GEOLOGICAL SURVEY CIRCULAR 53

August 1949

COAL RESOURCES OF MONTANA

By

John X. Combo, Donald M. Brown, Helen F. Pulver

and Dorothy A. Taylor

UNITED STATES DEPARTMENT OF THE INTERIOR
J. A. Krug, Secretary
GEOLOGICAL SURVEY
W. E. Wrather, Director

WASHINGTON, D. C.

Free on application to the Director, Geological Survey, Washington 25, D. C.

COAL RESOURCES OF MONTANA

By

John X. Combo, Donald M. Brown

Helen F. Pulver, and Dorothy A. Taylor

CONTENTS

ILLUSTRATIONS

TABLES

PREFACE

This report on the coal resources of Montana is the first of a series of State summary studies being undertaken by the Geological Survey as part of a program to reappraise the coal reserves of the United States. The last estimate of coal reserves in the Nation was made by M. R. Campbell of the Geological Survey in 1928 after a lifetime of work on the geology and distribution of coal. Mr. Campbell's estimates have been extensively quoted and, with minor revisions, have been presented at times by the Geological Survey and other agencies. Since 1928, estimates of coal reserves in several States and in individual mining districts have been made by State Surveys, but for most States—and for the Nation as a whole—no comprehensive reappraisal has been attempted.

The Geological Survey has long been aware of the need for new and revised summary information about the Nation's coal reserves, and during the last 20 years many detailed field surveys have been completed in anticipation of the opportunity of preparing new and more accurate reserve estimates. As the first step in the reappraisal of the coal reserves in the United States, this report presents a new provisional estimate of original reserves in Montana, calculated by counties, by ranks of coal, by classes of coal according to the reliability of the information on which the calculations were based, and by coal beds in different thickness groups. It is believed that this new estimate of Montana coal reserves, which is based on a careful and conservative analysis of the data available in the files of the Geological Survey, will have greater usefulness than earlier estimates.

WILLIAM E. WRATHER,
Director.

INTRODUCTION

The coal fields of Montana cover approximately 51,300 square miles, or 35 percent of the total area of the State. The coal ranges in rank from lignite to bituminous, and locally, as in the Electric and Great Falls fields, coal capable of producing nonferrous metallurgical coke occurs in small quantities. The coal fields are well distributed throughout most of the State, but the great concentration of reserves is in the Great Plains region east of the Rocky Mountains, where the coal is of lignite and sub-bituminous rank.

The present report summarizes the results of a careful reappraisal of the coal reserves in Montana that was carried out as part of the Interior Department's program for the development of the Missouri River Basin. Like all estimates of coal reserves made in the present state of knowledge, it is provisional and subject to modifications and improvements. It does, however, provide a more accurate estimate of the coal reserves of Montana than has heretofore been available, and it presents the data more systematically and in greater detail than any previous estimate. Thus it furnishes a systematic framework to which additions and corrections can be made as other data are obtained.

According to the present, provisional estimate, the total original tonnage, before mining, of coal of all ranks in Montana is 222,046,940,000 short tons. This amount is 42 percent less than previous estimates, all of which are based on the work of M. R. Campbell in 1928. As quoted in an estimate published in 1943, Mr. Campbell reported an original tonnage of coal of all ranks in Montana of 381,114,000,000 tons.1/ The two estimates are not directly comparable, for—as will be shown—they are based on somewhat different assumptions. Nevertheless, it is noteworthy that a modern, conservative estimate of the total original reserves in Montana should so closely approach the earlier, more generous estimate.

In the present report, the coal is classified according to the amount of metamorphism it has undergone. On this basis, every coal occupies a fixed position in a continuous natural series ranging from lignite to anthracite. This position is known as rank, as distinguished from grade or purity, of the coal. The classification used conforms to the standard specifications for classification of coals by rank of the American Society for Testing Materials 2/ as reproduced on page 4.

1/ Buch, J. W., Hendricks, T. A., and Toenges, A. L., Coal, in Mineral position of the United States: Hearings before a subcommittee of the Committee on Public Lands, U. S. Senate, 80th Cong., 1st sess., pp. 231-235, May 15, 16, and 20, 1947.

2/ American Society for Testing Materials, Standard specifications for classification of coals by rank, (A. S. T. M. Designation: D 388-38): 1939 Book of A. S. T. M. Standards, pt. 3, pp. 1-6.

MONTANA COAL FIELDS

The Montana coal fields are in the Great Plains and Northern Rocky Mountain provinces. The Great Plains province includes the large Fort Union region and its subsidiaries, the Bull Mountain and Garfield County fields, and also the North-central region, which is composed of the Great Falls and Lewistown fields, the area surrounding the Bearpaw Mountains, and the Blackfeet-Valier area. The Northern Rocky Mountain province includes the Bridger, Silvertip, Stillwater, Red Lodge, Electric, Livingston-Trail Creek, Lombard, and Flathead fields and the Tertiary lake-bed deposits in the southwestern part of the State. (See fig.1.)

The coal-bearing formations in Montana are of Cretaceous and Tertiary age. The Fort Union formation of Paleocene age contains more than 90 percent of the total coal reserves of the State and is the main coal-bearing formation in the Fort Union region, the Bull Mountain field, the Garfield County field, and the Red Lodge field. Other coal-bearing formations are the Kootenai formation of Lower Cretaceous age; the Eagle sandstone and the Judith River and Hell Creek formations of Upper Cretaceous age; the Tullock formation of Paleocene age; the Wasatch formation of Eocene age; and the Kishenehn (?) formation, made up of lake-bed deposits of Oligocene or Miocene age. The accompanying diagram (fig. 2.) shows a generalized stratigraphic section of coal-bearing rocks in Montana and indicates the main producing formations in each field. Further discussion of the stratigraphy is contained in the descriptions of the several fields.

In the Great Plains province, in the eastern part of the State, the coal-bearing rocks generally are flat lying or have been little disturbed, and the coal is low in rank. Near the North Dakota State line, for example, the coal is classed as lignite. In the Northern Rocky Mountain province, the coal-bearing rocks lie in basins between the mountain ranges and commonly exhibit gentle to moderate dips. The coal beds in these rocks range in rank from sub-bituminous to bituminous. The Tertiary lake beds, which are in small basins in the mountain valleys of the southwestern part of the State, are relatively so young that metamorphism of the coal has not progressed beyond the rank of lignite.

Although details of the geology and coal deposits of much of Montana are imperfectly known, large areas have been mapped and described in the Geological Survey bulletins that are listed and indexed in the selected bibliography on pages 24-26. In addition, analyses of coal from many parts of the State have been made by the Bureau of Mines.3/ Unless otherwise stated, the information contained in the following paragraphs describing the various fields has been abstracted from these publications.

3/ Analyses of Montana coals, U. S. Bur. Mines Tech. Paper 529, 1932.

CLASSIFICATION OF COALS BY RANK.[a]

Legend: F.C. = Fixed Carbon. V.M. = Volatile Matter. Btu. = British thermal units.

Class	Group	Limits of Fixed Carbon or Btu. Mineral-Matter-Free Basis	Requisite Physical Properties
I. Anthracitic	1. Meta-anthracite	Dry F.C., 98 per cent or more (Dry V.M., 2 per cent or less)	
	2. Anthracite	Dry F.C., 92 per cent or more and less than 98 per cent (Dry V.M., 8 per cent or less and more than 2 per cent)	
	3. Semianthracite	Dry F.C., 86 per cent or more and less than 92 per cent (Dry V.M., 14 per cent or less and more than 8 per cent)	Nonagglomerating[b]
II. Bituminous[d]	1. Low volatile bituminous coal	Dry F.C., 78 per cent or more and less than 86 per cent (Dry V.M., 22 per cent or less and more than 14 per cent)	
	2. Medium volatile bituminous coal	Dry F.C., 69 per cent or more and less than 78 per cent (Dry V.M., 31 per cent or less and more than 22 per cent)	
	3. High volatile *A* bituminous coal	Dry F.C., less than 69 per cent (Dry V.M., more than 31 per cent); and moist[c] Btu., 14,000[e] or more	
	4. High volatile *B* bituminous coal	Moist[c] Btu., 13,000 or more and less than 14,000[e]	
	5. High volatile *C* bituminous coal	Moist Btu., 11,000 or more and less than 13,000[e]	Either agglomerating or nonweathering[f]
III. Subbituminous	1. Subbituminous *A* coal	Moist Btu., 11,000 or more and less than 13,000[e]	Both weathering and nonagglomerating
	2. Subbituminous *B* coal	Moist Btu., 9500 or more and less than 11,000[e]	
	3. Subbituminous *C* coal	Moist Btu., 8300 or more and less than 9500[e]	
IV. Lignitic	1. Lignite	Moist Btu., less than 8300	Consolidated
	2. Brown coal	Moist Btu., less than 8300	Unconsolidated

[a] This classification does not include a few coals which have unusual physical and chemical properties and which come within the limits of fixed carbon or Btu. of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less than 48 per cent dry, mineral-matter-free fixed carbon or have more than 15,500 moist, mineral-matter-free Btu.

[b] If agglomerating, classify in low-volatile group of the bituminous class.

[c] Moist Btu. refers to coal containing its natural bed moisture but not including visible water on the surface of the coal.

[d] It is recognized that there may be noncaking varieties in each group of the bituminous class.

[e] Coals having 69 per cent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of Btu.

[f] There are three varieties of coal in the high-volatile C bituminous coal group, namely, Variety 1, agglomerating and nonweathering; Variety 2, agglomerating and weathering; Variety 3, nonagglomerating and nonweathering.

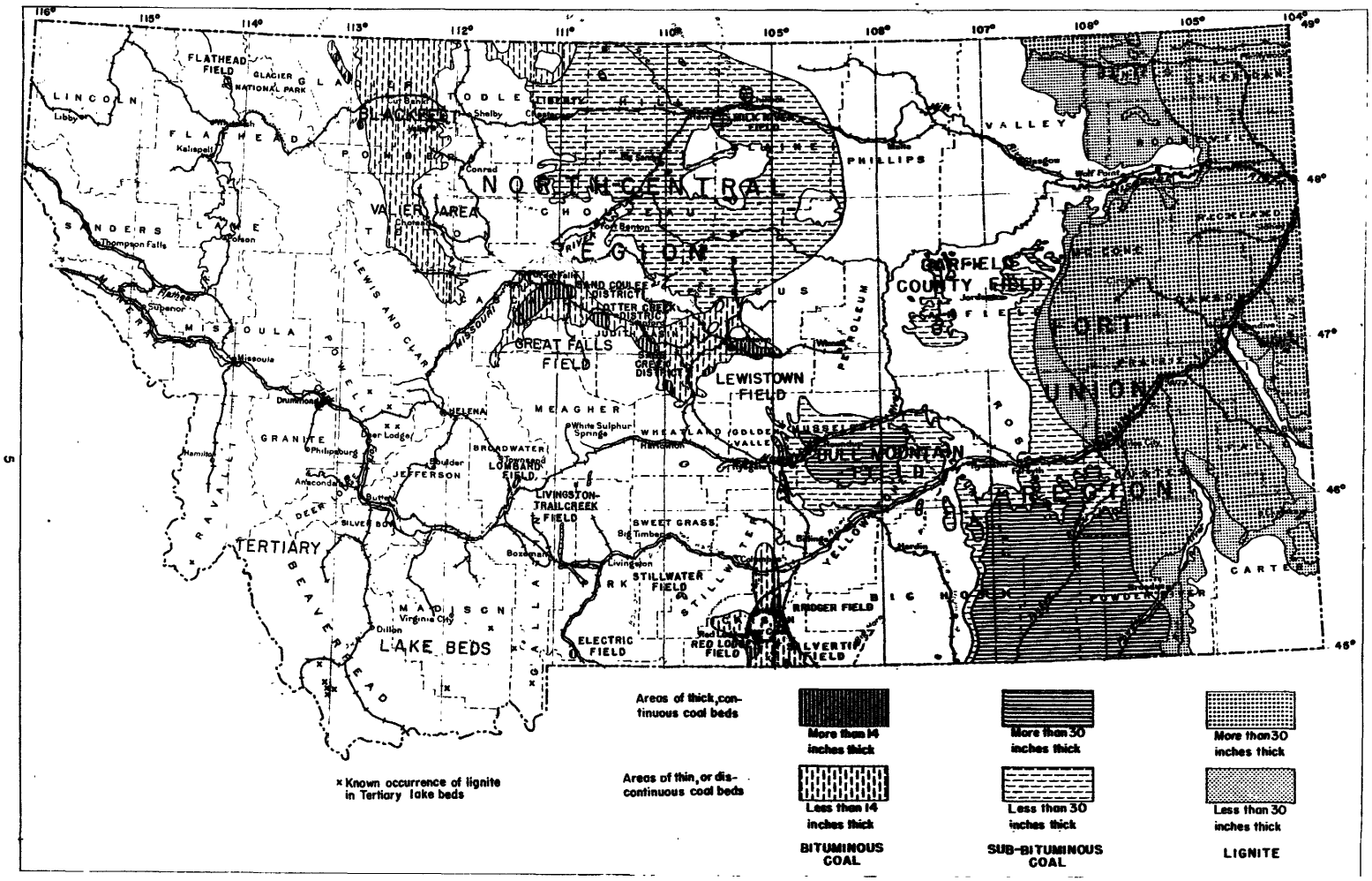


FIGURE I. MAP OF MONTANA SHOWING COAL FIELD AREAS

Figure 2.—Generalized stratigraphic section of Cretaceous and Tertiary rocks and principal coal-bearing formations in the Montana coal fields

[X=Main coal-bearing formation in field; x=Minor coal-bearing formation in field.]

Era and Period		Series	Group, formation, and member	Range of thickness (in feet)	Lithology	Region or field												
						Fort Union region	Garfield County field	Bull Mountain field	Great Falls and Lewistown fields	Area surrounding the Bearpaw Mountains	Blackfeet-Valier area	Bridger, Silvertip, and Stillwater	Red Lodge field	Electric field	Livingston-Trail Creek field	Lombard field	Flathead field	Tertiary lake beds
CENOZOIC	Tertiary	Miocene or Oligocene	Kishenehn (?) formation	1,500 to 3,000	Fresh-water lake deposits												X	X
		Eocene	Wasatch formation	0 to 472	Variegated sand and clay	x												
		Paleocene	Fort Union formation: Tongue River member	1,000 to 1,500	Light-gray to tan sandstone, massive and thin-bedded	X	x	X		x			X					
			Fort Union formation: Lebo shale member	150 to 160	Light- to dark-colored shale, interbedded sandstone	x	X	x										
			Tullock formation	450 to 950	Yellowish sandstone and shale	x	X	x			1/X							
MESOZOIC	Cretaceous	Upper	Hell Creek formation		Alternating sandstone and clay	x												
			Montana group: Lennep sandstone (Fox Hills)	25 to 150	Buff to brown sandstone													
			Montana group: Bearpaw shale	250 to 1,100	Dark marine shale													
			Montana group: Judith River formation	425 to 600	Grayish-white sandstone and light- to dark-colored shale					X	2/X							
			Montana group: Claggett shale	500 to 850	Dark marine shale													
			Montana group: Eagle sandstone	135 to 250	Buff sandstone					X		X		X	X			
			Montana group: Telegraph Creek formation	0 to 350	Yellow and sandy shale and sandstone													
			Colorado shale	1,500 to 2,500	Dark-gray to black shale with occasional sandy zone													
		Lower	Kootenai formation	220 to 2,500	Gray sandstone and shale with red shale				X							X		

1/ St. Mary River formation. 2/ Upper part of the Two Medicine formation.

Fort Union region

The Fort Union region includes most of eastern Montana and contains the greater part of the coal reserves. Most of the coal in this region occurs in the Fort Union formation of Paleocene age, but a few thin beds are present also in the basal part of the overlying Wasatch formation, in the underlying Tullock formation, and near the top of the Hell Creek formation. The Fort Union formation consists of alternating beds of sandstone, shale, and coal approximately 1,500 feet thick. The formation is divided on the basis of lithologic differences into an upper, or Tongue River, member, consisting mainly of sandstone, and a lower member, the Lebo shale. Near the North Dakota border the Lebo shale member is not recognized, and rocks occurring at the same stratigraphic position are known as the Ludlow formation. The Tongue River member, which is the chief coal-bearing member of the Fort Union formation, is about 1,100 feet thick in the eastern part of the State and tends to become progressively thicker to the west and south. This increase is accompanied by an increase in the number and thickness of the coal beds. In the western and southern parts of the region, for example, as many as 20 coal beds are present, some of which are as much as 40 feet thick.

Coal deposits underlie the entire Fort Union region, but the beds generally are discontinuous, and they may vary greatly in thickness, so that correlations of individual beds between fields are difficult to establish. This is particularly true in the northeastern and north-central part of the State where the cover of glacial drift has obscured most of the natural outcrops.

The rank of the coal in the Fort Union region increases progressively westward from lignite near the North Dakota State line to sub-bituminous C coal west of Miles City and sub-bituminous B farther west in southern Rosebud and eastern Big Horn Counties. This change is very gradual, and the rate of change varies somewhat in different beds. Because of this gradual change and because of the precise analytical data necessary to classify coals by rank,4/ many more analyses than are available at present would be required to establish the exact position of the boundary between lignite and sub-bituminous coal. The line on the accompanying map (fig. 1), however, shows the approximate position based on available analyses, of this boundary. It should be noted that although the coal near the North Dakota State line may have heat values of less than 7,000 B. t. u. on the as-received basis and coal from the area around Colstrip, Rosebud County, may contain more than 9,000 B. t. u. on the same basis, there is little significant difference between coal of the two ranks near the boundary line.

4/ American Society for Testing Materials, Standard specifications for classification of coals by rank, (A. S. T. M. Designation: D 388-38): 1939 Book of A. S. T. M. Standards, pt. 3, pp. 1-6.

As the heat value of the coal increases westward, the moisture content decreases. The lignite in eastern Montana, for example, has a maximum moisture content of 43 percent, whereas farther west near Colstrip the coal has a moisture content of only about 25 percent. The percentage of impurities shows much less variation. Throughout the Fort Union region the ash content of the coal ranges from 5 to 10 percent and the sulfur content from 0.3 to 1.7 percent. It should be noted, however, that most of the analyses show sulfur contents ranging typically from 0.5 to 1.0 percent.

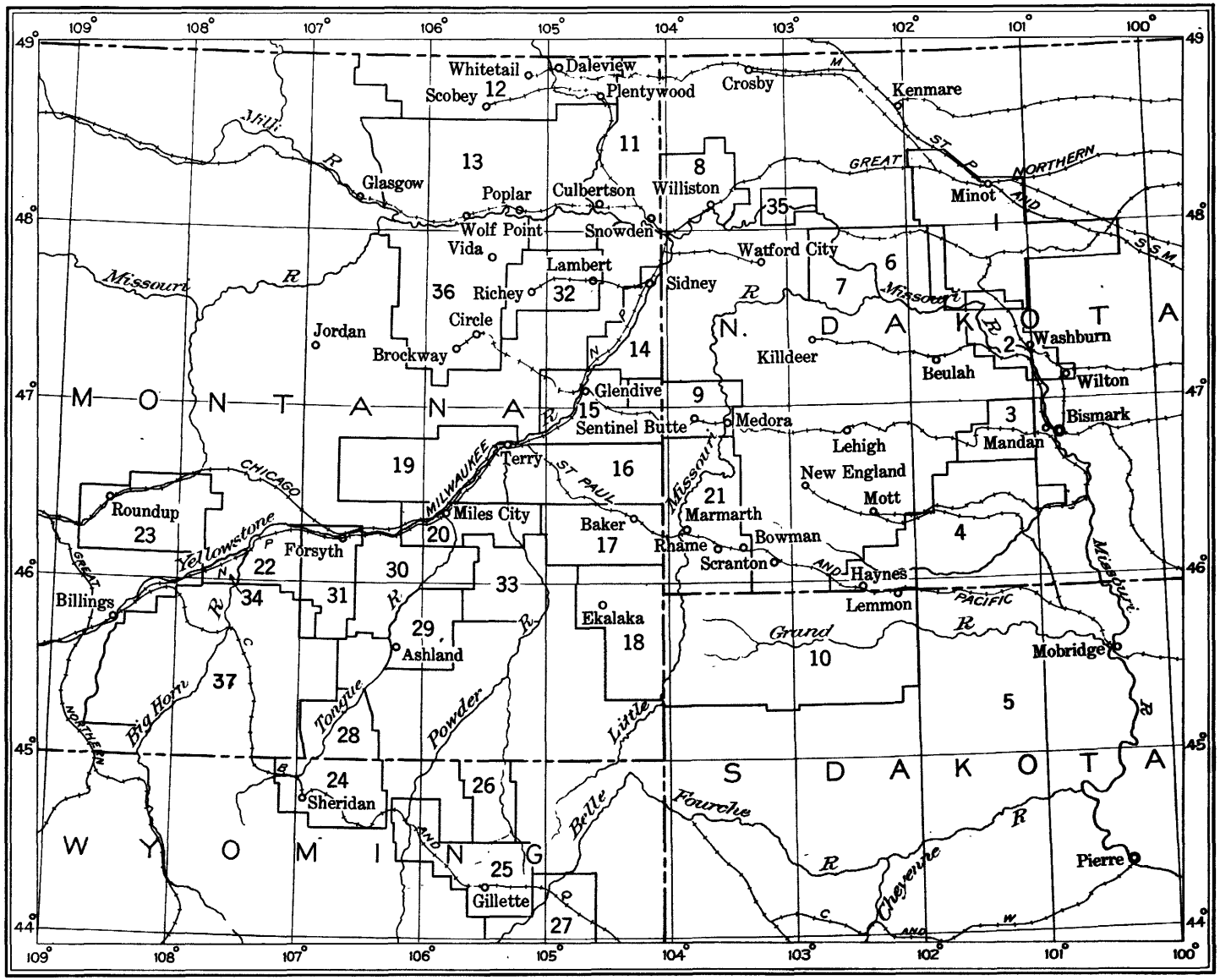
The coal in the Fort Union region tends to burn spontaneously when exposed to the atmosphere. In the southern part of the region, where no protecting cover of glacial drift was deposited and where the coal-bearing rocks are dissected, burned and clinkered outcrops are a characteristic feature. Some of the higher beds in this part of the region have been almost completely destroyed by burning.

As the Fort Union region is large and the coal beds and stratigraphy of the coal-bearing rocks vary in different parts of the region, it is divided for the purpose of discussion into two areas—an eastern, lignite-bearing area and a western, sub-bituminous coal bearing area as previously defined.

Lignite area.—The lignite-bearing area of the Fort Union region is made up of the following fields, named from nearby towns or well-known localities and described for the most part in Geological Survey bulletins under titles bearing the same names: the Ekalaka, Baker, Terry, Glendive, Mizpah, Sidney, Richey-Lambert, McCone County, Fort Peck Indian Reservation, Scobey, and Culbertson fields and the eastern parts of the Miles City and Little Sheep Mountain fields. (See fig. 3.)

Most of the coal in the lignite-bearing area of the Fort Union region is contained in the Tongue River member of the Fort Union formation; subordinate amounts are present, however, in the Lebo shale member of the Fort Union and in both the Tullock and Hell Creek formations. The Tongue River member is 1,000 to 1,500 feet thick throughout most of the lignite-bearing area and is composed primarily of light-gray to tan sandstone, massive and thin-bedded, containing interbedded shale and coal. Many of the coal beds in the Tongue River member are relatively free from partings and are thick and continuous over large areas. In the Glendive field, in Dawson and Wibaux Counties, a bed 4 feet or more thick is known to be generally present for a distance of more than 150 miles along the outcrop. In the Sidney field, in east Dawson, north Wibaux, and south Richland Counties, bed H is recorded as being continuous, with an average thickness of 4.7 feet over long distances. Besides these and other thick beds, there are many thinner, less persistent seams in both the Glendive and Sidney fields. In the northern Scobey and Culbertson fields, in Daniels and Sheridan Counties, the beds are somewhat thinner, and less is known about the continuity of the

Figure 3.—Index map of eastern Montana and adjoining States showing location of coal fields in the Fort Union and nearby regions described in bulletins of the U. S. Geological Survey



EXPLANATION

No. on map	Coal field	USGS Bull. No.
1	Minot, N. Dak.	906-B
2	Washburn, N. Dak.	381-A
3	New Salem, N. Dak.	726-A
4	Cannonball River, N. Dak.	541-G
5	Standing Rock and Cheyenne River, S. Dak.	575
6	Fort Berthold, N. Dak.	381-A 471-C
7	Fort Berthold, N. Dak.	726-D
8	Williston, N. Dak.	531-E
9	Sentinel Butte, N. Dak.	341-A
10	Northwestern South Dakota	627
11	Culbertson, Mont.	471-D
12	Scobey, Mont.	751-E
13	Fort Peck Indian Reservation, Mont.	381-A
14	Sidney, Mont.	471-D
15	Glendive, Mont.	471-D
16	Terry, Mont.	471-D
17	Baker, Mont.	471-D
18	Ekalaka, Mont.	751-F
19	Little Sheep Mountain, Mont.	531-F
20	Miles City, Mont.	341-A
21	Marmarth, N. Dak.	775
22	Tullock Creek, Mont.	749
23	Bull Mountain, Mont.	647
24	Sheridan, Wyo.	341-B
25	Powder River, Wyo.	381-B
26	Little Powder River, Wyo.	471-A
27	Gillette, Wyo.	796-A
28	Northward extension of Sheridan, Mont.	806-B
29	Ashland, Mont.	831-B
30	Rosebud, Mont.	847-B
31	Forsyth, Mont.	812-A
32	Richey-Lambert, Mont.	847-C
33	Mizpah, Mont.	906-C
34	Pine Ridge, Mont.	541-H
35	Nesson anticline, N. Dak.	691-G
36	McCone County, Mont.	905
37	Big Horn County, Mont.	856

outcrops. This is due partly to difficulty in tracing outcrops because of the concealing cover of glacial drift.

In the western part of the lignite-bearing area, in the Miles City and Little Sheep Mountain fields, the beds generally are discontinuous, and many are thin or contain too many partings to be mined profitably. These fields are in the transitional belt between the lignite-bearing area and the sub-bituminous coal bearing area. Locally the upper beds in the transitional belt are more lignitic than the lower ones.

The lignite-bearing part of the Fort Union region contains many small wagon mines, most of which are abandoned as soon as mining has progressed a short distance from the outcrop. A modest total production for local use is obtained from these mines each year (see table 5), but because of the difficulty of shipping and storing lignite no large-scale mining operations are carried on.

Sub-bituminous coal area.—The sub-bituminous coal bearing part of the Fort Union region includes the Forsyth, Rosebud, Ashland, Sheridan (northward extension), Tullock Creek, Crow Indian Reservation, Birney-Broadus, and Moorhead fields and the western parts of the Miles City and Little Sheep Mountain fields. (See fig. 3.)

As in the eastern part of the Fort Union region, the Tongue River member of the Fort Union formation contains most of the coal in the sub-bituminous coal bearing area. Where the complete section of the formation is exposed in this area, it ranges from about 1,500 to 1,700 feet in thickness and may contain as many as 20 coal beds.

The Forsyth field, in central Rosebud County, contains several thick persistent beds of coal relatively free from partings. The most valuable of these is the Rosebud bed, which is mined by the Northwestern Improvement Co. at Colstrip, where the bed is 485 feet above the base of the Tongue River member of the Fort Union formation and averages 28 feet in thickness. The coal is mined on a large scale by stripping approximately 50 feet of overburden of weathered sandstone and alluvium. A representative sample of coal from the Rosebud bed at this mine, analyzed on the as-received basis, had a heat value of 9090 B. t. u., with ash and sulfur contents of 7.3 and 0.7 percent, respectively. Another valuable bed in the field is the Burley bed, 130 feet above the base of the Tongue River member, which averages about 3 feet in thickness in the west-central part of the field.

In the Rosebud field, in Rosebud and Custer Counties, the Burley bed, which is correlated with the bed of that name in the Forsyth and Ashland fields, contains the most coal. The Burley bed has a thickness range of 2 inches to 8.5 feet in the Rosebud field and contains clean coal of good quality. The Rosebud bed, which also is present in this field, attains a thickness of more than 20 feet but crops out over a smaller area than the Burley bed and has been removed in part by burning.

The Ashland coal field, in parts of Custer, Rosebud, and Powder River Counties, is south of the Rosebud field and east of the Forsyth field. Many townships in this field contain five to eight coal beds with average thicknesses of more than 6 feet, and outcrops of coal beds 10 feet thick are common. Beds 20 to 25 feet thick occur in several localities and are continuous, as well as consistent in thickness throughout areas of several square miles. In general, the coal beds are remarkably free from partings. Cropping out along the Tongue River, which cuts across the center of the field, are the Knoblock bed, 300 feet above the base of the Tongue River member of the Fort Union formation; the Sawyer bed, 600 feet above the base; and the E bed, 875 feet above the base. These intervals decrease eastward as the lower half of the Tongue River member becomes thinner.

In the northward extension of the Sheridan field, which is south of the Ashland field, the Anderson bed attains a maximum thickness of 25 feet and in several places is measured as 20 feet thick. Except where burned at the outcrop, this is the thickest and most persistent bed in the field. The Dietz bed is commercially valuable in the southern half of the field, where it averages between 8 and 12 feet in thickness. Other thick beds are the Canyon and the Wall.

The Tullock Creek coal field is in southern Treasure and northern Big Horn Counties east of the junction of the Big Horn and Yellowstone Rivers. Most of the coal in this field is contained in the Tongue River member of the Fort Union formation, but subordinate amounts are present in the Tullock formation. The coal in the Tongue River member occurs in six beds ranging from 1 foot to 24 feet in thickness. In the four thickest beds, designated M, P, Q, and R in published reports, the coal is in thick benches unbroken by partings. All the beds, however, are commonly burned at the outcrops. Coal beds more than 18 inches but less than 5 feet thick are present locally at 10 horizons in the Tullock formation. The Tullock Creek field is undeveloped except for small wagon mines.

In the eastern part of the Crow Indian Reservation field, in Big Horn County, as in the Tullock Creek field, most of the coal is in the Tongue River member of the Fort Union formation. About 20 beds of minable thickness have been mapped in this area, and some of great lateral extent have been tentatively correlated with beds farther east in the northward extension of the Sheridan coal field. Coal occurs also in the Cloverly, Parkman, Bearpaw, Hell Creek, Tullock, and Wasatch formations in the Crow Indian Reservation field, but the beds are of small extent and are generally too thin and impure to be of commercial value.

The Birney-Broadus and Moorhead fields, lying predominantly in Powder River County in the southeastern part of the State, contain many thick continuous coal beds, and the concentration of coal in these areas is greater than in any other part of Montana. Detailed surveys of these fields have recently been completed by the Geological

Survey, and preparation of maps showing the position of the coal beds and correlations with beds in adjoining fields is now in progress. The calculation of coal reserves in these areas has been completed, however, and the results, as shown in the accompanying tables, give Powder River County 19.5 percent of the total reserves of the State as compared to 19.6 percent for Big Horn County and 17.5 percent for Rosebud County. It is clear, therefore, that most of the coal in Montana is concentrated in the southern part of the Fort Union region.

Garfield County field

The Garfield County field is west of the Fort Union region. Most of the coal in this field occurs in the Hell Creek formation of Upper Cretaceous age and in the Tullock formation of Tertiary (Paleocene) age. In the southern part of the field, a small amount of coal is present in the Tongue River member of the Fort Union formation. The coal is of sub-bituminous C rank over the greater part of the field and, as compared to that in other fields in eastern Montana, is thin and relatively unimportant.

In the northern part of the field, minable coal occurs in two beds. Bed A, which is 40 to 90 feet below the top of the Hell Creek formation, averages about 4.5 feet in thickness and contains the best coal in the field. Bed B, at the base of the overlying Tullock formation is generally thinner, softer, and higher in ash than bed A. In the southern part of the field, no minable coal is present in the Hell Creek and Tullock formations. There is a coal bed, however, at the base of the Tongue River member of the Fort Union. This bed is very thin, ranging from a few inches to 30 inches in thickness.

The beds in the Garfield County field, as in the Fort Union region, are nearly flat lying. The axis of the Blood Creek syncline trends eastward through the center of Garfield County, and the beds on either side dip toward it at angles of less than 1°.

Bull Mountain field

The Bull Mountain field is mainly in Musselshell and Yellowstone Counties but extends into Golden Valley, Stillwater, Treasure, and Rosebud Counties. (See fig. 1.) The coal-bearing rocks in the field are the Tongue River member of the Fort Union formation and, to a lesser extent, the underlying Lebo shale member and the Tullock formation. The coal is of sub-bituminous B and sub-bituminous A ranks.

The Tongue River member of the Fort Union, which is the main coal-bearing unit in the field, is about 1,700 feet thick and contains 26 persistent coal beds in addition to many thin and lenticular beds. Most of the commercial mining is in the Roundup bed, which crops out in the northern and northwestern part of the field. In the vicinity of Roundup this bed is 500 feet above the base of the Tongue River member and ranges in thickness from 4 to 6 feet. This thickness decreases to the east, gradually at first and then sharply, until at a point about 12 miles from Roundup it measures only 1.6 feet. A representative analysis, on the as-received basis, of coal taken from this bed shows a heat value of 11,000 B. t. u. and ash and sulfur contents of 7.5 and 0.4 percent, respectively. The Carpenter Creek bed, which is about 50 feet below the Roundup bed, is commercially important in the northeastern part of the field, where it ranges in thickness from 4 to 8 feet. An analysis of a typical sample of coal from this bed, on the as-received basis, shows a heat value of 10,170 B. t. u. and ash and sulfur contents of 4.3 and 1.3 percent, respectively.

Coal was actively mined from these beds in 1940 by the Bair Collins Co., the Jeffries Coal Mining Co., the Republic Coal Co., and the Roundup Coal Mining Co.

The Lebo shale member of the Fort Union formation contains, for the most part, only carbonaceous shale in the Bull Mountain field. The Big Dirty coal bed, which occurs near the middle of the member, ranges in thickness from 2 to 24 feet, but although it is a prominent marker in the field, it contains only 2 inches to 1 foot of clean coal. Economically this bed is unimportant. Most of the beds in the Tullock formation are thin, and only one, the Homestead, is of minable thickness. In a prospect in T. 10 N., R. 27 E., the total thickness of coal in the Homestead bed is 2.9 feet. An analysis of coal from this bed, on the as-received basis, shows a heat value of 10,420 B. t. u. and ash and sulfur contents of 4.2 and 0.9 percent, respectively.

Most of the central part of the Bull Mountain field is a broad, shallow synclinal basin, the axis of which trends generally northwestward. The beds dip gently at angles of 1° to 5° toward the center of the basin but are flatter to the east and south of the axis and steeper to the north. Most of the coal in the Bull Mountain field is in this broad central part of the basin where the rocks are undisturbed and the dips are low. Toward the northwest the dips steepen to as much as 30°, and the coal-bearing rocks form two sharply accentuated, northwest-trending synclinal folds, separated by an equally sharp anticlinal fold from which the coal-bearing rocks have been removed by erosion.

North-central region

The North-central region includes all the coal-bearing lands in the north-central part of the State. For discussion in this paper, this region has been subdivided into three parts: in the south, the Great Falls and Lewistown fields; in the north and east, an area surrounding the Bearpaw Mountains; and in the west, the Blackfeet-Valier area, which is separated from the main part of the North-central region by the Sweetgrass arch, a prominant structural feature that trends southward through Toole, Pondera, and Teton Counties. The coal in the North-central region ranges in age from Lower Cretaceous through Tertiary (Paleocene) and, in rank,

from bituminous to sub-bituminous. In contrast to the Fort Union region in the eastern part of Montana, where a great proportion of the land is underlain by minable coal, the North-central region contains only scattered areas where coal of minable thickness has been found.

Great Falls and Lewistown fields.—The Great Falls and Lewistown fields are located in Cascade, Judith Basin, and Fergus Counties. The Great Falls field extends east from the Missouri River near Great Falls for a distance of 60 miles along the base of the Little Belt Mountains to a point east of Stanford where it merges with the Lewistown field in Judith Basin and Fergus Counties. The two fields are continuous, and both contain coal in the Kootenai formation of Lower Cretaceous age. The coal occurs in a zone about 60 to 90 feet above the base of the formation and is of high volatile B and C bituminous rank. The roofs of the mines in these two fields usually consist of 1 foot or 2 feet of dark shale overlain by 60 feet of massive gray sandstone, which serves as a distinctive marker for the coal horizon. Below the coal are soft greenish shales.

In the Great Falls field, the Kootenai formation has a thickness of 475 feet and consists mainly of alternating beds of sandstone and shale. The coal does not occur in a continuous horizon of workable coal but is found in three basins of deposition called the Sand Coulee, Otter Creek, and Sage Creek districts, which together cover a minimum area of 334 square miles.

The Sand Coulee district is by far the largest and most important of the three. It is directly south of Great Falls and includes the area drained by the Sand Coulee and its tributaries. At the town of Belt, in the northeastern part of the district, the average total thickness of the coal is 4.6 feet, whereas at Sand Coulee the average total thickness is 8.6 feet and along Smith River it is 7.5 feet. At Belt Creek the coal is in three benches, the lower and upper of which are about equal in thickness and much thicker than the middle one. In Sand Coulee the coal is in two benches, the upper one of which is much thicker than the lower. Above the top bench at Sand Coulee, however, are two higher beds of coal with a maximum total thickness of 5.7 feet. At Smith River the coal beds are similar in thickness and distribution to those near Sand Coulee.

The Otter Creek district is about 45 miles east of Great Falls, extending along both sides of Otter Creek for a distance of about 10 miles. Only one coal bed, which ranges from 3 to 6 feet in total thickness, is present in the district. Generally the coal in this bed is separated by a bony parting into two benches, the lower of which is usually the thicker and has the better-quality coal. On the whole, the coal bed is thickest in the center of the district and thins to the sides.

The Sage Creek district, which is in the eastern part of the Great Falls field a few miles south of Stanford, contains only one coal bed, which ranges in total thickness, including partings, from 6 to 18 feet. The total thickness of coal present in this bed ranges from 2.5 feet to 7 feet and usually occurs in three benches. The lowest bench is 2 feet thick and is regarded as the best.

A typical sample of coal from this field, analyzed on the as-received basis, shows a heat value of 10,120 B. t. u. and ash and sulfur contents of 18.1 and 1.7 percent, respectively.

Certain benches of the coal possess coking properties, and the Anaconda Mining Co. formerly operated coke ovens at Belt. The ovens were abandoned, however, because of the difficulty and expense of separating coking from noncoking coal.

The rocks in the Great Falls field dip gently northward away from the little Belt Mountains at angles of 3° to 5°, except in a narrow area at the foot of the mountains where dips may be as much as 10° or 15°. Low undulations interrupt the regional dip, and minor faults with displacements of 5 to 20 feet are present throughout the field. A few basalt dikes that do not cut the coal beds have also been observed. None of these features has caused more than slight inconvenience in mining.

The Lewistown field extends southwest from the vicinity of Lewistown along the north slopes of the Big Snowy and Little Belt Mountains and joins the Great Falls field. The Kootenai formation, which contains the coal in the Lewistown field, averages 500 feet in thickness in the vicinity of Lewistown as compared to 475 feet in the Great Falls field. The coal beds in the Lewistown field are not continuous but are broken by nonproductive zones of carbonaceous shale. The most important of the productive areas are the Buffalo Creek district, on the north slope of the Little Belt Mountains; the Rock Creek district, on the north slope of the Big Snowy Mountains; the Lewistown district, on Big Spring Creek north of Lewistown; and the MacDonald Creek district, on the east edge of the field south of the Judith Mountains. The MacDonald Creek district is the largest and best developed in the Lewistown field.

Where coal is mined in the Lewistown field, the beds range in thickness from 2.5 feet to 8 feet and usually occur in two or more benches, with partings of bone and shale, as in the Great Falls field. The coals of the two fields are very similar in composition except that in the Lewistown field the ash content is lower, averaging about 8 percent, whereas the relatively high sulfur content averages over 4 percent.

The structure is simple in that part of the Lewistown field adjoining the Great Falls field, where the beds dip to the north at low angles away from the Little Belt and Big Snowy Mountains. Farther east, the beds are arched and faulted locally and are intruded by laccoliths associated with the Judith and Moccasin Mountains.

Area surrounding the Bearpaw Mountains.—North of the Great Falls and Lewistown fields is an area of approximately 10,500 square miles underlain by essentially flat-lying, coal-bearing rocks. It includes all of Hill County and parts of Toole, Liberty, Chouteau, Fergus, and Blaine Counties. Because of the cover of glacial drift, which extends over most of this area, determination of the extent of coal beds has been difficult. Coal occurs in the Eagle sandstone and Judith River formation of Upper Cretaceous age and locally in the Fort Union formation of Tertiary (Paleocene) age. Coal of sub-bituminous A and B ranks and locally, near intrusives, of high volatile C and B bituminous ranks occurs sporadically throughout the area. In most places, however, the coal is too thin and lenticular to allow commercial operations.

In northern Chouteau County, at the Big Sandy mine, coal of sub-bituminous rank occurs in minable thicknesses in a small, downfaulted area that has preserved beds of Fort Union age. Other thin, lenticular coal beds are present in the Judith River formation and the Eagle sandstone.

The Milk River field, which is farther north in Hill and Blaine Counties, contains coal of sub-bituminous rank in the upper part of the Judith River formation. Mining has been carried on in this field at Havre and Chinook on the Great Northern Railroad, both of which supply small, local demands for fuel. The coal bed at Havre, in Hill County, ranges from 2.5 to 6.7 feet in thickness, but much of the bed is impure and contains partings of bone and shale. At Chinook, to the east in Blaine County, the coal is of essentially the same thickness and character.

Farther west, in western Hill and eastern Liberty Counties, the Judith River formation contains coal in thin, lenticular beds in a zone about 200 feet from the base of the formation. The thickness of these beds is generally about 1 foot to 1.5 feet, although locally it exceeds 3 feet.

In northwest Liberty and northeast Toole Counties, analyses show the coal to be locally of high volatile B bituminous rank. This is probably due to alteration of the beds by igneous intrusions in this part of the field. No beds of minable thickness have been mapped here.

Except for a few minor undulations, the rocks in the area surrounding the Bearpaw Mountains dip gently northeastward to eastward from the crest of the Sweetgrass arch. Several thrust faults, together with a few intrusive igneous masses, break the continuity of the beds, but in areas where mining has been carried on these have caused little difficulty.

Blackfeet-Valier area.—The Blackfeet-Valier area begins in Cascade County approximately 30 miles south of Chouteau and extends north in a belt 6 to 16 miles wide through Teton, Pondera, and Glacier Counties to the Canadian border. The name has been taken from two small fields that are in Pondera and Glacier Counties. The coal in the Blackfeet-Valier area occurs in the Two Medicine and St. Mary River formations of Upper Cretaceous age. The Two Medicine formation is correlated with the Claggett and Judith River formations of eastern and central Montana, and the St. Mary River formation is correlated with the Hell Creek and Tullock formations. The coal in the Blackfeet-Valier area occurs at five horizons, three in the Two Medicine formation and two in the St. Mary River formation, but throughout most of the area it is thin, bony, and sporadic in distribution. On the basis of available analyses, the coal is of high volatile C and B bituminous ranks.

Coal has been mined to the greatest extent from the Valier field in Pondera County where the beds are nearly flat lying. There, clean coal about 20 inches thick, including a 2-inch parting, has been taken from the upper bed of the Two Medicine formation. The Blackfeet field to the northwest in the Blackfeet Indian Reservation in Glacier County contains minable coal at the base of the St. Mary River formation. Very little mining has been done in this field because steeply dipping strata, together with thrust faults, carry the coal below minable depths within short distances from the outcrops. Clean coal is present with a maximum thickness of 3.5 feet.

The Blackfeet-Valier area can be divided into two parts on the basis of differences in the structure of the rocks. In the eastern part, which includes the Valier field and comprises about two-thirds of the total area, the beds dip gently westward at angles ranging from nearly horizontal to 5°. In the western part of the area, which includes the Blackfeet field, the beds are steeply dipping, folded, and broken by thrust faults.

Bridger and Silvertip fields

The Bridger and Silvertip fields are in the south-central part of Montana in eastern Carbon County. The two fields are part of a larger area of coal-bearing rocks that is a northward extension of the Bighorn Basin region of Wyoming. The coal in each of the two fields is of high volatile C bituminous rank. It occurs in the Eagle sandstone, which consists of several massive sandstone members, individually about 35 to 75 feet thick, separated by carbonaceous shale. Three discontinuous beds of coal are found in the shale zones.

Bridger field.—Although the three coal horizons mentioned above are all present in the Bridger field, coal of workable thickness is present at only one horizon in any one locality.

Coal has been mined near Joliet, Fromburg, and Bridger. Near Joliet, in the northern part of the Bridger field, a section measured in the Barret mine shows 2.5 feet of coal in two benches, with a sandstone roof and a shale floor. Farther

south, near Fromburg, approximately the same relationships prevail. At Bridger the coal is thicker, ranging from 4 to 6 feet in thickness, and usually occurs in two or three benches separated by bone and shale partings. South of Bridger the coal thins again; the southernmost exposure of workable coal is in T. 9 S., R. 24 E., where it is 2.5 feet thick with a 6-inch parting of shale near the top. An analysis on the as-received basis, of coal near Bridger shows a heat value of 10,040 B. t. u. and ash and sulfur contents of 13.4 and 0.3 percent, respectively.

The coal of the Bridger field crops out along the eastern edge of a southwest-dipping monocline that forms part of the east side of the Bighorn Basin of Wyoming. The dips in the field range from 2° to 20°. Faults, generally trending at right angles to the strike of the coal beds, occur in nearly all parts of the field but, as a rule, do not interfere with mining. A notable example is a large fault, about 4 miles north of Bridger, where the coal beds have been offset horizontally nearly 2 miles.

Silvertip field.—The Silvertip field is a small coal-bearing area south of the Bridger field at the Montana-Wyoming border. The coal-bearing formation, as in the Bridger field, is the Eagle sandstone, which is brought to the surface at this point by the Silvertip anticline, an elliptical structure 8 miles long and 4 miles wide. Three coal beds, which probably correspond to the beds in the Bridger field, are present in the Silvertip field. The lower bed is not workable, but coal is mined from the upper two. The total thickness of coal in the middle bed ranges from 1 foot to 5 feet, and that in the upper bed from 3.3 to 5.5 feet. The coal beds dip away from the axis of the anticline at angles of 15° to 20° SW. and 22° to 45° NE. Many northeast-trending normal faults are present.

Stillwater field

Another small field that contains coal in the Eagle sandstone is the Stillwater field in the valley of the Stillwater River in Stillwater County. Here the Eagle sandstone is 300 feet thick, with coal present in one bed near the top of the formation. Analyses show the coal to be of high volatile C and B bituminous ranks. The coal generally occurs in three benches separated by bone, shale, and sandstone partings. The total thickness of coal in the section of coal-bearing rocks ranges from 4 to 5 feet. The dip of the coal beds at the outcrop is about 10°. A short distance from the outcrop, however, an increase in angle of dip carries the coal to considerable depths. An analysis, on the as-received basis, of coal from this field shows a heat value of 10,130 B. t. u. and ash and sulfur contents of 18.7 and 0.5 percent, respectively.

The Red Lodge field

The Red Lodge field is at the foot of the Beartooth Mountains in Carbon County about 20 miles west of the Bridger and Silvertip fields. Unlike these fields, however, the coal in the Red Lodge field occurs in the Fort Union formation of Tertiary (Paleocene) age, which is several thousand feet higher stratigraphically than the coal-bearing Eagle sandstone of the Bridger and Silvertip fields.

The Fort Union formation in the Red Lodge field is composed mainly of sandstone and shale and is believed to be about 5,000 feet thick. It contains in its upper third a coal-bearing zone 825 feet thick between an upper and a lower barren member. The coal is tentatively assigned to the high volatile C bituminous rank on the basis of its apparent resistance to weathering. Mining has been carried on at the towns of Red Lodge and Bear Creek. In the vicinity of Red Lodge, eight beds of coal known as Nos. 1, 1½, 2, 3, 4, 4½, 5, and 6 have been worked. Concerning these beds, Woodruff 5/ states:

...bed No. 1 contains 7 feet of coal overlain by carbonaceous shale and underlain by 4 to 6 inches of shale above sandstone. Bed No. 1½ contains 5 feet of bright coal with many thin partings and has a sandstone roof and shale floor. Bed No. 2 contains 8 feet of coal in six benches, with partings of shale one-half to 1 inch thick. It rests upon shale and is covered by sandstone. Bed No. 3 contains 10 feet of dirty coal.... Bed No. 4 has 10 feet of good coal occurring in three benches, with a parting 1 inch thick 23 inches below the top. This bed is underlain by sandstone and covered by gray shale. Bed No. 4½ is composed of 3½ feet of coal which occurs in several benches and has shal both above and below.... Bed No. 5 contains 12 feet 1 inch of coal in four benches, with partings one-half to 2 inches thick, and lie: between beds of hard shale. Bed No. 6 shows 4 feet 11 inches of coal in a single bench, with both roof and floor composed of sandstone. The coal below bed No. 6 ... is placed in one group because the interval between the beds is not sufficient to allow any one coal to be mined without disturbing those above.

Most of the coal mined has been obtained from beds Nos. 2, 3, and 4.

The coal beds in the Red Lodge field thin in a southwesterly direction and apparently coincide with a shallow basin of deposition. They dip gently but irregularly from the outcrop on the east side of the field to the southwest. At the town of Red Lodge the dip is 18°, decreasing toward the southeast to 9° in the western part of the Bear Creek district and to 3° a short distance farther south. The coal beds are terminated to the west by the Beartooth Mountain fault, whose eastern side is downthrown 500 to 600 feet. The coal beds are believed to continue to the northwest, but in this direction the Fort Union formation passes beneath a cover of alluvium and gravel and cannot be observed. The coal-bearing rocks have been cut at a few places by small igneous intrusions, which, however, have not interfered with mining.

5/ Woodruff, E. G., The Red Lodge coal field, Montana: U. S. Geol. Survey Bull. 341, p. 99, 1909.

A typical analysis, on the as-received basis, of coal from bed No. 4 at Red Lodge, shows a heat value of 10,330 B. t. u. and ash and sulfur contents of 12.7 and 1.3 percent, respectively.

Electric field

The Electric field, which is in southern Park County in south-central Montana, covers an area of less than 20 square miles, of which only about 3 square miles can be considered to be underlain by minable coal. The coal in this field occurs in rocks of Upper Cretaceous age that are designated as the Montana group, undifferentiated. These sediments, which are about 1,000 feet thick, probably are equivalent, at least in part, to the Eagle sandstone, but this correlation has not been firmly established. Three beds of coal, each ranging in thickness from 3 to 5 feet, including thin partings of clay and sandstone, are present in a stratigraphic interval of 300 feet in the Montana group. Only the uppermost of these three beds has been mined extensively.

The Electric field is in a fault block that has been depressed several thousand feet in relation to the surrounding rocks. The rocks in the block are highly folded and faulted, and the coal, which is believed to be deeply buried in much of the region, is exposed at the surface in two small synclinal areas. These are known as the Aldridge district, in the northern part of the fault block and the Electric district, in the southeastern part. In both these districts the coal beds dip steeply from a minimum of about 24° to nearly vertical and are broken by numerous minor faults. Igneous intrusions also are present in the area, but few have been encountered in mining.

The coal in the Electric field is higher in rank than most bituminous coal in the West and ranges, in general, from high volatile A bituminous to low volatile bituminous, according to the amount of deformation it has undergone. An analysis, on the as-received basis, of a typical sample of coal from the area shows 11,410 B. t. u. and ash and sulfur contents of 19.5 and 1.3 percent, respectively.

The coal in the Electric field, particularly that in the uppermost bed, has coking qualities, and most of the coal mined from the field in the past was used for the manufacture of coke. This coke was used for a time at the smelters at Anaconda and Butte; it was reported to be of good quality but so high in ash that the operators were unable to meet smelter requirements for coke containing less than 18 percent ash.

Livingston-Trail Creek field

The Livingston-Trail Creek coal field forms a narrow Y-shaped belt that extends across three townships for a distance of approximately 22 miles in Gallatin and Park Counties.

The coal-bearing formation in the field is made up dominantly of sandstone beds totaling 750 to 900 feet in thickness at the base of the Montana group of Upper Cretaceous age. This unit probably is equivalent to the Eagle sandstone, which is the basal formation of the Montana group at most localities in the State. Coal of workable thickness occurs in three or four beds ranging from 2 to 5 feet in thickness. Several partings of clay, shale, or bone separate the coal into benches that at most places contain 1 foot to 3 feet of coal.

The coal beds in this area are on the steeply dipping flanks of anticlinal folds and locally are broken by faults. Because the rocks have dips that normally range between 40° and 65° and in some places are vertical or overturned, the coal is too deeply buried a short distance from the outcrops to be mined profitably. Locally the coal has been crushed by differential movements in the overlying and underlying beds.

The coal in the Livingston-Trail Creek field varies in rank according to the amount of deformation it has undergone, but in general it is of high volatile A, B, or C bituminous rank. An analysis, on the as-received basis, of a typical sample of coal from the field shows 10,950 B. t. u. and ash and sulfur contents of 8.5 and 0.6 percent, respectively.

In the past, coal mined from several parts of this field has been used for the manufacture of coke, and at one time 100 beehive ovens were in operation at Cokedale.

Lombard field

The Lombard coal field is in Broadwater and northern Gallatin Counties. Coal is present over an area of about 6 square miles between the towns of Toston and Lombard. The coal, which typically is of high volatile A or medium volatile bituminous rank, has coking properties, but because of its high ash and sulfur content it has never been mined for the commercial production of coke. An analysis of coal on the as-received basis shows 10,060 B. t. u. and ash and sulfur contents of 29.7 and 8.2 percent, respectively.

The coal beds in the Lombard field have been much distorted and disturbed by shearing and squeezing, so that the coal occurs in pockets and lenses. Parts of some beds that were mined in the past, however, were as much as 6 feet thick. Because of the distortion and shearing, the coal has been metamorphosed differentially and locally may be graphitic.6/

Flathead field

The Flathead field covers about 150 square miles along the North Fork Flathead River in northern Flathead County. The coal in this field occurs in the Kishenehn (?) formation, which is of lake-bed origin, of Tertiary (Oligocene or Miocene) age. The

---

6/ Stebinger, E., The coal fields of Montana: Am. Inst. Min. Eng. Trans. [1913], vol. 46, p. 910, 1914.

coal is of sub-bituminous B rank.

The coal is of less than minable thickness throughout most of the field, but a composite bed made up of several benches, the thickest of which is about 3 feet, occurs in the region of the old Emerson mine. A typical analysis, on the as-received basis, of mined coal from the area shows 8,120 B. t. u. and ash and sulfur contents of 15.4 and 2.9 percent, respectively.

The coal-bearing rocks in the Flathead field lie in a down-faulted block, and the coal beds dip steeply to the northeast at angles of 40° or more.

Tertiary lake beds

The lake-bed deposits of Tertiary (Oligocene or Miocene) age, which occur in many parts of southwestern Montana, contain local deposits of lignite. The areal extent of these deposits is uncertain, and no attempt has been made to show them on the index map (fig.1). Areas where lignite has been mined or prospected, however, have been indicated on the index map by crosses. The lignite beds are known to be lenticular in shape and variable in thickness, and they probably occur at different stratigraphic horizons.

Lignite has been mined at localities near Missoula and Drummond, where it is present in beds ranging in thickness from 5 to 25 feet. Many of these beds contain bone and clay partings, which separate the lignite into benches. A typical analysis, on the as-received basis, of a sample of lignite from this region shows 6,727 B. t. u. and ash and sulfur contents of 19.9 and 0.9 percent, respectively.

The Tertiary lake beds have been somewhat deformed since their deposition; typically they lie in broad, shallow synclines or monoclines. In general, the lake beds near the margins of the deposits dip at moderate angles toward the centers, but locally they are interrupted by minor faults.

MONTANA COAL RESERVES

In preparing the accompanying estimate of Montana coal reserves, published and unpublished detailed geologic reports in the files of the Geological Survey, publications of the Montana State Bureau of Mines and Geology, and similar sources were analyzed. Much additional information is believed to be available in the files of mining and drilling companies, railroads, and private individuals, and this information ultimately will be solicited and incorporated in subsequent estimates. The present provisional estimate, however, indicates the correct extent of the reserves on the basis of the assumptions stated and is presented now to aid those interested in the development of Montana resources.

For the present estimate it was necessary to establish and define several categories of coal according to the rank, the reliability of the data available, and the thickness of the beds. As a large amount of information is available concerning the nature and thickness of coal at the outcrop in Montana, and as relatively little mining and development have been carried on, it was necessary also to devise a method of limiting the assumed extent of each coal bed at depth. These and other similar factors that entered into the preparation of the reserve figures are discussed in the following paragraphs.

The rank of the coal was determined according to the standard specifications of the American Society for Testing Materials as presented in the introductory pages of this report, and separate calculations were made for lignite, sub-bituminous coal, and bituminous coal.

The assumed area of each coal bed was determined in several ways. If the continuity of a bed was well established by maps of the outcrop, mine workings, or drill holes, the entire area of occurrence was included even though points of information were widely spaced. Similarly, a continuous bed extending around a basin or spur was considered to underlie the area enclosed by the line of outcrop. For all other beds the length of outcrop, within chosen thickness limits, was considered to establish the presence of coal in a semicircular area extending from the outcrop and having a radius equal to half the length of the line of outcrop. Where the information consisted of an isolated mine working, the coal bed was considered to extend beyond the working in an arc with a radius of 1 mile. Where the information consisted of data from an isolated drill hole too far removed to be incorporated with other established coal areas, the coal bed was considered to extend in a circle with a radius of half a mile around the hole. Coal in the narrow weathered zone at the outcrop was included in the assumed areas of coal occurrence, as was also coal under roads, railroads, and the like. However, all known areas of burned coal were excluded.

Two classes of coal, based on the reliability and quantity of the information available for making reserve estimates, were established.

The class termed "measured and indicated" reserves includes coal for which positive information about thickness and extent was available from surveys of the outcrop, mine workings, and drill records. The extent of such coal underground was limited everywhere, however, by a line drawn 2 miles from the outcrop, so that all coal classed as measured and indicated reserves is less than 2 miles from the outcrop and more than 50 percent less than 1 mile. From a statistical viewpoint, therefore, about 25 percent of the measured and indicated reserves could be considered "measured", though it was not feasible or desirable to make such a separation.

"Inferred" reserves include, in general,

coal within the areas delimited as described above but lying more than 2 miles from the outcrop.

For a few areas in Montana published reserve figures were available for individual townships. These figures were not differentiated by beds in different thickness groups and, for some townships, included beds as thin as 18 inches, which is thinner than the limits established for making the current calculation. As the percentage of coal included in the thin beds in these few areas was inconsequential, the figures were incorporated without change in the present estimate, but pending a detailed check of the work and a breakdown of the figures by beds in different thickness groups, such coal is shown in a separate column headed "Unclassified as to thickness" in the accompanying tables. For a few other areas known to contain coal, but where only general information was available as to thickness or extent of beds, tonnage values were assigned on the basis of detailed calculations in nearby areas. This coal also is included in the column headed "Unclassified as to thickness" in the accompanying tables. When final reserve figures for Montana are prepared, it is anticipated that most of this tonnage will be transferred to the "measured and indicated" class and that much of it will be added to the totals in the thicker beds.

Several large areas believed to be coal bearing, but for which no information was available concerning the thickness or extent of the beds, were not considered in preparing the accompanying provisional estimate.

The location and extent of these areas is shown in tabular form below:

Areas of coal-bearing lands in Montana omitted in reserve estimates

County	Area of coal-bearing lands omitted (square miles)	Total area of coal-bearing lands in county (square miles)	Percent of total coal-bearing lands omitted
Carter	108	1,305	8.3
Custer	270	3,635	7.4
Dawson	915	2,228	41.1
Fallon	36	1,383	2.6
Garfield	410	1,880	21.8
Prairie	1,000	1,712	58.4
Richland	800	2,026	39.5
Roosevelt	460	2,003	23.0
Rosebud	6	3,283	0.2
Sheridan	660	1,700	38.8
Wibaux	110	822	13.4
Total	4,775	.....	....

All the areas of coal-bearing lands listed contain lignite and, in general, are concentrated in the northeastern part of the State where the coal-bearing rocks are concealed by a covering of glacial drift. Detailed work in these areas should materially increase the estimate for lignite. It should be noted that the total of 4,775 square miles of coal-bearing lands omitted in preparing the estimates is only 9.3 percent of the total area of coal-bearing lands in Montana.

Except as noted, calculations were made by individual beds and by townships, and the work was summarized by counties for presentation in the tables. It is hoped that the use of small unit areas in making calculations has eliminated the possibility of large cumulative errors in the work and will facilitate later revision as new data become available.

The minimum thickness of coal considered in preparing the present estimate was 14 inches for bituminous coal and 30 inches for lignite and sub-bituminous coal. For the purpose of classifying the reserves, however, separate totals were prepared for coal in the following thickness ranges:

Bituminous coal:
- More than 36 inches.
- 24 to 36 inches.
- 14 to 24 inches.

Sub-bituminous coal and lignite:
- More than 10 feet.
- 5 to 10 feet.
- 30 inches to 5 feet.

In December 1948, the National Bituminous Coal Advisory Council recommended to the Secretary of the Interior that estimates of bituminous coal reserves in the eastern United States be made for the thickness ranges 28 to 42 inches and more than 42 inches. This recommendation was received too late for these thickness ranges to be adopted for estimating bituminous coal reserves in Montana. It is believed, however, that the 24- to 36-inch range selected as a basis for preparing the accompanying estimates of bituminous coal will be almost as useful as the 28- to 42-inch range, particularly if note is made of the fact that in Montana the estimated tonnage of bituminous coal in the 24- to 36-inch range is approximately 15 percent less than the tonnage would be in the 28- to 42-inch range.

In making calculations, the average thickness used for each bed was obtained by weighting, as far as possible, all thickness values according to the area covered by coal of the recorded thickness. Partings three-eighths of an inch or more thick, plus an equivalent amount of coal, were subtracted from the bed thickness. This extremely conservative procedure was followed originally by the Geological Survey in establishing values of classified coal lands,7/ and as many local reserve calculations had been made in Montana on this basis, it was followed throughout in preparing the present provisional estimate. Where partings were thicker than the adjoining splits of coal, the splits were considered as separate beds if they were thicker than the minimum figures of 14 and 30 inches for bituminous coal and sub-bituminous coal, respectively; otherwise they were omitted.

On the basis of about 20 specific-gravity determinations of coal from various parts of Montana, the value of 1,770 short tons per acre-foot was selected as being representative of lignite and sub-bituminous coal, and 1,800 tons per acre-foot for all bituminous coal except in the Red Lodge field, Carbon County, where 1,890 tons per acre-foot was used.

The method, as outlined, of determining the assumed area of occurrence of each coal bed eliminated from consideration practically all coal more than 2,000 feet below the surface. The present estimate was restricted, therefore, to coal lying between the surface and a depth of 2,000 feet. Of the total amount of coal included in this range, however, a very large fraction, perhaps 75 percent, is no more than 1,000 feet below the surface.

Tables 1, 2, 3, and 4 show the original coal reserves in Montana calculated by rank of coal, by county, by class of coal according to the reliability and abundance of information available for making estimates, and by coal beds in different thickness groups. A comparison of the totals for each rank with totals obtained by Campbell 8/ in 1928 shows several differences, which are due in part to differences in the assumptions used in making the two estimates. The original reserves of coal in each rank according to the present estimate and Campbell's estimate are as follows:

	Present estimate (short tons)	Campbell's 1928 estimate (short tons)
Bituminous coal	2,362,610,000	2,655,000,000
Sub-bituminous coal	132,151,060,000	62,985,000,000
Lignite	87,533,270,000	315,474,000,000
Total	222,046,940,000	381,114,000,000

7/ Smith, G. O., and others, The classification of the public lands: U. S. Geol. Survey Bull. 537, p. 70, 1913.

8/ Buch, J. W., Hendricks, T. A., and Toenges, A. L., Coal, in Mineral position of the United States: Hearings before a subcommittee of the Committee on Public Lands, U. S. Senate, 80th Cong., 1st sess., pp. 231-235, May 15, 16, and 20, 1947.

Table 1.—Estimated original bituminous coal reserves in Montana, in millions of short tons

County	Measured and indicated reserves				Inferred reserves				Unclassified as to thickness	County total
	In beds 14 to 24 inches thick	In beds 24 to 36 inches thick	In beds more than 36 inches thick	Total	In beds 14 to 24 inches thick	In beds 24 to 36 inches thick	In beds more than 36 inches thick	Total		
Broadwater.	.....	5.66	.....	5.66	.....	....	.....	.....	.....	5.66
Carbon.....	39.33	113.11	621.97	774.41	42.65	82.12	348.04	472.81	.....	1,247.22
Cascade....	81.10	74.70	234.12	389.92	38.37	....	6.83	45.20	.....	435.12
Fergus.....	59.28	83.38	126.75	269.41	31.16	30.73	10.10	71.99	.....	341.40
Glacier....	6.75	19.14	6.30	32.19	.....	1.17	.....	1.17	.....	33.36
Judith Basin	65.70	45.65	44.77	156.12	54.90	29.11	3.80	87.81	.....	243.93
Meagher....	.....	.....	0.53	0.53	.....	....	.....	.....	.....	0.53
Park.....	.....	.....	.....	.....	.....	0.61	20.22	20.83	.....	20.83
Pondera....	21.89	.....	.....	21.89	.....	....	.....	.....	.....	21.89
Stillwater.	4.73	6.05	1.89	12.67	.....	....	.....	.....	.....	12.67
Total.	278.78	347.69	1,036.33	1,662.80	167.08	143.74	388.99	699.81	0.00	2,362.61

Total coal in beds 14 to 24 inches thick.....	445.86
Total coal in beds 24 to 36 inches thick.....	491.43
Total coal in beds more than 36 inches thick.....	1,425.32
Total coal in beds of unclassified thickness.....	0.00
Grand total.....	2,362.61

Table 2.—Estimated original sub-bituminous coal reserves in Montana in millions of short tons

County	Measured and indicated reserves				Inferred reserves				Unclassified as to thickness	County total
	In beds 2½ to 5 feet thick	In beds 5 to 10 feet thick	In beds more than 10 feet thick	Total	In beds 2½ to 5 feet thick	In beds 5 to 10 feet thick	In beds more than 10 feet thick	Total		
Big Horn...	420.46	1,273.54	2,478.46	4,172.46	322.02	1,717.75	2,685.54	4,725.31	34,602.88	43,500.65
Blaine.....	.....	.....	.....	.....	21.63	.....	.....	21.63	18.10	39.73
Chouteau...	0.90	0.58	.....	1.48	.....	.....	.....	.....	.....	1.48
Custer.....	163.58	1,570.48	779.80	2,513.86	.....	.....	.....	.....	165.00	2,678.86
Fergus.....	1.49	.....	.....	1.49	0.05	.....	.....	0.05	.....	1.54
Garfield...	425.66	110.28	26.87	562.81	39.31	10.62	.....	49.93	.....	612.74
Hill.....	28.00	.....	.....	28.00	48.55	.....	.....	48.55	.....	76.55
Musselshell	4.12	.....	.....	4.12	.....	.....	.....	.....	3,467.37	3,471.49
Park.....	0.44	.....	.....	0.44	3.91	8.05	.....	11.96	.....	12.40
Phillips...	.....	.....	.....	.....	3.50	.....	.....	3.50	.....	3.50
Powder River	2,842.72	8,034.63	18,525.97	29,403.32	760.26	3,295.87	7,525.03	11,581.16	.....	40,984.48
Rosebud....	1,504.74	4,496.11	4,559.09	10,559.94	1,126.92	4,213.65	5,764.35	11,104.92	17,208.92	38,873.78
Treasure...	.....	.....	.....	.....	.....	.....	.....	.....	1,303.66	1,303.66
Yellowstone	.....	.....	.....	.....	.....	.....	.....	.....	590.20	590.20
Total.	5,392.11	15,485.62	26,370.19	47,247.92	2,326.15	9,245.94	15,974.92	27,547.01	57,356.13	132,151.06

Total coal in beds 2½ to 5 feet thick 7,718.26

Total coal in beds 5 to 10 feet thick 24,731.56

Total coal in beds more than 10 feet thick .. 42,345.11

Total coal in beds of unclassified thickness. 57,356.13

Grand total..... 132,151.06

Table 3.—Estimated original lignite reserves in Montana, in millions of short tons.

County	Measured and indicated reserves				Inferred reserves				Unclassified as to thickness	County total
	In beds 2½ to 5 feet thick	In beds 5 to 10 feet thick	In beds more than 10 feet thick	Total	In beds 2½ to 5 feet thick	In beds 5 to 10 feet thick	In beds more than 10 feet thick	Total		
Carter.....	366.99	56.40	.....	423.39	40.08	.....	.....	40.08	.....	1/463.47
Custer.....	1,219.46	162.43	117.60	1,499.49	31.22	.....	.....	31.22	668.14	1/2,198.85
Daniels.....	.....	.....	.....	.....	.....	.....	.....	.....	3,964.72	3,964.72
Dawson.....	301.28	883.85	.....	1,185.13	1,088.98	1,388.38	.....	2,477.36	7,448.00	1/11,110.49
Fallon.....	416.54	247.45	.....	663.99	487.56	18.09	.....	505.65	1,374.44	1/2,544.08
Granite.....	.....	.....	.....	.....	.....	.....	.....	.....	23.00	23.00
McCone.....	.....	.....	.....	.....	371.00	.....	.....	371.00	24,500.57	24,871.57
Missoula....	.....	.....	.....	.....	.....	19.70	.....	19.70	.....	19.70
Powder River	271.18	177.33	1,335.99	1,784.50	8.87	205.32	435.00	649.19	.....	2,433.69
Prairie.....	235.46	565.69	160.89	962.04	153.04	147.91	.....	300.95	318.28	1/1,581.27
Richland....	366.78	1,281.58	830.90	2,479.26	4,436.79	8,213.70	.....	12,650.49	5,955.87	1/21,085.62
Roosevelt...	657.71	1,591.33	0.46	2,249.50	839.24	1,035.49	.....	1,874.73	40.00	1/4,164.23
Rosebud.....	.....	.....	.....	.....	.....	.....	.....	.....	10.10	1/10.10
Sheridan....	467.60	210.97	100.01	778.58	225.25	1.54	.....	226.79	4,758.45	1/5,763.82
Valley.....	.....	.....	.....	.....	.....	.....	.....	.....	257.93	257.93
Wibaux.....	573.17	1,436.04	20.18	2,029.39	2,495.72	2,105.75	.....	4,601.47	409.87	1/7,040.73
Total.	4,876.17	6,613.07	2,566.03	14,055.27	10,177.75	13,135.88	435.00	23,748.63	49,729.37	1/87,533.27

1/ Incomplete. See p. 16.

Total coal in beds 2½ to 5 feet thick.....	15,053.92
Total coal in beds 5 to 10 feet thick.....	19,748.95
Total coal in beds more than 10 feet thick....	3,001.03
Total coal in beds of unclassified thickness..	49,729.37
Grand total.....	1/87,533.27

Table 4.—Total estimated original coal reserves in Montana, in millions of short tons

County	Bituminous	Sub-bituminous	Lignite	Total	Percent of total
Big Horn....	. . . . .	43,500.65	. . . . .	43,500.65	19.6
Blaine.....	. . . . .	39.73	. . . . .	39.73	(1)
Broadwater..	5.66	. . . . .	. . . . .	5.66	(1)
Carbon.....	1,247.22	. . . . .	. . . . .	1,247.22	0.6
Carter.....	. . . . .	. . . . .	2/463.47	2/463.47	0.2
Cascade.....	435.12	. . . . .	. . . . .	435.12	0.2
Chouteau....	. . . . .	1.48	. . . . .	1.48	(1)
Custer.....	. . . . .	2,678.86	2/2,198.85	2/4,877.71	2.2
Daniels.....	. . . . .	. . . . .	3,964.72	3,964.72	1.8
Dawson.....	. . . . .	. . . . .	2/11,110.49	2/11,110.49	5.0
Fallon.....	. . . . .	. . . . .	2/2,544.08	2/2,544.08	1.1
Fergus.....	341.40	1.54	. . . . .	342.94	0.2
Garfield....	. . . . .	612.74	(2)	2/612.74	0.3
Glacier.....	33.36	. . . . .	. . . . .	33.36	(1)
Granite.....	. . . . .	. . . . .	23.00	23.00	(1)
Hill.....	. . . . .	76.55	. . . . .	76.55	(1)
Judith Basin	243.93	. . . . .	. . . . .	243.93	0.1
McCone.....	. . . . .	. . . . .	24,871.57	24,871.57	11.2
Meagher.....	0.53	. . . . .	. . . . .	0.53	(1)
Missoula....	. . . . .	. . . . .	19.70	19.70	(1)
Musselshell.	. . . . .	3,471.49	. . . . .	3,471.49	1.6
Park.....	20.83	12.40	. . . . .	33.23	(1)
Phillips....	. . . . .	3.50	. . . . .	3.50	(1)
Pondera.....	21.89	. . . . .	. . . . .	21.89	(1)
Powder River	. . . . .	40,984.48	2,433.69	43,418.17	19.5
Prairie.....	. . . . .	. . . . .	2/1,581.27	2/1,581.27	0.7
Richland....	. . . . .	. . . . .	2/21,085.62	2/21,085.62	9.4
Roosevelt...	. . . . .	. . . . .	2/4,164.23	2/4,164.23	1.9
Rosebud.....	. . . . .	38,873.78	2/10.10	2/38,883.88	17.5
Sheridan....	. . . . .	. . . . .	2/5,763.82	2/5,763.82	2.6
Stillwater..	12.67	. . . . .	. . . . .	12.67	(1)
Treasure....	. . . . .	1,303.66	. . . . .	1,303.66	0.6
Valley.....	. . . . .	. . . . .	257.93	257.93	0.1
Wibaux.....	. . . . .	. . . . .	2/7,040.73	2/7,040.73	3.2
Yellowstone.	. . . . .	590.20	. . . . .	590.20	0.3
Total.	2,362.61	132,151.06	2/87,533.27	2/222,046.94	99.9

1/ Less than 0.1 percent.
2/ Incomplete. See p. 16.

Table 5.—Coal production in Montana during the years 1937-47, in short tons
(Figures from U. S. Bureau of Mines, Minerals Yearbooks, 1938-48, inclusive)

County.....	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947
Blaine.....	15,327	1/12,216	....	....	....	10,833	13,127	9,189	2/11,278	8,985	7,810
Carbon.....	389,036	331,118	....	388,903	411,098	635,839	546,437	637,317	564,571	344,421	266,818
Cascade....	434,595	490,587	....	461,692	506,261	438,569	489,174	482,603	209,962	121,447	50,557
Chouteau...	8,033	8,021	5,627	5,018	5,854	3,741	3,930	2,623	....	2,700	1,026
Custer.....	3/10,288	3/7,697	4/6,898	4/8,579	4/19,681	4/19,967	5/23,780	15,783	15,080	13,281	13,204
Dawson.....	....	1,438	....	....	....	....	....	6/4,674	2,560	2,560	2,704
Fergus.....	3,485	....	....	....	....	2,235	....	1,016	....	1,215	1,502
Flathead...	11,079	7/4,261	....	....	....	2,547	....	....	....	....	....
Hill.....	....	8,738	6,759	7,988	7,342	4,551	....	....	....	....	....
McCone.....	....	8/8,784	3,295	4,358	3,455	....	....	....	1,133	1,079	1,021
Musselshell	787,665	9/1,815,707	737,947	787,355	843,766	970,246	1,136,340	1,142,808	1,084,172	751,392	829,323
Richland...	14,667	12,911	13,828	10/19,362	10/15,834	11/8,950	11/20,423	11/13,096	6,409	8,022	8,357
Roosevelt..	12,337	7,559	4,527	....	....	....	....	....	2,933	2,320	2,460
Rosebud....	1,248,837	....	....	1,127,915	1,399,350	1,708,641	12/2,579,658	2,514,605	2,555,208	2,452,753	1,982,185
Sheridan...	8/17,019	15,156	15,148	15,965	19,823	20,221	20,180	18,056	13,482	12,751	10,923
Other.....	13/12,825	14/7,457	15/1,995,970	16/27,238	17/21,270	18/2,342	....	19/2,179	....	....	....
Total.	2,965,193	2,731,650	2,803,804	2,267,200	3,253,724	3,828,682	4,833,049	4,844,049	4,466,788	3,722,926	3,177,890

1/ Includes Phillips County.
2/ Includes Chouteau County.
3/ Includes Wibaux County.
4/ Includes Dawson County.
5/ Includes Dawson and Valley Counties.
6/ Includes Valley County.
7/ Includes Pondera County.
8/ Includes Daniels and Valley Counties.
9/ Includes Rosebud County.
10/ Includes Roosevelt County.
11/ Includes McCone and Roosevelt Counties.
12/ Includes Fergus County,
13/ Includes Judith Basin, Phillips, Pondera, Powder River, and Toole Counties.
14/ Includes Gallatin, Park, Powder River, and Stillwater Counties.
15/ Includes Blaine, Carbon, Cascade, Fergus, Flathead, Gallatin, Judith Basin, Park, Phillips, Pondera, Powder River, and Rosebud Counties.
16/ Includes Blaine, Fergus, Flathead, Judith Basin Park, Phillips, Pondera, and Powder River Counties.
17/ Includes Blaine, Fergus, Flathead, Gallatin, Judith Basin, Park, Phillips, Pondera, and Powder River Counties.
18/ Includes Park and Powder River Counties.
19/ Includes Toole County.

It should be noted in comparing these figures that although the same minimum thicknesses were assumed for coal in both estimates, the present estimate was based on extremely conservative assumptions as to the areal extent and volume of each bed and includes only coal no more than 2,000 feet below the surface, whereas Campbell's estimate included coal lying between the surface and a depth of 3,000 feet. Also, Campbell made statistical allowance for coal in unmapped coal-bearing areas and for coal in areas covered by glacial drift. In general, no such allowances were made in preparing the present estimate. The increase in the present estimate of original reserves of subbituminous coal in spite of the conservative methods of calculating tonnage is due to the inclusion of large tonnages of coal in southeastern Montana, where much detailed mapping has been done in recent years by the Geological Survey. The decrease in the present estimate of the original reserves of lignite is due in part to the fact that no allowance was made for coal in areas in eastern Montana where coal is known to be present, but where no mapping has been done, and for large areas in northeastern Montana where the coal-bearing rocks are concealed by glacial drift. It is believed, therefore, that further work in coal-bearing areas not included in the present estimate will result in an increase in the total original reserves.

Table 5 shows the total production of coal in Montana by counties for the years 1937-47, inclusive. It is noteworthy that six counties,—Big Horn, Powder River, McCone, Rosebud, Richland, and Dawson,—which contain 82 percent of the original reserves, yield less than 50 percent of the annual production of the State. Furthermore, Big Horn County, which contains 19.6 percent of the original reserves, has never produced enough coal to be included in the production table, and Powder River County, which contains 19.5 percent of the total reserves and the largest apparent reserves of thick coal of any county in the State, has produced only a few thousand tons. Rosebud County, the largest producer in recent years, contains 17.5 percent of the original reserves, whereas Musselshell County, the second largest producer, contains only 1.6 percent of the reserves. These differences are explained primarily by the lack of markets near the reserves, the lack of transportation facilities, and also the fact that the lower ranks of coal slack easily during transportation and storage.

Three counties—Flathead, Gallatin, and Toole—are listed in the production table but do not appear in the reserve tables. This is in accord with the principles, followed in preparing the estimates, of omitting areas known to contain thin and bony coal and areas where quantitative information about the coal was lacking.

The total recorded production of coal in Montana from established mines since operations began to January 1, 1949, is about 155 million tons. Actual production, including that from wagon mines, is probably about 175 million tons. Studies made in 1923 of the bituminous coal mining industry have shown that the average amount of coal lost in mining is 34.7 percent of the coal originally in the ground.9/ For each ton produced, therefore, more than half a ton (0.5314) is lost. Assuming mining losses of this magnitude for Montana, the total coal mined and lost in mining in Montana to January 1, 1949, is approximately 268 million tons. The remaining reserve is about 221,779 million tons, or 99.8 percent of the original reserves. It should be noted that losses of approximately 35 percent may be expected in mining the remaining reserves.

9/ Rice, G. S., and Paul, J. W., Amount and nature of losses in mining bituminous coal in eastern United States: U. S. Coal Comm. Rept., pt. 3, pp. 1841-76, 1923.

SELECTED BIBLIOGRAPHY

The following bibliography lists only publications that contain detailed information about Montana coal resources. Most of these publications are bulletins of the Geological Survey; they contain maps showing outcrops of the coal beds, structure of the coal-bearing rocks, detailed measured sections of the coal beds, and related information. The publications are listed in numerical order according to the following classification: Geological Survey bulletins, other publications of the Geological Survey, and miscellaneous publications. The publications of the Geological Survey marked by an asterisk (*) are out of print. The bulletins not so marked were available on April 1, 1949, from the Superintendent of Documents, Washington 25, D. C., at the prices indicated. All the publications listed are available for consultation in most large public and university libraries and frequently are obtainable from dealers in second-hand scientific books. In Montana, many of the publications should be available at the libraries of the Montana State College, Bozeman; Montana School of Mines, Butte; Historical Society of Montana and Public Library, Helena; Fergus County High School, Lewistown; and State University, Missoula. An index to the publications in the bibliography is given on succeeding pages.

Bulletins of the United States Geological Survey

*225.(j) Coal of the Bighorn Basin in northwest Wyoming, by C. A. Fisher, pp. 345-364, 1903.

*285.(f) Development of the Bear Creek coal fields, Mont., by C. A. Fisher, pp. 269-270, 1906; The North Dakota-Montana lignite area, by A. G. Leonard, pp. 316-330, 1906.

*316.(c) The Great Falls coal field, Mont., by C. A. Fisher, pp. 161-173, pl. x, 1907; Coals of Carbon County, Mont., by N. H. Darton, pp. 174-193, pl. xi, 1907; The coal fields of Dawson, Rosebud, and Custer Counties, Mont., by A. G. Leonard, pp. 194-211, pl. xii, 1907.

*341.(a) The Sentinel Butte lignite field, N. Dak. and Mont., by A. G. Leonard and C. D. Smith, pp. 15-35, pl. ii, 1909; The Miles City coal field, Mont., by A. J. Collier and C. D. Smith, pp. 36-61, pl. iii, 1909; The Bull Mountain coal field, Mont., by L. H. Woolsey, pp. 62-77, pl. iv, 1909; Coal near the Crazy Mountains, Mont., by R. W. Stone, pp. 78-91, pl. v, 1909; The Red Lodge coal field, Mont., by E. G. Woodruff, pp. 92-107, pl. vi, 1909; The Lewistown coal field, Mont., by W. R. Calvert, pp. 108-122, pl. vii, 1909.

*341.(b) Coal fields of the northeast side of the Bighorn Basin, Wyo., and of Bridger, Mont., by C. W. Washburne, pp. 165-199, pl. x, 1909.

*356. Geology of the Great Falls coal field, Mont., by C. A. Fisher, 85 pp., 12 pls., 1909.

*381.(a) The Fort Peck Indian Reservation lignite field, Mont., by C. D. Smith, pp. 40-59, pl. iii, 1910; The central part of the Bull Mountain coal field, Mont., by R. W. Richards, pp. 60-81, pls. iv-v, 1910; The Milk River coal field, Mont., by L. J. Pepperberg, pp. 82-107, pl. vi, 1910; Notes on the coals of the Custer National Forest, Mont., by C. H. Wegemann, pp. 108-114, pl. vii, 1910.

*390. Geology of the Lewistown coal field, Mont., by W. R. Calvert, 83 pp., 5 pls., 1909.

*431.(b) The eastern part of the Bull Mountain coal field, Mont., by C. T. Lupton, pp. 163-189, pls. vi-vii, 1911.

*471.(d) Geology of certain lignite fields in eastern Montana, by W. R. Calvert, pp. 187-201, 1912; The Baker lignite field, Custer County, Mont., by C. F. Bowen, pp. 202-226, pls. xiv-xv, 1912; The Terry lignite field, Custer County, Mont., by F. A. Herald, pp. 227-270, pls. xvi-xviii, 1912; The Glendive lignite field, Dawson County, Mont., by J. H. Hance, pp. 271-283, pls. xix-xx, 1912; The Sidney lignite field, Dawson County, Mont., by Eugene Stebinger, pp. 284-318, pls. xxi-xxiv, 1912; The Culbertson lignite field, Valley County, Mont., by A. L. Beekly, pp. 319-358, pls. xxv-xxvii, 1912.

*471.(e) The southern extension of the Milk River coal field, Chouteau County, Mont., by L. J. Pepperberg, pp. 359-383, pl. xxviii, 1912; The Livingston and Trail Creek coal fields, Park, Gallatin, and Sweetgrass Counties, Mont., by W. R. Calvert, pp. 384-405, pl. xxix, 1912; The Electric coal field, Park County, Mont., by W. R. Calvert, pp. 406-422, pl. xxx, 1912.

*471.(j) Miscellaneous analyses of coal samples from various fields of the United States, pp. 629-655, 1912.

*531.(f) The Little Sheep Mountain coal field, Dawson, Custer, and Rosebud Counties, Mont., by G. S. Rogers, pp. 159-227, pls. xi-xiii, 1911.

*531.(g) Coal in the Tertiary lake beds of southwestern Montana, by J. T. Pardee, pp. 229-244, pl. xiv, 1911.

*531.(m) Miscellaneous analyses of coal samples from various fields of the United States, pp. 331-355, 1911.

*541.(h) Lignite in the vicinity of Plentywood and Scobey, Sheridan County, Mont., by C. M. Bauer, pp. 293-315, pls. xv-xvii, 1912; Geology and coal resources of the area southwest of Custer, Yellowstone and Bighorn Counties, Mont., by G. S. Rogers, pp. 316-328, pl. xviii, 1912; Coal discovered in a reconnaissance survey between Musselshell and Judith, Mont., by C. F. Bowen, pp. 329-337, pl. xix, 1912; The Cleveland coal field, Blaine County, Mont., by C. F. Bowen, pp. 338-355, pl. xx, 1912; The Big Sandy coal field, Chouteau County, Mont., by C. F. Bowen, pp. 356-378, pl. xxi, 1912.

*541.(k) Analyses of coal samples from various fields of the United States, by M. R. Campbell, pp. 491-526, 1912.

*621.(k) Geology and coal resources of northern Teton County, Mont., by Eugene Stebinger, pp. 117-156, pl. xv-xvi, 1915.

*621.(p) Analyses of coal samples from various parts of the United States, by M. R. Campbell and F. R. Clark, pp. 251-375, i-vii [including title page, contents, list of illustrations, and index to volume], 1915.

*641.(g) Geology of the Upper Stillwater Basin, Stillwater and Carbon Counties, Mont., with special reference to coal and oil, by W. R. Calvert, pp. 199-214, pls. xx-xxi, 1917.

*641.(h) Geology of the Hound Creek district of the Great Falls coal field, Cascade County, Mont., by V. H. Barnett, pp. 215-231, pl. xxii, 1917.

*647. The Bull Mountain coal field, Musselshell and Yellowstone Counties, Mont., by L. H. Woolsey, R. W. Richards, and C. T. Lupton, 218 pp., 36 pls., 1917.

*661.(i) Phosphatic oil shales near Dell and Dillon, Beaverhead County, Mont., by C. F. Bowen, pp. 315-328, i-viii [including title page, contents, list of illustrations, and index to volume], 1918.

*729. Oil shale of the Rocky Mountain region, by D. E. Winchester, 204 pp., 18 pls., 1923.

*749. Geology of the Tullock Creek coal field, Rosebud and Big Horn Counties, Mont., by G. S. Rogers and Wallace Lee, vi, 181 pp., 16 pls., 1923.

*751.(e) The Scobey lignite field, Valley, Daniels, and Sheridan Counties, Mont., by A. J. Collier, pp. 157-230, pls. xxi-xxix, 1923-24.

*751.(f) The Ekalaka lignite field, southeastern Montana, by C. M. Bauer, pp. 231-267, pls. xxx-xxxiv, 1923-24.

806.(b) The northward extension of the Sheridan coal field, Big Horn and Rosebud Counties, Mont. by A. A. Baker, pp. 15-67, pls. 6-29, 1928. 45 cents.

*812.(a) The Forsyth coal field, Rosebud, Treasure, and Big Horn Counties, Mont., by C. E. Dobbin, pp. 1-55, pls. 1-10, 1929.

*822.(a) Geology and mineral resources of parts of Carbon, Big Horn, Yellowstone, and Stillwater Counties, Mont., by R. S. Knappen and G. F. Moulton, pp. 1-70, pls. 1-5, 1930.

831.(b) The Ashland coal field, Rosebud, Powder River, and Custer Counties, Montana, by N. W. Bass, pp. 19-105, pls. 3-37, 1931-32. 80 cents.

847.(b) The Rosebud coal field, Rosebud and Custer Counties, Mont., by W. G. Pierce, pp. i-v, 43-120, pls. 5-21, 1936. $1.25.

847.(c) The Richey-Lambert coal field, Richland and Dawson Counties, Mont., by F. S. Parker, pp. i-iv, 121-174, pls. 22-27, 1936. 35 cents.

847.(f) Geology and mineral resources of north-central Chouteau, western Hill, and eastern Liberty Counties, Mont., by W. G. Pierce and C. B. Hunt, pp. i-iv, 225-270, i-vi, pls. 36-43, 1937. [Includes title page, contents, list of illustrations, and index to volume.] 35 cents.

*856. Geology of Big Horn County and the Crow Indian Reservation, Mont., with special reference to the water, coal, oil, and gas resources, by W. T. Thom, Jr., G. M. Hall, C. H. Wegemann, and G. F. Moulton, vii, 200 pp., 15 pls., 1935.

905. The coal resources of McCone County, Mont., by A. J. Collier and M. M. Knechtel, vii, 80 pp., 16 pls., 1939. 75 cents.

906.(c) The Mizpah coal field, Custer County, Mont., by F. S. Parker and D. A. Andrews, pp. i-v, 85-133, pls. 16-40, 1939 [1940]. $1.50

Other publications of the United States Geological Survey

*A 22 III.(j) Twenty-second Annual Report, pt. 3, ch. j: The Rocky Mountain coal fields, by L. S. Storrs, pp. 415-471, pls. xxix-xxx, 1902.

*P 100. (a) Professional Paper 100, ch. a: The coal fields of the United States, General introduction, by M. R. Campbell, pp. 1-33, pl. i, 1929 [originally published in June 1917].

*GF 1. Geologic Folio 1: Livingston, Mont., by J. P. Iddings and W. H. Weed, [5] pp., 4 maps, 1894.

*GF 24. Geologic Folio 24: Three Forks, Mont., by A. C. Peale, [7] pp., 4 maps, 1896.

*GF 55. Geologic Folio 55: Fort Benton, Mont., by W. H. Weed, [9] pp., 4 maps, 1899.

*GF 56. Geologic Folio 56: Little Belt Mountains, Mont., by W. H. Weed, [11] pp., 4 maps, 1899.

*W 221. Water-Supply Paper 221: Geology and water resources of the Great Falls region, Mont., by C. A. Fisher, 89 pp., 7 pls., 1909.

*W 518. Water-Supply Paper 518: Ground water in Musselshell and Golden Valley Counties, Mont., by A. J. Ellis and O. E. Meinzer, vi, 92 pp., 5 pls., 1924.

*W 599. Water-Supply Paper 599: Ground water in Yellowstone and Treasure Counties, Mont., by G. M. Hall and C. S. Howard, vi, 118 pp., 7 pls., 1929.

W 600. Water-Supply Paper 600: Geology and ground-water resources of central and southern Rosebud County, Mont., by B. C. Renick, x, 140 pp., 12 pls., 1929. 35 cents.

Miscellaneous publications

M 11. Geology and artesian water resources along Missouri and Milk Rivers in northeastern Montana, by E. S. Perry: Montana Bur. Mines and Geology Mem. 11, 34 pp., 1934.

MU 1. Geology and economic deposits of a portion of eastern Montana, by J. P. Rowe and R. A. Wilson: Montana Univ. Studies, ser. 1, pp. 5-58, 1916.

MU 37. Montana coal and lignite deposits, by J. P. Rowe: Montana Univ. Bull. 37, geol. ser. 2, 82 pp., 1906.

MU 50. Some economic geology of Montana, by J. P. Rowe: Montana Univ. Bull. 50, geol. ser. 3, 67 pp., 1908.

T 529. Analyses of Montana coals: U. S. Bur. Mines Tech. Paper 529, 123 pp., 1932.

INDEX TO BIBLIOGRAPHY

This index refers to the preceding bibliography. The abbreviations used for various publications are as follows: A, Annual Report, U. S. Geological Survey; B, Bulletin, U. S. Geological Survey; GF, Geologic Folio, U. S. Geological Survey; P, Professional Paper, U. S. Geological Survey; M, Memoir, Montana Bureau of Mines and Geology; MU, Bulletin, University of Montana; T, Technical Paper, U. S. Bureau of Mines; W, Water-Supply Paper, U. S. Geological Survey.