# Availability of the Springfield Coal for Mining in Illinois

Colin G. Treworgy, Christopher P. Korose, Cheri A. Chenoweth, and Daniel L. North

Illinois Minerals 118

Department of Natural Resources
ILLINOIS STATE GEOLOGICAL SURVEY

# Availability of the Springfield Coal for Mining in Illinois

Colin G. Treworgy, Christopher P. Korose, Cheri A. Chenoweth, and Daniel L. North

Illinois Minerals 118



Department of Natural Resources
ILLINOIS STATE GEOLOGICAL SURVEY
William W. Shilts, Chief
Natural Resources Building
615 East Peabody Drive
Champaign, IL 61820-6964
(217) 333-4747

## ACKNOWLEDGMENTS

We are especially appreciative to the following mining experts who gave us information on criteria that limit the availability of coal: Manny Efframian, Tom McCarthy, David Johnson, George Martin, James Niemeyer and Monna Nemecek, AMAX Coal Company; Greg Bieri and Philip Deaton, Arch Minerals; Dan Pilcher, Arclar Coal Company; Philip Ames, Bruce Dausman, Christopher Engleman and Christopher Padavic, Black Beauty Coal Company; Brent Dodrill, James Hinz, Edward Settle and Randy Stockdale, Consolidation Coal Company; S.N. Ghose, Dana Meyers, Marvin Thompson and John Williams, Cyprus-AMAX Coal Company; Michael Caldwell, Neil Merryfield and Roger Nance, Freeman United Coal Mining Company; Dan Ganey and Thomas Denton, Kerr-McGee Coal Company; Alan Kern, Michael Meighan and John Popp, MAPCO Coal Inc.; James Grimm, Midstate Coal Company; Jeffrey Padgett, Monterey Coal Company; Eric Quam, Old Ben Coal Company; Michael Anderson, Vick Daiber, Marc Silverman and Grady White, Peabody Coal Company; Robert Gullic and Walter Lucus, Sahara Coal Company; Steve Short and Dennis Oliver, Sugar Camp Coal Company; Scott Fowler and Guy Hunt, Turris Coal Company; Douglas Dwosh, Kenneth Ginard and David Thomas, Weir International Mining Consultants; and Daniel Barkley and Dean Spindler, Illinois Office of Mines and Minerals.

This project was supported by the U.S. Geological Survey, Department of the Interior, under the following agreements: 14-08-0001-A0773, 14-08-0001-A0841, 1434-92-A0940, 1434-93-A1137, 14-94-A1266, 1434-95-A01346, 1434-HQ96AG-01460, 1434-HQ97AG-01759 and 1434-98HQAG-2015. We especially thank Harold J. Gluskoter and M. Devereux Carter of the USGS for their guidence and support. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government. This manuscript is published with the understanding that the U.S. Government is authorized to reproduce and distribute reprints for governmental use. The Illinois State Geological Survey considers its publications to be in the public domain.


**Cover photo:** *Longwall mining the Springfield Coal at Kerr-McGee Coal Company's Galatia Mine.*




*Printed by authority of the State of Illinois/1999/500*

*Printed with soy ink on recycled paper*

## CONTENTS



FIGURES

TABLES

## EXECUTIVE SUMMARY

Of the 65.1 billion tons of original resources of Springfield Coal in Illinois, 63 billion tons or 97%, remain, the second-largest remaining coal resource in the state. The other 2.2 billion tons have been mined or was lost in mining during the more than 100 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 a potential negative impact on mining costs.

Approximately 41% of the original Springfield Coal resources (27 billion tons) are available for mining (table 1). Available means that the surface land-use and geologic conditions related to mining of the deposit (e.g. thickness, depth, in-place tonnage, stability of bedrock overburden) are comparable to other coals currently being mined in the state. Of these resources, 23 billion tons are 42 to 66 inches thick and 4 billion tons are greater than 66 inches thick.

The available resources are primarily located in the central and southeastern portions of the state and 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 located predominantly in rural areas free from oil wells and other surface development and are situated 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 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 62 billion tons of the remaining Springfield Coal resources have greater than 2.5 pounds of sulfur per million Btu and are therefore mostly suited for the high-sulfur coal market. Only 1.4 billion tons of the Springfield resources have a sulfur content of 0.6 to 1.7 pounds of sulfur per million Btu. However, the majority of these medium to low sulfur resources (1 billion tons) are classified as available or available with conditions. Technological factors, such as geologic conditions associated with faults and channels, are the primary restrictions on mining these lower sulfur deposits.

An additional 3 billion tons of the Springfield Coal resources are available, but have geologic or land-use conditions that may make them less desirable for mining (table 1). Technological factors (geologic conditions and engineering parameters such as size of reserve block) restrict mining of 47% of the resources and land-use factors (e.g. towns, highways) restrict mining of 5% of the resources.

Most of the available Springfield Coal resources will have to be mined by underground methods. Of the 63 billion tons of original resources that are at least 75 feet deep (and therefore potentially minable by underground methods), 41% (26 billion tons) are available for underground mining. An additional 4% are available but with conditions that make the resources less desirable. These conditions include the

**Table 1** Availability of the Springfield Coal for mining in Illinois, billions of tons. Numbers in parentheses are percent of original resources. Note: surface and underground resources do not add to the total because coal that lies between 75 and 200 feet deep is included in both categories.

| | | Potential Mining Method | | Pounds of Sulfur/M Btu | |
|---|---|---|---|---|---|
| | Total | Surface | Underground | <1.67 | >1.67 |
| Original | 65.1 | 7.8 | 63.0 | 1.8 | 63.3 |
| Mined | 2.2 (3) | 1.1 (15) | 1.8 (3) | 0.4 (23) | 1.8 (3) |
| Remaining | 63.0 (97) | 6.7 (85) | 61.2 (97) | 1.4 (77) | 61.5 (97) |
| Available | 27.0 (41) | 0.9 (12) | 26.1 (41) | 0.8 (46) | 26.2 (41) |
| Available w/ conditions | 2.6 (4) | <0.1 (<1) | 2.6 (4) | 0.2 (12) | 2.4 (4) |
| Technological restrictions | 30.1 (47) | 4.5 (57) | 29.4 (47) | 0.3 (16) | 29.9 (47) |
| Land-use restrictions | 3.2 (5) | 1.2 (16) | 3.0 (5) | <0.1 (4) | 3.1 (5) |

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 thin interburden between the Springfield Coal and an overlying seam (17%), coal less than 42 inches thick (14%) and unfavorable thicknesses of bedrock and unconsolidated overburden (13%). Land-use restricts underground mining of 5% of the original resources and 3% have already been mined or lost in mining.

Only about 8 billion tons of the original Springfield Coal resource lie at depths of less than 200 feet and are potentially minable by surface methods. Of these resources, 15% have already been mined and 12% (just under 1 billion tons) are available for surface mining. Land-use factors, primarily towns, restrict 16% of the resources. Technological factors, primarily stripping ratio and thick unconsolidated material, restrict 57% of the surface-minable resources.

To avoid high mining costs resulting from unfavorable geologic conditions, companies siting underground mines should avoid areas of thick drift and thin bedrock cover, close proximity to the Galatia Channel and faults, areas of closely-spaced oil wells and areas at the margins of the Dykersburg Shale. The areas of low-cost surface minable resources (areas with low stripping ratios that are free of conflicting land-uses) are limited and will only support small, limited-term operations.

This report is one of a series that explain the availability of coal in Illinois for future mining. Earlier reports in the series assessed 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 this statewide assessment of the availability of the Springfield Coal 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 that has 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 and there is little concern that a shortage of coal could develop in the foreseeable future. The important issue for society is where the greatest resources that are most favorable for mining are located and 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 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 Springfield Coal resources in Illinois and 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 a potential 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 coal 28 or more inches thick and more than 150 feet deep. 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 75 or more feet deep. Note that by these definitions, some resources may be both surface and underground minable. The USGS and other states use 14 inches (not 18 or 28) as the minimum thickness for resources. This difference in minimum thickness used to define resources does not significantly affect the resource totals for the Springfield 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 man-made or natural features that are illegal or impractical to disturb by mining. Technological restrictions include geologic or mining-related factors that negatively impact the economics or safety of mining. Resources in the available category are not necessarily economically minable at the present time, but the term designates that these deposits are expected to have mining conditions comparable to 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 conditions". This term is used to designate 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 numerous, but not excessive, oil wells, and potentially unstable roof conditions are examples of conditions that 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 conditions + available resources.

The USGS classification system uses the terms of 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 was 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).

## Geology and Mining of the Springfield Coal

The Springfield Coal underlies about two-thirds of Illinois as well as portions of western Indiana and western Kentucky (fig. 1). 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). Remaining identified resources of Springfield Coal in the three states total 82 billion tons, of which 76% (62 billion tons) are in Illinois (fig. 4; Indiana and Kentucky totals from Carol Conolly and Jerry Weisenfluh, respectively, personal communication). This represents about 31% and 30% of all the identified coal resources in Illinois and the Illinois Basin, respectively. The Springfield Coal has been

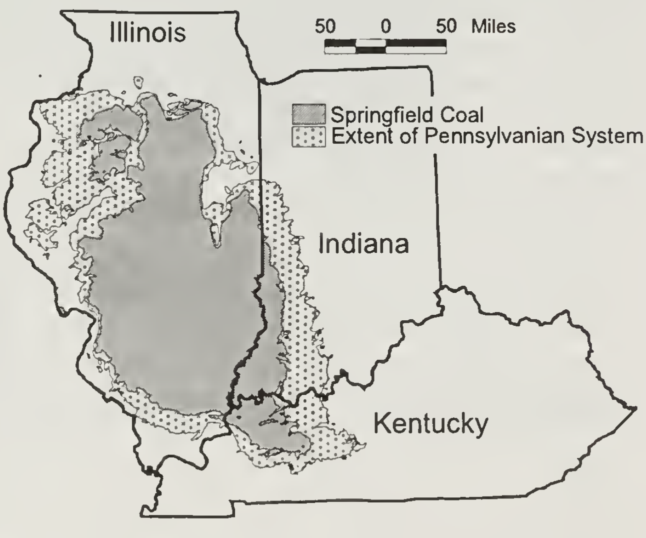



**Figure 1** Extent of the Springfield Coal in the Illinois Basin.

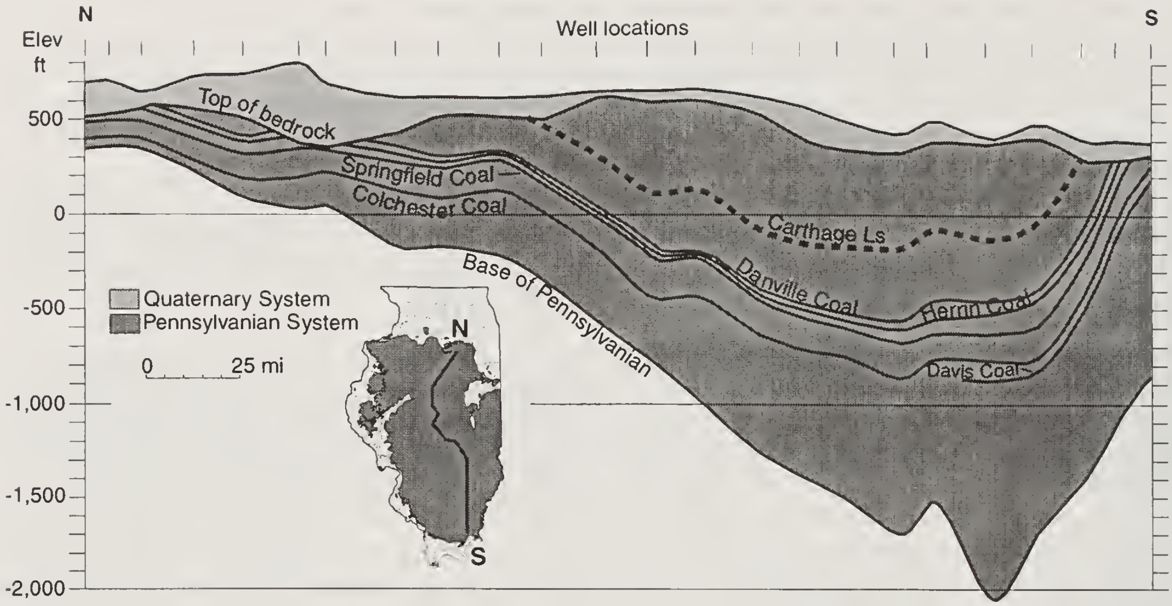



**Figure 2** North-south cross-section of the Pennsylvanian System in Illinois.

mined in Illinois for well over 100 years (fig. 5). In 1998, five Illinois mines produced a total of 12 million tons from the Springfield Coal; approximately 30% of total state production (Illinois Office of Mines and Minerals, personal communication). The thickest resources of Springfield Coal in Illinois are found in the central part of the state around the city of Springfield and in the southeastern part of the state along the Galatia Channel (fig. 6). Recent and historical mining of the coal has been concentrated in these areas and in shallow surface minable deposits west of the Illinois River. The coal is thin or absent in the southwestern and extreme northern portions of the coal field.

## Quality of Coal

The Springfield 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), with slightly lower ash contents reported in the southeastern part of the state. The sulfur content of the coal is commonly in the range of 3 to 5% (as received) except for areas in southeastern Illinois associated with the Galatia Channel (fig. 6). In these areas the sulfur content of the coal is as low as about 1%. 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 (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 been able to confirm 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 as a factor in determining the availability of coal. Although quality of coal is an extremely important factor in individual sales contracts and the magnitude of demand for coal, availability for mining of a specific deposit of Springfield Coal cannot be ruled out based strictly on coal quality. Because most of the Springfield Coal resources have a relatively high sulfur content, the demand for these resources is currently limited. However, the market for high sulfur coal, though 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 Springfield 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, much more coal quality data are needed to make such a characterization feasible.

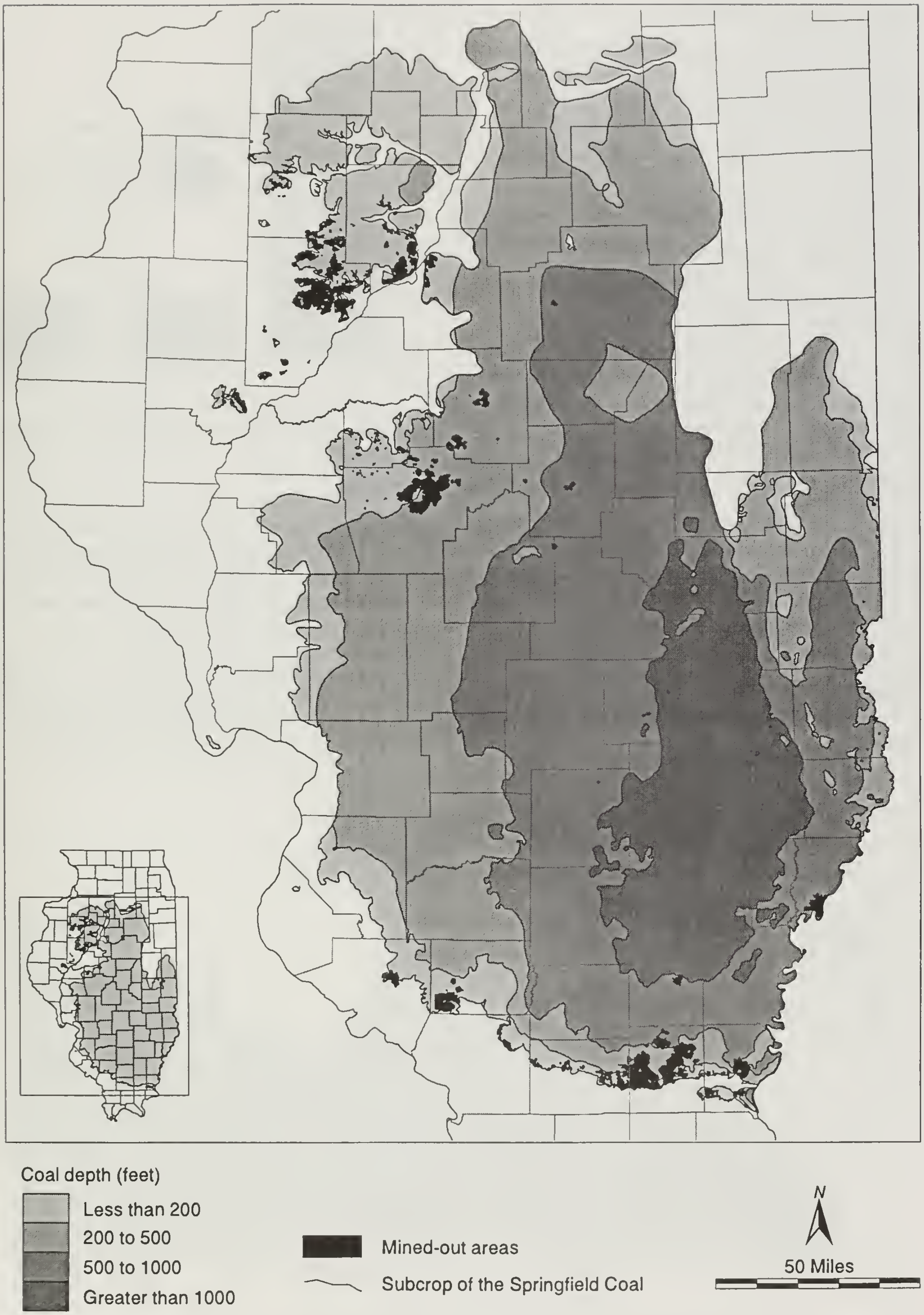



**Figure 3** Depth of the Springfield Coal.

## Quadrangle Studies

The criteria defining available resources were developed through a series of 21 assessments of 7.5-minute quadrangles (fig. 8; Treworgy et al. 1994, Treworgy et al. 1995, Jacobson et al. 1996, Treworgy et al. 1996a, Treworgy et al. 1996b, Treworgy et al. 1997a, Treworgy et al. 1998, Treworgy 1999, Treworgy et al. 1999, Treworgy and North forthcoming). 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).

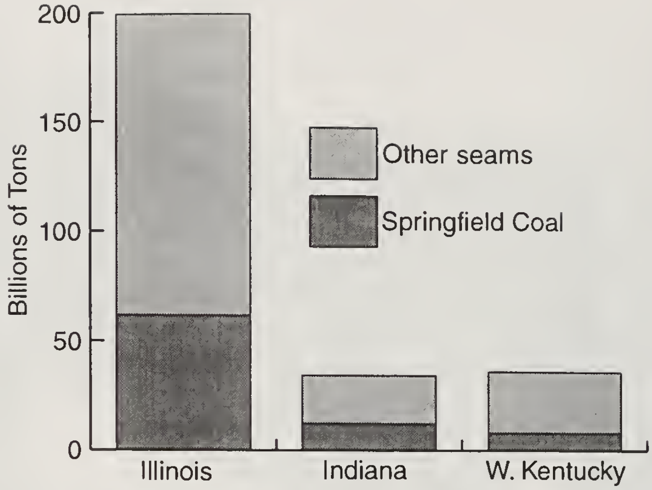



**Figure 4** Remaining coal resources in the Illinois Basin.

Quadrangles were selected to cover the range of physiographic and geologic conditions associated with mining Illinois coals. 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

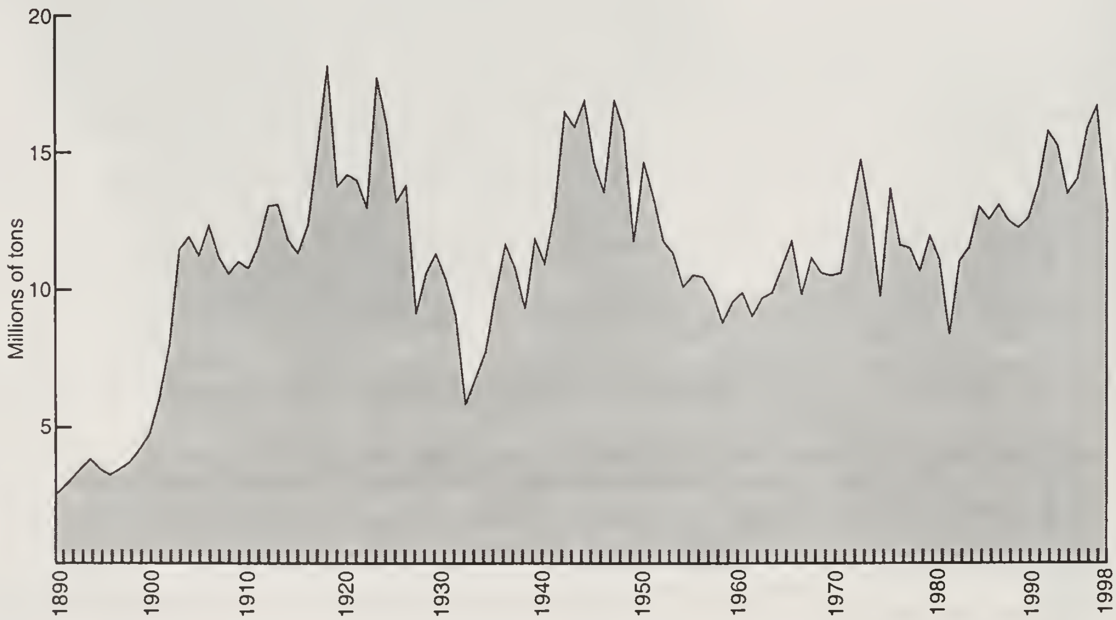



**Figure 5** Annual production of the Springfield Coal in Illinois.

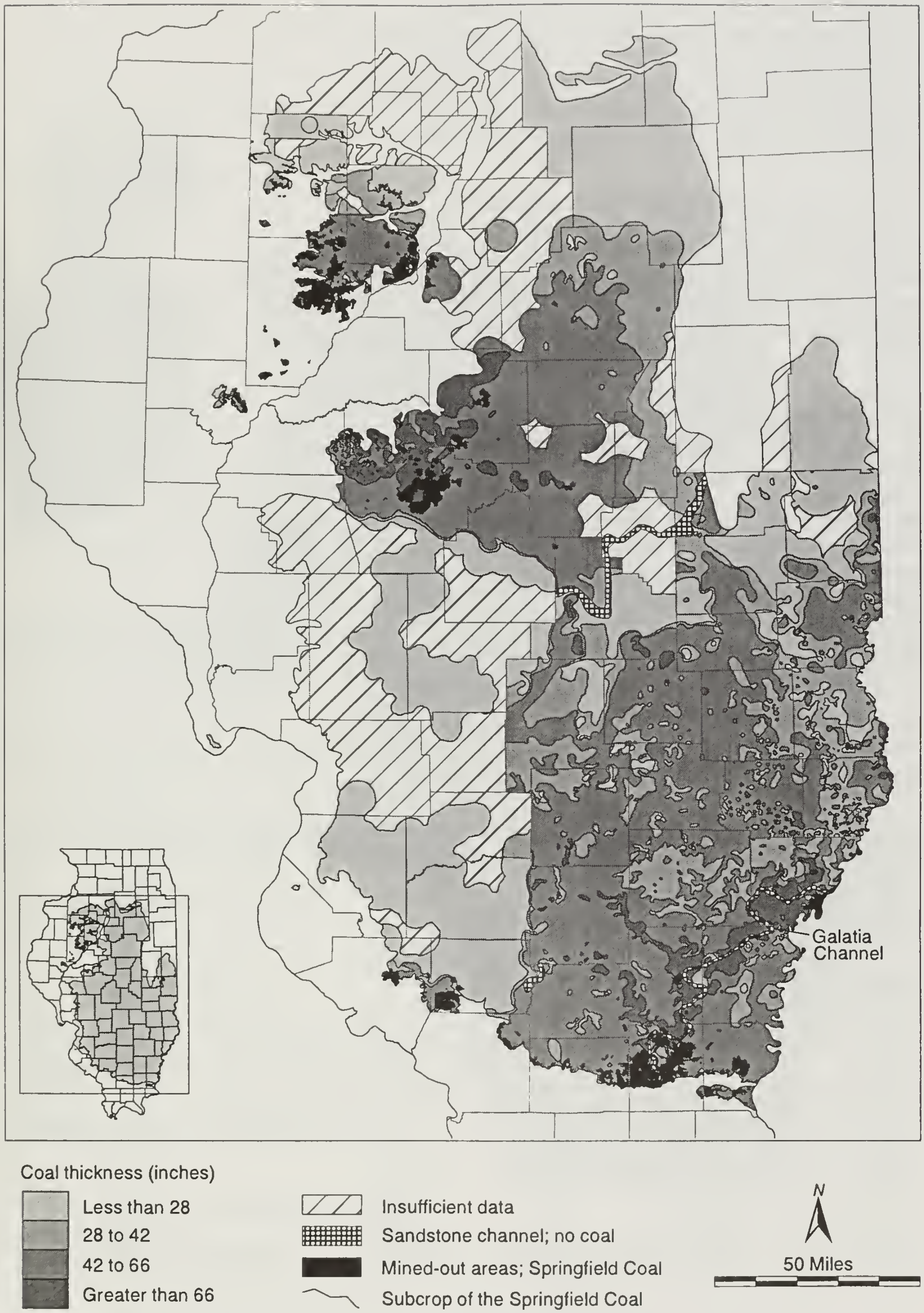



**Figure 6** Thickness of the Springfield Coal.

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 identify the factors that restrict significant quantities of resources from being minable.

Of the 21 quadrangles studied, 14 included some resources of the Springfield Coal (fig. 8, table 2). The total resource of Springfield Coal in these 14 quadrangles was more than 3 billion tons, about 5% of the original Springfield resources in the state. Availability of the coal in the 14 quadrangles ranged from none to 74% and was 38% overall.

## Sources of Data and Limitations of Maps

The data for this study were obtained from a variety of public and private sources and were of varying degrees of completeness and accuracy. Although some of the original data was accurate to within a few tens of feet (e.g. outlines of active mines), other data were more generalized. The overall accuracy of the combined data is designed for a map resolution of 1:500,000. Features or details of features smaller than about one-half mile across may not be accurately portrayed or may be omitted altogether.

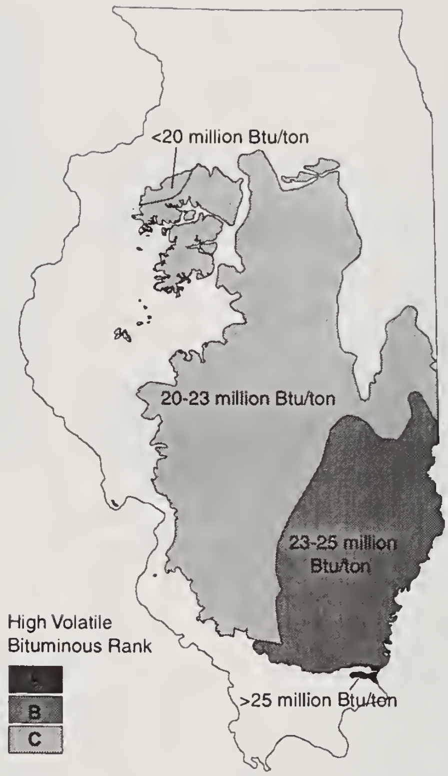



**Figure 7** Rank and heat content of the Springfield Coal (modified from Treworgy et al. 1997b).

**Table 2** Results of individual quadrangle studies. Tonnages are millions of tons. Numbers in parentheses are percent of original resources.

| | | | | Available | | Restrictions | |
|---|---|---|---|---|---|---|---|
| Quadrangle | Original | Mined | Remaining | Available | W/conditions | Technological | Land-use |
| Albion South | 438 | | 438(100) | 295 (67) | 34 (8) | 103 (24) | 7 (2) |
| Galatia | 296 | 88 (30) | 208 (70) | 44 (15) | | 133 (45) | 31 (10) |
| Middletown | 316 | 2 (1) | 314 (99) | 211 (67) | | 100 (32) | 3 (1) |
| Mt. Carmel | 303 | | 303 | 189 (62) | | 93 (31) | 21 (7) |
| Newton | 266 | | 266 | 0 (0) | | 250 (94) | 16 (6) |
| Peoria West | 180 | 53 (29) | 127 (71) | 7 (4) | 55 (31) | 28 (16) | 37 (21) |
| Pinckneyville | 139 | 21 (15) | 117 (84) | 22 (16) | 45 (32) | 11 (8) | 39 (28) |
| Princeville | 59 | | 59 | 0 (0) | | 51 (88) | 7 (12) |
| Shawneetown | 230 | 33 (14) | 198 (86) | 139 (60) | | 48 (21) | 11 (5) |
| Snyder-W. Union | 243 | | 243 | 0 (0) | 181 (75) | 60 (25) | 2 (1) |
| Springerton | 330 | | 330 | 245 (74) | 19 (6) | 60 (18) | 6 (2) |
| Tallula | 312 | 5 (2) | 308 (99) | 40 (13) | | 234 (75) | 33 (11) |
| Villa Grove | 21 | | 21 | 0 (0) | 0.4 (2) | 18 (86) | 3 (13) |
| Vincennes | 215 | | 215 | 77 (36) | | 101 (47) | 36 (17) |
| All combined | 3,348 | 202 (6) | 3,146 (94) | 1,270 (38) | 335 (10) | 1,290 (39) | 250 (7) |

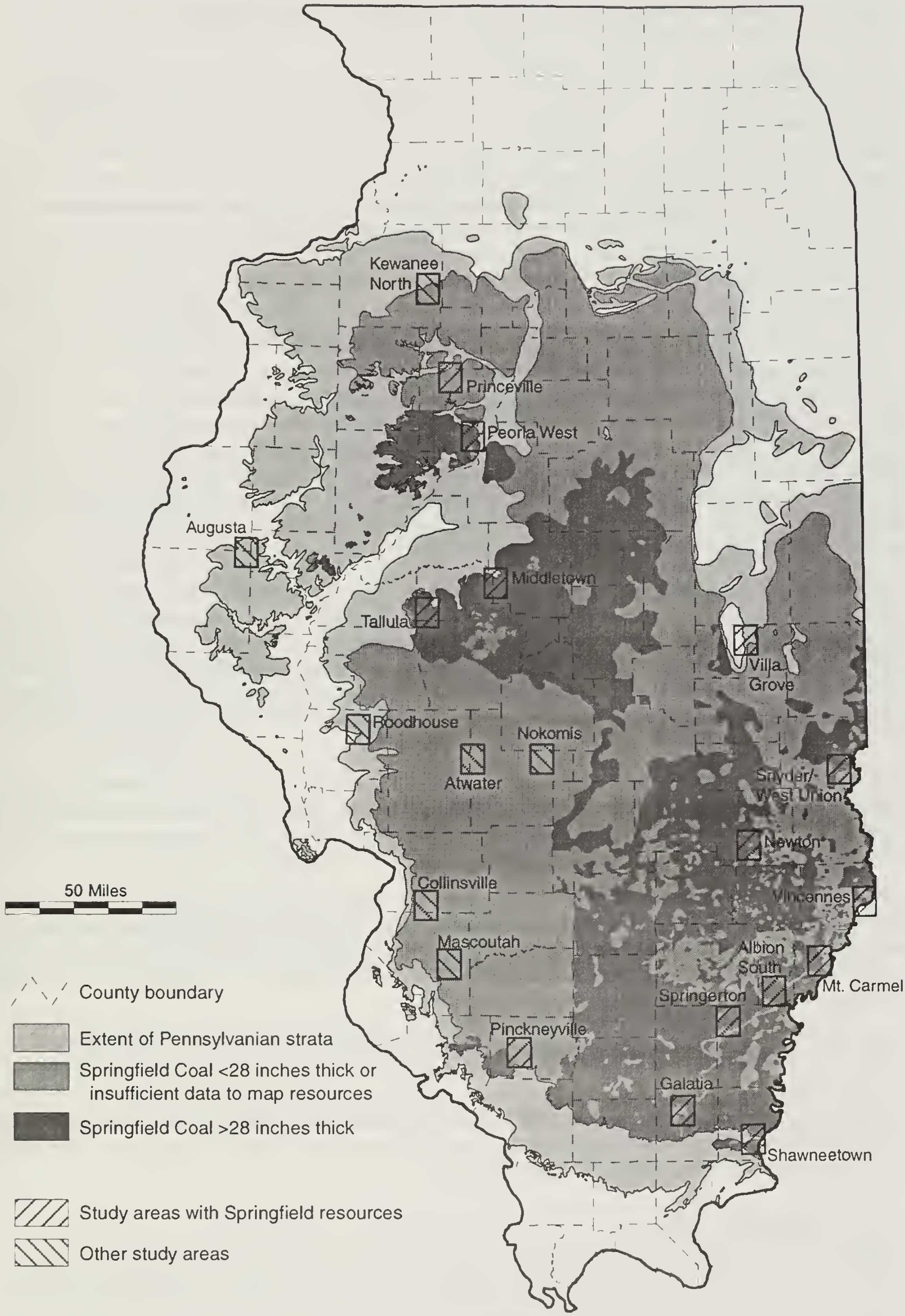



**Figure 8** Quadrangle study areas used to identify criteria for coal available for mining.

## 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 makes coal that is more expensive to mine uneconomic and 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 Springfield Coal are a composite set of rules based on our interviews with mining companies and the assessments of the 21 quadrangles. Additional information can be found in the reports on individual quadrangle studies 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 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.

Most factors used in this assessment could apply to any coal seam in Illinois. However, the specifics of certain criteria will vary from seam to seam. For example, the minimum thickness of bedrock for the Springfield Coal differs from that of the Herrin Coal because of the different competency 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 75 feet (if there is sufficient bedrock), resources that are 75 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 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 choice of surface or underground methods will depend 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

Table 3a Criteria used to define Springfield Coal available for surface mining in this study and previous quadrangle studies. See text for a detailed explanation of differences in criteria.

| Surface Mining Technological Restrictions | Statewide Study | Quadrangle Studies |
|---|---|---|
| Minimum seam thickness | 18 in. | 12 inches |
| Maximum depth: | 200 ft | 200 ft |
| Maximum unconsolidated overburden: | 60 feet | various* |
| Stripping ratio (cubic yards of overburden/ton of raw coal; volumes and weights not adjusted for swell factors or cleaning losses) | | |
| 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 ft of overburden**: | 150 | various |
| More than 50 ft of overburden**: | 500 | various |
| **Land-use restrictions** (width of unminable coal around feature) | | |
| Cemeteries | Not used | 100 ft |
| State parks & preserves | 100 ft | 100 ft |
| Railroads | 100 ft | 100 ft |
| Federal & state highways | 100 ft | 100 ft |
| Other paved roads (Peoria West only) | Not used | 100 ft |
| Major airports | 100 ft | 100 ft |
| High voltage transmission towers | Not used | 100 ft |
| Pipelines | 100 ft | 100 ft |
| Underground mines | 200 ft | 200 ft |
| Subdivisions | Not used | 500 ft |
| Towns | 0.5 mi | 0.5 mi |
| **Available with Conditions** | | |
| Only if surface mined in combination with overlying or underlying seam: | Not identified | Identified |
| Potential land-use conflicts: | Identified | Identified |
| All otherwise available surface minable coal in areas where land-use patterns are incompatible with mining. | | |

* Quadrangle studies used a sliding scale based on depth of coal.
** Quadrangle studies used less than 40 ft and more than 40 ft of overburden.

may elect to mine all of the coal by underground methods. Coals may be unavailable for surface mining due to their stripping ratio, a function of depth and thickness. Stripping ratio is discussed separately below.

**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, but Springfield Coal less than 18 inches thick is not known to 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.

Table 3b Criteria used to define Springfield Coal available for underground mining in this study and previous quadrangle studies. See text for a detailed explanation of differences in criteria.

| Underground Mining Technological Restrictions | Statewide Study | Quadrangle Studies |
|---|---|---|
| Minimum seam thickness: | 42 in. | 42 in. |
| Minimum bedrock cover: | 75 ft | 75 ft |
| Minimum ratio of bedrock to unconsolidated overburden | 1:1 | not used |
| Minimum interburden between minable seams: | 40 ft | 40 ft |
| 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 ft | variable |
| Subsidiary faults | 100 ft | none |
| Rend Lake Fault System | 200 ft | |
| Centralia Fault | 300 ft | |
| Wabash Valley Fault System | 800 ft | 1,000 ft |
| Galatia Channel: no mining within | 0.5 mi | 0.5 mi |
| Dykersburg Shale: | * | * |
| Partings: | | |
| Minimum yield: | Not used | 65% clean coal |
| Maximum thickness | Not used | ** |
| **Land-use restrictions** (width of unminable coal around feature) | | |
| Surface and underground mines | 200 ft | 200 ft |
| Towns | 0 ft | various |
| Subdivisions | Not used | various |
| Churches and schools | Not used | 100 ft |
| Cemeteries | Not used | 100 ft |
| High voltage transmission towers | Not used | 100 ft |
| Interstate Highways | 100 ft | 100 ft |
| Major airports | 100 ft | 100 ft |
| Dams | 100 ft | 100 ft |
| Closely-spaced oil wells | >7 wells per 40 acres | not used |
| **Available with Conditions** | | |
| 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 within in areas where land use patterns are incompatible with mining. | Identified | Identified |
| Coal quality limitations: | None | Resources with chlorine contents > 0.4% |
| Bedrock cover | 75-100 ft | not used |
| Dykersburg Shale | * | * |

* In this study, the transition zone at the edge of the Dykersburg shale is identified as a zone of potentially unstable roof, but not used as a restriction. In the Springerton and Albion South Quadrangles, there was no mining in areas with abrupt changes in Dykersburg Shale thickness

** The Springerton and Albion South Quadrangle studies stipulated no mining of individual benches of Springfield Coal where partings are more than 3 feet thick

**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, clay) and we did not use them in our calculations. Cubic yards of overburden was 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.

**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. 9). 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 dependent on the lithologic composition 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.

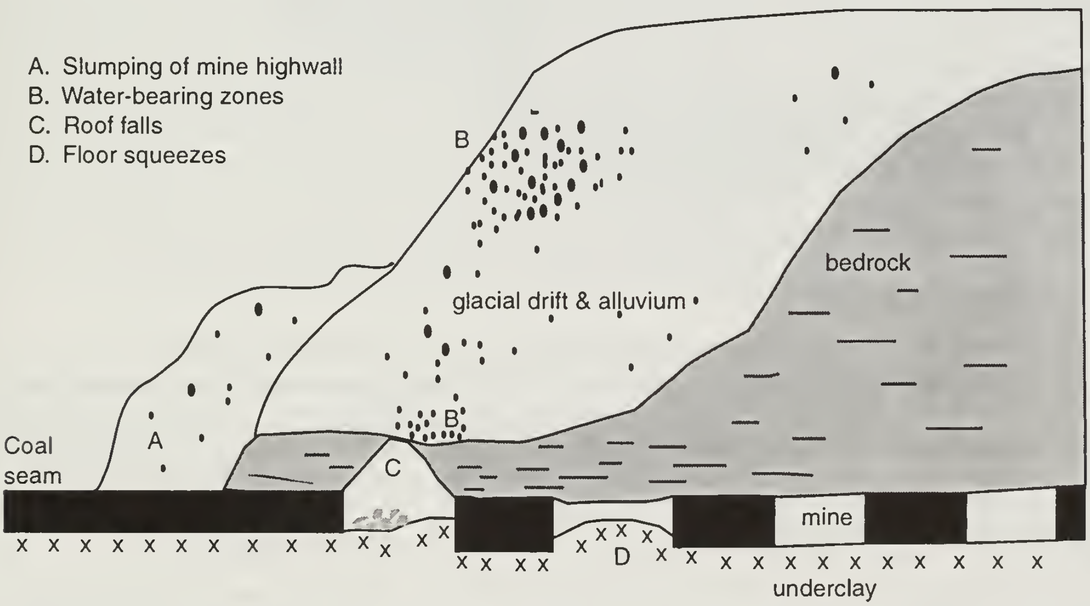



**Figure 9** Problems encountered in surface and underground mines that have overburden consisting of thick unconsolidated sediments over thin bedrock (from Treworgy et al. 1998).

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 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 will be avoided.

Because of the resolution of the bedrock cover and drift thickness maps used in this study, the only criteria we used for surface mining was a maximum of 60 feet of unconsolidated overburden. Thick, unconsolidated sediment limits surface mining in the southeastern corner, central and northwestern areas of the coal field (fig. 10).

**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. drilling, land acquisition, construction of surface facilities, initial box cuts and shafts and purchase of equipment). Because of lower development costs, greater equipment mobility and flexibility in operating plans, surface mines can be developed with smaller reserves and mining blocks than underground mines. Surface mines can be developed using trucks and earthmoving 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 making 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 and 80 acres, respectively.

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 irregular-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, though 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, we found it impractical to map small features such as transmission towers, rural subdivisions, schools, churches and cemeteries. Since these features typically affected less than 1 percent 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. 11).

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.

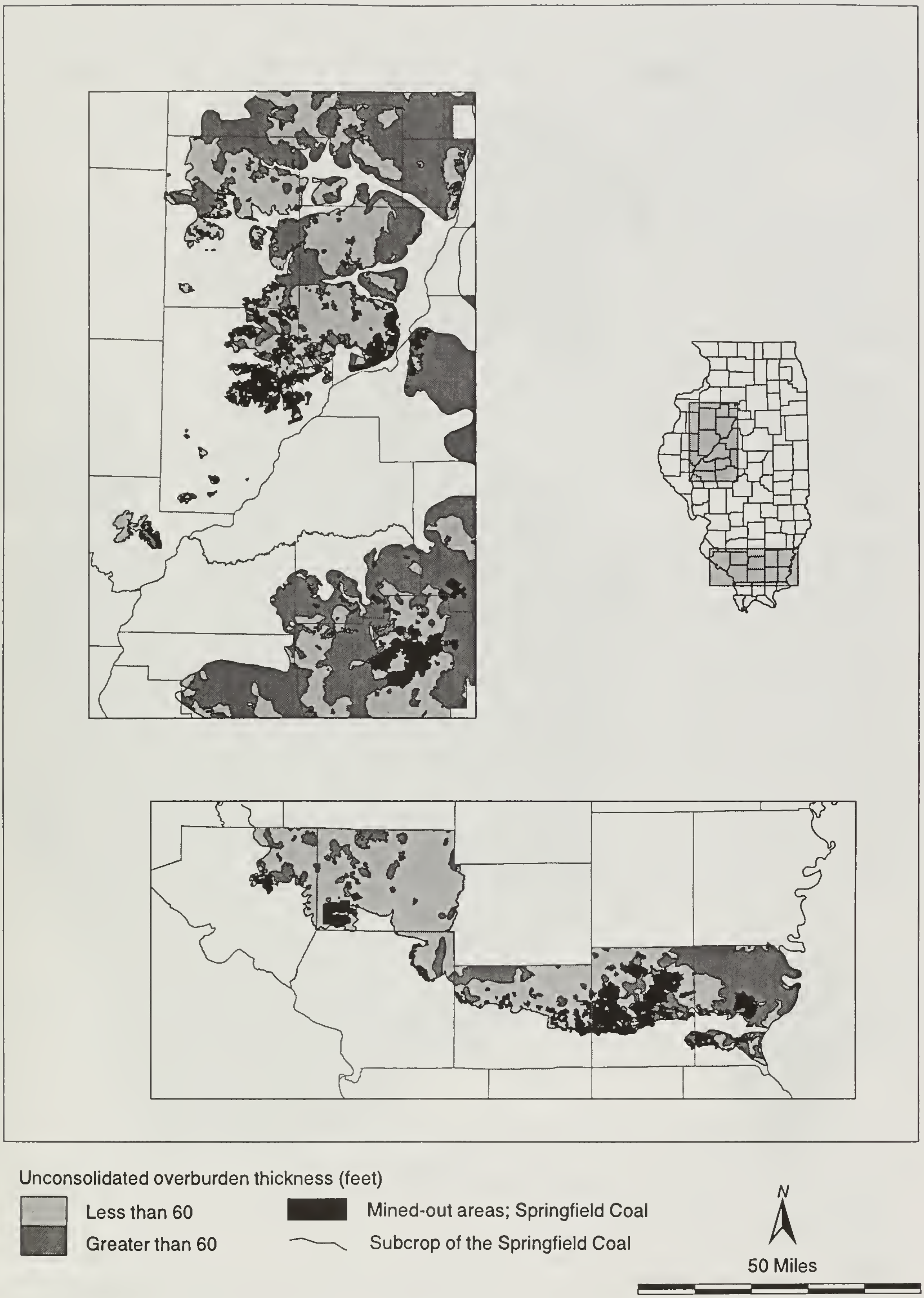



**Figure 10** Thickness of unconsolidated overburden in counties with surface minable resources of Springfield Coal.

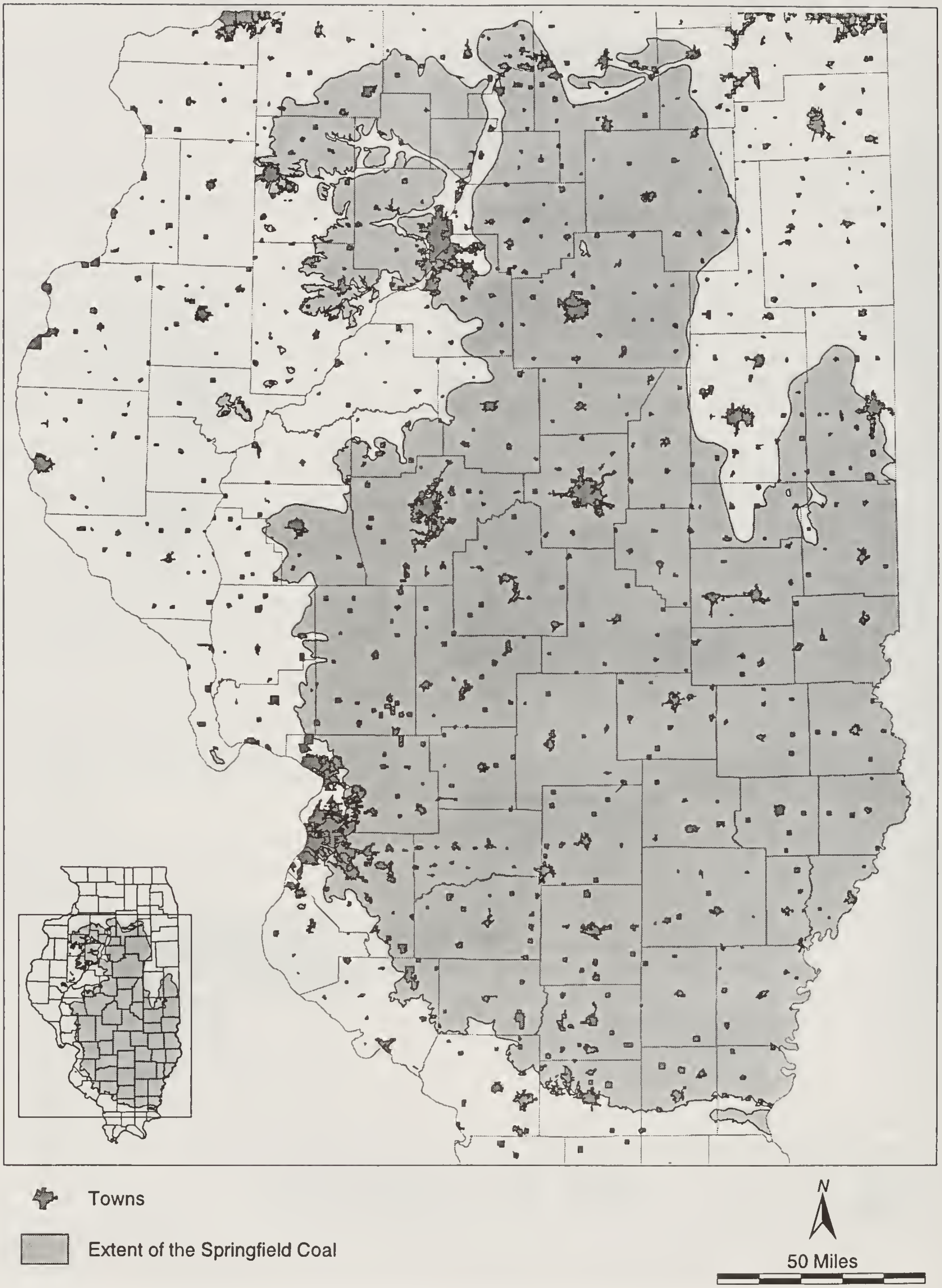



**Figure 11** Towns in the vicinity of the Springfield Coal.

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. 12). An additional 1 to 2% of resources are 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 13, 14 and 15). 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 will 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, we assumed that surface mines will be permitted to mine through any mine in an overlying seam and to mine within 200 feet of underground mines in the Springfield Coal.

**Surface Mining of Multiple Seams** In our assessments of the Peoria West and Pinckneyville Quadrangles we found that additional Springfield Coal was available for surface mining if mined in combination with the overlying Herrin Coal. In these cases the additional tonnage of the overlying Herrin Coal reduces the stripping ratio of the Springfield Coal to less than 25:1. The interval between the coals in the Pinckneyville Quadrangle is only 25 feet and combined mining of the two seams adds 34% of the Springfield resources to the available category. In the Peoria West Quadrangle, the interval between the seams is about 65 feet and the additional available tonnage amounts to only 2% of the resources.

Opportunities for multi-seam mining were not evaluated in this statewide assessment of the Springfield Coal. Although the assessments of the Pinckneyville and Peoria West quadrangles showed that additional Springfield Coal would be available if mined in combination with the Herrin Coal, the potential for this is limited to a small area. Multi-seam mining probably could increase the tonnage of available coal in parts of northwestern Illinois by a few percent, but the potential for multi-seam surface mining in west-central and southwestern Illinois is limited. Also, the recent trend in southern Illinois is to mine the Herrin Coal underground, even where it is at a depth that could be surface mined in combination with the Springfield Coal.

## Underground Minable Coal

**Depth of Seam** The Springfield 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. Springfield Coal as deep as 800 feet is currently being mined, and other coals as deep as 1,000 feet are mined.

**Thickness of Seam** For this study, 42 inches is the minimum thickness of available coal 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. This high initial capital investment, 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 uneconomic 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 this scenario is not large.

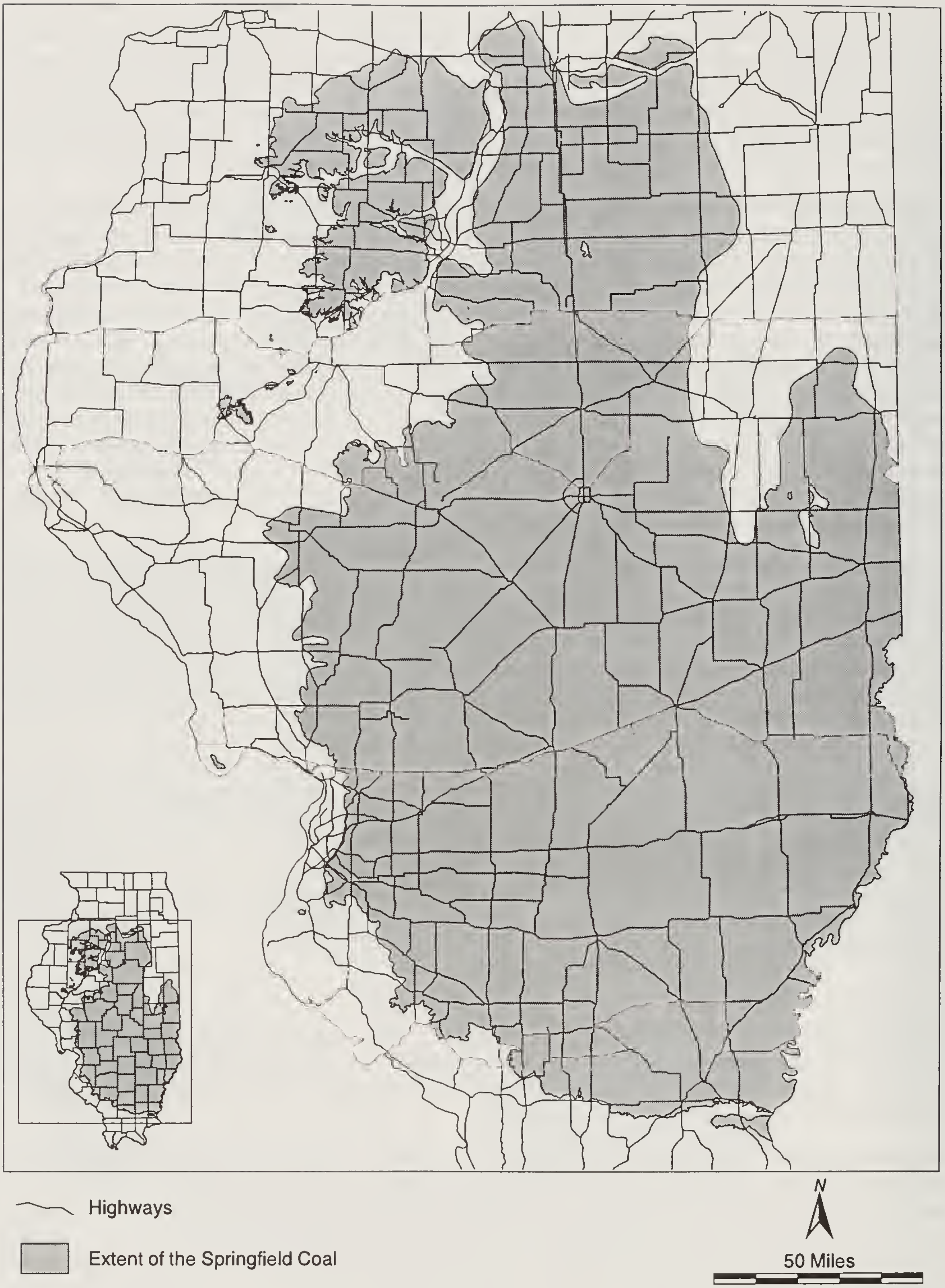



**Figure 12** State and Federal highways in the vicinity of the Springfield Coal.

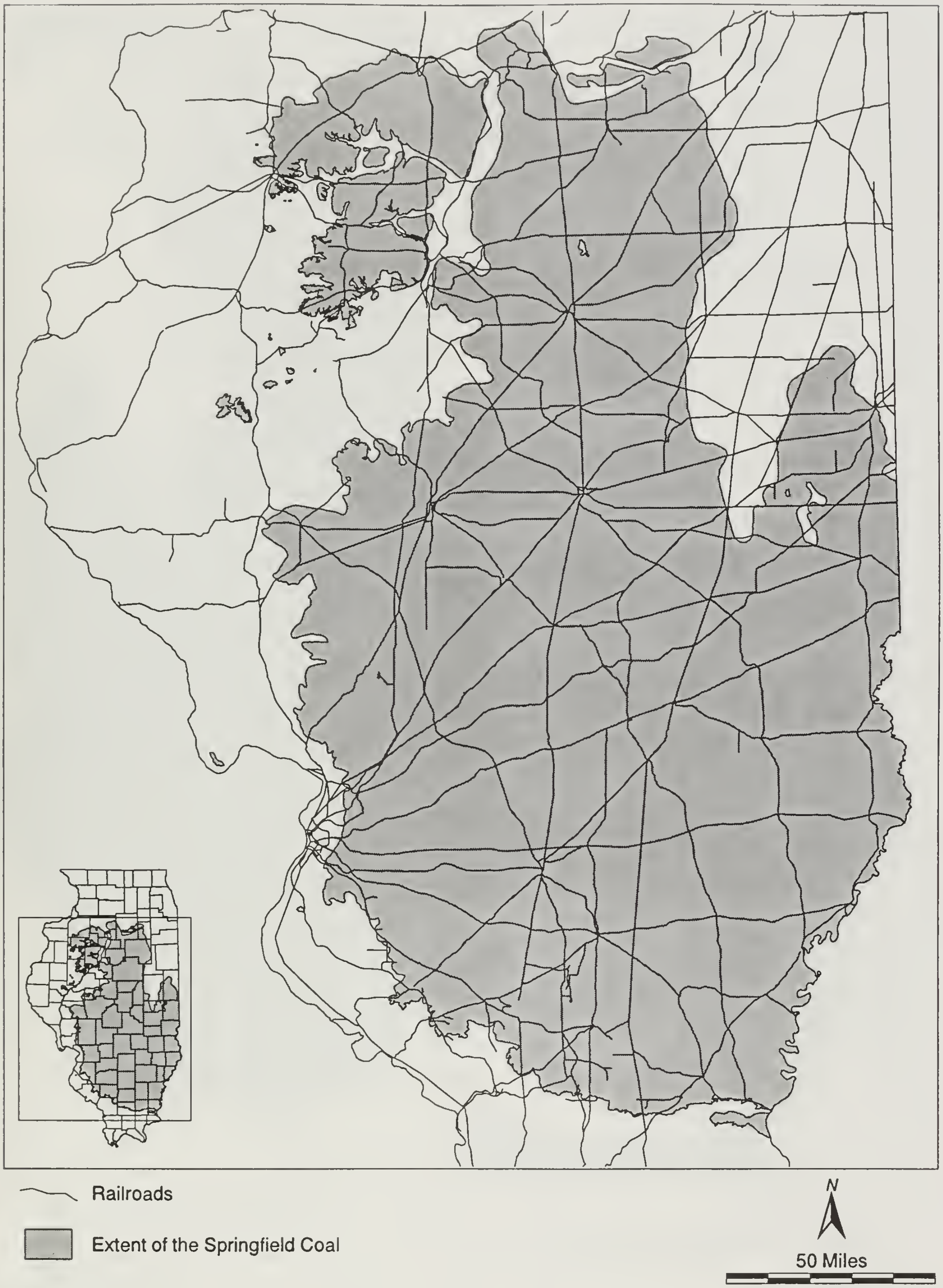



**Figure 13** Railroads in the vicinity of the Springfield Coal.

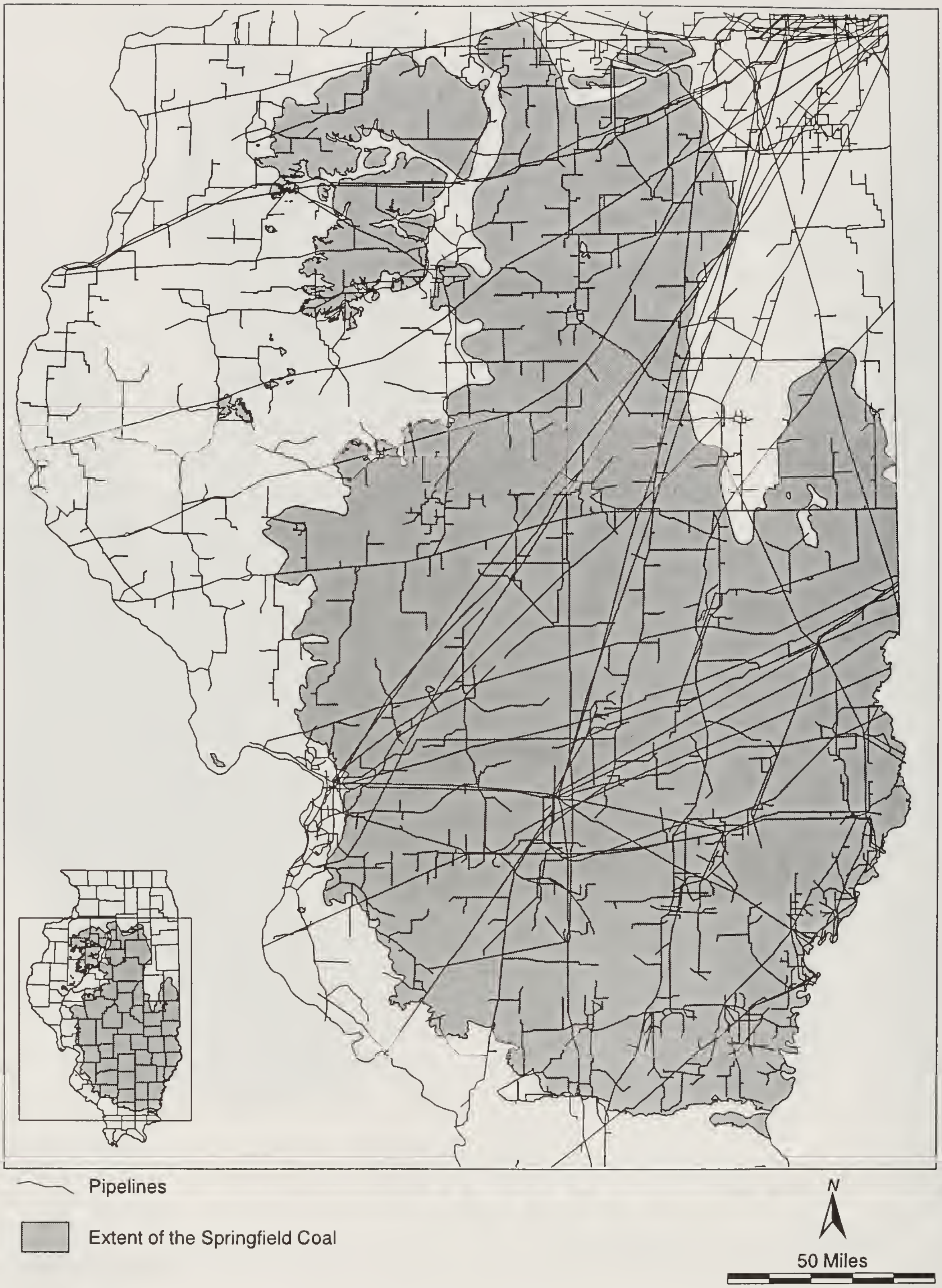



**Figure 14** Pipelines in the vicinity of the Springfield Coal.

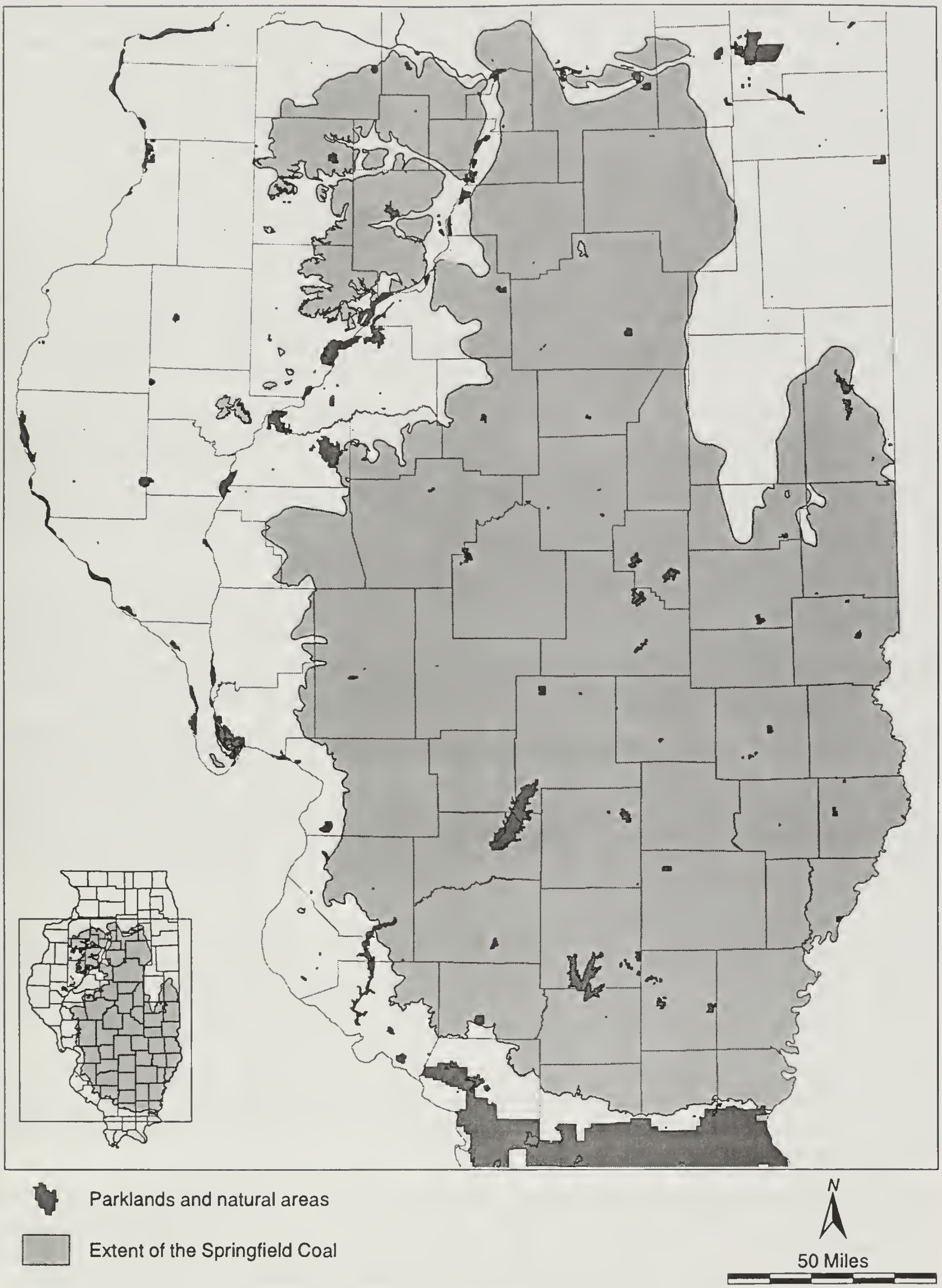



**Figure 15** Parks and natural areas in the vicinity of the Springfield Coal.

**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. 9). If the bedrock cover is too thin (or is significantly weathered), the mine roof may not be strong enough to support the overburden. Unconsolidated overburden material (glacial drift and alluvium) is not self-supporting and can add considerable pressure to the mine roof and pillars. 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.

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 and allow water to enter the mine. At best, water seepage makes the movement of equipment more difficult and creates additional expenses for pumping and disposing of the water. In the worst case, the influx of water is rapid and equipment may be damaged and the lives of miners threatened. In 1883, 69 miners drowned in the Diamond Mine near Braidwood (Illinois Dept. 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).

A conservative rule used by some companies that is likely to guarantee good mining conditions is that the thickness of bedrock overburden should exceed the thickness of unconsolidated overburden (i.e. the ratio of bedrock to unconsolidated overburden should be greater than 1:1). The amount of bedrock required can vary, depending on local geologic conditions such as the depth of the seam, composition of the bedrock overburden and thickness of the glacial overburden. Rock strength tests are needed to determine the minimum bedrock for specific areas.

For these studies we used two criteria: a minimum bedrock thickness and a minimum ratio of bedrock to unconsolidated material. We used 75 feet as the minimum thickness of bedrock for underground mining of the Springfield Coal based on mining experience in areas near the outcrop. In most areas of the state, the overburden above the coal consists of shale with few if any competent limestone beds. Thin bedrock cover is found along the outcrop of the Springfield Coal throughout the state (fig. 16).

For areas further from the outcrop with excessively thick unconsolidated sediments (100 to 300 feet thick), mine experience suggests a minimum ratio of 1:1 bedrock to unconsolidated overburden 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 not been any 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 criteria is applicable or whether a certain minimum bedrock thickness may be adequate.

Areas where the ratio of bedrock to unconsolidated overburden is less than 1:1 are especially widespread in the northern part of the state due to the presence of deep bedrock valleys filled with unconsolidated sediment (fig. 17). 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 criteria have less than 200 feet of bedrock and more than 200 feet of unconsolidated overburden.

Resources with 75 to 100 feet of bedrock and a bedrock to unconsolidated overburden ratio of greater then 1:1 were classified as available with conditions. These resources probably can be mined successfully, but depending on local conditions, some precautions may be necessary to mitigate potential problems from thin bedrock cover.

**Thickness of Interburden Between Seams** The interburden between two coal seams must contain competent strata of sufficient thickness so that mining of one seam will not disrupt the stability of the roof or 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, 1987b). Mining experts interviewed for Illinois commonly cited 40 feet as the minimum thickness of interburden. In cases where the interburden is less than 40 feet thick only one of the seams may be mined (fig. 18). 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.

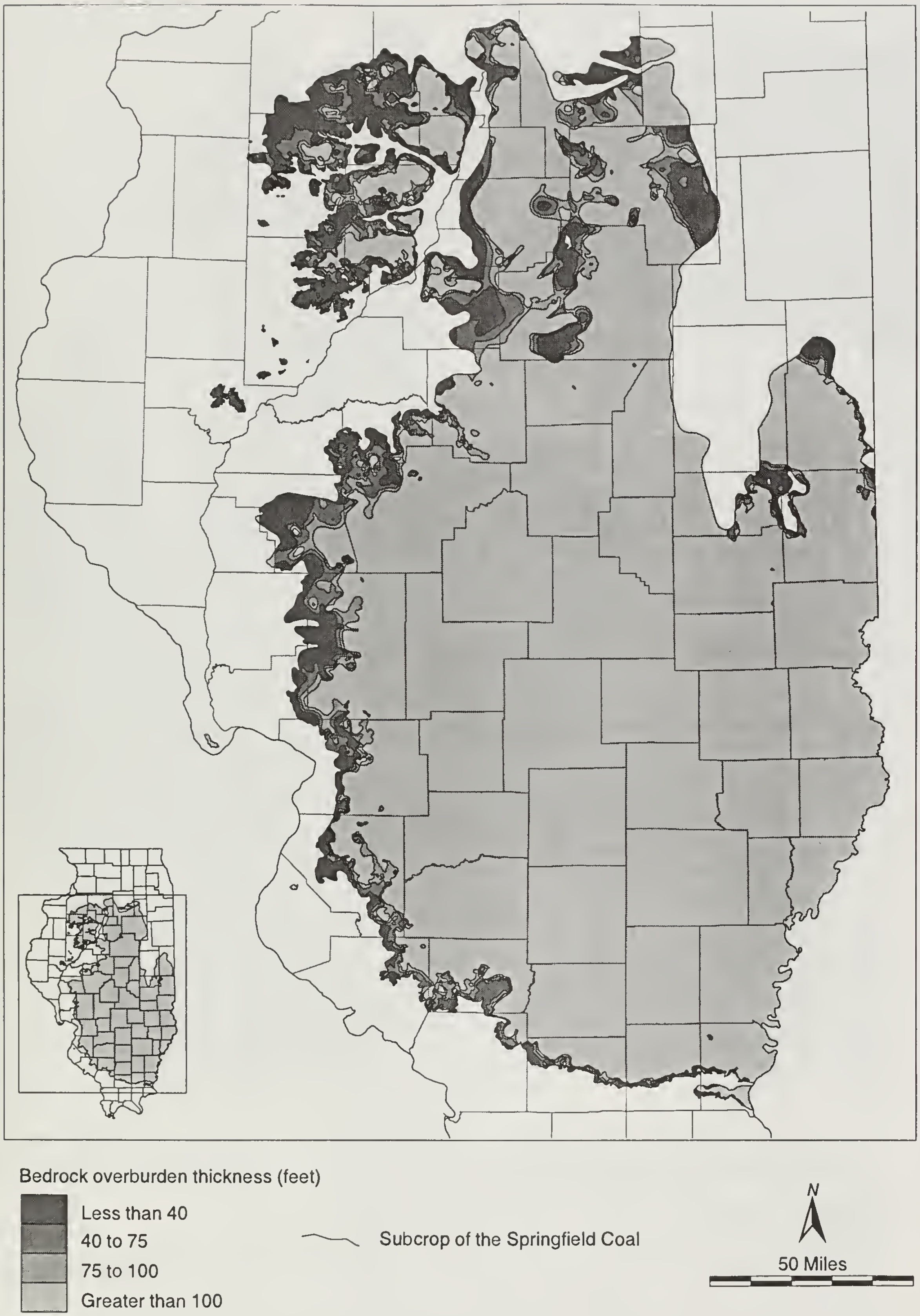



**Figure 16** Thickness of bedrock overburden, Springfield Coal.

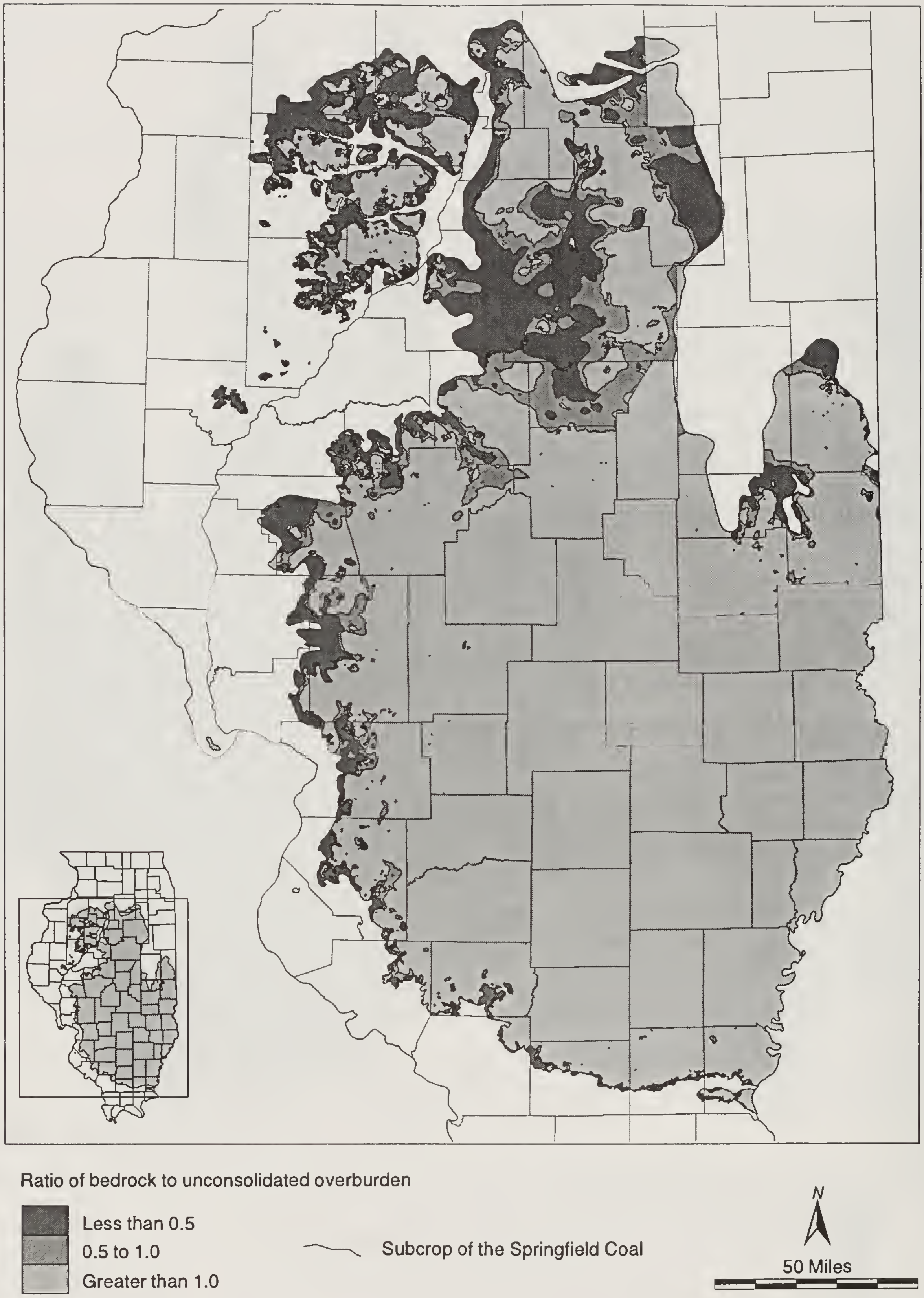



**Figure 17** Ratio of the thickness of bedrock to unconsolidated overburden, Springfield Coal.

Three coal seams are found within 40 feet of the Springfield Coal: the Herrin and Briar Hill Coals above and the Houchin Creek Coal below. Commonly, the Briar Hill and Houchin Creek Coals are thinner than the Springfield and therefore the Springfield will be the preferred seam of the three for mining. The Herrin Coal may be equal to or greater in thickness than the Springfield Coal and has already been mined in a large area of southern Illinois where the two seams have less then 40 feet of interburden (fig. 19).

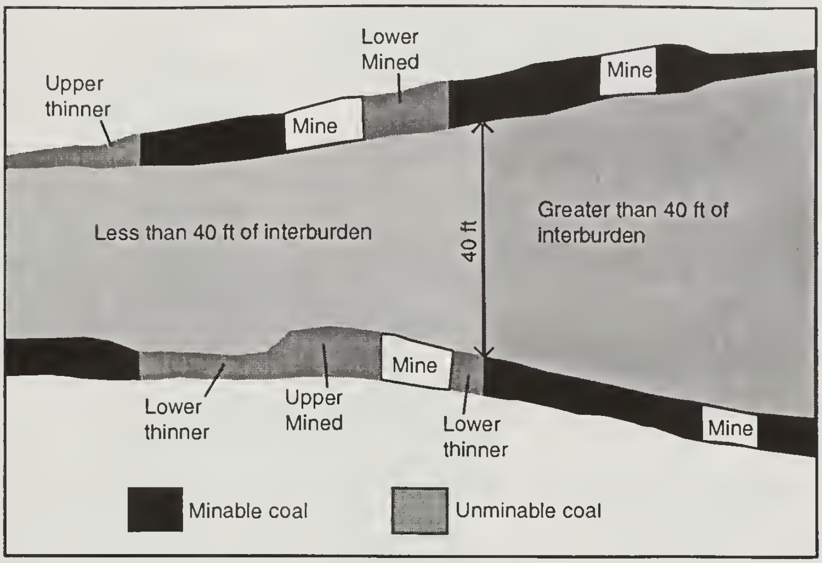



**Figure 18** Effect of interburden thickness on the minability of coal seams.

**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 re-enter 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, the fault zone may contain multiple, parallel faults that create a zone of disturbance hundreds of feet wide (fig. 20).

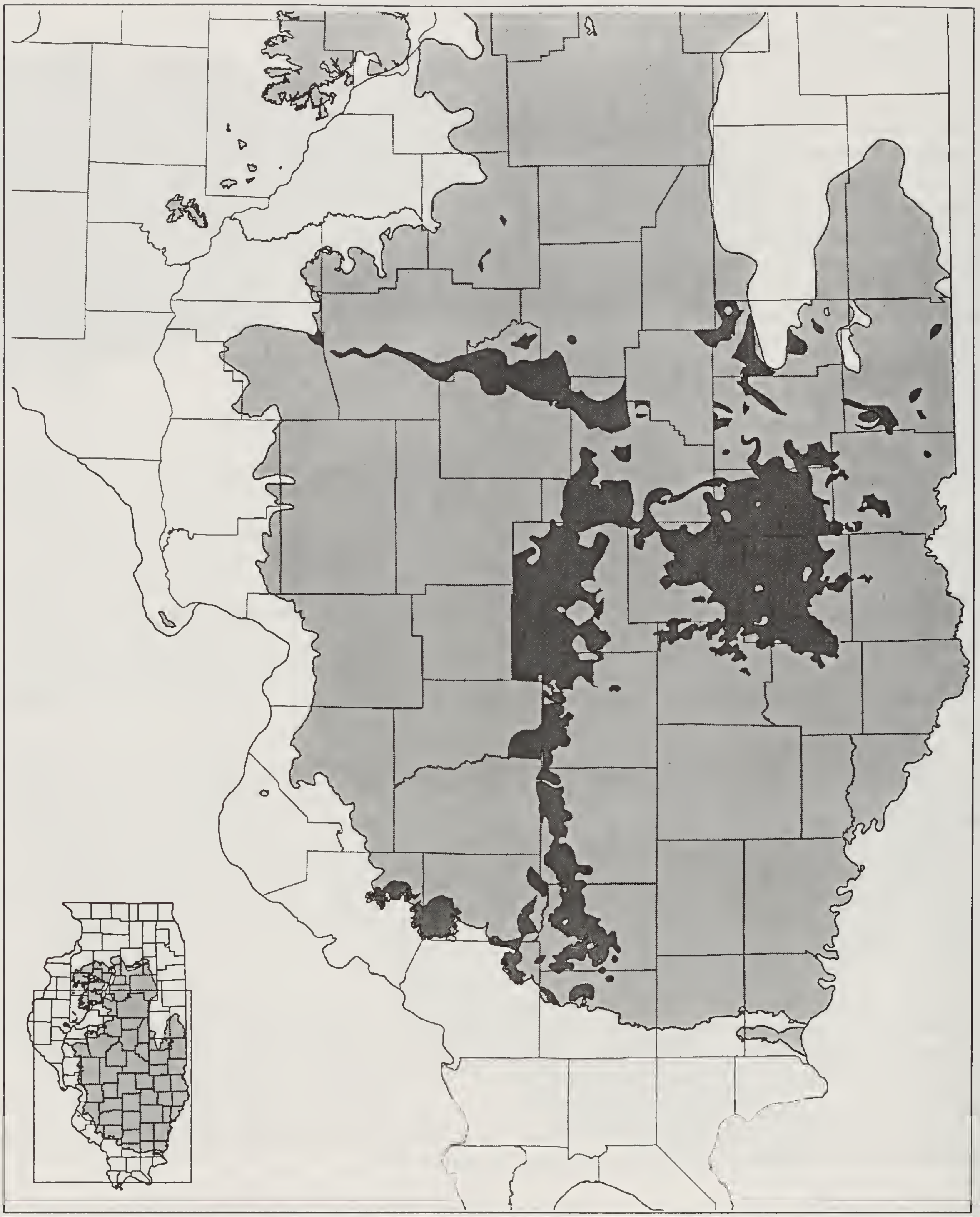
For example, mine operators in the Wabash Valley Fault System have encountered numerous minor faults, intense jointing and substantial dips in the coal seam within a zone several hundred feet wide parallel to the main fault (Marvin Thompson and Alan Kern, personal communication). Some large inflows of 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. 21).

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 Springfield 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. 22 and table 4).

**Table 4** Average total width of fault zone assumed to be unminable (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 |

**Igneous Dikes** Vertical or near-vertical wall-like, linear masses of igneous rock are found in southwestern 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. Although one 300-foot wide dike has been encountered, most dikes are a 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



Interburden thickness (feet)

Less than 40 and Herrin thicker than Springfield or Herrin mined

Greater than 40 or Herrin thinner than Springfield

Subcrop of the Springfield Coal

N

50 Miles

**Figure 19** Areas where the thickness of the interburden between the Herrin and Springfield Coals may restrict underground mining of the Springfield Coal.

dike would be left unmined. This tonnage is included in the tonnage restricted by faults.

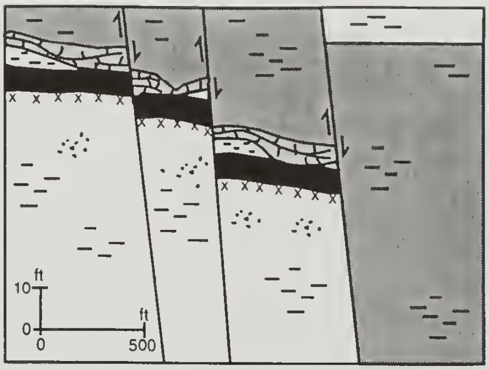



Figure 20 Cross section illustrating multiple, parallel faults displacing a coal seam.

**Partings** Accumulation of peat was periodically interrupted by deposition of clastic sediments from nearby streams. These layers of sediment, commonly called partings, can be a fraction of an inch to tens of feet thick (fig. 23). 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 more than a few inches thick in coal left in the mine as pillars tend to slough off and reduce the stability of pillars (Jeffrey Padgett, personal communication). Over time, this 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. 24). Partings restrict mining if they create inaccessible coal or unstable roof conditions or if the yield of clean coal (tonnage of saleable coal divided by tonnage of material mined) falls below an economical level. Small areas of low yield will be mined if necessary to access other reserves. Large areas with excessive parting material are not mined.

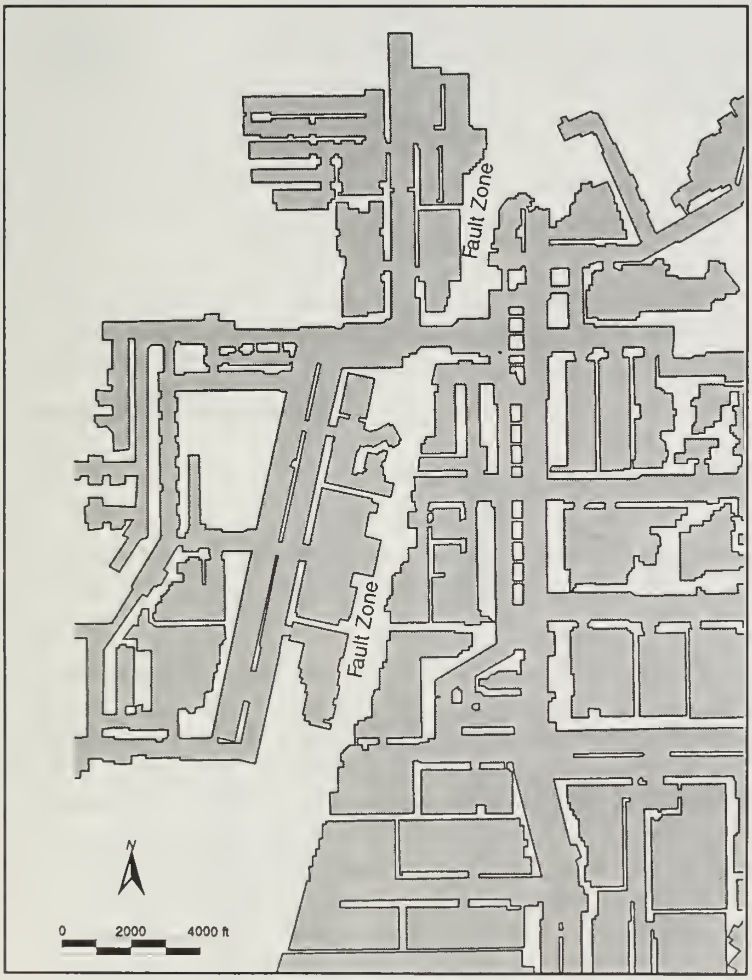



Figure 21 Unmined areas adjacent to one of the faults in the Wabash Valley Fault System (from Treworgy et al. 1998).

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 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. However, thick partings in the Springfield Coal adjacent to the Galatia Channel, as shown in figs. 24d-g, present special problems. These partings thicken over such a short distance that the upper bench of coal has too steep a pitch to mine. The parting material consists of laminated shale that is so weak it is difficult to bolt and massive roof falls are common. The companies familiar with these conditions said they would avoid mining either bench of coal. For this statewide assess-

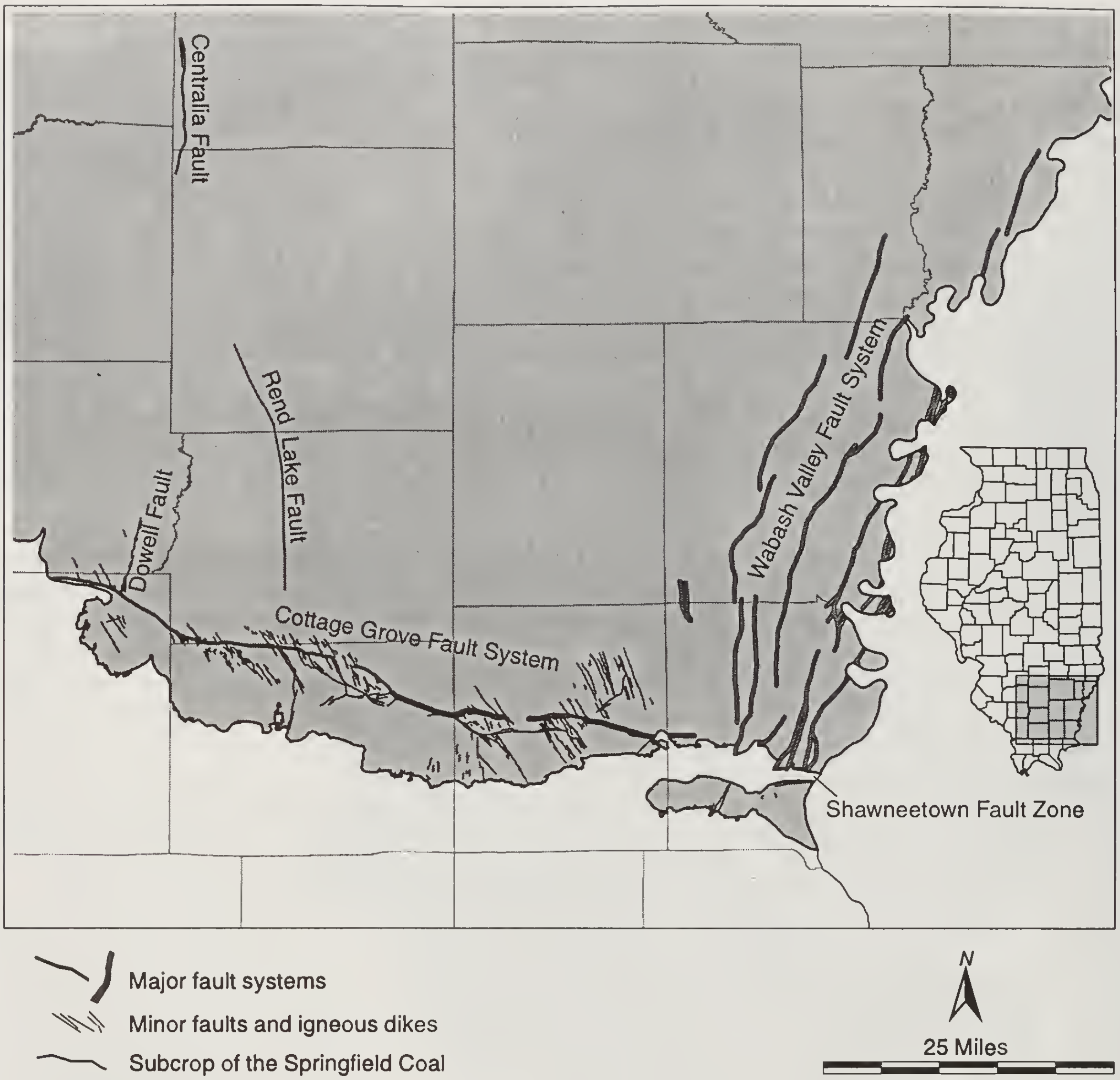



**Figure 22** Areas of Springfield Coal affected by faults and igneous dikes.

ment, we assumed that most thick partings will occur within the zone of coal restricted by the Galatia Channel and no separate mapping of partings was carried out (see following section on the Galatia Channel).

**Galatia Channel and Dykersburg Shale** The Galatia Channel, a drainageway through and contemporaneous with the peat swamp of the Springfield Coal, has strongly influenced the thickness, quality and minability of the Springfield Coal (figs. 25 and 26). The coal is generally thick (6 feet to more than 8 feet) in a zone along and extending from one to several miles away from this channel (Hopkins 1968). 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 Dykersburg Shale Member. This is a unit of light to dark gray shales, siltstones and sandstones deposited directly on top of the Springfield Coal along a wide zone along the Galatia Channel. The unit is as much as 100 feet thick adjacent to the channel and thins and pinches out from the channel for several hundred feet to several miles.

The Dykersburg makes a stable roof with two known exceptions: certain facies found near the Galatia Channel and in areas where there is an abrupt change in thickness of the Dykersburg over a short distance (fig. 26). Near the channel, finely laminated shale and water-bearing sandstone are found. Both lithologies make unstable mine roofs. Areas of abrupt thinning, (e.g. thinning 60 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. Because of the severity of the roof falls experienced in these areas, companies avoid mining under areas of abrupt changes in the thickness of the Dykersburg.

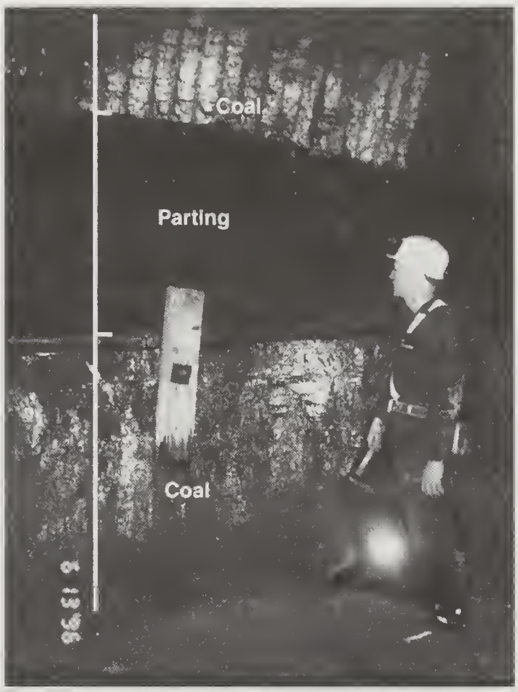



**Figure 23** Parting in the Springfield Coal in an underground mine near the Galatia Channel.

A possible third zone of weak roof conditions may exist at the edges of the Dykersburg Shale. Mining companies reported encountering poor roof conditions in some areas of both the Energy Shale (a unit above the Herrin Coal, but depositionally analogous to the Dykersburg) and the Dykersburg Shale at the deposit's margins where the shale is about 10 to 20 feet thick (Rogers 1981, Treworgy et al. 1996b, Frankie et al. 1996). The shale in these areas does not bond well to the overlying strata and is difficult to hold with roof bolts. Coal has been mined under the margins of the Dykersburg Shale only in limited areas, so the extent and severity of mining problems that may be encountered is not fully understood (fig. 25). The transition zone between thick Dykersburg Shale and the edge of the Dykersburg was delineated for this study. Because unstable roof conditions may be encountered in this transition zone, the coal within this zone that would otherwise be available for mining was placed in the "available with conditions" category.

Other problems that create poor mining conditions encountered near the Galatia 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 abandoned if conditions are found to be unfavorable. In some areas, severe problems have been encountered as much as a mile from the channel.

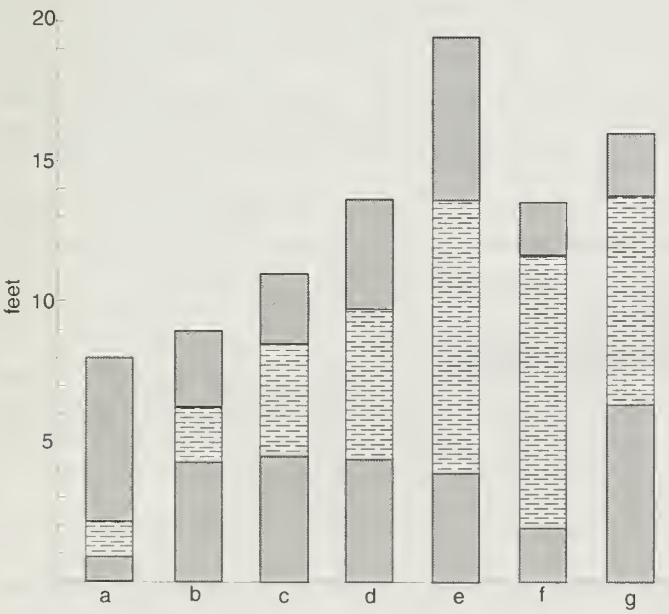



**Figure 24** Examples of partings in the Springfield Coal in the Springerton Quadrangle (from Treworgy et al. 1998).

Because drill holes spaced only a few hundred feet apart are needed to identify many of the undesirable geologic features associated with the Galatia Channel and the Dykersburg 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 Galatia Channel, this study considered coal less than a half mile from the channel to be unavailable for mining. In some areas this coal may ultimately be found to be minable, but in other areas coal farther from the channel will likely be found to be unminable.

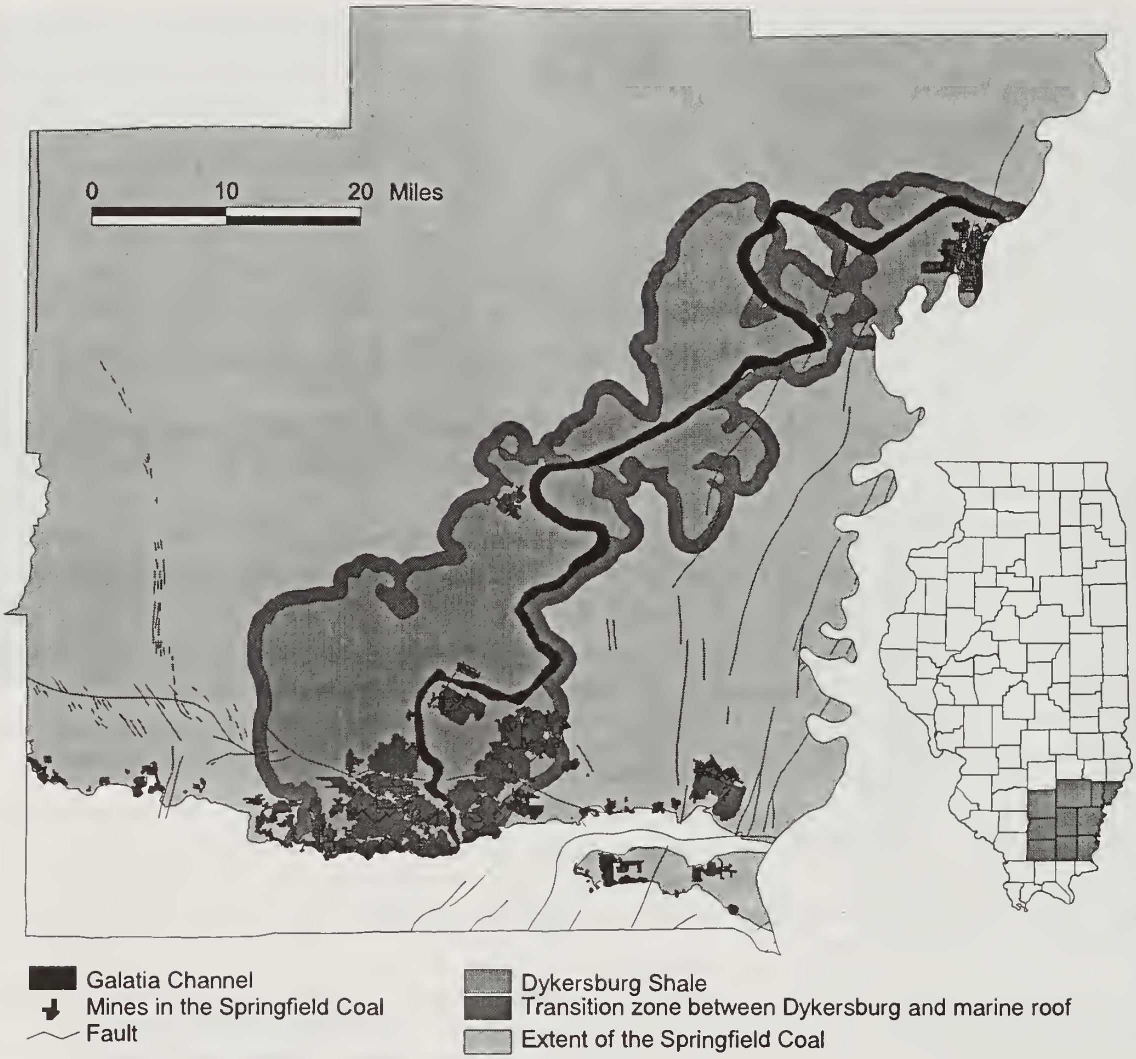



**Figure 25** Extent of the Dykersburg Shale and the Galatia Channel.

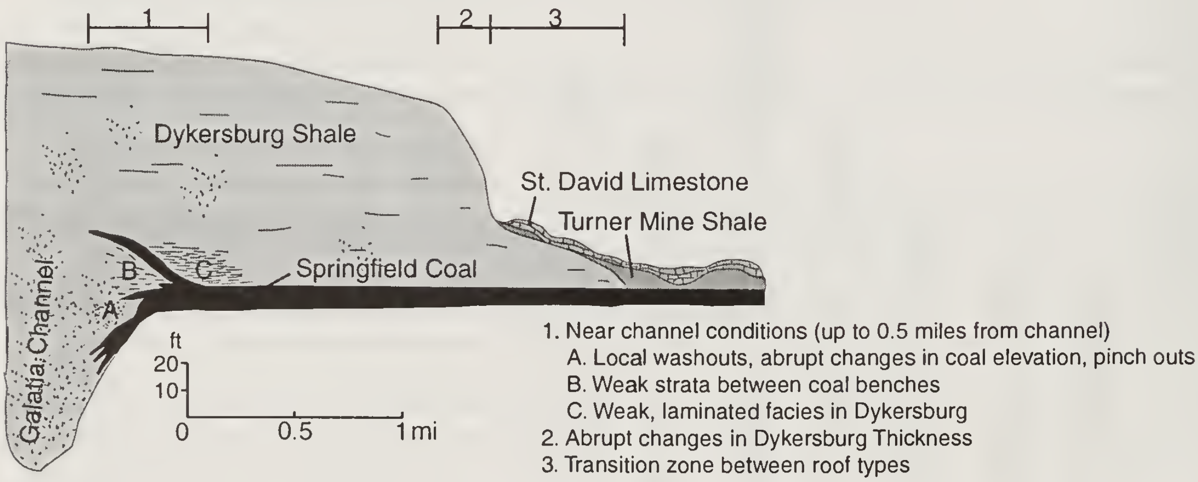



**Figure 26** Areas of adverse mining conditions in the Springfield Coal near the Galatia Channel (from Treworgy et al. 1998).

**Size and Configuration of Mining Block** In the quadrangle assessments of the Springfield Coal, 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, boxcut or shallow slope and 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 these investments.

Mine blocks must also have dimensions that are suitable for layout of a mine. Narrow blocks of coal with convoluted shapes (such as between abandoned mines or other barriers) cannot be safely and 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 was in narrow blocks between mined areas that had configurations unsuitable for layout of a mine.

**Land Use** The quadrangle studies identified a number of features 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 companies that we have 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 for 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. Some oil fields developed during this period have wells on spacings of 5 acres or less. 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 constitute 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 not insignificant). If a well is active, the company must negotiate its purchase. 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, as well as 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, whereas wells in strategic areas needed for main entries or development of longwall panels may be worth plugging.

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. 27). Resources in areas with four to seven wells per 40 acres are considered to be available with conditions 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 8 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 Springfield Coal occur in the vicinity of Peoria, East Peoria and Pekin. These communities and related developments extend for miles away from the Illinois River along major roadways. 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.

**Sandstone Overlying Coal** In our quadrangle assessments of the Herrin Coal we learned that severe roof problems are encountered in places where the Anvil Rock Sandstone 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 roof bolts, is commonly 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. Similar conditions can be expected in the Springfield Coal where a sandstone (either the Vermilionville Sandstone, a sandy facies of the Dykersburg, or possibly the Anvil Rock Sandstone) is present in the immediate roof. Companies reported difficult conditions in their mines where one of these sandstones was present above the coal. The Vermilionville Sandstone is known to be present in southeastern Illinois. Because none of the mines in the Springfield Coal in Illinois have encountered these conditions and no maps have been made of areas where these conditions are likely to occur, the presence of sandstone in the immediate roof was not considered in this assessment. However, companies should be aware of this situation when evaluating specific sites.

**Turner Mine Shale** Our assessment of the Middletown Quadrangle identified areas with thick (>4 feet) Turner Mine Shale as having unstable roof conditions that restrict mining. The thickness of this shale varies widely over a short distance and requires closely-spaced (e.g. 300 foot centers) drilling to delineate. Due to the lack of such closely-spaced drilling data, we were unable to determine the extent of this condition and have not used it as a restriction in this study. Based on the findings of the study of the Middletown Quadrangle, this factor would restrict less than 1 percent of resources.

**Weak Floor** The rock underlying the coal seam (referred to by miners as the floor), is commonly a claystone or shale. A floor that is weak (i.e. has a low bearing capacity) will squeeze out from around pillars into the rooms (fig. 28). Our assessment of the Middletown Quadrangle identified weak floor conditions that required pillar sizes to be larger, thereby reducing recoverability of the Springfield Coal

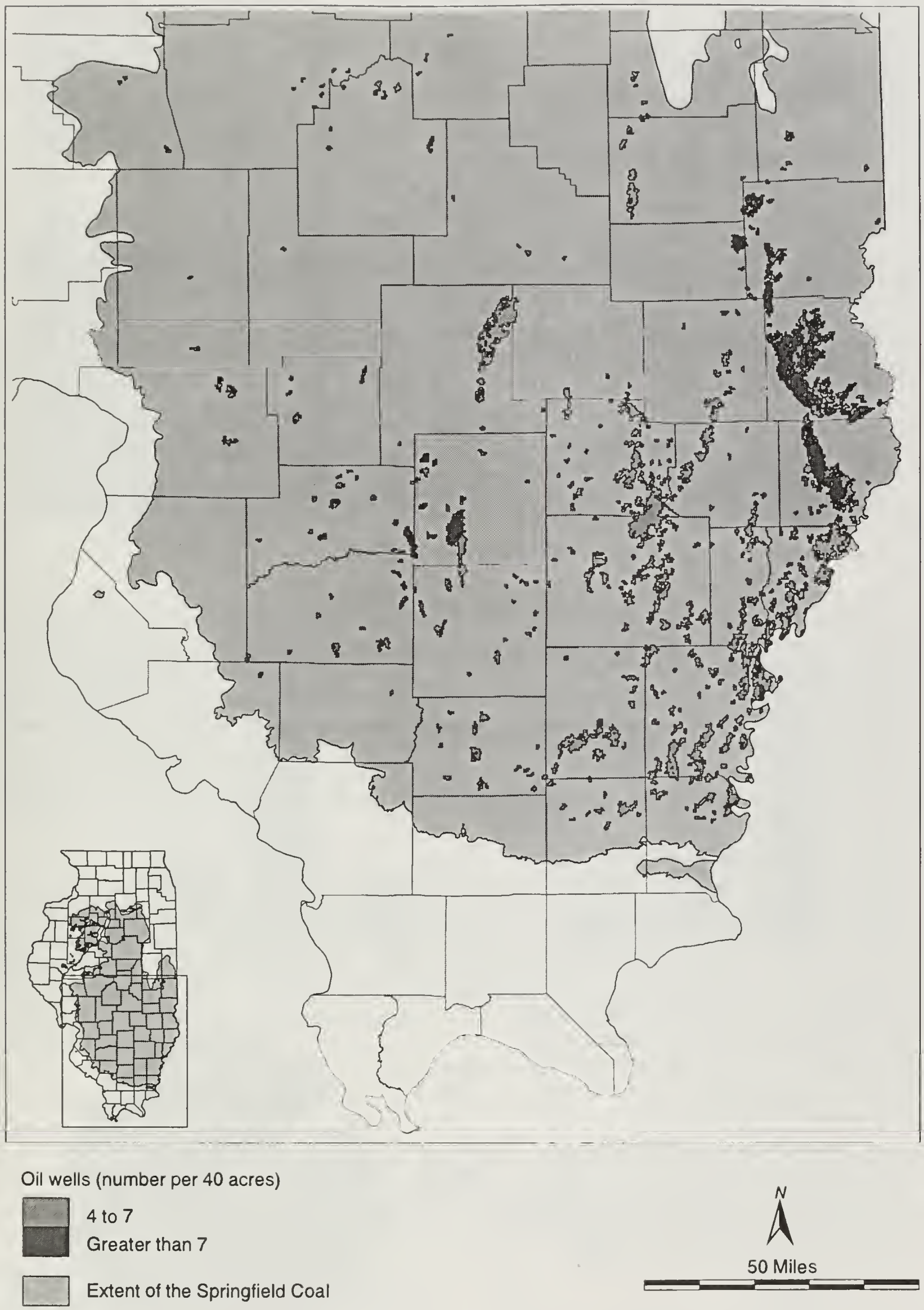



**Figure 27** Areas of Springfield Coal containing closely-spaced oil wells.

**Figure 28** Floor squeeze in an underground mine in Illinois.

by 5 to 10%. We did not have drilling data to map floor strength, but based on mining experience in the area, available resources were arbitrarily reduced by 5% in areas with more than 100 feet of bedrock, and 10% in areas with less than 100 feet of bedrock. This condition was not found in any other quadrangle study. In retrospect, it is possible that the weak floor conditions are related to the thin bedrock and thick unconsolidated overburden in the Middletown Quadrangle. The company that described the weak floor conditions to us was mining under thin bedrock conditions and has since found that where the bedrock is thicker, there are fewer problems related to floor strength. Due to the uncertainty and lack of information about floor conditions, this factor was not included in our statewide assessment.

## AVAILABLE RESOURCES

Statewide, about 27 billion tons (41%) of the original 65 billion tons of Springfield Coal resources are available for mining (fig. 29 and table 1). An additional 3 billion tons are available with conditions. This consists of resources that meet the criteria for available coal, but are located in areas where geologic or land-use conditions may increase the cost of mining. These include areas that have a medium density of oil wells or 75 to 100 feet of bedrock overburden, are overlain by the transitional zone between the Dykersburg and Turner Mine Shales, or are near rapidly developing urban areas. Technological factors restrict mining of 47% of the resources (30 billion tons) and land-use restricts 5% (3 billion tons).

Of the available resources, 23 billion tons are 42 to 66 inches thick and 4 billion tons are greater than 66 inches thick (table 5, fig. 30). Only 0.8 billion tons of the available resources have a medium to low sulfur content.

About 37 billion tons of the remaining resources of Springfield Coal are in the Inferred Category of reliability (see section on Coal Resource Classification System)

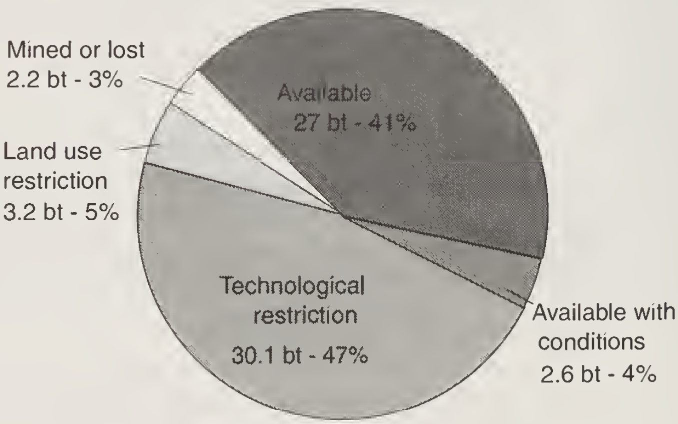



**Figure 29** Availability of the Springfield Coal for mining in Illinois. (bt = billion tons).

and only about 15 billion tons of these are available for mining (table 6, fig. 31). A slightly higher percentage of the measured and indicated resources are available compared to the inferred 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, compared to 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 tonnages are anticipated.

**Table 5** Availability of the Springfield Coal by thickness category (billions of tons and percent of original resources in the category).

| | 18-28 in. | 28-42 in. | 42-66 in. | >66 in. | Total |
|---|---|---|---|---|---|
| Original | 0.6 | 12.7 | 43.5 | 8.4 | 65.1 |
| Mined | | 0.01 (<1) | 1.1 (3) | 1.1 (13) | 2.2 (3) |
| Remaining | 0.6 (100) | 12.7 (100) | 42.4 (97) | 7.3 (87) | 63.0 (97) |
| Available | 0.04 (7) | 0.06 (<1) | 22.9 (53) | 4.0 (48) | 27.0 (41) |
| Available w/ conditions | | 0.03 (<1) | 1.8 (4) | 0.8 (10) | 2.6 (4) |
| Technological restrictions | 0.5 (83) | 12.0 (94) | 15.5 (36) | 2.1 (25) | 30.1 (46) |
| Land-use restrictions | 0.07 (11) | 0.6 (5) | 2.2 (5) | 0.3 (4) | 3.2 (5) |

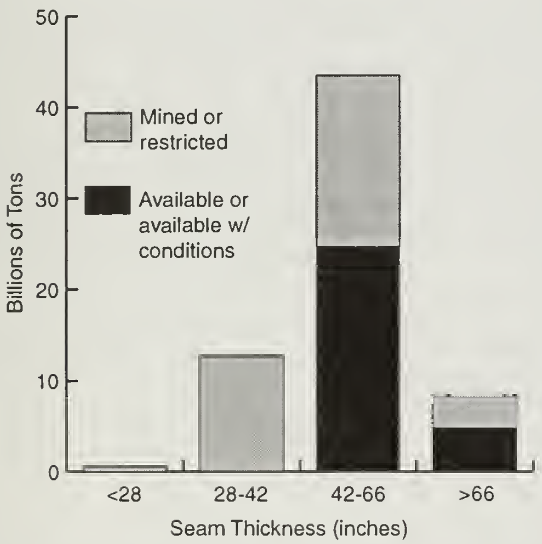



**Figure 30** Availability of the Springfield Coal by thickness category.

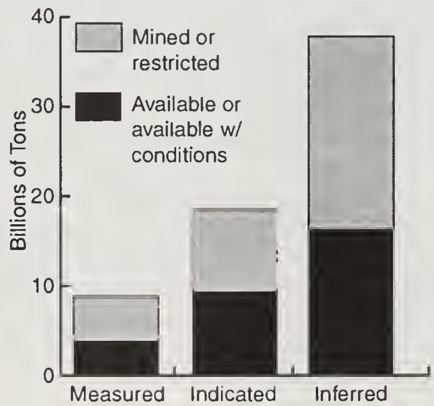



**Figure 31** Availability of the Springfield Coal by reliability category.

**Table 6** Availability of the Springfield Coal by reliability category (billions of tons and percent of original resources in the category).

| | Measured | Indicated | Inferred | Total |
|---|---|---|---|---|
| Original | 8.8 | 18.5 | 37.9 | 65.1 |
| Mined | 2.2 (25) | | | 2.2 (3) |
| Remaining | 6.6 (75) | 18.5 | 37.9 | 63.0 (97) |
| Available | 3.5 (40) | 8.3 (45) | 15.2 (40) | 27.0 (41) |
| Available w/ conditions | 0.4 (5) | 1.1 (6) | 1.1 (3) | 2.6 (4) |
| Technological restrictions | 2.3 (26) | 7.7 (42) | 20.0 (53) | 30.1 (46) |
| Land-use restrictions | 0.4 (5) | 1.3 (7) | 1.5 (4) | 3.2 (5) |

## Coal Available for Underground Mining

About 63 billion tons of the original Springfield Coal resources lie at depths greater then 75 feet and are therefore potentially minable by underground methods. Of these, about 41% (26 billion tons) are available for mining and an additional 4% (3 billion tons) are available with conditions (fig. 32 and table 7). Technological factors restrict mining of 48% of the resources and land-use about 5%. The major technological restrictions are thin interburden between the Springfield and overlying Herrin Coal

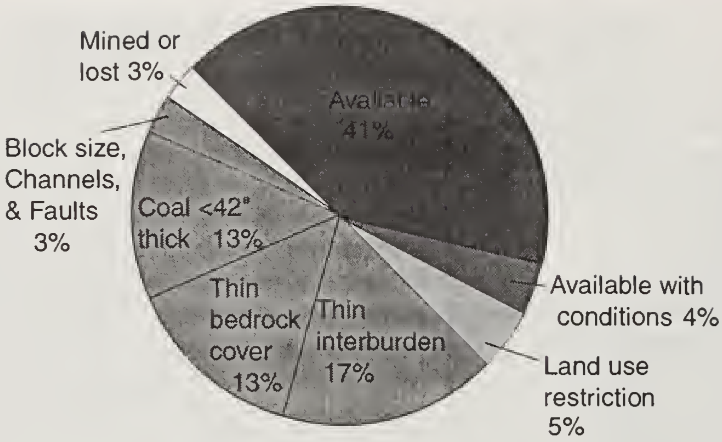



**Figure 32** Availability of the Springfield Coal for underground mining.

**Table 7** Resources of Springfield Coal available for underground mining. A comparison of this study versus quadrangle studies (millions of tons and percent of original resources).

| | Statewide | Quadrangles |
|---|---|---|
| **Original** | 62,995 | 3,240 |
| **Mined** (percent of original) | 1,764 (3) | 199 (6) |
| **Remaining** (percent of original) | 61,231 (97) | 3,040 (94) |
| | | |
| **Available** | 26,109 (41) | 1,380 (43) |
| **Available w/ conditions** | 2,708 (4) | 109 (3) |
| Oil wells | 1,326 (2) | 53 (2) |
| Transitional roof | 954 (2) | not used |
| Bedrock 75 to 100 ft thick | 352 (<1) | not used |
| Potential land-use conflict | 77 (<1) | 56 (2) |
| **Land-use restrictions** | 2,979 (5) | 201 (7) |
| Towns | 1,765 (3) | 113 (3) |
| Public lands | 463 (<1) | 17 (<1) |
| Oil wells | 457 (<1) | not used |
| Abandoned mines | 190 (<1) | 47 (1) |
| Roads | 100 (<1) | 4 (<1) |
| Major airports | 5 (<1) | 4 (<1) |
| Dams | 0.3 (<1) | 0 |
| Railroads | not used | 6 (<1) |
| Cemeteries | not used | 8 (<1) |
| Transmission lines | not used | 0.2 (<1) |
| Churches & schools | not used | 1 (<1) |
| **Technological restrictions** | 29,436 (47) | 1,352 (42) |
| Thin interburden | 10,688 (17) | 248 (8) |
| Seam <42 inches thick | 8,354 (13) | 296 (9) |
| Thin bedrock cover | 8,131 (13) | 390 (12) |
| Block size | 1,306 (2) | 156 (5) |
| Near channel | 617 (1) | 182 (6) |
| Faulted | 339 (<1) | 51 (2) |
| Weak floor | not used | 13 (<1) |
| Partings | not used | 9 (<1) |
| Poor roof conditions | not used | 7 (<1) |

(17% of original resources), coal less than 42 inches thick (13%) and thin bedrock cover and thick drift cover (13%). Size of mining block, unfavorable geologic conditions near channels and faults restrict a total of only about 4% of the resources.

Most of the available resources are in the southern half of the state (fig. 33). 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.

In most cases the percentage of resources restricted by individual criteria were similar in both the quadrangle and statewide assessments (table 7). The greatest variation in percentage restricted involved thin interburden, seam thickness less than 42 inches, channels, faulting, mined areas and potential land-use conflicts. Most of these differences can be explained by the focus of quadrangle selection on areas with the greatest potential for mining. These areas were naturally away from the area of thin coal and concentrated in areas that contained the Galatia channel (a feature that is found adjacent to thick, lower-sulfur resources) and abandoned mines. Coincidentally, these areas were also away from the area of thin interburden and in areas of faulting. The potential land-use conflict was over-represented in the quadrangle studies because it occurred only in the Peoria region, an area covered by a quadrangle study.

## Coal Available for Surface Mining

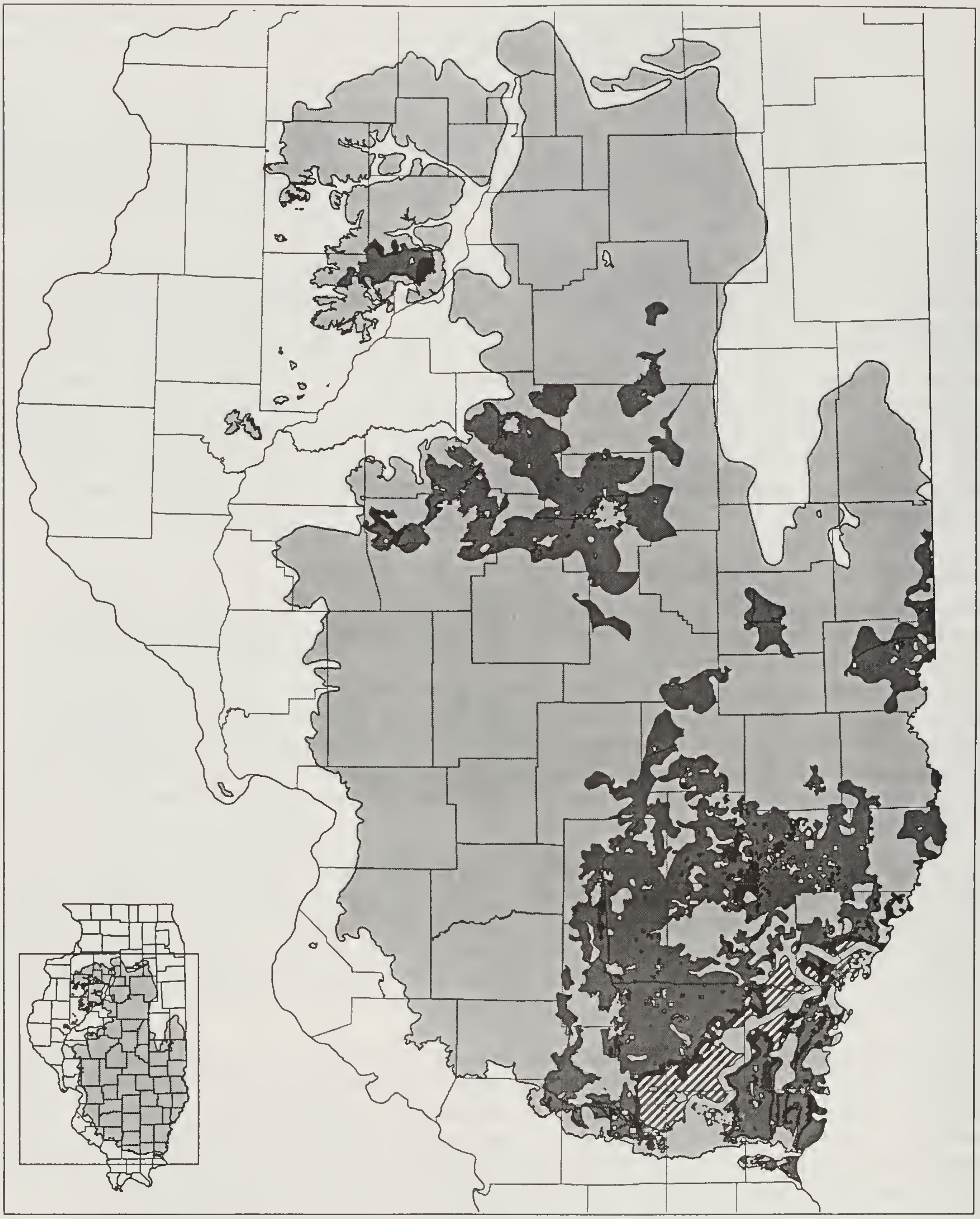
Only about 12% (almost 8 billion tons) of the original Springfield Coal resources lie at depths shallow enough to be considered for surface mining (less than 200 feet deep). Of these, only 12% (1 billion tons) are available for surface mining (fig. 34 and table 8). Technological factors restrict 57% of the resources. These factors include unfavorable stripping ratio (38%), unfavorable drift thickness (15%) and mine block size (3%). Land-use restricts surface mining of 16% 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 only 4% of resources. Most of the available surface minable resources are located in the western part of the state, but surface minable blocks are scattered along the southern crop as well (fig. 35).

The percentage of resources available for surface mining was similar in both the quadrangle (12%) and statewide (10%) assessments (table 8). However, the percentages affected by the category "available with conditions" as well as land-use and technological restrictions, differed. These differences are due to three factors: 1) the bias in quadrangle selection towards areas with the greatest potential for mining, 2) procedural differences that were necessary to complete the statewide assessment at a reasonable cost and 3) inadvertent over-sampling of certain conditions.

The smaller percentage of resources affected by stripping ratio and greater percentage affected by underground mines reflects 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 multi-seam mining was not considered in the statewide assessment, but was considered and probably over-represented in the quadrangle studies. The actual percentage of surface minable resources that would be available if mined in combination with the Herrin Coal is estimated to be on the order of 2%. Similarly, the amount of resources restricted by public lands or potential land-use conflicts was probably over-represented in the quadrangle studies.

# CONCLUSIONS

The Springfield Coal is a major energy resource in Illinois. Approximately 27 billion tons of the Springfield Coal resources (41% of original resources) are available for mining. "Available" means that the surface land-use and physical characteristics of the deposit (e.g. thickness, depth, in-place tonnage, stability of bedrock overburden, etc.) are comparable to the conditions where this and other coals are



Springfield Coal

Available

Available with low to medium-sulfur coal

Available with restrictions

Restricted or mined out

Subcrop of the Springfield Coal

N

50 Miles

**Figure 33** Areas of Springfield Coal available for underground mining.

currently being mined in the state. Of these resources, 23 billion tons are 42 to 66 inches thick and 4 billion tons are greater than 66 inches thick.

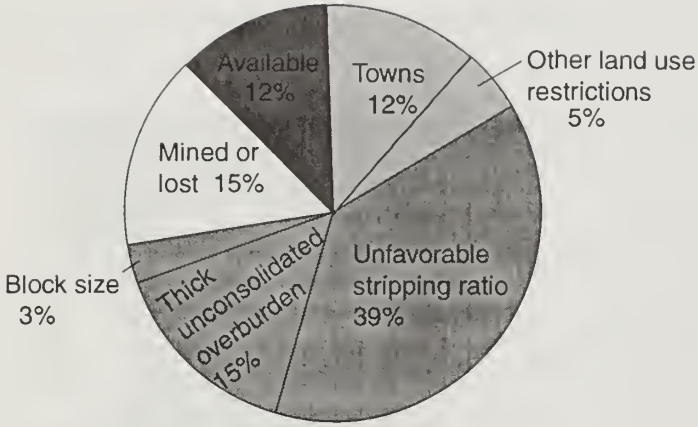



**Figure 34** Availability of the Springfield Coal for surface mining.

About 97% (26 billion tons) of the available Springfield Coal resources will have to be mined by underground methods. An additional 3 billion tons of resources are also available for underground mining, but with conditions 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 Springfield 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 in minable blocks of hundreds of millions of tons.

Only about 8 billion tons of the Springfield Coal resources lie less than 200 feet deep and are potentially minable by surface methods. Of these, less than 1 billion tons are available for mining. The relatively small amount of surface-minable resources suggests that future surface mining of the Springfield Coal will be limited to a few small operations in the southern and possibly northwestern part of the state.

Springfield Coal resources are mostly suited for the high sulfur coal market. Only 1.4 billion tons of the resources have a sulfur content between 0.6 and 1.7 pounds of sulfur per million Btu; about 1 billion tons of these medium to low sulfur resources are available for mining. Technological factors, such as geologic conditions associated with faults and channels are the primary restrictions to mining these lower sulfur deposits.

Technological factors cause the most significant restrictions on the availability of the Springfield Coal. For underground mining, these factors include thickness of interburden between seams, thickness of drift and bedrock cover and thickness of the coal seam. To select sites for mining that avoid geologic conditions that can raise mining costs, companies should avoid areas of thick drift and thin bedrock cover, the Galatia Channel, faults, areas of closely-spaced oil wells and the edge of the Dykersburg Shale.

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

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

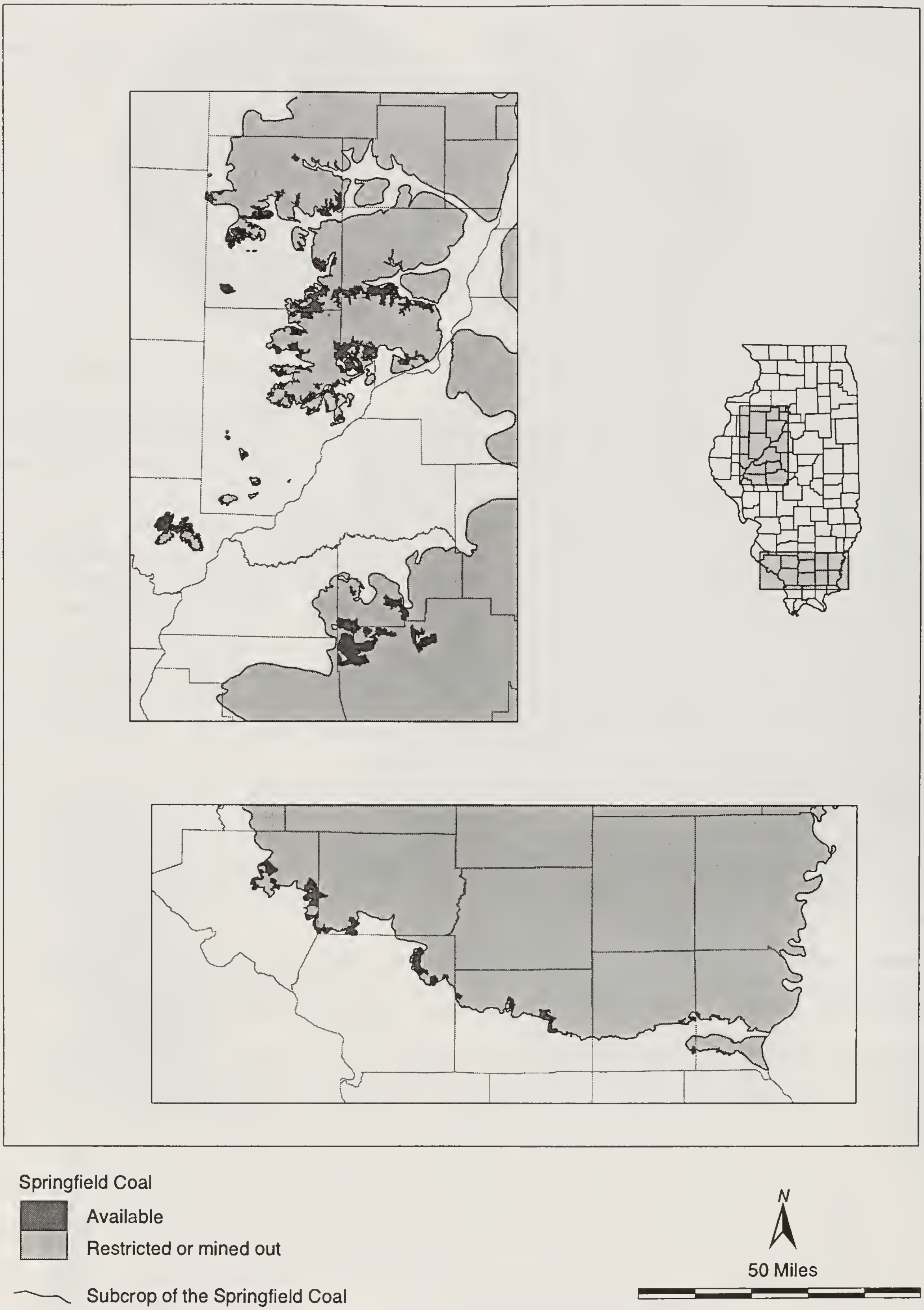



**Figure 35** Areas of Springfield Coal available for surface mining.

Table 8 Resources of Springfield Coal available for surface mining. A comparison of this study versus quadrangle studies (millions of tons and percent of original resources).

| | Statewide | | Quadrangles | |
|---|---|---|---|---|
| **Original** | 7,804 | | 751 | |
| **Mined** (percent of original) | 1,148 | (15) | 112 | (15) |
| **Remaining** (percent of original) | 6,655 | (85) | 639 | (85) |
| | | | | |
| **Available** | 920 | (12) | 74 | (10) |
| **Available w/ conditions** | 15 | (<1) | 61 | (8) |
| Potential land-use conflict | 15 | (<1) | 13 | (2) |
| Mined w/ other seams | not used | | 48 | (6) |
| **Land-use restrictions** | 1,247 | (16) | 153 | (20) |
| Towns | 909 | (12) | 87 | (12) |
| Roads | 65 | (1) | 12 | (2) |
| Pipelines | 62 | (1) | 0.02 | (<1) |
| Public lands | 39 | (<1) | 17 | (2) |
| Railroads | 39 | (<1) | 6 | (<1) |
| Underground mines | 131 | (2) | 26 | (3) |
| Airports | 2 | (<1) | 4 | (<1) |
| Transmission lines | not used | | 0.8 | (<1) |
| Cemeteries | not used | | 0.6 | (<1) |
| Churches & schools | not used | | 0.03 | (<1) |
| Major dams | <1 | (<1) | 0 | |
| **Technological restrictions** | 4,472 | (57) | 350 | (47) |
| Stripping ratio | 3,064 | (39) | 107 | (14) |
| Thick unconsolidated material | 1,195 | (15) | 216 | (29) |
| Block too small | 214 | (3) | 27 | (4) |



## REFERENCES

Allsman, P.T. and P.F. Yopes, 1973, Open-Pit and Strip-Mining Systems and Equipment, *in* SME Mining Engineering Handbook, Society of Mining Engineers of The American Institute of Mining, Metallurgical and Petroleum Engineers, Inc., New York, NY, v. 2, 180 p.

Ault, Curtis H., 1997, Map of Posey County, Indiana, showing Structure on the Springfield Coal Member of the Petersburg Formation (Pennsylvanian), Indiana Geological Survey, Miscellaneous Map 60.

Bristol, H. M. and J. D. Treworgy, 1979, The Wabash Valley Fault System in Illinois, Illinois State Geological Survey Circular 509, 19p.

Brownfield, R. L., 1954, Structural History of the Centralia Area, Illinois State Geological Survey Report of Investigations 172, 31 p.

Chekan, G. J., R. J. Matetic and J. A. Galek, 1986, Strata Interactions in Multiple-Seam Mining—Two Case Studies in Pennsylvania: United States Department of the Interior, Bureau of Mines, Report of Investigations 9056, 17 p.

Chou, C.-L., 1991, Distribution and Forms of Chlorine in Illinois Basin Coals, in Chlorine in Coal, J. Striger and D. D. Banerjee, *eds.*, Elsevier Science Publishers, Amsterdam, p. 11-29.

Chou, M.-I., J.M. Lytle, S.C. Kung, K.K. Ho, L.L. Baxter and P.M. Goldberg, 1998, "Effects of chlorine in coal on boiler corrosion," 1995-1998 program, Final Report to the Illinois Coal Development Board, Illinois Clean Coal Institute, 28 p.

Chou, M.-I., J.M. Lytle, S.C. Kung and K.K. Ho, 1999, Effects of Chlorine in coal on boiler superheater/ reheater corrosion, *in* Preprint. Papers, American Chemical Society, Division of Fuel Chemistry, v. 44, no. 2, p.167-171.

Clegg, K.E. and J.C. Bradbury, 1956, Igneous Intrusive Rocks in Illinois and Their Economic Significance, Illinois State Geological Survey Report of Investigations 197, 19 p.

Eggleston, J.R., M.D. Carter and J.C. Cobb, 1990, Coal Resources Available for Development - A Methodology and Pilot Study: U. S. Geological Survey Circular 1055, 15 p.

Frankie, W.T., R.J. Jacobson, B.G. Huff, M.B. Thompson, K.S. Cummings and C.A. Philips, 1996, Guide to the Geology of the Mount Carmel Area, Wabash County, Illinois, Illinois State Geological Survey Field Trip Guidebook 1996D, 94p.

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

Hsiung, S. M. and S. S. Peng, 1987a, Design guidelines for multiple seam mining, part I: Coal Mining, v. 24, no. 9, p. 42–46.

Hsiung, S. M. and S. S. Peng, 1987b, Design guidelines for multiple seam mining, part II: Coal Mining, v. 24, no. 10, p. 48–50.

Illinois Department of Mines and Minerals, 1954, A Compilation of the Reports of the Mining Industry of Illinois from the Earliest Records to 1954, Springfield, Illinois, 263 p.

Jacobson, R.J., C.G. Treworgy and C. Chenoweth, 1996, Availability of Coal Resources for Mining in Illinois, Mt. Carmel Quadrangle, Southeastern Illinois, Illinois State Geological Survey Mineral Note, 39 p.

Keys, J. N. and W. J. Nelson, 1980, The Rend Lake Fault System in Southern Illinois, Illinois State Geological Survey Circular 513, 23p.

Koehl, K.W. and D. Meier, 1983, Mining across the New Harmony Fault, Wabash County, Illinois, Proceedings of the Illinois Mining Institute, p. 35-43.

McCabe, P.J., 1998, Energy Resources-Cornucopia or Empty Barrel?, American Association of Petroleum Geologists Bulletin, v. 82, no. 11, p. 2110-2134.

Monroe S. L. and R. J. Clarkson. 1994, Pilot-scale evaluation of a high-chlorine Illinois Basin coal for effects on fireside corrosion, Final report prepared for Southern Company Services, Kerr-McGee Corp., Electric Power Resarch Institute and Illinois Clean Coal Institute, SRI-ENV-94-346R-8180, 43 p.

Nelson, W. J., 1981, Faults and their effect on coal mining in Illinois, Illinois State Geological Survey, Circular 523, 39 p.

Nelson, W. J. and H.-F. Krausse, 1981, The Cottage Grove Fault System in Southern Illinois, Illinois State Geological Survey, Circular 522, 65p.

Nelson, W.J., 1983, Geologic Disturbances in Illinois Coal Seams, Illinois State Geological Survey Circular 530, 47 p.

Nelson, W. J. and D. K. Lumm, 1987, Structural Geology of Southeastern Illinois and Vicinity, Illinois State Geological Survey, Circular 538, 70p.

Rogers, P.R., 1981, Roof Fall Study of the Harrisburg (No. 5) Coal in Portions of Saline and Williamson Counties, Illinois, MS thesis, Department of Geology, Southern Illinois University, Carbondale, IL, 65 p.

Tanner, G.F., J.N. Stellavato and J.C. Mackey, 1981, Map of Southwestern Gibson County, Indiana, Showing Structure on Springfield Coal Member (V) of the Petersburg Formation (Pennsylvanian), Indiana Geological Survey Miscellaneous Map No. 32.

Treworgy, C.G., G.K. Coats and M.H. Bargh, 1994, Availability of Coal Resources for Mining in Illinois, Middletown Quadrangle, Central Illinois, Illinois State Geological Survey Circular 554, 48 p.

Treworgy, C.G., C.A. Chenoweth and M.H. Bargh, 1995, Availability of Coal Resources for Mining in Illinois: Galatia Quadrangle, Saline and Hamilton Counties, Southern Illinois, Illinois State Geological Survey Illinois Minerals 113, 38 p.

Treworgy, C.G., C.A. Chenoweth and R.J. Jacobson, 1996a, Availability of Coal Resources for Mining in Illinois, Newton and Princeville Quadrangles, Jasper, Peoria and Stark Counties, Illinois State Geological Survey Open File Series 1996-3, 47 p.

Treworgy, C.G., C.A. Chenoweth and M.A. Justice, 1996b, Availability of Coal Resources for Mining in Illinois, Atwater, Collinsville and Nokomis Quadrangles, Christian, Macoupin, Madison, Montgomery and St. Clair Counties, Illinois State Geological Survey Open File Series 1996-2, 33 p.

Treworgy, C.G., C.A. Chenoweth, J.L. McBeth and C.P. Korose, 1997a, Availability of Coal Resources for Mining in Illinois, Augusta, Kewanee North, Mascoutah, Pinckneyville and Roodhouse East Quadrangles, Adams, Brown, Greene, Henry, Perry, Schuyler and St. Clair Counties, Illinois State Geological Survey Open File Series 1997-10, 72 p.

Treworgy, C.G., E.I. Prussen, M.A. Justice, C.A. Chenoweth, M.H. Bargh, R.J. Jacobson and H.H. Damberger, 1997b, Illinois Coal Reserve Assessment and Database Development: Final Report, Illinois State Geological Survey Open File Series 1997-4, 105 p.

Treworgy, C.G., J.L. McBeth, C.A. Chenoweth, C.P. Korose and D.L. North, 1998, Availability of Coal Resources for Mining in Illinois, Albion South, Peoria West, Snyder-West Union, Springerton and Tallula Quadrangles, Clark, Edwards, Hamilton, Menard, Peoria, Sangamon and White Counties, Illinois State Geological Survey Open File Series 1998-1, 92p.

Treworgy, C. G., 1999, Coal Resources Map and Availability of Coal for Mining, Villa Grove Quadrangle, Douglas County, IL, Illinois State Geological Survey IGQ Villa Grove-CR.

Treworgy, C.G., D.L. North, C.L. Conolly, and L. Furer, 1999, Coal Resources Map and Availability of Coal for Mining, Vincennes Quadrangle, Lawrence County, Illinois and Knox County, Indiana, Illinois State Geological Survey IGQ Vincennes-CR.

Treworgy, C.G., D.L. North, forthcominig, Availability of Coal Resources for Mining in Illinois, Shawneetown Quadrangle, Gallatin County: Illinois State Geological Survey Open File Series 1999.

Wood, G.W., Jr., T.M. Kehn, M.D. Carter and W.C. Culbertson, 1983, Coal Resource Classification System of the U.S. Geological Survey, U.S. Geological Survey Circular 891, 65 p.