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Availability of Coal Resources for Mining in Illinois

Shawneetown Quadrangle, Gallatin County, Illinois and Union County, Kentucky

Colin G. Treworgy and Daniel L. North

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Department of Natural Resources
ILLINOIS STATE GEOLOGICAL SURVEY
William W. Shilts, Chief

Natural Resources Building
615 East Peabody Drive
Champaign, Illinois 61820-6964
(217) 333-4747

CONTENTS

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EXECUTIVE SUMMARY

This report is one of a series examining the availability of coal resources for mining in Illinois. The report describes coal resources and related geologic features in the Shawneetown Quadrangle in southeastern Illinois and identifies factors that restrict mining. Mining conditions in the quadrangle are representative of those in southeastern Illinois and particularly the area known as Eagle Valley. Mining experts were interviewed to determine how regulatory restrictions, cultural features, mining technology, and geologic, economic and environmental conditions affect resource availability in the quadrangle.

This study found that the majority of the resources of Davis and Springfield Coal are available for mining. The resources of Dekoven Coal are for the most part restricted from underground mining because of the thin interburden between it and the underlying Davis Coal. However, where less than 200 feet deep, the thin interburden results in a favorable stripping ratio for surface mining the Dekoven and Davis together. Because of its relative thinness, the Herrin Coal is not available for underground mining and is available for surface mining only in limited areas.

The Fluorspar Fault Complex and the Shawneetown and Wabash Valley Fault Zones have varying degrees of impact on mining. Minor faults paralleling the major faults, and abrupt changes in seam dip create conditions unfavorable for mining in and near these zones. A belt of disturbed coal extends on the order of 600 feet from the major faults of the Wabash Valley Fault Zone and 1,000 feet from the Shawneetown Fault Zone. Isolated minor faults associated with these fault zones and the Fluorspar Fault Complex affect narrower zones of about 100 to 200 feet wide.

Although not as widespread a problem as in the central and northern parts of the state, thin bedrock cover and unfavorable ratios of bedrock to unconsolidated cover were found to restrict mining of some resources in the Shawneetown Quadrangle.

Original resources in the Shawneetown Quadrangle total 720 million tons from four coal seams: the Herrin, Springfield, Dekoven and Davis Coals. More than 328 million tons (46% of original resources) are available for mining, 41 million tons (6%) have been mined or lost in mining, 325 million tons (45%) have technological restrictions, and 27 million tons (4%) have land-use restrictions (table 1). Most of the resources in the quadrangle are more than 75 feet deep and potentially minable by underground methods; only 105 million tons of the resources in the quadrangle are less than 200 feet deep and potentially minable by surface methods. Of the 328 million tons of available resources, 308 million tons are underground minable and 30 million tons are surface minable (about 10 million are minable by either method).

The technological restrictions on underground mining are: seam less than 42 inches thick (20% of original underground-minable resources), interburden too thin (13%), faulted (9%), block too small (5%), and bedrock cover too thin (3%). The two largest land-use restrictions are towns (2%) and abandoned mines (1%).

The technological restrictions on surface mining are stripping ratio (30% of original surface-minable resources), small block size (14%) and thick unconsolidated overburden (2%). Stripping ratios for the Davis and Springfield Coals include the tonnage of Dekoven and Herrin Coals, respectively, that would be recovered by removing the overburden.

Table 1 Summary of the original coal resources and their availability for mining in the Shawneetown Quadrangle; thousands of tons and (percent of original resources).

	Herrin		Springfield		Dekoven		Davis		Total	
Original	82,124		230,922		187,900		218,962		719,909	
Available	6,859	(8)	139,211	(60)	6,816	(4)	175,003	(80)	327,889	(46)
Mined out	4,839	(6)	32,655	(14)	1,393	(1)	1,616	(1)	40,503	(6)
Land-use restriction	6,602	(8)	11,016	(5)	2,528	(1)	6,541	(3)	26,687	(4)
Technological restriction	63,824	(78)	48,041	(21)	177,162	(94)	35,802	(16)	324,830	(45)

INTRODUCTION

Accurate estimates of the amount of coal resources available for mining are needed for planning by federal and state agencies, local communities, utilities, mining companies, companies supplying goods and services to the mining industry, and other energy consumers and producers. Current inventories of coal resources in Illinois provide relatively accurate estimates of the total amount of coal in the ground (e.g. Treworgy et al. 1997b), but the actual percentage that is minable is not well defined. Environmental and regulatory restrictions, the presence of towns and other cultural features, current mining technology, geologic conditions and other factors significantly reduce the amount of coal available for mining. Although there is little concern that Illinois' coal resources will be exhausted at any time in the foreseeable future, this study helps to identify the location of the state's resources most favorable for mining and provides information as to how they may be best extracted.

Recognizing this difference between the reported tonnage and the tonnage of actual minable coal, the United States Geological Survey (USGS) initiated a program in the late 1980s to assess the amount of available coal in the United States (Eggleston et al. 1990). As part of this ongoing, cooperative effort, the Illinois State Geological Survey (ISGS) is assessing the availability of coal resources for future mining in Illinois. This report assesses the availability of coal resources in the Shawneetown Quadrangle in southeastern Illinois (fig. 1). The 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).

Selection of Quadrangles

Treworgy et al. (1994) divided Illinois into seven regions, each representing a distinct combination of geologic and physiographic characteristics (fig. 1), and selected two to four quadrangles representative of the mining conditions in each region. Quadrangle selection and resource assessment both focus on resources that have the highest potential for development (e.g., thick or lower sulfur content seams). This approach ensures that the most economically important deposits receive sufficient study and that little time is spent on coal that is unlikely to ever become available for mining.

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

The Shawneetown Quadrangle was selected as representative of surface and underground mining conditions in southeastern Illinois. Coal mining has been conducted in this area of the state since at least the 1800s. In addition to the Herrin and Springfield Coals, the Dekoven and Davis Coals and small deposits of the Briar Hill and other coals have been mined. Although not the thickest resources in the state, the coals in this area are attractive because of their high rank and heat content. Mining is complicated by the convergence of three major fault complexes. The southeastern edge of the quadrangle, consisting of the Ohio River and unoccupied floodplain, extends a few miles into Union County, Kentucky.

Coal Resource Classification System

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

The term "original resources" refers to the amount of coal resources originally in the ground prior to any mining. The ISGS has traditionally defined resources as all coal in the ground that is 18 or more inches in thickness and less than 150 feet deep, or all coal 28 or more inches thick. This definition was modified for this report to include coal less than 200 feet deep and at least 12 inches thick. These

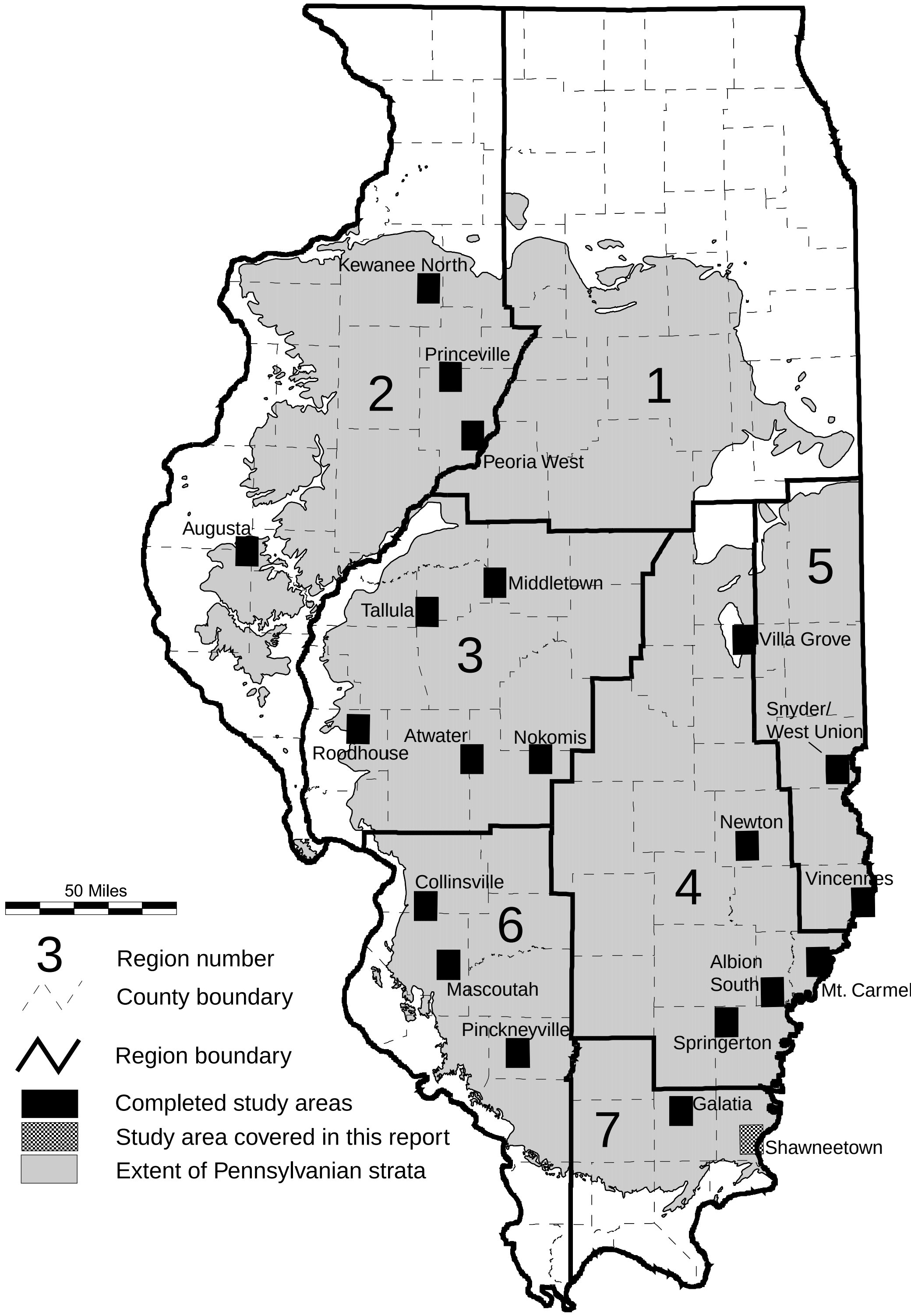

Figure 1 Coal resource regions and quadrangle study areas.

modifications were made to provide consistency with our estimates of original and available resources in the quadrangles previously studied.

The term “available coal” is not a formal part of the USGS system, although it is commonly used by the USGS and many state geological surveys. Available coal, as used in this report, does not imply that particular coal deposits can be mined economically at the present time. Rather, the term designates deposits that have no significant characteristics likely to make them technically, legally, or economically unminable for the foreseeable future. Determining the actual cost and profitability of these deposits requires further engineering and marketing assessments.

Sources of Data

Geologic data for this study were compiled from drillers logs, core descriptions and geophysical logs from coal and oil tests. Boundaries of mines were digitized directly from company maps or extracted from an earlier compilation of mine outlines. In cases where no map was available, the location of the mine was marked with a point symbol and, if possible, the general area of mining was delineated. Surface elevations and information on land cover features such as cemeteries, roads, railroads and towns were extracted from USGS Digital Line Graph files. All major land cover features were verified by field reconnaissance.

Previous Investigations

The ISGS has evaluated the availability of coal resources in twenty other quadrangles located throughout the state’s coal field (Treworgy et al. 1994, Treworgy et al. 1995, Jacobson et al. 1996, Treworgy et al. 1996a, 1996b, Treworgy et al. 1997a, Treworgy et al. 1998, Treworgy 1999, Treworgy et al. 1999). Nineteen coal seams have been assessed in these studies. The coal found to be available for mining in each quadrangle ranged from as little as 15% to as much as 77% of the original resources.

Each quadrangle represents a different geologic and geographic setting in Illinois and each quadrangle study identifies and defines factors that influence the availability of resources in that setting. Some factors, such as roof conditions, are different for each seam while other factors, such as minimum seam thickness, are applicable to all seams. Some factors, such as cemeteries, have the same effect on mining throughout the state while the effects of other factors, such as roads, are dependent on the region of the state and value of the underlying coal.

Surface Features in the Shawneetown Quadrangle

The Shawneetown Quadrangle contains, for Illinois, a relatively diverse topography. The Ohio River cuts across the southeast quarter of the quadrangle and forms the state line between Illinois and Kentucky (fig. 2). A broad floodplain extends one to two miles on both sides of the river. The Saline River, with a floodplain less than a mile wide, cuts across the southwest corner of the quadrangle. The northwest quarter of the quadrangle is a broad level plain created by a large glacial lake. The Shawneetown Hills in the northern part of the quadrangle, Gold Hill in the center of the quadrangle, and the hills south of the Kuykendall Valley stand, in some places, more than 200 feet above the surrounding lowlands.

The towns of Old Shawneetown, Shawneetown, and Junction were once home to many of the miners of the area. A railroad, terminating at Old Shawneetown, is used to transport supplies to and from the river docks to other parts of southern Illinois. State Route 13 is the only major highway in the quadrangle and many of the other roads are unpaved.

Geology, Coal Quality and Mining History of the Shawneetown Quadrangle

Although bedrock outcrops can be found in the hilly sections of the quadrangle, most of the lowlands are covered by unconsolidated sediment consisting of glacial deposits and recent alluvium. These deposits are 50 to more than 150 feet thick (fig. 3).

The geology and economic resources of the Shawneetown Quadrangle have been described by Smith (1957) and Nelson and Lumm (1986). The quadrangle covers an area of complex structural geology.

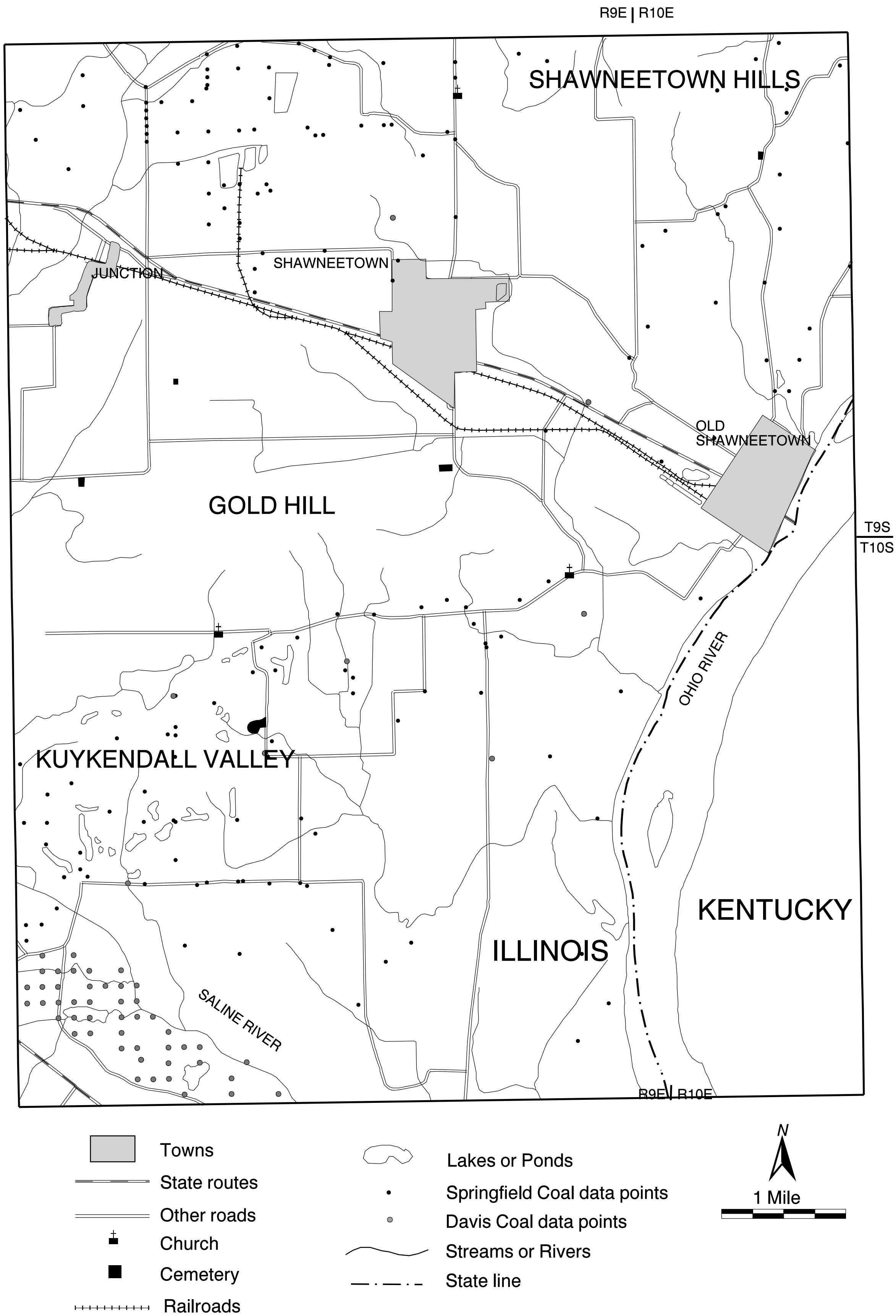

Figure 2 Surface features, Shawneeton Quadrangle.

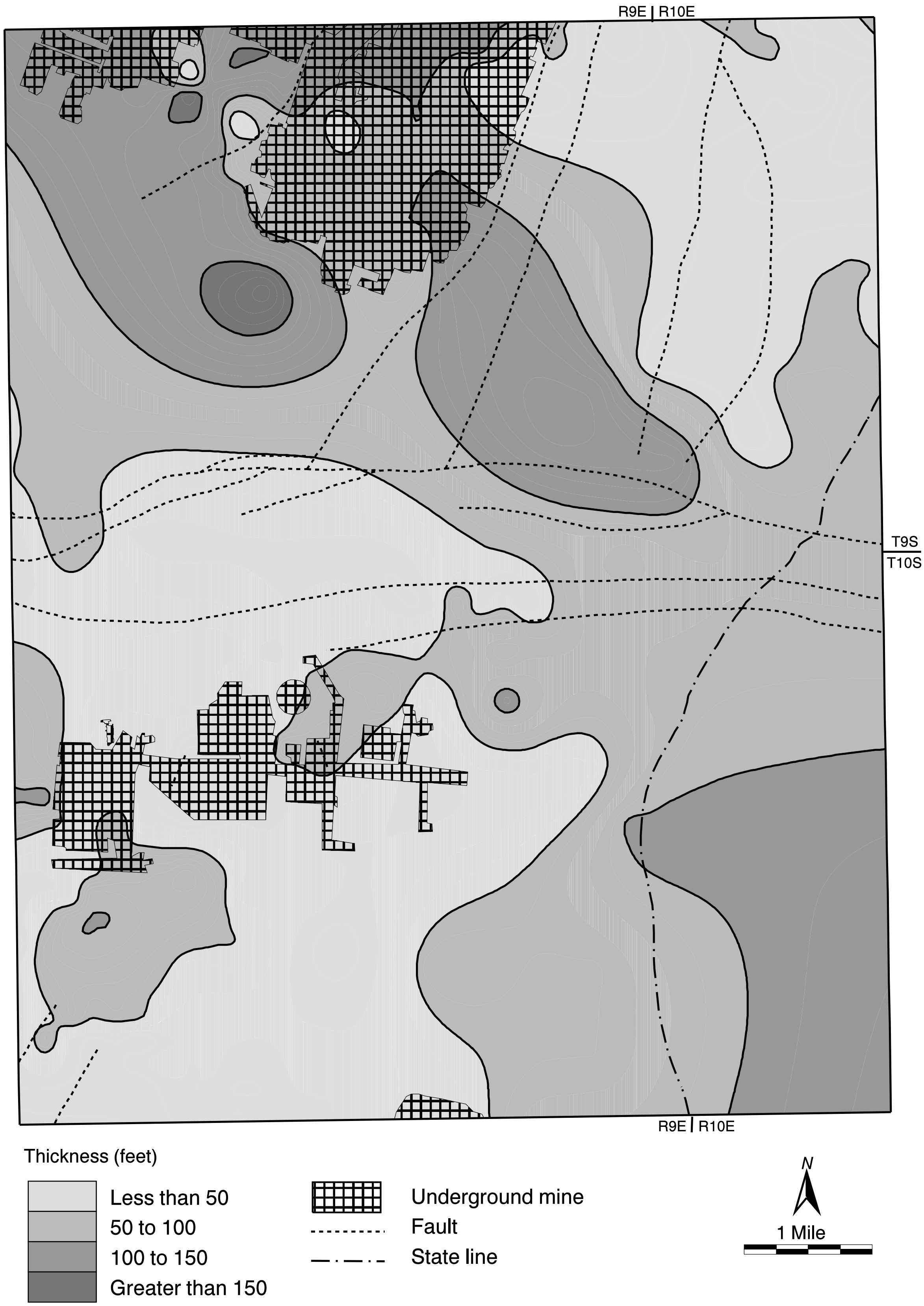

Figure 3 Thickness of unconsolidated sediments, Shawneetown Quadrangle.

The east-west trending Shawneetown Fault Zone bisects the quadrangle and marks the boundary between the Fairfield Basin to the north and the Eagle Valley-Moorman Syncline to the south. The Inman Faults, part of the Wabash Valley Fault System, extend in a general northeastward trend from the Shawneetown Fault Zone. Minor faults from the Fluorspar Area Fault Complex extend into the quadrangle from the south. The coals of the Carbondale Formation crop out and dip to the north along the Front Fault of the Shawneetown Fault System, just south of the Shawneetown Hills (figs. 4 and 5). These coals are also present south of the fault system in the Eagle Valley Syncline. The coals are at surface-minable depths in the syncline on the west side of the quadrangle and dip at 5 to 10 degrees to the east into the Moorman Syncline in Kentucky. These coals are more than 1,000 feet deep at the southeast edge of the quadrangle.

The coals in the Shawneetown Quadrangle are some of the highest in rank and heat contents in the state. The rank of most seams is expected to be high-volatile A and heat contents should be in the range of 12,500 to 14,000 Btu/lb (dry basis). The sulfur content of the Herrin and Springfield Coals is expected to be in the range of 3 to 5% and average around 3.5 to 4% (dry basis). The Dekoven and Davis Coals are believed to have a slightly lower sulfur content and probably average just under 3% sulfur.

Coal has been mined off and on in the Shawneetown Quadrangle since at least the 1800s. Nelson and Lumm (1986) reported that the earliest mining was in the Davis Coal. The only extensive mining of the Davis or Dekoven Coals was surface mining conducted by Peabody Coal Company's Eagle Mine in the late 1960s and early 1970s. During this same period, Peabody operated the Eagle Underground Mine (later known as Eagle No. 1) in the Springfield Coal. The mine closed after only seven years of operation, reportedly because of labor problems and low productivity. During this same period, Peabody opened its Gold Hill Mine in the Springfield Coal north of the Shawneetown Fault Zone. The mine was renamed Eagle No. 2 and operated until 1993. Several small underground mines operated in the Springfield Coal for short periods of time prior to the 1970s. The extent of workings of these mines is poorly documented. The Springfield Coal was surface mined in limited areas along its northern outcrop in Eagle Valley. The Herrin Coal was surface mined over several square miles by Peabody Coal Company's Eagle Surface Mine. The only other mines in this seam were small drift mines that affected a few acres.

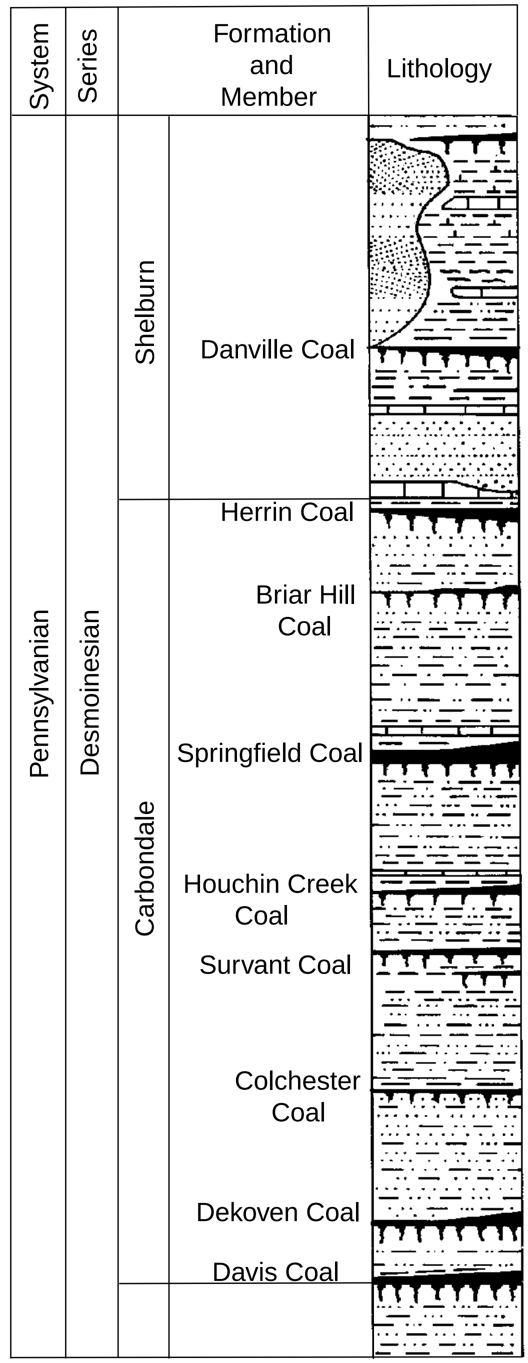

Figure 4 Selected stratigraphic units in the Shawneetown Quadrangle. (Modified from Nelson and Lumm 1986).

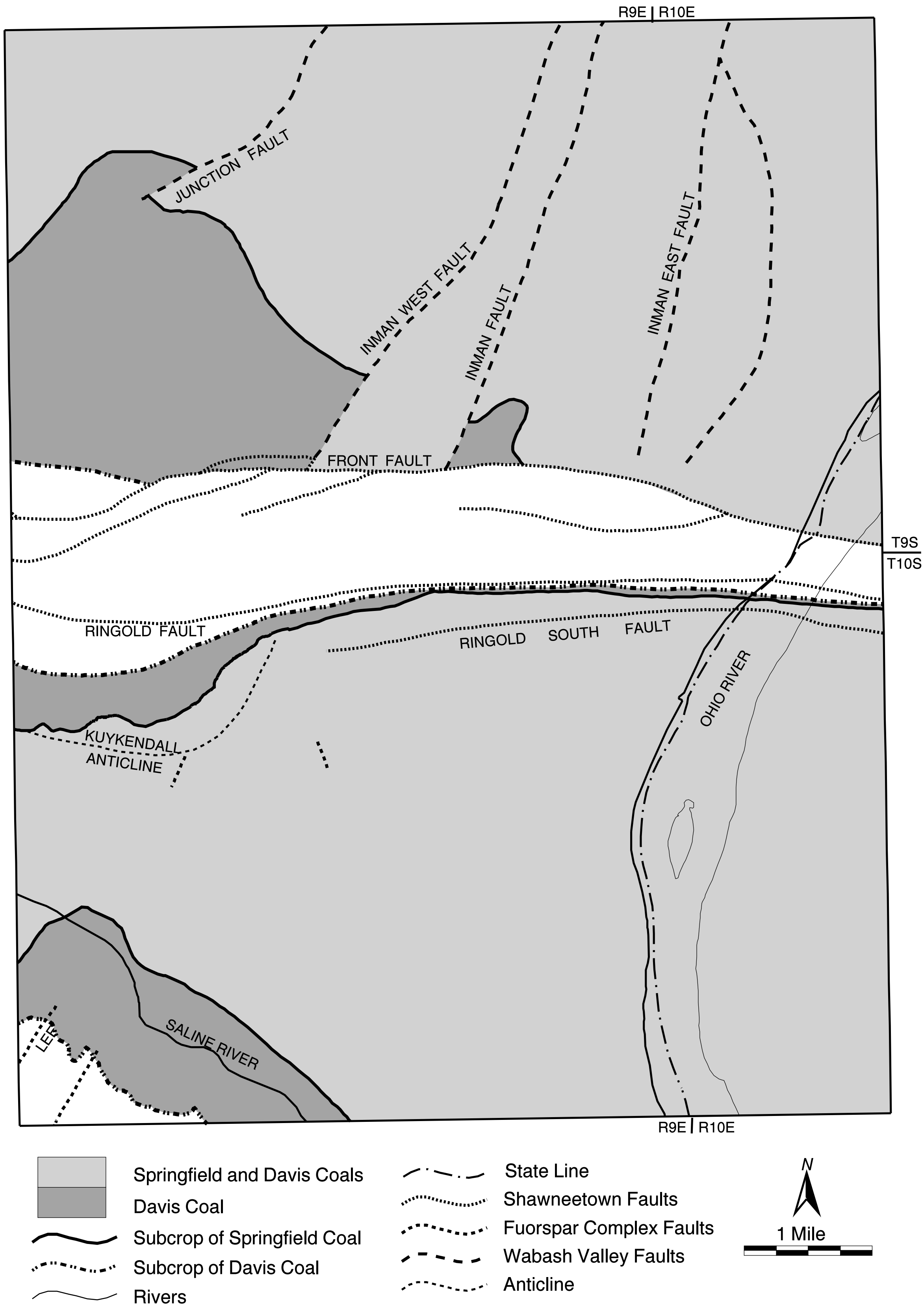

Figure 5 Structural features, Shawneetown Quadrnagle.

FACTORS AFFECTING THE AVAILABILITY OF COAL

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

The quality of coal has a great influence on its marketability, but generally not on its minability. For example, coals with low sulfur and chlorine content and high heat content are more marketable then coals with high sulfur and chlorine content and lower heat content. In some cases, a premium quality coal may command a high enough price to allow companies to absorb the higher cost of mining under unfavorable geologic conditions. The coals in the Shawneetown Quadrangle have a higher heat content than most other coals in Illinois and therefore may be sold for a slightly higher price per ton. However, this premium is probably already factored into the criteria we use for available coal and may explain in part why there has been mining in the quadrangle when thicker and less faulted resources can be readily found elsewhere in the state.

The following factors, defining available coal in the Shawneetown Quadrangle, are a composite set of rules based on our interviews with mining companies (table 2). The restrictions are organized according to the mining method they apply to: surface or underground mining as currently practiced in Illinois.

Surface Minable Coal

Depth of Seam Depending on their thickness, coals less than about 200 feet deep can be mined by either surface methods or underground methods (provided there is sufficient bedrock cover). The choice of surface or underground methods will depend on the comparative cost of extraction and the overall character of a company's reserves at a specific site. For example, if a company's reserve block is primarily deeper than 150 feet, it may elect to mine all of the coal by underground methods. Coals may be unavailable for surface mining due to their stripping ratio, a function of depth and thickness. Stripping ratio is discussed separately below.

Thickness of Seam The minimum thickness of coal for surface mining is 1 foot for the lowermost seam in an interval to be mined, and 0.5 feet for overlying seams within the interval. Thinner seams are impractical to recover because the amount of out-of-seam dilution becomes too great a percentage of the material handled.

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

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

Some companies use a "swell factor" to account for the increase in volume of overburden after it is blasted. Swell factors for lithologies typically encountered in Illinois mines range from 1 (no swell) for sand to 1.7 for shale (Allsman and Yopes 1973). Use of this swell factor requires such detailed site-specific knowledge about the quantities of different lithologies in the overburden (e.g., shale, limestone,

Table 2 Criteria used to define available coal in the Shawneetown Quadrangle.

Surface Mining
- **Technological Restrictions**
  - Minimum seam thickness
    - Main seam: 1 foot
    - Overlying seams: 0.5 feet
    - Underlying seams: 1 foot
  - Maximum depth: 200 feet
  - Maximum glacial and alluvial overburden: see table 3
  - Stripping ratio (cubic yards of overburden/ton of raw coal; volumes and weights not adjusted for swell factors or cleaning losses)
    - 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:
      - Less than 40 ft of overburden: 150 thousand tons
      - More than 40 ft of overburden: 500 thousand tons
- **Land-use restrictions**
  - 100 ft buffer:
    - Cemeteries
    - Railroads
    - State highways
    - High-voltage transmission towers
  - 200 ft buffer: Large underground mines
  - 500 ft buffer: Subdivisions
  - 2,640 ft buffer: Towns

Underground Mining
- **Technological Restrictions**
  - Minimum seam thickness: 3.5 ft
  - Minimum bedrock cover: 75 ft
  - Minimum size of mining block (clean coal): 20 million tons
  - Average unminable area adjacent to faults
    - Main branch of Shawneetown: 1,000 ft
    - Inman, Inman East, and Inman West faults: 600 ft
    - Other faults: 100 ft
  - No mining in areas where sandstone is within 5 ft of coal
- **Land-use restrictions**
  - 200 ft buffer:
    - Abandoned mines
  - 100 ft buffer:
    - Towns and subdivisions
    - Churches and schools
    - Cemeteries
    - Railroads

sand, clay) that we did not use it in our calculations. Cubic yards of overburden were calculated simply from the total thickness of consolidated and unconsolidated material overlying the coal.

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

The stripping ratios calculated for the Davis and Springfield Coals take into consideration the tonnage of Dekoven and Herrin Coal that would be recovered in excavating the overburden to the lower seam. In both cases, the presence of the upper seam significantly improves the overall stripping ratio. Our calculations do not consider the benefit of recovering additional minor seams such as the Briar Hill (above the Springfield) or the Danville (present in some areas above the Herrin).

Thickness of Bedrock and Unconsolidated Overburden Thick deposits of glacial drift or alluvial sediment can restrict surface mining because of their potential to slump into the pit, fail under the weight of large draglines, and allow excessive groundwater flow into the pit (fig. 6). A minimum amount of bedrock overburden is needed to ensure that the coal is not weathered, and to provide stable material to hold the toe of the spoil pile. The maximum thickness of unconsolidated material that can be handled is dependent on the lithologic composition of the overburden, its physical properties (e.g., load bearing capacity, permeability), and the presence or absence of groundwater. The minimum bedrock and maximum glacial drift thicknesses that were handled by the companies we interviewed also depended on the mining plan and the type of equipment they were using to remove overburden.

We did not compile sufficient information to assess the lithology and physical properties of the unconsolidated sediment in the quadrangles studied. The experience of the companies suggests that for an overburden thickness of 50 feet or less, a minimum of 10 feet of bedrock cover is needed. For overburden between 50 and 100 feet thick, one-third to one-half the material should be bedrock (table 3). The maximum thickness of unconsolidated overburden that can be handled over a large mining area is approximately 50 feet. Small areas of thicker unconsolidated overburden can be mined, but large areas of thick unconsolidated overburden will be avoided.

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

Although there are exceptions, most Illinois coals are cleaned to some degree before final shipment. The coal can be trucked from the mine pit over the existing road network to a central preparation plant. The minimum reserve for a surface mine is 10 million saleable tons. For this study we assumed that this

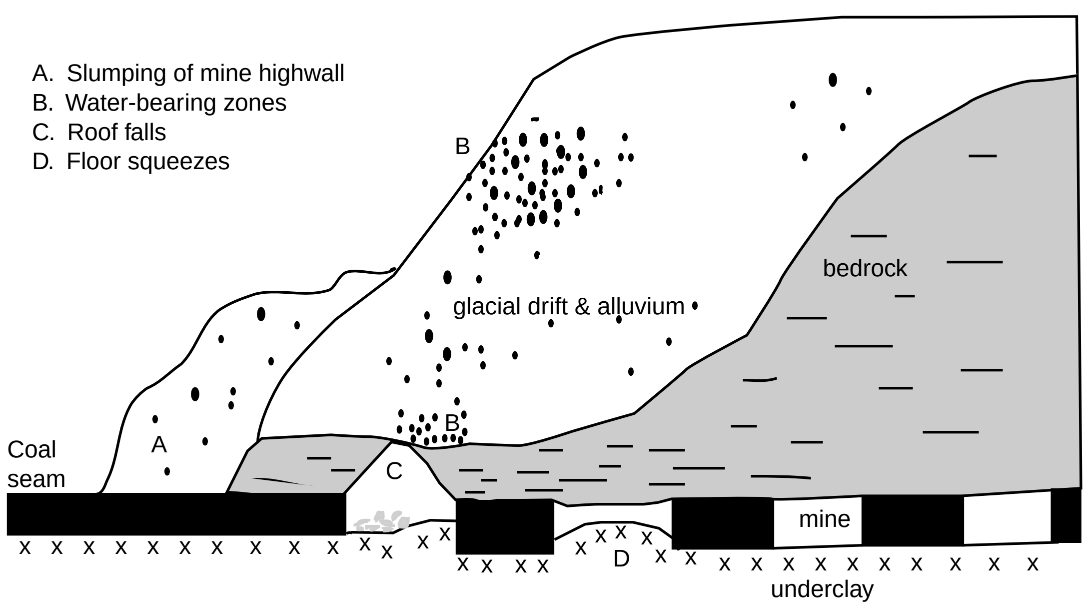

Figure 6 Problems encountered in surface and underground mines that have overburden consisting of thick unconsolidated sediments over thin bedrock.

is equivalent to about 12.5 million tons of raw coal in place. The reserve may be distributed among a number of adjacent blocks. Each mining block should contain at least 150 thousand tons of saleable coal if the coal is less than 40 feet deep, or 500 thousand tons if the coal is greater than 40 feet deep.

Table 3 Minimum thickness of bedrock and maximum thickness of unconsolidated deposits surface-minable for specified thicknesses of overburden (feet).

Overburden	Min. Bedrock	Max. Unconsolidated
10	10	0
20	10	10
30	10	20
40	10	30
50	10	40
60	20	40
70	23	47
80	30	50
90	40	50
>100	50	50

Land Use Although any type of land use or surface feature can be undermined or mined through if a company obtains permission from the owner and agrees to repair damages, companies generally find it impractical to mine under or through certain features because of the expense of restoring the feature, or the social and political hurdles required to obtain the necessary permission. The Shawneetown Quadrangle consists largely of rural areas. Surface features present in the quadrangle that cause the underlying coal to be unavailable for surface mining are towns, railroads, churches, and cemeteries.

Roads can be a significant barrier to surface mining in some areas of the state. However because coal mining has had a long historical presence in the Shawneetown area and most roads are lightly used, only the state highway was considered a restriction to surface mining.

A buffer of unmined coal must be left around any property or surface feature that cannot be disturbed. State law requires that surface mines leave a 100 foot buffer around churches and schools. Although the law requires only a 100 foot buffer around dwellings, in practice a larger buffer of about one-half mile is left around towns because of the potential disturbance by dust, vibrations from blasting, and disruption of water wells.

Abandoned Mine Workings Illinois law requires that surface mines have an unmined barrier of coal 500 feet wide around active or abandoned underground mine workings. This requirement may be waived under certain conditions, and surface mines have in many instances mined through all or portions of small abandoned underground mines. This may be done because the extent of the underground workings is not known or the area of the underground workings is so small that it is not worth the expense of diverting the surface operation around it. Large abandoned underground mines are commonly avoided by surface mining because the amount of recoverable coal is significantly reduced and there is a potential for large quantities of water to be present in the abandoned mine. For this study, we assumed that surface mines will obtain waivers to mine through small abandoned underground mines and to mine within 200 feet of large abandoned underground mines.

Underground Minable Coal

Depth of Seam The depth of coals in the Shawneetown Quadrangle (most resources are less than 1,200 feet deep) is not by itself a technological restriction on mining. Coals as deep as 1,000 feet are currently being mined elsewhere in the state. In general, it is more expensive to develop a mine in deeper resources. Because of the dip of the coal seams, most resources in the quadrangle can be accessed from a relatively shallow slope or shaft.

Thickness of Seam For this study, 3.5 feet is considered the minimum thickness of available coal for underground mining. Mining large areas of thinner seams, although technologically possible, is economically unfeasible because larger reserve blocks are required, movement of miners and equipment is more difficult, normal out-of-seam dilution from the roof and floor becomes a larger percentage of the material handled, and the tonnage produced per mining cycle is reduced. These factors make it difficult to extract coal at a rate sufficient to recover the capital investment in facilities for a modern underground mine.

Thickness of Bedrock and Unconsolidated Overburden Underground mining requires adequate bedrock overburden to support the mine roof and seal the mine against water seepage from the surface (fig. 6). If the bedrock cover is too thin (or significantly weathered), the mine roof may not be strong enough to support the overburden. Unconsolidated overburden material (glacial drift and alluvium) is not self-supporting and can add considerable pressure to the mine roof and pillars. Weak underclay, which can block mine entries and make the roof unstable by squeezing out from under pillars, is commonly associated with areas where less than half of the overburden is bedrock.

In addition to the dangers and expense of roof failures and floor squeezes, fractures resulting from mine roof failure may extend to the bedrock surface and allow water to enter the mine. At best, water seepage makes the movement of equipment more difficult and creates additional expenses for pumping and disposing of the water. In the worst case, the influx of water is rapid, and equipment may be damaged and the lives of miners threatened. In 1883, 69 miners drowned in the Diamond Mine near Braidwood (Dept. of Mines and Minerals 1954). Other, less serious, cases of mine flooding have occurred over the years.

A conservative rule used by some companies that is likely to guarantee good mining conditions is that the thickness of bedrock overburden should exceed the thickness of unconsolidated overburden. However, the amount of bedrock required can vary, depending on local geologic conditions such as the depth of the seam, composition of the bedrock overburden, and thickness of the glacial overburden.

Rock strength tests are needed to determine the minimum bedrock for specific areas. For these studies we have used a minimum bedrock overburden thickness of 75 feet. This number is based on mining practice in nearby areas of Springfield Coal with similar roof strata. There is little industry experience in underground mining of the Davis and Dekoven Coals.

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

In the Shawneetown Quadrangle, only the thickness of interburden between the Dekoven and Davis Coals is of concern. The interburden consists of varying amounts of shale, siltstone, sandstone and claystone. Where this interburden is less than 40 feet thick, only one of the coals can be mined.

Faults Faults disrupt mining operations and increase mining costs by displacing the coal seam, weakening the mine roof, and creating paths for the flow of gas or water into the mine (Nelson 1981). Displacements of even a few feet are difficult or impossible for longwall equipment to negotiate. Larger displacements block all mine advancement and may require extensive tunneling through rock to re-enter the coal bed on the opposite side. The amount of coal restricted from mining by faults depends on the characteristics of the specific fault. If a fault is a single sharp plane, mining can advance up to it from both sides and little if any coal is lost. In other cases, the fault zone may consist of several displacements within a belt hundreds of feet wide (fig. 7). In this case, mining commonly stops at the edge of the belt leaving a significant tonnage of unmined coal.

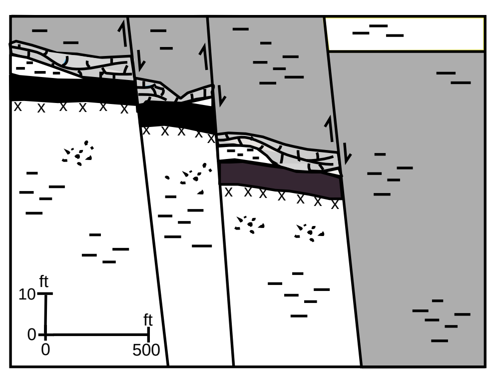

Figure 7 Cross section illustrating multiple, parallel faults displacing a coal seam.

Three different widths were used to delineate the zones of disturbed coal adjacent to the faults in the Shawneetown Quadrangle (table 4). The major faults of the Shawneetown Fault System are high angle normal and reverse faults with displacements of hundreds to thousands of feet. According to Nelson and Lumm (1986), the fault zone is 3,500 to 7,500 feet wide. The coals are missing in the central part of this zone and are steeply dipping adjacent to the fault zone. The area of coal unminable due to the presence of faults or steep dips, is estimated to average 1,000 feet wide on either side of the major mapped faults.

Mine operators in the Wabash Valley Fault System have encountered numerous minor faults, intense jointing, and substantial dips in the coal seam within a zone several hundred feet wide parallel to the main fault (Marvin Thompson and Alan Kern, personal communication). Some large in-flows of water and some squeezing of the floor after mining were experienced in this area. Using careful advance planning and extra exploratory drilling, operators have mined across these zones (Koehl and Meier 1983). Mining within the fault zone is kept to a minimum because of the expense and delay of supporting the weakened mine roof and altering the mine plan to work through or around displaced blocks of coal. In practice, mining operations routinely advanced to within 200 to 2,000 feet of the main fault trace (fig.8). The distance of advance is dependent on conditions encountered at the time of mining. Based on information from mines and drill holes in this area, this report assumes that there is a width of 600 feet of unminable coal adjacent to the Inman Faults of the Wabash Valley Fault System in this quadrangle. Faults of the Fluorspar Complex and minor faults of the Wabash Valley Fault System affect a narrower zone of coal. In this report the zone of affected coal was assumed to be 100 feet.

Size and Configuration of Mining Block Because of the shallow depth of coal in much of the Shawneetown Quadrangle, underground mines can be opened from a highwall, boxcut, or shallow slope. The minimum reserve block for this type of underground mine is 20 million tons of clean coal (equivalent to approximately 40 million tons of raw coal in place, excluding partings). This assumes room-and-pillar mining and a recovery rate, after cleaning, of 50%. Higher recovery can be attained with longwall mining, but this is offset by the need for more saleable coal to pay back the higher initial investment in equipment.

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

Land Use Limited extraction may take place under small towns with populations of a few hundred. However, unless such an area is crucial to development of the mine layout, it will generally be avoided. This study considers all coal under towns, schools, churches, and cemeteries as unavailable for underground mining. Some companies that we have interviewed do not mine under railroads. However, at least two recent longwall mines in Illinois have extracted coal underlying railroads because it was less expensive to repair the track then to align the

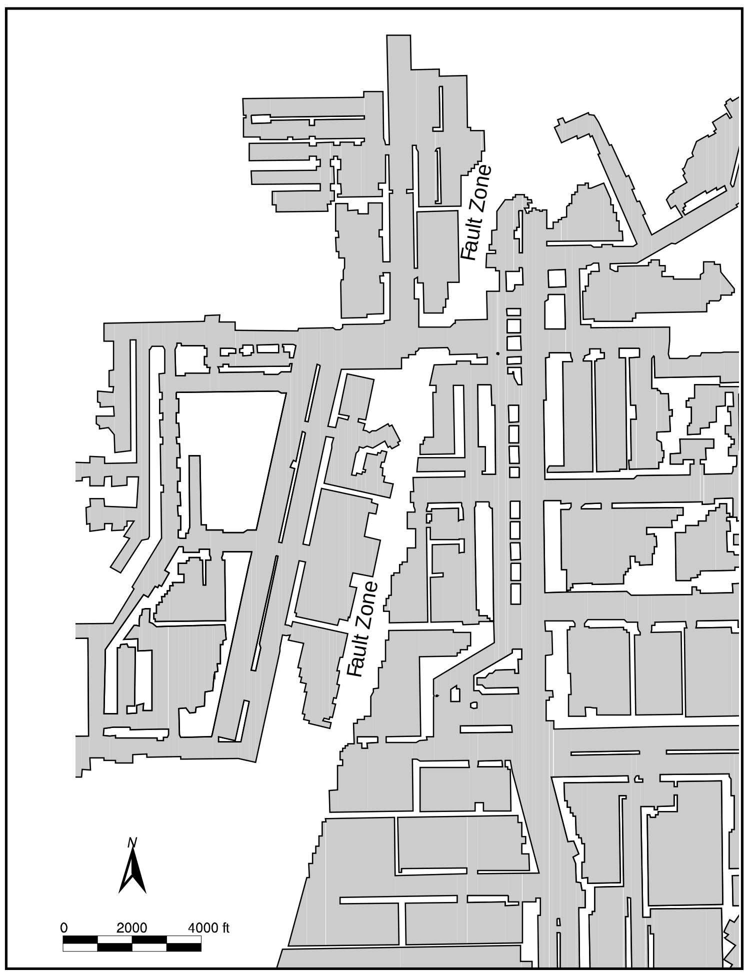

Figure 8 Unmined areas adjacent to one of the faults in the Wabash Valley Fault System (from Treworgy et al. 1998).

Table 4 Estimated width of disturbed coal adjacent to each side of faults, Shawneetown Quadrangle.

Shawneetown Fault Zone	1,000 ft
Inman Faults	600 ft
Minor faults	100 ft

longwall panels to avoid the railroad. Because the only railroad in the Shawneetown Quadrangle is located near and parallel to the outcrop of the coals and the presence of faults in the area favors the use of room and pillar mining rather than longwall methods, it is likely that companies would choose to avoid the railroad rather than incur the expense of mitigating subsidence.

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

COAL RESOURCES AND AVAILABLE COAL

Coal resources in the Shawneetown Quadrangle were mapped for the Herrin, Springfield, Dekoven and Davis Coals by using data from mines and drill holes. No resources were mapped for these coals along the southeast edge of the quadrangle due to a lack of drilling records. The coals in this area are more than 1,000 feet deep and, given the abundance of shallower resources elsewhere in the quadrangle, there is little incentive to drill holes to explore these deeper resources. Although Nelson and Lumm (1986) reported the presence of a number of other coals, there is not sufficient data to map resources in these seams. Available resources were calculated by applying the criteria listed in table 2. Note that because of the overlap in the feasible depths for surface and underground mining, some resources are potentially both surface and underground minable.

The original resource of the four seams is 720 million tons; 679 million tons remain in place and 328 million tons are available for mining (table 1, fig. 9). Technological restrictions limit mining of 45% of the resources and land use restricts mining of 4% of the resources. About 6% of the original resources have been mined or left as pillars.

Most of the available resources (308 million tons) are minable by underground methods. Only 30 million tons are available for surface mining. The availability of resources and type of restrictions on mining varies considerably from seam to seam and is discussed in the following sections.

Herrin Coal

The Herrin Coal in the Shawneetown Quadrangle ranges in thickness from less than 2.5 feet to more than 5 feet (fig. 10). There is a general trend of thickening from east to west which matches that seen for the larger region as well. The depth of the coal ranges from at or near the surface along its crop to more than 1,000 feet in the southeast corner of the quadrangle (fig. 11). The Herrin Coal is too thin to be of interest for underground mining in most of the quadrangle and too deep for surface mining. Much of the shallowest resources have been surface mined and only limited areas of the remaining resources have a favorable stripping ratio (fig. 12).

Of the 82 million tons of original resources of Herrin Coal, 77 million tons are remaining, and 7 million tons (8 %) are available for mining (table 5). All of the available Herrin Coal is surface minable and located along the crop in Eagle Valley (fig.13). Unfavorable stripping ratio was the primary restriction on surface mining. No resources were available using underground mining primarily because of the seam being too thin or the block too small to support an underground mine. Thin bedrock cover and faults restricted less than 10% of the resources.

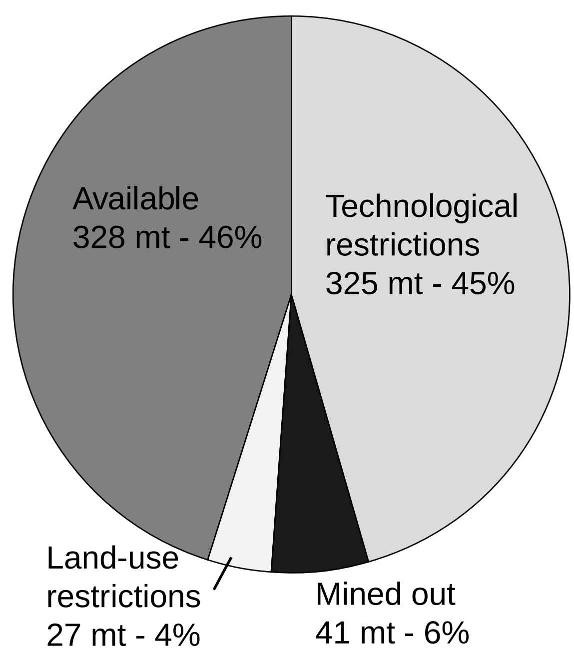

Figure 9 Availability of coal resources in the Shawneetown Quadrangle.

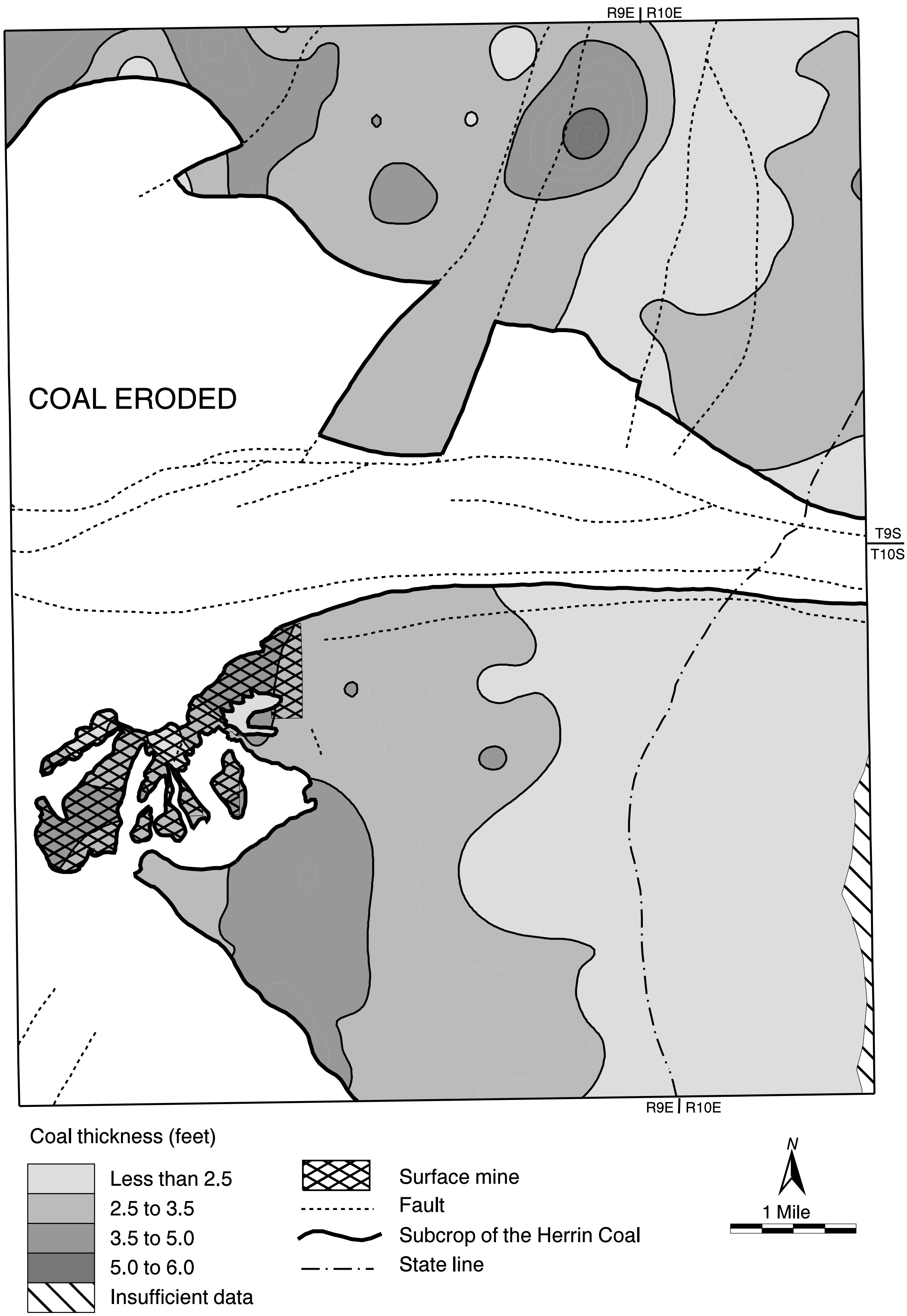

Figure 10 Thickness of the Herrin Coal, Shawneetown Quadrangle.

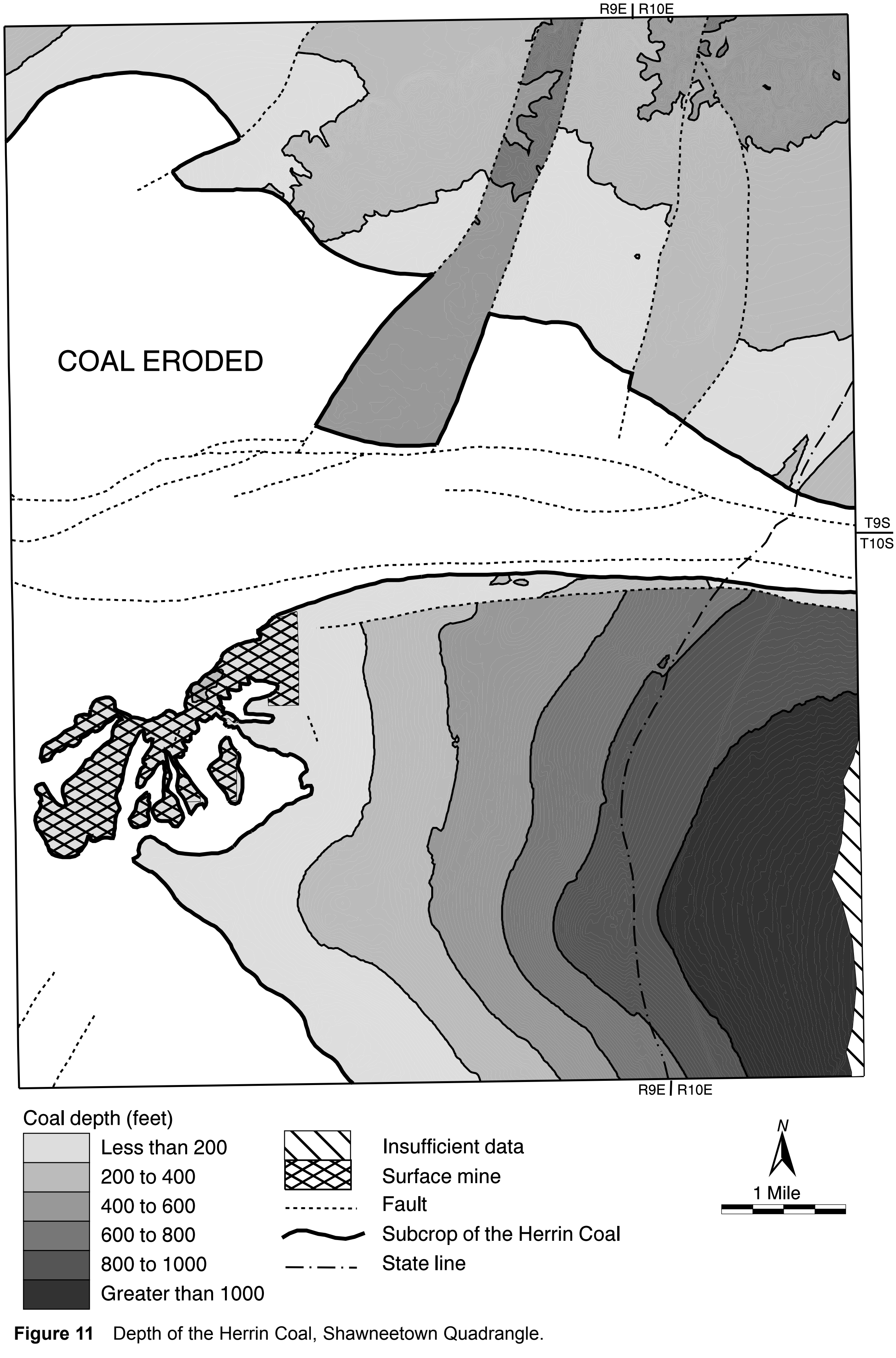

Figure 11 Depth of the Herrin Coal, Shawneetown Quadrangle.

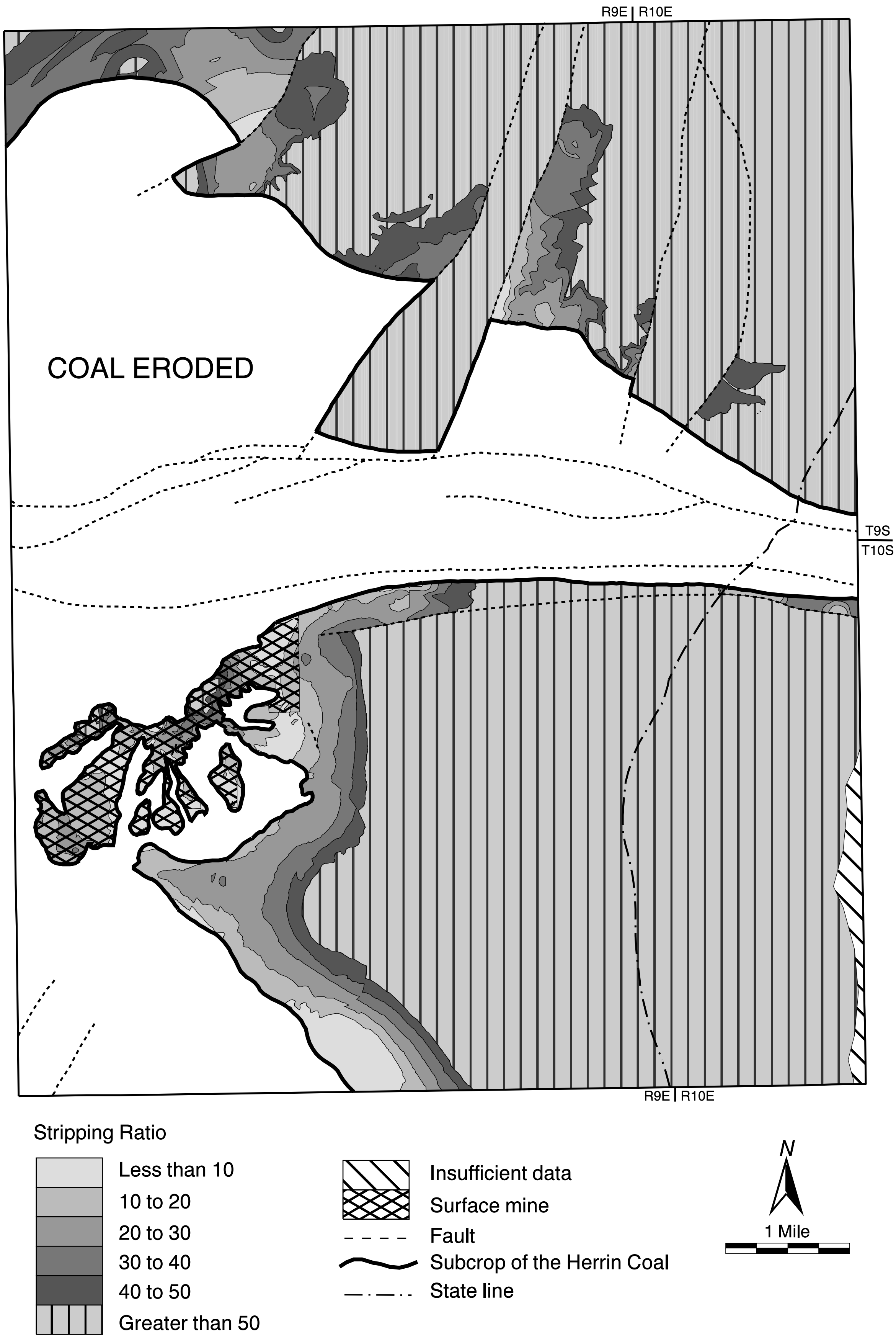

Figure 12 Stripping ratio of the Herrin Coal, Shawneetown Quadrangle.

Table 5 Availability of coal resources for mining in the Shawneetown Quadrangle; thousands of tons and (percent of original resources). Note: resources that are 75 to 200 feet deep can be mined by either surface or underground methods and are reported in both categories.

	Herrin		Springfield		Dekoven		Davis		Total	
Original	82,124		230,922		187,900		218,962		719,909	
Available	6,859	(8)	139,211	(60)	6,816	(4)	175,003	(80)	327,889	(46)
Mined out	4,839	(6)	32,655	(14)	1,393	(1)	1,616	(1)	40,503	(6)
Land-use restriction	6,602	(8)	11,016	(5)	2,528	(1)	6,541	(3)	26,687	(4)
Technological restriction	63,824	(78)	48,041	(21)	177,162	(94)	35,802	(16)	324,830	(45)
Surface minable (0 to 200 ft deep)										
Original	37,864		48,904		8,564		10,060		105,392	
Available	6,859	(18)	8,316	(17)	6,816	(80)	8,054	(80)	30,045	(29)
Mined out	4,700	(12)	7,912	(16)	1,345	(16)	1,560	(16)	15,517	(15)
Land-use restriction	6,602	(17)	4,348	(9)	211	(2)	237	(2)	11,398	(11)
Technological restriction	19,702	(52)	28,329	(58)	192	(2)	209	(2)	48,432	(46)
Land-use restrictions										
Towns	6,457	(17)	1,832	(4)	48	(<1)	59	(<1)	8,396	(8)
Cemeteries	88	(<1)	11	(<1)					99	(<1)
Church or school					3	(<1)	3	(<1)	6	(<1)
Railroad	56	(<1)	727	(2)					783	(<1)
Highways	0.5	(<1)	445	(1)					446	(<1)
Near underground mine			1,334	(3)	161	(2)	175	(2)	1,670	(2)
Technological restrictions										
Stripping ratio	17,369	(46)	14,240	(29)	116	(1)	119	(1)	31,845	(30)
Unconsolidated overburden	1,138	(3)	768	(2)					1,769	(2)
Block size	1,332	(4)	13,320	(27)	76	(1)	90	(1)	14,818	(14)
Underground minable (>75 ft deep)										
Original	68,228		228,953		187,851		216,441		701,474	
Available	0		136,983	(60)			171,046	(79)	308,029	(44)
Mined out	929	(1)	32,415	(14)	1,345	(<1)	612	(<1)	35,301	(5)
Land use restriction	0		11,009	(5)	2,348	(1)	6,474	(3)	19,830	(3)
Technological restriction	67,299	(99)	48,546	(21)	184,159	(98)	38,309	(18)	338,313	(48)
Land-use restrictions										
Towns			4,330	(2)	1,964	(1)	4,882	(2)	11,175	(2)
Cemeteries			45	(<1)			152	(<1)	198	(<1)
Church or school					5	(<1)	5	(<1)	11	(<1)
Railroad			466	(<1)	348	(<1)	1,255	(<1)	2,069	(<1)
Near mine			6,167	(3)	30	(<1)	180	(<1)	6,378	(1)
Technological restrictions										
Thin interburden					89,393	(48)			89,393	(13)
Thin bedrock	4,122	(6)	12,486	(6)	208	(<1)	370	(<1)	17,187	(3)
Block size	11,721	(17)	11,073	(5)	3,010	(2)	5,645	(3)	31,450	(5)
Coal <3.5 ft thick	49,628	(73)	413	(<1)	80,828	(43)	6,627	(3)	137.197	(20)
Faulted	1,828	(3)	24,574	(11)	11,018	(6)	25,666	(12)	63,087	(9)

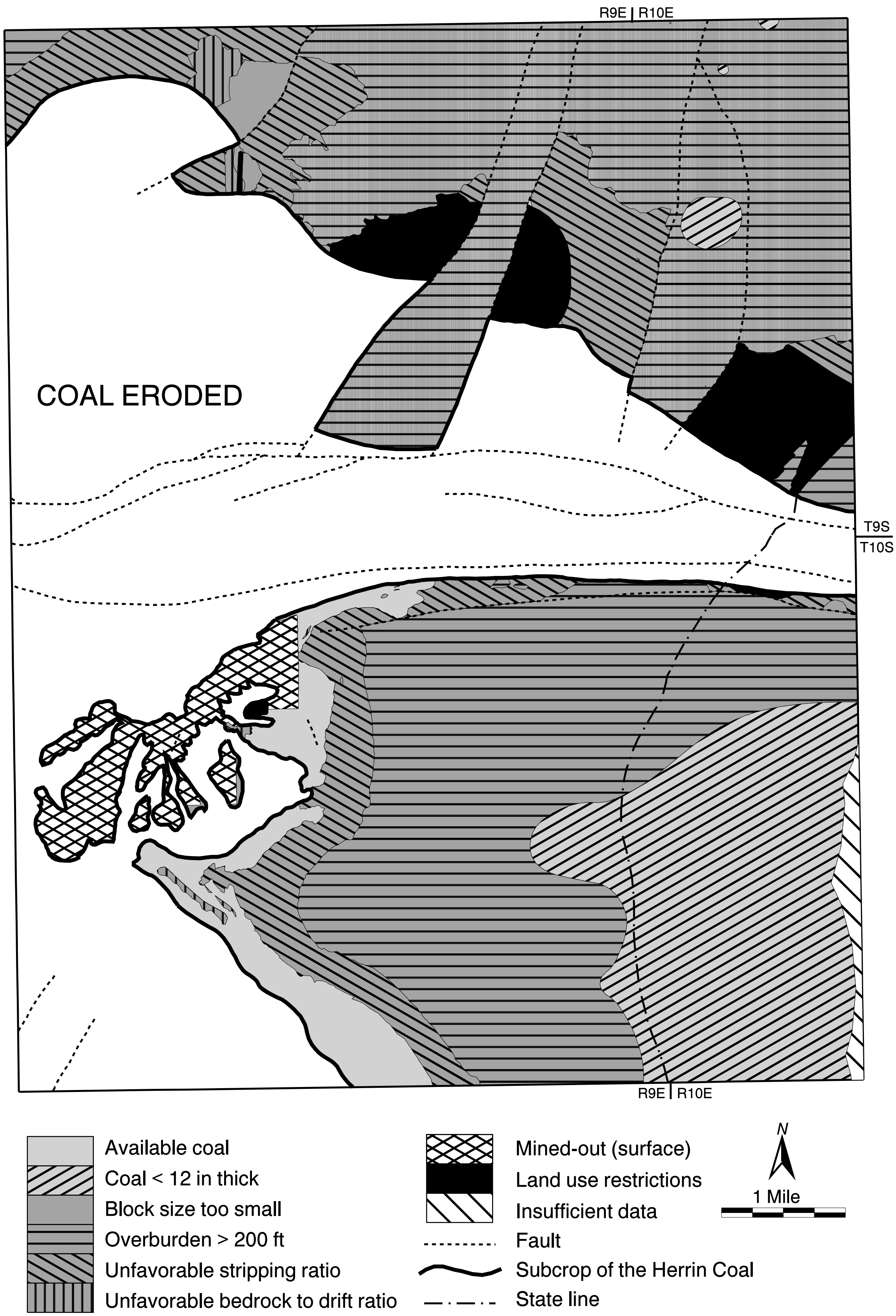

Figure 13 Availability of the Herrin Coal for surface mining, Shawneetown Quadrangle.

Springfield Coal

The Springfield Coal, found about 100 feet below the Herrin Coal, is more than 3.5 feet thick throughout most of the quadrangle and more than 5 feet in thickness in some areas (fig. 14). The coal is less than 200 feet deep in limited areas along the crop and more than 1,000 feet deep in the southeast corner of the quadrangle (fig. 15). However, because of the thickness of unconsolidated sediment overlying much of the outcrop area, the stripping ratio of the coal is greater than 20 to 1 in most areas (fig. 16). The thick unconsolidated cover also results in areas that have bedrock cover too thin for underground mining or an unfavorable ratio of bedrock to unconsolidated overburden (figs 17 and 18).

Of the 231 million tons of original resources of Springfield Coal in the quadrangle, 198 million are remaining and 139 million (60%) are available for mining (table 5). Technological factors restrict mining of 48 million tons and land use restricts about 11 million tons. Most of the available coal must be accessed by underground mining (fig. 19). Underground mining of the Springfield Coal is restricted by thin bedrock cover in small areas near the crop and by faulting. The coincidence of the crop with faults, thin bedrock, abandoned mines, and some surface land use divides some of the resources that would otherwise be available into blocks too small to support an underground mine.

Only 49 million tons of the resources are less than 200 feet deep and potentially surface minable. Of these, only 8 million tons (17%) are available for mining (fig. 20). The Springfield Coal has a favorable stripping ratio to a considerable depth because of the presence of the Herrin Coal. The stripping ratio will be further enhanced if the Briar Hill Coal proves to be present as well.

Dekoven and Davis Coals

The Dekoven Coal is stratigraphically about 200 to 220 feet below the Springfield Coal. About half the area of the Dekoven Coal in the quadrangle is less than 3.5 feet thick; the remainder is 3.5 to 5 feet thick (fig. 21). The Davis Coal, 20 to 30 feet below the Dekoven Coal, is 3.5 to 5 feet thick throughout most of the quadrangle (fig. 22). The thin interburden between the coals improves the prospects for surface mining of the two seams, but severely limits the potential for underground mining. Where less then 200 feet deep, the two coals can be surface mined together and their combined thickness expands the area of favorable stripping ratios (fig. 23). Because of the thin interburden, however, only one of the seams can be mined by underground methods. The Davis, being slightly thicker than the Dekoven in most areas, is the likely seam to be mined (fig. 24).

Of the 188 million tons of original resources of Dekoven Coal in the quadrangle, 7 million tons are available for surface mining (table 5, fig. 24). Almost all of the remaining resources less than 200 feet deep are available for surface mining. None of the resources are available for underground mining because of the thin interburden between the Dekoven and underlying Davis Coal.

Of the 219 million tons of original resources of Davis Coal in the quadrangle, 175 million tons are available for mining. Only 10 million tons of these resources are less than 200 feet deep and of these 8 million tons (80%) are available for surface mining (fig. 24). About 171 million tons of the Davis resources are available for underground mining (table 5, fig. 25). The major restriction on underground mining is disturbance of the coal by faulting.

CONCLUSIONS

About 46% of the original resources in the Shawneetown Quadrangle (328 million tons) are available for mining. The availability of resources varies sharply between seams, and ranges from 4% for the Dekoven Coal to 80% for the Davis Coal. Technological restrictions are the primary factor in limiting the availability of coal. The specific restrictions on mining differ between each seam.

Much of the resources of the Herrin Coal are less than 3.5 feet thick; consequently they are unavailable for underground mining and have a favorable stripping ratio for surface mining in only limited areas. About 60% of the Springfield resources are available for mining, most of these by underground methods. Faulting and thin bedrock cover are the major technological restrictions on underground mining of the Springfield. The resources of Dekoven Coal are for the most part restricted from underground mining. The thickness of the interburden between the Dekoven and Davis Coals is less than 40 feet

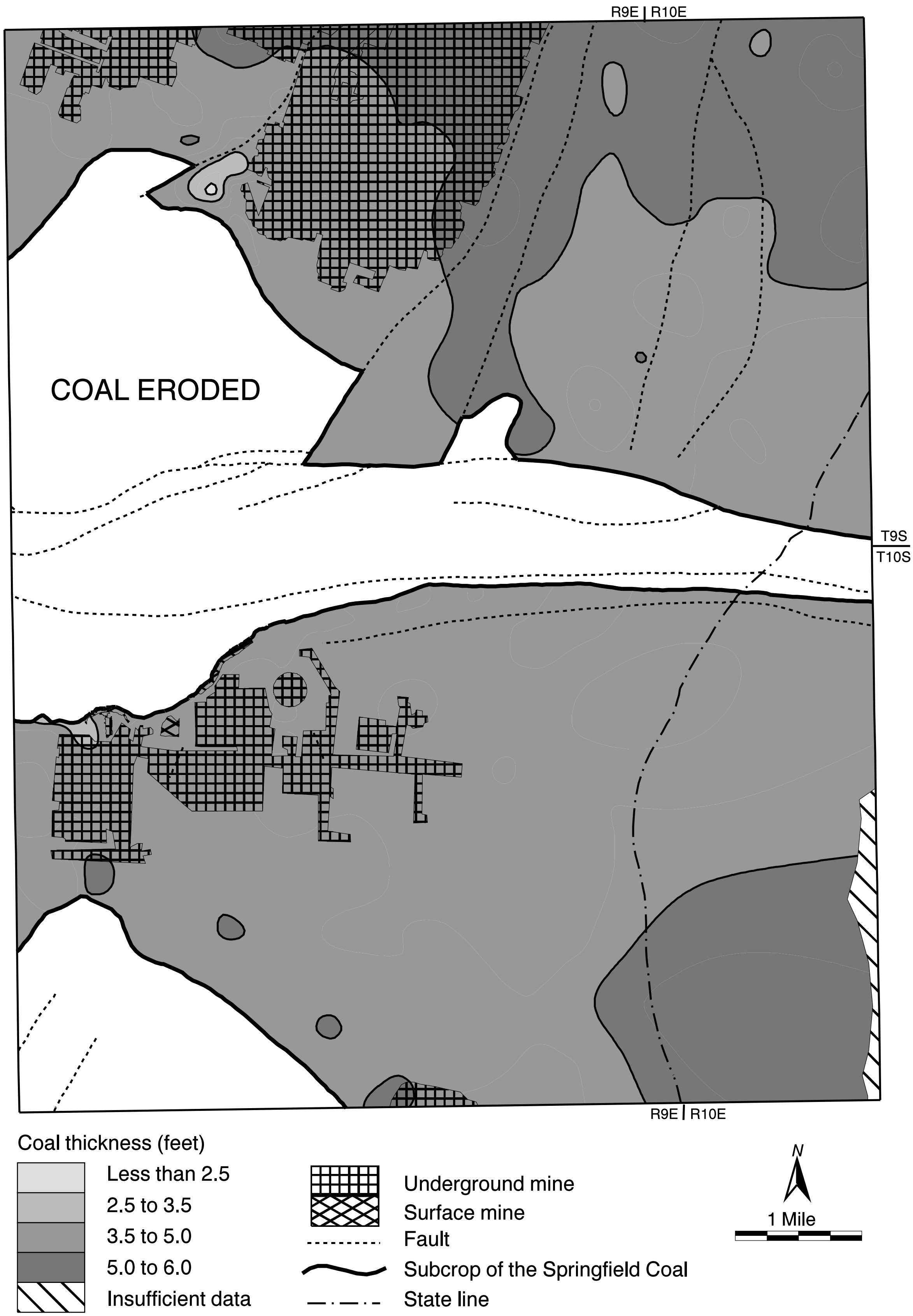

Figure 14 Thickness of the Springfield Coal, Shawneetown Quadrangle.

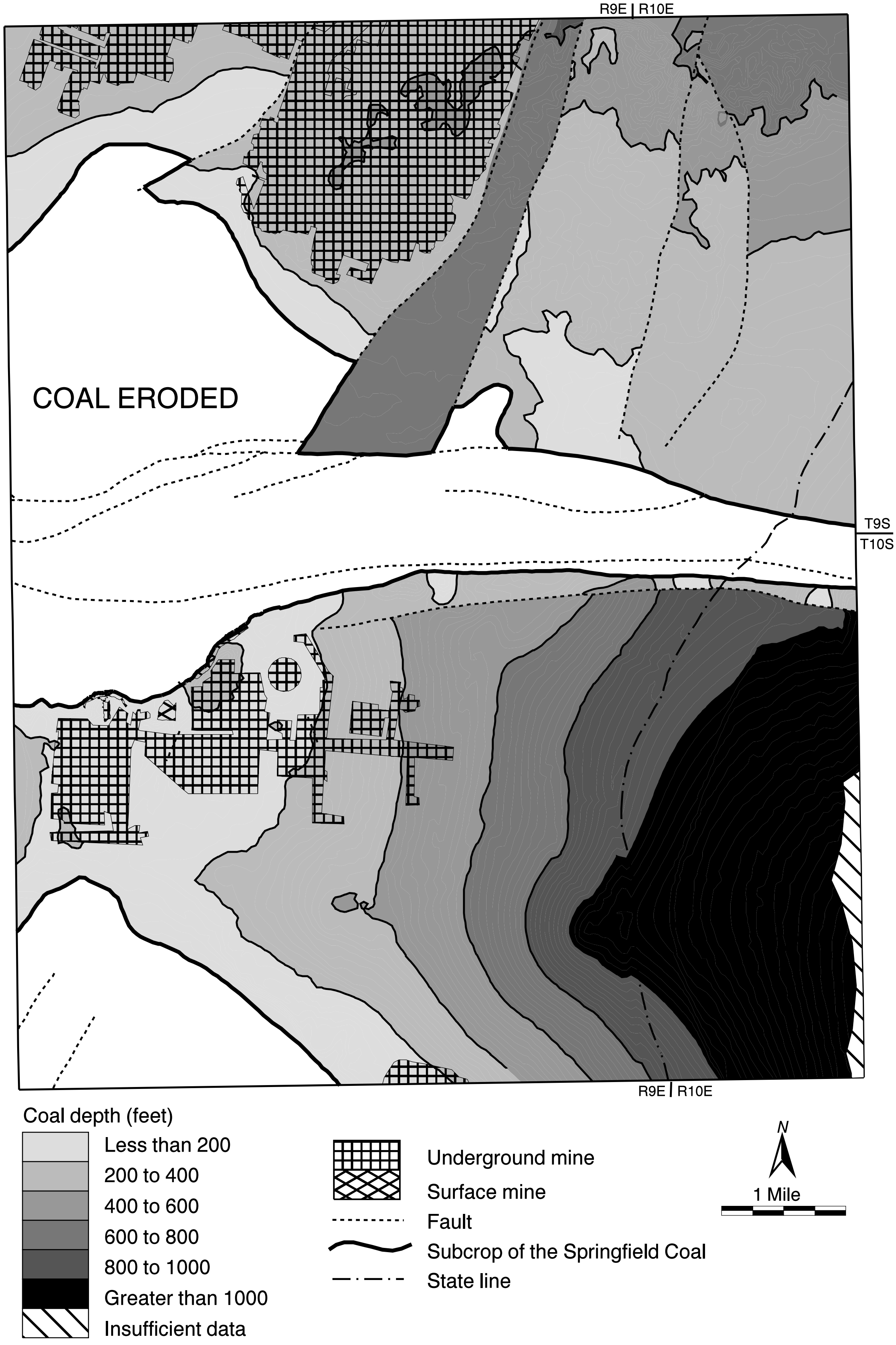

Figure 15 Depth of the Springfield Coal, Shawneetown Quadrangle.

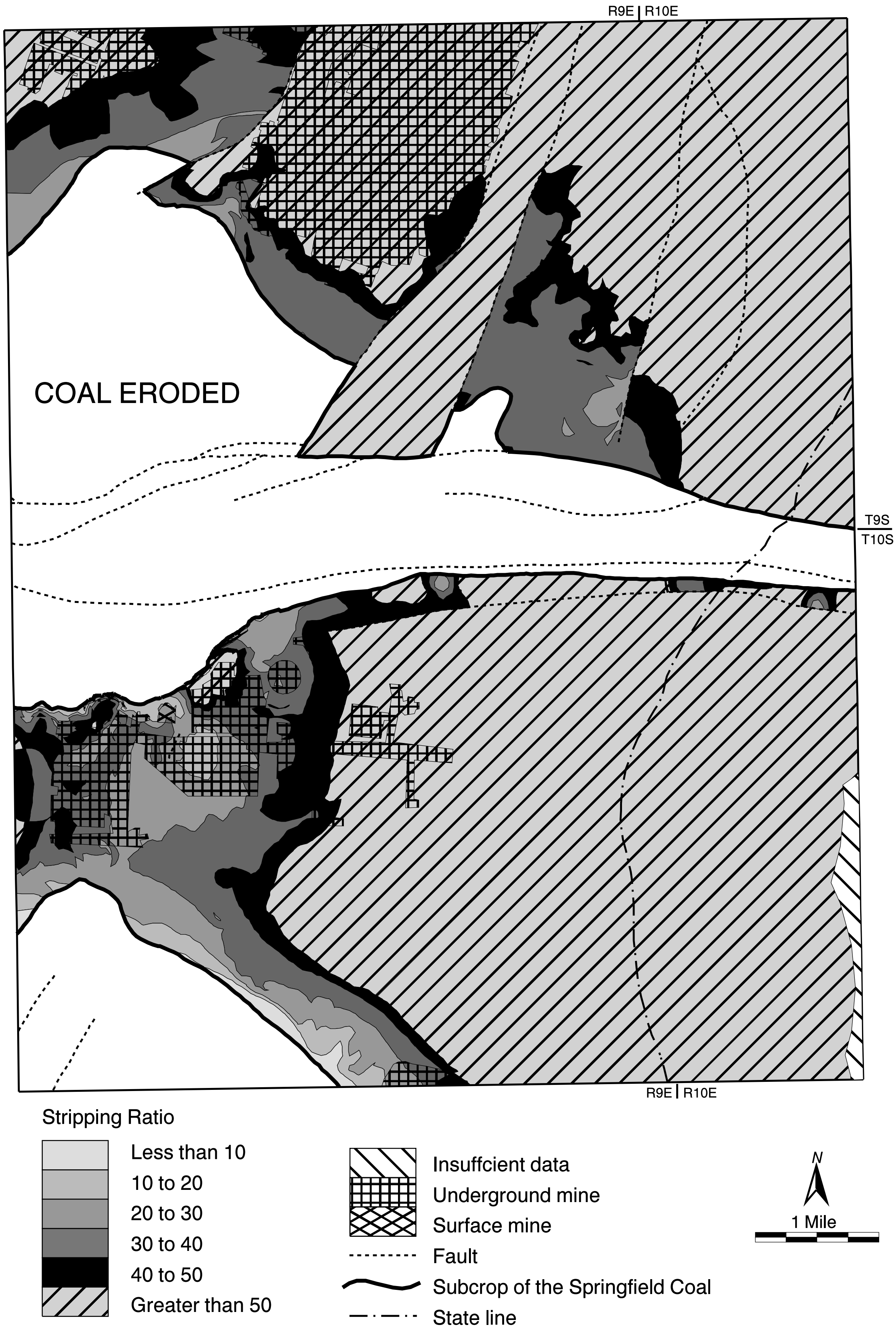

Figure 16 Stripping ratio of the Springfield Coal, Shawneetown Quadrangle.

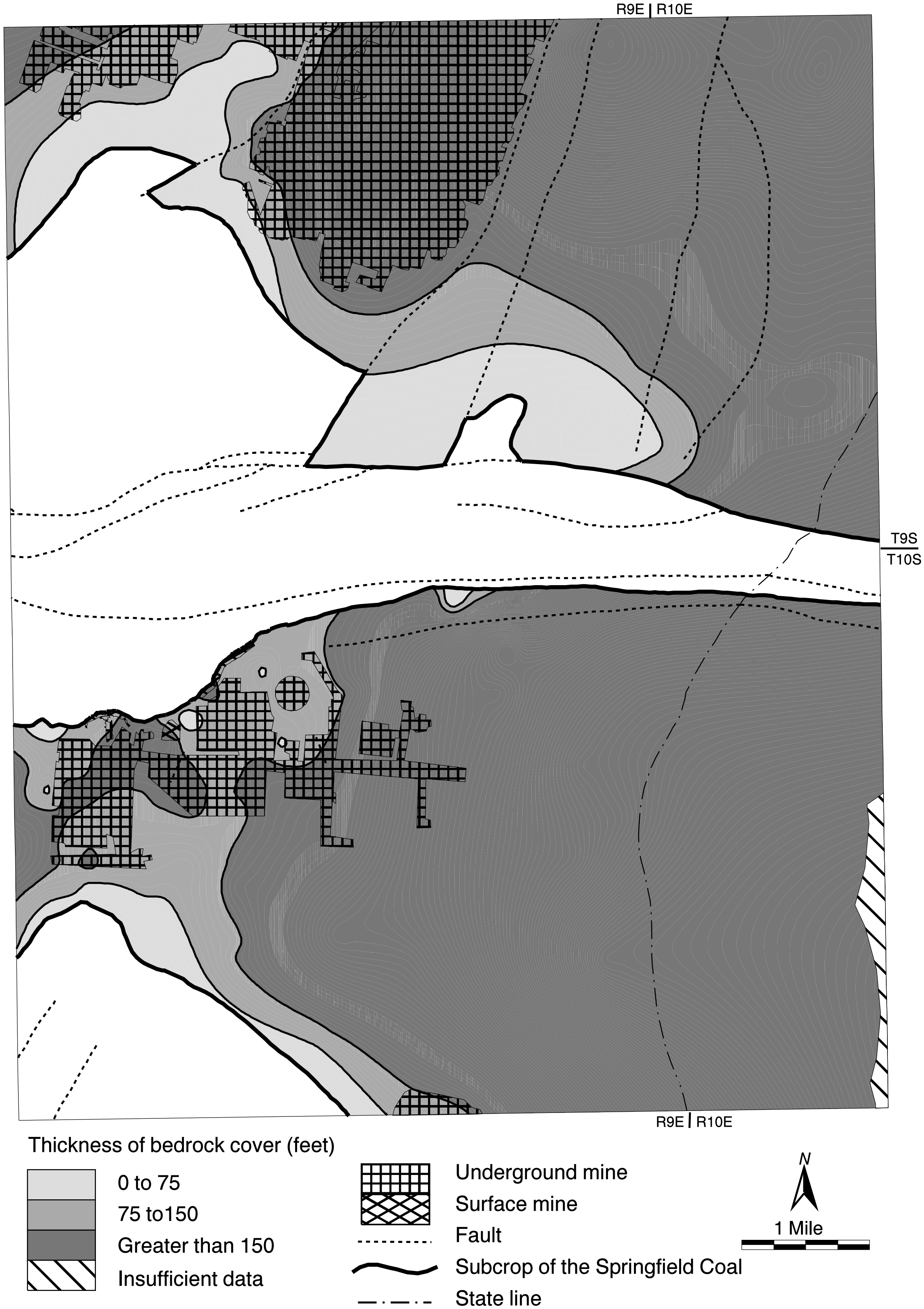

Figure 17 Thickness of bedrock overburden, Springfield Coal, Shawneetown Quadrangle.

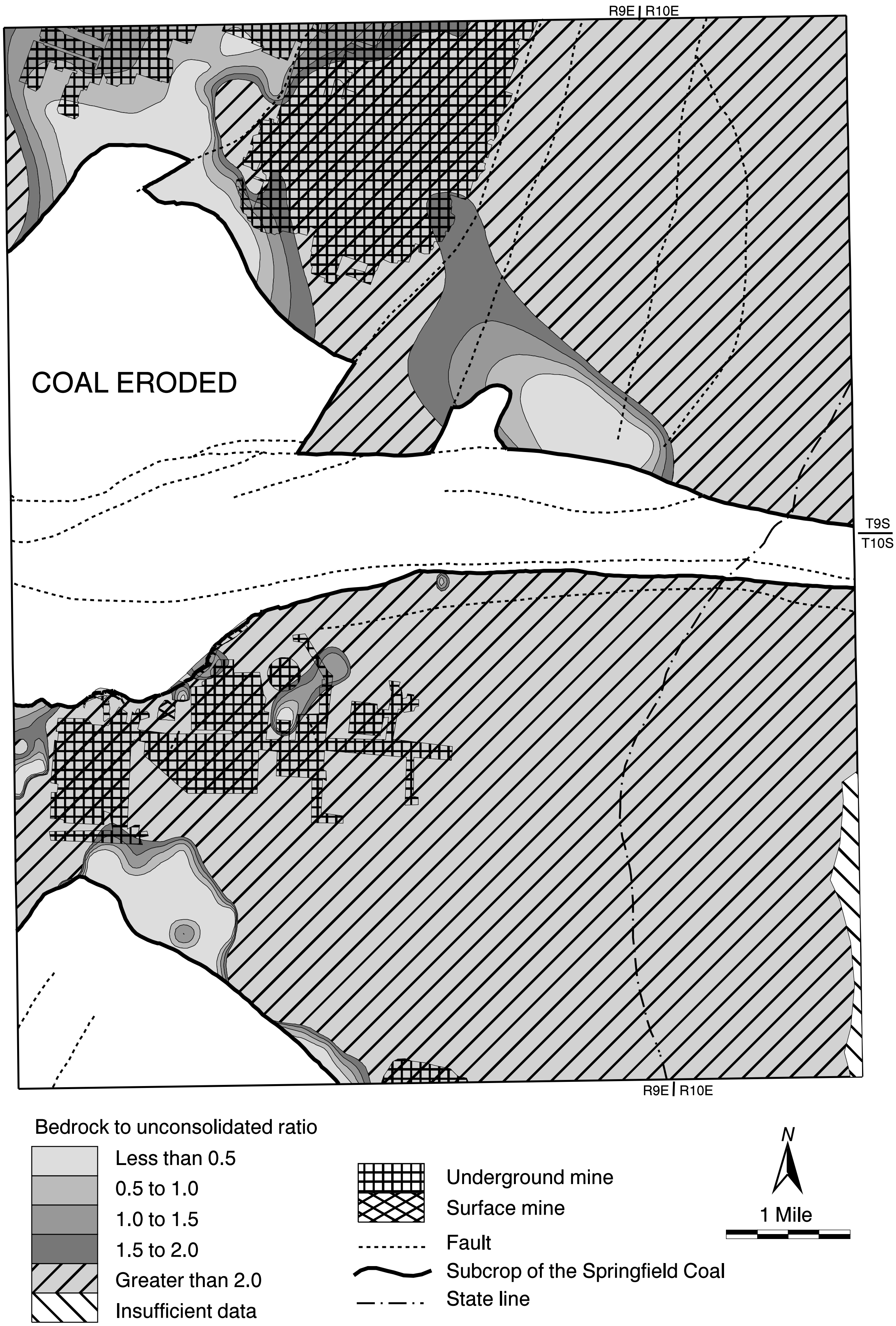

Figure 18 Ratio of bedrock to unconsolidated overburden, Springfield Coal, Shawneetown Quadrangle.

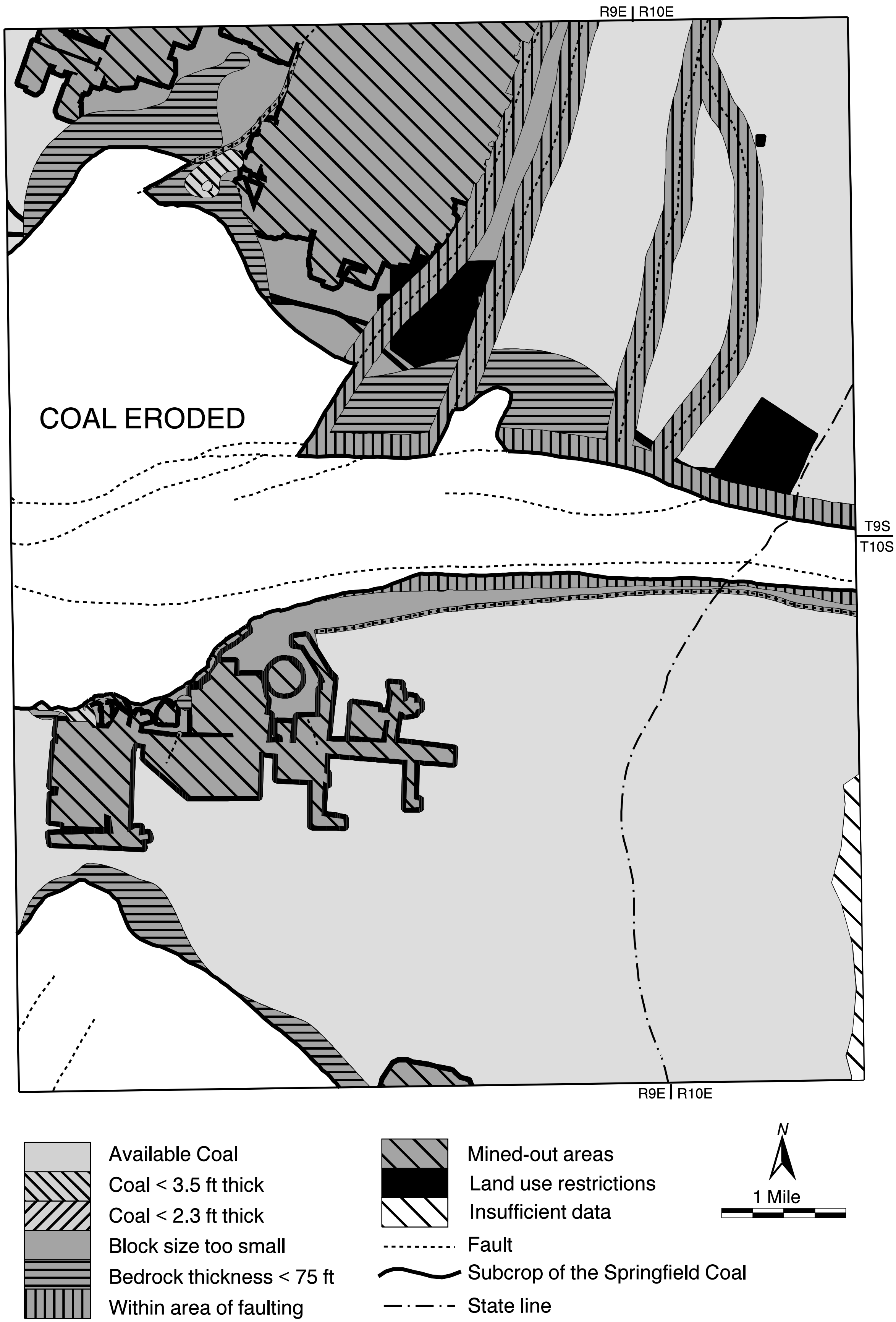

Figure 19 Availability of the Springfield Coal for underground mining, Shawneetown Quadrangle.

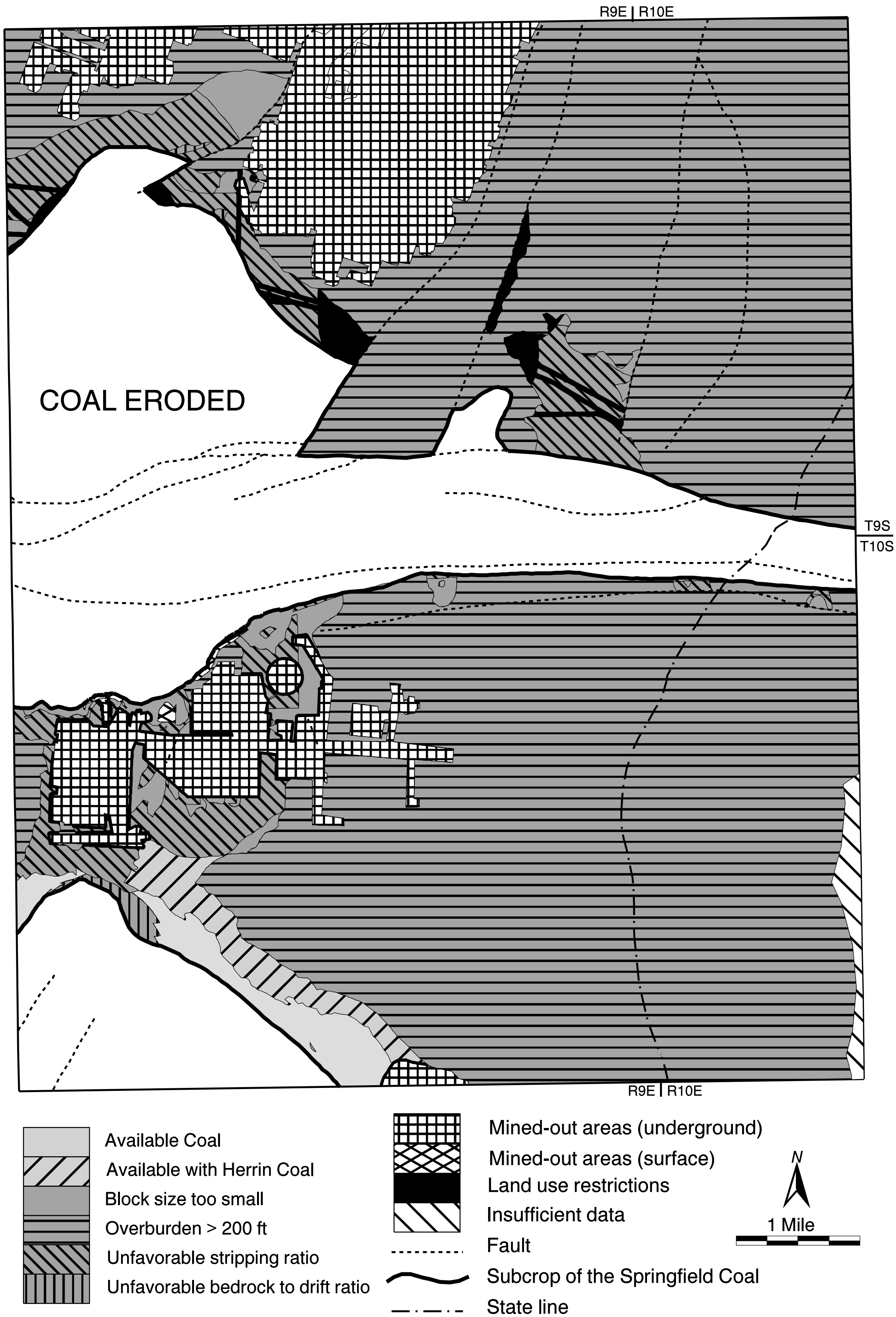

Figure 20 Availability of the Springfield Coal for surface mining, Shawneetown Quadrangle.

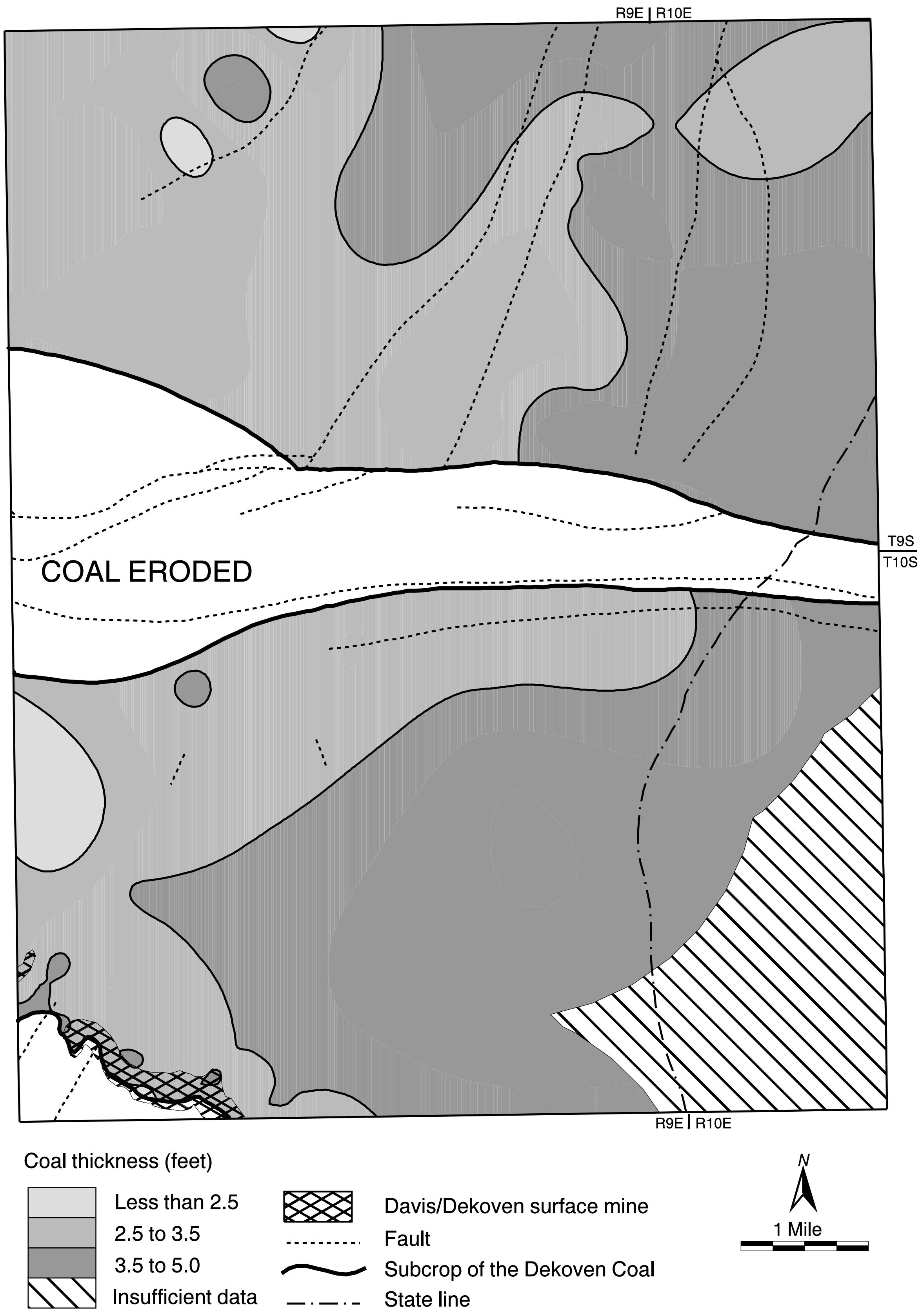

Figure 21 Thickness of the Dekoven Coal, Shawneetown Quadrangle.

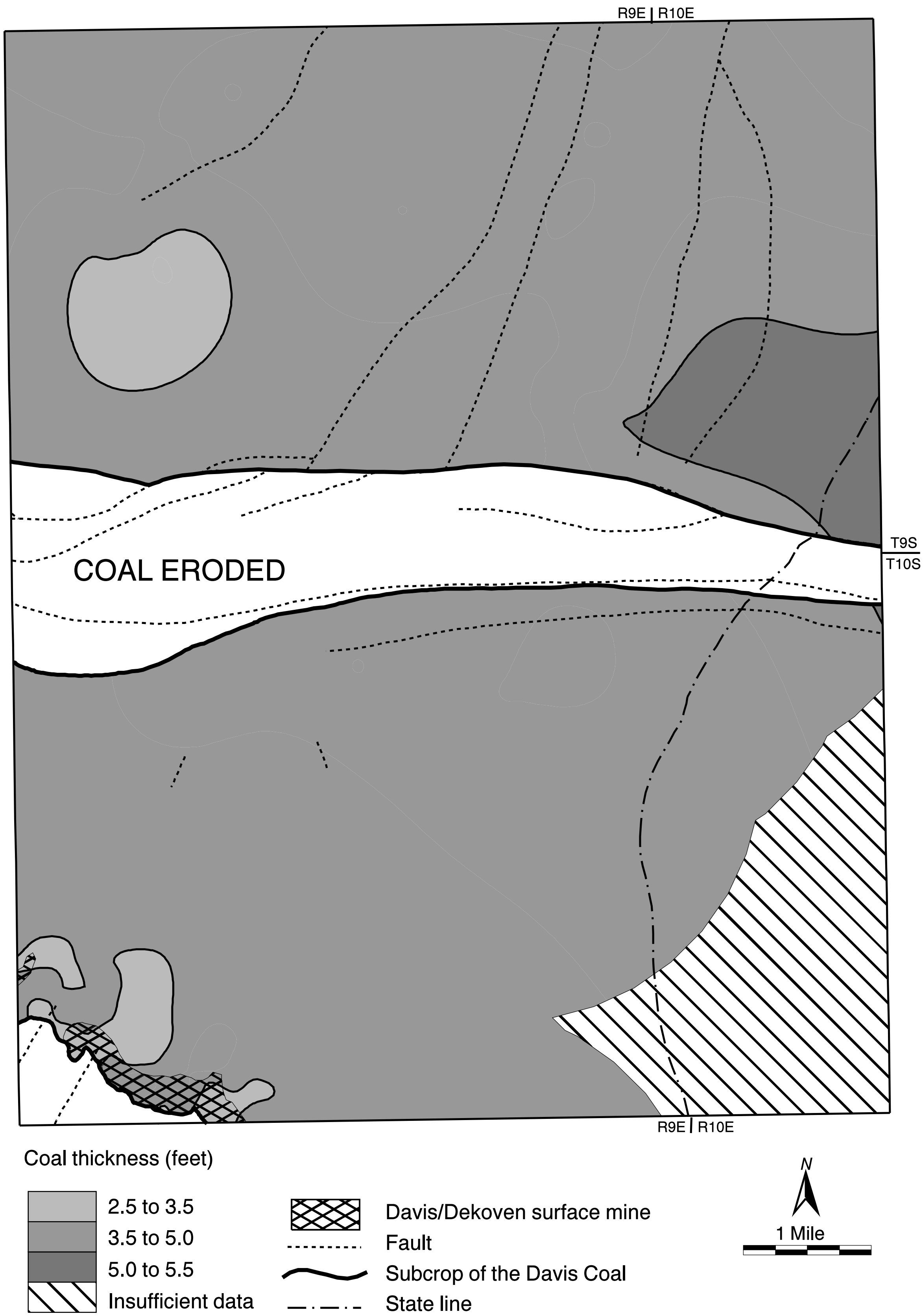

Figure 22 Thickness of the Davis Coal, Shawneetown Quadrangle.

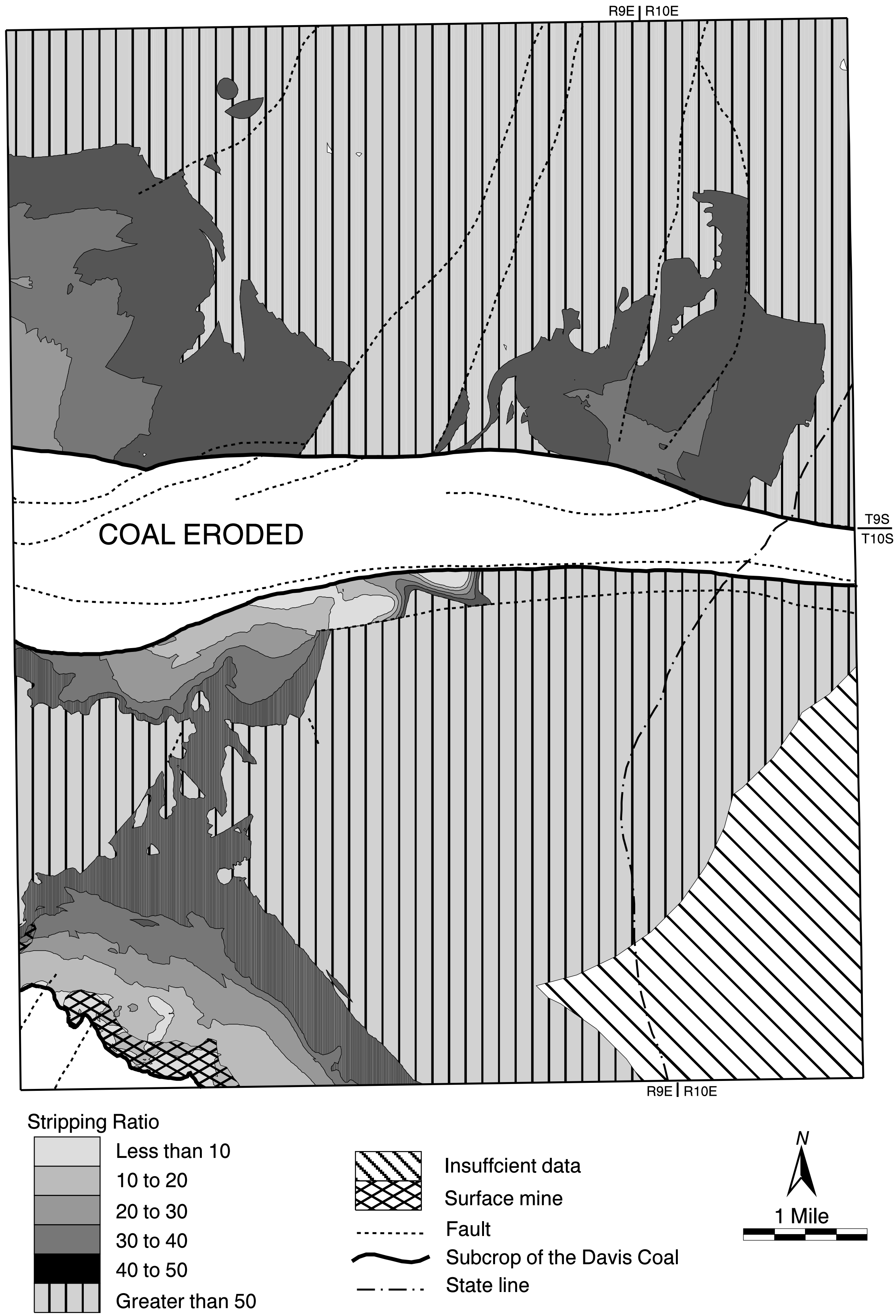

Figure 23 Stripping ratio of the Dekoven and Davis Coals combined, Shawneetown Quadrangle.

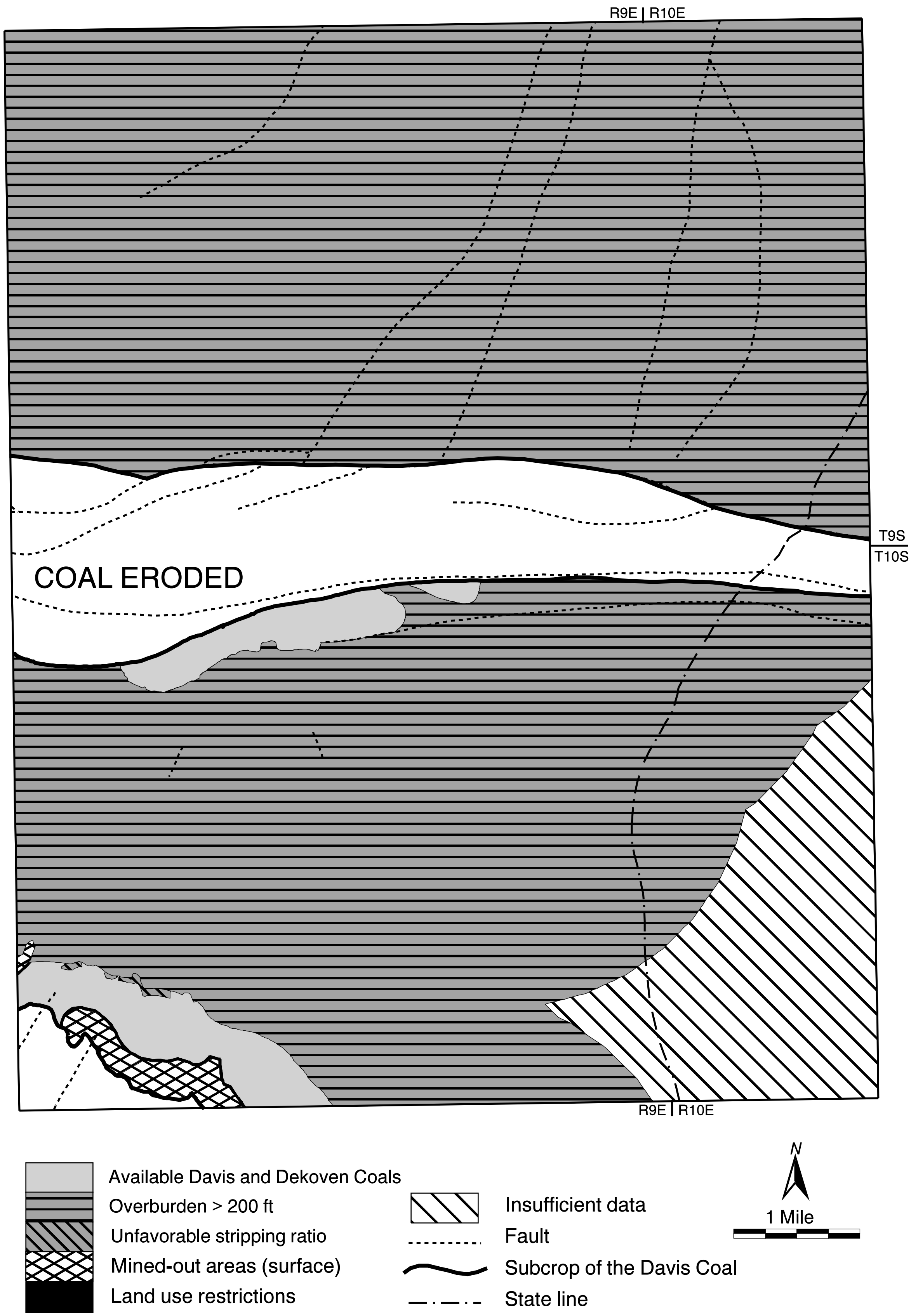

Figure 24 Availability of the Dekoven and Davis Coals for surface mining, Shawneetown Quadrangle.

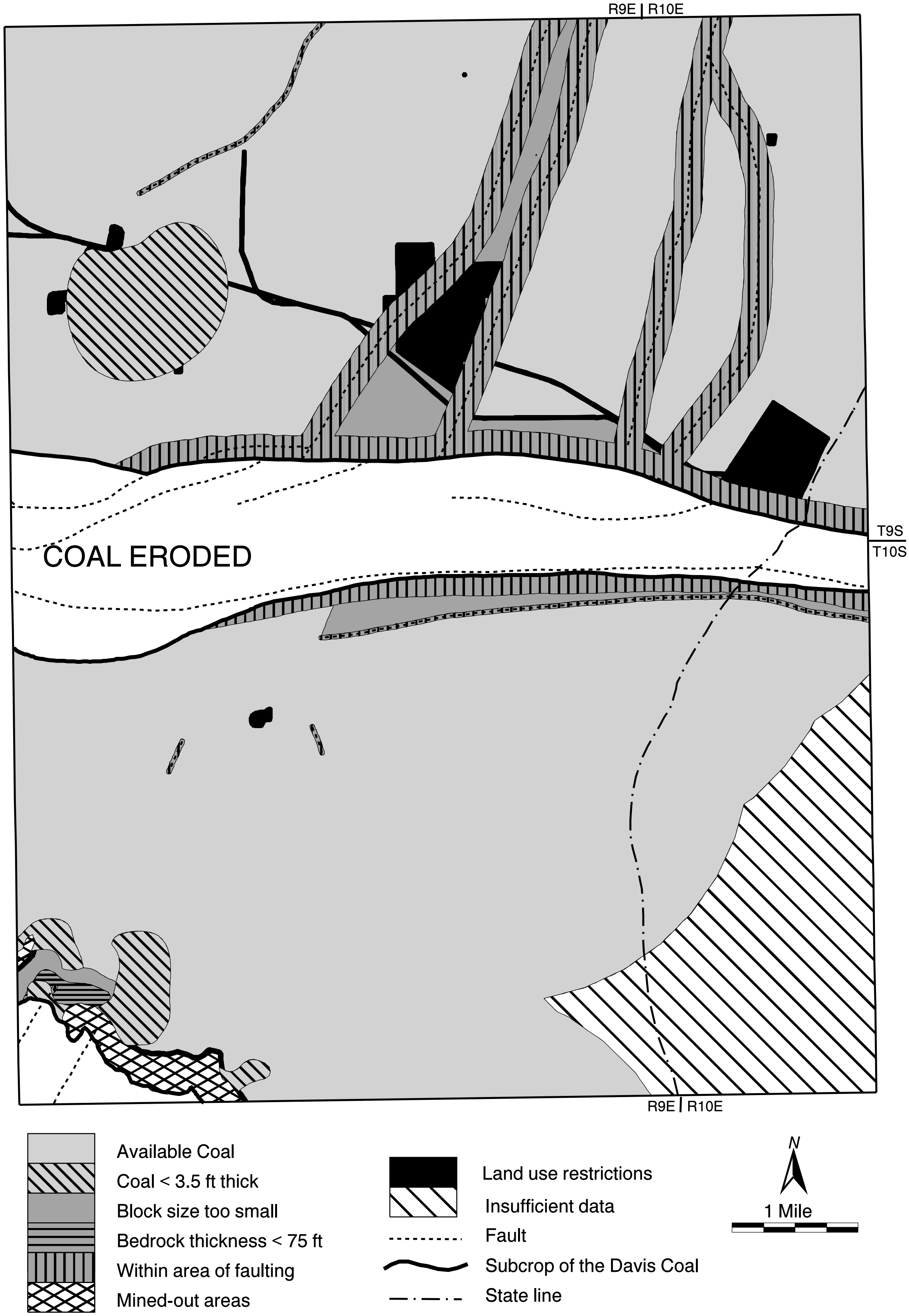

Figure 25 Availability of the Davis Coal for underground mining, Shawneetown Quadrangle.

over most of the quadrangle and the underlying Davis Coal is commonly thicker and more attractive for mining. Few restrictions to mining the Davis Coal have been identified: faulting is the main restriction.

The Fluorspar Fault Complex and the Shawneetown and Wabash Valley Fault Zone have varying degrees of impact on mining. Minor faults paralleling the major faults and abrupt changes in seam dip result in conditions unfavorable for mining in and near these zones. A belt of disturbed coal extends on the order of 600 to 1,000 feet from the major faults of the Wabash Valley and Shawneetown Faults Zones, respectively. Isolated minor faults associated with these fault zones and the Fluorspar Fault Complex affect narrower zones on the order of 100 to 200 feet wide.

Although not as widespread a problem as in the central and northern parts of the state, thin bedrock cover and unfavorable ratios of bedrock to unconsolidated cover were found to restrict mining of some resources in the quadrangle.

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