Availability of Coal Resources for Mining in Illinois

Galatia Quadrangle, Saline County, Southern Illinois

Colin G. Treworgy, Cheri Chenoweth, and Margaret H. Bargh

ILLINOIS MINERALS 113 1995

Department of Natural Resources
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ABSTRACT

This report is part of a series examining the availability of coal resources for development in Illinois. Many of the geologic and physiographic conditions common to the southernmost part of Illinois are found in the Galatia Quadrangle.

Environmental and regulatory restrictions, cultural features, mining technology, geologic conditions, and economic conditions all affect resource availability. Interviews with experts from coal companies and state government indicated how these conditions restrict mining.

Coal resources and related geologic features in the Galatia Quadrangle were described and mapped for this report. Original resources for 12 seams underlying the quadrangle totaled 1.1 billion tons; 1 billion tons remain in the ground, and 377 million tons (34% of the original resources) are estimated to be available for mining. Technological factors related to mining practices and geologic conditions restrict about 51% of the original resources, and land use restricts 6%.

Of the more than 1 billion tons of original deep minable resources in the quadrangle, 369 million tons (36%) are available for mining. In addition, 7 million tons of Herrin Coal less than 150 feet deep, and thus classified as surface minable, are also available for underground mining. Deep minable resources may be restricted because seam thickness is less than 4 feet (31%), block size is too small (10%), geologic conditions are unfavorable (6%), land uses are incompatible with mining (6%), faults disrupt coal (1%), and bedrock overburden is too thin (<1%). About 10% of the original deep minable coal has been mined.

Of the 89 million tons of original surface minable resources in the quadrangle, only 1.6 million tons (2%) are available for mining. Surface minable resources may be unavailable because the stripping ratio is unfavorable (45%), block size is too small (31%), faults disrupt coal (15%), and land uses conflict with mining (6%). Less than 1% of the surface minable coal has been mined.

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 that supply goods and services to the mining industry, and energy consumers and producers. Current inventories of coal resources in Illinois provide relatively accurate estimates of the total amount of coal in the ground. There is serious doubt, however, regarding the percentage of coal resources that can actually be mined. Environmental and regulatory restrictions, the presence of towns and other cultural resources, current mining technology, geologic conditions, and other factors significantly reduce the amount of coal available for mining. This report is one of a series that examines the availability of coal resources for development.

The state was divided into seven regions to provide a framework for selecting quadrangles and extrapolating results to larger areas (fig. 1). The Galatia Quadrangle was selected as representative of many of the geologic and physiographic conditions in region 7, the southern end of the Illinois coal field.

Mining experts from coal companies and state government were interviewed for information about how various factors might restrict the availability of the coal resources in the Galatia Quadrangle for mining. The information from these interviews was used to develop a set of criteria for defining available coal in the quadrangle. The location and quantity of available resources were delineated and tabulated using these criteria. Results from this and other quadrangle studies will be applied to each region and combined with coal-quality data to produce a statewide assessment of the availability and usability of coal resources. For a complete description of the background and framework of these studies of coal availability, see the appendix.

GEOLOGIC AND PHYSIOGRAPHIC SETTING OF REGION 7

Region 7 is a historically important mining area in Illinois. Extensive mining has taken place in this region since the 1800s and continues to this day. Almost one-third of the state's coal is produced from this region. Large surface mining operations and underground mines have altered more than 100 square miles of the land surface. Large mines are concentrated in the northern half of the

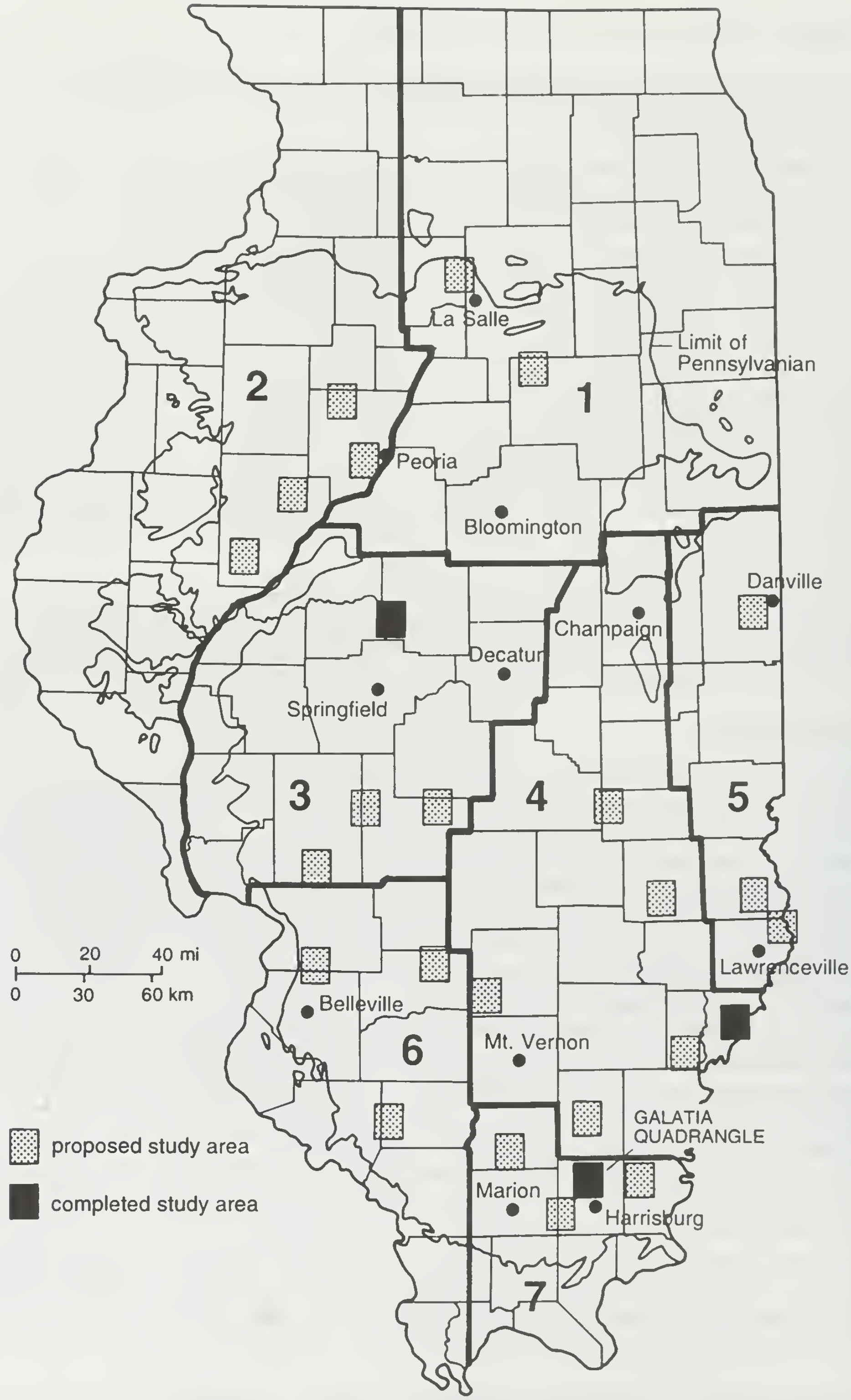

Figure 1 Coal resource regions and quadrangles for coal availability evaluation.

region, where surface acreage is most affected. Mines in the southern half are smaller and have affected less acreage.

The northern half of the region consists primarily of gently rolling farmland and pasture. The southern half of region 7 has greater topographic relief and is covered by large tracts of forest broken by small areas of pasture and farmland. Much of the southern half of the region is occupied by the Shawnee National Forest. In addition to the national forest, the region contains a number of state parks, preserves, and natural areas.

Geology

In the northern part of the region, the bedrock surface is concealed by a thin layer of glacial and alluvial deposits composed of clay, silt, sand, and gravel. Drift and glacial lake deposits are less than 50 feet thick on the preglacial upland surfaces and as much as 100 feet thick where they fill lowlands and bedrock valleys. The regional dip of bedrock strata is northward at a low angle towards the central part of the state. Locally, the strata in the southern part of the region have been affected by tectonic forces associated with the Shawneetown Fault Zone, Fluorspar Area Fault Complex, and the formation of the Eagle Valley Syncline. Upper Pennsylvanian strata have been almost completely eroded from region 7. Middle Pennsylvanian rocks constitute the bedrock surface in the northern part of the region. Middle and lower Pennsylvanian rocks occur at the surface in the southern part of the region.

Structure

Region 7 contains a number of major geologic structures (fig. 2). The Cottage Grove Fault System and Shawneetown Fault Zone cross the region in a general east-southeast to west-northwest trend. Small branch faults extend northwestward and southeastward off the master fault of the Cottage Grove Fault System in a number of areas. The Wabash Valley Fault System, Fluorspar Area Fault Complex, New Burnside and McCormick Anticlines, and the western tail of the Shawneetown Fault Zone cross the region in a northeast–southwest direction. The Rend Lake Fault Zone is present in the northwestern part of the region.

Molten rock from deep within the earth intruded into some faults and fractures in southern Illinois, formed igneous dikes that penetrated the coal seam, and coked the adjacent coal within zones several inches to several feet wide. The dikes may extend hundreds of feet or several miles laterally and generally are several feet to 30 feet wide.

Coal Resources

Coal resources have been mapped in more than a dozen coal seams in region 7. The thickest coals (in some places more than 8 feet thick) are in the middle Pennsylvanian Carbondale Formation, which covers the northern part of the region. These coals have extensive lateral continuity and have been the main targets for exploration and mining. The coals in the lower Pennsylvanian (in the southern part of the region) are generally thinner and laterally discontinuous. Only a few of the lower seams, such as the Reynoldsburg and New Burnside Coals, have been surface mined.

Northward from the subcrops, the major coals deepen to almost 1,000 feet. The Herrin Coal (formerly called the No. 6 Coal) is the state's largest coal resource as well as the largest in region 7 (fig. 3). The Herrin has been mined extensively in the western part of region 7 where the coal has a low to moderate sulfur content and has been extensively surface mined along its crop. The Springfield Coal (formerly called the No. 5 Coal) also is a major resource in the state as well as the region (fig. 4). It has been extensively mined in the north-central part of the region, where its sulfur content is low to moderate. The Dekoven and Davis Coals also contain large resources, but they have not been extensively mined because they are slightly thinner and deeper than the Herrin and Springfield Coals. Other coal seams, including the Chapel (formerly No. 8), Danville (formerly No. 7), Briar Hill (formerly No. 5A), Houchin Creek (formerly Summum or No. 4), Survant (formerly Shawneetown or No. 2A), Colchester (formerly No. 2), Mt. Rorah, and Murphysboro are present in this region (fig. 5), but they are generally thin and have had limited mining.

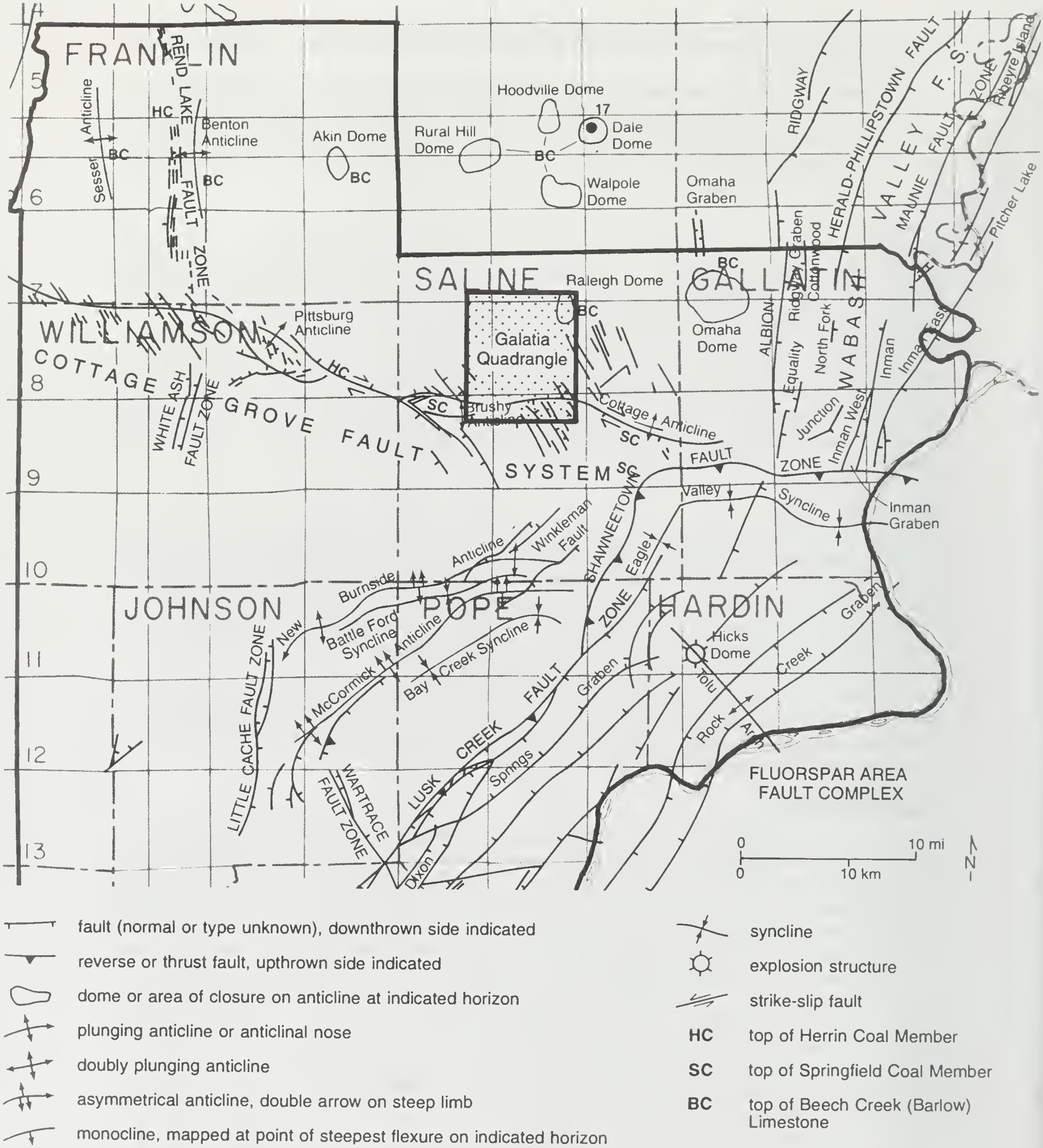

Figure 2 Structural features in the coal-bearing portion of region 7 (from Nelson 1995).

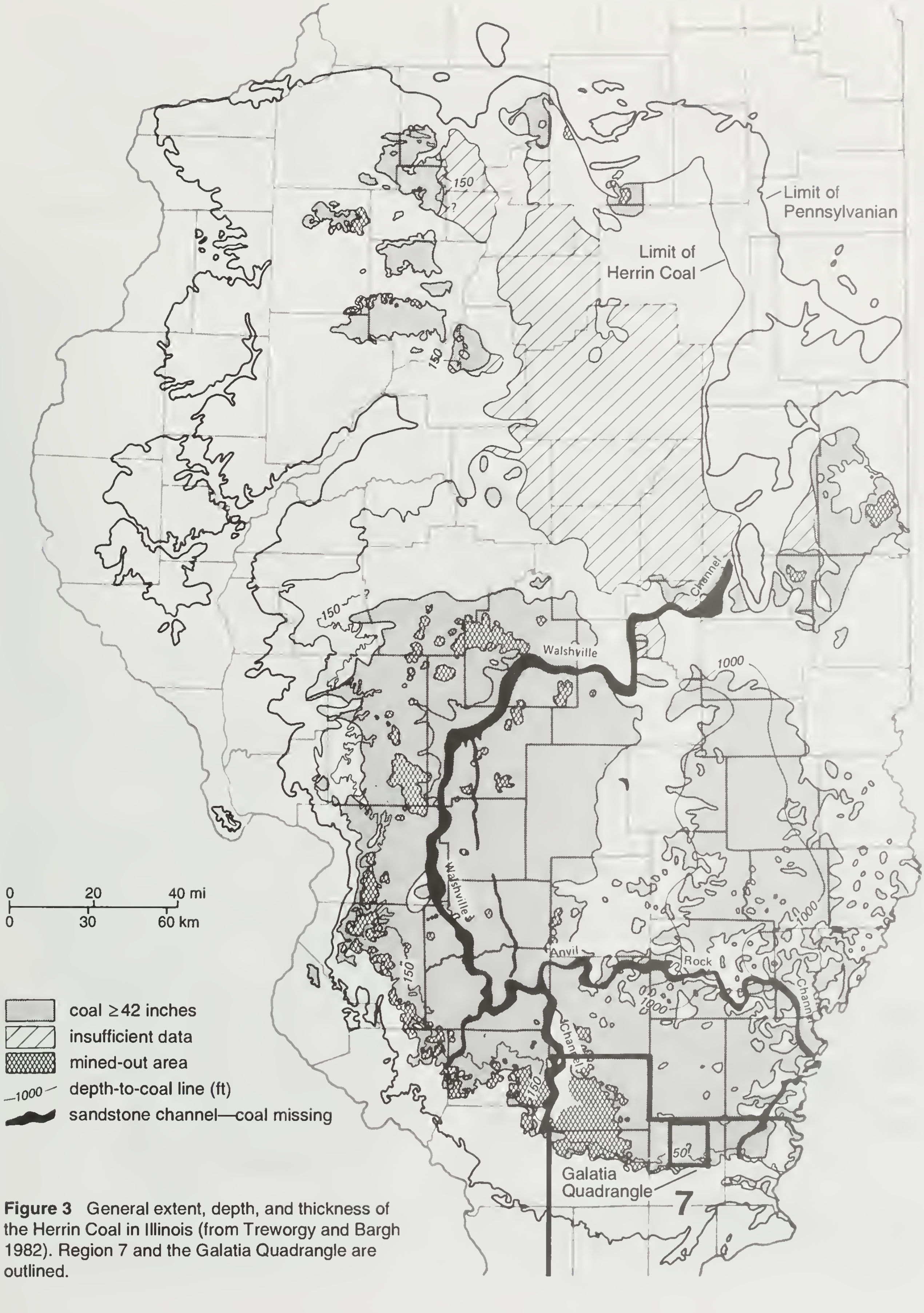

Figure 3 General extent, depth, and thickness of the Herrin Coal in Illinois (from Treworgy and Bargh 1982). Region 7 and the Galatia Quadrangle are outlined.

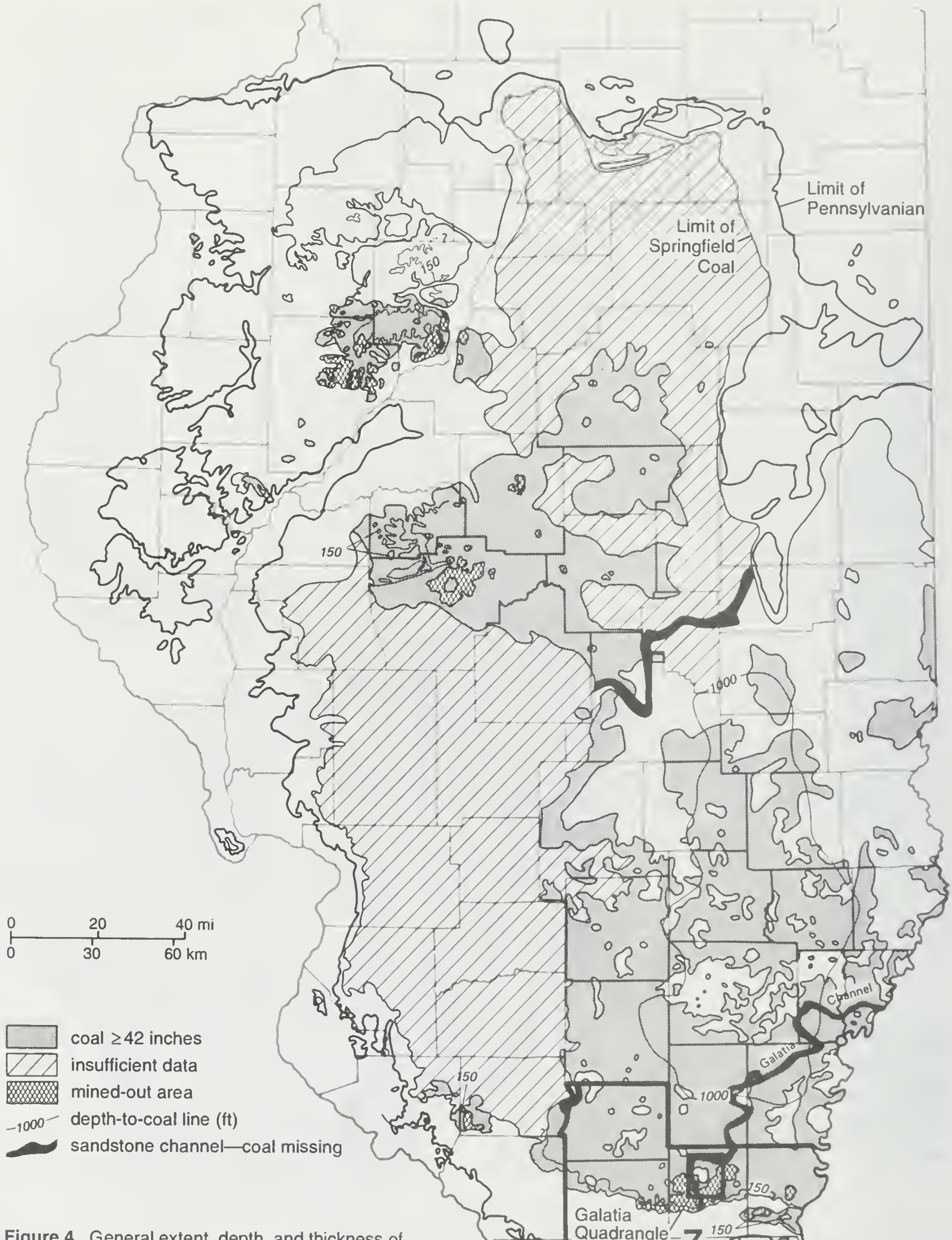

Figure 4 General extent, depth, and thickness of the Springfield Coal in Illinois (from Treworgy and Bargh 1982). Region 7 and the Galatia Quadrangle are outlined.

Galatia Channel

The Galatia Channel, a drainageway through the ancient peat swamp of the Springfield Coal, has strongly influenced the thickness, quality, and minability of the Springfield Coal in southern Illinois (figs. 4 and 6). The coal is generally thick (6 to more than 8 feet) in a zone along and extending from 1 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 Galatia Channel, the coal is missing, and the stratigraphic position is occupied by sandstone, siltstone, and shale.

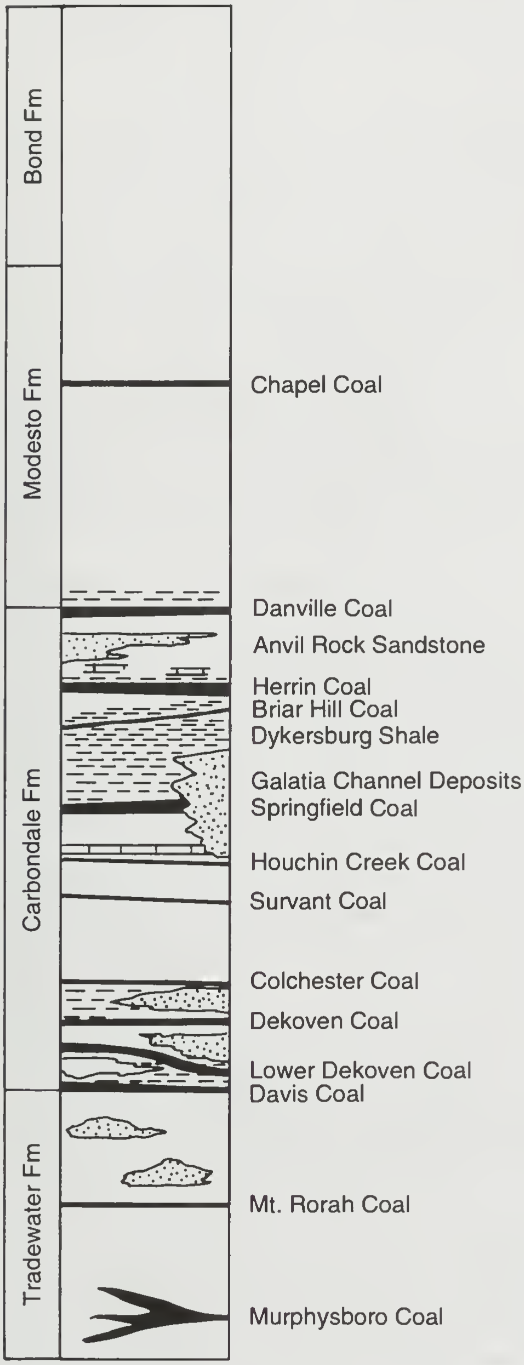

Figure 5 Selected stratigraphic units present in the Galatia Quadrangle. Vertical scale: 1 inch equals approximately 130 feet.

Previous Investigations of Coal in Region 7

Smith (1957) mapped surface minable coals for region 7 (at least 1.5 feet thick and less than 150 feet deep). Treworgy et al. (1978) partially evaluated the availability of surface minable resources in region 7. Their study demonstrated how factors such as stripping ratio, size and configuration of the mining block, and surface land use limit the availability of surface minable resources. Of the more than 1 billion tons of surface minable resources in the region, only about 25% was found to be suitable for mining. Several significant factors were not evaluated in that study, including average stripping ratios of mine blocks, loss of resources in minor seams because of preferential mining of thicker, underlying seams, and proximity of mine blocks to towns and important natural areas.

Deep minable coal resources in this region have been mapped by a number of Illinois State Geological Survey (ISGS) studies, most recently Treworgy and Bargh (1982). Their study evaluated these resources with respect to thickness, depth, proximity to areas densely drilled for oil, and selected categories of surface land use (towns, interstate highways, public lands, and cemeteries). Of the more than 13 billion tons of deep minable resources in the region, they ranked almost 25% (including almost all remaining resources in the Galatia Quadrangle) as having a high potential for development. Other factors remained to be evaluated, however, including thickness and composition of strata between seams, recovery of coal above or below previously mined areas, proximity of channels and faults, partings and clastic dikes in seams, roof and floor conditions, size and configuration of mining blocks, and thickness of bedrock overburden. Jacobson (1993) mapped additional resources of the Dekoven and Davis Coals.

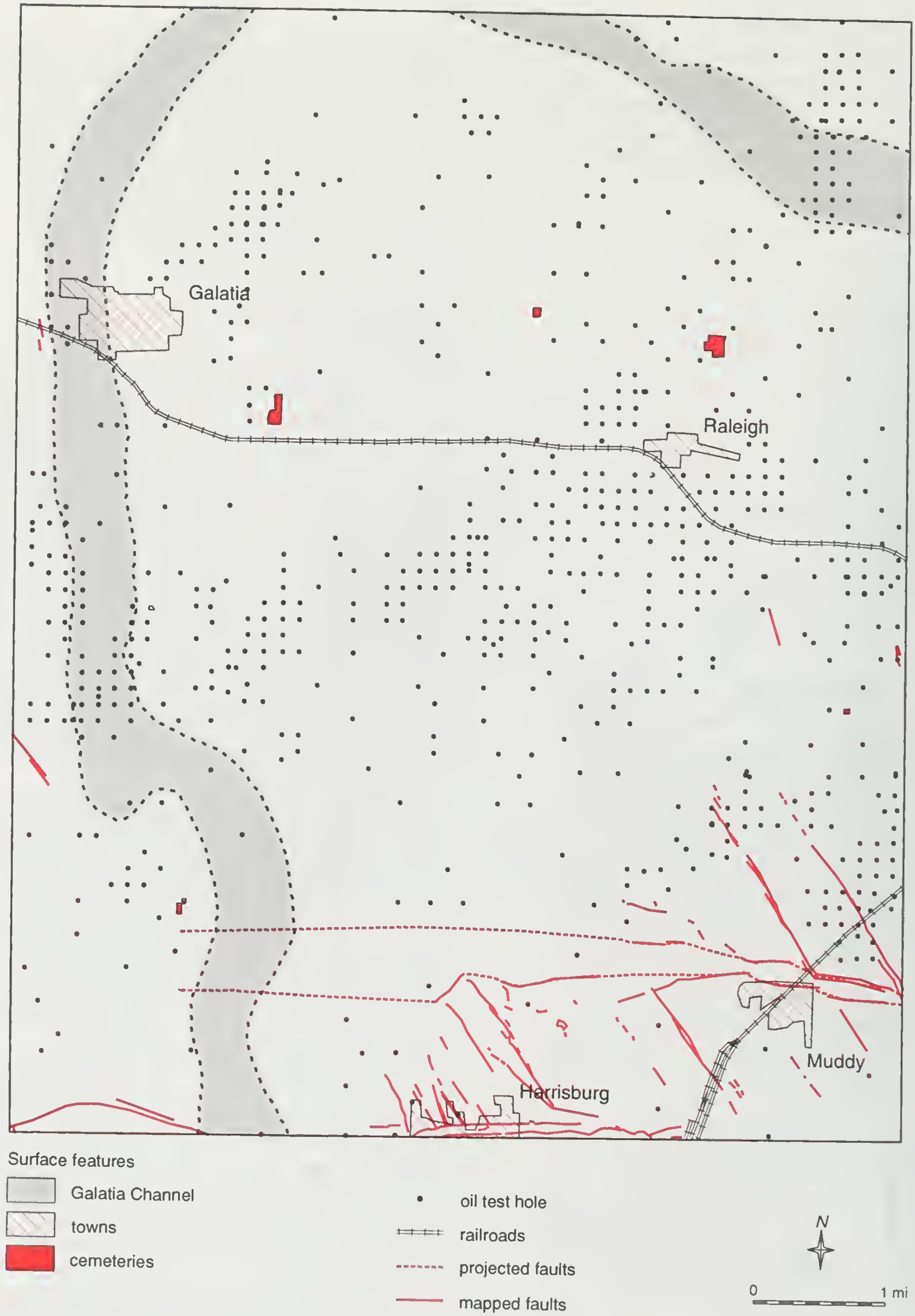

Figure 6 Selected surface and geologic features in the Galatia Quadrangle.

LAND COVER AND OTHER FEATURES OF THE GALATIA QUADRANGLE

The Galatia Quadrangle is a predominantly rural area covering approximately 56 square miles just north of the city of Harrisburg. The north edge of Harrisburg and the small communities of Muddy, Raleigh, and Galatia occupy less than 5% of the quadrangle (fig. 6). The broad floodplains of Brushy Creek, Bankston Fork, and the Middle Fork of the Saline River cross the southern half of the quadrangle. The land between the floodplains, as well as in the northern half of the quadrangle, consists of gently rolling farmland, pasture, and woodland. With the exception of several small knobs deposited by glaciers, the land surface in much of the southern part of the quadrangle has little topographic relief. Total relief in the quadrangle is about 150 feet.

GEOLOGY OF THE GALATIA QUADRANGLE

The subsurface geology of the Galatia Quadrangle was mapped for this study using data from 1,600 boreholes within the study area and a 2-mile zone surrounding it. Almost 1,000 of these holes were coal tests. The remainder, including most of the holes drilled deeper than the Springfield Coal, were generally oil test holes. There were about 1,350 data points for the Herrin Coal, the shallowest of the major seams, and 1,100 points for the Springfield Coal, the most extensively mined seam (fig. 5). The Davis Coal, the deepest of the major seams, was penetrated by about 600 holes; only 22 of these were coal tests.

Unconsolidated Sediments

Drift, glacial lake deposits, and alluvium consisting of clay, silt, sand, and gravel cover the entire quadrangle (Willman and Frye 1970, Piskin and Bergstrom 1975). These deposits, which range in thickness from less than 20 feet to more than 120 feet, complicate exploration in this quadrangle by concealing faults and outcrops of bedrock units.

Bedrock Stratigraphy

The bedrock strata in the Galatia Quadrangle dip northward, and thus a succession of units from the lowermost section of the Bond Formation to the upper part of the Carbondale Formation can be found at the bedrock surface. Total thickness of the Pennsylvanian strata in this area is 1,200 to about 1,600 feet. This section of strata contains all of the major coals mined in Illinois and several minor coals. Most coal test holes in this area penetrate only to the Springfield Coal. Coals below this have been mapped primarily on the basis of geophysical logs from oil test holes. Coals below the Davis have not been systematically mapped.

A great deal of more detailed information on the geology of the bedrock strata, particularly the coals, can be found in the unpublished mine notes and drilling records of the ISGS Coal Section, as well as in numerous publications (e.g., Cady 1916, Cady 1919, Smith 1957, Hopkins 1968, Allgaier and Hopkins 1975, Willman et al. 1975).

Structure

The master fault zone of the Cottage Grove Fault System crosses the Galatia Quadrangle about 2 miles north of the south boundary (figs. 2 and 6). Nelson and Krausse (1981) interpret the fault zone to be the result of right-lateral strike-slip movement. Both normal and reverse displacements occur along the fault zone. A normal displacement of 63 feet is reported by Nelson and Krausse (1981) just west of the large mined area in the southeast corner of the quadrangle. Displacements as high as 150 feet are reported to the east along this fault (Nelson and Krausse 1981). The master fault is apparently discontinuous and was not encountered by some of the mines on the west edge of the quadrangle. A second zone of east–west faults runs along the south edge of the quadrangle, parallel to the master fault zone. Displacements of 20 to more than 50 feet are reported along this section of the fault (Amax Coal Company permit application). Strata are raised north of this fault. This uplift as well as preglacial erosion and modern down-cutting by the Bankston Fork creek have eroded the Danville and Herrin Coals in some areas.

Igneous dikes in the Galatia Quadrangle strike northwest and follow or run parallel to subsidiary faults of the Cottage Grove Fault System (Nelson 1983). Although they are occasionally penetrated by drill holes, the dikes are generally only discovered during mining because of their thin, linear extent.

Galatia Channel

The Galatia Channel crosses the north and west edges of the Galatia Quadrangle (figs. 4 and 6). Environments of deposition associated with the channel have resulted in zones of both unusually thick and thin Springfield Coal (fig. 7), the low to moderate sulfur content of the coal (less than 1%–2% sulfur), and severe mining conditions (described later in this report). The channel has been penetrated by numerous oil test holes and several coal tests (fig. 6). The Galatia Mine of the Kerr-McGee Coal Company has the best exposure of the channel. Just north of the quadrangle boundary, the company has excavated a mile-long tunnel through the channel to provide access to reserves on the north side of the channel.

MINING HISTORY OF THE GALATIA QUADRANGLE

The first known mine in the quadrangle was the Galatia Coal Company Mine No. 1, which opened in 1903 near the town of Galatia. This mine initially produced from the Herrin Coal; after a number of years, the shaft was deepened to the Springfield Coal. O'Gara, Sahara, Peabody, Wasson, and other coal companies operated large, underground mines in the Springfield Coal. Most of these mines operated between 1910 and 1930. In 1982, Kerr-McGee Coal Company opened its Galatia Mine in the north-central part of the quadrangle. The mine originally produced from both the Herrin and Springfield Coals. Production from the Herrin Coal ceased in 1994 because of weak demand for high sulfur coals. The only other currently active mine in the quadrangle is the Amax Delta Mine, a surface operation in the Herrin Coal located in the southwest corner of the quadrangle.

FACTORS AFFECTING THE AVAILABILITY OF COAL IN THE GALATIA QUADRANGLE

Eggleston et al. (1990) defined available resources as remaining coal resources minus coal restricted by land use and technological considerations. These restrictions vary regionally because of types of mining, local regulations, land use, and geologic conditions. Land use restrictions are defined by local regulations, mining practice, and cost limitations. Technological considerations include mining safety, mining practice, and limitations of cost and equipment.

The factors affecting the availability of coal for mining in the Galatia Quadrangle were identified through interviews with mining engineers and geologists from four coal companies that have mines in geologic and physiographic settings similar to those found in the quadrangle. Together, these companies accounted for almost 40% of the state's 1992 coal production. Staff members of the Illinois Department of Mines and Minerals (IDMM), the state agency responsible for permitting and inspecting mines, were also interviewed. Although this sampling of experts does not represent the views of all mining companies, it provides a reasonable basis for assessing the availability of coal in the Galatia Quadrangle.

Availability of coal must be evaluated with respect to the mining method that will most likely be used to recover the coal. In Illinois, coal is mined by both surface and underground methods. The equipment and procedures used in each method change in response to economic pressures, new technologies, and legal restrictions. This evaluation of coal availability is based on current mining practices of companies active in Illinois. Significant advancements in mining technology could alter the availability of coal, but no such potential advances were apparent at the time of this study.

In several cases, the values of factors that limit the availability of coal for mining are specified by law (e.g., the width of unmined coal to be left between underground mines). In most cases, however, the limits used for this study are based on a general consensus of mining experts on minimum coal thickness, maximum coal depth, minimum bedrock cover, and minimum size of mining block. Some factors, such as poor mining conditions associated with the Galatia Channel or the Cottage Grove Fault System, cannot be fully mapped in advance of mining. The areas delineated for these features represent a reasonable approximation of their zone of influence.

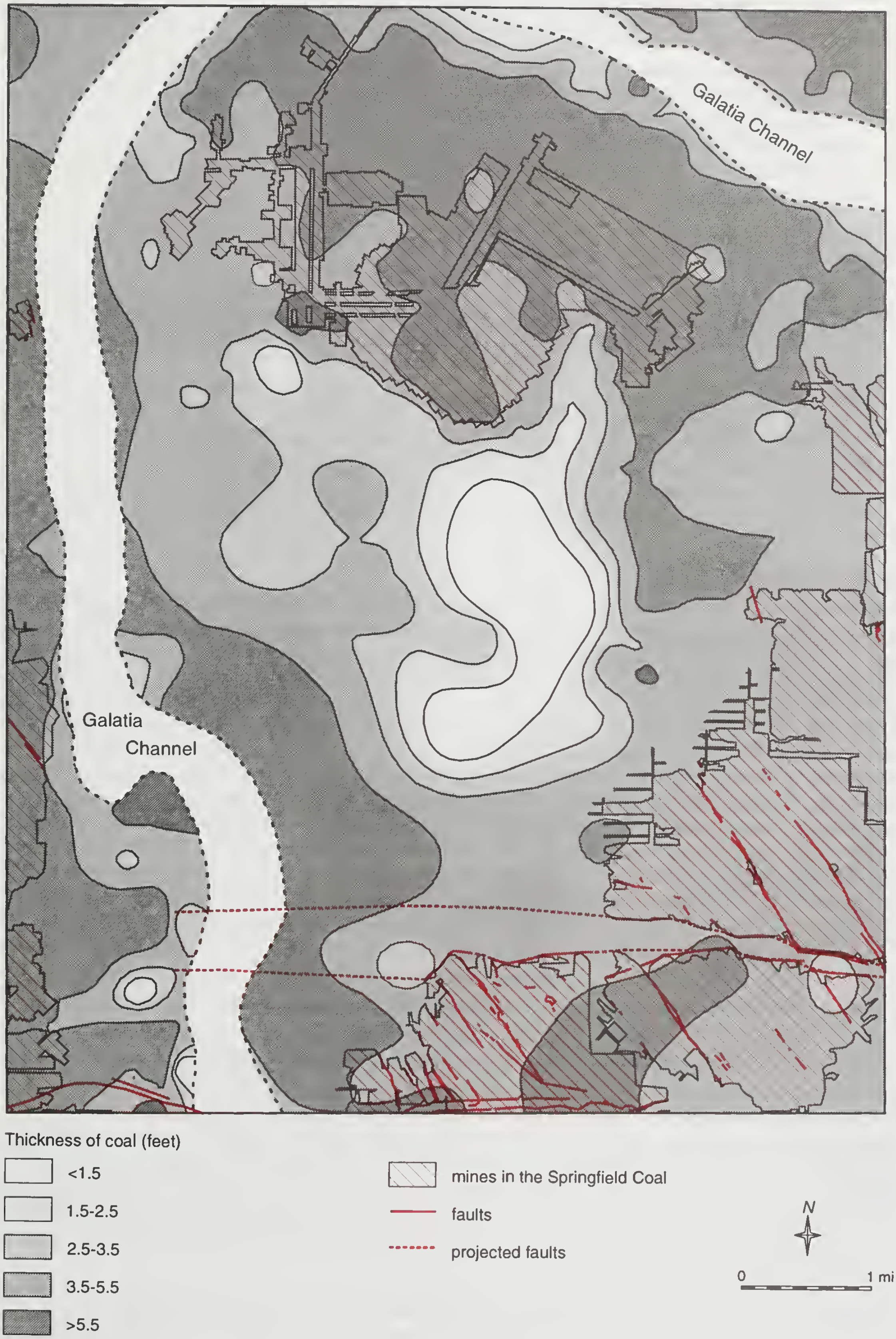

Figure 7 Thickness of the Springfield Coal in the Galatia Quadrangle.

Table 1 Criteria used to define available coal in the Galatia Quadrangle.

Surface Mining

Minimum seam thickness
- Main seam: 18 inches
- Overlying seams: 12 inches

Maximum depth
- 175 feet

Maximum stripping ratio
- 25:1

Maximum average stripping ratio
- 20:1

Minimum block size
- 11 million tons in-place (assumes existing preparation plants will be used)

Restricted mining in some faulted areas

Land use restrictions
- 200 feet around mines, cemeteries, and railroads
- 1,000 feet around towns
- No buffer around oil wells

Underground Mining

Minimum seam thickness
- 4 feet

Maximum in-seam parting
- 1 foot

No maximum depth

Minimum bedrock cover
- 75 feet

Minimum block size
- 80 million tons in-place

Poor mining conditions exclude Springfield Coal within 0.5 miles of Galatia Channel

Restricted mining in some faulted areas

Land use restrictions
- 200 feet around towns, cemeteries, and railroads
- 300 feet around mines
- No buffer around oil wells

Surface Minable Coal

Factors that affect the availability of coal for surface mining in the Galatia Quadrangle are thickness of the coal and overburden, stripping ratio, size of the mining block, faulting, and land use restrictions (table 1). The following section discusses the basis for these criteria and their regional applicability.

Thickness of coal The use of large excavating equipment for removal of overburden and loading of coal results in the unavoidable loss of several inches of coal from the top and bottom of the seam. Additional coal is lost in transporting and washing the coal. These losses are higher as a percentage of the original coal in-place when the seam is thin. Seams less than a certain minimum thickness are impractical to mine because too much of the seam is lost.

The U.S. Geological Survey (USGS) generally considers 14 inches to be the minimum seam thickness for surface minable coal but acknowledges that this minimum may vary from one region to another (Wood et al. 1983). The ISGS has traditionally used 18 inches as the minimum thickness for defining surface minable coal resources in Illinois (Smith 1957). The mining companies interviewed agreed that 18 inches is a reasonable minimum thickness for the main seam in a mining operation. However, other coals present in the overburden will be recovered if they are at least 12 inches thick. In this area, for example, surface mines in the Herrin Coal will commonly mine the overlying Danville Coal if it is at least 12 inches thick.

Thickness of overburden Most surface mines in Illinois use large draglines, shovels, or wheel excavators to remove overburden from the coal. Small draglines or a combination of small shovels and trucks are used in some mines. According to the engineers interviewed, these methods currently have an effective limit of 150 to 175 feet of overburden. Although small areas of thicker overburden (e.g., a small ridge dividing a property) can be surface mined, underground mining methods are more economical for recovering large, contiguous blocks of coal at depths of greater than 175 feet. Although higher prices for coal could make it profitable to remove greater thicknesses of overburden, the economics of current mining practice favors underground mining of resources deeper than 175 feet.

Stripping ratio The stripping ratio is the number of cubic yards of overburden that must be removed to recover 1 ton of coal. Whereas the minimum thickness of coal and maximum thickness of overburden that can be mined are values 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 rises relative to production costs.

Under present economic conditions, the maximum stripping ratio for a deposit is 25:1, and the maximum average stripping ratio for a deposit must be less than 20:1. The incremental stripping ratio may exceed 20:1 for portions of a mine block, but the average stripping ratio for the entire block must not exceed this ratio. If two or more coals are present within the maximum overburden limit of 175 feet, their combined thickness may be used in calculating the stripping ratio.

Block size and configuration Opening a surface mine of any size entails certain fixed costs for exploration, land acquisition, mine planning, and permitting, as well as construction of offices and facilities for equipment maintenance, coal cleaning, storage, and transportation. If a mine is to be profitable, the block of coal to be mined must contain more than enough tonnage to recover these fixed costs. A mining block for a surface mine does not have to be a contiguous deposit of coal; it may consist of two or more smaller blocks relatively close to each other and not separated by barriers (e.g., a river) that impede the movement of equipment. Blocks must also have a geometric configuration suitable for the anticipated mining methods. For example, a long, narrow deposit having a deeply buried subcrop is not suitable for area mining or small truck and shovel operations.

In the Galatia Quadrangle, average overburden thickness is high, initial box cuts are quite deep, extensive exploratory drilling is required to delineate fault blocks as well as the subcrops of the coals (concealed beneath a thick layer of unconsolidated sediments), and major drainage channels must be levied and/or relocated. Given these conditions, a mine block of 11 million tons of coal (i.e., about 10 million tons recoverable) would be needed to develop a mine.

Restricted mining in faulted areas Coal resources in the southern part of the Galatia Quadrangle are disrupted by the Cottage Grove Fault System. In many areas the displacements are relatively small and do not represent a serious obstacle to mining. Areas of the Herrin Coal in the southwestern part of the quadrangle appear to be severely disturbed by the east–west master fault and by subsidiary faults. Displacements of 20 to almost 75 feet have been reported. The coal is missing in a number of scattered areas as a result of displacement along the fault zone as well as Quaternary erosion of upthrown blocks of coal by downcutting of the Bankston Fork creek. Extensive, closely spaced drilling is required to confirm the presence and elevation of the coal. Information currently available indicates that the extreme changes in elevation of the coal, combined with irregular areas of eroded coal, make surface mining unfeasible in this area.

Igneous dikes Igneous rock is very hard and difficult to cut or remove with coal mining equipment. For this reason, dikes are treated in a manner similar to faults: the dike and its bordering zone of altered coal are avoided and only mined where necessary to gain access to other reserves. Although dikes interfere with mining operations, they do not appear to be a significant restriction on the availability of coal in the Galatia Quadrangle.

Land use restrictions State laws do not specifically prohibit surface mining of any area; however, rules governing the mining of certain features have the effect of prohibiting or severely restricting the mining of certain areas. Cemeteries (fig. 6) cannot be mined, for example, unless all surviving family members give permission to move the graves of their ancestors. It is usually so time consuming and expensive to fulfill this requirement that most cemeteries are not mined.

Mining through towns or other large developed areas is also impractical because the cost of purchasing the surface property is likely to exceed the value of the coal. Although laws do not prohibit mining up to the edge of a town, companies are required to control dust levels and vibrations from blasting. These restrictions make it difficult to mine near towns. The distance that mining must be kept from populated areas is highly subjective and to an extent dependent on the general acceptance of surface mining in the area. The Galatia Quadrangle has historically been a coal mining area, and many people derive income directly or indirectly from coal mining. The experts interviewed thought that surface mining could be conducted within 1,000 feet of developed areas in the quadrangle.

Surface mining through roads, railroads, pipelines, or transmission lines requires permission from the owners or governing authorities. Generally, it is less expensive to avoid all but minor roads and pipelines. In the Galatia Quadrangle, a buffer of about 200 feet would probably be left between surface mines and railroads and cemeteries. None of the roads overlying surface minable deposits in the quadrangle would restrict mining.

For engineering, environmental, and safety reasons, companies generally leave a buffer of unmined coal (usually 200 feet wide) around underground mine workings. In some cases, however, mining through a small abandoned underground mine may be necessary to access adjacent areas of unmined coal.

Surface mining may be restricted in environmentally sensitive areas (e.g., floodplains). Applications for mining permits in floodplains are carefully scrutinized to ensure that environmental damage will not occur. The surface minable resources in the Galatia Quadrangle are traversed by Brushy Creek and the Bankston Fork and Middle Fork of the Saline River. All three of these rivers have been channelized to control flooding, and stretches of the Bankston Fork to the west of the quadrangle have been relocated to allow surface mining. Because they have historically been altered by human activities, these floodplains and rivers are not thought to represent a barrier to surface mining in the Galatia Quadrangle.

Deep Minable Coal

Where the thickness of overburden or the stripping ratio is too great, coal must be mined by underground methods. There is no definite depth limit between surface minable and deep minable deposits. Rather, there is a range of depths where either method is technically feasible. The criteria used to identify coal available for deep-mining in the Galatia Quadrangle include thickness and depth of coal, in-seam parting, bedrock cover, block size and configuration, mining conditions, faulting, and land use restrictions (table 1).

Thickness of coal The thickness of the seam controls the amount of coal that can be produced per acre and the ease of moving miners and machinery within the mine. Thin seams are more costly to mine because of the amount of roof control and longer haulage required per ton mined. Also, miners work more efficiently when they can move freely and the working face is fully visible. Equipment used for underground mining is selected for optimal performance within a limited range of seam thickness. If thicker coal is encountered in mining, a portion of the seam may be beyond the cutting height of the equipment and left unmined (generally as top coal). A more serious problem is coal thinner than the equipment design. This will require that roof or floor rock be mined along with the coal, a situation that slows mining operations and increases equipment wear and coal cleaning costs.

As noted earlier, the USGS considers all coals 14 inches or greater in thickness to be resources (Wood et al. 1983). The ISGS has traditionally used 28 inches as the minimum seam thickness for deep minable resources in Illinois (Cady 1952). These thicknesses are far less than the minimum thickness currently considered minable in Illinois. The average thickness of coal mined in the state is about 6 feet. According to the experts interviewed, mining coal less than 4 feet thick is prohibitively expensive, although short spans of thinner coal and even rock may be mined to gain access to thicker coal. For example, other factors being equal, the cost of production from a 3-foot seam would be on the order of twice that of a 6-foot seam. Although there are examples of thin coals being mined in other parts of the country, these are due to special local conditions that either increase the value of the coal (e.g., a metallurgical grade coal) or reduce the cost of developing a mine (e.g., a seam outcropping along the side of a mountain eliminates the cost of a shaft and reduces exploration costs).

In addition to these considerations, the experts we interviewed reported that areas of thin Springfield Coal in the Galatia Quadrangle are commonly associated with partings, washouts, and bad roof (see "Poor mining conditions" below). Because of this association, areas of thin Springfield Coal are avoided. In this study, 4 feet was used as the minimum thickness for available coal.

In-seam parting During the Pennsylvanian Period, deposition of peat along the Galatia Channel was apparently interrupted periodically by water and sediment flowing out of the main channel. Partings in the coal and areas of thin or missing coal (due to erosion or lack of deposition) are commonly encountered in the vicinity of the channel. Partings may be in the form of one or more shale benches from several inches to several feet thick. In other cases the partings occur as extremely thick areas of interlaminated coal and shale (Nelson 1983). When a seam is split by partings, one bench of the seam may be left unmined or the parting material may be mined with the coal and separated during cleaning. The action taken depends on a number of factors including thickness of the individual benches of coal, thickness and number of partings, and company policy. The experts we interviewed said they would mine a maximum of 1 foot of parting material in the Springfield Coal.

Depth of coal A major cost in opening an underground mine is the cost of constructing slopes or shafts for ventilation and for the movement of miners, machinery, supplies, and coal. The deeper the coal, the more expensive it is to construct these facilities and extract the coal. Although the coals in the Galatia Quadrangle are as much as 1,000 feet deep, none of the experts interviewed considered coal depth to be a significant factor in limiting the availability of these coals.

Bedrock cover A minimum amount of bedrock cover is needed to support the mine roof and seal the mine from surface water seepage. If the bedrock is too thin, the mine roof may be unstable; fractures resulting from any failure of the mine roof may propagate to the bedrock surface and allow water to enter the mine.

The minimum thickness of bedrock overburden needed above a seam depends on the composition of the bedrock and the thickness of unconsolidated sediments (glacial and alluvial deposits) overlying the bedrock. Thick, continuous limestone or sandstone beds and thin, overlying, unconsolidated sediments are the most suitable geologic conditions. The bedrock overburden must be proportionately thicker to support areas overlain by thick glacial deposits. Although mines in the vicinity of the Galatia Quadrangle have been permitted to mine coal with as little as 40 feet of bedrock cover, the mining experts interviewed considered this to be impractical for large areas because of the mining problems that are likely to be encountered. For a mine block as a whole, the minimum thickness of bedrock in this study area was considered to be 75 feet. If the bedrock is less than 75 feet thick, severe roof problems may be encountered, and there is a risk that water from the unconsolidated deposits will enter the mine through fractures from roof falls.

Block size and configuration The development of an underground mine entails fixed costs for exploration, land acquisition, mine planning, permitting, and construction of facilities including mine shafts and a preparation plant. The block of coal to be mined must contain enough recoverable tonnage so that the return from selling the coal exceeds the cost of mining. The companies we interviewed estimated that about 40 million tons of recoverable coal would be needed to justify the development of an underground mine that includes a preparation plant and rail loading facilities. If 50% of the coal can be recovered after mining, cleaning, and loading, then a mine block of approximately 80 million tons in-place is the minimum needed.

In addition to containing sufficient tonnage, the mine block must have a configuration suitable for laying out main entries and panels. Rectangular blocks allow a maximum amount of coal to be recovered while minimizing the distance miners travel from the shaft to the working face. Irregularly shaped blocks may require longer main entries. Less coal is typically recovered from these entries than from panel areas. Also, if faults, igneous dikes, washouts, or other unfavorable conditions are encountered, the ability to change the alignment of mine entries may be restricted.

It is feasible to mine smaller blocks under certain conditions. For example, if the seam can be reached through a highwall (which requires that the coal be within about 200 feet of the surface) and if existing preparation and rail loading facilities can be used, a block of only 20 million tons of in-place coal may be sufficient. This is equivalent to a block of 10 million tons of recoverable coal.

As with surface minable coal, the minimum block size can be achieved by mining multiple seams from a single shaft, drift, or highwall. At least two mines in this quadrangle have mined both the Herrin Coal and Springfield Coal from the same shaft.

Poor mining conditions Unstable mine roof, abrupt variations in seam thickness, washouts of the seam, and other features create poor mining conditions. Such conditions cause dangerous working conditions for miners, slow the rate of advance, require additional materials and extra procedures for roof control, and increase the costs of transporting coal from the mine face as well as the costs of washing the coal. Companies will mine in these conditions for short distances if they think they will eventually encounter better conditions. However, large areas of poor mining conditions will generally be avoided. These conditions are difficult to predict and delineate without data from closely spaced drill holes and a record of extensive experience in mines with identical geology. In this study area, mining conditions are well documented for only two seams, the Herrin and Springfield Coals. The mining conditions that would be encountered when mining other seams, such as the Davis Coal, are not known. With the exception of faulted areas, mining conditions are not a limiting factor in determining availability of the Herrin Coal in the quadrangle.

The likelihood of encountering unstable roof, partings, or washouts in the Springfield Coal increases with proximity to the Galatia Channel. These features are difficult to detect and trace even with closely spaced drill holes. Mines are generally laid out so that areas of potential problems can be probed by mining and abandoned if conditions are unfavorable. Mining has come close to the channel in some areas, but in other areas severe problems have been encountered as much as a mile from the channel. To obtain a rough estimate of the amount of coal that may be restricted from mining as a result of partings, unstable roof, or other adverse geologic conditions related to the Galatia Channel, this study considered coal less than 1/2 mile from the channel to be unavailable for mining. In some areas this coal may ultimately be found to be minable. In other areas coal farther from the channel will likely be found to be unminable.

Restricted mining in faulted areas As previously described, the Cottage Grove Fault System disrupts coal resources in the Galatia Quadrangle. In many cases these faults cause only a minor reduction in the available coal. Mining operations advance to the fault zone from opposite sides and leave a relatively narrow zone of unmined coal. The data available from mines and drill holes are only sufficient for mapping the presence of faults in the Danville, Herrin, and Springfield Coals. Seismic profiles show that the Cottage Grove Fault System deforms the entire Pennsylvanian succession as well as all Paleozoic rocks and Precambrian basement. Large faults dip steeply to vertically so that the map pattern of major faults does not differ greatly from one seam to another. However, in-mine mapping and cross sections based on closely spaced test drilling show that the pattern of smaller structures (faults and folds) may change substantially with depth (Nelson and Krausse 1981, Nelson 1991).

Igneous dikes Igneous dikes have been encountered in underground mines in the Galatia Quadrangle. As discussed previously, the dike and zone of altered coal are only mined where necessary to gain access to other reserves. Although dikes interfere with mining operations, they do not appear to be a significant restriction on the availability of coal in the Galatia Quadrangle.

Land use restrictions Except for requiring a 200-foot buffer between underground mines, state laws do not specifically prohibit underground mining of any area. Rules governing the mining of certain features have the effect, however, of prohibiting or severely restricting the mining of these areas. For example, damage caused by mine subsidence must be repaired. Consequently, it is generally not economical to mine under towns. Also, the regulations controlling the disturbance of cemeteries (as discussed previously in the section on surface mining) must be adhered to by underground mines.

Mining is feasible under most roads, railroads, pipelines, and transmission lines, but mine layouts are generally planned to keep mining under these features to a minimum. Because of the costs of mitigation should subsidence occur, the undermining of interstate highways or main railroad lines is avoided, except where necessary for main entries to gain access to coal.

Buffers must be left around oil wells unless they are abandoned and known to be adequately plugged. Although large concentrations of wells are a potential obstruction to mining, our interviews indicate that they are not a significant restriction on availability of coal in the Galatia Quadrangle. The density of oil wells is relatively high in the central part of the quadrangle (fig. 6); however, many of the oil wells are abandoned or produce only small amounts of oil. The coal companies interviewed indicated that they would mine through wells that were abandoned or that could be purchased (replugging them if they were not known to be adequately plugged). Pillars would be left around wells that could not be plugged. Because mines in this quadrangle can probably be laid out so that most of the wells are within the normal mine pillars, oil wells do not restrict resource availability in this area.

This finding has significant implications for estimates of Illinois coal resources. Past ISGS resource studies have identified more than 9 billion tons of coal statewide that have been classified as unminable because of oil-drilling activities. The findings from this study suggest that much of this excluded coal may actually be available for mining.

As mentioned previously, state laws require that underground mines stay at least 200 feet from the boundary of old mine works. This restriction prevents miners from accidently punching into an old mine opening, a situation that could lead to an explosion or flooding of the active mine. Because of the number of geologic faults known to extend from the old works in this quadrangle, the experts we interviewed suggested using a buffer zone of 300 feet.

Environmentally sensitive areas, such as rivers and floodplains, can restrict underground mining. To receive a permit to mine, companies must demonstrate that mining will not cause flooding or environmental damage. Because the major rivers and creeks in this quadrangle have already been channelized and altered by agricultural activities, it is unlikely that underground mining would be restricted.

Interval thickness between seams and resources destruction by order of mining Where two or more seams of minable thickness are present, both seams cannot be mined unless the strata between them (interburden) are sufficiently thick and competent (Chekan et al. 1986). If the interburden is too thin, ground control problems may occur in both the upper and lower seams. The thickness of interburden required depends on several geologic and engineering parameters, including the method and sequence of mining the seams (Hsiung and Peng 1987a, 1987b). Coal mining causes fracturing and subsidence of overlying strata and can render the resources in overlying coal seams unminable. The amount of destruction of resources depends on several variables, including the thickness and competency of the interburden and the mining method.

According to the experts interviewed, the interburden between the main seams of the Herrin, Springfield, and Davis Coals is sufficient to permit mining of all of them within a given area in any sequence. At least two mines have successfully mined the Herrin Coal after the underlying Springfield Coal was mined. Some doubt exists as to whether the Dekoven Coal could be mined in the same area as the underlying Davis Coal. These seams are as little as 15 feet apart. If the Davis is mined first, the roof of the Dekoven Coal may be disturbed by fractures extending upwards from roof falls above the Davis Coal. If the Dekoven is mined first, the strata between the coals may not be competent enough to distribute the stresses properly.

COAL RESOURCES AND AVAILABLE COAL IN THE GALATIA QUADRANGLE

The original and remaining coal resources of the Galatia Quadrangle were calculated using the standard ISGS classifications for surface minable and deep minable coal. Surface minable resources must be at least 1.5 feet thick and less than 150 feet deep. Deep minable resources must be at least 2.3 feet (28 inches) thick and more than 150 feet deep.

Available resources were calculated according to the criteria described in the preceding section. Note that according to the criteria defining available coal in this quadrangle (table 1), the ranges of depths for surface and deep minable coals overlap one another and differ from the depth limits used for the standard definition of resources in the ISGS coal resource classification system. The maximum depth for surface mining is 175 feet, but the minimum depth of deep minable coal can be as shallow as 75 feet, given the requirement that the minimum thickness of bedrock cover for underground mining is 75 feet. Because of these definitions, some coal deposits are potentially both surface and deep minable.

Table 2 Coal resources in the Galatia Quadrangle (thousands of tons).

	Original	Remaining	Available	Restrictions	
				Land use	Technological
Chapel	15,942	15,942	0	1,163	14,779
Danville	30,533	30,451	215	685	29,551
Herrin	329,906	311,357	232,473	17,666	61,213
Briar Hill	8,185	8,185	0	903	7,282
Springfield	296,035	208,077	44,219	30,790	133,068
Houchin Creek	22,766	22,766	0	1,700	21,066
Survant	6,356	6,356	0	0	6,356
Colchester	5,570	5,570	0	70	5,500
Dekoven	91,799	91,799	0	3,156	88,643
Lower Dekoven	23,446	23,446	0	921	22,525
Davis	270,662	270,662	100,519	7,769	162,372
Mt. Rorah	9,345	9,345	0	0	9,345
Total resources	1,110,545	1,003,956	377,426	64,823	561,700

Note: totals may not add up exactly because of rounding.

Total original resources for the 12 seams underlying the quadrangle are 1.1 billion tons; 1 billion tons remain in place and 377 million tons are estimated to be available for mining (table 2). Technical factors (e.g., seam thickness, roof conditions, and stripping ratio) restrict use of 51% of the original coal resources (fig. 8). Land use restrictions (e.g., proximity to towns or abandoned mines) account for 6% of original resources.

Of the 89 million tons of original surface minable resources, less than 2% remains available for mining (fig. 9, table 3). An unfavorable stripping ratio restricts 45%; blocks of less than 11 million tons constitute 31%; faulting restricts 15%; and land use factors interfere with mining 6% of the original resources. Less than 1% of this coal has been removed by mining or left as pillars.

Of the 1 billion tons of original deep minable resources in the quadrangle, 36% remains available for mining. In addition, 7 million tons of surface minable resources are available for underground mining. The factors restricting availability of potentially deep minable coal are coal thickness of less than 4 feet (31% of original resources), mining blocks of less than 80 million tons in-place (10%), proximity to the Galatia Channel (6%), land use restrictions (6%), faulting (1%), and insufficient bedrock cover (<1%) (fig. 10, table 3).

Common Resource/Reserve Classifications and Available Coal

Federal and state agencies responsible for estimating coal resources and reserves use special terms to describe the relative degree of geologic certainty and economic minability of deposits. Two widely reported categories are *identified resources* and *demonstrated reserve base. Available resources* is a new term coined by the USGS and now used by a number of states in describing resources.

Identified resources In the USGS resource classification system, this category is generally used to report coal resources. It represents resources for which "the location, rank, quality, and quantity are known or

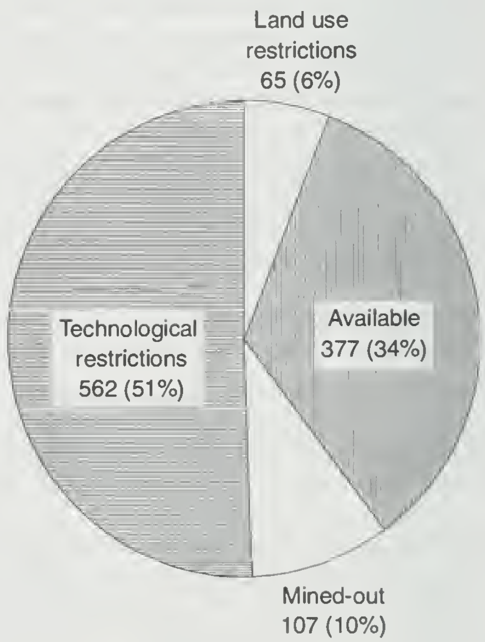

Figure 8 Available, restricted, and mined-out coal resources in the Galatia Quadrangle (millions of tons and percentage of resources). See table 1 for definitions.

estimated from specific geologic evidence" (Wood et al. 1983). All remaining resources in the Galatia Quadrangle (1,004 million tons) are considered identified resources, and 38% of the coal is available for mining.

Demonstrated reserve base The Energy Information Administration of the U.S. Department of Energy maintains estimates of the demonstrated reserve base (DRB) of coal in the United States. The DRB represents coal resources with a high degree of geologic assurance and some degree of economic minability. DRB figures are commonly used for purposes of planning, particularly for forecasting the source, characteristics, and price of future coal supplies.

For Illinois, the DRB consists of resources in the "proved" and "probable" categories of geologic assurance. The coal may be 18 or more inches thick and less than 150 feet deep, or 28 or more inches thick and less than 1,000 feet deep. Of the identified resources in the Galatia Quadrangle, about 80% (808 million tons) is classified as part of the demonstrated reserve base, of which 47% is available for mining.

AVAILABLE RESOURCES IN THE GALATIA QUADRANGLE BY SEAM

Chapel Coal

The Chapel Coal is the uppermost coal for which resources have been mapped in the Galatia Quadrangle. The coal is as much as 3 feet thick and ranges in depth from about 50 feet along its buried subcrop to more than 200 feet at the north edge of the quadrangle (fig. 11). This coal can be traced through much of region 7. Because it is thin, it is of interest only where it is shallow enough to surface mine. No analyses of the coal are available; however, the sequence of strata overlying the coals has been used as an indicator of relative sulfur content of the underlying coal (Gluskoter and Simon 1968, Gluskoter and Hopkins 1970). Along the east side of the Galatia Quadrangle, the Chapel Coal is overlain by a black shale, a roof type commonly associated with high sulfur coals (3%–5% sulfur). In the central and western parts of the quadrangle, a sequence of shale, siltstone, and sandy shale ranging from a few feet to more than 30 feet thick is deposited between the coal and the overlying black shale. This sequence of lithologies indicates the Chapel

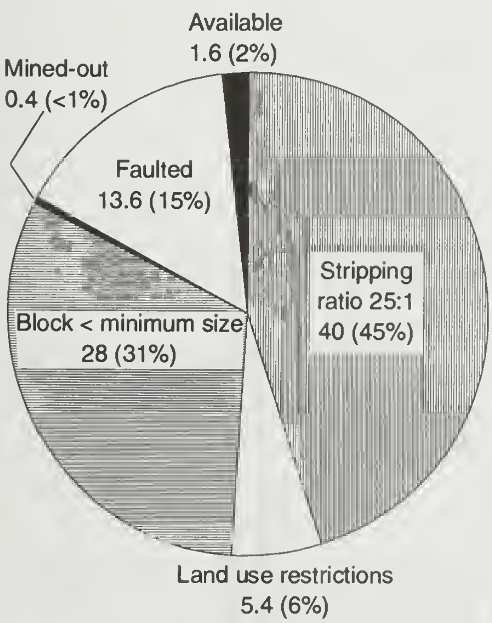

Figure 9 Available, restricted, and mined-out surface minable coal resources in the Galatia Quadrangle (millions of tons and percentage of original resources). See table 1 for definitions.

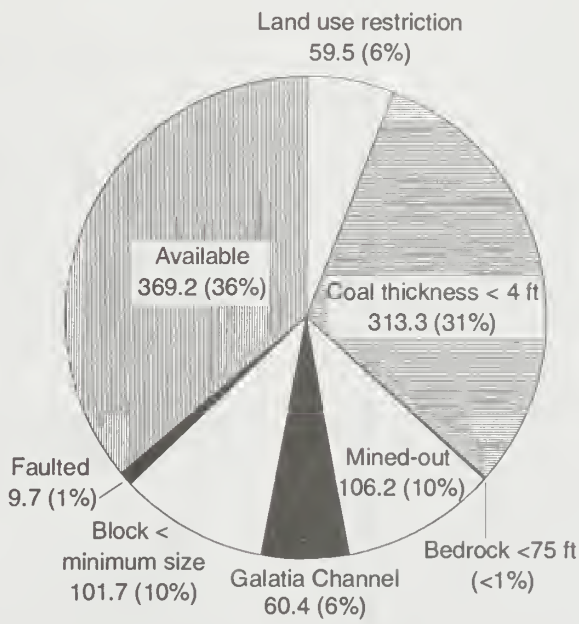

Figure 10 Available, restricted, and mined-out deep minable coal resources in the Galatia Quadrangle (millions of tons and percentage of original resources). See table 1 for definitions.

Table 3 Surface minable coal resources by seam in the Galatia Quadrangle (thousands of tons).

					Land use restrictions				Technological restrictions			
									Stripping ratio			
	Original	Remaining	Available	Mined	Near mines	Towns	Railroads	Cemeteries	>25:1	Ave >20:1	Block size	Faulted
<150 ft deep												
Chapel	15,942	15,942	0	0	0	0	1,051	112	11,704	0	3,075	0
Danville	24,346	24,264	215 *	82	67	391	227	0	20,858	0	1,894	612
Herrin	46,663	46,350	1,358	313	265	3,108	6	44	1,867	5,626	21,269	12,805
Briar Hill	2,060	2,060	0	0	97	0	0	0	0	0	1,762	201
Total	89,011	88,616	1,573	395	429	3,499	1,284	156	34,429	5,626	28,000	13,618
150–175 ft deep												
Chapel	3,241	0	0	0	0	0	0	3,241	0	0	0	0
Danville	3,875	0	0	0	0	0	0	3,875	0	0	0	0
Herrin	27,396	0	0	0	0	1,408	1,027	127	7,441	11,581	3,050	2,762
Briar Hill	2,943	0	0	0	0	0	2	0	37	0	2,904	0
Total	37,455	0	0	0	0	1,408	1,029	127	14,594	11,581	5,954	2,762

*Minable as part of a surface mine in the Herrin Coal.

Note: totals may not add up exactly because of rounding.

Figure 11 Thickness of the Chapel Coal in the Galatia Quadrangle.

Coal may have a low or moderate sulfur content (<2.5% sulfur) in this area. Sampling and analysis of the coal are needed to determine the actual coal quality.

The total resources of the Chapel Coal in the quadrangle are 16 million tons (table 3), all less than 150 feet deep and classified as surface minable. None of the Chapel Coal resources are available for mining primarily because the stripping ratio for most of the resources is well in excess of 25:1. The resources with a stripping ratio of less than 25:1 are found in blocks of a few hundred thousand tons. Small blocks of the Womac Coal, a coal similar to the Chapel Coal, have been mined by a number of operators in the vicinity of Corinth, west of the Galatia Quadrangle. The coal at that location has a relatively low stripping ratio (generally less than 20:1) and a low sulfur content. By selectively mining only part of the seam, an operator can produce a relatively clean product that does not require washing, making it feasible for operators to mine very small blocks of coal. It is unlikely that small blocks of the Chapel Coal will be mined in the Galatia Quadrangle because the subcrop of the coal appears to be at depths of 80 feet or more. Mining at this depth requires a large investment in earth-moving equipment, and this investment cannot be recovered by mining only a few hundred thousand tons of coal. Even if companies somehow found it worthwhile to mine these small blocks, the tonnage produced would not be significant.

Danville Coal

The Danville Coal lies about 200 feet below the Chapel Coal and 50 to 85 feet above the Herrin Coal. The coal is present throughout the quadrangle except in areas of the southwest corner where it lies near the surface and has been eroded. The coal is generally 1.5 to 2.5 feet thick and ranges in depth from less than 25 feet along the south edge of the quadrangle to more than 400 feet at the north edge (fig. 12). Because it is thin, the Danville Coal in southern Illinois is only mined in surface mines where the underlying Herrin Coal is the main target. Analyses from nearby areas indicate the coal has a high sulfur content (3%–5%).

Less than 1% of the 31 million tons of Danville coal resource in the quadrangle is available for mining (fig. 13). Most of the surface minable resources have a stripping ratio greater than 25:1, and most of the deep minable resources are considerably less than 4 feet thick (tables 3 and 4). The only Danville Coal resources available for mining are those that can be surface mined as part of a multiseam operation mining the underlying Herrin Coal (figs. 13 and 15).

Herrin Coal

The Herrin Coal is a major resource in southern Illinois and has been extensively mined throughout the area (Treworgy and Bargh 1982). Numerous studies have documented the geology and mining conditions associated with the coal (Allgaier and Hopkins 1975, Krausse et al. 1979, Nelson 1981, Nelson 1983). The coal is generally 4 to 6 feet thick in the Galatia Quadrangle, as it is through much of southern Illinois (fig. 14). In a few areas of the quadrangle, the coal is thin (1–2 feet) or missing. These anomalies may be the result of drill holes that have intersected faults or erosion of up-thrust fault blocks by the Bankston Fork and Middle Fork creeks. The Herrin Coal is less than 70 feet deep in the southeast corner of the quadrangle and more than 550 feet deep along the north edge. The coal has been mined in both surface and underground operations in and adjacent to the Galatia Quadrangle. The coal in this area has a high sulfur content (3%–5%).

Nineteen million of the 330 million tons of Herrin Coal resources originally in the quadrangle have been mined or left as pillars. Less than 2 million tons (3%) of the surface minable resources are available for mining (table 3, fig. 15), but 224 million tons (85%) of the remaining deep minable resources are available (table 4, fig. 16). In addition, 7 million tons of the Herrin Coal are less than 150 feet deep and available for mining by underground methods.

The area of surface minable coal is broken up by two extensively faulted zones of the Cottage Grove Fault System (fig. 15). Within these zones, exploratory drilling has encountered extreme changes in elevation, steeply dipping beds, and small areas where the coal has been thrust upward and eroded. Our interviews with mining experts indicate that the Herrin Coal is unlikely to be surface mined within these zones and that most mining will likely only take place south of the southernmost zone. The area between these two zones has a favorable stripping ratio, but it is

Table 4 Deep minable coal resources in the Galatia Quadrangle (thousands of tons).

					Land use restrictions				Technological restrictions				
	Original	Remaining	Available	Mined	Near mines	Towns	Railroads	Cemeteries	Coal <48 in. thick	Thin bedrock	Block size	Faulted	Galatia Channel
>150 ft deep													
Danville	6,187	6,187	0	0	0	0	0	0	6,187	0	0	0	0
Herrin	283,243	265,007	224,449	18,236	5,358	5,007	2,800	1,078	12,526	1,614	7,035	5,137	0
Briar Hill	6,125	6,125	0	0	806 *	0	0	0	5,319	0	0	0	0
Springfield	296,035	208,077	44,219	87,958	26,258	2,703	1,324	505	28,530	0	39,595	4,516	60,429
Houchin Creek	22,766	22,766	0	0	0	1,608	0	92	20,969	0	97	0	0
Survant	6,356	6,356	0	0	0	0	0	0	6,172	0	184	0	0
Colchester	5,570	5,570	0	0	0	0	70	0	4,377	0	1,124	0	0
Dekoven	91,799	91,799	0	0	0	3,060	0	96	86,482	0	2,161	0	0
L. Dekoven	23,446	23,446	0	0	0	819	0	102	22,525	0	0	0	0
Davis	270,662	270,662	100,519	0	0	5,297	1,661	811	110,956	0	51,416	0	0
Mt. Rorah	9,345	9,345	0	0	0	0	0	0	9,299	0	46	0	0
Total	1,021,534	915,340	369,187	106,194	32,422	18,494	5,855	2,684	313,342	1,614	101,658	9,653	60,429
75–150 ft deep													
Herrin	22,264	22,264	6,666	0	0	896	0	0	1,254	0	8,727	4,721	0
Briar Hill	2,059	2,059	0	0	96	0	0	0	0	0	1,762	201	0
Total	24,323	24,323	6,666	0	96	896	0	0	1,254	0	10,489	4,922	0

*Seam too close to overlying mined-out area.
Note: totals may not add up exactly because of rounding.

Figure 12 Thickness of the Danville Coal in the Galatia Quadrangle.

Figure 13 Availability of Danville Coal resources for surface mining in the Galatia Quadrangle.

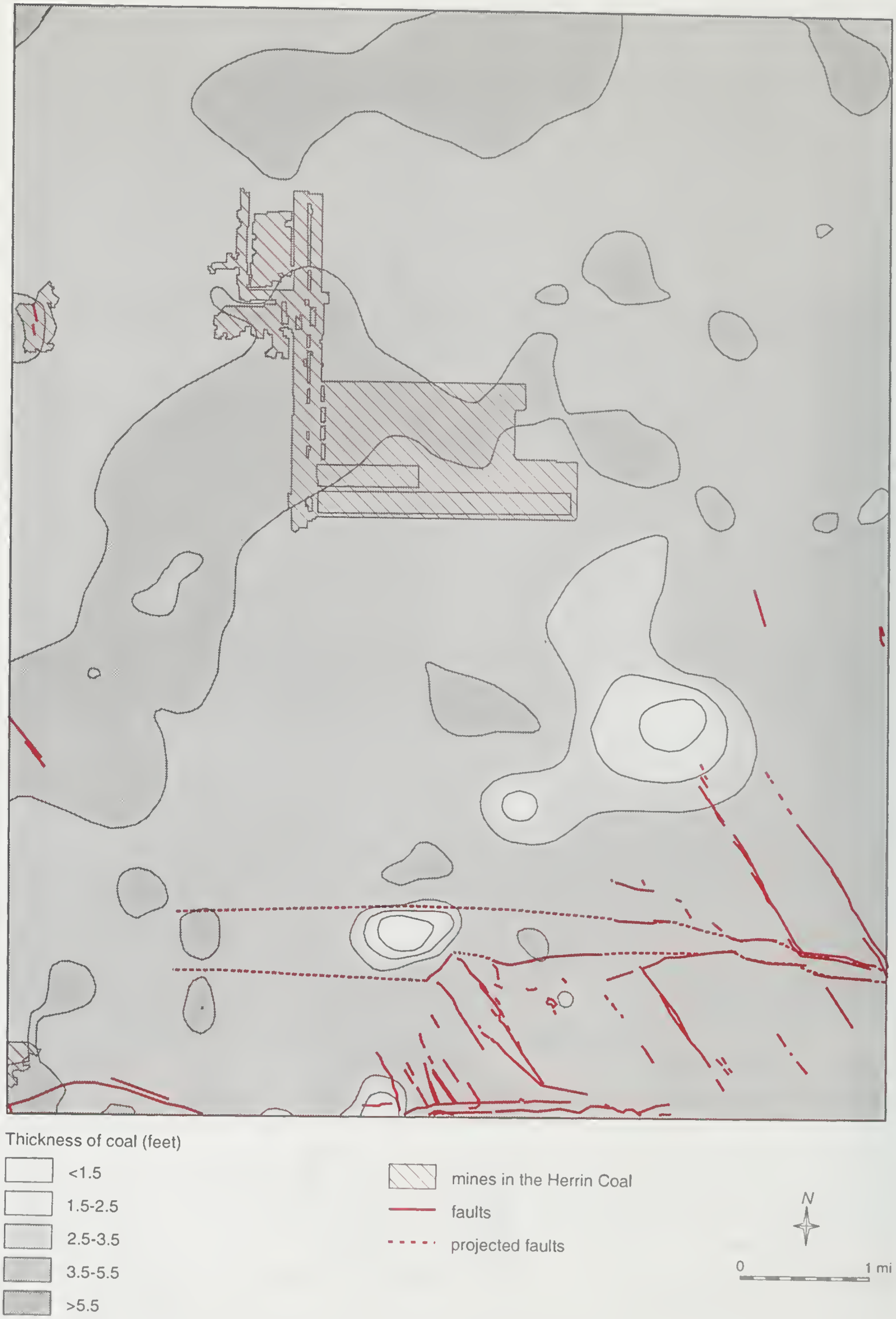

Figure 14 Thickness of the Herrin Coal in the Galatia Quadrangle.

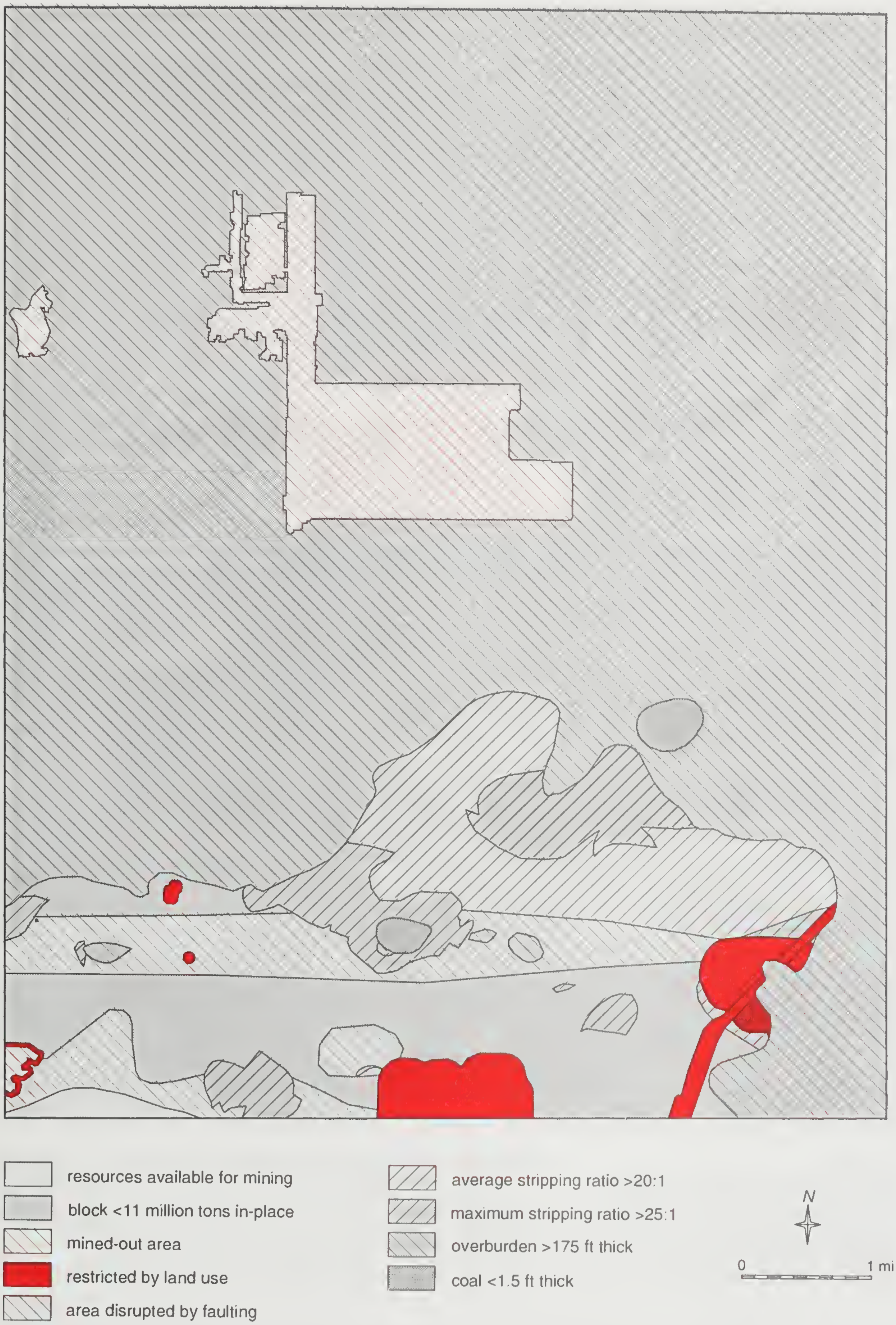

Figure 15 Availability of Herrin Coal resources for surface mining in the Galatia Quadrangle.

Figure 16 Availability of Herrin Coal resources for underground mining in the Galatia Quadrangle.

considered unavailable for mining because of its irregular configuration, limited tonnage, and numerous obstacles (e.g., Bankston Fork creek and development along the fringes of the towns of Harrisburg and Muddy).

The deep minable resources of the Herrin Coal have the highest percentage of availability of any seam in the quadrangle (85%). There are few restrictions to the availability of the Herrin resources north of the area disturbed by the Cottage Grove Fault System (fig. 16). Unfortunately, the high sulfur content of the coal makes these resources difficult to market at the present time. Kerr-McGee Coal Company, which operated a large underground mine in the Herrin Coal in the northern part of the Galatia Quadrangle, recently ceased production from this seam because of the difficulty in finding customers for the high sulfur coal. Although large portions of these resources have been or will be undermined by mines in the underlying Springfield Coal, the interval between the seams is sufficient to prevent disruption of the Herrin Coal. Several mines in the Herrin Coal in this area have successfully mined above old works in the Springfield Coal. Therefore, these resources should remain largely available for mining whenever the market for high sulfur resources improves.

Briar Hill Coal

The Briar Hill Coal is a thin, but widely persistent, seam present in the southeastern part of the state. It is generally less than 2.5 feet thick and lies 15 to 40 feet below the Herrin Coal and 50 to more than 100 feet above the Springfield Coal. Surface mines that are mining the Springfield Coal occasionally mine the Briar Hill Coal as well. The Briar Hill Coal has not been mined in the Galatia Quadrangle.

There are 6 million tons of deep minable resources of the Briar Hill Coal in the Galatia Quadrangle; none are considered available for mining. In addition to being less than 4 feet thick and in blocks too small for mining, some of these resources lie 20 feet or less below mined areas in the Herrin Coal (tables 3 and 4).

Springfield Coal

The Springfield Coal, where present in the Galatia Quadrangle, varies in thickness but may be more than 8 feet thick (fig. 7). The coal lies 75 to 150 feet below the Herrin Coal at depths of less than 200 to almost 700 feet.

Through much of Illinois, the Springfield Coal is overlain by a marine black shale and limestone sequence (the Turner Mine and St. David Members). In areas adjacent to the Galatia Channel, including all of the Galatia Quadrangle, the coal is overlain by a nonmarine or marginal marine sequence of gray shale, siltstone, and sandstone called the Dykersburg Shale (Hopkins 1968). Areas of Springfield Coal overlain by 20 feet or more of the Dykersburg Shale generally have a sulfur content of less than 1% to about 2.5%. Coal overlain by the marine black shale and limestone sequence typically has a sulfur content in the range of 3% to 5%.

The original resources of the Springfield Coal in the Galatia Quadrangle were 296 million tons, of which 88 million tons have been mined or left as pillars (table 2). All of the remaining 208 million tons of resources are deep minable, and 44 million tons (22%) are available for mining (fig. 17). Factors restricting the availability of the coal are proximity to the Galatia Channel (29% of remaining resources), block size (19%), land use (15%), thickness less than 4 feet (14%), and faulting (2%) (table 4). These resources have been and will continue to be the target of mining operations because of their low to moderate sulfur content.

Houchin Creek, Survant, Colchester, Dekoven, Lower Dekoven, and Mt. Rorah Coals

Excluding the Davis Coal, more than 159 million tons of resources have been mapped in the six seams below the Springfield Coal (table 2). None of the resources are available for mining primarily because the coals are less than 4 feet thick. Land use and block size also limit availability of these coals.

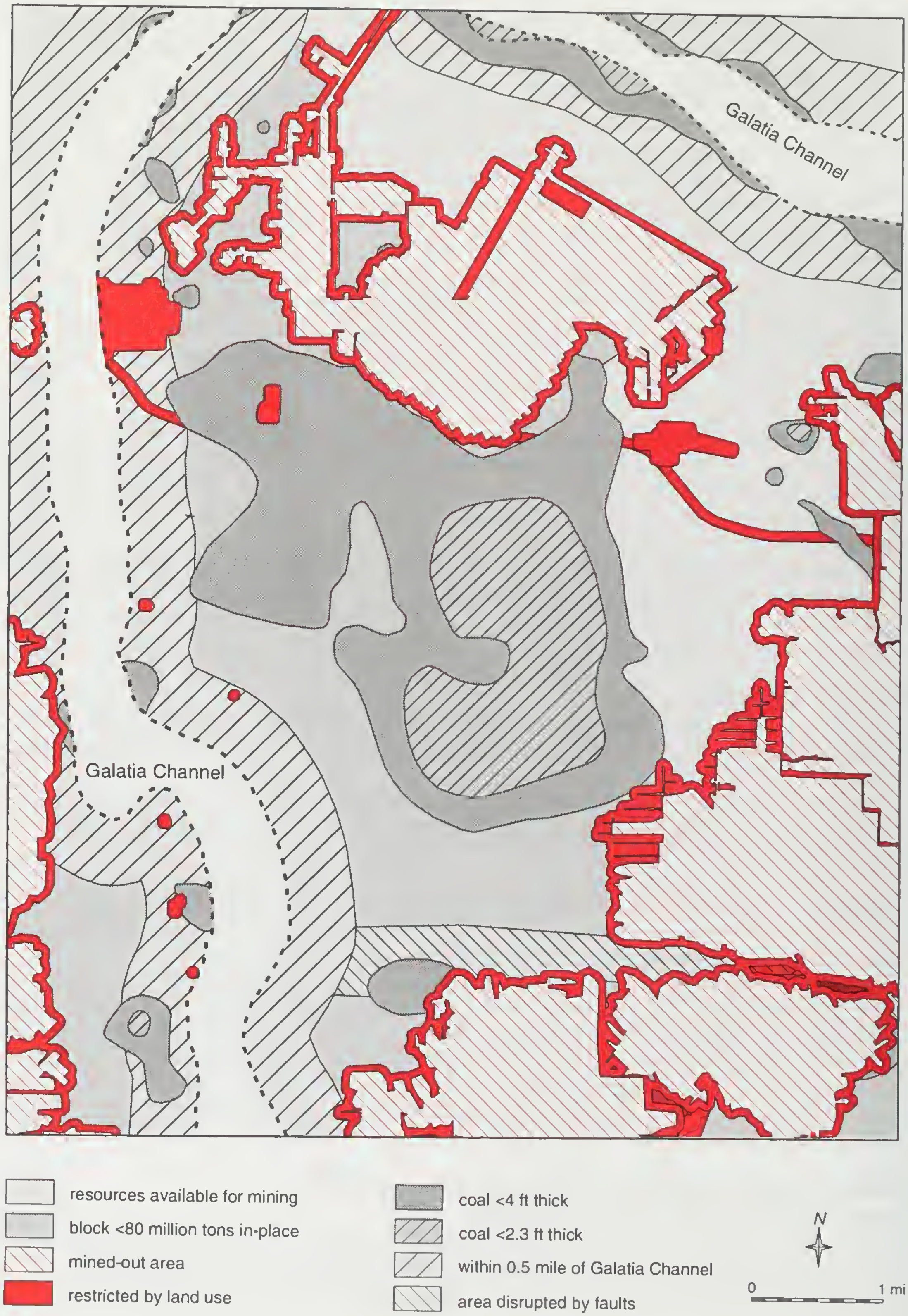

Figure 17 Availability of Springfield Coal resources for underground mining in the Galatia Quadrangle.

Figure 18 Thickness of the Davis Coal in the Galatia Quadrangle.

Figure 19 Availability of Davis Coal resources for underground mining in the Galatia Quadrangle.

Davis Coal

The Davis Coal is the most important resource below the Springfield Coal. The coal is found throughout southeastern Illinois and has been correlated with the Seelyville Coal in east-central Illinois (Jacobson 1987, 1993). The Davis generally lies 200 to 260 feet below the Springfield and is 3.5 to 5 feet thick through most of the Galatia Quadrangle (fig. 18). The coal is mined in both surface and underground mines along its outcrop in region 7. It has not been mined in the Galatia Quadrangle, and no analyses of the coal are available from the quadrangle area. The coal is commonly overlain by a black shale roof and elsewhere has been reported to have a high sulfur content (Jacobson 1993).

The 271 million tons of Davis Coal resources in the Galatia Quadrangle is the third largest of any seam in the quadrangle. More than 100 million tons (37%) are available for mining (fig. 19). Thicknesses less than 4 feet and block size are the major factors limiting the availability of this coal.

CONCLUSIONS

This study identified 377 million tons of coal resources available for mining in the Galatia Quadrangle (34% of the original resources). Unfavorable geologic conditions associated with the Galatia Channel and Cottage Grove Fault System were identified as features that limit the availability of coal in this area. As in previous studies in this series, block size, thin coal, stripping ratio, and land use were also found to be significant limitations on coal availability.

Of the more than 1 billion tons of original deep minable resources in the quadrangle, 106 million tons (10%) are mined out, and 369 million tons (36%) are available for mining. In addition, 7 million tons of Herrin Coal, classified as surface minable resources because they are less than 150 feet deep, are also available for underground mining. Deep minable resources may be unavailable because thickness is less than 4 feet (31%), block size is too small (10%), geologic conditions are unfavorable (6%), land uses are incompatible with mining (6%), faults disrupt mining (1%), and the bedrock overburden is too thin (less than 1%).

Of the 89 million tons of original surface minable resources in the quadrangle, 0.4 million tons (<1%) are mined out, and only 1.6 million tons (2%) are available for mining. Surface minable resources may be unavailable because the stripping ratio is unfavorable (45%), block size is too small (31%), faults disrupt mining (15%), and land uses conflict with mining (6%).

Areas of closely spaced oil wells were found to have little, if any, restriction on the availability of coal in the Galatia Quadrangle. This finding is consistent with our study of the Mt. Carmel Quadrangle, which also had large areas of closely spaced wells. Past ISGS resource studies have identified more than 9 billion tons of coal statewide that have been classified as unminable because of drilling for oil. Without the restriction of oil wells, 55% of these resources would have been ranked as having a high or moderate development potential (Treworgy and Bargh 1982). Much of this coal may be available for mining.

The findings on available coal from this quadrangle will be combined with information gained from other quadrangle studies to assess the availability of coal resources throughout Illinois.

APPENDIX: BACKGROUND AND FRAMEWORK OF STUDIES OF AVAILABLE COAL IN ILLINOIS

Previous Investigations of Available Coal Resources

The difference between estimates of Illinois' total coal resources and the portion of the resources available for development was discussed as early as 1969 by Risser and later by Attanasi and Green (1981). Zwartendyk (1981) described this difference as a major problem with all estimates of mineral resources.

Recognizing the need for estimates of available coal, Treworgy et al. (1978) used a relatively simple set of criteria to make a general, statewide assessment of surface minable resources in Illinois. Treworgy and Bargh (1982) conducted a similar examination of deep minable resources in the state. The latter study ranked coal into four categories of development potential: high, moderate, low, and restricted. Deposits with a high potential for development had characteristics similar to deposits currently being mined, whereas those with moderate or low potential had less favorable characteristics. Restricted deposits were considered unminable because of constraints resulting from surface land use or oil fields.

These two studies demonstrated that large portions of the state's coal resources have characteristics that restrict development potential. Because of the statewide approach used in these studies, however, many factors that restrict the development of coal were not considered, for example, the geology of roof and floor strata, thickness of the interval between seams, and thickness of the bedrock overburden. The actual amount of available coal may thus be significantly lower than indicated by the initial estimates. Treworgy et al. (1978) estimated that 6 billion of the 20 billion tons of surface minable resources are suitable for mining. Industry sources have suggested that the amount of surface minable coal available is actually much lower. The steady decline since about 1970 in the number of surface mines in the state (down from 35 to 15 mines) and the annual percentage of the state's total production from surface mines (down from 51% to 26%) appears to confirm this view.

In 1987, the National Coal Council concluded that lack of information on the availability of coal resources is a nationwide problem that should be rectified. In the late 1980s, the USGS began sponsoring assessments of the availability of coal resources in eastern Kentucky (Eggleston et al. 1988, Carter and Gardner 1989). Studies have since been expanded to include many of the major coal-producing states in the central Appalachians and the Illinois Basin (Jake 1989, Carter et al. 1990, Sites et al. 1991, Weisenfluh et al. 1992, Treworgy et al. 1994, Cetin et al. 1994).

The USGS-sponsored studies examine in detail the factors affecting the availability of coal for mining within a 7.5-minute quadrangle (about 56 square miles). The relatively small study areas permit more complete and comprehensive data collection and assessment than is practical or economical to conduct for a larger area (Eggleston et al. 1990). The quadrangles selected represent the geology and mining conditions found in surrounding quadrangles, and the results of the detailed investigations can be used to estimate the availability of coal resources in these regions.

Framework for Studies of Available Coal in Illinois

The Illinois coal field was divided into seven regions to provide a statewide framework for selecting representative quadrangles and extrapolating results from individual quadrangle studies to larger areas. Each region had a distinct combination of coal resources and geologic and physiographic characteristics (fig. 1). The La Salle Anticlinorium roughly follows the boundary between regions 4 and 5, and the Du Quoin Monocline separates region 6 from 4 and 7. The other boundaries are arbitrary, but they serve to divide the central part of the basin (region 4) from the surrounding shelf areas.

The resources of most individual coal seams are concentrated in one or two regions. For example, the resources of Danville Coal are primarily in regions 1 and 5; the Jamestown and Survant Coals are primarily in region 5; the Seelyville, Davis, and Dekoven Coals are in regions 4, 5, and 7; and the resources of the Colchester Coal are primarily in regions 1 and 2. The Springfield and Herrin Coals have resources in all regions.

Significant quantities of coal resources remain in all regions (fig. A-1), and all but regions 1 and 2 have significant resources with a low to medium sulfur content (fig. A-2). All regions have had a large amount of production (fig. A-3), and all but region 1 are currently producing some coal (fig. A-4). The disproportionate amount of mining in certain regions relative to the quantity of resources in each region is an indication that large amounts of resources may be unavailable for mining.

Two to four quadrangles must be assessed in each region to obtain a sample suitable for characterizing the availability of the resources of that region (see table A-1); 26 quadrangles have been identified for study (fig. 1). The proposed quadrangles will be reevaluated periodically as the study progresses. Some quadrangles may be dropped and others added to address new factors that may be identified or to incorporate new data that may become available.

Quality of Coal Resources

Although the quality of coal is an important factor in determining the market demand for specific deposits and consequently their value, coal quality is not assessed in this study. The techniques used to combine coal quality characteristics with resource data differ substantially from the quadrangle mapping approach used to assess available coal. Several of the important coal quality characteristics can easily be mapped statewide using regional trends or geologic associations (e.g., sulfur, rank, and chlorine). The distribution of other parameters is not well understood and additional sampling is needed (e.g., ash and certain trace elements). The quality of a delivered coal product is also dependent on the coal's washability and the handling and preparation procedures used by individual mines. The ISGS has recently studied the quality of delivered coals (Demir et al. 1994). For these reasons, the quality of coal resources will be assessed in a separate study.

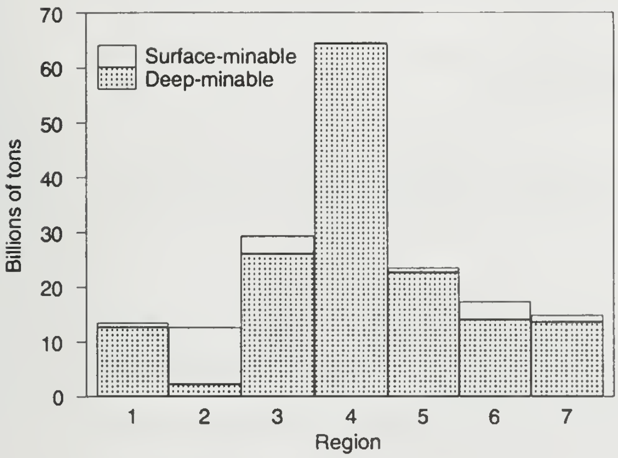

Figure A-1 Remaining coal resources in each region.

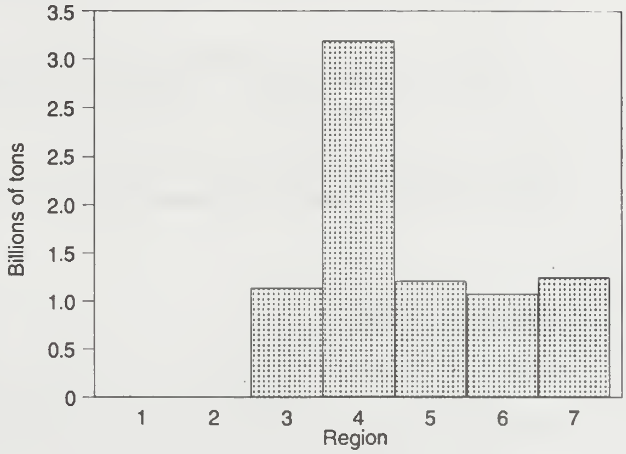

Figure A-2 Remaining resources of low- to medium-sulfur coal in each region.

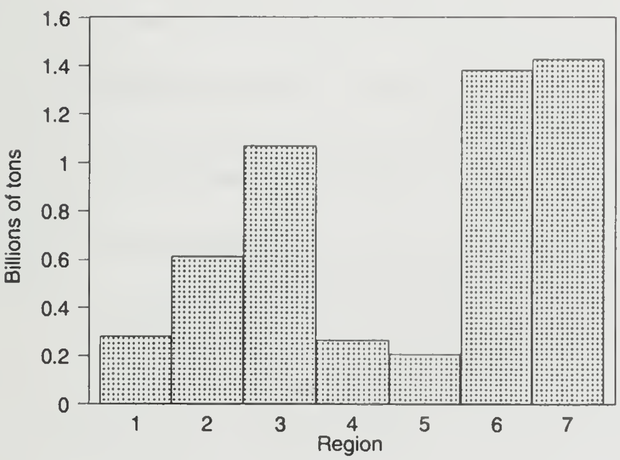

Figure A-3 Historical record of coal production.

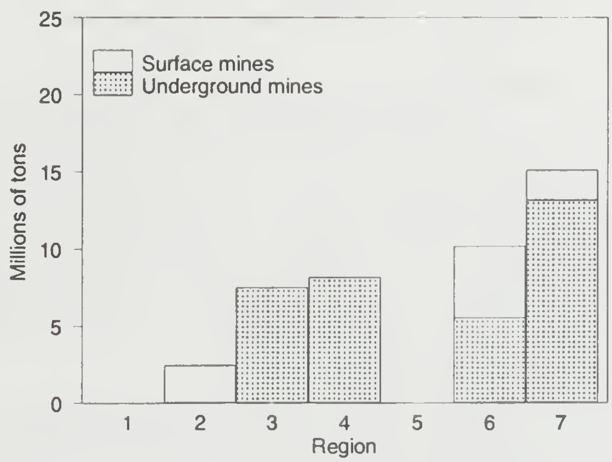

Figure A-4 Coal production in each region in 1993.

Table A-1 Guidelines for selection of quadrangle study areas.

- The minimum sample size for a region is two quadrangles. Three or four quadrangles may be needed to sample all of the significant combinations of seams, mining conditions, and physiography.
- Select at least one quadrangle per region with surface minable resources and one with deep minable resources.
- Quadrangles should generally contain a significant quantity of resources screened as having a high development potential*.
- All seams in the region that have resources with a high potential for development should be represented by at least one quadrangle.
- Selected quadrangles should include all the significant land cover/land use settings characteristic of the region.
- Select at least one quadrangle in each of the major low-sulfur deposits (Quality Circle, Hornsby, Troy, Charleston, Galatia, Darwin, Murphysboro, and Francis Creek).

* High potential for development is defined for deep minable coal in Treworgy and Bargh (1982) and has been extended to include the reserve blocks of surface minable coal delineated in Treworgy et al. (1978).

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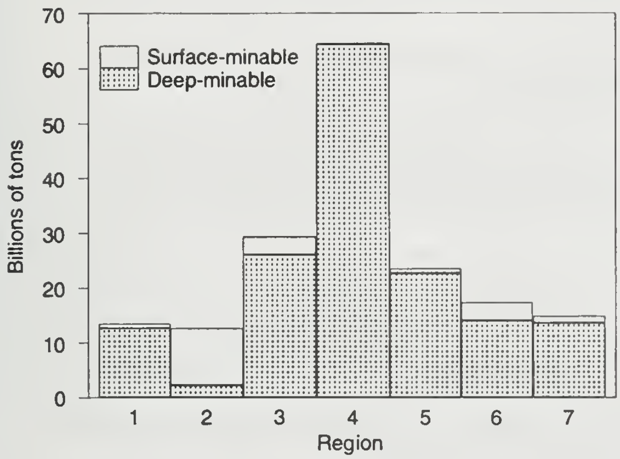

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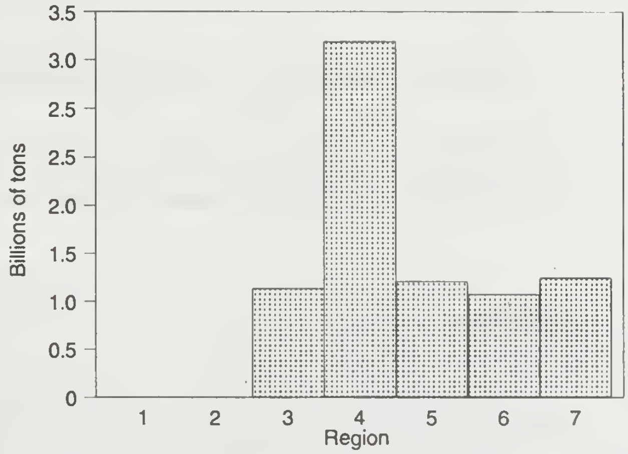


Figure A-2 Remaining resources of low- to medium-sulfur coal in each region.

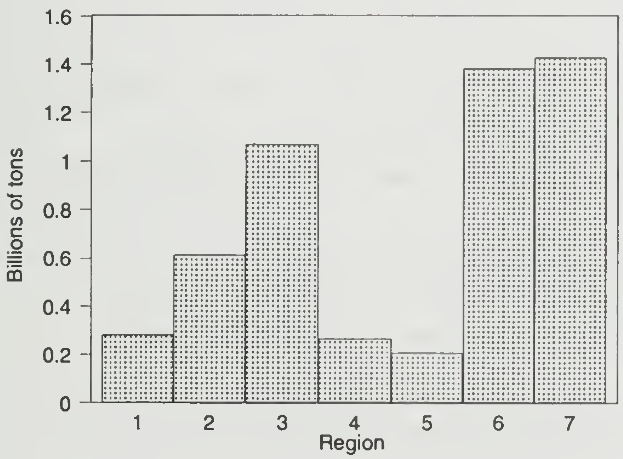
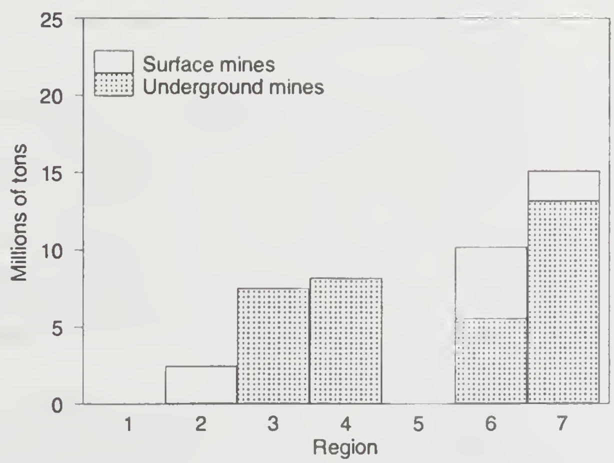


Figure A-3 Historical record of coal production.



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