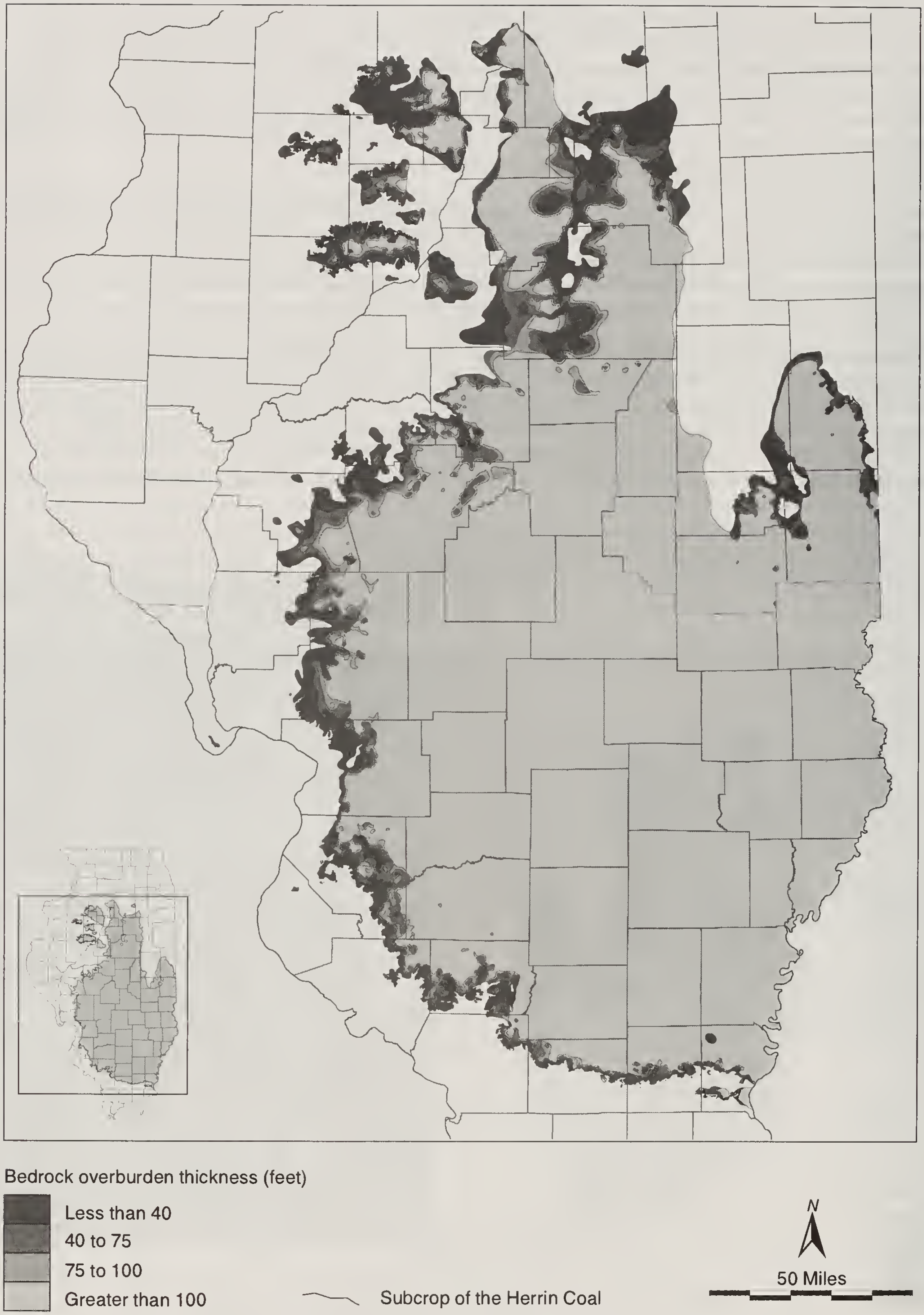
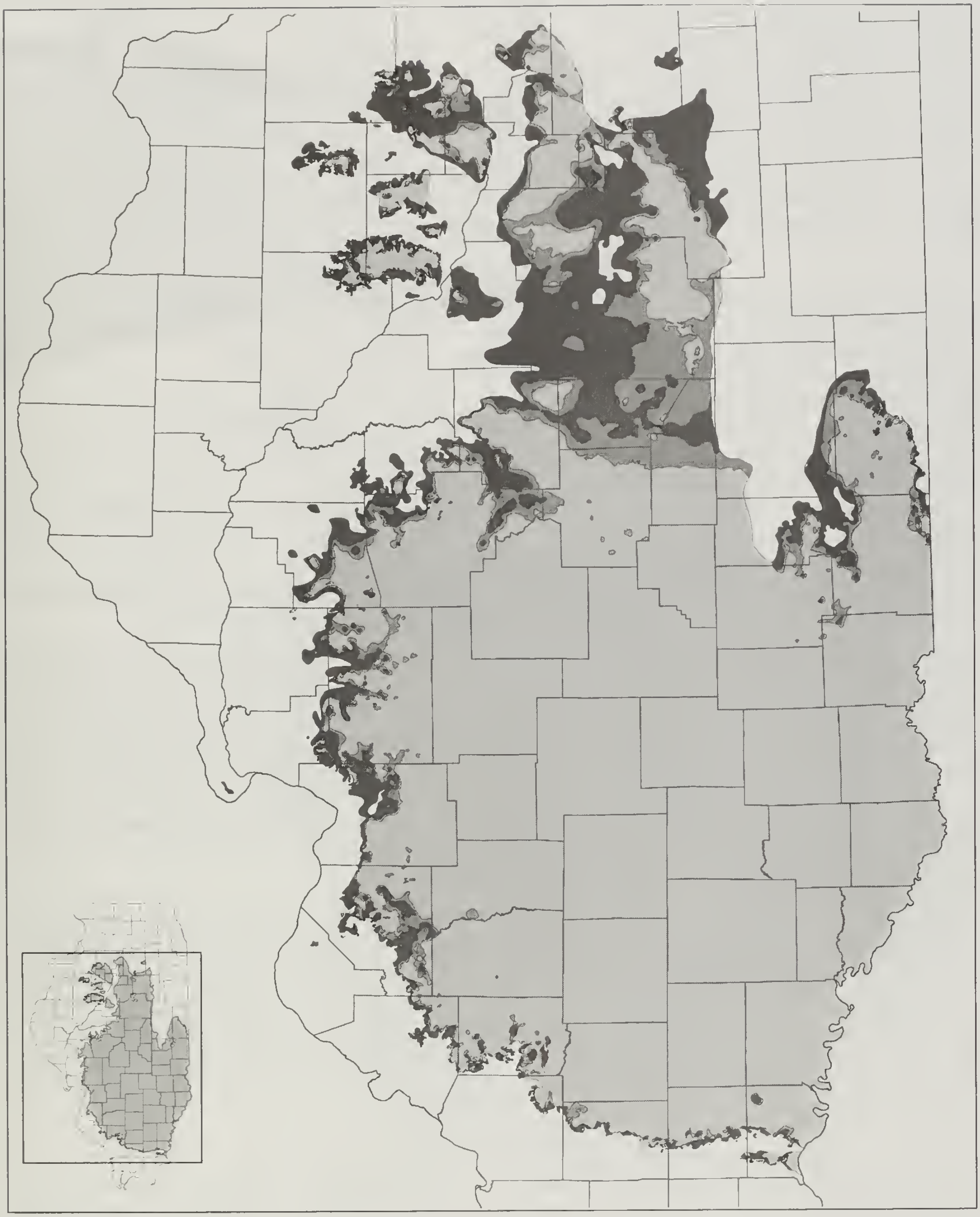


Figure 22 Thickness of bedrock overburden, Herrin Coal.



Ratio of bedrock to unconsolidated overburden

- Less than 0.5
- 0.5 to 1.0
- Greater than 1.0

Subcrop of the Herrin Coal

N

50 Miles

Figure 23 Ratio of the thickness of bedrock to unconsolidated overburden, Herrin Coal.

mum thickness of interburden. In cases where the interburden is less than 40 feet thick, only one of the seams may be mined (fig. 24). This will usually be the thicker of the two seams, but if either the upper or lower seam is already mined, the other seam is considered unminable.

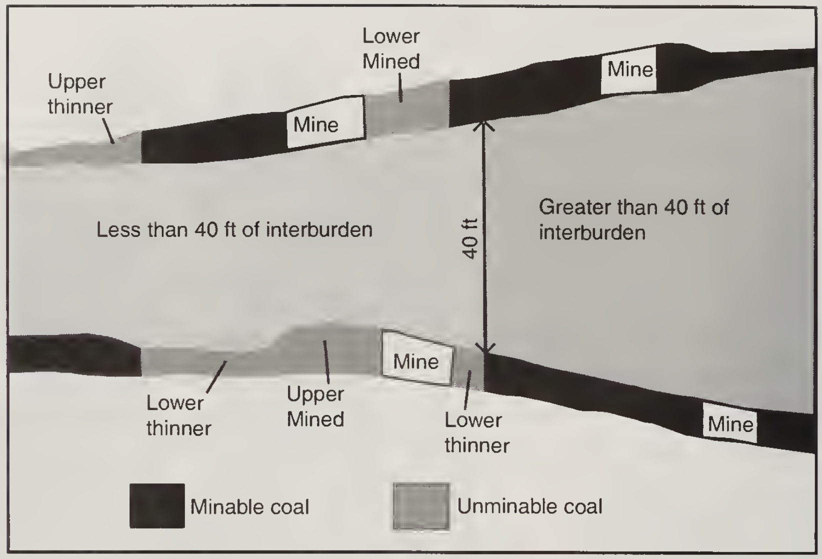


Figure 24 Effect of interburden thickness on the minability of coal seams.

Four coal seams are found within 40 feet of the Herrin Coal: the Jamestown and Danville Coals above and the Briar Hill and Springfield Coals below. Commonly, the Briar Hill Coal is thinner than the Herrin and therefore the Herrin will be the preferred seam for mining. The Danville, Jamestown, and Springfield Coals may be equal to or greater in thickness than the Herrin Coal, and the Danville or Springfield may have already been mined in areas where the two seams have less than 40 feet of interburden (fig. 25).

Faults Faults disrupt mining operations and increase mining costs by displacing the coal seam, weakening the mine roof, and creating paths for the flow of gas or water into the mine (Nelson 1981). Displacements of even a few feet are difficult or impossible for longwall equipment to negotiate. Larger displacements block all mine advancement and may require extensive tunneling through rock to reenter the coal bed on the opposite side. The amount of coal restricted from mining by faults depends on the characteristics of the specific fault. If a fault is a single sharp plane, mining can advance to it from either side, and little if any coal is lost. In other cases, strata may be broken and disrupted for some distance on either side of a fault and/or the fault zone may contain multiple, parallel faults that create a zone of disturbance hundreds of feet wide (figs. 26 and 27).

For example, mine operators in the Wabash Valley Fault System have encountered numerous minor faults, intense jointing, and substantial dips in the coal seam within a zone several hundred feet wide parallel to the main fault (Marvin Thompson and Alan Kern, personal communication). Some large inflows of water and some squeezing of the floor after mining were experienced in this area. Using careful advance planning and extra exploratory drilling, operators have mined across these zones (Koehl and Meier 1983). Mining within the fault zone is kept to a minimum because of the expense and delay of supporting the weakened mine roof and altering the mine plan to work through or around displaced blocks of coal (fig. 28).

In practice, mining operations routinely advance only to within 100 to 2,000 feet of the main fault trace. The major fault zones affecting the Herrin Coal are the Cottage Grove (Nelson and Krausse 1981), Centralia (Brownfield 1954), Dowell (Keys and Nelson 1980), Rend Lake (Keys and Nelson 1980), Shawneetown (Nelson and Lumm 1987), and Wabash Valley (Bristol and Treworgy 1979, Tanner et al. 1981, Ault 1997). For this report, maps of mine workings in the vicinity of each zone were examined. A buffer zone was constructed around the center of each fault zone or major fault trace to represent the approximate area that might be left unmined (fig. 29, table 5).

Igneous Dikes Vertical or near-vertical wall-like, linear masses of igneous rock are found in southeastern Illinois (Clegg and Bradbury 1956, Nelson 1983). The dikes, like the subsidiary faults of the Cottage Grove Fault System, generally trend in a northwest-southeast direction and may extend for a few hundred feet or several miles. Most of the dikes that have been mapped were encountered in mines in the Springfield Coal. We assumed that the dikes extend upward through the overlying Herrin Coal (an interval of about 100 feet). Although one 300-foot wide dike has been encountered, most dikes are

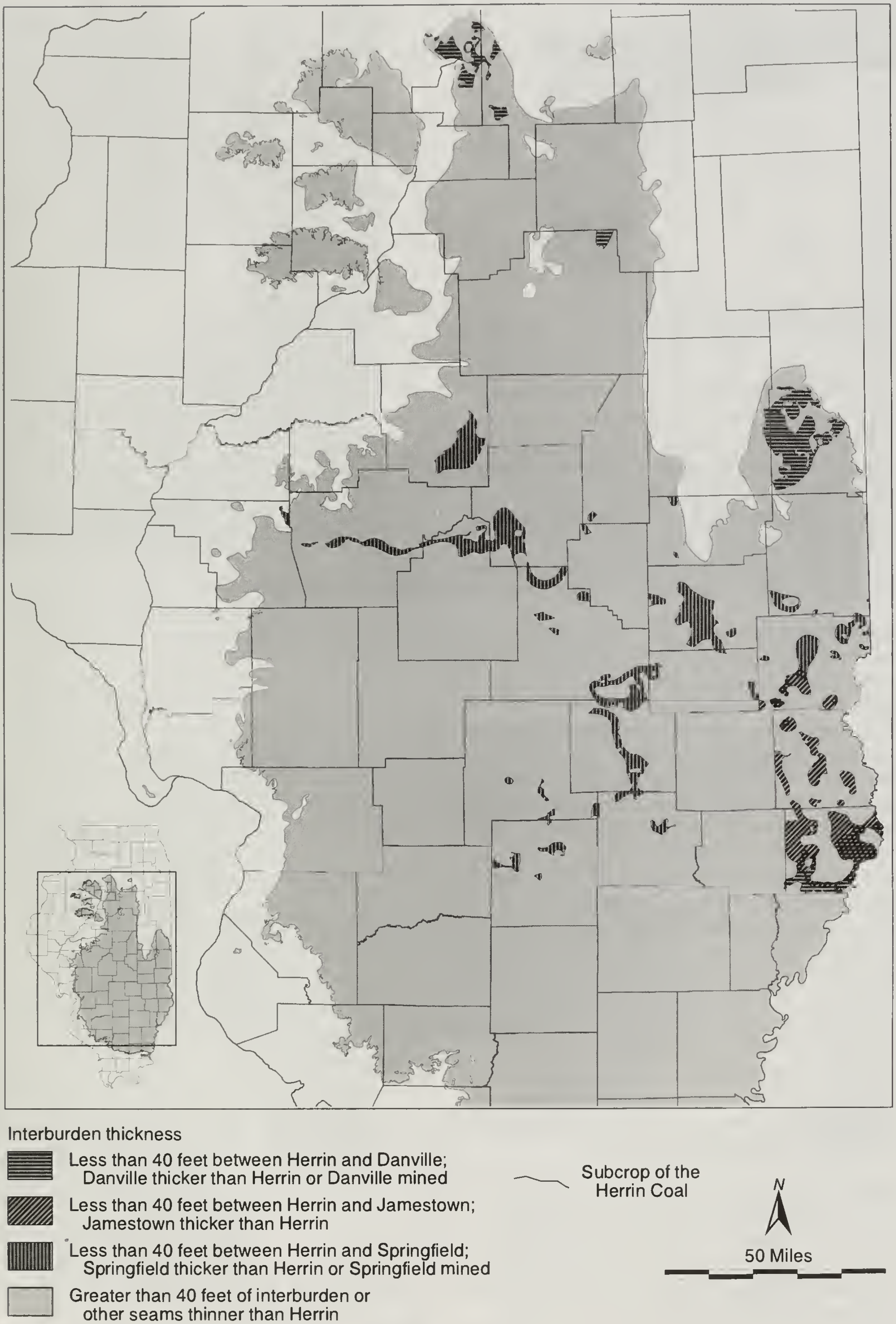


Figure 25 Areas of Herrin Coal restricted because of the thickness of interburden between overlying or underlying seams.

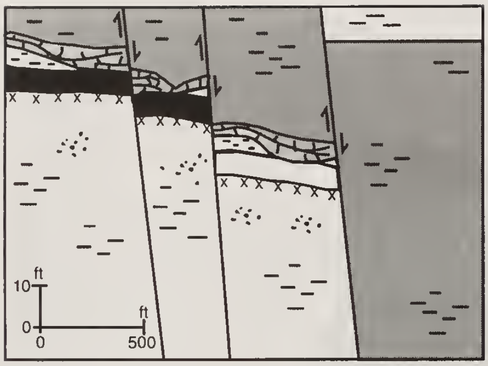


Figure 26 Cross section illustrating multiple, parallel faults displacing a coal seam.

few feet to 30 feet wide. Several inches to several feet of coal adjacent to the dikes are altered or coked. The dike material is extremely difficult to mine through, and the adjacent altered coal is unsaleable. For tonnage calculations in this study, we assumed that an average of 30 feet of coal on either side of a dike would be left unmined. This tonnage is included in the tonnage restricted by faults.

Partings During deposition of the coal beds, accumulation of peat was periodically interrupted by deposition of clastic sediments. These sediments may represent overbank deposits from nearby streams or deposits that accumulated in a backwater lake or estuary. The layers of sediment, commonly called partings, can be a fraction of an inch to tens of feet thick (fig. 30). Most partings in the Herrin Coal are local features associated with the Walshville Channel, and they are seldom traceable as individual beds for more than several hundred feet. A notable exception to this is the blue band parting that has been reported throughout the Illinois Basin Coal Field and described in many reports on the Herrin Coal (Cady 1916, 1952; Kay 1922; Nelson 1983). The "blue band" is a layer of shale or clay commonly 0.5 to 3 inches thick in the lower half of the seam. The origin of the blue band has never been conclusively explained, nor has it been demonstrated that the blue band is actually the same parting throughout the basin.

Partings can cause roof stability problems, reduce the productivity of a mine, increase the wear of mining and coal preparation equipment, reduce the efficiency of the mine's preparation plant, and increase the amount of waste material that must be stored in waste piles and slurry ponds. Partings that are more than a few inches thick in coal left in the mine as pillars tend to

Figure 27 Highly fractured roof strata adjacent to a fault displacement, Peabody No. 44 Mine, Saline County (ISGS files).

Figure 28 Unmined areas adjacent to one of the faults in the Wabash Valley Fault System (from Treworgy et al. 1998).

slough off (rib rashing), reducing the stability of pillars (Jeffrey Padgett, personal communication; fig. 31). Over time, this instability may result in roof falls in the mine and subsidence damage to surface property.

Partings may vary in number, thickness, and position within the seam (fig. 32). Partings may restrict mining if they create inaccessible coal or unstable roof conditions or if the yield of clean coal (tonnage of saleable coal/tonnage of material mined) falls below an economical level. Small areas of low yield will be mined if necessary to access other reserves, but large areas with excessive parting material are not mined.

Table 5 Average total width of fault zone assumed to be unminable.

Fault zone	Feet
Centralia	600
Cottage Grove	
Master fault	1,000–2,000
Subsidiary faults	200
Dowell	200
Rend Lake	400
Shawneetown	2,000
Wabash Valley	1,600

Where partings are less than a few feet thick, the entire seam is mined, and the rock material must be separated from the coal at the cleaning plant. Because of the extra wear on equipment and the longer cutting time required, one foot of parting material is considered the maximum that is feasible to mine for any extended area. A yield of clean coal equal to 65% of the

Figure 29 Areas of the Herrin Coal affected by faults and igneous dikes.

tonnage of material mined is considered by most companies to be the minimum necessary for an operation to be economic. Mining only the lower or upper bench of coal may be a solution, but mining conditions can be difficult. Nelson (1983) offered two detailed case studies of mining in areas of extensive partings.

Figure 30 Shale partings in the Herrin Coal near the Walshville Channel, Old Ben No. 11 Mine, Franklin County (Coal Section files, ISGS).

Because areas of extensive partings have highly variable coal thickness and require numerous, closely spaced data points to accurately map resources, past ISGS studies have not mapped coal thickness or calculated resources in these areas but have simply mapped them as areas of "split coal." For this statewide assessment, we also assumed that these areas would be unminable and made no attempt to calculate the tonnage of affected coal in the previously identified areas. A few additional areas where numerous, thick partings are present were identified in this study. The total tonnage of resources in the areas of partings is estimated to be about 1 billion tons.

Walshville Channel and Energy Shale The Walshville Channel, a drainageway through and contemporaneous with the peat swamp of the Herrin Coal, has strongly influenced the thickness, quality, and minability of the Herrin Coal (figs. 8 and 33). The coal is generally thick (7 feet to more than 14 feet) in a zone along and extending from one to several miles away from this channel. Immediately adjacent to the channel, the coal is commonly split into two or more benches separated by shale, siltstone, and sandstone a few inches to tens of feet thick. Within the course of the channel, the coal is missing and is replaced by sandstone, siltstone, and shale. Associated with the channel is the Energy Shale Member. This unit is light to dark gray shales, siltstones, and sandstones deposited directly on top of the Herrin Coal along a wide zone along the Walshville Channel. The unit is more than 100 feet thick adjacent to the channel and thins and pinches out from the channel for several hundred feet to several miles.

Figure 31 Rib rashing in the Herrin Coal; note the position of the blue band.

Although locally the Energy Shale and underlying coal may be disturbed by structural or deformational features such as rolls and low-angle shear zones, this unit commonly makes a stable roof unless exposed to moist, humid air (Krausse et al. 1979, Nelson 1983). Two known exceptions to this stable roof are certain planar-bedded facies and the margins of the unit where the thickness of the Energy Shale changes abruptly over a short distance. A finely laminated or planar-bedded shale, siltstone, and sandstone facies of the Energy Shale make an unstable mine roof (Krausse et al. 1979, Breyer 1992; figs. 34 and 35). The rock easily splits along these partings, and extensive roof control measures are required. In addition, the sandstone and siltstone facies may contain water, which also contributes to weakening of the roof strata and the degradation of mining conditions. The distribution and extent of these facies are not known, and data are insufficient to map them for this study.

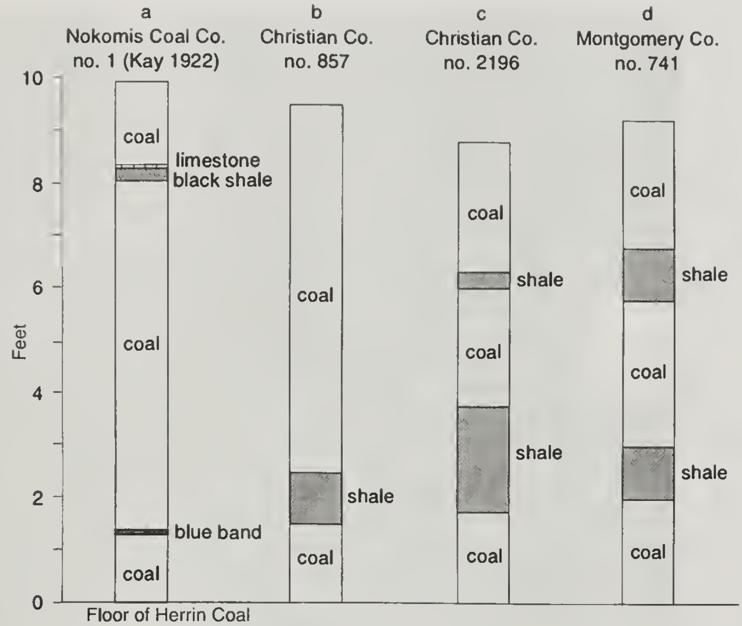


Figure 32 Examples of partings in the Herrin Coal in the Nokomis Quadrangle (Treworgy et al. 1996b).

The margins of Energy Shale deposits, characterized by areas of abrupt thinning (e.g., thinning 60 feet to 80 feet over less than 0.5 miles), have been correlated with severe roof conditions in mines. It is not known whether the weakness of the roof in these areas is due to the effects of differential compaction of sediments, a change in facies, ancient slumps of the unlithified sediments, or a combination of these and other factors (fig. 36). Because of the severity of the roof falls experienced in these areas, companies commonly avoid mining in the vicinity of the deposit margins (fig. 37). Mines that attempt to mine coal under both the Energy Shale and adjacent deposits have found it necessary to minimize the amount of mining in this transition zone. The exact boundaries of this zone are not known.

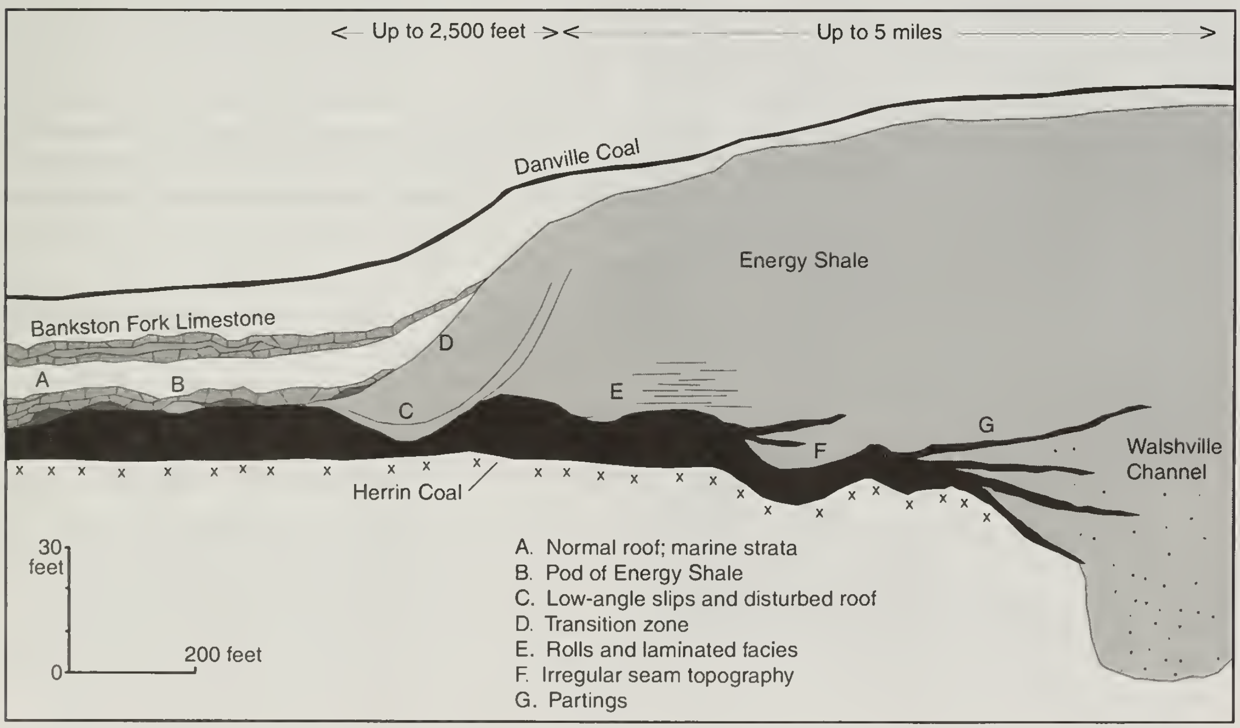


Figure 33 Areas of adverse mining conditions in the Herrin Coal near the Walshville Channel.

Figure 34 Core of the laminated siltstone and shale facies of the Energy Shale, Douglas County (Coal Section files, ISGS).

Figure 35 Large roof fall in laminated Energy Shale, Jefferson County (Coal Section files, ISGS).

For purposes of estimating the amount of coal that may be restricted by these severe roof conditions, this study defined the transition zone as a belt 1,500 feet wide that roughly corresponds to the area where the Energy Shale thickens abruptly from 5 to 30 feet. In practice, mining companies may find this zone to be wider or narrower, depending on local conditions as well as variables associated with mine design (e.g., roof bolting plan, size of rooms).

Other problems that create poor mining conditions near the Walshville Channel include abrupt variations in the thickness of coal or partings, steep changes in the elevation of the coal, and local washouts of the seam. These conditions are difficult to predict and delineate, even with data from closely spaced drill holes. Mines are commonly laid out so that areas of potential problems can be probed and mining plans abandoned if conditions are found to be unfavorable. In some areas, severe problems have been encountered as much as several miles from the channel (Nelson 1983).

Because drill holes spaced only a few hundred feet apart are needed to identify many of the undesirable geologic features associated with the Walshville Channel and the Energy Shale, these features could not be specifically delineated in this study. To estimate the amount of coal that may be unminable because of conditions related to the Walshville Channel, this study considered coal less than a half mile from the channel to be unavailable for mining (fig. 38). In some areas, this coal may ultimately be found to be minable, but in other areas, coal farther from the channel will likely be declared unminable.

Anvil Rock Channel and Sandstone Overlying Coal The Anvil Rock Sandstone Member consists of various related facies of clastics deposited some time after the Herrin peat swamp had drowned and been buried by several cyclic sequences of shale and limestone (Hopkins 1958). During the period of Anvil Rock deposition, a river or rivers eroded sediments down to and through the Herrin Coal across wide areas of southern Illinois (fig. 38). In addition to partially or totally removing the coal in some areas, the Anvil Rock Sandstone creates severe roof problems where it is within 5 feet of the top of the coal bed (Treworgy et al. 1998). In these areas, the Brereton Limestone, the preferred target for anchoring

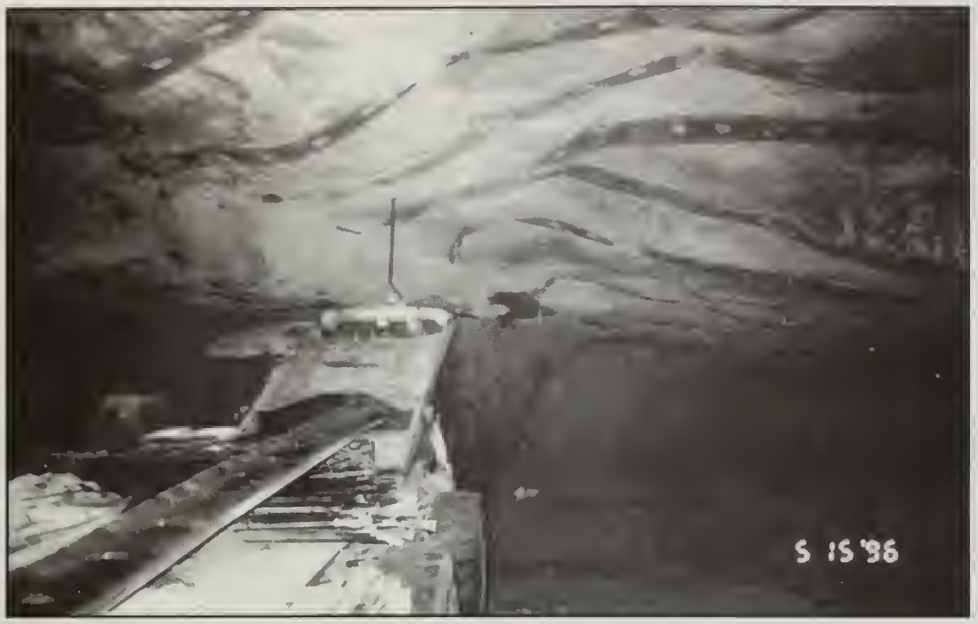


Figure 36 Extensive roof bolting used to hold Energy Shale roof in an area disrupted by slump-like features (see C, fig. 33).

roof bolts, may be missing. The rock between the coal and the sandstone is commonly weak, particularly if the normal rock sequence has been removed by channel scour. In addition, holes drilled into the sandstone for roof bolting allow water to enter the mine, especially if the water is under artesian pressure, as it is in some areas.

Areas of Herrin Coal in southern Illinois restricted from mining by the Anvil Rock Sandstone were identified for this study by creating an 1,800-foot buffer zone along the main Anvil Rock Channel and mapping additional areas away from the channel where the sandstone was within 5 feet of the coal seam. Our experience and knowledge of the mines near the Anvil Rock Channel indicated the zone where the coal is closely overlain by sandstone and where roof problems may be encountered. This zone extends approximately 1,800 feet from the edge of the main area of eroded coal. Too few drilling data are available to map this zone along the entire length of the channel. Examination of drill logs along the channel in areas where sufficient data were available confirmed that, although this zone is wider in some areas and narrower in others, 1,800 feet is a reasonable figure to use for estimating the amount of restricted coal (fig. 39). Additional areas where the sandstone was within 5 feet of the top of the Herrin were mapped using drilling records in the public files of the ISGS. These areas were found to roughly corresponded with the areas of thick sandstone mapped by Hopkins (1958).

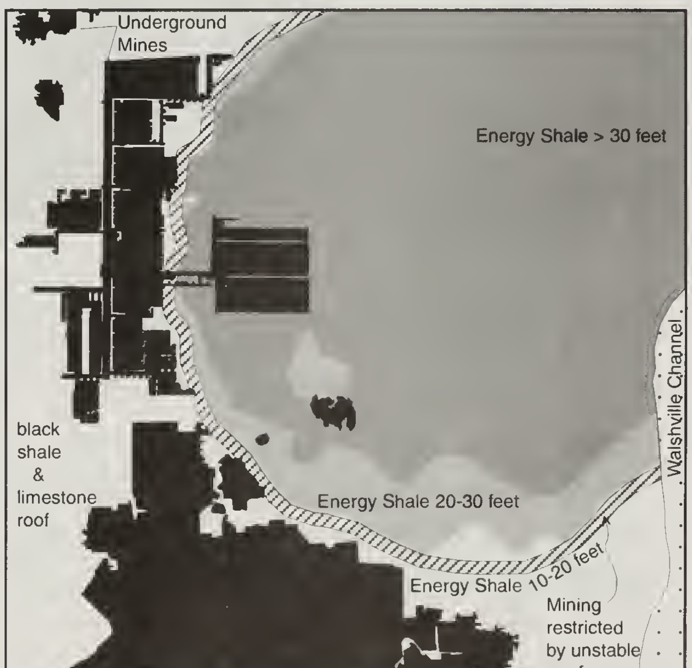


Figure 37 Patterns of underground mining and type of roof strata, west-central Illinois.

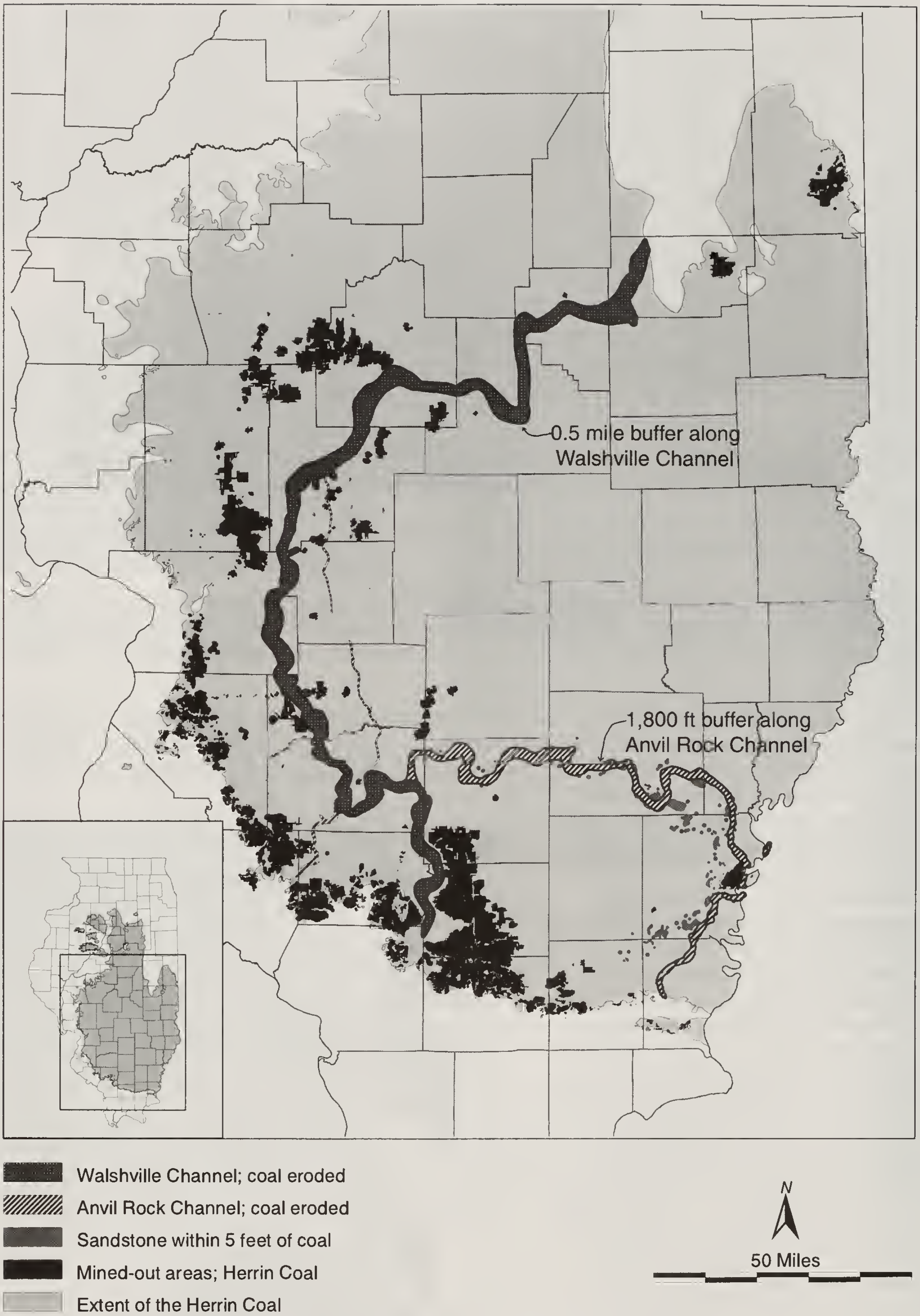


Figure 38 Areas of the Herrin Coal with Anvil Rock Sandstone within 5 feet of the roof.

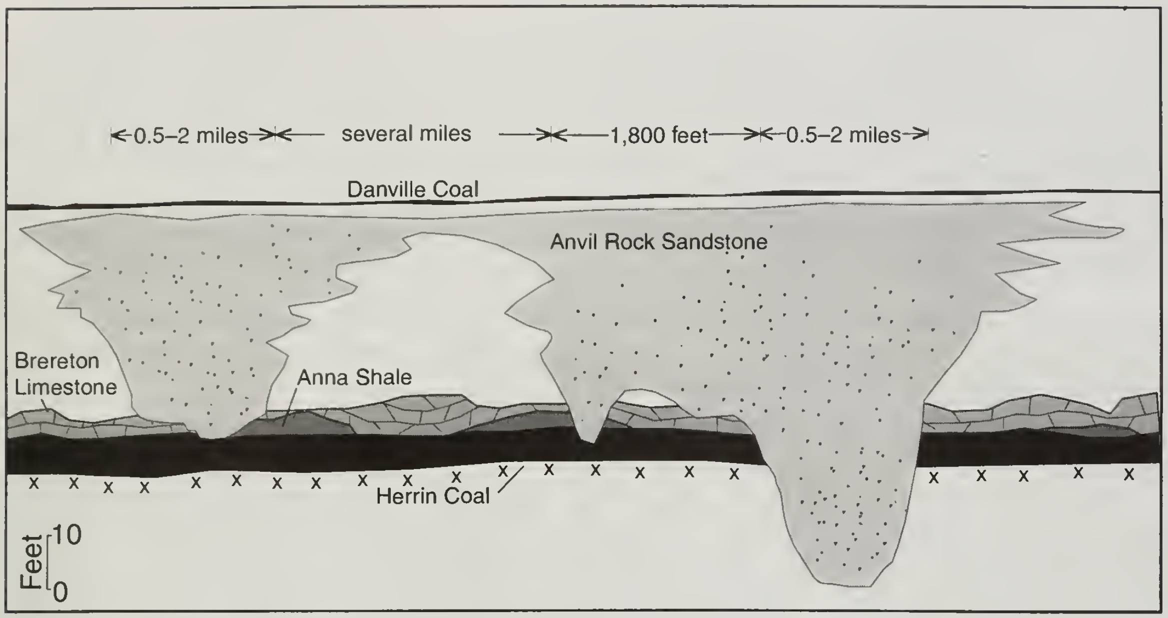


Figure 39 Schematic cross section showing the relationship of the Anvil Rock Sandstone to other stratigraphic units.

Potter and Simon (1961) mapped what was thought to be the Anvil Rock in west-central Illinois. The major sandstone body mapped by Potter and Simon has since been determined to be an older sandstone filling the Walshville Channel. Minor bodies of Anvil Rock Sandstone are present west of Taylorville and south of Hillsboro. Although the sandstone in these areas has caused local mining problems, the tonnage of resources affected is not significant (DeMaris and Nelson 1990, Nelson 1983). Broad areas where the sandstone is within 5 feet of the top of the coal are not known to be present, and the coal is minable up to these minor channels.

Size and Configuration of Mining Block In the quadrangle assessments, the minimum block sizes for underground mining ranged from 40 to 100 million tons in place, depending on the depth of the resources. Mines at a shallow depth (e.g., less than ~250 feet) can be opened from a highwall, box cut, or shallow slope; exploratory drilling will be relatively inexpensive. Deeper mines require higher initial exploration and development costs, so a larger block of coal is needed to recover those investments.

Mine blocks must also have dimensions that are suitable for the mine layout. Narrow blocks of coal with convoluted shapes (such as between abandoned mines or other barriers) cannot be safely or economically mined by underground mining methods.

In this statewide assessment, we used a single minimum block size of 80 million tons in place. This simplification did not have a material effect on the tonnage of coal eliminated because of block size. Only about 400 million tons of coal less than 250 feet deep were in blocks less than 80 million tons in size, and most of this coal lay between mined areas in narrow blocks that had configurations unsuitable for the layout of a mine.

Land Use The quadrangle studies identified ten land uses that restrict underground mining: towns, rural subdivisions, interstate highways, schools, churches, cemeteries, high-voltage transmission lines, public lands, airports, and dams. Limited extraction may take place under many of these features if permission is obtained, including under small towns with populations of a few hundred. However, unless such an area is crucial to development of the mine layout, it will generally be avoided. Because of the expense of mapping features relative to the amount of coal restricted, this statewide assessment delineated only towns, interstate highways, public lands, and large airports and dams. Some of the companies that we interviewed do not mine under railroads. However, in recent years, at least two longwall mines in Illinois, the Monterey No. 1 Mine and the Orient No. 6 Mine, have extracted coal underlying railroads. This study, therefore, considers coal underlying railroads to be available for underground mining.

A buffer of unmined coal must be left around any property or surface feature that cannot be disturbed. The size of the buffer depends on the depth and thickness of the coal, the composition of the overburden, and the angle of draw used to calculate the area that could be affected by subsidence from underground mining. Although the individual quadrangle studies used buffer sizes ranging from 100 to 400 feet, depending on the depth of the coal, this statewide assessment used a single buffer size of 100 feet or all features except towns. Towns were not buffered at all because the municipal boundaries of the majority of towns in the southern two-thirds of the state commonly extend past the area of actual surface development. In this study, the variation between the tonnage in areas measured as restricted by land use and that which might be obtained by more thorough mapping of features is not significant.

Abandoned Mine Workings Illinois law requires that underground mines leave an unmined barrier of coal 200 feet wide around abandoned underground mine workings. A larger barrier may be required if the extent of the mine workings is not accurately known.

Closely Spaced Oil Wells A block of unmined coal must be left around oil wells unless they are abandoned and known to be plugged to standards set by the U.S. Department of Labor's Mine Safety and Health Administration. Numerous, closely spaced oil wells (e.g., one well every 20 acres or less), whether active or abandoned, can restrict the availability of coal for mining, either by limiting access to the coal or raising the cost of mining. Unless closely spaced wells are plugged, they limit the development of entries and panels and prohibit longwall mining. Prior to the late 1940s there were no controls on the spacing of oil wells in Illinois. Some oil fields developed during this period have wells on spacings of 5 acres or less (fig. 40). In addition, these old wells may be poorly located and improperly plugged. Wells drilled since the late 1940s have been on spacings of one well per 10 or 20 acres.

There are no regulations or clear-cut formulas for determining what number or spacing of wells constitutes a restriction to mining, nor can the area of coal restricted by wells be precisely defined prior to the development of a mine plan. If a well is abandoned, the mining company has only the expense of plugging the well (which is significant). If a well is active, the company must negotiate its purchase or design the mine layout to leave a pillar of coal around the well (fig. 41). The benefits of plugging a well are measured on a well-by-well basis and determined by the value of the coal that can be recovered and by the efficiencies that may be achieved in the mine layout. Areas of coal on the edge of a mine property may be left unmined if they contain numerous wells, but wells in strategic areas needed for main entries or development of longwall panels may be worth plugging.

Figure 40 Closely spaced oil wells, Salem Oil Field, Marion County (ca. 1943, ISGS files).

For this study we examined mining patterns of current or recent mines operating in areas with many oil wells. Based on this examination, two categories of resources in areas of closely spaced oil wells were delineated (fig. 42). Resources in areas with four to seven wells per 40 acres are considered to be available with potential restrictions because the cost of mining these deposits will be higher than areas with few oil wells. Room and pillar mining can be conducted in these areas, but mining costs will be higher than areas without oil pools because of the need to buy and/or plug selected wells, tailor mining layouts to fit between wells, and extract a lower percentage of coal per acre. Resources in areas with eight or more wells per 40 acres are considered unminable. In addition to the high cost of plugging this many wells in an area, it may be difficult to locate all the wells. These increased costs and safety issues make it unlikely that mining will be attempted in these areas in the foreseeable future.

Potential Land-Use Conflicts This category is used to represent "available" resources that, although lacking any specific land-use or technological restrictions, are in areas that are relatively densely populated and experiencing ongoing suburban development. In addition, land values in these areas are probably unfavorably high for mining, and both surface and underground mines are likely to be viewed by the local population and government as incompatible with community development. The potential for community opposition to and interference with mining activities, as well as the long-term liability for subsidence damage from underground mining, are significant deterrents to mining. All of the mining experts we interviewed said that they would not risk their company's financial resources by attempting to put together a mining block and developing a mine in such areas. Potential land-use conflicts involving the Herrin Coal occur east of Saint Louis, especially the communities of Belleville, Collinsville, and Edwardsville; in the vicinity of Peoria, East Peoria, and Pekin; and around La Salle. Intermixed with this development are fingers of resources that meet our criteria for available coal but are unlikely to be mined because of the surrounding development.

AVAILABLE RESOURCES

Statewide, about 51 billion tons (58%) of the original 89 billion tons of Herrin Coal resources are available for mining (fig. 43, table 1). Of these available resources, 21 billion tons are 42 to 66 inches thick and 30 billion tons are greater than 66 inches thick (table 6, fig. 44). An additional 3 billion tons are available with potential restrictions because they are located in areas where geologic or land-use conditions may increase the cost of mining. These areas include those that have a medium density of oil wells or 75 to 100 feet of bedrock overburden or are near rapidly developing urban areas. Technological factors restrict mining of 24% of the resources (21 billion tons), and land use restricts 4% (4 billion tons).

Only 3 billion tons of the available resources have a medium- to low-sulfur content (<1.67 pounds of sulfur per million Btu). These lower sulfur resources are available primarily by underground mining. Examination of these medium-and low-sulfur resources by mining district shows that almost all of the resources in the Quality Circle district have been mined out (table 7). The largest remaining available resources of medium- to low-sulfur coal are in the Charleston district. Significant quantities of available lower sulfur resources are potentially restricted by land use in the Troy (St. Louis metropolitan area) and Quality Circle (Rend Lake) districts.

About 68% (54 billion tons) of the remaining resources of Herrin Coal are in the measured and indicated categories of reliability (see section

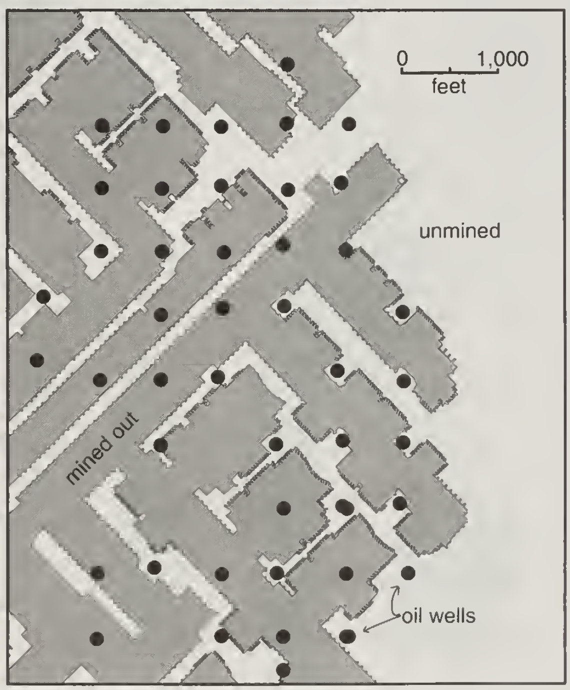


Figure 41 Underground mine workings in an area of closely spaced oil wells. Wells within mined area were plugged and mined through.

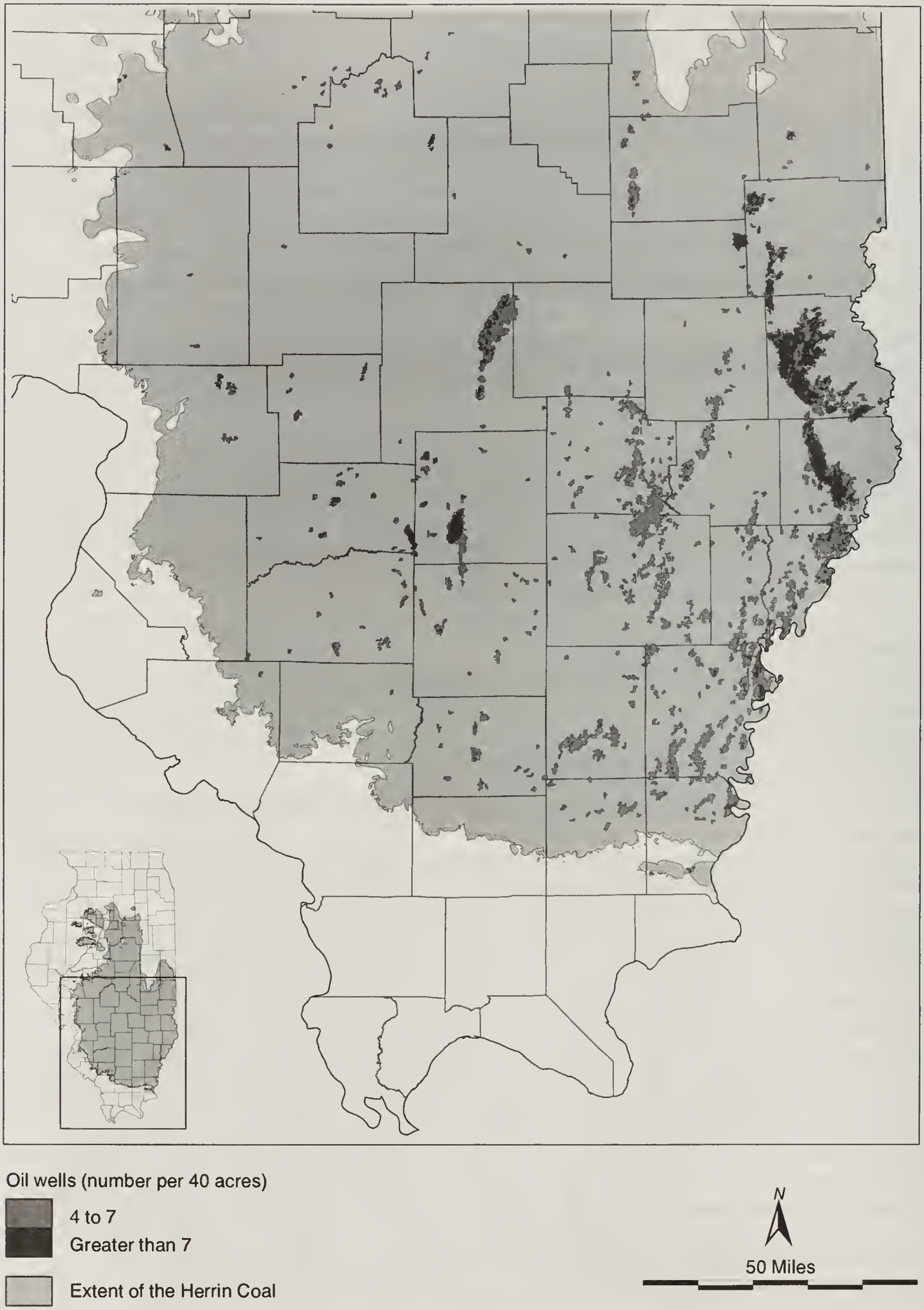


Figure 42 Areas of the Herrin Coal containing closely spaced oil wells.

on the coal resource classification system), and 74% (38 billion tons) of these are available for mining (table 8, fig. 45). A slightly lower percentage (53%) of the inferred resources are available compared with the measured and indicated resources, a reflection of the greater density of drilling carried out in the most attractive areas for mining. Land use restricts a lower percentage of the inferred resources than measured and indicated, probably because the inferred resources are largely away from towns, the historical centers of mining. Although the availability of some resources will be reclassified as a result of additional drilling, no major changes in the total tonnages are anticipated.

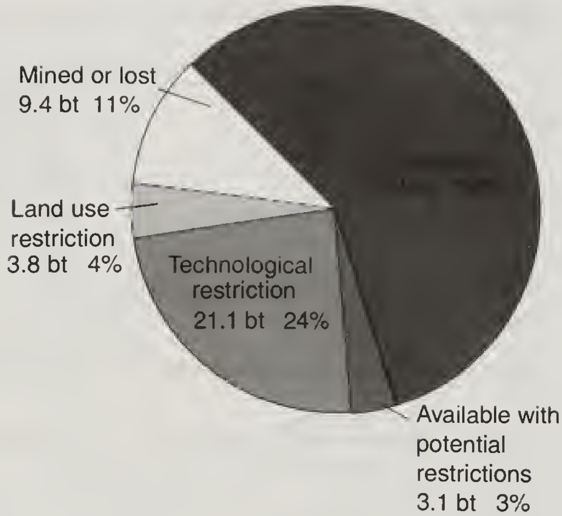


Figure 43 Availability of the Herrin Coal for mining in Illinois (bt = billion tons).

Coal Available for Underground Mining

About 86 billion tons of the original Herrin Coal resources lie at depths greater then 40 feet and are therefore potentially minable by underground methods. Of these, about 57% (49 billion tons) is available for mining, and an additional 4% (3 billion tons) is available with potential restrictions (table 9, fig. 46). Technological factors restrict mining of 25% of the resources, and land use restricts about 5%. The major technological restrictions are thin bedrock and/or thick drift cover (9% of original resources), coal less

Table 6 Availability of the Herrin Coal by thickness category (billions of tons).

	18–28 inches	28–42 inches	42–66 inches	>66 inches	Total
Original	0.8	10.9	30.8	46.0	88.5
Mined	<0.1	<0.1 (<1)	0.6 (2)	8.8 (19)	9.4 (11)
Remaining	0.8(100)[1]	10.9 (100)	30.2 (98)	37.4 (81)	79.0 (89)
Available	<0.1 (1)	0.1 (1)	21.3 (69)	29.6 (64)	51.0 (58)
Available with potential restrictions	... ...	<0.1 (<1)	1.5 (5)	1.6 (3)	3.1 (3)
Technological restrictions	0.7 (89)	10.3 (94)	6.2 (20)	4.0 (9)	21.1 (24)
Land-use restrictions	<0.1 (10)	0.5 (5)	1.2 (4)	2.1 (5)	3.8 (4)

[1]Numbers in parentheses are percent of original resources.

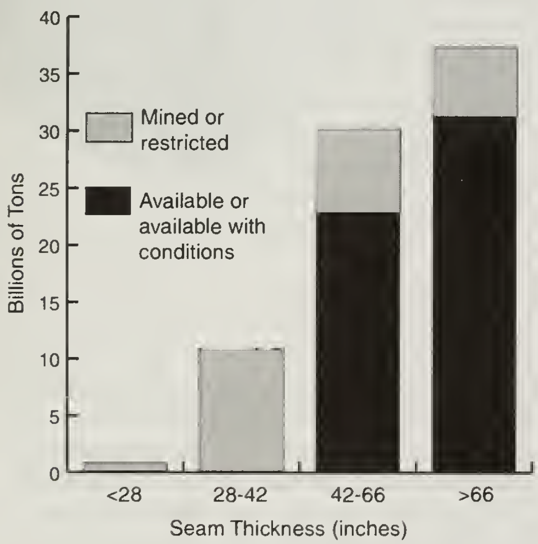


Figure 44 Availability of the Herrin Coal by thickness category.

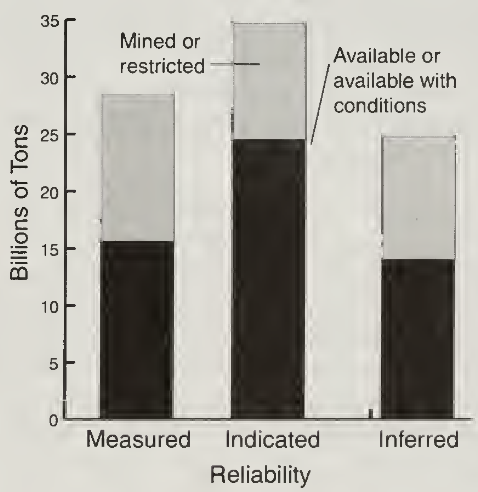


Figure 45 Availability of the Herrin Coal by reliability category.

Table 7 Availability of medium- and low-sulfur Herrin Coal by mining district (millions of tons).

	Charleston	Hornsby	Quality Circle	Troy	Total
Original	3,849	777	2,799	933	8,357
Mined	64 (2)[1]	28 (4)	2,536 (91)	50 (5)	2,677 (32)
Remaining	3,785 (98)	748 (96)	263 (9)	883 (95)	5,678 (68)
Available	1,674 (44)	665 (86)	53 (2)	432 (46)	2,825 (34)
Available with potential restrictions	32 (1)	0 (0)	65 (2)	249 (27)	346 (4)
Technological restrictions	1,977 (51)	61 (8)	69 (2)	159 (17)	2,266 (27)
Land-use restrictions	102 (3)	22 (3)	76 (3)	42 (5)	242 (3)

[1]Numbers in parentheses are percent of original resources.

Table 8 Availability of the Herrin Coal by reliability category (billions of tons).

	Measured	Indicated	Inferred	Total
Original	28.6	34.9	25.0	88.5
Mined	9.4 (33)[1]			9.4 (11)
Remaining	19.2 (67)	34.9 (100)	25.0 (100)	79.0 (89)
Available	15.0 (52)	22.8 (66)	13.2 (53)	51.0 (58)
Available with potential restrctions	0.6 (2)	1.7 (5)	0.8 (3)	3.1 (3)
Technological restrictions	2.8 (10)	8.3 (24)	10.0 (40)	21.1 (24)
Land-use restrictions	0.8 (3)	2.0 (6)	0.9 (4)	3.8 (4)

[1]Numbers in parentheses are percent of original resources.

than 42 inches thick (8%), and thin interburden between the Herrin Coal and resources in underlying or overlying coals (4%). Size of mining block, unfavorable geologic conditions near channels, and Anvil Rock Sandstone in the immediate roof, faults, and partings restrict a total of about 5% of the resources.

Most of the available resources are in the southern half of the state (fig. 47). These available resources are well suited for high-efficiency longwall mining. The resources are relatively flat-lying; have a consistent seam thickness over large areas; are relatively free of faults, channels, or other geologic anomalies; are predominantly in rural areas free from oil wells and other surface development; and occur in minable blocks of hundreds of millions of tons.

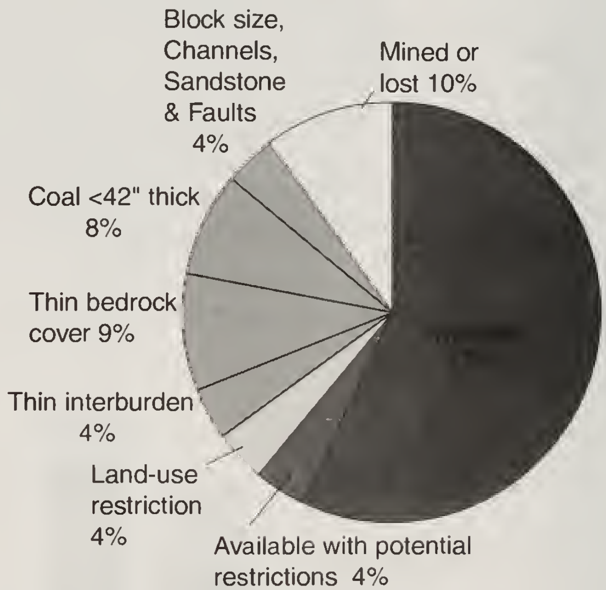


Figure 46 Availability of the Herrin Coal for underground mining.

The quadrangle assessments of available coal conducted prior to this statewide assessment sampled about 4% of the Herrin Coal resources that are potentially minable by underground methods. In most cases the percentages of resources found to be restricted by individual factors were similar in both the quadrangle and statewide assessments (table 9). These results indicate that the set of quadrangles used to identify criteria was a fairly representative sampling of the mining conditions associated with the Herrin Coal. However, the differences between the statewide and quadrangle assessments reveal some shortcomings in the selection of quadrangles. The percentage of available coal was larger and the percentage of tonnage already mined or restricted by land use or block size was smaller

Table 9 Resources of the Herrin Coal available for underground mining in this study and previous quadrangle studies (millions of tons).

	Statewide		Quadrangles	
Original	86,331		3,775	
Mined (percent of original)	8,388	(10)[1]	487	(13)
Remaining (percent of original)	77,943	(90)	3,288	(87)
Available	49,299	(57)	1,898	(50)
Available with potential restrictions	3,254	(4)	81	(2)
Oil wells	1,528	(2)	32	(1)
Bedrock 75 to 100 feet thick	1,065	(1)	not used	
Potential land-use conflict	661	(<1)	49	(1)
Land-use restrictions	3,611	(4)	326	(9)
Towns	1,980	(2)	181	(5)
Abandoned mines	775	(<1)	96	(3)
Public lands	529	(<1)	1	(<1)
Oil wells	230	(<1)	not used	
Roads	92	(<1)	5	(<1)
Major airports[2]	4	(<1)	6	(<1)
Dams	<1	(<1)	<1	(<1)
Railroads	not used		7	(<1)
Cemeteries	not used		11	(<1)
Transmission lines	not used		<1	(<1)
Churches and schools	not used		1	(<1)
Technological restrictions	21,778	(25)	1,000	(26)
Thin bedrock cover[3]	7,377	(9)	252	(7)
Seam <42 inches thick	6,631	(8)	329	(9)
Thin interburden	3,354	(4)	0	(0)
Block size	2,086	(2)	267	(7)
Near channel[4]	985	(1)	29	(1)
Sandstone within 5 ft of coal	687	(<1)	11	(<1)
Poor roof conditions under Energy Shale	384	(<1)	18	(<1)
Faulted	273	(<1)	18	(<1)
Partings	. . .[5]		77	(2)

[1]Numbers in parentheses are percent of original resources.

[2]The data set used to delineate airports in the statewide assessment restricted resources only under runways, taxiways, and buildings, whereas the quadrangle study used the property boundary of the airports, including undeveloped land.

[3]Includes resources restricted because bedrock cover was relatively thin and the area was within a floodplain.

[4]Includes resources near either the Walshville or Anvil Rock channels.

[5]Not calculated (see text). Estimated to be on the order of 1 billion tons, about 1% of original resources.

in the statewide assessment than indicated by the individual quadrangle assessments. This probably reflects a bias in the quadrangle studies that resulted from selecting quadrangles in or near active mining areas. Areas that have been actively mined for many years have more surface development and smaller remaining blocks of coal than do undeveloped resources away from the active mining areas. The difference between the statewide and quadrangle assessments in percentage of coal restricted by thin interburden (4% versus none) is surprising and represents the failure of any of the quadrangle studies to be located in an area where this condition was present. A larger sample set of quadrangles might have detected and more accurately measured this factor.

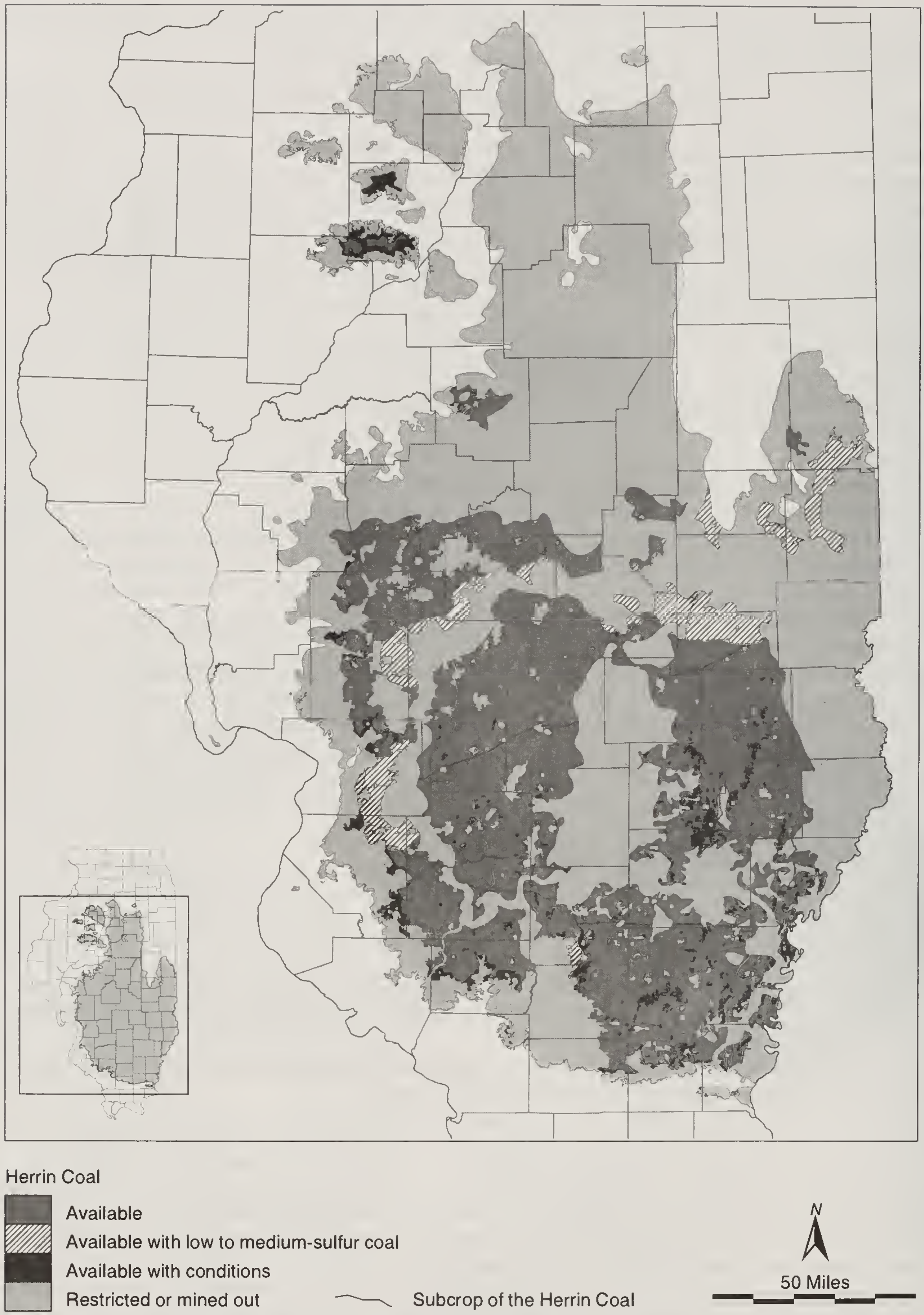


Figure 47 Areas of the Herrin Coal available for underground mining.

Table 10 Resources of the Herrin Coal available for surface mining as indicated by this study and previous quadrangle studies (millions of tons).

	Statewide		Quadrangles	
Original	14,885		1,316	
Mined (percent of original)	3,091	(21)[1]	183	(14)
Remaining (percent of original)	11,794	(79)	1,133	(86)
Available	2,215	(15)	223	(17)
Available with potential restrictions	243	(2)	33	(2)
Potential land-use conflict	243	(2)	19	(1)
Mined with other seams	not used		14	(1)
Land-use restrictions	2,578	(17)	261	(20)
Towns	1,742	(12)	190	(14)
Roads	118	(<1)	20	(2)
Pipelines	108	(<1)	2	(<1)
Public lands	78	(<1)	6	(<1)
Railroads	75	(<1)	5	(<1)
Underground mines	452	(3)	27	(2)
Airports	3	(<1)	7	(1)
Transmission lines	not used		0.8	(<1)
Cemeteries	not used		2	(<1)
Churches and schools	not used		0.04	(<1)
Major dams	0		0	
Technological restrictions	6,759	(45)	617	(47)
Stripping ratio	3,861	(26)	175	(13)
Thick unconsolidated material	2,789	(19)	362	(28)
Block too small	108	(<1)	64	(5)
Faulted	not used		16	(1)

[1]Numbers in parentheses are percent of original resources.

Coal Available for Surface Mining

About 17% (almost 15 billion tons) of the original Herrin Coal resources lie at depths shallow enough to be considered for surface mining (less than 200 feet deep). Of these, only 15% (2 billion tons) are available for surface mining. An additional 2% (243 million tons) is available with potential restrictions (table 10, fig. 48). Technological factors restrict 45% of the resources. These factors are unfavorable stripping ratio (26%), unfavorable drift thickness (19%), and size or geometry of mining block (<1%). Land use restricts surface mining of 17% of the resources. Towns are the major land-use restriction (12% of resources). Cumulatively, public lands, underground mines, dams, railroads, pipelines, highways, and airports restrict 6% of resources. Most of the available surface-minable resources are located in the western and southwestern part of the state, but surface-minable blocks are also present along the southern crop and in small areas of east-central and northern Illinois as well (fig. 49). In recent years, the high cost of reclamation combined with excellent conditions for underground mining have led companies to favor underground mining of much of the potentially surface-minable resources in southwestern Illinois.

Figure 48 Availability of the Herrin Coal for surface mining.

Almost 9% of the Herrin resources that are potentially surface minable were sampled by the quadrangle studies (table 10). The percentages of resources in the categories of available, available with potential restrictions, land-use restrictions, and technological restrictions were similar in both the quadrangle and statewide assessments. However, the percentages affected by the individual technological restrictions—stripping ratio, thick unconsolidated material, and block size—differed widely. As was the case for the sampling of underground-minable resources, these differences are probably due to a bias in quadrangle selection towards active mining areas. These areas tended to have lower stripping ratios and more mining blocks that were too small (because of the mined-out areas created by past mining) than resources that had been removed from active mining areas.

The smaller percentage of resources affected by stripping ratio and the greater percentage affected by underground mines reflect the bias of quadrangle selection toward areas with the greatest potential for mining. The decreased percentage of resources restricted by unconsolidated overburden and roads results from procedural differences between the quadrangle and statewide assessments. Had the statewide assessment been conducted with the same detail of mapping used in the quadrangle studies, both of these categories probably would be found to restrict a greater percentage of resources. Similarly, the potential for multiseam mining was not considered in the statewide assessment but was considered and probably overrepresented in the quadrangle studies. The amount of surface-minable resources that would be available only if mined in combination with the Springfield or Danville Coals is estimated to be a few percent of the total originally suitable for surface mining.

CONCLUSIONS

The Herrin Coal is the largest energy resource in Illinois. Approximately 51 billion tons of the Herrin Coal resources (58% of original resources) are available for mining. "Available" means that the land-use and physical characteristics of the deposit (e.g., thickness, depth, in-place tonnage, stability of bedrock overburden) are comparable with the conditions where this and other coals are currently being mined in the state. Of these resources, 30 billion tons are greater than 66 inches thick, and another 21 billion tons are 42 to 66 inches thick.

The majority of the available Herrin Coal resources (49 billion tons) are available for mining by underground methods. An additional 3 billion tons are also available for underground mining but with potential restrictions that make them less desirable, such as the presence of closely spaced oil wells, less stable roof strata, or close proximity to developing urban areas. The available Herrin resources are well suited for high-efficiency longwall mining. The resources are relatively flat-lying with a consistent seam thickness over large areas; they are relatively free of faults, channels, or other geologic anomalies; they are predominately in rural areas free from oil wells and other surface development; and they are present in minable blocks of hundreds of millions of tons.

Only about 15 billion tons of the Herrin Coal resources lie less than 200 feet deep and are potentially minable by surface methods. Of these, slightly more than 2 billion tons are available for mining. The relatively small amount of surface-minable resources suggests that future surface mining of the Herrin Coal will be limited. In addition, a significant portion of the available surface-minable resources in southwestern Illinois have characteristics that make them available for underground mining as well, and in recent years companies have shown a preference for underground mining in these situations. Future surface-mining operations are likely to be smaller than they historically have been in Illinois and will be located mostly in the northwestern and southern margins of the coal field.

Although the majority of the Herrin Coal resources are suited only for the high-sulfur coal market, about 9 billion tons of the original resources have a sulfur content between about 0.6 and 1.7 pounds of sulfur per million Btu. Of these original low- to medium-sulfur resources, approximately one-third have been mined, one-third are available for mining, and one-third are restricted, mostly by technological factors.

Technological factors cause the most significant restrictions on the availability of the Herrin Coal. For underground mining, the major restrictions are thickness of drift and bedrock cover, thickness of the coal seam, and thickness of interburden between seams. To minimize negative impacts of geologic conditions on mining costs, companies should avoid areas of thick drift and thin bedrock cover, areas with Anvil Rock Sandstone in the immediate roof, areas in close proximity to the Walshville Channel, faulted areas, areas of closely spaced oil wells, and the edge of the Energy Shale.

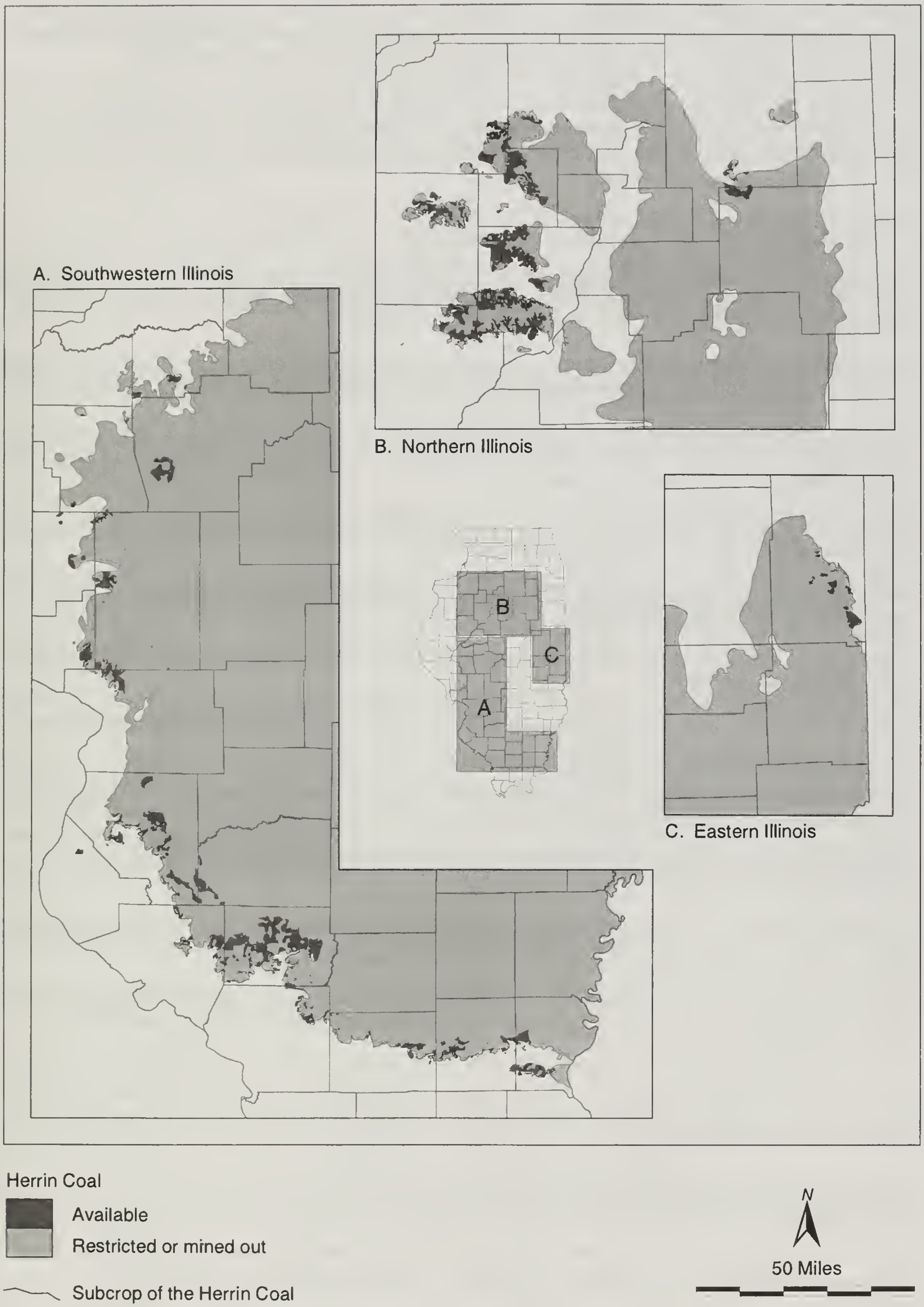


Figure 49 Areas of the Herrin Coal available for surface mining.

For surface mining, the major technological restrictions are stripping ratio and thickness of drift. These conditions make the cost of surface mining the Herrin Coal too high to compete successfully with local underground mines or with surface-mined coal from western states in today's markets.

In most parts of Illinois, land use is a relatively minor restriction for underground mining of the Herrin Coal. The major land-use restrictions on underground mining are related to urban development in the St. Louis metropolitan area and in the vicinity of Peoria. Land use, particularly proximity to towns, is a significant restriction to surface mining.

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APPENDIX 1 Source maps for coal resources.

County	Source (ISGS publications)	Map year	Scale (×1000)
Bond	Treworgy et al. 1997	1996	50
Bureau	Cady 1952, Smith and Berggren 1963	1950	125
Cass	This study	1999	50
Champaign	Treworgy and Bargh 1982	1978[1]	62.5
Christian	Treworgy and Bargh 1982	1978	62.5
Clark	Treworgy et al. 1997	1996	50
Clay	Allgaier and Hopkins 1975	1975	125
Clinton	Treworgy et al. 1997	1996	50
Coles	Treworgy et al. 1997	1996	50
Crawford	Treworgy et al. 1997	1996	50
Cumberland	Treworgy et al. 1997	1996	50
DeWitt	This study	1999	50
Douglas	Treworgy et al. 1997	1996[1]	50
Edgar	Treworgy et al. 1997	1996[1]	50
Edwards	Treworgy and Bargh 1982	1978	62.5
Effingham	Treworgy et al. 1997	1996	50
Fayette	Treworgy et al. 1997	1996	50
Franklin	Treworgy and Bargh 1982	1978	62.5
Fulton	Smith and Berggren 1963	1963	125
Gallatin	Treworgy and North 1999, Smith 1957 Treworgy and Bargh 1982	1999[1]	62.5
Greene	Smith 1961	1961	125
Grundy	Jacobson 1985	1985	62.5
Hamilton	Treworgy and Bargh 1982	1978	62.5
Henry	Smith and Berggren 1963	1963	125
Jackson	Smith 1958	1958	125
Jasper	Treworgy et al. 1997	1996	50
Jefferson	Treworgy and Bargh 1982	1978	62.5
Jersey	Smith 1961	1961	125
Knox	Smith and Berggren 1963	1963	125
La Salle	Jacobson 1985	1985	62.5
Lawrence	Treworgy et al. 1997	1996	50
Livingston	Jacobson 1985	1985	62.5
Logan	Work map by J. Treworgy	1983[1]	62.5
McLean	This study	1999	50
Macon	Treworgy and Bargh 1982	1978[1]	62.5
Macoupin	Smith 1963, Treworgy and Bargh 1982	1963[1]	62.5
Madison	Smith 1963, Treworgy and Bargh 1982	1963	62.5
Marion	Treworgy and Bargh 1982	1978	62.5
Marshall	Cady 1952	1950	62.5
Menard	This study	1999	50
Monroe	Smith 1958	1958	125
Montgomery	Treworgy and Bargh 1982	1978[1]	62.5
Morgan	This study	1999	50
Moultrie	Treworgy et al. 1997	1996[1]	50
Peoria	Smith and Berggren 1963	1963	125

(continued)

APPENDIX 1 (continued) Source maps for coal resources.

County	Source (ISGS publications)	Map year	Scale (×1000)
Perry	Smith 1958, Treworgy and Bargh 1982	1978	62.5
Piatt	This study	1999	50
Putman	Treworgy and Bargh 1982	1978	62.5
Randolph	Smith 1958, Treworgy and Bargh 1982	1958	125
Richland	Treworgy et al. 1997	1996	50
St. Clair	Smith 1958, Treworgy and Bargh 1982	1978	125
Saline	Smith 1957, Treworgy and Bargh 1982	1978	125
Sangamon	Treworgy and Bargh 1982	1978[1]	62.5
Scott	This study	1999	50
Shelby	Treworgy et al. 1997	1996[1]	50
Stark	Cady 1952, Smith and Bergren 1963	1950[1]	125
Tazewell	Smith and Berggren 1963, Treworgy and Bargh 1982	1978[1]	125
Vermilion	Jacobson and Bengal 1981, this study	1999	62.5
Wabash	Treworgy and Bargh 1982	1978	62.5
Washington	Treworgy and Bargh 1982	1978	62.5
Wayne	Treworgy and Bargh 1982	1978	62.5
Williamson	Smith 1957, Treworgy and Bargh 1982	1978	125
Woodford	This study	1999	50

[1]Minor revisions made for this report.