Geol Survey

Availability of the Colchester Coal for Mining in Northern and Western Illinois

Christopher P. Korose, Scott D. Elrick, and Russell J. Jacobson

Illinois Minerals 127 2003

Rod R. Blagojevich, Governor

Department of Natural Resources
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ILLINOIS STATE GEOLOGICAL SURVEY
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Cover photo: *Bucket wheel excavator removing overburden from the Colchester Coal, Freeman United Coal Co. Industry Mine, McDonough County, Illinois, 1989.*

ILLINOIS DEPARTMENT OF NATURAL RESOURCES

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Contents

Executive Summary

The Colchester Coal, as mapped in this study, makes up about 9% (19 billion tons) of Illinois' original resources. This coal bed is present throughout the Illinois Basin coalfield, but is typically thinner than the more extensively mined Herrin Coal, Springfield Coal and the other coals described in earlier reports in this series (Treworgy et al. 1999a, 2000; Korose et al. 2002). Thus, resources have been mapped only in northern and western Illinois where the Colchester is thickest. This coal was mined extensively in northern Illinois during the nineteenth and early to middle twentieth centuries. The degree to which the remaining Colchester Coal resources are utilized in the future depends on the availability of deposits that can be mined economically and competitively with other coals and alternative fuels. This report identifies those resources that have the most economically favorable geologic and land-use characteristics for mining and alerts mining companies to geologic conditions that have a potentially negative impact on mining costs.

Of the 19 billion tons of original Colchester resources, approximately 1 billion tons are available for mining (table 1). "Available" means that the surface land-use and geologic conditions related to mining the deposit (e.g., thickness, depth, in-place tonnage, and stability of bedrock overburden) are comparable with those of other coals currently being mined in the state. "Technological" factors (e.g., coal too thin to mine economically, and size of the in-place reserve block) are the major restrictions to mining and restrict 86% (16.1 billion tons) of the resources. "Land-use" factors (e.g., towns and highways) restrict 7% (1.4 billion tons) of the resources, and mining has depleted 2% of the original resources.

The Colchester Coal has the fourth-largest resources (19 billion tons) of all coal seams in the state, but only 5% (1 billion tons) is available for mining. The vast majority of the coal is too thin to mine economically using underground methods in the current mining environment. Thus, all of the available Colchester resources are available for mining by surface methods only.

Whether or not the resources of this coal are ultimately mined depends on a variety of other factors that are beyond the scope of this study to assess, including the willingness of local landowners to lease the coal, demand for a particular quality of coal, accessibility of transportation infrastructure, proximity of the deposit to markets, and cost and availability of competing fuels. To avoid high mining costs resulting from unfavorable geologic conditions, companies could generally avoid areas of thick drift and thin bedrock cover, areas with potentially weak or water-bearing sandstone in the immediate mine roof, large areas of excessive partings in the coal, and faulted areas. Areas with low-cost, surface-minable resources are limited and will likely support only small, short-term operations.

This report is the fourth in a series to explain the availability of coal in Illinois for future mining. Previous reports assessing the availability of the Springfield and Herrin Coals contain important background information explaining the criteria used in this report to identify available coal (Treworgy et al. 1999a, 2000; Korose et al. 2002). These statewide assessments of coal resources are based on earlier publications that reported the availability of coal in 21 study areas. The study areas were 7.5-minute quadrangles representative of mining conditions in various parts of the state. Coal resources and the 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 experienced in mining Illinois coals. The major restrictions identified in these individual study areas were used for the statewide assessments of the availability of coals for mining.

Table 1 Availability of the Colchester Coal for mining in Illinois, in billions of tons.

	Total		Potential mining method[1] Surface		Underground	
Colchester Coal						
Original	19.0		10.7		13.4	
Mined	0.5	(2)[2]	0.3	(2)	0.2	(2)
Remaining	18.5	(98)	10.4	(98)	13.2	(98)
Available	1	(5)	1	(10)	0	
Available with conditions	0		0		0	
Technological restrictions	16.1	(86)	7.9	(73)	12.4	(92)
Land-use restrictions	1.4	(7)	1.5	(15)	0.8	(6)

[1] 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. Values are rounded to the nearest 0.1 billion tons. See appendix 1 for information tabulated by county. The term "original resources" refers to the amount of coal originally in the ground prior to any mining. 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, whereas underground minable coal is all coal 28 or more inches thick and lying 75 or more feet deep.

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

Introduction

This report is the fourth in a series to assess the availability of coal resources for future mining in Illinois. The reader is referred to reports by Treworgy et al. (1999a, 2000) for background details and the general criteria used to define resources available for mining.

Coal Resource Classification System

The Illinois State Geological Survey (ISGS) follows the terms and definitions of the U.S. Geological Survey (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 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; "underground minable coal" is all coal 28 or more inches thick and lying 75 or more feet deep. Coal that is 28 or more inches thick and lying from 75 to 200 feet in depth is considered in calculations as both surface minable and underground minable.

In recent years, the USGS has promoted the idea of further defining the characteristics of resources by dividing remaining resources into two categories: "restricted" and "available" (Eggleston et al. 1990). Restricted resources are those that have some economic factor that makes it unlikely they will be mined in the foreseeable future. The terms "technological" and "land use" are used to distinguish between basic differences in these economic restrictions. Land-use restrictions include manmade 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 are expected to have mining conditions comparable with those currently being mined. Determining the actual cost and profitability of these deposits requires further engineering and market assessments and site-specific studies.

This study follows the USGS example of dividing resources into available or restricted categories. The ISGS also uses an additional category, "available with potential restrictions," which designates resources that are not restricted by the land-use or technological restrictions but that have some known special condition that makes them less favorable for mining. Close proximity to rapidly developing urban areas, the presence of a relatively high density of oil wells or test holes, and potentially unstable roof conditions are examples of potential restrictions that have resulted in resources being placed in this category. In this study, therefore, remaining resources are the sum of resources restricted by land use factors, resources restricted by technological factors, resources available with potential restrictions, and available resources.

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

Sources of Data, Limitations, and Mapping Procedure

The maps that accompany this report were largely compiled from previously published maps, which are listed in appendix 2. These maps were compiled digitally, and necessary adjustments were made where two or more maps bordered or overlapped one another. Past ISGS studies describe in detail the process of constructing digital coal resource base maps from original paper sources, the resulting necessary adjustments made to certain map areas, and coal tonnage calculations (Treworgy et al. 1997b, Treworgy and Bargh 1982).

The source maps have varying degrees of completeness and accuracy, are designed for a regional assessment, and have a 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. Source data for the maps was obtained from a variety of public and private sources: drilling logs, core descriptions, and geophysical logs obtained from companies and descriptions of mine and outcrop exposures made by ISGS geologists.

For this study, resources of the Colchester Coal were revised or newly mapped in Bureau, Fulton, Henry, Knox, Morgan, Peoria, and Stark Counties utilizing newly available data. Minor corrections and revisions were made to maps from other counties. New mapping was prioritized in areas where the coal was thought to be of mineable thickness and where the density of available coal test data was the greatest. Previous mapping of Colchester Coal resources was concentrated in northern and western Illinois; elsewhere, the coal is likely too thin to be of economic interest and is beyond the scope of this study to assess. Mined areas were updated to April 1, 2002, by using maps obtained from coal companies.

Geology and Mining

The coal-bearing rocks of Illinois were deposited during the Pennsylvanian Period approximately 290 to 323 million years ago (Geological Society of America 1999). The strata of the Pennsylvanian System underlie about two-thirds of the state. Only the northern fourth of Illinois and narrow belts along the Mississippi, Ohio, and Illinois Rivers have no Pennsylvanian rocks. The coal-bearing strata of Illinois extend into southwestern Indiana and western Kentucky as a single continuous coalfield known as

Figure 1 Extent of the Pennsylvanian System in the Illinois Basin (modified from Treworgy et al. 2000).

the Illinois Basin or Eastern Interior Coal Field (fig. 1).

Within the Pennsylvanian strata, coal seams of Illinois and the midcontinent are present as part of cyclic rock sequences called cyclothems, in which a succession of sandstone, shale, limestone, and coal units mark the shifting ancient shoreline environment during a complete cycle of marine invasion and retreat (Udden 1912, Wanless and Weller 1932). The seams are not evenly distributed through the approximately 3,000-foot-thick section of coal-bearing rocks in Illinois, and most occur in the middle of the Pennsylvanian section. These Pennsylvanian coals are continuous over large areas and generally crop out along the margins of the basin (fig. 2), although the thickness of any particular seam may be quite variable.

In excess of 20 coal seams have been mined commercially in Illinois, but fewer than 10 are important in terms of past and present production. Included in figure 3 and in order of geologic age these major seams in Illinois are the Danville (youngest), Herrin, Springfield, Colchester, Seelyville, Dekoven, and Davis Coals. Some of the coals in the Illinois Basin can be correlated across state boundaries.

Colchester Coal The 19 billion tons of Colchester Coal resources are the fourth-largest in the state and constitute about 9% of the state's total original coal resources. The Colchester Coal Member of the Carbondale Formation (Hopkins and Simon 1975; fig. 3) is found near the base of the Carbondale throughout southern Illinois, where the base of the formation is defined by the Davis Coal; the Colchester remains the base of the Carbondale in northern and western Illinois where the Davis is absent or not identified (Jacobson et al. 1985). The Colchester Coal is a normal, bright-banded coal present throughout the Illinois Basin coalfield. The coal and its overlying black shale, the Mecca Quarry Shale, are key marker beds that have been traced throughout the basin using core data and wireline logs. Over most of the basin the Colchester is generally thin, ranging from less than one inch to18 inches thick in southern, central, and eastern Illinois, and resources have not been mapped in these areas. The coal is typically thicker throughout most of northern and western Illinois, where the coal is 2 to 3.5 feet thick (locally 4 feet) and has been extensively mined (fig. 4). The coal crops out along the margins of the Illinois Basin and reaches a maximum depth in southeastern Illinois of about 1,500 feet (fig. 5).

Jacobson (1985) noted that, over much of northern Illinois, thickness patterns of the Colchester showed a strong relationship to geologic structures of the La Salle Anticlinorium, where in the synclinal troughs the Colchester reaches its greatest thickness (up to 3 to 4 feet), and on the anticlinal crests it thins to as little as 1 to 2 feet. Peppers and Pfefferkorn (1970) also found significant variation in the flora of the Colchester Coal on top of these anticlinal crests (northwest Ancona Anticline, formerly the Ancona and Garfield Domes, fig. 6). Peppers and Pfefferkorn (1970) concluded that the variation represented drier conditions because of the higher topographic elevation of this structural feature and

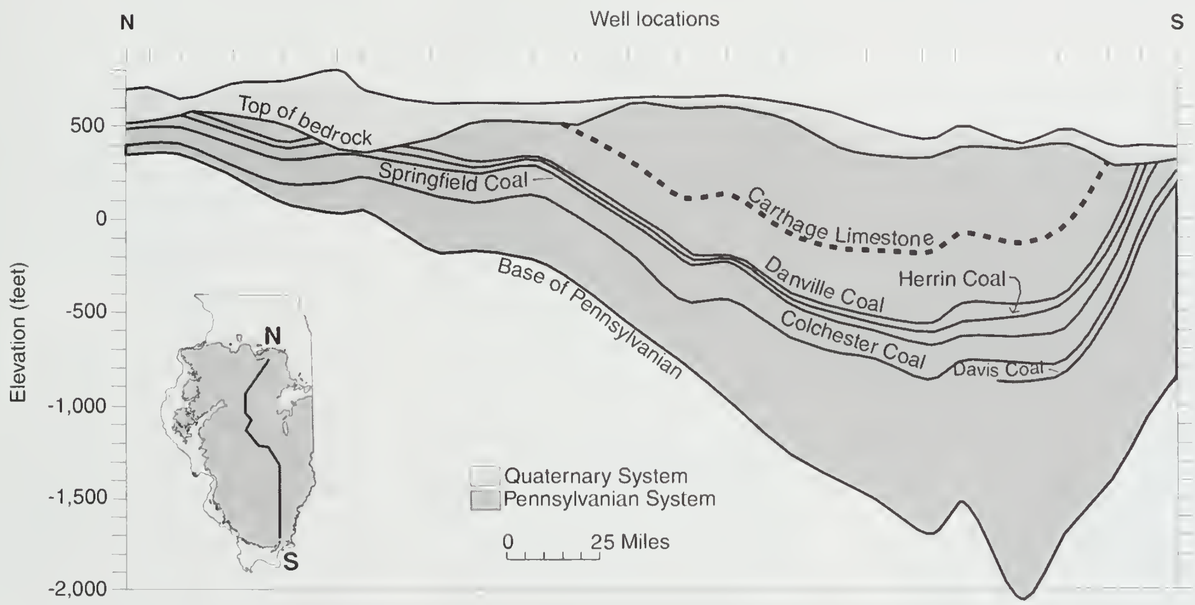


Figure 2 North-south cross section of the Pennsylvanian System in Illinois (from Treworgy et al. 2000).

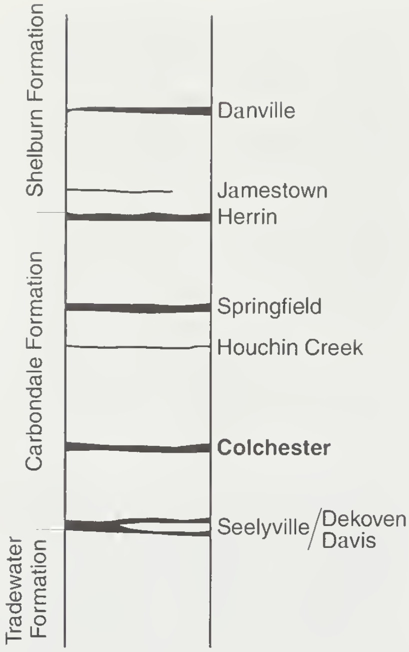


Figure 3 General stratigraphic position of the Colchester Coal. Coals are shown in order of geologic age (youngest seam at top). Formal nomenclature is from Jacobson et al. (1985).

its effect on the paleoenvironment of the local Colchester swamp. Their findings demonstrate that these structures were developing during peat formation and that the deeper, wetter synclinal troughs accumulated more peat than the higher, dryer anticlinal crests.

The name Colchester was first used by Worthen (1868) for the exposures of the coal near Colchester, McDonough County. The type section for the Colchester was designated by Wanless (1956) in Sec. 12, T5N, R4W. Over the years, several local names were applied by miners and coal companies to this seam including the La Salle No. 2 Coal or the "Third Vein" in northern Illinois. The Colchester Coal is perhaps the most widespread minable seam in North America and is correlated with the Croweburg Coal of Missouri and Kansas, the Schultztown of western Kentucky, the Broken Arrow (or Croweburg) of Oklahoma, the Whitebreast of Iowa, the Colchester Coal Member (IIIa) of Indiana, the Lower Kittanning Coal of Ohio, the Princess No. 6 of eastern Kentucky, and the No. 6 Block of West Virginia (Willman et al. 1975, Peppers 1996).

At one time, the Colchester Coal was the principal seam mined in Illinois, but current production of Colchester Coal has dropped to almost nothing. The first major coal industry in Illinois centered on the Colchester in the northern part of the state, where the transportation costs were lower because of the coal's close proximity to the Chicago market. Low transportation costs were the main factor in development of this coal resource. Early operations in the Colchester existed in shallow underground mines in Grundy, Kankakee, and Will Counties; in small mines near the coal's outcrop along the Illinois River in LaSalle County; and in deeper mines west of the LaSalle Anticlinorium (fig. 6; Nelson 1995) in LaSalle, Bureau, and Putnam Counties.

This area, referred to as the "Longwall District," is the oldest mining district in Illinois. Three shaft mines opened in LaSalle County in 1856, and mining commenced at Wilmington in 1866. By 1880, LaSalle County ranked second in total coal output and Will County ranked third (Andros 1915). Longwall mining (described and illustrated in detail by Andros 1914, 1915) permitted the operators to recover a much larger percentage of coal resources than their room-and-pillar competitors in southern Illinois. Higher recovery partially offset the productivity losses inherent in mining thin coal seams such as the Colchester. However, production in the Colchester appears to have peaked in northern Illinois around 1900 and had begun a serious decline by 1915 (Cady 1915). At that time, local industries using the coal for fuel included brick and ceramic manufacturers, glass makers, cement plants, rolling mills, and zinc smelters (Cady 1915, Stull and Hursh 1917). In many cases, the raw materials for these operations came from the same mines or pits as the coal, or the sources were located closely to the coal mines. These uses of coal have since been mostly replaced by petroleum and natural gas or the industries themselves have gone away.

Since the 1920s, surface mining of the Colchester Coal in Illinois has proven to be more economical than underground mining, and, during the late 1920s through the 1960s, several large-scale surface mines operated in Grundy, Kankakee, and Will Counties. In addition, some mining of the Colchester (mostly in smaller surface mines) has occurred in western Illinois in Adams, Brown, Hancock, McDonough, and Schuyler Counties. With general reductions in shipping costs over the years, the mining of thicker and shallower coal seams in southern Illinois gradually took precedence over the Colchester. Innovations such as unit trains and modern earth-moving equipment now allow power plants in Illinois to buy cleaner-burning Wyoming coal more cheaply than some Illinois coals.

Social and cultural changes have also weighed heavily in the decline of Colchester Coal mining and of the Illinois coal industry as a whole. Changing public attitudes have led to increasingly more stringent safety, health, and reclamation laws and increasing restrictions on where coal can be mined. One result of such restrictions is an industry-wide trend that has seen the decline of smaller-scale, local-owner mining in the state; only the large mining companies are able to afford compliance with these laws. Surface mining the Colchester Coal, which tends to occur in small reserve blocks, was unattractive to the larger mining companies, but was a good source of livelihood for the small- and medium-sized coal producers of the twentieth century. At the time of this report, only one surface mine near the Schuyler/McDonough county line is actively mining the Colchester Coal in Illinois.

Floor and Roof Stratigraphy The Colchester Coal is underlain by a well-developed underclay— a paleosol, which is an ancient soil that developed prior to peat accumulation. This underclay is a claystone to sandy-claystone that, in many places along the Illinois River near LaSalle, was mined extensively for brick manufacturing. At least two underground mines in LaSalle County have reported "floor heave," or the squeezing of the

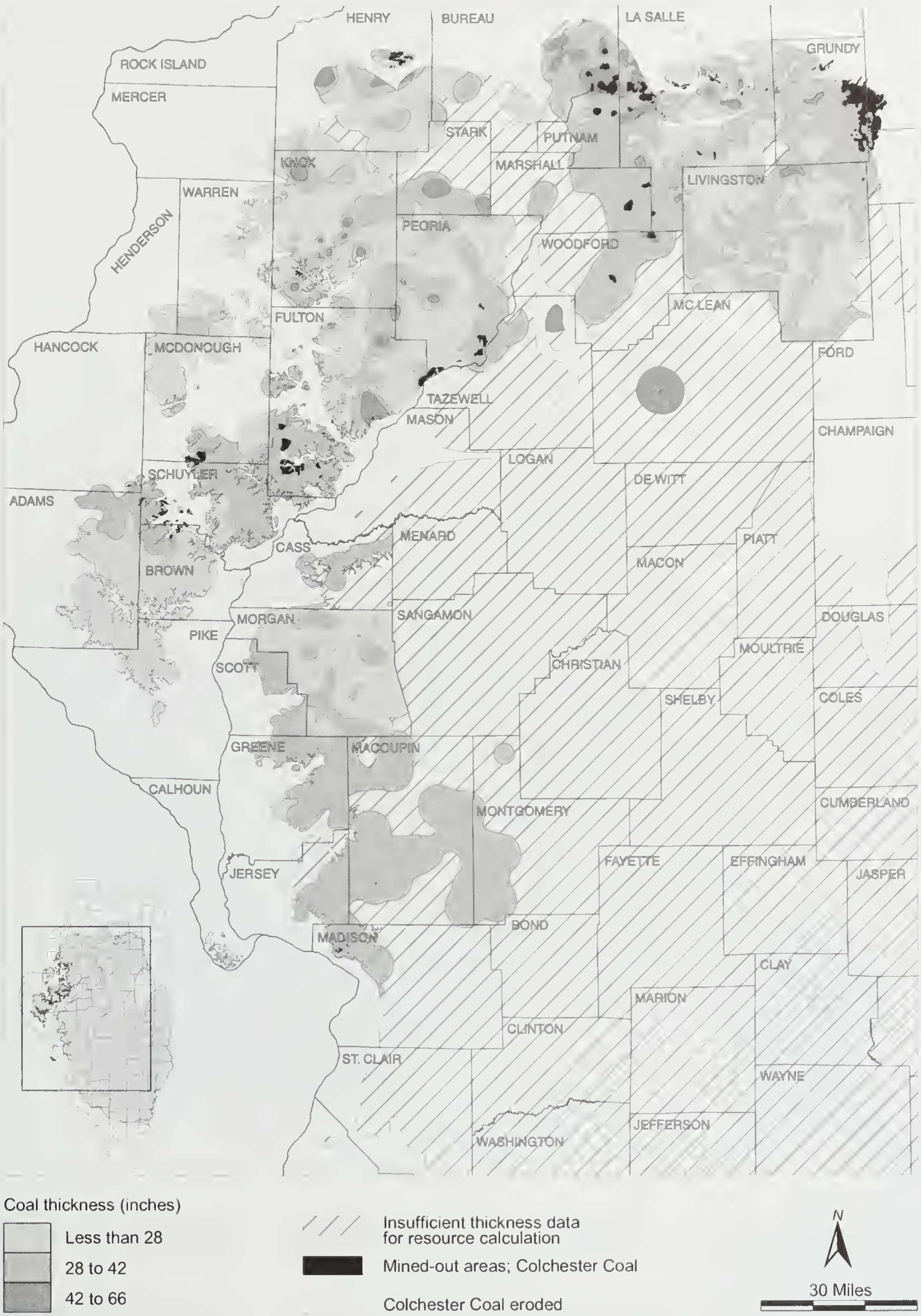


Figure 4 Thickness of the Colchester Coal.

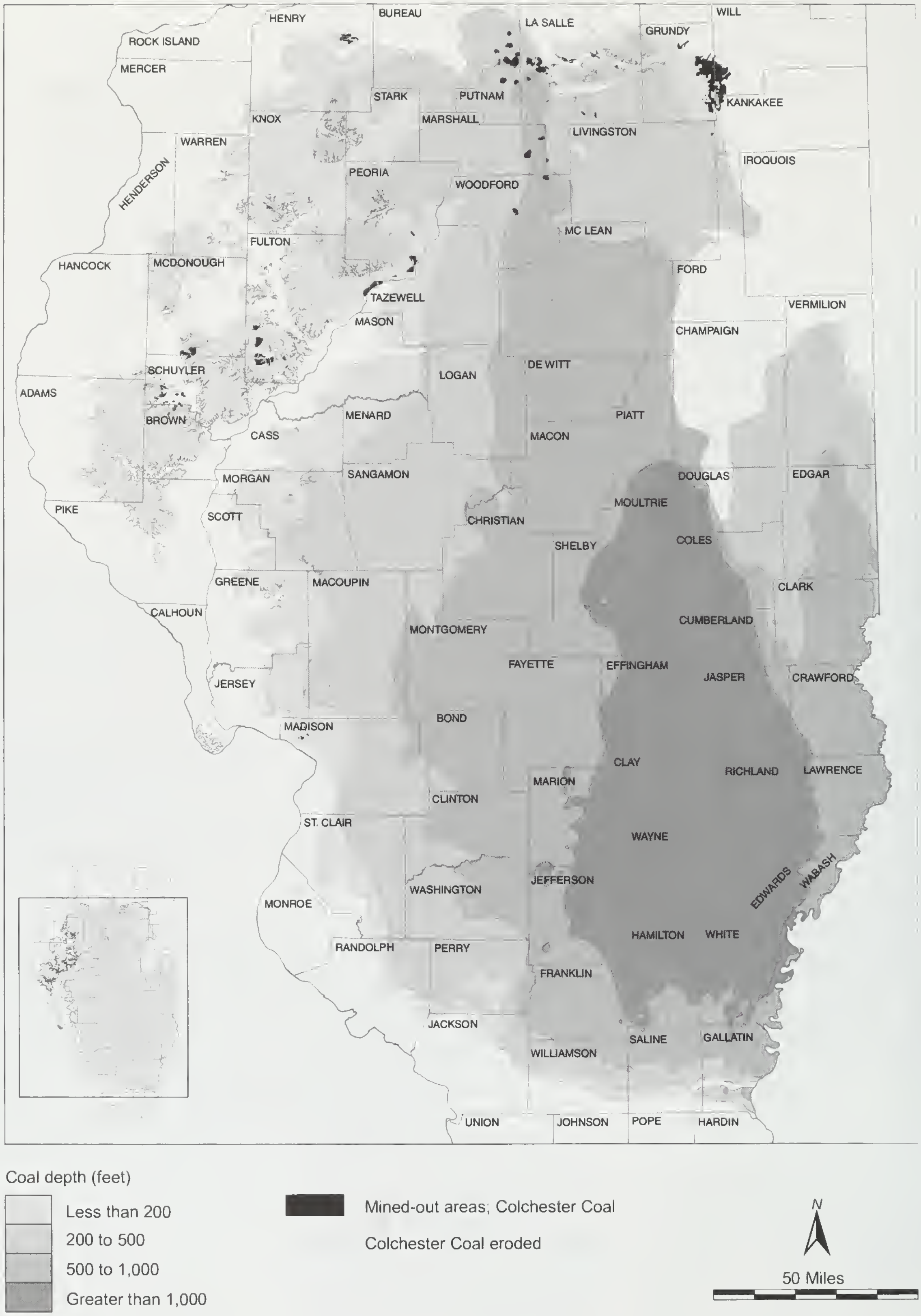


Figure 5 Depth of the Colchester Coal.

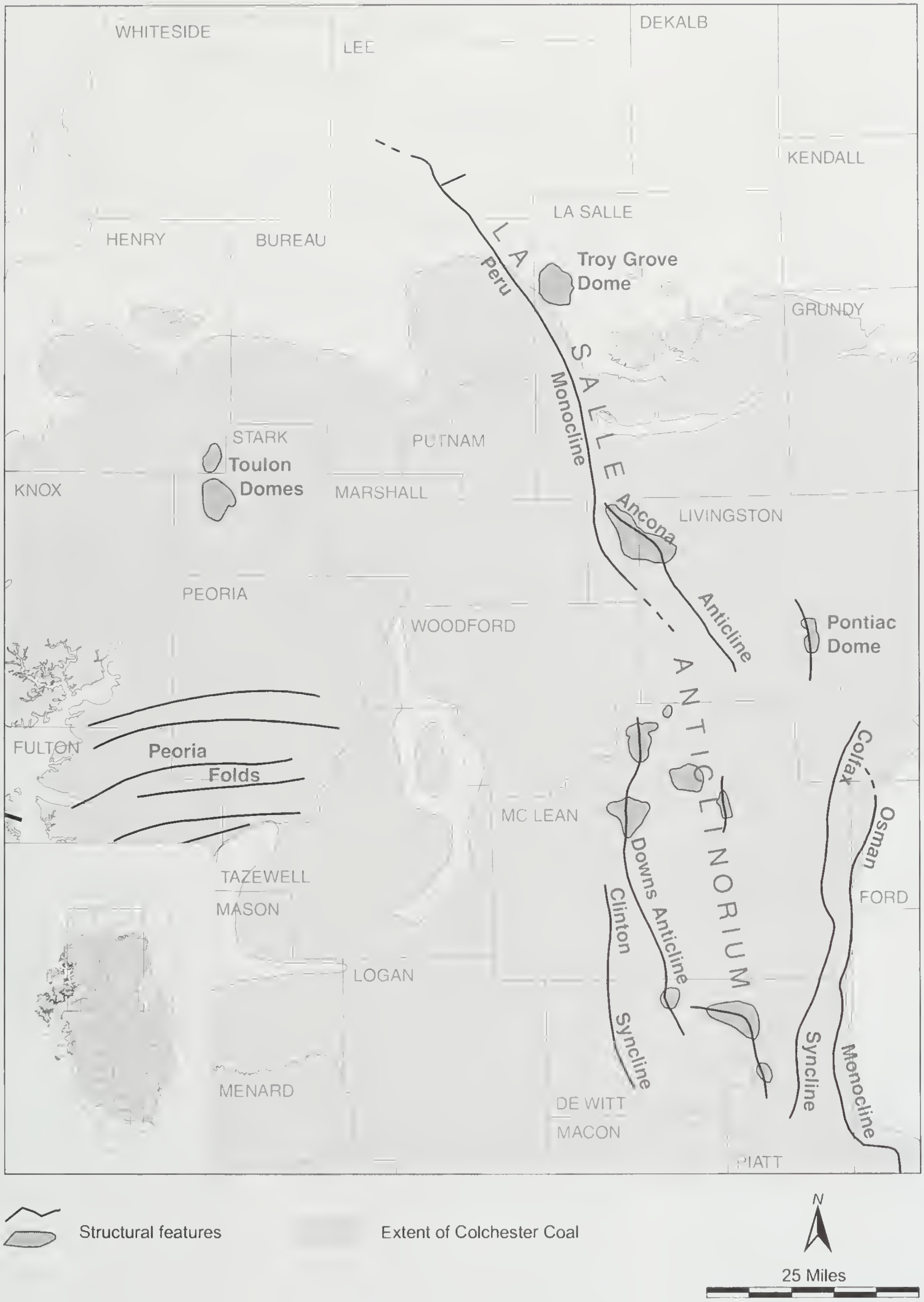


Figure 6 Selected structural features in northern Illinois (modified from Nelson 1995).

underclay into the mine from underneath coal support pillars, especially where the claystone was thick or contained less sand (unpublished mine notes, ISGS Coal Section). Weakening of the nearby roof and/or constricted mine openings can potentially result from such adverse mine floor conditions.

Directly overlying the Colchester Coal in many parts of western and northern Illinois is the Francis Creek Shale Member of the Carbondale Formation (fig. 7; Hopkins and Simon 1975), a medium gray, silty shale that locally exceeds 80 feet thick in the northeastern part of the Illinois Basin coalfield. The Francis Creek forms a large clastic wedge that extends across the northern part of the coalfield and thins out to the west and south in the western part of the basin (fig. 8; Smith 1970). It is best known for the famous Mazon Creek sideritic concretions found in parts of Kankakee, Will, and Grundy Counties in the northeastern part of the basin and also in western Illinois in Fulton County. These concretions have yielded a fossil fauna and flora (including many soft-bodied organisms that are rarely preserved and known nowhere else, such as the Illinois State Fossil, the "Tully Monster") that give clues to the depositional environments of the Francis Creek and hence some understanding of the distribution of lower-sulfur values in some of the Colchester Coal beneath the Francis Creek roof (Coal Quality section).

In northeastern Illinois, where the Francis Creek reaches its maximum thickness, the unit is much more silty and sandy and consists largely of siltstone and sandstone. Toward the south and west, the Francis Creek becomes less silty and sandy as it thins. However, in parts of Fulton County, the amount of sandstone and siltstone increases locally and reaches a maximum thickness of 18 feet along a 1-mile-wide, north-south outcrop belt where the Francis Creek grades upward into or is locally eroded by the sandstone deposits.

Locally, in northeastern Livingston and southeastern Grundy Counties, the channel-fill Cardiff Coal is found and mined a short distance above the Colchester (Cady 1915). The coal is recognized in this area only and is present in localized, linear deposits, often occurring as multiple benches of coal up to 12 feet thick, separated by gray shale. Although it has been both underground and surface mined, the resources of Cardiff Coal are small, and detailed drilling would be required to identify any additional deposits. The Cardiff Coal may overlie the Colchester directly or be separated from it by up to 10 feet of unnamed gray shale that is lithologically similar to the Francis Creek Shale (Jacobson 1985).

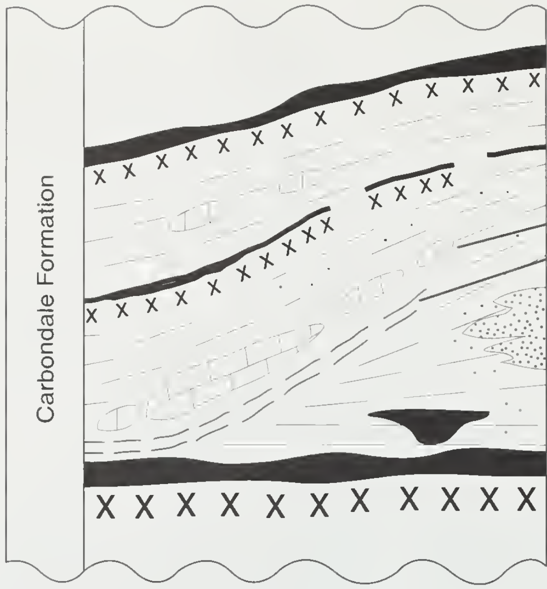


Figure 7 Generalized stratigraphic section from the Colchester Coal underclay to the Houchin Creek Coal (modified from Jacobson 1985).

ISGS geologists who visited underground mines in LaSalle County reported "rolls," or local irregularities, in the Colchester Coal roof contact with the Francis Creek Shale. In these areas, the coal thinned under a locally thicker shale roof, which made mining more difficult. The Oglesby Mine (in LaSalle County) also noted "bad roof" conditions where the Francis Creek was "filled with slickensided slip planes." These horizontal slip features along the Francis Creek bedding planes caused the roof to "fall in rather irregular masses" (unpublished mine notes, ISGS Coal Section), which likely resulted in dangerous mining conditions that required additional roof control.

The Mecca Quarry Shale Member of the Carbondale Formation (Hopkins and Simon 1975) overlies the Francis Creek Shale and rests directly on the Colchester Coal where the Francis Creek is absent. It is a hard, fissile, black shale that locally reaches 4 feet in thickness but generally ranges from 1 to 2 feet thick. The shale contains a marine fauna dominated by floating and bottom-dwelling forms. Large limestone concretions and small phosphatic lenses and nodules are locally abundant in the shale. The Mecca Quarry is a unit even more widespread than the Colchester, being present throughout most of the basin and into adjacent states. The Mecca Quarry is an important stratigraphic marker because of its distinctive low-resistivity signature on electric logs and very high gamma-ray log readings.

The Oak Grove Limestone, which overlies the Mecca Quarry Shale, varies from a horizon of large septarian concretions or multiple thin limestone nodules to a more-or-less continuous single bed of argillaceous limestone (or calcareous shale, in some areas).

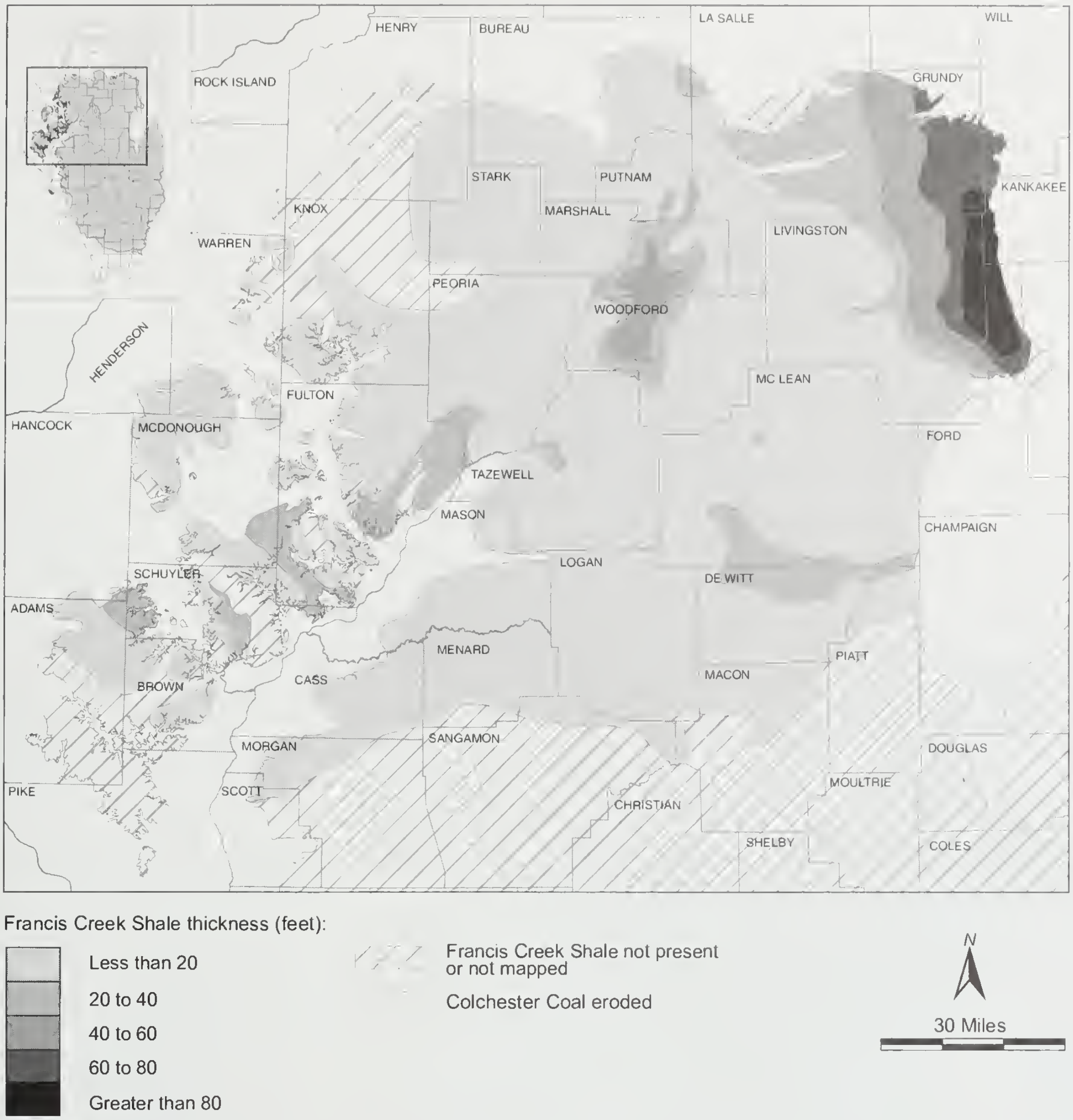


Figure 8 Regional thickness of the Francis Creek Shale (from Smith 1970).

Over much of northern and western Illinois (Hopkins and Simon 1975), the Oak Grove is made up of a persistent succession of thin but paleontologically and lithologically distinct limestone beds, many of which are only a few inches thick and are interbedded with dark gray to black shale. The Oak Grove Limestone interval typically does not exceed 15 feet and it, like the Mecca Quarry Shale, disappears in areas where the Francis Creek exceeds 40 feet in thickness. Limestone units are much less abundant in southern Illinois within the Oak Grove interval.

Coal Quality

The quality of coal was not considered as a factor in determining its availability. Although coal quality is an extremely important factor in individual sales contracts and the magnitude of demand for a particular coal, availability for mining of a specific resource cannot be ruled out based strictly on quality. Coal washing, blending with other seams, and other techniques can be used to mitigate some undesirable quality characteristics of coals. Because most Illinois coal resources have a relatively high-sulfur content, the demand for these resources is currently limited. However, the market for high-sulfur coal, although less than in the past, is expected to continue and may increase as power plants with new emission control technologies come into production.

Illinois Basin coals, including the Colchester, are high-volatile, bituminous coals that range in rank from rank A in the southeastern corner of the state to rank C in the northwestern two-thirds of the state (Treworgy et al. 1997b).

For these coal ranks and over the same area, respectively, heat content ranges from more than 25 million BTU per ton to less than 20 million BTU per ton (as received). The Colchester Coal resources identified in this report are rank C.

The sulfur contents of several Illinois coal seams, including the Colchester, are closely related to the depositional history of the coals and the roof strata (Gluskoter and Simon 1968, Treworgy and Jacobson 1986). In areas where the peat swamp was inundated with marine waters, the sulfur content of the coal is commonly in the range of 3 to 5% (as-received basis, equivalent to 2.5 to 5 pounds of sulfur per million BTU). In these areas, the coal is overlain by marine rocks including black shale and limestone. In areas where the peat was buried by a thick (more than 20 feet) layer of estuarine or deltaic clastic sediments in fresh or brackish water before or shortly after the swamp was inundated by marine waters, the sulfur content of the coal is generally less than 2.0% and may be as low as 0.5%.

Hence, depositional conditions associated with low-sulfur Colchester Coal are tied to the distribution of the Francis Creek clastic wedge. Low-sulfur Colchester Coal was reported by Gluskoter and Simon (1968) from mines in the area of northeastern Illinois where thick (20 to 80 feet) Francis Creek deposits composed largely of siltstone and sandstone are found (parts of Will and Grundy Counties, fig. 8). However, high-sulfur coal also was found in other mines in the general area. Elsewhere throughout the distribution of the Francis Creek, one mine in Woodford County had reportedly low-sulfur values. At the Banner Mine in Peoria and Fulton Counties, Hopkins and Nance (1970) reported that the pyritic sulfur of the Colchester decreases as the Francis Creek thickens, but the content of the organic sulfur (which is difficult to remove by conventional coal-preparation techniques) remains constant.

As already stated, Illinois coals overlain by thick, apparently non-marine shales such as the Francis Creek are, in many cases, lower in sulfur over much of their distribution, especially where the gray shales are over 20 feet thick. The Francis Creek seems generally to fit this pattern, but the variability in northeastern Illinois is puzzling. The Francis Creek seems to have prograded mostly from the northeast over the coal swamp, with possibly a second progradation into western Illinois from the north, into the Fulton and Peoria County area, where it merges with the larger area from the northeast (Wright 1965; Shabica 1970; Jacobson, unpublished field studies). Peat in the northeastern part of the Francis Creek coverage area (fig. 8) may have been covered early by the thick sandstone, siltstone, and shale of the Francis Creek, which protected the peat while it was still under fresh to brackish conditions. In western Illinois (the southwestern extent of the Francis Creek), the peat may have been largely contaminated by sulfur-bearing saline marine waters before the Francis Creek was deposited.

The complexity in sulfur values in the northeastern part of the coalfield may possibly be related to two main factors. First, the lower sulfur values in this region of thick Francis Creek are found in a transitional area between marine and non-marine deltaic conditions. The fossil faunas and floras found in the sideritic concretions support the interpretations of a transitional zone as some of the fossil assemblages found are distinctly marine in origin and others are non-marine. Thus, it is likely that, during the time the Francis Creek was being deposited, marine conditions prevailed locally, which could have contaminated the peat with additional sulfur (Treworgy and Jacobson 1986).

A second factor in the local occurrences of the higher sulfur values may have to do with the lithology of the Francis Creek. Throughout the basin, where similar gray shales have been observed (Energy Shale over the Herrin Coal and the Dykersburg Shale over the Springfield Coal), localized, predominately sandstone areas occur above the coal as deltaic or crevasse splay channel sandstones, and the coal beneath these channels has significantly higher sulfur values. This phenomenon is probably related to the porosity of the coarser clastics such as these sandstones, which were likely porous enough to let sulfate-bearing waters percolate downward to the peat, even though the mostly non-marine clastic deposits (gray shales) protected the majority of the peat from the next marine transgression in the area.

Both factors likely relate to the variation of sulfur values for the Colchester Coal in the northeastern part of the basin, but relationships between the factors are not possible to determine given the current data. There is no detailed information on sandstone distribution or the actual detailed paleoenvironments indicated by the concretion faunas for a given area of Francis Creek, or how this information might relate to the few known low-sulfur occurrences. Thus, any occurrences of lower-sulfur areas are likely to have poorly definable boundaries associated with the paleoenvironments and variable lithologies of the delta lobe represented by the Francis Creek deposits. Detailed exploration is needed to delineate these deposits.

Chlorine content of Illinois coals is loosely correlated to depth. For the Herrin Coal, chlorine increases from less than 0.1% (as received) at shallow depths along the margins of the basin to greater than 0.4% in the central part of the basin (fig. 9; Chou 1991). Few analyses for chlorine are available for the Colchester Coal. Because chlorine is thought to be related to basin fluids, not coal genesis, throughout the basin, the Colchester should have slightly higher chlorine levels than the Herrin Coal does. Yet, based on this projection, chlorine content should be similar to those of other coals commonly used in current Illinois markets, as most of the remaining Colchester resources in northern and western Illinois are located along the margins of the Illinois Basin. Although chlorine content in British coals has been correlated with corrosion and fouling of high-temperature boilers, no studies have found such a correlation for chlorine in Illinois coals (Monroe and Clarkson 1994; Chou et al. 1998, 1999).

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

Quadrangle Studies

The criteria defining available coal resources were developed through a series of 21 assessments of 7.5-minute quadrangles (fig. 10; Jacobson et al. 1996; Treworgy 1999; Treworgy et al. 1994, 1995,1996a, 1996b, 1997a, 1998, 1999b; Treworgy and North 1999). These assessments included interviews with more than 40 mining engineers, geologists, and other mining specialists representing 17 mining companies, consulting firms, and government agencies actively involved in the Illinois coal industry. Additional background of this program and a detailed description of the framework for the investigations in Illinois are provided in previous reports (e.g., Treworgy et al. 1994, 1999a, 2000).

Of the 21 areas studied, 3 quadrangles in northwestern Illinois included some resources of the Colchester Coal (fig. 10; table 2; Treworgy et al. 1997a). The total for Colchester Coal resources in these quadrangles was 187 million tons or about 1% of the original Colchester resources in the state. Availability of the coal in the 3 quadrangles ranged from 0 to 34% and averaged 26% when tonnages were factored in. None of the coal was thick enough to be available by underground mining methods. Stripping ratio accounted for the majority of the technological restrictions to surface mining of the Colchester Coal.

Table 2 Resources of the Colchester Coal in individual quadrangles studied, in millons of tons.

Quadrangle	Original	Mined	Remaining	Available	Restrictions: Technological	Restrictions: Land use
Augusta	75	1 (2)[1]	74 (98)	19 (24)	48 (64)	7 (10)
Kewanee North	23		23 (100)		22 (94)	1 (6)
Roodhouse East	89		89 (100)	30 (34)	47 (53)	12 (13)
Total	187	1 (<1)	186 (99)	49 (26)	117 (62)	20 (11)

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

Table 3 Criteria[1] used in this study to define resources available for surface mining.

Technological restrictions	
Minimum seam thickness	18 inches
Maximum depth	200 feet
Maximum unconsolidated overburden	60 feet
Stripping ratio[2]	
Maximum	25:1
Maximum average	20:1
Minimum size of mine reserve (clean coal)	
Cumulative tonnage needed to support a mine and preparation plant	10 million tons
Individual block size (thousands of tons)	
Less than 50 feet of overburden	150
More than 50 feet of overburden	500
Land-use restrictions (width of unminable coal around feature)	
Cemeteries	not used
State parks and preserves	100 feet
Railroads	100 feet
Federal and state highways	100 feet
Other paved roads	not used
Major airports	100 feet
High-voltage transmission towers	not used
Pipelines	100 feet
Underground mines	200 feet
Towns	0.5 miles
Available with potential restrictions	
Potential land-use conflicts	land-use patterns are incompatible with mining[3]

[1] See previous investigations in this series for a detailed explanation of differences in criteria (Treworgy et al. 1999a, 2000).

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

[3] No available coal resulted within the identified areas.

Technological and Land-Use Factors that Affect the Availability of Coal for Mining

A detailed description of the criteria used in this study to define available and restricted resources and their effect on mining was given in previous reports (Treworgy et al. 1999a, 2000). These criteria are a composite set of rules developed based on interviews with mining companies, observations of mining practice, and the assessments of the 21 quadrangles.

In tables 3 and 4, the criteria are organized according to the relevant mining methods (surface or underground mining) 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. Such 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, such coal is minable by underground methods. Except for seam thickness,

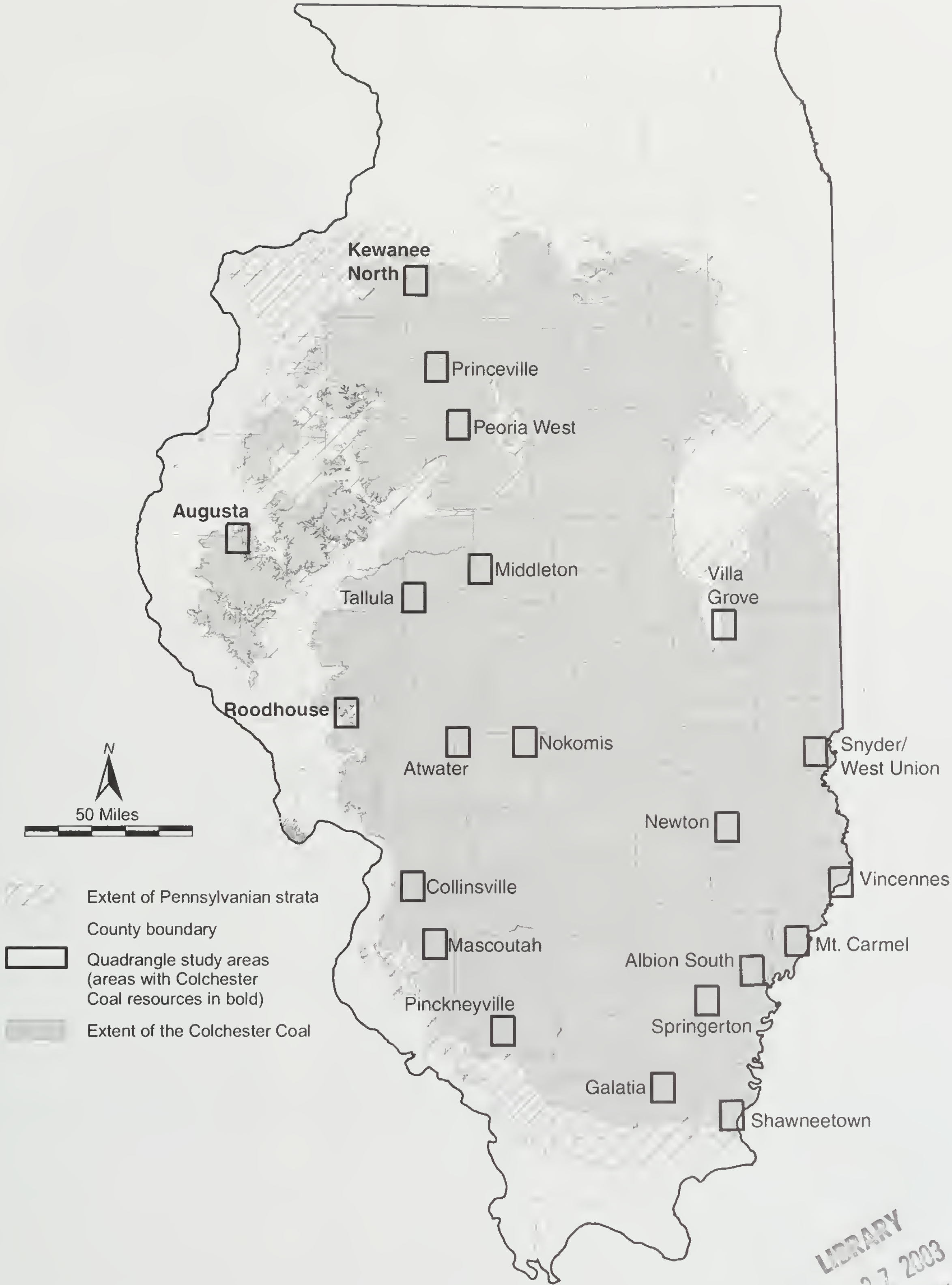


Figure 10 Quadrangle study areas used to identify criteria for coal available for mining.

Table 4 Criteria[1] used in this study to define resources available for underground mining.

Technological restrictions	
Minimum seam thickness	42 inches
Minimum bedrock cover	75 feet
Minimum ratio of bedrock to unconsolidated overburden	1:1
Minimum interburden between minable seams	40 feet
Minimum size of mining block (clean coal)	40 million tons
Faults (width of zone of no mining)	
Cottage Grove Fault System	
Master fault	500 to 1000 feet
Subsidiary faults	100 feet
Rend Lake Fault System	200 feet
Centralia Fault	300 feet
Wabash Valley Fault System	800 feet
Land-use restrictions (width of unminable coal around feature)	
Surface and underground mines	200 feet
Towns	0 feet
Subdivisions	not used
Churches and schools	not used
Cemeteries	not used
High-voltage transmission towers	not used
Interstate highways	100 feet
Major airports	100 feet
Dams	100 feet
Closely spaced oil wells[2]	fewer than 7 wells per 40 acres
Available with potential restrictions	
Closely spaced oil wells[2]	4 to 7 wells per 40 acres
Potential land-use conflicts	land-use patterns are incompatible with mining[3]
Bedrock cover	greater than minimum but less than 100 feet

[1] See previous investigations in this series for a detailed explanation of differences in criteria (Treworgy et al. 1999a, 2000).

[2] Two categories of resources in areas of closely spaced oil wells are used in this study.

[3] Resources initially in this category were ultimately restricted by insufficient size of the reserve block.

Table 5 Availability of the Colchester Coal for mining, by thickness category, in billions of tons.

	18 to 28 inches		28 to 42 inches		42 to 66 inches		>66 inches	Total	
Original	4.3		13.4		1.3			19.0	
Mined	< 0.1	(< 1)[1]	0.4	(4)	< 0.1	(1)		0.5	(2)
Remaining	4.3	(100)	13.0	(96)	1.2	(99)		18.5	(98)
Available	0.3	(8)	0.6	(4)	0.1	(7)		1.0	(5)
Available with conditions	0		0		0			0	
Technological restrictions	3.4	(79)	11.7	(87)	1.0	(78)		16.1	(86)
Land-use restrictions	0.6	(13)	0.7	(5)	0.1	(14)		1.4	(7)

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

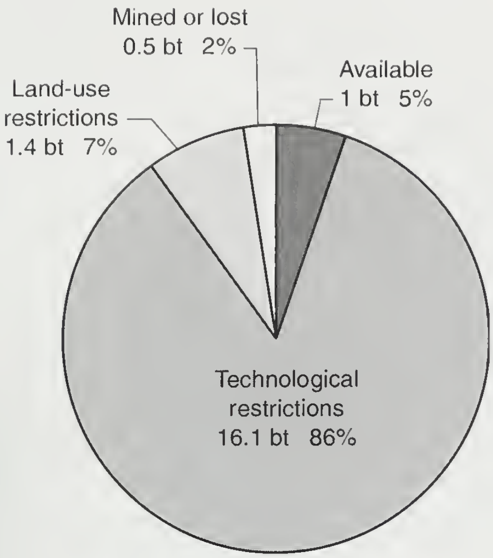


Figure 11 Availability of the Colchester Coal for mining in Illinois (bt = billion tons).

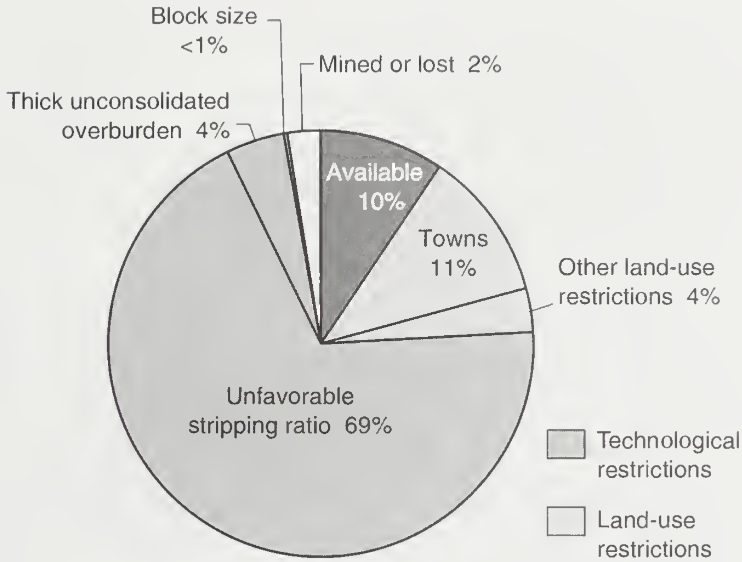


Figure 12 Availability of the Colchester Coal for surface mining (based on 10.7 billion tons).

most of the factors that restrict underground mining also restrict auger or highwall mining. The amount of additional tonnage that is recoverable by these methods is likely not significant.

All technological or land-use factors that restrict mining are based on economic and social considerations, and most 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, for example, to mine through or under 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 damage. The maximum stripping ratio is an economic limit, and areas of coal 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. Similarly, previous economic and social conditions, at times, have enabled companies to mine in areas where factors are now restrictive. The current highly competitive price environment in the coal industry is expected to prevail in the Illinois Basin indefinitely. This situation makes it uneconomical to produce coal that is more expensive to mine.Therefore, the criteria used to determine available coal for this report are likely to cover mining conditions for the foreseeable future.

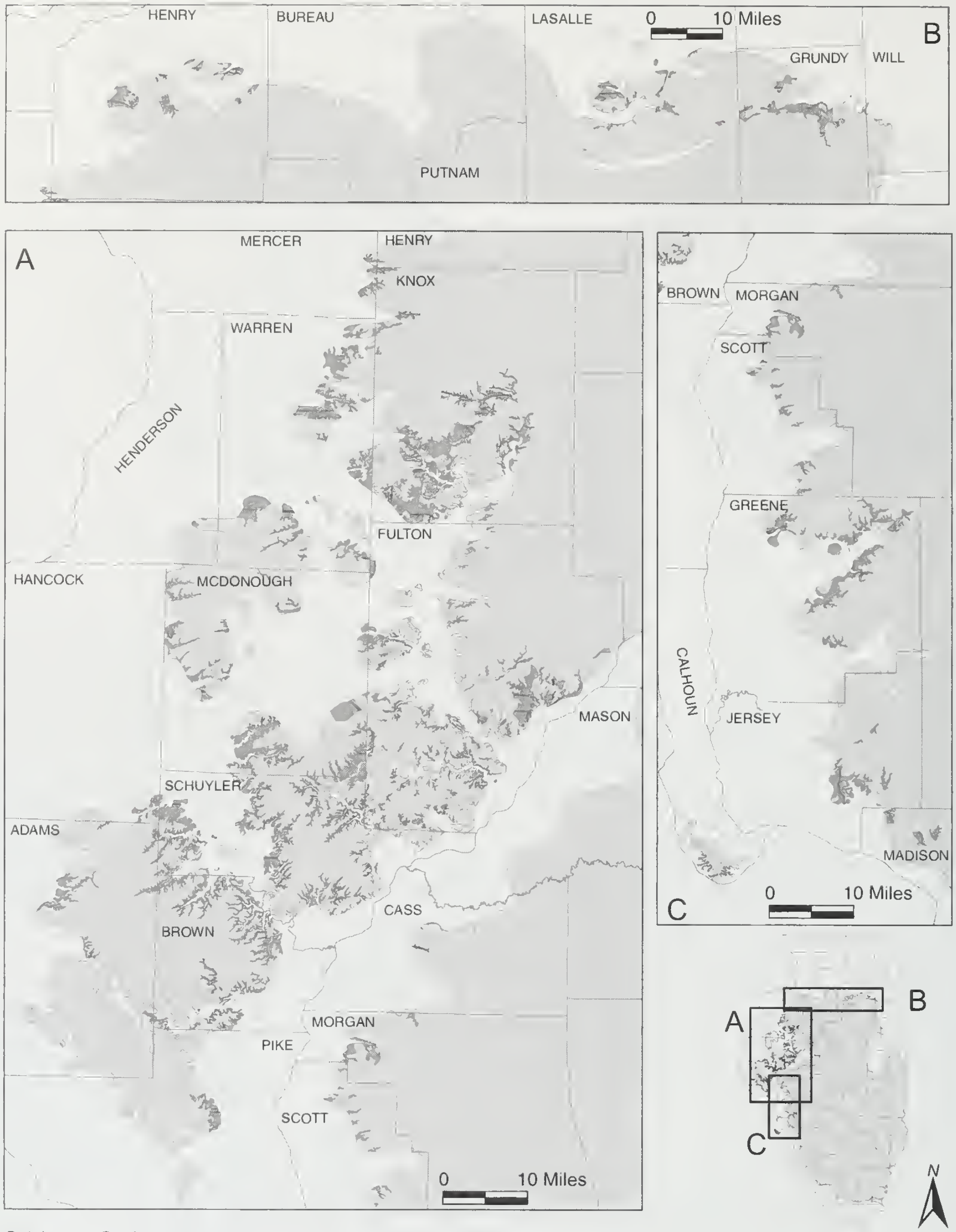
Available Resources

One billion tons (5%) of the original resources of Colchester Coal are available for mining (fig. 11). Of these available resources, about 600 million tons are 28 to 42 inches thick, and 100 million tons are 42 to 66 inches thick (table 5). All of the available Colchester resources are available for mining by surface methods only. Technological factors restrict 86% of the original coal resources (16.1 billion tons), land use restricts 7% (1.4 billion tons), and 2% (0.5 billion tons)of the original Colchester resources have been previously mined.

About 10.7 billion tons of the original Colchester Coal resources lie at depths shallow enough to be considered for surface mining (less than 200 feet deep). Of these, 1 billion tons (about 10%) are available for surface mining (fig. 12). Technological factors restrict 73% (7.9 billion tons) of the surface minable resources, and the majority of these are restricted by unfavorable stripping ratio (69% of resources). Unfavorable drift thickness restricts 4% of the resources, and size or geometry of the mining block restricts less than 1%. Land use restricts surface mining of 15% (1.5 billion tons) of the resources; 11% is restricted by towns. Areas of Colchester Coal available for surface mining occur throughout several counties in north-central and western Illinois. These areas consist mainly of smaller blocks that parallel the crop of the coal (figure 13).

About 13.4 billion tons of the original Colchester Coal resources lie at depths greater than 75 feet and are potentially minable by underground methods. The majority of these resources are less than 42 inches thick (the minimum thickness for underground-available coal), and, of the coal resources thicker than 42 inches, no resources are available for underground mining. Small areas of available coal resulted after our initial classifications; however, these areas consisted of tonnage blocks less than the minimum required to meet the mine reserve and were thus considered restricted.

Technological factors restrict 92% (12.4 billion tons) of the potentially underground minable resources, land use restricts 6%, and 2% of the resources have been previously mined



Colchester Coal

Available

Restricted or mined out

Colchester Coal eroded

Figure 13 Areas of the Colchester Coal available for surface mining.

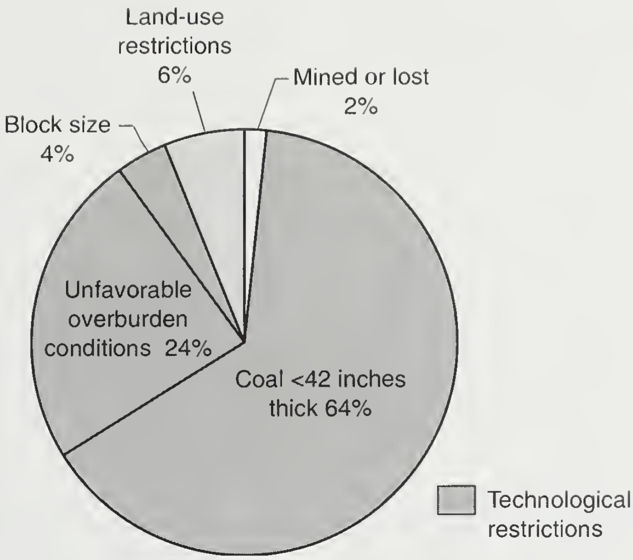


Figure 14 Restrictions to the Colchester Coal for underground mining (based on 13.4 billion tons).

(fig. 14). The major technical restrictions are coal less than 42 inches thick (64%) and thin bedrock or thick unconsolidated overburden (24%). Mining reserve blocks of insufficient size restrict almost 4% of the resources. Areas of Colchester Coal evaluated for underground mining generally correspond to the resources indicated in figure 4 (thickness of the Colchester Coal), except for shallow coal lying less than 75 feet deep.

Conclusions

The Colchester Coal represents 19 billion tons (9%) of the state's original coal resources, and 1 billion tons of this coal are available for mining. "Available" means that the land-use and physical characteristics of the deposit (e.g., thickness, depth, in-place tonnage, and stability of bedrock overburden) are comparable with the conditions under which these and other coals are currently being mined in the state. All 1 billion tons of the available Colchester resources are available by surface mining methods only.

Technological factors cause the most significant restrictions to the availability of the Colchester Coal. For underground mining, these factors include thickness of the coal seam, undesirable overburden characteristics, and insufficient size of the reserve block. Although coal less than the minimum thickness identified in this report has been mined underground in recent years in the Appalachian region, those seams have certain quality characteristics that warrant a higher market price. The Colchester Coal is not known to have any quality characteristics that make it significantly more valuable than other coal resources. Thus, the availability of surface minable resources and underground minable resources in other, thicker coal seams makes the likelihood of underground mining of the Colchester Coal so remote that it is not considered available under current economic conditions.

For surface mining, the major technological restrictions to mining the Colchester Coal are stripping ratio and thickness of drift. These conditions make the cost of surface mining too high to compete successfully with underground mining of thicker seams or with surface-mined coal from western states in the current markets. To minimize the negative impacts of geologic conditions on surface mining costs, companies could avoid areas of thick drift and high stripping ratios. Land use, particularly close proximity to towns, is also a significant restriction to surface mining.

In the reports in this series, the factors that restrict mining are based on economic and social considerations and most are not absolute restrictions on mining. Available resources are not necessarily economically minable at the present time, but the term available designates that these deposits are expected to have mining conditions comparable with those resources currently being mined in Illinois. Ultimately, the feasibility of surface mining the Colchester Coal is still dependent upon a variety of other factors that are beyond the scope of this study to assess, including the willingness of local landowners to lease the coal, demand for a particular quality of coal, accessibility of transportation infrastructure, proximity of the deposit to markets, and cost and availability of competing fuels.

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Appendix 1

Remaining Colchester Coal resources and availability by county (millions of tons).

County	Remaining resources	Total available by surface mining methods
Adams	637	24
Bond	2	
Brown	411	63
Bureau	777	
Calhoun	12	4
Cass	232	1
Fulton	1,402	142
Greene	613	74
Grundy	820	60
Hancock	30	7
Henderson	53	1
Henry	624	53
Jersey	269	31
Kankakee	57	
Knox	1,445	164
LaSalle	1,466	26
Livingston	1,521	
McDonough	576	109
McLean	287	
Macoupin	1,470	
Madison	229	14
Marshall	494	
Mercer	15	5
Montgomery	554	
Morgan	797	13
Peoria	832	
Pike	159	9
Putnam	377	
Schuyler	606	123
Scott	255	12
Stark	423	
Tazewell	214	
Warren	347	90
Will	14	
Woodford	517	
Total	18,535	1,026

[1] Values are rounded to the nearest 1 million tons.

Appendix 2

Source maps for Colchester Coal resources.

County	Source (ISGS publications)	Map year	Scale (×1000)
Adams	Reinertsen 1964	1964	125
Bond	Cady 1952	1950	62.5
Brown	Reinertsen 1964	1964	125
Bureau	Cady 1952, Smith and Berggren 1963, Smith 1968, this study	1950	125
Calhoun	Reinertsen 1964	1964	125
Cass	Smith 1961	1961	125
Fulton	Smith and Berggren 1963, this study	1963	125
Greene	Smith 1961, Cady 1952	1950	125
Grundy	Jacobson 1985	1985	62.5
Hancock	Reinertsen 1964	1964	125
Henderson	Reinertsen 1964	1964	125
Henry	Smith and Berggren 1963, this study	1963	125
Jersey	Cady 1952, Smith 1961	1950	125
Kankakee	Cady 1952, Smith 1968	1950	125
Knox	Cady 1952, Smith and Berggren 1963, this study	1950	125
La Salle	Jacobson 1985	1985[1]	62.5
Livingston	Jacobson 1985	1985	62.5
McDonough	Reinertsen 1964	1964	125
McLean	Cady 1952	1950	62.5
Macoupin	Cady 1952, Smith 1961	1950[1]	62.5
Madison	Cady 1952, Smith 1961	1950	62.5
Marshall	Cady 1952	1950	62.5
Mercer	Reinertsen 1964, Searight and Smith 1969	1964	125
Montgomery	Cady 1952	1950	62.5
Morgan	Smith 1961, Cady 1952, this study	1950	125
Peoria	Smith and Berggren 1963, Cady 1952, this study	1950	125
Pike	Reinertsen 1964	1964	125
Putman	Cady 1952	1950	62.5
Schuyler	Reinertsen 1964	1964	125
Scott	Smith 1961, Cady 1952	1961	125
Stark	Smith and Berggren 1963, this study	1963	125
Tazewell	Cady 1952, Smith and Berggren 1963	1950	125
Warren	Smith and Berggren 1963	1963	125
Will	Smith 1968	1968	125
Woodford	Cady 1952	1950	62.5

[1] Minor revisions made for this report.

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