Mineable Coal Reserves of Missouri

by Charles E. Robertson

RI 54

COVER:

Mined land reclamation is now a part of all coal strip mining in Missouri. At Peabody Coal Company's Power Mine in Henry County, which supplies fuel for Kansas City Power and Light Company's steam-electric power plant at Montrose, reclamation closely follows mining. While a monster stripping machine works to uncover a coal seam, a bulldozer and small dragline smooth ridged spoil, to be followed by seeding and other treatment to return the land to some productive use.

Photo courtesy Peabody Coal Co.

Report of Investigations No. 54
1984
Second Printing

MINEABLE COAL RESERVES OF MISSOURI

By Charles E. Robertson

MISSOURI DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGY AND LAND SURVEY
Wallace B. Howe, Director and State Geologist
P.O. Box 250, Rolla, Missouri 65401

MINEABLE COAL RESERVES OF MISSOURI

By Charles E. Robertson

Air Pollution Demonstration
Grant No. 70 B-2801 D

Missouri's mined-land reclamation laws became effective in 1972, but reclamation was being practiced in some areas prior to enactment of legislation requiring it. Lands mined in 1968 and reclaimed and reseeded in 1969 are back in productive use at the Power Mine of Peabody Coal Company, near Montrose in Henry County.
Photo courtesy Peabody Coal Company.

Library of Congress
Card Catalog No. 73-620124

Robertson, Charles E., 1984, MINEABLE COAL RESERVES OF MISSOURI: Missouri Department of Natural Resources, Division of Geology and Land Survey, Rept. Inv..54, viii + 71 p., 20 figs., 18 tbls.

October 1983

MISSOURI DEPARTMENT OF NATURAL RESOURCES

DIVISION OF GEOLOGY AND LAND SURVEY

***Wallace B. Howe, Ph.D., Director and State Geologist**
***Jerry D. Vineyard, M.A., Assistant Director for Geological Survey and Water Resources**
Robert E. Myers, P.E., L.S., Assistant Director for Land Survey and Dam Safety

ADMINISTRATION AND GENERAL SUPPORT

DIVISION ADMINISTRATION

Edith E. Hensley, Executive I
Tami Martin, Adm. Secretary
Charlotte Pepmiller, Clerk-Typist III
Joanne Bick, M.S., Programmer II
Elena A. Lenox, Terminal Operator
Barbara Evans, Account Clerk II

Lois Miller, Clerk-Typist II
Walter Bruss, Labor Foreman
Gene Lewis, Maint. Man I
Robert Fryer, Laborer II
Danny Sherman, Laborer II

INFORMATION SERVICES

**W. Keith Wedge, Ph.D., Chief*
Robert H. Hansman, Editor
Arthur W. Hebrank, B.S., Geologist III
Barbara Miller, Composer Operator I
Marcia Cussins, Asst. Librarian
Mary Jo Horn, Clerk-Typist II

Kittie Hale, Publications Dist. Mgr.
Betty Harris, Clerk-Typist II
Gary Clark, B.S., Artist III
Susan C. Dunn, B.F.A., Artist II
Billy G. Ross, Artist II
Phillip Streamer, Artist I

GEOLOGICAL SURVEY

*Jerry D. Vineyard, M.A., Asst. State Geologist and Program Director

**J. Hadley Williams, Ph.D., Principal Geologist*
Thomas L. Thompson, Ph.D., Sr. Research Geol.
Vacant, Geologist III

Gregory M. Lovell, Chemist I
Sharon Lemasters, Clerk III
Sandra E. Miller, Clerk-Typist II

ENGINEERING GEOLOGY

Thomas J. Dean, B.S., Chief
James W. Duley, B.S., Geologist III
James Vaughn, B.S., Soil Scientist III
Mark W. Reising, B.S., Geologist II
Donald H. Meier, B.S., Geologist II
Gary St. Ivany, B.A., Geologist II
Peter Price, B.S., Geologist II
Jon Kraft, B.S., Geologist I
Deborrah Breuer, Clerk-Steno. III

OIL & GAS/ SUBSURFACE GEOLOGY

Ira R. Satterfield, M.S., Chief
Bruce Netzler, M.S., Geologist III
Rex Bohm, B.S., Geologist II
James Palmer, B.S., Geologist II
Ken Deason, B.S., Geologist II
Kim Haas, Engineering Tech. I
Golda Roberts, Clerk-Typist III
Valda Fuhring, Clerk-Typist II
Jerry Plake, Lab. Tech.
Hairl Dayton, Jr., Lab. Tech.

METALLIC & INDUSTRIAL MINERALS

**James A. Martin, M.S., Chief*
Heyward Wharton, M.A., Geologist III
Eva B. Kisvarsanyi, M.S., Geologist III
Ardel W. Rueff, B.A., Geologist III
John W. Whitfield, B.A., Geologist III
Mark Middendorf, B.S., Geologist II
Michael McFarland, B.S., Geologist II
James C. Brown, Jr., B.S., Geologist I
Kathryn Adamick, Clerk-Steno II

MINERAL FUELS

Charles E. Robertson, M.A., Chief
David Work, B.S., Geologist II
**David C. Smith, B.S., Geologist II*
Larry Nuelle, M.S., Geologist II
Joy L. Bostic, B.S., Geologist II
Thomas Beard, Engineering Tech. I
Sandra E. Miller, Clerk-Typist II

WATER RESOURCES RESEARCH AND PLANNING

*Jerry D. Vineyard, Program Director

Jeanette A. Barnett, B.S., Planner I

WATER RESOURCES DATA AND RESEARCH

Don E. Miller, M.S., Chief
James Vandike, M.S., Geologist III
Mark Marikos, B.S., Geologist II
Artney Lewis, B.S., Geologist II
Donald Hammer, B.S., Planner II
Donald Wortham, B.S., Geology Tech. I
Donley Jones, B.S., Engineering Tech. I
D. Jean Hale, Clerk-Steno. II

WATER RESOURCES PLANNING

Robert Dunkeson, M.A., Planner IV
Charles P. Michael, B.A., Planner II
Vacant, Geologist I
Elaine R. Luebbert, Clerk-Typist II

LAND SURVEY

Robert E. Myers, P.E., L.S., State Land Surveyor and Program Director

Glenda Henson, Clerk-Steno. III
Carolyn Ellis, Clerk-Typist II
Ruth Allen, Corner Registration Clerk
Ralph Hess, Draftsman I

FIELD SURVEYS

Norman L. Brown, P.E., L.S., Chief of Field Surveys
Robert L. Wethington, P.E., L.S., Project Surveyor
John D. Paulsmeyer, L.S., Project Surveyor
J. Michael Flowers, L.S., Project Surveyor
O. Dan Lashley, L.S., Project Surveyor
Bruce D. Carter, Land Survey Tech. I
Michael W. Lloyd, Engineering Tech. I
Michael Cape, Engineering Aid

LAND SURVEY RECORDS REPOSITORY

Jack C. McDermott, Land Survey Records Manager
James L. Matlock, Microfilm Technician
Diane R. Hess, Microfilm Records Technician
Linda S. Miller, Jacketing & Indexing Specialist
Thomas M. Cooley, Land Survey Tech. I

DAM AND RESERVOIR SAFETY

Robert E. Myers, P.E., Program Director

Brian J. Swenty, P.E., Chief Engineer
Russell C. Adams, P.E., Engineer
James L. Alexander, B.S., Engineer
Marge Paulsmeyer, Clerk-Typist II

*Certified Professional Geologist

P.O. Box 250
Rolla, MO 65401
314-364-1752
837-4082, 4083 tie line

CONTENTS

ILLUSTRATIONS

TABLES

MINEABLE COAL RESERVES OF MISSOURI

By Charles E. Robertson

ABSTRACT

New estimates of Missouri's coal resources show total coal resources of 49 billion tons. Of this total, 12.3 billion tons is classed as a remaining reserve and 3.7 billion tons is a strippable reserve.

Missouri possesses ample coal to support an expanded coal mining industry, according to new estimates. The immediate primary use of Missouri coal will continue to be for firing mine-mouth steam-electric power plants. Eventually, a more important use may be conversion to other fuels, including pipeline gas, solvent refined coal, low Btu gas and liquid petroleum substitutes.

Remaining reserves are classified according to sulfur content. Data indicate that no significant areas of low-sulfur coal are present in Missouri. Approximately half of the state's coal reserve contains from 4 to 5 percent sulfur, and one-fourth has from 3 to 4 percent sulfur. Less than one-tenth contains less than 3 percent sulfur and the remainder more than 5 percent.

INTRODUCTION

The decade of the 1960's will be remembered as the years in which the national and, in fact, the worldwide energy crisis became evident. Early in the decade energy consumption in the United States had progressed to a point where supplying the ever increasing amounts of fuels needed to feed the growing demand had become a pressing national problem. Further development of Missouri's coal resources is a small but important part of the answer to that problem.

Other related problems emerged during the decade. These are the problems of air and water pollution and of land disturbance by mining which are directly related to coal production in Missouri. Missouri coal is high in sulfur, which is considered to be an air pollutant, and practically all of it is produced by strip mining.

The present study was undertaken to provide useful information that can be used in solving these problems.

Missouri has been an important (though not a major) producer of coal since the mid-19th Century and possesses significant reserves of mineable coal. Production reached its peak in 1917 when nearly 6 million tons were mined. It fluctuated between 3 and 5 million tons per year from 1917 until 1948, when a general decline in coal mining began. The loss of the retail market to gas and fuel oil and of the railroad market to diesel-fueled locomotives caused a steady decline in coal production, until a low of 2.5 million tons was reached in 1948.

This decline was short-lived, however, and the following years ushered in a new era in Missouri coal mining. The retail and railroad markets were replaced by the electric utilities market with the construction of large mine-mouth power plants.

The resurgence of coal mining in the state in the late 1950's and early 1960's, with the promise of a rapidly increasing and long-term market for coal, portended an expanding coal mining industry in Missouri. With this in mind, the Missouri Geological Survey began to compile data on coal resources in the early 1960's.

The twofold purpose of this investigation was to document the fact that Missouri possesses ample resources to support an expanded coal mining industry and to provide information that would aid in the discovery and development of coal deposits.

In 1968 the Missouri Geological Survey entered into an agreement with the National Air Pollution Control Administration (now OAP) to study Missouri's coal resources under joint financing by the Survey and NAPCA. Although NAPCA was at that time interested primarily in reserves of low-sulfur coal and no reserves of low-sulfur coal were known in Missouri, it was agreed that Missouri coal would of necessity continue to be used as a source of fuel for steam-electric power plants. Therefore, an updated resource estimate would be of great importance in solving problems related to the national energy crisis. Furthermore, it was recognized that if the removal of sulfur compounds from stack gases was required, sulfur content of the coal would be of great importance. Also, if raw coal was used with no provision for sulfur removal, coal containing a high Btu content but with a relatively low sulfur content would be the preferred fuel. It was also recognized that under extremely favorable circumstances, where the sulfur could be marketed as a by-product sulfur compound such as sulfuric acid, then a high sulfur content could become an asset rather than a liability and a potentially masterful conservation measure could be achieved. Therefore, much emphasis was placed on the sulfur content of Missouri's coal deposits.

A 3-year, two-stage research program was outlined. Stage I lasted a year, and was completed June 30, 1970. Its purpose was to compile and publish maps and tonnage estimates concerning the quantity and quality of Missouri's coal resources. Results were published by the Missouri Geological Survey as Report of Investigations No. 48, Evaluation of Missouri's Coal Resources (Robertson 1971). Included are resource estimates by region and county according to coal bed, bed thickness and sulfur content, and maps of the more important coal beds showing areas favorable for exploration and development.

ACKNOWLEDGMENTS

The National Air Pollution Control Administration of HEW (now Office of Air Programs of EPA) provided financial aid for the project. Dr. Albert P. Talboys arranged for financial aid during the early stages of the project and Russell C. Flegal provided guidance and encouragement during the course of the project.

Personnel of the U. S. Bureau of Mines Energy Research Center in Pittsburgh, Pennsylvania analyzed core samples of coal collected during the drilling program. Special thanks are due Forrest E. Walker, Chemist-in-Charge of Coal Analysis and his staff, whose cooperation is deeply appreciated.

Bernard Browning of Browning Testing Laboratories, the drilling contractor, and his crew completed the drilling program most satisfactorily despite difficult drilling conditions and bad weather.

The author is indebted to Dr. Wallace B. Howe, State Geologist, for his encouragement and help and to Ardel Rueff of the Survey staff who aided materially in the completion of this project.

Special credit is due Keith Wedge of the Survey staff, whose patience at compiling statistical data and attending to small but important details contributed much to the successful completion of this research effort.

The cooperation of the State Highway Department, on whose property the holes were drilled, is greatly appreciated.

Research was financed in part by Air Pollution Demonstration Grant No. 70 B-2801 D.

COAL FIELDS

DISCOVERY AND PRODUCTION

In 1806, Captain Zebulon Pike reportedly noticed coal cropping out along the Osage River in western Missouri. Coal was mined near the Osage River not far from the present site of Rich Hill in Bates County, prior to 1843. Coal mining also began in the early 1840's at other localities in western Missouri, most notably near Lexington in Lafayette County and near Deepwater in Henry County. Most of these early mines were local-trade wagon mines and were entered by drifts beginning at the outcrop and driven back into the coal seam a few hundred feet, or as far as natural ventilation would allow.

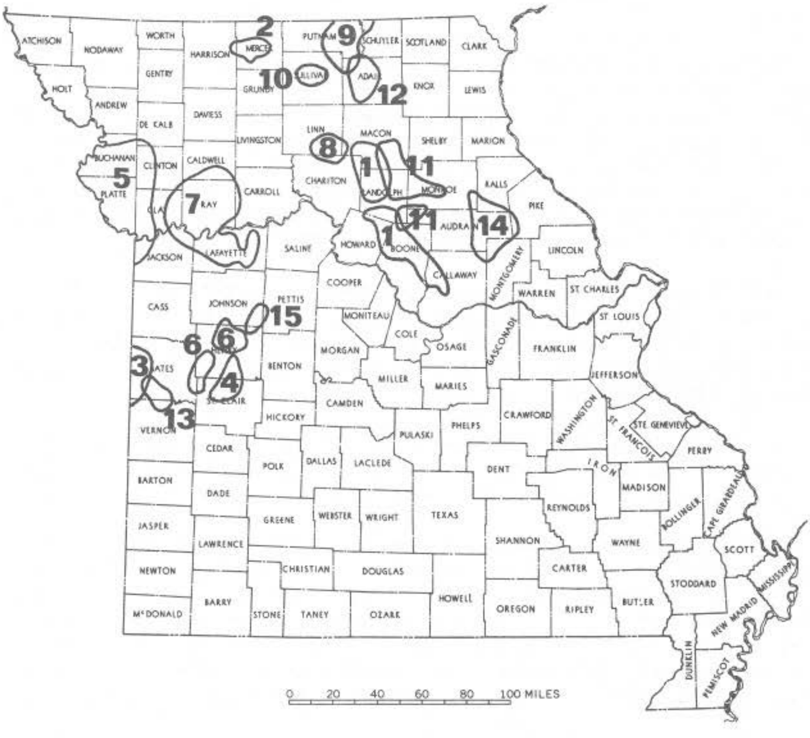
In 1840, 8,000 long tons of coal were produced in Missouri and by 1880, coal mining had become a thriving enterprise. Coal was being used by the railroads for locomotive fuel and some shipping mines had been developed. Most mining was by underground methods. Drifts were driven deeper beyond the outcrop and shafts were being sunk to reach deeper coal.

Most early coal discoveries were accidental. The important Bevier Field was reportedly discovered in 1860 when a young man hired to dig a well complained of having to dig through 6 feet of coal.

Coal production in Missouri reached its peak in 1917 when nearly 6 million tons were mined. Markets included steam coal for railroads plus retail sales for domestic use, industrial plants, and power generation. Production fluctuated between 3 and 5 million tons per year from 1917 until 1948, when a general decline began. Production declined steadily, reaching a low of 2.5 million tons by 1958. This decline was caused by the loss of the retail market to natural gas and fuel oil and of the railroad market to diesel-fueled locomotives.

The following decades, however, ushered in a new era in Missouri coal mining. Strip mining came into its own in Missouri in the 1930's when it began to grow at the expense of underground mining. By the mid-1960's, underground mining had all but ceased in Missouri and strip mining had emerged as the accepted coal-mining method. Replacement of the retail and railroad markets by the electric utilities market paralleled the increase in stripping activity. The trend to large power plants which transmit power long distances required the development of equally large mines which, in turn, required large reserves of strip coal. Existing power plants in Missouri require 3/4 to 2 million tons of coal yearly. If we assume a life expectancy of 40 years for such plants, reserves in excess of 40 to 80 million tons of coal must be available for each facility.

Several plants of this size are now in existence in the state, one very large one which is fired in part by Missouri coal is located just over the state line in Kansas, and doubtless others will be constructed in the future.



1. Bevier Field
2. Cainsville Field
3. Foster Field
4. Jordan Field
5. Leavenworth Field
6. Lewis Field
7. Lexington Field
8. Marceline Field
9. Mendota Field
10. Milan Field
11. Mulky Field
12. Novinger Field
13. Rich Hill Field
14. Vandalia Field
15. Windsor Field

Figure 1

Arrangement of coal fields in Missouri. After Hinds, 1912, p. 28.

Regenerated by these developments, coal production in Missouri soared from a low of 2.5 million tons in 1958 to nearly 4.5 million tons in 1970, and to slightly more than that figure in 1972 after a minor decline in 1971.

LOCATION

Coal-bearing strata underlie more than 23,000 square miles in northern and western Missouri. Most coal mining in the state has been near the line of outcrop where depth to coal is least; this is where the major coal fields are located.

Hinds (1912) divided Missouri's coal mining areas into 15 fields. The important Bevier and Lexington fields were subdivided into districts. Figure 1 illustrates Hinds' arrangement of coal fields. Searight (1949) offered a slightly different interpretation of Missouri's coal fields (fig. 2).

Robertson (1971) recognized Hinds' and Searight's classifications but established nine coal resource regions, some containing more than one coal field, for the purpose of regional discussion. Each region includes several counties, and regional boundaries are drawn at county lines. Robertson's regions are designed so that important coal fields fall entirely within regional boundaries and (where possible) so that coal areas possessing similar or related characteristics are included in the same region. Robertson's regions are shown in figure 3.

Delineation of coal fields and districts is based primarily on mining and/or exploration activity, and many good deposits are located in areas some distance from named coal fields. These deposits are usually remote from population centers or transportation facilities, or lie at some depth beneath the surface and remain undeveloped. They may be regarded as potential coal fields or districts awaiting development.

TOPOGRAPHY

Most of the coal-bearing region of Missouri lies at elevations between 500 and 1,000 feet above mean sea level. A few areas in extreme western and northwestern Missouri slightly exceed 1,000 feet in elevation.

The topography of the entire coal-bearing region is subdued, consisting mostly of flat and rolling plains with a few areas of low hills. Much of the area north of the Missouri River is covered by glacial drift.

Figure 2

Area of coal deposits in Missouri and major coal fields (past and present). After Searight, 1949.

VEGETATION AND LAND USE

Most of the region's vegetation originally consisted of a mixture of grasslands and oak-hickory forests. The northwestern corner of the region was never forested and was originally covered by prairie grasses. The entire region is now a part of the Central Feed Grains and Livestock Region (National Atlas, p. 157) and has been converted to crop and grazing land. Very little virgin prairie remains.

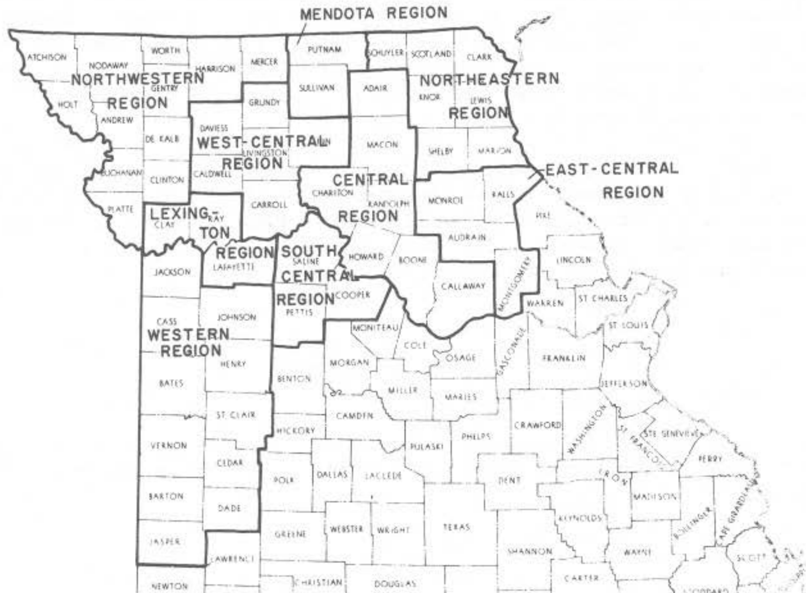


Figure 3

Coal resource regions of Missouri. After Robertson, 1971.

CLIMATE

The entire region is temperate. Average annual precipitation ranges from 40 inches in the south to 32 inches in the northwest, and there is from 14 inches of snowfall in the south to approximately 30 inches in the northwest. Average July temperatures range from 77.3^{o} in the northwest to 79.1^{o} in the southern part of the region. Average January temperatures range from 23.9^{o} in the northwest to 32.8^{o} in the south.

INDUSTRY AND POPULATION

The coal fields of Missouri are located in a predominantly agricultural region, although the greater number of the population is centralized in several urban centers. Kansas City, St. Joseph and Columbia are located directly in the coal area, while Joplin, Springfield, Jefferson City and St. Louis lie near the fringes of the coal fields. Industry and public utilities in all these cities except St. Louis are supplied largely by Missouri coal. Coal needs of the St. Louis area are supplied by the nearby Illinois fields.

Many of the agricultural counties in the coal area are faced with declining population and depressed economic conditions caused by decreasing demand for farm labor. Development of industrial centers within the region would provide jobs and curtail the exodus. The coal resources of the area are a favorable factor in the inducement of industry to the region.

TRANSPORTATION

Fine networks of highways, railroads and pipelines serve the area and could serve as transportation arteries for the products of an expanding coal industry.

QUALITY OF MISSOURI COAL

The quality of a particular coal bed is defined by its rank and grade. A coal's rank is its position in the coalification series: peat through lignite, subbituminous and bituminous coal, to anthracite. Rank reflects the degree to which vegetable matter has been changed by natural geologic processes to the more compact, harder and purer fossil fuels. Grade is the quality of coal related to heating value, ash and sulfur content, and other characteristics of combustion.

Missouri coals are bituminous in rank. The more important characteristics of Missouri's coals are discussed below.

HEATING VALUE

The most important characteristic of a coal is its heating value, which is usually expressed in British thermal units (Btu) per pound. Average heating values were determined for United States coals by Flynn (1949) and are shown in table 1.

Table 1

HEATING VALUES OF UNITED STATES COALS

Rank	Average As Received Btu Content (Btu/lb.)
Anthracite	12,750
Bituminous	13,100
Subbituminous	9,550
Lignite	7,000
All ranks	13,000

(Compiled from Flynn 1949, U.S. Bureau of Mines Information Circular 7538)

Table 4

AVERAGE OF ANALYSES BY COAL BED

				Proximate Analysis				Ultimate Analysis					
Coal Bed	BTU AR	BTU MF	BTU MAF	Moisture AR	VM AR	FC AR	Ash AR	H AR	C AR	N AR	O AR	S AR	Ash AR
Lexington	10,990	13,310	14,280	17.5	40.2	36.7	5.6	6.2	60.8	1.1	23.1	3.2	5.6
Bevier	10,094	11,794	14,047	14.5	35.8	36.0	13.8	5.5	55.7	1.0	18.6	5.4	13.8
Wheeler	10,018	11,672	13,890	14.1	36.1	35.9	13.9	5.4	56.0	1.0	19.0	4.8	13.9
Croweburg	10,706	12,514	14,173	14.4	37.2	38.3	10.0	5.8	59.1	1.1	19.4	4.6	10.0
Lower Ardmore and Fleming	10,750	12,430	14,135	14.3	38.1	37.8	9.7	5.8	60.1	1.1	20.1	3.0	9.7
Mineral	8,970	10,187	13,540	11.7	33.5	32.6	22.1	4.6	50.4	0.8	17.5	4.3	22.1
Tebo	11,085	12,325	14,070	10.1	42.9	35.7	11.2	5.6	61.2	1.0	16.3	4.6	11.2
Eureka	8,470	9,580	13,510	11.6	29.8	32.9	25.7	4.3	44.1	0.8	10.7	14.4	25.7
Cainsville	10,455	12.055	14,185	13.3	36.9	36.6	13.1	5.5	57.8	1.0	16.5	6.0	13.1
Princeton	11,200	13,097	14,460	14.5	35.4	43.0	8.1	5.9	62.5	1.1	18.6	3.7	8.1
Unnamed	10,983	12,713	14,363	13.6	35.2	41.2	9.9	5.6	61.3	1.1	18.5	3.5	9.9
Unnamed	10,905	12,725	14,440	14.3	35.5	39.7	10.3	5.6	60.5	1.0	17.1	5.3	10.3
Unnamed	9,610	10,980	13,760	12.5	33.5	36.3	17.7	5.0	53.2	0.9	14.1	9.1	17.7
Overall Average	10,326	11,952	14,066	13.6	36.2	37.1	13.1	5.4	57.1	1.0	17.7	5.5	13.2

Flynn gives an average heating value of 11,320 Btu/lb. for Missouri coals on an "as-received" basis. This is below the national average for bituminous coals but ranks well above that given for subbituminous coals and lignite. This value also compares favorably with those given for the adjoining states of Iowa (9,940 Btu/lb.) and Illinois (11,250 Btu/lb.).

Table 2 was compiled from data from U.S. Bureau of Mines Technical Paper 366. Data from 78 face samples from 11 different coals are tabulated and an average heating value of 11,016 Btu/lb. is derived. This figure is somewhat lower than that determined by Flynn and is probably a very representative value for Missouri coal.

A core drilling program in north-central Missouri during 1970 and 1971 was a part of the research leading to the preparation of this report. Coal beds penetrated were sampled and the samples were sent to the U.S. Bureau of Mines Energy Research Center at Pittsburgh for analysis. Tables 3 and 4 summarize the results of these analyses.

The average "as-received" heating value for coal beds encountered during this drilling program was 10,352 Btu/lb. This is well below the averages derived previously. There are three factors which account for the apparent lower heating values of the coal beds encountered. They are: the method of sample collection, the fact that inferior coal beds which would ordinarily not be mined were included and the possibility that there is some small real decrease in coal quality in the region drilled.

The first factor cited is the most important. When face samples are collected, bands or lumps of impurities which in mining would be removed at the tipple are discarded. In this investigation, however, columnar sections of the entire core were submitted for analysis. Impurities were not discarded. It was felt that this procedure gives a better representation of the coal bed as it is. However, since the impurities are non-combustible their inclusion reduces the heating value of the coal, just as they would if they were not removed at the mine. Thus, the method of sample collection was primarily responsible for lowering the "as-received" heating value of the coal. This is verified by comparison with heating values in the moisture- and ash-free column (MAF) (tbl. 4), which shows the heating value of these coals to be quite satisfactory on that basis. It follows, then, that many of these coal beds, if cleaned after mining, would be of good quality based on their heating values. Reference to the ash column (tbl. 4) also substantiates this conclusion. Both the Mineral and Eureka coals, which show very low "as-received" heating values, are very high in ash. Much of this ash is originally present in the coal bed in the form of bands and lumps of easily removed materials.

The second factor, inclusion of the inferior coal beds also serves to lower the overall average heating value. Both the Mineral and Eureka coals are too high in ash (at least in the areas where they were sampled) to be mined. Exclusion of the samples representing these coals from the overall average gives "as-received" heating value of 10,679 Btu/lb. This figure is much nearer the average for Missouri coals as determined by previous investigators.

Table 3

SUMMARY OF ANALYSES

				Proximate Analysis				Ultimate Analysis					
No. of Sample	BTU AR	BTU MF	BTU MAF	Moisture AR	VM AR	FC AR	Ash AR	H AR	C AR	N AR	O AR	S AR	Ash AR
					Lexington Coal								
30	10,990	13.310	14,280	17.5	40.2	36.7	5.6	6.2	60.8	1.1	23.1	3.2	5.6
Average	10,990	13,310	14,280	17.5	40.2	36.7	5.6	6.2	60.8	1.1	23.1	3.2	5.6
					Bevier Coal								
1	11,270	12,770	14,300	11.8	42.3	36.5	9.4	5.7	62.0	1.0	16.3	5.6	9.4
4	8,320	9,670	13,830	14.0	29.7	30.4	25.9	4.8	45.4	0.9	16.8	6.2	25.9
9	10,740	12,810	14,290	16.2	36.6	38.6	8.6	6.0	59.1	1.2	21.1	4.0	8.6
26	10,740	12,290	14,130	12.6	36.3	39.7	11.4	5.6	60.1	1.2	17.9	3.8	11.4
31	10,520	12,490	14,130	15.8	38.8	35.6	9.8	6.0	58.4	1.0	20.6	4.2	9.8
41	9,700	11,350	13,840	14.6	34.2	35.9	15.3	5.3	53.2	0.9	19.1	6.2	15.3
42	9,370	11,180	13,810	16.2	32.4	35.5	15.9	5.2	51.5	1.0	18.3	8.1	15.9
Average	10,094	11,794	14,047	14.5	35.8	36.0	13.8	5.5	55.7	1.0	18.6	5.4	13.8
					Wheeler Coal								
5	10,570	12,290	14,200	14.0	37.9	36.5	11.6	5.7	57.9	1.0	18.1	5.7	11.6
10	9,050	10,260	13,280	11.8	34.7	33.5	20.0	4.6	52.0	0.9	17.9	4.6	20.0
20	11,220	13,120	14,300	14.5	39.4	39.0	7.1	6.0	63.0	1.2	20.3	2.4	7.1
27	8,730	10,250	13,460	14.9	32.5	32.3	20.3	4.9	48.8	0.8	19.5	5.7	20.3
35	10,140	11,910	13,910	14.9	36.0	36.9	12.2	5.6	56.5	1.0	20.5	4.2	12.2
43	10,400	12,200	14,190	14.7	36.5	36.9	11.9	5.5	57.8	1.0	17.7	6.1	11.9
Average	10,018	11,672	13,890	14.1	36.1	35.9	13.9	5.4	56.0	1.0	19.0	4.8	13.9

Croweburg Coal

2	10,700	12,360	14,170	13.4	37.9	37.7	11.0	5.5	59.2	1.0	16.8	6.5	11.0
6	10,160	11,680	13,860	13.0	35.9	37.4	13.7	5.3	55.6	0.9	17.0	7.5	13.7
7	10,150	11,940	14,040	15.0	34.6	37.7	12.7	5.6	56.7	1.0	19.5	4.5	12.7
11	12,030	13,850	14,440	13.2	39.1	44.1	3.6	6.3	66.3	1.2	19.3	3.3	3.6
21	10,490	12,810	14,340	18.1	35.0	38.1	8.8	6.1	58.3	1.1	22.8	2.9	8.8
32	10,760	12,620	14,110	14.7	39.9	36.4	9.0	5.9	59.2	1.0	20.8	4.1	9.0
44	10,650	12,340	14,250	13.7	38.0	36.8	11.5	5.8	58.4	1.2	19.5	3.6	11.5
Average	10,706	12,514	14,173	14.4	37.2	38.3	10.0	5.8	59.1	1.1	19.4	4.6	10.0

Lower Ardmore and Fleming Coals

8 (Flem.)	11,740	13,190	14,220	11.0	41.8	40.7	6.5	5.9	65.9	1.1	17.4	3.2	6.5
12 (Flem.)	11,300	13,190	14,370	14.3	39.9	38.7	7.1	6.1	62.6	1.2	20.0	3.0	7.1
28 (Flem.)	9,250	11,230	13,990	17.7	33.9	32.1	16.3	5.5	51.7	0.9	22.2	3.4	16.3
36 (L.A.)	10,710	12,510	13,960	14.4	36.8	39.9	8.9	5.8	60.5	1.1	21.1	2.6	8.9
Average	10,750	12,430	14,135	14.3	38.1	37.8	9.7	5.8	60.1	1.1	20.1	3.0	9.7

Mineral Coal

13	8,670	9,760	13,780	11.2	31.4	31.5	25.9	4.8	48.0	0.9	16.3	4.1	25.9
33	10,450	12,120	13,810	13.7	38.9	36.8	10.6	5.6	58.1	0.9	19.1	5.7	10.6
37	7,790	8,680	13,030	10.3	30.2	29.6	29.9	4.0	45.1	0.7	17.1	3.2	29.9
Average	8,970	10,187	13,540	11.7	33.5	32.6	22.1	4.6	50.4	0.8	17.5	4.3	22.1

Tebo Coal

38	11,320	12,520	14,090	9.6	43.9	36.4	10.1	5.7	62.2	1.1	16.0	4.9	10.1
29	10,850	12,130	14,050	10.6	42.0	35.1	12.3	5.5	60.2	1.0	16.6	4.4	12.3
Average	11,085	12,325	14,070	10.1	42.9	35.7	11.2	5.6	61.2	1.0	16.3	4.6	11.2

Eureka Coal

3	8,470	9,580	13,510	11.6	29.8	32.9	25.7	4.3	44.1	0.8	10.7	14.4	25.7
Average	8,470	9,580	13,510	11.6	29.8	32.9	25.7	4.3	44.1	0.8	10.7	14.4	25.7

Cainsville Coal

14	9,720	11,220	13,820	13.4	35.3	35.0	16.3	5.3	53.6	0.9	15.4	8.5	16.3
22	11,190	12,890	14,550	13.3	38.5	38.3	9.9	5.7	62.0	1.2	17.6	3.6	9.9
Average	10,455	12,055	14,185	13.3	36.9	36.6	13.1	5.5	57.8	1.0	16.5	6.0	13.1

(continued to next page)

Table 3 - SUMMARY OF ANALYSES (continued).....

					Proximate Analysis					Ultimate Analysis			
No. of Sample	BTU AR	BTU MF	BTU MAF	Moisture AR	VM AR	FC AR	Ash AR	H AR	C AR	N AR	O AR	S AR	Ash AR
					Princeton Coal								
15	11,270	13,210	14,470	14.6	35.6	42.4	7.4	6.0	62.7	1.1	19.6	3.2	7.4
16	10,840	12,580	14,320	13.9	35.4	40.2	10.5	5.7	60.7	1.1	17.5	4.5	10.5
23	11,490	13,500	14,590	14.9	35.2	43.5	6.4	5.9	64.2	1.2	18.8	3.5	6.4
Average	11,200	13,097	14,460	14.5	35.4	42.0	8.1	5.9	62.5	1.1	18.6	3.7	8.1
					Unnamed Coal								
40	11,180	12,610	14,130	11.3	37.8	41.3	9.6	5.6	62.9	1.1	17.4	3.4	9.6
17	10,350	12,310	14,430	15.9	31.9	39.8	12.4	5.8	57.7	1.2	20.5	2.4	12.4
24	11,420	13,220	14,530	13.6	36.0	42.6	7.8	5.5	63.4	1.1	17.5	4.7	7.8
Average	10,983	12,713	14,363	13.6	35.2	41.2	9.9	5.6	61.3	1.1	18.5	3.5	9.9
					Unnamed Coal								
18	11,190	12,850	14,440	13.0	37.1	40.3	9.6	5.7	61.8	1.1	16.2	5.6	9.6
25	10,620	12,600	14,520	15.7	34.0	39.2	11.1	5.5	59.3	1.0	18.0	5.1	11.1
Average	10,905	12,725	14,480	14.3	35.5	39.7	10.3	5.6	60.5	1.0	17.1	5.3	10.3
					Unnamed Coal								
34	9,610	10,980	13,760	12.5	33.5	36.3	17.7	5.0	53.2	0.9	14.1	9.1	17.7
Average	9,610	10,980	13,760	12.5	33.5	36.3	17.7	5.0	53.2	0.9	14.1	9.1	17.7
					Atypical Sample (probably lower bench; Princeton Coal near pinch out)								
39*	4,710	5,300	--	11.0	18.0	20.5	50.5	3.6	27.3	0.6	16.9	1.1	50.5
Average	4,710	5,300	--	11.0	18.0	20.5	50.5	3.6	27.3	0.6	16.9	1.1	50.5

* Too high in ash to be classified as coal

The above reasoning applies also to the averages for the individual coal beds. For instance, the average "as-received" heating value for the Wheeler coal is lowered substantially by samples 10 and 27 (tbl. 3), both of which are very high in ash.

Searight (1949) suggests that rank and, therefore, heating value of Missouri coals increases from north to south. The number of samples analyzed during this project is too small to either substantiate or negate this view, but any decrease in heating value of north-central Missouri coals below the state average is small.

SULFUR CONTENT

Recent concern by governmental agencies over the emission of oxides of sulfur from the stacks of coal-burning facilities has resulted in the setting of limits on the sulfur content of the coal burned, or on the sulfur content of emissions.

Regardless of whether the limits are set on the coal or on the emissions, the sulfur content of coal is now of primary importance to both producer and consumer. If the limits apply to coal, then high-sulfur coal cannot be burned; if the limits apply to emissions, then the sulfur must be removed from the coal before it is burned, or from stack gases before they are emitted.

It has long been known that Missouri coals are high in sulfur. Robertson (1971) tabulated the remaining coal reserves of Missouri according to sulfur content. He found that over half contains 4 to 5 percent sulfur, that one-fourth contains from 2 to 3 percent sulfur, and that most of the remainder has a sulfur content greater than 5 percent. He also found that only a small fraction of Missouri's coal reserve contains less than 2 percent sulfur.

Although Robertson's work pertained only to remaining reserves, which account for only 24 percent of Missouri's estimated coal resource base, there is no reason to suspect that the remaining unexplored coal resources will differ in sulfur content.

Results obtained during the recent drilling program substantiate this conclusion. Figure 4 shows the sulfur content of remaining mineable coal reserves. Figure 5 illustrates the sulfur content of mineable reserves of strip coal.

Sulfur occurs in coal in three forms: as iron sulfide, as sulfates, and as organic sulfur. In Missouri coal, by far the greater amount occurs in combination with iron as the iron sulfide, pyrite. Pyrite occurs as large nodules or concretions as vein deposits in joints or cleats and as finely disseminated particles in the coal macerals.

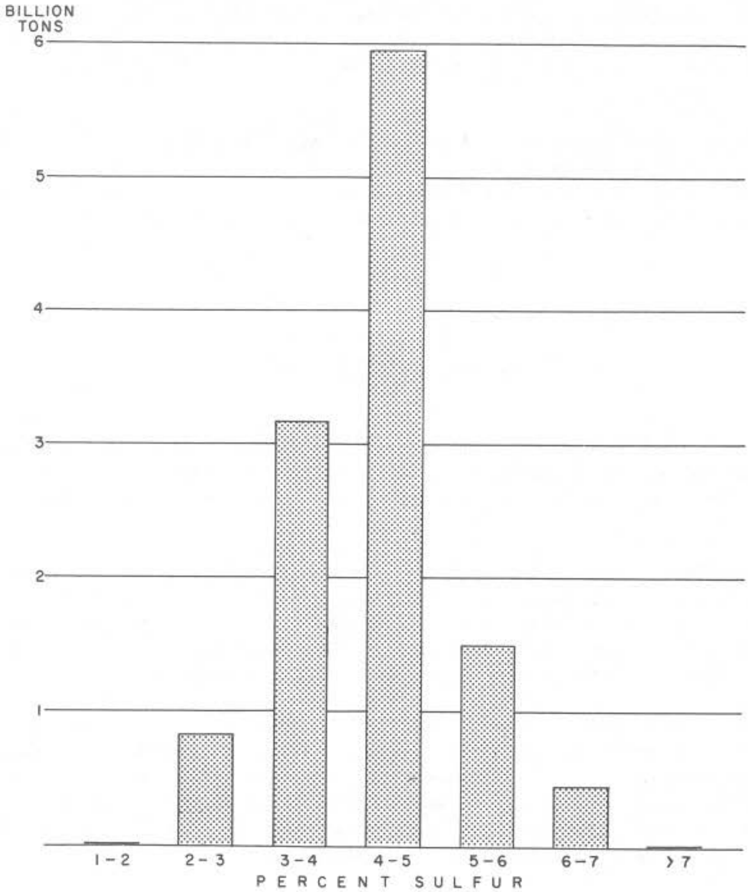


Figure 4
Sulfur content of remaining mineable coal reserves.

Although each form of pyrite presents a distinct coal-cleaning problem of its own, all forms of pyrite are much more easily removed than the second most abundant sulfur form, organic sulfur. Organic sulfur occurs in chemical combination with the organic coal substance and is therefore extremely difficult to remove. Sulfur as sulfate occurs in very small amounts and does not present a problem in coal utilization.

Table 4

AVERAGE OF ANALYSES BY COAL BED

				Proximate Analysis				Ultimate Analysis					
Coal Bed	BTU AR	BTU MF	BTU MAF	Moisture AR	VM AR	FC AR	Ash AR	H AR	C AR	N AR	O AR	S AR	Ash AR
Lexington	10,990	13,310	14,280	17.5	40.2	36.7	5.6	6.2	60.8	1.1	23.1	3.2	5.6
Bevier	10,094	11,794	14,047	14.5	35.8	36.0	13.8	5.5	55.7	1.0	18.6	5.4	13.8
Wheeler	10,018	11,672	13,890	14.1	36.1	35.9	13.9	5.4	56.0	1.0	19.0	4.8	13.9
Croweburg	10,706	12,514	14,173	14.4	37.2	38.3	10.0	5.8	59.1	1.1	19.4	4.6	10.0
Lower Ardmore and Fleming	10,750	12,430	14,135	14.3	38.1	37.8	9.7	5.8	60.1	1.1	20.1	3.0	9.7
Mineral	8,970	10,187	13,540	11.7	33.5	32.6	22.1	4.6	50.4	0.8	17.5	4.3	22.1
Tebo	11,085	12,325	14,070	10.1	42.9	35.7	11.2	5.6	61.2	1.0	16.3	4.6	11.2
Eureka	8,470	9,580	13,510	11.6	29.8	32.9	25.7	4.3	44.1	0.8	10.7	14.4	25.7
Cainsville	10,455	12,055	14,185	13.3	36.9	36.6	13.1	5.5	57.8	1.0	16.5	6.0	13.1
Princeton	11,200	13,097	14,460	14.5	35.4	43.0	8.1	5.9	62.5	1.1	18.6	3.7	8.1
Unnamed	10,983	12,713	14,363	13.6	35.2	41.2	9.9	5.6	61.3	1.1	18.5	3.5	9.9
Unnamed	10,905	12,725	14,440	14.3	35.5	39.7	10.3	5.6	60.5	1.0	17.1	5.3	10.3
Unnamed	9,610	10,980	13,760	12.5	33.5	36.3	17.7	5.0	53.2	0.9	14.1	9.1	17.7
Overall Average	10,326	11,952	14,066	13.6	36.2	37.1	13.1	5.4	57.1	1.0	17.7	5.5	13.2

Because the three forms of sulfur, particularly the pyritic and organic forms, present diverse problems of removal, it is desirable to know not only the average sulfur content but also the percentage of sulfur that occurs in each form. Table 5 was compiled from data presented in U. S. Bureau of Mines Information Circular 8301, Forms of Sulfur in U.S. Coals, and shows percentage by sulfur form for various Missouri coal beds.

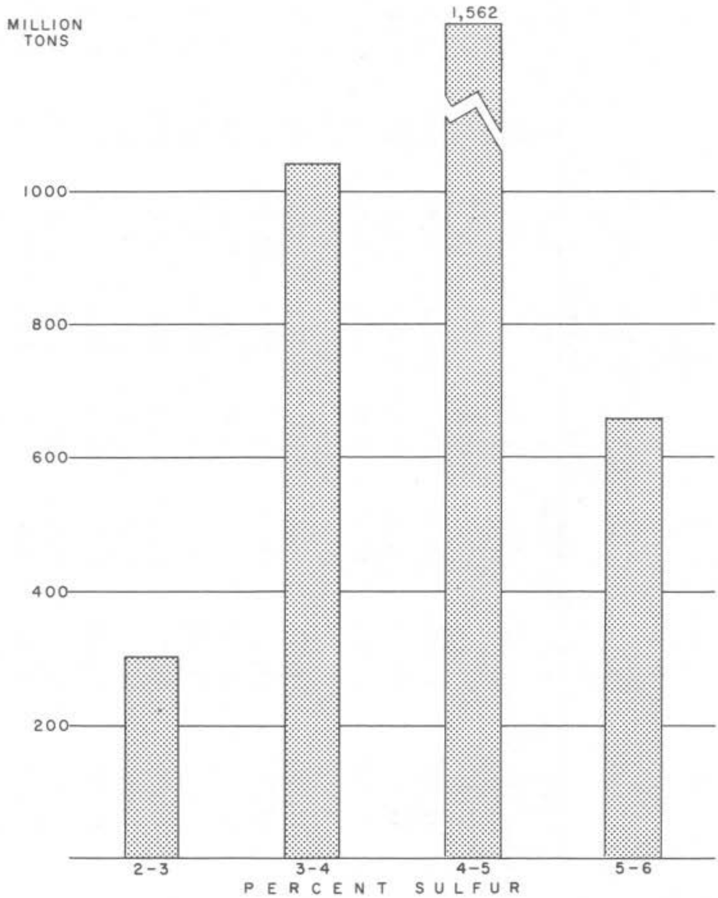


Figure 5

Sulfur content of mineable reserves of strip coal.

Table 5

FORMS OF SULFUR IN MISSOURI COALS

Coal Bed	No. Samples	Sulfur As Received Sulfate	Pyritic	Organic	Total
Bevier	8	0.07	2.68	1.44	4.19
Lexington	5	0.04	2.38	1.83	4.25
Tebo	2	0.12	1.40	1.83	3.35
Croweburg	3	0.09	3.62	1.56	5.27
Averages		0.08	2.52	1.66	4.27

(Data from U.S. Bureau of Mines IC 8301, Forms of Sulfur in U.S. Coals)

From the data it is readily apparent that Missouri coal beds averaging highest in sulfur content contain a large amount of pyritic sulfur. The average sulfur content for all coal beds is 4.27 percent. Of this, 2.52 percent is pyritic sulfur and 1.66 percent is organic sulfur. Therefore, promising new coal-cleaning processes which are designed to leach essentially all of the pyritic sulfur from coal could substantially reduce the sulfur content of Missouri coals.

Table 6 (showing forms of sulfur) was compiled from the analyses of samples collected during the recent drilling program in north-central Missouri. The samples were collected by the Missouri Geological Survey and analyses were done by the U.S. Bureau of Mines Energy Research Center. The overall averages correspond very closely with those presented in table 5, with the organic sulfur content averaging slightly lower. Of particular interest is the low average organic sulfur content of the "Princeton" coal. However, this average is based on only three samples and may not be truly representative.

Perhaps the future of utilization of Missouri coal will be closely bound to the success of the solvent-refined-coal process. This process, which is more fully discussed in the section dealing with coal conversion, not only removes most of the ash, but it is said that this process removes all the pyritic sulfur and about half of the organic sulfur. This would reduce the sulfur emissions of most Missouri coal to an acceptable level.

Table 6

FORMS OF SULFUR IN SAMPLES FROM NORTH-CENTRAL MISSOURI

County	Locality	Sulfate	Pyritic	Organic	Total Sulfur
	Bevier and Wheeler Coals				
Macon		0.00	3.19	2.39	5.6
Sullivan	Green City - Bevier	0.05	4.98	1.15	6.2
Sullivan	Green City - Wheeler	0.01	3.98	1.70	5.7
Mercer	Goshen - Bevier	0.01	2.81	1.14	4.0
Mercer	Goshen	0.02	3.72	0.86	4.6
Mercer	Mill Grove - Wheeler	0.01	0.50	1.86	2.4
Harrison	Mt. Moriah - Bevier	0.01	2.54	1.28	3.8
Harrison	Mt. Moriah - Wheeler	0.05	4.59	1.06	5.7
Mercer	Princeton East - Bevier	0.00	2.34	1.89	4.2
	Bevier Averages	.02	3.18	1.48	4.7
	Princeton Coal				
Mercer	Goshen U. Bench	0.01	2.53	0.65	3.2
Mercer	Goshen L. Bench	0.00	3.42	1.09	4.5
Mercer	Mill Grove	0.01	2.63	0.87	3.5
	Princeton Averages	.01	2.86	0.87	3.7
	Lexington Coal				
Mercer	Princeton East	0.01	1.27	1.88	3.2
	Croweburg Coal				
Chariton	Bynumville	0.02	5.49	0.98	6.5
Sullivan	Green City	0.37	5.00	2.51	7.5
Sullivan	Milan	0.02	3.25	1.20	4.5
Mercer	Goshen	0.01	1.07	2.23	3.3
Mercer		0.00	1.34	1.56	2.9
	Croweburg Averages	.08	3.23	1.69	4.9

County	Locality	Sulfate	Pyritic	Organic	Total Sulfur
		Eureka Coal			
Chariton	Bynumville	0.02	14.27	0.10	14.4
		Unnamed Coal			
Mercer		0.10	1.41	0.88	2.4
Mercer	Mill Grove	0.00	3.48	1.21	4.7
	Unnamed	.05	2.44	1.04	3.5
		Unnamed Coal			
Mercer		0.01	5.02	0.62	5.6
Mercer	Mill Grove	0.00	4.24	0.84	5.1
	Unnamed Averages	.01	4.63	0.73	5.4
		Fleming Coal			
Sullivan	Milan	0.01	0.80	2.40	3.2
Mercer	Goshen	0.00	1.21	1.83	3.0
	Fleming Averages	.01	1.01	2.11	3.1
		Mineral Coal			
Mercer	Goshen	0.01	2.37	1.75	4.1
Mercer		0.03	3.78	1.92	5.7
	Mineral Averages	0.02	3.07	1.83	4.9
		Tebo Coal			
Harrison	Mt. Moriah	0.01	2.70	1.72	4.4
	Overall Averages*	.02	2.89	1.66	4.7

*Excludes abnormally high value for Eureka coal

FACTORS AFFECTING UTILIZATION

DEMAND FOR COAL

The demand for energy in the United States approximately doubles every ten years. At present, oil and natural gas supply 67 percent of the total energy consumed, coal and lignite provide more than 20 percent, and the remainder is supplied by water and nuclear power.

In the rapidly expanding electric utilities market, however, coal is the leader. In 1969 coal-fired plants generated 705.6 billion kilowatt hours of electricity; gas-fired plants, 333.7 billion; oil-fired plants, 137.7 billion; and nuclear plants, 13.9 billion.

To produce coal's share of electricity, 310 million tons of coal were burned. The demand for coal will continue to be strong in the electric utilities market. Despite a predicted rapid growth for nuclear energy in this market, the use of coal for utilities power production will reach more than 600 million tons by 1990 and continue to increase beyond the year 2000.

The predicted continuing growth in demand for petroleum and natural gas may create a second large market for coal. Production of petroleum and natural gas is beginning to outstrip discovery of new reserves. In a very short time, demand for these products will surpass production. Since coal can readily be converted to pipeline gas and petroleum products, the market possibilities are obvious. The demand for coal, then, should be increasingly strong in future years.

MISSOURI COAL AND THE ENERGY MARKET

The United States is fortunate in possessing a large portion of the earth's coal resources. Therefore, Missouri coal must compete with coal from other U.S. coal fields for its share of the energy market. Figure 6 depicts the coal fields of the United States. Chief competition for Missouri coal will come from the coal fields of Illinois and those in the Rocky Mountain states.

Illinois coal commands an advantage over Missouri coal in the St. Louis area because it occurs in thicker beds and because the Illinois coal fields lie nearer the St. Louis metropolitan area than do the coal fields of western and northern Missouri. The present marketing area for Missouri coal is western and northern Missouri. Utilities providing electricity for this area draw much

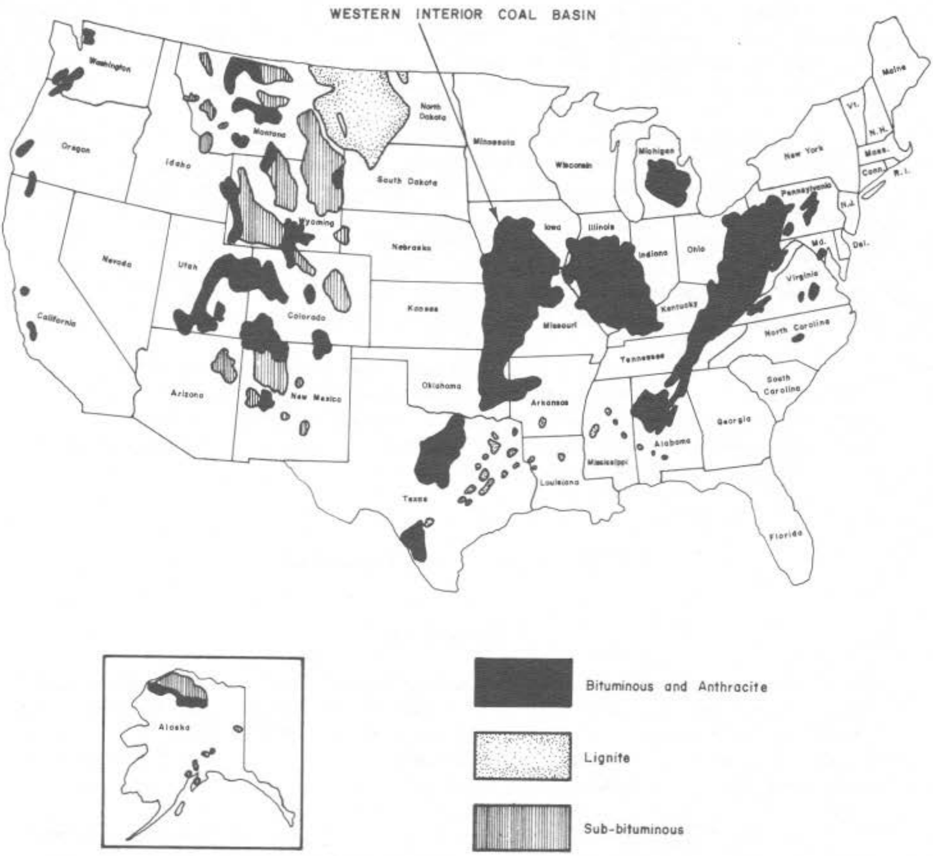


Figure 6
Coal and lignite fields in the United States.

of their power from several mine-mouth power plants located in the area. Smaller municipal and institutional power plants in northern and western Missouri also use Missouri coal.

Coal from the Rocky Mountain states of Wyoming and Montana is beginning to find its way to some municipal power plants in northern and western Missouri. This is because coal from deposits in these states is low in sulfur and, therefore, is considered to be a less-polluting fuel than Missouri coal.

Rocky Mountain coal could supply electrical energy to Missouri in two ways. First, it could be shipped directly to Missouri power plants by unit train or, second, electricity could be transported by wire directly from proposed huge generating centers located in the northern and central Rockies.

In all probability much low-sulfur Western coal will be involved in the Missouri energy supply picture both by direct shipment and by transmission by wire as electricity. However, because of the rapid growth in demand for electrical power, Missouri coal will continue to compete for and capture part of this market. The extent to which Missouri coal will be utilized will depend on several factors. Most important will be the ability to economically reduce sulfur emissions from the stacks of plants burning high-sulfur coal or to remove sulfur from coal before it is burned. Other factors are discussed later in this section.

Illinois coal will doubtless continue to find markets in Missouri, particularly in the St. Louis area, although it, too, faces the disadvantage of containing more than the allowable amounts of sulfur. Some low-sulfur coal from the East, particularly eastern Kentucky, might find its way into the Missouri market by way of the Ohio and Mississippi Rivers.

PROSPECTING AND DEVELOPMENT

Prospecting

Before coal can be mined, it must be found. Even a known coal deposit must be examined in detail before mining can be considered. The thickness and persistence of the coal seam and the quality and amount of coal must be determined. The same is true on a greater scale for an entire coal field before a coal-based industry can be planned for a region.

During the early developing years of our nation, discovery of coal deposits, like other mineral deposits, was mostly accidental. Coal was found cropping out along streams and in hillsides by explorers, trappers and farmers. Development of coal fields discovered in this manner was extremely haphazard.

In the early years of development, small mines were opened in populated areas to furnish coal for domestic use. The first mines were developed along the lines of outcrop of the coal seams. When the crop-lines were under full development in a particular region, it became necessary to prospect for near-surface extensions of coal seams where they were covered by soil and vegetation. Many miners became quite expert at chasing the outcrop of the coal seam across the countryside, and in this way more became known about the extent of each coal field and about the tonnages they might be expected to contain.

By the mid-19th Century, industrial sites began to grow around large coal fields and railroads began to seek sizeable deposits of coal for fuel. As coal became more important to the nation's economy and industrial development, it became necessary to determine accurately the extent of the various coal fields and the amount of coal each contained.

Both private industry and government agencies were involved in this task. To assure themselves of enough coal to continue operations, mining companies proved large tonnages of coal by test drilling. The usual procedure was to drill out and extend previously known coal fields that had been developed earlier although, in later years, "wildcatting" in likely areas for major new coal deposits was done occasionally.

Coal evaluation by federal and state agencies drew heavily on the science of geology and the talents of the geologist to map areas underlain by coal-bearing strata and to determine reserves available for future development Coal analysis work by both private industry and government agencies determined the quality of the coal available.

In this way the location and extent of the major coal fields gradually became known, as did the amount and quality of coal available from each. Much work remains to be done in this respect however.

Missouri coal fields have never been fully developed and, therefore, prospecting has been confined for the most part to those areas where the coal crops out and where early mining developed. Although drilling back from the outcrop has been done around known mining areas, much remains to be done in the way of evaluation of the state's coal resources.

Much of the "easy-to-find-and-mine" coal has been mined, bought or leased. The point will soon be reached where a more scientific approach will be needed to find and evaluate coal deposits in Missouri. A proper understanding and use of geologic principles will be the key to successful prospecting.

Mining

Most of the early coal mining in Missouri was by underground methods; however, stripping is now the accepted coal mining method in the state.

Strip Mining

Small-scale stripping was among the earliest coal mining methods used in Missouri. Horse-drawn scrapers were used to remove soil or shale from coal beds cropping out in creek bottoms. Only a very small tonnage was usually recovered because the overburden quickly became too thick or hard roof-rock was soon encountered, either of which rendered this type of stripping impossible.

Use of steam-powered shovels aided by blasting permitted the stripping of thicker and tougher overburden and, shortly after the turn of the century, large strip pits were in operation. Stripping is ideally suited to Missouri coal seams which, though thin, lie relatively near and parallel to the surface and tend to be persistent in areal extent.

Modern strip mines make use of extremely large, electric-powered shovels and draglines that are capable of removing overburden up to 100 or more feet thick.

The most common stripping plan used is area stripping, in which overburden is removed by strips. The first cut made is a "box cut" along the line of outcrop. This cut is 10's of feet wide, but may extend from several hundred feet to more than a mile in length. As the stripping machine, a shovel or dragline, removes overburden along the cut, it leaves a strip of uncovered coal which is broken up and loaded by other equipment. When the stripping machine reaches the end of its first run it begins a return run adjacent to and parallel with the first. A second strip of coal is uncovered and the overburden is dumped into the previous cut, from which coal has been removed.

This procedure is continued over and over as the stripping machine makes its way across the terrain uncovering coal a strip at a time and casting the overburden into the previously mined strip. As the machine crosses the countryside, it leaves a series of giant furrows resembling a gigantic plowed field. The area stripping plan is more amenable to reclamation than other stripping plans because the area stripped is easily leveled. This method works best where large deposits of coal lie approximately horizontal. Too much dip on the coal seam interferes with the operation of the stripping equipment, particularly stripping shovels which sit directly upon the coal seam. Either rough terrain or steeply to moderately dipping coal beds pose difficulties sometimes insurmountable to the conventional stripping shovel.

In some important Missouri coal fields, much of the thick coal, which lies in horizontal beds with low overburden in level terrain, has been mined. However, much good strippable coal remains in many of these areas. The key to recovering coal in areas which present difficult stripping problems is imagination, particularly in the choice and use of stripping equipment.

More attention should be given to geologic factors and topography before mining begins. Ideally, geologic and geologic-structure maps of the coal fields should be available before a mining plan is developed. These would provide, at low cost, the needed information on the thickness and nature of overburden and structure of the coal seams. Mining equipment could then be chosen to fit anticipated mining conditions. This would be a much more profitable procedure than searching for coal to fit the equipment.

Mine operators who make thorough use of geologic principles will probably be more successful than those who ignore them. By the same token, those who choose imagination and innovation in mining methods will find themselves far less frustrated than those who attempt to mine every coal deposit with a predetermined technique.

Conservation and Reclamation

In recent years much controversy has centered about the practice of strip mining. Most of the opposition is caused by two obvious factors which are inherent in stripping. First, the land surface-sometimes quite a large area-is disturbed by strip mining. In some instances the land is literally turned upside down. Second, as coal beds and overlying strata are uncovered, acid solutions are formed by the breakdown of iron sulfides which are brought to the surface. The acid solutions sometimes escape from the pit and find their way into streams, where they are detrimental to water quality. Objection to both of these problems is quite legitimate. It is hoped, however, that under Missouri's new land reclamation law both of these problems will be greatly reduced or even eliminated. To be sure, public acceptance of coal strip mining in the future will greatly depend on the industry's willingness to eliminate most of the damage done by stripping.

It should be emphasized, however, that despite these special problems there is a positive side to strip mining. First, it is sound conservation from the standpoint of coal recovery. From 75 to 90 percent of the coal seam is usually recovered by stripping, while underground methods usually recover only about 50 percent; much of the remainder is unrecoverable and is therefore wasted. Close attention to recovering thin seams overlying the main seam could improve this conservation principle even more. Second, some coal seams which could not be recovered at all by underground mining are recoverable by stripping methods. Thus, energy needs of many areas served by strip coal might otherwise be served by other means which could be more detrimental in the long run.

For instance, if it is necessary to ship coal or other fuel long distances, the total national energy budget will be significantly increased, for it requires much energy in the form of fuel for locomotives or trucks to haul this fuel. Another very positive factor favoring strip mining is the safety factor. Underground mining inevitably costs more in the way of men's lives than does stripping.

Another area of conservation in which coal mining, both underground and stripping, is effective should be mentioned. That is the conservation of forests. If it were not for the utilization of coal deposits for energy uses and for steel making, the state's forests would have been depleted long ago.

Underground Mining

In the early years of coal mining in Missouri most mining was done by underground methods, despite the fact that Missouri coal occurs in notoriously thin seams. Coal seams less than 42 inches in thickness are the rule (although a reserve of more than 2 billion tons remains in thicker seams) and, indeed, much coal has been mined underground from coal beds less than 28 inches in thickness. Coal in the very productive Lexington Field averaged only about 20 inches in thickness. Underground production in these seams was possible because of the good lateral persistency of the seams, fair coal quality, good roof conditions, plentiful labor supply and a ready market.

Underground mining in Missouri began to decline steadily in the 1930's in favor of strip mining. By the mid-1960's underground mining had all but ceased due to competition from stripping and loss of markets.

The future of underground mining in Missouri is largely dependent on the future demand for coal. Quite large reserves of strip coal are available and, unless there is a significant upturn in the demand for Missouri coal, stripping will probably continue to meet the demand. However, there are some deposits which are recoverable only by underground mining which are of sufficient thickness and tonnage to be of interest. Some of these are discussed later in this report.

Present underground mining methods have been developed since underground mining was phased out in Missouri. Mining technology has become highly mechanized and present emphasis is on high production from "big coal" or thick seams.

In many areas in the vast coal fields of the East, however, the "big coal" is being rapidly mined out and it is the opinion of many that in the not-so-distant future the trend will be to "small" or thin coal (Erwin, 1971). According to Erwin, mining techniques will be altered to meet the demands of mining thin coal seams. Development of such a technology would encourage interest in mining Missouri coal underground, since present methods are not entirely suited to many deposits of Missouri coal. It is perhaps prophetic that advertisements of mining machines capable of mining coal as low as 27 inches are beginning to appear in leading trade journals.

Beneficiation

The primary aim in coal beneficiation is upgrading the coal by increasing Btu content and decreasing deleterious factors such as ash and sulfur content. Sizing and a general overall clean appearance are also goals of beneficiation. Since most coal presently being mined in Missouri is burned in utilities plants designed to burn raw coal, very little Missouri coal is cleaned. However, those mines that do ship coal to plants requiring cleaned coal process the coal in modern plants.

Sulfur is the most serious contaminant of Missouri coal. Current and forthcoming air-quality regulations place severe restrictions on sulfur emissions from coal-burning power plants. Removal of sulfur is the leading cleaning problem in the beneficiation of Missouri coal. The amount of sulfur must be reduced either by cleaning the coal before burning or by removing sulfur from the stack gasses after the coal is burned. The sulfur problem must be solved if Missouri coal is to continue to capture its share of the utilities market.

At present, stack scrubbing, removal of sulfur from coal by leaching, or conversion to solvent-refined coal seem to be the most practical solutions to sulfur removal. Much attention will be focused on the recently completed LaCygne, Kansas plant to see if the new equipment installed removes sulfur effectively and economically.

TRANSPORTATION

Missouri is served by a fine network of highways and rail lines. Highways are present in all coal regions, while rail lines serve most coal fields and are reasonably near all coal-producing areas. Both the Mississippi and Missouri Rivers are navigable and pipelines serve the northern and western parts of the state.

UTILIZATION

Practically all coal mined in Missouri at present is burned by utilities to produce electricity. A small amount is sold at the mine for domestic uses and a few small mines serve the domestic market only.

Power generation will continue to be the primary use for Missouri coal, for the next decade at least. Additions to existing power plants and construction of others using Missouri coal will probably take place in the future. The growth rate of this market will depend greatly on the development and utilization of equipment to reduce or eliminate sulfur emissions from plants using high-sulfur coal. If this problem can be controlled, the utilities market will be very good for Missouri coal.

CONVERSION

It appears that a very bright future lies ahead for the coal industry in the field of coal gasification and liquefaction. As the demand for natural gas and petroleum products increases and as reserves of these products become harder to find, it seems natural that conversion of coal to these products should take place on an increasingly large scale. Many experts believe that, indeed, this is coal's ultimate future.

That such prognostications are well within the realm of possibility is demonstrated by fact. The practicality of conversion of coal to gas and petroleum products has been demonstrated not only by experiment, but also by actual production. The Union of South Africa routinely practices coal conversion. Several commercial gasification plants are scheduled to go on line in the United States, one as early as 1975. Government and private research groups are developing various types of coal-conversion processes. All this indicates that coal may have an interesting and exciting future.

Coal-conversion processes which are most likely to prove beneficial to Missouri coal producers and consumers are: (a) coal to low-Btu gas, (b) coal to solvent-refined coal, (c) coal to pipeline gas, and (d) coal to liquid petroleum substitutes. Of these, the first three are of the most immediate interest:

a. Low-Btu Gas. Low-Btu gas has been produced from coal for many years. This gas was once widely used as furnace fuel but has been replaced over the years by low-cost, clean natural gas. Producer gas, as it was called, was somewhat objectionable even in its day because it was high in dust, soot, tar and sulfur.

With changes in production methods to produce a clean fuel on a large scale, this type of gas could again become an important source of fuel for the electric-power industry. Hottel and Howard (1971) predict that an effective second-generation process could be available within 10 years. Accurate cost figures are not available, but fuel from this process would be much more expensive--perhaps twice as expensive--as the cheapest fuel available today. However, with refinement, it could become competitive with coal shipped long distances.

b. Solvent-Refined Coal. Removal of ash and most of the sulfur from coal by treating finely crushed coal with organic solvents produces a clean, high-Btu fuel. This fuel can be used as a liquid in close coupling with power plants or it may be allowed to cool and solidify, in which case it can be shipped as a high-Btu, clean fuel. The original process was developed by Spencer Chemical Corporation and the Pittsburg and Midway Coal Mining Company. Preliminary cost estimates by Hottel and Howard (1971) indicate that this process is economically competitive. The solvent-refined coal process seems to hold promise for the development of Missouri coal reserves.

c. Pipeline Gas. Natural gas accounted for 33 percent of the nation's energy budget in 1971 and the demand for this clean, desirable fuel continues to increase rapidly. At the same time reserves of natural gas are being depleted and it is becoming increasingly difficult to discover new reserves. It has been estimated that production of natural gas in the United States (exclusive of Alaska) will peak in about 1978 (M. King Hubbert, 1969) and thereafter decline due to a decrease in potential reserves.

Because coal can be converted to pipeline-quality gas, this market has great potential. Several coal-to-gas conversion plants are scheduled to go on-line in the next decade. There are several areas in Missouri which contain ample reserves to feed coal-to-gas conversion plants, but competition from Illinois and the Rocky Mountain states (regions which contain vast coal reserves), somewhat dims the prospects for establishing such plants within the state, at least in the immediate future. Areas possessing a potential for coal-to-gas conversion are discussed later under regional discussions.

d. Liquid Petroleum Substitutes. Several processes for the production of liquid petroleum products, including gasoline, from coal are under development. Actual production of liquid petroleum products from coal lies further in the future than the production of pipeline gas and faces competition from tar sands and oil shale. Establishment of such coal-to-liquid fuels plants in Missouri seems less likely than the establishment of coal-to-pipeline gas plants.

There is no doubt that a coal conversion industry would be beneficial to certain parts of the state from the standpoint of jobs and to the state as a whole from the standpoint of fuel supply. At least 1,000 workers would be needed in the mine and plant alone, not to mention supporting services.

Like any such huge industry, however, there would be environmental problems. For instance, if 120 million tons of coal were strip mined, between 20,000 and 40,000 acres would be disturbed, depending on the coal thickness. This would, of course, be spread over the entire life of the plant. If mining were by underground methods, little if any damage to the surface would occur, but disposal of mine waste and ash would be a problem. Careful planning, however, could reduce or eliminate these problems. Figure 20 shows coal resource regions which contain coal reserves large enough to support gasification plants.

e. In-situ Coal Gasification. Although admittedly impractical at present because of a lack of technological development, the use of coal in the ground without mining has many obviously desirable attributes. By gasifying coal in place and tapping the gas supply by drilling, environmental damage could be reduced to a minimum. There is renewed interest in this technique, as exemplified by the U.S. Bureau of Mines' planned tests of underground gasification of a thick coal bed near Hanna, Wyoming.

There are areas in Missouri which contain coal deposits for which this method may ultimately prove to be the best and, in some cases, perhaps the only method of recovery. For instance there are areas which contain large tonnages of coal in a number of very thin coal beds. While the individual beds are too thin to mine, it is conceivable that a technology could be developed whereby multiple seam gasification might yield large quantities of gas.

In-situ gasification of coal in areas previously mined underground would be a very desirable application of the technique. In some abandoned mining districts as little as 40 percent of the coal has been removed, but the remaining coal has been rendered unrecoverable by mining. Recovery of the remaining coal by in-situ gasification would have the effect of adding to the state's recoverable reserve inventory.

SUPPORTING RESOURCES

A factor often overlooked in evaluation of the coal resources of an area is the availability of other resources that are needed to support the coal mining industry. As industry operations become larger and more complex, these supporting resources assume more important roles.

Water is an important resource in the production of electric power by steam-electric plants and looms even more important in the production of coal-conversion (gas or petroleum) products. Missouri possesses ample resources of both surface and ground water. One of the more promising methods of sulfur removal is burning either calcium or magnesium carbonate with the coal, thus removing the sulfur as calcium or magnesium sulfate. Experimentation is continuing in efforts to determine the right composition of calcium or magnesium carbonate to burn with various coals. Missouri possesses an almost unlimited supply of carbonate rocks of varying purity and composition. Many of the coal seams themselves are associated with limestone-bearing strata. Several are associated with limestone cap rocks or bottom rocks which might be mined along with the coal, making separate quarrying of these rocks unnecessary.

Table 7

VALUE AT BITUMINOUS COAL AND LIGNITE MINES IN THE UNITED STATES, 1969, BY STATE[1]

STATE	AVERAGE VALUE PER TON[2]	STATE	AVERAGE VALUE PER TON[2]
Alabama	$7.47	New Mexico	$3.66
Alaska	$6.54	North Dakota (lignite)	$1.85
Arkansas	$7.90	Ohio	$4.10
Colorado	$5.27	Oklahoma	$5.80
Illinois	$4.32	Pennsylvania	$5.87
Indiana	$4.13	Tennessee	$3.80
Iowa	$3.76	Utah	$6.31
Kansas	$5.42	Virginia	$5.42
Kentucky	$4.14	Washington	$8.21
Maryland	$3.85	West Virginia	$5.73
Missouri	$4.33	Wyoming	$3.36
Montana	$2.13		
		United States[3]	$4.99

[1]Modified from U.S. Bureau of Mines Minerals Yearbook, 1969, tbl. 16, p. 32-33.

[2]Value received or charged for coal f.o.b. mine. Includes a value for coal not sold but used by producers, such as mine fuel and coal coked, as estimated by producers at average prices that might have been received if such coal had been sold commercially.

[3]Data may not add to totals shown because of independent rounding.

ECONOMICS AND PRACTICAL DESIRABILITY OF DEPOSITS

COST

The cost of producing coal is determined by many interrelated factors. Chief among these are the costs of prospecting, acquiring coal lands, purchase of mining and processing equipment, development and production. The price of coal at the point of destination is determined by these costs, plus marketing conditions, including shipping costs. Cost of coal f.o.b. at the mine approaches the cost of finding, acquiring and mining the coal. In 1969 (U.S. Bureau of Mines Minerals Yearbook), the average value of Missouri coal at the mine was $4.33 a ton. This compared favorably with an average value of $4.99 for the entire U. S. (table 7).

A very important cost figure to the consumer of electrical power is the f.o.b. price of coal at the plant. This figure is determined not only by the cost of production but also by the cost of transportation. The average f.o.b. price at the plant for Missouri in 1970 was $5.34 per ton (tbl. 8). This is much lower than the national average and is exceeded in economy by only four states, two of which produce coal much lower in heating value. The high price per ton in Michigan and Wisconsin is due to the cost of shipping coal long distances to plants in those states. In Missouri, over half of the total 11 million tons consumed was shipped from other states, particularly Illinois.

A breakdown of the Missouri totals reveals some interesting facts. For instance, cost at the state's three large mine-mouth power plants averaged only $4.07 per ton, or $1.27 cheaper per ton than the state average. These figures emphasize the economy of the mine-mouth power plant.

Of even greater interest to the power-consuming public is the cost of coal per million Btu, for this price factor directly affects the cost of electricity. The average cost of coal per million Btu f.o.b. at the plant for Missouri in 1970 was 24.8¢ (tbl. 8). This figure is surpassed in economy by only eight major coal-using states. The cost at Missouri's three mine-mouth plants averaged only 21.1¢ per million Btu, a very favorable figure indeed and one that argues strongly for the construction of other mine-mouth plants in the state (above cost data from Steam Electric Plant Factors, 1971 edition, National Coal Association).

Table 8

STEAM ELECTRIC PLANT CAPACITY, COAL BTU, AND UNIT COSTS, 1970[1]

STATE	COAL CAPACITY (THOUS. TONS)	COST PER TON F.O.B. PLANT	BTU PER POUND	COST PER MILLION BTU (CENTS) F.O.B. PLANT
Alabama	16,252	$ 5.90	11,657	25.3¢
Arizona	401	$ 5.70	10,619	26.8¢
Colorado	3,217	$ 5.07	10,765	23.5¢
Connecticut	1,871	$10.90	11,774	46.3¢
Delaware	1,495	$10.54	12,093	43.6¢
District of Columbia	673	$14.49	12,960	55.9¢
Florida	5,144	$ 6.85	11,374	30.1¢
Georgia	7,498	$ 9.02	11,878	38.0¢
Illinois	28,884	$ 6.22	10,501	29.6¢
Indiana	22,817	$ 5.38	11,016	24.4¢
Iowa	3,932	$ 6.74	10,444	32.3¢
Kansas	348	$ 6.55	12,050	27.2¢
Kentucky	18,163	$ 4.77	10,926	21.8¢
Maryland	5,966	$10.52	12,306	42.7¢
Massachusetts	577	$10.95	11,630	47.1¢
Michigan	20,135	$ 8.99	12,101	37.1¢
Minnesota	6,215	$ 6.98	10,137	34.2¢
Mississippi	489	$ 6.64	12,049	27.6¢
Missouri	11,061	$ 5.34	10,759	24.8¢
Montana	724	$ 2.96	7,737	19.1¢
Nebraska	1,014	$ 8.23	11,957	34.6¢
Nevada	544	$ 7.86	12,827	30.6¢
New Hampshire	957	$ 9.61	13,716	35.0¢
New Jersey	3,994	$12.53	12,472	50.2¢
New Mexico	5,492	$ 2.32	8,983	12.9¢
New York	11,157	$11.83	12,332	48.0¢
North Carolina	17,714	$10.31	12,057	42.8¢
North Dakota	3,429	$ 2.08	6,833	15.2¢
Ohio	35,319	$ 6.61	11,250	29.4¢
Pennsylvania	29,135	$ 7.18	11,874	30.2¢
South Carolina	3,358	$11.11	12,137	45.8¢
South Dakota	301	$ 5.19	8,286	31.1¢
Tennessee	15,149	$ 5.07	11,297	22.4¢
Utah	432	$ 5.73	12,406	23.1¢
Vermont	51	$10.76	12,435	43.3¢
Virginia	6,680	$ 9.75	12,391	39.3¢
West Virginia	14,957	$ 5.84	11,659	25.0¢
Wisconsin	10,502	$ 8.61	11,223	38.4¢
Wyoming	3,572	$ 3.56	8,267	19.8¢

[1]Modified from Steam Electric Plant Factors, National Coal Association, tbl. 1, p. 3-50.

Cost of Reclamation

Missouri, as well as other states in which coal strip mining is practiced, has become concerned about disturbance of land by this mining method. Therefore, in 1971 the Mined Land Reclamation Act was passed creating the Missouri Land Reclamation Commission and providing for the enforcement of land reclamation measures. Most operators estimate that the cost of conforming to the state's reclamation regulations will be between 5 and 10 cents per ton. This would average less than 1/2 cent per million Btu. The highest estimate was slightly over 15 cents per ton.

Cost of Sulfur Removal

The cost of meeting federal air-quality standards for sulfur emissions by removal of sulfur from the coal or stack gases may be the determining factor in the marketability of Missouri coal for the utilities. At present, reliable figures are not available on this cost, but the initial installation of equipment is expensive.

COAL RESOURCES

The term "coal resources", as used in this report, refers to all the coal in the ground in beds 12 inches or more thick which can reasonably be assumed to exist. *Coal reserves, on the other hand, are deposits of coal which have been proven to exist and which can be mined with existing technology and under existing economic conditions.

Original reserves are those which were present in the ground before mining was undertaken and include coal which has since been mined and lost in mining, as well as that which remains.

Remaining reserves are those which remain in the ground after the amount mined and lost in mining has been subtracted. It is generally accepted that for every ton of coal mined an equal amount is lost or rendered unmineable. Therefore, the amount subtracted from the original reserves of an area to give remaining reserves is twice the amount mined.

Recoverable reserves are generally taken to be one-half of the figure obtained for remaining reserves. This is based upon the assumption that for every ton of coal mined a like amount is lost in mining or rendered unrecoverable.

* Definition modified from Flawn, 1966, Mineral Resources, p. 10.

Since much of Missouri's coal is potentially strippable, a higher recovery percentage is likely. However, this is counterbalanced by the fact that some coal lies beneath cities, towns, roads, railroads, pipelines and other cultural features which, in most instances, renders it unrecoverable by stripping. Therefore, recoverability of all remaining reserves in Missouri is figured at the usual 50 percent.

Robertson (1971) presented a detailed estimate of Missouri's coal resources and gave the total coal resource base of the state as 49.4 billion tons. Of this total, 31.7 billion tons was classified as determined by mapping and exploration and 18.2 billion tons as being present in untested areas. In addition, 10.4 billion tons was classified as a remaining reserve and 5.2 billion tons as a recoverable reserve. Additional data gathered during the course of the present investigation have allowed updating of the 1971 estimates. The most significant change is in the remaining reserve category. Remaining reserves are now set at 12.3 billion tons (tbl. 9), an increase of 1.9 billion tons over the 1971 estimate. Table 9 presents the first detailed estimate of reserves of strippable

Table 9

COAL RESOURCES AND REMAINING RESERVES BY REGION

Region	Total Original Resources Determined by Mapping & Expl. (Million tons)	Total Additional Possible Resources in Untested Areas (Million tons)
East-Central	1,177.96	----
Lexington	1,852.19	910.00
Mendota	2,715.83	1,818.00
Central	8,697.06	621.18
Western	7,586.13	4,033.10
Northwestern	6,761.06	5,159.38
Northeastern	71.78	329.00
South-Central	173.50	100.00
West-Central	2,824.06	4,518.80
Totals	31,859.57	17,489.46

coal ever made for Missouri. A total of slightly more than 3.7 billion tons of strippable coal remains. Of this, an estimated 1.85 billion tons is considered recoverable.

Total recoverable coal reserves are sufficient for nearly 1,300 years at the present rate of production. Recoverable strippable reserves would support the present production rate for nearly 400 years. Additional exploration would undoubtedly substantially increase recoverable reserve tonnage at the expense of the 49 billion ton resource base.

The reader is referred to Robertson (1971) for detailed discussion of the coal seams and resources of each region. Only those regions or parts of regions in which more detailed work has recently been done or which are thought to contain mineable deposits of coal are discussed in this report. Table 9 shows the distribution of coal resources, remaining reserves and strippable reserves by region. Breakdowns of all the state's coal regions by county are given in tables 10-18.

Total Original Resources (Million tons)	Remaining Reserves (Million tons)	Strippable Coal (Million tons)
1,177.96	840.46	491.32
2,762.19	1,148.99	90.94
4,533.83	996.34	300.00
9,318.24	3,589.25	1,205.29
11,619.23	3,182.24	1,604.94
11,920.44	1,341.50	----
400.78	2.00	.50
273.50	5.54	5.54
7,342.86	1,158.52	3.00
49,349.03	12,264.84	3,701.53

REGIONAL DISCUSSIONS

EAST-CENTRAL REGION

The East-Central Region consists of four counties (Audrain, Monroe, Montgomery, and Ralls) which have produced small to moderate tonnages of coal in past years. Most of the production was from the Mulky bed. Figure 7 depicts the distribution of coal deposits in the region and shows areas in which mining has occurred in past years. There has been no coal production in the East-Central Region since 1962.

Reserves

Practically all the mineable coal in the region occurs in the Mulky bed which ranges in thickness from 12 inches to slightly over 28 inches. The Mulky is of fair quality with respect to heating value. It averages 11,450 Btu/lb., which is above average for Missouri coal. The Mulky is high in sulfur content, however, averaging 4.7 percent sulfur.

The East-Central Region possesses a resource base of 1,178 million tons and a remaining reserve of 840.5 million tons. A strippable reserve of 491 million tons has been computed for the region. There is no coal production in the region at present, and no meaningful prediciton can be made as to possible utilization patterns in the near future.

Stripping Potential

Strip mining is possible in most of the region since overburden is rarely more than 100 feet thick. The most probable areas for stripping are the Perry area in southern Ralls County, eastern Audrain County and northwestern Montgomery County. In many localities in these areas, coal thickness, quality and overburden factors appear favorable for stripping. However, the reported "faulty" nature of the coal and the presence of clay slips continue to discourage the development of stripping operations in this field.

Underground Mining Potential

The thin and "faulty" nature of the Mulky coal seam does not present a favorable picture for the resumption of underground mining in the East-Central

Region. In the eastern part of the region, however, where the average thickness of coal is more than 28 inches, underground mining could be practical under very favorable marketing conditions. Past experience has shown, however, that the presence of clay slips and faults makes underground mining very expensive and noncompetitive here.

Development Potential

At the present time there are no large utilities plants in the region. A sufficient strippable reserve appears to be present to support one or two large

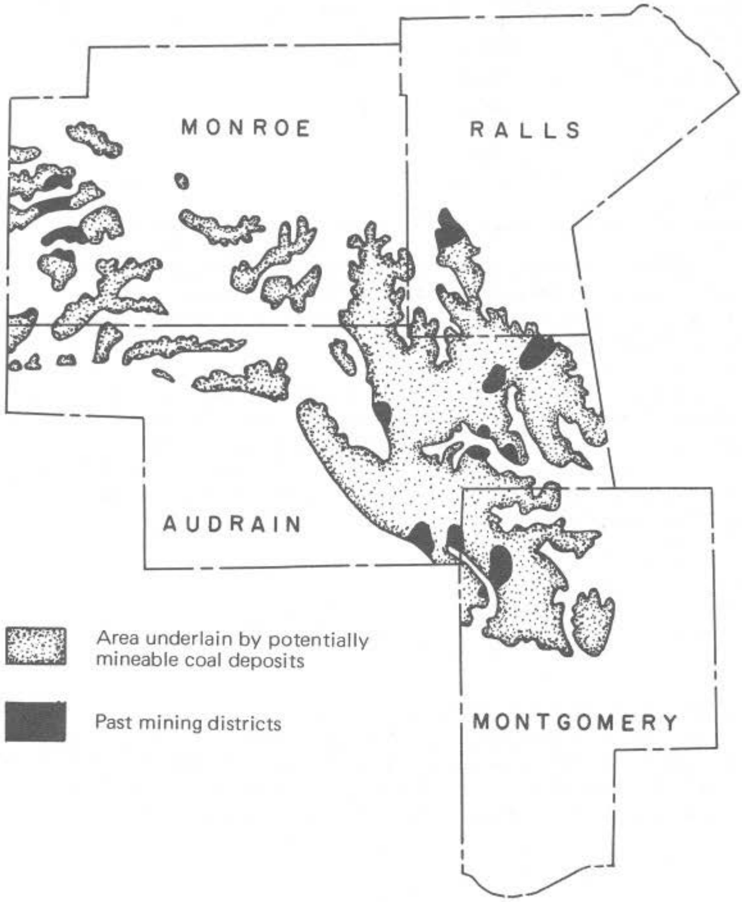


Figure 7

Coal deposits in the East-Central Region.

Table 10

COAL RESOURCES AND REMAINING RESERVES
OF THE EAST-CENTRAL REGION

County	Total Original Resources Determined by Mapping & Expl. (Million tons)	Total Additional Possible Resources in Untested Areas (Million tons)
Audrain	587.02	---
Montgomery	294.00	---
Monroe	215.00	---
Ralls	81.94	---
Totals	1,177.96	---

plants. However, recent exploration efforts have apparently not turned up deposits that are considered economically competitive at this time. The coal reserves of this region, however, stand as a ready reserve to be developed when more desirable deposits are exhausted.

The East-Central Region possesses sufficient reserves to supply a coal-conversion plant. The problem here, as elsewhere in the state, is acquiring enough coal so that it can be concentrated in a small area. The East-Central Region is not one of the most favorable areas in Missouri for this type of facility; however, the presence of so large a reserve of strippable coal precludes ruling it out entirely.

LEXINGTON REGION

The three west-central Missouri counties of Clay, Ray and Lafayette make up the Lexington Region (fig. 8). Although several coal beds have been mined in the region, the Lexington bed is by far the most important. The Waverly bed also has some potential for development. Almost all mining in the region has been by underground methods. The last mine closed in 1963.

Reserves

By far the greater amount of potentially mineable coal in this region is contained in the Lexington bed. The average heating value on an "as-received" basis for this bed is 10,549 Btu/lb. which is somewhat below the average for

Total Original Resources (Million tons)	Remaining Reserves (Million tons)	Strippable Coal (Million tons)
587.02	585.89	451.32
294.00	147.54	30.00
215.00	61.15	---
81.94	45.88	10.00
1,177.96	840.46	491.32

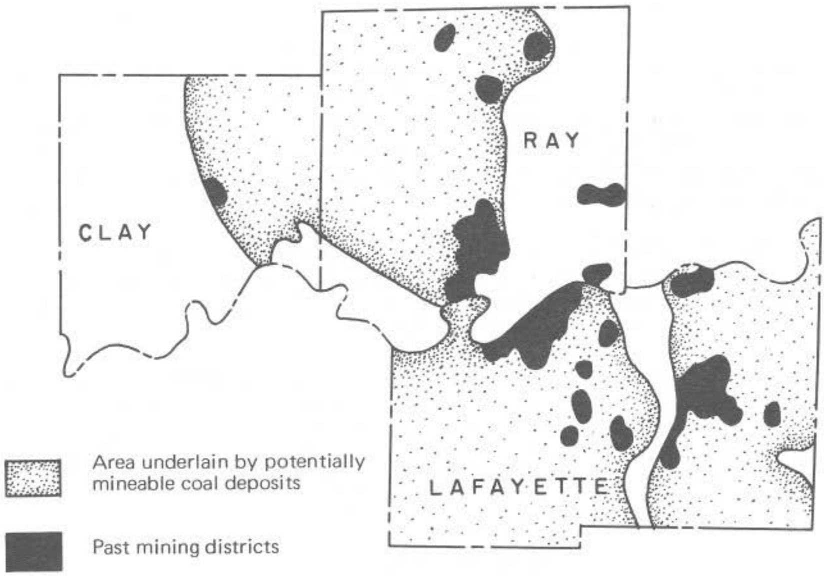


Figure 8
Coal deposits in the Lexington Region.

Table 11

COAL RESOURCES AND REMAINING RESERVES
OF THE LEXINGTON REGION

County	Total Original Resources Determined by Mapping & Expl. (Million tons)	Total Additional Possible Resources in Untested Areas (Million tons)
Clay	268.85	460.00
Lafayette	829.15	----
Ray	754.19	450.00
Totals	1,852.19	910.00

the state. Other factors, however, including a relatively low sulfur content, make coal from this bed a desirable fuel. The sulfur content averages 3.4 percent, second lowest for Missouri coal. Average heating value for the Waverly coal is 10,725 Btu/lb. This is slightly better than the Lexington, but difficult mining conditions will probably hinder mine development in this bed. The Waverly also runs very high in sulfur, averaging 5.9 percent.

The Lexington Region contains a total coal resource base of 2,762 million tons and a remaining reserve of 1,149 million tons. This indicates that a recoverable reserve of over 570 million tons is available in the region. Reserves of strip coal are estimated at 90.9 million tons.

The last operating mine closed in 1963. The presence of a large reserve of high-quality coal would seem to indicate a potential for development in the forseeable future. However, the coal is thin and much of it must be recovered by underground methods, a combination that is not conducive to mine development under prevailing economic and technologic conditions.

Stripping Potential

The greatest potential for stripping in the Lexington Region is in northern Lafayette County near Lexington, and southeast of Richmond in Ray County. The area southeast of Richmond is faulty, with the coal being replaced by channel sandstone in some areas.

Total Original Resources (Million tons)	Remaining Reserves (Million tons)	Strippable Coal (Million tons)
728.85	146.28	---
829.15	423.49	90.94
1,204.19	579.22	---
2,762.19	1,148.99	90.94

Underground Mining Potential

In the early years, the Lexington bed was mined underground at Higginsville, Corder and Lexington in Lafayette County, and near Richmond in Ray County In these areas extensive underground workings were developed despite the fact that the coal bed was only about 20 inches thick. The thin character of the coal was offset by good roof conditions that were well-suited to the longwall plan of mining. In later years, shaft mines were opened in northwestern Ray County and eastern Clay County. Here the Lexington coal lies 200 to 500 feet beneath the surface, but is somewhat thicker, attaining a thickness of 30 inches in parts of Ray County.

Although 30 inches is considered thin for underground mining by today's standards, a very large reserve exists in Ray and eastern Clay Counties. If "thin coal" mining technology becomes a reality in the United States, this area possesses some potential for the development of underground mining. Roof conditions are reportedly good and the coal is persistent in areal extent.

Coal was also recovered by underground methods from the Waverly beds at Waverly. The coal reached maximum thicknesses of 36 to 48 inches, but was faulty and irregular, and its potential for development is considered poor.

Development Potential

The Lexington Region possesses sufficient reserves to support a major utilities power plant or coal conversion plant. However, development of power or gasification or other type of coal conversion plants would probably be dependent upon the resumption of underground mining in the region since it is doubtful that a sufficient reserve of strip coal could be acquired.

MENDOTA REGION

Putnam and Sullivan Counties make up the Mendota Region (fig. 9). Although several coal beds of potential importance underlie the region, the Lexington bed is by far the most important. The Bevier bed also contains potentially mineable deposits of coal.

Although several small mines have been operated in Putnam County in recent years, only one active mine is known at present. Missouri Mining, Inc. is presently stripping an area along Shoal Creek. Current production is at the rate of about 100,000 or more tons per year.

Reserves

The Lexington bed in Putnam County and northeastern Sullivan County contains some of Missouri's best coal. Heating value ranges from 10,500 to

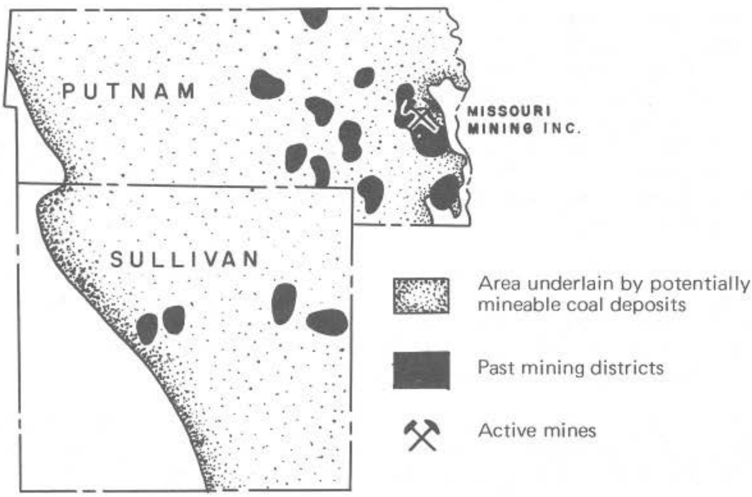


Figure 9
Coal deposits in the Mendota Region.

slightly over 11,000 Btu/lb., "as-received". The coal averages slightly over 3 percent sulfur. The Bevier bed averages slightly over 10,800 Btu/lb. in heating value and averages 4.3 percent sulfur.

The Mendota Region possesses a coal resource base of over 4.5 billion tons and a remaining reserve of over 996 million tons. At least 450 million tons may be considered a recoverable reserve and, perhaps of greater significance, the region possesses a strippable reserve of at least 300 million tons.

During the past few years mining has continued on a small scale. Small drift and strip mines have furnished coal for local users, while larger strip mines have sold coal to municipal power plants in southeastern Iowa and northern Missouri. At present only one strip mine is in operation. The large recoverable coal reserves of the Mendota Region make it a leading mine-mouth power plant contender.

Stripping Potential

In recent years, strip-mining operations have been confined to eastern Putnam County, where rim-stripping (contour stripping) has been pursued along the larger stream valleys. At least 300 million tons of strippable coal are available in this area and in northeastern Sullivan County. The coal ranges in thickness from 24 to 42 inches and overburden ranges from 0 to slightly over 100 feet in areas where the coal is considered strippable.

Underground Mining Potential

In past years, shipping mines were developed at Mendota where the Lexington coal was recovered through shafts. Many small drift mines existed along stream valleys in which the coal bed was exposed. The Bevier coal has been mined on a very small scale through drifts in southeastern Putnam County and to a greater extent through shafts at Milan in Sullivan County. A core hole was put down at Mystic in eastern Sullivan County as a part of the Survey's drilling program. The hole penetrated 31 inches of coal at the Bevier horizon, indicating the presence of a large area of coal between 28 and 39 inches in thickness between the Novinger Field in Adair County and the Milan Field in Sullivan County (fig. 2). If a trend to mining thin seams were to develop, this part of eastern Sullivan County would merit consideration for underground mining.

Development Potential

The Mendota Region is an ideal area for development of a mine-mouth utilities power plant or a coal-conversion plant. A large uncommitted reserve of strip coal of good quality is available, chiefly in the Lexington bed.

Table 12

COAL RESOURCES AND REMAINING RESERVES
OF THE MENDOTA REGION

County	Total Original Resources Determined by Mapping & Expl. (Million tons)	Total Additional Possible Resources in Untested Areas (Million tons)
Putnam	1,097.82	1,268.00
Sullivan	1,618.01	550.00
Totals	2,715.83	1,818.00

CENTRAL REGION

The Central Region, consisting of seven counties in north-central Missouri, is one of the two most important coal-producing regions in the state (figs. 10 and 11). By far the most important coal bed in the Central Region is the Bevier bed, although the Mulky, Lexington and Summit are also important.

At present there are two large strip mines active in the Central Region. The largest is the Bee Veer mine in Macon County which produced over one million tons of coal in 1970, most or all of which was used to fire Associated Electric's Thomas Hill power plant. The Prairie Hill mine in Randolph County produced over 486,000 tons which was also used at the Thomas Hill plant. The Mark Twain mine in Boone County was closed in 1972. Coal from this mine had been shipped to various smaller installations, including the City of Columbia's power plant. Several small mines are also operating in the region, providing coal for domestic use and city utilities.

Reserves

Coal from the region's three principal beds--the Bevier, Mulky and Lexington--ranges in heating value from about 10,500 Btu/lb. to over 11,400 Btu/lb. on an "as-received" basis. Average heating value for the Bevier bed (in which by far the greatest reserve is contained) is 10,827 Btu/lb. Average sulfur contents are 4.3 percent for the Bevier, 4.7 for the Mulky and 3.4 for the Lexington.

Total Original Resources (Million tons)	Remaining Reserves (Million tons)	Strippable Coal (Million tons)
2,365.82	500.00	200.00
2,168.01	496.34	100.00
4,533.83	996.34	300.00

The Central Region possesses a coal resource base of over 9 billion tons and a remaining reserve of more than 3.5 billion tons. A recoverable reserve of more than 1.7 billion tons is available, of which at least 600 million tons is strippable.

In recent years, almost all coal mined in the Central Region has been used to fuel various types of public utilities power plants. The entire production of the Bee Veer and Prairie Hill mines is committed to the Thomas Hill mine-mouth plant of Associated Electric. The Mark Twain mine and smaller strip mines in the region have shipped coal to smaller plants, including municipal utilities. A few very small mines have provided fuel for domestic uses.

In the foreseeable future these patterns will remain the same, with perhaps some increase in coal use by large power plants.

Stripping Potential

The Central Region contains a recoverable reserve of over 600 million tons of strippable coal. Potential stripping areas are present in all seven counties.

Underground Mining Potential

The Central Region contains nearly 1.2 billion tons of coal in beds 42 or more inches in thickness. Over 600 million tons of this may be considered a recoverable reserve and all of it is theoretically recoverable by underground

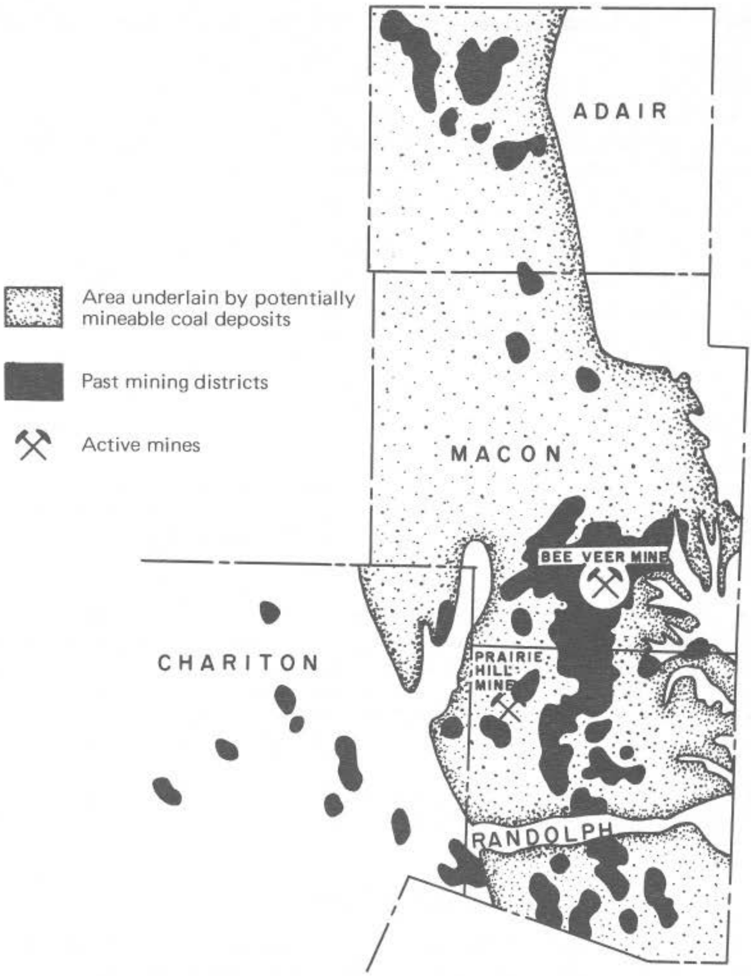


Figure 10
Coal deposits in the northern half of the Central Region.

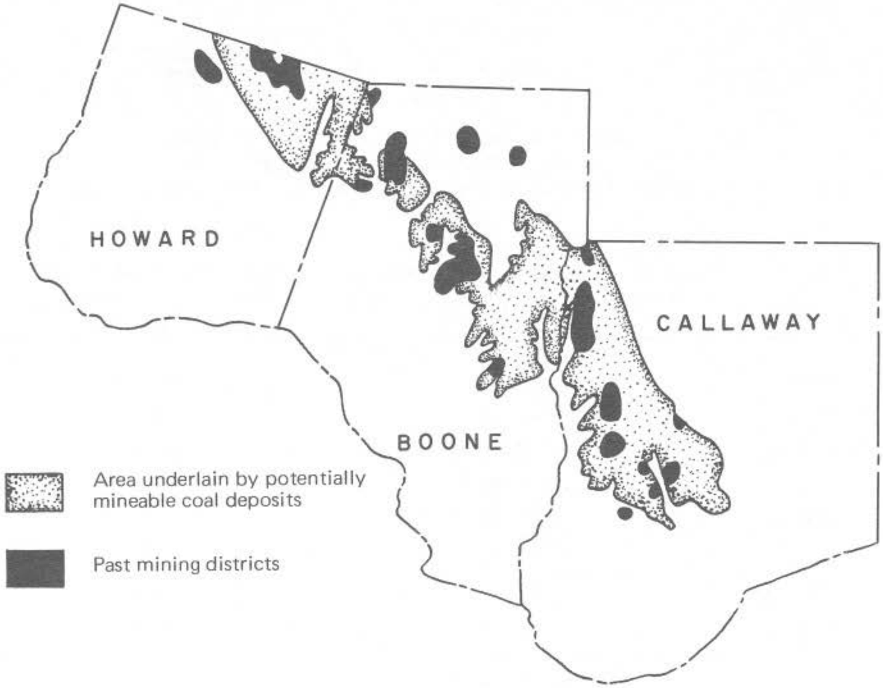


Figure 11
Coal deposits in the southern half of the Central Region.

methods. However, it is unlikely that underground mining will be resumed in the region in the near future because a large reserve of strippable coal is available.

Development Potential

The Central Region contains ample coal reserves to support the development of additional mine-mouth power plant generating capacity.

In addition, an ample coal reserve is present to provide fuel for coal gasification or other types of conversion facilities. The problem of acquiring enough coal concentrated in a small area exists, but is no greater than it would be elsewhere in the Midwest or in the East.

Table 13

COAL RESOURCES AND REMAINING RESERVES
OF THE CENTRAL REGION

County	Total Original Resources Determined by Mapping & Expl. (Million tons)	Total Additional Possible Resources in Untested Areas (Million tons)
Adair	1,587.47	221.18
Boone	497.59	----
Callaway	695.88	300.00
Chariton	1,138.94	----
Howard	931.00	100.00
Macon	2,339.10	----
Randolph	1,507.08	----
Totals	8,697.06	621.18

WESTERN REGION

The Western Region is the largest of Missouri's coal-producing regions and includes two important coal fields, the Tebo Field and the Southwest Field (fig. 1). Coal is produced from at least seven coal beds.

Reserves

The most important coal beds in terms of production are the Tebo, Rowe and Mulberry. Other beds from which coal is produced in varying amounts are the Weir-Pittsburg, Mineral, Fleming and Croweburg. These coals are all very similar in heating value. All average over 11,000 Btu/lb. ("as-received"); the overall average is 11,453 Btu/lb. — the best in the state. These coals do not vary substantially from the state average in sulfur content, averaging generally between 4 and 5 percent. The one exception is the Mulberry bed. Analyses of 6 face samples gave an average sulfur content of 2.7 percent for this bed.

The coal resources of the Western Region are vast (figs. 12 and 13). A resource base of nearly 12 billion tons is present, of which 3.18 billion tons is considered to be a remaining reserve. Approximately 1.5 billion tons of this is recoverable.

As elsewhere in Missouri, production of electrical power by public utilities is the prime market for coal produced in the Western Region. Nearly 2.75

Total Original Resources (Million tons)	Remaining Reserves (Million tons)	Strippable Coal (Million tons)
1,808.65	882.49	77.45
497.59	386.02	386.02
995.88	396.91	132.30
1,138.94	277.86	139.40
1,031.00	245.14	202.13
2,339.10	574.38	67.99
1,507.08	826.45	200.00
9,318.24	3,589.25	1,205.29

million tons is used yearly to fuel three large mine-mouth power plants. Most of the remaining coal produced is used in smaller municipal and institutional power plants throughout the region. A small amount is shipped outside the region.

These utilization patterns are expected to continue well beyond 1985, with a substantial increase in coal produced for mine-mouth plants.

Stripping Potential

The Western Region contains a remaining reserve of strippable coal of 1.6 billion tons. Approximately 800 million tons of this is considered recoverable. At the present rate of production (2.5 million tons yearly) this is enough coal to last over 300 years. Four large strip mines are presently operating in the region to fire three major mine-mouth power plants.

Although these mines have much of the mineable coal in their immediate vicinities under lease or ownership, it is certain that continued exploration for coal will prove additional mineable reserves.

Underground Mining Potential

Because of the availability of large reserves of strip coal in the Western Region, it is doubtful that underground mining will be resumed there in the foreseeable future.

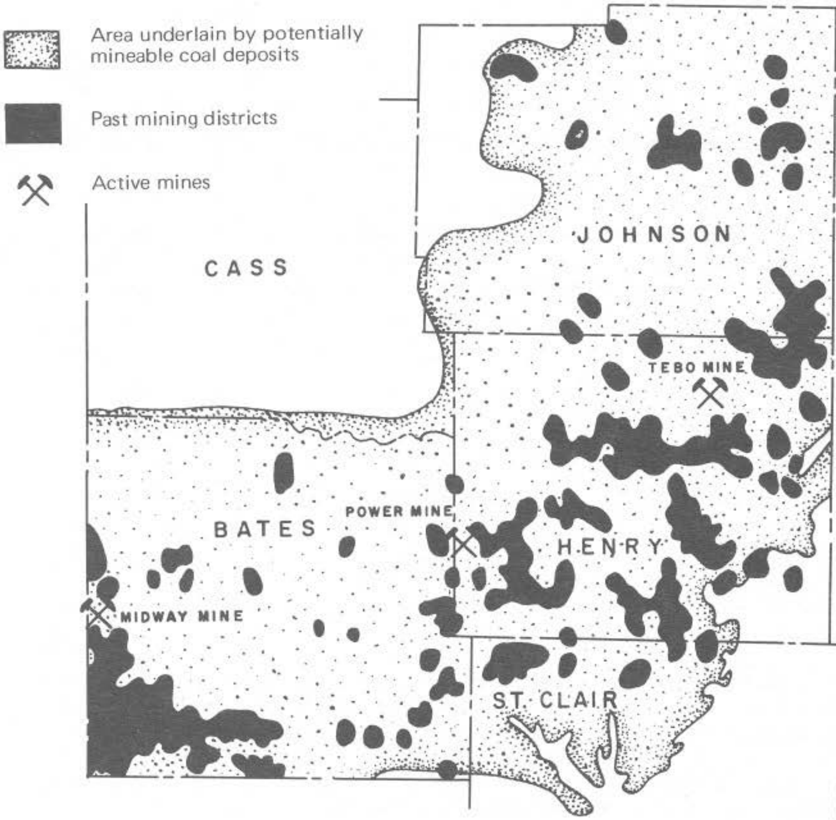


Figure 12
Coal deposits in the northern half of the Western Region.

Most of the region's coal beds are either too thin or too irregular to be mined underground under prevailing mining and economic conditions. There are a few areas, however, that contain deposits that could be mined underground if conditions should change to encourage underground recovery of thin coal seams.

The Tebo bed contains coal averaging 28 inches or slightly more in thickness in relatively large areas of northern Henry and southeastern Johnson Counties. The coal is remarkably persistent in areal extent and this, combined with the presence of a good limestone cap rock, should make for excellent mining conditions.

There are other areas in the Western Region which contain coal deposits which might prove mineable by underground methods under more favorable marketing conditions. It would require extensive exploration data to determine the potential mineability of these deposits.

Development Potential

Three large mine-mouth utilities plants are now fired by coal mined in the Western Region. Despite this heavy demand on the region's coal deposits, the recoverable remaining reserve of 800 million tons of strip coal assures the

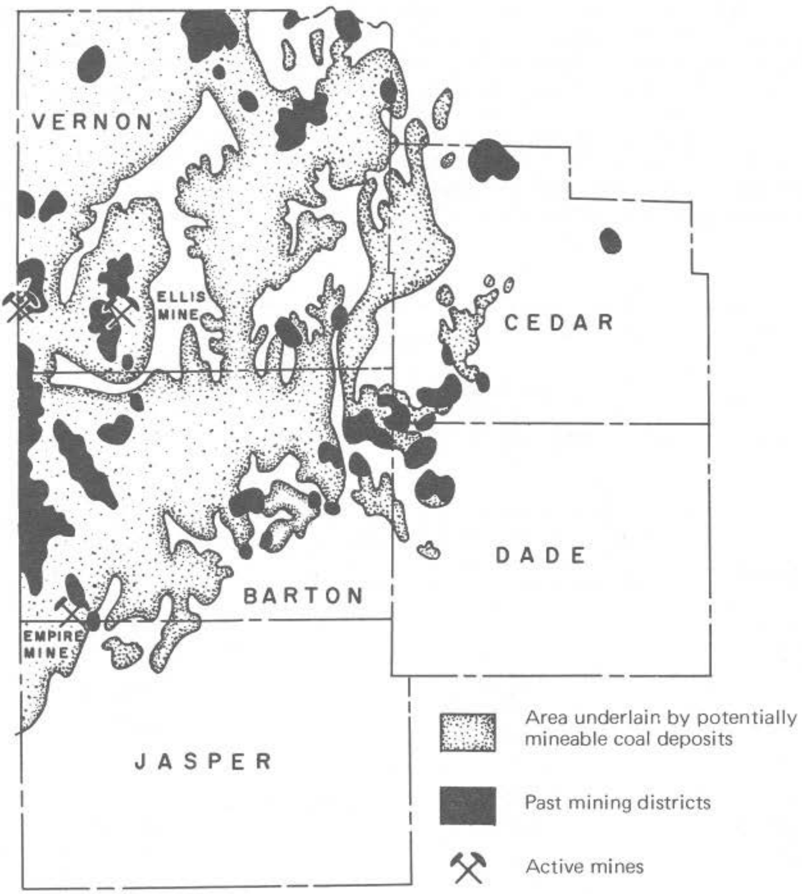


Figure 13
Coal deposits in the southern half of the Western Region.

availability of fuel for additional plant capacity, as well as for more sizable coal-conversion plants. The problem here, as elsewhere, would be acquiring a large enough reserve concentrated in a small area.

NORTHWESTERN REGION

The Northwestern Region consists of 12 counties in the northwestern corner of the state (figs. 14, 15, 16). The more important coal beds lie deep beneath the surface in most of the region. Several relatively unimportant coal beds crop out and have been mined on a minor scale in Nodaway County.

The potential of this region for coal production is great for it possesses an estimated coal resource base of nearly 12 billion tons. However, because of the depth to the major coal horizons and the lack of exploration data, very little is known about the thickness and lateral persistence of most of these deposits.

Table 14

COAL RESOURCES AND REMAINING RESERVES
OF THE WESTERN REGION

County	Total Original Resources Determined by Mapping & Expl. (Million tons)	Total Additional Possible Resources in Untested Areas (Million tons)
Barton	367.57	100.00
Bates	1,467.02	844.70
Cass	72.86	1,380.00
Cedar	40.00	130.00
Dade	26.72	20.00
Henry	1,534.27	----
Jackson	220.80	470.40
Jasper	93.60	----
Johnson	2,753.76	400.00
St. Clair	283.37	323.00
Vernon	726.16	365.00
Totals	7,586.13	4,033.10

For this reason, mining development in the foreseeable future is considered unlikely, except possibly in the Cainsville area, which contains large deposits of coal in relatively thick beds.

Reserves

Most of the known potentially mineable coal in the Northwestern Region is contained in two coal beds, the Cainsville and the "Princeton". Available data indicate that both of these coals are of good quality, based on heating value. The Cainsville bed was mined at Cainsville, where its average heating value was 10,820 Btu/lb. The average heating value for the two samples collected during the recent drilling program was somewhat less (10,455 Btu/lb.). The "Princeton" bed has never been mined, but analyses of samples taken from the two drill holes that penetrated this bed during the recent drilling program indicate that it is of excellent quality. *The average heating value for samples from these two drill holes is 11,220 Btu/lb. The Cainsville bed is very high in sulfur, averaging 5 percent. The "Princeton" bed averages 3.7 percent sulfur.

* Sample 34 was not included because correlation of the coal bed from which it was taken with the "Princeton" is uncertain, and the drill hole from which it was taken lies outside the area of mineable Princeton coal.

Total Original Resources (Million tons)	Remaining Reserves (Million tons)	Strippable Coal (Million tons)
467.57	256.47	256.47
2,311.72	405.03	368.53
1,452.86	72.74	----
170.00	14.32	14.32
46.72	26.72	----
1,534.27	977.50	564.72
691.20	220.80	----
93.60	5.80	----
3,153.76	434.12	----
606.37	139.73	----
1,091.16	629.01	400.90
11,619.23	3,182.24	1,604.94

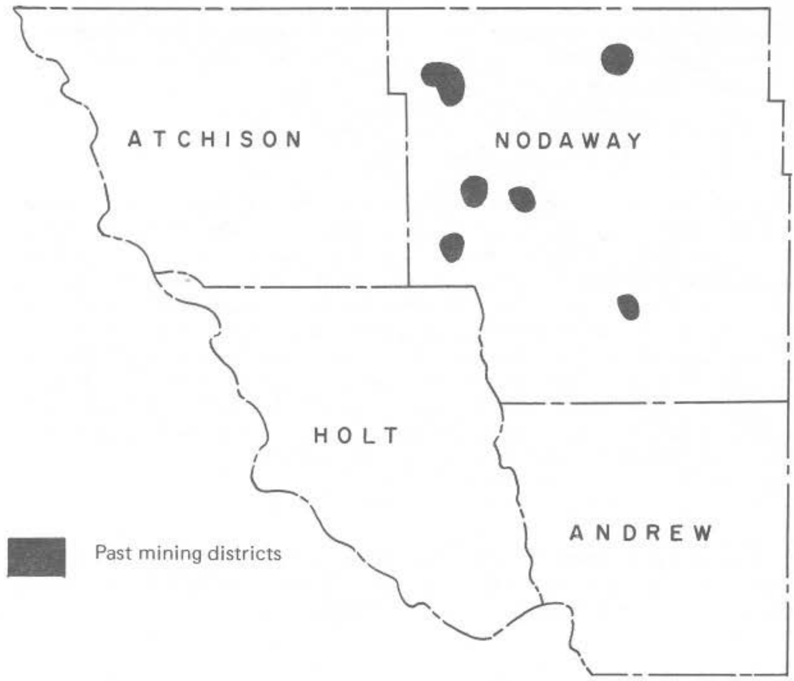


Figure 14
Coal deposits in the northwestern part of the Northwestern Region.

The Northwestern Region possesses a very large resource base of undeveloped coal deposits. The estimated coal resource base is nearly 12 billion tons. Of this, over 1.3 billion tons is considered a remaining reserve. No coal has been mined in the Northwestern Region in recent years.

Stripping Potential

The more important coal beds lie too deep beneath the surface to be strip mined and, therefore, no strippable coal reserve has been figured for the Northwestern Region.

Underground Mining Potential

The Northwestern Region is within the Forest City basin, which contains a thick wedge of coal-bearing sediments. Little is known of the distribution and

Figure 15
Coal deposits in the southwestern part of the Northwestern Region.

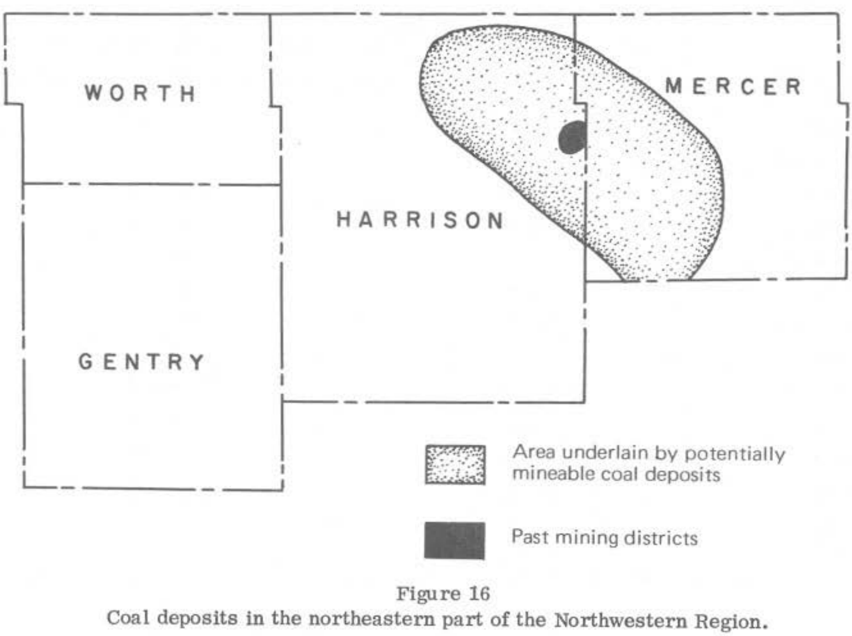


Figure 16
Coal deposits in the northeastern part of the Northwestern Region.

thickness of the coal beds underlying most of the region because of a lack of drillhole data.

However, in the Cainsville-Princeton area, mining and drilling have revealed the presence of a potentially large reserve of mineable coal. Therefore, during the recent drilling program the decision was made to put down several holes in the Princeton-Cainsville area to test the persistence of the coal beds and to obtain samples from which much-needed analytical data could be obtained. One significant discovery resulting from the drilling is that not one but two thick, mineable coal beds, as well as several thinner ones, are present in the district.

The Cainsville area is relatively small, consisting of approximately 140 square miles in western Mercer and eastern Harrison Counties.

A coal bed averaging 48 inches in thickness was previously mined at Cainsville. Later, several drillholes at Princeton intersected a thick coal bed which was presumed to be the Cainsville. During the current drilling program,

Table 15

COAL RESOURCES AND REMAINING RESERVES OF THE NORTHWESTERN REGION

County	Total Original Resources Determined by Mapping & Expl. (Million tons)	Total Additional Possible Resources in Untested Areas (Million tons)
Andrew	280.86	214.00
Atchison	263.95	----
Buchanan	544.26	586.00
Clinton	200.69	363.78
De Kalb	36.48	585.60
Gentry	146.42	100.00
Harrison	1,681.98	1,000.00
Holt	167.04	300.00
Mercer	2,956.82	500.00
Nodaway	172.80	400.00
Platte	78.83	710.00
Worth	230.93	400.00
Totals	6,761.06	5,159.38

however, a hole was drilled at Goshen (see cross section, fig. 17) which intersected two coal beds of good thickness. The upper bed, 34 inches thick, is correlated with the Cainsville bed and the lower one, 48 inches thick, is correlated with a thick split seam which was penetrated by the drill beneath the Cainsville coal at Cainsville and with the thick split seam drilled at Princeton. Assuming that this interpretation is correct, there are two thick, mineable coal beds in the Cainsville-Goshen area. The Cainsville bed is present at Princeton, but it is thin and badly split and, therefore, was not recognized by previous prospectors, who considered the first thick coal penetrated to be the Cainsville. The lower mineable bed has tentatively been named the "Princeton" coal bed.

A very significant reserve tonnage has been figured for the Cainsville-Princeton area. A total coal reserve of 1.3 billion tons has been computed. This figure includes all coal in beds over 12 inches thick; some is therefore too thin to mine by underground methods and too deep to strip. Over 950 million tons, however, occurs in beds 28 inches or more thick and could possibly be mined by underground methods. Furthermore, over 400 million tons occurs in

Total Original Resources (Million tons)	Remaining Reserves (Million tons)	Strippable Coal (Million tons)
494.86	----	----
263.95	----	----
1,130.26	----	----
564.47	----	----
622.08	----	----
246.42	----	----
2,681.98	370.58	----
467.04	----	----
3,456.82	910.13	----
572.80	----	----
788.83	----	----
630.93	60.79	----
11,920.44	1,341.50	none

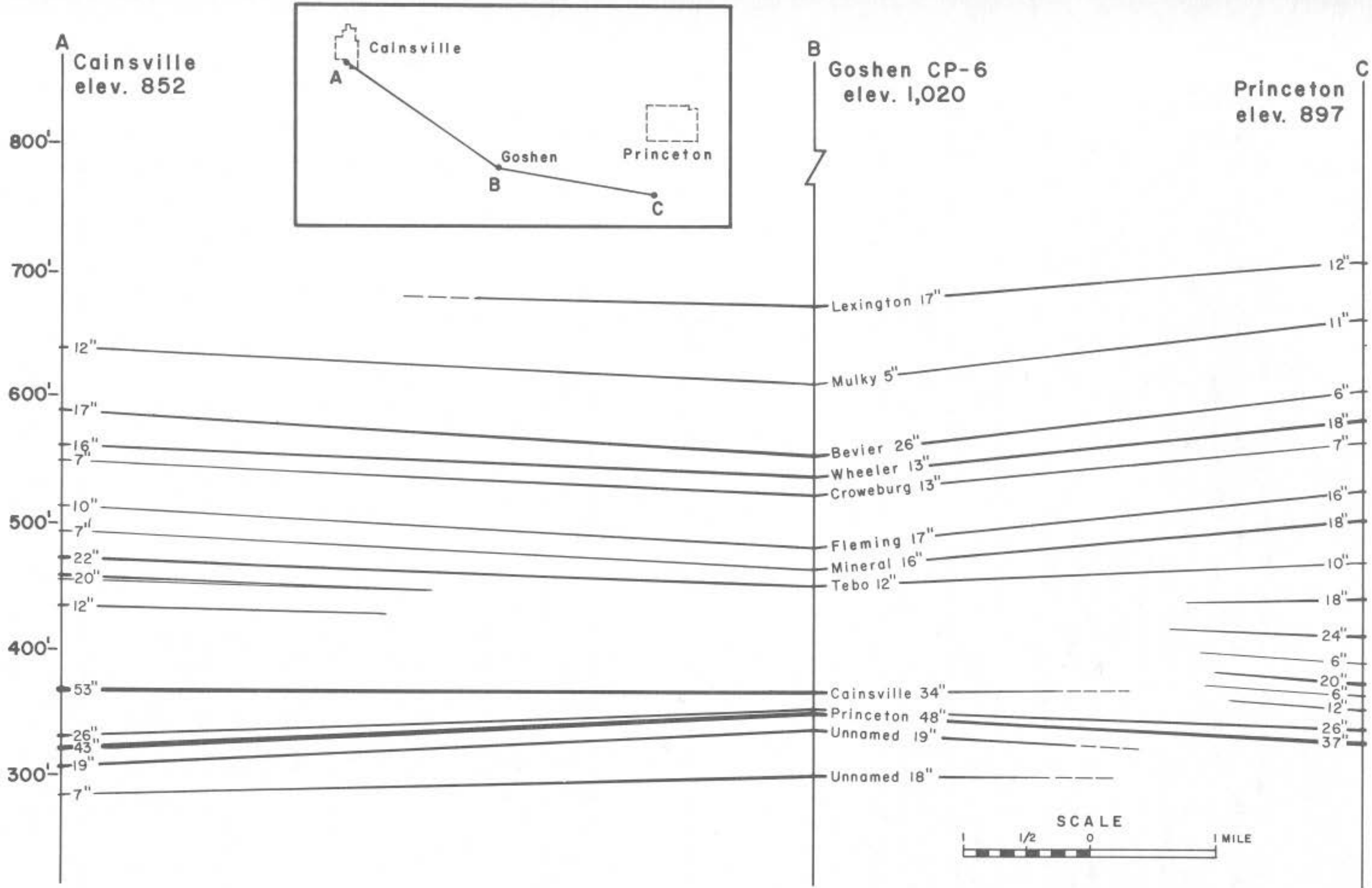


Figure 17
Cross section -- Cainsville to Princeton.

beds 42 inches or more thick and in all probability could be mined by underground methods.

Development Potential

The coal resources of the Northwestern Region are of great potential importance because they are sufficient to support a coal-to-gas conversion plant in an area that could serve such nearby cities as Kansas City, Omaha and Des Moines, as well as smaller cities in adjacent parts of Missouri, Iowa and Nebraska. Herein is an opportunity to at once help relieve the energy shortage, convert a high-sulfur fuel to a clean fuel, provide gas to an area not rich in reserves of natural gas and to promote industry in a depressed area. Although more exploratory drilling will be necessary to actually prove and delineate areas of mineable coal, there is no doubt that the Cainsville-Princeton area should at least be given consideration as a source of fuel for coal-to-gas conversion.

Geological knowledge gained from a study of the drill cores indicates that other areas containing coal deposits similar in form and tonnage to that of the Cainsville-Princeton area might be expected to lie buried beneath the surface and undetected in northwest Missouri.

OTHER REGIONS

The Northeastern Region, the South-Central Region and the West-Central Region are not discussed in detail because they have no significant mineable reserves. Tables 16, 17, and 18 show coal reserves and remaining reserves for these regions.

Table 16

COAL RESOURCES AND REMAINING RESERVES
OF THE NORTHEASTERN REGION

County	Total Original Resources Determined by Mapping & Expl. (Million tons)	Total Additional Possible Resources in Untested Areas (Million tons)
Clark	2.00	50.00
Knox	---	---
Lewis	.10	---
Marion	---	---
Schuyler	67.68	259.00
Scotland	2.00	20.00
Shelby	---	---
Totals	71.78	329.00

Table 17

COAL RESOURCES AND REMAINING RESERVES
OF THE SOUTH-CENTRAL REGION

County	Total Original Resources Determined by Mapping & Expl. (Million tons)	Total Additional Possible Resources in Untested Areas (Million tons)
Cooper	31.50	---
Pettis	30.00	100.00
Saline	112.00	---
Totals	173.50	100.00

Table 18

COAL RESOURCES AND REMAINING RESERVES
OF THE WEST-CENTRAL REGION

County	Total Original Resources Determined by Mapping & Expl. (Million tons)	Total Additional Possible Resources in Untested Areas (Million tons)
Caldwell	440.77	675.00
Carroll	408.38	400.00
Daviess	196.98	1,000.00
Grundy	168.95	994.80
Linn	1,289.30	528.00
Livingston	319.68	921.00
Totals	2,824.06	4,518.80

Total Original Resources (Million tons)	Remaining Reserves (Million tons)	Strippable Coal (Million tons)
52.00	2.00	0.50
---	---	---
.10	---	---
---	---	---
326.68	---	---
22.00	---	---
---	---	---
400.78	2.00	0.50

Total Original Resources (Million tons)	Remaining Reserves (Million tons)	Strippable Coal (Million tons)
31.50	.54	.54
130.00	5.00	5.00
112.00	---	---
273.50	5.54	5.54

Total Original Resources (Million tons)	Remaining Reserves (Million tons)	Strippable Coal (Million tons)
1,115.77	128.42	---
808.38	3.00	3.00
1,196.98	154.44	---
1,163.75	31.10	---
1,817.30	832.56	---
1,240.68	9.00	---
7,342.86	1,158.52	3.00

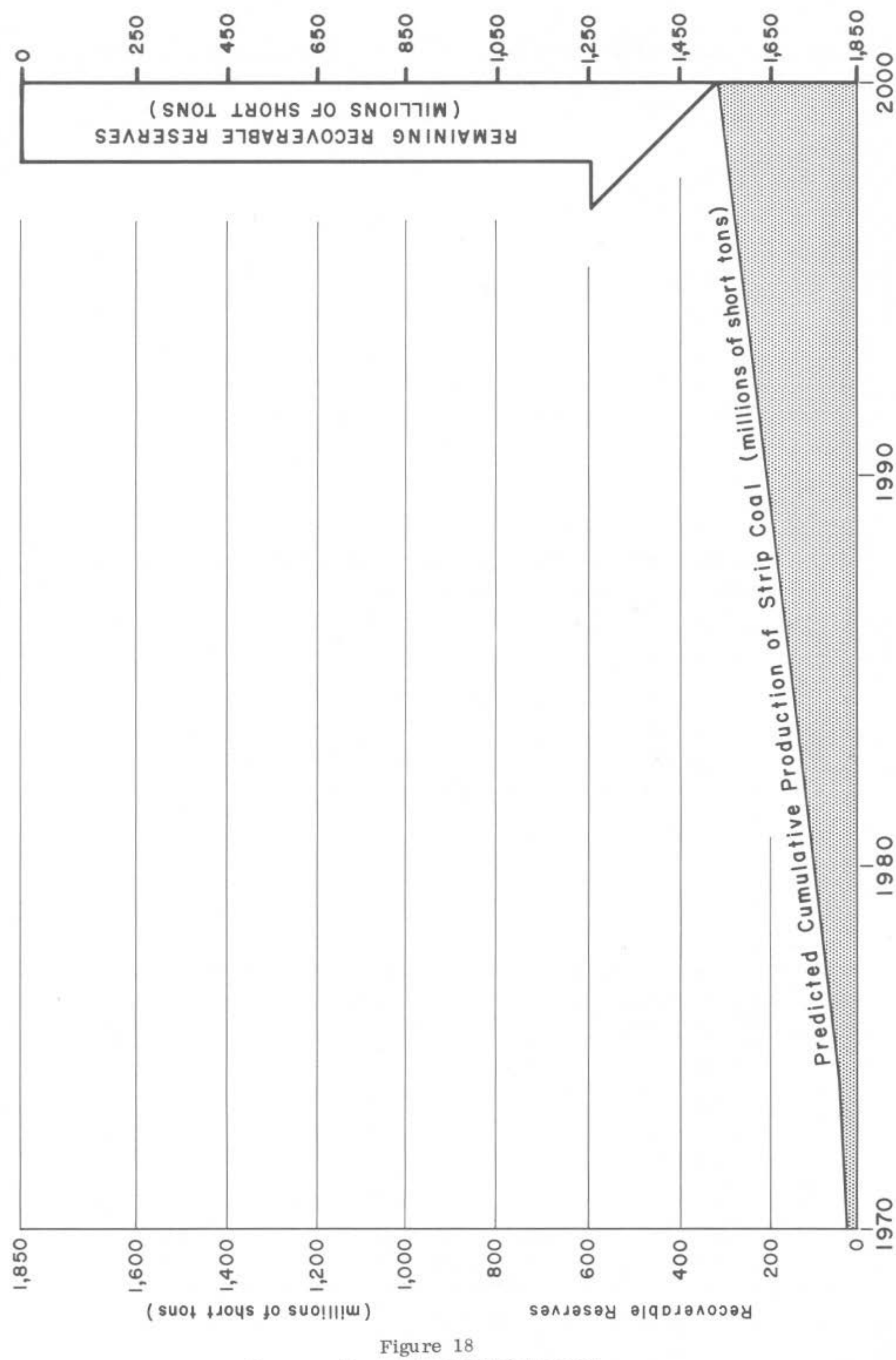


Figure 18
Recoverable reserves of strip coal.

SUMMARY AND CONCLUSIONS

Missouri has a substantial coal resource base sufficient to support a greatly expanded mining industry. The state's total coal resource base is over 48 billion tons. Nearly 12.3 billion tons is classed as a remaining reserve and over 6 billion tons as a recoverable reserve. Missouri's recoverable reserve of strip coal is figured at just over 1.8 billion tons. *Figure 18 shows remaining recoverable reserves of strip coal plotted against predicted cumulative production through the year 2000. It is clearly shown that this reserve is more than sufficient to absorb expansion of strip mining well beyond the turn of the century.

Figure 19 is a similar plot showing total remaining recoverable reserves plotted against predicted cumulative production. The inset portrays graphically the relationship between recoverable reserves, remaining reserves and the total resource base. It is seen that predicted cumulative production of 500 million will only slightly decrease the remaining recoverable reserve of over 6 billion tons. Additional exploration would enlarge the remaining recoverable reserve at the expense of the resource base of 49.3 billion tons.

The existence of a large coal resource base does not mean, however, that there will be a great expansion of coal mining in Missouri in the near future. Economic and regulatory considerations will be the determining factors. Missouri coal is expensive to mine because it occurs in thin seams. Strip mining is by far the most economical method of recovery. In simple terms, where it is less expensive to mine Missouri coal than it is to mine and ship coal from competitive coal-producing states, Missouri coal will be mined. This should continue to be the case for mine-mouth power plants.

Government regulations limiting sulfur emissions from plant stacks add an additional cost factor which will have an adverse effect on the utilization of Missouri coal and favor coal production in the low-sulfur fields. The full import of this cost factor cannot be evaluated at this time. It is certain that much--

* Production curve is based on the assumption that the average annual production between the present and the year 2000 will be 10 million tons. This probably represents the maximum production that can be expected and actual production could be much lower.

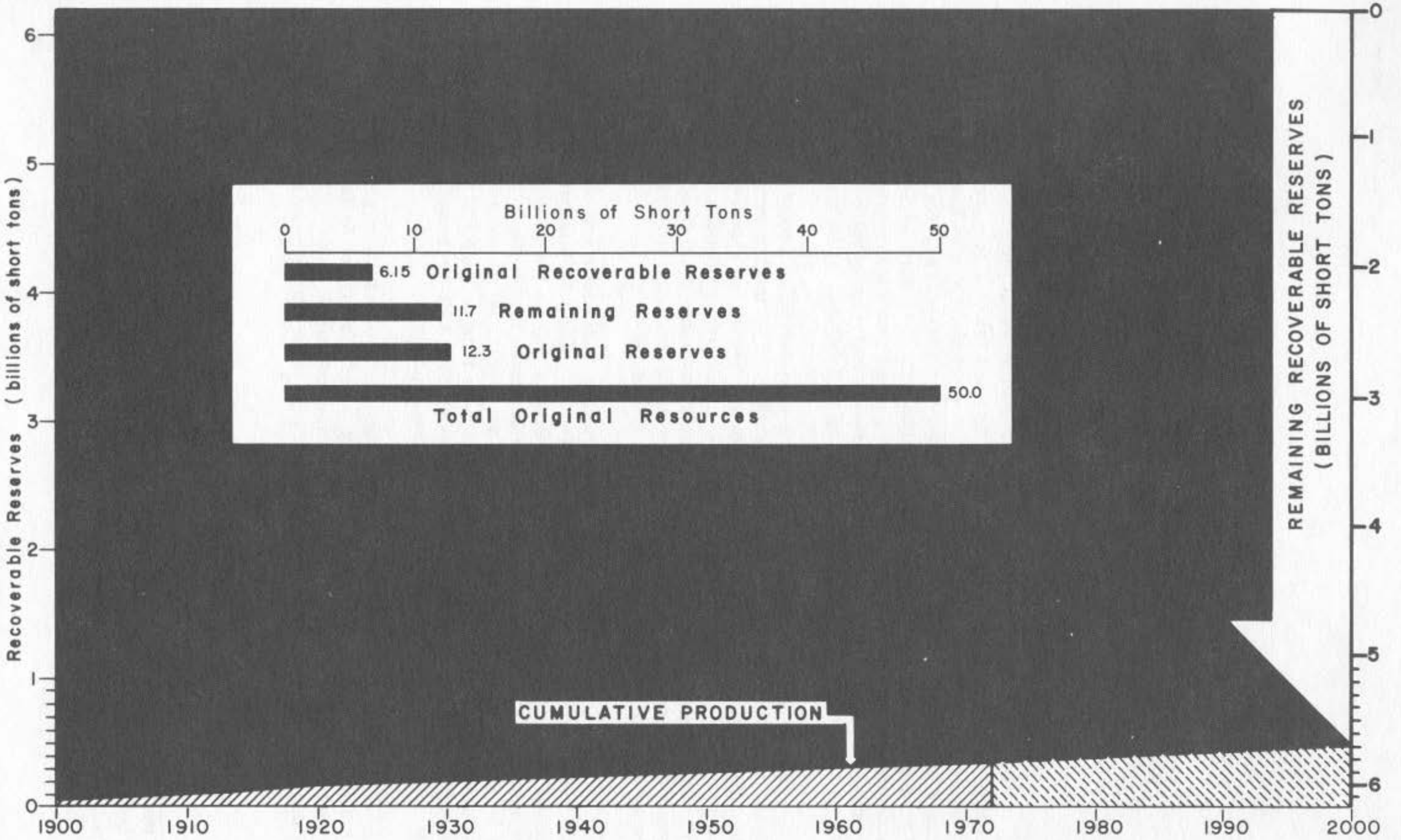


Figure 19
Recoverable reserves.

perhaps the bulk--of coal-produced energy utilized in Missouri will come from outside the state. Some will be transported as coal, some by wire as electrical energy and some by pipeline as gas or coal slurry.

The extent to which Missouri coal will be utilized will depend on comparative mining costs, transportation costs and the cost of reducing sulfur emissions from the stacks of plants burning Missouri coal. In all likelihood, the production of electricity by mine-mouth power-plants will continue to be the

Figure 20
Potential development sites in Missouri.

primary use of Missouri coal in the short term. Most or all production will be supplied by strip mining.

There is some possibility that Missouri could capture part of the predicted coal-conversion market. Figure 20 shows regions which could support coal-conversion complexes as well as those which can support additional development of mine-mouth power plants. The conclusion that these regions can support the indicated industries is based entirely on the presence of sufficient reserves of recoverable coal. Economic factors are not taken into consideration.

Resumption of underground mining in Missouri will depend on an increased demand for Missouri coal and the development of thin-seam mining technology in the United States.

REFERENCES

Averitt, Paul, 1967, Coal resources of the United States: U.S. Geol. Survey, Bull. 1275, 116 p.

Erwin, Robert B., 1971, The Survey's role: West Virginia Newsletter, 15th Issue.

Federal Power Commission, 1970: F.P.C. News, v. 3, n. 11, p. 3.

Fieldner, A.C., H.M. Cooper and F.D. Osgood, 1926, Analysis of mine samples: U.S. Bur. Mines, Tech. Paper 366, p. 8-9, 1 tbl.

Flynn, George J., Jr., 1949, Heating values of American coals by rank and by states: U.S. Bur. Mines, Inf. Circ. 7538, 11 p.

Gallagher, J.J., and L.W. Westerstram, 1969, Coal---bituminous and lignite, in Minerals Yearbook: U.S. Bur. Mines, v. 1 and 2, p. 309-371.

Hinds, Henry, 1912, The coal deposits of Missouri: Mo. Bur. Geol. & Mines, 2nd. ser., v. 11, 505 p., 23 pls., 92 figs., 7 maps.

Hottel, H.C., and J.C. Howard, 1971, New energy technology, some facts and assessments: MIT Press, 364 p.

National Coal Association, 1971, Steam-electric plant factors: Natl. Coal Assn., 114 p., 1 fig., 8 tbls.

Robertson, Charles E., 1971, Evaluation of Missouri's coal resources: Mo. Geol. Survey & Water Resources, Rept. Inv. 48, 92 p., 5 figs, 1 tbl., 4 apps.

Searight, Walter V., 1949, Coal production, distribution and consumption in Missouri: Mo. Geol. Survey & Water Resources, Inf. Circ. 3, 52 p., 1 pl., 12 figs., 2 tbls., 2 apps.

U.S. Geological Survey, 1970, The national atlas of the United States of America: U.S. Geol. Survey, 417 p.

RI 54

MISSOURI DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGY AND LAND SURVEY
MINEABLE COAL RESERVES OF MISSOURI
Wallace B. Howe, State Geologist
GEOLOGICAL SURVEY P.O. Box 250, Rolla, MO 65401