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Chapter J

# Coal Availability, Recoverability, and Economic Evaluations of Coal Resources in the Northern and Central Appalachian Basin Coal Regions

By M. Devereux Carter, Timothy J. Rohrbacher, Dale D. Teeters, David C. Scott, Lee M. Osmonson, Gerald A. Weisenfluh, Edward I. Loud, Roy S. Sites, Allan G. Axon, Mark E. Wolfe, and Leonard J. Lentz

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2000 RESOURCE ASSESSMENT OF SELECTED COAL BEDS AND ZONES IN THE NORTHERN AND CENTRAL APPALACHIAN BASIN COAL REGIONS

By Northern and Central Appalachian Basin Coal Regions Assessment Team

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*By* M. Devereux Carter,[1] Timothy J. Rohrbacher,[2] Dale D. Teeters,[3] David C. Scott,[3] Lee M. Osmonson,[2] Gerald A. Weisenfluh,[4] Edward I. Loud,[5] Roy S. Sites,[6] Allan G. Axon,[7] Mark E. Wolfe,[8] and Leonard J. Lentz[9]

## ABSTRACT

Studies in selected areas nationwide of available, recoverable, and economically extractable coal resources have been an integral part of the U.S. Geological Survey's energy program since 1986. Thirty-two 7.5-minute quadrangle studies in the northern and central Appalachian Basin coal regions are complete and the final six are in progress. The nearly completed modeling in these two coal regions shows that the amounts of coal in the areas of study that are available for mining (coal that is accessible within regulatory, land-use, and technologic constraints) range from 24 to 82 percent of the original, in-place resource, with a mean of 53 percent. The amount of recoverable coal (coal after mining and washing losses) ranges from 12 to 58 percent of the original resource and averages 32 percent. The amount of coal that can be extracted and marketed at current break-even costs ranges from less than 1 to 43 percent of the original resource and averages 11 percent.

## INTRODUCTION

The availability of environmentally acceptable and reliable energy sources is an important issue for Federal, State, and local planners. Conventional Federal and State coal-resource estimates have not accounted for many societal and physical restrictions to mining that could lead planners to overestimate the future supply of our Nation's coal. Therefore, the U.S. Geological Survey (USGS) and State geological surveys of the principal coal-bearing States initiated a cooperative project in 1986 to address these deficiencies. The Coal Availability Studies project was designed to identify and delineate current major restrictions to mining and to estimate the amount of remaining coal resources that may be available for development under those constraints. In 1990, the former U.S. Bureau of Mines (USBM) joined the project by conducting the subsequent Coal Recoverability Studies project to determine that part of available coal resources that might

[1]U.S. Geological Survey, MS 956, Reston, VA, 20192.

[2]U.S. Geological Survey, Denver Federal Center, MS 939, Denver, CO 80225.

[3]DST and Associates, 14293 West Baltic Avenue, Lakewood, CO 80225.

[4]Kentucky Geological Survey, 228 Mining and Mineral Resources Building, University of Kentucky, Lexington, KY 40506.

[5]West Virginia Geological and Economic Survey, P.O. Box 879, Morgantown, WV 26507.

[6]Virginia Division of Mineral Resources, P.O. Box 3667, Charlottesville, VA 22903.

[7]North Carolina Department of Environment and Natural Resources, Information Technology Services, 1608 Mail Service Center, Raleigh, NC 27699.

[8]Ohio Division of Geological Survey, 3307 South Old State Road, Delaware, OH 43015.

[9]Pennsylvania Bureau of Topographic and Geologic Survey, P.O. Box 8453, Harrisburg, PA 17105.



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be economically recoverable. With the closure of the USBM in 1995, the coal recoverability studies are now conducted by the USGS.

The combined Coal Availability/Recoverability Studies (CARS) project has developed a national geographic information system- (GIS-) based systematic effort to collect, analyze, and depict data characterizing the relation between restrictions to mining and the potential development of the Nation's coal resources. Currently, the coal availability (CA) teams at the USGS and State geological surveys identify restrictions to mining (land use, environmental, societal, technologic, and geologic) and apply those restrictions as overlays to maps of coal-bed thickness, depth, and mined and lost-in-mining areas. Tonnage of original, mined and lost-in-mining, remaining, restricted, and available coal resources is calculated. The resultant digital data files are transferred to the coal recoverability (CR) team of scientists at the USGS for estimation of future mining and washing losses and for economic evaluations to determine the amount of economically recoverable coal.

Initially, the project was designed to study selected 1:24,000-scale 7.5-minute quadrangles (50 to 60 $mi^2$ areas). With advancements in computer technology, the CARS project has progressed from the earlier studies of multiple beds in individual 7.5-minute quadrangle areas to larger areas of multiple quadrangles. Recently, State scientists have completed larger and even Statewide (subregional) CA studies of single coal beds.

To date, CA studies have been completed in more than 100 selected 7.5-minute study areas in the northern and central Appalachian Basin coal regions; the Illinois, Powder River, and San Juan Basins; and several coal fields in the Uinta and Green River Basins of Colorado and Utah. Together, these seven regions and basins provide 85 percent of current U.S. coal production. CR studies have been completed in more than half of the quadrangles.

This report presents a summary of the results of the CARs project in the northern and central Appalachian Basin coal regions and also provides statistics and summary information for the six coal beds featured in the USGS National Coal Resource Assessment (NCRA). The six coal beds are the Fire Clay, Pond Creek, and Pocahontas No. 3 in the central Appalachian Basin coal region and the Pittsburgh, Upper Freeport, and Lower Kittanning in the northern Appalachian Basin coal region. The CARS project assessed only the principal potentially minable coal beds within the Fire Clay and Pond Creek coal zones (see Chapters F and G, this report). All CARS work in the Appalachian Basin has been a cooperative effort between the USGS, former USBM, Kentucky Geological Survey (KGS), West Virginia Geological and Economic Survey (WVGES), Virginia Division of Mineral Resources (VDMR), Ohio Division of Geological Survey (OGS), and Pennsylvania Topographic and Geologic Survey (PAGS).

## ACKNOWLEDGMENTS

All of the data summarized in this chapter were collected, compiled, analyzed, and reported by more than fifty geologists, geoscientists, mining engineers, and computer specialists during the past twelve years of the CARS project. The authors thank each and every one of the participants. Names of many of the contributors are included in the cited references. The names of other, no less important contributors, those who contributed through unpublished reports, can be found in Appendix 1 (Selected References). We especially wish to express our gratitude to the many computer scientists who enabled us to conduct the studies by developing new techniques for modeling resource-related data. Most recently, James McDonald of the OGS, broke new ground that allowed the State survey to model a coal availability study on one coal bed over its entire extent in the eastern part of the State.

## METHODOLOGY

The Coal Availability/Recoverability Studies (CARS) project is a nationwide undertaking wherein studies are conducted in areas selected on the basis of production history, resource potential, and availability of data. Figure 1 depicts the detailed 7.5-minute quadrangle studies in seven major coal-producing regions of the U.S. Each detailed study area is chosen to represent the variations in geology, topography, land-use patterns, and mining practices of its locality. These initial detailed studies were intended to identify the most significant availability and recoverability factors within each region, so that future small-scale (large area) studies could utilize those factors. The expectation is that an approximate 3 to 4 percent sampling of detailed studies should sufficiently characterize the variables and determine the significance of each variable in the region before attempting studies of larger areas (Richard B. McCammon, USGS, written commun., 1988). As studies expand to include larger areas, the knowledge gained during the individual quadrangle studies may be applied with confidence throughout the region.

The USGS, cooperating State geologic surveys, and the former USBM developed a sequence of steps for the systematic determination of coal availability and economic recoverability of the Nation’s coal resources. They are as follows:

Original Coal Resources
- minus -
Past and Current Mined and Lost-in-Mining Areas
- minus -
Land-Use and Technologic Restrictions

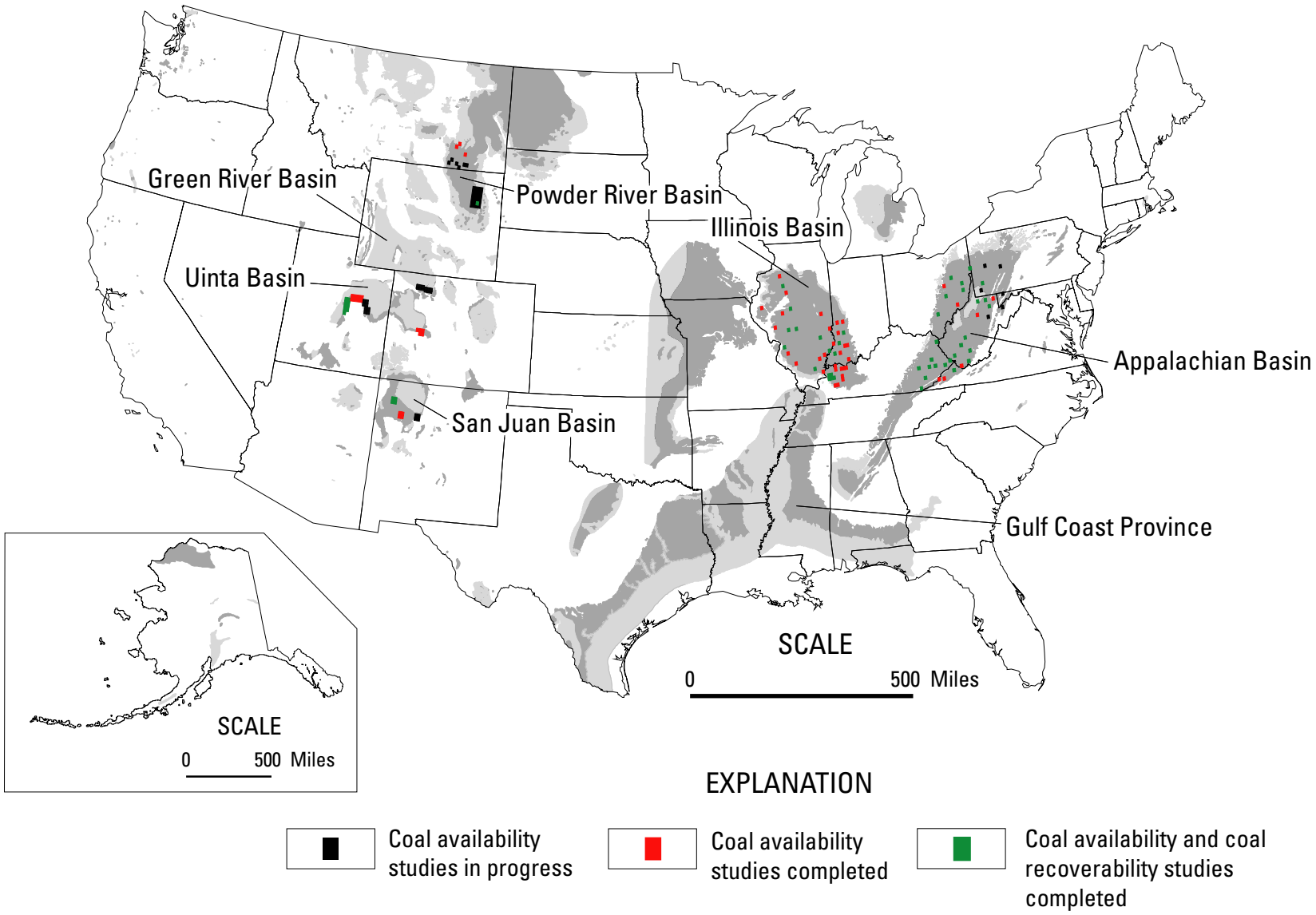


**Figure 1.** Map showing coal-bearing regions of the conterminous United States and Alaska. Individual 7.5-minute quadrangles are shown where coal availability and coal recoverability studies are in progress or complete in the Appalachian, Illinois, Powder River, San Juan, Green River, and Uinta Basins. Dark-gray areas represent coal that is of higher commercial potential; light-gray areas represent coal that is of lesser commercial potential because the coal beds are thinner, deeper, less accessible, or of less desirable quality. Map modified from Tully (1996).

- equals -
**Coal Resources Available for Development**
- minus -
Future Mining and Washing Losses
- equals -
Recoverable Coal Resources
- restricted by -
Mining Costs and Sales Prices
- equals -
**Economically Recoverable Coal Resources (Reserves)**
- factor in -
Rates of Resource Depletion
Mining-Related Employment
Income Reliance on Mining
- yields -
**Socioeconomic Impact Analysis**

Land-use/environmental/societal and technologic/geologic restrictions are the two general categories of constraints on coal mining. Land-use/environmental/societal restrictions are placed upon mining by policies to preserve those surface features or entities that could be adversely affected by mining. Such restrictions may change as societal interests evolve. Land-use restrictions applied to the areas studied to date include power lines, pipelines, cemeteries, oil and gas wells, roads, railroads, towns, major streams, wetlands, alluvial valley floors, parks, and protected forests and wildlife. Such regulatory restrictions mostly apply to surface mining, but may also affect underground mining.

Technologic/geologic restrictions primarily affect the economics or safety of mining and are determined by current levels of technology. Technologic restrictions include safety zones (buffers) around active or abandoned mines, coal beds that are considered too thin or too deep to mine, mined and minable beds that are stratigraphically too close together to mine both of them safely, unstable roof or floor rock, and other geologic factors such as washouts, faults, disturbed areas, and impurities in the coal. These restrictions also can change, mainly with advances in science and engineering or changes in economic conditions. Technologic/geologic restrictions affect both surface and underground mining, but generally are more prohibitive to underground mining. For convenience in this chapter, the two primary types of restrictions to mining hereafter will be referred to as simply “land use” and “technologic.”

Currently, State and Federal coal-mining regulations are identified, and local coal-industry engineers, geologists, and mine operators are consulted to ascertain actual local mining practices. These factors are then taken into consideration, with actual local practice taking precedence over both State and Federal regulations, in delineating coal resources available for mining. Descriptions of CARS methodologies, applied criteria, and modeling techniques are reported in Carter and Gardner (1989), Eggleston and others (1990), Rohrbacher and others (1993b), and Rohrbacher, Teeters, Osmonson, and Plis (1994).

## COAL AVAILABILITY (CA) STUDIES

Three basic types of data are collected for ongoing coal availability (CA) studies. The first type is linear and polygonal data consisting of coal-bed outcrops, mined and lost-in-mining areas, and restrictions to mining. These data are identified, plotted on 7.5-minute topographic maps, and digitized. The second data type is point-source information on coal-bed thickness, elevation relative to sea level, and coal quality. These data commonly are retrieved from the State geological survey stratigraphic and geochemical databases or from the USGS National Coal Resources Data System (NCRDS) stratigraphic database. The third type of data consists of USGS digital elevation models (DEMs) represented by computer grids of land topography scaled to 7.5-minute quadrangle sizes. The subsurface coal-bed elevations are subtracted from DEM elevations to determine coal depth and thickness of coal-bed overburden.

Compiled data for the CA studies are imported into a GIS for manipulation and subsequent coal-resource calculations. Figure 2 depicts the major GIS layers used to progress from the original coal resource in the ground to those resources available for development. Programs are run to calculate original, mined and lost-in-mining, remaining, restricted, and available coal resources. Resources are calculated and reported in accordance with the USGS coal classification system (Wood and others, 1983).

All GIS data files generated by State geological survey and USGS geologists during the CA studies are provided to the geologists and mining engineers performing follow-on coal recoverability studies (USBM, 1990–1995; USGS, 1996 to present). Figure 3 illustrates the flow of tasks and responsibilities as the studies progress from determination of the original coal resource in the ground through the estimation of the amount of coal that may be economically recoverable.

## COAL RECOVERABILITY (CR) STUDIES

In the coal recoverability (CR) studies, GIS programs are used to lay out mine plans for optimum recovery, and cost-analysis programs estimate the amounts of coal that will be economically recoverable at current (at the time of the study) mining costs. The CR study team receives the digital files of coal-bed outcrops, coal and parting thicknesses, mined and lost-in-mining areas, restrictions to mining, overburden and interburden data, DEMs, and other relevant data from the CA study teams. The CR study team then reconstructs the original resource so that it includes not

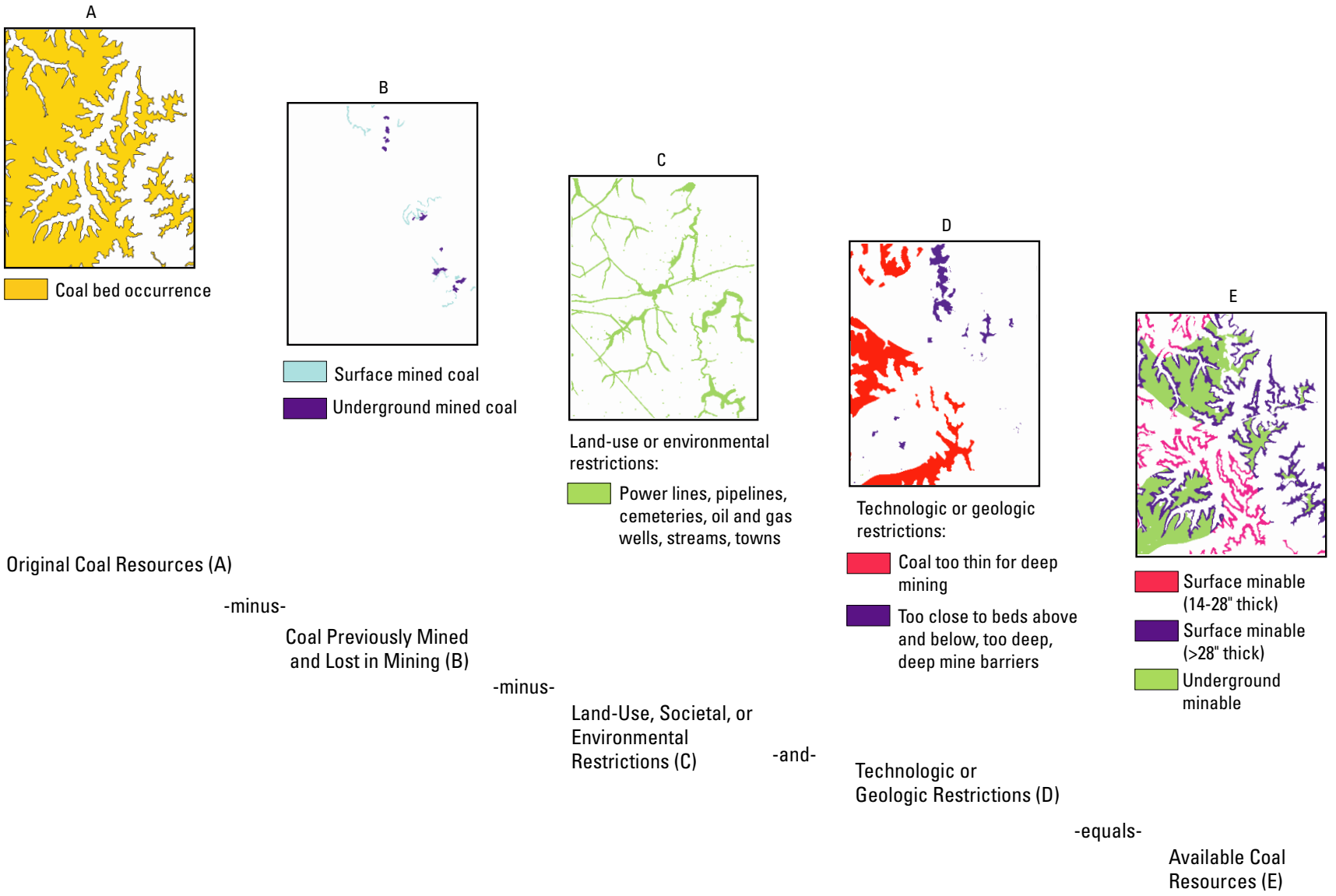


**Figure 2.** Diagram showing geographic information system (GIS) map layers illustrating the methodology of the coal availability studies in the progression from original coal resources, through coal mined and lost in mining, and restrictions to available coal resources, using the Upper Elkhorn No. 3 coal bed in the Matewan 7.5-minute quadrangle, Kentucky and West Virginia, as an example.

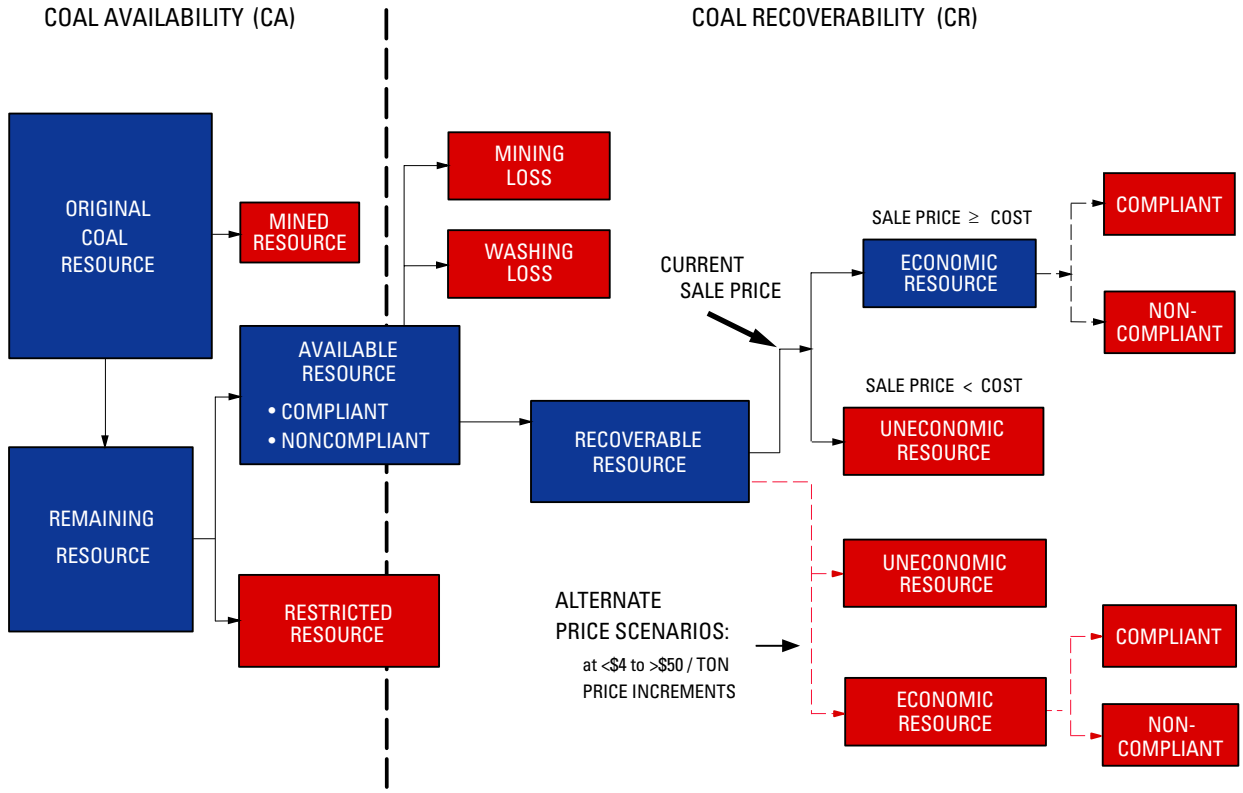


**Figure 3.** Diagram showing the flow of activities involved in preparing the coal availability (CA) and coal recoverability (CR) studies. The heavy dashed black line indicates the conceptual division of responsibilities of the CA study team and the CR study team. The solid black lines with arrows (between the blue boxes) depict the flow from original to economically recoverable resource where the selling price of the coal equals or is greater than the cost of producing the coal. The dashed red lines represent a path to alternate resource estimates at different coal sales prices generated primarily in $5 increments (cost curves). Emission-level compliance (whereby coal contains less than or equal to 1.2 pounds of sulfur dioxide per million Btu) is not considered a restriction to mining, but is a factor in its marketability. Compliance is included in both CA and CR reports when sufficient data are available.

only coal (as in the CA study's resources) but also partings in the coal and dilution (that part of the rock above and (or) below the coal bed that will be mined with the coal). Original, mined and lost-in-mining, remaining, restricted, and available resources (including both coal and parting and dilution materials) are calculated. A computerized prefeasibility mine planning program (Rohrbacher and others, 1993b; Rohrbacher, Teeters, Osmonson, and Plis, 1994) then is applied to plan mines in the available resources based on geologic models, topographic surfaces, and basic mining method models. The mine-planning program, MINEPLAN (developed by the former USBM), yields tonnage estimates resulting from each mining method and mining losses. Dilution, based on mining method, and washing losses are then calculated. The total mining and washing losses are then subtracted from the available resources to determine the amount of recoverable coal resources (fig. 3).

Finally, all of the potentially recoverable coal resources are analyzed using an interactive, prefeasibility resource recoverability/mine-costing program, COALVAL (Suffredini and others, 1994) that was developed by the former USBM and enhanced by the USGS. The results are printed in summary tables containing total tonnage, tonnage lost during the mining and washing operations, and recoverable tonnage yielded by mining method. The costs are summarized in $5 increments from less than $4/short ton to costs greater than $50/short ton (cost curves). The cost figures also include a break-even cost to determine that amount of the recoverable coal resource that can be mined and sold at cost at a set point in time (current at the time of the study). All economically recoverable resource tonnage is divided into compliant and noncompliant amounts.

Three assumptions embedded in the programs used in the CR studies are worth noting. The first premise is that the entire surface area and all of the coal beds within a study area have a single ownership and that the owner is amenable to development of all of the coal in the area. The second premise is that all future mining will progress in a logical sequence from the top bed downward. The third is that the coal mined will be sold up to the point where operating

costs connected with mining the coal are equal to its sales price (that is, with no profit). Because none of these three premises is likely to occur, the CR studies' estimates of economically recoverable coal resources may be somewhat on the high side.

All results presented in this chapter depict original, mined and lost-in-mining, remaining, restricted, and available coal resources as determined by the CA studies. The recoverable resources and economically recoverable resources (at break-even cost) are determined by the CR studies. The CR reports also provide estimates of original, mined and lost-in-mining, remaining, restricted, and available tonnage; however, unlike the CA estimates, the CR tonnage estimates include both coal and the associated parting and dilution materials that will be mined with the coal. For simplicity, coal plus parting and dilution tonnage estimates for these CR studies are not reported in this chapter, but are included in all the CR studies' reports cited in this chapter.

For the CARS resource analysis and modeling studies, computer techniques are a critical component in handling the multitude of parameters considered, overlain, combined, and calculated. The computer permits relatively quick and straightforward updates as restrictions are added or modified, mining costs change, and new estimates are generated. Programs developed by the Federal Government, such as prefeasibility cost analysis of resources by mine plan, are available from the USGS. In addition to published reports, several States have released studies on their agency Web sites.

## APPALACHIAN BASIN

Coal availability (CA) studies for 32 7.5-minute quadrangles in the northern and central Appalachian Basin coal regions are complete and the final six are in progress (fig. 4). Coal recoverability (CR) studies have been completed for 25 of the 32 quadrangles. Because time and funding constraints preclude conducting a CR study for each CA study, no additional 7.5-minute quadrangle CR studies are planned. There have been no CARS evaluations in the southern Appalachian Basin coal region and none are planned. Table 1 shows the land-use and technologic restrictions that have been applied to the studies in the northern and central Appalachian Basin coal regions and the area affected by each restriction. Many of the regulations that restrict mining differ in detail between States, and some regulations can be mitigated through mine permit variances.

Stratigraphic relationships across the Appalachian Basin are complex, and, in many areas, precise correlation of individual coal beds is difficult. For specific details, see Chapter B of this report. Because the names given to a coal bed often vary from area to area, a list of CARS coal-bed names and how they relate to the National Coal Resource Assessment (NCRA) bed names is presented in table 2.

Hereafter, the statistics, figures, and tables in this chapter characterize the results of the 7.5-minute CA and CR studies, unless stated otherwise. Results of two subregional CA studies are discussed in separate sections of this chapter.

### COAL QUALITY

For the purposes of the CARS project, the sulfur content of coal that does not meet current sulfur dioxide ($SO_2$) emission standards of less than or equal to 1.2 pounds of sulfur dioxide per million British thermal units (1.2 lbs $SO_2$/million Btu) (Clean Air Act Amendments of 1990, Public Law 101-549) is not considered a restriction to mining. However, emissions can be a significant factor in the marketability of a coal, making it less attractive than competitive coal that is in compliance with current standards. Thus, CARS scientists conduct either mapping or statistical analysis of potential $SO_2$ generation where a sufficient number of chemical analyses of coal-bed samples are available. However, State and Federal databases seldom contain sufficient amounts of analytical data within a single 7.5-minute quadrangle to prepare a realistic estimate of coal quality. Table 3 provides a summary of coal compliance data from CARS reports in the northern and central Appalachian Basin coal regions, by quadrangle study area for the six coal beds of the NCRA. The compliance data reported in the CA studies are derived from the State geological survey geochemical databases; the data reported in the CR studies are primarily from commercial coal production and related coal quality databases.

## CENTRAL APPALACHIAN BASIN COAL REGION

CA studies of selected 7.5-minute quadrangles began in the central Appalachian Basin coal region during 1987. Since that time, the USGS and the State geological surveys of Kentucky, Virginia, and West Virginia have completed CA studies in 18 quadrangles (Blake and Fedorko, 1988; Campbell and Sites, 1988; Loud, 1988, 1999; Sergeant, 1988, 1989a,b; Carter and Gardner, 1989; Loud and others, 1989, 1990; Sites, 1989; Davidson and others, 1990; Sites and Hostettler, 1990, 1991; Anderson, 1991; Weisenfluh and others, 1992, 1993; Andrews and others, 1994). For more specific information, see Appendix 1. Follow-on CR studies have been completed in 15 of the 18 quadrangles (Rohrbacher and others, 1993a; Rohrbacher, Teeters, Sullivan, and Osmonson, 1994; Rohrbacher, Teeters, Osmonson, and Plis, 1994; Scott, 1995; U.S. Bureau of Mines, 1995; Teeters, 1997).

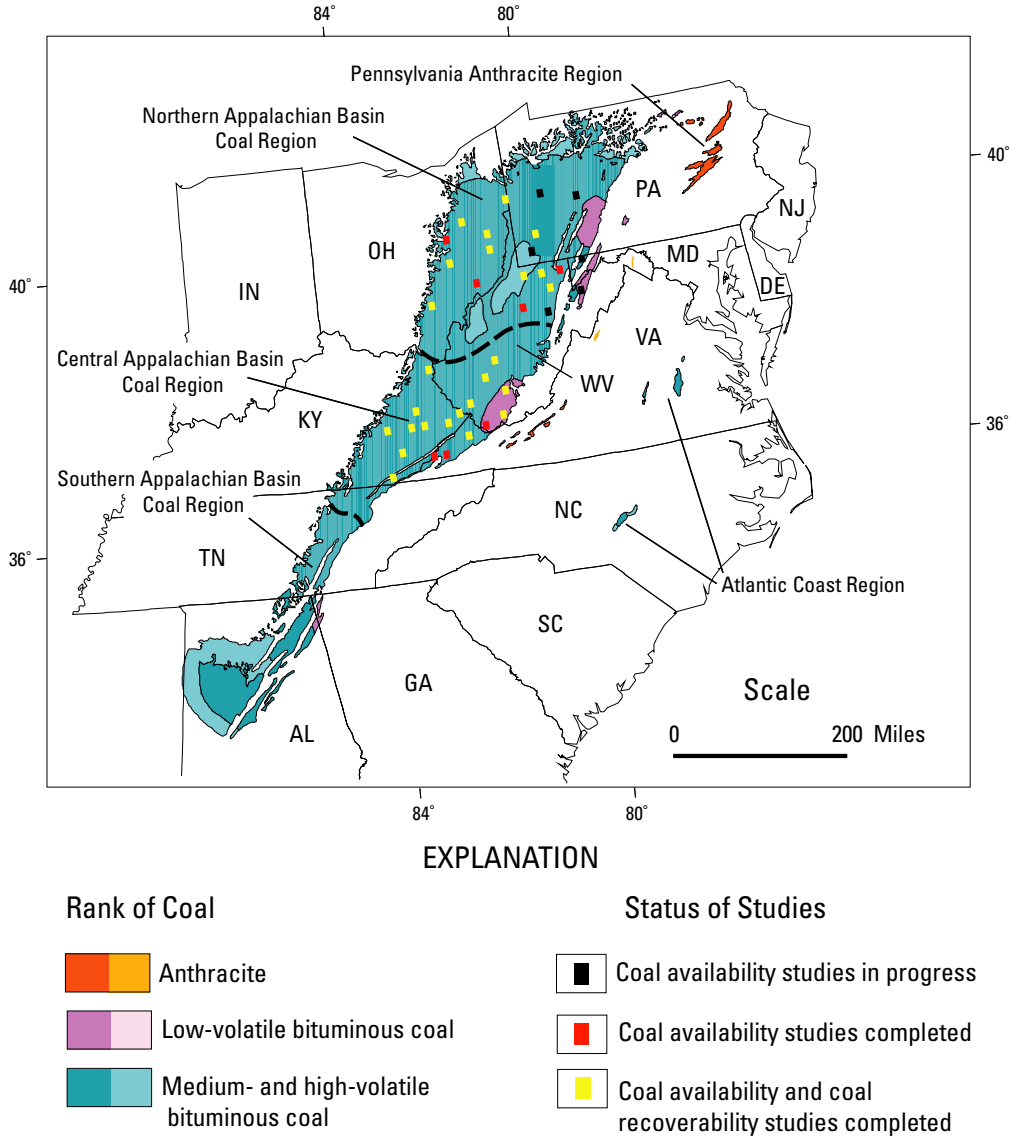


**Figure 4.** Map of the Appalachian Basin coal regions showing the individual 7.5-minute quadrangles studied during the Coal Availability/Recoverability Studies (CARS) project. Colors depicting the rank of coal are darker where coal is of higher commercial potential and lighter where of lesser commercial potential because the coal beds are thinner, deeper, or of less desirable quality. Map modified from Tully (1996).

The 18 quadrangles for which CA studies were completed constitute a 5 percent sampling of the approximately 350 7.5-minute quadrangles that encompass the central Appalachian Basin coal region. As this meets our goal of 3 to 4 percent sampling, there are no plans to conduct additional 7.5-minute-scale studies in the region. However, KGS scientists are conducting subregional small-scale studies of individual coal beds in Kentucky (see a discussion of this in the subregional studies section of this chapter). In addition, coal geologists at the WVGES are creating GIS-based 1:24,000-scale resource maps for all important coal beds over the entire State of West Virginia. These resource maps will provide the basis for future subregional small-scale studies.

Although there is a fairly wide variation between the individual areas studied, results indicate that, overall, only about one-half of the estimated original 12.8-billion-short-ton coal resource in the 18 quadrangles is available for development, as shown in table 4. Coal mined and lost in mining accounts for a 16 percent reduction of the total original resource. Land-use restrictions account for another 3 percent and technologic restrictions for 31 percent reduction.

**Table 1.** Restrictions identified for the Coal Availability/Recoverability Studies (CARS) project in the central and northern Appalachian Basin coal regions showing the range of applicable buffer zones and categories to which they may apply.

[The restrictions and their buffer zones vary from State to State and area to area, depending upon regulations, conditions, and local practices.]

| Restriction | Area + buffer zone (in feet) | Type of restriction | | Type of mining | |
|---|---|---|---|---|---|
| | | Land-use | Technologic | Surface | Deep |
| Airport | Area + 100 | X | | X | X |
| Cemetery | Area + 100 | X | | X | X |
| National, State, or private forest | Area | X | | X | X |
| Hunting or fishing area | Area | X | | X | |
| Lake | Area, Area + 100 | X | | X | |
| National or State park | Area, Area + 300 | X | | X | |
| Pipeline | Area + 100 | X | | X | |
| Power line | Area + 100 | X | | X | |
| Protected plant or wildlife area | Area, Area + 1 mile | X | | X | |
| Radio tower | Area + 100 | X | | X | |
| Railroad | Area + 100 | X | | X | |
| Road | Area + 100 | X | | X | |
| Town or dwelling | Area, Area + 300 | X | | X | X |
| Watershed | Area | X | | X | |
| Wetland | Area, Area + 100 | X | | X | |
| Oil or gas well | 100-300 | X | X | X | X |
| River or stream | Area + 100 | X | X | X | X |
| Coal too thin | Area | | X | | X |
| Fault | Area + 50, + 100 | | X | X | X |
| Geologically disturbed area | Area | | X | X | X |
| Interburden <25 ft, <40 ft | Area | | X | | X |
| Mine barrier | Area +50, +100, +200, +300 | | X | X | X |
| Mining within 25 ft, 40 ft | Area | | X | X | X |
| Sandstone channel | Area | | X | X | X |

**Table 2.** National Coal Resource Assessment (NCRA) bed names and corresponding names used in the Coal Availability/Recoverability Studies (CARS) project in the central and northern Appalachian Basin coal regions, by State and 7.5-minute quadrangle.

[Dash (—) indicates bed not included in studies because it does not occur in the quadrangle, is below minable thickness, and (or) has insufficient data within the quadrangle.]

**Central Appalachian Basin coal region**

| State and quadrangle | NCRA coal bed names: Fire Clay coal bed or zone | Pond Creek coal bed or zone | Pocahontas No. 3 coal bed |
|---|---|---|---|
| **Kentucky** | | | |
| Boltsfork | — | — | — |
| Booneville | — | — | — |
| Handshoe | Hazard No. 4 | — | — |
| Hoskinston | Fire Clay C | — | — |
| Matewan | Fire Clay | Lower Elkhorn B | — |
| Middlesboro North | — | Path Fork D | — |
| Millard | Fire Clay B | Lower Elkhorn | — |
| Noble | Fire Clay | — | — |
| Salyersville South | Fire Clay | — | — |
| **Virginia** | | | |
| Appalachia | Phillips | Imboden | — |
| Vansant | — | — | Pocahontas No. 3 |
| Wise | — | Imboden | — |
| **West Virginia** | | | |
| Beckley | — | — | No. 3 Pocahontas |
| Crumpler | — | — | No. 3 Pocahontas |
| Mammoth | Hernshaw | Eagle | — |
| Man | Fire Clay | Eagle | — |
| Sylvester | Hernshaw | Eagle | — |
| War | — | — | No. 3 Pocahontas |

**Northern Appalachian Basin coal region**

| State and quadrangle | NCRA coal bed names: Pittsburgh coal bed | Upper Freeport coal bed | Lower Kittanning coal bed |
|---|---|---|---|
| **Ohio** | | | |
| Bethesda | Pittsburgh | — | — |
| East Palestine | — | Upper Freeport | Lower Kittanning |
| Jewett | Pittsburgh | Upper Freeport | Lower Kittanning |
| Lower Salem | Pittsburgh | — | — |
| Randle | — | — | Lower Kittanning |
| Strasburg | — | — | Lower Kittanning |
| Zaleski | — | — | Lower Kittanning |
| Zanesville East | — | Upper Freeport | Lower Kittanning |
| **Pennsylvania** | | | |
| Hackett | Pittsburgh | — | — |
| **West Virginia** | | | |
| Camden | Pittsburgh | — | — |
| Glover Gap | Pittsburgh | — | — |
| Rivesville | Pittsburgh | — | — |
| Thornton | Pittsburgh | Upper Freeport | Lower Kittanning |
| Valley Point | — | Upper Freeport | Lower Kittanning |

**Table 3.** Summary of coal emission-level compliance data (in lbs of $SO_2$/million Btu), as reported in the Coal Availability/Recoverability Studies (CARS) results in the central and northern Appalachian Basin coal regions, by State and 7.5-minute quadrangle.

[Abbreviations and symbols are as follows: NCRA, National Coal Resource Assessment; CA, coal availability study; CR, coal recoverability study; dash (—) indicates bed not included in study in this quadrangle; one asterisk (*) indicates CA study report does not include compliance data specifically on this coal bed; two asterisks (**) indicate CR study not conducted in this quadrangle; C, compliant with sulfur-dioxide emission standard (1.2 lbs $SO_2$/million Btu) specified by Clean Air Act Amendments of 1990 (Public Law 101-549); 60% C, 60 percent of the coal is compliant. CA values are from State agency databases; CR values are from commercial sources.]

| | Central Appalachian Basin coal region | | | | | |
|---|---|---|---|---|---|---|
| | NCRA coal bed names | | | | | |
| | Fire Clay coal bed or zone | | Pond Creek coal bed or zone | | Pocahontas No. 3 coal bed | |
| State and quadrangle | CA | CR | CA | CR | CA | CR |
| **Kentucky** | | | | | | |
| Boltsfork | — | — | — | — | — | — |
| Booneville | — | — | — | — | — | — |
| Handshoe | * | 1.31 | — | — | — | — |
| Hoskinston | * | 2.08 | — | — | — | — |
| Matewan | * | 1.16 | * | 0.81 | — | — |
| Middlesboro North | — | — | * | 1.71 | — | — |
| Millard | * | 1.15 | * | 0.76 | — | — |
| Noble | * | — | — | — | — | — |
| Salyersville South | * | 2.38 | — | — | — | — |
| **Virginia** | | | | | | |
| Appalachia | * | ** | C | ** | — | ** |
| Vansant | — | — | — | — | 60% C | 1.10 |
| Wise | — | ** | * | ** | — | ** |
| **West Virginia** | | | | | | |
| Beckley | — | — | — | — | 1.0 | 1.08 |
| Crumpler | — | — | — | — | * | 0.68 |
| Mammoth | 1.0 | 1.27 | 1.0 | 1.35 | — | — |
| Man | * | 1.72 | * | 1.43 | — | — |
| Sylvester | 1.0 | 1.42 | 1.1 | 1.03 | — | — |
| War | — | ** | — | ** | 0.8 | ** |

| | Northern Appalachian Basin coal region | | | | | |
|---|---|---|---|---|---|---|
| | NCRA coal bed names | | | | | |
| | Pittsburgh coal bed | | Upper Freeport coal bed | | Lower Kittanning coal bed | |
| State and quadrangle | CA | CR | CA | CR | CA | CR |
| **Ohio** | | | | | | |
| Bethesda | * | 3.05 | — | — | — | — |
| East Palestine | — | — | * | 4.50 | * | 3.43 |
| Jewett | * | 5.57 | * | 3.34 | * | 6.84 |
| Lower Salem | * | ** | — | ** | — | ** |
| Randle | — | ** | — | ** | * | ** |
| Strasburg | — | — | — | — | * | 7.08 |
| Zaleski | — | — | — | — | * | 8.86 |
| Zanesville East | — | — | * | 7.95 | * | 8.24 |
| **Pennsylvania** | | | | | | |
| Hackett | * | 3.05 | — | — | — | — |
| **West Virginia** | | | | | | |
| Camden | * | ** | — | — | — | — |
| Glover Gap | * | 3.30 | — | — | — | — |
| Rivesville | * | 2.81 | — | — | — | — |
| Thornton | * | 3.07 | * | 1.90 | * | 3 .59 |
| Valley Point | — | ** | * | ** | * | ** |

**Table 4.** Summary of estimated coal resources (in millions of short tons) for 18 coal availability (CA) and 15 coal recoverability (CR) study areas in the central Appalachian Basin coal region, by State and 7.5-minute quadrangle.

[Totals may not equal sum of components because of independent rounding. Symbols are as follows: Dash (—) indicates no data because CR study was not conducted; asterisk (*) indicates value was calculated on the basis of 15 CR studies, with original resources totaling 9,695 million short tons.

| State and Quadrangle | Original | Mined and lost in mining | Remaining | Land-use restrictions | Technologic restrictions | Total restrictions | Available | Recoverable | Economically recoverable | Percent of original resources | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Available | Economically recoverable |
| **Kentucky** | | | | | | | | | | | |
| Boltsfork | 243 | 12 | 232 | 12 | 47 | 58 | 173 | 85 | 13 | 71 | 5 |
| Booneville | 80 | 9 | 70 | 1 | 29 | 30 | 40 | 20 | 16 | 50 | 20 |
| Handshoe | 645 | 12 | 633 | 10 | 220 | 230 | 403 | 235 | 16 | 62 | 2 |
| Hoskinston | 498 | 10 | 488 | 21 | 213 | 234 | 254 | 95 | 47 | 51 | 9 |
| Matewan | 986 | 128 | 858 | 17 | 228 | 245 | 613 | 402 | 266 | 62 | 27 |
| Middlesboro North | 339 | 11 | 328 | 35 | 139 | 174 | 155 | 60 | 26 | 46 | 8 |
| Millard | 843 | 66 | 777 | 30 | 400 | 430 | 347 | 294 | 67 | 41 | 8 |
| Noble | 460 | 61 | 399 | 77 | 51 | 129 | 270 | 129 | 20 | 59 | 4 |
| Salyersville South | 183 | 23 | 160 | 13 | 66 | 79 | 81 | 50 | 15 | 44 | 8 |
| **Virginia** | | | | | | | | | | | |
| Appalachia | 1,350 | 344 | 1,006 | 26 | 277 | 303 | 704 | — | — | 52 | — |
| Vansant | 1,008 | 142 | 866 | 1 | 277 | 278 | 587 | 374 | 132 | 58 | 13 |
| Wise | 807 | 36 | 771 | 32 | 219 | 251 | 520 | — | — | 64 | — |
| **West Virginia** | | | | | | | | | | | |
| Beckley | 575 | 247 | 328 | 6 | 161 | 167 | 161 | 136 | 21 | 28 | 4 |
| Crumpler | 588 | 316 | 273 | 6 | 124 | 130 | 143 | 88 | 77 | 24 | 13 |
| Mammoth | 982 | 109 | 873 | 4 | 474 | 478 | 393 | 292 | 102 | 40 | 10 |
| Man | 1,020 | 240 | 780 | 7 | 312 | 318 | 462 | 227 | 81 | 45 | 8 |
| Sylvester | 1,242 | 80 | 1,162 | 12 | 324 | 335 | 827 | 559 | 77 | 67 | 6 |
| War | 985 | 234 | 751 | 12 | 409 | 421 | 330 | — | — | 34 | — |
| **Total** | 12,837 | 2,080 | 10,757 | 321 | 3,970 | 4,290 | 6,464 | 3,045* | 977* | 50 | 10* |
| **Percent of original** | 100 | 16 | 84 | 3 | 31 | 33 | 50 | 31* | 10* | | |

**Table 5.** Original, remaining, restricted, available, recoverable, and economically recoverable resources of the Fire Clay coal bed, as reported in the Coal Availability/Recoverability Studies (CARS) results in the central Appalachian Basin coal region, by State and 7.5-minute quadrangle (in millions of short tons).

[Totals may not equal sum of components because of independent rounding. Symbols are as follows: Dash (—) indicates coal recoverability (CR) study not conducted in this quadrangle and (or) on the coal bed; asterisk (*) indicates value was calculated on the basis of eight CR studies, with original resources totaling 538 million short tons. For further details, see Appendix 2.]

| State and quadrangle | Original | Remaining | Restricted | Available | Recoverable | Economically recoverable |
|---|---|---|---|---|---|---|
| **Kentucky** | | | | | | |
| Handshoe | 106 | 103 | 33 | 70 | 44 | 6 |
| Hoskinston | 68 | 68 | 37 | 31 | 18 | 3 |
| Matewan | 30 | 29 | 2 | 27 | 19 | 13 |
| Millard | 8 | 7 | 2 | 6 | 4 | 3 |
| Noble | 28 | 28 | 20 | 7 | — | — |
| Salyersville South | 62 | 62 | 33 | 29 | 21 | 2 |
| **Virginia** | | | | | | |
| Appalachia | 36 | 36 | 3 | 33 | — | — |
| **West Virginia** | | | | | | |
| Mammoth | 63 | 63 | 59 | 4 | 10 | 0 |
| Man | 32 | 32 | 21 | 11 | 8 | 4 |
| Sylvester | 170 | 152 | 24 | 128 | 86 | 19 |
| **Total** | 602 | 579 | 234 | 345 | 210* | 51* |
| **Percent of original** | 100 | 96 | 39 | 57 | 39* | 10* |

In fact, 40 percent (4 billion short tons) of the remaining coal resource is considered unavailable for future development because of restrictions to mining within the 18 quadrangles, unless there are changes to regulations or breakthroughs in technology in the future. Less than one-half of the estimated available coal resource is considered to be recoverable (31 percent of the total original resource) in the 15 CR study reports, and only 10 percent of the total original coal resource in the 15 CR study quadrangles can be extracted and marketed economically under current conditions.

## NCRA COAL BEDS IN THE CENTRAL APPALACHIAN BASIN COAL REGION

The CARS project began nine years before the NCRA started in 1995. Three of the NCRA coal beds or zones (Fire Clay, Pond Creek, and Pocahontas No. 3) of the central Appalachian Basin coal region are important components of the CARS project. The geology, characteristics, and resources of each of the three NCRA coal beds or zones are described thoroughly in Chapters F, G, and H of this report and will not be repeated in this chapter. Results of the CARS project in the central Appalachian Basin coal region, including individual detail on each of the three NCRA coal beds or zones are described in the following pages. Emission-level compliance data, in terms of pounds of sulfur dioxide per million Btu (lbs $SO_2$/million Btu), for these three coal beds in the CA and CR study quadrangles are reported in table 3.

As stated previously, the CARS project has assessed only the principal potentially minable coal bed within each of the Fire Clay and Pond Creek coal zones. Therefore, all of the following discussion uses the terms “coal bed” rather than the “coal zone” terminology of Chapters F and G in this report

### FIRE CLAY COAL BED

The Fire Clay coal bed is included in 10 of the 18 CA study quadrangles and in 8 of the 15 CR study quadrangles in the central Appalachian Basin coal region (fig. 5). The 10 CA studies represent slightly more than 10 percent of the area of known resources of the Fire Clay coal bed as shown in both figure 5 of this chapter and figure 11 of Chapter F of this report. The estimated original, remaining, restricted, available, recoverable, and economically recoverable coal resources are presented in table 5. Estimated original resources of Fire Clay coal in the 10 CA study quadrangles

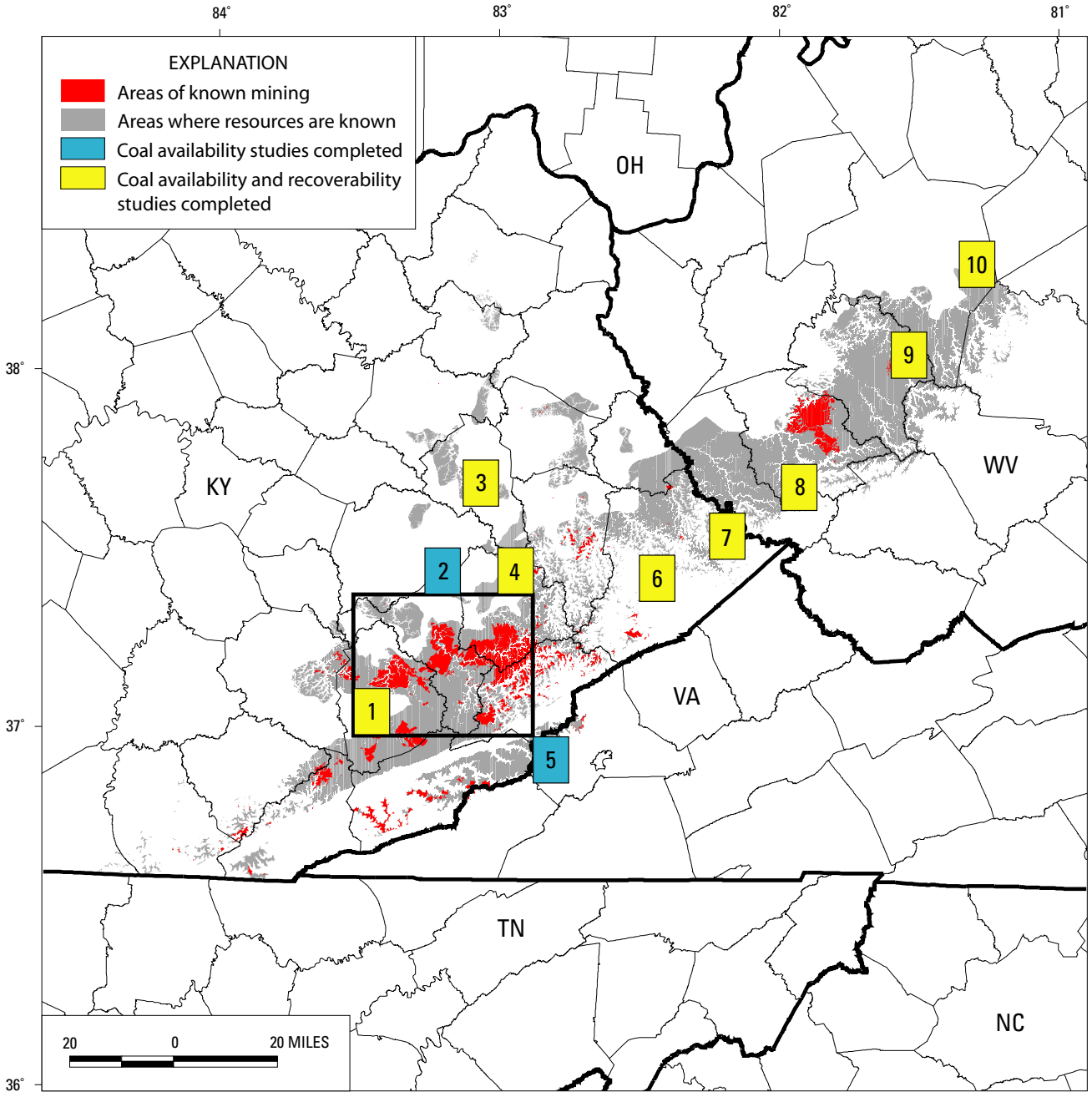


**Figure 5.** Map of the Fire Clay coal bed showing the coal availability (CA) and coal recoverability (CR) study areas that include the Fire Clay. The 7.5-minute quadrangles are numbered as follows: 1, Hoskinston; 2, Noble; 3, Salyersville South; 4, Handshoe; 5, Appalachia; 6, Millard; 7, Matewan; 8, Man; 9, Sylvester; 10, Mammoth. The heavy solid black line outlines the 15-quadrangle CA-study area of Greb and others (1999). Coal bed map modified from figure 11 in Chapter F of this report.

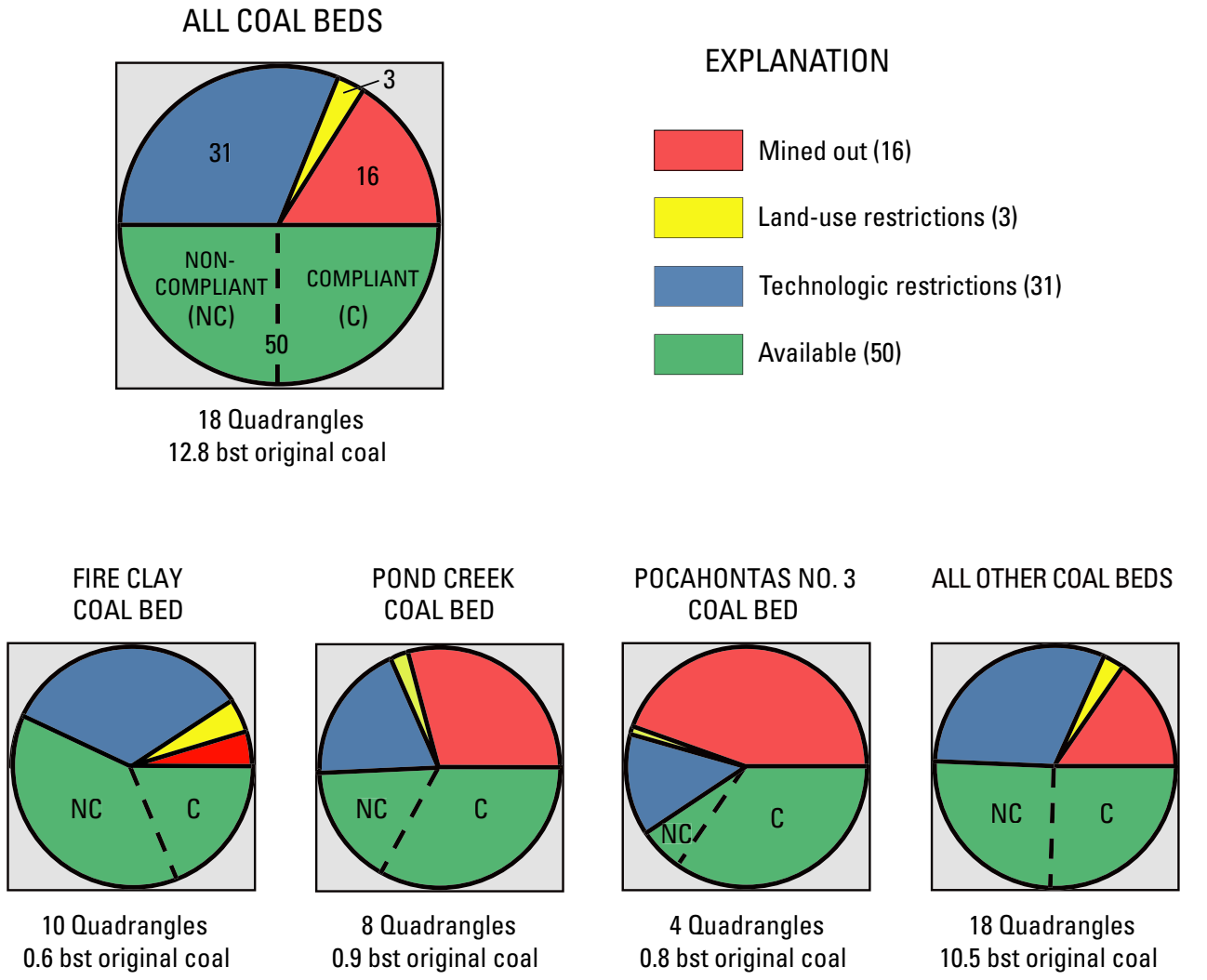


**Figure 6.** Pie charts summarizing the estimated original, mined and lost-in-mining, restricted, and available coal resources of the 18 7.5-minute quadrangles for which coal availability (CA) studies were prepared in the central Appalachian Basin coal region. The large pie chart summarizes all of the beds included in the 18 CA study areas. The small pie charts characterize each of the three National Coal Resource Assessment (NCRA) coal beds (Fire Clay, Pond Creek, and Pocahontas No. 3). The last small pie chart represents all of the other coal beds (excluding the three NCRA coal beds) in the 18 CA study quadrangles. Abbreviations are as follows: C, compliant with Phase II emission standard of the Clean Air Act Amendments of 1990 (Public Law 101-549), which is 1.2 pounds of sulfur dioxide per million Btu; NC, noncompliant; bst, billion short tons.

make up 5 percent of the total original resources of all coal beds in the 18 CA study quadrangles in the region (table 4). Estimates of Fire Clay coal (in millions of short tons) in those 10 quadrangles are as follows: original resources, 602; remaining resources, 579; restricted resources, 234; available resources, 345 (fig. 6, table 5, Appendix 2). In the 8 CR study quadrangles, estimated recoverable resources are 210 million short tons and economically recoverable resources are 51 million short tons (table 5). The estimated economically recoverable resource constitutes 10 percent of the estimated original Fire Clay coal resource of 538 million short tons in the 8 CA study quadrangles for which CR studies were conducted (table 5). One the basis of data compiled during the CARS project (table 3), only about one-third of the Fire Clay coal in the study areas may meet current compliance standards.

### POND CREEK COAL BED

The Pond Creek coal bed is included in 8 of the 18 CA study quadrangles and in 6 of the 15 CR study quadrangles in the central Appalachian Basin coal region (fig. 7). The 8 CA studies represent approximately 10 percent of the area of known resources of the Pond Creek coal bed as shown in both figure 6 of this chapter and figure 10 of Chapter G of

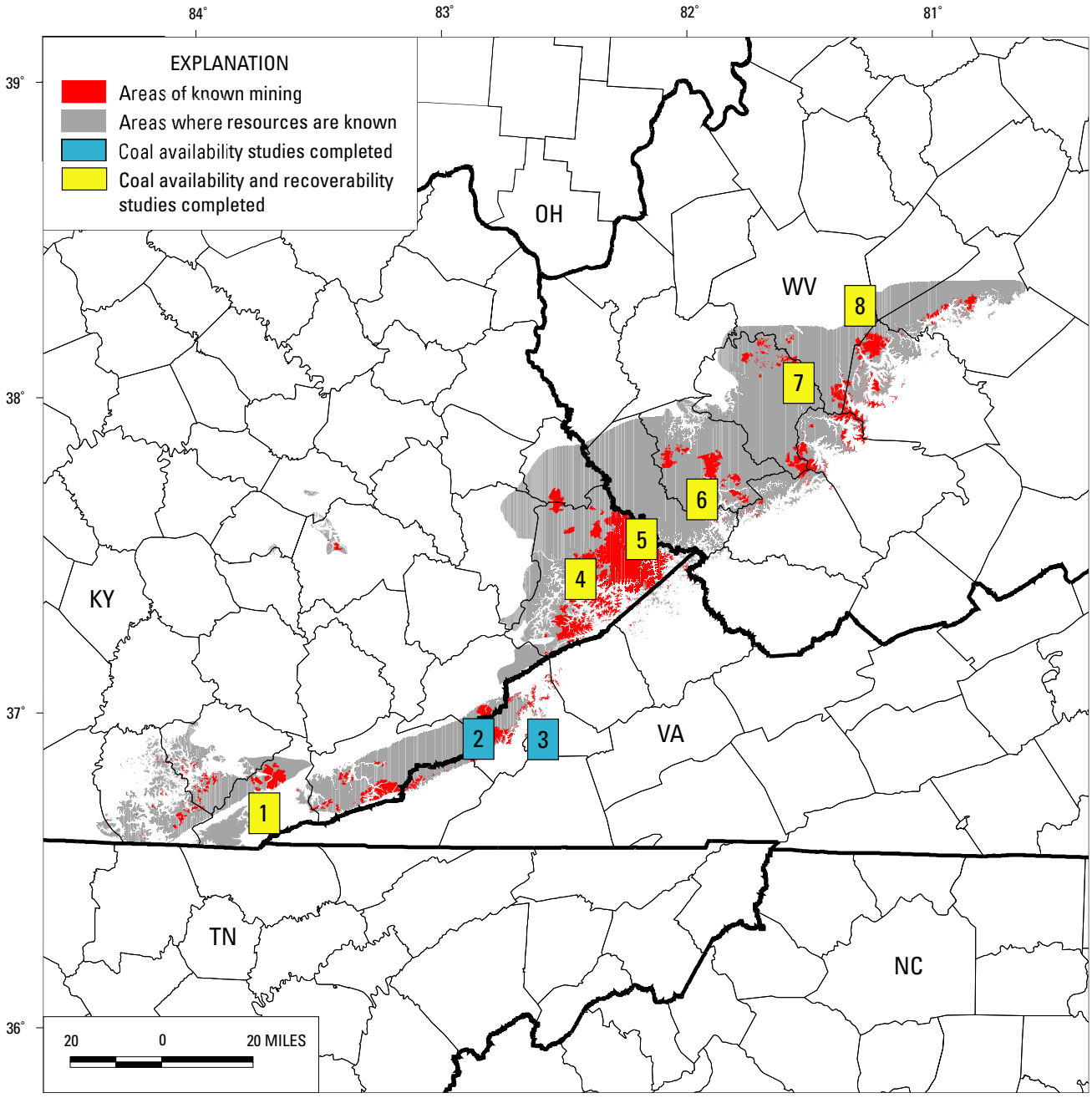


**Figure 7.** Map of the Pond Creek coal bed showing the coal availability (CA) and coal recoverability (CR) study areas that include the Pond Creek. The 7.5-minute quadrangles are numbered as follows: 1, Middlesboro North; 2, Appalachia; 3, Wise; 4, Millard; 5, Matewan; 6, Man; 7, Sylvester; 8, Mammoth. Coal bed map modified from figure 10 in Chapter G of this report.

**Table 6.** Original, remaining, restricted, available, recoverable, and economically recoverable resources of the Pond Creek coal bed, as reported in the Coal Availability/Recoverability Studies (CARS) results in the central Appalachian Basin coal region, by State and 7.5-minute quadrangle (in millions of short tons).

[Totals may not equal sum of components because of independent rounding. Symbols are as follows: L, less than 0.5 million short tons; dash (—) indicates coal recoverability (CR) study not conducted in this quadrangle and (or) on the coal bed; asterisk (*) indicates value was calculated on the basis of six CR studies, with original resources totaling 674 million short tons. For further details, see Appendix 2.]

| State and quadrangle | Original | Remaining | Restricted | Available | Recoverable | Economically recoverable |
|---|---|---|---|---|---|---|
| **Kentucky** | | | | | | |
| Matewan | 198 | 95 | 9 | 86 | 44 | 38 |
| Middlesboro North | 15 | 14 | 4 | 10 | 3 | 2 |
| Millard | 69 | 54 | 21 | 32 | 26 | 8 |
| **Virginia** | | | | | | |
| Appalachia | 238 | 101 | 25 | 76 | — | — |
| Wise | 1 | L | L | L | — | — |
| **West Virginia** | | | | | | |
| Mammoth | 91 | 91 | 55 | 36 | 22 | 2 |
| Man | 116 | 108 | 39 | 69 | 25 | 3 |
| Sylvester | 184 | 184 | 46 | 138 | 100 | 11 |
| **Total** | 912 | 648 | 200 | 448 | 219* | 63* |
| **Percent of original** | 100 | 71 | 22 | 49 | 33* | 9* |

this report. The estimated original, remaining, restricted, available, recoverable, and economically recoverable coal resources are presented in table 6. Estimated original resources of Pond Creek coal in the 8 CA study quadrangles make up 9 percent of the total original resources of all coal beds in the 18 CA study quadrangles in the region (table 4). Estimates of Pond Creek coal (in millions of short tons) are as follows: original, 912; remaining, 648; restricted, 200; available, 448 (fig. 6, table 6, Appendix 2). In the 6 CR study quadrangles, estimated recoverable resources are 219 million short tons and economically recoverable resources are 63 million short tons (table 6). The estimated economically recoverable resource constitutes 9 percent of the estimated original Pond Creek coal resource of 674 million short tons in the 6 CA study quadrangles for which CR studies were conducted (table 6). On the basis of data compiled during the CARS project (table 3), approximately two-thirds of the Pond Creek coal in the study areas may meet current compliance standards.

### POCAHONTAS NO. 3 COAL BED

The Pocahontas No. 3 coal bed is included in 4 of the 18 CA study quadrangles and in 3 of the 15 CR study quadrangles in the central Appalachian Basin coal region (fig. 8). The 4 CA studies represent slightly more than 10 percent of the area of known resources of the Pocahontas No. 3 coal bed as shown in both figure 7 of this chapter and figure 32 of Chapter H of this report. The original, remaining, restricted, available, recoverable, and economically recoverable coal resources are presented in table 7. Estimated original resources of Pocahontas No. 3 coal in the 4 CA study quadrangles make up 6 percent of the total original resources of all coal beds in the 18 CA study quadrangles in the region (table 4). Estimates of Pocahontas No. 3 coal (in millions of short tons) in those 4 quadrangles are as follows: original resources, 828; remaining resources, 461; restricted resources, 155; available resources, 306 (fig. 6, table 7, Appendix 2). In the 3 CR study quadrangles, estimated recoverable resources are 200 million short tons and economically recoverable resources are 114 million short tons (table 7). The estimated economically recoverable resource constitutes 17 percent of the estimated original Pocahontas No. 3 coal resource of 692 million short tons in the 3 CA study quadrangles for which CR studies were conducted (table 7). On the basis of data compiled during the CARS project (table 3), nearly all of the Pocahontas No. 3 coal in the study areas meets current compliance standards.

## DISCUSSION

Figure 6 shows a summary pie chart for the coal beds in the 18 CA study 7.5-minute quadrangles in the central Appalachian Basin coal region, pie charts that characterize

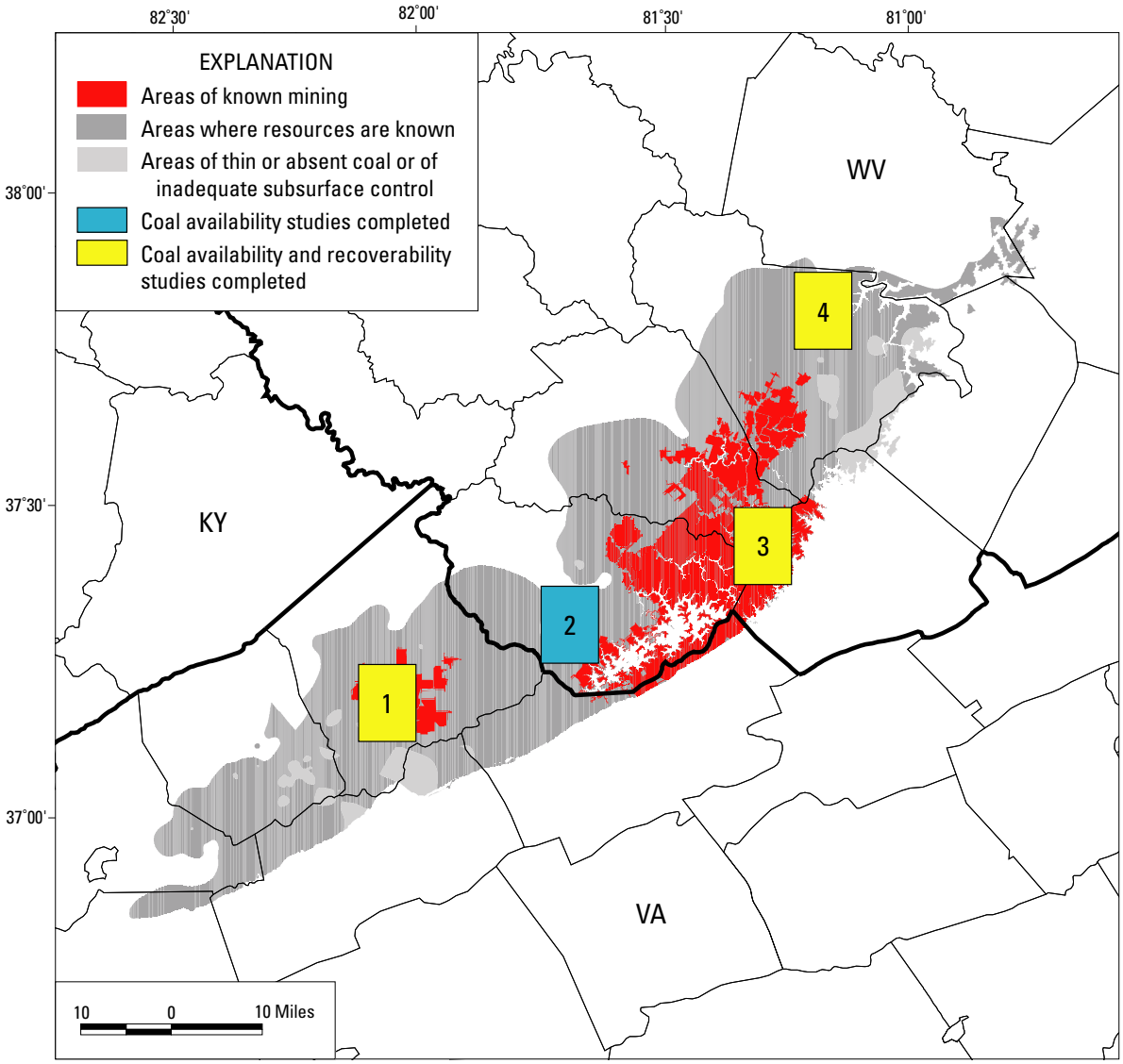


**Figure 8.** Map of the Pocahontas No. 3 coal bed showing the coal availability (CA) and coal recoverability (CR) study areas that include the Pocahontas No. 3. The 7.5-minute quadrangles are numbered as follows: 1, Vansant; 2, War; 3, Crumpler; 4, Beckley. Coal bed map modified from figure 32 in Chapter H of this report.

**Table 7.** Original, remaining, restricted, available, recoverable, and economically recoverable resources of the Pocahontas No. 3 coal bed, as reported in the Coal Availability/Recoverability Studies (CARS) results in the central Appalachian Basin coal region, by State and 7.5-minute quadrangle (in millions of short tons).

[Totals may not equal sum of components because of independent rounding. Symbols are as follows: Dash (—) indicates coal recoverability (CR) study not conducted in this quadrangle and (or) on the coal bed; asterisk (*) indicates value was calculated on the basis of three CR studies, with original resources totaling 692 million short tons. For further details, see Appendix 2.]

| State and quadrangle | Original | Remaining | Restricted | Available | Recoverable | Economically recoverable |
|---|---|---|---|---|---|---|
| **Virginia** | | | | | | |
| Vansant | 289 | 197 | 18 | 179 | 121 | 109 |
| **West Virginia** | | | | | | |
| Beckley | 144 | 142 | 75 | 67 | 76 | 3 |
| Crumpler | 259 | 8 | 3 | 6 | 3 | 2 |
| War | 136 | 114 | 59 | 55 | — | — |
| **Total** | 828 | 461 | 155 | 306 | 200* | 114* |
| **Percent of original** | 100 | 56 | 19 | 37 | 29* | 17* |

each of the three NCRA coal beds, and a pie chart for the collective other non-NCRA coal beds in the region. Of the 12.8 billion short tons of original coal resource identified in the 18 completed CA studies, 16 percent have been mined and lost in previous mining, 3 percent are constrained by land-use considerations, and 31 percent are constrained by technologic factors, leaving 50 percent of the original resource available for development. There are a sufficient number of studies that include each of the three coal beds to make some general observations (see Appendix 2 for details).

The number of coal beds per quadrangle, within the 18 quadrangles in the central Appalachian Basin coal region, ranges from two at the western edge of the region to 25 in the east-central area where the stratigraphic section is the thickest. The average number of coal beds per quadrangle in the region is 13; the median and mode are both 14. The three NCRA coal beds together constitute one-fifth (18 percent) of the estimated 12.8 billion short tons of original resources in the 18 quadrangles studied. All of the other coal beds combined constitute four-fifths (82 percent) of the estimated total original resource. As shown in figure 6, the statistics of each of the three individual coal beds vary significantly, yet the statistics for all other coal beds are essentially the same as for all beds combined, including the three NCRA coals.

Land-use restrictions in all of the 18 quadrangles exclude only 3 percent of the original resource; towns (populated areas) and parks or forests make up two-thirds of that 3 percent (fig. 9). Land-use restrictions are uniformly low in all three coal beds, ranging from less than 1 to 3 percent of the original resource. The effects of each land-use restriction category, however, exhibit a wide variation between each of the 7.5-minute quadrangle study areas and each of the three coal beds. For example, a State park might cover a significant part of one individual study area, but may be completely absent in neighboring study areas. Based on the results of a multiquadrangle area study in eastern Kentucky (Greb and others, 1999), the effects of individual land-use restrictions, dominant within any specific study area, might be diminished on a regional basis (see the following section in this chapter on the Fire Clay coal subregional study).

Technologic restrictions in the 18 quadrangles affect nearly one-third of the original resource and more than three-fourths of that is due to the thinness of the coal beds (fig. 10). This is true both for the region and each of the three individual coal beds. In the central Appalachian Basin coal region, where there are many potentially minable coal beds that split and merge frequently, the second most significant technologic restriction is where the coal beds come close together vertically and the interburden becomes so thin as to restrict one or the other beds from being mined.

Results from 18 CA study and 15 CR study quadrangles in the central Appalachian Basin coal region indicate that, in the areas studied, (1) 50 percent of the original coal resource is available for mining, (2) one-third of the available coal will be lost in future mining and washing of the coal, (3) two-thirds of that recoverable coal will not be economical to mine at current mining costs, and (4) only 10 percent of the original coal resource will be economically recoverable (fig. 11). Further, approximately one-half of the economically recoverable coal in this prime low-sulfur coal region can meet current emission-level compliance standards of 1.2 lbs $SO_2$/million Btu.

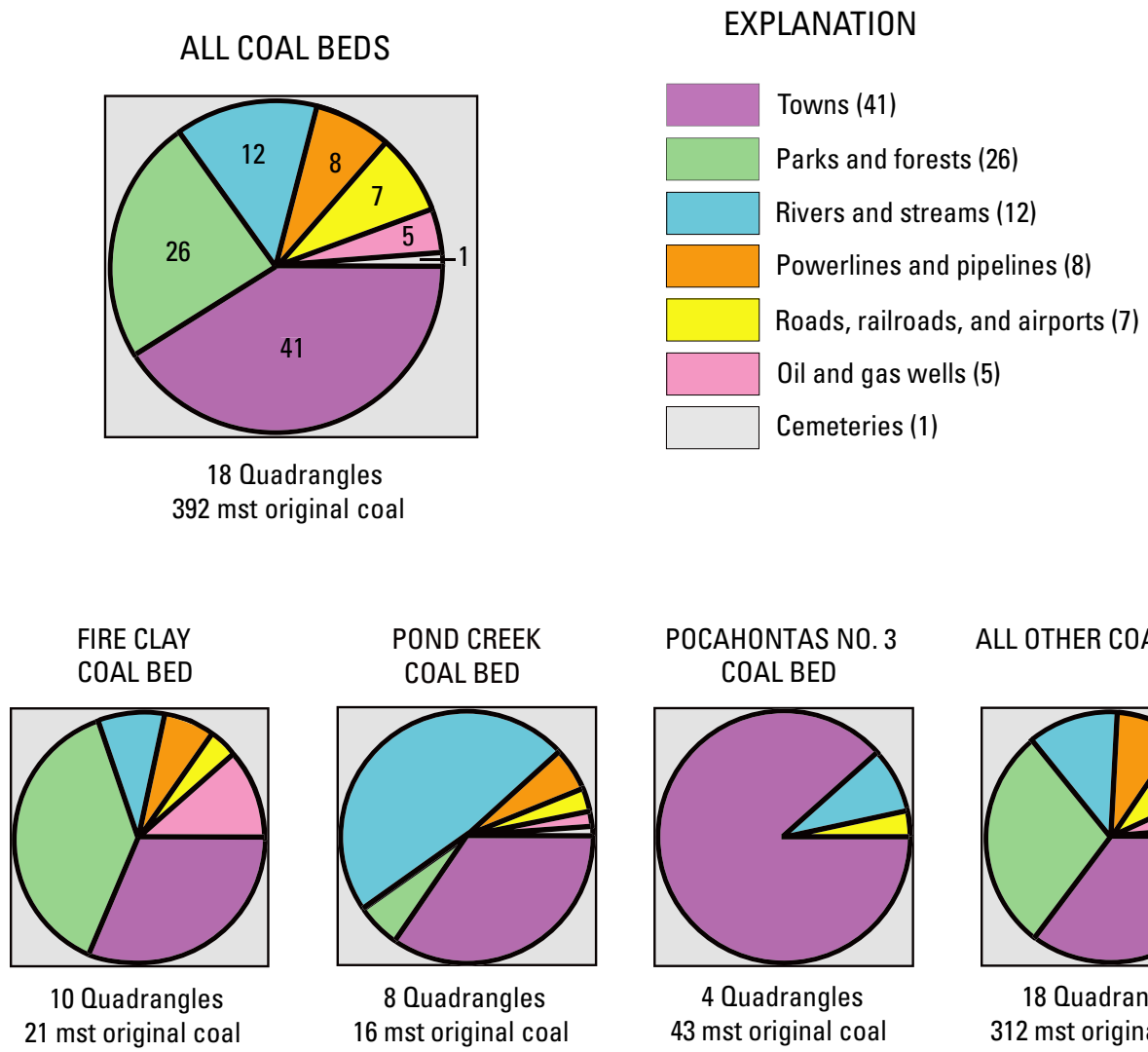


**Figure 9.** Pie charts summarizing the land-use restrictions (3 percent of the original coal resource, from figure 6) in the 18 7.5-minute quadrangles in the central Appalachian Basin coal region for which coal availability (CA) studies were conducted. The largest pie chart summarizes all of the beds included in the CA study areas in the 18 quadrangles. The small pie charts characterize each of the three National Coal Resource Assessment (NCRA) coal beds: Fire Clay, Pond Creek, and Pocahontas No. 3. The last small pie chart represents all of the other coal beds (excluding the three NCRA coal beds) in the 18 quadrangles. mst, millions of short tons.

Results from the CARS project for the three NCRA coal beds can be summarized as follows. The Fire Clay coal bed has had relatively little mining in the 10 quadrangles studied, but the subregional study data suggest significant depletion in Kentucky, particularly of the thicker coal. In the 10 CA study areas, somewhat more than half of the original resource of the Fire Clay coal bed is available for mining and, in the 8 CR study areas, 10 percent is economically recoverable; however, based on data compiled during the CARS project (table 3), only about one-third may meet compliance standards. In the 8 CA study quadrangles, the Pond Creek coal bed is nearly one-third depleted, has less than half of the regional average of technologic constraints, and is nearly 50 percent available for mining. In the 6 CR study areas, less than 10 percent of the original resource is economically recoverable, and two-thirds of the resource is compliant. Although the Pocahontas No. 3 coal bed is nearing 50 percent depletion in the 4 CA study quadrangles, the land-use restrictions are negligible and there are relatively few technologic constraints on future mining of the coal; therefore, two-thirds of the remaining coal resource are available for development. Further, in the 3 completed CR study quadrangles, almost 20 percent of the original resource of the Pocahontas No. 3 coal is economically recoverable and nearly all of the coal resource is compliant.

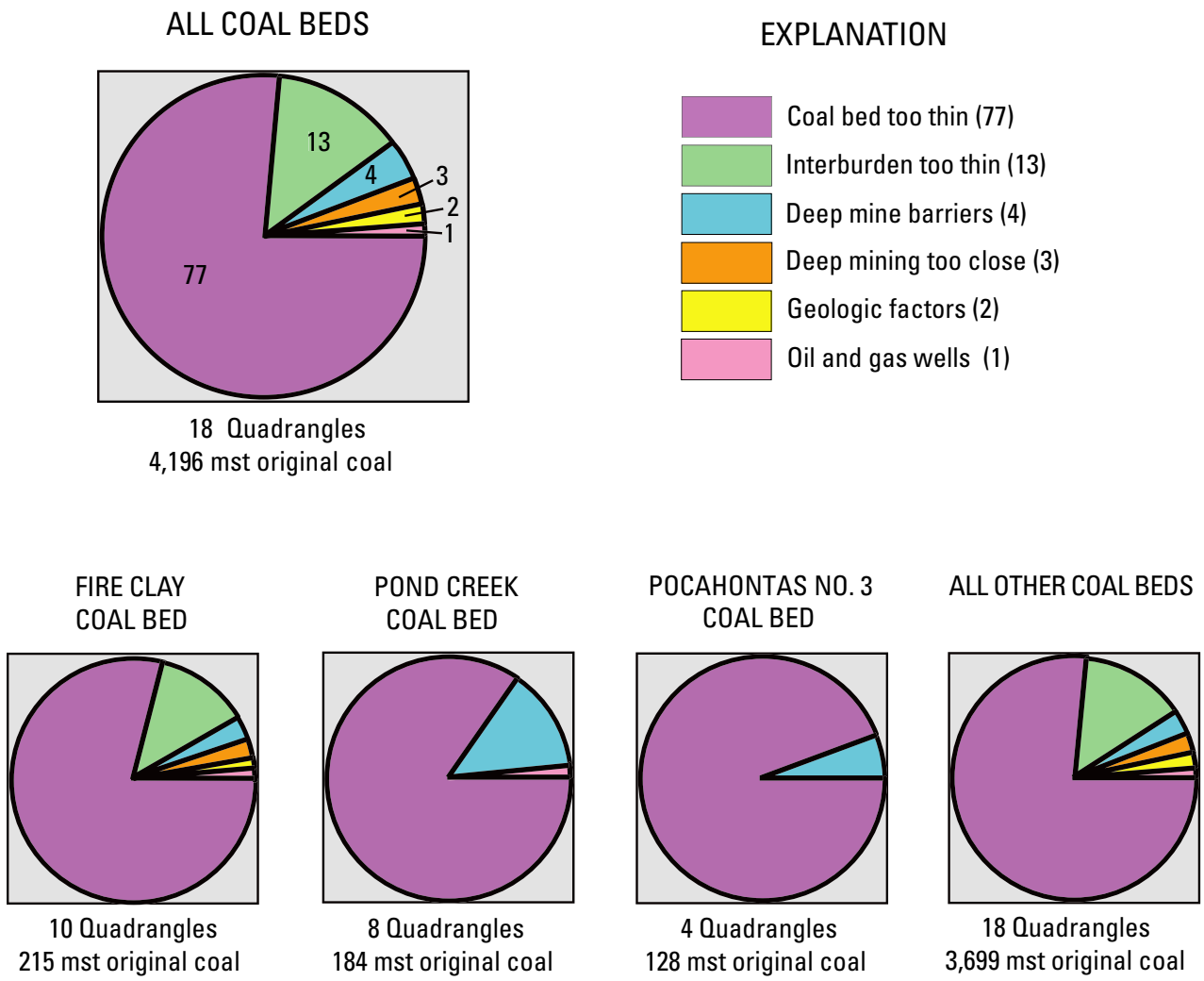


**Figure 10.** Pie charts summarizing the technologic restrictions (31 percent of the original coal resource, from figure 6) in the 18 7.5-minute quadrangles in the central Appalachian Basin coal region for which coal availability (CA) studies were conducted. The largest pie diagram summarizes all of the beds included in the CA study areas in the 18 quadrangles. The small pie charts characterize each of the three National Coal Resource Assessment (NCRA) coal beds: Fire Clay, Pond Creek, and Pocahontas No. 3. The last small pie chart represents all of the other coal beds (excluding the three NCRA coal beds) in the 18 quadrangles. mst, millions of short tons.

## SUBREGIONAL STUDIES IN THE CENTRAL APPALACHIAN BASIN COAL REGION

Although the CA study results indicate that coal available for development averages 50 percent of the original resource, the reasons for restricted coal vary widely from study to study. This is particularly true for land-use restrictions, which tend to be localized. The most important availability factor is technologic: coal often is too thin to mine by underground methods, a factor almost uniformly found in all studies. For example, in eastern Kentucky, 50 percent of the original coal resource is less than 28 inches thick, which is too thin to economically mine underground. Because previous mining in the region tends to be clustered geographically for each coal bed, the broad sample of availability studies has been a poor indicator of coal depletion for the most important resource beds. Larger areas should be assessed in order to obtain better estimates of this factor.

The KGS coal geologists recently have completed a pilot project in Kentucky to apply the coal availability method to larger areas. A contiguous 15-quadrangle area of approximately 900 $mi^2$ (fig. 5) was assessed for the Fire Clay coal (Greb and others, 1999). The Fire Clay coal is a premium coal in eastern Kentucky with a long history of mining, is currently mined, and is generally low in both ash yield and sulfur content (Weisenfluh and others, 1996). The Fire Clay coal underlies all of the study area except for a tiny area in the southeastern part of the study area on the southeastern side of the Pine Mountain thrust fault where it was not deposited (fig. 12).

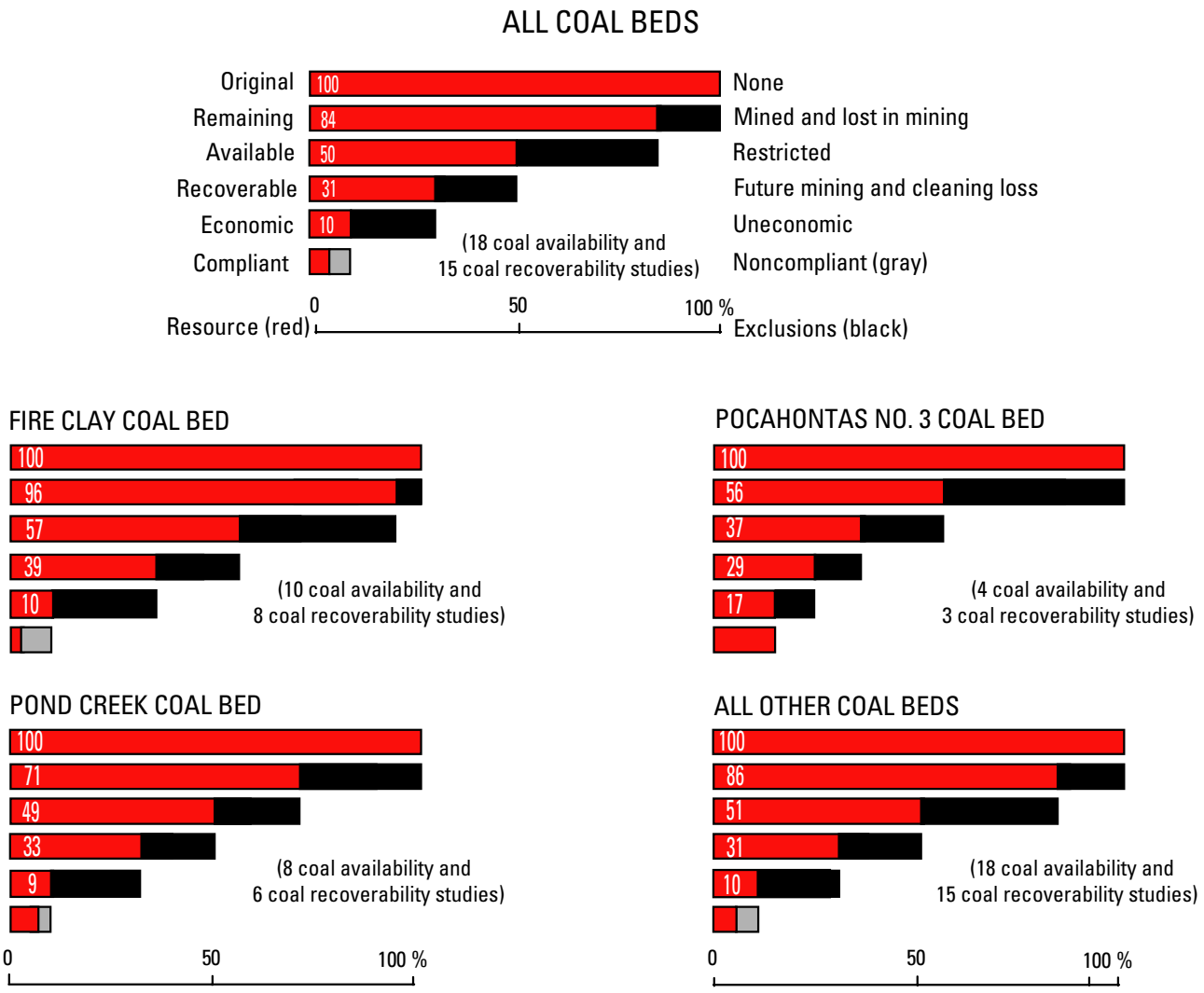


**Figure 11.** Bar charts summarizing the estimated original, mined and lost-in-mining, restricted, available, recoverable, economic, and compliant coal resources of the 18 7.5-minute quadrangles for which coal availability (CA) studies were conducted and the 15 7.5-minute quadrangles for which coal recoverability (CR) studies were conducted in the central Appalachian Basin coal region. The upper bar graph summarizes all of the beds included in the 18 CA study areas and 15 CR study areas. Three of the lower bar graphs characterize each of the National Coal Resource Assessment (NCRA) coal beds: Fire Clay, Pond Creek, and Pocahontas No. 3. The fourth lower bar graph represents all of the other coal beds (excluding the three NCRA coal beds) in the quadrangles.

The original resources are estimated at 1.8 billion short tons and 52 percent is available for mining. The estimate of mined resources is significantly higher in the 15-quadrangle study area than the average for the 6 previous individual CA study quadrangles in Kentucky, and confirms the general knowledge that mining has depleted the thickest coal preferentially. Land-use restrictions, already found to be a minor factor in the 7.5-minute studies, are further diminished in the larger area. Technologic restrictions in the 7.5-minute studies are slightly higher than the regional average in the CA studies. However, because a higher percentage of the remaining coal in Kentucky is in thinner beds, technologic restrictions will most likely be more important at the basin scale.

Results of the study (Greb and others, 1999) indicate that the CA study methodology can be applied to larger areas without sacrificing data accuracy. If the results of the Fire Clay subregional study also apply to the Pond Creek coal bed, the availability of the Pond Creek coal also will diminish due to greater depletion and thinner remaining coal. The KGS geologists currently are conducting studies for the Pond Creek coal bed.

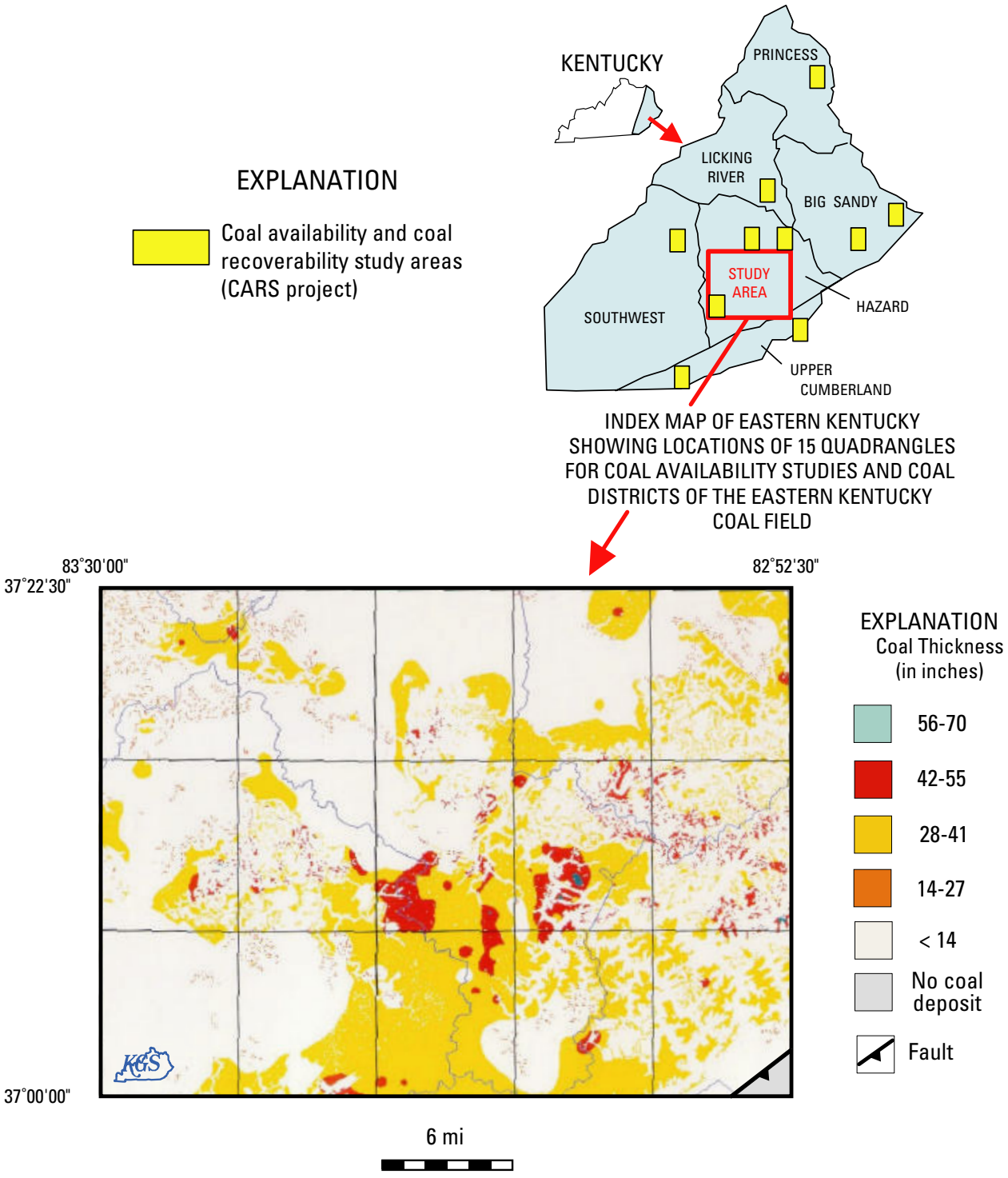


**Figure 12.** Coal availability study map of Fire Clay coal resources in a study area that consists of 15 7.5-minute quadrangles in eastern Kentucky. Modified from Greb and others (1999).

### SOCIOECONOMIC IMPACT STUDIES

In addition to the CR studies, the former USBM conducted analyses of the economic impact of the coal mining industry within two counties in the central Appalachian Basin coal region. The study of Pike County, Ky., reported that coal mining in 1990 provided 46 percent of the county's total industry output, 21 percent of total employment, 37 percent of other income, and 40 percent of employee compensation (Geroyan and others, 1994). The CARS project in the Matewan and Miller quadrangles in Pike County (Carter and Gardner, 1989; Sergeant, 1989b; Eggleston and others, 1990; Rohrbacher and others, 1993a; U.S. Bureau of Mines, 1995) reported that 27 and 8 percent, respectively, of the original resource is considered to be economically minable. Application of the above information by Geroyan and others (1994) to the estimate of the county's resources translates into less than 50 years of coal reserves in the county, at 1990 levels of production. The second study was in Boone County, W. Va., wherein coal mining provided 79 percent of the county's total industry output, 41 percent of total employment, 63 percent of other income, and 71 percent of employee compensation (Geroyan and Teeters, 1995). The single CARS project in Boone County (Sylvester quadrangle) estimated that only 6 percent of the original resource was economically recoverable. Bearing in mind that this quadrangle was only one of a dozen or so in the county studied during the CARS project, application of the CARS findings by Geroyan and Teeters (1995) to the county's estimated coal reserves would indicate that the county could maintain current production levels for approximately 20 years.

Socioeconomic studies, combined with the findings of the CARS results, enable government and industry planners to anticipate and plan for alternative industry and services growth. These socioeconomic impact analysis studies ended with the closure of the USBM in 1995.

## NORTHERN APPALACHIAN BASIN COAL REGION

The CARS project began in the northern Appalachian Basin coal region in 1993 and is more than two-thirds complete. The State geological surveys of Ohio, West Virginia, and Pennsylvania have completed 14 CA studies (Axon, 1994, 1995a,b,c, 1996a,b,c,d; Wolfe, 1997; Lentz, 1999; Loud, 1999, 2000). CA studies of six additional individual 7.5-minute quadrangles are in progress in West Virginia, Pennsylvania, and Maryland. A total of 20 quadrangles should complete the planned CA study sampling project in the northern Appalachian Basin coal region. CR studies have been completed for ten of the CA study quadrangles (Scott, 1995; Teeters, 1997; Scott and Teeters, 1998). When those 20 are complete, 4 percent of the approximately 500 quadrangles in the northern Appalachian Basin coal region will have been sampled. As this meets the goal of 3 to 4 percent sampling, no additional individual quadrangle studies at 1:24,000 scale will be started. The OGS has completed all planned CA studies in 8 7.5-minute quadrangles and has begun modeling individual coal beds on a subregional basis within the State.

Because studies are still in progress, the following discussion may only approximate the final results in the northern Appalachian Basin coal region. As in the central Appalachian Basin coal region, there is a wide variation between the individual quadrangle results. However, an overall average of 59 percent of the estimated original 6.6-billion-short-ton coal resource in the 14 quadrangles is available for development, as shown in table 8. Coal already mined and lost in mining accounts for a 16 percent reduction of the original resource (the same as in the central Appalachian Basin coal region). Land-use restrictions are a small factor at 7 percent (but more than double that of the central Appalachian Basin coal region where there is less population, the majority of people live in the valleys, and mining takes place mostly in the hills). Technologic restrictions exclude 19 percent of the original resource. This is less than two-thirds of that in the central Appalachian Basin coal region, in part because coal beds in the northern Appalachian Basin coal region are more tabular than those in the central Appalachian Basin coal region, are fewer in number, and are rarely within 25 to 40 ft of each other. Approximately 1.7 billion short tons, or 30 percent of the remaining coal resource, are estimated to be unavailable for future mining because of restrictions within the 14 CA study quadrangles. Less than one-half of the available coal resource in the 10 CR study quadrangles is considered recoverable (33 percent of the original resource), and only 14 percent of the total original resource in these study areas can be extracted and marketed economically at current conditions.

### NCRA COAL BEDS IN THE NORTHERN APPALACHIAN BASIN COAL REGION

The CARS project began in the northern Appalachian Basin coal region in 1993, shortly before the NCRA started. The three coal beds (Pittsburgh, Upper Freeport, and Lower Kittanning) studied in the NCRA are in the majority of the CARS reports. The geology, characteristics, and resources of each of the three coal beds are described thoroughly in Chapters C, D, and E in this report and will not be repeated in this chapter. Results of the CARS project in the northern Appalachian Basin coal region, including data on each of the three NCRA coal beds, are presented in the following pages. Emission-level compliance data, in terms of pounds

**Table 8.** Summary of estimated coal resources (in millions of short tons) for 14 coal availability (CA) and 10 coal recoverability (CR) study areas in the northern Appalachian Basin coal region, by State and 7.5-minute quadrangle.

[Totals may not equal sum of components because of independent rounding. Abbreviations and symbols are as follows: L, less than 0.5 million short tons; dash (—) indicates no data because CR study was not conducted; asterisk (*) indicates value was calculated on the basis of 10 CR studies, with original resources totaling 5,710 million short tons.]

| State and quadrangle | Original | Mined and lost in mining | Remaining | Land-use restrictions | Technologic restrictions | Total restrictions | Available | Recoverable | Economically recoverable | Percent of Original | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Available | Economically recoverable |
| **Ohio** | | | | | | | | | | | |
| Bethesda | 643 | 95 | 548 | 47 | 4 | 50 | 498 | 222 | 2 | 77 | L |
| East Palestine | 443 | 23 | 421 | 48 | 140 | 188 | 232 | 82 | 22 | 52 | 5 |
| Jewett | 904 | 67 | 837 | 17 | 162 | 179 | 658 | 415 | 155 | 73 | 17 |
| Lower Salem | 123 | 9 | 113 | 7 | 10 | 17 | 96 | — | — | 78 | — |
| Randle | 131 | 18 | 113 | 4 | 1 | 5 | 107 | — | — | 82 | — |
| Strasburg | 194 | 46 | 148 | 7 | 2 | 9 | 139 | 38 | 18 | 72 | 9 |
| Zaleski | 323 | 22 | 300 | 80 | 23 | 103 | 197 | 53 | 19 | 61 | 6 |
| Zanesville East | 454 | 16 | 438 | 95 | 17 | 112 | 326 | 90 | 19 | 72 | 4 |
| **Pennsylvania** | | | | | | | | | | | |
| Hackett | 607 | 272 | 335 | 72 | 10 | 83 | 252 | 112 | 2 | 42 | L |
| **West Virginia** | | | | | | | | | | | |
| Camden | 263 | 14 | 249 | 13 | 108 | 121 | 128 | — | — | 49 | — |
| Glover Gap | 986 | 16 | 970 | 1 | 317 | 317 | 653 | 575 | 426 | 66 | 43 |
| Rivesville | 617 | 418 | 199 | 19 | 33 | 52 | 148 | 73 | 31 | 24 | 5 |
| Thornton | 541 | 2 | 539 | 10 | 296 | 306 | 233 | 234 | 77 | 43 | 14 |
| Valley Point | 393 | 44 | 349 | 31 | 108 | 139 | 210 | — | — | 53 | — |
| **Total** | 6,620 | 1,062 | 5,558 | 450 | 1,232 | 1,682 | 3,877 | 1,895* | 771* | 59 | 14* |
| **Percent of original** | 100 | 16 | 84 | 7 | 19 | 25 | 59 | 33* | 14* | | |

**Table 9.** Original, remaining, restricted, available, recoverable, and economically recoverable resources of the Pittsburgh coal bed, as reported in the Coal Availability/Recoverability Studies (CARS) results in the northern Appalachian Basin coal region, by State and 7.5-minute quadrangle (in millions of short tons).

[Totals may not equal sum of components because of independent rounding. Abbreviations and symbols are as follows: L, less than 0.5 million short tons; dash (—) indicates coal recoverability (CR) study not conducted in this quadrangle and (or) on the coal bed; asterisk (*) indicates value was calculated on the basis of six CR studies, with original resources totaling 1,510 million short tons. For further details, see Appendix 3.]

| State and quadrangle | Original | Remaining | Restricted | Available | Recoverable | Economically recoverable |
|---|---|---|---|---|---|---|
| **Ohio** | | | | | | |
| Bethesda | 302 | 257 | 9 | 248 | 119 | 1 |
| Jewett | 73 | 19 | 5 | 14 | 9 | L |
| Lower Salem | 28 | 27 | 8 | 19 | — | — |
| **Pennsylvania** | | | | | | |
| Hackett | 370 | 111 | 35 | 76 | 48 | L |
| **West Virginia** | | | | | | |
| Camden | 148 | 140 | 86 | 54 | — | — |
| Glover Gap | 471 | 455 | 14 | 441 | 345 | 345 |
| Rivesville | 291 | 1 | 1 | 0 | 0 | 0 |
| Thornton | 3 | 1 | 0 | 1 | 1 | 1 |
| **Total** | 1,686 | 1,011 | 157 | 854 | 522* | 347* |
| **Percent of original** | 100 | 60 | 9 | 51 | 35* | 23* |

of sulfur dioxide per million Btu (lbs $SO_2$/million Btu), for these three coal beds are reported in table 3. All data reported in the 14 CARS quadrangles in the northern Appalachian Basin coal region indicate that, prior to washing, none of the coal in the study areas meets current emission-level compliance standards.

### PITTSBURGH COAL BED

The Pittsburgh coal bed is included in 8 of the 14 CA studies and in 6 of the 10 CR studies that have been completed to date in the northern Appalachian Basin coal region (fig. 13). The 8 CA studies that have been completed represent 5 percent of the area of known resources of the Pittsburgh coal bed as depicted in both figure 13 of this chapter and figure 14 of Chapter C of this report. One of the six CA studies that are in progress includes the Pittsburgh; when complete, the results presented in this chapter may be altered somewhat. The estimated original, remaining, restricted, available, recoverable, and economically recoverable resources are presented in table 9. Estimated original resources of Pittsburgh coal in the 8 CA study quadrangles make up one-quarter of the total original resources of all coal beds in the 14 CA study quadrangles in the region (table 8). Estimates of Pittsburgh coal (in millions of short tons) in those 8 quadrangles are as follows: original resources, 1,686; remaining, 1,011; restricted, 157; available, 854 (fig. 14, table 9, Appendix 3). In the 6 CR study quadrangles, estimated recoverable resources are 522 million short tons and economically recoverable resources are 347 million short tons (table 9). The estimated economically recoverable resource constitutes 23 percent of the estimated original Pittsburgh coal resource of 1,510 million short tons in the 6 CA studies for which CR studies were conducted (table 9).

### UPPER FREEPORT COAL BED

The Upper Freeport coal bed is included in 5 of the 14 CA studies and in 4 of the 10 CR studies that have been completed to date in the northern Appalachian Basin coal region (fig. 15). The 5 CA studies that have been completed represent slightly less than 2 percent of the area of known resources of the Upper Freeport coal bed as depicted in both figure 15 of this chapter and figure 20 of Chapter D of this report. Five of the 6 CA studies that are in progress include the Upper Freeport; when complete, the results presented in this chapter may be altered considerably. Estimated original, remaining, restricted, available, recoverable, and economically recoverable resources are presented in table 10. Estimated original resources of Upper Freeport coal in the 5 CA study quadrangles make up 9 percent of the total origi-

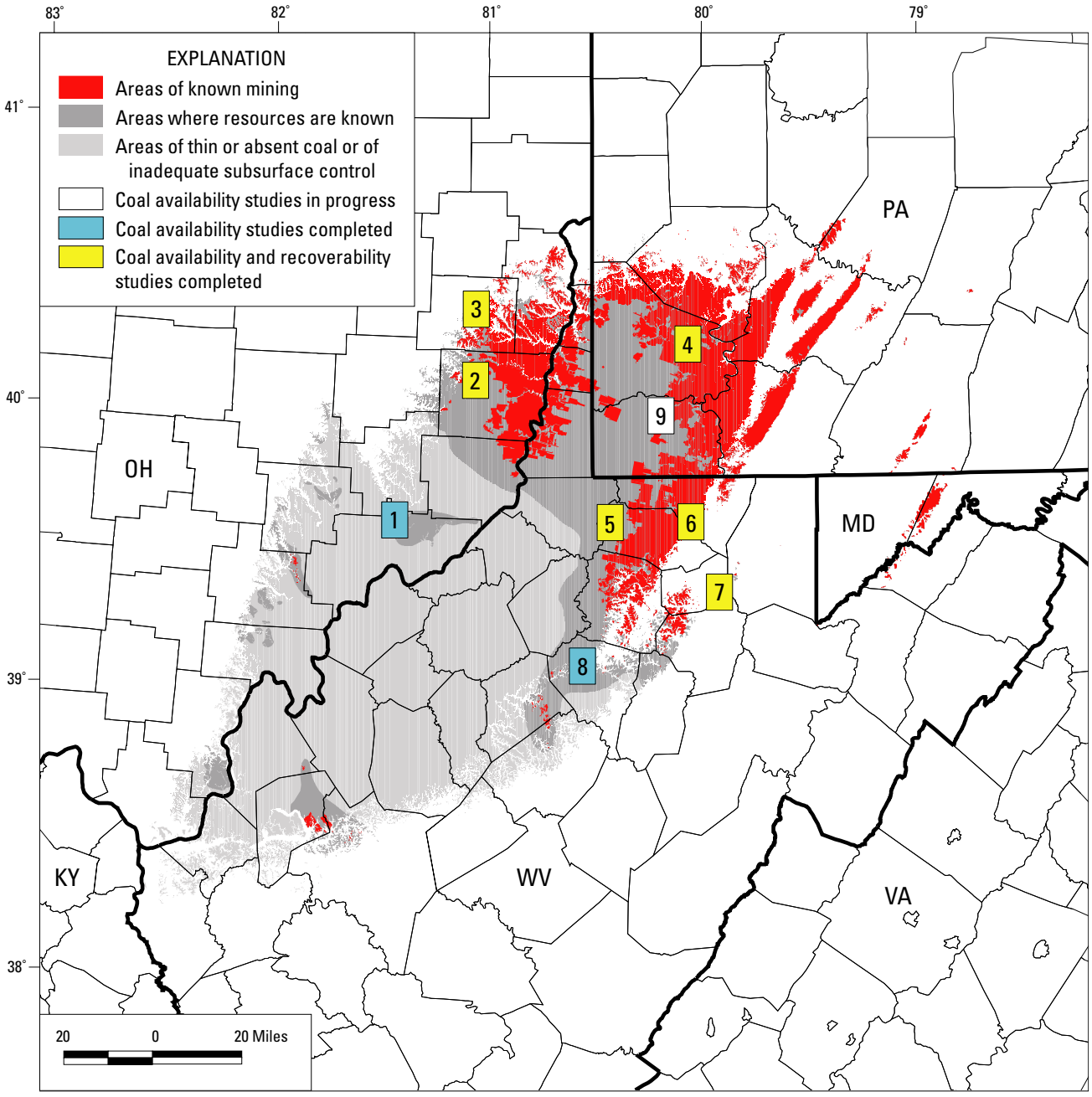


**Figure 13.** Map of the Pittsburgh coal bed showing the coal availability (CA) and coal recoverability (CR) study areas that include the Pittsburgh coal bed. The 7.5-minute quadrangles are numbered as follows: 1, Lower Salem; 2, Bethesda; 3, Jewett; 4, Hackett; 5, Glover Gap; 6, Rivesville; 7, Thornton; 8, Camden; 9, Waynesburg. Coal bed map modified from figure 14 in Chapter C of this report.

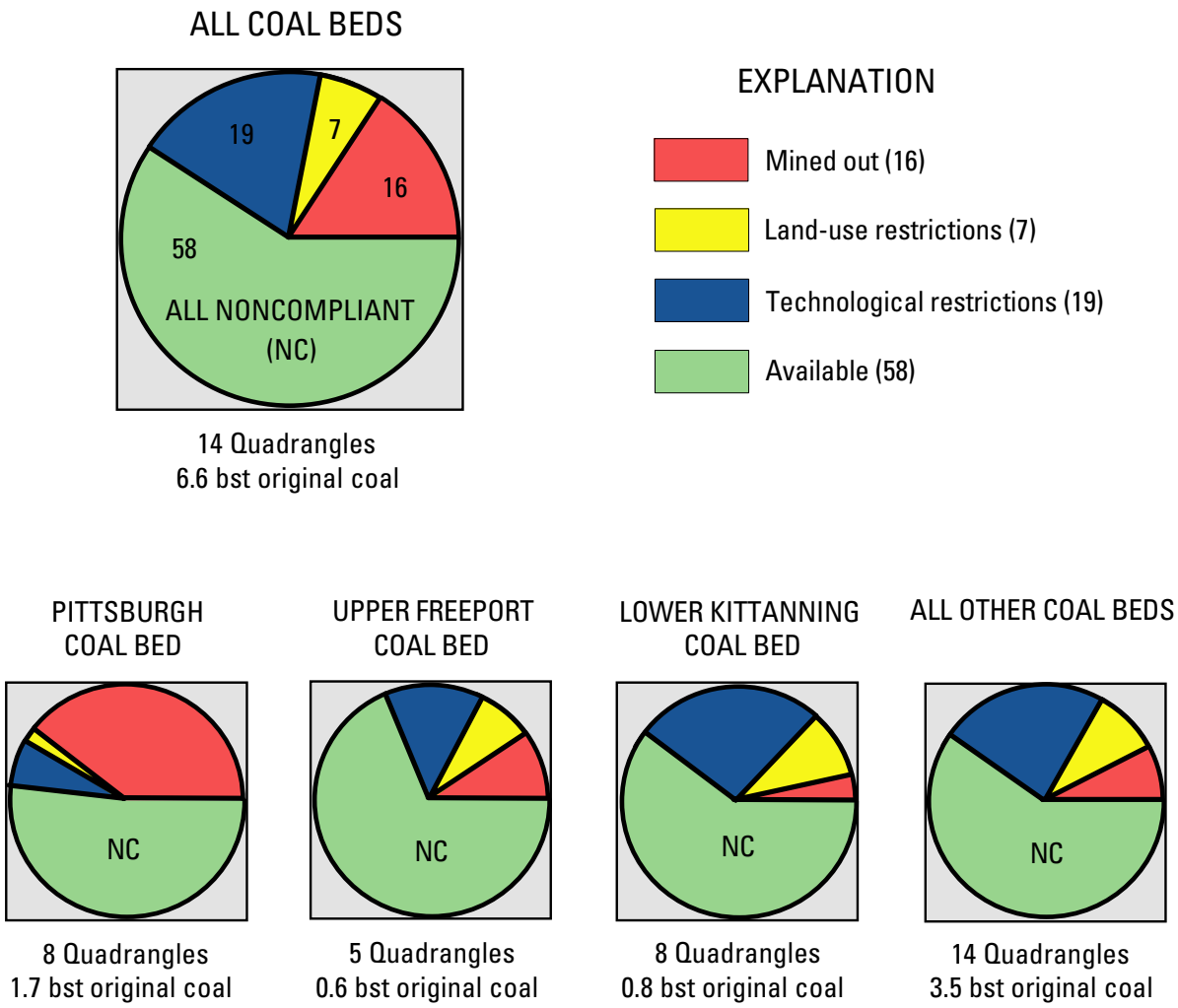


**Figure 14.** Pie charts summarizing the estimated original, mined and lost-in-mining, restricted, and available coal resources of the 14 7.5-minute quadrangles for which coal availability (CA) studies were conducted in the northern Appalachian Basin coal region. The large pie chart summarizes all of the beds included in the 14 CA-study areas. The small pie charts characterize each of the three National Coal Resource Assessment (NCRA) coal beds: Pittsburgh, Upper Freeport, and Lower Kittanning. The last small pie chart represents all of the other coal beds (excluding the three NCRA coal beds) in the 14 CA study quadrangles. Abbreviations are as follows: NC, noncompliant with Phase II emission standard of the Clean Air Act Amendments of 1990 (Public Law 101-549), which is 1.2 pounds of sulfur dioxide per million Btu; bst, billion short tons.

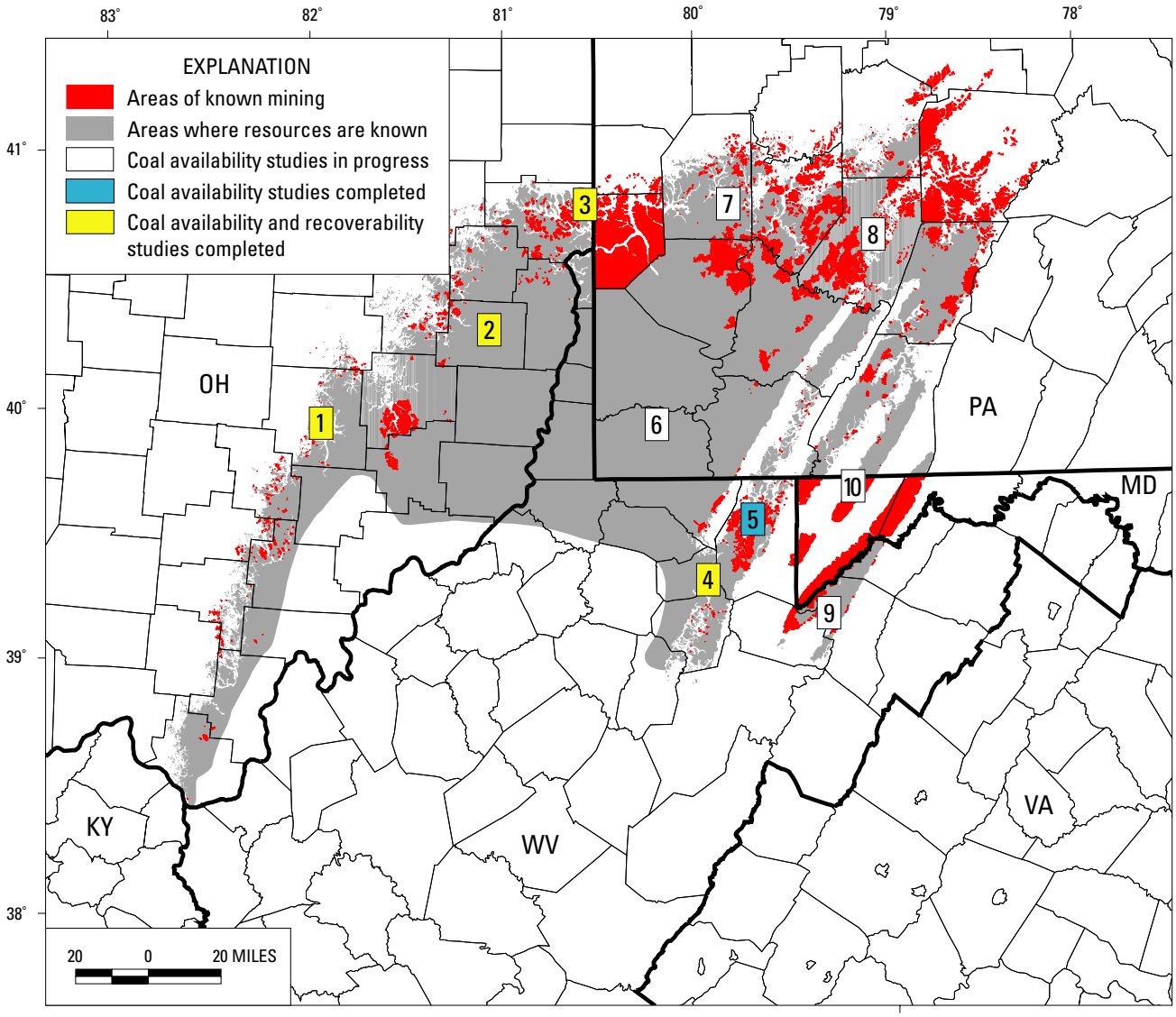


**Figure 15.** Map of the Upper Freeport coal bed showing the coal availability (CA) and coal recoverability (CR) study areas that include the Upper Freeport. The 7.5-minute quadrangles are numbered as follows: 1, Zanesville East; 2, Jewett; 3, East Palestine; 4, Thornton; 5, Valley Point; 6, Waynesburg; 7, Saxonburg; 8, Clymer; 9, Mount Storm Lake; 10, Grantsville. Coal bed map modified from figure 20 in Chapter D of this report.

**Table 10.** Original, remaining, restricted, available, recoverable, and economically recoverable resources of the Upper Freeport coal bed, as reported in the Coal Availability/Recoverability Studies (CARS) results in the northern Appalachian Basin coal region, by State and 7.5-minute quadrangle (in millions of short tons).

[Totals may not equal sum of components because of independent rounding. Symbols are as follows: Dash (—) indicates coal recoverability (CR) study not conducted in this quadrangle and (or) on the coal bed; asterisk (*) indicates value was calculated on the basis of four CR studies, with original resources totaling 490 million short tons. For further details, see Appendix 3.]

| State and quadrangle | Original | Remaining | Restricted | Available | Recoverable | Economically recoverable |
|---|---|---|---|---|---|---|
| **Ohio** | | | | | | |
| East Palestine | 92 | 80 | 13 | 67 | 27 | 1 |
| Jewett | 223 | 223 | 23 | 200 | 120 | 41 |
| Zanesville East | 86 | 81 | 21 | 60 | 38 | 1 |
| **West Virginia** | | | | | | |
| Thornton | 89 | 89 | 62 | 28 | 38 | 2 |
| Valley Point | 135 | 93 | 24 | 69 | — | — |
| **Total** | 625 | 565 | 143 | 423 | 224* | 53* |
| **Percent of original** | 100 | 91 | 23 | 68 | 46* | 11* |

nal resources of all coal beds in the 14 CA studies in the region (table 8). Estimates of Upper Freeport coal (in millions of short tons) in those 5 quadrangles are as follows: original, 625; remaining, 565; restricted, 143; available, 423 (fig. 14, table 10, Appendix 3). In the 4 CR study quadrangles, estimated recoverable resources are 224 million short tons and economically recoverable resources are 53 million short tons (table 10). The estimated economically recoverable resource constitutes 11 percent of the estimated original Upper Freeport coal resource of 490 million short tons in the 4 CA studies for which CR studies were conducted (table 10).

#### LOWER KITTANNING COAL BED

The Lower Kittanning coal bed is included in 8 of the 14 CA studies and in 6 of the 10 CR studies that have been completed to date in the northern Appalachian Basin coal region (fig. 16). The 8 CA studies that have been completed represent 2 percent of the area of known resources of the Lower Kittanning coal bed as depicted in both figure 16 of this chapter and figure 5 of Chapter E of this report. Five of the 6 CA studies that are in progress include the Lower Kittanning; when complete, the results presented in this chapter may be altered considerably. The estimated original, remaining, restricted, available, recoverable, and economically recoverable resources are presented in table 11. Estimated original resources of Lower Kittanning coal in the 8 CA study quadrangles make up 12 percent of the total original resources of all coal beds in the 14 CA studies in the region (table 8). Estimates of Lower Kittanning coal (in millions of short tons) in those 8 quadrangles are as follows: original, 769; remaining, 736; restricted, 275; and available, 461 (fig. 14, table 11, Appendix 3). In the 6 CR-study quadrangles, estimated recoverable resources are 206 million short tons and economically recoverable resources are 88 million short tons (table 11). The estimated economically recoverable resource constitutes 12 percent of the estimated original Lower Kittanning coal resource of 706 million short tons in the 6 CA studies for which CR studies were conducted (table 11).

## DISCUSSION

Figure 14 shows a summary pie chart for the coal beds in the 14 CA study quadrangles in the northern Appalachian Basin coal region, pie charts that characterize each of the three NCRA coal beds, and a pie chart for the collective other non-NCRA coal beds in the region. Of the 6.6 billion short tons of the original coal resources identified in the 14 completed CA studies in the northern Appalachian Basin coal region, 16 percent have been mined and lost in mining, 7 percent are constrained by land-use considerations, and 19 percent are excluded by technologic factors, leaving 58 percent of the original resource available for development (fig. 14). Appendix 3 contains details by quadrangle and coal bed. The Upper Freeport and Lower Kittanning coal beds exhibit very similar results, although neither bed has been mined extensively in CARS quadrangles (10 percent and 4 percent, respectively), and an unusually high amount (two-

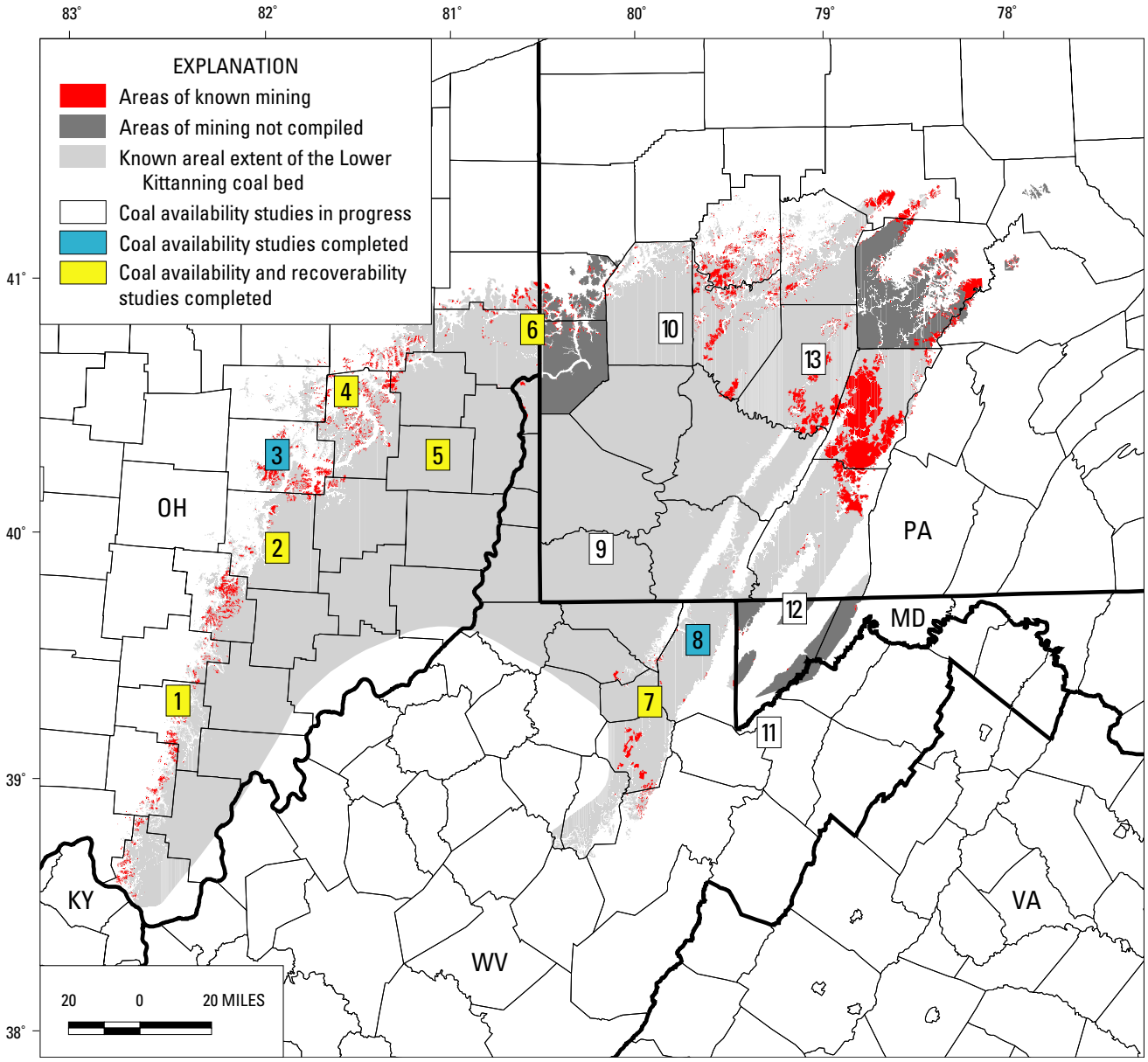


**Figure 16.** Map of the Lower Kittanning coal bed showing the coal availability (CA) and coal recoverability (CR) study areas that include the Lower Kittanning. The 7.5-minute quadrangles are numbered as follows: 1, Zaleski; 2, Zanesville East; 3, Randle; 4, Strasburg; 5, Jewett; 6, East Palestine; 7, Thornton; 8, Valley Point; 9, Waynesburg; 10, Saxonburg; 11, Mount Storm Lake; 12, Grantsville; 13, Clymer. Coal bed map modified from figure 5 in Chapter E of this report.

**Table 11.** Original, remaining, restricted, available, recoverable, and economically recoverable resources of the Lower Kittanning coal bed, as reported in the Coal Availability/Recoverability Studies (CARS) results in the northern Appalachian Basin coal region, by State and 7.5-minute quadrangle (in millions of short tons).

[Totals may not equal sum of components because of independent rounding. Symbols are as follows: Dash (—) indicates coal recoverability (CR) study not conducted in this quadrangle and (or) on the coal bed; asterisk (*) indicates value was calculated on the basis of six CR studies, with original resources totaling 706 million short tons. For further details, see Appendix 3.]

| State and quadrangle | Original | Remaining | Restricted | Available | Recoverable | Economically recoverable |
|---|---|---|---|---|---|---|
| **Ohio** | | | | | | |
| East Palestine | 106 | 105 | 56 | 53 | 18 | 1 |
| Jewett | 128 | 128 | 86 | 41 | 23 | 0 |
| Randle | 32 | 31 | 2 | 30 | — | — |
| Strasburg | 32 | 6 | L | 5 | 2 | 2 |
| Zaleski | 15 | 11 | 6 | 5 | 3 | 3 |
| Zanesville East | 206 | 206 | 58 | 148 | 32 | 11 |
| **West Virginia** | | | | | | |
| Thornton | 219 | 219 | 55 | 164 | 128 | 70 |
| Valley Point | 31 | 31 | 16 | 15 | — | — |
| **Total** | 769 | 736 | 275 | 461 | 206* | 88* |
| **Percent of original** | 100 | 96 | 36 | 60 | 29* | 12* |

thirds) of the original Upper Freeport coal resource is available for development. The Pittsburgh, of course, has been mined heavily (40 percent mined out) in the areas studied, land-use restrictions are almost nonexistent, and technologic restrictions are minimal. Slightly over one-half of the original Pittsburgh resource is available for mining (fig. 14).

In the northern Appalachian Basin coal region, the number of coal beds studied per 7.5-minute quadrangle ranges from 2 to 8, with 5 the average and 6 both the median and mode. The three coal beds together constitute nearly one-half (47 percent) of the estimated 6.6 billion short tons of original resources in the 18 quadrangles studied. All of the other coal beds combined represent little more than one-half (53 percent) of the total original resource. As shown in figure 14, the statistics of the three individual NCRA coal beds vary significantly, yet the statistics for all of the other coal beds are essentially the same as for all of the beds together, including the three coal beds.

Land-use restrictions (fig. 17) are 7 percent of the original resource; populated areas (towns) account for 42 percent of those restrictions (nearly the same as in the central Appalachian Basin coal region). Parks or forests have less of an impact in the northern Appalachian Basin coal region (18 percent) than in the central Appalachian Basin coal region (26 percent), but roads and railroads play a bigger role in restricting mining (23 percent) in the northern Appalachian Basin coal region. The Upper Freeport and Lower Kittanning coal beds show a nearly 50 percent impact from towns while the Pittsburgh exhibits a larger impact by parks and forests.

Technologic restrictions constrain approximately one-fifth of the original resource, and four-fifths of that is caused by the thinness of the coal beds. Coal beds too close above or below affect neither the Pittsburgh nor the Upper Freeport coal beds, but nearly one-eighth of the Lower Kittanning coal bed is restricted from mining by thicker beds above or below (interburden is too thin, fig. 18). Active oil and gas wells account for more than one-eighth of the technologic restrictions on the Pittsburgh coal.

Results from 14 CA studies and 10 CR studies in the northern Appalachian Basin coal region indicate, in the areas studied, that while 59 percent of the original coal resource is available for development, more than one-third of the available coal will be lost in future mining and washing of the coal, and less than one-half of the recoverable coal will be economic to mine at current mining costs (fig. 19). While an average of 14 percent of the original resource of all beds in the CARS quadrangles is economically recoverable, the Pittsburgh is estimated as 21 percent, the Upper Freeport as 9 percent, and the Lower Kittanning as 12 per-

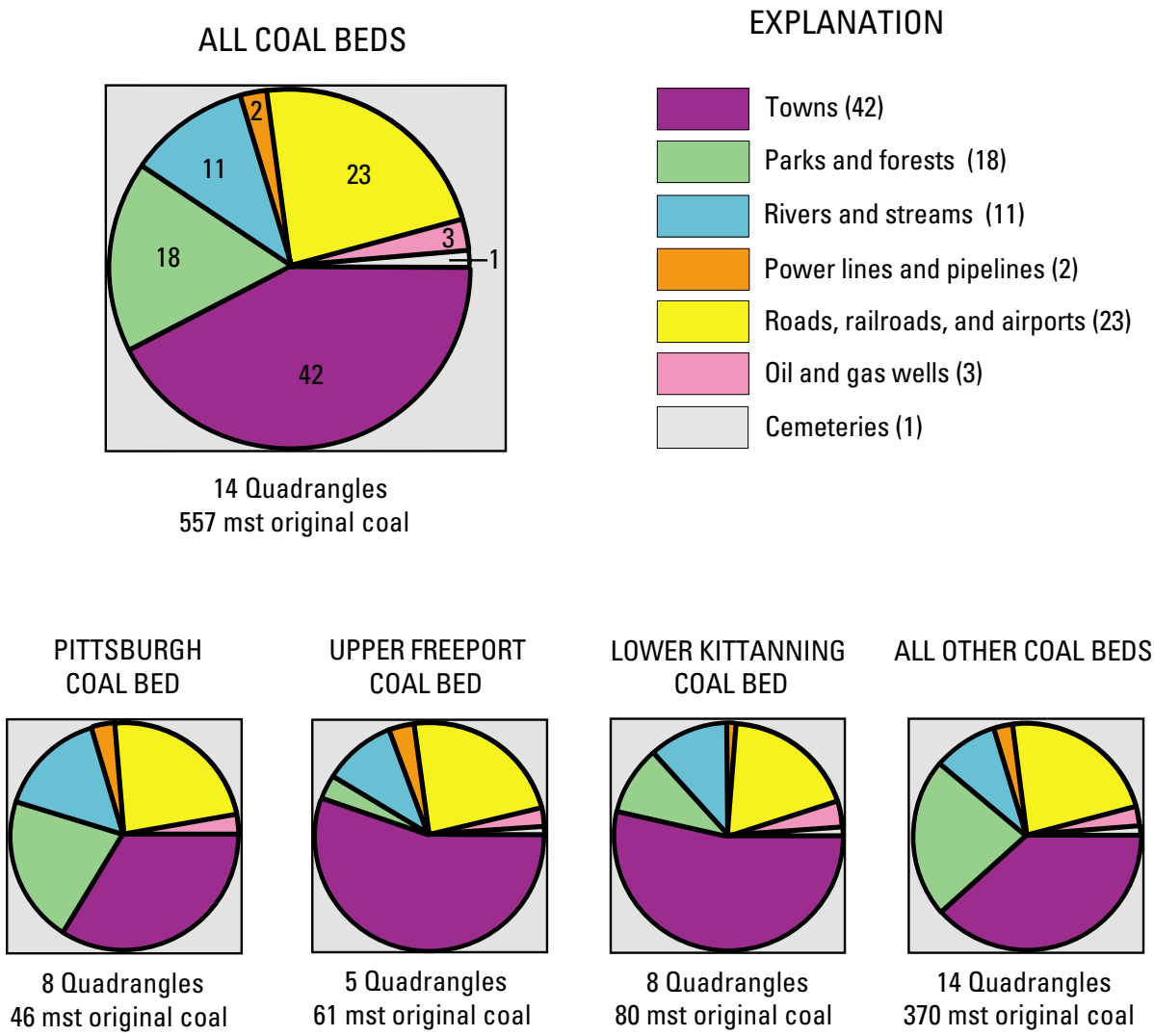


**Figure 17.** Pie charts summarizing the land-use restrictions (7 percent of the original coal resource, from figure 14) in the 14 7.5-minute quadrangles in the northern Appalachian Basin coal region for which coal availability (CA) studies were conducted. The largest pie diagram summarizes all of the beds included in the CA study areas in the 14 quadrangles. The small pie charts characterize each of the three National Coal Resource Assessment (NCRA) coal beds: Pittsburgh, Upper Freeport, and Lower Kittanning. The last small pie chart represents all of the other coal beds (excluding the three NCRA coal beds) in the 18 quadrangles. mst, millions of short tons.

cent. None of the available coal in the 14 areas studied meets the current emission-level compliance standards of 1.2 lbs $SO_2$/million Btu.

## SUBREGIONAL STUDIES IN THE NORTHERN APPALACHIAN BASIN COAL REGION

The OGS recently completed the first subregional small-scale coal availability study in the northern Appalachian Basin coal region (McDonald and Wolfe, 1999). The Upper Freeport coal bed was selected because of its production history and potential, and also because it is one of the beds studied in the NCRA. The study covers more than 130 7.5-minute quadrangles and approximately 7,000 $mi^2$ (fig. 20). The available resources are estimated as 7.2 billion short tons, 67 percent of the original resource.

Comparison with individual 7.5-minute quadrangle studies in the northern Appalachian Basin coal region indicates that the subregional area is impacted more by technologic restrictions than the other study areas. This is logical, however, because the regional study covers the entire extent of the Upper Freeport within the State, including the deeper part of the Appalachian Basin where the coal is thinner, deeper, and unmined. The previous three CA study 7.5-

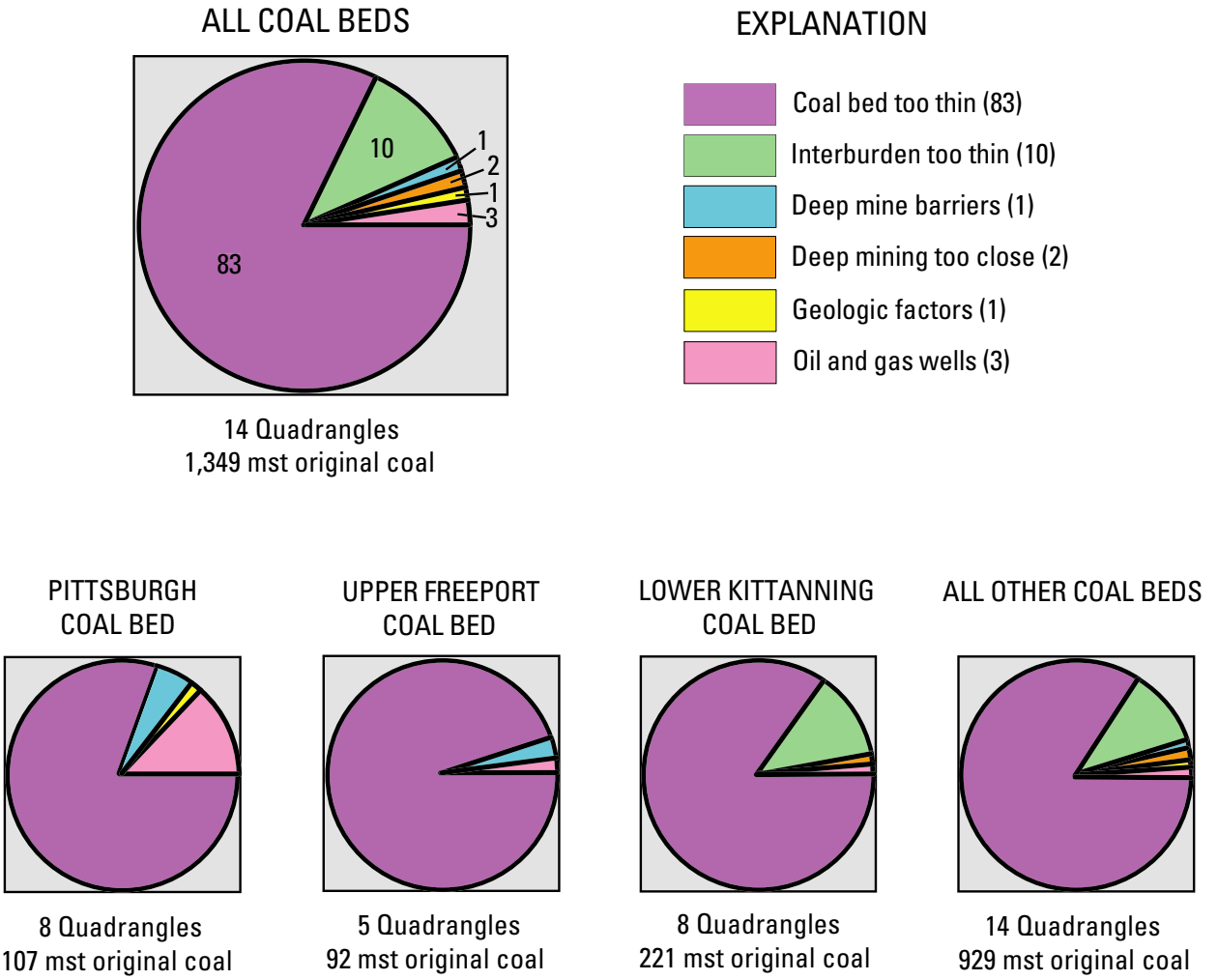


**Figure 18.** Pie charts summarizing of the technologic restrictions (19 percent of the original coal resource, from figure 14) in the 14 7.5-minute quadrangles in the northern Appalachian Basin coal region for which coal availability (CA) studies were conducted. The largest pie diagram summarizes all of the beds included in the CA study areas in the 14 quadrangles. The small pie charts characterize each of the three National Coal Resource Assessment (NCRA) coal beds: Pittsburgh, Upper Freeport, and Lower Kittanning. The last small pie chart represents all of the other coal beds (excluding the three NCRA coal beds) in the 14 quadrangles. mst, millions of short tons.

minute quadrangles in Ohio were located along the shallower western edges of the coal region where mining has been active and data are available. Results of the subregional study indicate that 67 percent of the Upper Freeport coal is available for mining; the results are almost identical to the results of five individual quadrangle studies that include the Upper Freeport in the northern Appalachian Basin coal region.

## CONCLUSIONS

Overall, the results of the CARS project for 32 individual 7.5-minute quadrangles that have been completed in the northern and central Appalachian Basin coal regions, although differing in detail, are remarkably similar. In both of the northern and central Appalachian Basin coal regions, 16 percent of the original coal resource has been mined and lost in mining; 3 and 7 percent, respectively, are constrained by land-use considerations; 31 and 19 percent by technologic restrictions; 50 and 59 percent are available; 31 and 33 percent are recoverable; and 10 and 14 percent are economically recoverable. The main difference between CARS results completed within the two regions is that approximately one-half of the coal, prior to washing or blending, in the central Appalachian Basin coal region would meet the current emission-level compliance standard of 1.2 lbs $SO_2$/million Btu, while in the northern Appalachian Basin coal region none would qualify as compliant coal at current standards.

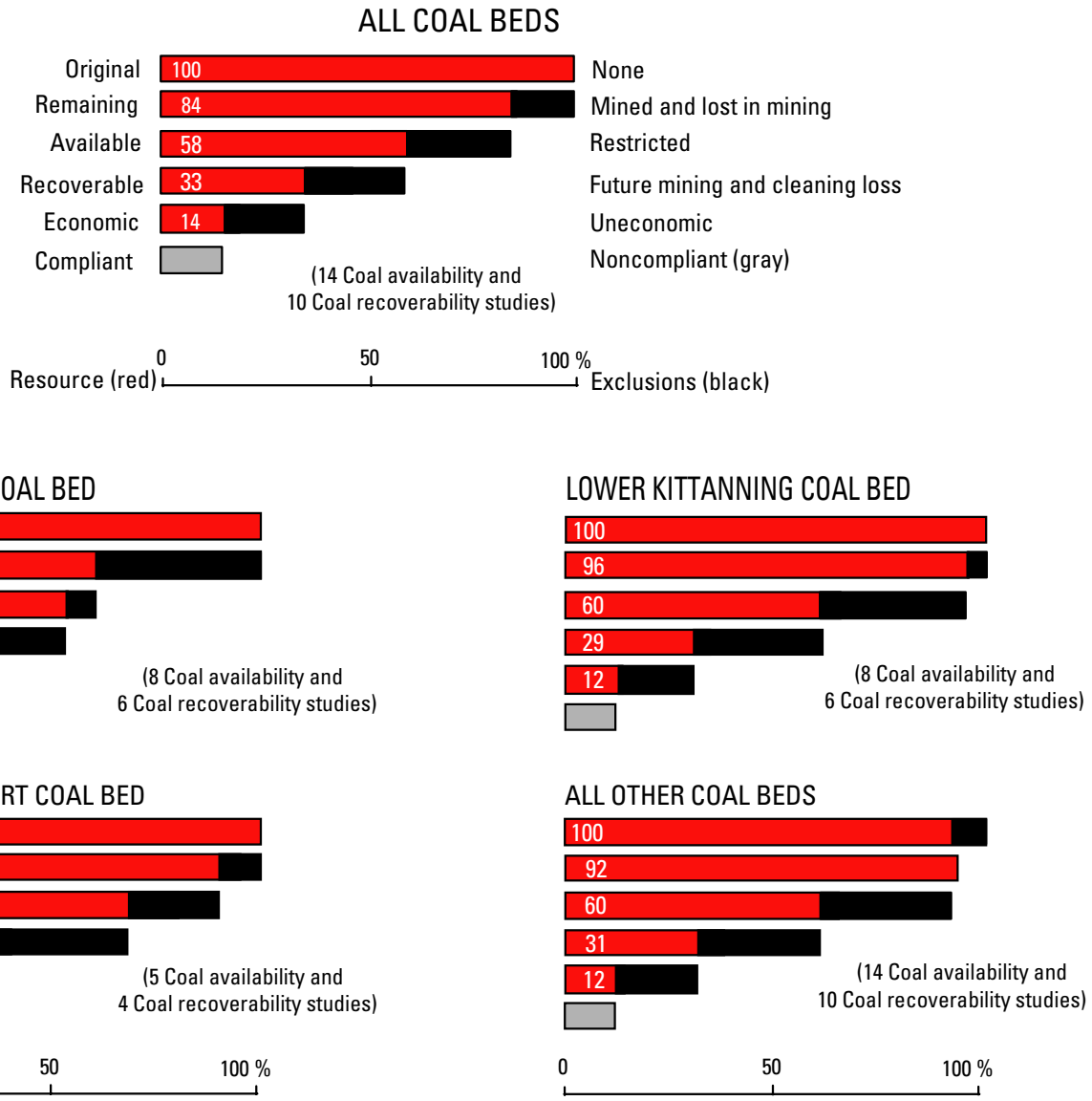


**Figure 19.** Bar charts summarizing the estimated original, mined and lost-in-mining, restricted, available, recoverable, economic, and compliant coal resources in the 14 7.5-minute quadrangles for which coal availability (CA) studies were conducted and the 10 7.5-minute quadrangles for which coal recoverability (CR) studies were conducted in the northern Appalachian Basin coal region. The upper bar graph summarizes all of the beds included in the 14 CA study areas and 10 CR study areas. Three of the lower bar graphs characterize each of the National Coal Resource Assessment (NCRA) coal beds: Pittsburgh, Upper Freeport, and Lower Kittanning. The fourth lower bar graph represents all of the other coal beds (excluding the three NCRA coal beds) in the quadrangles.

When the CARS project first began, it was believed that by carefully selecting study areas characteristic of their locale, the results could be extrapolated from each individual quadrangle to ones nearby. From the 32 individual quadrangles studied in the northern and central Appalachian Basin coal regions, the numbers are fairly constant on an overall regional basis; however, results vary significantly even between adjacent quadrangles and from bed to bed within each quadrangle. Therefore, results from individual quadrangle studies should not be extrapolated to predict availability and recoverability results either at any individual specific sites or throughout the region. Nevertheless, detailed GIS-assisted study of the individual 7.5-minute quadrangles is an important first step in gaining insight as to the significant factors affecting availability and economic recoverability in each locale. The significant factors then may be applied, but not extrapolated, on a regional basis.

The study areas completed to date have shown that the GIS techniques can produce detailed, accurate results from both large-scale and small-scale study areas. Restrictions to mining have a significant impact on the potential for coal resource development. Not only do the CARS data delineate

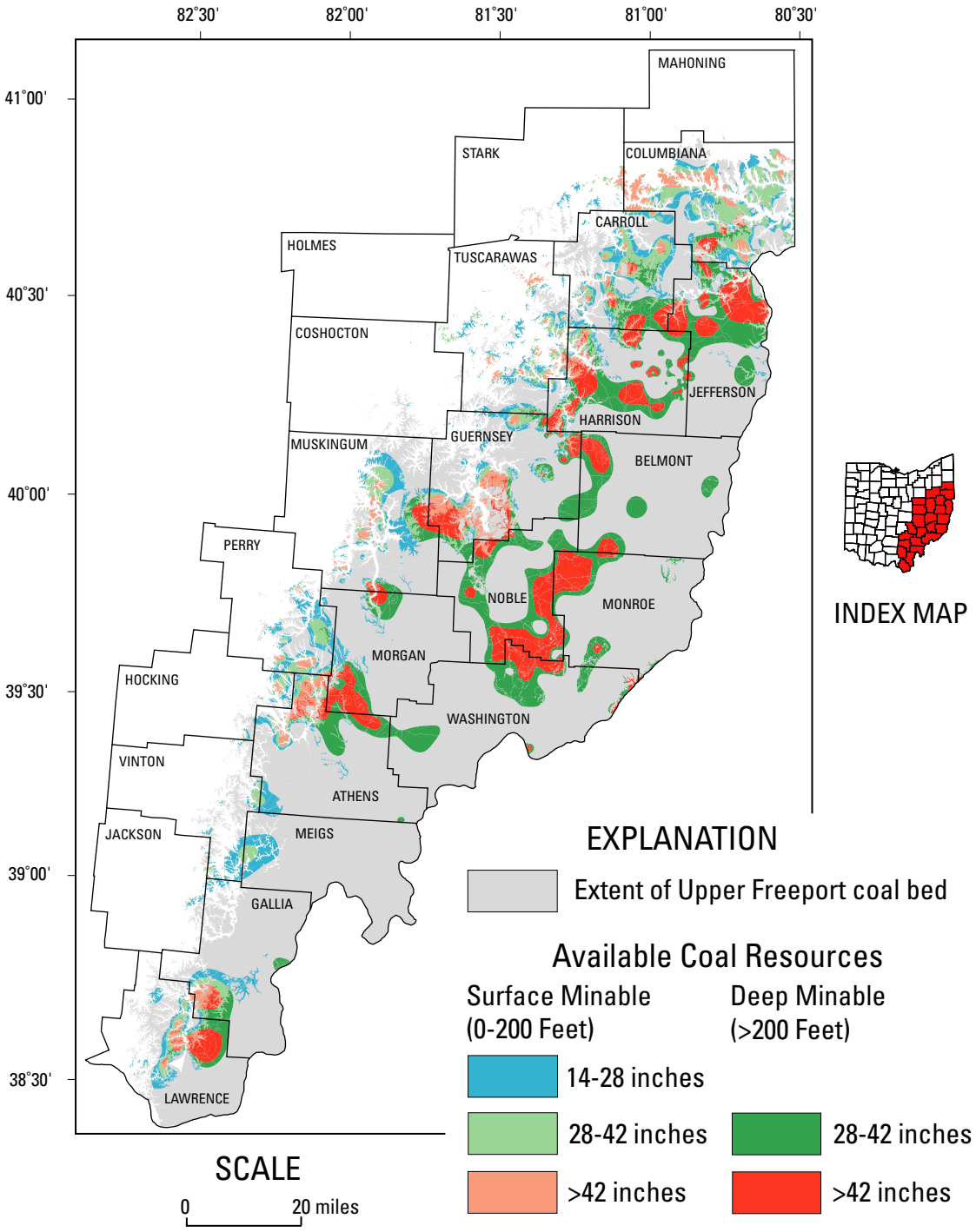


**Figure 20.** Coal availability (CA) study map of available resources of the Upper Freeport coal bed in Ohio. This is the largest single area (equivalent to approximately 150 7.5-minute quadrangles) studied in the Appalachian Basin. The results closely match those of the five quadrangles that contain the Upper Freeport coal bed. Modified from McDonald and Wolfe (1999).

where coal is restricted from mining, but the GIS programs also identify and depict areas where coal may be economically recoverable. Improved GIS techniques and databases allow the study of multiple quadrangle areas in single models and a more regional approach within a reasonably short time frame. The CARS methodology can and should be applied more routinely to future coal resource assessment. Application of the CARS findings can predict which coal beds will be mined in the near future on a cost-competitive basis. Finally, the two socioeconomic reports prepared as part of CARS suggest that traditional coal-producing regions and local areas within the Appalachian Basin may be severely impacted as their economically recoverable and environmentally acceptable coal resources approach depletion.

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# APPENDIX 1

## PUBLISHED AND UNPUBLISHED REPORTS THAT HAVE CONTRIBUTED TO THIS CHAPTER, BY COAL REGION AND STATE

[The name of each 7.5-minute quadrangle for which a coal availability or recoverability study was performed is shown in boldface.]

### Central Appalachian Basin Coal Region

#### Kentucky


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## Northern Appalachian Basin Coal Region

### Ohio

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## APPENDIX 2

### SUMMARY OF ESTIMATED COAL RESOURCES IN 18 COAL AVAILABILITY AND 15 COAL RECOVERABILITY STUDY AREAS IN THE CENTRAL APPALACHIAN BASIN COAL REGION, BY STATE, 7.5-MINUTE QUADRANGLE, AND COAL BED (IN THOUSANDS OF SHORT TONS)

[Tonnage is as reported in the 7.5-minute quadrangle source documents that are cited in Appendix 1. Totals may not equal sum of components because of independent computer generation and rounding. The percent of original is equal to the economically recoverable resource tonnage divided by the original coal resource tonnage, expressed as a percentage. Abbreviations and symbols are as follows: NCRA, National Coal Resource Assessment; dash (—) indicates no entries in the recoverable, economically recoverable, and percent of original fields when a coal recoverability study has not been conducted in the quadrangle or on an individual coal bed; asterisk (*) indicates calculation performed on the basis of 15 coal recoverability studies, with original resources totaling 9,695 million short tons.]

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## APPENDIX 3

### SUMMARY OF ESTIMATED COAL RESOURCES IN 14 COAL AVAILABILITY AND 10 COAL RECOVERABILITY STUDY AREAS IN THE NORTHERN APPALACHIAN BASIN COAL REGION, BY STATE, 7.5-MINUTE QUADRANGLE, AND COAL BED (IN THOUSANDS OF SHORT TONS)

[Tonnage is as reported in the 7.5-minute quadrangle source documents that are cited in Appendix 1. Totals may not equal sum of components because of independent computer generation and rounding. The percent of original is equal to the economically recoverable resource tonnage divided by the original coal resource tonnage, expressed as a percentage. Abbreviations and symbols are as follows: NCRA, National Coal Resource Assessment; dash (—) indicates no entries in the recoverable, economically recoverable, and percent of original fields when a coal recoverability study has not been conducted in the quadrangle or on an individual coal bed; asterisk (*) indicates calculation performed on the basis of 10 coal recoverability studies, with original resources totaling 5,710 million short tons.]

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